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Kentucky Water Resources Research Institute
Annual Technical Report
FY 2008

Introduction

The 2008 Annual Technical Report for Kentucky consolidates reporting requirements of the Section 104(b) base grant award into a single document that includes: 1) a synopsis of each research project conducted with grant funds during the period, 2) citations for related publications, reports, and presentations, 3) a description of information transfer activities, 4) a summary of student support during the reporting period, and 5) notable awards and achievements during the year.

Research Program Introduction

The activities supported by the Section 104(b) program funds and required matching are interwoven into the total program of the Kentucky Water Resources Research Institute. Additional research, service, and technology transfer activities were funded through a variety of other sponsors. Memoranda of Agreement projects with the Kentucky Division of Water included TMDL development for several Kentucky streams. Three projects were funded by the Kentucky Cabinet for Health and Family Services (related to technical issues involving radiation and other contaminants at the Maxey Flats Nuclear Disposal Site and at the Paducah Gaseous Diffusion Plant). The Kentucky River Authority supported watershed management services in the Kentucky River basin. The National Institute of Environmental Health Sciences supported research translation activities through the Superfund Public Outreach Program. The Metropolitan Sewer District funded activities addressing Beargrass Creek combined sewer overflows in the Louisville area. The Kentucky Department for Environmental Protection also supported 6 students through an Environmental Protection Scholarship Program coordinated by the Institute.

The Kentucky Consortium for Energy and Environment, led by Lindell Ormsbee (Director of KWRRI), continued as a collaborative program integrating faculty and students from the University of Louisville, Murray State University, and the University of Kentucky. The consortium was funded through the US Department of Energy to assist with efforts supporting a variety of environmental assessment and cleanup activities at the Paducah Gaseous Diffusion Plant.

Seven student research enhancement projects were selected for support through 104(b) FY2008 funding. One project was subsequently withdrawn due to technical problems. Projects were conducted at the University of Kentucky (2), Eastern Kentucky University (1), Murray State University (1), Northern Kentucky University (1), and Morehead Sate University (1). Projects represented a variety of discipline areas including: civil engineering (1), geology (2), biology (1), geography (1), and soil science (1). The goal of this approach is to support a number of small student-based efforts representing a variety of discipline areas at numerous institutions. Many state agencies are currently experiencing a significant loss of personnel through retirement and it is critical that undergraduate and graduate students are well trained and available to help fill this void. Project completion synopses for the six student research enhancement projects follow. An additional doctoral-level project was supported with 104(b) funding and a synopsis of that project is also included in this annual report. All projects presented their results at the Kentucky Water Resources Annual Symposium on March 2, 2009.

Evaluation of short-term soil and nutrient loss following a prescribed burn in the Crooked Creek watershed

Basic Information

Title:	Evaluation of short-term soil and nutrient loss following a prescribed burn in the Crooked Creek watershed
Project Number:	2008KY105B
Start Date:	3/1/2008
End Date:	2/28/2009
Funding Source:	104B
Congressional District:	KY First
Research Category:	Water Quality
Focus Category:	Water Quality, Nutrients, Geochemical Processes
Descriptors:	erosion, nutrient transport, forest management
Principal Investigators:	Mike Kemp, Andy Kellie

Publication

**Evaluation of Short-Term Soil and Nutrient Loss
Following a Prescribed Burn in the Crooked Creek Watershed**

This project was predicated and dependent upon the successful completion of a prescribed burn in the Crooked Creek Watershed. Due to excessive rainfall and extensive flooding of the watershed in Spring 2008, the Forest Service was unable to complete the burn as planned. As a consequence, the proposed evaluation of soil and nutrient losses following the burn was not possible and the project was withdrawn by the investigators.

Efforts were subsequently made to identify an alternate project at Murray State University that could be supported with the funds during the remaining budget period, but these efforts were ultimately unsuccessful due to timing constraints and a lack of required matching funds for the alternate project.

The effect of clay mineralogy on the infiltration capacity of grass lawns

Basic Information

Title:	The effect of clay mineralogy on the infiltration capacity of grass lawns
Project Number:	2008KY106B
Start Date:	3/1/2008
End Date:	6/30/2009
Funding Source:	104B
Congressional District:	KY Fourth
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Irrigation, Management and Planning
Descriptors:	soil moisture, irrigation, management and planning
Principal Investigators:	Samuel Boateng

Publication

1. Knuehl, Georgia and Samuel Boateng, 2009, The Effect of Clay Mineralogy on Infiltration of Grass Lawns, in Proceedings of the Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 85.

The Effect of Clay Mineralogy on the Infiltration Capacity of Grass Lawns

Problem and Research Objectives

Infiltration capacity is the rate at which water is absorbed by soil. Factors such as clay mineralogy can affect infiltration capacity of soils. Highly expansive smectite clay in the soil can cause rapid reduction in infiltration rate. A reduction in infiltration capacity results in increased storm runoff and may enhance the erosion of the soil. The adverse consequences of increased storm runoff and soil erosion may lead to increased bed and suspended loads in streams, and also increased non-point source pollution. In compliance with USEPA regulations, the Sanitation District 1 has implemented an urban stormwater management program in Northern Kentucky. The purpose of the proposed program is to mitigate and reduce the environmental risks associated with increased stormwater runoff. Understanding the effect of clay mineralogy on infiltration on permeable surfaces, such as grass lawns, will help stakeholders in making management decisions related to stormwater runoff. This is especially critical in managing irrigation to avoid excessive rates on relatively less permeable soils.

This study investigated the effect of clay mineralogy on infiltration capacity of grass lawns on the campus of Northern Kentucky University at Highland Heights, Kentucky. Soil texture and moisture content were other factors that were considered during the investigation. Smectite, kaolinite, and illite are the three clay minerals tested for during this study. An XRD was used to determine the clay mineralogy of the soils. A double ring infiltrometer was used to determine the infiltration rate at each sample site. The objectives of this study were to answer the following research questions:

1. What is the effect of clay mineralogy on soil infiltration rates?
2. How do soil moisture and soil texture affect soil of a particular mineralogy?

Methodology

The methods used include (1) Infiltrometer Test, (2) Soil Texture Analysis, (3) Soil Moisture Analysis, and (4) XRD Analysis.

Infiltrometer Test

A double ring infiltrometer was used to determine the infiltration rate at each site. All the grass at the test location was clipped to expose the soil. All loose organic cover was removed whilst being careful not to disturb the soil. The infiltrometer cans were twisted into the soil to about 2 – 5 cm. Water was poured into both rings. The water in the outer ring was maintained to a level that approximated the level in the inner ring throughout the test. Care was taken to prevent leaking of water to the surface around the rim of the outer ring. As the water level in the inner ring reached the upper reference mark, a stop watch was started. The time it took for the water level in the inner ring to reach the lower reference mark was recorded. These steps were repeated for about 45 minutes or until two consecutive times were within 10 seconds. Two other infiltration measurements were made within each 5 m diameter area. The infiltration rate was determined by dividing the distance that the water level decreased by the time required for that decrease. The rate of decrease of infiltration rate was noted. The final infiltration rate recorded was the equilibrium infiltration rate.

Soil Moisture Analysis

The gravimetric moisture content at each site was determined before and after the infiltrometer test. Before the start of the test, soil samples were taken to a depth of about 0-5 cm around the test location. The samples were immediately placed in a bag and sealed. The weight of each bag was determined before sampling. Similar samples were taken after the test at the spot where the infiltration test was performed. The weight of each sample was determined. The sample was then oven-dried at a temperature of about 110^{o}C for no less than 8 hours. The difference between the initial weight and the oven-dried weight was divided by the oven-dried weight to determine the gravimetric moisture content. The difference in the gravimetric moisture content before and after the infiltration test was used to determine the effect of soil moisture on infiltration for a particular soil.

Soil Texture Analysis

The goal of the soil texture analysis was to determine the percentage sand, silt, and clay at each lawn site. Each site had a dimension of at least 5 m x 5 m. All sites were located on the NKU Highland Heights campus. The soil texture was determined by performing particle size distribution analysis of the samples in the laboratory. Soil samples were taken from beneath the location of each infiltrometer test. Part of the samples were used for the XRD analysis described below. The laboratory tests were performed in accordance with ASTM standard D422, Standard Test Method for Particle-Size Analysis of Soils. The proportion of sand was the percentage retained on the 75 μm sieve, silt was the percent passing the 75 μm but larger than a diameter of 0.005 mm, and clay was the percent of particles smaller than 0.005 mm.

XRD Analysis

An X-Ray Diffraction analysis was performed on part of the samples taken for the soil texture analysis. A centrifugation technique was used to separate the clay fractions from the silt. This resulted in clay and other minerals of 4 μm or less. The samples weree treated with acetic acid to remove carbonates. Also, all organic particles were removed by using hydrogen peroxide. These treatments were necessary to avoid broad humps on the X-ray powder diffraction patterns. Dried specimens were used for the XRD analysis. The diffraction patterns were used to identify the clay mineralogy. For example, intense 10 angstronm 001 and 3.3 angstrom 003 peaks is typical of illite. Detailed description of the XRD procedure can be found at the website of the Coastal and Marine Geology Program of the USGS or the USGS Open-File Report 01-041.

Principal Findings and Significance

The study involved the investigation of the effect of clay mineralogy on infiltration capacity of grass lawns on the campus of Northern Kentucky University at Highland Heights, Kentucky. Five grass lawns were selected for sampling and testing. Soil texture and moisture content were investigated. XRD analyses were conducted to determine the clay mineralogy of the soils. A double ring infiltrometer was used to determine the infiltration rate at each sample site.

The XRD showed illite as the predominant clay mineral in most of the samples. There were also diffraction patters for chlorite and vermiculite is some samples. Generally, infiltration rates were relatively higher at sites with high sand and low clay percentages. At these sites, the silt portion showed stronger diffraction patterns for illite. Higher percentage sand alone did not seem to be associated with higher infiltration rate. Expansive clays, such as smectite, were not detected at any of the sites. Infiltration capacity seems to be influenced by the proportion of illite within the silt sized fraction. The lower the percentage of clay minerals within the clay sized portion, the higher the observed relative infiltration rate. Soil moisture seemed to influence only the initial infiltration rate.

Development of a composite sediment transport model applicable to watersheds in the Bluegrass Region of Kentucky

Basic Information

Title:	Development of a composite sediment transport model applicable to watersheds in the Bluegrass Region of Kentucky
Project Number:	2008KY107B
Start Date:	3/1/2008
End Date:	6/30/2009
Funding Source:	104B
Congressional District:	Kentucky Sixth
Research Category:	Engineering
Focus Category:	Geomorphological Processes, Models, Sediments
Descriptors:	erosion, streambanks, in-stream storage
Principal Investigators:	James F. Fox

Publication

1. Russo, J.P. and J.F. Fox, 2009, Investigation of land-use change and hydrologic forcing upon streambank erosion and in-stream sediment processes using a watershed model and sediment tracers, in Proceedings Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 23-24.
2. Fox, J., C. DAvis, J. Russo, and D. Martin, 2009, Nitrogen isotopes to study variability of sediment transported from a lowland watershed in the Bluegrass, in Proceedings Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 47-48.
3. Russo, J.P. and J.F. Fox, 2009, Investigation of land-use change and hydrologic forcing upon streambank erosion and in-stream sediment processes using a watershed model and sediment tracers, American Society of Civil Engineers Environmental Water Resources Institute 2009 Congress, Kansas City, Missouri, May 2009.

Development of a Composite Sediment Transport Model Applicable to Watersheds in the Bluegrass Region of Kentucky

Problem and Research Objectives

Sediment represents the number one pollutant impacting the water quality of streams in Kentucky according to the Kentucky List of Impaired Waters (Kentucky Division of Water, 2004). Excess sediment can kill fish and other aquatic life. In addition, other potentially hazardous pollutants, such as fertilizers and pesticides, can attach to the sediment particles and degrade in-stream water quality. In the Bluegrass Region of Kentucky, sediment transport at the watershed scale is dominated by streambank erosion and high in-stream sediment storage as well as surface erosion processes. The processes are impacted by agricultural, urban, and suburban land uses (Sliter, 2007). The mechanisms by which these sediment transport processes are predicted as well as sediment loads attributed to these processes need to be better understood before proper erosion control measures can be implemented (Bohn and Kershner, 2002).

There is a need to build erosion models that are conceptually simple, but that capture all of the necessary sediment processes with reasonable data requirements. The overall objective of this project was to gain a better understanding of in-stream and upland sediment transport processes at the watershed scale by developing a modeling tool that can simulate multiple erosion processes under varying environmental conditions for application to land use change and climatic change scenarios.

A composite watershed model was developed by using an existing modeling tool that estimates surface erosion and sediment routing on hillslopes together with sediment transport equations for in-stream sediment processes including streambank erosion, sediment deposition, and resuspension from intermittent storage zones. The composite model allows routing of sediment through watersheds (with processes similar to those observed in the Bluegrass) and will be used to simulate storm events that carry high sediment loads that can impact water quality. This research worked towards the coupling of sediment fingerprinting with watershed erosion and sediment transport modeling so that stream bank erosion can be more accurately modeled at the watershed scale. The long-term objective of this research was to work towards the development of a watershed modeling tool and its application for land-use change and climate change scenarios.

Methodology

The following scope was detailed for the research project. Physically-based surface erosion watershed models (e.g., WEPP and WESPl), empirical models (e.g., RUSLE, SEDD, and AGNPS) and conceptual model frameworks (e.g., LASCAM and HSPF) were reviewed, and the model most applicable to the South Elkhorn Watershed was chosen for developing a composite framework that includes in-stream storage and streambank erosion processes. The chosen model was set up for upland sediment transport and hydrology. A set of equations was used in the model for streambank erosion and prediction of channel storage and sediment routing. Data were collected for model input and calibration. In addition to geospatial data and standard sediment and flow measurements (e.g., total suspended solids and flowrate), sediment tracer data from past research were used (e.g., Sliter, 2007). Initial calibration was performed. A sensitivity analysis of the in-stream processes upon the watershed model results will ultimately be performed to determine parameter sensitivity. The model will be calibrated and validated based on data from past events. A set of tests will be designed and the model will be run to examine how changes in hydrology and remediation impact sediment processes including sediment loading and storage at the in-stream sources.

The coupled fingerprinting-watershed modeling framework is presented in the following steps: 1) traditional sediment transport data collection methods were used to measure the sediment yield from the study watershed; 2) the fraction of the sediment yield derived from the stream banks was estimated using the sediment fingerprinting approach, and the data were used for the watershed sediment transport model calibration and verification; 3) a conceptually simple yet representative model of bank erosion processes was constructed, calibrated, and integrated into a watershed erosion and sediment transport model. Data collection included flow and stage data, geospatial data, and suspended sediment data at the outlet of the South Elkhorn Watershed. Sediment tracer data including mixture data at the outlet and source samples upstream were also collected. Suspended sediment samples were collected over storm events at either one or two hour intervals. Microscopy samples, sediment tracer samples, and total suspended solids samples were analyzed at the Hydrosystems Laboratory and the Environmental Research and Training Laboratory (ERTL) at UK. Model development and numerical analysis were completed in the UK Student Computer Services Laboratory.

The model was formulated using an off-the-shelf hydrologic model coupled to new sediment transport and biogeochemical frameworks. The Hydrologic Simulations Program-Fortran (HSPF) was chosen as the hydrologic model because of its ability to model a variety of land covers, its variable time step, its well documented use in literature, and its ability to model watersheds of varying sizes. HSPF is a conceptually based watershed modeling tool that uses a storage routing approach to budget flow conditions over space and time. The stream-reach component of HSPF is modeled as

$$V^{(j)}_{\left(i+\frac{1}{2}\right)} = V^{(j)}_{\left(i-\frac{1}{2}\right)} + Q^{(j)}_{in\ (i)}\Delta t + P^{(j)}_{(i)} - E^{(j)}_{v(i)} - [k_s Q^{(j)}_{out\left(i-\frac{1}{2}\right)} + (1-k_s)Q^{(j)}_{out\left(i+\frac{1}{2}\right)}]\Delta t\,, \qquad \text{(Eq. 1)}$$

$$Q^{(j)}_{in\ (i)} = k_s Q^{(j-1)}_{out\left((i-1)-\frac{1}{2}\right)} + (1-k_s)Q^{(j-1)}_{out\left((i-1)+\frac{1}{2}\right)}, \qquad \text{(Eq. 2)}$$

where (*j*) represents the stream-reach and (*i*) represents the time step. $V^{(j)}_{(i+1/2)}$ is the volume of water in the stream-reach at the end of the time step [m^3], $V^{(j)}_{(i-1/2)}$ is the volume of water in the stream-reach at the beginning of the time step [m^3], $Q_{in}{}^{(j)}{}_{(i)}$ is the flow rate into the stream-reach throughout the time step [m^3/s], $P^{(j)}{}_{(i)}$ is the precipitation into the stream-reach throughout the time step [m^3], $E_v{}^{(j)}{}_{(i)}$ is the evaporation from the reach during the time-step [m^3], $Q_{out}{}^{(j)}{}_{(i\text{-}1/2)}$ is the flow rate out of the reach at the beginning of the time step [m^3/s], $Q_{out}{}^{(j)}{}_{(i+1/2)}$ is the flow rate out of the reach at the end of the time step [m^3/s], Δt is the time step [s], and k_s is the flood wave coefficient.

The new sediment transport model is conceptually based and includes equations for stream bank, stream bed, incised bank erosion, and deposition in depositional areas as well as surface fine grained lamina (SFGL) deposition. These processes are included because they all control the sediment yield at the outlet and the shape of the sedigraph. Sediment transport for the in-stream component is routed in a similar manner.

$$SS^{(j)}_{\left(i+\frac{1}{2}\right)} = SS^{(j)}_{\left(i-\frac{1}{2}\right)} + \sum_{k=1}^{N} E^{(j)}_{(i)(k)} - D^{(i)}_{(j)} + Q^{(j)}_{s\sin(i)}\Delta t - Q^{(j)}_{ssout(i)}\Delta t \,, \qquad \text{(Eq. 3)}$$

where (j) represents the stream-reach, (i) represents the time step, (k) represents the source term, and N represents the number of sediment sources. $SS^{(j)}{}_{(i+1/2)}$ is the mass of sediment in suspension at the end of the time step [kg], $SS^{(j)}{}_{(i\text{-}1/2)}$ is the mass of sediment in suspension at the start of the time step [kg], $E^{(j)}{}_{(i)(k)}$ represents the mass of eroded sediment [kg], $D^{(j)}{}_{(i)}$ is the deposited mass of sediments [kg], $Q^{(j)}{}_{ssin(i)}$ is the sediment flow rate into the stream reach during the time step [kg/s], and $Q^{(j)}{}_{ssin(i)}$ is the sediment flow rate out of the reach during the time step [kg/s]. Erosion and deposition are mutually exclusive and cannot occur simultaneously in a stream-reach during a time step. The occurrence of erosion or deposition is dependent upon the relationship between the sediment transport carrying capacity of the flow during the time step and the sediment load currently being carried by the stream reach during the time step.

Mixing of sediment sources is accounted using a tracer-based, extended sediment fingerprinting model. The model is based on the following mass balance equation

$$\delta^{15}\mathrm{N}_{SPOM} = X_{BED}\delta^{15}\mathrm{N}_{BED} + X_{BANK}\delta^{15}\mathrm{N}_{BANK} \,, \qquad \text{(Eq. 4)}$$

where X is the mass fraction of sediment from bed and bank sources and the nitrogen signatures of bed, bank and transported sediments are included. Equation (4) is a simple end-member mixing model, where the nitrogen isotopic signature of sediment particulate organic matter (SPOM) collected at the watershed outlet can be used to help calibrate the contribution of sediment sources from the streambed and streambanks. The present formulation also accounts for the fate of sediment in the streambed, where nitrogen can experience accumulation and decomposition. Sediment organic nitrogen (SON) in the SFGL of the sediment bed is mineralized and denitrified by heterotrophic bacteria and algae. Mineralization and denitrification processes are accompanied by a fractionation performed by the microbes/algae because the decomposers prefer the N-14 atoms from the SON substrate. A Rayleigh-type model is used to model how the SON substrate pool becomes enriched due to microbial/algal mineralization and denitrification.

The Rayleigh model is set up as:

$$\delta^{15}N_{BED(i)} = \delta^{15}N_{BED-SOURCE} - \varepsilon_{total} \times LN(\mathrm{R}), \qquad \text{(Eq. 5)}$$

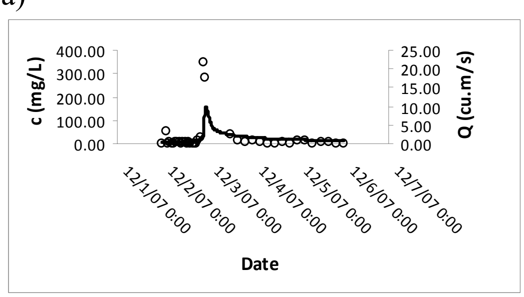
where $\delta^{15}N_{BED}$ is the nitrogen isotopic signature of SON substrate pool at the bed after mineralization and denitrification processes have occurred at time (*i*), $\delta^{15}N_{BED-\,SOURCE}$ is the nitrogen isotopic signature of the bed source SON prior to mineralization denitrification, ε_{total} is the fractionation factor associated with nitrogen uptake during microbial/algal mineralization and denitrification, and *R* is the mass fraction of SON remaining in the sediment bed system. The biogeochemical model requires the fraction of deposited and buried sediment to estimate R and changing signature of $\delta^{15}N_{BED-\,SOURCE}$ over time.

Flow, sediment and biogeochemistry data were collected in the watershed. Flow data from the USGS gaging station at Fort Springs, Kentucky were used. The gage data provided discharge and depth data at the watershed outlet. In order to calculate suspended sediment yield in the watershed, suspended sediment samples were collected at the outlet of the South Elkhorn with an automated water sampler and the Einstein (1950) approach was used to the estimate sediment yield. One and a half years of storm data collected using an automated ISCO water sampler were available. Sample collection occurred over storm events at one or two hour intervals. Figure 1 shows the sediment concentration and flow data for all storms that were used (some storms were omitted due to incomplete sampling data).

Sediment traps were also used to collect biogeochemistry data. Trap mass data collected for a sediment fingerprinting study has been collected weekly for the past three years using an in situ sediment trap. The sediment was analyzed for its nitrogen isotopic signature to calibrate the model. Sediments were analyzed using stable isotopic ratio mass spectrometry.

Figure 1. Concentration (points) and flow rate (solid black) data for a) December 2, 2007, b) February 21, 2008, c) April 10, 2008, d) May 15, 2008, e) July 30, 2008, f) July 31, 2008, and g) October 7, 2008.

a)



b)

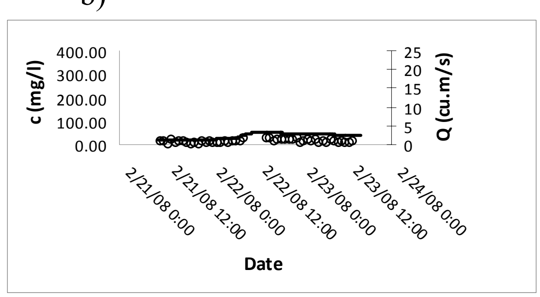
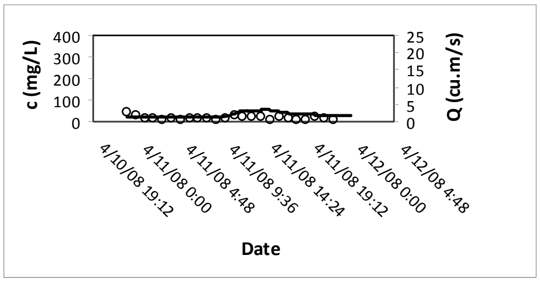
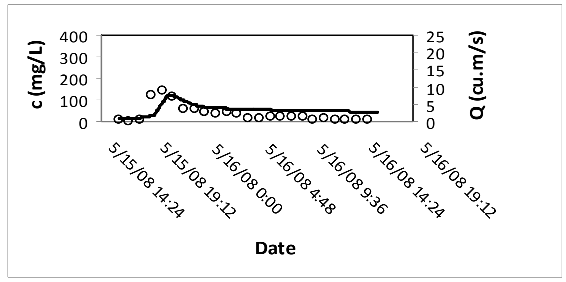


Figure 1 (continued)

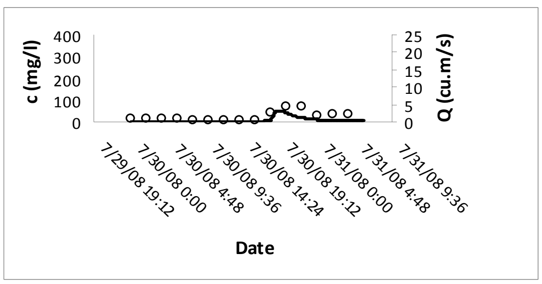
c)



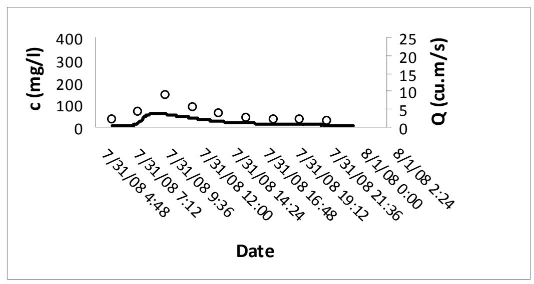
d)



e)



f)



Figures 2 and 3 show the calibration and validation of the hydrologic component of the model. Simulated yearly volumes of water have a 7% error when compared with observed volumes, and the simulated time series has a correlation coefficient of 0.73 when compared with the observed time series. Calibration of the sediment and biogeochemistry components is on-going and will be completed summer 2009. After the new sediment transport model is calibrated, a sensitivity analysis will be run to determine what watershed properties have the most dominant effect on sediment erosion and decomposition. Watershed parameters will be varied through realistic maximum and minimum values and the effects on the sediment erosion and decomposition will be noted. The range of the erosion and decomposition rates will be compared with the range of the other variables to determine which parameters dominate the modeled processes.

Application of the coupled model for prediction scenarios will involve altering the climate and land use data of the South Elkhorn watershed to predict how erosion rates, sediment yield, and sediment decomposition change. Scenarios to be run on the calibrated and verified model include 1) current land use conditions, 2) increased urbanization without erosion controls, 3) increased urbanization with erosion controls, 4) repeat of scenarios two and three with predicted temperature increase. This analysis will predict how erosion and sediment decomposition change with land use and climate and how this affects the global carbon budget.

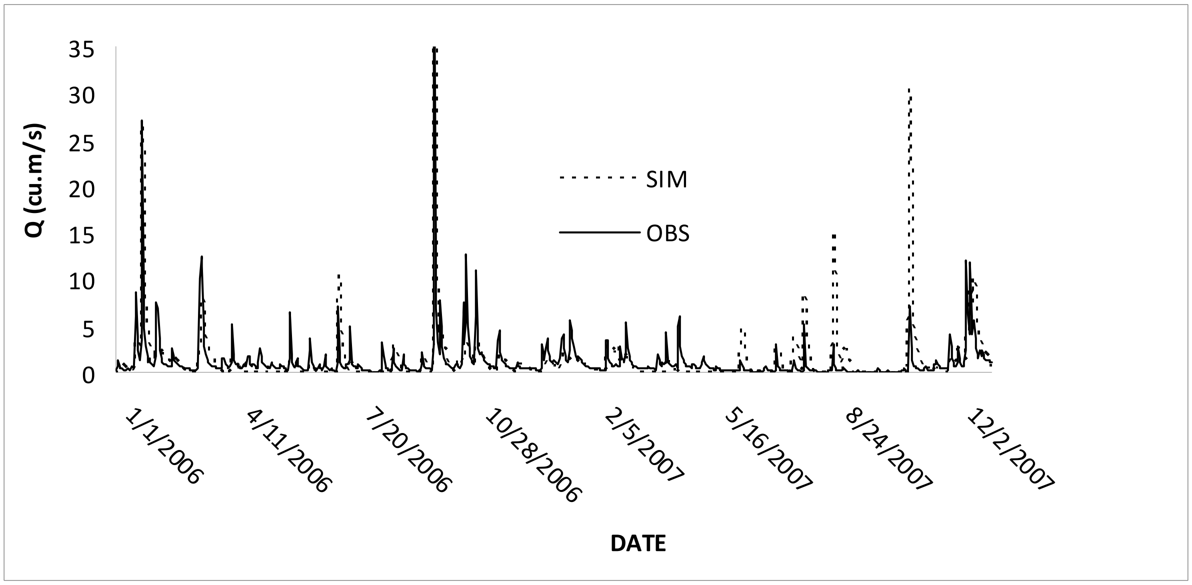


Figure 2. Observed and Simulated flow for the Calibration Period

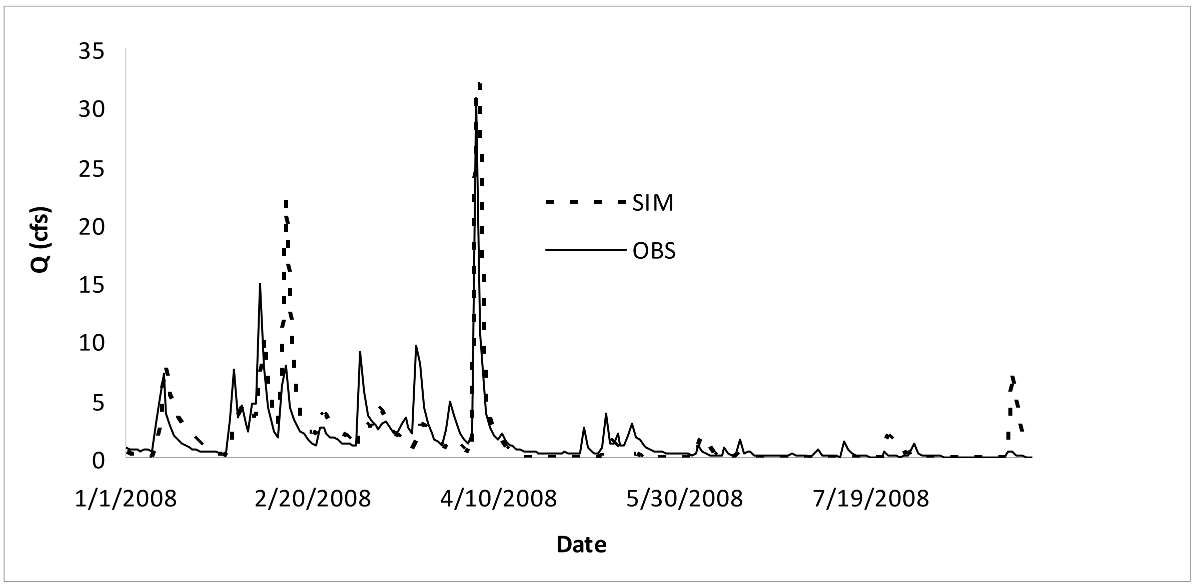


Figure 3. Observed and Simulated flow for the Validation Period

Principal Findings and Significance

A schematic of the formulated model is shown in Figure 4. Modeling sediment transport and fate at the watershed scale required the coupling of three important computer models: 1) a watershed hydrologic model, 2) an in-stream hydraulic and sediment transport model, and 3) a biogeochemical model. Sediment transport is dependent upon stream flows and a hydrologic model is needed to provide the boundary conditions for the in-stream hydraulic model. The in-stream model uses the flow rates from the hydraulic model to drive the sediment transport functions, including stream bank, stream bed, and incised bank erosion, and deposition. The biogeochemical model accounts for the fate of the sediment particles being transported and uses the mass fractions from the in-stream model to drive sediment decomposition equations. A review of current watershed scale models and developing sediment erosion and transport models found that watershed scale models do not account for the fate of the sediment particles and do not model stream bank and stream bed erosion and in-stream deposition well. Thus, addition of these components was unique.

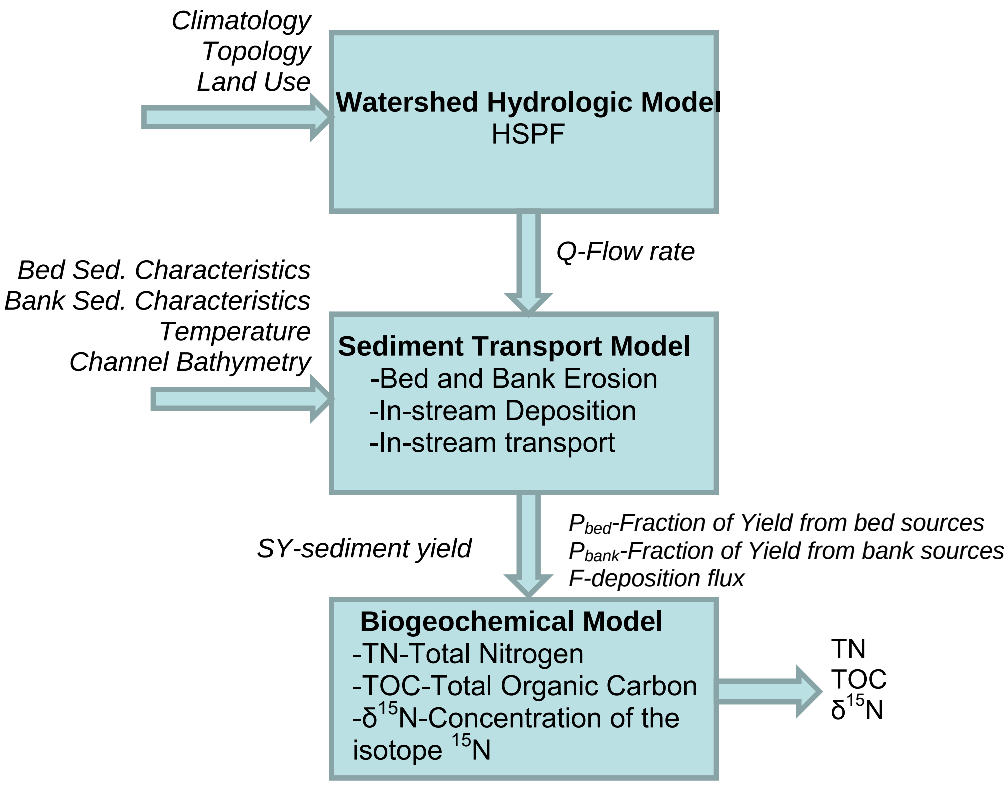


Figure 4. Coupled Model Framework.

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Kentucky Division of Water (2004). Kentucky's 2004 303(d) List of Waters. September 2005.

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Comparison of eastern hemlock and hardwood dominated forest stream assemblages

Basic Information

Title:	Comparison of eastern hemlock and hardwood dominated forest stream assemblages
Project Number:	2008KY108B
Start Date:	3/1/2008
End Date:	6/30/2009
Funding Source:	104B
Congressional District:	KY Fifth and Sixth
Research Category:	Biological Sciences
Focus Category:	Ecology, Surface Water, None
Descriptors:	aquatic diversity, fish, macroinvertebrates
Principal Investigators:	Sherry Harrel

Publication

1. Payne, Aric J., 2009, Influence of eastern hemlock (Tsuga canadensis) on aquatic biodiversity in eastern Kentucky, MS Thesis, Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky, 50 p.
2. Payne, Aric J. and Sherry L. Harrel, 2009, Influence of eastern hemlock (Tsuga canadensis) on the aquatic biodiversity in eastern Kentucky, in Proceedings Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 19-20.
3. Payne, Aric J., 2008 Influence of eastern hemlock (Tsuga canadensis) on aquatic biodiversity in eastern Kentucky, in Proceedings 2008 Kentucky Academy of Science, October 31, 2008.

Comparison of Eastern Hemlock and Hardwood Dominated Forest Stream Assemblages

Problem and Research Objectives

Eastern hemlock (*Tsuga canadensis*) is a foundation species that creates locally stable conditions required by many other species. In addition, eastern hemlocks stabilize fundamental ecosystem processes such as productivity and water balance. Previous studies have indicated headwater streams drained by hemlock and mixed hardwood forests support substantially different benthic communities, along with differences in fish assemblages in terms of density, trophic structure, and functional diversity.

Eastern hemlock forests have been significantly altered by the hemlock woolly adelgid (*Adelges tsugae,* HWA) since the 1950's. Since being discovered in West Virginia in the 1950's, the adelgid has now spread in hemlock stands along the east coast north through southern New England. Since its introduction, the HWA has caused extensive decline and mortality of hemlocks in Virginia, Pennsylvania, New Jersey, and Connecticut. Ultimately, the HWA causes defoliation in overstory trees, saplings, and seedlings, and therefore has the potential to eliminate *T. canadensis* from a site within a few years.

In March 2006, the HWA was found in Harlan County, Kentucky, and has since spread to Pike, Leslie, Letcher, Clay, and Bell counties. With the rapid movement of the HWA observed thus far, it can be expected the adelgid will continue to move throughout the hemlock forests located in eastern Kentucky.

The objectives of this study were: (1) to compare abiotic stream factors such as temperature, overstory cover, and physicochemical factors between streams draining hemlock and hardwood forests, (2) to evaluate species and trophic diversity of benthic macroinvertebrates between streams draining hemlock and hardwood forests, (3) and to evaluate the species and trophic diversity of fish assemblages to determine any differences between hemlock and hardwood streams.

Methodology

Three types of samples (stream habitat samples, macroinvertebrate samples, and fish samples) were collected from the eight sample sites.

To measure stream temperatures, HOBO® pro v2 water temperature data loggers were placed in each of the streams (one per stream at 1 meter in depth) and left from May through September, 2008. The data loggers measured temperature (ºC) every 15 minutes. Other physicochemical measurements taken during spring and fall sampling periods included pH, specific conductivity (µs), dissolved oxygen (mg/l), percent saturation, and instantaneous temperature (ºC).
A habitat assessment was also conducted for each stream by using the Kentucky Division of Water Rapid Bioassessment Protocol (KDOW 2002). Canopy cover provided by hemlock and hardwood trees was estimated for each stream using a GRS densiometer.

Macroinvertebrates were collected using semi-quantitative and qualitative methods to include the many types of habitats existing within the stream (KDOW 2002). Riffle samples were collected by taking four 0.25 m^2 samples from each riffle. A multi-habitat sample was also collected, focusing on undercut banks, vegetation, and bedrock. The multi-habitat samples were composited into one container and considered as a qualitative analysis that was not statistically justified. For statistical analysis, macroinvertebrates were identified to the lowest possible taxonomic level.

Fish sampling was conducted by using two commonly accepted methods for fish collection (KDOW 2002); backpack electroshocking for 1800 seconds per stream, and by seining for 30 minutes. Collected specimens were identified and released downstream of the upstream advancing electroshocker. Unidentifiable specimens were fixed in 10% formalin and identified in a laboratory setting.

Differences in physicochemical factors including pH, conductivity (µs), dissolved oxygen (mg/l) and percent saturation, along with habitat assessment factors including habitat scores and overstory cover (%), were tested between hemlock and hardwood streams using a two sample T-test. Maximum daily temperatures were compared with data collected every 15-minutes from the Optic Stowaway™ temperature loggers and were tested using a two sample T-test.

Three measures of macroinvertebrate assemblage structure were compared: (1) total density, (2) evenness (J), (3) and taxa richness. Taxonomic (H_s) and functional (H_f) diversities were calculated for each stream using the Shannon-Weiner diversity index. Trophic composition was analyzed using four commonly accepted trophic groups: shredder-detritivores, collector-detritivores, grazer-algivores, and predators. A two sample T-test was used to test differences between density, richness, trophic composition, and species and functional diversities between macroinvertebrate communities in hemlock and hardwood streams.

For fish communities, species and functional diversities (H_s and H_f) were calculated for each stream using the Shannon-Weiner diversity index (Shannon and Weaver 1949). For trophic composition analysis, fish were assigned commonly accepted trophic levels; piscivore, insectivore, and omnivore. A two sample T-test was used to test the differences between density, richness, trophic composition, and species and functional diversities between fish communities in hemlock and hardwood streams.

Principal Findings and Significance

Physicochemical

Physicochemical factors were highly variable among both hemlock and hardwood dominated streams. Mean differences between hemlock and hardwood streams were not significantly different for any of the physicochemical parameters tested during spring and fall samples. Overstory cover (%) was significantly different between hemlock and hardwood streams, with hemlock dominated streams having an average of 19% more overstory canopy cover than hardwood streams (t = 2.72, p = 0.035). Maximum daily temperatures were significantly different between hemlock and hardwood streams (t = 22.96, p = .0001).

Hemlock streams were cooler (Figure 1) and less variable (Figure 2) than hardwood streams. On average, hemlock streams did not exceed temperatures of 20° C, while hardwood stream temperatures did not drop below 20° C.

Macroinvertebrates

Seventy-four taxa were identified from semi-quantitative and qualitative benthic macroinvertebrate samples. From the specimens collected, two taxa were identified to family, 67 taxa were identified to genus, and five taxa were identified to species. Sixteen of the 74 taxa collected (22%) were found only in hemlock streams while 12 taxa (16%) were found only in hardwood streams.

Due to large variance within stream types, no statistical differences were found in any of the macroinvertebrate assemblage variables, although trends were noticed. Average density of macroinvertebrates between hemlock and hardwood streams was not significantly different in spring or fall samples (p = 0.189; 0.446, respectively). On average, hardwood streams were two times as dense (mean difference = 140 individuals $\cdot$ m^{-2}) than hemlock streams during spring samples and 1.3 times more dense (mean difference = 85 individuals $\cdot$ m^{-2}) during fall samples.

There was no significant difference in trophic composition of macroinvertebrates between hemlock and hardwood streams (Figure 3). On average, collectors, shredders, and grazers composed a larger proportion of the macroinvertebrate community in hemlock streams for spring (difference = 0.07, 0.07, and .010, respectively) and fall samples (difference = .07, 0.08, and 0.01, respectively). Conversely, predators composed a larger proportion of the macroinvertebrate community in hardwood streams for spring and fall samples (difference = 0.19 and 0.18, respectively).

Fishes

A total of 2,021 fish was collected in the spring and fall samples representing 40 species and eight families. When compared to hemlock streams, hardwood streams were found to have a significantly higher average density of fishes in both spring and fall samples (t = 2.70, p = 0.035; t = 4.33, p = 0.005, respectively). Seventeen of the 40 species (43%) were found only in hardwood sites, while only 3 species (8%) were specific to hemlock sites.

Forest-specific differences in trophic composition of fishes were observed (Figure 4). On average, insectivores composed a significantly larger proportion of the fish community in hardwood streams for both spring and fall samples (t = 3.31, p = 0.016; t = 3.02, p = 0.023, respectively) (mean proportion = 0.73 and 0.70, respectively) than in hemlock streams (mean = 0.37 and 0.21, respectively). Conversely, omnivores composed a significantly larger proportion of the fish community in hemlock streams for both spring and fall samples (t = 3.77, p = 0.009; t = 3.09, p = 0.021, respectively) (mean = 0.61 and 0.78, respectively) than in hardwood streams (mean = 0.26 and 0.28, respectively). No significance was observed in piscivore proportions, as they were similar in spring and fall samples (p = 0.63; p = 0.321, respectively) for hemlock and hardwood streams (mean = .005 and .008, respectively). Spring and fall species diversities (H_s) of fishes were significantly different between hemlock and hardwood streams ($t = 3.58$, $p = 0.011$; $t = 2.72$, $p = 0.034$, respectively).

Conclusion

The results from this study indicate that hemlock and hardwood streams support significantly different fish communities. Differences in benthic communities were less apparent, which is likely due to the effects of drought during late 2007. Further, results indicate overstory cover and temperature regimes, along with available nutrients, explain differences and trends in fish and macroinvertebrate community structure and composition. Based on these observations, the expected decline in hemlocks may have a long term effect on fish trophic structure, with a possible reduction in macroinvertebrate diversity, which may cause a long-term change in aquatic assemblages of hemlock dominated streams in eastern Kentucky.

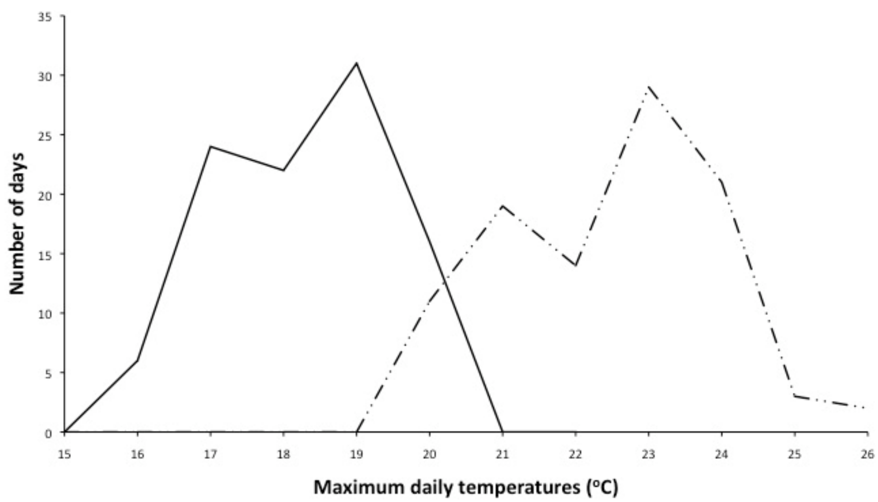

Figure 1. Comparisons of the distributions of summer maximum daily temperatures between streams draining hemlock and hardwood forests May to September 2008. Solid lines represent hemlock streams and dashed lines represent hardwood streams.

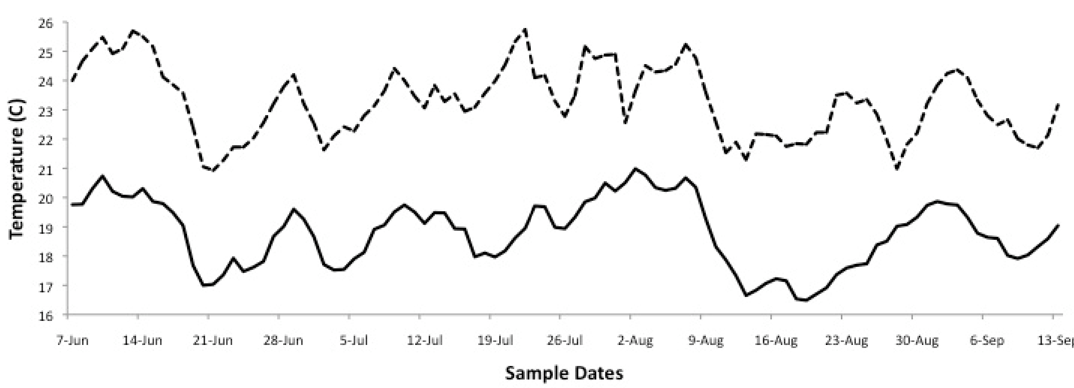

Figure 2. Distribution of summer temperatures between streams draining hemlock and hardwood forests, June to September 2008. Solid lines represent hemlock streams and dashed lines represent hardwood streams.

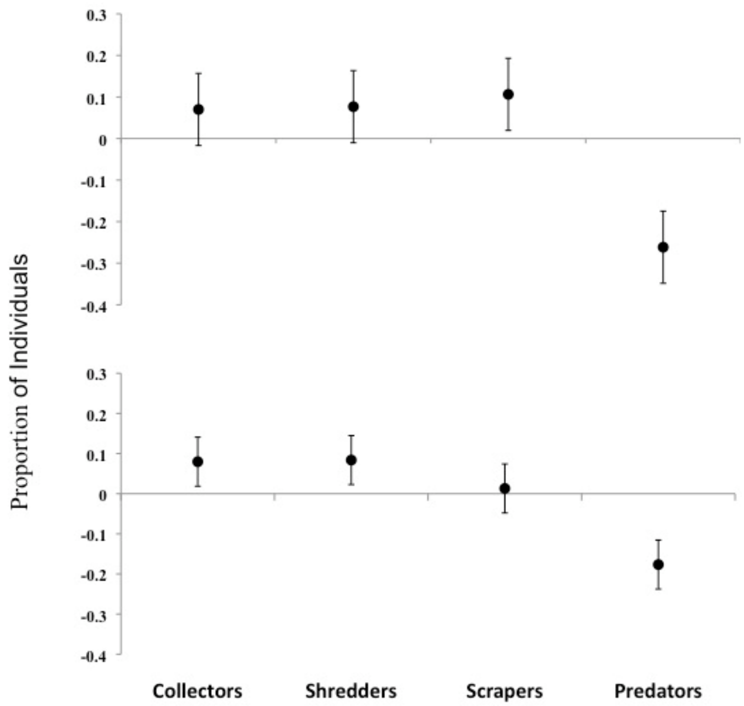

Figure 3. Comparisons of mean differences in macroinvertebrate trophic composition between hemlock and hardwood streams ± SE. Positive values indicate higher means for hemlock streams. Top graph represents May sample and bottom graph represents September sample.

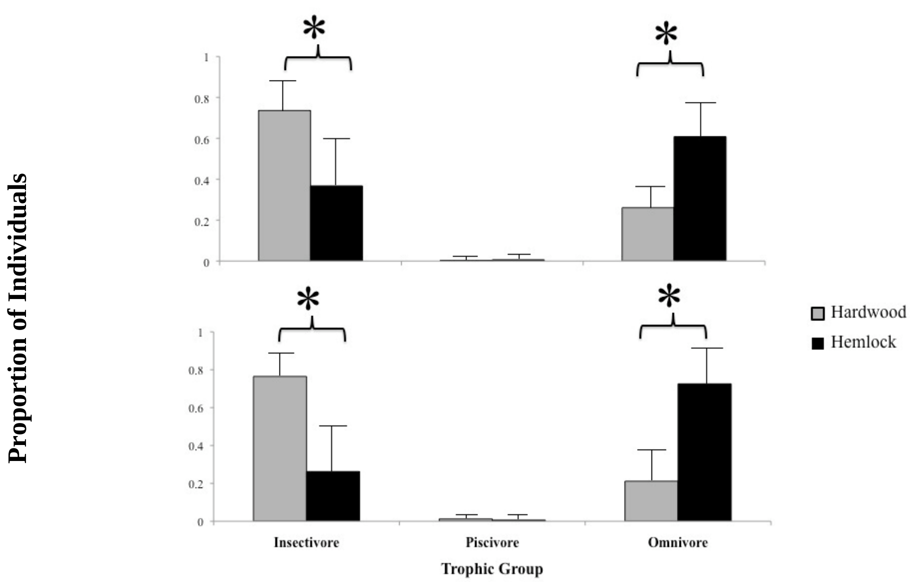

Figure 4. Comparisons of fish trophic composition between hemlock and hardwood streams. Graph shows mean proportions ± SD. Top graph represents May sample and bottom graph represents September sample. * Indicates statistical significance ($N = 4$, $P < 0.05$)

A comparison of methods for measuring suspended sediment and discharge in wadeable streams

Basic Information

Title:	A comparison of methods for measuring suspended sediment and discharge in wadeable streams
Project Number:	2008KY110B
Start Date:	3/1/2008
End Date:	6/30/2009
Funding Source:	104B
Congressional District:	KY Fifth
Research Category:	Water Quality
Focus Category:	Methods, Hydrology, Sediments
Descriptors:	sediment load, discharge measurement, monitoring activities
Principal Investigators:	Christine E. McMichael, Steven Reid

Publication

1. Williams, Samuel, Steven K. Reid, and Christine McMichael, 2009, Suspended sediment in the Dry Creek watershed, Rowan County, Kentucky, in Proceedings Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 17-18.
2. Brown, Susan, April Haight, Sam Williams, Alex Hunley, Steve Reid, 2009, Preliminary comparison of nutrient and total suspended sediment data on water samples collected using Teledyne portable autosampler and EPA field methods for wadeable streams, in Proceedings Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 69.
3. Williams, Samuel, Susan Brown, April Haight, Steven Reid, Christine McMichael, and Alex Hunley, 2009, Preliminary comparison of discharge data obtained by Teledyne portable autosampler and USGS/EPA field methods for wadeable streams, in Proceedings Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 99.

A Comparison of Methods for Measuring Suspended Sediment and Discharge in Wadeable Streams

Problem and Research Objectives

Triplett Creek has been listed as impaired under section 303(d) of the Clean Water Act and is on Kentucky's first priority list. It does not support primary contact recreation (swimming) but partially supports aquatic life. Documented pollutants in Triplett Creek include pathogens, nutrients, organic enrichment/low dissolved oxygen, and sediment.

This study focused on the Dry Creek Watershed, a tributary of Triplett Creek, which is included on the state's second priority list (partially supports aquatic life and is polluted by sediment). Sedimentation has resulted in the degradation of the waterway's ability to support aquatic life. Ongoing assessment and monitoring activities in this tributary of Triplett Creek have employed three approaches: a) trained personnel using very accurate, but labor intensive field methods, b) automatic sampling devices ('autosamplers') and c) some combination of autosamplers and trained field personnel. While manual methods are widely accepted and have been used for decades, the accuracy and reliability of suspended sediment and discharge measurements obtained using autosamplers is unknown.

In order to optimize future planned assessment and monitoring activities in the Triplett Creek and other watersheds, a better understanding of the relationships between manually- and automatically-collected water samples and water quantity data is needed. The objective of this project was to collect and compare suspended sediment and discharge data obtained using a Teledyne portable autosampler, EPA-based methods, and USGS-based methods. This information was used to quantitatively compare the accuracy and reliability of data obtained by these approaches.

Methodology

Autosampler and manual field measurements of discharge and sampling for total suspended solids (TSS) and suspended sediment concentration (SSC) were conducted at two sites. At each site, measurements and samples were collected simultaneously during periods of low, moderate and high flow. Data collection included eight site visits. Field workers remained on-site for six hours during each visit.

Autosamplers were installed at each site and several measurements and samples were collected during each site visit. The exact time of each measurement or sample collection was carefully noted to allow comparison with autosampler results. First, TSS dip samples and SSC samples were collected. The first SSC sampling used the equal width increment (EWI) method and a DH-48 sampler (Edwards and Glysson, 1998) whenever flow conditions permitted. One vertical of the EWI sampling coincided as closely as possible with the location of the autosampler intake. Immediately following collection of TSS and SSC samples, discharge was measured using the manual field methods of Rantz et al. (1982) and the staff gage near each site was read. At one-hour intervals thereafter, a USGS-type AA or pygmy meter was used to measure flow velocity as close as possible and just downstream of the velocity sensor of the autosampler. Additional TSS and simple SSC samples (dip or single vertical) were collected at one-hour intervals for the duration of the site visit. Staff gage readings were also taken at one-hour intervals. Additional measurements and samples were taken during rapidly changing flow conditions.

Autosampled and manually collected water samples were taken to the lab and analyzed for TSS and SSC. Suspended sediment concentration was determined at Morehead State University following the methods of Guy (1969) and ASTM (2002). The filtration method was used for samples containing less than 10,000 mg/L sand and less than 200 mg/L clay. The evaporation method was used for samples containing higher concentrations of sand or clay. TSS concentrations were determined by filtration followed by drying (American Public Health Association, 1998).

Principal Findings and Significance

- Teledyne Portable Autosampler generally overestimated depth when compared to meter stick or wading rod measurements

- Teledyne Portable Autosampler generally overestimated velocity when compared to Price Pygmy velocity meter and may have a logarithmic relationship

- Teledyne Portable Autosampler generally overestimated discharge when compared to the Velocity-Area method. May partially be attributed to restricted stream profile choices in programming, measurement of only one velocity in profile, and depth measurement disparities

- Samples collected by Autosampler may be biased due to purging and location of strainer in the profile when compared to single vertical with DH-48 sampler

- Discrepancies in Autosampler data appear to propagate through calculations of sediment loads and yields

- The extensive technical and field training required to correctly operate the Teledyne Portable Autosampler, combined with apparent measurement uncertainties, may constrain its application in future studies

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Evaluating carbon pool patterns in agricultural and forested streams along Kentucky Lake

Basic Information

Title:	Evaluating carbon pool patterns in agricultural and forested streams along Kentucky Lake
Project Number:	2008KY111B
Start Date:	3/1/2008
End Date:	6/30/2009
Funding Source:	104B
Congressional District:	KY First
Research Category:	Water Quality
Focus Category:	Agriculture, Geochemical Processes, Water Quality
Descriptors:	riparian, sediment, stream ecosystems, biogeochemical processes
Principal Investigators:	Iin Handayani

Publication

1. Tokosh, R. and I.P. Hnadayani, 2009, Soil carbon pools in soil and sediment of two contrasting creek ecosystems, in Proceedings Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 83-84.
2. Tokosh, R. and I.P. Hnadayani, 2009, Evaluating riparian soil properties in Panther Creek, TN and Ledbetter Creek, KY, 13th Symposium on the Natural History of Lower Tennessee and Cumberland River Valleys, Land Between the Lakes, KY, April 2009.

**Evaluating Carbon Pool Patterns in
Agricultural and Forested Streams Along Kentucky Lake**

Problem and Research Objectives

Naturally occurring organic carbon in river sediments is a key component for chemical, physical and biological processes. Total organic carbon contributes significantly to water chemistry, nutrient availability and controls the solubility and toxicity of contaminants. Particulate organic carbon (POC) regulates the benthic macro-invertebrate and bacterial communities. POC can also act as a carrier to transport contaminants along rivers. Carbon (C) pools can be used as a tool for assessing the functional characteristics of restored stream ecosystems (Handayani et al., 2008). Previous studies show that natural processes and human activities have changed the distribution of C pools in soils and sediments. However, there is limited information about C pool patterns in soil and sediment under contrasting watershed land-uses, such as agriculture and forest. Kentucky Lake is the largest reservoir in the southeastern United States impounded for the purposes of power generation, flood control, and transportation and provides a unique study site to investigate the C pool patterns with respect to differences in land-use and water quality in two contrasting stream environments.

In recent years, several studies have been devoted to measuring sediment total organic carbon (TOC) contents in rivers and lakes. Feng et al. (1998) reported that TOC contents in sediments of the Hudson River in New York, USA, vary from 1.06 to 2.73%. Mueller et al. (1982) reported that approximately half of TOC input into the Hudson River was due to waste waters. These authors further argued that the variations of TOC contents could also be caused by differences in particle size and lability of C with respect to microbial degradation. Jia and Peng (2003) found that sediment TOC contents in the Pearl River estuary of southern China ranged from 0.61 to 1.54%. A study in Lake Apopka of central Florida, USA showed that the sediment TOC contents range from 33 to 37% and originate mainly from the primary producer community (Silliman and Schelske, 2003). Previous study in Ledbetter Embayment of Kentucky Lake showed that the sediment organic matter content ranged from 1.0 to 4.0% and had a good correlation with the distribution of oligochaetes (Ramsey and White, 2007). These studies provide good insights into TOC contents in salt and freshwater sediments, but no specific information about particulate organic matter (POC).

POC plays an important role as a carrier to transport contaminants along rivers (Trefry et al., 1992). Decomposition of POC associated with contaminants in water columns and sediments regulates river water quality. However the patterns and stratification of TOC and POC in sediments and riparian soils associated with contrasting watershed land-use are still poorly understood. The objectives of this study were to determine the impacts of watershed land use on TOC and POC in soil and sediment, to evaluate the stratification of TOC and POC in soil at depth intervals of 0-10 cm, 10-20 cm, and 20-30 cm, and to observe the effect of sampling time (August and November) on the distribution of TOC and POC in soil and sediment. Results from this research provide background biogeochemistry data on the C pools that can be used to interpret the results of water chemistry and biota studies at these sites. More immediately, it can provide guidance for best soil management for land-use (forest and agriculture management) that reduces contaminants to water bodies.

Methodology

Study Sites

The study sites were Ledbetter Creek (36.74ºN, 88.15ºW) located in the northeastern part of Calloway County, Kentucky and the South Fork of Panther Creek (36.51ºN, 87.98ºW) located in the northwestern corner of Stewart County, Tennessee. Ledbetter Creek has approximately 55% second growth oak-hickory forest and 45% agriculture/rural development areas, while the Panther Creek basin is more than 95% second growth oak-hickory forest with small patches of grassland (Jin et al., 2007). Ledbetter sites are in an agricultural watershed, and Panther sites are in a forested watershed in the Land Between the Lakes National Recreation Area (White et al., 2007). The characteristics of the study sites are shown in Table 1.

Table 1. Two creeks with contrasting watershed land-use (physical, geological and chemical characteristics have been identified).

Characteristics	**Ledbetter Creek**	**Panther Creek**
Watershed area (ha)	1103	830
Agricultural area (%)	45	4
Chanel slope	0.49	0.62
Nitrate (mg/liter)	0.003-0.540	0.017-0.049
Phosphate (mg/liter)	0.03-0.086	0.012-0.136
Geology	Noncalcareous silt,sand,clay,gravel, and chert derived from the continental deposits, Loess, Fort Payne, and Clayton and McNairy formations	Limestone and chert, derived from St. Louis and Salem Limestone, Warsaw Limestone, and Port Payne Formations
Location	36.74ºN,88.15ºW	36.51ºN,87.98ºW

Source: Jin et al. (2007)

Soil and Sediment Sampling

Soil samples were collected from three sites on riparian areas during August and November 2008. Five disturbed soil samples were mixed from each site at the depth of 0-10 cm, 10-20 cm, and 20-30 cm. Large debris and materials > 2.00 mm were removed and the soil samples were allowed to dry under room temperature before analyzing for TOC and POC. At the same time, sediment samples were taken from wet and dry areas from three locations on each study site. They were air-dried and ground using mortar and pestle and sieved using a 2.00 mm screen to discard the pebbles, stones and plant residues.

Total organic C was determined using 10 g of dry soil placed into a pre-weighed tin. The tin and soil samples were heated in an oven at 105°C for 24 hours. After weighing, all the samples were placed into a muffle furnace at 800°C for five 5 hours and then weighed again. Total organic C content was calculated according to Lal et al. (2001). Particulate organic matter was extracted using 5% sodium hexametaphosphate as a dispersing agent with a 250 µm diameter screen. Particulate organic C was processed and measured according to Cambardella and Elliot (1992). All the data were evaluated using a t test at the 5% level to determine significant differences between ecosystems and sampling time.

Principal Findings and Significance

● Soil analysis indicated that TOC and POC were significantly affected by watershed land-use, particularly at the surface, with the highest amounts of TOC and POC in forested and agricultural watersheds, respectively.

● In August, TOC in riparian soil of the forested watershed had more stratification within a depth of 0-30 cm than in the agricultural watershed, but in November no similar stratification was observed (Figure 1).

● TOC in soil was higher in August than in November for both land uses (Figure 1).

● There was inconsistent stratification of POC in soil samples collected in November (Figure 2).

● Total organic C in soil varied significantly between sampling times (influenced by the water level in Kentucky Lake), but TOC in sediment did not (Figure 3).

● Particulate organic C in soil and sediment was affected by sampling time (Figure 4).

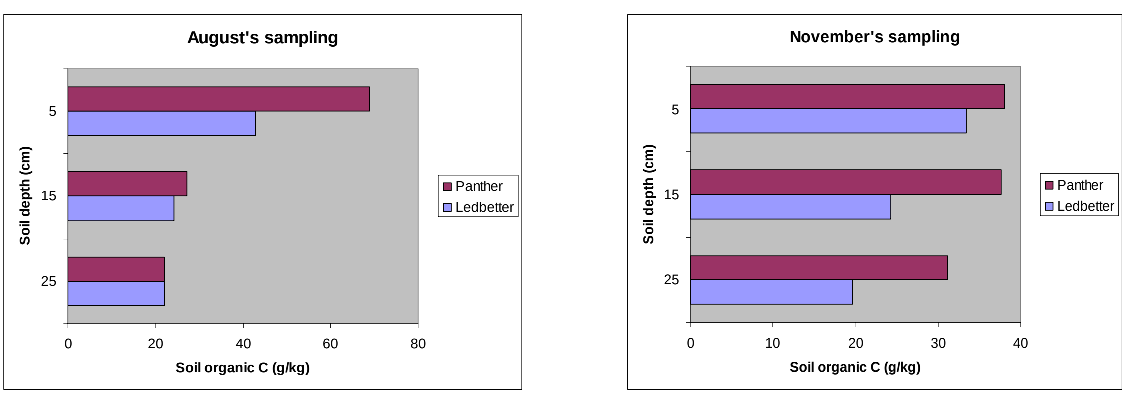

Figure 1. Soil organic C as affected by watershed land use. Panther Creek indicates forested watershed and Ledbetter Creek is dominated by agriculture activities.

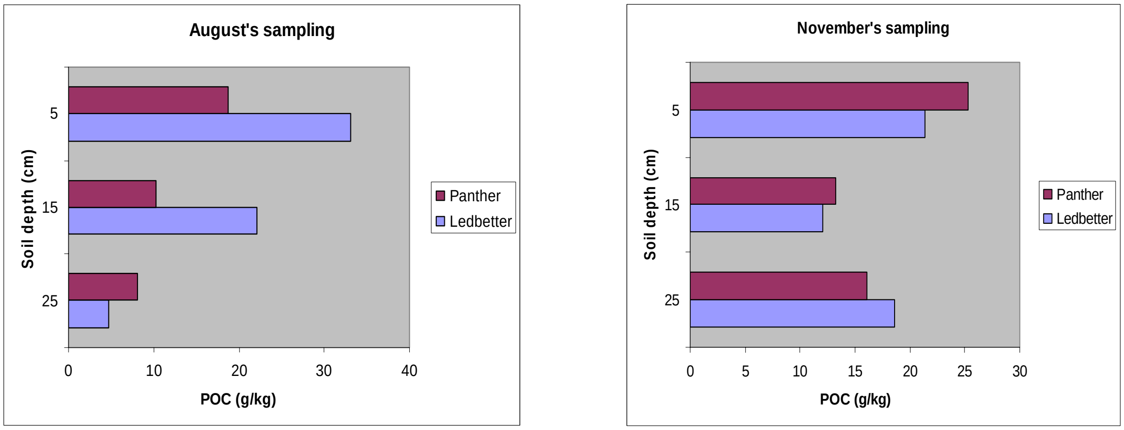

Figure 2. Soil particulate organic C is affected by watershed land use. Panther Creek is a forested watershed and Ledbetter Creek is dominated by agricultural activities.

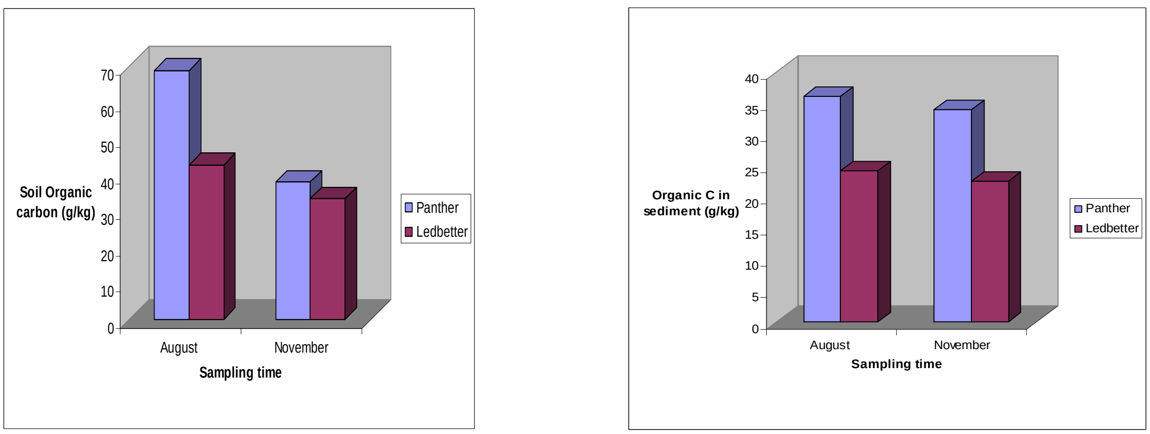

Figure 3. Organic C from soil surface and sediment during August and November sampling. In August, the creek was flooded and in November the creek was dry.

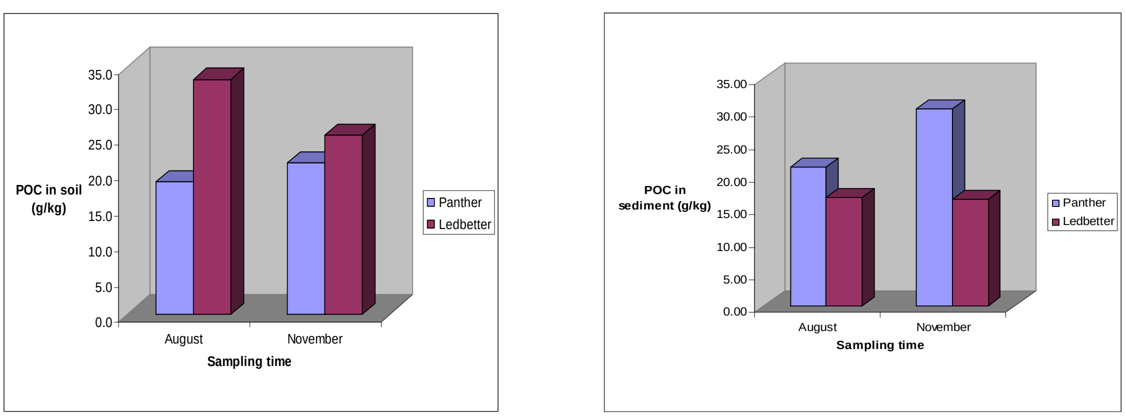

Figure 4. Particulate organic C in surface soil and sediment during August and November sampling. In August, the creek was flooded and in November the creek was dry.

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Identification of human and animal fecal sources in central Kentucky watersheds by PCR of 16sDNA markers from host specific fecal anaerobes

Basic Information

Title:	Identification of human and animal fecal sources in central Kentucky watersheds by PCR of 16sDNA markers from host specific fecal anaerobes
Project Number:	2008KY112B
Start Date:	3/1/2008
End Date:	6/30/2009
Funding Source:	104B
Congressional District:	KY Sixth
Research Category:	Water Quality
Focus Category:	Methods, Water Quality, Acid Deposition
Descriptors:	microbial source tracking, Bacteriodes, polymerase chain reaction
Principal Investigators:	Gail Montgomery Brion, Alan Fryar

Publication

1. Coakley, Tricia, Gail Brion, and Alan Fryar, 2009, Identification of human and animal fecal sources in central Kentucky watersehds by PCR of 16sDNA markers from host-specific fecal anaerobes, in Proceedings Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 21.

Identification of Human and Animal Fecal Sources in Central Kentucky Watersheds by qPCR of 16sDNA Markers from Host Specific Fecal Anaerobes

Problem and Research Objectives

The two most common water pollutants in Kentucky waterways are human and animal waste and sediment (6). Although we can easily enumerate bacterial populations and determine the relative level of fecal pollution at sampling locations, this does not provide the information necessary to eliminate the problem. Defining the source of fecal pollution (fecal source tracking [FST]) has quickly become one of the most rapidly growing focus areas in water research. Many methods have been proposed for effective source tracking and each has its pros and cons. Molecular methods are currently favored for their specificity, but there are still many of these techniques to choose from and much debate over the applicability of a method in a geographical region different from that where the method was developed (9). PCR of the 16s DNA markers for *Bacteroides* bacterial species is a favorite of many researchers worldwide and is rapidly growing in popularity. This method is inexpensive compared to library dependant methods, easily implemented and very specific, but the efficacy of the method in Kentucky watersheds had not been determined.

Bacteroides bacteria are obligate anaerobes found in the intestines of humans and animals in large concentrations relative to other enteric bacteria. Fortunately for those interested in fecal source tracking, they have been shown to have 16S rRNA genetic markers specific to the host animal (8). The presence of these specific markers in environmental water samples has been shown to correlate well with known source information and with other source tracking tools (1,4,5,7,8,9). This study of the Wolf Run, Cane Run, and Glenn's Creek watersheds in Fayette, Scott and Woodford counties of Kentucky attempts to determine the usefulness of published PCR primers specific for bovine or human *Bacteroides* markers and to compare the atypical/total colony (AC/TC) ratios (2) with the molecular signal.

Methodology

Thirty-four (34) samples were analyzed from watersheds in the Bluegrass region of Kentucky that were known to receive inputs from human sewage, animal wastes, and/or urban runoff. The study area included three watersheds in three counties. *E. coli* concentrations (MPN/100mL) were enumerated by Idexx colilert™ media in quantitrays 2000™. AC/TC ratios were determined from the total coliform (sheen) and atypical (non-sheen) colony counts on m-Endo media at multiple dilutions (2). *Bacteroides* genetic markers were analyzed by qPCR using the Allbac, Hubac and Bobac primers and probes developed by Alice Layton at the University of Tennessee Center for Environmental Biotechnology and a BioRad iCycler IQ™ (7). Allbac is a general primer set for identification of fecal pollution from any animal and is not specific to human or bovine. Hubac primers were used for the identification of human specific markers and Bobac primers were used for the identification of bovine specific markers. Samples were collected in sterile 1-L polypropylene containers and transported to the lab on ice. 250-mL aliquots were filtered through 0.45-µm cellulose ester membrane filters. DNA was extracted from the filters using UltraClean Water DNA isolation kits (MoBio^{TM}). Each 25 µL PCR reaction consists of 12.5 µL IQ supermix (BioRad^{TM}), 10 pmol forward primer (Allbac, Hubac, or Bobac), 10 pmol of the corresponding reverse primer, 5 pmol of the corresponding fluorescently labeled molecular probe, and 2 µL extracted sample. Host specific marker clones were used for calibration and covered a range of 0 to $1x10^7$ DNA copies/mL. PCR protocols consisted of 50°C for 2 minutes, 95°C for 10 minutes and 50 cycles of 95°C for 30 seconds and 60°C for 45 seconds (57°C for Bobac). All PCR reactions were run in triplicate. Five duplicate samples and two filtration blanks were carried through the entire method to ensure precision and absence of contamination at each step. Waste-water treatment plant influent was used as a positive control for general and human signals and a floor washings sample from a dairy barn was used as a positive control for bovine signal. This work was completed in the Environmental Research and Training Labs (ERTL) of the University of Kentucky.

Principal Findings and Significance

Fecal loadings, as indicated by *E. coli* concentrations, were variable and ranged from 10 to 17,329 MPN/100mL. The Allbac genetic marker (non-host-specific, general *Bacteroides*) was present in all samples analyzed and its log-transformed concentrations were weakly proportional to log-transformed *E. coli* concentrations (Figure 1). The Bobac marker was only found in significant concentration at one location in the Glenn's creek watershed of Woodford County and this location was determined (upon visual inspection) to be impacted by a large cattle operation. The Hubac marker (human specific *Bacteroides*) was detected at all but one sample site, with concentrations ranging across four orders of magnitude. No genetic marker concentrations were detected in the method blanks. The average relative percent difference between sample duplicates for all markers was 15%. The AC/TC ratios varied from a minimum of 1.1 to a maximum of 97.8, denoting a range of fecal age conditions from very fresh to very aged.

When the real time PCR quantified Hubac signal was divided by the Allbac signal (Hubac/Allbac) at each site, qualitative apportionment of the amount of human fecal pollution present was possible. Hubac percentages ranged from <10% to 60% and were consistently higher in urban areas. In the Cane Run watershed of Fayette and Scott Counties, Human specific marker concentrations were found to be less than 20% of the total Allbac signal at all sample sites. More work should be done in Cane Run using a horse specific genetic marker due to the large equine population in this watershed. In the Wolf Run Watershed of Fayette County, thirteen sample sites were found to have Hubac marker concentrations of greater than 10,000 DNA copies/mL, but when calculated as percentages of Allbac signal, only three locations had greater than 30% of the total fecal concentration attributed to human sources. In the Glenn's Creek watershed of Woodford County, none of the seven locations sampled had Hubac marker concentrations greater than 10,000 DNA copies/mL. One sample from the headwaters, however, had 40% of the total fecal marker signal indicated as human.

The AC/TC ratio supported the Hubac/Allbac findings with values that were suppressed from those expected based on previous studies of non-sewage impacted, urban creeks in the region. Higher Hubac signals were associated with AC/TC ratios of less than 20, while ratios greater than 20 were associated with lower Hubac signal strength (Figure 2). Of the 34 sample locations tested, 15 sites showed AC/TC values of less than 20 and *E.coli* concentrations of greater than 500 MPN/ 100mL. Of these 15 sites, 7 locations were further shown to be probable "hot spots" of human fecal contamination (potentially from broken or leaking sewer lines) by human specific marker concentrations of greater than 20% of the corresponding general fecal marker concentrations (Table 1). Of the 34 samples analyzed, only one (D04) had a human marker percentage of greater than 20% (21.42%) but did not have both an AC/TC value and an *E.coli* concentration that would have placed it in the potential "hot spot" category for further examination by molecular methods. The AC/TC of sample D04 was 4.62 but the *E.coli* concentration was only 148 MPN/100mL.

Molecular fecal source tracking by qPCR is currently expensive and requires technical expertise not readily available to community action groups and local governments with limited budgets seeking to pinpoint human fecal hotspots within their watersheds. The less expensive AC/TC ratio can provide additional information on the relative fecal age at each site, with lower values (<20) defining areas of concern. Based on our results, we suggest preliminary screening of local watersheds by canvassing the area with the collection of samples for all three indicators at many sites, analysis of all samples for the least expensive indicators (*E. coli* and AC/TC) and then prioritization of those sites with AC/TC ratios of less than 20 and *E.coli* counts of greater than 500 MPN/ 100mL for further analysis by qPCR of both Hubac and Allbac source specific genetic markers. Bobac marker concentrations should be measured as well in an agricultural watershed or when the concentration of Allbac marker is very high but there is no detection of the Hubac marker.

By measuring the real-time-PCR quantified Hubac marker concentrations, it is possible to visualize general areas of concern within the watershed but impossible to determine the exact locations of greatest need for abatement efforts due to the widespread occurrence of the marker. When the Hubac concentration was divided by the Allbac concentration (Hubac/Allbac) at each site, relative apportionment of the amount of human fecal pollution present was possible. Viewing these percentages of human marker, rather than the actual concentrations of the marker, allows much greater ability to identify locations of greatest concern and therefore more effective data interpretation.

This study highlights the need to sample across a large spatial and/or temporal range. Even with the ability to quantify the marker concentration with qPCR methods, a limited number of samples permit only the determination of marker presence or absence. Without the relative concentrations of human marker throughout the watershed, a single sample location can be misinterpreted as the "hot spot" when the actual site of concern is elsewhere.

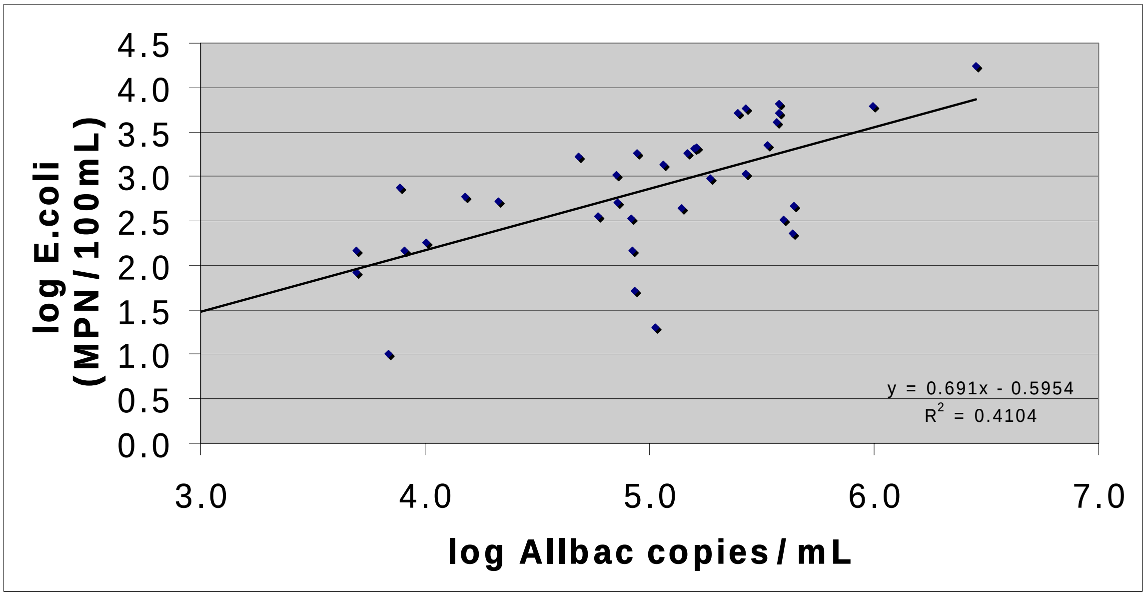

Figure 1. log of *E.coli* concentrations vs. log of general fecal marker concentrations

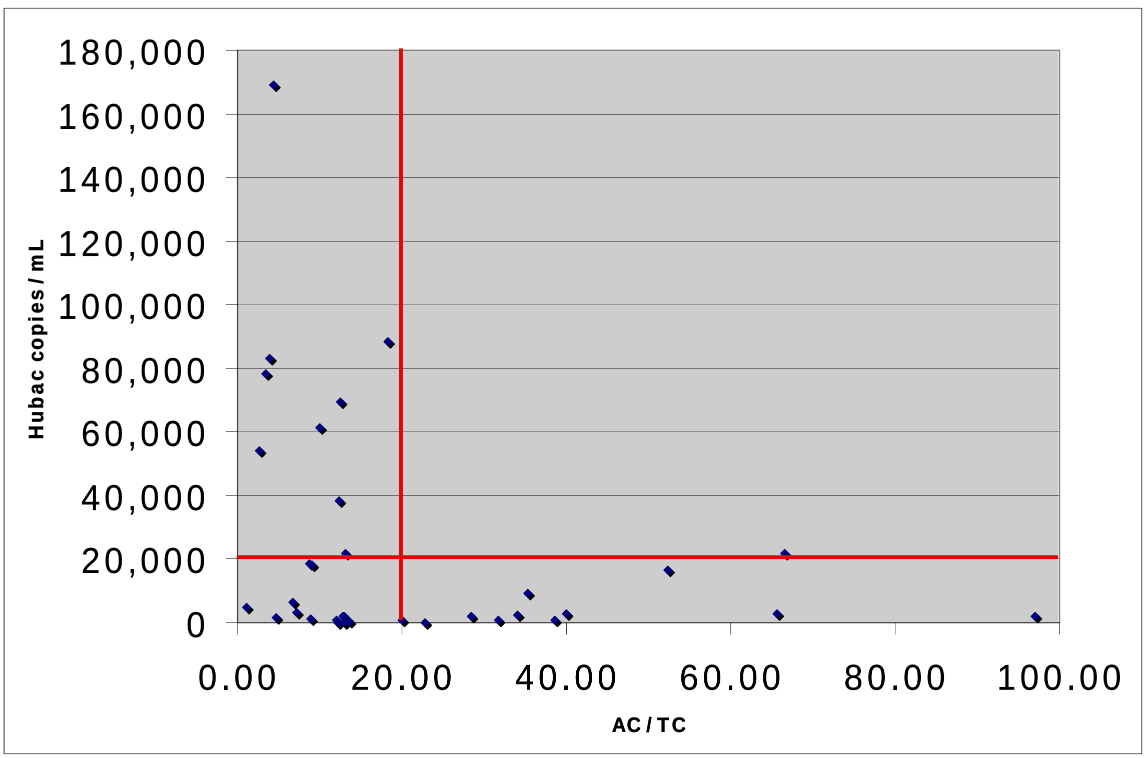

Figure 2. Correlation of Human marker concentration with AC/TC values. All samples with Hubac concentrations greater than 20,000 DNA copies/ mL had AC/TC values of less than 20. No samples with AC/TC values of greater than 20 had Hubac concentrations of greater than 20,000 DNA copies/ mL.

site ID	(Hubac/Allbac)*100	AC/TC	*E.coli*
K005	0.1	22.86	437
K054 /D03	19.65	8.93	10
K085	2.67	28.5	504
K096	0	5	0
K126	0.79	31.67	341
K307/D19	9.3	6.76	1054
K461 /D01	7.87	1.13	359
K465/D18	11.33	8.99	2142
K466/D14	60.29	12.57	1376
K467/D20	1.75	12	1664
K468/D15	24.24	12.33	2035
K470 /D13	44.9	4.38	6488
K471/D10	7.91	3.49	6131
K472/D07	1	65.64	1071
D17	6.56	13.1	2247
K184/D16	12.6	8.68	1850
D11	31.03	3.87	5794
D12	14.25	2.69	5172
D02	5.78	N/A	17329
D06	23.97	18.24	4106
K305/D08	5.01	66.52	231
D04	21.42	4.62	148
D05	24.81	9.94	5172
CR1	16.51	34.04	594
CR2	0.2	13.58	959
CR3	0.7	12.4	84
CR4	1.82	97.08	20
CR5	10.96	35.38	52
CR6	19.71	52.41	146
K619	40.03	7.16	749
K615	0.72	40	331
K617	4.58	20	520
K616	0.44	12.86	465

Table 1. Highlighted cells indicate values that would cause the site to be flagged as a potential "hot spot" of concern when used as a single indicator. Of the 34 sample locations, 15 would be carried forward to molecular qPCR analysis when using *E.coli* and AC/TC as screening parameters. 7 of those were identified as the most likely locations for successful human fecal abatement based on a percentage of human specific marker contribution.

As demand for these methods increases while funding for environmental study remains limited, it is important to maintain data integrity with well-designed sampling plans, stringent quality-control efforts, and careful interpretation. We conclude that molecular fecal source tracking methods are very selective and very sensitive but they carry a great risk of data misinterpretation if used with a limited sample set or if samples are measured for only one host-specific marker.

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Inventory and assessment of combined sewer overflow discharges within Kentucky communities

Basic Information

Title:	Inventory and assessment of combined sewer overflow discharges within Kentucky communities
Project Number:	2008KY118B
Start Date:	3/1/2008
End Date:	6/30/2009
Funding Source:	104B
Congressional District:	Kentucky Sixth
Research Category:	Water Quality
Focus Category:	Acid Deposition, Treatment, Water Quality
Descriptors:	pathogens, disinfection, CSO, peracetic acid
Principal Investigators:	Lindell Ormsbee

Publication

1. Coyle, Elizabeth and Lindell Ormsbee, 2009, Assessment of combined sewer overflows, in Proceedings Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 63.

Inventory and Assessment of Combined Sewer Overflow Discharges within Kentucky Communities

Problem and Research Objectives

Wet weather flows (WWFs) consist of combined sewer overflows (CSOs), sanitary sewer overflows (SSOs) and storm water discharges from municipal separate storm sewer systems (MS4s). Each of these types of WWFs can cause water quality violations in surface waters, exceeding water quality standards designed to protect human health and aquatic life in receiving waters. Nationwide, approximately $50.6 billion dollars will be needed to reach an 85% reduction in CSOs by volume and approximately $4 billion will be needed to address the reduction of SSOs (EPA, 2004). In the state of Kentucky, 17 communities have been mandated by the Kentucky Department of Environmental Protection and the US EPA to address their WWFs. The three largest sewer districts, Louisville, Northern Sanitation District 1, and Lexington are facing estimated costs of $500 million, $880 million and $300 million, respectively, to bring their WWFs into compliance with the Clean Water Act.

While traditional technologies exist to address WWFs, they are often cost prohibitive to the rate payers of the individual communities faced with the responsibility of compliance. Many of the current technologies can yield toxic by-products. In areas of older infrastructure, space for facilities to treat overflows is often limited if available at all. As such, more cost effective technologies requiring less space and producing less harmful by-products are currently being explored. One possibility is alternative high-rate disinfection using peracetic acid (PAA). The decomposition of peracetic acid results in only the non-toxic by-products oxygen, carbon dioxide and water. The disinfection reaction occurs in a short contact time and with a high kill rate. Thus, this technology can prove effective where space is limited, but it is also extremely environmentally sound. The objective of this research is twofold; 1) to determine the effectiveness of PAA as a disinfectant for WWFs and 2) to determine the cost of implementing PAA as a high-rate disinfectant in comparison to traditional technologies.

Methodology

The CSO Control Policy indicates that CSOs should receive a minimum of: 1) "Primary clarification (removal of floatables and settleable solids may be achieved by any combination of treatment technologies or methods that are shown to be equivalent to primary clarification.)"; 2) "Solids and floatables disposal"; and 3) "Disinfection of effluent, if necessary, to meet water quality standards, protect designated uses and protect human health, including removal of harmful disinfection chemical residuals, where necessary." Since it is apparent that CSO discharges will require primary clarification and solids and floatables removal prior to disinfection, the WWFs investigated in this research were also assumed to have equivalent preliminary treatment prior to the disinfection process. The source of simulated WWFs used in experimentation was the primary effluent of the Lexington, Kentucky Town Branch Wastewater Treatment Plant that had received both primary clarification and solids and floatable removal. The water quality was varied to simulate a representative range of WWFs including 1) dilute storm water, 2) moderate strength combined sewer overflow water, and 3) concentrated sanitary sewer overflow water by using different dilution factors with the same primary effluent.

Once the primary effluent sample was collected and the simulated WWF was generated, the initial concentration of E coli., ammonia, total phosphorus, total suspended solids, chemical oxygen demand, pH, specific electric conductance and dissolved oxygen were monitored and recorded prior to treatment. These parameters are commonly monitored at permitted facilities that have discharge limits for the treated water and each of these parameters may affect the efficiency of the disinfectant.

In order to determine the effectiveness of PAA as a disinfectant, each of the simulated WWFs was treated with nine different combinations of PAA dose (mg/l) and contact time (minutes). In addition, replicate data were secured for statistical analysis and for quality control and assurance (each treatment done in triplicate at least three times on varying water qualities). Based on the range of water quality being investigated and some preliminary bench testing, PAA doses of 5, 10 and 15 mg/l appeared to be strong enough to meet water quality standards. In addition, contact times of 2, 5 and 10 minutes were used since traditional technologies are commonly designed for 15 minute contact times. Shorter contact times are desired as they translate into cost savings by reducing the size (capital costs) of disinfectant contact tanks and making disinfection more feasible in areas with limited space. The remaining E coli. concentration was monitored for each treated sample at the end of each contact time to determine the difference between the initial and final concentration (the total kill) for each treatment. The process by which data were collected to analyze the performance of PAA as a disinfectant is shown in Figure 1.

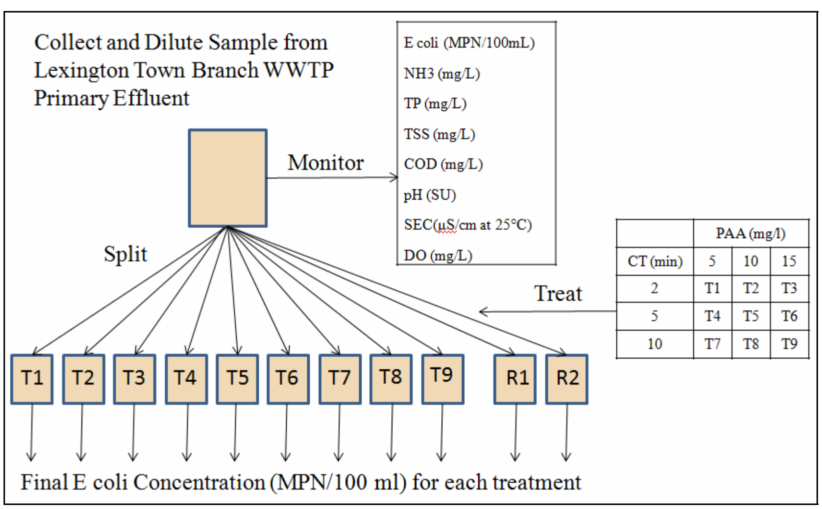

Figure 1. Data Generation Process to Determine the Efficacy of PAA as a Disinfectant

A mathematical relationship can be developed such that the performance of the disinfection system can be modeled given the initial concentration of E coli., the concentrations of other possible influential parameters, the final concentration of E coli., the dose of PAA applied, and the contact time. Given any water quality (within the range modeled), the dose, the contact time, and the final E coli concentration can be determined and likewise the attainment of water quality standards can be determined. To date, this system has been modeled with multivariate regression analysis using *SAS* (a proprietary statistical analysis package). However, genetic algorithm fixed set function analysis will also eventually be used to generate a model of the PAA disinfection system. In the end, a comparison of the genetic algorithm function and the multivariate regression equation will be conducted to determine which model is more accurate. This evaluation will be based on the calibration and validation results.

Non-linear constrained optimization will be performed on the superior numeric model as determined above. The optimized system model should yield, given a specific initial water quality, the most cost effective combination of disinfectant (PAA dose) and capital costs (based on contact time) over the anticipated life of the facility that will consistently meet water quality standards. In order to predict the optimal combination of PAA dose and contact time, the Shuffle Complex Method of optimization will be used. In the end, this information will indicate the cost of this technology to meet water quality standards and to determine if it is cost competitive with traditional technologies. If it is determined that this technology is more expensive than traditional technologies, the modeling techniques can also be used to determine what the cost of this technology (particularly the chemical costs) needs to be to compete with the traditional but larger and less environmentally sound technologies.

Principal Findings and Significance

The efficiency of the PAA was measured using E coli. concentrations that were considered strong, medium and weak WWFs. The strong WWFs ranged from approximately 1,500,000 MPN/100 ml to 1,000,000 MPN/100 ml. Moderate WWFs were considered those flows with E coli. concentrations less than 1,000,000 MPN/100 ml but greater than 100,000 MPN/100 ml. Finally, weak WWFs were those with concentrations less than 100,000 MPN/100 ml. For each strength, the combinations of contact time (i.e. 2, 5 and 10 minutes) and PAA concentration (i.e. 5, 10, and 15 mg/L) were evaluated.

Figure 2 presents the performance curves for varying strengths of WWFs. A concentration of 1,000 cols/100 ml is met with 10 - 15 mg/l of PAA in two to five minutes. In addition, the primary water quality standard of 130 col/100 ml is met with 15 mg/l PAA up to a concentration of 1,500,000 MPN/100 ml and with 10 mg/l PAA up to 1,000,000 MPN/100 ml within five minutes. One thing to note from each of these figures is that the majority of kill occurs in the first 5 minutes (regardless of the initial concentration) using either the 10 or 15 mg/l PAA dosages.

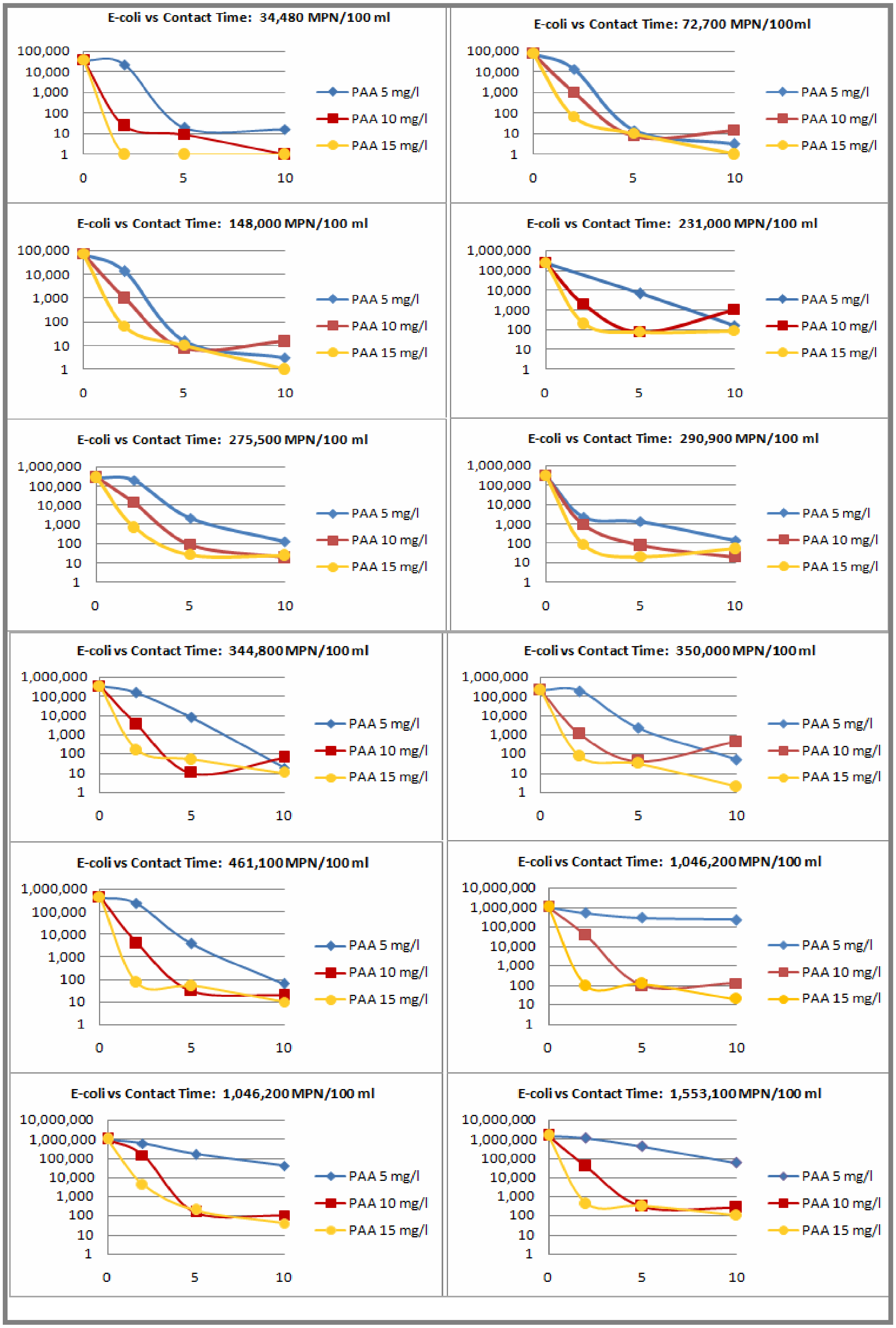

Figure 2. Performance Curves for the Disinfection of E coli with PAA

For moderate WWFs, the primary water quality standard for E coli. of 130 cols/100 ml is met consistently with the 10 and 15 mg/l doses and achieved or very closely approached with 5 mg/l. With a contact time of 2 minutes, this water quality standard is met with the 15 mg/l dose and again the majority of the disinfection occurs within the first 5 minutes (if not the first two) with the higher dosages. If a 10 minute contact time is desired such that less PAA is used, it appears that a dose of 5 mg/l or slightly higher would achieve primary water quality standards. All doses applied to moderate strength WWFs achieved concentrations less than 1,000 cols/100 ml. As with the moderate strength WWF results, weak WWF tests resulted in the three doses achieving primary water quality standards with the majority of the disinfection occurring within the first 5 minutes of treatment.

Based on the data generated for the performance curves and the water quality parameters monitored, multivariate regression analysis was performed on a number of statistics with the most closely identified distributions as follows:

- Normal Distribution
  $$\text{Percent Kill Rate} = \frac{\text{Initial Concentration} - \text{Final Concentration}}{\text{Initial Concentration}} \times 100$$
- Negative Binomial Distribution
  Total Kill = Log(Initial Concentration – Final Concentration)

- Logistic Distribution
  $$\text{Kill Rate} = \frac{\text{Initial Concentration} - \text{Final Concentration}}{\text{Initial Concentration}}$$

Using the percent kill rate, which closely approximated a normal distribution, the best fit model yielded Equation 1. The multivariate regression modeling of this statistic resulted in a better fit without the influence of the additional water quality parameters. However, it did not yield a model with an acceptable level of performance.

$$(EO-EF)/EO*100 = (65.025 + 1.874*PAA + 1.729*CT) \qquad \text{Eq. 1}$$

Total kill was found to closely mimic a negative binomial distribution which when limited to positive values yields a Poisson distribution (as is commonly found in bacteriological data). The multivariate regression analysis again yielded an equation that resulted in a better fit without additional parameters. Equation 2 is the best fit equation based on total kill with a negative binomial distribution. Again, this model does not meet an acceptable level of performance.

$$EO-EF = e^{(-4.1434 + 1.0958*Log(EO) + 0.0234*PAA + 0.0205*CT)} \qquad \text{Eq. 2}$$

Finally, kill rate was analyzed as logistically distributed (rather than normally distributed as with percent kill rate). Equation 3 resulted from this analysis and yielded an acceptable r-squared value of 0.71. The model of this statistic resulted in a better fit when all water quality parameters were taken into consideration. Thus, this multivariate function accounts in part, for the influence of the other water quality parameters.

$$(EO\text{-}EF)/EO = 1/[1+e^{-(-17.8373+(0.5691)PAA+(0.4252)CT+(0.3421)NH3+(0.4815)pH+(0.00358)SEC+(0.1609)TP+(0.00791)TSS-(0.0401)COD-(0.0176)DO}] \quad \text{Eq. 3}$$

It appears that PAA is an appropriate disinfectant for WWFs with harmless byproducts and shorter contact times than traditional disinfection technologies. Potential cost savings are apparent although they have not yet been fully quantified. It has been estimated that 30% of capital costs for traditional technologies is for de-chlorination. Thus a 30% reduction in capital costs for disinfection systems can be realized with PAA while meeting water quality standards. In addition, due to the speed of the disinfection reaction, the remaining 70% of capital costs for disinfection can be further reduced by perhaps 1/3 to 2/3 because disinfection can be done in 1/3 or 2/3 of the contact time. Based on preliminary results, it appears that PAA will be highly cost competitive from a capital cost perspective. Upon finalization of the modeling and cost optimization (which will include both capital and chemical costs) a determination of cost competitiveness for the entire system will be completed.

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Information Transfer Program Introduction

Information transfer activities are an important part of the overall program of the Kentucky Water Resources Research Institute. There are two main components, an annual symposium and the institute web site (including an electronic newsletter). The institute also participates in and supports numerous other technology and information transfer activities throughout the year.

Kentucky Information Transfer Activities

Basic Information

Title:	Kentucky Information Transfer Activities
Project Number:	2008KY122B
Start Date:	3/1/2008
End Date:	6/30/2009
Funding Source:	104B
Congressional District:	Kentucky 6th
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	symposium, internet, newsletter
Principal Investigators:	Lindell Ormsbee, Anna Goodman Hoover, James A. Kipp

Publication

1. Proceedings of the Kentucky Water Resources Annual Symposium, March 2, 2009, Kentucky Water Resources Research Institute, Lexington, Kentucky, 100 p.

Kentucky Information Transfer Activities (2008KY122B)

Problem and Objectives

Section 104(b) of the Water Resources Research Act of 1984 requires the Institutes or Centers to:

(1) “plan, conduct, or otherwise arrange for competent applied and peer reviewed research that fosters –

- (A) improvements in water supply reliability;
- (B) the exploration of new ideas that –
  - (i) address water problems; or
  - (ii) expand understanding of water and water-related phenomena;
- (C) the entry of new research scientists, engineers, and technicians into water resources fields; and
- (D) the dissemination of research results to water managers and the public.

(2) "cooperate closely with other colleges and universities in the State that have demonstrated capabilities for research, information dissemination, and graduate training in order to develop a statewide program designed to resolve State and regional water and related land problems."

(3) "cooperate closely with other institutes and other organizations in the region to increase the effectiveness of the institutes and for the purpose of promoting regional coordination."

Kentucky information transfer activities are conducted in support of these objectives.

Methodology

Information transfer activities are an important part of the overall program of the Kentucky Water Resources Research Institute. There are two main components, an annual symposium and the institute web site (including an electronic newsletter). The institute also participates in and supports numerous other technology and information transfer activities throughout the year.

The Associate Director develops the program for the Annual Water Resources Symposium. Presentations in both platform and poster format allow for researchers and practitioners to share progress on planned, ongoing, and completed water-related activities throughout the Commonwealth each year.

The Information Specialist Senior assists with creating program announcements and the proceedings volume for the symposium. She also prepares articles for the electronic newsletter that is distributed through e-mail and is continuously available on the web site. She develops and maintains content for several web sites including the main Institute page at: www.uky.edu/WaterResources/. Links for additional sites describing projects and activities (for example volunteer sampling results and watershed pages for the Kentucky River Basin) are provided on the main web site. Research translation to make results accessible for a variety of audiences is a major goal for all of the technology transfer activities of the unit.

The institute also cooperates closely with other groups and agencies in planning additional technology transfer activities in the Commonwealth. These efforts include support for seminars/lectures, other web sites, an open house during Earth Science week, and a weeklong summer camp for high school sophomores from eastern Kentucky counties. Institute staff members serve a variety of support roles on technical committees and advisory panels for agencies and volunteer organizations to help disseminate relevant information about ongoing activities and research results.

Principal Accomplishments and Activities

Kentucky Water Awareness Month is an educational program of the University of Kentucky Cooperative Extension Service, Environmental and Natural Resource Issues Task Force (Associate Director of KWRRI is a member). The program promotes overall water awareness for the citizens of Kentucky during May each year. Materials are developed by a committee at the state level, and distributed to all of the 120 county Extension offices in the state. Individual county agents are encouraged to tailor the program to fit their county's specific needs and to use the materials to enhance their program efforts. The materials remain available throughout the year for use by classroom teachers, 4-H volunteers, and others interested in water issues through the ENRI internet site: www.ca.uky.edu/enri/

The Robinson Scholars Program serves first generation college-bound students from 29 eastern Kentucky counties who have demonstrated the potential to succeed, but who might encounter economic, cultural, or institutional impediments to completion of a four-year college degree. The program provides general support, leadership development opportunities, and a University of Kentucky scholarship upon graduation from high school. The Water Pioneers Water Quality Initiative was developed by KWRRI for rising high school sophomores in the program. It is held for five days in June and immerses the teens in activities designed to open their eyes to the importance of healthy watersheds using a diverse curriculum designed to show nature’s interconnectivity. Following the camp, the students use the knowledge that they gain to partner with educators, volunteers, and other interested groups in their home counties to increase awareness of best management practices for water quality through a community service/outreach project of their own design. During the past year, the program was recognized for significant contributions to the environment when it received a 2008 Earth Day Award from the Kentucky Environmental Quality Commission.

An open house was held on Wednesday evening 10/15/2008 during Earth Science Week. This event was co-sponsored with the Kentucky Geological Survey. KWRRI staffed a water exhibit for the elementary, middle school, and high school students and their parents who attended the event (approximately 200 people).

KWRRI continues participation in the Bluegrass Partnership for a Green Community, a cooperative effort between the University of Kentucky, the Fayette County public school system, the Lexington-Fayette Urban County Government, and numerous other partners. Staff members are active with the water/stormwater team.

Cyberseminars provided through the Consortium for the Advancement of Hydrologic Sciences, Inc. were made available by the KWRRI on the University of Kentucky campus for interested faculty, staff, students, and local professionals.

The Kentucky Water Resources Annual Symposium was held on March 2, 2009. Although the date of the symposium fell outside of FY2008, most of the planning and preparation occurred during the fiscal year. Two concurrent sessions provided time slots for 32 platform presentations. Eighteen posters were also presented during a separate poster session. The 6 student research enhancement projects funded during FY2008 by the 104(b) program presented their results. Approximately 110 people attended the meeting. Abstracts for all of the presentations were distributed to participants on the day of the meeting: Proceedings of the Kentucky Water Resources Annual Symposium, 2009, Kentucky Water Resources Research Institute, Lexington, Kentucky, 100 p. The full proceedings document is also available online through a link on the Institute's web site. The document includes contact information for all authors and presenters and an abstract for each presentation. Symposium participants also receive a list of attendees providing basic contact information for each individual who pre-registered for the symposium. Attendees include researchers, personnel from local, state, and federal agencies, undergraduate and graduate students, participants from volunteer groups and NGOs, and members of the general public. Conference registration fees are kept low through partial subsidy of symposium expenses to ensure accessibility to individuals from all potential audiences.

Maintenance of the institute web site provides open access for those interested in the activities of the Institute as well as providing links to related sites and information maintained by others. Creation and maintenance of the web site are ongoing throughout the year. Links on the site provide direct access to the Association of State Dam Safety Officials, the Kentucky Research Consortium for Energy and the Environment, the Kentucky River Watershed Watch Database, the National Institutes for Water Resources, PRIDE, the Tracy Farmer Center for the Environment, the UK Superfund Basic Research Program Research Translation Core, and the Kentucky River Basin Watershed Page. The Institute's newsletter WATERWORKS is also available in electronic format through a link on the web page.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	5	0	0	0	5
Masters	6	0	0	0	6
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	12	0	0	0	12

Notable Awards and Achievements

Project 2008KY108B - Aric Payne was judged first place oral presentation in zoology at the 2008 Kentucky Academy of Science 10/31/2008.

Project 2008KY111B - Robert Tokosh received the 2009 Sigma Xi multidisciplinary poster competition award at Murray State University.

Publications from Prior Years

1. 2007KY88B ("Determination of Nutrient Sources in a Eutrophic Lake Impacted by Human Activity") - Conference Proceedings - Borowski, Walter, Theresa Aguiar, Jill Hunter, Erin Jolly, and Richard Stockwell, 2009, Nutrient and Fecal Microbe Sources for a Eutrophic Lake and Recommended Remediation Steps, Wilgreen Lake, Madison County, Kentucky, in Proceedings of the Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 75.
2. 2006KY69B ("Pervious Concrete for Solid/Liquid Separation and Waste Remediation") - Articles in Refereed Scientific Journals - Luck, Joe, Stephen Workman, Mark Coyne, and Stephen Higgins, 2008, Solid Material Retention and Nutrient Reduction Properties of Pervious Concrete Mixtures, Biosystems Engineering, 100(2008), Elsevier Ltd, p 401-408.
3. 2006KY69B ("Pervious Concrete for Solid/Liquid Separation and Waste Remediation") - Articles in Refereed Scientific Journals - Luck, Joe, Stephen Workman, Mark Coyne, and Stephen Higgins, 2009, Consequences of Manure Filtration through Pervious Concrete During Simulated Rainfall Events, Biosystems Engineering, 102(2009), Elsevier Ltd, p 417-423.
4. 2007KY89B ("Diatom Colonization Patterns in Freshwater Springs in Relation to Underlying Geology") - Articles in Refereed Scientific Journals - Hunt, Courtney and Susan Hendricks, 2008, Diatom Species Composition and Environmental Conditions at Four Perennial Springs in Western Kentucky and Tennessee, Journal of the Kentucky Academy of Science, 69(2), p. 141-151.
5. 2004KY41B ("Linking chemical tolerance to reproductive resilience: CYP1A as a metric for predicting fish species distributions in chemically impacted habitats") - Conference Proceedings - Brammel, B.F. and Adria Elskus, 2009, Linking Chemical Tolerance to Reporductive Fitness: Initial Results of in vitro Experiments Examining Pollutant Effects in Teleost Primary Hepatocytes, in Proceedings of the Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 77.