Water Resources Center
Annual Technical Report
FY 2003

Introduction

Research Program

Research priorities for the Illinois Water Resources Center (IWRC) include: Watershed and stream protection; integrated water management for multiple users; wetland processes; and emerging issues, including other innovative research topics that are not included in the priorities above.

Two IWRC funded projects, which began in March 2003 will be completed by February 2005. The projects are detailed below. A new Request for Proposals will be issued in May of 2004. The Center takes a special interest in helping your 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 in both the internship program with the Illinois District Office of USGS, and the individual grants to faculty researchers.

In addition, 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 State Water Survey. MTAC began funding four new projects in 2003. These projects include: evaluation of water treatment technology, source water protection planning, mitigation of nitrate contamination and cost-effective arsenic removal.

The Illinois Water Resources Center also assists in administering 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. Research topics include: water quality tracking, aquatic nuisance species mitigation, oyster disease, and aquaculture. Outreach topics include: aquatic nuisance species education and prevention.

Water Rates and Ratemaking Practices in Illinois Community Water Systems

Basic Information

Title:	Water Rates and Ratemaking Practices in Illinois Community Water Systems
Project Number:	2003IL21B
Start Date:	3/1/2003
End Date:	7/15/2004
Funding Source:	104B
Congressional District:	12
Research Category:	Social Sciences
Focus Category:	Economics, Management and Planning, Water Use
Descriptors:	
Principal Investigators:	Ben A. Dziegielewski, Tom Bik, Jack Kiefer

Publication

PROBLEM AND RESEARCH OBJECTIVES

Water rates and pricing structures embody a mix of both broad and specific allocative, environmental, and administrative objectives. Economic theory dictates that price is the most basic factor that consumers will use in their decisions on the quantity of water that they will consume. Aside from the economic efficiency criterion, there is little theoretical or practical guidance to establish the price of water services.

The primary objective of this research is to collect information on the rates and ratemaking practices of community water systems in Illinois in order to characterize rate making practices, and to organize industry experience into a rate-setting framework and corresponding model that relates pricing practices to various water utility characteristics and pricing objectives. A secondary objective is to develop a county-level water price measure that can be used to represent the influence of price in water demand models.

METHODOLOGY

A mail survey questionnaire was developed and mailed to all non-state/federal, community water systems in Illinois that serve more than 100 persons (*N=1,466*). The survey included a set of questions about service area characteristics and requested that participants also return copies of all rate schedules that have been in effect since 1985 at their water systems.

A second mail survey was sent to all of the water systems that responded to the first survey that had returned copies of water rate schedules, and that had included the name of the person at their system responsible for rate design (*N=381*). The second questionnaire was designed to elicit information on the rate-setting process and the factors that drive the evolution of water rates.

The analysis of rate schedule information will consist of a review of rate types, water prices at various volumes and for various user categories, the history of rate increases, changes in rate structures, and the correlation of rates and rate types to relevant water system characteristics.

Mathematical scoring and statistical modeling will serve as the principal tools to design a rate assessment model that will be used to analyze the responses of the *"*ratemaking*"* component of the study. This analysis will be used to establish a theoretical construct for what can be termed as *rate acceptability*.

PRINCIPLE FINDINGS AND SIGNIFICANCE

During the past year the research team has developed and implemented both mail surveys and collected a considerable volume of information water rates and ratemaking practices in Illinois. The analysis of this information is still in progress and the major findings of the study have not yet been determined.

Rapid Solar Transformation of Nutrients in Natural Waters

Basic Information

Title:	Rapid Solar Transformation of Nutrients in Natural Waters
Project Number:	2003IL22B
Start Date:	3/1/2003
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	15th
Research Category:	None
Focus Category:	Water Quality, Nutrients, Surface Water
Descriptors:	None
Principal Investigators:	Gary R. Peyton, Gary R. Peyton

Publication

Problem and Research Objectives

Solar phototransformation of nitrogen nutrients between forms such as organic nitrogen, nitrate, and ammonia can provide significant sources and sinks for the individual nutrient forms, and generate reactive species including free radicals, that can drive other transformations. One example of such phototransformations is the now well-established generation of ammonia by photolysis of aquatic NOM. Recognition of these contributions to the concentration of various nutrient species may impact the setting of water quality standards and best management practices for nutrients, as well as their modeling. The objectives of the project are to 1) measure the photogeneration of ammonia in several Illinois waters, 2) identify important transformation pathways for nitrogen nutrients, and 3) derive models for the process rates in terms of water quality parameters, for adaptation into water quality models.

Methodology

Photoammonification rates are being measured in water samples brought to the laboratory, using simulated solar light and standard methods for ammonia measurement (phenate) and other important water quality parameters. Natural organic material (NOM) that makes up dissolved organic carbon (DOC) is not a mixture of compounds, but rather is primarily a mixture of similar but nonidentical macromolecules; therefore, chemical change in DOC can not be followed by measuring specific compounds, and the development of "surrogate" methods is necessary. The photo- and free-radical chemistry of nitrogen functional groups that occur in NOM is being investigated in this study using model compounds for which individual byproducts can be measured, in order to determine the types of products that are formed in these reactions. This may allow the development of surrogate characterization tests that can be used to measure the extent of reaction of various functional groups without having to rely on quantification of individual compounds for mass balance. Recent work [Vairavamurthy and Wang, ES&T, 36(2002)3050-56] indicates that amides and pyridine groups represent a significant portion of the organic nitrogen present In humic and fulvic material, but the technique (XANES spectroscopy) used by those authors was unable to quantify the relative amount of amine functional groups present. We therefore chose monomeric and polymeric model compounds containing these functional groups (discussed below) for our studies. Specific radicals will be produced in water samples by known reactions, to determine which radicals are primarily responsible for ammonia production. Specific radical "probe" compounds will be used to measure radical production in the natural waters upon irradiation with simulated sunlight in several spectral regions. This information will be compared for various waters, and, along with the solar emission and water absorbance spectra, may be used to develop simple mechanistic/kinetic models for prediction of ammonia photoproduction.

Principal Findings and Significance

In addition to considerable effort spent on the development of an investigation strategy, progress to date has been made in four areas:

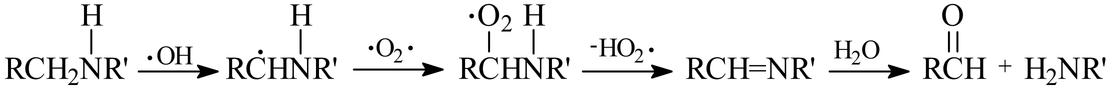
1) *Measurement of Photoammonification in Natural Waters* – Experiments were carried out on six local Illinois waters last fall, sampled from Clinton Lake, Salt Creek below Clinton Lake, Homer Lake, Collins Pond (Homer Lake Park), Salt Fork of the Vermillion River, and Windsor Creek. The increase in ammonia in these samples ranged from 10% in Clinton Lake to 220% in Collins Pond. It is too early to draw conclusions concerning the effect of DOC source from these results; however, it is obvious that the photoproduction of ammonia can vary widely from one water to the next within a small geographic region. In addition, the shape of the ammonia evolution curves varied, ranging from rapid initial increase and early plateau, to continuous accumulation, to induction period followed by increase followed by plateau of ammonia concentrations. These widely different curve shapes imply differences in the photoactivity and amount of precursor present, as well as whether precursor is initially present (immediate ammonia production) or needs to be produced from other substances through intermediate reactions (induction period). QA/QC experiments using replicate samples indicated an analytical precision of about 2.5% on ammonia analyses of triplicate samples (not triplicate analyses of a single sample), and a point-to-point variation of about 6% for samples from successive time points taken periodically from a single experiment after a plateau in ammonia production. Each of these curve shapes can be fit

with simple kinetic models, which will be made more specific after more is known about the NOM functional groups that are involved. Sampling of additional waters is now beginning for spring.

2) *Development of Analytical Procedures for Model Compounds and for Surrogate Functional Group Measurement* – The primary analytical tool being used is HPLC with UV/visible detection, because gas chromatography requires thermal volatilization of the sample, which would not occur with macromolecular NOM. Use of a derivatization method that increase the sensitivity of detection of a particular function group (e.g., aldehydes) relative to the rest of the NOM spectrum (by introducing a chromophore) minimizes interferences, so that it may be possible to use these methods on substances of unknown structure to quantitate the formation or destruction of particular functional groups, even though analysis of individual compounds is not possible. We have adapted previously developed methods for quantifying aldehydes (as the corresponding dinitrophenylhydrazones) and amines (as the substituted phenylthiourea) suspected to be intermediates in the mechanism previously postulated for ammonia production from diethylamine by hydroxyl radical attack, and are using those methods to verify or refute the proposed mechanism (see below). We will investigate the value of these “surrogate” methods in tracking the progress of reactions in DOC, first by the use of nitrogen-containing polymeric model compounds polyvinylpyrrolidone, polyacrylamide, and polyethyleneimine, then with actual water samples. We are still looking for a way to make polyvinylpyridine sufficiently water-soluble to use it as a model macromolecule for the pyridine functionality. Polyvinylphenol can be used to simulate the carbon backbone of NOM.

3) *Verification of One Postulated Mechanism for Photoammonification* – In recent experiments, we have subjected aqueous diethylamine (DEA) solutions (1 mM) to hydroxyl radical generated by UV (254 nm) photolysis of hydrogen peroxide, to determine whether the byproducts and kinetics are consistent with the mechanism hypothesized in scheme I in the proposal.

scheme I



$$\mathrm{R\overset{H}{C}H_2NR'} \xrightarrow{\cdot\mathrm{OH}} \mathrm{R\dot{C}\overset{H}{H}NR'} \xrightarrow{\cdot\mathrm{O_2}\cdot} \mathrm{R\overset{\cdot O_2}{C}\overset{H}{H}NR'} \xrightarrow{-\mathrm{HO_2}\cdot} \mathrm{RCH{=}NR'} \xrightarrow{\mathrm{H_2O}} \mathrm{R\overset{O}{\overset{\|}{C}}H} + \mathrm{H_2NR'}$$

For DEA, the stable products for these steps should be acetaldehyde and ethylamine, while a similar attack on ethylamine should yield another molecule of acetaldehyde and one of ammonia. Control experiments showed that neither UV photolysis nor peroxide treatment alone causes significant decomposition of DEA., so that DEA removal observed in the combined UV/H_2O_2 experiment is due to hydroxyl radical, and ceases when the peroxide is exhausted. Byproducts identified during the DEA degradation were ethylamine, acetaldehyde, and ammonia, consistent with the mechanism shown in Scheme I. This result supports the proposed mechanism for DEA degradation and suggests that a similar mechanism may be operative for primary and secondary amines in NOM, since ethylamine degradation was observed as well. Since the precursor for ammonia (ethylamine) must be produced before ammonia can be generated, a lag time (induction period) in ammonia is expected.

4) *Development of a Screening Procedure for Ammonia Precursors* - Mechanisms other than OH radical must be considered as well. For example, In a recent study of photactivity of waters from the Calumet River watershed, OH radical was shown to be of secondary importance in photo-removal of the general probe compound 2,4,6-trimethylphenol from various Calumet area waters. In addition, the NO_2X produced (along with HOX radical) by the photolysis of nitrate is also a strong but more selective oxidizing agent than OH radical. Amines are also known to be vulnerable to photosensitization, and NOM has been shown to be a good photosensitizer for some reactions, so this pathway will be investigated as well, by adding DEA to natural waters and/or purified water containing NOM that has been previously isolated from natural water. “Standard” humic and fulvic acids isolated from the Suwannee River are available from the

International Humic Substances Society and are used by many investigators to allow direct comparison of their work.

The following reactive species have been reported to be photochemically formed from NOM, nitrate, or nitrite: XOH, RO_2X (peroxyl radicals), NO_2X, NOX, $^1O_2$ (singlet oxygen), e^-_{aq} (hydrated electron), CO_3^-X (carbonate radical) and NOM* (excited state of NOM, i.e., photosensitization). Of these, hydrated electron is sufficiently reactive with oxygen in surface water, that significant reaction would be expected only with the most reactive of compounds, i.e., halogen compounds that are 2-4 orders of magnitude more reactive with e^-_{aq} than are amines. Hydroxyl radical, carbonate radical, peroxyl radicals, and nitrogen dioxide are all one-electron oxidants or add to the ring in aromatics, with OH radical being equal to or a stronger oxidizer than carbonate radical, peroxyl radicals, or NO_2 for virtually all substrates. Therefore, for screening model compounds for ammonia production, reaction with hydroxyl radical will identify possible reactions for all four oxidizing radicals, or, conversely, if a compound does not produce ammonia when reacting with OH, it probably won't produce ammonia through the action of the other three oxidizing radical types either, and only OH need be tried if it fails to produce ammonia. Screening for singlet oxygen and sensitizers is a little more complicated, since singlet oxygen is usually made by using a sensitizer. We are still considering conditions to discriminate between these two cases. The intended screening strategy will be to check for photoammonification from amines, amides, pyridines, oxypyridines, and NOM by reaction with excited NOM* and with OH radical. Reaction with OH will be carried out as described above for diethylamine, while reaction with NOM* will be evaluated by adding the model compound to natural water and comparing any ammonia formation to that from the water alone and that formed in the model compound photolysis blank. Subsequent in-depth studies will focus on processes that caused photoammonification in the screening experiments.

Work for the next reporting period will follow the strategy described above, including 1) the extension of these methods to other forms of nitrogen (amides, pyridines) thought to occur in NOM, using the model compounds acetamide and ethylacetamide, and pyridine or a substituted pyridine, as well as the corresponding polymeric model compounds; 2) evaluation of the surrogate methods for characterization of NOM reactivity; 3) continuation of ammonia production measurement in Illinois waters; and 4) correlation of ammonia production with water quality parameters such as bicarbonate (alkalinity), DOC, DON, nitrate and nitrite content of the water.

Development and Validation of a 3D Coupled Hydrologic-Biogeochemical Model for Evaluation of the Impact of Water-Table Management on Nitrate Loads from Tile-Drained Agricultural Fields

Basic Information

Title:	Development and Validation of a 3D Coupled Hydrologic-Biogeochemical Model for Evaluation of the Impact of Water-Table Management on Nitrate Loads from Tile-Drained Agricultural Fields
Project Number:	2002IL7G
Start Date:	9/1/2002
End Date:	8/31/2004
Funding Source:	104G
Congressional District:	15th
Research Category:	Water Quality
Focus Category:	, Non Point Pollution, Solute Transport
Descriptors:	
Principal Investigators:	Robert J. Hudson, Albert Joseph Valocchi

Publication

1. Yue, Feng, August 2003, "Physically-based three dimensional hydrological conjunctive modeling of water movement in tile-drained fields," MS Thesis, Department of Civil and Environmental Engineering, College of Engineering, University of Illinois, Urbana, IL.
2. Hudson, Robert J.M., Albert J. Valocchi, David Hill, Feng Yue, Stephen P. Wente, Jaswinder P. Singh, 2002, "Modeling Denitrification in Agroecosystems of Central Illinois: Investigations at the Field and Watershed Scale" in EOS Transactions of American Geophysical Union, 84(47), Fall Meeting Supplement, p. F270-271.
3. Yue, Feng, 2004, "Phsyically-based three-dimensional hydrological conjunctive modeling of water flow in tile-drained fields," M.S. Thesis, Department of Civil and Environmental Engineering, College of Engineering, University of Illinois, Urbana, IL.

4. Problem and Research Objectives:

One of the most promising approaches to minimizing nitrate export to rivers draining agricultural watersheds is the use of water table management, or controlled drainage. The Illinois District of the USGS is conducting a field pilot study of the benefits of controlled drainage at an active farm in east-central Illinois. Two adjacent 40-acre plots, one with tile management and the other without, have been instrumented for collecting a variety of data. Modeling is required to fully interpret the field data and to extend the results to other farm conditions. A portion of the project involves modeling studies with Drainmod-N, a widely-applied quasi 2-dimensional model. However, because raising the water table of a farm field may increase the amount of runoff and change its subsurface interactions with the larger-scale groundwater flow field, we hypothesize that a fully 3-dimensional model is required to properly quantify the hydrologic and nitrogen budgets of the study site. Our model will simulate both surface runoff/runon and subsurface flow between the adjacent managed/conventional plots (and adjacent fields), processes which can only be represented very approximately in DRAINMOD. The improved hydrology of the model will also allow us to improve our analysis of the N budgets of the two plots, since it accounts more accurately for nitrate exchange between adjacent plots by the above hydrologic paths and will better simulate differences in denitrification in surface ponds/puddles and in the subsurface due to increases in water and solute residence times.

Our primary objective is to develop a physically-based, 3-dimensional model that couples surface and subsurface flow with a biogeochemical model for nitrogen fate. The model will be calibrated and validated using the field data collected by the USGS and other existing data from fields in central Illinois.

Our secondary objective is to apply our newly developed automatic calibration tools to DRAINMOD in order to understand the hydrology and nitrogen budgets of the controlled-drainage field study. We will attempt to quantify differences in denitrification using the model and calibrate field-specific parameters for use in the 3-dimensional model.

5. Methodology:

The project involves using two different modeling approaches to analyze data being collected by USGS researchers from a paired set of agricultural fields with and without controlled subsurface drainage. The first approach employs automatic calibration of an existing pseudo 2-dimensional groundwater/nutrient transport model (DRAINMOD) to investigate causes for the differences in nutrient export between the two fields. The second approach involves continuing development and application of a 3-dimensional model of hydrologic and solute transport.

6. Principal Findings and Significance:

Automatic calibration

We have developed a code for automatic calibration of the latest version of DRAINMOD Nitrogen (DMN2) of Skaggs and co-workers. In addition, we continued the refinement and testing of objective functions for calibrating the DRAINMOD nitrogen and hydrologic models.

3-Dimensional Modeling

At this stage of research and model development, HCM3D has been able to efficiently simulate long-term conjunctive water movement at typical tile-drained fields. Five important hydrological components – overland flow, infiltration, subsurface flow, tile flow and evapo-transpiration – have been included into the model. The theoretical framework for coupling all these components, especially the alternative external coupling approach among surface flow, infiltration, and subsurface flow, has shown favorable stability and computational efficiency after previous tests and field applications.

In our current efforts the surface/subsurface hydrologic components are solved with computationally efficient Larkin ADE (Alternating-Direction-Explicit) methods and integrated together through an alternative external coupling that promises fast long-term simulations. The Larkin ADE method was found to have significant mass balance errors that preclude its use for our purposes. The flux-limiting and flux-updating algorithms have also been applied to ensure stable and mass-conserving results. This approach is currently being tested.

The results from applying the flow model to a tile-drained farmland in Illinois have been analyzed.

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 Conference on the Illinois River

Basic Information

Title:	Governor’s Conference on the Illinois River
Project Number:	2003IL43B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	15
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	outreach, conference, river, management
Principal Investigators:	Lisa Merrifield

Publication

1. Merrifield, Lisa, ed., 2003, Governor’s Conference on Management of the Illinois River, Conference Proceedings of the 9th biennial conference, November 7-9, 2003, Illinois Water Resources Center, Urbana, Illinois.

The IWRC program specialist serves on the planning committee for the Governor's Conference on Management of the Illinois River, which was held on October 7-9, 2003. IWRC serves as a cosponsor for the conference by producing the speaker abstract book and the conference proceedings.

Illinois Water 2004 Conference

Basic Information

Title:	Illinois Water 2004 Conference
Project Number:	2003IL44B
Start Date:	10/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	15
Research Category:	Not Applicable
Focus Category:	Education, None, None
Descriptors:	Conference, Illinois Water
Principal Investigators:	Lisa Merrifield

Publication

Illinois Water 2004 is a statewide conference currently being organized by IWRC for all citizens, groups, and students interested in water resource issues in Illinois. The conference will be held at the Holiday Inn, Urbana, Illinois, on October 13 - 14. Attention will focus on science, technology, and policy developments, while also bringing major water resource organizations and interests together to explore common ground.

"Breathing New Life into the National Water Program" will be the topic for featured speaker, Roberta Savage, Executive Director/Secretary, Association of State and Interstate Water Pollution Control Administrations, and President of the Board and Chief Executive Officer, America's Clean Water Foundation. Themed sessions will cover topics including designated uses of surface water, glacial aquifers, agricultural drainage management and water quantity. Twelve technical sessions will provide an in depth discussion of a wide variety of Illinois issues. Prior to the workshop, a special discussion focused on the development of a state water monitoring council and during the conference a panel will discuss career opportunities with students.

IWRC Web Site

Basic Information

Title:	IWRC Web Site
Project Number:	2003IL46B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	15th
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	Website, education, water, information
Principal Investigators:	Lisa Merrifield

Publication

The Illinois Water Resources Center web site (www.environ.uiuc.edu/iwrc) provides direct links to IWRC publications, news, and funding opportunities. Links to grant information from other Illinois and federal sources; information about issues important to Illinois waters, such as aquatic nuisance species and gulf hypoxia; and information for kids have also been developed. Information about the biennial Illinois Water conferences is maintained as part of this site. A FAQ section provides answers to questions about Illinois water issues.

Over the past year, we have begun to scan all or part of our more recent publications and provide links to those documents from our web site. The response from users has been very positive.

We are also in the process of updating the look of the IWRC web site. We hope to complete the transformation in the coming year.

IWRC Newsletter

Basic Information

Title:	IWRC Newsletter
Project Number:	2003IL47B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	Education, None, None
Descriptors:	newsletter
Principal Investigators:	Lisa Merrifield, Irene Miles

Publication

1. Miles, Irene, ed., 2004, Illinois Water Resources Newsletter: Fall 2003, Illinois Water Resources Center, University of Illinois at Urbana-Champaign.

The IWRC newsletter is published annually to update the over 600 subscribers about research and outreach activities IWRC is undertaking. The distribution list includes faculty on university campuses around the state, government officials, scientists, researchers and concerned citizens.

Midwest Technology Assistance Center

Basic Information

Title:	Midwest Technology Assistance Center
Project Number:	2003IL48B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	15th
Research Category:	Water Quality
Focus Category:	Water Quality, Treatment, None
Descriptors:	water systems, assessment, evaluation
Principal Investigators:	Richard Warner, Kent Smothers

Publication

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	3	0	0	0	3
Masters	1	2	0	0	3
Ph.D.	3	1	0	0	4
Post-Doc.	0	0	0	0	0
Total	7	3	0	0	10

Notable Awards and Achievements

In the past year, IWRC had several notable achievements. Arthur Schmidt won the prestigious and competitive UCOWR Dissertation Award for his dissertation focusing on development of more accurate measures of water flow rates in streams. Schmidt was one of two winners from across the country.

Researchers Hudson and Valocchi, University of Illinois, made great strides in improving methods for calibrating hydrologic models to better simulate flow and nutrient fluxes from agricultural fields. The model can simulate runoff and subsurface flow in 3-dimensions, even in fields with irregular subsurface drainage.

Research Gary Peyton, Illinois State Water Survey, has confirmed a significant increase in ammonia content of rivers and lakes due to solar radiation, indicating that his hypothesis about the breakdown of nitrogen nutrients in water due to exposure to sunlight is accurate. Peyton has also been able to verify a proposed pathway for ammonia production from amines in waterways.

Researcher Ben Dziegielewski and his colleagues, Southern Illinois University, has completed his survey of water ratemaking practices and is currently analyzing the data and making the information available on line. The database contains current and historic rate schedules for 385 Illinois water systems. The database is a unique contribution from this project.

Publications from Prior Projects

1. 2001IL4241B ("Multi-Objective Decision Support Tools for Protection of Streams in Urbanizing Watersheds") - Dissertations - Allerd, Kyle, 2004, "Multi-Objective Spatial Decision Support for Protection of Streams in Urbanizing Watersheds, Department of Civil and Environmental Engineering, College of Engineering, Southern Illinois University, Carbondale, IL, 69.