Final Program & Abstract Book

Science to Solutions

Reducing Nutrient Export to the Gulf of Mexico

A Workshop for Managers, Policy Makers, and Scientists

December 9-11, 2009 ◆ Des Moines, Iowa

Sponsored by:

USDA

USGS science for a changing world

United States Environmental Protection Agency

Soil and Water Conservation Society

Soil and Water Conservation Society
945 SW Ankeny Road
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Science to Solutions

Reducing Nutrient Export to the Gulf of Mexico

A Workshop for Managers, Policy Makers, and Scientists

Sponsored by the U.S. Department of Agriculture, U.S. Geological Survey
and U.S. Environmental Protection Agency, and facilitated
by the Soil and Water Conservation Society

Welcome to Des Moines and the Science to Solutions Workshop. This three day workshop will provide a forum for interactive discussions among managers, policy makers, and scientists. The workshop objectives are:

- To convey relevant scientific findings on potential solutions to resource managers and policy makers,
- To assure that science continues to inform decisions and that decision makers are getting the information they need,
- To improve communication on what scientific findings mean in defining the key land and water issues and in finding real solutions, and
- To advance monitoring, assessment, and modeling in the Mississippi River Basin needed to support specific management actions that ultimately reduce nutrients in streams and rivers in the Basin and in the Gulf of Mexico.

The workshop consists of five sessions with invited speakers, a breakout workshop discussion, 59 posters and five technology demonstrations to provoke thought and discussion on assessing and reducing nutrient export to the Gulf of Mexico from the midwest portion of the Mississippi River Basin. Whether you come to represent federal, state, or local government, watershed groups, nonprofit organizations, universities, or other groups, we encourage all workshop participants to look for creative solutions and new possibilities for synergy and collaboration on nutrient assessments and management in the Mississippi River Basin.

We look forward to a productive workshop.

Science to Solutions Organizing Committee

Mike Woodside, USGS	Bob Kellogg, USDA-NRCS	Lisa Duriancik, USDA-NRCS
Rich Alexander, USGS	Doug Karlen, USDA-ARS	Dave Wolock, USGS
John Kessler, Ohio DNR	Pixie Hamilton, USGS	Dewayne Johnson, SWCS

USGS science for a changing world

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

SOIL AND WATER CONSERVATION SOCIETY

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Workshop Agenda

Wednesday, December 9

1:00 – 2:00 p.m. — **Opening Session** — ***All Presentations in Hall of Cities/Des Moines Room***
Welcome: Mike Woodside, USGS, and Robert Kellogg, USDA-NRCS

Regional Ocean Partnerships; the Times They are a –Changin'
Dr. Bill Walker, Executive Director, Mississippi Department of Marine Resources and Chairman, Gulf of Mexico Alliance

2:00 – 4:15 p.m. (15 min. break at 3p) — **Session 1: Management issues, day-to-day decisions, tools**
Session Lead: John Kessler, Ohio Department of Natural Resources

- Dean Lemke, Iowa Department of Agriculture and Land Stewardship
- Peter Tennant, Ohio River Valley Water and Sanitation Commission
- Sherry Wang, Tennessee Department of Environment and Conservation
- James Baumann, Wisconsin Department of Natural Resources
- Martin Adkins, Natural Resources Conservation Service, Iowa

4:15 – 5:30 p.m. — **Session 2: The Human Dimension—Socioeconomic factors that influence decision making and adoption**
Session Lead: Lisa Duriancik, USDA, Natural Resources Conservation Service

- Marc Ribaudo, USDA, Economic Research Service: Review of economic factors that influence farmer's conservation practices. What kinds of policies/programs and economic incentives seem to work best?
- Linda Prokopy, Purdue University: An Overview of socio-economic factors that influence farmer's conservation decisions. What kinds of incentives seem to work the best? Emphasis on social and cultural aspects including barriers to adoption.
- Kevin Erb, University of Wisconsin Extension and Robin Shepard, North Central Cooperative Extension Association: Review role that community action and local organizations play in achieving nutrient reductions. What were the common factors/processes among successful efforts?

5:30 – 7:30 p.m. — **Evening poster and technology demonstration session**
With interactive modeling and decision-making demonstrations and social function

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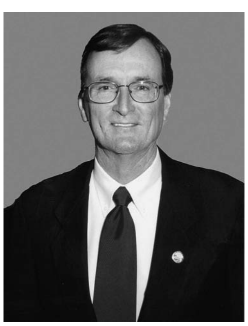
Opening Keynote:
William W. Walker was appointed Executive Director of the Mississippi Department of Marine



Resources by Gov. Ronnie Musgrove on July 8, 2002.

Walker received his B.S. in botany and microbiology from Southeastern Louisiana University and his M.S. and Ph.D. in soil microbiology and biochemistry from Mississippi State University.

Prior to his appointment to the Mississippi Department of Marine Resources, he was employed by the U.S. Environmental Protection Agency and was serving as a Legislative Fellow in the Office of Sen. Trent Lott in Washington, DC.

Walker completed a 28-year career at the University of Southern Mississippi (USM) — Gulf Coast Research Laboratory where he served as Associate Director and was instrumental in building a variety of environmental toxicology programs.

Walker has served as adjunct faculty at USM and the University of Mississippi, is a member of the Mississippi Academy of Sciences and numerous national societies and is well published in national and international scientific journals.

Thursday, December 10

8:00 – 10:00 a.m. **Session 3: Overview of small watershed studies and implications of the research for controlling nutrients**
Session Lead: Doug Karlen, USDA-ARS
- James Baker, Iowa State University: Summary of UMRSHNC workshop and overview of case studies in Iowa and Illinois
- Deanna Osmond, North Carolina State University: Overview of CSREES CEAP Watershed Studies
- John Sadler, USDA, Agricultural Research Service: ARS CEAP Benchmark Watershed Studies

Panel discussion to follow presentations.

10:00 – 10:30 a.m. **Break**

10:30 – 12:00 p.m. **Session 4: Data Availability and Gaps**
Session Lead: Dave Wolock, U.S. Geological Survey
- Dale Robertson, U.S. Geological Survey: Water-quality monitoring data and water-quality trends
- Jane Frankenberger, Purdue University: Agricultural effects data (fertilizer use, sources, manure, point sources, landscape, land use, water quality, stream networks, conservations practices)
- Anne Hoos, U.S. Geological Survey: Data Availability and Gaps in Permitted Wastewater Discharges and Urban Runoff

Noon – 1:30 p.m. **Workshop Luncheon** ***Iowa Ballroom: Salons D-H (2nd Floor)***
Introduction: Jim Gulliford, Soil and Water Conservation Society

Chesapeake Bay: Lessons in Adaptive Management
Tom Simpson, President and Executive Director, Water Stewardship, Inc.

Workshop Luncheon Speaker:
Dr. Tom Simpson is President and Executive Director of Water Stewardship, Inc., a nonprofit

dedicated to verified continuous improvement in agricultural water quality protection and ecosystem service assessment and verification. Dr. Simpson has a BS from Virginia Tech and an MS and Ph.D. from Penn State, all in Soil Science. From 1980 to 1992, he was Assistant to full Professor at Virginia Tech and was Professor at the University of Maryland from 1992-2008. Tom coordinated science-policy activities regarding nonpoint source pollution for Maryland, chaired the Chesapeake Bay Program's Nutrient Subcommittee and led the nine-university Mid-Atlantic Water Program.

Dr. Simpson has served on numerous panels and boards, including the National Academy of Science Panel on Implementing the Clean Water Act in the Mississippi River Basin. He also worked on nutrient issues in the Danube/Black Sea Basin and Israeli-Palestinian transboundary waters. Dr. Simpson currently focuses on improved accountability and continuous improvement in agricultural conservation and ecosystem service assessment and verification but continues to work on biofuels, BMP effectiveness, and integration of science into water policy.

Thursday, December 10 - Continued

1:30 – 4:30 p.m. (10 min. break at 3p)

Session 5: Benefits and Limitations of Small Scale and Large-scale models and Implications for Solutions, Trends, and Tracking

Session Lead: Wayne Anderson, Minnesota Pollution Control Agency

- Matt Helmers, Iowa State University: Riverine nutrient export in Iowa watersheds and relations to landscape properties and agricultural land use
- Mark David, University of Illinois: Riverine nutrient export in the Mississippi Basin and relations to watershed inputs and balances
- Hafiz Munir, Minnesota Pollution Control Agency: Integrating Nutrient Load Simulation into Basin-scale Watershed Models
- Jeff Arnold, USDA-ARS: Use of HUMUS-SWAT in the Mississippi Basin to assess nutrient sources and the effects of management practices
- Rich Alexander, USGS: Use of SPARROW to assess nutrient sources, transport, and fate in the Mississippi Basin
- Dave Mulla, University of Minnesota: Panel overview presentation, comments/reflections on the model presentations related to the capabilities, limitations, uncertainties, and applications of the models

4:30 – 5:30 p.m.

Session 6: Modeling Panel Discussion

Moderator: Tom Simpson, Water Stewardship, Inc.

5:30 – 6:30 p.m.

Evening poster and technology demonstration session

With interactive modeling and decision-making demonstrations and social function

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Friday, December 11

8:00 – 9:30 a.m.

Session 7: Workshop Breakout Discussions

Please report to the room assigned for the breakout discussions:

- Cedar Rapids (Red)
- Council Bluffs (Orange)
- Davenport (Yellow)
- Dubuque (Green)
- Sioux City (Blue)

9:30 – 10:00 a.m.

Break

10:00 – Noon

Closing Plenary and Workshop Synopsis

Closing Panel:

- Otto Doering, Purdue University (Moderator and Opening Speaker)
- Darrell Brown, U.S. Environmental Protection Agency
- Tom Christensen, USDA-Natural Resources Conservation Service
- Craig Cox, Environmental Working Group
- John Kessler, Ohio Department of Natural Resources
- Donna Myers, U.S. Geological Survey

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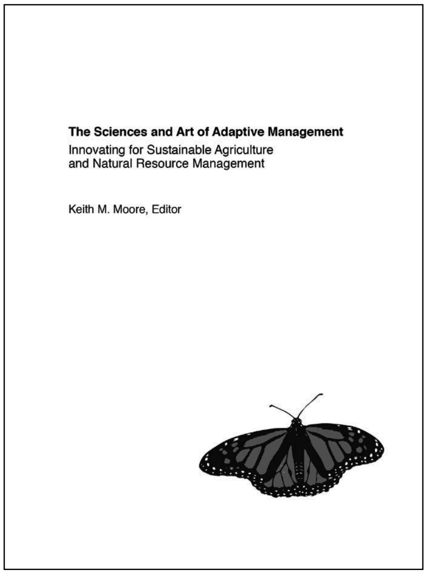
SOIL AND WATER CONSERVATION SOCIETY

New from the Soil and Water Conservation Society



The Sciences and Art of Adaptive Management

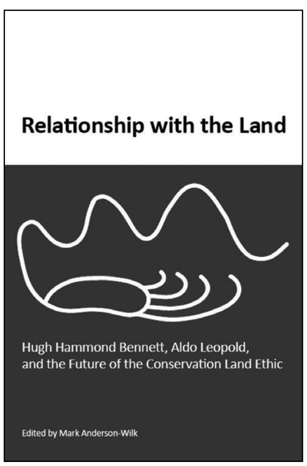
Edited by Keith M. Moore
264 pages
$28/copy
ISBN 978-0-9769432-7-3

This book is the newest addition to the SWCS publications. The 25 authors represent a rich international knowledge base related to sustainable agriculture and natural resource management.

As Moore describes in the preface, "Adaptive management is a structured process of learning by doing." Adaptive management is not just a trendy term of the day; it is an approach that will become even more essential in the future to adequately understand the interlinking systems that affect landscape health and to successfully mitigate negative impacts on the environment. Landscapes are described in the book as "complex adaptive systems." Managing landscape resources requires considering the interplay of many factors, from biophysical to cultural. The book develops an approach that promotes resilient systems over nonresilient systems.

The Sciences and Art of Adaptive Management is an indispensable resource for the conservation community and the basis of much future work—research, policy, and practice.

Relationship with the Land



Edited by Mark Anderson-Wilk
150 pages
$18/copy
ISBN 978-0-9769432-6-6

This book presents an analysis of Hugh Hammond Bennett and Aldo Leopold as developers of the conservation land ethic. Key essays included in this book represent the past, current, and future of environmental ethics.

This is an easy to read and thought-provoking book that has applications to policy, science, and practice. It offers a multidisciplinary look at conservation philosophy.

Relationship with the Land includes four sections:

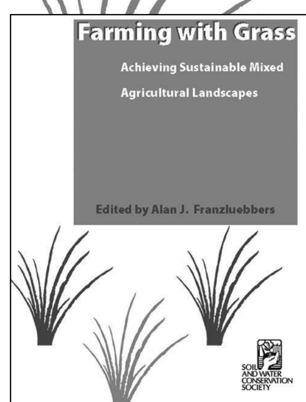
- Hugh Hammond Bennett and the Soil Conservation Movement
- Aldo Leopold and the Land Ethic
- Development of Conservation Thought on Land Stewardship and Natural Resource Values
- The Future of the Conservation Land Ethic

Farming with Grass: Achieving Sustainable Mixed Agricultural Landscapes

While much of United States farm policy, agricultural research, and SWCS advocacy have focused on cropland issues, over half of US agricultural land is in grass. There is great potential to increase the role of grasslands within agricultural landscapes to address diverse environmental concerns.

The Farming with Grass Conference was created to address these issues, and this book assembles the invaluable information from the conference.

Jean Steiner, USDA ARS;
Farming with Grass
Conference organizer



Edited by Alan J. Franzluebbers
E-book, 238 pages
$24/copy

Visit the SWCS Online Store (http://store.swcs.org) or call 1-800-843-7645 (1-800-THE-SOIL) to buy these and other books published by the SWCS

Science to Solutions
Reducing Nutrient Export to the Gulf of Mexico

Papers and Abstracts for Oral Presentations

Session 2: The Human Dimension

Policy Instruments for Addressing Agricultural Nonpoint Source Pollution
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Keywords: water quality, nonpoint-source pollution, economic incentives, standards, education

Water quality is a major environmental issue. Pollution from nonpoint sources is the single largest remaining source of water quality impairments in the U.S. Agriculture is a major source of a several nonpoint-source pollutants, including nutrients, sediment, pesticides, and salts. A fundamental goal of nonpoint source policy is to induce landowners to explicitly consider the costs they impose on society through their production-related activities. An ideal goal of policy is to maximize the expected net economic benefits to society from pollution control. Designing policies to achieve efficiency, however, is often impossible because of the relationship between economic damages and nonpoint pollution is seldom known. Instead policies can be designed to achieve specific environmental goals at least cost, given the policy instruments available to a resource management agency, relevant policy transactions costs, and any other political, legal, or information constraints that may exist.

Four classes of policy instruments have either been applied to nonpoint-source pollution, or are feasible tools. These are economic incentives (positive or negative), standards, research and education, and liability. Policies can be designed to directly influence performance (reduction of discharges to water) or to directly influence technology choices (encourage adoption of "environmentally friendly" practices). Their effectiveness depends on the strength of the incentive provided, and the influence of factors related to the nonpoint source pollution process.

The characteristics of nonpoint-source pollution tend to render performance-based policies infeasible. Research and education can be valuable in a support role, but cannot stand alone. Design-based policies are the most viable options. The characteristics of nonpoint-source pollution and the diversity of resource conditions important to agriculture rule against a single tool being applied to all problems.

An Overview of Socio-Economic Factors that Influence Farmers' Conservation Decisions. What Kinds of Incentives Seem to Work the Best? Emphasis on Social and Cultural Aspects Including Barriers to Adoption

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Keywords: social indicators, adoption, BMPs, nonpoint source, education and outreach

Understanding what motivates farmers to adopt or not adopt conservation practices or Best Management Practices (BMPs) is critical to reducing nutrient export to the Gulf of Mexico. With knowledge about motivations and barriers to adoption, effective education and outreach programs can be implemented. For over 25 years, researchers in the United States have been trying to understand this complex issue largely through surveying farmers. A recently concluded meta-analysis of this literature reveals that there are several variables that are commonly thought to be important to the adoption decision. These variables largely fit into categories of capacity, attitudes, awareness and farm characteristics. Disappointingly, there are no factors that consistently determine BMP adoption. However, there are some variables that generally trend toward having a significant impact on adoption rates. These variables include access to information, awareness, utilization of social networks, and attitudes about environmental quality; these all have a positive relationship more often than a negative relationship with adoption. Evidence from this work suggests that there are few discernable trends about demographic characteristics of farmers.

An important part of the adoption decision focuses not on the farmer but on the actual practice. Qualitative findings from Indiana show that high levels of relative advantage (e.g. reduced inputs, time savings, and on-farm and environmental benefits), compatibility (with farm systems and needs of producer), and observability are most important in increasing adoption of conservation practices. Risk and complexity associated with specific practices were only infrequently found to limit adoption. This work suggests that conservation promoters should generally focus on raising awareness of on-farm and financial benefits of conservation practices, the necessity of practices, and compatibility of practices.

Perhaps the biggest finding from existing research on adoption is that there is no consistent answer. Findings differ by conservation practice, watershed, farm type, etc. This suggests that it is imperative for local conservation promoters to understand their specific audience. Education and outreach programs will be most effective when they are designed locally and based upon social characteristics of the specific audience. Using knowledge of social indicators, researchers in the Midwest have developed education and outreach programs in four watersheds. This talk will conclude with a brief description of how these programs were developed and how they are to be evaluated.

Lessons Learned from Implementing a Market-Driven Certification Program for For-hire Manure Applicators

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Keywords: Market Based, manure, animal waste, incentives, human dimensions

Authors:
Kevin Erb, CCA, Conservation Professional Development and Training Coordinator, UW Extension
Robin Shepard, Executive Director, North Central Cooperative Extension Association

A series of unrelated manure runoff events in 2002 in Wisconsin (80% of which involved for hire manure applicators with less than 2 years experience) convinced the industry that something needed to be done to improve professionalism in the industry. Through their association (Professional Nutrient Applicators of Wisconsin), they approached University of Wisconsin-Extension about putting together a voluntary training and certification program for the industry.

While surveying other states to determine what model might work best, we discovered that Michigan's applicators had made a similar request of MSU Extension. With interest from Extension in Illinois, we created a 3 state model of voluntary training and certification, and received initial funding from NIFA (CSREES's) 406 grant program that met the needs of applicators in all three states.

Early on, we heard from applicators in states with mandatory programs that a top down approach did not create motivation in the field employee to improve their performance. That realization led us to work intensively with the applicators in the three states to determine what approach would be most effective in not only reducing risk, but would motivate firms and employees towards continual improvement. We spent time understanding what other challenges faced the industry (pollution liability insurance, road weight limits, regulations) and asked the questions "Which other problems can we solve?" and "What can we do to motivate private businesses to participate in a voluntary program?"

Using this and our needs analysis as the basis, Extension created a 3-tier or 3 level program for the industry, balancing the needs and desires of the industry with a financial incentive for participation.

- Level 1: Basic training and testing for each field employee.
- Level 2: Advanced technical training for crew supervisors.
- Level 3: EMS/ISO 14001 implementation

The program progresses through three certification levels. Firms must meet Level 1 requirements to gain Level 2, and meet Level 2 requirements to achieve Level 3.

• Level 1 provides information on spill response, common sense application and handling, road safety issues, confined space safety, and Wisconsin nutrient management planning and regulation. An exam is given at the end of the training to help evaluate learning, reinforce educational messages and improve subsequent training and teaching performance.

• Level 2 requires crew supervisors and business owners to complete 6 to 8 hours of continuing education every two years. The Level 2 program covers topics such as manure application and handling, safety, sensitive area identification, financial planning, business management, environmental issues, and employee relations.

• Level 3 requires business owners to develop and implement an Environmental Management System (EMS) plan for their business. The EMS requires documentation of environmental performance and implementation. An independent audit is conducted every 12-18 months by an independent 3rd party to insure compliance and improve the EMS impact.

To meet the needs of the industry, we sought out insurance industry partners who would provide a financial incentive to firms participating in the program. Five companies agreed to provide a 10% discount on general liability premiums if the firm completed Level 1 and additional discounts of 10% to 40% if the firm completes level 3. Premiums for $1, 000, 000 pollution polices have held steady for 4 years due to our improving track record, and participating firms can achieve a 50% premium reduction for level 3 certification.

Saving small businesses $500-$8, 000 per year has a significant impact on their bottom line, as well as playing a powerful incentive for implementation. The insurance underwriters and agents have also taken the responsibility of the annual audits of level 3 certification, saving an average of $500 in agency expense each year for each firm in the program. The 3rd party auditors also documented an 80% drop in claimable incidents for firms completing level 3.

More than half of the applicators in Wisconsin participate annually, and the program's insurance discounts have proven so popular that firms in 4 states with mandatory programs also complete Level 3 to earn the discounts.

Our overall objective when we started was to reduce manure spills and increase nutrient management plan implementation. Spill numbers have increased in each of the three states, but regulatory agency staff attribute this to the fact that both for-hire applicators and farmers are more willing to report spills than they were in the past. But we also know that when spills happen, the environmental impact is significantly lessened.

- between Dec 01-Apr 02, 80% of reported incidents involved professional applicators
- between Dec 04-Apr 05, <15% did.

On the path to certification, an unexpected thing happened: The for-hire manure applicators began talking to each other. Prior to this project, these small businesses viewed each other as fierce competitors. As they have helped develop the training program, they have seen that while they still compete for the same clients, they can work together as well. Examples of such partnerships include sharing equipment innovations, sharing expensive, underutilized equipment and firms working together to keep farmers in compliance with environmental regulations.

The UMRSHNC Workshop; the Basis for the Cedar River Watershed Case Study

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Keywords: nutrients, TMDL, nitrate, nitrogen

In September 2005 the Upper Mississippi River Sub-basin Hypoxia Nutrient Committee (UMRSHNC) organized a workshop on "Gulf Hypoxia and Local Water Quality Concerns" to assess tools to reduce agricultural nutrient losses to water resources in the Corn Belt. Authors were identified to participate in the workshop and to write a paper to be presented and critiqued at the workshop. The paper was not to be an extensive literature review, but more a consensus and expert opinion on the topic. As such, only a limited amount of pertinent literature was cited.

The topics covered were:

- Importance of hydrology/land-use on nutrient transport.
- Potential of improved water mgt. to reduce nitrate-nitrogen leaching losses.
- Off-site practices (wetlands/buffer strips) to reduce nutrient export.
- Nitrogen management (rate, timing, forms, additives) to reduce losses.
- Fertilizer- and manure-phosphorus management. to reduce losses.
- Benefits of erosion control on reducing nutrient losses.
- Use of cover crops/living mulches/perennials to reduce nutrient losses.
- Avoiding actions with unintended side effects (e.g., reduced soil quality).
- Field- and watershed-scale tools for planning.
- Evaluation of management changes in reducing nutrient losses.
- Where to from here?

Relative to the importance of hydrology/land use, the emerging science suggests that current nutrient impairment problems are not mainly due to mismanagement of fertilizers and manures, but more to historic change in land use and hydrology that came with the conversion of prairie and wetlands to cropland. The authors of the "Integrated Assessment" also recognized the importance of hydrology and site-specific information when they stated: *"Any program for reducing N loading to the Gulf should consider local hydrologic conditions and the characteristics of agricultural production, the resource base, and the producers."*

A major part of the historic change in hydrology was the installation of subsurface drainage in wet but productive areas which allows timely tillage, planting, chemical application, and harvesting for row-crop production – currently primarily corn and soybean. The hydrologic effects of subsurface drainage on a field-scale are:

- Increases infiltration rate/volume
- Delays initiation of surface runoff
- Reduces surface runoff volume
- Possibility increases subsurface drainage
- Possibility decreases deep percolation/recharge

On the watershed-scale, it is less clear how subsurface drainage affects total and peak flows, especially as related to floods – this is an area that needs additional research. The water quality benefits of delayed and reduced surface runoff with subsurface drainage are reduced losses of:

- sediment
- phosphorus

- ammonium-nitrogen
- pesticides
- micro-organisms
- anti-biotics

However, the increased subsurface drainage increases nitrate-nitrogen leaching losses.

The current understanding on nutrient losses relative to two opposing agricultural landscapes is that:

- In tile-drained landscapes:
  - Nitrogen losses are greater
  - Carrier, subsurface drainage water
  - Dominated by nitrate form
  - Occur with sustained flows
  - Usually in spring at time with little ET/nutrient uptake
- In "rolling" landscapes with good surface drainage:
  - Phosphorus losses are greater
  - Carriers, runoff water and sediment
  - Usually dominated by phosphorus in sediment
  - Occur with "flashy" rainfall-runoff events
  - Year around, worse in spring with less vegetative cover

The general conclusions that can be derived from the workshop are:

- Soil nutrient levels must be sufficient for good crop growth.
- Whenever excess water moves, nutrient losses will occur.
- Nutrient impairment problems are not mainly due to "excess nutrients", but historic changes in land-use and hydrology.
- Some improvement in in-field nutrient management is possible, but off-site practices also are needed.
- Targeting/site-specific design is necessary.
- Economics must play a role, especially in considering land-use changes.
- No easy answers; improvements will be incremental.
- Must avoid promotion of wrong practices.
- Care must also be taken in "promising too much;" variability in weather dominates both short- and long-term outcomes.

Information from the workshop on the expected efficiency of various management tools in reducing nitrogen losses was used in a "case study" of Iowa's Cedar River watershed. This study is funded mostly by the state of Iowa through the Iowa Department of Agriculture and Land Stewardship, with some funding also through an EPA grant to UMRSHNC. A 13-member team made up of personnel from Iowa State University, the Iowa Farm Bureau, and state and federal agencies, have augmented the physical efficacy data from the workshop with cost estimates for implementation of chosen practices.

Currently there is a TMDL for the Cedar River watershed because the river is a drinking water source for the city of Cedar Rapids, and the nitrate-nitrogen levels sometimes exceed the 10 mg/L drinking water standard. The goal is to reduce maximum nitrate-nitrogen concentrations to 9.5 mg/L (using a 5% safety factor), and it is estimated that it will take a 35% reduction in nitrate-nitrogen load to achieve that concentration goal. This amounts to 10, 000 tons a year, which is equal to 5.5 lb/ac/yr over the 3.6-million acre watershed; the estimate of current loss is 15.6 lb/ac/yr. The non-point source allocation is 92% of the total or 9, 200 tons a year. The watershed is about 73% row-crop, mostly corn rotated with soybean; about 4% of the watershed is in continuous corn. It is estimated that two-thirds of the watershed has subsurface drainage. Annual precipitation averages about 34 inches, and stream flow averages about 8 inches, with "base flow" being about 65% of the total. Because the newly revised nutrient reductions goals for reduction of hypoxia in the Gulf of Mexico include both total nitrogen and total phosphorus, and are 45% for each, these values were also taken into consideration, although decisions on specific practices and costs to needed to achieve those goals have not as yet been made. Phosphorus is a particular problem because of the difficulty of translating field-loss reductions to in-stream and Gulf-of-Mexico-delivery reductions.

The potential nitrogen management practices chosen to be considered to achieve the TMDL nitrate-nitrogen reduction goal for in-field were: nitrogen rate, nitrogen timing, cover crops, and water management. Conservation tillage, particularly no-till, has some potential to reduce nitrate-nitrogen leaching concentrations, but because there is the potential for increased leaching volumes that could offset lower concentrations, it was felt the beneficial effect was not consistent enough to warrant analysis at this time. The off-site practice that was chosen to be considered was constructed wetlands. Buffer strips, which have the potential to reduce transport of other agricultural pollutants, were not considered as an off-site practice to reduce nitrate-nitrogen losses in this landscape because tile drains passing under the buffer strips "short circuit" their effect.

Relative to nitrogen rate, the starting point, or current nitrogen application rate on corn is critical. NASS fertilizer data for 2005 for four northeast Iowa sub-regions averaged 124 lb/yr. Data on nitrogen fertilizer sales, which are taxed in Iowa, indicate that for 2001-05 the state-average for nitrogen applied to corn was 137 lb/ac. ISU recommendations for nitrogen applied to corn following soybean is a range from 100 to 150 lb/ac; for corn following corn, it is from 150 to 200 lb/ac. It is estimated that there may be as much as 35% additional nitrogen available in the watershed from manure generation. Taking manure storage and application losses into consideration, it was decided to use 150 lb/ac for the starting point for analysis of corn following soybean, and 200 lb/ac for continuous corn. Using relationships for nitrogen rate effects on nitrate-nitrogen concentrations in subsurface drainage from corn and soybean and on corn yields developed in the UMRSHNC workshop, and assuming $4.00 a bushel for corn and nitrogen costs of $0.40/lb, the results shown in Table 1 were generated for reducing the nitrogen rate 50 lb/ac for both rotations (i.e. from 150 to 100 lb/ac or 33% for corn-soybean, and from 200 to 150 lb/ac or 25% for continuous corn). Note that the leaching loss reduction was not proportional to the nitrogen rate reductions, being less at 25 and 20%, respectively, for corn-soybean and continuous corn. Because the cost associated with a reduced corn yield with reduced nitrogen application is spread over two years (i.e. the effect of reduced nitrate-nitrogen concentrations occurs in the soybean year too), the cost efficiency for reduced rate is better for the corn-soybean rotation. This efficiency is also better because of slightly greater nitrate-nitrogen loss reduction at a slightly lower reduction in corn yield.

However the practice of lowering the nitrogen rate at best only reduces nitrate-nitrogen losses 25% relative to a TMDL goal of 35% (or a hypoxia goal of 45% for total nitrogen, of which nitrate-nitrogen is roughly only two-thirds). Table 2 shows the cost of trying to use a further reduction in rate, another 50 lb/ac for a total of 100 lb/ac, to achieve a further reduction in nitrate-nitrogen losses. As shown, one could achieve the 35% reduction, but now the costs become much greater. In addition, at these rates, the concern for the nitrogen mass balance and possible enhanced depletion of soil organic matter is even worse.

Relative to nitrogen application timing, nitrate-nitrogen leaching data from southern Minnesota reported at the UMRSHNC workshop indicates that leaching losses might be as much as 15% less for spring versus fall application (although limited data from one site in north-central Iowa has failed to demonstrate any differences due to timing). In Iowa, 25 to 33% of nitrogen is usually applied in the fall; mostly in the ammonia form. It is estimated that the additional infrastructure needed if all nitrogen had to be applied in the spring might add $0.05/lb; however, that increase would be applied to all nitrogen sold, not just that normally sold in the fall. Assuming a 15% reduction in loss with a spring application would equate to about $6.00/lb of nitrate-nitrogen loss reduction. It is believed that more definitive data are needed to determine if side-dressing/split applications have significant potential to reduce nitrate-nitrogen leaching.

Relative to cover crops, results from the UMRSHNC workshop and recent plot data from the USDA Soil Tilth Laboratory indicate that fall-planted rye or ryegrass planted in the fall after harvest will sequester soil nitrogen and prevent it from leaching. The reduction in nitrate-nitrogen leaching loss is estimated to be 50%. Further it is estimated that it would take a $30/ac incentive payment to cover the costs for seed, planting, dealing with the living plants in the spring, and possible crop yield reductions. This would equate to a cost of about $3.00/lb of nitrate-nitrogen leaching loss reduction. Oats were also considered; the cost would be slightly less due to winter-kill, but the reduction in leaching with oats as a cover crop is also believed to be less.

Relative to drainage water management, decreases in nitrate-nitrogen leaching losses from fields within the Midwest with water management or “controlled drainage” were calculated, using the RZWQM model, to be about 50% for a corn-soybean rotation. It was assumed that one-half of the drained soils with slope class of 0-1% and one-fourth of the drained soils with slope class of 0-2% are suitable for drainage water management; for the Cedar River watershed this translates to 167, 000 ac or about 5% of the total land area. It was assumed each drainage control structure installed would cost $1000, and that one structure is needed for every 12 ac of existing drainage system or for every 20 ac for newly installed pattern drainage systems. If a 20-yr life and 4% interest rate is assumed, and $10/ac incentive is paid for management, the cost for nitrate-nitrogen leaching loss reduction would be $1.56/lb.

Relative to constructed wetlands, monitoring and modeling reported in the UMRSHNC workshop proceedings indicate that an Iowa wetland, with an area 0.5 to 2% of the drainage area, would be expected to remove via denitrification an average of 50% of the nitrate-nitrogen input to the wetland with subsurface drainage. Establishment costs based on Iowa CREP program data average $250 per acre of “treated field.” If a 50-yr life and 4% interest rate is assumed, the cost for nitrate-nitrogen leaching loss reduction would be $1.45/lb.

Table 3 below gives one example scenario of practices to reduce nitrate-nitrogen leaching losses 35%. These practices are only considered effective on and applied to the two-thirds of the row-cropped area that has subsurface drainage. In this scenario, the nitrogen rate on all corn grown is reduced 50 lb/ac, all fall application would be avoided, and drainage water management would be applied to all suitable area. Rye cover crops would be applied to 10% of the cropland area, and wetlands would be constructed to receive drainage from 45% of the cropland area. One disadvantage of multiple practices applied to the same area is that the nitrate-nitrogen loss reduction effects are multiplicative and not additive. For this scenario, the total cost is $20.69 million or $1.12/lb of nitrate-nitrogen leaching loss reduction. To achieve an additional 10% loss reduction to get to a 45% goal would require applying more cover crops and wetlands at greater costs ($3.00 and $1.45) per lb reduction. For additional perspective, the total subsurface drainage area in the state is about five times that in the Cedar River watershed.

Table 1. Results for a 50 lb/ac nitrogen application reduction on corn.

	Corn soybeans	Continuous corn
assumed initial rate (lb N/ac)	150	200
nitrate loss	20.8 lb/ac/yr	24.2 lb/ac/yr
loss reduction with 50 lb/ac N rate reduction (33 &25%)	25%	20%
nitrate-N loss reduction	10.5 lb/ac* * over two-year rotation	4.8 lb/ac
corn yield reduction	5.3 bu/ac	5.7 bu/ac
cost of N loss reduction	$0.10/lb	$0.57/lb

Table 2. Results for a 100 lb/ac nitrogen application reduction on corn.

	Corn soybeans	Continuous corn
assumed initial rate (lb N/ac)	150	200
nitrate loss	20.8 lb/ac/yr	24.2 lb/ac/yr
loss reduction with 100 lb/ac N rate reduction (67 & 50%)	39%	36%
nitrate-N loss reduction	16.3 lb/ac* *over two-year rotation	8.8 lb/ac
corn yield reduction	20.8 bu/ac	19.7 bu/ac
cost of N loss reduction	$2.66/lb	$4.40/lb

Table 3. Example scenario to reduce nitrate-nitrogen leaching losses 35%.

Practice	% reduction	Acres* treated	Tons reduced	Cost per lb	Total cost/yr
150 to 100 N rate - CB	25% or 5.2 lb/ac/yr	all or 1.6 M ac	4, 160	$0.10	$0.83 M
200 to 150 N rate - CC	20% or 4.8 lb/ac/yr	all or 0.10 M ac	240	$0.57	$0.27 M
Avoid fall application	15% or 2.5 lb/ac/yr	all or 300, 000 ac	375	$6.00	$4.50 M
Rye cover crops	50% or 8 lb/ac/yr	10% or 170, 000 ac	680	$3.00	$4.08 M
Water mgt.	50% or 8 lb/ac/yr	10% or 167, 000 ac	670	$1.56	$2.09 M
Construct. wetlands	50% or 8 lb/ac/yr	45% or 0.76 M ac	3, 075	$1.45	$8.92 M
TOTALS		[*2/3 of 2.55 M crops drained]	9, 200	$1.12	$20.69 M/yr

Session 3: Lessons Learned: Small Watershed Studies

Overview of the Neuse River Basin and CSREES CEAP Watershed Studies

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Over the past four decades, considerable resources have been invested in programs implementing conservation practices on the nation's farms in an effort to reduce the impacts of nonpoint source (NPS) pollution on the nation's waters, restore and protect soil and water quality, and foster continued agricultural productivity. While an extensive body of research has documented the effectiveness of conservation practices in reducing pollutant delivery from farm and range land at the plot- or field-scale, fewer studies have adequately or successfully evaluated the cumulative effects of programs of conservation practices implemented at the watershed scale. Historically these national watershed studies (Model Implementation Program, Rural Clean Water Program, Hydrologic Unit Area and Demonstration, and the Section 319 National Nonpoint Source Monitoring Program), which started in the late 1970s, have built on each other. In addition to federally funded watershed programs, there have been many state efforts to relate agricultural conservation practices to water quality changes. This talk will highlight lessons learned from one state project (the Neuse River Basin in North Carolina) and one federal effort (CSREES-Conservation Effects Assessment Project (CEAP)). Both the state and federal efforts have attempted to use conservation practices to reduce nutrient pollution from agricultural activities.

The Neuse River Basin drains 1.2 million acres in central and eastern North Carolina, including rapidly growing metropolitan areas, productive farmland, and extensive forests. The Neuse River Estuary has experienced harmful algae blooms and fish kills over the past three decades, resulting in state regulations mandating 30% reductions in annual nitrogen loading from all sources by 2003. These regulations, referred to as the "Neuse Rules were implemented in 1997.

Agricultural land uses throughout the Neuse River Basin are estimated to contribute more than half of the total nitrogen load to the estuary. Producers were expected to implement best management practices that would reduce nitrogen export by over 1 million pounds annually. The Neuse Rules prescribed that any individual who applied nutrients to 50 acres or more must either use a certified nutrient management plan or attend nutrient management training conducted by NC Cooperative Extension. Extension specialists in the Soil Science department developed a comprehensive nutrient management training program targeted to farmers and agribusiness professionals. Extension agents trained over 2, 000 farmers, lawn care personnel, and container nursery professionals in a 2-year period. Our results suggest that the training has not made a difference in nutrient management implementation.

Farmers in the Neuse were required to use mandatory conservation practices or join a local area committee that would demonstrate at least a 30% N reduction using a nitrogen tracking tool. The Nitrogen Loss Estimation Worksheet (NLEW) was the tool developed to track nutrient management implementation and nitrogen reductions. Despite NLEW information suggesting that producers have reduced nitrogen by 40% through the combined use of nutrient management, crop and land shifts, and conservation practices, data suggests that conservation practices may not be as effective as originally believed because the practices are not being implemented or have been implemented in the wrong landscape position.

Despite over 12 years of work in the Neuse River basin and a reduction of nitrogen from point sources of over 70%, total loading of nitrogen in the Neuse Estuary has remained essentially unchanged. It is unclear as to the reasons that nitrogen has not been reduced despite serious efforts by all nutrient contributors - point, agricultural and urban sources.

An on-going federal effort to relate water quality changes to conservation practices revolves around the federal CEAP projects. These projects were targeted to evaluate the impacts of interactions among conservation practices and their biophysical setting on water quality at a watershed scale, while simultaneously evaluating social and economic factors that influence implementation and maintenance of practices. The project was also designed to conduct outreach education for knowledge transfer from this effort to farmers, ranchers, community leaders, and other stakeholders. Besides the 14 USDA-Agricultural Research Service (ARS) Benchmark Watersheds and 10 USDA-NRCS Special Emphasis Watersheds, there are 13 USDA-CSREES Competitive Grants Watersheds.

These CSREES-CEAP projects have finished or are finishing and the results and lessons learned are being currently being synthesized. This science-based evaluation (synthesis) is focusing on the effectiveness of suites of conservation and land management practices, as influenced by timing and the spatial distribution throughout a watershed, and with respect to their cumulative influence on water quality.

To date, 7 of the 13 projects have been completed or are almost complete. Based on information developed by these projects and site visits, about half of the projects have been able to demonstrate water quality changes relative to conservation practice implementation. There are multiple reasons why not all projects have been able to demonstrate the effectiveness of conservation practices ranging from difficulty with water quality monitoring designs to insufficient land treatment. Preliminary lessons learned from the CSREES-CEAP projects will be presented in further detail.

Notes

Lessons Learned from the ARS CEAP Watershed Assessment Studies
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The Conservation Effects Assessment Project (CEAP) has two major components: 1) a National Assessment and 2) a Watershed Assessment Study (WAS, including ARS, CSREES [now NIFA], and NRCS Special Emphasis Watersheds). The National Assessment uses NRCS data and ARS watershed-scale models to estimate conservation benefits at the national scale. Within WAS, the ARS Benchmark Watershed Assessment Study has since 2003 assessed effects and benefits of conservation practices at the watershed scale. The WAS goals are to provide detailed assessments of conservation programs in a few selected watersheds, a framework for improving the performance of the national assessment models, and support for coordinated research quantifying effects of conservation practices across a range of resource characteristics (e.g. climate, terrain, land use, and soils). The results have advanced our knowledge of how watershed scale assessments can capture impacts at multiple scales. They have also improved our understanding of what conservation practices can and cannot provide beyond the edge of a farm field.

Fourteen ARS Benchmark Watersheds support watershed-scale assessment of environmental effects of USDA conservation program implementation. Thirteen of these represent primarily rainfed cropland and one is entirely irrigated. Many contain some areas of grazingland, wetlands, and confined animal feeding operations. Environmental effects and benefits have been estimated primarily for water and soil resources, with some assessment of wildlife habitat and air quality benefits in a few watersheds. The benchmark watersheds and their ARS units are located in Pennsylvania, Maryland, Ohio, Indiana, Georgia, Iowa, Missouri, Mississippi, Oklahoma, Texas, and Idaho, with modeling research being conducted in Colorado and Oregon. Of these, the Ohio, Iowa, Missouri, Mississippi, and Oklahoma watersheds drain into the Mississippi River and are thus directly relevant to the Gulf Hypoxia theme of this conference. The Indiana watershed drains to Lake Erie, but represents the conditions in southern Indiana that are within the Mississippi River Basin (MRB). Likewise, much of the research in other watersheds has also provided results that are applicable to the MRB.

The CEAP results to date illustrate how critical it is to fully understand the system being considered for conservation practices. Furthermore, as there are a number of potential contaminants, BMP choices must be balanced among them and accommodate the complex, dynamic environmental interactions associated with each site. Often, we have observed that BMPs implemented for and successful in mitigating one environmental concern have caused an unintended increase in offsite effects of another contaminant. Changing public interests and knowledge have prompted re-interpretations of some research and asked questions that must be pursued using different experimental designs. To fully measure environmental effects of a BMP, we need to know information about flow, sediment, nutrients, and sometimes pesticides, pathogens, and emerging issues such as antibiotics and endocrine disruptors. It is also important to recognize what producers have already done and what limitations (e.g. time, labor, economic) they face.

One example of the complexity of BMP interactions is provided by the Iowa watershed studies. In the South Fork of the Iowa River, ARS scientists found that during the past 150 years, an average of 2.6 feet of sediment has been deposited in the floodplain, affecting an area up to 260 feet wide. This deposition and concurrent loss of floodplain storage likely causes higher stages and exacerbated flooding. Furthermore, channel straightening increases flow velocity and bank erosion. Another study showed distinguishable land use (watershed treatment) and climate trends (time) through simultaneous shifts in how energy (evaporative demand) and water (precipitation) were partitioned. In four Midwest watersheds, the observed trend toward increasing discharge was more attributable to climate change than land-use change. The assessment methodology allows subtle cause-effect relationships to be teased out of an extremely dynamic hydrologic signal.

At several CEAP watersheds (e.g., MS, IA, and MO) it has been demonstrated that channel sources of sediment are dominant at certain times, and are substantially larger on a long-term basis than previously thought. Thus, upland erosion practices may have less impact on sediment load at the watershed outlet than stream bank stabilization practices. Reducing sediment load is relevant to hypoxia because some nutrients (e.g., P) bind to sediments and are thus transported with them.

Reducing sediment alone may not be sufficient to reduce environmental effects if the dissolved nutrient load is unchanged and significant. In this regard, several BMPs that substantially reduce erosion and sediment transport may actually exacerbate dissolved phase transport. The net effect depends on the balance between sediment-bound and dissolved nutrients, and there is no single answer that dominates. In several locations, tile drains, pothole risers, and parallel terrace risers have been shown to allow dissolved nutrients to bypass parts of the landscape (including some BMPs) and be deposited directly into streams. In an effort to maintain the trafficability, productivity, and erosion control benefits of these practices, a number of BMPs have been studied that mitigate nutrient loads before their discharge into streams or drainage ditches. These include blind or French drains instead of risers in potholes (IN), C-rich materials placed between the tile and the ditch for tile drainage (IA), and wetlands or buffers intercepting underground outlets from parallel terraces (MO). Another approach, used in OH and elsewhere, has been to reduce the wintertime flow of water and dissolved nutrients by raising flashboard risers or other devices during the off season.

Modeling results from a number of watersheds suggests that local knowledge of the system is required to satisfactorily calibrate and validate watershed-scale models of hydrology and contaminant transport. Knowledge of unusual soils or land use practices, beyond the local information on land use, soils, and weather, has usually been incorporated into the models, contributing to make them more applicable to other contexts. This illustrates that modeling, without benefit of the local information, may arrive at less than optimal results.

Two critical lessons learned from WAS research are that a number of unanswered questions remain, and that answering them may prove troublesome. For instance, catastrophic episodes of flooding and erosion have been observed and found important over longer and broader timeframes. Understanding these events remains a critical need for research. Another question that the CEAP watershed studies should be poised to address is the impact of climate change on agriculture. Based on preliminary indications, substantial progress toward scaling results is expected. Continued improvement in the performance of watershed models is also expected as a result of research in these watersheds. From a national perspective, the benchmark watershed studies have provided and are expected to continue to provide rigorous science in support of conservation policy.

Water-quality Monitoring Data and Water-Quality Trends in the Mississippi River Basin and the Upper Midwest

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An important component of most watershed modeling studies is assembling a water-quality database that can be used to calibrate and/or verify the accuracy of the models being used. As part of developing regional SPARROW (SPAtially Referenced Regression on Watershed attributes) models for the United States, a nutrient database was created from data collected from 1970 through 2007 by 186 federal, state, and local agencies and universities at over 125, 000 stream sites. After screening these data (to identify sites with sufficient coinciding water-quality and streamflow information), data from 2, 755 sites from 73 sampling agencies were available for estimating nutrient loads required in SPARROW modeling. Data from these sites are now available to be used in other water-quality studies. The final sites cover the areas being modeled by the regional SPARROW models, demonstrated here for the Mississippi River Basin, and represent a wide range in nutrient concentrations, loads and yields, as well as watershed sizes and environmental characteristics.

In addition to being used in water-quality modeling, these data can be used to quantify trends in nutrient concentrations and loads. Data collected from streams throughout the Upper Midwest demonstrate general decreases in total phosphorus concentrations and loads from 1970 to 2007, except in eastern North Dakota where concentrations and loads increased at most sites. Trends in total nitrogen concentrations and loads, however, were more variable in comparison to total phosphorus. Decreases in total nitrogen concentrations and loads were found in northern parts of North Dakota, Minnesota, and Wisconsin, eastern parts of West Virginia, Pennsylvania, and New York, and Kentucky; whereas, increases in total nitrogen concentrations and loads were found in Iowa, southern Minnesota, and southern Wisconsin.

The number of sites in the Mississippi River Basin and Upper Midwest that are potentially suitable for computing loads increased rapidly following the Clean Water Act in 1972 but has decreased since about 1980. Recent decreases in monitoring sites are likely due to a combination of a decreasing number of sampled sites and some agencies not incorporating their information into databases readily accessible by outside researchers.

Data Gaps that Impede the Assessment of Nutrient Exports from Agricultural Landscapes and the Effects of Conservation Practices

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Despite the progress made in recent decades in understanding the effects of agricultural practices on nutrient exports and water quality, important data gaps remain. Some of these gaps are significant enough to prevent or reduce the potential to understand agriculture's effects on nutrient losses, quantify the impacts of conservation practices, and use adaptive management to develop and implement improved policies and practices.

Two types of data gaps will be addressed. The first consists of data that are not currently collected because they are too difficult, complex, or expensive to measure with adequate temporal and/or spatial resolution. Examples include fertilizer and manure application rates, timing, and method at the site-specific level, soil quality information, nitrogen transformation processes, and even site-specific weather. One data gap that is increasingly identified as critical in recent years is the location of agricultural drainage, which was last collected by the agricultural census in 1985. Because subsurface drainage has a critical effect on nitrate export, efforts to assess watershed-scale nutrient exports cannot succeed without filling this critical data gap.

The other type of gap includes data that are collected, but not currently made available to researchers or decision-makers who could use the data to improve policies and practices, because of privacy concerns. Most important are the locations of conservation practices implemented through USDA programs. Farm Bill privacy requirements have prevented access to precise location information, even for research focused on determining the water quality impact of conservation practices in response to the need for accountability and cost-effectiveness of the nation's conservation programs. If geospatial location data were available, modern simulation models could be utilize ever-improving data on soil, topography, and cropping practices to determine the disproportionate effect of practices installed at various locations in the landscape. Impacts of this data gap, and how researchers are attempting to bridge the gap, will be discussed.

Accounting for the contribution from point sources and urban land uses to nutrient delivery into the Gulf of Mexico

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Accurate accounting of the nutrient loads contributed by point source discharges of wastewater and by diffuse sources in urban areas is important for developing science-based solutions for reducing nutrient loads from the Mississippi-Atchafalaya River Basin into the Gulf of Mexico. National watershed-based regression models (SPARROW) estimate that urban and population sources account for about 10 percent of the nutrient load delivered to the Gulf of Mexico, but these models are based on surrogate measures of urban sources and do not distinguish the relative contribution of point and diffuse sources. Recent advances by the USGS and USEPA in estimating nutrient loads in point source discharges throughout the Basin begin to address this limitation; however, due to minimal effluent monitoring of nutrients in the Basin the loads are estimated from indirect measurements and are subject to error. These concerns may limit understanding of load contributions at the watershed scale. We describe and evaluate the remaining data gaps and look ahead to changes in policy and improved understanding that may help fill these gaps.

Notes

Riverine nutrient export from Iowa watersheds and relationships to landscape properties and agricultural land uses/management

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Within Iowa and many other Midwestern cornbelt states there is increasing concern related to nutrient loss from agricultural lands. In particular, there is concern about nitrate-nitrogen loss and subsequent impacts on downstream water quality both locally and regionally. As a result there is a need for tools that can be used by a variety of stakeholders to increase the understanding related to the impacts of agricultural management practices. Riverine nitrate-nitrogen export is strongly influenced by the percent row-crop in a given watershed with the majority of the nitrate-nitrogen from row-crop land being transported to streams through subsurface drainage systems due to higher nitrate-nitrogen concentrations compared to surface runoff. In addition, monitoring studies have measured dramatically lower nitrate-nitrogen concentrations in drainage systems from grass/alfalfa cover versus corn-soybean cover. Within row-crop land, nitrate-nitrogen concentrations exiting drainage systems can vary greatly depending on in-field nitrogen management practices. One of the main management practices that influences nitrate-nitrogen concentrations is nitrogen application rate. In-field management impacts the export of nitrate-nitrogen through tile lines, but concentrations and losses are highly variable with time because they are also strongly influenced by local weather conditions. However, use of long-term monitoring data provides information that can be used to estimate the impact of in-field management on nitrate-nitrogen loss.

Understanding how nitrogen management impacts nitrate-nitrogen concentration in tile drained lands is important for estimating nitrogen loss to streams and for working with stakeholders to understand the impacts of in-field nutrient management on downstream water quality. Using long-term monitoring data from replicated plots, a regression model has been developed that relates nitrate-nitrogen concentration in tile lines to nitrogen application rate on corn. This provides a simple tool that can be used to estimate how changes in nitrogen application rate may impact nitrate-nitrogen concentration in tile lines. Simple small-scale models such as this have limitations in that they may not truly reflect the response in all cases due to site differences including weather conditions and soil variables. However, a simple tool such as this regression model is understandable to a range of stakeholders.

This estimated relationship between nitrogen application rate and nitrate-nitrogen concentrations was recently utilized in a Cedar River Case Study conducted in Iowa. This case study looked at a suite of practices to reduce nitrate-nitrogen export to the Cedar River. The impact of nitrate-nitrogen concentration was estimated using the relationship between application rate on row crop land in the watershed and then applying a rate reduction. For example, if the present nitrogen application rate on corn in a corn-soybean rotation was 150 lb-N/acre (168 kg-N/ha) and this rate was reduced by 50 lb-N/acre (56 kg-N/ha) to an application rate of 100 lb-N/acre (112 kg-N/ha) on all corn acres in a corn-soybean rotation, it is estimated that there would be a nitrate-nitrogen concentration reduction of 25% due to the 33% rate reduction. This nitrate-nitrogen response curve can also be coupled with a yield response curve relating corn yield to nitrogen application rate.

From this, the cost or benefit to a producer as a result of reducing nitrogen application rate can be computed based on crop and nitrogen prices. In some cases where producers are applying nitrogen at rates exceeding the economic optimum nitrogen application rate there can be an economic as well as environmental benefit of reducing application rate. From this case study it was evident that a critical piece of information in any assessment of how management practice changes might be expected to impact nutrient loading is the starting point of nutrient inputs. Not only is the average application rate important but also the range and distribution is important since the nitrate-nitrogen response curve is non-linear. Knowledge of the distribution of nutrient inputs including spatial distribution would be important for future assessments as well as targeting of educational programs or implementation of best management practices.

Riverine Nutrient Export in the Mississippi Basin and Relations to Watershed Inputs and Balances

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Riverine nitrate-N and P fluxes from the upper Mississippi River basin (MRB) have been identified as the dominant source area contributing to the overall load of N and P to the Gulf of Mexico, which is a major contributor to the hypoxic zone that forms each summer. The upper MRB has the most productive soils in the basin with intensive agricultural production, predominately corn and soybean, often at 90 to 95% of watershed areas, with a landscape that has undergone extensive hydrological modifications. These hydrological modifications include channelization of the headwater streams and intensive tile (subsurface, artificial) drainage to lower water tables and efficiently route water to streams. However, nitrate-N, total and reactive P, and pesticides can easily move to streams during tile flow), and much of the annual loss can occur during a few days to weeks in the winter and spring. Many modeling methods have been utilized to better understand the source areas of nitrate in the MRB. These methods typically focus on inputs of N and P (fertilizer, atmospheric deposition, manure, and sewage effluent), and then relate the inputs to riverine loads. One method has used net N inputs (NNI, or sometimes NANI, net anthropogenic N inputs) to relate inputs and outputs of N at various scales, typically utilizing state or regional data. Net N inputs is thought to be the N available for leaching and therefore riverine export, field denitrification losses, or additions to the soil N pool. Many studies have found that for large regions about 25% of NNI was exported through rivers. In tile drained regions, however, this percentage can equal 100% or more of NNI. Recent mass balances in the cornbelt have also indicated that NNI is not large enough to account for losses, and that a small net depletion of soil organic N may be occurring. These recent observations about NNI suggest that this metric may not be that useful in the tile-drained Midwest in predicting nitrate export.

None of these modeling or NNI approaches has used recent data at the county scale, combined with one of the most critical landscape factors, tile drainage, to examine the source areas of and controls on nitrate-N and total P across the MRB. Therefore, our objectives were to: 1) relate agricultural and human inputs and outputs of N and P across the MRB to winter/spring riverine nitrate and total P export utilizing a county scale data base, and 2) determine the most important drivers and areas leading to riverine nitrate and total P export. We utilized readily available, multi-year and recent data for the MRB, and focused on the flow period known to be important in causing hypoxia, rather than annual data. This analysis will help to identify where in the MRB conservation efforts, or changes in agricultural production systems, will need to be targeted if the type of riverine reductions (45% reduction in riverine loads compared to 1980 to 1996 average loads) called for in the most recent Gulf Hypoxia Action Plan are to be successful.

We constructed a state and county level database (1768 counties) for the entire MRB (surface area of 3.67 million km2) using a variety of data sources, including annual data on fertilizer, crops, animals, atmospheric deposition, and human populations from 1997 through 2006. Crop production estimates were used to determine N and P harvested for each crop and year. Biological N2 fixation was estimated for soybean and hay crops using known rates, and animal manure estimated using standard coefficients. A tile drainage county level data set was obtained and modified to estimate the fraction of each county in the MRB that had tile drained. Other landscape factors such as slope, precipitation, streamflow, and clay content of soils were estimated for each county. We calculated several N and P balances using our data base, all both a state and county level basis. A large number of watersheds

were utilized with available nitrate-N (188 watersheds) and dissolved reactive P and total P (131 watersheds) concentrations and flow data in the MRB where we could calculate January-June and April-June nitrate load estimates. Data were obtained from USGS, USEPA, and state agency web sites for 1997 through 2006. The nitrate and total P concentrations were averaged for either the six month or three month period, and multiplied by average flow during this period, and then divided by the watershed area for a yield estimate. Watershed level estimates of all independent variables were made by aggregating all county data in the watershed. We did include in-stream losses of N and P, but rather focused on sources of nutrients to streams/rivers throughout the basin.

We found that at large scales in the MRB, nitrate export as a fraction of NNI varied greatly among subbasins. The Missouri and lower Mississippi basins had average riverine nitrate-N/NNI fractions of about 0.1, the Ohio about 0.25, and the upper Mississippi 0.35. A tile drained watershed in Illinois had a fraction of 1.5, suggesting depletion of soil organic N was occurring. Using the county data set, we found that nitrate export could best be predicted using fertilizer sales, animal manure, population (sewage effluent), and tile drainage combined with runoff. Counties with high fertilizer usage also were heavily row cropped and tile drained, suggesting that row crop intensity overall was leading to high nitrate export. Animal manure explained a small amount of the variation, much less that the other variables. NNI was not a good predictor of nitrate export, reflecting the recent changes in N balances in tile drained watersheds of the cornbelt. For P, fertilizer, human population (sewage effluent), and precipitation were the best predictors of both total P and dissolved reactive P. Animal manure was correlated with total P export, but much less so than the other factors. For particulate P, precipitation, fraction of the land in row crops, and human population numbers best explained the riverine flux, no doubt reflecting the two major sources of sewage effluent and erosion of soil particles.

Our results indicate that the highly row cropped, fertilized, and tile drained corn belt is the major source of nitrate and total P (and DRP) to rivers in the MRB, with sewage effluent also important, particularly for P (both DRP and particulate). Animal manure seemed to be much less important for both nutrients, possibly because many of the counties with high animal numbers were located in areas of the MRB with less precipitation and runoff. It is important to note that net N inputs did not provide important information on understanding basin nitrate fluxes. This analysis presents another approach to examining sources of N and P to the riverine system of the MRB, that could be useful to targeting management actions.

Notes

Session 5: Small and Large Scale Models

Integrating Nutrient Load Simulation into Basin-scale Watershed Models

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The Minnesota Pollution Control Agency (MPCA) water program has evolved from an initial program with a focus on control of wastewater to a complex effort to manage pollution from a number of sources within the context of the Federal Clean Water Act requirements, state laws, and stakeholder expectations. Last year this effort increased significantly with the passage of the Clean Water, Land, and Legacy Amendment by the Minnesota voters. As a result today the program is made up of numerous independent operating parts which are being coordinated to restore impaired waters and protect waters as well. Recently MPCA's goal has been to use an adaptive watershed approach to better coordinate and integrate various components of water functions, activities, and resources using the major watersheds as the preferred scale. This approach basically involves systematic monitoring and assessment at the 8-digit HUC level on a 10 years cycle, as mandated by the Minnesota Legislature, and forms the basis for planning and carrying out programmatic work including TMDL studies, watershed planning, and restoration efforts. Comprehensive watershed evaluations are to be used to establish watershed goals and targets for restoring impaired as well as protecting unimpaired water resources since watershed goals and targets directly influence agency actions, e.g. permits and implementation strategies.

One of the strategic goals of the MPCA Water Program is to develop watershed and water quality models at the 8-digit HUC level for all the 81 major watersheds in the state located outside the twin city metro area using BASINS modeling framework. The various models available within the framework will be employed to highlight critical areas and support the stressor identification process in each major watershed. A fine scale modeling effort will be followed in each critical area for more site specific BMP targeting and implementation efforts.

Modeling at different scales and complexities has been utilized as a tool by the MPCA to develop TMDLs and address a variety of planning and regulatory issues throughout the state. These modeling efforts include approaches ranging from simple spreadsheet models to the state of the art hydrologic and pollutant fate and transport models. Each model has its own strengths and weaknesses relative to issues like the scale, both temporal and spatial, at which the models are applied in a watershed. As we utilize the BASINS modeling framework to develop TMDL protection studies on our 8-digit HUC major watersheds, we would like to be able to evaluate stream nutrient criteria by testing against the predicted stream response to various model runs, and the associated predicted reductions in nutrient loading.

MPCA has developed a basin scale HSPF model of the Minnesota River basin to address dissolved oxygen (DO) and turbidity impairments in the basin. Basin scale models like HSPF are spatially lumped such that they can operate at many thousands of square miles and an hourly time step. The model works well for hydrology and sediment, but there are issues associated with scaling in space and time. Agricultural management occurs at the field scale, not the spatial scale represented in the model. Activities such as tillage, drainage, and fertilization must be approximated at the model sub-basin scale. Temporally, subsurface loading of nutrients (particularly N) may operate at a scale of weeks to years, presenting challenges for simulation in a surface runoff model operating at an hourly time step. Existing lumped, basin-scale models like HSPF can do a good job of representing a complete mass balance of P because loading is primarily by surface pathways and sediment-associated. For N, most large-scale models have less ability to represent a full mass balance because much of the loading is by subsurface pathways (tile drains and ground water). Most watershed-scale models either do not attempt or tend to do a poor job of simulating a complete subsurface N mass balance.

Newer grid-based models which can be used at the watershed scale like GSSHA (Gridded Surface Subsurface Hydrologic Analysis) are attempting to do the full surface/subsurface mass balance, but are (1) still experimental and not fully tested, (2) cumbersome to run at large spatial scales, and (3) very data intensive requiring large amount of difficult to access information. On the other hand, field-scale agricultural models, such as DRAINMOD-N, SWAT-DRAINMOD can do a good job of simulating both N and P loading. But there is still a strong need for large-scale integrative models that can simulate large areas, account for instream processes, and have the ability to integrate a full surface and subsurface mass balance for N into basin-scale watershed models. Possible solution could be to take advantage of the strengths of each modeling approach.

An alternate approach would be to build a combined model in which the N loading time series from representative agricultural lands including soils, cropping, and fertilization management are simulated on a per acre basis using field scale models like SWAT-DRAINMOD and input into basin-scale models like HSPF. In this presentation we will share our experience of using small and large scale models, highlight various modeling efforts currently underway around the state, and the challenges that we face in these efforts. We will also present the HSPF modeling application in the Minnesota River basin as a case study.

Notes

Session 5: Small and Large Scale Models

Benefits and Limitations of Small Scale and Large-Scale Models and Implications for Solutions, Trends, and Tracking

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The CEAP analysis system consists of three major components: 1) the APEX model to simulate edge-of-field loadings for cultivated lands, 2) the SWAT model to simulate loadings from non-cultivated lands and route all loads through rivers and reservoirs, and 3) data bases for land management (from detailed farm surveys), climate, soils, topography, point sources, and atmospheric deposition. In this study, the Upper Mississippi River Basin is divided into 131 8-digit subbasins (around 3, 000 sq km) and sources are aggregated for each subbasin and then added and routed through the river basin. The system predicts the impact of conservation practices on flow, sediment, nitrogen, phosphorus, and pesticide loads from each subbasin and loads and concentrations at the outlet of each subbasin. One major benefit of the system is that the models are physically based and operate on a daily time step. This allows direct simulation of the impact of climate and detailed land management scenarios. The associated limitation is that the models are data intensive requiring detailed land management practices, daily climate, soil physical properties, and pond and reservoir data. Another advantage of the CEAP system is that detailed simulation of conservation practices and scenarios are simulated and routed to determine both on site and off site impacts on water quality. A current limitation is that landscape processes within a subbasin are simulated with delivery ratios. Also, calibration, validation, and uncertainty analysis are complicated in a comprehensive, multi-scale system like CEAP. We will show model results for several scenarios including current conditions, no management practices, no cultivated land contribution, and several scenarios targeting under treated areas.

Notes

Use of SPARROW to Assess Nutrient Sources, Transport, and Fate in the Mississippi River Basin

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Keywords: nutrients, SPARROW, watershed modeling, stream monitoring

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The widespread eutrophication of inland waters and seasonal occurrence of hypoxia in many coastal ecosystems in the United States, including the northern Gulf of Mexico, underscore the need for an improved understanding of the effects of land use, climate, and landscape and aquatic processes on nutrient transport over broad spatial scales. Many of these problems are related to the long-distance, inter-jurisdictional transport of nutrients from a diversity of upstream sources and watersheds, which complicates the development of effective management solutions. Moreover, the watershed-science community continues to stress the need for less complex hydrological and biogeochemical models to enhance understanding of the dominant process controls in watersheds and to improve the accuracy of predictions of water and material flux across a broad range of environmental settings and spatial scales. Although complex physically-based models are traditional tools that have advanced process understanding and management in watersheds, their use in large, heterogeneous basins is challenging because of the intensive data and technical requirements and uncertainties over model accuracy.

To assist with these needs, the U.S. Geological Survey (USGS) has developed the SPARROW water-quality model (SPAtially Referenced Regressions On Watershed attributes)—a hybrid statistical and process-based mass-balance approach that estimates the sources, transport, and fate of stream contaminants over watershed, regional, and continental scales. SPARROW assessments of nutrient sources and transport have been completed for the Mississippi River basin, the Chesapeake Bay watershed, and other major drainages of the United States. Regional nutrient models are being developed by the USGS for 2002 conditions in six major drainages of the conterminous United States; four of the models include drainage in the Mississippi and Atchafalaya River basins (MARB). SPARROW applications have also been completed for suspended sediment and fecal bacteria for the conterminous United States and for dissolved solids in the Colorado River basin. SPARROW supports management activities and information needs in these watersheds, such as point and diffuse source apportionment (including Total Maximum Daily Load calculations), the identification of watersheds with large stream loads and delivery to downstream waters, and the use of the model to forecast the effects of land-use change (e.g., corn ethanol production) on stream loads and to inform the calibration and use of dynamic simulation models (e.g., SWAT, HSPF).

This presentation provides a summary of the SPARROW model, including how the model is structured, calibrated, and evaluated, with example applications in the MARB. We highlight the capabilities, advantages, and limitations of the model. We also discuss current modeling activities and key data and research needs to support SPARROW and other watershed models. In this abstract, we briefly summarize selected aspects of the model and its applications.

SPARROW is a spatially explicit model that predicts the long-term mean annual contaminant load in streams, based on the steady-state application of a nonlinear transport equation that accounts for factors affecting the supply, terrestrial and aquatic transport, and fate of contaminants in watersheds. The spatial structure is defined according to a river reach network, coupled to digital topography of the land area that drains to individual stream reaches. The model separates landscape and aquatic features according to three structural components: (1) contaminant sources expressed as mass loadings (e.g., farm fertilizers, wastewater effluent, atmospheric deposition) or area (e.g., cropland and forest area); (2) exponential land-to-water delivery functions that reflect the effects of climatic and landscape properties on the sub-surface and overland delivery to streams (e.g., precipitation, temperature, soil permeability, slope); and (3) non-conservative transport in streams and reservoirs expressed as a first-order decay process in relation to water travel time in streams and reservoir areal hydraulic load. The model estimation (i.e., calibration) is subject to mass-balance constraints that are common to dynamic mechanistic models, with parameter values and uncertainties determined from nonlinear estimation methods. Contaminant source inputs are assumed to be in steady state with measured in-stream loads such that mass is conserved among the model components that describe the sources, sinks, and in-stream flux of contaminants. The complexity of a particular model application (i.e., number and types of source and transport functions and variables) is influenced by: (1) knowledge of the anthropogenic, hydrological, and biogeochemical factors that influence water-quality conditions; (2) the environmental conditions and gradients in the geographic domain of the model; (3) the availability and resolution of the geospatial data for describing these conditions (e.g., stream monitoring, contaminant sources); (4) evaluations of model accuracy to identify parsimonious models with statistically significant and physically interpretable variables and predictions; and (5) the intended uses of the model for research and management.

Model output includes mean annual predictions for stream reaches of the contaminant load (mass per time), yield (mass per unit area per time), concentration (mass per volume), and source-share contributions. The stream load and yield are reported for three spatial domains (total upstream drainage, incremental reach drainage, and delivery to downstream waters) that provide management-relevant information about the sources and fate of contaminants at local and regional spatial scales. Source shares may be expressed as loads, yields, or percentages of the stream load, all reported separately for each source and the three spatial domains. Predictions are also available for the contaminant mass removed within stream reaches and reservoirs. All model predictions are based on model calibrations to the flow-weighted mean annual load at monitoring sites; thus, spatial variations in the predictions are generally indicative of conditions during the high-flow periods of the year that often occur during the winter and spring. The statistical estimation of the model provides information that is used in bootstrapping procedures to derive estimates of uncertainty for model parameters and predictions. As with any watershed model, SPARROW predictions may be less accurate at spatial scales smaller than that of the stream monitoring and geospatial data used to calibrate the model.

SPARROW is an adaptable model that can be used reliably to describe the major sources and environmental factors that affect the stream load of contaminants across a wide range of environmental settings and drainage sizes—information that can guide both management and monitoring activities. SPARROW is frequently applied to large geographic areas, which enhances both the quantity (numbers of calibration sites) and quality (variability related to broad environmental gradients) of the data for statistically estimating the model parameters. The current steady-state model design, based on predictions of mean annual stream load standardized to mean hydrologic conditions, is well suited to quantify the effects of natural and human-related processes that supply and remove constituents from watersheds over long time periods; these processes have long-term impacts on elemental budgets in aquatic ecosystems. This emphasis of the model has led to advances in understanding of the long-term average rates of in-stream nutrient removal (via denitrification, for example) and the large-scale cumulative effects of nutrient removal on contaminant fate and delivery to inland waters and coastal estuaries. By contrast, SPARROW is not currently designed to predict seasonal loads or short-term intra-annual cycling and storage processes (e.g., soil and water nitrification, mineralization); these dynamics are common to mechanistic simulation models, although they are subject to considerable uncertainties, especially over large spatial scales.

The current development of SPARROW nutrient models by the USGS for six major regions of the conterminous United States has greatly expanded the number of MARB calibration sites (from ~125 to ~1, 300) and the range of monitored environmental conditions represented in the model. These models have benefited from the compilation of an extensive collection of stream monitoring data from local, State, and other federal agencies. Models for the eastern United States (two of the six regions) are also based on the more detailed 1:100, 000 scale NHD (National Hydrologic Data) river network that improves connectivity to monitoring sites in small catchments. Despite these advances, a continuing limitation for SPARROW (and other watershed models) is that the geospatial data for nutrient sources and agricultural practices are not available at a commensurate spatial and temporal scale as the watershed hydrologic, climatic, and stream chemistry data. Improved data are needed, for example, on wastewater-treatment-effluent discharges, combined sewer overflows, septic systems, fertilizer use, tile drainage, and best management practices. Much of the current data is available for relatively few locations or at coarsely resolved spatial scales (e.g., counties).

In contrast to current SPARROW models with assumed constant parameter values over space and time, the next-generation models are anticipated to have temporally and spatially varying parameters, informed by the substantially expanded stream monitoring data currently used in the regional models. SPARROW model parameters provide a measure of the marginal effects of water-quality processes on stream loads (e.g., the stream load response per unit of applied fertilizer; the fraction of nutrient removal in streams per unit water travel time). Whereas the currently assumed constant parameter values allow a parsimonious, steady-state form of the model to be readily applied over a wide range of conditions, this may oversimplify the expected stream load response to unit changes in the explanatory variables. SPARROW has the capacity to statistically evaluate whether spatial or temporal differences exist in the model parameters. Such differences may be caused by latent processes, related to landscape heterogeneity or process interactions, for which surrogate measures of their effects may not be available in geospatial datasets. For example, in agricultural systems these latent effects may include temporal and spatial differences in nutrient balances and cycling, related to changes in the rates of mineralization and immobilization in soils or the effects of changing management practices. National SPARROW models are currently being developed with temporally variable parameters to assess historical and future changes in land-use and climate conditions on nutrients. Research is also needed to support model descriptions of seasonal water-quality conditions and models that account for ground water storage and temporal lags in transport.

Finally, the USGS is developing a web-based decision support tool for SPARROW that will allow model users to easily access national and regional results for the conterminous United States and to evaluate alternative scenarios for reducing constituent loadings in streams. Web-based decision tools are needed to encourage active, transparent communication among modelers and stakeholders, which can lead to the development of models and geospatial datasets that better address management needs.

Notes

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Poster Abstracts

Session 1: Management Issues

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USDA-NRCS Engineering Conservation Practices Targeting Nutrient Loading, Water Quality, And Water Quantity Challenges Associated With Non-Point Source Pollution Related to Agriculture

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The Gulf of Mexico Hypoxia problem has been linked to nutrient loading from non-point source pollution related to agriculture. Engineering Practices 607A - Vegetative Agricultural Drain (MS-ENG-607A), and 656 - Constructed Wetland (MS-ENG-656-01) are two USDA-NRCS cost shared practices that primarily address water quality.

Constructed Wetlands are wetlands designed as treatment wetlands to maximize contact time between runoff (stormwater and irrigation return flows) and plants for the trapping and processing of sediment, pesticides and nutrients. The Constructed Wetland is located at the collection point of several field drains.

Vegetative Agricultural Drains are field ditches that are designed to maximize contact time between runoff (stormwater and irrigation return flows) and plants for the trapping and processing of sediment, pesticides, and nutrients. The Vegetative Agricultural Drain is located at the bottoms of fields and at the end of furrows (single edge of field drain).

MS-ENG-607A-01 and 656-01 are described with construction and maintenance requirements detailed.

Landowners may address nutrient loading into farm ditches, streams, lakes, rivers and other water bodies through cost shared USDA-NRCS Engineering Practice 436 - Irrigation Storage Reservoir (MS-ENG-436). An irrigation storage reservoir is a water storage structure constructed to store a supply of water for irrigation made by constructing a dam, embankment, or pit. These reservoirs are typically used as a component of a water supply system as a means to increase overall irrigation water supply on a farm utilizing surface water sources (stream flow, runoff, groundwater) or to capture and utilize tailwater. By capturing and reusing runoff, these systems trap and process nutrients and pesticides, improving water quality.

Excavated versus Embankment Storage Reservoirs are defined and discussed with associated cost comparisons as a decision support tool. Water Quantity is also discussed in the context of constructing and implementing MS-ENG-436.
The organization Delta F.A.R.M. (Farmers Advocating Resource Management) is discussed. If USDA made cost share available for all pollutant trapping systems, organizations such as Delta F.A.R.M. would be an effective way for increasing awareness and participation by farmers in reducing non-point source pollution related to agriculture.

Keywords: constructed wetlands, embankment irrigation reservoir, hypoxia, nutrient loading, vegetative agricultural drain, water quality, water quantity

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What's In Your Toolbox? Biophysical and socio-economic tools for water quality

When designing site-scale solutions to improve water quality and reduce nutrient export, resource managers need innovative, science-based decision-support tools capable of addressing a range of landowner concerns. Landowners consider a variety of economic, biophysical, and social issues in their decision-making process on whether or not to adopt water quality practices. Due to each individual's unique situation, resources, and personal value system, these issues are weighted differently in every potential application of a water quality practice. Consequently, resource managers need tools flexible enough to accommodate the range of potential issues and each landowner's unique decision-making process. Because one decision support tool will not satisfy all of these demands, a suite of tools must be created. Ideally, these tools should be

loosely coupled rather than intricately woven together, allowing users to select tools appropriate for their situation and facilitating the integration of new tools into the toolbox.
The USDA National Agroforestry Center has developed several tools that can be used for designing site-scale water quality practices. The publication Conservation Buffers: Design Guidelines for Buffers, Corridors, and Greenways synthesizes over 1, 400 research articles into illustrated guidelines for designing buffers to protect soil, improve air and water quality, enhance fish and wildlife habitat, produce economic products, provide recreational opportunities or beautify the landscape. Buffer$ is a simple-to-use spreadsheet tool that calculates the cost-benefits of implementing a water quality buffer in comparison to a traditional cropping practice. The CanVis Visual Simulation Kit provides image-editing software that can be used to create photo-realistic simulations of proposed practices and land-use scenarios to improve water quality. The communicative and non-threatening nature of simulations encourages landowners to invest time in the design process and offer feedback on alternatives, encouraging adoption and long-term support for the final action. These tools and others can provide managers with the resources to design acceptable, science-based solutions for reducing nutrient export to the Gulf of Mexico.

Keywords: Design, Decision support tools, Buffers, Decision-making, Visual simulations, Planning

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A Vision for Information Centric Natural Resource Management

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Current natural resource management practices have resulted in excess runoff and erosion, nutrient loss, and soil carbon loss. However, appropriate management practices, especially those focused on environmentally sensitive areas such as wetlands, highly erodible lands, and gullies, can significantly reduce these losses. The use of information technology to encourage appropriate natural resource planning and compliance has the potential to revolutionize the effectiveness, methods, and speed of conservation technology application. Currently conservation assessments are conducted at the HUC-8 level and cannot be readily updated or extended to the field scale where conservation decisions occur. We propose to replace the current system with high resolution, standardized, geospatial datasets in conjunction with environmental models and automated report generating systems to rapidly identify sensitive areas, appropriate management techniques, quantify impacts of changes, and simplify assessment reporting. Such a shift would decrease report generation costs by standardizing reporting and eliminating duplication and provide benefits by enabling research and policy projects such as:

How have crop rotations and tillage management practices changed over time?

How do we obtain better estimates of soil moisture and tile drainage conditions for improved flood prediction?

Which areas of a field are responsible for net carbon and nitrogen emissions and what is the net change?
Iowa already has many of the datasets needed for such a project, such as elevation from LiDAR, hydrologic connections from LiDAR derivatives and infrastructure datasets, and land cover and crop rotations from the USDA Common Land Unit (CLU) maps and Cropland Data Layers. Additional datasets on land management practices such as tillage and fertilization could be developed based on remote sensing and other state datasets. Conservation practices such as terraces can be mapped using LiDAR and buffer strips can be delineated from CLU maps of CRP near areas of concentrated flow. Dataset standardization will facilitate the use of models such as WEPP, RUSLE2, SWAT, MIKE-SHE, and DAYCENT by enabling detailed implementation over large areas to answer the previous, and other, critical questions, ultimately resulting in better and more efficient decision making. Example datasets and model results are shown for a trial watershed in central Iowa.

Keywords: erosion, nutrients, runoff, modeling, monitoring, assessment, decision support, management, remote sensing, LiDAR

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Using model results to set planning targets

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USDA-NRCS provides conservation planning assistance and technical service support to landowners and producers in order to allow them to make management decisions concerning the manipulation of natural resources within their control. These conservation practices provide benefits not only to the environment but also to economic well-being and production to the producers. Producers are concerned about their impact on their land and surrounding environment; therefore they plan and carry out their operations in such a way so not to have adverse effects on the resources that are being utilized to provide production, like soil, water, and air. In order for the producer to make good decisions on resource management they are looking for acceptable planning levels that they can attain to produce a economic rewarding product and not adversely impact their surroundings. The model results form the conservation effects assessment project (CEAP) has given some insight to what is attainable for minimizing environmental issues while maintaining agricultural production. CEAP model results provide the quantified benefits of using various conservation and management techniques on cropland. These benefits can be compared to the individual risks that are present in the local landscape. Setting regional planning targets for soil and water management will give the producer the guidance they need during their production management. Additional model scenarios will offer the producer alternatives to meeting their goals. Planning target levels are being developed for the Upper Mississippi River Basin which reflects the results of the CEAP model and analyses. Planning targets have also been used to assess the conservation treatment needs of the region. A tremendous amount of work remains in order to provide conservation planning targets to every producer in the country given the number of climate, soil, and cropping system combinations that are currently being used.

Keywords: planning targets, agronomic limits, sediment, nitrogen, phosphorus

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Conservation Marketplace of Minnesota: Partnering Ecological Service Science and Policy

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Market-based programs for ecosystem services can bring economically efficient implementation alternatives to land managers and producers, encouraging them to generate credits that are saleable in local, regional or national markets. In Minnesota, market-based environmental programs are established or developing for water quality credit trading (WQCT), greenhouse gas emissions, source water protection and renewable fuels. The Conservation Marketplace of Minnesota [CMM] will develop and institutionalize a market infrastructure with locally-led service providers and the tools necessary to provide simple and easy access to these markets that make them sustainable. With significant market and regulatory drivers in-place, these markets will provide economic and regulatory certainty rooted in sound science with local champions that support the process. Standard policies, operational methods, crediting protocols and monitoring requirements are being established and maintained to sustain the market. The CMM is a model of how science and policy decisions can be brought together to improve the implementation of nutrient management practices and land conservation in the Mississippi basin.

Keywords: ecosystem services, credits, market-based, trading

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Developing collaborative environmental effects of agricultural practices studies in the Midwest

Recent meetings with agricultural scientists, managers, and producers have confirmed the need for science-based information to make land, wildlife, and water resource management decisions that may mitigate the environmental effects of agriculture practices. Among the research gaps identified as priorities for USGS science were connecting USGS science to cultural and economic needs, including transferring vast databases into useful tools; valuing ecosystem function and health, and forecasting the effects of sustained agricultural production on natural resource availability and quality.

In response, USGS scientists and managers from throughout the central United States (USGS Midwest and North Central areas) have developed an Environmental Effects of Agricultural Practices (EEAP) initiative to address these needs. We have identified four primary science themes that build on our proven competencies with long-term data sets, understanding of ecosystem processes, and regional investigations. These themes are: Watershed Function and Resilience, Ecosystem Services, Wildlife and Human Health, and Energy, Water and Climate Change. This initiative depends on incorporating stakeholder input and needs while taking a multidisciplinary approach that integrates the diverse abilities of USGS with those of natural resource agencies, universities, and other organizations.

Keywords: Watersheds, Monitoring, Research, wildlife health, human health, ecosystem services, climate change, energy, best management practices

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Clean Water State Revolving Fund Loan Programs for Agricultural Best Practices: Iowa's Experience

Low-interest loan programs for water quality have traditionally funded infrastructure projects at the community, municipality, or state level. They are increasingly being used to support individual agricultural landowners' investments in best management practices (BMPs) for non-point source pollution abatement. Beginning in 2005, the Iowa State Revolving Fund initiated two low-interest loan programs, the Local Water Protection Program (LWPP) and the Livestock Water Quality (LWQ) program, with the objective of improving water quality by increasing the scope, scale, and rate of agricultural BMP establishment. By 2007, the programs had not attained desired levels of use among landowners, and utilization varied widely across the state. The Iowa Department of Natural Resources commissioned a study to answer two research questions: 1) why were Iowa landowners not taking full advantage of the programs, and 2) what was the experience of the landowners who had taken loans. The study focused on both the individual and organizational levels. Individual-level research consisted of a survey of 1) program participants and 2) landowners who had implemented eligible conservation practices through state or federal programs since 2005, but had not taken a loan. Organizational-level research consisted of focus groups with Soil and Water Conservation District staff across Iowa to assess factors that were facilitating or impeding program promotion and use. Loan recipients' assessments of program effectiveness were overwhelmingly positive, with near-universal satisfaction with both the loan product and process. Evidence strongly suggests that by helping program participants to overcome financial constraints, loans are facilitating larger and accelerated investments in conservation while lessening dependence on cost-share. Comparisons between groups revealed that loan recipients spent an average of 25 percent more on conservation practices than their peers who relied predominantly on cost-share, and they established a greater diversity of practices. While the research did identify several factors that are hindering implementation in some areas of the state-primarily landowner lack of knowledge of the programs-those problems appear to be easily remediable. Overall, results indicate that the loan programs are leading to significant benefits for Iowa's lands and waters, and should be expanded, both in Iowa and across the Midwest.

Keywords: Water Quality, Best Management Practices, State Revolving Loan Funds, Cost-Share, Incentives

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Supporting Adaptive Management and Nitrogen Loss Reduction by Protecting Farmers from Income Foregone

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In addition to feeding an additional 2.2 billion people worldwide by 2040, contributing to energy self-sufficiency, keeping our landscapes attractive and revitalizing rural communities, we need agriculture to help improve water quality. Adoption of both well-established and advanced practices designed to reduce nitrogen losses remains well below potential. More than twenty studies have identified foregone income as a primary reason. Extra inputs are a rational defense against income loss: Heavy rains in spring and early summer can wash away nutrients before they are taken up by the crop; bumper crop growing conditions can call for more nutrients than university recommendations provide. Developed by American Farmland Trust and Agflex with support from NRCS and others, the BMP CHALLENGE isolates foregone income by using check strips in farmer fields. The farmer applies his or her conventional nutrient management or tillage practice in the check strip. The rest of the field receives the BMP. A net returns assessment at harvest determines the impact on farmer net income. Farmers are compensated if net income declines. A third-party crop advisor supports and verifies implementation on site. This adaptive management approach has reduced nitrogen losses on more than 15, 000 acres nationwide. Prior to participation, 53% of

farmers were applying 25 lbs. or more nitrogen over and above University recommendations. Post participation, 59% of farmers plan to reduce nitrogen application rates and 94% were satisfied and/or would recommend the practice to others. Participants have reduced an average of 41.5 lbs. of nitrogen per acre.

Keywords: adaptive management, foregone income, nitrogen fertilizer, nutrient management

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Live Action Manure Spill Response Demonstrations Improve Response, Decrease Environmental Impact

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Applying manure to fields has changed greatly compared to the days of daily hauling solid manure. Today, many livestock farms have millions gallons of liquid manure applied to fields within a few days time. As farms have grown, the need to transport manure farther distances has grown. These changes in the dairy industry have led to an increased risk of a manure spill. Societal and regulatory expectations of managing a spill have also changed.

University of Wisconsin-Extension and Penn State Extension have been providing live manure spill response training to improve response and decrease environmental impacts. These trainings allow farmers, custom manure applicators, and first responders (SWCD, NRCS, state and local regulators) to learn how to control a simulated "spill" as opposed to learning these techniques in a classroom setting.

Planning a manure spill demonstration response should include all parties that would be involved if an actual event were to occur. All parties should be involved in the logistics of site selection, what will be demonstrated, and the equipment to be used in the demonstration. The most important part of the team planning approach is that any one person can cancel the manure release the day of the event if they are uncomfortable with the site conditions or weather forecast. Lastly, demonstration location is vital. An upland site that is well back from surface water is necessary. Evaluation of site and downslope potential risks such as wells, drain tile, and streams must be done well in advance.

These demonstrations provide the opportunity to demonstrate potential manure spill techniques based on specific features such as tile inlets, variable soil types, and slope differences within a field. The volume of manure released for these demonstrations has ranged from 500 gallons to over 10, 000 gallons (drag hose rupture simulation).
Since the training has begun in 2006, 10 manure spill incidents have occurred in Wisconsin where the farmer or applicator attended training. In each of these incidents, the spill was contained before it reached surface or groundwater. Pennsylvania has trained over 800 individuals to meet the state's commercial manure applicator and broker certification program.

Keywords: Human dimensions, peer pressure, animal waste

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Defining a nutrient management plan for regulatory purposes

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Nutrient management planning is one of the primary strategies advocated to reduce nutrient loss from agricultural fields. Traditionally nutrient management plans have been voluntary documents to help farmers understand and manage fertilizers on their farm. Recent changes to concentrated animal feeding operation (CAFO) regulations will require parts of the nutrient management plan be part of the terms and conditions of the CAFO's operating permit. Efforts to address hypoxia may also ultimately lead to more rigorous standards and requirements for developing, implementing and evaluating nutrient management plan results.

The effort to regulate CAFO nutrient management plans initially focused on dates and rates of application as the regulatory component of the plan. This focus resulted in an unrealistic expectation that farmers needed to apply manure only on the dates and at the rates designated in their plan. Such an approach ignored the unpredictable impact of weather and field conditions on farmer fertilizer application activities.

Instead a regulatory approach to nutrient management plans should focus on defining standardized methodologies and protocols used to define field-specific rates of nutrient application. Certain field characteristics, necessary to determine nutrient application rates, cannot be derived from a standardized test or by following a specific protocol. As a result, these field characteristics would also need to be incorporated as terms of the permit. The ideal approach thus requires integrating both standardized tests and protocols and selected field-specific parameters into the terms and conditions of the permit. We conclude that field-specific parameters of field location, field size, potential crops and potential crop yield goals should be terms of the permit. This information plus standardized protocols for soil testing, manure testing, nutrient loss assessment, nutrient availability calculations and record keeping will result in a nutrient management framework that allows farmers to adjust their management of nutrients to changing environmental conditions while giving external reviewers confidence that water quality goals are being met. We will also provide examples of how our proposed requirements and record keeping can be integrated into an easily reviewable assessment of a nutrient management plan and its implementation.

Keywords: Nutrient management plan

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Exploring the Complexity of Environmental Stewardship Attitudes on the Decision to Adopt BMPs

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Attempts to understand farmer conservation behavior based on quantitative socio-demographic, attitude and awareness variables have been largely inconclusive. In order to fully understand how farmers are making conservation decisions, 32 in-depth interviews were conducted in Eagle Creek watershed in central Indiana. Following an open coding process, several dominant themes were identified. Farmers who were motivated by off farm environmental benefits and those who identified responsibilities to others (stewardship) were more likely to adopt conservation practices. Those farmers who focused on the farm as business and were more concerned about profitability were less likely to adopt practices. While these are not surprising findings, the notion of environmental stewardship was found to be much more complex than the way it is traditionally measured in quantitative studies. Specifically the interplay between on-farm and off-farm benefits to practice adoption is an issue that quantitative studies largely do not address. This presents a data gap in understanding farmer behavior which this study begins to fill.

Keywords: conservation practices, adoption, qualitative, environmental attitudes

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The Social Indicator Planning and Evaluation System (SIPES) for NPS Management: Applications in the Great Lakes Region

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State Nonpoint Source (NPS) programs in the Great Lakes Region (USEPA Region 5) have been working collectively for several years to incorporate social indicators into NPS project planning and evaluation. Social indicators provide information about the social context, capacity, awareness, attitudes, and behaviors of individuals, households, organizations, and communities. Applied to NPS issues, they can help project staff identify appropriate combinations of technical, financial, and educational assistance for those making land management decisions that influence water quality. They can also provide consistent measures of change across projects, states, and regions.

A Great Lakes Regional project team consisting of university researchers and staff from state environmental agencies and USEPA (and convened through the CSREES Great Lakes Regional Water Quality Program), has developed the Social Indicator Planning and Evaluation System (SIPES) to support social indicator use. SIPES includes a set of core indicators and related processes for collecting, analyzing, and using indicator data. SIPES helps focus project planning and enables projects to measure social change due to NPS management efforts. The system is being applied to projects across the Great Lakes region during a multi-year pilot-testing phase to assess the indicators, the effectiveness of alternative methods for their collection, and the overall usability and utility of SIPES for NPS projects and state programs.
This poster will describe the system, the social indicators, collection methods, and how NPS projects are using initial results.

Keywords: social indicators, nonpoint source, environmental attitudes, BMPs

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A Method for Using Paired Watersheds to Test the Efficacy of NPS Education and Outreach Programs

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Paired watershed studies are a proven method for testing the effectiveness of Best Management Practices (BMPs) at reducing nonpoint source (NPS) pollution. In a paired watershed study, the watersheds should be as similar as possible so that conclusions may be drawn about the performance of BMPs. Typical criteria to evaluate if watersheds are comparable include size, slope, location, soil types, land cover and stableness of the channel. We have extended the paired watershed concept to examine the effectiveness of outreach and education programs by adding comparative criteria for social characteristics. For four different 8 or 10/11 digit HUCs in the Midwest, we have piloted a system for selecting paired subwatersheds. In each of the four areas, paired subwatersheds (all 14 digit HUCs) were selected using a cluster analysis of nine factors that captured the majority of the variance in eleven input variables. These variables included percent of population with a high school degree, average household income, population change from 1990-2000, land cover, and percent areas that are prime farmland. After selecting the subwatersheds, conversations were held with key informants in each watershed to insure that these subwatersheds were truly comparable. These conversations included questions about current level of funding for NPS work, history with education and outreach efforts, and unique social features (e.g. large Amish population). The way projects approach and engage landowners can be critical for successful BMP adoption. This method for selecting paired watersheds should be helpful for other researchers to test the effectiveness of outreach and education programs which is essential for improving science-based management of NPS pollution.

Keywords: paired watersheds, social indicators, NPS, education and outreach

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USDA-NRCS Mississippi Delta Conservation Practices Targeting Nutrient Loading from Agriculture

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The Gulf of Mexico Hypoxia problem has been linked to nutrient loading from non-point source pollution related to agriculture. The Gulf of Mexico Alliance and the Delta Nutrient Reduction task Force have targeted reductions of nitrogen and phosphorous from agricultural lands.

Research has been conducted by several agencies within the Lower Mississippi Alluvial Valley to evaluate several possible conservation practices that could be implemented by landowners with possible Environmental Quality Incentive Program financial assistance.

This poster describes some of the research used to validate the inclusion of several new practices to the list of eligible practices in the Mississippi Delta to address nutrient reduction and the hypoxia issue.

The proposed Engineering Practices include 607A - Vegetative Agricultural Drain (MS-ENG-607A), and 656 - Constructed Wetland (MS-ENG-656-01). Previously, constructed wetlands were utilized by NRCS for treatment of wastewater from confined animal feeding operations. The new application involves meeting flowrate requirements from stormwater runoff, rather than from fixed volumes from animal operations.

NRCS has assisted several of these research projects, including field scale projects, and have scaled the work from research plot to field application size. The basis of all this work is NRCS Technical Note No. 4, Nutrient and Sediment Control System.

Field scale research has shown that fall disked fields allowed to drain freely during winter exported 1120 kg/ha (1.1 metric tons/ha) of soil whereas impounded and thus flooded fields with stubble left undisturbed lost only 35 kg/ha (.035 metric tons/ha). Promoted by decreases in nutrient concentrations and/or runoff volume, mass export of other variables such as dissolved solids, orthophosphates, and sulfates were reduced by winter flooding as well.

Vegetated agricultural drainage ditches have been shown to help reduce nutrient loads leaving fields before they enter rivers, lakes, and streams. In a 2-year monitoring study, 57% of dissolved inorganic nitrogen and 44% of inorganic phosphorus were retained in ditches rather than contaminate receiving water bodies. Additional studies have demonstrated a 35% decrease in total suspended solids concentrations from inflow to outflow of vegetated ditches.

Irrigation storage reservoirs capture, store, and allow the re-application to the field of irrigation return flows and stormwater runoff. Nutrients in this runoff are thus recycled to the field, rather than contributing to downstream waters. The MS Delta is also suffering aquifer declines, so these practices would be addressing water quality and quantity concerns at the same time. These results and application to future farm planning to address nutrient reductions and the reduction of groundwater use will be described.

Keywords: constructed wetlands, hypoxia, nutrient loading, vegetative agricultural drain, water quality, water quantity

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Advances in Denitrification Bioreactor Design

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New and innovative practices are vital for landowners in the US Midwest to reduce nitrate loadings associated with agricultural drainage. Denitrification bioreactors (AKA woodchip bioreactors) are a promising new edge-of-field technology

to reduce these loadings to surface waters. Because this technology is still relatively new, there is a key gap in bioreactor knowledge in regards to optimized designs for maximum nitrate removal. The objective of this work was to determine if different bioreactor design geometries had a significant impact upon nitrate removal at various retention times. A secondary goal was to determine if calculated design retention times matched actual observed retention times. During summer 2009, three pilot-scale (1/10th scale) bioreactors of different geometries (rectangle, channel, and trapezoidal cross section) were used to investigate these questions. Preliminary results from these studies indicated that a trapezoidal cross section may provide the most mass reduction regardless of retention time compared to a rectangular cross section. The pilot-scale studies also made clear that observed tracer residence times were approximately twice calculated design retention times. This information has now been used to design a full scale bioreactor in Northeast Iowa. In conclusion, more work such as this to improve the design of denitrification bioreactors can lead to more effective nitrate removal and improved water quality.

Keywords: denitrification, bioreactor, nitrate, retention time, design

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Water Quality Performance of Wetlands Receiving Nonpoint Source Loads: Nitrate Removal Efficiency and Mass Load Reductions Using Targeted Wetland Restorations

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Wetland restoration is a promising strategy for reducing surface water contamination in agricultural watersheds and in particular for reducing nitrate loads to the Mississippi River and its tributaries. However, effectively using this strategy requires recognition of (1) the special characteristics of nutrient transport in agricultural landscapes, (2) the primary controls on wetland nutrient transformations at high nutrient loading rates, and (3) the variable and dynamic nature of non-point source hydraulic and nutrient loading rates. Nitrate is transported from cropland primarily in subsurface drainage, especially in extensively tile drained areas like the Corn Belt. If wetlands are to be effective in reducing nitrate loads in these landscapes, they must be sited to intercept tile drainage. Under the Iowa Conservation Reserve Enhancement Program (CREP), wetland restorations are strategically targeted to intercept loads from 500 to 4000 acre agricultural drainage basins. A unique aspect of the Iowa CREP is that nitrate reduction is not simply assumed based on wetland acres enrolled but rather is estimated based on the measured performance of CREP wetlands. As an integral part of the Iowa CREP, a subset of wetlands is monitored and mass balance analyses performed to document nitrate reduction. By design, the wetlands selected for monitoring span the 0.5% - 2.0% wetland/watershed area ratio range approved for Iowa CREP wetlands. The wetlands also span a 2-3 fold range in average nitrate concentration. The wetlands thus provide a broad spectrum of major external forcing functions affecting wetland performance: hydraulic loading rate, residence time, nitrate concentration, and nitrate loading rate. The selected wetlands are instrumented for continuous flow measurement and automated sampling at inflows and outflows. Mass balance analyses are used to calculate mass removal rates of nitrate, TN, TRP and TP. The wetlands span a broad range of hydraulic and nutrient loading rates and as expected vary considerably with respect to nutrient removal efficiency. However, analysis of 24 "wetland years" of mass balance data (11 wetlands with 1-4 years of data each) demonstrates that much of the variability in nitrate removal can be explained by a model incorporating hydraulic loading rate and nitrate concentration.

Keywords: Wetlands, nitrogen, nitrate, nutrient loads, water quality, hypoxia

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Fate and Effects of Nitrate in Macrophyte-Dominated Experimental Wetlands

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Nitrate concentrations have greatly increased in streams and rivers draining agricultural regions of the Midwestern United States. Increasing nitrate transport to the Gulf of Mexico has been implicated in the hypoxic conditions that threaten the productivity of marine fisheries. Increases in nitrate concentrations have been attributed to a combination of factors including agricultural expansion, increased nitrogen application rates, increased tile drainage, and loss of riparian wetlands. These landscape-level changes have resulted in a decreased natural capacity for nitrogen uptake, removal, and cycling back to the atmosphere. Land managers are increasingly interested in using wetland construction and rehabilitation as a management practice to reduce loss of nitrate from the terrestrial systems. Yet, relatively little is known about the limnological factors involved in nitrate removal by wetland systems. We conducted a series of studies to investigate the functional capacity of shallow, macrophyte-dominated pond wetland systems for uptake, assimilation, and retention of nitrogen (N) and phosphorus (P). We evaluated four factors that were hypothesized to influence nutrient uptake and assimilation: 1) nitrate loading rates; 2) nitrogen to phosphorus (N:P) ratios; 3) frequency of dosing/application; and 4) timing of dose initiation. Nutrient assimilation was rapid; more than 90% of added nutrients were removed from the water column in all treatments. Neither variation in N:P ratios (evaluated range: <13:1 to >114:1), frequency of application (weekly or bi-weekly), nor timing of dose initiation relative to macrophyte development (0%, 15-25%, or 75-90% maximum biomass) had significant effects on nutrient assimilation or wetland community dynamics. Maximum loading of nitrate (60 g N/m2; 2.4 g P/m2) applied as six weekly doses stimulated algal communities, but inhibited macrophyte communities. Predicted shifts from a stable state of macrophyte- to phytoplankton-dominance did not occur due to nutrient additions. Macrophytes, phytoplankton, and the sediment surface were all significant factors in the removal of nitrate from the water column. Overall, these shallow, macrophyte-dominated systems provided an efficient means of removing nutrients from the water column. Construction or rehabilitation of shallow, vegetated wetlands may offer promise as land management practices for nutrient removal in agricultural watersheds.

Keywords: wetlands, macrophytes, nitrogen, phosphorus, nutrient, assimilation,

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Assessing the Effects of Nutrients on Agricultural Streams: The Importance of Assessing Both Biological Response and Nutrient Processes

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The use of synthetic fertilizer and animal manure on crops has contributed to substantial growth in agricultural production in the United States. However, it has also led to elevated instream nitrogen and phosphorus concentrations, a leading cause of local and downstream water quality impairments according to the U.S. Environmental Protection Agency. Since 2003, the U.S. Geological Survey's National Water-Quality Assessment Program has studied nutrient-biota interactions in eight agricultural areas across the United States, four located within the Mississippi River Basin. These eight agricultural areas provide a gradient of low to high instream nutrient concentrations. Within each study area, 30 wadable stream sites were selected to capture the broadest possible nutrient gradient in a single ecoregion. Data on nitrogen and phosphorus, algal and invertebrate communities, benthic and sestonic algal chlorophyll a, and habitat conditions were collected at each site during the growing season. Stream metabolism and nitrogen processing were assessed at a subset of sites. Results from these studies illustrated that in agricultural streams: (1) nutrient concentrations and algal biomass were rarely correlated because of surplus nutrient supply, habitat limitation, and physical and biological interactions; (2) relations between nutrients and algal biomass cannot be found in ecoregions without a sufficient nutrient gradient; 3) high nutrient inputs and reduced retention times overwhelm natural ecosystem functions and lead to a large fraction of the original nitrogen load being exported downstream; 4) primary production is generally limited because of instream habitat conditions; 5) groundwater inflow can be a nitrogen source for an extended period regardless of changes in management practices; and 6) algal assemblages have a stronger response to low-level nutrient enrichment than macroinvertebrate or fish assemblages. These findings highlight the complex interactions between nutrient sources, habitat, and biota that are exacerbated by the excess nutrients in agricultural streams and need to be considered to realistically develop nutrient criteria and manage stream restoration.

Keywords: nutrient enrichment, biological communities, algal biomass

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Quantifying Nutrient and Sediment Attenuation by a Wetlands Reserve Program Wetland Along the South Skunk River in Iowa

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Hypoxia in the Gulf of Mexico is a major environmental concern for the Mississippi River Basin. Agricultural nonpoint source runoff from Midwestern states appears to be a significant source of excess nutrients to the Mississippi River and the Gulf of Mexico. Effective management and reduction of excess nutrient inputs is a major goal for improving local water quality and reducing Gulf of Mexico hypoxia. A two-year study has been focused on quantifying the attenuation of nutrients and sediment by a wetland restored as part of the Natural Resources Conservation Service Wetlands Reserve Program. The Bailey-Carpenter restored wetland is located approximately 10 miles northeast of Des Moines in Polk County, IA. A two square-mile watershed, composed of mostly agricultural land and restored prairie, drains into the wetland. The wetland is comprised of two distinct cells that are connected by a culvert. Water flowing out of the wetland eventually drains into the South Skunk River. Discharge was continuously measured at the inlet and the outlets of both wetland cells using stage/velocity meters. Water samples were collected using autosamplers at the inlet and outlets of the wetland during a variety of flow conditions and analyzed for suspended sediments and nutrients. Annual loads were calculated for each sampling site using the USGS Graphical Constituent Loading Analysis System. Preliminary analysis of the data suggests that the wetland was very efficient in removing suspended sediment, total residue, volatile solids, and nitrate. In contrast, the wetland was less efficient at removing total phosphorus and orthophosphate. This research is providing a better understanding the ecological benefits provided by restored wetlands.

Keywords: wetland, nitrogen, phosphorus, Iowa

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Soil Nitrate Testing Affects Nitrate Loss within a Watershed: An RZWQM Simulation

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Among the most promising tools available for determining precise N requirements are soil mineral N tests. The Walnut Creek Watershed in central Iowa is one of the few field studies that investigated the N loss in tile flow under late spring soil testing (1997-2000). We use this dataset with additional tile flow data from this watershed (1992-2001) to calibrate and test the Root Zone Water Quality Model (RZWQM). Results suggest that RZWQM accurately simulates significantly lower nitrate concentrations from spring soil testing (about 11 mg N/L) compared to fall N application (about 16 mg N/L). A statistical model we developed using RZWQM simulations from 1970-2005 shows that early season precipitation and early season temperature account for 90% of the interannual variation in late-spring nitrate test (LSNT) rates. Long-term simulations with similar average N application rates to corn (150.7 kg N/ha) also reveal that annual average N loss in tile flow were 20.4, 22.2, and 27.3 kg N/ha for LSNT, single spring N application, and single fall N application. These results suggest that: 1) RZWQM is a promising tool to accurately estimate the water quality effects of LSNT; 2) the vast majority of N loss difference between LSNT and fall applications is from over winter and preplant N losses; and 3) year-to-year LSNT determined rates are mainly due to variation in early season precipitation and temperature. We conclude that use of

RZWQM and further refinement of the statistical model will lead to simple tools that can be used in place of soil testing for applying the LSNT with a tremendous savings in labor and money and resulting in lower nitrate losses to surface waters compared to fall fertilizer applications.

Keywords: nitrogen, late spring nitrogen test, water quality

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Grazing Management Effects on Sediment and Phosphorus Losses from Stream Banks in Riparian Pastures

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Improved grazing management practices can reduce the amounts of sediment and phosphorus (P) in surface waters that originate from stream banks and riparian areas. In this study, we measured bank erosion, forage height, and the proportions of bare and manure-covered ground along streams in 13 pastures with varying cattle stocking rates in the Rathbun Lake watershed in southern Iowa from 2006 through 2009. We also measured bank erosion, forage height and mass, the proportions of bare and manure-covered ground, and sediment and P losses in the Willow Creek watershed in central Iowa from 2005 through 2009. The Willow Creek site included six 12-ha cool-season grass pastures, each bisected by a 196-m stream segment. Two replications of three management treatments [continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR), and rotational stocking (RS)] were assigned to the six pastures. Pastures were stocked with 15 fall-calving cows from May to October of each year. Erosion pins were used to estimate bank erosion in pastures within both watersheds. Soil P values, in conjunction with soil bulk density and erosion pin measurements, were used to estimate how much P is being lost through erosion of the stream banks. No differences in net bank erosion were observed among grazing management practices in any year within either watershed, suggesting that bank erosion of pasture streams is primarily affected by stream hydrology and not by grazing animals. Although no differences were observed in bank erosion during the study period, differences in both forage characteristics within the riparian area and cattle distribution patterns were observed, suggesting that alternative grazing management practices, such as rotational stocking and the use of reinforced stream access points, may positively impact riparian conditions and surface water quality over time.

Keywords: Grazing management, Stream bank erosion, Phosphorus Losses, Cattle distribution

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Evaluating Practices to Mitigate Nutrient Transport in a Tile-drained Subwatershed of the Mackinaw River, Illinois

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Using a paired-watershed approach, we evaluated effectiveness of focused outreach on implementation of best management practices (BMPs) and improving water quality in experimental versus reference subwatersheds (4, 000 ha) of the Mackinaw

River in Central Illinois. Land use in the subwatersheds was >80% row crop agriculture (corn-soybean rotation) with extensive subsurface tile drainage. Targeted outreach significantly increased implementation rates of three BMPs (grassed waterways, stream buffers and strip-tillage) throughout the experimental subwatershed. By comparing experimental to reference stream water quality over seven years, we observed no significant changes in nitrogen (NH_4, NO_3), phosphorus (DRP or TP), total suspended solids, or hydrologic variables following implementation of BMPs. Our results suggest that surface-water BMPs implemented within these subwatersheds were bypassed by subsurface drainage tiles. We are currently testing the effectiveness of intercepting tile water using wetlands to reduce nutrient exports from these agricultural lands. Specific questions include: (1) what is the watershed to wetland area ratio needed for wetlands to effectively retain tile water and reduce nutrients, and (2) where do these wetlands need to be placed on the landscape for maximum effectiveness? To answer the first question, we have constructed 3 experimental wetland systems, each with 3 consecutive wetland cells. Each wetland cell represents 3% of the surrounding farmland for a wetland to watershed ratio of 3%, 6% and 9% per wetland system. Monitors set at inlets and outlets of the wetland subunits measure water volume and nutrients as tile water moves through the wetland systems. Preliminary results from 2-year data suggest that a wetland to watershed ratio of 3%, 6% and 9% will remove a total of 18%, 34%, and 43% of nitrate nitrogen, respectively, and 43%, 55%, and 56% of orthophosphorus, respectively. To address the second question, Illinois State Water Survey is developing a hydrologic model to target where conservation practices will be most effective in the watershed. In 2010, we will begin testing this model in our paired watershed sites by constructing wetlands at targeted locations and monitoring their effectiveness. An additional component of this next step will be coordinating teams of local farmers to assist in outreach efforts.

Keywords: wetlands, nutrients, tile drainage, BMPs, paired watersheds

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Agricultural Tile Management: Key to decreasing nitrogen export and flooding in the Midwest Corn Belt

Agricultural tile utilized to transform poorly-drained soils into highly-productive cropland in over 40% of the Midwest Corn Belt has been identified as the conduit for nitrogen export and flooding in streams. Nitrogen fertilizer applied to fields is rapidly transformed by soil bacteria into nitrate nitrogen which can be readily leached from the soil into tile and piped directly into the receiving stream. Nitrate nitrogen concentration in tile outlets can range 20 to 50 mg/L and often 20-25 mg/L in the streams receiving tile drainage. Nitrate nitrogen represents approximately 80% of the total nitrogen export from the Midwest Corn Belt. Precipitation drained through the soil into the tile and to the stream has also accounted for over 80% of the total flow in streams draining areas of tile in the Midwest Corn Belt. Agricultural tile drainage has substantially altered the historical hydraulic connection and flow path of subsurface drainage and receiving stream. The original time and travel period of days to weeks for precipitation to infiltrate and reach the stream channels through subsurface flow was fundamentally changed with the installation of agricultural tiles. Installation of agricultural tile drastically decreased the time and travel of subsurface flow to minutes or hours using pipe flow for transporting infiltrated precipitation to the receiving drainage ditches and streams. Historical hydrographs of streams prior to agricultural tile installation was dominated by relatively slow subsurface flow drainage with streamflow volumes that increased gradually following a precipitation event to a sustained peak streamflow of moderate level followed by a steady and sustained decease in streamflow. In contrast, hydrographs of streams in watershed with extensive tile drainage mimic those streams that have flash flooding caused by expensive impervious areas or storm sewers; the hydrograph has streamflow rapidly increasing following a precipitation event to an extreme and short-term peak streamflow which is followed by an immediate decline in streamflow. Managing the timing and quantity of agricultural tile flow can be designed to substantially decrease nitrogen export through enhancement of soil denitrification and decrease the severity of floods by decreasing the amount of subsurface flow using the unsaturated soil as retention reservoirs.

Keywords: Tile drainage, nitrogen flux, flooding

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Nitrogen, phosphorus, and sediment capture and nitrogen cycling processes in a wetland complex along a tributary of the Upper Mississippi River: a comparison of reclaimed and natural wetlands.

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Many different types of constructed wetlands are used to mitigate sediment and nutrient runoff from non-point sources yet their effectiveness is seldom documented. Halfway Creek Marsh Complex, a riparian wetland near La Crosse, WI, was recently reclaimed by the U.S. Fish & Wildlife Service from agricultural use for water fowl habitat and sediment retention. Directly downstream is an unmodified and unmanipulated portion of the wetland. Over 3 years we estimated loads of nitrogen, phosphorus, and sediments in the Creek and losses to both wetlands. We also evaluated rates of nitrification, denitrification, sediment N and C and moisture to determine how well the reclaimed marsh (RM) performed as processors of N relative to natural marsh (NM). Denitrification was greatest in water-saturated areas of the NM (2.2 ug-N cm2 hr-1) and lowest in the RM (0.5 ug-N cm2 hr-1). Nitrification rates were highest in the drier areas of the NM (7.85 ug-N cm2 hr-1), and lowest in the RM (4.8 ug-N cm2 hr-1). The RM captured between 0.7 (2006: 5 mton) to 6.2 (2004: 573 mton) percent of the suspended sediment load of Halfway Creek while the NM captured between 64 (2006: 534 mton) and 70 (2005: 1698 mton) percent of the total load The RM captured 0.2 (2006: 6 kg) to 5.8 (2004: 764 kg) percent of the total phosphorus load, while the NM retained between 12.6 (2005: 779 kg) and 18.4 (2006: 538 kg) percent of the annual load of total phosphorus. Finally, the RM retained from 0.1 (2006: 24 kg) to 4.9 (2004: 2, 021 kg) of the load of total nitrogen, while the NM retained from 9.1 (2006: 2254 kg) and 15 (2005: 5526 kg) percent of the total N load in the Creek. Annual retention efficiency of sediment, N, and P was highest in the NM because of the greater annual hydrologic connection to the Creek; whereas the RM received Creek water only during large floods. N-removal capacity in both marsh types was correlated with sediment moisture and nitrate concentrations, which were determined by water management practices.

Keywords: wetlands, Upper Mississippi River, nitrogen, phosphorus, sediment, loads, retention, removal, denitrification

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Evaluating the Ability of Two-Stage Ditch Management to Increase Nitrogen Removal via Sediment Denitrification

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Floodplains connect streams to riparian areas and often function as hotspots for biological nitrogen (N) removal. Two-stage ditch management adds floodplain benches to formerly incised agricultural streams, with the intent of reducing erosion and increasing water residence time and subsequent sedimentation. In addition, floodplain benches, with their saturated organic-rich soils, may function to increase biological N removal through the promotion of microbial denitrification. Denitrification is the microbially-mediated conversion of nitrate to dinitrogen gas, which requires nitrate, organic carbon, and anoxic conditions to occur. In partnership with The Nature Conservancy, we quantified the N removal capacity of a northern Indiana two-stage ditch, using seasonal denitrification assays. We compared stream sediments to soils collected from newly-constructed benches and found that denitrification rates were generally lower in bench soils than stream sediments, but higher than in the adjacent upland grass buffer strip. In addition, microbial denitrification occurred deeper in the bench soils. In-stream sediment denitrification rates were controlled by stream water nitrate concentrations ($r2 = 0.52$, $p < 0.006$) and sediment organic matter content ($r2 = 0.23$, $p < 0.001$). In contrast, bench denitrification rates were weakly predicted by soil organic matter content ($r2 = 0.1$, $p < 0.03$), but not porewater nitrate or soil saturation. There was no evidence for N or carbon limitation in stream sediments, but bench soils responded positively to glucose addition, indicating significant carbon limitation of denitrification (2-way ANOVA, $p = 0.05$). Bench vegetation also influenced denitrification; we measured higher

rates in vegetated plots than in unvegetated plots (ANOVA, $p < 0.001$). Furthermore, the addition of high-nitrate stream water stimulated denitrification in vegetated plots (ANOVA, $p < 0.05$), but resulted in no difference in unvegetated areas. Thus far, our data indicate that bench construction increases bioreactive surface area and results in increased reach-scale N removal of up to 500%. Although results are encouraging, this additional denitrification translates to a removal of just 5-15% of the stream nitrate load, with most removal occurring when stream water nitrate concentrations are low. Reducing nitrogen exports from agricultural landscapes will thus likely be optimized with a combination of in-stream and on-field strategies.

Keywords: two-stage ditch, denitrification, nitrogen removal

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An Empirical Modeling Approach To Assess and Scale Wetland Ecosystem Services for Watershed Restoration Planning Efforts.

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Extensive conversion of the landscape towards agricultural and urban use has significantly altered the delivery of wetland ecosystem services such as water quality improvement, biodiversity maintenance, and carbon management. Increased hydrological and sediment loadings and a diminished intercepting wetland network are linked to problems of global concern such as coastal zone hypoxia and reduced carbon sequestration. A regression re-analysis of published wetland nutrient retention data correlating external processes and internal wetland characteristics according to wetland structure reveals performance variability by wetland type that should be accounted for when using natural, restored, and constructed wetlands for re-establishing wetland ecosystem services. Using the same approach to assess biodiversity as well as other ecosystem services provides a quantified basis for evaluating trade-offs between ecosystem services and provides a means for scaling up and evaluating these services at the watershed scale. Wetland type-based empirical models of performance, similar to the approach presented here, linked with Geographic Information System based models and decision analysis tools such as "alternative futures" analysis should enhance our ability to conduct watershed-scale planning for sustainable ecosystem service provisioning.

Keywords: Wetlands, Restoration, Modeling, Ecosystem Services

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Influence of Two-Stage Ditch Management on Substrate Composition and Sediment Flux in a Northern Indiana Agricultural Stream

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Conventionally-managed agricultural streams are generally channelized, and characterized by high nutrient and sediment export, and unstable banks. In the agricultural Midwest, these issues are exacerbated by flashy hydrographs resulting from floodplain disconnection and extensive tile drainage. Two-stage ditch management has been developed to mitigate these issues through the construction of floodplain benches within formerly trapezoidal ditch channels. The two-stage design is intended to lower stage height and reduce average water velocity at peak flows as a means to reduce erosive forces on stream channels and banks. In November 2007, in partnership with The Nature Conservancy, we converted 620m of an Indiana agricultural ditch to the two-stage design. The modified reach was paired with an upstream unmodified reference reach of comparable length. We measured habitat cover, sediment organic matter content, and continuous water column turbidity over three years (2006-2009), one year prior and two years post two-stage construction. We predicted that lower

stream water velocities would influence substrate composition and sediment flux. Specifically, we predicted that reduced water velocity would reduce water column turbidity, accompanied by deposition of organic-rich sediments on the benches and/or scouring of stream bottom fine organic sediments.

Post two-stage construction, we found decreased baseflow turbidity and mean daily sediment flux compared to the reference reach. Largest declines occurred in autumn, coinciding with lowest stream discharges. Bench organic matter content showed no significant increase after two-stage implementation. Likewise, there were no significant differences in reach-scale stream bottom coverage of sand or fine organic matter. There are two possible interpretations of these results: 1) water column turbidity is not derived from stream bottom sediments, rather from upstream or 2) benthic substrate composition is so thick that changes in sediments are not detectable on a percent-cover basis. Thus far, our results suggest that two-stage management has the potential to immediately reduce water column turbidity and stream sediment flux, but that changes in stream channel sediment distribution and composition may take longer to detect. Our future research will investigate differences in stream metric response time by focusing on two-stage ditches of varied ages, ranging from 1 to 7 years post construction.

Keywords: agricultural stream, two-stage ditch, turbidity, sediment transport, water quality

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Discerning Climate and Land-use Change Impacts on Watershed Hydrology: Implications for Gulf Hypoxia
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Impacts of climate change on watershed hydrology are subtle compared to cycles of drought and surplus precipitation (PPT), and difficult to separate from effects of land-use change. In the U.S. Midwest, increasing baseflow has been more attributed to increased annual cropping than climate change. The agricultural changes have led to increased fertilizer use and nutrient losses, contributing to Gulf of Mexico hypoxia. In a 25-year, small-watershed experiment in Iowa, when annual hydrologic budgets were accrued between droughts, a coupled water-energy budget (eco-hydrologic) analysis showed effects of tillage and climate on hydrology could be distinguished. The fraction of PPT discharged increased with conservation tillage and time. However, the fraction of evaporative demand (PET - Hargreaves) that was unsatisfied increased under conservation tillage, but decreased with time. A conceptual model was developed, illustrating that changes in ET associated with land-use change create monotonic shifts in the proportions of available water and energy that are unsatisfied, while climate change that shifts PPT:PET ratios causes contrasting shifts in those proportions. To extend this concept beyond experimental watersheds, a similar analysis conducted on long-term (>1920s) records from four large, agricultural Midwest watersheds underlain by fine-grained tills. At least three of these four watersheds showed decreases in PET, and increases in PPT, discharge, baseflow ($p<0.10$), and all four showed increases in PPT:PET ratios ($p<0.05$). An analysis of covariance showed the fraction of precipitation discharged increased, while unsatisfied evaporative demand decreased with time among the four watersheds ($p<0.001$); the conceptual model suggests such eco-hydrologic shifts are climate driven. Within watersheds, agricultural changes were associated with eco-hydrologic shifts expected with decreasing ET; but these only affected timing and significance, but not direction, of the dominant climate-driven trends. Thus, an ecohydrologic concept derived from small-watershed research, when regionally applied, suggests climate change has increased discharge from Midwest watersheds, especially since the 1970s. By inference, climate change has increased susceptibility of nutrients to water transport, exacerbating Gulf of Mexico hypoxia. This conclusion expands on evidence from other recent studies, which have suggested climate trends in the Midwest will require that conservation systems in this region be improved and better promoted.

Keywords: Ecohydrology, Climate change, Land use change, watershed analysis

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2-Stage Ditch Design: A Collaborative Evaluation of an Alternative Drainage Channel Design in the Midwest
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Much of the landscape in the Wabash River basin, a large-river watershed that drains to the Gulf of Mexico, has been converted to agricultural use. With this massive landscape conversion has come great altered hydrologic function and significant changes in the flow of nutrients and sediments out of smaller agricultural watersheds via tributaries. In some cases, these hydrologic alterations have also led to severe water quality problems, including accelerated rates of stream bank erosion, sedimentation problems, inadequate processing of nutrients and accelerated downstream transport, and increased turbidity. Each of these poses dire consequences for pollutant discharge to downstream receiving waters which includes the Ohio, Mississippi, and ultimately the Gulf of Mexico.

This collaborative project highlights the 2-stage ditch concept and is showing how biological, chemical, and physical monitoring parameters are positively influencing water quality. Two site level projects are currently being evaluated, one in the Tippecanoe River and one in the St. Joseph River.

The 2-stage ditch is reconnecting agricultural streams with an appropriately sized floodplain. Through the use of artificial floodplain "benches", which are constructed adjacent to the stream channel, we can slow down storm water flows as they race towards receiving rivers. The design allows for reductions in turbidity, and creates conditions that are favorable for nutrient removal through floodplain vegetation and microbial activity.

Monitoring is taking place both for chemical and physical changes in the water including streambed and overall stream health. Data regarding biotic and flow changes is also being collected. Nutrient uptake and assimilation data is being collected as are physical parameters of water quality. Newly constructed 2-stage channels immediately show increased nutrient uptake and removal, increased biodiversity, decreased turbidity, and lower peak discharge during storm events when compared to traditionally constructed and managed streams.

If installed at the appropriate scale and as a part of a conservation system that addresses on-farm nutrient application, buffering, conservation tillage and wetland restoration, the 2-stage ditch could be an important component of the conservation system that begins to address Gulf hypoxia, starting at the farm scale and ramping up to larger watershed areas.

Keywords: Hydrology, Denitrification, 2-Stage Ditch, Naturalized drainage channel

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Economic Analysis of Tillage and Nutrient Best Management Practices for Reducing Nutrient Export to the Gulf of Mexico from a Mississippi River Delta Watershed
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Importance:
With this socio-economic study, we describe research findings from our modeling analysis of field-based nutrient and tillage management BMPs to reduce nutrient export from an agriculturally dominated watershed in the Mississippi River Delta of Louisiana. Our research findings provide policymakers and producers with the necessary information to reduce nutrient export from freshwater systems to mitigate potential for Hypoxia formation in the Northern Gulf of Mexico (GOM) at minimal cost to producers.

Objective:
Analyze biophysical and economic effects of various BMPs designed to reduce nutrient outflow from agricultural fields.

Methods:
Simulation results from biophysical process model (AnnAGNPS) were integrated into a geo-spatial referenced economic model of the Cabin-Teele watershed in northeast Louisiana to compare current agricultural practices with BMPs to reduce nitrogen (N) and phosphorus (P) by 10-30%, at mouth of watershed, from baseline loads. Crops analyzed included corn, soybeans, sorghum, cotton and rice.

Results:
Results indicated that conservation tillage was the most cost-effective BMP analyzed for reducing P losses in the study watershed, despite prevalence of poorly drained soils. This finding was due to producers' limited options for addressing excess P in freshwaters systems; in this watershed the soils were saturated with P so that no external applications were made by producers. As anticipated, producers reduced acreage and nitrogen fertilizer application rates as more restrictive N loading criteria were implemented. As anticipated, farm income declined somewhat as nutrient restrictions at the mouth of the watershed increased.

Conclusions:
This research showed that conservation tillage and nutrient management provided economically viable options for producers to reduce nutrient export from watersheds. These findings provide policymakers evidence that there are readily available and economically feasible alternative management practices for reducing agriculturally produced nutrient pollutants. Our research provides policymakers and producers with the necessary information to address some of the negative externalities associated agricultural production while providing benefits to society from agriculture (food, feed, and fiber as well as water quality) at minimal private cost. Estimated losses in farm income provide lower bounds for levels of producer compensation or cost-shares to encourage adoption of these practices to reduce nutrient loading from agriculture.

Keywords: economics, BMPs, Louisiana, AnnAGNPS

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CEAP Cropland Management Survey Results for Nutrient Management Practices in the Upper Mississippi River Basin

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The CEAP cropland management survey data includes three years of detailed crop rotation, tillage, conservation practice, and nutrient and pesticide application data for the farm fields associated with 3, 702 National Resource Inventory (NRI) points in the Upper Mississippi River Basin (UMRB). The data collection includes farmer reported practices, conservation district office planning records, NRI data, and interpretive data such as Soil Tillage Intensity Ratings (STIR). We present summaries of practice prevalence for both those practices that directly involve nutrients (e.g., timing, rate, and method), and for those practices that affect nutrient behavior in the environment (e.g., tillage, residue management, and erosion and water control practices). Separate results are presented by soil erodibility class, use of manure, and by other important factors. A correlation between level of management and level of inherent nutrient loss risk is also given, e.g., high versus low level of management on erosive soils.

Preliminary findings include the following:

- Most cropland acres in the UMRB have evidence of some kind of nutrient management practice; however, only 13 percent of all acres have appropriate rate, time, and method of application for all crops and all applications in the rotation.
- According to additional criteria that were developed to classify nutrient management:
- About 44 percent of the acres had a high level of nitrogen management and about 21 percent had a high level of phosphorus management. About 40 and 20 percent of the acres had low levels of management for phosphorus and nitrogen, respectively.
- Farmers use some form of reduced tillage on 94 percent of cultivated cropland and about 70 percent of the cultivated cropland meets NRCS criteria for Residue and Tillage Management - reducing tillage intensity while also maintaining or enhancing soil organic carbon.
- Structural practices are in use on almost half of all cropland in the region, and on about three-fourths of highly erodible cropland. However, only about 9 percent of the acres have combinations of edge-of-field filtering and buffering practices with one or more in-field practices for control of overland flow and/or concentrated flow.

Keywords: CEAP, cropland, practices, conservation, nutrients, survey, management

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A comparison of select water quality parameters collected from the Missouri River main channel, tributaries, and created habitats

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The U.S. Army Corps of Engineers (USACE) initiated a comprehensive Water Quality Program (WQP) in 2008 as part of the Missouri River Recovery Program. The WQP was initiated to address questions related to endangered species recovery, habitat modifications, and overall ambient conditions of the lower Missouri River. For example, does ambient water quality impact endangered species recovery? How does ambient water quality impact plankton and macroinvertebrate populations (ie, prey) within the Missouri River? How does mainstem river water quality compare with that of tributaries and within created habitats? Additionally, EPA's Regional Technical Advisory Group (RTAG) is in the process of developing nutrient benchmarks for the Missouri River Basin. The question remains how this will affect ambient water quality relative to recovery efforts. Select water quality parameters were compared between the mainstem, tributaries, and created habitat along the lower Missouri River. Samples were collected during both high flow events and during base flow conditions. This poster will discuss water quality trends in the Missouri River, associated tributaries, and created habitats as well as the proposed nutrient benchmarks.

Keywords: Missouri River, water quality, U.S. Army Corps of Engineers

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National/regional data available for use in modeling nutrient load/delivery into major river basins and the Gulf of Mexico

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Modeling nutrient load and delivery within a watershed and the transmission of those nutrients further downstream into estuaries such as the Gulf of Mexico requires considerable input data to capture the complex processes involved. The input database for the models has to include data that not only effectively describe farming activities--such as tillage, cropping history, field operations, and crop rotations--but also include a credible representation of conservation activities in the study area. All data must be suitable for use with models and must capture weather and soil conditions, as well as landscape features such as drainage, hydrology and elevation. While some of these data are readily available, other data may have limitations with respect to access. Some data require aggregation that limits its usefulness for watershed modeling.

This poster's objective is to layout, review and highlight details about national/regional level data currently used to model nutrient load and delivery, while pointing out where limitations on access and data gaps exist. Ensuring wider access to data and knowledge about available data for modeling opportunities should promote more credible analysis, expose data gaps and point to opportunities for leveraging future data collection efforts.

Datasets described in the poster will include: Conservation Effects and Assessment Project (CEAP) Survey data, National Resources Inventory (NRI), National Agricultural Statistical Service (NASS) data--AgCensus, Chemical Use Survey, Irrigation, and Price Paid and Paid Index, Fertilizer Sales data, Agriculture Resource Management Survey (ARMS), National Hydrography Dataset (NHD), National Land Cover Database (NLCD), NRCS Progress Reporting System (PRS) and the National Conservation Database (NCDB), FSA Common Land Unit (CLU) database and easement data, Soil Survey Geographic (SSURGO) database, Parameter-elevation Regressions on Independent Slope Model System (PRISM), National Agricultural Imagery Program (NAIP), Light Detection and Ranging (LIDAR) data.

Keywords: science-based, models, limitations, gaps, conservation practices, landscape

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Limitations and Gaps of Data in the Permit Compliance System Data Base for Calculating Nutrient Loads from Municipal and Industrial Effluent
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To improve regional nutrient modeling results, the U.S. Geological Survey began using a census-based approach to calculate total nitrogen (TN) and total phosphorous (TP) from individual dischargers located in select major river basins in the United States. The nutrient loads were calculated based on effluent discharges (flow) and nutrient concentration information from the U.S. Environmental Protection Agency (USEPA) National Pollutant Discharge Elimination System (NPDES) Permit Compliance System (PCS) and from select State datasets. In the process of calculating point source nutrient loads, a number of data limitations and gaps were identified. Data limitations in the PCS data include coding errors, non-electronic data records, and inconsistent permitting and reporting among USEPA Regions. Nationally-consistent reporting requirements for site location and constituents would improve the PCS database. Additional quality-assurance and quality-control measures in the database would help eliminate coding, typographical, and unit-related errors. Finally, gaps in the federal datasets, such as those associated with minor (less than 1 million gallons per day) discharging facilities, could be improved through a nationally consistent reporting process.

Keywords: data gaps, data limitations, water quality, point source

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Using land-cover data to understand effects of agricultural and urban development on regional water quality
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The Land Cover Trends project is a collaborative effort between the Geographic Analysis and Monitoring Program of the U.S. Geological Survey (USGS), the U.S. Environmental Protection Agency (EPA) and the National Aeronautics and Space Administration (NASA) to understand the rates, trends, causes, and consequences of contemporary land-use and land-cover change in the U.S. The data produced from this research can lead to an enriched understanding of the drivers of future land-use change, effects on environmental systems, and any associated feedbacks.

Using the EPA Level III ecoregions as the geographic framework, USGS scientists process geospatial data collected between 1973 and 2000 to characterize ecosystem responses to land-use changes. General land-cover classes for these periods were interpreted from Landsat Multispectral Scanner, Thematic Mapper, and Enhanced Thematic Mapper Plus imagery to categorize and evaluate land-cover change using a modified Anderson Land Use Land Cover Classification System for image interpretation.

The rates of land-cover change are estimated using a stratified, random sampling of 10-kilometer (km) by 10-km blocks within each ecoregion. The sample block data are then incorporated into statistical analyses to generate an overall change matrix for the ecoregion. While the current strategy is a sampling strategy, the same methods could be extended to include all of the blocks for a given area or ecoregion to produce a more precise assessment. For example, the Illinois River runs through the Central Corn Belt Plains and Interior River Lowlands ecoregions before reaching the Mississippi. The sample blocks within these two ecoregions can be sub-sampled in order to create a new boundary that incorporates the sample blocks from both of the ecoregions for the specific area of interest creating a new, more localized statistical assessment. The new statistical assessment can be used to examine effect of land-cover change on water quality.

When USGS water quality data is coupled with the land-cover trends data the outcome may enhance the way scientists and policy makers plan future development or suggest ways to modify agricultural sustainability operations and best management practices.

Keywords: land-cover, Landsat Multispectral Scanner, Thematic Mapper, Enhanced Thematic Mapper Plus, Anderson Classification System

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Providing a Proof of Concept Watershed Study to Test the Effectiveness of Tile Drainage Treatment Wetlands

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Hypoxia in the Gulf of Mexico is a key societal issue that requires an effective solution. The primary contribution of excess nutrients to the Gulf of Mexico has been attributed to agricultural runoff in the tile-drained corn belt regions of Iowa, Illinois, and Indiana. While University of Illinois Research indicates that nitrogen levels leaving agricultural watersheds can be reduced 45% [the target recommended by the 2007 Science Advisory Board] by rerouting tile drainage effluent through wetlands in 5% of the effective tile-drained watershed. The effectiveness of such wetlands on a regional level has yet to be determined. Applying this wetland solution to all of the tile drained small grain cropland in the Upper Mississippi River basin would require construction or restoration of 1.2 million acres of wetlands costing an estimated $23 billion dollars. Before committing to such a cost we must be sure that this approach will be effective. Therefore we propose the development of a pilot scale proof of concept tile drainage wetland complex in Hydrologic Unit Code 05120112 at the mouth of the Camargo, Illinois USGS gaging station 03343400 known to export an average of 1700 Mg N yr-1 . The 186 square mile area would require 4, 464 acres of wetlands and 4, 464 acres of associated practices (buffers and filter strips). NRCS rental or easement costs would be $62.5 million and construction costs of wetland mitigation systems would be $23.2 million dollars. Amortized over 30 years, the cost of nitrate removal would be $0.68 per pound. Wetland construction, wetland restoration, and development of associated buffers and filter strips could be accomplished through USDA Farm Bill programs, e.g., the Wetland Reserve Program (WRP) or the Conservation Reserve Program (CRP), that cover most costs of construction, and compensate landowners for any maintenance or mid-contract management required. A system is in place that could target programs to achieve the greatest conservation benefits and technical expertise; and infrastructure exists within USDA, Natural Resource and Conservation Service and Farm Services agency to provide technical assistance to producers, design projects, and administer contracts and easements.

Keywords: Tile-drainage wetlands, nutrient removal, regional proof of concept

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Precipitation-Runoff Relations and Water-Quality Characteristics at Edge-of-Field Stations, Discovery Farms and Pioneer Farm, Wisconsin

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As part of the University of Wisconsin-Discovery Farms and University of Wisconsin-Platteville Pioneer Farm initiatives, the U.S. Geological Survey measured surface-water runoff, nutrients, and sediment year-round near field edges in grassed waterways on five privately owned farms and the UW-Platteville Pioneer Farm from 2003-2008. Runoff volumes were measured in H flumes and water samples were collected during most periods of runoff using refrigerated autosamplers. Runoff volumes and yields of nutrients and sediment were computed and averaged for each farm and each year - a total of 26 "farm-years."

Annual precipitation was typically within 20% of the 30-year average. Runoff volumes varied greatly between farms and years, but they were not necessarily related to annual precipitation amounts. Annual runoff averaged 2.5 inches per acre. Most runoff occurred in late winter (February and March) when the ground was typically frozen as the result of snowmelt and/or rain on snow. Another important runoff period was in May and June as the result of high-intensity and/or repetitive rainfall events with short recurrence intervals (and thus high antecedent soil-moisture conditions).

Average annual suspended sediment yields were 600 lb/acre, with 90% measured in runoff during non-frozen ground periods. Average annual total phosphorus (TP) yields were nearly 2 lb/acre. Sixty percent of TP was yielded in runoff during non-frozen ground periods. Particulate P was the dominant P form during non-frozen-ground periods (75% of TP), while dissolved P dominated during frozen-ground periods (60% of TP). Average annual total nitrogen (TN) yields were about 7 lb/acre, split nearly evenly between frozen-ground and non-frozen ground periods. Organic nitrogen was the dominant form of nitrogen measured during both periods of runoff, comprising over 50% of the TN measured annually. Ammonium nitrogen was primarily measured in runoff during frozen ground periods following winter manure applications.

These data observations have been used to inform producers, agency personnel, researchers, and legislators on agriculture's impact on surface water-runoff. Data have also been incorporated into improving runoff models to help managers develop recommendations for practices that focus on improving water quality.

Keywords: Discovery Farms, Edge-of-field runoff, nutrients, sediment

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Hydrograph Separations can Identify Contaminant-Specific Pathways for Conservation Targeting in a Tile-Drained Watershed

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Water quality issues continue to vex agriculture, partly due to perceived tradeoffs among different contaminants. Yet, agricultural water quality is influenced by contaminant-transport pathways unique to each watershed that are not well defined. More accurate information on contaminant pathways could provide a basis for mitigation through well-targeted approaches. This study determined dynamics of nitrate, total phosphorus (TP), E. coli, and sediment during a runoff event in Tipton Creek, Iowa, in an effort to distinguish the role of key sources and pathways in delivering each contaminant. The watershed, under crop and livestock production, has extensive tile drainage in the upper part, and discharges through a well-defined alluvial valley. A September 2006 storm yielded 5.8 mm of discharge during the ensuing seven days, which was monitored at the outlet (19, 850 ha), two upstream tile-drainage outfalls (1856 ha), and a runoff flume draining 11 ha in the lower valley. Hydrograph separations indicated 13% of tile discharge was from surface intakes. Tile and outlet nitrate-N loads were similar, verifying sub-surface tiles dominate nitrate delivery. On a unit-area basis, tile discharge delivered TP and E. coli loads that were about half and 30% of the outlet's, respectively. Both contaminants showed rapid, synchronous timing in tile discharge, indicating surface intakes that drain depressions are an important pathway. Flume results indicated surface runoff was also a significant source of TP and E. coli loads, but not the dominant source. At the outlet, sediment, P, and E. coli were reasonably synchronous. Radionuclide activities of 7Be and 210Pb in suspended sediments showed sheet-and-rill erosion sourced only 22% of sediment contributions; channel sediments dominated and were an important source of P and E. coli. The contaminants followed unique pathways, necessitating separate mitigation strategies. Results, while viewed in context of a late summer storm and mature crop cover, nonetheless inform on conservation efficacy in the watershed. To comprehensively address water quality, erosion-control and nitrogen-management practices currently encouraged could be complemented by buffering tile intakes and stabilizing streambanks. The study also demonstrates how detailed monitoring of rainfall-runoff events can provide contaminant-pathway information that is indiscernible from routine (e.g., weekly) monitoring intervals.

Keywords: Nutrients, pathogens, sediment, source separation

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Data Gaps in Iowa Nutrient Budget

In 2003 the Iowa DNR, in conjunction with ISU and Soil Tilth Lab scientists, estimated a nutrient budget for the state and by watershed. Inputs included fertilizer, legume fixation, manure, soil processes, atmospheric deposition and human and industrial waste. Outputs were crop harvest, grazing, volatilization, soil processes, denitrification and stream discharge. Although the state-wide picture showed the nitrogen budget to be fairly well balanced, the watershed budgets ranged from 94% to 128%, with 100% being in balance, <100% having more outputs than inputs and >100% having more inputs than outputs. However, it was evident there were many assumptions that had to be used to fill data gaps to provide watershed scale budgets. Many assumptions revolved around locations and application rates of fertilizer and manure to the landscape. Local fertilizer application rates were not available so estimation was made using state-wide sales data parsed by county expenditures from the USDA Agricultural Census. Watershed boundaries were then used to sum the fertilizer rates from counties. While estimates of livestock manure production can be reliably estimated based on the number and type of animal, storage type and application method, distributing the manure amounts across a watershed is problematic. Manure can be applied to the nearest crop ground or it can be applied to the local watershed. Depending on how these assumptions are applied can change the budget balance. Another potential source of error in the budget calculations was atmospheric deposition where a single value was applied over the whole state. The total amount of nitrogen input from atmospheric deposition agreed with the amount of nitrogen volatilized. However, the volatilization amounts varied around the state and the atmospheric deposition most likely should too. With animal agriculture and fertilizer usage increasing since the budget was completed, nitrogen balances may become even more variable in the future. However, without better data regarding nitrogen inputs and outputs, assessing the ongoing nitrogen balance of Iowa watersheds will be difficult as will developing models to properly evaluate those watersheds. Identifying areas where nitrogen budgets are out of balance is critical to developing solutions to excessive nitrogen loadings to rivers.

Keywords: nutrient budget, nitrogen, fertilizer, manure, Iowa

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The North American Soil Geochemical Landscapes Project: Providing national-scale data on soil composition with potential applications to understanding element loads in the Mississippi River
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Regional variation in water quality has a broad relationship to soil and bedrock composition within large drainage basins such as that of the Mississippi River. Knowledge of the natural geochemical variation in soils of such large drainage systems is important to understanding the natural sources of nutrient loads (e.g., P, N) and loads of potentially toxic elements (e.g., As, Cd, Hg, Pb) in the river. At present, there is no common understanding of either soil geochemical background variation within the Mississippi River basin or the processes that control this variation.

The North American Soil Geochemical Landscapes Project, a tri-national initiative among the United States, Canada, and Mexico, was designed to (1) develop a continental-scale framework for generating soil geochemical data and (2) provide soil geochemical data that are useful for a wide range of landscapes, applications, and disciplines. The Project is based on low-density sample collection over a spatially balanced array of 13, 596 sites for the North American continent (1 sample site per approximately 1, 600 km2). At this density, approximately 1, 400 sites are located in the Midwest portion of the Mississippi River drainage system. Three samples are collected at each site and represent both depth-based and horizon-based soil material. One depth-based sample is taken from 0 to 5 cm regardless of what soil horizon this represents. A composite of the A horizon (the uppermost mineral soil) and a composite of the C horizon (usually the weathered parent material of the overlying soil) are also collected at each site. The composition of 0-5-cm and A-horizon samples represent the effects of weathering potentially overprinted by anthropogenic influences, such as atmospheric deposition or agricultural practices. C-horizon samples will be more representative of geologic influence on soil composition. Each sample is sieved to <2 mm and

then ground to <150 µm prior to chemical analysis for over 40 major and trace elements. Each sample is routinely analyzed for P, but not for N. Several hundred grams of each sample are archived and available for reanalysis as needed. Sampling was initiated in 2007 and should be completed for the conterminous US in 2011.

Keywords: soil, geochemistry, regional-scale

Session 5: Small and Large Scale models

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SWAT: A Watershed Model for Environmental and Conservation Assessment

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SWAT is the acronym for Soil and Water Assessment Tool, a river basin, or watershed, scale model. SWAT was developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time. To satisfy this objective, the model: 1) Is physically based. Rather than incorporating regression equations to describe the relationship between input and output variables, SWAT requires specific information about weather, soil properties, topography, vegetation, and land management practices occurring in the watershed; 2) Uses readily available inputs. While SWAT can be used to study more specialized processes such as bacteria transport, the minimum data required to make a run are commonly available from government agencies; 3) Is computationally efficient. Simulation of very large basins or a variety of management strategies can be performed without excessive investment of time or money;

and 4) Enables users to study long-term impacts. Many of the problems currently addressed by users involve the gradual buildup of pollutants and the impact on downstream water bodies. Land processes include; weather, hydrology, sedimentation, nutrients cycling, pesticide dynamics, plant growth, soil temperature, management, pathogen fate and transport, and carbon sequestration. Channel routing processes include; flood routing, transmission losses, evaporation, sediment routing with degradation and deposition computed simultaneously, nutrients using a modified QUAL2E/WASP, and a pesticide toxic balance. SWAT simulates land management practices and a manual is currently being developed to aid in simulating management practices that include:

crop rotations, tillage/biomixing of soil, fertilizer applications, grazing, pesticide and irrigation applications, subsurface (tile) drainage, water impoundment(wetlands, ponds, and reservoirs), and urban areas (pervious/impervious areas, detention structures, street sweeping, lawn chemicals), edge-of-field buffers, pathogen fate and transport, and automated calibration and uncertainty analysis. In addition to the CEAP national assessment, SWAT is being used in TMDL (Total Maximum Daily Loads) for EPA and climate change analysis by numerous universities. There are currently 570 papers in the literature related to SWAT development and applications in 138 different journals.

Keywords: SWAT, CEAP, watersheds, models

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Offsite Water Quality Effects of Conservation Practices in Upper Mississippi River Basin

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The Conservation Effects Assessment Project (CEAP) was initiated by the USDA to quantify the environmental benefits of conservation practices for cropland at the national level . As part of the national assessment, specific water quality issues in

various regions are examined. For this assessment, an approach involving modeling and farmer surveys is used. The modeling strategy involves using a farm-scale model Agricultural Policy/Environmental Extender (APEX) and a watershed scale model Soil and Water Assessment Tool (SWAT) with GIS databases. APEX is used to simulate the conservation practices on cultivated cropland. Farmer surveys conducted on a subset of National Resource Inventory sample points provide information on current farming activities and conservation practices for APEX. Output from APEX is input into SWAT in the HUMUS (Hydrologic Unit Modeling for the United States) model setup. SWAT simulates non-cultivated land including pasture, range, forest, wetland and urban lands. The model routes the pollutants generated from non-cultivated land and point sources along with APEX loadings (from cultivated land) to each 8-digit and 4-digit watersheds and finally to the outlet of the river basin. The loadings generated by APEX for cultivated cropland with conservation practices currently in use is input to HUMUS/SWAT watershed modeling for the "Current Conservation Condition" scenario. The loadings generated by APEX without conservation practices is input to HUMUS/SWAT watershed modeling for the "No Practices" scenario. Water quality benefits of the practices are determined by comparing SWAT model outputs for these two scenarios at 8-digit/4-digit watersheds in a river basin. Benefits obtained from the practices are reported by reductions in in-stream concentrations and loadings of sediment and nutrients at major locations along the river system. This paper focuses on the benefits of conservation practices implemented on the cropland in the Upper Mississippi River Basin.

Keywords: CEAP, National Assessment, Soil and Water Assessment Tool, Agricultural Environment

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CEAP Estimate of Nutrient Management Practices and Edge of Field Losses in the Upper Mississippi River Basin

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The CEAP cropland management survey includes three years of detailed data for 3, 702 farm fields and NRI points in the Upper Mississippi River Basin (UMRB), conservation district office planning records, interpretive data such as Soil Tillage Intensity Ratings (STIR), and with-in and edge-of-field APEX model estimates of water, soil, and nutrient balances and losses. Results are presented by various categorical classifications of management and inherent environmental risk. APEX model estimates are provided for a baseline current condition and for "No Practice" and "Enhanced Management" scenarios.

Findings include:

- Most cropland acres have some kind of nutrient management practice; however, only 13 percent of all acres have appropriate rate, time, and method of application for the entire rotation.
- About 44 and 21 percent of the acres had a high level of nitrogen and phosphorus management and about 40 and 20 percent of the acres had low levels of management for phosphorus and nitrogen.
- Reduced tillage is used on 94 percent of acres and about 70 percent of the acres meet NRCS criteria for Residue and Tillage Management, including maintaining soil organic carbon.
- Structural practices are in use on almost half of all cropland in the region, and on about three-fourths of highly erodible cropland. However, only about 9 percent of the acres have combinations of edge-of-field filtering and buffering practices with one or more in-field practices for control of overland flow and/or concentrated flow.

Current practices have:

- Reduced surface flows 14 percent while increasing subsurface flows by 22 percent.
- Reduced sediment, Nitrogen, and Phosphorus losses by 62, 21, and 36 percent, respectively.

Simulation of enhanced management shows:

- Treatment of the most vulnerable 9 percent of the acres, identified by soil and landscape properties, provide the greatest per-acre benefit;
- Soil erosion control and moderate nutrient management will provide substantial reductions in sediment and nutrient loss in the region, except for sub-surface nitrogen loss.

- Enhanced nutrient management (right rate, time, form, and method while protecting yields) would reduce sub-surface nitrogen losses by 27 percent in the region.

Keywords: CEAP, cropland, practices, nutrients, edge of field, APEX, losses, nitrogen, phosphorus, soil

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A National Level Modeling Approach for Evaluating Effects of Conservation on Water Quality

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Physically based water quality models are useful for assessing the effects of conservation practice scenarios at various spatial and temporal scales on water quality and provide science based information for policy planning and program development. An analytical approach involving modeling strategy and farmers survey was developed to quantify the environmental benefits of conservation practices on cropland as part of the USDA's-Conservation Effects Assessment Project (CEAP) national assessment. This paper describes the modeling approach used for evaluating the effects of conservation practices on water quality in major river basins.

The modeling approach involves using a farm-scale model Agricultural Policy Environmental Extender (APEX) and a watershed scale model Soil and Water Assessment Tool (SWAT) with GIS databases. GIS databases consists of databases uniquely developed for national assessment on land use, soils, land use management, topography, weather, point sources and atmospheric depositions that are used to derive model inputs. APEX is used to simulate conservation practices on cultivated cropland and Conservation Reserve Program land based on a subset of farmer surveys. Output from APEX is input into the SWAT in the HUMUS (Hydrologic Unit Modeling for the United States) system. SWAT simulates non-cultivated land including pasture, range, forest, wetland and urban lands and atmospheric depositions on non-cultivated land. The model routes the pollutants generated from non-cultivated land and point sources along with APEX loadings from cultivated land to 8-digit and 4-digit watershed outlets and finally to the outlet of the river basin.

SWAT/HUMUS system is calibrated at 8-digit watersheds and at selected gauging stations for flow, sediment, nutrients and pesticides. Calibrated model is used to simulate various scenarios. Loadings generated by APEX for cultivated cropland with conservation practices currently in use (Current conditions) and without practices (No practices) and various conservation treatment (Alternative) scenarios are input into HUMUS/SWAT watershed modeling system. Effects of various scenarios are determined by comparing source loads and in-stream loads and concentrations at 4-digit watersheds and major locations in the river basin. Effects are reported as reductions in sediment, nitrogen, phosphorus and pesticides. Modeling tools has capability to provide potential science based solutions for implementing practices and conserving resources.

Keywords: CEAP, National Assessment, Soil and Water Assessment Tool, Agricultural Environmental Productivity Extender, Conservation Practices, Water Quality Benefits

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Potential Impact of Targeted Wetland Restoration on Nitrate Loads to Mississippi River Subbasins: Performance Forecast Modeling of Loads and Load Reductions

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Non-point source nitrogen loads to surface waters in the Midwest Corn Belt are among the highest in the Mississippi River Basin, and are suspected as a primary source of nitrate contributing to hypoxia in the Gulf of Mexico. Nitrate is transported from cropland primarily via subsurface drainage, especially in extensively tile drained areas like the Corn Belt. As a result, grass buffer strips, woody riparian buffers, and many other practices suited to surface runoff have little opportunity to intercept nitrate loads in these areas. However, wetlands sited to intercept tile drainage have the potential to significantly reduce nitrate loads, and this approach is particularly promising for heavily tile drained areas like the Corn Belt. A performance forecast modeling approach is used to estimate the total nitrate reduction that could be achieved using wetlands as nitrogen sinks in tile-drained regions across the upper Midwest. Not only does the extent of tile drainage vary but also the efficacy of wetlands for nitrogen reduction varies across the region. This is because several primary determinants of wetland performance vary longitudinally across the upper Midwest, including volume and timing of "runoff", nitrate concentration, and temperature. Our analyses suggest these factors would result in an order of magnitude range in mass nitrate removal per acre of wetland restored for different areas of the upper Midwest. The model was used to estimate the nitrate reduction that could be achieved using targeted wetland restoration in tile-drained regions of the upper Mississippi River (UMR) and Ohio River basins.

<u>Keywords:</u> Wetlands, nitrogen, nitrate, hypoxia, nutrient load

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A Design Aid for Determining Width of Filter Strips

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The effectiveness of watershed-scale programs often hinges on the proper application of mitigation strategies applied at numerous individual sites. Filter strip installation is a strategy often applied to reduce nutrient runoff from agricultural fields. The width of a filter strip is a key design parameter for determining its effectiveness. Watershed planners need a tool for determining width of filter strips that is accurate enough for developing cost-effective designs and easy enough to use for making quick determinations on a large number and variety of sites. We developed a graphical design aid for estimating the width needed to achieve target trapping efficiencies for different pollutant types under a broad range of agricultural site conditions. Model simulations using the process-based Vegetative Filter Strip Model (VFSMOD) were used to develop the design aid. The design aid consists of a graph containing a family of seven lines that divide the full range of possible relationships between width and pollutant trapping efficiency into fairly even increments. Simple rules guide the selection of the one line that best describes a given field situation by considering slope, soil texture, field cover management and slope length, and pollutant type (i.e., sediment, sediment-bound, dissolved). The design aid is easy to use and accounts for several major variables that determine filter strip effectiveness. It fills a wide gap between the overly-simple guides and the complex mathematical models that are currently being used.

<u>Keywords:</u> models, nonpoint source pollution, surface runoff, vegetative buffers, water quality, watershed planning

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Optimal targeting of conservation practices for nonpoint source pollution control in the Upper Mississippi River Basin

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While conservation practices can reduce nonpoint source pollution under specific cropping systems and field characteristics, the effectiveness of these conservation practices at the watershed level significantly depends on their placements in the watershed and the physical characteristics of the sites on which they are placed. In addition, multiple conservation practices exist, each of which has different effectiveness at controlling different pollution. This means that solving for the optimal location of conservation practices within a watershed for water quality improvement requires comparing a very large number of possible land use scenarios. An integrated modeling system developed for the Upper Mississippi River Basin (UMRB) at the Center for Agricultural and Rural Development was used in combination with multi-objective evolutionary algorithms to identify least cost combinations and placement of conservation practices to achieve nonpoint source pollution reduction. The modeling system integrates a watershed based bio-physical model Soil and Water Assessment Tool (SWAT), several software and interfaces including GIS and other executables with input databases on soil, climate, land use and land management, and cost data of establishing different conservation practices. Results will be presented describing the tradeoff relationship between nutrient reduction and the corresponding cost of placing selected sets of conservation practices in the UMRB. This modeling work will be very useful for policy makers and stakeholders to explicitly see the tradeoffs between nutrient reduction and the placement of conservation practices. This work could also be used to guide the design and implementation of conservation policy in the UMRB.

Keywords: Conservation Practices, Upper Mississippi River Basin, SWAT, Genetic Algorithm

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Effect of potential future climate change on the hydrology and water quality in the Upper Mississippi River Basin

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During the last century, much of the U.S. experienced gradually warming temperatures, increases in precipitation, and increase in intensity of precipitation events, as reported in the fourth assessment report (AR4) of IPCC. Water resources and aquatic ecosystems are highly vulnerable to these changes, with possible effects including increased occurrences of floods and droughts, and water quality degradation, and ecosystem impairment. Assessing and managing the risk of harmful future impacts will require an improved understanding of how future climate could impact the hydrology and water quality of the major basins. We used an integrated modeling system developed for the Upper Mississippi River Basin (UMRB) in combination with various global change models (GCMs) as well as regional climate models (RCMs) to evaluate the impact of potential climate change on streamflow and water quality in the UMRB. The modeling system integrates Soil and Water Assessment Tool (SWAT) model, several software and interfaces including GIS and other executables with input databases on soil, climate, land use and land management information. The UMRB-SWAT modeling system was driven by daily meteorological data from 10 GCMs produced by AR4. Analysis from multiple GCMs reveals that while all models project the Midwest to warm with increasing greenhouse gas concentrations, there is less agreement among models on whether precipitation will increase of decrease. Ensemble mean of GCMs projects increase in precipitation in north and east-central UMRB whereas a decrease in southern portion. The impact of future climate change impact on nitrate nitrogen as simulated by SWAT modeling system and driven by ensemble mean of GCM meteorological input was found to produce favorable condition for Iowa portion but worse condition for Illinois portion of the UMRB. Results will also be presented for the 6 high

resolution RCMs produced recently by the North American Regional Climate Change Assessment Program. The performance of GCM vs. RCM in producing streamflow through the modeling system for the contemporary climate will also be compared.

Keywords: Climate change, SWAT, Upper Mississippi River Basin, Climate models (GCM and RCM)

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Model Calibration of APEX and SWAT

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Physically based hydrologic and water quality modeling is useful for developing comprehensive plans for regional scale issues by capturing spatial and temporal variations across the regions. There is an ongoing national assessment study called Conservation Effects Assessment Project (CEAP) aimed to address the environmental benefits obtained from United States Department of Agriculture (USDA) conservation program expenditures. The modeling framework is a revised HUMUS (Hydrologic Unit Modeling for the United States) set up, comprising of SWAT (Soil and Water Assessment Tool) with updated databases and APEX (Agricultural Policy/Environmental Extender).

APEX is a farm scale model, aimed to simulate cultivated land with many different conservation practices. The primary focus of the CEAP project is on cropland where most of the conservation practices are implemented. Therefore, the field level modeling for CEAP will be conducted by APEX. Then the monthly outputs from APEX runs are organized at the 8-digit watershed level and input to SWAT. SWAT is used to simulate uncultivated land and route the flow, sediment, and pollutants from point sources, cultivated and uncultivated land to the outlet of each river basin. The entire simulation period is from 1960-2006 at annual time step. Calibration and subsequent validation of model results for flow and water quality are necessary to confidently use the models for making scenario runs and make decisions.

Calibration is carried out separately for APEX and SWAT because they model cultivated and uncultivated land separately. This also ensures reasonable amount of loads coming from different land cover categories of the basin. However, there is a lot of back and forth effort in making the overall reach level results (from all land covers of several 8-digit watersheds) acceptable with reference to observations. APEX uses four parameters for flow calibration and SWAT uses an automated procedure with nine parameters to match predicted flow with that of observations. Sediment, nutrient and pesticide calibration involves a lot of back and forth effort between the two models to make sure the loads as well as the transport mechanisms are correct. More details on calibration and the results obtained to date will be presented in the poster.

Keywords: CEAP, HUMUS, conservation, cultivated land, calibration, modeling

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Water Quality Effects of Corn Expansion in the Midwest

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While biofuels may yield renewable fuel benefits, there could be downsides in terms of water quality and other environmental stressors, particularly if corn is relied upon exclusively as the feedstock. The consequences of increased corn production will depend importantly on where (and how) the additional corn is grown, which in turn, depends on the characteristics of land and its associated profitability. Previous work has relied on rules of thumb for allocating land to increased acreage based on historical land use or other heuristics. Here, we advance our understanding of these phenomena by describing a modeling system that links an economics-driven land use model with a watershed based water quality model for the Upper Mississippi River Basin (UMRB). This modeling system is used to assess the water quality effects of increased corn acreage associated with higher relative corn prices. We focus on six scenarios based on six realistic pairs of corn and soybean prices which correspond to a scale of decreasing soybean to corn price ratio. These price-driven land use changes provide estimates of the water quality effects that current biofuel policies may have in the UMRB. Our analysis can help evaluate the costs and environmental impacts associated with implementation strategies for the biofuel mandates of the new energy bill.

Keywords: biofuels, water quality, Upper Mississippi River Basin,

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Methods for Simulating Conservation Practices and Estimating Effects
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There are two main components in CEAP; 1)The watershed assessment and 2) National assessment. This presentation will focus on the calibration aspect of the modeling component used in the National assessment. The primary focus of the project is on cropland where most of the conservation practices were implemented. Hence, field level modeling for CEAP will be conducted using the APEX model. Output from APEX will be input to a system of watershed scale SWAT models, known as HUMUS which route flow, sediment, and pollutants to the outlet of each watershed in different agricultural regions.

Environmental benefits at the national scale will be estimated based on differences in output from 1) before conservation practices and 2) after conservation practices have been applied. In this modeling approach, a calibration is necessary to compensate for uncertainties in the input data. Scale of the project limits manual calibration. Hense an automated calibration procedure is used to accomplish the large scale calibration effort. The auto-calibration procedure adjusts the input parameters in HUMUS and SWAT so that the average annual streamflow and sediment yield values correlate to SPARROW model estimates for every 8-digit watershed in the United States.

Acronyms Used: 1. CEAP (Conservation Effects Assessment Project) 2. APEX (Agricultural Policy/Environmental Extender 3. SWAT (Soil and Water Assessment Tool) 4. HUMUS (Hydrologic Unit Modeling for the United States) 5. SPARROW (SPAtial Reference Regression On Watershed attributes)

Keywords: CEAP, SWAT, EPIC, APEX

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Science and Technology Solutions for Streamlining Conservation Delivery
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The USDA Natural Resources Conservation Service (NRCS) delivers technical assistance to operators of many thousand farms and ranches through the network county level field service centers within the Mississippi River Basin. Technical assistance includes conducting resource inventories and developing alternatives for optimizing the productivity and sustainability of the producer's operation, as well as the watershed in which it is located. The models and tools to inventory, develop, and analyze solutions currently are not integrated into business processes in an efficient manner. Each tool is used separately with its own data and processing requirements, which limits their use. Furthermore, the additional workload to deliver financial assistance constrains time spent on technical assistance. To re-establish its emphasis on science-based technical assistance, NRCS has established the Conservation Delivery Streamlining Initiative (CDSI). In support of CDSI, a robust and flexible infrastructure must be built to provide the best science and tools available in developing estimates of system response as conservation planners provide technical assistance to producers. This infrastructure begins with a common user experience that field personnel will be trained once to use while the underlying toolset may vary with time and utility. This user interface is envisioned to operate in the field office or in the field on a portable handheld device while being equally functional to answer the resource inventory and assessment needs while working with the producer on site. The next layer of this infrastructure is the computational components that do the heavy lifting to generate the estimates of system response and formulate the conservation alternatives for the producer to choose. This computational layer will be based on a service oriented architecture that uses the USDA Object Modeling System (OMS) to facilitate the creation and utility of regionally derived modeling toolsets. It contains a library of science, control, and database components (modules), and methods to assemble selected components into a modeling package customized to the problem, data constraints, and scale of application. To help drive this computational system a flexible data provisioning system must be provided which pulls site specific data from a vast collection of geospatial oriented data sources across the enterprise and Internet cloud. The data system will be exposed as web services that can be used internally by a specific computational tool or provide data streams for offline use while working with the producer on site. Streamlined business workflows developed by CDSI and efforts such as the Mississippi River Basin Initiative will help drive the science that will be incorporated into the system and how it will be used.

Keywords: NRCS, MRBI, CDSI, OMS, Conservation, Field Office, SOA, Database, Component Based, Geospatial, Cloud Computing, Common Desktop, Assessment, Inventory, Streamlining, Infrastructure

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Using reservoirs to reduce river nitrate-nitrogen concentrations

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Excessive nitrate-nitrogen (nitrate) is a major cause of surface water impairment in the United States and contributes to Gulf of Mexico hypoxia. Reservoirs have been shown to have significant effects on nitrate mass balances in river systems but using reservoirs to reduce river nitrate levels is largely unexplored. In this study, we developed time-series models to evaluate the effectiveness of a large flood-control reservoir to reduce downstream river nitrate concentrations. Saylorville Reservoir is a 24.1 km2 impoundment of the Des Moines River located 10 km north of the City of Des Moines. Monthly nitrate concentrations upstream and downstream of the reservoir for a 30-year period were used to develop a dynamic regression model that described downstream nitrate concentrations as a function of upstream contributions. Results suggested that Saylorville Reservoir is reducing concentrations by 22±6%, a reduction that greatly exceeds previous estimates. In a second, more complex model, we developed a two-regime threshold dynamic regression model to account for the nonlinear relationship between upstream and downstream concentrations, with the reservoir residence time affecting the change in the regression relationship. Based on the threshold model, a reservoir management scheme is proposed for manipulating the discharge rate from Saylorville Reservoir to extend the residence time and achieve greater reduction in downstream nitrate concentrations. Simulation results suggest that downstream nitrate concentrations could be significantly reduced with reservoir discharge manipulation. In one scenario, nitrate concentrations in excess of 10 mg/l were reduced by 25.7% using the proposed control scheme. Modeling results are seen to provide encouragement that reservoirs may be used to provide nitrate concentration reductions in addition to flood control and recreation.

Keywords: reservoir, time-series, statistical model, nitrate

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Basin-wide and Targeting Strategies for Nitrate Load Reduction in the Des Moines River
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The Des Moines River that drains a watershed of 16, 175 km2 in portions of Iowa and Minnesota is impaired for nitrate-nitrogen (nitrate) due to concentrations that exceed regulatory limits for public water supplies. The Soil Water Assessment Tool (SWAT) model was used to model streamflow and nitrate loads and evaluate a suite of basin-wide changes and targeting configurations to potentially reduce nitrate loads in the river. The SWAT model comprised 173 subbasins and 2, 516 hydrologic response units and included point and nonpoint nitrogen sources. The model was calibrated for an 11-year period and three basin-wide and four targeting strategies were evaluated. Results indicated that nonpoint sources accounted for 95 percent of the total nitrate export. Reduction in fertilizer applications from 170 to 50 kg/ha achieved the 38 percent reduction in nitrate loads, exceeding the 34 percent reduction required. In terms of targeting, the most efficient load reductions occurred when fertilizer applications were reduced in subbasins nearest the watershed outlet. The greatest load reduction for the area of land treated was associated with reducing loads from 55 subbasins with the highest nitrate loads, achieving a 14 percent reduction in nitrate loads achieved by reducing applications on 30 percent of the land area. SWAT model results provide much needed guidance on how to begin implementing load reduction strategies most efficiently in the Des Moines River watershed.

Keywords: SWAT, TMDL, nitrate-nitrogen, watershed model

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Use Of Continuous Specific Conductance To Differentiate The Sources Of Water To An Agricultural Stream With Subsurface Drainage NetworksDRAINAGE NETWORKS
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The sources of water to natural streams include direct precipitation, overland flow, and ground-water inflow. In glaciated areas, the presence of artificial surface and subsurface drainage networks, a common practice for removing excess water from agricultural fields, provides additional pathways of water movement to the stream. The artificial drainage of agricultural fields allows rainfall to move quickly through the catchment to the stream transporting nutrients, pesticides and other agricultural-related constituents. A largely agricultural (about 90%), 31 km2 subcatchment of the South Fork of the Iowa River in north-central Iowa was studied for two years. Discharge and specific conductance (SC) were measured continuously and discreet water samples were obtained for analyses of nutrients and other constituents. SC is an electrical measurement of the total ion content in the water. The SC of the rain and ground-water is about 10 microS/cm and 800-1, 200 microS/cm, respectively. The typical, base-flow SC of the stream is 700-800 microS/cm. Within minutes after a substantial rain event, the stream discharge increases and the SC decreases (often times below 200 microS/cm). The rain water is processed through the catchment before it reaches the stream via direct overland flow, preferential flow to subsurface drains, vertical drains attached to subsurface drains in ponded areas, and/or soil infiltration to ground-water. Water moving through each of these pathways has different characteristic time scales and different degrees of interactions with the soil yielding different ionic content, thus different SC. Both the discharge and SC concurrently return to the typical base-flow values over the following days and weeks. Utilizing the different characteristic SC measurements inside of a simple hydrograph separation model, storm flow can be divided into the different hydrologic pathways. This strong relation between rainfall, discharge and SC is used to calculate the relative importance and time scale of the various hydrologic pathways. In addition to the two-year stream record, complementary discharge and SC data were collected in two subsurface drains and continuous ground-water levels collected from nearby observation wells. These data compared to the stream record demonstrate the quick response of subsurface drains and shallow ground-water to rainfall.

Keywords: specific conductance, subsurface drainage, sources, hydrologic pathways

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APEX: A Field/Farm Level Model for Environmental and Conservation Assessment

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APEX is a tool for managing whole farms or small watersheds to obtain sustainable production efficiency and maintain environmental quality. APEX operates on a daily time step and is capable of performing long term simulations (1-4000 years) at the whole farm or small watershed level. The watershed may be divided into many homogeneous (soils, land use, topography, etc.) subareas (<4000). The routing component simulates flow from one subarea to another through channels and flood plains to the watershed outlet and transports sediment, nutrients, and pesticides. This allows evaluation of interactions between fields in respect to surface run-on, sediment deposition and degradation, nutrient and pesticide transport and subsurface flow. The subarea component simulates hydrology, weather erosion (wind and water), N and P cycling, pesticide fate, soil temperature, plant growth, tillage, and economics. Effects of terrace systems, grass waterways, strip cropping, buffer strips/vegetated filter strips, crop rotations, plant competition, plant burning, grazing patterns of multiple herds, fertilizer, irrigation, liming, furrow diking, drainage systems, and manure management (feed yards and dairies with or without lagoons) can be simulated and assessed.

Keywords: APEX, CEAP, watershed

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Estimating Delivery Ratios for the Conservation Effects Assessment Project

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The Conservation Effects Assessment Project (CEAP) cropland national assessment is to provide estimates of the environmental benefits of conservation practices currently in use on cultivated cropland at the regional and national scale by comparing environmental indicators between the "current conservation condition" scenario with the "no-practice" scenario. Modeling is a necessary method for this scale of study. The Agricultural Policy Environmental eXtender (APEX) model was used to estimate the edge-of-field effects of practices on cultivated cropland. APEX modeling results were aggregated at the 8-digit watershed level and combined with modeling results from the Soil and Water Assessment Tool (SWAT) for the uncultivated land uses at each 8-digit watershed outlet. The combined modeling results were routed downstream in SWAT for estimating the offsite effects of practices at major river basin outlets. Sediment delivery ratios (SDRs) were used within both models to transport sediment, nutrients, and pesticides from simulation sites to the 8-digit watershed outlets. For CEAP, both APEX and SWAT compute SDR as a function of the time of concentration from the field or hydrological response unit and the time of concentration of the 8-digit watershed. This study was 1) to describe the delivery ratio procedures used within APEX and SWAT models; 2) to present the SDRs from the edge-of-fields to the 8-digit watershed outlets and the SDRs from 8-digit watershed outlets through major rivers to major USGS gauging stations in the Upper Mississippi River Basin (UMRB); and 3) to report sediment yields delivered to 8-digit watershed outlets and to major USGS gauging stations. Results indicate that the SDRs varied from 0.20 to 0.44, which are reasonable, comparing well to the delivery ratio suggested in literature. The UMRB test results are promising and show the potential of using the SDR procedures to other river basins of the United States for the CEAP project or similar large-scale studies.

Keywords: Delivery ratio, APEX model, SWAT model, Sediment yield, Upper Mississippi River Basin.

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Validation of the APEX Model

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The Agricultural Policy/Environmental eXtender (APEX) model was constructed to evaluate various land management strategies considering sustainability, erosion, water supply and quality, soil quality, plant competition, weather and pests. The APEX model was selected for the CEAP field-level cropland modeling due to its flexibility. Although the APEX model and its predecessor, the Environmental Policy Impact Climate (EPIC) model, have proven to be robust tools, continuous evaluations/testing were conducted to support the CEAP study and to expand the overall simulation domain to which the model can be applied. A summary of APEX model validation studies were provided in this presentation, followed by a case study at the North Appalachian Experimental Watersheds at Coshocton, Ohio. Long-term (1984-2005) data from two small watersheds (watersheds 109 and 118) were used to calibrate and validate the APEX model. The two watersheds were cropped with corn-soybean rotation and
managed with chisel tillage at watershed 109 (0.68 ha) and no tillage at watershed 118 (0.79 ha). Preliminary results from the case study show that the R2 values ranged from 0.75 to 0.98 for crop grain yields, runoff and sediment loads. The APEX calibration and validation results from literature (some were published during the course of the CEAP study) and this case study indicate that the APEX model can provide accurate accounting of different scenario impacts and is a useful tool for evaluating complex landscape and management scenarios.

Keywords: Validation, APEX model, CEAP, tillage

Abstracts for Technology Demonstrations

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CanVis Visual Simulation Kit: Visualizing Solutions

Natural resource professionals often hear the words, "What will it look like?" from landowners who have difficulty in understanding a proposed water quality plan. Planting plans and engineering drawings, while necessary, often mean little to the general public. When water quality practices require a long-term commitment like riparian forest buffers, landowners want to know what it will actually look like on the ground before committing to a plan. Now resource professionals have a tool to translate these plans into real-life pictures or images called visual simulations. Visual simulations are digital images which have been altered to illustrate design alternatives. Using image-editing software, proposed designs can be "created" by adding images of plants and other landscaping materials onto a base image of the landowner's property that has been acquired from either a scanned or digital photo. In a relatively short time, water quality practices can be illustrated at various stages of development, compositions, and arrangements on the landscape. The USDA National Agroforestry Center has developed the CanVis Visual Simulation Kit consisting of the Visual Simulation Guide, a multi-media, CD-reference manual on how to create simulations for natural resource planning and CanVis, an image-editing software program designed specifically for conservation applications. This tool will be demonstrated and free copies of the software will be available. By communicating ideas through visual simulations, tools like the Kit can greatly influence public participation in the planning and design process, enhancing adoption of practices to reduce nutrient export. As the old saying goes, a picture can really be worth a 1000 words!

Keywords: Visual simulations, decision-support tool, design

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Nitrate Treatment at Union Slough National Wildlife Refuge, Iowa

Between 1995 and 1997, the U.S. Fish and Wildlife Service monitored nutrient inputs and outputs at Union Slough National Wildlife Refuge. The Refuge is located in north central Iowa and contains a series of large wetland pools. The purpose of the study was to develop resource management strategies to reduce adverse ecological effects from nutrient enrichment and to understand the transport of nitrate out of the Refuge on into tributaries of the Mississippi River.

We estimated that Union Slough National Wildlife Refuge provides a high level of ecological services to the country by treating significant loads of nitrate before it enters the Gulf of Mexico. However, this nitrate treatment is at a cost to Refuge biodiversity. We would like to shift the nitrate treatment away from Refuge wetlands and into artificially created wetlands for that purpose. This shift in treatment will allow the Refuge to optimize production of ecological goods for the country.

Water holding times in the wetland pools at the Refuge ranged from 2.2 days to 87.2 days. We estimated significant losses of nitrate, but only during low flow with high water retention periods. The types of plants and invertebrates produced in the Refuge wetland pools are less than desirable for high waterfowl use. Our demonstration treatment wetland was 100% effective during certain times of the year.

Nutrient enrichment from the tile drainage systems has the potential to fuel undesirable plant and related invertebrate populations of a few nuisance aquatic species in the Refuge wetland pools. Excess nitrate that is not assimilated at the Refuge is transported into the Mississippi River via tributary rivers for transport to the Gulf of Mexico thus contributing to Gulf hypoxia.

Partnerships with agricultural and conservation interests in the Region is one of the strongest assets of the U.S. Fish and Wildlife Service. The nutrient reduction strategies for our partnerships include the following resource management actions: water level management to solidify loose sediments and promote forb production; water control to regulate inputs with

clean water sources; promote smart use of fertilizers in the watershed; and apply treatment wetlands higher in the watershed.

Keywords: National Wildlife Refuge, Nitrate Pollution, Eutrophication, Chemical Treatment

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Building Data Partnerships-A Key Step to Strengthen Science Partnerships

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USGS, in collaboration with USEPA, has developed compatible web services allowing retrieval of data from multiple sources in common formats for direct use in mapping, statistical, and modeling applications. The ability to retrieve data in common formats simplifies the task of bringing together a wide range of information that can be used to describe and better understand the status and trends of water quality across the Nation. Chemical, physical, and biological data from the National Water Information System (NWIS) of the USGS (http://qwwebservices.usgs.gov) and data housed in the Storage and Retrieval (STORET) of the EPA (http://www.epa.gov/storet/wqx.html) are now readily accessible online in a compatible format. The shared data exchange format is called the Water Quality Exchange (WQX). Data collected by USGS and by states and tribes (submitted to EPA-STORET) thereby conform to a common nomenclature for biological and physical elements, chemical substances, chemical groups, sites, types, and sampling media. In total, over 150 million water-quality results are available from the two systems.

USGS is working with data managers associated with other organizations, such as USDA-Agricultural Research Service (ARS) on extending the common web services to data housed in the STEWARDS database (http://www.ars.usda.gov/Research/docs.htm?docid=18622), which will help extend associations between ARS long-term research in agricultural landscapes and USGS long-term water quality/quantity data. Advances in common data elements and web services are critical in building science partnerships and assessments at local to national scales, including (1) in tracking effectiveness of conservation strategies on water quality within individual basins, and (2) in providing consistent and comparable data for regional and national models, such as the USGS WARP interactive mapping tool and the USGS SPARROW decision tools.
Interactive sessions of the data systems and case examples in selected areas will help to demonstrate the potential of the integrated and common web services for improving understanding of water quality in agricultural watersheds.

Keywords: data exchange, web services

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USGS SPARROW Decision Support System

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The USGS National Water Quality Assessment Program (NAWQA) is developing water-quality prediction models for nitrogen and phosphorus for eight Major River Basins of the conterminous United States. In addition to extrapolating measured water-quality conditions to unmonitored areas to help assess water-quality status, a calibrated Spatially Referenced Regressions On Watershed Attributes (SPARROW) model can be used to produce statistically defensible estimates of yield, flow-weighted concentration or load of any modeled constituent under various land use change or resource management scenarios.

A decision support infrastructure has been developed to offer sophisticated prediction capabilities for research and resource management. The intention is to provide users of the system with simulation capabilities through a standard web-browser without required proprietary software licenses or significant training.

The tool supports four general use cases. (1) View model input variables on a map to understand spatial patterns of source terms important to the modeled area. (2) Estimate load or concentration for river reaches of interest for specified source input or land use changes. Users can adjust source terms in upstream basins individually or across source categories and view maps of changes or export data to common formats. (3) Understand fate and transport of upstream loads to downstream receiving bodies by mapping the ratio of load that is delivered, and (4) export model predicted load as input for a downstream model via a web service call.

Keywords: SPARROW, watershed, regional, model, water quality

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A Web-Technology for End-to-End Conservation Assessment and Planning

This presentation demonstrates an innovative open-source web technology, called eRAMS, that enhances decision makers' capacity to assess and plan conservation practices for sediment, nutrient and pesticide control. The eRAMS technology automates spatial overlay of soil, land use, and other data layers in order to create input files for the field-scale APEX and the watershed-scale SWAT models. The technology also includes a system optimization module that fully explores the tradeoffs between socioeconomic and environmental criteria at the watershed scale, but more importantly, can unambiguously identify the range of solutions that are most consistent with stakeholders' priorities.

The eRAMS technology offers a participatory GIS that facilitates collection, organization, and sharing of geospatial information end-to-end on the internet. eRAMS takes technology transfer to a whole new level, because extension of the tool does not require installation of any specialized hardware and software by end-users. Thus, watershed planners will benefit from vast data resources and models that are currently accessible to the research community, and will be empowered to assess the costs and conservation benefits of alternative management scenarios. To foster broad participation, the web technology is designed under the supervision of an advisory group from agencies that are most likely to use the tool for the assessment and planning of conservation systems and making management decisions.

The results of a preliminary application of eRAMS in a primarily agricultural watershed in Indiana attest to the usefulness and versatility of the technology. This preliminary study aimed at designing a combination of conservation practices that would reduce total nitrogen loads discharging into the Kokomo reservoir by 40% at minimum costs. When compared to a random combination of conservation practices, it was evident the plan obtained from eRAMS would meet the water quality goals at nearly one third of the cost associated with the random plan. The technology also provides the location of the practices on high resolution Google maps. Visualization of the landscape position of practices highlighted that there are locations within the watershed that are more suitable for implementation of practices and provide greater opportunities for reduction of agrochemical loads at the watershed scale.

Keywords: Conservation Streamlining, Planning, Nutrients, SWAT, APEX, socioeconomics, water quality

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Notes

Questions/Comments

☐ **Management Session**
☐ **Human Dimension Session**
☐ **Lessons Learned from Small Watershed Studies**
☐ **Data Gaps**
☐ **Small and Large Scale Models/Panel Discussion**
☐ **Closing Panel**

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