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Kentucky Water Resources Research Institute, University of Kentucky

Kentucky Water Resources Annual Symposium

March 21, 2011

Marriott's Griffin Gate Resort
Lexington, Kentucky

UNIVERSITY OF KENTUCKY
Kentucky Water Resources Research Institute

Sponsored by
Kentucky Water Resources Research Institute
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PILOT STUDY TO INTEGRATE EXISTING KARST FLOW DATA FOR KENTUCKY INTO THE NATIONAL HYDROGRAPHY DATASET CREATED BY THE U.S. GEOLOGICAL SURVEY

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The U.S. Geological Survey's (USGS) National Hydrography Dataset (NHD) is a map layer of surface streams in the United States for use with geographic information systems (GIS). The NHD digital product was designed to also allow incorporation of various groundwater data.

The Kentucky Geological Survey (KGS) and Kentucky Division of Water (KDOW) have compiled and digitized karst flow data for more than half of the karst regions in Kentucky. These data, obtained from many investigators, have been published by KGS in the Kentucky Karst Atlas map series and are available as data files for use with GIS.

The USGS and KDOW have funded a pilot study, conducted by KDOW, to integrate existing karst data into the NHD. The pilot study area, located in the southwestern Mississippian Plateau Region of Kentucky, is the West Fork Red River watershed. This area was chosen because known karst flow data have been compiled and digitized and it provides good representation of a wide array of karst features present in Kentucky.

Karst flow data are being added using the NHD Geo Edit toolset, which was developed by the USGS. Karst features are classified using *Feature Types (FType)* and *Categories* as defined within the NHD. Subsurface flow routes are added using the *FType* 'Underground Conduit'. *Category* is then used to convey whether the subsurface flow route is inferred from dye tracing or based on cave surveys.

Incorporating previously omitted subsurface flow data into the NHD will provide several benefits, primarily: 1) demonstration of local deviation of karst drainage from topographic watershed divides, 2) establishing a baseline for mapping karst features and groundwater flow paths within the NHD, and 3) improving accuracy and applicability of information used for hydrologic modeling, research and field investigation.

NOTES

AN EVALUATION OF PHYSICAL AND CHEMICAL DISCHARGE PARAMETERS FROM A SPRING THAT DRAINS THE EPIKARST

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Physical and chemical parameters measured at a spring's discharge point can be used to determine recharge mode to the spring's groundwater recharge basin. This study showed that conductivity, temperature and stage, measured by a digital datalogger, can be used to determine the type and percentage of recharge, seepage versus quick-flow, that contribute to a spring's discharge point.

Ewers Alley Spring is a small perennial spring that drains a groundwater basin developed solely within the epikarst. This spring was fitted with a digital datalogger to determine if changes in temperature, conductivity and stage, which have been used to characterize springs that drain mature karst basins, can also be used to characterize recharge to a basin that is charged solely from groundwater stored in the epikarst.

The study determined that changes in temperature, conductivity and stage in response to precipitation events could be used to determine recharge type to a drainage basin located solely in the epikarst.

Changes in temperature, conductivity and stage indicate that Ewers Ally Spring is dominated by seepage recharge conditions, and at baseflow conditions the groundwater in all probability is saturated in respect to calcium carbonate. During wetter periods of the year when flow from the epikarst is greater, groundwater discharge from the spring is prone to be undersaturated in respect to calcium carbonate due to the influx of fresh water into the epikarstic system. In spite of the fact that seepage recharge conditions dominate the system, numerous vertical conduits and open channels, present in the epikarst, can transmit water rapidly into the system; resulting in quick-flow conditions that can travel quickly to groundwater receptors in the basin. However, the effects of quick-flow conditions on the spring's response are limited due to the predominance of the overlying soil cover and the restricted radius of influence of open pits and shafts.

Measured baseflow discharge at Ewers Ally Spring is 0.002 cubic feet per second. "Normalized Base Flow" per unit discharge, approximating Inner Bluegrass region karst drainage basins, calculates a spring recharge area or basin size of 7.3 acres.

NOTES

CHARACTERIZING HEALTH RISKS IN PRIVATELY-SUPPLIED DRINKING WATER DUE TO AGRICULTURAL PRACTICES IN RURAL WESTERN KENTUCKY, LEADING TO AN INTERVENTION STUDY

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At least 400,000 people in Kentucky rely on private water wells or springs for drinking water. Water well owners in Kentucky are responsible for testing and maintaining water quality. 551 households that rely on private water wells for drinking water were surveyed in 2009 about adverse health outcomes, including selected cancer incidence, adverse birth outcomes, and yearly incidence of diarrheal illness. Survey recipients were drawn from a population of well owners in the Jackson Purchase Region of Kentucky whose wells were tested for nitrate-nitrogen (NO3-N), triazine pesticides, and *E. coli* or total coliforms, by the Kentucky Geologic Survey within the previous 15 years. 214 questionnaires were returned and matched to water quality data for analysis; the effective response rate was 39%.

NO3-N contamination in water comes from artificial or organic nitrogen-containing fertilizers, and from human and animal fecal waste. Of 211 wells in this study with NO3-N results available, 11 (5.91%) had NO3-N concentration above the MCL of 10 mg/L. Of 189 wells in this study with triazine pesticide results available, 1 (0.53%) had concentration above the MCL of 3 µg/L; 123 (65.08%) had undetectable concentrations of triazine pesticides. NO3-N and triazine levels were not independently distributed; shallower bored well construction was predictive of higher concentrations of both contaminants, consistent with other research. *E. coli* contamination was detected in 14.5% of wells tested in the study population, and total coliforms were present in 59.3%. Over one-fifth (21%) of wells in the study population were contaminated with all three, total coliforms, triazine pesticides and NO3-N, above background concentrations, indicating the wells' vulnerability to surface-level contamination that can result from well construction and agricultural land use practices.

NO3-N is converted in the body to carcinogenic N-nitroso compounds. Survey respondents were asked about household incidence of non-Hodgkin's lymphoma and liver, stomach and breast cancers. SIRs were calculated to compare the study population with reference populations. The study population seemed to experience a higher incidence of liver cancer than reference populations. Odds ratios comparing cancer incidences in two above-background concentration categories for NO3-N suggest an association between NO3-N exposure in drinking water and cancer incidence, however, there was no significant relationship shown between NO3-N levels in well water and Non-Hodgkin's lymphoma, liver, stomach cancer or breast cancer incidence.

Adjusted odds ratio estimates from logistic regression analysis of risk for selected cancers as a result of nitrate concentration.	NO3-N concentration	N	OR estimate (95% CI)
Non-Hodgkin's lymphoma	<1 mg/L	1	
	>= 1 mg/L and < 2 mg/L	1	1.84 (0.11, 30.21)
	>= 2 mg/L	5	3.58 (0.41, 31.30)
Liver cancer	<1 mg/L	1	
	>= 1 mg/L and < 2 mg/L	2	3.68 (0.32, 41.90)
	>= 2 mg/L	3	2.10 (0.21, 20.65)
Stomach cancer	<1 mg/L	1	
	>= 1 mg/L and < 2 mg/L	0	(*not calculable*)
	>= 2 mg/L	1	0.69 (0.04, 11.27)
Breast cancer	<1 mg/L	3	
	>= 1 mg/L and < 2 mg/L	4	2.51 (0.53, 11.87)
	>= 2 mg/L	9	2.18 (0.57, 8.35)

Analysis of triazine concentration in the study population was suggestive of an association between higher concentrations in drinking water and adverse birth outcomes including intrauterine death, miscarriage and premature birth, with no statistically significant relationship shown.

Odds ratio estimates from logistic regression analysis of risk for selected adverse birth outcomes as a result of triazine concentration.	Triazine concentration	OR estimate (95% CI)
Intrauterine death	<0.1 µg/L	
	>= 0.1 µg/L	5.71 (0.51, 64.65)
Miscarriage	<0.1 µg/L	
	>= 0.1 µg/L	3.21 (0.98, 10.44)
Premature birth	<0.1 µg/L	
	>= 0.1 µg/L	9.13 (0.93, 89.81)

The presence of coliform bacteria in water indicates possible sewage pollution. Presence of *E.coli* or total coliform in the water from wells in the study population, whether modeled on a continuous or present/absent scale, was a poor predictor of yearly household incidence of gastrointestinal disease.

Small size limited the power of this study to generate statistical significance for some suggestive relationships between water contaminants and adverse health outcomes consistent with other research. Other improvements to study design should be made to address weaknesses. Further research is called for on how to make recommended drinking water testing accessible to water well owners.

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AQUEOUS GEOCHEMISTRY OF A CO_2-ENHANCED OIL RECOVERY PROJECT IN THE SUGAR CREEK OIL FIELD, HOPKINS COUNTY, KENTUCKY

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Approximately 7,200 tons of CO_2 were injected into the Mississippian Jackson Sandstone oil reservoir in the Sugar Creek field from May 2009 to May 2010. This enhanced oil recovery (EOR) project is part of the Midwest Geological Sequestration Consortium pilot program, which is headed by the Illinois State Geological Survey in collaboration with the state surveys of Kentucky and Indiana. Goals of this EOR project included: 1) assessment of the viability of using CO_2 for EOR in Kentucky, 2) characterization of aqueous geochemical responses to CO_2 injection, 3) estimation of the amount of CO_2 that remains sequestered, and 4) investigation of sequestration mechanisms in the reservoir.

Since its discovery in 1964, the Sugar Creek field has produced approximately 34 percent (905,000 barrels) of the estimated original oil in place (2,680,000 barrels). The reservoir is a stratigraphic trap in a double lobe shape. Both lobes dip downward to the south of the injection well with limited hydraulic interaction between the two lobes. Primary recovery was by solution gas drive, and secondary recovery via waterflood has been in place since 1993. Tertiary recovery was initiated by the injection of about 7,200 tons of CO_2 via a central well from May 2009 to May 2010, after which waterflood operations were resumed.

Geochemical monitoring was performed before, during, and after CO_2 injection. Aqueous geochemical changes in the reservoir were monitored by the monthly collection of brine samples from eight production wells surrounding the injection well. In addition, three shallow groundwater monitoring wells, two domestic water wells, and one water-supply well were sampled quarterly to assure the water quality of nearby shallow aquifers was not affected. During sampling, field measurements of temperature, specific conductance, pH, dissolved oxygen, and oxidation-reduction potential were taken for all wells. Water samples were analyzed for alkalinity, total CO_2, dissolved anions and metals, and total dissolved solids in the laboratory. An infrared gas analyzer was used to measure the concentrations of free-phase CO_2 at oil production wells. Gas samples were also collected for bulk and $\delta^{13}C$-CO_2 measurements. Lastly, reservoir pressure was monitored at the injection well and surface pressure was monitored at the production wells.

Free-phase CO_2 was detected in five oil production wells, all on the west side of the field. Typically, after the arrival of CO_2 to the wellbore (i.e., breakthrough), pH decreased one pH unit, and chloride, calcium, strontium, and iron concentrations increased, on average, by 200 mg/L, 115 mg/L, 45 mg/L, and 2.5 mg/L, respectively. The pH decrease occurred very closely to the time of CO_2 breakthrough. Barium concentrations, in contrast, decreased. Aqueous geochemical changes occurred less than 1 to 4 months after CO_2 breakthrough. Since CO_2 injection was halted, pH values have generally remained below pre-injection values and most other geochemical constituents have continued to increase in concentration. The sustained low pH values indicate that CO_2 is remaining in aqueous solution in the reservoir. No geochemical changes have been observed in the overlying aquifers that would indicate CO_2 leakage from the deeper reservoir formation. Post-CO_2 injection sampling is scheduled to continue through May 2011.

LAND-USE, STREAM CHANNEL DYNAMICS, AND MACROINVERTEBRATE COMMUNITY RESPONSES: A NORTHERN KENTUCKY CASE STUDY

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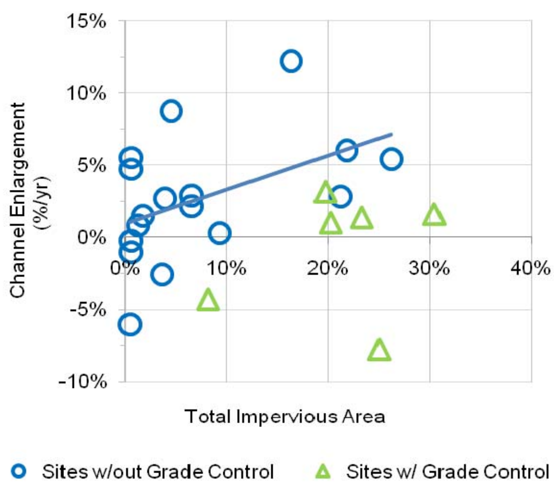
As land development progresses from urban corridors to suburban landscapes, watershed managers need an improved understanding of the impacts to Kentucky's water resources. Although there have been substantial expenditures on water chemistry data to study the effects on select water quality parameters, we have comparatively little geomorphic and biological data particularly as to how they relate to drainage areas. This empirical gap results in a limited understanding of how biological communities and their corresponding habitats are impacted by land-use dynamics. Consequently, stormwater management and land-use planning policies often do not account for these critical water-resource components. This presentation focuses on a coupling of geospatial, geomorphic, and biological datasets to explore the linkages of land-use characteristics on channel stability and biologic integrity in streams in an urbanized context.

A geospatial-based watershed descriptive metric approach was employed to derive an array of 45 hydrogeomorphic (e.g. drainage density, average watershed surface slope, etc.) and anthropogenic (e.g. road crossings per stream mile, impervious cover, etc.) metrics across watershed and riparian corridor scales that constitute the upstream drainage areas of 23 stream sites in northern Kentucky. The stream sites were selected as a representative subset of 46 field reconnaissance sites for a multi-year field data collection program. This field data collection effort included annually repeated level-tape surveys of the longitudinal profile and a representative riffle cross section, along with a 100-particle pebble count. Standard fluvial geomorphic variables were measured (e.g. bankfull top width, bank height and angle, etc.) and annual rates of geomorphic change were quantified across 21 metrics (e.g. longitudinal headcutting, change in channel depth, etc.). Benthic macroinvertebrates were also sampled at 21 of the 23 sites as a part of a broader biological sampling program conducted by Sanitation District No. 1 for 68 regional locations. Standard indices such as Kentucky's Macroinvertebrate Bioassessment Index (MBI) along with a multivariate examination of community structure were used to determine biological integrity.

Several statistical analyses indicated multiple relationships between upstream watershed characteristics and field site collected data. Based on preliminary results, geospatially derived metrics indicative of watershed urbanization such as greater amounts of impervious cover, changing land cover over time, and reduced tree canopy cover showed correlations with quantitative measures of channel instability (i.e. increasing cross sectional enlargement). One of the most intriguing relationships observed was a negative rate of change in riffle length with watershed imperviousness—that is, riffles in urban streams were becoming shorter.



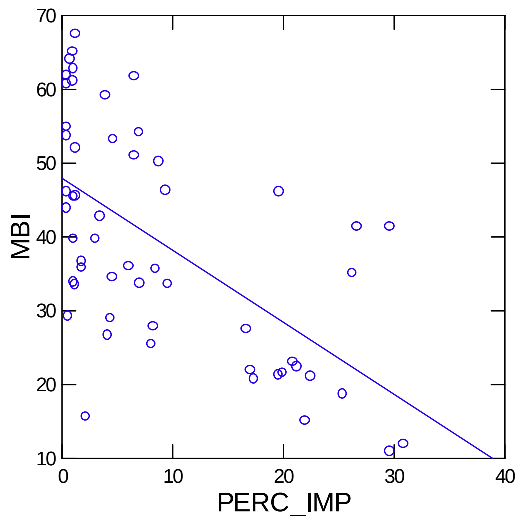


Figure 1 – (a) Channel enlargement and (b) MBI vs. imperviousness

Benthic metrics and indices corresponded to channel stability except in urban streams incised down to bedrock (grade control). Those five sites were geomorphically stable but had poor biological communities, likely due to the lack of habitat. Urban sites that lacked the stabilizing capacity of bedrock were geomorphically unstable, had differences in macroinvertebrate community structure, and showed poor biological values across several macroinvertebrate metrics, as well as MBI scores. The analyses indicate that imperviousness cover of upstream watershed drives many downstream biological metrics.

These findings demonstrate that 1) geospatial data can be used to link watershed characteristics to reach-scale morphologic and biologic field data, and 2) urbanization negatively correlates with indices of channel stability and biologic quality. It is our hope that these relationships will be expanded to other regions of Kentucky in order to improve stakeholder understanding of how land-use affects their water resources, and offer an additional framework for managers to consider these aspects of water quality in stormwater policies and practices.

KENTUCKY LiDAR MEETS NAIP MULTISPECTRAL IMAGERY: TOWARD DATA FUSION IN THE ASSESSMENT OF WATERSHED CHANGE

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Changes in land cover and topography can be highly dynamic and contemporaneous; measures of these rates of change can be used towards the development of environmental indicators of a watershed. Often, temporal land cover change detection is performed through analysis and classification of multispectral, multi-epoch images collected by passive sensors onboard satellites. Digital mapping cameras such as those used in cyclic collections of airborne orthophotography are now able to capture 4-band imagery routinely (Ryan and Pagnutti, 2009). Data acquisition by active remote sensing methods, e.g. LiDAR, has become commonplace for mapping elevation, making it also possible to explore its use in creating land cover classifications (Antonarakis et al., 2008).

As part of Kentucky's contribution to the Risk MAP Initiative (FEMA, 2009; FEMA 2010a), LiDAR was acquired on April 2010, for Magoffin County. LiDAR points were collected at approximately 1.0 m ground sampling distance with no snow on the ground, rivers at or below normal levels, and under cloud-free conditions; points were assigned classes of: "bare earth", "water" and "unclassified" (FEMA, 2010b). In the summer of 2010, 1-m, statewide, digital, multispectral 4-band ("red", "green", "blue" and "near infrared") orthoimagery was acquired as part of the National Agricultural Imagery Program (NAIP) (Kentucky Geography Network, 2010). The potential for synergy between these datasets was explored for the 2,270 Ha. Licking River watershed in Magoffin County, KY (14-digit HUC: 05100101010250); a watershed which experienced changes in topography and land cover over the 2006-2010 quadrennium.

Pre-existing 4-band, 0.61 m resolution 2006 NAIP images were tonally balanced, mosaiced, co-registered to the 2010 dataset and re-sampled to 1-meter spatial resolution using ERDAS IMAGINE® 2011 v.11.0.1. The Normalized Difference Vegetation Index (NDVI) (bands 4 vs. 1) and the first of four principal components (PC1) were used both to classify each image and to detect changes in the 2006-2010 image pair (Lawrence and Ripple, 1998; Lillesand et al., 2008; Shank 2009). QCoherent™ LP360™ v.2.0.0.7 was used as an extension to Esri® ArcGIS® Desktop v.10.0 to sample the LiDAR point cloud and generate surfaces. Samples of low, medium and high vegetation, structures (i.e. buildings, roads), exposed geology and water were extracted from the LAS tiles to create two metrics: a) first return-"bare earth" elevation difference (FRED); and b) first return intensity (FRI) which were then correlated with the 2010 spectral indicators. The classified images show promising, consistent trends for individual indicators, which in addition lacked significant correlation (data not shown) among themselves (*Table 1).*

	Indicator Mean Value			
Feature Sampled	FRED (m)	FRI	NDVI	PC1
Low Vegetation	-0.02	49.4	0.303	298
Medium Vegetation	8.12	15.7	0.296	292
High Vegetation	7.03	22.6	0.353	242
Rooftop	4.34	25.5	-0.068	435
Water	0.26	13.4	-0.346	171
Road	0.05	29.3	-0.015	406
Exposed Geology	0.12	25.1	-0.087	388

Table 1. LiDAR and spectral indicators for selected geographic features in the Licking River watershed (Magoffin County, Kentucky). See text for explanation.

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SEASONAL VARIATION IN WATER QUALITY AND DISSOLVED METHANE OF BARREN RIVER LAKE

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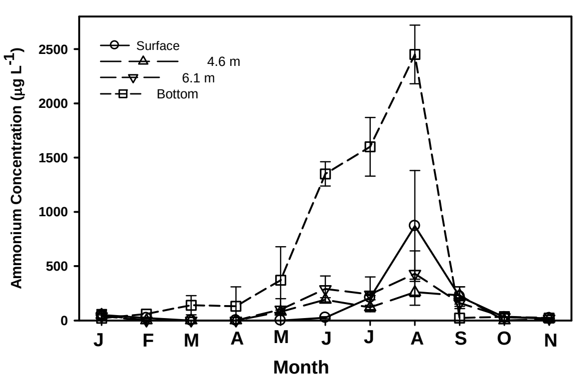
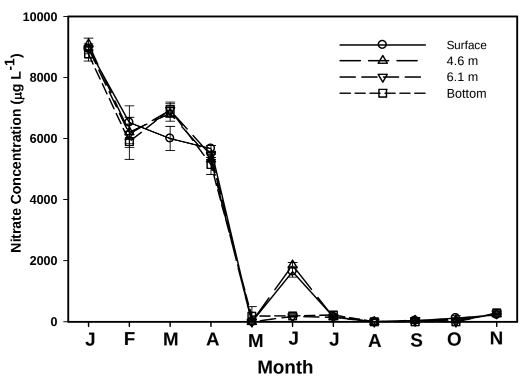
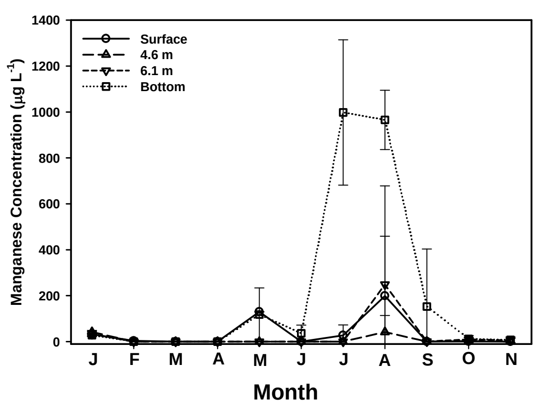
Using a method for water collection that we recently developed, we monitored water quality and dissolved methane in Barren River Lake for eleven months in 2009. During the spring and winter months, nitrate concentrations were essentially equal throughout the water column at eight to six mg L^{-1}. During summer stratification, on the other hand, nitrate concentrations fell and ammonium concentrations increased with depth.

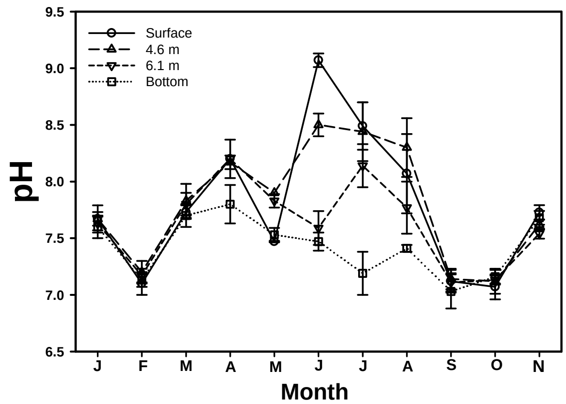




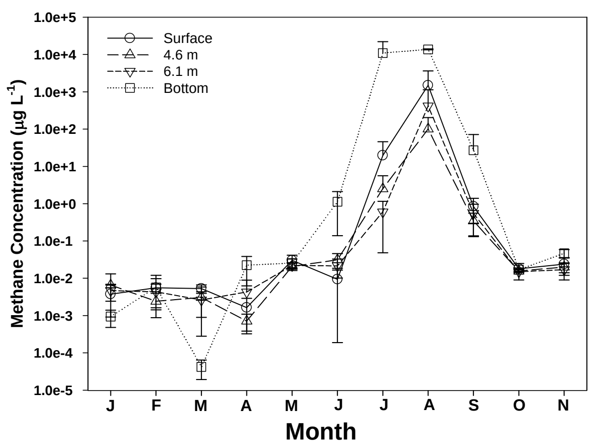
In the absence of thermal stratification, manganese concentrations throughout the water column were low. In the summer, however, manganese concentrations were high at the lake bottom, indicating dissolution from sediments. Other metals such as iron, copper and lead were not elevated during stratification.



Elevated manganese concentrations were not likely due to depressed pH that occurred during stratification. In the absence of stratification, pH was essentially equal throughout the water column. While there were pronounced differences in pH due to depth during stratification, however, this was due more to increases in pH at shallower depths rather than decreases in pH near the lake bottom.



Methane concentrations at the lake bottom were elevated during summer stratification, indicating anaerobic decomposition of detritus in the lake. As a result, significant fluxes of methane are likely to occur from the lake during the summer months.



In conclusion, marked seasonal differences in water quality occur in Barren River Lake due to a relatively narrow fetch length which prevents mixing of the lake's waters. These differences have importance in terms of the environment, recreational use and drinking water.

WATER QUALITY INVESTIGATION IN THE EASTERN KENTUCKY COALFIELDS

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A water quality monitoring study was conducted from 2007-2009 to document the existing water quality condition of headwater and wadeable streams downstream of active coal mining operations in the Carr Creek watershed in eastern Kentucky. Sampling was conducted over a thirteen month period at fourteen sites for physicochemical water quality parameters and biological communities. Parameters elevated above Kentucky numeric water quality standards include selenium, iron and mercury, and specific conductance indicated an exceedance of narrative criteria. Bacteria data (*E. coli*) also exceeded surface water standards at many sites. Data were obtained on surface flows across the seasons. All sampling sites were located below or in an adjacent watershed to an active surface and/or underground coal mining operation. Water quality samples collected from various sites within Carr Creek Lake indicate associated impacts on reservoir water quality.

NOTES

BUSH HONEYSUCKLE INDUCED AQUATIC HYPOXIA

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Allochthonus leaf litter from the invasive shrub Bush or Amur honeysuckle (*Lonicera maackii*) has been shown to deplete oxygen levels within water to as low as 1 mg/L. Originally, plant protein leachates were being considered as the possible culprit for binding. However, no proteins were ultimately found. Other potential causes of hypoxia under investigation included the formation of humics with chelating elements, or increased bacterial activity. Humics have been increasingly difficult to separate from solution, but fluorescence spectroscopy is being used to better determine the role of humics in Bush honeysuckle teas as well as to determine total organic content. An Inductively Coupled Plasma – Optical Emissions Spectrometer was used to chemically analyze both teas and leaves to determine elemental content and any possible chelating metals. Certain potential chelating metals including Ca, K, and Mg were found to leach more readily out of *L. maackii* leaves than from native tree leaves.

The most promising explanation for aquatic hypoxia has been bacterial activity. Standard plate count procedures were used to determine that teas made with Amur honeysuckle have roughly 10^3 times more bacteria than teas made with native riparian tree leaves. Gram stains were used to characterize the types of bacteria found. Pure cultures of different species of bacteria from the honeysuckle tea were created and then introduced to thyoglycolate tubes in order to determine the extent to which the microbes were aerobic or anaerobic. All those tested to date are aerobic.

Sterilization prior to or shortly after tea preparation was used to determine if hypoxia in teas still existed over time. UV irradiation to leaves failed to sterilize teas, but leaf teas created with hot water and filtered through 0.2 µm filters completely sterilize the teas. Dissolved oxygen readings were taken on multiple samples of the sterile filtered tea with results at or slightly above normal DO levels in comparison with unfiltered teas (Figure 1).

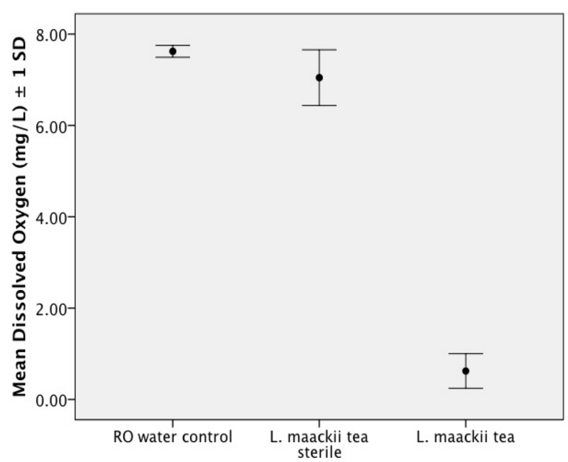

Figure 1. Dissolved oxygen levels of reverse osmosis (RO) water, sterilized and unsterilized Amur honeysuckle teas.

Finally, microbial activity was monitored in leaf teas over multiple weeks using closed system respirometry chambers with gas analysis instrumentation. Our results indicate that after only 4 days of exposure to water, the oxygen consumption rates and carbon dioxide production by bacteria decomposing Bush honeysuckle leaves statistically exceed the microbial activity in decomposition of native tree leaves or that found in a water control (Fig. 2).

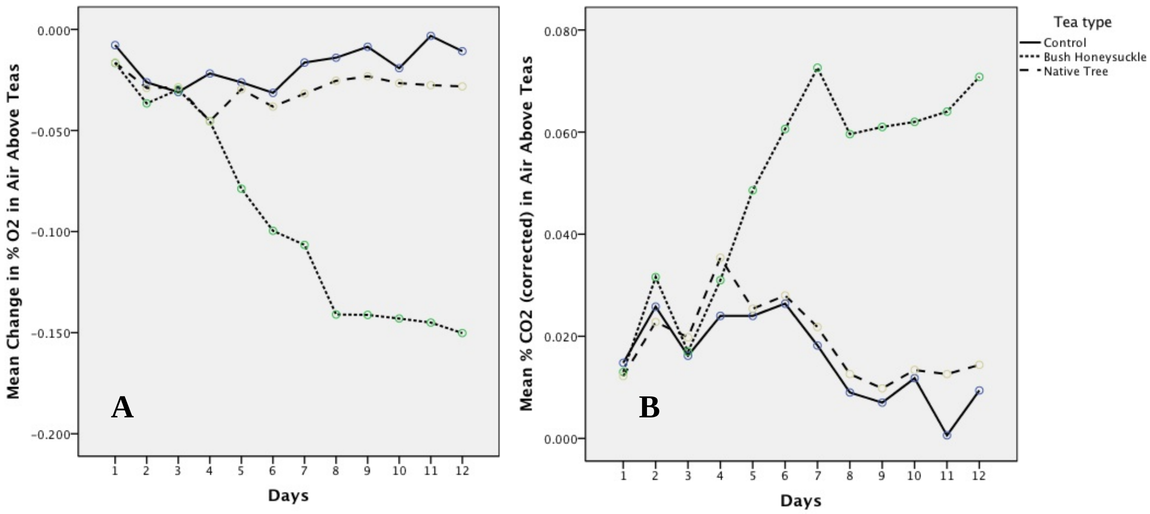

Figure 2. Microbial activity levels measured in oxygen consumption rates (**A**) and carbon dioxide production rates (**B**) within the water control (solid line), native riparian teas (dashed line) and Bush honeysuckle teas (dotted line).

Our most recent studies have determined the ratio leaf composition in native riparian leaf litter including the contribution of Amur honeysuckle to this mix (Fig. 3) These findings were used to establish mesocosms of single and mixed leaf composition, with and without Bush honeysuckle, at concentrations (g dry leaf matter/l water) found in natural wetland ecosystems. These mesocosms allow us to monitor dissolved oxygen levels in a "natural" setting to determine the degree and duration of hypoxia occurring naturally.

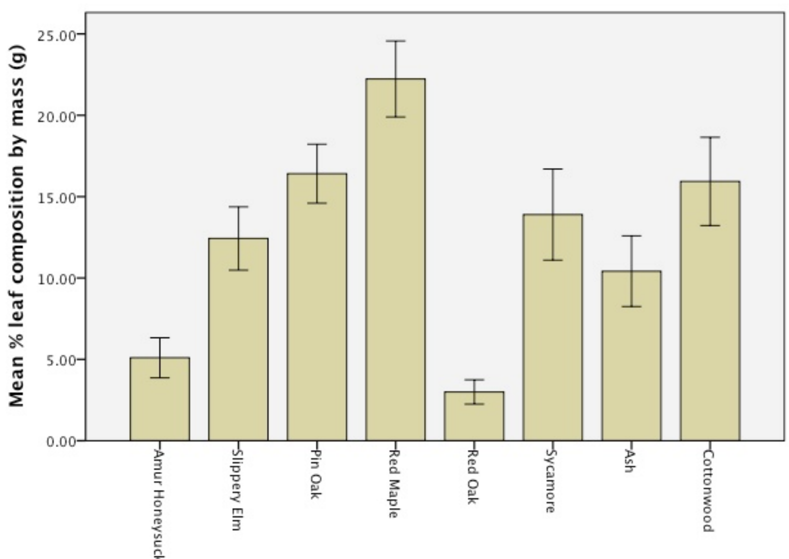

Figure 3. Leaf composition of litter fall in a riparian wetland forest.

A LABORATORY SCALE, CONTINUOUS FLOW BIOREACTOR FOR THE REMOVAL OF MANGANESE IN WATER SUPPLIES

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Bioreactors for removal of manganese (Mn) from water supplies are an emerging technology that are gaining wider acceptance from water treatment utilities partially due to the potential for lower operating costs compared to conventional physical/chemical treatment methods. Bioreactors exploit the mechanism of microbial oxidation of soluble Mn(II) to insoluble Mn(III,IV) oxides in thin biofilms that form and grow on granular biofilter media in packed beds. The brown Mn(III,IV) oxides accumulate on the biofilm surfaces and the biofilters are periodically backwashed for oxide removal as part of the treatment process. Communities of bacteria species are considered to be the dominant microbes responsible for Mn(II)-oxidation in the biofilms. Fundamental information regarding optimal bioreactor operating conditions for treatment of Mn(II) is lacking, and in addition, bioreactor performance is hindered by various problems including sudden, unpredictable releases of Mn from the biofilms.

To increase our understanding of biofilters for Mn(II) removal from water supplies, a laboratory-scale, continuous flow bioreactor was studied utilizing a single bacteria species, a *Pseudomonas Putida* isolate. This isolate, a Mn(II)-oxidizing, gram-negative, biofilm-forming, ubiquitous soil and freshwater bacterium, oxidizes Mn(II) to Mn(III,IV) oxides and accumulates the solids on its exterior surface. The bioreactor, constructed from a 20.13 cm L x 2.28 cm ID plastic tube packed with 4 mm glass beads, was operated for 200+ days. A continuous recycle flow was incorporated in the bioreactor design and the bioreactor hydraulic retention time (HRT) was 48 hrs., except for periods of increased influent flow rates for flushing releases of Mn from the biofilm into the surrounding liquid medium. The influent Mn(II) solution feed concentration was 0.500 ± 0.03 mg/L (500 ± 30 ppb) and the bioreactor solution pH and temperature were maintained at 6.50 ± 0.20 and 30.0° ± 1.0°C respectively for most of the operation period. The influent solution feed media consisted of α-glucose, nutrients (phosphate and nitrogen) and trace metals for most of the bioreactor operation period.

Following bioreactor start-up, influent Mn(II) levels of 0.500 mg/L (500 ppb) were treated to effluent levels of approx. 0.01 mg/L (10 ppb). The bioreactor experienced several failures to remove Mn(II) below the Mn SMCL of 0.05 mg/L (50 ppb). One of the failures was characterized by a gradual increase in the effluent Mn(II) level over several days and is best explained as a lack of the proper nutrients in the α-glucose feed media to support *P. Putida's* ability to sustain Mn(II)-oxidation in the biofilms. Several sudden failures characterized by large releases of Mn from the biofilm are explained as being due to rapid drops in the solution pH in the bioreactor. Most of the releases of Mn were in the Mn(II) oxidation state, indicative of reduction processes occurring on the biofilm. In addition, it is noteworthy that separate, preliminary bioreactor studies of shorter operation time duration revealed that high influent feed solution loads of certain inorganic and organic chemicals (acids) induced sudden releases of Mn from the biofilms, loading conditions which were abated in the 200+ day bioreactor.

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FLOOD IMPACT DUE TO DAM FAILURE: AN ASSESSMENT OF CURRENT STUDIES AND THE APPROPRIATENESS OF THE METHODOLOGIES APPLIED TO THE DIX DAM

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A large amount of hydraulic analysis conducted for flooding simulations is currently developed using a one-dimensional analysis program. Past developments in two-dimension hydraulic analysis programs have sparked an interest in developing new flooding simulation models. This study compares the accuracy and efficiency of the widely used one-dimensional model developed by the US Army Corps of Engineers® Hydrologic Engineering Center, HEC-RAS, and a cutting edge two-dimensional model, BreZo4.0. Both models are free to download which makes them easily obtainable by the engineering community. The study compares the modeling of linear one-dimensional rectangular ideal channels, as well as two-dimensional ideal rectangular channels with a confluence. Using identical ideal rectangular channels, differences resulting from the one-dimensional and two-dimensional calculations are easier to recognize.

Both models can handle unsteady flow analysis with a mixture of super and subcritical flows. The HEC-RAS model performs calculations of the one-dimensional energy equation between cross sections perpendicular to the main flow path. The BreZo4.0 model solves the shallow-water equations using a Godunov-type finite volume algorithm across a triangular mesh-grid allowing the model to solve in the main direction of flow as well as in the lateral projections. The HEC-RAS model solves for energy losses using the Manning's equation, whereas the BreZo4.0 model can incorporate the use of Manning, Chezy, and Darcy-Weisbach equations as well as simulate frictionless channels (which can be academically beneficial).

Having the benefit of being developed over decades, HEC-RAS includes a built in graphical user interface to view the flow profiles in two- and three- dimensions as well as a table including many pertinent pieces of information in regards to hydraulic properties.

BreZo4.0 exports information to a format that can be viewed using standard plotting software. Both sets of information have the ability to create animations so the data is easier to visualize.

The following figures are three dimensional examples of identical two-dimensional ideal rectangular horizontal channels taken at identical time steps in the simulation. Figure 1 is taken from the one-dimensional HEC-RAS simulation and Figure 2 is taken from the two-dimensional BreZo4.0 simulation. Each reach in the system are 1kilometer in length with the downstream reach (right side of figure) twice as wide as the two upstream reaches. The flood hydrograph was routed into the system through the upper left hand reach. The key difference in the figures is the intersection of the reaches as well as the wave front propagation thorough the system. The differences seen in the figures are the direct result of the difference in the one- and two-dimensional calculations.

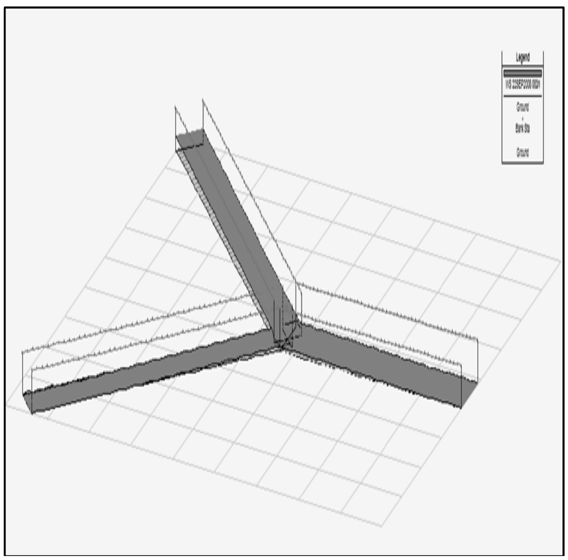

Figure 1: HEC-RAS Simulation

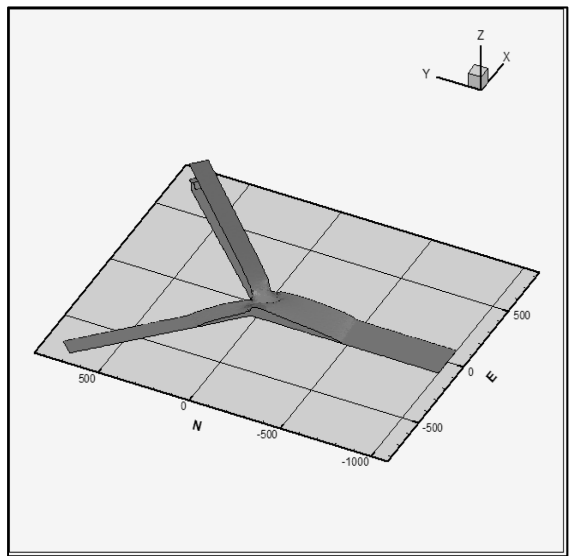

Figure 2: BreZo4.0 Simulation

Each model can use Digital Elevation Model (DEM) information from a Geographic Information System (GIS), but both need an intermediate step in the process, HEC-RAS uses information created through the use of HEC-GeoRAS and BreZo4.0 has a utility toolset. The HEC-RAS model uses information developed through the use of HEC-GeoRAS which automatically creates cross sections of a specified width along a user defined centerline for a channel. The utility toolset with BreZo4.0 converts USGS DEMs to information that can be turned into the mesh-grid necessary for the geometrical information and the shallow-water calculations.

The presentation will include visualizations of the wave front movement downstream and profiles along the channel calculated in both models for several different channel configurations.

DEVELOPMENT OF A COMPREHENSIVE SEDIMENT TRANSPORT METHOD IN FIRST ORDER WATERSHEDS WITH CONTOUR COAL MINING

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This research focuses on measuring and modeling sediment transport, including surface soil erosion, streambank erosion, streambed erosion and deposition, and sediment yield, in first order watersheds with surface coal mining in the Southern Appalachian forested region, USA. While recent research has established field-based methods and models for estimating soil erosion on surface coal mining sites, research methods are lacking that estimate sediment transport in watersheds with small operation contour mining that disturbs approximately 10% of the watershed surface area. To assess the amount of sediment originating from different land-use sediment sources $\delta^{13}C$, $\delta^{15}N$, TOC, TN, and C/N measurements were obtained from forest soils, reclaimed coal mine soils, streambanks, and transported sediments at the watershed outlet in four first-order watersheds with differing disturbances. It was found that the $\delta^{13}C$ and $\delta^{15}N$ tracers successfully discriminated between the sediment sources because of the $\delta^{13}C$ and $\delta^{15}N$ tracers' ability to reflect the biogeochemical changes that occur in the soil matrix. The $\delta^{13}C$ and $\delta^{15}N$ tracers also successfully reflected the differing magnitudes of disturbance in the watersheds. Additionally, it was determined that the $\delta^{13}C$ and $\delta^{15}N$ tracers not only reflect land-use disturbances, but they also indicate natural disturbances that occur in a watershed, such as, ice storms, rainstorms, and high velocity winds that cause tree throw. The simple un-mixing model in sediment fingerprinting was advanced for the use of the $\delta^{13}C$ and $\delta^{15}N$ tracers to account for the percentages of carbon and nitrogen eroding from sediment sources. A sediment transport model was developed to model erosion from the reclaimed coalmine land-use, erosion from the forest land-use, streambank erosion, and streambed erosion and deposition in two watersheds that have reclaimed surfaces. The

sediment transport model was run for multiple scenarios to determine the impact that reclamation practices have on first order watersheds. The results from the dual tracer un-mixing model were used to calibrate the sediment transport model to accurately reflect the erosion processes occurring in the watersheds.

THE CARBOXYLIC ACID-BOUND IODINE LAYER – TOWARDS AN ANTI-FOULING COATING FOR WATER SENSORS AND WATER TREATMENT FACILITIES

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Microorganisms such as bacteria and algae may grow on the wet surfaces of water sensors and water facilities. This fouling leads to damage and clogs. One common way to kill microorganisms is to add anti-biotic agents. However, those agents are normally soluble in cold water, which fails to provide continuous long-term protection for the wet surfaces. To address the problem, we designed a high surface energy, carboxylic acid-terminated surface, which tightly binds and slowly releases anti-biotic agents. We used iodine as the model anti-biotic agent to study the anti-fouling effectiveness for this designed surface. After the surface was loaded with iodine, we further coated an octadecyltrichlorosilane (OTS) film on the top of iodine to control potential leaching.

The amount of iodine leached off of our prepared surface in water was insignificant, as determined by iodide selective electrode measurement. The anti-fouling efficacy of our designed surface was demonstrated by algae and E. coli growth trials on iodine-loaded and iodine-free surfaces. Up to 3 weeks, only $2\pm1/mm^2$ algae cells were found on the iodine-loaded surface compared to $34\pm7/mm^2$ algae cells grown on the iodine-free surface. Similarly, 98% of E. coli observed on the iodine-loaded surface was dead, while the majority of E. coli on the iodine-free OTS surface was still alive and formed patches of colonies.

In summary, we demonstrate that the iodine-loaded carboxylic-acid-terminated surface is a low bio-fouling surface. Our method for surface treatment has the potential to be applied to water facilities to fight bio-fouling problems.

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AQUEOUS ARSENIC REMOVAL BY THIOL-CONTAINING FILTRATION COLUMNS

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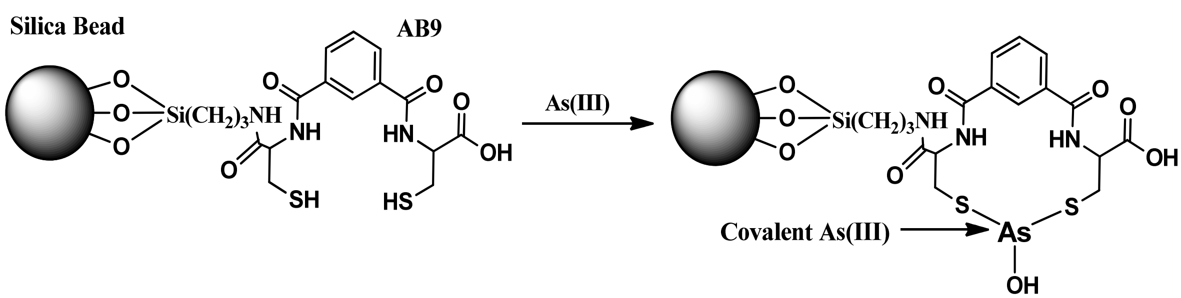
N,N'-bis(2-mercaptoethyl)isophthalamide) abbreviated, $BDTH_2$, is a novel reagent used for the complete precipitation of arsenic, mercury and other heavy metals from water. Arsenic, an ubiquitous element in the environment, is a toxic metalloid present in groundwater mainly in the form of As(III) and As(V). Groundwater contamination with arsenic is a serious problem with over 100 million people at risk of exposure to arsenic from excessive arsenic in drinking water in Bangladesh, West Bengal-state of India, Vietnam, Thailand, various parts of United States and many other countries. A solid-supported reagent with the metal capture ability of $BDTH_2$ would be ideal for removing arsenic from groundwater. This presentation will describe the successful preparation and use of a new solid-supported reagent, SiAB9, for the removal of arsenic(III) from water. SiAB9 demonstrated complete removal of arsenic(III) from water (from 200 ppb to < 5 ppb) by forming strong As-S covalent bonds,. Thus, SiAB9 could ultimately prove to be the method needed to provide clean drinking water in locations with arsenic-contaminated groundwater.



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GREEN CONSTRUCTION IN AN URBAN LANDSCAPE

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CDP Engineers was contracted by the City of Danville to analyze Sub Basin R and determine potential capital projects that would alleviate periodic flooding issues. For this area the City of Danville was interested in pursuing green alternatives to reduce their flooding issues. The steps to accomplishing this task included assessment of existing conditions, public involvement, hydrologic and hydraulic analysis, preliminary design alternatives, and final construction plans. Construction on four of the nine capital projects identified in the study was completed in 2010. The purpose of this presentation is to cover potential obstacles of "green" design in an urban landscape from project area assessment to construction.

Sub basin R in Danville, Kentucky is a 346 acre watershed, which encompasses one of the older residential neighborhoods outside the downtown area. The land use is primarily residential development with highly variable terrain that can be characterized from gently rolling hills to relatively steep slopes with multiple valleys. Much of the subdivision was built without curb and gutter and utilized grassed swales to move surface water runoff to collection points.

The project began with a survey sent out to all subdivision residents. Residents were asked if they had any drainage issues. Surveys that were returned with drainage issues were sent a second survey asking more specific questions related to their drainage problems. The returned survey information was input into a GeoSyncXG GIS database that provided a visual map of localized nuisance flooding areas.

Field reconnaissance was completed within the watershed by driving through the neighborhood and walking along all drainage paths. Specific attention was paid to problem areas that had been identified by the residents. Streams within the subdivision with areas of high erosion were identified and existing storm drain information including size and condition of the structure was collected. Field reconnaissance data were also input into the GeoSyncXG GIS database and provided to the city for future use.

From field reconnaissance, nine potential projects were identified within the subdivision to reduce flooding and improve water quality. Four of the nine preliminary capital projects were selected for construction. The first project was located at the headwaters of the watershed and drained a completely impervious shopping area. This project included construction of a bioswale to treat surface runoff from the shopping area, re-design of an existing detention basin to include a multi-stage riser to treat the water quality volume, and re-design of a headwater stream that had dropped 4 feet from the headwall outlet.

The second project included the design of an impervious groundwater drainage system to relieve standing water in several backyards. The third project included stream bank stabilization and the re-design of an existing basin that included two wetland areas and treatment of the water quality volume. The fourth project was a new detention basin that also included wetland areas and treatment of the water quality volume.

Due to the "green" aspects of the projects, a mandatory pre-bid meeting was held for all interested contractors. During the pre-bid meeting the design plans were reviewed and the planting plans for each project were discussed in detail with the survival rates of all plant material emphasized. Stabilization projects specified in the plans were discussed as well as erosion and sediment control measures.

Project construction hit several snags due to the urban nature of the projects. It is a sad fact that many of the older areas of development do not have good as built drawings available. As a result, several pipes were discovered during construction that were not previously known about. The project team (contractor, city, and design engineer) were fortunate to have excellent communication so that no damage occurred with any of the "surprise" discoveries. Additionally, all parties were very cooperative while working through unexpected field conditions and waiting for the required design change information before proceeding with construction.

As described above, wetland creation and native riparian plantings were an integral part of all but one of the designs and ultimately became the greatest topic of discussion. One public meeting was held after the nine preliminary capital projects were identified and "green" stormwater drainage techniques were discussed. Additionally, native vegetation was discussed and literature was available for residents to take home that provided more information.

During construction the contractor was often questioned about the design and what were wetlands. As soon as it rained and the wetlands appeared "wet" there were immediate cries that mosquitoes were a problem. CDP provided literature about mosquitoes and wetlands to the city to pass out to residents. The contractor passed out the materials as well when questioned by a resident.

An additional public meeting was held to discuss residential concerns over the projects and more specifically the wetlands. At the public meeting the projects were discussed as well as the design of each project. The benefits of native vegetation and wetlands to the watershed were also presented to meeting participants. From the meeting, it is clear that changing public perception is very difficult. The projects are working as designed and have eliminated the nuisance flooding that plagued many of the residents. However, the ultimate acceptance of the wetlands and native plants has yet to be determined.

DEVELOPING A STORM WATER MANAGEMENT PLAN IN THE JACKSON DITCH WATERSHED CITY OF TRENTON, BUTLER COUNTY, OHIO

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An overview of the process and technical approach used to develop a storm water management plan on a watershed scale is presented through a case study of a storm water management project that was completed by Stantec in Butler County, Ohio. Attendees will gain a better understanding of what a watershed management plan consists of; how a watershed plan is typically created; important steps in their development and implementation; and tips to make them more successful. Innovative stakeholder involvement concepts are also presented.

The process is illustrated through practical examples from the Jackson Ditch Watershed located near the City of Trenton, in Butler County, Ohio. The Butler County Storm Water District commissioned a watershed study and storm water management plan for the Jackson Ditch watershed in response to urban development pressure, increasing flood potential, and a desire to protect the underlying Great Miami River Aquifer from potential pollution associated with storm water runoff. Stantec balanced the input and desired outcomes of a diverse stakeholder group by using an award winning approach with a solid technical basis to successfully complete the project.

A watershed assessment and characterization was performed based on field investigation, data research, stakeholder interviews, and modeling. Research suggested most of the issues in the watershed could be controlled at the source by focusing on surface water control, thus eliminating the need for groundwater modeling of the aquifer and representing a cost savings to the client. Hydrologic, hydraulic, and surface water quality models were developed for the watershed using the HEC-HMS, HEC-RAS, and HSPF software packages. The models and data collectively formed a decision support system to assist with ongoing watershed management efforts. A source water protection and control program was ultimately recommended that reduces potential storm water impacts through the use of BMPs and control of development practices. The technical understanding of stakeholders involved in the process varied and several different communication methods were used to convey pertinent issues and outcomes of the study.

The focus of the presentation is on the innovative techniques used to complete the work and the motivation for using these techniques, some common limitations that can be encountered during these kinds of studies, some of the more technical facets of the findings that required special consideration, and positive and negative lessons learned.

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POLLUTANT REMOVAL EFFECTIVENESS OF THE MCCONNELL SPRINGS STORMWATER QUALITY WETLAND POND AND THE GAINESWAY POND RETROFIT PROJECT, LEXINGTON, KY

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In December of 2009 the Lexington-Fayette Urban County Government (LFUCG) completed construction of the McConnell Springs Stormwater Quality Wetland Pond. The facility has a “treatment train” of three main components: a pre-treatment gross debris trap, a three-cell settling forebay, and the main pond with 0.2 acres of deep pool and 0.5 acres of shallow marsh/littoral shelf area. The main purpose of this facility is to reduce non-point source (NPS) pollution entering the sensitive geologic features of McConnell Springs and the creeks that receive its flow, including Wolf Run, Town Branch, and South Elkhorn Creek, all designated as impaired streams by the Kentucky Department for Environmental Protection. The project’s secondary purpose is to provide demonstration to the public of the benefits of natural environments that provide water quality and quantity control. In the Spring of 2009, LFUCG also completed the remediation and renovation of the Gainesway Pond, located at Centre Parkway. The renovations were part of the Gainesway Retention Basin Water Quality and Environmental Education Project. The goal of this project was to retrofit the existing Gainesway Pond to increase pollutant removal through addition of constructed wetlands, aquatic plantings, an aerator, and upstream biofiltration and gross debris trap water quality units. As with McConnell Springs, the Gainesway project also provides the community with environmental educational opportunities. Both of these projects were funded in part through a §319(h) grant provided by the U.S. Environmental Protection Agency and administered by the Kentucky Division of Water.

To monitor the performance of these new facilities in reducing pollutant concentrations in the surface water, LFUCG Division of Water Quality collected water samples throughout 2010, with emphasis on capturing runoff samples during storm events. At McConnell Springs, the Friends of Wolf Run Inc. provided training to community volunteers who assisted with sample collection and delivery to the laboratory. As a public outreach and education component, McConnell Springs Nature Center Staff set up a mechanism for middle school, high school and college level science students to augment field data. At McConnell Springs, four sampling sites were identified (M1-M4) with an additional site (M5) added later in the year. Sites M1-M3 were located in the pre-treatment and forebay cells prior to the main pond (M4-M5). Gainesway Pond samples were collected from the following sites: upstream, mid-stream, wetland area, Pond A (next to wetland), and Pond B. A total of nine sampling events were conducted at McConnell Springs and four sampling events at Gainesway Pond in 2010. On-site measurements included: temperature, pH, ORP, dissolved oxygen (DO), conductivity, total dissolved solids (TDS), and salinity. Additional analysis included: alkalinity, hardness, carbonaceous biological oxygen demand (CBOD5), total suspended solids (TSS), total ammonia, nitrate, nitrite, total phosphorus, orthophosphate, bacterial cultures (*E. coli* and other coliforms), and turbidity. ICP analyses of metal samples were conducted by the Kentucky Geological Survey (KGS) Laboratory.

During sampling in 2010 at McConnell Springs, pH ranged from 7.0 to 9.8, which was within expected parameters. DO ranged from 3.03 to 8.4 mg/L, with site M3 having the highest DO levels. Overall DO levels obtained for this non-aerated system were expected. Initially, both total alkalinity and hardness were elevated, but concentrations decreased as the system became established. TSS concentrations at sites M1-M3 averaged 29 mg/L, whereas sites M4-M5 averaged 12 mg/L, indicating an initial settling of suspended solids. Overall ammonia levels decreased at sites M4-M5, except for an increase in 8/27/10, attributed to low-flow conditions. Nitrate and nitrite concentrations were somewhat low. Concentrations of total phosphorous and orthophosphates were observed to decrease over time. Counts for *E. coli* were highest at site M1 collected on 6/09/10 (9857 CFU/100 mL), but decreased to <1 CFU/100 mL at site M4. Of 30 metals tested, the following were not detected in any of the sites: antimony, beryllium, cadmium, chromium, gold, lead, selenium, silver, thallium, strontium, and vanadium. Concentrations of aluminum, copper, iron, nickel, sulfur and zinc decreased through the stormwater facility.

For Gainesway Pond samples collected in 2010 the pH levels were fairly constant, ranging from 7.23 to 8.85. DO was elevated during high-flow conditions (4/2/10 and 12/2/10) and decreased in the summer. Total alkalinity and hardness concentrations were lower in the ponds as compared to upstream stations. TSS values were initially lower in the ponds, but the concentrations increased in subsequent collections (12/2/10; upstream = 2 mg/L, Pond 4 = 8 mg/L). As with TSS, ammonia levels were initially lower in the ponds, but increased in later dates possibly due to wildlife observed at the site. Nitrate and nitrite levels were below detection on the first 3 collections for all sites. In 12/2/10 nitrate and nitrite levels were highest at the wetland area (16.50 and 0.17 mg/L, respectively) and decreased at Pond 2 (7.39 and 0.095 mg/L, respectively). Total phosphorous also increased in the ponds during the December collection. Additional monitoring is recommended to prevent detrimental algal blooms. As with TSS and ammonia, bacterial counts were highest upstream of the ponds, however, elevated counts were observed in the ponds during the December collection possibly due to wildlife.

This was the first monitoring year of the stormwater facilities at McConnell Springs and Gainesway Pond following their construction and renovations. Based on preliminary data, it appears that the structures are performing as expected. The ponds are retaining suspended solids and some metals prior to discharging into surrounding creeks. As part of their management, LFUCG will continue to monitor water quality as the systems further become established. In particular, close monitoring of ammonia, total phosphorous and bacterial counts will aid in preventing detrimental impacts to the facilities.

COMBINED SEWER SEPARATION: A CONSTRUCTED WETLAND APPROACH

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The City of Owensboro is one of 15 Kentucky communities with a state Consent Decree Judgment to address water quality issues stemming from combined sewer overflow (CSO) discharges. To address the requirements for CSO removal outlined in the consent order, Owensboro has taken several measures to eliminate CSOs from occurring. One of these measures includes removal of stormwater runoff from the Combined Sewer System (CSS) with a constructed wetland.

The constructed wetland project is located on Devin's Ditch, which was once a meandering stream running through the city on its way to the Ohio River. Since Owensboro's founding, the stream has gradually been channelized, routed through pipes, and paved over to make way for new development. By the early 1980's the last remaining portion of Devin's Ditch still exposed to daylight was little more than a highly channelized poor quality intermittent stream surrounded by agricultural fields, that discharged directly into Owensboro's CSS.

During the 1990's the city developed a stormwater master plan which identified 72 projects related to improving its municipal separate storm sewer system. The proposed projects involved redirection of stormwater from the CSS and into several ditches flowing away from the city. For Devin's Ditch, the stormwater master plan proposed an expanded stormwater detention basin with a pump station. The intent of the conceptual plan was to remove stormwater runoff currently entering the CSS by capturing it and pumping it to another ditch draining to the Ohio River.

At the onset of the project it became apparent that achieving all of the benefits from the master plan's idealized design were not possible with available funding. A high water table and a city-imposed two foot minimum cover requirement limited excavation depths. Limited excavation depths increased project costs by creating the need for additional property purchase in excess of what was anticipated to make up the differences in necessary storage. Required mitigation fees for over sixteen hundred feet of stream that would be impacted during construction further decreased the feasibility of traditional detention basin design.

The benefits of a constructed wetland provided solutions to the limitations associated with a traditional detention basin design. The wetland design allowed for excavation closer to the high water table, which increased extended detention capacity while keeping with the originally anticipated amount of property purchase needed. Mitigation fees were eliminated with the construction of 5,000 feet of a meandering "E" channel and creation of 21 acres of high quality wetland habitat. In addition, the wetland provides water quality treatment as the stormwater runoff meanders through a series of shallow riffle areas and deeper pools before ultimately being pumped to a stream discharging to the Ohio River.

Foremost, the wetland design emphasized flood control as presented in the stormwater master plan, with water quality treatment as an added benefit. The wetland is designed for extended detention and contains 75 ac-ft of storage which is the volume of runoff from the 25-yr storm event. Ponding depths vary from a few inches for small storm events to a maximum of 4 feet during extreme events. Water level is regulated by a duplex pump station.

Water quality treatment is provided through several pollutant removal pathways within the wetland. Incoming water is initially routed through a forebay designed to decrease velocities and promote sedimentation. Water then flows through two wetland cells in series, each designed to have a different wetland classification. The first wetland cell is a forested wetland containing tree peninsulas and wedges perpendicular to flow creating the sinuous "E" channel which increases runoff residence time. The second wetland cell is designed as an emergent wetland with low and high marsh areas dominated by native herbaceous vegetation including grasses, rushes and sedges. Pollutants are removed within the wetland cells through laminar settling in zero-velocity zones created by plant stems, microbial uptake removing dissolved nutrients, and wetland plant uptake.

This project provides a unique opportunity for public interaction with nature due to the wetlands close proximity to a public park and the city's greenway path dedicated to pedestrian and bicycle use. In the future a multi-use path connected to the existing greenway is planned that will circle the wetland. Located along the path will be educational signs to inform and invite visitors to stop and enjoy views that include native plants, trees and a variety of wildlife. This project will demonstrate to the public how a community can benefit in many different ways from viewing stormwater as a resource.

WATER QUALITY RETROFIT BASIN SELECTION PROCESS IN LOUISVILLE KENTUCKY

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The Louisville and Jefferson County Metropolitan Sewer District (MSD) is preparing Post Construction Stormwater Controls to fulfill its MS4 Permit which mandates improved water quality. One of the requirements of the new MS4 Permit will be to evaluate retrofit opportunities and encourage public/private partnerships to construct water quality retrofits in their jurisdictional area. Given the number of flood control basins in their system, MSD has a need to develop a ranking system to determine which of the over 800 basins is best suited to be retrofitted to provide improved water quality.

The presentation will outline the ongoing process that is being utilized to evaluate the opportunities to retrofit each basin for improved water quality. We will present the selected criteria and discuss how a ranking system was established and customized to reflect MSD's goals. We will give an overview of how the evaluation process has identified the basins that are best suited to be retrofitted. From these identified basins, five (5) basins will be selected to be retrofitted for demonstration projects.

The presentation will conclude with the goals and objectives of the demonstration projects and how they will be studied to determine functionality and effectiveness in improving water quality in the different environmental conditions present in Louisville, Kentucky. This Presentation will be beneficial to MS4 communities considering developing a retrofit program who are concerned about the requirements and financial incentives program.

NOTES

LIVE GREEN LEXINGTON: WATER PARTNER PROGRAM

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In 2008, the City of Lexington entered into a Consent Decree with the EPA, which stated that Lexington would fix the problems with the storm and sanitary sewer system over the next 11-13 years. Following this agreement, the Lexington-Fayette Urban County Government hired Bluegrass PRIDE, (Personal Responsibility In a Desirable Environment) to educate Fayette County's businesses and apartment complexes about the importance of water quality and storm-water management. This partnership led to the development of the Live Green Lexington Water Partner Program, which provides businesses and apartment complexes with resources for water quality and conservation, as well as information on implementing best management practices at work and home. Participating Water Partners have the opportunity to learn about water pollution issues such as Fats, Oils and Grease, (FOG), and best practices for managing storm water runoff, such as rain gardens and rain barrels. PRIDE believes that it is harder to remove the pollution from the water than it is to stop water pollution from occurring: therefore our education is geared toward pollution prevention. Apartment complexes have so far been the more receptive with a 21 percent participation rate, compared to a 10 percent participation rate among businesses. In addition to providing information directly to apartment complexes and businesses, PRIDE has assisted with public events such as The Dog Paddle, which informs the public about the importance of picking up after their dog, and the Gobble Grease Toss, which prevented one ton of grease from going into Lexington's already-burdened sewer system after Thanksgiving. PRIDE was also involved with the Cane Run Watershed Festival which taught an entire community about the importance of watersheds and how to protect them. PRIDE's outreach efforts are focused on teaching the general public about water quality and small actions that can be taken to improve it. While the program has only been in place for a year, the response has been successful. There are currently 30 businesses and 27 apartments participating in the Water Partner program and the goal for next year is to have 50 more businesses and 35 more apartment complexes sign up.

NOTES

BUILDING SUPPORT FOR PROTECTING AND RESTORING PLAIN, FRUMPY, DOWDY STREAMS

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Kentucky is blessed with a bounty of impressive lakes, rivers, streams, and wetlands. From the cool, clear creeks in the Big Sandy basin to the mighty Mississippi River oxbow at Kentucky Bend near New Madrid, Missouri, the Commonwealth is rich in high-wattage water resources. Few states can match the pizzazz and pure star appeal of a Cave Run Lake, the Red River at the Gorge, the feisty Rockcastle, the Kentucky at the Palisades, the wooded Green, the lazy Obion lowlands, or the hemlock-shaded coves of big Pine Mountain. But we have other waters as well.

Many of these lack the virility, zing, zip, vim, and vigor of the Outstanding State Resource or Special Designated Use waters. Ambling quietly through our farm fields, small towns, cities, and countryside wander dozens if not hundreds of streams that have seen better days. Those of lost luster – the frumpy and dowdy warm-water cousins of the supercool cover girl creeks of the Commonwealth.

It seems that for the public, it's hard to love a working class water, one that goes about its business of draining the landscape, sorting its sediments, and providing for its brood of fish, fly larva, flora, and fauna in a sort of low-brow, distinctively workmanlike manner. As one looks across the landscape, from the mountains to the Bluegrass and the Pennyrile and beyond, the sights – and sometimes the smells – of streams that aren't feeling the love are apparent.

One such stream lies between Bourbon and Nicholas counties, with headwaters along the KY 11 coal haul road south of Mt. Sterling. Hinkston Creek has marched its way to the south fork of the Licking River at Ruddell's Mill for millennia, running free and easy in its youth but now trudging wearily along, through constricting streambank fills and denuded corridors that once produced prodigious fish. The verdict on its current health from the stream doctors at the Division of Water lays out a litany of judgments familiar to many in the water resources field: not supporting aquatic life, unsafe for wading or swimming, too much sediment and bacteria, unstable streambanks, not enough trees.

There are rules and regulations for keeping Kentucky's waters clean, but they don't cover everything and there aren't enough people – or money – at KDOW to make it happen. The challenge for the Hinkston Creek Watershed Project – and dozens more like it – is to somehow make our most forgotten and forlorn streams lovable again. If our citizens will spend hundreds of dollars going to Gatlinburg to rent a wooden cabin surgically inserted into a hillside next to a gurgling Tennessee brook, surely we must find a way to check our creeks into a makeover program, a charm school, or something or other to shed them of their plain-Jane overnutrified frumpiness and make them the Biggest Loser!

For the Hinkston Creek project, we're trying out four approaches: 1) creek crossing and "entering the watershed" signs; 2) positive-reinforcement BMP billboards; 3) weekly newspaper columns on historical happenings (and water quality) in the watershed; and 4) a web site with assessment, planning, management, and other information. The project also includes water quality monitoring by Morehead State University students, characterization and load analyses by modeling professionals, management plan development, and some limited cost-share funding for BMP installation. But it is more than obvious that the scale of water quality improvements needed can only come about if there is a considerable change in the way people think about the creek – and act toward it.

The stream crossing bridge signs with the creek name inscribed are strictly for raising awareness that this is a waterway and it does have a name, linked to a Pennsylvania colonel who fought the Shawnee at the forks of Hinkston and Stoner in the late 1700s. Soon motorists will see the "Entering Hinkston Creek Watershed" signs, with the italicized plea at the bottom ("Help Keep It Clean"). The five BMP billboards are up now in Montgomery County, four with rural scenes and positive "Thank A Farmer" messages (i.e., for grassy waterways instead of eroding gullies, tree-lined buffers along the creek banks, soil and water conservation practices, and pasture practices that protect streams) and one asking the public to "Stop Muddy, Polluted Runoff! (by re-seeding bare areas, cleaning up spills and waste, storing materials under cover, and stabilizing ditches and channels).

The weekly columns have focused on historical happenings in and around Hinkston, from old Indian battles (James Estill was killed on the banks of the creek by Wyandottes in Montgomery County) and the 1901 Great Distillery Mash Pond Spill in Mt. Sterling (thousands of fish were killed, outraging farmers and anglers alike) to the first sewage treatment systems in the area (in response to repeated cholera outbreaks) and the slow but steady improvements in land management practices wrought by Chief Hugh Bennett and the Soil Conservation Service during the Great Depression of the 1930s. The web site (www.hinkstoncreek.org) is the archive and repository for everything – riparian buffer deficiency and septic system risk maps, nutrient load charts, soils information, photographs, weekly columns, BMPs, and the watershed plan.

Is any of this making a difference? It's still too early to tell. The historical newspaper columns have been very well received, there is a distinct "buzz" about the creek, and there is definite interest in the cost-share funding for BMP installation. The county Soil and Water Conservation boards have been extremely interested and supportive, and are co-sponsoring the "entering the watershed" signs and assisting with identifying appropriate high-value BMP installation sites. Building more awareness of the creek as a visual, recreational, and natural resource amenity in Mt. Sterling and the area will undoubtedly take some time, but early indications are positively hopeful.

MONITORING WATER QUALITY IN HINKSTON CREEK: PROVIDING INFORMATION FOR ACTION

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Hinkston Creek has been identified as an impaired waterway, in need of restoration and mediation. Our goal was to monitor the main stem and some tributaries of Hinkston Creek to quantify hydrology and concentrations of common surface water pollutants. We monitored twelve sites monthly from November 2009 through October 2010. In the field, we measured flow and discharge, as well as dissolved oxygen (DO), temperature, pH, and conductivity and TDS (assuming total dissolved solids (mg L^{-1}) = 0.667*conductivity (µS cm^{-1})). Water samples (two grab samples for nutrients, 100-mL sterile bottles for bacteria) were taken back to the lab, on ice, where we subsequently filtered 250-mL of a grab sample through pre-combusted, pre-weighed, 0.45 µm glass fiber filters. Filters were retained to measure total suspended solids (TSS). Filtered water was assessed for concentrations of dissolved nitrogen (nitrate, nitrite, ammonia). Unfiltered water was boiled with persulfate and sulfuric acid, neutralized to a pH of 8.1, then measured for orthophosphate using the ascorbic acid method to measure concentrations of total P. Unfiltered water was analyzed for organic nitrogen (total Kjeldahl nitrogen = TKN) by reflux boiling the sample with sulfuric acid, potassium sulfate, and copper (II) sulfate, then measuring the resultant ammonia concentration. Total Nitrogen was considered the sum of TKN + nitrate + nitrite. Bacteria (*Escherichia coli*) contamination was estimated by filtering water samples through membrane filters and incubating the filters on modified mTEC media for 22 h at 44.5^{o}C. Water temperatures were lowest (about 0^{o}C) in February, and highest (about 26^{o}C) in August. The pH measurements stayed between 6.0 and 9.0, with only one measurement higher than 9.0. The mean (±standard error) conductivity was 418.6±177.9 µS cm^{-1}; mean concentration of total suspended solids was 9.5±14.0 mg L^{-1}; ammonia concentration mean was 170±237 µg L^{-1}; nitrate concentrations averaged 770±685 µg L^{-1}. Total P and N were fairly high for surface waters, averaging 0.18±.21 and 3.42±2.59 mg L^{-1} respectively. Out of 136 samples tested for the presence of E. coli, 59.6% exceeded 130 colonies/100 mL. There were no statistically significant correlations ($p < 0.1$) between *E. coli* and water temperature, conductivity, or nutrients.

NOTES

THE STORY OF THE HINKSTON CREEK WATERSHED DATA

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The Hinkston Creek Watershed is located in the Outer Bluegrass region of Kentucky, in the headwaters of the South Fork Licking River just east of Lexington. Hinkston Creek originates in the southern and western portions of Montgomery County, flows through the city of Mt. Sterling, and then proceeds northward through Bourbon County, where it joins with Stoner Creek to form the South Fork Licking River. Approximately 70 percent of the watershed is covered with pasture, hay, and fallow fields and 2 percent is cultivated crops. Low intensity development comprises 7 percent of the watershed, while higher intensity development makes up only 0.5 percent of the watershed and is limited to areas in Mount Sterling, Carlisle, Millersburg, and Sharpsburg. Forested land and areas covered by shrubs act as natural filters within the landscape to treat water quality; these areas make up approximately 20 percent of the watershed. Approximately 21,000 people live in the Hinkston Creek watershed. The population is generally located in developed areas and is sparse throughout the rest of the watershed.

The 2010 Integrated Report to Congress on the Condition of Water Resources in Kentucky identified several lengths of waterways within the Hinkston Creek watershed as impaired to some degree for bacteria, sedimentation/siltation, and/or nutrient/eutrophication biological indicators.

In an effort to proactively address the identified waterway impairments and improve water quality, the Kentucky Division of Conservation and the Kentucky Division of Water have initiated the development of a Hinkston Creek Watershed Based Plan. A monthly sampling program was developed for part of the study and conducted by Morehead State University which included 12 stations located in the 260 square mile watershed. The monitoring consisted of physical and chemical parameters as well as bacteria. The data were used along with monitoring data collected in 2004 – 2005 by the Kentucky Division of Water TMDL Branch. These data and other information were used to assess sources, estimate magnitudes of pollutant load, and assist in plan formation. Determining the story from the data involves various technical methods and is a typical cornerstone in most projects. This presentation will summarize key data and findings as part of the Hinkston Watershed project.

NOTES

IMPLEMENTATION OF WATERSHED BASED PLANS IN THE DIX RIVER WATERSHED

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The Dix River Watershed Council was formed in 2004 to provide input into the analysis of pollutant sources in the watershed and to make specific recommendations for water quality improvement projects. An intensive monitoring study of the Dix River Watershed conducted from 2006 to 2008 found pathogen pollution from human sewage and animal wastes is the watershed's most serious impairment, in addition to poor aquatic habitat and excessive nutrients. Based on these sampling results, the Dix River Watershed Council, the Division of Water, and Third Rock Consultants developed two Watershed-Based Plans for the Clark's Run and Hanging Fork Subwatersheds of the Dix River.

This presentation will provide an overview of recent activities of the Dix River Watershed Council to implement remediation efforts in these two watersheds. In September 2010, the Council in partnership with the City of Danville received a 319(h) grant from the Division of Water to begin implementation of management measures recommended by the Watershed-Based Plans. This "Phase I" implementation project has two primary goals: reducing instream pathogen levels through the targeted correction of septic failures, and restoring a tributary of Clark's Run Creek in Danville to reduce storm-related flashiness. The Council has hired an AmeriCorps volunteer through the OSM/VISTA Appalachian Coal Country Team to conduct education and capacity building efforts. The AmeriCorps volunteer has conducted a variety of outreach efforts including educational mailings, meetings with local community groups, and conducting in the field water education events. The AmeriCorps volunteer will also assist with planning educational activities to facilitate public participation with the 319(h) funded implementation project. The efforts of the Dix River Watershed Council provide insight into the process of generating community interest and support for water projects.

NOTES

COMPARING THE KENTUCKY PHOPHORUS INDEX
WITH THE P LOSS CALCUALTED WITH A PROCESS-BASED MODEL

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Introduction: Eutrophication from excess phosphorus (P) loading is widespread among U.S. water bodies with a substantial portion of the P originating from agricultural fields. To reduce the impact agriculture has on water quality, USDA-NRCS includes P-based planning strategies in their 590 Standard to restrict P application to fields where the risk of P loss is high. In the 590 Standard, the most common strategy employed to rate a field's vulnerability to P loss is the P index. The P index is an assessment tool developed to identify fields which are most vulnerable to P loss by accounting for the major source and transport factors controlling P movement in the environment. USDA-NRCS is currently revising the 590 Standard and may require states to test the accuracy of their P index. When measured edge-of-field P loss data are scarce, as is the case in Kentucky, a P index can be tested against P-loss data generated from a validated process-based P transport model. With this in mind, the objective of this study was to compare KY P index values with simulated P loss data obtained from a validated P-loss model to identify areas where the index may need revising.

Methods: The Kentucky P index includes 10 field characteristics, each weighted by a factor of 1, 2, or 3 to reflect that factor's perceived importance on P loss. Each site characteristic is assigned a value rating of 1, 2, 4, or 8 points representing low, medium, high, and very high risk of P loss, respectively. The weighted value ratings for each characteristic are then summed to obtain a final P index value.

Risk values generated by the KY P index were compared with simulated P loss generated from the model of Vadas et al. (2009) to determine if values from the index were directionally and proportionately consistent with the P loss model. The index was first compared with simulated P loss data for field conditions where runoff P loss from soil is the dominant P loss pathway. Annual runoff required for the P loss model was calculated with the SCS curve number method using 30-yr daily precipitation data collected in Leitchfield, KY. Curve numbers (*CN*) for moisture condition II were obtained from SCS published tables for all four hydrologic soil groups for a cultivated field with conventional tillage. Curve numbers were modified to account for slope.

Output from the KY P index was also compared with simulated P loss data under conditions where the predominant pathway of P loss is through soil erosion. Soil loss was calculated for a representative field in Kentucky using the Revised Universal Soil Loss Equation (RUSLE). Because land cover is used as a surrogate for erosion in the KY P index, erosion rates were calculated for land cover values of 7, 22, 45, and 75 % representing low, medium, high, and very high risk values in the KY P index by modifying the cover management parameter (C) in RUSLE accordingly. Erosion rates were also calculated by modifying the RUSLE slope length and steepness factor (LS) for field slopes of 1.5, 3.5, 9, and 13 % representing low, medium, high, and very high risk values in the KY P index, respectively.

Results: Results show that the KY P index is directionally consistent with the Vadas P loss model when assessing the risk of dissolved P loss from soil. The increase in the P index with soil test P (STP), however, is nonlinear whereas the Vadas model predicts a linear increase in simulated P loss with runoff. A linear relationship between dissolved P and STP is often observed in P loss studies.

The KY P index uses both soil hydrologic group and field slope to calculate risk of P loss from runoff. Results show that the KY P index is directionally consistent with the simulated P loss data with increasing risk with increasing runoff potential. The increase in the P index with hydrologic soil group, however, is nonlinear whereas the increase in P loss with runoff is linear for the simulated P data with slope depending on STP. Differences in simulated P loss for soils with different STP values increases with increasing runoff, whereas for the KY index these differences are the same regardless of runoff.

Field slope is also included in the KY P index to account for risk of P loss through runoff. The effect of field slope on runoff depth is relatively minor when using the *CN* slope modification equation. As a result, predicted P loss increases only slightly with increasing slope as compared to increases in P loss with increasing runoff. The KY P index, on the other hand, is formulated in such a way that increasing slope has the same effect on calculated P loss risk as increasing field runoff potential. This discrepancy between the simulated data and the KY P index suggests a limitation in how field slope is weighted in the KY P index.

Comparison of P index values with simulated P loss data shows that output from both models increases nonlinearly with decreasing land cover (and thus increasing soil erosion). While the KY P index is directionally consistent with the output from the process-based model, it is not proportionately consistent with the model. This suggests that as formulated and weighted, the KY P index underestimates the impact that decreasing land cover has on the risk of P loss by eroding soil. An additional limitation to the KY P index is that it only uses land cover as a surrogate for erosion even though erosion is a function of many different factors.

Summary: Comparing the KY P index with output from a process-based P loss model suggests that in some areas the index does a good job in assigning P risk. However, this analysis also showed some important deficiencies in the index, including the neglect of important factors known to affect P loss and in how the different factors in the index are weighted. To reduce the amount of P that is exported from agricultural fields to waterways within Kentucky, effort and resources should be devoted to updating the KY P index as well as developing long-term monitoring sites where the index and process-based models can be evaluated against measured P loss data.

Reference: Vadas, P.A., L.W. Good, P.A. Moore Jr., and N. Widman. 2009. Estimating phosphorus loss in runoff from manure and fertilizer for a phosphorus loss quantification tool. Journal of Environmental Quality 38:1645-1653.

KENTUCKY NUTRIENT CRITERIA
DEVELOPMENT AND REDUCITON STRATEGY

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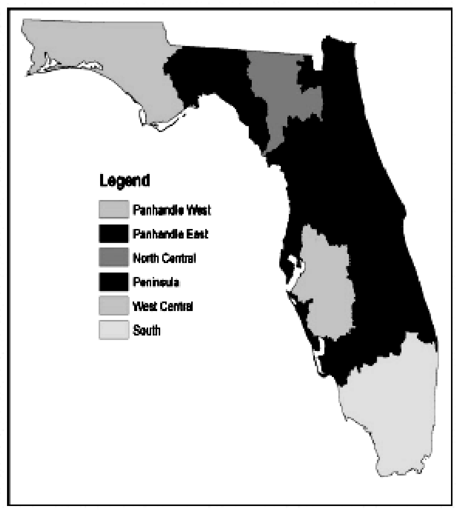
The presentation will: 1) summarize the nutrient problem nation-wide and in Kentucky including the number of impaired lakes and stream miles; 2) address how designated uses are affected; 3) outline economic and social costs of nutrient problems (water treatment costs, lost tourism dollars, reduced recreation opportunities, loss of stream ecosystem services), and 4) discuss EPA's push for numeric standards – rationale (assessment, TMDL targets, permit limits)

Florida standards for wadeable streams: utilizing a reference site approach

Nutrient Watershed Region (NWR)	Instream Protection Value Criteria	
	TN (mg/L)	TP (mg/L)
Panhandle West	0.67	0.06
Panhandle East	1.03	0.18
West Central	1.65	0.49
Peninsula	1.54	0.12
North Central	1.87	0.30

Concentrations are annual geometric means not to be surpassed more than once in a three-year period

Map of EPA's stream classification by NWRs used in final rule.



Kentucky's development of wadeable streams bioregional nutrient guidelines: Multiple lines of evidence.

- Stressor-response relationships (macroinvertebrates and algae)
- Reference stream nutrient ranges
- Nutrient ranges for sites with "passing" Macroinvertebrate Bioassessment Index
- Regionally relevant literature values for adverse effects or trophic status

Draft wadeable streams **bioregional nutrient guidelines** for Kentucky:

Bioregion	**TN (mg/L)**	**TP (mg/L)**
Mountains	0.65	0.03
Miss Valley - Interior River Lowland	1.40	0.07
Pennyroyal	1.40	0.05
Bluegrass	1.20	0.10*

Numbers are similar in magnitude in many cases to Florida regional criteria. While our approach has added benefit of weighing more lines of evidence, our datasets are much weaker (less confidence that the nutrient ranges are fully described by the data available – most data from summer baseflow conditions). Still, if EPA were to promulgate criteria for Kentucky, the numbers would very likely be similar to these.

Challenges in translating general guidelines to numeric standards

- Local factors important in predicting actual effects on uses
- Local factors important in determining expected natural inputs

Better nutrient standards are an important tool in reducing nutrient-related problems in surface waters. The current narrative standards have not prevented impairment of the uses and have not provided clear targets for restoration of uses. Establishing numeric criteria for instream concentrations is the prevailing approach to improving standards, but this is just a step in the process.

Nutrient Reduction Strategy
Kentucky-wide strategy to reduce nutrients through multi-dimensional approach.

Gaps: Research Areas and Data Needs

GENOTYPIC DIVERSITY OF *ESCHERICHIA COLI* ISOLATES FROM ENVIRONMENTAL SOURCES AND THE INFLUENCE ON TRANSPORT BEHAVIOR

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Escherichia coli (*E. coli*) is a dominant intestinal commensal organism, an important fecal indicator bacterium (FIB), a pathogen and a target for microbial source tracking (MST). Strain level differences (genotypic and phenotypic) in *E. coli* influence its fate and transport and therefore have important implications for its validity as an FIB and for MST. Strain survival and variation are regulated by environmental conditions and many of the factors that are important in virulence inside a host are also important when the organism is exposed to diverse and unpredictable environmental conditions outside of the host. Both environmental and cellular characteristics determine the fate and transport of microbial cells following deposition in soil or waters. Isolates that will be transported to water and sediments are the subset of the population that will be used for monitoring purposes. Therefore, the validity of the indictor paradigm and the feasibility of microbial source tracking can not be fully evaluated without a better understanding of the ecology of this important organism.

The goals of this study were to (1) evaluate the diversity of *E. coli* in manures from livestock and stream-water samples taken following dry and wet weather events; (2) evaluate the effect of strain level differences on the attachment and transport of *E. coli*. and; (3) compare the concentration of *E. coli* present in water samples taken following wet or dry weather events to that of other indicator groups (*Bacteroides*, enterococci, clostridia). To evaluate diversity, 1346 *E. coli* isolates were obtained from poultry, swine and dairy manures and from seventeen stream-water samples taken from the Bacon Creek Watershed located in western Kentucky. Bacon Creek is on the EPA 303(d) list of impaired streams for pathogen presence. The predominant land use within the 90.5 square mile watershed is agricultural, but there are also surrounding rural communities with straight-pipes or septic systems. Samples were collected from the same locations following one dry weather event (n = 9; 72 hours without any rain) and one wet weather event (n = 8; 72 hrs of no rain followed by enough rainfall to cause runoff that reaches the stream). Slurry and litter samples (10 g or 10 mL) were plated onto selective media. Stream-water samples (0.5ml, 5.0ml, and 10.0ml) were filtered and placed onto selective media. Strain diversity among the 1346 *E. coli* isolates was evaluated by BOX-PCR analysis. *E. coli* source sub-group isolates were evaluated for the presence of genes associated with adhesion (*afa/draBC*, *iha*, *agn*43, *eaeA* and *fimH*), toxin production (*hlyA*, stx_1, stx_2), capsular polysaccharide synthesis (*kpsMTII*) and siderophores ($iroN_{E.coli}$, *chuA*). Attachment efficiencies to quartz sand were calculated for 23 *E. coli* isolates following transport through saturated porous media. Concentrations of indicator groups were measured by quantitative, real-time PCR (qPCR).

Richness of genotype profiles for livestock samples was relatively low (25, 12 and 11 for swine, poultry and dairy, respectively) compared to that of *E. coli* isolates from stream-water following dry or wet weather events (115 and 126, respectively). Genotype profiles for *E. coli* isolates from stream-water clustered with isolates from livestock species; however, over 34% of *E. coli* isolates from stream-water had genotype profiles that were distinct from those of the tested livestock species. Furthermore, only 18% of the 84 *E. coli* isolates from the wet and dry events clustered together, suggesting a high degree of temporal diversity. Genes associated with virulence (adhesions, toxins and siderophores) were present in *E. coli* isolates from all sources. The most commonly detected genes were the adhesions *fimH* (present in 80% to 95% of isolates) and *agn43* (present in 40% to 100% of isolates). Bacterial attachment efficiencies among 23 *E. coli* isolates varied by an order of magnitude (0.039 to 0.44). The isolate with the highest attachment efficiency possessed the largest suite of targeted genes including those for adherence, surface exclusion and siderophores. The five *E. coli* isolates with the highest attachments efficiencies were all positive for *agn43*and *fimH*. Concentrations of *E. coli* were generally 1-2 orders of magnitude lower than those of other indicators. There were significant increases in most populations during the wet event as compared to the dry event. In fact, concentrations of enterococci increased by more than an order of magnitude in response to the wet weather event.

Data from this study underscore the large degree of genotypic and phenotypic variation that exists among *E. coli* isolates. The impact of this diversity on genetic exchange and the concomitant effect on the organisms' fate and transport under *in situ* environmental conditions require further investigation. Interestingly, each of the three livestock groups had at least two isolates with the highest attachment efficiencies, while *E. coli* isolates from stream-water had generally lower attachment efficiencies. Although studies of virulence genes present in *E. coli* isolates from water sources have been conducted, these have not been correlated with transport characteristics. This is an important factor that warrants further research given the importance of *E. coli* as an indicator organism. It is possible that current monitoring criteria select for the sub-set of the *E. coli* population that is more likely to be transported (i.e., non-adherent). This could lead to biases in data interpretation if, for example, ruminants are more likely to have *E. coli* isolates with fewer genes important to adherence while poultry are dominated by isolates with high levels of adherence. This speaks to the ultimate goal of these studies of genotypic and phenotypic diversity of *E. coli*, which is to address the ecology of this important indicator organism and to identify factors that influence its fate and transport in the environment. The validity of the indicator paradigm and the feasibility of MST can not be fully evaluated without a better understanding of the ecology of the targeted populations. These studies underscore the importance of assessing *in situ* environmental conditions and source inputs for purposes of monitoring, modeling, source tracking and/or risk assessment based on the occurrence of this important indicator organism.

A MULTIPARAMETER APPROACH FOR THE IDENTIFICATION OF LEAKING AND OVERFLOWING SANITARY SEWERS IN THE WOLF RUN WATERSHED

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The Wolf Run Watershed of Lexington is influenced by leaking sanitary sewer lines and combined sewer overflows. Smoke testing and imaging has been used to locate many of the problems, but data is needed before and after repairs to show effective remediation. The Environmental Research and Training Lab of the University of Kentucky has collaborated with LFUCG and the Friends of Wolf Run to develop an approach for risk characterization and relative ranking of locations within the watershed. The goals of the study are to pinpoint locations of leaking sewer lines and to provide microbial fecal data to show that remediation efforts have been successful. The approach proposed for use included indicators of fecal load, age, and source as well as a sampling plan that includes a wide spatial and temporal range. Samples were collected from twenty locations in the Wolf Run watershed on ten dates between April and August of 2010. These samples were analyzed for viable E.coli bacteria, the ratio of atypical colonies (AC) to total coliforms (TC), and the concentrations of general and human specific Bacteriodes DNA markers. Although all of these indicators were found at each of the sample locations throughout the watershed, and across time, the approach presented here allowed for not only the pinpointing of specific hotspots, but also allowed for the differentiation between sewer line breaches and combined sewer overflows.

NOTES

WATER QUALITY CREDIT TRADING FEASIBILITIES FOR KENTUCKY

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Water quality credit trading is a method by which firms and individuals can swap "rights to discharge" in order to lower the overall costs of reducing pollution while keeping the quality of the resource the same or better. Perhaps the most famous of these methods is used in air quality where sulfur emission allocations (credits) can be traded. Based on the notion of that program, quality credit trading is being considered in other environmental quality areas like water. However, this idea has also generated tremendous policy debate over the years. While trading water quality credits has been tried with various degrees of success in other states it has not yet been used in Kentucky. We discuss the potential costs and benefits that trading provides and the basic market structures that could be considered.

The basic idea of the program is simple: allow businesses and individuals to exchange rights to pollute, while holding the overall level of pollution to a given standard. This process gives an incentive to emitters who have relatively low costs of abatement to reduce their emissions as much as possible, by providing them with the ability to earn credits that they can sell to emitters that have relatively high costs of abatement. Thus, the overall costs are lowered–those with the lowest costs make the greatest amount of reductions, while those that find abatement expensive do not have to actually make reductions in effluent, but can purchase credits to cover their emissions. The overall quality of the resource does not change, at least in theory, because the number of credits available is limited to keep the total amount of pollution the same, as it would be without the program. The number of credits available can also be gradually reduced so that the overall level of pollution decreases.

The problem comes in setting up a system whereby trades can be made. Trades must be legally allowable–comply with all rules and regulations and credits must be set in such a way that the credit being offered for sale is equivalent to the credit that is needed by the buyer. The location of the trades should be similar so that the reductions take place in one local while the credit use (i.e. non-reductions) take place in another. And the pollutants (type and amount) involved in the trade should have the same biological impact, so that quality levels stay the same or improve. Trading ratios are developed to meet these requirements. Trading ratios in water quality have not been standardized–so the variables involved have to be carefully considered for the market system used.

There are several types of market systems that can be used for a basis for trading. Several market systems have been tried in other states; however, credit markets have not yet been evaluated within the state of Kentucky. Kentucky represents a unique environment because of its geology and socio-economic position. Geologically, the state is underpinned by limestone, which results in a karst environment. Numerous streams and rivers dip underneath the ground and resurface miles downstream making managing water pollution a challenge.

The most simple market system is one in which one emitter makes an arrangement with another for a particular credit allocation. This one-on-one approach, also known as bilateral negotiations, is administratively intensive for all involved. The buyer/seller must find each other, generate and agree to a contract for the credits. The regulatory agency then must approve the agreement–insuring that the quality trade does in fact result in no loss in environmental quality (EPA, 2008). This market structure does not encourage a high number of trades, because emitters have to go through so much work to make the trade.

At the other extreme a market exchange provides a trading environment in which buyers and sellers can easily find each other to make a trade. And because multiple trades are taking place, the going price of quality credits is easily observed. Credits and trading ratios have to be very uniform in this environment so that buyers and sellers can make comparisons between the prices and quantities being offered. Participants in this market also need the assurance that whatever credit they buy is equivalent to the credit they need for compliance (EPA, 2008). The only possible assurance is the regulatory standard by which the credits are generated, bought, and sold. Therefore, while relatively simple for buyers and sellers, the regulatory aspect of this program is intense.

The water-quality clearinghouse market structure is another trading environment. In this environment an intermediary like the government is responsible for generating the credits. Credits generated under this system are paid for and monitored by the third party and then sold to emitters that want to use them. This system combines the market exchange and the bilateral negotiations. However, the regulatory burden is still high under this system.

Finally, sole source offsets are often considered under trading programs even though they do not actually involve trades between multiple businesses or organizations. Under this system an emitter can generate credits for himself by reducing pollution in another area. These offsets can result in the same cost savings as traditional trades, but care must still be taken to not create a reduction in water quality as a result of the in-house trade.

We will conclude the discussion by outlining the policy debate regarding the water quality trading programs.

PARTICIPATION IN AGRICULTURAL GOVERNMENTAL COST SHARE PROGRAMS IN THE KENTUCKY RIVER WATERSHED IN THE CONTEXT OF WATER QUALITY TRADING

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Water Quality Trading (WQT) is an innovative approach for pollution mitigation that would trade pollution rights. With WQT, there is potential to include non-point sources (NPS) of pollution that have thus far been excluded from the federal regulations that are in effect for point sources (PS) of pollution through the Clean Water Act. There is interest to make Kentucky River watershed farmers participate in water quality conservation through a WQT scheme. Such a market would trade pollution rights between point sources and non-point sources of pollution. Through trades, pollution cost of compliance can be smaller compared to a pollution fee, and pollution can be reduced in a larger amount than with the tax option or standards. Such WQT innovative schemes between NPS and PS have not yet been very successful due to farmers' low participation (Breetz et al., 2004).

This study tries to find if a relationship exists between specific farm operations, extension programs and sources of government funding that target conservation practices. Farm profile that receives funding to engage in conservation in the potential context of a trading scheme of water quality is introduced. From the results, inferences can be made for the design of a successful feasibility study about WQT in the Kentucky River watershed.

This study makes the following contribution to the literature: First, this is the first such analysis ever conducted in the Kentucky River watershed. Second, in addition to farm and farmer characteristics, additional secondary data were gathered in this study, which may be more relevant to the decision of adoption. Such data included the impact of university extension contacts and programs that are related to environment protection and resource use. Third, we present our study in the context of WQT, which generates both pushes and pulls towards producers' decision to participate in government payment programs. The dynamics between cost-share funds and the incentives in WQT can be better explored.

With the help of the Farm Service Agency (FSA) monthly Conservation Reserve Program (CRP) Contract Reports, from the National Agricultural Statistical Service (NASS) of the 2007 Census of Agriculture (County data), secondary data on CRP payments (funding) per county were collected. Also data were collected on number of farms per county, average farm area, percentage of crop area per county, percentage of pasture area per county, the level of Environmental Quality Incentives Program (EQIP) payments per county, the level of Wildlife Habitat Incentives Program (WHIP) payments per county, from the Natural Resources Conservation Service (NRCS) KY State Conservationist County database. And finally, from the Kentucky Cooperative Extension System reports from the University of Kentucky, secondary data were also collected on the total number of extension contacts made by KY state extension specialists. Previous studies have used measurements of farmer education and have found they positively contributed to a larger participation in conservation programs through BMP adoption (P. Ghazalian, B. Larue, and G. West, 2009).

Preliminary results show that the level of CRP payments positively correlates with the number of farms, average farm size, and percentage of cropland in a county. But, the higher the percentage of pastureland in a county, the lower the CRP payments, which was expected since CRP is a land retirement program, it financially rewards conversion of cropland into grasslands or forestlands. CRP payments are affected by multiple program participation, where EQIP is positively related to CRP, whereas WHIP is negatively related. Finally, the number of concurrent extension contacts made by Kentucky state agriculture extension specialists does not have strong impact on the level of total CRP payments in a county. Further analysis is to prove the lagged effects of extension contacts.

Creating a market for water pollution mitigation from agriculture presents some challenges. Uncertainty over the number of offsets or allowances agriculture can produce is one issue. The transactions costs of bringing together buyers and sellers in a market for offsets can be high, because of agriculture's heterogeneous nature and the fact that offsets are associated with the land. Finally, lack of coordination between conservation programs and markets could affect market function. WQT markets and conservation programs may compete for the same land, driving up the price of offsets. Enrollment in conservation programs may raise the issue of additionality, and whether practices adopted with support from financial assistance can be a source of offsets or allowances. The present paper is successful in attempting to provide a framework for a WQT development, showing that regions that contain large farms and greater number of farms are prone to conservation practices adoption if there is compensation. Future research including farmers' inputs on the trading schemes and scenarios, and a thorough mapping of the region's physical characteristics and NPS and PS locations will conclude a successful assessment of the feasibility of a WQT.

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POINT SOURCE POLLUTERS IN THE KENTUCKY RIVER WATERSHED AND THE POTENTIAL FOR WATER QUALITY TRADING

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Introduction

Since the 1972 enactment of federal legislation known as the Clean Water Act (CWA), point-source (PS) polluters (e.g., municipal wastewater treatment plants) have been required to obtain permits and comply with effluent restrictions under the National Pollutant Discharge Elimination System (NPDES). Although significant progress has been made, substantial challenges remain. Reports indicate that up to 64% of assessed surface water bodies remain impaired, unable to support their designated uses (EPA, 2009). Non-point sources (NPS) of pollution—including nutrients (nitrogen and phosphorus) and sediment from agricultural runoff—are a leading factor in this impairment.

The Environmental Protection Agency (EPA), charged with administering regulations under the CWA, supports the use of water quality trading (WQT) programs as a means to address current water quality problems (EPA, 2003). Such programs have the potential to pursue several desirable objectives. Offset credit mechanisms can expand participation in water quality improvement to hitherto unregulated agricultural producers and similar NPS polluters, by providing financial incentives to engage in voluntary abatement.

It is widely held that the marginal abatement costs are lower for NPS than for the heavily regulated PS polluters, such that WQT has the potential to significantly lower the costs to society of achieving a given level of water quality (Faeth, 2000). However, cost-reduction can occur even when trading takes place among PS with heterogeneous cost structures (e.g., due to differences in age or type of equipment, economies of scale, nature of influents) without participation by NPS. WQT programs also have the potential to increase flexibility and availability of different options for improving water quality and to encourage innovation in related technology. Similar programs related to control of air quality have enjoyed substantial success (Stavins, 1998).

Research Objectives

This research develops a profile of current point-source pollution in the Kentucky River watershed, as part of a larger project to evaluate the feasibility of a WQT program in this area. Particular attention is paid to characteristics related to the objectives and requirements of WQT specified by EPA policy (EPA, 2003). Thus, we focus on nutrient-related impairments, examine PS locations relative to potential NPS participants, analyze potential trading areas corresponding to receiving waters and TMDL boundaries, and allow for non-degradation constraints for individual segments.

Data and Methodology

The study relies on NPDES permit and compliance data made available by the Kentucky Division of Water. We build upon the methodologies of Roberts, et al (2008) and Kieser & Associates (2004) to delineate potential WQT markets and analyze PS characteristics. We examine alternative regulatory scenarios to compare trading feasibility under different conditions. In addition, GIS software was used to examine the geospatial connections among PS, NPS, and impaired waters.

Results

Preliminary results suggest that potential for trading is limited under current regulatory standards. However, stricter regulation of point sources as states try to comply with water quality standards could create potential for WQT as a mechanism for decreasing the costs of such compliance.

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NONPOINT SOURCE ABATEMENT COSTS IN THE KENTUCKY RIVER WATERSHED

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Introduction

Nonpoint source (NPS) pollution from agricultural practices is generally exempt from federal regulation. However, some voluntary programs allow point sources subject to the Clean Water Acts's (CWA) effluent limitations to meet their standards by purchasing offset credits reflecting reductions in NPS discharges to the same waters (USEPA 2004). Such water quality trading (WQT) programs have been implemented in a number of states to reduce pollution abatement costs (Breetz et al 2004). In this setting, NPS supply pollution abatement when they implement best management practices (BMP) that reduce nutrient loads, and the cost of BMPs form a supply curve for credits. WQT programs are supported by the EPA as an important means for efficiently pursuing water quality goals (USEPA 2003).

Among the BMPs available for water quality management, riparian buffer strips have proven effective in mitigating the movement of nutrients and other pollutants into surface waters (Qiu et al 2006). Estimates of riparian buffer costs would be valuable for developing policy related to WQT and other conservation programs. This paper estimates the annual costs of buffer strips in six counties in the Lower Kentucky River Basin, as part of a project evaluating the feasibility of WQT programs in that area.

Objectives

The objectives of this study include: 1) Quantify the annualized costs of installing and maintaining a 200-foot riparian buffer strip on agricultural land adjoining waterways in the watershed. 2) Develop a supply curve for such buffer strips, which can be converted to the supply curve for offset credits in a WQT system.

Methodology

We select six counties in the Lower Kentucky River Basin, which are characterized by a high proportion of nutrient-impaired waterways and for which a total maximum daily load (TMDL) of pollutants either has been approved or is under development. These characteristics indicate that NPS offset credits may be in demand for those counties.

To estimate costs, we adapt the methodology used by Roberts et al (2009). Potential buffer strip areas are geographically located and their agricultural land uses are identified using National Land Cover Data (USGS, 2001) and ArcGIS software. In the Lower

Kentucky River Basin, a 200-foot riparian buffer strip throughout the entire watershed would cover 176,155 hectares (7.7% of all land in the basin). Of this area, 61,914 hectares are classified as pasture/hay and 2,949 hectares are classified as row crops.

The cost of riparian buffers on cropland includes the opportunity cost for forgone production, as well as the costs of establishing and maintaining the buffer strips. Forgone production (weighted average return per hectare, corn and soybeans) is determined from cropping practices and soil fertility, using spatially disaggregated data from the Web Soil Survey Database. The cost of riparian buffers on pasture land is derived from average rental rates and the cost of exclusion (fencing), as well as establishment and maintenance expenses.

These costs can be aggregated over the six counties, forming a supply curve of the buffer strip area that would be supplied at various prices, assuming that the price equals the marginal cost of an additional hectare of buffer strip. In turn, the supply of buffer strips can be converted into a supply function for NPS nutrient reductions, which can then be compared with demand for such credits by point sources seeking to reduce their emissions to comply with federal regulation.

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FATE OF STABLE ISOTOPE LABEL DURING PREDATION OF ^{15}N-TAGGED WILD-TYPE *ESCHERICHIA COLI* BY PROTOZOA

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Karst aquifers are an important source of drinking water for people around the world. Unlike clastic aquifers, karst aquifers have little filtration capability and thus are prone to contamination. Sinkholes, sinking streams, and other inlets allow water to travel directly to the aquifer without filtration. This presents a problem as unwanted dissolved and suspended matter (including pathogens) can enter the aquifer and be spread quickly. Waterborne pathogens cause a variety of health problems, including diarrhea, dysentery, hemolytic-uremic syndrome, urinary tract infections, eye infections, and abscesses in the brain and lungs. In Scott and Fayette counties, Kentucky, pathogenic bacteria are likely to be derived from a variety of human or animal sources and transported via runoff to Cane Run. These waters can then be transported to the Royal Spring aquifer with little or no filtration via sinkholes or sinking streams, resulting in contamination of the aquifer and ultimately the source of drinking water for Georgetown residents.

Previous work has evaluated the use of a new tracer method utilizing ^{15}N-labeled *Escherichia coli* in karst systems. Ultimately this type of tracer will help understand bacterial transport within karst systems and aid in remediation/prevention strategies. A field trace of 500 m done by James Ward (2008, dissertation, University of Kentucky) in the Blue Hole Spring basin in Woodford County, Kentucky, resulted in a significant signal. However, it is unknown how well this method will do under longer traces in more complex systems, such as the Cane Run/Royal Spring basin. It is anticipated that there will be a loss of the signal with a longer trace. A portion of this loss may be attributed to predation of the bacteria, especially by protozoa.

A lab study is being conducted to assess the loss of signal attributed to predation. Two protozoa species, *Tetrahymena pyriformis* and *Colpoda steinii*, have been selected as predators. *Tetrahymena* are considered representative of the phylum Protozoa in general, beyond having characteristics that would make them likely *E. coli* predators in karst systems. *C. steinii* are also known *E. coli* predators likely to be present, especially when associated with organic pollution such as fecal loading.

A wild strain of non-pathogenic *E. coli* used by John Warden (2010, Master's thesis, University of Kentucky) will be placed in microcosms of sterile Royal Spring water inoculated with the selected protozoa. These samples will be kept in the dark at 14°C to simulate karst conditions. Samples are being taken and analyzed for isotope composition. *E.coli* enriched in ^{15}N will then be distributed to the microcosms. After one week, samples will be analyzed for their isotope compositions. Pending results should allow us to assess potential loss of the ^{15}N signal when used in a trace of a natural system.

CANE RUN WATERSHED ASSESSMENT AND RESTORATION - PHASE ONE ACCOMPLISHMENTS

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The University of Kentucky has been coordinating a phased watershed assessment and restoration project in the Cane Run watershed. This watershed includes the recharge zone for the Royal Spring aquifer, a major source of drinking water for Georgetown, Kentucky (pop. 40,000). Phase one of the Cane Run Watershed Project will be completed in February 2011, and includes development of a watershed-based plan (WBP) and initial best management practice (BMP) implementation. The WBP utilizes water quality monitoring to characterize current watershed conditions and identify areas for restoration. Five miles of streamside "No Mow Zones" have been implemented in the watershed to improve water quality, protect stream banks, and support aquatic life. These areas have been developed into graduate student research plots for riparian management strategies. The University of Kentucky's Agricultural Experiment Station is located in the watershed, and is a major partner in the watershed project. BMPs installed on the University's farm include a 4,000 tree Conservation Reserve Program (CRP) reforestation project and improved stream crossings. The crossings will reduce stream bank erosion caused by livestock and farm equipment and were utilized by the World Equestrian Games endurance horse race. A 2009 pesticide amnesty in the watershed resulted in proper disposal of 6,700 pounds of outdated and unused pesticides. Local government officials developed an 8.5-mile multi-use recreational trail in the Cane Run watershed. A 26-acre easement for the trail includes streamside "No Mow Zones" and native plantings. Educational signage and kiosks have been placed along the trail to educate trail users about the watershed, its impairments, and restoration efforts. The city and University are also working together in urban sub-watersheds to identify sanitary sewer and stormwater problems. A watershed festival held in August 2010 promoted water quality awareness to over 300 watershed residents.

IMPROVING WATER QUALITY: RIPARIAN EDGE VERSUS RIVER CHANNEL

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Nitrogen polluted surface water runoff is a known cause of hypoxic dead zones that kill important plant and animal species. Riparian areas along waterways reduce nitrate concentrations before reaching coastal waters through denitrification, an anaerobic microbial process. Four paired sites were sampled along the Licking River from Pendleton County (Butler, KY) and ending in Campbell County (Newport, KY) near the confluence with the Ohio River. Monthly sampling of paired sites consisted of 3 sediment cores (5 cm diameter, 10-15 cm depth) from the riparian area adjacent to the river and 3 cores from the bottom of the river. Two water samples were also collected from each site. To determine differences in nitrogen removal capabilities between the riparian soil and river sediment, we measured potential denitrification rate using denitrification enzyme assays (DEA), soil organic matter and inorganic nitrogen concentrations. After analyzing the first eight months of data from our one-year study, we did not find inorganic nitrogen concentration to differ between the riparian and river cores at any of the sites. However, we did find greater soil organic matter in riparian soil than in channel sediment in July. Also, soil moisture was greater in channel sediment and we found ammonium-N concentration to increase with soil moisture. We did not find a trend in soil inorganic nitrogen concentrations along the urban to rural gradient; however water nitrate-N and ammonium-N for June was greatest in the rural areas, likely due to fertilizer runoff from farming. Our study will be used to develop more effective and efficient ways to increase denitrification rates and clean-up our water.

NOTES

MICROSCOPIC POPULATION DYNAMICS AND THEIR RELATIONSHIPS TO THE ACTIVATED SLUDGE PROCESS IN A 30 MGD WASTEWATER TREATMENT PLANT

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Population dynamics of filamentous bacteria, protozoa and higher-life forms in the activated sludge can provide useful information in monitoring and optimizing operations, and for toxicity assessments of wastewater treatment facilities. Monitoring of protozoan abundance in mixed liquor (ML) from the Town Branch Wastewater Treatment Plant (TBWWTP), Lexington, KY was initiated by the Town Branch Lab in March 2010. The TBWWTP is classified as a single-stage conventional activated sludge system with an average design flow of 30 MGD, which can hydraulically treat a maximum flow of 64 MGD. To differentiate filament characteristics, the filamentous bacteria were Gram and/or Neisser stained. Filament abundance was rated on a subjective scoring scale which ranged from 0 to 6, with 0 being no filaments observed and 6 being excessive filaments or filaments observed in all flocculations. At TBWWTP foaming in the ML basins is linked to a 4 to 6 rating of the filamentous bacteria, occurrence of Nocardia, and also corresponds with high settleable solids. Protozoan counts were grouped into four categories: amoebae/flagellates; free-swimming/crawling ciliates; stalked ciliates; and rotifers/nematodes. Trends in protozoan numbers (No./mg MLVSS) were compared with several parameters, including ML temperature, pH, alkalinity and total suspended solids; F/M ratios; and sludge age. Protozoan dominance was observed to be cyclical over time. As expected, dominance by amoebae/flagellates corresponded with decreases in abundance of both free-swimming/crawling ciliates and stalked ciliates, with converse results observed over time. Even though rotifers/nematodes tended to be less abundant, trends of their numbers over time were similar to those of the amoebae/flagellates. Protozoan's growth phases correlated with nutrient availability (F/M ratios), settleable solids, and sludge density indices (SDI). Along with protozoan enumerations, data generated from the filamentous bacteria identification will be compared to the above metrics providing a comprehensive view of the activated sludge treatment processes.

NOTES

SOUTHERN REGION DOWN-WELL CAMERA PROJECT

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The Southern Region Down-Well Camera Project is an education and outreach initiative within the Southern Regional Water Program. The Southern Regional Water Program is one of eight regional water programs under the National Institute of Food and Agriculture, which is an agency within the United States Department of Agriculture. The Southern Regional Water Program is comprised of Land Grant Universities within thirteen states (Kentucky, Arkansas, Tennessee, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Florida, Louisiana, Texas, Oklahoma, and New Mexico). These thirteen states are referred to as the Southern Region. For additional information pertaining to the Southern Regional Water Program, go to:

http://www.usawaterquality.org/default.html

High-quality groundwater resources are vital for meeting increasing water needs of the southern United States as its population expands. To protect groundwater quality, it is critical to provide information to well owners regarding the consequences of cross contamination between surface water and groundwater. Private well owners are responsible for monitoring the quality of their wells, and are often at greater risk for exposure to compromised water quality. Down-well cameras enable researchers, Cooperative Extension Service personnel, water-well drillers and well owners to go beyond the traditional above-ground inspection. These cameras enable water wells to be inspected from top to bottom from inside the well casing. The goal of the Southern Region Down-Well Camera Project is to enable Cooperative Extension Service personnel and well owners to replace conjecture with visual information regarding domestic water well issues.

The down-well camera project has attracted a team of experts from seven Southern Region states (Georgia, Kentucky, Tennessee, Louisiana, Texas, Oklahoma, and Alabama) who use the down-well cameras to address water well issues. Personnel in each state have received training on how to use the cameras and how to diagnose various water well issues. Down-well video footage is presented by Extension and in some cases, state natural resource agency personnel, during local meetings as a tool to inform rural water well owners regarding the condition of their wells and well problems typical for the hydrogeological conditions in the area. In addition, presentations of the video footage have been made at state, regional, national, and international meetings.

More than 100 videos taken from within water wells have been recorded throughout the Southern Region. The videos show cracked casing, rust holes in steel casing, root growth, calcified well screens, and the presence of dead animals or other foreign debris. These water well problems cannot be diagnosed above ground, but can lead to contaminated groundwater and pollution of aquifers.

Team members in Georgia and Kentucky have edited the video footage to produce educational videos tailored to local hydrogeology. The educational videos describe water-well construction regulations, well maintenance, impacts on drinking water and groundwater quality, local hydrogeology and risks to aquifers. These videos are available to Extension personnel and well owners, and may be viewed on the Southern Region Web site:
http://srwqis.tamu.edu/program-information/success-stories/regional-down-well-camera-video

In addition to the well education video, the Kentucky team has created a water-well education Web site, which features video footage collected from the project and additional footage collected by other Kentucky agencies. The Web site contains information on well types and construction, along with simplified descriptions of water-well construction regulations. The Web site provides video and still photo examples of problems that may occur in wells and recommendations for remediation. The Web site is a pilot project that will be used as a model to create Southern Region Water Well and Aquifer Web pages, which will be utilized during Southern Region Well Owner Network training.

The well-camera project has received funding for 2011 and is expected to expand to the remaining Southern Region states (New Mexico, Arkansas, Florida, Mississippi, South Carolina, and North Carolina). Newly collected video footage will be added to the Southern Region Web site.

ESCHERICHIA COLI CONTAMINATION OF THE TRIPLETT CREEK WATERSHED, ROWAN COUNTY, KENTUCKY

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Sections of the Triplett Creek Watershed have been identified as impaired for their designated use by the Kentucky Division of Water. Excessive levels of *Escherichia coli* bacteria contribute to this impairment. The purpose of this study is to assess the occurrence and density of *E. coli* in 34 sampling sites throughout the watershed over a 12-month period. Monthly sampling of the watershed was initiated in July 2009 and continued through June 2010. Additionally, three seasonal sampling events were conducted in which five samples were collected in 30 days during summer and fall 2009, and spring 2010. EPA Method 1640, which utilizes mTEC medium, was employed to detect and enumerate *E. coli* in the collected water samples. Numerous sites throughout the watershed and the study period exhibited *E. coli* densities that exceeded the KDOW standard of 130 *E. coli* CFU/100 mL (a geometric mean of five samples collected within 30 days) and/or 240 *E. coli* CFU/100 mL (single "grab" sample counts). These data indicate that sections in the watershed continue to exhibit impairment due to pathogen contamination. These data will be used to develop a watershed based plan that will address the impairments through the selection and implementation of appropriate best management practices. This study is supported by the Environmental Protection Agency (under §319(h) of the Clean Water Act) through the Kentucky Division of Water (Grant # C9994861-08), and the MSU Undergraduate Research Fellowship program.

NOTES

AN OVERVIEW OF THE PADUCAH GASEOUS DIFFUSION PLANT SITEWIDE GROUNDWATER FLOW AND TRANSPORT MODEL

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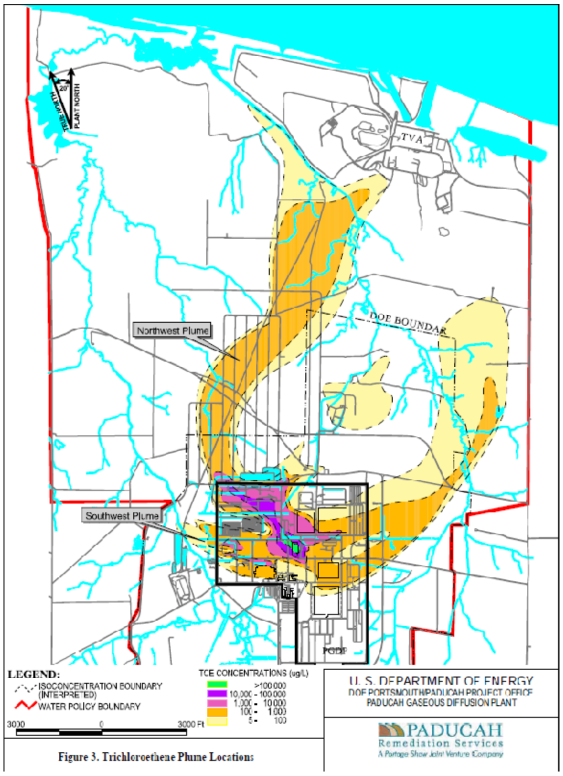
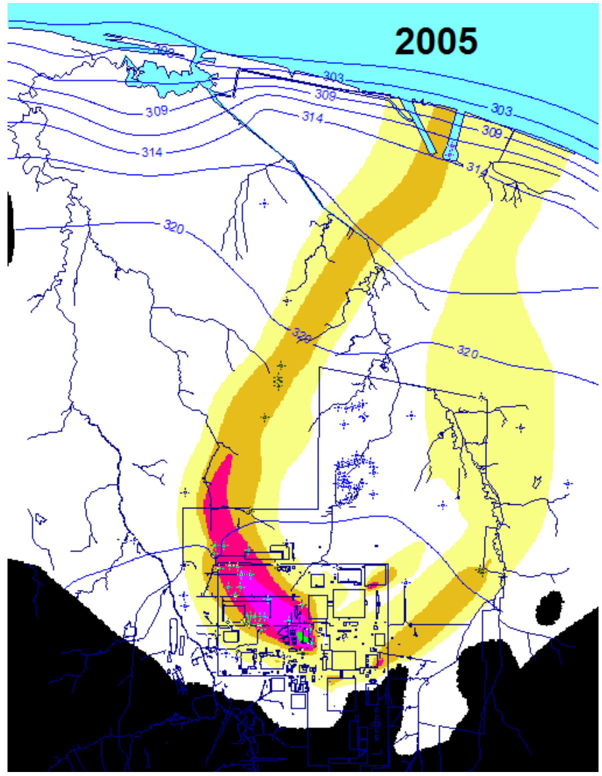
The Paducah Gaseous Diffusion Plant (PGDP) is an active uranium-enrichment facility owned by the U.S. Department of Energy (DOE). It is located in the Jackson Purchase region of western Kentucky, approximately 16.1 km west of Paducah, Kentucky and 6.5 km south of the Ohio River. Historic activities at PGDP have released hazardous, nonhazardous, and radioactive wastes to the environment, including PCBs, trichloroethene (TCE), uranium (multiple isotopes), and technetium-99 (^{99}Tc). PGDP is listed by the U.S. Environmental Protection Agency (EPA) as a National Priority List (NPL) Superfund site. TCE, a chlorinated solvent, is the most widespread groundwater contaminant associated with PGDP. TCE occurs as pure phase, dense nonaqueous phase liquid (DNAPL) in shallow silts and clays and in the Regional Gravel Aquifer (RGA). TCE contamination has resulted in multiple dissolved phase plumes that migrate from PGDP toward the Ohio River. ^{99}Tc, a man-made radioisotope, is also a widespread contaminant in the soils and burial grounds at the site, forming a plume in groundwater that extends from PGDP to the Ohio River.

Groundwater models are valuable tools to help understand the movement of water and transport of contaminants in the subsurface, and are widely used for planning remedial practices. Since 1990, several groundwater models have been developed for PGDP to simulate water flow and transport of TCE and ^{99}Tc. The models are aimed to assist in optimizing remedial actions, assessing potential remedies, evaluating of conceptual hydrogeological models, developing cleanup goals, and others. The most recent version of the PGDP flow and transport model was completed in 2008. The Kentucky Geological Survey (KGS) is conducting an independent review of this recent version of the model and will continue to develop and operate the model to simulate potential groundwater and source-area remedial scenarios at PGDP that are generally outside of the scope of DOE contractor modeling activities. This poster presents an initial overview of the latest groundwater flow and transport model. This version made significant changes from a previous flow model developed in 1997 in model discretization, boundary conditions, property zonation, and calibration method. This version also updated previous transport model efforts conducted between 1998 and 1999 by simulating contamination history and calibrating transport processes.

The figures below compare the measured and simulated TCE plumes in the latest model at year 2005.





Observed 2005 TCE Plume Map

Simulated TCE Plumes of 2005

(From *Trichloroethene and Technetium-99 Groundwater Contamination in the Regional Gravel Aquifer for Calendar Year 2005 at the Paducah Gaseous Diffusion Plant Paducah, Kentucky*)

DIFFERENTIAL GENE EXPRESSION IN ZEBRAFISH AND NATIVE SUNFISH FOLLOWING EXPOSURE TO GASEOUS DIFFUSION PLANT EFFLUENT

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Biomarkers are effective monitoring tools, allowing researchers to assess physiological responses to pollution thereby contributing to both pollutant detection and an understanding of the biological significance of contamination. We examined the expression of pollutant sensitive genes in zebrafish (*Danio rerio*) caged in either a reference area or in effluent or effluent receiving stream water emerging from the Paducah Gaseous Diffusion Plant (Paducah, KY). The streams surrounding the PGDP that are the focus of this study have a long and well documented history of contamination by both organic and inorganic contaminants. Zebrafish were exposed for seven days in individual cages at either a reference site or one of five effluent or effluent receiving stream sites. Expression of cytochrome P4501A1, metallothionien, and catalase were examined in both hepatic and gill tissue while cytochrome P450 1B1, 1C1, and uridine 5'-diphospho-glucuronosyltransferase were evaluated in hepatic tissue. Expression of hepatic cytochrome P4501A was significantly elevated (five fold) relative to controls in effluent 2, seemingly indicating the presence of an organic inducer. Interestingly both cytochrome 1B1 (six fold) and 1C1 (five fold) were elevated relative to controls in effluent receiving stream water but not in effluent 2. In addition, resident longear sunfish (*Lepomis megalotis*) and green sunfish (*Lepomis cyanellus*) were collected from both reference and effluent receiving sites for evaluation of hepatic gene expression. None of the genes examined in zebrafish have been sequenced for these sunfish species but primer design and sequencing efforts are currently underway. These results provide valuable information linking contaminant levels to biomarker response.

NOTES

PATTERNS OF HEAVY METAL CONCENTRATION IN CORE SEDIMENTS, WILGREEN LAKE, MADISON COUNTY, KENTUCKY

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Accumulation of heavy metals in ecosystems is a known environmental problem, and several possible industry sources occur within the watershed of Wilgreen Lake, which is fed its two major tributaries, Taylor Fork and Old Town Branch. Elevated levels of cadmium, copper, lead, and nickel were found within the waters of Wilgreen Lake during a preliminary survey in 2007. A possible source of these contaminant occurrences is diffusion from lake sediments, which record past and present activities within their drainage basins.

To obtain a history of anthropogenic practices within the drainage basin, we took 1-meter-long cores of lake sediment in each major tributary to see if metal concentrations changed with depth. The cores were taken from prominent levees that are relatively easy to sample and contain thick sediments with a good record of watershed history. We sub-sampled the core, freeze-dried the samples, and extracted metals from the sediments using hydrogen peroxide and trace-metal-grade nitric acid according to established U.S. Environmental Protection Agency (EPA) protocols. Samples were sent to Activation Laboratories and analyzed for a host of metals using ICP/OES.

Most trace metals (Sb, As, Cd, Co, Se, Ag, Tl, Th) show no pattern with core depth or between the Taylor Fork and Old Town Branch coring sites. Moreover, there was no correlation between core lithology and heavy metal content for any of the measured metals. Antimony, cadmium, and thallium show concentrations at or just above the method blank ($\leq$0.1 mg/L). Arsenic, cobalt, nickel, selenium, silver, thallium, and thorium show background concentrations of 5, 12, 17, 1.5, <0.1, 1.5, and 6 mg/L, respectively. Chromium, copper, and nickel within the Taylor Fork core respectively increase 43%, 25% and 19% in the upper 10 to 30 cm of the core from deeper baseline values, perhaps due to diagenetic precipitation. Lead increases markedly downcore within Taylor Fork sediments peaking at ~ 53 mg/L, or about 40% above a background concentration of 23 mg/L observed at Old Town Branch. Copper increases slightly downcore with a higher background level at Taylor Fork (18 versus 12 mg/L). Taylor Fork sediments thus display more lead and copper, consistent with industrial sites existing within this tributary's watershed. These elevated concentrations perhaps reflect industrial releases in the past.

NOTES

CONCENTRATION OF HEAVY METALS IN THE WATERS AND SURFACE SEDIMENTS OF WILGREEN LAKE, MADISON COUNTY, KENTUCKY: AN EVALUATION OF PLAUSIBLE SOURCES

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Heavy metal pollution remains a problem in natural waters, particularly for localities near plausible anthropogenic sources. We assayed the level of heavy metals in surface waters and within surface sediments of Wilgreen Lake, whose watershed drains industrial, urban, agricultural, and residential areas near Richmond, Kentucky. We sampled both surface (oxic) and deep waters (anoxic) when the lake was stratified over Summer 2010. Water samples were treated according to U.S. Environmental Protection Agency (EPA) protocols and were digested with trace-metal-grade nitric and hydrochloric acids. Sediment samples were collected with a grab sampler and digested using established EPA procedures with trace-metal-grade nitric acid and hydrogen peroxide. Both water and sediment samples were sent to Activation Laboratories for analysis, and were measured via ICP/MS and ICP/OES, respectively.

All water samples had heavy metal concentrations far below the safety limit for drinking water as determined by the EPA and Kentucky Division of Water (KDW). Lead and nickel were elevated above chronic criteria for aquatic habitat as established by the KDW, or 1.273 and 0.8 μg/L, respectively. Several metals - lead, thorium, and thallium - showed increases in concentration in deeper, anoxic waters compared to oxygenated, surface samples, implying their diffusion out of anoxic sediments. Water-borne lead concentration spiked up to 3 μg/L in anoxic waters of station TF-3; the acute exposure threshold for lead is 1.273 μg/L, with 2 additional samples exceeding this value.

In surface sediments, heavy metal concentrations mostly show no systematic increase or decrease at stations distributed across the lake. However, two stations, M2 and TF-1, located near the inflow of Taylor Fork, showed considerably higher concentrations of lead, chromium, and cobalt than other grab samples. For example, the background lead concentration within surface sediments is about 30 mg/L, but lead levels at stations M2 and TF-1 were 70 and 110 mg/L, respectively. Elevated metal concentrations within sediments in the upper reaches of Taylor Fork can occur from two very different sources. Metals may have originated in the watershed from upstream industrial sources and accumulated within sediments, or they may have entered the lake from septic systems and/or runoff from adjacent residential areas. We continue to investigate these possibilities.

NOTES

ASSESSING SHORT-TERM CHANGES TO HEADWATER STREAM STRUCTURE AND FUNCTION FOLLOWING ALTERNATIVE FOREST HARVESTING PRACTICES IN A CUMBERLAND PLATEAU WATERSHED

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Forested headwater stream systems are coupled tightly to the adjacent riparian forest and to downstream ecological processes, and provide habitat needs for a diverse suite of macroinvertebrate taxa. Headwater watersheds are typically small and more prone to anthropogenic disturbance than larger systems, yet paradoxically are also inadequately managed. Full-scale logging practices have been demonstrated to have adverse impacts, yet most of these studies were conducted prior to the implementation of Best Management Practices aimed at mitigating the negative influence on headwater systems. Forest harvesting can increase peak streamflows, modify channel morphology and woody debris distribution, reduce inputs of leaves and wood, and alter in-stream biotic communities and ecosystem-level function.

Riparian buffer zones, riparian reserves, or stream-side management zones (SMZs), are terrestrial lands directly adjacent to stream channels where the degree of forest harvesting can be either minimized or eliminated. Proper riparian zone management can alleviate the effects of logging related disturbance. The efficacy of riparian buffer zones, and the protection they provide from logging within headwater systems, is still relatively unknown. For example, there are few published studies detailing the effectiveness of specific SMZ widths. What are needed are assessments of how in-stream macroinvertebrate community structure and ecosystem function responds to alternative forestry practices across both a broad range of landforms and SMZ treatments. The use of benthic macroinvertebrates for assessing both natural environmental gradients and anthropogenic disturbances is well entrenched. The objectives of this project were to assess short-term responses by headwater stream macroinvertebrate communities to three distinct forest harvesting treatments in a Cumberland Plateau watershed. Short-term was herein defined as < 24 months between onset of logging (and completion) and sampling for macroinvertebrates.

This project was performed in Clemons Fork, a 3rd-order Cumberland Plateau watershed located in the Kentucky River Basin of eastern Kentucky and part of a series of Robinson Forest (RF) tracts. A series of eight tributary subwatersheds were established as replicates prior to the onset of forest harvesting in June 2008. Each tributary was divided longitudinally into intermittent and perennial hydrologic permanency stream reaches. Two subwatersheds serve as controls and have been not logged. The remaining six subwatersheds were grouped into three replicate SMZ pairs with different harvesting treatments in perennial and intermittent reaches

Short-term harvesting responses were based on macroinvertebrate sampling during April 2010 (post-harvesting) and compared to pre-harvesting sampling that occurred in April 2004 and April 2005. Taxa richness (total number of distinct taxa) and density (no./m^2) of six variables: total community, EPT (Ephemeroptera + Plecoptera + Trichoptera) fauna, and four functional group measures (shredders, scrapers, filtering-collectors and gathering-collectors, were calculated to assess the influence of the different harvesting practices. To date, however, only the SMZ treatment with the narrowest width (intermittent: 7.6 m; perennial: 16.8 m) and lowest proportion of commercially-valuable trees that remained after harvesting (intermittent: 0%; perennial: 50%) has been analyzed in full. We are currently processing macroinvertebrate samples from the remaining two treatments.

A comparison of macroinvertebrate community structure between pre- and post-harvesting conditions reveal different responses in the intermittent and perennial stream reaches. Most macroinvertebrate richness and density measures were lower in the intermittent reaches after harvesting, while in the perennial reaches macroinvertebrate measures were very similar during pre- and post-harvesting conditions. Although this is still preliminary since we still have samples from each of two remaining treatments to process and identify in full, our initial assessment suggests that these SMZ harvesting practices were more problematic for smaller headwater streams.

CATTLE AND KARST:
SOURCE TRACKING ASSESSMENT & BIOLOGICAL INDICATORS IN A NUTRIENT-POLLUTED WATERSHED

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Previously, Albright (2006) sought to characterize the cattle-producing Brushy Creek watershed in Rockcastle and Pulaski counties to determine whether the influences of cattle best management practices could be detected at the watershed scale. The results indicated no differences in water quality that could be attributed to the presence or absence of the BMPs. The study suggested that the lack of improvement in water quality could be explained, in part, by the fact that the karstic nature of the watershed was not considered in the development of the BMPs prescriptions and implementation.

The current study, slated for completion in the summer of 2011, seeks to determine whether karstic groundwater-surface water interaction adequately explains why the cattle BMPs have had little effect on water quality. To date, the land and hydrological conditions of the area have been characterized, including land use, groundwater movement, physical habitat assessment of riparian corridors, and censuses of fish and invertebrates.

<u>Source Tracking</u>

Quantitative real time polymerase chain reaction (qPCR) was conducted at the University of Kentucky's Environmental Research Training Laboratory (ERTL) on seasonally-spaced samples from the 18 stream sites used in the Albright study, plus 9 groundwater/spring sites to identify fecal sources of pollution using the bovine, human, and "all bacteria" markers ("*bobac*", "*hubac*", and "*allbac*", respectively) developed by Layton (2006). The *bobac/albac* ratio was used to classify sites for bovine source tracking on a five-point ordinal range from "very poor" to "excellent." The *hubac/albac* ratio was used to classify the same sites for human sources.

When analyzed geographically, the results suggest that karst may not be a large contributor to bovine contamination, but that it is a large contributor to human fecal sources in the stream.

The analysis suggests further, though, that qPCR as a method of source tracking analysis must be interpreted with a great deal of care because of the multiple opportunities for introducing variability through the multi-step laboratory process. We observed variation in PCR amplification efficiency between triplicates; differences in standard Ct values between runs; issues with the transparent adhesive film used to cover wells; and multiple opportunities for possible operator errors in pipetting, serial dilution of standards, and other laboratory steps.

In addition, to control for the reliability of the marker set, we tested fresh fecal material from three cows collected immediately after deposition. The results indicate that differences between our cattle population and the population used to develop the marker set.

Biological Indicators

Fish samples were collected and analyzed in October of 2009 by Dr. Sherry Harrel and Grayson Patton of the EKU Department of Biological Sciences and each site was ranked on a five-point scale from "very poor" to "excellent" based on the calculated fish IBI scores (KDOW 2003). Then, in May and June of 2010, macroinvertebrates were collected at the sites, and macroinvertebrate IBI (MBI) scores calculated (KDOW 2009).

The results suggest that biological health is not necessarily associated with fecal contamination. Further, the biological indicator rankings varied across species.

Comparison of Water Quality Rankings Between Source Tracking & Biological Indicators
Brushy Creek Watershed, Southeastern Kentucky

	Source Tracking Indicators			Biological Indicators	
Sites	**E.Coli MPN/100 mL**	**q PCR Bobac/Albac**	**q PCR Hubac/Albac**	**Fish IBI**	**Macro IBI**
BC2	VERY POOR	POOR	GOOD	FAIR	**
BC3	VERY POOR	VERY POOR	GOOD	FAIR	**
BC4	POOR	FAIR	GOOD	GOOD	FAIR
BC5	POOR	FAIR	POOR	EXCELLENT	EXCELLENT
BC7	VERY POOR	POOR	GOOD	EXCELLENT	**
BC8	POOR	FAIR	FAIR	GOOD	**
BLC1	VERY POOR	POOR	GOOD		**
BLC2	VERY POOR	FAIR	FAIR	FAIR	**
BLC3	VERY POOR	FAIR	GOOD	FAIR	**
BLC4	POOR	VERY POOR	GOOD	FAIR	**
BLC5	VERY POOR	FAIR	GOOD	GOOD	EXCELLENT
CC1	VERY POOR	POOR	FAIR		EXCELLENT
CC2	POOR	VERY POOR	GOOD	GOOD	**
CC3	POOR	FAIR	GOOD	GOOD	**
CC4	POOR	FAIR	GOOD	EXCELLENT	**
DC1	VERY POOR	FAIR	GOOD	EXCELLENT	FAIR
DC2	VERY POOR	GOOD	FAIR	*	**
S01	GOOD	FAIR	GOOD	*	FAIR
S02	VERY POOR	POOR	FAIR	*	FAIR
S03	VERY POOR	VERY POOR	GOOD	*	FAIR
S04	POOR	EXCELLENT	FAIR	*	POOR
S05	FAIR	EXCELLENT	VERY POOR	*	POOR
S06	EXCELLENT	EXCELLENT	GOOD	*	FAIR
S07	EXCELLENT	EXCELLENT	GOOD	*	VERY POOR
S08	FAIR	GOOD	FAIR	*	FAIR
S10	VERY POOR	EXCELLENT	VERY POOR	*	POOR
S11	VERY POOR	VERY POOR	GOOD	*	**
				*** awaiting analysis*	
				** sample not taken (insufficient water)*	

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REAL-TIME CONTINUOUS OBSERVATIONS FROM SENSORS AND LONG-TERM MONITORING OF WATER QUALITY ALLOW INCREASED UNDERSTANDING OF BIOLOGICAL AND HYDROLOGICAL PROCESSES IN A RESERVOIR, KENTUCKY LAKE (USA).

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Kentucky Lake (USA), impounded in 1942, is the largest man-made reservoir east of the Mississippi River and one of more than 40 TVA impoundments in the Tennessee River system. The reservoir is 260 km long and 1.6 km wide with a water retention time of 23 days under normal water management conditions. The Hancock Biological Station and Center for Reservoir Research began a long-term monitoring program on Kentucky Lake in 1988. Fourteen to 17 sites are sampled every 16 days (32 in winter) for a variety of physicochemical and biological parameters. Two subwatershed streams, one agricultural and one forested, are sampled every 32 days. Nearly 450 monitoring cruises have been completed to date. The data have been valuable in understanding annual and long-term chemical and biological patterns; however, many short-term events are missed. To address this problem, a real-time (15-min sampling interval) monitoring station was established at a mid-lake navigation pylon in 2005. The combination of long-term and real-time monitoring has already provided a wealth of information on the reservoir resulting in a number of publications. Real-time data are openly available on the Station's website at www.murraystate.edu/hbs. These and other data are being used in worldwide collaborations through the NSF supported Global Lake Ecological Observatory Network (GLEON). An NSF R2 collaboration (VOEIS) between Kentucky (Kentucky Lake) and Montana (Flathead Lake) is allowing us to expand the number of real-time sites using deployable buoys and optical sensors. Parameters being measured at 15 min intervals include water temperature, pH, dissolved oxygen, chlorophyll *a*, phycocyanin, specific conductance, oxidation-reduction potential, turbidity, and chromaphoric dissolved organic matter (CDOM). Accompanying meteorological stations on each buoy measure air temperature, barometric pressure, rainfall, wind speed, and photosynthetically active radiation (PAR). One new buoy has been placed in the agricultural watershed embayment and a second will be deployed in the forested watershed embayment in 2011. Additional real-time monitoring sites will be deployed in each stream this year as well. We presently are evaluating calibration needs, issues, and performance in a continuous-measurement environment.

Continuous, high-resolution water quality and meteorological data coupled with the long-term water quality monitoring program (16-day interval over 22 years) will be extremely valuable in helping us understand 1) solute and hydrological fluxes within

Kentucky Lake, 2) the influence of contrasting land-use watersheds in the Tennessee River basin, and 3) spatial and temporal shifts in biological components. For example, the long-term monitoring of sulfate in Kentucky Lake has demonstrated a significant decrease in SO_4 concentrations from over 23 mg/L in 1989 to less than 10 mg/L in 2010 (Figure 1) as well as long-term shifts in zooplankton phenology (Figure 4). Continuous high-resolution monitoring from buoy sensors has documented otherwise unobservable hydrologic and precipitation phenomena; for example, seiche activity occurred during Hurricane Ike in 2008 (Figure 2) and a 1.6 inch precipitation event on 01/01/2011 increased turbidity and CDOM entering the lake from the agriculturally impacted Ledbetter subwatershed (Figure 3).

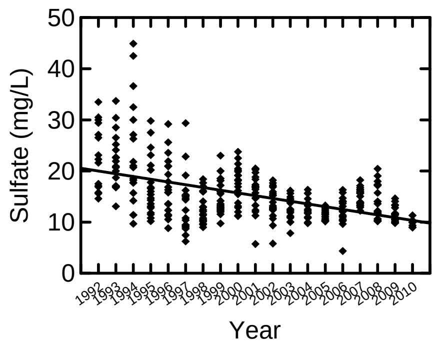

Figure 1. Decreasing sulfate concentration in Kentucky Lake from 1989 to 2010.

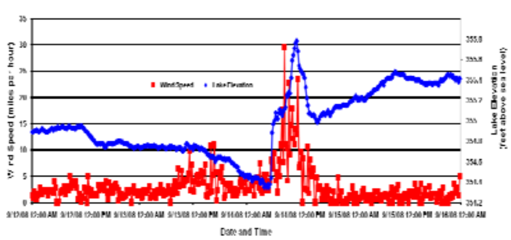

Figure 2. Hurricane Ike causes a seiche in Kentucky Lake on 09/14/2008.

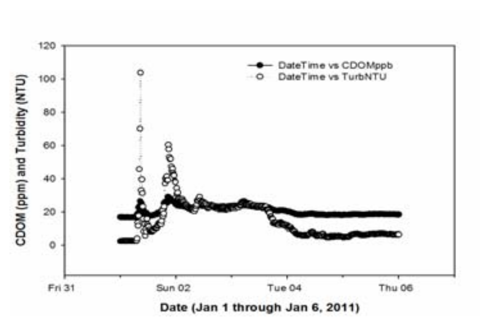

Figure 3. Effects of Jan 1, 2011 precipitation event (1.6") on turbidity and CDOM export from an agriculturally impacted subwatershed of Kentucky Lake.

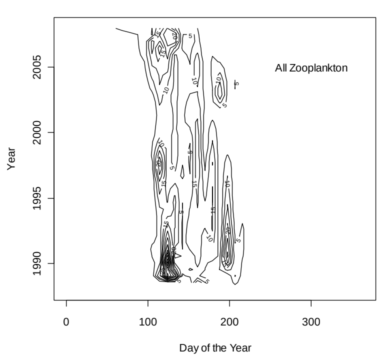

Figure 4. Contour plot of totaled zooplankton densities for site CH. Contours indicate interpolated temporal increases in zooplankton densities.

DEVELOPMENT OF NEW SENSORS FOR MONITORING VELOCITY AND SEDIMENT DISCHARGE IN A WATERSHED

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The broad objective of this research initiative is to develop a novel sensor network so that a real time monitoring system for velocity and sediment discharge of a watershed can be implemented in remote locations in a cost effective manner. The sensor network is a combination of new, inexpensive velocity, sediment concentration, and pressure sensors, which are designed to collect data necessary to represent the vertical velocity and sediment distributions in a channel cross-section. Results of this new technology include relationships developed for the new velocity and sediment concentration sensors. Laboratory testing has shown a strong correlation between measured light intensity at a known depth and sediment concentrations for sediments derived from the same watershed. Sediment concentrations and velocities have been quantified during field application using the laboratory relationships. The sensors predicted values of velocity and sediment concentration that were reasonably close to measured values. Ongoing results are expected to provide accurate data of suspended sediment load derived from watersheds so that this data can be used to calibrate hydrologic and suspended sediment transport models. Further research is needed to quantify the effect of secondary variables on the sediment and velocity sensors.

VARIABILITY OF PARTICULATE ORGANIC CARBON FLUX WITH MINING IN SMALL APPALACHIAN WATERSHEDS

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The Southern Appalachian Forest Region (SAFR) has experienced considerable land use disturbance by surface coal mining over the last several decades. Much is known about the effects of active mining on the environment, but substantially less information relating to the impacts of mining on watersheds after a site has been reclaimed. This research examines the effects mining has on the particulate organic carbon flux in first order watersheds in the SAFR. Samples of sediment were collected by in-situ sediment traps at the outlets of several first-order watersheds in the Southern Appalachian Forest Region in southeastern Kentucky, and analyzed using an isotope ratio mass spectrometer for various parameters including soil organic carbon content. These watersheds have experienced different levels of disturbances from surface coal mining. Two have also

experienced residential development. Four land uses--mined, reclaimed, residential, and grassland-- were identified by digitizing areal polygons from orthophotographs from the 2008 National Agricultural Imagery Program 2008. Flow data were also calculated using a simple runoff model with three parameters, including the area of the watershed, amount of rainfall, and a runoff coefficient based on the areas devoted to each land use. Average concentrations for sediment loads throughout rainfall events were calculated using data from ISCO samplers placed at the outlet of each watershed. Sediment flux was then calculated by rainfall event. When correlated with the carbon concentration data from the sediment samples collect at the outlets of the watersheds, particulate organic carbon flux by rainfall event can be calculated. The results support the accepted belief that surface coal mining leads to an increase in sediment flux. Further work is underway to finalize loading with respect to carbon in the watersheds.

LONG TERM ESTIMATES OF SOIL ORGANIC CARBON AND NUTRIENT DYNAMICS IN RECLAIMED APPALACHIAN MINE SOIL

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Soil health on reclaimed grassland mining sites impacts both carbon and nutrient storage at the site as well as downstream water resources issues. In this modeling research, the soil organic matter model known as CENTURY is being used to simulate soil organic carbon (SOC) development and turnover in reclaimed Southern Appalachian mine soils. While models have been produced for use on reclaimed mine soils in other regions and allow for a simple analysis, the few inputs do not accurately reflect biogeochemical processes occurring in the plant-soil ecosystem. This new approach will allow for the input of various initial elemental properties of the soil, as well incorporating nitrogen, phosphorus and sulfur sub-models. Simulations of soil development of up to 1000 years can be produced, while specifying important climate and land management factors that change with time. In addition to quantifying C, N, S and P dynamics, significant advancements over previous modeling will be the incorporation of stagnated rooting depth as a result of high bulk density, high presence of rock fragments and the contribution of geogenic organic matter in regards to nutrient dynamics. Preliminary results will be presented. Results are calibrated against existing SOC and carbon stable isotope data collected during the past two summers. An analysis of the previously collected data has provided a 14 year chronosequence of SOC uptake and development in the soil column. With this analysis, it has been established that these soils are well below their potential in terms of the ability to store and cycle carbon and other nutrients as well their ability to sustain a fully-functioning forested ecosystem typical for the region. It is expected that these results will further detail the long-term consequences of the current reclamation process and allow alternative methods to be investigated.

NOTES

INTEGRATED MODELING APPROACH TO PARTICULATE ORGANIC CARBON ESTIMATES ON A REGIONAL SCALE BASIN

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The transport of particulate organic carbon associated with fine sediments has been shown to account for 10 to 80% of total carbon flux in rivers; however variability is high requiring further estimates of POC for different watershed systems. Accurate estimates of POC fate and export in a fluvial system requires an integrated modeling approach. Currently, uniformity in methodology and quantitative estimates are lacking in the literature. This study provides a conceptual framework outlining the processes impacting POC transport in River systems. Thereafter, a model framework was developed to account for processes in the conceptual framework. The model framework incorporates coupling of hydrologic, soil organic carbon (SOC), erosion, hillslope routing, fate (biogeochemical processes), and transport models to generate POC estimates. The model is built such that estimates can be generated for systems of varying size. This study uses a sub-watershed POC flux model to inform a regional scale model. The subwatershed (Upper South Elkhorn) is a 61.8 km^2 basin located within the Inner Bluegrass Region of Central Kentucky. The South Elkhorn basin is a lowland, mixed land use (hay/pastoral agriculture and urban) system with limestone and dolomite for underlying geologic material. Such characteristics are typical across the Inner Bluegrass Region, hence processes in the sub-watershed are characteristic of processes throughout the region.

Data for the sub-watershed model were collected at the outlet of the watershed. Suspended sediment samples were collected for particulate organic carbon using a sediment trap, and sediment load samples were collected using an automated grab sampler. Hydrologic modeling was conducted using HEC-HMS, a well recognized commercial program developed by the Army Corp of Engineers, and calibrated using gage data from a USGS gauging station. Upland erosion and transport of POC to the stream channel was conducted using WEPP (Watershed Erosion Prediction Project). Likewise the Regional Scale model was developed using geospatial techniques. Sediment loads, including contributions from the uplands, was conducted using the SPARROW model (Model developed by the USGS). The land to delivery ratio was updated using results from the sub-watershed model. Thereafter, the associated particulate organic carbon content was estimated using a STATSGO SOC model and an enrichment ratio (estimated from the subwatershed model). Biogeochemical processes were estimated based on the sub-watershed model.

Initial results of the sub-watershed model show a POC flux of 1.5 $tC*km^{-2}yr^{-1}$. Carbon content of suspended sediments was found to vary seasonally as a result of biochemical processes in the bed sediments. Initial geospatial estimates show high variability of sediment loads. Ongoing research is being conducted in an effort to increase accuracy of the SPARROW model with increasing scale. Further, though estimates from lowland systems contribute smaller fluxes than mountainous rivers, they constitute larger areas and are heavily influenced by biochemical processes in bed sediments.

DETERMINATION OF CAFFEINE AS A MARKER FOR SEPTIC TANK CONTAMINATION OF WILGREEN LAKE

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Wilgreen Lake in Richmond, Kentucky, has been listed by both the state and the Environmental Protection Agency as an “impaired” lake due to excess nutrients, which may be in part contributed by domestic septic systems. Caffeine can be used as an anthropogenic marker to estimate the contribution of septic tank effluent to the lake. We have modified existing analytical methods to produce a viable method for the determination of caffeine in environmental water samples and applied the method to water samples collected from Wilgreen Lake. The modified method allows determination of caffeine in a concentration range of 75 to 10,000 ng/L in the water samples. Waters Oasis® HLB solid phase extraction cartridges are used to clean up and concentrate the water samples, which are then analyzed by liquid chromatography-tandem mass spectrometry. A Waters XTerra MS C18 olumn (3.5 µm film thickness, 2.1 x 100 mm column dimensions) is utilized in the separation. Carbon-13 labeled caffeine is added to all samples prior to extraction and serves as an internal standard. The parameters of the optimized method and results of the application of this method to water samples collected from Wilgreen Lake will be presented.

NOTES

A STORMWATER COURSE FOR GENERAL EDUCATION

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A course, Protecting Water Resources, was developed to teach undergraduate, non-science majors about water resource limitations, threats, the impact of non-point source pollution, the Clean Water Act, and stormwater regulations and control measures. The course is offered as a lecture with an optional laboratory component. To assess the effectiveness of this course as a stormwater education tool, a 50 multiple choice question exam was developed. Students enrolled in the course fall semester of 2010 were given the exam on the first day of the class and again at the end of the semester as a comprehensive final exam. Thirty-five students took the initial exam with an average of 18.7 questions correct out of 50. At the end of the semester, 34 students took the exam and the average was 43.4 correct answers out of 50. Wilcoxin Signed Rank mean comparison demonstrated that the final scores were significantly higher than the initial scores ($p = 0.000$). There was no difference in improvement between the students in the lecture only and those in the lecture and lab ($p < 0.05$). These results suggest that the material, format and course design is a valid method of stormwater education and meets the criteria described by the National Pollutant Discharge Elimination Systems (NPDES). This course is offered as a model for institutions of higher education to earn stormwater credits under the NPDES program through educational activities.

NOTES

HYDROLOGICAL MODELING OF HART DITCH, A TRIBUTARY TO LITTLE CALUMET RIVER, INDIANA USING HEC HMS AND RADAR DATA

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This research work is a part of the ongoing efforts in the flood management activities for Little Calumet River, located in northwest Indiana. The Little Calumet River drains to Lake Michigan through the Cul-De-Sag canal. Hart Ditch is a major tributary to this river. During 2008, due to the hurricane storm IKE, a major flood was caused in this river basin. Huge property damages were reported due to this flood. Subsequently, the US Army Corps of Engineers is enhancing the levees of this river for a 16 mile stretch to avoid future flooding in northwest Indiana. In this research work, hydrologic and hydraulic models were developed for Hart Ditch to examine the system response with varying conditions.

Watershed rainfall runoff model simulation and river channel hydraulic simulation was performed using HEC HMS (Hydrologic Engineering Center – Hydrology Modeling System, 2009) and HEC RAS (Hydrologic Modeling Center – River Analysis System) software, respectively. Radar rainfall data were extracted for the watershed for five major storms and converted to hourly rainfall using a Z-R convertor software developed at Purdue Calumet. Several layers of geospatial data were used to find SCS curve numbers (SCS, 1986), SCS unit hydrograph (McCuen 2005) and Muskingum channel routing parameters (Bedient et al 2008) (Figure 1) for different subwatersheds.

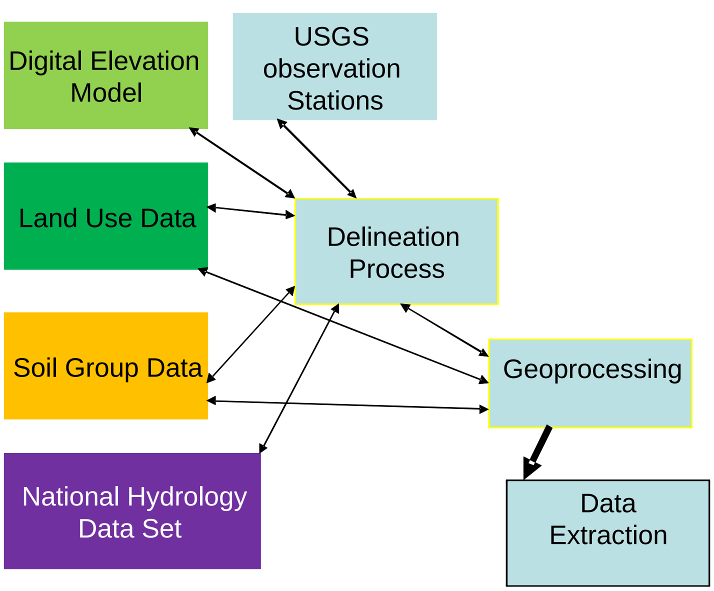

Figure 1. Initial Data Preparation

Traditionally, HEC HMS model calibrations are based on the 50 year or 100 year storms with priorities to match flood peak and time to peak. However, in this study, field data based calibration was attempted. USGS hourly observations and stage discharge relationship were used for this calibration. After calibrating the model using a few historic storms, it was verified with a few other storms. The 100 year flood event was then simulated to verify the stage levels observed at a nearby bridge.

Observations: Model calibration showed mismatches for both summer and winter storms. Model flow peaks did not match well with a storm prior to 1995. Recent land use changes in the system may be the reason for that.

Acknowledgement: Authors acknowledge the research grant support given by Little Calumet River Commission. Special thanks to Mr. Dan Repay, Deputy Director of Little Calumet River Commission for the valuable suggestions.

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BASEFLOW TRENDS IN NORTHWEST INDIANA

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Base flow is an important component of stream flow, which has the source from ground water storage and other delayed sources such as shallow storage, lakes and interflow (Smakhtin, 2001). Base flow characteristics provide many threshold values for watershed based decisions such as water quality and quantity estimates. Annual mean base flow is a function of annual precipitation. Sharp rise in temperature, land use pattern changes and precipitation pattern influences the base flow from a watershed. Less snow fall and quick snowmelt are noticed recently. Increasing temperature thaws frozen soil more rapid and thus lowers the ground water level. Researches indicated spatial and temporal variability of base flow in the past (Hinton et al 1993, Rose 1996).

Hart Ditch, Salt Creek, Little Calumet River East Arm and Trail Creek watersheds were considered for this analysis (Figure 1). These watersheds are located in Lake, Porter and La Porte counties of Northwest Indiana. They are part of the hydrologic unit codes (HUCs) 07120003 (Little Calumet River and Grand Calumet River System) and 04040001 (Little Calumet East arm with Salt Creek and Trail Creek River System). United States Geological Survey (USGS) data for five observation stations (Hart Ditch [USGS gage No.05536190], Little Calumet River [05536195], Little Calumet River East Arm [04094000] and Trail Creek [04095380]) were used for this analysis.

Individual station-based analysis and regional analysis were done systematically by considering monthly, seasonal and annual flow data. Further, the behavior of 90%, 75% and 50% probability of exceedance values were calculated. An annual time series involving number of days in each year with those flow magnitudes was examined in this study. Further, 7Q10 analysis was also performed on individual station data and the results were used in this study.

Observations: Hart Ditch located in North West Indiana showed increasing trend in the base flow (Figure 1). This watershed is predominantly an urban character. On the other hand, little calumet east arm watershed which is dominated by crop and pasture land is not showing increasing trends in base flow (Figure 2).

Acknowledgement: Authors thank DNR, IDEM for research support.

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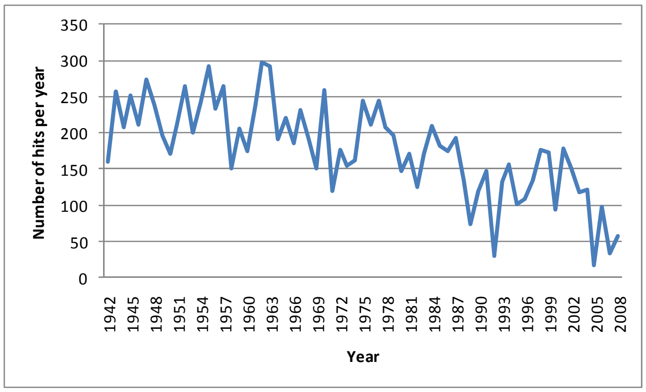

Figure 1. Number of days in each year, with flows less than 26 cfs (50% Probability of Exceedance) at Hart Ditch, Munster, Lake County, North West Indiana

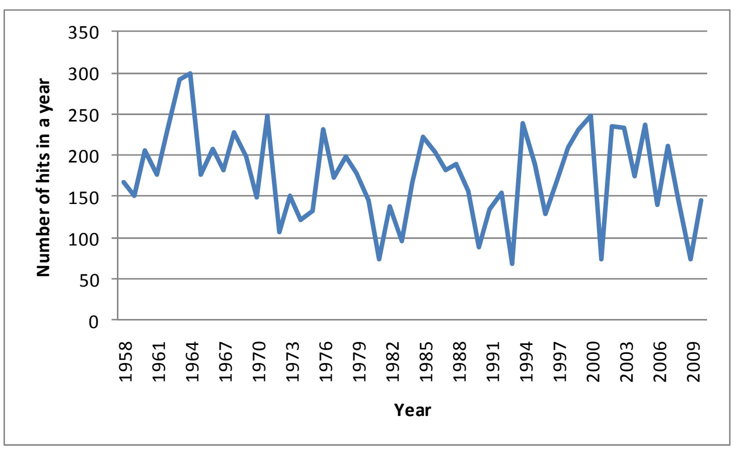

Figure 2. Number of days in each year, with flows less than 31 cfs (50% Probability of Exceedance) at Little Calumet East Arm, Porter, Porter County, North West Indiana

ANALYSIS OF LONG-TERM TRENDS IN ENVIRONMENTAL CONDITIONS AT A GASEOUS DIFFUSION PLANT USING MULTIPLE DATA SOURCES

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One of the major difficulties in assessing environmental trends at sites experiencing low to moderate levels of pollution is obtaining sufficient data over a broad enough range of time to distinguish if apparent trends are real or not. Natural variation in environmental systems can hide real trends so that large data sets are needed to provide sufficient numbers to achieve statistical significance, if it is present. Our laboratory is fortunate enough to have worked at the Paducah Gaseous Diffusion Plant (PGDP) in McCracken County Kentucky from 1987 to 1991 and from 1997 to the present. However, even with this long period of study, typically we are limited to only a few data points each year at a given sampling location. Fortunately, two major outside data sources were available for our use. The effluents from the plant are monitored under the Kentucky Pollutant Discharge Elimination System (KPDES). These effluents therefore have large datasets available covering a very broad array of pollutants, including the metals and PCBs our lab is primarily focused on monitoring, over a long period of time. Additionally, three gauging stations are maintained on the two streams near the plant that receive effluents (Bayou Creek and Little Bayou Creek) and a fourth station on a nearby stream serves as an off-site reference stream (Massac Creek). These provide high quality, continuous flow data covering a very long period of time. Additionally sampling of other parameters was conducted from 1991-1995, filling a gap in our lab's data set. Unfortunately, in both data sources, the time frame that metal and/or PCB data was collected did not extend as long as we had hoped, perhaps because of changing regulatory and monitoring requirements. However, they do permit certain analyses that would be impossible without them.

In order to assess the significance of flow level on the concentrations of different metals and PCB, statistical inference was conducted using unpaired two-sample t-tests. Here, the concentrations of different metals and PCB were compared between high and low flow days. Several graphs were produced to visualize relationships or differences between different variables. These include combined plots to display relations of the measured outcomes between streams or effluents over time, and plots of PCB concentration vs. flow level on the day before.

Despite the expanded data set, few conclusions could be made. While the data sets available were large, the data pertinent to particular sites was still quite limited in scope, often only covering a few years or was limited to flow. At one site on Little Bayou Creek, Zn levels were significantly higher ($p < 0.004$) during high flow events. This stream receives effluent from an area where Zn based anticorrosive paints have been in use for years. Additional analyses using the more general parameter of conductivity as a measure of dissolved material in the water may prove useful as many of these data are available from our lab's data set as well as the two other databases.

ESTIMATING IMPACTS OF LAND USE AND MANAGEMENT ON SOIL STRUCTURE

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Land use and management have important impacts on soil physical and soil hydraulic properties. Soil structure is influenced by soil use and management. The objective of this work is to characterize soil properties that related to soil hydrology and soil physics under two land use systems, pasture and cropland; and to show the impacts of soil management on soil structure. Data presented in this abstract are first measurements in an ongoing project.

A research site (4125 m^2) at Spindletop Research farm, Lexington KY, with two land use types, i.e., pasture and cropland was established. Sixty sampling points with a regular distance of 5 m are laid out in four transects. Part of the total of 60 points are four nests of six measurement points each being located in the middle of each transect. Within these nests, sampling locations are separated by 1 m distance. The nested sampling design was chosen in order to quantify the variability structure of each of the variables and their spatial association. Soil water content was measured using a capacitance probe for 10-cm vertical depth increments down to 1 m depth. Aggregate size distribution analysis was performed using the dry sieving method. Sixty soil cores (356.5 cm^3) were taken from both management zones for gas diffusion, air filled porosity, and bulk density measurements from a depth of 4-10 cm. Oxygen diffusivity in these undisturbed cores was measured using a quasi-stationary approach. Prior to the measurement, each soil core was equilibrated in a pressure plate apparatus to control air filled porosity. The soil sample was then attached to a gas chamber in which the oxygen concentration was lowered at the beginning of the experiment. Air samples were taken from the chamber and analyzed in a gas chromatograph. Based on the oxygen concentration increasing over time, the apparent gas diffusion coefficient was computed.

The pasture management has lower bulk density than the cropped management. Soil water storage measurements taken on September 16^{th} (cropland site) and 17^{th} (pasture site) of 2010 for 1 m depth showed that there is a significant difference between pasture soil and cropland soil (Fig. 1). Cropland soil had higher soil water storage and higher soil moisture content in the top 0.1 m than pasture soil. Soil water content can be influenced by evapotranspiration because the measurements were taken on two following days (no rain events were recorded on these two days). Soil water storage shown in figure 1 does not reflect the soil water retention capability.

Aggregate size distribution analysis for four aggregate classes (>2, 2-0.25, 0.25-0.05, <0.05 mm) was performed for samples taken from the cropland site. The class >2 mm was the dominating aggregate size and the class <0.05 mm contained the lowest fraction in the aggregate size distribution (Figs. 2 and 3). In the top soil (0-0.15 m), macro aggregates (>2 mm) were lower than in the subsequent depth from 0.15 to 0.30 m by 10% of the mean. Other aggregate classes 0.25-2, 0.05-0.25, and <0.05 mm were higher in the top than in the deeper layer by 9, 22, and 27% of the mean, respectively.

Relative oxygen diffusivity varied between 0.02 and 0.08 and air filled porosity varied between 0.06 and 0.16 cm^3 cm^{-3} in the pasture soil under 1/3 bar pressure (approximately field capacity). The result indicates that gas diffusivity is controlled by air filled porosity. Average relative oxygen diffusivity for five soil cores taken from the cropland site was lower than that for the pasture soil (30 cores) by 38%.

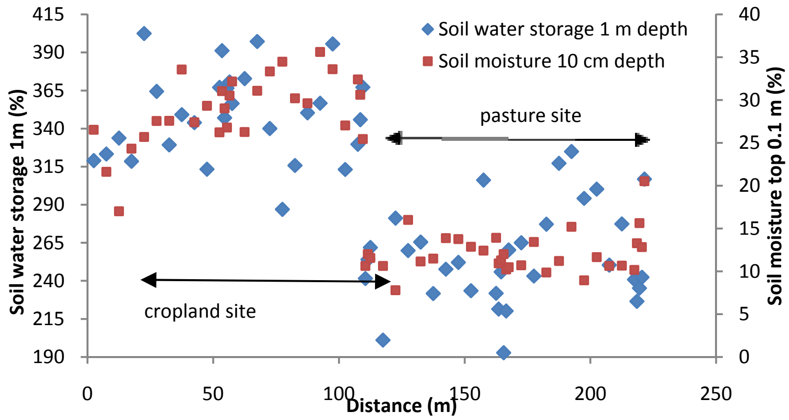

Fig. 1: Soil water storage, calculated by summation of ten depths (0-1 m depth), and soil water content for the top 0.1 m measured using the capacitance probe. Soil moisture content and storage measurements were not calibrated; therefore, the units are percentage.

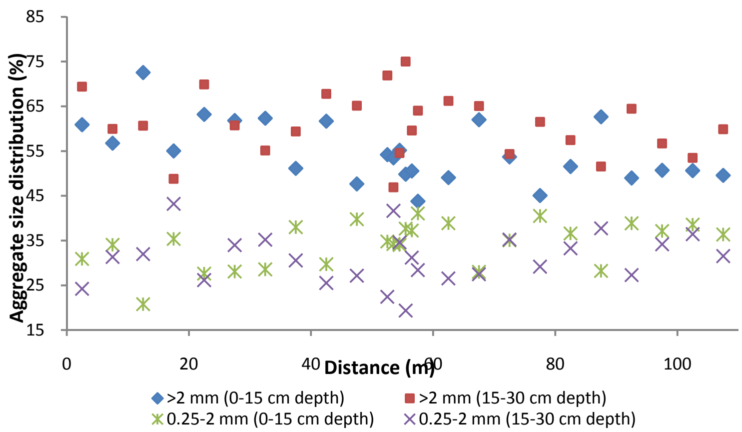

Fig. 2: Aggregate size distribution in cropland soil for two aggregate classes in two different soil depths.

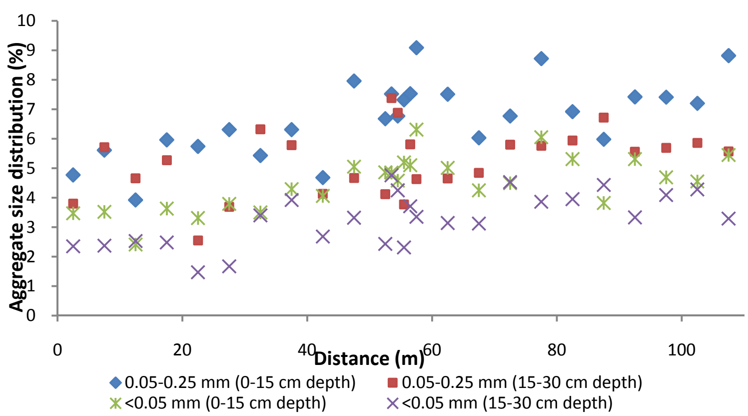

Fig. 3: Aggregate size distribution in cropland site for two aggregate classes in two different soil depths.

INTERACTIVE RISK COMMUNICATION ABOUT AN NPL SITE: THE PADUCAH GASEOUS DIFFUSION PLANT CASE STUDY

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Communicating with the general public about environmental risks can be challenging. The complexity of scientific and remediation issues, along with different levels of baseline technical and historical knowledge among stakeholders, urban legends, deeply-entrenched beliefs, and a lack of public trust, problematize unidirectional communication models. During the focus group stage of the Paducah Gaseous Diffusion Plant (PGDP) Community Future Vision Project, researchers from the Kentucky Research Consortium for Energy and the Environment worked with participants to identify more than 100 questions and credible information sources related to potential future land uses for the National Priority List Superfund site. For subsequent public information meetings in McCracken and Ballard Counties, the research team developed a unique interface for educating the public about the past, present and future of the site, as well as the science and cleanup implications related to specific land use decisions. After prioritizing, synthesizing, and paring down the focus group list to 30 questions, the research team created a unique, interactive, gameshow-based slide presentation, featuring multiple-choice questions, which audience members answered anonymously using keypads. The distribution of audience answers for each question was shown to the group before the correct answer, supporting data, and a source citation were displayed onscreen. After each question and answer, audience members had the opportunity to ask follow-up questions of the research team. At the end of the session, comment cards were provided, allowing individuals who disagreed with specific answers to refer the team to alternative information sources. Process evaluations from both public meetings illustrated that participants positively viewed the interactive format.

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