

Indiana Water Resources Research Center

Annual Technical Report

FY 2004

Introduction

Report Introduction Our mission is to coordinate the intellectual and physical resources of Indiana's universities, state agencies, and industries to resolve technical, economic, and other problems associated with water resources management, use, and preservation.

We seek to: Serve as a resource to state agencies and industries by providing the expert services of IWRRC faculty, conducting advanced research studies, and providing a forum for discussion and exchange of information; Provide a repository of knowledge and expertise available for use in problem-solving, planning, practical design, policy development, research and education; Develop a comprehensive water research program with statewide impact by utilizing faculty and facility resources at Indiana's institutions of higher education; Strengthen student education/training in water-related fields: encourage students to enter these fields, and provide the manpower necessary to solve future water resource problems; Facilitate interdisciplinary approaches to solutions of water resources issues in Indiana by gathering experts in several water-related areas such as agriculture, biology, chemistry, computer science, economics, engineering, law, political science, sociology, statistics, and wildlife ecology; Respond to public interest in the conservation, development, and use of water resources, while assisting planning and regulatory bodies at local, state, regional, and federal levels.

Research Program

Introduction: Program Administration and State Coordination

The objectives of the fiscal year 2004 program of the Indiana Water Resources Research Center (IWRRC) are: (1) to reinvigorate our water related research and educational activities within the State of Indiana; (2) to develop a suite of research programs that encompass several water issues; and (3) to strengthen interactions with the Indiana Department of Environmental Management, the Department of Natural Resources and other state groups.

In general, the administrative portion of the project has been used to support the Director as he reengages the center with the State of Indiana. The goal of this effort is simple: improve the quality of water resources in the State of Indiana. The funds in the administrative portion of the project have allowed the IWRRC Director a means to better join together with state and federal agencies. The IWRRC Director has worked with state and federal environmental agencies, the governments of Indiana's cities and counties and key citizen groups on water education and water resources planning activities. The IWRRC Director has participate in important regional and national meetings related to water and environmental protection.

During the project period, The Indiana Water Resources Research Center has developed two proposals (see below for details). Work from projects supported by the IWRRC has been leveraged by the PIs as part of their broader research efforts and has supported eight graduate students (5 Ph D and 3 MS). The IWRRC updated its website but the site is still in need of work. The IWRRC has also begun an aggressive

campaign to return to a leadership role in order to help solve Indianas water problem

Presentations:

The IWRRRC Director gave two formal presentations about IWRRRC function during the project period.
Title: Indiana Water Resources Research Center-IWRRRC Presented to Midwest Groundwater Association Meeting. Bloomington, Indiana.

Title: Indiana Water Resources Research Center-IWRRRC Presented to The Greater Lafayette Chamber of commerce Water Subcommittee, Lafayette Indiana.

The IWRRRC Director met with:

Director Indiana Save the Dunes Foundation (Water Pathogens)

Director for the Indiana 319 Program (Septic Systems)

Director of research planning for ACT-1 (Water Treatment Technologies and to develop IWRRRC projects repeated meetings.)

Director of research and operations for Velia Water (Indianapolis Water) to develop projects (repeated meetings)

Director of Center for Earth and Environmental Science IUPUI, (Water Projects) developing a winter water conference to update the Hoosier Water Summit.

Met with the leadership of the Indiana Water Resources Association to discuss a stronger relationship between the two groups.

NIWR 5-Year annual review committee to discuss the outcome from the five year review.

IWRRRC Developed Proposals

To: NOAA- Oceans and Human Health Initiative, External Grants Program

Title: Development of a rapid identification method allowing pathogen tracking to enhance coastal water protection.

PI: Von Sigler (PI), University of Toledo Ron Turco (co-PI), Purdue University, IWRRRC

Total proposed cost: \$405,536 Budget period: 10-01-2005 through 09-30-2008

Abstract: Fecal pollution continually impacts two important beach locations along Lake Erie (Ohio) and Lake Michigan (Indiana) resulting in unsafe recreation conditions and a loss of local revenue. It is assumed that fecal pollution at both beach locations originates from multiple host sources and that water carrying the bacteria is input from tributary rivers and ditches associated with Wolf Creek- (Ohio) and Dunes Creek (Indiana) watersheds. Modern bacterial fingerprinting technologies can improve bacterial source tracking and problem area identification by permitting a screening of potential sources of indicator bacteria such as Escherichia coli (E. coli). Traditional source identification involves library dependent

methods that match phenotypic or genotypic traits among numerous indicator bacteria isolates collected from pollution sink- and potential source sites. However, these methods require the prerequisite development of an isolate library and the identification and typing of hundreds of isolates of *E. coli* per site, and are therefore expensive and time consuming. In contrast, library-independent methods avoid the prerequisite development of isolate libraries by detecting genetic markers in DNA isolated directly from environmental samples. Previous work completed by our group has identified several genetic markers specific to *E. coli* that when subjected to polymerase chain reaction (PCR) and denaturing gradient gel electrophoresis (DGGE) can (i) sensitively detect *E. coli*, and (ii) differentiate *E. coli* communities associated with specific animal hosts. The work outlined in this proposal aims to characterize the sources of fecal pollution in the Wolf Creek and Dunes Creek watersheds by combining a novel use of DGGE, *E. coli* enumeration, and traditional, library-based fingerprinting (BOX-PCR) to determine the identity of contributing fecal sources. The proposed approaches will allow us to identify geographic hot-spots of fecal pollution inputs by simultaneously assessing *E. coli* number and population structure changes at several locations within a watershed. The ultimate goal of the project is to use this advanced approach is to identify targeted areas of concern within each watershed in an effort to improve upstream remediation strategies that effectively treat impacted waters. Work in this project will provide a novel approach for watershed planners to utilize when developing remediation technology.

To: EPA Targeted Watersheds Program

Title: Creating sustainable drinking water supplies for central Indiana: Innovations to achieve reductions in watershed and reservoir nutrient levels

PI: Central Indiana Water Resources Partnership Lenore P. Tedesco, Ph.D. IUPUI Center for Earth and Environmental Science 723 West Michigan Street Indianapolis, Indiana 46202-5132 317.274.7154

In Conjunction with: Indianapolis Department of Waterworks Purdue University Indiana Water Resources Research Center Town of Zionsville Sewage Department Hamilton County Soil and Water Conservation District Upper White River Watershed Alliance

Total proposed cost: \$1,496,068 Budget period: 10-01-2005 through 09-30-2007

Abstract: Indianas Upper White River Watershed suffers water quality impairments associated with agricultural and urban practices. Three drinking water reservoirs, serving 1.1 million people, are at risk of not meeting designated uses. Blue-green algae blooms, causing nuisance taste and odor metabolites and blooms of known toxin-producing phytoplankton, are making cultural eutrophication of these reservoirs a potential economic and health hazard. The Central Indiana Water Resources Partnership along with the Indianapolis Department of Waterworks, Purdue University, a municipal wastewater treatment plant, and soil and water conservation districts have joined together to implement watershed nutrient reduction projects to improve the water supply. Projects will demonstrate: a) the effectiveness of managed drainage and variable width riparian buffers to reduce nutrients; b) practical limits for phosphate removal from municipal wastewater facilities; c) precision phosphorous application for turfgrass; d) thermocline disruption methods in a shallow reservoir and e) the agronomic and economic impacts of no-till farming.

Minimizing Runoff and Nonpoint Source Pollution Due to Urbanization

Basic Information

Title:	Minimizing Runoff and Nonpoint Source Pollution Due to Urbanization
Project Number:	2003IN110B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	4
Research Category:	Engineering
Focus Category:	Hydrology, Management and Planning, Models
Descriptors:	
Principal Investigators:	Bernard Engel, Jon Harbor

Publication

1. Engel, B.A. Choi, J.Y. Harbor, J. Pandey, S. 2003. Web-based DSS for hydrologic impact evaluation of small watershed land use changes. *Computers & Electronics in Agriculture*. 39:241-249.
2. Tang, Z. Engel, B.A. Choi, J. Sullivan, K. Sharif, M. Lim, K.J. 2004. A Web-based DSS for erosion control structure planning. *Applied Engineering in Agriculture*.

Title: Minimizing Runoff and Nonpoint Source Pollution Due to Urbanization

Focus Categories: HYDROL, M&P, MOD, WQL, WQN

Keywords: runoff, water quality, urbanization, optimization

Project duration: 1 year

Funding requested: \$20,000

Matching funds pledge: \$40,000

PI Names and affiliations: Bernard Engel, 1146 ABE, Purdue University, W. Lafayette, IN 47907, Phone: 765.494.1198, Email: engel@ecn.purdue.edu; and Jon Harbor, Professor Department of Earth and Atmospheric Sciences, Purdue University W. Lafayette, IN 47907

Congressional District:4

Abstract

Urbanization of land uses can have significant negative consequences on runoff and water quality. Proper land use planning can potentially reduce the effects of urbanization on runoff and water quality. The magnitude of the potential benefits of land use planning that considers impacts on water and water quality is largely unknown. This project builds on significant past and ongoing work to create models to assess the impact of land use changes on long-term runoff and nonpoint source (NPS) pollution (<http://www.ecn.purdue.edu/runoff>). These models will be used to quantify the potential for reducing runoff and nonpoint source pollutants from urbanization through optimal placement of proposed land use changes within watersheds. Historical and projected land use changes within representative watersheds will serve as inputs to these models in conducting the assessments. Optimization techniques will be used to identify areas within the watersheds that minimize runoff and NPS pollution for the observed or proposed urbanization. The magnitude of reductions in runoff and NPS pollution will be quantified for these situations, thereby providing estimates of the benefits such planning approaches might have. Optimization techniques that force contiguous and compact development to simulate minimization of infrastructure development costs and reduction of “sprawl” will be utilized to identify development patterns that minimize changes in runoff and NPS pollution for such constraints. Again, the magnitude of reductions in changes in runoff and NPS pollutants will be quantified for representative watersheds. The results will provide guidance for land use planners and stakeholders interested in minimizing the impacts of development on water quality and runoff. The runoff and NPS pollution model and optimization system will be made widely available as a web-based decision support tool. By integrating the results into the current WWW-based model, the target audience for this work will be reached.

Statement of critical regional or state water problem

Urban expansion requires the careful selection of areas for development or urbanization to insure sustainable environmental development. Land managers and urban planners have long realized the importance of land allocation in urban planning. However, the development of a land acquisition strategy has generally not been included as part of the formal planning process. The reason for this neglect is largely the lack of good analytical tools for modeling land allocation, although this need has been expressed by land managers, decision makers, urban planners, and others. In particular, little or no research has been conducted in the field of applying spatial

optimization techniques to land use planning from the perspective of minimizing surface runoff and associated NPS pollutants.

Statement of results/benefits

This research will identify the magnitude of historic and proposed urbanization on long-term runoff and NPS pollution for representative watersheds in the Midwestern US. Optimization techniques will be used to identify the minimum impacts on runoff and NPS pollution that could have been attained for the same magnitude of land use changes within the watersheds with no constraints on locations of land use changes within the watersheds and with constraints that would represent minimization of economic costs of urbanization. The results will provide guidance regarding the potential reductions in runoff and NPS pollutants that can be achieved for urbanization of land uses. The integrated runoff and NPS modeling tools and optimization techniques will result in a decision support capability that can be used by land use planners and other decision makers to identify land use plans that minimize runoff and NPS pollutants for a desired set of land uses. As a result, they could modify the location of the proposed land use development to reduce environmental impacts. In other instances they may wish to compare the impact of their proposed development to the optimal situation. In other instances, regulations might be developed based on the results of this work that require land use plans to minimize impacts on runoff and NPS pollutants or incorporate best management practices that would allow the area they wish to develop to achieve runoff and water quality that are comparable to the optimal location for the planned development. Since the proposed research builds on a significant base of past research and development that has been used by land use planners and local decision makers (<http://www.ecn.purdue.edu/runoff/lthianew/>), the resulting decision support capabilities will have an immediate sizable audience.

Minimizing Runoff and Nonpoint Source Pollution Due to Urbanization

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Nature, scope, and objectives of the project

Urbanization has become a significant concern nationwide. Open space and farmland loss has been increasing at an alarming rate. Between 1982 and 1997, the United States lost almost 500,000 acres of "prime" farmland to development each year. One of the direct environmental consequences of this development is degradation of water resources and water quality. The conversion of farm land, forests, wetlands, and other open spaces to urban and suburban uses creates acres of impervious surfaces, which in turn increases the volume and rate of surface runoff and consequently degrades water quality by the means of NPS pollution. Development or urbanization is therefore considered a critical environmental issue and presents considerable challenges for urban planners, decision makers, and stakeholders.

From the standpoint of protecting environmental quality, it is very natural to raise the following questions:

- 1) Does the current planning approach consider impacts on surface runoff?
- 2) Can the impact of urban expansion on surface runoff and NPS pollution be minimized while planning for land use change?

Many land use models have been developed to assist planners in identifying suitable areas for multiple-use or single use problems. Urban planning decisions and suitability evaluation involves a complex array of critical factors drawing from economic, social, technical and environmental disciplines. Therefore, multi-criteria decision making (MCDM) is the typical approach utilized in suitability assessment. However, surface runoff itself is often not a separate criterion to be considered in the MCDM approach in urban planning. There may be room for minimizing surface runoff and NPS pollutants while satisfying other development criteria.

The objectives of this research are:

- 1) to assess land use change impact on surface runoff and NPS pollution for representative watersheds,
- 2) to develop a web-based tool to minimize the impacts of land use changes on surface runoff and NPS pollution, and
- 3) to quantify the reductions in runoff and NPS pollutants possible within representative watersheds that are possible by optimizing placement of land use changes.

Methods, procedures, and facilities

The proposed work builds on significant past and ongoing efforts to quantify the impacts of land use change or urbanization on long-term runoff and NPS pollution (see <http://www.ecn.purdue.edu/runoff/>). Researchers at Purdue have developed a simple, user-oriented hydrologic and non-point source pollution impact assessment model (Harbor, 1994; Bhaduri et al, 1997, 2000; Pandey et al, 2000, 2001; Grove et al., 2001). Making use only of data readily available to the public, web-based and downloadable GIS versions of the model can be used by planners, consultants, farmers, and decision makers to assess the relative impacts of past, present, and alternate future land management decisions. Model results make use of location-sensitive data, such climate, land use, and soils, and thus the user can generate results for a specific watershed or subwatershed. In addition, the model allows users to modify parameters such as nonpoint source pollutant loading rates, based perhaps on local data or management approaches, and thus the model is flexible enough to allow for very local and site specific comparisons of different management alternatives. The model is simple to use, and is freely available at www.ecn.purdue.edu/runoff/.

Assessments of the impacts that land use changes have on long-term runoff and NPS pollutants have been conducted using L-THIA for numerous locations including comprehensive assessments by the PIs for watersheds around Indianapolis and in Florida. Additional assessments of the impacts of land use changes on runoff and NPS pollution will be conducted for an additional watershed using the L-THIA (Long-Term Hydrologic Impact Assessment) model (see <http://www.ecn.purdue.edu/runoff/>) in a manner similar to that used in past efforts (Pandey et al., 2000).

The Muskegon River watershed that drains to Lake Michigan will be used due to the extensive land use planning analyses and projections that have been done for this watershed. In addition, this watershed complements the other study watersheds around Indianapolis and along the east coast of Florida, in that the land uses and climate differ significantly. Historical land use changes and projected urban expansion scenarios within the Muskegon River watershed for 2020 and 2040 using a land use transformation model (LTM) are available. The urban expansion projections assumed normal development rates and patterns based on past observed conditions and sprawl rates and patterns. L-THIA will be used with the land use data (observed and projected), soils and historical rainfall data to evaluate the effects of urbanization on long-term surface runoff and NPS pollution. The results of the analysis of the Muskegon River watershed will be compared and contrasted to those for watersheds near Indianapolis and along the east coast of Florida. A manuscript will be prepared based on these results.

An optimization component will be developed and added to the existing L-THIA model. This component will identify the locations of proposed land uses that produce the minimum runoff and NPS pollutant increase for a user proposed land use change. The input data required from the user would include location (state, county), current land uses with corresponding hydrologic soil groups and areas, and user proposed urban land uses and corresponding areas. The user would also be allowed to provide their own plan for placing the proposed land uses within their watershed or area of interest. The resulting output from the integrated L-THIA and optimization system will provide suggested land use modifications that result in minimal changes in surface runoff and NPS pollutants. The outputs would also provide surface runoff depth, runoff volume and NPS pollutant masses for the following scenarios: minimum runoff increase (optimal solution), maximum runoff increase (worst case solution), and if provided, runoff for the user proposed land use change plan. Runoff and NPS pollutant information for the current watershed conditions (without the land use change) will be provided as well. With this information, users can determine the optimal locations for proposed urbanization, compare results for optimal placement of land use urbanization with the current situation, the worst case situation and with alternatives they may be considering.

The algorithm that will be used is essentially based on the change in curve numbers. For instance, to find the land use that should be changed that will provide the minimum runoff increase, the algorithm uses the following steps:

- 1) Calculate the curve number for current land use and corresponding soil combinations
- 2) Calculate the curve number for the proposed urban land uses and soil combinations for each available land use
- 3) Identify the minimum curve number increase for the same soil group for the first element in the proposed urban land use group.
- 4) Calculate the area difference between identified current and proposed land use.
- 5) If the proposed area is bigger than the current land use, replace the proposed land use with this difference in area and return to step three. If the proposed area is smaller than the current land use, proceed to the second element in the proposed urban land use group.

- 6) Search through the proposed urban land use group and assign each member of this group to a current land use

This algorithm can be modified slightly to obtain the maximum runoff increase for a proposed land use urbanization. This algorithm is simple and will require a very short computation time so it can be readily added to the current L-THIA WSW model. However, there is an assumption required by the algorithm: a linear relationship exists between runoff depth and curve number. However, this assumption has been widely made when using the curve number technique in estimating runoff. The impact of this assumption will be explored and the possibility of developing an algorithm based on runoff increase, not curve number, without sacrificing computational time will be explored if this assumption is problematic.

Another limitation of the proposed algorithm is that the optimal placement of proposed land uses on current land use and soil group combinations may result in placement of proposed land uses that is not contiguous. Such solutions may not be realistic for development in some cases but the optimization approach would allow proposed solutions in such instances to be evaluated with respect to the best and worst case scenarios.

As discussed earlier, current land use planning strategies require a multiple criterion decision making process. However, surface runoff is often not directly addressed as a separate criterion. The indirect criterion to deal with surface runoff may include flooding frequency considerations, or restricted development in areas such as forested and wetland areas. Often land development requires contiguous and compact areas so that infrastructure and other development and social costs are minimized. Wallace's enhanced regional aggregation model and algorithm (Wallace, 2002) will be utilized to create a spatial runoff optimization technique that can utilize multiple criteria in the decision process and identify areas that are contiguous and compact for proposed land use changes. The L-THIA GIS version will be employed to provide suitability maps for use in the region aggregation model. This approach will allow runoff and NPS pollutant minimization and allow the solution to be constrained to provide areas that are contiguous and compact.

The integrated L-THIA and optimization approaches (truly optimal and optimal for contiguous, compact area) will be applied to the study watersheds (east coast of Florida, Indianapolis, Muskegon River in Michigan) for historical land uses. Initial land uses will serve as the starting point and the observed land use changes will serve as the proposed land use changes. The optimization techniques will quantify the reductions in runoff and NPS pollutants that would have been achieved if optimal placement of land use changes had occurred. A similar analysis for projected land uses within the Muskegon River watershed will be performed. The results of the runoff and NPS pollution minimization will be analyzed to determine the magnitude of reductions in runoff and NPS pollution that would have been realized for truly optimal placement as well as land use change placement that requires contiguous and compact development. The results will be documented in a manuscript for publication. Land use planners and decision makers will find this information helpful in determining whether minimization of runoff and NPS pollution should be considered for their local situations.

Related research

Virtually every urban area in the United States has expanded substantially in land area in recent decades (EPA, 2001). Between 1954 and 1997, urban land area has almost quadrupled, from 18.6 million acres to about 74.0 million acres in the contiguous 48 states. Development claimed more than half of the wetlands in the lower 48 states between the 1700s and the mid-1980s (USDA, 1997). In recent years, the newly developed land has come mostly from forests, pasture and range, and cropland (USDA, 1997). The changes of land use patterns certainly provide many social and economic benefits. However, they also come at a cost to the natural environment. Two major direct environmental impacts of development are: (1) habitat loss and fragmentation and (2) the degradation of water resources and water quality (EPA, 2001).

Conversion of agricultural, forests, grass, and wetlands areas to urban areas, such as buildings, parking lots, and roads, usually come with a vast change of impervious surface which can alter the natural hydrologic condition within a watershed. Numerous research efforts have investigated and evaluated the process and outcome of this alteration. The impact of land use change on discharge behavior is well documented in the literature. Brun and Band (1999) indicated the existence of a threshold percent impervious cover, above which the runoff ratio changes more dramatically. Moscrip and Montgomery (1997) used discharge records to study how increasing impervious surfaces alters flood frequency before and after urban expansion. Zheng and Baetz (1999) evaluated development options from a hydrology perspective. Cheng and Wang (2002) developed a method to define the degree of change in a runoff hydrograph for urbanizing basins. Crooks and Davies (2001) assessed the flood frequency changes in relation to land use change for 30 years. Long term impact of land use change on hydrology is assessed as well (Bhaduri et al., 1997; Kim et al., 2002). In general, the increase of impervious area is the reason for increased rate and volume of surface runoff and decreased infiltration, time to concentration, and ground water recharge in an urbanized watershed. Increased peak discharges and shorter lag times between storms and the resultant runoff lead to larger and more frequent incidents of local flooding (Richard, 1982). This loss of ground water recharge can reduce residential and municipal water supplies, and decrease base flow into stream channels during dry weather (Harbor, 1994).

Surface runoff has been identified as one of the major contributors to ongoing water quality problems in this county (EPA, 2001). Surface runoff and eroded sediment pose a potential threat to the receiving water column as both physical pollutants by decreasing turbidity and chemical pollutants by transporting nutrients and other contaminants such as heavy metals and pesticides. If contaminated sediments deposit in rivers, water-quality degradation may persist even when other pollution sources are controlled. Monitoring and modeling studies have shown consistently that urban pollutant loads increase with watershed imperviousness (Schueler, 1995).

To minimize the negative environmental impacts of urban development, site selection for urban development has become critical. Site selection is a complex process. It must reflect both economic realities and the conflicting environmental and social requirements. Typically, planning decisions and suitability evaluation are made on the basis of a number of criteria and are a multi-criteria decision making (MCDM) problem (Brookes, 1997). The general objective of MCDM is to assist the decision maker in selecting the 'best' alternative from the number of feasible alternatives under the presence of multiple choice criteria and diverse criterion priority.

MCDM conducts systematic suitability assessment for a series of decision criteria and provides the user the solution for the best alternative. The end product is a suitability map in which the value of each feature contains the overall suitability as determined by all criteria.

Surface runoff itself is often not a separate criterion to be considered in the MCDM approach in urban planning. In another words, the increase of surface runoff and its impact on NPS pollution is not directly evaluated in building up a suitability map. There is a room to minimize surface runoff while meeting other criteria in searching for a land allocation for a given purpose or use. Suitability maps created using MCDM, however, don't provide such land allocation. For instance, although the most suitable cells can be identified from a raster suitability map, these cells may not be contiguous and therefore some further processing is needed to identify suitable locations. This further processing problem is the land acquisition problem defined by Wright (1983). With the aid of a suitability map, a spatial optimization process is needed to identify suitable locations to achieve minimum runoff increase.

The land acquisition problem, also known as the regional aggregation problem and land allocation problem, is noted as one of the most exciting new areas of land management modeling (Church, 2002). In general, it is a multi-objective spatial optimization problem that attempts to allocate an optimal or non-inferior region among a set of candidate parcels or cells, while satisfying specified constraints on such things as contiguity, area, and shape. The site allocation model has been applied in the practical problems of siting recreational location and landfill design. No previous research has applied this spatial optimization technology in the environmental protection field. The aggregation model and Simple Shapes Algorithm (SSA) developed by Wallace (2002) will be employed to minimize surface runoff and NPS pollution in this research.

Student training

The project will provide training for a Ph.D. student in Agricultural and Biological Engineering who has completed her coursework. Additional students will be trained as a result of leveraged funds including two M.S. students programming the hydrology and water quality model and an undergraduate student assisting with testing the modeling system.

Expected deliverables

The project will provide several deliverables including a research report, student thesis, journal manuscripts and a web-based decision support tool. The research report, student thesis and journal manuscripts will document the potential reductions in runoff and NPS pollutants for optimized placement of land use changes within watersheds. The potential reductions in runoff and NPS pollutants will be documented for truly optimized placements of land uses in watersheds and for optimization that requires contiguous and compact development patterns. Perhaps the most significant deliverable will be a decision support tool capability delivered at a WWW site. The optimization approaches will be incorporated with an existing WWW-based runoff and NPS pollutant modeling tool at <http://www.ecn.purdue.edu/runoff/lthianew>. The current web-based tool estimates runoff and NPS pollutants for land use changes that are described within an easy-to-use web interface. A significant user base has been established for the model, and ICMA (International City and County Management Association) has recently adopted the tool to promote to its members. Incorporation of the research results and

optimization capability within this web-based model will insure the target audience has access to the research results.

References cited

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Soil and Mineralogical Processes Involved in Septic System Failure

Basic Information

Title:	Soil and Mineralogical Processes Involved in Septic System Failure
Project Number:	2003IN112B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	4 & 6
Research Category:	None
Focus Category:	Non Point Pollution, Waste Water, None
Descriptors:	None
Principal Investigators:	Brad Lee, Brad Joern

Publication

1. Krenz, J.L., B.D. Lee, D.G. Schulze, P.J. Schoeneberger, D.P. Franzmeier, S.K. Sears, and H. Vali. 2005. Illitic soil mineralogy: Bluffton Till Plain and associated moraines in northeast Indiana. In Agronomy abstracts, ASA, Madison, WI.
2. Hart, K.S., B.D. Lee, P.J. Schoeneberger, and J. Krenz. 2005. Soil hydraulic conductivity on the Wabash Moraine, Wells County, IN. Purdue Cooperative Extension, RW-2 (in review).
3. Lee, B.D., D.P. Franzmeier, and P.J. Schoeneberger. Northeast Indiana moraine soils project. Indiana Assoc. Professional Soil Classifiers. January, 21, 2004. (56 participants)

Title: Soil Mineralogical Processes Involved in Septic System Failure

Focus Categories: NPP (non-point pollution), WW, (wastewater)

Keywords: septic systems failure, Allen County, clay mineralogy, soil absorption fields

Project duration: 1 year

Funding requested: \$20,000

Matching funds pledge: \$40,000

PI Names: Brad Lee (lead PI)* and Brad Joern
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Congressional District: 4 & 6 (Allen County)

Abstract

One-third of Indiana residents utilize septic systems, however the Indiana State Department of Health (ISDH) estimates that 25% of these septic systems operate inadequately. These 200,000 failing septic systems represent approximately 32 billion gallons of untreated effluent discharged annually to surface and groundwater. A 1997 survey of county health department administrators indicated that problematic soils are the primary reason for septic system failure. More recently, the ISDH has stated that northeastern Indiana soils are the cause of premature septic system failure in 16 counties. These failures result in ponding of effluent on the soil surface due to hydraulic overloading of the septic system soil absorption field within months to a few years after installation however, the cause of these premature failures is unknown. These problematic fine-textured soils formed on recessional moraines and till plains deposited by the Erie-Ontario glacial lobe about 15,000 years ago. Because soil is an integral part of wastewater treatment in a septic system, it is imperative that a thorough investigation of soil processes involved in septic system septic system failure be conducted before a properly functioning septic system design can be developed. We propose to evaluate the spatial extent and distribution of septic system failures related to soil and geologic properties, and evaluate the applicability of current septic system design parameters used by ISDH in these problematic soils. Due to the recent trend in migration of urban populations to rural areas, the results of this study will be pertinent to current and future land use issues throughout northeastern Indiana.

Critical Regional Water Problem

Within Allen County, approximately one-third of the 18,000 septic systems installed are failing (Gary Chapple, personal communication, 2002). The majority of these failed systems cannot be repaired for two reasons: 1) the system is located on a lot that is too small to build a new system, or 2) the soils are not suitable for a new system under the current state regulatory rule 410 IAC 6-8.1. Allen County is not alone in this issue as 16 counties in northeastern Indiana have similar history of septic system failure.

Failed septic systems within this region are of considerable concern from a natural resource and human health perspective. According to the 1990 Census (the 2000 Census did not inquire about septic systems), 108,205 homes in this 16 county area were utilizing on-site

wastewater disposal systems, which represent approximately 17.8 billion gallons of wastewater effluent per year. When septic systems fail in areas that are great distances from municipal wastewater treatment systems, connection to a sanitary sewer is not an economically viable option. Therefore, homeowners have three choices: repair the system, pump and haul their septage from the septic tank, or discharge illegally to the soil surface, an open tile, or drainage ditch. System repairs on lots where soils cannot pass the current regulations are not being repaired because a permit cannot legally be issued. Pumping and hauling of septage is often cost prohibitive for most families (estimated cost for Allen County ranges from \$7800 to \$21,900 annually per household). As a result, many homeowners choose not to report failures and thus discharge illegally.

Due to political pressure and with little background information about the soils within the region, the ISDH responded to these failures in June 2001 by issuing a memorandum that changed the soil evaluation protocol for 16 counties in northeastern Indiana. The memorandum described a soil testing protocol involving laboratory analysis and field tests that must be followed, and the soil must pass before a septic system permit can be issued. This protocol is considerably more extensive and expensive (\$600 – \$1100) than the soil examination required by law (ISDH Rule 410 IAC 6-8.1). Many sites did not pass, and were subsequently declared unsuitable for development. By threatening county administrators with lawsuits, developers pressured many health departments to ignore the memorandum from ISDH. Therefore houses continue to be built in areas likely to have septic system problems.

Concerned state legislators addressed the issue of failing septic systems in Allen County by passing Senate Enrolled Act 461, which will provide homeowners with small lots and unsuitable soils an opportunity to obtain a surface discharging septic system. These discharging systems will include tertiary treatment with chlorine or ultraviolet radiation to remove pathogens prior to discharging the treated effluent to surface waters. Due to the high cost associated with these systems (~\$15,000), maintenance requirements, and potential for direct contamination of surface waters, it is imperative that these homes utilize discharging systems as a last resort. Therefore, a thorough investigation into the cause of soil based septic system failure is needed.

Results/Benefits

At the present time the state of Indiana does not understand why septic systems fail in northeastern Indiana soils. We anticipate the results of this study will be useful in developing a better understanding of the soil processes involved in septic system failure. The benefits of this study are relevant at three scales: local, regional, and state.

1. At the local level the results from this study will assist the Ft. Wayne-Allen County Health Department in assessing the soil conditions and develop a better understanding of septic system failure.
2. Because the soils in northeastern Indiana are derived from the same parent material, results from this study can be extrapolated throughout 16 counties.
3. At the state level, recently passed legislation suggests that there is an interest in resolving the septic system failure issue in northeastern Indiana. Results from this study are critical in developing an understanding of the soil processes involved in septic system failure.

If the results of this study can reduce septic system failure in Allen County by 20%, this will reduce the discharge of untreated wastewater by 166 million gallons per year (Jones and Lee, 2002).

Regional Water Problem and Need Soil Mineralogical Processes Involved in Septic System Failure

Within the state of Indiana regulatory system, all septic systems are required to discharge wastewater effluent into the soil. Because of this requirement, soils are the most limiting factor in septic system performance. A recent survey of county health departments throughout the state indicates that soils are the major reason for septic system failure (Taylor et al., 1997). Within northeastern Indiana, septic systems have failed within months of installation (Linda Mauller, Wells County Health Department, personal communication, 2001). The Indiana State Department of Health (ISDH) has utilized a prescriptive regulatory code for septic system management, which relies heavily on design and assumes that a system is functioning adequately if designed properly. Recently, a system designed by the ISDH and installed under their supervision, failed within months after installation in northeastern Indiana. This incident combined with documented premature septic system failures throughout northeastern Indiana counties, suggests that Indiana may need to reevaluate the current prescriptive code and take a closer look at the northeastern Indiana soils and the processes involved in septic system failure.

The soils in northeastern Indiana are of unique origin relative to the rest of the state. Around 15,000 years ago a glacier moved southwest from Lake Erie into northeastern Indiana (Wayne, 1966). The resulting landscape of this glacial advance includes a series of concentric recessional moraines and a fine-textured glacial till plain (Fig. 1). The topographic relief of the recessional moraines is slightly higher with more rolling swell and swale topography than the flat till plain between

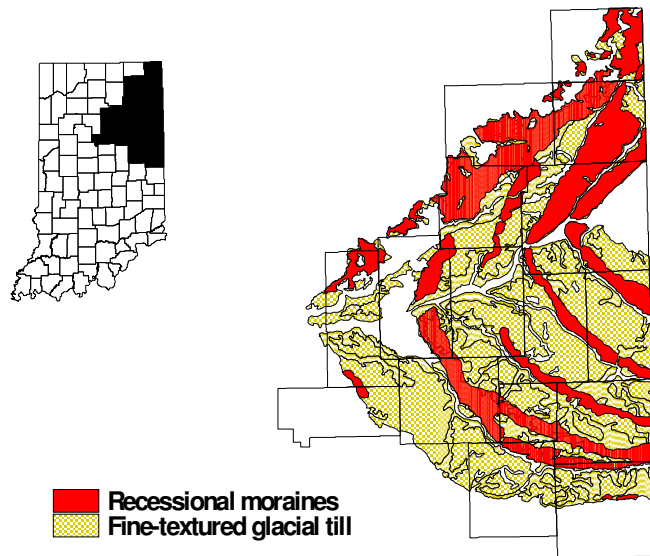


Fig. 1. Recessional moraines and fine-textured till plain in the 16 counties affected by the ISDH soil testing protocol memorandum.

These moraines formed 15,000 years ago in northeastern Indiana are now a focus of concern for 16 counties. In 1995, the Wells County Health Department identified the moraines as a problem area for septic systems. Several septic systems on the moraines failed prematurely, discharging untreated wastewater to the surface within months of installation. Since that time, health officials in other northeastern Indiana counties have observed numerous premature septic system failures as more and more people moved into rural areas. Due to political pressure and

with little background information about the soils within the region, the ISDH responded to these failures in June 2001 by issuing a memorandum that changed the soil evaluation protocol for 16 counties in northeastern Indiana. The memorandum described a soil testing protocol involving laboratory analysis and field tests that must be followed, and the soil must pass before a septic system permit can be issued. This protocol is considerably more extensive and expensive (\$600 – \$1100) than the soil examination required by law (ISDH Rule 410 IAC 6-8.1). Many sites did not pass, and were subsequently declared unsuitable for development. By threatening county administrators with lawsuits, developers pressured many health departments to ignore the memorandum from ISDH. Therefore houses continue to be built in areas likely to have septic system problems.

Recently the issue of failing septic systems in northeastern Indiana has become the focus of state legislation. Senate Enrolled Act 461 focuses on onsite wastewater technologies that may be used on problematic soils in Allen County. Due to recent outbreaks of West Nile Virus in Allen County (58 infections and 3 suspected fatalities (Gary Chapple, Ft. Wayne-Allen County Health Department, personal communication, 2002)), county administrators and state legislators have a renewed urgency to reduce the number of failed septic systems that result in organic-rich, open surface waters. Of the 20,000 septic systems in Allen County, it is estimated that 6500 are in failure (Jones and Lee, 2002). This represents 2.2 million gallons of effluent discharging to the soil surface and surface waters each day.

A significant amount of water quality data has already been collected by the Ft. Wayne - Allen County Health Department. During a consecutive two year water quality survey of 100 ditches and streams in Allen County, 94% did not meet the water quality standards for *E. coli* and some waterbodies were over 178 times the acceptable body contact limit for this pathogen.

Ninety-eight percent of the soils within Allen County are not suitable for conventional on-site septic systems (USDA-NRCS, 2002). Prior to the promulgation of 410 IAC 6-8.1, evaluations in Allen County as well as elsewhere in Indiana were done using "perc" tests. Most percolation tests in Allen County did not meet the 60 minutes per inch limit required at the time for a conventional septic tank. Lots unsuitable for soil absorption systems usually were allowed to install buried sand filters with chlorination and discharge. Operating permits were issued for these systems, but the level of operation and maintenance conducted was entirely dependent on the homeowner.

The current method of obtaining a septic system permit in Indiana is to first evaluate selected soil morphological and physical properties in the field. From this information, a soil wastewater loading rate estimate is derived from a matrix table in the ISDH Rule 410 IAC 6-8.1 (Table 1), which is an estimate of the quantity of wastewater that the soil can absorb without discharging to the soil surface. This loading rate was derived from hydraulic conductivity and physical property data collected by the Natural Cooperative Soil Survey during the mid-1900s, which may be a good estimate for statewide assumptions but may not be useful in the soils of northeastern Indiana.

Table 1. Abbreviated statewide septic system soil absorption field loading rate table (gallons day⁻¹ ft⁻²) (ISDH, 1990).

Soil Texture Class	Soil Structural Class				
	Granular, platy	Strong blocky	Moderate blocky	Weak blocky	Very coarse prismatic
Sandy clay loam	0.75	0.75	0.50	0.50	0.00
Loam	0.75	0.75	0.50	0.30	0.00
Silt loam	0.60	0.60	0.50	0.30	0.00
Silty clay loam, clay loam, sandy clay	0.60	0.60	0.30	0.25	0.00
Silty clay, clay	0.60	0.50	0.30	0.25	0.00

According to a statewide survey of county sanitarians, soil hydraulic overloading was the primary cause of system failure within glacial till soils of northeastern Indiana (Taylor et al., 1997). Based on this anecdotal evidence from health departments, a thorough investigation of the soil processes involved in septic system failure is the next logical step to resolve this problem.

Information on Midwest glacial tills is sparse as only a few studies are available. Gooding (1973) characterized some glacial tills from the eastern edge of Indiana, and Steiger and Holowaychuk (1971) characterized some from western Ohio. Data showed that the Indiana tills were much higher in clay content than those immediately across the state border. Within Indiana, Franzmeier et al. (1985) observed a trend in increasing clay content from Howard County (the extent of the Ontario-Erie glacial lobe) to Allen County, and suggested that the clay increase was due to subtle parent material changes within the source of the glacial till. For the northeastern Indiana glacial till plains, very little information about soil properties is available. More importantly, little research has been conducted to investigate the soil processes involved in the premature septic system failure phenomenon that is occurring within northeastern Indiana, nor has there been an evaluation of the necessity or usefulness of the additional soil tests suggested in the ISDH memorandum.

The USDA Natural Resource Conservation Service classifies the mineralogy of northeastern Indiana as being illitic. Illite is considered to be a non-expanding mineral, therefore septic system performance should not be adversely affected by the shrinking and swelling of the soil during wet and dry periods. However, direct observation of large cracks in the soil profile of several locations within Allen County, suggest that shrinking and swelling is a major pedogenic process within these soils.

Since May of 2002, we have conducted two preliminary studies focusing on failing septic systems in the problematic soils in the region. Results to date suggest that the hydraulic conductivity of the soil is overestimated in the ISDH current septic system design parameters. However, these results are only preliminary and a graduate student is needed to conduct a more thorough investigation of the soil processes involved in septic system failure.

Results/Benefits

The overall purpose of this study as well two others in Allen County and the surrounding area is to reduce the amount of untreated wastewater reaching Indiana's surface and groundwater resources. This study focuses on the soil processes involved in septic system failure and will provide a better understanding of the influence of wastewater effluent and soil mineralogy on septic system performance. This information, integrated with the results from ongoing studies, will provide benefits at three scales: 1) local, 2) regional, and 3) state.

At the local level, the conclusions of this study will be summarized and presented to the newly formed Allen County Onsite Management District Oversight Committee. This group is composed of a county commissioner, health department representatives, a representative of the septic system installation and maintenance industry (septic system installer or pumper/hauler), and a member of the general public. The Oversight Committee was formed in response to Senate Enrolled Act 461, which will allow residents with failing septic systems to obtain discharging septic system permits. The benefits gained from this study will be factual information integrated into the overall strategy for selecting potential sites for discharging septic systems, with the overall goal of decreasing the amount of untreated effluent reaching the environment.

At the regional level, the information gained in this study will be integrated with other ongoing investigations. Currently, there is a two-year preliminary soils investigation conducted cooperatively by the USDA-NRCS, Department of Natural Resources, and Purdue University that is evaluating soil morphological characteristics across the sequence of recessional moraines from Grant County to Allen County. The information gained within this study will provide some insight into the soil morphologic features that may result from the mineralogy of the northeastern Indiana soils. Although the focus of regional study is not entirely about septic system problems, the conclusions from the Allen County study will be presented to the Recessional Moraine Task Force that was formed in 2001 to address the premature septic system failures that occur in northeastern Indiana. The Task Force will use the results of both studies to develop soil-based septic system designs that may function within these problematic soils.

Within the state, numerous county health departments have indicated that problematic soils are the primary reason for septic system failures (Taylor et al., 1997). In addition, recent legislation (Senate Enrolled Act 461) suggests that there is statewide interest in resolving the septic system failure issue. The results from this proposed study will help explain the relationship between soil mineralogy and septic system failures. This information could be extrapolated to other regions of the state and may lead to modification of ISDH prescriptive designs in Rule 410 IAC 6-8.1 by incorporating mineralogy into the code.

Nature, Scope, and Objectives

The nature and scope of this research project will focus on the identification of mineralogical processes involved in septic system failure. An understanding of the soil mineralogy at the interface between the effluent in the absorption trench and the soil in and below the absorption

field is critical to understanding septic system failure in the problematic soils of northeastern Indiana.

Objective

Determine the mineralogical and chemical state at the absorption field trench wall and natural soil interface. *We hypothesize that mineralogical changes due to interactions of the wastewater and soil mineralogy adversely impact the infiltration rate in the soil absorption field.*

Timeline

	J	A	S	O	N	D	J	F	M	A	M	J
Soil description and sampling	x											
Pre-processing mineral samples		x	x									
Impregnation of peds		x	x									
Chemical analysis of wastewater	x			x			x			x		
Soil chemical analysis			x	x	x							
Micromorphology					x	x	x					
Clay mineral analysis							x	x	x			
Assimilation, interpretation										x	x	x
Final summary												x

Methods, Procedures, and Facilities

Field Description and Sampling

With the assistance of the Ft. Wayne-Allen County Health Department three similar residential, three bedroom homes with failed septic systems will be selected for study. All failed septic systems will be located on the same soil according to the Allen County soil survey (USDA-NRCS, 2002). At each residence, homeowners will be interviewed to determine historical water use information. This information will be evaluated to determine the impact of hydraulic overloading due to overuse. Within the septic tank, wastewater will be collected once seasonally for a total of 4 times and stored in sterile, sealed polyethylene bottles at 4 degrees C. Within one day after sampling, wastewater chemistry (pH, Eh, EC, basic cations, anions, BOD₅, TSS, P, Mn, Al and Fe) will be determined. These results will represent the wastewater chemistry in the absorption field trench. A small soil pit will be excavated approximately 30 cm adjacent to the downslope septic system absorption trench and at least 45 cm deeper than the trench. At the maximum depth of the soil absorption trench, intact soil clods as well as bulk soil will be collected in 10 cm increments from the trench wall to 30 cm outside the trench according to standard methods (Schoeneberger et al., 1998). Upslope and at least 5 meters from the absorption trench a soil pit will be excavated to the same depth as the bottom of the absorption field trench pit. Intact soil clods and bulk soil will be collected at the same depth as the bottom of the absorption field trench. These samples will serve as a control. The soil wastewater analysis will be sent to a private laboratory for analyses and interpretation of the data will be conducted by a graduate student under the direction of the PI.

Soil Micromorphological Analysis

Soil micromorphologic techniques will allow us to examine the soil and its components in situ, unaltered and undisturbed by preparation or analytical procedures. To accomplish this analysis,

soil clods will be impregnated with a resin containing an ultraviolet excitable dye. From the impregnated soil clods, polished thin sections will be cut for examination using petrographic microscope techniques. The mineralogy and fabric analysis will be described according to standard methods (Brewer, 1974). The pore space will be characterized from digital images collected from the thin sections illuminated with UV light similar to procedure used by Lee et al. (2002). The micromorphological analysis will be conducted within the Agronomy Department at Purdue University which is equipped with a petrographic microscope.

Clay Mineralogy

Clay mineralogical investigations will focus on determining the shrink and swell component of these soils. The clay (< 2 μ m) fraction will be separated by centrifugation and sedimentation techniques (Jackson, 1979). Alkylammonium methods coupled with x-ray diffraction will be used to identify the mineral species within the sample. X-ray diffraction is commonly used to identify crystalline layer silicates in soil and clay mineral samples (Bish, 1994). When alkylammonium techniques are coupled with XRD, interlayered minerals (e.g. randomly interstratified illite/smectite) can be readily detected (Lagaly, 1981). Other studies have coupled these techniques to identify randomly interstratified chlorite/vermiculite (e.g. Lee et al., 2003). These procedures will be conducted within the Agronomy Department at Purdue University that is equipped with an x-ray diffractometer.

Soil Chemical Analysis

The bulk soil will be used for chemical analyses. Soil pH, electrical conductivity, basic cation and anion concentration will be determined on saturated paste extracts as these will be more similar to natural conditions within the soils near the absorption field. Dithionite (crystalline compounds) and oxylate (poorly crystalline and amorphous) extractable Fe, Al, Mn, and P will be determined on bulk soil samples (Jackson et al., 1986) to determine the concentration of secondary minerals outside of the absorption trench which have been shown to contribute to septic system failure (Lee et al., 2002). These soil chemical analyses will be conducted within the Agronomy Department at Purdue University.

Related Research

Allen County Investigations

Currently there is an on-going collaborative investigation with the Ft. Wayne-Allen County Health Department, USDA-NRCS, and Purdue University funded by Allen County. The focus of this collaborative study is to evaluate the variability of soil conditions across the sequence of recessional moraines in northeastern Indiana. Preliminary results suggest that the soil hydraulic conductivity within intermoraine soils and moraine soils is similar near the surface however discontinuous and intermittent sand lenses were observed in the intermoraine soils. The additional detailed mineralogical work provided by this proposed study will be a key component to the recessional moraine study.

Soil Mineralogy in Absorption Fields

In a recent study in Elkhart County, several septic systems failed due to a mineral precipitate that formed approximately 15 cm outside of the absorption trench and formed a continuous band surrounding the trench. The Fe and Mn rich precipitate filled the pore space with the soil matrix and subsequently reduced the hydraulic conductivity of the soil surrounding the absorption trench (Lee et al., 2002). We suspect that similar processes may be occurring within the soils of Allen County.

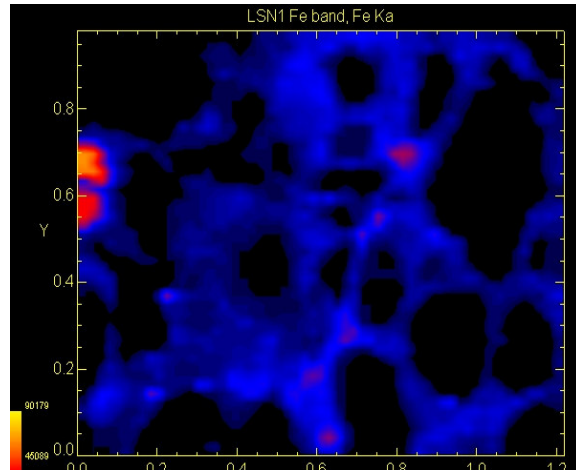


Fig. 2. Iron rich precipitate filling the pore space between sand grains 15 cm from the absorption field trench wall.

Student Training

The work will be conducted by a graduate student in the Agronomy Department at Purdue University, West Lafayette Campus. The student will be involved in all aspects of the project, from sampling to presenting the results at the Indiana Environmental Health Association conference.

If additional funds are provided, the study will be expanded for a second year to determine the influence of inputs on the septic system. Column studies will be used to replicate field conditions determined in this proposed project (control) while simulated inputs of wastewater constituents (e.g. water softener recharge) will be modified to determine if water use or homeowner habits influence the system.

Expected Deliverables

A formal presentation of conclusions will be made at the Indiana Environmental Health Association Spring conference. An extension publication will be developed describing soil mineralogical processes below septic system absorption fields. Upon completion of other on-going studies in Allen County, the results from this study will be integrated into a comprehensive journal publication describing the soil processes involved in septic system failure.

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Hydrologic and land use control on the nature and cycling of allochthonous of organic carbon in mixed land use water sheds within Central Indiana

Basic Information

Title:	Hydrologic and land use control on the nature and cycling of allochthonous of organic carbon in mixed land use water sheds within Central Indiana
Project Number:	2004IN155B
Start Date:	3/1/2004
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	4th
Research Category:	Climate and Hydrologic Processes
Focus Category:	Ecology, Agriculture, Geochemical Processes
Descriptors:	
Principal Investigators:	Timothy R. Filley, Chad Jafvert

Publication

1. Crooker, K., Filley, T.R., Frey J., and Six, J. A comparison of molecular and isotopic chemistry of overland flow DOM and POM to soil sources. American Geophysical Union Fall 2004 Meeting.

Annual Report: Filley

Title: Hydrologic and land use control on the nature and cycling of allochthonous of organic carbon in mixed land use water sheds within Central Indiana :

Focus categories: ECL, AG, GEOCHE, HYDGEO

1. PROBLEM AND RESEARCH OBJECTIVES,

The control of short-lived hydrologic events (e.g. snow melt, storms) and land use (e.g. row crop agriculture) on the nature (source, structure) and reactivity (chemical, biological) of allochthonous organic matter (AOM) transferred to streams is poorly understood yet it is of critical importance in understanding a wide range of issues including surface water quality, general aquatic ecosystem function, coastal hypoxia, and even global carbon budgets. The ambiguity concerning the biogeochemical cycling of AOM is a function of many factors including the inherent chemical complexity of aquatic organic matter pools, poor temporal sampling resolution, and a lack of application of sophisticated biogeochemical techniques to the study. The goal of this investigation is to perform a detailed assessment of how the nature of soil organic matter and the frequency and intensity of hydrologic pulses control the quantity, source, and size distribution of AOM in mid sized and small agricultural water sheds in Central Indiana that ultimately discharge to the main stem of the Wabash River. This study will integrate both laboratory and field components combining a detailed molecular, isotopic and physical fractionation of soils and AOM from streams and tile drains.

2. METHODOLOGY AND PRINCIPAL FINDINGS

2.1. Methodology:

a. Sampling sites. Samples of allochthonous organic matter in water and soil organic material were collected, as described below, over the course of two consecutive growing seasons that alternate between conventional tillage and non-tilled agriculture at a field scale study, 2.4 mi², in the Sugar Creek basin at Leary-Weber Ditch (LWD). This site represents an existing collaboration with the United States Geologic Survey-Water Resources Division USGS-WRD (contact person Dr. Jeffery Frey, Indianapolis USGS Office). Additionally, event-based sampling was performed at Big Pine Creek Watershed, Warren County at Williamsport located at the bridge where Moore's Hill Road (CR 125 E) crosses the creek.

b. Aggregate SOC fractionation. Six paired soil samples were acquired in the spring of 2004 at discrete distances from the overland flow water-sampling weir at Leary Weber Ditch. Each sample was first separated into two layers (0-5cm) and (5-15cm) and fractionated into three different size classes. The physical fractionation scheme that was used is a recently developed method for isolating four functional C pools: (1) the non-protected particulate organic matter (POM) not occluded within microaggregates, (2) the microaggregate protected POM, (3) the silt and clay protected C, and (4) the biochemically protected pool or non-hydrolyzable silt and clay associated C. Coarse POM, microaggregates, and silt + clay C will be isolated from air-dried and sieved (2 mm) soil. These fractions were isolated as described by Six *et al.*, (2000)

c. AOM Isolation: AOM was isolated from overland flow sites, watershed creek sampling stations, and select tile drains in LWD and the stream station at BPC and fractionated into size or molecular weight ranges using convention filtration and hollow fiber ultrafiltration (Marley *et al.*, 1994; Guo *et al.*, 2000). We will collected fine particulate organic matter (FPOM), colloids and high molecular weight DOM (HWDOM), and low molecular weight DOM (LDOM) using glass

fiber filters (GF/F nominally 0.7 mm), 0.2 micron filters, and 1000 Da nominal cut off filters, respectively. The isolations were performed in the field or in the lab of the PI Tim Filley. Sampling was targeted to rainfall events that generated overland flow or ditch flow.

c. Biopolymer (molecular and isotopic) analysis of soil and AOM fractions: A molecular-level chemical degradation scheme designed to isolate the low molecular weight fragments of the refractory biomolecules was employed to track carbon source and cycling in soils and AOM fractions. Thus far most samples have been chemically analyzed using alkaline copper oxide oxidation in order to discriminate between C₃ and C₄ lignin and wax components of the aggregate and aquatic fractions. Lignin phenols were quantified by analysis of the trimethylsilane (TMS) derivatives of eight lignin phenol monomers (vanillin, acetovanillone, syringaldehyde, vanillic acid, acetosyringone, syringic acid, *p*-hydroxycinnamic acid, and ferulic acid) using a 5 point calibration curve for each of the target compounds relative to the IRS ethyl vanillin. The trimethylsilane (TMS) derivatives of nine hydroxy fatty acids and fatty di-acids were analyzed based upon target and proxy standards relative to the IRS of DL-12, hydroxystearic acid in a five-point calibration curve using extracted ion profiles. Total cutin and suberin acids are defined here as the sum of 16-hydroxyhexadecanoic acid, hexadecanoic diacid, 18-hydroxyoctadec-9enoic acid, and semiquantitation of 9,16&10,16 dihydroxyhexadecanoic acid, 9-octadecene1,18dioic acid, 7&8 hydroxyhexadecane dioic, 9,10,18 trihydroxyoctadec12enoic, and 9,10,18-trihydroxyoctanoic acid. A Shimadzu QP5050A quadrupole mass spectrometer interfaced to a GC17a gas chromatograph was used to identify and quantify selected mass fragments of the IRS and target compounds. Successful TMS derivatization of samples and GC/MS instrument performance was verified with a methyl 3,4-dimethoxybenzoate recovery standard which was added prior to derivatization of all samples and blanks.

The lignin analyses provide information on the oxidation state of the lignin compounds and the nature of the plant inputs to the soil. For example, information about the oxidation state of lignin can be inferred from the relative abundance of vanillic acid to vanillin (Ac/Al)_v and syringic acid to syringaldehyde (Ac/Al)_s, as microbial degradation of lignin increases the ratio of carboxylic acids to aldehydes. Additionally, the nature of plant inputs to the soil can be inferred by comparing the yield of syringyl or cinnamyl compounds normalized to yield of vanillyl compounds (S/V and C/V, respectively) where a high C/V and S/V is found for corn residues while a low C/V and high S/V is found for soy residues.

2. PRINCIPAL FINDINGS

Thus far molecular analysis of lignin source, quantity, and decomposition state have been completed on almost all of the LWD samples. The BPC analyses have yet to begin. We still await stable carbon isotope analyses on the sample. We anticipate these being completed by the end of July.

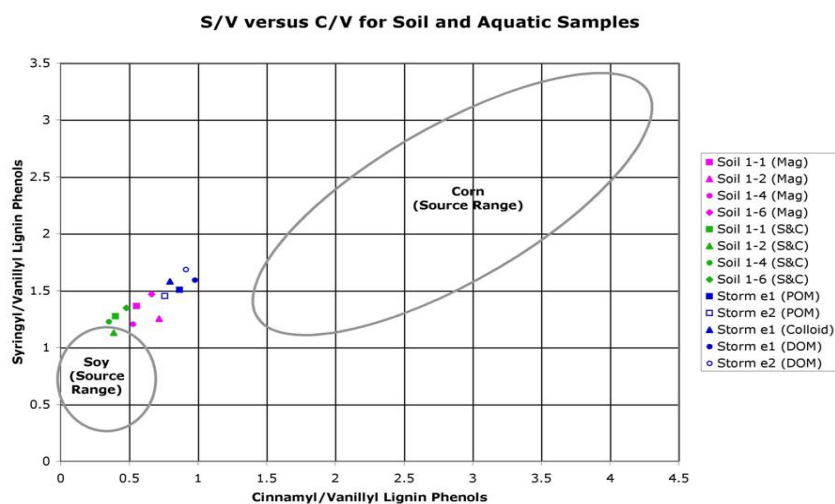


Figure 1. source proxy plot for LWD soil and aquatic fractions

Figure 1 shows the S/V and C/V source proxy plots for samples from LWD. By this graphical presentation we can investigate the sources of plant components in the two component system (soy and corn) to the soil, overland flow, and aquatic fractions. The silt and clay (S+C) and microaggregate fractions each plot near the soy residue suggesting that mineral associated organic matter and microaggregated SOM have an abundance of soy residues (most likely roots) associated with them. In contrast the storm flow aquatic fractions (dissolved organic matter-DOM, particulate organic matter -POM) plot further toward the corn residues suggesting that storm flow mobilizes corn stover at the surface rather than silts and clays of the soil.

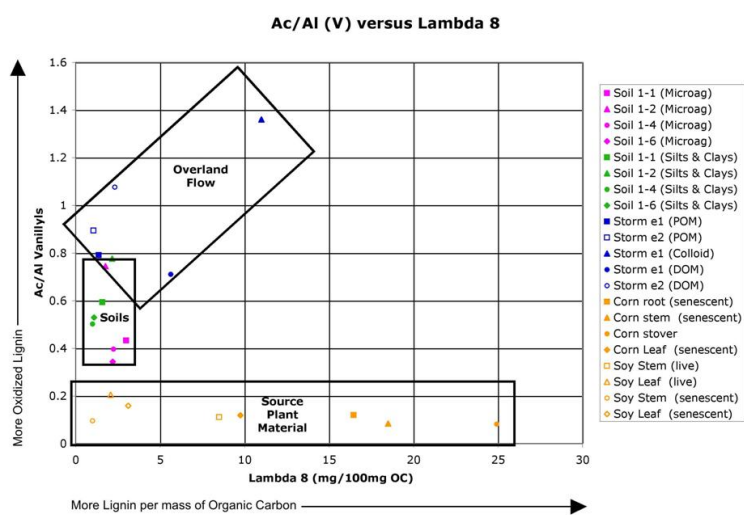


Figure 2. Plot of lignin yield and oxidation state for all fractions collected at LWD.

For the two storm events studied thus far the soil organic matter has significantly less lignin than most of the plant starting materials indicating progressive oxidation. Additionally,

overland flow exhibits elevated Ac/Al and a bit low to moderate lignin yields. Overland flow colloids appear to be selectively enriched in lignin above other size fractions from the events. Upon analysis of the stable carbon isotopes we should be able to determine what percentage the organic matter is of corn and soy and how hydrodynamic sorting acts to mobilize one over the other.

3. SIGNIFICANCE of the PROJECT

The export of AOM as dissolved, colloidal, or particulate forms has local to global significance as riverine carbon along with other coupled nutrients is both an important component of the global carbon cycle and also has important controls on water quality (e.g. THM production) and aquatic biology (e.g. hypoxia). For example, the net heterotrophic state of our land-use impacted rivers and streams may be a function of not just the quantity but also the forms and “reactivity” of AOM. It is unknown how much of this impact is inherited from the inherent reactivity or recalcitrance of the organic matter in the terrestrial plants or soils.

It is of local and national interest to be able to predict not just the quantity but also the reactivity and thus source of AOM exported to aquatic systems with the ultimate goal prediction of the fate of this carbon and co-mobilized nutrients or anthropogenic compounds. In fact, the rivers often provide the conduit for the co-mobilization of metals, pesticides, or other anthropogenic compounds that are bound or sorbed to AOM. These are issues that have been identified as being of high importance by the U.S. Global Change Research Program (USGCRP) as well as the NSF Water Cycles Research Program

4. STUDENTS,

This grant has funded in part the MS thesis for Mr. Keith Crooker, Department of Earth and Atmospheric Sciences (EAS). His anticipated graduation date in Dec 2005. This project also funded partially EAS undergraduate Megan Uttley.

5. THESIS TITLES, PAPERS, AND ABSTRACTS.

Poster Presentation . K. Crooker, Filley, T.R., Frey J., and Six, J. A comparison of molecular and isotopic chemistry of overland flow DOM and POM to soil sources. American Geophysical Union Fall 2004 Meeting.

Characterizing Errors in Distributed Hydrologic Modeling

Basic Information

Title:	Characterizing Errors in Distributed Hydrologic Modeling
Project Number:	2004IN157B
Start Date:	3/1/2004
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	4th
Research Category:	Engineering
Focus Category:	Floods, Hydrology, Models
Descriptors:	
Principal Investigators:	Rabi H. Mohtar

Publication

Title: Characterizing Errors in Distributed Hydrologic Modeling

Focus Category: Floods, Hydrology, Models, Non-Point Pollution, Surface Water

Keywords: Hydrologic Models, Runoff Estimation, Distributed Modeling, Error Estimation, Spatial Hydrology, Finite Element Analysis, GIS, Physically-Based Models, Pollution Prevention.

Principal Investigators: Rabi H. Mohtar and Jagadeesh Anmala, Department of Agricultural and Biological, Engineering; Purdue University; West Lafayette, IN 47907, phone: 765-494-1791

Abstract:

Estimating surface water flow after a storm is critical in our humid region for flood analysis and water quality predictions among numerous other uses. Watershed hydrology is a mix of interacting processes that cuts across cascading and overlapping scales of time and space. Modeling these systems offers a unique tool for understanding and integrating the multi-scale processes when real observations and field monitoring fail due to the prohibitive time and cost required. To fully capture the real hydrologic system, modeling watershed hydrologic processes have survived years of empirical estimates. Although simple to develop and apply and are still in good use, empirical modeling fails to bring the accuracy, precision, and the needed details of the processes and their intermediate output. Physically-based and process oriented modeling has the potential to overcome this shortcoming; however, these more complex tools face numerous challenges. Addressing some of these challenges is the goal of this proposal. This research proposal is intended to establish the relationships among the hydrologic parameters and how they are impacted by the scales of the watershed and to evaluate the sources of errors associated with the numerical solution of overland flow. The result of this work will generate guidelines that will be implemented by hydrologic models to improve their efficiency and accuracy of simulation.

PROBLEM AND RESEARCH OBJECTIVES

The accurate determination of watershed runoff requires accurate determination of time-step for numerical simulations of kinematic wave shallow water equations in surface watershed hydrology. A time-step and Courant number based framework for error analysis for kinematic wave shallow water equations is developed for this project. The numerical simulation of watershed runoff hydrograph suffers from problems of estimability, non-uniqueness, multi-parameter heterogeneity and its representation, grid dependence and time-step. Therefore, two approaches namely- finite element method and finite volume method have been employed for the simulation of runoff hydrograph. Fourier (or von-Neumann) analysis is performed for Galerkin-formulated finite element system of error equations and Reynolds transport theorem based discrete form of difference equations using finite volume method.

The principal research objectives of the current project are to: (1) determine time-step for numerical simulations in two-dimensional watershed hydrology (2) perform stability analysis of shallow water equations using Fourier (or von-Neumann) analysis for consistent, lumped and upwind finite element schemes and finite volume schemes at node and at an element (3) compare the stability-based criteria for element and nodal based errors using finite element and finite volume methods (4) determine upper and lower bounds for time-step and Courant number for each finite element scheme using coefficient method (5) perform accurate analysis using eigen-value method (6) develop time-step and Courant number results for explicit, semi-implicit and implicit finite element and finite volume schemes.

METHODOLOGY AND PRINCIPAL FINDINGS

Fourier stability analysis is adapted for kinematic wave shallow water error equations. Fourier stability analysis requires approximation of nodal solution errors by grid discretization-dependent spatial and temporal error harmonics or individual Fourier components and estimation of magnitude of error amplification factor in wavenumber space. The Fourier analysis at the element level results in a single error equation for each element. Applying the Fourier stability analysis for all the element and nodal error equations, we obtain the amplification factor which shows evolution of error amplitude. The amplification factor is plotted for all the wavenumbers in wavenumber space, to check if the magnitude is lower than unit magnitude of amplitude to avoid numerical instability. If the amplification factor exceeds unit magnitude of amplitude for any wavenumber for any computational grid node, the time-step should be changed from its current value to ensure numerical stability. This is tantamount to changing the Courant number from its current value to other values for the same grid discretization. The same method is applied to all of the remaining element and nodal error equations using consistent, upwind, lumped for each of explicit, implicit, and semi-implicit finite element and finite volume schemes.

The principal research findings of the current project are summarized below:

1. Rigorous and conditional stability criteria are established for two-dimensional consistent, lumped and upwind formulations using explicit, semi-implicit and implicit finite element and finite volume schemes.
2. The error analysis at finite element level formulation is different from finite element nodal level formulation for two-dimensional problems. The

- generalization of finite element nodal level error analysis is more accurate, as only nodal equations are truly solved, than finite element level error analysis. For unit magnitude of amplification factor, all of the finite element nodal evaluations yield the theoretical result $Tan\theta = i$ for all the methods consistent, upwind, and lumped using explicit, semi-implicit, and implicit schemes.
3. In the case of finite element method, the amplification factors determined using lower bound solutions of Courant numbers of coefficient method match closely with that of integer multiples of scalar eigen-value problem. The amplification factors determined using upper bound solutions of Courant numbers of coefficient method match closely with that of integer multiples of matrix eigen-value problem.
 4. The nodal amplification factors expressed as a function of Courant number are evaluated to be equal for each consistent finite volume scheme- explicit, semi-implicit, and implicit. In the case of finite volume method, the amplification factors determined using coefficient method are compared with those obtained using exact eigen-value method. The close agreement between the amplification factors determined using integer multiples of Courant number of coefficient method and exact eigen-value method indicates that the solution given by coefficient method is a possible solution of kinematic system of shallow water equations.

SIGNIFICANCE OF PROJECT

The numerical simulation of kinematic wave shallow water equations requires large amount of two-dimensional watershed hydrological input data, surface roughness data, and storm data. For large-scale watershed runoff numerical simulations, we require accurate analysis of error equations using finite element or finite volume method. We would also need an accurate estimation of time-step to reduce simulation time and to obtain solution accuracy for kinematic wave shallow water equations. The significance of the project lies in establishing a theoretical framework for error analysis of systems of error equations using finite element and finite volume methods, in obtaining solutions for linearized shallow water equations in the form of amplification factors, in developing lower and upper bounds for scheme specific time-step, in upscaling of individual event or storm based time-step results from small to large-scale watershed runoff simulations, and in development of grid-discretization and time-step dependent simulation Courant numbers for computational, flood-plain watershed hydrology.

Three refereed publications and two conference presentations at the International ASAE meeting this July are in preparation to document these findings

Potential of Controlled Drainage to Reduce Nitrate Contamination at the Watershed Scale

Basic Information

Title:	Potential of Controlled Drainage to Reduce Nitrate Contamination at the Watershed Scale
Project Number:	2004IN158B
Start Date:	3/1/2004
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	4th
Research Category:	Engineering
Focus Category:	Agriculture, Nitrate Contamination, Surface Water
Descriptors:	
Principal Investigators:	Jane R. Frankenberger, Eileen J. Kladvko

Publication

Title: Potential of Controlled Drainage to Reduce Nitrate Contamination at the Watershed Scale

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Problem and Research Objectives

About 50% of all cropland in Indiana is artificially drained with subsurface tile drainage systems. While artificial drainage is necessary for insuring field operations and crop production, it has environmental costs, increasing nitrate-N load to surface water. Controlled drainage has been shown, in plot- and field-scale studies, to reduce nitrate losses from subsurface-drained soils. Control structures are used to hold the water table at a higher level during the non-growing season in November to March when most of the drainage and nitrate loss occur. Controlled drainage could have an important impact on annual nitrate load in streams and rivers that drain heavily-drained watersheds. Although field and modeling studies provide estimates of potential nitrate loss reduction at the field scale, no studies exist that estimate how much nitrate reduction is possible from implementation of controlled drainage at the mid-size watershed scale. The goal of this study is to quantify the potential benefit of controlled drainage in reducing nitrate-N load to surface water in mid-sized watersheds, under the weather and soil conditions in Indiana.

Methodology and Principal Findings

Watersheds less than 1000 square miles in area, having both nitrate concentration data (minimum 48 nitrate samples since 1990) and daily stream flow were identified from USGS and Indiana Department of Environmental Management (IDEM) data. This resulted in 33 watersheds (Figure 1), for which we are delineating watershed boundaries and estimating drained area in each watershed from land use and soil drainage classes, based on the assumption that row-crop fields in poorly drained soil are very likely to have tile drainage in Indiana.

We then calculated average monthly nitrate-N load per unit watershed area by averaging nitrate load (nitrate-N concentration multiplied by daily flow) for each month through all the years of data. In order to see the variation of nitrate load through years, monthly nitrate load for three watersheds were plotted versus time. From field measurements, we know that tile drain affects nitrate concentrations mostly from January to July, while point sources often remain more or less constant throughout the year. Three examples are presented in Figure 2. The estimated percentage of the area that is tile-drained row crops, ranging from 0% to 71%,

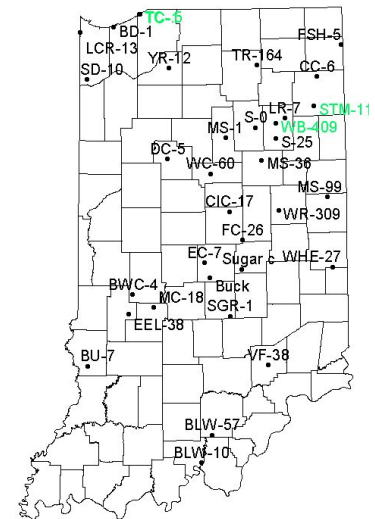


Figure 1: Streamflow gauges where sufficient nitrate-N concentration data are available.

is shown in the legend. From January to July, average nitrate-N load per unit area is higher in more highly drained watersheds, while from August to December, nitrate-N load per unit area is not correlated to drained area.

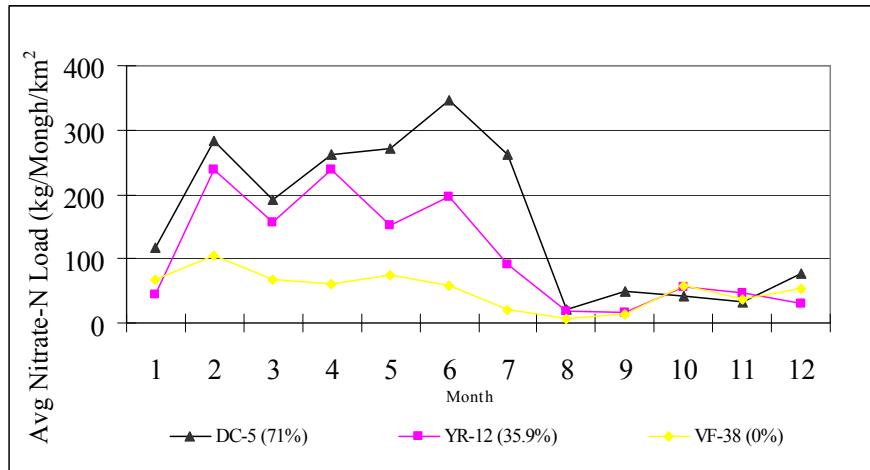


Figure 2. Long term average nitrate-N load by month (kg/Month/km²) for 3 watersheds with high, medium, and low percentage of the watershed that we estimate to be drained agricultural land

We are currently expanding this analysis, and developing a means to estimate the total nitrate load from tile drainage for a particular watershed from statistical analyses of the temporal and spatial relationships of these nitrate-N loading patterns. A preliminary regression study on the difference of average monthly concentration over March, April and May versus Aug., Sept., and Oct. and the percentage of drained area was done for 11 watersheds.

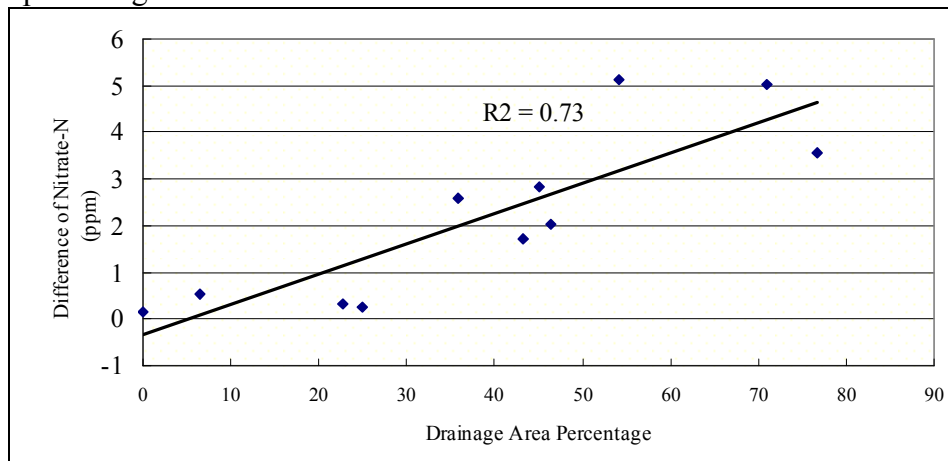


Figure 7. Linear regression of nitrate difference (average concentration in March, April, May versus Aug., Sep., and Oct.) and drained area percentage

Once we have completed the analysis of current nitrate loading from tile drains, we will then estimate potential reductions at the watershed scale from implementation of controlled drainage in areas where it is an appropriate management practice.

We have also begun work on simulating one of the most highly-monitored watersheds, Sugar Creek, with the Soil and Water Assessment Tool (SWAT) model. SWAT uses digital elevation data, land use, soils maps, daily precipitation, temperature and solar radiation for the watershed to predict the effects of different management scenarios on water quality. The new SWAT-2003 version (released in early 2005) has been modified to better simulate landscapes with tile drains, particularly to predict nitrate-N loadings.

Significance

Controlled drainage, or drainage water management, is being promoted by the drainage industry. New NRCS practice standards have made cost-share available in many watersheds. However, the impact of this practice at the watershed level remains unknown. This study will provide the first mid-size watershed estimates of potential impacts of the practice, which will aid policy makers and technical agency staff in evaluating the potential of controlled drainage to benefit local, regional, and national interests. Expected local and regional benefits of the practice include decreased nitrate loading to streams, and national benefits include reduced nitrate loading to major river systems and to the Gulf of Mexico. This study will help determine the magnitude of the benefits.

Students

Roxanne Mitchell, Ph.D. student, has carried out background study on controlled drainage. Yinghui Sui, Ph.D. student, has carried out GIS and data analyses, and SWAT modeling.

Thesis Titles, Papers, Abstracts

This work is still in progress and has not yet been presented. The information gained will be delivered to the agricultural community, the drainage industry, environmental officials, and the public.

Norms, public opinion, and preservation of non-charismatic aquatic and riparian species

Basic Information

Title:	Norms, public opinion, and preservation of non-charismatic aquatic and riparian species
Project Number:	2004IN160B
Start Date:	8/1/2004
End Date:	7/31/2005
Funding Source:	104B
Congressional District:	4th
Research Category:	Social Sciences
Focus Category:	Law, Institutions, and Policy, Management and Planning, Conservation
Descriptors:	
Principal Investigators:	Leigh S. Raymond

Publication

1. Raymond, L. and Laura Schneider 2005. Who Wants to Save That? Legitimizing Policies To Protect Non-Charismatic Species. Poster to be presented at the 2005 annual meeting of the American Political Science Association, September 2005, Washington D.C.

Title: Norms, public opinion, and preservation of “non-charismatic” aquatic and riparian species

Principle Investigator: Leigh Raymond

PROBLEM AND RESEARCH OBJECTIVES

The protection of endangered species is a growing issue in Indiana. To date, twenty species with habitat in Indiana are listed as endangered, threatened, or candidates for listing under the federal Endangered Species Act (ESA). Of these, six live directly within bodies of water and another six rely on wetlands or coastal areas for all or a substantial part of their habitat. Thus, the majority of endangered species in the state rely directly on rivers, wetlands, or coastal zones for their survival.

For many of these species, the situation is dire. All six mussels on the list are endangered and at critical risk of extinction, and the prospects for the other six aquatic or coastal species are not much better. Both of the species considered in this study face substantial challenges for survival. The Fanshell Mussel (*Cyprogenia stegaria*), found only in large river bottoms, is seriously threatened by dredging, dams, and agricultural and industrial pollution, among other factors. At present, only three of the twelve known populations of the mussel are reproducing (USFWS 1997). The Eastern Massasauga rattlesnake (*Sistrurus c. catenatus*) is a candidate species for listing, meaning that there is substantial biological information that the species is at risk. The ongoing draining of wetlands for farming and urban development, as well as direct hunting and eradication efforts are among the more serious threats faced by the Massasauga (USFWS 1998).

Despite the perilous condition of these species, efforts at recovery have been limited. Public controversy over endangered species protection has grown in the past decades, as habitat demands have placed increasingly strong limitations on private property development and usage (Sheldon 1998, Sax 1997, Mann and Plummer 1995). While public support for the ESA and environmental protection in general remain strong, discontent with the way the act is implemented and enforced have grown. At the same time, a fear of regulation under the ESA combined with a lack of sympathy for certain species has led to perverse strategies by private property owners, including “scorched earth” policies to eradicate any potential endangered wildlife habitat on a parcel or the illegal but reportedly common strategy of “shoot, shovel, and shut up” when finding an actual endangered species on one’s land (Bean 2002, 1997).

In light of these challenges, policy makers in Washington and Indiana have tried to balance the needs of species and private property owners through regulatory innovations like “safe harbor” agreements and habitat conservation plans (Farrier 1995). However, better public education regarding the merits of species conservation is also a crucial part of any successful endangered species policy. Despite the hostile climate, efforts to protect certain high-profile species like California condors or Grizzly Bears continue to receive strong public approval (and the lion’s share of public funding for recovery). Less attractive and low-profile species, however, garner only lukewarm support or even open hostility (Huddy and Gunnthorsdottir 2000). In general, aquatic and riparian species such

as invertebrates (including mollusks), and reptiles are among those with the least funding or public support for recovery (Miller *et al.* 2002, Czech *et al.* 1998). Yet such species are crucial to many aquatic and riparian ecosystems, and also merit protection under the law as much as their more charismatic peers.

Thus, public support for the preservation of these “non-charismatic” species is crucial to maintaining their place in the aquatic ecosystems of Indiana. Yet management agencies are struggling with how to promote the protection of these species among the public. The purpose this project is to identify the relative public appeal of various normative and practical arguments used to justify the protection of endangered species. In this regard it seeks to apply qualitative and quantitative methods to better understand the role of public opinions and ideas about species protection in implementing and legitimating public policy.

The specific **objectives** of the project include the following:

- * Accepting or rejecting the primary research hypothesis that ethical, normative arguments regarding species preservation will be more persuasive than other justifications based on practical principles
- * Identifying what kinds of arguments are most effective at creating or maintaining public support for preservation of “non-charismatic” aquatic and riparian species
- * Identifying to what degree the persuasiveness of such arguments varies among species based on their threatening nature to humans (the Massasauga) or existence largely outside daily human experience or awareness (the Fanshell Mussel)
- * Identifying if age, sex, occupation or other factors have a significant impact on the findings
- * Providing guidance to policy makers and regulatory agencies seeking to garner public support for the preservation of such species under the ESA and other laws.

METHODOLOGY AND PRINCIPAL FINDINGS

This project combines quantitative and qualitative approaches to test the research hypotheses. The initial stage of the research was composed of four focus groups session regarding participant attitudes toward protection of the two noncharismatic aquatic species in question, two other non-aquatic species (the Indiana Bat and the Bald Eagle) used for comparison purposes, as well as of endangered species in general. Focus groups were led by the PI, and were conducted for approximately one hour each. They were taped, and the recordings were then transcribed for subsequent analysis. Each included a similar set of questions regarding endangered species conservation in general, property rights, and the conservation of specific species found in Tippecanoe County.

Each session took place with a distinct group with some interest in the issue of endangered species conservation. The first session was a group of Purdue students interested in environmental matters and active in the campus greens chapter. The second was with a local “environment” committee of the Lafayette Chamber of Commerce. The third was with a group of members of a local environmental organization (the NICHES land trust), and the fourth was with a group of farmers working in Tippecanoe county. All subjects received \$20 compensation for their participation.

The second stage of the project was a detailed direct mail survey sent to approximately 995 households in Tippecanoe County. Addresses were selected randomly from a sample frame composed of the more than 54,000 property owners of record in the county recorded at the county courthouse. The survey itself was a 12-page instrument composed of questions regarding endangered species conservation and property rights. Questions were drawn from the initial focus group instrument, with revisions and adjustments based on findings emerging from those sessions. All surveys were mailed with cover letters and postage-paid return envelopes, working in collaboration with Purdue’s mailing services department. Although data collection is ongoing for the survey, to date we have obtained approximately 420 completed surveys for a response rate of more than 42%. We are still hopeful of getting a final return rate of 50%.

Specific findings from the project are limited in the current reporting period, since most data analysis of the surveys in particular will take place this summer. However, some tentative initial results did emerge from the initial focus group sessions including the following:

- 1 The hypothesis that moral arguments are a stronger justification for non-charismatic species gets limited support from the focus groups. Instead, ecological reasons are strongest.
- 2 In general, there was a strong split on reasons to preserve species among the groups. Moral and Ecological reasons were strongest for Environmentalists, Ecological and Practical reasons were strongest for business interests and farmers.
- 3 Ecological reasons seem the strongest overall for preserving species; symbolic reasons were weakest.
- 4 Environmentalists find that reasons to protect do not vary by species (charismatic or not), others argue against this idea.
- 5 Surprisingly, there is strong support for financial compensation for private owners to protect species, at least in some circumstances, among all groups
- 6 Eagle seen as most important species to conserve among non-environmentalists, Mussel as most important among environmentalists.

- 7 Eagle is the most appealing species to non-environmentalists, Bat or “all equally appealing” most common view among environmentalists.
- 8 Eastern Massasauga seems to be least appealing or “charismatic” to all groups.
- 9 Eagle least important to protect among environmentalists, but not other groups.

SIGNIFICANCE of the PROJECT

When completed, the primary result of this proposal will be the determination of what arguments are most persuasive to the public for preserving non-charismatic, water-based endangered species. By supporting or rejecting the project’s basic hypothesis—that an ethical justification for protecting such species is the most effective way to sway public opinion—the project will make a specific contribution to those trying to design, implement, and legitimate such policies. Currently, the FWS and other agencies and advocates tend to rely more on practical reasoning regarding the value of endangered species to human beings, rather than more ethical arguments, in promoting their policies. If this study’s primary hypothesis is confirmed, the validity of this particular strategy will be placed in doubt. Instead, agencies and policy makers may want to return to more basic, normative arguments to encourage support for and cooperation regarding their endangered species policies in this context. Thus, one practical result of the project would be information on public attitudes and beliefs regarding endangered species common to aquatic habitats. These results should help policy makers and agency personnel alike in their efforts to protect various species like the Massasauga, the Fantail, or other aquatic and riparian creatures and their threatened habitats.

In addition, the research will also provide more general insights regarding public opinion about endangered species. Other non-charismatic species include, in some contexts, land-based reptiles and invertebrates as well as large predator species like the Florida Panther or the Gray Wolf. The results of this study should hold interesting implications for those trying to support and craft policies to protect these other endangered species, beyond the aquatic and coastal areas of the state of Indiana. Finally, this project will offer interesting results regarding the role of normative ideas in political life and policy in general. Normative ideas appear to play a central role in the creation and implementation of many public policies, both environmental and not, yet the specific role of these normative ideas in shaping such policy processes and outcomes remains poorly understood (Raymond 2003). To the degree that normative ideas play an important role in public acceptance of endangered species preservation, that finding will also bear on this larger intellectual question.

STUDENTS (id as to grad or undergrad),

The project has been supported for the entire academic year by Laura Schneider, a 3rd year PhD student in Political Science. Laura is a co-author on the upcoming conference

presentation for the project, and will also co-author any journal articles that result from the project. Although funding for the project ends in May, she will remain involved throughout the summer and fall of 2005 in writing and revising any results.

Thesis titles, papers, and abstracts.

Who Wants to Save That? Legitimizing Policies To Protect “Non-Charismatic” Species
Poster to be presented at the 2005 annual meeting of the American Political Science Association, September 2005, Washington D.C.

Abstract:

Consistent with the 2005 APSA conference theme, the mobilization of public support is critical to the democratic legitimation of any public policy. How to best mobilize such support is a difficult question. Policies like the Endangered Species Act struggle with this issue, particularly with regard to the protection of “non-charismatic” species of reptiles, mollusks, and invertebrates. Recovery efforts for the Bald Eagle or Chinook Salmon benefit from public approval and substantial funding, even as other endangered species go without (Miller *et al.* 2002; Baker 1999). This is not surprising—scholars have shown that physically attractive, “charismatic” species of mammals and birds evoke greater public approval than less appealing species (Huddy and Gunthorsdottir 2000; Czech *et al.* 1998; Kellert 1996). Thus, the present research question: what arguments would mobilize the greatest public support and legitimation for policies faced with the difficult task of protecting non-charismatic endangered species?

The study turns to the literature on the role of ethical norms in policymaking for a promising alternative (Raymond 2003, 2001; Ostrom 2000, 1998; Elster 1992). “Norms” in this context are generally defined as non-legal rules of behavior that are culturally determined, commonly held, and socially enforced (Coleman 1990). Scholars have established that *ethical* norms of justice and fairness influence human attitudes and behavior even in the face of substantial personal costs (Ahn *et al.* 2003; Eavey 1991; Hoffman & Spitzer 1985). Normative ideas appear to play a central role in the creation and implementation of public policies, both environmental and not, yet the specific political role of these normative ideas remains poorly understood (Raymond 2003). Such norms seem to offer a promising alternative for mobilizing support in the context of non-charismatic species, however, where fear and ignorance pose significant emotional and psychological barriers to a species’ protection.

Thus, the hypothesis investigated by this paper is that policy makers could increase public support for biodiversity policies *by explicitly promoting an ethical argument* that extinction is morally wrong. Specifically, the paper documents public attitudes about protection of two “non-charismatic” endangered species: the Eastern Massasauga Rattlesnake, and the Fanshell Mussel. The paper marshals qualitative and quantitative data from a series of four focus groups and a mail survey of 1,000 residents of Tippecanoe County, Indiana, to test what arguments are most or least persuasive in supporting protection of these species.

The paper is of theoretical and practical significance. Normative ideas of fairness have been shown to be important to obtaining the public’s “contingent consent” to other

coercive policies like military conscription (Levi 1997). Studying the role of other ethical norms in this context will expand our understanding of how widely moral ideas affect policy legitimation in general. In addition, better knowledge of these public attitudes should aid the implementation and legitimation of endangered species policies. Currently, agencies emphasize practical arguments for conserving such non-charismatic species, with little success (USFWS 2003; Plater 1997). Yet non-charismatic species like snakes and shellfish are equally important to ecosystems, making this research all the more policy-relevant.

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Phosphorus Deposition in an Agricultural Drainage Ditch and Constructed Wetlands System

Basic Information

Title:	Phosphorus Deposition in an Agricultural Drainage Ditch and Constructed Wetlands System
Project Number:	2004IN162B
Start Date:	12/1/2003
End Date:	11/30/2004
Funding Source:	104B
Congressional District:	4th
Research Category:	None
Focus Category:	Agriculture, Non Point Pollution, Nutrients
Descriptors:	None
Principal Investigators:	George Parker

Publication

1. Kohler, E.A., V.L. Poole., Z.J. Reicher, and R.F. Turco. 2004. Nutrient, metal, and pesticide removal during storm and non-storm events by a constructed wetland on an urban golf course Ecological Engineering 23: 285-298

Septic System Permit Database

Basic Information

Title:	Septic System Permit Database
Project Number:	2004IN164B
Start Date:	8/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	4th
Research Category:	Ground-water Flow and Transport
Focus Category:	Management and Planning, Treatment, None
Descriptors:	
Principal Investigators:	Brad Lee

Publication

1. Lee, B.D., D.P. Franzmeier, and P.J. Schoeneberger. Northeast Indiana moraine soils project. Indiana Assoc. Professional Soil Classifiers. January, 21, 2004. (56 participants)
2. Lee, B.D. Soils and septic systems. Indiana Environmental Health Association Spring Conference. April 30, 2004 (165 participants).
- 3.
- 4.

Title: Mineralogy and hydraulic conductivity of selected moraines and associated till plains in NE Indiana

Principal Investigators:

J. L. Krenz and B.D. Lee

Graduate Student and Assistant Professor of Agronomy

Agronomy Department, Purdue University, West Lafayette, IN

Problem and Research Objectives:

One-third of Indiana residents utilize soil wastewater infiltration systems (septic systems), however, the Indiana State Department of Health (ISDH) estimates that 25% of these septic systems do not function properly. A 1997 survey of Indiana county health departments identified problematic soils as the most common reason for septic system failure. In 2001, the ISDH issued a memorandum stating that northeastern Indiana soils have caused premature septic system failure. The ISDH now requires 16 counties to conduct additional soil analyses before septic systems can be permitted.

Soils in northeastern Indiana and northwestern Ohio pose unique land use challenges due to poor drainage, high clay content, high shrink-swell capacity, and low hydraulic conductivity. A better understanding of the relationships between soil mineralogy, hydraulic conductivity, and soil physical properties is essential to the development of better soil-water management strategies.

Results from this study will assist northeastern Indiana county health departments in assessing soil conditions and developing a better understanding of the factors that contribute to septic system failure. The objectives of this study are to:

1. determine the soil hydraulic conductivity in major soils on the Bluffton Till Plain, NE Indiana
2. characterize the clay mineralogy in major soils of the Bluffton Till Plain

Methodology:

With the cooperation of the Natural Resources Conservation Service, twelve pedons were selected, sampled and described according to standard Natural Resource Conservation Service (NRCS) methods. Similar landscape positions were sampled at each site which are representative of the surrounding landscape. These sites form a transect through northeastern Indiana from Allen County to Hamilton County. At each pedon location, samples were collected for analysis at the National Soil Survey Center (NSSC), and at Purdue University. The samples sent to the NSSC will be fully characterized, with analysis including: particle size, total carbon, nitrogen, and sulfur; extractable bases, CEC, % base saturation, pH, percent carbonate as CaCO₃,

and clay mineralogy. We expect to receive the complete soil characterization data from the NSSC in late 2005.

The samples collected for Purdue will be used for clay mineral determination. These samples were fractionated into 3 size fractions: fine silt (2-5 μm), coarse clay (0.2-2 μm) and fine clay (<0.2 μm) by settling and centrifugation (Jackson, 1969). X-ray diffraction analysis and high resolution transmission electron microscopy coupled with octadecylalkylammonium techniques will be used to identify the clay minerals present in these samples.

Field saturated hydraulic conductivity (K_{sat}) measurements were collected with a constant compact head permeameter for selected horizons at each pedon location using a constant head permeameter. Saturated hydraulic conductivity measurements were collected in four depths, five replicates per depth.

Principal Findings:

Results listed below are based on data available at this time. Hydraulic conductivity data and soil morphology data are complete for the entire transect. Soil chemical data is available for 8 of 12 pedons at this time. We anticipate updating these results and completing the interpretations when the data set is complete.

Saturated hydraulic conductivity (k_{sat}):

In all but two of the pedon locations, the surface horizons had the highest hydraulic conductivity. Water could move through the surface horizon at least 2 fold faster than any other soil horizons analyzed. The Bt horizons show a dramatic decrease in hydraulic conductivity, due to the increased clay percentages and amount of fine clay. The Cd horizons in all of the pedons showed the slowest hydraulic conductivities. This horizon is quite compact at all of the sites, causing slow permeability of water through the soil.

Clay percentages:

Clay percentages in the Cd horizons (parent material) increased from around 15% in the southwest to 35% in the northeast. This is important because it shows that the parent material of these soils is not uniform across the transect.

Fine clay to total clay ratios:

The fine clay to total clay ratios for the Bt horizons show that fine clay makes up 33 to 47 percent of the total clay percentage. Because fine clays are more likely to be expandable and have a larger surface area, they can contribute to decreased soil hydraulic conductivity.

Depth to carbonates:

The depth to carbonates in 11 of the 12 pedons was less than 40 inches. This depth is limiting for installation of conventional septic systems in Indiana. The Indiana State Department of Health requires 42 inches of soil without carbonates for a conventional septic system to be installed at a site. This requirement would make nearly all of our sites unsuitable for conventional systems.

X-ray diffraction analysis:

The preliminary x-ray diffraction analysis supports the hypothesis that the fine clay fraction of the Bt horizons has a greater abundance of expandable 2:1 clay minerals. Clay mineral analysis is ongoing.

Significance:

This study has begun to characterize the physical and mineralogical properties of soils in northeastern Indiana. A better understanding of the relationships between soil mineralogy, hydraulic conductivity, and soil physical properties is essential to the development of better management strategies. Results from this study will assist northeastern Indiana county health departments in assessing soil conditions and developing a better understanding of the factors that contribute to septic system failure. With a better understanding of the soils, developers and installers as well as county health sanitarians will have a better idea of the types of systems that will work successfully in these areas, and reduce the need for expensive site specific soil tests. These results will be pertinent to current and future land use issues throughout northeastern Indiana, as the population grows and people continue to move into rural areas.

Our study results show that soils in northeastern Indiana have 15-35% clay in the Cd horizons with around 45% of this clay as fine clay. The fine clay fraction is dominated by expandable 2:1 clay minerals. Most of the pedons we sampled had carbonates between 38 and 66 cm from the surface. The carbonates indicate that very little water is being leached through the soil at this depth. The saturated hydraulic conductivity data supports this, as the values were much lower in these layers than in the horizons above them. Although the soils in northeastern Indiana are well suited for growing crops, they are not well suited for conventional onsite wastewater treatment systems (septic systems). Non-conventional septic systems may provide a better means of treating effluent in these soils.

Students Supported by IWRRC Funds

Jennifer L. Krenz, M.S. expected December 2005

Kelli S. Hart, M.S. expected March 2006

Abstracts

Hart, K.S., B.D. Lee, P.J. Schoeneberger and D.P. Franzmeier. 2005. Hydraulic conductivity across a toposequence on the Wabash moraine, northeast Indiana. *In* Agronomy abstracts, ASA, Madison, WI.

Krenz, J.L., B.D. Lee, D.G. Schulze, P.J. Schoeneberger, D.P. Franzmeier, S.K. Sears, and H. Vali. 2005. Illitic soil mineralogy: Bluffton Till Plain and associated moraines in northeast Indiana. *In* Agronomy abstracts, ASA, Madison, WI.

Presentations

Lee, B.D., D.P. Franzmeier, and P.J. Schoeneberger. Northeast Indiana moraine soils project. Indiana Assoc. Professional Soil Classifiers. January, 21, 2004. (56 participants)

Lee, B.D. Soils and septic systems. Indiana Environmental Health Association Spring Conference. April 30, 2004 (165 participants).

Krenz, J.A., B.D. Lee, D.P. Franzmeier, P.A. Schoeneberger and K.S. Hart. Soil properties of the moraines and associated till plains in NE Indiana. Indiana Association of Professional Soil Classifiers Winter Conference, Jan. 26, 2005. Indianapolis, IN. (85 participants)

Publications

Hart, K.S., B.D. Lee, P.J. Schoeneberger, and J. Krenz. 2005. Soil hydraulic conductivity on the Wabash Moraine, Wells County, IN. Purdue Cooperative Extension, RW-2 (*in review*).

Grants Leveraged with IWRRC Funds

Recessional moraine soil hydraulic conductivity investigation: Northeastern Indiana. Indiana State Department of Health, Center for Disease Control Preventative Health and Health Services Block Grant Program. 2004. Brad D. Lee, PI (\$26,999)

Northeastern Indiana soil chemical and physical properties involved in premature septic system failure. Indiana State Department of Health, Center for Disease Control Preventative Health and Health Services Block Grant Program. 2005. Brad D. Lee, PI (\$19,160)

Mineralogy of the moraines and associated till plains in northeastern Indiana. Geological Society of America, Graduate Student Research Grant. 2005. Jennifer A. Krenz, PI (\$1500)

Stormwater Guidance and Implementation in Indiana: Perspectives on the new Rule 13

Basic Information

Title:	Stormwater Guidance and Implementation in Indiana: Perspectives on the new Rule 13
Project Number:	2005IN169B
Start Date:	9/1/2004
End Date:	12/31/2004
Funding Source:	104B
Congressional District:	9th
Research Category:	Engineering
Focus Category:	Hydrology, Toxic Substances, Water Quality
Descriptors:	
Principal Investigators:	Jack Wittman, Jack Wittman

Publication

1. Karstedt, Wenke, 2005. A Comparison of Stormwater Management in the US and Germany. MS Dissertation Indiana University.

Title: Stormwater Guidance and Implementation in Indiana: Perspectives on the new Rule 13

Principle Investigator: Jack Wittman

PROBLEM AND RESEARCH OBJECTIVES

Over the past two years the Indiana Department of Environmental Management has developed a new rule and guidance material for implementing phase two of the Clean Water Act (Rule 13). This new rule is designed to reduce the water quality impairments caused by stormwater inflows to Indiana's streams and rivers. The basic idea is that the diffuse development that occurs in watersheds in urban and urbanizing areas needs to account for the increases in stormwater runoff that is caused by the impervious areas in the watersheds of the state. These new rules are to be implemented by the designated MS4 operator with limited background (virtually no institutional history) and in most cases, very limited funding. While it is not uncommon for Indiana's municipal governments to bear the burden of state regulation, it is not common for the state to be requiring performance standards with no experience in evaluating the performance of any measure that is proposed as a best management practice by the stormwater management authority. The implementation problems associated with this new rule are related both to the *institutional capacity* of the jurisdictions doing stormwater management and the *technical* nature of stormwater management (where to protect and from what contaminants).

Like many other rules adopted by the State Water Pollution Control Board, implementation of Rule 13 will not be uniform across Indiana. Some counties have more resources and internal capacity to manage new rules related to fairly technical topics. Some counties have limited resources and yet they are required to satisfy the same rules with the same performance requirements. The current rule 13 guidance refers to existing standards and programs (e.g., total maximum daily loads, wellhead protection, etc.) and forces the counties to be responsible for a new world of problems and impacts.

Reckoning with these problems, while new to Indiana, is part of the existing landscape of Europe. Most European countries have been using stormwater management for stream water quality improvement for over ten years. In Germany, for instance, research and water quality sampling programs have been adopted that demonstrate how particular stormwater management strategies alter water quality. If a particular method for managing stormwater quality works in one area (soil type, vegetation, cropping pattern, etc.) and not in another, there is generally data to indicate what methods work in different hydrologic and development settings. It is clear that we could benefit from the experiences of municipal governments in Europe.

The objectives of this research are to:

- 1) compare German and American approaches to stormwater management
- 2) make recommendations about stormwater management that can be included in the local plan

METHODOLOGY AND PRINCIPAL FINDINGS

Methodology

A German graduate student with experience with stormwater issues spent a semester in Bloomington reviewing the local ordinances and state laws, attending meetings of the county drainage board, and evaluating stormwater problems in South-Central Indiana. The primary problems identified were related to the ability of the local government to enforce residential development design and the lack of local data to use in determining the effectiveness of any particular management practice.

Principal Findings

The most important conclusions drawn from the review were:

- Despite the various jurisdictions of government's role in defining environmental problems related to stream water quality, there is very little data available to local governments about the development impacts.
- In general the land use shift occurring in the state is from woodland/pasture to residential land use. In the unglaciated portions of the state the natural hydrograph was buffered by interception storage as well as the substantial leaf litter and organic layer that held water during storm events and improved stream water quality. New development reduces the storage in the watersheds and more water is leaving the landscape sooner after each storm.
- Recommendations are made to require (or promote) development that includes distributed detention systems that store rain water within the development and allow the landscape to store more water higher up in the basin. These systems, rather than enhancing recharge (which is often used in the sandier German landscape) can instead supplement base flow in small streams. This is an effective approach to smoothing the hydrograph to reduce flooding, these smaller basins may also be able to reduce pollutant loading in streams.
- Based on the German experience in stormwater management with detention ponds, the critical factor that determines effectiveness of these systems is regular inspection and maintenance. This may

SIGNIFICANCE OF THE PROJECT

This project identified critical problems with our understanding of stormwater

management in the state. The most important issue identified was the lack of rainfall-runoff data to use in designing residential development in the state. Based on this finding another proposal was developed and funded to collect rainfall and runoff information in watersheds that are developed with a range of different stormwater management techniques.

In addition, the graduate student – Wenke Karstedt – has completed her master's thesis on this topic and will be defending her thesis in late June, 2005. Her completed work will be used to inform the county drainage board as they move toward implementation of Rule 13.

STUDENTS

- name: Wenke Karstedt
- thesis title: A Comparison of Stormwater Management in the US and Germany
- date of defense: June 23, 2005

Information Transfer Program

Introduction to Information Transfer Program

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Hoosier Water Summit

Basic Information

Title:	Hoosier Water Summit
Project Number:	2003IN113B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	4
Research Category:	Not Applicable
Focus Category:	Water Supply, Non Point Pollution, Water Quality
Descriptors:	
Principal Investigators:	Stephen Lovejoy, Stephen Lovejoy, Ron F. Turco

Publication

Update on the Water Summit.

The Hossier Water Summit is being planned for the Winter of 2005 to be held in Indianapolis, Indiana. The program has expanded to include major role by the faculty at IUPUI-CEESE. Dr. Lenora Tedesco is working with IWRRRC to organize the effort. Our tentative outline is listed below and is somewhat different than was previously planned.

Towards Sustainable Water Resources Translating Research into Action

Outcomes: A White Paper documenting water resources sustainability issues in Indiana

Who: Academic Researchers, Government Agencies, Environmental Practitioners,
Conservation Organizations, Watershed Management Groups, Industry

When: First conference will be held in November, 2005 with annual conferences to follow.

Program Plan

Day One

8:30 – 9:00 Registration

9:00 – 9:20 Program Opening – IUPUI and Purdue Administrative Welcome, Program
Introduction – Tedesco and Turco

9:20 – 10:15 Speaker: Regional Framework for Water Issues – EPA Official

10:15 – 10:30 Break

10:30 – 11:30 Speaker: Indiana Framework for Water Issues – TBA

11:30 – 12:00 Networking and Move to Lunch

12:00 – 1:00 Lunch

1:00 – 2:00 Keynote Address: National Speaker discussing major water issue (Gulf of Mexico hypoxia, other?)

2:00 – 4:00 Panel Discussion: Midwestern Regional Water Resource Center Directors (Illinois, Kentucky, Michigan, Ohio, Wisconsin, Minnesota, Indiana)
Question-based discussion vs prepared statements

4:30 – 6:00 Cocktail Reception

Day Two

Science Meeting – call for papers as well as invited papers

15-20 minute presentations

Focus on Indiana water resources issues

Watershed Management

Wetland Restoration/Isolated Wetlands

Toxic Algal Blooms

Eutrophication of Surface Water Resources

Round Table Discussion to discuss White Paper content and procedure for draft and review

Student Support

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

Notable Awards and Achievements

Notable Achievements and Awards

Provide a brief description of any especially notable achievements and awards resulting from work supported by your base grant, National Competitive Grant awards, and by supplemental grants during the reporting period.

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Publications from Prior Projects