Institute of Water Research
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Introduction

The Institute of Water Research (IWR) at Michigan State University (MSU) continuously provides timely information for addressing contemporary land and water resource issues through coordinated multidisciplinary efforts using advanced information and networking systems. The IWR endeavors to strengthen MSU's efforts in nontraditional education, outreach, and interdisciplinary studies utilizing available advanced technology, and partnerships with local, state, regional, and federal organizations and individuals. Activities include coordinating education and training programs on surface and ground water protection, land use and watershed management, and many others. (An extended introduction can be found in our FY2001 Annual Technical Report.) We also encourage accessing our web site which offers a more comprehensive resource on IWR activities, goals, and accomplishments: www.iwr.msu.edu.

The Institute has increasingly recognized the acute need and effort for multi-disciplinary research to achieve better water management and improved water quality. This effort involves the integration of research data and knowledge with the application of models and geographic information systems (GIS) to produce spatial decision support systems (SDSS). These geospatial decision support systems provide an analytical framework and research data via the web to assist individuals and local and state government agencies make wise resource decisions. The Institute has also increasingly become a catalyst for region wide decision-making support in partnership with other states in EPA Region 5 using state-of-the-art decision support systems.

The Institute also works closely with the MSU Cooperative Extension Service to conduct outreach and education. USGS support of this Institute as well as others in the region enhances the Institute credibility and facilitates partnerships with other federal agencies, universities, and local and state government agencies. The Institute also provides important support to MSU-WATER, a major university initiative dealing with urban stormwater issues with funding from the university Vice President for Finance. A member of the Institute's staff works half-time in facilitating MSU-WATER activities so the Institute enjoys a close linkage with this project. The following provides a more detailed explanation of the Institute's general philosophy and approach in defining its program areas and responsibilities.

General Statement

To deal successfully with the emergence of water resource issues unique to the 21st century, transformation of our knowledge and understanding of water for the protection, conservation, and management of water resources is imperative. Radically innovative approaches involving our best scientific knowledge, extensive spatial databases, and intelligent tools that visualize wise resource management and conservation in a single holistic system are likewise imperative. Finally, holistic system analysis and understanding requires a strong and integrated multi-disciplinary framework

Research Program

Research Program
The management of water resources, appropriate policies, and data acquisition and modeling continue to be at the forefront of the State Legislatures agenda and numerous environmental and agricultural organizations. Our contribution to informing the debate involved numerous meetings, personal discussions, and most importantly, the enhancement of web-based information to aid in the informed decision-making process.

Unique Capabilities: Decision Support Systems as the Nexus
IWR, with its extended research family, is exceptionally well-positioned to integrate research conducted within each of the three principal water research domains: hydrologic sciences, water resources, and aquatic ecosystems. Integrated decision support both reflects and forms the nexus of these three research domains. Expanding web accessibility to the decision support system nexus (formed by the intersection of the three research domains) will facilitate broad distribution of science-based research produced in these domains. The Institute's extensive experience in regional and national networking provides exceptional opportunities for assembling multi-agency funding to support interdisciplinary water research projects and multi-university partnerships.

Using A Multi-Disciplinary Framework
Using a multi-disciplinary framework facilitates dynamic applications of information to create geospatial, place-based strategies, including watershed management tools, to optimize economic benefits and assure long-term sustainability of valuable water resources. New information technologies including GIS and computational analysis, enhanced human/machine interfaces that drive better information distribution, and access to extensive real-time environmental datasets make a new intelligent reality possible.

Effective watershed management requires integration of theory, data, simulation models, and expert judgment to solve practical problems. Geospatial decision support systems meet these requirements with the capacity to assess and present information geographically, or spatially, through an interface with a geographic information system (GIS). Through the integration of databases, simulation models, and user interfaces, these systems are designed to assist decisionmakers in evaluating the economic and environmental impacts of various watershed management alternatives.

The ultimate goal of these new imperatives is to secure and protect the future of water quality and supplies in the Great Lakes Basin and across the country and the worldwith management strategies based on an understanding of the uniqueness of each watershed.

Grant No. 05HQGR0170 Integrating ACOE Sediment Runoff Predictive Tool into DW-L-THIA System

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Project Summary

Erosion is a major environmental concern in the areas surrounding the Great Lakes waters in the United States (and Canada). The Great Lakes Tributary Modeling Program was established by the U.S. Army Corps of Engineers (USACE) to develop computer modeling tools for Great Lakes watersheds to facilitate management planning by various stakeholders to reduce erosion and associated water quality problems. As part of the program, a Web-GIS (World Wide Web-Geographic Information System) based watershed management system was developed for two watersheds in northwestern Indiana, which drain into Lake Michigan. The management system is fully Web-based and was built by linking two existing Web-GIS applications hosted separately at Purdue University (the Long-Term Hydrologic Impact Assessment, L-THIA, Web modeling tool) and Michigan State University (Digital Watershed Web mapping tool). The two systems were extended and made interoperable by passing dynamically re-projected vector GIS data and modeling results between the two sites. The integrated system allows users to browse GIS data, dynamically delineate watershed boundaries, make changes in land use and/or apply Best Management Practices (BMPs) within a watershed, and run hydrologic and erosion models to assess management impact on hydrology, water quality, and sediment yield. It also allows preliminary sizing and cost estimation for building a number of erosion and sediment control structures. The Web-GIS was publicized as a spatial decision support system (SDSS) to support state and local measures that are designed to reduce tributary loadings of sediments and pollutants. This work is helping to reduce the need for, and costs of, navigation dredging, while promoting actions to delist Great Lakes' area of concerns (AOCs). The system was well received during a stakeholder workshop for its user-friendly graphical user interface (GUI) design and usefulness in potential grassroots management efforts to combat erosion and nonpoint source (NPS) pollution in the Great Lakes region. The SDSS is available on the Internet at http://danpatch.ecn.purdue.edu/~eqip/erosion/.

Introduction & Research Objectives

Nonpoint pollution of the Great Lakes has prompted the US Environmental Protection Agency (EPA) and Canadian authorities to jointly identify highly polluted areas, or areas of concerns, in the Great Lakes region and to develop comprehensive remedial action plans (RAPs) to reduce

pollution (http://www.great-lakes.net/envt/pollution/rap.html). The RAPs call for concerted efforts to reduce erosion and NPS pollution from identified watersheds. These efforts are community driven with active support from state and local authorities. The US Army Corps of Engineers (USACE) is responsible for maintaining the navigability of harbors and connecting channels in the Great Lakes region. Dredging channels to remove excessive sediment due to erosion from surrounding watersheds has been a major time-consuming and costly undertaking.

The Great Lakes Tributary Modeling Program was established as part of the coordinated efforts to prevent erosion and NPS pollution from further polluting the Great Lakes (http://glc.org/tributary/). The major aim of the program is to develop computer modeling tools for watersheds that drain into federal navigation channels in the Great Lakes region. These tools will be used to facilitate integrated watershed management planning by various stakeholders to reduce erosion. As part of the program, the Chicago District of the U.S. Army Corps of Engineers, Michigan State University, and Purdue University developed plans for a watershed management system for two critical watersheds in northwestern Indiana, the Burns Ditch and Trail Creek watersheds that are part of the Grand Calumet River Basin that drains into Lake Michigan. These two watersheds had been identified as contributing significant loadings of sediment,nitrates, and phosphorus from agricultural lands.

Effective environmental management to reduce pollution has always included an indispensable spatial dimension. Local communities have critical roles in the success (or failure) of any management plan to curb soil erosion and NPS pollution. Hence, public participation and grassroots efforts are key elements in the design of successful watershed management systems. Such systems require readily-available geospatial data and easy-to-use computing tools to allow quantitative assessment of management options by local decision makers who often either lack technological skills or technical resources, or both. In this context, the combination of the World Wide Web (the Web) and mapping capability of a Geographic Information System (GIS) is selected as the platform for the watershed management system. This type of system provides maximum availability to local stakeholders and citizens whose actions result in direct impacts on environmental quality.

Web-GIS has increasingly been adopted to develop various decision support systems (DSS) with strong spatial components. Spatial Decision Support Systems (SDSS) have proven to be effective in a variety of applications such as flood prediction (Al-Sabhan et al., 2003), river water quality evaluation (Wang et al., 2005), and conservation program management and best management practices assessment (Rao et al., 2006). These systems typically include a Web mapping component, hydrologic model, and GIS database. The modeling component frequently requires a large volume of complex input data for detailed hydrologic simulations, which require greater user skills and aptitude that are geared for technically savvy users. Sometimes, the computer model is tightly integrated with a GIS mapping software, and lacks the flexibility for frequent updates during system development cycles. Despite the proliferation of Web-GIS based DSSs, most are stand-alone systems that utilize the computing resources and GIS data from a single server without collaboration among available Web services. This often leads to unnecessary duplication of data and a waste of computing resources among physically separate servers.

In this project, the goal is to develop a fully Web-based watershed management SDSS for two critical watersheds in Indiana, the Burns Ditch and Trail Creek watersheds, on the southern end

of Lake Michigan. The SDSS was built on two existing Web-GIS mapping/modeling systems hosted separately at Purdue University and Michigan State University (MSU). The two systems are introduced in the following background section. The two separate systems will be made interoperable and take advantage of their complementary data and modeling capabilities to construct a complete SDSS to facilitate management decision making for erosion and NPS pollution reduction. Specific objectives include: 1) expansion of the two existing systems to allow BMP application and erosion modeling; 2) establish interoperable linkage between MSU's Digital Watershed system and Purdue's watershed modeling system to allow seamless integration of the various mapping and modeling components of the resulting watershed management system; and 3) disseminate the developed modeling system through workshops and evaluate the system based on user feedback.

Methodology

Project area

The Burns Ditch (a man-made waterway) and Trail Creek watersheds discharge to Lake Michigan at Burns Waterway Harbor in Portage and Michigan City Harbor, respectively (Figure 1). The Burns Ditch basin includes portions of Porter, Lake, and La Porte counties, and covers 857 square kilometers. Major sub-tributaries to the Burns Ditch include the East and West Branches of the Little Calumet River, Deep River, and Turkey Creek. The Trail Creek basin falls entirely within La Porte County and covers approximately 153 square kilometers. Major sub-tributaries to Trail Creek include the East and West Branches, Wolf Run, and Waterford Creek.

Land use within the two watersheds is primarily agricultural, with some forested, urban, and industrial areas. Within the Burns Ditch basin, the East Branch of the Little Calumet River is a main source of sediment due to high agricultural use. Urban development in the upstream portions of the basin contributes to elevated levels of sedimentation in Lake George, a manmade lake created by the City of Hobart in the mid-1800s. The Lake George Dam also has important effects on the river reach located downstream of the lake. As a result, dredging has been conducted along the East Branch of the Little Calumet River and in Lake George at an expense of more than $2 million. Similarly, in the Trail Creek basin, the federal navigation channel at Michigan City acts as a sediment trap requiring frequent maintenance dredging.

1). The identified environmental concerns in the two watersheds include: Sedimentation in Lake George (in the Burns Ditch basin) required 590,000 cubic yards of dredging in 2000;

2). Sediment contaminants of concern in the East Branch of the Little Calumet River include E. Coli and cyanide, while Trail Creek sediments contain E. Coli, cadmium, cyanide, and phenol;

3). Water quality problems in Trail Creek include low oxygen levels and high turbidity. Detailed description of the two critical watersheds can be found at The Great Lakes Tributary Modeling Program web site at http://glc.org/tributary/.

Erosion modeling

To estimate soil erosion, sediment yield, and the impact of implementing BMPs, the Revised Universal Soil Loss Equation model (RUSLE) was chosen. RUSLE is an erosion prediction

model that estimates long-term average annual soil loss resulting from the detachment of soil due to raindrop splash and overland runoff from field slopes in specific cropping and management systems and from rangeland (Renard and Ferreira, 1993). RUSLE is a replacement for the Universal Soil Loss Equation (USLE) and retains its six factors in that equation, as shown below.

$$\mathbf{A = R \bullet K \bullet LS \bullet C \bullet P}$$

where **A** is the long-term average annual soil loss (ton $acre^{-1}$ yr^{-1}), **R** is rainfall erosivity in [(hundreds of ft-ton) inch $acre^{-1}hr^{-1}yr^{-1}$], **K** is the soil erodibility in [ton $acre^{-1}$ (hundreds of ft-ton)$^{-1}inch^{-1}$ acre hr], **LS** is the dimensionless slope length and steepness factor, and **C** and **P** represent the dimensionless impacts of cropping and management systems and of erosion control practices, respectively. The RUSLE model was first developed by the USDA-Agricultural Research Service and was first released in 1993. It has been widely used by USDA-Natural Resources Conservation Service (NRCS) nationally, and it has been adopted internationally as well. There is a wealth of information and data available for its application for many locations.

The RUSLE model predicts long-term average annual erosion. In this project, however, the desired erosion related estimate is the sediment yield. Soil erosion refers to the soil dislodged from its original location due to rainfall and/or overland runoff. Not all of the dislodged soil, however, is transported in runoff water to a nearby stream or lake. A portion of the eroded soil is deposited at lower points in the watershed whenever runoff slows down. The amount of eroded soil that actually reaches a stream or other water body is called sediment. Hence, for a given watershed, the long-term average annual sediment yield can be estimated by multiplying the long-term average annual soil erosion potential by a sediment delivery ratio. The sediment delivery ratio is the ratio between the actual lost sediment to the total erosion (detached soil) potential from a watershed. The sediment delivery ratio varies between 0 and 1. There are different ways to determine sediment delivery ratio for a watershed. In this project, a relationship between watershed size and sediment delivery ratio is used. In other words, the sediment delivery ratio for a watershed is determined as a function of the watershed size.

In this project, the RUSLE equation is applied to a watershed by way of multiplying the raster (or grid) data layers (10 meter resolution) for the factors in the RUSLE equation in a watershed. Then, total watershed soil loss is calculated by summing up soil loss from all cells in the watershed. Finally, the sum is multiplied by the sediment delivery ratio for the watershed to arrive at the sediment yield value in tons yr^{-1}.

The erosion BMPs considered for this project include both structural and non-structural BMPs. Non-structural BMPs include no till, reduced till, and conservation tillage on agricultural field and riparian buffer strip. No till refers to the total cover (100 percent) of soil surface with crop residue. Conservation tillage leaves at least 30 percent of the soil covered by crop residues. Reduced tillage is an in-between tillage type. Structural BMPs include sediment basins and grassed waterways. To represent the different types of BMPs in the RUSLE equation, the **C** and **P** factors are adjusted for each of the BMPs accordingly.

The Web-GIS based SDSS for erosion and water quality management

The overall layout of the Web-GIS SDSS is shown in Figure 2. There are three common components in any Web-based modeling system, the user interface, backend server databases and modeling programs, and the Web server situated in between handling Hypertext Transfer Protocol (HTTP) connection and Common Gateway Interface (CGI) or Internet Server Application Programming Interface (ISAPI) calls.

The Purdue Web-GIS interface is built using the open source MapServer (http://mapserver.gis.umn.edu/) software with a java applet front end. It handles watershed delineation based on an user-specified outlet point and user digitization of areas within a delineated watershed for land use change or erosion BMP implementation. Its hydrologic models, introduced earlier, can provide before and after land use change hydrologic impact assessment for the delineated watershed.

The MSU Digital Watershed Web-GIS system is built using Internet Mapping software from ESRI. It stores the raster data layers for the **K**, **LS**, and **C** factors for RUSLE simulation for the project area. The default **P** factor is assumed to be 1.

Through the interoperable approach, described later, watershed and BMP area boundaries are first delineated by the Purdue Web-GIS system and sent to the MSU Digital Watershed system, which are used to clip raster layers of the erosion factors. BMP type specific **C** or **P** factors are then incorporated into the corresponding raster data layers for the user-defined areas. Then, the RUSLE model is run for the watershed to calculate total erosion, which is then modified by a sediment delivery ratio to arrive at long-term average annual sediment yield for the watershed. The results are then displayed back in user's Web browser.

Interoperability

The interoperability operations of data passing and other related operations are carried out behind the scene without the need of explicit intervention by the user. This would ensure seamless integration of the two Web-GIS systems. The proposed watershed management system links the two physically separate Web-GIS systems by passing dynamically re-projected vector GIS data and modeling results between them, as shown in Figure 3.

As shown in Figure 3, users can identify a drainage outlet point on a stream line within the MSU Digital Watershed Web-GIS environment. The outlet point's latitude and longitude coordinates are sent to Purdue Web-GIS system, where they are re-projected to Universal Transverse Mercator (UTM) Coordinate System, Zone 16 coordinates for the project area. Then, the Purdue Web-GIS uses the point to delineate a watershed based on DEM derived flow accumulation and flow path data. From within the Purdue Web-GIS environment, users can delineate watersheds and digitize areas within the watershed to assign land use change or apply erosion BMPs. The boundaries of the watershed and the digitized areas are saved on the Purdue Web-GIS as ESRI shapefiles, which is then re-projected from UTM zone 16 coordinate to Latitude-Longitude coordinate. The locations of the shapefiles in the Purdue Web-GIS system's file structure are

then sent to the MSU Digital Watershed, which in turn retrieves the shapefiles and uses them as masks for clipping data layers for erosion calculations.

In the traffics in both directions, information (may it be locations' lat-long coordinates or Web address of the boundary shapefiles) is passed through Hypertext Transfer Protocol (HTTP) Common Gateway Interface (CGI) or Internet Server Application Programming Interface (ISAPI) calls on programs that reside on destination Web Servers.

Principal Findings

Burns Ditch and Trail Creek Web-GIS based SDSS

The watershed management system for the Burns Ditch and Trail Creek watersheds is available online at http://danpatch.ecn.purdue.edu/~eqip/erosion/. Users can choose entry of the SDSS from either the Purdue Web-GIS interface or MSU Digital Watershed interface based on their preferences. Both ways will lead to the same system capability.

The general procedure for watershed management using the SDSS is shown in Figure 4. From the initial entry page, may it be from Purdue Web-GIS or MSU Digital Watershed, the user would zoom in to identify the area of interest and nearby stream, and then initiate watershed delineation by a single click on the stream (Figure 4a). A watershed is delineated in approximately ten seconds based on the user specified outlet point and underlying DEM data. The user can then activate the online digitizing interface to either manually digitize areas for BMPs or allow the system to determine the contributing areas in the case of grassed waterways and sediment basin structural BMPs. Then, the user specifies the type of BMP for the digitized area using the land use/BMP dialog box (Figure 4b). For grassed waterways, the user also needs to digitize a line inside the contributing area to define the location of the waterway. Tillage BMPs can only be applied to agricultural land uses. Once the changes are made and saved by the online digitizing tool, a before and after land use and BMP summary is given, along with a modeling toolbox for hydrologic and erosion modeling (Figure 4c). The available models can then be used to obtain a quantitative estimate of the impact from the land use changes made or BMPs applied (Figure 4d). The whole process can be repeated for the same delineated watershed as many times as the user would like. This allows multiple management scenarios to be evaluated and compared.

Case study using the SDSS

The Turkey Creek watershed, as part of the Burns Ditch watershed in Lake County, was identified by the City of Hobart, Indiana (Lake County) as having critical water quality problems. It drains into Lake George and eventually into Burns Ditch and Lake Michigan. Lake George is the central feature of the City of Hobart and has been the focus of significant downtown revitalization and economic development initiatives for the community. The Turkey Creek watershed produces excessive pollutants, particularly total suspended solids and nutrients. Such pollution appears to strongly correlate with the potential soil erodiblity (**K** factor in RUSLE equation) ratings and the presence of significant highly erodible lands (HEL) in the watershed. There also appears to be a strong correlation between the agricultural land uses and the elevated concentrations of total suspended solids and nutrients identified. Based upon these observations,

management of agricultural and HELs in the watershed was prioritized for installation of BMPs to reduce erosion/sedimentation and nutrients entering the streams in the watershed.

In this case study, a watershed on a tributary of Turkey Creek was identified to examine the effectiveness of agricultural and structural BMPs such as sediment basins in terms of sediment yield reduction. First, the watershed was delineated by identifying the drainage outlet on the tributary. Upon watershed delineation, the SDSS extracts land use and hydrologic soil type data for the watershed and summarizes it in a table (Table 1).

Table 1. Land use and hydrologic soil group area (acres) summary for the delineated watershed

Land use	**Hydrologic soil group**		
	B	**C**	**D**
Water	0.0	0.0	2.4
Commercial	0.0	0.9	0.0
Agriculture	16.3	106.2	5.1
Low density residential	0.0	15.0	0.4
Grass/Pasture	0.9	24.9	0.9
Forest	4.1	109.9	7.1
Industrial	0.0	0.9	0.0
Total watershed area (acres)	296.4		

The watershed has significant agricultural land use (43 percent of the total watershed area is agriculture) (Table 1). Hence, common agricultural BMPs, such as no till, reduced tillage, and conservation tillage were evaluated in this watershed. The sediment basin was also tested to see its effectiveness in reducing sediment yield.

Using the online digitizing tool user interface, three agricultural fields were selected in the watershed for implementing the tillage BMPs (Figure 5a). The SDSS reports the areas of the three fields as 17.8, 18.0, and 12.4 acres for field 1, field 2, and field 3, respectively. In addition, two sediment basins were tested on the two tributaries in the watershed. The SDSS takes the point outlet identified by the user (using the ‘Siting’ tool in the online digitizing interface) to delineate the contributing sub-watershed, hence, the impact area of the potential sediment basins (Figure 5b,c). Using the SDSS, the tillage BMPs and the sediment basins were examined in various combinations to evaluate their effectiveness in reducing sediment leaving the watershed.

Estimated sediment yield from the watershed for various combinations of the BMPs are listed in Table 2.

Table 2. Simulated sediment yields (tons/year) from the watershed

	Sediment basin			
	Without	1	2	1 and 2
Current condition	161.2	142.1	115.2	96.6
No-till	134.6	119.7	94.9	80.6
Conservation tillage	146.3	127.7	104.3	87.3
Reduced tillage	156.8	136.8	112.9	93.1

As seen from Table 2, when no sediment basins are installed, the three tillage BMPs all reduce sediment yield from the watershed, compared to that of the current condition. When used along with sediment basin, may it be 1, 2 or both, tillage BMPs (no-till, conservation tillage, and reduced tillage) help reduce sediment yield from the watershed, comparing to that at current condition without sediment basin implementation. It is also shown that sediment basin 2 consistently reduced more sedimentation from the watershed compared to sediment basin 1. Overall, significant sediment yield reduction from the watershed calls for the implementation of both sediment basins 1 and 2, along with tillage BMP. In this exercise, only one type of tillage BMP is assumed on all three agricultural fields (Figure 5a). Users can easily specify any type of BMPs at any location to evaluate their combined effectiveness. This case study demonstrates the flexibility with which the SDSS can be used to quickly evaluate multiple management scenarios and to choose the best potential strategies.

Training Workshop

The watershed management system was delivered at a stakeholder workshop on December 19, 2006 at the Northwestern Indiana Regional Planning Commission (NIRPC), Portage, Indiana. Participants of the workshop represented a diverse group of stakeholders including local water resource managers (Save the Dunes Council, Great Lakes Commission, Little Calumet River Basin Commission, Michigan City Port Authority), state agencies (Indiana Department of Environmental Management, Indiana Department of Natural Resources), county environmental planners, consultants (Integrated Environmental Solutions), and US EPA region 5 personnel. The workshop started with the introduction of the Web-GIS SDSS, presenting its work flow, capability, and underlying theories for quantifying impacts of land management decisions and BMPs on sedimentation within the focus area of the Burns Ditch and Trail Creek watersheds. Then, a hands-on training session was conducted for three hours. Case exercises were provided to the participants who used their own laptop computers to access the Web-GIS SDSS via the

Internet through wireless connections. At the conclusion of the workshop, various aspects of the SDSS were discussed and feedback forms were distributed among the participants.

The returned user feedback is summarized in Table 3. Overall, the feedback from participants was overwhelmingly positive. The workshop was rated excellent or good for its content and presentation by six out of seven completed user surveys. The Web site design and content of the SDSS were scored from 4.0 to 4.2 on a scale of 1 to 5, with 1 being poor and 5 being exceptional. The modeling tools in the SDSS were scored from 3.8 to 4.3 on a scale of 1 to 5, with 1 being poor and 5 being exceptional. The participants stated that they would continue to use the Web-GIS SDSS for watershed management planning and implementation in target areas and for quantifying changes in water quality and evaluating nutrient reductions from various BMPs (using the NPS results from L-THIA) to identify economic value and support cost/benefit calculations.

There was another indication that the SDSS was embraced by the participants as it encouraged them to actively participate in the management thinking process. That is, despite the lack of modeling experience from most participants of the workshop, they were able to provide specific constructive suggestions for future improvement after the workshop. For example, the feedback from one participant, regarding the L-THIA model, reads: "Would like ability to change assumption to consider agricultural land with land application of manure". Another feedback from a participant, regarding the BMP implementation, reads: "Conversion of agricultural land to urban development is one of our biggest threats. For future updates, it would be nice to incorporate various development types (traditional, LID, conservation design, etc) to provide planners with additional discussion. … Also expand BMP options if possible".

Table 3. User feedback summary for the evaluation of the U.S Army Corps of Engineers (USACE) Sediment Runoff Predictive Tool and Training Workshop, December 19th, 2006 at NIRPC, Portage, Indiana

Evaluation of the USACE Sediment Runoff Predictive Tool and Training Workshop

Training Material	Total number of response received: 7		
	Excellent	Good	Fair
- content	4 out of 7	2 out of 7	1 out of 7
- presentation	4 out of 7	1 out of 7	2 out of 7
Web Site Design and Content		Scale: 1= poor, 5= exceptional	
4.0	Navigability is good. Links are clearly labeled. Can move from page to page easily.		
4.0	This site offers interactivity. The visitor is engaged using the site.		
4.0	This site uses appropriate page format. Pages are not inordinately long.		
4.0	Can easily find information		
4.1	This site is aesthetically appealing. Good use of graphics and color.		

4.0	Additional resource links are included.
4.0	Information is useful
4.2	Rich content and will likely be revisited.
4.1	How this website compares in content to similar websites
4.1	Please indicate the usefulness of the Watershed Tools and Summary?

Modeling tools in the SDSS		Scale: 1= poor, 5= exceptional
	Score	User-envisioned usage
View watershed/Apply BMPs	4.3	1 Target specific problems 1 This can provide a “first peak” into land use changes
Estimate sediment	4.0	1 Look at and compare drainage calculations for new projects 1 to protect coldwater fishery
Estimate Imperviousness	4.2	1 Look at and compare drainage calculations for new projects 1 to protect coldwater fishery
Estimate Peak Runoff	4.0	1 Look at and compare drainage calculations for new projects 1 calculate rough number for peak discharge 1 Impacts on flooding and water quality impacts
Run L-THIA Model	4.0	1 Changing land use—for watershed planning
Run SEDSPEC Model	3.8	1 To identify areas of concern

The user feedback appears to echo the findings from DSS researchers such as Jarupathirun and Zahedi (2005). In their attempt to explore the influence of users’ perceptual factors in the success of web-based spatial DSS, they found that well-designed, user friendly, and focused SDSS can help improve its perceived task-technology fit (TTF) and perceived goal commitment, which in turn improves users’ self-efficacy and their satisfaction in decision quality from using the SDSS. This would lead to more adoption of the SDSS in real life decision making process. Other researchers also attributed the greater community acceptance and participation of a Web-based SDSS to developing customized, focused, and user friendly tools for community users who do not have extensive technical skills (Rattray, 2006). From the outset, Web-based GIS improves the availability of geospatial data and the adoption of spatially explicit analysis, and, at the same time, incurs no cost to the end-user through the use of web clients (Peng and Tsou, 2003). Indeed, after the conclusion of the modeling system development and the workshop, users have been communicating with the development team to provide feedback on their experiences using the tool and suggestions for improvement.

There are some weaknesses in this watershed management system. First, as pointed out by a number of users after the workshop, the system only considers a limited list of erosion BMPs. Second, the land use classification considered by the current SDSS is overly broad, lacking the

representation of variations within some of the land use types, e.g. residential area of different densities. These deficiencies are largely due to the lack of site specific information and data for models to develop such capabilities.

Significance for Project

A Web-GIS watershed management system was developed as part of the Great Lakes Tributary Modeling Program administered by the U.S. Army Corps of Engineers. The system targets the Burns Ditch and Trail Creek watersheds in northwestern Indiana that drain into Lake Michigan. The system is built on the basis of two existing Web-GIS modeling/mapping systems hosted at Purdue University and Michigan State University. The two systems were made interoperable by passing vector GIS data through HTTP CGI/ISAPI calls to programs on destination servers. New capabilities were developed in the two systems. Specifically, Purdue Web-GIS was extended to represent common tillage BMPs (no-till, reduced tillage, and conservation tillage) and structural BMPs (sediment basin, grassed waterways, and riparian buffer strips) through a new online digitizing tool for location specific assignment of land use change and BMP applications within a watershed. The MSU Digital Watershed Web-GIS was extended to have the RUSLE modeling capability.

The two enhanced Web-GIS systems were seamlessly integrated into a Web-based SDSS that allows user to delineate watershed, make land use change, apply erosion BMP in a delineated watershed, run hydrologic and erosion models to assess the impact on hydrology, NPS pollution, and sediment yield due to land use change or applied BMPs. Multiple scenarios can be evaluated and compared in one session of analysis.

The SDSS was disseminated at a workshop for local stakeholders and was very well received. It has continuously attracted user feedback with constructive suggestions. The SDSS has proved to be a user-friendly decision support system that allows grassroots efforts in the land management decision making process. Future improvement of the system will focus on the expansion of the list of BMP types that can be represented in the system.

Figures:

Figure 1. Burns Ditch and Trail Creek project area. ADD MAJOR STREAMS (Burns ditch, Burns Waterway, Little Calumet River, Trail Creek, Lake George, etc.)

Figure 2. Schematic of the watershed management system built on interoperable Web-GIS modeling and mapping systems at Purdue and MSU.

Figure 3. Interoperability between Purdue Web-GIS and MSU Digital Watershed through data passing and HTTP CGI/ISAPI calls.

Figure 4. Schematic of the procedure for a complete watershed management analysis. (a) Entry page of the SDSS; (b) making land use change or apply BMPs; (c) run hydrologic model and soil erosion model; (d) erosion, hydrology, and NPS results before and after land use change or BMP implementation.

Figure 5. Case study of a watershed on a tributary of Turkey Creek. (a) Digitizing three agricultural fields for tillage BMP implementation; (b) Siting of sediment basin 1 and the delineated contributing sub-watershed; (c) Siting of sediment basin 2 and the delineated contributing sub-watershed.

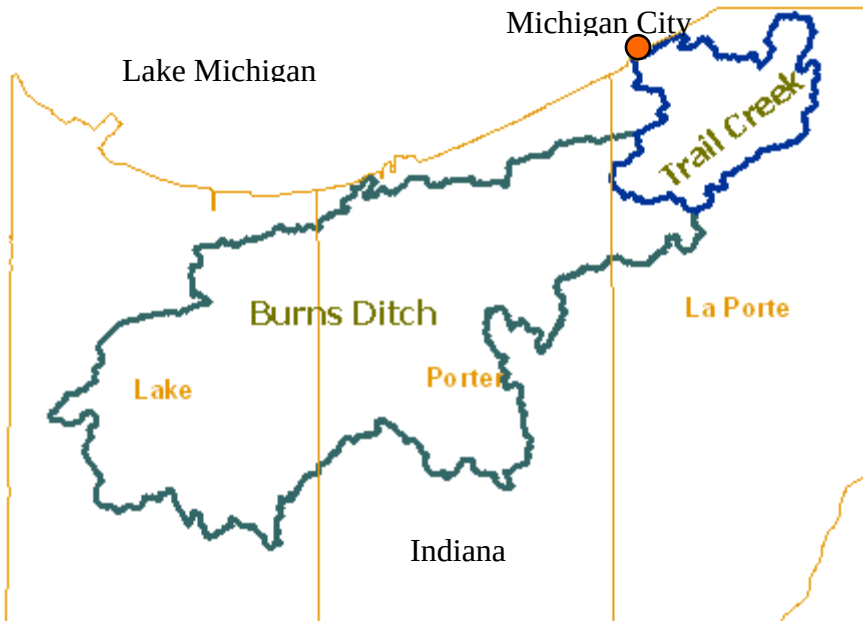


Figure 1

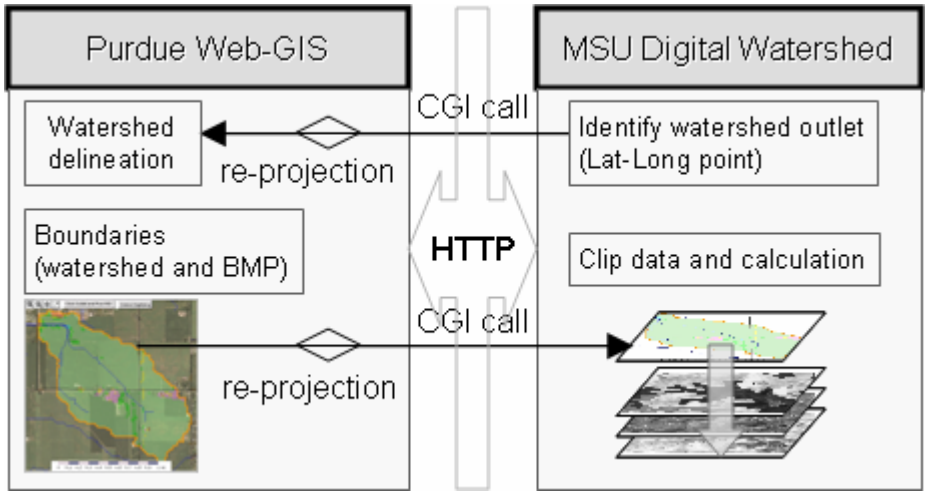


Figure 3

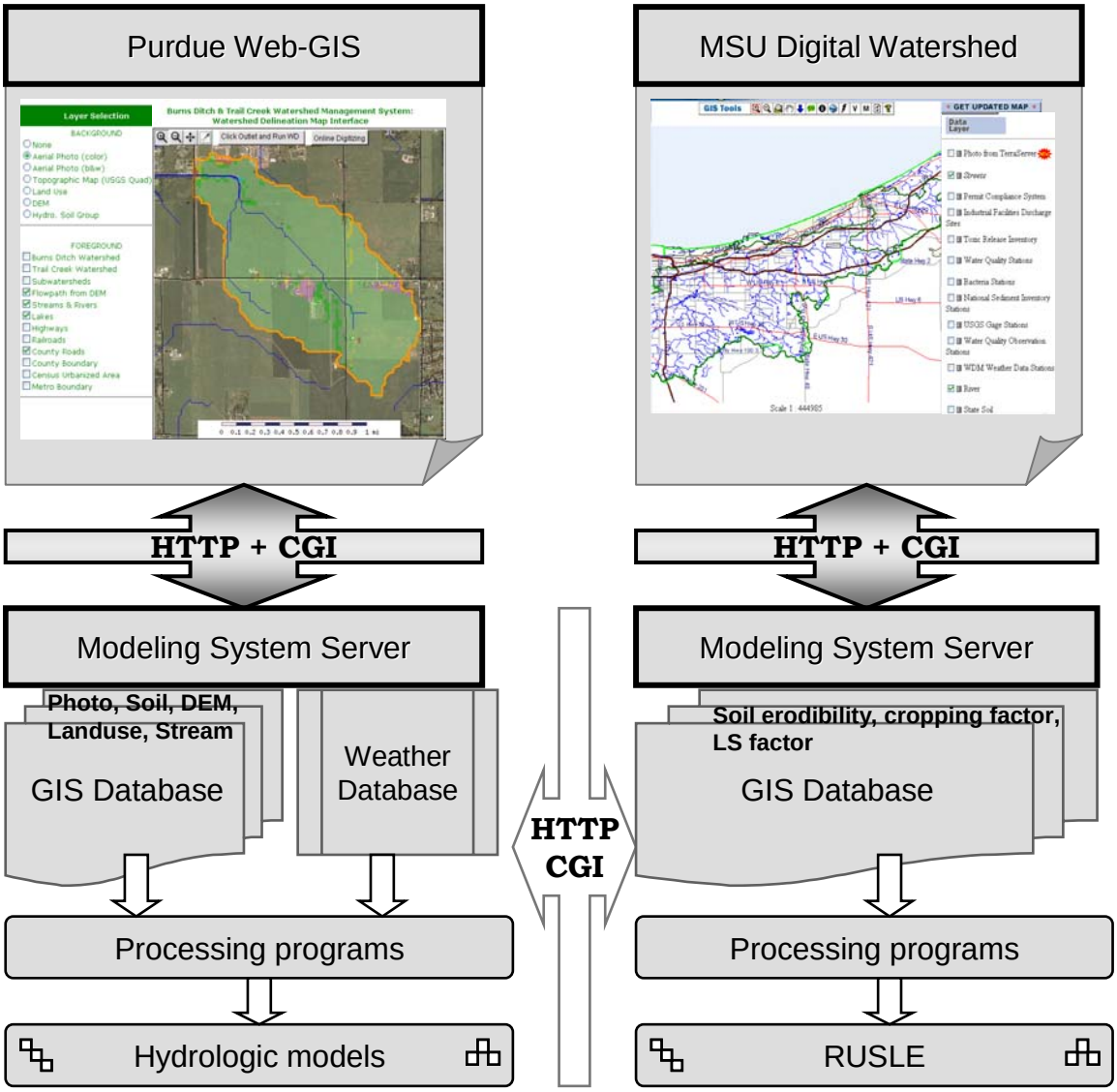

Purdue Web-GIS
MSU Digital Watershed
HTTP + CGI
HTTP + CGI
Modeling System Server
Modeling System Server
Photo, Soil, DEM, Landuse, Stream
GIS Database
Weather Database
Soil erodibility, cropping factor, LS factor
GIS Database
HTTP CGI
Processing programs
Processing programs
Hydrologic models
RUSLE

Figure 2

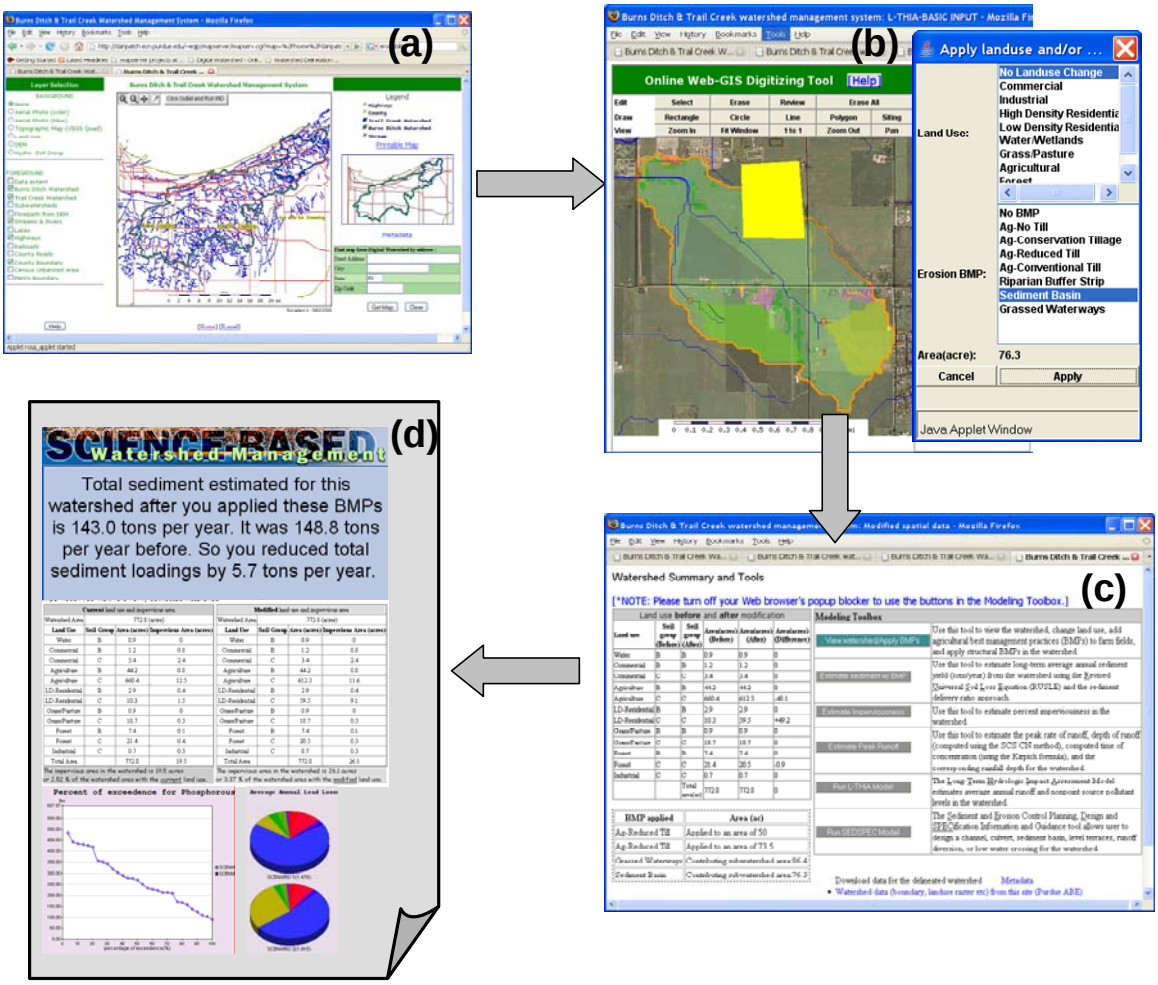
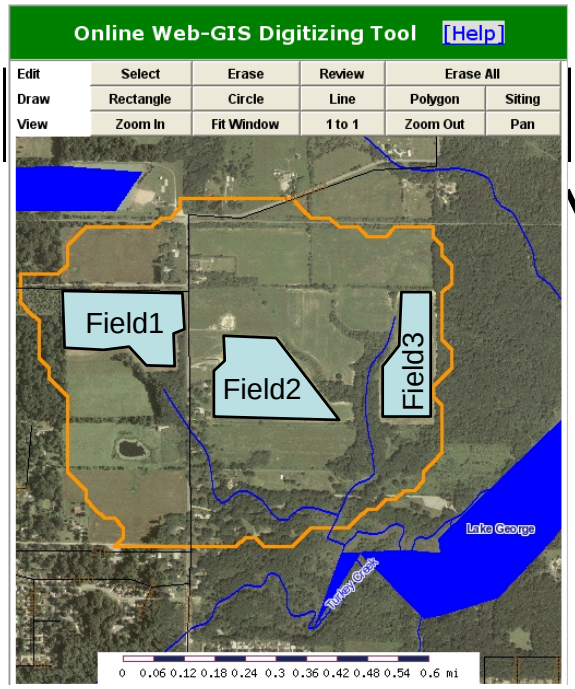
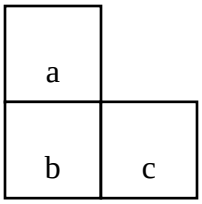

(a)
(b)
Online Web-GIS Digitizing Tool
Apply landuse and/or ...
Land Use:
No Landuse Change
Commercial
Industrial
High Density Residentia
Low Density Residentia
Water/Wetlands
Grass/Pasture
Agricultural
Erosion BMP:
No BMP
Ag-No Till
Ag-Conservation Tillage
Ag-Reduced Till
Ag-Conventional Till
Riparian Buffer Strip
Sediment Basin
Grassed Waterways
Area(acre):
76.3
Cancel
Apply
Java Applet Window
(c)
Watershed Summary and Tools
(d)
SCIENCE-BASED
Watershed Management
Total sediment estimated for this watershed after you applied these BMPs is 143.0 tons per year. It was 148.8 tons per year before. So you reduced total sediment loadings by 5.7 tons per year.

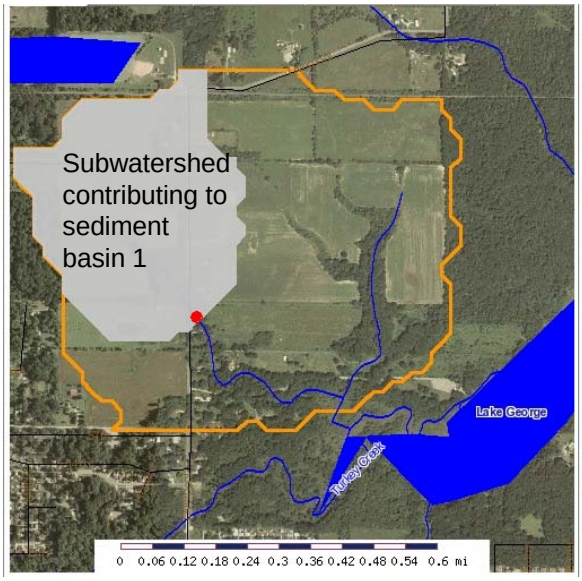
Figure 4





Online digitizing toolbar.

The 'Rectangle', 'Circle', 'Line', and 'Polygon' buttons allow manual delineation of area. 'Siting' tool allows delineation of



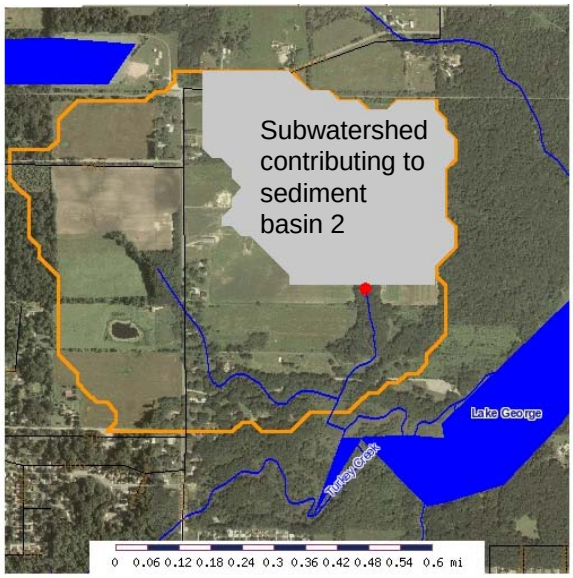


Figure 5

Grant No. 05HQGR0172 Strategic Conceptual Plan for Submittal to the Army Corps of Engineers for the 516(e) Great Lakes Tributary Modeling Program

Basic Information

Title:	Grant No. 05HQGR0172 Strategic Conceptual Plan for Submittal to the Army Corps of Engineers for the 516(e) Great Lakes Tributary Modeling Program
Project Number:	2005MI97S
Start Date:	9/1/2005
End Date:	8/31/2009
Funding Source:	Supplemental
Congressional District:	8th
Research Category:	Water Quality
Focus Category:	Water Quality, Sediments, Models
Descriptors:	Spatial Decision Support System
Principal Investigators:	Jon Bartholic, Jeremiah A Asher, Ouyang Da, Da Ouyang, Saichon Seedang, Yi Shi

Publication

Project Number: 2005MI97S

Start: 09/01/05(actual)

End: 08/31/09 (actual)

Title: Strategic Conceptual Plan for Submittal to the Army Corps of Engineers for the 516(e) Great Lakes Tributary Modeling Program

Investigators: Jon F. Bartholic, Institute of Water Research, Michigan State University

Focus Categories: Water Quality, Sediments, Models

Congressional District: eighth

Descriptors: Spatial Decision Support System

Introduction

Task 1 Deliverables. **Will include written summaries of the Advisory Teams comments and evaluations.**

The Advisory Committee met again on October 16th for a hands-on session to simulate how one would use the web-based tools in the work place. A review of the web-based tools with a computer exercise and question/answer session were on the agenda for each of the following web-based tools, Understanding Your Watershed via Digital Watershed, Burns Ditch and Trail Creek Watershed Decision Model and High Impact Targeting for Managing Sediment Loading (HIT). A survey was developed by the IWR staff and was completed by the committee members at the conclusion of this meeting. The committee members and IWR staff concluded that this hands-on forum was a favorable method for a training model for web-based systems. Also the overall consensus was that the web-based tools could be used as a tool for different aspects in the decision-making process. A summary of the written responses are grouped by the survey's questions with similar responses stated once.

Question1.1: Please provide your evaluation and your suggestions from having used the Digital Watershed System.

A) Technical Difficulty:

- *I experienced no technical difficulties.*
- *I think the tool works fine and ease of use is adequate.*
- *I am sure if it was more intensively field tested in some field offices they would come up with some little tweaking things...there was nothing that stood out at me.*

B) User Friendliness:

- *The site very easy to navigate.*
- *This is good in what I saw.*
- *Just fine, no glitches.*

Suggestion: *Header of column and information contained in water quality observation station layer needs more of an explanation.*

C) Usefulness:

- *As a first cut to find water quality stations, industrial discharge sites, toxic release inventory etc it is useful.*
- *Something else helpful would be the option/ability to print out a record of the calculations...i.e. what land covers, acres, and hydrologic groups were used for the calculations.*
- *To make the system more useful it would be beneficial to have web based access to the data from the facilities identified and a way of exporting that information to a downloadable shape file or excel spreadsheet.*
- *It would be preferable if SURGO soil data from NRCS was used. Information does not tell anything about the soil other than the MUID. It would be helpful to have information like hydrologic group, prime agriculture land, locally important agricultural land etc. included.*
- *It would be useful to have units associated with data sets and erosion/deposition model.*
- *It would be very helpful to have a graphic version of a scale associated with map.*
- *May want to consider replacing the river RF3 with the NHD.*

Question 2.1: How do you think information from the HIT system could assist you in the planning processes below? Please explain.

- *This would be useful to identify areas that may be contributing sediment. Field staff would be directed to these area identified by the model to validate or disprove its findings.*
- *This model could be used to prioritize field investigations.*
- *Use would be more at the watershed level to do watershed analysis and the rapid assessment work. We need tools to look at the 8 Digit HUC units and tell us we need "x acres of new riparian buffers, y acres of grass waterways, z acres of conservation tillage", etc. And we need a tool that can tell us if we apply mix a (x acres of filter strips and y acres of conservation tillage) to the watershed we will get this result....sediment reduced, etc, versus what we get if we apply mix b of the practice combination.*
- *I realize they 8 digit watersheds are large but that is what we are supposed to be working at. Even if we had something we could easily run for a smaller area and then aggregate the runs for the larger watershed that would be better than what we have now. I have some real reservations about the average c factor use, even in the rapid assessments, and will discuss them below.*
- *Another use would be for a local district conservationist or planner to run the tool for an individual farm in the conservation planning process, to show land user visually (maps, visualizations, etc) where their treatment needs were and*

the effects of applying various alternative conservation practices to the farm. The visualization would be very very helpful, including graphs, charts, maps of the output. This would be especially good if the planner could input changes incrementally for the farm where he/she was making the run....for instance add a specific rotation to the run of say c-sb-w, or alternative tillage systems such as 50% mulch till versus 100% no till. If they could specify an input of rotation, tillage and buffers, they could then make various runs of different combinations and then compare outputs with the farmer. (See additional comments below on ways to input rotations and tillage). Our current RUSLE requires tremendous amount of time to run....to automate this could be a time saver. I will add the caveat that some of our people would have heartburn that you are not now using RUSLE 2. But I think what you are working on would have tremendous potential for this use in conservation on individual tracts of land.

Question 2.2: Do you think you would use the HIT system to guide your decisions about the locations for implementation of BMPs at farm level? Why or Why not?

- *No, as with all modeling exercises there needs to be an on the ground verifications. I see the model greatest asset as a desk top problem identification tool.*
- *I see a more practical use for field offices of identifying general areas, or lists of landowners, that we could target for informational mailings, group informational meetings, etc., we just have to be careful how we couch it.*

Question 2.3: What is your expectation from the HIT system? Please explain.

- *I think the HIT system with some modifications could be very helpful in the Rapid Assessments*.

Question 3.1: What additional data sets would you like to see incorporated into the DW or HIT systems?

- *Land use/land cover*
- *303d listed waters*
- *Riparian buffers*
- *Water quality data*
- *Precipitation/climate*
- *Water use*
- *Prime farmland*
- *Floodplain boundaries*
- *CAFOs*
- *Threatened and Endangered Species*
- *Updated wetland inventory layer*

Task 2 *Deliverable*: Will be specific preliminary 3-D visualization and 2-D improved web mapping software.

Conceptual Design of Customized 3D Visualization of Topography
The customized 3D visualization of topography function will allow end users to generate customized 3D images of the terrain for the area they are viewing in the mapping window. An extra button will be added to the Digital Watershed toolbar. Once users click on it, a dialog box will pop up so they can set different parameters such as viewing angle and height to look at local terrain in details. This function will enable users to do virtual terrain survey online if the underlying DEM data are sufficiently accurate.

Digital Watershed now linked with Google Earth

Digital Watershed users can now click the Google Earth icon on the tool bar to access this new feature. Google Earth provides a 3D interface to the planet.

"We're excited about this newest Digital Watershed feature," Dr. Jon Bartholic, Director of the Institute, stated. "We constantly look for ways to upgrade and improve our web-based information services---and Google Earth provides a great new feature to go with our Digital Watershed."

Users see watershed boundaries that are supplied and drawn by Digital Watershed and applied to Google Earth images.

The idea for Google Earth is simple, according to the Google Earth web site. You point and zoom to anyplace on the planet that you want to explore. Satellite images and local facts zoom into view. You can zoom to a specific address or site to check out a natural feature or a specific building. Google images are photographs taken by satellites and aircraft sometime in the last three years and are updated on a rolling basis.

Digital Watershed already features links with EPA's Surf Your Watershed and also features over 20 data layers that provide a maximum amount of information to users for watershed planning and water quality improvements

Task 3 *Deliverable*: Will be a web accessible HIT system with reports plus an assessment of the cookbook/education modules success.

A web accessible High Impact Targeting System (HIT) for addressing prioritized sediment reduction with reports plus an assessment of the cookbook/education modules success.

The IWR HIT system is currently in its second version. An initial system was developed in the latter half of 2006. That version allowed web-users to prioritize 12-digit watersheds by erosion and sediment loading data in tabular, graphical, or spatial formats. Linking HIT with Digital Watershed also allowed users to view sediment loading risk maps at a field-level resolution. Several key upgrades were made to HIT in late 2006 early 2007. Aesthetic upgrades included a simplified and streamlined user interface to facilitate the user inputs. This was accomplished by providing users with a live and interactive map for selecting watersheds and utilizing AJAX web-scripting to consolidate multiple user-input pages into a single page. Substantive upgrades included expanding the scale of watershed prioritization by allowing users to rank 10-digit watersheds, reducing data redundancy in the system's core database, accepting user-specified BMP costs and recalculating total costs and cost benefits on the fly, and providing users with simple and detailed versions of metadata. The HIT

system currently offers data on sediment loading and erosion for four watersheds: the Maple River (HUC8: 04050005), the River Raisin (04100002), the Pigeon-Wiscoggin (04080103), and the Lower Maumee River (04100009).

The system homepage includes a link to a thorough description of the system and how it could be utilized. This page will serve as the foundation for a more detailed how-to guide on the HIT system. As part of a Conservation Innovation Grant (CIG) from NRCS, half-time conservation district technicians are testing the tool and previewing it to potential user groups. Their effort is on-going, and will guide us in the development of the how-to document and the project's larger outreach plan.

The CIG technicians are currently conducting field evaluations of HIT's predicted sediment loading risk areas. This effort will measure how accurately HIT targets areas within a particular field, and will help IWR refine the system to more accurately predict areas at high-risk for sediment loading.

Efforts are also underway to evaluate HIT's quantified results for sediment loading. A USGS 104B proposal is allowing IWR to work with MSU Biosystems and Agricultural Engineering and the Kellogg Biological Station to compare the HIT and SWAT model results for the Kalamazoo River watershed against monitored water quality data gathered throughout the watershed. IWR is conducting similar research in the River Raisin and Auglaize River watersheds.

Task 4 *Deliverable*: Will be reports on each detailed perspective and an assessment from the advisory team on the completeness and usefulness of these "tools".

In comparing the impact of conservation tillage practices in the Garret Creek sub-watershed with the Wolf River sub-watershed (both 12-digit watersheds within the 8-digit Lower Maumee), it is clear that focusing on the Garret with its higher rate of sediment delivery will have a greater positive environmental impact. In the Garret Creek watershed, if no till is implemented on the worst 10% of contributing areas, HIT estimates that sediment loadings will reduce by 368 tons compared to 84 tons in the Wolf Creek watershed. The second table compares predicted reductions between no-till and grass buffers; and illustrates the impact targeting the worst areas within a sub-watershed can have. This type of data can empower a conservation district manager, the Army Corps of Engineers, or a drain commissioner to truly focus for effect.

Applying BMP (no-till) on highest risk acres in contrasting watersheds

Watershed	Acres	Tillage	Total Sediment (tons)	Reduction (tons)	Percent Change
Garret	18,065	current practice	1,591	0	0%
Garret		no till on worst 5%	1,322	269	17%
Garret		no till on worst 10%	1,223	368	23%
Wolf	17,440	current practice	286	0	
Wolf		no till on worst 5%	216	69	
Wolf		no till on worst 10%	202	84	

1

Institute of Water Research

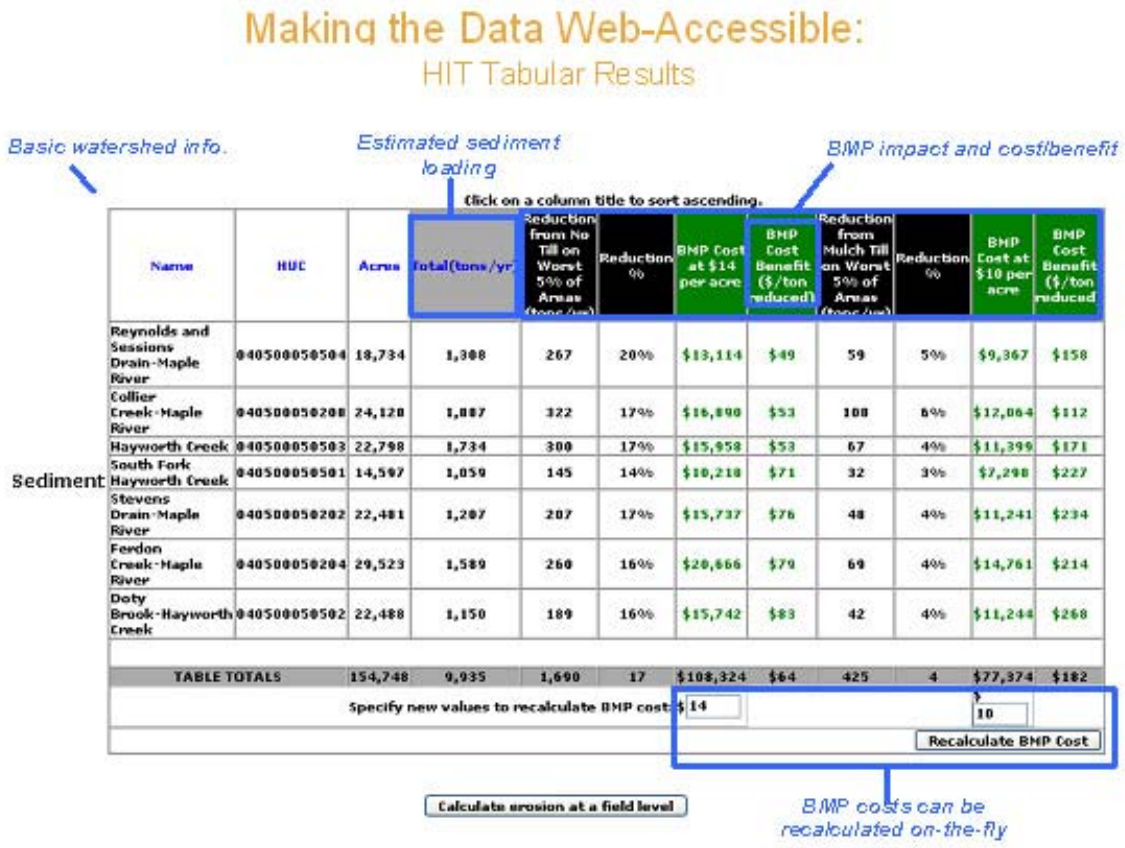
Applying BMP (no-till) on highest risk acres in contrasting watersheds

Watershed	Acres	BMP	Total Sediment (tons)	Reduction (tons)	Percent Change
Garret	18,065	current practice	1,591	0	0%
		no till on worst 5%	1,322	269	17%
		no till on worst 10%	1,223	368	23%
		grass on worst 5%	1,070	521	33%
		grass on worst 10%	863	728	46%

2

Institute of Water Research

Within HIT, users can perform cost benefit analyses of BMPs across sub-watersheds. In the table below information on predicted reductions to sediment loading resulting from two BMPs is presented for several sub-watersheds of Michigan's Maple River. The HIT user was shown the baseline condition (column with grey header), the predicted reductions from particular BMPs (columns with black headers), and the economic cost benefit of each BMP (columns with green headers). The BMP costs in this example are based on the EQIP payments for the BMPs, though users can specify a dollar amount themselves. The BMP cost benefit is performed by dividing the BMP cost by the BMP's predicted reduction in sediment loading. This feature of HIT allows conservationists with limited funds to truly prioritize their efforts where they will realize a maximum return on their investment; and where targeting will have the highest impact.



Task 5 *Deliverable*: A report on the extent to which the required data is available, any data gaps, and estimates of our ability to use this data to implement a watershed supporting system for the selected watersheds.

Since the selected watersheds have yet to be defined, here is an assessment of data availability for the Great Lakes Basin.

Streams

HIT utilizes the National Hydrography Dataset's high resolution data for the required streams and river input. The high-resolution NHD is available for the entire basin except for the

Baraboo (WI – 07070004), Castle Rock (07070003), Lower Fox (WI – 04030204) and Thornapple (MI – 04050007). In these areas medium resolution NHD data is available, and would suffice for HIT's needs.

Elevation

When available, HIT's spatial results are best viewed at a 10 meter resolution. This requires a 10 meter digital elevation model (DEM) from the USGS' National Elevation Dataset. All of New York, Ohio, and Indiana, and the parts of Illinois within the basin, have 10 meter DEMs available. The majority of Michigan, and about half of Wisconsin and Minnesota do not have the 10 meter data available. In those areas HIT modeling would have to use 30 meter DEMs. As part of the aforementioned CIG project, IWR has partnered with the USGS in Rolla, MO to build the 10 meter DEMs for the project's study area (the Maple, Raisin, and Pigeon-Wiscoggin watersheds). In an initial assessment of the reliability of HIT results based off of 10 meter DEMs to those based off of 30 meter DEMs it seemed that the finer resolution results were much more spatially sensitive to eroding areas that could potentially form into gullies, even though the predicted sediment totals were essentially unchanged. The CIG's current field evaluation is looking at 30 meter HIT results. Later on a re-evaluation will be conducted looking at 10 meter HIT results. That effort will yield a more detailed assessment of the benefit of the higher resolution DEMs over the coarser ones.

Land Cover

Previous HIT analyses utilized the 1992 National Land Cover Dataset (NLCD). Within the past few months the 2001 NLCD has become available. It was, obviously, a temporal improvement over the 1992 data; but it also employed improved image processing algorithms to yield a more reliable result. The 2001 NLCD is available for the entire nation.

Soils

Where available, HIT utilizes NRCS' SSURGO dataset for soils data. SSURGO data is available at a county level for all of Indiana and Wisconsin; the entire lower peninsula of Michigan and most of the upper peninsula; nearly all of Ohio and Illinois; most of New York and Minnesota. In areas where SSURGO is not available the coarser STATSGO soils data can be used.

Grant No. 07HQGR0003 Developing the Water Withdrawal Assessment Tool

Basic Information

Title:	Grant No. 07HQGR0003 Developing the Water Withdrawal Assessment Tool
Project Number:	2006MI114S
Start Date:	10/1/2006
End Date:	9/30/2007
Funding Source:	Supplemental
Congressional District:	8
Research Category:	Water Quality
Focus Category:	Models, Water Quantity, Water Quality
Descriptors:	
Principal Investigators:	Jeremiah A Asher

Publication

Project Number: 2006MI114S
Start: 10/1/2006 (actual)
End: 9/30/2007 (actual)
Title: Developing the Water Withdrawal Assessment Tool
Investigators: Jeremiah Asher, Institute of Water Research, Michigan State University
Focus Categories: Water Quality, Sediments, Models
Congressional District: eighth
Descriptors: Spatial Decision Support System

** Project Update*

Introduction
In order to better manage and protect the tremendous water resources that support Michigan's economy, environment, and quality of life, the legislature has established new laws that address reporting, registering, environmental protection standards, and permitting requirements for large quantity withdrawals from groundwater and surface water.

A "large quantity withdrawal" is a withdrawal greater than 100,000 gallons per day (gpd) averaged over a consecutive 30-day period. Under the new law, these types of withdrawals must be registered with the Michigan Department of Environmental Quality (MDEQ), report volume withdrawal annually, have a permit, and demonstrate no adverse impact to nearby streams and lakes. An adverse impact is defined as impairing the lake or stream's ability to support its characteristic fish population. The Michigan Department of Natural Resources (MDNR) can determine the characteristic fish population of a stream by comparing the amount of groundwater contributing to stream flow to the size of the stream's watershed. Taking too much water from a stream will change the flow depth, velocity, and temperature of the stream and hence the types of fish expected to be found there.

The primary objective of this project is to work with MDNR and USGS to develop a web-based GIS interface, called the Water Withdrawal Assessment Tool (WWAT) interface to link with newly developed hydrologic and fish habitat models. The interface will be used as a screening tool to determine if newly proposed withdrawals from groundwater or surface water will have an adverse impact to characteristic fish populations in nearby streams and lakes. It is currently being recommended to the state that individuals seeking to implement new large water withdrawals be required to use the WWAT as one of the first steps in the process for getting certified. By using the WWAT the applicant can use a sophisticated mapping system to pin-point the location of their proposed water withdrawal. The system collects valuable characteristics about the withdrawal from the user and physical characteristics from the map. These values are passed to the hydrologic and fish models and a result are instantly displayed indicating whether the proposed withdrawal has calculated adverse impact on the nearby fish population. If the applicant's withdrawal passes the WWAT screening process, they can use the system to register the withdrawal with MDEQ. If they fail the screening process

they can modify characteristics of their withdrawal and rerun the model, or work with the MDEQ and run the model again using more site specific data.

This project is very unique in that it was mandated by the Michigan Legislator and during the current development of the WWAT, IWR has worked closely with the Ground Water Conservation Advisory Council to develop an interface that incorporates the requirements of the new law and the concerns of the different industry sectors involved in the process. The Ground Water Conservation Advisory Council was appointed by the governor and legislator to provide guiding principles and recommendations regarding adverse impact and use of the Water Withdrawal Assessment Tool in the new legislation.

Natural Resources Integrated Information System

Basic Information

Title:	Natural Resources Integrated Information System
Project Number:	2006MI69B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	8th
Research Category:	Water Quality
Focus Category:	Management and Planning, Water Quality, Models
Descriptors:	None
Principal Investigators:	Jon Bartholic

Publication

Institute of Water Research
Annual Technical Report
FY 2006

Introduction

The Institute of Water Research (IWR) at Michigan State University (MSU) continuously provides timely information for addressing contemporary land and water resource issues through coordinated multidisciplinary efforts using advanced information and networking systems. The IWR endeavors to strengthen MSU's efforts in nontraditional education, outreach, and interdisciplinary studies utilizing available advanced technology, and partnerships with local, state, regional, and federal organizations and individuals. Activities include coordinating education and training programs on surface and ground water protection, land use and watershed management, and many others. (An extended introduction can be found in our FY2001 Annual Technical Report.) We also encourage accessing our web site which offers a more comprehensive resource on IWR activities, goals, and accomplishments: http://www.iwr.msu.edu.

The Institute has increasingly recognized the acute need and effort for multi-disciplinary research to achieve better water management and improved water quality. This effort involves the integration of research data and knowledge with the application of models and geographic information systems (GIS) to produce spatial decision support systems (SDSS). These geospatial decision support systems provide an analytical framework and research data via the web to assist individuals and local and state government agencies make wise resource decisions. The Institute has also increasingly become a catalyst for region wide decision-making support in partnership with other states in EPA Region 5 using state-of-the-art decision support systems.

The Institute also works closely with the MSU Cooperative Extension Service to conduct outreach and education. USGS support of this Institute as well as others in the region enhances the Institute credibility and facilitates partnerships with other federal agencies, universities, and local and state government agencies. The Institute also provides important support to MSU-WATER, a major university initiative dealing with urban storm water issues with funding from the university Vice President for Finance. A member of the Institute's staff works half-time in facilitating MSU-WATER activities so the Institute enjoys a close linkage with this project. The following provides a more detailed explanation of the Institute's general philosophy and approach in defining its program areas and responsibilities.

General Statement

To deal successfully with the emergence of water resource issues unique to the 21st century, transformation of our knowledge and understanding of water for the protection, conservation, and management of water resources is imperative. Radically innovative approaches involving our best scientific knowledge, extensive spatial databases, and "intelligent" tools that visualize wise resource management and conservation in a single holistic system are likewise imperative.

Finally, holistic system analysis and understanding requires a strong and integrated multi-disciplinary framework

Research Program

The management of water resources, appropriate policies, and data acquisition and modeling continue to be at the forefront of the State Legislatures agenda and numerous environmental and agricultural organizations. Our contribution to informing the debate involved numerous meetings, personal discussions, and most importantly, the enhancement of web-based information to aid in the informed decision-making process.

Unique Capabilities: Decision Support Systems as the Nexus

IWR, with its "extended research family," is exceptionally well-positioned to integrate research conducted within each of the three principal water research domains: hydrologic sciences, water resources, and aquatic ecosystems. Integrated decision support both reflects and forms the nexus of these three research domains. Expanding web accessibility to the decision support system nexus (formed by the intersection of the three research domains) will facilitate broad distribution of science-based research produced in these domains.

The Institute's extensive experience in regional and national networking provides exceptional opportunities for assembling multi-agency funding to support interdisciplinary water research projects and multi-university partnerships.

Using A Multi-Disciplinary Framework

Using a multi-disciplinary framework facilitates dynamic applications of information to create geospatial, place-based strategies, including watershed management tools, to optimize economic benefits and assure long-term sustainability of valuable water resources. New information technologies including GIS and computational analysis, enhanced human/machine interfaces that drive better information distribution, and access to extensive real-time environmental datasets make a new "intelligent reality" possible.

Effective watershed management requires integration of theory, data, simulation models, and expert judgment to solve practical problems. Geospatial decision support systems meet these requirements with the capacity to assess and present information geographically, or spatially, through an interface with a geographic information system (GIS). Through the integration of databases, simulation models, and user interfaces, these systems are designed to assist decision makers in evaluating the economic and environmental impacts of various watershed management alternatives.

The ultimate goal of these new imperatives is to secure and protect the future of water quality and supplies in the Great Lakes Basin and across the country and the world—with management strategies based on an understanding of the uniqueness of each watershed.

Project Number: 2006MI69B

Start: 03/01/06(actual)

End: 02/28/07 (actual)

Title: Natural Resources Integrated Information System

Investigators: Jon F. Bartholic, Institute of Water Research, Michigan State University

Focus Categories: M & P, WQL, MOD

Congressional District: eighth

Descriptors: Data Analysis, Data Storage and Retrieval, Information Dissemination, System Analysis, Geographic Information Systems, Water Quality Management, Watershed Management

Areas of Relevant Research

The management of water resources, appropriate policies, and data acquisition and modeling continue to be at the forefront of the State Legislature's agenda and numerous environmental and agricultural organizations. Our contribution to informing the debate involved numerous meetings, personal discussions, and most importantly, the enhancement of web-based information to aid in the informed decision-making process.

Results and Benefits

Extensive investigation and research is needed to achieve effective coupling of human management needs with geospatial databases and decision support systems to assist better decision-making. Multiple research funding opportunities exist to support linking understanding of various phases of the hydrologic cycle with impacts on water use, management, and conservation. As a result, outstanding opportunities to develop scientific water management skills and techniques for the 21st Century are clearly within reach.

Development of geospatial decision support systems complement and build on the extensive scientific knowledge of the role of the hydrologic balance in the functioning of dynamic ecosystems. Based on current development of geospatial databases and modeling systems, a model of the hydrologic balance for the state can be developed to assist water management and conservation. By incorporating extensive geospatial data with the analytical capacity of decision support systems, university researchers are providing decision-makers and managers with a more refined understanding of the hydrologic cycle and water balance functions at watershed and statewide scales.

Our USGS investments over the past two years led to a two-year $540,000 grant from the Great Lakes Protection Fund awarded to Michigan State University and the Institute of Water Research (IWR) for a project entitled "Restoring Great Lakes Basin Waters Through the Use of Conservation Credits and an Integrated Water Balance Analysis System." The IWR is responsible for coordinating and collaborating multidisciplinary teams from various organizations including the World Resources Institute, Institute for Fisheries Research of the Michigan Department of Natural Resources, Public Sector Consultants of Lansing, US Geological Survey District Office, and MSU Departments of Agricultural Economics,

Biosystems and Agricultural Engineering; Geography, Civil and Environmental Engineering; and the Community, Agriculture, Recreation and Resource Studies (CARRS). The website for this just completed grant is: http://www.iwr.msu.edu/research/projects.html

Water Withdrawal Assessment Tool

In addition to a significant role in developing the assessment tool, we anticipate a major role in using the results of our project for application in a new water use conflict resolution process. Those seeking permits for large quantity withdrawals are encouraged by the new legislation to establish a Water User Committee for that permit to evaluate current water resources, water uses, and trends in water use in the watershed and assist in long-term water resource planning in the watershed. Water User Committees will include all water withdrawal registrants, water withdrawal permit holders, and local government officials in the watershed. Solutions to water use conflicts developed by these committees could include water conservation offset credit as pioneered by this project. While this committee process is not required, it will certainly behoove any permit seeker to follow this process in light of Michigan's recent history with time-consuming court cases and formidable public opposition to large water withdrawals.

The new legislation also calls for the state Department of Environmental Quality (DEQ) to use "clear and convincing scientific evidence" in determining whether adverse resource impacts "are, or are likely, to occur from one or more large-quantity withdrawals in the watershed." The DEQ will be responsible for notifying the watershed Water Users Committee or meeting with water use registrants and water withdrawal permit holders to attempt facilitation of an agreement for using voluntary measures to prevent adverse resource impacts.

We anticipate that the findings regarding our voluntary, water conservation offset credit approach may be directly applied to create a science-supported scheme that accommodates all water users and avoids costly, time-consuming legal conflicts and divisive dissatisfaction in the community. By integrating our data into a readily-usable and web-accessible system for Water User Committees, timely and valuable information will be delivered to those who need it most. Future opportunities appear abundant for assisting the local watershed conflict resolution process and for creating viable options, including offsets and conservation credits, to prevent adverse resource impacts. These scenarios will be supported by science-based research supported by the GLPF.

The bottom line shows a unique convergence of our NIWR/USGS and the Great Lakes Protection Fund project with the implementation of recently-enacted state legislation and with the next phase of state policy making. As prescribed in recent legislation, a set of policy recommendations addressing the sustainability of groundwater will be submitted by the Groundwater Conservation Advisory Council (GCAC) July 1, 2007 and the GCAC process needs to be informed by hard science and knowledge of state water resources and watershed management. In addition, the Groundwater Conservation Advisory Council is responsible for guiding the overall implementation of the legislative mandates for related water policy development as well designing the water withdrawal assessment tool. As some members of our project Advisory Committee serve on the Groundwater Conservation Advisory Council, a robust linkage provides an important mechanism for the Institute's role in developing the assessment tool and assisting in conflict resolution processes. *See report 2006MI114S Grant No. 07HQGR0003 Developing the Water Withdrawal Assessment Tool.*

Figure 1. Nation-Wide Digital Watershed http://www.iwr.msu.edu/dw

Web-based Offerings

Our web-based offerings continue to expand. A Nation-Wide Digital Watershed web site (Figure 1) has been developed to allow individuals from across the United States locate themselves by using their address, watershed, or by regional areas established by the EPA. The illustration shows the software developed in the IWR that can be applied to a national situation. The data used in the system was acquired from EPA Basin data via the web. The site for Michigan allows users to zero-in on the eight-digit watersheds and then down to the 12-digit watershed system known as "Know Your Watershed."

USDA Awards $600,000 Conservation Innovation Grant to Michigan Department of Agriculture for MSU Institute of Water Research Project (CIG-MDA)

The Institute of Water Research at Michigan State University and the Michigan Department of Agriculture (MDA) have teamed up to land a $600,000 Conservation Innovation Grant (CIG) to improve and protect water quality in three state watersheds.

The grant, awarded by the USDA Natural Resources Conservation Service (NRCS), funds implementation of the Institute's new GIS-based High-Impact Targeting (HIT) program in three Michigan watersheds. NRCS funds will be distributed by the MDA as incentives to qualified farmers for supporting the implementation of conservation best management practices (BMPs).

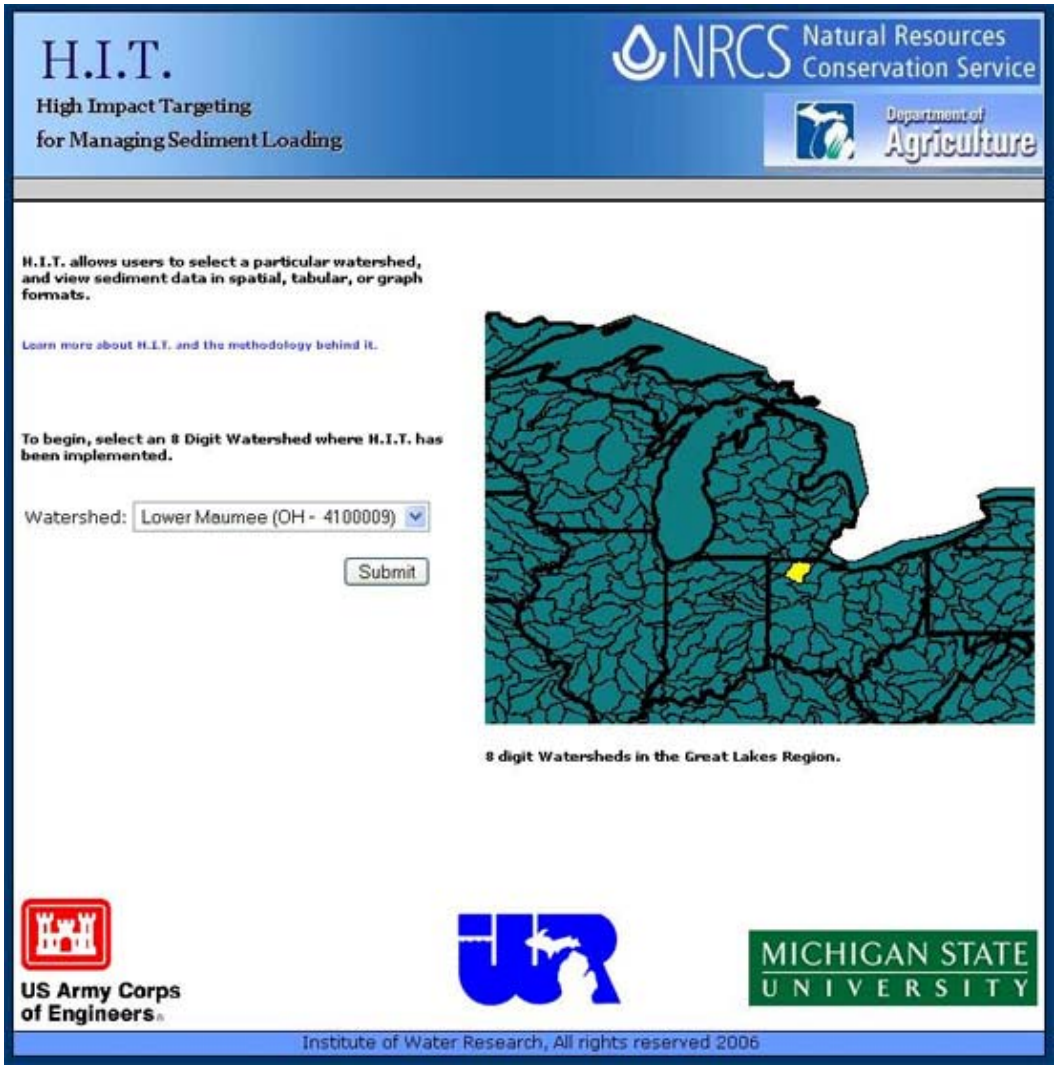


Figure 2. Conservation Innovation Grant (CIG). http://www.iwr.msu.edu/CIG-MDA/

"The HIT program (Figure 2) will help protect water quality in rural areas through the targeted application of appropriate conservation BMPs," said Jon Bartholic, director of the Institute of Water Research.

The Institute will work closely with MDA and soil conservation district staff to implement the HIT approach in three watersheds: the Maple River, Saginaw Bay, and the River Raisin. The HIT program complements the USDA-funded Conservation Reserve Enhancement Program and Conservation Security Program implemented by the MDA in those watersheds.

The HIT program targets installation of conservation BMPs on high-risk erosion areas with the greatest potential to contribute sedimentation and associated loadings to state waterways. The Institute has developed this new technology with Geographic Information Systems (GIS) capacity to increase the efficiency of federal and state conservation programs delivery.

"The CIG is a wonderful opportunity that will allow farmers and landowners to improve water quality, prevent soil erosion, and enhance wildlife habitat through a targeted approach," said Mitch Irwin, MDA Director.

“Michigan’s conservation districts will benefit from using this new technology to target their conservation work to areas in critical watersheds to greatly improve water quality and wildlife habitat,” said Gordon Wenk, MDA Environmental Stewardship Division director.

“We’re enthusiastic about this collaborative project, which builds on our long and successful relationship with the Michigan Department of Agriculture,” Bartholic said. “We look forward to using our research and outreach capacity in cooperation with the MDA to deliver this new HIT technology in watersheds where it can best be used to improve water quality and prevent soil erosion.”

The project team is made up of the NRCS, the USDA’s Farm Services Agency, the Michigan Departments of Environmental Quality, Natural Resources, and Agriculture as well as the MSU Institute of Water Research and Huron, Lenawee, and Clinton County soil conservation districts. Visit: http://www.iwr.msu.edu/CIG-MDA/ for more information.

Figure 3. Comprehensive Assessment Tool (Watershed CAT)

Watershed Comprehensive Assessment Tool (Watershed CAT)

The need for accurate geospatial data to develop effective watershed management plans has been well known to watershed managers, environmental government agencies and non-governmental organizations (NGOs) that specialize in restoring or maintaining the quality of water resources. Many online data sources offer web-services that freely distribute these data. However, it is difficult for a user to access, view and analyze watershed-scale, geospatial data without extensive GIS capabilities, even though it is a vital step to identify critical areas or pollution sources in a watershed. The Watershed Comprehensive Assessment Tool (Watershed CAT) Figure 3 fills this

gap in watershed management by assembling a variety of data layers into one data viewer and coupling the viewer with a number of web-based tools. This allows users to analyze watershed data more efficiently and with more detail, and ultimately leads to developing highly effective management plans.

The primary objective of this project is to develop an online system to house a data viewer, data analysis tools and decision support tools. Using the primary data viewer (Digital Watershed), data layers from a variety of sources can be assimilated together to observe physical and hydrological spatial trends within the watershed. Using the numerous analytical tools, such as Analytical Tools Interface for Landscape Assessment (ATtILA), Regional Vulnerability Assessment (ReVA), Online access to Long-Term Hydrologic Impact Assessment (L-THIA) and the High Impact Targeting (HIT) system contained in the Watershed CAT, users will be able to identify landscape stressors, calculate the amount of impervious surfaces, identify areas of high erosion, etc. Finally, using decision support tools provided by the Watershed CAT, users will be able to compare and the cost effectiveness of numerous sediment erosion management practices.

The U.S. Environmental Protection Agency (EPA) has developed an extensive manual documenting the watershed management plan process, and is commonly referred to as the EPA Watershed Handbook. This guide highlights every step in the process of developing a watershed management plan, and many of those steps require substantial data collection and analysis. Many of these data-intensive steps are also necessary to be completed in order for the plan to be considered for funding under section 319 of the Clean Water Act. These requirements include creating a watershed data inventory, identifying causes of impairment and pollutant sources, and descriptions of the non-point source management measures to be taken to reduce pollutant loadings. The Watershed CAT system will provide a large majority of data necessary for the inventory, as well as several modeling options that can facilitate the completion of these funding requirements by watershed organizations.

Local watershed management forms the basis for continued economic development and environmental improvement in the United States. Success depends on an integrated approach that brings together scientific, education and training advances made across many individual disciplines and modified to fit the needs of the individuals and groups, who must write, implement, evaluate, and adjust their watershed management plans.

New and Future Development for Digital Watershed

As a key technical component of Midwest Spatial Decision Support System Partnership, the Institute of Water Research's Digital Watershed (DW) website has been recognized by EPA Office of Research and Development as an important environmental computing portal for a suite of EPA's environmental decision support tools. Funding is underway to support the future development of DW to achieve this goal. The first step is to integrate EPA's ATtILA (Analytical Tools Interface for Landscape Assessments) tool into DW and provide watershed comparison function at 8-digit watershed level. This work will lay a solid foundation for the integration of other EPA decision support tools such as Regional Vulnerability Assessment Program's EDT (Environmental Decision Toolkit).

The Institute of Water Research was also awarded a grant by the US Army Corps of Engineers Chicago District to create a tool that integrates a GIS-based sediment runoff predictive tool, MUSLE (Modified Universal Soil Loss Equation), into Digital Watershed (DW) and the Long-

Term Hydrologic Impact Assessment (L-THIA) system and its associated EQIP tools. The resulting modeling and decision support tool will be easily accessed and used by a wide variety of expertise levels in determining the effects of development and different agricultural practices to the sediment loadings within two tributaries to Lake Michigan in Northwest Indiana; Burns Ditch/Little Calumet East Branch and Trail Creek. We've recently completed EQIP and the preliminary MUSLE integration on the project. In the near future, users will be able to model different BMP scenarios using this online tool.

Another new function that's already up and operational on Digital Watershed is the Google Map and Google Earth interoperability capability. Users can explore their own watersheds on Google Maps or Google Earth by simply click a button on Digital Watershed interface. We've received a lot of positive feedbacks on this new development.

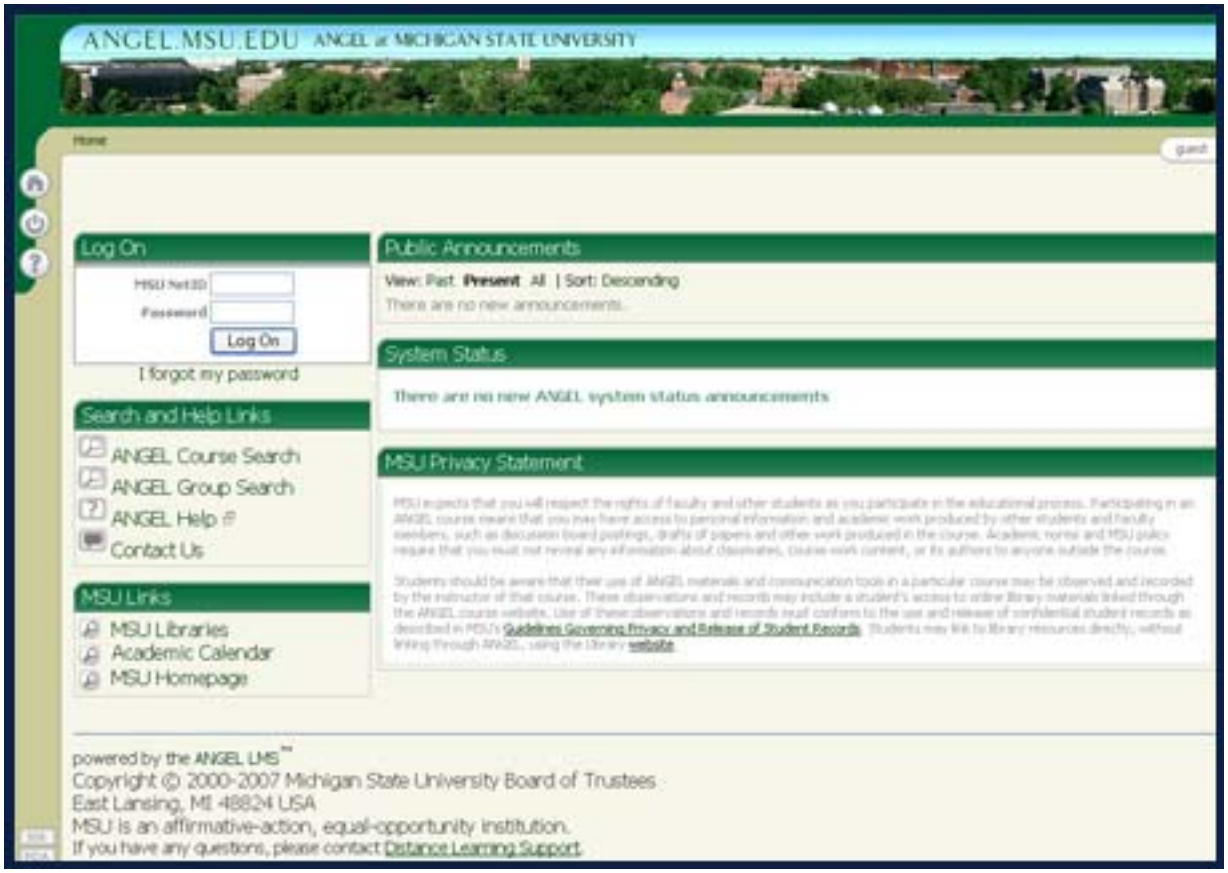


Figure 4. Virtual Watershed Management Courses

Virtual Watershed Management Courses

The web-available Mapping is used extensively in IWRs Virtual Watershed Management courses (Figure 4). This past year we offered all four 3-credit modules of Watershed Management each semester in the series for Certification. There are now over 120 students registered per year in these courses.

Related Research

We continue to obtain synergistic impacts by closely aligning our efforts with support from such organizations as the Corps of Engineers, USDA, US Forest Service and numerous other agencies and NGO's. This past year we received a grant from the Corps of Engineers for $75,000 which involves estimating sediment delivery from each of the eight-digit watersheds within the entire U.S. side of the Great Lakes Basin. This database is not only of value to the Corps in prioritizing their efforts but also provides us with a broad set of additional information that we can use in other programs, and for assisting with the prioritization of high risk areas for erosion throughout the region. USDA funds involve a coordinating effort of outreach and research among all states within the EPA Region V. IWR personnel are partially funded through this regional project which coordinates and facilitates the communication of research methodologies, approaches, and results from our research and aides with region-wide outreach programming.

Training Potential

New graduates and graduate training continue to be a high priority of IWR. Unfortunately, graduate stipends have increased to the extent that a 1/2 time graduate student with fringe benefits, requires from $35,000-$45,000 (per year). We will make every effort to continue incorporating graduate students but with the high cost, it is increasingly difficult to employ more than a few students at any given time. As part of our partnership philosophy, we have jointly supported numerous graduate students with other departments and units on campus.

Protecting Critical Trout Streams Via a Water Quantity Cap and Trade Scheme

Basic Information

Title:	Protecting Critical Trout Streams Via a Water Quantity Cap and Trade Scheme
Project Number:	2006MI71B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	8th
Research Category:	Social Sciences
Focus Category:	Economics, Water Use, Management and Planning
Descriptors:	
Principal Investigators:	Sandra Batie

Publication

FY 2006 USGS 104(B) Annual Technical Report

Project Number: 2006MI71B
FY 2006 Federal Funds: $15,000
FY 2006 Non-Federal Funds: $38,001
Start: 3/1/2006 (actual)
End: 2/28/2007 (actual)
Title: Protecting Critical Trout Streams Via a Water Quantity Cap and Trade Scheme
Project type: Research
Focus Categories: Economics, Water Use, Management and Policy
Research Category: Social Science
Congressional District: eighth
Key Words: water quantity, cap and trade, economic policy, offset credits, environmental mitigation, market driven water conservation

Principal Investigator: Sandra Batie, Dept. of Agricultural Economics, Michigan State University

Protecting Critical Trout Streams via a Water Quantity Cap and Trade Scheme

INTRODUCTION:

Our Great Lakes are the single largest source of freshwater on the planet with 21% of the world's surface freshwater supply. These magnificent 'sweet-water seas,' as they were called by their first European visitors, provide water to support the various uses of residents, agriculture, commercial businesses, industry, and plant, fish and aquatic wildlife. In spite of their vast size, the Great Lakes are vulnerable to a plethora of threats—invasive species, over use and depletion, pollution from point/non-point sources, poor and indiscriminate water and land use practices, and atmospheric deposition. Many regions outside the Great Lakes Basin are faced with or anticipate serious water shortages, and potentially look to Great Lakes waters to solve their water shortage problems. Contemplative and science-informed management has never been more important. Our goal was to design a W*ater Conservation Credit System* that sustains groundwater resources and related ecological functions while providing a flexible environment for the development and expansion of valuable economic enterprises.

RESEARCH PROGRAM

Project summary: We first established an *Advisory Committee* comprised of representatives from environmental and conservation groups; business/industry/utility; agricultural organizations; state planners; policy consultants; and citizens to help guide us in the development of the conservation credit and integrated water balance analysis systems. To obtain additional insights we surveyed ground water experts in 19 other riparian states about the successes of their revised regulations and the lessons that we could learn from them. We then developed a W*ater Balance Analysis System* based on integrating scientific knowledge of water resources and, using web-based models, to facilitate adoption of a water management system using market based water conservation

credits. Capitalizing on experiences from other parts of the country using credit trading and related mechanisms and instruments we developed a model water conservation credit system. The necessary conditions of a voluntary, cost-effective conservation "offset credit purchase program" were defined within an institutional context consistent with our knowledge of Great Lakes Basin policies and governance. This offset credit system can be used to "grow water", i.e., provide offsets for restoration of impaired watersheds to enhance flows and ecological functionality in critical areas. Development of this system required a solid foundation of hydrologic and ecological understanding of the impacts of withdrawals to quantify the appropriate values of conservation credits and corresponding values associated with specific conservation techniques.

The researchers integrated the results of a water balance analysis model (surface and groundwater models) into an ecological model (stream temperature and fish habitat models) to demonstrate the use of this integrated model results applied to a case study watershed and a hypothetical permitting process. Our researchers were able to evaluate the impacts of groundwater withdrawals on stream flow, water temperature, and fish habitat, and established criteria for setting threshold impacts on trout populations. In addition, we recommended conservation activities that could receive credit in the permitting requirements. The potential offset actions derived from the study model scenarios involve management and changes of land uses and characteristics (for example, alternate crop production or a change from impervious residential surface to forest growth or crop production). In addition, when various management actions are insufficient to reduce or offset flow impact, well locations can to be moved to areas further removed from streams to reduce negative impacts on trout populations and habitat. Our survey respondents suggested permitting fee structures that would allow for additional modeling to be done on a case by case basis to determine better locations without placing undue burden upon the state.

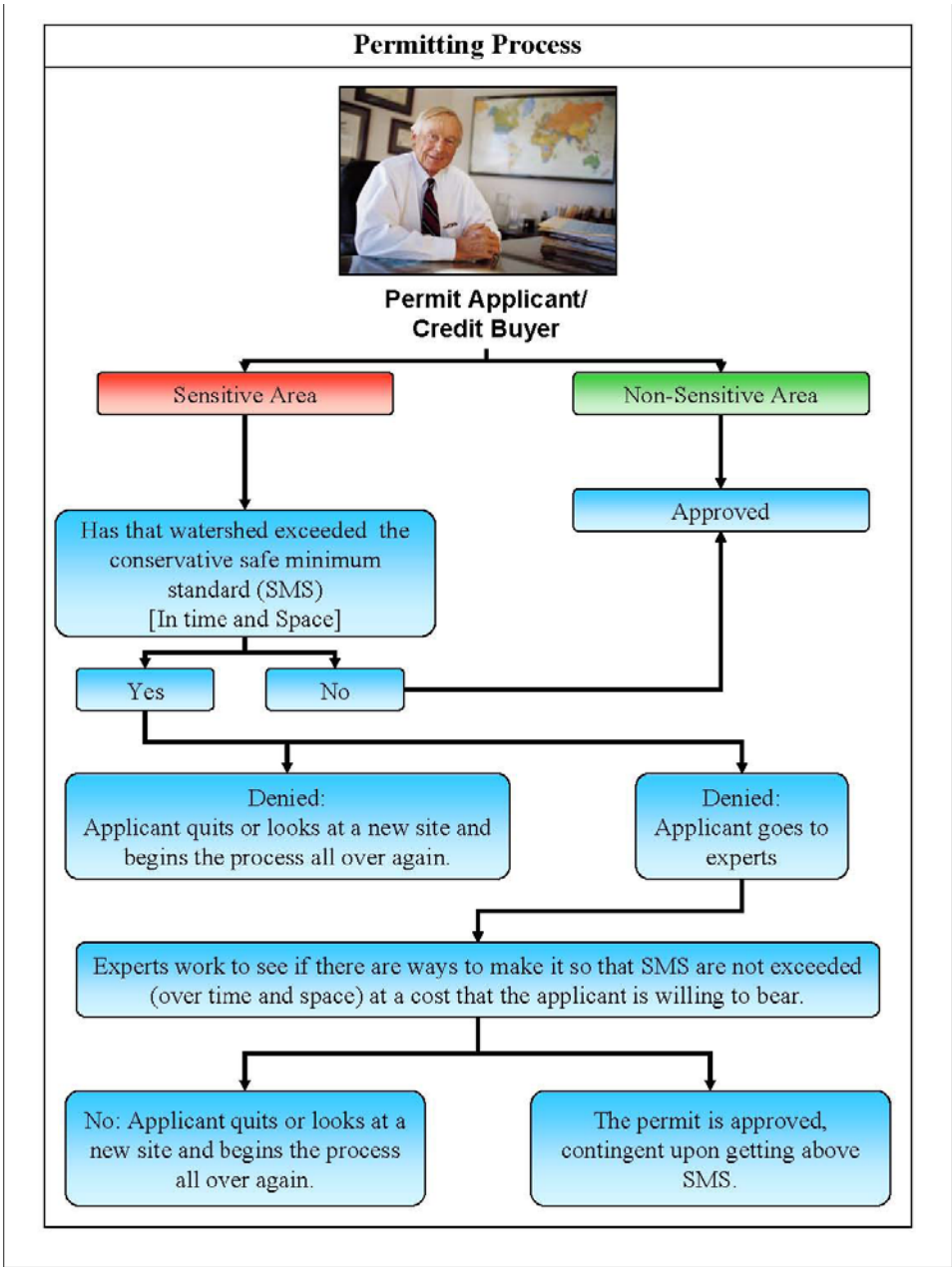
Development of this suite of models and analysis tools to produce a watershed balance analysis system was the cornerstone of the project. This water balance analysis system integrated modeling of the hydrologic partitioning of precipitation at the earth's surface, the static water table and horizontal flow to nearby streams, and the impacts on the affected aquatic ecosystem. Our work used a fishery model related to trout survival as a key component of an integrated assessment tool that was the basis for developing policy relevant economics that will be valuable for policy discussions. The pilot demonstration of a potential web-accessible user assistance interface shows promise as a way to lower transaction costs, and provide buyers and sellers with immediate access to geospatial information for simple and uncomplicated analysis of all the components of the conservation credit system and the water balance analysis system. The system was developed for statewide and Basin-wide application. System feasibility was demonstrated in a high-risk watershed for which extensive hydrologic data was available. A hypothetical market-based purchase of conservation credit offsets was demonstrated with a hypothetical case study of a proposed groundwater withdrawal. In our case study, a proposed new groundwater withdrawal that was expected to cause an adverse impact on the ecological functions of an adjacent trout stream was allowed to go forward by purchasing offset conservation credits from sellers in the watershed. We will continue to seek and take advantage of opportunities to apply project findings and provide the broadest possible dissemination of

this new knowledge and technology to support the sustainability of water resources across the Great Lakes Basin.

Problem and Research Objectives

Our goal was to provide an economic framework that uses the newly created surface and groundwater modules to demonstrate how a market-based trading system can assist in protecting critical watersheds as demonstrated in a real world case study of the Augusta Creek, Michigan, watershed. We achieved that goal. We created a water allocation framework (i.e. trading system) that can be applied throughout the state (and the nation) that protects the surface water conditions favorable for trout survival while minimizing the negative impacts on development and current water users.

The diagram below illustrates the process that we developed to implement our proposed water allocation framework.



Methodology

We began by reviewing existing literature while paying special attention to the following issues: mitigation and offsets, safe minimum standards, market based incentives, and necessary conditions for a working market. We then developed the criteria for critical watersheds based on SMS for trout as trout are an indicator species of water based ecosystem health. Some of our survey respondents emphasized the importance of defining a cap based on both time and location and using scientific models we did exactly that. We developed a table of potentially desirable outcomes and the recommended policies that would help achieve these outcomes. We suggested politically viable option(s) for the creation of a trading scheme and we developed a matrix of potential mitigations and offsets for the market. To make this unique case study useful to the entire state of Michigan, we outlined the necessary variables that must be measured for each watershed. We used a case study method focusing on the Augusta Creek watershed to demonstrate the applicability of our work.

Principal Findings

Our proposed policy includes the following characteristics:

1) The market-like policy functions only in sensitive watersheds or sub-watersheds where increased groundwater pumping may have negative impacts on the stated environmental policy objective. By remaining within a specific boundary, such as an environmentally critical sub-watershed, it simplifies the management of potentially adverse pumping activities and focuses scarce agency time and resources strictly on those areas viewed as sensitive and valuable.
2) We defined the environmental policy objective as preserving, restoring, and maintaining high-quality, unique and special cold water ecosystems suitable as trout habitat.
3) The hypothetical permit system, as applied to our case study, requires permit applicants in these sensitive watersheds to bear the costs of the permit scheme and the identification, design, and enforcement of any contracts to implement conservation credits purchased to offset the potential ecosystem damages from pumping. Thus, because these costs are borne by the applicants, those applicants who propose withdrawals with either low-value uses or do not have to locate their proposed wells in a sensitive watershed or sub-watershed have incentives to consider other less sensitive areas for locating their wells.
4) Allowances can be allocated at no cost (e.g. grandfathering) and/or by using an auction. In terms of environmental effectiveness, there is no appreciable difference between these two methods
5) Anyone pumping a significant amount of groundwater within the identified groundwater-shed boundaries must obtain a withdrawal permit. The significant level of pumping will be determined via groundwater modeling so that the minimum uses of water will not require permits. Although existing uses may be grandfathered, they still require a permit. As a result, all groundwater uses are recorded; total use of the groundwater in the sensitive watersheds or sub

watersheds are “capped” at a level that meets the environmental policy objective with due attention given to spatial and temporal variability. The permit, once obtained, will also be subject to periodic reviews at agreed to intervals such as every 5 years.

6) As designed for this hypothetical case study, the total number of allowances will not allow pumping of volumes that would exceed the ‘cap” (i.e., the amount that would have a negative impact on the policy objective), taking into account temporal and spatial variations. The impacts of pumping on trout habitat and populations can be predicted via groundwater and fish habitat and survival models.

7) The selection of appropriate actions for conservation credits will depend on the responsible agency's policy objective.

8) The allowances of groundwater available for pumping with any permit in a sensitive watershed are transferable to others, and thus holding a permit in a sensitive watershed or sub-watershed is the equivalent to holding a market asset that can be sold to others, subject to regulatory review. An applicant needing more groundwater pumping allowances than allowed in his or her proposed permit may obtain additional allowances by purchasing them from others—with regulatory oversight as well as with the recording of the sale.

9) Conservation credits are certified credits given by the state agency to those landowners who adopt practices or techniques that conserve or reduce groundwater use. These credits can be bought by a groundwater user to expand his or her pumping beyond the allowance indicated in the original permit. If so used, these credits will be incorporated into the applicant’s permit. Offset credits can be environmental suspect if not monitored and assessed well. The offsets need to result in equivalent improvements in either water quality and/or temperature to what would have occurred with a reduction in pumping by the permit applicant. There needs to be adequate baseline accounting for those holding permits that wish to sell those or reduce their permit to provide an offset credit for sale. While this requirement involves a regulatory oversight, the costs of such oversight can be paid by the applicant. For this research, the researchers assumed that the applicant will bear these costs and must enlist third parties to conduct such monitoring, albeit overseen by the regulatory agency.

10) Liability issues—who holds liability and how liability is determined—often pose significant challenges to the implementation of environmental trading programs. Liability for credit malfeasance could potentially rest with either the credit buyer or the seller. This case study assumes that the buyer bears liability and must bear the costs of assuring that permit requirements are met. This placement of liability thus discourages location of high volume wells in sensitive watersheds.

11) Because the use of conservation credits (and the changes in activities that they represent) may have various levels of uncertainty associated with them as to how much their implementation will ameliorate potential damages from increases in groundwater pumping, there may be requirements in a permit that sufficient

credits must be purchased to cover more than 100 percent of potential damages. For example, an applicant may have to purchase sufficient conservation credits and/or permits to account for 120% of the potential damages as predicted by expert modelers. The extra quantity, called the "trading ratio" can be changed if real monitoring data is acquired and the certainty of the credits can be verified. The verification of the efficacy of the applicant's proposed offsets or allowance transfers would be the responsibility of the applicant, but with third party verification by an agency. This "trading ratio" is a strategy often employed in water quality trading markets to overcome uncertainty associated with nutrient reduction from best management practices as well as to provide a net water quality benefit.

12) The buying and selling of allowances and conservation credits will be overseen and facilitated by an agency or certified broker. Third party verification of the use of permits will be required. Modeling and analysis by experts of the impacts of proposed activities and of use of permits will be required of and paid for by the applicant.

Significance for Project

Utilizing advice supplied by both our advisory committee and our survey respondents we explored a hypothetical groundwater withdrawal permit system supplemented with the use of conservation credits--and illustrated this approach with our case study. This type of a market-like structure, particularly when compared with outright prohibitions or restricted use regulations, affords significant advantages. If this program approach is well designed and effectively enforced, this market-like structure discourages low- value uses of groundwater in sensitive watersheds and sub-watersheds when there are competing needs for the use of the groundwater resources. At the same time, this market-like structure allows for new or expanded high-value uses which require location in a critical area; and compensates those groundwater users who reduce their groundwater withdrawals to offset a new or expanded use. This type of market-like structure can be cost-effective in achieving the objective of protecting the natural resources (e.g., trout populations) provided that administrative and enforcement costs are not excessive.

Publication citations associated with the research project

USGS is acknowledged in the credits of the GLPF final report available at:
http://www.hydra.iwr.msu.edu/iwr/glpf/FinalPublic/GLPF-Final%20Report.asp

NOTABLE AWARDS AND ACHIEVEMENTS.

Funding from USGS (2006-104b) has supported a graduate student's, Mariah Branch, efforts. Her accomplishments during the funding period will be presented at the AAEA 2007 Annual Conference in July 2007.

PUBLICATIONS FROM PRIOR PROJECTS

NONE

Exploring the Legal Landscape of Michigan's Groundwater

Basic Information

Title:	Exploring the Legal Landscape of Michigan's Groundwater
Project Number:	2006MI72B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	8th
Research Category:	Social Sciences
Focus Category:	Law, Institutions, and Policy, Water Use, Management and Planning
Descriptors:	Water Use, Groundwater Regulations, Riparian Rights, Legal Landscape
Principal Investigators:	Michael D Kaplowitz

Publication

FY 2006 USGS 104(B) Annual Technical Report

Project Number: 2006MI72B
FY 2006 Federal Funds: $10,000
FY 2006 Non-Federal Funds: $21,256
Start: 3/1/2006 (actual)
End: 2/28/2007 (actual)
Proposal Title: Exploring the Legal Landscape of Michigan's Groundwater
Project type: Research
Focus Categories: Law Institutions, and Policy, Water Use, Management and Planning
Research Category: Social Science
Congressional District: eighth
Key Words: Water Use, Groundwater Regulations, Riparian Rights, Legal Landscape

Principal Investigator:
Michael D. Kaplowitz, J.D., Ph.D. Michigan State University

* The NIWR report headings did not fit for the laws of Michigan

Groundwater Law and Regulated Riparianism

INTRODUCTION

In the United States, Groundwater Law arose separately from the law governing surface water withdrawal, whether riparian doctrine or prior appropriation. Now we have a much better understanding of hydrology and geology and that groundwater and surface water are often inextricably linked, to the point that withdrawal of water from the ground often results in a direct reduction of water from the surface, and vice versa[1]. However, until the beginning of the mid- 1800s with the emergence of Darcy's Law,[2] groundwater movement was not understood to be connected to surface water flow in any predictable way, and was deemed to be so "secret, occult and concealed, that an attempt to administer any set of legal rules in respect to [it] would be involved in hopeless uncertainty, and would be, therefore, practically impossible."[3] Therefore, the Rule of Capture (also known as the English Rule or the Absolute Ownership Rule[4]) was the first common law of groundwater, and was first articulated in the British 1843 case of *Acton v. Blundell*[5],

[1] *See* Mich. Citizens for Water Conservation v. Nestle Waters N. Am., Inc., 709 N.W.2d 174, 190 (Mich. Ct. App. 2005) (finding that groundwater pumping of 400 gpm (gallons per minute) reduced the flow of a nearby stream by 345 gallons per minute).
[2] See H. Darcy, Les Fontaines Publiques de la Ville de Dijon, Dalmont, Paris (1856) and Stauffer, Philip H. (2006). "Flux Flummoxed: A Proposal for Consistent Usage". *Ground Water* **44** (2): 125–128. DOI:10.1111/j.1745-6584.2006.00197.
[3] Frazier v. Brown, 12 Ohio St. 294, 311 (Ohio 1861).
[4] *See* James N. Christman, *Riparian Doctrine, in* WATER RIGHTS OF THE EASTERN UNITED STATES 21, 30 (Kenneth R. Wright, ed., 1998).
[5] (1843) 152 Eng. Rep. 1223 (Ex. Ch.).

which stated that a landowner can pump any amount groundwater from her property, even if an adjoining landowner is harmed[6].

RESEARCH PROGRAM

a. Project summary

Today, we have a better understanding of groundwater flow and its effects on surface water can often be understood. Most state courts have overturned the Rule of Capture[7], although a few still apply it[8]. Those states that no longer apply the Rule of Capture apply Prior Appropriation[9] (an analogous rule to the surface water rule of Prior Appropriation), Reasonable Use[10] (a perhaps misleading name, this rule for groundwater is much like the Rule of Capture for on-track uses of water, however, off-track uses are deemed not reasonable and can be enjoined by on-track users), Correlative Rights[11] (a doctrine for groundwater which arose in California and is like the Reasonable Use doctrine for surface water; and includes the limitation that off-tract uses are not reasonable); or the Restatement approach,[12] (that uses a reasonableness balancing test for both on-tract and off-tract uses of groundwater).

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[6] *Id*. at 1235.

[7] *See, e.g.*, State v. Michels Pipeline Constr., Inc., 217 N.W.2d 339, 348 (Wis. 1974) (overruling previous decisions which upheld the absolute Rule of Capture, and creating a rule of reasonable use for Wisconsin); Cline v. American Aggregates Corp., 474 N.E.2d 324, 327 (Ohio 1984) (overruling the prior common law of the Rule of Capture and instead adopting the Restatement (Second) of Torts § 858 as the law of Ohio).

[8] *See, e.g.*, Sipriano v. Great Spring Waters of Am., Inc., 1 S.W.3d 75, 76 (Tex. 1999) (upholding the Rule of Capture for Texas on the ground that any change should come from the legislature); Maddocks v. Giles, 728 A.2d 150, 152 (Me. 1999) (upholding the Rule of Capture for Maine using the premise that groundwater "is the absolute property of the owner of the land, just like the rocks and soil that compose it").

[9] *See, e.g.*, Chatfield East Well Co. v. Chatfield East Prop. Owners Ass'n, 956 P.2d 1260, 1268 (Colo. 1998)

[10] *See* Martin v. City of Linden, 667 So. 2d 732, 738-39 (Ala. 1995) (finding that a city's pumping of water away from the land from which it pumped was unreasonable); Mich. Citizens for Water Conservation v. Nestle Waters N. Am., Inc., 709 N.W.2d 174, 197 (Mich. Ct. App. 2005) (explaining the different common-law doctrines for groundwater withdrawal).

[11] *See, e.g.*, Los Osos Valley Associates v. City of San Luis Obispo, 36 Cal. Rptr. 2d 758, 762 (Cal. Ct. App. 1994) (explaining that "[u]nder the 'correlative rights doctrine,' as between the owners of land overlying strata of percolating waters, the rights of each to the water are limited, in correlation with those of others, to his 'reasonable use' thereof when the water is insufficient to meet the needs of all") (citations omitted).

[12] *See, e.g.*, Cline v. American Aggregates Corp., 474 N.E.2d 324, 327 (Ohio 1984). The Restatement (Second) of Torts § 858, entitled "Liability for Use of Ground Water" reads:

> (1) A proprietor of land or his grantee who withdraws ground water from the land and uses it for a beneficial purpose is not subject to liability for interference with the use of water by another, unless (a) the withdrawal of ground water unreasonably causes harm to a proprietor of neighboring land through lowering the water table or reducing artesian pressure, (b) the withdrawal of ground water exceeds the proprietor's reasonable share of the annual supply or total store of ground water, or (c) the withdrawal of the ground water has a direct and substantial effect upon a watercourse or lake and unreasonably causes harm to a person entitled to the use of

Problem and Research Objectives

Michigan historically used the reasonable use Riparian Rights rule for surface water withdrawals, whereby each riparian owner's reasonable use is balanced against other riparian owners' reasonable uses.[13] While Michigan law regarding surface water use has been relatively straightforward and stable, the law regarding groundwater use has evolved with different court cases. The leading groundwater withdrawal case in Michigan was the 1917 case of *Schenk v. City of Ann Arbor*[14], where the court declared that the rule of Reasonable Use for groundwater applied in Michigan; under this rule, groundwater withdrawals for use not connected with the land were permitted, but only to the extent that they did not interfere with an adjacent user's reasonable on-tract use[15], while groundwater withdrawals for use connected with the land were absolutely permitted, even if it harmed a neighbor's use.[16] However, later on the courts changed this rule to a rule which balanced two on-tract uses of groundwater against each other, instead of the prior rule which would have allowed each use absolutely.[17] Most recently, the Court of Appeals of Michigan has adopted a "reasonable use balancing test" to determine disputes between riparian and groundwater users, and to determine whether all uses of water, whether surface water or groundwater, are reasonable.[18] Perhaps in part as a reaction to this case, in order to avoid the future litigation and associated costs involved in finding out what a "reasonable use" is for a water withdrawer, the legislature of Michigan passed in 2006 a new law which implemented a Regulated Riparian system for Michigan.[19] Under this new system, no new withdrawals of over 100,000 gallons per day which have

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its water. (2) The determination of liability under clauses (a), (b) and (c) of Subsection (1) is governed by the principles stated in §§ 850 to 857.

RESTATEMENT (SECOND) OF TORTS § 858 (1979). The principles stated in §§ 850 to 857 are the Restatement's reasonable use rules for surface water.

[13] *See* Dumont v. Kellogg, 29 Mich. 420, 423-24 (Mich. 1874) ("as between different proprietors on the same stream, the right of each qualifies that of the other, and the question . . . [is] whether under all the circumstances of the case the use of the water by one is reasonable and consistent with a correspondent enjoyment of right by the other").

[14] 163 N.W. 109 (Mich. 1917) (city does not have a right to pump water off the land it owns if to do so will materially injure neighbors in their reasonable use of the water).

[15] *Id*. at 112.

[16] *Id*.; *see also* discussion above on the Reasonable Use rule for groundwater.

[17] *See* Hart v. D'Agostini, 151 N.W.2d 826, 828 (Mich. Ct. App. 1967) (withdrawing water in order to sink a sewer line is not an unreasonable use of water such that damages must be paid to the neighbor harmed by the use); Maerz v. United States Steel Corp., 323 N.W.2d 524, 530 (Mich. Ct. App. 1982) (adopting the Restatement approach for the resolution of groundwater withdrawal conflicts (*see* groundwater withdrawal law discussion above for description of the Restatement approach)).

[18] *See* Mich. Citizens for Water Conservation v. Nestle Waters N. Am., Inc., 709 N.W.2d 174, 201 (Mich. Ct. App. 2005) (bottled water company permitted to pump 200 gallons per minute until the trial court works out how much pumping should be allowed under the reasonable use doctrine to reasonably protect the plaintiff's riparian rights in enjoying a stream). Under this reasonable use balancing test, all uses of surface water and groundwater are balanced against each other, considering the factors of "(1) the purpose of the use, (2) the suitability of the use to the location, (3) the extent and amount of the harm, (4) the benefits of the use, (5) the necessity of the amount and manner of the water use, and (6) any other factor that may bear on the reasonableness of the use." *Id*. at 203. Additionally, natural uses are preferred over artificial uses, and uses on the land are preferred over uses that "ship the water away." *Id*. at 204.

[19] *See* S.B. 0850 (Mich. 2006) available at http://www.legislature.mi.gov/documents/2005-2006/billconcurred/Senate/pdf/2005-SCB-0850.pdf.

an adverse impact on designated trout streams are permitted,[20] and new withdrawals of over a certain amount are required to obtain a permit[21]. (Note, this language suggests that existing uses are exempted from permit requirements.) Additionally, more study was mandated by the legislature so that the state could achieve ways of preventing "adverse resource impacts" by water withdrawals.[22]

Methodology

While many landowners believe that their right to the groundwater below the surface of their land belongs to them individually and absolutely, subject to no limitations, this view is based upon outdated and now invalid law. Today, an individual's right to groundwater in Michigan is considered an *exclusive right*, as opposed to an *absolute right*. An absolute right would be the absolute unlimited right to any and all groundwater under one's land. An exclusive right, in contrast, is less then an unlimited right but only subject to certain limitations set by the government. The holder of an exclusive right still has priority over any other individual to the groundwater under his land. A good example of an exclusive right would be that you may be the only one with the legal right to build a structure upon your land; however, you may be required by the local, state, or federal government to get a permit to do so.

Principal Findings

Like surfacewater riparian users, groundwater users do not have a personal ownership (or absolute) right in the water flowing underneath their land. However, unlike surfacewater riparian users who are subject to reasonable use, the users of Michigan's groundwater have an exclusive right in the water flowing underground and do not follow a reasonable use standard, but instead follow a reasonable use balancing test standard *similar to* the rule stated in the Restatement (Second) of Torts, section 858 (section 858 has *not* been explicitly adopted by Michigan).[23]

> "(1) A proprietor of land or his grantee who withdraws ground water from the land and uses it for a beneficial purpose is not subject to liability for interference with the use of water by another, unless

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[20] *See* MICH. COMP. LAWS §§ 324.32701, 324.32721 (2006) (no person may make a new large quantity withdrawal which has an "adverse resource impact on a designated trout stream," and in two years no new withdrawal which has an "adverse resource impact" will be allowed).

[21] A permit must be issued to a person with the capacity to withdraw more than 2,000,000 gallons of water per day from the waters of the state, other than the Great Lakes and their connecting waterways, or, a person who has the capacity to make a new withdrawal of more than 5,000,000 gallons of water per day from the Great Lakes and their connecting waterways. MICH. COMP. LAWS § 324.32723 (2006).

[22] *See* MICH. COMP. LAWS § 324.32803 (2006).

[23] Maerz v. United States Steele Corp., 116 Mich. App. 710, 720, 323 N.W.2d 524, 530 (Mich. Ct. App. 1982) and Michigan Citizens for Water Conservation v. Nestle Waters North America Inc., 269 Mich. App. 25, 53, 709 N.W.2d 174, 194 (Mich. Ct. App. 2005).

(a) the withdrawal of ground water unreasonably causes harm to a proprietor of neighboring land through lowering the water table or reducing artesian pressure,

(b) the withdrawal of ground water exceeds the proprietor's reasonable share of the annual supply or total store of ground water."[24]

For disputes between groundwater users utilizing the same underground water source, M.C.L. § 600.2941(1) addresses *groundwater waste* and states that if the water of a groundwater well is "unnecessarily allowed to run to *waste* in an unreasonable manner to the depletion or lowering of the head or reservoir thereof to the detriment or damage of other wells supplied from the same head or reservoir, is a nuisance, and (the well) owner and the owner of the land on which it is situated are subject to all the actions for abatement and damages in favor of the person or persons injured, as provided by law for other nuisances or tortious acts" (*Italics added*).

M.C.L. § 600.2941(2) addresses *unreasonable* use of groundwater and states:

"[w]here any well is supplied by a head, reservoir, stratum, or vein or by percolating waters common to other springs or wells, and the owner thereof or his lessee or licensee puts its waters to a use *unreasonable or unnecessary* (even if the use is not wasteful), in view of the condition and situation of the land on which it is situated, and through such unreasonable or unnecessary use, lowers or depletes the head, pressure, or supply of water of any spring or well dependent on the same head, vein, or stratum, to the detriment or injury of the owner or any person entitled to the use thereof, the well so unreasonably and unnecessarily used, is a nuisance, and its owner and the owner of the land on which it is situated are subject to all the actions for abatement and damages in favor of the person or persons injured, as provided by law for other nuisances or tortious acts."

So, if one groundwater withdrawer's wasting or unreasonable use of withdrawn water causes any harm to a neighboring withdrawer, the one causing harm must correct those harms according to M.C.L. § 600.2941(3). By either reducing their own withdrawals to some practicable volume and/or adequately supplying the other user's water needs by (1) paying for the equipment and installation needed to get an adequate supply for the harmed user or (2) paying for another source of water to adequately supply the harmed user as stated in *Bernard v. City of St. Louis*. It is a possibility that a user causing harm to another user could perhaps avoid the costs of supplying an adequate supply of water to the harmed user by *leasing* the water rights, essentially paying the harmed user for their lost water (*purchasing* these rights are probably not an option since water rights in Michigan are connected to the land and generally cannot be separated from that land). Remember that the Michigan Legislature has begun to implement restrictions designed so as to ensure that (1) all legitimate users will have access to

[24] Restatement (Second) of Torts § 858 (1979)

enough water to fulfill their adequate needs and (2) Michigan's environment will not suffer adverse impacts due to unreasonable withdrawals.

Significance for Project

Today, we have a better understanding of groundwater flow and its effects on surface water can often be understood. Most state courts have overturned the Rule of Capture[25], although a few still apply it[26]. Those states that no longer apply the Rule of Capture apply Prior Appropriation[27] (an analogous rule to the surface water rule of Prior Appropriation), Reasonable Use[28] (a perhaps misleading name, this rule for groundwater is much like the Rule of Capture for on-track uses of water, however, off-track uses are deemed not reasonable and can be enjoined by on-track users), Correlative Rights[29] (a doctrine for groundwater which arose in California and is like the Reasonable Use doctrine for surface water; and includes the limitation that off-tract uses are not reasonable); or the Restatement approach,[30] (that uses a reasonableness balancing test for both on-tract and off-tract uses of groundwater).

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[25] *See, e.g.*, State v. Michels Pipeline Constr., Inc., 217 N.W.2d 339, 348 (Wis. 1974) (overruling previous decisions which upheld the absolute Rule of Capture, and creating a rule of reasonable use for Wisconsin); Cline v. American Aggregates Corp., 474 N.E.2d 324, 327 (Ohio 1984) (overruling the prior common law of the Rule of Capture and instead adopting the Restatement (Second) of Torts § 858 as the law of Ohio).

[26] *See, e.g.*, Sipriano v. Great Spring Waters of Am., Inc., 1 S.W.3d 75, 76 (Tex. 1999) (upholding the Rule of Capture for Texas on the ground that any change should come from the legislature); Maddocks v. Giles, 728 A.2d 150, 152 (Me. 1999) (upholding the Rule of Capture for Maine using the premise that groundwater "is the absolute property of the owner of the land, just like the rocks and soil that compose it").

[27] *See, e.g.*, Chatfield East Well Co. v. Chatfield East Prop. Owners Ass'n, 956 P.2d 1260, 1268 (Colo. 1998)

[28] *See* Martin v. City of Linden, 667 So. 2d 732, 738-39 (Ala. 1995) (finding that a city's pumping of water away from the land from which it pumped was unreasonable); Mich. Citizens for Water Conservation v. Nestle Waters N. Am., Inc., 709 N.W.2d 174, 197 (Mich. Ct. App. 2005) (explaining the different common-law doctrines for groundwater withdrawal).

[29] *See, e.g.*, Los Osos Valley Associates v. City of San Luis Obispo, 36 Cal. Rptr. 2d 758, 762 (Cal. Ct. App. 1994) (explaining that "[u]nder the 'correlative rights doctrine,' as between the owners of land overlying strata of percolating waters, the rights of each to the water are limited, in correlation with those of others, to his 'reasonable use' thereof when the water is insufficient to meet the needs of all") (citations omitted).

[30] *See, e.g.*, Cline v. American Aggregates Corp., 474 N.E.2d 324, 327 (Ohio 1984). The Restatement (Second) of Torts § 858, entitled "Liability for Use of Ground Water" reads:

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Publication citations associated with the research project

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163 N.W. 109 (Mich. 1917) (city does not have a right to pump water off the land it owns if to do so will materially injure neighbors in their reasonable use of the water).

Id. at 112.

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See Hart v. D'Agostini, 151 N.W.2d 826, 828 (Mich. Ct. App. 1967) (withdrawing water in order to sink a sewer line is not an unreasonable use of water such that damages must be paid to the neighbor harmed by the use); Maerz v. United States Steel Corp., 323 N.W.2d 524, 530 (Mich. Ct. App. 1982) (adopting the Restatement approach for the resolution of groundwater withdrawal conflicts (*see* groundwater withdrawal law discussion above for description of the Restatement approach)).

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See S.B. 0850 (Mich. 2006) available at http://www.legislature.mi.gov/documents/2005-2006/billconcurred/Senate/pdf/2005-SCB-0850.pdf.

See MICH. COMP. LAWS §§ 324.32701, 324.32721 (2006) (no person may make a new large quantity withdrawal which has an "adverse resource impact on a designated trout stream," and in two years no new withdrawal which has an "adverse resource impact" will be allowed).

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See MICH. COMP. LAWS § 324.32803 (2006).

Maerz v. United States Steele Corp., 116 Mich. App. 710, 720, 323 N.W.2d 524, 530 (Mich. Ct. App. 1982) and Michigan Citizens for Water Conservation v. Nestle Waters North America Inc., 269 Mich. App. 25, 53, 709 N.W.2d 174, 194 (Mich. Ct. App. 2005).

Restatement (Second) of Torts § 858 (1979)

NOTABLE AWARDS AND ACHIEVEMENTS.

Through this project endeavor utilizing the USGS 104(B) project number 2006MI72B, the Institute of Water Research was awarded a $540,000.00 grant from the Great Lakes Protection Fund to research "*Restoring Great Lakes Basin Water Through the use of Conservation Credits and Integrated Water Balance Analysis System*." Project Number 763.

PUBLICATIONS FROM PRIOR PROJECTS

Great Lakes Protection Fund Final Report. "Restoring Great Lakes Basin Water Through the Use of Conservation Credits and Integrated Water Balance Analysis System. Project Number 763. http://www.iwr.msu.edu/research/projects.html

Economic Implications of Restoring Aquatic Ecosystems of the Muskegon River watershed

Basic Information

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Project Number:	2006MI76B
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End Date:	2/28/2007
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Descriptors:	None
Principal Investigators:	R. Jan Stevenson, David Hyndman, Saichon Seedang

Publication

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Investigators: Saichon Seedang, R. Jan Stevenson, and David Hyndman, Michigan State University

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Congressional District: eighth

Descriptors: aquatic ecosystem restoration, economic information, ecosystem benefits, best management practices, ground water modeling, aquatic ecosystem modeling

INTRODUCTION

The impact of human land use activities, such as groundwater withdrawal and agricultural nutrient runoff, often results in stream flow reduction and water quality degradation, subsequently impacting the beneficial uses of aquatic species. Many research studies have emphasized an examination of the effects of these anthropogenic activities on aquatic ecosystem degradation, especially at the watershed scale. Increasingly, scientific information is emerging to assist decision makers' understanding of natural ecosystems, and the problems, causes and consequences of human activity on ecosystem heath. This information proves useful to a resource manager attempting to identify management strategies to restore ecosystems. However, when faced with budget or resource constraints, it becomes necessary to bring economic information (e.g., costs, benefits, efficient restoration/conservation tradeoff options) into the decision making process.

This technical report provides information on the estimated value of ecosystem services in the Muskegon Watershed, Michigan, specifically those values related to supporting aquatic ecosystem functions. This information is helpful when making decisions related to the tradeoff between conservation implementation and restoration investment in the Muskegon River watershed.

RESEARCH PROGRAM

Project summary

Benefit transfer (BT) methodology was used for estimating the values of ecosystem services for wetlands, lakes and rivers. We reviewed non-market value studies from over 100 peer-reviewed papers related to these ecosystem services. The publications ranged from 1970-2006. Our criteria for selecting potential publications that were transferable to our study site (Muskegon River Watershed, Michigan) were based on several criteria related to relevance of geographical and population area, valuation method, unit of measurement, and statistical estimated values. Wetland and water (lakes and rivers) ecosystem services were our main focus. It was found that of the over 100 peer-reviewed

papers, only 20 percent could be used for BT in our study site. Due to insufficient value studies to transfer, we were able to transfer the values for 3 types of services (aesthetics/amenity, nutrient cycling and waste assimilation and recreation) for wetlands, and only "recreation values" for river and lakes. We compare the estimated values for wetland to the wetland metadata analysis compiled by Woodward and Wui (2001), and found that our BT wetland values are compatible and lie at the lower bound of the values in metadata studies. For water ecosystem services, we reported the individual consumer surplus per trip for our study site, which ranged from $53-$164. Rivers provide a significant value for fishing while lakes provide recreation value for boating and fishing activities. The values reported in this study are initial values. If we have more papers to incorporate into the database; it would help improve the value transfer to our site.

Problem and Research Objectives

It is important to quantify the values of ecosystem services, especially those not normally captured in market transaction activities. Many public policies on restoration and conservation are simply assigned a "zero" value for ecosystem services, while they may have values for human welfare greater than zero (e.g., existence value) (Dailey, 1997). This results in an under estimation of the benefit of their conservation or restoration policy and may lead to an inefficient public policy decision.

Rivers and wetlands are important to support the proper functioning of aquatic habitats and several recreation activities. They also provide many services to humans including water supply and purification, as well as flood and erosion reduction. In this paper we employ a resource valuation methodology called "Benefit Transfer (BT)" to estimate the value of ecosystem services to guide future ecosystem restoration efforts in the Muskegon River Watershed, Michigan. We focus on qualifying the benefits of rivers/lakes and wetlands services, as they are key for maintaining the health of aquatic ecosystems.

Methodology

Economists have developed a variety of non-market methods (e.g., travel cost method, contingent valuation method, hedonic property value method) that can be used to quantify the value of ecosystem services (note: the details of each method and others can be found in many publications). These methods involve conducting an original benefit estimate study at a detailed site-specific location and involve a large expense of both budget and time of public resources for collecting primary data.

In this paper we apply the BT estimation method, which is relatively less expensive and time consuming, to estimate values of ecosystem services at our study site (Muskegon River Watershed). BT is a method to transfer existing values estimated at one site (originally estimated by a variety of non-market methods) to another site (policy site) where agencies face budget and time constraints (Brouwer, 2000; Boyle and Bergstrom, 1992)). BT has been used by government agencies for many years for various natural resource policy contexts and it is rigorous enough for use in an informed resource manager's decision (Piper, 2001).

There are two approaches for benefit transfer; 1) value transfer and 2) function transfer (Rosenberger and Loomis (2001). Value transfer is the transfer of a single (point) benefit

estimate from a study site, or a measure of central tendency for several benefit estimates from a study site or sites (such as an average value). Function transfers encompass the transfer of a benefit or demand function from a study site, or a meta regression analysis function derived from several study sites. Function transfers then adapt the function to fit the specifics of the policy site such as socio-economic characteristics, extent of market and environmental characteristics.

This paper uses the BT methodology for estimating the non-market value of ecosystem services (use values) in the Muskegon Watershed of Michigan. We employed a value transfer approach including a single point estimate and/or average values of several studies where appropriate.

Principal Findings

Our initial search provided over 100 economic value studies for wetlands, rivers, and lakes in the U.S. These studies were primarily found through several online bibliographic databases, electronic journals, and online-search engines. Examples of these online databases are The Environmental Valuation Reference Inventory (EVRI) and the ENVALUE environmental valuation database, and search engines such as Google Scholar, and EconLit.

The EVRI is an international database of over 1500 non-market studies (http://www.evri.ca/). It allows users to choose the services valued and identifies studies with potential for BT (e.g., geography, environmental stressors, specific/general goods and services, and valuation techniques). The ENVALUE was developed by the Environmental Protection Agency in New South Wales, Australia (http://www.epa.nsw.gov.au/envalue/). It is a collection of more than 400 peer-reviewed studies containing data on environmental values (air, water, land, recreation, etc). The database can be searched by “environmental values”, “valuation method”, and “geographic location”.

We did an initial review of these articles and eliminated those not relevant to our study (e.g., not an empirical study, not a non-market value study, experimental study or preliminary study, not a peer-reviewed paper, unclear study timeframe, not a study site in the mainland U.S., etc). Table 1 summarizes the number of articles found though these search databases classified by land use (wetland and water (lakes and rivers)).

Table 1. Summary of articles found and those used for BT

Land use/ecosystem services	Number of articles found for initial review	Number of articles to be reviewed in detail	Number of article used for BT for the policy site	Ranges of publication period
Wetlands	49	26	9	1974-2007
River/Lakes	70	49	14	1980-2007
Total	119	75	23	1974-2007

Further review efforts were done only on those studies identified as most relevant with potential to be transferred to our study site. In this step we developed a review sheet for each article and developed a database containing information necessary to perform the BT. This information included valuation method, year of value given, geographic region, ranges and value estimates, units, statistical ranges and assumptions. All values were also adjusted by consumer price index to reflect the dollar value for 2006. The database allows us to compare value study information among articles.

The final step was to decide which values/studies could be transferred to our study site. The researcher made the final justification for those values using several criteria. Other than geographic relevance to the Midwest and/or the Great Lakes region, the major criteria were; 1) valuation methodology - we focused on the two measurements of welfare surplus (consumer and producer surplus). Therefore two methods, travel cost and contingent valuation approaches were our preferred methodologies; 2) unit measurement and reported value - we focused on individual consumer surplus per unit area, or in the case of recreation activities, reported the consumer surplus per trip, day and season. The estimated values were used in combination with local data, such as acres of wetlands in a watershed, number of trips and the population of recreational participants in a watershed; 3) Ecosystem services to be measured - to avoid double counting, we made certain the original study had an objective clearly stating what services were to be measured. Table 2 shows the values estimated for the Muskegon Watershed. The final column compares the values estimated to the wetland metadata analysis complied by Woodward and Wui (2001). Most of our estimated values are lower, or somewhat lower, than the wetland metadata study.

Table 2. Summary of estimated values using BT method for the Muskegon Watershed, Michigan[1]

Ecosystem Sever ices	Estimated value for rivers and lakes	Estimated value for wetlands	Wetland meta-data study[2]
Aesthetic/Amenity	Insufficient peer-review for BT	$16 per acre	$1.51-$21.59 per acre (Wetland)
Nutrient Cycling/Waste Assimilations	N/A (already measured their values through wetland values)	$1067-$2040 per acre	Not applicable to comparison
Recreation (sport fishing, hunting, wildlife watching)	$53-$164 per trip (Lake) and $82-$131 per trip (River)	$12-$83 per acre	$82-1,400 per acre (Wetland)

Note:
[1] all estimated values are year 2006
[2] Complied by Woodward and Wiu (2000) with values converted to 2006 dollars

Significance of Project

The values reported in Table 2 represent the values of ecosystem services for wetland and water recreation that can be used for the Muskegon Watershed. These values can be used for economic analysis of restoration or conservation policies implemented in the watershed. It should be noted that the values represent limited ranges of ecosystem services for wetlands, lakes and rivers. There are some important non-market services, such as erosion control, pollination, water regulation and water supply, which cannot be estimated for this study due to their limitation for data transfer or their inappropriateness for transfer. In addition, the values of ecosystem services reported here include only "use values", they do not include "non-use" or "passive" values (i.e., options, existence and bequest) where resources may have a significant value and importance to human welfare.

Publication citations associated with the research project

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Rosenberger, R.S.; Loomis, J.B. 2001. Benefit transfer of outdoor recreation use values: a technical document supporting the Forest Service Strategic Plan (2000 revision). Gen. Tech. Rep. RMRS-GTR-72. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 59 p.

Woodward, R., Y. S. Wiu. 2001. The economic value of wetland services: a meta-analysis. Journal of Ecological Economics 37(2001) 257-270.

NOTABLE AWARDS AND ACHIEVEMENTS.

n/a

PUBLICATIONS FROM PRIOR PROJECTS

n/a

Information Transfer Program

Since the Institute of Water Research Information Dissemination and Technology Transfer Training Program began in the early 1970s, it has been responsive to the informational needs of a wide variety of user groups. Many modes of information exchange have been used to further this program and provide the latest research information to user groups, including conferences, training workshops, exhibits, publications, email exchanges, and other printed materials.

Information Dissemination and Technology Transfer Training Programs

Basic Information

Title:	Information Dissemination and Technology Transfer Training Programs
Project Number:	2006MI70B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	8th
Research Category:	Water Quality
Focus Category:	Education, Groundwater, Surface Water
Descriptors:	None
Principal Investigators:	Lois G Wolfson

Publication

1. Taylor, William, Michael Schetcher, and Lois Wolfson (editors). In Press. Globalization: Effects on Fisheries Resources. Cambridge University Press, Cambridge, UK.
2. Bruhn, L. and L. Wolfson. 2006. Citizens Monitoring Bacteria: A Training Manual for Monitoring E. coli. Michigan State University, East Lansing, MI. 40 pp.
3. Wandell, Howard, Lois Wolfson, and Jane Herbert. 2006. Protecting Michigan's Vanishing Native Lakeshore. The Michigan Landscape 49 (11): 27-31.
4. Moy, Jessica, William Hudson, Ruth Kline-Robach, Ashton Shortridge, Sarah AcMoody. 2006. Modeling Socioeconomic Data Sources to Estimate Non-Point Source Pollution. [poster]. Planning for Prosperity, Land Use Conference. East Lansing, MI.
5. Wolfson, Lois and Ruth Kline-Robach.. 2006. Water Quality Programs at Michigan State University [poster]. USDA CSREES National Water Quality Conference, San Antonio, TX.
6. Iles, J., Crighton, L., Liukkonen, B., O'Brien, E., Stepenuck, K., Wolfson, L. 2006. Volunteer Monitoring of E. coli in Upper Midwest Streams: Comparison of Methods and Preference. USDA-CSREES National Water Quality Conference, San Antonio, TX.
7. Crighton, L., Iles, J., Liukkonen, B. O'Brien, E., Stepenuck, K., Wolfson, L. 2006. Building the Capacity of Volunteer Monitoring for E. coli in the Upper Midwest, North American Lakes Management Society International Symposium, Indianapolis, IN.
8. Felix, A.B., N. Lamp, R.B. Christoffel, D. Kramer, D. Hayes, L. Wolfson, K. Millenbah, and H. Campa. 2006. Development of a Natural Resources Field Course: Shaping Future Professionals through Experiential Learning and Teaching. American Fisheries Society Annual Meeting, Lake Placid, NY.

FY 2006 USGS 104(B) Annual Technical Report

Project Number: 2006MI70B
Start: 03/01/06 (actual)
End: 02/28/07 (actual)

Title: Information Dissemination and Technology Transfer Training Programs
Investigators: Lois G. Wolfson, Institute of Water Research, Michigan State University
Focus Categories: EDU, GW, SW, WQL
Congressional District: Eighth
Descriptors: Water Quality; Watershed Management; Macroinvertebrates; Volunteer Monitoring

Introduction

Since the Institute of Water Research Information Dissemination and Technology Transfer Training Program began in the early 1970s, it has been responsive to the informational needs of a wide variety of user groups. Many modes of information exchange have been used to further this program and provide the latest research information to user groups, including conferences, training workshops, exhibits, publications, email exchanges, and other printed materials.

Research Program

The following programs were developed and delivered for fiscal year 2006-2007.

Great Lakes Conference

An annual conference is convened on current and emerging issues related to the Great Lakes. This year the IWR co-sponsored the 16th Great Lakes conference, titled: *The Great Lakes: A Changing Ecosystem*. The conference presented topics including Economic Impacts of Invasive Species, Beach closings, Bacteria, and Human Health, Fish Stocking and Ecosystem Changes in the Great Lakes, Impacts of Double-Breasted Cormorants on the Great Lakes Ecosystem: Fisheries, Vegetation, and Co-occurring Species, Great Lakes Collaboration Efforts, The Detroit River: Visions for Restoration and Development, and Great Lakes Restoration and Ecosystem Changes. A capacity crowd of over 200 people attended the meeting representing state and local agency personnel, researchers, educators, environmental organizations, and interested citizens.

Conference Proceedings

As a follow-up to a successful symposium at the American Fisheries Society annual conference, a group of papers was solicited for the production of a book on Globalization: Effects on Fisheries Resources. Staff from the IWR served as one of the editors. The book consists of 21 chapters dealing with global governance, ecosystems, exotic species, fish diseases, and a variety of other subjects. The book is currently in press and will be published by Cambridge University Press in 2007.

Training

Staff of the Institute provided two training sessions for adult volunteers on stream monitoring with emphasis on the sampling and analysis of *E. coli* in streams. The participants then participated in a study (funded with other funding) which involved collecting samples, plating

the sample using bacteria kits, reading plates and comparing results with laboratory analysis. Data is currently being analyzed and will be presented on a web site. A paper is also being written and will be submitted for publication in 2007.

The Lake and Stream Leader's Institute convened its alumni program in 2006. The goals of the program, including developing local water/land resource leaders and educating participants on a variety of lake and stream issues ranging from ecology to local government to mediation, were met through this program. Over 80% of the original Institute class also attended the alumni program, and presented updates on their work on lake and stream issues in their communities. Staff of the IWR has been involved in both the development and implementation of this program and worked with colleagues for this program. An IWR staff member led hands-on session in lake and stream management and provided advisory and logistical support.

An IWR staff member helped developed a lake and stream ecology session and took part in The *Conservation Stewards Program*, a comprehensive eight week program to assist local decision makers, agency personnel, and interested citizens with tools and information concerning land and water ecosystems. The 10-hour session, divided into two days, consisted of lectures, interactive sessions, and hands-on lake and stream ecology. Approximately 35 attendees took part in the class.

A class directed towards undergraduate students was offered as a one-week class through the Department of Fisheries and Wildlife. With funding from another source, the class, Development of a Natural Resources Field Institute: Shaping Future Professionals through Experiential Learning and Teaching, provided opportunities for students to take part in hands-on field work, develop projects, and present their results. IWR staff lent support for this course by helping to teach two days of the class focusing on lake and stream ecology and management.

The Institute helped MSU Extension and 4-H at its annual Great Lakes camp. This one entire week event, located next to Lake Huron, promotes science, leadership, and educational and career development for youth. IWR staff led and taught daily interactive sessions on lake water quality and management and nature photography. Approximately 60 students attended the camp.

Internet-Based Programs and Decision Support Systems
IWR staff members continue to improve and enhance the IWR's decision support system development. Two programs, the Watershed Mapping program (www.iwr.msu.edu/water) and Digital Watershed (www.iwr.msu.edu/dw) were expanded to make more data readily available as well as comprehensive. This fiscal year, new models were linked to the system, and staff worked with the modelers from Purdue University on incorporating a variety of sediment and hydrologic models into the system. Images from the Terra Server were also linked to the program which enabled the Institute to access digital photographs in any area of the continental United States and use them in the digital watershed program. The IWR also continued to publish its bi-monthly on-line newsletter, *The Watershed Post* to provide current information on Institute activities as well as general articles of interest. Contributions were made by faculty, staff, students and grantees.

Economics of Lakes
The IWR assisted a team of researchers, industry representatives, and government agency personnel in formulating a study to determine the market and non-market value of inland lakes throughout the state. The purpose of the study was to be to inform state and local policy makers about: the extent, location, quality, character, monitoring and management of the inland lake resource in Michigan; the economic and non-market values and fiscal impact of inland lakes in Michigan; and the gaps in knowledge about inland lakes and their economic and other values and fiscal impact. Funding was provided to acquire data on lakes in the state, lake property values, estimated tourist spending, and boater gas tax revenue. The information gathered from this project led to the development of a more comprehensive study that will be funded with FY2007 USGS funds.

Exhibits and Demonstrations
IWR staff members took part in various programs hosted by other University units or outside agencies. The IWR participated in the Michigan Science Olympiad by serving as the State Supervisor for Water Quality in the state finals. This annual event included 48 junior high school participants who competed in a variety of science related events. Winners of the state finals continued onto the national finals.

In mid-July, MSU's Ag Expo, an agricultural oriented exposition was held. Approximately 35,000 people attended the event. The Institute partnered with several other departments on campus and featured its web-based programs, "Understanding Your Watershed". Participants were given the opportunity to overlay several layers of data, such as wetlands, rivers, streams, or watershed area onto digital rectified aerial photograph of their property, and print out a copy to take with them. Of the total number of people visiting the Expo, approximately 1000 people visited the multi-departmental tent over the three day event.

The IWR also continued its participation in the Children's Water Festival, an event that brings together nearly 2000 elementary school children from across the tri-county area to be introduced to a variety of natural resources and science-related topics. The IWR led two topic areas, one featured aquatic macroinvertebrates and their role as water quality indicators, while the other focused on aquifer vulnerability and used ice cream, dyes, and candy to depict aquifers and contaminants. Six classes for each topic were held with 25 to 40 students per class.

Lectures and Seminars
The Institute staff gave many presentations in FY06-07 on a variety of topics such as ecosystem health, *E. coli* sampling, high impact targeting for reducing soil erosion, wellhead protection, indicator species, watershed management plans, and exotic species. Audience participants included legislators, community personnel, watershed managers, students, and interested citizens. Staff gave class lectures in the Departments of Fisheries and Wildlife, Community, Agriculture, Recreation and Resources and the Honors College. Audience or class participation varied.

Personnel and Facilities
The Institute of Water Research maintains a variety of computer workstations and servers for its growing web based decision support systems. In addition to computer-related supplies and equipment, the IWR also has video editing and photographic equipment, color printers, and field supplies for its Information Dissemination Program. The Institute's technology transfer program is under the direction of Principal Investigator Dr. Lois Wolfson, with several Institute personnel contributing to the project, including Dr. Jon Bartholic, Ruth Kline-Robach, Pam Hunt, and Jeremiah Asher.

Problem and Research Objective
Michigan has an abundant and widespread supply of water due in large part to its geographical location within the Upper Great Lakes Region. Although plentiful, the increasing demand on and use of the water resources in the state often result in both water quantity and quality problems as well as risk of depleting supplies and water degradation. As impacts on water become more widespread, the need for action at the watershed level becomes increasingly important. Since movement of pollutants across a watershed is not constrained by political boundaries, activities in one political jurisdiction may lead to water degradation in another. Further, water withdrawals from both surface water and groundwater may result in decreased stream flow, reduced lake levels, or decreased well capacity and lead to both water quantity and quality problems and user conflicts. Assessing impacts from nonpoint source pollution, water withdrawals or other sources are often difficult and time-consuming. The more information that is collected, analyzed, interpreted and distributed, the better prepared citizens and decision makers will be to determine science-based steps for action.

An effective information dissemination and training program facilitates the transfer of science based information needed towards the protection of the water resources in the state and helps inform scientists, legislators, and citizens of the most recent information available. Today, all types of information are now easily and readily available over the internet. The information may or may not be accurate, and in some cases, completely false. It is critical for Universities to be dependable sources of accurate, non-biased science-based information, whether that information is accessed via the web or is available in an alternate format. It must be current, reliable and readily transferable to a wide audience in formats that are easily understood.

The Institute of Water Research has developed and expanded upon its information dissemination and training program addressing real-world water resources problems and issues and providing timely information to scientists, decision makers, farmers, riparians and other interested citizens throughout the state. The objectives of the information dissemination and technology transfer program are to develop and present educational programs designed to increase the public's awareness and appreciation of the water quality and quantity problems in Michigan and to address the economic trade-offs required to solve water related problems. These programs are offered in the form of conferences, training workshops, demonstrations, computer models and decision support systems, web-based programs, and printed material.

Methodology
Methods used to meet the objectives are to: (1) sponsor state of the art conferences and workshops that deal with pressing water related issues; (2) prepare lecture/demonstrations, audio-visual materials; and power point presentations (3) develop training sessions and workshops to assess trends in water quality; (4) present web based programs that provide users with information and other data needed for addressing or solving problems; (5) compile, interpret, and distribute water related information as well as direct users to appropriate sources of expertise and information; and (6) cooperate with the Michigan State University Extension to make water related information available through the county cooperative extension educators.

Principal Findings and Significance
The dissemination portion has involved a number of technology transfer mechanisms such as seminars, workshops, and conferences; web based information systems, data and virtual courses; and pamphlets, exhibits and demonstrations. Each program is designed to make the latest information available to the appropriate user groups. Local, state, and federal agency personnel as well as students, staff, and others are given the opportunity to hear and interact with outstanding researchers and have access to a variety of written materials and multi-media presentations. Participants have been able to use the information gained from these programs in their decision-making processes concerning water resources.

Significance for Project
With the plethora of information available over the web, it is critical to provide science-based information that presents multiple views of a subject along with possible recommendations or other dependable sources of information. The technology transfer and information dissemination program has provided citizens throughout the state with current information on critical environmental issues thus enabling them to make better informed decisions based on science based data and information.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	6	0	0	0	6
Masters	9	0	0	0	9
Ph.D.	0	0	0	0	0
Post-Doc.	2	0	0	0	2
Total	17	0	0	0	17

Notable Awards and Achievements

The Institute of Water Research was awarded a $120,000 grant from the U.S. EPA to help integrate information for watershed planning Comprehensive Assessment Tool (CAT) see Figure 3.

Dr. Bartholic was invited to present at the North American Land Cover Summit, National Academy of Sciences representing the Regional Midwest Spatial Decision Support Systems Partnership group in Washington, DC., September 20-22, 2006. The objective was to pursue collaboration among institutional and government agencies across the continent, advancing the development and application of comprehensive land cover information.

The legislature has established new laws that address reporting, registering, environmental protection standards, and permitting requirements for large quantity withdrawals from groundwater and surface water. The primary objective of this project is to work with MDNR and USGS to develop a web-based GIS interface, called the Water Withdrawal Assessment Tool (WWAT) interface to link with newly developed hydrologic and fish habitat models. The interface will be used as a screening tool to determine if newly proposed withdrawals from groundwater or surface water will have an adverse impact to characteristic fish populations in nearby streams and lakes. It is currently being recommended to the state that individuals seeking to implement new large water withdrawals be required to use the WWAT as one of the first steps in the process for getting certified. See Grant No. 07HQGR0003 Developing the Water Withdrawal Assessment Tool.

Michigan's Institute of Water Research and MSU Extension are working with five upper Midwestern states to assess the quality, reliability and usability of five different E. coli test kits with volunteer stream monitors. The project group is making recommendations of the best E. coli testing kits for use with volunteers and has developed uniform methods and training to help ensure consistency across states. The project group was recently awarded the **Gold Award** from the Ag and Natural Resources Extension Professionals Association for best team project. The project is sponsored by the U.S. Department of Agriculture's Cooperative State Research, Education, and Extension Service (CSREES) 406 Water Quality program with additional funds from the CSREES Great Lakes Regional Water Program.

The Institute of Water Research at Michigan State University and the Michigan Department of Agriculture (MDA) have teamed up to land a $600,000 Conservation Innovation Grant (CIG) to improve and protect water quality in three state watersheds. More information can be viewed online at: http://www.hydra.iwr.msu.edu/water/nl-headline.asp?st_id=135&read=yes&archived

The Institute of Water Research (IWR) hosted a Junior Faculty visitor Rovshan Abbasov from Azerbaijan and is a Fellow of the Junior Faculty Development Program (JFDP). He successfully completed the IWR's Virtual Watershed Management Course. His work was supported by Junior Faculty Development Program (USA), Michigan State University, US Geological Survey and Scientific-Research Hydrometerological Institute of the Hydrometeorological Department of Azerbaijan. Data for the study were provided by Hydrometeorological Department of Azerbaijan Republica dn Michigan State University. Authors thanks to director of Water Research Institute of the Michigan State University Dr. J. Bartholic for his assistance and support.

Dr. Jon Bartholic, Director of the Institute of Water Research received a select invitation from Dr. P.L. Gautam, Vice Chancellor of Govind Ballabh Pant University of Agriculture and Technology (GBPUAT) in Uttarakhand, India, to participate in a special workshop focusing on Emerging Trends in Curriculum Development in India and Land Grant Universities in the USA. Dr. Bartholic joined an elite group of esteemed colleagues from several U.S. land grant universities and like colleagues from India to participate in this workshop held in New Delhi, India in January 2007. The goals of this workshop focused on developing a comprehensive hands-on agricultural education curriculum at the post-graduate level with far reaching implementation. Such an opportunity exemplifies the kind of international collaboration typical of Michigan State University.

The Michigan Legislature has mandated that an assessment tool for water withdrawal be developed so that those who withdraw water can determine whether or not they will have a potential impact. This mandate arose from two legislative pieces which required users of ground water who pump more than 100,000 gallons per day to obtain a permit and determine whether their withdrawal could have a negative impact on surface waters. The Institute of Water Research was asked by the MI Department of Natural Resources and the USGS Science Center to coordinate the review of the models to be used in support of the new groundwater legislation. Staff assisted the model developers by convening a technical advisory panel to review and critique the assessment tool. The comments and written critique submitted have been used to help refine the model and address issues not previously incorporated into the model's development.

Publications from Prior Projects

1. 2001MI3001B ("Natural Resources Integrated Information System") - Other Publications - Wolfson, L., Asher, J, and Zeng, L. 2001. Tutorial Module in Understanding Your Watershed: An Interactive Mapping Program to Explore Michigan Watersheds. (http://www.hydra.iwr.msu.edu/water/)
2. 2002MI7B ("Information Dissemination and Technology Transfer Training Programs") - Other Publications - Asher, J., O. Da, S. Yi. 2002. Digital Watershed (http://www.iwr.msu.edu/dw/)
3. 2002MI17B ("Information Dissemination and Technology Transfer Training Programs") - Other Publications - Wolfson, Lois, Del Mokma, Ger Schultink and Eckhart Dersch. 2002. Development and Use of a Wetlands Information System for Assessing Wetland Functions. Lakes & Reservoirs: Research and Management 7:207-216.
4. 2002MI17B ("Information Dissemination and Technology Transfer Training Programs") - Other

Publications - Muzzall, P., T. Burton, R. Snider, and N. Coady. 2003. Occurrence, Distribution, and Control of the Parasites that Cause Swimmers Itch in Michigan. Edited by L. Wolfson and R. Snider. WQ 58. Michigan State University Extension, East Lansing, MI 30 pp.

5. 2001MI3001B ("Natural Resources Integrated Information System") - Other Publications - Wolfson, Lois, Del Mokma, Ger Schultink and Eckhart Dersch. 2001. Development and Use of a Wetlands Information System for Assessing Wetland Functions (Abstract). Pages S1-S4 in Toward Sustainable Management of Lake-Watershed Ecosystems. The Shiga-Michigan Joint Symposium 2001, Hikone, Shiga, Japan.
6. 2002MI17B ("Information Dissemination and Technology Transfer Training Programs") - Other Publications - Asher, J., O. Da, S. Yi. 2002. Digital Watershed (http://www.iwr.msu.edu/dw/)
7. 2002MI17B ("Information Dissemination and Technology Transfer Training Programs") - Other Publications - Wolfson, Lois, Del Mokma, Ger Schultink and Eckhart Dersch. 2002. Development and Use of a Wetlands Information System for Assessing Wetland Functions. Lakes & Reservoirs: Research and Management 7:207-216.
8. 2002MI17B ("Information Dissemination and Technology Transfer Training Programs") - Other Publications - Muzzall, P., T. Burton, R. Snider, and N. Coady. 2003. Occurrence, Distribution, and Control of the Parasites that Cause Swimmers Itch in Michigan. Edited by L. Wolfson and R. Snider. WQ 58. Michigan State University Extension, East Lansing, MI 30 pp.