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Kentucky Water Resources Annual Symposium

March 2, 2009



Marriott's Griffin Gate Resort
Lexington, Kentucky

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UNIVERSITY OF KENTUCKY
Kentucky Water Resources
Research Institute

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Kentucky Water Resources Research Institute
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INTEGRATED SURFACE AND GROUNDWATER QUALITY ASSESSMENTS IN KARST REGIONS OF KENTUCKY

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Recent groundwater quality studies in Kentucky's karst regions have integrated surface- and ground-water quality assessment approaches to better define the nexus between the two flow systems. Surface and ground water are conjunctive systems, no more directly so than in karst terranes. Surface-water assessments (§305b report) in the well-developed karst areas, such as the sinkhole plain and the Bluegrass regions, are limited due to a relative lack of flowing surface streams. Particularly in the sinkhole plain of south-central Kentucky, karst spring basins represent large areas of contribution to the Green River that are un-assessed for water quality. Subsurface streams that drain these basins can only be assessed via their discharges to surface waters at discrete springs. Any adequate strategy for assessing these flows must meet the requirements for surface-water assessment protocols.

An integrated approach attempts to address the deficiencies of inadequately assessed "stream segments" and provide needed information on spring conditions relative to non-point source impacts to both surface water and ground water in Kentucky. Such assessments have implications relative to listing and de-listing springs as water bodies in the 305(b)/303(d) integrated report, TMDLs, watershed planning, and the availability of grant funds (e.g. §319(h)) for watershed projects in these areas. Two separate study areas in the Kentucky River and Green River basins served as pilot projects for this holistic watershed approach. Water-quality samples (including major ions, nutrients, TOC, TSS, TDS, pH, alkalinity, metals, VOCs, and pesticides) were collected monthly for one year from each spring. Total coliform and E. coli bacteria samples were also collected monthly from May through October. Of the ten springs assessed in the Green River basin, nine springs were "Not Supporting" for Primary Contact Recreation (PCR), and one spring was "Partially Supporting" for PCR. Five of these springs were "Fully Supporting" for Aquatic Life Use; the other five springs were "Partially Supporting." In the South Elkhorn watershed, 18 springs were found "Not Supporting" PCR, and three springs were "Fully Supporting" PCR. Aquatic Life Use was not determined for springs in the South Elkhorn watershed.

Comparison of hydrologic maps developed using dye-trace data to the USGS 11- and 14-digit Hydrologic Unit Code (HUC) boundaries indicates that a significant amount of mapped karst groundwater basins deviate from hydrologic boundaries based on topographic divides. Accurate hydrologic mapping is necessary to calculate water budgets and in developing watershed models for TMDLs, for implementing watershed-based solutions to water quality and quantity problems, and for first responders to spills.

THE KARST POTENTIAL INDEX FOR KENTUCKY: PROGRESS REPORT

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A karst classification method is needed for Kentucky because qualitative descriptors are inadequate to compare the relative vulnerability of karst lands. Karst has been classified by many authors. Weary and Orndorff (2001) related karst development to structure and hydraulic gradient and used GIS files of doline polygons, spring points, and cave entrances to calculate a karst density. Klimchouk and Ford (2000, p.54-64) discussed the lithologic characteristics affecting bedrock solubility and cave genesis. Most notable is their statement that “limestone with more than 20–30% clay (argillaceous limestone) forms little karst...” and that “most limestone and dolostone caves are associated with bulk purities of greater than 90%.” They also mentioned the greater rate of solubility of limestone versus dolostone. Beds greater than medium thicknesses (10–30 cm) are more favorable for cave development because of the concentration of flow to comparatively few bedding planes. The absence of insoluble material (clay, silt- and sand-size quartz) from calcareous rock is widely recognized as the most important single factor promoting karstification (Klimchouk and Ford, 2000). If the rock has a significant fraction of insoluble minerals, it will not form karst because the incipient pathways become blocked with insoluble residue, inhibiting groundwater flow and further dissolution. Klimchouk and Ford (2000) considered 50 percent clayey insoluble residue as the practical limit for karst development. The Waltham and Fookes (2003) method also has similarities to the classification system proposed here. They described a five-class karst system that is based on the concept of a summation of sinkhole density, cave size, and "rockhead" relief, or local relief between a limit of grike depth and pinnacle top. We developed a linear algorithm to quantify the propensity of carbonate rocks in Kentucky to develop karst: the Karst Potential Index (KPI). We also compared the KPI to a second measure, the Karst Development Index (KDI), to test the validity of the KPI.

The first use of a linear algorithm for ranking or indexing natural systems, (Karr, 1981) was to evaluate the health of aquatic biological communities, specifically fish. Karr modified his equation from the communication theory work of Shannon and Weaver (1964). Shannon and Weaver used the linear equation to quantify various components of a discrete, noiseless signal, L_i with probability p_i , such that the composite signal L equals the sum of the components: $L = L_i p_i + L_{i+1} p_{i+1} + \dots + L_{i+n} p_{i+n}$. An index of biological integrity, or an index of any other natural system, can be conceptualized as analogous to a signal with two or more alternative components (Karr, 1986). Karr's Index of Biotic Integrity (IBI) is now extensively used for assessing biological integrity of streams and other biological applications (U.S. EPA, 2004).

The KDI evaluates karst geomorphologic development utilizing the presence and aerial density of karst features. All of the measures evaluated for use in the KDI were irregularly distributed because of inconsistent reporting and incomplete exploration. We used the number of sinkholes, the total area of sinkholes, and number of karst openings in the polygon. Karst openings is the count of cave entrances, combined with springs and swallow holes, because many cave entrances are former or active springs or swallow holes. The criteria utilized for the KDI were selected because of the relative uniformity of the data sets. The feature counts and feature areas were divided by the formation area and assigned a rank of 1 to 4 based on quartiles. The resulting ranks were calculated as follows:

$$KDI = 1(Sc) + 2(Ko) + 3(Sd), \text{ ranging from 6 to 24}$$

where **Sc** = sinkhole coverage/formation area: weight = 1, score range ($1 \leq Sc \leq 4$), **Ko** = karst openings (springs, swallow holes, and caves)/formation area: weight = 2, score range ($1 < Ko \leq 8$), and **Sd** = sinkhole density (count of closed basins)/formation area: weight = 3, score range ($1 \leq Sd \leq 12$).

The KPI score is based on the lithology of stratigraphic units mapped on geologic quadrangle maps. The 7½-minute, 1:24,000-scale geologic maps for Kentucky have been digitized and combined into thirty-two, 30x60 minute quadrangle maps (Anderson and others, 1999). Each polygon has attributes assigned to it, which include formation code and name. We hypothesized that the KPI, based on lithology, is a predictor of karst development. We designated all rocks with greater than 50 percent insolubles as nonkarstic. The KPI scores criteria for *bedding thickness, percentage of the stratigraphic unit that is insoluble, carbonate*

grain size, and the percentage of the carbonate bedrock that is calcite. Unlike the KDI, the KPI can be calculated statewide because of the complete geologic mapping coverage. The KPI is evaluated by noting the quartile into which the data fall and then noting the rank. Assignment of a significance weight is subjective, but based on the importance of each criterion as described in the literature. The rank for each criterion is then multiplied by the significance weight, and the weighted scores summed to produce the overall KPI score. A spreadsheet was used to calculate the KPI linear equation below:

$$KPI = 4(Ir) + 3(Bt) + 2(Gs) + 1(Cp),$$

where **Ir** = percentage of insoluble rock in stratigraphic section: weight = 4, score range ($4 \leq IR \leq 16$); **Bt** = bedding thickness: weight = 3, score range ($3 \leq Bt \leq 12$); **Gs** = carbonate grain size: weight = 2, score range ($2 \leq Gs \leq 8$); **Cp** = calcite percentage of the carbonate rock: weight = 1, score range ($1 \leq Cf \leq 4$).

All of the approximately 217,000 polygons of stratigraphic units were evaluated for the presence of features from the three KDI data sets. The complete set of features occurred in 1,128 polygons. The number of polygons was further reduced by eliminating those with stratigraphic units with greater than 50 percent noncarbonate. The remaining polygons were joined according to stratigraphic unit, resulting in 57 stratigraphic polygons for which we calculated the KPI. Most of the polygons eliminated represented insoluble rocks (caprock) overlying carbonate rocks and alluvium in valleys (mantled karst). The 57 pairs were further reduced to 33 paired values by averaging the KDI of groups of different stratigraphic units with a common KPI. Averaging the KDI values for the stratigraphic units with a common KPI data further smoothed the irregular availability of data for the KDI.

The KPI and KDI were compared using STATGRAPHICS software by Statpoint, Inc. Both the 57 and 33 paired value sample sets were evaluated for distribution, equivalence of means and correlation. The 57 paired values were not normally or log normally distributed for KDI, but were normally distributed for KPI. The 33-pair data set was not found to be statistically different from a normal distribution for both indices, using the Kolmogorov-Smirnov test for both indices. The means of the 33 paired KDI and KPI are statistically different at the $\alpha = 0.95$ confidence interval. The KPI and KDI scores were then correlated. The correlation coefficient (r^2) was 0.70 for the 57-pair set when KDI was compared to KPI, and was 0.78 for the 33 paired scores. The regression equation was $KPI = (1.05 \text{ KDI} \times + 8.66) \text{ } r^2 = 0.78$ at $\alpha = 0.95$ confidence interval.

The findings suggest that the KPI and KDI are independent measures (different means) and that the KPI is a reliable predictor of karst development as estimated by the KDI (positive correlation among stratigraphic units). The results further suggest that the KPI has merit as a predictive tool for karst development in the climatic and geologic setting of Kentucky and potentially in other areas of the Interior Low Plateaus.

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DNA ANALYSIS OF FECAL BACTERIA TO TRACE TRANSPORT OF AGRICULTURAL PATHOGENS AT CRUMP'S CAVE, KY

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A rainfall simulation experiment was performed to investigate the transport behavior of fecal-derived bacteria through shallow karst soils and through the epikarst. The experiment was conducted at Crump's Cave located just south of Mammoth Cave National Park on the Pennyroyal Plateau Sinkhole Plain of South Central Kentucky. Using a rainfall simulator, water containing 514 ppm sulforhodamine B was applied at a rate of 6.6 cm/hr for 4 hrs to 150 kg cow manure spread over a 7.5 m² plot on the surface. A waterfall inside the cave, predetermined to be hydrologically connected to the surface area where the manure was applied, was sampled using a tipping bucket that delivered samples to ISCO fraction collectors at 15-minute intervals. Fecal and *E. coli* MPN numbers were determined by the Idexx Colilert system.

For DNA analysis, samples were centrifuged to collect suspended material including bacteria. DNA was extracted from the sedimented material by direct lysis, and the total DNA concentration was measured by fluorometry. DNA was further characterized by quantitative Real-Time PCR (qRT-PCR) with specific primer pairs to amplify and quantify Eubacterial DNA (all bacteria) and *Bacteroides* DNA (fecal-specific bacteria) in the samples. Results of DNA analysis supported the results seen with Colilert MPN analysis for fecal bacterial contamination of the karst aquifer.

Both methods show a bimodal distribution of fecal bacteria as it infiltrated through the soil and epikarst. Fecal bacterial numbers and DNA concentrations peaked ahead of the tracer dye followed by a second peak of fecal bacteria and DNA which roughly corresponded to the dye peak. DNA analysis also revealed that a surge of non-fecal bacteria was carried along just ahead of the dye front. These data suggest that a mobile population of non-fecal bacteria in the soil was displaced by the rain event, and that the fecal bacteria followed two routes of transport through the soil and epikarst - some fecal bacteria applied to the surface reached the waterfall quickly via a pore exclusion pathway while other fecal bacteria infiltrated through soil and interstitial fluids along with the dye front. Another advantage of using DNA analysis is that PCR products from the qRT-PCR reaction may be further analyzed to identify the bacteria in the fractions.

**PROCESS WATER MANAGEMENT (PWM) FOR
ACHIEVING WATER CONSERVATION MANAGEMENT (WCM)**
Cam Metcalf & Tom Wright

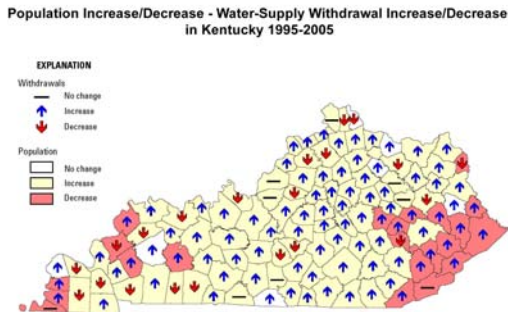
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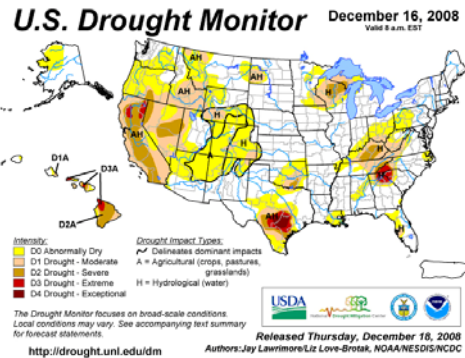
With the overall growth of both industry and population in Kentucky, the use of water by industrial, commercial, residential and public sectors continues to increase (See Chart #1). Abnormally low rainfall over the past several years has created an urgent need for water conservation management practices as surface waters and groundwater aquifers are not being replenished at a normal rate. Due to ongoing droughts and increased demand, the supply of water is less stable and predictable across Kentucky and the United States (See Chart #2). To maintain this life sustaining natural resource, an intensive, proactive focus on water use management and conservation is essential.

Chart #1-Kentucky



Source of Chart Information: USGS Website

Chart #2-United States



To assure Kentucky’s future supply of water, the state must focus on its major water consumers and have an understanding of the daily demands placed on surface waters and groundwater aquifers. Inadequate or slow planning and implementation of water conservation practices could result in serious economic consequences for Kentucky and for the United States as a whole.

KPPC recognized the urgent need for Water Conservation Management (WCM) and initiated a technology-based program called Process Water Management (PWM) in 2007. PWM was designed to assist Kentucky businesses in implementing water management, pollution prevention (P2) and energy efficiency (E2) through technology

advancements and improved management practices. In the early stages of this program, KPPC discovered that by implementing water management practices, water-intensive businesses could protect and conserve this natural resource. At the same time, these businesses improved their overall environmental performance through source reduction (pollution prevention), energy efficiency, and natural resource conservation. KPPC's PWM program provides Kentucky businesses proven methods for improving environmental performance and lowering operating costs.

Innovation: The Process Water Management (PWM) program is a new P2 approach. KPPC's PWM program uses activity-based costing and process mapping tied to a business metric, namely, cost reduction. The program focuses on implementing PWM projects in water-intensive industries and businesses to reduce water usage and identify potential chemical reductions and energy efficiency opportunities. The PWM program uses a seven step systems approach (adapted from the U.S. EPA's Energy Star Program) for clients to follow. KPPC provides a toolkit to client businesses to help them identify water usage, reduction opportunities, implementation plan development and ongoing program advancement.

Measurable Results: During the last two years, KPPC introduced process water management to Kentucky businesses through workshops and focus groups. Several water-intensive businesses (metal finishing & stamping, painting, office complexes and aluminum manufacturers) requested technical assistance from KPPC as a result of workshop participation. Most companies assume that water is a relatively inexpensive component of their operations and not worthy of a significant management effort. However, through education the companies learned that water costs only begin at the meter and that additional, potentially significant costs accumulate through the aqueous operational processes and waste water treatment prior to effluent discharge. With minimum initial investments, KPPC's client companies realized significant savings: 25.9M gallons of water usage; 7.4M pounds of chemicals; 20.4 MMBTUs; 121,500 KWHs; and \$2.25M in total costs saved.

Transferability: KPPC's PWM program is not regional or sector specific and can be applied to nearly every organization that employs water-intensive processes. This ranges from metal finishing and food processing, to HVAC systems in large office complexes in Kentucky and across the U.S. KPPC's ultimate goal is broad-based adoption of proven PWM technologies and methodologies being demonstrated and deployed by P2 service providers to help water-intensive businesses improve P2 implementation. KPPC recommends the PWM program model for all P2 service delivery organizations nationwide. KPPC provides information on the PWM program model on its Web site, at conferences and technology forums and has published program information in trade and research journals and in newsletter articles.

KOHONEN SELF ORGANIZING MAP FOR ANALYZING RAINFALL AND INFLOW PATTERNS WITH INDIANA RESERVOIR SITES

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Inflows to reservoir systems are influenced by trends in rainfall patterns. Reservoir system operation can be improved if these trends are modeled properly. This analysis attempted to understand trends in rainfall and reservoir inflow patterns. This study was performed using 8 reservoir sites located in Indiana. All the considered reservoirs are maintained and operated by US Army Corps of Engineers. Daily data series from 1983 to 2008 were used. Rainfall at the reservoir sites and inflows to the reservoirs were considered. Based on the locations of the reservoirs, regional changes were examined in this study.

Kohonen Self Organizing Map (SOM) ((ASCE 2000a) is a neural network model, which uses an unsupervised training approach to perform clustering. It is easy to change the learning steps in the model so that the classification can be better controlled than using standard statistical tools. During training, the SOM algorithm preserves the neighborhood relationships of the input data (technically known as topology). While training, after identifying the closest neuron (called winning neuron) to the input data using Euclidean distance, the weights of the winning neuron were readjusted by the algorithm. In this way, every dataset gets clustered with one neuron. Several applications were reported in the recent past where SOMs were used for data mining and knowledge discovery in data bases. By considering these advantages, SOMs were used in this study for understanding the seasonal patterns of inflows to reservoir systems.

Several analyses were performed using SOM training including rainfall patterns, inflow patterns and combined rainfall and inflow patterns. SOM were defined using 12 nodes for all analyses. Principal Component Analysis (PCA) was performed with the original database before the modeling work. Characterization of each node was done using historical data. Available data were split into training and validation datasets for understanding the performance of the model. Validation datasets were used to characterize the node class and to understand the generalization capabilities of the modeling approach.

In this analysis, clustered daily data from SOM were examined. Basic statistical properties of each cluster for each station were considered for interpretation of results. Based on these statics, classified neurons were studied and the nature of each cluster was identified (Table 1). During training SOM in the combined rainfall – inflow model, inflow data were converted to depth units (inches) using the watershed catchment area for each site prior to PCA analysis. For each cluster, the number of hits within a year was

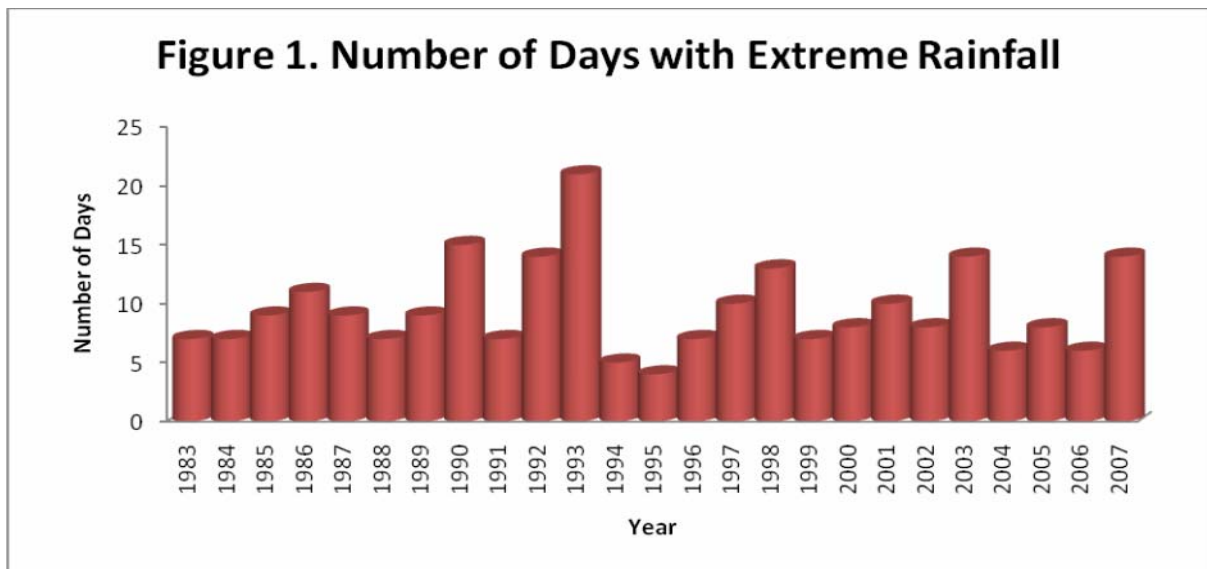
initially used to study the trends (Figure 1). By classifying the events as Very Low, Low, Moderate, High, Very High and Extreme, inferences were documented in this study.

References:

1. ASCE (2000a). Task Committee on Artificial Neural Networks in Hydrology, Artificial neural networks in hydrology. I. Preliminary concepts, *Journal of Hydrologic Engineering*, ASCE, 5(2), 115-123.
2. Kohonen, T. (2001) Self Organizing Maps, 3rd edition, Springer, London.

Table 1: Classified Clusters using Rainfall data of 8 Reservoir Sites

Neuron Number	Nature of the Cluster
1	Northern: very low ; Central: very low ; Southern: very low
2	Northern: very low ; Central: very low ; Southern: very low
3	Northern: moderate ; Central: low ; Southern: very low
4	Northern: very low ; Central: low ; Southern: moderate
5	Northern: moderate ; Central: moderate ; Southern: moderate
6	Northern: high ; Central: moderate ; Southern: low
7	Northern: very low ; Central: high ; Southern: high
8	Northern: high ; Central: high ; Southern: high
9	Northern: very high ; Central: high ; Southern: high
10	Northern: high ; Central: very high ; Southern: extremely high
11	Northern: very high ; Central: extremely high ; Southern: very high
12	Northern: extremely high ; Central: very high ; Southern: very high



WATERSHED CLUSTERING BASED ON GEOMORPHIC AND HUMAN INDUCED LANDSCAPE MODIFICATIONS: A CENTRAL KENTUCKY EXAMPLE

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Watershed boundaries rather than political boundaries are increasingly advocated to address a variety of water resource issues. Effective watershed assessment processes are needed that classify watersheds by geomorphic and human modified landscape scale characteristics. This platform presentation expands upon the poster presentation at the 2008 KWRI Symposium. The research continues exploring the opportunities and constraints of an ongoing descriptive pilot categorization approach. Watershed sample size has been increased to nearly 400 watersheds in and around Lexington-Fayette County, Kentucky. Using a semi-automated process through ModelBuilder of ArcGIS and publically available data from the Kentucky Geography Network, almost 40 landscape scale indicators are derived by Hydrologic Unit Code (HUC) 14 watersheds to describe land surface conditions. Example indicators include proportion and spatial configuration measures of human population, imperviousness, and agriculture/forest cover characteristics.

Watersheds can be visualized geographically with a color ramp indicating conditions for each indicator independently. A quantitative matrix can also be made to allow for comparisons by indicator across the study area. The process provides a guide to relative watershed condition both in relation to a specific indicator and amongst all indicators. This enables indicator recombination as needed for particular issues under consideration by planners, policy makers and interested stakeholders for more informed watershed scale land use decision-making. These data are also expected to lead to a better understanding of watershed categorization. Preliminary cluster analysis based on geomorphic and human influenced variables was utilized to identify similar watersheds. Combining the two sets of indicators in a single cluster analysis was not found to provide data clarity. Furthermore, the results differ dramatically depending on analysis choices made, transformations completed, and indicators utilized.

“TRUE RELIEF”? ASYNCHRONOUS TOPOGRAPHIC CHANGE DETECTION AND CONCOMITANT LAND COVER AND HYDROLOGIC IMPLICATIONS

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Changes in topography, such as elevation, slope, and aspect are frequently associated with geomorphologic and land cover/land use changes, having also potential implications for hydrologic and hydrographic properties of the areas affected. In Kentucky, temporal changes due to reshaping of its relief (e.g. through mountain top removal, cut and fill operations, road cuts) come into evidence when comparing “legacy” digital elevation model (DEM) information with more recent topographic data acquired through active remote sensing techniques (e.g. RADAR, LiDAR). In previous research, topographic modification or change was assessed by subtracting the February 2000, Shuttle Radar Topography Mission (SRTM) data from the National Elevation Dataset (NED) (Gesch, 2006). This calculation represents the basic idea for the United States Geological Survey’s (USGS) data service designed to provision information contained in a national inventory of significant topographic change – in the form of topographic modification delineations (<http://topochange.cr.usgs.gov/>). To provide geospatial context to these topographic changes vis-à-vis land cover change, information was pooled from two sources covering two adjacent temporal windows: *a*) the USGS’s National Land Cover Dataset (NLCD) 1992/2001 Retrofit Land Cover Change Product (LCC9201) (<http://www.mrlc.gov/multizone.php>); and *b*) the 2001-2005 land cover change product (LCC0105) created by the Kentucky Landscape Census Project (KLC) (<http://kygeonet.ky.gov>). A subset of all data was extracted and geoprocessed to the extent and boundary of Kentucky. Spatial distribution metrics were calculated using the granularity imposed by the 12-digit hydrologic unit boundary dataset for Kentucky (<http://kygeonet.ky.gov>). The initial epoch used in the pair-wise comparisons of SRTM-NED spanned 50 years and ends in the early 90’s – coincident with the initial date of the LCC9201. Fully attributed, 708 regions of topographic change occurred in 142 quadrangles, with a maximum of 66 polygons delineated in one of them (Figure 1; Table 1). In the subset of 186, 12-digit hydrologic units containing SRTM-NED topographic change polygons, approximately 22,000, 179,000 and 88,000 acres were accounted for topographic change, decadal land cover change (LCC9201), and quadrennial land cover change (LCC0105), respectively as contiguous change regions greater than 2.47 acres. Analysis of those watershed change regions shows a persistent pattern of change, perhaps at an accelerated rate, strengthening the case for the need for the cyclic, synchronous acquisition of a statewide elevation dataset, currently under discussion.

Year	Polygons	Topographic Quadrangles	Area Affected (Acres)	Height Difference – SRTM-NED (feet)		
				Minimum	Maximum	Mean
1946	2	1	24	-97	-88	-92
1947	29	5	746	-151	210	-60
1948	1	1	20	-85	-85	-85
1949	10	11	272	-126	-45	-69
1950	92	22	2,082	-120	182	-53
1951	143	36	3,501	-171	255	-61
1952	382	23	13,247	-277	230	-14
1953	28	8	1,024	-140	171	-34
1960	1	1	14	206	206	206
1967	2	2	58	-86	-64	-75
1968	1	1	30	79	79	79
1972	1	1	13	-72	-72	-72
1973	1	1	25	-92	-92	-92
1978	3	1	128	-93	-84	-89
1981	6	1	170	-82	71	-6
1987	2	2	55	-93	-93	-93
1993	4	1	269	-155	93	25
Total (Average)	708	118	21,678	(-91)	(51)	(-34)

Table 1. Epochal and spatial distribution of the topographic quadrangle sources and elevation differences in Kentucky (SRTM-NED contrast).

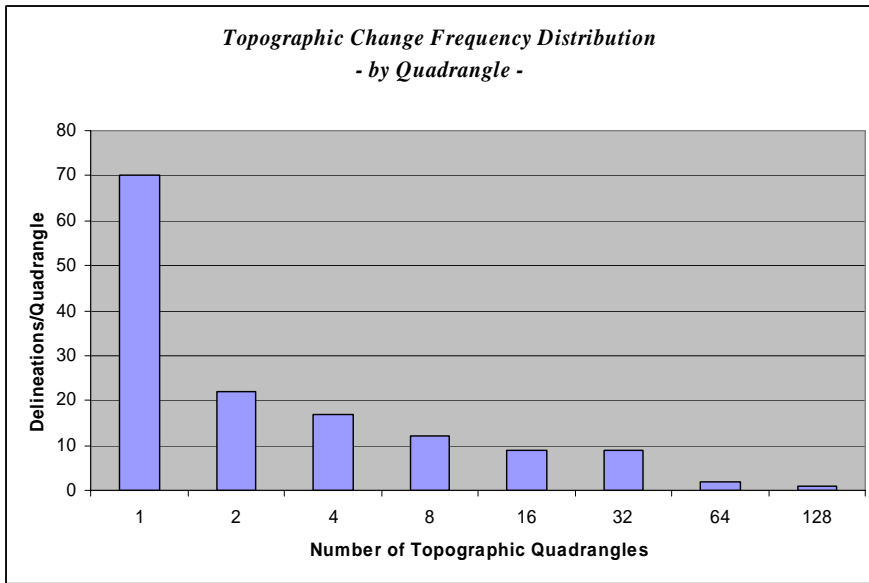


Figure 1. Distribution – by number of quadrangles - of topographic change polygon frequencies; 1946-1993 period.

References

Gesch, D.B. 2006. An inventory and assessment of significant topographic changes in the United States. Ph.D. dissertation. South Dakota State University.

CUMULATIVE IMPACTS ASSESSMENTS FOR 404 MINING PERMITS
A WATERSHED APPROACH

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ICG Hazard, LLC (ICG) operates the Thunder Ridge Surface Mine, located in Leslie County, KY within the Middle Fork of the Kentucky River watershed. Surface mining operations began in the early 1990's with approximately 16 million tons being mined to date. Approximately 2,500 acres have been fully reclaimed. On February 15, 2007, ICG filed an application for a Department of the Army (DA) 404 permit with the Louisville District. The Army Corps of Engineers issued a CWA Section 404 authorization for the five fills included in Amendment #8 on December 3, 2007. In response to a lawsuit filed against the Corps on 12/06/07 by the Sierra Club and Kentucky Waterways Alliance, the Corps suspended the Section 404 authorization effective 12/26/07.

The Corps requested a **cumulative effects assessment** of Lower Bad Creek, Greasy Creek, and the Middle Fork Kentucky River Watersheds utilizing a scope of analysis which includes the stream channel and the adjacent riparian buffer.

The Council on Environmental Quality (CEQ) regulations [40 CFR 1500-1508], implementing the procedural provisions of NEPA, define cumulative effects as "the impact on the environment which results from the incremental impact of the action when added to other past, present and reasonably foreseeable future actions, regardless of what agency (Federal or non-Federal) or person undertakes such other actions [40 CFR 1508.7]." Engineering Consulting Services, Inc. (ECSI) was retained to assemble and manage a multi-disciplinary project team to conduct this Cumulative Impact Assessment (CIA). ECSI was charged with preparing the CIA in a comprehensive manner to address all anticipated questions and issues. The approach selected by ECSI was to involve several consulting groups familiar with the region, supplemented by University of Kentucky researchers who have been working in surface mine reclamation, stream reconstruction and hydrologic impacts and mitigation. The results would be compiled and evaluated in an effort to relate the story of human activities in the Middle Fork of the Kentucky River, including the long-term effects of mining, reclamation, and mitigation. This presentation will summarize the project status to date.

SUSPENDED SEDIMENT IN THE DRY CREEK WATERSHED,
ROWAN COUNTY, KENTUCKY

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The 2007 Kentucky Environmental and Public Protection Cabinet list of impaired streams identifies a segment of Dry Creek from its mouth to 0.5 miles upstream as partially supporting aquatic life due to sedimentation/siltation and organic enrichment (sewage). Urbanization in the Dry Creek watershed is accelerating. Data collected between March 2007 and January 2009 provide a snapshot of suspended sediment concentrations (SSC), suspended sediment loads, and suspended sediment yields within the Dry Creek watershed. Results have been combined with field reconnaissance to identify sources and land uses that apparently contribute to impairment by sedimentation/siltation.

Suspended sediment sampling used the methods of Edwards and Glysson (1998). Whenever possible, the equal-width-increment method and DH-48 sampler were used. Very high or low discharge events required the use of dip or single vertical sampling. Suspended sediment analysis followed procedures of ASTM D3977-97 and Guy (1969). Discharge was measured using the velocity-area method or neutrally buoyant object method (Rantz et al., 1982) depending on flow conditions.

SSC values range from 0 to 341.30 mg/L for days when all sites were visited (Figure 1). Instantaneous suspended sediment loads range from 0 to 510 tons/day for days when all sites were visited (Figure 2). Sediment yields range from 5.00×10^{-6} to 1.68×10^{-1} tons/day/acre for days when all sites were visited (Figure 3).

Graphical results can be related to different geomorphic conditions and land uses identified through field reconnaissance. Site NB samples the upper 56% (4900 ac) of the Dry Creek watershed, which includes headwater areas and is generally the least developed portion of the basin. High SSC and loads at site NB (Figures 1, 2) probably reflect excessive stream bank erosion upstream. Morgan Fork, a tributary of Dry Creek, usually displays very high SSC, loads, and yields compared to other sampling sites in the watershed (Figures 1, 2, 3). Examination of the highest discharge event sampled to date indicates that Morgan Fork (MF) contributed nearly half of the sediment load to the next downstream site (PO), the sampling site closest to the mouth of Dry Creek (Figure 4). Sediment yield for Morgan Fork is extreme compared to other sites (Figure 5) despite the fact that Morgan Fork represents only 15% (1300 acres) of the entire Dry Creek watershed (8800 acres). The very high suspended sediment yield from Morgan Fork

reflects poor land use and inadequate erosion mitigation practices prior to and during recent highway construction in the Morgan Fork watershed.

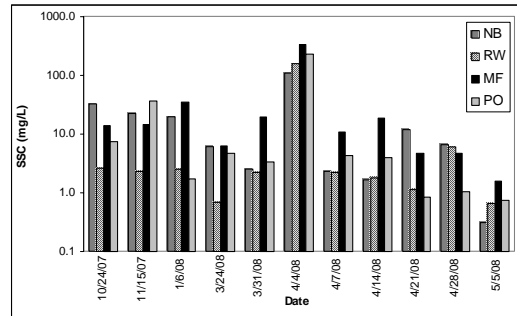


Figure 1. Comparison of suspended sediment concentrations on dates when all sites were sampled.

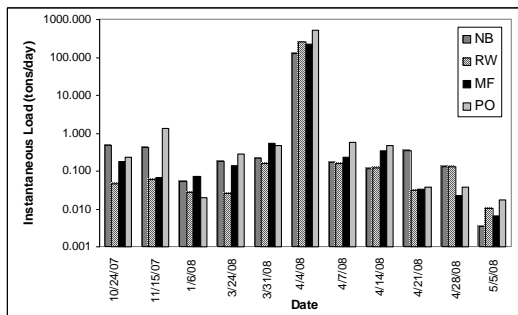


Figure 2. Comparison of instantaneous loads for dates when all sites were sampled.

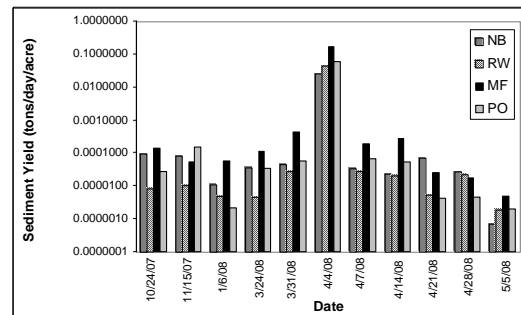


Figure 3. Comparison of sediment yields on dates when all sites were sampled.

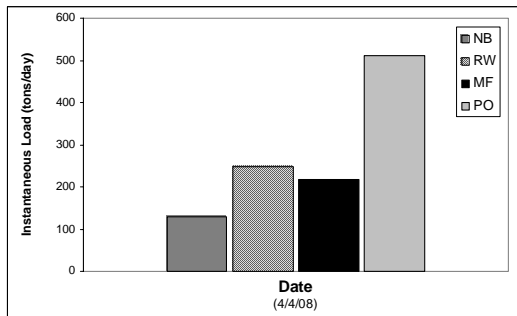


Figure 4. Comparison of instantaneous loads for all sites during highest discharge event.

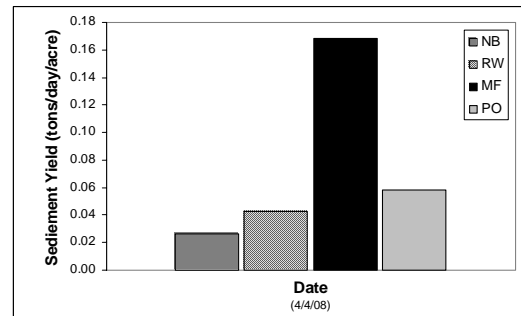


Figure 5. Comparison of sediment yield for all sites during highest discharge event.

Results of this study have led to a new study involving bank-pinning and measurement of channel cross-sections to quantify sediment contributions due to bank instability and erosion along Dry Creek. In addition, a focused study of the impact of recent highway construction has been initiated.

INFLUENCE OF EASTERN HEMLOCK (*Tsuga canadensis*) ON THE AQUATIC BIODIVERSITY IN EASTERN KENTUCKY

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This research experiment is aimed at comparing the aquatic diversity between fish and macroinvertebrate assemblages in eastern hemlock dominated forests and hardwood dominated forests. The eastern hemlock (*Tsuga canadensis*) plays a unique role in the eastern forest landscape, occupying ecological niches not easily filled by other tree species. It is an extremely long-lived and shade-tolerant conifer that grows in dense stands, creating an environment that is characterized as a cool, damp microclimate with low light levels and depauperate understory vegetation cover (Lutz 1928; Rogers 1978, 1980). *T. canadensis* is one of the principle riparian and cove canopy species in the Southern Appalachian Mountains and commonly the only evergreen canopy species in mesic sites. Therefore, it is likely an important species in terms of direct and indirect effects on hydrologic processes (Ford et al. 2007). Consequently, plant and animal species may have evolved in association with hemlock stands and may be dependent upon them for habitat (Ross et al. 2003).

Recently, *T. canadensis* forests have been rapidly declining due to the introduction of the hemlock woolly adelgid (HWA, *Adelges tsugae*), a small aphid-like insect. First discovered in West Virginia in the 1950's, *A. tsugae* has now spread in hemlock stands along the east coast north through southern New England. Since its introduction, the adelgid has created extensive decline and mortality of *T. canadensis* in Virginia, Pennsylvania, New Jersey, and Connecticut (Orwig and Foster 1998). In March 2006, *A. tsugae* was found in Harlan County, Kentucky and since, has spread to Pike, Leslie, Letcher, Clay, and Bell Counties. With the rapid movement of the adelgid in only a few years, it can be expected that the adelgid will continue to move throughout hemlock forests located in eastern Kentucky.

Much research has been conducted on terrestrial communities associated with eastern hemlock forests, however, little emphasis has been placed on investigating aquatic communities. To determine the potential long-term impacts of hemlock forest decline on aquatic biodiversity, we conducted a comparison study of streams in the Daniel Boone National Forest on fish and macroinvertebrate communities, along with stream habitats. We found fish community structure to be distinctive to its correlating forest composition. Streams draining hardwood forests were more diverse and more productive than streams draining hemlock forests. In addition, there were distinct differences in fish trophic structure, with predators more common and insectivores less common in hemlock

streams. Conversely, insectivores were more common and predators were less common in hardwood streams. Stream temperature data indicated that streams draining hemlock forests were an average 4°C cooler during summer months than hardwood streams. When compared to other literature, it is suggested that hemlock streams are cooler in the summer months and warmer in the winter months, maintaining more stable hydrologic and thermal regimes. In conclusion, our findings suggest that the expected decline of the eastern hemlock in Kentucky may result in long-term ecological impacts on aquatic biodiversity.

IDENTIFICATION OF HUMAN AND ANIMAL FECAL SOURCES IN CENTRAL
KENTUCKY WATERSHEDS BY PCR OF 16sDNA MARKERS FROM HOST-
SPECIFIC FECAL ANAEROBES

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Lexington and other communities in Kentucky are experiencing problems associated with increased fecal bacterial loads in storm water runoff and surface water tributaries, which raise the *E. coli* concentrations above regulatory limits. The sources of these fecal pollutants must be identified before the concentration levels can be decreased. This study was designed to investigate multiple proposed indicators for fecal source identification and apportionment in a local watershed impacted by numerous and varied sources. Samples were analyzed for *Bacteroides* source-specific genetic markers, *E. coli*, and the ratio of atypical colonies (AC) to total coliforms (TC) for the purpose of determining source, load, and relative age of the fecal contaminants, respectively. This study will also determine the usefulness of the *Bacteroides* 16sDNA markers to pinpoint the presence of human sewage in an urban watershed and to quantitatively apportion the impact of humans versus other animals.

A total of 31 samples were analyzed from Wolf Run, Cane Run, and Glenn's Creek watersheds in Fayette, Scott, and Woodford counties. *E. coli* was enumerated by a most probable number method using Idexx colilertTM media and quantitray 2000TM bubble packs. AC/TC ratios were determined from the total coliform and atypical colony counts on m-Endo media at multiple dilutions. *Bacteroides* genetic markers are identified and quantified using the Allbac, Hubac, and Bobac primers and probes developed by Alice Layton at the University of Tennessee Center for Environmental Biotechnology with a BioRad iCycler IQTM real-time PCR instrument.

Preliminary results show that fecal loads, as indicated by *E. coli* enumerations, are variable and range from 10 to 17,329 MPN/100mL. The Allbac genetic marker (non-host-specific, general fecal marker) is ubiquitous across the samples analyzed and its concentration is proportional to the *E. coli* concentration. The human-specific *Bacteroides* marker, Hubac, is found across the study area and concentrations are variable. Work is ongoing to elucidate the apportionment of general, human and bovine sources in these watersheds.

INVESTIGATION OF LAND-USE CHANGE AND HYDROLOGIC FORCING UPON
STREAMBANK EROSION AND IN-STREAM SEDIMENT PROCESSES USING A
WATERSHED MODEL AND SEDIMENT TRACERS

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The production of sediment from sources in the stream corridor including the banks and bed of the river remains a topic of research that needs further investigation for the environmental water resources community. Few researchers have been able to integrate sediment transport from stream banks and stream beds successfully into a watershed scale model. The nature of this work is to numerically model sediment transport processes, including stream bank erosion and in-stream storage, with a watershed scale model in order to better understand the sensitivity of these processes to land-use change and hydrologic forcing. The novelty of the modeling approach is that improved equations for streambank erosion and in-stream sediment resuspension and deposition are formulated within an existing watershed sediment transport model, and these new equations are calibrated using sediment fingerprinting modeling results based on carbon and nitrogen stable isotope tracers to quantify sediment loading from streambanks and streambeds. The South Elkhorn Watershed, located in the Bluegrass Region of Kentucky, was chosen to be modeled because of the dominance of streambank erosion and stored fine sediments impacting this system and the availability of historic sediment tracer and sediment loading data from a previous study. The existing watershed model that is modified is the Hydrologic Simulations Program-FORTRAN model. The modified model is calibrated using the sediment fingerprinting results and sediment loading measurements taken over a three year period. After calibrating the model, a sensitivity analysis is run to discover which parameters control bank and bed erosion and transport in the model in both a distributed sense throughout the watershed and from an integrated loading perspective.

The results of this study are expected to aid in our understanding of watershed and climate disturbance upon sediment, advance modeling of the watershed including calibration of source processes, predict future problem with ever increasing urban development, and determine to what extent a sediment erosion problem already exists.

WATER/WASTEWATER TECHNICIAN TRAINING INSTITUTE:
THE FIRST YEAR RETROSPECTIVE

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The Center for Water Resource Studies (CWRS) and the Bowling Green Community College (BGCC) of Western Kentucky University (WKU) formed a partnership to address an anticipated Water and Wastewater Operator/Technician shortage over the next five to seven years. The Water and Wastewater Technician Training Institute (WTTI) is a joint initiative with the employment sector (water and wastewater utilities, municipalities, and/or districts), state primacy agencies, technical assistance and trade associations to refine an industry needs driven curriculum that utilizes on-line course delivery to provide options for both traditional and non-traditional students. This paper will review the accomplishments and the lessons learned by this program over the first year of operation.

The WTTI program requires sixty-seven (67) credit hours, including twenty-five (25) hours of General Education requirements, twenty-one (21) hours of Business Technology courses, and twenty-one (21) hours of Operations Track courses. The Operations Track courses can be focused toward either Water or Wastewater Operations. The program is designed to be delivered entirely online, allowing students to pursue their degree with unparalleled flexibility. The WTTI courses are delivered through an open-source Course Management System (CMS) known as MOODLE (Modular Object-Oriented Dynamic Learning Environment). The first Operations Track class, WTTI200C, Water Supply & Wastewater Control was developed and offered during the 2008 Fall Semester. As courses are developed, approval is sought for Continuing Education/Contact Hours from Operator Certification Boards in the individual states. Academic content is being provided by core university faculty with support from adjunct faculty eligible staff. All instructors involved in the program are undergoing collaborative professional development to ensure that they are receptive to the unique structure of the program.

As a demonstrably functional framework is being put in place, the program is being extrapolated to address other regional policy, academic discipline and industrial sector issues beyond the initial Kentucky and Tennessee target area. University-offered Water and Wastewater Operator Certificate Programs are being developed to fast-track students into the industry and allow current operators to reach advanced certification levels at an accelerated pace. Partnering utilities and municipalities are developing internship and cooperative educational opportunities to ensure work-based experiences for students.

Trade associations have committed to developing scholarship programs to lessen the financial burden for potential students. In addition, some individual utilities are offering tuition reimbursement for current employees who are pursuing academic degrees or certificate programs. Finally, an educational outreach program that integrates into high school science curricula is being developed. This program is aimed at recruiting young adults into the water and wastewater industry.

WATER ANALYSIS, TRAINING, EDUCATION AND RESEARCH SERVICES: A 'FARMER'S COOPERATIVE' MODEL FOR CAPACITY DEVELOPMENT

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Upon its inception, WATERS Laboratory in Bowling Green, Kentucky was envisioned as a 'farmer's cooperative' of labs. This consortium of local, state and regional private and public sector entities maximizes each partner's ability to further their goals through resource sharing.

The foundation of the lab was established in 2004 when Western Kentucky University (WKU) and Mammoth Cave National Park (MACA) of the National Park Service (NPS) entered into a Cooperative Agreement to share laboratory analytical equipment and personnel to maximize utility, productivity and scope of service. The Cooperative Agreement has resulted in the establishment of an operating environment that integrates and furthers the research, training and service components of the partners in the area of overlap pertinent to the natural resource protection mission of the NPS and the training and educational mission of WKU. This facility consolidates the research and regulatory grade environmental analytical instrumentation available to each partner and has resulted in optimal utilization of resources.

The Water Analysis, Training, Education and Research Services (WATERS) consortium espouses the following integrated goals through cooperation:

- Water Analysis: Provide high quality environmental data collection, management and analysis of drinking water, wastewater and source water to utilities, industry, researchers, government entities and the general public.
- Training: Provision of formal training and certification of field, laboratory and environmental technicians serving an immediate need for the Commonwealth of Kentucky through workshops and on-site demonstrations.
- Education: Provide hands-on work experience for university students.
- Research Services: Maximize each partnering agency's ability to further their research missions through the optimal utilization of research grade instrumentation.

This partnership permits programs to attain and exceed institutional goals for data collection, determination, analysis and visualization through coordinated collaboration and access to services traditionally beyond the resource capacities of each individual organization.

UTILIZING A CONTENT MANAGEMENT SYSTEM FOR AN EMERGENCY RESPONSE NETWORK FOR WATER AND WASTEWATER DISTRICTS

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Following the impacts of Hurricane Katrina and then Hurricane Rita, it became apparent that even with the extraordinary efforts of utilities, water associations and the State Emergency Operations Center, the demand for resources and knowing where those resources were available overwhelmed the ability to effectively coordinate the initial response.

Realizing that utilities needed a different approach, a committee in the water community and state agencies have joined together to create the Kentucky Water/Wastewater Response Network or KYWARN

with a mission to support and promote statewide emergency preparedness, disaster response, and mutual assistance matters for public and private water and wastewater utilities.

The Kentucky WARN system utilizes a content management system (CMS) called Drupal. Drupal includes the ability to add packages written and maintained in a collaborative environment. This system facilitates changes and additions to the KYWARN system. Additionally the power of the system allows for tools to be utilized with minimal cost for development.

The CMS in use includes packages to incorporate interactive mapping, inventory systems, notifications, SMS notification, authentication and sign up, tracking, and member status. Features are being developed and added to the system by the Center for Water Resource Studies. The KYWARN system has been available for membership for one year and is currently at 30 members with nine member communities having signed a Mutual Aid Agreement.

WATER RESOURCE MANAGEMENT CAPACITY DEVELOPMENT:
A SMALL SYSTEMS TECHNOLOGY TRANSFER MODEL

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The Center for Water Resource Studies (CWRS) at Western Kentucky University (WKU) promotes and facilitates a public/private sector partnership focused on the development and transfer of water resource management technologies that specifically target the small to medium sized industry market. This market includes municipalities, water and wastewater utilities and districts serving populations less than 25,000, local and state government agencies, commercial and non-profit organizations providing engineering, scientific, technical, financial, managerial and analytical services, and the industry relevant trade associations.

The size and scope of services needed/offered in this market sector tend to limit the rate of return of product development investment, and, as a result, only a few companies tend to invest in this sector. The partnership integrates small technology startup entrepreneurial firms with the end-user/target market sector and the water resource technology development capacity of the partnering universities to facilitate the translation of market need into technological concept, development, transfer and commercialization. The needs and capacity of the target market dictate a high-volume, low-margin approach to be commercially feasible, and so is typically under-served. By relying on small startup firms for commercialization, and minimizing licensing burden, the partnership promotes a technology development and transfer model process that is sustainable.

The partnership focuses on developing processes for rapid identification, development, transfer and commercialization of incremental advances in technology that have an immediate benefit on the target market. The key to success of the partnership is the adoption of the successful "Red Hat Business Model," that relies on integrating the end-user into an open product development process. Key principles incorporated into such a business model include a "first-to-market" philosophy, a highly responsive consumer feedback process, and a balanced reliance on product service and intellectual property protection for commercialization.

RESULTS OF A KENTUCKY STORMWATER SURVEY
IN MS4 PHASE II REGIONS

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The Kentucky Transportation Cabinet (KYTC), along with 100 communities throughout Kentucky, has been required to participate in the MS4 Phase II permit program since 2003. The requirements of the Phase II MS4 program include public education, public involvement, illicit discharge detection and elimination, construction site stormwater runoff control, post construction management, and pollution prevention/good housekeeping.

In 2007, the KYTC, in collaboration with the Kentucky Environmental Education Council (KEEC), designed and implemented a stormwater education program as a means to expand the public education and public involvement portions of the Phase II, MS4 program. As part of this stormwater education program, a telephone survey was designed by the KYTC and KEEC to measure the knowledge, attitudes and behaviors of the general public concerning stormwater pollution issues. The survey was administered in 2008-09 by the University of Kentucky Survey Research Center to a random sample of adults in Kentucky MS4 Phase II regulated cities and counties.

Specific areas measured by the survey included knowledge about water quality, stormwater and stormwater drain systems, sources of runoff pollution, actions that protect water quality; and awareness of sources of information about ways to prevent stormwater pollution. Attitudinal measures of the survey included the level of concern about water quality and concern about stormwater runoff pollution. Behaviors that contribute to or help to prevent stormwater runoff pollution were also reported on the survey.

The results of the survey were analyzed and reported for MS4 Phase II regions of Kentucky and for individual communities in which there were more than 25 survey respondents. The purpose of the survey was to set baselines for MS4 Phase II permittees to use in monitoring the ongoing effectiveness of their Public Education and Public Participation strategies over the life of their 2008-2013 permits.

This presentation will include an overview of the stormwater survey, results of the survey, and implications for stormwater public education and participation programs. A website address will be provided for participants to review the survey questions and statewide results of the survey.

THE BLUEGRASS RAIN GARDEN ALLIANCE: AN APPROACH TO IMPROVING STORMWATER QUALITY FOR MS4 COMMUNITIES IN CENTRAL KENTUCKY

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The Bluegrass Rain Garden Alliance (BRGA) was founded in early 2008 through a partnership between the Kentucky Department of Fish and Wildlife, EcoGro, the Tracy Farmer Center for the Environment, CDP Engineers, and Bluegrass PRIDE. The goal of the BRGA is to educate people in Central Kentucky about the water quality and quantity benefits of rain gardens, encourage their construction, and to register 2,010 rain gardens in by the year 2010.

Rain gardens are built with a shallow depression and planted with native plants to capture stormwater runoff from impervious surfaces, such as rooftops, patios, driveways, and parking lots, before it enters the storm water system. They use natural processes to improve water quality by filtering pollutants through the roots of the plants and the soil and by reducing the amount of stormwater allowed to leave the property. The deep roots of native plants allow water to more easily infiltrate the soil and most rain gardens are designed to percolate all water into the ground within 24 hours of a rain event. Included in the BRGA's objectives is to teach people about the dual value of rain gardens planted with native plants. In addition to stormwater benefits, gardens with native plants increase habitat and food sources for native animals, thereby decreasing the effects of habitat fragmentation on threatened or endangered species.

Rain gardens have been proven to dramatically improve storm water quality and reduce its quantity. A study done in Burnsville, MN documented in Land and Water magazine showed that rain gardens can reduce storm water runoff by up to 90% in suburban areas compared to similar areas with no rain gardens. Another study, documented by the EPA, shows rain gardens' ability to minimize pollutants in rain water; up to 97% of the copper, 95% of the lead, 87% of the phosphorous, 92% of the ammonium, and 49% of the nitrogen were removed by the natural filtering processes rain gardens utilize.

To achieve its goals of education and storm water improvement, the BRGA steering committee created three separate committees each addressing a different segment of people who might be interested in rain gardens. There is a committee of homeowners, one of educators, and one for people in the commercial sector. The homeowner committee worked on various projects throughout the year including a public rain garden tour of seven rain gardens which boasted nearly 100 participants and a demonstration rain

garden at the Green Living Expo in Lexington. One of the commercial group's most notable accomplishments was a two-day demonstration of the construction of two commercial rain gardens in a business district in Lexington which attracted over 60 attendees. In September of 2008, the school group announced the winners of its \$500 rain garden grant. Henry Clay High and Montessori Middle in Lexington and Bridgeport Elementary in Frankfort each won \$500 to start rain gardens on their campuses. The BRGA is planning teacher workshops at two schools in the spring. As an extension of the educational component, environmental educators from Bluegrass PRIDE go into schools to teach about the benefits of rain gardens with K-12 students. In addition core content aligned curriculum and resources are available on the website.

The BRGA website, www.BluegrassRainGardenAlliance.org, also includes resources for homeowners and those interested in commercial rain gardens. The website has upcoming events and announcements and people can go there to register their rain gardens to be included in the count to 2,010.

To date the BRGA has 36 gardens registered with 12,438 sq ft of land converted into rain gardens in Woodford, Scott, Fayette, Madison, Jessamine, Garrard, and Washington counties. We have been recently highlighted in the Herald Leader and Business Lexington, and in the spring of 2009 Do It Best hardware's nationwide magazine will run an article called Rain, Rain, Come to Stay in which the Bluegrass Rain Garden Alliance is discussed and members are quoted. BRGA staff and volunteers have distributed hundreds of rain garden "how-to" manuals, tabled at festivals, completed one master gardener workshop, three homeowner workshops, two commercial demonstration workshops, and a rain garden tour of Lexington, with the total participation of over 600 people. Three \$500 grants to schools have been awarded in Fayette, Franklin, and Madison counties. Many people who have registered their gardens with the Alliance rave about the success they've had in decreasing the amount of stormwater on their property, improving issues of flooding and erosion, and adding beauty to their yard.

Future plans for the Alliance include two school workshops to educate teachers about rain gardens as outdoor classrooms and functional stormwater management systems, the distribution of a \$500 community rain garden grant, and another rain garden tour among other outreach and educational presentations.

GIVE YOUR BRAIN TO SCIENCE:
RESOURCE MATERIALS FOR TEACHERS

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Take a moment to think about the resources you have developed or obtained as part of your work. Perhaps even a talk you are giving today. There's a good chance that some of those materials might be of use in the classroom. K-12 education in Kentucky may benefit from your work if you make it available to teachers. There are a variety of ways to get the word out.

The Kentucky Geological Survey has been very successful with its Maps to Teachers program which makes maps, PowerPoint presentations, and other materials available to teachers. Included are Generalized Geologic Maps for Land-Use Planning for each of the 120 counties; a brochure/PowerPoint presentation Maps Tell Us About Where We Live; Kentucky Terrain, which illustrates the geology and landscapes of Kentucky's regions; Geologic Hazards in Kentucky, a map with illustrations of the different geologic hazards and where they might occur; and a PowerPoint presentation, A Brief History of Earth.

Communication outlets used to get out the word have included:

- Kentucky Science Teachers Association annual meeting
- Kentucky Science Teachers Association Web site
- K-12 Science Teachers listserv, UK Water Resources Institute
- *Kentucky Teacher* newsletter, article: Geological Maps Becoming Popular in the Classroom
- *Kentucky Teacher* newsletter, Resources Available
- UK Cooperative Extension—Environmental & Natural Resources Issues Newsletter
- Tracy Farmer Center for the Environment, Institute for Sustainability, Energy and the Environment Web site
- Kentucky Conservation Districts
- KGS Web site, Earth Science Education
- UK Earth Science listserv, earthK-12.lsv.uky.edu

Not everyone was reached through these outlets, of course, but nearly 1,000 classrooms and libraries in 350 schools were.

Ideally, materials are provided to teachers free or at minimal cost. PowerPoint presentations, PDF's, and other digital materials can be made available online through your Web site.

What do you have that might be useful in the classroom? Make it available.

Geological maps becoming popular in Kentucky classrooms

By Jennifer Humble, Paul Laurence Dunbar High
Cathey Seaton, Ballard County Middle School
Dan Carey, Kentucky Geological Survey

Hundreds of teachers across Kentucky have responded enthusiastically to the offer of free, laminated county geology maps through the Maps-to-Teachers service from the Kentucky Geological Survey (KGS) at the University of Kentucky (UK).

A *Generalized Geologic Map for Land-Use Planning* has been developed – with an accompanying brochure/PowerPoint, *Maps Tell Us About Where We Live* – for each of Kentucky's 120 counties. The idea is to help students.

"Maps seem to attract people of all ages—from my 3-year-old grandson to senior citizens—who want to see and learn more about the places where they live," said Program Coordinator Dan Carey. "Providing these maps to classrooms across the state seemed to be a great way to realize both the KGS and UK missions of service and dedication to applying, sharing and disseminating knowledge across Kentucky, as we work to make the state a better place to live and learn."

Jennifer Humble, a teacher at Paul Laurence Dunbar High (Fayette County), uses the Fayette County map to show her students the complexities involved in land use planning for selecting a hospital site in the county. Humble used the free *Generalized Geologic Map for Land Use Planning* with Google Earth so that students could see satellite images of Fayette County, their homes and the Geologic map at the same time.

To use the map, students located where they lived through Google Earth and discussed geological features near their homes. Finding features such as sink holes and earthquake fault lines made the Geologic Map personal to them and enhanced their interest.

The project officially began when students obtained per capita income and population density data geographical maps that also were placed into Google Earth. By combining the information from the maps, students were able to find a site to build their hospital. To share their site location, students wrote a report summarizing their findings and presented it to their peers. Humble said the project was very interesting to her students, and they gained insight regarding their county and the initial processes that can go into selecting an area to build a large structure.

Cathey Seaton, a teacher at Ballard County Middle School, was an earth science major, so she was delighted to have the chance to share that interest with her students. She divided her 6th-grade classrooms into groups accord-



Photo by Amy Wallot

At Paul Laurence Dunbar High (Fayette County), juniors Ailin Shen, left, Elizabeth Osbourne, middle, and Darshali Vyas, all students in Jennifer Humble's Math, Science and Technology Center's Earth Space class, use Google Earth, a map of Fayette County plus population density and area income information to decide where a new hospital should be located.

ing to the part of the county in which they lived. They used geologic quadrangle maps to reproduce those areas. Each group then got six sheets of flexible foam to make a rough physical model of the landform.

"They couldn't believe that those curved lines on the map really do show what the land really looks like," Seaton said.

The students referred to the geologic map provided by UK to determine what kinds of rock types were found in the area. "The kids loved it," she said. "They thought it was pretty neat that Ballard is a 'baby,' geologically speaking, meaning the county is composed of deposits from the two youngest geologic time periods."

Each group presented its findings to the class, showing its model and relating the geologic information researched. Since Ballard County is located along the New Madrid fault line, Seaton also gets earthquake noti-

fications from the U.S. Geological Survey in Memphis, which the class graphs according to frequency and intensity.

The lessons fulfilled part of the social studies applications standards in Kentucky's Core Content for Assessment related to using maps to interpret patterns and locations on the Earth's surface. Seaton's students now know how to read contour maps, a skill many adults haven't mastered. They also learned to recognize different soil types and have a better understanding of geologic time periods, she continued. "And they got to get up and move around, which is always a plus for middle-schoolers."



Photo submitted by Cathey Seaton

Naoma Curtis, a 6th-grade student at Ballard County Middle, refers to geologic and topographic quadrangle maps of her home as she prepares topographic models during teacher Cathey Seaton's class.

MORE INFO...

www.uky.edu/KGS/announce/landuse_teacher.htm

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INTEGRATING ENVIRONMENTAL EDUCATION IN THE CURRICULUM

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We have undertaken a comprehensive plan to integrate environmental education (EE) by using two approaches: institutionalizing EE at KSU by incorporating environmental topics in the curriculum through faculty mini-grants and forming a collaborative partnership with local middle and high schools to assist them in implementing an environmental education program in the schools. The primary goal of the faculty mini-grants program is to improve environmental literacy for all KSU graduates, especially those who plan to become teachers. These mini-grants are designed as part of our efforts to institutionalize environmental education at KSU by creating or supporting coursework that provides in-depth, cross-disciplinary instruction that is ecologically sound and promotes responsible civic actions toward the environment. The program provides support for either development of new courses or enhancing existing courses by incorporating environmental issues or topics. We have also established an EE Center on a 300 acre nature preserve that serves as an outdoor classroom for these activities. Last summer, we developed a stream ecology program and offered it to Kentucky school teachers. Forty two teachers participated in the 1st week-long summer workshop. We focused on stream ecology principles, human impacts, field methods, macroinvertebrate identification, data analysis, and Shannon Diversity. In order to ensure adoption into classroom curriculum, we are conducting follow-up workshops and providing the necessary equipment and support to the participating schools. We will present dissemination methods, lessons learned from our summer workshop, services that will benefit teachers and curriculum adoption, and the results of the fall follow-up workshop.

Project Funded by USDA Capacity Building Grant Program
and The Kentucky Environmental Education Council

WATERSHED BASED PLANNING IN THE UPPER EAST FORK OF CLARKS RIVER

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In May of 2005, the Kentucky Division of Water (KDOW) approved a project for watershed based planning in the Upper East Fork of Clarks River to be performed by the Jackson Purchase RC&D Foundation, Inc. (JPF). The KDOW agreed to match 60% of the total project cost, approximately \$108,000. JPF provided the remaining 40% of the project cost, approximately \$72,200. Portions of this watershed are listed on Kentucky's current 303d list of impaired streams. Contaminants of concern in this watershed include pathogens, siltation, organic enrichment/low dissolved oxygen, and nutrients. The goals of this project include the improvement of habitat and water quality in the Clarks River watershed, and the reduction of nonpoint source pollution from all sources in both the tributaries and the main stem of Clarks River.

Environmental data collection was performed throughout the entire East Fork Clarks River and West Fork Clarks River watersheds to determine threats to water quality in the watershed, locate sources of impairment in the watershed and determine the causes of these impairments. Sampling locations were determined by Strand Associates, Inc. (SA), an engineering firm providing technical support to the project, and the Four Rivers Basin Team (FRBT), a group of representatives from nonprofit organizations, local governments, private corporations, and state and federal agencies. Dry weather sampling was conducted to determine baseline conditions for the watershed. Baseline data indicated high levels of *E. coli* contamination, high baseline temperatures in some areas of the watershed, low dissolved oxygen levels in some areas of the watershed, and low natural alkalinity levels in some areas of the watershed. Three wet weather sampling events were conducted at six sites to determine pollutant load rates in the watershed and potential sources of pollutants. These sampling events indicated significant spikes in *E. coli* levels and total suspended solid (TSS) concentrations during rainfall events.

Environmental data collection identified four main pollutants of concern, *E. coli*, TSS, nutrients, and temperature. The final Watershed Based Plan for the East Fork Clarks River identified critical areas in the watershed where best management practices should be implemented to reduce pollutant load rates, thus improving water quality in the watershed. Best management practices identified by SA and the FRBT include vegetated buffer strips, erosion control practices, soil testing and precision agriculture, animal waste management, removal of straight pipes, maintenance of septic systems, fencing livestock away from streams, and the construction of wetlands. The specific best management

practices to be implemented in the watershed will depend on the area of interest, main pollutants of concern, and immediate local source of the pollutants.

This project also included an educational component provided by the Calloway County Conservation District. As part of this component, representatives from the Calloway County Conservation District worked with students from Murray High School and Calloway County High School to stress the importance of clean water, identify problems in their watershed, and identify ways these problems can be addressed.

With strong local support and a plan of action for moving forward, this project is an excellent example of local communities coming together to protect and enhance their local waterways.

KENTUCKY INSTITUTE FOR WATERSHED MANAGEMENT SUPPORT

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The Center for Water Resource Studies (CWRS) at Western Kentucky University (WKU) has established the Kentucky Institute for Watershed Management Support (KIWMS) for the purpose of providing regional planning support to communities throughout the Commonwealth in order to maintain the natural and economic resources of their watersheds. The CWRS expanded its scope of services, leveraging on existing expertise as a water, wastewater, utility and municipal technical assistance provider, to assist communities with realizing the fundamental goal of holistic watershed management. The vision is for KIWMS to leverage synergy between local, state and other resource agencies at a watershed level by providing infrastructure and support for accountability and the technical basis to ensure measurable results.

KIWMS will connect local communities with regional planning entities to achieve local change that positively impacts watershed health. A key strategy in the community-specific implementation of the KIWMS is a public education campaign. KIWMS will promote strategies for wastewater minimization for both residential and commercial establishments. KIWMS will also provide technical, financial and managerial assistance to develop and implement functional and extensible wastewater management alternatives for communities throughout Kentucky to improve watershed health and promote economic development. This assistance will be provided through detailed situation assessments, technology demonstrations, public education, and technical, managerial and financial alternatives. The techniques developed and resources accessed to further wastewater minimization strategies will be transferable to other project areas.

KIWMS will focus on the community of Glendale, Kentucky (population 1,800) as a demonstration of the way in which stakeholders at the local and regional level will be engaged in a collaborative problem solving process to develop sustainable and technically sound solutions for pervasive failures in onsite wastewater systems that potentially contribute to the pathogen impairment of the neighboring Valley Creek segment and limit the community's economic growth. The CWRS has been actively engaged with the Glendale Merchants Association, the Hardin County Planning and Development Commission, and Hardin County Water District #2, to develop technological and management alternatives.

OVERVIEW OF THE TMDL DEVELOPMENT FOR PANTHER CREEK AND LONG FALLS WATERSHEDS IN DAVIESS AND MCLEAN COUNTIES, KENTUCKY

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The Total Maximum Daily Load (TMDL) Development for the Panther Creek and Long Falls Watersheds is an ongoing water quality project where the Kentucky Division of Water (KDOW) and the Center for Water Resource Studies (CWRS) at Western Kentucky University work together to accomplish the requirements for the KDOW TMDL Program, Annual Work Plan under Section 106 of the Clean Water Act. KDOW is responsible for coordinating the overall project, collecting and identifying biological samples, determining Aquatic Life Use and review of all data prior to Environmental Protection Agency (EPA) submission. CWRS will be responsible for all daily activity including: project management, data sampling and analysis, data modeling, modeling reports, quarterly progress reports and development of TMDL documents. Once the project is complete CWRS will also address all questions from EPA, KDOW and the Public.

This overview will include discussion of the public meetings held, data collection, analysis and current modeling for TMDL development. This project involves selected impaired stream segments in the Panther Creek and Long Falls Creek watersheds in Daviess and McLean Counties, KY. All impaired water bodies are listed on the 2004 303(d) List of Waters for Kentucky, except for the pathogen impairment on South Fork Panther Creek river miles 13.5 to 17.7 which is in the Assessment Database as nonsupport and will be on the 2006 303(d) list. Impaired streams are listed for pathogens, pH, total dissolved solids (TDS), sulfates, organic enrichment (sewage) biological indicators, metals (copper), phosphorus (total), and nitrogen (total), and are not meeting the Designated-Use Criteria for Primary Contact Recreation (Swimming) and/or Aquatic Life.

NITROGEN ISOTOPES TO STUDY THE VARIABILITY OF SEDIMENT
TRANSPORTED FROM A LOWLAND WATERSHED IN THE BLUEGRASS

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Stable isotope ratio mass spectrometry was used to measure the nitrogen isotopic signature of transported sediment particulate organic matter at different spatial locations and for a 27 month period in a lowland watershed with pronounced temporary storage of fine sediments in the stream channel. The research worked to fill a need to assess the temporal and spatial variability of the biogeochemical sediment tracers for sediment transport source and fate studies at the watershed scale. We assessed the hypothesis that the nitrogen isotopic signature varies seasonally due to the interaction of biogeochemical

processes within sediment storage deposits in the bed of the stream and hydrologic processes impacting the suspension of sediments in the dynamic bed.

Sediment sources were characterized and thereafter sampled in the South Elkhorn Watershed, a lowland watershed in the Bluegrass Region of central Kentucky with pronounced streambank erosion and fine sediment storage. Samples were analyzed using stable isotope ratio mass spectrometry. The nitrogen isotopic signature of the streambed sediments was found to be significantly different than the banks and supported the hypothesis that the isotopic signature of the streambed reflects biogeochemical processes including accumulation and decomposition of organic matter and growth of microorganisms and benthic algae.

Weekly samples of transported sediments were also collected from the South Elkhorn using *in situ* sediment trap samplers from March 2006 to June 2008 at different locations in the watershed. Bulk sediment-water samples collected from the traps were prepared in the laboratory to isolate the fine fraction of sediment with particle diameter less than 53 μm and then further prepared and analyzed for their nitrogen isotopic signature on the stable isotope ratio mass spectrometer. Transported fine sediments collected from seven in-stream sampling stations showed longitudinal variability of the nitrogen isotopic signature reflecting the increased proportion of streambank erosion lower in the watershed. The time-series of the nitrogen isotope was analyzed for a mean/seasonal trend and compared with water temperature data as well as the timing of significant hydrologic events that have been found to transport sediments in the watershed. The results support the idea that during transport of sediments from the watershed, the nitrogen isotopic signature of sediment particulate organic matter varies seasonally and that the enrichment and depletion of the isotopic signature is reflective of organic matter decomposition and accumulation in the streambed sediment deposits across seasons. The nitrogen isotope seasonal variability lags behind water temperature reflecting the interaction of the biogeochemical and hydrologic processes in the dynamic bed that includes temporary sediment storage and intermittent sediment flushing during a significant hydrologic event in the lowland watershed system.

The temporal results exemplified the conclusion that the nitrogen isotopic signature of transported fine sediments can vary considerably over seasons in lowland watersheds which should be accounted for when performing tracer studies to assess sediment source and fate in a watershed. After accounting for this variability, a mass balance un-mixing model analysis was performed to estimate the contribution of sediment from streambed and streambank end-members to the transported load throughout the basin and Monte Carlo sampling was included to assess the variability associated with the estimates.

WESTERN KENTUCKY DEEP SALINE RESERVOIR CO₂ STORAGE TEST

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The Kentucky Legislature passed House Bill 1 in 2007 mandating the Kentucky Geological Survey to conduct research in carbon storage. One of the mandated projects is to test the feasibility of storing carbon dioxide in deep saline aquifers in the Western Kentucky Coal Field. The monies granted by HB-1 were to be used as seed money to attract private and government partnerships. Early in 2008 the Kentucky Geological Survey partnered with industry interests to form the Kentucky Consortium for Carbon Storage to drill the Western Kentucky Deep Saline Aquifer Test.

The geologic constraints on the test were that the targeted saline aquifers would be penetrated at depths deep enough that the carbon dioxide behaves in a supercritical manner, at reasonable depths less than ~8000 ft, and that the porosity and permeability of any sandstone aquifers would not be affected by diagenetic alteration. After conducting a preliminary investigation of the geology of the Western Kentucky Coal Field, and the reservoir characteristics of identified deep regional saline aquifers, a site in eastern Hancock County was selected.

The projected total depth of the well is 8350 ft which will penetrate Precambrian basement rocks. The long casing string will be set at about 3850 feet and all target zones to be tested are between 3850 and 8000 ft. Three regional deep aquifers have been targeted by the project. Two of the aquifers are in sandstones, the Ordovician St. Peter Sandstone and the Cambrian Mount Simon Sandstone. The third aquifer consists of porosity zones within the Cambro-Ordovician Knox Dolomite. Rock units that will act as seals to keep injected gas from returning back to the surface are as important as the reservoir rocks. Several sealing rock units are present within the rock column to be penetrated by the test hole. The principal sealing horizons are the Cambrian Eau Claire Shale, above the Mount Simon, the Maquoketa Shale, massive carbonate rocks of Ordovician age above the St. Peter Sandstone, and the Devonian New Albany Shale.

The spud date for drilling is February 2009, with injection testing to be completed in April 2009. During the drilling phase cores and geophysical logs will be taken to evaluate the reservoirs and sealing strata. After the targeted units are evaluated, stepped injection tests using KCl brine and CO₂ will be conducted to test the individual aquifers for storage potential. At the completion of injection tests, and evaluation of the results, the well will be plugged and abandoned to meet state and federal requirements. Subsequent to abandonment of the well, the drilling site will be monitored for CO₂ emissions for a period of five years.

WESTERN KENTUCKY DEEP SALINE RESERVOIR CO₂ STORAGE TEST:
PRELIMINARY ENVIRONMENTAL ASSESSMENTS AND MONITORING

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In 2007, the Kentucky Geological Survey was mandated by House Bill 1 to assess the potential of injecting carbon dioxide into deep saline aquifers located within the Western Kentucky Coal Field. Aquifers of interest are the St. Peter Sandstone, Knox Dolomite and Mt. Simon Sandstone. Plans are underway to install an 8,300 ft deep injection well in Hancock County, Kentucky.

The purpose of this presentation is to summarize the various environmental assessment and monitoring programs associated with the installation of the Hancock County test well and carbon dioxide injection. Prior to the test well being installed, an environmental site assessment was conducted, shallow seismic was run near the installation site to identify any large voids in the underlying limestone, onsite soil gas chemistry was determined, a domestic well inventory was conducted within a two-mile radius of the test well, and a domestic water well, located on site, was sampled to collect shallow, baseline groundwater-quality data.

Work to be completed during the installation of the test well includes the sampling of each operational domestic well identified in the two-mile radius inventory and additional soil gas testing. After the test well is installed, a monitoring well will be installed to monitor the water quality associated with the first saline aquifer below the

undifferentiated Tar Spring/Glen Dean Formation. The monitoring well will be located within 400 ft of the test well and will be sampled before any injection occurs, weekly during injection, and quarterly, thereafter, for three years. Identified domestic wells will also be sampled weekly during injection. After injection occurs, surrounding domestic wells will be sampled quarterly and soil gas measurements will be collected periodically to monitor any potential groundwater and soil gas changes.

Groundwater monitoring will include field measurements (pH, electrical conductivity, dissolved oxygen, temperature and turbidity), alkalinity, TDS, total CO₂, dissolved inorganic carbon, metals, anions, and isotopes (H, C, and O). Groundwater sampling protocols will vary throughout the project. Soil gas monitoring will include CO₂ and CH₄ fluxes, bulk sampling of CO₂, CH₄, C₂H₆, and C₃H₈, and isotopic composition of the atmosphere and soil gases down to 3ft below land surface.

Updates and data related to all environmental assessments and monitoring associated with this project can be reviewed at www.kyccs.com.

ARSENITE OXIDATION BY A CHEMOSTAT CULTURE OF *THIOMONAS*
ARSENIIVORANS STRAIN B6

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Arsenic is a toxic metalloid known for its carcinogenicity in drinking water. Both anthropogenic and natural means are responsible for release of arsenic to the environment. The most common forms of arsenic in water are arsenite (oxidation state: +3) and arsenate (oxidation state: +5), with the former being at least 100 times more toxic and harmful than the latter. Current treatment technologies include a pre-oxidation step which oxidizes As (III) to As (V) and As (V) is finally removed through adsorption. Microbial oxidation of As (III) is considered as a cost-effective and an alternative mean of performing this pre-oxidation step compared to the conventional chemical methods. Biological oxidation of As (III) is achieved using both heterotrophic and autotrophic cultures. However, autotrophic As (III) oxidation is preferred due to the low nutritional requirement compared to heterotrophic strains.

Very few studies have investigated the potential of As (III) oxidation in a continuous flow bioreactor using an autotrophic strain. This present study evaluated the performance of a continuous stirred tank reactor in oxidizing As (III) to As (V) using the chemoautotrophic *thiomonas arsenivorans* strain b6. The reactor was operated continuously for 115 days with the attainment of eight steady-states, under a wide range of influent As (III) concentrations (300-4000 mg/L), and hydraulic retention times (HRTs) (21.7-74.9 h). Optimal growth conditions for the strain b6 were maintained in the reactor; with arsenic removal efficiency exceeding 99% for all the eight steady-states. The reactor quickly recovered from an As (III) overloading of 4847.4 ± 290.9 mg /L/day operated at a HRT of 21.7 h. An arsenic mass balance analysis revealed that As (III) was mainly oxidized to As (V) with the unaccounted arsenic within the analytical error of measurement.

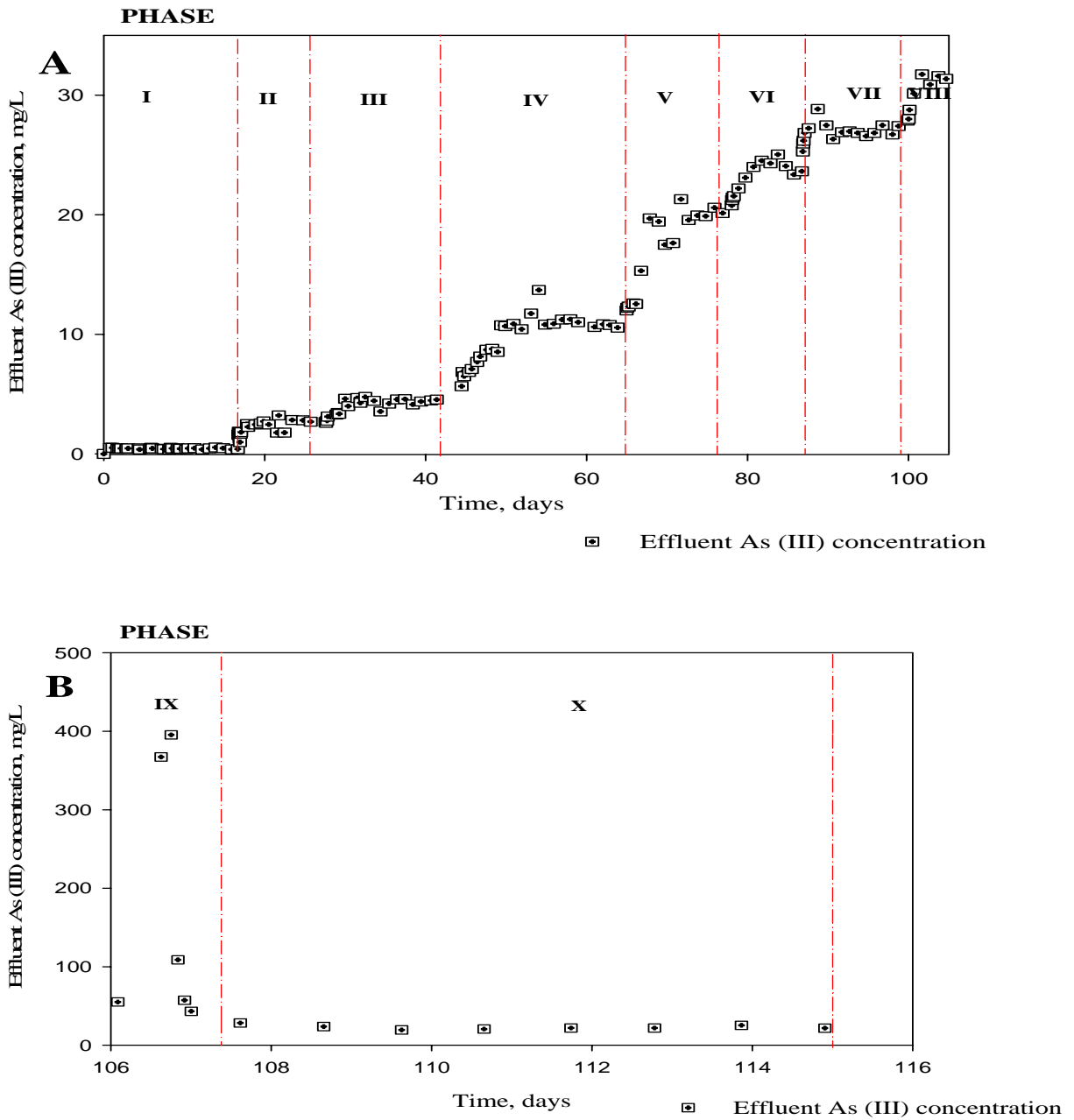


Figure 1. (A) Eight steady states under different influent As (III) and HRTs, and (B) failure and recovery of the CSTR from the As (III) overloading.

BIOLOGICAL CONTROL OF MANGANESE IN WATER SUPPLIES – A NEW
Mn(II)-OXIDIZING BACTERIA ISOLATE

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Manganese (Mn) is a common contaminant in water supplies largely due to the dissolution of manganese-rich rocks and soils and the kinetic stability of Mn at the pH and oxidation/reduction (E_h) conditions of these environments. In levels above the drinking water SMCL of 0.05 mg/L, manganese causes odor, taste, turbidity and color problems and can precipitate in water pipes, stain laundry and plumbing fixtures. Physical/chemical and biological treatment methods are used to control manganese in water supplies. Physical/chemical methods remove manganese by conversion of soluble Mn(II) to insoluble Mn(IV) through intense aeration or chemical oxidation followed by filtration of the oxidized insoluble products. Biological treatment methods are less frequently used and predominantly employ manganese-oxidizing bacteria that colonize granular filter media as biofilms which oxidize and accumulate Mn for removal. Physical/chemical processes can fail to provide consistent effluent quality which meets the SMCL for manganese in the presence of naturally occurring humic substances due to metal complexation. High oxidant doses or pre-oxidation with chemicals such as chlorine, ozone or permanganate are needed to remove humic substances for effective manganese control by conventional processes. These oxidants can react with natural organic matter to produce undesirable disinfection-by-products (DBPs), or smaller molecular weight organics that can lead to bacterial regrowth problems in distribution systems. For these reasons, interest in biological treatment methods for manganese control is increasing.

A Mn(II)- oxidizing bacteria strain has been recently isolated from a surface soil sample and will be used to improve our understanding of Mn(II) oxidation in batch and continuous flow bioreactors. The isolate has been identified based on partial sequencing of the 16S rDNA gene. The reconstructed sequence of the 16S rDNA was identified using GenBank Databases and a 100% match with *Pseudomonas Putida*, a gram-negative rod-shaped soil bacterium, was made.

Batch studies with this isolate have been performed to evaluate the relationship between substrate utilization rate, rate of Mn (II)-oxidation, and rate of bacterial growth utilizing α -D-glucose as the sole carbon source. Mn(II)-oxidation for this isolate begins in the early stationary growth phase and higher concentrations of Mn(II) delay the onset of Mn(II) oxidation. Mn(II) concentrations up to 15 mg/L do not appear to inhibit oxidation. Figure 1 shows experimental batch results for removal of Mn(II) from solution by this isolate. Optimal pH conditions for Mn(II)-oxidation are 7.0 to 7.5. Optimal temperatures for Mn(II)-oxidation are 25° to 30° C.

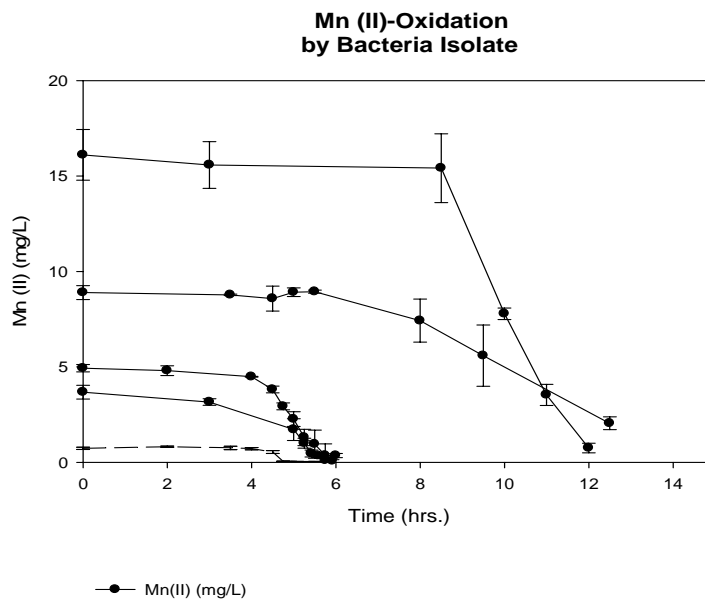


Figure 1. Mn(II)-oxidation experimental (triplicate) results with initial Mn(II) concentrations of 1, 4, 5, 9, and 17 mg/L.

Mn(II) –oxidation was modeled utilizing the Monod equations and the kinetic parameters were obtained using nonlinear regression analysis. This strain can oxidize Mn(II) utilizing several organic sources as the sole carbon source including humic substances. We now plan bench-scale batch and continuous flow biofilm bioreactor studies to investigate the efficacy of this strain to remove Mn(II) utilizing humic substances as the sole carbon source.

THE WARREN COUNTY BLUEWAYS INITIATIVE

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This presentation is about development of a Blueways trail system with access points throughout Warren County, KY and the adjacent counties. The project involved students from Western Kentucky University working in documenting and mapping the rivers in Warren County for the purpose of motorized and non-motorized watercraft use. Through GIS coordinate mapping and web page development, the project provides a living document easily printed from a computer for river users. The project continues through the work of multiple partners including government, public, not-for-profit, and private sectors.

What are the benefits of this project?

1. Potential improvement of the quality of life in Warren County and the region by opening up new possibilities for recreation.
2. By improving awareness of rivers and riparian areas in the region, citizens have become aware of the resources and their necessity for conservation of riparian zones.
3. Improvement of river access has resulted in more and easier access to river opportunities.
4. Economic development through tourism has resulted as the rivers become a destination for travel and recreation.
5. Blueways have become another venue for marketing and promotion of opportunities in Warren County
6. A new paddling club has developed as greater interest in rivers has developed.
7. River signage has increased awareness of public access points, thus decreasing land-owner/trespass issues and increasing safety.
8. Motorized boat traffic has been provided a way to distinguish which areas are suitable and safe for motor-boating. This includes jet skis, water skiing, and wakeboarding.
9. Fishing and waterfowl hunting (out of the city limits of Bowling Green) has been made more accessible
10. Instruction for all forms of watercraft uses and river rescue will be a natural extension of this program. Instruction in various types of activities like canoe, kayak, and river rescue are currently available.
11. And ultimately, by *bringing the rivers back* to the people of the region, the health of our community has improved.

Who were the partners in this project?

WKU students and faculty were engaged in public service while working on this project. This project has *engaged* students in *applied action* while completing a practical, valued project at the local level (think globally and act locally).

Government sectors involved in this project included County, Municipal, and State cooperation. The Warren County Fiscal Court implemented the river access improvements. Western Kentucky University's Outdoor Leadership Program implemented the Blueways mapping project. Additional partners included the GIS Program at WKU; Greenways Commission of Bowling Green and Warren County; Bowling Green and Warren County Parks Departments; Kentucky Division of Water; Kentucky Department of Fish and Wildlife Resources; and the Kentucky Watershed Management Branch. Not-for-profit agencies like the American Canoe Association's Water Trails program were also involved as was *We Make Things Happen Corporation* (a local company that donated graphic and web resources).

What about the future?

Through the web page and continued updating of this informational resource, ongoing information will continue as future access points are added to the blueways. The project is dynamic and continues to evolve. A future goal of this project is to be recognized by the American Canoe Association as an ACA-Recommended Water Trail.

Each summer, the American Canoe Association selects twelve water trails from the U.S. and Canada as ACA-Recommended Water Trails. ACA-Recommended Water Trails meet a set of basic criteria and stand out as particularly good destinations for paddlers. These trails earn the right to use a special ACA logo in maps, signs and other printed material related to the trail.

http://www.americancanoe.org/pdf/arwt_logo_sample.pdf

They also receive special recognition in the ACA's Water Trails database.

<http://www.americancanoe.org/recreation/watertrails.lasso>

The ACA requirements for inclusion in the ACA-Recommended Water Trails have served as guidelines in development of river stewardship throughout this project. These have included:

- a. Published information (Printable Blueways map on web page which identifies access points, GPS coordinates, and distances from access points).
- b. Conservation and Leave-No-Trace educational materials utilizing the Blueways webpage to encourage appropriate low-impact ethics for water trail users.
- c. Signage at access points.

THE BIG SANDY “BIG DIP”:
EFFECTIVENES OF A COMMUNITY-ORIENTED
AND GEOGRAPHICALLY INTENSIVE APPROACH TO ASSESSING
SMALL HEADWATER STREAM HEALTH

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Between May 2007 and August 2008, water samples were collected in headwater streams in the Big Sandy River basin, with the purpose of establishing baseline watershed health data for a suite of common water quality measures including dissolved oxygen, pH, temperature, conductivity, alkalinity, hardness, and iron. The study sought to further test a community-oriented geographically intensive sampling methodology first employed in the Kentucky River basin, and to refine both the sampling and analysis methods of the preceding study. Data were collected using teams of student and community volunteers using relatively simple to perform and low-cost field collection methods (e.g., multi-parameter probes and test strips). The results were then assembled into a GIS to examine geographic patterns in water quality.

In addition to discussing the general patterns of water quality observed in the Big Sandy Basin, the authors will discuss the advantages and drawbacks to the community-based sampling approach. Advantages include active engagement with local community members on matters they feel are of personal concern; the ability to deepen understanding of trends and observations with local knowledge; the large physical area that can be covered in a relatively short amount of time. Challenges include the training and organizing itinerant volunteers; and the necessary limits to the interpretation of the data.

SANITATION DISTRICT MANAGEMENT OF REPLACED/REPAIRED
INDIVIDUAL AND CLUSTERED WASTEWATER TREATMENT SYSTEMS IN
OLYMPIA, KENTUCKY

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A partnership composed of the Bath County Health Department, Bath County Sanitation District, Bath County Fiscal Court, Gateway Area Development District, Tetra Tech, and others was convened in 2006 to address bacteria contamination in Rose Run, a small stream in Bath County that empties into Slate Creek just southeast of Owingsville. The partnership was supported in part by Clean Water Act Section 319(h) funding provided by the KY Division of Water.

Consultation with Gateway and Bath County Health Department staff and local residents, reviews of water quality monitoring data, and windshield/walking surveys of the area indicated that likely sources of bacteria were pastured cattle and aging, malfunctioning septic systems in and around Olympia. Stream sampling indicated high bacteria concentrations in Rose Run adjacent to the community of Olympia, and a sanitary survey of selected homes found that many wastewater systems were old and in poor condition. High groundwater, low permeability soils, and small lots in the community complicated the situation. In addition, several “straight pipe” discharge lines were observed emptying poorly treated sewage into roadside ditches that drained into Rose Run.

Tetra Tech staff worked with the Bath County Sanitation District and the Health Department to assess wastewater treatment options for the community. The Sanitation District had recently assumed operation of a fairly large cluster system in nearby Preston, which featured septic tank effluent pump collection piping and a single-pass media filter followed by low pressure drip dispersal. That system was installed by public and other funding for about 110 homes at a cost of around \$21,000 per connection, according to project reports. Monthly service bills for customers began at approximately \$32 per month and have risen slightly over the past several years.

A similar soil-discharging centralized project concept for Olympia was developed by Tetra Tech, and subjected to preliminary design and cost analysis. Options including piping the septic tank effluent to Preston, several miles away; constructing a media filter and drip dispersal area for Olympia; and using a low-tech system replacement/repair approach to install individual and clustered septic tank / leaching chamber systems with imported fill and expanded drainfields where necessary. Capital costs for the first two options were approximately \$18 - \$23,000 per connection, similar to the Preston project. Monthly service fees were also projected to be similar, but would have to start out at around \$40 per month in order to generate enough revenue to maintain the pumped collection and pressure drip dispersal systems. This was judged to exceed the financial means of local residents.

Staff from the Bath County Health Department and Tetra Tech then conducted soil map reviews, soil assessments, and targeted lot-by-lot surveys to assess the possibility of repairing and/or replacing existing septic systems with new treatment units consisting of 1,500 gallon reinforced

concrete tanks with risers to the surface, concrete distribution boxes, gravelless leaching chambers, and – where necessary – imported soil to ensure that minimum system depth and separation distance requirements were met. Opportunities to cluster systems serving homes with very small lots or unfavorable site conditions were also considered, along with projected capital and monthly operation/maintenance charges. Staff from the Kentucky Division of Water Nonpoint Source Pollution Branch reviewed the preliminary repair/replacement option, and requested that details be presented and addressed in the project's *BMP Implementation Plan*.

Cost and other analyses regarding the system replacement/repair option were completed in early 2008, and the option was developed for KY DOW review. The Division of Water approved the *BMP Implementation Plan*, and work was scheduled to begin as soon as soil conditions improved. During the spring of 2008, project staff met with partner organizations and the certified system installers in the area to discuss possible site assessment, permitting, and installation procedures. The Bath County Sanitation District agreed to waive \$400 of its usual \$500 customer enrollment fee as part of the project "matching support" requirements. System installers also agreed to donate services, including some exploratory excavation work, removal and disposal of the old tank, final grading and seeding, and other tasks. In-kind match was also secured from a University of Kentucky student internship program, the Licking River Watershed Watch monitoring organization, the Bath County Health Department, and other sources.

Newspaper advertisements and articles informed local residents about the project, and flyers placed in the single local gas and grocery store provided additional details. Public meetings had been planned as part of the project's educational program, but they were found to be unnecessary due to the small size of the community, the ease in getting the word out, and the ongoing interaction among project partners and community members through the site assessment and sign-up activities. Project applicants were required to pay the \$100 reduced fee to the Sanitation District and signed an agreement to continue as a customer by paying \$25 per quarter for ongoing system inspections, pumping, and repair service. Drainfield easements for five small cluster systems were donated as part of the match, or purchased, in two cases. Soil to ensure proper system cover was also donated or purchased, depending on the site. Several installations required septic tank effluent pumping to upgradient areas with suitable soils for dispersal.

A total of 60 homes were served by the project, with most in the village of Olympia and a few others within the upper watershed of Rose Run, the project area. Water quality improvements were noted at the monitoring sites near Olympia, where bacteria concentrations declined from a high of 1220 CFUs per 100 ml to less than 200 CFUs. One particular sampling location near Olympia was the site of an odiferous blackwater pool within the Rose Run channel during dry weather, and was believed to consist mostly of poorly treated effluent from malfunctioning septic systems. Homes near the sampling site were connected to a small cluster system or received new individual systems. Nearly all of the sites where straight pipe discharges were observed were addressed by the project. Problems associated with post-installation soil settling, construction disruptions, contractor payments, and provision of match arose at times, but were quickly resolved. The dramatic slowdown in the construction industry no doubt helped the project by providing a strong incentive for system installers to participate and assist with matching support, but nearly all of them were from the area and expressed interest in supporting the effort for personal reasons. Final monitoring results for Rose Run are expected in the Summer of 2009.

ASSESSMENT OF COMBINED SEWER OVERFLOWS

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Kentucky currently has 13 communities that are impacted by combined sewer overflow (CSO) discharges. Each of these communities has entered into a consent decree agreement with the state of Kentucky to address ongoing water quality problems associated with such discharges. Given the state of the infrastructure of many of these systems, in-line storage or sewer separation may be cost prohibitive. As a result, alternative treatment strategies such as high rate disinfection may be preferable, at least in the short term. Chlorine is the most commonly used wastewater disinfectant, but alternatives to the chlorination of wastewater are desired due to the costs and hazards involved in transportation, storage and operation, particularly in highly populous areas. In addition, heightened public concern regarding the use of chlorine compounds which can produce toxic, mutagenic and carcinogenic by-products has stimulated the desire for alternative disinfectants. Thus, alternatives to chlorine disinfection are being sought for treatment of CSOs. Preliminary experiments conducted in Spring 2007 at the University of Kentucky showed promise for increased pathogen disinfection efficiency using the oxidant hydrogen peroxide along with metallic catalyst, VTX. This study is attempting to validate these results for a wide range of wastewater characteristics from multiple wastewater systems in Kentucky.

KENTUCKY AGRICULTURE WATER QUALITY ACT WEB TOOL

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The Agriculture Water Quality Act was passed by the Kentucky State Legislature in 1994. It states that landowners with 10 or more acres in agricultural or silvicultural (forestry) production must develop a water quality plan. This plan documents best management practices being followed to protect water resources.

Early tools for developing water quality plans included a printed booklet and a computer-based program. Both had limitations, and became cumbersome to update plans. A new tool has been developed to help landowners complete their plans. The web tool is available at www.ca.uky.edu/awqa.

To implement a water quality plan, a landowner must first look at the activities in his/her operation. Then the landowner can use the web tool to answer questions about his/her operation. By answering these questions, the landowner can identify the appropriate best management practices needed. The landowner documents that these practices are being used and properly maintained. In many cases, proper practices are already in place. Creating an Agriculture Water Quality plan just provides the landowner with a document that says he or she is doing the right things to protect water quality on their farm.

By implementing an agriculture water quality plan, landowners will be helping to protect both surface and groundwater from agricultural and silvicultural contaminants. Keeping the water resources of the Commonwealth clean protects human and animal health, and reduces the cost of treating drinking water.

CANE RUN WATERSHED COUNCIL
AN ADVENTURE IN WATERSHED INVOLVEMENT

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Watershed councils can serve as an open forum for discussion, bringing together diverse parties to identify and address watershed issues. These watershed advisory and action teams can positively impact a watershed project by generating interest at the local level and providing expertise and energy for specific issues. The Cane Run watershed assessment and restoration project has included the development of a watershed council. The council formed in December 2007 with the goal of facilitating community input and involvement in the Cane Run watershed. Members of the council include local officials, state and federal government representatives, private business representatives, non-profit organizations, and watershed residents. Activities have included a stream walk with city council members, a community clean-up, and coordination with the Friends of Cane Run for contaminant-specific roundtable discussions. Facilitating a watershed council requires respect of diverse opinions, patience, and encouragement of progress for the group. Throw in a cast of characters, a novice facilitator, and an impaired watershed and watch the fun unfold.

Impact statement:

The Cane Run Watershed Council has coordinated a stream walk with city council members, a community clean-up event, and roundtable discussions. These events have involved about 100 people, and are working toward the reduction of water pollutants to restore an impaired stream. The council has leveraged partnerships and funding from the Friends of Cane Run and Lexmark International, Inc., as well as partnerships from private consulting firms, citizens, and state and local officials. Development and continued facilitation of the council has exemplified the importance of partnerships and community buy-in for watershed project success.

PRELIMINARY COMPARISON OF NUTRIENT AND
TOTAL SUSPENDED SEDIMENT DATA ON WATER SAMPLES
COLLECTED USING TELEDYNE PORTABLE AUTOSAMPLER AND
EPA FIELD METHODS FOR WADEABLE STREAMS

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This study compares laboratory data of water samples collected using Teledyne portable autosamplers and standard EPA field method (grab) collected water samples. By examining the two collection methods, we are determining if the laboratory results are the same for both field collection methods. The study compared water samples collected by autosamplers to simultaneously collected water samples using the grab method. Water samples were collected from two creeks in Rowan County, Kentucky over a six hour time period. Two samples (one autosampler and one grab sample) were collected every hour and the samples represent different water levels and weather conditions. Water samples were analyzed using commonly used tests (alkalinity, organic carbon, organic nitrogen, total phosphorus, total suspended sediments, dissolved phosphorus, dissolved ammonium, dissolved nitrate, dissolved sulfate, and total iron). In addition, discharge was measured using both field and autosampler data. The two data sets, autosampler versus grab, show a significant difference between many of the traditional grab and autosampler collected water samples. However, some of the nutrient results were comparable between the collection methods. The differences in the laboratory results varied from nutrient to nutrient, as well as with water level.

GROUNDWATER PROTECTION PLANS

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401 KAR 5:037, the Groundwater Protection Plan Regulation, was promulgated in 1994 and went into effect in August, 1995. This administrative regulation requires anyone engaged in activities that have the potential to pollute groundwater to develop and implement a Groundwater Protection Plan (GPP). Unlike many environmental regulations, the GPP Regulation is proactive in that its purpose is to prevent groundwater pollution through public education and development of GPPs.

A GPP identifies activities at a site that have the potential to pollute groundwater and defines the best management practices used to protect groundwater. Other components of a plan include employee training, inspections, and record keeping. The regulation required the Division of Water to develop generic GPPs for on-site sewage disposal systems and water wells. In addition to the required generic GPPs, the Division has also developed generic GPPs for monitoring wells, home heating oil tanks, and poultry operations that are less than 5 acres. These plans are available free from the Watershed Management Branch or may be downloaded at the GPP Program's Web site <http://water.ky.gov/gw/gwprotection/gwplans>.

The activities that require the development of a GPP are listed in Section 2(2), (a) through (p) of the regulation, which can be accessed at the GPP Program's Web site. There are no specific qualifications, educational or professional, that a person must possess in order to develop a plan. Facility owner/operators may opt to develop the GPP themselves or have an employee develop the plan. Some choose to work with the GPP Program as they develop their plan; others engage a consulting or engineering firm. However, the Regulation does not require that a professional engineer or a professional geologist develop or sign off on the plan.

The GPP must be implemented immediately following development. Implementation does not depend upon approval of the GPP by the GPP Program. Submittal of a GPP for review and approval is optional unless

- it is required by an inspector from the Department for Environmental Protection
- it is requested by the GPP Program
- it is required by the Division of Enforcement as part of an Agreed Order.

The regulation requires that a GPP must be revised or recertified every three years or whenever there is a change in activities or personnel. At that time, the GPP must be reviewed to determine if activities have changed, if protective practices are working, and if there have been any changes in key personnel. If changes have occurred, the GPP must be revised. If no changes have occurred and protective practices are working, the GPP may be recertified for another three years by signing and dating a new Certification Statement. In either case, records must be retained for six years.

The GPP Program resides within the Groundwater Section of the Watershed Management Branch, Kentucky Division of Water. Any questions regarding the GPP Regulation or development of a GPP may be addressed to Patricia Keefe, P.G., coordinator of the program.

USE OF SURFACE GEOPHYSICAL TECHNIQUES TO LOCATE A KARST CONDUIT IN THE CANE RUN - ROYAL SPRING BASIN, KENTUCKY

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Groundwater flow in karst terrains is often focused through conduits that do not necessarily coincide with land-surface features. Mapping these conduits can be challenging, particularly when they cannot be accessed via techniques such as caving. We employed surface geophysical techniques in an attempt to locate the trunk conduit feeding Royal Spring, which is the primary water supply for the city of Georgetown, Kentucky. The upper part of the Royal Spring groundwater basin, which has been delineated by qualitative dye tracing, coincides with the Cane Run watershed. We conducted electrical resistivity (ER) and self potential (SP) surveys at three sites along Cane Run based on sinkhole locations and dye tracing. The ER exploration target is the low resistivity of water in the conduit, as compared to the high background resistivity of limestone bedrock. The SP technique has been used by various researchers to detect the electrokinetic potential generated by groundwater flow in karst.

ER and SP profiles were oriented perpendicular to the inferred trunk conduit. We measured eight ER profiles using a dipole-dipole configuration with electrode spacings of 2 to 3 m (total profiled distance 1252 m). The inversion software EarthImager 2D (version 2.2.0) was used to process the ER data. We measured SP along most of the same profiles and a test profile using a stationary reference electrode and a roving electrode moving at a fixed distance. Field drift in SP data was sensitive to temperature changes during the time of measurement. SP data collected over multiple days along the test profile differed significantly but showed similar trends. Six of seven SP profiles measured over a period of several months were found to be reproducible. The low-resistivity anomalies in the 2D inverted sections could be water-filled conduits, although mud-filled voids encountered during drilling suggest that these may be tributary conduits rather than the trunk conduit. Except for one SP profile at the UK agricultural research farm, low-resistivity anomalies corresponded to negative SP anomalies.

NUTRIENT AND FECAL MICROBE SOURCES FOR A EUTROPHIC LAKE AND
RECOMMENDED REMEDIATION STEPS,
WILGREEN LAKE, MADISON COUNTY, KENTUCKY

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Wilgreen Lake is a man-made lake, classified as nutrient-impaired (303d list) by the EPA and State of Kentucky. The lake drains a watershed with residential developments, cattle pasture, modified woodlands, and some industrial/urban usage in the city of Richmond. The principal tributaries are Taylor Fork and Old Town Branch that meet to form the trunk of the lake approximately one mile in length. The upper reaches of Taylor Fork are adjacent to a densely-packed (quarter-acre lots) housing development with septic systems, and its watershed drains some portions of southern Richmond. Old Town Branch drains cattle pasture and residential areas of moderate to large lot size. An intermittent tributary flowing into Pond Cove drains cattle pasture and one small housing development.

Fecal material contributes both nutrients and microbes to Wilgreen Lake. Both cattle and human fecal material enter the lake as documented by high fecal microbes counts and DNA tracing techniques. DNA tracing methods are limited by our sampling frequency but show that bovine *Bacteroides* microbes dominate water samples even at loci where suspected septic effluent enters the lake. The nitrogen isotopic composition ($\delta^{15}\text{N}$) of lake plankton and algae are broadly consistent with nitrogen input from human fecal material, but results are equivocal. We suspect that large amounts of nutrients do enter the lake through septic groundwater input, however, the strong bovine signal clearly suggests deployment of remediation methods that would limit runoff from pastures adjacent to Wilgreen Lake and within its watershed. Such methods include fencing cattle off from drainages and the lake, and planting vegetative buffers around stream and lake margins. Our data alone cannot justify elimination of septic systems by costly implementation of a sewage treatment system.

LINKING CHEMICAL TOLERANCE TO REPRODUCTIVE FITNESS: INITIAL RESULTS OF IN VITRO EXPERIMENTS EXAMINING POLLUTANT EFFECTS IN TELEOST PRIMARY HEPATOCYTES

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The disruptive effects of polychlorinated biphenyls (PCBs) on reproduction in a number of vertebrates including fish are well established and include altered hormone levels, reduced fecundity, decreased hatching success, and lower offspring survival. PCB resistant fish display lowered levels of the pollutant-inducible metabolizing enzyme cytochrome P4501A (CYP1A) in response to PCB exposure relative to non-resistant fish. The present study examines the consequences of natural resistance on the anti-estrogenic effects of PCBs in vitro. Isolated primary hepatocytes of PCB responsive fish (juvenile rainbow trout, *Oncorhynchus mykiss*) and a PCB resistant fish (gonadally mature male green sunfish, *Lepomis cyanellus*) were treated with estradiol in the presence and absence of two concentrations of the potent CYP1A agonist PCB 126. Activity of CYP1A and production of the egg yolk protein vitellogenin (VTG) were quantified. As anticipated CYP1A activity was significantly elevated over controls in PCB treated rainbow trout but not green sunfish cells. PCB exposure suppressed VTG production in vehicle but not estradiol treated rainbow trout hepatocytes. Green sunfish cells exhibited no VTG response to estradiol treatment, either in the presence or absence of PCBs. The results of this study demonstrate lack of VTG response in green sunfish hepatocytes despite exposure to conditions known to induce VTG synthesis in other teleost species; future work with this species should optimize cell culture conditions and include estrogen priming prior to hepatocyte isolation to improve VTG response to E2. The results of this study, while unable to address the original hypothesis, provide confirmation of *in vivo* CYP1A observations in a novel *in vitro* model, green sunfish hepatocytes, as well as data on the regulation of VTG in teleost hepatocytes.

GROUNDWATER DATA ON THE WEB:
SEARCH ENGINES FOR THE KENTUCKY
GROUNDWATER DATA REPOSITORY

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Since its inception in 1990, the Kentucky Groundwater Data Repository has compiled statewide groundwater data from several sources and disseminated these data to the public. Initially, customers had to call in their data requests, and for a fee, hardcopy printouts were then mailed. During the past seven years, however, a major effort has been underway to provide these data free of charge via the internet. Now, users have a choice of five different options to compile, view, map or download groundwater data.

Three types of groundwater data search engines and two interactive map services can be accessed online at kgsweb.uky.edu/DataSearching/watersearch.asp. Users can perform water-well or spring searches, groundwater-quality data searches, or conduct statistical evaluations and graphical comparisons of data retrieved from the site. Data points can be viewed on the interactive map services, or users can view statewide groundwater-quality maps already completed for 38 parameters in five categories (water properties, volatile organic compounds, nutrients, pesticides, and inorganic solutes). All data can be downloaded for use in GIS packages or other software. A karst potential map service is also available on the Web site.

This presentation will review procedures for searching, downloading, and displaying groundwater data from the three search engines available through the Repository (Fig. 1). For more information, contact the Survey at 859-257-5500 x162.

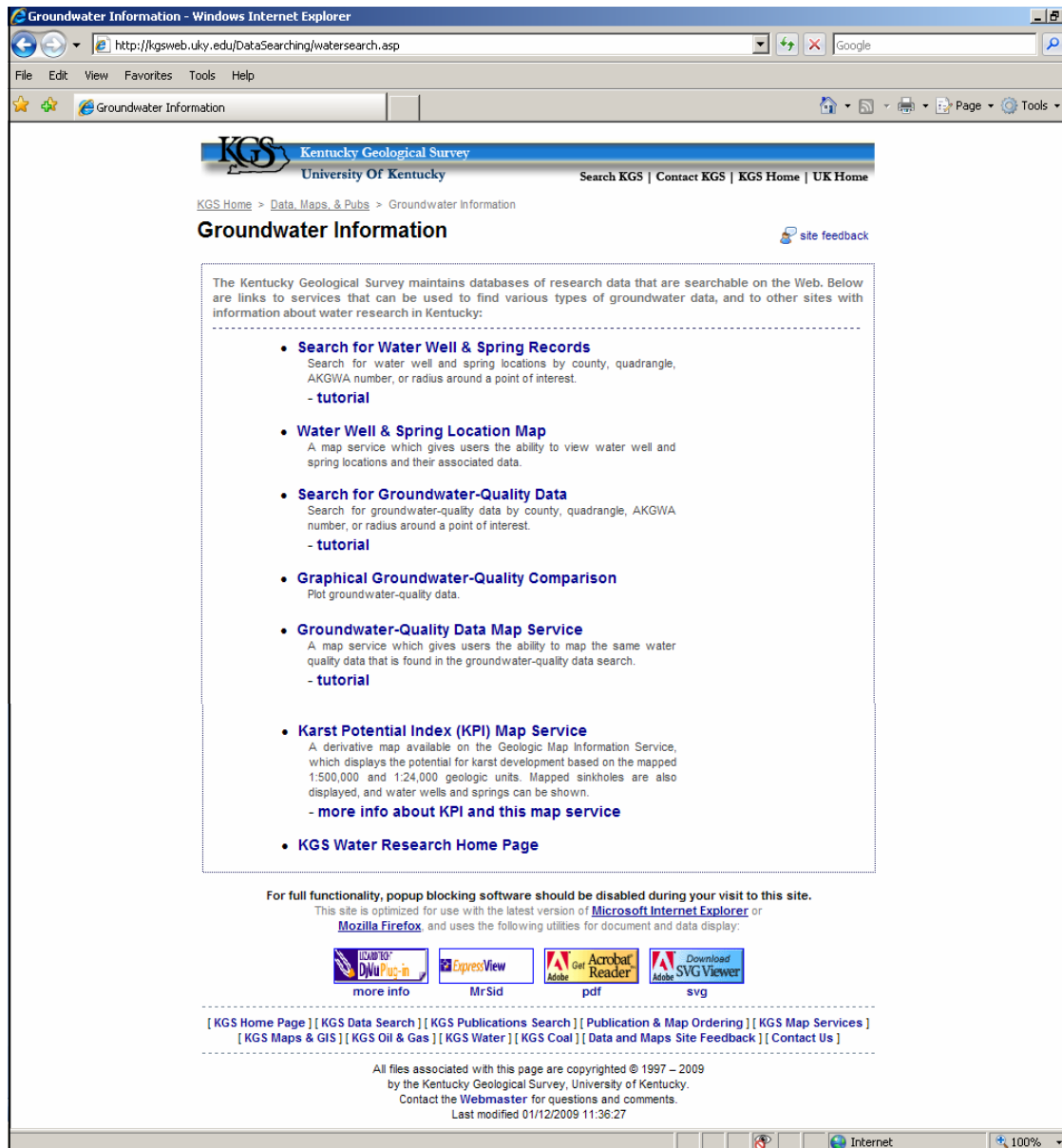


Figure 1. "Groundwater Information" Web page for the Kentucky Groundwater Data Repository, showing the various search engines and map services available.

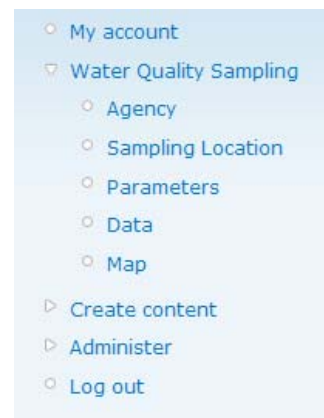
INTEGRATING WATER QUALITY SAMPLING DATA MANAGEMENT WITHIN AN ONLINE CONTENT MANAGEMENT SYSTEM

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Data management is essential to all companies and industries. The Data Management Association considers data management as the process of development, execution and supervision of plans, policies, programs and practices that control, protect, deliver and enhance the value of data and information assets. For data to become a useful resource it must be accurate, secure, easy to access for authorized users, and organized.

The internet provides a good access point for everyone to be able to easily enter and view the data. The Center for Water Resource Studies (CWRS) at Western Kentucky University (WKU) implements this online approach.

The CWRS houses an integrated data management system with its existing content management system (CMS) on its website, <http://waterky.org>. The Water Quality Sampling component of the site is designed to collect water quality sampling data and to provide Geographic Information System (GIS) tools for spatial analysis. It provides a place to add information about the agency, sampling location, parameters, and data. The information is stored and can be displayed in table form or on a map.



The CMS implemented by the Center for Water Resource Studies is called Drupal, an open source platform based on MySQL, an open source database system, and the PHP scripting language. Drupal is an easy to use, modify, and expand. Modules can be added for more functionality. The CWRS uses several additional modules for a robust content management system including one that adds mapping and GIS tools in real time on the site.

ASSESSING CARBON POOLS IN RIPARIAN SOILS AND SEDIMENTS OF TWO CONTRASTING CREEK ECOSYSTEMS

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Organic matter pools in soil and sediment are important factors influencing the dynamics of biogeochemical processes in creek ecosystems that may control both water quality and biota. Soil Carbon (C) pools can also be used for evaluating the functional characteristics of restored stream ecosystems. Total organic carbon (TOC) contributes significantly to water chemistry and nutrient availability and controls the solubility and toxicity of contaminants. Particulate organic carbon (POC) is an allocthonous source of energy for creek ecosystems and regulates the microbial communities and activities. POC can also act as a carrier to transport contaminants along water systems and influence water quality. Previous studies indicate that land use has changed the distribution of soil organic matter. However, there is limited information about Carbon pool patterns under contrasting creek ecosystems. The objectives of this research are to determine the effect of two creek ecosystems (agriculture and forest) on TOC and POC in riparian soils and sediments and to observe the effect of water fluctuations on these properties.

Samples were taken from Panther and Ledbetter Creeks, representing forest and agriculture watershed ecosystems, respectively. During August (high water period) and November (low water period), soil samples were collected from the riparian areas at depth intervals of 0 to 10, 10 to 20 and 20 to 30 cm. Six sites were selected for soil samples and three sites were selected for sediment samples at each creek. Soil and sediment samples were analyzed for TOC and POC. A parametric statistic (t-test) at α 0.05 was used to evaluate the effects of treatments on each variable response imposed at each depth. The effect of sampling time was analyzed by ecosystem at each depth.

The results indicate there was a significant effect of creek ecosystem on POC in soil at depths of 0 to 20 cm and in sediment at both sampling date. In November, TOC was significantly different between forest and agriculture ecosystem soils. There was no significant effect of ecosystem on TOC or POC in sediment during November. This research also shows that water fluctuations had a significant impact on the dynamics of POC in the forest soil and TOC in agriculture soil at the depth of 0-10 cm. Particulate organic C and TOC in sediment were significantly influenced by water fluctuations.

This study reveals the magnitude of changes in C pools due to different creek ecosystems and water fluctuations. The output provides background data to begin monitoring the riparian buffers in Ledbetter Creek (the agricultural watershed). It also provides a frame of reference for the potential contribution of C pools in soil and sediment which may impact the water quality in the creek.

THE EFFECT OF CLAY MINERALOGY ON INFILTRATION OF GRASS LAWNS

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Infiltration capacity is the rate at which water is absorbed by soil. Factors such as clay mineralogy affect infiltration capacity of soils. Highly expansive smectite clay in the soil can cause rapid reduction in infiltration rate (Romkens et al., 1995). A reduction in infiltration capacity results in increased storm runoff and even 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 (McCuen, 1998). Recently, 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 the irrigation of permeable surfaces to avoid excessive rates of irrigation on relatively less permeable surfaces.

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 are other factors that 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 results showed illite as the predominant clay mineral in most of the samples. There were diffraction patterns for chlorite and vermiculite in some samples. Generally, infiltration rates were relatively higher at sites that have both 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 cause 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 portion. The lower the clay minerals within the clay size portion, the higher the relative infiltration rate. Soil moisture seems to influence only the initial infiltration rate. Further studies may be necessary to determine the effect of the distribution of the silty illite particles around the sandy particles on infiltration.

THE USE OF THE ADV AND NEW VELOCITY SENSORS FOR STUDYING
TURBULENT PROCESSES IN THE FIELD AND LABORATORY

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Sediment derived from erosion and deposition in a watershed represents one of the predominant pollution sources impacting surface waters in Kentucky rivers, streams and reservoirs. This critical water problem is particularly difficult for the water resources community to solve because of the lack of accurate modeling tools for predicting the erosion of sediments. One of the reasons for error in sediment transport models is due to the lack of accurate linking between turbulence processes in the flow and sediment erosion and deposition. Once we gain an understanding of these turbulence processes, it can be used to understand the sediment/pollutant fate in rivers. This knowledge can also help us in designing better sediment control structures or stream restoration projects. In the past turbulent processes were studied primarily in the laboratory under varying isolated conditions. However in the actual rivers or streams isolated conditions do not exist. A number of phenomenon which effect turbulence processes occur together. This

has made the understanding turbulence processes as one of the biggest challenges to the water resources communities as the processes that occur in turbulence flows vary with a number of parameters including the Reynolds number, Froude number, relative roughness and wall roughness. All laboratory studies are performed at moderate Reynolds number where as in the field flows are generally of a high Reynolds number.

The objective of this study is to understand turbulent process for a range of hydraulic parameters. To carry out this objective, measurements are performed in both the field and lab under a range of flows using an acoustic Doppler velocimeter as well as new velocity sensors, which are calibrated in the laboratory. These new velocity sensors are left in the field to collect large amounts of instantaneous velocity data. The collected data are analyzed using both time-average and instantaneous analysis of the flow. The analyzed field and laboratory data are compared to understand the turbulence processes at high Reynolds number. This poster presentation details analysis of the initial results for this study and places particular focus on comparison of data from the acoustic Doppler velocimeter and the new velocity sensors. Additional results are on-going as this project continues to develop and the goals and obstacles recently encountered will also be presented.

REVIEW OF CARBON AND NITROGEN ELEMENTAL AND ISOTOPIC
MEASUREMENTS FOR ASSESSING THE SOURCE, FATE AND TRANSPORT OF
SEDIMENT AT THE WATERSHED SCALE

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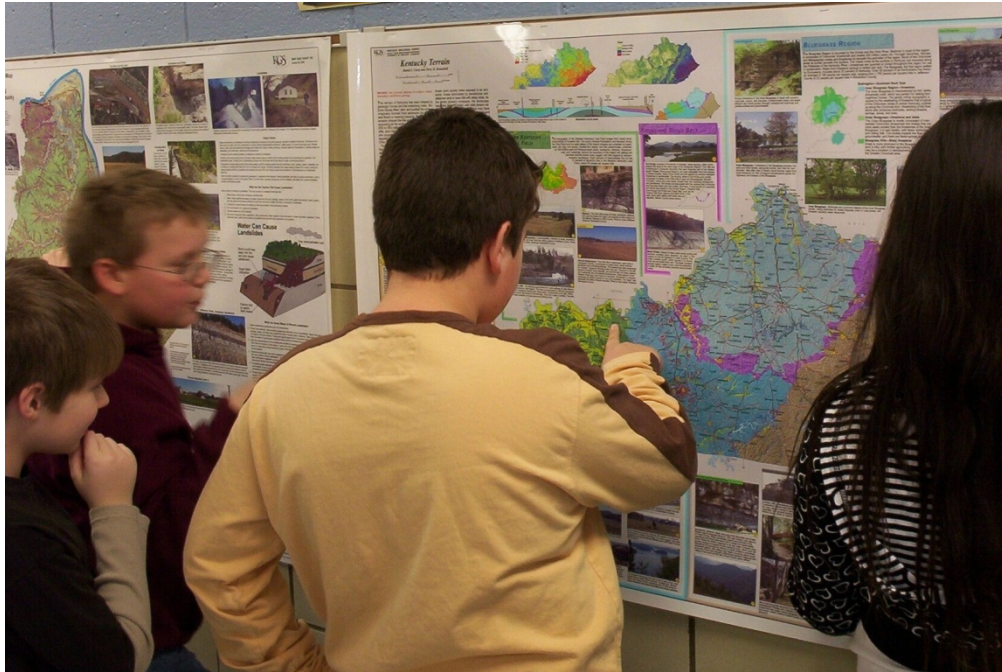
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This poster presentation provides a literature review that analyzes and discusses several of the reasons that carbon and nitrogen isotopes are used as tracers for the assessment of the source, fate, and transport of sediment in a watershed. Carbon and nitrogen isotopes in a watershed are fractionated at their soil organic matter (SOM) sources due to the processes associated with land-use and land management and are then eroded into streams and termed sediment particulate organic matter (SPOM). The isotopic signatures of transported SPOM can be analyzed by mass balance un-mixing within the sediment fingerprinting method to identify the contribution of SPOM from each of the SOM sources. Reported $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, and C/N values are reviewed and compiled from a number of studies for various land-use sources in order to provide a database so that researchers use the information as a tool when performing source identification studies. In addition to changes across land use, carbon and nitrogen isotope values have been reported to increase as soil depth increases due to the enrichment of soil, which must be integrated in sediment transport studies where the erosion depth is pronounced. The isotopic variation with depth and associated processes are discussed and the data is compiled here. Finally, it is known that SPOM can be changed biogeochemically as it is transported from its source due to the fate by microbial processes in-stream. These processes are discussed and reviewed with emphasis on seasonal changes. The literature is commonly not specific enough regarding tracer fate in-stream and it is suggested that methodological advancement of sediment fingerprinting with carbon and nitrogen isotopes is needed that overcomes this limitation.

SCIENCE IN THE CLASSROOM: MAPS TO TEACHERS

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In an effort to reach out to teachers across the state, the Kentucky Geological Survey has launched its Maps to Teachers service. Teachers may request free, laminated copies of maps for their classrooms by contacting Dan Carey at KGS, carey@uky.edu.



Generalized Geologic Maps for Land-Use Planning are now available for all Kentucky counties (kgsweb.uky.edu/download/geology/landuse/lumaps.htm), complemented by a PowerPoint presentation Maps Tell Us About Where We Live (kgsweb.uky.edu/download/geology/mapbook.ppt). The statewide map, “Kentucky Terrain” (kgsweb.uky.edu/olops/pub/kgs/mc187_12.pdf) displays the different landscapes across the state. “Geologic Hazards in Kentucky” shows the type and extent of geologic hazards in the state (kgsweb.uky.edu/olops/pub/kgs/mc185_12.pdf). The purpose of all these maps is to help students and the general public better understand the geology of where they live and how the rocks that form the land may affect human activities. All maps are illustrated with photos and diagrams, and supplemented with text to explain geologic issues.

As of January 2009, more than 1,000 KGS maps were in more than 360 schools across Kentucky. The following quotes demonstrate the success of the program:



"Thank you so much for sending my class the geology map for Fayette County. I have it prominently displayed in the classroom and my students started using it as soon as I hung it up to find sinkholes near their homes. The resource that you have provided will greatly enhance my instruction by clearly illustrating to my students the importance of earth science in their daily lives. Also, thank you for the Web site links!"

"On behalf of our entire Science Department, I want to thank you for the beautiful map of Mason County. It is full of terrific learning opportunities for our kids."

"Thank you so much for sending the maps of Allen County. They are very neat. I shared one of mine with the social studies teacher. However, when one of the other S.S. teachers saw them she really wanted one. If you are capable of sending another set that would be great! Once again thank you for sending such a wonderful resource to us at no cost!"

"I recently received the Floyd County map and it is wonderful. In fact it is so nice that the social studies teachers in my building and the rest of the science department asked if they could each get one. That is a total of seven teachers. Just checking if it would be possible to get some more of those? Have a great day and great job on the map."

EXTENDING A DECISION SUPPORT SOFTWARE OBJECT MODEL FOR USE IN KENTUCKY HYDROLOGIC MODELING

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The 1996 Amendments to the Safe Drinking Water Act required that each State prepare a source water assessment for all public water systems (PWS) regulated by the State to determine whether a drinking-water source might be susceptible to natural or anthropogenic contamination. Consequently, in 1998 the U.S. Geological Survey, in partnership with the Texas Commission on Environmental Quality (TCEQ), began development of a scientifically defensible methodology for assessing susceptibility of Texas PWS to contamination. A primary product of this ongoing project is SWAP-DSS, a decision-support system for source-water susceptibility assessment. The SWAP-DSS evaluates attributes and indicator values according to decision rules to produce susceptibility ratings for each assessed contaminant for each public drinking-water source.

During 2003, TCEQ staff used SWAP-DSS to assess susceptibility of more than 6,200 public water supplies, which represent more than 18,000 individual source assessments, to some 227 contaminants. TCEQ is currently using the latest version of SWAP-DSS to re-assess susceptibility of Texas PWS to contamination in a continuing effort to protect public drinking water. In order to address the broad scope of this effort, which requires many datasets, attributes, indicators, ratings, and decision rules, a component-based assessment methodology and supporting software architecture (an application) was developed. Components were developed to address (1) physical integrity of the PWS; (2) intrinsic characteristics; (3) potential non-point and point sources of contaminants; (4) area of primary influence activity; (5) contaminant occurrence; and (6) source and system susceptibility. These components are organized within a layered framework where decision rules and application logic code (business layer) are separated from database and data access code (data layer) and user interface code (ui interface layer); this represents a significant change from past software development practices where code functionality was mixed.

High-level applications are then organized utilizing the MVC software design pattern where the Controller handles application flow; the Model represents the data; and the View takes care of presentation. In this way, custom applications may be created where the user is able to bring complex modeling components to bear on real world problems - without having extensive database or modeling expertise. Further, using the same underlying software components, the application can be presented within a traditional user-interface framework, a web-based framework, or a framework where no user interface is necessary such as command line or web services.

The SWAP-DSS component-based software architecture, based on object-oriented development principles, has proven to be valuable to ongoing modeling work and cooperative efforts, both in providing a blueprint for new development, and in providing computer code which can be extended or modified for use in Kentucky hydrologic applications. In particular spatial-analysis code such as computing land-use area or spatially-distributed method code such as water budgets, load estimation, etc., have been created and organized into software “objects.” These objects are organized into components representing a particular part of the hydrologic problem domain, and in this way components may be re-used to develop higher-level model applications.

The Water-Availability Toolbox for Environmental Resources (WATER) is a custom application currently under development at the USGS Kentucky Water Science Center that uses the hydrologic components discussed here. The WATER toolbox is an effort to provide easy to use hydrologic modeling tools for a number of cooperative projects within the state. Examples are modeling stream response to historic hydrologic events in non-karst areas of Kentucky and water-budget estimation using daily rainfall, soils, and topographic wetness indices.

APPLICATION OF GIS HYDROLOGIC DATA MODELS TO KARST TERRAINS

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Hydrologic Data Models (HDMs) are digital representations of surface-drainage networks created from Digital Elevation Model datasets (DEMs) using GIS terrain-processing methods and specialized software such as ESRI's Arc Hydro (Maidment, 2002). HDMs are used frequently to address complex water-resources management issues. However, in karst terrains, the presence of sinkholes and subsurface conduit flow makes the creation and use of HDMs highly problematic. As part of the USGS Ground-Water Resources Program Karst Hydrology Initiative, a pilot study was conducted to determine how conventional HDM processing techniques can be modified for use in karst. The Graham Springs basin, located in the Western Pennyroyal karst region of Kentucky, was used as a test case. This large (360 km²) well-developed karst basin is characterized by extensive sinkhole topography, sinking streams, a complex network of subsurface conduits, and discharge to multiple underflow and overflow karst springs.

As summarized in Taylor and others (2008), conventional and specially-developed terrain-processing methods were used to assemble the necessary GIS datasets, and various ArcGIS and Arc Hydro networking tools were applied to create a digital drainage network to represent the physical hydrologic framework of the Graham Springs basin. The Arc Hydro hydrologic features schema was applied to create topologically correct links between basin inputs (sinkhole catchments, dye-tracer-input sites, and sinking streams), and outputs (karst springs and surface streams), by way of tracer-inferred throughputs (conduit flow paths). Spatial-temporal variability in karst discharge or flow routes is also represented. The resulting karst HDM can be used as an effective new tool to manage and visualize complex karst hydrologic data, and to identify contributing areas, surface and subsurface flow routes, and downstream water receptors, under varying hydrologic conditions. The karst HDM can also be used to track and assess spatial and temporal changes in field-monitored hydrologic parameters such as discharge measurements and water-quality data.

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KENTUCKY STREAM RECONNAISSANCE FOR EMERGING CONTAMINANTS

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Emerging contaminants are prescription and over the counter drugs, detergent by-products, fragrances, cosmetics, sunscreen agents, diagnostic agents and other compounds frequently used in modern society that are subsequently found in the environment. An important component of emerging contaminant research is to determine the environmental occurrence by answering the fundamental questions: What compounds enter the environment? How often and at what levels do they occur? In what mixtures do they occur? These questions are addressed by field reconnaissance studies at national, regional, and local scales. In 2008, the USGS Kentucky and Kansas Water Science Centers, in Cooperation with the Kentucky Division of Water, sampled raw water and sediments from selected stream reaches in Kentucky. Six of these sites bracketed the outfalls of wastewater treatment facilities, one bracketed several concentrated animal feeding operations (CAFO), and two were control reaches on which no detections of any contaminant were expected. Initial results indicate that these contaminants are present in Kentucky streams. The data from this reconnaissance is brought into regional and national perspective through on-going studies conducted by the USGS through such programs as the Toxic Substances Hydrology Program where greater than 120 research papers have been written on the subject of emerging contaminants.

PRELIMINARY COMPARISON OF DISCHARGE DATA OBTAINED BY
TELEDYNE PORTABLE AUTOSAMPLER AND USGS/EPA FIELD METHODS
FOR WADEABLE STREAMS

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Ongoing assessment and monitoring activities in the Triplett Creek watershed of Rowan County, Kentucky 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. The objective of this preliminary report is to compare discharge data obtained using a Teledyne portable autosampler and manual USGS/EPA field methods.

Variables used to compute discharge include velocity, width, and depth. The autosampler measures velocity with a sensor that emits ultrasonic soundwaves that are reflected by bubbles and particles carried by the stream and then received by a second transducer. The velocity is derived from the degree of Doppler shift measured for the reflected signal. In order to test the accuracy of these measurements, velocity was measured adjacent to the sensor using manual methods (flow meter or neutrally buoyant object method of Rantz et al., 1982). The autosampler measures depth using a pressure transducer. To test the accuracy of these measurements, water depth was measured adjacent to the pressure transducer using a wading rod or rule. The autosampler does not measure width. Instead, width of the entire stream is measured with a tape and entered into the autosampler. To date, discharge (Q) using autosampler data is calculated as $Q=VxDxW$, a single rectangular cross-section multiplied by velocity. Manually acquired data was used to calculate Q according to the methods of Rantz et al. (1982).

Preliminary results for one site indicate that the velocity measured by the autosampler is about 14% less than velocity determined by flow meter. The velocity measured by the autosampler is about 56% lower than velocity determined by the neutrally buoyant object method. Manual and autosampler depths differ by about 5%. Discharge calculated with autosampler data ($Q=VxDxW$) is about 50% greater than discharge manually determined with a flow meter and the velocity-area method but about 30% lower than discharge determined by the neutrally buoyant object method.

