Indiana Water Resources Research Center Annual Technical Report FY 2007

Introduction

IWRRC 2007 Program and Management Overview:

This report covers the activities of the Indiana Water Resources Research Center (IWRRC) for the period March 1, 2007 to February 28, 2008. The report is provided to meet requirements and obligations under the 104 (B) program. The objectives of the fiscal year 2007 program of the IWRRC have been: (1) to continue to engage the water community in the State of Indiana as related to water research and education; (2) to develop a suite of research programs that encompass several state water issues; (3) develop an outreach program related to water and water quality (in particular rural water safety and septic systems) and (4) to strengthen interactions with State and Federal Agencies (largely through grant applications).

Briefly, in the last year we have supported three externally reviewed 104(B) projects, through a well developed interconnection between IWRRC and a USDA−CSREES facilitation grant (EPI−Net.org) we have helped organized and participated in workshops on water and water borne pathogens, participated in a visioning sessions on the future of Indiana's water resources (both quality and quantity), worked with our advisory boards, maintained a functional website (www.iwrrc.org) been involved in the development and submission of number of grant proposals with one major collaborative watershed project receiving federal 319 funding. We helped a recently awarded 104(g) project on Nutrient and carbon delivery to streams in artificially drained landscapes of the Midwest: matrix flow, overland flow or macropore flow become functional and continued to work on the CEAP grant that was funded last year. We worked with City of Lafayette, Indiana and the Wabash River Enhancement Corporation (WREC) to facilitate discussions on long−range planning for Wabash River Redevelopment. This is done in conjunction with a Purdue Center for the Environment and a number of local agencies. This lead to our soon to be funded 319 effort entitled: Developing a watershed management plan (WMP) for the Middle Wabash−Little Vermillion Basin (HUCs 05120108−010, 05120108−020, and 05120108−030). The IWRRC has been active with the Indiana Department of Natural Resources (IDNR) where the IWRRC director is now serving on the state's Water Shortage Task Force.

For this reporting period, we continue the strategic outreach alliance with the Purdue Pesticide Program office for the development of document and educational materials on the environmental impact of “Aboveground Petroleum Tanks” (PPP−73) and Securing the Load: A Guide to Safe and Legal Transportation of Cargo and Equipment. Our second outreach alliance is with the Purdue Septic Systems Program to support them in the development of educational programs related to water quality and septic system installation and maintenance. In a prior year we supported (104(B) money) the development of a septic system inventory system and usage of this system will be part of the new effort. For both outreach programs, we are providing support to their core efforts and using the opportunity to include the IWRRC in many of their other programs. The long−term goal is establish a constant and vital outreach effort.

The IWRRC 104(B) research program included work on fish biology in the Wabash River, development of the tools needed to establish a water quality monitoring program on the Wabash River, nutrient transport in a major drainage way leading to Wabash River and project looking at the factors effect BMP maintenance a long major waterways.

Research Program Introduction

Project 01: Program Administration and State Coordination

In general, the administrative portion of the project has been used to support the management of the IWRRC's research projects and to facilitate the development of other research projects. These projects have the ultimate goal of improving 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 invest time in the efforts to integrate with state and federal agencies. The IWRRC director has work 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. In this way, the results from the research projects can be transferred to interested individuals in the state. The IWRRC director will participate in important national and international meetings related to water and environmental protection.

Projects Areas

1. Working with the Wabash River Enhancement Corporation (WERC) in developing a strategy for improving the Wabash River. This relationship now underpins our major effort in the state, as we have decided on the Wabash River as our target of opportunity. 2. Continued meetings with the director and staff at the USGS office in Indianapolis. This was the first substantial interactions with the USGS leadership in a number of years. 3. The interaction with USGS−Indianapolis led to IWRRC being a sponsor on a meeting to establish a “State Water Monitoring Council” with a kickoff meeting held in the Fall of 2007. We are now developing a major conference “Improving Indiana's Waters: Using Monitoring Data to Measure Impact” Wednesday, Dec. 3, 2008 – Indiana Government Center. 4. Preliminary development of a white paper on a water quantity and biofuel production that has lead to a number of proposal submissions. 5. Working with Dr. Fred Whitford and the Purdue Pesticides Program Office to establish an outreach effort centered on water protection emphasizing pesticide and farmstead management. 6. Working with Dr. Brad Lee, Purdue's septic system expert. We have now elevated the role of the IWRRC in water protection as related to septic systems management. Indiana, like most of the Midwest, is dependent on septic systems for waste handling. We are developing a program to better educate the professional installer and developing educational materials to support this effort. 7. Meetings with faculty at the University of Toledo as part of wetlands enhancement and pathogen tracking programs. Work is to be joined with efforts at the In Save the Dunes; developing a Great Lakes theme. 8. Continued an ongoing interaction with the Lake LaSalle homeowners and water management group to review and recommend management priorities for improving the water quality in Lake LaSalle. 9. Continued interactions with a number of consulting firms related to water quality issues.

Grant Applications Submitted thorough/with IWRRC:

a. (Funded) USDA Conservation Effects Assessment Program. $660,000. Watershed−Scale Evaluation of BMP Effectiveness and Acceptability: Eagle Creek Watershed, Indiana. Developed with Jane Frankenberg, Lenore Tedesco, Jerry Shively, Linda Prokopy. This was an outgrowth of an effort submitted last year to EPA but note funded: Creating sustainable drinking water supplies for Central Indiana: Innovations to achieve reductions in watershed and reservoir nutrient levels.

b. (Continued Funding) USEPA Fate of hormones in tile−drained fields and impact to aquatic organisms under different animal waste management practices. Linda Lee, S. Brouder, C. Jafvert, M. Sepulveda and R. Turco.

c. (Continued Funding) IDEM−319—Development and Demonstration of Outcomes−Based Evaluation Framework for the Indiana Nonpoint Source Program. Developed with Jane Frankenberger, Linda Prokopy, and Shorna Broussard. Additional support has been given to Linda Prokopy for work on Social Indicators.

d. (Continued Funding) Advanced Concepts and Technologies International, LLC — Improved Detection &Remediation of NBC/CBRN/TIC/TIM Contaminants in Potable Water. Developed with Drs. Inez Hua and Chad Jafvert. IWRRC provided organizational and management input.

e. (Continued Funding) Center for the Environment. Living Laboratories on the Wabash (LLOW). Developed with Kim Wilson, Linda Prokopy, Larry Nies and Dan Sheperson. This proposal now serves as a major driving force for many of the IWRRC's efforts.

f. (Pending) USDA NRI, Managed Ecosystems. Ecological services of agro−biofuels: productivity, soil C storage, and air and water quality. $399,999. Submitted Dec. 2007. S.M. Brouder, PI, R.F. Turco, J.J. Volenec, D.R. Smith and G. Ejeta CoPIs.

g. (Funded) IDEM 319: Wabash River: Lafayette−West Lafayette Reach of the Wabash River Watershed Management Plan. Submitted in conjunction with the Wabash River Enchantment Corporation $600,000. L. Prokopy, L. Bowling, K. Wilson and R. Turco.

h. (Not Funded) Sungrant. Comparative biofuel productivity potential and environmental impact of Switchgrass, Miscanthus, and Maize. $1,000,000. Submitted April, 2007. S.M. Brouder, J.J. Volenec, R.F. Turco. Research

i. (Not Funded) USDA DOE, Biomass Research and Development Initiative. Comparative Feedstock Productivity, and Carbon, Nitrogen, and Water Economies of Switchgrass, Miscanthus, maize, and a Big Bluestem−dominated Prairie for Biofuels. $1,000,000. Submitted: Nov., 2007. S.M. Brouder, PI, J.J. Volenec, R.F. Turco, and D.R. Smith

j. (Not Funded) EPA Star Program. Integrated BioSensors for Rapid Detection of Cyanobacteria and their Toxins in Municipal Water Systems. 600,000 July 2007. R. Bashir, M. Ladisch, R. Turco.

k. (Not−Funded) NSF Critical Zone Observatory Program. Critical Zone Observatory for Managed EcoSystems (CZOMES). S. Brouder, C. Jafvert, G. Michalski, W.V. Sigler, R. Turco, P. Owens, M. Crawford. $4,000,000. (Establishes a water quality observatory in the St. Joseph Watershed.) .

l. (Not Funded) USDA−NRI Tracking the survival and distribution of Mycobacterium avium subsp paratuberculosis in the agroecosystem: implications for animal health. E. Rizaman, C. Wu and R. Turco.

External Board of Advisors Membership: Dr. Lenore Tedesco, Director Center for Earth and Environmental Science, Indianapolis IN Dr. Jack Wittman, President, Wittman Hydrosciences, Bloomington IN Dr. John C. Steinmetz, Director, Indiana Geological Survey Indiana University Bloomington IN Dr. Dennis Wichelns, Hanover College, Hanover IN Ms. Christine Livingston, Watershed Coordinator, Save the Dunes, Michigan City, IN Dr. Linda Lee, Associate Director Center for the Environment, Purdue University Ms. Martha Clark−Mettler, Director Watersheds Program IDEM, Indianapolis IN

Faculty Advisory Committee: Dr. Linda Lee, Associate Director Center for the Environment Dr. Jane Frankenberger, Agriculture and Biological Engineering Dr. Larry Nies, Civil and Environmental Engineering Dr. Inez Hua, Civil and Environmental Engineering Dr. Dev Niyogi, Agronomy Department, and State Climatologist

The Director's Key Program Areas:

LLOW Project Focus for 2007: A significant portion of the Directors' time is spent in coordination of larger water related research efforts. Of note is our continuing effort with the Living Laboratories on the Wabash (LLOW) project. Many of our proposal submissions are now derived from this group as the effort has become a cornerstone for our efforts. Of note was the recent Wabash River 319 project. This effort was a product of the LLOW group and the LLOW group is receiving direct project support from IWRRC. Dr. Turco is a key member of the LLOW group. The IWRRC is playing a major role in directing efforts that will focus attention on Indiana's greatest river. The focus of the Living Laboratories On the Wabash (LLOW) Project will be to develop a plan of work to establish a discovery, learning and outreach project for the 1,410 acre floodplain along the Wabash River between U.S. Highways 52 and 231 (see attached map). Partnering with the Wabash River Enhancement Corporation (WREC). The goal of the LLOW team is to establish a ‘living laboratory' that will integrate discovery, learning and outreach and act as a model for other river communities in Indiana and elsewhere. This will be accomplished through graduate and undergraduate research and service−learning projects, development of a community participation process and public educational programs, and improved participation and coordination between local, state, and federal agencies.

Wabash River: Lafayette−West Lafayette Reach, Watershed Management Plan 2007−2009

Purpose: Write a watershed management plan for 3 11−digit hydrologic units in the Lafayette Reach of the Wabash River. This plan will guide future development and practices in a way that protects water quality.

Vision: Ensure an environmentally and economically healthy watershed.

Why this area? This domain includes, and extends beyond, all the land area that drains to the Wabash between the new water quality monitoring station at the 9th Street Bridge and a proposed station at Granville Bridge. Therefore this is the area that has to be managed to control water quality in this reach of the Wabash. Several of the streams in this area are already listed as impaired while others are threatened by future road and suburban development.

Why now? There are many exemplary efforts related to water quality ongoing in the Lafayette Reach of the Wabash already; however, these are not guided by a planning effort that identifies and prioritizes critical issues and areas. A plan developed through a participatory process that collects and analyzes scientific data will help prioritize ongoing and new initiatives to maximize impacts on water quality.

Why WREC in partnership with Purdue University? The Wabash River Enhancement Corporation in partnership with Purdue University is well positioned to oversee the development of this management plan. WREC is currently conducting a master plan for the Wabash corridor in Tippecanoe County; this watershed management plan will strengthen this ongoing work. WREC has a long−term commitment to the health of the Wabash River. Purdue's Living Laboratory on the Wabash (LLOW), a Center for the Environment funded project and a long−term WREC partner, will provide technical expertise and lead the outreach initiative.

What will WREC do with the grant? Hire a coordinator; conduct public meetings; engage in intensive stakeholder involvement; analyze existing water quality data; monitor 1−2 additional water bodies; and write a watershed plan that follows EPA's recommended guidelines to prioritize critical issues and areas that are impacting water quality.

Other Projects:

Conservation Effects Assessment Program (CEAP) Focus for 2007: Watershed−Scale Evaluation of BMP Effectiveness and Acceptability: Eagle Creek Watershed, Indiana. Over the last 30 years, the implementation of best management practices (BMPs) has been a mainstay of conservation programs designed to improve water quality while maintaining agricultural productivity. While the value of BMPs can be demonstrated at the small scale, the aggregated effects across a watershed are unclear and largely undocumented. This project integrates a watershed investigation with a social and economic benefits analysis and education program by bring together experts in modeling, social sciences, and economics with a research group managing both historical data and ongoing watershed sample collections. Our target watershed is the 77,000 acre Eagle Creek Watershed north of Indianapolis, which feeds into Eagle Creek and the city's major storage reservoir. Eagle Creek Reservoir supplies water for the Indianapolis water system and the city's 780,000 residents. In spite of the use of BMPs, water quality in the watershed has continued to decline. Our effort has two purposes: the first is to analyze and model an extensive water quality database for the watershed so that we can correlate trends in water quality with current BMPs and then using modeling, compare the trends in water quality to what would be achieved if different BMP management approaches were used. The model is constructed to allow us to explore different scenarios and management intensities. The second purpose of the project is to develop an understanding of the social and economic limitations to the adoption of BMPs and by analyzing the current social limitations to acceptance of water quality management alternatives devise strategies to accelerate positive change. In essence, we will use real data to drive scenario modeling as a means to inform our educational program so that we can influence decision making about practices in the Eagle Creek Watershed. As we have a long−term data set, the impact of this process can be fully assessed and documented.

The Environmental Pathogens Information Network (EPI−Net) 2007: EPI−Net is a keystone organization that provides a stable, centralized resource of water microbiological contamination and environmental pathogens related information, encourages information sharing, connects a network of stakeholders, regulatory officials and technical experts, provides a reliable point of references and increases our ability to develop a coherent national research agenda and good public policy. Epi−net's impact is found in our help to the general public as they work to understand the science and possible environmental consequences of pathogenic bacteria in the environment. The purpose of this information network is to provide the scientific and user communities with a centralized source of information about environmental pathogens, in a way that benefits both the scientific regulatory community. Epi−Net will also better inform our citizens of the problems associated with pathogens and provides prevention approaches. The overarching goal of EPINet is to develop and then transfer the fullest possible understanding of how microbial pathogens enter into and then function in watersheds so that we can properly manage and prevent the spread of microorganisms (and the diseases they cause). To reach that goal EPI−Net developed a series of workshops and information packages that are held in various U.S locations and available in the website www.epi−net.org.

Held EPI−Net Second workshop – “E. coli at the Beach” in Merrillville, IN February 2, 2007 There is a growing demand from the public that the health and quality of our beaches be restored and maintained. While the presence of contamination is a problem, even the perception of contamination can affect tourism. Therefore, a timely and state of the art monitoring program is mandatory to ensure public protection. The purpose of this workshop was to provide current information to professionals working on pathogens and E. coli as part of a beach monitoring program; while many pathogens were considered, we focused on E.coli. We explore and discussed what has been determined from recent environmental research and provided input as to the use of information in a management planning. The main topics discussed at the workshop were: Pollution at the beach, Monitoring of recreational waters, Methods for pathogen detection and government regulations. The participants had a chance to share information about common problems as well and to suggestions for improvements and techniques.

Speakers: Dr. Ron Turco − Purdue University, IN Dr. Von Sigler – University of Toledo, OH Dr. Richard Whitman – USGS, IN Rebecca N. Bushon – USGS, OH Holiday Wirick – EPA, IL David C. Rockwell – EPA, IL Christine Livingston – Save the Dunes Conservation Fund, IN

Held EPI−Net Third Workshop – “Microbial Source Tracking” in Chicago, IL September 14, 2007 There is an increased concerned about the health of our water bodies. Fecal contamination in water and soil has been studied intensively in the past years. Knowing the source of the contamination is very important as it will provide means to improve conditions by implementing best management practice. The purpose of this workshop was to discuss the applications of Microbial Source tracking (MST) for pathogen detection to help increase the health of our water bodies (beaches) by decreasing the numbers of E. coli and possibly other enteric organisms (pathogens). The main topics discussed at the workshop were: Pathogens in the environment, Methods for pathogen detection and microbial source tracking methodology. Participants had a chance to discuss data with other researchers on the field. This meeting portrayed and important case study which was very informative and useful for the participants. This case study was so important that participants commented and how much it helps them to see techniques worked on real life situations and how they can adapt similar strategies for their own site. Speakers: Dr. Ron Turco − Purdue University, IN Rebecca Bushon – USGS, OH Dr. Jorge Santo Doming – EPA, OH Dr. Von Sigler – Toledo University, OH Dr. Mike Sadowsky – University of Minnesota, MN Dr. Julie Kinzelman – Racine Health Department, WI

Wireless Monitoring of Purdue's Constructed Wetland

Basic Information

Title:	Wireless Monitoring of Purdue's Constructed Wetland
Project Number:	2006IN187B
Start Date:	3/1/2007
End Date:	5/31/2008
Funding Source:	104B
Congressional District:	4th
Research Category:	Water Quality
Focus Category:	Nutrients, Education, Water Quality
Descriptors:	
Principal Investigators:	Chad Jafvert, Rao S. Govindaraju

Publication

Statement of Critical Regional or State Water Problem

In 1999, a constructed wetland, owned by Purdue University, was installed along Marshall Ditch, approximately 7 miles Northwest of Purdue University's main Campus in Tippecanoe County. The water treated by the wetlands originates from Purdue's Aquaculture Center (Fish Farm) and Marshall Ditch, itself. Upstream of the wetlands influent, Marshall Ditch drains approximately 2000 tiled areas, including land occupied by Purdue's Dairy Farm. The primary purpose of the constructed wetland is to reduce nutrient (primarily nitrate) concentrations in Marshall Ditch, effectively decreasing non-point source pollution from Purdue's agricultural fields.

The wetlands has been used extensively by students in Purdue's Department of Forestry and Natural Resources for wildlife-related research projects; however, over the past 6 years, it has been under-utilized as a research and education facility for its intended use of improving water quality within the local watershed. For example, there are no formal water quality monitoring studies currently being conducted at the site, and no infrastructure exists at the site to allow for continuous wireless monitoring of any water quality parameters or water quantity (inflow and outflow). Without wireless monitoring and control, maintenance and operation has become problematic, as pumps must be turned-off and on on-site during periods where the temperature varies around the freezing point, and problems may go unnoticed for days to weeks. Even the simplest data collection, such as measuring water flow rates currently must be performed on-site. Clearly Purdue's constructed wetlands is an idea research facility to for developing both research and educational programs associated with the installation, maintenance, and data evaluation associated with environmental sensors and sensor arrays in natural and engineered environments. This overall topic of deploying wireless sensor arrays is currently of considerable national interest. For example three major initiatives are underway through the National Science Foundation for development and deployment of related sensors and sensor networks in the environment. These are: NEON (National Ecological Observatory Network), CLEANER (Collaborative Large-Scale Engineering Analysis Network for Environmental Research, and CUAHSI (Consortium of Universities for the Advancement of Hydrologic Sciences, Inc.). Within the past 3 months, NSF has combined the CLEANER and CUAHSI initiatives into one that will develop a Major Research Equipment and Facilities Construction (MREFC) proposal to be presented to the U.S. Congress in approximately 2008 to fund the development and construction of environmental sensor networks across the nation, focusing primarily on surface water quantity and quality. Through this program, regional field stations will be constructed, and it is likely that each field station will monitor tens to hundreds of unique site locations (i.e., nodes) within our Nations waterways and coastal zones via wireless technology. The regional field stations will collect data that are of general importance, and data that will address scientific questions that are unique to the regional ecosystem or watershed. As with other MREFC initiatives, such as EarthScope, the initial 5 year development and construction budget is expected to be in the range of $200-300 million dollars. Prof. Jafvert currently is a member of a CLEANER organization committee, and Prof. Govindaraju currently is involved in the CUAHSI initiative. Clearly, the more experience the co-PIs and other researchers within the State of Indiana have in working with environmental sensors and sensor networks, the greater the potential will be to attract nationally-funded large-scale networks to the State's watersheds to examine water quality issues at the large watershed scale.

Statement of Results/Benefits

The potential results and benefits of this project include the following:

1) Continuous and grab sample water quantity and water quality data will be collected at a constructed wetland used to treat surface water draining from agricultural fields. Specific continuous data to be collected include: volumetric flow rate; turbidity, dissolved oxygen concentration, temperature, specific conductivity, and pH. Grab samples will be collected, either by hand or with ISCO samplers to monitor with time: total phosphate, nitrate ion, ammonia, E. coli, and suspended solids. Because the study site is a constructed wetlands, all surface water inflows to and outflows from the four wetlands cells pass through four V-notch weir boxes in which parameters can be monitored or samples can be taken to assess parameter changes before and after treatment by the wetlands. In the case of volumetric flow rate, a pressure transducer will measure the elevation of water behind each V-notch weir, from which the volumetric flow rate over the weir is determined. All data will be made available on-line, with the continuous data being made available in near-real time through the EPICS class website. The data will be accessed for publication in either engineering education journals or water quality journals.

2) The instrumentation and wireless routers purchased through this project will be installed and maintained by undergraduate students enrolled in the Constructed Wetlands/Water Quality (CWWQ) section of EPICS (EPICS is Engineering Projects in Community Service, and the class website can be found at: http://epics.ecn.purdue.edu/cwwq/). As a result, funding of this project will directly contribute to the education of undergraduate students in sensor and wireless technologies as they relate to environmental assessment and protection. Because the data will be made available online, it is anticipated that after this project is completed, additional web-based tools will be development through the EPICS class that can be used in K-12 education. One of the clients for the CWWQ team is the Tippecanoe County Soil and Water Conservation District. In future semesters, the EPICS students will work with the District to develop such educational tools that serve there needs, including K-12 education. It is critical that university engineering programs participate in this type of outreach. In the U.S., only 5% of college students are graduating in engineering, compared to 13% in the European Union and 17% in Asia. The U.S. Department of Education National Center for Educational Statistics reports that high school student interest in engineering has decreased 18% since 1991. Clearly, more positive outreach activities are needed to reverse these trends.

3) By gaining more familiarity with the specific sensors and wireless instruments employed in this study, the PIs will be in a much stronger position to attract nationally-funded large-scale networks to the State’s watersheds to examine water quality issues at the large watershed scale. As indicated above, large national programs for deploying sensor arrays in the environment are currently at the conceptual stage, and it is critical that researchers within the State of Indiana take advantage of these programs in promoting the study of regional watershed issues.

An Indiana Water Resources Research Center Proposal (2006) Entitled:

Wireless Monitoring of Purdue's Constructed Wetland

Chad T. Jafvert and Rao S. Govindaraju, Co-PIs

Statement of Critical Regional or State Water Problem:

The purpose of this proposal is to request funds for the purchase of water quality monitoring instrumentation and wireless routers to be installed at Purdue's constructed wetlands, and maintained by Purdue University undergraduate students enrolled in the EPICS course: Constructed Wetlands/Water Quality (class website: http://epics.ecn.purdue.edu/cwwq/). EPICS is the acronym for "Engineering Projects in Community Service" and is a collection of engineering courses taken for credit but undergraduate students, with the Constructed Wetlands/Water Quality section having extensive enrollment from across campus. This projects focus is on: (1) employing innovative wireless continuous monitoring strategies for assessing water quality at remote locations, (2) training undergraduates in sensor and wireless technologies as they relate to environmental assessment and protection, and (3) leveraging project infrastructure and results to attract additional resources to the State of Indiana to monitor environmental parameters at a broader scale (i.e., watershed level).

In 1989, a multidisciplinary research initiative began at Purdue to use a local, mostly agricultural watershed as a study area, with the study area designated as the Indian-Pine Natural Resources Field Station. Within the watershed, is Marshall Ditch, an agricultural headwater of Little Pine Creek, a tributary of the Wabash River. After nearly a decade of measuring water quality and flows within the Field Station, a constructed wetlands was planned, and installed in 1999 along Marshall Ditch, approximately 7 miles Northwest of Purdue's main Campus in Tippecanoe County. The water treated by the wetlands originates from Purdue's Aquaculture Center (Fish Farm) and Marshall Ditch, itself. Upstream of the wetlands influent, Marshall Ditch drains approximately 2000 tiled areas, including land occupied by Purdue's Dairy Farm. The primary purpose of the constructed wetland is to reduce nutrient (primarily nitrate) concentrations in Marshall Ditch, effectively decreasing non-point source pollution from Purdue's agricultural fields.

Funding for installation of the constructed wetlands was from several sources, including: Purdue's FNR department, J. F. New and Associates, Eli Lilly, IDEM, and the Indiana DNR. FNR managed construction, with Purdue's EPICS (Engineering Projects in Community Service) Constructed Wetlands class taking lead roles in portions of the pluming, planting, and educational materials development. Two 40 ft by 40 ft settling basins, and four wetland cells, each approximately 40 ft wide by 400 ft long (approximately 2 acres total) were constructed and planted and seeded in 1999.

The wetlands has been used extensively by students in Purdue's Department of Forestry and Natural Resources for wildlife-related research projects; however, over the past 6 years, it has been under-utilized as a research and education facility for its intended use of improving water quality within the local watershed. For example, there are no formal water quality monitoring studies currently being conducted at the site, and no infrastructure exists at the site to allow for continuous wireless monitoring of any water quality parameters or water quantity (inflow and outflow). Yet, it is an extremely opportune time for developing both research and educational programs associated with the installation, maintenance, and data evaluation associated with environmental sensors and sensor arrays in natural and engineered environments, as this is a topic of considerable national interest. For example three major initiatives are underway through the National Science Foundation for development and deployment of related sensors and sensor networks in the environment. These are: NEON (National Ecological Observatory Network), CLEANER (Collaborative Large-Scale Engineering Analysis Network for Environmental Research), and CUAHSI (Consortium of Universities for the Advancement of Hydrologic Sciences, Inc.). Within the past 3 months, NSF has combined the CLEANER and CUAHSI initiatives into one that will develop a Major Research Equipment and Facilities Construction (MREFC) proposal to be presented to the U.S. Congress in approximately 2008 to fund the development and construction of environmental sensor networks across the nation, focusing primarily on surface water quantity and quality. Through this program, regional field stations will be constructed, and it is likely that each field station will monitor tens to hundreds of unique site locations (i.e., nodes) within our Nations waterways and coastal zones via wireless technology. The regional field stations will collect data that are of general importance, and data that will address scientific questions that are unique to the regional ecosystem or watershed. As with other MREFC initiatives, such as EarthScope, the initial 5 year development and construction budget is expected to be in the range of $200-300 million dollars. Prof. Jafvert currently is a member of a CLEANER organization committee, and Prof. Govindaraju currently is involved in the CUAHSI initiative. Clearly, the more experience the co-PIs and other researchers within the State of Indiana have in working with environmental sensors and sensor networks, the greater the potential will be to attract nationally-funded large-scale networks to the State's watersheds as these initiatives develop.

A major difference between large-scale wireless monitoring networks, such as the proposed CLEANER-CUAHSI network, and small-scale wireless monitoring systems (besides scale), is the need for an extensive cyber-infrastructure to support the much larger networks. At the local scale of 2-4 nodes, most issues related to the sensors and the local network remain the same, independent of the total number of nodes. Hence, while the scientific focus of this proposal is on specific questions that are related to the semi-continuous monitoring of influent and effluent of constructed wetland cells, the information and experience gained during this study will be valuable in designing larger scale networks. During the funding period of the project, emphasis will be on measuring the mass balances of water volume and chemical species across constructed wetlands cells, requiring long-term (months to years) monitoring due to the extensive retention time within the wetland cells. The robustness of off-the-shelf sensors, the required calibration frequencies, and methods used in data reduction to calculate mass fluxes of chemical constituents into and from the wetland cells will be evaluated. Because the PIs' competences are in the area of water chemistry (Jafvert) and hydrology (Govindaraju), and not on cyber-infrastructure, these are logical technical questions that can be posed and evaluated within the framework of an undergraduate course structure.

Statement of Results or Benefits:
The potential results and benefits of this project include the following:

1) Continuous and grab sample water quantity and water quality data will be collected at a constructed wetland used to treat surface water draining from agricultural fields. Specific continuous data to be collected include: volumetric flow rate; turbidity, dissolved oxygen concentration, temperature, specific conductivity, and pH. Grab samples will be collected, either by hand or with ISCO samplers to monitor with time: total phosphate, nitrate ion, ammonia, E. coli, and suspended solids. Because the study site is a constructed wetlands, all surface water inflows to and outflows from the four wetlands cells pass through four V-notch weir boxes in which parameters can be monitored or samples can be taken to assess parameter changes before and after treatment by the wetlands. In the case of volumetric flow rate, a pressure transducer will measure the elevation of water behind each V-notch weir, from which the volumetric flow rate over the weir is determined. All data will be made available on-line, with the continuous data being made available in near-real time through the EPICS class website. The data will be accessed for publication in either engineering education journals or water quality journals.

2) The instrumentation and wireless routers purchased through this project will be installed and maintained by undergraduate students enrolled in the Constructed Wetlands/Water Quality section of EPICS. As a result, funding of this project will directly contribute to the education of undergraduate students in sensor and wireless technologies as they relate to environmental assessment and protection. Because the data will be made available online, it is anticipated that after this project is completed, additional web-based tools will be development through the EPICS class that can be used in K-12 education. One of the clients for the CWWQ team is the Tippecanoe County Soil and Water Conservation District. In future semesters, it is likely that the EPICS students will work with the District to develop such educational tools, including K-12 outreach. It is critical that university engineering programs participate in this type of outreach. In the U.S., only 5% of college students are graduating in engineering, compared to 13% in the European Union and 17% in Asia. The U.S. Department of Education National Center for Educational Statistics reports that high school student interest in engineering has decreased 18% since 1991.

3) By gaining more familiarity with the specific sensors and wireless instruments employed in this study, the PIs will be in a much stronger position to attract nationally-funded large-scale networks to the State's watersheds to examine water quality issues at the large watershed scale. As indicated above, large national programs for deploying sensor arrays in the environment are currently at the conceptual stage, and it is critical that researchers within the State of Indiana take advantage of these programs in promoting the study of regional watershed issues of important to the State.

Nature, Scope, and Objectives of the Project:
Over the past decade, the use of constructed wetlands for treating agricultural runoff has been evaluated and reported in the literature (1-5). Most of these studies have evaluated the performance of wetlands quantitatively, although without the proper mass balance approach. For example, concentrations of chemicals (e.g., nitrate) or bacteria (e.g., E Coli) within the

influent and effluents of wetlands are often determined, however it is rare that concentrations are normalized to water flow, providing a more accurate assessment of mass loss of each across the wetland (6-7). This requires that both water flow and water quality parameters be measured simultaneously, either continuously or semi-continuously. In this study, through the use of V-notch weir boxes, inflow and outflow will be monitored continuously at the constructed wetlands site, and through a sampling campaign over January-May 2007, specific chemical and biological parameters will be measured to calculate mass balances of water and chemical and biological constituents across the wetlands. Funding of this proposal will allow for the purchase of standard instrumentation that will allow for this study to be completed, and also will allow for easily supplementing the site with additional instrumentation when newer innovative sensors become available.

The total project length is 15 months, scheduled to start on March 1, 2006. From March 1 to the end of the semester (May, 2006), the instrumentation will be purchased and upon its arrival will be set-up and evaluated within the laboratory to test probes and wireless communication software and hardware. During this time, the students will document operation and calibration protocols such that new students enrolling in the course in the fall semester will have a knowledge base from which to work. Installation at the wetlands will occur in the fall semester (August – December, 2006), with tools developed for web-based monitoring of sensor measurements. During the spring semester (January – May, 2007), both sensor and grab sample data (i.e., phosphate, nitrate, ammonia, and E. coli) will be collected and analyzed to calculate removal efficiency of these chemical and biological species by the wetlands. The last month of the project (June, 2007) will be used by the PIs to document project results. Although the formal project will end in June, 2007, this instrumentation will continue to be used by the EPICS class to monitor the constructed wetlands after the project expires.

Methods, Procedures, and Facilities:

A schematic of Purdue's Constructed Wetlands is shown in Figure 1. Water is pumped from Marshall Ditch to a weir box where the flow is split equally, flowing by gravity to two small settling ponds, and then to the first two wetland cells. From these cells, the water flows through pipes to the last two wetland cells in series, one of which is a subsurface flow cell. Water is also pumped from Purdue's Aquaculture Center into a weir box, from which it flows equally and directly into the first two cells.

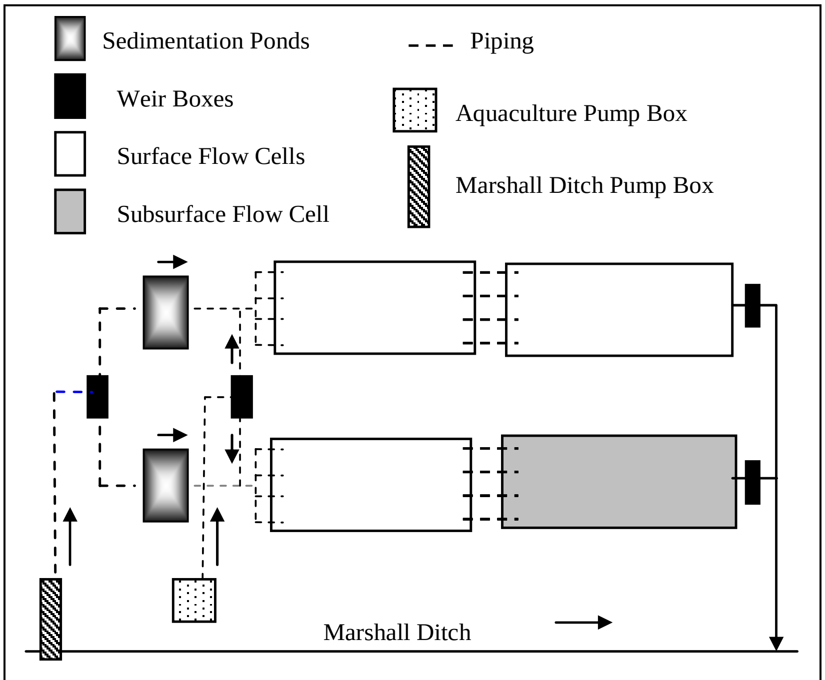

Figure 1. Flow diagram of Purdue's Constructed Wetlands

Due to rain events, infiltration, and evapotranspiration, the volume of water entering and leaving the wetlands is never equal. Because only one of the four cells within the two series of cells is a subsurface wetland, differences in the water balance also occur between the two independent series. The logical placement of any wireless sensors is in the weir boxes, since all flowing water entering and leaving the four wetland cells flows through the four weir boxes - two located at the inflows, and two located at the outflows. Also, the main purpose of a weir box, besides acting as a good device to split the flow, is to measure the flow rate by applying a simple equation that relates the height of water behind the weir to the flow rate of water over the weir. Hence, placement of a pressure transducer with a box allows for continuous monitoring of the flow rate. During construction in 1999, all four weir boxes were built of treated wood, however due to deterioration, the EPICS class is in the process of replacing all four with new weir boxes made of aluminum. One has been replaced, with a second box scheduled to be replaced in spring 2006. The new aluminum weir boxes are designed to have sufficient space to locate sensors and probes within them. A maximum flow rate of 60 gallons per minute has been used for the design of each box. With two weir boxes at the wetland's influent and two at the effluent approximately 800 ft apart, the design for wireless monitoring includes locating data-loggers at each location, connected to a series of probes and devices for monitoring water flow rate and water quality constituents. To ensure software-hardware compatibility, all probes, dataloggers, and software and peripherals will be purchased from the same vender – Campbell Scientific, Inc., and will include the following:

1) CS547A Conductivity and Temperature Probe (4 at $335 each = $1,340)
   Conductivity range: Approximately 0.005 to 7.0 mS cm^{-1}
   Temperature measurement range: 0° to 50°C
2) CS511-l Dissolved Oxygen probe (4 at $380 each = $1,520)
   Range: 0 to 20 mg l^{-1} with accuracy of ±2%
3) OBS-3-L Turbidity probe (by D&A Instruments, from Campbell Sci) (2 at $2,420 = $4,840)
   Ranges: 0 – 4000 NTU
4) CSIM11 pH probe (4 at $225 each = $900)
   Accuracy: ±0.1% over full range
5) *Pressure Transducer* (4 @ $595 = $2,380)
6) *CR10X Datalogger* (2 at $1,250 each = $2,500)
7) *Modem:* RF400 Spread Spectrum Radio Modem (3 at $425 each = $1,275)
8) *Antennae:* 9 dBd Yagi Antenna (quantity =2 at $155 each), and 3 dBd Omni-Directional Antenna (1 at $183 each) (Total = $483). The one omni-directional antenna will be placed at the weir boxes located at the effluent of the wetlands, relaying data to the datalogger located at the influent weir boxes, which in turn relays the data to the PC at the Dairy Farm through the two bidirectional antennae.
9) *Software:* Loggernet 2.1 (1 copy at $200)
   This software allows the operator(s) to: Create custom datalogger programs; Display or graph data; Build a custom display screen to view data or control flags/ports; Collect data on demand or schedule; Retrieve data using above telecommunications options; Post process data files; Export data to third-party analysis packages; Communicate with storage modules
10) *Solar panels:* MSX10 10-Watt Solar Panel with Mounts (2 at $200 each = $400)
   Provides a 10 W typical peak power; Dimension each: 42.0 x 26.9 x 2.3 cm

11) *Batteries:* CH100 12 Volt Charger/Regulator (2 at $185 each = $370)
12) *Misc. computer supplies*: $665

A general schematic of the proposed remote sensing system is shown in Figure 2.

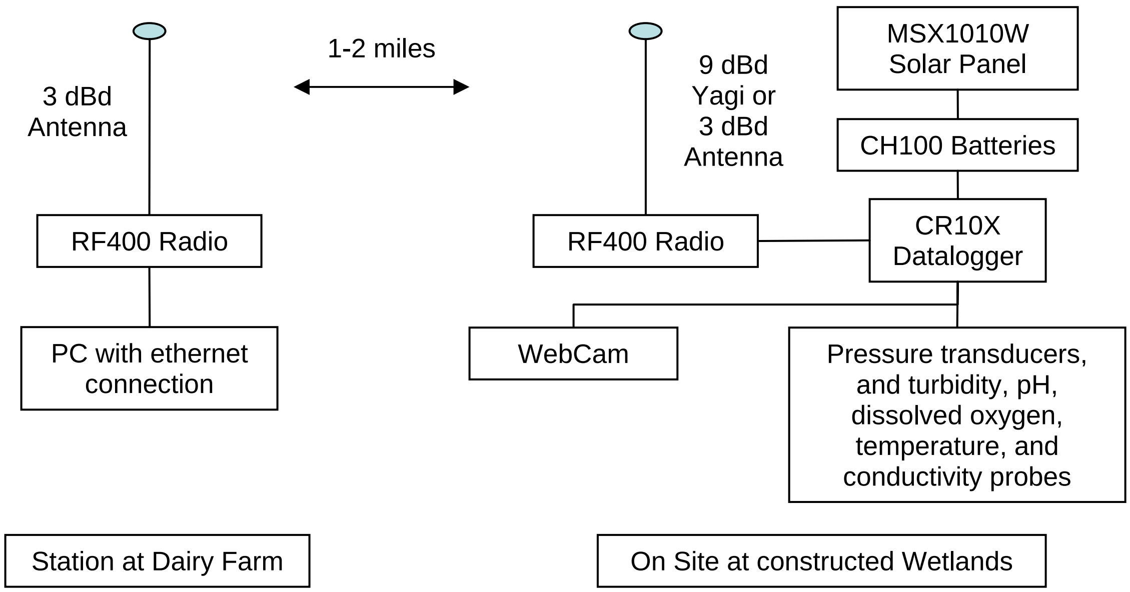

Figure 2. Schematic of the proposed wireless monitoring system

For simplicity, Figure 2 shows only one "On Site" station, and only one "collection" of probes and sensors, although two "On Site" stations will exist in the field (i.e., one each at the influent and effluent weir boxes), and 4 sets of probes will exist (i.e., one set located in each weir box). Line power is available near the influent weir boxes; however, power will be supplied to the instruments located at the effluent boxes via solar panels and batteries. Data will be transmitted via 900 MHz radio to a computer located less than two miles away at Purdue's Diary Farm, equipped with high speed internet service. From here, the information will be made available in near real-time on the worldwide web.

Figure 3. Observation deck constructed by EPICS students (l), and two of the wetland cells (r)

Related Research:

Greenfield Rest Area Constructed Wastewater System: Prof. Govindaraju has been involved with a constructed wetlands project located and the Greenfield Rest Area located along Interstate Highway I-70, east of Indianapolis, IN. The wetlands treats effluent from the septic system used to pretreat wastewater from the rest area facilities. Currently, a number of flow measuring devices are placed in strategic locations at the site to acquire a complete picture of the hydraulics of the system. A V-notch weir and a couple of Palmer-Bowlus flumes were installed for open-channel flow measurements. Magnetic flow meters were used to measure pressurized flows. Four automatic samplers were also installed to collect wastewater samples at various points in the system. A weather station was also installed to provide data on rainfall, wind speed, temperature, and estimates of evapotranspiration.

Grand Calumet River Monitoring Project: Prof. Jafvert is lead PI on an industry sponsored project that monitors water elevations in over 50 wells, piezometers, and stream gauges located near and in the Grand Calumet River in northwest Indiana. Water elevations are measured manually in all wells and piezometers on a biweekly basis and in 14 piezometers and stream gauges with programmable pressure transducers, from which the data are downloaded on a monthly basis. In addition, the flow of water across the sediment-water boundary is periodically measured with a meter designed and constructed by Prof. Jafvert and Dr. Carl Enfield (retired from the U.S. EPA) specifically for this task. Although the meter can be employed in the field for long-term monitoring, it has only been used continuously only for short periods of time of less than 10 hrs.

Student Training:
As the name implies, EPICS (Engineering Practice In Community Service) teams perform planning, design, and assembly of useful materials for community partners. In the case of the Constructed Wetlands team, Purdue University, itself, has been the primary client, although Eli Lilly, Alcoa, and the Tippecanoe County Soil and Water Conservation District (SWCD) have all participated as team clients or advisors over the years. Team membership has been stable of the years, with broad representation of undergraduates within Engineering and across campus. Students, from the freshman to senior level may take EPICS as an elective course. A summary of projects performed by EPICS students at Purdue's Constructed Wetland include:

1999 – The team sized the pumps and pipes and constructed a weir box, and made initial measurements on the split flow entering the first two cells. On May 1, the team and friends planted all wetland plants.

2000 – The team constructed and installed V-notch weir boxes for the outfall of the wetlands, so flow could be monitored prior to entering Marshall Ditch.

2001 – The team continued the upkeep of the site and surrounding area, and constructed an observation deck to allow better viewing of the wetlands ecosystem.

2002 – Completed the steps to observation deck and performed maintenance on the weir boxes.

2003 – 2 large information signs, 4 observation deck signs, and 14 quickfact signs were constructed for visitors to view. Invasive vines and rooted trees were removed.

2004 – A Constructed Wetlands Design Manual was written, new weir boxes were designed. Remote monitoring instruments are being evaluated.

2005 – Completed construction and installed an aluminum weir box and designed a second one to be built in spring, 2006.

Over the next three semesters, the students in this course will play and integral role in installing, maintaining, and operating the wireless sensors at the wetlands. This effort will be the major focus of the course over the next two years. Tom Copper, the hydraulics area laboratory manager in Civil Engineering, will also be involved during periods when courses are not in-session as issues arise. Because of the extensive hands-on laboratory nature of EPICS, graduate teaching assistants are assigned to each laboratory session, providing additional support for this project.

Expected Deliverables:
The expected deliverables include the following:
1) Each semester, the EPIC class prepares a presentation and final report that are posted on the website at: http://epics.ecn.purdue.edu/cwed/ (see team docs, and previous semester docs). The reports relay to the project's clients the activities and accomplishments of that semesters effort. Over the course of this project, three such reports and presentations will be generated and posted on the website.
2) As soon as possible after quality assurance (QA) measures are documented, measured, and evaluated, the data will be made available on the website. Any data for which QA measures are not taken will be noted as such on the website.
3) Final results will be presented at educational conferences, such as those held by the Association of Environmental Engineering and Science Professors, and potentially submitted for publication in the peer-reviewed engineering education or scientific literature.

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2. Bezbaruah, A. N. and Zhang, T. C. Performance of a Constructed Wetland with a Sulfur/Limestone Denitrification Section for Wastewater Nitrogen Removal. *Environ. Sci. Technol.* 37: 1690-1697, 2003.
3. Bruland, G. L.; Hanchey, M. F.; and Richardson, C.J. Effects of agriculture and wetland restoration on hydrology, soils, and water quality of a Carolina bay complex, *Wetlands Ecology and Management* 11: 141-156, 2003.
4. Fleming-Singer, M. and Horne, A.J. Enhanced Nitrate Removal Efficiency in Wetland Microcosms Using an Episediment Layer for Denitrification. *Environ. Sci. Technol.* 36: 1231-1236, 2002.
5. Scholz, M.; Trepel, M. Water quality characteristics of vegetated groundwater-fed ditches in a riparian peatland. *Science of the Total Environment* 332: 109-122, 2004.
6. Baresel, C. and Destouni, G. Novel Quantification of Coupled Natural and Cross-Sectoral Water and Nutrient/Pollutant Flows for Environmental Management. *Environ. Sci. Technol.* 39: 6182-6190, 2005.
7. Schulz, R. and Peall, K.C. Effectiveness of a Constructed Wetland for Retention of Nonpoint-Source Pesticide Pollution in the Lourens River Catchment, South Africa. *Environ. Sci. Technol.* 35: 422-426, 2001.

Biographical Sketch - Chad T. Jafvert

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a) Professional Preparation

Institution	**Major**	**Degree and Year**
Iowa State University	Biochemistry	B.S., 1979
The University of Iowa	Civil and Environmental Engineering	M.S., 1982
The University of Iowa	Civil and Environmental Engineering	Ph.D., 1985

b) Appointments

1999-present, **Professor**, School of Civil Engineering, Purdue University (effective 8/15/99)
1996-2001, **Area Head**, Environment & Hydraulic. Eng. Area, Purdue U. (elected 1996 &1999)
1995-1999, **Associate Professor**, School of Civil Engineering, Purdue University
1991-1995**, Assistant Professor**, School of Civil Engineering, Purdue University
1986-1991 **Research Environmental Engineer**, U.S. EPA, Environmental Research Laboratory, College Station Road, Athens, GA, assigned to the Chemistry Branch
1985-1986 **Research Associate**, National Research Council, assigned to the U.S. EPA, Environmental Research Laboratory, Athens, GA.

c) Relevant Publications

i) Five papers most related to the proposal topic

Jafvert, C. T., Lane, D., Lee, L.S., and Rao, P.S.C. Partitioning of Mono- and Polycyclic Aromatic Hydrocarbons in River Sediment Adjacent to a Former Manufactured Gas Plant Site, *Chemosphere*, in press, 2005.
Hyun, S., Jafvert, C. T., Lee, L.S., and Rao, P.S.C., “Laboratory Studies to Characterize the Efficacy of a Sand Cap Placed over Tar-Contaminated Sediment,” in press *Chemosphere*, 2005.
Fábrega-Duque, José R., Chad T. Jafvert, Hui Li, and Linda S. Lee, “Modeling Competitive Cation Exchange of Aromatic Amines in Water-Saturated Soils,” *Environmental Science and Technology*, 35: 2727-2733, 2000.
Jafvert, Chad T., Beth K. Vogt, and Jose R. Fabrega, "Induced Desorption of DDT, DDD, and DDE from a Contaminated Sediment," *Journal of Environmental Engineering*, 123: 225-233, 1997.
Jafvert, Chad T. "Sorption of Organic Acid Compounds to Sediments: Initial Model Development," *Environmental Toxicology & Chemistry*, 9: 1259-1268, 1990.

ii) Five additional papers

Ahn, Mi.-Youn., Timothy R. Filley, Chad T.Jafvert, Loring Nies, Inez Hua, and Juan Bezares-Cruz, “Photodegradation of Decabromodiphenyl Ether Adsobed onto Clay Minerals, Noncrystalline Minerals, and Sediment, in press, Environ. Sci. Technology, 2005.
Bezares-Cruz, Juan, Chad T. Jafvert, and Inez Hua, “Solar Photodecomposition of Decabromodiphenyl Ether: Products and Quantum Yield,” *Environmental Science and Technology*, 38: 4149-4156, 2004.
Hua, Inez, Namgoo Kang, and Chad T. Jafvert, “Heterogeneous and Homogeneous Photochemical Reactions of Decabromodiphenyl Ether,” *Environmental Toxicology and Chemistry*, 22: 798-804, 2003.
Chu, Wei., James R. Hunt, Chad T. Jafvert, “Modeling the Sequential Photodechlorination of Hexachlorobenzene in Surfactant Micelles,” *Water Research*, 36: 843-850, 2002.
Lin, Ching-Chieh, Chad T. Jafvert, “A Triple Layer, Planar Coordinate Model for Describing Counter-Ion Association to Micelles, *Langmuir*, 16: 2450-2456, 2000.

d) Synergistic Activities

1. Chair or co-chair of four Workshops and Symposia (1987, 1990, 1992, 1996)
2. Member, Science Advisory Panel (SAP) for U.S. EPA Food Quality Protection Act (FQPA) Science Review Board (SRB), in support of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)), 2001-present.
3. Manuscript and proposal reviewer for 29 different journals and organizations (Editorial Board, J. Environmental Toxicology and Chemistry)
4. Member, CLEANER Organization Committee, Organized by U. of Illinois, U. of Iowa, and Drexel University through an NSF grant, 2005-present.
5. Courses taught include: Water Chemistry, Water Quality Modeling, and Computer Programming in Civil Engineering
6. Citation Index lists > 700 citations of Jafvert's research papers

e) Collaborators & Other Affiliations

i) Collaborators (past 48 months)

Mi.-Youn Ahn, U. of Florida; Bruce Applegate, Purdue U.; Wei Chu, Hong Kong Polytechnic U; Natalie Carroll, Purdue U.; Claude Diehl, Purdue U.; Bernard Engel, Purdue U.; Chihhao Fan, Ming-Chi Institute of Technology; José R. Fábrega-Duque, U. of Connecticut; Timothy Filley, Purdue U.; R.S. Govindaraju, Purdue U.; Inez Hua, Purdue U.; Midhat Hondzo, U. of Minnesota; James R. Hunt, U. of California, Berkeley; Brian Johnson, Sevee & Maher Engineers, Cumberland, MA; Richard A. Larson, U. of Illinois; Linda S. Lee, Purdue U.; Hui Li, Michigan State U; Ching-Chieh Lin, Kun Shan University, Taiwan; Dennis A. Lyn, Purdue U.; Karen A. Marley, U. of Illinois; Loring Nies, Purdue U.; Dev Niyogi, Purdue University; Ronald Turco, Purdue U.; P. Suresh C. Rao, Purdue U.; Timothy Strathmann, U. of Illinois; Ching Yuan, National University of Kaohsiung, Taiwan

ii) Graduate and Postdoctoral Advisors

Ph.D. Advisor: Richard Valentine, University of Iowa, Dept. of Civil & Environ. Eng.
Post-Doctoral Advisor: N. Lee Wolfe, U.S. EPA, Environ. Res. Lab, Athens, GA

iii) Thesis Advisees and Postgraduate Scholars sponsored by Jafvert (past 5 years & academic)

Wei Chu, (Ph.D. 8/94) currently Associate Professor, Department of Civil and Structural Engineering, The Hong Kong Polytechnic University, Hun Hom Kowloon, Hong Kong.

Timothy Strathmann, (M.S. 12/96), currently Assistant Professor, U. of Illinois, Champaign/Urbana

Ching Yuan, (Ph.D. 12/95) currently Chair and Associate Professor, Department of Environmental Engineering, National University of Kaohsiung, Kaohsiung, Taiwan

Chihhao Fan, (Ph.D. 5/97) currently Assistant Professor and Chair, Department of Environmental and Safety Engineering, Ming-Chi Institute of Technology, Taipei County, Taiwan.

Ching-Chieh Lin (Ph.D. 7/99) currently Assist. Professor, Dept Env. Eng., Kun Shan U., Taiwan

José R. Fábrega-Duque (Ph.D. 7/99, postdoctoral scholar, 7/99-7/00) Research Engineer, Universidad Tecnologica de Panama (Technological University of Panama)

Fuad Dahan (Ph.D. 5/02), currently Research Environmental Engineer, URS, Wayne, NJ

Seunghun Hyun, Postdoctoral scholar (8/03 – present)

Total number of Students advised who have graduated: Ph.D., 7; M.S. Thesis, 8; postdoctoral scholars, 3.

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a. Professional Preparation

Institution	Major	Degree, Year
Indian Institute of Technology, Kharagpur, INDIA	Civil Engineering	B.Tech., 1984
University of Kentucky, Lexington, KY. USA.	Civil Engineering	M.S., 1986
University of California, Davis, CA. USA.	Civil Engineering	Ph.D., 1989

b. Appointments

August 2001-present	Professor, Purdue University
August 1997 – July, 2001	Associate Professor, Purdue University
May 1996 – July, 1997	Associate Professor, Kansas State University
Jan. 1993 - May 1996	Assistant Professor, Kansas State University
Oct., 1989 - Dec., 1992	Research Associate, Univ. of California, Davis

c. Relevant Publications

(i) Papers related to the proposal topic

1. Chan, T.P. and R.S. Govindaraju (2004). “Predicting soil water retention curve from particle-size distribution data based on the theory of polydisperse sphere systems.”, Vadose Zone Hydrology, 3(4), 1443-1454.
2. Chan, T.-P. and R.S. Govindaraju (2003). “A new model for soil hydraulic properties based on a stochastic conceptualization of porous media.” Water Resources Research, SBH 10, 1-14, (DOI 10.1029/2002/WR001943).
3. Govindaraju, R.S. (ed.) (2002), Stochastic Methods in Subsurface Contaminant Hydrology, ASCE Press, New York, 410 pages.
4. Chan, T.-P. and R.S. Govindaraju (2001).”Analyzing Vertical Field-Scale Solute Movement by Applying Interval Computing Methods to the Stochastic-Convective Transport Model.” ASCE Journal of Hydrologic Engineering, 6(6), 480-489.
5. Govindaraju, R.S. (1996) 'Stochastic analysis of movement of fine particles in porous media.' ASCE Journal of Hydrologic Engineering, 1(4), 161-168.

(ii) Additional 5 papers

6. Nahar, N., R.S. Govindaraju, C. Corradini, and R. Morbidelli (2003). ‘On the representation of field-scale infiltration and overland flow over spatially variable soils.’ Journal of Hydrology, 286, 36-51.
7. Corradini, C., Govindaraju, R.S., and Morbidelli, R., 2002. ‘Simplified modeling of areal average infiltration at hillslope scale.’ Hydrological Processes, 16, 1757-1770.
8. Govindaraju, R.S., R. Morbidelli, and C. Corradini (2001). ‘Areal infiltration over soils with spatially-correlated hydraulic conductivities,’ ASCE Journal of Hydrologic Engineering, 6(2), 150-158.
9. Govindaraju, R.S., L.N. Reddi and S.K. Kasavaraju (1995). 'A physically based model for mobilization of kaolinite particles under hydraulic gradients.' Journal of Hydrology, 172, 331-350.
10. Govindaraju, R.S., Or, D., Kavvas, M.L., Rolston, D.E. and Biggar, J.W. (1992), Error analyses of simplified unsaturated flow models under large uncertainty in hydraulic properties, Water Resources Research 28(11), 2913-2924.

d. Synergistic Activities

1. Surface Water Editor, Journal of Hydrologic Engineering, American Society of Civil Engineering.
2. Member of the surface and groundwater committees of Environmental Water Resources Institute. Vice-chair of the surface water committee of ASCE/EWRI.
3. Co-authored or edited three books in surface and subsurface water movement, and contaminant transport. Teaches undergraduate and graduate courses in these areas.

4. Development of a strong collaborative effort with local state agencies and Indiana Department of Environmental Management.
5. Co-PI in a USA/Canada/Mexico exchange program involving two universities from each country. The project deals with extensive cross-fertilization of research and teaching activities between the researchers and students at the universities.

e. Collaborators and Other Affiliations (Over Last 5 years)

(i) **<u>Collaborators</u>**:

Banks, M.K. (Purdue University); Birdie, T. (Kansas Geological Survey); Brion, G.M. (Univ. of Kentucky); Chen, Z.-Q. (Univ. of California, Davis); Corradini, C. (Univ. of Perugia, Italy); Cushman, J.H. (Purdue University); Dandy, G.C. (Univ. pf Adelaide, Australia); Das, B.S. (I.I.T. Kharagpur, India); Deo, M.C. (I.I.T. Bombay, India); Dougherty, D.E. (Subterranean Research, Inc., Vermont); Dowla, F.U. (LLNL, Livermore); Dracup, J.A. (Univ. of California, Berkeley); Engel, B. (Purdue University); Elshorbagy, A. (Lakehead Univ., Canada); Erickson, L. (Kansas State University); Gao, X. (Univ. of Arizona); Ginn, T.R. (Univ. of California, Davis); Graham, W.D. (Univ. of Florida); Gupta, H.V. (Univ. of Arizona); Haghighi, K. (Purdue University); Hantush, M.M. (USEPA, Cincinnati); Harter, T. (Univ. of California, Davis); Hogarth, W.L. (Griffith Univ., Australia); Hsu, K.-L. (Univ. of Arizona); Islam, S. (Univ. of Cincinnati); Johnson, V.M. (LLNL, Livermore); Kalita, P. (Univ. of Illinois, Urbana); Kapoor, V. (Georgia Tech.); Khalil, M. (Lakehead Univ., Canada); Kitanidis, P.K. (Stanford Univ.); Kluitenberg, G.J. (Kansas State University); Koelliker, J.K (Kansas State University); T. Koos (Univ. of California, Davis); Kothari, R. (Univ. of Cincinnati); Lingireddy, S. (Univ. of Kentucky); Lockington, D. (Univ. of Brisbane, Australia); Markus, M. (Bethesda, MD); Maier, H.R. (Univ. of Adelaide, Australia); Mohtar, R. (Purdue University); Morbidelli, R. (Univ. of Perugia, Italy); Moroni, M. (Univ. of Rome, Italy); Or, D. (SAFL, Lausanne); Nearing, M. (Purdue University); Panu, U.S. (Lakehead Univ., Canada); Parlange, M.B. (Johns Hopkins University); Parlange, J.Y. (Cornell University); Perkins, S. (University of Kansas, Lawrence); Rajaram, H. (Univ. of Colorado); Rao, A.R. (Purdue University); Rao, P.S.C.R. (Purdue University); Reddy, J.M. (Colorado State Univ.); Rizzo, D.M. (Subterranean Research, Inc., Vermont); Rogers, L.L. (LLNL, Livermore); Roig, L. (Waterways Experiment Station, MS); Salas, J.D. (Colorado Statte Univ.); Schwab, A.P. (Purdue University); Serrano, S.E. (Univ. of Kentucky); Shin, H.-S. (Pusan, South Korea); Shrestha, P.L. (Hydroqual, Inc. NJ); Silverman, D. (Univ. of California, Berkeley); Singh, V.P. (Louisiana State University); Sophocleous, M.A. (Kansas Geological Survey); Sorooshian, S. (Univ. of Arizona); Thirumaliah, K. (I.I.T. Bombay, India); Tokar, A.S. (NOAA, MD); Valocchi, A.J. (Univ. of Illinois, Urbana); Wilamowski, B.M. (Univ. of Wyoming); Wraith, J.M. (Montana State Univ.); Wu, J.-L. (Univ. of California, Davis).

(ii) **<u>Graduate and Post Doctoral Advisor:</u>**

M.L. Kavvas (Univ. of California, Davis)

(iii) **<u>Thesis Advisor and Postgraduate-Scholar Sponsor</u>:**

(Total of 1 post-graduate scholar, and 21 students advised)

Arabi, M. (Purdue University); Chan, T.-P. (Purdue University); Davis, V. (Kansas State Univ.); Debjani, D. (Purdue Univ.), Hunter, J. (Purdue Univ.); Kao, S.C. (Purdue Univ.); Kalin, L. (USEPA, Cincinnati); Nahar, N. (Purdue University); Nedunuri, K.V. (Central State University, OH); Parashar, R. (Purdue University); Ramireddygari, S. (Hydroqual, Inc, NJ); Sultana, S. (Purdue UNiv.); Thomas, C. (Monash, Australia); Schmidt, J. (Purdue Univ.); Zhang, B. (TetraTech., Chicago).

Fish Assemblages of Shallow Inner Bend Habitats of the Wabash River During 30 Years of Human Impacts

Basic Information

Title:	Fish Assemblages of Shallow Inner Bend Habitats of the Wabash River During 30 Years of Human Impacts
Project Number:	2007IN219B
Start Date:	3/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	6th
Research Category:	Climate and Hydrologic Processes
Focus Category:	Ecology, Hydrology, Sediments
Descriptors:	None
Principal Investigators:	Mark Pyron, Mark Pyron

Publication

FISH ASSEMBLAGES OF SHALLOW INNER BEND HABITATS OF THE WABASH RIVER DURING 30 YEARS OF HUMAN IMPACT

2008 Report for the Indiana Water Resources Research Center

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Abstract –We sampled fishes at 17 sites by seine in 2007 to compare to collections from 1977 and 1997. We used the same methods as in previous years and we collected a total of 37 species. Mean species richness per site in 2007 (15) was significantly higher than in 1977 (11) and 1997 (12). Mean site Shannon-Wiener diversity, Evenness, and abundance for all years were similar. We used a detrended correspondence analysis (DCA) to test for multivariate patterns in fish assemblage structure among all sites and all years. The DCA resulted in distinct assemblages in each collection-year, suggesting major shifts in assemblage composition among years. We suggest that these changes in assemblages were caused by changes in water quality, hydrology, and other disturbances. We used DCA to examine fish assemblage variation in individual years. Variation that corresponded to an upstream-downstream pattern was present in 1977, but not in the more recent periods. This analysis demonstrates that the fish assemblages of inner bend habitats of a large river have high diversity and likely provide a refuge from predation for these smaller individuals.

Introduction

Fish assemblages vary spatially and temporally. A large literature documents the responses of fishes to habitat variation and habitat quality (Matthews 1998, Simon 1999, Taylor et al. 1993). In small to medium streams habitat variables explain a large proportion of variation among fish assemblages (Schlosser 1987, Gido et al. 1997). Similar habitat associations of fish assemblages occur in large rivers (Barko et al. 2004), although studies of large river fish assemblages are not as frequent (Koel & Sparks 2002). Schlosser (1987) suggested that smaller-order streams have frequent stochastic environmental variation that results in lower stability of fish assemblages. Downstream locations are suggested to have lower climatic variation and increased stability.

Temporal variation in fish assemblages has been examined frequently to test a variety of hypotheses (Matthews 1998). Frequent or severe disturbance events produce increased temporal variation in fish assemblages (Ross et al. 1985). Thus, streams that have harsher conditions in temperature, dissolved oxygen, or discharge extremes tend to have higher variation in fish assemblage attributes than streams with moderate conditions. The frequency and strength of disturbance regimes has a strong effect on how quickly a fish community recovers (Detenbeck et al. 1992). However, when long-term variation in fish assemblages is examined in locations without disturbances or human effects, fish assemblages are found to be relatively stable (Matthews 1998, Gido et al. 2000, Pyron et al. 2006). Similarly if a disturbance or human impact results in an effect at a particular location or locations on a stream, the result is spatial variation among fish assemblages. Identification of the stability of a fish assemblage can change with metric choice and interpretation (Grossman et al. 1990), and stability is temporally and spatially scale-dependent.

Human impacts result in increased assemblage variation, or altered assemblages (Simon 1999). A large component of the habitat utilized by fishes and other stream biota is controlled by hydrological flow patterns (Poff et al. 1997, Allan 2004). Humans have altered flow regimes through a wide variety of impacts including reservoir construction, navigation, water removal by municipalities, agriculture, and industry, and altered drainage from agricultural fields and urbanizations. The result of altered flow regimes impacts stream organisms through multiple direct and indirect effects. Stream organisms have evolved life histories in response to natural flow regimes that include predictable high and low flow events and predictable variations in flow. Altered flow regimes frequently result in decreased recruitment, or even local extirpations of native populations that require natural flow regimes (Poff et al. 1997). In addition, altered hydrologic regimes result in indirect negative changes in substrata through scouring and deposition patterns that result in absences of appropriate substrata for benthic or other organisms with specific habitat requirements. In the Wabash River, effects from changes in the hydrologic regime were observed over 100 years ago (Gammon 1998). Water clarity changed from clear to turbid from 1845 to 1900, likely a response to the magnitude of basin effects from increasing agriculture within the watershed, and during the 20th century, other related human impacts.

Pyron and Lauer (2004) suggested that fish assemblages were responding to an altered hydrologic regime in the Wabash River. Further analyses of Gammon’s 25-year dataset from 1974 to 1998 showed gradual, directional changes in the fish assemblage of the Wabash River at the scale of the 160-mile reach that appear to have hydrological relationships (Pyron et al. 2006). At this river scale, the fish assemblages of the Wabash River have been impacted by humans, and impacts appear to be driven largely by hydrologic alteration. Hydrologic alterations include moderated seasonal flows in upstream reaches from reservoir releases, and increased flow variability in downstream reaches, largely from agricultural water drainage patterns. These hydrologic alterations are still present and appear to be augmented by increased precipitation over the past century (Pyron et al. 2006).

We sampled fishes at 17 reaches where Gammon (1994) collected during 1977 and 1997 to examine inner bend fish assemblages to delineate changes in the fish assemblages over this 30-year interval. We predicted shifts in species composition that are in response to the altered river hydrology or water quality. The responses of the fish assemblages were expected to include an upstream-downstream gradient as found by Pyron & Lauer (2004).

Materials and Methods

A total of 17 stations (Fig. 1) on the Wabash River from river mile 329 downstream to river mile 231 were sampled for fish during summer 2007, when discharge was low. These inner bend habitats were sampled with a 10-m long, 2-m high, 5-mm mesh seine for 30-m of shoreline (same distance sampled by Gammon [1994]). Fish were identified, measured, weighed, and released. Individuals that could not be identified readily in the field were preserved (in 10 % formalin) and brought to the lab for processing. Substrate, depth and current velocity at each site were quantified using a method that was modified from ORSANCO (Ohio River Sanitation Commission, Erich Emery, pers. comm.). Our modification was to eliminate landuse information which did not provide significant explanation of our previous fish assemblages in the Wabash River (Pyron, unpublished data). This approach characterizes substrate categories and depths at 3-m increments from shore, for three transects spaced at 10-m along the shoreline using a 3-m copper pole (= nine points per site). Sediment was classified as boulder, cobble, gravel, sand, fines, or hardpan at each point. Current velocity was measured at approximately 0.6 max depth once per transect with a Marsh-McBirney flow meter. The resulting raw data are substrate categories as percentages, depth frequencies, and current velocity estimates. Substrate data were reduced with principal components analysis (PCA) and the resulting axes used in predicting variation among fish assemblages in DCA (detrended correspondence analysis) as described below. Percentage data were transformed by arcsin-root and frequency data were transformed by log base 10.

Fish abundance data were analyzed by examining metrics of mean abundance, mean Shannon-Wiener diversity, and mean evenness, and testing for differences among years with one-way ANOVA followed by Tukey multiple comparisons. We used rarefaction to standardize species richness for differences in abundances among compared samples (Gotelli and Graves, 1996; Taylor et al. in review). Species richness estimates were generated in EcoSim software (Gotelli and Entsberger, 2001) for each year using 1000 random samples at specified abundance and mean species richness levels. We compared mean species richness among years by upper and lower 95 % confidence intervals. We rarefied samples to the abundance levels of the smallest samples for comparisons of species richness for sites, by year with one-way ANOVA using Minitab 15.1 software (minitab.com). We also compared observed species richness values for the three time periods using one-way ANOVA. We used DCA in PC-ORD (McCune and Grace, 2002) to test for variation in the 1977, 1997, and 2007 fish assemblages, after deleting rare species (fewer than three sites) and log (x + 1) transformation. We used the options to downweight rare species and rescale axes in PC-ORD. Our approach was to use two approaches to examine multivariate assemblage variation. The first approach examined temporal variation among the three collection periods by including all years in the analysis. In our second approach we used separate DCA analyses to examine within year spatial variation among sites for each year. We tested for correlations of DCA axes with river distance. In addition, we tested our 2007 DCA axes for correlations with substrate PC axes.

We used a Mantel test in PC-ORD (McCune and Grace, 2002) to test for concordance in abundance of the 11 species with highest abundance in each collection year (Gido et al. 2000). The Mantel tests were performed on matrices of correlations between species pairs, as a test of associations. A significant correlation between matrices indicates similar species associations (Gido et al. 2000).

Results

Mean depth (± SD) of the sites was 0.28 (± 0.13) m and mean CV depth was 0.78. Median substrate frequencies were 92 % for gravel, 8 % for sand and 0 for cobble, fines, and hardpan (these categories were not used in the PCA). Mean depths for substrate categories were 0.13 (± 0.16) m for sand and 0.24 (± 0.19) m for gravel. Mean current velocity was 20 (± 8) cm / s. The PCA of substrate variation resulted in two axes that explained 46.3 and 21 % of variation.

The total abundance of all fishes was 3672 in 1977, 3937 in 1997, and 6671 in 2007. Total species richness was 39 overall, 33 in 1977, 36 in 1997, and 36 in 2007. All collection periods had similar Shannon-Wiener diversity, mean evenness, and mean abundance (Table 2). Rarefaction curves for overall species richness were not significantly different among the three time periods (Fig. 2). Species richness for individual sites was not significantly different among years, when samples were rarefied to the smallest sample (59) ($F = 1.01$, $P = 0.38$). Observed species richness values were significantly different for individual sites ($F = 6.76$, $P < 0.003$).A

Tukey multiple comparison procedure resulted in the 2007 samples with significantly higher species richness than the other years.

The DCA analysis of all collection years combined resulted in distinct separation of the 2007 sites on the first axis (Fig. 3). The 2007 collections had higher abundances of longnose gar, mimic shiner, shorthead redhorse, river carpsucker, and steelcolor shiner than the 1977 and 1997 collections (Fig. 2a). The 1977 and 1997 collections had higher abundances of channel catfish, slenderhead darter, hornyhead chub, white bass, Mississippi silvery minnow, and striped bass. The ordination of the first DCA axis resulted in each collection year in significantly different locations than the other collections (Tukey multiple comparison procedure, 98 % confidence level). The 1997 and 2007 collections were distinct on the second DCA axis based on increased abundances of channel catfish, slenderhead darter, and hornyhead chub. The 1977 collections had higher abundances of common carp, river carpsucker, and speckled chub than the 1997 and 2007 collections. Although the collections in the three time periods resulted in similar species richness and diversity patterns, ordination analyses revealed that the assemblages were disparate.

The DCA of the individual collections by year are presented in Fig. 4. The 1977 collections resulted in an ordination in which the first axis was strongly correlated with river distance ($r = -0.76$, $P < 0.001$). The species that were responsible for the structure of the first DC axis in 1977 were increased abundances of silver redhorse, smallmouth buffalo, and river chub in the upstream reaches, and gizzard shad in the downstream reaches (Fig. 4). DCA analysis of the 1997 and 2007 collections did not result in significant correlations of DC axes with river distance (Fig. 4). The DCA for the 2007 collections produced an ordination with one axis that was significantly correlated with the first substrate PC axis.

The Mantel tests resulted in concordance of species associations only for the comparison of 1977 and 2007 collections (Mantel r = - 0.19, P = 0.043). However, concordance was negative indicating negative associations. Mantel tests comparing 1977 and 1997 resulted in a lack of concordance of species associations (r = - 0.12, P = 0.16), and the comparison of 1997 with 2007 resulted in a lack of concordance of species associations (r = - 0.03, P = 0.43).

Discussion

One interpretation of these results is that assemblage changes in this 30-year period were the result of human impacts during this time period. Point source inputs were largely reduced as a result of federal legislation (Clean Water Act, Payment in Kind Program; Gammon 1998). Nonpoint pollution and sewage effluent from multiple facilities and urbanizations are still released into the river. Hydrologic alterations of the flow regime are also present and likely cause further degradation of riverine habitat (Pyron et al. 2006).

The assemblages in 1977 produced a DCA ordination that was correlated with river distance. Our prediction is that fish assemblage upstream-downstream trends were a response to a similar upstream-downstream gradient in habitat variables. Pyron and Lauer (2004) found fish assemblage variation with river distance based on annual electrofishing collections in 2001-2, that included the same upstream river locations and extended 74 km downstream. Species that occurred in higher abundance in upstream reaches in 2001-2 were silver redhorse, shorthead redhorse, mimic shiner, and sand shiner. Species that occurred in higher abundance in downstream reaches in 2001-2 were spotted bass, shortnose gar, and bluegill. Only silver redhorse had a similar trend in 1977. The more recent collections were quite different than in

1977 and 1997. Lohr & Fausch (1997) similarly found changes in fish assemblages in the Purgatoire River of Colorado during an 11-year period. Their results were increased variation in abundance of species at individual sites than for all sites combined.

The substrate composition of these habitats is based on scouring and depositional patterns, controlled by the hydrologic regime of the river. We suggest that hydrologic alterations modify the scouring and depositional patterns and subsequent substrate composition at individual sites. The Wabash River mainstem has had significant hydrologic alterations during recent decades compared to historic flows (Pyron and Neumann 2008). Variation in substrate composition at individual sites are linked to extreme discharge events, and the local fish assemblages at our electrofishing sites covary with substrate composition (Pritchett & Pyron, unpubl. data). Koel & Sparks (2002) found significant effects of hydrologic alterations from dam operations on young-of-year fishes in the Illinois River.

Fish assemblages change temporally with human effects and frequently result in local or regional extinctions (Matthews 1998). Although we did not identify extinctions in the Wabash River, Gammon (1998) found three local extinctions: lake sturgeon (*Acipenser fulvescens*), muskellunge (*Esox masquinongy*), and stargazing darter (*Percina uranidea*). The Wabash River is not a pristine ecosystem and has multiple current anthropogenic impacts, including altered hydrologic regime, agricultural effects, and urbanization (Pyron et al. 2006).

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Table 1. Results of Tukey comparisons of mean species richness, Shannon-Wiener diversity, and evenness for 1977, 1997, and 2007 collections at 17 inner bend sites on the Wabash River. We used simulations to compare mean species richness among years (Fig. 2).

Statistic	Year	Mean	Tukey comparisons
Species richness	1977	11	
	1997	12	
	2007	14.8	
S-W diversity	1977	1.41	A
	1997	1.39	A
	2007	1.74	A
Evenness	1977	0.13	A
	1997	0.12	A
	2007	0.12	A
Abundance	1977	216	A
	1997	232	A
	2007	392	A

Table 2. Abbreviations, relative abundance, rank abundance, and CV for fishes captured at inner bend sites on the Wabash River. No abbreviations are supplied for species that were in low abundance and not included in DCA.

		Percent abundance			Rank abundance		
Species	Abbrev	1977	1997	2007	1977	1997	2007
Spotfin shiner	SPS	24.9	36.3	26.8	1	1	2
River shiner	RIS	21.4	2.9	6.0	2	6	6
Gizzard shad	GIZ	0.1	28.0	0.4	22	2	18
Sand shiner	SAS	5.8	8.9	11.4	5	3	3
Emerald shiner	EMS	16.8	4.6	2.5	3	5	8
Bluntnose minnow	BLM	15.8	2.0	1.1	4	8	14
Steelcolor shiner	STS	…	…	4.1	…	…	7
Bullhead minnow	BUM	…	2.0	1.7	…	7	11
River carpsucker	RIC	5.0	…	26.8	6	…	1
Shorthead redhorse	SHR	…	…	8.4	…	…	4
Mississippi silvery minnow	MSM	…	8.5	…	…	4	…
Golden redhorse	GOR	0.4	0.2	5.6	14	18	5
Smallmouth buffalo	SBU	2.2	…	…	7	…	…
Central stoneroller	STO	1.4	0.5	2.4	8	11	9
Suckermouth minnow	SUM	1.3	0.4	0.2	9	13	20
Striped shiner	STB	…	1.8	…	…	9	…
Spotted bass	SPB	…	0.03	1.9	…	28	10
Bigmouth buffalo		1.1	…	…	10	…	…
Silver redhorse	SIR	0.2	…	1.6	17	…	12
Silverjaw minnow	SJM	1.1	0.3	0.4	11	16	17
Black redhorse	BRH	0.1	0.5	1.3	24	12	13

Bluegill	BLG	0.4	0.4	0.001	12	14	30
White bass	WHB	…	0.8	0.04	…	10	28
Speckled chub	SPC	0.4	…	…	13	…	…
Mimic shiner	MMS	…	…	1.0	…	…	15
Common carp	CAR	0.3	…	…	15	…	…
Northern hogsucker	HOG	0.2	0.03	0.8	18	31	16
Freshwater drum	FRD	…	0.3	0.1	…	15	24
Mosquitofish	MOF	…	0.1	0.2	…	23	19
Logperch	LOP	0.3	0.1	…	16	26	…
Bigeye chub	BEC	0.03	0.1	0.2	26	21	22
Channel shiner	CHS	…	…	0.1	…	…	21
Smallmouth bass	SBA	0.2	0.2	0.01	19	17	35
Bigeye shiner		…	…	0.01	…	…	23
Creek chub	CRC	0.1	…	0.04	21	…	26
Channel catfish		…	0.2	0.03	…	19	31
River chub		0.1	0.03	0.01	23	30	33
Longnose gar	LOG	…	0.03	0.06	…	32	25
Brindled madtom		0.05	…	…	25	…	…
Slenderhead darter	SLD	…	0.1	…	…	22	…
Blackside darter		0.03	0.03	…	27	36	…
Rosyface shiner	ROS	0.03	…	0.04	31	…	27
Rainbow darter	RAD	0.03	0.08	…	30	24	…
Hornyhead chub	HOC	…	0.08	…	…	25	…
Blue sucker		…	…	0.1	…	…	29
Largemouth bass		0.03	0.03	…	29	33	…
Fathead minnow		…	…	0.01	…	…	32
Striped bass	STB	0.03	…	…	33	…	…
Silver chub		0.03	0.3	…	32	20	…

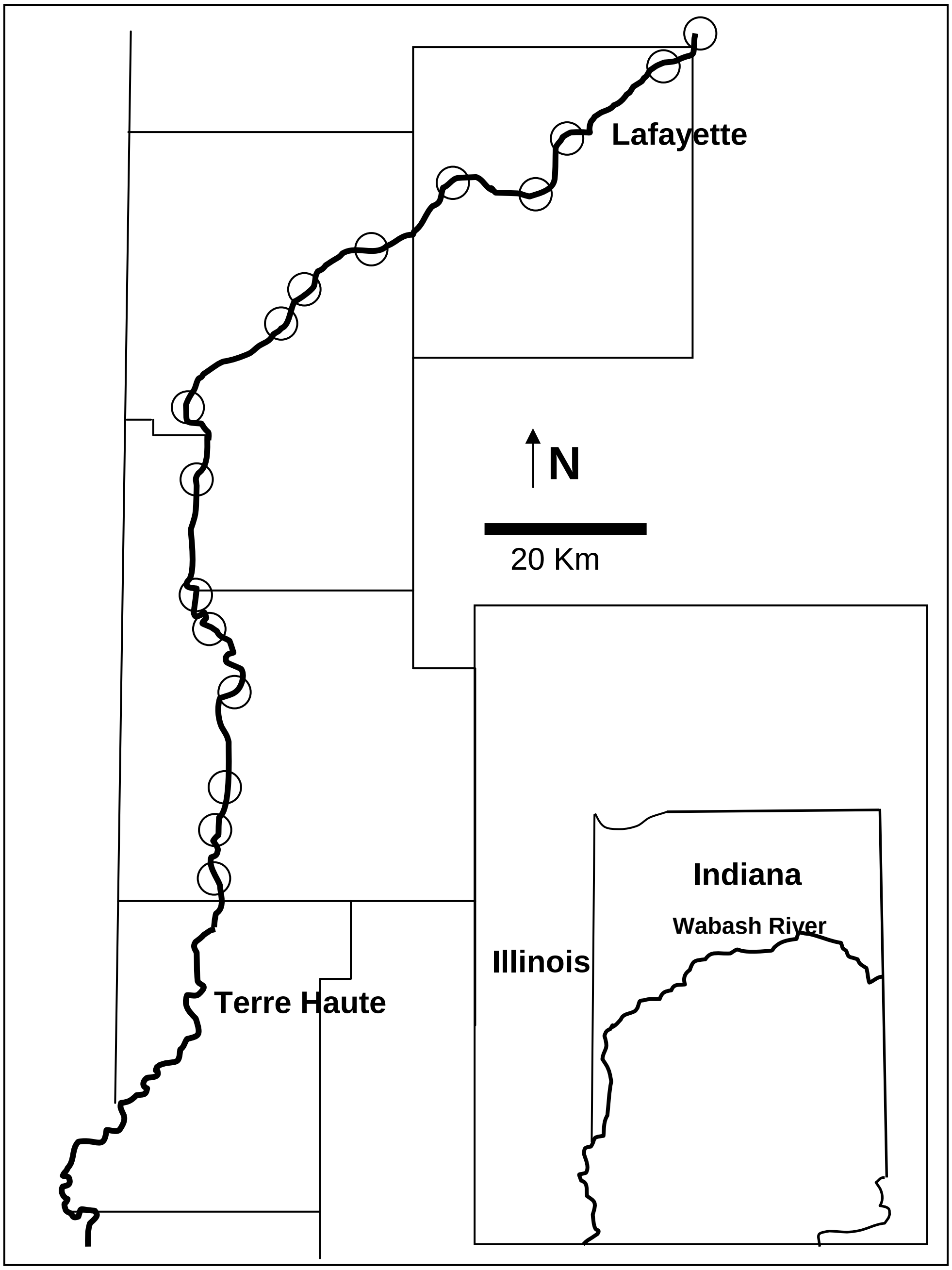
Rosefin shiner		…	…	0.01	…	…	34
Dusky darter		…	0.05	…	…	27	…
Shovelnose sturgeon		…	0.03	…	…	29	…
Johnny darter	JOD	0.16	0.03	…	20	34	…
Greenside darter		…	0.03	…	…	35	…
Stonecat		…	…	0.01	…	…	36
White sucker		…	…	0.01	…	…	37
Gravel chub		…	0.03	…	28	…	…

Fig. 1. Map of collection sites on the Wabash River.

Fig. 2. Species richness estimates from simulations in EcoSim for 1977 (filled circles), 1997 (squares), and 2007 (open circles). Upper and lower 95 % confidence intervals are dotted lines for 1977, dashed lines for 1997, and solid lines for 2007.

Fig. 3. Results of a detrended correspondence analysis of the fish assemblages at 17 Wabash River sites during three sample periods. Species scores are on the top plot (codes for species are in Table 1). Sites are on the lower plot.

Fig. 4. Results of DCAs for individual years 1977, 1997, and 2007 at 17 sites. Only 1977 collections resulted in a significant correlation of the first axis with river location.


Lafayette
N
20 Km
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Wabash River
Illinois
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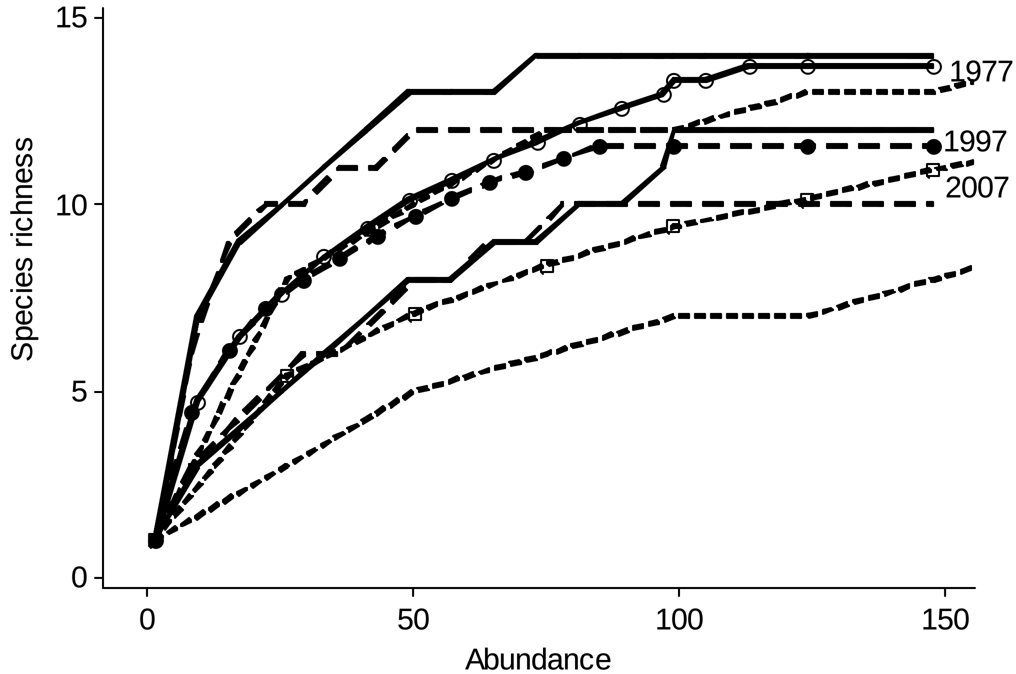
15
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Species richness
0
50
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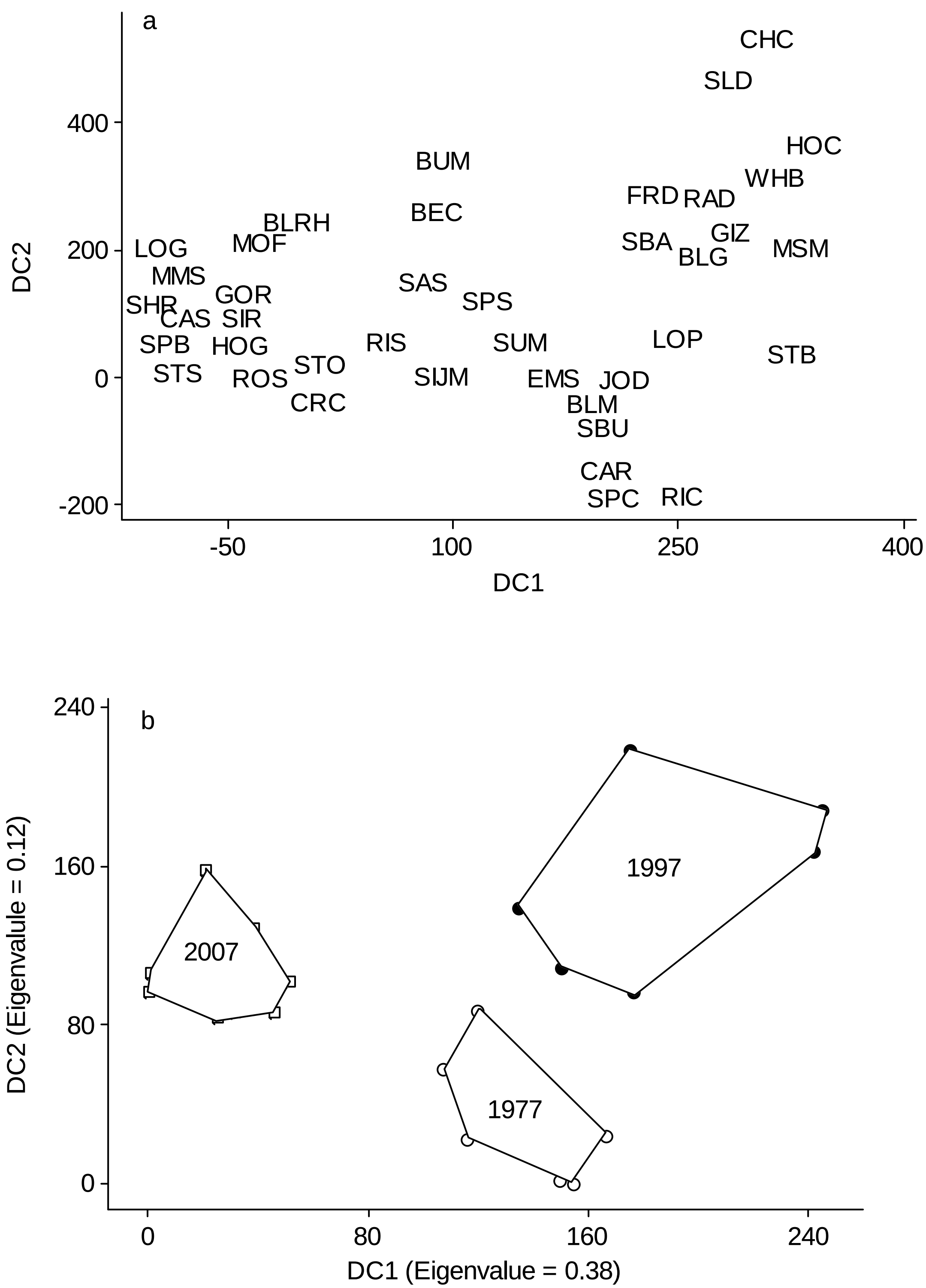
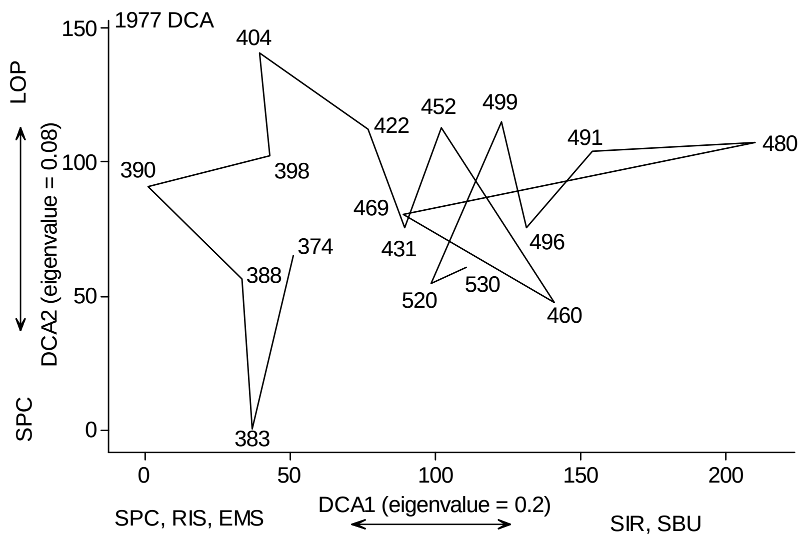
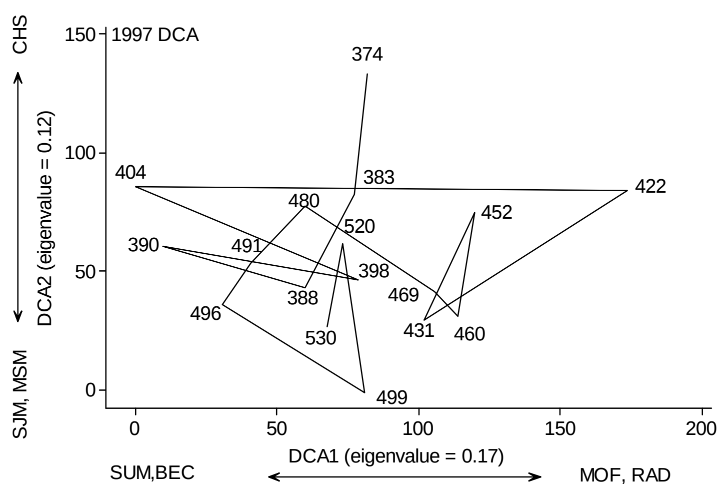
Abundance
1977
1997
2007


a
CHC
SLD
HOC
WHB
BUM
FRD
RAD
BEC
BLRH
GIZ
SBA
MOF
LOG
BLG
MSM
MMS
SAS
GOR
SPS
SHR
CAS
SIR
LOP
SPB
HOG
RIS
SUM
STB
STO
STS
ROS
SIJM
EMS
JOD
CRC
BLM
SBU
CAR
SPC
RIC
400
200
0
-200
-50
100
250
400
DC2
DC1
b
240
160
80
0
0
80
160
240
1997
2007
1977
DC2 (Eigenvaluie = 0.12)
DC1 (Eigenvalue = 0.38)



1977 DCA
LOP
SPC
DCA2 (eigenvalue = 0.08)
DCA1 (eigenvalue = 0.2)
SPC, RIS, EMS
SIR, SBU
404
422
452
499
491
480
390
398
469
374
431
496
388
530
520
460
383



1997 DCA
CHS
SJM, MSM
DCA2 (eigenvalue = 0.12)
DCA1 (eigenvalue = 0.17)
SUM,BEC
MOF, RAD
374
404
383
422
480
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390
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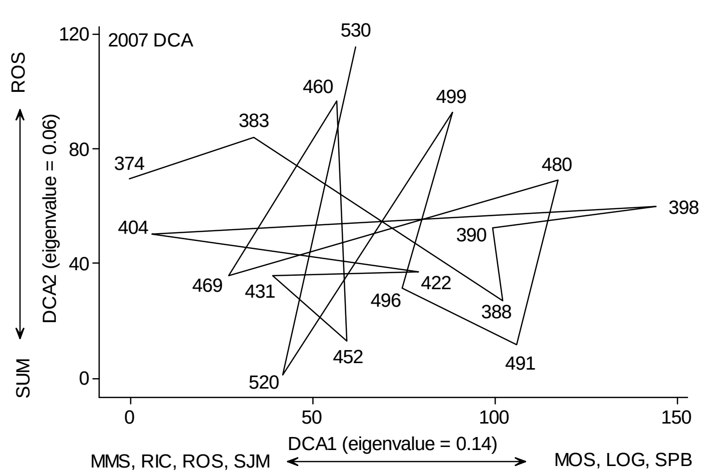

2007 DCA
ROS
SUM
DCA2 (eigenvalue = 0.06)
DCA1 (eigenvalue = 0.14)
MMS, RIC, ROS, SJM
MOS, LOG, SPB
530
460
499
383
374
480
398
404
390
469
431
422
496
388
452
491
520

Assessing BMP Maintenance: Creating a Remote Sensing Scale and Measuring the Influence of Social Factors

Basic Information

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3. Baumgart−Getz, A., L.S. Prokopy “Using aerial images to assess the condition of vegetative BMPs” Target journal: International Journal of Remote Sensing
4. Baumgart−Getz, A., L.S. Prokopy “What motivates landowners to maintain their BMPs?” Target journal: Journal of American Water Resources Association

IWRRC Report

Title: Assessing BMP Maintenance: Creating a Remote Sensing Scale and Measuring the Influence of Social Factors

Submitted by: Dr. Linda Stalker Prokopy & Adam Baumgart-Getz

Funding Period: March 1, 2007 – February 28, 2008

Problem: The EPA (2006) lists nonpoint source (NPS) pollution as the leading cause of water quality impairment. Best Management Practices (BMP), a group of structural and nonstructural practices, are widely regarded as the most efficient approach to reducing NPS pollution. Various federal programs exist to increase awareness of and help offset the cost of BMPs. While the federal government is spending billions of dollars per year on programs focused on getting people to install BMPs, little is known about how these BMPs fare. One method of BMP evaluation surveys landowners about BMP maintenance (Cunningham, Benham et al. 2003). While this allows for data collection on numerous BMPs, it suffers from self-evaluation bias and requires non-experts to provide technical responses.

The more common method involves field inspections. Expert site evaluation, however, is too labor intensive for assessing the condition of all BMPs in a watershed, let alone a state (Fisher 2007). Field inspection of BMPs also requires landowner permission. In order to receive cost-share money, a landowner usually gives signed consent to assess the BMP for a period of time (usually 3-5 years). Little is known, however, about BMP maintenance once this period ends. The NRCS has landowners inspect their BMPs installed through CRP (Fisher 2007). This alleviates the labor requirements and BMP accessibility, but results in untrained individuals performing the BMP inspections, and self-evaluation bias. Without greater knowledge on BMP condition, it is difficult to assess the effectiveness of BMPs.

Advances in remote sensing, data availability, and analysis of this information make now an opportune time to develop a computer based tool for BMP evaluation. This research will create a scale for BMP condition that will be designed for use with aerial photography and other available remote sensing data. While it is unlikely such a tool could provide the same level of detail as a field assessment, it could estimate the condition of all known BMPs. This gives a better overall understanding of BMP functionality and helps prioritize which BMPs should be evaluated in the field. Additionally, this type of monitoring can continue indefinitely, and could provide a much greater understanding of the conservation state of a watershed.

While the literature on what motivates BMP adoption is rich, few studies address why individuals sustain behavior, such as BMP maintenance. It is crucial to understand this relationship because of the critical role BMPs can have on water quality. Understanding why some farmers maintain their BMPs better than others can improve education and outreach efforts. This will also mean that the money spent each year on mitigating the impact of NPS pollution will be more effective.

Research Objectives:

- Provide a comprehensive summary of the BMP adoption literature.
- Create a remote sensing tool to evaluate vegetative BMP condition
- Determine the influence of social factors on landowners' maintenance of BMPs

Methodology:

Preliminary data and arrangements

In cooperation with IDEM's Office of Water Quality, we have obtained paper files containing every BMP installed since the inception of the Indiana 319 program which dates back to 1990. We estimate 340 BMPs will be identifiable using available remote sensing data. These files are currently being used to create to a GIS layer with each BMP location. We will finish this layer in December, 2006. In addition all of the remote sensing data required for this project is already available and ready for use. These data sets are described in greater detail in the Remote Sensing & Spatial Data subsection below.

The development of the remote sensing scale of BMP maintenance requires individuals with expertise in onsite evaluation of BMP maintenance. Working with
IASWCD, local SWCD offices, and several other local watershed groups we are currently arranging for these expert panel workshops. They will likely take place in the Clifty Creek watershed or Dearborn County.

Remote Sensing & Spatial Data

The recent release of Indiana leaves-off aerial photos gives one meter resolution for the entire state of Indiana (Indiana Spatial Data Portal 2006). Using a GIS layer obtained from IDEM, the location of 319 restoration and preservation sites can be identified on the aerial photos. Based on initial examination of our dataset, we are confident the Indiana aerial photography's resolution will suffice for our needs. Additionally, Indiana has a 2004 leaves-on aerial photography set. This data can be used to augment the information available from the 2005 leaves-off aerial photography set. Once this process in done on the 2005 aerial photos, it can be replicated using the 2004, 1998, and 1990 aerial photos. This will allow us to use a longitudinal study, again maximizing the extractable information from this study.

BMP Maintenance

While there are several methods available for assessing BMP maintenance first hand, we have not found any appropriate methods for use with aerial photography. To remedy this deficit, we will develop an appropriate assessment tool for each BMP type. We draw on several studies which utilize aerial photography to analyze coral reef destruction and benthic organism habitat in coral reefs that assess small areas with similar technology (Mumby et al. 1997; Lewis 2002; Roelfsema et al. 2004). While different, there are lessons to be learned from these investigations. This assessment tool will likely take the form of a five-point scale ranking BMP maintenance from absent, poor, fair, good, or excellent.

One component of this tool will be vegetation density. Since these photos were taken in March of 2005, it is unclear as to how effective this dataset will be for capturing photosynthesis of cold season grasses. The 2004 aerial photos were taken during the summer months, and can be used to measure vegetation density. The percentage of area remaining from the installed BMP can also be included in the BMP maintenance scale.

This can be done using ArcGIS since the original area installed will be entered according to IDEM's files. The other component will be to develop a scale of BMP maintenance based on the 2005 aerial photography set. This will require small groups of experts on field evaluation of BMP condition or maintenance, and is discussed below.

Panels of experts on BMP Maintenance

In cooperation with IDEM and IASWCD, we will create panels of technicians experienced in field evaluation of BMPs and individuals familiar with remote sensing data analysis. We have already spoken with IDEM and IASWCD and they are eager to be a part of this process as they see the long-term benefits to their work. There will be several panels, each assessing BMPs grouped together based on visually identifiable features. These categories are currently: cold season grasses, warm season grasses, and structural BMPs such as water and sediment control basins or grade stabilization. The expert panels will help develop a scale that categorizes BMP maintenance as absent, poor, fair, good, or excellent.

Using the BMP layer and aerial photography, we will identify four BMPs of each type in relatively close proximity to each other. Ideally these will range from poor to excellent condition. Each of the panels will make a field evaluation of the selected BMPs. During this evaluation the panel will observe aerial photos of the BMP. Examining aerial photography during a field inspection will allow the panels to identify a scale of BMP maintenance appropriate for aerial photographs. These panels serve not only to develop the initial scale for BMP maintenance, but also to train the students in field assessment as well as facilitate their training for the remote sensing evaluation. Follow up contact with these experts will be done using Purdue's computer conferencing ability so the BMP layer, aerial photography, and other remote sensing data can be shared with these experts.

Field Calibration & Confirmation

Ultimately this method will save IDEM, Soil Water Conservation Districts (SWCD) and other interested parties considerable time. However, developing the method is very time-intensive. After creating the scale for BMP maintenance through the panel workshops, we will begin developing its reliability as a measure of BMP maintenance in Indiana. The first step will be to calibrate the remote sensing scale with field evaluation. Because the BMP layer will not be completed until late December, a field evaluation of a random sample of the BMPs will not be possible. Without this preliminary sampling we cannot determine the amount of variability between sampling, and therefore defer to others who have created methods of evaluating land surface characteristics using remote sensing. To this end, many experts cite Congalton and Green (1999), who recommend 50 site inspections per evaluation system. Since we have identified 3 categories of BMP we plan on 150 site calibration inspections.

To maximize the effectiveness of the remote sensing BMP maintenance scale, we will need field confirmation of BMPs assessed using only remote sensing data. We estimate a stratified sample of 20% of the sites not used for calibration will suffice. As mentioned previously, we are working with IDEM, IASWCD, and several local watershed groups which have all agreed to help us gain access to the required sites. All sites will be photographed to help maintain consistency across different sites.

Social Indicator Data

Using the surveys being developed for the regional social indicator project, we will collect data regarding landowner attitudes and awareness. The variables for farm characteristics and individual capacity identified in the meta-analysis will also be collected. This information will be coded so that we can match each landowner's survey to a specific BMP while insuring anonymity.

Because the results of different survey methods are not always compatible, we will use interviewer-mediated phone interviews. These are more labor intensive than mail surveys, but also produce significantly higher response rates (Dillman 2000). Prior to calling farmers, we will first send a letter announcing the purpose of the survey and approximately when they may receive a call. This letter will assure the landowner that everything they say will be kept confidential and will not be reported to IDEM or any other agency. The PhD student will conduct all the phone surveys to keep content and style of delivery consistent.

Data Analysis

Buffer Maintenance

The dependent variable is the scale of BMP maintenance, ranging from absent to excellent. The data will be analyzed using a categorical dependent variable model, most likely a probit or a probit derived model. The independent variables will include individuals' attitudes, awareness, capacity, and characteristics collected from the social indicators from the post-project survey, and any other variables that become relevant upon examining the available records from the environmental monitoring.

Principal Findings

Summary Our initial investigations have identified the determinants of BMP adoption that are important across the US. Additionally we have done interviews with farmers and BMP professionals in the Midwest to fill in any missing factors that may influence BMP maintenance by landowners. From this we have created a survey that will test what motivates individuals to maintain their BMPs.

The second component to this research was developing a method to utilize high resolution aerial photos to evaluate the condition of BMPs. This remote sensing evaluation has been created and will be tested in July and August of 2008.

Results and Significance We found that access to agency, local, and business networks were major predictors of BMP adoption. Extension training, pro-environmental attitudes, and awareness of BMP programs were the other large positive impacts of BMP adoption. Interviews with landowners found that secondary benefits, especially game habitat, were important in motivating BMP maintenance. One of the biggest problems, however, facing the adoption literature is the inconsistent use of and collection of data.

We also found that BMP vegetation quality and signs of erosion are visible in the Indiana high resolution aerial orthophotographs and can be used to evaluate BMP condition in the field.

Major Conclusions We have compiled a comprehensive quantitative summary of the United States BMP adoption literature. This meta-analysis confirms the approach taken by different agencies that emphasize building capacity through increased awareness, creating pro-environmental attitudes in individuals, networking, and extension training. Additionally this summary shows that researchers need to be more consistent in how we collect and interpret BMP adoption data.

We have also created a method to evaluate BMP condition. This will vastly reduce the labor requirement of tracking how BMPs fare after installation. This should lead to much more efficient outreach and extension efforts as we will be able easily see which BMPs need attention.

Publications

Accepted paper:

L.S. Prokopy, K. Floress, D. Klotthor-Weinkauf , and A. Baumgart-Getz (2007) "Determinants of agricultural BMP adoption: Evidence from the literature" slated to be published in the Journal of Soil and Water Conservation in the September/October edition.

Working Papers:
A. Baumgart-Getz, L.S. Prokopy “Why landowners adopt BMPs: A quantitative summary of BMP adoption determinants”
Target journal: American Journal of Agricultural Economics

A. Baumgart-Getz, L.S. Prokopy “Using aerial images to assess the condition of vegetative BMPs”
Target journal: International Journal of Remote Sensing

A. Baumgart-Getz, L.S. Prokopy “What motivates landowners to maintain their BMPs?”
Target journal: Journal of American Water Resources Association

Students

Student Training
PhD Student: Adam Baumgart-Getz: This project allows Adam to combine his previous experience in watershed management, community organizing, and Public Administration to create a management tool to evaluate vegetative BMPs. This tool will be an important asset to those working with BMPs. Additionally, the knowledge gained through the process of creating this tool will greatly increase Adam’s ability and capacity as an environmental manager.

Undergraduate Student: Several undergraduate students have worked on this project. The skill set gained will make these students an excellent candidate for any position requiring knowledge of NPS pollution, specifically related to BMP design and maintenance. This student will also learn key skills related to designing and implementing outreach programs and surveys. Additionally, this project will increase the capacity of the environmental management community to utilize spatial data through ArcGIS and remote sensing programs such as ERDAS Imagine and Multispec.

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Quantification of sediment nutrient interaction as affected by drainage ditch management

Basic Information

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End Date:	2/28/2008
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Principal Investigators:	Indrajeet Chaubey, Laura C. Bowling

Publication

1. Merriman, K. R., I. Chaubey, L. Bowling, and S. Ale. July 2008. Quantification of nutrient dynamics in agricultural drainage ditches in Hoagland Ditch watershed in Northern Indiana. American Society of Agricultural and Biological Engineers. Providence, RI.

IWRRC Report

Title: Quantification of sediment nutrient interactions as affected by drainage ditch management

Submitted by:

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Problem:

Aquatic systems have an intrinsic ability to assimilate nutrients and have a capacity to sustain a certain degree of nutrient loading. When nutrient loading in a stream exceeds its assimilative capacity, water becomes eutrophic resulting in reduced nutrient retention efficiency of the streams. Nutrient retention efficiency indicates the rate at which nutrients cycle between the dissolved state in the water column, benthic sediments and biota of the stream. Retention, cycling, and export of nutrients from watersheds are greatly influenced by processes occurring within a stream.

Even though agricultural land use has been identified as a principal contributor of nonpoint source (NPS) pollution most studies in agricultural catchments have focused on measurement and modeling of the import of nutrients to the stream environments. Very few studies have assessed the control of sediment-nutrient interactions on the movement and transport of nutrients within the stream ecosystems. This is especially true for artificially drained agricultural systems where the role of biotic and abiotic processes controlling nutrient dynamics at the sediment-water interface is not clear. Most studies on nutrient transport and retention have been conducted in nutrient depleted headwaters such as forested streams and desert streams. Agricultural drainage ditches are living ecosystems where a number of biotic and abiotic processes actively regulate the fate and transport of nutrients. Impact on a downstream waterbody is directly linked with the in-channel processes affecting nutrient transport. As adverse impacts on receiving water bodies are driving many of the watershed management strategies, e.g. TMDL development at smaller spatial scales, and hypoxia in the Gulf of Mexico at larger spatial scales, it is very important to understand the fluvial processes that regulate timing, magnitude and form of in-channel nutrient transport. Understanding these processes is critical to linking upland agricultural activities with downstream water quality impacts.

Research Objectives:

The goal of this study was to assess sediment-nutrient interactions, and nutrient retention efficiency in agricultural drainage ditches. The objectives of study was to: (1) evaluate spatial and temporal variability in easily exchangeable N and P, and P buffering capacity; (2) assess equilibrium between sediments and water column P; and (3) evaluate variation in stream nutrient retention efficiency using short-term nutrient additions.

Methodology:

Study Area

The Hoagland Ditch watershed, located in primarily in White County, was used in this study. It is 182 km^2 with a sparse rural population of 1900 (DeBroka et al., 2001). Its land use is 92% agricultural, where the main crops are a rotation of corn and soybeans.

Three different study sites within Hoagland Ditch watershed were used for this study. Site selection took place in February 2007; sites were chosen based on recommendations from extension faculty, permission from the landowners, and current use of BMPs within the watershed. Two sites were selected because of BMPs already in practice. One ditch was vegetated, and another had a history of dredging. The third ditch was neither vegetated nor dredged.

Nutrient Injections

A short-term nutrient injection is a commonly used field experiment to determine nutrient retention within streams. A Mariotte bottle was used to provide a constant flow of nutrient solution. Ammonium in the form of NH_4Cl, nitrate in the form of Na NO_3, and P in the form of Na_2HPO_4 was used as the nutrient solution. Chloride (Cl^-) in the form of NaCl was used as a conservative solute (tracer) for dilution correction. Ammonium and nitrate were injected on different days.

The desired nutrient concentration in stream during injections was 2-4 times ambient nutrient concentrations. The injected solution concentration (C_a) was calculated by mass balance with ambient (denoted by subscript w), injection solution (denoted by subscript a), and during injection (denoted by subscript r) concentrations (C) and flow rates (Q).

$$C_a = \frac{(Q_r * C_r) - (Q_w * C_w)}{Q_a} \qquad (1)$$

A reach length ranging (60-150 m in length) was selected downstream of the injection point and five transects were established within the stream reach to collect water samples for nutrient uptake length estimations.

Injections began after a background water sample was collected and filtered with a 25 mm, 0.45 μm nylon membrane syringe filter into a 60mL Nalgene bottle. Conductivity was measured at one minute intervals at the most upstream sampling station, middle, and the most downstream sampling station using YSI 85 conductivity meters. Water samples were taken during the injections with the rise and fall of the conductivity with a 250mL Nalgene bottle and immediately filtered using a 25 mm, 0.45 μm nylon membrane syringe filter into a 60mL Nalgene bottle. The samples were stored on ice until return to the laboratory. They were then acidified with 150 µL of 50% H_2SO_4. The samples were stored in refrigerators until further analyses. After the injection was completed, properties such as water depth, stream width, cross sectional area, and stream flow were measured at each sampling stations.

Chloride, nitrate, and phosphate were analyzed by Dionex DX600 Ion Chromatography (EPA 300.1; Sunnyville, CA). Ammonium was analyzed with Seal

Analytical Autoanalyzer AQ2+ (EPA 350.1; Mequon, WI). Nutrient concentrations during injections were corrected for background concentrations and dilution correction of groundwater inflow (C_x).

$$C_x = \frac{(C_{Px} - C_{Bx})}{(C_{P1} - C_{B1})} * \frac{(T_{P1} - T_{B1})}{(T_{Px} - T_{Bx})} \quad (2)$$

Where C_P is the concentration at saturation, C_B is the background concentration before injection, the subscript x is the sampling location (1 denotes the first transect), and T is the concentration of the conservative chloride tracer.

In order to estimate the uptake length, corrected nutrient concentration (C_x) at each sampling station was divided by the corrected nutrient concentration at the first station (Co) and regressed against distance (x) downstream from first sampling station.

$$C_x = C_0 * e^{-kx} \quad (3)$$

where, k is the nutrient uptake coefficient (m^{-1}) and nutrient uptake length (S_w) was estimated as the inverse of k.

The mass transfer coefficient (v_f) represents the velocity at which nutrients in the water column move toward benthic sediments and quantifies demand for nutrients relative to supply in the water column (Davis and Minshall, 1999). It was calculated as follows:

$$v_f = \frac{v * d}{S_w} \quad (4)$$

where, v is water velocity ($m\ s^{-1}$), d is mean water depth (m), S_w is uptake length (m), and v_f is mass transfer coefficient ($m\ s^{-1}$).

Sediment Interactions

Unfiltered water samples were collected from ditch at each site to determine sediment equilibrium phosphorus concentration (EPCo), phosphorus sorption index (PSI), exchangeable P (Ex-P), and exchangeable N (Ex-N). Benthic sediment samples were collected from each transect perpendicular to the discharge; the top layer (top 2-5cm) of the ditch bottom was removed with a trowel and stored in Ziploc bags on ice in the dark until arrival at the laboratory for analysis. The water sample from each site was also collected and stored in the dark on ice and analyzed for nitrate-nitrogen (NO_3-N), ammonia-nitrogen (NH_4-N), total Kjedal nitrogen (TKN), phosphate-phosphorus (PO_4-P), and total P (TP).

Upon return to the laboratory, the water samples were vacuum filtered with a VWR vacuum filtration system (0.45 µm pore size). The filtered stream water was spiked with additional PO_4-P solution (0, 5, 10, 20, and 50mg/L) for the sediment EPC_o extraction. In a 250mL Erlenmeyer flask, 100mL of the spiked stream water as added to 25g of wet, fresh sediments. The flasks were covered with Parafilm and shaken for one hour on a reciprocating horizontal shaker at 100rpm, stopping every 15 minutes to shake the flasks vigorously by hand. Afterwards, the solutions were allowed to settle for 30 minutes to an hour. A vacuum filtering unit and nylon filter membranes (45mm diameter, 0.45 µm pore size) were used to remove the supernatant, into in Nalgene bottles and stored at 4°C until PO_4-P analysis. The remaining sediment was placed in aluminum pans and dried for 48 hours in an oven at 80°C to determine dry sediment mass.

A linear isotherm was made of between the initial amount of PO_4-P in the sediments and the concentration of PO_4-P absorbed by the sediments. The x-intercept of the regression is the sediment EPC_o.

$$\text{P adsorbed} = \frac{[\text{P}]_{\text{spike}} - [\text{P}]_{\text{o}} * 0.1}{\text{Dry sediment wt}/1000} \qquad (5)$$

where $[P]_{spike}$ is the PO_4-P concentration of the supernatant and $[P]_o$ is the PO_4-P concentration (mg/L) in the background water sample.

Similarly to sediment EPC_o, PSI was determined by spiking 100mL of filtered ditch water with 2.0mg/L PO_4-P solution and mixing it with 25g of fresh sediments in a 250mL Erlenmeyer flask. The slurry was then shaken for an hour on a horizontal shaker at 100 rpm, stopping every 15 minutes to vigorously shake the flask by hand. A 60mL aliquot was removed and vacuum filtered (45mm diameter, 0.45 µm pore size) into in Nalgene bottles and stored at 4°C until analyzed for PO_4-P. The remaining sediments were oven dried for 48 hours at 80°C to determine dry sediment mass. To calculate PSI, the amount of PO_4-P (mg/kg dry sediment) absorbed by the sediments (X) was divided by the log of the final nutrient concentration after an hour (C):

$$\text{PSI} = \frac{\text{X}}{\log(\text{C})} \qquad (6)$$

The exchangeable phosphorous or nitrogen content of the sediments was determined by adding 25g of sediments to 100 mL of 1 M $MgCl_2$ and 100mL of 2M KCl, respectively, in a 250mL Erlenmeyer flask (Ruttenberg, 1992). The mixture was shaken, filtered, and stored as in the EPC_o method. The remaining sediments were oven dried for 48 hours at 80°C to determine dry sediment mass. Phosphate-P and NH_4-N concentrations were determined for Ex-P and Ex-N, respectively. The exchangeable nutrient concentration was found with the following equation:

$$\text{Ex} - \text{P or Ex - N} = \frac{\text{mg nutrient}\left(\text{L}^{-1}\right) * 0.1\text{L}}{\text{kg dry sediment mass}} \qquad (7)$$

Sediment water samples were analyzed for phosphate and ammonium using a Seal Analytical Autoanalyzer AQ2+ (EPA method 365.1 for phosphate, EPA method 350.1 for ammonium; Mequon, WI).

Principal Findings

Summary

Nutrient transport is a great concern in the Midwest. Recent research suggests that a bulk of the nutrient contributing to the seasonal hypoxia in the Gulf of Mexico comes from corn and soybean production in this area. Much of the agricultural area requires tile drainage to prevent suffocation of crop roots with excess water. Tile drains are used in conjunction with artificial drainage ditches. This system of drainage is considered to expedite downstream nutrient transport and prevent denitrification within soils. Very little research has been performed in this area on the mechanics of nutrient movement within these ditches.

This study focused on seasonal nutrient dynamics within three agricultural drainage ditches with different management practices, such as dredging and presence/absence of vegetation, in the Hoagland Ditch watershed in northern Indiana. The BMPs explored were dredged ditches and vegetated ditches, with the third ditch being both undredged and nonvegetated as a control. Short-term nutrient injections were performed in the ditches to determine nutrient uptake length (Sw) during spring and fall conditions. Summer injections were not viable due to low flow conditions. There was no uptake of nitrate due to already high ambient concentrations. Phosphate Sw ranged from 27-154m; ammonium Sw was 28-89m. To determine sediment-nutrient interactions, sediment extractions including equilibrium phosphorus concentration (EPC0), phosphorous sorption index (PSI), exchangeable nitrogen (Ex-N), and exchangeable phosphorous (Ex-P) were performed at all sites for each season. The results are currently being analyzed to evaluate seasonal and BMP difference in nutrient transport and sediment nutrient interactions in agricultural drainage ditches.

Results and Significance

Nutrient Retention

Downstream nutrient concentrations decreased with distance from the injection point for all experiments. The ambient nitrate concentrations were very high for the control site (1-12 mg/L) and none of the nitrate (NO_3-N) injections showed significant nitrate uptake within the study reach ($p<0.1$). NO_3-N was most likely transported downstream without significant retention as the ditches were already N saturated.

Ammonium uptake was significant ($p<0.1$) for three injections. The fall injection for Site 2 was not significant ($p>0.1$). Ammonium uptake length ranged from 28-89m. Other literature reports values between 3-1350m (Mulholland et al., 2002; Wallace et al., 1995). Ammonium S_w was greatest at Site 2 during the spring injection and lowest at Site 3 during spring. The fall injection at the vegetated site yielded a S_w almost threefold longer than at the spring site. The mass transfer rate (V_f) was greatest at Site 2 during the spring injection and smallest during the fall injection at Site 3. Site 3 had a lower V_f in the fall than the smaller.

Table 1. Ammonium uptake lengths (S_w) and mass transfer rates (V_f) for the study sites in Hoagland Ditch. The asterisk indicates that the slope of the regression line used to estimate S_w was not significant ($p<0.1$).

	Sampling date	**S_w (m)**	**V_f (mm s^{-1})**	**Treatment**
Site 2	5/14/2007	89	0.128	Control
Site 3	5/14/2007	28	0.100	Vegetated
Site 2	11/20/2007	*	*	Control
Site 3	11/8/2007	84	0.041	Vegetated

Phosphate uptake at the sampling sites was significant ($p <0.05$) on three out of four injection experiments. Phosphate S_w ranged between 27 – 154 m, which is within the range (20-900m) reported in other studies (Haggard et al., 2001; Marti and Sabater, 1996). The mass transfer coefficient (V_f) was between 0.074 to 0.170 mm s^{-1} which is comparable to other values reported for PO_4-P (Davis and Minshall, 1999; Ensign et al., 2006; Hoellein et al., 2007). The fall injection for Site 3 had a much shorter uptake length than the spring injection. Temperatures were higher on the spring injection dates compared to those on the fall dates.

Table 2. Phosphate uptake lengths (S_w) and mass transfer rates (V_f) for the study sites in Hoagland Ditch. The asterisk indicates that the slope of the regression line used to estimate S_w was not significant ($p<0.05$).

	Sampling date	**S_w (m)**	**V_f (mm s^{-1})**	**Ditch Condition**
Site 2	5/1/2007	*	*	Unvegetated
Site 3	5/11/2007	72	0.074	Vegetated
Site 2	10/27/2007	154	0.170	Unvegetated
Site 3	11/4/2007	27	0.114	Vegetated

Uptake lengths values in the fall for PO_4-P differed between Site 2 and 3 by an order of magnitude, however, V_f values were similar 0.170 mm/s and 0.114 mm/s, respectively. Velocity and depth are proportional to V_f and were higher at Site 2 than Site 3, increasing the solute transfer rate. The greatest V_f occurred in conjunction with the longest S_w.

Generally, P retention increases with temperature (Chen, 1974; D'Angelo et al., 1991; Elwood et al., 1981), however, the increase in the in-stream vegetation and decreased discharge in fall is likely to have caused the greater P uptake. Increased velocity from spring to fall in Site 3 reduced contact time between solute, sediments, and plant roots which results in less uptake indicated by its lower V_f and longer S_w.

Sediment Retention

Analyses for EPC_o PSI, and Ex-N are currently underway and will be discussed in the final report.

Exchangeable Phosphorus

Figure 1 shows the average exchangeable phosphorus (Ex-P) concentrations with their standard deviations at all three sites during the spring, summer, and fall of 2007. The Ex-P values ranged from 1.06 to 30.36 mg/kg of dry sediment. There was less variability in Ex-P between sites for the spring where Ex-P ranged from 1.09 to 1.75 mg/kg dry sediments, while there was a greater range of values for summer (2.74 to 8.46 mg.kg dry sediments) and fall (1.50 to 30.36 mg/kg dry sediments). The highest Ex-P was observed at Site 1 during fall 2007; the lowest Ex-P was seen at Site 1 in the spring. Site 3 had consistently higher Ex-P values than Site 2.

In drainage ditches in Northeast Indiana, Smith et al. (2005) saw Ex-P between 0.49 and 9.35 mg/dry sediments. If Site 1 summer is excluded, the values fall within this range. Dredging at Site 1, after the summer experiment, most likely influenced Ex-P during the fall.

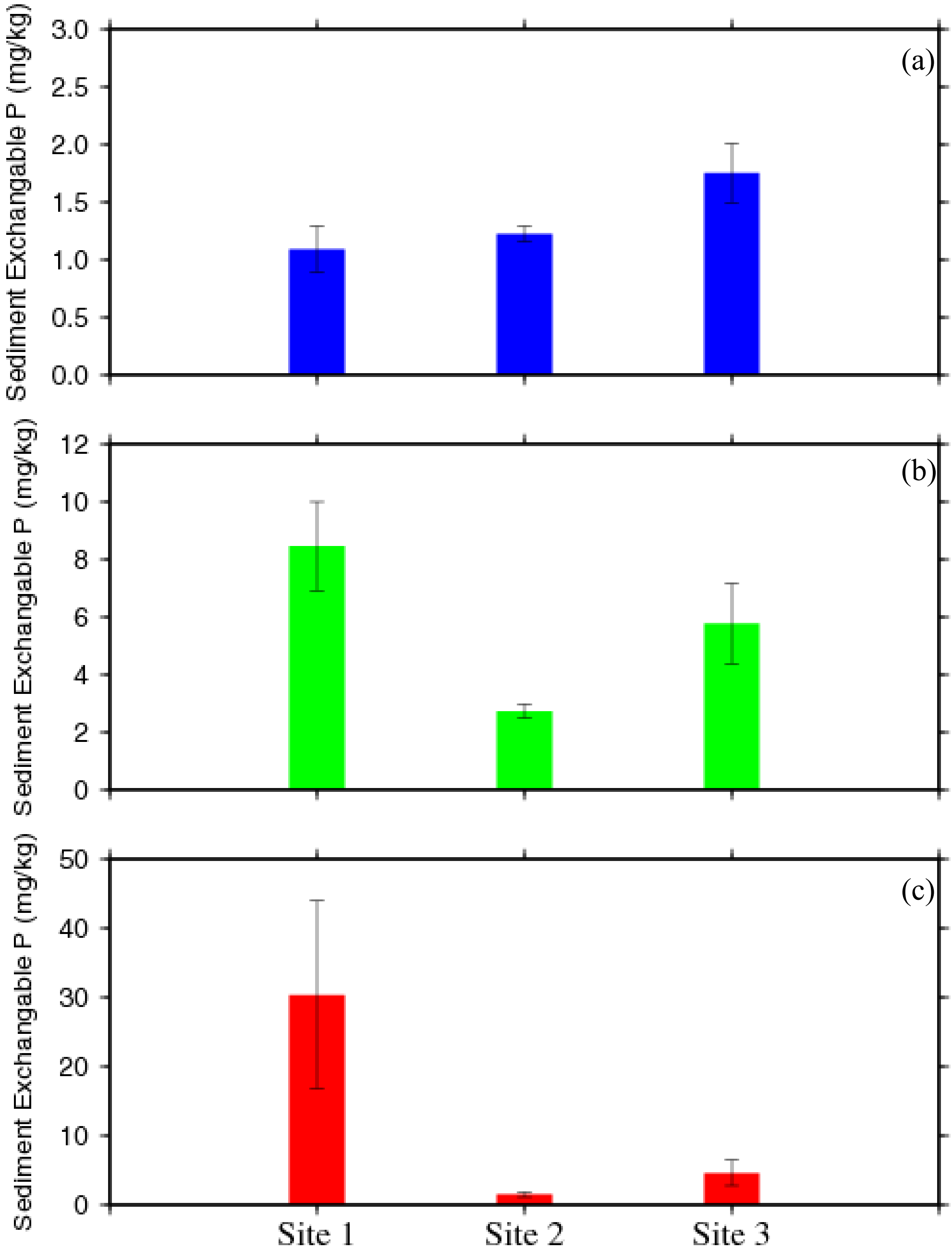

Figure 1. Estimated average sediment exchangeable phosphorus (Ex-P) content at Sites 1, 2, and 3 during spring (a), summer (b), and fall (c) of 2007.

Major Conclusions

Midwest drainage ditches are conduits of nutrient transport causing downstream water quality problems, like the hypoxia in the Gulf of Mexico. This study quantifies the nutrient uptake length (S_w), or degree of nutrient retention, of phosphate, ammonium, and nitrate to give a measure of nutrient retention within ditches. Phosphate Sw ranged from 27 to 154 m; ammonium S_w was between 28 to 89m. Nitrate uptake was negligible due to already high ambient concentration. Ammonium uptake, instead, of nitrate shows a preference to the form of nitrogen. Vegetated ditches did have an effect on uptake length within the ditches as S_w was shorter in the vegetated ditches for both phosphate and ammonium.

We found that nitrate was being transported downstream without any removal because of the high ambient concentrations. Alexander et al. (2008) shows watersheds in Indiana can export 50-100% of their nitrogen loads to the Gulf of Mexico. Combating nitrate problems needs to begin at the headwaters, such as drainage ditches, because in stream attenuation decreases with increasing stream order and flow. If there is no nitrate uptake within the drainage ditches, the nitrate load increases downstream as other ditches and streams merge.

Publications

Merriman, K. R., I. Chaubey, L. Bowling, and S. Ale. July 2008. Quantification of nutrient dynamics in agricultural drainage ditches in Hoagland Ditch watershed in Northern Indiana. American Society of Agricultural and Biological Engineers. Providence, RI.

Students

Graduate Students: Katherine Merriman, M.S., Srinivasulu Ale, Ph.D.

Grant No. 08HQGR0007 Web−Based Low Impact Development Decision Support and Planning Tool

Basic Information

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Principal Investigators:	Ron F. Turco, Bernard Engel

Publication

IWRRC Report

Title: Web-Based Low Impact Development Decision Support and Planning Tool

Submitted by:
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Problem: Mitigating the adverse water quantity/quality impacts of urban development is of national importance. The use of Low Impact Development (LID) practices help in the reduction of pollution and hydrologic instability from stormwater arising from increases in impervious surfaces and land development practices. However, significant obstacles to the adoption and acceptance of LID practices by federal, state, and local agencies stem from the lack of tools to quickly and easily predict the impact of LID practices within an area. The use of currently available models for stormwater management precludes the use by a greater audience due to needed extensive expertise and their technical difficulty, which prevents widespread application for preliminary assessments.

Research Objectives: The development of this L-THIA/LID tool involves identifying specific LID practices to be modeled and quantifying LID performance based on soil characteristics, treatment efficiency, runoff reduction and design specifications. The capabilities of the LID practices will be evaluated by L-THIA to estimate changes in runoff and nonpoint source pollution (NPS) resulting from proposed land use and LID implementation. Evaluation of the tool will be through suitable case studies identified through discussions with stakeholders. Dissemination of the model and supporting materials will be done by freely available web access.

Methodology: The L-THIA model employs the SCS curve number method and event mean concentration (EMC) methods for simulation of surface runoff and NPS loading. L-THIA (Long-Term Hydrologic Impact Assessment) model and decision support capabilities estimates long-term average annual runoff and NPS pollutants for a land use configuration based on 30-year climate data, soils, and land use data for an area. The model is widely used by local decision makers to estimate the impact of land use changes on runoff and water quality.

Principal Findings: Models and decision support tools are needed to help quantify the site specific impacts of LID practices to allow the identification of the most appropriate BMPs. L-THIA/LID is an easy to use tool that can use readily available data that will provide such capabilities.

Summary: In response to increasing demands for information about LID and tools for comparing LID practices to conventional development practices, an easy to use web-based LID decision support and planning tool, **L-THIA/LID**, has been developed as a

simple to use screening tool to evaluate the benefits of LID practices. The Long-Term Hydrologic Impact Assessment (L-THIA) web application is a decision support system based on an integration of web-based programs, geographic information system (GIS) capabilities, and databases, and enables support for decision makers who need information regarding the hydrologic impacts of water quantity and quality resulting from land use change. Drawing upon the existing capabilities and past success of L-THIA, the web-based **L-THIA/LID** tool will enable various stakeholders to quickly and easily evaluate: (1) the impact of urban development on average annual runoff volume; and (2) the potential stormwater and pollutant reduction of proposed LID practices. Water quantity and water quality results of the proposed land use change are displayed in tables, bar charts, and pie charts. Case studies will be used to demonstrate the model's ability to assess the impact of LID practices within a watershed. The model's results will enable decision makers to formulate an effective watershed management plan to achieve desired stormwater management and water quality goals.

Results and Significance: In order to meet the principle decision making needs of individuals and organizations looking to utilize L-THIA/LID, two interrelated screening levels (low level screening and high level screening) were developed. Low level screening includes practices that aim that reduce the amount of stormwater principles of reducing imperviousness, minimization of development, and conservation of natural features. High level screening includes integrated storrmwater management practices at the lot level which include the concepts of the low level screening, plus the sizing of sidewalks, driveways, parking lots, streets and sidewalks, porous pavement, water harvesting with rain barrels and cisterns, vegetated rooftops; bioretention systems (rain gardens), grass swales, and filter strips. Modeling these practices will allow users to understand the impact of these practices to intercept, retain, and infiltrate stormwater, as well as the reduction of pollutants by physical, chemical, and biological processes.

Major Conclusions L-THIA/LID will enable regulatory agencies, voluntary organizations, and watershed practitioners to quickly: (1) select their watersheds or area(s) of interest for evaluation; (2) evaluate the impact of urban development on runoff volume and NPS pollutants; and (3) screen potential LID practices impacts on stormwater and NPS reduction.

Publications: http://cobweb.ecn.purdue.edu/runoff/lthianew/lidIntro.htm

Students (1) Graduate Students: Prathima Rao; Post-Doctoral Associates: James Hunter

Information Transfer Program Introduction

Securing The Load − A Guide to Safe and Legal Transportation of Cargo and Equipment

Basic Information

Title:	Securing The Load − A Guide to Safe and Legal Transportation of Cargo and Equipment
Project Number:	2007IN214B
Start Date:	3/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	4th
Research Category:	Water Quality
Focus Category:	Agriculture, Groundwater, Law, Institutions, and Policy
Descriptors:	None
Principal Investigators:	Fred Whitford

Publication

1. Title: Securing the Load: A Guide to Safe and Legal Transportation of Cargo and Equipment

Submitted by: Fred Whitford, Purdue Pesticide Programs, 915 West State Street, Purdue University, West Lafayette, Indiana, 47907-2054, phone (765-494-1284), email (fwhitford@purdue.edu)

Funding Period: March 1, 2007 – February 28, 2008

Principal Deliverables:

Publication:

Securing the Load: A Guide to Safe and Legal Transportation of Cargo and Equipment has been sent to the printers. It is an 88 page, full color publication. Expected delivery of the publication is mid-July, 2008. Cost for publishing 10,000 copies will be $20,500. Publication be available in the Purdue University Media Distribution Center, on-line at www.btny.purdue.edu/ppp, sent to county educators across Indiana, and sent to each pesticide coordinator at the land grant universities. One copy each will be mailed to 3,000 business licensed by the Office of Indiana State Chemist to apply pesticides for hire.

Public Presentations:

Using webs and chains to tie down farm loads. Rush County Private Applicator Recertification Program. Rushville, Indiana.

How to comply with DOT regulations. Tenbarge Education and Trade Show. Evansville, Indiana.

DOT regulations for farmers. Farm Fertilizers & Seeds Winter Meeting. Knox, Indiana.

Securing pesticides and cargo on trucks and trailers. National Railroad Conference Association Weed Control Seminar. Indianapolis, Indiana.

How to keep your pesticides and equipment on the trailer and off the roadway. Professional Landscape Management School. Evansville, Indiana.

Securing pesticides and equipment for the road, and Securing pesticides and equipment for the road (Spanish session). Green Industry Professional Seminar. Annandale, Virginia.

Securing pesticides and cargo on trucks and trailers. Indiana Arborist Association. Indianapolis, Indiana.

Getting tanked and strapped with Fred. Purdue Pest Management Conference. West Lafayette, Indiana.

Securing your load with straps and chains. Great Lakes Trade Exposition. Grand Rapids, Michigan.

DOT rules of the road for farmers. District 10 Indiana Farm Bureau Conference. Seymour, Indiana.

Securing pesticides and cargo on trucks and trailers. Indiana Society of American Foresters. Indianapolis, Indiana.

What farmers need to know about chains and webs. Carroll County Private Applicator Recertification Program. Flora, Indiana.
Close encounters with DOT troopers: a farmer's perspective. Shipshewana, Indiana.
DOT rules of the road. Indiana Farm Bureau State Convention. Indianapolis, Indiana.
Transporting pesticides: safety issues and regulations. Northeast Indiana Landscape and Turf Seminar. Fort Wayne, Indiana.
Securing your load with chains and webs. Tennessee Vegetation Management Association. Chapel Hill, Tennessee.
Proper use of tie downs: Keeping pesticides and equipment on trucks and trailers. Kentucky Turfgrass Conference. Bowling Green, Kentucky.
Chains and webs: how to tie down loads. Precision Soya Annual Grower Meeting. New Castle and Markle, Indiana.

Consultations: A number of farm and business visits were made during the reporting period. These voluntary environmental audits have part of its mission to examine how products are being transported, stored and how pesticide application equipment is being filled. Much of that part of the environmental and safety audit is to suggest best management practices to prevent surface and ground water contamination.

Summary: We all experience anxious moments when we look in the rear view mirror and see our cargo leaning precariously, pesticide containers bouncing up and down as we drive, a disengaged load binder bouncing merrily off the pavement, a 500-gallon fertilizer tank shifting to one side, or a commercial lawn mower rolling back and forth in the bed of the truck.

Imagine your cargo spilling onto the roadway, vehicles on both sides of the road instinctively swerving toward the shoulder, others crossing the center line into the path of oncoming traffic. Imagine someone running over your spilled cargo, having a blowout and losing control. Imagine a horrible accident—all because you failed to properly secure your load.

Losing cargo on the road is serious business. First of all, it's a loss; whatever falls is spilled, damaged, or destroyed. Falling cargo can cause direct or indirect human injury and destruction of personal property. There may be environmental impacts if a fallen chemical contaminates surface water; and if your insurance doesn't cover the cost of remediation, you have to pay for cleanup and restoration.

2. IWRRC Outreach Report (Continuation of Past Project)

Title: Aboveground Petroleum Tanks: A Pictorial Guide

Submitted by: Fred Whitford, Purdue Pesticide Programs, 915 West State Street, Purdue University, West Lafayette, Indiana, 47907-2054, phone (765-494-1284), email (fwhitford@purdue.edu)

Funding Period: March 1, 2006 – February 28, 2007

Problem:

Principal Deliverables:

***Publication*:** *Aboveground petroleum Tanks: A Pictorial Guide* was printed on September 9, 2007. It is a 112 page publication that shows in full colors examples of bad and good aboveground tank storage practices. A total of 2500 copies were printed at a cost of $15,000. It has been placed online at www.btny.purdue.edu and copies have been widely distributed. It can be ordered at the Purdue Media Distribution Center by request. In addition, the publication has been handed out at many farm and business programs around the state. The Indiana Lawn and Landscape Association handed all of its members a copy when they attended their fall meeting in 2007. Only 460 copies of the publication still remain in inventory.

News Release:

January 31, 2008

Tanks a lot: Purdue publication full of fuel container tips

WEST LAFAYETTE, Ind. - Anhydrous ammonia tanks have become favorite targets of methamphetamine makers, costing farmers thousands of dollars in stolen nitrogen fertilizer.

Thieves are now turning their attention to another chemical container: The aboveground petroleum tank, said a Purdue University Extension specialist.

"With the price of gas and diesel fuel going up, some people are now a little bit more apt to help themselves to your fuel tanks," said Fred Whitford, coordinator of Purdue Pesticide Programs. "When that happens, you're lucky if all you lose is the gas or diesel, because all you've lost is the money for that fuel.

"The real problem is when these thieves and vandals turn the power to the tank on, they put as much fuel as they need into their truck and then let the rest run onto the ground. Now you've not only lost a product, but you've also got soil contamination. You can prevent a lot of this, and it isn't that hard."

Farmers can learn how to safeguard fuel tanks, select the right tank for a farm, handle fuel spills and related issues in the just-released Purdue Extension publication, *Aboveground Petroleum Tanks*. The publication is available in print and online versions. Whitford is the publication's lead author.

Fuel tanks vary in size, with most holding 500 gallons or more. For years, many farmers stored fuel below ground. Because they were not visible, the underground tanks provided natural security from thieves and vandals.

When some underground tanks began to leak and create environmental problems, stricter federal regulations governing the construction and use of buried fuel tanks were introduced. Most farmers abandoned the underground tanks and started storing fuel above ground. As fuel prices topped $3 a gallon, petroleum thefts increased, Whitford said.

Aboveground Petroleum Tanks outlines security measures farmers can take to discourage fuel thieves.

"You can install lights around the tank and put locks on the tank," Whitford said. "At nighttime you can turn the electricity off to your tank. You can even turn the circuits off from inside your barn or farm building. Some people have even gone so far as to put up security cameras."

The 110-page publication is loaded with illustrations. More than 230 photos show examples of both proper and improper fuel tank practices. The photos come from 15 years of Whitford's travels to commercial businesses and farms across Indiana.

Four primary themes run throughout the publication, Whitford said.

"One important thing you need to do is have a tank in the right place so that if a spill takes place fuel does not get into surface water," he said. "Second, do everything you can, within reason, to keep the area clean. Third, do a little security to at least make it more difficult for a person to cause you harm. Then lastly, you want to prepare for an emergency. Most of our insurance policies will not cover cleaning up contamination. So if you had a fuel spill, the cleanup would come out of your pocket."

The fuel tank guide - Purdue Extension publication PPP-73 - can be ordered for $1 plus shipping by calling the toll-free Purdue Extension hotline at 1-888-EXT INFO (398-4636) or by e-mail at media.order@purdue.edu. The publication also can be downloaded free online at http://www.btny.purdue.edu/Pubs/PPP/PPP-73.pdf.

For more information about the publication or aboveground fuel tanks, contact Whitford at (765) 494-1284 or by e-mail at fwhitford@purdue.edu.

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Related Web site:
Purdue Pesticide Programs: http://www.btny.purdue.edu/PPP/

Presentations:

Environmental audits: What to look for and why. 2007. Midwest Agricultural Banking School. West Lafayette, Indiana.

Using chemicals and protecting natural waterways. 2007. Indiana Association of Floodplain and Stormwater Management. Angola, Indiana.

Reviewing the farm's operations: What should the insurance agent ask and look for? 2007. Remington Farmers Mutual Insurance Company Agent Training. Monticello, Indiana.

Reviewing the farm's operations: what should the insurance ask and look for? 2007. Farm and Rural Risk Conference. Indianapolis, Indiana.

Summary: Petroleum products such as gasoline, diesel fuel, biofuels, lube oils and engine oils are essential to farm operations, commercial pesticide application businesses, and American commerce. However, on-site fuel storage carries a risk potential that can be reduced by following a set of safety, security, environmental, and regulatory guidelines. Poorly managed aboveground storage of petroleum products can be costly. Spills and other consequences of poor management can involve years of cleanup efforts and lengthy legal battles. Issues of concern include the following: soil and water contamination, decreased property value, cleanup costs, theft and vandalism, potential for terrorist activity, high cost of insurance coverage for environmental pollution, and adverse environmental audit that may prevent the sale of the property.

This publication addresses these potential problems and consequences. It describes field-tested management procedures and security measures to use when storing, dispensing, and disposing of petroleum products. It will raise your awareness of federal and state petroleum regulations that impact your facility. Hopefully, it will motivate you to upgrade management practices at your facility by implementing those that we suggest. Your mishap probability—and your liability potential—will decrease as a result.

Impact: A number of farm and business audits were made during this reporting period. Of part of the on-site review of pesticide and fertilizer storage and transportation practices, fuel tanks became a major part of the voluntary inspection program. A number of phone calls from growers on issues surrounding aboveground fuel tanks have been received by Purdue Pesticide Programs. There were a number of interviews with trade magazines as of a result of a release by Purdue Ag Communications Department.

Summary: Purdue Pesticide Programs is an Outreach Cooperator with the Indiana Water Resources Institute. A total of seventeen Core Commercial Pesticide Applicator Training programs were held. Protecting surface and ground water are discussed in detail during the day long course.

A number of programs were delivered that addressed water quality issues from preventing surface and water contamination by implementing best practices. Topics included preventing poly chemical tanks from breaking, use of chains and webs to keep pesticide and fertilizer products on trucks and trailers, safe use of pesticides around the home, reacting to a pesticide spill from a truck, proper storage of large quantities of pesticides and fertilizers, disposing of unwanted pesticides, responsible pesticide use, and protecting natural waterways,

The following provides a sample of the groups representing the public, farming, and commercial industries: Rush County Private Applicator Recertification Program, county Master Gardener Program, Washington State Pest Management Association, Southwest Indiana Crop Clinic, Indiana. Johnson County Private Applicator Recertification Program, Wabash Soil and Water Conservation District Annual Meeting, Grant County Private Applicator Recertification Program, Northern Indiana Management Seminar; National Railroad Conference Association, Tipton County Soil and Water Conservation District Annual Meeting, Wayne, Fayette, and Union County Private Applicator Recertification Program, Professional Landscape Management School., Virginia Green Industry Professional Seminar, Indiana Arborist Association, Wisconsin Turfgrass and Greenscape Expo. Madison, Wisconsin, Illinois Crop Protection Technology Conference. Urbana, Illinois, Purdue Pest Management Conference. West Lafayette, Indiana, Great Lakes Trade Exposition, Co-Alliance Emergency Response Workshop, Indiana Society of American Foresters, Carroll County Private Applicator Recertification Program., Warren County Private Applicator Recertification Program. Warren County Private Applicator Recertification Program, Minnesota Crop Production Retailers Trade Show., Scotts Lawnservice Annual Franchise Conference; Midwest Agricultural Banking School, Northeast Indiana Landscape and Turf Seminar, Oregon Vegetation Management Association. Tennessee Vegetation Management Association, Kentucky Turfgrass Conference, Terminex Fall Recertification Seminar, The Ohio State University Farm Science Review, Indiana Association of Floodplain and Stormwater Management Association, Remington Farmers Mutual Insurance Company Agent Training, Precision Soya Annual Grower Meeting, Midwest Regional Turf Field Day, Hoosier Energy Electric Cooperative Training Workshop, Michigan State University Comprehensive Core Training, Indiana Department of Transportation Maintenance Conference, Florida Vegetation Management Association, Louisiana Pesticide Applicators Association Winter Conference, Indiana Vector Control Association, Madison Private Applicator Recertification Program, Indiana Golf Course Superintendents Association, Wabash County Private Applicator Recertification Program, Farm and Rural Risk Conference, Jasper County Private Applicator Recertification Program, Crop Fertility Specialists, and PrestoX Company Annual Technical Conference.

Soil and Septic System Field Guide

Basic Information

Title:	Soil and Septic System Field Guide
Project Number:	2007IN216B
Start Date:	3/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	1−9
Research Category:	Ground−water Flow and Transport
Focus Category:	Education, Groundwater, Surface Water
Descriptors:	None
Principal Investigators:	Brad Lee

Publication

Title: Soil and Septic System Field Guide

Submitted by: Brad Lee
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Funding Period: March 1, 2007 – February 28, 2008

Problem: One of the most problematic programs that county health departments administer is the septic system program. The day-to-day management of the septic system program falls to an individual on staff (Environmental Health Specialist) that maintains a number of programs (e.g. vector control, lead abatement, pool inspections and hotel inspections). Because their tasks are so diverse, training time in one particular area or another is very limited. In addition, many of these individuals, although talented and well qualified, do not have a science based education that would assist them in interpreting soil reports that are required for septic system permitting. This lack of knowledge is compounded by a high turnover rendering most environmental health specialists without the ability to interpret a soils report. A better understanding of soils, soil processes and soil reports by environmental health specialists will result in better decision making at the local level. By providing environmental health specialists with better interpretive and decision making skills, septic system permits will be issued decisively by a much more knowledgeable regulator. This will result in better septic system design selection and placement which will increase system longevity and reduce septic system failures.

Outreach/Extension Objectives: Educate the county environmental health specialists that permit septic systems about soils and the relationship between soil properties and septic system performance

Methodology: Since 2001 Purdue University offers two Soil and Septic System Workshops each year. The development of a "text book" for this workshop will provide environmental health specialists with reference material for this course. The manual will be developed primarily from three resources: Indiana's Rule for regulation septic systems (Rule 410 IAC 6-8.1), the NRCS Field Book for Describing and Sampling Soils Ver. 2.0, and Purdue University Extension Publication Indiana Soils and Evaluation Manual, AY-323.

Principal Deliverables

Summary: Septic system failure is a problem throughout the United States. About 1/3rd of Hoosiers utilize septic systems, and of these 800,000 systems, the Indiana State Department of Health estimates that about 25% are failing. Many of these failures have been attributed to problematic soil conditions that are prominent throughout the state. The governing law regarding residential septic systems (Rule 410 IAC 6-8.1) is

administered at the local level by county health departments. County health departments issue septic system permits based on soils information submitted in a report by consulting soil scientists. Unfortunately, many Indiana health departments lack the expertise to make sound, unbiased interpretations based on these soil reports. Instead they rely on experience, advice from consulting soil scientists and rote analysis of reports. We are developing a soil report reference field manual for county health department staff. This manual will be the basic "text" for the annual Soils and Septic System Workshops.

Impact: *Work is in progress.* Expected impact includes better decision making by our county environmental health specialists when evaluating septic system permit requests. The long-term impact will include fewer septic system failures.

Publications: *In progress.*

Students and Staff: Graduate students Jason de Koff, Edwin Winzeler, Zamir Libohova were involved in this project and were an integral part of its success.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR−USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	28	0	0	0	28
Masters	1	0	0	0	1
Ph.D.	1	0	0	1	2
Post−Doc.	0	0	0	1	1
Total	30	0	0	2	32

Notable Awards and Achievements

Publications from Prior Years

1. 2004IN158B ("Potential of Controlled Drainage to Reduce Nitrate Contamination at the Watershed Scale") − Articles in Refereed Scientific Journals − Anmala, J., and R.H. Mohtar. Fourier Stability Analysis of Two−Dimensional Finite Element Schemes for Shallow Equations. International Journal for Numerical Methods in Fluids. In review.
2. 2004IN158B ("Potential of Controlled Drainage to Reduce Nitrate Contamination at the Watershed Scale") − Book Chapters − Mohtar, R.H., T. Zhai, J−Y Choi, and B. Engel. 2008. Web−based GIS Hydrologic Modeling for Siting Water Harvesting Reservoir. In: Watershed Management in Dry Areas, Challenges and Opportunities. Eds. Bruggeman, A., M. Ouessar, and R. H. Mohtar. ICARDA Press. Alleppo Syria.
3. 2004IN158B ("Potential of Controlled Drainage to Reduce Nitrate Contamination at the Watershed Scale") − Book Chapters − Zhai, T. and R.H. Mohtar. 2005. Informatics and Model Based Analysis and Management. In: Systems Analysis and Modeling in Food and Agriculture [Eds. David H. Fleisher, K.C. Ting, and Luis F. Rodriguez] Encyclopedia of Life Support Systems. Developed under the Auspices of the UNESCO, Eolss Publishers, Oxford, UK [http:www.eolss.net].
4. 2004IN158B ("Potential of Controlled Drainage to Reduce Nitrate Contamination at the Watershed Scale") − Book Chapters − Braudeau, E. and R.H. Mohtar. 2004. Soil Water Functions in Pedostructure. In Encyclopedia of Water Science. Marcel Dekker, Stewart and Howell, eds. DOI:10.1081/E−EWS 120021076
5. 2004IN158B ("Potential of Controlled Drainage to Reduce Nitrate Contamination at the Watershed Scale") − Conference Proceedings − Mohtar, R.H., T. Zhai, J.−Y. Choi, A. Bruggeman, M. Ouessar, F. Abdelli and B.A. Engel. 2006. Web−based GIS−Hydrologic Modeling for Siting Water Harvesting Reservoirs. The 14th conference of ISCO International Soil Conservation Organisation 2006, Marrakech, May 14−19. 5 p.
6. 2004IN158B ("Potential of Controlled Drainage to Reduce Nitrate Contamination at the Watershed Scale") − Other Publications − 2DSTREAM®: Two−Dimensional Surface Stream Flow model: http://pasture.ecn.purdue.edu/~water/2dstream/. 2−D STREAM Watershed Management Model, a finite element model for the estimation of flow depth and velocity in a watershed
7. 2004IN158B ("Potential of Controlled Drainage to Reduce Nitrate Contamination at the Watershed Scale") − Conference Proceedings − Anmala, J. and R.H. Mohtar. 2005. Time−step Criteria and Fourier (von Neumann) Stability Analysis of Two−Dimensional Finite Element Schemes for Shallow Water Equations. ASAE Paper #05−3077. Tampa, Florida. Mohtar, R.H. and J. Anmala. 2005. Error Analysis of Control Volume Finite Element for Overland flow Shallow−Water Equations (SWE). ASAE Paper #05−3082. Tampa, Florida.
8. 2005IN173B ("The Effects of Landscape Transformation in a Changing Climate on Indiana's Water Resources") − Articles in Refereed Scientific Journals − Davis Todd, C., Goss, A., Tripathy, D., and Harbor, J., 2007. The effects of landscape transformation in a changing climate on local water resources. Physical Geography, 28, p.21−36.
9. 2005IN173B ("The Effects of Landscape Transformation in a Changing Climate on Indiana's Water Resources") − Other Publications − Davis−Todd, C., Harbor, J. and Lim, E., (in prep) Long−term trends in peak precipitation and streamflow for small watersheds across the U.S. Davis−Todd, C., and Harbor, J. (in prep) Decadal trends in seasonal precipitation and streamflow in small watersheds in the Midwestern United States.
10. 2006IN189B ("Environmental Risk Assessment of Soybean Rust Fungicides Use in Indiana") − Other Publications − Bialkowski, W. and Ochoa−Acuña, H. Toxicity of soybean rust fungicides to freshwater algae and Daphnia magna. To be submitted to Ecotoxicology. Yale, G., Bialkowski, W., Yu, G., and Ochoa−Acuña, H. Toxic interactions among strobilurin and conazole fungicides and organophosphorous insecticides. To be submitted to Aquatic Toxicology.

11. 2006IN189B ("Environmental Risk Assessment of Soybean Rust Fungicides Use in Indiana") − Dissertations − Walter Bialkowski (M.S.) – “Impact of soybean rust fungicides and an organophosphorous insecticide in mixtures to the aquatic invertebrate, Daphnia magna."