Water Resources Center
Annual Technical Report
FY 2001

Introduction

Research Program

Research priorities for the Illinois Water Resources Center include: groundwater quality; potential insufficiencies in water resources, including the management of water resources among competing uses; controlling pollution from nonpoint sources; recovering water-based fish and wildlife habitat; developing and evaluating means for formulating policies that are based on limited data; and emerging issues, including other innovative research topics that are not included in the five priorities above.

IWRC is currently funding two projects, both of which began in March 2001. The projects, detailed below, will be completed February 2003. A new Request for Proposals will be issued in May of 2002. The Center takes a special interest in helping young scientists establish a track record in water resources research. The Water Resources Center encourages new scientists to submit proposals and gives their proposals extra consideration. The proposals must be of significant scientific merit (as determined by the reviewers and the Executive Committee) and have relevance to the water research priorities of Illinois to be judged worthy of funding. Virtually all projects supported by the IWRC contribute significantly to the education of students, both graduate and undergraduate, who participate in the research projects. The Student Support table lists students supported by both the internship program with the Illinois District Office of USGS and the individual grants to faculty researchers.

In addition, the Illinois Water Resources Center (IWRC) continues to receive EPA funding for a regional center that provides research and other forms of technical assistance to drinking water systems in small communities. The Midwest Technology Assistance Center (MTAC) started in November 1998 and is a collaborative effort of the IWRC and nine other water resources research institutes in the Midwest and the Illinois Water Survey. MTAC began funding three new projects in 2002. The projects address: evaluation of arsenic rules for non-community public water supplies; a pilot study to test arsenic removal in water treatment facilities; development of an interactive training tool to teach communities how to create a source water protection plan; and development of financial benchmarks for small water systems.

The Illinois Water Resources Center (IWRC) also administers the research component of the Illinois-Indiana Sea Grant College program in partnership with the University of Illinois, Purdue University and the National Oceanic and Atmospheric Administration (NOAA). IWRCs involvement in this program has increased the Centers opportunities for coordinating research activities with other water-related programs in the Midwest. In 2001, 3 national competitions and 1 state competition were held. A total of 15 proposals were funded in Illinois and Indiana including: 5 research proposals funded through Illinois-Indiana Sea Grant College program, 3 research proposals funded through the National Sea Grant Office and 6 outreach proposals funded through the National Sea Grant Office. Research topics include: water quality tracking, aquatic nuisance species mitigation, oyster disease, and aquaculture. Outreach topics include: aquatic nuisance species education and prevention.

In March 2002, Center Director Richard E. Sparks retired. Associate Vice Chancellor for Research, Richard Warner has been appointed as the new Director of the Illinois Water Resources Center.

Dentrification Rates and Controls in Sediments of Illinois Surface Waters

Basic Information

Title:	Dentrification Rates and Controls in Sediments of Illinois Surface Waters
Project Number:	2000IL2B
Start Date:	7/1/1999
End Date:	6/30/2001
Funding Source:	104B
Congressional District:	IL-15
Research Category:	Water Quality
Focus Category:	Water Quality, Sediments, Non Point Pollution
Descriptors:	Agriculture, Dentrification, Nitrogen, Water Quality, Streams
Principal Investigators:	Mark B. David

Publication

Problem and research objectives:

In agriculturally-impacted streams of the midwestern United States, the dissolved nitrogen (N) pool is dominated by nitrate (NO_3^-), which can approach 20 mg NO_3^--N L^{-1} following precipitation events (e.g., David et al. 1997). The agricultural Midwest has been identified as a major source of N to the Gulf of Mexico where coastal eutrophication and hypoxia have become problematic (Turner and Rabalais 1994, Alexander et al. 2000). In east-central Illinois, the dominant land use is row-crop agriculture (corn and soybeans) involving the widespread application of commercial, N-based fertilizer. Denitrification, the microbial reduction of NO_3^- to N_2O or N_2, has been suggested as a potentially major sink for NO_3^- in agricultural streams (Hill 1983). Land use in many east-central Illinois watersheds is >90 % row-crop agriculture, providing an opportunity to examine the role of denitrification in intensively farmed areas. However, measurements of denitrification in agricultural streams of the Midwest are few and no measurements have been reported for east-central Illinois.

Our primary objective in this study was to examine denitrification rates determined with and without chloramphenicol in three NO_3^--rich streams in east-central Illinois. Chloramphenicol is an antibiotic that prohibits the *de novo* synthesis of proteins but does not, except at extremely high concentrations, inhibit the action of existing enzymes. In the presence of chloramphenicol, denitrifying bacteria cannot produce additional enzymes in response to the conditions of the assay and, therefore, assays conducted with the antibiotic provide a more accurate measure of rates of denitrification than those performed without it. Smith and Tiedje (1979) used chloramphenicol in conjunction with the acetylene block method in microcosm studies of soil denitrification and identified two phases of N_2O production (i.e., denitrification). In assays performed without chloramphenicol, Phase I was a short-term, linear rate of denitrification and was followed by an increased, often non-linear rate, termed Phase II. In the presence of chloramphenicol, the difference between Phase I and Phase II was slight or nonexistent. Smith and Tiedje (1979) concluded that Phase I was representative of actual in-field rates of denitrification whereas Phase II reflected the new synthesis of denitrifying enzymes and microbial growth subsequent to the reduced oxygen tension. We were interested in whether Phase I and Phase II patterns, such as Smith and Tiedje (1979) observed in soils, could be discerned in stream sediments and, if present, if the patterns were consistent during the course of summer and early autumn when NO_3^- concentrations change dramatically.

Methodology:

Our study streams included the Embarras River near Camargo, Illinois; Black Slough, a first-order tributary to the Embarras River; and Big Ditch, a third-order tributary to the Sangamon River. We used the C_2H_2 inhibition method (e.g., Knowles 1990, Tiedje et al. 1989) to measure rates of denitrification in slurries of sediment from each of the study streams. In the laboratory, 25-30 mL of sediment slurry was placed in a 150 mL media bottle with a butyl septum in the lid. Unfiltered stream water was added to bring the total sediment-water volume to 75 mL. Eight media bottles were used for each assay: 4 of which had chloramphenicol added to achieve a final concentration of 5 mM and 4 of

which received no chloramphenicol. For the routine assays, no NO_3^- or DOC was added beyond that in the unfiltered stream water. The ambient NO_3^- and DOC concentrations for each assay were determined with an ion chromatograph (Dionex DX-120) and carbon analyzer (Dohrmann DC-80), respectively.

Oxygen in the headspace and slurry was removed by purging the media bottles with ultra pure Helium (He) for 5-7 minutes with periodic shaking. Using gas-tight syringes, approximately 10% of the He atmosphere in the media bottles was removed and replaced with C_2H_2. Gas samples from the headspace of each media bottle were analyzed for N_2O (the end-product of denitrification in the presence of C_2H_2) on a Varian 2600 gas chromatograph equipped with a Porapak Q column and a ^{63}Ni electron-capture detector. Following removal of the final gas sample, the sediment in each bottle was collected and the dry mass and ash-free dry mass (AFDM) determined. This was done by obtaining the initial mass after drying the sediment at 60°C, combusting the organics at 550°C, re-wetting the sediment, drying at 60°C, and obtaining the final mass (difference between pre- and post-combustion mass = AFDM). The amount of N_2O produced and the rates of denitrification were then calculated with standard equations.

Principal findings and significance:

The assays during July 2000 were conducted when in-stream NO_3^- concentrations were high (>8 mg N L^{-1}) and water temperatures were 20°C or more. The three sites showed a consistent pattern in that assays without chloramphenicol produced N_2O exponentially during the duration of the 3-4 hr period (Fig. 1). Conversely, when the sediment slurries contained a 5 mM concentration of chloramphenicol the production of N_2O was linear and considerably lower than assays without chloramphenicol. The linear denitrification rates were 0.08, 1.52, and 14.3 μg N_2O g $AFDM^{-1}$ hr^{-1} and the exponential rate coefficients were 0.2412, 0.8151, and 0.7659 hr^{-1} in Black Slough, the Embarras River, and Big Ditch, respectively.

By mid-August, NO_3^- concentrations in the streams had fallen 10-fold or more from those in July but water temperatures remained similar. Regardless of whether or not chloramphenicol was used, no assay during August showed an exponential production of N_2O (Fig. 2). Big Ditch, the stream with the greatest denitrification rate in July, had the lowest rates in August and displayed no substantial difference between assays with or without chloramphenicol (0.11 and 0.07 μg N_2O g $AFDM^{-1}$ hr^{-1}, respectively). In the Embarras River and Black Slough, denitrification rates from assays without chloramphenicol were, respectively, 4.3 and 1.7 times greater than assays with chloramphenicol (Fig. 2). Denitrification rates from assays with chloramphenicol for Black Slough and the Embarras River were 16.1 and 2.4 μg N_2O g $AFDM^{-1}$ hr^{-1}, respectively – an increase from values in July despite the lower nitrate concentrations. Assuming the chloramphenicol-amended assays estimated the actual benthic denitrification rates, failure to use the antibiotic would have overestimated denitrification by approximately 3 % in the Embarras River and 76 % in Black Slough.

Our results show that the two phases of denitrification observed in soil by Smith and Tiedje (1979) also can occur in stream sediments. It is not likely, however, that denitrification in benthic sediments occurs in an exponential fashion – if this was the case the supply of electron acceptors quickly would be depleted, even in the NO_3^--rich streams

of the agricultural Midwest. As suggested by Tiedje and Smith (1979), we believe the first phase to be representative of actual in-stream denitrification rates whereas the exponential, second phase is representative of the microbial response to the anoxic conditions of the assay. Chloramphenicol prevented the onset of the exponential phase and it appears that assays conducted without chloramphenicol might overestimate in-stream rates of denitrification, particularly in NO_3^--rich streams. Further work is needed to determine how chloramphenicol affects estimates of denitrification from other locations and stream types.

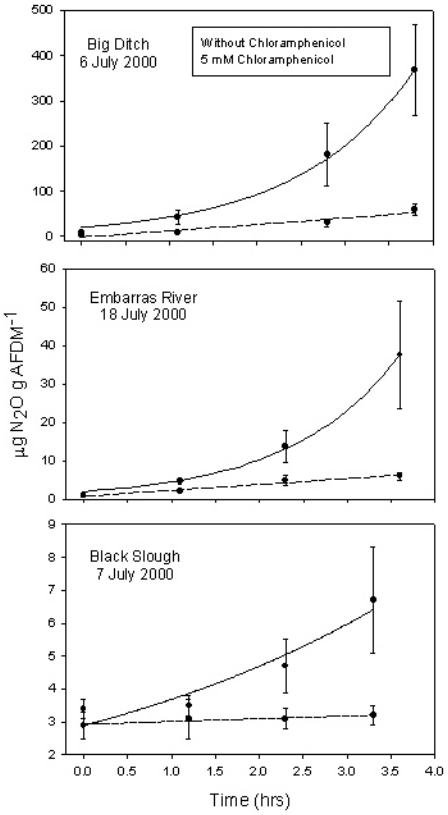

Figure 1. Denitrification measured with and without chloramphenicol in July 2000.

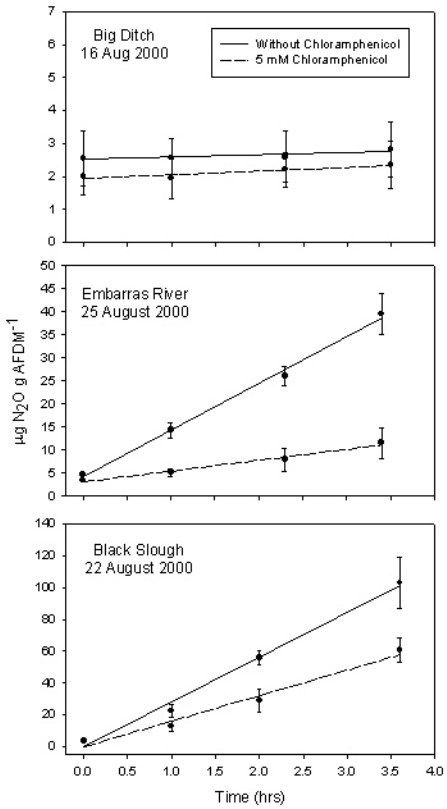

Figure 2. Denitrification measured with and without chloramphenicol in August 2000.

Literature Cited:

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David, M.B., L.E. Gentry, D.A. Kovacic, and K.M. Smith. 1997. Nitrogen balance in and export from an agricultural watershed. J. Environ. Qual. 26:1038-1048.

Hill, A.R. 1983. Denitrification: its importance in a river draining an intensively cropped watershed. Agriculture, Ecosystems and Environment 10:47-62.

Knowles, R. 1990. Acetylene inhibition technique: development, advantages, and potential problems. Pages 151-166 in (N.P. Revsbech and J. Sorensen, editors) Denitrification in soil and sediment, Plenum Press, New York.

Smith, M.S. and J.M. Tiedje. 1979. Phases of denitrification following oxygen depletion in soil. Soil Biol. Biochem. 11:261-267.

Tiedje, J.M., S. Simkins, and P.M. Groffman. 1989. Perspectives on measurement of denitrification in the field including recommended protocols for acetylene based methods. Pages 217-240 in (M. Clarholm and L. Bergstrom, editors.) Ecology of arable land, Kluwer Academic Publishers, Dordrecht, the Netherlands.

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Relative Scales of Hydrodynamic and Geomorphologic Influence on the Hydrologic Response in the Illinois River Basin

Basic Information

Title:	Relative Scales of Hydrodynamic and Geomorphologic Influence on the Hydrologic Response in the Illinois River Basin
Project Number:	2000IL5B
Start Date:	6/1/1999
End Date:	5/31/2001
Funding Source:	104B
Congressional District:	IL-15
Research Category:	Climate and Hydrologic Processes
Focus Category:	Geomorphological Processes, Hydrology, Floods
Descriptors:	Geomorphology, channels, watershed management, hydrologic models
Principal Investigators:	Praveen Kumar, Bruce Rhoads, Ben Yen

Publication

1. White, Amanda B., Praveen Kumar, Patricia M. Saco, Bruce L. Rhoads, and Ben C. Yen. 2001, Hydrodynamic and Geomorphologic Dispersion: Scale Effects in teh Illinois River Basin. Illinois Water Resources Center, University of Illinois at Urbana-Champaign, Urbana, IL. 40 pp.

Problem and Research Objectives:

The objective of the proposed work was to determine the relative effects of geomorphologic dispersion and hydrodynamic dispersion on the hydrological response of the Illinois River system as scale increases. The specific hypothesis tested was that as basin size increases, the river network structure, as compared to channel hydrodynamic properties, plays an increasingly dominant role in determining the hydrological response. The research also explored the effects of human actions, namely the modification of network structures via land drainage activities, on contemporary hydrologic conditions. The addition of headwater tributaries through land drainage activities in the late 1800s has undoubtedly greatly modified the geomorphologic dispersion, however the influence of this activity is unknown. The results provide important information and predictive capabilities for assessing the influence of future management scenarios on the hydrology of the Illinois River.

The geomorphologic dispersion coefficient, D_G, is a measure of the tendency of a disturbance to be dispersed by the river network structure. This concept incorporates the idea that raindrops falling on different areas at the same time will not reach the outlet at the same time (Rinaldo et al. 1991). The hydrodynamic dispersion coefficient, D_L, is a measure of the tendency of a disturbance to disperse longitudinally as it travels downstream. This dispersion is caused by the turbulence induced by the shearing effect of channel boundaries (Henderson, 1966; Mesa and Mifflin, 1986; Rinaldo et al., 1991). The two dispersion coefficients constitute the variance of an instantaneous unit hydrograph, as shown in Figure 1.

Methodology:

Task 1. Assess the reliability of the DEM extracted data for the Illinois River Basin.

This research uses 90-m digital elevation model (DEM) data to estimate the properties of the stream network. The aim of this task is to evaluate the consistency of the DEM extracted river network with the surveyed river network. The following activities were performed under this task:

1) Obtained the stream network for the Illinois River Basin from the EPA's Reach files (RF3).
2) Compared the stream network derived from the DEM to the EPA network. The derived network corresponded to the EPA network well. Figure 2 is an overlay of the two networks. Also note that the EPA network is a fifth order basin, whereas the DEM-extracted network is a sixth order basin.

Task 2. Determination and comparison of dispersion coefficients as scale increases.

The geomorphologic and hydrodynamic dispersion coefficients were determined for eight of the major watersheds in the Illinois River Basin (Fox, Des Plaines, Kankakee, Vermilion, Mackinaw, Spoon, La Moine, and Sangamon) as follows:

1) The geomorphologic dispersion coefficient, D_G, was determined as:

$$D_G = \frac{u}{2\overline{L}(\Omega)}\left(\sum_{\gamma\in\Gamma} p(\gamma)\left[\overline{L}(\gamma)\right]^2 - \left[\sum_{\gamma\in\Gamma} p(\gamma)\overline{L}(\gamma) \right]^2 \right)$$

where u is the kinematic wave celerity ($u = \alpha u^*$, α is an empirical constant dependent upon the channel cross-section shape, and u^* is the reference flow velocity), Ω is the order of the basin, $\overline{L}(\Omega) = \sum_{\gamma\in\Gamma} p(\gamma)\overline{L}(\gamma)$, γ is the specific path a raindrop follows, i.e., for a third order basin:

$$\gamma_1 \rightarrow O_1 \rightarrow C_1 \rightarrow C_2 \rightarrow C_3 \rightarrow \text{outlet}$$
$$\gamma_2 \rightarrow O_1 \rightarrow C_1 \rightarrow C_3 \rightarrow \text{outlet}$$
$$\gamma_3 \rightarrow O_2 \rightarrow C_2 \rightarrow C_3 \rightarrow \text{outlet}$$
$$\gamma_4 \rightarrow O_3 \rightarrow C_3 \rightarrow \text{outlet}$$

where O_i and C_i represent the hillslope and channel states, respectively, i is the Horton-Strahler order of the hillslope or channel state, $\Gamma = \{\gamma_1, \gamma_2, \gamma_3, \gamma_4\}$, $p(\gamma)$ is the probability that a raindrop will follow path γ_i, and $\overline{L}(\gamma)$ is the mean length of path γ_i.

2) The hydrodynamic dispersion coefficient, D_L, was computed as:

$$D_L \cong \frac{uh}{3\overline{S}}$$

where h is the flow depth and $\overline{S}$ is the mean slope of the channel.

3) The flow velocities and flow depths, as a function of the frequency of occurrence of a particular discharge F and the order of the channel ω, were calculated using the downstream hydraulic geometry equations developed from discharge data (Stall and Fok, 1968). The geomorphologic data, i.e., channel length, drainage area, slope, etc., were derived from the DEM.
4) The two dispersion coefficients were computed for each order of the eight watersheds, averaged by order, and then compared. Note that an increase in order signifies an increase in scale. Figure 3 displays the ratio of D_G to D_L, D_R, as a function of order ω and frequency F.

Task 3. Evaluation of changes in network structure on the hydrological response of the Mackinaw River Basin.

The anthropologic effects on the hydrologic response were determined as follows. To evaluate changes in network structure, the Mackinaw River Basin was chosen as the focus.

1) The geomorphologic instantaneous unit hydrograph (GIUH) was determined for the channel portion of the eight basins for each order, representing the change in scale of the hydrologic response. The inverse gaussian formulation of the GIUH (Rinaldo et al., 1991) was used to compute the GIUHs for each order of each basin.
2) Plats developed from public and private land surveys performed between 1804 and 1855 were used to establish a "pre-settlement" river network and the DEM-extracted network was considered as the "post-settlement" river network.
3) Two orders of tributaries were added upstream of the pre-settlement network, thus the first order of the pre-settlement network corresponds to the third order of the post-settlement network.
4) The pre- and post-settlement hillslope response was determined using the kinematic wave model and convolved with the pre- and post-settlement channel response (determined in item 1), respectively, to estimate the hydrologic response of the entire basin.
5) The pre- and post-settlement IUHs for equivalent orders, i.e., $\omega_{post} = \omega_{pre} + 2$, were compared (Figure 4).

Principal Findings and Significance:

1) A river network derived using DEM data adequately reflects the actual river network (Figure 2); hence the reliability of information from the DEM-extracted network was confirmed.
2) Both D_G and D_L increase with increasing order and decreasing flow frequency, however D_L generally increases at a faster rate with respect to order than D_G. With respect to frequency, the ratio of D_G to D_L, D_R, increases exponentially (Figure 3a). With respect to order, D_R increases for third through fifth order subbasins, decreases for sixth and seventh order subbasins, then increases for eighth order subbasins (Figure 3b). As frequency decreases, the crests and troughs of the curves of the ratio become less pronounced. The form of these curves indicate that the relative influence of geomorphologic dispersion on hydrologic response is greatest in low-order watersheds at high flow frequencies. In high-order watersheds, hydrodynamic dispersion plays an increasingly important role with respect to the hydrologic response; however, geomorphologic dispersion is still the governing influence.
3) These results have important implications in hydrologic modeling. The focus of modeling efforts in the past has been on measuring and surveying channel characteristics such as flow depth, top width, discharge, channel bed roughness, channel cross-sectional area, etc., to determine the hydrologic response of a river basin. These results show that the hydrologic response tends to be governed by geomorphologic dispersion at a variety of spatial scales, hence, the network structure plays a dominant role. Current models have substantial data requirements that are challenging and expensive for large or ungauged watersheds, but the network structure parameters are relatively simple to extract from DEMs, creating an environment in which the hydrologic response could be reasonably approximated without elaborate, expensive fieldwork.

4) The effects of European settlement on the Mackinaw River Basin's hydrologic response are consistent with those seen in urban watersheds, i.e., increases in peak discharges and decreases in the time to peak (Figure 4). For a frequency of occurrence of a particular discharge, F, of 0.1, these changes are more prominent in low-order watersheds (29.41% increase in the peak discharge for $\omega_{post} = 3$) and the less prominent in high-order watersheds (2.74% increase in the peak discharge for $\omega_{post} = 6$).

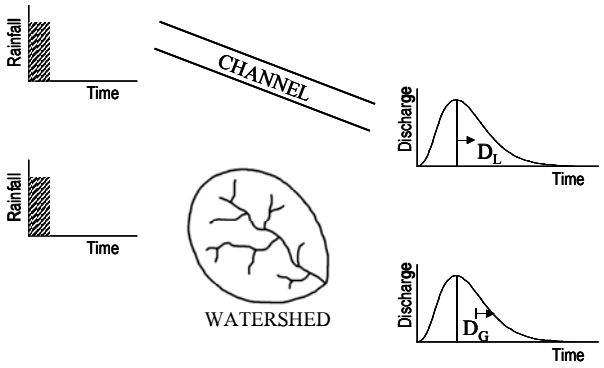


Figure 1. Hydrodynamic (D_L) versus geomorphologic (D_G) dispersion with respect to the variance of the instantaneous unit hydrograph.

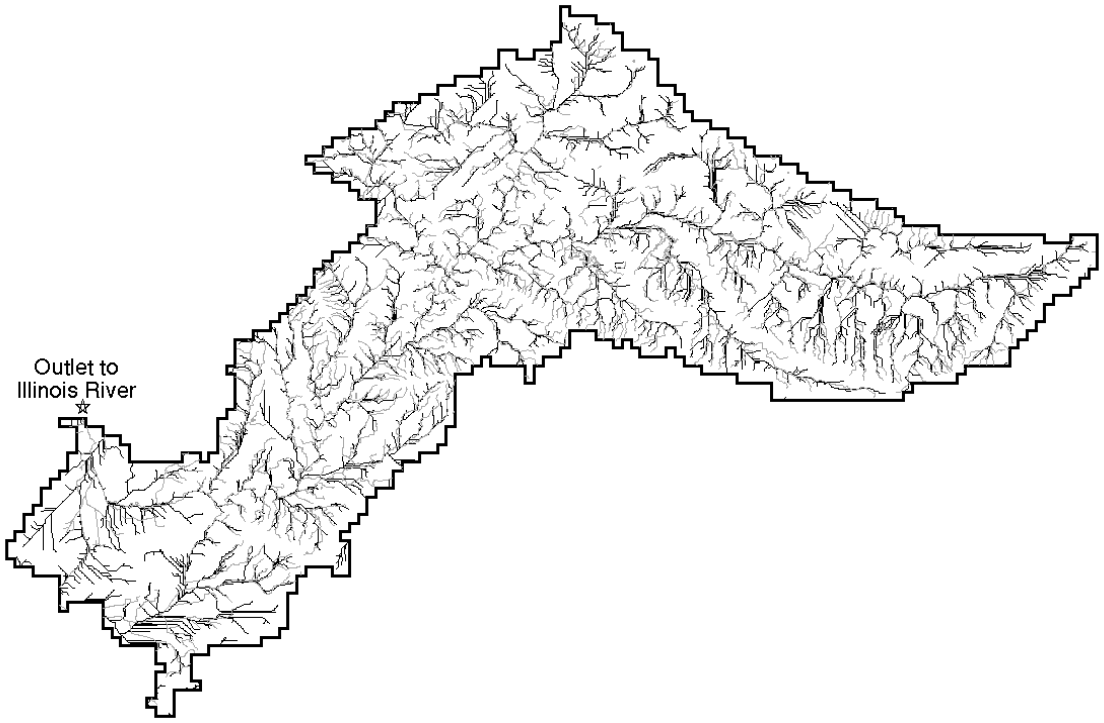


Figure 2. Overlay of the EPA river network (dashed lines) with the DEM-extracted river network (solid lines).

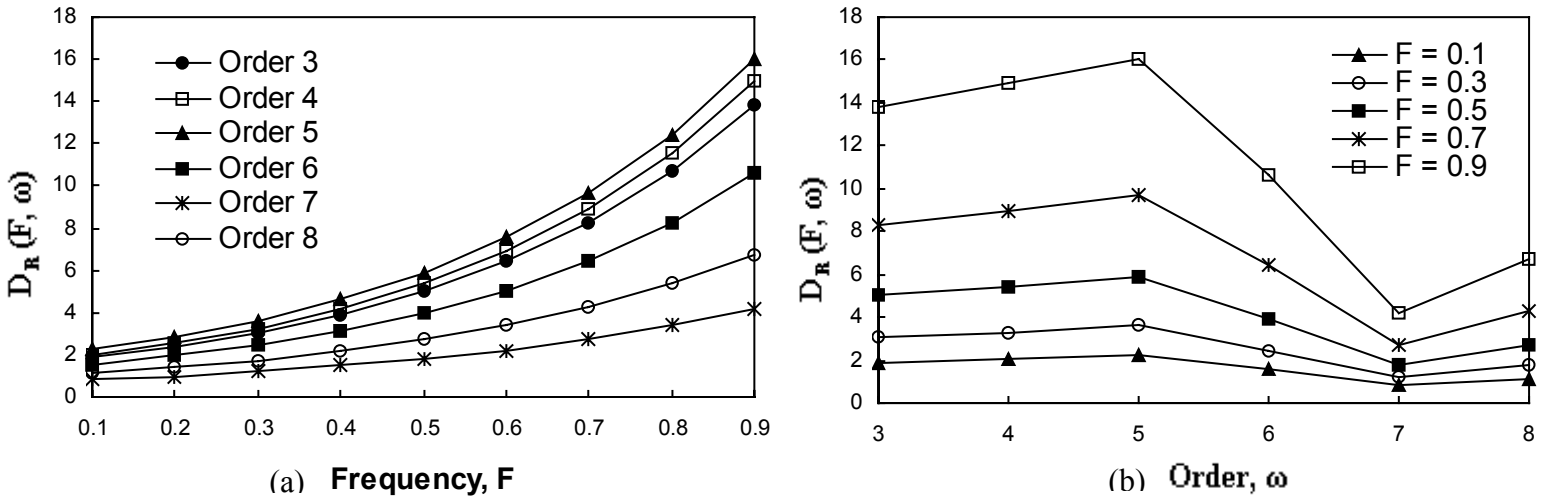
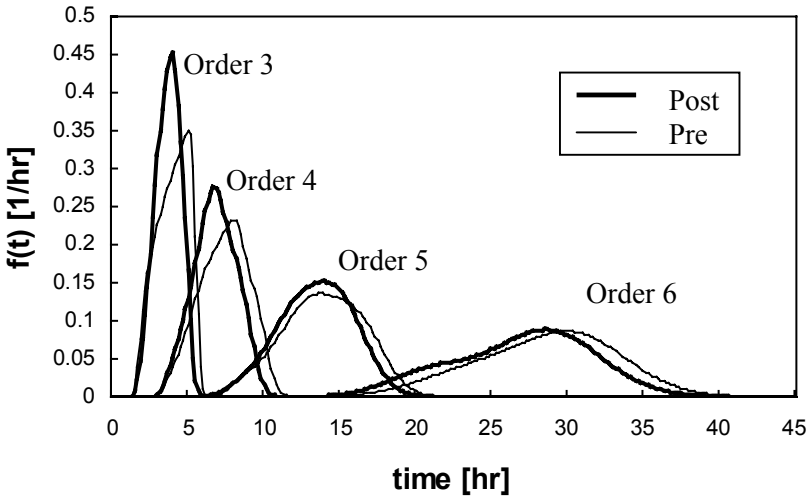


Figure 3. Ratio of D_G to D_L, D_R, (a) as a function of frequency F for various orders ω and (b) as a function of order ω for various frequencies F.

Figure 4. Comparison of pre- and post-settlement IUHs where the order represents the post-settlement river network configuration (F=0.1).



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[1] Henderson, F. M., 1966: Open Channel Flow, Macmillan, New York.

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[3] Rinaldo, Andrea, Alessandro Marani, and Riccardo Rigon, April 1991: Geomorphological dispersion. *Water Resources Research*, Vol. **27**, No. 4, pp 513-525.

[4] Stall, John B. and Yu-si Fok, July 1968: Hydraulic geometry of Illinois streams. *University of Illinois Water Resources Center Research Report No. 15*, Illinois State Water Survey, Urbana, Illinois.

The Cricket Frog (Acris crepitans) as a Biological Indicator of Watershed Health

Basic Information

Title:	The Cricket Frog (Acris crepitans) as a Biological Indicator of Watershed Health
Project Number:	2000IL12B
Start Date:	2/20/1999
End Date:	4/30/2001
Funding Source:	104B
Congressional District:	IL-15
Research Category:	Biological Sciences
Focus Category:	Ecology, Water Quality, Non Point Pollution
Descriptors:	Amphibian, anuran, frog, tadpole, herbicides, pesticides, pollutants, ponds, streams, wetlands, water quality, runoff, indirect effects, atrazine, mutagenicity, conservation, ecosystems, health effects, ecotoxicology
Principal Investigators:	Val Richard Beasley, A. Lane Rayburn

Publication

1. Cope, Rhian., Craig Miller, Margaret Post, Nohra Mateus-Pinilla, Joseph Murphy, and Val Beasley. 2000. Use of synthetic human luteinizing hormone releasing hormone for induction of breeding in the cricket frog (Acris crepitans). Journal of Herpetological Medicine and Surgery. 10:7-8.
2. Miller, Craig., David Bunick, and Val Beasley (2000). Identifying a genetic marker of sex in cricket frogs (Acris crepitans), a declining amphibian species, in Environmental Horizons 2000, The Environmental Council, University of Illinois at Urbana-Champaign, IL, p 44. (Abstract).
3. Rayburn, A. Lane, Jennifer L. Freeman, Nathan J. Beccue, Joe Murphy and Val Beasley. 2001. Amphibians as Biological Indicators of Watershed Health - poster presentation North Central American Society of Agronomy meetings, Peoria, IL

Problem and Research Objectives:

There is a global consensus that amphibian populations are declining at rates exceeding other wild vertebrates (Phillips, 1990; Vitt et al., 1990; Wake, 1990; Dunson et al., 1992). Suspected causes include habitat destruction, UV exposure, infectious diseases, and pollutants, including those that alter sexual development. Amphibians, which have lives dependent upon water and land, fulfill essential roles in the environment. They are important converters of algae and periphyton to animal tissues (as tadpoles); they serve as important prey species; and they are predators on insects, and a host of other small and often prolific animal species. In addition, amphibians rely on both aquatic environments and the terrestrial landscape. Accordingly, amphibians are unique sentinels of ecosystem health.

Cricket frogs (*Acris crepitans*) have experienced a severe decline in recent decades in the upper Midwest. Two of our studies have suggested that the widely used herbicide, atrazine, may cause intersex gonads in cricket frogs, and a mixture of polychlorinated biphenyls and polychlorinated dibenzofurans was associated with a marked sex ratio reversal (Reeder et al., 1998; Reeder et al., in preparation). Also, there are concerns about atrazine acting as a mutagen, especially after prolonged exposure. However, genetic markers of sex in the frogs remain to be identified, whether temperature extremes can alter sex determination in cricket frogs creating a confusion factor is unknown, and the properties of atrazine as a mutagen in amphibians remains to be adequately studied. The objective of this study was to gain background knowledge essential to understanding cricket frog declines. Our research specifically **1)** searched for a genetic marker of sex in the cricket frog; **2)** examined the influence of atrazine and temperature on sexual development in cricket frogs; and **3)** examined the role of atrazine as a mutagen in frogs.

Methods:

Methods for Objective 1: Search for a Genetic Marker of Sex in Cricket Frogs
Cricket frogs (n=145) were collected across Illinois to search for a sex-linked genetic marker. Frogs were sexed based on gross and histologic appearance of gonads. We employed random screens for sex-linked genes using PCR and RAPD analysis. DNA was obtained from leg muscle of individual frogs using the DNeasy Tissue Kit (Qiagen, Valencia, CA) following the DNA isolation protocol for rat tail. DNA was quantified based on absorbance at 260 nm using a GeneQuant DNA/RNA calculator (Pharmacia LKB Biochem Ltd., Cambridge, England). To ensure the DNA was not degraded, it was electrophoresed (120 volts for 2 hours in 0.8% agarose gel). To optimize the assay, different DNA concentrations were tested (50, 100, 200 and 500 ng) with both 5 and 25 picomoles of a 10-mer primer. Later, DNA (50, 100 and 500 ng) was tested with 5, 25, and 50 picomoles of a 10-mer primer. While individual stocks of cricket frog DNA were maintained, DNA also was pooled into four groups (two male and two female) with DNA from 5 individuals in each pool for both Clinton and Fayette Counties. The four DNA pools were then screened with random 10-mer primers in Random Amplified Polymorphic DNA analyses to search for a primer that would produce a different banding pattern between the sexes. While non-sex-specific bands would be expected to occur in both male and female pools, band(s) unique to one sex or the other would suggest the presence of a sex-linked gene. The PCR reaction conditions employed are listed in Table 1.

Table 1: PCR Reaction Conditions

Reagent	Concentration	Volume
DNA	10 ng/µL	5 µL
dNTP	1.25 mM	2 µL
10x Buffer	1x	2.5 µL
MgCl2	25 mM	2 µL
Water	100%	10.5 µL
Primer	25 pmoles/µL	2 µL
Taq	0.5 U/µL	1 µL

Protocols for amplification reactions were followed according to Operon Technologies (Alameda, CA). Seakem ME agarose (2%) (FMC Bioproducts, Rockland, ME) gels were made, and 15 μL of amplification products were electrophoresed at 40 mV for 6.5 hours to separate the DNA by size and allow photographic imaging. Once a promising primer was determined by comparison of male and female pool banding patterns, individual male and female DNA was screened using the same protocol. The DNA band of interest was isolated, amplified using a TOPO Kit, and sequenced. PCR data were confirmed via Southern blotting.

Methods for Objective 2: Examine the Influence of Atrazine and Temperature on Sexual Development in Cricket Frogs

To examine the influence of atrazine and temperature on sexual development, it was necessary to breed cricket frog tadpoles in order to begin with subjects that had not been exposed to atrazine and/or unusual temperature extremes. In these studies cricket frogs, were induced to breed via hormonal treatment for the first time (Cope et al., 2000). Embryos were placed individually in aquaria with 6 different treatments consisting of room temperature (19-22°C), high temperature (30°C), low temperature (16°C), room temperature with 20ppb atrazine, room temperature with 200 ppb atrazine, and a positive control (ethynlestradiol). A single tadpole was placed in a one-gallon glass mason jar for a total of sixty jars/treatment. All jars were placed randomly within the experimental layout. At the conclusion of the study, tadpoles were anesthetized in MS-222 (tricaine methane sulfonate) before blood was collected for analysis in the mutagenicity component of the study. Tadpoles were then preserved in 10% neutral buffered formalin in preparation for gross and histopathologic analysis of sexual development.

Methods for Objective 3: Examine the Role of Atrazine as a Mutagen

Animals and Exposures: As noted below, in Year 1, our cricket frog microcosm studies were unsuccessful due to high mortality in all groups. Also, the limited availability of the appropriate cricket frog life stages from other sources, and the small size of tadpoles made this species poorly suited for this research.

To compensate for the loss of laboratory-based exposure data on cricket frogs, blood was collected blood from metamorphic leopard frogs captured from 36 ponds in Minnesota as part of an EPA funded project to examine leopard frog health in relation to spatial, biotic and abiotic parameters. Included among these parameters was an analysis of water and sediment from each pond for the presence of pesticides as well as water quality measurements including temperature, dissolved oxygen and pH. Analysis of leopard frog health included tissue screens for toxicology, a parasitology survey of each animal, and histopathologic examinations of selected organs. We believed that analysis of the blood of metamorphic leopard frogs, as part of this EPA study, would provide a similar spectrum of exposure to both endocrine disrupting chemicals as well as developmental temperatures under real environmental conditions. Further, it would provide the opportunity for more detailed analysis with the larger database of leopard frog and pond data. This work is ongoing.

Also, we undertook laboratory exposures to atrazine on tadpoles of the American toad (*Bufo americanus*), bullfrog (*Rana catesbeiana*), wood frog (*Rana sylvatica*) and the gray tree frog complex (*Hyla versicolor/chrysoscelis*). In addition, since *Xenopus laevis* is a well-studied laboratory amphibian species and tadpoles can be readily obtained commercially at all times of the year, they served as a reference model in this study. Tadpoles of the American toad *(Bufo americanus)*, a native North American amphibian species, were used in experiments in the spring when egg clutches were readily available in the wild.

In a pilot study to assess toxicity, tadpoles of both *X. laevis* and *B. americanus* were exposed to atrazine at a range of concentrations up to 1000 ppb. To assess mutagenicity, tadpoles were exposed to atrazine at 3, 30, 300 and 3000 ppb for 1- and 4-week periods. The concentrations were selected to represent either regulatory or environmental exposure levels. Thus, 3 ppb represents the current maximum contaminant level (MCL) for drinking water as set by the EPA. Thirty ppb is a likely concentration that may be proposed as a new MCL. Three hundred ppb reflects concentrations found in watersheds adjacent to agricultural lands. And 3000 ppb represents atrazine concentrations that can be found running through field tiles. The exposure regimen also was selected to approximate what occurs during the growing season.

Given the typical spring/summer rainfall patterns, the 4-week exposure period was designed to simulate the period during which a developing aquatic animal may be exposed to a pulse of agricultural runoff containing atrazine.

Mutagenicity Assays: Anurans have nucleated blood cells and so it is possible to collect a DNA sample for analysis by collecting the blood. Blood samples were obtained from tadpoles, anesthetized in MS222, via heart puncture or exsanguination. Blood was placed in Storage Buffer containing DMSO and cryoprotectant and flash frozen in liquid nitrogen. Following standard procedures for analysis via laser beam flow cytometry, DNA was extracted from the samples, tagged with propidium iodide (a dye that will fluoresce from excitation by the laser beam) and run through a Coulter XL laser beam flow cytometer. A summary of DNA fragmentation, a measure of DNA strand breakage by mutagens and clastogens, is expressed as a coefficient of variation (CV). A comparison of the CV from treated vs control animals provides an assessment of the mutagenic potential of a toxicant.

Principal Findings and Significance

Findings and Significance, Objective 1: Search for a Genetic Marker of Sex in Cricket Frogs
One RAPD PCR primer (B1) initially seemed to show great promise in differentiating males from females when Clinton Counter frogs were examined. When individuals from additional sites were examined, it identified a unique band in nearly all phenotypic males, nearly all intersex individuals, and some phenotypic females as shown in Table 2.

Table 2: Cricket Frog DNA Exhibiting Band with Primer B1

County of Origin	Males (ratio bands/total)	Females (ratio bands/total)	Intersex (ratio bands/total)
Cass	4/4	5/5 *	1/1
Clinton	5/5	0/5	--
Fayette	5/5	3/5	--
McDonough	2/3	2/2	--
Schyler	5/6	3/3	--
Champaign (6-99)	14/14	4/8	3/3
Champaign	0/0	2/4	0/0
Piatt	8/8	4/6	½
Unknown	--	1/1	2/2
TOTAL	43/45 (95.5%)	24/39 (61.5%)	7/8 (87.5%)

There is more than one possible explanation as to why some phenotypic females have the putative "male" sex-linked band identified by marker B1. While this band in females may represent a gene(s) of a similar size with sufficient homology to bind the marker, we believe it is more likely that, in cricket frogs as in certain races of *Rana temporaria* and *Rana catesbeiana*, all individuals develop initially as phenotypic females regardless of whether they are genetically male or female. Later in those species/races, sex-determining genes of genetic males are expressed, leading to the development of the male gonad and regression of the female gonad. Under this hypothesis, adult phenotypic female cricket frogs with the "male" band may represent sex-reversed males. In actuality, they failed to express their male phenotype. This hypothesis would also explain why we have found intersex cricket frogs that possess this "male" band. They may represent genetically male individuals in the transition phase from female to male phenotype. While it seems highly likely that endocrine disrupting chemicals would have an effect on this developmental process, it has been difficult to study this without a means for reliable differentiation of the genetic sex from the phenotypic sex. We have isolated DNA from the male band, sequenced it, and compared it to known sequences in Genebank. We were unable to find a match, suggesting this sequence may be part of a previously unknown gene on a region of the sex chromosome in cricket frogs. Southern blotting also failed to confirm that it was related to a known sex-linked gene. This study sets the stage for an ongoing analysis.

Understanding genetic programming of sex determination in cricket frogs will enable mechanistic studies of sex determination in this species and probably other amphibians. After a sex-linked gene is identified, the probe could be used in studies to establish whether contaminants or temperature disrupt endocrine

function. This would enable determination of concentrations of contaminants at which expression of sex-determining genes are disturbed, facilitating regulation of pesticides to protect amphibians. Furthermore, the RAPD-PCR technique explored in this study may be of benefit to other species. It should be possible to identify and characterize a sex-linked sequence in any species that possess heterogeneous chromosomes.

Findings and Significance for Objective 2 - Influence of Atrazine and Temperature on Sexual Development

This component of the study was unsuccessful due to high mortality in all treatment groups. This high mortality was associated with infections of the liver and kidneys as determined via histopathology. The unexpected high mortality and inability to rear animals through metamorphosis left us with too few individuals for a statistically meaningful analysis of cricket frogs. In an effort to compensate for the situation, we examined the gonads of gray tree frog (*Hyla versicolor*) metamorphs from an earlier study in which mesocosms containing the tadpoles had been treated with atrazine at 0, 20, 200, or 2000 ug/L. Unfortunately, gonads in these recently metamorphosed hylids were just beginning to differentiate, making it impossible to interpret the effect of atrazine exposure with regard to altering male/female gonadal development as well as the presence/absence of intersex. Of controls that were clearly in the process of differentiation, 10 were consistent with differentiation into males and 5 appeared to be intersex. No normal females were found.

Stages of tadpole development and metamorphosis encompass a period of rapid and dramatic change in the development of all organ systems. Establishing a baseline of normal development in a number of target anuran species (including cricket frogs and gray tree frogs) by conducting a sequential histologic examination of gonad morphogenesis from early tadpole stages through completion of metamorphosis and maturation would aid in interpretation of the potential toxic effects of endocrine disrupting chemicals.

Findings and Significance for Objective 3 – Role of Atrazine as a Mutagen

Due to the high mortality in the cricket frog treatments and the relationship of this mortality to disease as described above, there were too few surviving animals from which to draw blood to provide a statistically meaningful analysis.

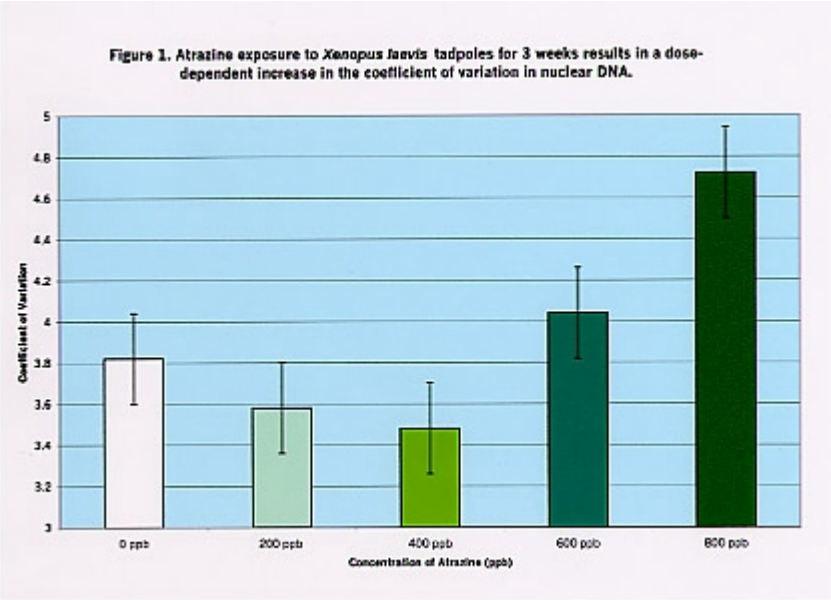
Our preliminary studies indicate that high levels of atrazine do adversely affect the tadpoles of both *X. laevis* and *B. americanus* species. At levels above 1000 ppb, a significant increase of mortality occurs. The tadpoles begin to die at one-week exposure and at two weeks, many are dead. Beyond two weeks, few animals are left in the treated tanks. *Xenopus* tadpoles seem to be more susceptible than *B. americanus* to this toxicity.

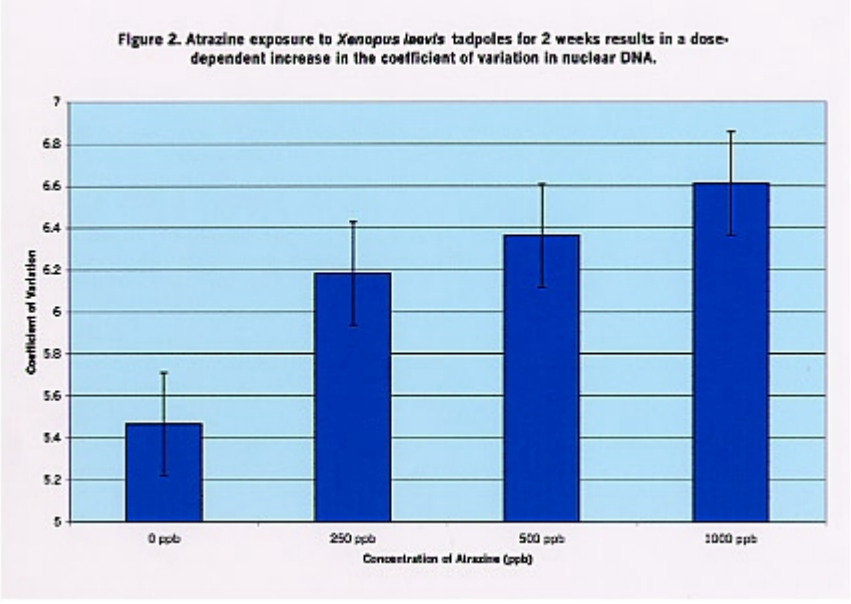
To date, analysis of leopard frog DNA has been completed from 16 of the 36 sites in Minnesota for a total of 240 samples. The average CV of these samples was 2.04 with a standard deviation of 0.2. In general, the CVs of leopard frogs from most sites examined appeared normal. In nearly all sites, the CVs from leopard frogs collected within a site had CVs similar to those collected among sites. While analysis of sediment samples is still pending, these results compare with the water quality results. No significant concentrations of pesticides were detected at these sites. By contrast, at one highly contaminated site presenting, the CV was much wider, indicating likely DNA damage.

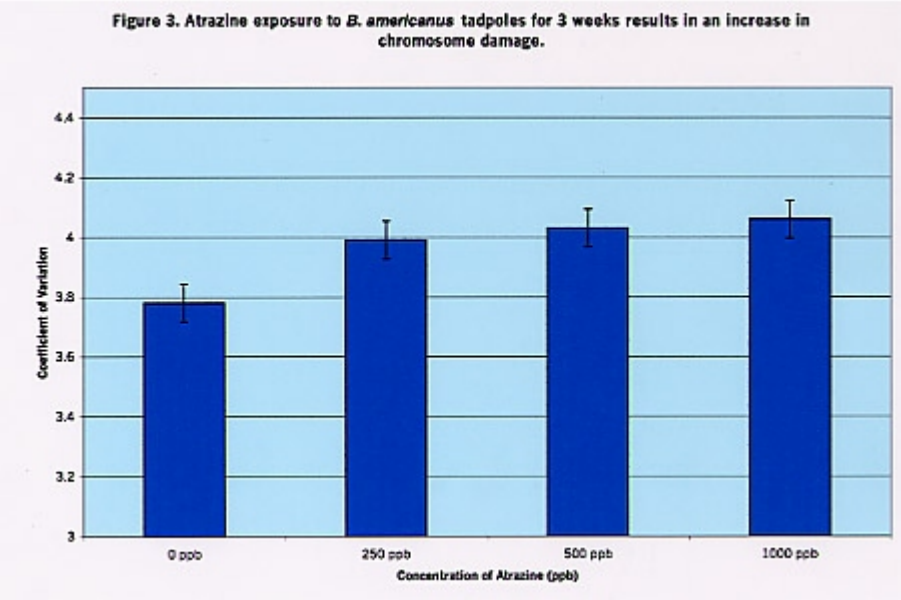
Further work with the gray treefrog complex has proven especially interesting. The two-species in this complex, *Hyla chrysoscelis* and *Hyla versicolor* are phenotypically indistinguishable from one another. Identification of each species, for purposes of establishing distribution ranges, is currently accomplished employing a call survey. The mating calls of males of each species are quite distinguishable and can be identified at night during the breeding season. Cytogenetic analysis of chromosomes in the lab (a time consuming and labor intensive process) was the only other means by which to distinguish the two species. The chromosome number of the *H. chrysoscelis* is diploid while that of its sibling species, the gray treefrog *H. versicolor* is tetraploid. Using laser beam flow cytometry and correlating this with call survey data from the 36 ponds in our EPA study sites, we have shown that it is possible to demonstrate the presence of either or both species at a site based on identifying gray treefrog tadpoles that are diploid and tetraploid. This technique correlated well with our field-based call survey data and in cases where these species were not heard calling by our field personnel, but tadpoles were collected, it became possible to identify the species

and fill in missing data. In addition to facilitating species distribution efforts, this technique will augment provide a means determine whether these closely related species hybridize.

Atrazine appears to be genotoxic in both species. In *Xenopus*, at both three week and two-week exposure, tadpoles at the higher levels of atrazine have increased chromosome date as measured by flow cytometry. The increase appears to be in a dose dependent fashion (Figures 1 and 2). A similar phenomenon is also seen in the American toad. At high concentrations of atrazine, an increase in chromosome damage is occurring at three weeks (Figure 3).







Although these results are preliminary, they do indicate that atrazine does have a genotoxic affect on tadpoles. Interestingly, the effect seems greater on *Xenopus* tadpoles. Since the American toad tadpoles were collected in areas that may have atrazine exposure it may be hypothesized that they have developed a tolerance to atrazine. In addition, it appears that the most genotoxicity occurs at concentrations of atrazine over 500 ppb.

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Analysis of Water Use Trends in the United States: 1950 - 1995

Basic Information

Title:	Analysis of Water Use Trends in the United States: 1950 - 1995
Project Number:	1999IL0012G
Start Date:	9/1/1999
End Date:	8/31/2001
Funding Source:	104B
Congressional District:	12th
Research Category:	Water Quality
Focus Category:	Water Use, Conservation, Models
Descriptors:	Water Demand, Water Use Data
Principal Investigators:	Ben A. Dziegielewski, Subhash C. Sharma

Publication

1. Dziegielewski, Ben, Thomas J. Bik, Xiaoying Yang, Subhash C. Sharma and Heru Margona. 2002, Analysis of Water Use Trends in the United States: 1950-1995. Illinois Water Resources Center, University of Illinois at Urbana-Champaign, Urbana, IL. 420 pp.

Multi-Objective Decision Support Tools for Protection of Streams in Urbanizing Watersheds

Basic Information

Title:	Multi-Objective Decision Support Tools for Protection of Streams in Urbanizing Watersheds
Project Number:	2001IL4241B
Start Date:	6/1/2001
End Date:	5/31/2003
Funding Source:	104B
Congressional District:	12th
Research Category:	Water Quality
Focus Category:	Management and Planning, Hydrology, Models
Descriptors:	Land Management, Urbanization, Modeling, Decision Support, Optimization
Principal Investigators:	John W. Nicklow, Leslie Aileen Duram

Publication

1. Nicklow, J.W., M.K. Muleta, 2002, Integrative decision making for watershed management using evolutionary algorithms, in Proceedings of the 2002 Conference of the Environmental and Water Resources Institute, ASCE, Reston, VA.

Illinois Water Resources Center
Annual Report

1. **Project Number:** 01-1

2. **Project Title and PIs:** Multi-Objective Decision Support Tools for Protection of Streams in Urbanizing Watersheds; Dr. John W. Nicklow, Assistant Professor of Civil Engineering, Southern Illinois University at Carbondale, and Dr. Leslie A. Duram, Associate Professor of Geography, Southern Illinois University at Carbondale

3. **Research Category:** Land Management, Urbanization, Decision Support System

4. **Problem and Research Objectives:** The 20th century has witnessed the conversion of a large number of natural and agriculturally dominated watersheds to urban developments. The Lower Kaskaskia watershed, located in the Metro East area of southwestern Illinois, is an example of a basin that is undergoing extensive land use changes through urbanization. It is clear that such drastic landscape changes in this and other watersheds stimulate a corresponding cascade of dynamic adjustments in both water quantity and quality at locations further downstream. Sophisticated hydrologic simulation models and Geographic Information Systems (GIS) have become the standard means for assessing the impacts of urban sprawl on water resources systems. Simulation and GIS models alone, however, are incapable of directly revealing optimal land development patterns that meet specified objectives. More comprehensive watershed-scale modeling techniques are needed to overcome this limitation and assist decision makers in the planning of new developments. Therefore, the objectives of this study are (1) to develop an adaptive, basin-wide decision support model that could be used by land use managers and watershed management institutions to identify optimal land use changes in the Lower Kaskaskia and other similar watersheds, and; (2) investigate stakeholder concerns and reactions regarding formulation and application of the model in order to ensure continuous local support. Outcomes of this two-year project will include the decision support software package; a historical survey and conceptual model of the relationship between urbanization and the hydrologic and water quality variability in the Lower Kaskaskia basin; results of the decision support model when applied to the Lower Kaskaskia basin; and a summary and set of conclusions concerning the social science investigation.

5. **Methodology:** The decision support model has been created by integrating the U.S. Department of Agriculture's Soil and Water Assessment Tool (SWAT) for comprehensive hydrologic simulation, a GIS for generating input and visualizing output, and an evolutionary optimization algorithm for identifying weighted, optimal land use patterns. The combination of these modules results in a single, multi-objective decision framework capable of yielding land use changes that solve the following problem:

Minimize → (i) The adverse effects on water quality and quantity caused by urbanization, and (ii) $-1 \times$ economic growth and profit to be earned through urbanization;

Subject To → (i) Physical, chemical and biological laws governing watershed hydrology; and (ii) realistic bound constraints on the feasible land development.

Within this problem formulation, scaled weighting factors are assigned to each of the two objectives so that the user can convey his or her personal hierarchy of objectives to the decision model. The independent decision matrix is comprised of alternative landscapes, which incorporate specific land use changes on a spatial and temporal scale. Dependent variables are those that describe water quantity and quality variability and economic growth. By using SWAT to solve constraints that govern watershed hydrology and ecology, the complex interactions between land use changes and water quality and quantity are fully captured. The remaining constraint that allows only feasible land use changes is handled directly by the optimization algorithm. Two types of evolutionary algorithms, a genetic algorithm and an artificial life algorithm, are being investigated for solution to this problem. At least initially, the optimal landscape is defined as that which minimizes sediment yield in subsequent streams, while simultaneously maximizing anticipated profit from urban development. Profit due to urbanization has been defined through a simple distance relationship; lands closer to the Metro East region or in the vicinity of major interstates will be more likely to incur larger profits from urbanization. Additional water quality objectives and a more comprehensive economic relationship will be sought once the initial model has been tested and feedback from stakeholders has been obtained. Following an extensive review of watershed planning activities in the Lower Kaskaskia basin, key stakeholders have been identified. Meetings with these stakeholders have been scheduled to aid in the determination of other locally valued parameters that should be included in the model and allow the effective dissemination of results to key individuals.

6. **Principal Findings and Significance:** Tasks completed to date include:
   - Mathematical formulation of the watershed management problem that involves minimizing sediment yield while maximizing economic benefit of urbanization;
   - Collection of SWAT data and thematic GIS data and construction of a basemap and digital elevation model for the Lower Kaskaskia basin;
   - Development of a real-valued genetic algorithm software module;
   - Modification of SWAT source code in preparation for an optimization linkage;
   - Construction of the interface between SWAT and the genetic algorithm;
   - Initial testing and application of the decision model to the Lower Kaskaskia basin;
   - Completion of a historical population survey from census tracts within the Lower Kaskaskia watershed (1970-2000);
   - Initiated a historical survey of water quality parameters and evaluation of parameters to be generated by SWAT for development of the conceptual model;
   - Identification of key stakeholders in the Lower Kaskaskia watershed, and;
   - Scheduled two stakeholder meetings (July and September, 2002).

Principal findings thus far can be categorized into the modeling component and social science aspect of the research. First, results of preliminary testing indicate that the integrative modeling approach is likely to be an efficient method for watershed planning in urbanizing basins. The initial model is capable of directly identifying optimal landscapes that meet both sediment reduction and economic objectives. Second, an extensive investigation of stakeholder involvement has identified two primary environmental planning and management activities in the Lower Kaskaskia basin. The first is the Kaskaskia River Corridor Stewardship Plan (1995), which brought stakeholders together to form the Kaskaskia River Private Lands Initiative Committee. Stakeholders include the Southwest Illinois Resource Conservation and Development Council (SWILRC&D), National Resource Conservation Service, Okaw River Basin Commission, Illinois Dept. of Agriculture, U.S. Fish and Wildlife Service, Farm Bureau, Soil and Water Conservation Districts, County Board members, Sierra Club, The Nature Conservancy, U.S. Army Corps of Engineers, and others. The second is the Metro East Sustainable Growth Resource Group (MESGRG), which has been recently active as part of the Illinois Growth Task Force. The MESGRG is comprised of numerous stakeholders including the SWILRC&D, Homebuilders Association, American Bottomland Conservancy, Sierra Club, County Planners, Illinois Dept. of Natural Resources, and others.

7. Graduate Students Supported with Funding

Name	Department	College	Institution	Degree Sought	Date Degree was or will be awarded
Kyle Allred	Civil Engrg.	Engineering	SIUC	MSCE	May 10, 2003

8. Publications and Presentations

Nicklow, J.W., M.K. Muleta, 2002, Integrative decision making for watershed management using evolutionary algorithms, in Proceedings of the 2002 Conference of the Environmental and Water Resources Institute, ASCE, Reston, VA.

9. Notable Achievements: The strategic interface between an optimization algorithm and a comprehensive watershed simulation model represents a new methodology to guide cost effective and environmentally sound watershed planning decisions. Consequently, the resulting model provides land use managers and watershed management institutions with a useful visualization tool for planning and communicating urbanization activities that will affect watershed health.

10. Related and Seed Projects

Beaulieu J., J. Nicklow, S. Kraft, C. Lant, 2001, Decision support for water quality planning in multiple ownership watersheds: The case of the Cache River and applications in other Illinois watersheds, Illinois Council for Food and Agricultural Research: Water Quality Strategic Research Initiative. Period Covered: 7/01-6/02, Funds Received: $65,000.

Integrated Engineering and Geomorphological Analysis for Assessing the Performance of Bendway Weirs in Southern Illinois

Basic Information

Title:	Integrated Engineering and Geomorphological Analysis for Assessing the Performance of Bendway Weirs in Southern Illinois
Project Number:	2001IL4321B
Start Date:	6/1/2001
End Date:	5/1/2003
Funding Source:	104B
Congressional District:	15
Research Category:	Not Applicable
Focus Category:	Geomorphological Processes, Hydrology, Models
Descriptors:	streambank, erosion, bendway weirs, fluvial geomorphology, hydraulic modelling
Principal Investigators:	Bruce Rhoads, Marcelo Garcia

Publication

Illinois Water Resources Center
Annual Report Format
Spring 2002

1. Project Number:

2. Project Title and PIs: Integrated Engineering and Geomorphological Analysis for Assessing the Performance of Bendway Weirs in Southern Illinois, Bruce Rhoads, Marcelo Garcia.

3. Research Category:
Geomorphological and engineering analysis of bendway weirs

4. Problem and Research Objectives:
The purpose of this study is to conduct an integrated geomorphological and engineering evaluation of the performance of bendway weirs in streams in Illinois. The research will integrate a geomorphological analysis of bendway weirs supported by the Illinois Department of Natural Resources with an engineering-based assessment that uses numerical modeling of flow through bends with weirs to evaluate the impact of these structures on fluvial processes. The goal is to provide a wide-ranging, theoretically based evaluation of bendway weir performance for a variety of meander configurations. Specific objectives are: 1) to develop a general computational fluid-dynamics (CFD) model to accurately predict patterns of three-dimensional flow through meander bends with bendway weirs and 2) use field data collected as part of the IDNR-funded geomorphological assessment to test the predictive capabilities of the model developed in phase 1 for real-world cases.

5. Methodology:
The methodology will involve the development of a CFD model of flow through bends with weirs. The three-dimensional numerical model FLOW-3D will be adapted for this purpose. Once the model is developed and calibrated, the influence of bendway weirs of different types on flow through hypothetical meander bends of different configurations will be explored through a series of numerical simulations. Finally the model will be used to simulate flow through two real-world bends that contain bendway weirs: one site where weirs have effectively mitigated erosion and one site where the weirs have failed to mitigate erosion. Field data collected as part of the IDNR-supported study will provide the basis for developing these simulations and for evaluating predicted patterns of 3-D velocities relative to measured patterns of 3-D velocities

6. Principal Findings and Significance:
The first year of activities was devoted to extending the capabilities of STREMR, a 2-D depth-averaged flow model, so that it could handle sediment transport in rivers. In particular, the code is being generalized to handle suspended and bedload transport as well as bed level changes associated with sediment scour and deposition. Our goal is to be able to use the code to predict both hydrodynamic and morphological changes caused by bendway weirs in Illinois streams.

STRMR has been modified to include sediment transport (Garcia, 2001). Bed deformation is accounted for by means of the Exner Equation-sediment conservation equation. This equation has been implemented in the subroutine MAGIC of STRMR. Bed level changes are computed with the help of bedload transport rates and suspended

load rates. To estimate sediment entrainment rates, several different available transport functions can be used, depending on the characteristics of the stream being modeled.

The modified version of STRMR was used to model a bend of Sugar Creek at Brookside Farm, Illinois. This site is of particular interest since the Geomorphology group of Professor Bruce Rhoads has been conducting measurements around a bendway weir field. We are currently in the process of coupling the flow field with the sediment bed to predict potential sediment erosion and deposition areas within the bend.

Field work has produced data sets on three-dimensional flow through weir fields at three sites in Illinois – one along Big Creek in Clark County, one along Sugar Creek in McLean County and one along Kickapoo Creek in McLean County. All sets of measurements were obtained when flow was at or near the crests of the weirs at each site. These data provide the basis for field testing of the predictive capabilities of the STREMR model.

References

Garcia, M.H., Modeling Sediment Entrainment into Suspension, Transport, and Deposition in Rivers, Chapter 15 in Model Validation: Perspectives in Hydrological Science, Edited by Malcolm G. Anderson and Paul D. Bates, John Wiley & Sons, England, 2001.

7. Graduate Students Supported with Funding

Name	Department	College	Institution	Degree Sought	Date Degree was or will be awarded
Jorge D. Abad	Civil and Env. Engineering	Engineering	Univ. of Illinois	M.A.	Anticipated May 2003

8. Publications and Presentations

9. Notable Achievements:

The research is developing a state-of-the-art predictive tools that can be used to enhance the success of stream restoration.

10. Related Seed Projects

The research is a companion project to a grant to PI Rhoads from the Illinois Department of Natural Resources to develop a manual for geomorphological assessments of bendway weirs.

Information Transfer Program

The major functions of the Illinois Water Resources Center are to oversee a research program and convey the results of research and development within the water resources field to specialists and the interested public. Information transfer is accomplished through workshops, conferences, published proceedings, a website, and maintenance of a library of Illinois Water Resources Center reports and videotapes. In addition, the Center Director and staff serve on state advisory committees and consult with government agencies.

Governor’s Illinois River Conference 2001

Basic Information

Title:	Governor’s Illinois River Conference 2001
Project Number:	2001IL29B
Start Date:	3/1/2000
End Date:	10/31/2001
Funding Source:	104B
Congressional District:	IL-15
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	Outreach, conference, river, management, restoration, basin
Principal Investigators:	Robert Frazee, Stephen P. Havera

Publication

1. 2001 Governors Conference on the Management of the Illinois River System. Proceedings of the Eighth Biennial Conference, October 2-4, 2001, Peoria, Illinois, Alesia Strawn, Editor. Illinois Water Resources Center, Special Report No. 27.

Both the IWRC Director and the communication's specialist served on the planning committee for the 2001 *Governor's Conference on the Management of the Illinois River System*, which was held on October 2-4, 2001 in Peoria, Illinois. IWRC staff set up a display in the exhibition area of the Governor's Conference, and the communication's specialist produced the Conference program, abstracts, and proceedings.

Publication: *2001 Governor's Conference on the Management of the Illinois River System.* Proceedings of the Eighth Biennial Conference, October 2-4, 2001, Peoria, Illinois, Alesia Strawn, Editor. Illinois Water Resources Center, Special Report No. 27.

Watershed Academy

Basic Information

Title:	Watershed Academy
Project Number:	2001IL30B
Start Date:	3/1/1999
End Date:	6/30/2002
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Category:	Water Use, None, None
Descriptors:	Watershed, Planning, management, water quality
Principal Investigators:	Richard E. Sparks, L. Chris Johns

Publication

1. Illinois Water Resources Center, University of Illinois, Illinois Department of Natural Resources, and Illinois Environmental Protection Agency. 2002. Watersheds in Transition; Workbook. 200p.

WATERSHED ACADEMY: A top-down regulatory approach has worked to control pollution from point sources (industrial and municipal sources). The same cannot be said of problems originating from nonpoint sources (excessive nutrients, pesticides, excessive sediment, water flow extremes), partly because of the diffuse nature of the sources and complexity of the problems and partly because of socio-political concerns about retaining local control and protecting private property rights. Watershed management addresses the complexity issue and watershed partnerships provide a bottom-up, collaborative alternative to top-down control. However, the partnerships will not succeed and water quality will not improve unless some degree of technical competence and organizational skill can be transferred to the local partnerships. Connections must be made between the partnerships, delivery systems (e.g., extension), and the expanding knowledge base in both nonpoint pollution control and local governance. A Watershed Academy developed by the Illinois Water Resources Center provides those connections.

Following the first curriculum about basic watershed science (2000) and the second curriculum (2001) on effective leadership, a third curriculum was developed in 2002 about watershed planning in the context of a changing landscape. A team of Academy members from the University of Illinois, Illinois Department of Natural Resources, American Farmland Trust, USACE Construction Engineering and Research Laboratory, Northeastern Illinois Planning Commission, Conservation Design Forum, Integrated Lakes Management and Purdue University Extension presented the workshop *Watersheds in Transition,* March 13-15, 2002, to twenty-four Illinois watershed leaders. A 200-page loose-leaf resource manual was prepared and tested during the workshop.

Publication: Illinois Water Resources Center, University of Illinois, Illinois Department of Natural Resources, and Illinois Environmental Protection Agency. 2002. *Watersheds in Transition*; Workbook. 200p.

Midwest Technology Assistance Center (MTAC)

Basic Information

Title:	Midwest Technology Assistance Center (MTAC)
Project Number:	2001IL31B
Start Date:	11/1/1998
End Date:	6/30/2003
Funding Source:	104B
Congressional District:	15
Research Category:	Water Quality
Focus Category:	Water Quality, None, None
Descriptors:	Water systems, assessment, evaluation
Principal Investigators:	Richard E. Sparks, Kent Smothers

Publication

MIDWEST TECHNOLOGY ASSISTANCE CENTER (MTAC): MTAC is a cooperative effort of the ten states of the Midwest (congruent with USEPA regions 5 and 7), led by the Illinois Water Resources Center and the Illinois State Water Survey. The participation of each state in MTAC is led by the Director of their Water Resources Institute. Following a national competition, the Midwest Technology Assistance Center (MTAC) was established October 1, 1998 to provide assistance to small public water systems throughout the Midwest with funding from the United States Environmental Protection Agency (USEPA) under the 1996 amendments to the Safe Drinking Water Act.

The mission of MTAC is to assist small community water systems in the assessment, evaluation, and implementation of technological solutions to their drinking water problems.

In 2001, the Midwest Technology Assistance Center produced a CD-ROM-based Emergency Planning Guide for small systems, so small communities anywhere in the nation can handle droughts, power outages, and other emergencies that threaten water supplies. MTAC also created a web site and held a workshop to disseminate information to the small systems. MTAC and the Missouri Technology Center co-sponsored the workshop for small public water systems on February 29, 2000 in St. Louis, Missouri.

Water 2002

Basic Information

Title:	Water 2002
Project Number:	2001IL32B
Start Date:	12/1/2000
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Category:	Education, None, None
Descriptors:	Science, Policy, Regulation
Principal Investigators:	John B. Braden, Tim Feather

Publication

1. Water 2002 Connections. Conference proceedings of the 3rd biennial conference. November 6 and 7, 2002, The Chancellor Hotel and Convention Center, Champaign, IL. Edited by Nancy Koeneman. 71 p.

WATER 2002: The Center will host the third statewide biennial conference on water issues (Water 2002) on November 6-7, 2002. The conference will address science, technology, and policy developments in water resources and engage citizens, researchers, and groups interested in water issues. Specific issues to be addressed are integrated ecosystem management, the role of science in policy and regulation, and water supply and treatment.

IWRC Web Site

Basic Information

Title:	IWRC Web Site
Project Number:	2001IL33B
Start Date:	3/1/1999
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	Web site, education, water, information
Principal Investigators:	L. Chris Johns

Publication

IWRC WEB SITE: The Illinois Water Resource Center web site (www.environ.uiuc.edu/iwrc) provides direct links to IWRC publications, news, funding sources, and a calendar of events. Links to current topical resources include TMDL's, Gulf hypoxia, and aquatic invasive species. The IWRC homepage links to the National Institutes for Water Resources (wrri.nmsu.edu/niwr/) where all 54 State Water Research Institute's home pages are listed, to the Universities Council on Water Resources (www.uwin.siu.edu/ucowr/index.html), and the Illinois-Indiana Sea Grant home page (www.iisgcp.org/). Links to over 50 government and non-government websites about water resource topics can be accessed from the IWRC main page link to Watershed Science on the Web (www.environ.uiuc.edu/iwrc/watershed_science_on_the_web.htm).

WATERSHED ACADEMY ON THE WEB: The Illinois Watershed Academy website (www.environ.uiuc.edu/iwrc/WatershedAcademy/) provides information about upcoming Academy workshops, registration information and forms, and materials that are part of the developing curricula.

the Link

Basic Information

Title:	the Link
Project Number:	2001IL34B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	Education, None, None
Descriptors:	Newsletter
Principal Investigators:	Nancy Koeneman, Parna Mehrbani

Publication

1. the Link. Fall 2001 and Spring 2002 Newsletters. Environmental Council and Illinois Water Resource Center, University of Illinois at Urbana-Champaign.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	0	0	5	2	7
Masters	2	0	0	0	2
Ph.D.	0	0	0	3	3
Post-Doc.	0	0	0	1	1
Total	2	0	5	6	13

Notable Awards and Achievements

Safe drinking water for small communities. The Midwest Technology Center (MTAC) helps thousands of small communities in Illinois and elsewhere in the Midwest meet new drinking water standards, cope with natural and willful hazards (including sabotage and terrorism), and continue to provide safe drinking water. In 2001 MTAC developed a CD-based Emergency Planning Guide for small systems, so small communities anywhere in the nation can handle droughts, power outages, and other emergencies that threaten water supplies. Funded by USEPA, MTAC is a joint program of the Illinois Water Resources Center and the Illinois State Water Survey.

Decision support for stream protection in urbanizing areas. Drs. John W. Nicklow and Leslie A. Duram, Southern Illinois University at Carbondale, are combining hydrologic simulation, geographic information systems, and cutting-edge decision support methods (including optimization and visualization) to identify land use patterns that minimize impacts on surface waters while maintaining economic development opportunities. Their work is applied to the Lower Kaskaskia River watershed in the Metro East region, across the Mississippi River from St. Louis, where stakeholder involvementd is part of the project. This project is supported by the U.S. Geological Survey through a Water Resources Research Institutes core grant and by Southern Illinois University.

Assessment of bendway weirs in Midwest streams. Bendway weirs are used to reduce erosion in meandering midwestern streams. But, their effects on stream dynamics are not well-understood, so designing these measures remains an art rather than a science. Drs. Marcelo Garcia and Bruce L. Rhoads of the University of Illinois at Urbana-Champaign are using engineering and geomorphologic methods to improve the scientific basis for predicting the performance of bendway weirs. Their work is being tested at three sites in Illinois. This research is supported by the U.S. Geological Survey through a Water Resources Research Institutes core grant and by the Illinois Department of Natural Resources and the University of Illinois.

Invasive species population dynamics. The spread of zebra mussels has been a major challenge for midwestern rivers and lakes. In order to control them, we must understand how they grow and spread. Through intensive field research, Drs. Daniel Schneider and James Stoeckel have discovered that zebra

mussels in the Illinois River are seeded by source populations in Southern Lake Michigan. This means that blocking larval transfers through the Chicago canal system is an essential part of reducing populations in the Illinois River. This project is supported by the U.S. Geological Survey through a Water Resources Research Institutes core grant and by Illinois-Indiana Sea Grant, the National Sea Grant Program, and the University of Illinois.

Restoration of the Illinois River Basin. The Illinois River, a major recreational and economic resource for Illinois (more than 90 percent of the states population lives in this basin of 30,000 square miles), has deteriorated. The Center and the Illinois District Office of USGS have played important roles in the development and implementation of a restoration plan, with funds and technical assistance provided by the state, non-governmental organizations, and by the U.S. Army Corps of Engineers, USEPA, and the U.S. Department of Agriculture. At the suggestion of the Illinois Water Resources Center, a Science Advisory Committee (SAC) was created to assist in the implementation of the Plan and in the assessment of progress. The effort has been widely publicized in Illinois and elsewhere. With support from the National Science Foundation, the Illinois Water Resources Center is conducting research on strategic renewal of the River.

Illinois Watershed Academy. Illinois, like many states, has turned to citizen stakeholders for leadership in protecting watersheds. Many of the citizen volunteers involved in watershed protection efforts lack a thorough understanding of the natural and social science relevant to their work. The Illinois Water Resources Center created the Watershed Academy to assemble university experts and develop training materials to assist these groups. The Academy offers workshops on various aspects of watershed protection. It is supported by the Illinois Department of Natural Resources, the Illinois Environmental Protection Agency, and the University of Illinois, was well as by the U.S. Geological Survey through a Water Resources Research Institutes core grant.

Publications from Prior Projects

1. Dziegielewski, B., S. Sharma, T. Bik, H. Margona, and X. Yang. 2002. Analysis of Water Use Trends in the United States: 1950-1995. Project Completion Report. Illinois Water Resources Center Special Report 28. University of Illinois, USGS Water Resources Research National Competitive Grants Program, Grant No. 99HQGR0222, Subgrant No. 00-312. Southern Illinois University. Carbondale, Illinois.
2. Dziegielewski, B., S. Sharma, T. Bik, X. Yang, H. Margono, and R.Sa. 2002. Predictive Models of Water Use: Analytical Bibliography. USGS Water Resources Research National Competitve Grants Program, Grant No. 99HQGR0222, Subgrant No. 00-312 Southern Illinois University. Carbondale, Illinois.
3. Nicklow, J.W., J.A. Bringer, 2001, Optimal control of sedimentation in multi-reservoir river systems using genetic algorithms, in Proceedings of the 2001 Conference of the Environmental and Water Resources Institute of the American Society of Civil Engineers, ASCE, Reston, VA.
4. Nicklow, J.W., 2000. Discrete-time optimal control for water resources engineering and management. Water International, 25(1), 89-95.