Mississippi Water Resources Research Institute
Annual Technical Report
FY 2017

Introduction

Background. The Mississippi Water Resources Research Institute (MWRRI), established by the Mississippi legislature in 1984, is a quasi-state agency located at Mississippi State University (MSU) created to provide a statewide center of expertise in water resources and associated land uses that incorporates all of Mississippi's Institutions of Higher Learning in its activities. MWRRI's diverse statutory responsibilities are: 1) assist state agencies in developing and maintaining a state water management plan; 2) consult with state and local agencies, water management districts, water user associations, the Mississippi legislature, and other potential users to identify and establish water research, planning, policy, and management priorities; 3) negotiate and administer contracts with local, regional, state and federal agencies and other Mississippi universities to mitigate priority water and related problems; 4) report to the appropriate state agencies each year on research projects' progress and findings; 5) disseminate new information and facilitate transfer and application of new technologies as they are developed; 6) be a liaison between Mississippi and funding agencies as an advocate for Mississippi water research, planning, policy, and management needs; and 7) facilitate and stimulate planning and management activities that address water policy issues facing the state of Mississippi, support state water agencies' missions with research on encountered and expected problems, and provide water planning and management organizations with tools to increase their efficiency and effectiveness.

MWRRI staff work with departments and programs from Institutions of Higher Learning across Mississippi, state and federal agencies, and stakeholder organizations willing to participate in its collaborative approach in a team environment to develop approaches and projects to address the state's water resources management and research priorities.

Advisory Board. The legislation that established MWRRI also created a strong and diverse Advisory Board. The Advisory Board's role is to provide input on current and emerging priority state, regional and national water and water-related land research problems; identify opportunities to effectively collaborate with local and state governments and agencies, water user associations, other universities, federal government agencies, and the legislature in formulating MWRRI's research program; assist on the selection of research projects to be funded from USGS funds; and advise on disseminating and transferring information and technology produced by research. Designated Advisory Board members include representatives from the Mississippi Public Service Commission, Mississippi Department of Environmental Quality, Mississippi Department of Marine Resources, U.S. Army Corps of Engineers Engineering Research and Design Center, Mississippi/Alabama Sea Grant Consortium, University of Mississippi, University of Southern Mississippi, Jackson State University, Delta Council, USDA Natural Resources Conservation Service, Mississippi Soil & Water Conservation Commission, U.S. Geological Survey, USDA National Sedimentation Laboratory, and the Mississippi Water Resources Association. Five at large seats representing water stakeholders/users in private sector business and regional water management/waterway districts also serve on the Advisory Board.

Center of Excellence for Watershed Management. On April 9, 2013, MWRRI was designated by Region 4 of the U.S. Environmental Protection Agency (EPA Region 4) and the Mississippi Department of Environmental Quality (MDEQ) as a Center of Excellence for Watershed Management with the formal signing of a Memorandum of Understanding (MOU) by these parties. The MOU acknowledges that the MWRRI had demonstrated to the satisfaction of EPA and MDEQ that it has the capacity and capability to identify and address the needs of local watershed stakeholders and that it has support at the appropriate levels of MSU. It also specifies the Center of Excellence to serve as the point of contact and primary coordinating entity for colleges and universities in Mississippi. The primary purpose of the Center of Excellence is to utilize the diverse talent and expertise of colleges and universities by providing hands on practical products and services to help communities identify watershed-based problems and develop and implement locally-sustainable solutions. The MOU also guides the Center of Excellence to actively seek out watershed-based stakeholders that need assistance with project development and management, research and monitoring, education and outreach, engineering design, computer mapping, legal and policy review, and other water resource planning and implementation needs. Annual commitments of the MWRRI are also identified in the MOU.

Research Program Introduction

Background. Effective environmental planning and water resources management must first be informed and supported by scientifically-accepted research, the development of which is MWRRI's primary function. For over 30 years, MWRRI through its member Institutions of Higher Learning has worked with agencies and organizations in Mississippi and beyond to support and advance water resources research. Today, more than ever, research is vitally needed in Mississippi to advance our understanding of the science and dynamics of multiple interconnected and interdependent water-related issues and to inform our water resources planners, managers, users, and stakeholders. Since its creation and as part of its statutory responsibility, MWRRI has identified water resources research priorities through its Advisory Board and, supported by the U.S. Geological Survey through the 1984 Water Resources Research Act, has provided funding for selected research proposals that address these priorities.

External Review Process. MWRRI's approach to integrated water resources research seeks to explore the linkages among natural science, engineering, and the dynamics of social and economic systems that underpin water management decisions. As one of its core functions, MWRRI facilitates an annual, statewide competitive grants program to solicit research proposals for potential USGS 104b funding support. Proposals are prioritized as they relate to the research priorities established/affirmed annually by MWRRI's Advisory Board and by the ability of proposing parties to obtain letters of support and external cost share support from non-federal sources in Mississippi. MWRRI’s Advisory Board consists of 20 members with water-related missions/programs – 5 state agencies, 4 federal agencies, 4 major research universities, 3 NGOs, 1 water management district, and 3 industry representatives. As mentioned previously, a major activity of this Board is to review and recommend 104b proposals for potential funding. Each year, Advisory Board members are distributed all proposals submitted for potential 104b funding along with review criteria and individual proposal grading forms. After self-reviews are conducted, the full Advisory Board convenes to discuss the merits of each proposal, individual proposal grades, and then develops funding recommendations through consensus.

Water Research Priorities MWRRI and Advisory Board annually work together to review and update MWRRI’s research priorities. These priorities guide research for the MWRRI/USGS 104b Water Research Program and collaborative proposals developed for external funding. During the 2016 104b funding cycle, the research priorities recommended by the Advisory Board and adopted by MWRRI are listed below: Climatic Water Research Topics • Predictions of future water needs in various regions of the State under various climatic and/or pumping scenarios • Innovative water capture techniques and applications

Groundwater Research Topics • Innovative approaches to estimate aquifer recharge • Development of water budgets • Determining aquifer transmissivities and characteristics

Surface Water Research Topics • Evaluation of BMP effectiveness, site placement, reliability, and maintenance • Research and development to support water quality and ecosystem health assessment applications • Identification of appropriate response measures for Mississippi’s waters and linkage between nutrient concentrations and the identified response measures • Analysis of nutrient loading trends Coastal-specific Research Topics • Harmful algal bloom and early pathogen detection research for Mississippi coastal waters • Various topics (see Full Descriptions)

Water Use Efficiency and Water Reuse Research Topics • Water reclamation and reuse • Water use efficiency

Drinking Water and Waste Water Research Topics • Mitigation of lead corrosion in PWSs • Protection of source water resources • Innovative and affordable waste water treatment for small communities

Modeling and Tool Development • Development of models and tools

Social Sciences Research • Development of social indicators • Development of social science applications to advance water resource management

Economics Research • Economic analysis of reducing nutrient loadings

Emerging and Innovative Technologies • Current and potential use of Unmanned Aerial Vehicles (UAVs)

All 2017 104b proposal submittals were required to address at least one of these priorities. These priorities also guided MWRRI staff efforts to develop collaborative multi-agency project proposals for submission to other external funding sources. Four projects were funded during 2017. These projects are:

1. Study of Sediment and Nutrients in Pelahatchie Bay and Upland Mill-Pelahatchie Creek Watershed 2. Assessing the Effectiveness of Community-Based Research Strategies to analyze Risk of Lead Contamination in Public Water Supplies in the Mississippi Delta 3. Applied Use of Unmanned Aerial Vehicles in Surface Water Quality Protection 4. Assessing and Predicting In-Stream Processes in the Catalpa Creek Watershed

During 1017, final reports were received that address the 2016 104b-funded projects. These projects were:

1. Oxbow Lake-Wetland Systems as a Source of Recharge to the Mississippi River Valley Alluvial Aquifer 2. Wastewater Management in Mississippi Coastal Communities

In addition to the 104b-funded projects, MWRRI is actively implementing the following externally-funded projects: 1. Using Social and Civic Engagement Indicators to Advance Nutrient Reduction Efforts in the Mississippi/Atchafalaya River Basin – Phase 2 (funded by USEPA) 2. Using Social Indicators and Civic Engagement to Advance Nutrient Reduction Initiatives throughout the Mississippi River/Gulf of Mexico Watershed (funded by the Gulf of Mexico Alliance)

Using Social and Civic Engagement Indicators to Advance Nutrient Reduction Efforts in the Mississippi/Atchafalaya River Basin – Phase 1. MWRRI received from EPA a notice of $194,100 for this phased project. Grant monies have been made available for Phase 2 which address the development of civic engagement measures in support of the Hypoxia Task Force through SERA-46.

Using Social Indicators and Civic Engagement to Advance Nutrient Reduction Initiatives throughout the Mississippi River/Gulf of Mexico Watershed. MWRRI also received a grant award from the Gulf of Mexico Alliance's Gulf Star Program in the amount of $13,500. This grant award will provide resources for Gulf States that are not members of the Hypoxia Task Force to participate in the effort to develop social indicators and civic engagement measures. This award will allow activities of the EPA award to be leveraged among all 15 Hypoxia Task Force and Gulf of Mexico Alliance member states within the Mississippi River/Gulf of Mexico Watershed, facilitate the development of correlatable metrics across the entire region, and advance cooperation between these two organizations.

Oxbow Lake-Wetland Systems as a Source of Recharge to the Mississippi River Valley Alluvial Aquifer

Basic Information

Title:	Oxbow Lake-Wetland Systems as a Source of Recharge to the Mississippi River Valley Alluvial Aquifer
Project Number:	2016MS205B
Start Date:	3/1/2016
End Date:	8/31/2017
Funding Source:	104B
Congressional District:	MS-001
Research Category:	Ground-water Flow and Transport
Focus Categories:	Groundwater, Wetlands, Hydrology
Descriptors:	None
Principal Investigators:	Gregg R. Davidson, Andrew Michael OReilly

Publications

1. Quarterly reports submitted to Mississippi Water Resources Research Institute.
2. Gratzer II, M.C., G. Davidson, A. O'Reilly, J.R. Rigby. Quantifying recharge to the Mississippi River Valley Aquifer (MRVAA) from oxbow lake-wetland systems. Oral presentation made at 2017 Mississippi Water Resources Conference, Jackson, MS, April 11-12, 2017. http://www.wrri.msstate.edu/pdf/2017_wrri_proceedings.pdf, p. 82
3. Davidson, G.R., A.M. O'Reilly, M.C. Gratzer II. Oxbow Lake-Wetland Systems as a Source of Recharge to the Mississippi River Valley Alluvial Aquifer. Final technical report submitted to Mississippi Water Resources Research Institute, Mississippi State University, Mississippi State, MS, 35 pgs.

Oxbow Lake-Wetland Systems as a Source of Recharge to the Mississippi River Valley Alluvial Aquifer

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Final Report

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Introduction

Though many southern states receive more than enough rainfall to make up for groundwater withdrawals, the fine-grained surface deposits of the Mississippi River floodplain severely limit recharge, and groundwater levels in many places are declining. Groundwater deficits are particularly severe in the Mississippi River Valley alluvial aquifer (MRVAA) in the Delta region of northwest Mississippi where withdrawals have lowered the water table below local streams and lakes, and created a depression centered in Sunflower County. Understanding the sources of recharge in this region is critical to managing this resource, but the role of the ubiquitous oxbow lakes and wetlands remains poorly characterized. It has been assumed that the fine-grained sediment accumulating in the bottoms of oxbow lakes minimizes downward flow, but data from previous studies (Davidson et al., 2006; C. Lahiri, pers. comm.) suggest that the forested perimeters of many of these lakes provide preferential pathways for downward flow, resulting in significant recharge to the underlying aquifer.

The goal of the study described herein is to enhance our understanding of the role oxbow lake-wetland systems play in recharging the MRVAA. Research focused on Sky Lake, a large oxbow in Humphreys County near Belzoni. In this south-central region of the Delta, heavy pumping for irrigation has resulted in a substantial depression in the local water table. The study is the first to characterize and quantify the role of an oxbow lake-wetland in supplying water to the underlying MRVAA. This information will greatly improve the confidence placed in groundwater models of the region that are employed to evaluate risks and manage critical groundwater resources. The work will also provide useful information for managers and citizen groups contemplating the construction of flow control structures to raise the water level in oxbow lakes, whether as a source of irrigation water or for recreational purposes.

Background

Hydrogeology and Water Management of the Alluvial Aquifer

The MRVAA underlies much of the heavily cropped acreage in the Lower Mississippi Valley and is the major source of irrigation for the region (Fig. 1). The aquifer unit averages 30 m in thickness and is overlain by a layer of fine sediments that act as a confining unit in some portions of the aquifer, and limits direct recharge from precipitation throughout. All of the approximately 18,000 permitted irrigation wells in the region derive their water from this unit, supplying more than 2/3 of row crop acreage with water (YMD, pers. comm.).With increasing development of groundwater resources beginning in the 1970s, a regional cone of depression has gradually developed in the MRVAA, with maximum drawdowns near Sunflower, MS (Fig 2). At the center of the cone of depression, the saturated thickness of the aquifer has declined substantially with continuing declines of ~30 cm/yr, threatening even short-term water supply for some agricultural producers. A recent USGS study of groundwater depletion in 40 regional aquifers in the United States reported the MRVAA as one of the most overdrawn (Konikow, 2013).

Recharge to the MRVAA is currently poorly understood. Sources of recharge include the Mississippi River, connections with the bluff hills aquifers along the margin of the alluvial valley, surface streams whose channels have incised into the alluvial sands, hydraulic connection with underlying aquifers, direct areal recharge by precipitation, and possibly connection with surficial water features such as oxbow lakes and wetlands. While many recharge sources are recognized, the quantities supplied by each, as well as the factors influencing variability of those sources, are very poorly known (Barlow and Clark, 2011).

Local, state, and federal agencies are working assiduously with stakeholders to develop the hydrologic understanding necessary to build a sustainable water resources plan for the region before the situation becomes critical. The required research is wide ranging, from evaluation and development of conservation practices to investigations of fundamental processes governing the water budget of the region. A water budget for the region must accurately account for connections between surface and subsurface water bodies. Traditionally, wetlands are thought to be in poor connection with the aquifer because of the fine-grained sediments accumulating in these environments. The extreme spatial heterogeneity of subsurface deposits combined with the presence of macro-pores in wetlands, however, make it impossible to rule out wetlands as a significant source of recharge without further study.

Previous Work

Long-term investigation at Sky Lake, a large oxbow lake-wetland in the Mississippi Delta region, has supplied evidence that oxbows may be a greater source of recharge than once thought. Davidson et al. (2006) documented a wide range of hydraulic conductivities in the wetland soils, spanning more than five orders of magnitude, due to the presence of decaying root systems and fallen, buried tree limbs. The same study found that pores in the root zone in some places were readily flushed with surface water when water depths exceeded approximately 1 m.

Ongoing research at the lake has shown additional indirect evidence of downward movement of water through the wetland soils. The redox potential of saturated sediments is typically very low due to rapid oxygen consumption. Redox measurements over the course of a full year, at depths of 30 and 60 cm, documented isolated zones of oxidizing conditions when water levels were high, consistent with downward flow and delivery of oxygenated surface water along preferential flow pathways.

Previous monitoring of a single well near the center of the Sky Lake meander loop indicates changes in water level consistent with recharge from the lake to the underlying aquifer. Figure 3 shows a general trend of rising groundwater level during periods of high water in the oxbow lake, and falling groundwater level during periods when the lake is low or dry. A single well, however, is insufficient to confirm that the cause of rising groundwater is recharge from the overlying lake. The apparent correlation could also be due to common dependency on local precipitation. Rainfall events resulting in regional infiltration and filling of the lake could produce the same observed result. A more extensive well network is required to establish the oxbow lake as a significant source of recharge.

Methods

Study Area

Sky Lake, located in Humphreys County in the Delta region of Mississippi (Fig. 4), is an oxbow of the ancient Mississippi-Ohio River system (Saucier, 1994; Wren et al., 2008), and currently sits between the Yazoo and the Big Sunflower Rivers. The lake is one of the few in the region supporting old growth bottomland cypress predating European settlement. Sky Lake receives runoff from approximately 1,900 ha of predominantly agricultural land. During high flow in the Yazoo River, water will flood Wasp Lake to the east which in turn will overflow into Sky Lake, resulting in periodic fluctuations in water level of up to 4 m. Fluctuations as large as 3 m have been observed within a two week window. The vegetated fringe-wetland is fully inundated when the lake level is high. The site is part of long-term eco-hydrogeology investigations that include lake and groundwater level measurements, soil chemistry and cypress tree growth responses to changes in water depth, sediment accumulation history, and identification of downward flux of water along preferential flow pathways (Chen et al. in press;

Galicki et al., 2008a; Galicki et al., 2008b; Wren et al., 2008; Davidson et al., 2006; Davidson et al., 2004).

Coring

Two sediment cores were collected in the Sky Lake wetland on July 15-16, 2016: one approximately two-thirds of the way down the Sky Lake boardwalk and one near the end of the boardwalk (SLW-1 and SLW-2, respectively, Fig. 4). A Wink Vibracoring system (Wink Vibracore Drill Company Ltd., Richmond, BC, Canada) was used to collect sediment in clear, rigid plastic tubes (~5 cm in diameter and ~1.5-m in length) to a depth of 7 m. Core tubes were capped and transported to the University of Mississippi for later description and analysis.

Water Levels

A total of 10 wells were installed during this study (Table 1). Two small-diameter wells (¾ - inch galvanized pipe) were installed using the Wink vibracorer at the same locations as the two wetland cores. Eight wells were drilled using mud-rotary technique by the Mississippi Department of Environmental Quality by mid-November 2016 in the vicinity of Sky Lake (SL-1 through SL-8, Fig. 4). Wells were 5-cm or 10-cm diameter PVC and varied in depth from 24.4 to 42.7 m.

Pressure transducers (Level TROLL 400, non-vented, 30 psia, In-Situ, Fort Collins, CO) were installed in each of the 10 new wells and in the existing “Center” well (Fig. 4), which is a former irrigation well. Barometric pressure at the Sky Lake boardwalk was measured using a telemetry system (Cube 300R, In-Situ, Fort Collins, CO). Well transducer water pressures were corrected for barometric pressure effects. Well measuring-point elevations were surveyed by YMD, and groundwater level elevations were calculated using the corrected pressure transducer data.

Wetland surface water level was monitored using a pressure transducer in a stilling well adjacent to well SLW-1. Wetland surface water elevation was computed in the same manner as for the wells.

Temperature Profiles

Soil Temperature

Soil temperature was measured in the wetland at two locations near well SLW-1. Thermistors (TM- L50, Dynamax, Houston, TX) were installed in pairs at depths of 30 and 60 cm in two groups, one located ~12.7 m west of the boardwalk (Group 1) and one located ~1 m east of the boardwalk (Group 2). Each group comprised five pairs of thermistors located ~1.46 m apart at the vertices of an approximate pentagon (vertices A-E). This installation pattern was used to capture potential heterogeneity in wetland soil properties, in particular possible macro-pores contributing to preferential flow paths. Thermistors were installed when the wetland was dry by inserting a rod of slightly smaller diameter to make a pilot hole to the desired depth. The thermistor was inserted snugly into the hole, and small amount of natural sediment was packed around the wire where it entered a small diameter conduit at ground surface that ran to the data logger on the boardwalk. One thermistor was installed immediately below ground surface (< 2 cm) in order to monitor surface temperature. Wetland surface-water temperature was measured using an IButton autonomous temperature sensor (iBWetLand 22L, Alpha Mach Inc., Ste-Julie, QC, Canada) suspended in the stilling well used to measure wetland surface-water level.

Results and Discussion

Coring and well drilling were conducted in the summer and fall of 2016. Continuous monitoring of wetland surface-water level, groundwater levels in each well, and soil temperatures commenced in December–January 2017 and concluded in June 2017.

Lithology

From the wetland core collected at the location of SLW-1, we have interpreted that the wetland in the area of SLW-1 is underlain by <1 cm of organic matter, about 6.24 m of fines, about 0.01 m of transition zone between dominantly clay above this zone and dominantly sand below this zone, about 0.29 m of consolidated sand, overlying at least about 0.64 m of unconsolidated sand with pebbles.

From the wetland core collected at the location of SLW-2, we have interpreted that the wetland in the area of SLW-2 is underlain by about 6.39 m of clay, about 0.02 m of transition between dominantly clay above and dominantly silt below, about 0.05 m of dominantly silt, about 0.02 m of transition between dominantly silt above and dominantly sand below, overlying at least about 0.57 m of sand and silt.

Hydrographs

From the pressure transducers, we have tabulated water levels from early December to late April. We have plotted hydrographs for several groundwater wells and the wetland surface water level (Figures 5-12). Increasing surface water levels in the wetland produced faster increases in groundwater levels directly beneath the wetland than in surrounding wells, providing direct evidence consistent with recharge to the MRVAA from the wetland.

The hydrograph of one of the wells in the wetland (SLW-1) is a muted version of the hydrograph of the wetland surface water level (SLL-1) from January 22 to February 28 (Figures 4-5). From about January 11 to February 28, the hydrographs of the other well in the wetland (SLW-2) and a well outside of the wetland and about 0.38 km south of SLW-1 (SL-1) exhibit very similar phenomena to SLW-1 (Figure 6). Therefore, the wetland groundwater hydrographs (SLW-1 and SLW-2) and a groundwater hydrograph outside of but near the wetland (SL-1) exhibit similarities to the wetland water level (SLL-1) hydrograph (Figure 7). The hydrographs of two wells outside the meander loop (SL-5 and SL-7) and two wells inside the meander loop but farther from the wetland than SL-1 (SL-8 and the Center well) are similar to each other and differ from those of SLL-1, SLW-1, SLW-2, and SL-1 from January 18 to February 4. The water levels in the wells closer to and within the wetland rise from around January 18 to at least January 31 and then decrease until around February 4, whereas the water levels in the peripheral wells do not exhibit the same rise and fall (Figures 8-9). The wells that are farther from the wetland and lake (SL-5, SL-7, SL-8, and Center) show little correlation to wetland water level.

The hydrographs of SLW-1, SLW-2, SL-1, and SL-2 from February 14 to April 28 are similar to each other in overall trend but the water level changes that occur from April 2 to April 28 distinguish the wetland wells from those outside the wetland (Figure 10). The wetland well hydrographs rise faster, level off sooner and for a longer period of time, begin decreasing sooner, and decrease faster than the hydrographs of the wells outside the wetland. The trend in these four hydrographs exhibits a correlation to SLL-1; for example, the rise and fall in SLL-1 water level from April 2 to April 17 is reflected in the rise and fall in water level in the four aquifer wells from around April 4 to at least the end of the plotted period, April 28 (Figure 11). While it may appear that groundwater levels are responding instantaneously to surface water level rise on April 2, we hypothesize that this response results from a change in pressure and/or a loading effect. It is the sustained rise and delayed fall over the course of about three weeks (April 5-25) that suggests actual groundwater response to surface water change.

Looking at the hydrographs of SLL-1, SLW-1, SL-1 and SL-8 from about April 2 to April 28, we see lesser slopes and later peaks moving from SLL-1 to SLW-1 to SL-1 to SL-8. This indicates a delayed response to surface water level changes as one moves away from the wetland. This delay in response outside the wetland may be consistent with vertical recharge from Sky Lake and the wetland. Such vertical recharge would locally alter the regional westward hydraulic gradient, slowing the westward movement of groundwater and leading it to build up during events of heightened downward flux of lake and wetland water. Wells closer to the perimeter of the lake and wetland would likely respond to this buildup sooner than wells farther from these waterbodies. From January 1 through February 28, we also saw a delayed response to wetland water level in SL-1 compared to SLW-1. One thing that is unique about February 14 through April 28 is that SL-8 has a stronger correlation to SL-1 than it did from January 1 through February 28. The average wetland water level from February 14 through April 28 is higher than that during January 1 through February 28. That the correlation between SL-1 and SL-8 is stronger when the surface water level is higher suggests that higher surface water level increased downward flux of lake and wetland water enough around April 7 to alter the hydraulic gradient and make groundwater build up as far away from Sky Lake and the wetland as SL-8.

<u>Potentiometric Maps</u>

Based on the water levels measured on March 15, 2017 and April 23, 2017, we have constructed two potentiometric surface maps of the MRVAA, the March water levels representing a period of lower water levels and the April water levels representing a period of higher water levels (Figures 13-14). The gradient of the potentiometric surface is steepest on the west side of the lake, forming a groundwater ridge beneath the lake, consistent with direct recharge to the MRVAA from the wetland and subsequent groundwater flow to the west.

The potentiometric surface map based on March 15 water levels (Figure 13) shows water levels mostly decreasing from east to west in keeping with the regional westward gradient. This map shows a possible groundwater ridge with an axis oriented approximately east-west.

Hydraulic gradients are steeper in the west than in the east and outside of the meander loop than inside the meander loop.

The potentiometric surface map based on April 23 water levels (Figure 14) shows water levels generally decreasing from east to west in keeping with the regional hydraulic gradient. Water levels are generally higher inside the meander loop than outside the meander loop. Exceptions to these observations are the wells in the wetland, which have water levels lower than wells west of them and lower than one well outside the meander loop (SL-7). This map shows a groundwater ridge whose axis extends from about 0.5 km north of SL-2 to the location of SL-5; therefore, this axis is oriented slightly south of due west. As one moves from east to west, hydraulic gradients generally increase significantly west of SL-2. Similar to March 15, hydraulic gradients are greater outside the meander loop than inside the meander loop. The greatest hydraulic gradient, ~0.0014, is from SL-2 to SL-5, and the least hydraulic gradient, $\sim 1.5 \times 10^{-5}$ is from the Center well to SL-1.

Soil Temperature

From the soil thermistors in the wetland, we have collected soil temperature data from mid-February to mid-June. We have plotted temperature time series for several thermistors (Figures 15-16). Thermistors are referred to by three-character ID's, where the first character refers to group number (1, which is west of the boardwalk, or 2, which is east of the boardwalk), the second character is a letter (A, B, C, D, or E) that refers to vertex of the pentagonal pattern of sensor placement, and the third character represents depth below ground (3 representing 30 cm below ground and 6 representing 60 cm below ground). Soil temperature profiles at different locations in the wetland demonstrate variable responses to surface temperatures and wetland water levels, consistent with the presence of preferential flow paths.

Soil temperatures at 30-cm depth generally are similar in trend and magnitude with the exception of one sensor (2E3) east of the boardwalk (Figure 15). The two sensors west of the boardwalk (1A3 and 1D3) are similar in terms of lag times, but 1A3 is more similar to the surface temperature than 1D3 from April 23 to April 26 (Figure 15). From around March 3 to March 16, 2E3 is the 30-cm thermistor that tracks the surface temperature in finest detail, has the shortest lag times, and is most similar to the surface in terms of the amounts by which its temperature rises and falls. From around March 3 to April 28, 2E3 is the sensor that is most similar to the surface in terms of the amounts by which its temperature rises and falls. That 2E3's temperature time series correlates stronger to the surface temperature than the other thermistors suggests that a preferential flow path might intersect location 2E.

From around March 11 to March 16, surface temperature decreases and this temperature decrease propagates into the subsurface, as evidenced by the 30- and 60-cm thermistors, resulting in the temperature in each thermistor decreasing by more than it does during any other part of the plotted period (even though this is not the largest decrease in surface temperature during the plotted period) (Figures 15-16). The largest decrease in surface temperature during the plotted period is from February 24-February 26, but the subsurface temperatures decrease more in response to the mid-March temperature drop. The wetland water depth during the late February temperature drop is lower than the wetland water depth during the mid-March drop in temperature. This suggests that the higher water level depth in mid-March might have led to a greater downward flux of surface water into the subsurface, causing a greater response at depth to the surface temperature drop. As wetland water levels rise even further in early April, we see all of the plotted 60-cm thermistors responding to the rise in surface temperature. During the late February temperature drop, 2E6 responded quicker and more dramatically to surface changes than the other thermistors, whereas in mid-March all of the thermistors behave in concert, correlating just as strongly as 2E6 to surface temperature rise. This further supports the hypothesis that high surface water depth increases downward flux.

Soil temperatures measured by two 60-cm thermistors west of the boardwalk and one 60-cm thermistor east of the boardwalk (1A, 1D, and 2D) are similar in trend over time from February 14 to April 28 (Figure 16). At certain times, the magnitudes of their temperatures become very close: For example, 1A6 temperatures become very close to 1D6 temperatures from March 17 to March 20, a period during which the wetland water level stays fairly constant at about 0.246 m ASL, which is relatively high in comparison to the depth in mid- to late February of about 0.154 m ASL. Additionally, 2D and 1D temperatures are very similar from March 29 to April 19, a period that includes when the wetland water level is highest from April 3 to April 12. The other two plotted 60-cm thermistors on the west side of the boardwalk (1B and 1E) are similar to 1A, 1D, and 2D in trend; however, 1B and 1E differ from 1A, 1D, and 2D from March 15 to March 29 with 1B and 1E exhibiting shorter lag times behind the surface temperature time series. The 60-cm thermistor at 2E differs from those at 1A, 1B, 1D, 1E, and 2D in magnitude and trend during most of the plotted period; 2E shows the strongest correlation to the ground surface temperature.

Based on these observations, both the 30- and 60-cm thermistors at location 2E are the most strongly correlated to the surface temperature, suggesting a possible vertical preferential flow path intersecting the locations of these thermistors.

Summary and Conclusions

The Mississippi River Valley alluvial aquifer (MRVAA) is being depleted by unsustainable pumping for irrigation. To better manage this resource we must identify and quantify sources of recharge, which may include oxbow lakes such as Sky Lake, an ancient oxbow of the ancient Mississippi-Ohio River system that is located near the center of a regional cone of depression in the Mississippi Delta. Sky Lake and many other oxbows are surrounded by heavily forested wetland fringes, whose trees potentially create preferential flow paths for surface water to infiltrate the subsurface. In order to determine whether Sky Lake and its associated wetland contributes significant recharge to the MRVAA, we collected core in the wetland, measured groundwater levels, and measured vertical soil temperature profiles in the wetland. Then we described the core and plotted hydrographs, potentiometric surface maps, and soil temperature time series. Through this analysis, we have found the following:

1. A groundwater ridge lies beneath the lake, consistent with direct recharge to the MRVAA from the wetland.
2. Rising water in the wetland produced faster increases in groundwater levels directly beneath the wetland than in surrounding wells, providing direct evidence consistent with recharge the MRVAA from the wetland.
3. The general hydraulic gradient is to the west, consistent with regional models of flow toward a groundwater basin created by excessive withdrawals.
4. The groundwater gradient is steepest on the west side of the lake, consistent with recharge to the MRVAA from wetland and flow to the west.
5. Temperature profiles in the wetland demonstrate variable responses to surface temperatures and wetland water levels, consistent with the presence of preferential flow paths.

References Cited

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Tables

Table 1. Well and wetland monitoring sites.

ID	Latitiude, degrees N	Longitude, degrees W	Depth (per Driller, in ft)	Owner	Notes
SL-1	33.28455	90.48242	105	WMA	Gravel lot outside WMA center
SL-2	33.27810	90.50048	140	WMA	Boundary between Sorrell and WMA property, tree line that extends inward
SL-3	33.26488	90.48518	85	Sorrell	On levee where trees start
SL-4	33.29775	90.49907	80	WMA	Near gas pipeline
SL-5	33.27750	90.50628	80	McBride	0.7 mi west of T on Sky Lake Road, McBride outfitters
SL-6	33.24940	90.51517	90	Rogers	Gravel lot and small building, #1 choice for Billy Rogers
SL-7	33.24993	90.47677	90	Rogers	Billy Rogers' yard, behind pampas grass at mailbox
SL-8	33.27905	90.46898	80	WMA	East of Four Mile Lake, through locked WMA gate; for gate access contact Caleb Hinton 601-606-3099
SLL-1	33.28862	90.48332	NA	WMA	Wetland surface water level, boardwalk, on left, PVC pipe
SLW-1	33.28862	90.48332	30	WMA	Boardwalk, on left, galvanized pipe
SLW-2	33.28958	90.48347	30	WMA	End of boardwalk, on right, galvanized pipe
Center	33.27463	90.48185	Unknown	WMA	Follow trail, at ~0.6 mi west of gate turn left, well on left ~0.1 mile south (a few 100 ft past ditch)

Figures

Figure 1. Mississippi River Valley alluvial aquifer (USGS, 2015).

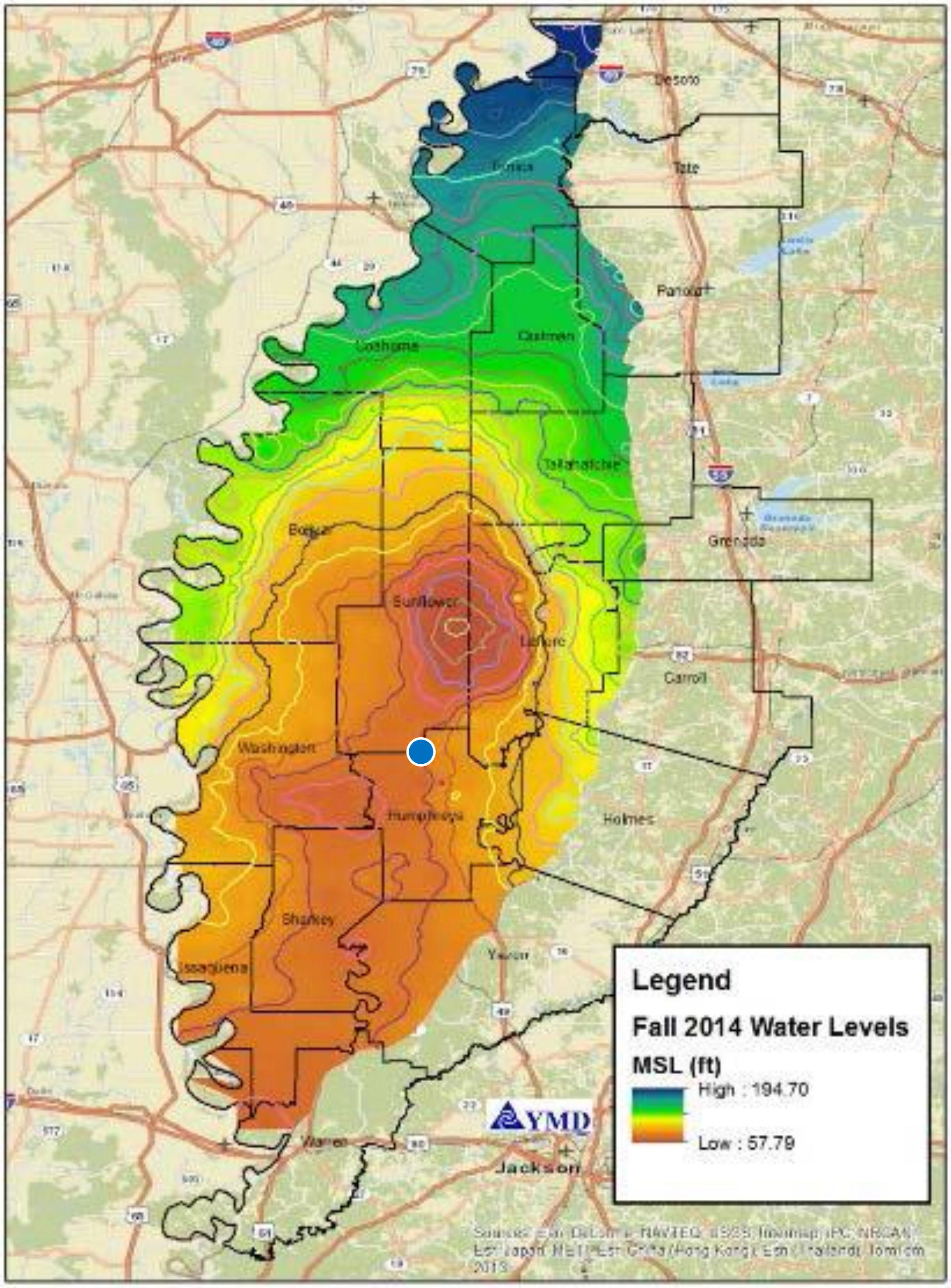

Figure 2. Water table elevations showing groundwater depression (YMD, 2014). Blue dot is location of Sky Lake.

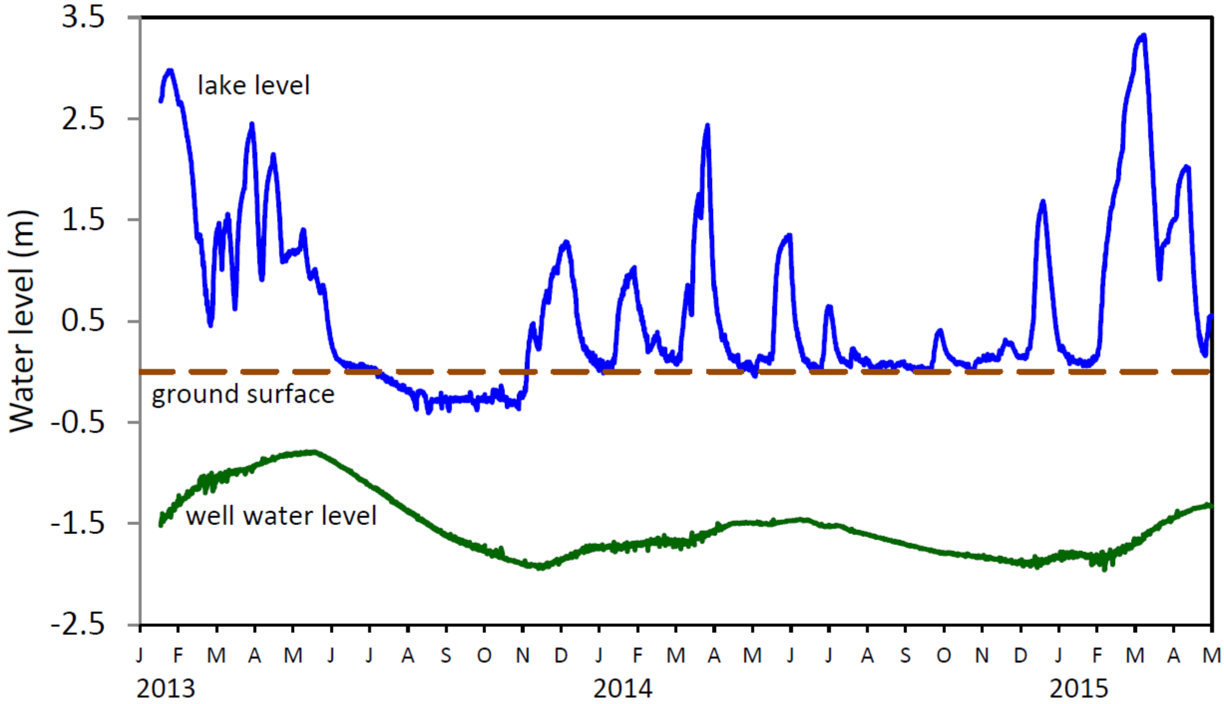

Figure 3. Water depth in Sky Lake and groundwater level for a well near the center of the meander loop ("Center" well on Fig. 4). The groundwater level is approximately 4 m lower than shown on the graph.

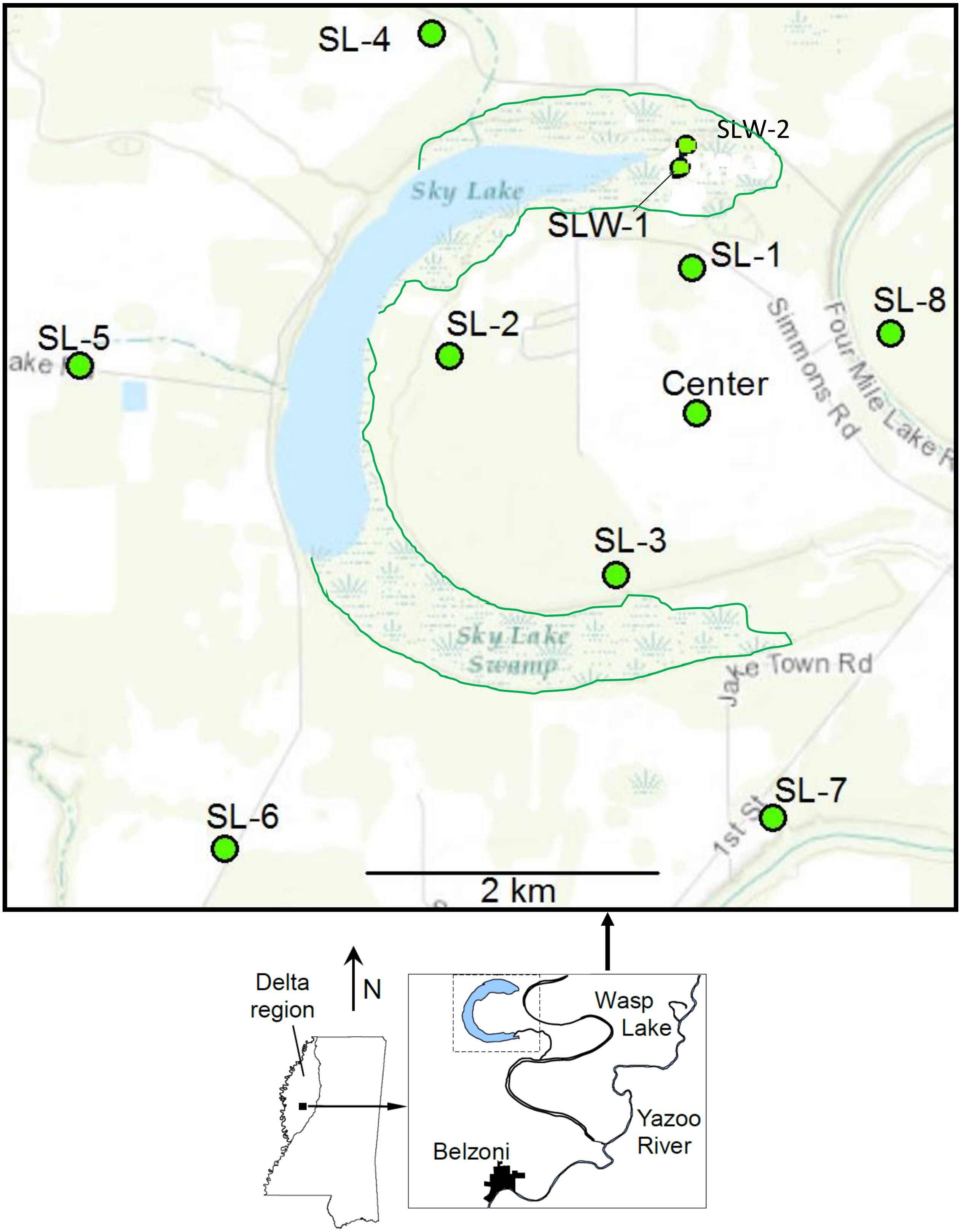

Figure 4. Map of location of study area and monitoring wells. SLL-1 is located in the same location as SLW-1. The bold green line denotes the wetland perimeter.

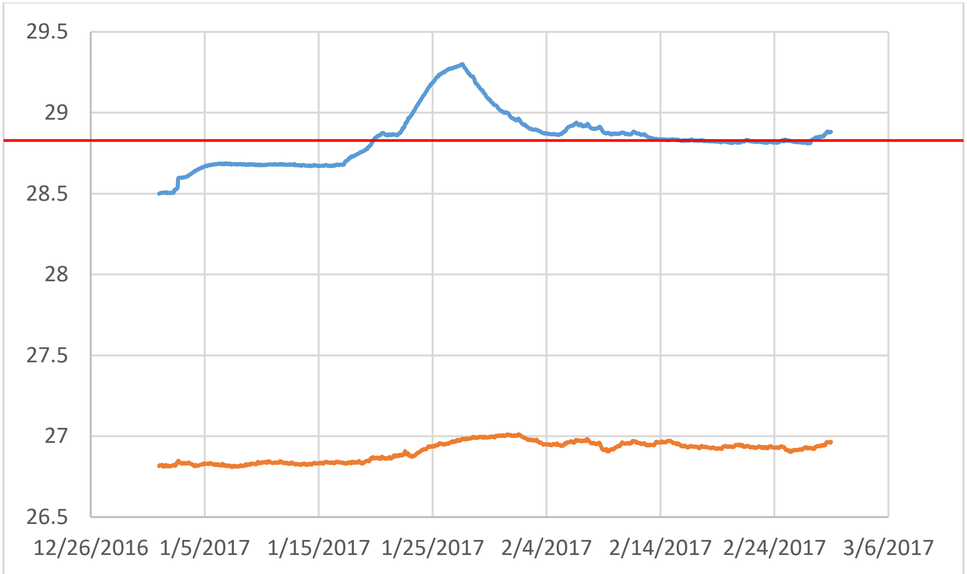

Figure 5. Hydrographs of SLL-1 (blue) and SLW-1 (orange) from January 1 to February 28. The bold red line indicates ground surface elevation.

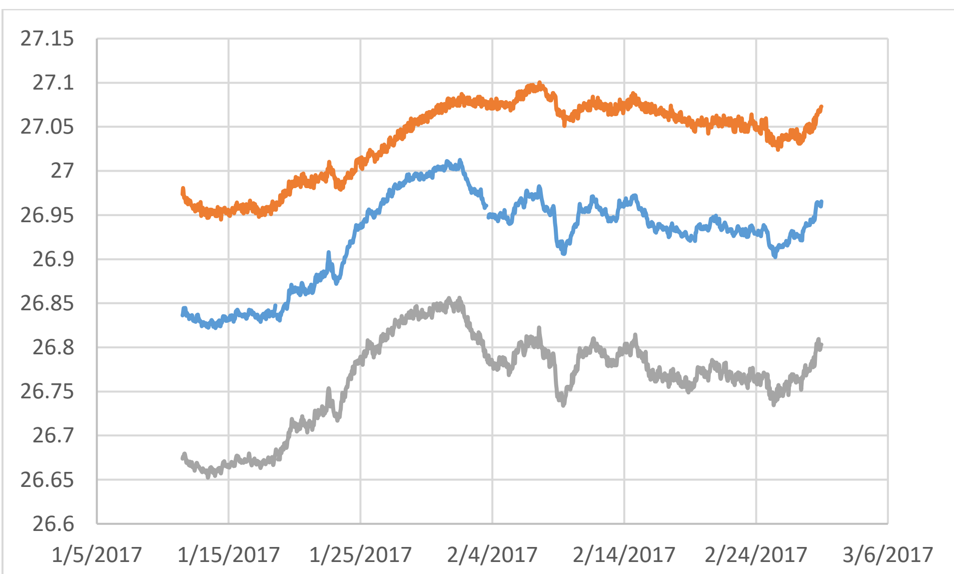

Figure 6. Hydrographs of SLW-1 (blue), SLW-2 (gray), and SL-1 (orange) from January 11 to February 28.

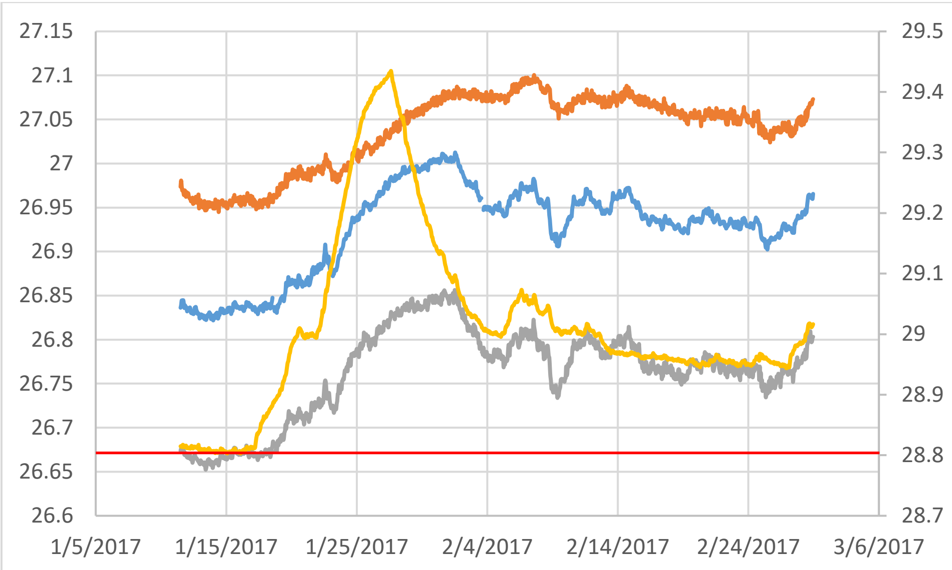

Figure 7. Hydrographs of SLL-1 (yellow), SLW-1 (blue), SLW-2 (gray), and SL-1 (orange) from January 11 to February 28. SLL-1 is plotted on the right axis. The bold red line indicates ground surface elevation (on the right axis).

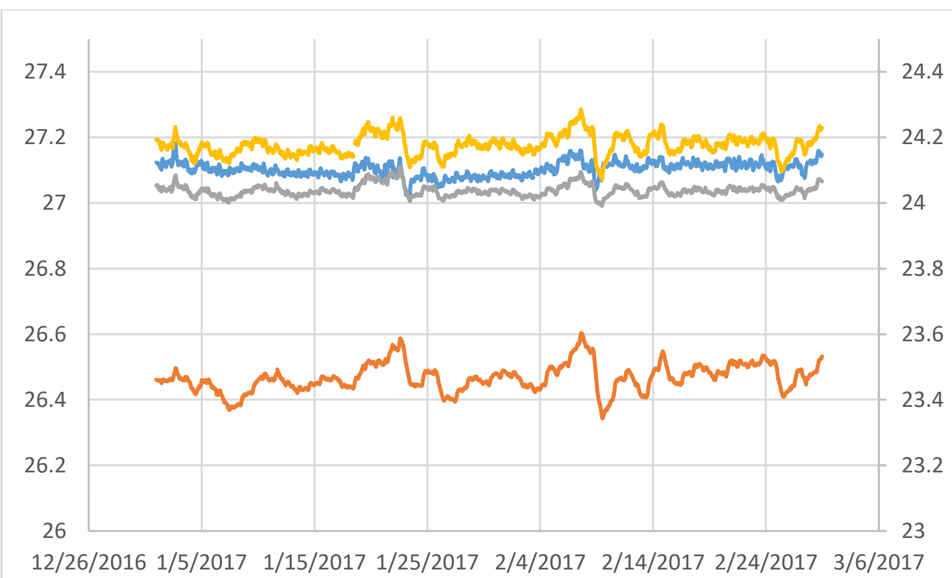

Figure 8. Hydrographs of SL-5 (orange), SL-7 (gray), SL-8 (yellow), and Center well (blue) from January 1 to February 28. SL-5 is plotted on the right axis.

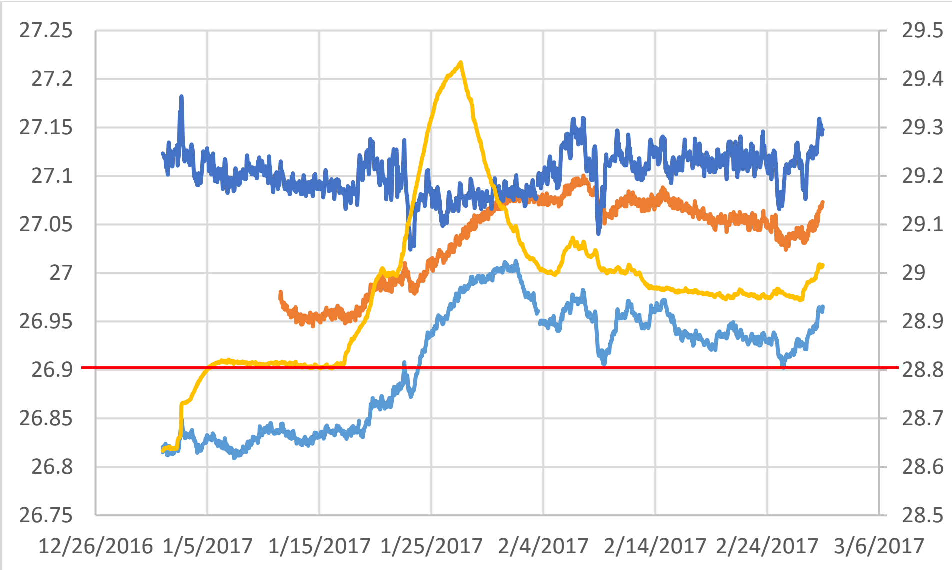

Figure 9. Hydrographs of SLL-1 (yellow), SLW-1 (light blue), SL-1 (orange), and Center well (dark blue) from January 1 to February 28. SLL-1 is plotted on the right axis. The bold red line indicates ground surface elevation (on the right axis).

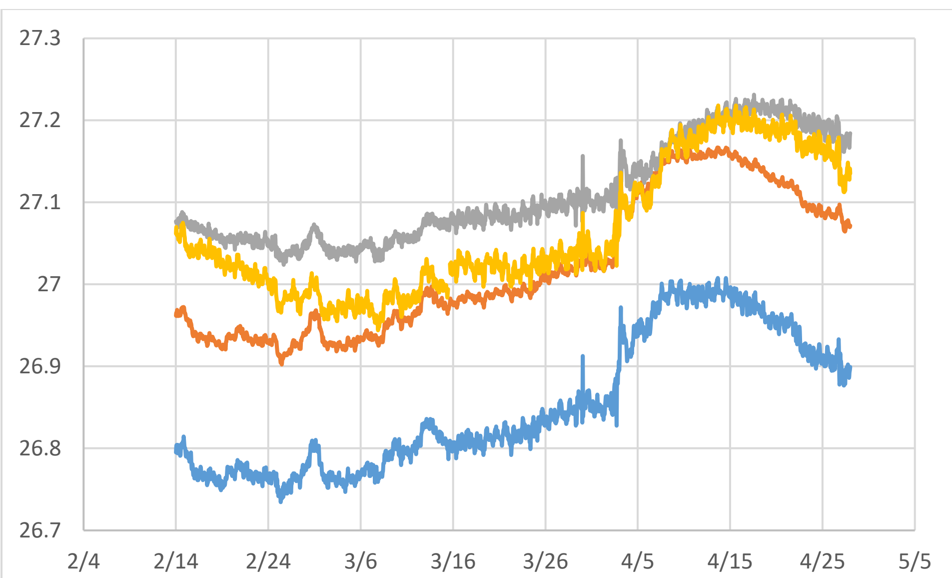

Figure 10. Hydrographs of SLW-1 (orange), SLW-2 (blue), SL-1 (gray), and SL-2 (yellow) from February 14 to April 28.

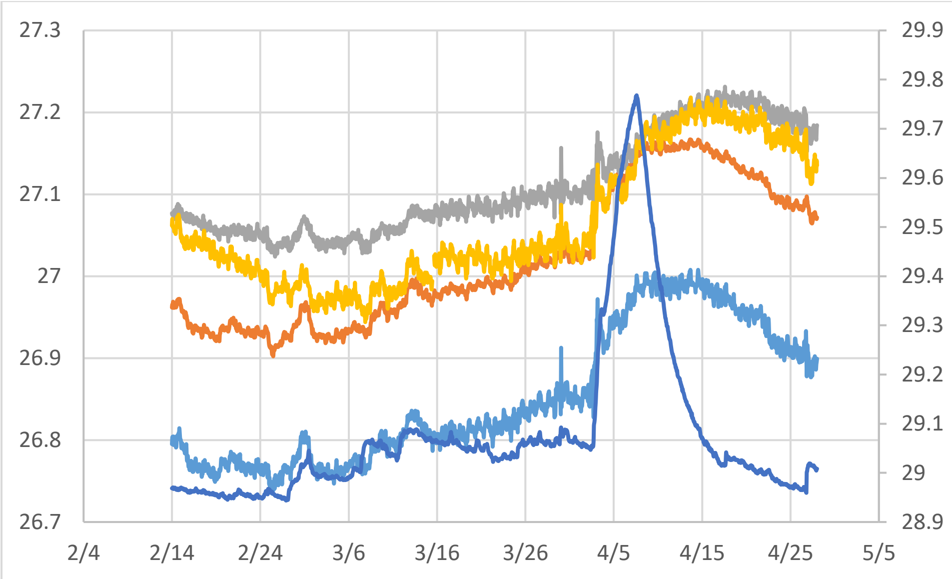

Figure 11. Hydrographs of SLL-1 (dark blue), SLW-1 (orange), SLW-2 (light blue), SL-1 (gray), and SL-2 (yellow) from February 14 to April 28. SLL-1 is plotted on the right axis.

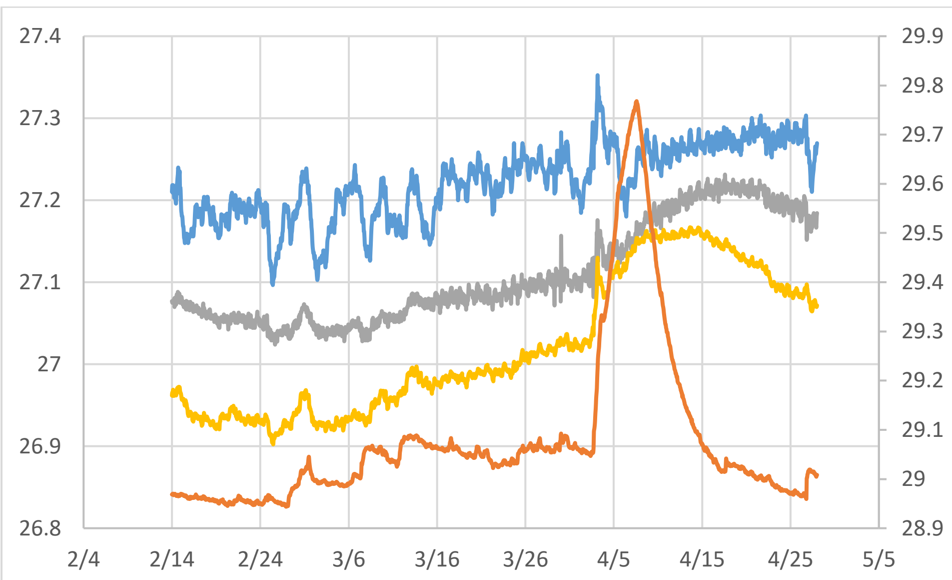

Figure 12. Hydrographs of SLL-1 (orange), SLW-1 (yellow), SL-1 (gray), and SL-8 (blue) from February 14 to April 28. SLL-1 is plotted on the right axis.

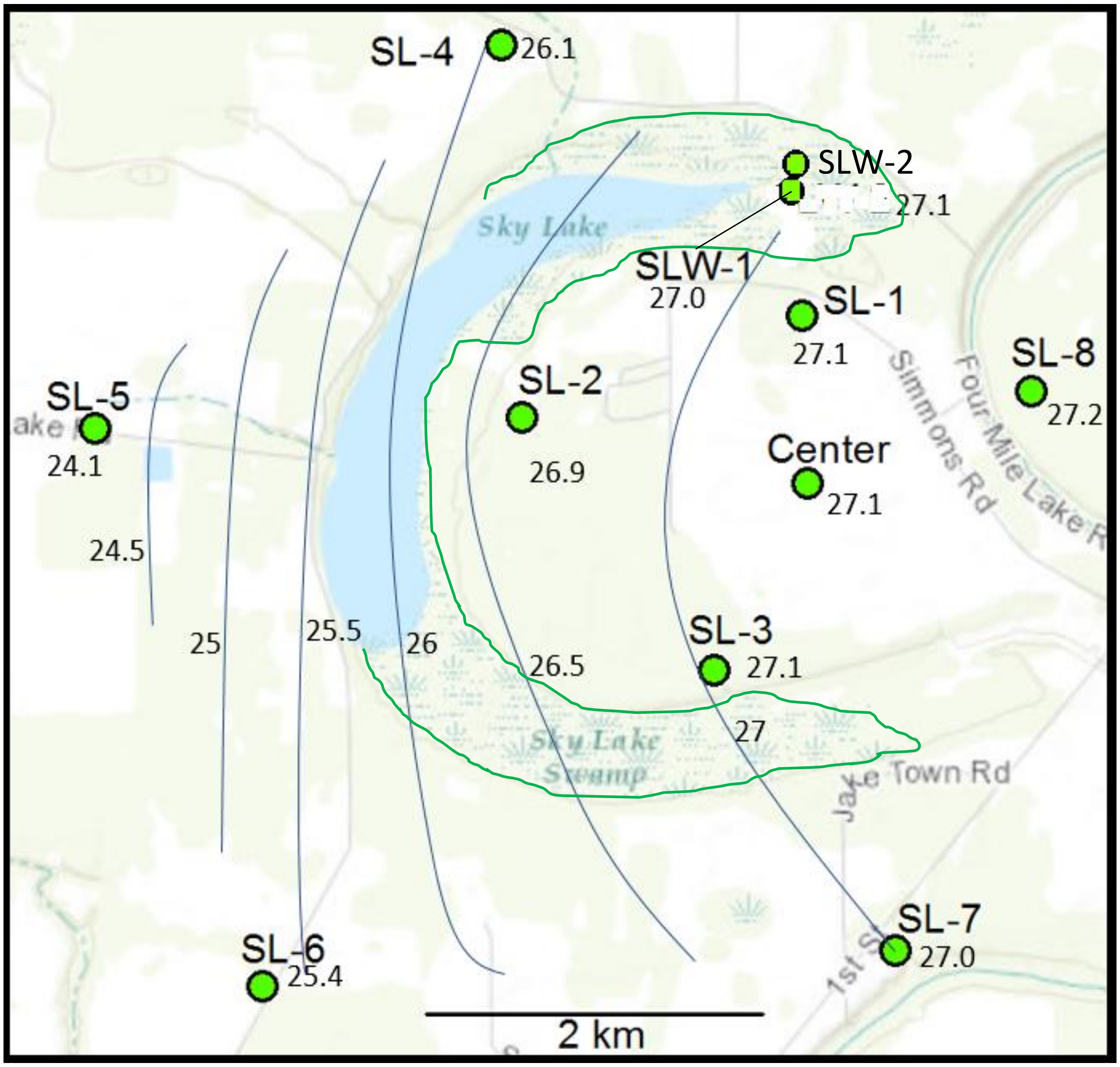

Figure 13. Potentiometric surface map of Mississippi River Valley Alluvial Aquifer based on water levels measured on March 15, 2017. Contour interval is 0.5 m. Green line denotes wetland perimeter.

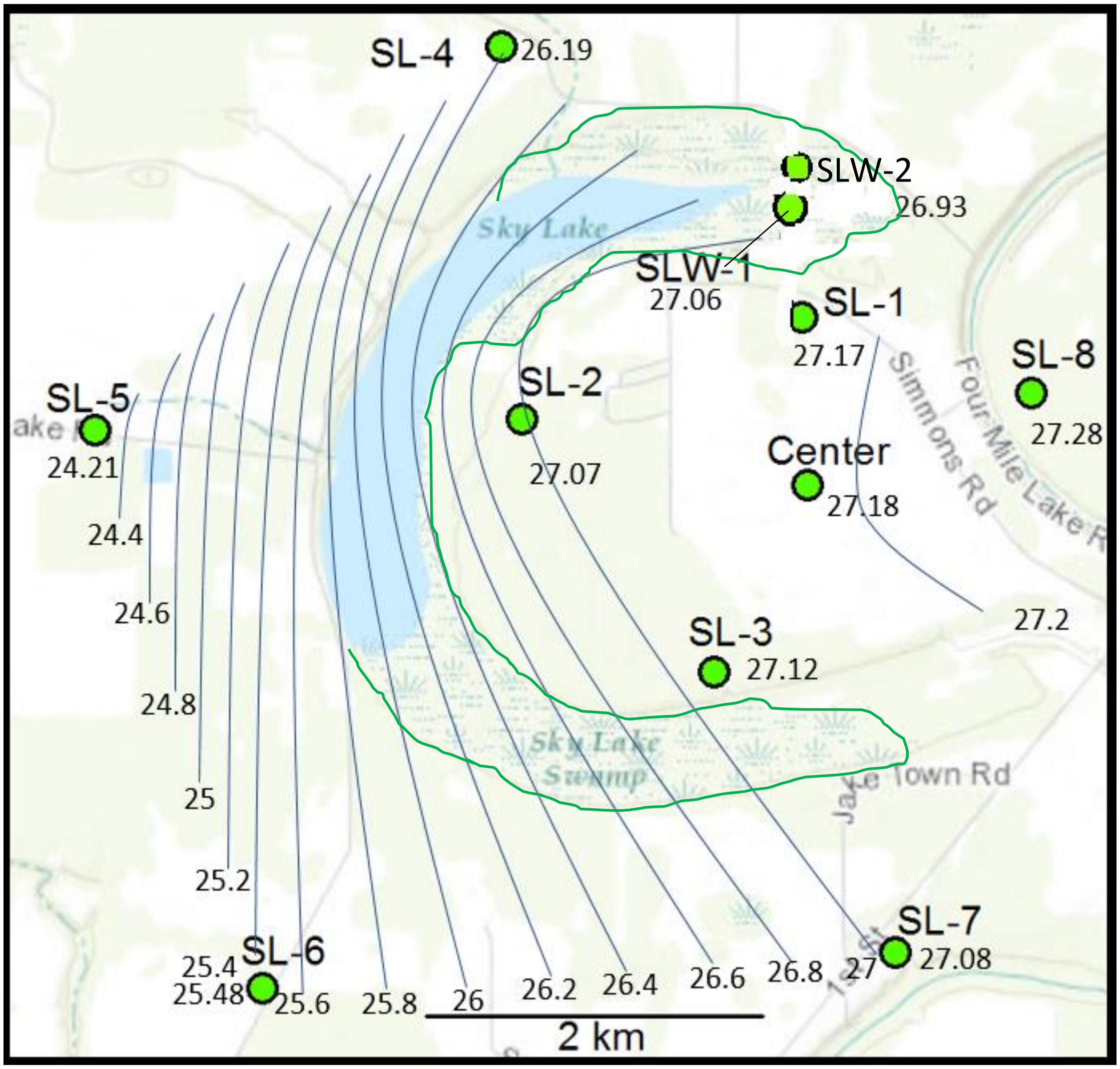

Figure 14. Potentiometric surface map of Mississippi River Valley Alluvial Aquifer based on water levels measured on April 23, 2017. Contour interval is 0.2 m. Green line denotes wetland perimeter.

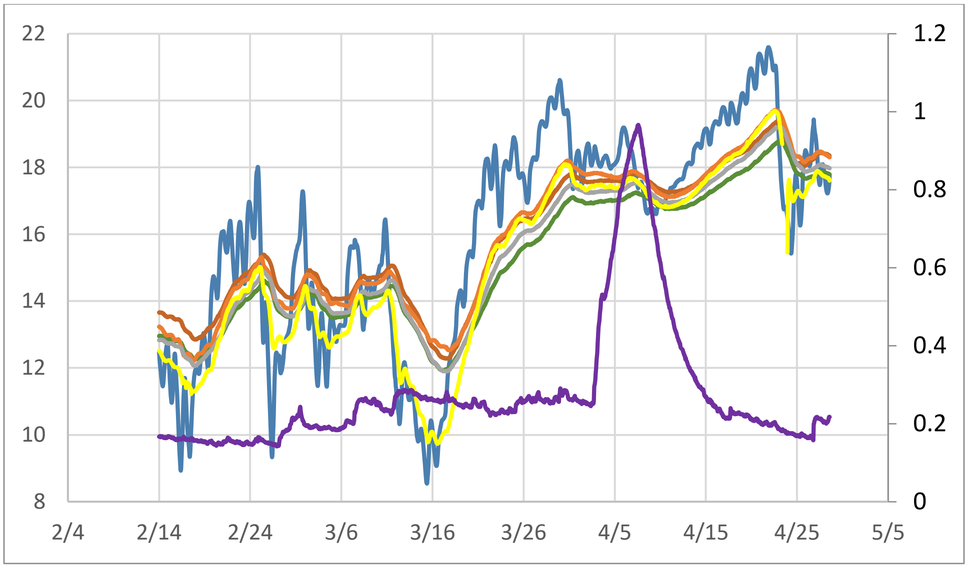

Figure 15. Temperature time series (degrees Celsius) measured by the ground surface thermistor (blue) and thermistors 30 cm below ground at locations 1A (red), 1D (green), 2A (orange), 2B (gray), and 2E (yellow). The wetland surface water depth is plotted in purple on the right axis in meters.

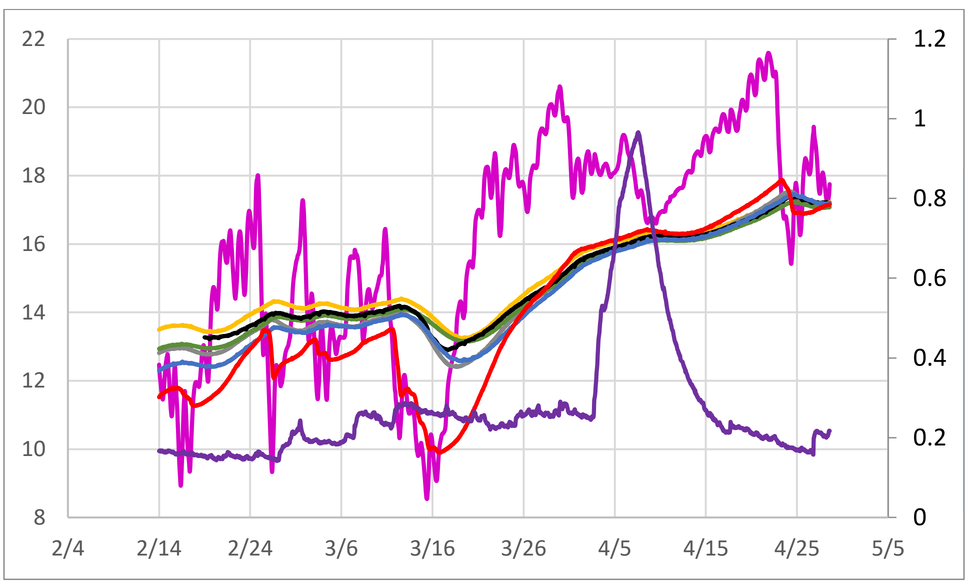

Figure 16. Temperature time series (degrees Celsius) measured by the ground surface thermistor (magenta) and thermistors 60 cm below ground at locations 1A (yellow), 1B (gray), 1D (green), 1E (black), 2D (blue), and 2E (red). The wetland surface water depth is plotted in purple on the right axis in meters.

Wastewater Management in Mississippi Coastal Communities

Basic Information

Title:	Wastewater Management in Mississippi Coastal Communities
Project Number:	2016MS206B
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End Date:	5/31/2017
Funding Source:	104B
Congressional District:	MS-003
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Descriptors:	None
Principal Investigators:	Veera Gnaneswar Gude, James Martin

Publications

1. Quarterly reports submitted to Mississippi Water Resources Research Institute.
2. Rainey, B., Gude, V.G., Truax, D.D., Martin, J.L. Wastewater Management in Small Communities in the Jourdan River Watershed, Proceedings of Mississippi Water Resources Annual Conference, April 5-6, 2016.
3. Gude, V., Rainey, B. Decentralized and onsite wastewater management issues of small communities in Jourdan River Watershed, Mississippi. In Proceedings of the 1st Int. Electron, Conf. Water Sci., 15-29 November 2016; Sciforum Electronic Conference Series, Vol. 1, 2016, a007; doi: 10.3390/ecws-1-a-007.
4. Rainey, B., Gude, V.G., Potential Impacts of Onsite Wastewater Treatment on Sensitive Mississippi Coastal Waters, 81st Annual Mississippi Academy of Sciences Meeting, Hattiesburg, MS, Feb 23-24, 2017.
5. Rainey, B.,Gude, V.G., Truax, D.D., Martin, J.L. Identification and Evaluation of Potential Impacts of Onsite Wastewater Treatment Systems in Decentralized Communities within the Jourdan River Watershed, Mississippi Water Resources Conference, April 11-12, 2017.
6. Rainey, B., Gude, V.G., Truax, D.D., Martin, J.M., Evaluation of water quality parameters and verification of potential impacts of onsite wastewater treatment systems on sensitive water bodies of Jourdan River Watershed, Mississippi ASCE-EWRI World Environmental and Water Resources Congress, Sacramento, CA, May 21-25, 2017.
7. Gude, V.G. Wastewater Management in Mississippi Coastal Communities. Final technical report submitted to Mississippi Water Resources Research Institute, Mississippi State University, Mississippi State, MS, 26 pgs.

Mississippi Water Resources Research Institute (MWRRI) / US Geological Survey

Final Report for Award Number

Wastewater Management in Mississippi Coastal Communities

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Keywords: small community wastewater treatment technologies; linkages between N and P concentrations and ecosystem response variables; identification of potential sources of contamination, performance and effectiveness of innovative and established nutrient, sediment, bacteria, and storm water management methodologies

Project Period: March 1, 2016 - May 31, 2017

Abstract

About 11% of the surface water streams in Mississippi coastal region received fair or poor ratings indicating possible point or non-point source pollution loads into these surface streams. The Jourdan River watershed is designated as a priority watershed for improving the water quality in this region. Primary water quality concerns for the Jourdan River have been identified as faulty septic and wastewater systems, sediment from soil and stream bank erosion and nutrient enrichment. This research project evaluated the performance of current on-site wastewater treatment systems for decentralized communities in the coastal region of Mississippi where the effluent standards might be at risk. The investigation included assessment of effectiveness of current wastewater treatment approaches from the surface and ground water quality and economic feasibility perspectives.

We have identified representative sites in the watershed and evaluated the existing on-site wastewater treatment systems. A sample collection and analysis program was implemented for representative sites to measure pH, temperature, biochemical oxygen demand (BOD), total suspended solids (TSS), total nitrogen (TN including TKN), nitrates and nitrites, and total phosphorous (TP) and fecal coliform bacteria. Established methods were used to measure these constituents from the select representative sites at designated time intervals to represent dry and wet weather and cold and hot weather conditions over seven months. These results were analyzed to determine the feasibility of on-site wastewater treatment systems and estimate nutrient loads released through effluent discharges.

Outcomes from this project include (i) a compilation of data on current on-site, decentralized wastewater treatment facilities in the Jourdan River watershed and characterization of wastewater management practices for the coastal region; and (ii) analysis of water quality parameters for representative sites to assess performance of on-site wastewater treatment systems. This study shows that the onsite wastewater treatment and management systems in the areas surrounding the sample collection sites are not the major contributing sources for fecal coliform contamination in the tributaries studied. Additionally, constituents normally found in wastewater effluent were not found in high concentrations in the water samples collected from these tributaries. This indicates that the majority of the onsite wastewater treatment and management systems in the areas surround the sample collection sites are functioning properly, and that alternative means of contamination should be explored. A poor correlation was also observed between the precipitation events and coliform and nutrient concentrations in the tributaries. These observations suggest that a more detailed, long-term sampling program is required to determine the non-point sources contributing to the impairment of these tributaries in the Jourdan River watershed.

1. Wastewater Treatment and Management in Coastal Communities

Assessment of water and wastewater is crucial to safeguard the public health and the environment; however, water quality data on fresh and marine waters in the Mississippi coastal region are still sparse and uncoordinated [1-5]. Therefore, monitoring these parameters is important for the assessment of impacts to the environment, public health, and sensitive water bodies. Roughly 11% of the surface water streams in the Mississippi coastal region have received fair or poor ratings, indicating possible point or non-point source pollution loads into these surface streams. **Figure 1** shows the six coastal counties that lie within a 50-mile reach of the shoreline in Mississippi and their land uses [1]. Note that the coastal areas have medium to high intensity development while other areas have only low intensity development.

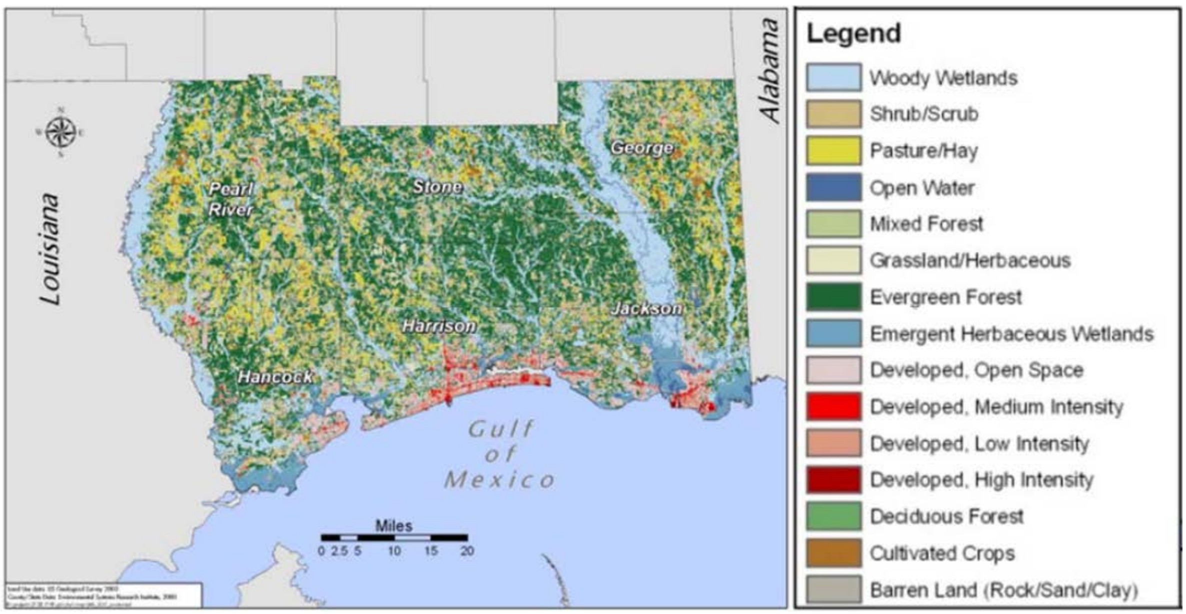

Figure 1. Mississippi coastal counties and land use in these counties

Sanitary sewer service is unavailable in large parts of the Mississippi coastal region, particularly in unincorporated areas. The residents and businesses in these areas operate individual on-site wastewater treatment and disposal systems. These units typically consist of septic tanks and absorption fields located on the property where the wastewater is generated. These systems tend to fail with poor maintenance and inappropriate soil applications. Sewage discharges are a major component of water pollution, contributing to oxygen demand and nutrient loading of the water bodies, promoting toxic algal blooms, and leading to a destabilized ecosystem. This problem is compounded in areas where wastewater treatment systems are simple and less efficient, as is the case in most rural communities in the Mississippi coastal region. An estimated total of 7.3 million gallons per day of improperly treated sewage is released into the environment from failing individual on-site systems in the Mississippi coastal region. Soils in the Mississippi coastal region generally are not conducive to the installation of absorption fields for septic tanks. Relative suitability ranges from only about 8 percent in Hancock County to roughly 75 percent in George County [2]. When soil conditions will not support the effective operation of septic tanks and absorption fields, residents must use aerobic treatment systems. These mechanical systems are more complicated to operate than conventional septic systems and often fail due to inappropriate or complete lack of maintenance by the homeowner. **Figure 2** presents the statistical data of on-site treatment units in the six counties within the Mississippi coastal region. Note that Jackson County contains the majority of the failing units with an estimated total flow of 2.24 MGD, followed by Harrison County with an estimated flow of 1.9 MGD. **Table 1** shows a comparison of the wastewater treatment systems suitable for on-site wastewater management. Conventional septic systems (septic tank with absorption field) are economical with lower capital and operation and maintenance costs. Intermittent and recirculating sand filters perform better than conventional systems, but do so at higher capital and operation and maintenance costs.

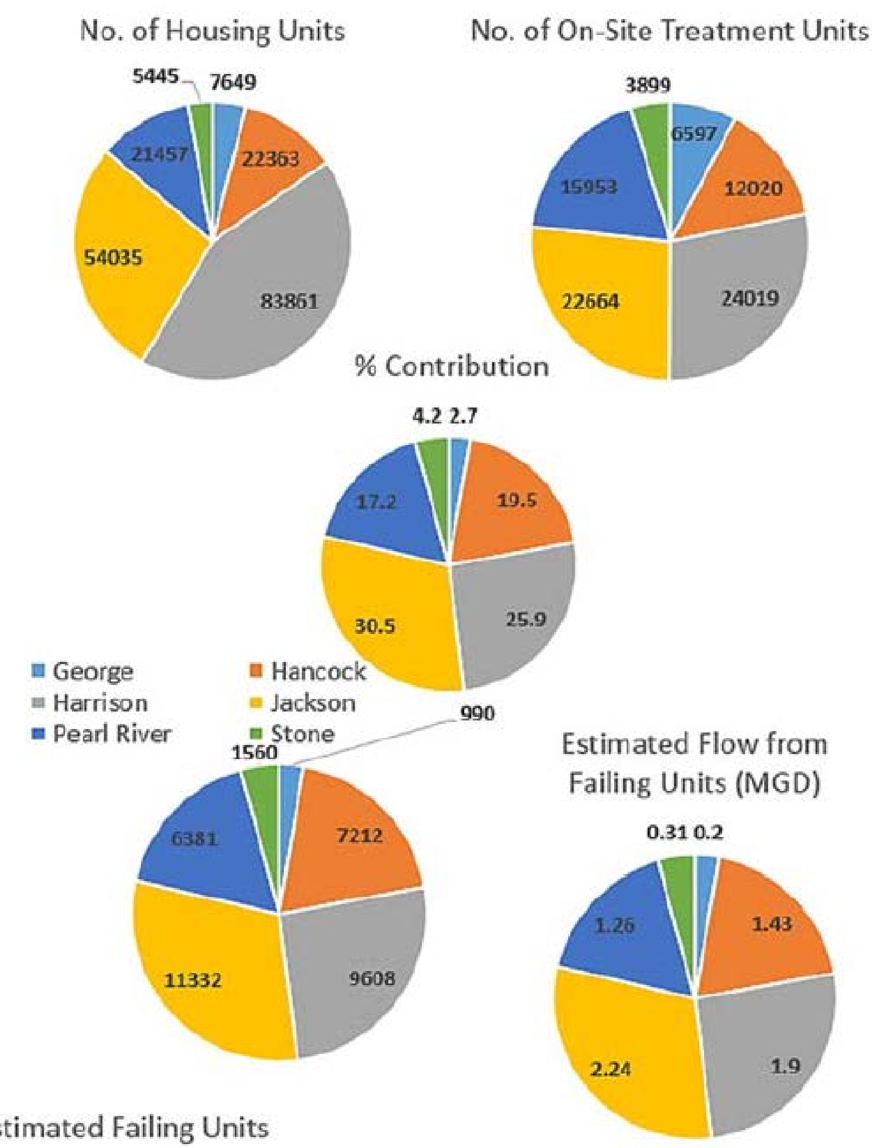

Figure 2. Number of housing units with on-site treatment units, failing units, and the estimates flow (MGD) from the six coastal counties of Mississippi

Table 1. Comparison of current on-site wastewater treatment systems

System	Cost		Treatment Levels			
	Installation	*Annual*	*BOD₅*	*TSS*	*Nitrification*	*Denitrification*
Conventional	$1,500 - $4,000	$250 - $550	10 mg/L	10 mg/L	-	-
Intermittent Sand Filter	$10,000	$155 + Power	95% Removal	85% Removal	80% +	-
Recirculating Sand Filter	$25,000 +	$350 + Power	95% Removal	95% Removal	Near Complete	Up to 50%

As shown in **Figure 3**, roughly 40 – 50 percent of the population in the Mississippi coastal region can be classified as low to moderate income families [3]. It is important to provide cost-effective on-site wastewater treatment systems for these communities, as the affordability for installation and operation and maintenance is not favorable.

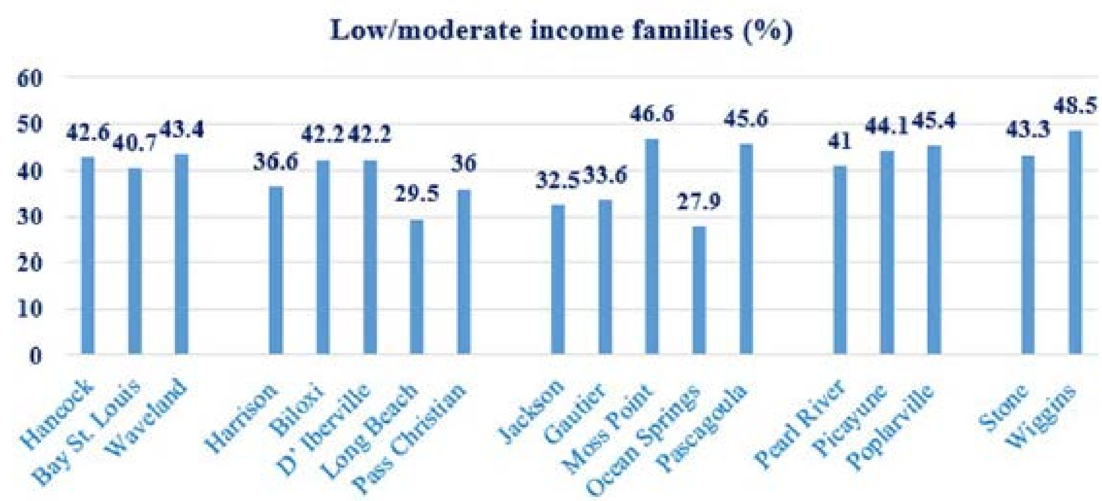

Figure 3. Percentage of low to moderate income families in the six coastal counties of Mississippi

2. Approach

Assessment of water and wastewater quality is crucial to safeguard public health and the environment. However, water quality data on fresh and marine waters in the Mississippi coastal region, especially in the Jourdan River watershed, are still sparse and uncoordinated. Therefore, monitoring these parameters is important for the assessment of the environmental and public health impacts on these water bodies. This research is concerned with the water quality in tributaries of the Jourdan River that could be potentially impacted by discharges from onsite wastewater treatment systems in the surrounding small communities. The tributaries monitored during this study (Bayou Bacon, Orphan Creek, and Bayou LaTerre, see **Figure 4**) feed directly into the Jourdan River. Eight sample collection sites were established along the tributaries, with two along Bayou Bacon and three each along Orphan Creek and Bayou LaTerre.

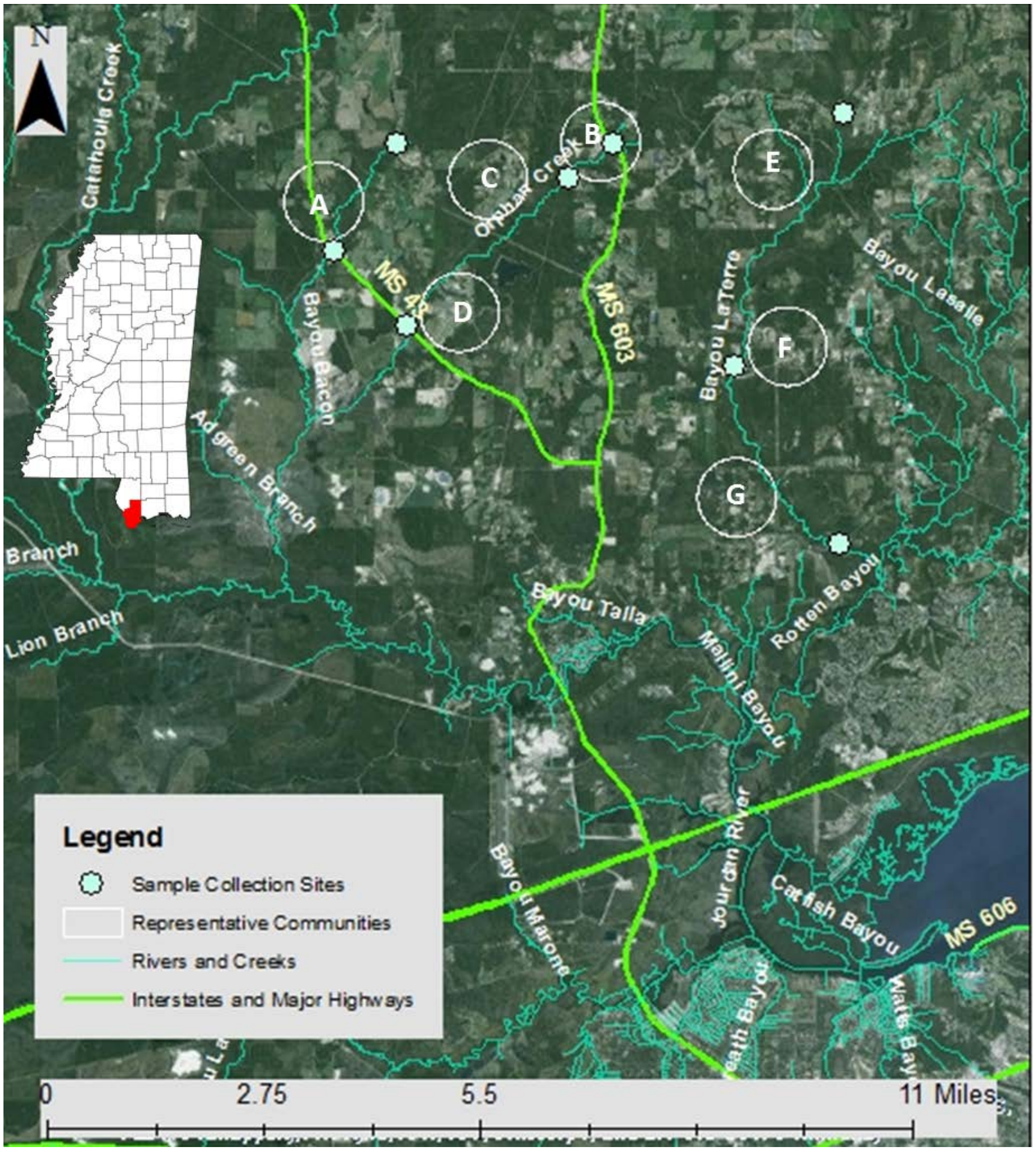

Figure 4. Sample collection locations: [1] Bayou Bacon 1; [2] Bayou Bacon 2; [3] Orphan Creek 1; [4] Orphan Creek 2; [5] Orphan Creek 3; [6] Bayou LaTerre 1; [7] Bayou LaTerre 2; [8] Bayou LaTerre 3

Actual physical coordinates of the locations:
BB 1 - 30°29’17.8”N 89°28’35.2”W – Old Dossett Rd
BB 2 - 30°28’07.4”N 89°29’24.4”W – Hwy 43
OC 1 - 30°29’18.5”N 89°25’50.4”W – Hwy 603
OC 2 - 30°28’55.5”N 89°26’24.1”W – Crazy Horse Rd
OC 3 - 30°27’17.8”N 89°28’28.3”W – Hwy 43
BLT 1 - 30°29’37.6”N 89°22’53.1”W – Rocky Hill Dedeaux Rd
BLT 2 - 30°26’49.8”N 89°24’17.3”W – Firetower Rd
BLT 3 - 30°24’51.0”N 89°22’57.2”W – Kiln Delisle Rd

The water quality parameters analyzed during this study were defined based on standard physical, chemical, and bacterial water quality standards. Analysis of the water samples included temperature, pH, dissolved oxygen (DO), turbidity, conductivity, total dissolved solids (TDS), nitrate, nitrite, chemical oxygen demand (COD), and fecal coliform bacterial counts. Special attention was given to those constituents commonly found in wastewater discharge (total nitrogen, total phosphorus, and ammonia nitrogen) to determine if a large number of the onsite wastewater treatment and management systems in the small communities identified for the study were discharging improperly treated effluent into a tributary.

2.1 Sample Collection

Water samples were collected twice monthly from each of the eight sample collection locations shown in Figure 1 over a four-month period. All samples were collected during winter months, and samples were collected from all eight sample stations during each collection trip. A YSI 6600 V2 multiparameter water quality sondes was used in the field to collect temperature, pH, dissolved oxygen, turbidity, conductivity, and total dissolved solids data at each of the sample collection sites. Continuous samples were taken at ten second intervals for a total of ten data points for each water quality parameter at each sample collection location. Additionally, a minimum of 1.5 liters of water samples was collected. Grab samples were retrieved using a Van Dorn bottle lowered a minimum of one foot below the water surface. The samples were transferred to sterilized, nonreactive polyethylene bottles for transport back to the laboratory facilities at Mississippi State University for analysis. Each sample bottle was placed on ice immediately after collection to be kept at a temperature below 4°C until laboratory testing began. Samples were also preserved with sulfuric or hydrochloric acid, as appropriate, to lower the pH of the water sample below 2.

2.2 Sample Analysis

2.2.1 Physical Water Quality Parameters

Data for physical water quality parameters such as temperature, pH, dissolved oxygen, turbidity, conductivity, and total dissolved solids was collected using a YSI multi-parameter water quality sondes. With the exception of temperature and dissolved oxygen, each of these parameters was measured again in a laboratory setting to ensure no accurate data.

2.2.2 Chemical Water Quality Parameters

Chemical water quality parameters were analyzed in laboratory facilities belonging to the Department of Civil and Environmental Engineering at Mississippi State University. EPA approved and equivalent testing methods for HACH Test 'N Tube (TNT) reagent kits were used to analyze concentrations of total nitrogen, nitrate, nitrite, ammonia nitrogen, total phosphorus, and chemical oxygen demand.

The simplified TKN method (Method 10242; HACH TNT plus 880) was used to analyze 2.3 mL of water sample preserved with concentrated sulfuric acid. The test provides results for concentrations of total Kjeldahl nitrogen, combined nitrate and nitrite, and total nitrogen. The dimethylphenol method (Method 10206; HACH TNT plus 835) was used to analyze 0.2 mL of water sample for nitrate concentrations. Further, the dianotization method (Method 10207; HACH TNT plus 839) was used to analyze 2.0 mL of water sample for nitrite concentration. The salicylate method (Method 10205; HACH TNT plus 831) was used to analyze 0.5 mL of water sample preserved with concentrated hydrochloric acid for ammonia nitrogen concentrations. The ascorbic acid method (Method 10209; HACH TNT plus 845) was used to analyze 0.4 mL of water sample for total phosphorus concentrations. Lastly, the reactor digestion method (Method 8000) was used to analyze 2.0 mL of water sample for chemical oxygen demand.

2.2.3 Bacterial Water Quality Parameters

Water samples were tested for fecal coliform bacteria levels following the Standard Methods for the Examination of Water and Wastewater APHA method 9222D – fecal coliform membrane filter procedure. Ten mL of water sample was analyzed from each location.

2.3 Statistical Analysis

Data analysis and statistical software STATA version 14.2 for Windows was used for the statistical analysis of the data collected during the study. Descriptive statistics were applied to determine the mean values and standard deviations of the physical, chemical, and bacterial parameters evaluated at each of the eight sample collection points. A multivariate test of means was performed for each parameter to identify significant differences in mean values among the sample collection sites. The level of significance was considered to be $p \leq 0.05$. Additionally, a box plot was constructed for each water quality parameter analyzed to identify any possible outliers in any data set and to illustrate the range over which each data set lies.

3.0 Results

All samples were collected during winter months (November through April). The mean values for temperature were found to be 15.73 ± 2.77, 16.54 ± 2.36, 15.65 ± 3.10, 15.68 ± 3.07, 15.93 ± 2.41, 17.16 ± 2.64, 18.24 ± 3.08, and 16.68 ± 3.15 °C for Bayou Bacon 1, Bayou Bacon 2, Orphan Creek 1, Orphan Creek 2, Orphan Creek 3, Bayou LaTerre 1, Bayou LaTerre 2, and Bayou LaTerre 3, respectively. The variations among the mean temperature for each of the sample collection locations were only significant among location 6 (Bayou LaTerre 1) and the others, and location 7 (Bayou LaTerre 2) and the others. The other locations have insignificant variations among mean temperature values. **Figure 5** shows the mean temperature values and associated standard deviations at each sample collection location. The box plot in **Figure 6** shows there are no outliers among the temperature data collected during the study, but illustrates a relatively wide range of temperature values at each sample collection location.

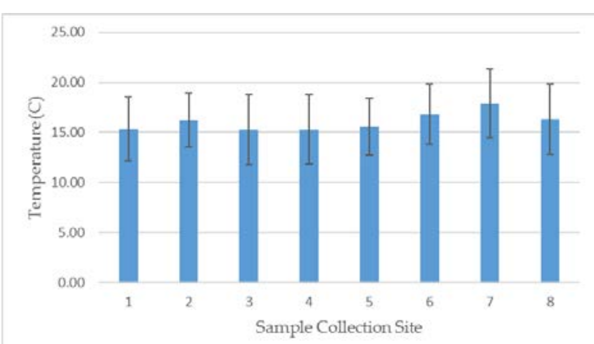

Figure 5. Mean values of temperature (°C) at each sample collection site (n=15).

Figure 6. Box plot for temperature (°C) at each sample collection location (n=15).

The mean values for pH were found to be 5.51 ± 0.45, 5.65 ± 0.52, 6.25 ± 0.57, 6.04 ± 0.29, 6.14 ± 0.48, 6.26 ± 0.30, 6.21 ± 0.38, and 6.12 ± 0.54 for Bayou Bacon 1, Bayou Bacon 2, Orphan Creek 1, Orphan Creek 2, Orphan Creek 3, Bayou LaTerre 1, Bayou LaTerre 2, and Bayou LaTerre 3, respectively. Recorded pH values at both sample collection locations in Bayou Bacon (locations 1 and 2) are consistently lower than in the other six locations. **Figure 7** illustrated the mean pH levels and the associated standard deviations at each of the sample collection locations. The box plot in **Figure 81** shows that locations 3 (Orphan Creek 1), 7 (Bayou LaTerre 2), and 8 (Bayou LaTerre 3) contain outliers in the data.

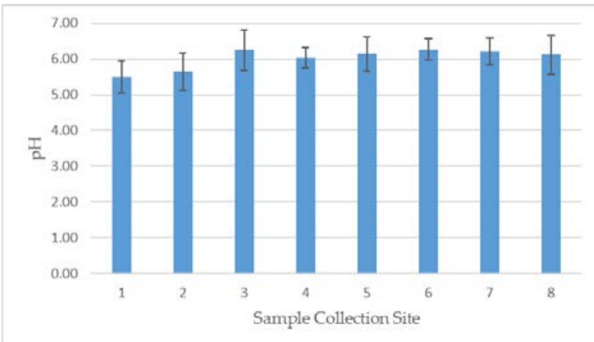

Figure 7. Mean values of pH at each sample collection site (n=15).

Figure 8. Box plot for pH at each sample collection location (n=15).

The mean values for dissolved oxygen were found to be 7.93 ± 0.58, 7.92 ± 0.56, 7.24 ± 0.82, 7.71 ± 0.71, 8.08 ± 0.49, 9.64 ± 0.70, 9.23 ± 0.52, and 9.18 ± 0.72 mg/L DO for Bayou Bacon 1, Bayou Bacon 2, Orphan Creek 1, Orphan Creek 2, Orphan Creek 3, Bayou LaTerre 1, Bayou LaTerre 2, and Bayou LaTerre 3, respectively. While variations in mean values at locations 6 (Bayou LaTerre 1), 7 (Bayou LaTerre 2), and 8 (Bayou LaTerre 3) are significant compared to the remaining five locations, they are insignificant when compared to each other. The same is true within the other two tributaries. Locations 1 and 2 (Bayou Bacon 1 and 2) have significant mean variations from all other locations, but not when compared to each other. Likewise, locations 3, 4, and 5 (Orphan Creek 1, 2, and 3) follow the same trend. **Figure 9** shows the mean values for dissolved oxygen and the associated standard deviation at each sample collection site. The box plot in **Figure 10** shows that only location 7 (Bayou LaTerre 2) contains an outlier in the data set. The figure also illustrates that all three collection locations within Bayou LaTerre have significantly higher dissolved oxygen concentrations than collection locations within the other tributaries.

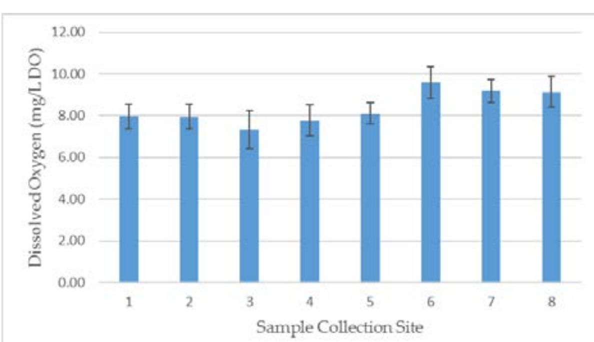

Figure 9. Mean values of dissolved oxygen (mg/L DO) at each sample collection site (n=15).

Figure 10. Box plot for dissolved oxygen (mg/L DO) at each sample collection location (n=15).

Visual observations indicated the clearest water samples were generally collected from Bayou LaTerre; however, some there were some exceptions. The mean values for turbidity were found to be 16.15 ± 10.24, 14.19 ± 8.89, 25.79 ± 9.94, 22.83 ± 9.29, 18.94 ± 12.75, 15.20 ± 16.64, 19.48 ± 22.29, and 23.29 ± 29.43 NTU for Bayou Bacon 1, Bayou Bacon 2, Orphan Creek 1, Orphan Creek 2, Orphan Creek 3, Bayou LaTerre 1, Bayou LaTerre 2, and Bayou LaTerre 3, respectively. It was determined that variations found among mean turbidity values at each of the sample collection sites were highly significant. **Figure 11** shows the mean turbidity values and associated standard deviations at each of the sample collection sites, and the box plot in **Figure 12** shows that all sample collection locations along Bayou LaTerre contain outliers in the data sets.

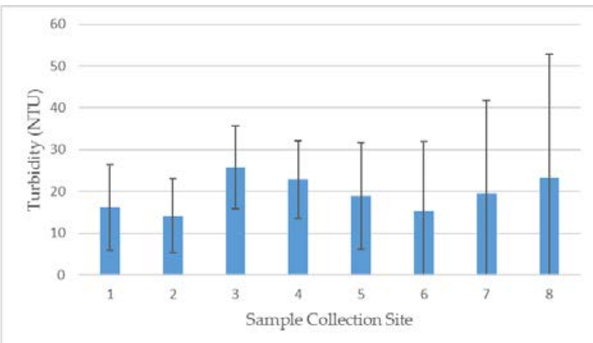

Figure 11. Mean values of turbidity (NTU) at each sample collection site (n=15). p=0.0001

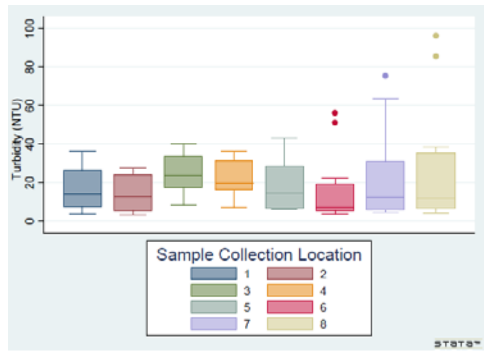

Figure 12. Box plot for turbidity (NTU) at each sample collection location (n=15).

The mean values for conductivity were found to be 36 ± 5, 33 ± 9, 48 ± 9, 48 ± 10, 46 ± 8, 53 ± 19, 49 ± 4, and 48 ± 5 μS/cm for Bayou Bacon 1, Bayou Bacon 2, Orphan Creek 1, Orphan Creek 2, Orphan Creek 3, Bayou LaTerre 1, Bayou LaTerre 2, and Bayou LaTerre 3, respectively. Variations among mean conductivity values at locations 1 and 2 (Bayou Bacon 1 and 2) were found to be highly significant when compared to the other six locations. **Figure 13** shows the mean conductivity values and associated standard deviations at each of the sample collection locations. The box plot in **Figure 14** shows outliers in data sets at every sample collection location with the exception of site 7 (Bayou LaTerre 2).

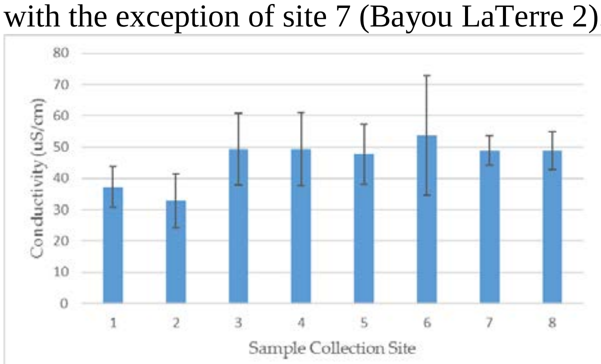

Figure 13. Mean values of conductivity (μS/cm) at each sample collection site (n=15).

Figure 14. Box plot for conductivity (μS/cm) at each sample collection location (n=15).

The mean values for total dissolved solids were found to be 23 ± 2, 23 ± 2, 28 ± 6, 28 ± 10, 28 ± 5, 36 ± 5, 32 ± 4, and 31 ± 3 mg/L TDS for Bayou Bacon 1, Bayou Bacon 2, Orphan

Creek 1, Orphan Creek 2, Orphan Creek 3, Bayou LaTerre 1, Bayou LaTerre 2, and Bayou LaTerre 3, respectively. While variations in mean values at locations 6 (Bayou LaTerre 1), 7 (Bayou LaTerre 2), and 8 (Bayou LaTerre 3) are highly significant when compared to the remaining five locations, they are insignificant when compared to each other. The same is true within the other two tributaries. Locations 1 and 2 (Bayou Bacon 1 and 2) have significant mean variations from all other locations, but not when compared to each other. Likewise, locations 3, 4, and 5 (Orphan Creek 1, 2, and 3) follow the same trend. **Figure 15** shows the mean values and associated standard deviations of total dissolved solids at each sample collection site. The box plot in **Figure 16** shows that sample collection locations 4 (Orphan Creek 2) and 6 (Bayou LaTerre 1) contain outliers in the data set.

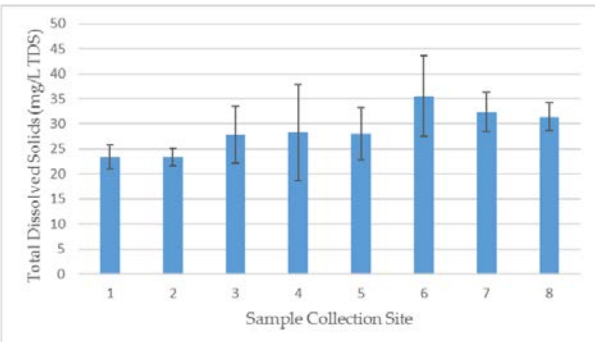

Figure 15. Mean values of total dissolved solids (mg/L TDS) at each sample collection site (n=15).

Figure 16. Box plot for total dissolved solids (mg/L TDS) at each sample collection location (n=15).

The mean values for fecal coliform bacteria levels were found to be 843 ± 1339, 853 ± 1347, 4081 ± 8337, 3862 ± 8363, 4736 ± 9594, 2255 ± 3569, 1902 ± 3235, and 1743 ± 2758 coliform forming units (CFUs)/100 mL for Bayou Bacon 1, Bayou Bacon 2, Orphan Creek 1, Orphan Creek 2, Orphan Creek 3, Bayou LaTerre 1, Bayou LaTerre 2, and Bayou LaTerre 3, respectively. Variations among mean values of fecal coliform bacteria counts at each sample collection location follow the same trend as total dissolved solids and dissolved oxygen: variations among mean values at locations 1 and 2 (Bayou Bacon 1 and 2) are insignificant when compared to each other, but highly significant when compared to the other six sample collection locations, and so on. **Figure 17** shows the mean values of fecal coliform bacteria counts and the associated standard deviations at each sample collection site.

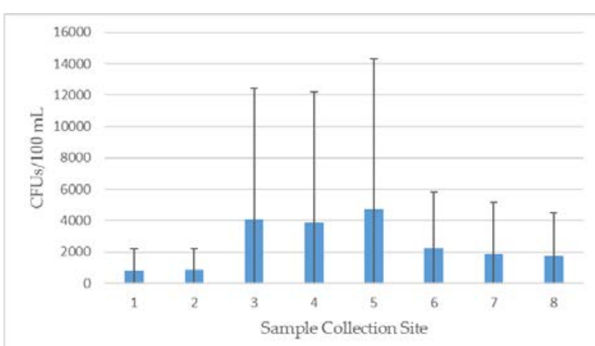

Figure 17. Mean values of fecal coliform counts (CFUs/100 mL) at each sample collection site (n=15).

Because the water quality standard for bacteria in coastal recreational waters is based on the geometric mean values of fecal coliform bacteria counts, the data for this water quality parameter was analyzed to determine geometric mean values in addition to traditional mean values at each sample collection site [5]. Geometric mean values for fecal coliform bacteria levels were found to be 270, 231, 686, 643, 641, 548, 373, and 410 CFUs/100 mL for Bayou Bacon 1, Bayou Bacon 2, Orphan Creek 1, Orphan Creek 2, Orphan Creek 3, Bayou LaTerre 1, Bayou LaTerre 2, and Bayou LaTerre 3, respectively. While the variations among geometric mean values of fecal coliform bacteria counts at each sample collection location mostly follow the same trend as variations among the traditional mean values of fecal coliform bacteria counts, the variations among sites 6, 7, and 8 (Bayou LaTerre 1, 2, and 3) are highly significant. **Figure 18** shows the geometric mean values of fecal coliform bacteria counts at each of the sample collection locations. The box plot in **Figure 19** shows several outliers at every location with the exception of site 8 (Bayou LaTerre 3). The figure also illustrates that all Orphan Creek locations (site 3, 4, and 5) contain multiple significant outliers which lie orders of magnitude above the third quartile. With the exception of these outliers at each location, the data does not appear to span an exceptionally wide range.

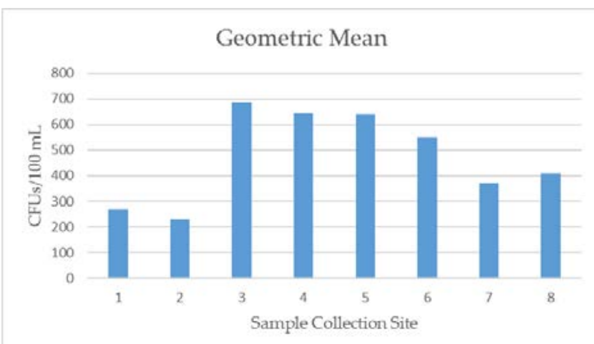

Figure 18. Geometric mean values of fecal coliform bacteria (CFUs/100 mL) at each sample collection site (n=15).

Figure 19. Box plot for fecal coliform counts (CFUs/100 mL) at each sample collection location (n=15).

The mean values for total nitrogen were found to be 1.32 ± 0.94, 1.00 ± 0.61, 1.15 ± 0.36, 1.21 ± 0.41, 1.02 ± 0.52, 1.05 ± 0.37, 0.91 ± 0.57, and 1.01 ± 0.57 mg/L TN for Bayou Bacon 1, Bayou Bacon 2, Orphan Creek 1, Orphan Creek 2, Orphan Creek 3, Bayou LaTerre 1, Bayou LaTerre 2, and Bayou LaTerre 3, respectively. It was determined that variations found among the mean values of total nitrogen concentrations at each of the sample collection sites was highly significant. **Figure 20** shows the mean values and associated standard deviations of total nitrogen concentrations at each sample collection location. The box plot in **Figure 21** shows that only locations 5 (Orphan Creek 3) and 7 (Bayou LaTerre 2) contain outliers in the data set; however, it illustrates a relatively wide range on total nitrogen concentrations at each of the sample collection locations.

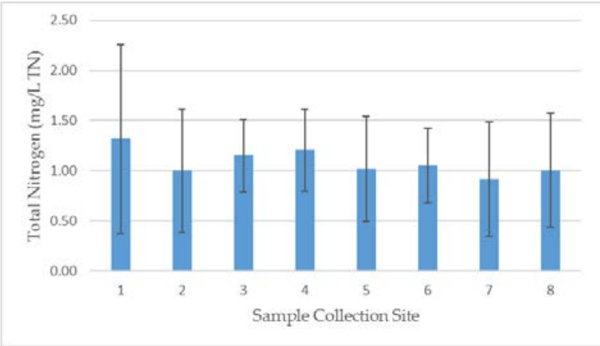

Figure 20. Mean values of total nitrogen (mg/L TN) at each sample collection site (n=15).

Figure 21. Box plot for total nitrogen (mg/L TN) at each sample collection location (n=15).

The mean values for nitrate were found to be 0.76 ± 0.40, 0.56 ± 0.10, 0.66 ± 0.17, 0.72 ± 0.15, 0.64 ± 0.22, 0.76 ± 0.28, 0.60 ± 0.21, and 0.58 ± 0.21 mg/L NO_3^- for Bayou Bacon 1, Bayou Bacon 2, Orphan Creek 1, Orphan Creek 2, Orphan Creek 3, Bayou LaTerre 1, Bayou LaTerre 2, and Bayou LaTerre 3, respectively. It was determined that variations found among the mean values of nitrate concentrations at each of the sample collection locations was highly significant. **Figure 22** shows the mean values and associated standard deviations of nitrate concentrations at each sample collection site. The box plot in **Figure 23** illustrates that only location 1 (Bayou Bacon 1) contains an outlier in the data set, and the data to not span a wide range of concentrations.

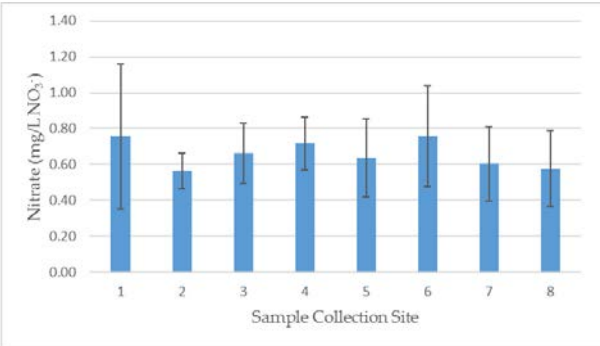

Figure 22. Mean values of nitrate (mg/L NO_3^-) at each sample collection site (n=15).

Figure 23. Box plot for nitrate (mg/L NO_3^-) at each sample collection location (n=15).

The mean values for nitrite were found to be 0.048 ± 0.032, 0.037 ± 0.025, 0.076 ± 0.029, 0.070 ± 0.027, 0.054 ± 0.039, 0.046 ± 0.054, 0.049 ± 0.063, and 0.061 ± 0.073 mg/L NO_2^- for Bayou Bacon 1, Bayou Bacon 2, Orphan Creek 1, Orphan Creek 2, Orphan Creek 3, Bayou LaTerre 1, Bayou LaTerre 2, and Bayou LaTerre 3, respectively. Variations among mean values of nitrite concentrations at each of the sample collection locations were determined to be highly significant. **Figure 24** shows the mean values and associated standard deviations of nitrite concentrations at each of the sample collection sites. The box plot in **Figure 25** shows that locations 3 (Orphan Creek 1) and 6 (Bayou LaTerre 1) contain outliers in the data set, and the data at each location generally spans a wide range of concentrations.

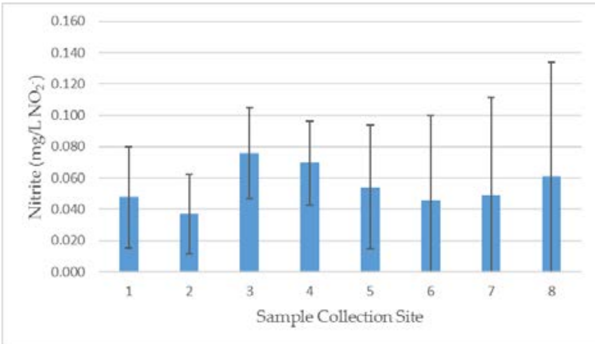

Figure 24. Mean values of nitrite (mg/L NO_2^-) at each sample collection site (n=15).

Figure 25. Box plot for nitrite (mg/L NO_2^{--}) at each sample collection location (n=15).

The mean values for ammonia nitrogen were found to be 0.10 ± 0.04, 0.09 ± 0.03, 0.13 ± 0.04, 0.11 ± 0.05, 0.11 ± 0.05, 0.09 ± 0.05, 0.10 ± 0.07, and 0.10 ± 0.05 mg/L NH_3-N for Bayou Bacon 1, Bayou Bacon 2, Orphan Creek 1, Orphan Creek 2, Orphan Creek 3, Bayou LaTerre 1, Bayou LaTerre 2, and Bayou LaTerre 3, respectively. Variations among mean values for ammonia nitrogen concentrations at each sample collection location were found to be slightly significant $p < 0.04$. **Figure 26** shows the mean values and associated standard deviations of ammonia nitrogen concentrations at each of the sample collection locations. The box plot in **Figure 27** shows outliers in three locations: locations 2 (Bayou Bacon 2), 6 (Bayou LaTerre 1), and 7 (Bayou LaTerre 2). An outlier at location 8 (Bayou LaTerre 3) appears to correspond to the maximum value. All locations appear to span a wide range of concentrations.

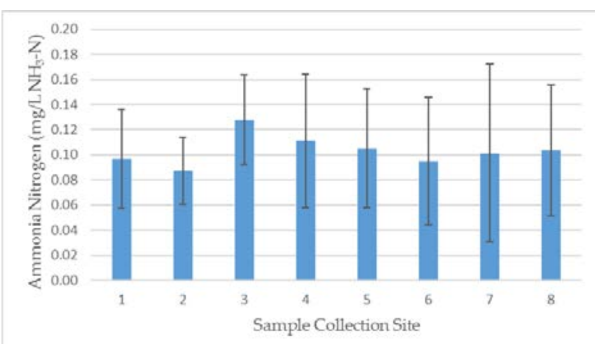

Figure 26. Mean values of ammonia nitrogen (mg/L NH_3-N) at each sample collection site (n=15).

Figure 27. Box plot for ammonia nitrogen (mg/L NH_3-N) at each sample collection location (n=15).

The mean values for total phosphorus were found to be 0.109 ± 0.227, 0.019 ± 0.025, 0.063 ± 0.043, 0.067 ± 0.045, 0.047 ± 0.054, 0.080 ± 0.055, 0.078 ± 0.100, and 0.067 ± 0.067 mg/L TP for Bayou Bacon 1, Bayou Bacon 2, Orphan Creek 1, Orphan Creek 2, Orphan Creek 3, Bayou LaTerre 1, Bayou LaTerre 2, and Bayou LaTerre 3, respectively. Variations among mean values of total phosphorus concentrations at each sample collection site were determined to be significant ($p < 0.01$). However, when locations within the same tributary were compared, variations among total phosphorus concentrations at sample collection sites within Bayou LaTerre were found to be insignificant ($p > 0.05$). While the same holds true for locations within Orphan Creek, variations among mean values of total phosphorus concentrations at sample collection locations within Bayou Bacon were determined to be highly significant ($p < 0.001$). **Figure 28** shows the mean values and associated standard deviations of total phosphorus concentrations at each sample collection site. The box plot in **Figure 29** shows that, with the exception of two significant outliers at location 1 (Bayou Bacon 1), the data does not span a wide range of concentrations.

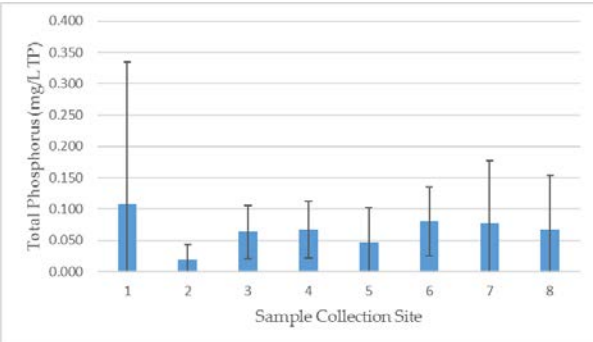

Figure 28. Mean values of total phosphorus (mg/L TP) at each sample collection site (n=15).

Figure 29. Box plot for total phosphorus (mg/L TP) at each sample collection location (n=15).

The mean values for chemical oxygen demand were found to be 38 ± 13, 30 ± 14, 39 ± 10, 37 ± 9, 37 ± 15, 30 ± 12, 24 ± 12, and 27 ± 14 mg/L COD for Bayou Bacon 1, Bayou Bacon 2, Orphan Creek 1, Orphan Creek 2, Orphan Creek 3, Bayou LaTerre 1, Bayou LaTerre 2, and Bayou LaTerre 3, respectively. The variations among mean values of chemical oxygen demand at each sample collection site were found to be highly significant ($p < 0.001$). **Figure 30** shows the mean values and associated standard deviations of chemical oxygen demand values at each sample collection location. The box plot in **Figure 31** shows that, while there are no outliers, the data appears to span a relatively significant range of concentrations.

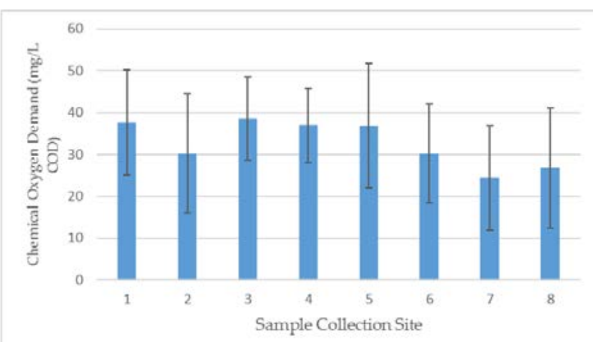

Figure 30. Mean values of chemical oxygen demand (mg/L COD) at each sample collection site (n=15).

Figure 31. Box plot for chemical oxygen demand (mg/L COD) at each sample collection location (n=15).

5.0 Discussion

As a general note concerning data for all water quality parameters, there appears to be a high degree of variance. While not all data groups contain outliers, they are present in the majority of data sets. Also of note is the degree of variance among the mean values at each different collect site. While this may be contributed to the distance between each site, land use surrounding each site is also a contributing factor. For many of the water quality parameters, the variance among mean values at each sample collection location within a single tributary is insignificant, but this is not true for all parameters.

The Jourdan River is classified by the Mississippi Department of Environmental Quality (MDEQ) for recreational use. The tributaries sampled during this study are each classified as fish and wildlife. According to the *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters* published by MDEQ's Office of Pollution Control, waters under this classification "shall also be suitable for secondary contact recreation".

All recorded temperature values are below 32.2°C, thus, within the water quality standard limits. Recorded pH levels in all sample collection locations contain data points below standard limits for pH values. Bayou Bacon has the lowest pH values among all eight sample collection points, with most recorded pH values falling below 5.5. While the other six collection locations contain some data points below 6.0, the majority of these data points lie above 6.5.

The mean turbidity levels were below the limit of 50 NTU at all eight sample collection locations; however, samples collected within Bayou LaTerre did exceed this limit during a single sample collection date. This accounts for the high degree of variation at these locations.

The total dissolved solids concentration at each of the sample collection locations is below the water quality standard limit of 750 mg/L. Bayou Bacon has the lowest TDS concentrations, increasing from location 1 to location 2. Bayou LaTerre has the highest concentrations, increasing from location 8 to location 7 to location 6. The concentrations within Orphan Creek increase from location 3 to location 4 to location 5. The concentrations increase along the downstream direction within Bayou Bacon and Orphan Creek. Alternatively, they increase along the upstream direction within Bayou LaTerre. The conductivity levels follow the same trend.

All locations within Orphan Creek have higher mean and geometric mean fecal coliform bacteria counts than in other Bayou Bacon and Bayou La Terre; however, these locations also have the highest standard deviations among all eight sample collection sites. Bayou Bacon has the lowest bacterial counts, while the bacterial counts within Bayou LaTerre lie between the two other tributaries. The counts within both Orphan Creek and Bayou LaTerre increase from the location furthest downstream to the location furthest upstream, while the opposite is true for Bayou Bacon. Per MDEQ standards, fecal coliform bacterial counts during winter months (November through April) for waters classified for fish and wildlife shall not exceed a geometric mean of 2000 colonies per 100 mL based on a minimum of five samples collected over a 30-day period. While each of the sample collection locations contain single data points that exceed this standard, none of the collection sites have a geometric mean that violates the water quality standard for fecal coliform bacteria.

There is not one tributary with all sample collection sites having higher total nitrogen concentrations than the other tributaries. The same is true for nitrate and nitrite concentrations. Ammonia nitrogen concentrations, however, are highest in sample collection locations within Orphan Creek. The concentrations decrease from the sample collection point furthest upstream to the point furthest downstream. Bayou Bacon has the lowest ammonia nitrogen concentrations decreasing from the upstream to the downstream sample collection location. The ammonia nitrogen concentrations within Bayou LaTerre increase from the sample collection location furthest upstream to the sample collection location furthest downstream.

Apart from two significant outliers in the data for sample collection site 1 (Bayou Bacon 1), Bayou LaTerre has the highest total phosphorus concentrations, increasing from upstream to downstream sample collection locations.

Orphan Creek has the highest chemical oxygen demand concentrations decreasing from the upstream to the downstream location. Bayou LaTerre has the lowest COD concentrations; however, the concentrations do not steadily decrease along the upstream or downstream direction. Locations in order from highest concentration to lowest are 6 (Bayou LaTerre 1), 8 (Bayou LaTerre 3), and 7 (Bayou LaTerre 2).

Nine sample collection trips have been completed. The water samples have been tested and are being analyzed against rainfall data, and the water quality parameters are being compared amongst themselves to identify any possible correlations. The results from water quality parameters at sample collection locations upstream of representative communities are still being compared to results downstream of those communities to determine if there is any decline in water quality in the stream possibly caused by the community. Of the seven representative communities, none consistently have better or worse water quality conditions at the upstream location versus the downstream location (see the data presented in **Table A1-A4 in Appendix**). However, there does appear to be a mild correlation between rainfall levels and elevated water quality parameter concentrations (see **Figures 32-35 and Figures A1-A3 in Appendix**).

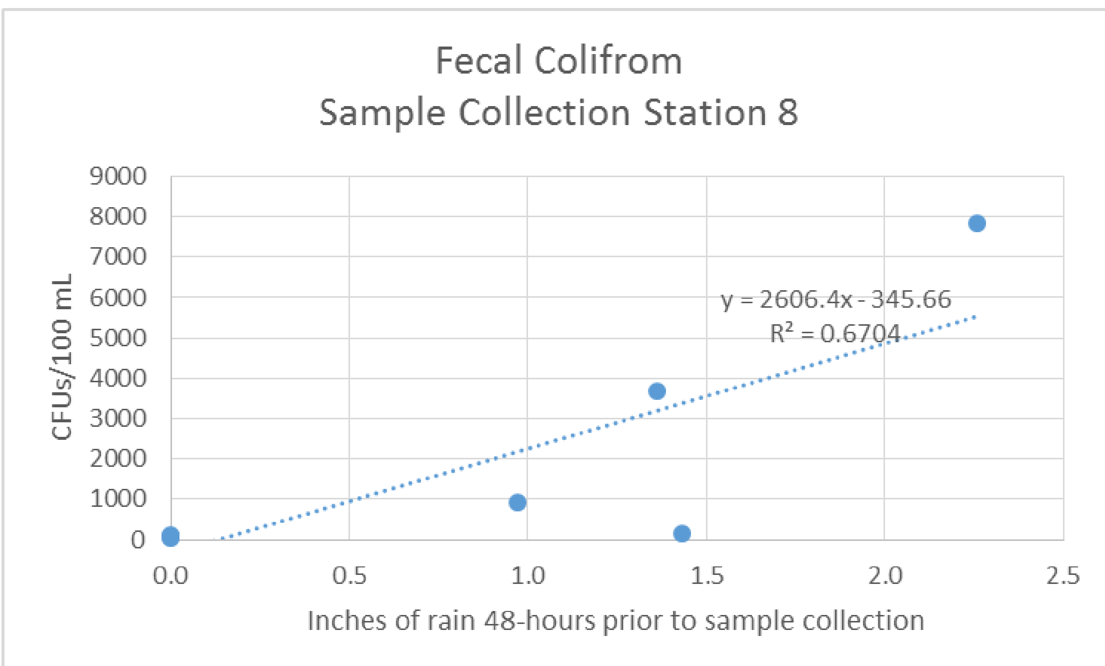

Figure 32. Correlation between precipitation events and coliform levels in the streams.

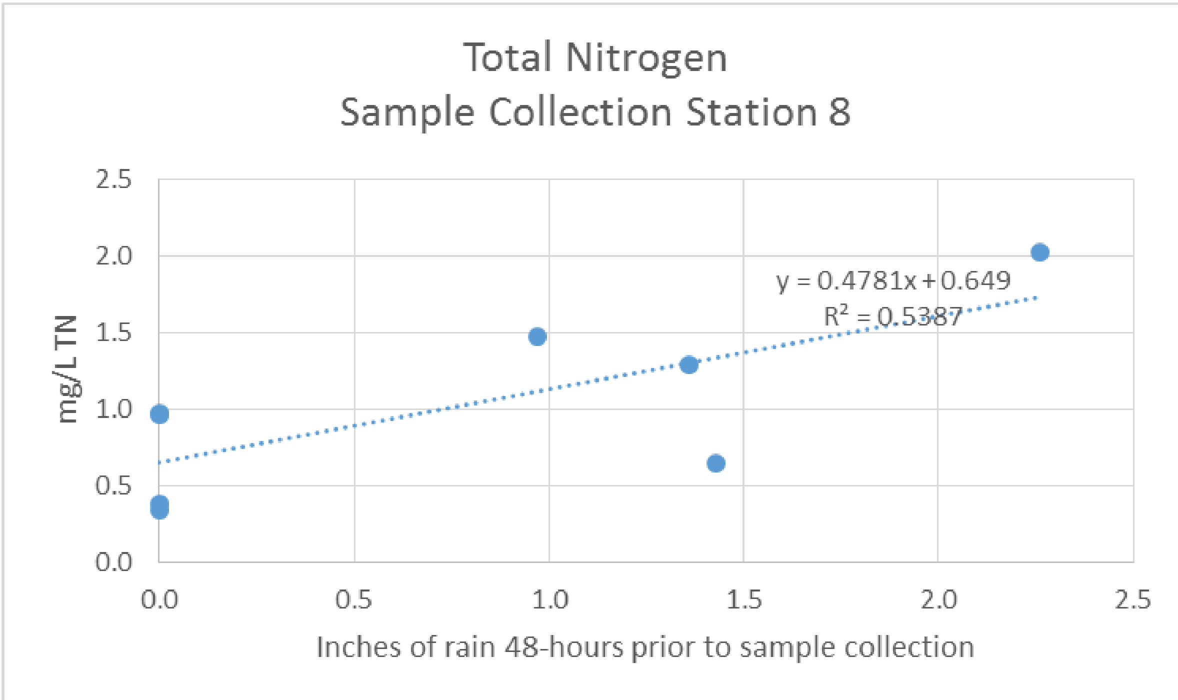

Figure 33. Correlation between precipitation events and total nitrogen levels in the streams

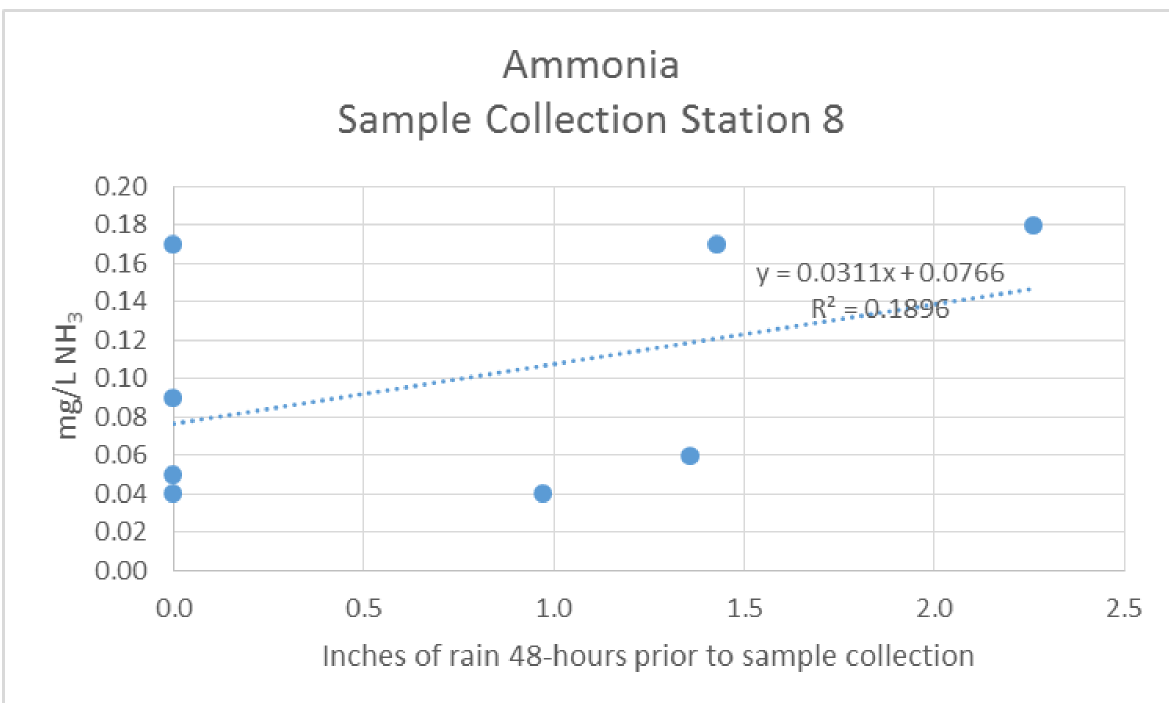

Figure 34. Correlation between precipitation events and the ammonia levels in the streams

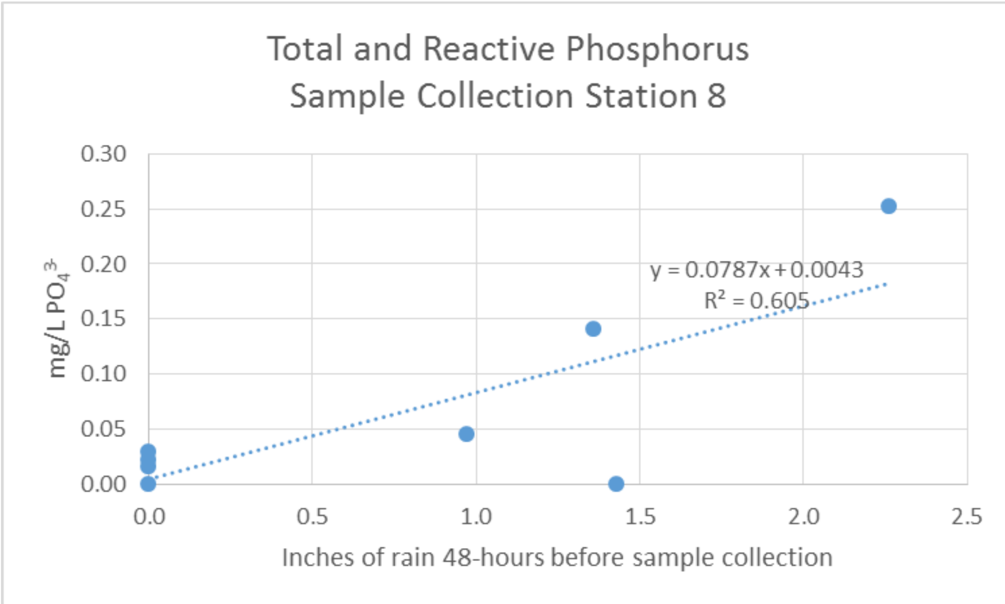

Figure 35. Correlation between precipitation events and phosphorus levels in the streams

5. Conclusions

This study shows that the onsite wastewater treatment and management systems in the areas surrounding the sample collection sites are not the major contributing source fecal coliform contamination in the tributaries studied. Additionally, constituents normally found in wastewater effluent were not found in high concentrations in the water samples collected from these tributaries. This suggests that the majority of the onsite wastewater treatment and management systems in the areas surround the sample collection sites are functioning properly, and that alternative means of contamination should be explored. A poor correlation was also observed between the precipitation events and coliform and nutrient concentrations in the tributaries. These observations suggest that a more detailed, long-term sampling program is required to determine the non-point sources contributing to the impairment of these tributaries in the Jourdan River watershed.

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[1] Mississippi Department of Environmental Quality (MDEQ), (2011, March 14). *Mississippi Coastal Nutrient Reduction Strategies.* http://www.deq.state.ms.us/mdeq.nsf/pdf/WMB_MSCoastalNutrientReductionStrategies/$File/Mississippi%20C.

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[5] Mississippi Department of Environment Quality (MDEQ), (2007, August 23). *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters.*

6. Information Transfer and Dissemination

Conference Presentations

1. Rainey, B., **Gude, V.G.**, Truax, D.D., Martin, J.M., Evaluation of water quality parameters and verification of potential impacts of onsite wastewater treatment systems on sensitive water bodies of Jourdan River Watershed, Mississippi, ASCE-EWRI World Environmental and Water Resources Congress, Sacramento, CA, May 21-25, 2017

2. Rainey, B., **Gude, V.G.**, Truax, D.D., Martin, J.L. Identification and Evaluation of Potential Impacts Of Onsite Wastewater Treatment Systems in Decentralized Communities within the Jourdan River Watershed, Mississippi Water Resources Symposium, April 11-12, 2017

3. Rainey, B., **Gude, V.G.**, Potential Impacts of Onsite Wastewater Treatment on Sensitive Mississippi Coastal Waters, 81st Annual Mississippi Academy of Sciences Meeting, Hattiesburg, MS, Feb 23-24, 2017.

4. **Gude, V.G.**, Rainey, B. Decentralized and onsite wastewater management issues of small communities in Jourdan River Watershed, Mississippi. *In Proceedings of the 1st Int. Electron. Conf. Water Sci.*, 15–29 November 2016; Sciforum Electronic Conference Series, Vol. 1, 2016 , a007; doi:10.3390/ecws-1-a007

5. Rainey, B., **Gude, V.G.**, Truax, D.D., Martin, J.M. Wastewater management issues of small communities in the Jourdan River watershed, Mississippi Water Resources Symposium, April 5-6, 2016

Publications

1. **Gude, V.G.**, Rainey, B. Decentralized and onsite wastewater management issues of small communities in Jourdan River Watershed, Mississippi. *In Proceedings of the 1st Int. Electron. Conf. Water Sci.*, 15–29 November 2016; Sciforum Electronic Conference Series, Vol. 1, 2016 , a007; doi:10.3390/ecws-1-a007

2. Rainey, B., **Gude, V.G.**, Truax, D.D., Martin, J.M. Wastewater management issues of small communities in the Jourdan River watershed, Mississippi Water Resources Symposium, April 5-6, 2016

7. Student Training

Ms. Bailey Rainey, Graduate Research Assistant, MS Civil Engineering (Concentration: Environmental Engineering)
Graduate date: December 2017

Now Engineer in Training, Pickering Consulting Firm, Jackson, MS

Ms. Cayla Cook, Undergraduate Research Assistant, BS Civil Engineering (Concentration: Environmental Engineering)

Graduated May 2017
Will be a Ph.D. Environmental Engineering student at Arizona State University

Mr. Jeffrey Steinwinder, Undergraduate Research Assistant, BS Civil Engineering (Concentration: Environmental Engineering)

Graduated May 2017
Will be a MS Environmental Engineering student at Auburn University

ACKNOWLEDGEMENTS

The authors of this work would like to thank Dr. John Ramirez-Avila and Ms. Sandra Ortega-Archury and the faculty of the Civil and Environmental Engineering department at Mississippi State University for their assistance or support either through important discussions or laboratory analysis during this project.

Appendix

Figure A. Images of decentralized communities under study.

Community A - Bayou Bacon

Community B (centralized) - Orphan Creek

Community C - Orphan Creek

Community D - Orphan Creek

Community E - Bayou LaTerre

Community F - Bayou LaTerre

Community G (centralized) - Bayou LaTerre

Table A1. Numerical values of fecal coliform concentrations in the samples

Fecal Coliform Geometric Mean at Designated Sample Collection Location								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
November	145	80	15	135	255	110	200	110
December	0	100	130	105	135	100	65	55
January	313	369	1440	802	867	1789	550	1017
February	37	41	186	207	165	80	44	73
March	1745	1253	6791	5824	8662	3874	3853	1853
April	255	150	50	135	63	204	275	283

Table A2. Numerical values of total concentrations in the samples

Percent Increase/Decrease in Total Nitrogen Concentrations from Upstream to Downstream Locations at Designated Communities					
	A	**B**	**C and D**	**E and F**	**G**
November 13	+10	+54	28	13	9
December 11	+14	7	8	46	17
January 5	+4	3	32	44	15
January 22	36	2	18	+96	5

February 5	27	+29	44	+1	18
February 26	+15	3	16	19	19
March 9	12	2	10	40	+183
March 26	35	+4	+24	36	+16
April 9	47	+11	27	34	+24

Table A3. Numerical values of total concentrations in the samples

Percent Increase/Decrease in Fecal Coliform Levels from Upstream to Downstream Locations at Designated Communities					
	A	**B**	**C and D**	**E and F**	**G**
November 13	45	+800	+89	+82	+100
December 11	+100	19	+29	35	15
January 5	0	81	+77	57	0
January 22	+183	21	+65	51	+191
February 5	+175	+52	36	58	+125
February 26	63	18	0	29	+20
March 9	8	26	91	4	40
March 26	51	0	+15	+3	61
April 9	41	+170	52	+34	+22

Table A4. Numerical values of total concentrations in the samples

Percent Increase/Decrease in Total Phosphorus Concentrations from Upstream to Downstream Locations at Designated Communities					
	A	**B**	**C and D**	**E and F**	**G**
November 13	+10	+482	96	100	+100
December 11	0	0	0	0	0
January 5	0	44	100	100	0

January 22	96	33	16	+1073	17
February 5	100	+22	83	75	34
February 26	0	+7	49	68	23
March 9	3	+25	34	49	25
March 26	35	+12	+13	21	+16
April 9	+33	+44	65	62	44

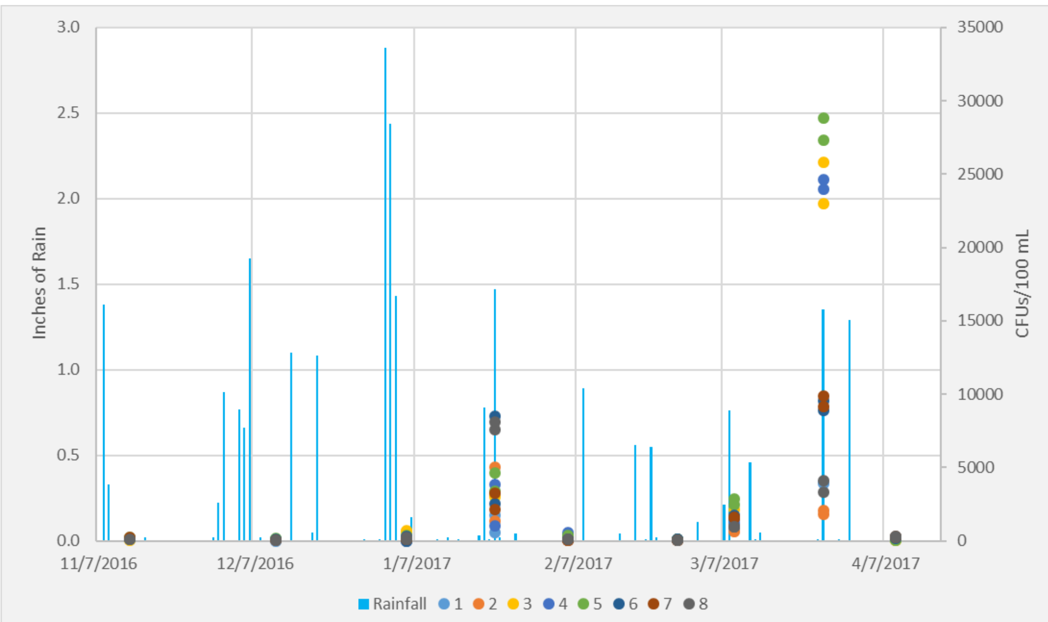


Figure A1. Individual sample fecal coliform bacterial counts in relation to rainfall data surrounding each sample collection date

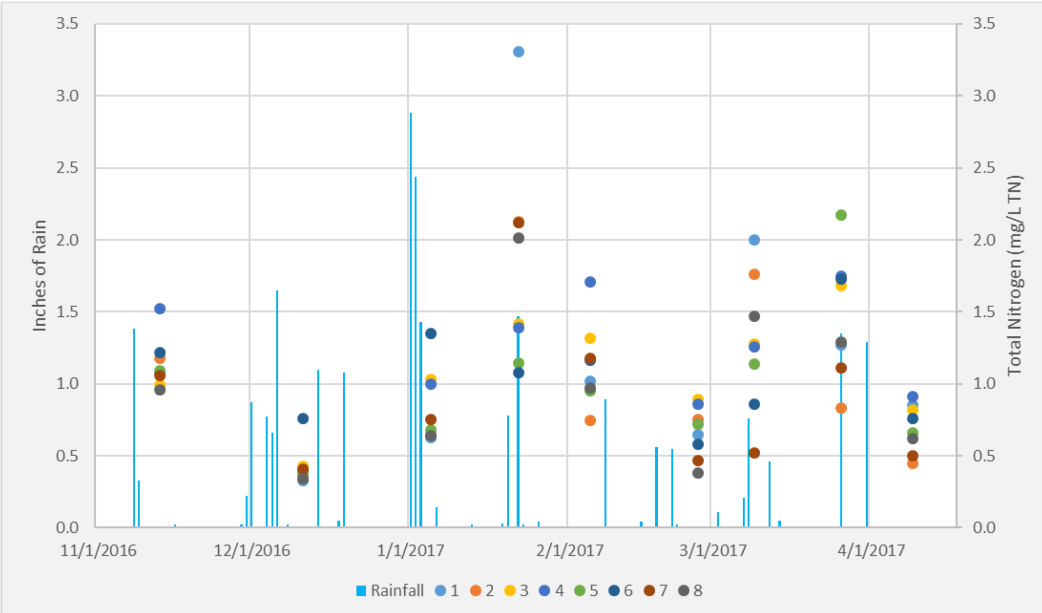


Figure A2. Individual sample total nitrogen concentrations in relation to rainfall data surrounding each sample collection date

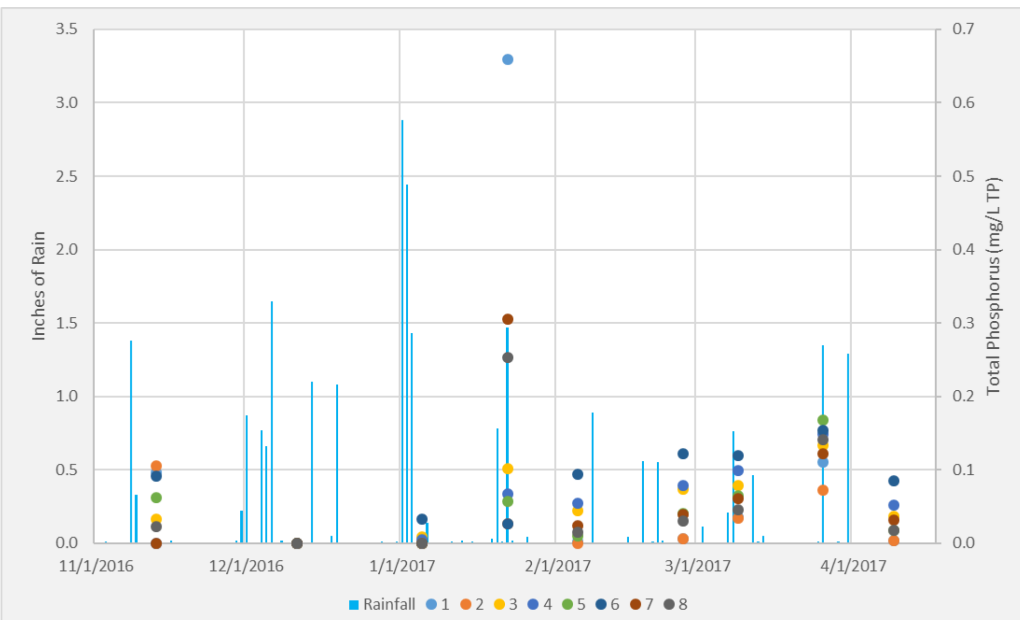


Figure A3. Individual sample total phosphorus concentrations in relation to rainfall data surrounding each sample collection date

Study of Sediment and Nutrients in Pelahatchie Bay and Upland Mill-Pelahatchie Creek Watershed

Basic Information

Title:	Study of Sediment and Nutrients in Pelahatchie Bay and Upland Mill-Pelahatchie Creek Watershed
Project Number:	2017MS207B
Start Date:	3/1/2017
End Date:	9/1/2018
Funding Source:	104B
Congressional District:	MS-001
Research Category:	Water Quality
Focus Categories:	Conservation, Water Quality, Surface Water
Descriptors:	None
Principal Investigators:	Xiaobo Chao

Publications

1. Quarterly reports submitted to Mississippi Water Resources Research Institute.
2. Chao, X, Bingner, R.L., Zhang, Y., Yasarer, L. and Jia, Y. (2018), Study of sediment and nutrients in Pelahatchie Bay and upland Mill-Pelahatchie Creek- Watershed, Mississippi Water Resources Conference, Jackson, MS, April 3-4.
3. Chao, X, Bingner, R.L., Zhang, Y., Yasarer, L. and Jia, Y. (2018), Numerical modeling of flow and sediment in Pelahatchie Bay and its upland watershed, The 13th International Conference on Hydroscience & Engineering, Chongqing, China, June 18-22.

Annual Status Report

Study of Sediment and Nutrients in Pelahatchie Bay and Upland Mill-Pelahatchie Creek- Watershed

Xiaobo Chao Ronald L. Bingner Yaoxin Zhang and Lindsey Yasarer

1. INTRODUCTION

Fresh water is one of the most important natural resources on earth. However, deterioration of water quality has been frequently observed in many rivers, lakes and coastal waters, which greatly affects human lives and economic development. Water quality is generally the result of the physical, chemical and bio-chemical processes in water bodies; and is also strongly influenced by human and natural activities in the surrounding watersheds that produce a significant amount of sediment, nutrients, pathogen and other pollutants. Best Management Practices (BMPs), such as constructed-wetlands, establishment of grassed buffers, sediment erosion control, reduced-tillage, no-tillage, etc., have been applied to reduce the loads of sediment and nutrients in watersheds, resulting in the improvement of water quality in surface water bodies. However, these measures often have limitations and the water quality of the downstream waterbody may still have problems. Evaluating the effectiveness of these practices by analyzing the response of water quality in surface waters to the BMPs implemented in the upland watersheds is critical to the success of watershed management and restoration plans.

This research studies the response of water quality in a receiving waterbody to incoming sediment and pollutant loads from upland watersheds. The hydrodynamics, sediment transport, and water quality processes are be studied using numerical simulations. The Annualized Agricultural Non-Point Source (AnnAGNPS) pollutant loading watershed management model, developed at the USDA ARS, National Sedimentation Laboratory (NSL), is applied to simulate the loads of runoff, sediment and nutrients from the upland watershed. The simulated results is used as boundary conditions for CCHE3D, a free surface flow, sediment and water quality model developed at the National Center for Computational Hydroscience and Engineering (NCCHE), to simulate flow, sediment transport and water quality processes in the waterbody.

The Mill-Pelahatchie Creek Watershed (MCW) in Rankin County, Mississippi, is selected as the study site due to the high sediment yield production there. The AnnAGNPS model is used to simulate the loads of runoff, sediment and nutrients in the upland watershed. The CCHE model is applied to simulate the hydrodynamics and sediment transport in the Pelahatchie Bay. The simulated results were validated using the available field measurements and satellite image.

2. RESEARCH NARRATIVE

1) Model Descriptions

AnnAGNPS watershed model

The Annualized Agricultural Nonpoint Source Pollution (AnnAGNPS) model is an advanced technological watershed evaluation tool that has been developed through a partnership between two US Department of Agriculture (USDA) agencies – the Agriculture Research Service (ARS) and the Natural Resources Conservation Service (NRCS) to aid in the evaluation of watershed responses to agricultural management practices (Bingner and Theurer, 2001). AnnAGNPS is a continuous-simulation, daily time-step, pollutant loading model designed to simulate long term chemical and sediment movement from agricultural watersheds (Bingner et al., 2005). The spatial variability of soils, land use, and topography within a watershed are accounted for by dividing the watershed into many user-specified, homogeneous, drainage-area-determined cells. For individual fields (cells), runoff, sediment, and pollutant loadings can be predicted from precipitation events that include rainfall, snowmelt, and irrigation.

In this model, the watershed cells and stream networks are generated from a watershed DEM using TOPAGNPS module; the soil properties and land use information are obtained from NRCS database; the management operation and schedule data are obtained from RUSLE database; the climate information can be obtained from local weather station or agGEM model.

The model routes the physical and chemical constituents from each cell into the stream network and finally to the watershed outlet. The model outputs include runoff, sediment, nutrient and pesticide at a temporal scale ranging from daily to yearly. All model outputs can be obtained at any desired location such as specific cells, stream reaches, feedlots, gullies, or point sources.

CCHE3D receiving water model

CCHE3D is an integrated software package developed at NCCHE. It is a general numerical model for three-dimensional simulation and analysis of free surface flows and associated processes. These processes are solved with full three-dimensional Reynolds equations, mass conservation equation, mass transport equations with forcing terms representing specific processes in sediment transport, pollutant transport and water quality, etc.

This model uses finite element method, and the staggered grid is adopted in the model. The grid system in the horizontal plane is a structured conformal mesh generated on the boundary of the computational domain. In vertical direction, either uniform or non-uniform mesh lines are employed.

The unsteady equations are solved using the time marching scheme. A second-order upwinding scheme is adopted to eliminate oscillations due to advection. In this model, a convective interpolation function is used for this purpose. This function is obtained by solving a linear and steady convection-diffusion equation analytically over a one-dimensional local element. Although there are several other upwinding schemes, such as the first order upwinding, the second order upwinding and Quick scheme, the convective interpolation function is selected in this model due to its simplicity for the implicit time marching scheme.

The velocity correction method is applied to solve the pressure and enforce mass conservation. Provisional velocities are solved first without the pressure term, and the final solution of the velocity is obtained by correcting the provisional velocities with the pressure solution. The system of the algebraic equations is solved using the Strongly Implicit Procedure (SIP) method. In the model, the flow fields and sediment transport are solved at each time step.

2) Model Application to Mill-Pelahachie Creek Watershed

Study site

Ross Barnett Reservoir (RBR) is the largest drinking water source in the state of Mississippi. The water quality in RBR is generally affected by the physical, chemical and bio-chemical processes in the reservoir, and is also significantly influenced by the Upper Pearl River watershed and Ross Barnett Reservoir Watershed. Six priority issues in the reservoir and its watershed have been identified and recommended for reducing and controlling: 1) watershed erosion/sedimentation; 2) nutrient enrichment and algal growth; 3) pathogens; 4) invasive aquatic plant species; 5) pesticides; and 6) litter/trash in the reservoir and around the shoreline.

Pelahatchie Bay (PB) is a part of RBR, located in the southeast corner of the reservoir. The bay is separated with RBR by the “Northshore Parkway”, and only a limited amount of water flows in/out of RBR through a relatively narrow opening under a bridge of the parkway. The upland watershed, Mill-Pelahatchie Creek Watershed (MCW) contains a high percentage of construction sites and developed area, causing a lot of sediment and associated pollutants to discharge into the bay through runoff. In addition, sediment, nutrients, and other pollutants may also flow into Pelahatchie Bay from the upstream Pelahatchie Creek.

The major water quality problem in PB is sedimentation, which causes high turbidity and limits boat navigation in the bay. The levels of nitrogen and phosphorus in the bay are relatively high and cause excessive growth of aquatic plants. The dense aquatic vegetation may reduce the water surface area, cause more sediment deposition and affect boat navigation. The pathogen level in the bay is also relatively high, which may influence the recreational value of the PB and RBR.

The MCW watershed has a total drainage area of approximately 74 square kilometers, and the surface area of the PB bay is about 9% of the area of MCW. The averaged water depth of the bay is about 2.2 meters. The wind is the major driving force of the flow hydrodynamics in the bay. The upland runoff and flow in the upstream Pelahatchie Creek may also affect the flow field in the bay. In addition, the wind induced waves may cause sediment resuspension near the shoreline.

In MCW watershed, USGS has a gage station (USGS 02485498) to measure the flow discharge and water surface elevation (Figure 1). In the bay, water samples were collected by MDEQ (Station shown in Figure 1), and the water quality constituents, including sediment, nitrogen, phosphorus, chlorophyll, and bacteria were analyzed. Those measured data will be used for model calibration and validation. Figure 2 shows the land use and land cover of the upland watershed MCW. This watershed contains pasture, forest, wetland, agricultural land, and a high percentage of developed area. It is found that the developed areas are primarily around Pelahatchie Bay, which may cause lots of sediment and associated pollutants discharge into the bay (Figure 2). In addition, some sediment, nutrients, and other pollutants may also flow into PB through the upstream Pelahatchie Creek. To improve the water quality in PB, BMPs have been implemented or designed in the upland watershed, including the establishment of grassed buffers, and stabilization of disturbed surface soil and channel banks.

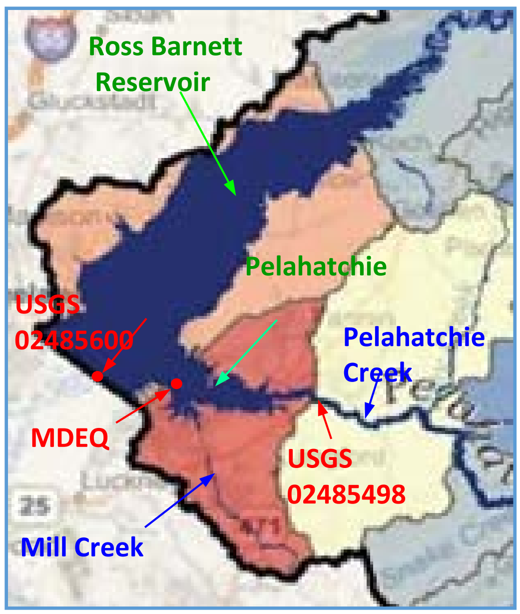


Fig. 1 Pelahatchie Bay and the surrounding watershed

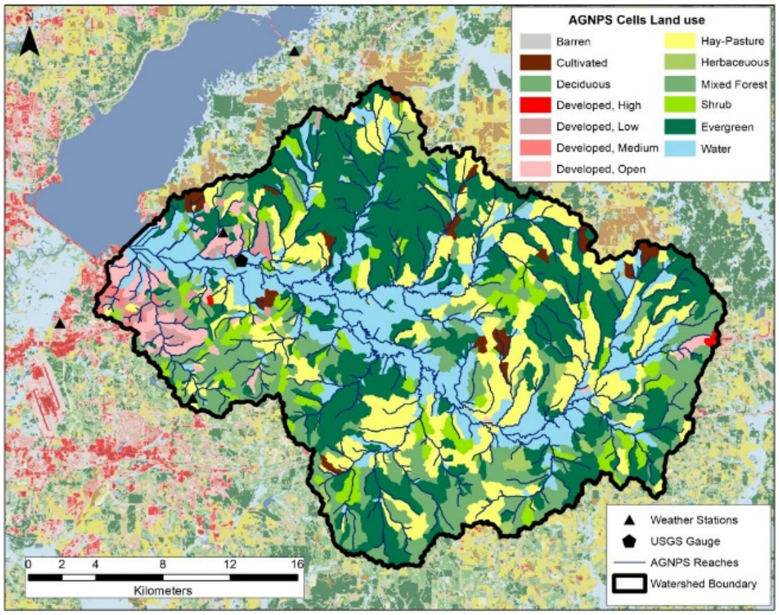


Fig. 2. Land use/land cover of Mill-Pelahatchie Creek Watershed

AnnAGNPS watershed model simulation

An AnnAGNPS simulation was developed to evaluate the loads of runoff, sediment and nutrients from MCW into the PB Bay under current conditions and before and after BMP implementation. In the model, the LU/LC parameters were modified based on the implementation BMPs, including the establishment of grassed buffers along the streamside and shoreline, stabilization of disturbed soil on urban construction sites and bank erosion control measures. Through the use of the DEM, climate data, soil properties and management information in the watershed, the runoff, sediment and nutrient loads can be simulated using AnnAGNPS model.

CCHE3D model simulation

Based on initial bed elevation data, the computational domain was discretized into a structured finite element mesh using the CCHE Mesh Generator (Zhang 2011). In the horizontal plane, the computational domain was represented by a mesh with 213x255 nodes. In the vertical direction, the domain was divided into 8 uniform layers. A simulation period from Feb. 1 to April 20, 2016, was selected for model test.

Two inlet boundaries were set for model simulation: Pelahatchie Creek and Mill Creek (Fig. 3). The measured flow discharge at USGS 02485498 Station can be used as flow boundary conditions for Pelahatchie Creek. The sediment concentration in Pelahatchie Creek, as well as the flow and sediment concentration in Mill Creek can be obtained from the simulation results of AnnAGNPS. The outlet boundary conditions can be obtained based on the field measurements at

USGS 02485600 Station. The wind speeds and directions during the simulation period can be obtained from nearby Jackson Airport. The flow velocity and sediment concentration in Pelahatchie Bay can be simulated using CCHE3D model.

3) Simulation Results

Figures 3 and 4 show the simulated runoff and sediment in Mill-Pelahatchie Creek Watershed using AnnAGNPS model.

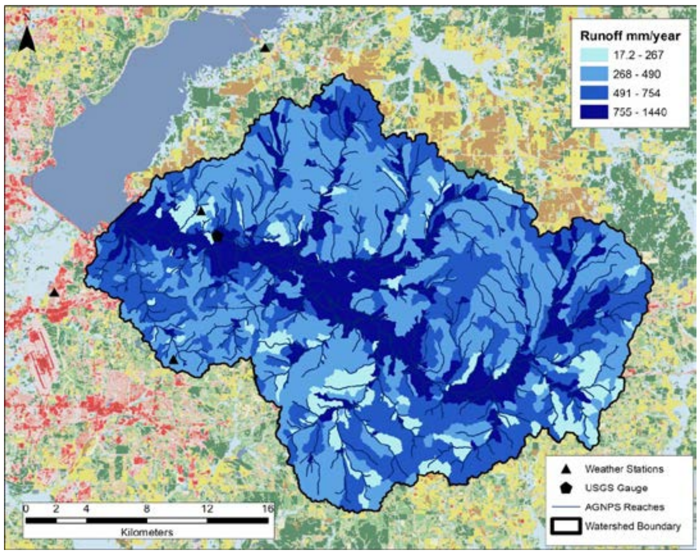


Fig. 3. Simulated runoff in Mill-Pelahatchie Creek Watershed using AnnAGNPS

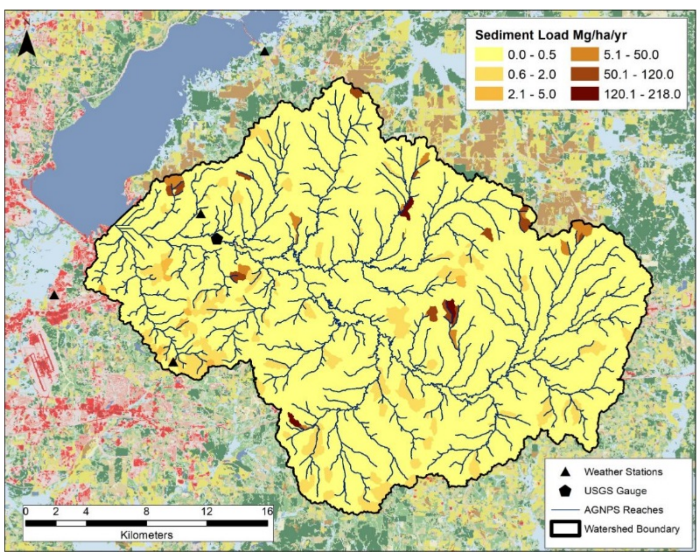


Fig. 4. Simulated sediment loads in Mill-Pelahatchie Creek Watershed using AnnAGNPS

Figure 5 shows the comparison of flow discharge between the AnnAGNPS model results with USGS measurements. The simulated results are generally in good agreement with field measurements. It shows that spring is the major raining season, causing a large amount of sediment discharge into the bay.

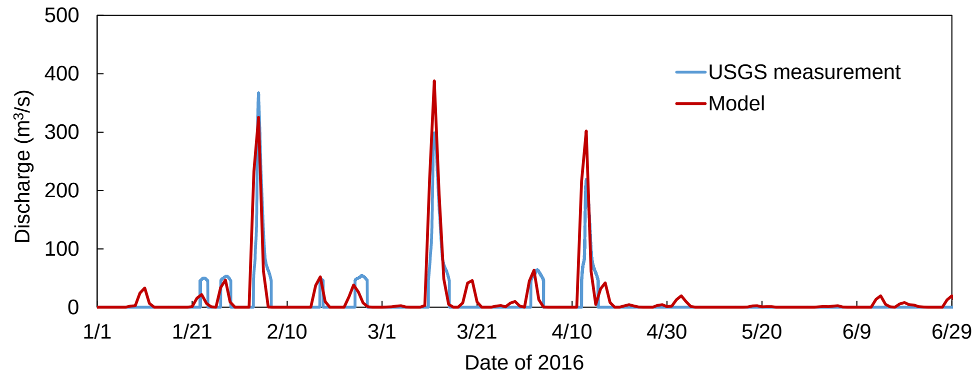


Fig. 5. Comparison of flow discharge between the AnnAGNPS results with USGS measurements

Figures 6 shows the flow velocities on the water surface during a storm event in March 2017. The flow patterns are induced by the upstream river discharge as well as the wind forces. Due to the storm event, large amount of sediment and nutrients may discharge into the bay.

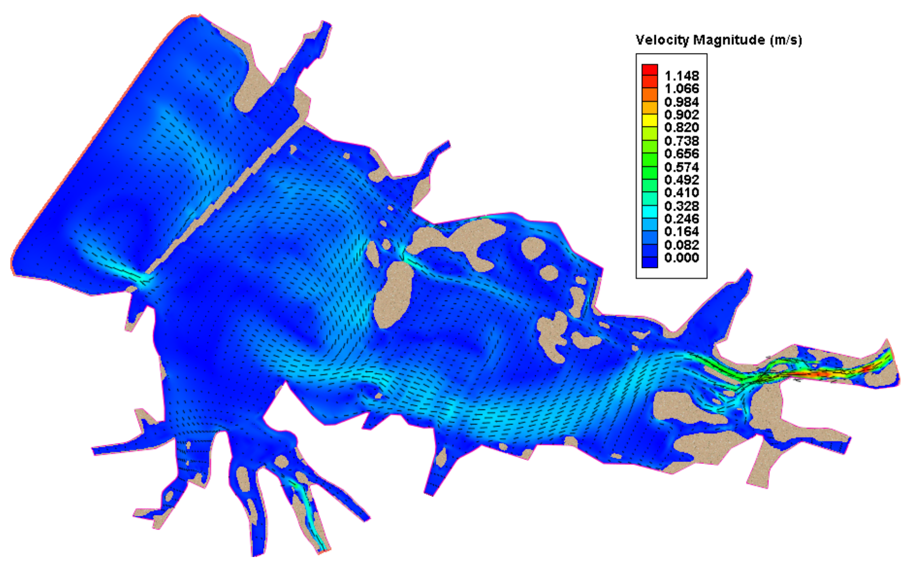
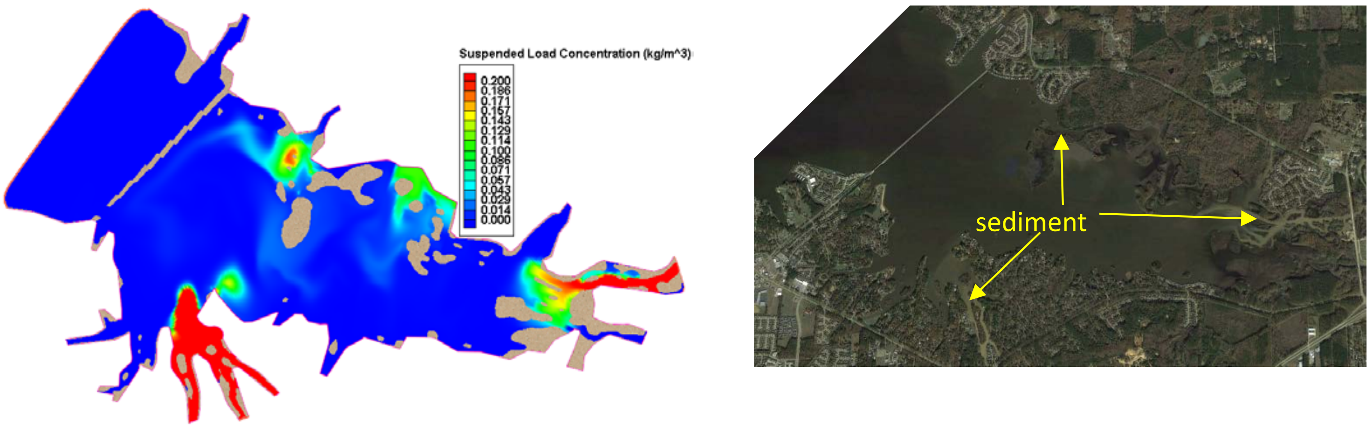


Fig. 6 Simulated flow patterns near surface in Pelahatchie Bay using CCHE3D model

Fig. 7 shows the simulated concentration of suspended sediment in the bay when a storm event occurred. It is generally in good agreement with the results obtained based on satellite image. The two inlets (Pelahatchie Creek and Mill Creek) are the major sources of sediment discharged into the bay.



a. Simulated sediment concentration in the bay

b. Satellite image

Figure 7. Comparison between the model results and satellite image of sediment concentration

3. RESEARCH SUMMARY

1) The loads of flow, sediment and nutrients of the Mill-Pelahatchie Creek Watershed have been successfully simulated using AnnAGNPS watershed model.

2) The flow fields and sediment concentrations in Pelahatchie Bay have been simulated using CCHE3D receiving water model.

3) Sediment samples in Pelahatchie Bay were collected, and the sediment size and concentrations were measured. Those results can be used for model validation.

4) The nutrients concentration in the bay will be simulated and the effects of upland watershed on the water quality of receiving water body will be analyzed.

4. OTHERS

1) Student Training

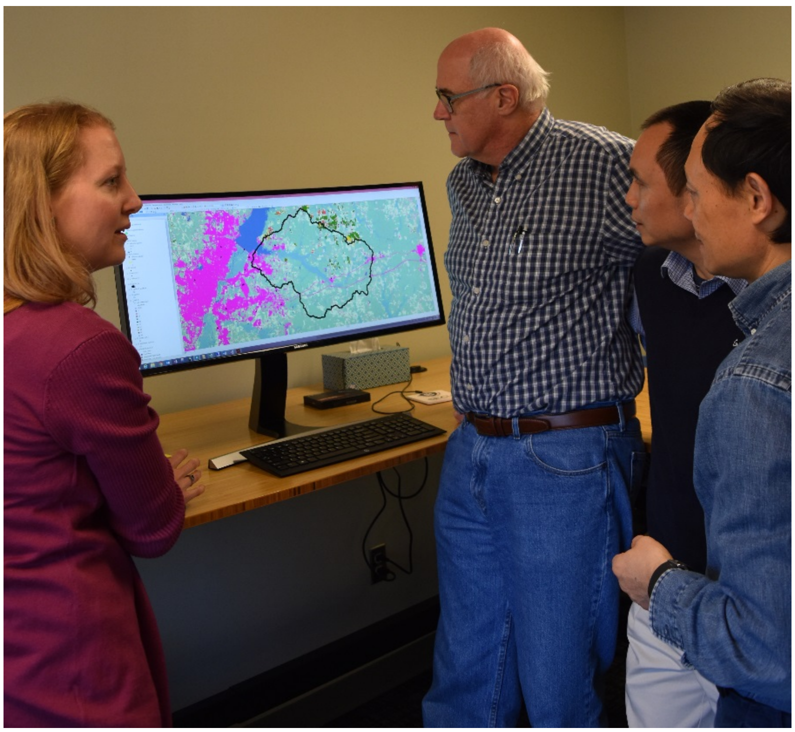
A Ph.D student Jiayu Fang participated in the project to simulate flow and sediment concentration using CCHE3D model.

2) Presentations and Publications

Chao, X, Bingner, R.L., Zhang, Y., Yasarer, L. and Jia, Y. (2018), Study of sediment and nutrients in Pelahatchie Bay and upland Mill-Pelahatchie Creek- Watershed, Mississippi Water Resources Conference, Jackson, MS, April 3-4.

Chao, X, Bingner, R.L., Zhang, Y., Yasarer, L. and Jia, Y. (2018), Numerical modeling of flow and sediment in Pelahatchie Bay and its upland watershed, The 13th International Conference on Hydroscience & Engineering, Chongqing, China, June 18-22.

3) Research Activities



Picture 1. Discussion the model results at National Sedimentation Laboratory

Picture 2. Collected water sample at USGS Pelahatchie Creek Station near Hwy 25

Applied use of unmanned aerial vehicles in surface water quality protection

Basic Information

Title:	Applied use of unmanned aerial vehicles in surface water quality protection
Project Number:	2017MS208B
Start Date:	3/1/2017
End Date:	7/31/2018
Funding Source:	104B
Congressional District:	MS-003
Research Category:	Water Quality
Focus Categories:	Agriculture, Sediments, Conservation
Descriptors:	None
Principal Investigators:	Joby Czarnecki, John J Ramirez-Avila

Publications

1. Quarterly reports submitted to Mississippi Water Resources Research Institute.
2. Prince Czarnecki, J.M., L. A. Hathcock, J. J. Ramirez-Avila, A.C. Linhoss, and T.J. Schauwecker, 2017. Unmanned aerial vehicles and structure from motion techniques and their use in protecting surface water quality. 2017 American Water Resources Association Annual Conference, Nov. 5-9, 2017, Portland, OR, oral presentation.
3. Ramirez-Avila, J. J., Langendoen, E. J., Ortega-Achury, S. L., McAnally, W. H., Martin, James L., Schauwecker, T., & Prince Czarnecki, J. M. 2017. Estimación y Predicción de Descargas de Sedimentos y Tasas de Erosión de Bancos Fluviales. 1st International Congress and 2nd National Congress of Rivers and Wetlands. Neiva, Colombia.
4. Grafe, J., Ramirez-Avila, J. J., Schauwecker, T., Ortega-Achury, S. L., Prince Czarnecki, J. M., & Langendoen, E. 2018. Understanding Relations between Streamflow, Turbidity, and Suspended-Sediment Concentration in an Impaired Mississippian Stream. Mississippi Water Resources Research institute. Jackson, MS. Oral Presentation.
5. Ramirez-Avila, J. J., Grafe, J., Schauwecker, T., Prince Czarnecki, J. M., Ortega-Achury, S. L., Martin, James L. & Noble, T. 2018. Impacts of Riparian Buffer Zones on Stream Water Quality: A Quantitative Assessment in the Catalpa Creek Watershed. Mississippi Water Resources Conference. Jackson, MS. Oral Presentation.
6. Ramirez-Avila, J. J., Schauwecker, T., Martin, James L., Ortega-Achury, S. L. & Prince Czarnecki, J. M. 2018. A Project Based Learning Study Oriented to Develop a Natural Stream Restoration Design. Mississippi Water Resources Conference. Jackson, MS. Oral Presentation.
7. Ramirez-Avila, J.J., T. Schauwecker, J. Czarnecki, E. Langendoen, S. Ortega-Achury, J. Martin, 2018. Quantifying and Modeling in-Stream Processes: A first step to restore the Catalpa Creek. 2018 World Environmental & Water Resources Congress. Minneapolis, MN. Oral Presentation.

Annual Report

Project Title: Applied use of unmanned aerial vehicles in surface water quality protection
Principal Investigators: Joby Czarnecki and John Ramirez-Avila
Collaborators: Tim Schauwecker, Eddy J. Langendoen
Institution: Mississippi State University
E-Mail: joby.czarnecki@msstate.edu, jjr149@cee.msstate.edu

Project Overview:

The objective of this research is to evaluate the accuracy of erosion calculations derived from Structure from Motion (SfM) captured with unmanned aerial vehicles (UAVs). The research project will combine results from SfM assessments of erosion with ground-truthed measurements of erosion to determine the accuracy of this approach for use in calculating erosion values, and extend this approach to evaluate the ability of SfM to monitor erosion over time. Derived values will be incorporated into existing models (e.g., BSTEM) to determine if SfM data are a valid model input. The result of this research is a scientific validation of the accuracy of erosion calculations derived from UAV-collected SfM assessments. The research serves as a proof-of-concept project to develop a method by which UAVs could be employed to identify, quantify, and monitor erosion in drainage channels and other eroded areas. This would enable federal, state, and local agencies to utilize this technology to more efficiently monitor, remediate, and regulate degradation of surface waters. Outputs from this research project include transfer of information on the appropriate data collection strategies for UAV-based SfM assessments, as well as best practices, along with methods, estimates of accuracy, and any necessary cautions. This data will be communicated to stakeholders through scientific exchange and interaction, in addition to the established University Extension network.

Progress to date:

Regarding data collection and imagery analysis, we succeeded in securing a new unmanned aerial vehicle (UAV), a DJI Inspire2, to collect our aerial imagery (Fig. 1). The appeal of this specific aircraft was the ability to obtain unobstructed 360° view with the camera. This is possible because of two unique features of this aircraft that were not available on other models. First, the aircraft can transform its frame to pull the landing gear out of the line of sight of the camera (https://goo.gl/dW4wtU). Second, it is possible to operate the camera independent of flight control.

In the fall, we worked in a southern area of South Farm on a 750-m reach of Catalpa Creek (https://goo.gl/phwdfg). Flights were conducted to generate 3D surface models of the reach (https://goo.gl/UTBzQn). At the same time, a significant field data collection effort was underway to obtain ground truth data (Fig. 2). These models were compared against field survey with a survey grade GPS unit (Fig. 3). The disparity and error between the collected data and the 3D surface model was attributed primarily to vegetation within the channel. This issue appears to plague other forms of data capture, such as LiDAR and terrain laser scanning.

We made key changes to research methods to overcome issues experienced in the first half of the study. At the beginning of this year, we decided to move into a shallower area with less vegetation. We moved into a tributary that comes from the 21 Apartments area of Starkville and flows into Catalpa near the bridge to the Aquaculture facility (https://goo.gl/d83qrF). Because this reach is less vegetated and shallower, but highly active, we felt it offered excellent potential to continue testing our methods and devising guidelines for technology transfer.

Figure 1 (left). Preparation of the DJI Inspire 2 for her maiden flight.

Figure 2 (right). Collection of survey data on eroded stream banks for ground truth against 3D surface models.

Figure 3. Comparison of elevation sampled from 3D surface model and GPS-reported elevation. Color increase from blue to yellow shows increasing disparity between modeled and measured elevation. Increased size of dots coincides with decreased precision of GPS instrument (as reported by the instrument under vertical dilution of precision). Small dots with blue, pink, or red are acceptable.

It was also noted that there is a compounding effect on disagreement between modeled and measured values when the horizontal precision of the GPS instrument is low because measurements are taken on sloped streambanks (thus, being in the wrong place on the slope inherently results in the wrong elevation being reported).

Figure 4 (top). Aerial image of rebar cap used for georeferencing of images.

Figure 5 (middle). Construction of calibration boxes using salvaged materials.

Figure 6 (bottom). Painting of calibration boxes using highly visible colors. Sides are painted in differing colors for edge detection in imagery.

We also changed our field data collection protocols to utilize more traditional forms of landscape survey. We are currently investigating methods that utilize total stations, and traditional survey poles. Finally, we have changed our type and placement of calibration materials. We started with soccer cones, but found these were not durable enough for the environment. We upgraded to rebar with caps which could be permanently placed on-site (Fig. 4). The attrition rate for rebar in highly erodible areas was quite high, and the introduction of rebar likely increased erosion on-site. After reviewing work at other universities, we settled on calibration boxes which could be used for georectification, as well as height and volume calibration. These boxes were built from salvaged materials (Fig. 5) and painted for maximum visibility (Fig. 6). Boxes can be measured within 3D surface models to verify height and volume are reported correctly by the model.

We have just begun rigorous examination of cross sections between each method of data collection. This includes comparison between traditional and GPS survey methods against 3D surface models. We are generating our 3D surfaces using multiple tools. Several cloud-based processing services are available in the marketplace for automatic processing of UAV imagery into 3D surface models. We are currently comparing the quality versus effort potential for these services against a highly controlled, desktop software approach.

Regarding model integration, the Bank Stability and Toe Erosion Model (BSTEM), developed by the National Sedimentation Laboratory in Oxford, MS has been selected for being one of the most advanced and commonly used tools for modeling streambank erosion and failure. The model is being setup and will be compared to field measurements for fluvial erosion and streambank instabilities.

The user input necessary to evaluate BSTEM includes streambank geometry, specific streambank material characterization for the stratified profile and watershed and stream hydrologic and hydraulic information. For each individual layer BSTEM requires information about material characteristics related to water movement (grain size distribution, bulk and particle density, porosity), resistance to erosion (critical shear stress and erodibility) and resistance to failure (cohesion, friction angle, suction angle). We've partially completed determination of water movement characteristics and are currently advancing assessment of resistance to erosion and failure characteristics. We can evaluate if the 3D model generated from SfM can be of use in obtaining information necessary for this model on streambank geometry. Hydrologic and hydraulic characteristics of the model are to be setup from field measurements and watershed analysis. The completed assessment is fundamental to support the model evaluation.

Student Training:

In the last year, the following students have assisted with data collection and processing, with and without direct support from project funds.

Name	*Level*	*Department*
James Grafe	Graduate	Civil and Environmental Engineering
Taylor Noble	Undergraduate	Civil and Environmental Engineering
James Steele	Undergraduate	Civil and Environmental Engineering
Katelyn Polk	Undergraduate	Civil and Environmental Engineering
Lucas Whittenton	Undergraduate	Agricultural Economics
Gage Creel	Undergraduate	Agricultural and Biological Engineering
Adam Goldman	Undergraduate	Agricultural and Biological Engineering
Shelby Adair	Undergraduate	Agricultural and Biological Engineering
Dillion Drake	Undergraduate	Agricultural and Biological Engineering
William Jarrell	Undergraduate	Agricultural and Biological Engineering
Garrett Prater	Undergraduate	Agricultural and Biological Engineering
Jesse Mitchell	Undergraduate	Landscape Architecture

As Catalpa Creek watershed has become an experimental laboratory used by different instructors in their academic exercise, students enrolled in the course Stream Reconnaissance (Fall 2017) advanced the hydrologic characterization of different reaches and the main stream within the watershed while gaining experience in these techniques. In addition, several students have been trained to collect stream information related to temporal and spatial variability of flow and sediment loads along the studied reaches. This dataset is also to be considered as a reference for modeling purposes.

Presentations:

Prince Czarnecki, J. M., Hathcock, L. A., Ramirez-Avila, J. J., Linhoss, A. C., & Schauwecker, T. J. 2017. Unmanned Aerial Vehicles and Structure from Motion Techniques and their Use in Protecting Surface Water Quality. 2017 American Water Resources Association Annual Conference, Nov. 5-9, 2017, Portland, OR. Oral presentation. Online at: https://goo.gl/5L1xhr

Ramirez-Avila, J. J., Langendoen, E. J., Ortega-Achury, S. L., McAnally, W. H., Martin, James L., Schauwecker, T., & Prince Czarnecki, J. M. 2017. Estimación y Predicción de Descargas de Sedimentos y Tasas de Erosión de Bancos Fluviales. 1st International Congress and 2nd National Congress of Rivers and Wetlands. Neiva, Colombia.

Grafe, J., Ramirez-Avila, J. J., Schauwecker, T., Ortega-Achury, S. L., Prince Czarnecki, J. M., & Langendoen, E. 2018. Understanding Relations between Streamflow, Turbidity, and Suspended-Sediment Concentration in an Impaired Mississippian Stream. Mississippi Water Resources Research institute. Jackson, MS. Oral Presentation.

Ramirez-Avila, J. J., Grafe, J., Schauwecker, T., Prince Czarnecki, J. M., Ortega-Achury, S. L., Martin, James L. & Noble, T. 2018. Impacts of Riparian Buffer Zones on Stream Water Quality: A Quantitative Assessment in the Catalpa Creek Watershed. Mississippi Water Resources Conference. Jackson, MS. Oral Presentation.

Ramirez-Avila, J. J., Schauwecker, T., Martin, James L., Ortega-Achury, S. L. & Prince Czarnecki, J. M. 2018. A Project Based Learning Study Oriented to Develop a Natural Stream Restoration Design. Mississippi Water Resources Conference. Jackson, MS. Oral Presentation.

Ramirez-Avila, J.J., T. Schauwecker, J. Czarnecki, E. Langendoen, S. Ortega-Achury, J. Martin, 2018. Quantifying and Modeling in-Stream Processes: A first step to restore the Catalpa Creek. 2018 World Environmental & Water Resources Congress. Minneapolis, MN. Oral Presentation.

Future efforts:

It was noted that undercutting is occurring in our new reach and this is not apparent in 3D models. The Inspire 2 is ideal for capturing undercutting, therefore we will conduct one additional test to determine if we can accurately characterize undercutting. A significant literature on this exists in glacial research, and we are reviewing those methods to design our collection.

We are attempting to assess one more cloud-based processing service, however, this has yet to be approved for purchase. Because of the cloud-based nature of the service, we must undergo security review before our purchase will be approved. With end of the FY purchasing deadlines and the review process, it is not clear if there will be sufficient time to conduct this assessment before the project ends.

Otherwise, we will finish our assessment of accuracy for our various methods of collection and processing and prepare our user guide for agency personnel. Preliminary results are very promising for a low-cost, rapid turn-around site assessment with UAVs and SfM. It is not apparent if the accuracy levels will be sufficient for modeling inputs at this time. We will evaluate the benefits of this information to the BSTEM model, and if results are adequate, provide a workflow to users for inclusion of this information as well.

Assessing and predicting in-stream processes in the Catalpa Creek Watershed

Basic Information

Title:	Assessing and predicting in-stream processes in the Catalpa Creek Watershed
Project Number:	2017MS209B
Start Date:	3/1/2017
End Date:	9/30/2018
Funding Source:	104B
Congressional District:	MS-003
Research Category:	Water Quality
Focus Categories:	Conservation, Geomorphological Processes, Water Quality
Descriptors:	None
Principal Investigators:	John J Ramirez-Avila, Sandra Liliana OrtegaAchury

Publications

1. Quarterly reports submitted to Mississippi Water Resources Research Institute.
2. Prince Czarnecki, J.M., L. A. Hathcock, J. J. Ramirez-Avila, A.C. Linhoss, and T.J. Schauwecker, 2017. Unmanned aerial vehicles and structure from motion techniques and their use in protecting surface water quality. 2017 American Water Resources Association Annual Conference, Nov. 5-9, 2017, Portland, OR, oral presentation.
3. Ramirez-Avila, J. J., Langendoen, E. J., Ortega-Achury, S. L., McAnally, W. H., Martin, James L., Schauwecker, T., & Prince Czarnecki, J. M. 2017. Estimación y Predicción de Descargas de Sedimentos y Tasas de Erosión de Bancos Fluviales. 1st International Congress and 2nd National Congress of Rivers and Wetlands. Neiva, Colombia.
4. Grafe, J., Ramirez-Avila, J. J., Schauwecker, T., Ortega-Achury, S. L., Prince Czarnecki, J. M., & Langendoen, E. 2018. Understanding Relations between Streamflow, Turbidity, and Suspended-Sediment Concentration in an Impaired Mississippian Stream. Mississippi Water Resources Research Institute. Jackson, MS. Oral Presentation.
5. Ramirez-Avila, J. J., Grafe, J., Schauwecker, T., Prince Czarnecki, J. M., Ortega-Achury, S. L., Martin, James L. & Noble, T. 2018. Impacts of Riparian Buffer Zones on Stream Water Quality: A Quantitative Assessment in the Catalpa Creek Watershed. Mississippi Water Resources Conference. Jackson, MS. Oral Presentation.
6. Ramirez-Avila, J. J., Schauwecker, T., Martin, James L., Ortega-Achury, S. L. & Prince Czarnecki, J. M. 2018. A Project Based Learning Study Oriented to Develop a Natural Stream Restoration Design. Mississippi Water Resources Conference. Jackson, MS. Oral Presentation.
7. Ramirez-Avila, J.J., T. Schauwecker, J. Czarnecki, E. Langendoen, S. Ortega-Achury, J. Martin, 2018. Quantifying and Modeling in-Stream Processes: A first step to restore the Catalpa Creek. 2018 World Environmental & Water Resources Congress. Minneapolis, MN. Oral Presentation.
8. Steele, J., J. Grafe and J.J. Ramirez-Avila. 2018. Analyzing Suspended Sediment Transport in Catalpa Creek. 2018 World Environmental and Water Resources Congress. Minneapolis, MN. Oral Presentation and Undergraduate Research Paper.
9. Wilkinson, H., B. Spiller, N. Forbes, J. Ramirez-Avila. 2018. A comparison of water quality conditions of stream segments under forested and herbaceous riparian zones. 2018 World Environmental and Water Resources Congress. Minneapolis, MN. Oral Presentation and

Undergraduate Research Paper.

10. Grafe, J., Ramirez-Avila, J.J., Schauwecker, T., Ortega-Acury, S.L., Prince Czarnecki, J.M., and Langendoen, E. 2108. Understanding Relations between Streamflow, Trbidity, and Suspended-Sediment Concentration in an Impaired Mississippian Stream. Mississippi Water Resources Conference. Jackson, MS. Oral Presentation.

Assessing and predicting in-stream processes in the Catalpa Creek watershed

John J. Ramirez-Avila (jjr149@msstate.edu), Sandra L. Ortega-Achury (slo51@msstate.edu)
Mississippi State University

Collaborators: Tim Schauwecker, Joby Czarnecki, Eddy J. Langendoen, James L. Martin, John Cartwright, Debra Veeder

Status Report May 2018

Summary

Hypothesizing in-stream processes are important mechanisms driving sediment supply into the streams and an important portion of the sediment budget for the Catalpa Creek Watershed, this research will focus on the identification, assessment, evaluation and prediction of in-stream processes within the study watershed. To address the research objectives three studies are undertaken using a combination of methods including field reconnaissance and detailed data collection, laboratory analysis, and channel modeling. Modeling results can help to determine critical areas to be potentially considered for future management and restoration activities, as well as to optimize a design for a desired outcome and to understand what results might be expected. The project has been subdivided in three studies oriented to respond specific objectives related to the spatial variation and change of sediment loads, the occurrence of in-stream processes and the capability of the models to predict streambank erosion and instabilities for the study area. The project involves important collaborative efforts with MSU faculty members from other departments and institutes and from state and federal research and educations institutions. The training of students with different levels of involvement has been of fundamental support to the performance of the project. Project results will be transferred to a broad group of academic, technical and research stakeholders, supported in collaboration with private, federal and state agencies.

Progress Report

Study 1. Analysis of spatial and temporal variation of suspended sediment transport rates and initial assessment of dominant mechanisms driving sediment supply and exportation for the Catalpa Creek.

Weekly data collection has been advanced along 40 stations in the main stream and tributaries, in order to quantify stream hydrologic and hydraulic characteristics (flow velocity and depth), water quality characteristics (pH, turbidity, temperature, total dissolved solids) and collect grab water samples for assessing total suspended concentrations. Automatic samples have also been collected at two stations along the main stream, in which an ISCO auto sampler and an area-velocity device have been installed.

Biological assessment of two tributaries to identify spatial and temporal distribution of macroinvertebrates along studied reaches was initiated during the spring semester 2018.

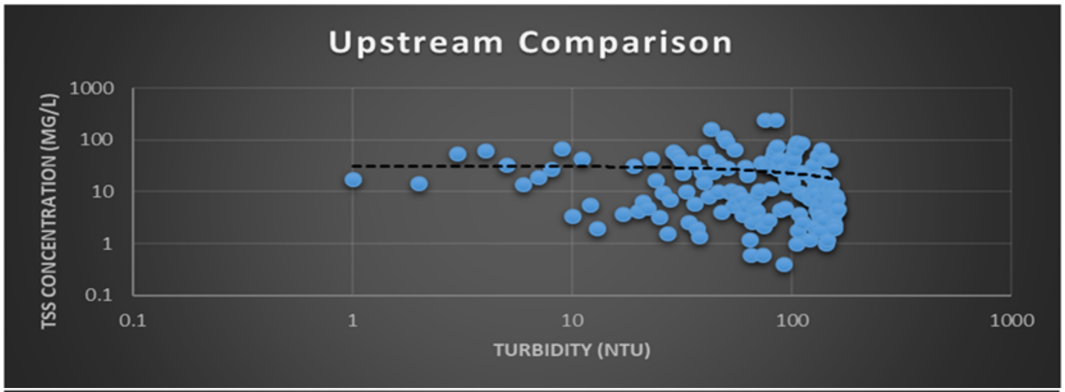
Preliminary results have been used to relate:

- Differences in water quality conditions along stream segments under different coverage conditions of riparian zones.
- Temporal variability of sediment concentration and loads along the main stream under baseflow and stormflow conditions.
- Relationship between sediment concentrations and loads with stream water turbidity.

- Macroinvertebrate presence in Catalpa Creek to suggest potential biological red flags.

Figure 1. Stream monitoring and laboratory analysis

Figure 2. Biological assessment along tributaries


Upstream Comparison
TSS CONCENTRATION (MG/L)
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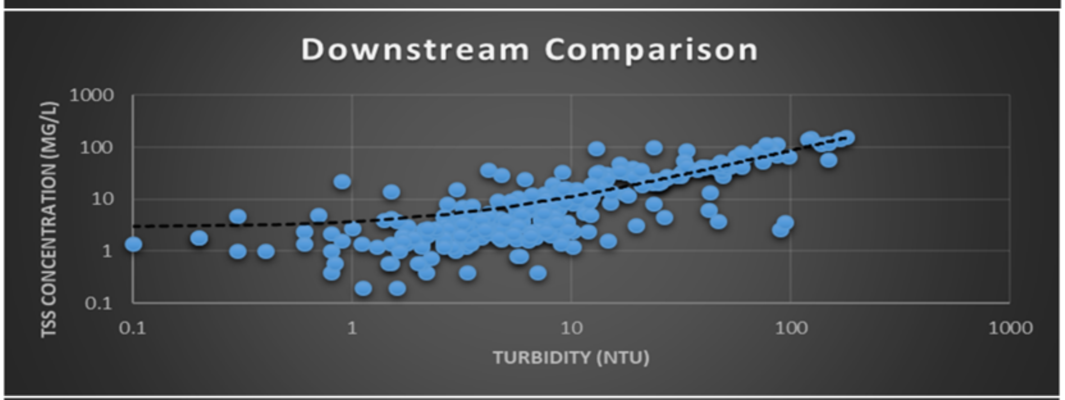
TURBIDITY (NTU)


Downstream Comparison
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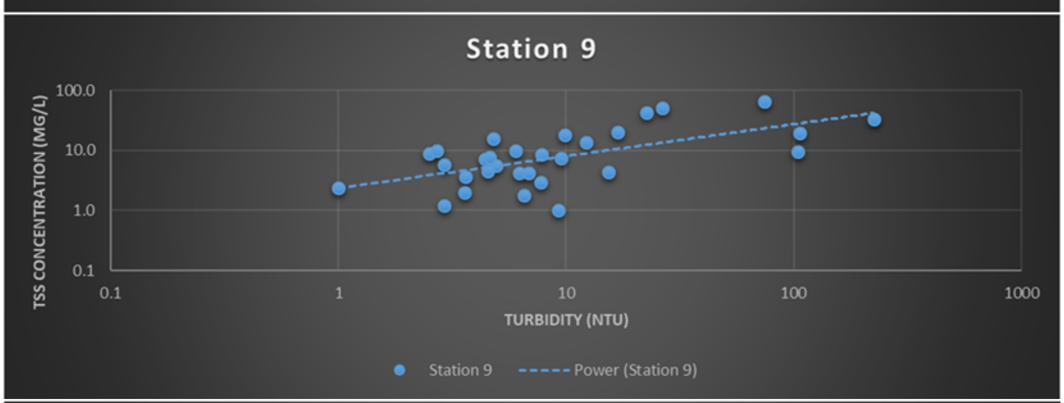
TURBIDITY (NTU)


Station 9
TSS CONCENTRATION (MG/L)
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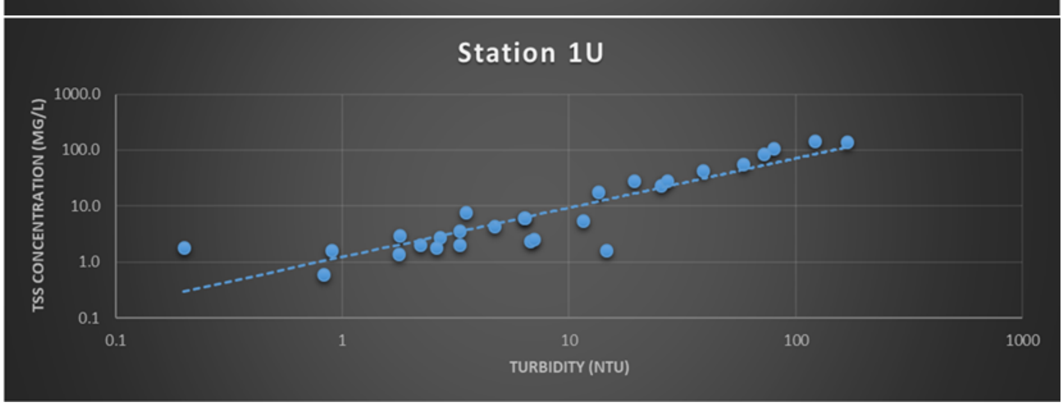
TURBIDITY (NTU)
Station 9
Power (Station 9)


Station 1U
TSS CONCENTRATION (MG/L)
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TURBIDITY (NTU)

Figure 3. Relationships between sediment concentrations and turbidity for grouped and individual stations

Study 2. Assessment of in-stream erosion or deposition rates along the main channel reach and main tributaries.

Cross sections along the upper four miles of the main stream and tributaries have been periodically surveyed in collaboration with researchers from the Landscape Architecture, the Geosystem Research institute (GRI) and the Mississippi Agricultural and Forestry Experiment Station (MAFES). Changes in channel morphology are evaluated to quantify erosion and sediment deposition rates along streambanks and streambed. Corrections of the filed procedures have been taken in consideration to properly compare changes in monitored cross sections.

Preliminary results and field observations have evidenced significant contributions of streambank material and important morphological changes in streambed and streambank erosion in different locations along the main stream and tributaries.

Figure 4. Upper figure evidences significant toe and streambed erosion. As a reference, the rock in the middle part of the image was partially covered by sediment at the beginning of the study. Lower figure evidences significant streambank instabilities along an upper tributary of the Catalpa Creek.

Study 3. Assessing the application of the computational model CONCEPTS and HEC-RAS, to predict in-stream processes within the Catalpa Creek watershed, and evaluate stream restoration design scenarios.

In order to setup the HEC-RAS and CONCEPTS models to evaluate streambank erosion and instability, some streambank material characteristics related to water movement (grain size distribution, bulk and particle density, porosity, permeability), resistance to erosion (critical shear stress and erodibility) and resistance to failure (cohesion, friction angle, suction angle) are in progress to be estimated and determined.

As a component of the collaborative work advanced with Dr. Tim Schauwecker and Dr. Joby Czarnecki, the HEC-RAS model has been setup to evaluate hydrologic and hydraulic responses from different return period rainfall events within the entire watershed area. The model is expected to be the base to develop a sediment transport model within the entire watershed. In addition, the latest version of HEC-RAS (V. 5.0.2) includes routines to evaluate streambank instability and toe erosion from the model CONCEPTS. We are working with Dr. Eddy J. Langendoen, developer of CONCEPTS, to evaluate fulfil the objectives of the study using the mentioned tool.

As Catalpa Creek watershed is an experimental laboratory used by different instructors in their academic exercise, students enrolled in the courses Open Channel Hydraulics and Stream Reconnaissance (fall 2017) amd Engineering Hydrology (spring 2018) advanced:

- a hydrologic characterization of different reaches and the main stream within the watershed involving the use of the hydrologic model HEC-HMS;

- an analysis of stream functionality and a preliminary stream restoration design for headwater tributaries of the Catalpa Creek, involving the use of the models HEC-HMS and HEC-RAS.

The different assessment performed by the students is fundamental to support the final model evaluation for this project.

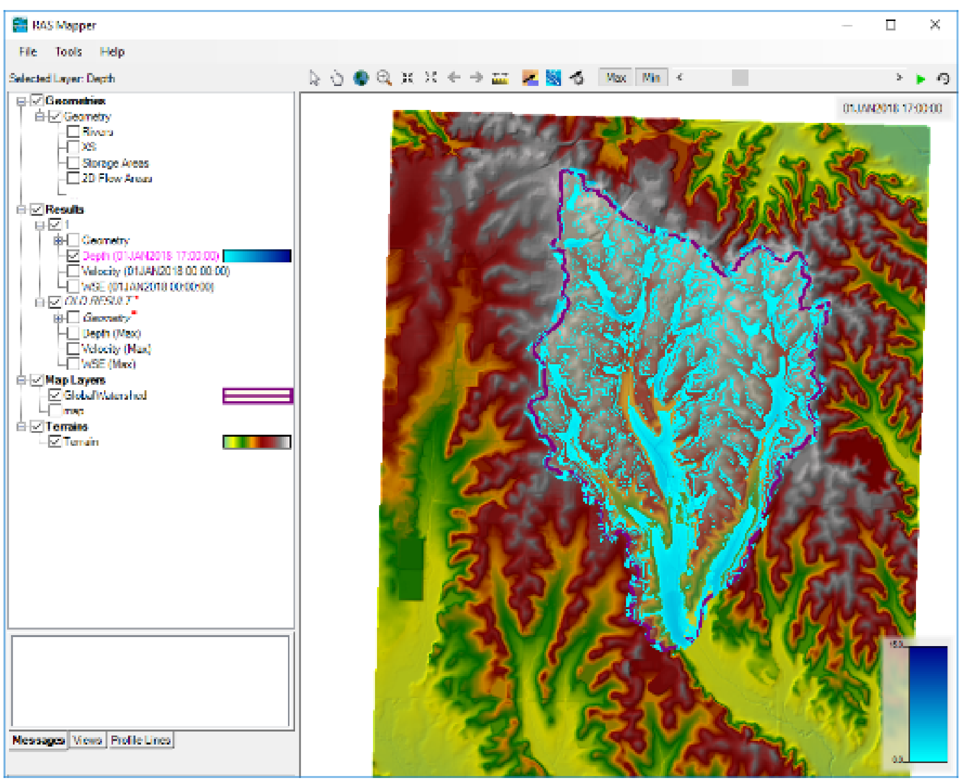
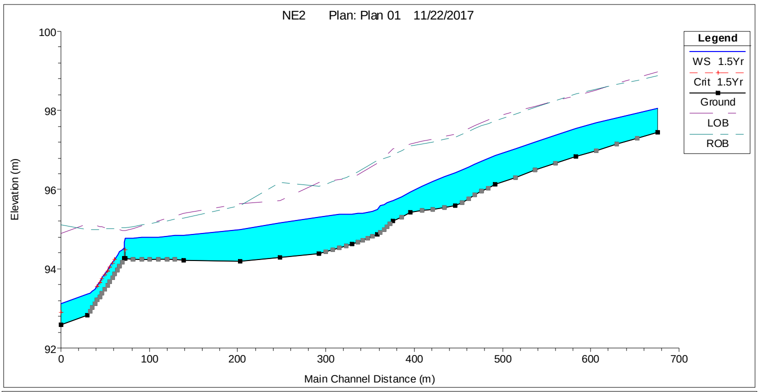


Figure 5. HEC-RAS model for headwaters areas of Catalpa Creek



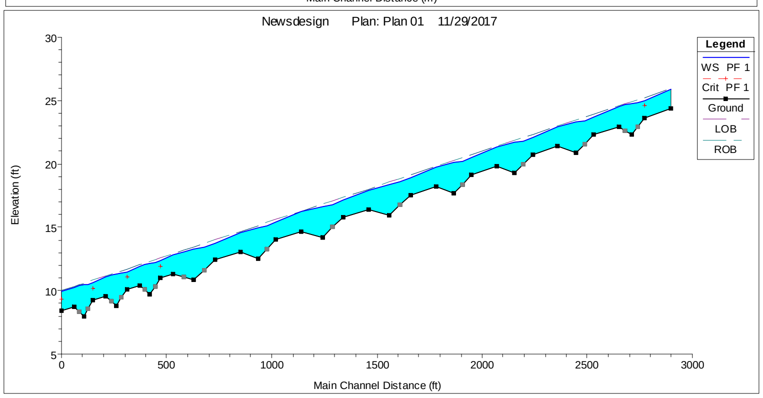


Figure 6. HEC-RAS profile for pre and post restoration design for a tributary of the Catalpa Creek

Student Training

Student involvement has played a significant role in the performance of this project and related collaborative efforts. The following students have been involved in the different activates of the project working as graduate research assistants, undergraduate researchers sponsored by the Bagley College of Engineering, MAFES, MWRRI, undergraduate researchers advancing Directed Individual Study or volunteering their work, all of them integrating the Watersheds and Water Quality Research Lab (http://www.cee.msstate.edu/wwqrl/). In addition, students in the courses Open Channel Hydraulics, Engineering Hydrology and Stream Reconnaissance have been involved in the research activities by advancing academic exercise through the completion of Final Projects to fulfill the course requirements.

James Grafe - Master Student, Civil and Environmental Eng
Bradley Richardson – PhD Student, Wildlife, Fisheries & Aquaculture
Jim Steele - Senior, Civil and Environmental Eng
Taylor Noble - Senior Civil and Environmental Eng
Harley Wilkinson - Senior, Civil and Environmental Eng
Jennifer Deignan, Senior, Civil and Environmental Eng
Geneva Cattle - Senior, Agricultural and Biological Eng
Taylor Buie - Senior, Civil and Environmental Eng
Ben Spiller - Senior, Civil and Environmental Eng
Claire Ray - Senior, Civil and Environmental Eng
Germaine Cole - Senior Civil and Environmental Eng

Diana Linder - Senior Civil and Environmental Eng
Nathan Forbes - Senior, Civil and Environmental Eng

Future Work

During the summer 2018 the different parameters needed to setup the proposed models will be estimated and determined. Models will be setup and completed. A Master thesis is in progress, however, the completion of the graduate study and the related final document is not expected to occur before the submission of the final report of this project. Presentations involving the different projects associated to the Catalpa Creek will be given at different regional and National Conferences during the summer and fall semester.

We expect to finish our analyses and assessments to have more conclusive results, but preliminary results and observations validate our proposed research hypothesis.

Conference Presentations and Posters

Ramirez-Avila, J.J., T. Schauwecker, J. Czarnecki, E. Langendoen, S. Ortega-Achury & J. Martin, 2018. Quantifying and Modeling in-Stream Processes: A first step to restore the Catalpa Creek. 2018 World Environmental & Water Resources Congress. Minneapolis, MN. Oral Presentation.

Ramirez-Avila, J. J., Schauwecker, T., Martin, James L., Ortega-Achury, S. L. & Prince Czarnecki, J. M. 2018. A Project Based Learning Study Oriented to Develop a Natural Stream Restoration Design. Mississippi Water Resources Conference. Jackson, MS. Oral Presentation.

Ramirez-Avila, J. J., Grafe, J., Schauwecker, T., Prince Czarnecki, J. M., Ortega-Achury, S. L., Martin, James L. & Noble, T. 2018. Impacts of Riparian Buffer Zones on Stream Water Quality: A Quantitative Assessment in the Catalpa Creek Watershed. Mississippi Water Resources Conference. Jackson, MS. Oral Presentation.

Ramirez-Avila, J.J., E. Langendoen, T. Schauwecker, S. Ortega-Achury, J. Czarnecki, W. McAnally and J. Martin. 2017. Estimación y predicción de descargas de sedimentos y tasas erosión de bancos fluviales. Invited Speaker. 1st International Congress of Rivers and Wetlands. Neiva, Colombia. (Invited Speaker)

Ramirez-Avila, J. J. 2017. Sediment Budget: From Hillslope to in-Stream Processes. 2017 ASA, CSSA, and SSSA Annual Meeting. Symposium -Managing Water Resources for a Secure Future. Tampa, FL. (Invited Speaker)

Students Papers and Presentations

Steele, J., J. Grafe and J. J. Ramirez-Avila. 2018. Analyzing Suspended Sediment Transport in Catalpa Creek. 2018 World Environmental & Water Resources Congress. Minneapolis, MN. Oral Presentation and Undergraduate Research Paper.

Wilkinson, H., B. Spiller, N. Forbes, J. Ramirez-Avila. 2018. A comparison of water quality conditions of stream segments under forested and herbaceous riparian zones. 2018 World Environmental & Water Resources Congress. Minneapolis, MN. Oral Presentation and Undergraduate Research Paper.

Grafe, J., Ramirez-Avila, J. J., Schauwecker, T., Ortega-Achury, S. L., Prince Czarnecki, J. M., & Langendoen, E. 2018. Understanding Relations between Streamflow, Turbidity, and Suspended-

Sediment Concentration in an Impaired Mississippian Stream. Mississippi Water Resources Conference. Jackson, MS. Oral Presentation.

Assessing the Effectiveness of Community-Based Research Strategies to Analyze Risk of Lead Contamination in Public Water Supplies in the Mississippi Delta

Basic Information

Title:	Assessing the Effectiveness of Community-Based Research Strategies to Analyze Risk of Lead Contamination in Public Water Supplies in the Mississippi Delta
Project Number:	2017MS210B
Start Date:	3/1/2017
End Date:	12/30/2018
Funding Source:	104B
Congressional District:	MS-001
Research Category:	Social Sciences
Focus Categories:	Water Quality, Law, Institutions, and Policy, Education
Descriptors:	None
Principal Investigators:	Kristine L. Willett

Publications

1. Quarterly reports submitted to Mississippi Water Resources Research Institute.
2. Showalter Otts, S., J. Green, K. Willett, C. Janasie, L. Woo. M.A. Fratesi, C. Thornton, B. Avula, and J. Rhymes. 2017. "Testing for Lead in Drinking Water in the Mississippi Delta through Community-Engaged Research: Findings from a Pilot Study and Next Steps for Expansion." Poster Presented at the Delta Regional Forum of the Delta Directions consortium. Clarksdale, MS.
3. Charleston Cooking class, September 2017 (Title: Community-Based Research Strategies to Analyze Risk of Lead Contamination in Public Water Supplies in the Mississippi Delta)
4. Train-theTrainers workshop with Right! From the start maternal and child health program.
5. Willett, K.L., Otts. S.S., Green, J.J., Janasie, C., Woo, L., Thornton, C., Fratesi, A., Avula, B., Khan, I., Rhymes, J. Research Strategies to Engage Communities in the Analysis of Lead Contamination of Water Supplies in the Mississippi Delta. Poster Presentation. Society of Environmental Toxicology and Chemistry. November 2017.
6. J. Green, L.C. Woo, M. Fratesi, B. Parkman, S. Otts, C. Janasie, C. Thornton, B. Avula, K. Willett, J. Rhymes, S. Snell, Strategies to Analyze Risk of Lead Contamination in Public Water Supplies in the Mississippi Delta: Contributions from Community-Based Research 2017 Mississippi Public Health Association (MPHA) conference, Oct. 12-13, 2017, Jackson, MS.
7. S. Otts and C. Janasie, National Sea Grant Law Center, How Safe is the Water?: An Analysis pf the Lead Contamination Risks of Public Water Supplies in the Mississippi Delta (Dec. 2017), http://nsglc.olemiss.edu/projects/lead-contamination/files/howsafeiswater.pdf.
8. Wolfe, J., Identifying and responding to lead hazards in water. HLS Mississippi Delta Spring Break Pro Bono Trip 2018.
9. Syedman. Proactively reducing exposure to lead through water. HLS Mississippi Delta Spring Break Pro Bono Trip 2018.
10. Lee, Jude. Identifying and treating children with EBLLs. HLS Mississippi Delta Spring Break Pro

Bono Trip 2018.

11. Green John J., Mary Alexandra Fratesi, Lynn Woo, Kristie Willett, Cammi Thornton, Bharthi Avula, Ikhlas Khan, Stephanie Otts, and Catherine Janasie. April 3-4, 2018. Informing Environmental Health through Community-Engaged Research: Testing for Lead in Drinking Water in the Mississippi Delta." Poster presented at the Mississippi Water Resources Conference. Jackson, MS.
12. Otts, S.and C. Janasie. April 3-4, 2018. An Analysis of the Lead Contamination Risks of Public Water Supplies in the Mississippi Delta. Platform presented at the Mississippi Water Resources Conference. Jackson, MS.
13. Willett, K.L., Green, J.J., Otts, S. April 4, 2018. Strategies toAnalyze Risk of Lead Contamination in Public Water Supplies in the Mississippi Delta: Contributions from Community-Based Research, University of Mississippi Medical Center Research Day 3-Minute Lecture. Jackson, MS.
14. Alex Fratesi. April 7, 2018. "Lead Exposure in Drinking Water: What It Means and Ways to Manage It" presented at New Pathways to Health Fair. Ruleville, MS.
15. Drinking Water and Lead Contamination in the Mississippi Delta, National Sea Grant Law Center, http://nsglc.olemiss.edu/projects/lead-contaimination/index.html (project webpage).

Mississippi Water Resources Research Institute (MWRRI)

Annual Report – 07/01/2017 – 05/25/2018

Project Title: Assessing the Effectiveness of Community-Based Research Strategies to Analyze Risk of Lead Contamination in Public Water Supplies in the Mississippi Delta
Principal Investigator: Kristine Willett; Co-Investigators: John Green and Stephanie Otts
Institution: University of Mississippi
Address: 303A Faser Hall University, MS. 38677
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E-Mail: kwillett@olemiss.edu

Background: Childhood lead poisoning is a challenging social issue that requires the coordination of health, housing, and environmental law and policy. There is no safe blood level for lead, and the Centers of Disease Control (CDC)[1] states that "all sources of lead exposure for children should be controlled or eliminated." Since 1978, when the use of lead-based paint was banned in the United States, environmental and health policy has focused on reducing childhood exposure to lead-based paint and the dust produced as it deteriorates. Policy-makers have focused much less attention to the exposure to lead through other sources, despite the fact that in up to 30% of cases of children with elevated blood lead levels there is no immediate lead paint hazard[2].The environmental health crisis in Flint, Michigan has raised awareness of the danger that may be present in drinking water when the delivery infrastructure includes lead pipes.

Mississippi communities face similar public health threats from lead exposure. A recent HealthGrove analysis of state reporting data from 2014 ranked Mississippi as one of the top 20 (#18) worst states for lead poisoning[3]. Each year around 200 children in Mississippi are diagnosed with lead poisoning. The actual number of cases is likely much higher, as screening is not mandatory and the number of children screened in Mississippi has declined in recent years. African-American children and children of low-income families are at greater risk of lead exposure due to economic, health, and housing disparities (living in older or poorly maintained housing). As such, research on lead hazards has significant racial and environmental justice components[4,5].

Like national policy-makers and agencies, the Mississippi State Department of Health (MSDH) has predominately focused on lead-based paint hazards. In recent months, however, lead contamination of drinking water has begun to garner some attention. Under the federal Safe Drinking Water Act, the EPA has issued regulations covering lead and copper contamination in drinking water, known as the Lead and Copper Rule (LCR). Under the LCR, the lead action level is exceeded if the concentration of lead in more than 10 percent of tap water samples is greater than 0.015 mg/L (15 ppb)[6]. In January 2016, the City of Jackson, MS revealed that 22% of homes tested in a June 2014 sampling event had lead levels exceeding federal action levels. On February 24, 2016, the MSDH issued an advisory to residents receiving water from the City of Jackson Water System to take precautions to minimize lead exposures, citing ongoing concerns with the City's corrosion control system. Almost 11% of homes tested in a 2016 sampling event exceeded federal action levels[7].

Little is known about the contribution of lead pipes and water treatment to lead poisoning in the state. The use of lead pipes in public water systems and residential plumbing was banned in 1986. Federal law, however, did not require the removal or replacement of existing lead service lines. Homes and drinking water systems built before 1986 are therefore likely to have lead pipes and an increased risk of lead contamination. According to the U.S. Census Bureau's American Community Survey, 70% of the current housing stock in the U.S. was built before 1989[8]. The housing stock in the Mississippi Delta is slightly older. In some counties, pre-1989 structures account for over 80% of the housing stock[9]. Given the age of housing in the region and lack of resources to upgrade public infrastructure, drinking water may be a significant contributing factor to childhood lead poisoning.

The LCR required public water systems to conduct an evaluation of pipes and plumbing materials within their distribution systems to inform the development of LCR sampling plans. In February 2016, the EPA encouraged states to increase transparency in LCR implementation by, among other things, working with public water systems to make these materials inventories publicly available. In response, the MSDH's Bureau of Public Water Supply has stated that it will require all water systems subject to the LCR to annually submit a material inventory or map of lead service lines and lead plumbing[10]. EPA released a LCR Revisions White Paper[11] that reinforces the requirement that drinking water utilities update their distribution system materials inventory to identify the number and location of lead service lines in their system and to identify and evaluate incentives and creative funding mechanisms related to the use of Drinking Water State Revolving Fund. Complying with this directive will be difficult for many public water systems within the state as federal law did not expressly require the retention of records related to the LCR materials inventory. Many water systems, therefore, may have little to no information regarding the location of lead materials within their distribution systems. This deficiency has been noted by the MS WRRI in that the 2017 Research Priority Areas now include a new emphasis area under the "Drinking Water and Waste Water Research" category associated with Mitigation of Lead Corrosion in PWSs.

The monitoring of lead is done through sampling of household tap water. Under federal law, samples are supposed to be collected from sites that are more likely to have lead in their plumbing materials. Sampling, however, often occurs at locations without lead service lines. As mentioned, public water systems may not know where the lead service lines are or sample sites may be selected based on ease of access or homeowner cooperation. Independent testing, such as that performed in Flint[5] and other cities[12], often reveal discrepancies as a result of different site selection.

In order to engage communities and empower homeowners, the Project Team proposes to leverage and expand our existing collaborations with two programs underway in the Mississippi Delta. Our research is designed to inform policy and decision-making on the current state of lead contamination of drinking water in Mississippi and to quantitatively investigate the most effective ways to engage community stakeholders in issues of their own safety and health.

Methods: The Project Team has worked with community and regional organizational partners to conduct this study using five methods of outreach, engagement, and recruitment. Depending on the recruitment method, the Project Team shared information about the public health risks associated with lead-contaminated drinking water through formal workshops, classroom presentations, and "train-the-trainer" activities. All participants received a general overview of the problem of lead contamination in drinking water, including presentations and information on water quality, environmental law, environmental toxicology, and health. Participants were trained on how to identify lead plumbing materials and water sampling methods with specific instructions on how to collect and handle a "water from the tap" sample.

Figure 1. The seven delta counties that will be the focus of this research project (grey).

Following the education and training phase, project participants collected water samples from their homes (or with one initiative from service-recipients' homes) and delivered the samples to the Project Team for lead analysis. Participants collected one-liter samples of cold tap water in HDPE bottles provided by the Project Team. As most consumers do not routinely flush their pipes before drinking or using tap water, participants collected "first draw" samples – a one-liter sample collected from a tap after a greater than 6 hour holding time in household plumbing. Samples were stored by project partners for no more than two weeks before collection by Project Team. The pH of the samples were measured before they underwent standard acid preservation (preserved to pH < 2) before analysis. The water samples were analyzed in compliance with EPA Method 200.8 (ICP-MS)[13] to quantify the total recoverable lead in drinking water. All samples were analyzed in duplicate and at least 10% of the samples were injected twice for ICP-MS quality control. The six point standard curve ranges from zero to 100 ppb. Samples were analyzed blind to sample collection location.

The Project Team also conducted research on the effectiveness of community engagement strategies through a comparative analysis of five different outreach and engagement methods designed to engage a wider segment of community members in the Mississippi Delta. Thus, our research question was: Which of our five different approaches to community engagement will be most effective? Which approach(es) will lead to the highest return rate of water sample bottles? The effectiveness of the outreach and recruitment strategy will be measured by the number of survey and water sample pairs returned. These five strategies are outlined below.

1. Continued partnership with the Tri-County Workforce Alliance's health professions program and other health education and professional development programs for middle and high school students and their families. Building off the successful pilot project described above, incoming students and their parents will be invited to participate in a workshop to learn about environmental health, drinking water, and lead concerns. They will participate in a survey on household characteristics and housing conditions and then receive a water bottle and training for collecting water samples. To avoid duplication of water sampling efforts, water samples will be collected only once from students and their families participating in TCWA during multiple years and across programs. These students, however, will be encouraged to participate in additional training workshops and collect information on plumbing materials, which was not a component of the 2016 project.

2. Partnership with an existing school health promotion program – School health council students and their families will be engaged through the Tri-County Workforce Alliance and Aaron E. Henry Community Health Services Center. Similar to the other students in TCWA's programs, school health council students will receive information on environmental health, drinking water, and lead concerns. The school health council students and their families will participate in the housing survey and receive training on the collection of water samples and identification of lead plumbing materials. The distribution and collection of sample bottles will be conducted in association with school health council events or programming.

3. Partnership with a summer camp for youth – Healthy, Set, Go Summer Camp for Youth families will be engaged through the Tri-County Workforce Alliance and Aaron E. Henry Community Health Services Center. Parents who enroll their children in this two-week summer camp will be asked to participate in this project. Education and outreach activities on the risks of lead contamination and environmental health concerns will be incorporated in the summer camp's existing curriculum and programming. Sample bottles will be distributed and collected during the two-week summer camp.

4. Partnership with a home-visiting program for maternal-child health – Right! from the Start Initiative mothers who are breastfeeding babies will be engaged by Women and Children Health Initiatives. Infants are especially susceptible to the impacts of lead and can be exposed to lead if formula is prepared using lead contaminated tap water18. Community health workers, social workers, and lactation consultants providing services to mothers who are breastfeeding their babies will be trained for this project, and they will then provide their mothers with the opportunity to participate in this project. As with the TWCA participants, Right! from the Start Initiative mothers who agree to participate will complete the housing survey, provide water samples, and gather information on plumbing materials in their homes.

5. Partnership with a health fair organized by the UM School of Pharmacy or associated organization (e.g. Tallahatchie Wellness Center) – The Project Team will design and staff an educational booth/tent on lead contamination of drinking water at a community health fair in the Mississippi Delta during the project period. Attendees interested in participating in the water sampling efforts will be asked to complete the survey and provided with a water bottle and training for collecting water samples. The Project Team will identify a central location for sample drop-off/pick-up.

All project participants received individual letters sharing the water testing results from their homes and encouraging them to attend a community workshop(s) where the overall project results will be shared. Individual results are added to project databases and shared with project participants as they become available.

Following the water sampling/analysis and survey collection, the Project Team undertook legal and demographic/socio-economic research to more fully understand the socio-economic factors affecting the quality of drinking water in the Delta. The Project Team conducted legal research on existing federal and state law and policy enacted to address lead contamination risks within public water systems in the state.

The Project Team analyzed the neighborhood/community conditions (including population and housing units, age of housing, poverty, and other indicators). Utilizing the aggregated spatial data, analytic capabilities, and mapping resources of the Center for Population Studies and its State Data Center, this research identified the characteristics of the places where the lead levels are the highest, which could then help to inform where additional testing or infrastructure funding is needed.

Results:

The project team organized six collection events (New Pathways to Health Initiative/Tri-County Workforce Alliance, Right! from the Start church program, a healthy cooking class at the James C. Kennedy Wellness Center, a Free Well-Owner Workshop and Screening event, a Train-the-Trainers Workshop with Right! from the Start Maternal and Child Health Program, and a New Pathways to Health Fair) this year, distributing 170 bottles. 151 water samples were returned for testing and 169 surveys were also received (147 households responded to the survey and returned water samples).

At the New Pathways to Health Initiative/Tri-County Workforce Alliance event, 69 of 88 (78%) bottles were returned. The pH of these samples ranged from 7.04-8.23. Forty-five of the 69 bottles had non-detectable concentrations of lead. Twenty-four of the 69 bottles had lead concentrations ranging from 0.101-3.33 ppb. None of the 69 samples exceeded 15 ppb lead. At the Right! from the Start church program event, 42 of 42 (100%) bottles were received The pH of these samples ranged from 7.7-8.7. Twenty-four of the 42 samples had non-detectable concentrations of lead. Eighteen of the 42 samples had lead concentrations ranging from 0.32-7.4 ppb. None of the 42 samples exceeded 15 ppb lead. At the James C. Kennedy Wellness Center (healthy cooking class) in Charleston, MS., 7 of 10 (70%) bottles were returned. The pH of the water ranged from 7.27-7.94. One of the seven samples had non-detectable concentrations of lead. Five of the seven samples had lead concentrations ranging from 0.58-1.5 ppb. None of the seven samples exceeded 15 ppb lead. At the Free Well-Owner Workshop and Screening event at the Panola county extension office, 21 of 39 (54%) bottles were returned. The pH ranged from 5.84-8.36. Five of the 20 samples had non-detectable concentrations of lead. Fifteen of the 20 samples had lead concentrations ranging from 0.29-14 ppb. None of the 12 samples exceeded 15 ppb lead. At the Train-the-Trainers Workshop (Right! from the start maternal and child health program), 12 of 12 (100%) bottles were returned. The pH of these samples ranged from 7.45-8.57. Four of the 12 samples had non-detectable concentrations of lead. Eight of the 12 samples had lead concentrations ranging from 0.20-6.5 ppb. None of the 12 samples exceeded 15 ppb lead. At the New Pathways to Health Fair in Ruleville, MS., 21 of 23 (91%) bottles were returned. The pH ranged from 7.66-8.45. These samples are currently being run to quantify the lead present. Overall, the pH of the waters ranged from 5.84 to 8.69. All concentrations were below the EPA 15 ppb action level. Of the 149 waters analyzed to date, 82 samples (55%) had non-detectable lead concentrations. Therefore, 45% (67 samples) had detectable lead concentrations that ranged from 0.102 to 14.3 ppb. Of those 67 samples with detectable lead, 8 samples exceeded 5 ppb lead. Five of the eight samples that had lead concentrations above 5 ppb had pH levels below 7 suggesting a correlation between acidic water leaching lead from pipes. However, seven samples had pH less than 7 and the lead concentrations did not exceed 5 ppb, with one of those samples being non-detectable. Therefore, low pH does not always indicate the presence of lead in drinking water.

The National Sea Grant Law Center produced a webpage (http://nsglc.olemiss.edu/projects/lead-contamination/index.html) and report entitled “How Safe is the Water?: An Analysis of the Lead Contamination Risks of Public Water Supplies in the Mississippi Delta.” (http://nsglc.olemiss.edu/projects/lead-contamination/files/howsafeiswater.pdf). This report summarized the legal framework governing the provision of public water supplies in Mississippi and presents the lead monitoring data of public water systems in selected counties in the Mississippi delta. This data was extracted from the Mississippi Drinking Water Watch, a publicly accessible databased maintained by the MSPH and U.S. Environmental Protection Agency. This research reveals a number of legal gaps and challenges to reducing lead exposure from public drinking water supplies in Mississippi. The report concludes with a discussion of these challenges and considers actions that policy-makers, water supply systems, community organizations, and others might take to better protect public health. This report will assist the project team in targeting future collection events to high-risk counties and public water systems and developing more in-depth outreach presentations and materials on the legal framework.

Table 1. Lead in water project household characteristics
(Households returning both questionnaires and water samples)

Characteristics		*f*	%
Housing tenure (n=144)	Renters	36	25.0
	Owners	102	70.8
	Other arrangement	6	4.2
Housing type (n=146)	House	122	83.6
	Mobile home	10	6.8
	Apartment	14	9.6
Know when built (yes) (n=142)		80	56.3
Built 1985 or earlier (yes) (n=77)		37	48.1
	Yes	21	16.4
		43	33.6
		64	50.0
		39	26.5
		43	29.3

Table 2. Lead and pH levels in water project testing results (ppb)
(Households returning questionnaires and water samples, n=147)

Characteristics	Lead (ppb)	pH
Mean	0.91	7.65
Median	0.01	7.75
Standard deviation	2.13	0.51
Minimum	0	5.84
Maximum	14.32	8.69

Some of the problems that we have encountered during this year have included participants not recording the date the sample was collected, which it is important for the samples to be acidified within 2 weeks of collection to preserve the lead, and participants not recording the address on the sample bottles, which we use to verify that the address on the sample bottle corresponds to the address on the survey. Therefore, we will be working to develop methods to ensure participants’ understanding of the sampling protocols.

Summary: The methods used for this project were effective for obtaining water samples from a range of households and places. The data are now being analyzed in the context of census geographies and water districts to identify geographic, demographic, and socioeconomic patterns. The research team is also assessing the efficiency and efficacy of the community engagement methods to scale up and inform policy recommendations. The project is being expanded to include more households by working with additional partners.

Future Plans:

- Tri-County Workforce Alliance’s High School Mentorship Program in the Health Care Professions campus tours on June 13, 2018.
- Presentation at the University Council on Water Resources conference in Pittsburg, PA June 26-28, 2018.
- Informational table and bottle distribution at Health Centers (Aaron E. Henry Community Health Services Center, Inc. (specifically Tunica and Batesville) and Delta Health Center (potentially Greenville, Hollandale, and Moorehead).
- Propose a joint session at the 2018 Delta Regional Forum in Clarksdale (July 18-19).
- Expansion of summary report to include remaining at-risk counties for lead (additional 11

counties throughout the state).

Publications/Presentations:

- Showalter Otts, S., J. Green, K. Willett, C. Janasie, L. Woo, M. A. Fratesi, C. Thorton, B. Avula, and J. Rhymes. 2017. “Testing for Lead in Drinking Water in the Mississippi Delta through Community-Engaged Research: Findings from a Pilot Study and Next Steps for Expansion**.”** Poster Presented at the Delta Regional Forum of the Delta Directions Consortium. Clarksdale, MS.
- Charleston Cooking Class, September 2017 (Title: Community-Based Research Strategies to Analyze Risk of Lead Contamination in Public Water Supplies in the Mississippi Delta)
- Train-the-Trainers workshop with Right! from the start maternal and child health program.
- Willett, K.L., Otts, S.S., Green, J.J., Janasie, C., Woo, L., Thornton, C., Fratesi, A., Avula, B., Khan, I., Rhymes, J. Research Strategies to Engage Communities in the Analysis of Lead Contamination of Water Supplies in the Mississippi Delta. Poster Presentation. Society of Environmental Toxicology and Chemistry. November 2017.
- J. Green, L.C. Woo, M. Fratesi, B. Parkman, S. Otts, C. Janasie, C. Thornton, B. Avula, K. Willett, J. Rhymes, S. Snell, Strategies to Analyze Risk of Lead Contamination in Public Water Supplies in the Mississippi Delta: Contributions from Community-Based Research 2017 Mississippi Public Health Association (MPHA) conference, Oct. 12-13, 2017, Jackson, MS.
- S. Otts & C. Janasie, National Sea Grant Law Center, How Safe is the Water?: An Analysis of the Lead Contamination Risks of Public Water Supplies in the Mississippi Delta (Dec. 2017), http://nsglc.olemiss.edu/projects/lead-contamination/files/howsafeiswater.pdf
- Willett, Green, and Showalter-Otts collaborated with Susana Cervantes from Harvard Law School in mentoring three students during the HLS Mississippi Delta Spring Break Pro Bono Trip 2018. Three reports summarizing their research were written resulting from this mentorship.
    - Wolfe. Identifying and responding to lead hazards in water. HLS Mississippi Delta Spring Break Pro Bono Trip 2018
    - Svedman. Proactively reducing exposure to lead through water. HLS Mississippi Delta Spring Break Pro Bono Trip 2018
    - Lee, Jude. Identifying and treating children with EBLLs. HLS Mississippi Delta Spring Break Pro Bono Trip 2018
- S. Otts & C. Janasie, An Analysis of the Lead Contamination Risks of Public Water Supplies in the Mississippi Delta, Mississippi Water Resources Conference, April 4, 2018, Jackson, MS. http://nsglc.olemiss.edu/projects/lead-contamination/files/mwrri2018.pdf
- Green, John J., Mary Alexandra Fratesi, Lynn Woo, Kristie Willett, Cammi Thornton, Bharthi Avula, Ikhlas Khan, Stephanie Otts, and Catherine Janasie. April 3-4, 2018. "Informing Environmental Health through Community-Engaged Research: Testing for Lead in Drinking Water in the Mississippi Delta." Poster Presented at the Mississippi Water Resources Conference. Jackson, MS.
- Willett, KL., Green, JJ., Otts, S. April 4, 2018. “Strategies to Analyze Risk of Lead Contamination in Public Water Supplies in the Mississippi: Contributions from Community-Based Research” University of Mississippi Medical Center Research Day 3-Minute Lecture. Jackson, MS.
- Alex Fratesi. April 7, 2018. “Lead Exposure in Drinking Water: What It Means and Ways to Manage It” New Pathways to Health Fair. Ruleville, MS.
- Drinking Water and Lead Contamination in the Mississippi Delta, National Sea Grant Law Center, http://nsglc.olemiss.edu/projects/lead-contamination/index.html (project webpage).

Student Training:

Name	Level	Major
Alex Fratesi	Undergraduate	Chemistry
Rachel Haggard	Graduate	Sociology
Katrina Alford	Graduate	Sociology
Heather Costa-Greger	Graduate	Sociology

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Information Transfer Program Introduction

MWRRI has a robust information transfer program that includes the following components:

1. The annual Mississippi Water Resources Conference, hosted by MWRRI, was held at the Jackson Hilton on April 11-12, 2017. Over 130 pre-registered to attend the conference – a 15% decrease from 2016 – a few participants registered onsite. Student participation also decreased slightly. The Proceedings can be reviewed at http://www.wrri.msstate.edu/pdf/2017_wrri_proceedings.pdf.

Researchers and students from colleges and universities as well as water resources planners, managers, and policy-makers from state and federal agencies, industry, and other backgrounds presented 53 oral presentations on the following topics: – Delta Sustainable Water Resources: Monitoring and Modeling – Water Treatment and Management – Delta Sustainable Water Resources: Irrigation Efficiency and Alternative Water Supplies – Statewide Management of Water Resources: MDEQ Office of Land and Water Resources – Agricultural Water Storage and Reuse – Modeling Applications – Coastal Restoration Projects – Nutrient Reduction – Surface Water-Groundwater Interaction – Ecological Studies – Innovative Studies and Applications I – Climate and Agronomics – Innovative Studies and Applications II – Mississippi River Basin Additionally, 14 posters were presented.

The opening plenary speakers were a panel discussion led by Mississippi Department of Environmental Quality presenting on Water Management to Ensure Water of Sufficient Quantity and Quality for a Sustainable Environment and Economy in Mississippi. Panelists included Kay Whittington, Kim Caviness-Reardon, Valerie Alley, Adrien Perkins, and Natalie Segrest. The lunch plenary speaker on Tuesday, April 11 was Kurt Readus, USDA NRCS State Conservationist, who spoke on NRCS' Efforts to Support Sustainable Water Resources in the Mississippi Delta.Wednesday's lunch speaker was Brian Clark, Hydrologist with U.S.Geological Survey Lower Mississippi-Gulf Water Science Center. Brian spoke about USGS' Regional Modeling Initiatives.

Through sponsorships, a student oral presentation competition was re-instated during this year's conference. Of the 33 students registered for the conference, 25 gave either oral or poster presentations. Cash prizes of $100 for 1st place, $75 for 2nd place, and $50 for 3rd place were awarded to the winners in both categories.

2. MWRRI website (http://www.wrri.msstate.edu/about.asp) is maintained by MSU's Agricultural Communications Department and is constantly updated with information on water resources research and management activities.

3. MWRRI publishes an annual report every year detailing activities, funded research, and publications/presentations.

4. MWRRI Listserv contains over 900 members who regularly receive updates on water resources information.

5. MWRRI staff present numerous presentations throughout the year and participate in water resources-related meetings throughout the state.

6. MWRRI reports to MSU's Vice Presidents for Research and Economic Development and Agriculture, Forestry, and Veterinary Medicine and closely collaborates with MSU Extension and Mississippi Agriculture and Forestry Experiment Stations.

7. MWRRI’s DREAMS (Demonstration, Research, Education, Application, Management and Sustainability) Center, when established, will be primarily focused on technology transfer.

USGS Summer Intern Program

None.

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	25	0	0	0	25
Masters	7	0	0	0	7
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	34	0	0	0	34

Notable Awards and Achievements

Implementation Plan for the Red Bud-Catalpa Creek Watershed – Phase 1. During 2016, MWRRI led development of the Implementation Plan for the Red Bud–Catalpa Creek Watershed Phase 1. The Phase 1 implementation plan builds upon the comprehensive Water Resources Management Plan for the Red Bud–Catalpa Creek Watershed developed collaboratively by 18 University units during 2015, and describes specific water quality and habitat restoration activities recommended for the headwaters of the Red Bud–Catalpa Creek Watershed in the proximity of MSU's H.H. Leveck Animal Research Center (South Farm). The comprehensive plan calls for the installation of 24 best management practices (BMPs) in three delineated critical management areas, details an information and education program, describes a monitoring program to quantify the effectiveness of the installed BMPs, establishes an implementation schedule with measurable milestones and project outcomes, and contains a detailed budget. The plan also includes the coordination and leveraging of four complementary monitoring and modeling projects. The plan was developed by numerous contributors from Mississippi State University's Agricultural and Forestry Experiment Station; Department of Animal and Dairy Sciences; Department of Fisheries, Wildlife, and Aquaculture; Department of Civil and Environmental Engineering; Department of Landscape Architecture; Extension Service; Geosystems Research Institute; REACH (Research and Education to Advance Conservation and Habitat) Program; Mississippi Water Resources Research Institute as well as staff from the Mississippi Department of Environmental Quality, Mississippi Soil & Water Conservation Commission, and USDA's Natural Resources Conservation Service.

Funding to support implementation of the plan was awarded from the Mississippi Department of Environmental Quality and USEPA through the 319(h) Nonpoint Source Program ($274,726 award with a match requirement of $182,971), the Mississippi Agriculture and Forestry Experiment Station and its Strategic Research Initiative ($17,980 in awards with a match total of $33,300). The total investment to implement the Phase 1 plan is $620,471 with all funding secured.

Watershed DREAMS (Demonstration, Research, Education, Application, Management and Sustainability) Center. The establishment of a Watershed Demonstration, Research, Education, Application, Management and Sustainability (DREAMS) Center on the South Farm will serve as a showcase for watershed management throughout the state and southeast through the watershed-based restoration and protection activities affiliated with the Catalpa Creek Watershed Project. This center will be useful to state and federal agencies, water management districts, stakeholder and community service organizations, university departments and programs, secondary education teachers and students, local governments, and others. Beyond complementing the Catalpa Creek project, the center will focus generally on water resources, watersheds, and the ecosystem services they provide in a hands-on interactive way. It is envisioned that the Center will: • Demonstrate the effectiveness of innovative and established sediment, nutrient, pathogen and other Best Management Practices (BMPs); • Demonstrate innovative water management approaches; • Advance innovative concepts and applications that address water resources and watershed management research needs; • Provide for technology transfer of applications developed by MSU researchers to water resources planners, managers, water users, and other stakeholders; • Educate water resources and watershed planners, managers, policy-makers, and other stakeholders about important watershed concepts; and • Demonstrate MSU's capacity to effectively address a wide range of water resources and watershed issues occurring throughout the state and region.

MSU's campus and its South Farm (H.H. Leveck Animal Research Center) are located in the headwaters of the Catalpa Creek Watershed which presents numerous opportunities for leveraging numerous MSU activities and assets. Of all the land grant universities in the United States, the South Farm is one of the largest land reserves adjacent to a university campus. It encompasses about 1,600 acres used for cattle, equine and poultry management research. The South Farm also hosts a NRCS Grazing Lands Conservation Initiative demonstration site, 18 acres of aquaculture ponds, and various water quality research projects. These projects include monitoring nutrient and sediment runoff under varying climatic conditions and cattle management scenarios, comparison of hydrologic modeling outcomes to evaluate pre and post BMP implementation related to dairy and poultry management, identification of potential environmental problem areas throughout South Farm that could impact Catalpa Creek, and development of baseline water quality information and a monitoring plan for Catalpa Creek.