COMPARISON OF CONSTRUCTION COSTS FOR VEGETATIVE TREATMENT SYSTEMS IN THE MIDWESTERN UNITED STATES

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ABSTRACT. *Vegetative treatment systems (VTSs) provide an alternative to containment basin systems for beef feedlot runoff control. Beef producers in the Midwestern United States have shown an increasing interest in using VTSs as a perceived lower cost option to containment basin systems. This article reports the actual construction costs associated with 23 VTSs (nine on permitted Concentrated Animal Feeding Operations (CAFOs) and 14 on non-permitted Animal Feeding Operations (AFOs)) and four containment basins located throughout Iowa, Minnesota, South Dakota, and Nebraska. The VTS construction costs are reported on a per head space basis in 2009 adjusted dollars for each system. Cost comparisons are presented for CAFO and AFO facilities, and by system type. Additionally, estimated construction cost comparisons between open feedlots with VTS systems, open feedlots with containment basins, monoslope barns and hoop structures for beef production systems are provided. Results from the cost comparison indicate the average construction cost in 2009 dollars for an AFO or CAFO is $655 per head space for animals housed in a monoslope barn with a concrete floor and $395 per head space for animals housed in a hoop structure. For AFOs and CAFOs, the average cost of an earthen lot with a containment basin costs is $361 per head space, while the average cost of an earthen lot implemented with a VTS is $283 per head space. If only the feedlot runoff control system is considered, VTSs designed for CAFO facilities are less expensive on average to construct ($85 per head space on average) than traditional containment basins ($136 per head space on average). Similarly for AFO feedlot runoff control systems, a VTS was less expensive to build on average ($79 per head space on average.) than a containment basin on a similar facility ($205 per head space). The data indicated on average the least expensive VTS for an AFO is a gravity VTS ($54 per head space average.) followed by a sprinkler VTS ($94 per head space average.) and a pump and gravity VTS ($101 per head space average.). Statistical analysis showed no significant difference between the VTS construction cost per head space of cattle for an AFO compared to a CAFO (p=0.07, alpha=0.05) while there was a statistical difference between system type (p=0.02, alpha=0.05).*

Keywords. *Beef feedlot runoff, Vegetative treatment systems, Economic analysis, Manure management.*

U.S. Environmental Protection Agency (USEPA) rules have required concentrated animal feeding operations (CAFOs) to contain all of the wastewater and runoff produced from a 25-year, 24-h design storm (U.S. EPA, 2008). The 2003 CAFO rule allowed the use of alternative technologies that meet or exceed the performance of traditional containment basin systems. Manure containment systems can be costly to construct and require manure storage over a long period of time. Generally, runoff collected and stored in containment basins are land applied twice a year (spring and fall) as either fertilizer or irrigation water when field conditions allow manure application (MWPS-18, 2001). Beef producers have expressed interest in non-basin technology systems that eliminate the need for the long-term storage of feedlot manure runoff (Woodbury et al., 2005).

Until the 2003 CAFO rule, manure management systems for CAFO beef feedlot facilities were restricted to runoff retention ponds or containment basins. Periodically, the effluent in these structures was land applied to maintain sufficient storage capacity for a 25-year, 24-h rain event. However, occasional precipitation and chronic wet periods exceeded the design capacity of these basins and limited or prevented the application of runoff water to land application areas. During these chronic wet periods, the potential for large discharges increased from these structures and subsequently increased environmental liability. Some facilities increased their containment basin capacity to 125-150% of original design capacity requirements as a means to compensate. The result was larger containment basins to enable greater storage between application periods which in turn raised the construction cost associated with the manure handling systems. Such oversized structures do not necessarily reduce the environmental risk to the operation should they discharge. For these reasons, beef producers in

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the Midwestern United States have shown an increasing interest in using vegetative treatment systems (VTSs) as a lower cost option and possibly lower environmental risk to containment basins.

Beef animal feeding operations (AFOs) were defined by the EPA as a facility where animals are confined on a lot or in a facility that does not sustain vegetation for at least 45 days in a 12-month period. Animal feeding operations that meet the regulatory definition of a CAFO are regulated under the National Pollutant Discharge Elimination System (NPDES) permitting program (US EPA, 2008). Concentrated animal feeding operations that have 1,000 head of cattle or greater are required to be permitted under the NPDES program. Animal Feeding Operations less than 1,000 head may be designated as a CAFO by the permitting authority and be required to obtain an NPDES permit; thus these producers have an incentive to manage their runoff to avoid violations.

This article reports the actual construction costs associated with 23 VTSs (9 on permitted CAFOs and 14 on non-permitted AFOs) and four containment basins located throughout Iowa, Minnesota, South Dakota, and Nebraska. Additionally, estimated cost comparisons were made between open feedlots with VTSs, open feedlots with a containment basin system, monoslope barns, and hoop structures for beef production systems. The large CAFO VTSs reported in this study were all permitted under the NPDES program. These permits were issued under the alternative performance criteria specified in the Section 40, part 412 of the Code of Federal Regulations (U.S. EPA, 2008). All large CAFO VTSs demonstrated in their permit documentation to be at least as equivalent in performance to a conventional runoff retention pond system. Additional information about these large CAFO VTS systems can be found in Bond et al. (2010).

System Descriptions

Vegetative Treatment Systems

Vegetative treatment systems provide an alternative to containment basins for feedlot runoff control. Typical components of a VTS are shown in figure 1 and consist of a solid settling basin (SSB), optional vegetative infiltration basin (VIB), and a vegetative treatment area (VTA). Vegetative treatment systems produce both solid manure and liquid runoff. The solid manure comes from cleaning out the settled particles in the settling basin and cleaning the manure accumulated within the feedlot. Liquid runoff is produced during rainfall events where the ground is saturated. During these events, feedlot runoff is contained by berms surrounding the lot and conveyed into a solid settling basin where solids are allowed to settle out of suspension. The settled solids are collected after runoff events and land applied or stockpiled until appropriate field conditions occur. The effluent is temporarily stored within the SSB until appropriate VTA application conditions exist (i.e., VTA not frozen or saturated). The effluent is then released from the SSB and pumped or allowed to gravity flow to the VTA where it is evenly applied across the top width of the VTA. The applied effluent is treated by vegetation through the mechanisms of infiltration and plant uptake. VTS Systems for CAFO's are designed to either prevent or minimize any discharge from the system. Some systems contain an optional VIB between the solid settling basin and the VTA. The VIB receives effluent from the SSB and is constructed with an independent grid of tile lines buried approximately 1.2 m (4 ft) under the ground surface to encourage effluent infiltration. The soil above the tile lines acts as a filter to further remove solids and nutrients still in suspension. The effluent collected from the tiles then enters a sump where a pump transports the effluent to a VTA. Gated pipe and concrete spreaders are typical devices used to evenly apply effluent to a VTA. VTA's can be either sloped (1-5%) or level (0-1%). A level VTA (fig. 2) is similar to a sloped VTA with an initial slope of 1-5% at the top of the VTA while a level VTA has a level area (0-1% slope) located at the bottom of the VTA surrounded by a berm. Level VTA's are similar to VIB's except they do not include a tile drain system. Sloped VTAs use overland flow to distribute effluent across the VTA, while level VTAs use a flooding effect to obtain even effluent distribution at the end of the VTA. For the purpose of this article, systems consisting of either sloped VTAs or level VTAs will be referred to as gravity VTSs. VTS designs and terminology vary depending on the location and local regulations. The coupling of more than one style of VTA has been reported to enhance the performance of VTS systems (Koelsch et al., 2006).

Pump and gravity VTSs (fig. 3) are a variation of a gravity VTS where effluent is pumped from a settling basin to the top of a VTA. Gravity is then used to convey effluent down the length of the VTA for treatment and infiltration. Pump and gravity VTSs allow VTSs to operate at locations where the VTA is located at a higher elevation. Like a gravity VTS, a pump and gravity VTS relies on even distribution and overland flow across a gravity sloped VTA. Some pump and gravity VTSs are designed to re-circulate effluent from the bottom of a VTA back into the sump for reapplication creating a closed system.

Some VTSs utilize an irrigation system to apply effluent to a VTA. These VTSs utilize various irrigation equipment, including solid set sprinklers and towline systems to apply

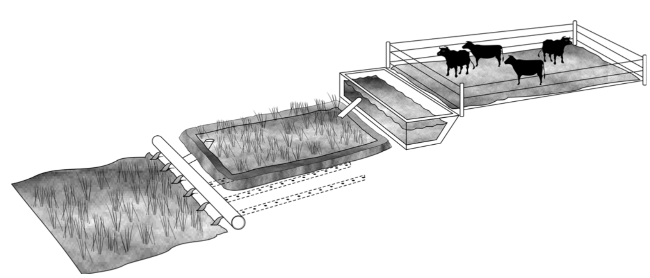

Figure 1. A typical VIB-VTA gravity flow vegetative treatment system (Henry, 2004).

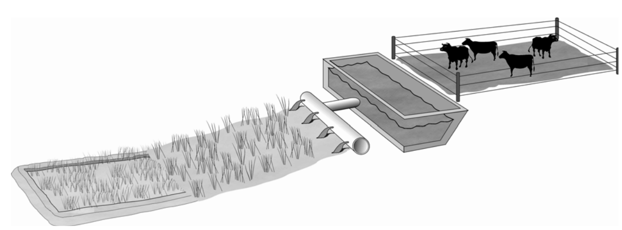

Figure 2. A typical gravity VTS coupled with a level VTA (Henry, 2004).

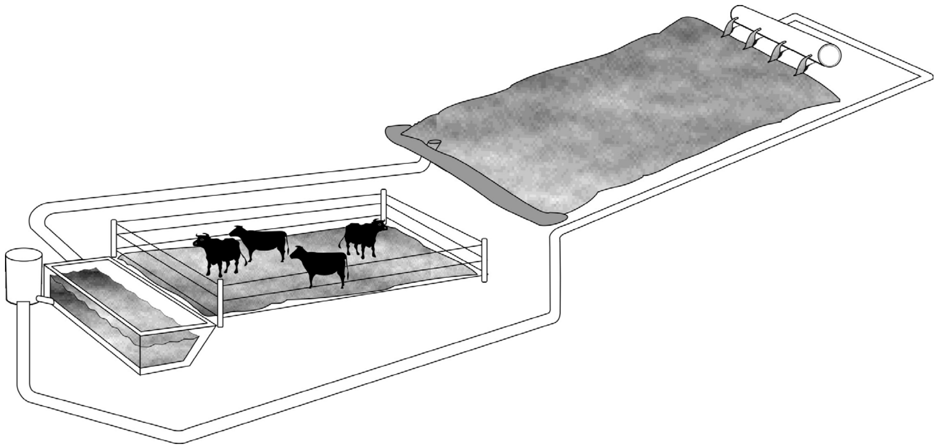

Figure 3. A typical pump and gravity VTS system (Henry, 2004)

effluent to a vegetated area. Examples include the sprinkler irrigation of dairy parlor water to a sod filter area using a solid-set sprinkler system (Winker, 1989) and solid set sprinkler irrigation of milk-house waste water to a vegetative infiltration area (Christopherson et al., 2003). More recently this same approach has been used to apply beef feedlot run-off to vegetative treatment areas in Nebraska (Gross and Henry, 2007, 2010). These systems are constructed similar to a gravity VTS described above except for the addition of a pump and irrigation sprinklers (Gross and Henry, 2007). Irrigation systems allow effluent disposal on rolling and irregular land and generally cost more to construct than other manure application systems but overcome topographical challenges where gravity systems would not work. The irrigation VTS cost information presented in this article is for the sprinkler VTS (fig. 4) developed in Nebraska for beef feedlot runoff.

Containment Basin System

Open feedlots with manure containment basins usually consist of an earthen or concrete lot, a solid settling basin, and a containment basin (fig. 5). The lots are typically designed for 23.2 square m (250 square ft) of pen space per animal (Lawrence et al., 2006). During a rainfall event, effluent travels down the feedlot gradient and collects in the solid settling basin where solids are allowed to settle out of suspension. After adequate time has passed for solid settling, the effluent is released into a containment basin to be stored until land application.

Containment basin systems produce both solid manure and contaminated runoff. The solid manure comes from cleaning out the settled particles in the settling basin and cleaning the feedlot itself. The manure from these two components needs to be removed periodically and either land applied or stockpiled until appropriate field conditions occur. Contaminated runoff contains suspended and dissolved nutrients and other pollutants and is collected in the containment basin.

Roofed Systems with Manure Storage

Monoslope barns feature complete animal confinement with solid concrete floors (fig. 6). These barns are designed for approximately 3.7 square m (40 square ft) of open space per animal (Lawrence et al., 2006). Bedding is placed in the middle of the pens forming a bedding pack to absorb manure and is typically collected twice a week depending on management practices. Manure from these facilities is handled as a solid and stockpiled for field application when conditions are appropriate. Stockpiled solid manure must be stored in a way that meets all state and federal regulations regarding runoff. Current regulations require permitted facilities to collect and control the runoff associated with uncovered manure stockpiles. Feeding bunks are typically

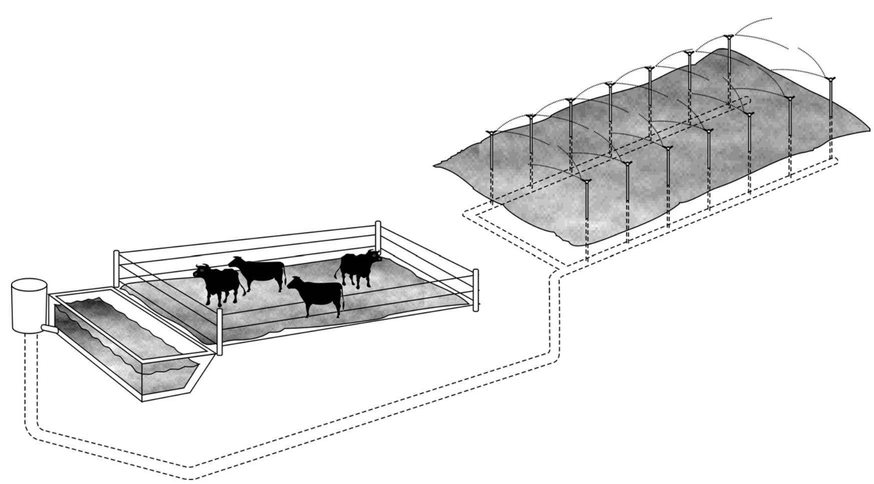

Figure 4. Sprinkler VTS (Henry, 2004).

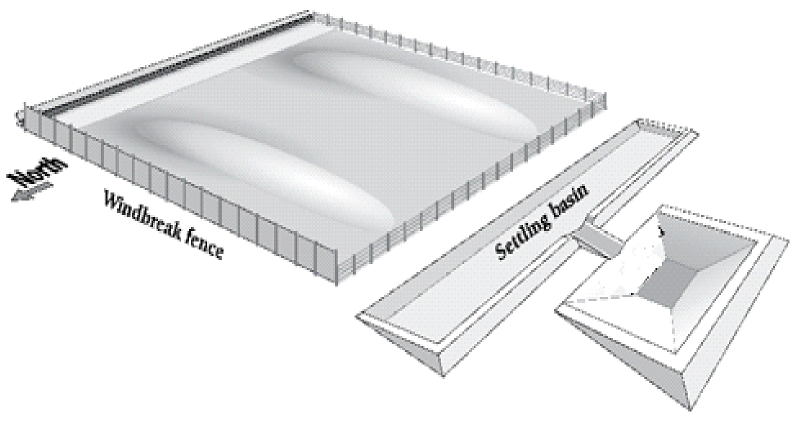

Figure 5. Open feedlot with a containment basin system (Lawrence et al., 2006).

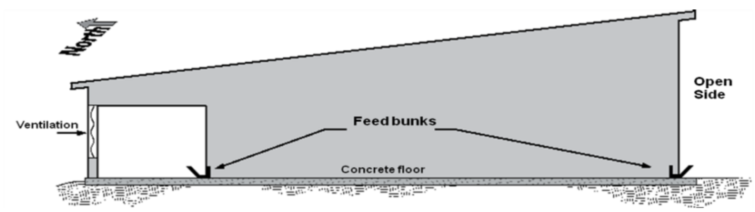

Figure 6. Monoslope barn with a solid concrete floor (Lawrence et al., 2006).

located on both sides of the barn to allow 0.3 m (1 ft) of bunk space per head (Lawrence et al., 2006).

Hoop barns were first developed in Canada during the early 1990s (Connor, 1993) and were introduced to the United States in the mid-1990s (Honeyman, 2005). These structures were rapidly accepted by many farmers due to their low cost and versatility in agricultural production systems. The framework of these structures (fig. 7) consists of tubular steel arches (trusses) spanning across the sidewalls of the barn (Honeyman, 2005). These arches are attached to posts on each side of the structure creating a steel framework to support a UV-resistant, polyvinyl tarp (Shouse et al., 2004). The floor covering in this system is either concrete or a dirt floor depending on the producer's decision. Hoop barns are designed for natural ventilation and contain curtains on the sidewalls to adjust ventilation rates especially in the summer months. These facilities are typically designed with an overhang covering the feed bunks to exclude any rainfall that might enter the system.

Manure management for hoop barns is handled by selectively cleaning portions of the barn or by applying additional layers of bedding to soak up moisture (Shouse et al., 2004). Bedding typically consists of corn stalks applied evenly throughout the facility's flooring. If selective cleaning (i.e., cleaning based on visual inspections) is chosen, the collected manure needs to be stockpiled in a way that meets state and federal regulations regarding runoff. Current regulations require permitted facilities to collect and control the runoff associated with uncovered manure stockpiles. Typically the manure is then spread directly on fields when appropriate conditions are met.

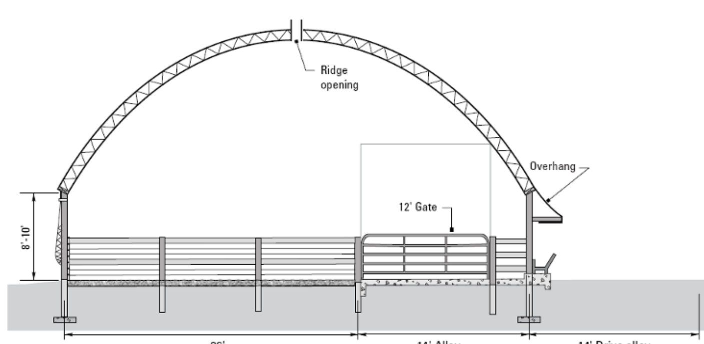

Figure 7. Hoop barn with feed bunk overhang (Honeyman et al., 2008).

METHODS

ACTUAL COST EVALUATION FOR VEGETATIVE TREATMENT AND CONTAINMENT BASIN SYSTEMS

The VTS feedlot construction data for this article was provided by Iowa State University, University of Nebraska-Lincoln, and South Dakota State University. The feedlots were located throughout Iowa, Nebraska, Minnesota, and South Dakota representing both AFO and CAFO feeding operations. The presented costs were actual system costs paid by producers and represent the as built cost associated with integrating a VTS system into an existing feedlot.

The construction cost data was collected and organized by research personnel from Iowa State University, University of Nebraska-Lincoln, and South Dakota State University. Each researcher was provided a VTS cost template (i.e., word document) which consisted of the following general categories: electrical materials, electrical labor, earthwork, concrete materials, concrete labor, construction materials, equipment rental, engineering consultant costs, along with other VTS costs. Due to the diverse VTS designs presented within this article, the initial categories were modified to better represent each individual VTS based on the components associated with its design. Examples of additional categories include but are not limited to pump, pipe, irrigation equipment, cut and fill earthwork, gravel, and sand. Depending on the billing structure of each contractor, certain categories were grouped together into one bill (i.e., one bill for the purchase of a pump, pipe, and installation of these components) while other categories were separated into more specific components. Therefore, the cost information was reported in three general categories common to all 23 sites and consisted of supplies/labor, earthwork, and engineering costs. The actual cost data was collected from producer records and consisted of the following documents: contractor invoices, receipts, NRCS cost share documents, and producer interviews when needed.

The VTS construction costs are reported on a per head space of cattle basis for each system based on actual cost in the year they occurred and were adjusted to 2009 dollars. The average yearly inflation rate was calculated from the Producer Price Index compiled by the Bureau of Labor Statistics for the years 2001 through 2009 (United States Department of Labor, 2009); the calculated rates were used in conjunction with the future worth equation to adjust the construction cost for inflation to a common 2009 base year.

The cost analysis for each site was based only on the VTS construction and engineering design cost and did not include the following items: feedlot construction, feed and cattle handling facilities, fencing, feeding equipment, or operation and maintenance costs. The operation and maintenance cost associated with a VTS was not collected due to inadequate operator records. The in-kind costs (i.e., material and labor supplied or performed by the producer) were also not included within the analysis. The values reported in this article represent the amount a producer might expect to pay to implement a VTS on an existing feedlot.

Some feedlots reported in this article were designed by public entities while others were designed by private consultants. In order to create a fair comparison between sites designed by different entities, the engineering design cost was normalized with an average billing rate of $84 per hour. This engineering rate was calculated from a 2009 phone survey of seven agricultural engineering consulting firms located in the Midwest. The average billing rates were categorized into the following occupational categories: licensed and non-licensed engineers, drafting and technology, and surveying personnel. These billing rates were then weighted by the average percent of employee time allocated for a typical engineering project located in the Midwest. The average billing rates for each occupation and the average percent of employee time per project is located in table 1.

The actual containment basin construction data for this article was derived from Environmental Quality Incentive Program practice payment documents. The cost share documents were based on receipts paid by the producer for cost shared construction practices. This data was provided by the Nebraska Natural Resource Conservation Service (Reedy, 2009). Some components were not cost shared such as pivot application equipment; therefore the producers were interviewed by the University of Nebraska (Henry, 2009). The cost data for the actual containment basin construction cost represented four holding basins and land application systems installed between 2003 and 2007 by the Nebraska NRCS. The containment basin systems were located on three AFO and one CAFO feeding operation in Nebraska. The presented construction costs were paid by the producer and represent the cost associated with construction and materials while the design cost was normalized using the weighted average billing rate of $84 per h for the design hours reported. Some producers used a combination of existing irrigation equipment while others purchased used or new equipment to apply effluent. For each feedlot, an estimated cost of implementing new irrigation equipment was reported along with the actual cost paid by the producer. To accurately report the overall basin cost per head space of cattle, the estimated new irrigation cost was used since producers may not have access to used irrigation equipment.

COST ESTIMATION FOR CONTAINMENT BASINS AND ROOFED FACILITIES

The estimated construction cost information for traditional open beef feedlots and monoslope facilities was collected from the ISU Beef Feedlot Systems Manual produced by Iowa State University and the Iowa Beef Center. This publication reported feedlot cost based on new feedlot construction and current Iowa regulations at the time of publication. Additional items included in the cost of a new feedlot are feed storage structures, cattle handling facilities, and feeding equipment. For the purpose of this article, these

Table 1. The average billing rate and percent of time per engineering project reported from seven consulting firms located in the Midwest.

Firm Occupations	Average Billing Rate ($/h)	% of Time per Project	$/h
Licensed engineer	109	25	27
Non-licensed engineer	77	43	33
Drafting/technology	68	22	15
Surveying	90	10	9
	Total	100	84

items were removed from the analysis since existing feedlots already contain these items.

Basic assumptions for both the open feedlot and monoslope facilities are as follows based on the ISU Beef Feedlot Systems Manual (Lawrence et al., 2006):

- each pen contains 150 head spaces,
- 0.3 m (1 ft) of bunk space per head space for all systems,
- earthen lots have 4.9 m (16 ft) wide concrete aprons placed along the feed bunks,
- outdoor lots over 1,000 head have settling and detention basins designed for a 132-mm (5.2-in.) storm,
- all lots assume fence and gates at $33 per m ($10 per ft).

For comparison purposes, the construction cost for an AFO with a containment system was estimated based on the following assumptions; CAFO engineering costs/efforts would remain constant for an AFO system of the same type, the feedlot area, run-off volume, and basin size would be proportional to a 1,500 head space operation. According to the ISU Beef Feedlot Systems Manual (Lawrence et al., 2006), the engineering costs for a 1,500 and 5,000 head operation are reported as the same value since the design time will be approximately the same for both feedlot sizes. In order to justify the estimate using proportions between a 750 and 1,500 head feedlot, the AFO is assumed to be designed for a 25 year, 24-h rain event. Accounting for these assumptions, the construction cost and irrigation was calculated for the 1,500 head CAFO facility on a per head basis, and multiplied by 0.5 to yield the estimated total cost for each system component (SSB, detention basin, and irrigation system) for a 750 head feedlot.

Results

AFO Vegetative Treatment Systems

The AFO VTS facilities were separated into three categories: gravity VTS, pumped and gravity VTS, and sprinkler VTS. The gravity VTSs reported in this article are gravity flow systems where effluent is applied via gated pipe or concrete spreaders. These systems may contain a level VTA constructed at the end of the VTS. The pump and gravity VTS category is similar to the gravity VTS except for the need to pump effluent to a VTA (i.e., gravity flow is not utilized). Therefore, a pump and gravity VTS has the additional expense of a pump potentially creating higher operating cost compared to a gravity VTS. The sprinkler VTSs reported in this article consists of a pump and irrigation equipment to apply effluent to a VTA. The irrigation equipment used by the four sites presented in this article consisted of moveable towlines and solid set sprinklers. The VTS construction cost data for AFO facilities is provided in table 2.

Table 2 shows the overall cost on average for a VTS constructed on an AFO was $79 per head space while the lowest VTS design cost on average for a beef feedlot was a gravity flow VTA. These systems averaged $54 per head space with a range of $25 to $99 per head space. The feedlots ranged in size from 120 to 700 head space of cattle. Compared to the other two systems, the gravity VTS had the fewest components to design and construct which resulted in a lower overall cost.

The sprinkler VTS systems averaged $94 per head space with a range of $67 to $110 per head space. These systems were more expensive on average than a gravity VTS due to the additions of a pump and irrigation equipment. These four

Table 2. Vegetative treatment system construction costs for 14 animal feeding operations less than 1,000 head located in Nebraska, Minnesota, and South Dakota in 2009 inflation adjusted dollars.

CAFO < 1,000 Head											
					Engineering Costs			Construction Cost[c]			
VTS Type	Location	No. of Head	VTA Area (ha)	Year	Hours	Actual[a]	Normalized[b]	Earthwork	Supplies/labor	Total Cost[d] (2009 $)	2009 Dollars Per Head
Gravity VTS	NE	359	1.5	2005	36	NA	$ 3,024	$ 6,655	$ 1,345	$ 13,608	$ 38
Gravity VTS	NE	290	1.0	2006	66	NA	$ 5,544	$ --	$ 8,597	$ 16,447	$ 57
Gravity VTS	NE	700	2.9	2006	45	NA	$ 3,780	$ 9,988	$ 1,500	$ 17,757	$ 25
Gravity VTS	NE	450	1.2	2007	53	NA	$ 4,452	$ 7,500	$ 4,690	$ 18,144	$ 40
Gravity VTS	NE	120	0.2	2007	59	NA	$ 4,956	$ 1,991	$ 400	$ 8,010	$ 67
Gravity VTS	SD	450	10.2	2005	110	NA	$ 9,240	$ 21,078	$ 5,912	$ 44,722	$ 99
Pump and gravity VTS	NE	285	2.0	2006	52	NA	$ 4,368	$ 4,137	$ 17,994	$ 30,820	$ 108
Pump and gravity VTS	NE	780	2.0	2009	70	NA	$ 5,880	$ 27,852	$ 2,024	$ 35,755	$ 46
Pump and gravity VTS	SD	300	1.2	2007	239	$ 11,979	$ 20,076	$ --	$ 27,519	$ 51,889	$ 173
Pump and gravity VTS	SD	665	3.8	2006	90	NA	$ 7,560	$ 8,496	$ 28,191	$ 51,462	$ 77
Sprinkler VTS	NE	210	0.9	2009	64	NA	$ 5,376	$ 3,250	$ 12,203	$ 20,829	$ 99
Sprinkler VTS	NE	800	3.0	2009	88	NA	$ 7,392	$ 5,700	$ 40,565	$ 53,657	$ 67
Sprinkler VTS	NE	450	1.9	2007	72	NA	$ 6,048	$ --	$ 35,115	$ 44,877	$ 100
Sprinkler VTS	NE	720	3.4	2009	88	NA	$ 7,392	$ 14,735	$ 57,060	$ 79,187	$ 110

[a] Actual engineering design costs.
[b] Normalized design cost based on $84 per hour.
[c] Cost as provided for the year the system was built.
[d] Total cost associated with normalized engineering rate; for comparison, all totals were converted to 2009 using the Producer Price Index - Earthwork costs were billed with supplies/labor

systems ranged from feedlots containing 210 to 800 head of cattle. Three of the four sites used a towable sprinkler distribution system and the other used a solid set system. These sprinkler VTSs cost on average almost twice as much as a gravity flow VTSs to construct.

The pump and gravity VTS systems averaged $101 per head space with a range of $46 to $173 per head space. These facilities ranged from 285 to 780 head of cattle. The pump and gravity VTSs were on average an additional $47 more per head space than a gravity VTS making this the most expensive VTA system to construct per head space for AFOs. The additional cost per head space was due to the addition of a pump and pump station to convey liquid to the VTA. While looking at the engineering design costs for a pump and gravity VTS, one site displayed an extremely high engineering design cost compared to other systems similar in size. If this site was excluded from the average cost per head space calculation, the new overall average for these systems would be reduced to $77 per head space of cattle making these systems less expensive per head space than a sprinkler VTS. However, other factors affect the overall cost of a pumping system including the pumping distance, dynamic head and flow requirements from the pump station, pipeline size, pressure rating, and land leveling costs for gravity VTSs that are not necessary analogous for sprinkler VTSs.

Within each category, the lowest average system cost per animal space corresponded with the largest number of animals but the highest cost was not necessarily associated with the smallest number of animals. The overall cost of a VTS depends on several site specific design variables such as the amount of earthwork, the type of pump and sprinkler system, the pumping distance from the SSB to the VTA, and the design costs (hours) associated with different consulting firms. These variables were determined to be the main factors affecting the various overall costs per head space between the VTS facilities.

CAFO Vegetative Treatment Systems

The CAFO VTSs were split into three categories: gravity VTS, pump and gravity VTS, and a VIB-VTA system. The construction costs associated with nine CAFOs are provided in table 3. The gravity VTS used gravity to transport the effluent through the system while the pumped sloped VTA used a pump to transport effluent to the top of the VTA. Therefore the pumped sloped VTA contains extra construction costs compared to the gravity VTSs. Additional costs associated with a VIB-VTA system included a pump and the design/construction costs for an extra basin (the VIB). The engineering design hours for two out of the nine VTSs (one in Iowa, one in South Dakota) were unavailable. Therefore the actual engineering design cost for these systems was used instead of a normalized design cost.

The average CAFO construction cost for a gravity flow system is $79 per head space and approximately $83 per head space for a VIB-VTA system. The VIB-VTA system has a slightly higher average cost per head space for two reasons: installation of tile lines in the VIB, and purchasing a pump to transport infiltrated effluent from the VIB to the VTA. The pump and gravity VTS site showed a greater average cost per head space compared to the VIB-VTA systems; effluent at the pumped slope VTA site was transported a longer distance from the SSB to the top of the VTA due to site layout. An additional return pipe connecting the VTA to the SSB sump collected ponded effluent in the VTA and returned it back to the system. The additional piping and trenching costs associated with this type of system could be the primary factor for this higher cost per head. The South Dakota site produced the largest sloped and level VTS cost per head space at $107. Explanations for this high cost are potentially due to the greater distance from the feedlot to the VTA thus resulting in an increased earthwork cost. For the site, a long earthen channel was designed to transport SSB effluent to the VTA.

Containment Basins

The actual containment basin cost data provided by the University of Nebraska-Lincoln (table 4) resulted in an average cost of $206 per head space for an AFO facility. Data for one CAFO facility was reported resulting in a cost of $103 per head space. One of the three AFO sites purchased all new irrigation equipment, therefore the actual and new irrigation

Table 3. Vegetative treatment system construction costs for nine animal feeding operations greater than 1,000 head in 2009 inflation adjusted dollars.

CAFO > 1,000 Head											
					Engineering Costs			Construction Cost[c]			2009
VTS Type	Location	No. of Head	VTA Area (ha)	Year	Hours	Actual[a]	Normalized[b]	Earthwork	Supplies/ labor	Total Cost[d] (2009 $)	Dollars Per Head
Gravity VTS	IA	1,500	2.1	2005	246	$ 22,522	$ 20,664	$ 19,483	$ 38,734	$ 97,369	$ 65
Gravity VTS	IA	3,400	5.4	2005	222	$ 39,379	$ 18,669	$ 111,422	$ 102,360	$ 286,931	$ 84
Gravity VTS	IA	2,300	4.0	2007	208	$ 32,000	$ 17,510	$ 32,655	$ 44,326	$ 103,017	$ 45
Gravity VTS	IA	5,500	18.4	2006	NA	$ 179,507	NA	$ 107,495	$ 55,872	$ 398,790	$ 73
Gravity VTS	SD	2,000	6.4	2009	260	$ 27,181	$ 21,843	$ 118,950	$ 60,157	$ 214,416	$ 107
Gravity VTS	MN	2,750	4.6	2005	NA	$ 46,816	NA	$ 19,601	$ 150,881	$ 268,227	$ 98
VIB-VTA system	IA	4,000	1.5	2005	231	$ 29,411	$ 19,383	$ 36,963	$ 206,231	$ 322,217	$ 81
VIB–VTA system	IA	2,500	0.5	2005	318	$ 21,822	$ 26,712	$ 32,000	$ 115,658	$ 215,237	$ 86
Pump and gravity VTS	NE	1,200	4.5	2007	650	NA	$ 54,600	$ 15,493	$ 68,121	$ 150,686	$ 126

[a] Actual engineering design costs.
[b] Normalized design cost based on $84 per hour.
[c] Cost as provided for the year the system was built.
[d] Total cost associated with normalized engineering rate; for comparison, all totals were converted to 2009 using the Producer Price Index.

Table 4. Containment basin costs associated with three AFOs and one CAFO in 2009 inflation adjusted dollars

Location	No. of Head	Engineering Costs			Construction	Irrigation Costs		Total Cost[c] (2009 $)	Dollars Per Head
		Year	Hours	Normalized[a]	Cost[b]	Actual	New		
NE	800	2003	560	$ 47,040	$ 47,060	$ 55,000	$ 55,000	$ 202,413	$ 253
NE	900	2007	580	$ 48,720	$ 18,185	$ 9,800	$ 56,800	$ 134,867	$ 150
NE	800	2006	500	$ 42,000	$ 54,465	$ 25,600	$ 61,000	$ 171,642	$ 215
NE	2500	2007	560	$ 47,040	$ 99,880	$ 34,400	$ 106,160	$ 258,588	$ 103

[a] Normalized design cost based on $84 per hour.
[b] Cost as provided for the year the system was built.
[c] Total cost associated with new irrigation equipment.

costs were reported with the same value located in table 4. As mentioned previously, the total basin cost included the estimated values for new irrigation equipment as well as normalized engineering costs.

Based on economic analysis data from Lawrence et al. (2006) that have been updated to 2009 inflation adjusted dollars, an estimated containment basin system (table 5) designed for a 1,500 or 5,000 head beef operation would cost on average approximately $136 per head space and a 750 head operation would cost $205 per head space. The construction cost on a per head space of cattle basis decreased as the cattle numbers increased since the cost was spread over a larger cattle population. The trend shown in table 5 suggested an increase in animal numbers would produce a lower overall containment basin cost per head space.

Vegetative treatment systems designed for CAFOs cost less on average to construct per head space than a traditional containment basin. If all nine of the reported CAFO VTS types were averaged together, the total cost was approximately $85 per head space. This value is considerably less than a containment basin constructed for a 1,500 to 5,000 head feedlot at $167 and $105 per head space, respectively. AFOs show similar results with a total system average of $79 per head space (average across all VTS types) and an estimated 750 head containment system costing $205 per head space.

VTS Comparison to Confinement Buildings and Feedlot Systems

In order to compare the construction cost of VTSs with that of monoslope barns, open feedlots with containment basins, and hoop structures, the cost associated with constructing a feedlot needs to be included with the cost of the VTS. This additional cost was necessary since monoslope and hoop structure facilities house not only solid manure produced from the cattle, but also the cattle themselves. Adding the cost of a feedlot component to a VTS creates a complete operable animal production system (i.e., manure handing component and animal space component) comparable to a confinement building. In order to get an estimate of the total construction cost associated with an open feedlot outfitted with a VTS, the actual VTS cost per head (reported previously) was added to the estimated feedlot construction cost per head from the ISU Beef Feedlot Systems Manual adjusted for inflation to 2009 dollars. The solid manure and bedding collected from the confinement buildings was assumed to be stored inside the building until land application. Therefore no additional costs were included for manure storage or runoff control structures for stockpiled manure. After adjusting for inflation, the cost of a 750 head open feedlot (earthen) without any manure management system was $208 per head while the costs of a 1,500 and 5,000 head feedlot were $200 and $197 per head, respectively (table 6). The accuracy of this calculation is dependent upon how close the interested feedlot is to the number of cattle reported for each feedlot size in the Beef Feedlot Systems Manual. For instance, if the 720 head VTS sprinkler system costs $110 per head, an additional feedlot cost of $208 per head would yield a total system cost of $318 per head.

Based on economic analysis data from Lawrence et al. (2006) that have been updated to 2009 inflation adjusted dollars, concrete monoslope facilities cost $662, $655, and $649 per head for a 750, 1,500, and 5,000 head operations, respectively (table 7). Monoslope barns were the most expensive form of cattle feeding operations in both the AFO and CAFO categories. The total system cost for a CAFO was slightly lower than an AFO facility due to the cost being spread over a larger number of cattle.

Beef hoop structures cost approximately $395 per head in inflation adjusted 2009 dollars based on assumptions for a hoop structure as described in the system descriptions

Table 5. Estimated construction costs for a containment basin system consisting of a SSB, detention basin, and irrigation system adjusted for inflation in 2009 dollars.[a]

	750 Head	1500 Head	5000 Head
Engineering Costs	$ 58,154	$ 58,154	$ 58,154
Construction Costs	$ 52,339	$ 104,677	$ 348,924
Irrigation System	$ 43,616	$ 87,231	$ 116,308
Total	$ 154,108	$ 250,062	$ 523,386
$ per head	$ 205	$ 167	$ 105

[a] Source: Lawrence et al. (2006).

Table 6. Earthen feedlot construction costs adjusted for inflation in 2009 dollars.[a]

Facilities and Equipment	750 Head	1500 Head	5000 Head
Building	$ -	$ -	$ -
Concrete	$ 80,253	$ 157,016	$ 523,386
Feed bunks	$ 13,085	$ 26,169	$ 87,231
Fencing	$ 43,616	$ 78,508	$ 247,155
Site preparation	$ 8,723	$ 17,446	$ 58,154
Windbreaks	$ 10,468	$ 20,935	$ 69,785
Building engineering cost	$ -	$ -	$ -
Total system cost	$ 156,144	$ 300,075	$ 985,711
Total system cost per head	$ 208	$ 200	$ 197

[a] Source: Lawrence et al. (2006).

Table 7. Concrete monoslope barn construction costs adjusted for inflation in 2009 dollars.[a]

Facilities and Equipment	750 Head	1500 Head	5000 Head
Building	$ 261,693	$ 523,386	$1,744,621
Concrete	$ 207,610	$ 408,241	$ 349,173
Feed bunks	$ 13,085	$ 26,169	$ 87,231
Fencing	$ 12,212	$ 17,446	$ 46,523
Site preparation	$ 1,745	$ 3,308	$ 11,631
Windbreaks	$ -	$ -	$ -
Building engineering cost	$ -	$ 3,489	$ 3,489
Total system cost	$496,345	$ 982,040	$3,242,668
Total system cost per head	$ 662	$ 655	$ 649

[a] Source: Lawrence et al., 2006

(Honeyman et al., 2008). The cost estimate reported above assumes flooring constructed primarily of limestone screenings with a small concrete pad located in front of the feed bunk and a manure scrape alley extending the length of the barn. This system was designed for approximately 4.6 square m (50 square ft) of floor space per head (Honeyman et al., 2008).

Discussion

Vegetative treatment system design and overall construction cost depends heavily on the location of the planned VTS. Certain VTS types, such as sprinkler VTSs or pump and gravity VTSs, are typically constructed in locations where gravity cannot be used to transport effluent to a VTA (i.e., VTA is located at a higher elevation). At these locations a sprinkler VTS may be a more appropriate design than a gravity VTS and end up costing less to construct. Therefore, depending on location, some sites may be limited to a certain type of VTS. Although VTSs can be implemented at locations with less than ideal conditions, these sites typically will have larger construction costs associated with the design. For example if a feedlot is located at the bottom of a hill, then a pump and gravity VTS might be a more appropriate system than a gravity VTS since a considerable amount of earthwork might be needed to create a VTA below the feedlot. This extra earthwork results in a more expensive VTS and could potentially cost more than implementing a sprinkler VTS. Many site limitations for various VTS designs include but are not limited to the topography of the site, water table depth, soil characteristics, and producer management practices. Therefore, VTSs are designed on a site-by-site basis and the overall construction cost between different systems may be difficult to draw conclusions about which system is the least expensive to construct.

The initial construction cost of VTSs were less expensive on average to construct on a per head space basis than containment basins in both the AFO and CAFO categories. Since this analysis only reported the initial construction cost for both AFOs and CAFOs, (i.e., construction and engineering design for both VTS and basins), overall conclusions may not be drawn between these systems without including operation and maintenance cost associated with each system. Examples of operational and maintenance cost associated with both systems consist of system maintenance, life expectancy, and management labor, and opportunity cost for removing potential row crop production land by constructing VTSs. Additional research is needed to compare each of the previously mentioned operation and maintenance cost for each system in order to provide insight on the long term overall annualized cost of both systems.

The initial construction cost on average for VTSs constructed for AFO facilities produced a larger cost saving per head space than CAFO facilities when compared to a containment basin for feedlot runoff control. Although the average VTS cost savings depends on the site location and type of system, an AFO implemented with a VTS displayed a larger cost advantage than a CAFO compared to a conventional basin. The overall average cost to construct a VTS for an AFO facility was $79 per head space (average of all types) while a basin constructed for an AFO facility was $205 per head space on average. This resulted in a construction cost savings of $126 dollars per head space for an AFO. When compared to a CAFO, the overall average VTS construction cost for a CAFO facility was $85 per head space (average of all types) while the cost associated with constructing a basin ranged from $103 per head space (actual cost) to $136 per head space (estimated average, Lawrence et. al., 2006). This resulted in a cost saving of $18 to $51 per head space depending on using actual or estimated basin cost values. The cost of a VTS constructed on a CAFO feedlot ranged from a low of $45 per head space of cattle to a high of $126 per head space. Since the CAFO cost per head space for a VTS overlapped the cost for a containment basin, a CAFO VTS may not always be the lowest cost option for runoff control depending on site location and system type. Therefore, VTSs implemented on AFOs may provide a larger cost savings per animal space on average than VTSs implemented on CAFOs.

The cost of VTSs cannot be predicted based only on feedlot head space. Statistical analysis software, SAS 9.2, was used to analyze the construction cost data collected from each site. An analysis of variance (ANOVA) procedure was used within SAS to compare the means of the construction cost per head space between beef AFO and CAFO facilities and between each system type (i.e., gravity VTS, pump and gravity VTS, sprinkler VTS, and VIB-VTA system). The statistical analysis showed no significant difference between the VTS construction cost per head space of cattle for an AFO compared to a CAFO ($p = 0.07$, alpha = 0.05) while there was a statistical difference between system type ($p = 0.02$, alpha = 0.05). However, using an alpha of 0.10, the cost difference between and AFO and CAFO is significant. Since there is substantial variation and uncertainty in the dataset, it may be more appropriate to use a higher alpha. Since the p-value is halfway between the alpha of 0.05 and 0.10, it could be considered nearly significant and one could surmise that there is a difference between the cost of a VTS for a CAFO and an AFO, although it is narrow. Additionally a difference of only $8 per head was reported between the average cost per head space of the two feedlot sizes. Therefore, while there may be a subtle difference, feedlot capacity is likely not a reliable indicator of the cost of a VTS. Figure 8 supports this claim by graphically showing no visible trend between the cost per head space compared to the total feedlot size ($R^2 = 0.0001$).

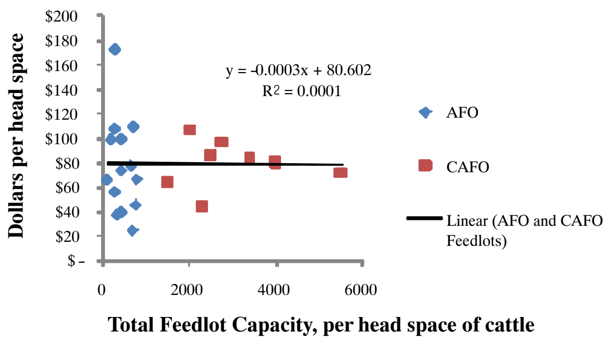

Figure 8. Graphical representation of dollars per head space vs. total feedlot capacity.

The results of the ANOVA procedure comparing the means of each system type (AFO and CAFO VTS type combined) on a per head space of cattle showed a statistical difference between two of the system types (gravity VTS, pump, and gravity VTS) using an alpha value of 0.05. This analysis showed the cost per head space for a gravity VTS was significantly different from the cost per head space for a pump and gravity VTS. If the data is analyzed with an alpha value of 0.1, a statistical difference is shown between three system types; a gravity VTS with both a sprinkler VTS and pump and gravity VTS. This means the cost per head space for a gravity VTS was significantly different than the cost per head space for a sprinkler VTS and pump and gravity VTS. The statistical analysis between system type could be slightly misleading at the 0.05 alpha level since one pump and gravity VTS recorded a system cost approximately $47 per head larger than the next largest pump and gravity VTS site. Including this site in the analysis raises the average of the pump and gravity VTS cost per head space to a value larger than the cost of a sprinkler VTS.

The total construction cost of VTSs varied on the type of system and the topography of the area. The construction cost was broken down into two categories: earthwork and supplies/labor. Earthwork cost consisted of general excavation, trenching, and site leveling while the supplies/labor category consisted of the materials used for the VTS construction (i.e., valves, concrete, labor, inlets, and outlets) and construction labor charged by the contracting companies. As mentioned previously, the in-kind costs were not included within this analysis. The construction cost for certain sites could not be broken down into smaller categories due to construction bills combining cost into broad categories. Therefore, the construction costs associated with only nine AFO sites and four CAFO sites were used to calculate the percent of construction cost. Based on these nines sites, the supplies/labor category (53%) was the largest cost associated with constructing a VTS on an AFO followed by earthwork (28%), and engineering design (19%). The CAFO analysis displayed similar results when compared to the AFO categories. Four CAFO VTSs were used to calculate the percent of each category. Results from these four CAFO sites showed the largest cost category associated with a VTS was supplies/labor (66%) followed by engineering design (18%), and earthwork (16%). An explanation for the increase in supplies/labor between an AFO and CAFO might be due to the cost associated with concrete work. The CAFOs reported in this article typically used more concrete in their VTS designs than AFOs possibly due to their larger scale and regulatory requirements. Engineering design remained approximately the same between an AFO and a CAFO (19%, 18%).

Conclusions

Three important conclusions were drawn from the research presented within this analysis. The first conclusion showed the average initial construction cost of VTSs were less expensive to construct on a per head space basis than containment basins in both the AFO and CAFO categories. The second conclusion drawn from this research showed VTSs constructed on AFOs may provide a more economical benefit than VTSs constructed on a CAFO when compared to a containment basin. This information supported the initial perceived idea that VTSs were less expensive to construct than containment basins. The third conclusion showed VTS cost cannot be predicted solely on feedlot head space.

The animal feeding operation vegetative treatment system with the lowest cost per head to construct was a gravity VTS ($54 per head average) followed by the sprinkler VTS ($94 per head average) and the pump and gravity VTS ($101 per head average). The major factors affecting the overall price of these systems was dependent upon the amount of earthwork, type of pump and sprinkler system, and pumping distance from the SSB to the VTA. Systems which use gravity to transport effluent through the VTS are generally lower cost to construct per head.

The least expensive VTS design on average for a CAFO facility was a gravity VTS ($79 per head average) followed by a VIB-VTA system ($83 per head average) The $4 per head increase for a VIB-VTA compared to a gravity VTS was primarily due to the addition of a pump and the design/construction costs associated with an extra basin (VIB).

Vegetative treatment systems designed for CAFOs cost on average $85 per head (averaged regardless of type) and range from $45 to $126 per head depending on the type of VTS system while the estimated cost of a containment basin was $105 to $167 per head depending on the number of animals. The average cost of a VTS system designed for an AFO facility was $79 per head (averaged regardless of type) ranging from $25 to $173 per head while an estimated containment system for a 750 head facility would cost $205 per head. In both cases the VTS was the lowest cost option compared to a containment system.

Monoslope barns were reported to be approximately $662 per head for a 750 head AFO and $655 per head for a 1,500 head CAFO facility (Lawrence et al., 2006) and were the most expensive system to construct for a beef manure system. Hoop structures were the next highest cost per head and could be built for approximately $395 per head (Honeyman et al., 2008). The average cost of an earthen lot with a containment basin was $361 per head while a feedlot implemented with a VTS would cost approximately $283 per head on average. Although monoslope barns and hoop structures were more expensive to construct per head, these systems handle only solid manure and are not required to handle feedlot runoff since the cattle are confined indoors.

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