Kentucky Water Resources Research Institute
Annual Technical Report
FY 2006

Introduction

The 2006 Annual Technical Report for Kentucky consolidates reporting requirements of the Section 104(b) base grant award into a single techincal report that includes: 1) a synopsis of each student research enhancement project conducted during the period, 2) citations for related reports and presentations, 3) a description of information transfer activities, 4) a summary of student support during the reporting period, 5) notable awards and achievements during the year, and 6) publications from prior projects.

Research Program

The activities supported by Section 104(b) program funds and required matching are interwoven into to total program of the Kentucky Water Resources Research Institute. Additional elements of the program during FY2006 included the Environmental Protection Scholarship Program and other research, service, and technology transfer activities funded through a variety of sponsors. Memoranda of Agreement projects with the Kentucky Division of Water included TMDL development for several Kentucky streams. Other projects were funded by the Kentucky Cabinet for Health and Family Services (technical issues related to radiation and other contaminants at the Maxey Flats Nuclear Disposal Site and the Paducah Gaseous Diffusion Plant). The Kentucky River Authority supported watershed management services for the Kentucky River. The National Institute of Environmental Health Sciences supported research translation activities through the Superfund Public Outreach Program. East Kentucky PRIDE supported volunteer sampling for water quality assessment, and the Metropolitan Sewer District funded activities addressing Beargrass Creek Combined Sewer Overflows in Louisville.

In addition, the Kentucky Consortium for Energy and Environment, led by Lindell Ormsbee (Director of KWRRI), continued as a collaborative program involving faculty and students from the University of Kentucky, the University of Louisville, and Murray State University. The consortium was funded by the Department of Energy to assist with efforts supporting a variety of environmental assessment and cleanup activities at the Paducah Gaseous Diffusion Plant. Over 20 separate projects were active during 2006 and most of these dealt with issues related to groundwater or surface water.

Eleven student research enhancement projects received support through 104(b) FY 2006 program funding. Projects were conducted at the University of Kentucky (7), Northern Kentucky Uviversity (2), and Murray State University (2) and represented a variety of discipline areas (civil/environmental engineering, plant and soil sciences, forestry, biosystems and ag engineering, biology, and geology). The goal of this approach (increased number of smaller projects involving students) was to enhance the research training experience of a greater number of students in a wider variety of disciplines focusing on water resources. Many state ageincies 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 eleven student research efforts follow. All projects reported results at the Kentucky Water Resources Annual Symposium on March 26, 2007.

Feasibility of using 3D CFD Models in Simulating Hydrodynamics in Dam Design/Rehabilitation

Basic Information

Title:	Feasibility of using 3D CFD Models in Simulating Hydrodynamics in Dam Design/Rehabilitation
Project Number:	2006KY60B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	KY 6th
Research Category:	Engineering
Focus Category:	Hydrology, Models, Methods
Descriptors:	numerical model, FLUENT, free surface simulation
Principal Investigators:	Scott Yost

Publication

1. Shao, Z.S. and S. A. Yost, 2007, Toward Using a Three-Dimensional Numerical Model for Simulating Hydrodynamics Near a Dam for Constructing the Rating Curve, in Proceedings of the Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 9-10.

Problem and Research Objectives

Lock and Dam 9, located on the Kentucky River just downstream from the Valley View Ferry on KY 169, was constructed by the United States Army Corps of Engineers (USACE) between 1902 and 1907 (Figure 1). It provides water storage for local water suppliers and maintains a pool for recreational and navigational use along the river. The Kentucky River Authority recently decided to stabilize and renovate Lock and Dam No. 9 to secure the structure against failure and major leak losses, and to add storage capacity. The existing dam consists of three main components: the main dam, the auxiliary dam and the navigation lock chamber (Figure 1). A concrete-filled, cellular sheet pile structure was proposed for the renovated dam. In the proposed design, eight circular cells positioned across the river will be connected with "arc cells." It is important for the new structure to maintain the same hydraulic characteristics (discharge-stage relationship, permanent pool elevation) as the existing dam. Therefore, a hydraulic study of the proposed design is important to make sure that the new construction will not change the flow pattern on the existing river system.

Figure 1 2001 Aerial Photo of Lock & Dam 9 (Source: FMSM Engineers Inc.)

Traditional approaches for studying hydrodynamics near structures involve field measurements and setting up laboratory physical models. However, laboratory models poorly satisfy hydraulic similarity with the original physical structure because some dominant non-dimensional parameters can not be represented well in a laboratory model. Also, lab models do not provide much flexibility. Numerical models are more flexible and can be used to simulate several possible scenarios without much extra effort. FLUENT is a standard industry computational fluid dynamics code used in a wide range of flow simulations. It has been used for applications ranging from inkjet printers to aerospace. However previous applications of FLUENT in water resources have been fairly limited and application of FLUENT to complicated large scale hydraulic structures (such as a dam) has not been widely studied. The objective of this study was to develop a three-dimensional numerical model using FLUENT to simulate flow near the dam site and ultimately to compare the rating curves of pre- and post-construction conditions.

Methodology

In this study, a three-dimensional numerical model was developed for the renovated Lock & Dam 9 post-construction conditions using the FLUENT program. The procedures used to develop the model are described below.

a. Simplify Geometry - The geometry of the post-construction condition of Lock & Dam 9 was simplified and input in the mesh generator - Gambit. Geometries of the existing dam and the proposed design were obtained from FMSM Engineers Inc. The total study section length was about 1,000 feet. The side slope of the river bank was treated as uniform along the study section. The model included deposited sediments near the river bed, but the geometry of the deposit was simplified as a flat bottom
b. Mesh Generation. A mesh generator – GAMBIT, embedded as a preprocessor in FLUENT software, was used to generate a three-dimensional mesh for the study area. The total number of resulting nodes was 480,000 and the total number of cells was 1.3 million. The computational domain upstream from the cellular dam was meshed with a uniform hexahedral grid while the rest of the dam was meshed with a non-uniform tetrahedral grid (Figure 2).
c. Unsteady Model. An unsteady state simulation was chosen for the overall calculation. The time step size varied between 0.1second to 0.5 second.
d. Turbulent Model. A k-ε model was selected to simulate the turbulence near the dam (k-ε is a standard turbulent model widely used in industry). With different treatment and calibration of wall function, the k-ε model simulates turbulence with large Reynolds number very well.
e. Free Surface Simulation. A Volume of Fraction (VOF) scheme was chosen to simulate the free surface feature of the simulated flow. VOF can handle long waves, short waves, and breaking waves.
f. Appropriate boundary conditions. A given mass flow rate was specified as the inflow boundary condition upstream of the computational domain. A fixed depth was also specified in FLUENT at the upstream boundary to initiate the calculation.

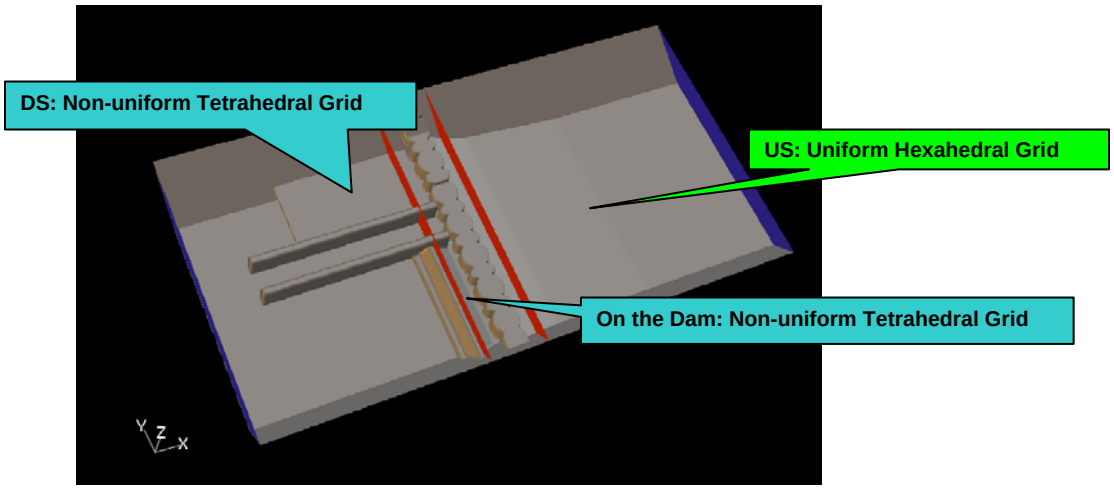


Figure 2 Computational Grids generated in Gambit

Principal Findings and Significance

Using commercial software for analyzing hydrodynamics around a dam requires a learning curve for both the software and the grid generation. FLUENT was a particularly complex package with many attributes that needed to be understood so that the model could be used for the chosen application. While the investigators found that this tool is well worth the learning effort, consulting companies who are driven by tight time-lines may never schedule the time or commit sufficient resources to fully utilize the numerical tool. It would likely require $50,000 to $80,000 to generate a final rating curve comparison. Of this, 75% of the resources would be a one time upfront cost to learn the details of the commercial software. After a full year of intense learning and investigation, well beyond the actual duration of the project, we are just now obtaining meaningful preliminary results. With an appropriate numerical grid developed compatible with FLUENT, simulation of flow across the dam is now possible. Figures 3 and 4 show the propagation of the free surface along the channel at time = *90s* and *290s*. These results are not steady-state, but steady-state conditions will be needed in order to generate a point for the stage discharge rating curve.

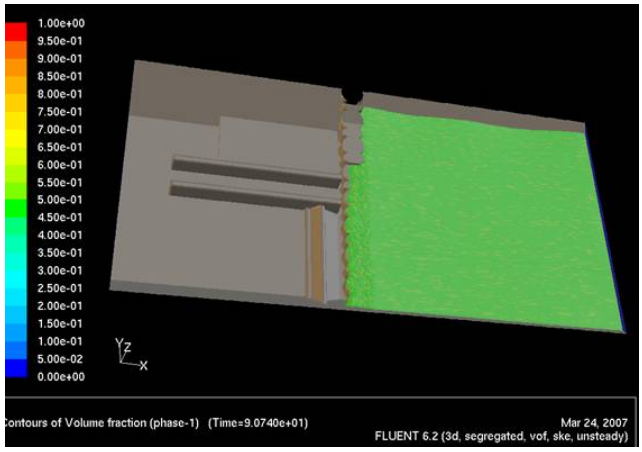


Figure 3 Free Surface at t=90s

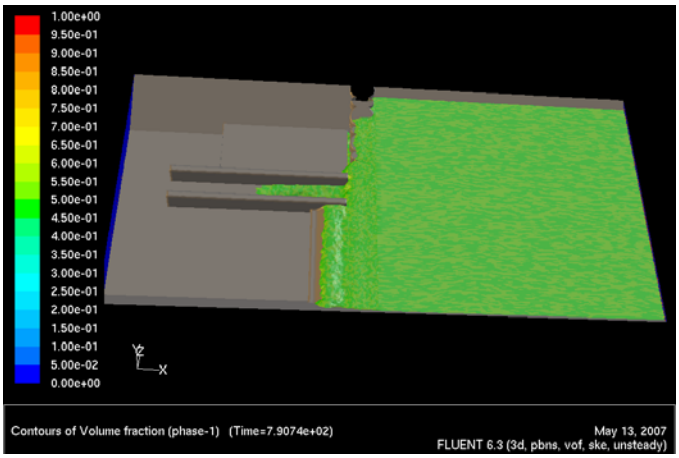


Figure 4 Free Surface at t=290s

Figure 5 shows the dynamic pressure contour at time = *290s*. Even though the results are unsteady, the pressure around the dam is nowhere near hydrostatic. While anyone familiar in fluid mechanics would know this to be true, many consulting companies still use simple models (ie, HEC-RAS) to attempt to generate stage-discharge information. The results from those studies are, at best, suspect because of the complex dynamics involved. The investigators hope to compare the steady state results of the FLUENT model to that of HEC-RAS to gain understanding of the errors due to the oversimplification.

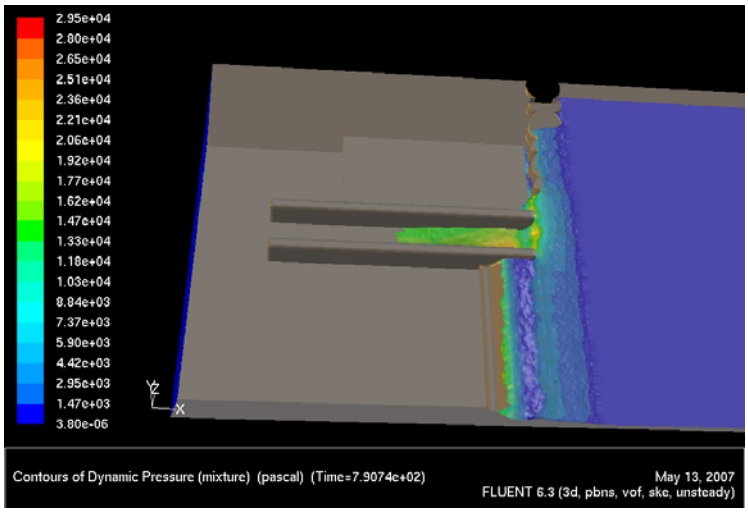


Figure 5 Dynamic Pressure at t = 790s

Figure 6 shows the sobering reality of using advanced numerical tools. While the HEC-RAS model's computational time is a fraction of the actual simulation time, it is just the opposite for models like FLUENT where the computational time is orders of magnitude greater than the simulation time. Parallel processing is an absolute necessity for making these advanced models useful for practicing engineers. Fortunately, the University of Kentucky has a supercomputing center that ranks in the top 10 public facilities in the country, and the top 200 in the world.

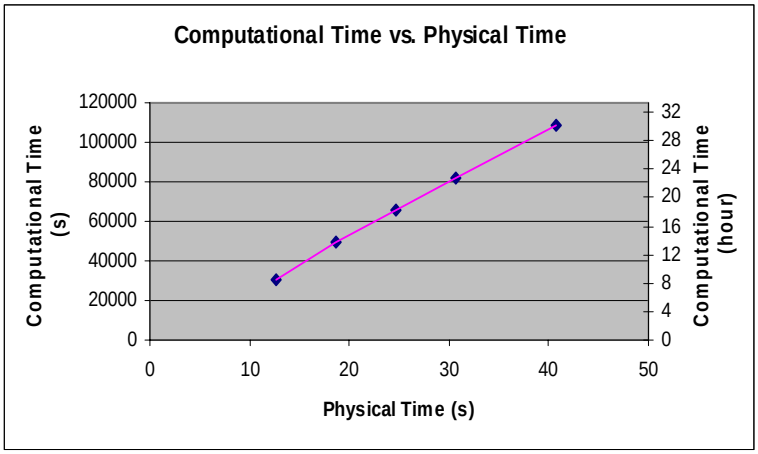


Figure 6 Computation time vs. Physical

Identification of Potential Bacterial Sources and Levels, Red Duck Creek, Mayfield, Kentucky

Basic Information

Title:	Identification of Potential Bacterial Sources and Levels, Red Duck Creek, Mayfield, Kentucky
Project Number:	2006KY61B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	KY 1st
Research Category:	Water Quality
Focus Category:	Surface Water, Water Quality, Non Point Pollution
Descriptors:	coliform bacteria, urban stream
Principal Investigators:	Mike Kemp

Publication

1. Vorbeck, Brooke, Travis Martin, and Mike Kemp, 2007, Identification of Potential Bacterial Sources and Levels, Red Duck Creek, Mayfield, Kentucky, in Proceedings of the Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 57-58.

Problem and Research Objectives

Red Duck Creek is an urban stream running through Mayfield, Kentucky. Land use along the stream includes a farm chemical manufacturer, apartments, single family dwellings, and light commercial development. Several municipal sewer lines run adjacent to the creek or cross it. Much of the creek is easily accessible by the public, and high levels of coliform bacteria have been previously documented.

Sources of the fecal coliforms and problematic reaches along the stream must be identified to protect public health. We proposed two intensive sampling periods, one in late spring when the stream flow is typically higher, and one in early fall during low flow. Unfortunately, funding was delayed, and the spring sampling could not be conducted. Sampling was initiated in September and continued through December in an attempt to obtain results representing both high and low flow conditions.

Methodology

Twelve potential sampling locations were identified. Originally, samples were to be collected biweekly. Because of the delay and subsequent weather and stream flow conditions, samples were collected twice in September, twice in October, once in November and once in December.

The samples were analyzed for Escherichia coliform and total coliform, using the IDEXX Coliert system (Standard Method 9223). Field chemistry was measured at each station during sample collection (pH, conductivity, dissolved oxygen, turbidity, and temperature). Data were statistically evaluated based on sample location. Geometric means of the coliform data were used in some of the statistical evaluations. Stream flows were too low and inconsistent to obtain meaningful flow results.

Findings and Significance

Because of the typical low flow conditions in the fall, samples could not be collected from all sites during each sampling event. Also, field measurements were not obtained during the second sampling event in September because the trip resulted from a spur of the moment decision to catch runoff following a storm event.

Correlations among the field parameters and the fecal and total coliform analyses were weak, and no trends could be identified in the individual parameters. Statistically, the coliform results among locations upstream, within, and downstream of the city of Mayfield could not be differentiated as significantly different. Therefore, specific potential point sources of bacterial contamination could not be identified. Bacterial contamination during this sampling period appeared to be due to widely dispersed sources. Additional work to identify the origins of the fecal bacteria could be useful.

Linking Land Use to Water Quality in Northern Kentucky

Basic Information

Title:	Linking Land Use to Water Quality in Northern Kentucky
Project Number:	2006KY62B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	KY 4th
Research Category:	Water Quality
Focus Category:	Surface Water, Water Quality, Non Point Pollution
Descriptors:	urbanization, water quality degradation, aquatic habitat
Principal Investigators:	Rebecca Evans

Publication

1. Evans, Rebecca L. and Alicia Sullivan, 2007, Eutrophic Conditions in Three Northern Kentucky Streams, in Proceedings of the Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 91-92.

Problem and Research Objectives

Census Bureau data indicates that the Northern Kentucky region, with a population growth of more than 13.5% since 2000, is rapidly transforming from an agricultural to an urban landscape. With urbanization comes pollution and water quality degradation. Eutrophication, a highly productive condition caused by excess nutrient loading from agricultural runoff and/or treated sewage effluent from urbanized areas, causes noxious algal blooms promoting diurnal dissolved oxygen and pH swings that degrade water quality and aquatic habitat integrity. Water quality typically declines when impervious surfaces reach 10% of watershed area and at 25% channels incise, banks erode, and sediment load is transported downstream where it settles out and destroys physical habitat (Pelley, 2004). Though agriculture does contribute to nutrient enrichment, urbanization is currently the biggest threat to local and regional water resources in northern Kentucky. Urbanization leads to impaired chemical and physical conditions that negatively impact the biological component of surface waters. Though degraded water quality associated with both agricultural and urban land use is well documented, no data existed that described the trophic state of area streams or land use impacts.

There were three main objectives in this study. The first was to document the trophic status of 12 Mile Creek, Doe Run, and Banklick Creek by sampling bi-weekly for a year and comparing data to U.S. EPA criteria for water quality protection. Second, to assess the relationship between trophic indicators: pH, dissolved oxygen, conductivity, nitrogen and phosphorus concentrations, sestonic and benthic algal biomass, and phosphorus concentration in benthic algae in the sampled streams. And, finally, to examine the potential for developing a model of water quality parameters that quantifies land use impacts on northern Kentucky streams.

Methodology

This project was planned and carried out as a bi-weekly sampling regime of the three study sites. pH, oxygen, temperature, conductivity and total dissolved solids (TDS) were measured at streamside using calibrated, portable, field meters. Triplicate water samples were collected, stored on ice for transport and processed in the lab for measurement of sestonic algal biomass, total phosphorus, soluble reactive phosphorus, nitrate, and ammonia (nitrate and ammonia were used for estimation of total inorganic nitrogen). Duplicate (originally planned as triplicate) rock scrubs were taken from a random sample of bottom rocks at each site. The slurry produced from each rock scrub was collected and processed to measure total benthic algal biomass and phosphorus concentration per unit dry weight.

Principal Findings and Significance

We successfully completed all sampling dates as scheduled and all chemical analysis of samples has been completed. Data analysis is still being conducted because the dataset is so large and requires in depth statistical comparisons of multiple variables in multiple dimensions. Plans are to present final conclusions at the 2007 Kentucky

Academy of Sciences annual meeting in poster format as indicated in the original proposal. The additional data analysis will allow for completion of the data analysis and more robust conclusions. Preliminarily, we conclude that all 3 Northern Kentucky streams sampled as part of this study are eutrophic during some portion of the year. Land use variables appear to be most closely associated with the variation in seasonal eutrophic conditions and further data analysis may aid in quantifying this relationship.

The first objective in this study was to document the trophic status of 12 Mile Creek, Doe Run, and Banklick Creek by sampling bi-weekly for a year and comparing data to U.S. EPA criteria for water quality protection. This objective was met and completed as proposed.

The second objective was to assess the relationship between trophic indicators: pH, dissolved oxygen, conductivity, nitrogen and phosphorus concentrations, sestonic and benthic algal biomass, and phosphorus concentration in benthic algae in the sampled streams. This assessment is still underway in the form of statistical analyses. All data needed to meet this objective have been collected.

The third objective was to examine the potential for developing a model of water quality parameters that quantifies land use impacts on northern Kentucky streams. This objective is still being assessed by way of data analysis. As with the second objective, all data necessary to meet this objective have been collected.

Experimental Study of the Impact of Upland Sediment Supply upon Cohesive Streambank Erosion

Basic Information

Title:	Experimental Study of the Impact of Upland Sediment Supply upon Cohesive Streambank Erosion
Project Number:	2006KY63B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	KY 6th
Research Category:	Engineering
Focus Category:	Sediments, Geomorphological Processes, Surface Water
Descriptors:	fluid turbulence, turbulence decomposition, particle image velocimetry
Principal Investigators:	James F. Fox

Publication

1. Belcher, Brian and Jimmy Fox, 2007, Experimental Study of the Impact of Upland Sediment Supply upon Cohesive Streambank Erosion Part 1: Fluid Turbulence, in Proceedings of the Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 7-8.

Problem and Research Objectives

This project was initially formulated to study the impact of upland sediment supply upon cohesive streambank erosion. Due to the complexities of understanding the impacts of fluid turbulence on erosion, the focus was shifted to study the structure of turbulence in gravel-bed rivers. Thus the fluid characteristics were focused upon for this work, with studies of sediment characteristics planned for future research. It is well recognized by the scientific and engineering communities that turbulent structure impacts scour-deposition, contaminant mixing, solute fluxes at river boundaries and aquatic habitats. However, the cyclical nature of turbulent structure (form) and the source-sink energy transfer attributed to turbulent bursting phenomena (function) remain poorly understood, particularly in gravel-bed rivers, where high gradients and high turbulent intensity make measurements of instantaneous turbulent processes difficult. To overcome those problems and study turbulence over gravel beds, we developed a scientific method that utilizes advanced velocity instrumentation with high spatial and temporal resolution and accepted visualization filtering methods (i.e. turbulence decomposition), advanced statistics, and theoretical analysis of turbulence length and frequency scales. We used this method in a fixed gravel-bed flume in order to isolate potential parameters impacting turbulent structure within a controlled setting.

Methodology

Experiments were performed in two different 12-m-long open-channel flumes with fixed roughness elements placed on the bed. Spatial data was collected with particle image velocimetry (PIV) and this data was decomposed using turbulence filtering techniques to visualize eddy structure. Time-series data were collected at a point using acoustic Doppler velocimetry (ADV) and decomposed using a temporal equivalent decomposition method to visualize the impact of eddy structure upon velocity time-series data. The decomposition methods provided plots of large- and small-scale coherent structures in the turbulent field. These plots were statistically analyzed for length scales and topological description of eddies; as well as the turbulent bursting phenomena such as sweeps, ejections, inward interactions and outward interactions. Results were further analyzed to provide a comprehensive conceptual model of turbulence for the range of conditions tested.

Principal Findings and Significance

Our specific findings are (1) particle image velocimetry coupled with turbulence filtering methods are excellent tools to visualize and measure characteristics of the dominant scales of turbulent structures in rough-bed channels; (2) spatial and temporal fluctuations of important turbulent processes are related to the birth, growth and destruction of the characteristic eddies, which are projected along larger scale patterns that spatially encompass $>6.5H$ in the streamwise direction, where H is the flow depth; and, (3) existing structural models may be extended to rough-bed flows in open channels.

Evaluating Denitrifier Stratification in Fragipan Soils

Basic Information

Title:	Evaluating Denitrifier Stratification in Fragipan Soils
Project Number:	2006KY64B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	KY 6th
Research Category:	Ground-water Flow and Transport
Focus Category:	Nitrate Contamination, Agriculture, Non Point Pollution
Descriptors:	fragipans, denitrifying bacteria, soil amendments
Principal Investigators:	Mark Steven Coyne

Publication

1. Wu, Tingting and Mark S. Coyne, 2007, Denitrifier Ecology in Fragipan Soils of Kentucky, in Proceedings of the Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 69-70.

Problem and Research Objectives

Very little is known about denitrification processes in subsurface environments. Fragipans are a significant subsurface feature in Kentucky that result in seasonal perched water tables. These environments may contribute to substantial loss of NO_3^- through leaching past the root environment. Our objectives were to evaluate whether surficial land treatments influenced the distribution of denitrifiers by depth in fragipan soils and whether population changes in denitrifiers could be driven by the selection of soil amendment and incubation condition. Our original proposal called for sampling three sites with fragipans. We reduced this number to two sites, but maintained our ability to compare sites with historical evidence of animal waste application.

Methodology

Intact soil cores (4.4 cm diameter, 90 cm long) were taken in fragipan soils (Zanesville silt loam) identified in a formerly cultivated soil with poultry litter amendment (one treatment with 22.4 Mg ha^{-1} litter added; another treatment with no litter added) and an unamended pasture site in Princeton, KY. Soil cores were divided into subsamples by distance relative to the estimated fragipan/soil interface (5 cm above, 5 cm and below, and in 15 cm increments from the interface to the soil surface). Subsamples were analyzed in terms of denitrifier population (by most probable number analysis), and denitrifier activity (by potential denitrification enzyme activity assay). In addition, DNA was isolated from the subsamples using UltraClean Soil DNA Isolation Kits (MoBio Laboratories, Solana Beach, CA.) as specified by the manufacturer. Commercial NESTLÉ® CARNATION® NonFat Dry Milk was added (40 mg g^{-1} soil) to the bead solution tube of the kit to improve extractions. Isolated DNA was quantified using a spectrophotometer. Fragments of *nirK*, *nirS* and *nosZ* genes were amplified using primer pairs *nirK*1aCuF (5'ATC ATG GT(C/G) CTG CCG CG 3')-*nirK*3CuR (5'GCC TCG ATC AG (A/G) TTG TGG TT 3') for *nirK; nirS* cd3aF(5'GT(C/G) AAC GT(C/G) AAG GA(A/G) AC(C/G) GG 3')- *nirS* 3cdR (5' GA(C/G) TTC GG (A/G) TG(C/G) GTC TTG A 3') for *nirS*; and *nosZ*-F (5'CG(C/T) TGT TC (A/C) TCG ACA GCC AG 3') - *nosZ*1622R (5'CGC (G/A) A (C/G) GGC AA (G/C) AAG GT (G/C) CG) for *nosZ* (Throbäck et al., 2004). A 33-bp GC-clamp (5' GGC GGC GCG CCG CCC GCC CCG CCC CCG TCG CCC3') was attached to the 5' end of 3CuR, 3cdR and 1622R primer respectively, for denaturing gradient gel electrophoresis (DGGE) analysis. Intact cores (with plastic liners) from the unammended pasture site with average fragipan depth at 70 cm were used for the treatment application assay with three treatments (1mM glucose, 1mM KNO_3, and water only) in duplicate. All cores were maintained with a 15 cm water table above the fragipan/soil interface. Subsamples were taken at 0, 4, and 8 weeks after the application of amendments and analyzed as previously described to assess whether the amendment influenced the number and distribution of denitrifying bacteria.

Results and Significance

Depth to fragipan at the formerly cultivated site varied from 53 to 62 inches. Depth to fragipan at the pasture site ranged from 43 to 81 cm and for the purposes of this study was further divided into shallow (43-54 cm), moderate (70-72 cm), and deep (75-81 cm).

Within every soil core, soil organic carbon (SOC) and total N of the surface soil were significantly different from subsurface soils ($P<0.05$) (Table 1). However, SOC and total N of soil at the same depth showed no difference between the two poultry litter amendment levels from the formerly cultivated site (Fig. 1), which indicated no permanent effect of the litter amendments on C and N levels at the rates employed.

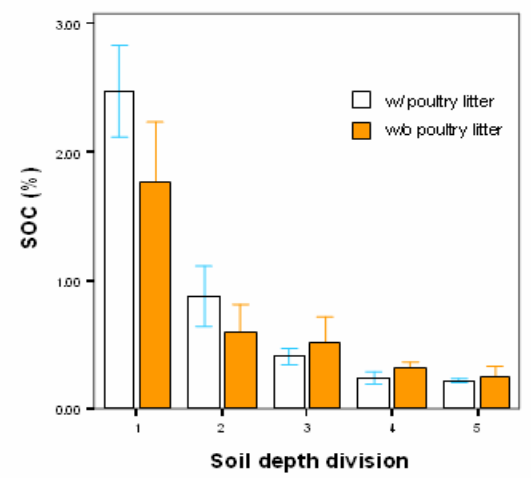
Table 1 Soil water content, SOC, and TN of the soil samples[†].

Properties	Soil core divisions				
	Layer1	Layer2	Layer3	Layer4	Layer5
	Plot with poultry litter amendment				
Soil water content (%)	24.83±3.04	24.59±1.01	25.44±0.6	21.91±0.64	23.71±1.2
Organic carbon (SOC%)	2.47±0.36	0.88±0.23	0.41±0.07	0.24±0.05	0.22±0.02
Total Nitrogen (TN%)	0.16±0.021	0.06±0.012	0.04±0.004	0.03±0.005	0.03±0.004
	Plot without poultry litter amendment				
Soil water content (%)	25.52±4.43	24.37±1.27	25.16±1.56	24.49±2.51	22.57±2.31
Organic carbon (SOC%)	1.76±0.47	0.61±0.21	0.51±0.20	0.33±0.04	0.25±0.08
Total Nitrogen (TN%)	0.11±0.03	0.05±0.014	0.04±0.01	0.03±0.009	0.02±0.007
	Native pasture site				
Soil water content (%)	27.07±4.68	23.71±2.52	22.99±2.33	20.67±2.61	21.01±1.61
Organic carbon (SOC%)	2.73±1.20	0861±0.28	0.37±0.11	0.30±0.07	0.40±0.32
Total Nitrogen (TN%)	0.84±1.75	0.20±0.38	0.09±0.15	0.11±0.14	0.06±0.09

[†] Layer 1: surface soil; layer 2: 35 cm above the fragipan; layer 3: 20 cm above the fragipan; layer 4: 5 cm above the fragipan; layer 5: 5 cm below the fragipan.

Evidence of denitrifiers, as revealed by consumption of NO_3^- in facultatively anaerobic conditions, was found in all depths in all soil cores. As anticipated, the population of denitrifiers declined exponentially from the surface to the depth of the fragipan (Fig. 2).

If the relative populations of denitrifiers to heterotrophs were plotted, in some cases it appeared that denitrifiers made up a greater portion of the microbial population at the fragipan interface (Fig. 3). However, the evidence that the denitrifiers had stratified above the fragipan in either site was inconsistent, most probably because of the extended period in which neither site received supplemental organic C and N. This contrasts with previous findings that fragipan soils receiving continual manure applications do demonstrate stratification. Given the current microbial distribution we observed in these samples, we should be able to observe a significant effect of surface amendment on denitrifier population distribution if such an effect does in fact occur.



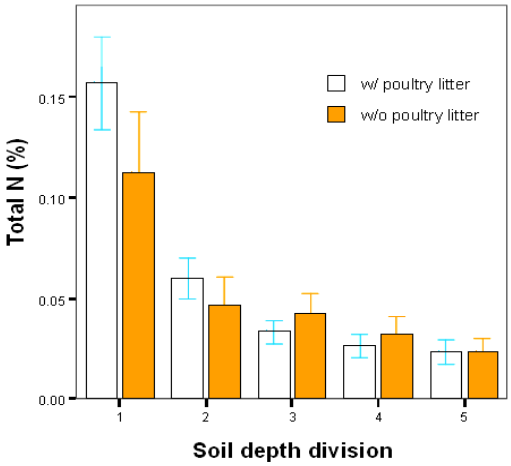


Figure 1. SOC and total N of soils of two treatments from Site 1. Soil depth division: 5: 5cm below fragipan/soil interface; 4: 5cm above fragipan/soil interface; 3: 20cm above fragipan/soil interface; 2: 35cm above fragipan/soil interface; 1: surface soil.

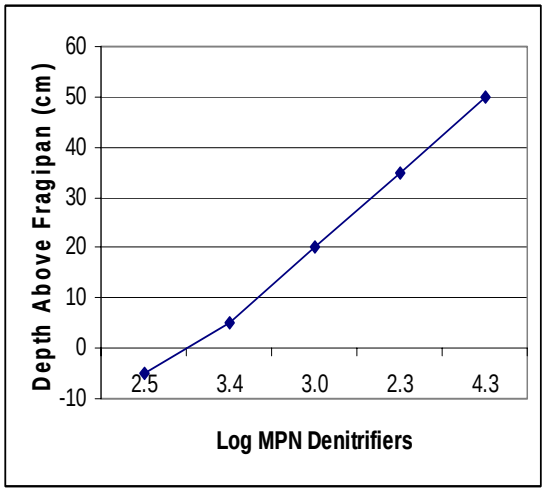


Figure 2. Distribution of denitrifiers by depth from an intact soil core removed from a fragipan soil in Princeton, KY. Depth to fragipan was approximately 50 cm. No amendments had previously been applied to this soil. This represents one-of-twelve unique cores for which MPN analyses were performed at each depth.

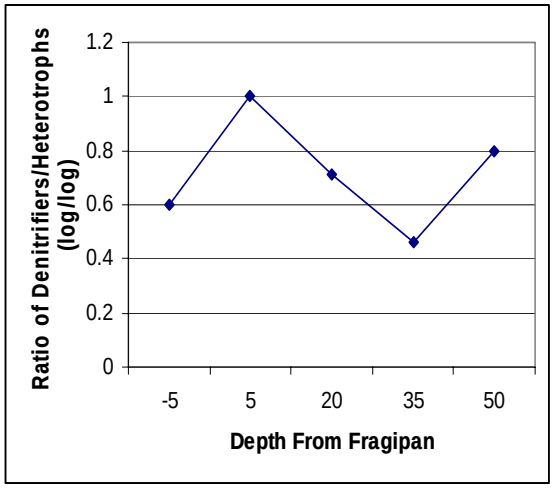


Figure 3. Ratio of denitrifiers to total facultatively anaerobic heterotrophs in soil with depth. Soil core is the same as reported in Fig. 2.

With amendment of 10 mM NO_3-N and 10 mM Glucose, DEA rates of 0.5-0.9 ng of N_2O-N per g dry soil per min were recorded within the first 4 hours of incubation for most of the surface soils, which was 2 to 3 fold higher than the rates of the subsurface soils, which were sometimes not detectable. No significant differences were found in the DEA rate between soils 5 cm above and 5 cm below the fragipan/soil interface. Even though in some samples we found

denitrifier population (determined by MPN) to be stratified above the fragipan, it was not necessarily true that the denitrification rate also stratified, as shown by DEA assay. Besides the anaerobic environment, sufficient substrates such as C and N also affect both denitrifier population and activity.

DNA extraction from soils above the fragipan was greatly improved by adding skim milk to the reaction mix of the commercial DNA extraction kits (Fig. 4). This has not been previously noted. Recovered DNA were significantly different between the subsurface and surface soils, ranging from 3 μg ml^{-1} to 128 μg ml^{-1}, and were stratified in some samples, showing the same population distribution pattern indicated by MPN.

Primers used in this study did not work for all samples. Adjustments and new primers may be necessary for subsequent study.

Soil cores for the amendment experiment have been incubated at room temperature for at least 6 weeks. Samples were taken from the area where the 15 cm-water table was maintained above the estimated fragipan/soil interface at time 0 and after 4 weeks incubation, and were stored in Eppendorf tubes at -80^{o}C for future DNA analysis.

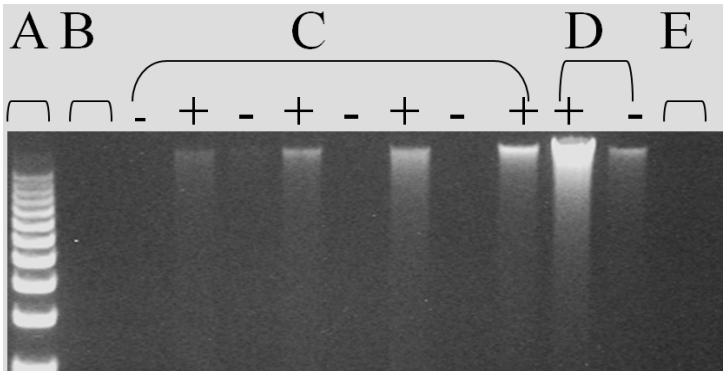


Figure 4. Agarose gel electrophoresis of DNA isolated using a commercial kit: without skim milk (-); with skim milk (+); A, Ladder; B, Skim milk control; C, Subsurface soil; D, surface 15 cm soil; E, H_2O control.

We successfully isolated denitrifier-specific DNA from above the fragipan of agricultural and pasture soil. This has not previously been accomplished. The amount of extracted DNA reflects the paucity of microbial populations at these interfaces in the absence of substantial additions of organic C. Different primers for the amplification of Cu-type (*nirK*) and heme type (*nirS*) nitrite reductases suggested that the Cu-type was more prevalent in the subsurface soil environment. Prior addition of organic material in the form of poultry litter had little effect on the population of denitrifiers above the fragipans, which suggests that frequent amendment is required to manipulate these bacteria. The DEA and MPN assays both suggested that in the absence of active denitrifier populations, the rates of NO_3^- reduction at these interfaces may be low even if perching occurs.

Lethal and Sublethal Effects of Agricultural Nutrient Pollution on Tadpoles

Basic Information

Title:	Lethal and Sublethal Effects of Agricultural Nutrient Pollution on Tadpoles
Project Number:	2006KY65B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	KY 1st
Research Category:	Biological Sciences
Focus Category:	Ecology, Agriculture, Nutrients
Descriptors:	non-point source pollution, aquatic environments, developmental stability
Principal Investigators:	Howard H. Whiteman

Publication

1. Earl, Julia E. and Howard H. Whiteman, 2007, Lethal and Sublethal Effects of Nutrient Pollution on Amphibians, in Proceedings of the Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 65-66.

Problem and Research Objectives

Agriculture is a major source of non-point source pollution including nutrients such as nitrates and phosphates from fertilizers. Nutrient pollution commonly enters streams and ponds through runoff and erosion (Schlesinger 1997). The influence of such pollution on aquatic environments and organisms is not widely known (Diana and Beasley 1998). Nitrate is toxic to amphibians (Baker and Waights 1994; Rouse et al. 1999), but most studies have concentrated on only a few amphibian species and focused solely on lethal effects (Rouse et al. 1999). Sublethal effects on growth and development may be more relevant for realistic nitrate concentrations (Meredith and Whiteman, in prep.) Most studies also concentrate on constant levels of a toxin, yet because runoff of pollutants is caused by precipitation events that flush chemicals from the terrestrial environment into the aquatic environment, nutrient levels could increase in sharp peaks, or pulses. Such variability could have different effects on amphibians compared to individuals exposed to constant concentrations.

The purpose of this study was to determine the effects of nitrates on larval Cope's Gray Treefrogs, *Hyla chrysoscelis*, and larval American Toads, *Bufo americanus*, and phosphates on larval *Hyla chrysoscelis*, by measuring survival, growth, time to metamorphosis, and developmental stability (as measured by deviations from a normal phenotype). This study examined both the lethal and sublethal effects of these nutrients in constant concentrations and in pulses, to better understand how such pollutants might actually affect amphibians in the natural environment.

Methods

Hyla chrysoscelis and *Bufo americanus* eggs were collected from the Jackson Purchase Area of Kentucky. Larvae from collected eggs were used for three separate experiments. In each experiment, larvae, at hatching, were placed in 100 mL fingerbowls filled with an artificial soft water solution with dissolved Na_2PO_4 for concentrations of 0, 1, 10, 100, and 200 mg/L P-PO_4 for a 15-day LC50 on *Hyla chrysoscelis* and $NaNO_3$ for concentrations of 0, 1, 2.5, and 5 mg/L N-NO_3 for two experiments investigating sublethal affects. The two nitrate experiments investigated the effects of pulses of nitrate on both *Hyla chrysoscelis* and *Bufo americanus*. The concentration of 5 mg/L N-NO_3 was introduced at three different stages: directly after hatching, the middle of the larval period, and directly preceding metamorphosis. In each group, the concentration was decreased every two days to simulate the gradual decline in concentration that would occur naturally in a small pond. Four other treatments were implemented for comparison: one control treatment and three treatments with constant concentrations of 1, 2.5 and 5 mg/L N-NO_3. The *Bufo americanus* experiment was terminated after 32 days, and the *Hyla chrysoscelis* experiment was terminated at metamorphosis. *Hyla chrysoscelis* metamorphs were frozen for analysis of the nitrogen content of muscle tissue with a CHN analyzer. Size, body mass, and developmental stability were assessed for each individual using digital imaging at the termination of each experiment. In the phosphate experiment and the *Hyla chrysoscelis* nitrate experiment, there was one tadpole per fingerbowl, and forty fingerbowls per treatment. In the *Bufo americanus*

experiment, there were four tadpoles per fingerbowl and twelve replicates of each treatment.

The concentrations used in these experiments were chosen based on the literature and preliminary experiments. The nutrient concentrations were tested every two to three days using a Lachat Quikchem Flow Injection Analyzer and changed accordingly for static renewal. At experiment termination, tadpoles or metamorphs were weighed, measured and photographed for analysis. Photographs were analyzed using morphometric software.

Findings and Significance

In the 15-day phosphate LC50, there was no significant difference in mortality or growth effects among any of the treatments, indicating that phosphate is not toxic to *Hyla chrysoscelis* at any reasonable concentration. The addition of phosphate did cause a significant increase in the pH of the test water, which, in conjunction with other stressors, may have negative affects within aquatic communities. However, phosphate could also positively affect anuran tadpoles by increasing algal food resources. Because phosphate is a ubiquitous pollutant, further testing using more complex experimental designs is warranted.

In the nitrate pulse experiment for *Bufo americanus*, there was no difference among the treatments in growth or developmental stage. Directional asymmetry was found in both eye width and the distance from eye to nare, but there were no differences among treatments after correcting for the skew. In the *Hyla chrysoscelis* experiment, more extreme directional asymmetry was found in the middle and late pulses in two limb-related traits, indicating that the sudden change in concentration of nitrate decreased the level of developmental stability in the tadpoles. Many scientists disregard traits with directional asymmetry, claiming that only fluctuating asymmetry can be used for studies on developmental stability (Palmer 1994). Recent evidence has shown a shift from fluctuating asymmetry to directional asymmetry with extreme levels of stress (Graham et al. 1993; Lens and Van Dongen 2000). These studies, in conjunction with this one, suggest that traits with directional asymmetry should not be disregarded. Additionally, these results indicate that nitrate has subtle but important effects at low doses. Also, species may be better able to deal with pulses that occur early rather than late in development. Similar results may have been found in the *Bufo americanus* experiment if it had lasted until metamorphosis, so that limb-related traits could be utilized. However, the nitrate concentrations may not have been high enough to induce sublethal effects in this species. Many types of environmental stresses occur in pulses. This study suggests that the temporal regime of stresses may alter the effects of the stress. This type of knowledge will help conservation biologists manage populations and prevent population declines.

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Property Taxation, Forest Fragmentation and Development in Kentucky's Green River and Lower Cumberland River Watersheds

Basic Information

Title:	Property Taxation, Forest Fragmentation and Development in Kentucky's Green River and Lower Cumberland River Watersheds
Project Number:	2006KY67B
Start Date:	1/1/2006
End Date:	1/1/2007
Funding Source:	104B
Congressional District:	KY 1st & 2nd
Research Category:	Social Sciences
Focus Category:	Law, Institutions, and Policy, Management and Planning, Economics
Descriptors:	tax assessment, property values, forest management
Principal Investigators:	Tamara Cushing

Publication

1. Brodbeck, Scott and Tamara Cushing, 2007, Property Taxation and Forest Fragmentation in Kentucky Watersheds, in Proceedings of the Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 11-12.
2. Brodbeck, Scott, 2007, Property Taxation and Forest Land Assessment in Kentucky Watersheds, MS Thesis, Department of Forestry, University of Kentucky, Lexington, Kentucky, 49 p.

Problem and Research Objectives

The Green River and the Lower Cumberland River watersheds in Kentucky are among the top fifteen watersheds in the United States expected to experience increased development and forest fragmentation according to the U. S. Forest Service. As development pressures influence land uses and property values, the likelihood of forests being converted to other uses is a potential threat to water quality because of the loss of the natural filtration services that forested areas provide (serving as buffers to reduce the amount of sediment and other pollutants carried to streams by runoff). The objectives of this research were to characterize current practices used to assess timberland for property tax purposes in counties located in the Green River and Lower Cumberland River watersheds in Kentucky and to determine the impact of property taxes on profitability.

Methodology

Personal interviews were conducted with 36 property valuation administrators in counties in the study area (defined by the selected watersheds). Each administrator was asked how an assessed value was determined for forested property in their county and to provide a value (or range of values) based on a particular set of characteristics. After the information on assessment methods was gathered, the actual values were used to generate a property tax bill for a hypothetical property and to determine potential impact on profitability. Property valuation methods were identified, grouped, and used to compare the net present value of a single forest rotation for a hypothetical property using the different assessment methods reported. A sensitivity analysis was performed to determine the impact of each of the assumptions used in calculating net present values. As long as forest management remains profitable, landowners will be less likely to fragment their forest properties.

Principal Findings and Significance

Seventy-five percent of the counties surveyed were using a state generated guideline with local adjustments to determine assessed value for forested land. The eight remaining counties used methods such as a previous assessor's value or flat values to determine assessed value. The range of property assessment values was $95-$500 per acre, resulting in tax bills from $0.83 to $3.22 per acre in the counties studied. When this tax range was applied to a hypothetical property and the time value of money was accounted for, forest management was sometimes not profitable. This was particularly true when assessors strayed from the published state guidelines and based the assessed value on "personal knowledge of the county." Inconsistent valuation methods can cause two otherwise similar properties to differ in profitability based solely on taxes and this could contribute to further forest fragmentation in the study area.

Monitoring Soil Moisture for Efficient Use of Irrigated Water on Selected Grass Lawn

Basic Information

Title:	Monitoring Soil Moisture for Efficient Use of Irrigated Water on Selected Grass Lawn
Project Number:	2006KY68B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	KY 4th
Research Category:	Climate and Hydrologic Processes
Focus Category:	Irrigation, Methods, Water Use
Descriptors:	tensiometers, soil texture, slope
Principal Investigators:	Samuel Boateng

Publication

1. Koenig, Jason and Samuel Boateng, 2007, Monitoring Soil Moisture for Efficient Use of Irrigated Water on Selected Grass Lawns, in Proceedings of the Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 87-88.

Problem and Research Objectives

Soil moisture is the amount of water in the unsaturated zone that is available to growing plants. Soil moisture, at different locations in the unsaturated zone, varies with changes in the amount of precipitation (and/or irrigation) and the amount of evapotranspiration. Infiltration capacities of soils are considerably reduced with increased soil moisture. A reduction in infiltration capacity results in increased storm runoff. The adverse consequences of increased storm runoff include increased erosion, increased bed and suspended loads in streams, and increased non-point source pollution. Excess irrigation can cause a drastic increase in soil moisture with the consequent adverse effects of increased storm runoff. Recently, Kentucky Sanitation District 1 initiated a program to manage urban storm water in Northern Kentucky in compliance with USEPA regulations. The purpose of this project was to mitigate the adverse environmental and ecological effects of increased storm runoff related to irrigation. Efficient use of irrigated water on grass lawns has the potential to reduce excess soil moisture and decrease the potential for increased runoff during storm events. Thus, the study considered factors affecting infiltration to help in planning irrigation schedules to reduce excess soil moisture.

Effective monitoring of the soil moisture of irrigated fields has been shown to help in controlling the cost of irrigation and conserving valuable resources. This is achieved by using instruments such as tensiometers and neutron probes to monitor soil moisture. On an irrigated grass lawn, the ideal condition will be to maintain soil moisture between field capacity and wilting point. The objective of this study was to answer the following research questions:

1. What is the effect of soil texture on soil moisture changes during irrigation?
2. What is the effect of slope on the amount of moisture retained in the soil?
3. Can monitoring of soil moisture help in optimizing the use of irrigation water?

Methodology

Soil Texture Analysis

The goal of the soil texture analysis was to determine the percentage sand, silt, and clay at each lawn site. Each plot had a dimension of at least 5 m x 5 m. All sites were located on the Northern Kentucky University (NKU) Highland Heights campus. Soil texture was determined by particle size distribution analysis of the soil samples in the laboratory. Soil samples were taken from each site during the installation of the tensiometers (described below under soil moisture monitoring). The laboratory tests were performed in accordance with ASTM standard D422, Standard Test Method for Particle-Size Analysis of Soils. In general, the proportion of sand was the weight percentage retained on the .075 mm sieve, silt was the percent passing the 75 mm but larger than a diameter of 0.005 mm, and clay was the percent of particles smaller than 0.005 mm.

Slope Measurements

Three categories of slopes were used in selecting the grass lawns (a gentle to flat slope (0 to 10^o), a medium slope (10^o to 15^o), and a steep slope (more than 15^o). Two sites were selected to represent each category for a total of six sites. Originally, the slopes of the sites were to be measured by using a tape and a hand-held GPS, but the errors registered by the GPS device on the elevation values were too large for the data to be useful. Therefore, a Total Survey Station was used to measure the elevation using a local coordinate and a local elevation. The elevation and coordinates of about 25 data points were measured for each plot. The average distance between nearby points was about 1 meter. The data was processed by using the GIS software, ARCVIEW, to plot a contour of slope angles.

Soil Moisture Monitoring

Originally, two tensiometers were to be installed at depths of 15 cm (6 inches) and 30 cm (12 inches) at each of the three grass lawn sites. However, during the installation the insertion tool only could penetrate an average depth of 20 cm (8 inches). This resulted in the installation of the tensiometers at uniform depths of 20 cm. The tensiometers consist of a sealed, water-filled tube with a vacuum gage at the upper end and a porous ceramic tip that goes into the ground at the lower end. A compatible (in diameter) soil insertion tool was used to remove soil to the desired depth before installing the tensiometers. The soil removed was saved for the soil texture test as previously described. The installations were made so that the porous ceramic tips were in tight contact with the soil. As the soil dries, the soil-water tension increases and capillary forces in the soil pull water from the tube, creating a partial vacuum, which the gage at the above-ground end of the tube detects. When water is added to the soil around the tip through rainfall or applied irrigation, the soil-water tension is reduced and consequently the reading on the vacuum gage falls. The tensiometers could record a maximum of 0.85 atmospheres. Daily air temperature and precipitation amounts were gathered from NKU's Department of Physics and Geology weather center and the Northern Kentucky Airport Weather Station.

Readings were recorded at 6 pm every day instead of noon as originally proposed. This was done at the convenience of the NKU Grounds Department. Each day, NKU Grounds was provided with the tensiometer readings with advice to irrigate or not irrigate specific lawns. Irrigation of each lawn was resumed when the suction pressure became too high for the respective soil type. In heavy clay soils, irrigation did not resume until the suction pressures reached 70-80 centibars. However, in fine sandy soils, irrigation resumed when the pressures reached between 30 and 40 centibars. Generally, the finer the soil texture the higher the reading before the resumption of irrigation.

Findings and Significance

Slight variations in the composition of the soils at each site had just as much influence on the infiltration and runoff rates as did the slope. All other conditions being equal, lawns with gentle slopes tended to dry faster than steep slopes. This may be due to the high incidence angle of the sun on the gentle slopes. Lawns with even a small percentage more silt and clay tended to allow infiltration more slowly. Once such soils were wet, it took much longer for the water to

evaporate and higher moisture contents were maintained for longer periods. Overall, the steep slope sites with high silt and clay content maintained higher moisture for longer periods once the site was wet. At air temperatures of about 27^{o} C (80^{o} F) and higher, all the grass lawns dried relatively quickly regardless of the soil composition and the slope. Because of moderate air temperatures during the fall and spring months, a regular irrigation schedule is not necessary and irrigation should be done on an as-needed basis. Irrigation during the summer months is necessary, and the frequency should be determined by the moisture content. An irrigation schedule which waters the lawns every other day or every third day would be an acceptable start to establishing a set schedule. As dry spells warrant, the frequency and intensity of irrigation need to be increased. Daily irrigation is only needed when air temperatures are continuously above 27^{o} C (80^{o} F).

Conservative estimates of an irrigation rate of 3 gallons per minute for an hour every day results in 180 gallons of water per lawn per day. An irrigation schedule based on soil moisture content will typically result in watering of the lawns every other day. Thus, about 90 gallons of water per lawn per day may be saved. At least 9000 gallons of water may be saved a day, given the areas of lawns on NKU's Highland Heights campus. In addition, this may result in the reduction of stormwater runoffs during storm events.

Pervious Concrete for Solid/Liquid Separation and Waste Remediation

Basic Information

Title:	Pervious Concrete for Solid/Liquid Separation and Waste Remediation
Project Number:	2006KY69B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	KY 6th
Research Category:	Engineering
Focus Category:	Agriculture, Non Point Pollution, Nutrients
Descriptors:	porosity, permeability, solid/liquid separation
Principal Investigators:	Steve Workman

Publication

1. Workman, Stephen R. and Joe David Luck, 2007, Effects of Pervious Concrete on Potential Environmental Impacts from Animal Production Facilities, in Proceedings of the Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 75-76.
2. Luck, Joe, 2007, Effects of Pervious Concrete on Potential Environmental Impacts from Animal Production Facilities, MS Thesis, Department of Biosystems and Agricultural Engineering, University of Kentucky, Lexington, Kentucky, 61 p.

Problem and Research Objectives

An increasing problem associated with animal production is the runoff of manure, nutrients, and pathogens into surface and ground water resources. Confinement barns, handling facilities, manure storages, and composting sites are designed to concentrate the animals which, in turn, can concentrate the waste generated by these animals. These systems are effective for animal production, but are far from perfect at controlling or reducing runoff laden with excess nutrients and pathogens. The majority of nutrients in the runoff from these facilities are associated with solids in the wastewater. Means to control or limit solids from leaving an area will affect the ultimate quality of water in the region.

Pervious concrete is a mixture of coarsely graded aggregate and cement that results in a material that easily transmits water. Pervious concrete has mainly been used to control runoff from parking lots and to allow groundwater recharge. Research conducted in recent years has shown that there may be some water quality benefits from using pervious concrete in urban areas. Since the concrete mixture has a porosity and permeability, there could be several advantages of using pervious concrete for agricultural purposes including solid/liquid separation and waste remediation. We utilized laboratory testing to demonstrate how the properties of pervious concrete could provide new methods for conserving natural resources.

Methodology

Few tests have been conducted on pervious concrete to determine the hydrologic characteristics of different concrete mixtures and their capability to separate solids from liquids. Consequently, laboratory tests on the pervious concrete specimens were used to determine the effects of porosity and permeability on solids transport through the concrete matrix.

Additional tests were conducted on replicated samples of pervious concrete made from two aggregate sources (river gravel and limestone) with two size fractions of each aggregate. Compost composed of beef cattle manure and bedding was placed on top of the pervious concrete specimens and one liter of water was filtered through the compost and pervious concrete for two separate daily leaching events. This process was also conducted using a non-reactive No. 80 wire mesh screen. The effluent from both filtration methods were collected and analyzed for BOD, EC, DOC, ammonium, nitrate, nitrite, total nitrogen, soluble phosphorus, and total phosphorus. The results were compared to determine the solid/liquid separation characteristics of pervious concrete versus the wire screen.

Weekly rainfall simulations were conducted after manure was applied to the surface of pervious concrete specimens. The effluent from the manure and pervious concrete was tested for five-day BOD, dissolved organic carbon, ammonium, nitrate, nitrite, total nitrogen, soluble phosphorus, total phosphorus, and fecal coliform. The

results were analyzed to determine the effects of multiple rainfall events on nutrient and analyte concentrations from the animal manure and pervious concrete. The effects of the pervious concrete on fecal coliform populations in the effluent were also observed. Between rainfall events, gaseous carbon dioxide and ammonia concentrations were measured to determine if microbial activity and decomposition were occurring in the animal waste applied to the surface.

Principal Findings and Significance

Laboratory tests were able to demonstrate that different aggregate types used in the pervious concrete mixtures have an effect on the amount of material retention within the pervious concrete specimens. T- tests indicated that the mass of compost retained on the surface was significantly greater when smaller aggregate sizes (#8 river gravel) were used ($p = 0.012$). Nutrient analyses were conducted on the effluent from the compost and pervious concrete and compared to values from an identical test performed by filtering water through compost on a No. 80 wire mesh screen. These tests indicated that filtering the compost effluent through pervious concrete resulted in significant reductions in total nitrogen, soluble phosphorus, and total phosphorus compared to the wire screen. There were no consistent significant differences between the effects of filtering with pervious concrete or wire mesh screen with respect to other analytes (e.g. dissolved organic carbon, ammonium, nitrate, and nitrite). Effluent BOD levels from the compost and pervious concrete for both daily leaching events (38.7 and 42.5 mg/l, respectively) averaged above typical allowable wastewater concentrations of 30 mg/l. Use of the pervious concrete for filtering resulted in significantly higher (p value <0.0001) pH (9.3) compared to the effluent pH from the wire mesh screen (7.7).

Statistical analysis indicated that significant increases and decreases can occur in analyte concentrations as a result of multiple rainfall events. The highest concentrations of some analytes (five-day BOD, nitrate, total nitrogen and total phosphorus) in the effluent occurred after the first rainfall simulation. Maximum concentrations for other analytes (DOC, ammonium, nitrate, and soluble phosphorus) occurred after subsequent rainfall events. Further analysis of the effluent indicated a significant decrease in fecal coliform concentration one week after the initial rainfall simulation. Ammonia and carbon dioxide emissions from the manure and pervious concrete specimens were also monitored for a five day period following three weekly rainfall events. Results indicated that the pervious concrete was capable of providing an environment where ammonia and carbon dioxide could be volatilized. The carbon dioxide emissions indicate microbial activity where immobilization of nutrients and decomposition of the manure could occur. Therefore, additional nutrients could be retained by microorganisms in animal waste deposited on the pervious concrete surface.

Nitrate and Nitrite Transformation by Fe(II) adsorbed on Kaolinite

Basic Information

Title:	Nitrate and Nitrite Transformation by Fe(II) adsorbed on Kaolinite
Project Number:	2006KY70B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	KY 6th
Research Category:	Ground-water Flow and Transport
Focus Category:	Agriculture, Nitrate Contamination, Water Quality
Descriptors:	microbial reduction, geochemical cycling
Principal Investigators:	Christopher John Matocha

Publication

1. Rakshit, Supdipta and Christopher J, Mothocha, 2007, Nitrite Reductions by Fe (II) Associated with Kaolinite, in Proceedings of the Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 89-90.
2. Rakshit, Sudipta, 2006, Abiotic Interactions of Iron (II) Species with Nitrate and Nitrite, Ph.D. Dissertation, Plant and Soil Science Department, University of Kentucky, Lexington, Kentucky, 73 p.

Problem and Research Objectives

The microbial reduction of solid Fe(III) hydr(oxide) minerals by iron reducing bacteria is an important process in biogeochemical cycling of nutrients and trace metal contaminants. The presence of nitrate (NO_3^-) can inhibit the net Fe(III) reduction to Fe(II) under anoxic conditions. There are several mechanisms proposed to explain such phenomena.[1] One proposed mechanism involves simultaneous NO_3^- and Fe(III) reduction coupled to chemical reoxidation of Fe(II) to Fe(III) by nitrite (NO_2^-), the intermediate of NO_3^- reduction. Several researchers hypothesized this pathway both in agricultural soil slurries and pure cultures.[2-4] A majority of the Fe(II) produced during microbial Fe(III) reduction exists in precipitated or sorbed forms.[5,6] In fact, Kukkadapu et al. (2001) reported that in Fe(III) oxide-rich subsoils with mixed mineralogy, dissolved biogenic Fe(II) adsorbed strongly to kaolinite. Accordingly, the objective of this study was to investigate the role of Fe(II) associated with kaolinite in the reduction of NO_2^-.

Methodology

Reference Georgia kaolinite (KGa-1b, Clay Minerals Repository, University of Missouri) was purchased and sieved to <45 μm fraction size. The mineral was characterized by x-ray diffraction, total surface area, surface charge, optical spectroscopy (UV-VIS-NIR), and chemical extractions. The chemical extractions were performed using 0.5 and 6.0 mol/L HCl. Stirred-batch experiments were conducted in an anaerobic chamber under argon to simulate Fe(III)-reducing conditions. The following treatments were implemented: 1) Solution Fe(II)-NO_2^-, 2) Fe(II)-kaolinite- NO_2^-, 3) Control (kaolinite- NO_2^-), and 4) Blank (NO_2^- alone). All experiments contained 120 m^2 kaolinite L^{-1}, initial NO_2^- level of 0.45 mmol L^{-1}, Fe(II) concentration of 25 μmol L^{-1}, and pH 6. Parallel experiments were conducted where nitrous oxide (N_2O) gas was measured in the headspace of Fe(II)-kaolinite-NO_2^- slurries. Gas chromatography was employed to quantify N_2O using a thermal conductivity detector. At pre-selected time points, suspensions were filtered through a 0.2 μm membrane filter paper. Solution NO_2^- and Fe(II) concentrations were measured by ion chromatography and optical spectroscopy, respectively. Total Fe was quantified by flame atomic absorption spectrophotometry.

Principal Findings and Significance

Nitrite was reduced rapidly by Fe(II) associated with kaolinite when compared with solutions devoid of kaolinite. The NO_2^- reduction rate was roughly sixteen-fold greater by Fe(II)-kaolinite when compared to solution Fe(II). One of the major products of NO_2^- reduction was N_2O, an important greenhouse gas. In the process, Fe(II) was reoxidized to Fe(III). In addition, it was found that NO_2^- was reduced by the control (kaolinite-alone) with no added Fe(II). Further experiments revealed the presence of Fe(II) and Fe(III) impurities in kaolinite which participated in NO_2^- reduction. This supports the chemical reoxidation pathway of Fe(II) by NO_2^- in contributing to the inhibition of Fe(III) reduction. Further experiments will be conducted to better understand the mechanism of the electron transfer process between NO_2^- and adsorbed Fe(II). Stimulating Fe(III) reduction to produce reactive Fe(II) species may be a useful

strategy to remove NO_3^- from water supplies. This research is timely given the desire to protect water resources from elevated NO_3^- levels.

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The Mobility of Fecal Indicator Microoganisms within a Karst Groundwater Basin in the Inner Bluegrass Region, Kentucky

Basic Information

Title:	The Mobility of Fecal Indicator Microoganisms within a Karst Groundwater Basin in the Inner Bluegrass Region, Kentucky
Project Number:	2006KY71B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	KY 6th
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Water Quality, Methods
Descriptors:	latex microspheres, isotopically tagged bacteria
Principal Investigators:	Alan Fryar

Publication

1. Ward, J.W., A.E. Fryar, G. M. Brion, and M. S. Coyne, 2007, Solute and Particle Tracer Movement Under Various Flow Conditions in a Karst Groundwater Basin, Inner Bluegrass Region, Kentucky, in Proceedings of the Kentucky Water Resources Annual Symposium, Kentucky Water Resources Research Institute, Lexington, Kentucky, p 13-14.

Problem and Research Objectives

Preferential flow paths, such as conduits and sinkholes, characteristic of karst aquifers make these ground-water systems highly vulnerable to point and non-point-source pollutants. Some of these non-point-source pollutants include microorganisms that can pose a considerable health concern. The primary focus of this research was to assess the mobility of fecal indicator microorganisms within the Blue Hole Spring karst basin located in Versailles, Woodford County, Kentucky. At this site, a series of groundwater traces using solute tracers (conservative ions and fluorescent dyes), latex microspheres and isotopically tagged bacteria occurred to evaluate the mobility of microorganisms under various-flow conditions within the karst system.

The primary area of interest is the karst conduit network between Blue Hole Spring and a swallet in Big Spring Park, ~ 500 m away, where tracer tests have been conducted via slug injection into the karst conduit through a piezometer. At this location, a solute trace was conducted under low-flow conditions on June 2, 2006 using rhodamine WT fluorescent dye and the conservative ion bromide (Br^-). A second trace on July 11, 2006, under storm-flow conditions used the same solutes in combination with 1-µm-diameter fluorescent latex microspheres (used to mimic microorganisms). A third trace was conducted on April 1, 2007, under storm-flow conditions using the same solutes and latex microspheres in combination with a mass growth of ^{15}N-enriched wild-type *E. coli*.

Methodology

Analyses from these traces were conducted at the Kentucky Geological Survey (KGS) and at Environmental Research and Training Laboratory (ERTL) located at the University of Kentucky. A method was developed using a Nikon E-600 series epifluorescent microscope, located at ERTL and used primarily for counting viruses, to detect the fluorescent labeled 1-µm diameter latex microspheres (Bangs Laboratories, Inc., Fishers, IN). Samples were stored in 1-L polypropylene bottles at 4ºC at ERTL until analysis. Prior to filtration, samples were mixed by inverting 25 times, sonicated for approximately 30 seconds and then inverted another 25 times to obtain a homogeneous suspension and dislodge any microspheres possibly attached to the sides of the sample bottles. Microspheres were removed from solution using a typical membrane filtration assembly used for microbial filtration, which was washed between samples to prevent cross-contamination. A maximum of 100 mL of sample can be filtered before sediments begin to interfere with viewing the microspheres. Microspheres were removed from solution through 47-mm diameter, black, gridded cellulose nitrate filters with a nominal filter size of 0.8 µm. Once the sample was filtered, the filter was placed on a pre-washed 50-mm microscope slide with the grid parallel to the edge of the slide. The filters were then viewed with the 40× objective and counted beginning at the top and moving downward in a side-to-side motion. Typically a filter can be scanned in 30 minutes; any longer will result in drying of the filter, causing it to detach from the slide.

Methods for isotopically enriching a wild strain of *E. coli* were also conducted over the past year. This strain was isolated from Blue Hole Spring water using a MUG

auger technique, stored in soy auger slants and placed in a 4ºC cooler, allowing for culture preservation over extended time periods. Mass cultures of the isolated *E. coli* were grown in 1-L volumes of M-9 media using substrates enriched in ^{15}N to obtain isotopically labeled microorganisms via metabolic processes. The 1-L volumes of *E. coli* were then centrifuged down and resuspended into 6 L of autoclaved Blue Hole water for storage until use. This will allow for analysis of samples by an isotope-ratio mass spectrometer (IRMS). Proof-of-concept laboratory experiments to assess isotopic labeling of cells have been performed and indicate that these labeled microorganisms should work successfully as an environmental tracer.

Rainfall was limited prior to the June 2, 2006 low-flow trace, totaling 0.25 cm within 2 weeks prior to the slug injection. For this trace, 125 mL of 20 % rhodamine WT and 2 kg of sodium bromide (NaBr) salt were combined with on-site water in a 20-L carboy. The 20-L solution was inverted and shaken for 1 minute to facilitate homogeneous mixing of the slug. The slug was then poured into the piezometer and chased with ~ 100 L of water. Base-flow discharge for the trace averaged 0.079 m^3/s. Rhodamine WT arrived at the spring ~ 6.16 hours post-injection with the maximum concentration occurring at 7.8 hours; concentrations fell below detection after 21.16 hours. Bromide arrived at the spring ~ 6.5 hours after injection with a maximum concentration occurring at 7.75 hours; concentrations fell below detection 12.66 hours after injection (Fig. 1). The analytical detection limit (DL) was 0.1 µg/L for rhodamine WT (determined by fluorescence spectrophotometer) and 0.1 mg/L for Br^- (determined by ion chromatograph). Calculated mass recoveries were 79.15 % for rhodamine WT and 84.19 % for Br^-. EC averaged 608 $\mu S/cm^3$ @ 25 ºC and water temperature averaged 14.65 ºC for the duration of the low-flow trace.

The July 11, 2006 summer storm-flow trace included 250 mL of 20 % rhodamine WT, 6 kg of NaBr and 20 mL of dragon green microspheres ($1.875x10^{10}$ microspheres/mL, Bangs Laboratories, Inc., Fishers, IN), which were combined with on-site water in two 20-L carboys. The solutions were mixed, injected, and chased as before. Rainfall totaled 2.4 cm over a 5-hour period prior to injection, with another 11.6 cm of rainfall occurring during the 2-week monitoring period. Spring discharge during the storm-flow trace averaged 0.165 m^3/s, with a maximum of 0.262 m^3/s. Breakthrough began ~ 2.33 hours post-injection for the solutes and ~ 2.5 hours post-injection for the microspheres. Rhodamine WT and Br^- concentrations at the spring peaked ~ 2.67 hours after injection. Rhodamine WT was < DL 14 hours after injection, while Br^- was < DL 5.5 hours after injection. Calculated mass recoveries were 56.67 % for rhodamine WT and 52.61 % for Br^-. Microspheres were detected at the spring until 164 hours after injection (Fig. 2). Breakthrough curves for the solutes are very smooth, but the microsphere breakthrough curve is very jagged, with a pronounced peak at ~ 2.67 hours post-injection (Fig. 3). EC averaged 506 $\mu S/cm^3$ @ 25 ºC (maximum 575 $\mu S/cm^3$ @ 25 ºC) and water temperature averaged 17.55 ºC (maximum 18.83 ºC) for the duration of the trace.

The April 1, 2007 spring storm-flow trace included 200 mL of 20 % rhodamine WT, 7 kg of NaBr and 20 mL of plum purple microspheres ($1.875x10^{10}$

microspheres/mL, Bangs Laboratories, Inc., Fishers, IN), which were combined with on-site water in two 20-L carboys. The solutions were mixed, injected, and chased as before. Rainfall totaled 2.06 cm over an 8-hour period prior to injection, with another 7.5 cm of rainfall occurring during the 2-week monitoring period. Spring discharge during the early spring storm-flow trace averaged 0.100 m^3/s, with a maximum of 0.357 m^3/s. Breakthrough began ~ 0.75 hours post-injection for the solutes and ~ 1.08 hours post injection for the microspheres. Rhodamine WT and Br^- concentrations at the spring peaked ~ 0.92 hours after injection. Rhodamine WT was < DL 5.75 hours after injection, while Br^- was < DL 2.75 hours after injection. Calculated mass recoveries were 79.32 % for rhodamine WT and 27 % for Br^- (Fig. 4). Microsphere analysis of all samples is currently being completed. Like the summer storm-flow trace, breakthrough curves for the solutes were relatively smooth with steep upward limbs, while the microsphere breakthrough curve remained very jagged. EC averaged 514 µS/cm^3 @ 25 ºC (maximum 645 µS/cm^3 @ 25 ºC) and water temperature averaged 14.0 ºC (maximum 16.5 ºC) for the duration of the trace. Analyses of isotopically enriched *E. coli* samples are pending.

Principal Findings and Significance

These data demonstrate differences in tracer behavior under low- and storm-flow conditions. Mass recoveries for rhodamine WT and Br^- were similar (within 5 %) for the first two traces, suggesting that both tracers are conservative under both flow regimes, yet the mass recoveries for rhodamine WT and Br^- were very different for the early spring storm-flow trace. This difference in mass recovery is possibly due to the quick breakthrough of this trace: the Br^- slug may not have had sufficient time for complete mixing to occur within the system and the primary plume was most likely missed during sampling. Rhodamine WT mass recoveries were lower for the summer storm-flow trace, which may indicate that part of the solute breakthrough curve was missed, that some discharge from the conduit network occurs downstream of Blue Hole Spring (such as via high-level overflow passages, which have not been delineated), or possibly, that loss of the tracers in portions of the epikarst occurred due to the higher stage within the system. Near-simultaneous breakthrough occurred for all tracers for each trace. Rhodamine WT tailing relative to Br^- may be an artifact of the lower DL for the dye. Continued detection of microspheres after rhodamine WT became undetectable may reflect sedimentation and/or resuspension of the particles (Fig. 3) (Marshall et al., 1998). Our results demonstrate that bacteria-sized particles can remain mobile for at least several days after introduction, which is consistent with studies in other karst terranes (Goldscheider et al., 2006; Davis et al., 2005).

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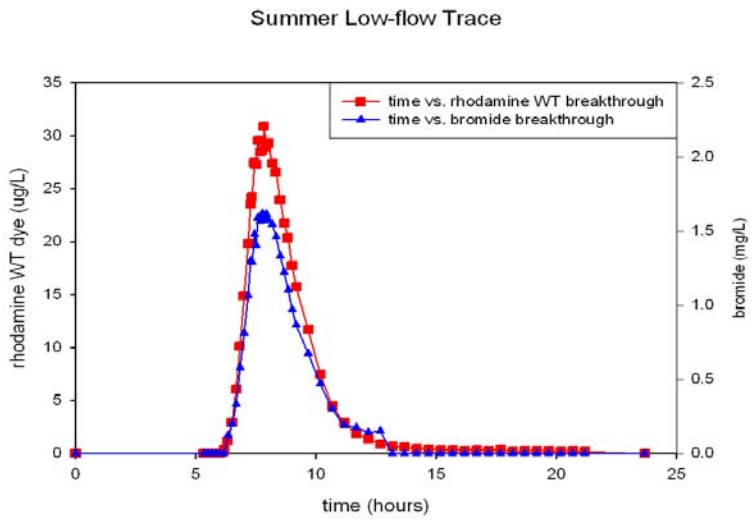

Figure 1, Rhodamine and bromide breakthrough vs. time during summer low-flow trace.

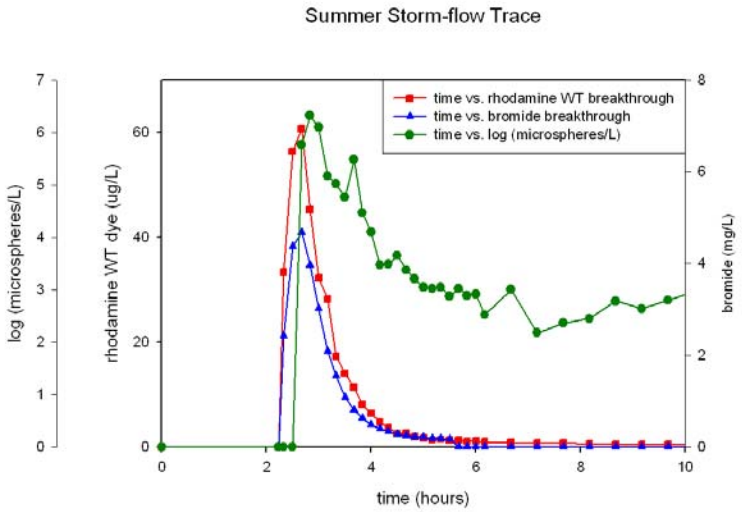

Figure 2, Rhodamine, bromide and microsphere breakthrough vs. time during summer storm-flow trace.

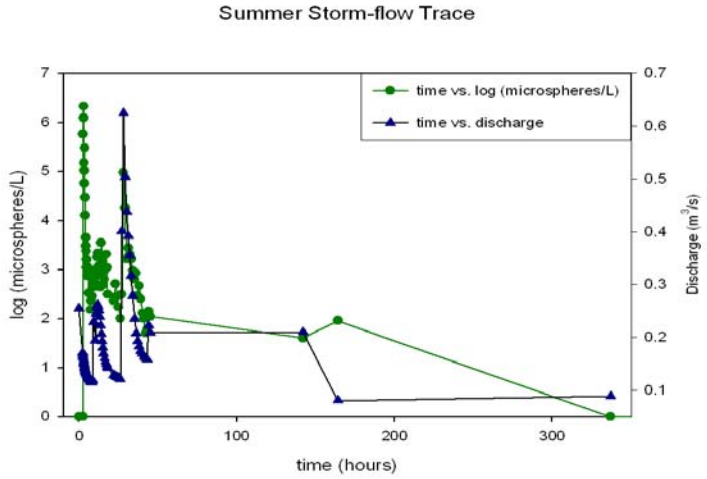

Figure 3, Latex microsphere breakthrough and remobilization over time compared to discharge during summer storm-flow trace.

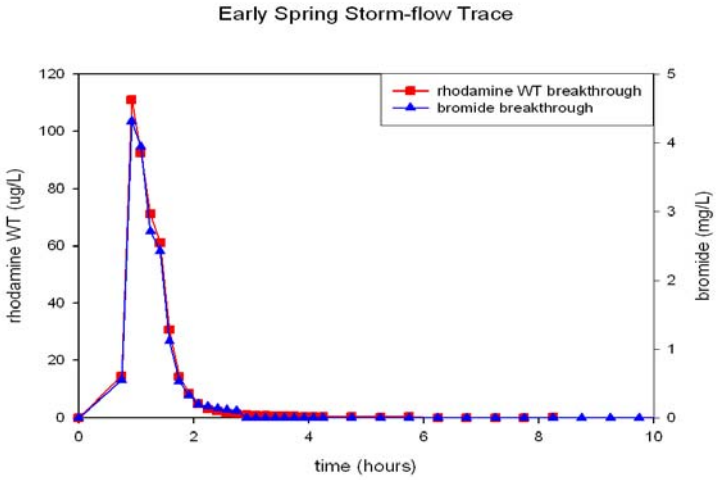

Figure 4, Rhodamine and bromide breakthrough vs. time during early spring storm-flow trace.

Information Transfer Program

The Information Transfer Program of KWRRI has numerous components including lectures, seminars, a symposium, publications, and a web site. Efforts during FY2006 included:

May is designated as Kentucky Water Awareness Month. This observance is an educational outreach of the University of Kentucky Cooperative Extension Service through its Environmental and Natural Resource Issues Task Force (Associate Director of KWRRI is a member). The task force is dedicated to developing and implementing environmental education programs for all Kentuckians. Program materials are assembled each year and packets are distributed to each of the 120 county extension offices. 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: http://www.ca.uky.edu/enri/. Since 1996, more than 100,000 people have been reached through this annual observance.

KWRRI joined twenty other partners in one of the largest water education projects in the southeastern United States. The Commonwealth Water Education Project (CWEP) formally kicked off its five-year campaign during National Earth Month 2006. The $1.4 million project aims to raise public awareness of nonpoint source pollution. CWEP seeks to educate Kentuckians about the sources and solutions to nonpoint source pollution and encourage citizens to improve the quality of streams and rivers by changing small individual behaviors that collectively can have large impacts on water quality. In support of CWEP, Kentucky Educational Television (KET) produced and aired a documentary "Common Ground, Cleaner Water." Additional promotion is occurring through television and radio spots targeted to regional audiences. KET will also produce a virtual watershed tour for classroom use in Kentucky schools.

06/11-16/2006 Water Pioneers Camp. 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 their completion of four-year college degrees. The Water Pioneers Water Quality Initiative was developed by the KWRRI for rising high school sophomores in the Robinson Scholar Program. Students participated in an in-depth study of watersheds during a week-long summer program at Mammoth Cave National Park. They subsequently used the knowledge they gained to partner with educators, volunteers, and other interested groups in their local counties to increase awareness of Best Management Practices for water quality through a community service/outreach project of their own design.

KWRRI is participating in the Bluegrass Partnership for a Green Community, a cooperative effort between the University of Kentucky, the Fayette County School System, the Lexington-Fayette Urban County Government, and numerous other partners. Our staff members are active with the Outreach & Communication and Water & Stormwater Teams. KWRRI staff helped with the development of a web site for the initiative: (www.uky.edu/sustainability/greencities/). Initial plans include posting watershed signs in public parks in Fayette County (funds have been secured) and utilizing ads being developed through the Commonwealth Water Education Project (www.inyourwater.org) by adding local information and placing them in community newsletters and neighborhood newspapers for general public education. Longer term goals include developing educational opportunities associated with the World Equestrian Games to be held locally at the Kentucky Horse Park in 2010 (stream restoration project and potential demonstration of low impact development approaches at the main venue).

8/10&11/2006 Creating a Greener Bluegrass Conference. KWRRI assisted the Bluegrass Partners with planning a conference to consider: "What is a Sustainable City?" The program included topics such as historic preservation, water quality, greenways, flood control, purchase of development rights, urban forestry, and high density redevelopment. A field trip following the conference included stops at the McConnell Springs Nature Area and the Town Branch Wastewater Treatment Plant as examples of sites contributing to the sustainability of the local community.

KWRRI played an integral role in 2006 in the implementation of the exhibit "Keeping Current" a natural history exhibit focused on the Kentucky River by providing technical and design consultation to the Explorium. Components of the exhibit include a working lock and dam, maps illustrating the watershed, and twenty-seven feet of running water replicating the river at the point that the Valley View Ferry operates. Attendance at the Lexington Explorium averages 85,000 visitors annually, and as the only children's museum in the state, the Explorium serves a much broader area than just the local community. The running water and manipulatives in the model help create a fun, dynamic, hands-on learning environment to inspire children's imagination and curiosity.

10/11/2006 Earth Science Week Open House. An open house was held on Wednesday evening during Earth Science Week co-sponsored with the Kentucky Geological Survey. KWWRI distributed information about household water conservation to the elementary and middle school students (and their parents) who attended the event.

11/13&14/2006 Geological Society of America Hydrogeology Division 2006 Birdsall-Driess Distinguished Lecture (co-sponsored with the Kentucky Geological Survey). David Blowes, University of Waterloo, presented two lectures: 1) "Predicting, Preventing, and Remediating Acidic Drainage from Sulfide Bearing Mines and Mine Wastes" on Monday evening, and 2) "Permeable Reactive Barriers for Treating Groundwater Contaminated by Dissolved Metals" on Tuesday morning. Total attendance at the two talks was 57.

Cyberseminars provided through the Consortium for the Advancement of Hydrologic Sciences, Inc. (CUAHSI) 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 26, 2007. Although the date of the symposium fell outside of FY2006, most of the planning and preparation occurred during the fiscal year. Two concurrent sessions provided time slots for 28 platform presentations. Twenty-one posters were also presented during a separate poster session. The 11 student research enhancement projects funded in FY2006 by the 104(b) program presented their results (4 platform and 7 posters). In most cases, this was the first opportunity for the students to present research results at a professional meeting. There were 137 attending registrants. Abstracts for all of the presentations were included in the proceedings volume distributed to all participants on the day of the meeting: Proceedings Kentucky Water Resources Annual Symposium, 2007, Kentucky Water Resources Research Institute, March 26, 2007, Kentucky Water Resources Research Institute, Lexington, Kentucky, 98 p. The full proceedings document ia also available electronically through a link on the Institute's web site.

One issue of the newsletter WATERWORKS was published and distributed in paper copy in 2006. Plans were initiated to transfer publication and distribution to electronic format to reduce printing and postage costs and to shorten the lead time needed for publication.

The KWRRI website (www.uky.edu/WaterResources/) received a major revision in 2006 to remove dated material and to better organize the information available through the site. Future issues of the newsletter will be distributed online through the site.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	4	0	0	0	4
Masters	3	0	0	0	3
Ph.D.	5	0	0	0	5
Post-Doc.	0	0	0	0	0
Total	12	0	0	0	12

Notable Awards and Achievements

2006KY64B - preliminary results collected in this study resulted in EPSCoR funding ($7,200) for a new proposal titled "Characterizing Denitrifier Populations in Fragipan Soils of Kentucky using Quantitative- and Reverse Transcriptase-PCR"

2006KY65B - Honorable Mention at the Murray State University Sigma Xi poster competition for a poster describing the phosphate and nitrate experiments

The Kentucky River Authority supports several watershed management projects within the Kentucky River Basin administered through a contract with KWRRI to provide small seed grants in support of various watershed groups and projects. In 2006, two recipients of these grants, the Friends of Wolf Run and the Clark's Run Environmental and Educational Corporation, were recognized by the Kentucky Environmental Quality Commission at their Earth Day 2006 awards presentation at McConnell Springs.

Publications from Prior Projects

1. 2004KY44B ("Assessing groundwater age, regional flowpaths, and hydrochemical evolution of the Knox Group Aquifer in the Bluegrass Region of Kentucky") - Dissertations - Galvin, Rachel S., 2006, Cambro-Ordovician Knox Group Aquifer in the Bluegrass Region of Central Kentucky: Geochemical and Isotopic Constraints on Age, Flow-Path, and Hydrologic Evolution, MS Thesis, Department of Earth and Environmental Sciences, University of Kentucky, Lexington, Kentucky.