XVIIth World Congress of the International Commission of Agricultural and Biosystems Engineering (CIGR)

Hosted by the Canadian Society for Bioengineering (CSBE/SCGAB)
Québec City, Canada June 13-17, 2010

EVALUATING THE PERFORMANCE OF VEGETATIVE TREATMENT SYSTEMS ON OPEN BEEF FEEDLOTS IN THE MIDWESTERN UNITED STATES

BRADLEY J. BOND[1], ROBERT T. BURNS[1], CHRISTOPHER HENRY[2], TODD P. TROOIEN[3], STEVE H. POHL[3], LARA B. MOODY[1], MATTHEW J. HELMERS[1], JOHN D. LAWRENCE[1]

[1] Iowa State University, Ames, IA <bradbond@iastate.edu>
[2] University of Nebraska-Lincoln, Lincoln, NE
[3] South Dakota State University, Brookings, SD

CSBE101057 – Presented at Section II: Farm Buildings, Equipment, Structures and Livestock Environment Conference

ABSTRACT United States Environmental Protection Agency (US EPA) regulations require concentrated animal feeding operations (CAFOs) to control open feedlot runoff resulting from storms up to and including a 25 year-24 hour storm event. Runoff collection systems commonly used in the United States for open beef feedlots consists of a basin designed to intercept runoff and provide storage until field conditions exist for land application. An alternative system being evaluated by a three-state research team is a vegetated treatment system (VTS) designed to infiltrate all of the feedlot runoff. This paper reports the runoff volumes and the mass of five physical parameters released from nine CAFO's utilizing VTS's located in the U.S. Great Plains region (six sites in Iowa, two in Nebraska, one in Minnesota). Comparisons between sites were made based on the volume and mass of these parameters retained within the system. The performances of the nine VTS varied depending on site specific rainfall, stocking densities, feedlot to VTA ratio, and system design. Five of the nine VTAs monitored in 2009 did not report an actual release from their system. The percent runoff controlled varied by site ranging from a high of 100 percent to a low of -6 percent. The overall average percent of mass reduced from five tested parameters varied from 100 to 72 percent.

Keywords: vegetative treatment system, feedlot runoff, manure management

INTRODUCTION Animal feeding operations (AFOs) with greater than 1,000 head of cattle are required by the United States Environmental Protection Agency (US EPA) to contain the runoff produced from storms up to and including a 25 year, 24 hour storm event (US EPA, 2008). AFOs are defined by the US EPA as animals confined on a lot or a facility containing no vegetation for at least 45 days per year. Based on the regulatory definition, a beef AFO is defined as a large concentrated animal feeding operation (CAFO) when the facility contains greater than 1,000 head of beef cattle.

Historically, the only runoff control option available for large CAFOs consisted of a containment basin designed to collect and store feedlot runoff. In 2003, the US EPA revised the CAFO rules allowing the use of alternative technologies that meet or exceed the performance of traditional containment basins. One alternative technology of interest for producers and researchers was vegetative treatment systems (VTS). The majority of the previous research on these vegetative systems was performed on animal feeding operations smaller than 1000 head since federal regulations did not recognize these systems for use on CAFOs until 2003 (Koelsch et al., 2006). Khanijo et al. (2008) and Andersen et al. (2009) have reported monitoring and performance data from VTSs in Iowa designed to control and treat runoff from large beef CAFOs. Additional research is needed to test and confirm the performance of these systems in the Midwestern United States.

The 2006 to 2008 VTS performance data for six large CAFO facilities located in Iowa was reported by Andersen et al. (2009). In 2009, an additional year of monitoring was performed at these same six sites located in Iowa with three additional sites located in Minnesota and Nebraska. This paper evaluates the 2009 VTS performance data for nine sites located in the Midwestern United States. The nine locations represented various configurations of vegetative treatment systems, weather conditions, and geographical characteristics.

METHODS The nine VTSs analyzed were constructed on animal feeding operations containing greater than 1,000 head of beef cattle. All of the feedlots reported in this paper were permitted under National Pollution Discharge Elimination System (NPDES) permits and complied with state and federal regulations during the time of construction. The location of each feedlot reported within this paper is displayed in figure 1.

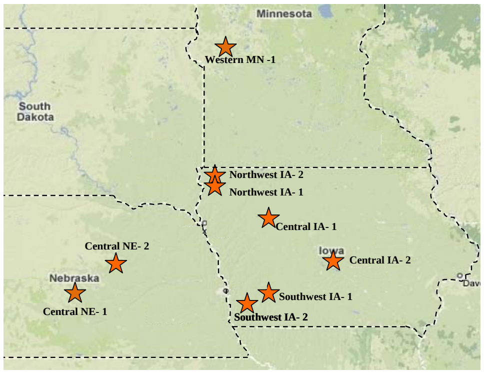

Figure 1. Nine VTSs monitored on large CAFOs in the Midwest.

Various combinations of VTS designs were located on the nine feedlots reported within this paper. Typical VTS designs have consisted of the following components: a solid settling basin (SSB), optional vegetative infiltration basin (VIB), and a vegetative treatment area (VTA). The designs varied from site to site depending on topography, land availability, and feedlot management considerations. Examples of various VTSs include but are not limited to sloped or sloped and level VTAs and pump sloped VTAs; descriptions for the VTS alternatives are provided in Bond et al. (2009). Some of the CAFOs reported within this paper contained multiple VTSs while others utilized only one VTS for the entire feedlot. Sites containing multiple VTSs and outlets typically contained one intensively monitored system for research data collection. Only the performance data collected from these research systems was reported within this paper. The individual research VTS information is provided in table 1.

The data reported in this paper represents the mass of the analyzed physical parameters and flow volume leaving each VTS component for the 2009 monitoring season. The 2009 monitoring season was site specific and depended on location and local weather conditions. The season typically began mid March and extended through the middle of November. Runoff samples were collected from either an automated sampler or by collecting grab samples during site visits. These samples were collected after each component of the VTS (i.e. SSB, VIB and VTA).

Table 1. 2009 research VTS information by site

2009 Research VTS Information

Parameter	Central IA 1	Central IA 2	Northwest IA 1	Northwest IA 2	Southwest IA 1	Southwest IA 2	Western MN 1	Central NE 1	Central NE 2
Capacity, head	1000	650*	1400	4000	2300	1200	1750	1200	1700
Feedlot Area, ha	3.09	1.07	2.91	2.96	7.49	3.72	3.56	4.8	4.76
Feedlot Surface	Earthen	Earthen	Earthen	Concrete	Earthen	Earthen	Earthen	Earthen	Earthen
Stocking Density‡	31	16	21	7.4	33	31	20	40	28
Feedlot Slope, %	2.3	0.6	4.0	3.0	7.5	8.6	4.0	2.5	0.2
SSB Volume, m^3	4289	51	3710	110	11550	6275	807	5029	NA†
VIB Area, ha	-	0.32	-	1.01	-	-	-	-	-
VTA Area, ha	1.53	0.24	1.68	0.91	4.0	3.46	3.524	4.45	3.8
VTA Length, m	313.9	76.2	478.5	109.7	121.9	298.7	91.4	243.8	365.8
VTA Width, m	48.7	31.7	35.1	54.9	329.2	115.8	385.6	19.5	142.34
Feedlot:VTA ratio	2 : 1	1.9 : 1	1.5 : 1	1.8 : 1	1.9 : 1	1.1 : 1	1 : 1	1.1 : 1	1.3 : 1

* Old permit was 800 Head

† This site utilizes a settling bench

‡ m^2 per head

To compare the flow volumes and mass of physical parameters released from each VTS component across the site, the data was normalized to account for variability in feedlot size (i.e. head of cattle, feedlot area) and annual precipitation. Therefore, the flow volumes (m^3) and mass release data (kg) were reported two ways, on the basis of 100 head of cattle per cm of annual rainfall and on the basis of feedlot area (hectare) per cm of annual rainfall. Some systems contained a monitored VTA outlet while others contained a level VTA or an earthen berm to minimize the chance of a release event from the system but not to a stream. For the purpose of this paper, a release from the VTA implies effluent leaving the system (i.e., ponding behind the berm and recycling events do not count towards an actual release). Effluent volume and mass data calculated during VTA recycling events were reported within this paper but were noted as not leaving the system.

Site Descriptions

Site descriptions of the nine VTS reported within this paper are provided in the following paragraphs. A complete description of the six VTS located in Iowa along with the monitoring protocols implemented from 2006 to 2008 was reported by Andersen et. al.

(2009). The Iowa site descriptions reported below provide a brief summary of the system including any site modifications made during the 2009 monitoring season.

Central Iowa 1 The VTS research portion consisted of one SSB and two VTAs to handle and treat runoff from 3.09 ha of earthen feedlot area. Earthen berms located around the feedlot conveyed effluent into the SSB where solids were allowed to settle out of suspension. The SSB outlet control structure consisted of a V-notch weir and a knife-gate allowing the producer to control the rate and amount of effluent applied to the VTA (Andersen et. al., 2009). Two pipes located in the outlet structure divided the effluent stream to produce similar effluent VTA loadings delivered to each of the VTAs. Concrete spreaders were used at the top of the VTA to evenly distribute effluent across the VTA inlet. Three earthen spreaders were constructed across each VTA to slow down the flow and redistribute the effluent across the VTA (Andersen et. al., 2009). Automated monitoring equipment located at the VTA H-flume outlet was used to measure flow and to sample release events leaving the system. A release from the system does not imply a direct release to surface waters of the state.

Central Iowa 2 The research portion of the VTS consisted of one SSB, one VIB, and one VTA. The SSB at this site utilized a porous dam constructed with round bales of hay to slow the feedlot runoff and filter the effluent reducing the amount of solids traveling through the SSB (Andersen et. al., 2009). A manually operated gate valve was used to release effluent from the SSB to the VIB. A network of independent tile drainage pipes was installed beneath the VIB soil to encourage drainage through the soil profile. The tile lines transported the infiltrated effluent to a sump, and a pump was then used to apply the effluent to a VTA through gated pipe. VTA releases were monitored using automated sampling equipment and an H-flume. A release from the system does not imply a direct release to surface waters of the state.

Northwest Iowa 1 The research portion of the VTS consisted of one SSB releasing effluent onto one VTA. Concrete spreaders were used to evenly apply effluent across the top of the VTA. Monitoring equipment was installed at the SSB and VTA outlet to measure and sample flow leaving each component. An earthen berm was constructed before the VTA outlet during June of 2009 to minimize releases resulting from direct rainfall onto the VTA. The berm was approximately 0.3 meters (12 inches) tall and contained two separate effluent outflow pipes to safely release ponded effluent located within the VTA (figure 2). The first pipe contained a gate valve allowing the producer to control the amount of runoff ponded in the bottom of the VTA to minimize vegetation stress from saturated soil conditions. The second pipe served as an emergency overflow system to safely remove effluent in the case of a large ponding event. Runoff released from either of these pipes did not necessarily mean a release to surface waters. Effluent from this VTA received further vegetative treatment before leaving the system through a monitored H-flume outlet.

Northwest Iowa 2 The VTS research portion at this site consisted of one SSB, one VIB, and two VTAs. The feedlot surface at this site was concrete. Effluent collected in the SSB where solids were allowed to settle. PVC stop logs were installed at the SSB outlet to provide flow control for the effluent released into the VIB. The flow leaving the SSB was measured in an H-flume. The effluent then entered a VIB where a grid of drainage tile pipes collected infiltrated effluent and conveyed it into a sump. A pump was used to transfer the effluent to a gated pipe at the top of the VTAs. In 2009, an additional VTA was constructed increasing, the VTA total to three. The new VTA was constructed to provide a larger application area to treat feedlot runoff. The additional VTA was constructed to the east of the original VTAs and utilized the same effluent application system as the original two VTAs. The total VTA plus VIB area increased from 1.61 to 1.91 hectares and changed the feedlot to VTA ratio from 1.84:1 to 1.5:1. The new VTA became fully operational and began accepting effluent from the VIB in August 2009. The SSB outlet structure was also modified in 2009 to utilize an organic filter to provide further effluent treatment before entering the VIB. The filter design consisted of a 6.1 by 9.1 meter (20 by 30 foot) concrete structure (figure 3) with a sloped entrance ramp for solids and filter removal. Two steel fabricated fences extended across the structure to confine the filter material and to keep it from floating away with the effluent. After the filter was operational, square wooden posts were bolted together and placed on top of the filter material to compact the material and help keep it in place. The producer has experimented with various filter materials, including corn cobs and soy bean stover.

Southwest Iowa 1 Ten VTAs and one SSB provided runoff control and treatment for 7.49 ha of feedlot area. Earthen berms constructed around the feedlot conveyed runoff into the SSB where solids were allowed to settle out of suspension. A butterfly valve released effluent from the SSB into a system of gated pipe extending across the top of all ten VTAs. In 2009, two additional VTAs were constructed to provide additional application area to treat effluent. These new VTAs were located to the west of the original system. However, to establish vegetation, they were nonoperational during the 2009 monitoring season.

Figure 2. Northwest IA 1 constructed an earthen berm located in front of the VTA outlet.

Figure 3. Northwest Iowa 2 SSB filter design

Southwest Iowa 2 The research portion of the VTS consisted of one SSB and one VTA. During a rainfall event, effluent from the feedlot was collected in the SSB and was then applied to a VTA through gated pipe. A knife-valve was used to control the effluent leaving the SSB. The management practices in 2009 were modified to include closing a gate valve located at the VTA outlet. During the 2006 to 2008 monitoring seasons, this valve was left open allowing a release to occur from the VTA. The entire 2009 monitoring period was operated with the valve closed. This modification was instrumented to retain direct rainfall runoff within the system especially during larger rainfall events.

Western Minnesota 1 The research VTS consisted of a 3.56 hectare feedlot permitted for 1,750 head of beef cattle. Runoff from the feedlot's 7 pens was drained into three concrete settling basins located on the east side of the pens (Ostrem, et al., 2009). The release structure at each basin consisted of a boarded gate operated manually by the producer. The boarded gate was used to release effluent into an H-flume where an automated sampler was used to collect samples and record flow leaving the basin. If research personal were present during a release, grab samples were collected from the H-flume. Effluent from the H-flume entered concrete spreaders extending the entire length of each basin. The spreaders evenly applied effluent across the top of the VTA. An earthen berm surrounded the VTA to contain any effluent reaching the end of the system.

Central Nebraska 1 This site contained an earthen feedlot permitted for 1,200 head of beef cattle. During a precipitation event, feedlot runoff collected within four SSBs located within the feedlot. An underground pipe network connected all four SSBs and gravity conveyed the effluent from the three upper SSBs into the fourth, lower SSB. During VTA application events, the producer released effluent from the fourth SSB into a concrete sump. A pump transported the effluent through an underground pipe to the top of the VTA where it was applied to one of eight VTA distribution areas. The applied effluent then traveled down the VTA and was allowed to infiltrate into the soil profile where vegetation utilized the nutrients contained within the effluent. An earthen berm located at the bottom of the VTA caught excess runoff which was then conveyed along a vegetated channel to a collection pipe where effluent was recycled back to the pumping station to create a closed system. Samples and flow measurements were collected by two automated samplers stationed in the sump and runoff return line. VTS management at this site used a "forced release" application method where effluent was applied to the VTA until runoff was produced through the return line.

Central Nebraska 2 This site maintained one VTA (3.8 hectares) centrally located between two feedlot pens containing a combined 3,000 head of beef cattle. This site utilized settling benches instead of settling basins to settle solids. A settling bench consisted of a level area located below a feedlot designed to reduce the velocity of the runoff leaving the feedlot allowing solids to settle out of suspension. The settling bench located at this site extended the entire length of the feedlot and was designed to have even flow across the entire bench. Since the feedlot runoff did not converge to a common point before entering the VTA, difficulties with monitoring and sampling this runoff were experienced. An automated sampler located at the VTA outlet pipe was used to collect runoff samples leaving the system.

RESULTS AND DISCUSSIONS

Flow & Mass Data The 2009 flow volumes, percent runoff controlled, and the mass release data for the SSB and VTA are reported in table 2, 3, and 4. The 2009 flow data represents the total flow recorded leaving or entering each VTS component analyzed on both a per 100 head per cm of rain (animal basis) and a per feedlot area per cm of rain basis (area basis). Normalizing the flow data two different ways (i.e., cattle based, area based) exposed certain facilities' traits while suppressing others in such way that may not be not have been shown using only one method. On the basis of animal number, Central IA 2, Northwest IA 2, and Western MN 1 displayed the lowest volume of SSB release (3.9, 2.7, 2.7 cubic meters per 100 head of cattle per cm of rainfall). These three sites had the highest cattle stocking densities compared to the other six sites. Specifically, Northwest IA 2 was a concrete feedlot and had the largest stocking density; this spread the flow volume over a large number of animals and resulted in the lowest flow volumes on a per animal basis. Conversely, when the same site was analyzed based on feedlot area, it appeared to have the second largest SSB volume released per area. However, Central IA 2 and Western MN 1 both still had the lowest flow volumes when analyzed based on feedlot area. The SSB flow at Central IA 2 was calculated using stage storage curves due to a leaky gate valve allowing effluent to seep out of the basin. Therefore, error could be associated with the release volumes monitored at this site. Another interesting point, Western MN 1 received 56 cm of rainfall while Central IA 2 received 82 cm. These totals represent the lowest and highest 2009 rainfall totals reported across the nine sites.

The sites were also ranked based on the percent runoff controlled by the VTS. Three VTS sites (Central IA 1, Southwest IA 2, Western MN 1) maintained 100 percent control of the 2009 runoff from the feedlot (i.e. no VTA release event). Out of the six remaining sites that recorded a release event, two of the sites (Northwest IA 2, Central NE 1) utilized an effluent recycle pipe confining the effluent within the system. The percent runoff control calculated for Central NE 1 (73%) may not represent the overall performance of the VTS due to a “forced release” effluent application method. Under this method, effluent was applied to the VTA until a “release” event occurred. This type of management produced a lower percent runoff control value since a “release” was expected during each VTA application event. Central IA 2 produced a negative percent runoff control (-6%). A negative value indicated more flow left the VTA than was applied from the SSB. Explanations for this negative value were due to a combination of rainfall landing on the VTA and VIB surface along with background tile flow collected from the VIB. Due to SSB monitoring difficulties experienced at Central NE 2, a percent runoff control value could not be calculated.

Five of the nine VTAs monitored in 2009 did not report an actual release from their VTS. Two of the VTS systems (Central NE 1, Northwest IA 2) utilized an effluent recycle line at the end of their VTA allowing the producer to “recycle” effluent from the bottom of the VTA back into the system creating a closed circuit. Both of these systems had similar monitored “release” volumes per feedlot area at 7.6 m^3 for Central NE 1 and 7.2 m^3 for Northwest IA 2.

The mass of five parameters released from the SSB per site is displayed in table 3 and represents the total mass entering the VTS. The mass data calculated for each site was ranked on TS as this parameter accounted for particulate and dissolved transport relating to the other four parameters tested. Mass was analyzed on both a 100 head per cm of rain and a per feedlot area per cm of rain basis. Unlike the flow volume analysis, the mass analysis appeared to make more sense when analyzing the data on a per head basis since each animal will excrete a certain amount of nutrients. A feedlot with a larger stocking density should produce more nutrients per area which is shown at Northwest IA 2. Central IA 2 produced the least amount of mass per 100 head per cm of rainfall for all five parameters

Table 2. Percent runoff controlled and volume released from VTS component

(† m^3/100 head/cm rain, ‡ m^3/ lot ha/ cm rain)

					Effluent Released				
	Cattle	Feedlot Area	VTS Area	2009 Rainfall	Animal Basis †		Area Basis‡		Percent Runoff
Site	Head	Hectares	Hectares	cm	SSB	VTA	SSB	VTA	Controlled
Central IA 1	1000	3.09	1.53	63.2	10.8	0.0	34.8	0.0	100
Southwest IA 2	1200	3.72	3.46	70.0	11.5	0.0	37.0	0.0	100
Western MN 1	1750	3.56	3.52	56.7	2.7	0.0	13.1	0.0	100
Northwest IA 1	1400	2.91	1.68	68.1	9.8	1.2	46.9	5.5	88
Northwest IA 2$^{\pm}$	4000	2.96	1.91	70.3	2.7	0.5	36.9	7.2	81
Central NE 1$^{\pm}$	1200	4.8	4.45	79.0	9.9	3.0	24.8	7.6	73
Southwest IA 1	2300	7.49	4.0	79.8	10.9	3.5	33.4	10.7	68
Central IA 2	650	1.07	0.56	82.4	3.9	4.2	23.8	25.3	-6
Central NE 2*	1700	4.8	3.8	57.7	---	2.6	---	9.4	---

* SSB flow data from this site is unavailable due to monitoring difficulties

± Site utilizes an effluent recycle pipe

Table 3. Mass of analyzed parameters released from the solid settling basin per site

(† kg/100 head/cm rain, ‡ kg/ lot ha/cm rain)

SSB-2009

Site	TS†	TS‡	NH$_3$-N†	NH$_3$-N‡	COD†	COD‡	Total P†	Total P‡	TKN†	TKN‡
Central IA 2	19	116	0.30	1.8	16	98	0.35	2.1	0.9	5.4
Western MN 1	20	101	0.36	1.8	20	98	0.26	1.3	1.1	5.5
Central NE 1	31	79	0.91	2.3	20	49	0.56	1.4	1.7	4.3
Central IA 1	36	116	0.46	1.5	32	103	0.57	1.9	1.4	4.7
Southwest IA 1	49	149	0.73	2.3	23	70	0.56	1.7	1.6	4.8
Northwest IA 1	64	307	1.35	6.5	40	191	0.66	3.2	2.8	13.3
Northwest IA 2	87	1180	1.21	16.4	81	1098	0.58	7.9	3.6	48.1
Southwest IA 2	88	283	1.00	3.2	48	156	0.84	2.7	2.6	8.3
Central NE 2*	---	---	---	---	---	---	---	---	---	---

* SSB concentration data from this site is unavailable due to monitoring difficulties

Table 4. Mass of analyzed parameters released from the vegetative treatment area per site

(† kg/100 head/cm rain, ‡ kg/ lot ha/cm rain)

VTA-2009

Site	TS†	TS‡	NH$_3$-N†	NH$_3$-N ‡	COD†	COD‡	Total P†	Total P‡	TKN†	TKN‡
Northwest IA 2*	3.0	40	0.08	1.04	2.8	38	0.03	0.45	0.18	2.38
Northwest IA 1	4.9	24	0.07	0.31	2.5	12	0.10	0.48	0.20	0.96
Central IA 2	7.0	43	0.06	0.38	4.8	29	0.07	0.42	0.23	1.38
Central NE 1*	7.6	19	0.20	0.50	4.8	12	0.14	0.35	0.43	1.09
Southwest IA 1	11.1	34	0.09	0.26	4.7	14	0.09	0.29	0.26	0.81
Central NE 2$^{\pm}$	27.6	99	0.49	1.75	14.8	53	0.33	1.19	0.97	3.47
Central IA 1	---No Release Occurred In 2009---------------------------------------									
Southwest IA 2	---No Release Occurred In 2009---									
Western MN 1	---No Release Occurred In 2009--									

* Site utilizes an effluent recycle pipe

± Only one VTA sample was collected

tested with the exception of Total P. This site also utilized a filter constructed from round hay bales placed in front of the SSB to assist in removing solids before entering the basin. The total solids data analyzed on a per head basis (i.e. kg per 100 head per cm of rain) showed a relatively steady increase in mass released across the eight sites. If the data was analyzed on a feedlot area basis (i.e. kg per lot hectare per cm rain), three sites (Northwest IA 1 & 2, and Southwest IA 2) released approximately twice as much mass from the SSB (307, 1180, 283 kg/hd/cm-rain) as the other five sites. These three sites had relatively large feedlot slopes (4, 3, 8.6 percent) resulting in effluent flowing at an increased rate allowing more solid transportation. Northwest IA 2 was also the only concrete feedlot reported within this paper.

Three sites recorded no VTA mass released in 2009 while six sites recorded a release from the system. Central NE 2 produced the largest mass released on both per head and per lot area analysis. Only one sample was collected for the 2009 monitoring season, therefore this single sample may not accurately represent the entire VTA flow leaving the system. Northwest IA 2 produced the least amount of total solids (3 kg/100hd/cm-rain) leaving the VTA. This site utilizes a VIB to filter the effluent by infiltrating through the soil.

Table 5 displays the percent mass reductions produced by each site. Sites displaying a 100 percent mass reduction did not have a monitored VTA release during the 2009 monitoring season. Excluding the sites without a monitored release, Northwest IA 2 produced the largest mass reduction (i.e., average reduction across all five parameters) while Central NE 2 produced the lowest percent mass reduction. As mentioned previously, Northwest IA 2 and Central NE 1 both contained an effluent recycling pipe. Therefore a release does not mean a release leaving the system. Due to the "forced release" management practices of Central NE 1, the percent mass reductions may not reflect the actual performance of the system. One would expect the mass reductions to increase for this system if the "forced release" concept was not used.

Table 5. Percent vegetative treatment system mass reductions

2009 Percent Mass Reductions

Site	2009 Rainfall cm	NH_3-N	COD	Total P	TKN	TS	Average
Central IA 1	63.2	100	100	100	100	100	100
Southwest IA 2	82.4	100	100	100	100	100	100
Western MN 1	68.1	100	100	100	100	100	100
Northwest IA 2[†]	70.3	94	97	94	95	97	95
Northwest IA 1	79.8	95	94	85	93	92	92
Southwest IA 1	70.0	88	80	83	83	77	82
Central NE 1[†]	56.7	78	76	75	75	76	76
Central IA 2	79.0	79	70	80	75	63	72
Central NE2*	57.7	---	---	---	---	---	---

* Percent mass reduction could not be calculated due to minimal SSB volume measurements

[†] Site utilizes an effluent recycle pipe

CONCLUSION The performances of the nine monitored VTSs varied depending on rainfall, stocking density, feedlot area, and most importantly by VTS designs. In 2009, five of the nine VTSs recorded no VTA release from the system; two of the five sites that did not have a VTA release utilized a recycling pipe.

The VTS percent runoff control ranged from a high of 100 percent down to a low of -6 percent. By excluding the site associated with the -6 percent runoff control, the next lowest percent runoff control was Southwest IA 1 at 68 percent control. Management practices along with various VTS designs likely affect the percent runoff controlled from the system. The analysis of the average mass released for five tested parameters from the SSB and VTA showed contrasting results for certain sites when analyzed on both a kg per 100 head per cm of rainfall and on a kg per feedlot area per cm of rainfall basis. The overall average percent of mass reduction based on the five measured parameters through the VTS ranged from a high of 100 percent (i.e., no monitored 2009 VTA release) to a low of 72 percent.

Acknowledgements. Information collected for this paper was funded by USDA- NRCS EQIP funds, EPA Section 319 funds administered by the South Dakota Department of Environment and Natural Resources, EPA Section 319 funds administered by the Nebraska Department of Environmental Quality, the Nebraska Environmental Trust Fund, and a USDA-NRCS Conservation Innovation Grant.

Special thanks to Daniel Ostrem, Crystal Powers, Daniel Andersen, and others involved with data collection at the University of Nebraska-Lincoln, South Dakota State University, and Iowa State University.

REFERENCES

Andersen, D., R. Burns, L. Moody, I. Khanijo, M. Helmers, C. Pederson, J. Lawrence. 2009. Performance of Six Vegetative Treatment Systems for Controlling Runoff form Open Beef Feedlots in Iowa. ASABE Paper No. 097054. St. Joseph, Mich.: ASABE

Bond, B. J, R. T. Burns, T. P. Trooien, S. H. Pohl, C. Henry, L. B. Moody, M. J. Helmers, J. D. Lawrence. Comparison of Construction Costs for Vegetated Treatment Systems in the Midwest. ASABE Paper No. 096524. St. Joseph, Mich.: ASABE.

Khanijo, I. 2008. Monitoring Vegetative Treatment System Performance for Open Beef Feedlot Runoff Control. M.S. thesis. Ames, IA. Iowa State University. Department of Agricultural Engineering.

Koelsch, R.K., J.C. Lorimor, K.R. Mankin. 2006. Vegetative treatment systems for management of open lot runoff: review of literature. *Applied Eng. in Agric*. 22(1):141-153.

Ostrem, D. T., T. P. Trooien, S. H. Pohl, A. Mathiowetz, R. Bogue, E. Hohbach, N. Brandenburg. 2009. Supporting Data for the Design Characteristics of Solid Settling Basins in a VTS. ASABE Paper No. SD09-503. St. Joseph, Mich.: ASABE

US EPA. 2008. Federal Register. Vol. 73, No. 225. Washington, D.C.