Iowa Water Center
Annual Technical Report
FY 2011
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 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. Iowa is somewhat unique in that it lies on a sharp precipitation gradient from east to west, making it a battle ground at times between water excess and water deficits. Our ability to manage water during extreme climatic events has been tested in recent years with the flood events in Iowa of 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 has been a primary focus this year and will be a focus 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.

Iowa has recently invested in LiDAR, giving the state elevation coverage with verticaln sensitivity of 20 cm. This unique asset allows the Iowa Water Center to support research addressing hydrology with detail that makes it unique compared to most other states. Research efforts will ultimately assist city planners and the general public in addressing storm water planning issue as well as improve our ability to understand surface water flow and its implication for both sediment and nutrient delivery to surface water.
Identifying the Primary Sources of Sediment in an Anthropogenically Altered Watershed

Basic Information

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<td>Principal Investigators:</td>
<td>Thanos Nicholas Papanicolaou, Marian V.I. Muste, Douglas Schnoebelen, Larry Weber, Christopher Wilson</td>
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Publications

There are no publications.
IDENTIFYING THE PRIMARY SOURCES OF SEDIMENT IN AN
ANTHROPOGENICALLY ALTERED WATERSHED

Annual Report – Year 2

Submitted to:
Director and Professor Rick Cruse
Iowa Water Center
2218 Agronomy Hall
Iowa State University
Ames, IA 50011-1010

Submitted by:
Prof. Thanos Papanicolaou
and
Dr. Christopher Wilson
IIHR-Hydroscience & Engineering
College of Engineering
The University of Iowa
Iowa City, Iowa 52242

May 2012
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The spatial and temporal scales of erosion processes in the upland areas and stream channels of Midwestern agricultural watersheds have been dramatically altered by anthropogenic activities including tillage and channel straightening. The combined effects of tillage-induced erosion and channel degradation have resulted in sediment becoming a major water quality problem in states like Iowa. To assist policy makers and watershed planners in identifying areas that are prone to erosion and determining the location, type, and number of Best Management Practices needed to control sediment-related problems, we have used an established tracing technique with naturally occurring radionuclides (Beryllium-7 and excess Lead-210) for quantifying and partitioning the primary sources (i.e., uplands, banks, and bed) of suspended sediment to stream loads under different magnitude, hydrologic events in a representative, agricultural, headwater system. During the second year of this two-year project, further analysis of the data collected in the first year was conducted and culminated into a recently published manuscript (Wilson et al., 2012). The additional analysis focused on the observed non-linearity or hysteresis between suspended sediment concentration and flow discharge during the sampled runoff events. This hysteresis was useful for interpreting the results from the radionuclide partitioning of the sediment sources to stream suspended load. Finally, the data collected during the first year of the study were made available for the verification of watershed erosion models. The initial set of simulations using WEPP-3ST1D proved promising, yet further study of the results is needed to explain the differences between measured and modeled sediment loads during the large third event, a flash flood.
IDENTIFYING THE PRIMARY SOURCES OF SEDIMENT IN AN ANTHROPOGENICALLY ALTERED WATERSHED

Annual report – Year 2
May 2012

Principal Investigators
Thanos Papanicolaou¹
Christopher Wilson¹
Larry Weber¹
Marian Muste¹
Doug Schnoebelen¹

External Collaborator
Mark Tomer²

Students Supported
Kevin Denn
Fabienne Bertrand
Tommy Sutarto
Matt Zager

¹IIHR – Hydrosience & Engineering
The University of Iowa
300 S. Riverside Dr.
Iowa City, Iowa 52242

²National Laboratory for Agriculture and the Environment
USDA-ARS
2110 University Boulevard
Ames, Iowa 50011-3120

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1a. Principle Investigator(s):
Dr. A.N. (Thanos) Papanicolaou, Professor, Department of Civil and Environmental Engineering, The University of Iowa, apapanic@engineering.uiowa.edu, 319-335-6448

Dr. Christopher Wilson, Assistant Research Scientist, IIHR – Hydrosience and Engineering, The University of Iowa, cgwilsn@engineering.uiowa.edu, 319-335-6168

Dr. Larry Weber, Director and Professor, IIHR – Hydrosience and Engineering, Department of Civil and Environmental Engineering, The University of Iowa, larry-weber@uiowa.edu, 319-335-5597

Dr. Marian Muste, Research Engineer, IIHR – Hydrosience and Engineering, The University of Iowa, marian-muste@uiowa.edu, 319-384-0624

Dr. Doug Schnoebelen, Director and Research Scientist, LACMERS, IIHR – Hydrosience and Engineering, The University of Iowa, douglas-schnoebelen@uiowa.edu, 319-335-6061

1b. External Collaborator(s):
Dr. Mark Tomer, Soil Scientist, U.S. Department of Agriculture, Agricultural Research Service, National Laboratory for Agriculture and the Environment, mark.tomer@ars.usda.gov, 515-294-0213

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1. INTRODUCTION

1.1 Problem Statement

The spatial and temporal scales of erosion processes in the upland areas and stream channels of Midwestern agricultural watersheds have been dramatically altered by anthropogenic activities including tillage and channel straightening. These changes have, thereby, complicated our understanding of sediment dynamics and predictions of sediment loads in these watersheds. Further, the combined effects of tillage-induced erosion and channel degradation have resulted in sediment being a major water quality problem in states like Iowa (Helmers et al., 2007). In response, governmental agencies have attempted to curb this sediment problem through the development and implementation of Best Management Practices, or BMPs.

To some degree, these BMP programs have been successful; however, in some instances, the downstream water quality has actually worsened even more than 10 years after the programs were installed (e.g., Garrison and Asplund, 1993; Schilling et al., 2007). This has led to questions, such as “Were the BMPs installed in the wrong place or does it just take several years to see the downstream benefits of the BMPs?”

To assist policy makers and watershed planners in attacking the sediment problem at the source, we have used an established tracing technique with naturally occurring radionuclides (Berylium-7, $^7$Be, and excess Lead-210, $^{210}$Pb$_{ex}$) for identifying the primary sources (i.e., uplands, banks, and bed) of suspended sediment to stream loads under different magnitude hydrologic events in a representative, agricultural, headwater system.

By quantifying the dominant sediment source(s) in these streams, we can identify and target those areas that need BMPs to control sediment and attached nutrients, such as phosphorus. Moreover, we can improve our water quality models, which are used to develop sound management strategies. The inability to identify key sediment sources in a watershed plagues Iowans as we struggle to keep our local fields productive and waterways healthy, while defending accusations from downstream communities.

1.2 Background

A widely used method of quantifying suspended sediment loads from a watershed is through direct monitoring of individual runoff events and developing a sediment budget. This is especially true in headwater systems, which are relatively small so there is no need for numerous sampling locations.

Tracing techniques have been utilized to supplement the direct monitoring of individual runoff events by characterizing the sources and pathways of soil and sediment within a fluvial system. Soil and sediment tracers (Foster, 2000) have been based on sediment properties including radionuclide characteristics (e.g., Walling and Woodward, 1992; Busacca et al., 1993; Smith and Elder, 1999; Vanden Bygaart and Protz, 2001) and stable isotopic chemistry (e.g., Allegre et al., 1996; Filippi et al., 1998; Kendall and Doctor, 2004; Fox and Papanicolaou, 2007). However, new technologies are still needed to specifically link tracer signatures to the parameters controlling erosion mechanisms across a watershed.
Naturally occurring fallout radionuclides are effective tracers and can help differentiate sediment sources, if appropriate tracers are used, with half-lives that are relative to the time scales of the driving forces. Single runoff events, which occur on timescales of hours and days, are best studied with radionuclides that decay on similar scales (e.g., Whiting et al., 2005; Wilson et al., 2008), as is the case with $^7$Be (half-life, $t_{1/2} = 53.3$ days), supplemented with $^{210}$Pb$_{xs}$ ($t_{1/2} = 22.3$ years).

$^7$Be is produced continuously in the atmosphere through spallation (or breaking up) of nitrogen and oxygen atoms by cosmic rays. $^{210}$Pb is produced as an intermediate daughter in the Uranium-238, $^{238}$U, decay series. The $^{238}$U ($t_{1/2} = 4.5 \times 10^9$ years) in soils decays through a series of daughters to gaseous Radon-222, $^{222}$Rn, ($t_{1/2} = 3.83$ days). A portion of the $^{222}$Rn remains in situ, while some of it diffuses into the atmosphere. The $^{222}$Rn in both the soil and the atmosphere further decays to $^{210}$Pb through a series of short half-lived daughters. The $^{210}$Pb produced within the soil is termed “supported”, while the atmospheric $^{210}$Pb is termed “excess” ($^{210}$Pb$_{xs}$) and is used in this study.

In the atmosphere, the $^7$Be and $^{210}$Pb$_{xs}$ attach to aerosol particles and are delivered to the landscape mainly during precipitation events. The radionuclides quickly and strongly bond to fine surface soils (namely, silt and clay; He and Walling, 1996) through cation exchange. Activities of $^7$Be and $^{210}$Pb$_{xs}$ decrease exponentially moving downcore in the soil column (e.g., Wallbrink and Murray, 1996; Bonniwell et al., 1999; Wilson et al., 2003) for only a few centimeters.

The fine, high activity, soils at the ground surface are preferentially mobilized by raindrop impact and eroded by runoff (Rhoton et al., 1979). The preferential removal of fine soil particles during storm runoff events leads to enrichment (Rhoton et al., 1979) of the radionuclide activity in the eroded sediment by concentrating the particles with high radionuclide activities.

The eroded surface soils and adsorbed radionuclides are transported downstream where they are mixed with sediment from collapsed stream banks and entrained streambed material (Figure 1). In contrast to the high activities of the eroded surface soils, the channel sediments tend to have lower activities. Stream banks receive little atmospheric input of the radionuclides due to near-vertical slopes (Whiting et al., 2005), and stream bank failure can remove large volumes of material (Thorne, 1992) that dilute the high-activity bank soil at the surface with a much larger volume of low-activity sediment from deeper in the collapsed bank. In addition, the sediment from the streambed has resided there for extended periods undergoing substantial decay without radionuclide replenishment.

The resulting signature of the suspended sediment will reflect the mixture of the surface soils and channel sediments. High radionuclide activities in the suspended sediment suggest a large proportion of

Figure 1. Depth distribution of $^7$Be and $^{210}$Pb$_{xs}$ in source areas. (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.
recently eroded surface soil. Conversely, lower activities suggest dilution by channel sediments. A simple, two end-member mixing model can determine the relative contribution of each source area (i.e., soil surface and channel) to the fine suspended sediment load. The radionuclide signatures of suspended sediment lie roughly along the mixing line between the signatures of the two end-member sources of sediment.

This method was coupled with direct flux measurements and developed sediment rating curves to parse out the different contributions to the fine suspended sediment loads of an agricultural stream. Multiple techniques used in conjunction with one another tend to produce clearer distinctions.

2. OBJECTIVES AND TASKS

The goal of this study was to quantify and, ultimately, partition fine suspended sediment loads in an intensively agricultural, headwater system that is representative of the U.S. Midwest during individual runoff events to understand the relationship between different sediment delivery processes. The long term vision of the study is to assist policy makers and watershed planners in identifying the areas that are prone to erosion (i.e., hotspots) and determining the location, type, and number of countermeasures, or BMPs, and in-stream stabilization structures, needed to control sediment-related problems.

3. METHODOLOGY

The nature of this study involved field, laboratory, and numerical undertakings to partition the sediment contributions of uplands, \( U_c \), channel banks, \( B_c \), and channel bed sediment, \( CB_c \), to the suspended sediment load, \( Q_s \), in the anthropogenically altered Clear Creek, IA Watershed (CCW; Figure 2). In order to address this goal, we identified three tasks. Tasks 1 and 2 were conducted during the first year of this study, much of which was discussed in the first annual report. Further analysis of the results from these tasks was completed in year 2 that culminated in a recently accepted, peer-reviewed, journal article (Wilson et al., 2012). In this annual report for year 2, Tasks 1 and 2 are summarized with only the additional analysis presented herein. Task 3 was focused in year 2 of this project with the results also presented herein.

Task 1: Develop sediment rating curves for CCW for different magnitude hydrologic events. One of the best means of quantifying suspended sediment loads from a headwater watershed is through direct monitoring of individual runoff events. However, this monitoring can become costly, laborious and, if it is conducted only at the system outlet, provides merely a net load estimate.
In this study, we developed sediment rating curves to determine a sediment budget for representative hydrologic events in CCW (Papanicolaou and Abaci, 2008). For constructing the sediment rating curves, we used in-stream pressure transducers to quantify the flux of water ($Q_w$). Sediment concentrations were determined from grab samples and in-stream samplers, as well as a Sedimeter, which measured turbidity continuously. These measurements were coupled with the flow data to determine $Q_s$. The sediment flux data from the uplands and the channel were integrated over different runoff events to provide a sediment budget (Figure 2).

**Task 2: Quantify the relative partitioning of sediment sources that contribute to the suspended sediment load of CCW using radionuclide tracers.** We quantified the relative proportions of eroded upland soils and channel derived sediments in the suspended load of sampled events using $^{7}$Be and $^{210}$Pb$_{xs}$ (e.g., Wilson et al., 2012). Initially, unique radionuclide signatures of the potential source sediments in the watershed (specifically uplands, channel banks, and the channel bed) were identified to quantify their contributions to the suspended load. The radionuclide activities of these sediment sources were compared to the activities of suspended sediment samples collected over different parts of sampled runoff events 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 were made available to the Clear Creek Digital Watershed for refinement and verification of different watershed models. The data were initially used in the coupled Watershed Erosion Prediction Project–Steep Stream Sediment Transport 1-D model (WEPP – 3ST1d; Papanicolaou and Abaci, 2008; Dermisis et al., 2011) to simulate the sampled events.

### 4. STUDY SITE

The 260-km$^2$ Clear Creek Watershed is a Hydrologic Unit Code (HUC) - 10 watershed in southeastern Iowa (Figure 3) that is representative of most watersheds in the Midwest especially regarding land use (predominantly agricultural), soil type/order (Alfisols and Mollisols), and climate (humid-continental). In addition, CCW is well instrumented by IIHR Hydrosience & Engineering at the University of Iowa to monitor rainfall, streamflow, soil moisture, and infiltration/runoff, as well as other water quality parameters making it an ideal natural laboratory.
Anthropogenic activities, including intensive agriculture, urbanization, and stream channelization, have strongly influenced flow and sediment processes within the watershed. The intensive agriculture, in conjunction with highly erodible soils and steep slopes, has produced some of the highest rates of erosion and non-point source pollution in Iowa and the United States (see the USDA-NRCS 2007 National Resources Inventory). Stream destabilization from widespread channelization and drainage system construction has further increased sediment loadings to the stream (Rayburn and Schulte, 2009). The high sediment loads have exacerbated damage resulting from recent flooding, thus prompting local concern.

This study was focused in a 26-km$^2$ headwater catchment of CCW, namely the South Amana sub-watershed (Figure 3). This sub-watershed is dominated by agriculture, with 85% of the land supporting corn/soybean fields and the remaining 15% under grassed pastures. Hillslopes have an average gradient of 4% (range = 1% to 10%) and contain silty clay loams of the Tama-Downs soil series in the uplands and Colo-Ely soil series along the floodplains.

The stream network consists of two 1st-order streams that are approximately 6 river km long with slopes of 0.16%. The streambed is dominated by sand-sized particles having a median grain size of 0.31 mm (Ellis, 2009). The channel banks range from gradually sloping (height ~0.5 m) to nearly vertical (height ~ 3 m) at the outlet.

The outlet of the sub-watershed was conventionally defined as a 76-m, straight reach below the confluence of the two 1st-order streams (Figure 3). The average water discharge and sediment loadings through this reach are 5.9 x 10$^6$ m$^3$/yr and 5.0 x 10$^3$ tons/yr, respectively (Abaci and Papanicolaou, 2009).
The general climate of CCW is typical of other mid-continental locations; hot summers, cold winters, and wet springs are the prevailing trends (Ruhe, 1956). An average growing season in southeast Iowa lasts approximately 180 days. Average annual precipitation is $889 \pm 220$ mm/yr with convective thunderstorms prominent in the summer and snowfall in the winter.

5. RESULTS AND DISCUSSION

5.1 Tasks 1 and 2

Continued analysis of the sediment rating curves was conducted in year 2 of this project for incorporation into a journal manuscript (Wilson et al., 2012). As a review, the suspended sediment fluxes ($Q_S$) from the sampled events were quantified over a 24-hour period from the initiation of the rainfall using the following methods: (1) multiplying the measured suspended sediment concentration ($C_S$) and the flow discharge ($Q_W$); (2) applying individual discharge-sediment flux relationships for each event (herein called individual event relationships; Figure 4); and (3) applying a cumulative discharge-sediment flux rating curve for the site incorporating measurements collected over 5 years (originally in Zager, 2009).

The suspended sediment loads (Table 1) that were calculated using the $C_S \cdot Q_W$ measurements and the individual event relationships were similar (<10% difference) for each event; however, the cumulative rating curve for the outlet under-predicted the suspended loads of smaller events (between 21% and 64%, when compared to the measurement-based load) and over-predicted the loads for larger events by about 27%.

<table>
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<tr>
<th>Event Number</th>
<th>Runoff (m$^3$)</th>
<th>$C_S \cdot Q_W$</th>
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<td>47,390</td>
<td>48,646</td>
<td>51,917</td>
<td>32,945</td>
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<td>2</td>
<td>83,031</td>
<td>222,062</td>
<td>241,523</td>
<td>83,360</td>
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<tr>
<td>3</td>
<td>977,623</td>
<td>3,640,256</td>
<td>3,531,750</td>
<td>4,494,017</td>
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One of the primary reasons for the differences between the sediment rating curve loads and the measurement-based loads was the non-linearity between $C_S$ and $Q_W$ during the runoff events. The sediment rating curve assumed as a linear relationship between sediment concentration and flow discharge, while the measured values and individual event relationships accounted for the nonlinearity, or hysteresis (Figure 5). During the sampled events, a clockwise hysteresis was observed. Clockwise hysteresis is often explained as resulting from source material exhaustion (e.g., Williams, 1989; Moog and Whiting, 1998; Baca, 2008; Salant et al., 2008; Smith and Dragovich, 2009) from the limited availability of loose fine material in the uplands.

Using the measurement-based sediment loads that accounted for the hysteresis along with the load partitioning analysis based on the radionuclide activities for three successive events showed that $67 \pm 20\%$ of the material was upland-derived during the first event. For the second event, $34 \pm 11\%$ of the suspended sediment was derived from the uplands. During the third event, however, the sediment load was dominated by channel sediments ($79 \pm 29\%$).
The radionuclide analysis showed a decreasing proportion of eroded upland soils in the three successive events, which was supported by the clockwise hysteresis from source material exhaustion. It should be noted that the slopes of the hysteresis trends decrease through the sequence of events. In Event 1, the slope is nearly vertical (Figure 5a), while for Event 2, the slope decreases to approximately 2 to 1 (Figure 5b), and the slope is nearly horizontal in Event 3 (Figure 5c). The slope decreases as the ratio between the concentration values and discharges decreases, which means less sediment is mobilized for the consecutively higher flows. This can be attributed to less material being readily available for erosion in the subsequent events since it was carried away by earlier events.

5.2 Task 3

For Task 3 of this project, the data collected during the first and second tasks were made available and applied to watershed models for verification purposes. Simulations using the coupled WEPP-3ST1D model for the South Amana sub-watershed were conducted using the new information gleaned from this study. The model had previously been calibrated in Abaci and Papanicolaou (2009) and Dermisis et al. (2011).

Briefly, WEPP is a spatially distributed, process-based, hydrologic/erosion model that includes detailed sets of management practices. Key sub-routines in the model also include climate generation, snow accumulation and melt, irrigation, topography (i.e., downslope curvature), infiltration, overland flow hydraulics, water balance, plant growth, residue decomposition, soil disturbance by tillage, and erosion/deposition. WEPP has been previously used to simulate erosion within the upland areas of CCW (Abaci and Papanicolaou, 2009).

3ST1D is a one-dimensional numerical model developed by Papanicolaou et al. (2004) for simulating unsteady flow and sediment transport in steep streams. The input
files of 3ST1D, including the boundary and initial conditions, grain size distribution and cross-sectional data, were modified to read basic output data from the WEPP hillslope simulations, such as runoff, storm duration and soil loss (Dermisis et al., 2011). This model routes the sediment from the hillslopes (determined by WEPP) through the stream channels.

The sampled events were simulated in succession by modifying relevant input parameters for the successive events with outputs from the previous events. The relevant parameters included 5-minute breakpoint precipitation, critical shear stress, effective hydraulic conductivity, initial saturation, cumulative rainfall since last tillage, initial canopy cover, and days since last tillage/harvest. Figure 6 shows the comparison between the measured values of runoff volume and suspended sediment load collected during the sampled events for the South Amana sub-watershed. For runoff volumes, the model simulations compared well with the measured values, having percent differences less than 16%. However, the percent differences between the measured and predicted suspended sediment loads were between 10 and 74%. The only value that did not simulate well was the suspended sediment load for the third event, which was an extreme flash flood. The model under-predicted the load value. On-going analysis is being conducted with these simulations; however, the data from this study are proving useful. Other simulation using AGNPS are currently being developed, with future simulations of SWAT on the horizon.

6. CONCLUSIONS

During the second year of this two-year project, a further analysis of the data collected in the previous year was conducted. This analysis culminated into a recently published, peer-reviewed manuscript (Wilson et al., 2012).

The additional analysis focused on the observed non-linearity or hysteresis between \( C_S \) and \( Q_W \) during the sampled runoff events. During three successive events, a clockwise hysteresis was observed. Clockwise

![Figure 5. Suspended sediment concentration and discharge relationships. Graphs showing the relationship between suspended sediment concentration and discharge, as well as the associated hysteresis, for each event. The dark, dashed lines show the general slopes of the hysteresis trends. (a) Event 1; (b) Event 2; (c) Event 3. From Wilson et al. (2012).]
hysteresis can be explained as the result of source material exhaustion from the limited availability of loose fine material in the uplands. This hysteresis was useful in further interpreting the results from the radionuclide partitioning of the sediment sources to stream suspended load.

The clockwise hysteresis from source material exhaustion and the decreasing slopes observed in the hysteresis plots (Figure 5) suggest that less material was readily available for mobilization during subsequent events. The radionuclide analysis showed a similar decreasing proportion of eroded upland soils in the three successive events. Hence, the majority of loose, fine sediment in the uplands was flushed during the first event.

Finally, the data collected during the first year of the study were used for the verification of watershed erosion model simulations. The initial set of simulations using WEPP-3ST1D proved promising, yet further study of the results is needed to explain the differences in the sediment load during the large third event.

7. REFERENCES


Community-wide Urban Storm water Planning Utilizing LiDAR, the WinSLAMM Model, and GIS.

**Basic Information**

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**Publications**

There are no publications.
Community-wide Urban Storm water Planning Utilizing LiDAR, the WinSLAMM Model, and GIS

Basic Information

Title: Community-wide Urban Storm water Planning Utilizing LiDAR, the WinSLAMM Model, and GIS.
Principal Investigators: Ramanathan Sugumaran, John DeGroote, Bernard Conrad
External Collaborators: Paul Meyermann, John Voorhees, Rebecca Kautern
Start Date: September 2011
End Date: May 2012

Publications


Community-wide Urban Storm water Planning Utilizing LiDAR, the WinSLAMM

Problem and Research Objectives

Urban watersheds are composed of a complicated spatial fabric and are influenced by a wide range of economic, policy, and public interest drivers and constraints. With increased regulation of storm water discharges taking place on a national basis, there are greater pressures on municipalities to develop effective urban storm water management strategies. Thus, there is a great need for effective tools which
can aid the design and execution of such strategies by identifying hot-spot areas contributing to excessive discharges and pollutants and to evaluate potential best management practices (Wong 2010). Although concern over urban storm water runoff quantity and quality has grown, there has been a lack of accurate spatially explicit models for better storm-water planning.

Urbanization of watersheds has been known to create problems in regards to water quality (Roesner 2001; Walsh 2000). Urban areas consist of manmade impervious structures that reduce infiltration made possible by permeable surfaces with streets considered to be the major contributor of pollutant runoff (Sartor, 1974). Urban runoff comes from a variety of different sources such as streets, sidewalks, and roofs (Bochis, 2005) which is conveyed by advanced water management systems quickly to natural waterways. However, water quality is important for human uses and ecological reasons to ensure that water sources do not become tainted from various pollutants such as sediment and phosphorus. Better Management Practices (BMPs) can reduce the amount of pollutants being discharged as well as slow down water movement by creating more effective infiltration areas (D’Arcy 2000). To effectively implement BMPs requires topographic knowledge of an area to determine optimal locations of such devices, such as biofiltration devices and detention ponds.

Determining urban drainage areas and patterns is a complex process that is drastically enhanced by incorporating a Geographic Information System (GIS) (Sui, 1999). GIS has capabilities to model hydrology to determine hazards or vulnerability by layering parameters including slope, soil characteristics, precipitation, and others (Clark 1998). Together with a Digital Elevation Model (DEM), GIS can be used to process and determine hydrological features of the ground’s surface (Garbrecht 1999). DEMs are available at different spatial resolutions and it is understood that a higher spatial resolution will result in more accurate results. Higher spatial resolution DEMs are increasingly being developed through LiDAR (Light Detection and Ranging) technology. Iowa is one of the first states in the United States to collect LiDAR data statewide.

To model urban hydrology a DEM is needed to provide an accurate topographic representation of the study area. Using a DEM with high spatial resolution is important to accurately display appropriate drainage areas (Liu 2005). LiDAR has become much more commonly used to create high spatial resolution DEMs available for analysis (Hodgson, 2003). Higher spatial resolution can be prone to errors, although if it is preprocessed carefully to remove errors, LiDAR data can lead to improved results (Barber 2005). Figure 1 shows a comparison between 1, 5, 10, and 30 meter DEMs created using LiDAR data.
Urban watersheds are complex structures that require sophisticated modeling to estimate runoff and pollutant loads. There are many urban storm water models available including MUSIC (Model for Urban Stormwater Improvement Conceptualization) and P8 (Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds) (Elliot, Trowsdale 2007). The Source Loading and Management Model (SLAMM) has been in existence since the late 1970s with constant updates and improvements with the purpose of modeling common small rainfalls (Pitt 2002). Many other urban storm water models are used to model heavy, less frequent rainfall. SLAMM was created to address some of the weaknesses of other models. Models such as MUSIC create drainage systems as well using links and nodes (Elliot, Trowsdale 2007). SLAMM estimates runoff and pollutant loads from areas with unique soil/land use combinations and lumps them by catchment area without drainage models because assumptions with the design of drainage systems are not appropriate for water quality models (Pitt 2002). SLAMM has been expanded to include a wide variety of source area and outfall control practices including: Infiltration practices, wet detention ponds, porous pavement, street cleaning, catchbasin cleaning, and grass swales (Pitt 2002).

The first objective of the project is to investigate the effect of spatial resolution for urban storm water modeling. The second objective is to derive precise topographic representation from LiDAR elevation data and high resolution remote sensing data and to incorporate those data into WinSLAMM to predict sediment and phosphorous runoff from an urban watershed. The study area is the University of Northern Iowa’s Campus located in
Cedar Falls, Iowa (Fig 1). The University of Northern Iowa resides within the Dry Run Creek Watershed. The size of campus is 912 acres consisting of buildings, impervious surfaces, pervious landscapes, and waterways.

![Study Area Map]

**Figure 2: Study Area**

**Methodology**

Figure 3 demonstrates the overall process and which were used to effectively utilize LiDAR data for WinSLAMM modeling of runoff and pollutant loads. The LiDAR data was processed using ESRI’s ArcGIS for Desktop Advanced. The process consisted of converting the 46 ASCII bare earth tiles into multipoint feature classes that could then be added to a terrain network and converted to a raster which is the final DEM. The DEM was then edited to fix the topography of areas that created “digital dams.” These digital dams are locations where water could flows through in the real world, such as underpasses or culverts, but which LiDAR was not able to accurately capture. A detailed and accurate stream network was used and slightly altered to match and was then “burned” into the DEM to force water to flow as it would naturally.

The remainder of the analysis consisted of utilizing the tools found available within ArcHydro, a hydrological modeling extension for ArcGIS. Tools used included Flow Direction which derives the direction of where the water would flow from any given cell. This is an important tool that is used to remove areas where water would puddle in. Once the DEM is completed, the Flow Accumulator can be used to set criteria that can be used to select pixels that other pixels flow into. These pixels are then extracted which make up streams and are used to extract sub-basins, which are used in WinSLAMM.
The delineated sub-basins were then used to split a feature class that contains detailed representation of land use/cover collected through field work (Table 1). This information is imperative for WinSLAMM to operate. The features were split to show all the land use/cover features that exist within each sub-basin. The areas of each sub-basin’s features were then aggregated together for easier user input. The features were then manually entered into WinSLAMM and the total sediment and phosphorus loadings were recorded for each sub-basin.

Figure 3: Methodology Flow Chart
Table 1: Feature descriptions gathered through field work

<table>
<thead>
<tr>
<th>Feature</th>
<th>Drainage</th>
<th>Paved/Unpaved</th>
<th>RoofType</th>
<th>Landuse</th>
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<td>Driveway</td>
<td>Connected/Disconnected</td>
<td>Paved/Unpaved</td>
<td>NA</td>
<td>Institutional/Industrial</td>
</tr>
<tr>
<td>Landscape</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>Institutional/Industrial</td>
</tr>
<tr>
<td>Other Impervious</td>
<td>Connected/Disconnected</td>
<td>NA</td>
<td>NA</td>
<td>Institutional/Industrial</td>
</tr>
<tr>
<td>Other Pervious</td>
<td>Connected/Disconnected</td>
<td>NA</td>
<td>NA</td>
<td>Institutional/Industrial</td>
</tr>
<tr>
<td>Parking</td>
<td>Connected/Disconnected</td>
<td>Paved/Unpaved</td>
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<td>Institutional/Industrial</td>
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<td>Road</td>
<td>Connected/Disconnected</td>
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<td>NA</td>
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<tr>
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<td>Pitched/Flat</td>
<td>Institutional/Industrial</td>
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<td>Sidewalk</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>Institutional/Industrial</td>
</tr>
<tr>
<td>Water</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>Institutional/Industrial</td>
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**Objective 1: Determine the best spatial resolution for urban storm water management.** After the DEM was created through LiDAR processing, it was then resampled from 1 meter into 5, 10, and 30 meter resolution DEMs. The process of delineating sub-basins was then redone for each new DEM and the results were presented based on the total number of sub-basins as well as the average size. **Objective 2: derive accurate spatial data from LiDAR elevation data and high resolution remote sensing and to incorporate data into WinSLAMM.** After the sub-basins were created, they were used to extract UNI campus source areas from a shapefile which was built by gathering data through field work. Once all the features were extracted based on the sub-basin, a printout was created through a Python script that accumulated the total area of unique land features within
the sub-basin. These values were used to parameterize WinSLAMM which was used to calculate runoff and pollutant loadings by each sub-basin.

**Principal Findings and Significance**

The first objective was to evaluate the most efficient spatial resolution to determine sub-basins. Four DEMs were created based on 1, 5, 10, and 30 m resolution DEMs (Figure 3). For each sub-basin the threshold used to delineate was 500 cells. This user defined threshold defines downstream cells which accumulate flow from at least the threshold (in this case 500) number of cells. By doing this a series of streams is created based on the DEM. There is a wide range of variability with selecting a threshold (Jenson 1991; Wang 1998; Da Ros 1997). A smaller threshold will result in a very detailed stream network while a large threshold will produce a stream network consisting of the main large, pronounced streams. The 1 Meter DEM was selected and used through the rest of the project with 78 sub-basins within the study area (Table 2). This is because the 1 m DEM allows the derivation of detailed sub-catchment boundaries which allow for more precise WinSLAMM modeling.

<table>
<thead>
<tr>
<th>Digital Elevation Model</th>
<th>1 Meter</th>
<th>5 Meter</th>
<th>10 Meter</th>
<th>30 Meter</th>
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<tr>
<td>Cell Threshold</td>
<td>500</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Sub-Basins</td>
<td>741</td>
<td>268</td>
<td>67</td>
<td>11</td>
</tr>
<tr>
<td>Average Area of Cell Size (Acre)</td>
<td>20.27</td>
<td>56.2</td>
<td>225.02</td>
<td>1371.98</td>
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Table 2: DEM Comparative Output
The results of the WinSLAMM modeling demonstrate heterogeneity in estimated levels of pollutants being discharged. The sediment load results (Figure 4A) show the amount of sediments that are predicted to be runoff from each sub-basin. The areas with the highest amount of runoff are within the areas with the highest amount of impervious surfaces. Areas in the southwest of the study area consist mostly of large undeveloped landscapes which are highly pervious resulting in a low predicted pollutant discharge. Central and northern sections consist of many impervious surfaces with small landscapes. These areas also contain high traffic due to parking lots. Areas in the Northeastern section of the study area contain large amounts of clay soil which can negatively contribute to the sediment discharge into waterways.

Also shown are the results from the phosphorus pollutant loads (Figure 4B) estimation. These results show similarities to the sediment loadings as well as high results near the southwestern industrial areas in the study area. The central and northwestern areas consist of maintained landscapes which can contribute to
phosphorus loadings due to fertilization which WinSLAMM generates based on the land use classification.

![Figure 5: Pollutant Loading Results. A: Sediment Loads. B: Phosphorus Loads.](image)

Five sub-basins were selected from the results based on their phosphorus and sediment outputs as well as available areas within each sub-basin that would have space to implement a biofiltration unit. WinSLAMM modeling scenarios were then carried out based on introduction of these biofiltration units. Each of these sub-basins contains a large amount of impervious surfaces which greatly contribute to the amount of pollutant output. Every sub-basin selected contains grass areas that allow infiltration to take place. The goal is to locate a BMP within a pervious surface that the impervious surfaces will drain into. Shown below are the impervious and pervious surfaces that are within each sub-basin (Figure 6). By locating a BMP within a pervious surface, the runoff from the impervious surfaces will greatly increase the rate of infiltration and reduce the amount of runoff that currently occurs.
Figure 6: Selected Sub-Basins for BMPs.

The potential BMP sites were located near large areas of impervious surfaces so that the majority of the runoff from these sites could be channeled into the BMP. Not all the sites shown (Figure 6) will contain a BMP but these sites were determined to be the most optimal location within these sub-basins. Detailed information regarding the expected biofiltration units were input into WinSLAMM. Shown below are the specifications of what each BMP will consist of including an expected size, depth, and engineered soil (Table 3).

As you can see many of the biofiltration units do not deviate from a standard structure. Current BMPs on UNI campus follow a similar structure which has been found effective. The only changing variable is the size of the unit itself which is based on the amount of room available and is a major factor in the amount of runoff that will be drained within the BMP. For example, sub-basin 34 contains a large amount of impervious surfaces without much pervious areas so it would require a larger BMP to allow more infiltration to occur. The biofiltration unit also consists of the vertical stand pipe and a broad crested weir for flood control.

Table 3: Expected Biofiltration Cell Details

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<th>Sub-Basin BMP</th>
<th>Top Area (sf)</th>
<th>Bottom Area (sf)</th>
<th>Total Depth (ft)</th>
<th>Rock Filled Depth (ft)</th>
<th>Rock Porosity (0-1)</th>
<th>Engineered Soil Infiltration Rate (in/hr)</th>
<th>Engineered Soil Depth (ft)</th>
<th>Engineered Soil Porosity (0-1)</th>
<th>Underdrain, Vertical Stand Pipe, Broad</th>
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The proposed BMPs were incorporated in WinSLAMM model scenarios and were compared to the previous results without the BMPs. Table 4 shows runoff reductions in both sediment and phosphorus loadings. These biofiltration cells are designed to collect water and allow slow infiltration which would reduce the amount of runoff. The results show large reductions after implementing the biofiltration BMPs. The most significant reductions were in sub-basins 34 and 36. Sub-basin 34 shows the highest reduction amount of total phosphorus loadings with a reduction of approximately 75%.

The goal of this project was to determine if GIS and a LiDAR-derived DEM could produce a more efficient WinSLAMM model. In theory utilizing a DEM with a higher spatial resolution should be effective in modeling the flow of water on the surface. In this project the LiDAR-derived DEM was used to successfully extract the sub-basins within Dry Run Creek through the tools available within ArcGIS and freely available extensions. Within this project it was determined that 1 meter DEM was more efficient to extract sub-basins. However, it would also be suitable to use the 5 meter DEM. The 5 meter was simply more generalized than the 1 meter DEM.

The proposed BMP sites were effective in reducing the amount of pollutants as well as total runoff from entering waterways. These results are modeled estimates and are not to be considered actual amounts. The results are realistic; however the cost of creating the BMP may not be economically feasible. This process of determining

<table>
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<th>After BMP</th>
<th>Percent Runoff Reduction</th>
<th>Total Pollutant Loading (lbs)</th>
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pollutant runoff requires a large amount of knowledge of the study area and all the features within it. WinSLAMM can operate without more limited data but will be able to process more realistically the more data available.

Storm water modeling software provides users with estimates of pollutant loadings being discharged from a given area based on multiple criteria. WinSLAMM gives outputs that can be considered reliable based on their multiple decades of research and data verification. Together with the powerful capabilities of GIS, as well as the temporal and high spatial resolution of LiDAR, a more effective WinSLAMM model can be created.

The first objective of this paper shows that high spatial resolution DEMs can be effectively used to determine urban watersheds. This project reports that the most optimal resolution is between 1 and 5 meters which show very similar results. The 1 meter DEM did require more processing to remove errors such as sinks. Compared to common models which use 10 to 30 meter DEMs, the results shown in this project allowed a higher level of detail to be conveyed which is important within a constantly varying environment such as in urban areas. WinSLAMM was effective in modeling potential urban runoff due to its ability to estimate data based on land use classifications. Combined with the high spatial resolution DEMs, it was possible to determine very accurate urban runoffs. WinSLAMM’s primary use is for urban planning but it can be an effective way of estimating runoff and pollutant loads from large areas without requiring a large amount of effort in collecting and measuring data through fieldwork.

The future goal of this project is to automate pre- and post-processing of WinSLAMM inputs and outputs through a free extension entitled “ArcSLAMM.” This extension will make the entire process undertaken thus far in this project more efficient through a coupling of ArcGIS, databases, and WinSLAMM.


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 2011 Information Transfer Project was on educating the public concerning the quality of water resources and the impacts of best management practices on these resources. Center activities take the form of conferences, scientific poster symposiums, field days, special publications, web page updates, and informational documents for educators and the general public.
Information Transfer Project

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Publication

The Iowa Water Conference held 7 and 8, March 2011 on the Iowa State University campus attracted 425 participants. The conference theme was: “More Water to Manage.” Conference partners included the Iowa Department of Agriculture and Land Stewardship, Iowa Department of Natural Resources, Iowa Association of Municipal Utilities, the Leopold Center for Sustainable Agriculture, Iowa Flood Center, Iowa Floodplain and Stormwater Management Association, Iowa Learning Farms, Iowa State University Extension, the Iowa Water Center, and the Iowa Storm Waters Education Program. The conference was expanded to a two-day venue.

Multiple outreach activities were conducted with the Iowa Learning Farm (ILF). These included presentations at field days across Iowa addressing a range of water related issues associated with agricultural management practices. The IWC was engaged to strengthen water related educational activities of the ILF. The IWC also partnered with the ILF on a funded proposal titled: Water Rocks. The IWC will receive support for the program coordinator (average 0.12 FTE) for the next two years from this grant.

The IWC developed with the ISU Soil and Water Conservation Club our third 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 the Environmental Science program 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, all attendees of the Iowa Water Conference, and the Iowa Environmental Council.

Multiple invited presentations were given by the director addressing water and water related issues, include the following:


The IWC director led the development of a peer reviewed document jointly published by the IWC and Council for Agriculture Science and Technology (CAST); the publication addresses land management impacts on stream water quality in agricultural watersheds. The document draft was completed in 2011, was reviewed in the fall of 2011 and ultimately published in March 2012.
USGS Summer Intern Program

None.
Notable Awards and Achievements

Chapter Achievement Award- SWCS: The Iowa State University Soil and Water Conservation Club which partners with the Iowa Water Center has received the Soil and Water Conservation Society’s Chapter Achievement Award. The student organization published its fourth 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 the Environmental Science program 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, all attendees of the Iowa Water Conference, and the Iowa Environmental Council.