38TH ANNUAL MISSISSIPPI WATER RESOURCES CONFERENCE

APRIL 15-16, 2008

JACKSON, MS

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Conference Sponsors:

Mississippi Department of Environmental Quality
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PROGRAM

Tuesday, April 15		
7:30 a.m.	Continental Breakfast - Salon A	
8:30 a.m.	**Climatology Change and Water Availability** **George Hopper**, Moderator Director, Mississippi Water Resources Research Institute	Salon A
8:45 a.m.	**Ed Martin** Chief, Customer Affairs Branch National Ocean Service, National Oceanic and Atmospheric Administration	
9:05 a.m.	**Tom Armstrong** Senior Advisor, Global Change Programs U.S. Geological Survey	
9:25 a.m.	**Charles L. Wax** Professor of Geography and State Climatologist Mississippi State University	
9:45 a.m.	**Donn Rodekohr** Research Associate, GIS and Remote Sensing Department of Agronomy and Soils, Auburn University	
10:05 a.m.	Break - Salon A	
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	Hamid Borazjani, Susan Diehl, Mary Hannigan, and M. Lynn Prewitt; Long-term performance of a pump and treat system at a wood treating site	
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	Kim S. Perkins, John R. Nimmo, Richard H. Coupe, Claire E. Rose, and Michael A. Manning, Potential for recharge in agricultural soils of the Mississippi Delta	
	***Germania Salazar-Mejia*, Jorge A. Ramirez, Luz S. Cadavid, and Jairo N. Diaz-Ramirez**; Aerobic-anaerobic lagoon evaluation in a small rural community in Columbia, South America	
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	K. Van Wilson Jr. and Michael G. Clair II, 1:24,000-scale watershed boundary dataset for Mississippi	

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PROGRAM

Tuesday, April 15 (continued)				
11:30 a.m.	Luncheon **Brandon Presley**, Keynote Speaker Northern District Public Service Commissioner			Penthouse
12:45 p.m.	**Concurrent Session** Session A: **Delta Water Resources** Dean Pennington, Moderator		**Concurrent Session** Session B: **Sedimentation** Russell Beard, Moderator	
12:45 p.m.	**Charles L. Wax**, Climatological and cultural influences on annual groundwater decline in the Mississippi Delta shallow alluvial aquifer	Amphitheater I	***John J. Ramirez-Avila***, Sediment transport analysis using HEC-RAS 4.0	Amphitheater II
1:05 p.m.	**Richard H. Coupe**, Characterization of water quality in unmonitored streams in the Mississippi Alluvial Plain, Northwestern Mississippi, May-June 2006		**Jeremy A. Sharp**, Sediment budget template applied to Aberdeen pool	
1:25 p.m.	**Heather L. Welch**, Influence of surface-water recharge on the potential for agricultural nutrient and pesticide transport to the Mississippi River alluvial aquifer, Northwestern Mississippi		***Heath Avery***, Vegetated swales and their effect on agricultural stormwater flow rates, a field verification of the FarmLatis Conservation Planning Tool	
1:45 p.m.	**Claire E. Rose**, Use of a field method for determining hydraulic conductivity in soils in the Bogue Phalia Basin in the Mississippi River alluvial plain			
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2:25 p.m.	Concurrent Session Session C: **Groundwater** Jamie Crawford, Moderator		Concurrent Session Session D: **Coastal and Wetlands** Barb Kleiss, Moderator	
2:25 p.m.	**Antonio L. Cerderia**, Nitrate in groundwater in a recharge area of Guarany aquifer in Brazil	Amphitheater I	***Seiji Miyazono***, Effects of landscape factors on limnological conditions of flood-plain lakes in the Yazoo River Basin	Amphitheater II
2:45 p.m.	**Lindy Rawlings**, Upper Leaf River basin base flow study: A preliminary study for surface water/groundwater interactions within the Pascagoula Basin		**Gregg Davidson**, Contaminant transport through riparian wetlands	
3:05 p.m.	**Jonathan R. McMillin**, An overview of the geology and hydrology of a proposed impoundment of the Upper Sand Creek, Choctaw County, Mississippi		**Greg Brown**, Evaluating water supply needs in rebuilding the Mississippi Gulf Region	
3:25 p.m.			**Russell Beard**, Bi-national harmful algal blooms observing system (HABSOS) and the phytoplankton monitoring network	
3:45 p.m.	Break - Salon A			

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PROGRAM

Tuesday, April 15 (continued)				
4:05 p.m.	Concurrent Session Session E: **Water Supply** **Sam Mabry**, Moderator		Concurrent Session Session F: **Surface Water Quality** **Glenn Odom**, Moderator	
4:05 p.m.	**Jairo N. Diaz-Ramirez**, The Mobile River Basin: A review of physiographic, climatic, water quantity, and water quality characteristics	Amphitheater I	***Leili Gordji***, Movement of water pollutants in Sardis Lake	Amphitheater II
4:25 p.m.	***Jared K. McKee***, A water budget: Tenn-Tom Waterway from Whitten Lock to Heflin Lock and Dam		**David R. Johnson**, River continuum concept and water quality stressor identification	
4:45 p.m.			**Todd Tietjen**, Comparing index of biotic integrity scores to traditional measures of water quality: Exploring the causes of impairment in streams of the Mississippi Delta	
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Wednesday, April 16				
7:00 a.m.	Continental Breakfast - Salon A			
8:00 a.m.	Concurrent Session Session G: **Agriculture** **Richard Rebich**, Moderator		Concurrent Session Session H: **Modeling** **William McAnally**, Moderator	
8:00 a.m.	**John J. Read**, Effects of harvest management on bermudagrass yield and nutrient utilization in a swine-effluent spray field	Amphitheater I	***Ayanangshu Dey***, Sensitivity analysis of simultaneous nitrification-denitrification process by simulation with activated sludge model number 1	Amphitheater II
8:20 a.m.	**Ardeshir Adeli**, Assessing the risks to water bodies from nitrogen vs. phosphorus-based broiler litter strategy		**Jeffrey Graschel**, National Weather Service flood inundation mapping	
8:40 a.m.	Break - Salon A			

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Wednesday, April 16 (continued)				
9:00 a.m.	Concurrent Session Session I: **Water Supply Systems** **Mike Davis**, Moderator		Concurrent Session Session J: **Invasives** **Todd Tietjen**, Moderator	
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9:20 a.m.	**Jeannie R.B. Barlow**, Decision support tools for implementing and managing regional utilities in Mississippi		***Joshua C. Cheshier***, Duckweed control in Mississippi waters	
9:40 a.m.	**Jason Barrett**, Improving the capacity of Mississippi's rural water associations through board management training		**John D. Madsen**, Littoral zone aquatic plant community assessment of the Ross Barnett Reservoir, Mississippi for 2007	
10:00 a.m.			***Wilfredo Robles***, Reservoir survey for invasive and native aquatic plants species within the Pat Harrison Waterways District	
10:20 a.m.	Break - Salon A			
10:40 a.m.	**Closing Plenary Session** **Mickey Plunkett**, Moderator Panel Discussion (speakers tentative and subject to change) **Chip Morgan** Executive Director, Delta Council **Bill Walker** Executive Director, Mississippi Department of Marine Resources **Bryon Griffith** Director, Gulf of Mexico Program Office, Environmental Protection Agency **Trudy Fisher** Executive Director, Mississippi Department of Environmental Quality			Salon A
12:15 p.m.	Luncheon and Awards Ceremony **Barbara Travis**, Keynote Speaker Executive Director of the Mississippi World Trade Center			Huntington's Grille

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OPENING PLENARY SESSION

Ed Martin
Chief, Customer Affairs Branch
National Ocean Service, National Oceanic and Atmospheric Administration

Ed Martin has been with the NOAA's Office of Coast Survey for 34 years. Martin also has managed NOAA's Marine Chart Division, Update Service and Chart Production Branch's construction, maintenance, quality assurance and critical Notice to Mariner corrections for the suite of raster, paper and electronic nautical charts products. He received bachelor degrees in Oceanography from the University of North Carolina and Marine Sciences from Cape Fear Community College, with additional graduate study in Geographic Information Systems and Program Management. He began his career with the National Ocean Service in 1974 serving eighteen years at sea, navigating over 200,000 nautical miles while conducting hydrographic surveys along the Atlantic and Gulf Coasts and the Great Lakes.

Charles L. Wax
Professor of Geography and State Climatologist
Mississippi State University

Charles L. Wax has teaching and research interests in climatology, meteorology, hydrology, and natural resources. As State Climatologist for Mississippi, he monitors climate events and impacts in the state and often speaks or presents workshops or shortcourses on weather and climate. His current research projects investigate climatological effects on land application of municipal wastewater and large hog farm wastewater, climatological potential for groundwater conservation in aquaculture, climatic water balance in Southern forests, climatic variability, and the effects of weather on phenological stages of soybeans in Mississippi. Wax received a bachelor of arts degree in political science from Delta State University and master's and doctoral degree from Louisiana State University in geomorphology and climatology, respectively.

Tom Armstrong
Senior Advisor, Global Change Programs
U.S. Geological Survey

Tom Armstrong is the USGS Senior Advisor for Global Change Programs. During his career at USGS, Tom has served as the principal for the Department of the Interior to the United States Climate Change Science Program, the U.S. Head of Delegation for the Arctic Monitoring and Assessment Programme (AMAP); Co-Lead for development of the Committee on Earth Observation Satellites (CEOS) response to Global Climate Observing System (GCOS) Implementation Plan, the U.S. delegate for the United Nations Framework Council on Climate Change, advisor on USGS' International Polar Year activities, and as Chair of the Science Sub-committee for the Department of the Interior Climate Change Task Force. Tom has also participated in numerous testimonies to various Congressional Committees and high-level briefings for the bureau, DOI and various international forums regarding climate change and International Polar Year activities.

Donn Rodekohr
Research Associate, GIS and Remote Sensing
Department of Agronomy and Soils, Auburn University

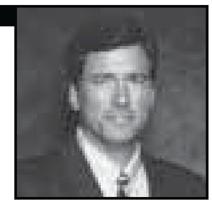
Donn Rodekohr is a Geospatial Analyst at Auburn University, Agronomy and Soils Department. His primary focus has been researching the geographic interrelationships among water, the landscape, and the policy actions that drive cultural actions. Prior to coming to Auburn he was involved with adjudicating water rights in New Mexico and Nebraska using GIS technologies. He was a task leader in the Nebraska Water Policy Issue Analysis program while with the University of Nebraska. Rodekohr received a bacherlor and master's degree from Nebraska in Fisheries Management. In addition to the nearly 2 decades of water related research he spent eight years in the software development industry in Georgia and five years as an engineering consultant in Colorado.

CLOSING PLENARY SESSION

Chip Morgan
Executive Director, Delta Council

Chip Morgan is the Executive Vice President of Delta Council. A native of Oxford, he graduated from Oxford High School in 1969 and received his bachelor's degree in public administration from the University of Mississippi in 1974. As Executive Vice President of Delta Council, Morgan has served in a coordinating role and developed strategies for the organization's input into national farm policy, major four-lane highway legislation for the State of Mississippi, and the successful completion of important flood control projects which have brought 100-year flood protection to communities such as Greenville, Greenwood, Cleveland, Belzoni, and many other smaller communities for the first time in history.

Bryon Griffith
Director, Gulf of Mexico Program Office, Environmental Protection Agency

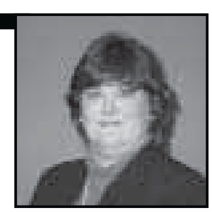


Bryon Griffith was appointed as Director of the Gulf of Mexico Program in July 2004. He previously served as Deputy Director starting in the fall of 1995. The Gulf of Mexico Program is a public and private partnership working to protect the natural resources and ensure the economic vitality of the Gulf region. Griffith is a native of Arlington, Va. After receiving his bachelor's degree from the University of Southern Mississippi, he began his EPA career as a management intern at the U.S. Environmental Protection Agency Headquarters in Washington. In this and other roles, he has transformed access and delivery of environmental data and information to communities throughout the region.

William W. Walker
Executive Director, Mississippi Department of Marine Resources

William W. Walker was appointed Executive Director of the Mississippi Department of Marine Resources by Gov. Ronnie Musgrove on July 8, 2002. Walker received a bachelors degree in botany and microbiology from Southeastern Louisiana University and a master's and doctroal degree in soil microbiology and biochemistry from Mississippi State University. Prior to his appointment to marine resources, he was employed by the U.S. Environmental Protection Agency and served as a Legislative Fellow in the Office of Sen. Trent Lott. Walker completed a 28-year career at the University of Southern Mississippi (USM) — Gulf Coast Research Laboratory where he served as associate director and was instrumental in building a variety of environmental toxicology programs.

Trudy Fisher
Executive Director, Mississippi Department of Environmental Quality



Trudy Fisher was appointed Executive Director of the Mississippi Department of Environmental Quality by Governor Haley Barbour and began serving in January 2007. Prior to her appointment, she was a partner with the Jackson-based Brunini, Grantham, Grower & Hewes law firm. She chaired their Regulatory Department and co-chaired the firm's Environmental Practice Group. She previously served as MDEQ's General Counsel. Fisher earned a bachelor of science degree from the Mississippi University for Women in 1982 and her juris doctor degree from the University of Mississippi School of Law in 1985, where she served as editor-in-chief of the Mississippi Law Journal.

LUNCHEON SPEAKERS

Brandon Presley
Commissioner, Mississippi Northern District Public Service Commission

Brandon Presley is currently serving as Northern District Public Service Commissioner. Commission. Presley was born in Nettleton. He is a 1997 graduate of Nettleton High School, and attended Itawamba Community College and Mississippi State University. He is a graduate of the 2001 Charter Class of the Community Leadership Institute and the 2004 State Executive Development Institute.

In May of 2001, at the age of twenty-three, Brandon was elected Mayor of Nettleton; becoming one of the youngest mayors in Mississippi History, garnering seventy-eight percent of the vote. He was unopposed in his second term for Mayor, which began in July 2005.

Commissioner Presley currently serves as Chairman of the Board of Trustees at Itawamba Community College. He is a past Board Member of the Mississippi Municipal League (MML) and was MML's Legislative Chairman for 2006 and 2007. He is also a member of the Board of Directors of Gilmore Memorial Hospital. He is past-Chairman of the Lee County Council of Governments and also served as President of the North Mississippi Mayor's Association.

He is past-President and current member of the Nettleton Lions Club and a member of the Nettleton Civitan Club. He is a member of the Nettleton First Baptist Church.

Barbara Travis
Executive Director, Mississippi World Trade Center

Barbara Travis is the executive director of the Mississippi World Trade Center. She also holds the titles of certified economic developer and state coordinator for Sister Cities International.

Travis holds a bachelor's degree from Mississippi University of Women and a master's degree from Mississippi State University. She has completed coursework for a doctoral degree in International Development from the University of Southern Mississippi.

Travis is the owner and president of MarketLynx Consulting, a firm focused on community marketing, research, and professional development. Her previous work includes regional shopping mall marketing, teaching merchandising and marketing at two Mississippi universities, and economic development positions on both state and local levels

Travis holds membership and leadership positions in numerous professional, service and civic organizations including Mississippi Economic Development Council, Southeast Economic Development Council, International Economic Development Council, Protocol & Diplomacy International, Rankin County Chamber of Commerce, Rotary Club and the Metro Jackson Salvation Army. In 1999 she was selected by the MS Business Journal as one of Mississippi's top 50 businesswomen and received Rankin County's Rotarian of the Year in 2004.

POSTER SESSION

The bi-national HASBOS

Barbara Ambrose
National Oceanic and Atmospheric Administration

Assessing water quality and phytoplankton in streams of the leaf river and black creek watersheds

Nestor R. Anzola, George F. Pessoney, and Carmen L. Hernandez
University of Southern Mississippi

Long-term performance of a pump and treat system at a wood treating site

Hamid Borazjani, Susan Diehl, Mary Hannigan, and M. Lynn Prewitt
Mississippi State University

Small farm plots and application of simulated rain to determine the potential for bacterial runoff after poultry litter surface application to bermudagrass

John Brooks and Ardeshir Adeli
USDA Agricultural Research Service

Sensitivity analysis of simultaneous nitrification-denitrification process by simulation with activated sludge model number one

Ayanangshu Dey and Benjamin S. Magbanua
Mississippi State University

Primary productivity, hydro perdio, and nutrient cycling in four flood-plain forest communities on a blackwater river

Marianne K. Burke, Mark H. Eisenbies, Charles A. Harrison, and Hal O. Liechty
USDA Forest Service

Interactions between ground water and surface water in the Bogue Phalia near Leland, Mississippi, Summer 2007

Curtis Gebhard and Katherine Stone
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National Weather Service flood inundation mapping

Jeffrey Graschel
National Weather Service

Potential for recharge in agricultural soils of the Mississippi Delta

Kim S. Perkins, John R. Nimmo, Richard H. Coupe, Claire E. Rose, and Michael A. Manning
U.S. Geological Survey

Aerobic-anaerobic lagoon evaluation in a small rural community in Columbia, South America

Germania Salazar-Mejia, Jorge A. Ramirez, Luz S. Cadavid, Jairo N. Diaz-Ramirez
Universidad Nacional de Colombia

The phytoplankton monitoring network

Angela Sallis
National Oceanic and Atmospheric Administration

Big Sunflower River water quality assessments following streamflow augmentation

Todd Tietjen and Gary Ervin
Mississippi State University

1:24,000-scale watershed boundary dataset for Mississippi

K. Van Wilson Jr. and Michael G. Clair III
U.S. Geological Survey

The bi-national HABSOS

Barbara Ambrose
National Oceanic and Atmospheric Administration
barbara.ambrose@noaa.gov

The Harmful Algal Blooms Observing System (HABSOS) is a regional coalition of U.S. and Mexican Federal and State agencies working together to study algal bloom events within the Gulf of Mexico Ecosystem. Algal toxins introduced into the ecosystem affect the health of humans and marine life, and disrupt social and economic activities.

The coastal zone manager is challenged to monitor, assess, and forecast bloom events to minimize societal impact. A bilingual (Spanish/English) HABSOS web site an Internet tools have been developed to support this effort. Data entered into the system are available for display and analysis in the HABSOS Internet Map Service (www.ncddc.noaa.gov/interactivemaps/harmful-algal-blooms-observing-system-habsos).

The HABSOS and Bi-National were developed and supported by U.S. Environmental Protection Agency (EPA) Office of Research and Development, EPA Gulf of Mexico Program, and the NOAA National Coastal Data Development Center (NCDDC).

Assessing water quality and phytoplankton in streams of the leaf river and black creek watersheds

Nestor R. Anzola, George F. Pessoney, and Carmen L. Hernandez
Department of Biological Sciences, University of Southern Mississippi
nestor.anzola@usm.edu

Physicochemical and phytoplankton data has been collected since 1998 at 26 permanent monitoring stations located in streams draining into the Leaf River and Black Creek in South Mississippi. These streams are fast flowing and originate within the boundary of the Camp Shelby Training Site. Bacteria, nutrients, and physical characteristics are measured quarterly. The measurements are designed to detect acute changes in water quality. A small discharge of pollutants can result in major stream impairment within the boundaries. The danger for contamination of these small streams is that a small point source could cause a large influence in the water quality downstream because there is little water for dilution. This paper summarizes the results of water quality in the period of 2002-2007. Influences outside of the camp area were more pronounced than the military uses within the boundaries. The study shows that there has not been environmental deterioration caused by the land uses at Camp Shelby. The phytoplankton was dominated by diatoms in numeric abundance. However, the Chlorophyta, although widespread in occurrence, included the largest number of genera. Other algae divisions were minor component of the plankton community. Water temperature, flow, and phosphate availability were statistically important factors affecting and controlling phytoplankton abundance and algal richness over time.

Keywords: water quality, streams, phytoplankton, surface water

student presenter

Long-term performance of a pump and treat system at a wood treating site

Hamid Borazjani, Susan Diehl, Mary Hannigan, M. Lynn Prewitt
Department of Forest Products, Mississippi State University
hborazjani@cfr.msstate.edu

A wood treating facility in South Mississippi was the site of a twelve year, pump and treat remediation. Two sixty-five thousand liter batch reactors treated approximately 250,000 liters of creosote and penta contaminated groundwater per day. Four liters of penta and creosote degrading bacterial culture and 5 kg of triple thirteen fertilizer were added to the reactors on a weekly basis. The approximate residence time in reactors was 12 hours. Samples were taken on bi-weekly basis for Total Suspended Solids (TSS), selected priority pollutant creosote constituents/polycyclic aromatic hydrocarbons(PAHs), Penta and Tetrachlorohenol (PCP&TCP), Biological Oxygen Demand (BOD), and microbial counts. Reduction of PAHs, PCP/TCP, BOD, and TSS were 97%, 44%, 61%, and 54% respectively; viable bacterial populations over (700,000 colonies/mL) were present in effluent samples during a twelve year period.

Key Words: Bioremediation, Pump and Treat, Groundwater

Introduction

Contaminated groundwater has been found in all fifty states. Some of this water is contaminated with chlorinated organic pollutants such as pentachlorophenol (PCP) and polycyclic aromatic hydrocarbons (PAHs). The wood treating industry in Mississippi has been in operation for over one hundred years. Groundwater contamination by these compounds has been the result of leaching of these wood preservatives from soil at waste disposal sites into groundwater reserves.

Bioremediation is the biological treatment of contaminated soil and groundwater. This technology involves the use of microorganisms which can degrade the contaminating compounds in both soil and water. Bioremediation requires an understanding of microbiological processes relative to biodegradation of the target contaminants as well as the contaminants' physical and chemical effects on these microbial processes. Often these systems utilize aerobic metabolism which require the addition of oxygen, usually as air, and inorganic nitrogen and phosphorus.

Several methods are available to remove organic pollutants from groundwater (Borow, 1989; CAA Bioremediation Systems, 1988; Campbell et al., 1989; Heyse et al., 1986; Looney et al., 1992; Taddeo et al., 1989; TeKroney and Ahlert, 1992; Yare et al., 1987; Yare et al., 1989). Two of the most common methods are filtration and biological treatment. Both of these methods are effective in certain situations for groundwater cleanup of organic contaminants. Filtration involves the pumping of groundwater through carbon filters to remove contaminating organics. The cost for filtration of groundwater containing wood treating chemicals averages $1.25-$5.25 per 1000 gallons depending on influent concentration and the type of carbon used. This method is labor intensive and the spent carbon used for filtration has to be disposed of in ways other than incineration. This only relocates the contaminants. Biological treatment (pump and treat) involves pumping the contaminated water into bioreactors where cleanup is carried out by means of microorganisms at a cost of $1.00 per 1000 gallons. Both bacteria and fungi have been shown to be important in the bioremediation processes (Borazjani et al. 2005).

This paper presents only analytical and biological data collected during twelve years (1990-2001) and will not compare these results with other ex-situ or in-situ bioremediation. The only comparative evaluation made is with activated carbon because it was used before pump and treat system installation.

Materials and Methods

A suitable site was selected at a south Mississippi location where creosote and PCP were present in both groundwater and subsoil. The facility had been in operation since the early 1970s. The site had three open lagoons containing either pentachlorophenol,

pentachlorophenol in a heavy oil, or creosote. The open lagoon practices resulted in groundwater contamination in this 100 acre facility. In the late 1980s open lagoons were decontaminated by removing penta and creosote sludges and as scraping the residual contaminated soils. The site geology is McLaurin series and consists of deep, well drained, moderately permeable soil which occurs on ridge tops and upper slopes of ridges dividing major streams. Creosote and pentachlorophenol contaminants in open lagoons migrated downward and laterally following preferential pathways and eventually contaminating groundwater. Contaminated groundwater was pumped from five contaminated wells into two sixty-five thousand litter batch reactors. Approximately 250,000 litters of creosote and pentachlorophenol contaminated groundwater was treated per day. The approximate contaminated groundwater residence time in reactors was 12 hours. Reactors and a 300,000 liter clarifier were placed outdoors on a concrete platform. Samples were taken bi-weekly for Total Suspended Solids (TSS), selected creosote constituents (benzo (b) fluoranthene, benzo (k) fluoranthene, chrysene, fluoranthene, naphthalene, and phenanthrene), penta and tetrachlorophenol (PCP/TCP), Biological Oxygen Demand (BOD), and microbial counts.

Four litters of bacterial culture (Arthrobacter sp.), previously isolated and known to efficiently degrade PCP and PAHs (Walker, 1992) and 5 Kg of "13-13-13" fertilizer were added to reactors on a weekly basis. Two air pumps and metal agitators provided oxygen and mixing for each reactor with pH ranging from 5.90 to 6.70 .

EPA Method 3520 was used for extraction of groundwater (US EPA, 1986). PAHs and PCP were analyzed using EPA Methods 8100 and 8140, respectively (US EPA, 1986). BOD and TSS were determined by the EPA methods 405.1 and 106.2 respectively (Clesceri et al, 1989)

Viable plate counts were performed in order to assess the rate of microbial reproduction and to determine the numbers of microorganisms present. In this procedure, serial dilutions were plated onto a suitable solid growth medium using the spread plate technique. The culture medium for bacteria counts was prepared and then autoclaved for 20 minutes at 15 psi and 120° C. Each plate was inoculated with 0.5 ml of the diluted groundwater sample. The agar plates were then incubated at 28° C for 24 – 48 hours. The concentration of bacteria in the original sample was determined by multiplying the number of colonies that developed by the dilution. The selective medium for monitoring creosote /PCP acclimated bacteria was consisted of prepared nutrient agar (Difco Laboratoris, Detroit, Michigan) amended with 1 ml of creosote (Koppers, Grenada, MS) and PCP (99%, Aldrich Chemicals, Milwaukee, Wisconsin) solution containing 20 mg/ml creosote and 5 mg/ml PCP in methanol. This solution was added to 1 L of autoclaved liquid nutrient agar.

Results and Discussion

Creosote constituents (PAHs) in influent during 1990 - 2001 averaged 5.75 mg/L while effluent samples averaged 0.16 mg/L or 97% reduction during these years (Figure 1). Naphthalene and phenanthrene were the two major constituents among selected PAHs.
Only small portion of naphthalene removal could be due to volatilization of this compound since reactors were not open systems.

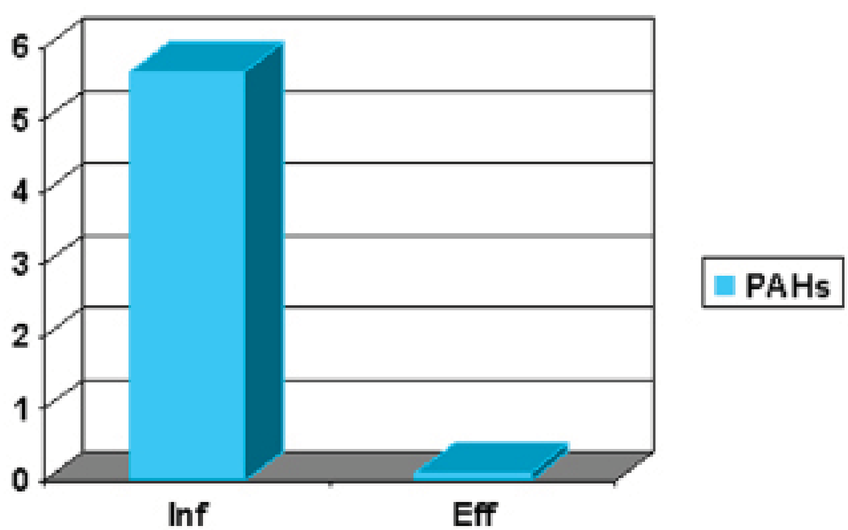

Figure 1: Concentration of selected PAHs during a period of 12 years. The results represent an average of 250 samples.

Pentachlorophenol concentration in influent and effluent averaged 0.042 mg/L and 0.022 mg/L respectively or 44% biodegradation of this wood preservative for the eleven years of sampling period. Tetrachlorophenol concentrations for influent and effluent remained below detection limit of 10 ppb throughout this project. (Figure 2)

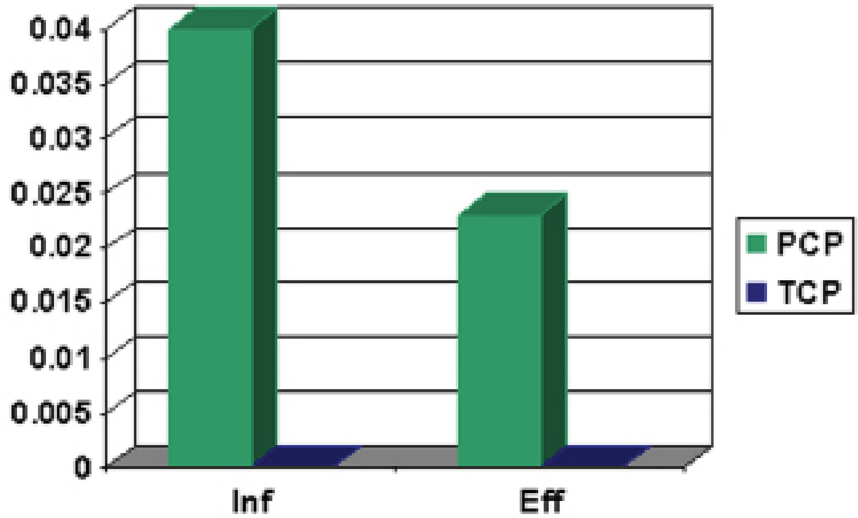

Figure 2: Concentration of selected PCP and TCP during a period of 12 years. The results represent an average of 250 samples.

Biological Oxygen Demand (BOD) results are summarized in Figure 3. Twelve year averages for influent and effluent BOD levels were 15.2 mg/L and 5.9 mg/L or 61% reduction, BOD levels in effluent reached as high as 9 mg/L in hot summer months.

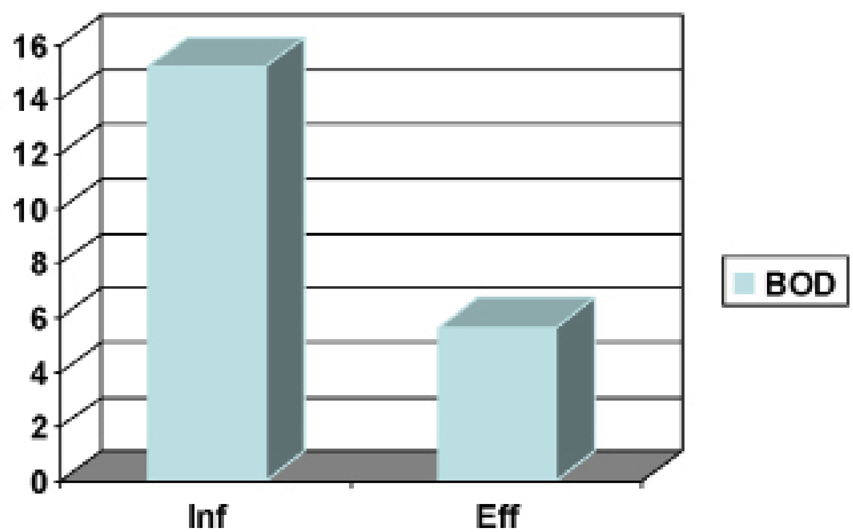

Figure 3: Concentration of selected BOD during a period of 12 years. The results represent an average of 250 samples.

Bacterial population fluctuated throughout the seasons with high numbers in fall, winter, and spring, but low numbers in hot summers. Overall the colony counts averaged for this eleven year period constantly remained over 750,000 colonies/mL. (Figure 4)

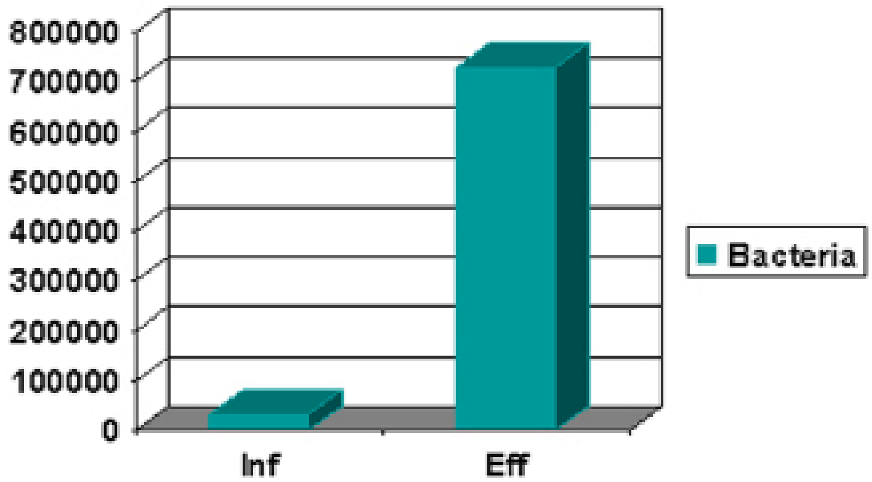

Figure 4: Bacterial Colonies per mL on creosote and PCP amended medium during 12 years of pump and treat. Results represent an average of 250 samples.

Total suspended solids results are shown in Figure 5. Concentrations of TSS in influent and effluent were 12 mg/L and 5.75 mg/L or 54% reduction. Aeration of groundwater removed significant amounts of iron present in most of south Mississippi's groundwater. Iron and other metal percipatants were removed from reactors during annual maintenance and clean up.

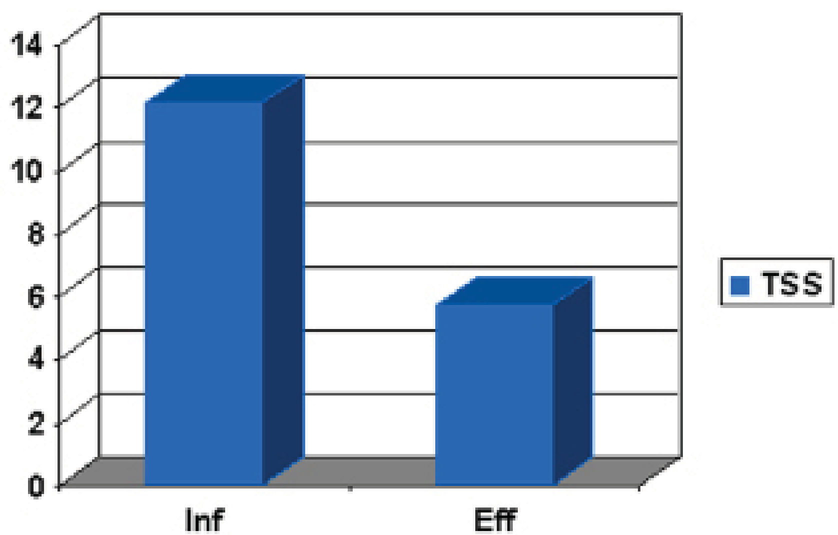

Figure 5: Concentration of selected TSS during a period of 12 years. The results represent an average of 250 samples.

Conclusion

Questions about efficiency of pump and treat systems might be answered by the use of sophisticated data analysis tools such as computerized mathematical models that can indeed be used to make predictions about future performance, but such predictions are highly dependent on the quality and completeness of the field and laboratory data utilized (Keely, 1989). The presented pump and treat system performed well for its intended purposes of preventing migration of contaminants to the surrounding areas and removing significant amounts of pollutants from the groundwater. The site is currently using natural attenuation remediation. During the twelve year study, the pump and treat cost was significantly lower than activated carbon filtration and was less labor intensive for the company considering the heterogeneous nature of contaminants that made it less amenable to treatment.

Acknowldegement

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Small farm plots and application of simulated rain to determine the potential for bacterial runoff after poultry litter surface application to bermudagrass

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Land application of poultry litter is an economical and environmentally viable use of this manure by-product. However the recent concern associated with fresh produce and pathogenic bacterial contamination has led to increased scrutiny regarding land applied manures. Runoff following a rain event is one possible source of environmental contamination resulting from manure application. In this second part of a two-part study a series of treatments involving litter (two rates), inorganic fertilizer, and no fertilizer controls were added to bermudagrass plots held on the Mississippi State south farm to simulate "real-world" conditions and extend the baseline data gathered during the greenhouse trials previously conducted. A rainfall simulator was used to simulate precipitation events and following each rain event, runoff samples were collected for microbial analyses. Total Heterotrophic Plate Count (HPC) bacteria, antibiotic resistant bacteria (ARB), thermal-tolerant coliforms, enterococci, staphylococci, and *Clostridium perfringens* were investigated. Over a period of 60 days, 5 rain events were simulated using a portable rain applicator and results indicated that staphylococci, enterococci, and clostridia correlated well with manure application, corroborating the previous greenhouse study. Analysis of runoff concentration means demonstrated that in most cases litter application increased the presence of indicator microorganisms in runoff water. Traditional indicators such as thermal-tolerant and total coliforms performed poorly as fecal indicators relative to the other bacteria assayed in this study. No "frank" pathogens such as *Salmonella* or *Campylobacter* were detected in the applied litter or runoff. Chi square analysis of ARB indicated that litter application influenced the overall presence of antibiotic resistant bacteria, particularly with respect to polymixin B and aminoglycoside resistance. This study indicated that poultry litter land application can contribute to microbial runoff, however proper land and agronomic management practices can mitigate this.

Keywords: Agriculture, Water Quality, Surface Water, Management and Planning

Introduction

Fecally-derived wastes have been the recipient of public scrutiny for many years now. This may be due in part to the lack of government oversite and recent food-borne outbreaks possibly related to the land application of animal manure on or near agricultural lands intended for food crop growth. Though much research has been conduced in the area regarding over or under applying N and P from manure and their contribution to surface water contamination, very little has been conducted on the subject of manure-borne pathogenic or antibiotic resistant bacteria. Precautions must be taken to avoid runoff of these manure-borne nutrients as well as manure-borne microorganisms, which can survive land application and potentially be moved horizontally via runoff following rain events (Malik 2004; Thurston-Enriquez 2005).

The purpose of this research was to identify the potential for manure borne bacteria to be horizontally transferred via surface water runoff following rain events. Runoff samples were collected from grass plots and analyzed for the presence of a wide range of bacteria. Antibiotic resistance profiles were obtained from select isolates. Runoff samples were also collected from control plots without manure application.

Materials and Methods

Bermuda grass (Cynodon dactylon) was established on small 84 sq ft plots located on the Mississippi State South Farm. Poultry litter (approximately 10 days old) was applied to the plots at two organic fertilizer rates of 250 lb N, and 50 lb P per acre, a high and a low rate respectively. Plots with inorganic fertilizer (250 lb N, and 50 lb P per acre) were used as control fertilizer; in addition plots with no fertilizer (organic or inorganic) applied were also used. Each plot was replicated in triplicate in a complete randomized block design. Rain was generated via the use of a constructed rain simulator and was operated from 27 to 50 mm/hr or the minimal volume and rate of rain necessary to generate runoff. A total of five rain events were simulated over a period of 70 days post application of litter, each lasting approximately 30 minutes. Field application took place in early May and rain events lasted 70 days after this.

Runoff water samples were collected from each plot following each rain event and were analyzed for microbial content including: Heterotrophic plate count bacteria (HPC), thermotolerant coliforms, Staphylococcus, Enterococcus, and Clostridium perfringens using modified standard methods. Antibiotic resistance profiles were generated from representative isolates. The Kirby Bauer method of assessing antibiotic resistance was used for antibiotic profiles of twelve antibiotics (Bauer et al., 1966).

Results and Discussion

Overall, microbial runoff total from the litter-applied plots confirmed that C. perfringens would appear to be the best indicator organism of land applied poultry litter (Fig. 1-5). While traditional fecal indicators, such as themotolerant coliforms and enterococci performed poorly, staphylococci and clostridia appeared to be more suitable indicators, thus confirming previously reported literature for other forms of manure (Thurston-Enriquez 2005). The failure of traditional indicators may have been due to abnormally high background concentrations in the soil and hence runoff from controls and inorganic fertilizer application. The site is not pristine as it is surrounded by agricultural land and experiment stations housing horses, cattle, and poultry. In addition, it appeared that all monitored organisms increased slightly in concentration over the 70 day period (Fig. 2-4), while C. perfringens, an anaerobic spore forming bacteria, did not demonstrate any growth with the exception of one control sample on day 16. This was not due to growth, but most likely due to detection limits sensitivity. This may lend credence to the use of these types of bacteria as they demonstrate little willingness to amplify in the environment, however given organic matter and moisture E. coli and other fecal indicators have been shown to increase while in the environment (Rivera et al., 1988).

Staphylococci and enterococci isolates were analyzed for antibiogram and of these isolates, only enterococci isolates demonstrated increased resistance profiles. While this is not surprising, since Enterococcus is a genus ripe with resistance genes, it is concerning that much of this could end up as runoff. Much of the resistance was to the macrolide and aminoglycoside classes of antibiotics, and may represent the overall dominant presence of one clone or strain of Enterococcus in this particular applied poultry litter. It is important to note that microbial quality of poultry litter will differ from farm to farm, and from state to state, and as such antibiotic resistance genes will also differ. An issue associated with antibiotic resistance is that unlike pathogenic bacteria, which can be readily inactivated via compositing or storage, antibiotic resistant bacteria may be more hardy and able to survive the pressures of manure storage as demonstrated by this study. Salmonella and E. coli in the freshly collected poultry litter decreased by orders of magnitude (data not shown) with a simple storage step of approximately seven days, but antibiotic resistant bacteria in the same litter failed to be reduced significantly.

The issues associated with microbial runoff following poultry litter land application are not simple, due to the many different types of poultry litter applied throughout the country and lack of oversite. Simple steps can be taken to mitigate the runoff problem, by using grass buffers, monitoring applications close to rain events, and applying only what is needed for crop growth (Entry 2000; Stout 2005). Compounding the issues with fecal contamination of surface waters are the presence of antibiotic resistant organisms that when exposed to pathogens may or may not be able to transfer their resistance genes (Dzidic 2003). This is an issue that will only continue to draw the nation’s ever watchful eye if not handled properly.

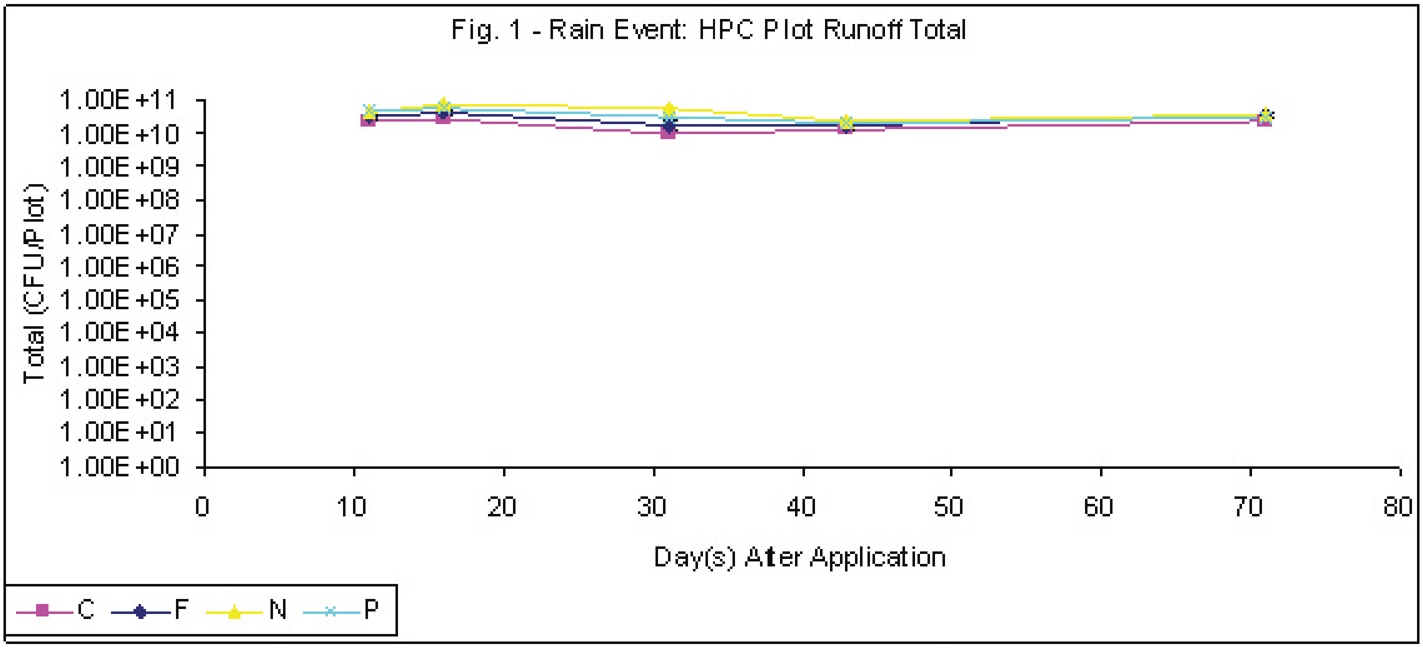


Fig. 1 - Rain Event: HPC Plot Runoff Total
Total (CFU/Plot)
1.00E+11
1.00E+10
1.00E+09
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
0
10
20
30
40
50
60
70
80
Day(s) After Application
C
F
N
P

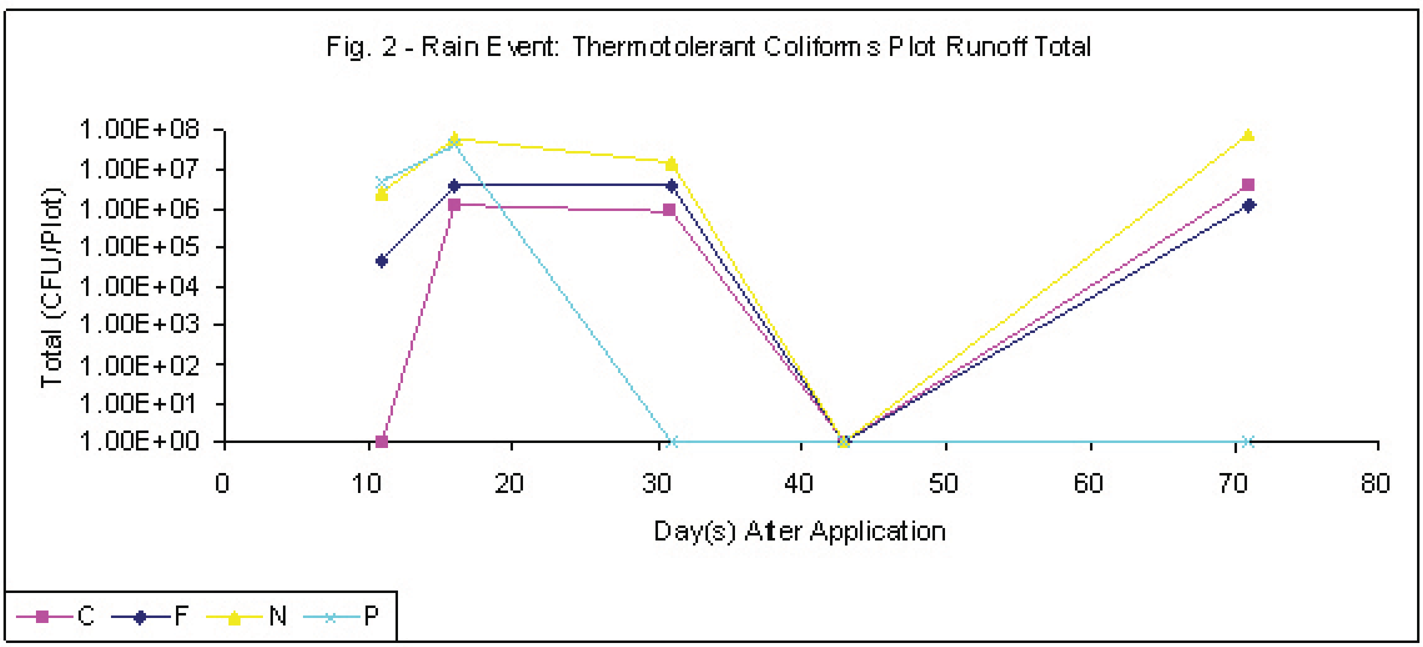


Fig. 2 - Rain Event: Thermotolerant Coliforms Plot Runoff Total
Total (CFU/Plot)
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
0
10
20
30
40
50
60
70
80
Day(s) After Application
C
F
N
P

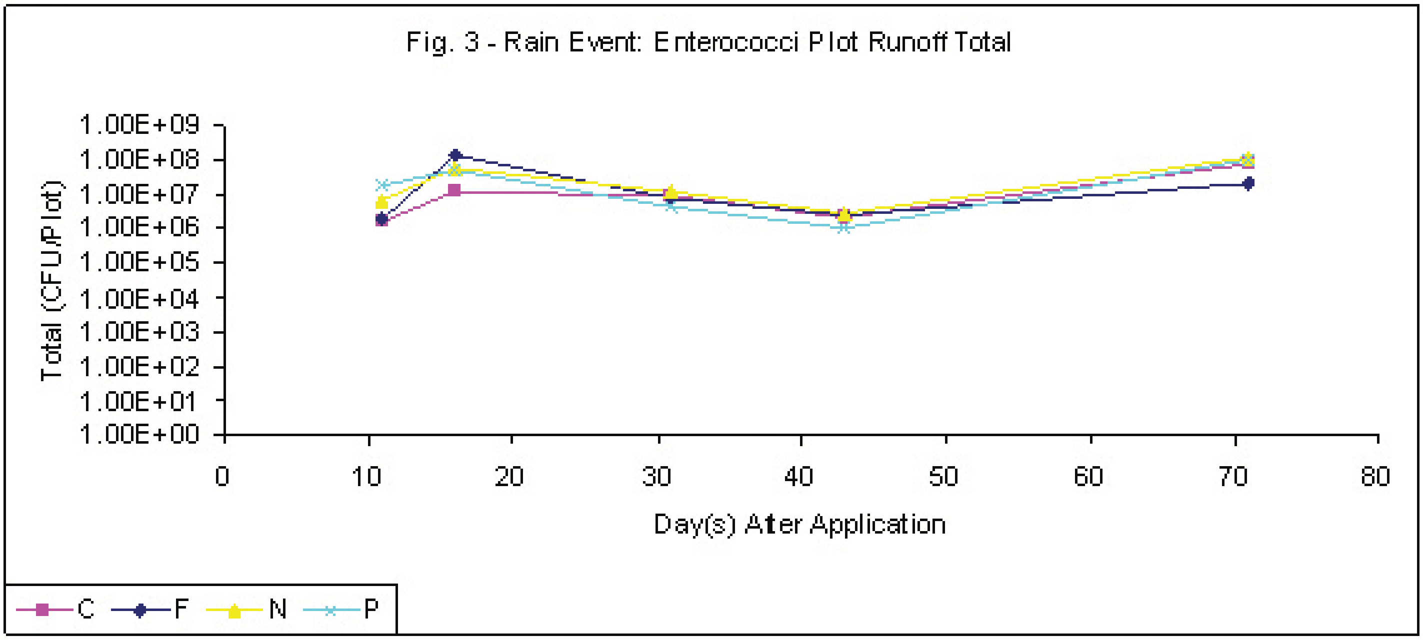


Fig. 3 - Rain Event: Enterococci Plot Runoff Total
Total (CFU/Plot)
1.00E+09
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
0
10
20
30
40
50
60
70
80
Day(s) After Application
C
F
N
P

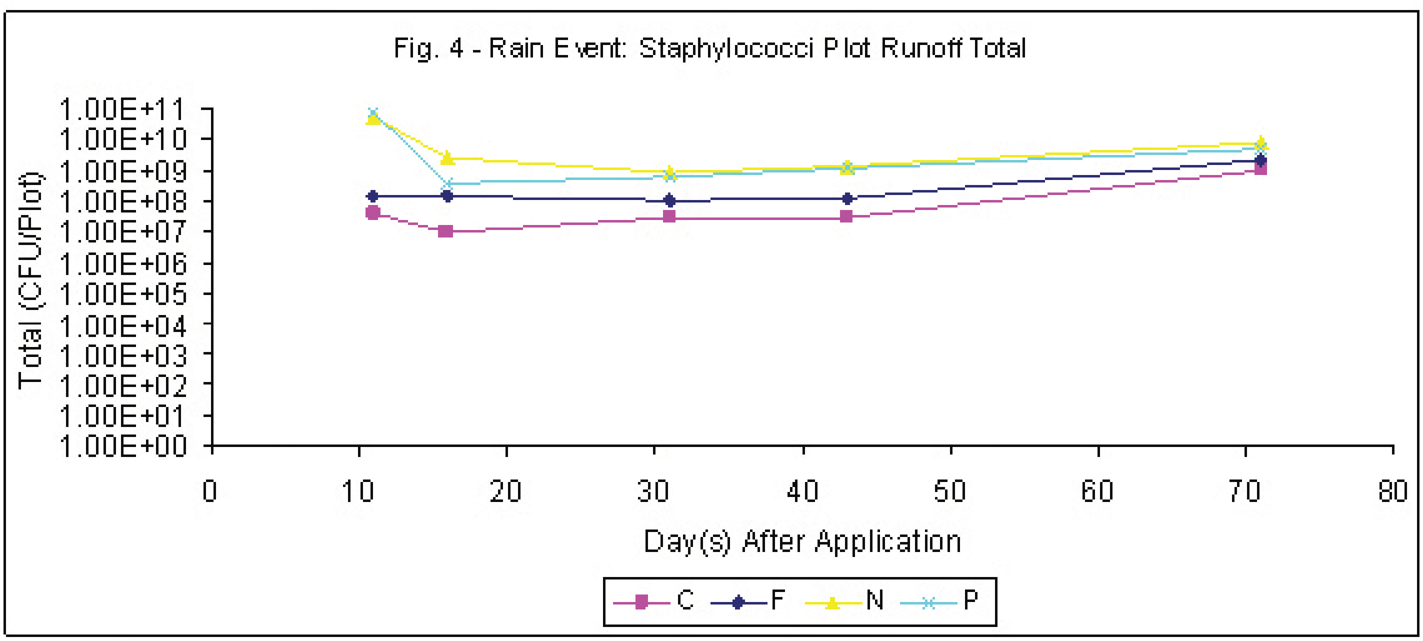
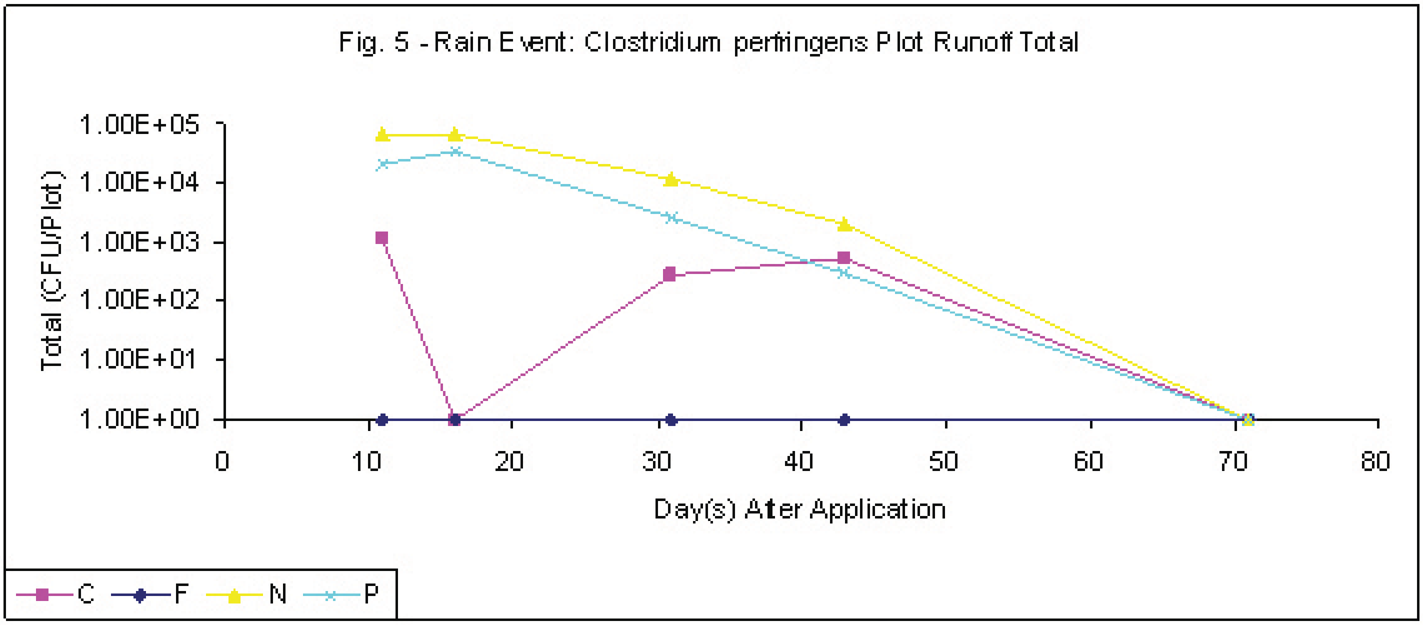


Fig. 4 - Rain Event: Staphylococci Plot Runoff Total
Total (CFU/Plot)
1.00E+11
1.00E+10
1.00E+09
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
0
10
20
30
40
50
60
70
80
Day(s) After Application
C
F
N
P



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Sensitivity analysis of simultaneous nitrification-denitrification process by simulation with activated sludge model number one

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Nitrogen removal by Simultaneous Nitrification-Denitrification (SND) has invited much attention in recent years due to possible reduction in capital and operating costs associated with wastewater treatment. The potential of biological nitrogen removal through this process and optimization of its operating parameters were investigated by simulations using Activated Sludge Model No. 1 (ASM1). Adopting typical properties of domestic sewage, simulations of SND process were performed in three sequential phases to optimize the operating parameters and assess reliability of the SND process over variation in the kinetic and stoichiometric parameters. Since dissolved oxygen (DO) concentration and solids retention time (SRT) were considered to have the most significant impact on nitrogen removal, the first set of simulations was aimed at identifying an applicable operating window for these parameters. Simulation results indicated that optimum nitrogen removal occurred at a DO concentration of 0.3 mg/L coupled with a SRT of 15 days. A second set of process simulations was run using this combination of operating DO and SRT to examine the effect of other process parameters; specifically the ratio of biodegradable COD to total Kjeldahl nitrogen (BCOD:TKN) in the influent, hydraulic residence time (HRT), and recycle ratio (R) on total nitrogen removal. The influent BCOD:TKN ratio significantly affected overall nitrogen removal, since availability of electron donor is essential to drive denitrification, with optimal nitrogen removal observed at a BCOD:TKN ratio of 11. Neither HRT nor R had a significant effect on nitrogen removal. The third set of simulations considered the natural variability of the kinetic and stoichiometric parameters of ASM1. Monte Carlo analysis was performed to evaluate the performance of an SND system operated at a DO of 0.3 mg/l and an SRT of 15 d using probability density functions developed by Cox (2004) for the model parameters. Results of these simulations were used to assess the potential reliability of an SND process designed using "typical" model parameter values. A sensitivity analysis was also performed to identify the model parameters that had most significant effect of nitrogen removal.

Key words: Models, Treatment, Wastewater, Water Quality

student presenter

Primary productivity, hydro period, and nutrient cycling in four flood-plain forest communities on a blackwater river

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A characterization of a blackwater river floodplain forest in South Carolina was conducted to 1) provide a reference for better management and restoration of this forest type, 2) test the subsidy stress hypothesis, 3) relate variations in hydroperiod to primary productivity and nutrient cycling among years and communities, 4) identify ecological processes potentially responsible for differences in productivity among communities and years, 5) identify mechanisms that contribute to water quality improvement by these forests, and 6) identify potential limiting nutrients on the site. The forest communities exhibited the classic subsidy stress curves of productivity along a flooding gradient over a period which included a wide range of moisture conditions. Greatest productivity occurred on the community occupying middle elevations. Also in that community, amplitude in productivity increased when flooding returned after several dry years, and this was attributed to luxury consumption of P during dry years and a fertilization e effect by N subsidies arriving with subsequent floods. Several mechanisms of N sequestration were identified, including uptake by trees with induced N deficiencies through luxury P uptake, and there was evidence of a N limitation of productivity in this nutrient rich and productive floodplain forest. Because eutrophication of marine systems is related to N runoff from terrestrial sources, these forests may be important to sustainable water quality on the coast.

Key words: Water Quality, Bottomland Hardwoods, Nitrogen, Phosphorus, Productivity

Interactions between ground water and surface water in the Bogue Phalia near Leland, Mississippi, Summer 2007

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Ground-water discharge is a key control on streamflow quality and quantity and associated aquatic ecosystems; however, factors that affect the spatial and temporal distribution of water flux across stream beds remain poorly understood. The objective of this study is to characterize ground-water and surface-water interaction in the Bogue Phalia, which drains an agricultural area in northwestern Mississippi. Study sites are located near the Bogue Phalia gaging station near Leland, MS. At the study sites, the Bogue Phalia is about 35 meters wide with a maximum depth at low flow of 1.2 meters and a discharge of 78 cubic feet per second during the study period (June – August 2007). Ground-water discharge was measured with pan and bag seepage meters fitted with extensions for deployment in deep (>1 meter) water. Five arrays were measured across the width of the river, with an average of 10 meters between each array and at least 5 meters per array. Seepage data were supplemented with measurements of head gradient, hydraulic conductivity, bed sediment grain size, and temperature in order to better understand interactions between ground water and surface water. Drought conditions in the area were temporarily relieved by storms in late June and early July when flow in the river reached a maximum of 5,120 cubic feet per second. Measurements were made both before the storms and after flow in the river returned to base conditions in order to evaluate the effects of flooding on ground-water discharge.

Preliminary results indicate that the highest ground-water discharge fluxes occurred along the central axis of the Bogue Phalia; whereas, the lowest fluxes occurred along the banks. The main channel was gaining at the study sites, although losing reaches were common in ditch-like tributaries. The average and (standard deviation) of vertical flux through the study area was 1.2 x 10-6 meters per second (m/s) (6.3×10^{-7} m/s), and ranged from a minimum of 3×10^{-8} m/s to a maximum of 5×10^{-6} m/s. Techniques for setting seepage meters in deeper water produced an average coefficient of variation (COV) of 0.5, which is greater than the typical value for shallow water application (COV = 0.3). The mean flux before the storms in late June and early July is statistically indistinguishable from the mean after the storms. Although the maximum flux increased slightly from 4.2×10^{-6}m/s (2.7×10^{-6} m/s) to 5.6×10^{-6}m/s (1.8×10^{-6}cm/s) and shifted position by approximately 30 m upstream following the storm. The highest fluxes always occurred in areas where the stream bed was composed of medium- to coarse-grained sand, whereas the lowest fluxes occurred where the bed sediment was fine-grained, primarily along the banks and particularly downstream of a tributary. Seepage-meter studies elsewhere in the Southeastern United States have shown average ground water discharge fluxes of approximately an order of magnitude greater than those at the Bogue Phalia, an effect that could be due to either ground-water pumping or drought conditions.

Keywords: Agriculture, Water Quality, Surface Water, Management and Planning

student presenter

Introduction

The Bogue Phalia River is located in the Delta region of MS. The Delta is located in north western Mississippi and accounts for a large portion of agriculture that occurs in the state. Crops grown in the Delta include but are not limited to rice, soybeans and cotton. Agriculture in the Delta relies on the underlying Mississippi Alluvial Aquifer for the majority of its hydrologic needs. The aquifer is comprised of coarse-grained sand and gravel with interbedded layers of clay, silt, and fine-grained sand. Average thickness of the aquifer is 41 meters *(Kerry, 2001)*. A low permeability zone comprised of clay, silt and fine-grained sand occur on the surface of the aquifer. This material is known as the upper confining unit and has an average thickness of 8 meters *(Kerry, 2001)*. Pumping rates of 7500 liters per minute from the alluvial aquifer are common for wells in the Delta *(Kerry, 2001)*. Withdraws from the aquifer are greatest during the summer months when agricultural needs are highest. Heavy pumping of the aquifer creates a head differential around wells, which will affect the flow of groundwater to rivers occurring in the Delta. The aquifer discharges to rivers in the Delta during periods of low river stages and is recharged during high river stages. Farming practices combined with the low permeability of the upper confining unit cause excess runoff to rivers in the Delta during storm events.

Purpose

During the summer of 2007, a field project was conducted with the purpose of characterizing the spatial and temporal distribution of groundwater and surface water interaction in the Bogue Phalia River, MS. The work was funded by the USGS NAWQA Study that is also observing the Bogue Phalia River. Measurements of vertical groundwater flux were compared to fluxes observed at similar sites in other regions of the United States. Bed sediments were classified to evaluate their affects on groundwater discharge. Storm events during the project allowed for the evaluation of temporal changes in groundwater discharge caused by large flow events.

Field Site

A location roughly 800 meters south of the USGS Bogue Phalia #07288650 gauging station, along Mark Rd, was chosen as the main area of study (Figure 1). The river at this location was roughly 35 meters wide with a maximum depth of 1.2 meters. Depth in the river increased to the north and south of the field site. The stretch of the river was relatively straight and had a tributary joining the main channel directly to the East. The main channel of the river is positioned along the left bank through much of the Northern portion of the field site. The reduction of surface water velocity in the central portion of the river allows coarse-grained material to accumulate in this area. Coarse-grained sediment was also present in and directly adjacent to the main channel. Fine-grained sediment occurs along the banks and where the tributary joined the main channel. Thickness of the fine-grained sediment on the bed surface was 38 cm in areas directly down stream from the tributary. Flow in the river during the study period was typically 2.2 m^3/s. The river incised the surrounding flat-lying topography by approximately three to five meters at the field site. During field operations pumping for irrigation throughout the watershed created elevated (0.1-0.3 m) water levels in the river due to increased runoff. The river was bounded to the east and west by agricultural fields. Crop dusting of the adjacent fields occurred on a weekly basis through field operations. Conditions were hot and humid with afternoon thunderstorms occurring periodically.

Equipment

Vertical flux of ground water through the stream bed was measured using modified pan-and-bag seepage meters. Pan-and-bag seepage meters offer a convenient way to accurately characterize vertical groundwater flux in stream beds. Devices of this type typically consist of an inverted bucket or drum that is inserted into the stream bed. A collection bag is attached to the drum using a piece of tubing. The bag is weighed before and after attachment to the pan and the time the bag is allowed to fill is recorded. The vertical flux can be calculated using the area of the pan, the time elapsed, and the weight gain of the bag. The calculation is based on Darcy's Law:

$$\frac{Q}{A} = K\left(\frac{dh}{dl}\right)$$

(1) Where Q is the discharge, K is the hydraulic conductivity of the material, and $\left(\frac{dh}{dl}\right)$ is the hydraulic gradient and A is the cross-sectional areas through which flow occurs. To calculate the flux using seepage meters the evaluation of the following terms are made (Sanders, 1998):

$$\text{Vertical Flux Through Streambed} = \frac{Q}{A} = \frac{\text{Volume Seeped Into Bag}}{\text{elapsed time} \times \text{cross sectional area of pan}}$$

(2) Meters used in the study were constructed from inverted five gallon buckets that were equipped with a hydrodynamic carapace. The carapace prevents scouring of the bed sediments (Figure 2), which can create an increase in observed flux. The system utilizes a bag that is formed from 25 – μm – thick nylon and polyethylene

film. It has a maximum capacity of 3500 ml. A piece of 0.95 cm tubing is inserted through the inflation port of the bag and secured with waterproof tape. The tubing can then be attached to the pan. The bag is sold commercially as a packing material by Inflatable Packing Inc as a Void-Fill Bag *(Craig 2005)*. Bags are also enclosed in a rigid PVC shell. Shells are constructed of 0.16 cm PVC and measure 30 cm by 30 cm by 8cm. The shell eliminates the affect of velocity head on the bag. Water flowing over the bag creates a differential pressure between the bag and the surrounding water column (*Shinn et al, 2002 and Murdoch and Kelly, 2003*). This creates a condition where the total hydraulic head in the bag is less than that of the surrounding water column. Field observations and theoretical analysis by *Kelly (2001)* and *Murdoch and Kelly (2003)* determined this effect can cause a 5 – 10% increase in observed flux. The shell holding the bag is attached to the pan using a high-flow quick disconnect adapted with a true-union ball valve. These meters were originally designed by *Kelly (2001)*, *Kelly and Murdoch (2003)*, and *Murdoch and Kelly (2003)*. The meters were then refined to their current design by *Craig (2005)* to be used in shallow water (0.3 meters >= water depth).

Water depths that exceeded 0.5 meters created difficulties in pan installation and bag retrieval. Modifications were made to the original design to alleviate these problems (Figure 3). The top of the pan was mounted with a 1.27 cm threaded flange fitting. Varying length of 1.27 cm PVC pipe was then mounted to the top of the pan. This aided in insertion and removal of the pan from the stream bed. This technique also provided a way to identify the pan in deep or cloudy water. Bag retrieval was aided by removing the shell and bag directly from the pan. The pan was mounted with a bulk head fitting and barb attachment so 1.27 cm diameter clear plastic tubing could be attached to the shell. The shell containing the bag was attached to the tube using a true-union ball vale and barb attachment. Varying length of tubing could be used depending on the depth of water. The shell was prevented from sinking using a 0.63 cm PVC frame, which was mounted with pool floats. The frame allowed the shell to rest approximately 15 cm below the surface of the water.

Procedures

Seepage meters were placed at the field site along Mark Rd during two time events during the summer of 2007. The first complete set of measurements was made from June 12th, 2007 – June 18th, 2007. The set consisted of Craig designed and modified meters. Four arrays across the river were made, which can be seen as arrays two – five in Figure 4. Each array consisted of at least five pans with a minimum of three meters between each pan. There was a spacing of approximately 10 meters down stream between each array. The first array was located the furthest upstream as so not to disturb sediments in downstream locations. Pans were placed in the morning and allowed to equilibrate for at least 30 minutes. Bags were pre-filled with a minimum amount of water to help induce flow and then attached to the shells and weighed. The shells were then attached to the pans and left to collect. Measurement times varied but averaged 30 minutes. Shells were collected and then re-weighed to obtain weight gain (positive flux) or loss (negative flux). A series of five measurements were made from each pan to obtain an average flux at each location. Pans were removed from the river after each series of five measurements and moved down stream at least 10 meters for the next array.

On June 19th a severe storm hit the area. This was followed by another storm on July 7th. Maximum gauge height during these two events was 5.2 m and 6.6 m, respectively. Max discharge during these two events was 70 m^3/s and 160 m^3/s respectively (Figure 5). Conditions in the river were un-safe and field observations were halted. Work continued on July 20th when conditions in the river were similar to those seen before the storms.

The second set of measurements was made from July 20th 2007 – July 29th 2007 and consisted of only deep water modified seepage meters. The set consisted of five arrays that can be seen as arrays one through five in Figure 4. Each array consisted of least five pans with 3 meters between each pan. A spacing of 10 meters up or down stream was used between each array. The first array in the set was located in the middle of the study area and continued down stream. When conditions permitted the arrays were moved up stream. Longer measurement times produced less variation in the results during the first set. Therefore, measurement times with an average of 50 minutes were used during this set. Pans were installed in the mid-morning and allowed to equilibrate for 30 minutes. Bags were prepared and attached to shells and then attached to the pans in the same manner as the first complete set of arrays. Five measurements were made from each pan to obtain an average at each location. The pans were then left in place overnight without the bags. A second series of five measurements were then made from each location upon arriving to the river the next morning. An average of both series of measurements could then be made at each location. After the second set of measurement the pans were moved up or down stream 10 meters for the next array.

Seepage meters were also emplaced at the Fratesi Boat Ramp on MS Highway 82 on two occasions. The Fratesi Boat Ramp is approximately two kilometers north of USGS gauging station #07288650. The river has greater depths and is wider at this location than at the field site along Mark Rd. Sediment size and distribution are similar to those at the Mark Rd. field site. The first flux measurements were taken on June 11th, 2007 before the storm events. Fluxes were measured again on July 1st, 2007 after the first storm event but before the second. One array that consisted of at least 5 meters was made across the river during each set. Procedures for bag preparation, installation, and removal were the same as at Mark Rd.

In addition to flux measurements, core samples were taken along arrays 1 and 3 (Figure 4) at the field site. A total of six samples were taken, three along each array. Samples were taken from the left and right banks and the main channel of the river. Cores were taken after the storm events on August 10th 2007. Cores varied in length from 38 to 104 cm. Core samples were taken using schedule 20, 1.27 cm, PVC pipe. The cores were capped for storage before leaving the river and opened at a later time.

Results

During the first set of measurements at the field site along Mark Rd, the river was gaining at all locations measured. Average flux during the time period was 1.2×10^{-6} m/s. The measurements had an average standard deviation of 8.1×10^{-7} m/s. The highest flux measured was 4.0 x 10-6 m/s and had a standard deviation of 2.7×10^{-6} m/s. This flux was measured along array 5 in the central part of the river where the water depth was 0.8 meters (Figure 6). The lowest flux was $3.2\ 10^{-8}$ m/s and had a standard deviation of 6.6×10^{-8} m/s. This flux occurred on array 2 along the right bank of the river. Highest fluxes occurred in and along the edges of the main channel, as well as in areas where coarse-grained sediment was able to accumulate. Lowest fluxes were concentrated along the banks of the river, where the tributary joined the river, and directly downstream of where the tributary joined the main channel.

The second set of flux measurements produced results similar to those of the first set. The average flux during these measurements was 1.2×10^{-6} m/s. The measurements had an average standard deviation of 4.5×10^{-7} m/s. The highest flux during this set of measurements was 5.6×10^{-6} m/s with a standard deviation of 1.7×10^{-6} m/s. This flux occurred along array 2 in the central part of the river where the water depth was 0.3 meters (Figure 7). Surface water velocity in the river was lowest in areas directly west of this location, allowing a large area of coarse-grained sediment to deposit. The lowest flux during this set was 1.3×10^{-7} m/s and had a standard deviation of 8.4×10^{-8} m/s. This flux occurred along array 5 on the left bank directly downstream of where the tributary joined the main channel. The depth of the river was 0.27 meters at this location. Highest fluxes were concentrated along the edges of the main channel rather than in the main channel as in the first set. Lowest fluxes were still observed along the banks of the river and where the tributary joined the main channel. Areas directly down stream of the tributary had the lowest fluxes during both sets of measurements.

Measurements made on June 11th at the Fratesi Boat Ramp had an average flux of 4.5×10^{-7} m/s. The average standard deviation of these measurements was 5.1×10^{-7} m/s. Flux values during this set varied from 1.7×10^{-6} m/s to 2.4×10^{-8} m/s. The highest flux during this set occurred in the main channel of the river. The second set of measurements had an average flux of 2.6×10^{-7} m/s with little variation from the mean. The lowest flux in this set was 4.9×10^{-8} m/s and occurred along the right bank of the river. Both sets of measurements displayed a general trend of lowest fluxes occurring along the banks and highest in the central parts of the river.

Core samples taken from the river at the field site along Mark Rd identified four major soil types in the river (Figure 8) according to the Unified Soils Classification System. Soils occurring on the surface of the river along array one varied from SP (uniform, clean, coarse-grained sand) to SM (coarse-grained sand containing non-plastic fines). Sand layers varied in thickness from 38.1 cm (entire length of core) to 48.3 cm. Sand layers transitioned into SC soils (dirty, coarse-grained sand containing plastic fines) and then into CH (plastic, sticky, fines) soil types of an unknown thickness at the bottom of the cores. Cores along array three all had SM soil types occurring on the surface of the river bed (Figure 8). The cores varied in the thickness of sand with and had SC and CH lenses occurring within the sand layers. Average thickness of sand layers along array three was 84.7 cm. All cores along this array transitioned into CH soil types of unknown thickness at the bottom of the cores.

Conclusions

The mean flux before and after the storm (1.2×10^{-6} m/s) are statistically indistinguishable. There was more variation in the measurements before the storms than after the storms. After the storms, the highest flux moved position upstream approximately 30 meters but was still located along the edges of the main channel. The highest flux increased by 1.6×10^{-6} m/s. The highest fluxes before and after the storm occurred in areas where coarse-grained sediment occurred on the bed surface. The mean low flux is 5.8×10^{-8} m/s and varied by 5.2×10^{-8} m/s. During both measurements these fluxes occurred in areas of fine-grained sediment accumulation either on the banks of the river or directly downstream from where the tributary joined the main channel. The variation in the magnitude of groundwater flux may be contributed to a re-distribution of fine grained material between and after storms.

Core samples indicate that a layer of fine-grained material with an unknown thickness underlies the river under the majority of the field site. The hydraulic conductivity of this sediment is much lower than that of the coarse-grained material that occurs on the majority of the river bed. Depending on the extensiveness of this layer, it could act as a barrier to flow and reduce the flux of groundwater to the river.

The mean fluxes observed at the Bogue Phalia River are one order of magnitude lower than mean fluxes observed at four sites elsewhere in the United States. Allison Craig *(2005)* made measurements of groundwater flux at Maple Creek, Nebraska and Leary –Weber Ditch, Indiana as part of the USGS ACT program. Both sites had shallower water depths and were not as wide as the Bogue Phalia River. Sediment on the surface of the bed at both sites was coarse-grained. Fine-grained sediment occurred along the banks but was not identified at depths. Fluxes at Maple Creek had a mean of 1×10^{-5} m/s *(Craig 2005)*. Highest fluxes at this site occurred in the central parts of the river in coarse-grained sediment. Lowest fluxes occurred along the banks of the river in fine-grained sediment. Mean flux at Leary-Weber Ditch was 1×10^{-5} m/s *(Craig 2005)*. The highest and lowest fluxes occurred at the same positions and sediment types as in Maple Creek.

Katherine Stone and colleagues characterized groundwater flux at Eighteen Mile Creek, South Carolina as part of an undergraduate research program at Clemson University. The stream is narrower, shallower, and contains less fine-grained sediment than the Bogue Phalia. The average flux at Eighteen Mile Creek was found to be 6.46×10^{-6} m/s. Highest fluxes occurred in the central parts of the river with lowest fluxes occurring along the banks. Susan Kelly *(2001)* measured flux at Twelve Mile Creek, SC. Twelve Mile Creek is approximately ten kilometers north of Eighteen Mile Creek, SC and is similar in all aspects of the river. Mean flux in the river was 1×10^{-5} m/s with highest fluxes occurring in the center of the stream and lowest fluxes occurring along the banks.

The Bogue Phalia has the same general trend of ground water flux as seen in other rivers in the United States. The trend is for greatest fluxes to occur in the central parts of the river and lowest fluxes to occur along the banks. The trend is the same but fluxes are one order of magnitude lower than that of other rivers studied by Clemson research teams. Two possibilities may be attributed to the low fluxes observed at the Bogue Phalia River. The presence of a fine-grained material occurring in and below the river could act as a barrier to flow and effectively reduce the amount of ground water discharge observed. Reductions may also be attributed to groundwater pumping during the field experiment. The head differential in the water table caused by pumping of the underlying aquifer may direct flow away from the river when pumps are being used. Pumps were in use over 70% of the time during the field experiments.

Acknowledgements

We would like the thank Dr. Richard Coupe and the United States Geological Survey in Pearl, MS for giving us the opportunity to work with the NAWQA division for the summer. We would also like to thank Dr. Larry Murdoch of Clemson University for his help in all aspects and details of this project.

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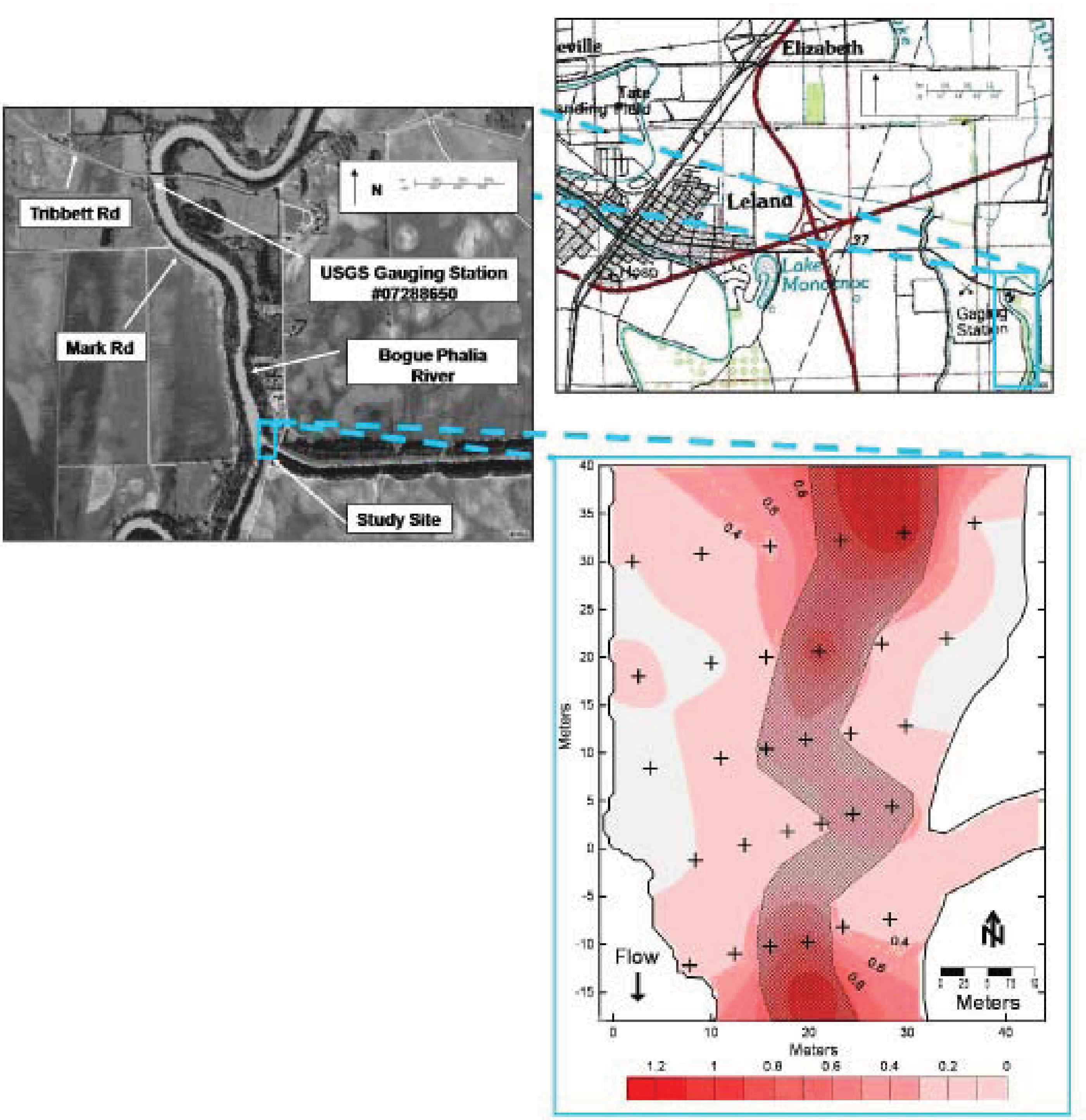

Figure 1. Road map and aerial photo of study area. Depth map of study area. The cross-hatch identifies the main channel of the river. Crosses indicate location of seepage meter measurements.

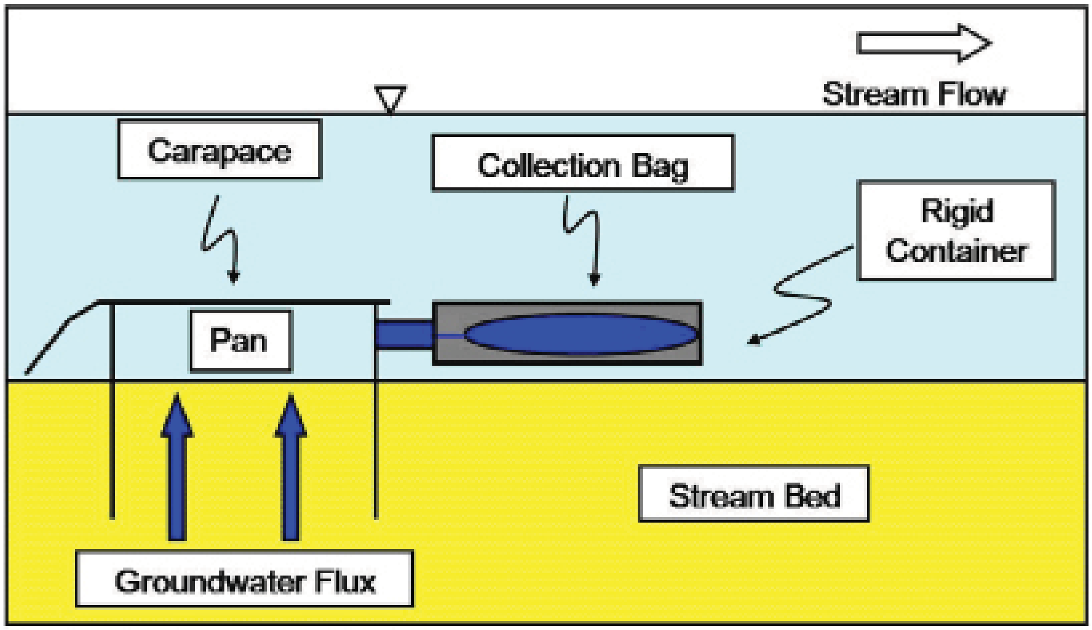

Figure 2. Cross sectional view of shallow water seepage meter.

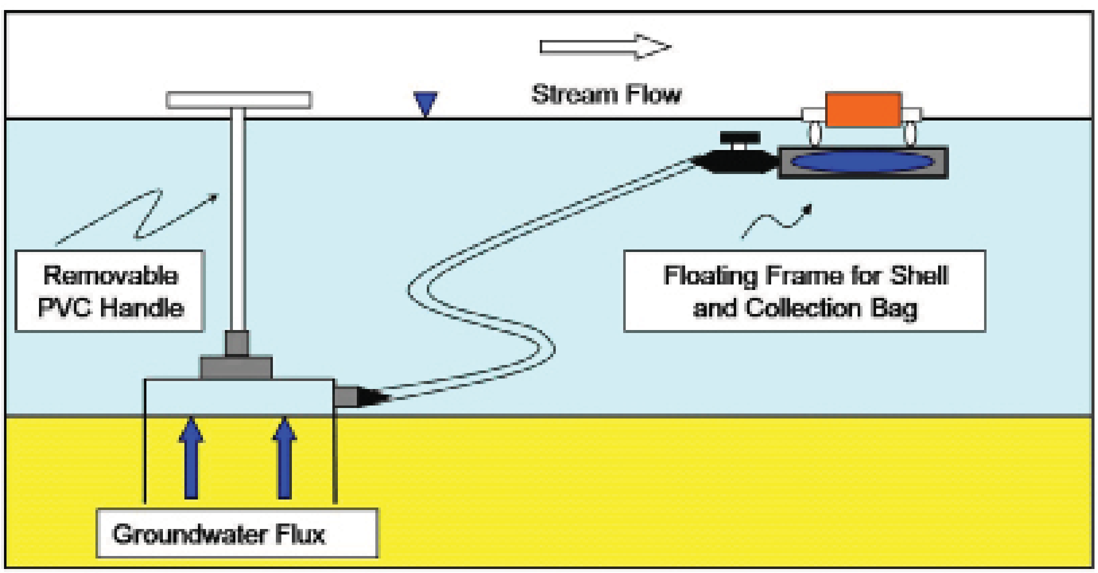

Figure 3. Cross sectional view of seepage meter that was used in water over 0.5 meters.

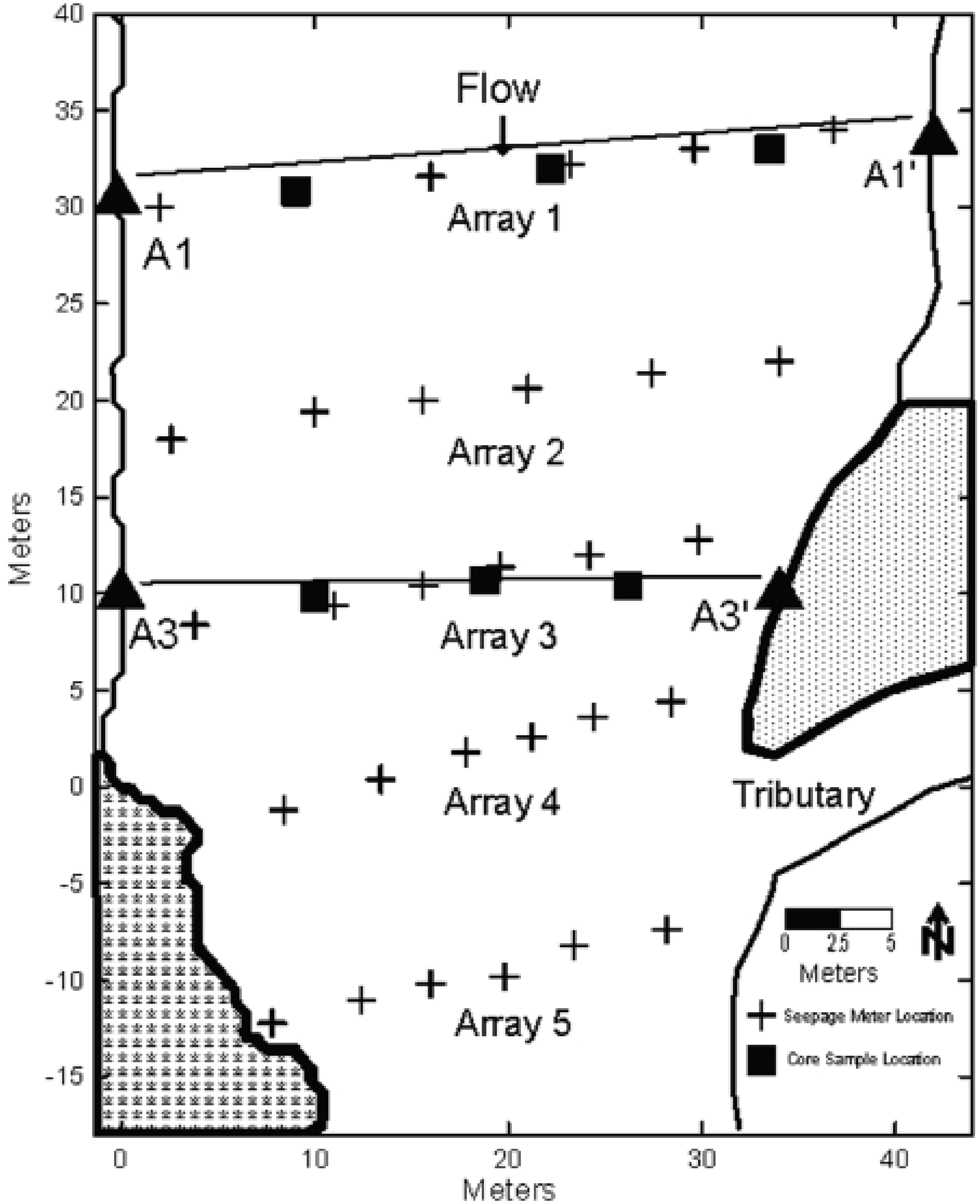

Figure 4. Base map of study area showing seepage meter locations (crosses) and core sample locations (squares).

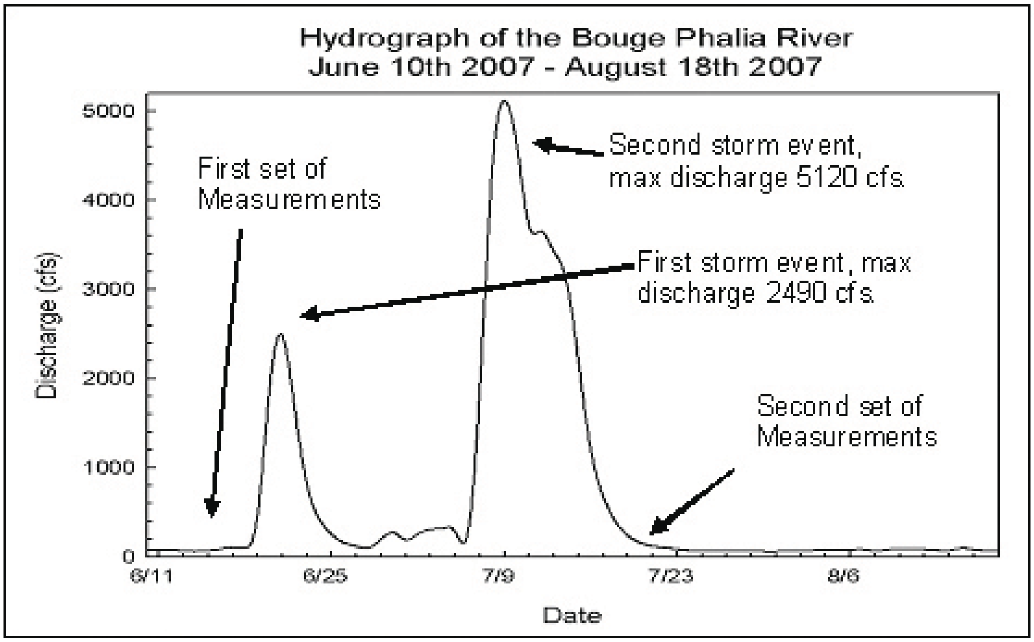

Figure 5. Hydrograph of the Bogue Phalia River during the field experiment. Data was taken from USGS Bogue Phalia #07288650 gauging station.

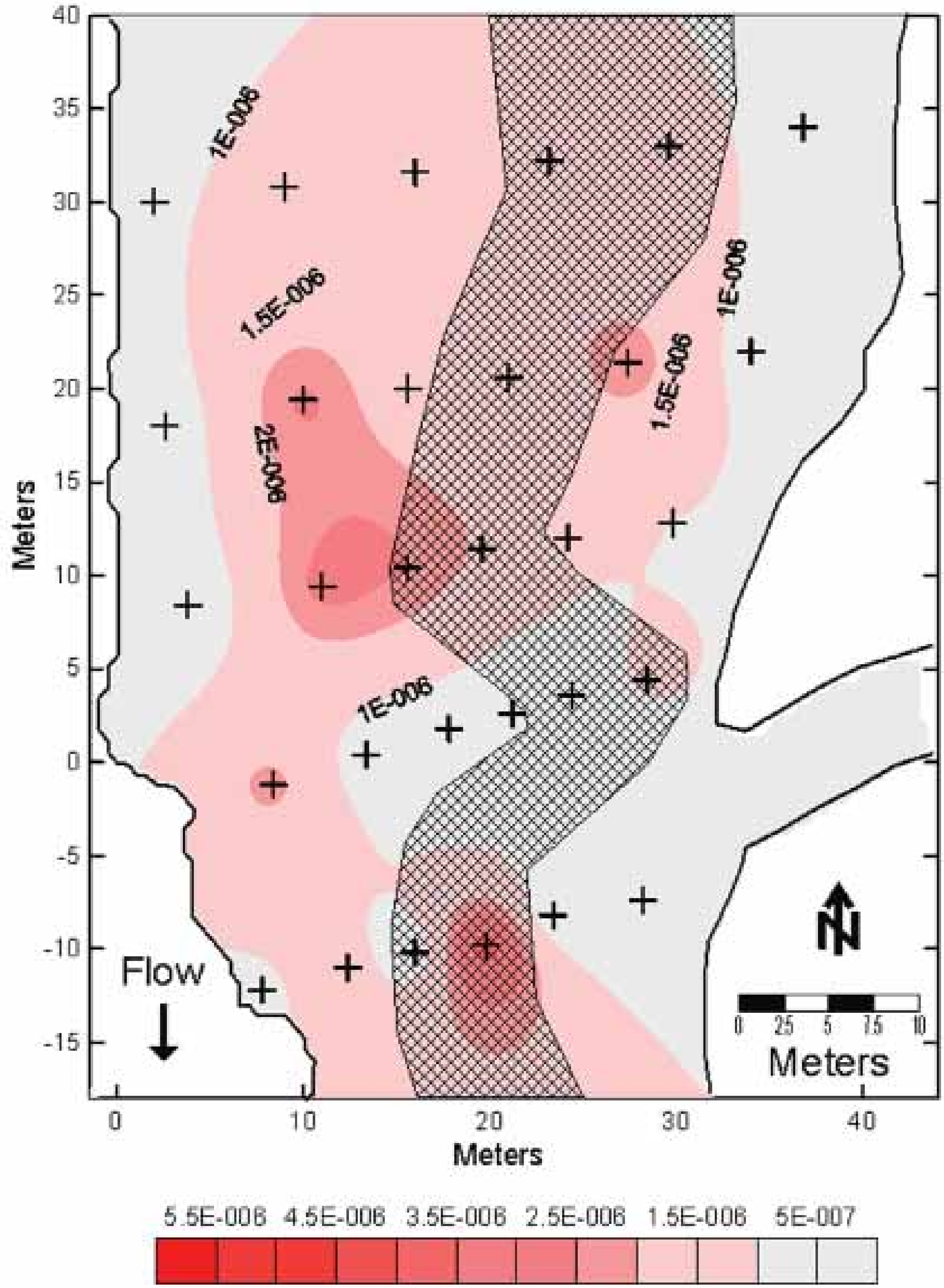

Figure 6. Map of vertical groundwater flux before the storm events at the Mark Rd Wading Station on the Bogue Phalia River.

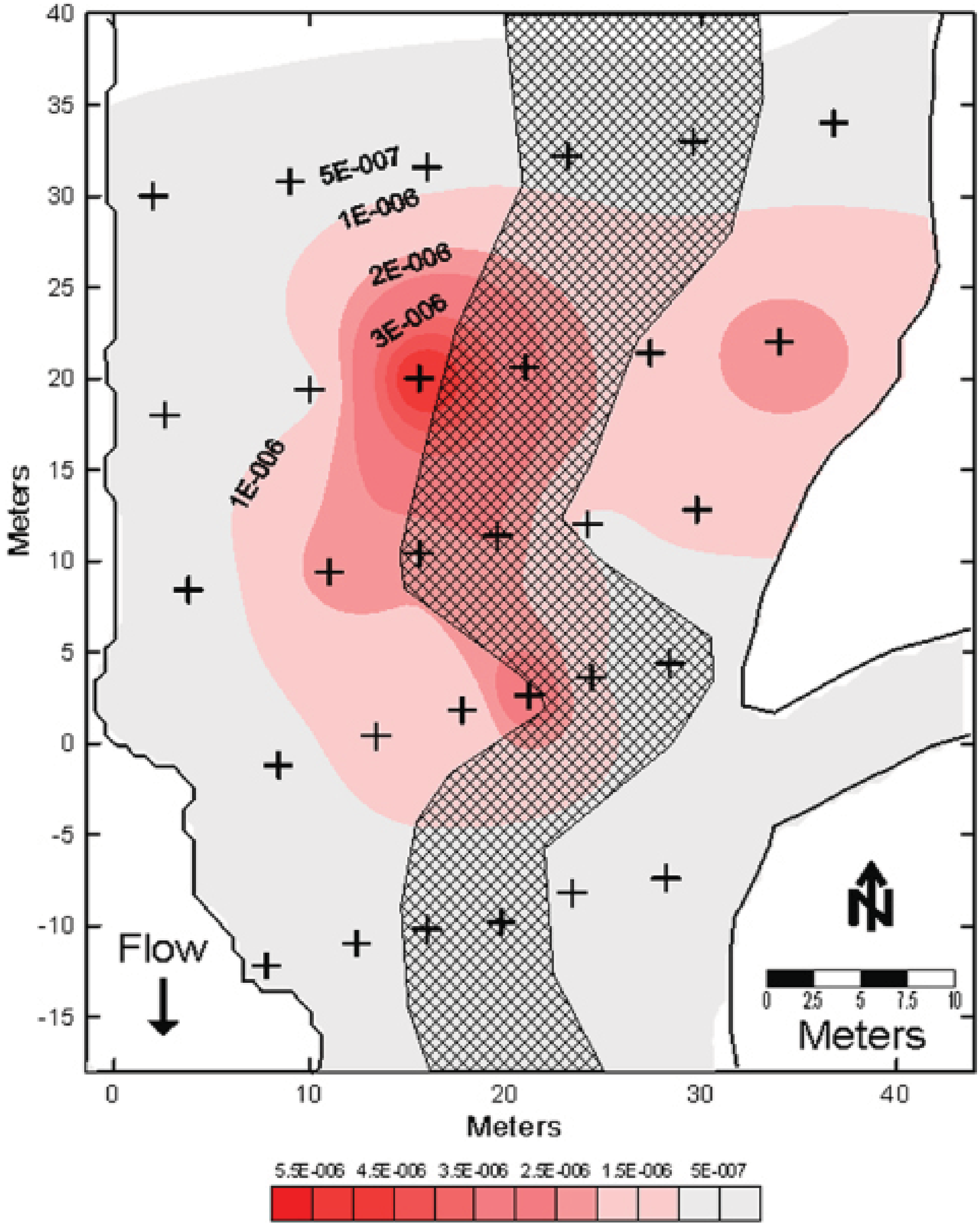

Figure 7. Map of vertical groundwater flux after the storm events at the Mark Rd Wading Station on the Bogue Phalia River.

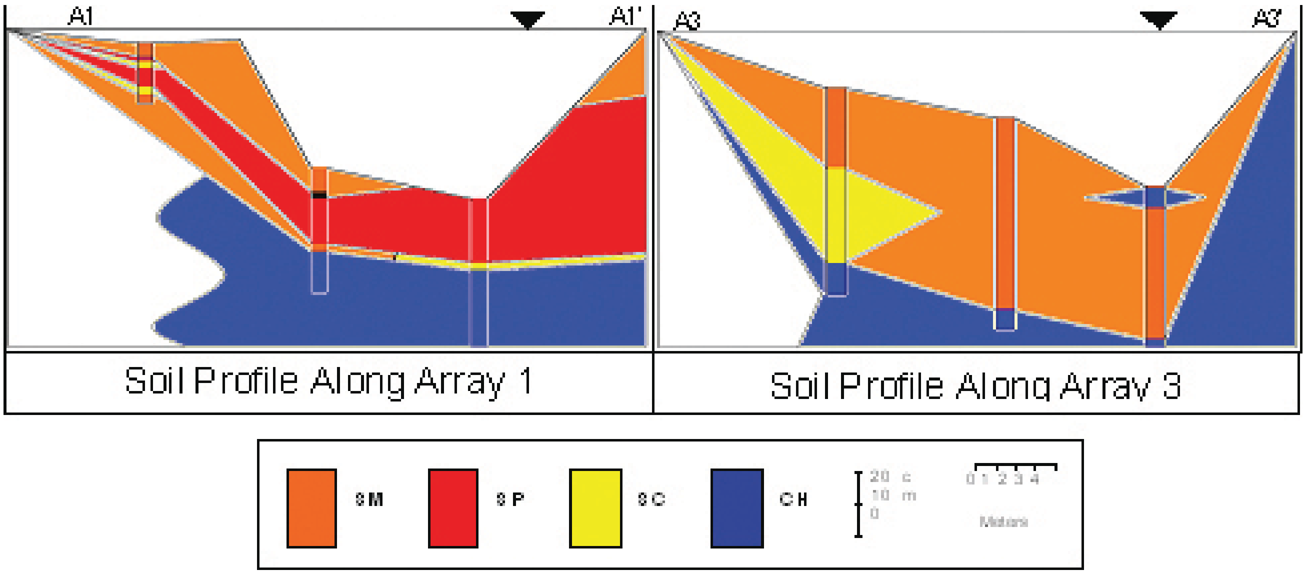

Figure 8. Cross-sectional view of soil distribution along specified arrays in the Bogue Phalia River at the Mark Rd Wading Station.

National Weather Service flood inundation mapping

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The National Weather Service (NWS) is responsible for issuing river and flood forecasts and warnings to mitigate the loss of life and property. Current NWS text-based products are utilized by emergency managers (EMs). One of the most often requested product from EMs is flood inundation mapping to show the areal extent of flooding. Flood inundation maps would translate the forecasted stages into inundation areas, making it easier for EMs to take action and alert the public. They would also prove invaluable to EMs in their outreach, mitigation, and educational efforts

By partnering with the Federal Emergency Management Agency (FEMA) and local communities, the NWS is developing flood inundation maps for their forecast locations. When a community performs flood studies to update FEMA Flood Insurance Rate Maps (FIRMs), much of the necessary data are available to develop flood inundation maps. For a small incremental cost above the cost to develop FIRMs, flood inundation maps at various stages above the NWS-established flood stage are being developed. This collection of maps will form a flood inundation map library that can be served up to the public via the Internet.

The NWS has partnered with FEMA and developed flood inundation map libraries at about 15 locations across the country. Currently, work is ongoing to produce these maps for an additional 30 sites in the states that border the Gulf of Mexico. The NWS has established a website and web structure to serve this data up to the public.

Keywords: Floods, Hydrology, Management and Planning, Models

Potential for recharge in agricultural soils of the Mississippi Delta

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Ground water models predict that 5 percent or less of precipitation in the Mississippi Delta region recharges the heavily-used alluvial aquifer; however high concentrations of agricultural chemicals in ground water suggest more substantial recharge. In a preliminary assessment of the potential for aerial recharge through the agricultural soils of the Bogue Phalia basin in the Mississippi Delta, we applied a method for rapidly measuring field-saturated hydraulic conductivity (K_{fs}) in 26 locations in cotton and soybean fields. The technique makes use of a portable falling-head, small-diameter, single-ring infiltrometer and an analytical formula for Kfs that compensates both for falling head and for subsurface radial spreading. Soil samples were also collected at the surface and at about 6 cm depth at each location for particle size analysis. K_{fs} values are generally higher than anticipated and vary over more than three orders of magnitude from 1×10^{-2} to 5×10^{-6} cm/s. There is also a correlation between K_{fs} and mean particle size which may prove useful in generalizing recharge rates over larger areas. A 2-m ring infiltration test is planned that will include the use of tracers and subsurface instruments for measuring water content and matric potential from the near surface to about 5 m to evaluate flow and transport below the root zone.

Aerobic-anaerobic lagoon evaluation in a small rural community in Columbia, South America

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Environmental State agencies have been supporting the construction of Wastewater Treatment Plants (WTPs) in Colombia, South America. There is not much technical evaluation of the performance of these WTPs. The objective of this research was to evaluate the performance of an aerobic-anaerobic lagoon located in the rural area of Palmira City, Valle del Cauca. The lagoon was constructed around 1984 and was originally designed for 240 people. However, uncontrolled habitat growth in the study area has resulted in the treatment plant receiving wastewater from approximately 500 people. Water quality data were collected between September and November, 2006 on the influent and effluent of the system. *In-situ* water quality measurements (temperature, pH, and dissolved oxygen) were observed every hour for 24 hours during five different days. Composite samples of every day were analyzed in the laboratory for chemical oxygen demand, five-day biochemical oxygen demand, coliforms, solids, conductivity, acid, oil and grease, nitrogen, and phosphorus. The lagoon reached the efficiency values according to standards declared by the 1984 Colombian National Government Law of Permit Limits. There was no preliminary treatment of the wastewater prior to reaching the lagoon; therefore, the system was trapping a lot of sediments and the actual effective volume of the WTP decreased approximately 65% from its original design. The lagoon was mainly working under anaerobic conditions because observed dissolved oxygen values were very low. The effluent of the lagoon can be used for crop irrigation or be discharged into a water body.

Keywords: Treatment, wastewater, and water quality

student presenter

The phytoplankton monitoring network

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The Phytoplankton Monitoring Network (PMN) is a volunteer regional data management network to assist the Harmful Algal Bloom Observing System (HABSOS) effort. PMN is an education and outreach program developed by NOAA's National Ocean Service to engage school and community volunteer groups in phytoplankton sampling and identification and to raise awareness of harmful algal blooms. The National Coastal Data Development Center (NCDDC) partnered with PMN to create an end-to-end data management system for the volunteers. Members are provided an on-line data entry tool to submit data, and are then able to visualize and analyze their own validated data as well as from Network peers in an Internet Geographic Information System (GIS) environment. Approved data is mapped to (www.ncddc.noaa.gov/website/SEPMN/viewer.htm). NCDDC has partnered with the newest NOAA Cooperative Research Institute, the Northern Gulf Institute (Mississippi State University, University of Southern Mississippi, Louisiana State University, Florida State University, and Dauphin Island Sea Lab) to train and equip the volunteer organizations.

Big Sunflower River water quality assessments following streamflow augmentation

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The Big Sunflower River is listed on the EPA Section 303(d) list of Impaired Waterbodies of Mississippi. Contributing to the decline in conditions in this system are the substantial decreases in baseflow during the late summer and fall as groundwater levels decline. In an attempt to improve water quality and ecological conditions the Yazoo Mississippi Delta Joint Water Management District has begun supplementing flows during critical periods using groundwater for the past 2 years. To assess the impact of streamflow augmentation we evaluated water quality trends through the 2006-2008 pumping periods and assessments of the quality of the riparian plant community during the summers of 2006 and 2007. Measurements of water quality (Temperature, Dissolved Oxygen, pH, Specific Conductance and Turbidity) were made at 11 locations on the Sunflower River between Indianola and North Clarksdale, at one location associated with the augmentation pumps and 1 location along the channel used to funnel pumped water to the Sunflower River. In general, water quality continued to be better above Clarksdale, with improvements in dissolved oxygen concentrations associated with increased flows and decreased temperatures. The riparian plant community was analyzed over a more focused portion of the upstream drainage basin with 2 sites south of Clarksdale, 2 sites north of Clarksdale and 1 within the city itself. Clarksdale represented a clear break in plant composition with higher numbers of moncots, invasive species and weedy early succession species encountered upstream (North) of Clarksdale. Taken together, there is a strong indication that supplementing natural stream discharge can have beneficial impacts on water quality in the near term and on broader measures of ecosystem quality in the long term.

Keywords: Ecology, Surface Water, Water Quality, Wetlands

1:24,000-scale watershed boundary dataset for Mississippi

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The U.S. Geological Survey, in cooperation with the Mississippi Department of Environmental Quality, U.S. Department of Agriculture Natural Resources Conservation Service, Mississippi Department of Transportation, U.S. Department of Agriculture Forest Service, and the Mississippi Automated Resource Information System developed a 1:24,000-scale Watershed Boundary Dataset for Mississippi including watershed and subwatershed boundaries, codes, names, and areas. The Watershed Boundary Dataset for Mississippi provides a standard geographical framework for water-resources and selected land-resources planning. The original 8-digit subbasins (Hydrologic Unit Codes) were further subdivided into 10-digit watersheds and 12-digit subwatersheds—the exceptions being the Delta part of Mississippi and the Mississippi River inside levees, which were subdivided into 10-digit watersheds only. Also, large water bodies in the Mississippi Sound along the coast were not delineated as small as a typical 12-digit subwatershed. All of the data—including watershed and subwatershed boundaries, subdivision codes and names, and drainage-area data—are stored in a Geographic Information System database.

Keywords: Hydrology, Surface Water, Management and Planning, Water Quantity, Water Supply

DELTA WATER RESOURCES

Dean Pennington, Moderator

Climatological and cultural influences on annual groundwater decline in the Mississippi Delta shallow alluvial aquifer

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Characterization of water quality in unmonitored streams in the Mississippi Alluvial Plain, Northwestern Mississippi, May-June 2006

Jeannie R. Bryson, Richard H. Coupe, and Michael A. Manning
U.S. Geological Survey

Influence of surface-water recharge on the potential for agricultural nutrient and pesticide transport to the Mississippi River alluvial aquifer, Northwestern Mississippi

Heather L. Welch and Melinda Dalton
U.S. Geological Survey

Use of a field method for determining hydraulic conductivity in soils in the Bogue Phalia Basin in the Mississippi River alluvial plain

Claire E. Rose and Richard H. Coupe
U.S. Geological Survey

Climatological and cultural influences on annual groundwater decline in the Mississippi Delta shallow alluvial aquifer

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The shallow alluvial aquifer in the Mississippi Delta region is heavily used for irrigation of corn, soybeans, and cotton, as well as for rice flooding and filling aquaculture ponds in the prominent catfish industry. Water volume in the aquifer is subject to seasonal declines and annual fluctuations caused by both climatological and crop water use variations from year-to-year. The most recently documented water volume decline in the aquifer is estimated at 500,000 acre-feet. This may represent a worst-case situation in which severe drought combined with consequent increased demand for irrigation. Additionally, the region was impacted by historic drought again during the growing season of 2007, and impacts to the aquifer have not yet been quantified.

Available climate, crop acreage, irrigation water use, and groundwater decline data from Sunflower County was used to represent the climate-groundwater interactions in the Mississippi Delta region. This research resulted in a model that simulates the effects of climatic variability, crop acreage changes, and specific irrigation methods on consequent variations in the water volume in the aquifer. Climatic variability was accounted for by predictive equations that related annual measured plant water use (irrigation) to growing season precipitation amounts. This derived relationship allowed the application of a long-term climatological record (45 years) to simulate the cumulative impact of climate on groundwater use for irrigation.

Results indicate that under the present use scenario, groundwater will remain stable in wet to normal precipitation years, but will decline during drought periods and not recover fully. Use of the model to simulate changes in irrigation methods and crop acreages from 2008 through 2053 shows potential to stabilize the water volume in the aquifer through implementation of various management strategies. The model appears to be a tool that can be used to assess the impact of climatic variability and changes in the cultural practices on groundwater use in the region—a tool that will be useful in making management decisions that will allow sustainable use of the groundwater resource.

Keywords: Climatological processes, Groundwater, Irrigation, Management and Planning, Water Use

Introduction

Agricultural producers in Mississippi are increasingly relying on irrigation to insure that crops receive the right amount of water at the right time to enhance yields. The shallow alluvial aquifer is the most heavily developed source of groundwater in the Mississippi Delta region and the entire state (Figure 1). The aquifer is heavily used for irrigation of corn, soybeans, and cotton, as well as for rice flooding and filling aquaculture ponds in the prominent catfish industry. Demand for the groundwater resource continues to grow at a rapid rate (Figure 2).

Water volume in the aquifer is subject to seasonal declines and annual fluctuations caused by both climatological and crop water use variations from year-to-year. These declines can be dramatic and are most notable during the period April-October of each year, particularly in years when normal crop water demands are accentuated by concurrent abnormally dry climatic conditions. Recharge during the remainder of the year has recently been insufficient to restore water volume, and the aquifer is now being mined at the approximate rate of 300,000 acre-feet per year (Figure 3). To underscore the critical nature of this water problem, the most recently documented water volume decline in the aquifer (October 2005-October 2006) is estimated at 500,000 acre-feet (Pennington, 2006). This may represent a worst-case situation in which severe drought combined with consequent increased demand for irrigation. It is estimated that water use for row crops doubled during this period (Pennington, 2006). Additionally, the region was impacted by historic drought again during the growing season of 2007, and impacts to the aquifer have not yet been quantified.

It is of critical importance to understand how climatological variability and cultural uses of the water cause the groundwater volume in the aquifer to vary. It is also critical to discover and implement management strategies to change irrigation methods and to use precipitation and other surface water sources as substitutes for aquifer withdrawals and thereby reduce the use of groundwater in the region. Stopping the consistent drop in water volume in the aquifer will require a curtailment averaging about 300,000 acre-feet of groundwater use each year, and the highest priority of this research project is to find and recommend solutions to this problem. This information is essential to agricultural producers in the region and to planners in the Yazoo Mississippi Delta Joint Water Management District who must design sustainable water use scenarios which will allow continuation of the productivity of the region.

Background Information

Agriculture is the major water consumer in the southeast region, and aquaculture specifically has the potential to become disproportionately consumptive. For example, most row crops in the region require 30-40 cm/yr, whereas catfish farming requires up to 100 cm/yr under current practices. In the Delta region of Mississippi where nearly 60% of U.S. farm raised catfish are produced, catfish production accounts for about 28% of all water used (Pennington, 2005).

Research to reduce reliance on groundwater in aquaculture has shown remarkable potential reductions in groundwater through use of management strategies to create storage capacity which can capture rainfall to keep ponds filled. For example, studies show the potential to reduce consumption of groundwater in delta catfish ponds by nearly 70% annually through precipitation capture (Pote and Wax, 1993; Pote, et al, 1988; Cathcart et al., 2006). Extension Services in Alabama and Louisiana include variations of those strategies as industry best management practices for reducing groundwater use in those states (Auburn University, 2002; LCES, 2003). In rice production, straight levee systems and use of multiple inlets have been shown to be specific irrigation methods that significantly reduce water use (Smith et al., 2006). Intermittent (wet-dry) irrigation has been shown to reduce water use and non-point source runoff by up to 50% with no yield losses in Mississippi field trials (Massey et al., 2006).

Methods

In order to assess the change in volume of water in the aquifer, it was necessary to collect climatological data, crop data, and water use data. In this study, these data were collected and analyzed for Sunflower County only. It was assumed that climate and cultural land uses (crops, acreages, irrigation methods) in Sunflower County were representative of the entire Delta region. These data were used in a model that was developed to identify and account for relationships between climatological variability and cultural water use. The model is interactive, allowing the user to change input values and alter the final output, thus allowing for specific scenarios to be simulated. Successive alternative combinations of variables were simulated with the model to determine possible methods and strategies to aid in groundwater conservation and management.

Climatological data
The climate record from Moorhead, MS (located centrally in Sunflower County) was used in the analysis. Specifically, daily precipitation data from the U.S. Historical Climatology Network were acquired and inspected for completeness. The data were arrayed in an Excel spreadsheet, and missing data were identified. Gaps in the data were filled with data from the next-nearest climate station location. The result was a serially complete and homogeneous daily record of precipitation from 1949-2006. The precipitation data were then organized into growing season totals for each year. Growing season was defined as May through September.

Crop data
Crop data for cotton, rice, soybeans, and catfish were collected from the U.S. Department of Agriculture's National Agricultural Statistics Service (NASS). For the four crops, total acres and total irrigated acres were retrieved for the years 2002-2006 (the only years for which water use data were available). Similar data for corn, which was not reported in NASS, were obtained through personal communication with the county agent for Sunflower County. The percentages of each type of irrigation or management method used for each of the five crop types in 2006 are shown in Table 1.

Water use data
Water use data were supplied by Yazoo-Mississippi Delta Joint Water Management District (YMD) in acre-feet/acre (A-F/A). For 2005 and 2006, these data were divided into the amount of water used by each specific irrigation method for cotton, corn, soybeans, and rice (as determined by a survey of 141 sites monitored by YMD shown in Figure 4), as well as the total average water use for each of the crops. For 2002-2004, only the total average water use amount for each of the four crops was provided. Therefore, a ratio based on the 2005-2006 specific irrigation methods-to-total average water use was formulated to identify relationships between the given average water use and constituent water use amounts associated with each specific irrigation method for the years 2002-2004.

Catfish water use is dependent upon whether the producer uses the maintain-full (MF) or the drop-add (6/3) management scheme. Only total average water use by catfish ponds was provided by YMD, also in A-F/A, and only for 2004 and 2006. So, the catfish water use model developed by Pote and Wax (1993) was used with the Moorhead climate data to estimate the amounts of water used by each of the management schemes in Sunflower County for the period 1960-2006. Then a ratio between the total average water use and the water use associated with the two possible management schemes in catfish ponds was developed, similar to the water use amounts determined for the specific irrigation methods of the row crops and rice.

These water use data for row crops, rice, and aquaculture were combined with acreage data to calculate the total amount of water used for irrigation for each crop in the county in 2006. This analysis provided a prototype evaluation of water use by crop type.

Rainfall-water use relationship
Recognizing that the amount of rainfall during a growing season significantly influences the amount of irrigation needed, a method was developed to account for this climatological variability. Growing season rainfall was regressed against the total average water use for cotton, corn, soybeans, and rice for 2002-2006 to develop a function for estimating the amount of water use by crops based on the amount of rain received. Catfish water use was obtained from model-estimates based on daily rainfall rather than total growing season rainfall. In this manner, water use by all five crops was linked to climatic variability each year.

Model development
The purpose of this research is to determine causes of short-term aquifer declines resulting primarily from cultural water uses and climatological processes. The climate data, crop data, water use data, and rainfall-water use relationships were used to develop a model that could assess water volume declines in the aquifer over a growing season. Based on crop average water use relationships in effect in Sunflower County in 2006, the model calculated amounts of water taken from the aquifer by each specific irrigation method and management method for each of the five crops. The model then summed the specific water uses for each year, resulting in a total annual reduction in the volume of water in the aquifer.

Using the 2006 Sunflower County land use and crop water use relationships with rainfall-water use relationships developed for each crop, growing season precipitation from the past 45 years (1961-2006) was used as a variable in the model to estimate the total water use for each year 45 years into the future (2008-2053). The average of the annual recharge volumes measured in the aquifer between1989-2006 was then used with the modeled water volume declines each year to characterize the cumulative water volume changes over the 45-year period. Then the model was used to simulate different scenarios of water use by changing crop acreages or irrigation methods from the static 2006 data, permitting assessment of changes in water volumes over time under different land use and management conditions. Consequently, the model was used to formulate recommendations for monitoring and managing water volume changes in the aquifer.

Results

The model is an interactive Excel spreadsheet consisting of 45 blocks with each block representing one year (Figure 5). Each block is comprised of 13 rows and 15 columns. It is interactive through column 'G' with columns 'H' through 'O' containing formulas based on the information entered in columns 'A' through 'G.' Single or multiple variables can be changed to alter the overall water use amount given in cell 'O13.'

Results of the first 45-year model simulation (2008-2053) using Sunflower County 2006 static cultural water uses (Table 1) for each year with rainfall recorded from 1961-2006 are shown in Figure 6. In this scenario, it can be seen that water volume in the aquifer begins at about -300,000 A-F and consistently drops to about -600,000 A-F in the first eight years. The drawdown stabilizes and water volume even rises between about 2015-2040, then water volume again drops consistently to about -1,000,000 A-F during the period 2041-2053. Subsequent simulations were conducted with alternative scenarios of land uses, irrigation methods, and management strategies employed.

Figure 7 shows the results when water use practices were changed to reflect more conservative water use methods for each crop: 100% pivot irrigation for cotton; 100% multiple inlet for rice; 40% straight, 3% pivot, 55% contour, and 2% zero grade for soybeans; and 25% MF, 75% 6/3 management strategy for catfish. The acreage planted in corn was also doubled for this model simulation. It can be seen that these changes resulted in consistent recovery of water volume beginning in about 2016, ending in 2053 with a positive volume of around 600,000 A-F.

Figure 8 shows the results when water use practices were changed to reflect the least conservative water use methods for each crop: cotton and corn 100% furrow irrigation; rice 100% contour; soybeans 100% pivot; and catfish 100% maintain full. These changes resulted in consistent water volume declines from the beginning of the 45-year period, ending at about -4,000,000,000 A-F in 2053.

Conclusions

The model is a sensitive tool that is useful for various forms of analysis. Growing season precipitation can be used to simulate interannual climatological variability through time. Crop acreages and irrigation methods can be used to account for cultural influences on water use through time. This combination of climatological and cultural drivers of groundwater demand can be used in the model to determine best and worst case scenarios in overall groundwater use in the aquifer. Results indicate that the aquifer responds to small changes in water use methods, and that the aquifer water volume is apparently very strongly related to changes in water use methods associated with climatological variability.

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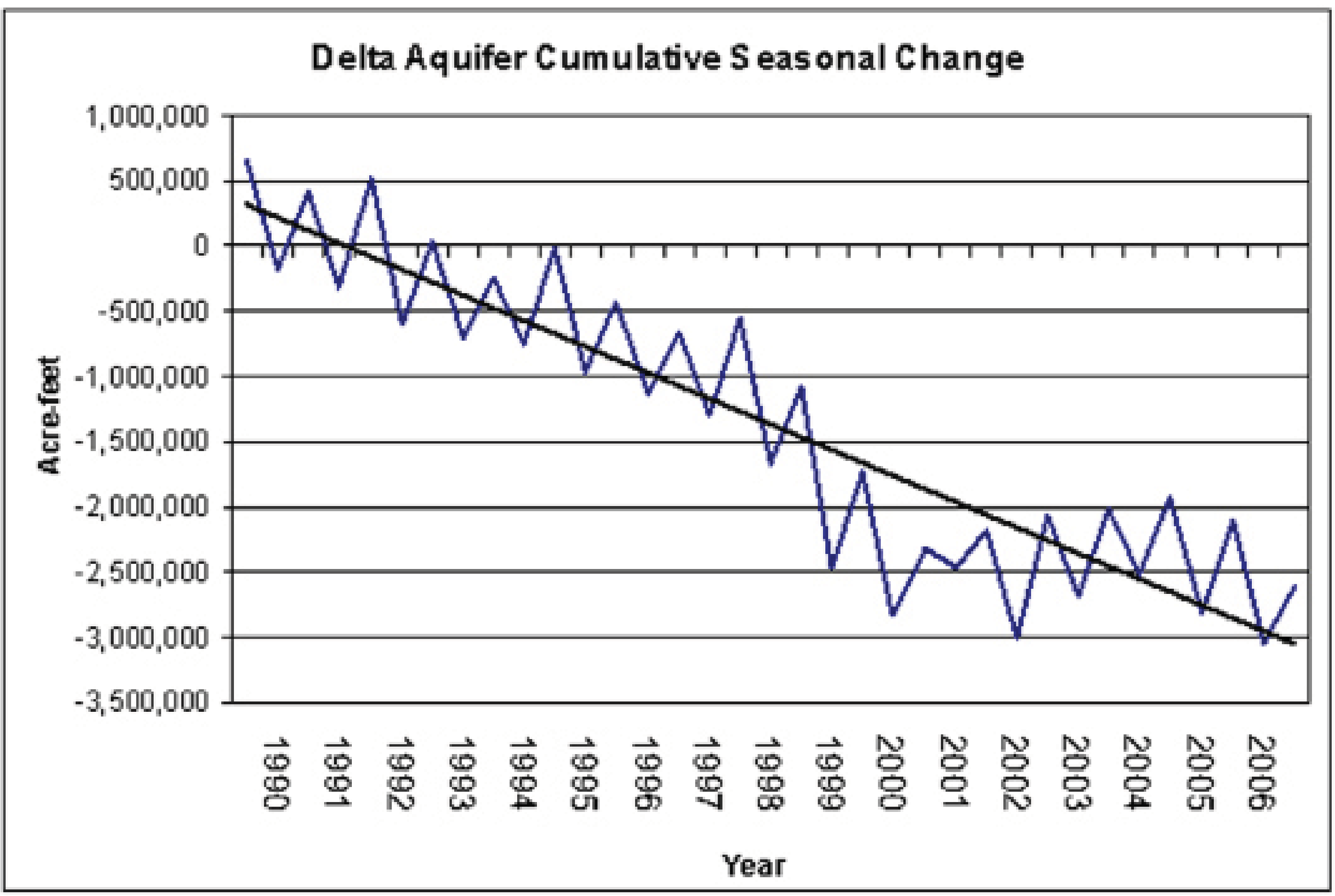
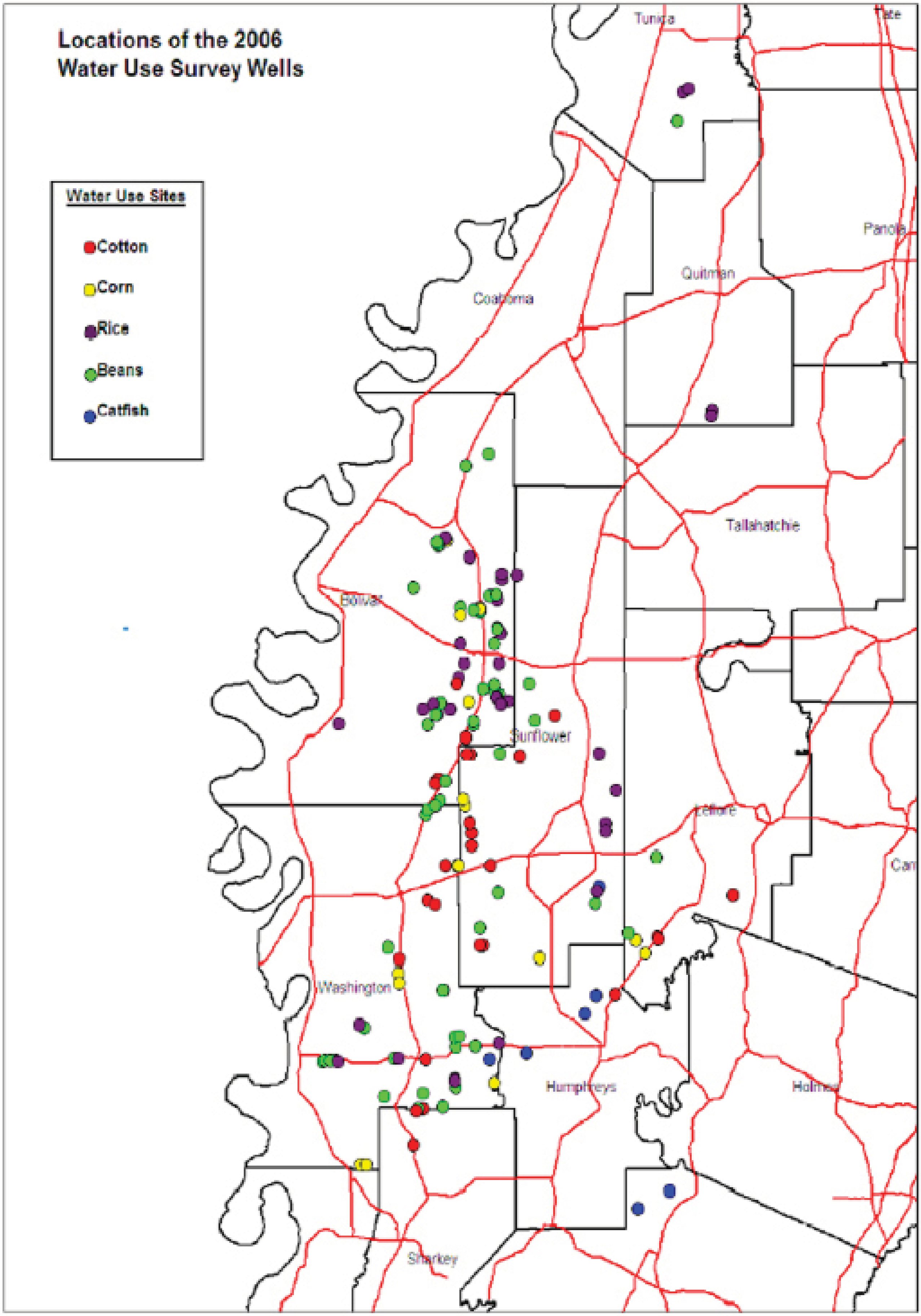
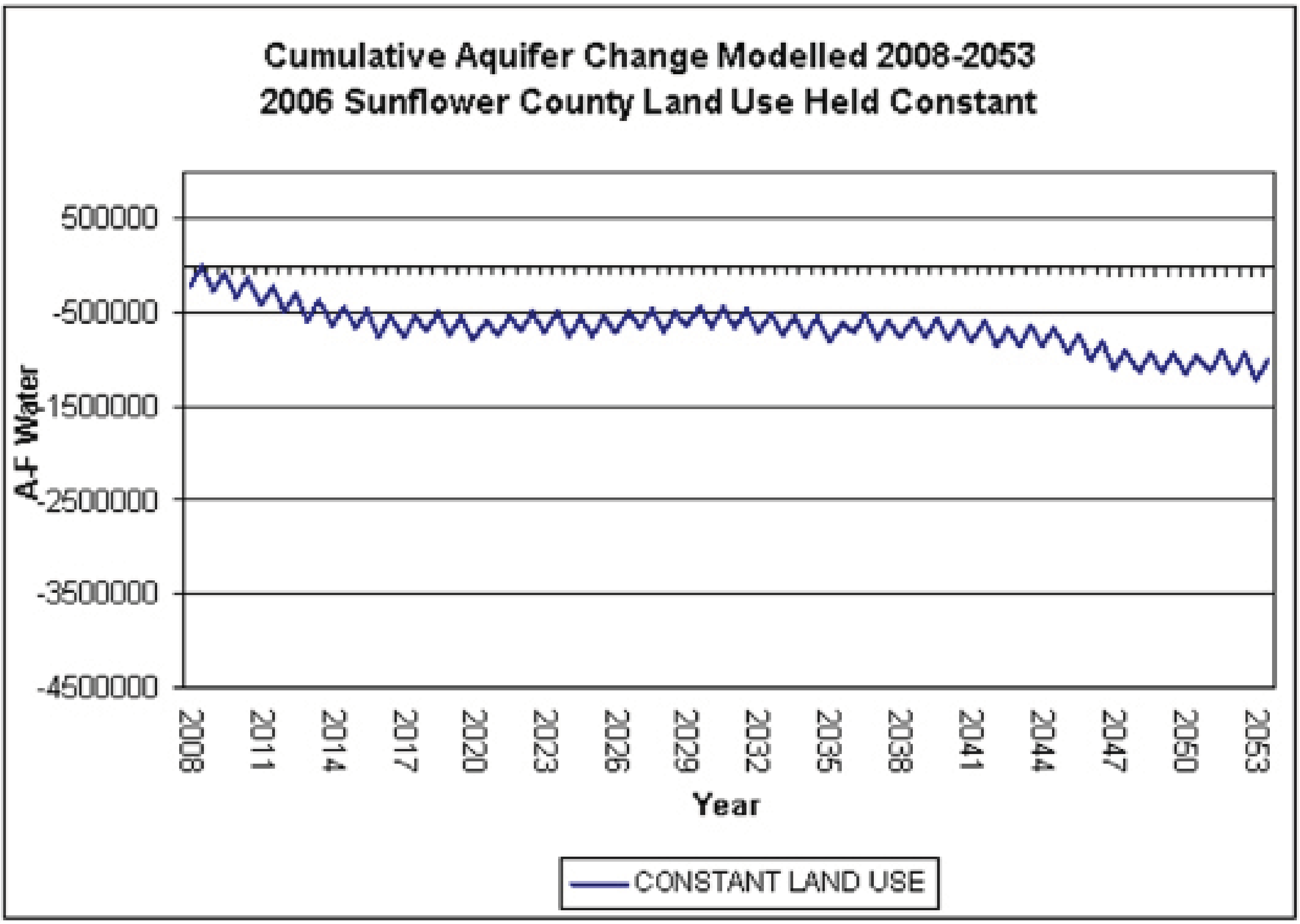
Table 1: Irrigated acres and type of irrigation or management method used for each crop type in Sunflower County, 2006

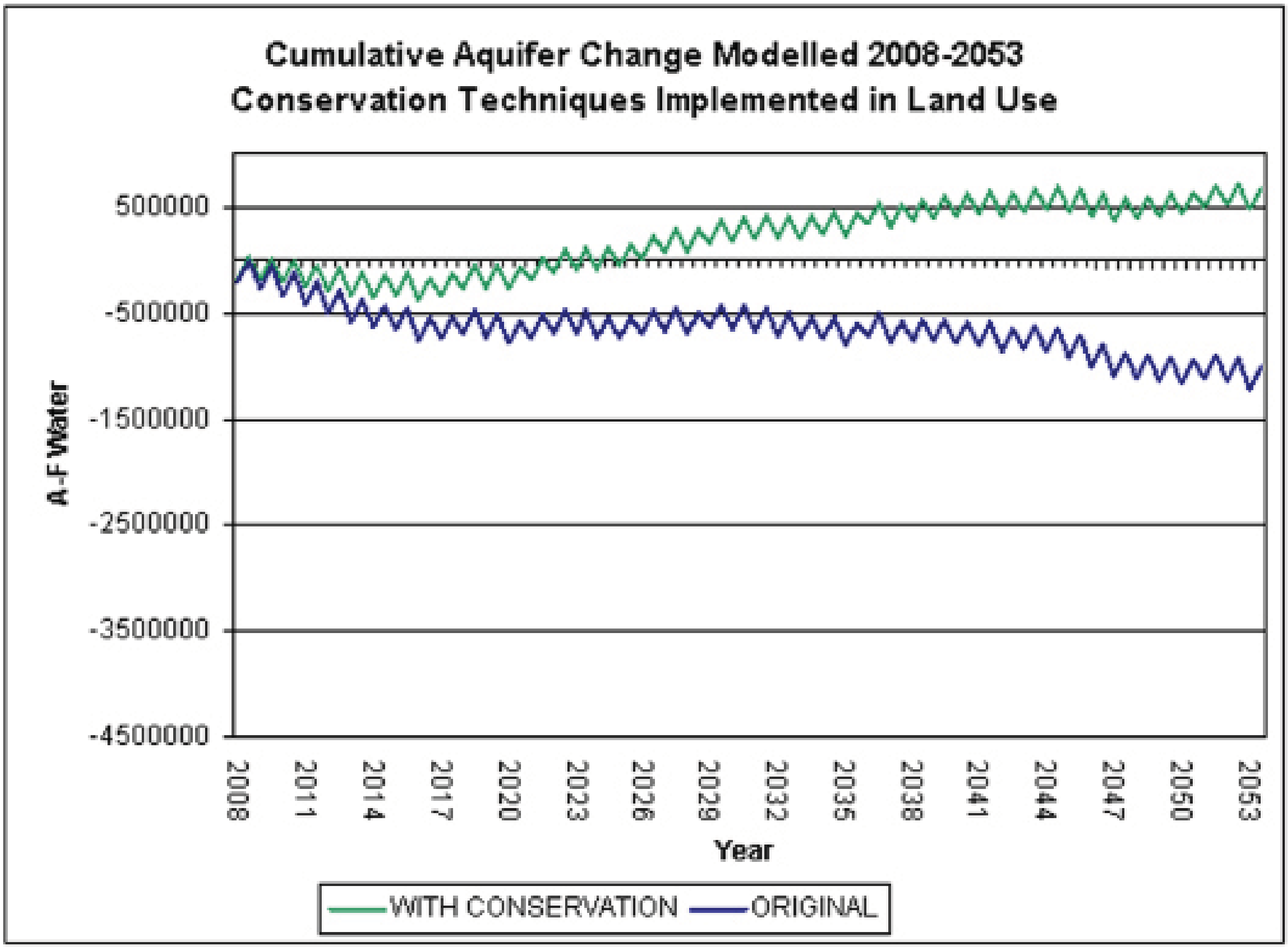
Crop	Acres irrigated	% furrow	% straight	% pivot	% contour	% zero grade	% multiple inlet	% MF	% 6/3
cotton	60,300	81		19					
rice	27,600		56		20	12	12		
corn	8,910	100							
soybeans	86,350	49	50	3	6	2			
catfish	24,300							42	58

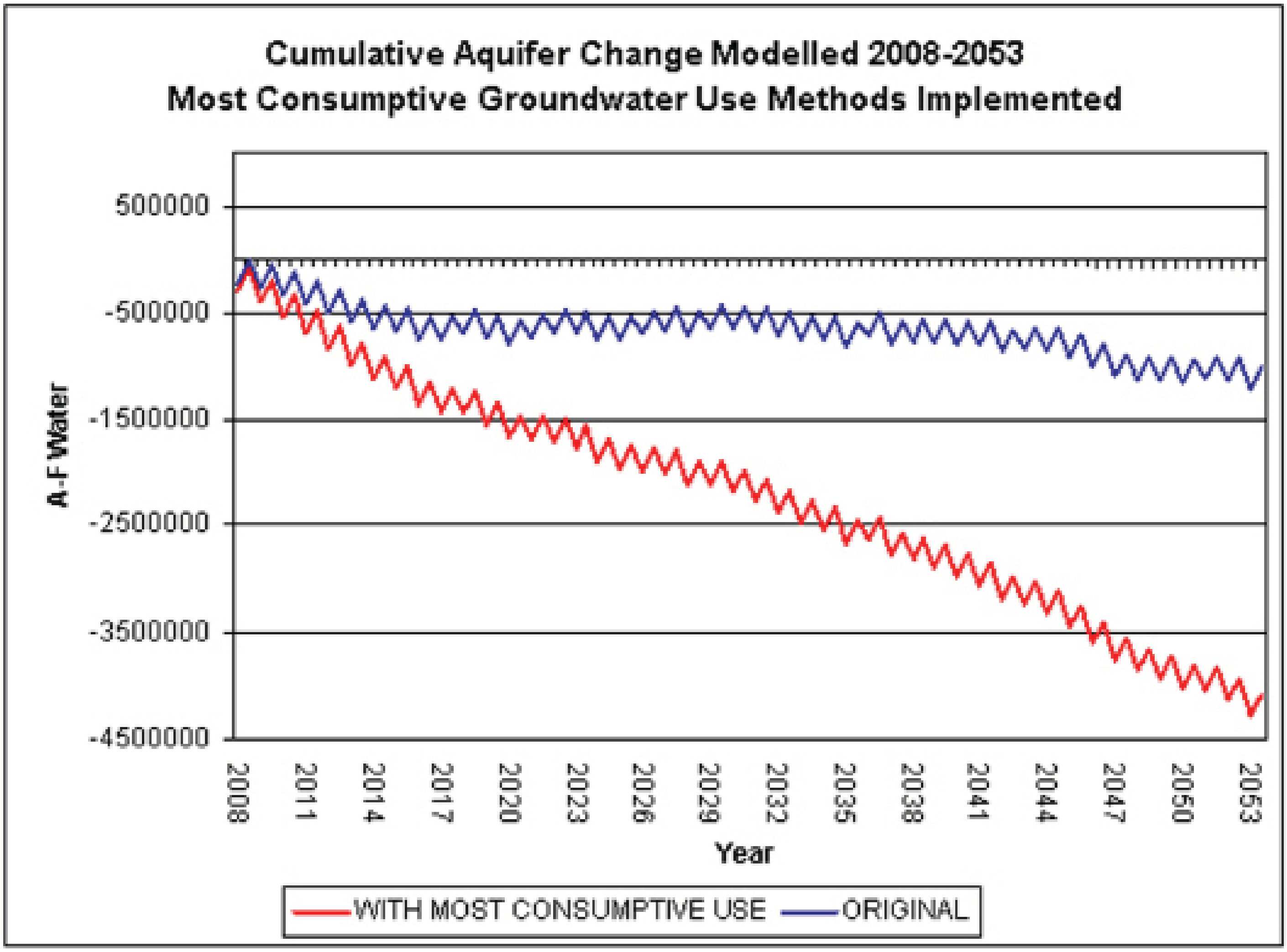




Locations of the 2006
Water Use Survey Wells
Water Use Sites
Cotton
Corn
Rice
Beans
Catfish
Tunica
Tate
Panola
Quitman
Coahoma
Tallahatchie
Bolivar
Sunflower
Leflore
Washington
Humphreys
Holmes
Sharkey


Cumulative Aquifer Change Modelled 2008-2053
2006 Sunflower County Land Use Held Constant
500000
-500000
-1500000
-2500000
-3500000
-4500000
A-F Water
2008
2011
2014
2017
2020
2023
2026
2029
2032
2035
2038
2041
2044
2047
2050
2053
Year
CONSTANT LAND USE


Cumulative Aquifer Change Modelled 2008-2053
Conservation Techniques Implemented in Land Use
500000
-500000
-1500000
-2500000
-3500000
-4500000
A-F Water
2008
2011
2014
2017
2020
2023
2026
2029
2032
2035
2038
2041
2044
2047
2050
2053
Year
WITH CONSERVATION
ORIGINAL



Cumulative Aquifer Change Modelled 2008-2053
Most Consumptive Groundwater Use Methods Implemented
500000
-500000
-1500000
-2500000
-3500000
-4500000
A-F Water
2008
2011
2014
2017
2020
2023
2026
2029
2032
2035
2038
2041
2044
2047
2050
2053
Year
WITH MOST CONSUMPTIVE USE
ORIGINAL

Characterization of water quality in unmonitored streams in the Mississippi Alluvial Plain, Northwestern Mississippi, May-June 2006

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The Mississippi Department of Environmental Quality is required to develop restoration and remediation plans for water bodies not meeting their designated uses, as stated in the U.S. Environmental Protection Agency's Clean Water Act section 303(d). The majority of streams in northwestern Mississippi are on the 303(d) list of water-quality limited waters. Agricultural effects on streams in northwestern Mississippi have reduced the number of unimpaired streams (reference streams) for water-quality comparisons. As part of an effort to develop an index to assess impairment, the U.S. Geological Survey collected water samples from 52 stream sites on the 303(d) list during May-June 2006, and analyzed the samples for nutrients and chlorophyll.

The data were analyzed by trophic group as determined by total nitrogen concentrations. Seven constituents (nitrite plus nitrate, total Kjeldhal nitrogen, total phosphorus, orthophosphorus, total organic carbon, chlorophyll *a*, and pheophytin a) and four physical property measurements (specific conductance, pH, turbidity, and dissolved oxygen) were determined to be significantly different ($p < 0.05$) between trophic groups. Total Kjeldhal nitrogen, turbidity, and dissolved oxygen were used as indicators of stream productivity with which to infer stream health. Streams having high total Kjeldhal nitrogen values and high turbidity values along with low dissolved oxygen concentrations were typically eutrophic (abundant in nutrients), whereas streams having low total Kjeldhal nitrogen values and low turbidity values along with high dissolved oxygen concentrations were typically oligotrophic (deficient in nutrients).

Keywords: water quality, surface water, ecology

Influence of surface-water recharge on the potential for agricultural nutrient and pesticide transport to the Mississippi River alluvial aquifer, Northwestern Mississippi

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In December 2006, the Agricultural Chemical Transport (ACT) topical team of the U.S Geological Survey National Water Quality Assessment (NAWQA) Program began a study in northwestern Mississippi to evaluate the influence of surface-water recharge on the occurrence of agriculturally related nutrients and pesticides in the Mississippi River alluvial aquifer. A series of nine piezometers was installed along a transect across the Bogue Phalia, a stream located near Leland, Miss., Washington County. Water levels were monitored continuously in nine piezometers and in one monitoring well approximately 1 mile north of the site. Local ground-water flow direction was determined using bi-annual water-level data collected by the Yazoo-Mississippi-Delta Joint Water Management District (YMD) in selected irrigation wells screened in the alluvial aquifer. Routine and event-driven water-quality samples were collected from 2006-2007 and were evaluated for major ions, nutrients, organic carbon, and physical parameters. In addition, water samples were analyzed for two commonly used pesticides in the area, atrazine and glyphosate.

Regionally, flow in the alluvial aquifer tends to be toward the axis of the Mississippi Embayment, which is the Mississippi River. Local ground-water flow patterns were evaluated to determine potential movement of nutrients and pesticides from streams to the alluvial aquifer. Historically, water-quality results indicate that nutrients are present in ground water. Although pesticides have occasionally been detected in ground-water samples, their detections indicate that there is potential for anthropogenic contamination of the alluvial aquifer. Data collected as part of this study will be used to quantify surface-water recharge to the alluvial aquifer as a transport mechanism for nutrient and pesticide movement into the ground-water system.

Key Words: Water Quality, Ground Water, Agriculture, Hydrology

Introduction

In 2006, the Mississippi Embayment (MISE) Study Unit of the National Water Quality Assessment (NAWQA) Program began data-collection activities in the Bogue Phalia Basin, northwestern Mississippi, as part of the U.S. Geological Survey's (USGS) Agricultural Chemical Transport (ACT) Study (http://in.water.usgs.gov/NAWQA_ACT/index.shtml). The Bogue Phalia Basin (fig. 1), one of seven watersheds currently being studied to determine the mechanisms and extent to which natural and agricultural factors influence chemical transport and water quality, is one of the most agriculturally productive (cotton, rice and soybeans) areas in the Nation. Data collection and analysis in each ACT study basin are designed similarly and a multi-scale approach is used to evaluate water and chemical transport. An integral part of the multi-scale approach is a network of shallow wells, in-stream piezometers, and surface-water gages that are used to monitor water levels, streamflow, and water quality.

The data-collection network for Bogue Phalia was designed to describe ground- and surface-water interaction and its effects on water quality. A series of shallow ground-water wells and in-stream piezometers were installed along a transect that crosses the Bogue Phalia (fig. 1). Continuous and synoptic water levels were recorded in each well beginning May 2006. An existing USGS real-time surface-water monitoring station is located less than a mile downstream from the transect and provides continuous measurements of gage height, discharge, and precipitation. Surface- and ground-water samples were collected quarterly beginning in late spring 2006 and after significant storm events in June and July 2007 and February 2008 following standard sampling protocols described by Koterba and others (1995) and the USGS National Field Manual (USGS, variously dated). Samples were analyzed for field parameters, major ions, sulfide, and nutrients. Additionally, surface-water-quality samples are collected at the Bogue Phalia weekly to bi-weekly as part of the NAWQA Status and Trends Assessment program (http://water.usgs.gov/nawqa/studies/regional_assessments.html).

The ACT study in the Bogue Phalia basin was designed to: (1) describe ground- and surface-water interaction in the Bogue Phalia basin; (2) determine whether surface water could be contaminating the shallow ground-water system; (3) determine the extent to which applications of pesticides and nutrients for agricultural production are affecting surface- and ground-water quality; and (4) use information developed as a result of this study to help further understand processes in similar environmental settings.

Ground-Water/Surface-Water Interaction

The Mississippi River alluvial aquifer is recharged from the west by the Mississippi River, from underlying aquifers and from the bluff hills to the east. But the largest contributor to recharge, larger than all the other sources combined, is infiltrated precipitation, which accounts for only 2.6 inches of recharge annually (Arthur, 2001). Understanding how, when, and if surface water recharges the Mississippi River alluvial aquifer is an important component to developing an understanding of how surface water may be affecting the water quality of the alluvial aquifer.

Ground-Water Flow Patterns

Regional ground-water flow patterns in the alluvial aquifer are typically from east to west toward the Mississippi River (Arthur, 2001); during the study period local ground-water flow in the alluvial aquifer was toward the Yazoo River, generally west to east except in areas near the Mississippi River where flow remains east to west (fig. 2). All nine piezometers along the flowpath had ground-water levels fluctuate in response to precipitation; whether these increases are the result of infiltrated precipitation or contributions from surface-water recharge into the aquifer is not well understood. Piezometers installed in the streambed of the Bogue Phalia indicate surface water recharges the shallow ground-water system when stage rises above about 10 feet (Bryson, 2006); this was a value calculated during the summer of 2005 and may change seasonally with fluctuating water levels.

In-stream piezometers showed varying responses to rising stage in the Bogue Phalia due to rainfall, most likely a result of discontinuous silt and clay layers that affect the rate of water flow between surface and ground water. Piezometers installed in the left, center, and right channels tend to have more interaction with the surface water than the other piezometers as indicated by hydrographs of water-surface altitude (fig. 3). The left, center, and right channel piezometers' ground-water levels have similar timing and magnitude of response to rainfall events as the Bogue Phalia stage, even during low-flow periods when the magnitude of stage fluctuations in the Bogue Phalia are relatively small (fig. 3).

Water Quality

Water-quality data are being examined to determine the interaction between surface and ground water in the study area. Non-parametric multidimensional statistics (MDS) were used to evaluate the potential surface- and ground-water interactions along the Bogue Phalia transect. Although most typically used in ecological applications, MDS significance testing of group distinctions (among other characteristics) is fully applicable to water-quality studies (Dan Calhoun, U.S. Geological Survey Georgia Water Science Center, oral communication, 2008). Samples were grouped into four categories: ground water, surface water, wells in the hyporheic zone (in-stream piezometers), and alluvial aquifer wells. Specific conductance, total dissolved solids, and nutrient concentrations were the constituents used in initial comparisons between groupings. Unlike traditional quantitative plots, the axes of an MDS plot only function to indicate the similarity among groups and are otherwise meaningless (Chan et al, 2005); therefore, for the purposes of this paper, the axes are not included in figure 4.

Preliminary analysis of water chemistry data, September 2005 through December 2007, using MDS plots, indicate that while most of the samples from individual groups plot together, on several occasions samples from aerial recharge well 1 (AR1) plot more similarly with samples from the Bogue Phalia (fig. 4). Future analysis will focus on determining the factors that allow well AR1 to behave chemically more like surface than ground water. Analysis will include examining different constituent combinations and how these combinations may affect the distribution of water types in the MDS plots. Additionally by varying constituent combinations, MDS analysis will help identify which particular constituents contribute most in determining similarity of water types.

Initial specific conductance (SC) data (fig. 5) indicate interaction to some degree between all wells and surface water. SC in the Bogue Phalia gradually rises during low-flow conditions from ground-water input, but then declines rapidly during run off events when rain water forms a large component of flow. During some run off events, the SC is lowered in some of the piezometers, presumably due to dilution of the ground water with surface water (fig. 5). This relation seems to be more pronounced in well AR1, located on the east side of the Bogue Phalia, than the other piezometers, and under certain conditions the SC changes similarly with the stage of the Bogie Phalia. Previous hypotheses about the direction of ground water movement in the Bogue Phalia basin assumed ground water flowed east to west, toward the Mississippi River. It appears here that, at the small scale, ground-water flow direction is west to east and is more highly dependent upon soils and local gradients and less influenced by regional flow.

Discussion

The change in the Bogue Phalia from a gaining to a losing stream has been determined using temperature data collected during Hurricanes Katrina and Rita (Bryson, 2006). Under normal conditions, the Bogue Phalia is a gaining stream, but after large storm events (when the gage height rises greater than about 10 feet) the alluvial aquifer is recharged by the stream, and so the potential exists for the quality of water in the alluvial aquifer to be affected by the introduction of surface water that may be carrying anthropogenic compounds. Water-quality data indicate that the water sampled from in-stream piezometers and shallow alluvial wells appears to be, at times, a mixture of surface and ground water. After storm events, water in well AR1 appears to be chemically similar to water in the Bogue Phalia; whereas water sampled in the other wells and piezometers seems to be less affected by high flows on the Bogue Phalia, probably due to the flow direction of localized ground water. Continued data collection at the site will allow further development of this hypothesis. Additionally, refining the model used in MDS analysis will aid in defining which constituents are important for determining the extent of surface and ground water interaction during periods of high or low flow.

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Figure 1. Location of Mississippi Embayment Study Unit, Bogue Phalia Basin, and Agricultural Chemical Transport Study flowpath.

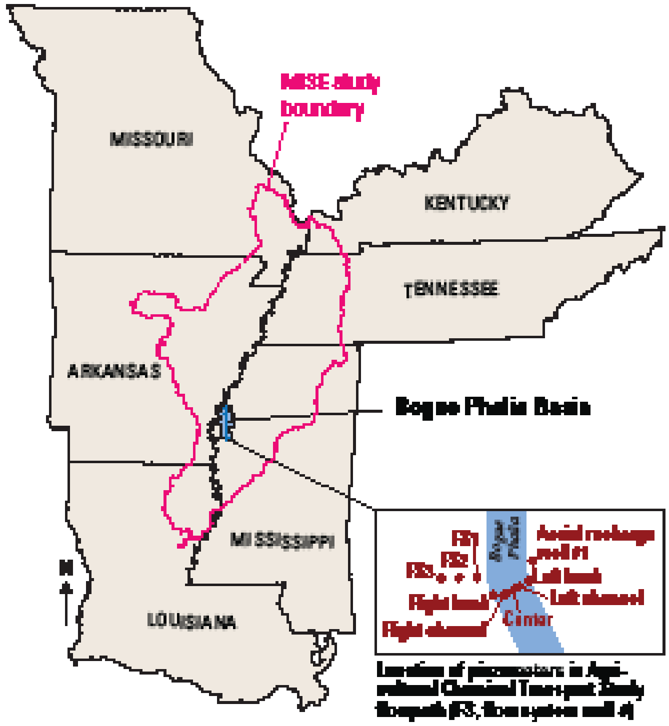


Figure 2. Potentiometric surface contours of the alluvial aquifer, fall 2006 and spring 2007 (Data from YMD, 2007).

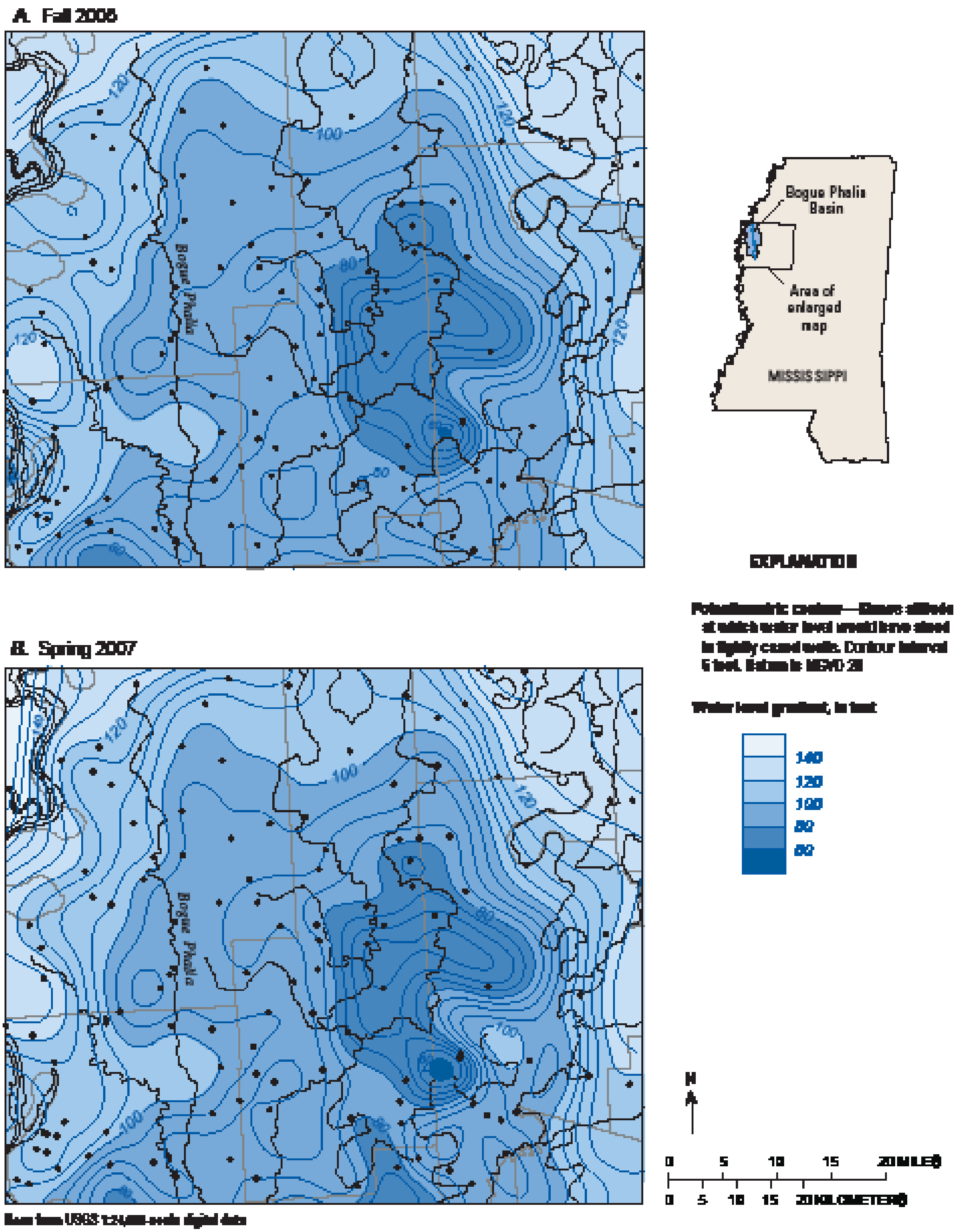


Figure 3. Water-surface altitudes for the Bogue Phalia and flowpath wells, (A) October-November 2006 and (B) April-May 2008.

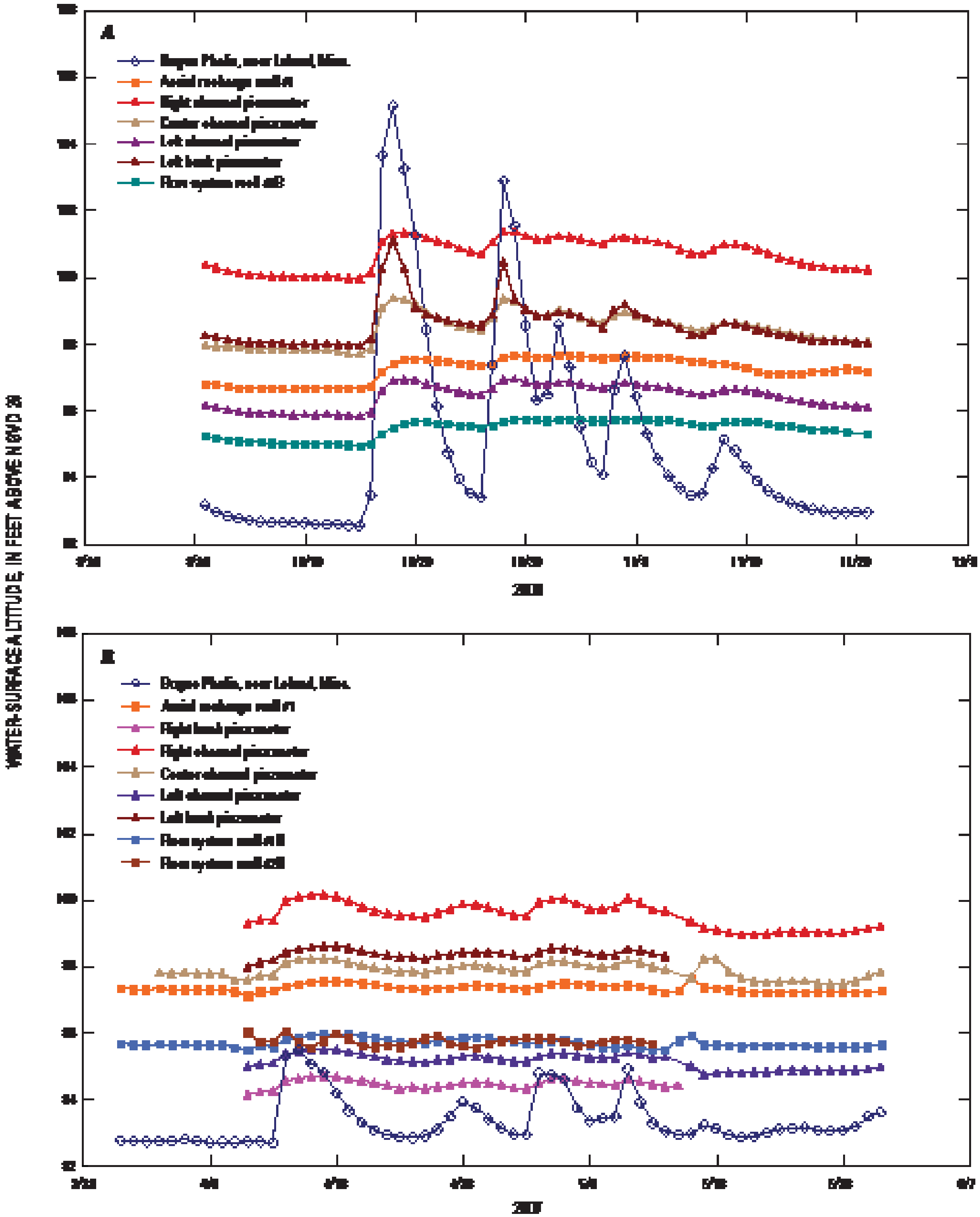


Figure 4. Comparison of water types along the Bogue Phalia transect using non-parametric multidimensional statistical plots of water-quality data.

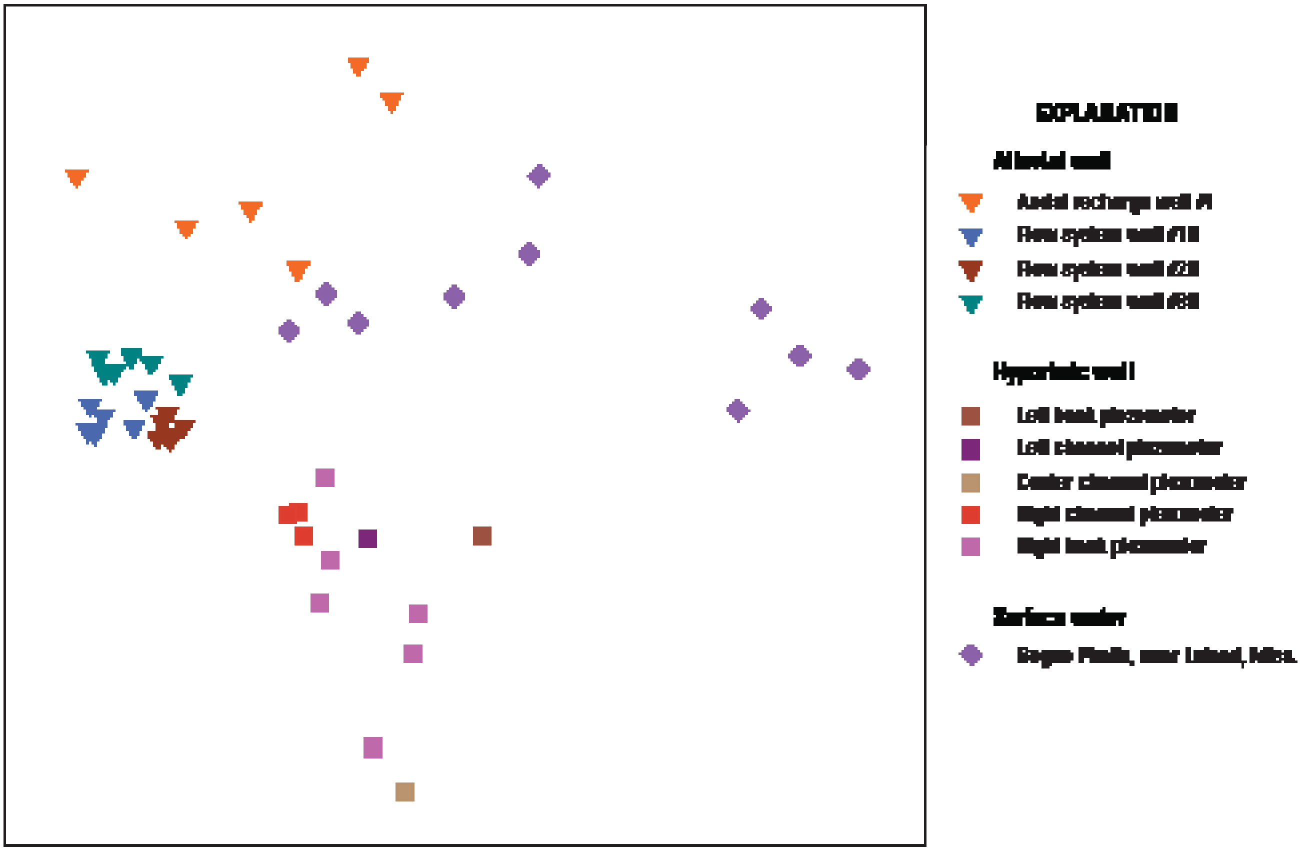
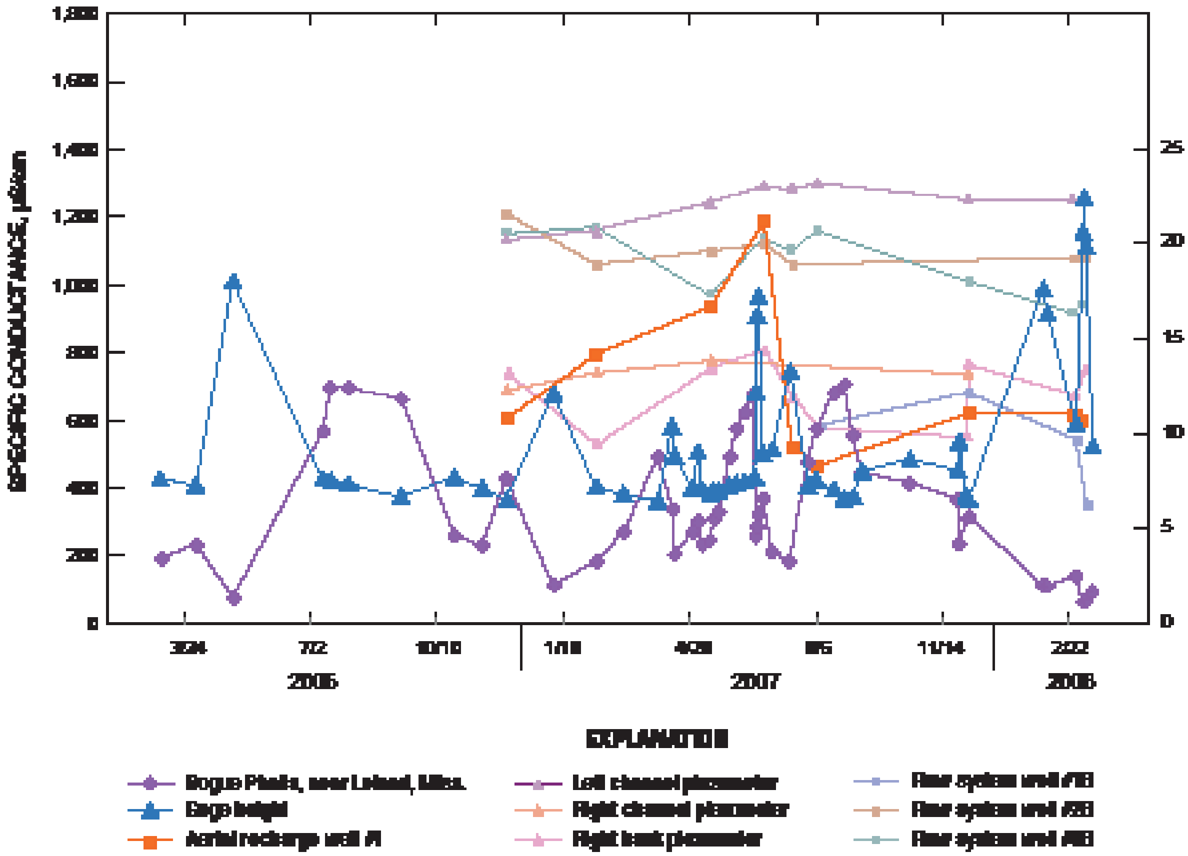


Figure 5. Specific conductance values measured at the Bogue Phalia, in-stream piezometers, flow system wells, and areal recharge well during quarterly sampling and storm events, 2006–2008.



Use of a field method for determining hydraulic conductivity in soils in the Bogue Phalia Basin in the Mississippi River alluvial plain

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Interest in the determination of hydraulic conductivity for soils in the Mississippi River Alluvial Plain is spurred by the heavy use of agricultural chemicals on these highly productive soils and the potential for offsite movement of these chemicals. Ground-water models indicate that up to 5 percent of the precipitation recharges the shallow alluvial aquifer, indicating a potential pathway for movement of these chemicals into ground water. A field method designed to rapidly measure field-saturated hydraulic conductivity (K_{fs}) on soybean and cotton fields in the Bogue Phalia Basin was used to evaluate the potential for recharge through agricultural soils. This technique uses a portable falling-head, small-diameter, single-ring infiltrometer and an analytical formula for K_{fs} that compensates both for the falling head and for subsurface radial spreading. Measured K_{fs} values generally were higher than expected and vary more than four orders of magnitude from $1x10^{-2}$ to $5x10^{-6}$ cm/s. Hydraulic conductivity was shown to vary spatially within an agricultural field and temporally due to soil moisture conditions.

Keywords: Ground Water, Geomorphological Processes, Nonpoint Source Pollution

Introduction

The Mississippi River alluvial plain (MRAP), a 7,000-square-mile area in northwestern Mississippi commonly called the Delta, is underlain by the Mississippi River alluvial aquifer (hereafter referred to as the alluvial aquifer in this report). The alluvial aquifer has the most water withdrawn from it in the state for agricultural and industrial purposes. The hydrology of the alluvial aquifer has been defined extensively by Arthur (2001), Boswell and others (1968) and Snider and Sanford (1981).

Arthur (2001) used MODFLOW, a modular 3D finite-difference ground-water flow model, to study the flow system of the alluvial aquifer. Arthur reported that up to 5 percent of annual precipitation recharges the alluvial aquifer and found that the most important source of vertical recharge to the aquifer is precipitation. The percentage of annual precipitation recharging the aquifer has not been directly measured, and the estimate is seemingly incongruent with the surficial lithology of the Delta. The estimate is a residual of all other water budget component estimates. Developing a better understanding of the infiltration capacity of MRAP soils would help to improve existing concepts regarding precipitation infiltration. The water table of the alluvial aquifer has been declining over time. To get a complete understanding of what happens, it is important to find a more direct way to measure the inputs and outputs to better manage the system. Additional study is needed in the Delta to better understand the magnitude and distribution of recharge from rainfall.

This paper demonstrates a method and apparatus for rapidly measuring field-saturated hydraulic conductivity (Kfs) of soils and presents the results from 42 infiltration tests on unconsolidated soils overlying the Mississippi River alluvial aquifer in the Bogue Phalia Basin. This report is limited to data collected from July through December 2007, using the "bottomless bucket" infiltrometer (Figure 1). Forty-two infiltration tests were completed under a variety of conditions, at 5 field sites, under 2 crop types, and different agricultural management practices. The entire study area was within the boundary of the Bogue Phalia Basin in northwestern Mississippi (Figure 2).

Background and Description of Study Area

In the early 2000s, the U.S. Geological Survey National Water-Quality Assessment (NAWQA) Program began studies in seven agricultural basins within the United States to better understand how the transport and fate of water and agricultural chemicals is affected by natural factors and agricultural management practices. The

Bogue Phalia Basin in MRAP is part of this study, and was selected because of its unique natural features (Figure 2).

The MRAP is made up of rich floodplain soils and has an ample water supply. The average rainfall for Washington County is 52 inches annually, which makes for an ideal agricultural setting (Taylor and Thompson, 1971). Land use in the study area is dominated by agriculture (cotton, soybeans, and rice); agricultural chemicals are heavily used in the study area and have been detected in surface water and rainfall since the 1990s (Coupe, 2000; Coupe and Capel, 2005). A further description can be found in Coupe (2002).

Five agricultural fields were used in this study. Two of the fields (AR2 and C-28) are non-irrigated cotton fields, located only three-fourths of a mile apart in the northern part of the Bogue Phalia Basin. Observation wells are on both fields. In the middle of the basin are two field sites, named Pace and Pace (New): both are soybean fields, one being irrigated and one non-irrigated, respectively. Installed at the Pace site are air and rain samplers, along with a rain gage. The final site, in the southern part of the basin, is a non-irrigated soybean field on which wheat is grown in the winter. Due to the array of observation wells installed across the adjacent Bogue Phalia to determine a ground-water flow path, the field is called the Flow Path site (Figure 2).

Previous Soil Infiltration Studies
Smiles (1974), did experimental studies in infiltration by ponding water on a laterally-restricted swelling soil. Smiles found that cumulative infiltration is a function of time. Bagarello and others (2004) reported a simplified falling-head technique for rapidly determining the kfs. Reynolds and others (2002) described infiltrometer tests using single and double ring infiltrometers. The equation developed for this paper is based on equations from Bagarello and others (2004) and Reynolds and others (2002).

Data Collection and Analysis
During July through December 2007, 42 infiltrometer tests were completed on 5 agricultural fields in the Bogue Phalia Basin in the MRAP. The "bottomless bucket" infiltrometer tests are described in the following section. Volume of water added, the time the water was added, and the depth to water with respect to time were collected for each test. These measurements were used in an analytical formula described in the following section to obtain the kfs.

Soil samples were collected at each infiltrometer test location from the soil surface and at a depth of 2-3 inches for texture determination. Soil samples were placed into plastic jars and were shipped to the U.S. Geological Survey in Menlo Park, California, for particle size analysis using the optical diffraction method (Gee, 2002).

Methods
Kfs was measured using a procedure based on the methods described by Reynolds and others (2002). A portable, single-ring, small diameter infiltrometer and an analytical formula were used to derive Kfs. This method uses inexpensive and common equipment. The infiltrometer used in this study was a standard 5-gallon PVC bucket, from which the bottom was removed. The infiltrometer was 35 centimeters (cm) high, and had a non-uniform diameter which tapered from 29 cm at the top to 27 cm at the bottom of the ring.

Once a suitable location was selected for the test, the infiltrometer was inserted into the ground by applying even pressure around the top rim, and twisting slightly so that the insertion depth was uniform at 5 to 8 cm. Care was used to ensure that no foreign material was caught under the lip of the infiltrometer, as this could cause a preferential flow pathway. If there was a small gap on the inside between the soil and the infiltrometer, it was sealed with soil from nearby to minimize lateral leakage.

The average depth from the top of the rim to the ground surface inside the infiltrometer was recorded. A plastic mat was placed on the ground surface inside the infiltrometer to keep the surface soil intact when the water was added, then the mat was removed during measurement. The volume of water required for each test depended on the need for an initial ponding depth of 0.03 to 0.1 meter (m) and the antecedent soil moisture conditions. The initial volume used for all tests was 4 liters (L), but when infiltration rates were high, additional water was required to obtain multiple measurements over time. Thereafter, depending upon conditions, 4 or 7 L were used.

After the water was added to the infiltrometer, the plastic mat was removed and measurements of the depth of water, with respect to the top rim of the infiltrometer, were recorded, along with the time. The measurements were recorded as quickly as possible for several minutes shortly after the start of the test, and then the intervals between measurements were increased based on how quickly the water was infiltrating (Figure 1). Measurements continued until all the water infiltrated the soil, or for as long as was practical. If there was any leakage, the test was terminated and the ring was moved to a new location.

The Kfs values reported are limited in depth and surface area, as the "bottomless bucket" infiltrometer was inserted into the ground to a depth of only 5 to 8 centimeters, and the diameter of the infiltrometer was only approximately 28 centimeters.

Analytical Formula Theory

The data-collection procedure used in this study can be classified as a falling-head single-ring ponded infiltration test, similar to those described by Reynolds and others (2002). Although the infiltrometer had a non-uniform diameter, use of the average diameter of the initially filled portion causes negligible error for a given test because of the small diameter of the ring; a more significant concern is the departure from one-dimensionality of flow, which must be compensated for in the calculations.

In some cases, the infiltration flux density (i) is considered as a first approximation of Kfs. However, this neglects the other phenomena that are known to occur. In order to calculate Kfs more accurately, an algorithm which accounts for the following factors was necessary: (1) gravity as a driving force, (2) matric suction as a driving force, (3) radial spreading of infiltrated water, (4) inhibition of radial spreading by the ring wall inserted to a finite depth, (5) positive water pressure applied at the soil surface, and (6) decline of applied water pressure with time.

Reynolds and Elrick's (1990) formula for gravity- and suction-driven angularly symmetric radial spreading below a finite insertion depth during constant-head ponding most closely approximates this design and procedure:

$$K_{fs} = \frac{i}{\left[1+\frac{\lambda+D}{C_1 d + C_2 b}\right]} \qquad (1)$$

where K_{fs} is field-saturated hydraulic conductivity, i is infiltration flux density, λ is macroscopic capillary length (White and Sully, 1987), D is the depth of ponding, b is the ring radius, d is the depth that the ring penetrates into the soil, and C1 and C2 are empirically determined constants. Reynolds and Elrick (1990) found optimal values for C1 (0.993) and C2 (0.578) by using a Richard's equation-based numerical analysis of K vs. i and indicated that the values C1 and C2 are relatively insensitive to the calculation of Kfs. The value of λ was chosen from one of four broad soil categories based on texture and structure. Elrick et al. (1989) showed that the value of λ had little sensitivity to the calculations of Kfs.

Adapting the Reynolds and Elrick (1990) formula to a falling-head test, the infiltration rate equals the rate of change of pond depth:

$$K_{fs} = \frac{-\frac{dD}{dt}}{\frac{1}{L_G}\left[L_G+\lambda+D\right]} \qquad (2)$$

where the ring-installation scaling length $L_G = C_1 d + C_2 b$ is defined for convenience. Rearranging, and integrating over time t_f, during which D falls from its initial value D_o to final value D_f,

$$\int_0^{t_f} K_{fs}\,dt = \int_{D_f}^{D_o} \frac{L_G}{\left[L_G+\lambda+D\right]}\,dD \qquad (3)$$

Thus, the formula accounting for matric suction, lateral spreading, and falling head is

$$K_{fs} = \frac{L_G}{t_f}\ln\left(\frac{L_G+\lambda+D_o}{L_G+\lambda+D_f}\right) \qquad (4)$$

This formula can be applied whether or not the test is continued until no water remains in the ring, as long as both D_0 and D_f have been measured. If the falling head is allowed to fall to 0, the formula simplifies to

$$K_{fs} = \frac{L_G}{t_f}\ln\left(1+\frac{D_o}{L_G+\lambda}\right) \qquad (5)$$

Results and Discussion

Kfs measurements from the 42 infiltrometer tests vary over more than four orders of magnitude, from 1.6x10-1 to 9.27x10-6 centimeters per second (cm/s). The infiltrometer tests yield substantially variable values of Kfs. The Kfs varies over time, Agricultural Management Practices (AMPs), antecedent soil moisture conditions, and Kfs also varies spatially due to soil heterogeneity. Figure 3 illustrates spatial and temporal variation in Kfs, as well as variation due to crop type, and each bar represents the Kfs value for one individual "bottomless bucket" infiltrometer test. The tests completed on agricultural sites AR2, C-28, and Flow Path were all done in July 2007. The tests completed on field sites Pace and Pace (New) were completed over a period of several months, illustrating the temporal variation of infiltration capacity (Figure 3).

Figure 4 shows the averages of the infiltrometer test values for each field site and illustrates how the differences in agricultural management practices can affect the infiltration capacity. For example, Pace and Pace (New) sites are within 1 mile of each other and are both soybean fields; however, Pace is irrigated and Pace (New) is not. Infiltrometer tests were done during the same seasons, yet the average kfs for the tests run at Pace (New) is higher (1.87x10-2 cm/s) than the average of Kfs for the tests run at Pace (4.73x10-4cm/s). The Pace (New) site probably developed more substantial macropores than Pace due to the development of shrinkage cracks without irrigation to keep the soil moist.

Table 1 lists the temporally averaged Kfs values, weather conditions, and agricultural management practices at the Pace and Pace (New) sites. The average Kfs determined from tests conducted on the Pace field in July, while soybeans were still growing, was 6.82x10-4 cm/s (Table 1). However, 2 months later in September, the average Kfs was greater, at 1.53x10-4 cm/s. It is probable that this difference is due to the antecedent soil moisture conditions, as September was dryer than July 2007. After October harvest, disking, and precipitation, the average infiltration capacity was lower, 6.40x10-5cm/s. This likely is due to the rehydration of the soil which promotes the sealing of existing cracks (Table 1).

Multiple tests were conducted on the Pace (New) field on four separate occassions: early September, mid-September, early October, and mid-December. The Kfs values were averaged by date. The early September tests were conducted soon after harvest and disking. Because lateral flow throughout the disked layer is probable, the average Kfs was higher than at any other time (4.27x10-2 cm/s). This higher Kfs may also be attributed, in part, to the presence of larger or more numerous macropores under the disked layer compared to those at the Pace site due to lack of irrigation, which would limit swelling potential. In mid-September, when surface soil cracks were 1.27 cm deep, the average infiltration capacity (for all tests run on this date) was 5.59x10-3 cm/s, lower than in early September 2007. This change of Kfs likely is caused by the settling of surface soil after disking. In early October, the average Kfs was 5.41x10-3cm/s, which is within the same order of magnitude as the mid-September average Kfs. In mid-December, the average Kfs of the field was lower than in mid-September, at 5.36x10-4 cm/s, although the soil had 0.31 cm cracks at the surface, this is a result of the wet conditions of the winter season (Table 1).

The range, median, mode, and average Kfs for each agricultural field site are found in table 2. The field site with the highest average, median, and mode of Kfs in cm/s is the non-irrigated Pace (New) soybean field. Temporal variability is evident in the data collected over a 3-month period at Pace (New) (Table 2).

The soil samples collected at each infiltrometer test location were analyzed for particle size distribution; one sample was taken from the soil's surface, and one from 2-3 inch deep. The averaged USDA particle size classes (Soil Survey Staff, 1975) as determined by the optical diffraction method are listed in table 3. Averages for all five field sites are representative of a silt loam textural type (Soil Survey Staff, 1975), or a soil in which nearly 80 percent of the particles are silt sized (Table 3).

Conclusion

It is clear that equation (5) considers the factors that affect the Kfs for this unique infiltrometer method. Kfs values derived from this method and equation vary spatially and temporally. Consequently, there is potential for a substantial amount of infiltration to take place under certain conditions and in certain areas. This method is ideal for creating a rapid and far-reaching assessment of the in situ infiltration capacity of a site, with ease and with minimal monetary commitment.

The data collected in this study have provided a better understanding of the vadose zone processes occurring within soils common to the Mississippi Delta, and give direct measurements related to the infiltration of precipitation into the surface soil. The question of what happens to the precipitation that does infiltrate still cannot be answered, as the "bottomless bucket" infiltrometer tests are limited to the surface of the soil to a depth of about 2-3 inches. This adds knowledge to other studies of vadose zone processes.

Future Studies

There are several possibilities to investigate the fate of infiltrated water; (1) it could potentially flow laterally to ditches and end up as surface water, (2) it could be taken up by evapotranspiration, (3) it could take up a long-term residence in the vadose zone, or (4) it could eventually recharge the alluvial aquifer.

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Figure 1. Diagram of infiltrometer.

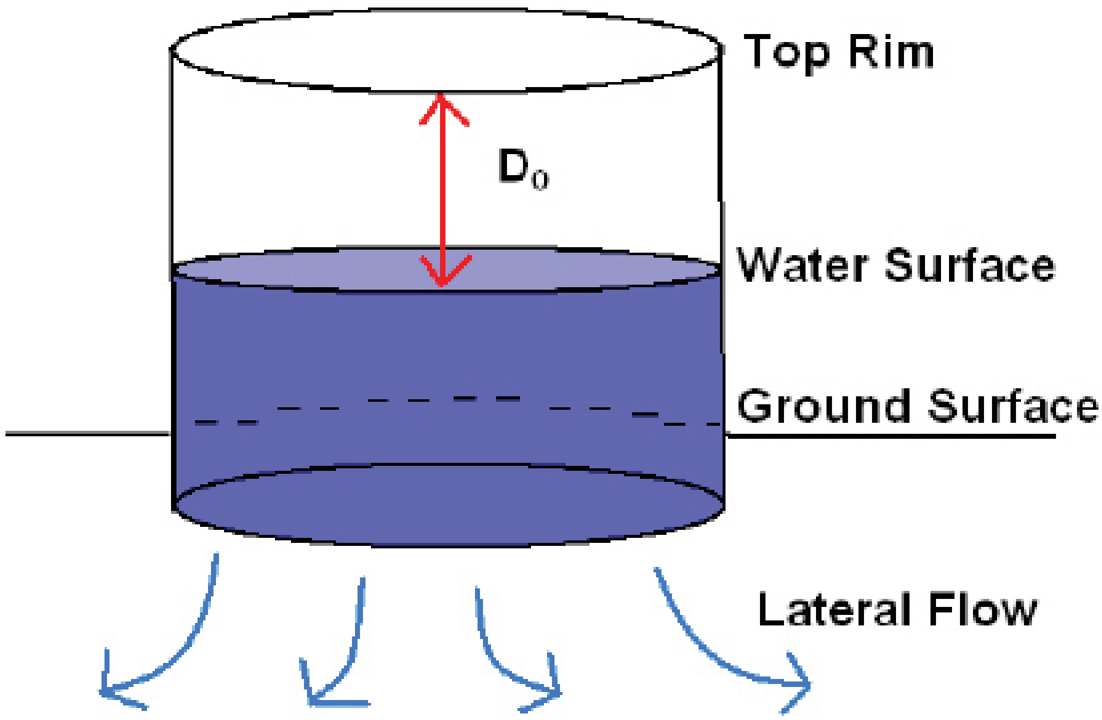


Figure 2. Study area and agricultural field locations.

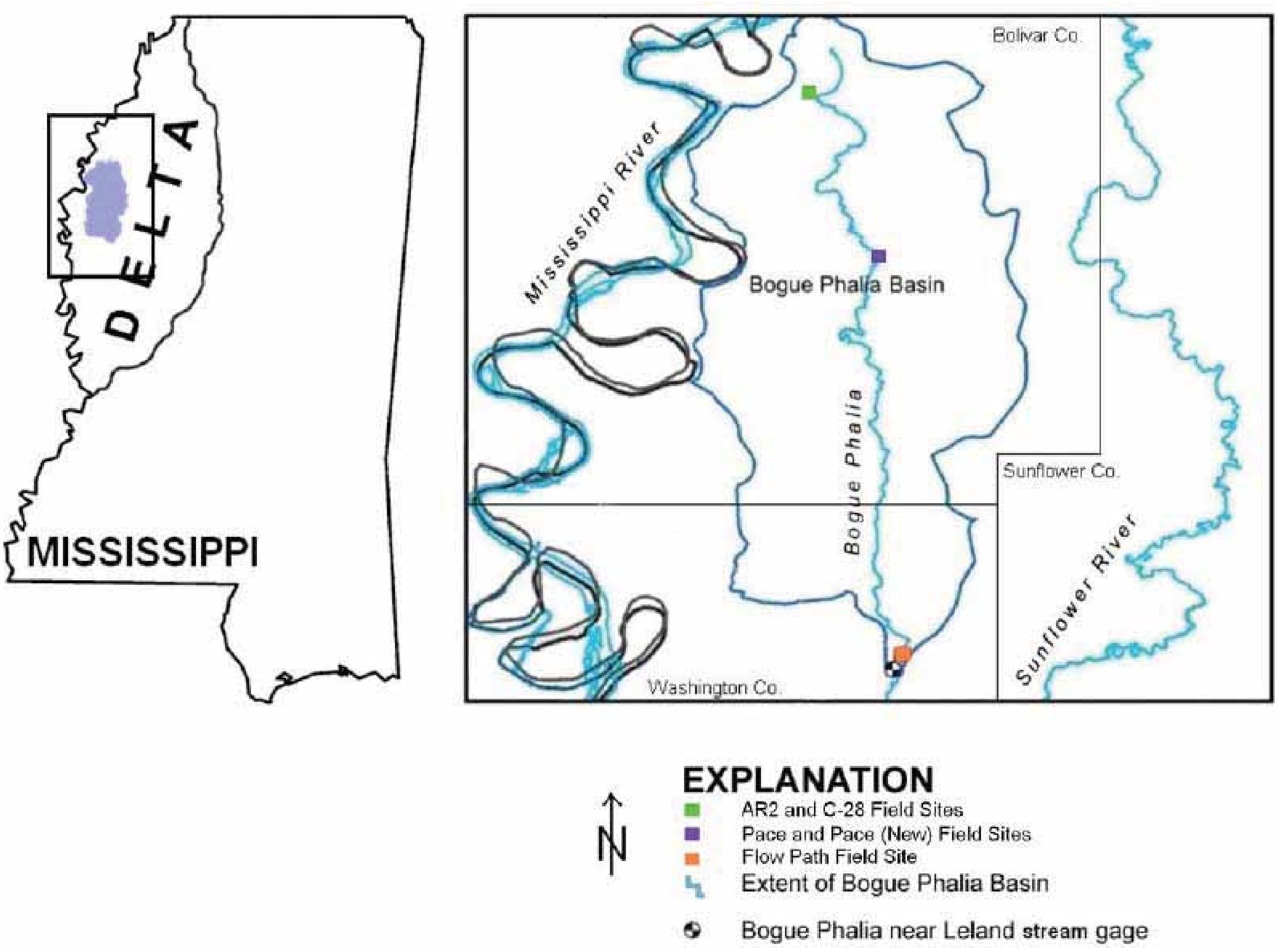


Figure 3. Kfs data for each infiltrometer test.

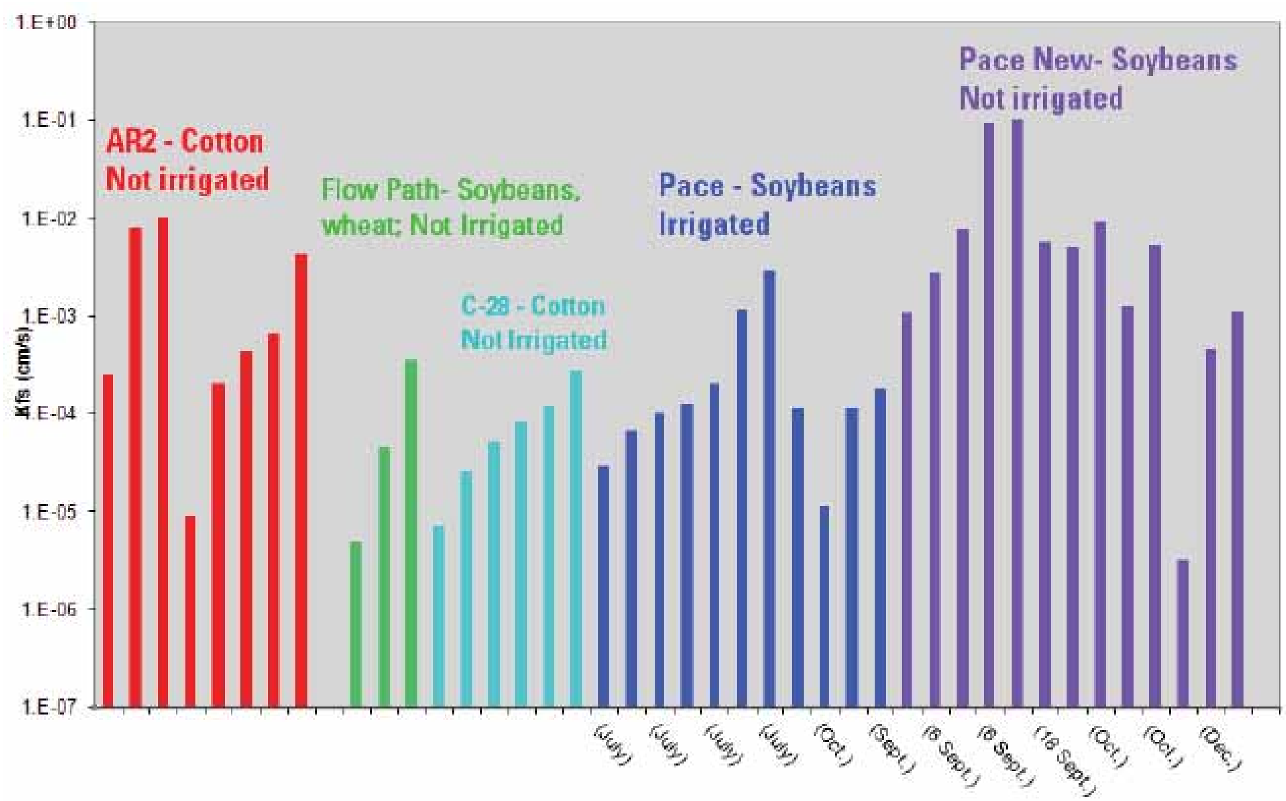
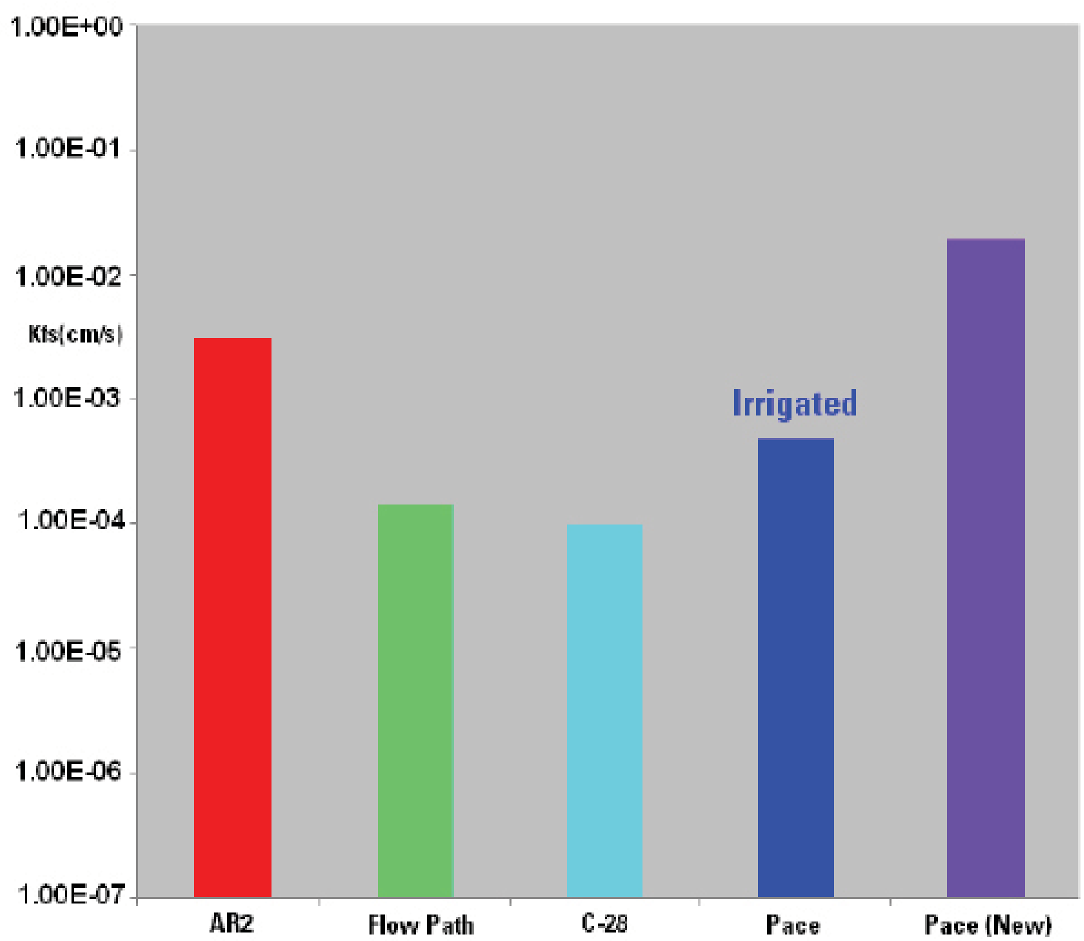


Figure 4. Average Kfs data for each agricultural field.



SEDIMENTATION

Russell Beard, Moderator

Sediment transport analysis using HEC-RAS 4.0

John J. Ramírez-Avila, Jairo N. Diaz-Ramirez, James L. Martin, and William H. McAnally
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Sediment budget template applied to Aberdeen pool

Jeremy A. Sharp and William H. McAnally
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Vegetated swales and their effect on agricultural stormwater flow rates, a field verification of the FarmLatis Conservation Planning Tool

Heath Avery and Timothy J. Schauwecker
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Sediment transport analysis using HEC-RAS 4.0

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The Hydrologic Engineering Centers River Analysis System (HEC-RAS) version 4.0 was used to simulate the transport of non-cohesive sediments in the Goodwin Creek Experimental watershed, Mississippi. HEC-RAS is one-dimensional in-stream model developed by the U.S. Corps of Engineers for simulating steady and unsteady flow, sediments, and water temperature. One month of observed data was used to setup and evaluate the model. Four sediment transport functions were evaluated: Ackers and White, Toffaleti, Englund and Hansen, and Laursen. The model predicted with acceptable accuracy the sediment transport (concentration, mass, and behavior) for the specified temporal and spatial conditions. The computational time step was the most sensitivity parameter for increasing the accuracy of the simulated results. However, the increase in accuracy increased the consumed time for the model by performing the computational analysis. Although Ackers and White function overestimated the sediment concentrations and sediment yield observed, it was the most descriptive function of the sediment transport behavior. Toffaleti's sediment transport function underestimated the observed conditions and did not describe an accurate behavior of the sediment transport process. It would be some condition in the model routine which produced inconsistent results which the generated in other studies, where generally, Toffaleti's estimations are higher than Ackers and White. Englund and Hansen, and Laursen functions significantly overestimated the observed conditions. HEC RAS also generated a spatial analysis of the different output parameters which permitted to identify specific conditions about the behavior and characteristics of the channel.

Keywords: Sediments, surface water, models.

student presenter

Sediment budget template applied to Aberdeen pool

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The purpose of this work is to create a sediment budget template, with Aberdeen Pool on the Tennessee-Tombigbee Waterway as the demonstration site. USGS data are used to define sediment concentrations and flows. The USGS data are the basis for the Power Curve Program which defines the sediment behavior in terms of a power function. The second program, Tier 1 Program, uses the power curve coefficients along with the bankfull discharge to define the sediment fluxes. Thirdly, the Tier 2 Program uses power curve coefficients with daily flows to calculate daily sediment flux which are integrated over each year to calculate the yearly fluxes. From the sediment fluxes, a mass balance equation is implemented to estimate total deposition. Lastly, the computer program SIAM is used to estimate deposition amount. Comparison among the three different methods provides a best estimate of the final depositional approximation.

Keywords: Sediments, Surface Water, Methods

Vegetated swales and their effect on agricultural stormwater flow rates, a field verification of the FarmLatis Conservation Planning Tool

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Water quality is progressively becoming more important in the planning process. A field verification of the FarmLatis conservation planning tool represents research into technology that is for use in the conservation planning process. A program is being developed by researchers from Mississippi State University that are from the Forest and Wildlife Research Center, the Departments of Landscape Architecture, Civil Engineering, and Agricultural and Biological Engineering that integrates hydrologic modeling (HSPF) and Best Management Practice (BMP) implementation, called Latis (Wilkerson et al. 2006). FarmLatis represents an agricultural extension of the Latis decision support system. Latis and FarmLatis are intended to help developers and conservation planners implement Low Impact Development (LIDs) and conservation planning strategies into their site designs. The application of hydrological modeling is a natural extension of these planning processes. The modeling process can assist in determining the different design alternatives for a specific site and assess their effectiveness in maintaining and improving water quality. FarmLatis and Latis use modeling tools which predict the time-varying runoff and water quality of stormwater. Three sites located at Mississippi State University are being modeled and monitored. Sites one and two are swales located in pasture land with runoff from cattle and a gravel road. Site three is a swale located at the end of a plowed row crop field. The research sites address the following areas in the drainage swales at all three sites: a field verification of FarmLatis modeling results, Best Management Practice design, seeking the most effective approach of installing plants (buttonbush) and structures (check dams), and the improvement of the BMP modeling and cost parameters used within FarmLatis. Research at these farm sites are excellent test cases for the application of FarmLatis.

Keywords: Conservation planning, vegetated swale, water quality, agricultural stormwater

student presenter

GROUNDWATER

Jamie Crawford, Moderator

Nitrate in groundwater in a recharge area of Guarany aquifer in Brazil

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Upper Leaf River basin base flow study: A preliminary study for surface water/groundwater interactions within the Pascagoula Basin

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An overview of the geology and hydrology of a proposed impoundment of the Upper Sand Creek, Choctaw County, Mississippi

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Nitrate in groundwater in a recharge area of Guarany aquifer in Brazil

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The region of Ribeirão Preto City located in São Paulo State, southeastern Brazil, is an important sugarcane, soybean and corn producing area. This region is also an important recharge area (Espraiado) for groundwater of the Guarany aquifer, a water supply source for the city and region. It has an intercontinental extension that comprises areas of eight Brazilian states, as well as significant portions of other South American countries like Argentina, Uruguay, and Paraguay, with a total area of approximately 1,200,000 Km^2. Due to the high permeability of some soils present in this region, the high mobility of the herbicides and fertilizers applied, and being a recharge area, it is important to investigate the potential transport of applied fertilizers to underlying aquifer. The cultivation sugar cane in this area demands the frequent use of nitrogen as fertilizer. This research was conducted to characterize the potential contamination of groundwater with nitrogen in the recharge area of groundwater. Seven groundwater sample points were selected in the Espraiado stream watershed, during the years of 2005 and 2006. Samples were collected during the months of March, July, and December of each year. Three replications were collected at each site. Groundwater was also collected during the same months from county groundwater wells located throughout the city. The following six wells were studied: Central, Palmares, Portinari, Recreio Internacional, São Sebastião, and São José. Nitrate water samples were analyzed by Cadmium Reduction Method. No significant amount of nitrate was found in the recharge, agricultural, area. However, nitrate levels were detected at concentrations higher than the Maximum Concentration Level (MCL) of 10mg/L in downtown, urban, well located away from agricultural sites with no history of fertilizer or nitrogen application.

Keywords: Groundwater, Nitrate Contamination, Nonpoint Source Pollution, Toxic Substances, Water Quality

Introduction

The region of Ribeirão Preto city, São Paulo State, located in Southeast of Brazil, is an important area for sugar cane production, with high level of herbicide and fertilizer utilization. It is also an important recharge area of the Guarany aquifer ground water, which extends to eight Brazilian states and part of Argentina, Uruguay, and Paraguay, with approximately 1,200,000 km2 (Figure 1). Geological studies in the region have identified a watershed, called Espraiado, with high risk of ground water contamination. Certain areas of the Espraiado watershed are highly permeable sandy soil allowing leaching of agrochemicals applied in crops (Miklós and Gomes 1996).

Several studies conducted in the region have detected low levels of pesticides used in agriculture particularly in groundwater on sugarcane area (Lanchote et al. 2000, Cerdeira et al. 2000, Gomes et al. 2000). One of those studies allowed ranking counties by contamination risk levels, defining priority regions for monitoring programs for nitrates (Rodrigues et al. 1997).

Due to the high permeability of some soils present in this region, the high mobility of the herbicides and fertilizers applied, and being a recharge area, it is important to investigate the potential transport of applied fertilizers to underlying aquifer. This research was conducted in Ribeirao Preto county in Brazil (Figure 2). The cultivation sugar cane in this area demands the frequent use of nitrogen as fertilizer. Nitrate ground water contamination is a frequent problem due to the massive use of fertilizers in agriculture (Rodrigues et al. 1997).

Drinking water and dietary sources of nitrate and nitrite can react in vivo with amines and amides to form N-nitroso compounds (NOC), potent animal carcinogens and nitrate is a widespread contaminant of drinking water supplies especially in agricultural areas (Ward et al. 2007; De Jong et al. 2007). The health effects of contamination are due to the transformation of nitrates into nitrites and possibly the transformation of nitrites into nitrosamines in the stomach.

The risk of methemoglobinemia in infants is due to nitrites contained in the water used to reconstitute milk for feeding (Levallois and Phaneuf 1994; Sacco et al. 2007). The use of nitrate-contaminated drinking water, N0-3-N, to prepare infant formula is a well-known risk factor for infant methemoglobinemia. Affected infants develop a peculiar blue-gray skin color and may become irritable or lethargic, depending on the severity of their condition (Knobeloch et al. 2000). According to a Sao Paulo State law in Brazil, the maximum concentration level (MCL) of nitrates is 6.0 mg/L (Alaburda and Nishihara 1998).

Because of the watershed vulnerability and high imput of nitrogen fertilizer applied, this research was conducted to characterize the potential contamination of groundwater with nitrates in the recharge area of groundwater and its vicinity

Materials and Methods

A survey conducted in the area has indicated that nitrate applied as nitrogen fertilizer, was regularly utilized and it was chosen for this study. Seven groundwater sample locations were selected in the recharge area watershed, during the years of 2005 and 2006. Samples were collected during the months of March, July, and December of each year.

Groundwater was also collected during the same months from five county municipal wells located outside of the watershed at the vicinity of the recharge area in addition to a well located in downtown far away from any agricultural activities (Figure 1). The following six urban wells were studied: Central, Palmares, Portinari, Recreio Internacional, São Sebastião, and São José. Three replications were collected at each site. (Table 1).

Estimation and Analysis of Nitrate Risk

Water samples (1L) were collected and nitrate was analyzed by Cadmium Reduction Method according to Greenberg et al. 1992. Health risk for the population was estimated according to Arumi et al. 2006, combining the following factors expressed as Risk Coefficient (RC), where RC , was function of C, the nitrate concentrations (mg/L) found in each well (Tables 2 and 3), V, Volume of water ingested in L/Day (2.0 for adults and 0.64 for infants), EF, Exposition Frequency in Days/year (350), BW, Body Weight (70 and 4.0 kg for adults and infants, respectively), and RfD, Reference concentration, which is the safe maximum level of exposition that causes no harm. This was obtained from literature from toxicological studies (United States Environmental Protection Agency). In this case, the RfD was 1.6 mg kg–1 day–1.

RC can vary from zero, no-risk, to 1.0, highest risk.

Results and Discussion

Very low amount of nitrates residues were detected in ground water of the recharge, agricultural area, where fertilizer (nitrogen) is applied (Table 2), even though a non-confined superficial water table with depths varying between zero to 20 m (Table 1) and porous sandy soil are found (Miklós and Gomes 1996). Analysis of municipal wells located at the edge of the recharge area have also shown low levels of nitrate (Table 3). However, nitrate levels were detected at concentrations higher than the MCL of 6.0 mg/L in downtown, urban, Central well located away from agricultural sites with no history of fertilizer or nitrogen application (Table 3).

RC Index evaluation has also shown values close to zero for all the wells with the exception to the Central, located in urban, non agricultural area. In this Central well we found RC index of nitrate close to 1.0, maximum, particularly for infants (Figure 2). This was also found in an aquifer beneath the old industrial city of Nottingham, UK, in shallow ground water originated mainly from residential and industrial areas, where high nitrate concentrations probably arising from leaking sewers and contaminated land were detected (Trowsdale and Lerner 2007). Arumi et al. 2006, also found in the Parral region of Chile, nitrate contamination of wells primarily linked to certain factors such as construction practices and the proximity of livestock. These factors affect the quality of drinking water in isolated cases. There was no risk found for the adult population, but there was for infants fed on formula mixed with water coming from the contaminated wells (Arumi et al. 2006). Alaburda and Nishimura, 1998, also found high level of nitrate in the metropolitan area of São Paulo city in Brazil.

Soil samples from the watershed were characterized by the determination of the sand, clay and silt content and texture. The sampled soils were classified as Dusky Latosol (Typic Haplorthox), Structured Dusky Latosol (Typic Eutrorthox), Dark Red Latosol (Quartzipsammentic Haplorthox), sandy loam Red-Yellow Latosol (Quartzipsammentic) and Quartzous Sand (Typic Quartzipsament). They were submitted to leaching studies in laboratory with samples from the watershed. The data have shown the clayey (Dusky Latosol, structured Dusky Latosol) and sandy loam (Dark Red Latosol and Red-Yellow Latosol) soils with medium infiltration potential of water as opposed to Quartzous Sand soil, which showed a high infiltration potential (Miklós and Gomes 1996)

As our data have shown, other studies have concluded that the principal cause of groundwater contamination by N0-3-N are the urban and industrial wastes dumped in the environment without treatment, and that contamination by agriculturally related fertilizers is a secondary cause (Schalscha et al., 1979). According to studies conducted by Arumi et al. 2005, contrary to expectations, the aquifers of the Central Valley of Chile also appear free from any significant nitrate pollution from agricultural sources in spite of the high levels of nitrogen-based fertilizers used in the agricultural activity, the irrigation practices and the active surface water-groundwater interactions.

Arumi et al. 2005, concluded that this could be due to a possible dilution effect that the amount of groundwater has on chemicals entering the groundwater system or related to the anion exchange capacity, which is very high in our study area also. Another reason pointed by the Author could be due to denitrification process by the presence of biodegradable organic carbon and presence of denitrifying bacteria, which are usually found in natural systems. The existence of naturally high levels of organic carbon in the soils in our study would contribute to this.

In conclusion, results have shown that nitrate was detected at levels higher than the MCL of 6.0 mg/L in well located in downtown area, which is away from the sugar cane plantations. Risk analysis has shown that the dangerous levels in wells located in down town is a health hazard mainly for infants, reaching the maximum risk levels of 1.0.

Acknowledgements

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Upper Leaf River basin base flow study: A preliminary study for surface water/groundwater interactions within the Pascagoula Basin

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The Pascagoula River System, draining 8,504 mi^2 in southern Mississippi, is the nation's largest, unregulated and pristine river system. Streams in the Pascagoula Basin are generally the first to be affected during times of drought. With the presence of several industries in this basin that use surface water, staff of MDEQ/OLWR are conducting studies within the basin to determine the sources of baseflow for the basin's streams. During October 2007, 25 sites near 7Q10 were individually measured during a baseflow study conducted in the Upper Leaf River Basin utilizing SonTek Flowtracker Acoustical Doppler Velocity meters. The Upper Leaf drains 1,752 mi^2 and has been in drought conditions throughout the year. The baseflow sites' discharge ranged from no-flow observations to a basin high of 375 ft^3/s discharging into the Lower Leaf River Basin. Utilizing ArcGIS, the basin's topography, geology and hydrology was mapped and analyzed. Results indicated that geology plays a pivotal role in the distribution of ground water flow into the surface water streams based on unit discharges per square mile. Generally, flows in the northern third of the Upper Leaf were non-existent correlating to geology. In the southern third, ground water discharge is more prevalent also correlating to the basin's geology. This study will form the foundation for further studies in the basin for ground water/surface interactions utilizing the mappable Miocene aquifer units and stream incision to locate significant ground water contributions. These methodologies can then be applied to the entirety of Pascagoula River Basin.

Keywords: SW/GW Interactions, GIS, Hydrology, Hydrogeology, Geomorphology

An overview of the geology and hydrology of a proposed impoundment of the Upper Sand Creek, Choctaw County, Mississippi

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The Upper Noxubee watershed, Choctaw County, Mississippi, constitutes a proposed site for a recreational and water management reservoir located on Sand Creek. Prior to the development of the site, the geology and hydrogeology of the watershed was investigated to determine suitability for impoundment. The proposed site is located within the Wilcox Group, a sequence of interbedded sands, silts, clays and lignites of Paleocene age. Geological cross sections derived from geophysical logs and field exploration provided information regarding facies distributions within the proposed site area. Discharge characteristics of both perennial and ephemeral streams offered data concerning surface runoff that can then be related to infiltration into the Lower Wilcox Aquifer. Along with a spring inventory, the discharge measurements aided in determining if there is sufficient water flow for impoundment. The Mississippi State University Chemical Laboratory conducted water analysis to establish the quality of the water to be impounded. All data collected and the characteristics of the proposed reservoir are mapped using ArcGIS 9.2 software.

Keywords: Geology, Hydrology, Surface Water, Water Quality

COASTAL AND WETLANDS

Barb Kleiss, Moderator

Effects of landscape factors on limnological conditions of floodplain lakes in the Yazoo River Basin

Seiji Miyazono, Nathan Aycock,
Leandro E. Miranda, and Todd Tietjen
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Contaminant transport through riparian wetlands

Gregg R. Davidson, Daniel G. Wren,
William G. Walker, and Steven G. Utroska
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Evaluating water supply needs in rebuilding the Mississippi Gulf Region

Gregory A. Brown
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Bi-national harmful algal blooms observing system (HABSOS) and the phytoplankton monitoring network

Russell H. Beard
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Effects of landscape factors on limnological conditions of floodplain lakes in the Yazoo River Basin

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The Yazoo River Basin of Mississippi includes several rivers that drain an area heavily impacted by agriculture that includes hundreds of floodplain lakes created by the meandering of these rivers. We studied 17 of these lakes distributed over the lower half of the Yazoo River Basin to document their water quality. Landscape factors were quantified with GIS and used to explore the relationships between water quality and the environment surrounding the lakes. Results of principal components analysis showed that the degree of connectivity and the presence of forested wetland buffers are major factors dividing the physicochemical characteristics of the lakes. Lakes with direct connections to the parent river and limited forested wetland buffers tend to be deeper, less turbid, and have lower phytoplankton fluorescence. Conversely, as connectivity to the parent river is reduced or eliminated and the presence of forested wetland buffers increase, lakes become shallow, turbid, and have higher phytoplankton fluorescence. We postulate that after lakes separate from their parent river they function as sinks for sediments introduced during flood events, resulting in loss of depth. As lakes become progressively shallower, area is reduced, and surrounding wetlands are increased. The effects of changes in connectivity of alluvial lakes need to be included in decisions concerning restoration efforts. Management goals associated with physicochemical parameters may be attainable by restoring or reducing connectivity to parent rivers and can be influenced by the development of forested wetland areas.

Keywords: Water Quality, Wetlands, Geomorphological Processes, Sediment

student presenter

Contaminant transport through riparian wetlands

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Riparian wetlands are perceived to be efficient scavengers of a wide variety of non-point source pollutants. This perception is based primarily on short-term studies, typically less than one year in duration, that have documented capture of contaminants entering a wetland. Little is known about the long-term fate of most sequestered contaminants. Preliminary results from a study of sediments deposited over the last century in lake-wetland systems in the Delta region of Mississippi suggest that sequestration of contaminants in riparian wetlands may not be permanent. At Sky Lake, an oxbow lake surrounded by agricultural lands and bordered by a cypress wetland, sediment cores were collected from the wetland and from a central open water area. Elevated Pb and As concentrations were found in sediments deposited approximately 80 years ago in only the open water environment. The most likely source of Pb and As is lead arsenate pesticide used in this area at the time these sediments were being deposited. Runoff from the surrounding fields passes through the wetland before reaching open water. Given the high affinity of Pb and As to solid surfaces, it is unlikely that either passed through the wetland without at least partial adsorption. Our hypothesis is that these contaminants were initially sequestered in the wetland when introduced in the late 1920's and 1930's, but subsequent seasonal flooding and aeration resulted in repeated remobilization and redistribution through the lake-wetland system. Permanent sequestration occurred only with burial in the perennially flooded open water environment. The work at Sky Lake is being expanded to other lake-wetland systems with similar geomorphology and history. Sediment cores have been collected from Hampton Lake, another oxbow lake in the Delta, to determine if a similar record is preserved.

Keywords: Hydro Geochemistry, Nonpoint Source Pollution, Sediments, Surface Water, Wetlands

Evaluating water supply needs in rebuilding the Mississippi Gulf Region

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In the months following Hurricane Katrina, the Mississippi Gulf Region faced a monumental rebuilding effort. One major component of this effort is insuring an adequate supply of potable water is available to satisfy residential, commercial, and industrial needs both in the near- and long-term. The Governor's Commission on Recovery and Renewal recommended adoption of a regional approach for critical infrastructure. The Mississippi Department of Environmental Quality was tasked with the development of the Gulf Region Water and Wastewater Plan, a document which identified water, wastewater, and stormwater management needs within the 6-county Gulf Region and proposed projects to address those needs.

With regard to water needs, existing sources of supply were identified and usage from these sources quantified to the extent practical. Information from several sources, including local entities involved in planning and development in the Gulf Region, was compiled to project water supply needs over the next two decades in terms of both quantity and location. Existing retail agents were evaluated for their ability to serve present and projected customers within their designated service area. From these sources, water supply projects were developed. The projects were conceived to both supplement existing systems and provide potable water in those key growth areas of the Gulf Region presently lacking adequate water supply infrastructure.

Keywords: Management and planning, Water supply, Water use

Bi-national harmful algal blooms observing system (HABSOS) and the phytoplankton monitoring network

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The Harmful Algal Blooms Observing System (HABSOS) is a regional coalition of U.S. and Mexican Federal and State agencies working together to study algal bloom events within the Gulf of Mexico Ecosystem. Algal toxins introduced into the ecosystem affect the health of humans and marine life, and disrupt social and economic activities. The coastal zone manager is challenged to monitor, assess, and forecast bloom events to minimize societal impact. A bilingual (Spanish/English) HABSOS web site an Internet tools have been developed to support this effort. Data entered into the system are available for display and analysis in the HABSOS Internet Map Service (www.ncddc.noaa.gov/interactivemaps/harmful-algal-blooms-observing-system-habsos). The HABSOS and Bi-National were developed and supported by U.S. Environmental Protection Agency (EPA) Office of Research and Development, EPA Gulf of Mexico Program, and the NOAA National Coastal Data Development Center (NCDDC)

In 2007, NCDDC added the associated Phytoplankton Monitoring Network (PMN) a volunteer regional data management network to assist the HABSOS effort. PMN is an education and outreach program developed by NOAA's National Ocean Service's to engage school and community volunteer groups in phytoplankton sampling and identification and to raise awareness of harmful algal blooms. NCDDC partnered with PMN to create an end-to-end data management system for the volunteers. Members are provided an on-line data entry tool to submit data, and are then able to visualize and analyze their own validated data as well as from Network peers in an Internet Geographic Information System (GIS) environment. Approved data is mapped to (www.ncddc.noaa.gov/website/SEPMN/viewer.htm). NCDDC has partnered with the newest NOAA Cooperative Research Institute, the Northern Gulf Institute (Mississippi State University, University of Southern Mississippi, Louisiana State University, Florida State University, and Dauphin Island Sea Lab) to train and equip the volunteer organizations.

Keywords: Water Quality, Invasive Species, Toxic Substances, Ecology, and Education

WATER SUPPLY

Sam Mabry, Moderator

The Mobile River Basin: A review of physiographic, climatic, water quantity, and water quality characteristics

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Mississippi State University

A water budget: Tenn-Tom Waterway from Whitten Lock to Heflin Lock and Dam

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The Mobile River Basin: A review of physiographic, climatic, water quantity, and water quality characteristics

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The Northern Gulf Institute (NGI) has been established with National Oceanic and Atmospheric Administrations' (NOAA) Office of Oceanic and Atmospheric Research funding. The NGI is funding a three-year project since 2007 called "Watershed Modeling Improvements to Enhance Coastal Ecosystems"; the main goal of this project is to improve watershed-wide decision support for resource management agencies with a demonstration project in the Mobile River watershed. The objective of this presentation is to show a review of physiographic, climatic, water quantity, and water quality characteristics of the Mobile River basin. The 113,959-Km^2 watershed drains waters in four states: Alabama, Mississippi, Georgia, and Tennessee with seven major subbasins (Coosa, Tallapoosa, Cahaba, Black Warrior, Tombigbee, Alabama, and Mobile). There are five Level III Ecoregions crossing the catchment: Coastal Plains, Appalachian Plateaus, Valley and Ridge, Piedmont, and Blue Ridge. The basin is mainly rural with the following land use distribution: forest (70%), pasture and hay (11%), cropland (8%), wetlands (6%), and urban (3%). This watershed is highly regulated with more than 100 dams. The Alabama Power generates hydroelectric power from 12 dams located in three subbasins: Black Warrior (Bankhead, Holt, and Smith dams), Tallapoosa (R. L. Harris and Martin dams), and Coosa (Mitchell, Jordan, Lay, Logan Martin, Walter Bouldin, Weiss, and H. Neely Henry dams). The Army Corps of Engineers operates 22 locks and dams in the Mobile River system. Water quality observed data from two U.S. Geological Survey stations, 02429500 Alabama River at Claiborne and 02469762 Tombigbee River, were analyzed. The drainage area of 02429500 and 02469762 stations represents 50% and 42% of the total watershed area, respectively. Almost thirty years (1974-2004) of discrete water quality data have been collected in these stations (around 200 samples). Cumulative distribution functions of total suspended sediments, total nitrogen, and total phosphorus were developed for each station. This entire physiographic, climatic, water quantity and water quality database is being used in hydrology, hydraulic, and sediment modeling evaluation of the Hydrological Simulation Program – FORTRAN (HSPF), the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) model, and the Hydrologic Engineering Centers River Analysis System (HEC-RAS) model.

Keywords: Hydrology, Water Quality, Sediments

A water budget: Tenn-Tom Waterway from Whitten Lock to Heflin Lock and Dam

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The Tenn-Tom Waterway was completed in 1984, linking the Tennessee River to Mobile Bay via the Tombigbee River. Water from the Tennessee River watershed flows through Whitten Lock near Bay Springs, Mississippi, and merges with flows from the Tombigbee Watershed. Although the primary authorized purpose for the Waterway is navigation, now it is being looked to for surface water supply to keep up with current and future water demands in Northeast Mississippi. Before watershed managers can make well-informed decisions about permitting withdrawals, the amount of water available must be quantified—a water budget. This was attempted through the compilation of data into a spreadsheet schematic of the Tombigbee River and Tenn-Tom Waterway. Data were acquired through various methods and sources including Geographical Information Systems, USGS Streamflow Data, MDEQ and USACE personal communication, and the MDEQ EnSearch Engine. A meld of these data into the spreadsheet format transforms them into the volumetric discharges for different flow situations at locations along the river and waterway.

Keywords: Surface Water, Water Supply, Hydrology

student presenter

SURFACE WATER QUALITY

Glenn Odom, Moderator

Movement of water pollutants in Sardis Lake

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River continuum concept and water quality stressor identification

David R. Johnson
U.S. Army Corps of Engineers

Comparing index of biotic integrity scores to traditional measures of water quality: Exploring the causes of impairment in streams of the Mississippi Delta

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Movement of water pollutants in Sardis Lake

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Comprising 39.9 million acres, lakes and reservoirs are a major water resource in this country. They provide drinking water and supply water for industry, irrigation, hydropower, and many recreational activities. Sardis Lake is a dammed reservoir in the state of Mississippi, located on the Little Tallahatchie River. This study is designed to test the movement of water pollutants throughout Sardis Lake and to assess how different water quality parameters are related. A numerical model, CCHE2D, is used to examine the transport of pollutants in Sardis Lake. CCHE2D was developed by the National Center for Computational Hydroscience and Engineering (NCCHE) at the University of Mississippi. This two-dimensional system is used for unsteady, turbulent river flow, sediment transport, water quality evaluation, and chemical transport. Water quality data was obtained from the Mississippi Department of Environmental Quality (MDEQ) and EPA's STORET database. Based on a digital elevation model (DEM) developed by NCCHE, a structured mesh is generated for the lake. By applying boundary conditions, initial conditions, and setting the model parameters, simulation is performed and the results are obtained. The second part of this study is to compare levels of water pollutants in the Little Tallahatchie River and at different locations in Sardis Lake. A statistical package, SPSS is used to analyze the data. The analysis of data is performed by two-tailed Spearman's correlation and regression analysis.

Keywords: Surface Water, Water Quality, Water Use

I. Introduction

Background

Water quality is a description of biological, physical, and chemical characteristics of water with respect to its use (USGS, 2005). The uses of lakes, rivers, ponds, and streams are greatly influenced by the quality of their water. Activities such as fishing, swimming, boating, shipping, and waste disposal have very different requirements for water quality. For example fishing waters must have higher quality than shipping waters.

There are two important laws to protect the quality of surface and ground water in the United States. The Clean Water Act addresses surface waters, mainly to control point source discharges (USEPA, 2007a). The Safe Drinking Water Act protects underground sources of drinking water (USEPA, 2007b).

Pollutants that are of some concern and can be found in surface runoff are suspended solids, heavy metals, nutrients, oxygen demanding substances, organic compounds, and bacteria.

Lakes and reservoirs must meet water quality standards because are important for fishing, supply of drinking water and water for industry, agriculture, and hydropower. They cover 39.9 million acres of land in the United States and support complex food web interactions, provide habitat for many species, and create recreational opportunities (U.S. ACE, 2007).

The productivity of a lake is a measure of its ability to support a food web. Algae form the base of this food web, supplying food for the higher organisms. A lake's productivity may be determined by measuring the amount of algal growth that can be supported by available nutrients. Lakes are classified based on their productivity as eutrophic, mesotrophic, and oligotrophic. Eutrophic lakes have high productivity due to abundant supply of algal nutrients, and oligotrophic lakes have low productivity due to deficiency of nutrients. Mesotrophic lakes are between these two types of lakes (PEARL, 2002 and

student presenter

Davis and Cornwell, 2006).

Algal growth is limited by the nutrient that is least available. Phosphorus is not readily available from the atmosphere or the natural water supply and it is the limiting nutrient in lakes (Chin, 2000). Therefore, the amount of phosphorus controls the quantity of algal growth, and as a result, the productivity of the lake. However, increased phosphorus generally results in reduced water quality because of undesirable changes that occur as algal growth increases (Ray, 1995). An example of that is the reduction of the most desirable fish as the population of undesirable fish increases. High productivity results in an abundant supply of algal nutrients, and algae cause the water to be highly turbid. Studies have shown that the phosphorus concentration should be below 10 to 15 µg/L to limit algal blooms (Davis and Cornwell, 2006).

Another important water quality parameter and nutrient in lakes is nitrogen. Nitrogen in lakes is usually in the form of nitrate (NO3-) and comes from external sources by way of inflowing streams or groundwater. In aerobic conditions, nitrogen changes from nitrate to organic nitrogen, then to ammonia, and back to nitrate (Mitch and Gosselink, 2000). Total Kjeldahl Nitrogen (TKN) is the sum of organic nitrogen and ammonia (NH3) as nitrogen in a water body. Total nitrogen concentration (TN) in a lake is equal to TKN plus NO3- plus NO2- as nitrogen.

Objective of the Study

This project has two objectives. The first objective is to analyze the relationship between selected water quality parameters at five different sites in Sardis Lake and to evaluate the lake's trophic state. The second objective is to computationally simulate the flow and transport of a hypothetical pollutant in Sardis Lake.

Study Sites

In the Yazoo Basin in northern Mississippi, there are four flood control reservoirs managed by the Vicksburg District of the U.S. Army Corps of Engineers. They are Enid, Arkabutla, Grenada, and Sardis Lakes. Sardis Dam was built on the Little Tallahatchie River to protect agricultural and industrial areas downstream by controlling its flow. Construction of Sardis Dam in 1940 resulted in the Sardis Lake System, an approximately 98,000-acre water resource development project. It extends into three counties: Union, Panola, and Lafayette. It serves a recreational use and has 5 million visitors annually (U.S. ACE, 2007).

Historical water quality data from five sampling sites in Sardis Lake were obtained from the Mississippi Department of Environmental Quality (MDEQ) in order to conduct the analyses in this project.

II. MATERIALS AND METHODS

The sampling sites are shown in Figure 1. They are: (1) Near Sardis Dam, (2) Near Clear Creek Landing Public Use Area, (3) Toby Tubby Creek Embayment, (4) Near Hurricane Landing Public Use Area, and (5) at upper end of the Lake.

Two different methods were used for analyzing the data: statistical data analysis (using the software SPSS) and hydrodynamic simulation (using the software CCHE2D).

Statistical Data Analysis

The data obtained from MDEQ ranged from 1997 to 2004 for all five Sites. Site 1 data were also available for 1994. The water quality parameters were measured at different depths varying from 0.15 m to 15.54 m below the water surface. For the parameters of interest, the highest number of data points available was at the depth of 0.46 m. Therefore, most analyses were performed at this specific depth. Parameters that were used in this study were water temperature (T), chlorophyll a (Chl-a), total suspended solids (TSS), total phosphorus (TP), and nitrogen in three different forms: TKN, NH3, and NO3- + NO2-. TN was obtained by the summation of TKN plus NO3- + NO2- as nitrogen. The highest number of sampling events at 0.46 m was for Site 1 (data points n = 28), Site 2 (n = 15), Site 3 (n = 14), and Site 4 (n = 15). Few data points were available for Site 5. Statistical analysis was not performed for this site. A two-tailed parametric correlation (Pearson Correlation) was performed between parameters of every site to determine the relationships between them.

One additional parameter used was chlorophyll a (Chl-a), found in all algae but not in other organic solids such as bacteria. Therefore, a criterion for the productivity of a lake is to determine the concentration of Chl-a in the lake. Table 1 shows the classification of a lake based on productivity (Wetzel, 1983).

The relationship between summer levels of chlorophyll a and measured total phosphorus concentrations for 143 lakes in the US can be estimated from Equation 1 (Jones and Bachmann, 1976).

$$\text{Log Chlorophyll a} = -1.09 + 1.46 \times \text{Log Total P}$$
(Equation 1)

Hydrodynamic Simulation
To analyze the movement of water pollutants and to assess the pattern of water quality parameters throughout the lake, a computational software package, CCHE2D, was used. This package was developed by the National Center for Computational Hydroscience and Engineering (NCCHE) at the University of Mississippi. CCHE2D is an integrated package for two-dimensional simulation and analysis of river flows, non-uniform sediment transport, morphologic processes, coastal processes, pollutant transport, and water quality. These processes are solved with the depth integrated Reynolds Equations, transport equations, sediment sorting equation, bed load and bed deformation equations. CCHE2D is composed of a graphical user interface (CCHE-GUI), a separate hydrodynamic numerical model (CCHE2D model), and a structured mesh generator (CCHE2D Mesh Generator). It is a two-dimensional structured and two-boundary algebraic mesh generator with graphical user interface (NCCHE, 2008).

III. Results and Discussion
Statistical Data Analysis
Based on all the data available for Sardis Lake from 1994 to 2004 at all sampling depths, average concentrations of TP and Chl-a were 69 ± 56 µg/L and 4.8 ± 2.0 µg/L, respectively. The average concentrations for the depth of 0.46 m were 68 ± 53 µg/L for TP and 4.4 ± 1.4 µg/L for Chl-a. Comparison of the results with Table 1 shows that the lake is classified as eutrophic considering the average concentration of TP and mesotrophic considering the average concentration of Chl-a. Data points in Figure 2 show the measured TP vs. Chl-a in Sardis Lake. The straight line was obtained by substituting the measured TP in Equation 1 and calculating Chl-a. If Sardis Lake had followed the same pattern as the 143 lakes used to generate Equation 1, the points would be scattered about the line. This result shows that for the concentration of TP, the lake has produced less Chl-a than expected.

Correlation analyses were performed for the data on the five sites in Sardis Lake individually at the depth of 0.46 m below the surface water from 1997 to 2004. At Site 1 (Near Sardis Dam), temperature negatively correlates with TSS, TP, and TN (-0.73 < r < -0.67, ⊠ < 0.01). r is correlation coefficient and ⊠ is the significance level. TSS positively correlates with TP and TN. Also, TN and TP positively correlate with each other (0.56 < r < 0.73, ⊠ < 0.01). Figure 3 shows the values in a column chart. Figure 4 shows the water quality parameters versus water temperature at Site 1. As water temperature increases, the concentrations of TSS, TP and TN decrease. Chlorophyll a was not used in this data analysis because the number of data points was few.

Water temperature negatively correlates with TSS (r = -0.71, ⊠ < 0.01) and TN (r = -0.70, ⊠ < 0.01) at Site 2. It negatively correlates only with TSS at Site 3 (r = -0.58, ⊠ < 0.05) and with both TSS (r = -0.73, ⊠ < 0.01) and TP (r = -0.81, ⊠ < 0.01) at Site 4. Figure 5 and Figure 6 show the concentrations of TSS, TP, and TN at different temperatures at Site 2 and Site 4, respectively. There is no strong correlation between temperature and TP at Site 2 or between temperature and TN at Site 4. TSS and TN correlate at Site 2 (r = 0.58, ⊠ < 0.01). TSS and TP correlate at Site 4 (r = 0.53, ⊠ < 0.05).

At Site 1, TN concentration correlates positively with three types of nitrogen: TKN (r = 0.93, ⊠ < 0.01) NH3 (r = 0.4, ⊠ < 0.05), and NO3- + NO2- (r = 0.8, ⊠ < 0.01). At Site 2, TN correlates positively with two types of nitrogen, TKN (r = 0.96, ⊠ < 0.01) and NO3- + NO2- (r = 0.7, ⊠ < 0.01). TN correlates with TKN (r = 0.99, ⊠ < 0.01) at Site 3. Also TN correlates with TKN (r = 0.92, ⊠ < 0.01) at Site 4. Figure 7 shows the percentage of contribution of three types of nitrogen in total nitrogen at Site 1. On Sept. 97 and Oct. 98 the percentage of ammonia is highest.

Correlations between parameters are higher at Site 1 compared to the other sites. Site 1 is near the dam and downstream of mixing points with other water bodies. Therefore, at Site 1, the parameters may have interacted with each other for more time and may have reached steady state.

Simulation Model
To simulate the flow and chemical transport using the software CCHE2D, five steps were followed: 1) generating a mesh, 2) setting boundary conditions, 3) setting initial conditions, 4) setting model parameters, and 5) running simulations. For the first step, the bathymetry data for Sardis Lake developed by NCCHE were used. The data were in ASCII format.

Flow simulation
Before conducting a chemical transport simulation, it was necessary to conduct a simulation of the water flow through the lake. For the flow simulation, the following conditions were set. One inlet (Little Tallahatchie River) and one outlet (Sardis Dam) were assumed for boundary conditions. For the initial condition, the inlet flow was

set at 80 m3/s. This flow rate is an estimate of a high discharge flood situation, based on historical discharges at the United States Geological Survey (USGS) gauge station at the Little Tallahatchie River at Etta (approximately 30 km upstream of the lake) and estimates of tributaries to the Little Tallahatchie River between Etta and Sardis Lake. The water surface elevation at the outlet of the lake was set at 80 m, which is a summertime elevation. The simulation time was 30 days to ensure that steady state flow was reached before the chemical transport simulation. The simulation time is different from the water travel time. The output results of the simulation in the graphical interface were: water depth, velocity in the x and y directions, velocity magnitude, specific discharge in the x and y directions, total specific discharge, shear stress in the x and y directions, total shear stress, Eddy viscosity, and Froude number. Figure 8 shows the water depth after steady state was reached. The water depth ranges from 16 m near the dam (Site 1) to less than 1 m at upper end of the lake (Site 5).

Figure 9 shows the velocity magnitude of water flow in the lake after steady state was reached. The flow ranges from zero near the dam (Site 1) to 2 cm/s at the upper end of the lake (Site 5).

Chemical Transport Simulation

To understand how a pollutant, introduced into Sardis Lake from the Little Tallahatchie River, may spread in the lake, a chemical transport simulation was carried out. Specific conductance, though not a pollutant in itself but a possible indicator of pollution, was used as a conservative parameter (that is, one that does not react) for the chemical transport simulation. A specific conductance of 79 µmhos/cm at 25C was assumed as a uniform initial condition in the lake. This number is a realistic initial condition for the lake and was taken from historical data from the lake obtained from the MDEQ. The input of a hypothetical pollutant was used as values of specific conductance from the Little Tallahatchie River into the lake. The input was modeled as a specific conductance of 202 µmhos/cm at 25^0C. Figure 10 shows the pattern and distribution of specific conductance throughout the lake 25 days after the initial high input of specific conductance. After 25 days, the hypothetical pollutant has traveled approximately 14,000 m along the length of the lake and has spread laterally through most of the lake's width. This output shows that it is possible to simulate the input of a conservative pollutant into the lake and obtain the concentration of that pollutant at a certain time at every point of the lake for different situations and initial conditions.

Simulation of water quality parameters in Sardis Lake allows a user to see the pattern and dilution of pollutants across the lake and to predict the concentration of pollutants in every point of the lake at any time. But to reach this goal, more data should be collected on potential pollutants, not only for the Little Tallahatchie, but also for other inlets to the lake.

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Lake Classification Based on Productivity			
Lake Classification		Chlorophyll a Concentration (μg/L)	Total Phosphorus Concentration (μg/L)
Oligotrophic	Average	1.7	8
	Range	0.3 - 4.5	3.0 - 17.7
Mesotrophic	Average	4.7	26.7
	Range	3.0 - 11.0	10.9 - 95.6
Eutrophic	Average	14.3	84.4
	Range	3.0 - 78.0	15.0 - 386.0

Table1. Classification of lakes based on productivity

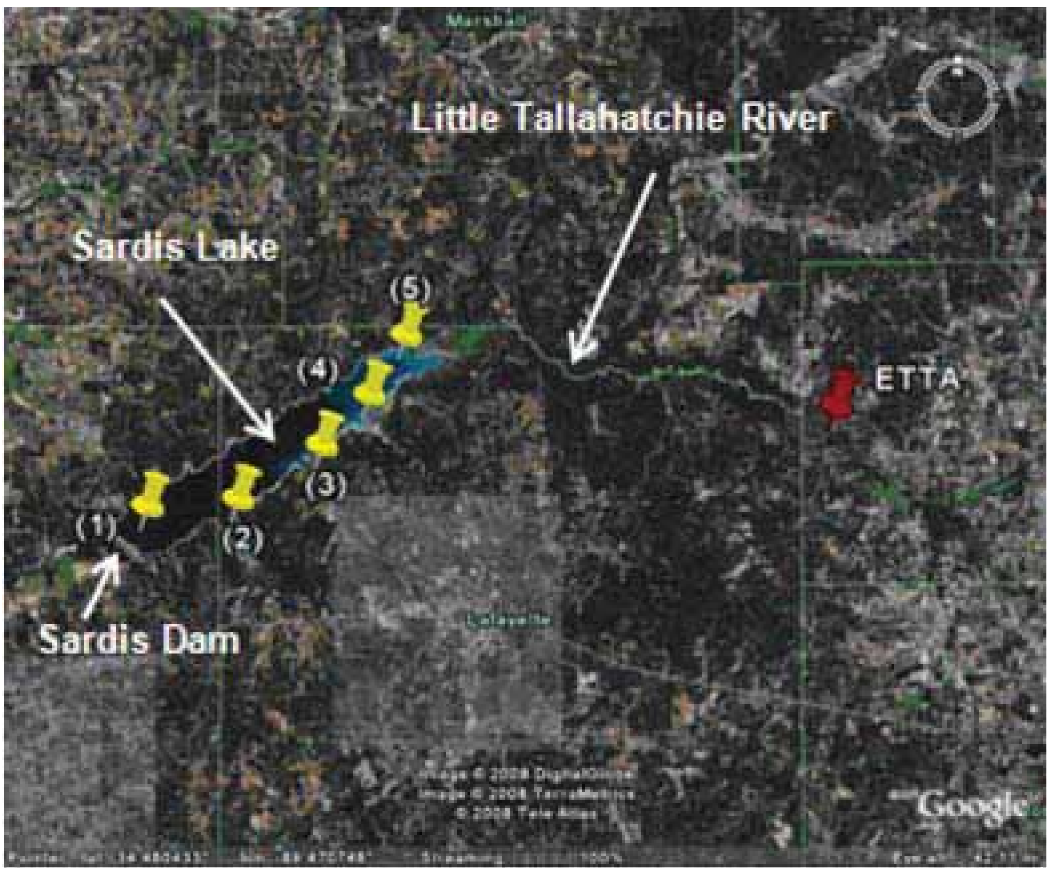

Figure 1. Satellite view of study area and study sites in Sardis Lake

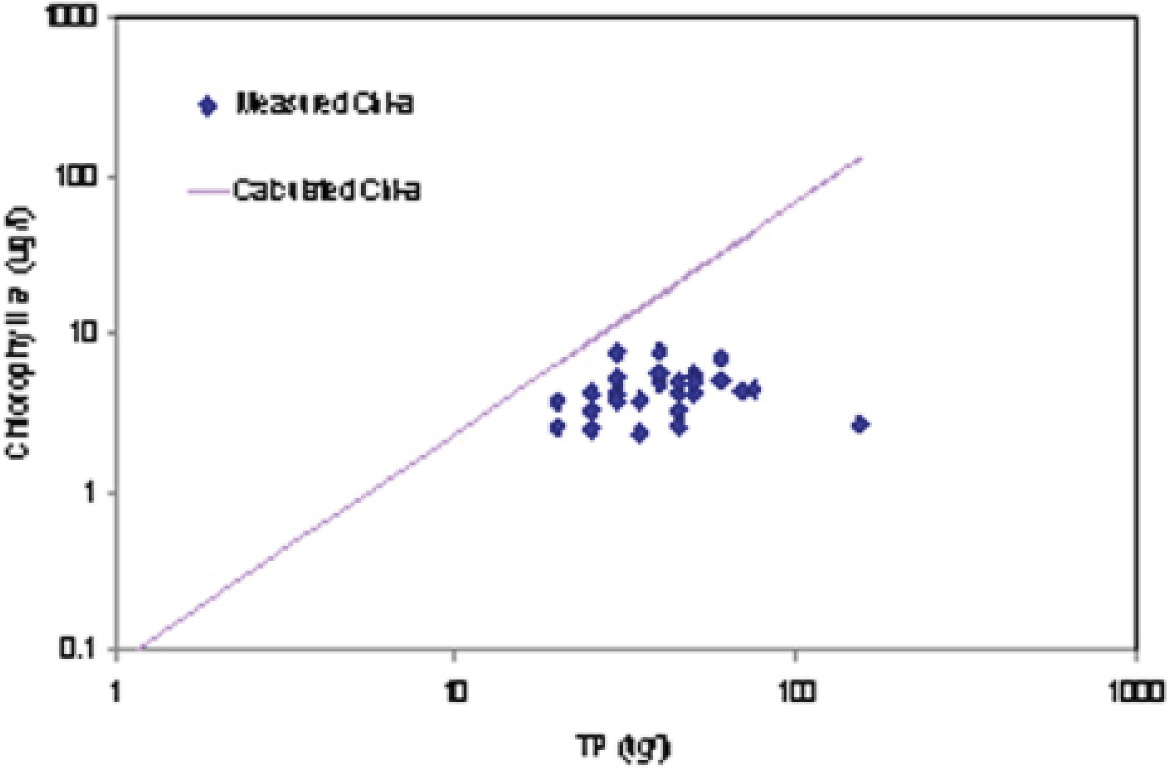

Figure 2. Relationship between TP and Chl-a

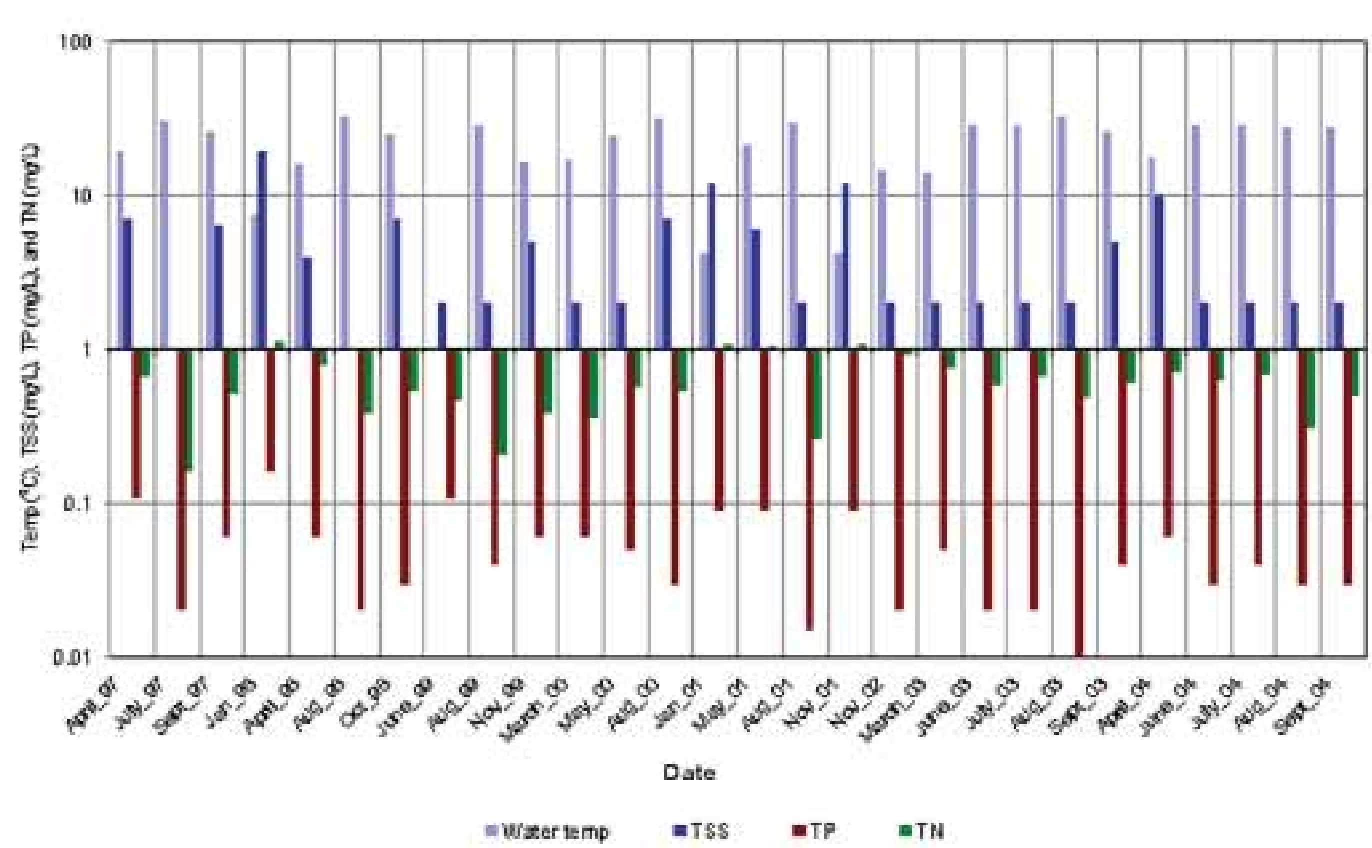

Figure 3. Variation of water temperature, TSS, TP, and TN at Site 1 from 1997 to 2004

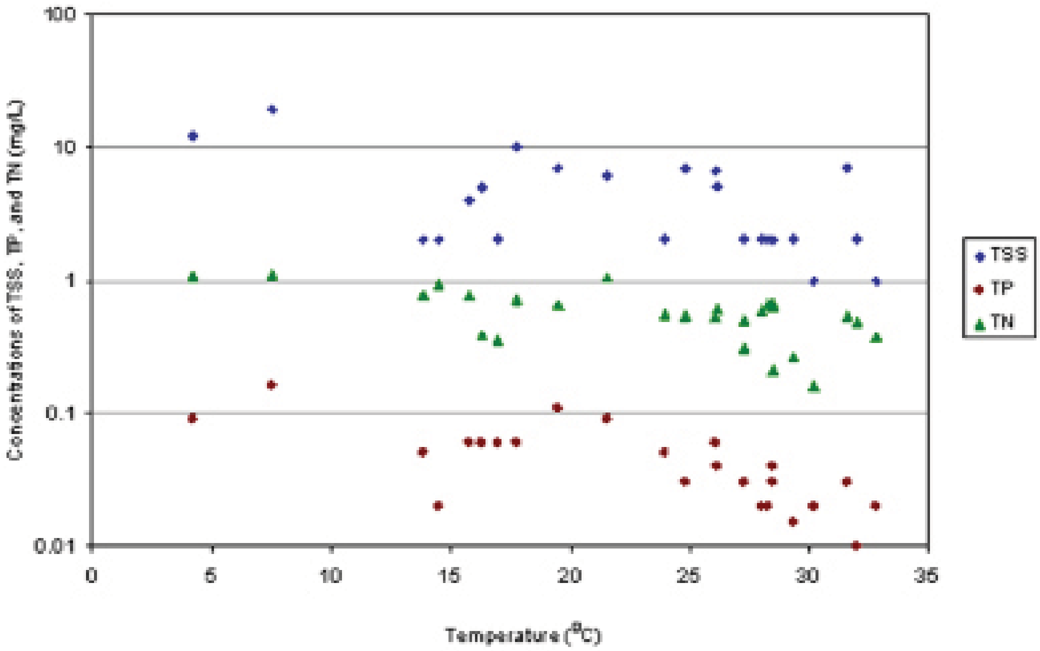

Figure 4. Variation of TSS, TP, and TN at different water temperatures at Site 1.

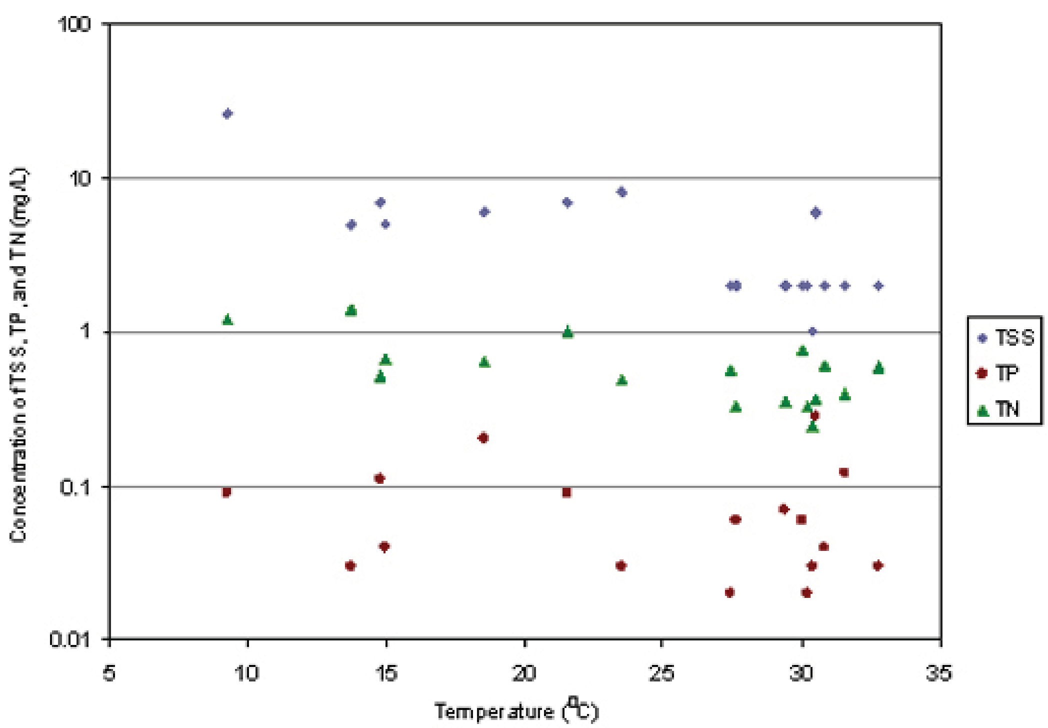

Figure 5. Variation of TSS, TP, and TN at different temperatures at Site 2

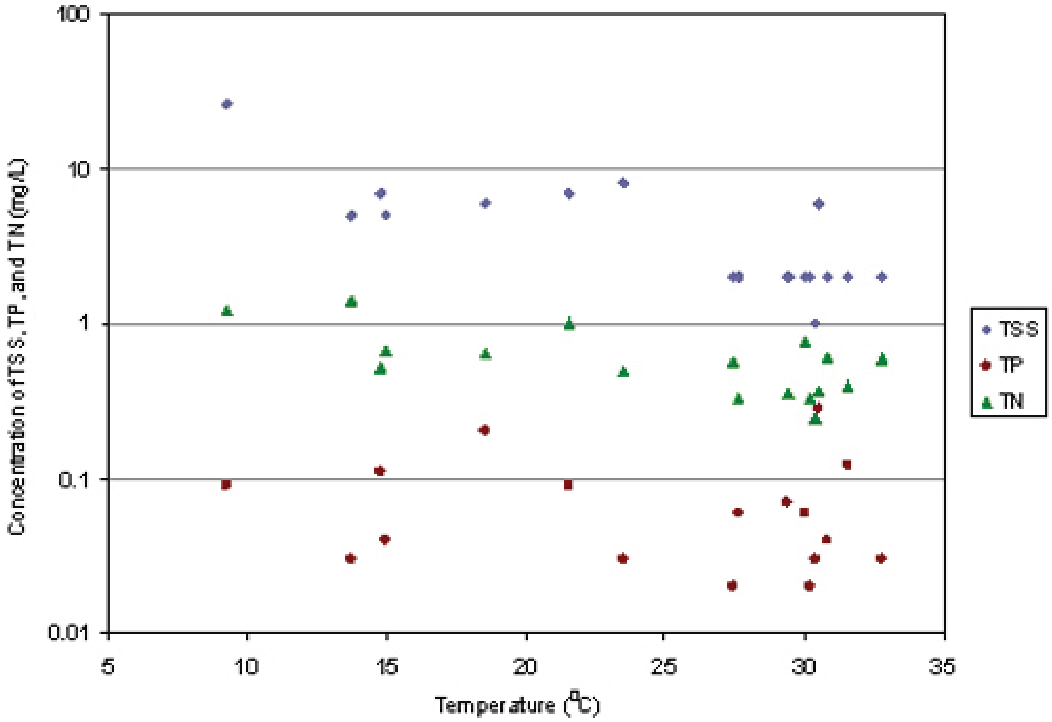

Figure 6. Variation of TSS, TP, and TN at different temperatures at Site 4

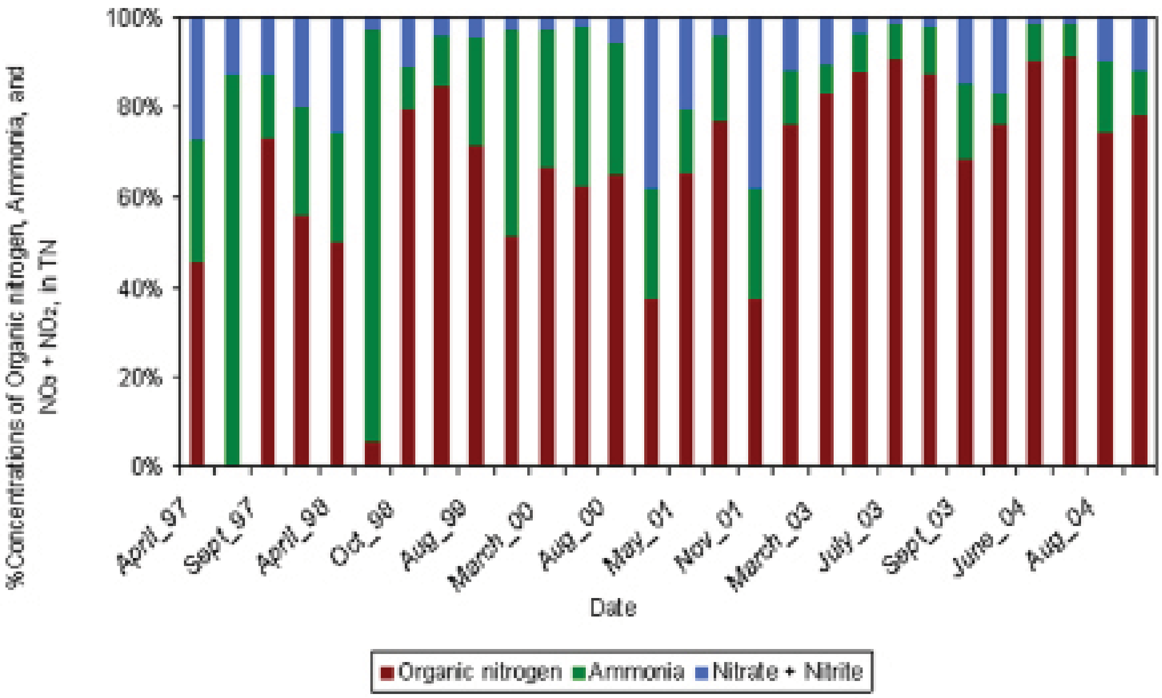

Figure 7. Contribution of three types of nitrogen in TN at Site 1

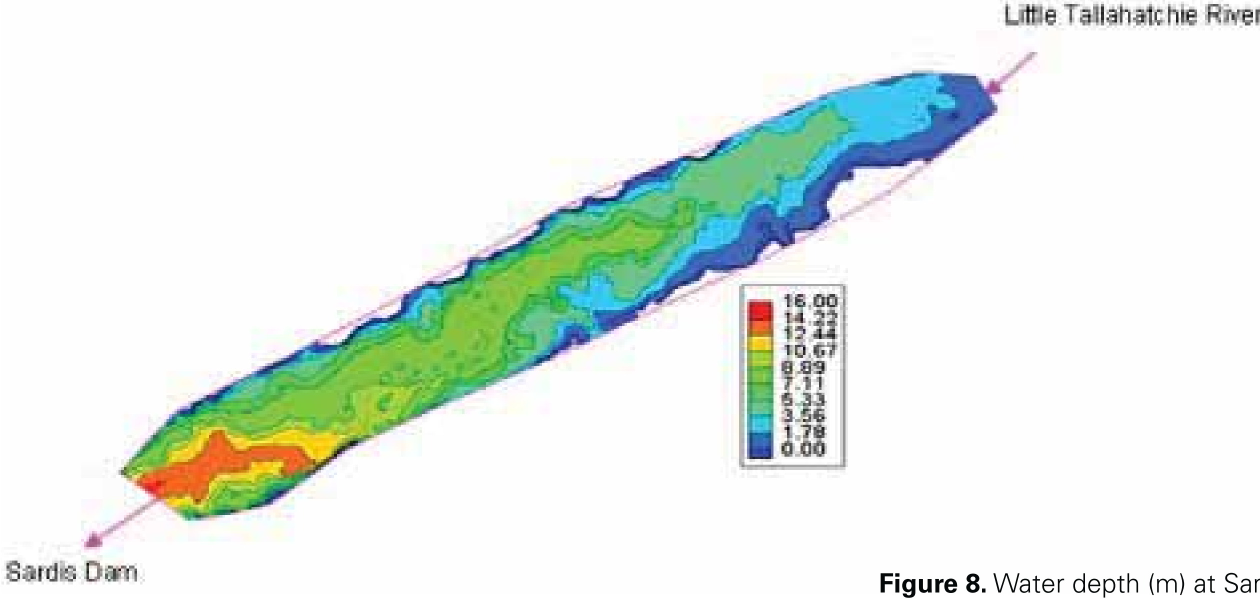

Figure 8. Water depth (m) at Sardis Lake

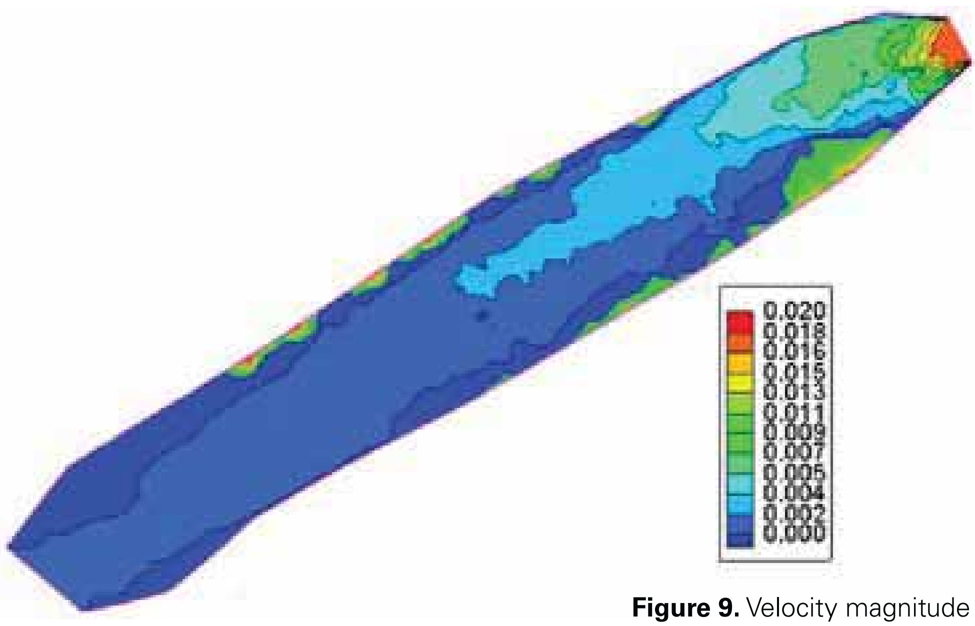

Figure 9. Velocity magnitude (m/s) at Sardis Lake

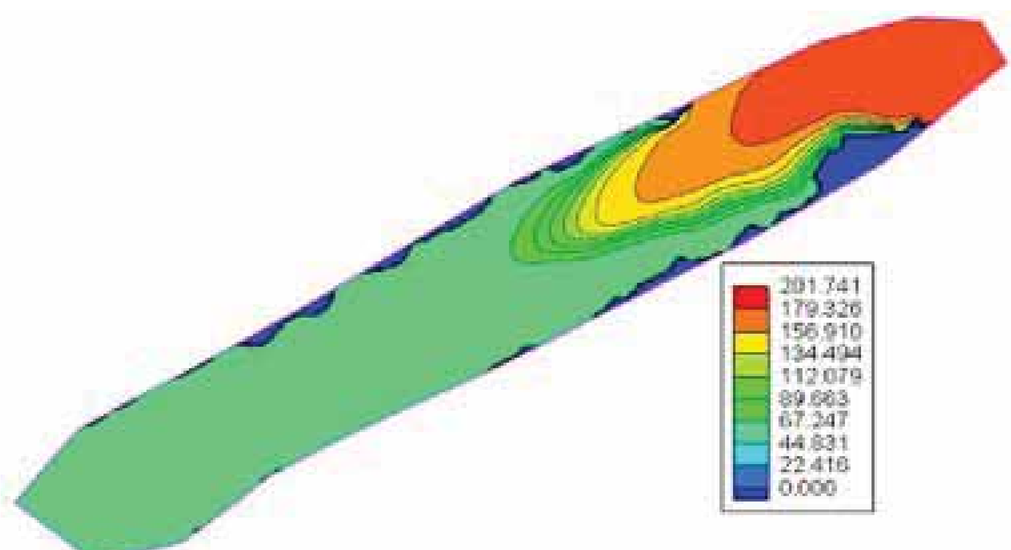

Figure 10. The pattern of specific conductance (µmhos/cm at 250^C) after 25 days

River continuum concept and water quality stressor identification

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During the last few years most states have been moving away from numeric water quality criteria and moving towards the use of Indices of Biological Integrity (IBI) to evaluate water bodies with regards to compliance with the Clean Water Act. IBIs function well with regards to determining compliance, but often fall short of identifying the stressors responsible for impairment. The Mississippi Department of Environmental Quality is in the process of developing a fishery IBI for the Yazoo Basin. A GIS database was used to generate land-use and stream data. This data coupled with expected fisheries information developed by applying the River Continuum Concept has identified some water quality stressors, and potentially could be used to identify other stressors.

Keywords: River Continuum Concept, Index of Biological Integrity, Stressor Identification, GIS

Comparing index of biotic integrity scores to traditional measures of water quality: Exploring the causes of impairment in streams of the Mississippi Delta

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The US Army Corp. of Engineers in conjunction with the Mississippi Department of Environmental Quality has worked to determine the quality of water in the streams of the Mississippi Delta region using an Index of Biotic Integrity (IBI) approach. This approach to water quality monitoring seeks to use information extracted from fish community composition and habitat parameters to provide an integrated and comprehensive picture of water quality that is reported to be superior to traditional grab samples analyzed for chemical water quality parameters. One difficulty encountered is that the Index of Biotic Integrity scores are based on a variety of fish community parameters, and therefore they cannot be directly related to specific pollutants or used to prescribe specific mitigation or restoration practices. We have collected periodic water samples from 20 of the sites which have previously been sampled and scored using the IBI approach. These samples will be analyzed for a variety of chemical (Nitrite+Nitrate-Nitrogen, Ammonium-Nitrogen, Soluble Reactive Phosphorus, Oxygen, pH), biological measures (Total Coliform bacteria, Fecal Coliform bacteria, Chlorophyll a, Chemical Oxygen Demand), and physical measures (suspended sediments, temperature). Overall this effort is attempting answer two questions: Can correlative relationships be developed between overall IBI scores and some combination of traditional water quality measurements? Can "classes" of pollutants be identified and correlated to IBI score ranges? Either of these answers will provide guidance need to make water quality improvements.

Keywords: Ecology, Surface Water, Water Quality, Streams and Rivers

AGRICULTURE

Richard Rebich, Moderator

Effects of harvest management on bermudagrass yield and nutrient utilization in a swine-effluent spray field

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U.S.D.A. Agricultural Research Service

Assessing the risks to water bodies from nitrogen vs. phosphorus-based broiler litter strategy

Ardeshir Adeli and John P. Brooks
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Effects of harvest management on bermudagrass yield and nutrient utilization in a swine-effluent spray field

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Swine waste management plans often include the use of lagoon effluent for the production of bermudagrass [*Cynodon dactylon* (L.) Pers.], the predominant warm-season forage in the southeastern USA. Producing bermudagrass hay from fields receiving swine effluent provides both high quality forage for ruminant livestock and a means of exporting manure nutrients to reduce potential surface and ground water impairment. The objective of this study was to determine harvest management effects on annual forage yield and uptake of N and P by common bermudagrass. Research was conducted in 2001-2003 in a swine-effluent spray field on a commercial farm in northeast Mississippi on a Prentiss sandy loam. Small plots (2 x 4 m) were irrigated with 15 cm ha^{-1} effluent from April–October, which provided about 520 kg ha^{-1} N and 110 kg ha^{-1} P during the growing season. After an initial harvest of all plots in early May, summer growth was harvested at 4, 6, 8, 10, and 12 week intervals and at 3- and 9-cm cutting heights using a sickle-bar mower. The year x harvest interval interaction effect was significant ($P<0.001$) for P uptake because maximum values were obtained at the 10-wk interval 2001 and at the 6-wk interval in 2002 and 2003. This interaction may be explained by seasonal changes in plant maturity, effluent nutrient concentration, irrigation rate or the combined effect of these factors. The year x height interaction effect also was significant ($P<0.05$); however, harvesting at 3-cm height consistently increased P uptake by about 18% in 2001, 28% in 2002, and 29% in 2004, as compared to 9-cm cutting height. These results provide information to producers and land managers on methods to enhance the uptake of manure nutrients by bermudagrass, and thereby decrease potential losses of N and P from hay fields receiving swine effluent. If the goal is to produce a high quality forage, bermudagrass should be cut frequently (< 5-wk interval) and as tall as practical in order to harvest more leaf tissue. If the goal is maximum utilization of manure nutrients in the effluent, bermudagrass should be cut at 6-10 wk intervals as close to the ground as possible in order to maximize annual forage yield.

Keywords: Agriculture, Ecology, Irrigation, Wastewater

Assessing the risks to water bodies from nitrogen vs. phosphorus-based broiler litter strategy

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The large amounts of poultry manure in localized areas and the high cost of implementing effective Best Management Practices (BMP's) often favor disposal rather than utilization of manure. Continual application of poultry manure at rates providing more N and P than removed by crops can increase soil N and P to levels that are of environmental rather than agronomic concern. Over application can enhance potential movement of N as NO3 to ground water and P in surface runoff. This study was conducted in 2007 at R.R. Foil Plant Science Research Center, Mississippi State University on a Mariate silt loam soil to investigate how N- vs. P-based poultry manure to perennial forage crops affects nitrate and P leaching from the crop root zones, N and P in surface runoff, crop removal and soil accumulation of the nutrients. An experimental field with bermudagrass has been established. Poultry manure was applied meeting the N or P requirement of Bermuda grass; fertilizer and control treatments serve as comparison purposes. Treatments replicated three times. Pen lysimeters were used to collect leachate for determining nitrate and P leaching losses. Runoff collection devices were installed for estimating runoff losses of N, soluble P and suspended solids. A rainfall simulator was used to simulate precipitation events and following each rain event, runoff and leachate samples were collected for nutrient analysis. Seasonal nitrate and P distributions in the soil profile will be monitored. Yield and nutrient utilization efficiency will be determined. This project will generate comprehensive and quantitative N and P data in both leachate and runoff when manure is applied at two contrasting rates to forage based system. Such data will provide much needed information for devising and effective decisions on how best to manage the vast amount of poultry manure nutrients for protecting waters while sustaining animal agriculture.

Keywords: Poultry manure, BMP's, Leachate, Runoff, Nitrate, Phosphorus

Introduction
Commercial broiler production in Mississippi generates approximately 500, 000 Mg broiler litter ha-1 which is mainly applied to nearby pastures or croplands as the most common method of disposal. Broiler litter contains significant concentration of N, P and K and is considered as an alternative source of fertilizer. Typically, broiler litter is about1.3 to 1.7% P on a dry weight basis with N:P ratios reported 2.3:1 by Baker et al. (1994). Since the N/P ratio in plant uptake is much greater than N/P ratio in broiler litter, repeated application of broiler litter based on N needs of the crop leads to the over-application of P to the soil and may result in accumulation of P(Adeli et al., 2007; Torbert et al., 2005). Accumulation of P in soils from broiler litter applications has been reported for soils used for forage (Sharpley et al., 1993; Kingery et al., 1994; Franzluebbers et al., 2004). Accumulation of P in surface soils raises concerns about losses in runoff and eutrophication of streams and water bodies contributing to water quality decline (Moore et al., 1995; Sharpley et al., 1994). Eutrophication can impair water use for drinking, recreation, habitat, and industrial use by producing algal blooms and reducing dissolved oxygen content of the water (Dougherty et al., 2004). With proper management practices, broiler litter can be a valuable source of nutrients for crop production with minimal or no adverse environmental impacts. Application of broiler litter based on P needs of the crop is being practiced recently. Therefore, our objective was to determine if broiler litter management would reduce the potential for excessive accumulation of soil P and runoff N and P concentrations.

Materials and Methods
This study was conducted at Plant Science Center (South farm), Mississippi State University, on Mariatta silt loan (fine-loamy, siliceous, active, thermic Fluvaquentic Eutrudepts) soil in which bermudagrass already established. Soil was slightly acidic having a pH of 5.4. Soil test P level at the 0-15 cm depth using Mississippi Soil Testing Laboratory before initiation of the experiment

was 55 mg P kg-1 which is greater than agronomic minimum response level of 50 mg P kg-1. Therefore, no P was applied to the control or inorganic fertilizer treatments during the experiment. The experimental design was a randomized complete block with four treatments replicated 3 times. Treatments included: (i) Control, receiving no N or P input; (ii) inorganic fertilizer N and P supplied by chemical fertilizer at the recommended rate for bermudagrss; (iii)N-based broiler litter, broiler litter applied to meet crop N uptake requirements; (iv)P-based broiler liter, broiler litter applied to supply crop P uptake requirements with the shortfall in N met using ammonium nitrate. Plot size was 14 ft by 7 ft. Runoff collectors were installed at the bottom of each plot. Runoff collector was build to collect 1/10 or 1/100 of total runoff volume in each plot.

Broiler litter was broadcast to individual plot at the rate of 9 Mg ha-1 for the N-based and 2.2 Mg ha-1 for the P-based treatments. Five days after broiler litter application, rainfall was generated by applying artificial rainfall using TeeJet1/2HHSS 50 WSQ nozzle (Spraying System Co., Wheaton, IL) placed approximately 10 ft above the soil surface. Rainfall was delivered at an average intensity of 27 mm h-1 and continued for approximately 5 min after initiation of runoff. Rainfall-runoff simulations were performed at 0, 7, 21, 42, 72 and 132 days after broiler litter application. Runoff was collected for each rain event and the volume was recorded. Unfiltered runoff samples were acid digested and analyzed for total N and P (Bremner, 1996). A 25-ml aliquot was centrifuged and filtered for NO3-N, NH4-N and dissoled P. Bermudagrass was harvested after each rain and dry weight yield was recorded. Forage samples were ground to pass 2 mm sieve. Total N and C contents were determined using C/N analyzer. Bermudagrass samples were also dry-ashed and total P in the plant samples was determined using ICP. Soil samples were taken at the end of growing season. Soil samples were extracted using both Mehlich 3 and KCL. Soil P and N concentrations were determined using ICP and Lachat systems.

Data were were subjected to analysis of variance for a randomized block design. Analysis of variance conducted using SAS (1998). All statistical tests performed at the 0.05 level of significance.

Results and Discussion

Dry matter yield and N and P uptake

Dry matter yields for all treatments were greater than the control. Dry matter yield for the N-based was similar to that for P based treatment. However, N-based treatment resulted in greater dry matter yield than the fertilizer treatment but no significant difference in dry matter production was obtained between P-based and fertilizer treatments. This indicates that broiler litter applied to supply the crop P requirements with additional N fertilizer can provide added nutrients to bermudagrass, similar to fertilizer application, with added the benefits of organic matter and micronutrients addition to the soil.

For broiler litter applications, N uptake by bermudagrss paralleled dry matter yield and no significant differences in N uptake was obtained between N-based and P-based treatments. However, fertilizer N application resulted in greater total N uptake than did the broiler litter treatments (Table 1). This reflects the inadequate amount of available N applied from broiler litter treatment as compared to inorganic fertilizer. Apparent N recovery was 88% for inorganic fertilizer, 55% for N-based treatment and 74% for P-based treatment. Although there was no significant differences in N uptake between N-based and P based treatments but N use efficiency was 26% greater for P-based treatment than N-based treatments. Phosphorus-based broiler litter application resulted in greater P uptake and P use efficiency than N-based treatment (Table 1). This is because smaller amounts of P were applied with P-based than with N-based application, indicating greater P use efficiency for lower P application rate (Eghball and Sander, 1989).

Nitrate and P losses in runoff

Application of broiler litter and inorganic fertilizer resulted in greater N and P losses in runoff the control (Table 2). Nitrogen-based litter application had greater total P, dissolved P and total N in runoff than the P-based broiler litter application (Table 2). However, no significant different in both P and N in runoff were observed between P-based broiler litter application and inorganic fertilizer treatments. Nitrate-N concentrations were 2.7, 10.1, 8.2 and 10.7 mg L-1 for the control, inorganic fertilizer, N-based and P-based broiler litter application respectively. The reason for the higher runoff NO3-N concentration in the P-based broiler litter application than N-based treatment can be explained that more N became available in the P-based broiler litter treatment, in which half of the N inputs broiler litter treatment was as inorganic N fertilizer, 100 of 191kg N ha-1) than in the N-based treatment which had much of the N in slowly mineralized organic forms.

Soil Phosphorus

Soil P concentration at the top 15 cm for all treatments were greater than those for the control plots (Fig. 1). This is because of removal of soil P by bermudagrass from the control plots, which did not receive P. Soil P concentrations at the top 15 cm were 20, 22, 34, and 69 mg kg-1 for the control, inorganic fertilizer, P-based and N-based treatments, respectively, indicating P accumulated at the soil surface when broiler litter applied to the bernudagrass based on N needs of the crop. Broiler litter application to provide for plant P requirements, with additional N as fertilizer, resulted in significantly lower soil P levels than the N-based broiler litter application

Conclusion

Phosphorus-based broiler litter application, was agronomically and environmentally advantageous as evidenced by similar bermudagrass dry matter production and resulted in greater P uptake or P use efficiency which avoided soil P accumulation. The concentration of P in runoff for P-based broiler litter treatment was lower than N-based treatment. Phosphorus based broiler litter application reduces the P transport to the surface water bodies.

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Table 1. Effects of broiler litter fertility regimes on bermudagrass dry matter yield, N uptake and P uptake.

Treatments	DMY	N input	N uptake	P input	P uptake
	Mg ha^{-1}	---------- kg ha^{-1} ----------			
Control	3.2 c	0	60 c	0	10 d
Recommended fertilizer	7.8 b	220	254 a	0	22 c
N-based	10.5 a	280	215 b	171	33 b
P-based + N fertilizer	9.1 ab	191	203 b	47	41 a
$LSD_{(0.05)}$	1.5	----	23.1	----	3.6

Table 2. Effects of broiler litter fertility regimes on runoff nutrient concentrations.

Treatments	Total P	Dissolved P	Total N	NO3-N
- mg L^{-1} -				
Control	1.3d	1.1c	3.1c	2.7 d
Recommended fertilizer	2.4 c	2.2 b	9.8 b	10.1 a
N-based	7.0 a	5.4 a	12.1 a	8.2 b
P-based + N fertilizer	3.2 b	2.3 b	7.5 b	10.3 a
LSD $_{(0.05)}$	0.36	0.29	2.4	0.67

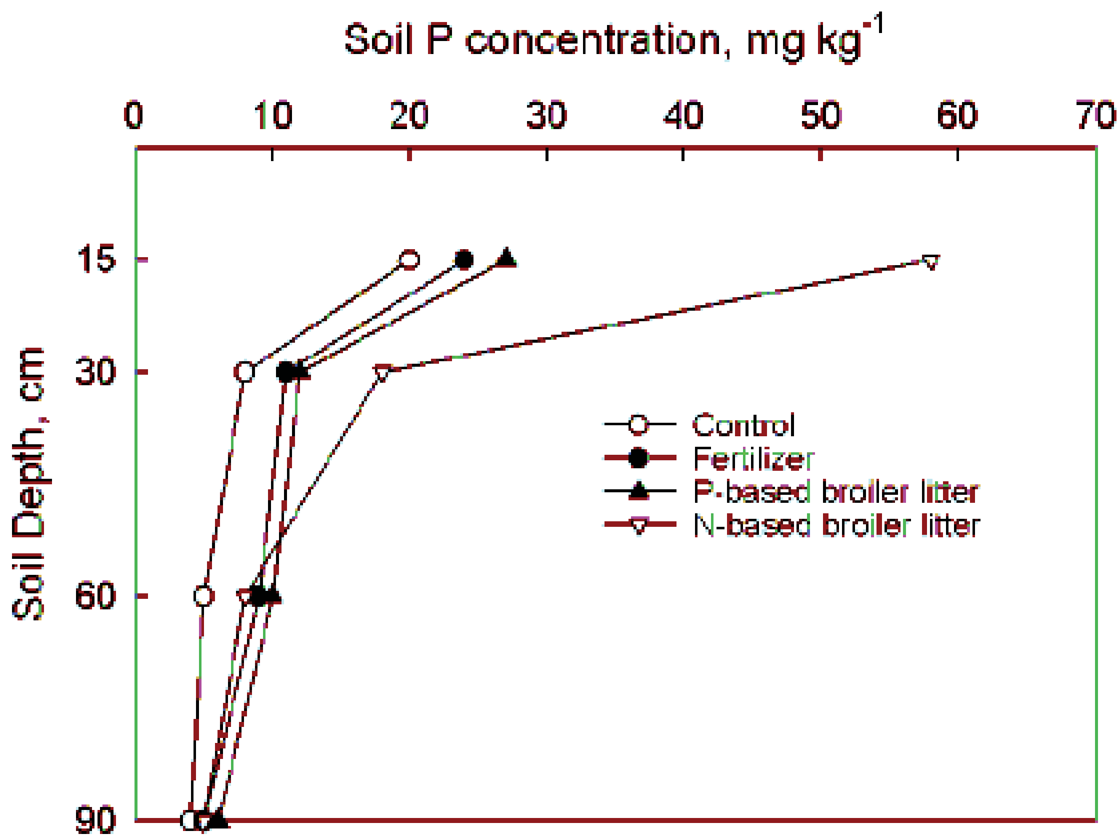

Fig. 1. Effects of broiler litter management on soil P concentration.

MODELING

William McAnally, Moderator

Sensitivity analysis of simultaneous nitrification-denitrification process by simulation with activated sludge model number one

Ayanangshu Dey and
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National Weather Service flood inundation mapping

Jeffrey Graschel
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Sensitivity analysis of simultaneous nitrification-denitrification process by simulation with activated sludge model number one

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Nitrogen removal by Simultaneous Nitrification-Denitrification (SND) has invited much attention in recent years due to possible reduction in capital and operating costs associated with wastewater treatment. The potential of biological nitrogen removal through this process and optimization of its operating parameters were investigated by simulations using Activated Sludge Model No. 1 (ASM1). Adopting typical properties of domestic sewage, simulations of SND process were performed in three sequential phases to optimize the operating parameters and assess reliability of the SND process over variation in the kinetic and stoichiometric parameters. Since dissolved oxygen (DO) concentration and solids retention time (SRT) were considered to have the most significant impact on nitrogen removal, the first set of simulations was aimed at identifying an applicable operating window for these parameters. Simulation results indicated that optimum nitrogen removal occurred at a DO concentration of 0.3 mg/L coupled with a SRT of 15 days. A second set of process simulations was run using this combination of operating DO and SRT to examine the effect of other process parameters; specifically the ratio of biodegradable COD to total Kjeldahl nitrogen (BCOD:TKN) in the influent, hydraulic residence time (HRT), and recycle ratio (R) on total nitrogen removal. The influent BCOD:TKN ratio significantly affected overall nitrogen removal, since availability of electron donor is essential to drive denitrification, with optimal nitrogen removal observed at a BCOD:TKN ratio of 11. Neither HRT nor R had a significant effect on nitrogen removal. The third set of simulations considered the natural variability of the kinetic and stoichiometric parameters of ASM1. Monte Carlo analysis was performed to evaluate the performance of an SND system operated at a DO of 0.3 mg/l and an SRT of 15 d using probability density functions developed by Cox (2004) for the model parameters. Results of these simulations were used to assess the potential reliability of an SND process designed using "typical" model parameter values. A sensitivity analysis was also performed to identify the model parameters that had most significant effect of nitrogen removal.

Keywords: Models, Treatment, Wastewater, Water Quality

Introduction

Biological nitrogen removal (BNR) is usually accomplished either by sets of reactors maintaining anoxic and aerobic phases discretely, or in a single reactor where suitable conditions are sequentially developed. Simultaneous nitrification-denitrification (SND) is the process of achieving nitrification and denitrification in a single activated sludge reactor without distinct spatial or temporal delineation in growth environment, by operating at a reduced dissolved oxygen (DO) level which permits both autotrophic nitrification and heterotrophic denitrification to occur simultaneously. This has invited particular attention in the past years over conventional systems by virtue of effective nitrogen removal in extended aeration type activated sludge (AS) systems and potential savings in capital and operational cost. For continuously operated plants, nitrogen removal obtained in a single tank can save the cost of a second tank, and low operating DO requirement can reduce energy cost in maintaining a higher DO level in aeration tank of conventional plants. Such process modifications, if applied effectively to existing plants, can help meet stringent nitrogen discharge standards.

Simultaneous occurrence of nitrification and denitrification in a single reactor need two apparently conflicting environmental conditions. In order for SND to occur, it is necessary that: (1) the operating DO level be correctly poised so that it is not so low that it cannot support autotrophic nitrification, or so high that it inhibits denitrification; (2) sufficient residence be provided to permit the establishment of a stable population of nitrifiers; and (3) adequate electron donor be available for

student presenter

heterotrophic denitrification. Rittmann (2001) concluded that that implementation of SND process required the effective combination of solids retention time (SRT), hydraulic retention time (HRT), and DO concentration. Hence, it is critical to examine and identify the operating conditions that these two processes, requiring two seemingly different conditions, can occur side by side leading to effective nitrogen removal.

Control strategies have been successfully implemented to enable AS operations that were designed primarily for organics removal to achieve biological nitrogen removal The DO concentration in the aeration tank has been identified as an important control parameter to achieve nitrogen removal at reduced operating cost (Lukasse et al., 1998; Copp et al., 2002; Sin et al., 2004; Insel et al., 2006). The fine tuning of operating DO, particularly at low concentration, was observed to be an effective approach for promoting simultaneous nitrification and denitrification resulting in increased nitrogen removal efficiency of the process (Drews et al., 1972 and 1973; Applegate et al., 1980; Daigger, et al., 2000).

In this study, SND in a conventional (plug flow) AS system was modeled using Activated Sludge Model No. 1 (ASM1), which incorporates seven (7) soluble and six (6) particulate components, 14 kinetic parameters, and five (5) stoichiometric coefficients. The model was initially used to identify suitable combinations of DO concentrations and solids residence time (SRT), and to discern interrelationships between the three parallel processes of heterotrophic substrate oxidation, autotrophic nitrification, and heterotrophic denitrification. Subsequent simulations were used to assess the effects of other process parameters, i.e. the ratio of biodegradable chemical oxygen demand (BCOD) to total Kjeldahl nitrogen (TKN), the hydraulic retention time (HRT), and recycle ratio (R).

Methodology

SND process simulations were performed using GPS-X (Hydromantis, Inc., Hamilton, Ontario), a simulation package that includes ASM1 modeling. The work has been done in three separate phases. The model system is a conventional activated sludge plant, consisting of a plug flow aeration basin and a secondary clarifier, with solids recycle and wasting. The aeration basin was modeled as four completely mixed compartments in series, while the clarifier was modeled as a point separator with 100% solids removal efficiency. Consequently, the modeling results specifically manifest the effect of parameter changes and variations of the biochemical performance of the system, while eliminating the effects of sludge separation and settleability. The model feed (Table 1) is based on typical domestic wastewater (Grady et al., 1999), except that the BCOD (partitioned between readily and slowly biodegradable fractions) was increased so that the influent BCOD: TKN ratio was 10. This ensured that sufficient electron donor was available to drive denitrification: an influent BCOD: TKN ratio > 10 is reportedly necessary to obtain efficient nitrogen removal (Grady et al., 1999; Rittmann and McCarty, 2001). Kinetic and stoichiometric parameters (Table 2) used for all simulations were based on a statistical analysis of recommended and calibrated parameter values from various sources (Cox, 2004).

Table 1 - Influent characteristics

Component[a]	ASM1 Symbol	Concentration[b], mg/L
Soluble inert organic material	S_I	0
Readily biodegradable substrate	S_S	160
Particulate inert organic material	X_I	30
Slowly biodegradable substrate	X_S	240
Non-biodegradable particulates from cell decay	X_D	0
Free and unionized ammonia	S_{NH}	25
Soluble biodegradable organic nitrogen	S_{ND}	6.5
Particulate biodegradable organic nitrogen	X_{ND}	8.5
Nitrate and nitrite	S_{NO}	0
[a]Typical values based on Grady et al. (1999), except as noted in text. Active biomass was absent from the influent.		
[b]Expressed as COD for organics, and as N for various nitrogen species.		

Table 2 – Typical parameter values, ranges, and distribution at neutral pH and 20° C for domestic wastewater (Cox, 2004)

Symbol	Units	Statistical Parameters [a] ξ	σ	Mean value[b]
Heterotrophic coefficients				
Y_H	mg biomass COD formed/ mg COD oxidized	-0.45	0.12	0.64
$\hat{\mu}_H$	day^{-1}	1.14	0.60	3.13
K_S	mg COD/L	1.44	0.76	4.22
b_H	day^{-1}	-1.06	0.81	0.35
K_{NO}	mg NO_3^--N/L	-1.55	1.01	0.21
$K_{O,H}$	mg O_2/L	-1.46	0.83	0.23
η_g	Fraction	0.10 [c]	0.90 [c]	0.50
Autotrophic coefficients				
Y_A	mg biomass COD formed/ mg N oxidized	-1.52	0.55	0.22
$\hat{\mu}_A$	day^{-1}	-0.51	0.44	0.60
b_A	day^{-1}	-1.97	0.28	0.14
K_{NH}	mg NH_3-N/L	-0.68	1.00	0.51
$K_{O,A}$	mg O_2/L	-0.82	0.96	0.44
Hydrolysis coefficients				
k_h	mg slowly biodegradable COD/ mg cell COD-day	0.83	0.36	2.29
K_X	mg slowly biodegradable COD/ mg cell COD	-2.82	1.34	0.06
η_h	fraction	-0.86	0.62	0.42
Other coefficients				
f'_D	mg debris COD/ mg biomass COD		*	0.08
$i_{N/XB}$	mg N/ mg COD in active biomass		*	0.086
$i_{N/XD}$	mg N/ mg COD in biomass debris		*	0.06
k_a	L/ mg biomass COD - hour		*	0.1608

[a] Represent the mean ξ and the standard deviation σ of a log-normal PDF, unless specified.
[b] Recommended parameter values, representing 10^{ξ} in a log-normal PDF and the central value in a uniform PDF
[c] η_g follows a uniform PDF with the tabulated values representing lower and upper limits, respectively.

An initial set of simulations was performed to identify appropriate combinations of DO concentration and SRT to support SND process were identified. A second set of simulations was then performed at a selected DO and SRT to examine the effect of other operating parameters (influent BCOD: TKN ratio, HRT, and R) on total nitrogen removal, where each of these process parameters was varied individually while holding all other process parameters were held constant. In both of these simulation sets, the listed mean parameter values for ASM1 (Table 3) were used.

Table 3. Values/ranges a of operating parameters used in SND process simulations

Parameter [b]	Set 1	Set 2	Set 3
SRT (θ_X), day	1 – 30	15	15
DO concentration, mg/L	0.1 – 2.0	0.3	0.3
HRT (θ), hr.	6	4 – 24	6
R	0.5	0.25 – 3.0	0.5
Influent BCOD: TKN	10	4 – 20	10

a Selected ranges typical of a range of SND process configuration (Rittman, 2001)

b Parameter symbols: DO – dissolved oxygen concentration in aeration tank, ▯X – solids residence time, ▯ – hydraulic retention time, and R – recycle ratio

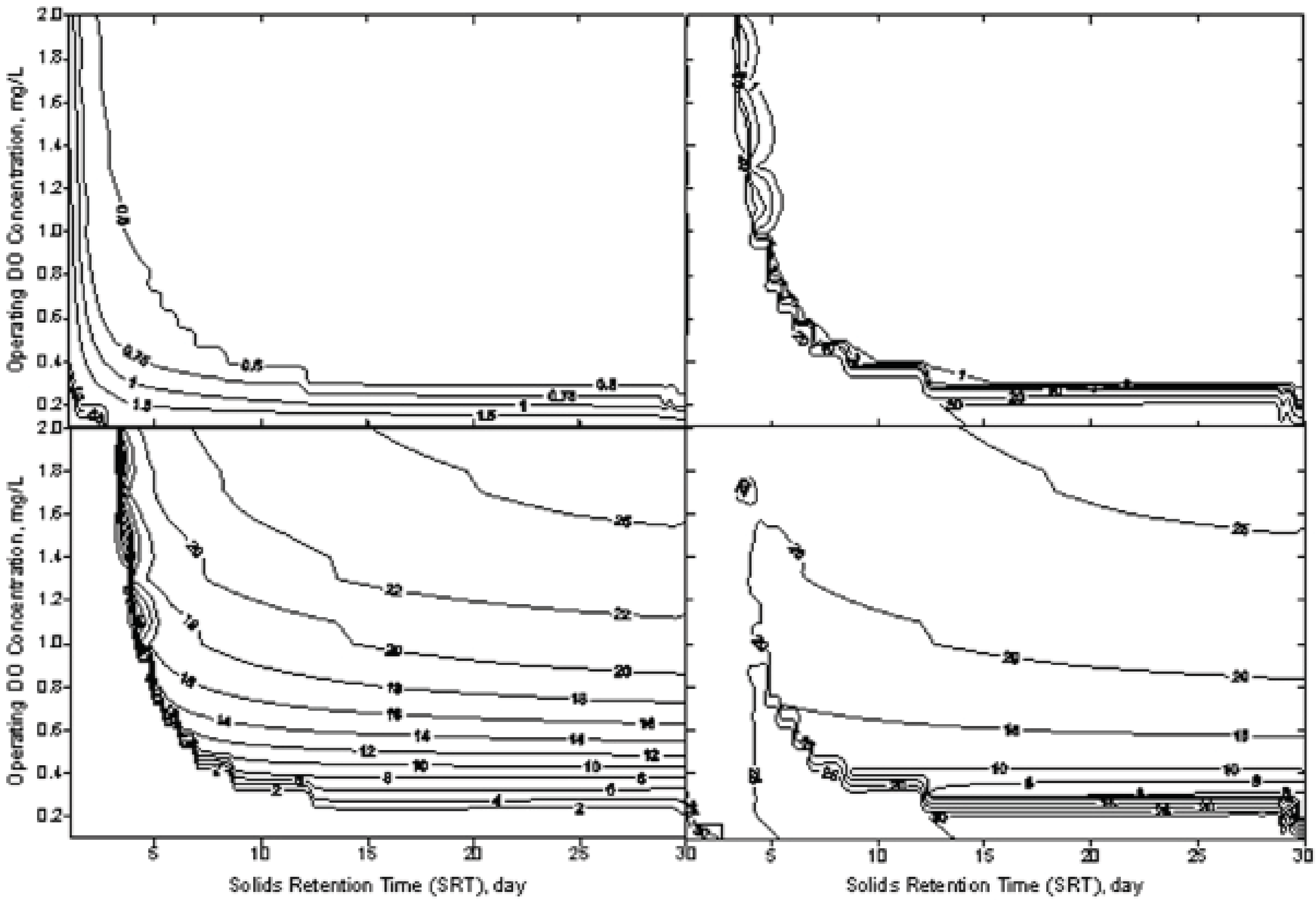
Finally, a set of Monte Carlo simulations was performed, where 15 of the 19 the model parameters were permitted to vary in accordance with reported (Cox, 2004) probability distribution functions (PDFs, Table 2). Output of this third simulation set was used to assess the sensitivity of SND process performance to ASM1 kinetic and stoichiometric parameters, based on a Spearman rank correlation matrix generated with the aid of the CORR procedure of SAS (The SAS Institute, Cary, NC), and to evaluate the inherent uncertainty in SND process performance, based on the empirical cumulative distribution functions (CDFs) of the effluent properties.

Results and Discussion

Identification of Optimal DO and SRT

Oxygen is required for nitrification but inhibits denitrification,hence, it was necessary to identify operating conditions that would permit these two processes to occur simultaneously. An appropriate operating window for the SND process was identified by running exhaustive simulations on different combinations of DO concentration and SRT. Simulation results (Figure 1) indicated that organic material in the wastewater was consumed almost entirely when the SRT was > 5 d and the DO level was ≥ 0.2 mg/L. The effluent total nitrogen (TN) was minimum at 0.3 mg/L and ~12.5 d SRT; higher SRT values provide little discernible improvement in TN removal. Higher DO levels inhibited denitrification, resulting in higher effluent nitrate concentrations. Further reducing the DO, however, prevented effective nitrification and resulted in increased effluent ammonia concentrations, or required operation at a higher SRT to permit the establishment of a nitrifying population. Hence, a DO concentration of 0.3 mg/L and a SRT of 15 d were selected as "optimal" for overall nitrogen removal, and subsequent simulations were performed under these conditions.

Figure 1. Effect of DO concentration and SRT on effluent concentrations of: (a) soluble COD mg/L; (b) ammonia (SNH), mg/L as N; (c) nitrate (SNO), mg/L as N; and (d) total nitrogen, mg/L as N.



Effect of Additional Process Operating Parameters

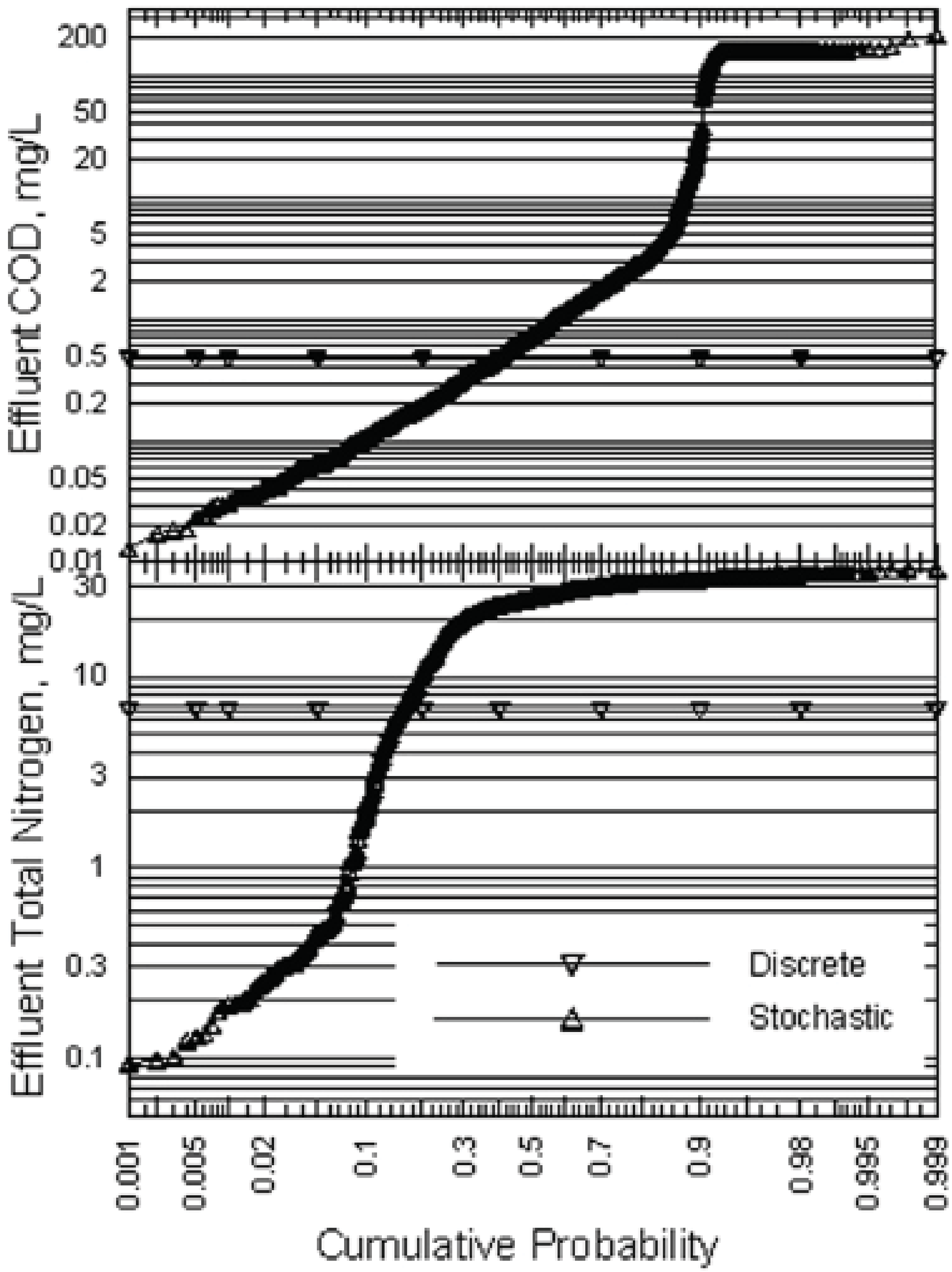
Simulations results showed that overall nitrogen removal approached 90% when the influent BCOD: TKN was between 12 and 16, and at least 80% when the influent BCOD: TKN was > 9. Note that these values are much higher than the stoichiometric ratio of 2.86 mg OD/mg NO3--N, since a substantial portion of the influent BCOD is used for cellular growth or is oxidized with oxygen as electron acceptor. Overall nitrogen removal dropped substantially, and effluent nitrate increased, when the influent BCOD: TKN was < 9, indicating that the available electron donor was insufficient to drive denitrification. The recycle ratio had a marginal impact on the overall nitrogen removal. A slight decrease in effluent TN concentration was observed with a rise in R, although overall nitrogen removal was all cases > 80%. The increased R permitted more efficient denitrification by returning effluent to
the reactor at an increased rate, as shown by a rise in COD consumption and a reduction in effluent nitrate concentration. Nonetheless, the impact of variations in the recycle ratio on overall nitrogen removal was not appreciable.

Nitrogen removal increased from 22% at an HRT of 4 h to more than 84% at when the HRT was 6 h, but was only slightly enhanced by further increases in the HRT. The extent of ammonia and COD oxidation were significantly reduced when the HRT was < 6 h, indicating insufficient contact time between the biomass and the wastewater.

Sensitivity and Uncertainty Analysis

Data generated using the Monte Carlo simulations were used to assess the sensitivity of the effluent COD, ammonia and nitrate concentrations on the ASM1 kinetic parameters and stoichiometric coefficients. Overall nitrogen removal was strongly correlated to the oxygen half-saturation coefficients for autotrophs (KO,A), in a positive direction, and strongest maximum specific autotrophic growth rate (Aμ̂), in a negative direction. The empirical CDFs of the steady state effluent COD and TN concentrations (Figure 2) suggest that these conform to truncated log-normal PDFs. Comparison of the discrete (deterministic) simulation results using the recommended model parameter values suggests that the certainty of achieving the predicted COD and TN removal are in the order of 40 and 20%, respectively.

Figure 2. Stochastic simulation results of steady state effluent COD and TN in SND system



Comparison of Simulation Results with Measured Performance

In general, laboratory and field results documented in the technical literature report SND at DO levels slightly higher and SRTs comparable to the optimal window determined by these simulations. Elisabeth et al. (1996) reported, at a DO of 0.5 mg/L, TCOD: TKN ratio of 9.4, HRT of 18 h, and SRT of 15 d, the rates of nitrification and denitrification would be similar and this might lead to complete SND. Zeng et al. (2003) achieved < 1 mg/L effluent TN at 0.5 mg/L DO concentration and 15 day SRT in a laboratory AS system. Bertanza (1997) reported significant nitrogen removal in pilot- and full-scale AS plants at 0.3 to 0.5 mg/L DO. Likewise, Münch et al. (1996) and Insel et al. (2005) suggest that SND can be achieved at a DO level of about 0.5 mg/L. Hence, while ASM1 was able to reasonably forecast general trends in the behavior of the SND process in response to variations in the operating parameters, specific values, particularly for the DO concentration, were not so accurately predicted. This suggests that, while the structure of ASM1 is suitable for modeling the SND process, specific model parameters may have to be calibrated for SND to more accurately model and simulate the process. The sensitivity analysis provides some initial suggestions as to specific model parameters that might be adjusted to properly calibrate ASM1 for SND process simulation.

Summary and Conclusions

The simultaneous nitrification de-nitrification (SND) process was simulated using ASM1 to identify an appropriate operating window, and to assess process sensitivity and uncertainty. Simulation results suggested that a DO level of 0.3 mg/L in the aeration tank and an SRT of 15 d were "optimal" for SND. An influent BCOD: TKN ratio > 9 was necessary to ensure that sufficient electron donor was available to drive denitrification and a high level of overall nitrogen removal. The recycle ratio and HRT, on the other hand, had little effect on overall nitrogen removal, provided they exceeded specific threshold values of 0.3 and 6 h, respectively.

Acknowledgement

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National Weather Service flood inundation mapping

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Lower Mississippi River Forecast Center, National Weather Service

The National Weather Service (NWS) is responsible for issuing river and flood forecasts and warnings to mitigate the loss of life and property. Current NWS text-based products are utilized by emergency managers (EMs). One of the most often requested product from EMs is flood inundation mapping to show the areal extent of flooding. Flood inundation maps would translate the forecasted stages into inundation areas, making it easier for EMs to take action and alert the public. They would also prove invaluable to EMs in their outreach, mitigation, and educational efforts

By partnering with the Federal Emergency Management Agency (FEMA) and local communities, the NWS is developing flood inundation maps for their forecast locations. When a community performs flood studies to update FEMA Flood Insurance Rate Maps (FIRMs), much of the necessary data are available to develop flood inundation maps. For a small incremental cost above the cost to develop FIRMs, flood inundation maps at various stages above the NWS-established flood stage are being developed. This collection of maps will form a flood inundation map library that can be served up to the public via the Internet.

The NWS has partnered with FEMA and developed flood inundation map libraries at about 15 locations across the country. Currently, work is ongoing to produce these maps for an additional 30 sites in the states that border the Gulf of Mexico. The NWS has established a web site and web structure to serve this data up to the public.

Keywords: Floods, Hydrology, Management and Planning, Models

Introduction

The National Weather Service (NWS) is responsible for issuing river and flood forecasts and warnings to mitigate the loss of life and property. Current NWS text-based products are utilized by emergency managers (EMs) to determine areas to evacuate and the appropriate measures to take to mitigate the loss of life and property. Information in these text-based products are ideally suited for integrating with a geographic information system (GIS) to develop maps of inundation areas to show the areal extent of flooding based on projected river crest heights. These inundation maps provide EMs information in a form more easily understood. These inundation maps are the most often requested products when customers are surveyed. The NWS has developed prototype procedures to develop these inundation maps.

Static and Dynamic Inundation Maps

After Hurricane Floyd caused widespread damages to homes and businesses in North Carolina, the NWS began an initiative to develop flood inundation maps. The NWS has been experimenting with two approaches:

(1) Dynamically Generated Inundation Maps (Dynamic Inundation Maps) – To prepare dynamic inundation maps, the NWS runs a hydraulic model such as the Flood Wave Operational Model (FLDWAV). In these model runs, real-time model runs of FLDWAV compute the water surface profile by solving the St. Venant equation of momentum and energy. The resultant water surface profile is then merged with available digital elevation model (DEM) data to determine the areal extent of flooding and a graphical image is created for display on the Internet. Preparing inundation maps dynamically allows a user to generate inundation maps based on non-steady state hydraulic model runs.

(2) Statically Generated Inundation Maps (Static Inundation Maps) - To prepare static inundation maps,

the NWS utilized the engineering expertise developed to prepare and update FEMA Flood Insurance Rate Map (FIRMs). In these analyses, the NWS had the contractor developing the new FIRMs run the Hydrologic Engineering Center- River Analysis System (HEC-RAS) hydraulic model in a steady state condition to simulate the water surface profile when the river was at flood stage. This water surface elevation was then combined with DEM data to produce a flood inundation map when the river level is at flood stage. A similar analysis is performed at 1 foot stage increments above flood stage until the flood of record is reached. These static inundation maps can be made available on the Internet for users to review and use in preparedness activities.

Over the past few years, the NWS has developed and continues to refine procedures to prepare both dynamic inundation maps and static inundation maps. Preparing dynamic inundation maps requires significant computer processing capabilities. These capabilities are usually required when the computer processing requirements at NWS offices is at their highest and available resources will likely not be available. Because of this, the NWS is focusing most of its efforts in developing static inundation maps for their forecast locations.

NWS Partnership Activities

To make static flood inundation maps available at more locations, the NWS is partnering with FEMA and the local communities to develop these maps. When engineering consulting firms prepare FIRMs, the large majority of the engineering work needed to prepare static flood inundation maps has been completed. The HEC-RAS model has been developed. Because of the work already completed, the static inundation maps can be made for a small increase in the costs. The NWS is working to inform communities of the possibility of developing inundation maps for a small incremental cost in the hopes that the local community will be willing to bear these costs. A sample static inundation map presentation is shown in Figure 1.

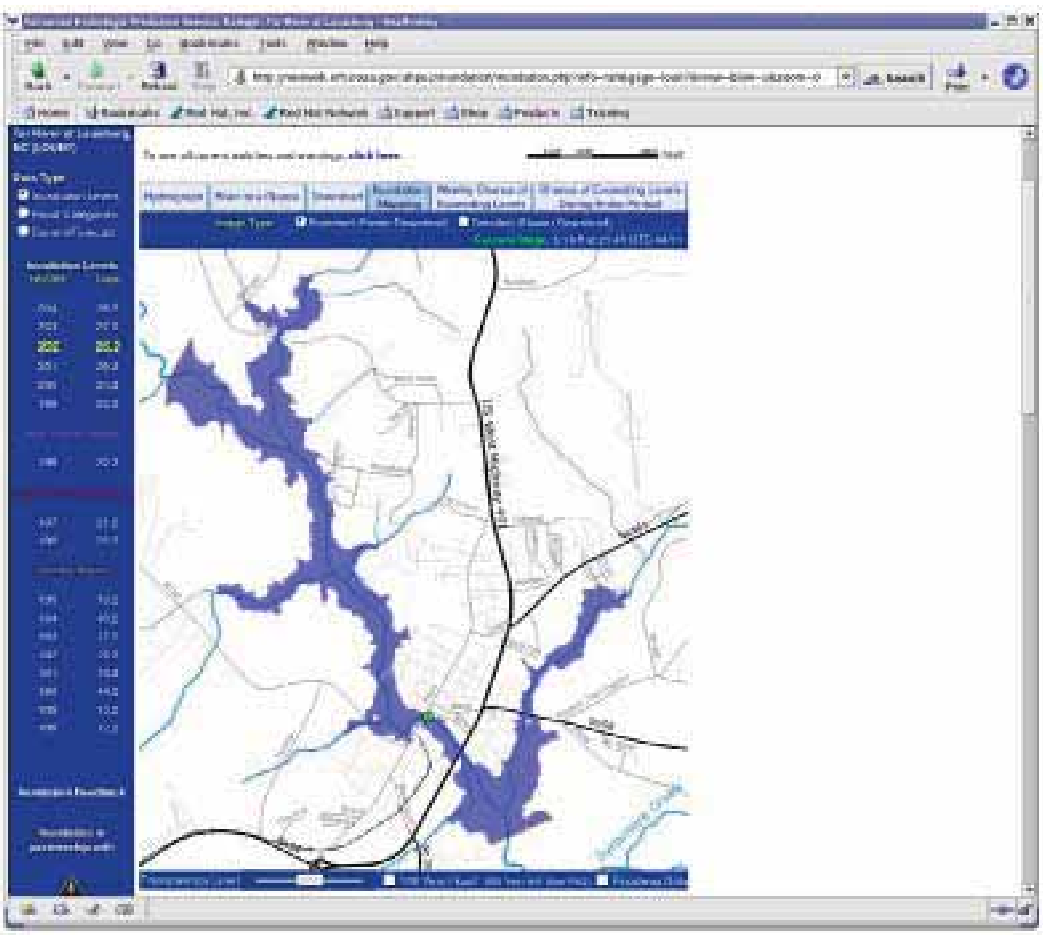

Figure 1 Sample static flood inundation map

In addition to working with local communities, the NWS is partnering with FEMA to define the specific engineering and data requirements to develop inundation maps. With these guidelines, communities who have already performed engineering work on drainage and flooding problems in their community may be able to have inundation maps developed from those studies.

Current Pilot Projects for Flood Inundation Mapping

The NWS has been working with its partners over the past year to implement static inundation maps for 16 sites in North Carolina. Inundation maps at these sites represent a culmination of several years of effort and extensive coordination between the NWS, FEMA, the US Geological Survey, and the state of North Carolina. These inundation maps can be viewed at http://www.weather.gov/ahps/inundation.php. Figure 2 shows the current sites in North Carolina where static inundation maps are available.

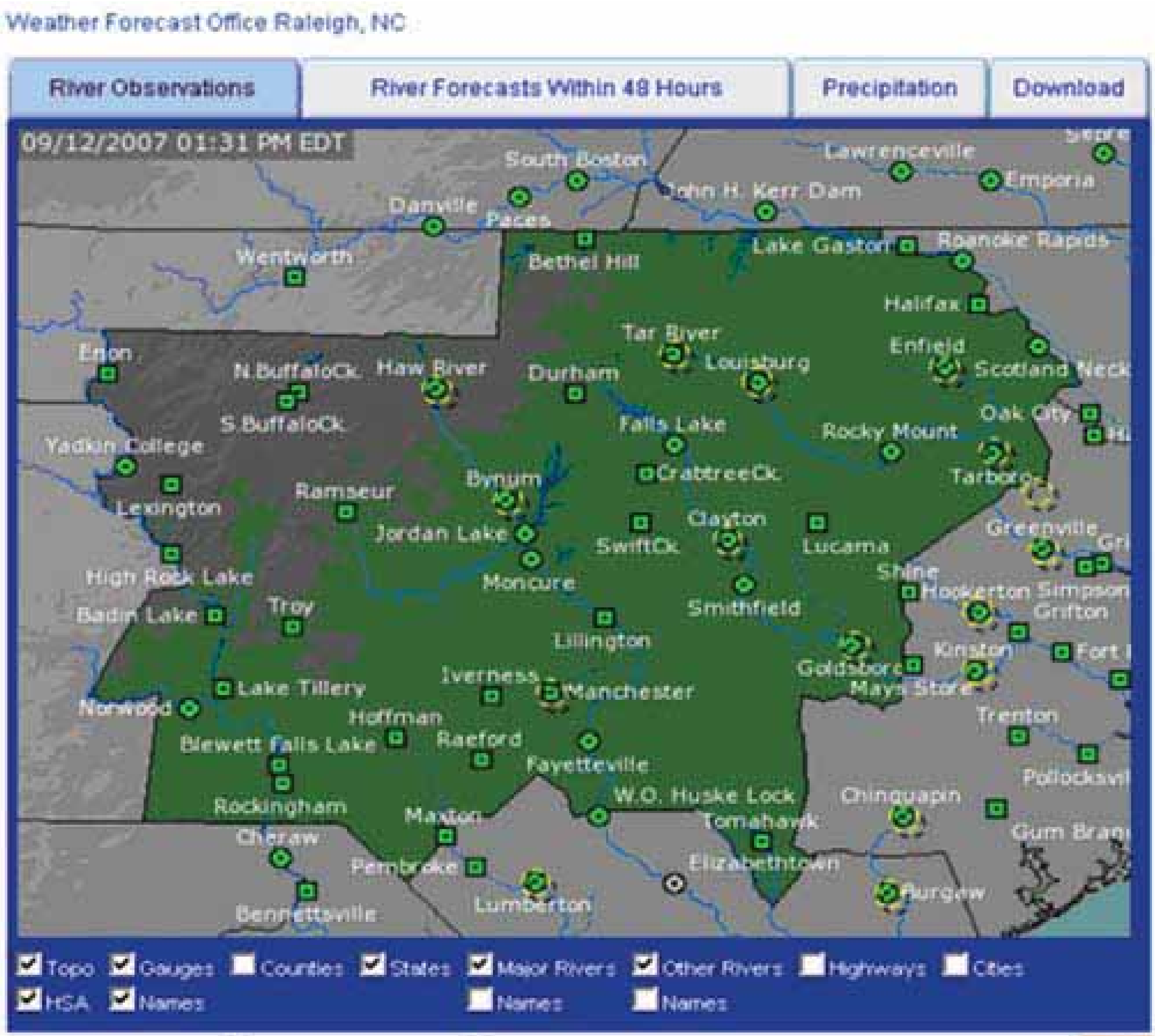

Figure 2 Static flood inundation map locations in North Carolina

After Hurricane Katrina, the NWS was funded to provide inundation maps for sites in Texas, Louisiana, Mississippi, and Alabama as a demonstration. Work is currently underway to develop inundation maps at about 30 locations in these states. The projected locations for inundation mapping in Mississippi and Louisiana are shown in Figure 3. These inundation maps will likely be available by the end of calendar year 2008.

Summary

Inundation maps provide valuable information to Emergency Managers and other interests along the major rivers of the US. The NWS is working to develop both dynamically generated inundation maps in real time and develop a library of inundation maps at various stages. The NWS hopes to partner with local communities to expand these products.

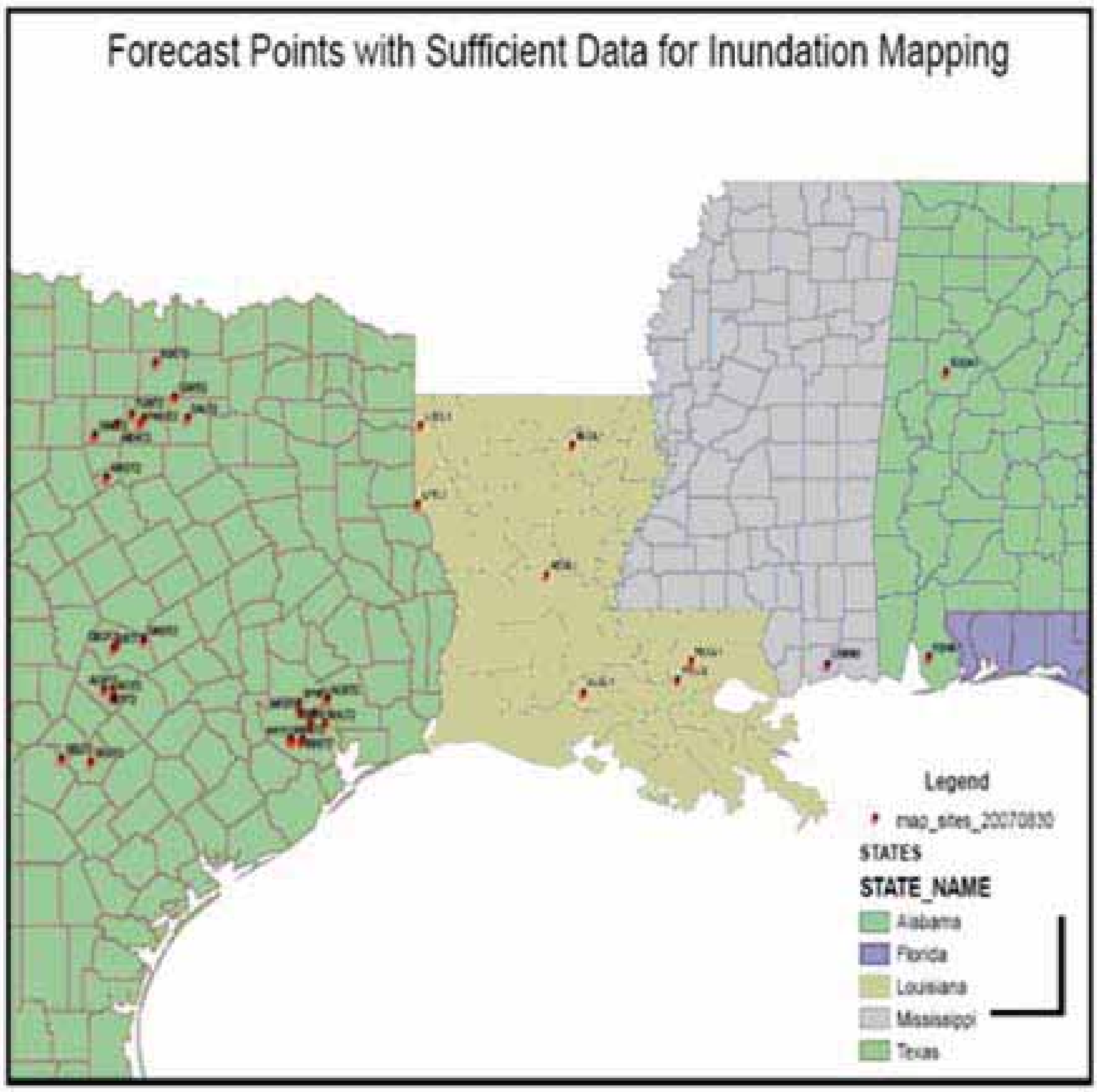

Figure 3 Locations for flood inundation mapping in the Gulf Coast states.

WATER SUPPLY SYSTEMS

Mike Davis, Moderator

Water supply calculation of Stonegate Arch

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Mississippi State University

Decision support tools for implementing and managing regional utilities in Mississippi

Jeannie R.B. Barlow and Greg Brown
Pickering Inc.

Improving the capacity of Mississippi's rural water associations through board management training

Jason Barrett and Alan Barefield
Mississippi State University

Water supply calculation of Stonegate Arch

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Stonegate Arch water supply system is modeled and calculated using EPANET 2 and AutoCAD based on related regulations, site survey data and waterline layout. In the hydraulic modeling, a reservoir is employed to provide the pressure for the whole on site water supply system. To simplify the modeling, the typical water supply points are assumed to be located at the midpoints of the corresponding pipe segments. One on site outdoor fire hydrant is open to check the whole water supply system so as to maintain an acceptable pressure in the distribution system. Minor loss coefficient for each pipe segment is identified and incorporated in the calculations. Five scenarios of the water supply system are calculated to show the pressure & velocity variations at the control points in Stonegate Arch water supply piping system. The results represent that fire flow has significant impact on the velocity & pressure in the scenarios with fire flow. In addition, water demand and the location of concern determine the value of velocity & pressure variations. For the scenarios without fire flow, domestic water demand and pipe size determine the value of pressure & velocity variation.

Keywords: Water Supply, EPANET 2, Domestic Water Demand, Fire Flow

Introduction

Stonegate Arch Water Supply System is designed to provide adequate flows for domestic uses and fire protection, and to maintain the integrity and reliability of the distribution system.

student presenter

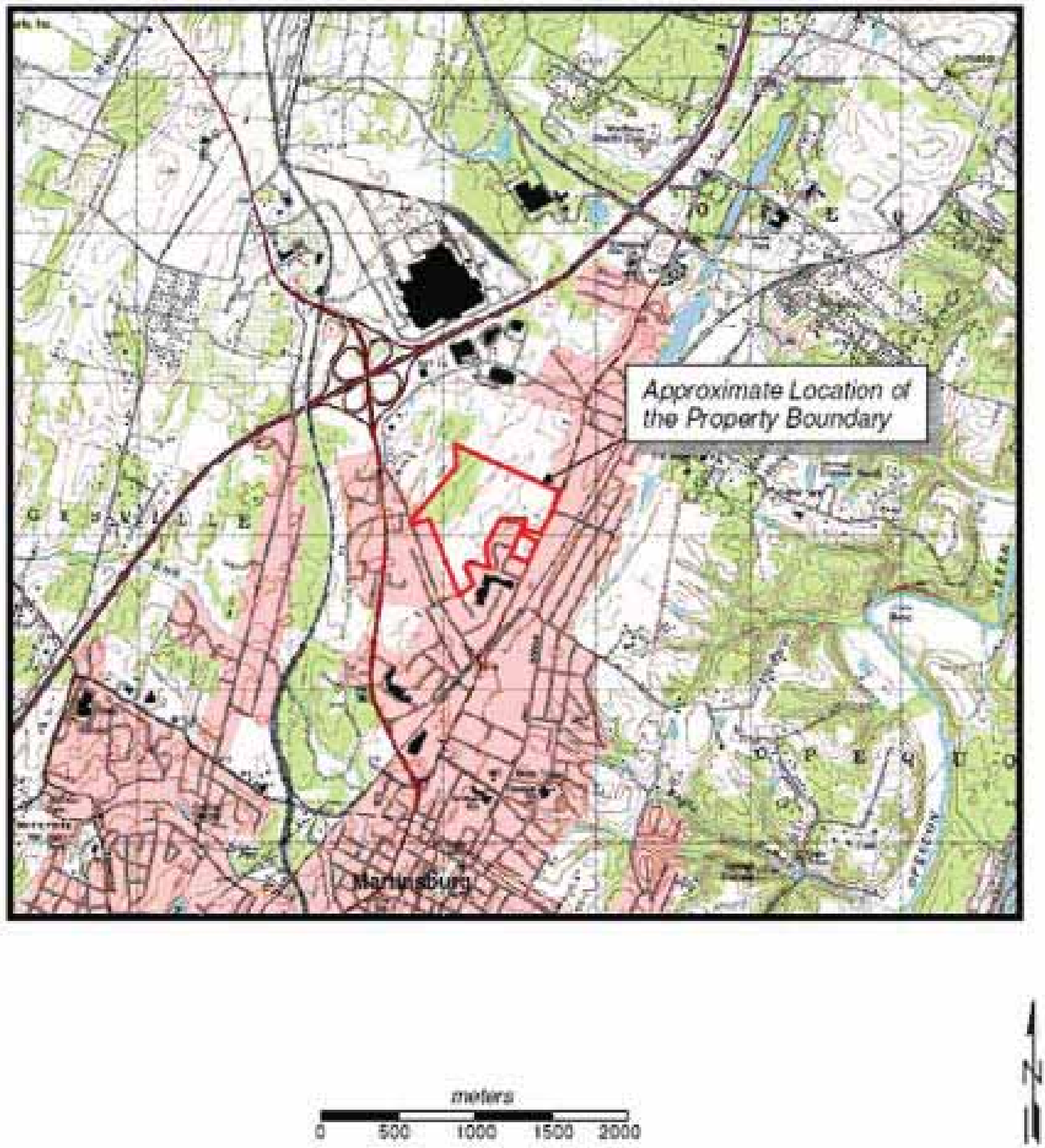

Figure 1. Site Location Map

The Stonegate Arch property (Fig. 1) located on the west side of Williamsport Pike (US Route 11), in Martinsburg, Berkeley County, West Virginia and is developed by American Homes of United Builders. It is approximately 104 acres of agriculture property bordered by residential and light commercial properties.

Design and Hydraulic Modeling Approach

Figure 2. AutoCAD Conceptual Plan of Water Supply System

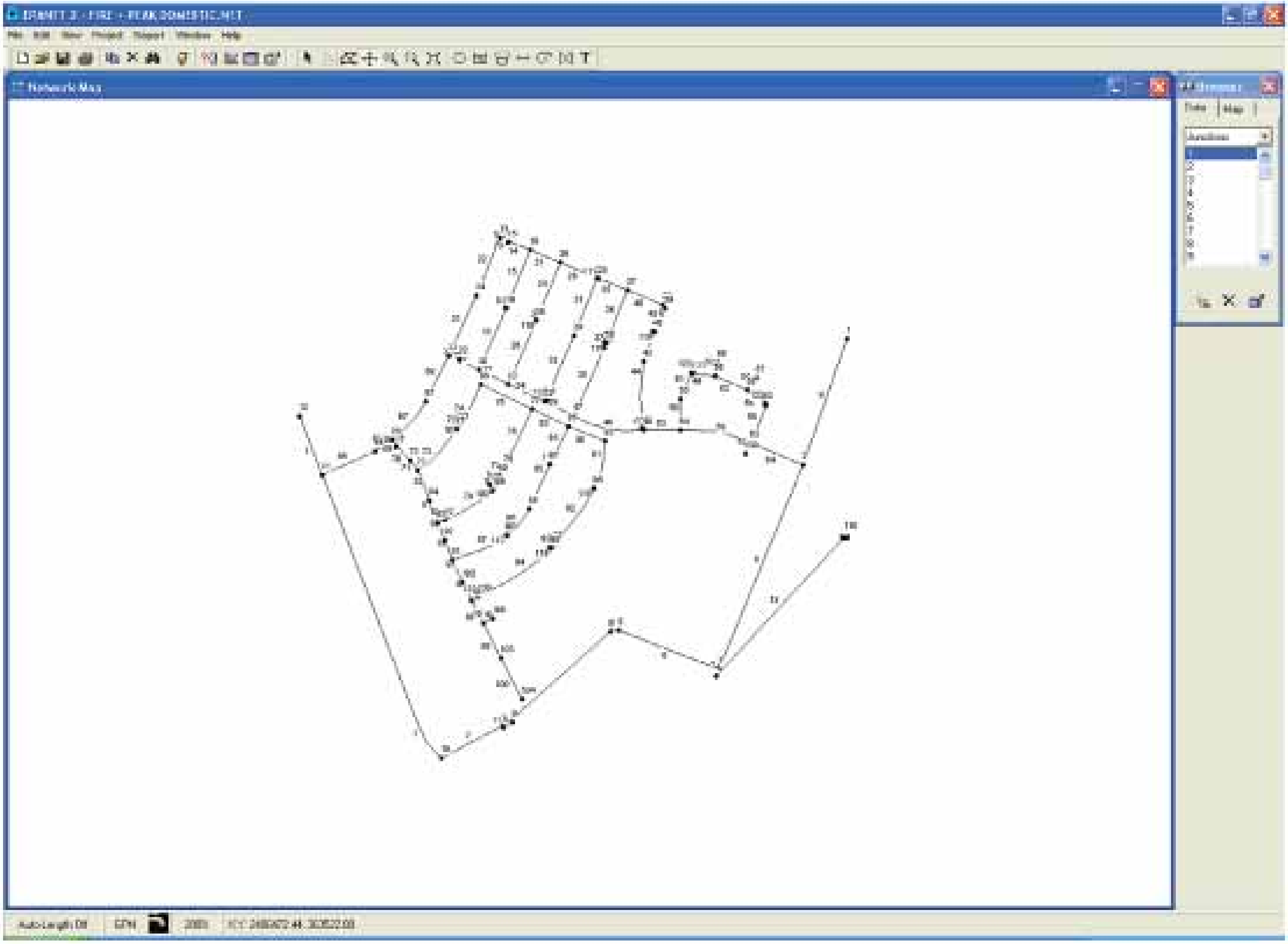

Figure 3. EPANET 2 Calculation Map of Water Supply System

Hydraulic calculations of water supply system were performed by EPANET 2, which was developed by EPA's Water Supply and Water Resources Division. Fig. 2 and 3 show the conceptual and calculation maps of the water supply system in AutoCAD and EPANET 2, respectively. For all proposed Stonegate Arch site, the total peak design domestic water demand is 326 gpm (use 0.5 gpm per home for 386 house units and 250 condos units, water demands of both retail and a couple of parks included as well) and the design fire demand for each outdoor fire hydrant is 500 gpm on the site. In the hydraulic modeling, a reservoir is employed to provide the pressure for the whole onsite water supply system. The result of existing fire hydrant outlet water pressure test was provided by Chris Thiel, from Berkeley County Public Service District. At the flow rate of 1300 gpm, the pressure drops from 78 psi to 60 psi at the location of the existing fire hydrant right beside the site.

The water lateral is located in front of each house. To simplify the modeling, the typical water supply points are assumed to be located at the midpoints of the corresponding pipe segments. One onsite fire hydrant is open to check the whole water supply system so as to maintain an acceptable pressure in the distribution system. Minor loss coefficient for each pipe segment is identified and incorporated in the calculations.

The hydraulic modeling is accomplished using the Hardy Cross method and the Hazen-Williams formula with a selection of roughness coefficient (C=145, PVC C909 CLASS 200 is selected for D<=8 inches; C=120, DIP CLASS 52 is selected for D>8 inches). Minimum water main size is 8 inches in diameter for the residential areas. One 6 inch PVC waterline is designed to serve each condo building and 1 inch water lateral is used for each family unit.

Water mains located in public or private residential streets should be placed outside of the roadway. Permanent easements are required for all water mains not located within the public street right-of-way. Flexible coupling will be used wherever the pipe runs into or out of concrete structures, at bends or miters, and at other points where differential settlement or normal expansion and contraction of the pipe are anticipated.

Results and Discussion

Five scenarios are calculated to describe the velocity & pressure variations at the control points in Stonegate Arch water supply system (636 units + other customers). The following are the results of the water supply system calculations for Stonegate Arch.

Scenario 1
Static (no fire flow & domestic water demand)

No fire-fighting & domestic water demand, onsite system pressures would range from 73.54 psi to 82.51 psi based on the 78.00 psi static pressure for the existing fire hydrant.

Scenario 2
Average Daily Water Demand (150 gpd per unit)

Time pattern is set in the EPANET 2 hydraulic modeling of this scenario and average daily water demand (150 gpd per unit) is applied.

Fig. 4 shows the changes of pressure (77.92 psi ~ 77.99 psi) in 24 hr at the location of the existing municipal fire hydrant. The pressure does not change much because of the low domestic water demands.

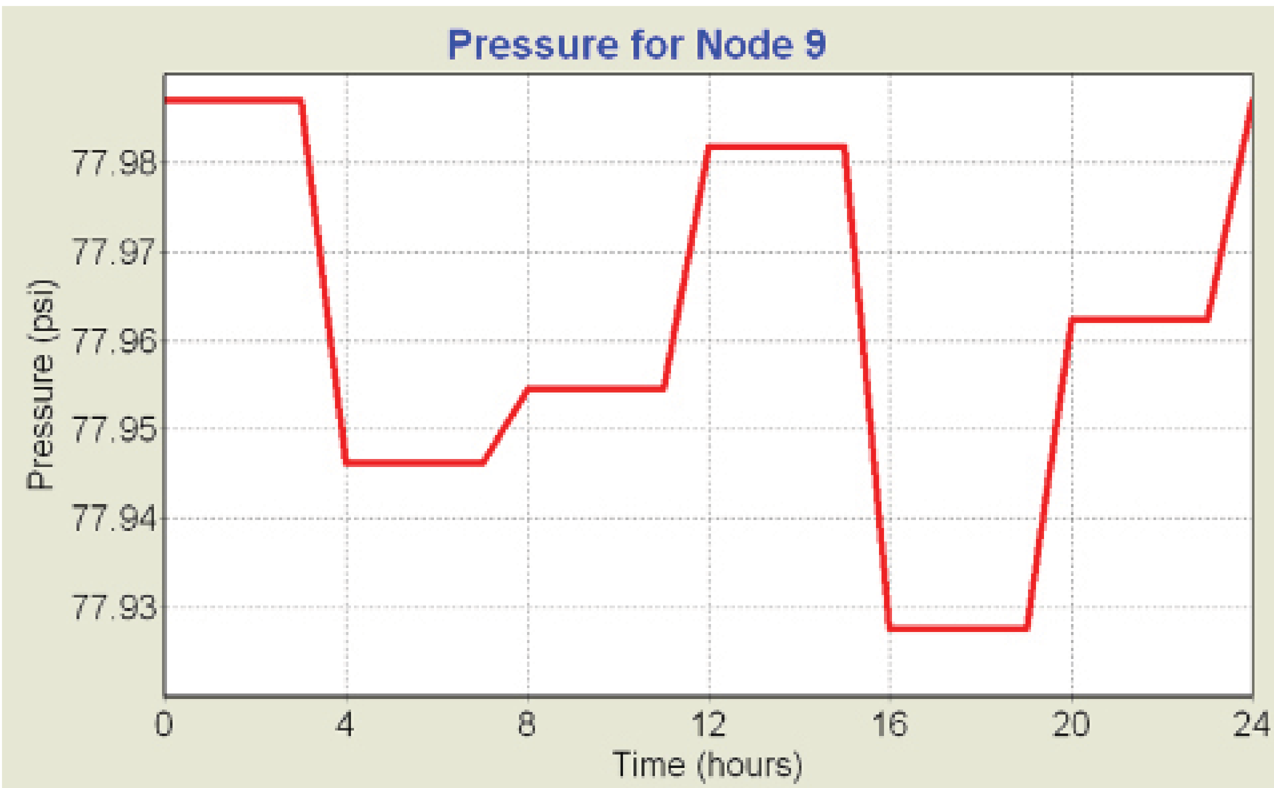

Figure 4. Pressure Variation for Existing Fire Hydrant (Node 9)

Figure 5. shows the daily pressure fluctuations (73.41 psi ~ 73.52 psi) at the control point.

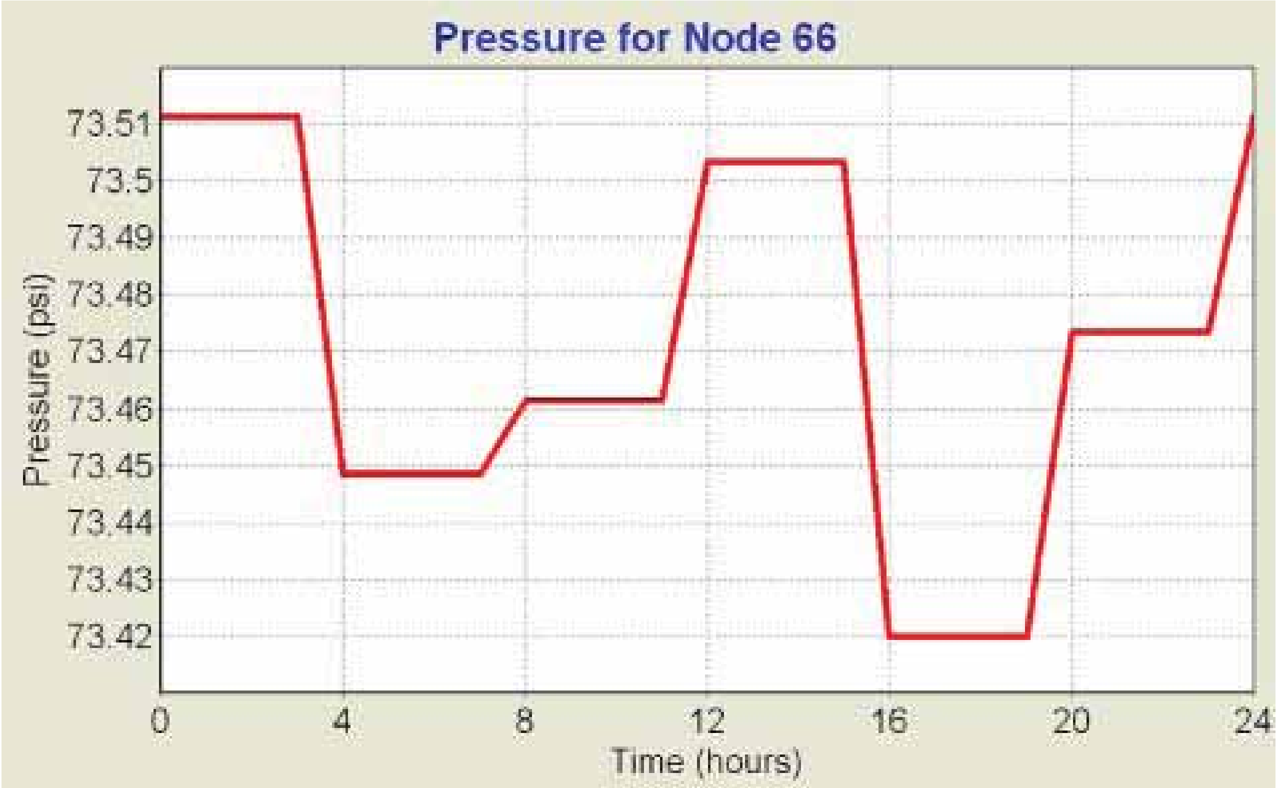

Figure 5. Pressure Variation for Control Point (Node 66)

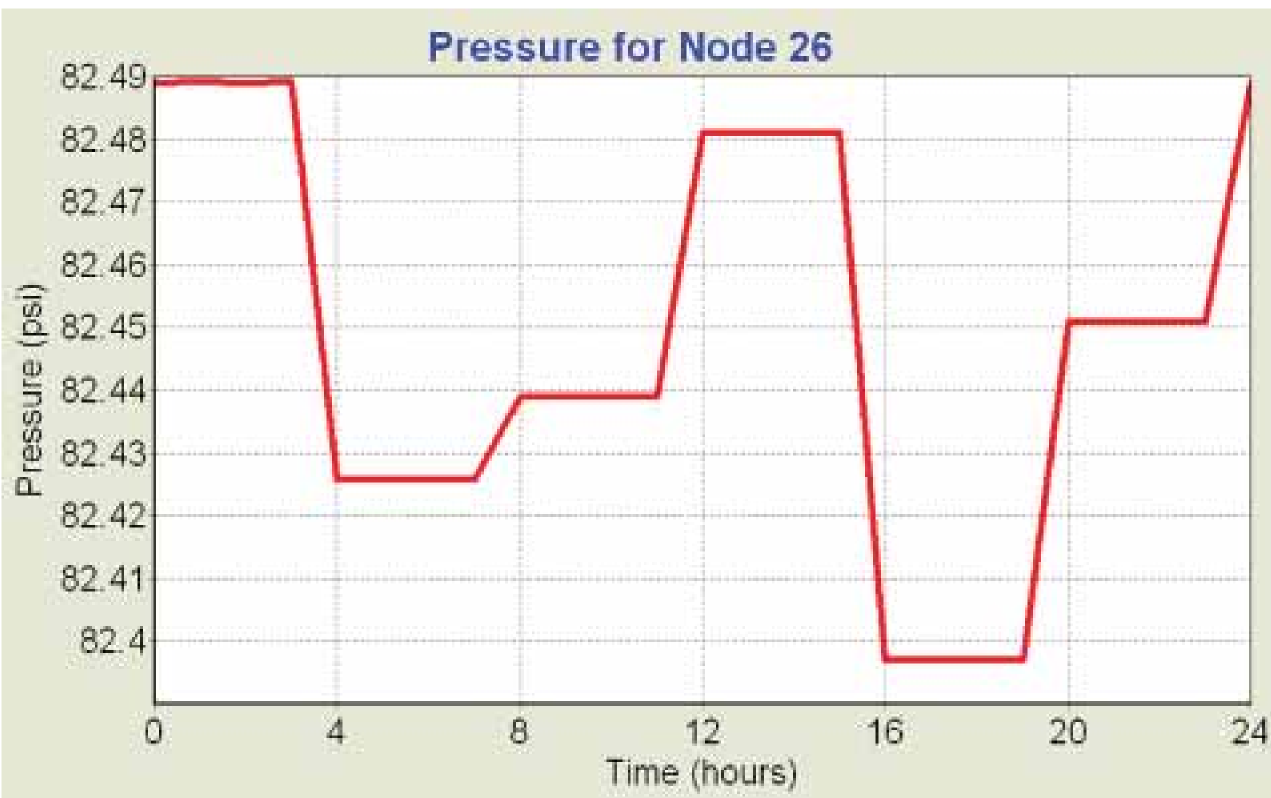

Figure 6. Pressure Variation for Highest Pressure Point (Node 26)

The daily changes of maximum pressure (82.39 psi ~ 82.49 psi) are shown in Figure 6.

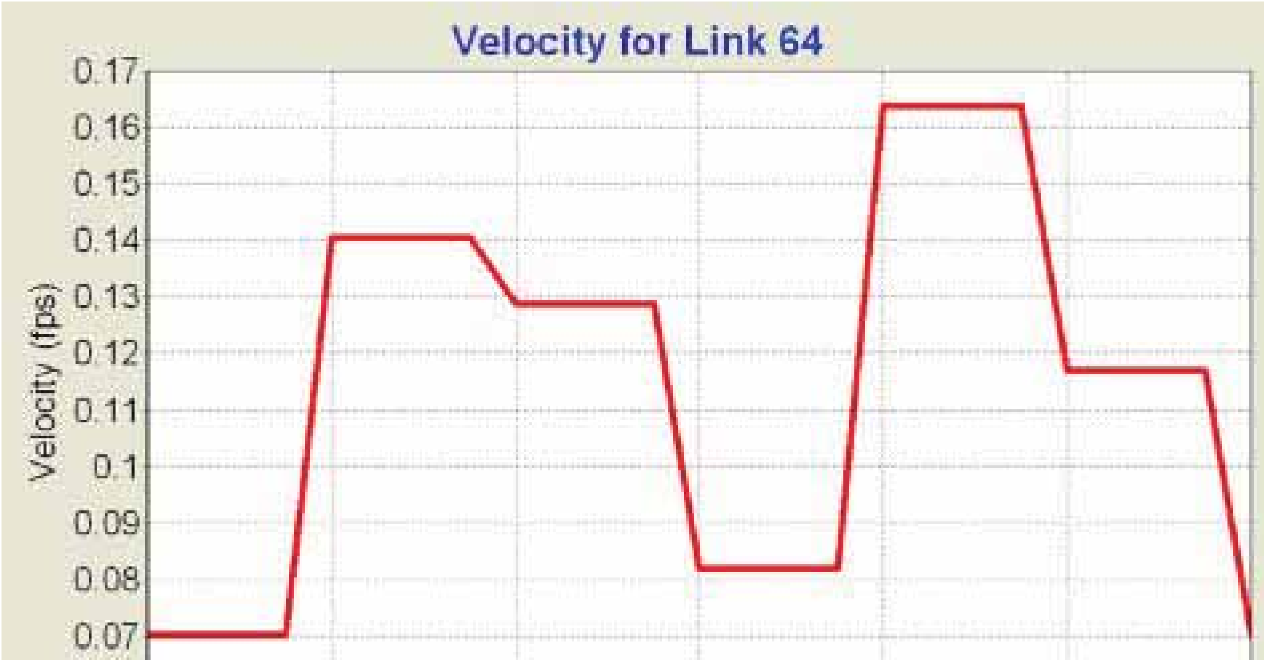

Figure 7. Velocity Variation for The Waterline with Highest Velocity (Link 64)

Figure 7. describes that the velocity varies between 0.06 fps and 0.17 fps at the waterline with general highest velocity.

Figure 8. Velocity Variation for Water Supply Point with Highest Velocity (Link 52)

Figure 8. describes that the velocity varies between 0.04 fps and 0.12 fps at the water supply point with highest velocity (to each condo).

From the above figures, it is obvious that water demand and pipe size determine the value of pressure & velocity variations. The pressure in the main are altered little because of the trivial water demand, while the velocity at the water supply point is changed relatively significant due to the changing water demand and small pipe size.

Scenario 3

Peak Domestic Water Demand (0.5 gpm per unit)

The water supply system is designed to provide a residential peak demand flow (no fire flow). The EPANET 2 hydraulic calculation shows the pipe pressures range from 72.31 psi to 81.28 psi. The pressure at the existing fire hydrant is 77.21 psi. In this case, 2.08 fps is the maximum flow velocity for all the pipes.

Scenario 4

Most Distant Outdoor Fire Hydrant (500 gpm) + Average Daily Water Demand (150 gpd per unit)

Time pattern is set in the EPANET 2 hydraulic modeling of this scenario and average daily water demand (150 gpd per unit) is applied. More importantly, the 500 gpm flow requirement of the most distant onsite fire hydrant through the first continuous 4 hours is considered.

Figure 9 shows the changes of pressure (75.90 psi ~ 77.99 psi) in 24-hour at the location of the existing fire hydrant.

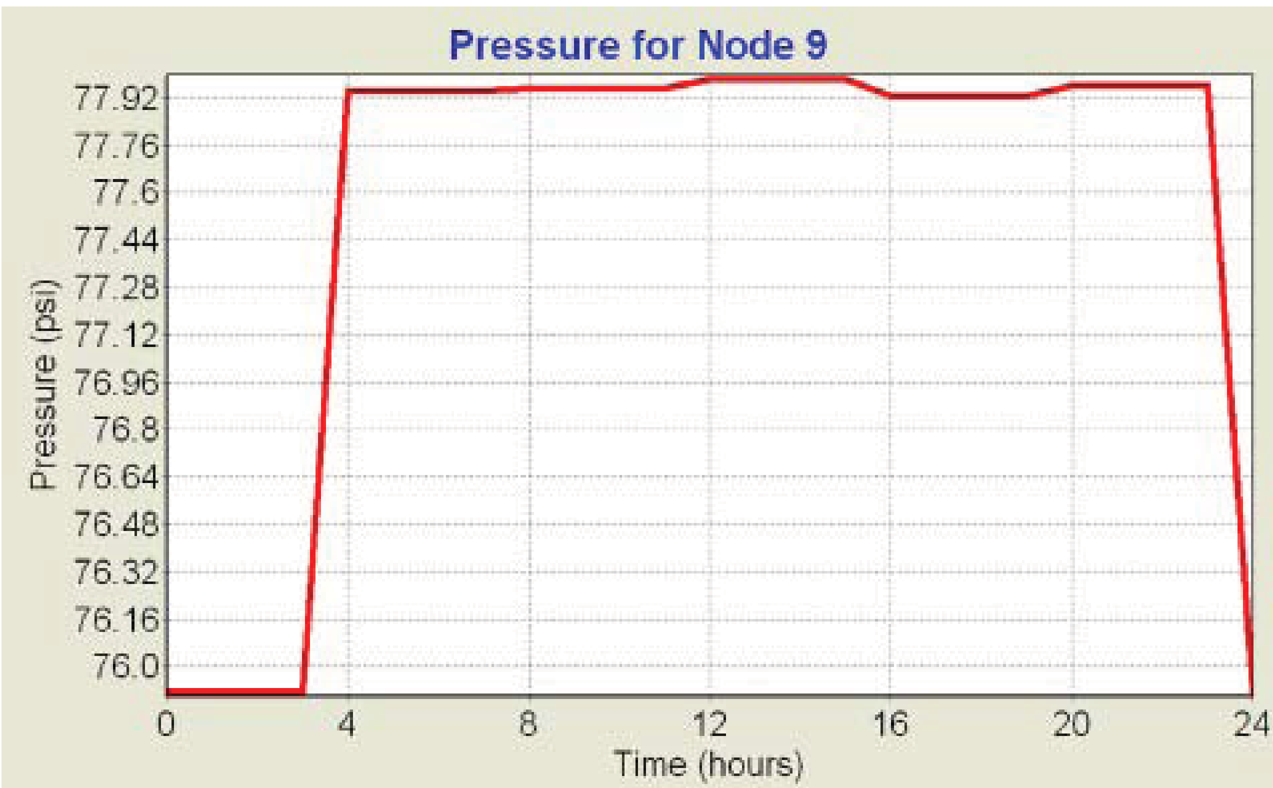

Figure 9. Pressure Variation for Existing Fire Hydrant (Node 9)

Figure 10. shows the daily pressure fluctuations (70.10 psi ~ 74.10 psi) at the control point.

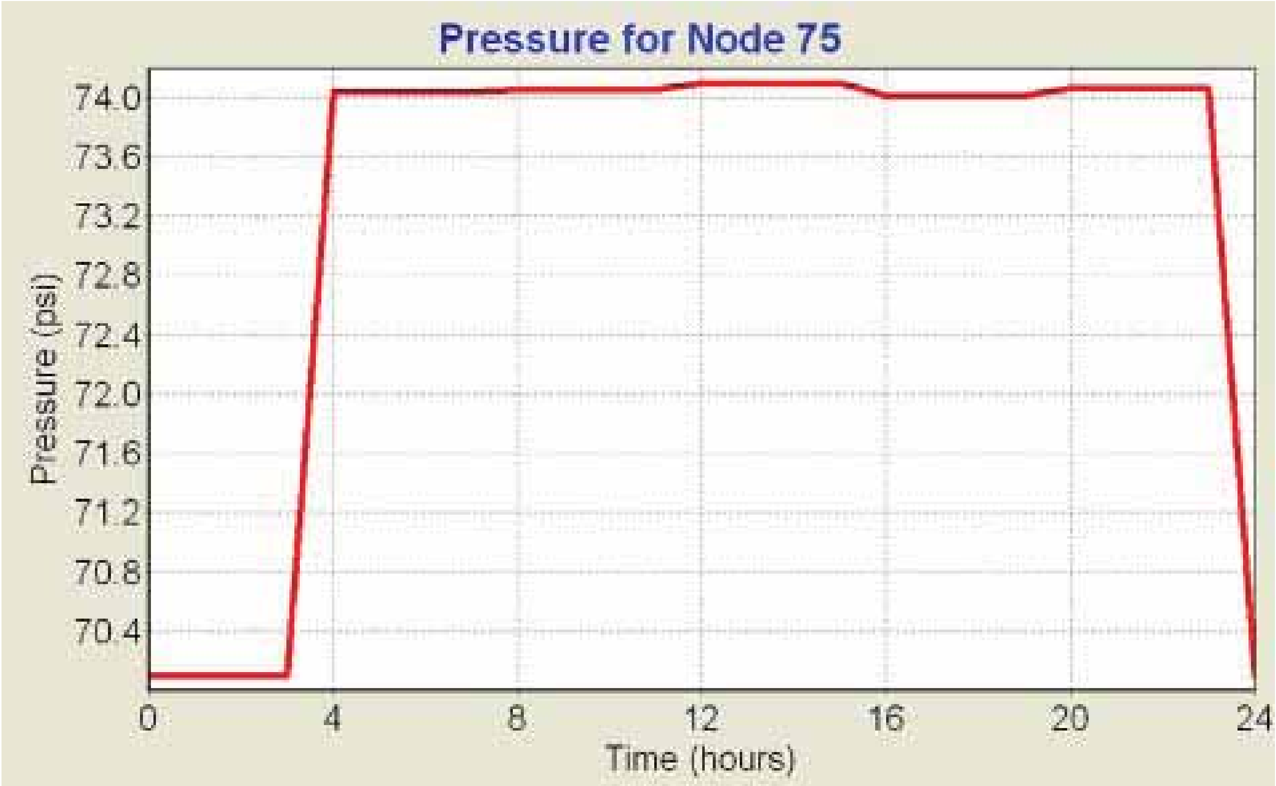

Figure 10. Pressure Variation for Control Point (Node75)

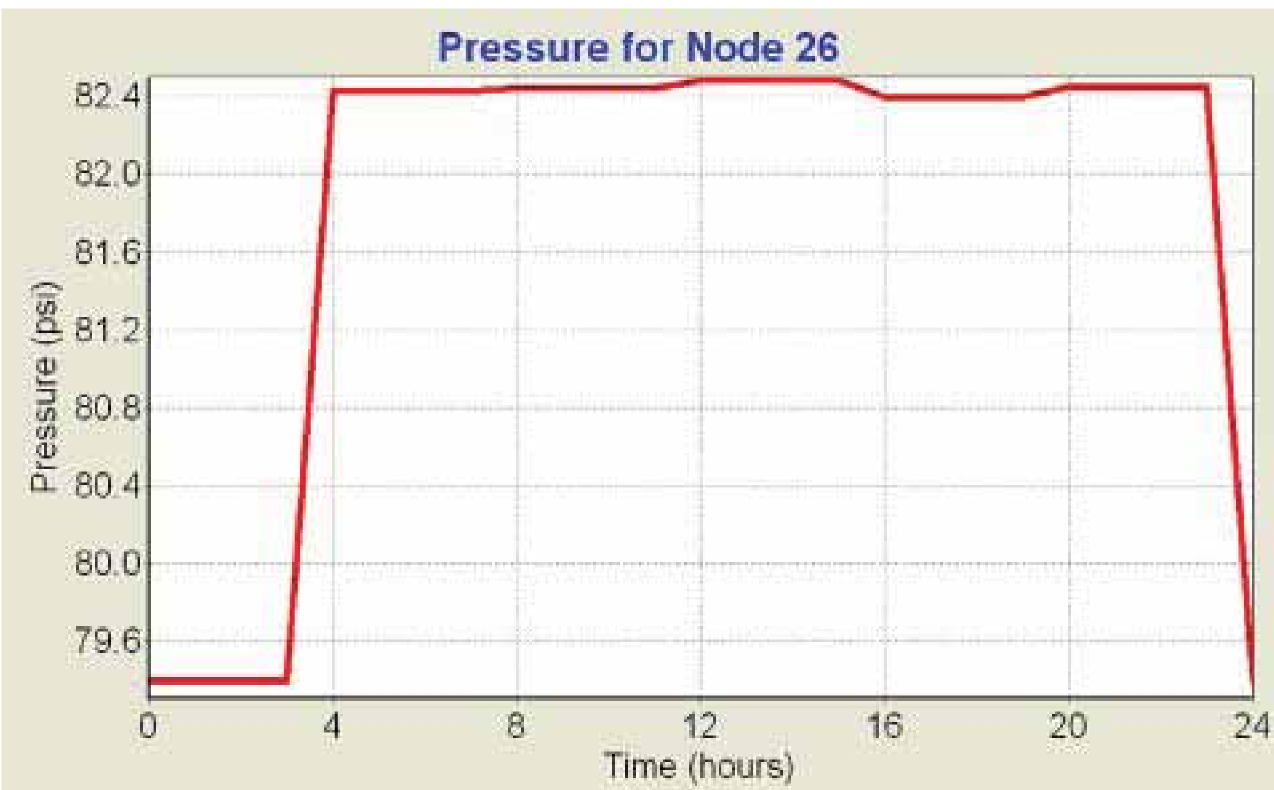

Figure 11. Pressure Variation for Highest Pressure Point (Node 26)

The daily changes of maximum pressure (79.30 psi ~ 82.50 psi) are shown in Figure 11.

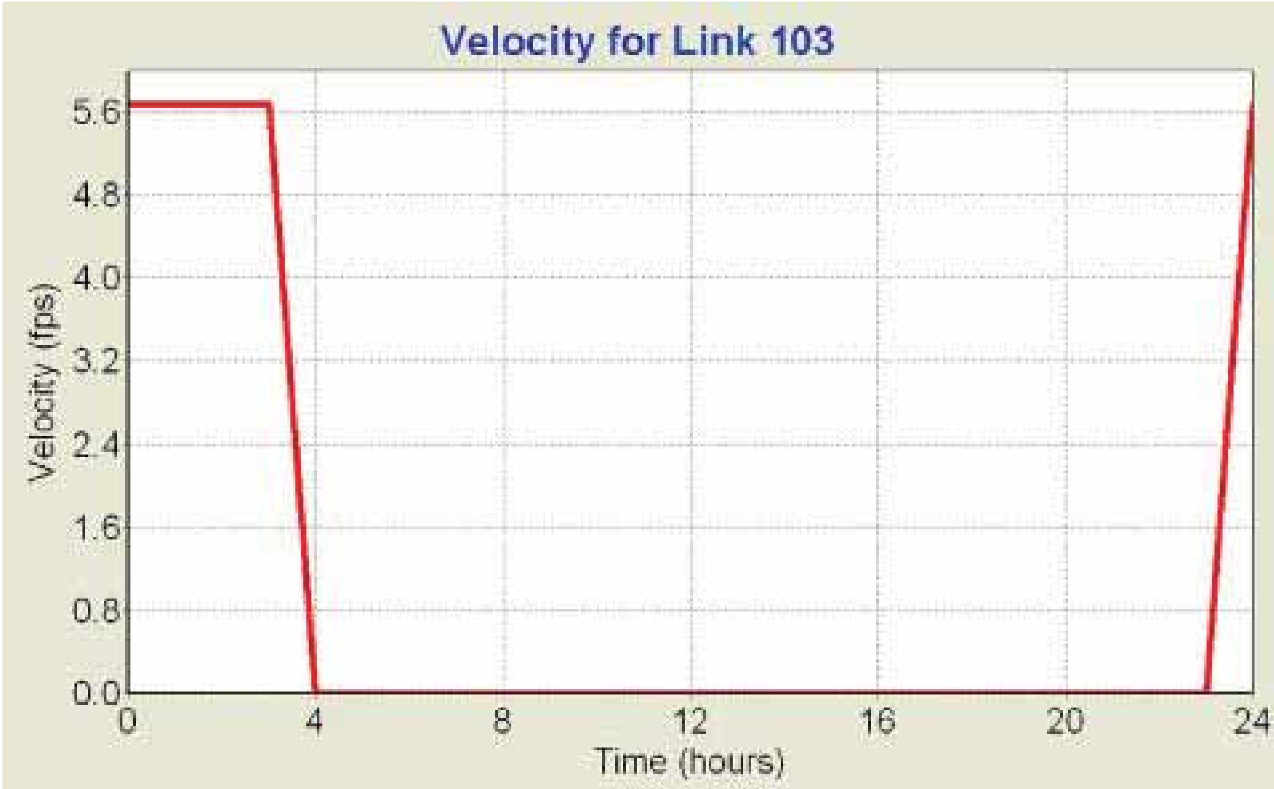

Figure 12. Velocity Variation for Waterline with Highest Velocity Pipe (Link 103)

Figure 12 describes that the velocity varies between 0.00 fps and 6.00 fps at the location of the most distant fire hydrant.

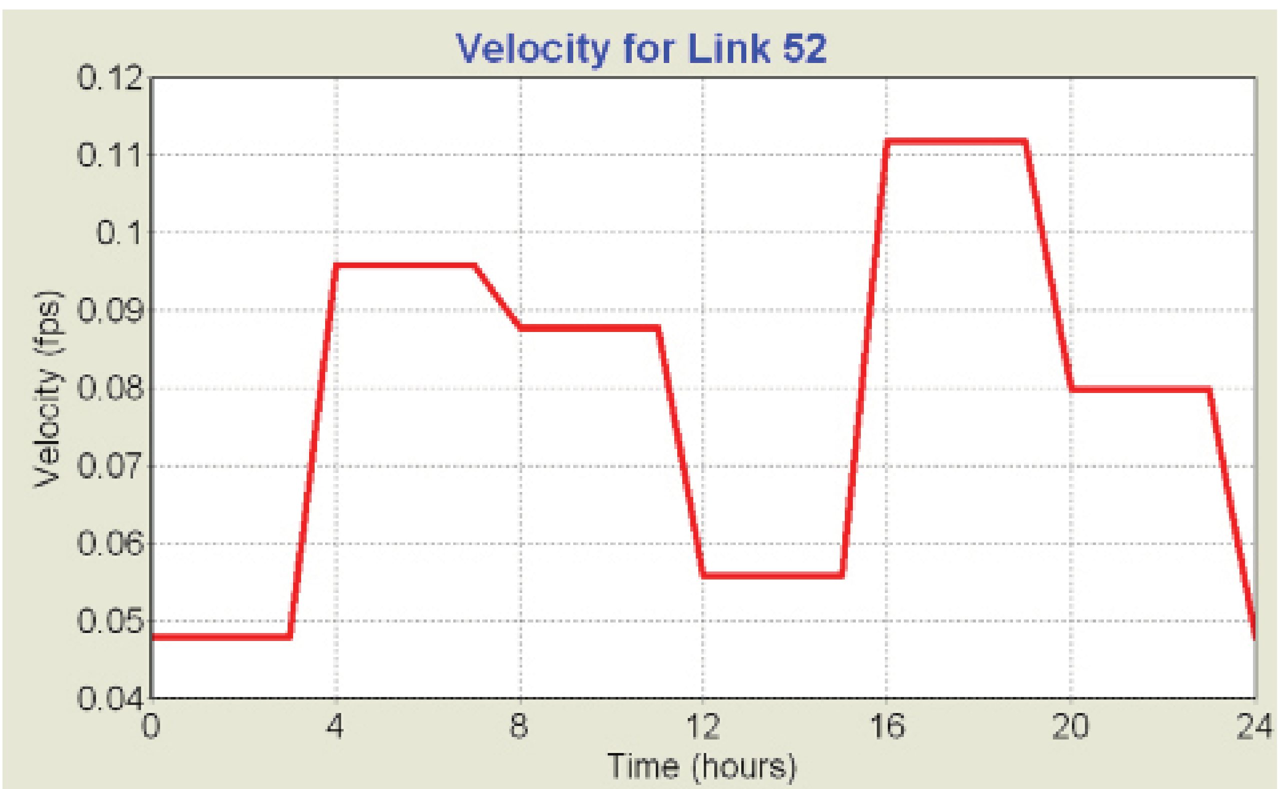

Figure 13. Velocity Variation for Water Supply Point with Highest Velocity (Link 52)

Fig. 13 describes that the velocity varies between 0.04 fps and 0.12 fps at the water supply point with highest velocity (to each condo). It seems that the fire flow has less effect on the velocity of the point than those of the points closer to the most distant fire hydrant at the first 4 hours.

From the above figures, it is obvious that water demand as well as the location of the pipe segment determine the value of pressure & velocity variations. And the velocity in the water main is changed significant due to the fire flow.

Scenario 5

Most Distant Outdoor Fire Hydrant (500 gpm) + Peak Domestic Water Demand (0.5 gpm per unit)

Furthest fire hydrant (500 gpm) is open and 0.5 gpm water demand is provided for each unit, the pipe pressures range from around 66.30 psi (at the location of most distant fire hydrant) to 75.60 psi on the site and the pressure for the existing fire hydrant is 73.48 psi at this condition. All flow velocities in the pipes are not more than 5.67 fps.

Conclusion

Stonegate Arch Water Supply System is modeled using EPANET 2 and AutoCAD. Five water supply scenarios are calculated to analyze the hydraulic conditions at the control points. As of the scenarios with fire flow, fire flow has significant impact on the velocity & pressure. In addition, water demand and the location under investigation determine the value of velocity & pressure variations. For the scenarios without fire flow, domestic water demand and pipe size determine the value of pressure & velocity variation.

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Decision support tools for implementing and managing regional utilities in Mississippi

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The regionalization of utilities can increase the efficiency and quality of any system. However, both the implementation and subsequent management of regional utilities involve a substantial effort for any municipality or government agency. The agglomeration of several smaller utilities requires careful planning and consistent management and maintenance. In the case of water and wastewater utilities, many of these systems are aging and the location and condition of infrastructure is unknown. Regionalization allows these systems to maximize their resources and streamline their day-to-day activities. One of the dominant tools aiding in the regionalization of utilities is Geographic Information Systems (GIS), which enables utility providers to link location with infrastructure. The use of GIS can greatly simplify the management of existing utilities and also strengthen the design of new utilities. The development of a GIS allows utility providers to quickly locate infrastructure and track repair and maintenance history. They can also use the information stored in the GIS to model future demand/capacity and plan for future infrastructure needs.

Keywords: Wastewater, Water Supply, Management and Planning, Methods

Improving the capacity of Mississippi's rural water associations through board management training

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The Mississippi legislature enacted legislation designed to increase the capacity of Mississippi's rural water associations' boards and small municipal water systems' government officials to provide safe drinking water and be aware of the technical and legal responsibilities assumed by these individuals. This legislation mandated that the Mississippi State Department of Health (MSDH), in cooperation with other organizations such as the Mississippi Rural Water Association (MWRA), provide training to the governing bodies of these systems. To this end, the MSDH contracted with the Mississippi State University Extension Service (MSUES) to develop training curricula and provide coordination and evaluative services to facilitate the provision of quality training opportunities accessible to clientele across the state. Furthermore, partnerships between MSUES, MWRA, the Mississippi Water and Pollution Control Operators Association, and the Community Resource Group, has resulted in the development of several cutting edge curricula that have been nationally recognized.

Keywords: Board Management Training, Capacity Enhancement, Curricula Development

INVASIVES

Todd Tietjen, Moderator

Influences of light intensity variations on growth characteristics of parrotfeather (*Myriophyllum acquaticum* (Vell.) Verdc.)

Ryan M. Wersal and John D. Madsen
Mississippi State University

Duckweed control in Mississippi waters

Joshua C. Cheshier, Ryan M. Wersal, and John D. Madsen
Mississippi State University

Littoral zone aquatic plant community assessment of the Ross Barnett Reservoir, Mississippi for 2007

John D. Madsen, Ryan M. Wersal, and Mary Love Tagert
Mississippi State University

Reservoir survey for invasive and native aquatic plants species within the Pat Harrison Waterways District

Wilfredo Robles, Victor Maddox and John D. Madsen
Mississippi State University

Influences of light intensity variations on growth characteristics of parrotfeather (*Myriophyllum acquaticum* (Vell.) Verdc.)

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Parrotfeather (*Myriophyllum aquaticum* (Vell.) Verdc) is a nonnative aquatic heterophyllous plant. Having both a submersed and emergent growth form may allow *M. aquaticum* to invade and colonize highly disturbed or less than optimal environments through changes in growth habit. The reallocation of resources to emergent or submersed growth likely allows *M. aquaticum* to overcome changes in light availability. Currently, little is known regarding the ecological and biological responses of *M. aquaticum* to perturbations in environmental factors. The objective of this study was to quantify *M. aquaticum* growth under different shading regimes. We hypothesized that *M. aquaticum* growth would increase as shading levels increased to a maximum of 70% of full sun light. The study was conducted using potted *M. aquaticum* plants growing in 24, 1100-liter tanks. Light treatments consisted of full sun, 30% shade, 50% shade, and 70% shade achieved using shade cloth with each treatment replicated six times. Biomass was harvested in two-week intervals for 12 weeks. Two pots from each tank were collected and both the roots and shoots of *M. aquaticum* were harvested. Measurements were taken of total plant length, emergent shoot length, submersed shoot length, and the total of number of emergent and submersed shoots were recorded. Plants were sorted to emergent shoots, submersed shoots, roots, stolons, and dried at 70 °C to a constant mass then weighed. *Myriophyllum aquaticum* biomass was significantly different ($F = 18.1$, d.f. = 47, $p < 0.01$) at the conclusion of 12 weeks between shade treatments. Differences in biomass were a result of greater emergent shoot growth in the 50% shade treatment and a reduction in the 70% shade treatment. Total plant length was also significantly different ($F = 7.44$, d.f. = 95, $p = 0.02$). The greatest plant length was observed in the 50% shade treatment with reductions in overall plant length observed in full sunlight. Both emergent and submersed shoot lengths were greatest in the 70% shade treatments. The total number of emergent and submersed shoots was not different between shade treatments. Our data suggests that intermediate light availability may be optimal for *M. aquaticum* growth.

Keywords: Invasive Species, Ecology, Water Use, Wetlands

Introduction

Parrotfeather (Myriophyllum aquaticum (Vellozo) Verdecourt) is a non-native invasive aquatic plant from South America. Populations of parrotfeather can impede stream flow and run off resulting in increased flood duration and intensity (Timmons and Klingman 1958). In South Africa, parrotfeather infests all of the major river systems where it poses a direct threat to the country's water supply (Jacot-Guillarmod 1977). Parrotfeather provides mosquito larvae a refuge from predation, which may ultimately lead to increases in diseases that can be transmitted to humans (Orr and Resh 1989). Plants are easily cultivated and transported often leading to new infestations. The aquaria landscaping trade is an avenue where plants are easily purchased and shipped throughout the world (Sutton 1985). Aiken (1981) reported observations of aquarium plant providers in the San Francisco Bay area placing parrotfeather into local waterways to have a convenient source of saleable material.

Parrotfeather is heterophyllous, meaning the plant has two distinct leaf forms that grow together on the same plant. Emergent leaves are feather-like and grayish green, stiff, and grow in whorls around the emergent shoot (Godfrey and Wooten 1981). Submersed leaves are typically orange to red and also grow in whorls around submersed shoots (Mason 1957). The emergent and submersed leaf forms can occur simultaneously on the same plant, or parrotfeather can persist as one growth form or the other converting when the environment changes. The light saturation point of emergent leaves is thought to approach full sunlight where as the light saturation point of the submersed leaves is between 250-300 μ-Em-2 s-1 indicating that photosynthesis of submersed plants is adapted to a shade environment (Salvucci and Bowes 1982).

Little is known of the ecology of parrotfeather as the majority of previous studies have focused strictly on management. Having both an emergent and submersed growth form may allow parrotfeather to invade and colonize highly disturbed or less than optimal environments through changes in growth habit. The reallocation of resources to emergent or submersed growth likely allows parrotfeather to overcome changes in light availability. Understanding of the environmental constraints posed by light intensities will indicate what environments parrotfeather can colonize and exploit to establish new infestations. These areas can be targeted for more aggressive monitoring to identify infestations at their onset before plants become firmly established. Our objective was to determine the effects of light intensity on growth characteristics of parrotfeather and to identify the light intensity at which growth was reduced.

Materials and Methods

Studies were conducted from May to August in 2006 and 2007 for 12 weeks at the R.R. Foil Plant Science Research Center at Mississippi State University. Twenty-four 1100 liter tanks were filled with water to a depth of approximately 50 cm. A total of 336 pots were planted and divided evenly so each tank contained 12 pots. Two parrotfeather shoots approximately 20 cm in length were planted into 3.78 liter plastic pots filled with a mixture of sand, silt, and top soil. Each pot was amended with Osmocote fertilizer (19-6-12) at rate of 2 g L-1 pot-1. Light intensity manipulations consisted of full sun, 30% shade, 50% shade, and 70% shade which was achieved using shade cloth. Each treatment was replicated in six tanks.

Parrotfeather mass was harvested in 2 week intervals for 12 weeks, however only the final harvest data are reported in this paper. Harvesting consisted of removing two pots from each tank and collecting both the roots and shoots of parrotfeather plants. Measurements of total plant length, emergent shoot length, and submersed shoot length were recorded. Additionally, the total number of emergent shoots and submersed shoots were recorded. Plants were then divided into emergent shoots, submersed shoots, stolons, and roots. Plant parts were dried at 70 C to a constant mass and then weighed to obtain the dry mass of parrotfeather. A mixed procedures ANOVA model using year as a random effect was developed using SAS (Littell et al. 1996) to assess differences in parrotfeather growth between treatments in 2006 and 2007. Treatment differences were separated using the Least Squares Means method.

Results and Discussion

At the conclusion of 12 weeks, parrotfeather mass was different ($p < 0.01$) between shade treatments (Figure 1). Differences in plant mass were a result of greater plant growth in the 30% and 50% shade treatment. Plants grown in full sun light had approximately a 30 g reduction in total plant mass. The increases in plant mass observed in the intermediate light levels may be partially explained by the fact that total plant length was also greatest ($p < 0.01$) in the 50% shade treatment with a reduction in plant length observed in full sunlight (Figure 2). However, the total plant length of plants grown in 30% and 70% shade were also greater than plants grown in full sun. When individual plants were divided it was found that emergent shoot length was reduced ($p < 0.01$) in full sun light with increased shoot elongation occurring when shade was provided (Figure 3). Submersed shoot length increased ($p < 0.01$) only when plants were grown in the 70% shade treatment. Although there were differences observed in overall plant mass and plant length, there were no differences in emergent shoot number ($p = 0.87$) or submersed shoot number ($p = 0.96$); indicating that plants were growing larger instead of producing more shoots in response to varying light intensities. Similar results were reported for Eurasian watermilfoil (Myriophyllum spicatum L.), hydrilla (Hydrilla verticillata Royle), and egeria (Egeria densa Planch.) submersed aquatic plants where shoot length increased with increasing levels of shade (Barko and Smart 1981). In low light environments, these submersed species reallocated energy to the development of a canopy through shoot elongation and an increase in upper branches and leaf whorls (Barko and Smart 1981). The anatomical and morphological differences in the emergent and submersed form of parrotfeather likely result from physiological adaptations to conditions in their respective environments (Sculthorpe 1967, Salvucci and Bowes 1982).

Parrotfeather has a light saturation point that approaches full sunlight (Salvucci and Bowes 1982). However, based on our data of reduced mass and shoot length, increases in light may not be optimal for this species. Increased light availability is often correlated to increases in temperature which may have resulted in water stress of parrotfeather in this study where transpiration from emergent shoots exceeded water uptake. However, in laboratory studies Sytsma and Anderson (1993) concluded that water loss due to transpiration was only 15 ml d-1 and biomass was produced with and economy of water use similar to C4 terrestrial plants. Parrotfeather, however, is a C3 plant (Salvucci and Bowes 1982) therefore photorespiration may have decreased as temperatures increased resulting in greater energy use in full sun light and an overall reduction in plant growth. Parrotfeather photorespiration ranges from high to very low depending upon the environment in which it is growing (Salvucci and Bowes 1982). Aquatic habitats that subject plants to reduced CO_2 availability, high O_2, light, and temperature may enhance CO_2 loss via photorespiration and adversely impact plant growth (Van et al. 1976).

Our results indicate that optimal growth of parrotfeather occurs in intermediate light intensities, although it can thrive in full sun light or survive in low light conditions primarily by submersed shoots. Adaptations that allow a species to optimize its capture and use of light are important determinants for success, especially in low light environments (Barko et al. 1986). Both plant morphology and specific leaf morphology are responsive to light regimes, in general producing fewer, longer shoots and leaves under reduced light conditions (Barko and Smart 1981, Barko et al. 1982). Species such as parrotfeather that are capable of elongating to the water surface and forming a canopy may have a competitive advantage over other species (Haller and Sutton 1975, Barko and Smart 1981).

Acknowledgements
We would like to thank the United States Geological Survey, Aquatic Ecosystem Restoration Foundation, and the Aquatic Plant Management Society for funding this project. We thank Dr. Patrick Gerard for assistance in developing the statistical model used for data analysis. We also thank Jimmy Peeples, Matt Gower, Waldemar Robles, Wilfredo Robles, and Joshua Cheshier for assisting during the study set up and countless hours of counting parrotfeather stems.

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Figure 1. Mean (±1 SE) total mass of parrotfeather grown in different light environments.

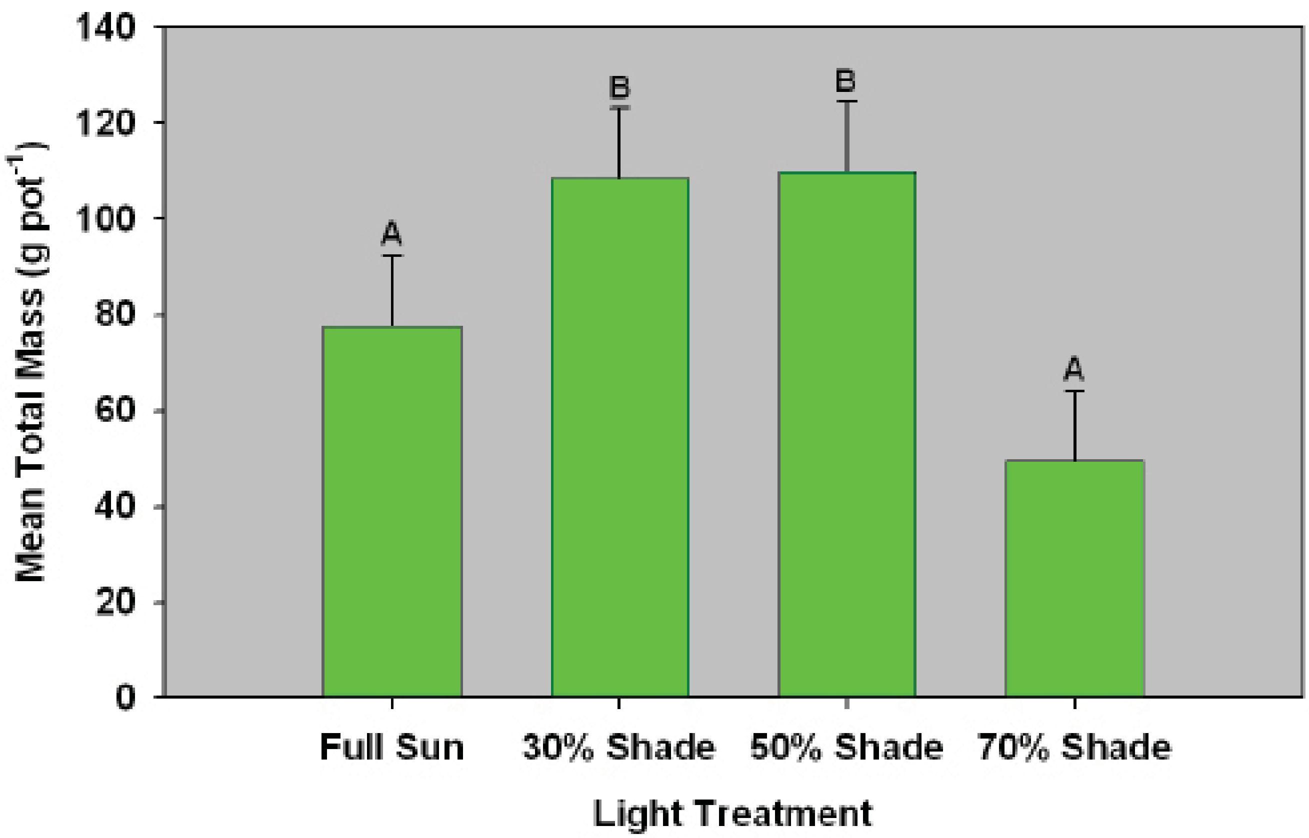


Figure 2. Mean (±1 SE) total plant length of parrotfeather grown in different light environments.

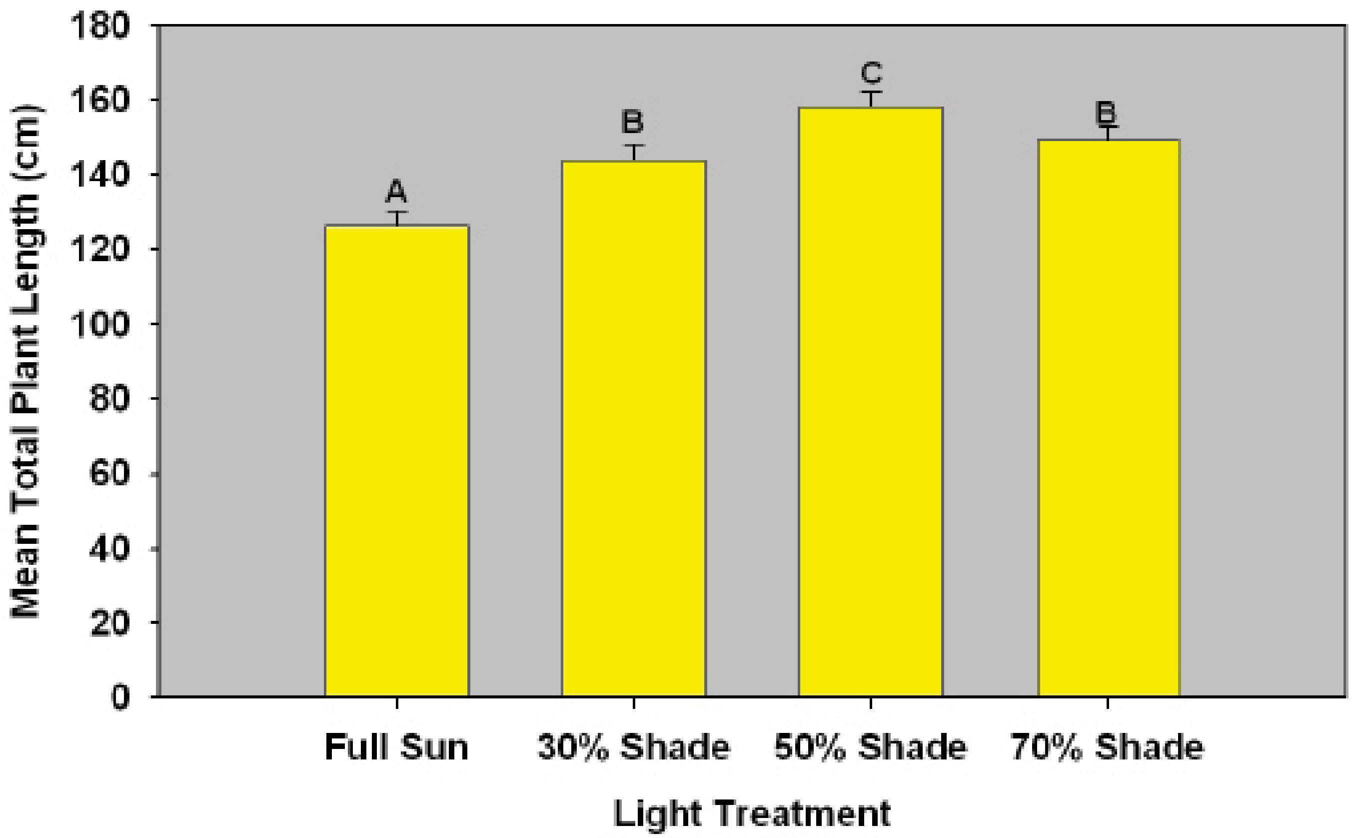


Figure 3. Mean (±1 SE) emergent shoot length of parrotfeather grown in different light environments.

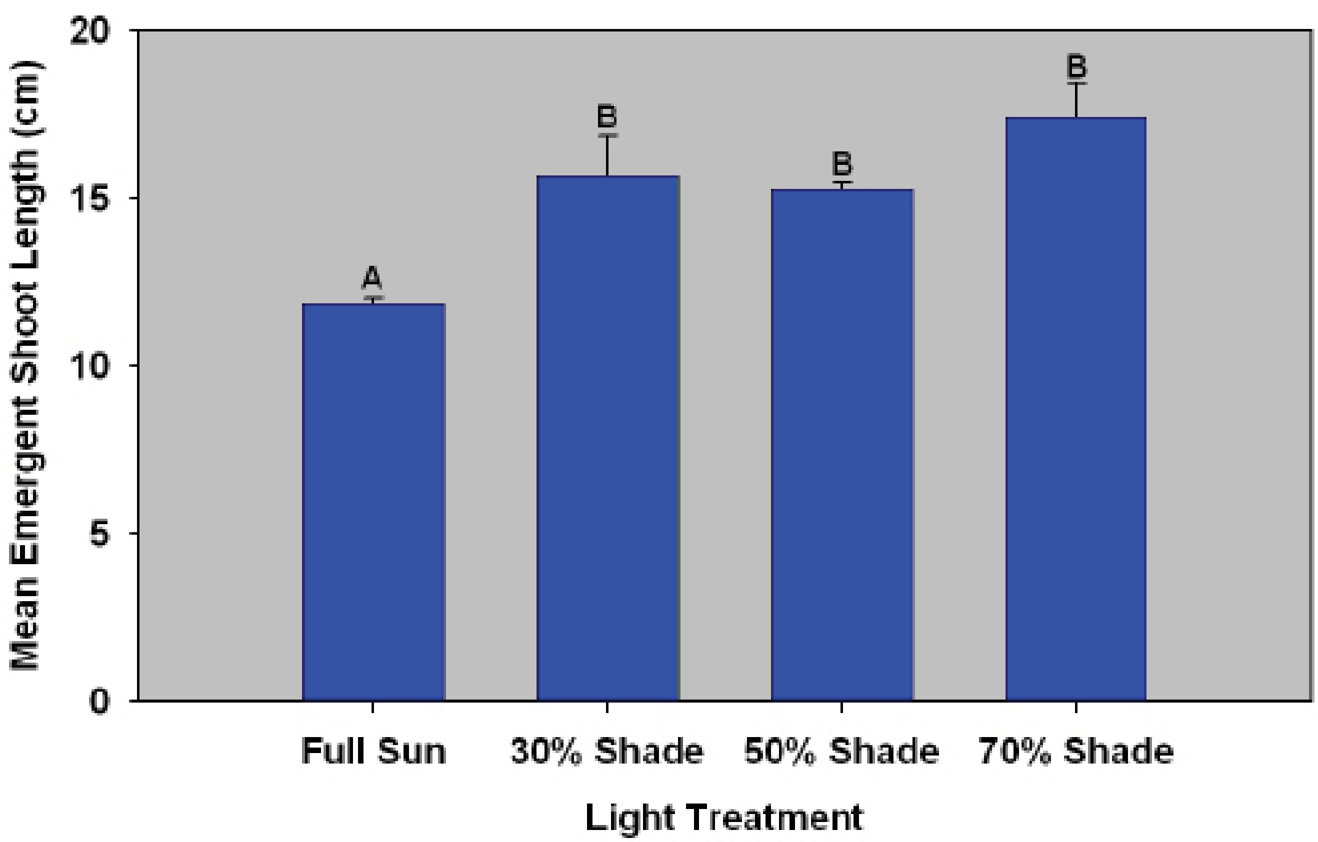
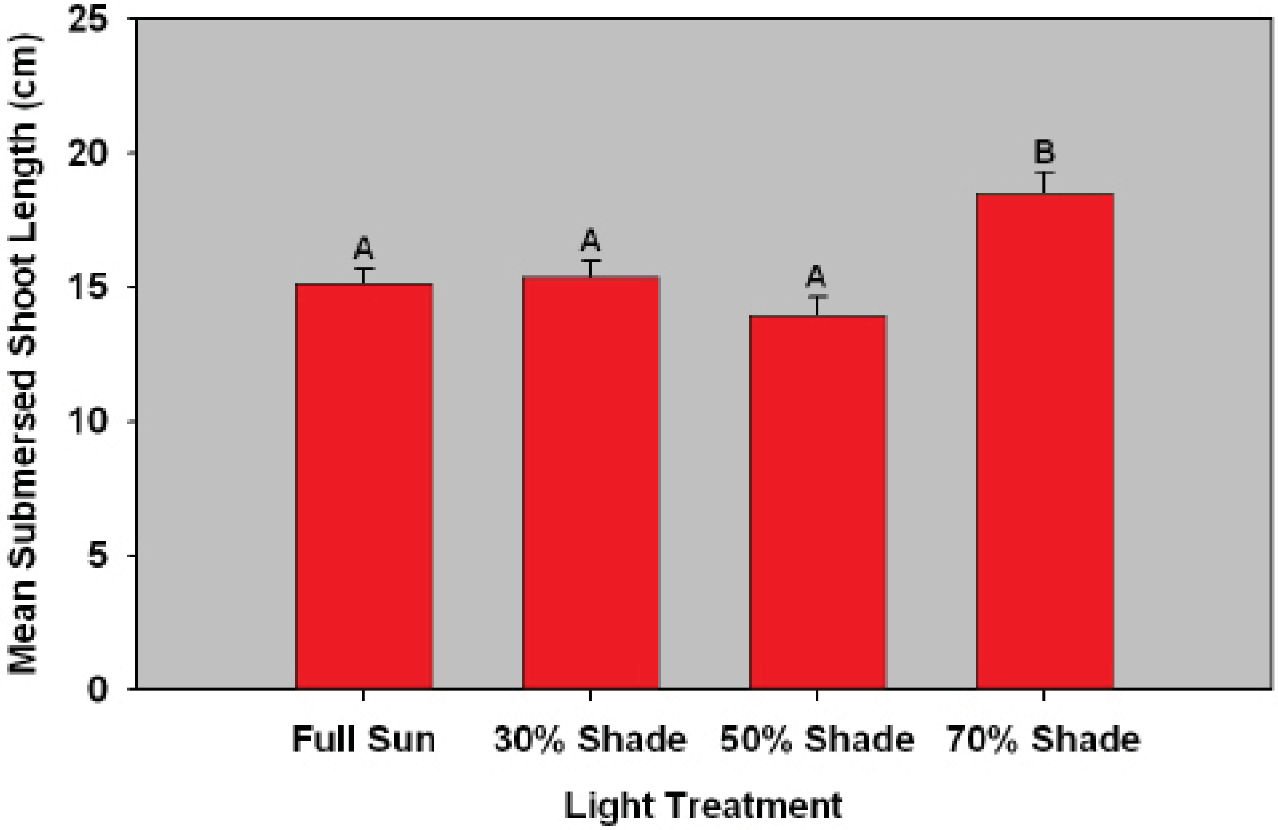


Figure 4. Mean (±1 SE) submersed shoot length of parrotfeather grwon in different light environments.



Duckweed control in Mississippi waters

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Duckweed (*Lemna minor* L.) is a free floating plant that is native to the southeastern United States. However, duckweed has an invasive growth habit and can overtake stagnant waters in both lakes and rivers. Two studies, a field demonstration and a replicated tank study, were done in Mississippi during 2007. The field demonstration was conducted in a 4.4 hectare lake near Holcomb, MS that was completely covered with duckweed. Fluridone was used in a sequential treatment of 50 parts per billion (ppb) on May 28th followed by 40 ppb treatment one month later. Duckweed biomass was reduced by greater than 90% following the second treatment ($p < 0.01$). The second study was conducted in outdoor 40 L tanks at the R.R. Foil Plant Science Research Station, Mississippi State University. Duckweed was treated with diquat at 0.37 parts per million (ppm) injected into the water, diquat at 0.37 ppm with a methylated seed oil (MSO) at 1% v/v injected into the water, diquat at 2 gallons per surface acre with 1% MSO applied to the surface, and 1% MSO alone. Biomass was significantly reduced 3 days after treatment ($p < 0.01$) with all treatments. We have demonstrated several different tools that may be used to control nuisance growths of duckweed in Mississippi waters.

Keywords: Invasive Species, Ecology, Wetlands

Introduction

Common duckweed (Lemna minor L.) (here after referred to as duckweed) is a floating aquatic plant that can cause severe nuisance problems in water bodies throughout the United States. Despite duckweed being a native plant, its invasive growth can cause severe environmental problems as well as aesthetic problems, such as impeding navigation, reduce plant diversity, and deplete dissolved oxygen which can lead to a reduction in fish productivity (Parr et al. 2002). Duckweed infestations are typically using one of two aquatic herbicides, diquat or fluridone.

Diquat [(6,7-dihydrodipyrido (1,2-a:2′,1′-c) pyrazinedium dibromide)] is often the prescribed herbicide for control of duckweed; however, it has at times been inconsistent in effectiveness. Previous studies have shown diquat to be an effective herbicide against duckweed infestations at both small laboratory scales as well as pond and lake scales (Berry and Schreck 1975, Blackburn and Weldon 1965, Langeland et al. 2002, Peterson et al. 1999). Fluridone [(1-methyl-3-phenyl-5-[3-trifluoromethyl)phenyl]-4(1H)-pyridinone)] is another commonly prescribed herbicide for duckweed control. Fluridone has been demonstrated to provide excellent control of duckweed in early screening trials with rates as low as 0.03 part per million (ppm) achieving 100 percent control eight weeks after treatment (McCowen et al. 1979).

While there are lab and controlled outdoor experiments of fluridone use for control of duckweed (McCowen et al. 1979), no publications are available to describe the efficacy of fluridone on duckweed under operational conditions. The objective of this study is to demonstrate the effectiveness of using fluridone to control duckweed at the pond scale.

Materials and Methods

The study was conducted on a 10.8 acre lake in Holcomb, Mississippi with an average depth of 5.7 ft. The study began in May 2007 and continued through September 2007. The lake was 67% covered two weeks prior to treatment with duckweed; however, at the time of treatment there was a 100% cover of duckweed throughout the 10.8 acre lake. Fluridone (as Avast® Aquatic Herbicide, SePRO Corporation 11550 North Meridian Street, Suite 600, Carmel, IN 46032) was applied at a total rate of 90 parts per billion (ppb) to the entire lake, split over two treatments; a 50 ppb initial treatment followed by a 40 ppb treatment one month later. The application was delivered using a 10 foot john boat outfitted with a sub-surface injection system calibrated to 20 gal/acre. A lower delivery volume for the treatment was used because of debris in the water column and the need to avoid exceeding the labeled rate for a particular area. Biomass was collected using a 2 in. (0.002 m2) PVC harvesting tool developed specifically for

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duckweed and similar species. Biomass was collected before, 30 and 120 days after treatment (DAT). Biomass samples were dried at 158°F to obtain a constant mass and weighed to determine post treatment biomass. Data was analyzed using a mixed model ANOVA with repeated measures. The analysis was conducted at the p= 0.05 level of significance using SAS (SAS Institute 2002).

Results and Discussion

Duckweed was highly susceptible to fluridone throughout the entire study. One month (30 DAT) following the 50 ppb initial treatment, duckweed biomass was reduced from 47.0 to 0.4 g DW m-2 ($p < 0.001$) (Figure 1). Duckweed biomass was reduced even further at 120 DAT from 0.4 to 0 g DW m-2; however this reduction was not significantly different from the 30 DAT biomass (p=0.9577) (Table 1). Biomass was significantly reduced from the pre-treatment assessment to the 120 DAT, from 47.0 to 0 g DW m-2 ($p < 0.001$) (Figure 1). Fluridone resulted in a 100% control of duckweed from the pond (Figure 1). Our results coincide with results found in laboratory screenings of duckweed control using fluridone (McCowen et al. 1979). The efficacy of fluridone may be due to the unique characteristics of this herbicide in combination with the nutrient uptake of duckweed. Fluridone is a slow acting herbicide and commonly requires 60 to 90 days of contact time to achieve acceptable control in submersed plants (Netherland et al. 1993, Netherland and Getsinger 1995). This longer contact time, combined with the ability of duckweed to take up nutrients not only from the water column (Ice and Couch 1987) and from the upper surface of the frond (Meijer and Sutton 1987), allows for thorough uptake of fluridone from the pond.

Results from this study indicate that duckweed can be controlled by fluridone applied using a subsurface application. Sequential applications of fluridone did not significantly differ in reduction of biomass. However, the second treatment of 40 ppb may have contributed to maintaining a lethal amount of fluridone in the system to continue controlling any new duckweed fronds that may have been formed during the study. Continued management of duckweed may be done with either fluridone or diquat. Selection of diquat versus fluridone for duckweed control may depend on the price of the available products and the relative amount of infestation. Diquat has been proven to adequately control duckweed as a foliar or subsurface application and is the better choice for partial infestations of the plant. Fluridone is preferred when the entire pond is infested with duckweed.

Acknowledgements

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Table 1. The results of the mixed procedures ANOVA model with repeated measures.

Effect	Survey	T Value	P Value
Survey	Pre x 30 DAT	7.06	<0.0001
Survey	Pre x 120 DAT	7.12	<0.0001
Survey	30 DAT x 120 DAT	0.05	0.9577

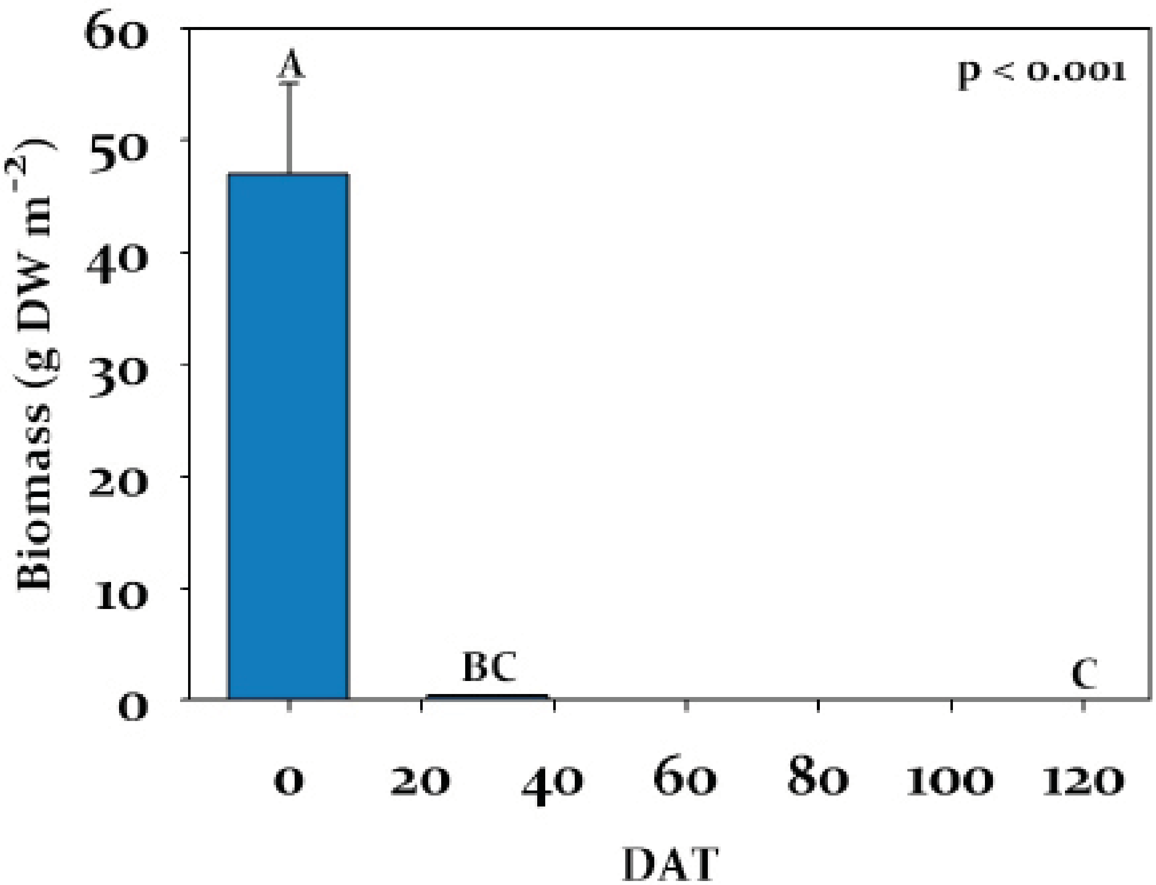

Figure 1. Mean biomass (± 1 SE) of duckweed (Lemna minor) harvested Pre-treatment, 30 DAT, and 120 DAT with sub-surface applications of fluridone.

Littoral zone aquatic plant community assessment of the Ross Barnett Reservoir, Mississippi for 2007

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As the threat of non-native plant species increases, the development and refining of methods to rapidly detect, monitor and ultimately control these species to mitigate negative impacts is critical. Three non-native aquatic plant species that have caused major problems throughout the United States are waterhyacinth (*Eichhornia crassipes*) alligatorweed (*Alternanthera philoxeroides*), and hydrilla (*Hydrilla verticillata*), and all three species. In Mississippi, these species can be found in the Ross Barnett Reservoir. Waterhyacinth and alligatorweed have been under intensive management for almost a decade, primarily through the use of contact herbicides. Hydrilla was first observed in the Reservoir in 2005 and has since undergone aggressive management through the use of the systemic herbicide fluridone. To ensure that these management techniques are successful and to assess impacts to the native plant community, we conducted a survey of the littoral zone to monitor and record changes in the occurrence of plant species. The survey of the Ross Barnett Reservoir yielded 19 species of aquatic and riparian plants. The dominant species was the native plant American lotus with a percent frequency of occurrence of 21.1%. The occurrence of each non-native species was below 5% with alligatorweed observed most often (4%). Hydrilla had a frequency of occurrence of 1.4%. The frequency of occurrence for both waterhyacinth and alligatorweed decreased significantly ($p \leq 0.01$) from 2005 to 2007. The frequency of occurrence for waterhyacinth in 2005 was 4.9% and declined to 2.9% and 1.2% in 2006 and 2007, respectively. The occurrence of alligatorweed was reduced from 21.1% in 2005 to 4.0% in 2007, approximately an 80% reduction. Furthermore, the removal of waterhyacinth and alligatorweed from some areas of the Reservoir has not impacted the overall species richness (mean number species per point) over the past three years. The occurrence of species (American lotus, white waterlily, American pondweed, and coontail) growing in association with both alligatorweed and waterhyacinth did not significantly change between years, indicating that waterhyacinth and alligatorweed are being selectively removed with little impact on native plant species or species richness. Additionally, hydrilla has been effectively removed from 5 areas of the reservoir totaling more than 161 acres.

Key words: Invasive Species, Ecology, Water Use, Wetlands

Introduction

Non-native plants affect aesthetics, drainage, fishing, water quality, fish and wildlife habitat, flood control, human and animal health, hydropower generation, irrigation, navigation, recreation, and ultimately land values (Pimentel et al. 2000, Rockwell 2003). The fraction of non-native plants that are harmful does not have to be large to inflict significant damage to an ecosystem (Pimentel et al. 2000). As the threat of non-native plant species increases, the development and refining of methods to rapidly detect, monitor and ultimately control these species to mitigate negative impacts is critical. Three non-native aquatic plant species that have caused major problems throughout the United States are waterhyacinth (Eichhornia crassipes) alligatorweed (Alternanthera philoxeroides), and hydrilla (Hydrilla verticillata). In Mississippi, all three of these species can be found in the Ross Barnett Reservoir. This is of concern because this reservoir is not only the largest reservoir in the state (33,000 acres), but it also supplies the City of Jackson with potable water. Waterhyacinth and alligatorweed have been under active management for almost a decade, primarily through the use of systemic herbicides. Hydrilla was first observed in the Reservoir in 2005 and has since undergone aggressive management through the use of the systemic herbicide fluridone and the contact herbicide endothall. To ensure that these management techniques are successful, we conducted a survey of the littoral zone plant community to monitor and record changes in the occurrence of plant species as well as to assess management techniques. Regular assessment of management effectiveness is a significant component of successful long-term maintenance management programs (Madsen 2007).

Objectives

Our objective was to monitor the aquatic plant community in the Ross Barnett Reservoir by mapping the distribution of aquatic plants in the littoral zone (water depths ≤ 10 feet), with special attention to invasive aquatic plant species.

Materials and Methods

Aquatic plant distribution was evaluated using a point intercept survey method using a 300 meter grid in July 2007 (Madsen 1999). Only those points occurring in water depths of ≤ 10 feet were sampled. Sampling points in this manner allowed for a more rigorous survey of the littoral zone, the portion of the reservoir most likely to be inhabited with aquatic plants. There were still areas within the littoral zone that were inaccessible by boat due to low water levels at the time of the survey. Points that were located in those areas were not sampled. The southern portion of the Reservoir was excluded due to greater water depths and the low likelihood of observing plant growth. For the purposes of recording sampling data, the Reservoir was divided into seven sections: Upper Reservoir, Middle Reservoir 5, Middle Reservoir 4, Lower Reservoir 3, Lower Reservoir 2, Lower Reservoir 1, and Pelahatchie Bay.

A hand-held personal digital assistant (PDA) outfitted with a global positioning systems (GPS) receiver was used to navigate to each point. Spatial data were directly recorded in the hand-held computer using Farm Works® Farm Site Mate software (Wersal et al. 2006a, Wersal et al. 2007, Wersal et al. 2008). Data were recorded in database templates using specific pick lists constructed exclusively for this project. The software provides an environment for displaying geographic and attribute data and enables navigation to the specific points of this survey. A total of 423 points were sampled during the survey by deploying a rake to determine the presence or absence of aquatic plant species at these points. Water depth was also recorded at each point during the survey.

Percent frequency of occurrence was calculated for each species by dividing the number of detections for that species by the total number of points sampled. The change in occurrence of plant species was determined using McNemar's Test to account for repeated measures (sampling the same points in multiple years) in the sampling design (Stokes et al. 2000, Wersal et al. 2006b). A pairwise comparison of species occurrences was made between years using the Cochran-Mantel-Haenszel statistic (Stokes et al. 2000, Wersal et al. 2006b). References and comparisons to the 2005 survey were done using only the littoral zone sample points that correspond to the surveys conducted in 2006 and 2007.

Results and Discussion

The survey of the Ross Barnett Reservoir yielded 19 aquatic and riparian plant species (Table 1). The dominant species was the native plant American lotus with a percent frequency of occurrence of 21%, followed by white waterlily at 5%. Other native plant species included coontail (4%) and American pondweed (2%). The occurrence of all non-native species was below 5%, with alligatorweed observed most often (4%). Hydrilla had a frequency of occurrence of 1%, followed by waterhyacinth. Hydrilla was observed at 5 locations during the littoral zone survey in July 2007, resulting in the 1% frequency of occurrence. Brittle naiad (Najas minor), a non-native plant from Europe, had a frequency of occurrence of 2% and was observed for the first time during the survey in July of 2007. It is unclear; however, how problematic it will become due to the presence of other submersed species such as hydrilla, the shading caused by American lotus, and stresses associated with fluctuating water levels. Brittle naiad does not typically cause the widespread nuisance problems of the other nonnative species, but it should be monitored in the future. The low water levels of the past two years may contribute to increased abundance of brittle naiad which, as an annual, is favored by this type of disturbance.

Water depths during the time of this survey were significantly lower than in 2005 ($p \leq 0.01$) (Wersal et al. 2008). The lower depths may have favored species that could tolerate the stresses associated with low water. Also, some shallow water areas were not accessible and therefore were not sampled, possibly resulting in some species being missed, which may be a plausible explanation for an overall reduction in species richness in 2006 and 2007 (Wersal et al. 2008). Submersed plant species growing in what were shallow areas in 2005 were likely killed as the water receded in 2006 and 2007 and bottom sediments were exposed to air. Typically, draw-downs favor the establishment of mud-flat annuals and emergent species in areas that were previously dominated by aquatic species (van der Valk 1981). Species such as American lotus reproduce vegetatively via rhizomes and also through the production of large seeds. The production of seeds represents a mechanism for survival of adverse conditions or a mechanism for spread during times of low water (Sculthorpe 1967). The frequency of occurrence of American lotus increased from 2005 to 2007, although the increase was not significant ($p = 0.08$). The frequency of occurrence for the native species white waterlily, American pondweed, and coontail did not change from 2005 to 2007 ($p = 0.44$, $p = 0.92$, and $p = 0.58$, respectively). White waterlily and American pondweed are floating leaved species and may be tolerant of water level fluctuations. Indeed, there was not significant relation found between floating plant species and drawdown (Van Geest et al. 2005). However, coontail is a submersed species and much more sensitive to water depth than the floating species. The fact that the occurrence of coontail did not change between 2005 and 2007 may suggest that it occurs in the deeper portions of the littoral zone, sheltering it from water fluctuations.

While we are confident of the estimates of floating and submersed plant distributions, we are concerned that alligatorweed and other emergent plants may be under-sampled. Alligatorweed may grow in very shallow water or even in moist soil. We propose using remote sensing (either aerial photography or satellite imagery) to validate our estimates of alligatorweed distribution from point sampling and determine areas of existence beyond the shoreline of the Reservoir.

While the frequency of native species has remained essentially unchanged over the past three years, the frequency of invasive species have changed significantly. Alligatorweed and waterhyacinth have significantly decreased significantly, due to both active management and a drop in water level. Hydrilla, on the other hand, has increased significantly, although active management has undoubtedly reduced the potential spread in the reservoir.

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Table 1. Percent frequency of occurrence for aquatic or riparian plant species observed in the littoral zone during the Ross Barnett Reservoir Survey, July 2007 (n=423). The percent frequency of occurrence reported for the 2005 data (n=677) and 2006 data (n=508) are from those points that where sampled in 10 feet of water or less during the time of that survey.

Species Name	Common Name	Native (N), Exotic (E) or Invasive (I)	2005 % Frequency	2006 % Frequency	2007 % Frequency	Signifigance[1] Value p = 0.05
Althernanthera philoxeroides	alligatorweed	E I	21.1	3.9	4.0	<0.01
Azollo caroliniana	mosquito fern	N	0.0	0.2	0.4	
Cabomba caroliniana	fanwort	N	2.2	0.0	0.5	
Ceratophyllum demersum	coontail	N	4.4	4.9	3.5	0.58
Colocasia esculenta	wild taro	E I	0.0	0.9	0.7	
Eichhornia crassipes	waterhyacinth	E I	4.9	2.9	1.2	<0.01
Hydrilla verticillata	hydrilla	E I	0.0	0.7	1.4	<0.01
Hydrocotyle ranunculoides	pennywort	N	6.4	0.5	1.4	
Lemna minor	common duckweed	N	3.1	2.5	1.9	
Limnobium spongia	American frogbit	N	1.5	0.7	0.7	
Ludwigia peploides	waterprimrose	N	4.9	7.4	4.3	
Myriophyllum aquaticum	parrotfeather	E I	0.7	0.0	0.2	
Najas minor	brittle naiad	E I	0.0	0.0	1.9	
Nelumbo lutea	American lotus	N	17.1	17.7	21.2	0.20
Nitella sp.	stonewort	N	0.1	0.0	0.0	
Nymphaea odorata	white waterlily	N	4.4	3.4	4.9	0.44
Potamogeton nodosus	American pondweed	N	2.7	2.7	2.4	0.92
Sagittaria latifolia	arrowhead	N	1.0	1.2	0.0	
Sagittaria platyphylla	arrowhead	N	0.0	1.8	0.8	
Scirpus validus	softstem bulrush	N	1.2	0.2	0.0	
Typha sp.	cattail	N	1.3	2.4	0.7	
Utricularia vulgaris	bladderwort	N	0.0	0.4	0.0	
Zizaniopsis miliacea	giant cutgrass	N I	1.5	3.5	1.9	

[1]Analyses were only conducted on the commonly occuring species, or the species most often growing in association with waterhyacinth, alligatorweed and hydrilla that may be impacted by control techniques.

Reservoir survey for invasive and native aquatic plants species within the Pat Harrison Waterways District

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The Pat Harrison Waterway is composed of nine water parks for recreational use (e. g. boating and fishing) located south Mississippi along the Pascagoula River Basin. Invasive aquatic plant species has been reported in some of these water bodies. Because recent information is lacking on the occurrence of native and invasive aquatic plant species in these systems, we were asked to perform surveys on six of the reservoirs in the system. Species occurrence information is important as a baseline to select and implement management methods on this water bodies. Aquatic vegetation surveys were conducted during the year 2007 over six Pat Harrison's water bodies using point-intercept method. This survey method consists in navigating to point locations covering the entire lake assisted by global positioning system (GPS). For all six water bodies, many native plant species were found and only four exotic plant species: *Myriophyllum aquaticum*, *Najas minor*, *Alternanthera philoxeroides*, and *Panicum repens*. The submersed *N. minor* was commonly found composing benthic aquatic vegetation. Emergent species *A. philoxeroides*, *P. repens*, and *M. aquaticum*, were found along shorelines and boat ramps. Chemical control using spot treatments of herbicides along with a monitoring program were recommended. The implementation of a monitoring program is the least expensive management approach to these nuisance plants because rapid response to the first detection of a new species' occurrence may prevent its further spread.

Keywords: Invasive Species, Ecology, Wetlands

Introduction

Invasive aquatic plants have been responsible for a variety of problems in water bodies worldwide. The introduction and growth of invasive aquatic plant species may impede boat traffic, increase susceptibility to flooding, and reduce biodiversity. Management of aquatic weeds costs over $100M each year in the United States (Pimentel et al. 2005). The least expensive approach to management of nuisance plants is to prevent their introduction through education, and respond rapidly to the first detection of their introduction. The Pat Harrison Waterways District is composed of nine water parks for recreational (e. g. boating and fishing) use located along the Pascagoula River Basin. Recreational use of water bodies is a significant vector in the introduction and movement of nonnative aquatic plant species (EPA 2007). For example, fragments of aquatic plants may tangle in boat propellers, allowing its spread between and within a water body. An aquatic plant inventory performed in 1993 found that Najas minor and Chara braunii were commonly found in two of their water parks, Archusa Creek, and Little Black Creek (Wooten 1993). To date, limited information on aquatic plants exists for these water bodies, which limits producing informed recommendations for managing these lakes. Some resource managers have suggested adding fertilizer to enhance the fisheries within each water park. However, lakes within the Pat Harrison Waterway are already eutrophic (MDEQ 2006). Adding more nutrients may lead to increased algal blooms, reduced water clarity, unsafe swimming conditions, increased taste and odor of the water and fish, and reduction of "ecosystem stability" (Wetzel 2001). In 2007, GeoResources Institute at Mississippi State University was contracted to survey six water bodies administered by the Pat Harrison Waterway District. The following aquatic plant survey was intended to inventory exotic invasive and native aquatic plants species that help to provide recommendations for lake management.

Methodology

Survey location description

The Pat Harrison Waterway is composed of nine man-

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made lakes for recreational use. All are impounded by a dam and located along the Pascagoula River Basin. Only six were surveyed (Figure 1) during growing season of 2007. Geographic coordinates and area cover for each lake are reported in Table 1 along with the total of points surveyed.

Aquatic vegetation surveys

One lake-wide survey of each water body was conducted using a point-intercept sampling method (Madsen 1999). Using ArcGIS software (ESRI 2005), a grid of points was placed over each entire lake. For the purpose of this document, only Archusa Creek was selected as an example to show the grid of points placed over the entire lake (Figure 2). A summary of lake size and survey point spacing is provided in Table 1. Each lake boundary with its respect grid of points was transferred into a hand-held personal digital assistant (PDA). Once the survey point information is in the PDA, Farm Works® Farm Site Mate software is used to load survey point information. A global positioning system (GPS) receiver was used with the PDA to provide geographic coordinate (latitude and longitude) information for each survey point and navigate sequentially to each point. Aquatic plant species present at each survey point were recorded with the PDA in the following format: 1 when the species was present and 0 when the species was absent. The following formula was used to determine the percent (%) of aquatic plant species frequency occurrence in the survey:

% Frequency occurrence = (number of points present / total points surveyed) * 100.

Results and Discussion

Lake-wide aquatic plant survey

In Maynor Creek Water Park; approximately 50% of the original points were actually surveyed due to low water. A total of 29 aquatic plant species, including the two macrophytic algae Chara sp. and Nitella sp., were found among all six lakes surveyed (Table 2). Among the 29 species found, only Alternanthera philoxeroides, Myriophyllum aquaticum, Panicum repens and Najas minor were invasive species. Although none of these exotic invasive species are listed on the federal or state noxious weed list, a management plan should be developed that is designed to avoid further spread. The following is a brief description of each water body surveyed.

Archusa Creek Water Park. The most common species found was the macrophytic alga, Nitella sp., followed by the exotic Najas minor (Table 2). Neither of these species were topped out nor posed a nuisance problem at the time of the survey. Another less frequent exotic found was Myriophyllum aquaticum growing among dense stands of the native Panicum hemitomon. Both invasive aquatic species found were previously reported to the Pat Harrison Waterway District in 1989 (Eubanks 1989).

Flint Creek Water Park. The most common species found was the native Eleocharis vivipara (Table 2). The exotic, Alternanthera philoxeroides was found at the boat ramp located in the northeastern portion of the lake. Although this location was not part of the lake-wide survey it was reported immediately due its threat of spread facilitated by boat movement within the water body. The native, Bacopa caroliniana was found covering entire coves in the northwestern portion of the lake.

Turkey Creek Water Park. The most common species found were the native floating-leaved species, Brasenia schreberi and Nymphaea odorata (Table 2). The exotic submersed, Najas minor was found at a low frequency occurrence of 2.44 % (Table 2).

Big Creek Water Park. The most common species found was the macrophytic alga, Chara sp. (Table 2). The native Eleocharis vivipara and the exotic Alternanthera philoxeroides both had a 8 % frequency of occurrence (Table 2). Most of the aquatic plant species in this lake were components of the shoreline vegetation with the exception of Chara sp. which composed benthic vegetation.

Maynor Creek Water Park. This lake was severely affected by the extreme drought of 2007 in the southern states. Administrative personnel of this lake indicated that the water was 8 feet below the normal level in the month of August. Consequently, most of the shoreline vegetation died due to the lack of water. Also, most survey point locations in areas with water were not reached because the area was too shallow to navigate with a boat. At the end of the survey, no aquatic vegetation was recorded although the presence of many aquatic species were previously reported (Eubanks 1989).

Little Black Creek Water Park. The most common species found was the native Myriophyllum pinnatum (Table 2). This species was very common and topped out in coves throughout the lake. The exotic, Panicum repens was commonly found on lake margins as part of shoreline vegetation. Najas minor, another invasive plant, was found at a low frequency of occurrence (Table 2).

Conclusions and Recommendations

It is concluded that only 4 exotic invasive aquatic plant species occurs at the surveyed water bodies. Brittle naiad was the most commonly occurring exotic but do not pose nuisance problems at the time of the survey. Spot treatments with herbicides for exotic aquatic plant control are recommended in all locations to avoid further spread. Applications must be done in spring or early summer during active plant growth for better efficacy. Repeat treatments when necessary.

The addition of nutrients to the water body would not be beneficial because these lakes are already eutrophic, meaning that the system has a high nutrient loading rate. The addition of more nutrients may lead to excessive algal blooms that consequentially promote bad odor and high turbidity in the systems. Water clarity in some of these lakes is already marginal for safe swimming, boating, or water skiing according to some state and U.S. Environmental Protection Agency standards (Madsen et al. 1999).

Aquatic plant assemblages at the discussed water bodies are considered diverse; composed by numerous native species and none where observed to form monotypic cultures. This means that all six water bodies may provide suitable habitat for fish spawning and shelter which consequentially sustain their populations. Aquatic plants provide habitat for fish and fish spawning. Loss of aquatic plants may lead to long-term degradation in water quality.

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Water body	County	Latitude	Longitude	Size (A)	Point spacing (m)	Total points surveyed
Archusa	Clarke	32.0338	-88.7140	430	150	72
Big	Jones	31.6859	-89.3423	70	50	64
Flint	Stone	30.8842	-89.1301	530	200	53
Little Black	Lamar	31.0883	-89.4958	516	150	87
Maynor	Wayne	31.6543	-88.7165	381	150	31
Turkey	Newton	32.4088	-89.1615	225	100	82

Table 1. Lake location and size reported in acres (A) with respective survey point intensity in meters (m).

Table 2. Aquatic plant species present in the Pat Harrison Waterways District with their respective frequency of occurrence. Growth forms are represented by: FL = floating-leaved, FF = free-floating, S = submerged, E = emergent. * = species present at boat ramp

			Water body				
Species	**Growth form**	**Native or Exotic**	**Archusa**	**Flint**	**Turkey**	**Little Black**	**Big**
	Frequency occurence (%)						
Nymphaea odorata Ait.	FL	Native	1	0	21	1	0
Potamogeton diversifolius Raf.	FL	Native	21	0	1	4	0
Myriophyllum aquaticum (Vell.) Verdc.	E/S	Exotic	1	0	0	0	0
Panicum hemitomon Schult.	E	Native	1	0	0	0	0
Najas minor All.	S	Exotic	35	0	2	1	0
Ceratophyllum demersum L.	S	Native	7	0	0	10	0
Hydrocotyle ranunculoides L. f.	E	Native	1	0	0	0	0
Brasenia schreberi Gmel.	FL	Native	3	0	18	11	0
Nitella sp.	S	Native	36	0	0	2	0
Potamogeton pusillus L.	FL	Native	18	2	0	0	0
Eleocharis vivipara Link	E/S	Native	4	21	0	37	8
Juncus repens Michx	E/S	Native	1	6	0	0	0
Juncus effusus L	E	Native	1	0	0	1	0
Alternanthera philoxeroides (Mart.) Griseb.	E	Exotic	0	*	0	0	8
Bacopa caroliniana (Walt.) Robins.	E/S	Native	0	6	0	0	0
Chara sp.	S	Native	0	0	10	0	55
Nelumbo lutea (Wild.) Pers.	FL	Native	0	0	2	0	0
Myriophyllum pinnatum (Walt.) BSP	S	Native	0	0	0	54	0
Scirpus cyperinus (L.) Kunth	E	Native	0	0	0	1	0
Utricularia macrorhiza Leconte	S	Native	0	0	0	22	0
Panicum repens L.	E	Exotic	0	0	0	7	0
Peltandra virginica (L.) Schott & Endl.	E	Native	0	0	0	2	0
Saccharum giganteum (Walter) Pers.	E	Native	0	0	0	1	0
Ludwigia peploides (HBK) Raven	E	Native	0	0	0	0	6
Sagittaria platyphylla Engelm.	E	Native	0	0	0	0	3
Hydrolea uniflora Raf.	E	Native	0	0	0	0	2
Pluchea camphorata (L.) DC.	E	Native	0	0	0	0	2
Cephalanthus occidentalis L.	E	Native	0	0	0	0	2
Sacciolepis striata (L.) Nash	E	Native	0	0	0	0	2

Figure 1. Reference locations of the six waterbodies surveyed within the Pat Harrison Waterway District in the state of Mississippi.

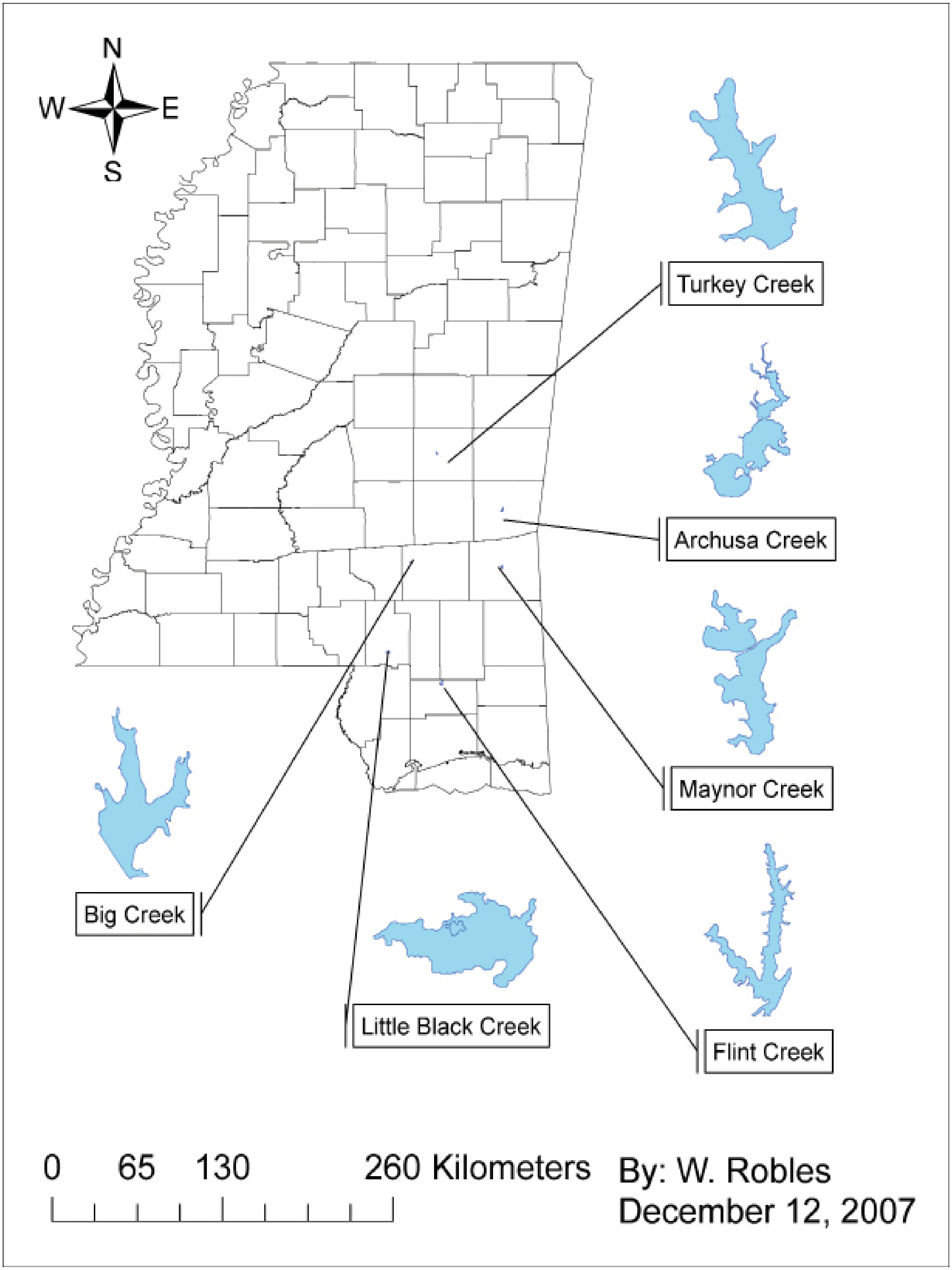
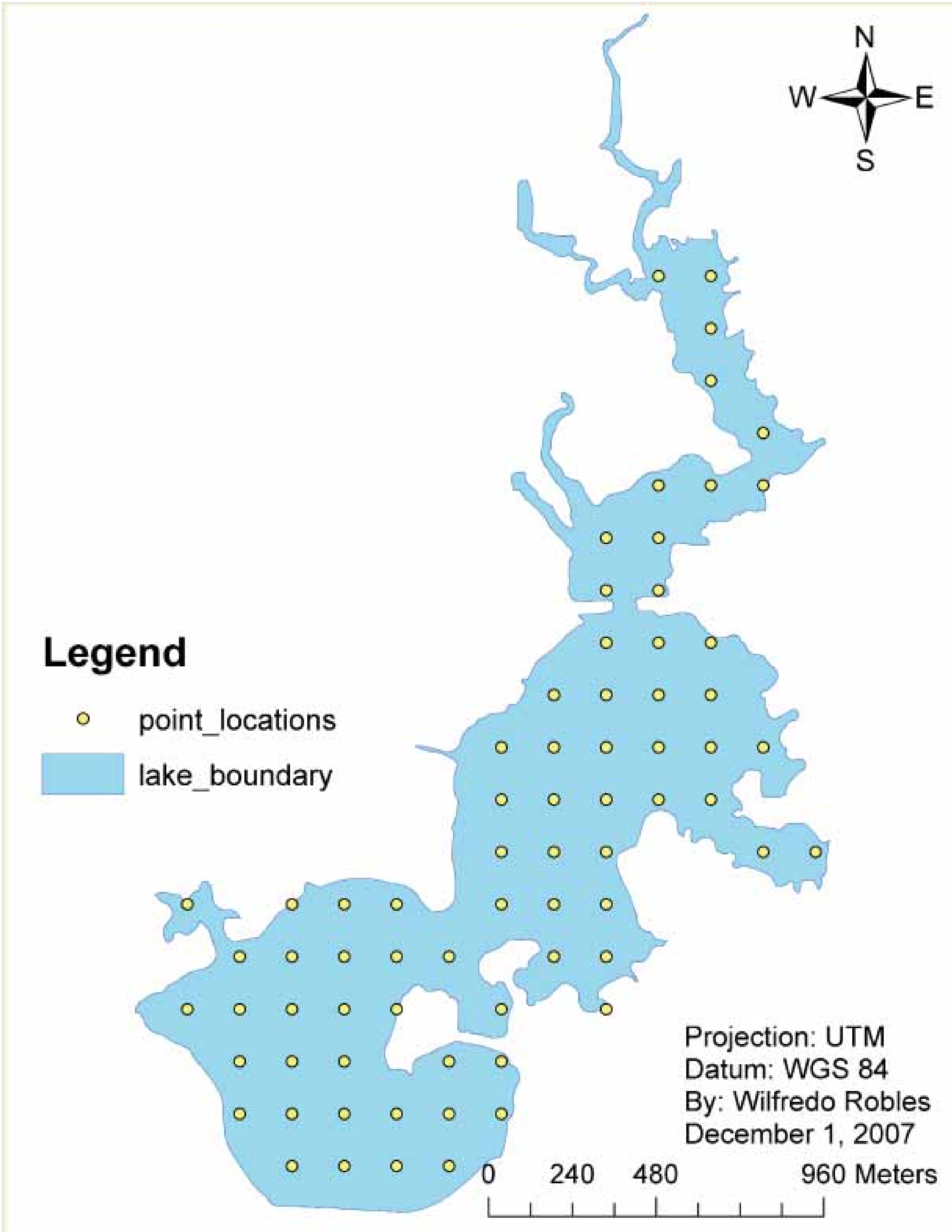


Figure 2. Point-intercept survey locations in Archusa Creek Water Park, MS.



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