Iowa Water Center
Annual Technical Report
FY 2010

Introduction

The Iowa Water Center is a multi-campus and multi-organizational center focusing on research, teaching and outreach activities. Its goal is to encourage and promote interdisciplinary, inter-institutional water research that can improve Iowa's water quality and provide adequate water supplies to meet both current and future needs of the state. The Iowa Water Center continues to build statewide linkages between universities and public and private sectors and to promote education, research, and information transfer on water resources and water quality issues in Iowa. The Center also plays a vital role in identifying critical water research needs and providing the funding or impetus needed to initiate research that cannot or is not being conducted through other means. Water quality remains a critical concern in Iowa.

Our ability to manage water during extreme climatic events has been tested in recent years with the flood events in Iowa of 2008 and again in 2010. While not so recent, severe drought has also affected the economy and ecology of Iowa in negative ways. Managing Iowa s water resources for flood or for drought is a difficult task. More challenging would be managing for the occurrence of flood and/or drought in rapid succession. Climatologists expect a warmer atmosphere in the coming decades, with more extreme fluctuations in our weather. The ability to manage and prepare for rapid variations in weather, especially precipitation, should be questioned. Do our land management systems perform well under both sides of the precipitation norm? How will water quality and quantity be affected under different cycles of extreme weather? Are the tools available to monitor and respond in adequate time to avoid adverse consequences to Iowa s economy and human health? A variety of issues linking land management and water quantity and quality at multiple scales require further study. Identifying Best Management Practices for managing water quantity and for acceptable water quality during rapid cycle of climate extremes will be a primary focus this year and in the years to come. The Iowa Water Center plays a role in addressing these questions through administering the 104B program and garnering additional funds for other research projects.

Research Program Introduction

The Iowa Water Center has continued its work on water quality and water quantity, with particular emphasis on the role that changes in climate patterns have on water management. Our ability to manage water during extreme climatic events has been tested in recent years with the flood events in Iowa of 2008 and again in 2010. While not so recent, severe drought has also affected the economy and ecology of Iowa in negative ways. Managing Iowa's water resources for flood or for drought is a difficult task. More challenging would be managing for the occurrence of flood and/or drought in rapid succession. Climatologists expect a warmer atmosphere in the coming decades, with more extreme fluctuations in our weather.

The ability to manage and prepare for rapid variations in weather, especially precipitation, should be questioned. Do our land management systems perform well under both sides of the precipitation norm? How will water quality and quantity be affected under different cycles of extreme weather? Are the tools available to monitor and respond in adequate time to avoid adverse consequences to Iowa s economy and human health? A variety of issues linking land management and water quantity and quality at multiple scales require further study. Identifying Best Management Practices for managing water quantity and for acceptable water quality during rapid cycle of climate extremes will be a primary focus this year and in the years to come. The Iowa Water Center plays a role in addressing these questions through administering the 104B program and garnering additional funds for other research projects.

Other research questions exist that are critical to understanding Iowa's water issues. They include: How can we improve models for predicting watershed responses to extreme events; can we utilize state-of-the art science and technology, such as LiDAR to improve our water risk forecasts? The Iowa Water Center will address these issues this year and in the years to come through its research program.

Identifying the primary sources of sediment in an anthropogenically altered watershed

Basic Information

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Project Number:	2010IA149B
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Descriptors:	
Principal Investigators:	Thanos N Papanicolaou, Marian V.I. Muste, Douglas Schnoebelen, Larry Weber, Christopher Wilson

Publications

1. Wilson, C.G., A.N. Papanicolaou, and K.D. Denn. 2011. Quantifying and partitioning fine sediment loads in an intensively agricultural headwater system. Journal of Soil and Sediments. Submitted.
2. Wilson, C.G, A.N. Papanicolaou, and R.A. Kuhnle. 2010. Quantifying sediment sources to the suspended load of a stream using radioisotopes. In: R. Unger (ed.) Getting Into Soil and Water:2010. Iowa Water Center, Ames, IA.
3. Sutarto, T., A.N. Papanicolaou, F. Bertrand, and C.G. Wilson. 2011. Fluvial erosion measurements of streambanks using Photo-Electronic Erosion Pins (PEEPs). 2011 James F. Jakobsen Conference, The University of Iowa, Iowa City, IA.
4. Papanicolaou, A.N., C.G. Wilson, F. Bertrand, and T. Sutarto. 2011. Fluvial erosion measurements of streambank using Photo-Electronic Erosion Pins (PEEP). 34th International Association of Hydraulic Engineering & Research (IAHR) Biennial Congress, Brisbane, Australia.
5. Wilson, C.G, A.N. Papanicolaou, and K.D. Denn. 2011. Quantifying relative rates of upland and bank erosion using radionuclide tracers in an agricultural watershed. 2011 Iowa Water Conference. Ames, IA.
6. Wilson, C.G, A.N. Papanicolaou, and K.D. Denn. 2010. Quantifying relative rates of upland and bank erosion using radionuclide tracers in an agricultural watershed. 2010 American Geophysical Union Fall Meeting. San Francisco, CA.
7. Denn, K. D., A.N. Papanicolaou, and C.G. Wilson. 2009. Using tracers to derive sediment provenance after the occurrence of a 500-year flood in a Midwestern stream. World Environmental & Water Resources Congress, Kansas City, MO.
8. Denn, K. D., A.N. Papanicolaou, and C.G. Wilson. 2009. Determining provenance of floodderived sediments after a 500-year flood in a Midwestern stream using isotopic tracers. 33rd International Association of Hydraulic Engineering & Research (IAHR) Biennial Congress, Vancouver, B.C.

Progress of Research Activities: March 1, 2010 - February 28, 2011
U.S. Geological Survey Grant No. 2010IA149B

Title: Identifying the Primary Sources of Sediment in an Anthropogenically Altered Watershed

Principal Investigators: Thanos Papanicolaou[1], Christopher Wilson[1], Larry Weber[1], Marian Muste[1], and Doug Schnoebelen[1]
[1]IIHR – Hydroscience & Engineering, The University of Iowa, 300 S. Riverside Dr., Iowa City, IA 52242

External Collaborator: Mark Tomer[2]
[2]National Laboratory for Agriculture and the Environment, USDA-ARS, 2110 University Boulevard, Ames, IA 50011-3120

Start Date: March 1, 2010
End Date: February 28, 2011

Problem and Research Objectives

In agriculture settings of Midwestern states, like Iowa, erosion of surface soils in the uplands had been exacerbated by intensive tillage (Williams, 1981), which consequentially translated to increased deposition on floodplains (Trimble, 1999). The increased deposition augmented flooding of bottomlands. To alleviate flooding concerns, streams were straightened and dredged to facilitate better flow. Although channel straightening was successful at mitigating floods, it accelerated channel degradation through bank collapse by causing higher flow velocities that produced higher erosive forces (Morris et al., 1996). *The combined effects of tillage-induced erosion in uplands and channel degradation in streams have made sediment a major water quality problem in states, like Iowa* (Helmers et al., 2007).

To address the issues of topsoil loss, water quality, and channel degradation, Best Management Practices (BMPs) have been developed. Traditionally, the majority of transported sediment was believed to originate from the uplands (Trimble, 1983) and for good reasons, namely tillage-enhanced erosion rates. Thus, most BMPs were developed for the landscape (Helmers et al., 2007). Numerous federal or state governmental agencies, including the Natural Resources Conservation Society (NRCS) and Iowa Department of Agriculture and Land Stewardship, have attempted to curb upland surface erosion by authorizing the construction of hundreds to thousands of grass waterways and sediment basins in Iowa over the last twenty years.

To some degree, these measures were successful. Apart from some success stories, many cases have been reported in the literature where extensive BMP programs were applied in agricultural areas, and yet downstream water quality worsened even more than 10 years after the BMPs were installed (e.g., Garrison and Asplund, 1993) prompting the following questions *"Were the BMPs installed in the wrong place or does it just take several years to see the downstream benefits of the BMPs?"* Because downstream sediment loads have not necessarily decreased (Schilling et al., 2007), researchers have begun to consider channels as significant contributors of sediment (e.g., Zaimes et al., 2004).

To assist policy makers and watershed planners in attacking the problem at the source, we used an established tracing technique, namely naturally occurring radionuclides (Berylium-7,

^{7}Be, and excess Lead-210, $^{210}Pb_{xs}$), for isolating the primary sediment sources (i.e., uplands, banks, and bed) to streams under different magnitude hydrologic events. If we can quantify the dominant sediment source(s) in streams, we can identify the areas, which need BMPs to control sediment and sediment-bound Phosphorus, and design our BMPs for better efficiency.

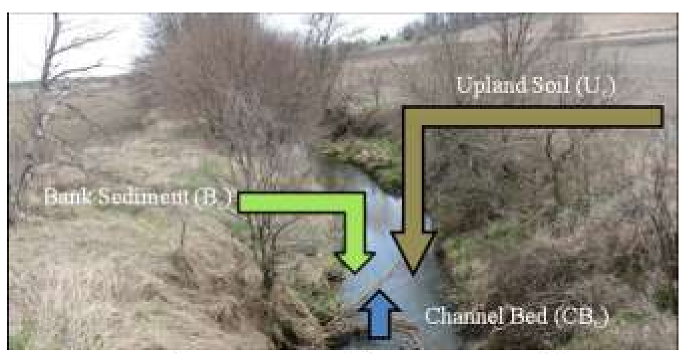
In this study, our central objective was to understand the relationship between different sediment delivery processes in an intensively agricultural headwater system, which is representative of the U.S. Midwest, during individual runoff events. To do so, we determined sediment budgets over these runoff events in a control volume downstream of the watershed and partitioned the sediment load into different source materials using naturally occurring radionuclides. This study will help provide an effective method for evaluating watershed management plans and determining BMP efficiencies, as well as quantifying Total Maximum Daily Loads (TMDLs), and verifying watershed erosion models.

To monitor effectively watershed management plans, which are suites of BMPs, sediment budgets in a downstream control volume over a single runoff event time scales are often used. However, two problems may hinder accurate results: (1) predominantly intensive agriculture areas are often in ungaged, upland watersheds, which do not allow for quantitative measurements and (2) sampling in a control volume downstream of these areas will contain a mixture of multiple source areas. Before the effectiveness of watershed management plans can be evaluated these shortcomings must be addressed.

Methodology

The nature of the study involved field, laboratory, and numerical undertakings. The primary goal for this study *was to partition the sediment contributions of uplands, U_c, channel banks, B_c, and channel bed sediment, CB_c to the total eroded sediment, Q_s, in the anthropogenically altered Clear Creek, IA Watershed* (CCW; Figure 1). In order to address this goal, we identified three tasks. During the first year of this study only Tasks 1 and 2 were conducted and Task 3 is proposed for year 2.

Task 1: Develop sediment rating curves for the CCW for different magnitude hydrologic events. Direct monitoring of individual runoff events provides the best means of quantifying sediment loads from a watershed. However, monitoring is costly, laborious and, if it is conducted only at the system outlet, provides merely a net load estimate. Several direct means of measuring water and sediment fluxes are available, which can provide a sediment rating curve to relate the flux of water (Q_w) and Q_s, to quantify total sediment loads.



$$Q_S = \int U_C + \int B_C + \int CB_C$$

Figure 1. A budget for a stream with sediment sources from the uplands, channel banks, and bed.

We developed sediment rating curves to determine a sediment budget for different hydrologic events using the established infrastructure of the CCW (Papanicolaou and Abaci, 2008). For constructing the sediment rating curve, we employed the unique flow and sediment data obtained from the in-stream sensors during each event. Sediment concentrations were determined from grab samples and in-stream samplers collected per each event, as well as a SediMeter, which measured turbidity. These measurements were coupled with flow data to determine sediment fluxes. Bank retreat data were also retrieved using pre- and post-event channel surveys, as well as by Photo-Electric Erosion Pins (PEEPs), which provide automated, continuous monitoring of bank erosion. The sediment flux data from the uplands and the channel were integrated over each event duration to provide a sediment budget.

Task 2: Quantify the relative partition of sediment sources contributing to the suspended sediment load of the CCW using radionuclide tracers. We quantified the relative proportions of eroded upland soils and channel derived sediments in the suspended load of the sampled events using ^{7}Be and ^{210}Pb$_{xs}$.

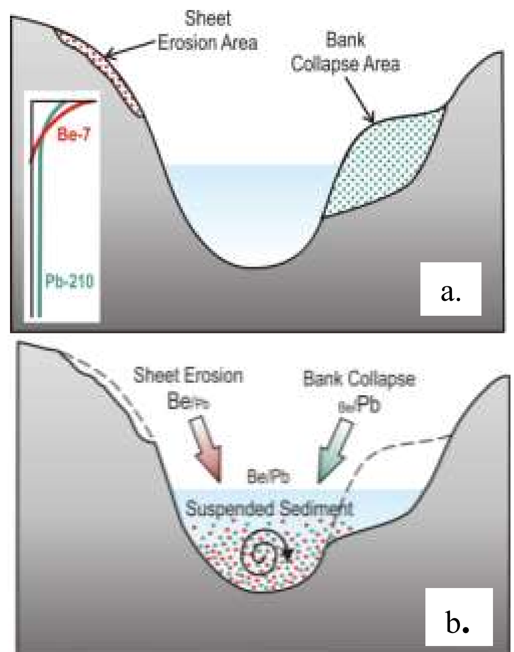


Figure 2. (a) Depth distribution of ^{7}Be and ^{210}Pb prior to the event. (b) Sediments from the eroded source areas are mixed in the channel as they are carried downstream.

The different erosion mechanisms affecting surface soils and channel sediments result in different radionuclide signatures for the resulting mobilized sediment (Figure 2). High radionuclide activities are located near the soil surface (Figure 2). Upland erosion processes (sheet and rill erosion) remove a thin layer of the surface soils, which is enriched in both ^{210}Pb$_{xs}$ and especially ^{7}Be. Channel erosion processes (e.g., bed resuspension and bank collapse) contribute essentially radioactively dead material, or sediment with a low radionuclide signature. Sediment from the stream bed has resided there for extended periods undergoing substantial decay without radionuclide replenishment.

Initially, unique radionuclide signatures of potential source sediments in the watershed (specifically uplands, channel banks, and the channel bed, Figure 1) were identified to quantify their contributions to the suspended load. Suspended sediment samples were collected during different runoff events. The radionuclide activities of sediment samples collected over different parts of the runoff events were compared to the activities of these source sediments to determine their relative contributions using a two end member mixing model.

Task 3: Incorporation of the unmixing model results into the Clear Creek Digital Watershed for model verification. The data from this study will be stored in the Clear Creek Digital Watershed and used for model verification and model refinement (e.g., AnnAGNPS-CCHE1D (Qi et al., 2008); WEPP – 3ST1d (Papanicolaou and Abaci, 2008); SWAT (Neitsch et al., 2002)). This will be conducted in Year 2 of the project.

Principal Findings and Significance

This summary focuses on a specific sequence of three representative late spring rain events out of four events. The cumulative rainfall for Event 1 (Figure 3a) totaled 25 mm with a maximum 5-minute precipitation rate of 38 mm/hr. During Event 2, the total rainfall was 20 mm and the maximum 5-minute precipitation rate was 52 mm/hr (Figure 3b).

Event 3 (Figure 3c) was extraordinary in that it caused flow levels at the site outlet to increase approximately 4 m in less than 1 hour. The total rainfall for the event was only 42 mm, which was in the 63rd percentile for the sub-watershed. However, the event had the sixth highest, 5-minute intensity (98 mm/hr) and second highest, 60-minute intensity (38 mm/hr) on record since September 2006. These extreme intensities produced large amounts of runoff that were quickly delivered to the stream causing flash flood conditions.

The rainfall characteristics (i.e., intensities and durations) for the three events produced distinctly different hydrographs. While the peak intensities and cumulative rainfall totals for Events 1 and 2 were similar, the total volumes of flow transported during the events were distinctly different. Event 2 produced greater amounts of runoff because Event 1 increased the average saturation of the soil, leading to reduced infiltration and increased overland flow in the subsequent event (Elhakeem and Papanicolaou, 2009). The Event 1 hydrograph (Figure 3a) shows a wider deviation from the mean discharge and a more gently sloping recessional limb compared to the hydrograph of Event 2 (Figure 3b). Event 3 produced a hydrograph (Figure 3c) with a long period of an extremely high flow rate. This was the result of even higher antecedent moisture conditions, higher rainfall

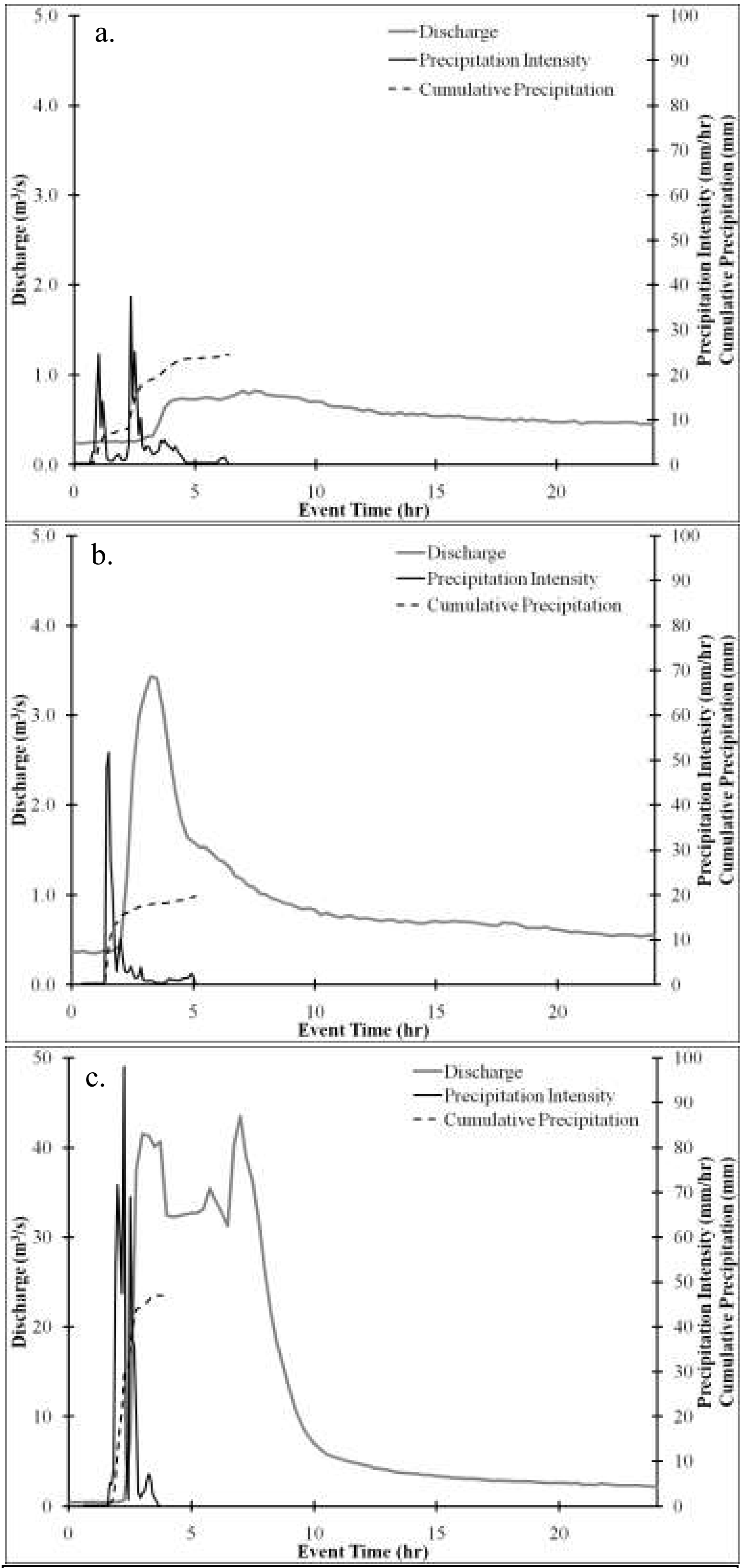


Figure 3: Runoff Event Hydrographs: (a) Event 1. (b) Event 2. (c) Event 3.

amounts, and extreme rainfall intensities.

The varying-rainfall intensities have been shown to affect suspended sediment concentrations significantly (Alexandrov et al., 2007; Smith et al., 2003). Thus, the hydrographs resulting from the differing rainfall intensities were plotted in relation to the sedigraphs (Figure 4). These charts in Figure 4 display the suspended sediment concentrations for the samples collected using the different sampling techniques, namely grab sampling, the Sigma sampler, and the SediMeter. Additionally, one suspended sediment sample using a DH-48 hand-held depth-integrating sampler was collected during Event 3.

The suspended sediment concentrations measured by the different techniques agreed well despite the differences in operating principles. The maximum percent difference between any of the two techniques for a single sample time was only 19%. This deviation, which occurred at the first sampling of Event 2, was attributed to the inherent differences between point measurements (i.e., Sigma or grab samples) and integrated concentration measurements from the SediMeter. Specifically, the grab sampling technique provided a point measurement from the top of the water column, the Sigma sampling technique gave a point measurement near the bottom of the water column, and the SediMeter presented an integrated profile of concentration

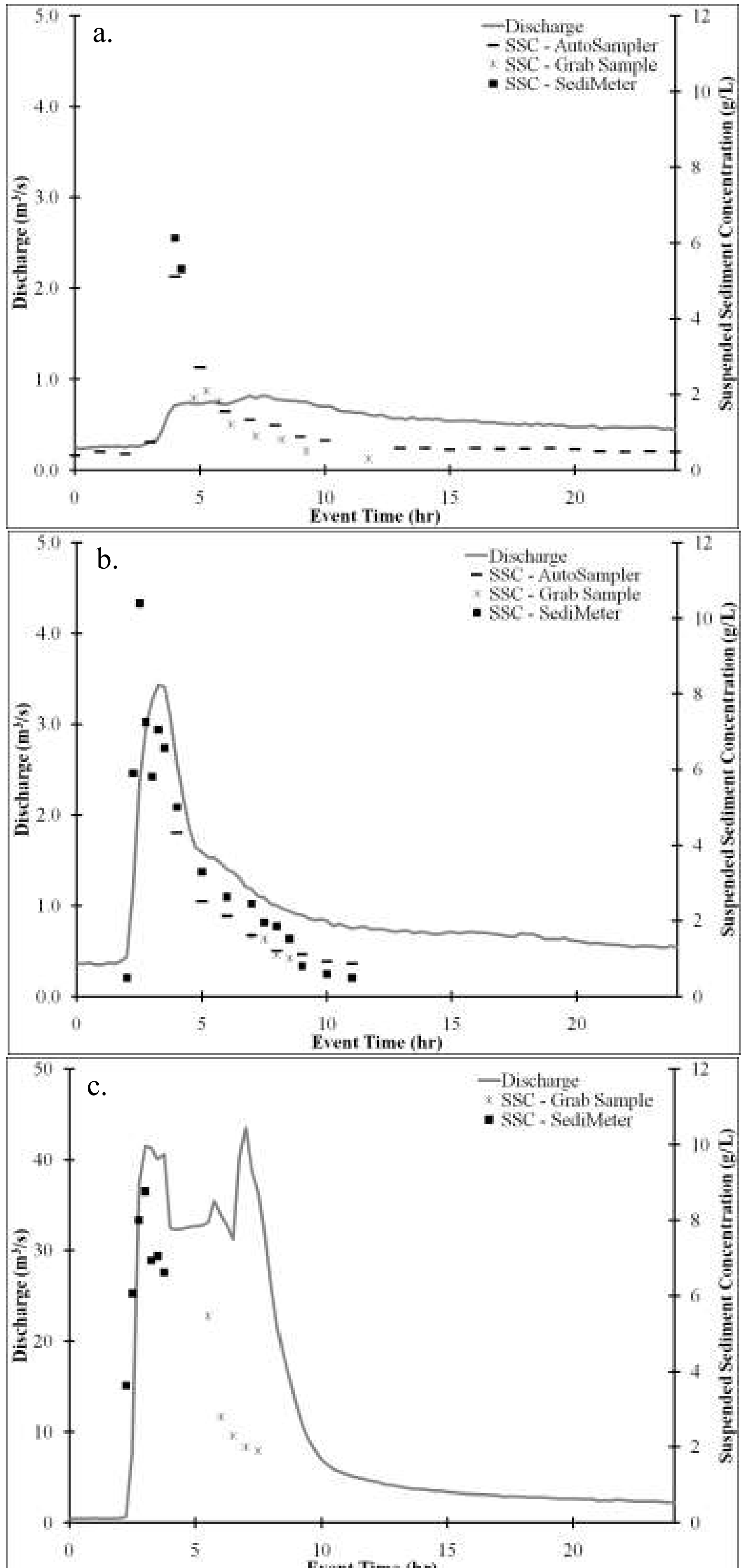


Figure 4: Suspended sediment concentrations in relation to the event hydrographs. (a) Event 1. (b) Event 2. (c) Event 3.

measurements (limited to the instrument height).

Pros and cons exist for the various suspended sediment sampling techniques used in this study. Continuous measurements were not feasible with either the grab or Sigma sampling techniques, prompting the need for fully automated measurements to capture more accurately intra-event variability in sediment fluxes. The SediMeter was able to provide unattended measurements during the peak of the hydrograph. However, during Event 3, excessive debris (corn tassels, leaves, and other forms of residue) wrapped around the SediMeter, thereby causing biofouling and erroneous suspended sediment measurements (e.g., Ridd and Larcombe, 1994). In addition, the Sigma samples collected during the high flows of Event 3 were excluded from the sediment budget calculations because overbank flow flooded the sample containers and compromised all Sigma samples for the event.

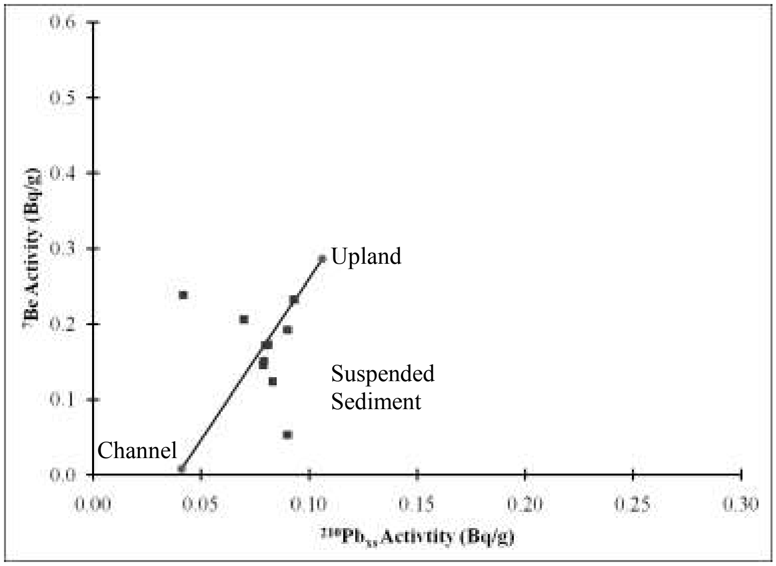


Figure 6: Example of two end member model (Event 1).

The total sediment flux (Q_S) during each event was quantified over a 24-hr period from the initiation of the rainfall by multiplying measured C_S and flow discharges (Q_W). In the three events, discharge was returning to baseflow conditions in this period. Using these parameters, Q_S was equal to 48,646 kg for Event 1; 222,062 kg for Event 2; and 3,640,256 kg for Event 3.

Sediment loads for the three events were also calculated using a sediment rating curve for the SASW Clear Creek outlet (Figure 5) originally developed by Zager (2009) but updated with these current measurements. Using this curve, the estimated Q_S were 32,945 kg for Event 1, 83,360 kg for Event 2, and 4,494,017 kg for Event 3. The flux for Event 1 was underestimated by the sediment rating curve by 21% while Event 2 was underestimated by 64%, while the flux for Event 3 was over-estimated by 27%.

One of the primary reasons that the sediment rating curve under-predicts the suspended sediment loadings for Events 1 and 2, while over-predicts for Event 3 is that the sediment rating curve assumes a linear relationship between Q_S and water flow rate (Q_W) while the actual relationship between Q_S and Q_W during high flow events is non-linear.

Thus, traditional sediment rating curves, such as the one developed by Zager (2009), should be used with caution when attempting to predict total sediment yield during high flow events. This shortcoming is magnified because a majority of the annual sediment load is transported during high flow events (Lenzi et al., 2003; Markus and Demissie, 2006).

The second task of this study was to partition the suspended sediment loads for the three events into relative contributions from the uplands and the channel using the activities of ^{7}Be and $^{210}Pb_{xs}$. The first step in the load partitioning was to identify the activities of the two source areas: (1) the eroded upland soil after the influx of radionuclides in precipitation and (2) the channel sediments in Clear Creek.

The activities of ^{7}Be and $^{210}Pb_{xs}$ from the surface soils collected in agricultural fields of the CCW were pooled to develop a composite profile of the upland source material for that watershed because of large spatial variabilites between sampling sites (^{7}Be: 19%; $^{210}Pb_{xs}$: 68%; Wilson et al., 2003).

The atmospheric influxes of ^{7}Be and $^{210}Pb_{xs}$ were then distributed over the composite soil profiles to a depth of 2.0 cm using an exponential function to determine the activity of the eroded surface soils (Wilson et al., 2003). The resulting radionuclide profiles were represented by an exponential function (Owens et al., 1996; Wallbrink and Murray, 1996; Bonniwell et al., 1999; Wilson et al., 2003) due to the rapid and strong bonding to surface soil particles, which is reflected in the high partition coefficients of the radionuclides ($K_d \sim 10^4$ to 10^6; Wilson, 2003).

The representative radionuclide activities of the eroded surface soils were then determined by plotting the logs of the activities and depths and fitting a linear function. From these constructed profiles, the activities of the eroded surface soils were assumed to be the surface activity, or the activity at depth = 0 cm suggested from the linear fit through the data (Wilson et al., 2003).

The activities of ^{7}Be and $^{210}Pb_{xs}$ from the bank cores were initially assumed to be near zero. The integration of the activities over the length of the bank face incorporates a vast majority of soil particles deficient in ^{7}Be and $^{210}Pb_{xs}$. ^{7}Be is found only within the top few centimeters of the soil column, and the activities of total ^{210}Pb is dominated by supported ^{210}Pb at depth, i.e., $^{210}Pb_{xs}$ is near zero (Wallbrink and Murray, 1996; He and Walling, 1997; Bonniwell et al., 1999; Wilson et al., 2003). Bank heights at the site are greater than 1.0 m. The measured activities of $^{210}Pb_{xs}$ and ^{7}Be from 1.0-m cores collected along an actively eroding bank faces were low relative to the eroded surface soils (Figure 6); therefore, bank material was dominated by supported ^{210}Pb and contained little ^{7}Be.

The average activities of ^{7}Be and $^{210}Pb_{xs}$ of the eroded surface soils and channel sediment were plotted (Figure 6) for the different events. Each event required the use of a separate two end-member unmixing model because the upland source activities for the

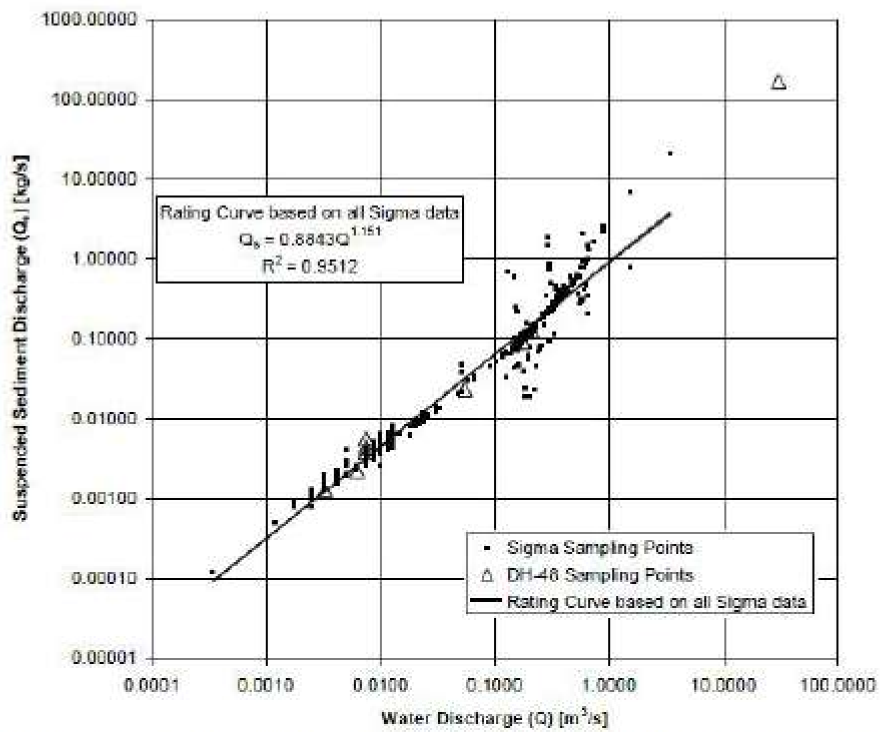


Figure 5: Sediment rating curve for SASW from Zager (2009).

events were different. The two source areas plotted at different ends of the graphs suggesting that the two activities used in relation to one another do provide a unique signature for each source material despite the potentially high spatial variability. When the activities of ^{7}Be and $^{210}Pb_{xs}$ of the fine suspended sediment collected during the event were added to the graph, each sample plotted along a mixing line between the two source materials. Each fine suspended sediment sample was projected at right angles towards the mixing line. The position where each sediment sample projected onto the line dictated the relative percentage of each source material contained in that sample.

The results from the two end-member unmixing models were represented in pie charts displayed over the event hydrographs (Figure 7). The proportion of black in each pie represented the relative amount of eroded upland soil contributed to the suspended sediment load at the time of collection; likewise, the proportion of grey in each pie chart represented the relative percentage from channel sources. The proportion of eroded upland soils was high in the beginning stages of Event 1, similar to the studies by Kuhnle et al. (2008) and Wilson et al. (2008).

The dominance of upland soils in the early stages of the event was due to rapid mobilization of fine loose particles by overland flow in the uplands. These easily entrained soils either were deposited during previous runoff events (Ghadiri et al., 2001) or were loosened by rainsplash. Once the easily entrained soils were swept away by the "first flush" of overland flow, the amount of material available to be readily mobilized by overland flow was significantly reduced (Stutter et al., 2008). This was in conjunction with cessation of the runoff, which delivered the eroded

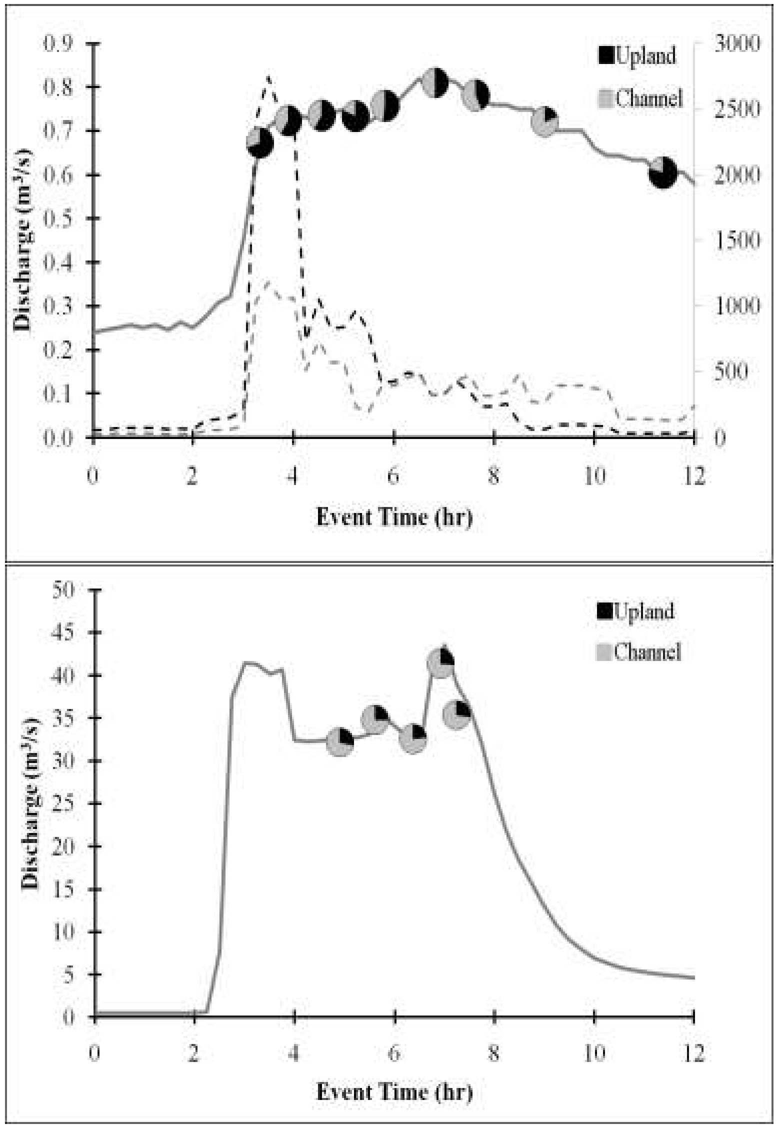


Figure 7. Pie charts showing the partitioning of the suspended sediment samples into eroded upland surface soils and channel sediments during Events 1 (a) and 3 (b) over the course of the event hydrographs. The black pie pieces represent the upland proportions. The grey pie pieces represent the channel proportions. The solid line represents the discharge during the event. The dashed lines (only in a) correspond to the sediment loads with the black dashed line for the upland load and the grey dashed line for the channel load.

surface soils to the stream. The exhaustion of the upland source allowed the channel to become the dominant contributor to the suspended load in the later stages of Event 1. Furthermore, sediment contributed to the flow by bank collapse typically occurs on the falling limb of the hydrograph (Springer et al., 1985; Thorne, 1982), further increasing the proportion of sediments derived from the channel during this period. These results were again similar to the studies by Kuhnle et al. (2008) and Wilson et al. (2008).

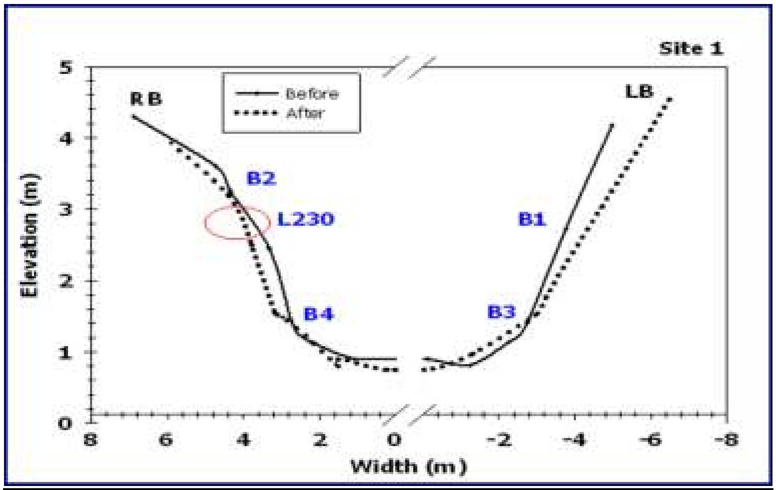


Figure 8: Cross sectional survey for the control volume.

Samples for radionuclide analysis were not collected for the beginning of Event 3; however, samples captured for the last half of the event had higher relative channel contributions than the upland source. This trend is important in the closure of the Event 3 sediment budget.

Based on the field measurements, the total sediment transported (Q_S) during Event 1 was 48, 646 kg. Combining the sediment loads for the 24-hr period of the event with the load partitioning analysis using the radionuclide activities from individual samples showed that the proportion of upland material was 60% of the total load. The partitioning of the integrated sample from the stream tube showed that 67% of the material was upland-derived. For Event 2, individual suspended sediment samples were not analyzed using gamma spectroscopy; however, the integrated sample using the stream tube was analyzed and showed that 34% of the transported sediment was derived from the uplands. Table 1 displays the contribution from each source to the suspended load (Q_s) throughout the event from the integrated sampler.

The amount of material contributed during Event 3 by the channel banks in the study reach, B_C, was determined was considerably greater (79%; Table 1), which was corroborated by the pre-event and post-event cross-sectional surveys (Figure 8) and PEEPs (Table 2). The bank retreat rates were between 9 and 58 cm for the study period.

Extensive rill and gully erosion in the SASW could cause error in the radionuclide tracer results. Because the activity of the upland soils decreases exponentially with depth, soil eroded from these areas would have lower activities than as theorized by the unmixing model (Wallbrink and Murray, 1993; Yang et al., 2006). This would cause the upland soils to have radionuclide signatures resembling the channel sediments after the formation of rills and gullies. Thus, sediments originating in the uplands may be misinterpreted as having come from the channel.

Table 1: Sediment load partitioning

	Upland	Bank
Event 1	67%	33%
Event 2	34%	66%
Event 3	21%	79%

Table 2: Comparison of Survey, PEEP, and erosion pin bank retreat measurements.

		PEEP SENSORS	
	Survey	**Automated**	**Manual measurement with tape**
PEEP B2	17.4	20.3	27.9
PEEP L230	Missing flag	11.8	8.9
PEEP B4	12.7	11.9	9.5
PEEP B1	58.7	Instrument washout by the flow	
PEEP B3	Deposition	Instrument washout by the flow	

* Erosion lengths are in cm

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Publications (if any)

List of relevant Grants generated from this 104 B seed grant

Grant Title: Automatic Bank Erosion System to Protect Highway Bridge Crossings at Abutments Total Project Costs: $60,000.00 Sponsor: University of Nebraska-Lincoln

Grant Title: Quantifying Infilling Rates and Differentiating Sediment Sources Using Isotopic Tracers in the Alec River-Black Swan Lake System for Targeting Restoration Efforts

Investigator Type: Project Director Total Project Costs: $72,868.00 Sponsor: US Department of Defense, Army

List of relevant publications

Wilson, C.G., A.N. Papanicolaou, and K.D. Denn. 2011. Quantifying and partitioning fine sediment loads in an intensively agricultural headwater system. Journal of Soil and Sediments. Submitted.

Wilson, C.G, A.N. Papanicolaou, and K.D. Denn. 2011. Quantifying relative rates of upland and bank erosion using radionuclide tracers in an agricultural watershed. 2011 Iowa Water Conference. Ames, IA.

Sutarto, T., A.N. Papanicolaou, F. Bertrand, and C.G. Wilson. 2011. Fluvial erosion measurements of streambanks using Photo-Electronic Erosion Pins (PEEPs). 2011 James F. Jakobsen Conference, The University of Iowa, Iowa City, IA.

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Nutrient Transport and Fate in Vegetative Treatment Systems

Basic Information

Title:	Nutrient Transport and Fate in Vegetative Treatment Systems
Project Number:	2010IA150B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	4th
Research Category:	Water Quality
Focus Category:	Agriculture, Wastewater, Nutrients
Descriptors:	None
Principal Investigators:	Daniel Anderson, Robert Burns, Michael Castellano, Lara Moody

Publications

1. Andersen, D.S., R.T. Burns, L.B. Moody, and M.J Helmers. Using total solids concentrations to estimate nutrient content of feedlot runoff effluent from solid settling basins, vegetative infiltration basins, and vegetative treatment areas. Applied Engineering in Agriculture. (In Press).
2. Baker, J., D.S. Andersen, R.T. Burns, L.B. Moody. 2011. Use of phosphorus sorption isotherms to project vegetative treatment life. Transactions of the ASABE. (Submitted for Publication).
3. Andersen, D.S., R.T. Burns, L.B. Moody, M.J. Helmers. 2010. Using total solids concentrations to estimate nutrient content of feedlot runoff effluent from solid settling basins, vegetative infiltration basins, and vegetative treatment areas. In Proc. 2010 Intl. Symp. on Air Quality and Waste Mgmt. for Agric. ASABE Paper No. 711P0510cd. St. Joseph, Mich.: ASABE.
4. Andersen, D.S., M.J. Helmers, R.T. Burns. 2011. Retention, accumulation, and movement of phosphorus in six vegetative treatment areas used for feedlot runoff control. 2011 ASABE Annual International Meeting. Louisville, Kentucky.
5. Baker, J., D.S. Andersen, R.T. Burns, L.B. Moody. 2010. Use of phosphorus sorption isotherms to project vegetative treatment life. 2010 ASABE Annual International Meeting. Pittsburgh, Pennsylvania. ASABE Paper No. 1008593. St. Joseph, Mich.: ASABE.

Nutrient Transport and Fate in Vegetative Treatment Systems

Daniel Andersen
Graduate Research Assistant, Iowa State University,dsa@iastate.edu, 515-294-3153

Problem and Research Objectives

Runoff from open beef feedlots is a contributor of nutrients (nitrogen and phosphorus) to the surface waters of Iowa. Concentrated Animal Feeding Operations (CAFOs), those over 1,000 head of cattle, are required to apply for and follow the guidelines set in their National Pollution discharge Elimination System (NPDES) permits. For non-CAFO operations, those below 1,000 head of cattle, the current Iowa regulatory standard is removal of settleable solids and no direct discharge to surface waters (Iowa AFO/CAFO Regulations 2006). Recent research has shown that high levels of nutrients may be discharged from settling basins; for passively managed solid settling basins ammonia-N, total phosphorus, and total solids concentrations have been reported to range from 71 to 354 mg/L, 34 to 235 mg/L, and 2,843 to 54,233 mg/L respectively (Moody et al., 2007). Discharge concentrations at these levels can adversely affect surface waters. To preserve water quality within the state, beef producers of all sizes need to be proactive in their approach to mitigate the release of runoff effluent to surface waters.

Vegetative treatment systems (VTSs) have been proposed and are being implemented as one form of feedlot runoff control in Iowa. A VTS is a combination of treatment components designed and managed to reduce the risk of a feedlot runoff effluent release. The VTS generally consists of a solids settling structured followed by additional treatment components that utilize perennial grasses and forages to reduce the quantity and improve the quality of the effluent. Research on VTSs located on CAFO feedlots around Iowa has indicated that proper design and operation of these systems can reduce the amount of nitrogen, phosphorus, and solids discharged by more than 80% (Andersen et al., 2009). The Iowa Small Feedlot Team and the Iowa DNR expect VTSs to play a large role in reducing the impacts feedlots have on water quality.

Better understanding of the transport and fate of the nitrogen and phosphorus applied to the VTS is required to improve system design and ensure sustainability. Currently, VTS design is based on the runoff control system hydrology. To protect Iowa streams and rivers from runoff effluent nutrients, design guidelines based on the nitrogen and phosphorous treatment capacities must be developed. Improving the scientific knowledge of the various nutrient treatment mechanisms occurring in the VTS will provide the data necessary for understanding the transport and fate of the applied nutrients. Moreover, improved understanding of the treatment mechanisms occurring in the system will provide information on how design and implementation of future system can be enhanced to improve nutrient treatment and retention.

The **objective** of this research was **to investigate the dynamics and transport of phosphorus and nitrogen applied to the vegetative treatment area**. Specifically our goals were to:

- Relate nutrient content and reductions in feedlot runoff control systems to solids reductions

- Measure phosphorus sorption isotherms on soils obtained from four vegetative treatment systems in Iowa and project vegetative treatment system life
- Develop phosphorus budgets for six vegetative treatment systems on feedlots in Iowa
- Develop preliminary nitrogen budgets for four vegetative treatment systems in Iowa
- Evaluate if nitrogen accumulation and stabilization is occurring in vegetative treatment soils

Using Total Solids Concentration to Estimate Nutrient Content of Feedlot Runoff Effluent from Solid Settling Basins, Vegetative Infiltration Basins, and Vegetative Treatment Areas

Methodology

Although not part of the original plan of work this investigation was inspired by the Iowa Water Center's call for proposals on improving models for prediction of sediment and nutrient movement. We hypothesized that nutrient content in feedlot runoff was strongly correlated to solids content. The objective of this study was to evaluate the use of total solids concentrations to predict nutrient and effluent quality indicator concentrations of feedlot runoff from solid settling basins and vegetative treatment components. This was conducted by performing correlation and regression analysis for effluent concentrations samples collected on six Iowa sites over a four year period. Prediction equation verification was performed by evaluating the developed regression equations ability to predict nutrient concentrations on a validation data set and by comparing annual mass releases from each VTS component to the estimated nutrient mass release based on effluent total solids concentration.

Principal Findings and Significance

Results of a correlation and primary factor analysis showed that most of the effluent concentrations were strongly correlated to each other, with a single factor capable of describing more than 60% of the total variability of the monitored parameters. Regression equations were developed to relate nutrient content and effluent quality indicator concentrations to total solids concentrations. Results were satisfactory for NH_3-N, BOD_5, COD, Cl^-, TP, and TKN, indicating that total solids concentrations provided significant insight into VTS performance relative to nutrient concentration and effluent quality indicators. A comparison between predicted, based on total solids content, and monitored annual mass release of the parameters was conducted. No statistical difference was found for NH_3-N, BOD_5, COD, Cl^-, TP, and TKN; indicating that effluent volume release along with total solids concentrations could be used to provide an estimate of nutrient mass in solid settling basin, vegetative infiltration basin, and vegetative treatment area effluent.

These results indicate that much of the treatment occurring within the vegetative treatment system is due to solids removal and indicate that by measuring solids concentrations a great deal of insight into how the system is performing can be obtained. Moreover, this information is useful for prioritizing sites in need of enhanced or improved runoff control systems as solids concentration analysis offers a quick and cost effective method of surveying the potential risk different sites pose to water quality. Currently we are working on extending this technique by developing and calibrating erosion models to predict solids transport for the feedlot surface as a function of feedlot size, shape, slope, cattle stocking density, and rainfall intensity.

Use of Phosphorus Sorption Isotherms to Project Vegetative Treatment Area Life

Methodology

Soil was collected in the fall of 2009 from each of the four VTA sites to develop the phosphorus isotherms. Phosphorus sorption isotherms were developed using the method of Graetz and Nair (2000). One gram of air-dried soil was placed into each of seven 50 mL vials and mixed with 25 mL of 0.01 M calcium chloride ($CaCl_2$) solution containing phosphorus concentrations of 0, 2, 5, 10, 50, 100, and 200 mg KH_2PO_4-P/L. Three drops of chloroform were added to each vial to inhibit microbial growth. Samples were shaken on an orbital shaker for 24 hours at 27±2°C. They were then allowed to settle for one hour. The supernatant was filtered through a 0.45 µm filter. Dissolved reactive phosphorus (DRP) concentrations were analyzed by an 880nm wavelength spectrophotometer (Genesys 6 , Thermo Electron Corporation, Madison, WI) using the ascorbic acid method (AWWA, 1998). This process was carried out three times for each site with duplicate samples used in each run. Soil phosphorus sorption isotherms were modeled with the Langmuir isotherm equation. A mass balance equation and the phosphorus sorption maximum was then used to project the amount of time it would take before the soil was no longer able to sorb phosphorus. A sensitivity analysis was utilized to determine what parameters had the most impact on treatment system life and to provide insight into the most effective methods in extending treatment system life.

Principal Findings and Significance

The four monitored VTAs in Iowa had calculated life expectancies that ranged from 4 to 9 years for the top six inches of the soil profile. The main factors that influenced VTA life were soil phosphorus sorption capacity and the phosphorus loading rate. The two VTAs with the highest sorption capacity had the longest life expectancies. The higher sorption capacity allowed the soil to sorb more phosphorus from the feedlot runoff before becoming saturated. This work found that there were two effective methods of extending vegetation treatment area phosphorus saturation life. The first method was to locate VTAs in areas where the soil has a high phosphorus sorption capacity and relatively low initial phosphorus content. The second method is to approximately balance phosphorus application with phosphorus removed with vegetation harvest. Methods of improving the balance include improving management of pretreatment components to lower phosphorus application onto the VTA, harvesting the VTA more frequently to increase phosphorus removal from the VTA, and constructing larger VTAs. At the locations investigated, between 30 and 60% of the applied phosphorus must be removed with vegetation harvest to achieve a 0.3 m phosphorus saturation life of 50 years (see figure 1). To obtain these phosphorus removals under current management conditions would require VTA to feedlot area ratios of approximately 3:1, 3:1, 1:1, and 6:1 for CN IA 1, NW IA 1, NW IA 2, and SW IA 2 respectively. These results provide practical design guidance to improve future vegetative treatment area designs to extend treatment area life to acceptable levels.

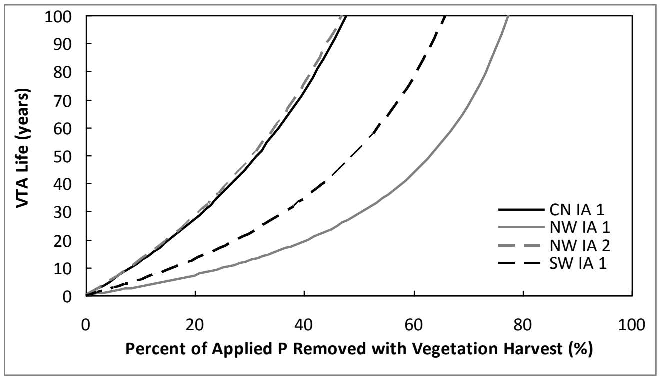

Figure 1. Plot of percent of applied phosphorus that needs to be removed with harvested vegetation versus 0.3 m VTA phosphorus saturation life for four VTAs on feedlots in Iowa.

This research also gave us a construct in which to view the results of a soil sampling effort we had conducted over a four year period on six vegetative treatment areas in Iowa. In general the results confirm the hypothesis of the phosphorus isotherm experiment and analysis. That to have reasonable design life's for these systems the amount of phosphorus most be in reasonable balance with the amount removed during vegetation harvest. If this doesn't occur, they the soils will quickly and significantly increase in Melich-3 extractable phosphorus concentrations and evidence of phosphorus leaching will occur within four or five years of system operation. Although this work can't provide definite guidance on exactly how large the treatment area must be as that would require a full economic analysis, it does lay the groundwork for the economic analysis and illustrate how to make these systems successful.

Nitrogen Stabilization and Accumulation in Soil Organic Matter

Methodology

Vegetative treatment systems receive high annual loadings of carbon and nitrogen. This could cause accumulation of nitrogen and carbon within the soil. Most models of soil organic matter suggest that this accumulated carbon can reside in one of two pools of variable recalcitrance. Several methods, including biological, chemical, and physical fractionations have been developed to determine which "pools" the nitrogen and carbon are accumulating in. In this study both physical and chemical methods were used to assess (1) if stabilization of nitrogen and carbon were occurring and (2) the relative stability of the carbon and nitrogen in the soil.

To separate stable and labile fractions of soil carbon and nitrogen a 365-day (currently at 275 days) incubation assay was conducted. In this method, soils are placed in a filtration apparatus (Buchner funnel) and repeatedly leached with carbon and nitrogen free leaching solution (Stanford and Smith, 1972). Leachate chemistry and soil respiration are monitored throughout the assay. Thus, this is assay defines the labile and stable fractions in functional terms, namely, those molecules that are mineralized within a year when incubated at optimal temperature and moisture conditions are considered labile; those that remain are considered stable. By using this methodology, the interaction between carbon and nitrogen pools and the rate at which they mineralize can be assessed.

Soil samples were collected from six locations located throughout Iowa. Two sites were selected at each location, one site was from the vegetative treatment area component of a feedlot runoff control system and the second was from a paired grass area that did not receive the feedlot runoff application. The vegetative treatment area had been in use for five years and had received heavy application of settled feedlot runoff effluent application. At each of the tested sites five soils samples were collected. Each sample was a composite from five randomly selected locations at the site. This provided sixty soil samples for use in this experiment. The collected soil samples were placed in a plastic bag, stored on ice, and transported back to the laboratory. Soil samples were air dried. Rocks and identifiable chunks of plant residue were removed. The soil samples were sieved through 2 mm sieve and stored in sealed containers in the lab until use.

A filtration apparatus was constructed for each sample out of the top of a plastic Buchner funnel. A VWR 696 and Whatman GF/D extra-thick glass filter were placed at the bottom of each funnel. Glass wool and approximately 100 grams of each soil sample was placed onto the filters. An 11-cm VWR 696 filter was placed on top of the soil sample to reduce dispersion when leaching solution was applied. Each funnel was placed in a plastic incubation chamber. The chambers had a screw-on cover with a septum in it. The soil samples were leached on day zero and moisture was adjusted to 65% of their water holding capacity. Soils were then placed in a constant temperature (35°C) room. Incubation chambers were covered with cling wrap to reduce evaporation of water while facilitating exchange of gas with the soil atmosphere.

Principal Findings and Significance

The carbon and nitrogen mineralization of the vegetative treatment area soil was compared to the paired grass area to evaluate if accumulation had occurred. Although not yet complete, thus far the soil incubations indicate that nitrogen and carbon has accumulated in the labile pool but not significantly in the stable pool. This indicates that while soil organic matter is serving as a sink for some of the added nitrogen it is not stabilized and protected from losses in following growing periods. Moreover, a mass balance of the applied nitrogen indicates that soil accumulate and plant uptake account for less than half of the applied nitrogen. As groundwater nitrate concentrations have decreased since installation of the treatment system it appears that a large fraction of the applied nitrogen is being lost in gaseous form either due to ammonia volatilization or through biological denitrification. Visual inspections have indicated that soil conditions are often conducive to denitrification; however, further evaluation is required to confirm magnitude of this pathway. If these findings are correct it indicates that vegetative treatment systems may be capable of processing large amounts of nitrogen in an environmentally secure manner.

USGS Award No. G11AP20048 Climate Change Impact Evaluation Coralville Reservoir Evaluation

Basic Information

Title:	USGS Award No. G11AP20048 Climate Change Impact Evaluation Coralville Reservoir Evaluation
Project Number:	2011IA187S
Start Date:	12/16/2010
End Date:	10/15/2011
Funding Source:	Supplemental
Congressional District:	
Research Category:	Climate and Hydrologic Processes
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Richard Cruse

Publications

There are no publications.

Problem and Research Objectives

There is a need to investigate the effects of climate change on flood and drought frequencies, reservoir operating policies, sedimentation, and dam safety. The effects of global climate change could significantly alter the quantity and frequency of reservoir inflows. Significant changes to project inflows may lead to increased frequency of major floods as well as reservoir deficits within the traditional low-flow late summer period.

The study scope will assess the reservoir in response to the following central question: How can climate change considerations be incorporated into reservoir operating policies that will be robust and adaptive to potential climate changes?

Methodology

A review of authorized reservoir purposes along with historical operations and policies will be conducted to assess vulnerabilities associated with climate change projections and to identify areas where adaptation may be needed to meet mission requirements.

Historical inflow, precipitation, and temperature data will be reviewed and assessed for trends of observed nonstationarity and potential vulnerabilities in current reservoir operations and policies. Next, future climate change scenarios will be selected and examined. First, the envelope of potential changes for particular greenhouse gas scenarios summarized in the IPCC AR4 report will be quantified. This activity will identify an anticipated range of changes in extremes of rainfall and temperature that relate to streamflow and evapotranspiration. The second goal is to better understand the physical processes leading to changes in weather and terrestrial variables. This activity will evaluate the extent to which climate simulations correctly simulate relationships between weather and terrestrial variables, lending confidence to the use of climate projections in management planning, and will identify whether anticipated changes are due to changes in intensity, duration, or frequency of processes already observed or are the result of new, emerging processes.

Principal Findings and Significance

We received funding for the project in December 2010, and our team has had two telecons since then. An overview of annual and seasonal changes in average temperature and precipitation has been prepared for and reviewed by US Army Corps management. Key findings are:

(1) Global Climate Model (GCM) results for NE Iowa project changes in the 30-yr average temperature and precipitation (2040-2069 minus 1970-1999) that range 1.2-4.4 C and -10% to +20%. Five out of 112 GCM simulations project increased springtime precipitation.

(2) Results from 6 Regional Climate Model (RCM) simulations, which provide more realistic physical processes in this region compared to GCMs, lie within the central range of the GCM results. The RCM simulations better capture the summer negative correlation between precipitation and temperature, suggesting they are better suited for use when considering summertime projections on water volume in Coralville Reservoir.

US Army Corps is very concerned with increased springtime rainfall. This would necessarily lead to an increase in streamflow, and, since Coralville reservoir is a fixed volume that can not be expanded, additional water volume is highly problematic. The GCM projections contain a range of increase in springtime (March-April-May) precipitation of 0% to 25%. Historically, 1% increase of precipitation results in 2% to 2.5% increase in streamflow in the Midwest, which means a rough estimate of projected change in streamflow is 0% to 50-70%.

Information Transfer Program Introduction

The Iowa Water Center organizes and conducts education and outreach activities throughout the year. The focus of the Iowa Water Center 2010 Information Transfer Project was on educating the public concerning the quality of water resources and the impacts of best management practices. Center activities take the form of conferences, scientific poster symposiums, field days, special publications, fact sheets, and informational brochures for educators and the general public.

Information Transfer Project

Basic Information

Title:	Information Transfer Project
Project Number:	2010IA151B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	4
Research Category:	Not Applicable
Focus Category:	Education, Water Quality, Agriculture
Descriptors:	None
Principal Investigators:	Richard Cruse, Hillary Ann Olson

Publications

There are no publications.

The Iowa Water Conference held March 8 & 9, 2010 in Ames, IA attracted 305 participants. The conference theme was: "Pulling It All Together: Policy, Programs and Practices." Conference partners included the Iowa Department of Agriculture and Land Stewardship, Iowa Department of Natural Resources, Iowa Natural Resources Conservation Service, Iowa Association of Municipal Utilities, and the Iowa Storm Waters Education Program. Multiple outreach activities were conducted with the Iowa Learning Farm (ILF). The IWC was engaged to strengthen water related educational activities of the ILF. The IWC receives $10,000 from ILF so support our partnership.

The IWC developed with the ISU Soil and Water Conservation Club our second annual educational/outreach publication, titled "Getting into Soil and Water." Approximately 1,600 copies have been distributed in Iowa, including to Iowa high school science teachers, potential students visiting selected programs in the College of Agriculture and Life Sciences, Iowa DNR offices, all Natural Resources Conservation Service offices in Iowa, selected ISU alumni, Iowa Extension offices, Iowa Environmental Council, and the Hawkeye Fly Fishing Association.

By invitation from Iowa Department of Natural Resources Director, joined the governor established Lake Delhi Recovery and Rebuild Task Force - The Environment Committee, which had the responsibility to "Lead long-term and community planning efforts and identify best practices with respect to managing the Maquoketa River watershed, reducing the likelihood of future damage by flooding and maintaining or improving water quality." The director of the IWC was invited to join the Center for Global and Regional Environmental Research, University of Iowa, November 18, 2010. The Center for Global and Regional Environmental Research (CGRER) is a state-funded institute devoted to studying and bettering our environment. It promotes interdisciplinary research on the many aspects of global environmental change. Areas of focus include regional effects on natural ecosystems, environments, and resources, and effects on human health, culture, and social systems.

The IWC director has lead, and is leading, the development of a peer reviewed publication from the IWC and Council for Agriculture Science and Technology (CAST); the planned publication addresses land management impacts on stream water quality in agricultural watersheds. The document is currently under review with a 2011 target for publication.

Invited presentations:

Cruse, R.M. Trends in Iowa Water Runoff. Presented at: A Watershed Year: Anatomy of the Iowa Floods of 2008. Lessons Learned, Preparing for the Future. Iowa State Historical Building, Des Moines IA. March 9, 2010.

Cruse, Richard, Brian Gelder, Robert Anex, and Hillary Olson. 2010. Water Foot Print of Various Biofuel Crops. American Society of Agronomy Annual meetings. Long Beach, CA. available at: http://a-c-s.confex.com/crops/2010am/webprogram/Paper57719.html

The Iowa Water Center also contributed $500 for the 2010 Climate Summit and the IWC director chaired technical session.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	1	0	0	0	1
Masters	1	0	0	0	1
Ph.D.	1	0	0	0	1
Post-Doc.	1	0	0	0	1
Total	4	0	0	0	4

Notable Awards and Achievements