SECTION 319 NONPOINT SOURCE POLLUTION CONTROL PROGRAM

FINAL REPORT

Evaluating the performance of vegetated treatment areas

by

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South Dakota State University

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This project was conducted in cooperation with the State of South Dakota and the United States Environmental Protection Agency, Region 8.

Grant numbers 9998185-01 and 9998185-04

Executive Summary

Project Title: Evaluating the performance of vegetated treatment areas

Grant numbers 9998185-01 & 9998185-04

Project Start Date: 1 December 2004
Project Completion Date: 31 December 2008

Funding:

Total EPA Grant C9998185-01		$20,000.00
Total EPA Grant C9998185-04		$260,300.00
State Conservation Commission grant	27,698.30	
Local Private cash match	48,927.65	
Local Private In-kind match	111,640.00	
SDSU Salaries and Benefits	28,708.00	
SDSU Unrecovered Indirect costs	34,068.00	
Subtotal Match		$251,041.95
Total Expenditures		$531,341.95

Summary of Accomplishments

Simulations performed at the beginning of this project indicated that sediment basin design and management could greatly improve the performance of the vegetated treatment system (VTS). Having adequate storage capacity in the sediment basin and releasing the water slowly to the vegetated treatment area (VTA) or waiting a day or two before allowing water to flow to the VTA can increase the simulated performance of a VTS and reduce potential releases from the VTA.

Performance data for 13 site-years have been collected. Six different sites have been part of this study. One site was discontinued after one year of monitoring and observation showed repeated water release from the VTA. Owners decided to not invest in upgrading their VTS. At another site, VTS performance was markedly improved (and VTA releases decreased) when water was adequately spread across the top of the VTA using gated irrigation pipe instead of from a single sediment basin outlet. At a western SD site, water was released from the VTA once in each of two successive years in response to rainfall amounts that exceeded the 25-yr, 24-hr storm. Other than those two large storms, there were no surface water releases from the VTA'S at the western SD site, a west-central SD site, or a west-central MN site. Nutrients- N and P- are accumulating in the soils of the VTA's, as is common in these systems. Harvested vegetation can remove large amounts of nutrients from the VTA but not as much as is added in the sediment basin outflow.

The project has been publicized via various outlets and media. Four field days were held at SD sites in 2008. Press releases and news stories have been picked up by various media and made available via the web. Three graduate students have completed their studies addressing various aspects of VTS performance. A fourth student is funded by the subsequent NRCS CIG grant and expects to receive an MS in Engineering in May 2010. Technical papers have been presented at a national waste management symposium and many regional conferences.

Monitoring at a subset of the sites included in this project will continue. That monitoring will continue through 2010 and is funded with an NRCS CIG grant via Iowa State University.

Introduction

Beef producers in South Dakota and across the eastern Great Plains and Midwest have expressed interest in Vegetated Treatment Systems (VTS's) for handling runoff from feedlots. Perceived advantages of VTS's include lower construction costs, reduced management requirements, and better aesthetics. Also, VTS's may perform better where soils, geology, topography, aesthetic, or other considerations might hinder the performance of a runoff basin. This project was performed to explore and measure the performance of VTS's in South Dakota.

Project Goals, Objectives, and Activities

Goal

The goal of this project was:

Evaluate the technical and financial feasibility of vegetated treatment areas (VTA's) as a best management practice for nutrient and sediment loads from animal feeding operations holding less than 1,000 animal units.

Objectives and Tasks

Objective 1: Characterize and establish the pilot AFOs that will be used to test the effectiveness of VTAs as an alternative animal waste management system BMP.

Task 1. Characterize and establish five VTA sites.

Products: Six VTS sites were used in various roles for this project.

Objective 2: Measure the surface water quality impacts of VTA's at the sites

Water quality effects of the VTA's will be determined by measuring the above-ground components of the water balance. Potential groundwater impacts will be estimated based on the remainder of the water balance (drainage or percolation) and soil samples analyzed for nutrient concentrations.

Task 2: Characterize water, nutrient, salt, sediment, and fecal coliform bacteria flows at each site.

Products: Results are outlined in Section 4, Monitoring Results.

Objective 3: Compare the performance and financial feasibility of each VTA to a wastewater basin at the same site.

Task 3: Compare performance of VTA systems to simulated performance of basins at all sites.

Products: Early simulation work indicated that VTS's could perform better than basins in some situations. This work was detailed in the first thesis produced within this project, by Sara Smith. For example, simulation of conditions from 1988 to 2004 showed greater water release from a basin at the

Miner site (8500 m^3 for the basin and 1200 m^3 for the VTS) and the Roberts site (15000 m^3 for the basin and 10500 m^3 for the VTS) However, simulations indicated greater water releases from a VTS at the Haakon site (3000 m^3 from a VTS and 2000 m^3 from a basin for the south side, 800 m^3 from a VTS and 0 from a basin for the north side). Simulations showed no release for either a VTS or a basin at the Meade site.

The simulation models have undergone extensive modification since that work was completed. Data from multiple CAFO's and AFO's from South Dakota, Minnesota, Iowa, and Nebraska (at least) will be used in the updated simulation models as part of the CIG project headed by Iowa State U and under which we are monitoring CAFO's.

Task 4: Complete economic comparisons of systems at all sites.

Products: The paper entitled "Comparison on construction costs for vegetated treatments systems in the Midwest", ASABE Paper No. 096524, was presented at the 2009 ASABE Meetings in June 2009. The senior author was, Bradley J Bond, Iowa State University. The paper outlined the constructions costs for VTS's and compared them to constructions costs for basins, monoslope barns, and hoop structures. Design and construction cost data for systems from South Dakota, Minnesota, Iowa, and Nebraska were included in the paper. The SD and MN data included information for 4 of the sites in this project. This paper is being revised based on reviewer comments then will be submitted to a peer-reviewed journal for potential publication.

The abstract of the ASABE paper follows:

"Vegetated 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 paper reports the actual construction costs associated with 21 VTSs (eight on permitted Concentrated Animal Feeding Operations (CAFOs) and 13 on non permitted Animal Feeding Operations (AFOs)) located within Iowa, Minnesota, South Dakota, and Nebraska. The VTS construction costs are reported on a per head basis in 2009 adjusted dollars for each system. Cost comparisons are presented between CAFO and AFO facilities, by location and by system type. Additionally, estimated construction cost comparisons between open feedlots with VTS systems, open feedlots with containment basins, monoslope barns and hoop structure beef production systems are provided. Results from the cost comparison indicate that monoslope barns with concrete floors are the highest cost at $621 per head on average followed by hoop structures at $395 per head. Vegetated Treatment Systems designed for CAFO facilities ($77 per head avg.) are less expensive to construct than a traditional containment basin ($129 per head avg.) The same results indicated that an AFO VTS ($62 per head avg.) was less expensive to build than a containment basin on a similar facility ($195 per head). The data indicated that the least expensive VTS for an AFO is a sloped or sloped and level VTA ($42 per head avg.) followed by a pump sloped VTA ($68 per head avg.) and a sprinkler VTS ($87 per head avg.)."

In addition, economic analyses can include the following exercise, using the Miner site during 2008 as an example. The dry matter yield for the two-harvest system was 8.25 Mg/ha (Table 3). For a hay value of

$88/Mg, the hay value from the Miner VTS in 2008 was $726/ha. The inflows to the VTA carried 818 kg N/ha and 212 kg P/ha. If N is valued at $0.66/kg and P at $0.44/kg, the 2008 inflow of these two nutrients represented a value of $633/ha. Potential alternate uses of the nutrients include application to other, higher-valued crops. That application would incur application costs, either by performing or hiring land-application, or through capital investment such as irrigation equipment to apply and water and nutrients.

Task 5: Information Transfer (I&E)

Products: A web site was established for this project (abe.sdstate.edu/vts). The site contains maps, stakeholder meeting minutes, images, reports, FAQ's, and other links. Other products are outlined in Section 6, Summary of Public Participation.

Technical reports from this project have included two MS theses in Engineering (emphasis: Agricultural and Biosystems Engineering). A third is expected in May 2010 but is not supported by this project. Papers have been presented at various technical conferences, including the National Air Quality and Waste Management Symposium in Sept 2007, ASABE conferences, multiple Eastern South Dakota Water Conferences, and others.

A series of articles was published in the SD Cattlemen's Association magazine during 2008. Articles in the addressed each site and highlighted the owners and their contributions to SDCA and the project.

A "10-minute seminar" and various other articles and stories were produced by SDSU Ag Communications and published via the web.

Field days were held at the four active VTS sites in SD during August 2008. A total of 110 people participated in the field days.

Objective 4: Develop recommendations for managing perennial grasses used as the vegetated component of a VTA based AWMS.

Task 6. Evaluate the effects of vegetation harvest systems on the ability of the VTA to maintain filtering capabilites and produce high quality forage.

Products: Results are outlined in Section 4, Monitoring Results.

3.0 Best Management Practices Developed and/or Revised

No BMP's were developed in this project but the engineering of VTS's was explored and tested extensively. The data from this project will be used in conjunction with data from other sites (Iowa, Nebraska) to develop design and management guidelines for VTS's in the future. Also, EPA will be evaluating simulation results to compare performance of VTS's to simulated basins at the same sites, to help them evaluate the long-term viability of VTS's (compared to basins) within the Federal guidelines for animal waste and runoff management.

4.0 Monitoring Results

4.1 Simulation

The VTS model was used to simulate discharge of water, nutrients, and solids (among other things) from the VTA, based on input soil, feedlot, and VTS parameters and weather data. An early version of the model was used in the early phases of this project to help identify the strengths and shortcomings of VTS's. Simulation model results were not used to evaluate the performance of the various VTS's themselves, but to show potential for performance and areas of improvement. The VTS model was developed at Iowa State University (ISU). The results of our model runs have been used by the engineers and scientists at ISU to help improve and refine the model. An updated version of the VTS model is currently being tested at ISU and is planned for calibration and use with our data as part of the data analysis and VTS performance evaluation in the followup research project, funded by USDA-NRCS (via CIG) and administered by ISU.

Simulations in our project showed that discharge of solids and water from the VTA are sensitive to change of input parameters such as soil bulk density and sand and clay content but not sensitive to parameters such as available water content and hydraulic conductivity (Fig. 1). Thus, soil sampling to obtain accurate estimates of parameters such as bulk density and sand and clay content would result in the greatest increase of simulation accuracy.

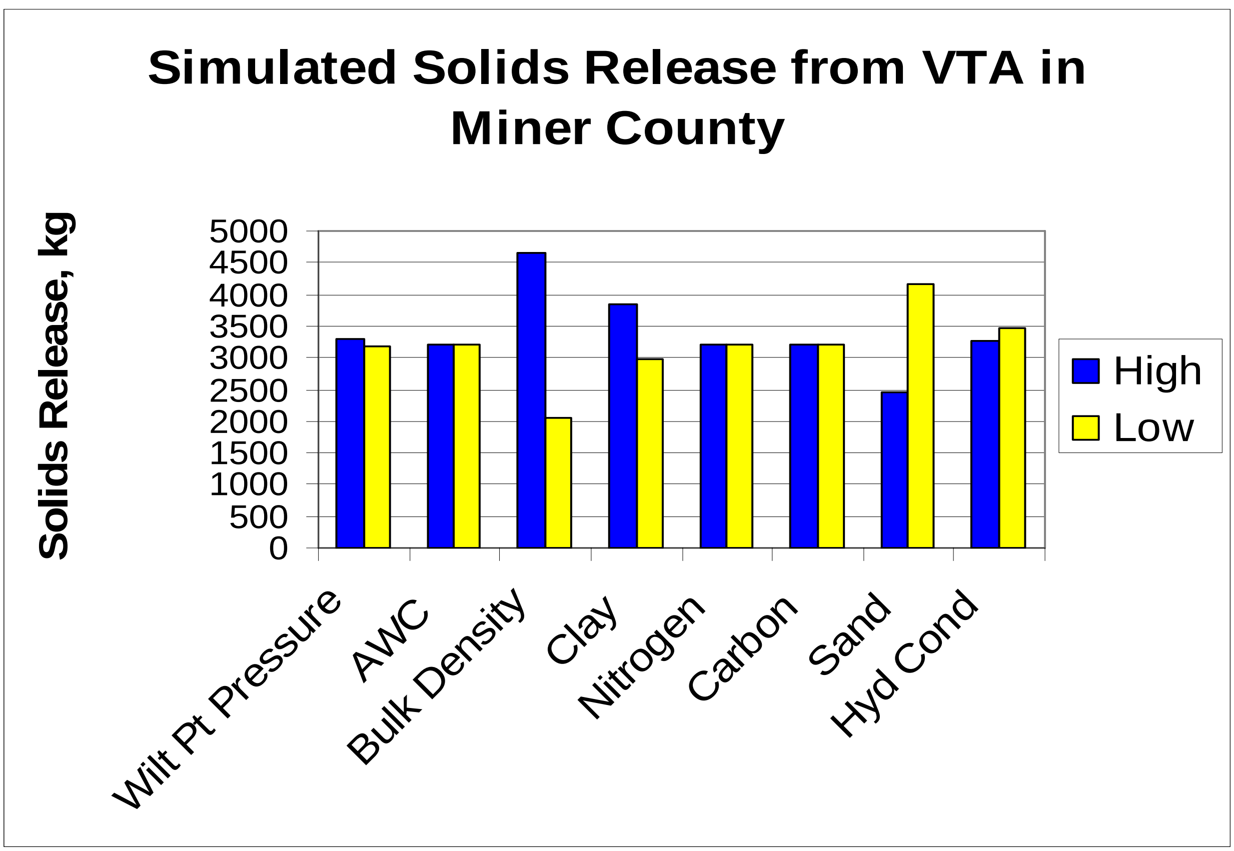

Figure 1. Sensitivity of simulated solids released from the Miner County VTS as related to soil parameters. If both bars of a pair are nearly the same length, the simulated solids release is not sensitive to change of that parameter.

Simulations also have been used to show that discharge from the VTA is sensitive to the water release rate from the sediment basin. A slower release from the sediment basin results in greater infiltration in the VTA and reduces discharge from the VTA. This is important because rate of release from the sediment basin is relatively easy to adjust (lengthen or reduce) by changing the sediment basin outlet. Even better would be use of a valve at the sediment basin outlet to completely control or stop basin outflow until the VTA dries, at least somewhat, after a storm. Care must be taken to make sure the sediment basin is drained within 72 hours, as required if the basin is not lined with clay or other impermeable material. An illustration of reduced VTA discharge with reduced sediment basin release rate is shown with a repeated model runs with a simulated storm at the Miner County site (Fig. 2), varying the sediment basin release pipe size (and outflow rate). Simulations showed that water discharged from the VTA was reduced from 878 to 210 to 0 ft^3 by reducing the sediment basin outlet pipe size from 203-mm to 127-mm to 114-mm (Fig. 2), respectively.

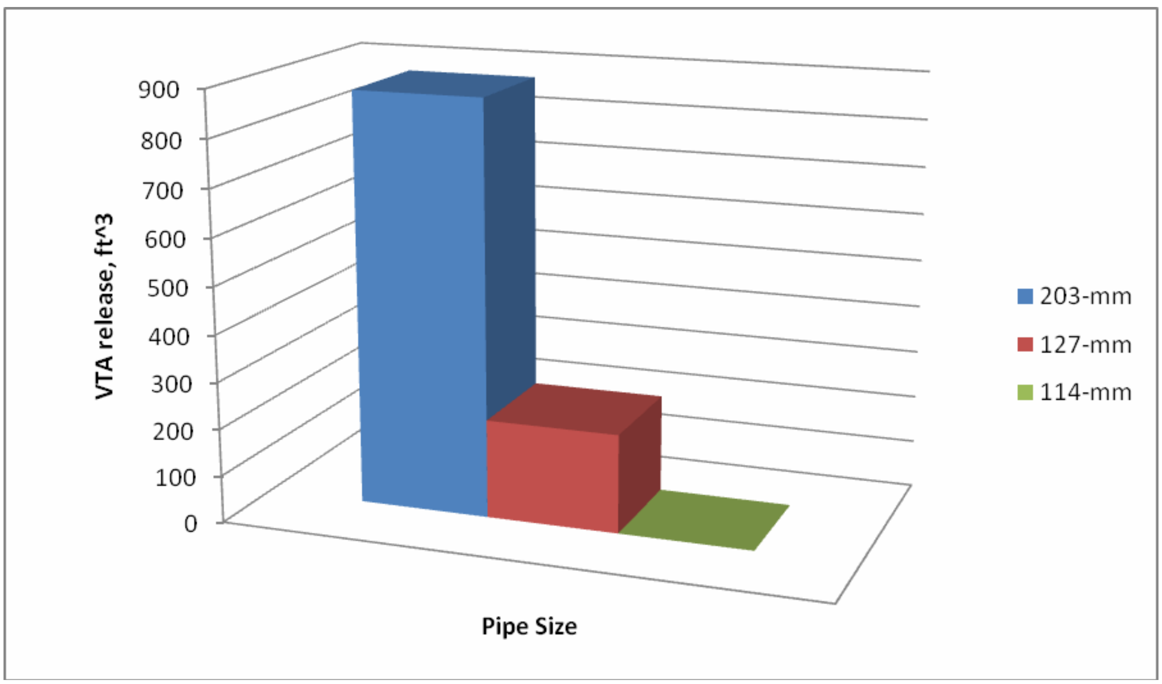

Figure 2. Simulated water discharge from the VTA for three sediment basin outlet pipe sizes.

4.2 Field sites

A total of 6 different sites were constructed and/or monitored during this project (Fig 3, Table 1). The original project plan was to monitor 5 sites for the duration of the 3-year project. Construction and installation delays resulted in some sites not getting monitored early in the project but the one-year, no-cost project extension provided additional monitoring opportunities. Data were collected for a total of 13 site-years during this project.

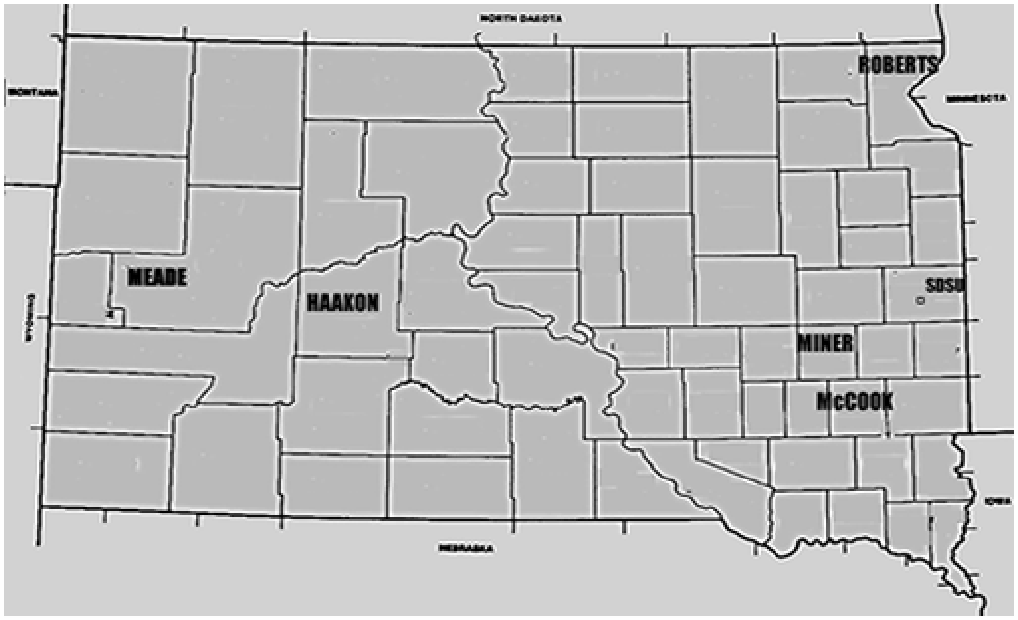

Figure 3. Locations of the five SD sites in this study. The Stevens MN site was 100 km ESE of the Roberts site.

Table 1. Parameters of the feedlots and VTS's in this project.

Parameter	Haakon	Miner	Roberts	Meade	Stevens,MN
Feedlot Area, m^2	39254	50586	12302	72440	35630
Feedlot Slope, %	5	4	4	1	4
Orientation, degrees	200	90	90	0	135
Settling Basin Depth, m	1.2	1.2	1.5	0.9	0.6
VTA Length, m	122	79	82	320	91
VTA Width, m	94	122	146	320	386
VTA Slope, %	1	2	2.5	0.5	3
Orientation, degrees	315	90	90	315	135
Vegetation	western wheatgrass	smooth brome	various (plots)	Alfalfa/pub whtgrass	Bluegrass/per rye/fescue
Effective width %	100	90	95	100	100
VTA:Feedlot Area Ratio	0.28	0.17	0.93	1.41	1.0
Water Table depth, m	6	6	>30	>30	>25
Percent Clay	56	35	43	48	N/A
Percent Sand	12	30	9	18	N/A

4.2.1 Miner County site

The Miner Co site consisted of a sediment basin and a single outlet to a pre-existing VTA. Monitoring during the first season (2005) showed that water flow concentrated into one "stream" upon leaving the sediment basin. This concentration of flow resulted in releases from the bottom of the VTA. To spread the water laterally across the VTA, gated pipe was added to the sediment basin outlet (Fig 4) prior to the second season of monitoring (2006). Also, a standpipe was added to the sediment basin outlet to completely prevent sediment basin outflow (VTA inflow) until water in the sediment basin reached a depth of about 1 m. At the same time, a siphon was added to the sediment basin outlet. The siphon performed three functions: it allowed manual control of the outlet unless water depth was greater than 1 m, it allowed a greatly reduced flow rate from the sediment basin to the VTA, and it drained the sediment basin completely when removal of solids was desired.

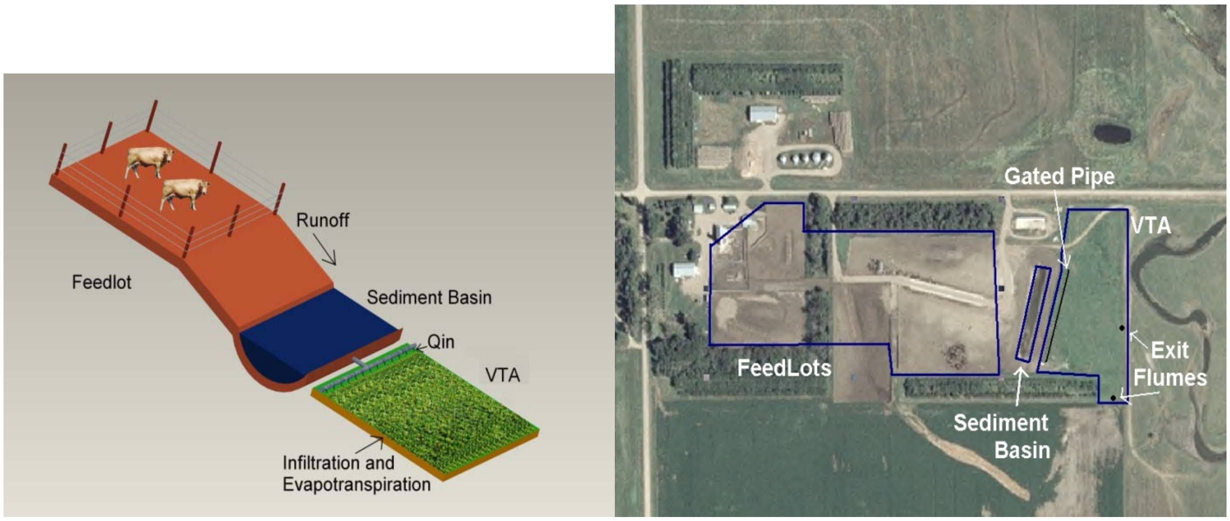

Figure 4. Schematic representation and aerial view of Miner VTS site.

Water monitoring at the Miner site during 2008 showed multiple inflows in response to rainfall (Fig 5). Combining the measured inflows with the nutrient concentrations of the samples collected from the inflows, a total of 818 kg N/ha and 212 kg P/ha entered the VTA in the water during 2008. No outflow was measured during 2008. The combination of slow release from the sediment basin, lateral spreading with gated pipe, thick vegetation (Fig 6), and favorable microtopography (depressions) at the bottom of the VTA have combined to prevent water release from the VTA.

Coliform monitoring showed that coliforms were moving with the water to the bottom of the VTA (Table 2). In fact, 2008 data show essentially no decrease of coliform concentrations at any location from the gated pipe VTA inlet to the bottom of the VTA (Table 2). Thus, control of the water and preventing it from leaving the VTA is essential to prevent coliforms from leaving the VTA.

The smooth brome within the VTA at the Miner site was highly productive (Fig. 6, note the lush growth). Two locations for harvest treatments were established within the VTA. One location was in the southeast corner of the VTA, near a VTA outlet. This was a wet area, low in the landscape, where water often ponded during wet periods. The other area was near the top of the VTA, about 2 m from the gated pipe. The treatments applied were three harvest strategies- one, two, or three harvests per year. The one-harvest treatment was harvested during late June or early July shortly after anthesis at peak standing crop. The two-harvest treatment was harvested at peak standing crop and the end of the growing season. The three-harvest treatment was harvested at peak standing crop, mid-summer, and the end of the growing season. For years 2007 and 2008, both experiments are averaged together for this analysis to give a better sense of the average yield and nutrient removal over the entire VTA. The first harvest of 2006 in Experiment II was lost so only Experiment I is reported for 2006.

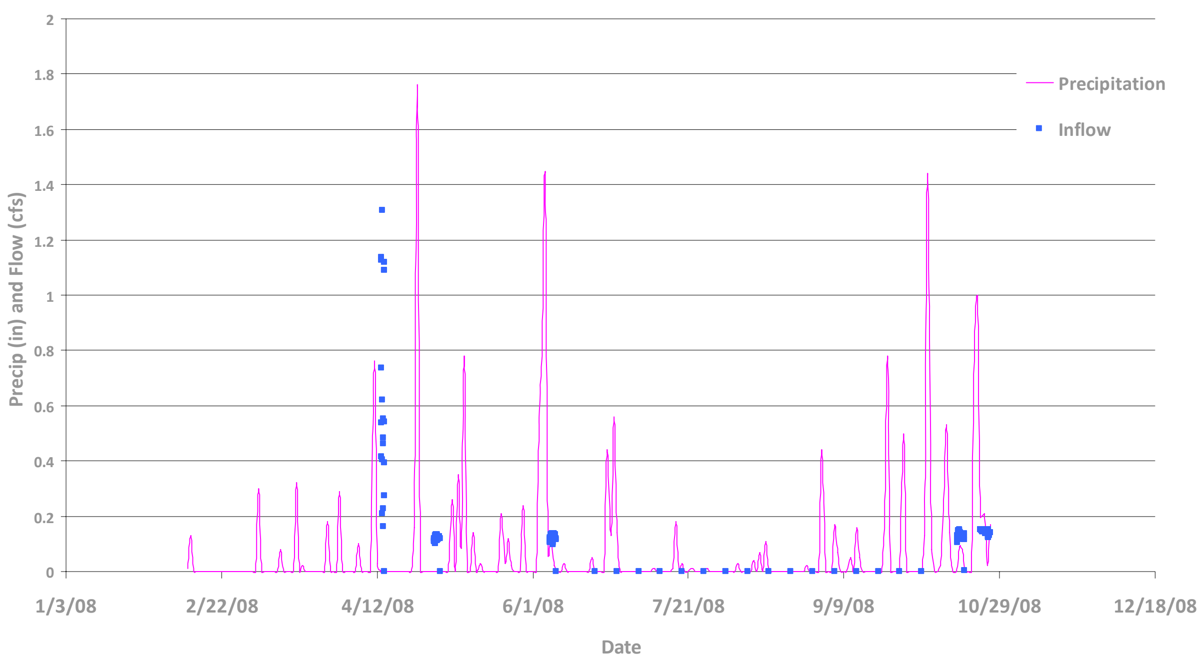

Figure 5. Precipitation and VTA inflow during 2008 at the Miner site.

Dry matter yield increased with increasing number of harvests (Table 3). The increase from 1 harvest to two harvests was considerable (3-year average of 2.21 Mg/ha) but the increase from 2 harvests to three harvests was modest (0.52 Mg/ha). By year 3 of this study, the first harvest of the three-harvest treatment was considerably reduced compared to the other treatments (data not shown). But the second and third harvests of that treatment were great enough to overcome the reduced yield from the first harvest. The first harvest of the two-harvest treatment was somewhat reduced, also (data now shown). Again, the later harvests were great enough to result in greater total dry matter harvest during the season.

Table 2. Fecal coliform concentrations at the Miner site during two sampling dates in 2008.

Date	Location	Coliform conc, CFU/mL
6 Jun 2008	VTA inflow	$4.6X10^5$
	40 m from VTA inlet (halfway point of VTA)	$3.5X10^5$
	60 m from VTA inlet	$6.0X10^5$
	River (W Fork Vermillion River)	$2.7X10^2$
26 Oct 2008	Average of 5 samples at top of VTA	$2.5X10^4$
	60 m from top of VTA, 20 m from outlet	$2.0X10^4$

Figure 6. Smooth brome grass within the Miner VTA.

Table 3. Total dry matter production from three harvest treatments for smooth brome in the Miner VTA, Mg DM per ha, Experiment I (2006) and average of experiments I and II (2007 and 2008).

Number of harvests	2006	2007	2008	3-year Average
1	4.52	6.74	6.28	5.85
2	8.16	7.78	8.25	8.06
3	8.48	8.64	8.62	8.58

Nutrient (nitrogen and phosphorus) removal in the vegetation also increased with increasing number of harvests (Table 4). Mirroring the dry matter yields, the increase from the one-harvest to the two-harvest treatment was considerable (3-year average of 74 Kg N/ha and 6 kg P/ha) while the increase to the three-harvest treatment was modest (3-year averages of 23 kg N/ha and 3 kg P/ha).

Table 4. Nutrient removal by 3 harvest systems for smooth brome in the Miner VTA, kg/ha, Experiment I (2006) and average of Experiments I and II (2007 and 2008).

No of	2006		2007		2008		3-year Average	
harvests	N	P	N	P	N	P	N	P
1	83	8	173	18	146	15	134	14
2	185	18	242	24	196	19	208	20
3	193	22	276	27	224	19	231	23

Nutrients, especially phosphorus, have accumulated in the VTA soils at the Miner site. The locations where the flow was concentrated in 2005 (sampling locations B-1 and B-3 in Fig 7) have actually experienced reduced nutrient concentrations. But the remainder of the VTA shows increased nutrient concentrations and accumulation from 2006 to 2008 (Fig 7). The average P concentrations in the soils show accumulation through 2008 (Fig 8). Accumulation of P and is not surprising given the excess of inflow P compared to the removal rates in the vegetation. Nitrate-N and TKN did not accumulate as quickly.

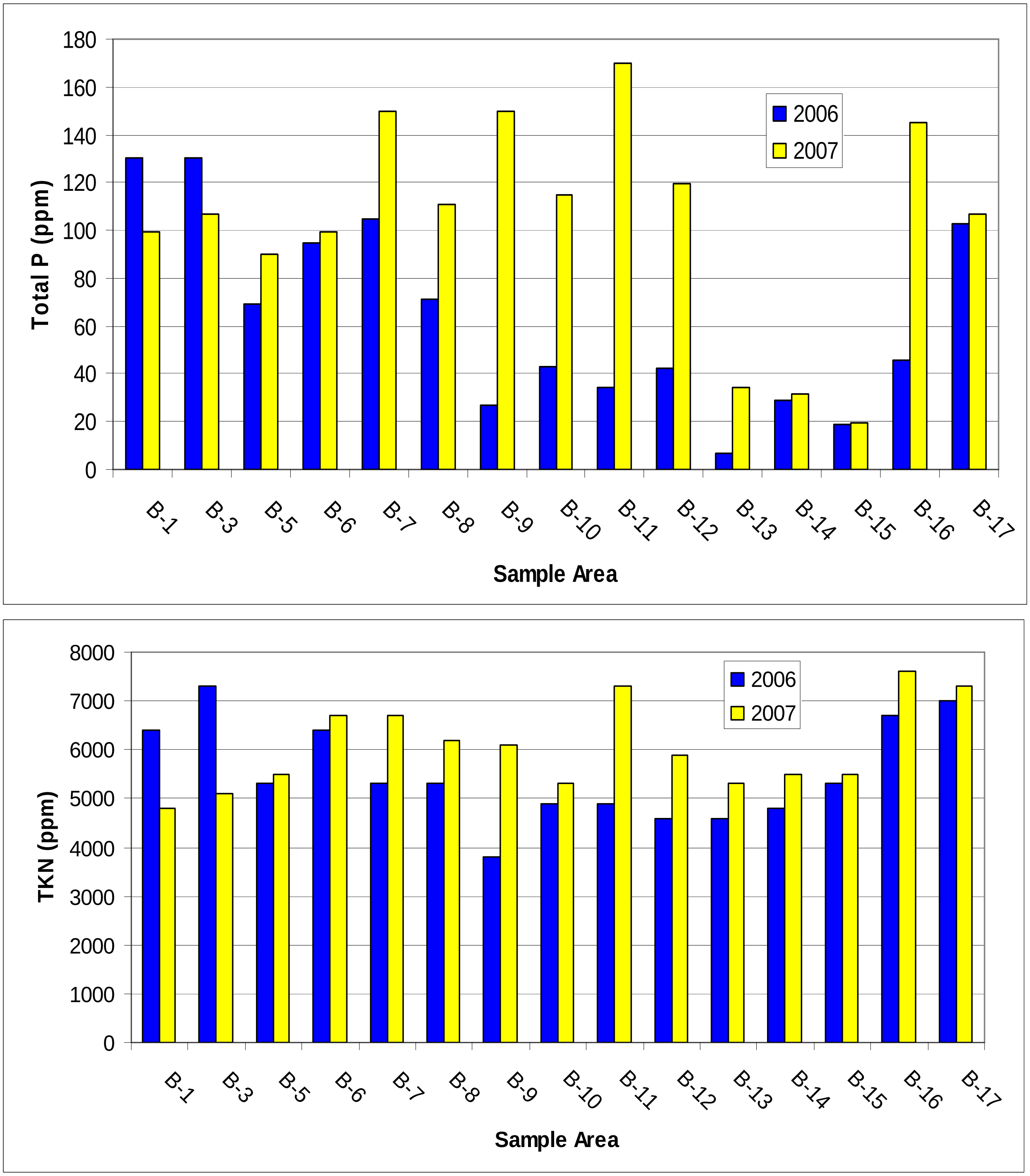

Figure 7. Nutrient concentrations in the top 150 mm for 15 locations in the VTA at the Miner site. Locations B-1 and B-3 were exposed to excessive flow amounts during 2005 but the amount was reduced after the gated pipe was installed in 2006.

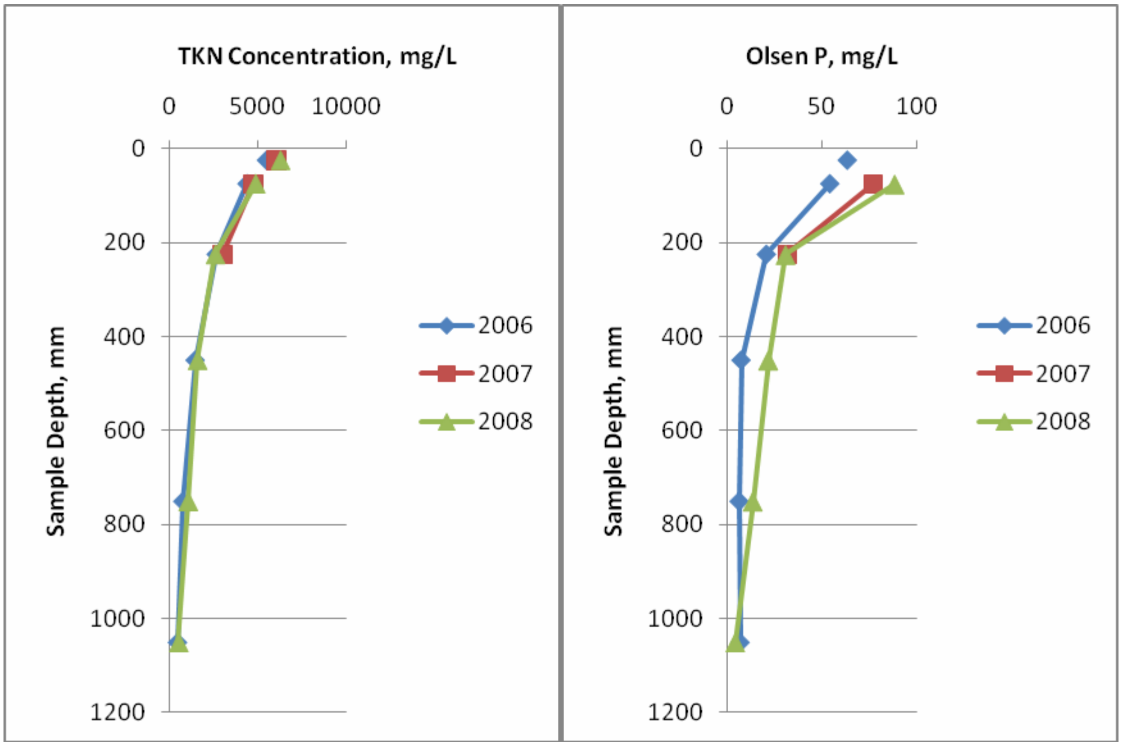

Figure 8. TKN and Olsen P concentrations in the soil profile in the VTA of the Miner site.

4.2.2 Meade County site

The Meade Co site consists of a sediment basin within the lots, a single discharge pipe leading to a conveyance channel, and the channel to a VTA that contains 3 different cells (Fig 9). Runoff is released from the conveyance channel to a cell via a level-lip ditch, providing water spreading at the top of each VTA cell. A berm was constructed at the bottom (north) end of the VTA to prevent release. The berm had a culvert with a valve to allow water release top prevent crop damage if the VTA became flooded. The system was designed by NRCS.

For the second year in a row, the Meade site experienced a 25-year storm event. During 2008, 161 mm (6.34 inches) of rain fell between May 18 and 24, with 91 mm (3.59 inches) falling on May 22 and 1.40 inches on May 23 (Fig. 10). The rain and inflow to the VTA filled the VTA. Water was then released from the VTA to keep the VTA crop from suffering flood damage. The VTA outflow volume was 3,300 m^3. In that outflow were 55 kg N and 10 kg P (or 5.4 kg N and 1 kg P per ha of VTA). The sum of all VTA inflows during 2008 brought a net addition of 48.4 kg N/ha of VTA and 10.8 kg P/ha of VTA. A similar storm during June 2007 required that water be released from the VTA to prevent crop damage due to flooding. Those data are not shown here because they are similar to the 2008 data.

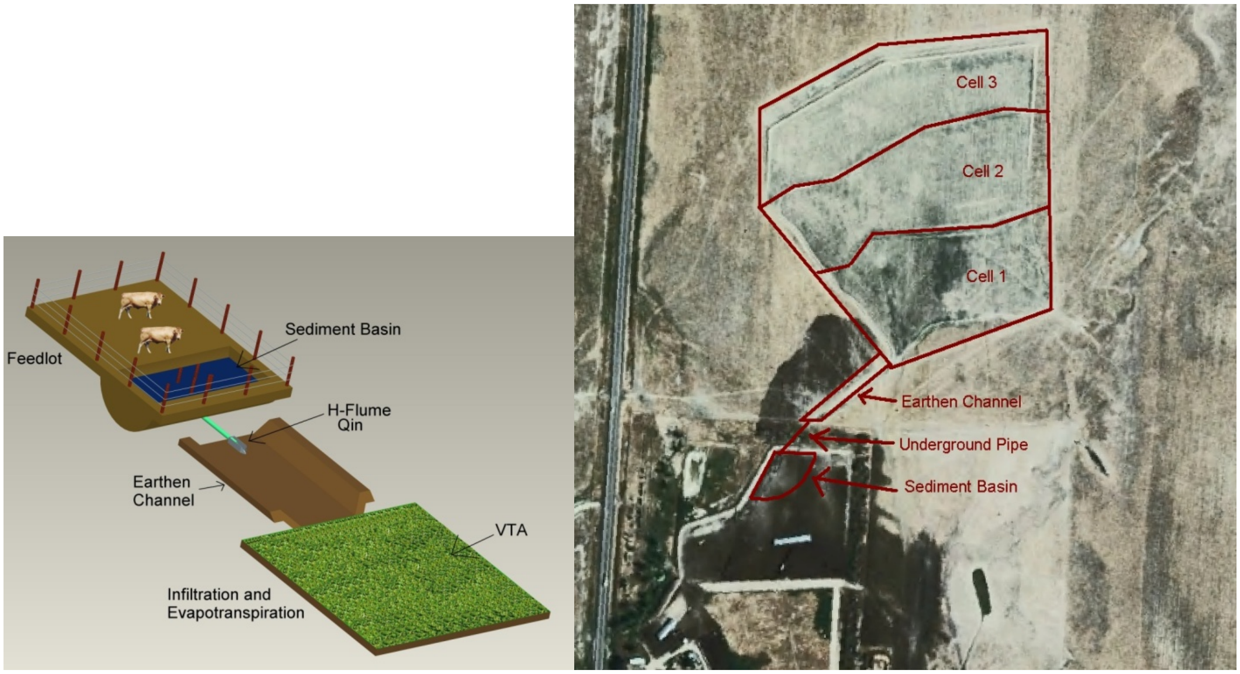

Figure 9. Schematic and aerial view of the Meade County site.

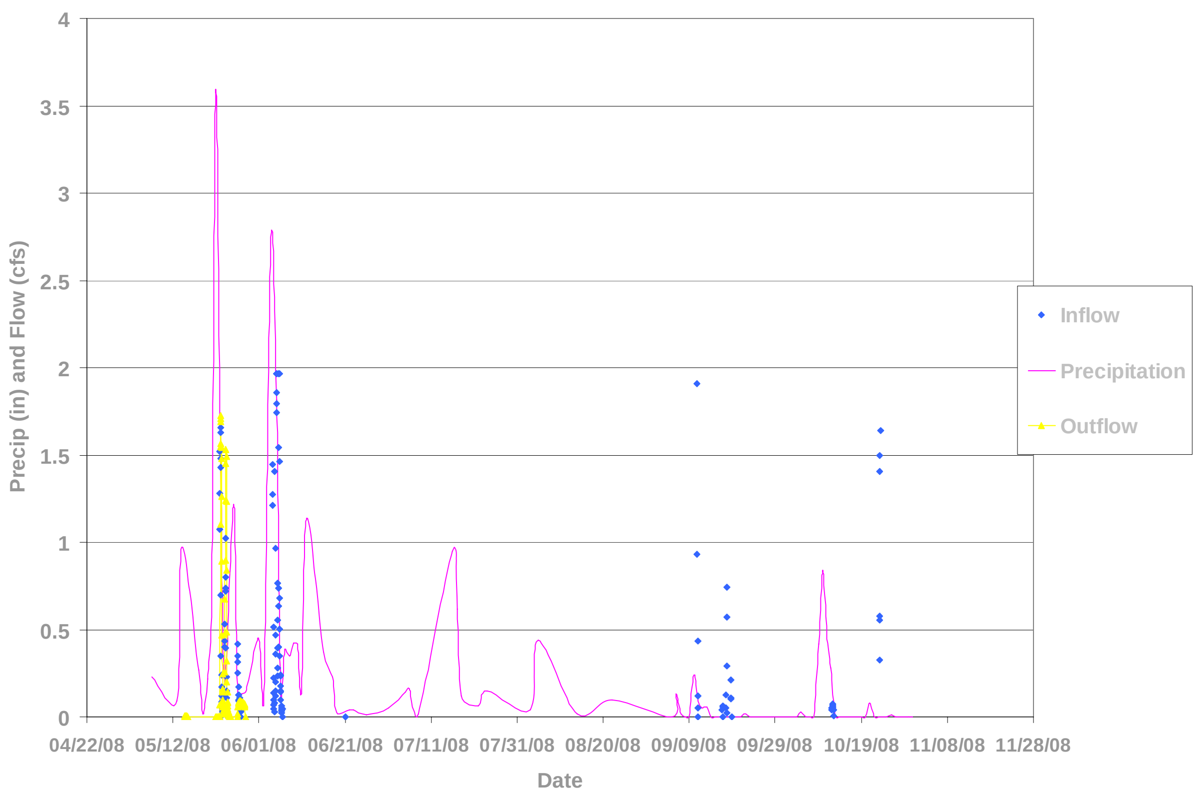

Figure 10. Precipitation and VTA inflows and outflows during 2008 at the Meade site.

The alfalfa/ pubescent wheatgrass mix in the VTA was sampled twice. The regrowth during 2007 was harvested; the first harvest was removed before it could be sampled. The average dry matter yield collected from the 3 cells of the VTA was 1.4 Mg/ha. Contained in that grass were 27 kg N/ha and 2.0 kg P/ha. The first harvest was collected during July 2008. The average dry matter yield was 4.9 Mg/ha.

The nutrient (nitrate-N and P) concentrations in the soil profile of the VTA showed little increase from 2007 to 2008 (Fig 11). There was some addition of nitrate-N in the 0 to 150 mm layer. These values reflect the modest net inflows of 48.4 kg N/ha and 10.8 kg P/ha. The TKN concentrations showed similar trends (data not shown). The data shown are averages of 6 locations- top and bottom of each of the three VTA cells.

Table 5. Nutrient concentrations in typical water samples during 2008 at the Meade site.

Sample Location	Date	TKN	P	K	TDS	TSS
				mg/L		
Basin outflow	5/1/2008	105	15.6	590	3570	520
Basin outflow	5/4/2008	107	26.4	370	2040	2520
Basin outflow	5/8/2008	109	24.2	580	3570	1300
Basin outflow	5/23/2008	64.3	17.9	320	2260	1400
Basin outflow	5/25/2008	96.8	17.9	530	3440	750
Basin outflow	6/4/2008	60.7	12.5	350	2530	410
Basin outflow	6/9/2008	87	17.4	500	2945	385
Water within the VTA	5/8/2008	31.3	6.99	150	1150	1230
Water within the VTA	5/10/2008	71.2	16.4	320	2020	1140
Water within the VTA	5/25/2008	20	4.04	160	920	56
Water within the VTA	6/6/2008	42	9.58	140	710	1040
Water within the VTA	6/19/2008	32.1	9.5	260	N/A	N/A
Basin outside VTA	6/19/2008	16.9	2.99	70	N/A	N/A

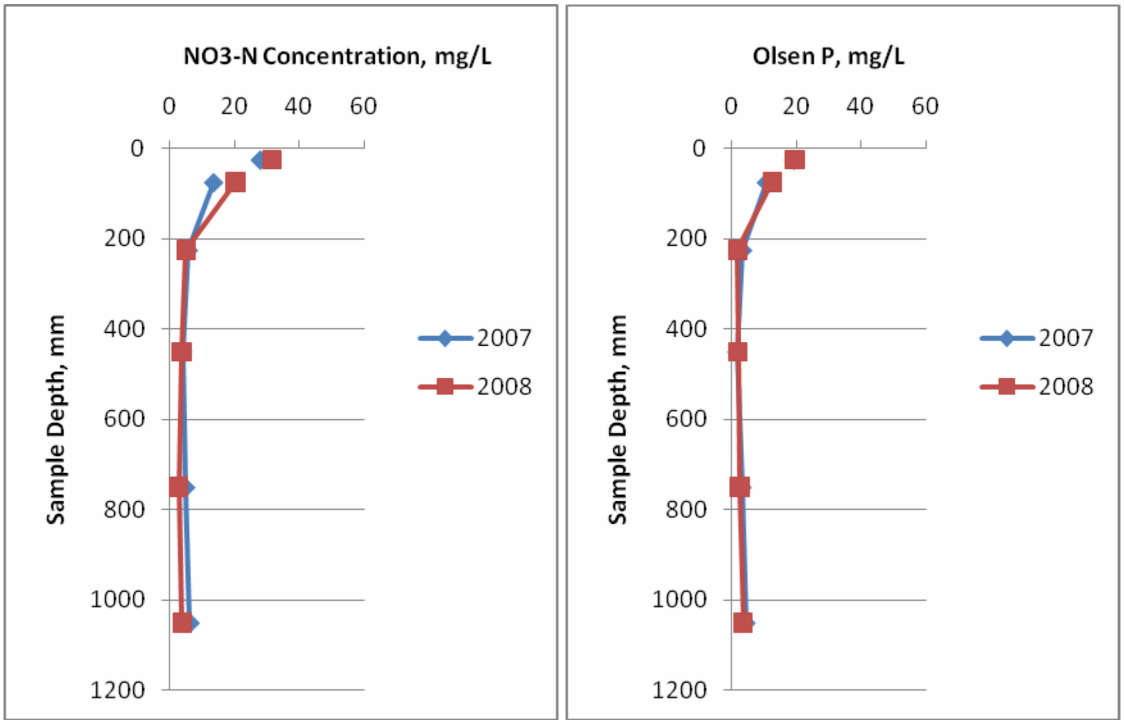

Figure 11. Nitrate-N and Olsen phosphorus concentrations in the soil profile at the Meade site, 2007 and 2008.

4.2.3 Haakon County site

The Haakon Co site actually had two separate systems. Only one side, the "south" side, was monitored in this project. The south VTS had a much smaller VTA to feedlot area ratio and thus provided a stronger test of the VTS technology and performance. The south VTS consisted of a sediment basin, a single outlet to the VTA, and a berm around the bottom of the VTA. The north system used a pump to move water from the sediment basin to the VTA via underground pipe. No landshaping took place so the original topography of the site remains for both VTA's except for the berm at the bottom of the south VTA.

No water was released from the monitored VTA at the Haakon site. The constructed berm has been effective at containing all water within the VTA. The relatively larger sediment basin also allows producer flexibility to reduce the rate of water flow to the VTA. Total seasonal VTA inflows during 2008 (Fig 13) contained a total of 94 kg N/ha and 26 kg P/ha.

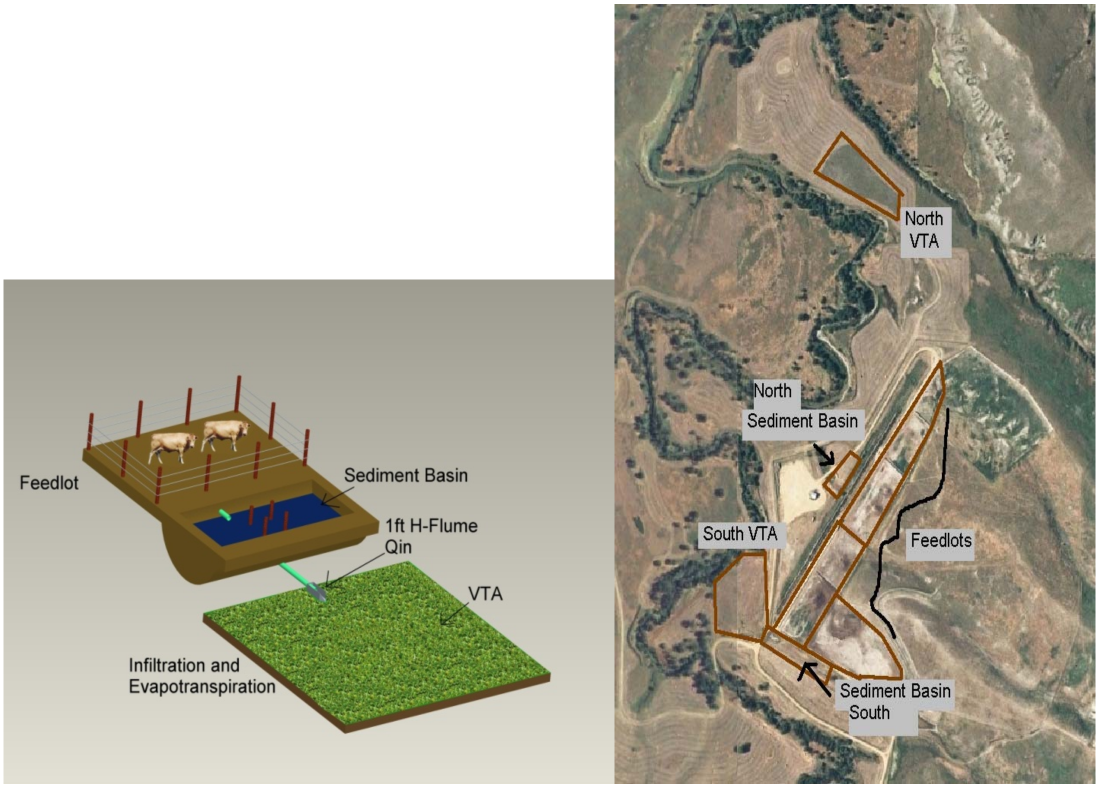

Figure 12. Schematic and aerial view of the Haakon site.

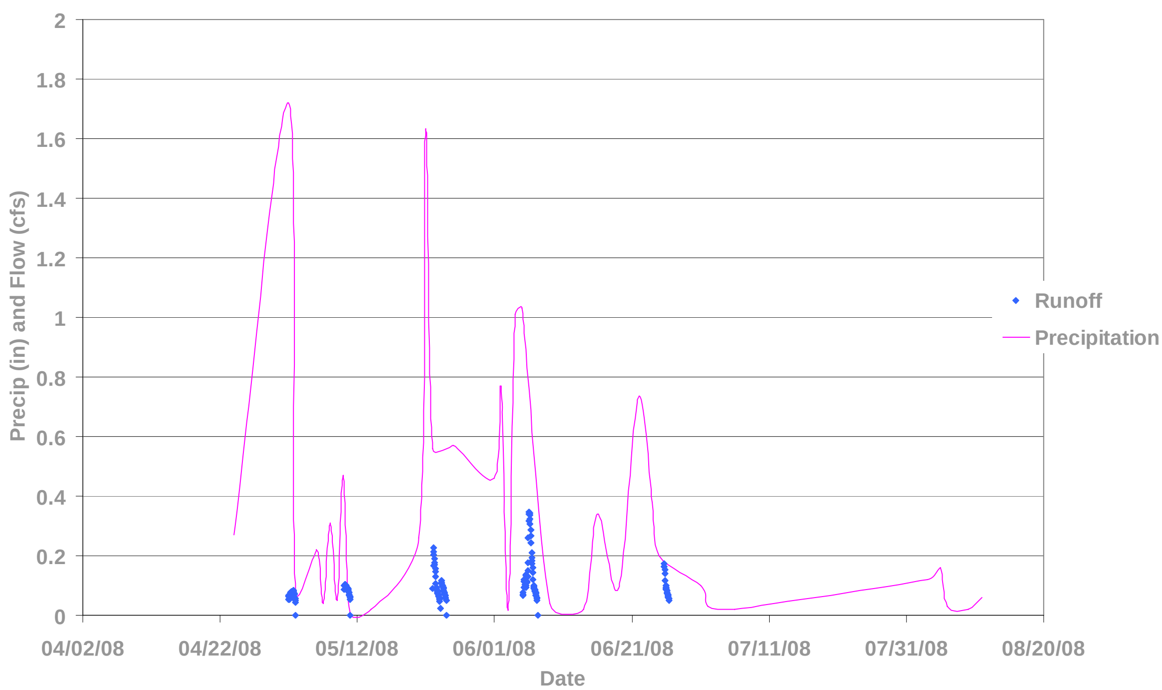

Figure 13. Precipitation and VTA inflows at the Haakon site during 2008.

Table 6. Nutrient concentrations of typical water samples at the Haakon site, 2008.

Sample Location	Date	TKN	P	K	TDS	TSS
				mg/L		
Basin outflow	5/2/2008	91.8	25	630	3920	1140
Basin outflow	5/2/2008	91.5	24.1	590	3840	770
Basin outflow	5/3/2008	60.1	16.7	390	3090	460
Basin outflow	5/10/2008	68.5	16	660	4610	296
Basin outflow	5/23/2008	60.1	14.6	530	3440	126
Basin outflow	6/3/2008	45.9	15.4	450	2870	860
Basin outflow	6/5/2008	44	15.2	400	2580	1120
Basin outflow	6/8/2008	35.2	9.39	390	2650	102
Basin outflow	6/10/2008	36.4	9.91	390	*	*
VTA standing water	5/23/2008	62.2	12.7	530	3270	128
VTA standing water	6/19/2008	39	9.84	380	*	*

Nitrate-N and Olsen-P concentrations in the soil profile increased in the top 300 mm of the soil profile (Fig 14). There was no increase of concentrations deeper in the soil profile, indicating little activity-infiltration of runoff- below the top 300 mm. TKN concentrations showed not change from 2007 to 2008 (data not shown).

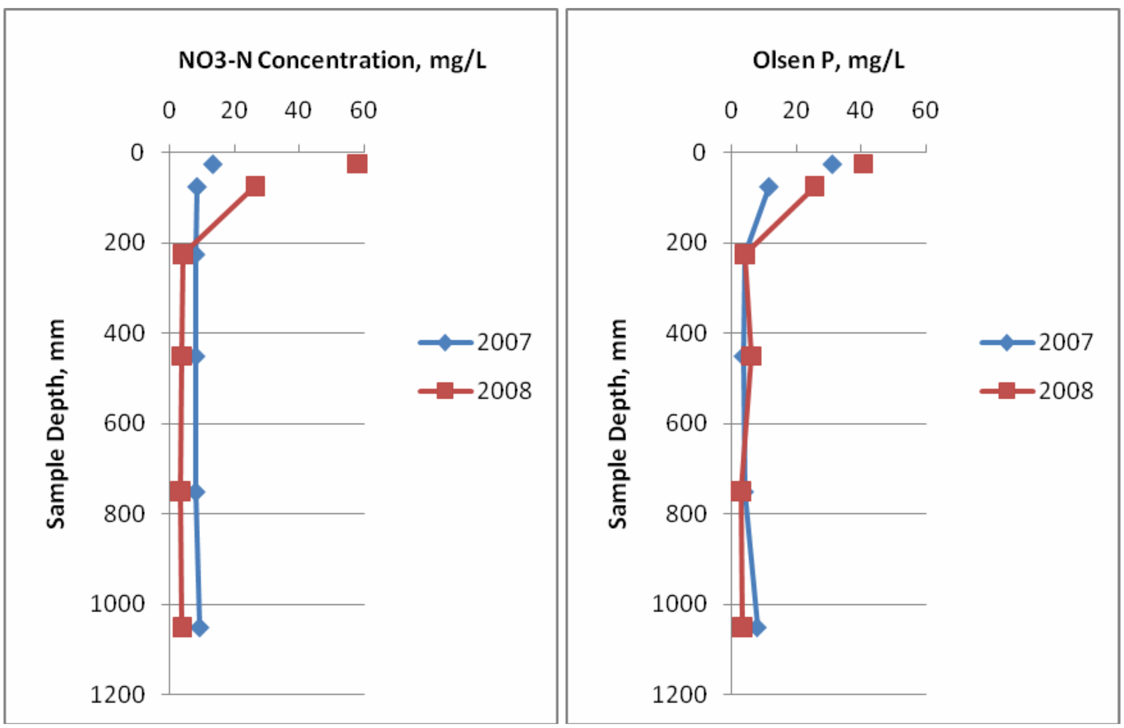

Figure 14. Nitrate-N and Olsen P concentrations in the soil profile at the Haakon site, 2007 and 2008.

4.2.4 Roberts County site

The Roberts County site is a pumped VTS. Feedlot runoff collects in the long sediment basin on the east edge of the lots. A pump is located at the south end of the sediment basin. Water is pumped to the gated pipe distribution system in the VTA to the south. Due to construction and site establishment delays, no monitoring data are available for the Roberts site. The system was designed by NRCS. The site is being monitored during the 2009 growing season under a different project. VTA inflows and outflows (if any) will be monitored. Three grass species have been established in a randomized complete block experiment with eight replications. Harvest measurements will be used to compare growth, yield, and nutrient removal properties of the three grasses. The grass species are smooth brome, intermediate wheatgrass, and reed canarygrass.

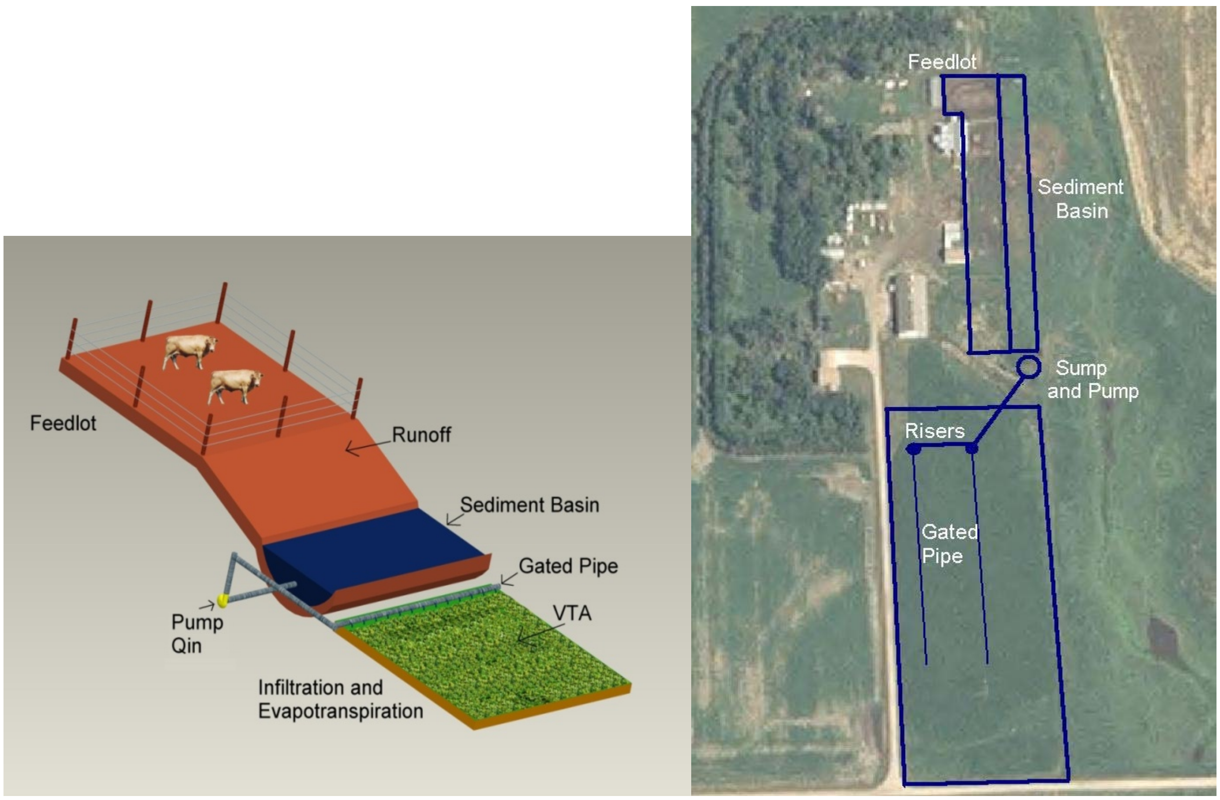

Figure 15. Schematic and aerial view of the Roberts site.

4.2.5 Stevens County MN site

The Stevens County MN site is a CAFO. It was added to this project when the McCook site was dropped and while the second phase project, now funded by NRCS CIG via Iowa State University (ISU), was in the planning phase. Monitoring at this site will continue as part of the CIG project.

Water moves in this VTS via gravity flow. The runoff from the pens is held in concrete-lined sediment basins at the bottom of the pens (Figs 16 and 17). Gates are used at the sediment basin outlets to control the sediment basin outflow manually. When the gates are opened, water from the sediment basins flows into a curb-and-gutter system to spread the water laterally at the top of the VTA.

Extensive land shaping was performed within the VTA when the system was constructed. The work by the heavy machinery at this site caused soil compaction and resultant infiltration reduction problems during the first year of operation. To help increase the infiltration rate, deep tillage was performed and corn was the grown in the VTA during the first year of operation. Grass was established for the second year of operation.

There are three separate sediment basins. All three have been monitored during this project. Data from just two basins (1 and 2) are shown here (Fig. 18) due to monitoring problems during part of 2008. Visual observations and occasional depth measurements confirmed that the volume from basin 3 was consistent with the volumes measured from basins 1 and 2.

Figure 16. Aerial view of the Stevens County site. Runoff flows from the pens in the middle of the image in a southeasterly direction. The VTA is most of the triangular area between the pens and trees in the bottom center of the image.

Water was well-controlled with this system. There were no releases from the VTA. In fact, after the spring thaw, there was no water even ponded at the bottom of the VTA during the rest of the season. The combination of slow release with gates on the sediment basins, berm at the bottom of the VTA, additional retention time allowed because the sediment basins are lined with concrete, and other factors all combine to make this an effective VTS. The VTA inflow contained a total of 292 kg N/ha and 69 kg P/ha. These values were calculated using the average concentrations in the flows from the three sediment basins (Table 7).

Dry matter yields for 2008 were modest- a total of 5.0 kg/ha for two harvests (Table 8). Although water generally does not limit vegetation growth at the Stevens site, the grass mix selected, including Kentucky bluegrass, would not be expected to be as productive as other grass species such as smooth brome.

Figure 17. Side view of the Stevens VTS at the south end, looking ENE. In the image are pens (far left), sediment basin (within the concrete walls), curb-and-gutter distribution system (center of image), and the VTA (far right). Runoff flows from left to right in the image.

Table 7. Concentrations in typical samples of sediment basin outflow, Stevens site.

Nutrients in Effuent (mg/L)	Date	TKN	P	K	TDS	TSS
Basin 1 outflow	5/12/2008	257	72.8	620	3480	4880
Basin 2 outflow	5/12/2008	158	33.7	560	3500	1000
Basin 3 outflow	5/12/2008	120	21.8	490	2810	900
Basin 1 outflow	6/13/2008	155	38.9	410	*	*
Basin 2 outflow	6/13/2008	204	50.8	400	*	*
Basin 3 outflow	6/13/2008	128	29.4	360	*	*

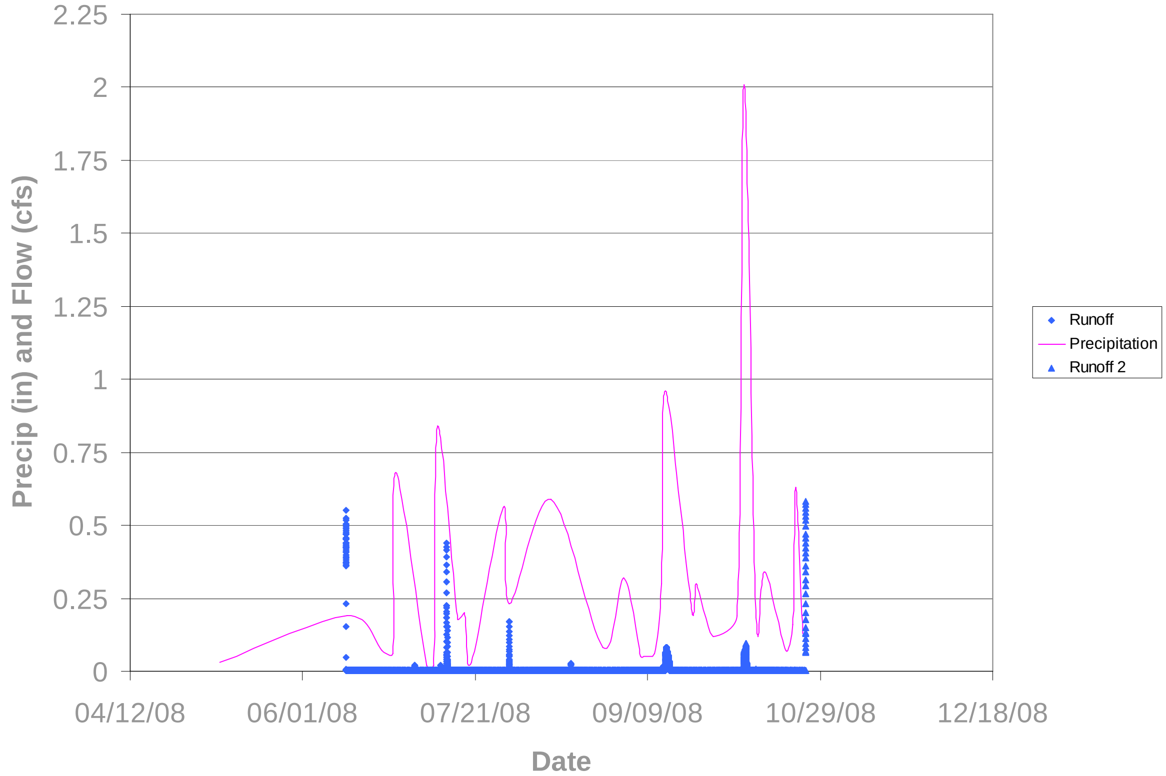

Figure 18. Precipitation and VTA inflow from basins 1 and 2, Stevens site, 2008.

Table 8. Dry matter yields at the Stevens site in 2008, reported by the owner.

Harvest Date	Yield, Mg/ha
August	3.6
September	1.4
Total	5.0

4.2.6 McCook County site

The system at McCook Co consisted of a constructed sediment basin running the entire width of the pens. From the sediment basin were multiple outlets, allowing water to exit the sediment basin and enter the VTA. The VTA consisted of a woodlot directly downhill from the sediment basin outlets then an established vegetated (grass) area. No landshaping was performed within the VTA. Even though the sediment basin had multiple outlets, the topography of the woodlot and VTA (slopes of up to 5% leading to a single “waterway” at the bottom) were such that water flow was quickly channeled into a single stream within the VTA.

This system was monitored during 2005. Visual observations revealed significant outflow from the VTA during 2005, although monitoring equipment failure prevented quantification of that outflow. Probable solutions to prevent VTA outflow would have required landshaping activities and other capital improvements by the owners. The owners declined to perform those improvements, citing uncertainties in the future of their feedlot, its size, and the VTS and its status as a research system. This site was no longer monitored after the 2005 growing season.

The performance of this site emphasizes the need to spread the water laterally in or near the top of the VTA and perform landshaping, where necessary to achieve lateral water spreading within the VTA.

5.0 Coordination Efforts

A stakeholders group was established at the beginning of this project. Entities that were represented at the stakeholder meetings included SD Cattlemen's Association, SD Farm Bureau, SD DENR, SD Dept of Ag, NRCS, engineering consultants, producers, and private citizens. Stakeholders met formally 8 times during the project, in December 2004, January 2005, February 2005, August 2005, November 2005, December 2006, February 2008, and February 2009 (delayed from Dec 2008).

A subsequent, companion, research project is active, monitoring CAFO VTS sites in 4 states in the Midwest. SDSU is participating in that project. The initial talks were led by the Cattlemen's Associations of various states, including SD, and led by Iowa. Since then, researchers at Iowa State University have assumed leadership of the project. SDSU is leading the monitoring of one CAFO site in SD, one CAFO site in MN, and perhaps another in SD, if the site is permitted and built in time to allow monitoring before the December 2010 end of the project. Other states in the CAFO project are IA and NE. A site in IL was planned but not built. Other states in early discussions but without subsequent monitoring sites included Kansas, Missouri, and North Dakota.

6.0 Summary of Public Participation

A stakeholders group was established at the beginning of this project and met multiple times during the project. See above for more details of the stakeholders group.

Field days were held at each of the four remaining SD AFO sites (Haakon, Meade, Miner, Roberts) during the summer of 2008. A total of 110 people attended and participated in the field days. External groups such as the SE SD Cattlemen participated in the field days at some of the sites by providing items such as food and beverages.

Numerous reports and popular publications came out of this project. Press releases prepared by SDSU and subsequently picked up by the popular press were published in places such as the Rapid City Journal and the Tri-State Neighbor. Electronic media reports include a report on Today's Ag describing the Miner site, web-based reports (), and the VTS web site (abe.sdstate.edu/vts). Publication of these data, especially at technical conferences and in reviewed journals, will continue.

7.0 Aspects of the Project that did not work well

This project monitored at private feedlots and thus was dependent on the feedlot owners to maintain their feedlots in the manner required. In one case (McCook Co), the owners were reluctant to invest further in the technology in research mode, and declined to upgrade their system to remove performance issues. It must be noted that, in other cases, owners were happy to upgrade their systems to overcome performance shortcomings revealed by monitoring.

This project was dependent on private feedlots and the good will of their owners to allow monitoring. The owners involved in this project were all outstanding to work with- helpful, accommodating, and happy to cooperate. However, owners must make business decisions and those decisions can result in sites becoming unsuitable for the project (such as the McCook site in this project). Also, timetables can be difficult to coordinate so construction and establishment can sometimes take longer than hoped or anticipated. Thus, the planned 15 site–years of data were not collected. It should be noted that the 13 site-years of monitoring provide adequate results from which to draw conclusions.

The annual hydrology of any site in the northern Corn Belt or (especially) northern Great Plains can be dominated by snowmelt and spring water movement. Monitoring water at that time is difficult because of the potential for freezing conditions causing damage to monitoring equipment. We were only partially successful in our monitoring efforts during the very early spring thaw and snowmelt season.

8.0 Future Activity Recommendations

The data presented here show that feedlot runoff is infiltrating into the VTA's; thus, the VTS's are performing their desired function. However, there are times when water flows beyond the boundaries of the VTA, whether due to controlled release (Meade site) or the inflow being great enough to flow out the bottom of the VTA (Miner). Further, these data do not conclusively answer the question, "Do VTS's control feedlot runoff as well as or better than basins?" Answering that comparison question will require further simulation work with the updated model from ISU. We are working with ISU and will run that model with input data from our sites when model editing is completed. Regardless of simulation outcome, data show that VTS's can reduce or eliminate water discharge from feedlots. These systems may be good options for non-regulated feedlots that wish to avoid using a basin.

The conditions that maximize the probability of good runoff control, and minimize the probability of runoff release from the VTA, are:

- Adequate sediment basin capacity to temporarily (up to the 3-day limit) store feedlot runoff before releasing it to the VTA,
- A form of sediment basin outlet management (valve or similar) to accomplish that temporary storage in the sediment basin,
- Effective water spreading laterally within the VTA,
- Maintenance of good vegetation within the VTA and harvest to remove biomass and nutrients, and
- A berm at the bottom of the VTA to prevent small releases.