Tennessee Water Resources Research Center Annual Technical Report FY 2014

Introduction

Introduction

Water Resources Issues and Problems of Tennessee

Tennessee is fortunate to have what many consider to be an abundant and good quality water supply. Historically, federal government agencies, such as the Tennessee Valley Authority (TVA), Army Corps of Engineers, Natural Resource Conservation Service, U.S. Geological Survey and others, have been the primary contributors to the management and monitoring of water resources. In recent years, however, the State, through the Tennessee Departments of Environment and Conservation, Wildlife Resources, Agriculture and others, have begun to develop a more active and aggressive role in the management and protection of these resources. The State has moved to establish an integrated and coordinated policy and administrative system for the management of water resources in Tennessee.

While the situation is improving, there remain many of the additional types of water problems. Although the overall supply of water is adequate, the distribution is still not optimal. Local shortages occur during dry periods. The summer of 2007 was a particularly hot and dry one. During this period over 35 water districts out of a total of 671 public systems in Tennessee experienced lesser degrees of difficulty in supply water. Beginning in 2006 and continuing on through the summer of 2008, Tennessee experienced another major drought period which severely strained the water supplies of many communities across the state. In recent years, many of the small municipal water suppliers and utility districts that rely on wells, springs, or minor tributaries for their water sources continue to face severe water shortage problems. All across the state many private, domestic, and commercial use wells have become severely strained, forcing users to seek alternative sources of water. Providing an adequate supply of water for industrial, commercial, and domestic uses and the protection of these surface and groundwater resources are of major concern in all regions of the state and vital to the economic development and growth of the state

Groundwater presents a particular challenge in Tennessee. Over 50% of the population of Tennessee depends on groundwater for drinking water supply. In West Tennessee, nearly all public suppliers, industries, and rural residents use groundwater. However, not enough is known about the quality and quantity of groundwater in the state, and consequently, maximum benefit from and protection of this resource cannot be easily accomplished. More information about the quality of the state's groundwater, particularly about the potential impact of recharge areas, is needed in order to develop an effective management and protection program for this valuable resource.

There is also the problem of potential contamination of groundwater from agricultural and urban non-point sources. The "fate and transport" of agricultural chemicals (herbicides and pesticides) and toxic substances in groundwater is a problem area that must be addressed if the state's groundwater protection strategy is to be effective in protecting this vital resource.

There is also the problem of potential contamination of groundwater from agricultural and urban non-point sources. The "fate and transport" of agricultural chemicals (herbicides and pesticides) and toxic substances in groundwater is a problem area that must be addressed if the state's groundwater protection strategy is to be effective in protecting this vital resource.

Water quality problems continue to persist from past industrial practices, from the surface mining of coal and other minerals (especially from abandoned mines), from agricultural and urban nonpoint sources and from improperly planned, designed and operated waste disposal sites. As has been the situation in the past, the state's program for the construction of municipal wastewater treatment facilities and improved operation and management of the facilities have experienced numerous set-backs due to shortfalls in funding and administrative delays. In major urban areas that have combined storm and sanitary sewers, urban storm water runoff causes increased pollution and, during periods of wet weather, bypasses treatment facilities, which allows raw sewage to enter receiving waters untreated. Tennessee cities, both large and small, are concerned about current (and future) impacts of the new NPDES storm water discharge permit requirements on clean up needs and costs. In certain regions of the state, failing septic fields and the practice of blasting bedrock for new septic fields are serious threats to surface and groundwater resources.

There are existing programs which can address many of these problems. However, some problems do not have easy solutions. Additional research can also play a role in understanding and solving these problems, but the greatest impediments are the lack of agreement between competing interests and a shortage of financial support for existing programs. From the viewpoint of the State government, the legal, institutional, and administrative aspects of water management are major concerns. The state is still working to develop new policy and to refine administrative structure for the effective management of its water resources.

To address the problems and issues of effective water resources management in the state of Tennessee, a truly interdisciplinary and well-coordinated effort is necessary. The Tennessee Water Resources Research Center has the capability and organization that can call upon the diverse set of disciplinary expertise necessary to address the key water issues of the state and region.

The Tennessee Water Resources Research Center: Overview of Program Objectives and Goals:

The Tennessee Water Resources Research Center serves as a link between the academic community and water-related organizations and people in federal and state government and in the private sector, for purpose of mobilizing university research expertise in identifying and addressing high-priority water problems and issues and in each of the respective state regions.

The Tennessee Water Resources Research Center, located at the University of Tennessee, is a federally-designated state research institute. It is supported in part by the U.S. Geological Survey of the U.S. Department of Interior under the provisions of the Water Resources Research Act of 1984, as amended by P.L. 101-397 and 10 I - 1 47. The Act states that each institute shall:

I. plan, conduct or otherwise arrange for competent research that fosters the entry of new research scientists into the water resources fields; the training and education of future water scientists, engineers and technicians; the preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena, and the dissemination of research results of water managers and the public

II. cooperate closely with other colleges and universities in the state that have demonstrated capabilities for research, information dissemination, and graduate training, in order to develop a statewide program designed to resolve state and regional water and related land problems.

In supporting the federal institute mandate, the TNWRRC is committed to emphasizing these major goals:

1. To assist and support all the academic institutions of the state, public and private, in pursuing water resources research programs for addressing problem areas of concern to the state and region.

2. To provide information dissemination and technology transfer services to state and local governmental bodies, academic institutions, professional groups, businesses and industries, environmental organizations and others, including the general public, who have an interest in water resources issues.

3. To promote professional training and education in fields relating to water resources and to encourage the entry of promising students into careers in these fields.

4. To represent Tennessee in the Universities Council on Water Resources, the American Water Resources Association (including Tennessee Section), the Water Environment Federation, the American Water Works Association, the International Erosion Control Association, the Soil and Water Conservation Society, the Lower Clinch Watershed Council, the ORNL-TVA-UT Research Consortium and the National Institutes for Water Resources (NIWR).

To work with these and other associations and with state, local and federal government agencies dealing with water resources in identifying problems amenable to a research approach and in developing coherent programs to address them. Particularly, to cooperate with the other state NIWR institutes and their regional groupings for assisting the U.S. Geological Survey in developing a national water resources management strategy.

In fulfilling the Center's major goals indicated previously, TNWRRC emphasizes the application of Section 104 grant and required matching funds for primarily supporting the research and training/education needs of the state. While the information dissemination and technology transfer portion of the Center's overall program does not receive direct or significant section 104 funding, this is accomplished primarily from the research and training activities of the Center from other funding sources--state, private, or non-profit. The Center recognizes that education and training, research, and information transfer are not independent objectives or are not mutually exclusive. Instead these goals are achieved through the administration of a coordinated, fully-integrated program within the limitations of the resources available to the Center.

Research Program Introduction

NONE

Evaluation of Bioretention Practices for Effective Stormwater Management and Treatment: A Laboratory to Field Study

Basic Information

Title:	Evaluation of Bioretention Practices for Effective Stormwater Management and Treatment: A Laboratory to Field Study
Project Number:	2011TN78B
Start Date:	3/1/2013
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	Second, Knox County, Tennessee
Research Category:	Water Quality
Focus Category:	Sediments, Non Point Pollution, Water Quality
Descriptors:	Stormwater Managemnet; Sediment; Infiltration; Bioretention; Water Quality
Principal Investigators:	Andrea Ludwig, Daniel Yoder

Publications

1. Ludwig, Andrea, R.A. Hanahan, R. Arthur, and T, Gangaware, 2013,Retrofitting Stormwater Infrastructure and perceptions in a Conventional Suburban Residential Development in East Tennessee, "in" Proceedings of the Twenty-Third Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN. 2B-6.
2. Ludwig, Andrea, M. P. Massey, and K. Neff,2013,Sate of LID in Tennessee, "in" Proceedings of the Twenty-Third Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN., 2A-16.
3. Ludwig, Andrea, R.A. Hanahan, R. Arthur, and T, Gangaware, 2013,Retrofitting Stormwater Infrastructure and perceptions in a Conventional Suburban Residential Development in East Tennessee, "in" Proceedings of the Twenty-Third Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN. 2B-6.
4. Ludwig, Andrea, M. P. Massey, and K. Neff,2013,Sate of LID in Tennessee, "in" Proceedings of the Twenty-Third Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN., 2A-16.
5. Ludwig, A.L.; J.R. Buchanan, 2013,Tennessee Storm-SMART Glossary of Terms for Stormwater Activity, Tennessee Extension, W301.
6. Ludwig, A.L.; R.A. Hanahan, 2013, Rainwater: Your Liquid Assess. A Homeowner Stormwater Activity, Tennessee Extension, W307.
7. Ludwig, A.L.; W.C. Wright, 2014, Measured Stormwater runoff Seasonal Variation in a Small Traditional Suburban Development in East Tennessee, "in" Proceedings of the Annual Conference of the Tennessee Stormwater Association, Nashville, TN.
8. Ludwig, A.L.;D. Yoder; J. Buchanan; J. Tyner, and T. Gangaware; 2015, Tennessee Runoff Reduction Assessment Tool (TNRRAT): A tool for Permanent Stormwater Management System Design, "in" Proceedings of the Twenty-fourth Annual Water Resources Symposium, Tennessee Section of the American Water Resources Association. Nashville, TN. pp. E12-16.

Evaluation of Bioretention Practices for Effective Stormwater Management and Treatment: A Laboratory to Field Study

Statement of Critical Regional or State Water Problems:

The leading cause of impairment in streams in the US is habitat alteration, which is a direct impact of sedimentation. Sediment pollution from urban areas has been shown to mostly come from failing streambanks that have eroded under increased bank shear stress. This increased shear stress is a result of the flashy hydrology that is characteristic of urban settings and is identified as one of the symptoms of the "urban stream syndrome," which describes the ecological degradation of streams draining urban landscapes (Walsh, Roy et al. 2005). Other symptoms are elevated concentrations of nutrients and pollutants, altered channel morphology, and reduced biotic richness.

There are over 60,000 stream miles in the State of Tennessee, and of the approximately 30,000 miles that have been assessed, only 54% were supporting all designated uses (Denton, Graf et al. 2010). This indicates that almost half of Tennessee streams exhibit degraded water quality. The leading causes of pollution in Tennessee streams and rivers are sediment/silt, habitat alteration, pathogens, and nutrients. Exacerbating this issue is a 60% loss of wetland areas in Tennessee as determined through historic data (Denton, Graf et al. 2010), which decreases land area that has the capacity to hold and treat flood waters and removes ecosystem services crucial to good water quality.

Statement of Results or Benefits:

The first phase of this project identified the following outcomes from the stated objectives: 1) a characterization of pollutants of concern for ecological function in surface waterways transported by stormwater from a residential development, 2) laboratory data to support recommendations of media layers for bioretention practices, 3) quantity and quality treatment efficiencies based on loading reductions due to BMPs in the Cedar Crossings development, and 4) begin a water quality monitoring database on the capacity of bioretention practices to meet infiltration requirements of permits for use by stormwater professionals.

The second phase will address the needs of the education and BMP adoption goals of the project team for Cedar Crossing neighborhood. The specific outcome will be a Home Stormwater Assessment Tool for assisting homeowners and stormwater professionals in selecting and implementing small-scale stormwater BMPs that will be transferable to other residential communities.

As of December 31, 2011, progress has been made on the stated objectives:

1) Characterization of pollutants: Two monitoring stations were installed in the project neighborhood to collect flow-weighted water quality samples and flow data during storm events. The first station is located at a drop inlet storm drain near the common space that is slated for the large-scale bioretention facility and sampling from a drainpipe that carries stormwater from an approximately 4-acre sewershed. This sewershed is representative of the single-family residential neighborhood. The second station is

located at the inlet to the detention basin that receives the majority of the runoff produced from the single-family units and condominiums. Stormwater hydrographs were developed for ten storm events between June and December 2011. Water quality analyses were performed on samples from five of these ten events. Additional sites were identified for grab water sampling in order to characterize stormwater at specific locations throughout the neighborhood.

2) Laboratory data for media: A prototype design was created for bioretention mesocosms that would be used in bench-scale experiments. Three different media mixtures and carbon sources were identified as test treatments in experiments and selection of appropriate instrumentation to measure storage volume has begun. A preliminary experiment was conducted to measure the amount of leachable nutrients from commonly used and readily assessable mulches.

3) Treatment efficiency determination: Treatment efficiencies will be characterized once BMPs are installed in the project neighborhood, beginning in 2012.

4) BMP water quality monitoring database: A database was conceptualized to include the following data on stormwater BMPs in Tennessee: site location (geographic coordinates), picture, stormwater source, inflow water quality data, outflow water quality data, storage, and other pertinent design parameters and site conditions.

This project neighborhood will serve as a long-term study location for ubran hydrology and stormwater management research. Additionally, it will be a demonstration of the retrofit of individual lots and neighborhood common spaces with small-scale stormwater practices. This demonstration is timely due to increasing regulations on stormwater from urban areas and the motivation of individual homeowners to minimize their impacts on the environment. The long-term goal of project cooperators is to increase BMP adoption by homeowners and condominium owners to create a model neighborhood community for retrofitting failing or substandard stormwater management controls. In order to accomplish this, residents must be educated on watersheds and stormwater management, potential impacts to water quality due to urban development, and effective solutions. An action plan was created by project cooperators to outline the approach, which is: 1) collect background data and anecdotal information regarding water quality and stormwater management in the area, 2) educate homeowners on the issues and needed solutions, 3) identify external cost-sharing opportunities for homeowners interested in lot-scale BMPs, 4) create a standardized method for assessing the stormwater footprint and appropriate BMPs for individual homes (the Home Stormwater Assessment), 5) identify and train needed professionals for stormwater BMP installations, 6) assist in neighborhood-scale implementations, and 7) continue to monitor hydrology and water quality throughout retrofit.

In October 2011, Cedar Crossing residents attended a 2-hr educational workshop from the *Tennessee Yards and Neighborhoods* team. Participants were given information about their home watershed (Beaver Creek), sources of stormwater in residential settings, and lot-scale BMPs to retain and filter stormwater. In phase two of this project, we will develop a 2-step Home Stormwater Assessment and pilot its use with residents of Cedar Crossing and the condominiums.

As of December 2012, progress was made on the following objectives:

1) Characterization of pollutants: Runoff rates and total volume accumulated per storm event were measured as to continue to characterize small-scale residential sewershed response to rainfall events. Water quality analyses for pollutants in stormwater runoff grab samples has been scaled down to specific storm events (approximately once a season).
2) Laboratory data for media: Bench-top experimental set-up was assembled to include 16 mesocosms, influent reservoir, effluent sampling hoses, and sample collection reservoirs. Drip diffusers were inserted along tubing running from the influent reservoir, and flow rate calibration was performed. Preliminary tests were conducted to determine the effect of course sand material selection (dredged river sand vs. manufactured sand from limestone) on effluent pH. Initial results indicate that effluent from manufactured sand infiltration practices are higher in pH than that coming from dredged river sand applications. Further studies will be conducted on innovative soil amendments for rain garden applications.
3) Treatment efficiency determination: Field determination of treatment efficiencies for bioretention practices will be limited due to the fact that only 3 lot-scale practices were implemented in the neighborhood due to grant funding reallocation. While total runoff volume and flow rate will continue to be monitored at the outlet of the 38-acre subdivision, significant change in overall hydrology is not expected due to the limited amount of on the ground practices.
4) BMP water quality monitoring database: Principle investigators were successful in obtaining state funding for work towards a green infrastructure design manual. In cooperation with this project, work towards the database continues to occur. The database will be established in 2013 and contribute towards state-sponsored documents.

In 2012, three lot-scale bioretention practices (rain gardens) were designed and implemented in the test neighborhood through state funding. Through this part of the project, we were able to pilot our homeowner educational tool, "Rainwater: Your Liquid Asset. A Home Stormwater Exercise." This tool is a 6-page Extension publication that steps a homeowner through an activity that maps the flow of stormwater on their property while educating them on how runoff is generated, where it goes, and how they can use lot-scale practices to minimize their footprint. This tool is currently in press at the UT Extension Communications Department. This will be a web publication that is accessible by anyone online and marketed for use specifically through county Extension offices and local Tennessee municipal governments. We have also used this publication as a pre-workshop activity for homeowners that enroll in our rain garden workshops. Participants are invited to map their pervious and impervious surfaces, downspouts, and stormwater conveyances, and then bring this to the workshop in order to help guide them towards successful designs and implementation.

Nature, Scope and Objectives of Research:

The nature of this research is to investigate to composition of stormwater runoff from an urban residential development and into an impaired waterway. In addition, the proposed research will study how variables associated with the media of bioretention practices will affect performance and evaluate field-scale practices. The scope of the project is bench-scale experimentation with controlled variables and field-scale monitoring of engineered solutions for stormwater management. Field data collection will be limited to a single neighborhood; however, this will begin the formation of a database of infiltration BMP monitoring data. Since success of the overall project hinges on the involvement and commitment of property owners in the study development, we reserve the right to change the location to another development in the face of currently unforeseen barriers in Cedar Crossings. If necessary, the new location would be selected based on the potential for technology transfer to other developments and pollutant reduction to Beaver Creek.

The objectives of this research are to 1) characterize stormwater volume and concentrations of pollutants of concern being transported from Cedar Crossings residential neighborhood and into Beaver Creek; 2) determine the effects of bioretention design variables (layer media composition, layer thickness, and saturation hydroperiod) on BMP performance through bench-scale laboratory column studies; 3) monitor the effectiveness of field-scale bioretention practices for peak flow and pollutant attenuation in Cedar Crossings; and 4) evaluate the effectiveness of selected bioretention practices for meeting infiltration requirements of new municipal stormwater management permits and demonstrate potential stormwater retrofit design. The larger project that is funding the BMP installations requires that technology transfer to other parts of the state be achieved, and therefore, we will adapt these broad objectives to the project as specific BMP designs are identified as practical for residential neighborhood stormwater retrofit.

<u>Methods, Procedures, and Facilities</u>:

The methods employed for this study on bioretention stormwater practices include: 1) sampling stormwater conveyances through grab samples during storm events and analyzing for sediment, nutrients, and other pollutants of concern; 2) a bench-scale factorial study using laboratory columns and simulated storm events (Hsieh, Davis et al. 2007) to examine the effects of bioretention design variables (layer media composition and thickness, and internal storage zones) on BMP performance; 3) field monitoring of BMPs with automated samplers for capturing timed and flow-composited samples and analyzing for load reduction of pollutants of concern; and 4) measurement of BMP outlet hydrograph and total precipitation to evaluate feasibility of practices to infiltrate 100% of the first inch of rainfall following a 72-hr dry period. Pollutant and runoff volume reductions will be determined through field water quality sampling for pollutant removal and flow measurements based on load estimations (Johnes 2007).

As the field-scale components of the study develop through the anticipated adoption of infiltration practices at the home-owner level, the contributing impervious surface area will decrease over the project timeline. This is expected to have an effect on the outflow from the development. To understand the hydrologic impact of BMP adoption, we will monitor stormwater flow in the storm sewer system and relate this to the changing *retention capacity* of the development. The *retention capacity* is the degree of connection of impervious surfaces to streams (Walsh, Roy et al. 2005). We will examine the relationship between stormwater hydrology and retention capacity over time.

Additionally, total suspended solids and turbidity data will be collected simultaneously during variable size storm events. Regression analysis will be performed to create a relationship between TSS and turbidity as to allow for future loading estimates from turbidity in disturbed urban soils in Eastern Tennessee.

The second phase of this project will engage homeowners and facilitate the adoption of lot-scale stormwater BMPs through the development and use of a Home Stormwater Assessment tool. This tool will be created through the work with Cedar Crossing residents and it's use piloted throughout the neighborhood. The overall goal is to create an easy-to-use tool that will be transferable to residential areas across the state (and region). The tool will have two steps: I) identifying the stormwater flow path, imperviousness, and potential pollutants (to be completed by homeowner), and II) on-site analysis for appropriate BMP selection and placement (to be completed by stormwater professional). Step I will not only build the capacity of the homeowner to understand the link between their home and water quality in their watershed, but also

Related Research:

Bioretention is an emerging stormwater best management practice for runoff reduction and peak attenuation and an element of better site design for residential developments (Johnes 2007). The mechanisms for stormwater management and treatment through bioretention are infiltration, evapostranspiration, media filtration, increase groundwater recharge, vegetation uptake of nutrients, media sorption of pollutants, and microbial conversion of nutrients. Secondary pollution reduction benefits are experience through reducing streambank erosion by reducing total runoff volume and peak flows.

In published studies, bioretention was an effective management practice for reducing runoff volume (Cosgrove and Bergstrom 2001; Davis 2008), attenuating heavy metal (Mason, Ammann et al. 1999; Davis, Shokouhian et al. 2001), and decreasing sediment loading in receiving waterways (Davis, Shokouhian et al. 2006); (Hsieh and Davis 2005). However, there is great variability in results reported for nutrient retention through bioretention (Table 1). Much of the variation may be attributed to design characteristics, such as hydraulic loading, media composition, and outlet design. Bioretention practices without underdrains (usually referred to as rain gardens) have also shown great hydraulic and pollution retention potential when designed to capture the first inch of runoff (typically required by state stormwater permits). Saturation zones in bioretention without underdrains decreased redox potential, which increases nitrate attenuation through denitrification (Davis, Shokouhian et al. 2006). Bioretention soil media has also shown to effect pollutant removal efficiencies (Johnes 2007). More research needs to be conducted to understand the effect of bioretention media mix, design layer depths, and internal storage zone hydroperiod on treatment performance for nutrient reduction.

Study Location	Bioretention Layers*	Nutrient Species	Average Inlet Concentration (mg/L)	Reported Mass Removal Effeciency (%)	Citation
Lab	Mulch, sand, sandy loam	TP	3.06	63-85	(Hsieh, Davis et al. 2007)
Lab	Mulch, topsoil, sandy loam	DP TKN NO_3	0.6 4.0 2.0	81 68 24	(Davis, Shokouhian et al. 2001)
Lab	Mulch, sandy loam	TP TKN NO_3	0.44 3.5 0.39	70-85 55-65 <20	(Davis, Shokouhian et al. 2006)
CT	Mulch, sandy loam, underdrain	NO_3 NH_3 TKN TP TN	0.9 0.04 0.6 0.015 1.6	67 82 26 -108 51	(Dietz and Clausen 2006)
NC	Mulch, soil, underdrain	TN NO_3 TKN TP OP	1.27 0.5 1.0 0.11 0.09	40 75 -4.9 -240 -9.3	(Hunt, Jarrett et al. 2006)

* TN – total nitrogen; TP – total phosphorus; OP – orthophosphate; NH_3 – ammonia; NO_3 – nitrate; DP – dissolved phosphorus; TKN – total kheldal nitrogen.

An Evaluation of Floodplain Forest Land Use Dynamics, Ecosystem Services and Conservation Policies in West Tennessee Watersheds

Basic Information

Title:	An Evaluation of Floodplain Forest Land Use Dynamics, Ecosystem Services and Conservation Policies in West Tennessee Watersheds
Project Number:	2011TN79B
Start Date:	3/1/2013
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	Second,Knox County, Tennessee
Research Category:	Social Sciences
Focus Category:	Wetlands, Economics, Ecology
Descriptors:	Ecosystem Services; River Restoration, Floodplain Forest
Principal Investigators:	Donald Hodges

Publications

1. Hodges, Donald; and Donald Grebner, 2013, Dealing with uncertainty and risk in uneven-aged hardwood management in the southern Appalachians of the United States, "in" International Symposium on Socio-economic Analyses of Sustainable Forest Management, International Union of Forestry Research Organizations, Prague, Czech Republic, pp. 35-42.
2. Hodges, Donald; and Donald Grebner, 2013, Dealing with uncertainty and risk in uneven-aged hardwood management in the southern Appalachians of the United States, "in" International Symposium on Socio-economic Analyses of Sustainable Forest Management, International Union of Forestry Research Organizations, Prague, Czech Republic, pp. 35-42.
3. Hodges, Donald; and D. Stuart Hale,2014,Decison support System to assess the role of ecosystem services in adapting to shifting framework conditions, "In" Proceedings, International Symposium of International Union of Forestry Research Organizations, Combined Conference of Research Groups 3.08 (Small-Scale Forestry) and 4.05 (Managerial Economics and Accounting) E. Schiberna and M. Stark, editors pp. 87-92.
4. Hodges, Donald; and Donald Grebner, 2013, Dealing with uncertainty and risk in uneven-aged hardwood management in the southern Appalachians of the United States, "in" International Symposium on Socio-economic Analyses of Sustainable Forest Management, International Union of Forestry Research Organizations, Prague, Czech Republic, pp. 35-42.
5. Hodges, Donald; and D. Stuart Hale,2014,Decison support System to assess the role of ecosystem services in adapting to shifting framework conditions, "In" Proceedings, International Symposium of International Union of Forestry Research Organizations, Combined Conference of Research Groups 3.08 (Small-Scale Forestry) and 4.05 (Managerial Economics and Accounting) E. Schiberna and M. Stark, editors pp. 87-92.

Statement of Critical Regional or State Water Problems:

The watersheds of West Tennessee contain a significant number of streams that have been listed by the Tennessee Department of Environment and Conservation on the 303(d) list as impaired, meaning they do not meet designated beneficial uses including biological integrity [40 CFR Part 130; TCA §69-3-101 and TDEC Rules Chapter 1200-4]. Due to historic channel alteration and riparian habitat alteration associated land use change over the past century, a large number of these impaired streams have been impacted by excessive siltation. In addition to local stream restoration and floodplain reforestation initiatives planned to support Total Maximum Daily Load implementation and watershed restoration, significant local attention is being devoted to developing ecosystem restoration strategies and sustainable management plans for West Tennessee rivers.

Most notably, the State of Tennessee submitted a formal request to the U.S. Army Corps of Engineers to reevaluate management options to control flood risk in the Obion and Forked Deer watersheds. This led the Corps of Engineers to publish a Notice of Intent in the National Register in May 2009 to prepare a Draft Supplement No. 2 to the Final Environmental Impact Statement for the West Tennessee Tributaries Project General Reevaluation. While the National Environmental Policy Act scoping process was initiated in late 2009, a number of local and national organizations voiced concern for the project and its potential implications for the west Tennessee ecosystem. Therefore, empirical evaluation of floodplain forest dynamics in West Tennessee watersheds can serve both to inform the scientific community as to the landscape-scale changes that have taken place throughout the region in past decades, and to guide public policies regarding land management and water resource planning throughout the region.

Statement of Results or Benefits:

While previous studies have explored the theoretical alternatives for restoring ecosystem services in agricultural watersheds, fewer studies have evaluated actual land use dynamics and how these are related to the provision of ecosystem services. Great potential exists for applying similar techniques to other agricultural watersheds throughout the Southeast. Therefore, this project will produce a methodology that incorporates economic values into estimating spatial and temporal changes in floodplain ecosystem service provision.

Given recent progress made by ecologists in recognizing the role of floodplain forests for river sustainability (Stanturf et al. 2009), appropriate attention must be placed on evaluating natural resource policies and developing management strategies that support floodplain restoration. Additionally, emerging interest in large-scale restoration of fluvial ecosystems is dependent upon the analysis of how past policies have influenced West Tennessee floodplains. Perhaps more importantly, the proposed re-conceptualization of the West Tennessee Tributaries Project by the US Army Corps of Engineers has increased focus on understanding how policies have impacted floodplain ecosystems in the region, and how management strategies can be successfully adapted to ensure the sustainability of river systems for multiple uses. Thus, the results provided by this study will hold a number of practical implications for floodplain ecosystem restoration in West Tennessee, and for river conservation policies throughout the world.

Nature, Scope and Objectives of Research:

In order to develop a more complete understanding of the functions, distribution, and dynamics of floodplain forests in West Tennessee, a multi-faceted study of the legal, political, and biophysical framework must be initiated (King et al. 2009). Rather than simply focusing on one component of regional floodplain ecosystems, this study will explore the relatively recent evolution of management paradigms, with particular focus on how shifts in natural resource policies have impacted the distribution of floodplain forests in West Tennessee, and subsequently how these land use dynamics are connected to the flow of ecosystem services from both public and private lands in the region. Therefore, a comprehensive research approach is proposed which incorporates multiple methodologies to better understand west Tennessee floodplain management issues, and to aid in developing conservation policies that promote ecosystem restoration and sustainable management of natural resources throughout the region.

Objective #1: Develop a comprehensive inventory of geospatial data documenting the distribution of floodplain ecosystems in West Tennessee.

Both Defries & Eshleman (2004) propose the integration of multiple disciplines into the emerging study of landscape change, particularly focusing on the implications of land use dynamics on hydrological function. As demonstrated by Hodges et al. (1998), integrating multiple modeling methodologies can aid in projecting future land use scenarios. Additionally, previous research by Carver et al. (2006) reveals the immense potential for applying spatial analysis techniques to evaluate specific forest policy initiatives, revealing meaningful information for restoration planning and natural resource decision-making in channelized watersheds in Southern Illinois.

A comprehensive geospatial database will be constructed that incorporates existing data sources on regional hydrography, stream quality, biodiversity and wildlife habitat, vegetation classification, land use, soil resources and other relevant data. The data also will be developed to include information needed to assess the level of ecosystem services in the watershed.

> **Progress To Date:** The geospatial database for the study area has been completed, including the data related to different ecosystem services, which have been gathered and processed. The data requirements for the InVEST model have been assessed and the data for each model have been compiled and processed. Carbon storage and sequestration, habitat quality and rarity, nutrient retention, water quality regulation, and timber production will be considered to assess the distribution of floodplain ecosystems using the InVEST model. For carbon storage and sequestration model, the land use and land cover raster dataset was obtained from National Land Cover Database. The carbon pools for aboveground, belowground, soil, and dead organic matter for each land uses and the current harvesting rate have been collected from available literature. The digital elevation model and soil depth, precipitation, evaporation, land use, and watershed data have been collected for the nutrient retention model. The digital elevation model is available for sediment retention model and rainfall erosion index and soil erodibility are other additional data required to run the model.

In order to assess the changes in the land use due to channelization, the available land use data for the year 1992, 2001, and 2006 have been obtained from the National Land Cover Database. Landsat images were obtained from U.S. Geological Survey (USGS)'s Global Visualization Viewer) to identify the chances in the land after the channelization before 1990s. Those Landsat images were classified into different land use categories applying Maximum likelihood classification in ArcGIS 10.

Objective #2: Evaluate the political and legal factors that have influenced West Tennessee river system management.

Because regional river management strategies have a long and complex history (Smith et al. 2009), it is necessary to develop both a background as to the public policies that have guided floodplain management in West Tennessee, and a deep understanding of the legal guidance that has directed river conservation strategies in the past few decades. Therefore, this study will include an analysis of the policies that have directed river management, including the Flood Control Act of 1948, the Fish and Wildlife Coordination Act, the National Environmental Policy Act and the Clean Water Act; as well as the legal cases that have influenced management activities and subsequent mitigation efforts such as *National Ecological Foundation v. Alexander, et al.*, Civil Action No. 78-2548-H, and *Akers v. Resor, et al.* Civil Action No. C-70-349.

The implications of recent federal and state policies designed to support stream ecosystem restoration must also be considered as an essential element of floodplain forest conservation policy. Farm Bill programs impacting private lands management, such as the Conservation Reserve Program and the Wetland Reserve Program, obviously play a great role in private land management in West Tennessee (Bridges 2010). Additionally, state stream and wetland protection legislation and associated watershed restoration initiatives will also be examined along a temporal gradient to examine how river management paradigms have evolved in West Tennessee over the past few decades. The evolution of the West Tennessee River Basin Authority's strategies for environmentally-sensitive stream maintenance and floodplain restoration, which differ significantly from earlier support for channelization (Johnson 2007), will also be examined as part of this objective.

A wide variety of data are available detailing the early scoping phases for the development of an additional supplement to the Environmental Impact Statement that would allow for the reformulation of the West Tennessee Tributaries Project as a flood control initiative. Scoping documents, proposed resource management plans and written comments received during the scoping process will be examined to better understand the complexities of floodplain management in West Tennessee.

Progress To Date: The publicly available documents have been obtained and have reviewed to develop a comprehensive assessment of the role that past and current federal and state policies have played in river management and stream ecosystem restoration. To build upon the lessons learned from the document analysis, key informant interviews are being administered to individuals knowledgeable about West Tennessee rivers issues and will be completed by August.

Objective #3: Explore spatial and temporal changes in the distribution and flow of ecosystem services derived from West Tennessee floodplain forests and wetlands.

Smith & Rosgen (1998) identified several questions for future researchers to explore as a means of informing West Tennessee river conservation policies, including the societal values associated with alternative floodplain management systems. Because of the immense ecological, economic and social values placed upon floodplain forests, the development of a methodology that quantifies the values associated with land use change in west Tennessee floodplains will provide much-needed guidance for restoration planning. Consequently, a key objective of this study is to examine the spatial and temporal changes in ecosystem service production associated with West Tennessee floodplain land use dynamics. Tremendous spatial variability is exhibited in the ecological characteristics of West Tennessee floodplains.

Progress To Date: As described for Objective 1 Progress above, the data for Objective 3 has been collected and processed. This resulted in two presentations at the International Union of Forest Research Organizations, Working Group 4.05.00 annual meetings (Hodges and Grebner 2013, Hodges and Hale 2014). An additional presentation is scheduled for the International Union of Forest Research Organizations World Congress in October as well (Hodges et al. 2014).

<u>Related Research</u>:

Multiple researchers associated with the University of Tennessee have applied a variety of expertise to the analysis of water resources and associated floodplain ecosystem research in West Tennessee over the past few decades. Early evaluation of the implications of river channelization throughout the Obion and Forked Deer systems helped to inform local decision-makers as to the cost of natural resource management alternatives (Smith & Badenhop 1975). More recent research projects have also included multiple evaluations of the influence of excess sediment loading on floodplain forest composition (Pierce & King 2008), and also the implications of forest habitat dynamics on wildlife communities (Summers & Gray 2009). Additionally, the geomorphological research of Smith, Diehl et al. (2009) is also helping to guide river restoration throughout the region.

While great attention has been placed regionally on the integration of ecosystem services (Lant et al. 2005) and associated economic implications into river resource management planning (Lockaby 2009), significant opportunity remains to explore the implications of natural resource policies on West Tennessee rivers and floodplains. The results of this project have served as the foundation for a research proposal submitted to the USDA National Institute for Food and Agriculture competitive grants program for 2014.

Determining Channel Protection Flows in Urban Watersheds Through Effective Strategies for Stormwater Management and Stream Restoration

Basic Information

Title:	Determining Channel Protection Flows in Urban Watersheds Through Effective Strategies for Stormwater Management and Stream Restoration
Project Number:	2012TN92B
Start Date:	3/1/2013
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	Second
Research Category:	Water Quality
Focus Category:	Ecology, Surface Water, Sediments
Descriptors:	None
Principal Investigators:	John S. Schwartz, John S. Schwartz

Publications

1. Schwartz, J.S., K.J. Neff, F.J. Dworak, and R.R. Woockman, 2014. Restoring riffle-pool structure in an incised, straightened urban stream channel using an ecohydraulic modeling approach. Ecological Engineering. DOI 10.1016/j.rcoleng.2014.06.002.
2. Grove, M.K., G.S. Bilotta, R.R. Woockman, and J.S. Schwartz. 2014. Suspended sediment regimes in contrasting reference-condition freshwater ecosystems: implications for water quality guidelines and management. Science of the Total Environment. DOI:10.1016/j.scitotenv.2014.09.054.
3. Schwartz, J.S.; R.R. Woockman, 2015, Evaluating the Impacts on Runoff of Landscape-based BMPs in Intensively Managed M Landscapes, "in" Proceedings of the Twenty-fourth Annual Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN. pp. D23-26.

Methods, Procedures, and Facilities:

Task 1 - Pilot Site Sampling and Setup:

Rainfall and flow monitoring equipment will be set up at each pilot. Composite samplers to capture water samples at different stages will be installed to evaluate suspended sediment. Continuous stage and weather data will be monitored at each site. Automated composite samplers with flow measurement sensors will be purchased with USGS grant. Field surveys will be performed on the channel and floodplain of each pilot stream. The initial survey will be used to describe the baseline geometry of the stream and prepare inputs to the hydrologic and channel erosion models. Erosion pins will be installed on the banks of three cross-sections at each site. Pins will be measured every six months and following rainfall events greater than 1.0 inches. Additionally, Rapid Geomorphic Assessment (RGA) and modified Wolman pebble count will be conducted at each site (Simon and Klimetz, 2008). Detailed soil and vegetation characterization will be performed at each pilot site. Soils at each of these pilot streams will be characterized from in-situ shear strength testing using a submerged jet device to measure in-situ critical shear and erosion rates for cohesive material.

Progress to Date: Composite samplers have been purchased, and set up at multiple locations. Model sites have also been set up with turbidity sondes, stage probes, and rain gauges. Laboratory analysis will be performed to provide a relationship between WQ samples from the composite samplers and in-situ sondes. Additional efforts for model calibration will include topographic surveys (completed), characterizing bedload particle distribution (completed), measuring critical shear in-situ (completed), and characterization of vegetated properties at the reach scale (completed).

It has been determined that erosion pins would be cumbersome and offer limited information towards the research goals within the time scales of the funded project. In lieu of erosion pins, historical cross-sections have been implemented at two research sites for analysis and comparison in futures studies.

It should be noted that the collected field data in this task support the modeling effort in Task 3.

Task 2 - Pilot Model Creation:

The project team will create detailed hydrologic/hydraulic and erosion models for each pilot stream so that model output can be incorporated into the SUSTAIN model. The model software will be public domain, approved by the EPA, and accepted by the professional community. For example, the hydrologic/hydraulic model recommended is EPA SWMM (EPA, 2008) or the Hydrological Simulation Program- Fortran (HSPF) model, and the geotechnical bank failure models will be USDA's Dynamic BSTEM. We will assume at this time that SWMM will be used. These models will be used in later tasks to evaluate the channel erosion, baseflow and WQ impacts of alternative stream protection options. The SWMM models includes rainfall, runoff, infiltration, evaporation, groundwater, hydraulic and baseflow components. Each model will be run to determine flow rates over the length of each pilot stream. Bank Stability and Toe Erosion Model (BSTEM) spreadsheets will be set up for continuous simulation to evaluate bank stability and toe erosion on each of the pilot streams. Dynamic BSTEM is a public-domain model developed by the USDA National Sedimentation Laboratory (USDA, 2009).Flow rates from the SWMM models will be introduced to the dynamic BSTEM spreadsheets at the appropriate locations. Soil and survey data will be used to describe the bed and bank materials and channel geometry in the model.

Progress to Date:

Paul Simmons, a MS graduate student on the project has calibrated multiple BSTEM models and correlated those to spatial heterogeneity on the banks and critical shear estimates using the mini-jet tester (modified version of the original USDA submerged jet tester). Paul completed his master's thesis titled "*A spatial analysis of streambank heterogeneity and its contribution to bank stability*" spring 2014 semester (University of Tennessee, Knoxville, May 2014). Paul is currently working towards modifying his thesis into *Geomorphology*, a peer reviewed publication.

Robert Woockman, a PhD graduate student, is working towards coupling hydrology with in-channel processes and form to provide an understanding of how different mitigation strategies will impact suspended sediment flux and channel modification. These models will represent contributing catchments for Pistol Creek in Maryville, TN and Little Turkey Creek in Farragut, TN. Coupling of models offers an understanding of the interaction of hillslope SMCs and in-channel restoration projects. This effort is time intensive, but extremely important to gaining an understanding of influence of form and processes at the watershed scale on mitigation success. Therefore, SUSTAIN modeling efforts are no longer intended in order to maximize coupled modeling efforts. Robert's work is expected to be included in his dissertation and efforts will be made to publish specific articles related to this research in peer reviewed journals.

Task 3 - Pilot Model Calibration:

The SWMM models will be run with the recent rainfall data collected by the nearby rain gauge. Relatively uncertain watershed characteristics of the model will be calibrated so that flow results match recorded flows as closely as possible. This calibration will reduce uncertainty and increase the reliability of the modelled flows. Flow results from these models will be entered into the BSTEM spreadsheets to drive the channel erosion analysis. Erosion results will be compared to those gathered by the yearly field surveys. The soils parameters of the BSTEM model will then be calibrated to match the observed measurements as closely as possible. This approach was similarly used by Simon and Klimetz (2008).The calibrated SWMM and BSTEM models can then be used to test any number of stream protection options or land use changes for their effect on long term stream health.

Progress to Date: Modeling efforts are currently in progress. See Task 2 for additional detail.

Task 4 - Shear Strength Guidance Creation:

The soils data calibrated in BSTEM will then be analyzed to determine which field-measured parameters (such as Torvane tester values, root density, etc.) are accurate predictors of shear strength. Relationships between the key parameters and shear strength will be determined. The project team will publish a simplified method for determination of bank and bed shear strength.

Proper use of inexpensive Torvane shear strength testers will be combined with field observations to determine a valid shear strength.

Progress to Date: There has been modification to this objective over the previous year. Only recently a great deal of research has been published or is in review regarding the spatial discontinuity of critical shear stress values with relation to soil parameters, root density, and temporal seasonal patterns. In light of this Paul Simmons MS research was restructured to provide a survey based method to determine channel resistance with respect to critical shear values and spatial heterogeneity of hard points on the banks. Simmons's research focused on using the mini jet tester device to characterize critical shear and relating these values through a geostatistical approach to channel resistance properties. Channel stability was determined through the use of BSTEM and incorporated vegetation estimates and critical shear at each site. The title of his completed thesis and intentions for publication is noted in Task 2 above.

Task 5 - Evaluation of Potential Channel Erosion for Pilot Streams:

The SWMM models for the reference streams will be altered by changing the land uses to residential and commercial and applying the long-term rainfall record. The increased flow hydrographs determined from SWMM will be fed into BSTEM until the channel geometry stabilizes for each stream. The progression of channel geometries will be compared to the geometries of the newly and historically urbanized pilot streams. The BSTEM models may be further calibrated based on this comparison, which will provide insight into the evolution of urban stream degradation. Several similar model runs will be performed after varying the stream channel characteristics in BSTEM for each pilot stream. The effects of several critical factors such as channel shear strength, bank angle and vegetation on sediment load will be determined. The total erosion load potential will then be tabulated for a range of stream and watershed conditions.

Progress to Date:

There have been some modifications to this task. Continuous Simulation Modeling will be performed for both the Pistol Creek and Little Turkey Creek catchments (see task 2). The results will be analyzed with emphasis placed on how various channel erosive resistance elements influence work performed on the channel boundaries and ultimate sediment loading.

Task 6 - Relationship between RGA Score and Erosion Potential:

The Rapid Geomorphic Assessment (RGA) technique developed by the USDA National Sedimentation Laboratory will be used to score each of the pilot stream reaches. The RGA provides an overall rating for the susceptibility of a channel to erosion. Erosion loads for the pilot streams will then be tabulated based on RGA score and hydrologic area to determine the relationship between these factors. This task is key in developing simplified field protocols that MS4s can implement, and optimally target restoration projects for channel protection. This RGA datasheet can be designed for easy incorporation into existing stream assessment protocols such as the "Maryland Protocol" (Yetman, 2001) that are currently being used across the country by MS4 staff.

Progress to Date: A primary objective of this research is to better inform mitigation efforts designed to reduce sediment loading that results from hydromodification effects. As the project has progressed the decision has been made to audit a number of stream sites outside of the modeling sites. These efforts include RGAs at each audit site, but include additional variables of interest to include vegetation, soils, and lithology. The data generated from these efforts will be used to identify possible states of stream channels in the region and how those states respond to hydrologic alteration. This effort has reduced the potential pool of modeled stream sites and therefore will impact the ability to relate RGA scores to modeled sediment loads. Yet, this characterization is equally important to advancing the knowledge base for effective mitigation of erosive flows.

Re-filling the Bucket: Recharge Processes for the Memphis Aquifer in the Exposure Belt in Western Tennessee

Basic Information

Title:	Re-filling the Bucket: Recharge Processes for the Memphis Aquifer in the Exposure Belt in Western Tennessee
Project Number:	2013TN102B
Start Date:	3/1/2013
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	7th Tennessee
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Groundwater, Management and Planning
Descriptors:	None
Principal Investigators:	Daniel Larsen, Scott Schoefernacker, Brian Waldron

Publications

1. Schoefernacker, Scott, D. Larsen; B. Waldron, 2015,For Better or for Worse: The State of the Former Shelby County Landfill, "in' Proceeding of the Twenty-fourth Annual Tennessee Water Resources, Tennessee Section of the American Water Resources Association, Nashville, TN., pp. D6-11.
2. Kingsbury, J.; D. Larsen; S. Schoefernacker, 2015, Groundwater Geochemistry and Age Along Two flow Paths in the Memphis Aquifer in West Tennessee, "in" Proceedings of the Twenty-fourth Annual Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN. pp.D1-5.
3. Larsen, D., S. Schoefernacker, B. Waldron, 2015, Fifteen years of Age-dating Groundwater for Production Wells in Shelby County, TN: Summary of Results, "in" Proceedings of the Twenty-fourth Annual Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN. pp. D12-16.

Introduction

Little is currently known regarding direct recharge to the Memphis aquifer across the unconfined region in western Tennessee; however, initial investigations indicate that little recharge may penetrate through the upland surfaces, taking possibly 100 years to move from the ground surface down to the water table. Observation of seasonal rise and fall in the water table in these areas requires operation of a more responsive recharge mechanism. Gaining an understanding of recharge processes in the unconfined region of the aquifer is critical to understanding input rates both spatially and temporally so as to ascertain the impact of land use and climate change on the long-term sustainability of this valuable and heavily relied upon natural resource. This project investigates recharge processes in the unconfined region of the Memphis aquifer at the Pinecrest research site, near LaGrange, Tennessee. Initial investigations have included using vadose-zone and saturated zone chloride mass balance methods (CMB) to estimate recharge in the upland region (i.e. thick vadose zone), installation of and continuous water level monitoring in two wells on an upland surface screened within the Memphis aquifer, and recurrent analyses of vadose zone soil moisture profiles within one of the wells using a neutron probe. Furthermore, geologic mapping and reconnaissance soil studies have clarified geologic and soil control on recharge processes.

The first year of WRRC funding supported installation of an additional monitoring well in the adjacent valley floor (VF), installation of 4 lysimeter and tensiometer (LT) clusters, sediment description of soil and installation of a Parshall flume to measure stream flow discharge along the intermittent stream in the valley floor, installation of a weather station at the hilltop location, and installation of a shallow monitoring well in the Memphis aquifer downgradient of the VF well and LT clusters (Fig. 1). The second year of funding provided for water quality monitoring and analysis of water obtained from the rain gauge, LT clusters, stream, and wells, water level monitoring in the wells, and discharge analysis in the intermittent stream. In addition, ^3H and SF_6 were sampled and analyzed in two wells and a bromide tracer was applied below the soil zone at the back slope (BS) LT cluster.

Methods, Procedures, and Facilities

Water level, stream flow, and weather station data were collected at 15-minute intervals from February 2014 through February 2015 to obtain a complete monitoring year of water data. Water volumes and soil tension data were obtained from the LT clusters on a bi-weekly basis throughout the monitoring year, except soil tension data, which were unavailable during the winter months due to freezing. Water from the rain gauge, lysimeters, and stream, if available, was sampled once a month and analyzed for field parameters and major solutes. Water from the hilltop (SS) well, valley floor well (VFW), and shallow drive-point (DP) well was sampled during August 2015 for field parameters, major solutes, and ^3H and SF_6. Anion analysis of F^-, Cl^-, Br^-, NO_3^-, PO_3^-, and SO_4^{2-} was conducted using a Dionex DX-120 ion chromatography unit and cation analysis of Na, K, Ca, Mg, Mn, and Fe was conducted using a Varian FS atomic absorption spectrometer. Approximately 100 L of 500 mg/L Br^- solution (from NaBr salt) was poured into a 3 m deep hole at the BS LT cluster in mid-November, 2014. Well and stream waters were sampled and analyzed for dissolved Br- for 6 months following injection to assess

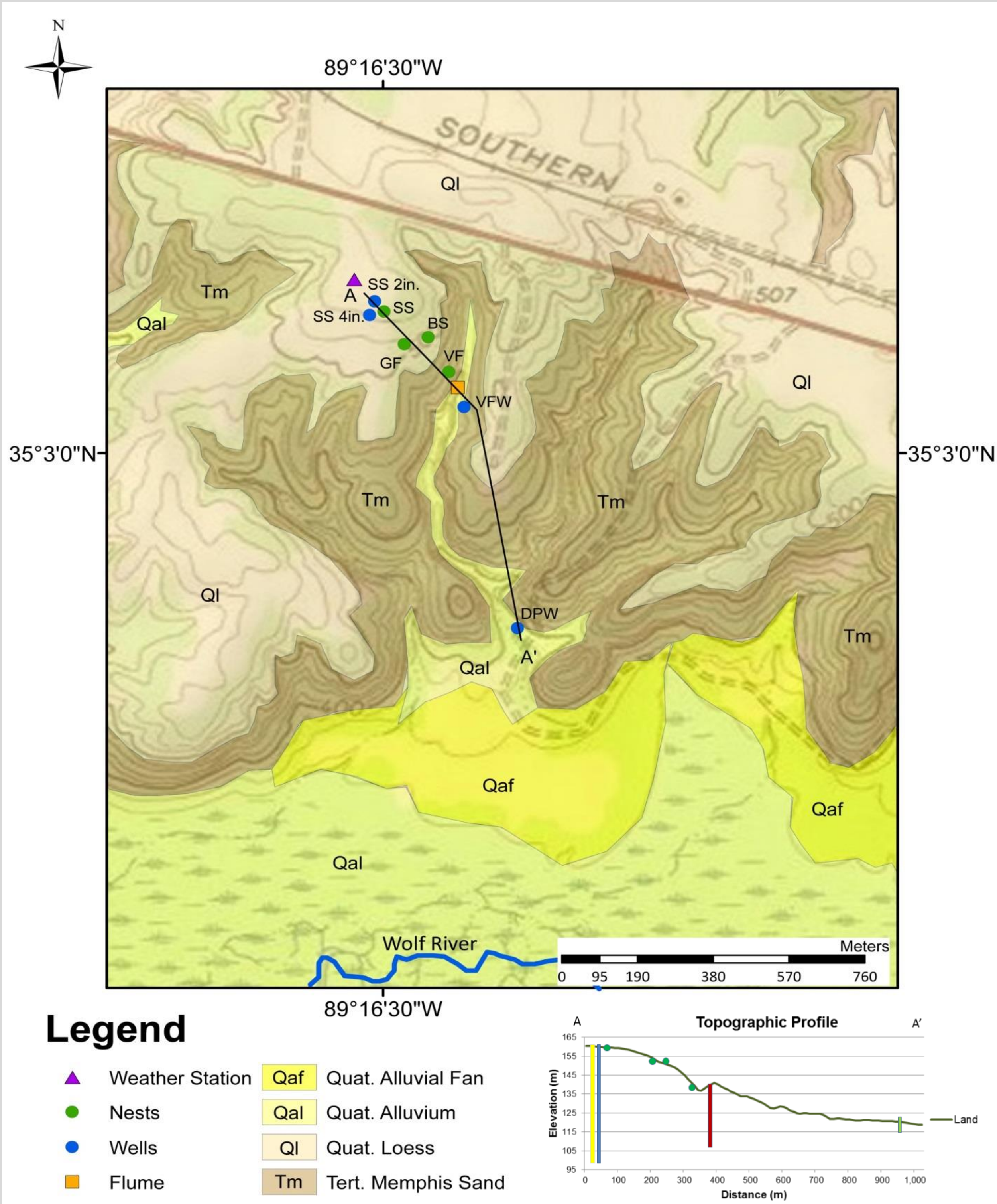

Figure 1. Geologic map of field area at Pinecrest Presbyterian Camp, LaGrange, Tennessee. Locations of weather station, nests (LT clusters), wells, and flume discussed in the text are illustrated. Topographic profile along A-A' illustrates the positions of wells relative to land surface.

the pathway of recharge from that surface site. Wells were sampled with a bailer in the well screen interval and all tracer samples were analyzed for Br^- by ion chromatography.

Preliminary Results

Lysimeter and tensiometer data indicate that infiltration rates are slowest at the shoulder slope (SS) LT cluster and fastest at the BS LT cluster, with intermediate rates at the gully floor (GF) and valley floor (VF) LT clusters (Fig. 2). Stream flow in the intermittent stream was generally responsive only to storms during April to November, but flow was more or less continuous from December through March (Fig. 3). Water levels in the SS and VF wells varied by less than 0.2 m during the year, with the SS well water level always approximately 0.4 m higher than that of the VFW and both wells showing a gradual 0.2 m rise during the summer months and similar decline during the fall (Fig. 4). Water levels in the DP well were responsive to rain events of >10 mm and generally 3 m higher than the SS and VF wells from March to July 2014 and December 2014 through March 2015. Water levels in the DP well dropped to values similar to the SS well during August 2014 and remained at that level until a significant rain event (>60 mm total) at the beginning of December 2014. Piston-flow SF_6 age of water from the SS well is 37 years and that of the VF well is 25 years, consistent with modern recharge and a groundwater flow direction from the SS to VF wells. Tritium data are generally consistent with these data with 5.5 TU in the SS well and 2.6 TU in the VF well. The bromide tracer injected in November at the BS LT cluster was first detected in mid-April 2015 at the VF well, but was likely influenced by 4 days of intermittent pumping in mid-April of a well east-southeast of the VF well that services a swimming pool on the property. Water quality data from most lysimeter clusters show limited seasonal variability in solutes, with specific conductance being highest during the summer months and lowest during the winter months (Fig. 5). Well waters have specific conductance values within the range of most lysimeter waters sampled at the 1.5 m depth. Water quality of the BS LT cluster shows much higher specific conductance, nitrate, alkalinity, and sodium than any other lysimeters.

Discussion

Drainage of water varies at each LT cluster and changes with the depth of the lysimeter and tensiometer. Water retention at the SS cluster, which has grass and shrubs at the site, is similar to that of most other site at 0.5 m depth and generally shows relatively high soil tension, probably due to the fine soil texture. However, at 1.0 and 1.5 m depths at the SS cluster the water retention is generally amongst the highest for the sites and shows the least soil tension. The VF site shows similar trends in water retention and soil tension as the SS cluster, although soil tension was commonly below detection at the 0.5 m depth, probably due to tensiometer drainage. Water retention at the BS cluster is generally the lowest of all the clusters, likely due to the sandy soils observed at this location. The sandy texture also influences the soil tension resulting in relatively moderate to high soil tension values. The greatest water retention and lower soil tension values at the BS cluster are observed at the 1.0 m depth, where fine silt and clay are enriched due to illuvial processes. The GF location generally shows water retention and soil tension values similar to the VF and SS locations at the 0.5 m depth, but tends to dry out during the summer and fall months at the 1.0 and 1.5 m depths, where the soils are sandier and

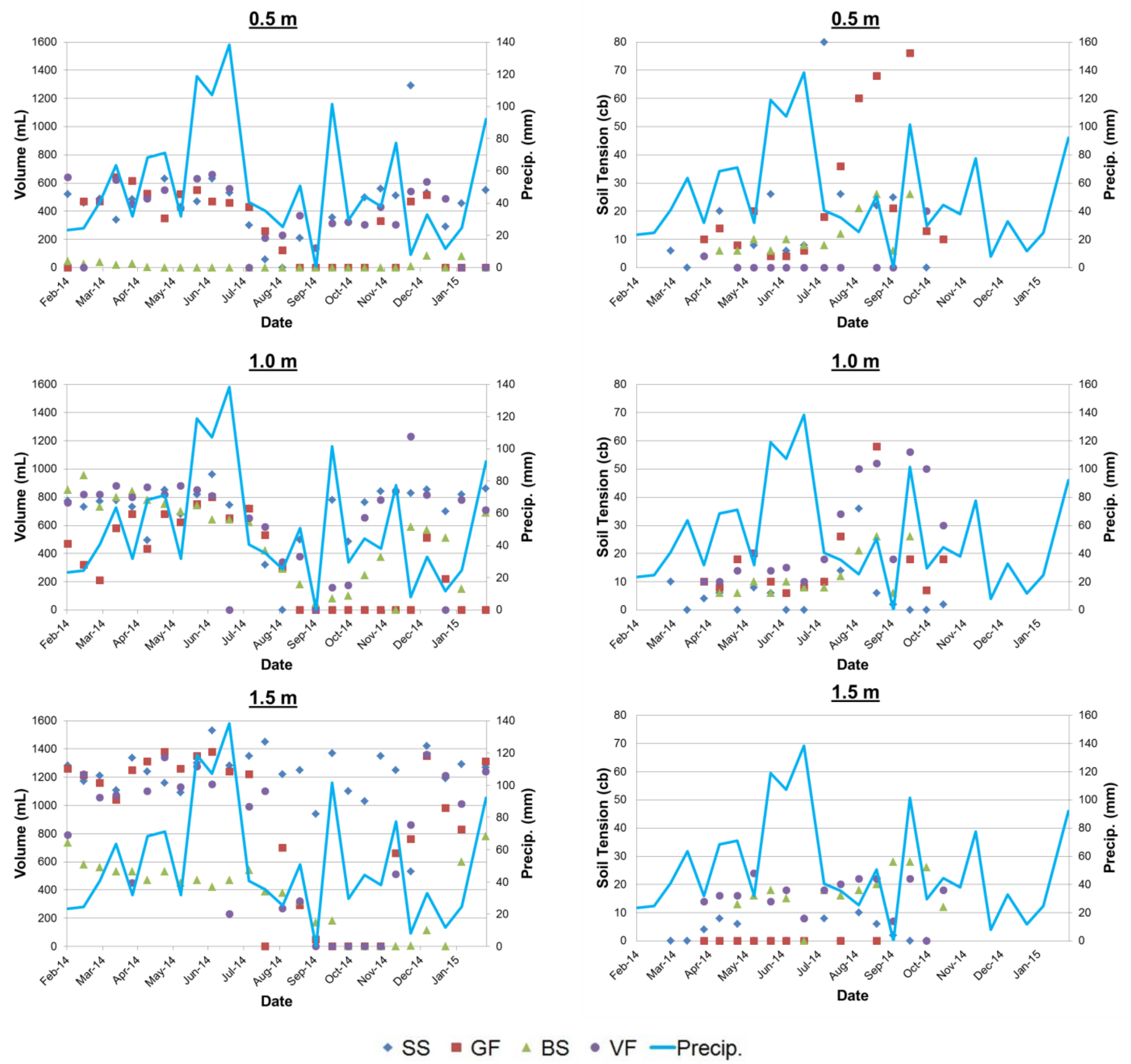

Figure 2. Lysimeter volume (left) and soil tension (in centibars - cb) (right) from the LT clusters (nests in figure 1) at 0.5, 1.0, and 1.5 m from February 2014 to February 2015. Missing water volume data indicate lysimeter malfunction during that sampling period. Missing soil tension data indicate loss of soil tension during sampling period, either due to drainage or malfunction. Precipitation data is from the biweekly rain gauge data. LT cluster abbreviations: SS – shoulder slope, GF – gully floor, BS – back slope, VF – valley floor.

behave more similar to those at the BS cluster. In general, the BS cluster shows the greatest potential for subsoil water infiltration due to the sandy texture of the soils and minimal soil water retention.

The discharge record suggests that runoff from the upstream segment of the intermittent stream watershed (e.g., LT cluster, SS, and VF well area) is almost exclusively tied to larger precipitation events, except during the winter months. One concern in the data during the winter months is the effect of freezing on the transducer in the flume, such that the winter flow may be more discontinuous than is suggested by figure 3. Water levels in the two deep wells (SS and VF) show little relationship to stream flow and appear to be hydrologically disconnected from surface water; however, the DP well is much more sensitive to individual precipitation events and to overall seasonal drying. The results suggest that the hydraulic gradient consistently slopes from the SS to VF wells, but the gradient between DP and VF (and SS) wells varies with the season, such that there is potential for groundwater flow from DP to the north during the wetter months.

Geochemical data from the LT clusters indicate dissolved solutes increase substantially in soil waters relative to rain water. Soil water concentrations and chemistry vary slightly amongst LT clusters SS, GF, and VF, with most showing summer and fall increases in solutes relative to winter and spring due to growing season conditions and evapotranspiration. The high alkalinity, sodium, and nitrate contents in the LT cluster BS waters are consistent with septic wastewater. A leach field for a small-volume septic system is located approximately 50 m upslope from LT cluster BS that likely contributes to lysimeter water by slope-parallel through-flow in the soil. Specific conductance and water chemistry of water from the SS 2-inch well and DP well are broadly similar to those of the lysimeters SS, GF, and VF at depths of 1.5 m, suggesting that infiltration of soil waters contributes to the groundwater in the area. The higher specific conductance, alkalinity, and sodium of the water from the VF well may indicate a contribution of water from the LT cluster BS location; however, the VF well also shows much higher chloride that may indicate infiltration from a leaky swimming pool on the property.

The SF_6 and ^3H tracer data from the SS 2-inch and VF wells confirm that recharge for these wells is primarily modern; however, some pre-modern water may be present that would lead to ^3H values less than those expected for the associated SF_6 ages of 37 and 25 years for the SS 2-inch and VF wells, respectively. The observation that bromide from tracer injection in November 2014 arrived in the VF well in May 2015 implies that recharge from the surface to the Memphis aquifer occurs on a seasonal basis. The presence of the bromide tracer at the VF well also supports the water chemistry data in suggesting a direct recharge pathway from the hillslope locations to the Memphis aquifer.

Training Activities

This study has included effort from several students from the departments of Civil Engineering and Earth Sciences at the University of Memphis. The project is the subject of the Masters Degree research for John Bursi, a graduate student in Earth Sciences. Drs. Larsen and Waldron, and Center for Applied Earth Science and Engineering Research staff members Scott Schoefernacker and Mary Dubose as well as students James Eason, Haley Gallo, Sarah Girdner, and Katie Dagastino have consistently performed the sampling and data acquisition. As many as 10 students in Department of Earth Sciences and Civil Engineering have been involved with various aspects of the project, including sampling, soil analysis, water-level measurements, and chemical analysis. In addition, Pinecrest serves as an environmental educational center for school children and adults where they learn about the regional aquifer system and the importance of the recharge zone.

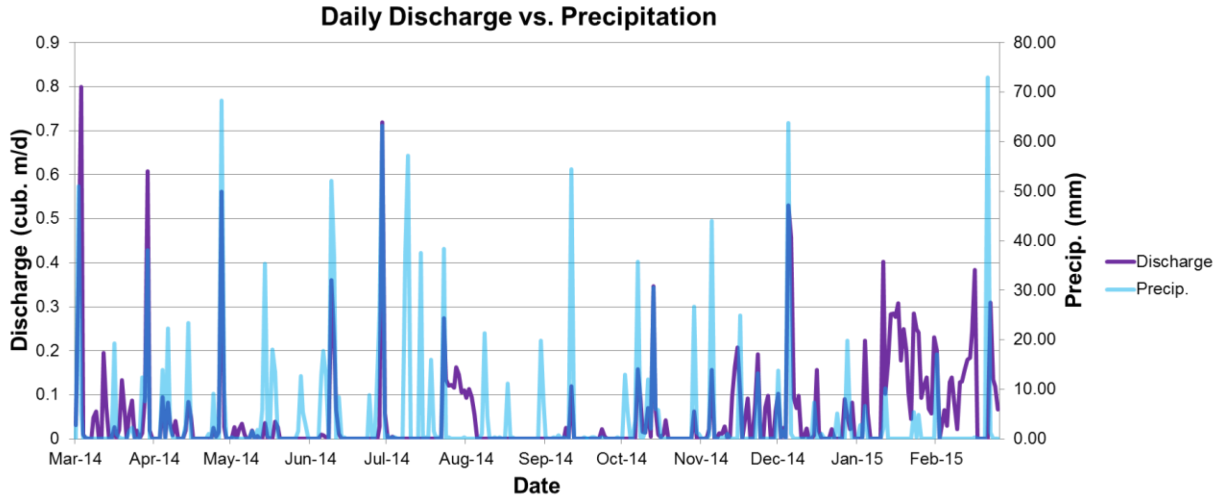

Figure 3. Discharge at flume in valley floor with precipitation data from the weather station. Discharge occurs only following precipitation events from March 2014 through November 2014, but discharge is more persistent during December 2014 through February 2015.

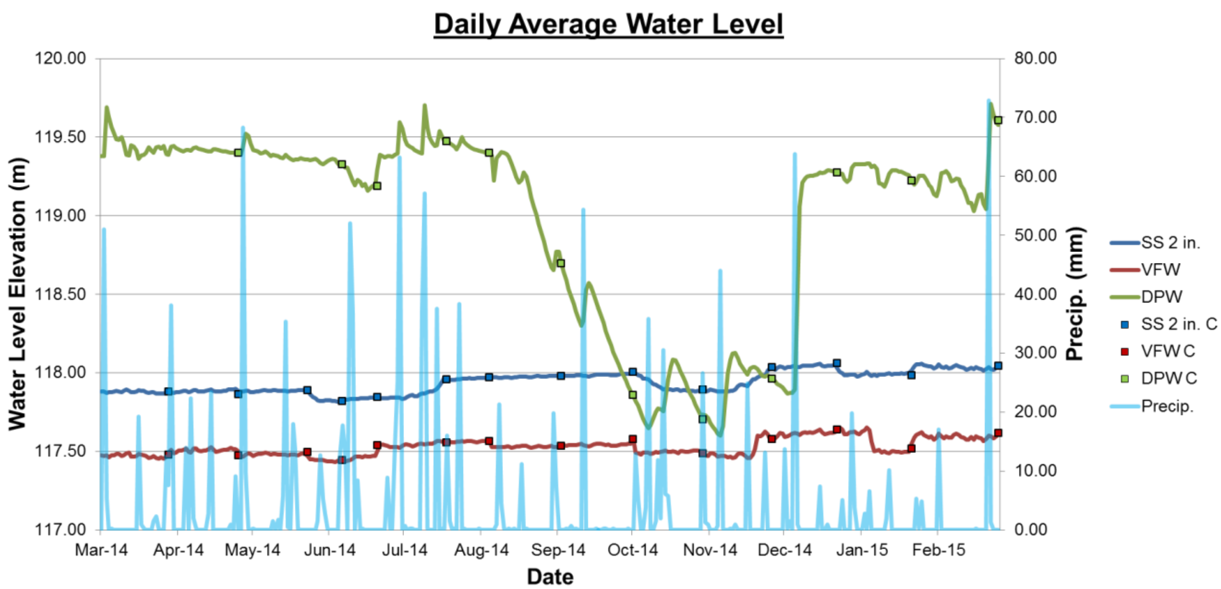

Figure 4. Water level in wells with precipitation data from the weather station. Data points represent measured water levels, whereas lines are water level data from tranducers compensated for barometric pressure. Abrupt changes in water levels of SS 2-inch and VF wells appear to be due to changes in transducer positioning within the well.

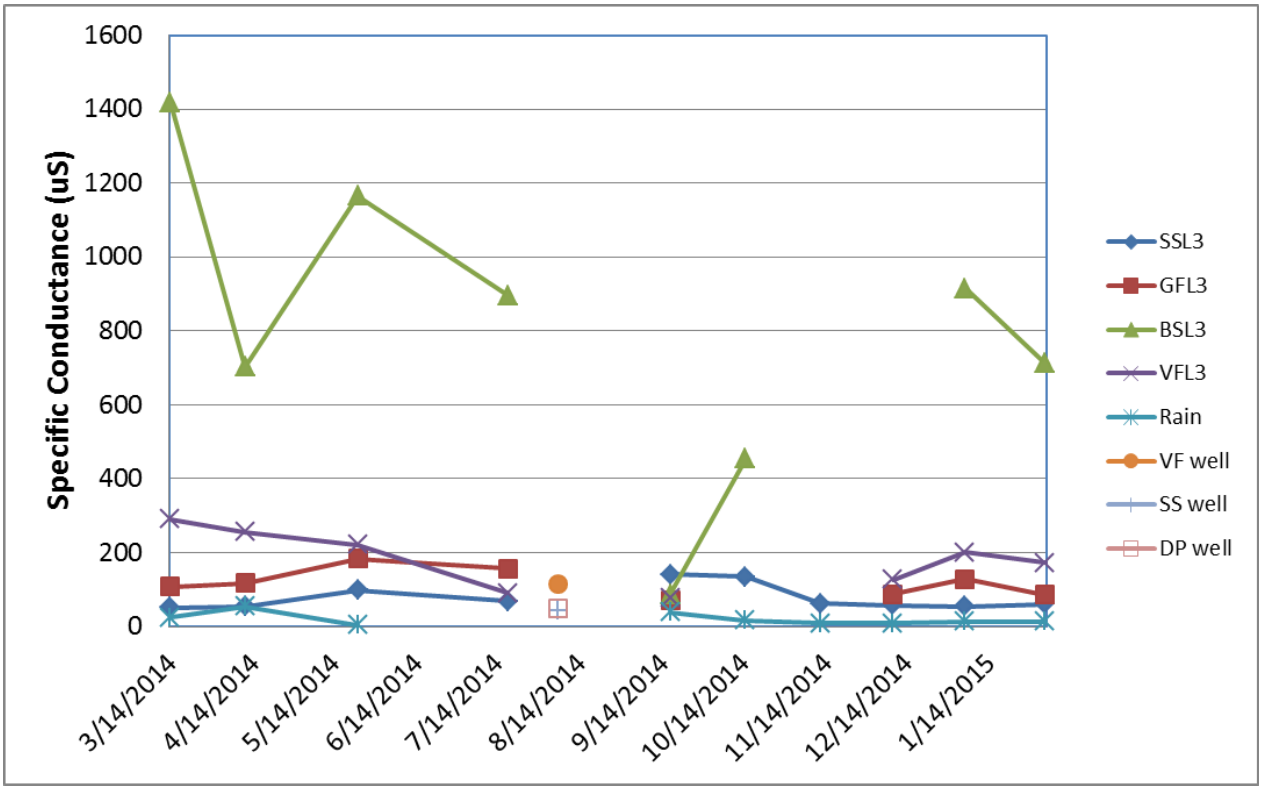

Fig. 5. Specific conductance (μS) of rain water, lysimeter water at 1.5 m depth, and well water sampled during monitoring year.

Engineered Strategy to Remediate Trace Organic Contaminants using Recirculating Packed-Bed Media Biofilters at Decentralized Wastewater Treatment Systems

Basic Information

Title:	Engineered Strategy to Remediate Trace Organic Contaminants using Recirculating Packed-Bed Media Biofilters at Decentralized Wastewater Treatment Systems
Project Number:	2013TN99B
Start Date:	3/1/2013
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	2nd Tennessee
Research Category:	Water Quality
Focus Category:	Wastewater, Non Point Pollution, Water Quality
Descriptors:	None
Principal Investigators:	John R. Buchanan, Jennifer DeBruyn

Publications

1. Buchanan, J.R. 2013. Recirculating media filters providing wastewater treatment at rural schools with ammonia discharge limits. "in" Proceedings National Onsite Wastewater Recycling Association, 22nd Annual Technical & education Conference, Millennium Maxwell House Hotel, Nashville, TN. November 17-20.
2. Buchanan, J.R. 2014. Decentralized Wastewater Treatment: Volume Three, Remediation of Polluted Water, in the Series, "comprehensive Water Quality and Purification", Elsevrer, Oxford, United Kingdom.

Nature, Scope and Objectives

A packed-bed media biofilter is a slow-rate, fixed-film (or attached-growth) unit process used for secondary and tertiary wastewater treatment. This process passes primary-treated effluent through a porous, inert media (the packed-bed) where waste constituents diffuse out of the bulk water and into the biofilms that form on the media. Aeration is provided as the wet media is exposed to atmospheric oxygen. A recirculating packed-bed media biofilter (RPBMP) recirculates the effluent through the media several times for enhanced organic carbon removal and nitrification (oxidation of ammonia to nitrate). After trickling through the media, effluent is divided between the recirculation tank (for additional passes through the media) and to final discharge (typically via a drip irrigation system). Because the influent from primary treatment is anaerobic, the recirculation tank is usually anaerobic and this reducing-environment allows for denitrification. Under reducing conditions, nitrate can be converted to nitrogen gas, thus reducing the nitrogen concentration in the effluent.

By design, the organic loading rate to RPBMBs is low (typically 2 to 5 kg BOD_5 100 m^{-2} d^{-1}). This loading rate minimizes the accumulation of biosolids within the media and starves the microorganisms for organic carbon rather than oxygen (endogenous respiration). It is possible that this operating mode may encourage the aerobic biodegradation of otherwise recalcitrant trace organic waste compounds (TOWC). Further, there is some evidence that changing from oxidizing to reducing conditions can enhance TOWC degradation. Lastly, the media provides tremendous trace organic contaminant adsorption/absorption potential. The primary objective of this project is to evaluate the removal of trace organic contaminants as domestic wastewater is being renovated by RPBMBs. We will gain insight as to the removal mechanisms.

The specific objective of this project is to determine whether the combination of endogenous respiration and reducing conditions found in a RPBMB can maximize the biodegradation of TOWCs found in domestic wastewater. We constructed a series of laboratory-scale RPBMB to monitor the removal of six commonly found TOWCs. The TOWCs will include triclosan, bisphenol-A, ibuprofen, diclofenac, naproxen, and 17α-ethinylestradiol.

Methods, Procedures and Facilities:

Four laboratory-scale recirculating media biofilters have been assembled. Each system includes a supply tank (simulating septic tank effluent), a column filled with media (3-5 mm fine gravel), a recirculation tank and a final product tank. Primary-treated wastewater from a community-scale decentralized treatment system serves as the wastewater source. The supply tanks emulate the discharge from primary treatment (liquid/solid separation) and feed into the recirculation tank on a diurnal basis – representing the higher wastewater flows that occur during mornings and evenings. Effluent in the recirculation tank is then micro-dosed to the column five times per hour. The discharge of the column flows through a three-way valve that determines whether the effluent flows back to the recirculation tank or to the final discharge. The recirculation rate is five to one. Every fifth time the recirculation pump doses the column, the three-way valve switches state, and the column effluent drains to the final discharge (Figure 1).

All system components were manufactured from stainless steel, glass, or coated with polytetrafluoroethylene (PTFE) in order to minimize the partitioning of the trace organic compounds to the system surfaces. Four of these systems were constructed. In order to gain rapid insight, we chose to evaluate three compounds concurrently. As such, columns 1, 2, and 3 received 0.1 ppm spiked-doses of ibuprofen, naproxen, and triclosan, respectively. Column 4 served as a control. Our wastewater source already contained measurable amounts of ibuprofen, naproxen, and triclosan and column 4 served as a control to monitor the removal of the non-spiked compounds. Concentrated solutions of ibuprofen, naproxen, and triclosan were dissolved in methanol; thus, a small volume of methanol was added to the column when the spike was added. An equivalent volume of methanol (without the TOWC) was added to the forth column to balance the organic loading across all columns.

Each system received primary treated wastewater for 20 days to establish the biofilm within the media. COD analyses was used to confirm that the biofilm was established and metabolically active. On a weekly basis, wastewater was brought in from the community wastewater treatment system to serve as the wastewater source for the laboratory scale systems. Analyses were conducted on the source wastewater to determine the TOWC concentrations and then the concentration of either triclosan, bisphenol-A, ibuprofen, diclofenac, naproxen, or 17α-ethinylestradiol was spiked to increase the concentration by 0.1 ppm in their respected columns. To determine TOWC removal, samples were taken from the discharge of each bench-scale system.

We have completed an eight week evaluation of triclosan, ibuprofen, and diclofenac; and have begun the evaluation of bisphenol-A, diclofenac, and 17α-ethinylestradiol. Figure 2 is a graph of the results. During the eight-week period, naproxen and ibuprofen columns produced less removal. At this time, it is speculated that the initial high rate of removal may have been due to media sorption. With time, the sorption sites have become limited and more the compounds are moving through the treatment systems. In order to determine if there are changes in the microbial communities due to metabolizing the various TOWCs, biofilm samples from each treatment will be taken after 60 days of activity, and frozen. The DNA collected and purified from these samples will be subjected to phylogenetic analyses via 454 pyosequencing of 16S rRNA genes.

A Biosystems Engineering Master of Science student is using this project for her thesis research. Two summer students are assisting her with the laboratory analyses. It is anticipated that this project will be complete by December 2015 and should deliver a M.S. thesis and two refereed journal articles.

Figure 1. The experimental setup for determining the removal of trace organic compounds by packed-bed recirculating media filters. The right-side glass jar is the recirculation tank and the left-side jar is the final product – a three-way valve under each column directs the effluent to the appropriate jar. The diaphragm pump is used to recirculate the effluent

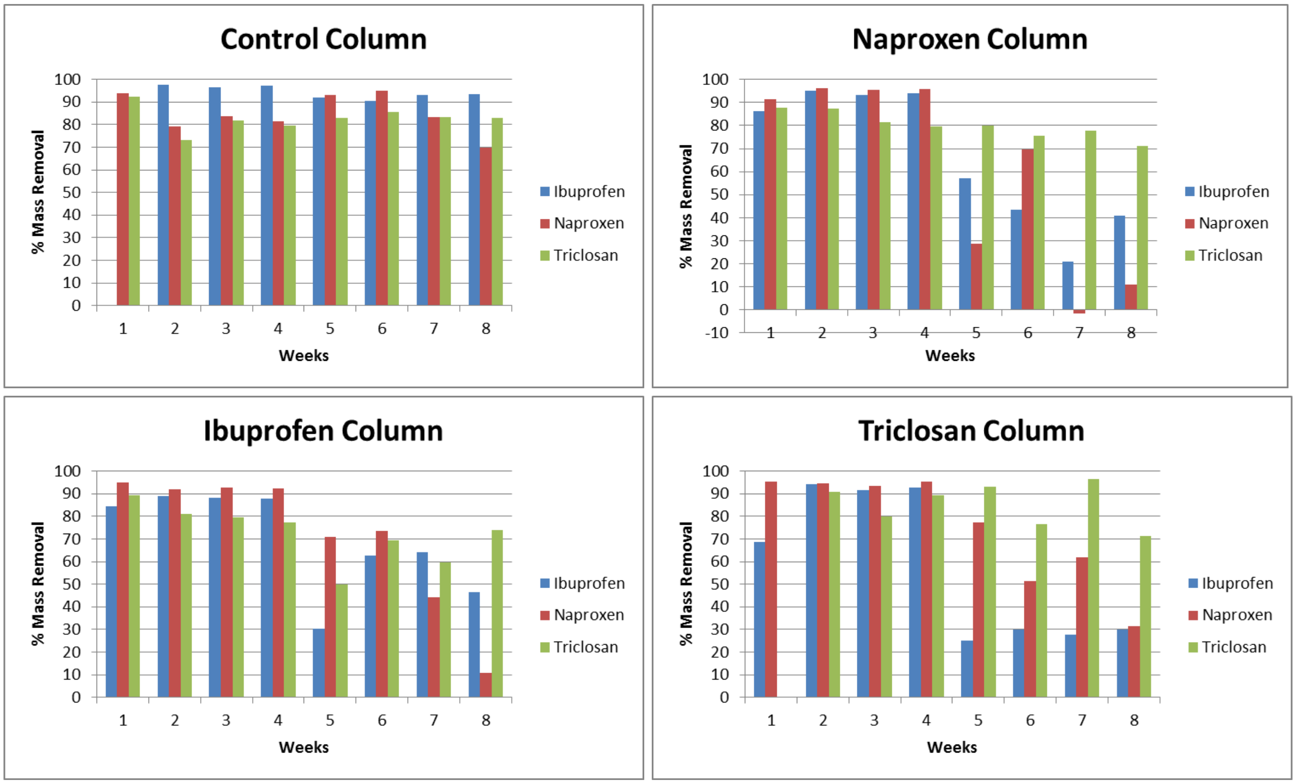

Figure 2. Results from the evaluation of ibuprofen, naproxen, and triclosan in the packed-bed media columns. The control column represents the source wastewater that already contained the three compounds of this study. The ibuprofen, naproxen, and triclosan columns represent source water plus a 0.1 ppm spike of the listed compound. Overall, naproxen seems to be the most difficult to remove while triclosan removal is relatively consistent.

Assessment of Watershed Land Use Stressors on the Biological Integrity of the Nolichucky River in Tennessee

Basic Information

Title:	Assessment of Watershed Land Use Stressors on the Biological Integrity of the Nolichucky River in Tennessee
Project Number:	2014TN103B
Start Date:	3/1/2014
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	Second
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Toxic Substances, Water Quality
Descriptors:	None
Principal Investigators:	J Brain Alford

Publications

There are no publications.

Introduction

In the Nolichucky River watershed of east Tennessee, there are five fish and seven mussel species listed as endangered or threatened by the State or the U.S. Fish and Wildlife Service, making it one of the most critically important "hot spots" for North American biodiversity. However, according to anecdotal observations, there has been an increase in the conversion of pasture/hay fields into vegetable "truck crop" agriculture, primarily tomatoes (Figure 1). Tomatoes demand pesticide spray treatments during the warm growing season; subsequently, runoff into tributaries and the Nolichucky main stem occurs. It is thought that pesticide runoff from tomato fields has caused acute fish mortalities in the watershed, one as recent as September 2012. Chronic levels of pesticide toxins may bioaccumulate into tissues of the biota, which can degrade biotic integrity and ecosystem function. The purpose of this project is to assess the influence of land use stressors in the Nolichucky River watershed on indicators of fish and invertebrate community health. We had two primary questions for this project: **(i)** is there a relationship between agricultural land use intensity (primarily that of tomato fields) and fish/invertebrate assemblage structure, and **(ii)** can indicator species be identified to potentially monitor impacts from agriculture?

Methods

Study Area

During July-October 2014, we surveyed 10 riffle-run-pool sites in the Nolichucky River watershed during low-flow periods and peak agricultural growing season (see Table 1 and Figure 2). Using a combination of aerial imagery and ground-truthing, sites were classified as "heavily impacted", "moderately impacted", and "least impacted" by agriculture to be able to detect differences in fish and invertebrate assemblages with respect to changes in agricultural land use intensity. Sites classified as most impacted had agricultural fields close to channel (< 10 m from the wetted margin), very turbid water, and fine sediments (silt and sand) prevalent in riffle-run-pool habitats of the channel. Moderately impacted sites had some observed agriculture in the watershed, but mostly a forested riparian zone and moderately clear water. Least impacted sites had a wide forested riparian buffer (>30 m from channel to field) and approximately 50% forested land in the watershed upstream of site, and the water was very clear with little or no evidence of sedimentation in the channel.

Figure 1. Photographs showing how agriculture in the Nolichucky watershed is impacting the streams. The top two photos show tomato fields near the Nolichucky River main channel. The top left is a field in full summer production of tomatoes. The top right shows a field near the river in April prior to planting. The lower left shows a canal that drains water and pesticides from a tomato field to the Pigeon River near Newport. The lower left is Lick Creek, a tributary to the Nolichucky that has constant suspended sediments in the water column due to heavy agricultural land use in the watershed. All photos were taken by J.B. Alford in 2014.

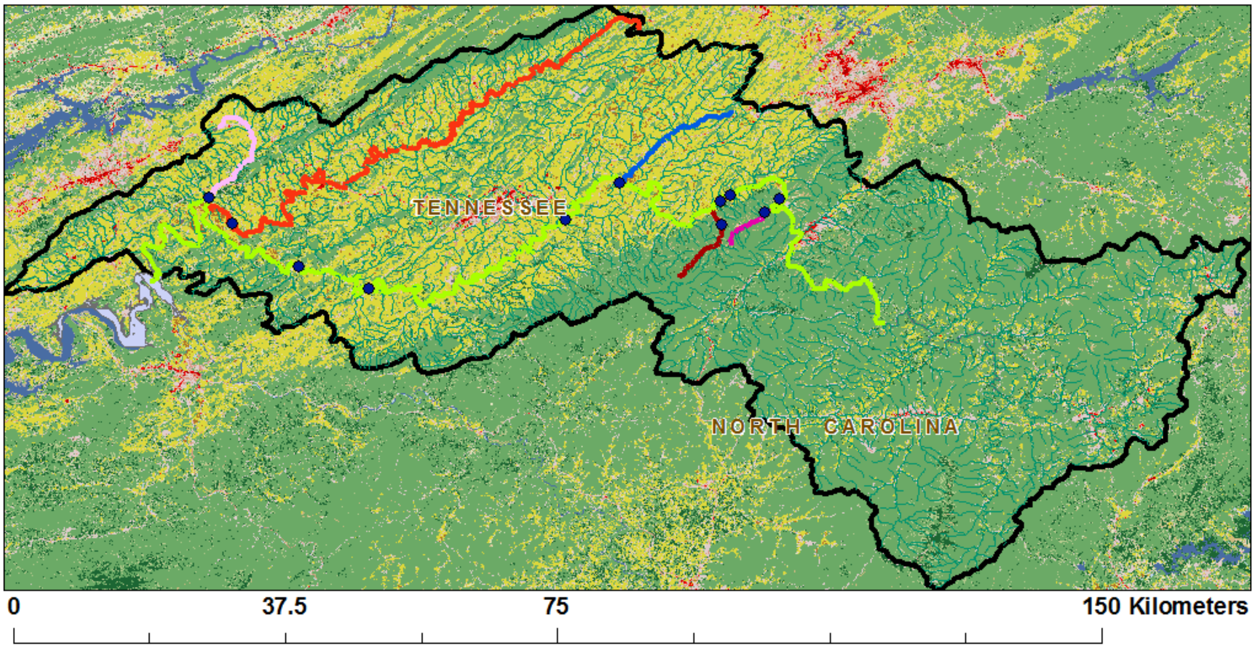

Figure 2. Remotely-sensed land use imagery for the Nolichucky watershed of Tennessee and North Carolina (data from 2001 U.S.G.S. National Land Cover Dataset). Green shades represent forest, yellow is agriculture (pasture/hay and row-crop), and red is urban land. The 2014 sample sites for fish and invertebrates in this project are the blue dots. The Nolichucky main stem (GIS flow line data) is highlighted in neon green, and tributary sites are highlighted in the remaining colors.

Table 1. A list of the 10 sample sites surveyed for fish and benthic macroinvertebrates during July-October 2014.

Stream Name	Location	Type	Latitude	Longitude	Elevation (ft)
Nolichucky River	Hwy 107	Main Stem	36.157082	-82.723426	1464
Nolichucky River	Jackson Island	Main Stem	36.186549	-82.519281	1811
Clarks Creek	Cherokee Nat. Forest	Tributary	36.150544	-82.529255	2080
Nolichucky River	Charlie Carson Rd.	Man Stem	36.180355	-82.531004	1855
Big Limestone Creek	Davy Crockett birthplace	Tributary	36.202830	-82.655933	1467
Nolichucky River	Riverpark Campground	Main Stem	36.183194	-82.457777	1873
Bumpus Cove Creek	Bumpus Cove Rd.	Tributary	36.165583	-82.475795	2005
Nolichucky River	Hwy 321	Main Stem	36.071230	-82.966965	1354
Lick Creek	Hwy 348	Tributary	36.151731	-83.135419	1177
Nolichucky River	Bewley Bridge	Main Stem	36.099304	-83.053388	1106

Physical habitat and *in situ* water quality were measured following USEPA Environmental Monitoring and Assessment Protocols (EMAP). Water quality data were collected with YSI model 650 multimeter sondes at all sites, which included dissolved oxygen, temperature, pH, total dissolved solids, and specific conductivity. Physical habitat data were collected for only the tributary sites. The

Nolichucky main stem, although mostly wadeable, was too swift and dangerous to collect these data, so they physical habitat data were not collected for these sites. Tributary streams and the main stem of the Nolichucky River were sampled for fish and invertebrates to account for the natural variation in community structure with changes in stream size and elevation. Using Tennessee Valley Authority (TVA) and Tennessee Department of Conservation (TDEDC) standard sampling protocols, fish were sampled with back-pack electrofishing in riffle-run habitats and 3 x 6 m seine nets in pool habitats. Benthic invertebrates were sampled semi-quantitatively with a 500 µm-mesh kick net a 2 riffle points (a fast riffle and slow riffle), sorted in the field to approximately Order taxonomic level, preserved in 45% ethanol, and identified to genus/species under light microscopy at the UT Fisheries Research Lab. Mussel and snail snorkel surveys were conducted initially for 5 sites, but only 1 live mussel was found. Therefore, we chose to eliminate this portion of the project, due to insufficient sample sizes of these taxa.

Indicator species analysis (ISA) was conducted in PC-ORD v. 6.0 software to determine which species could indicate an agricultural land use classification. The calculation of an ISA score uses the percent composition and frequency of occurrence data for each species at each site. Scores range 0-100, where ISA > 25 is considered to be strong for a particular classification type. Statistical significance (α = 0.05) of ISA scores are calculated using a 999 runs of a Monte Carlo randomization.

Results

Thus far, it appears that fish assemblage structure changes with respect to our site classifications. Overall, from riffle-run habitats only, we see a decrease in species richness (S) and Shannon-Wiener diversity (H`) metrics (Table 2) from sites least impacted to most impacted by agricultural land use. In terms of the 5 most dominant fish species sampled (percent composition and frequency of occurrence) from riffle-run habitats, the relative abundance of Sharphead Darter (*Nothonotus acuticeps*) and Bluebreast Darter (*Nothonotus camurum*) declined from least impacted to most impacted sites, while abundance of Banded Sculpin (*Cottus carolinae*) and Redline Darter (*Nothonotus rufilineatum*) increased in most impacted sites (Table 3).

The indicator species analysis (ISA) revealed that, for main stem riffle-run habitats, Sharphead Darter, Bluebreast Darter, and Greenside Darter (*Etheostoma blennioides*) were strong indicators (IV score > 25) of sites that were least impacted by agriculture (Table 4). For tributary riffle-run habitats, the Saffron Shiner (*Notropis rubricroceus*) and Snubnose Darter (*Etheostoma simoterum*) were strong indicators of least impacted condition. The Banded Sculpin was a strong indicator of the most impacted condition at all stream sizes. For pool habitats, regardless of stream size, the Telescope Shiner (*Notropis telescopus*) was a strong indicator of least impacted condition and the Warpaint Shiner (*Luxilus coccogenis*) was indicative of most impacted agricultural condition.

For benthic macroinvertebrate data, ISA could not be conducted, because only 9 of 10 samples have been identified completely (see Appendix A).

Discussion and Future Work

Although 10 sites have been surveyed for fish and invertebrates, we still need to sample 10 more sites during 2015 to get an adequate sample size for more precise analytical results. Nonetheless, it appears that, from a preliminary perspective, there is a difference in fish assemblage structure as riffle-run habitats become more impacted by agricultural land use. As agriculture increases in intensity in the immediate landscape surrounding a site, fewer fish species are present and species that prefer cobble substrates with little or no fine sediments and fast, clear water are absent (e.g., Sharphead Darter and Bluebreast Darter). In addition, tributary streams that are more turbid, due to suspended sediments, are void of water column, invertebrate drift feeders like the Saffron Shiner. More samples need to be taken in 2015, however, to determine if this relationship holds true. Benthic invertebrate assemblage data need to be analyzed as well to determine if the overall aquatic community is affected.

Table 2. Summary statistics describing the fish assemblage from samples collected in the Nolichucky River watershed during July-October 2104. S = species richness, E = evenness, H = Shannon-Wiener diversity index, D` = Simpson's Dominance index.

Riffle-run Habitats				
Ag Impact	**S**	**E**	**H**	**D`**
Least (36 sp.)	15.3	0.6	1.6	0.6
Mod. (30 sp.)	7.3	0.5	1.1	0.4
Most (24 sp.)	5.0	0.5	0.9	0.4
Pool Habitats				
Ag Impact	**S**	**E**	**H**	**D`**
Least (28 sp.)	3.4	0.5	0.7	0.3
Mod. (20 sp.)	1.9	0.2	0.4	0.2
Most (28 sp.)	3.5	0.4	0.7	0.3

Table 3. Relative abundance of the 5 most dominant fish species sampled in the Nolichucky River watershed during July-October 2014. Sites were classified as least, moderately, and most impacted by agricultural land use.

% Composition			% Occurrence		
Rank	**Species**		**Rank**	**Species**	**% Occurrence**

Least Impacted			Least Impacted		
1	Sharphead Darter		1	Greenside Darter	67
2	Bluebreast Darter		2	Bluebreast Darter	59
3	Greenside Darter		3	Sharphead Darter	58
4	Highland Shiner		4	Banded Darter	58
5	Mottled Sculpin		5	Highland Shiner	47
Mod. Impacted			Mod. Impacted		
1	Highland Shiner		1	Highland Shiner	61
2	Mimic Shiner		2	Banded Darter	55
3	Telescope Shiner		3	River Chub	52
4	Banded Darter		4	Mimic Shiner	46
5	Greenside Darter		5	Greenside Darter	41
Most Impacted			Most Impacted		
1	Banded Sculpin		1	Banded Sculpin	65
2	Central Stoneroller		2	Central Stoneroller	40
3	Greenside Darter		3	Greenside Darter	38
4	Banded Darter		4	Banded Darter	33
5	Redline Darter		5	Redline Darter	29

Table 4. Results of an indicator species analysis (ISA) using fish species sampled in the Nolichucky River watershed during July-October 2014. Sites were classified as least, moderately, and most impacted by agricultural land use. IV scores > 25 are considered strong indicators of a classification type.

Riffle-run Habitats			
Ag Impact	**Species**	**IV**	***P*-value**
Least	Sharphead Darter	55	0.0002
	Bluebreast Darter	55	0.004
	Greenside Darter	48	0.0002
	Saffron Shiner	39	0.0002
	Snubnose Darter	32	0.0002
	Mottled Sculpin	21	0.0002
Moderate	Mimic Shiner	35	0.0002
	River Chub	33	0.0002
Most	Banded Sculpin	38	0.003

	Redline Darter	22	0.0002
Pool Habitats			
Ag Impact	**Species**	**IV**	***P*-value**
Least	Telescope Shiner	36	0.0002
	Tennessee Shiner	14	0.007
Moderate	Smallmouth Redhorse	15	0.02
Most	Warpaint Shiner	51	0.0002
	Silver Shiner	19	0.002
	Mosquitofish	13	0.01

Appendix A. Most recent counts of benthic macroinvertebrates sampled from 9 sites the Nolichucky watershed during July-October 2014. The tenth sample is still being identified in the lab.

Class/Order	Family	Genus	Species	Total
Amphipoda				1
Coleoptera	Dryopidae	*Helichus*	*fastigiatus*	5
Coleoptera	Elmidae	*Dubiraphia*	*sp.*	1
Coleoptera	Elmidae	*Macronychus*	*glabratus*	7
Coleoptera	Elmidae	*Optioservus*	*ovalis*	13
Coleoptera	Elmidae			1
Coleoptera	Elmidae	*Oulimnius*	*latiusculus*	40
Coleoptera	Elmidae	*Promoresia*	*sp.*	1
Coleoptera	Elmidae	*Psephenus*	*herricki*	16
Coleoptera	Elmidae	*Stenelmis*	*sp.*	76
Coleoptera	Psephenidae	*Psephenus*	*herricki*	1
Coleoptera	Psephenidae			41
Coleoptera	Ptilodactylidae	*Anchytarsus*	*bicolor*	3
Coleoptera	Helophoridae	*Helophorus*	*sp.*	3
Coleoptera	Chrysomelidae			7
Coleoptera	Hydrophilidae	*Cerycon*	*sp.*	7
Coleoptera	Scirtidae	*Sacodes*	*sp.*	7
Diptera	Athericidae	*Atherix*	*lantha*	2
Diptera	Ceratopogonidae	*Prionocera*	*sp.*	2

Diptera	Chironomidae	*Ablabesmyia*	*mallochi*	1
Diptera	Chironomidae	*Cricotopus*	*sp.*	4
Diptera	Chironomidae	*Demicryptochironomus*	*sp.*	1
Diptera	Chironomidae	*Euryhapsis*	*sp.*	1
Diptera	Chironomidae	*Microtendipes*	*pedellus*	1
Diptera	Chironomidae	*Natarsia*	*sp.*	2
Diptera	Chironomidae	*Orthocladius*	*dubitatus*	74
Diptera	Chironomidae	*Pagastia*	*sp.*	2
Diptera	Chironomidae	*Polypedilum*	*flavum*	3
Diptera	Chironomidae	*Stempellinella*	*sp.*	6
Diptera	Chironomidae	*Thienemannimyia*	*sp.*	2
Diptera	Chironomidae	*Tvetenia*	*sp.*	5
Diptera	Chironomidae			11
Diptera	Empididae			3
Diptera	Simuliidae	*Cnephia*	*sp.*	3
Diptera	Simuliidae	*Simulium*	*sp.*	51
Diptera	Tanyderidae	*Protoplasa*	*sp.*	1
Diptera	Tipulidae	*Antocha*	*sp.*	40
Diptera	Tipulidae	*Cnephia*	*sp.*	18
Diptera	Tipulidae	*Limonia*	*sp.*	1
Diptera	Tipulidae	*Tipula*	*sp.*	4
Ephemeroptera	Baetidae	*Acentrella*	*sp.*	3
Ephemeroptera	Baetidae	*Baetis*	*sp.*	117
Ephemeroptera	Baetidae	*Heterocloeon*	*jubilatum*	1
Ephemeroptera	Baetidae			22
Ephemeroptera	Caenidae	*Caenis*	*sp.*	2
Ephemeroptera	Ephemerellidae	*Drunella*	*sp.*	1
Ephemeroptera	Ephemerellidae	*Serratella*	*deficiens*	4
Ephemeroptera	Ephemerellidae			49
Ephemeroptera	Ephemerellidae			1
Ephemeroptera	Heptageniidae	*Maccaffertium*	*mediopunctatum*	41
Ephemeroptera	Heptageniidae	*Maccaffertium*	*modestum*	12
Ephemeroptera	Heptageniidae	*Maccaffertium*	*terminatum*	3
Ephemeroptera	Heptageniidae			76
Ephemeroptera	Heptageniidae	*Stenacron*	*interpunctatum*	2
Ephemeroptera	Heptageniidae			8
Ephemeroptera	Heptageniidae	*Stenonema*	*sp.*	78
Ephemeroptera	Isonychidae	*Isonychia*	*sp.*	172
Ephemeroptera	Leptohyphidae	*Tricorythodes*	*sp.*	2
Ephemeroptera	Leptophlebiidae	*Leptophlebia*	*sp.*	17
Ephemeroptera	Leptophlebiidae	*Paraleptophlebia*	*sp.*	3
Hydrachnida	Leptophlebiidae			3
Megaloptera	Coydalidae	*Corydalus*	*cornutus*	14
Megaloptera	Coydalidae	*Nigronia*	*serricornis*	3
Megaloptera	Coydalidae			6

Odonata	Calopterygidae	*Hetaerina*	*sp.*	1
Odonata	Coenagrionidae	*Argia*	*sp.*	2
Odonata	Gomphidae	*Arigomphus*	*sp.*	8
Odonata	Gomphidae	*Hetaerina*	*americana*	1
Odonata	Gomphidae	*Lanthus*	*vernalis*	2
Odonata	Gomphidae			8
Odonata	Macromiidae	*Macromia*	*sp.*	1
Oligochaeta	Naididae			1
Oligochaeta				2
Plecoptera	Leuctridae	*Leuctra*	*sp.*	66
Plecoptera	Perlidae	*Acroneuria*	*sp.*	12
Plecoptera	Perlidae	*Agnetina*	*sp.*	7
Plecoptera	Pteronarcyidae	*Pteronarcys*	*proteus*	25
Plecoptera	Pteronarcyidae	*Pteronarcys*	*sp.*	2
Plecoptera	Peltoperlidae	*Tallaperla*	*sp.*	144
Trichoptera	Glossosomatidae	*Glossosoma*	*sp.*	2
Trichoptera	Hydropsychidae	*Brachycentrus*	*sp.*	134
Trichoptera	Hydropsychidae	*Ceratopsyche*	*morosa*	11
Trichoptera	Hydropsychidae	*Ceratopsyche*	*sparna*	24
Trichoptera	Hydropsychidae	*Ceratopsyche*	*sp.*	12
Trichoptera	Hydropsychidae	*Cheumatospsyche*	*sp.*	362
Trichoptera	Hydropsychidae	*Diplonectra*	*modesta*	1
Trichoptera	Hydropsychidae	*Hydropsyche*	*alvata*	17
Trichoptera	Hydropsychidae	*Hydropsyche*	*betteni/depravata*	10
Trichoptera	Hydropsychidae	*Hydropsyche*	*sp.*	217
Trichoptera	Hydropsychidae	*Neophylax*	*etnieri*	1
Trichoptera	Hydropsychidae	*Psychomyia*	*flavida*	1
Trichoptera	Leptoceridae	*Oecetis*	*sp.*	8
Trichoptera	Leptoceridae	*Petrophila*	*sp.*	8
Trichoptera	Polycentropodidae	*Cernotina*	*sp.*	1
Trichoptera	Polycentropodidae	*Cyrnellus*	*sp.*	2
Trichoptera	Rhyacophilidae	*Rhyacophila*	*formosa*	1
Trichoptera	Rhyacophilidae	*Rhyacophila*	*fuscula*	2
Trichoptera	Rhyacophilidae	*Rhyacophila*	*sp.*	6
Trichoptera	Psychomyiidae	*Psychomyia*	*sp.*	2
Trichoptera	Philopotamidae	*Dolophilodes*	*sp.*	2
Trichoptera	Hydroptilidae	*Oxyethira*	*sp.*	1
Trichoptera	Hydroptilidae	*Stactobiella*	*sp.*	1
Trichoptera	Lepidostomatidae	*Lepidostoma*	*sp.*	1
Grand Total				2217

High Resolution Monitoring of Urban Stormwater Quality

Basic Information

Title:	High Resolution Monitoring of Urban Stormwater Quality
Project Number:	2014TN104B
Start Date:	3/1/2014
End Date:	2/28/2016
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Focus Category:	Water Quality, Non Point Pollution, Surface Water
Descriptors:	None
Principal Investigators:	Jon M Hathaway, Kimberly Carter

Publications

1. Epps, T.H., J.M. Hathaway, 2015. Assessing Spatial Relationships of Distributed Urban Land Cover Compositions and In-stream, Flow Regime in Knoxville, TN., World Environmental and Water Resources Congress, Austin, TX. May18-20.
2. Epps, T.H., J.M. Hathaway, 2015. Assessing Spatial Relationships of Distributed Urban Land Cover Compositions and In-stream Flow Regime in Knoxville, TN. "in" Proceedings of the Twenty-fourth Annual Water Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN.. pp.B1-6.

Nature, Scope and Objectives

In the 2010 Tennessee Water Quality Assessment Report, urban runoff was identified as one of the primary causes of impairment in streams and rivers in the state. Similar results were found for the Southeast Region in states such as Georgia, Alabama, and Virginia (USEPA, 2014). As such, watershed restoration efforts (such as developing TMDLs) require consideration of stormwater runoff. Stormwater had been shown to transport nutrients, sediments, metals, and indicator bacteria to local surface waters (Burton and Pitt 2002). Despite this fundamental understanding, further research is needed to understand the fate and transport of pollutants in stormwater (Fletcher et al. 2013).

Modeling is an integral part of watershed restoration efforts, as is an understanding of the pollutant of concern's fate and transport and what factors influence the pollutant's variability. Modeling provides valuable insight into the pollutant sources, sinks, and processes within a given watershed (Vaze and Chiew 2003). This insight allows more targeted, efficient, and cost-effective pollution abatement efforts. High resolution data can aid in such efforts, offering a preliminary investigation of the variability of pollutants in stormwater and what factors influence this variability. In addition, pollutants such as *E. coli* and organic chemicals have not been extensively characterized in stormwater runoff, resulting in a lack of understanding as to the potential threat these pollutants pose to public and ecological health. The overall goal of this research is to better understand urban stormwater and provide sustainable ways to reduce its contribution to surface water degradation.

The specific objective of this project is to collect high resolution water quality data in an urban stream to allow an understanding of factors explaining the variability of pollutants observed in these systems.

Methods, Procedures and Facilities:

During FY2014, a gaging station was installed in Second Creek near its confluence with Lake Loudoun (Figure 1). This station is powered by a permanent electric supply run from Estabrook Road. The station consists of a refrigerated sampler connected to an ISCO Signature flow meter (Figure 2a). The flow meter utilizes an area velocity probe fixed to the channel bed to collect depth and velocity readings for the stream. A survey of the stream cross section (Figure 2b) was performed by graduate and undergraduate students to allow development of a stage discharge relationship for the station.

Samples are flow paced, allowing evenly distributed sample collection throughout targeted storm events. Samples are retrieved after storm events, and transported to the water quality analysis lab in the SERF building at the University of Tennessee. Samples are analyzed by UT students for *E. coli*, TSS, nutrients, and metals. Additionally, a composite sample is created for the event and is sent to an outside laboratory for analysis of organic compounds.

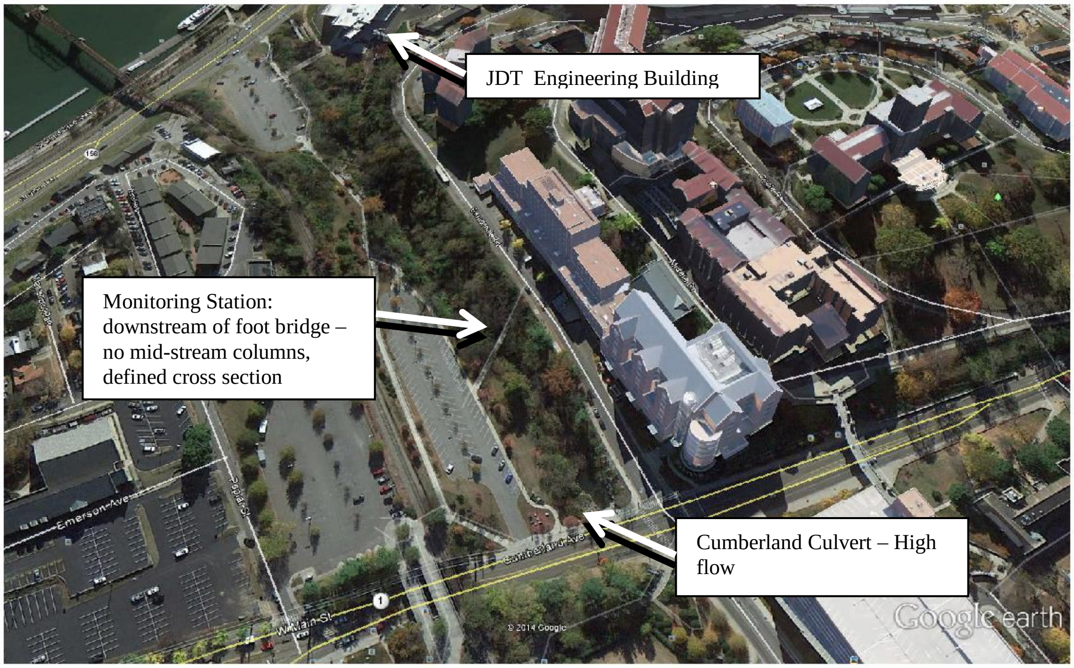


Figure 1: (a) Second Creek Monitoring Station Location Near Intersection of Cumberland Avenue and Estabrook Road

(a) **(b)**

Figure 2: (a) Second Creek Monitoring Installation, and (b) Undergraduate Student Surveying the Second Creek Cross Section

Results and Findings:

Since sampling began in September 2014, eight storm events have been collected (at the time of this document). An average of 13 samples were analyzed per sample resulting in well-defined pollutagraphs for the storm events monitored (Figure 3). The data collected thus far confirm high concentrations of sediments, indicator bacteria, and some forms of nitrogen (nitrate) in the storm samples. For instance, *E. coli* concentrations reached as high as 18,000 MPN / 100 ml during the storm event on 9/11/2014. This is over 140 times the average concentration desirable for primary contact in recreational waters. Organics analysis failed to result in positive identification of organic pollutants in the storm flows sampled in latter part of the year. Thus, additional analyses are being performed on base flow and sediments to identify possible causes for this lack of presence, as well as analysis to determine the presence of other organic species including perfluorinated and fluorinated compounds.

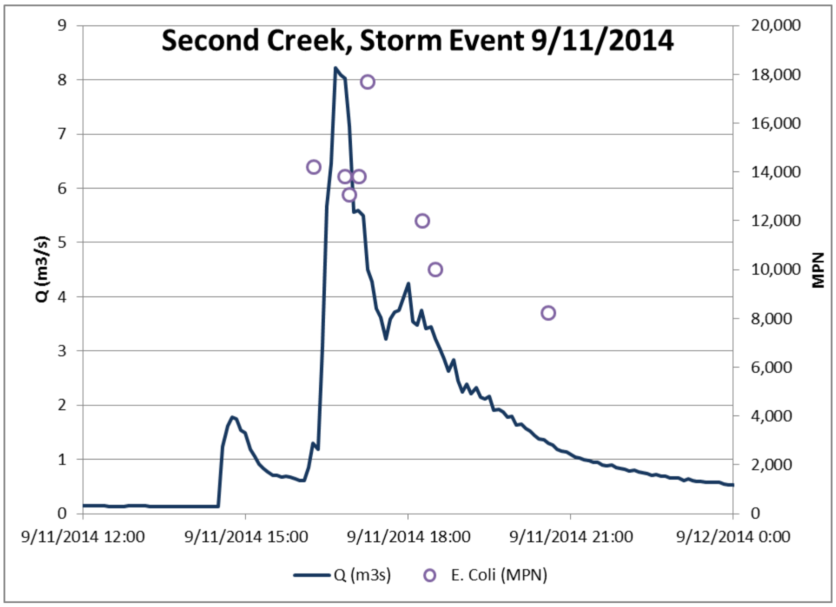


Figure 3: Example pollutagraph from Second Creek – *E. coli* concentrations and flow from 9/11/2014 storm event

In addition to insights into water quality made possible through this monitoring, the flow data collected from Second Creek are being paired with data from other streams in Knoxville by a doctoral student to investigate the patterns and connection of impervious areas in the city. Connected impervious areas have been found to most substantially impact the quality of receiving streams, thus, this is also a critical area of research need. Through this, more targeted approaches to watershed restoration may be possible.

Underground Reactive Barrier to Attenuate Contaminants from Agricultural Drainage

Basic Information

Title:	Underground Reactive Barrier to Attenuate Contaminants from Agricultural Drainage
Project Number:	2014TN105B
Start Date:	3/1/2014
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	Second, TN
Research Category:	Water Quality
Focus Category:	Nitrate Contamination, Nutrients, Treatment
Descriptors:	None
Principal Investigators:	Jaehoon Lee, John R. Buchanan, Jennifer DeBruyn, Shawn Hawkins, Andrea Ludwig, Forbes Walker

Publication

1. Lee, J., A.C. Shefy, F.R. Walker, A.l. Ludwig, J.R. Buchanan and N.S. Eash, 2014. Evaluation of biochar as a medium for underground reactive barrier to attenuate chemicals from agriculture drainage. 2014 World Congress of Soil Science (invited).

(1) Statement of Critical Regional or State Water Problem(s): Typical concentrated animal feeding operations such as dairy facilities produce large quantities of manure which is stored in lagoons or holding ponds before being applied to nearby crop or pasture fields. Off-site movement of the manure as well as other fertilizers through storm water runoff or percolation to groundwater has been well recognized as a major source of contamination of water bodies. This is especially true in east Tennessee with high rainfall and substantial topographic relief. The author of this proposal has been actively involved in assessing the new UT Little River Animal and Environmental Unit for the potential stream and groundwater contamination. Our preliminary data show that the underlying soil and rock of the unit is highly permeable and will allow a rapid movement of chemicals and pathogens to groundwater and surrounding streams and rivers. In Tennessee, there are 303(d) list of impaired water bodies due to excess pathogens and nutrients. There is a great need for cost-effective and proven best management practices to mediate the excess nutrients. Our research findings will create science-based recommendations for the use of underground reactive barriers in challenging environmental conditions found in many areas of the Tennessee. This project will also be a demonstration at the UT Research and Education Center, and data will continue to be collected in the future.

(2) Research Objectives:

There are two specific aims and hypotheses in this proposed project.

Specific Aims

- Evaluation of biochar and charcoal as a medium for reactive barrier to capture P and other organic chemicals (e.g., veterinary antibiotics and pesticides).
- Evaluate the effects of water level and temperature on the rate of treatment.

Hypothesis

- Underground reactive barrier using combined sawdust and biochar/charcoal will increase the level of nitrate (NO_3^-) removal as well as P and other organic chemicals.
- Control of water level and residence time in the barrier in conjunction with seasonal variations of drainage will improve the removal rate.

(3) Methods, Procedures and Facilities

Barrier construction: We will install underground reactive barriers in the new UT Little River Animal and Environmental Unit located at 3217 Ellejoy Road, Walland, TN; about a 30 minute drive from UT Campus. The research and education center is bounded by streams on three sides and lies in the floodplain of a state-declared exceptional waterway. A charcoal-woodchip barrier will be installed right next to the already planned 100% woodchip traditional barrier. The new barrier will use a mixture of sawdust (80%) and biochar or charcoal (20% in volume). The barriers will be approximately 1.5 m deep, 7 m wide, and 15 m long, and will be designed to catch surface runoff as well as shallow ground water. The locations of the barriers are already determined by a consultation with Dr. Bobby Simpson (Director of the East TN Research & Education Center) and support staff, considering 5 years of previous runoff and groundwater monitoring data.

Barrier Control: Two water level control structures similar to the Agri Drain will be installed to control water levels in the barriers and tile-drained field. One structure will be installed right before (inlet) the barrier and the other will be installed at the end of the barrier. The two structures will allow us to control water level of the tile-installed filed as well as the barrier itself. The structures bypass excess drainage and runoff to nearby drainage field, if there is more water than the barrier can handle. The structures will also be used for routine water sampling. Temperature sensors will be installed in two locations at two depths (30 and 90 cm) to monitor barrier temperature. It is well documented that saturation provides the best environment for denitrifiers and thus works best for N reduction. However, there are limited literatures about charcoal amendment in the barrier, especially related to treatment of P, other organic chemicals, and pathogens and its relationship with water level. The barrier will be maintained for the highest possible water level to provide the best reduction of N. However, when there is not enough water, we will record the water level and/or saturation rate, and closely monitor the rate of reduction for N, P and other organic chemicals.

Water quality monitoring: At least two samplings each month will be done for analysis of N, P, selected chemicals (e.g., tylosin, chlortetracycline, sulfamethazine, and a few pesticides as well), and fecal bacteria/pathogen. The investigators have two full-time research associates (one engineer and the other for soil and water analysis), and nearly 1500 square feet of modern lab space combined. We have an analytical chemistry lab equipped with all the equipment and apparatus necessary for the water sample analysis (e.g., HPLC, GC, ICP, AA, GC/MS).
The BESS also has qualified faculty, scientists, and technicians with extensive experience in both laboratory and field research, as well as students interested in this research topic. Several types of vehicles (vans, trucks, trailers, and tractors), and a well-equipped fabrication shop with two full-time staff members are also available.

(4) Principal Findings to date:

Pilot Scale Test: We did small scale experiments to test the efficacy of biochar and charcoal as a reactive barrier medium. Various ratios (5, 10 and 20% v/v) of biochar and charcoal with sawdust were evaluated for their removal of N, P and other agricultural chemicals. The results showed that 10% of charcoal by volume provided the most economic rate of treatment. We also found out that addition of silage leachate to the reactive barrier significantly increased denitrification. The silage leachate contains high carbon content and degrades nearby water, however, if added to the barrier, the carbon can be immediately used for the denitrification process.

Field installation of barrier: Two locations in the Center has been identified and prepared for installation. All the materials, liners, woodchips, sand, charcoal, construction equipment, sampling access tubes, etc., are secured and installation will begin this summer.

Recalibrating the SAGT SPARROW to Accommodate Changes in Agricultural Inputs

Basic Information

Title:	Recalibrating the SAGT SPARROW to Accommodate Changes in Agricultural Inputs
Project Number:	2014TN106B
Start Date:	3/1/2014
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	Second, TN
Research Category:	Water Quality
Focus Category:	Agriculture, Models, Water Quality
Descriptors:	None
Principal Investigators:	Dayton M Lambert, Christopher N Boyer, Christopher D Clark, John S. Schwartz

Publications

There are no publications.

Statement of Critical Regional or State Water Problems:

By 2022, the United States (US) Renewable Fuels Standard (RFS) mandates that 36 billion gallons of ethanol be blended into gasoline, with 21 billion gallons of that coming in the form of advanced biofuels, including at least 16 billion gallons of cellulosic ethanol (USDOE, 2015). In examining increased cellulosic ethanol production, the Biomass Research and Development Board (BRDB, 2008) assumed conservatively 4 billion gallons of cellulosic ethanol would originate from woody material in support of meeting the RFS by 2022. Other research suggests that 10.5 billion of the 21 billion gallon annual production targets for advanced biofuels mandated by the RFS could originate in the Southeastern United States (USDA, 2010).

Nearly all of the biofuel currently produced in the US comes from first generation feedstock, primarily corn grain. Meeting the RFS requirements will require increased biofuel production from second-generation feedstock, such as switchgrass, miscanthus, canola, camelina, or woody biomass. The increased market demand for energy crops is expected to result in extensive conversion of previously uncultivated land, fallow agricultural land, pastureland, or Conservation Reserve Program (CRP) land, potentially resulting in a substantial increase in land in agricultural production (Robertson et al., 2010; Perlack and Stokes, 2011; Demissie, Yan, and Wu, 2012). Increased biofuel production from second generation feedstock offers the possibility of reducing the amount of tilled land and mitigating climate change by reducing the emission of greenhouse gases (GHG) associated with transportation fuels. However, converting enough land to feedstock production to meet the RFS could significantly affect nutrient emissions from agriculture and regional water quality balances. Changes in fertilizer use, tillage practices, and vegetal cover may generate unintended consequences that affect the ecosystem services provided by the region's streams and rivers. Agriculture is a major contributor to the region's economy and communities and predicting the nature of these consequences is difficult because of the extended growing season and diverse types of agricultural practices currently employed in the region. Seasonal and spatial variability in rainfall, temperature, soil types, and access to water support an intensive and diverse agricultural production region (Ingram et. al., 2013).

This research modifies the South Atlantic-Gulf-Tennessee basin (SAGT) system SPARROW (Spatially Referenced Regression on Watershed Attributes) model (SAGT-SPAROW), developed by Hoos et al. (2008) and calibrated and applied by Hoos and McMahon (2009), to examine potential impacts of land use change resulting from a mature cellulosic biofuel industry on water quality in the SAGT basin. The primary data-generating and modeling challenges addressed in this research are 1) generating agronomic and economic data sets to reflect the distribution of feedstock production potential, attendant production costs, and crop nutrient demand, and 2) integrating the agronomic and economic data sets with hydrological data sets provided by the US Geological Survey (USGS) at commensurable geospatial scales. Both procedures make extensive use of internal GIS capabilities and data management algorithms. A data harmonizing procedure is developed to benchmark data collected by NASS with fertilizer use data available in the SAGT-USGS data sets. After compiling downscaled and integrated data sets, we augment variables in the USGS-SAGT data set reflecting agriculture's contribution of N and P to aggregate N and P emissions. The revised set of variables is used to compare *ex ante* a baseline scenario (an agricultural landscape's impact on N and P emissions absent the RFS) to various target biofuel production levels for the SAGT region based on the RFS mandate. Canola (for biodiesel) and short rotation woody crops (SRWC) (for pyrolysis) are the feedstock considered in the analysis.

This report describes the: i) development of regional canola budgets; ii) estimation of canola and SRWC yields; and iii) impacts of land use change following the establishment of biodiesel refineries in the SAGT region on N and P emissions into the SAGT basin. Component (i) was crucial for developing an estimate of opportunity costs, which drive the conversion of conventional cropland to feedstock production and the distribution of biofuel refineries. First-pass runs for component (ii) suggest the N and P emission impacts of canola on the SAGT are statistically insignificant evaluated at an aggregate, regional level. Discussion focuses on the impacts of a biodiesel industry using canola as a primary feedstock because all modeling steps for this industry have been completed. Work on similar analyses for SRWC continues.

Methods, Procedures and Facilities

Regional production costs and yields for canola

We begin by examining the feasibility of canola production in the Southeastern US on a profitably of production basis. To model the heterogeneity in production costs across the Southeastern US, we ideally would collect enterprise budgets for each state in the region to estimate per-acre costs of production. However, canola is not widely grown in the Southeastern US and we are not able to locate a budget for each state. So, we have to predict per-acre net returns in the counties where we do not have a budget. Therefore, using enterprise budgets from states in which canola is currently grown to provide cost of production data, we interpolate the per-acre net returns of canola production across counties in the Southeastern US. The budgets are aggregated on variable, fixed and total costs of production for each state. Each budget assumes a yield, typically based on historical averages for the region. In this study, we replace the assumed yield with a yield that is estimated by a plant growth model. Simulating yields with the plant growth model enables us to disaggregate yield estimates from the state- to the county-level. Utilizing the cost of production data and the estimated yields, net returns are calculated for the regions where we observe costs of production via the enterprise budgets. These observations are used to estimate a model which predicts per-acre net returns for the Southeastern US.

The canola budgets were collected from a variety of sources including Land Grant University Extension services. University Extension services provide enterprise budgets for crop production to aid in projecting costs and net returns as a guide in farm management. Although the focus of this project is on the Southeastern region, we collected budgets from as many states as possible, as future research may expand to areas outside the Southeastern US. Canola enterprise budgets (n = 29) representing 17 states (Georgia, South Carolina, North Carolina, Virginia, Tennessee, Kentucky, Texas, Oklahoma, Utah, Kansas, Missouri, Pennsylvania, North Dakota, Montana, Idaho, Washington and Oregon) were obtained. However, budgets from Utah, Kansas and Missouri were removed from the sample. The Utah and Kansas budgets did not report variable/operating costs or fixed/ownership costs and instead only listed total costs, while the Missouri budget did not report the year in which the budgets were generated, preventing the figures from being converted into current year prices and costs. After eliminating budgets from these three states, the remaining budgets represent 14 states, including seven of the nine states for which the US Department of Agriculture's National Agricultural Statistics Service (USDA NASS) reported commercial-scale canola production as of October 2014 (Idaho, Minnesota, Montana, North Dakota, Oklahoma, Oregon, Washington, Colorado and Kansas).

Multiple budgets were located for six of the states. For Idaho, we found three budgets, one for each of three different tillage methods (Conventional Tillage, Reduced Tillage and No Tillage). Two budgets for Montana were identified – one for irrigated and one for dryland production. Six budgets were found for North Dakota, one for each of six different multi-county regions. There are two budgets for Oregon, one for winter and one for spring canola varieties. Two budgets for Texas were found, with one budget assuming the planting of round-up ready seed and the other standard seed. Washington is represented by three budgets prepared for three different rainfall regions. One budget from each state was used to calculate net returns. With the exception of Texas and Washington, the budget selected was the one that reported higher per acre costs of production. In Texas, the budget with the higher per acre costs of production assumed the use of round-up ready seeds and, as a result, has a slightly higher assumed cost of production. The use of round-up ready seeds is an anomaly among the budgets, so the budget for standard canola seed and, thus, slightly lower production costs, was used. The budgets representing the state of Washington differ by rainfall region and the budget with the highest yield assumes production in the highest rainfall region, but not the highest cost of production. In this case the budget in the high rainfall region was selected.

Canola yields are estimated using the Environmental Policy Integrated Climate (EPIC) plant growth model (Figure 1). EPIC simulates the physical processes in hydrology, nutrient cycling and plant growth using readily available inputs (Larson et al 2005). EPIC has been extensively used throughout the US and in several foreign countries. The model provides erosion-productivity relationships for approximately 900 benchmark soils and 500,000 crop/tillage/conservation strategies throughout the US. Furthermore it is, computationally efficient and capable of computing the effects of management decisions (Williams et al 1989). Using yields estimated in EPIC and production costs projected in state enterprise budgets we calculate per-acre net returns.

Aggregating across the budgets poses a challenge due to inconsistencies in budget categories from one state to another. Production methods and the schedule of operations for canola vary by region, so it is natural to expect a varied projection of costs and returns. However, there is significant heterogeneity in the line item cost categories used in the budgets across the states and, thus, costs were aggregated into two categories; variable/operating costs and fixed/ownership costs. These two variables become the common variables to normalize on and the aggregated data set includes both variable and fixed costs for 13 of the 14 represented states, with Montana being the only state not to include both fixed and variable costs. To arrive at total cost, we sum the total variable costs and total fixed costs and then subtract costs for crop insurance and land rent where those cost categories were included in the budget. Crop insurance costs were excluded because crop insurance for canola is not available in all of the states for which budgets were obtained. Land rent was excluded because it is assumed to be invariant to land use. See Table 1.

Using aggregated versions of the budgets, per acre net returns for canola production in each county are calculated. It was found that break-even prices per bushel of canola approximate a normal distribution with a mean of $8.44, a minimum of $4.89 and a maximum of $13.71. Therefore, net returns are calculated using a range of $8 to $12 per bushel.

Focusing on the economic feasibility of canola production in the Southeastern US, we limit our sample to this region. To do so we exclude all states outside the Southeastern US from the interpolations. Therefore, predicted per-acre net returns for potential canola producing regions are interpolated using the calculated per-acre net returns in the sample of Southeastern states. Based on our cost of production data using the enterprise budgets, we have a statewide cost of production that is constant across counties within each state. Variation in net return across counties is due to the varying yields, which are estimated in the plant growth model EPIC. Therefore, based on our sample, net returns are calculated for each county in the states for which we have cost of production data. Using interpolation methods in ArcGIS, we then estimate our model and predict net returns for each county across the Southeastern US. Predicted net returns are estimated at three different prices - $8, $10 and $12 per bushel. There are several methods of interpolation to be considered. Using ArcGIS, the Inverse Distance Weighting (IDW) method and the Radial Basis Function (RBF) methods are used to estimate and predict net returns.

The IDW method implements the assumption that points closest in proximity to each other are more alike than those further away (ESRI 2014). Potential Canola producing regions with unobserved net returns are predicted using the calculated net returns surrounding the prediction region. Observed points nearest the prediction region are weighted more heavily in their influence. IDW assumes the level of influence observed points have on the prediction region diminishes with distance. Each observed point is assigned a weight, which is inversely proportional to the distance from the prediction region. The IDW formula is

$$\widehat{NR}_i = \frac{\frac{\sum_{i=1}^{n} NR_i}{d_i^p}}{\sum_{i=1}^{n} \frac{1}{d_i^p}},$$

where $\widehat{NR}_i$ is the predicted net return for point (i), NR_i is the observed net return for point (i), d_i is the distance between NR_i and $\widehat{NR}_i$ and p is the weighting power. The rate at which the weight decreases with distance is determined by the weighting power, p. As a result, as the distance increases, the weight decreases rapidly (ESRI 2014). The weighting power is determined by the researcher, and in this case the default value of $p = 2$ is used for IDW interpolation. Implementing IDW methods also requires the researcher to choose the shape of the search neighborhood. Search neighborhoods are areas surrounding the prediction region to be used in the estimation. The shape of the search neighborhood influences the distance and the area to look for observed net return values to be used in the prediction. In this case, the default standard search neighborhood is chosen for interpolation.

Radial Basis Functions (RBFs) are a spline fitting interpolation method. Common splines include thin-plate spline, spline with tension, completely regularized spline, multiquadric function and inverse multiquadric function (ESRI 2014). The most general form of a RBF is $h(x) = \varphi[(x-c)'R^{-1}(x-c)]$, where $\varphi(z)$ is a function, such as the multiquadric. The term $(x-c)'R^{-1}(x-c)$ is the distance between the input x, the center c in the metric defined by R (Orr 1996). The ArcGIS default, completely regularized spline is used for net return interpolation. RBF methods, like IDW, are an exact fitting interpolation method; meaning, the surface must pass through each observed value (ESRI 2014). An advantage of spline fitting is that they can generate accurate surfaces from only a small number of sample points (Azpurua 2010).

Both IDW and RBF interpolations are estimated and the mean squared errors are compared (See Table 2). It is found that RBF models generate the lowest mean squared error, thus RBF becomes the model of choice in subsequent interpolation. Using the Geostatistical Analyst Wizard in ArcGIS, the completely regularized spline RBF is estimated, which generates a prediction map that can be exported to a raster layer. From this raster layer, raster value statistics are calculated for the prediction area. These raster value statistics contain the mean predicted net return within each county. Because the raster is a surface fitted to observed points, each county contains a range of predicted net returns. In the case of counties where the data contain an observed point, the range of predicted net returns is zero or very close to zero and the mean predicted net return is nearly identical to the observed value for the county. In the case of counties with unobserved data the RBF obviously will not find an exact point to fit and therefore will generate a range of predicted values across a county. For example in Lafayette County

Mississippi there are no observed net returns, these values are interpolated. The RBF interpolation predicts a range of net returns for Lafayette County with a minimum of -0.114, a maximum of 1.94 and a mean of 0.33.

Using the predicted net return for each county, ArcGIS was used to generate maps for the Southeastern region of the United States. These states include Alabama, Louisiana, Mississippi, Tennessee, Kentucky, Virginia, South Carolina, North Carolina, Georgia, Missouri and Arkansas. Three maps are generated, representing interpolated net returns assuming canola price is \$8, \$10, and \$12 per bushel. When canola is assumed to be \$8 per bushel, counties in the states of Georgia, Kentucky and South Carolina are predicted to have positive net returns to canola production. As the price increases to \$10 per bushel, some counties within Alabama, North Carolina and Tennessee are predicted to have positive net returns. As the assumed price is increased to \$12 per bushel, all counties within the states of Georgia, Kentucky, South Carolina, and Tennessee are predicted to have positive net returns, while only a portion of the counties in the remaining states are predicted to have positive net returns. See Figure 2.

SPARROW model, SAGT data, and variable rescaling

Next, we develop a procedure capable of generating *ex ante* forecasts of the impacts land use change resulting from a mature cellulosic biofuel will have on water quality in the Southeastern US by modifying the SAGT-SPARROW model. For the present study, we confine our analysis to the SAGT region, which is comprise of the states of Florida, Tennessee, Alabama, Mississippi, Kentucky, North Carolina, South Carolina, Georgia and Virginia. The SAGT region is 802,723 km^2. In this region, there are 321 USGS monitoring sites collecting information about water flow, nutrient loading, and sedimentation flux. Areal data from the corresponding watersheds such as land use patterns (e.g., urban, residential, agriculture, or forest), pollution point sources, nutrient runoff from agriculture and urban activities, and geophysical features are used as regressors to fit the flux data. Given an appropriately fitting model, nutrient loading predictions are generated using the stream network configuration of the basin. In effect, loading predictions are estimated for each n = 8,321 watershed comprising the basin. As a null hypothesis, the conversion of cropland/pastureland to canola production on a scale sufficient to reach biofuel production targets is hypothesized to have no effect on the water quality of the SAGT region. We further hypothesize that the share of total N and P attributable to the agriculture sector will not be significantly affected by this conversion.

The SPARROW model generates *ex-ante* forecasts of the impacts land use change have on water quality through changes in point and non-point source nutrient emission variables. SPARROW uses nonlinear least squares regression to explain nutrient mass balance in watershed networks as a function of anthropogenic, geographic, and climatic factors. The SPARROW model has been used extensively to forecast changes in nutrient emissions in North Carolina (Ator et al., 2011), New England and the Mid-Atlantic states (Moore et al., 2011), and the Tennessee River basins (Hoos and McMahon, 2009). SPARROW models have also been previously developed in the U.S. over spatial extents ranging from the conterminous U.S. (Smith *et al.*, 1997; Alexander *et al.*, 2000, 2008) to large regions such as the Chesapeake Bay watershed (Preston and Brakebill, 1999) and smaller watersheds such as those draining to the North Carolina coast (McMahon *et al.*, 2003). SPARROW models have been applied in many ways to improve the understanding of water-quality conditions and controlling factors, including: (1) identifying major sources of nutrients in streams of the conterminous U.S. (Smith *et al.*, 1997; Alexander *et al.*, 2008) and in individual watersheds in support of Total Maximum Daily Load (TMDL) assessments (McMahon *et al.*, 2003; Moore *et al.*, 2004), (2) understanding the role of stream processing in the delivery of nutrients to coastal waters, such as the Gulf of Mexico (Alexander *et al.*, 2000, 2008), (3) identifying the sources of salinity affecting water supply in the southwest (Anning *et al.*, 2007), and (4) understanding the environmental factors affecting sediment loading to the Chesapeake Bay (Brakebill *et al.*, 2010). SPARROW models have also been applied in New Zealand (Alexander *et al.*, 2002) and are now being developed for evaluating water-quality conditions in other parts of the world.

Schwarz et al. (2006), Smith et al. (1997), Quian et al. (2005), and Hoos and McMahon (2009) provide details on estimation and calibration of the SPARROW model. The general structure of SPARROW is:

$$y_i = \begin{bmatrix} \sum_{j \in J(i)} y_j \cdot A\left(Z_i^S, Z_i^R; \theta_S, \theta_R\right) \\ + \sum_{m=1}^{M_S} \beta_m \cdot S_{m,i} \cdot D_m\left(Z_i^D; \theta_D\right) \cdot A\left(Z_i^S, Z_i^R; \theta_S, \theta_R\right) \end{bmatrix} + \varepsilon_i, \quad (1)$$

where:

y_i is the nutrient emissions in watershed *i* = 1,…8,321 of the SAGT basin (kg yr^{-1}) (observed data);

$S_{m,i}$ is nutrient source *m*, watershed *i* (observed data);

Z^D are physical landscape characteristics (observed data);

Z^S are physical stream characteristics (e.g., depth and velocity) (observed data);

Z^R are reservoir variables (e.g., reservoir hydraulic loading) (observed data);

J(*i*) indexes the upstream watersheds flowing into watershed *i*;

$D_m\left(Z_i^D; \theta_D\right)$ is a nutrient delivery function;

$A\left(Z_i^S, Z_i^R; \theta_S, \theta_R\right)$ are stream and reservoir attenuation functions;

(θ_D, θ_S, θ_R) are parameters governing the transport and movement of nutrients between watersheds (estimated); and

β_m are delivery ratio parameters characterizing the contribution of nutrient sources to stream emissions (estimated);

ε_i is an independent and identically distributed random disturbance with an expected value of zero and a constant variance.

Physical landscape characteristics include soil permeability (in natural logs), bedrock depth (in natural logs), mean annual precipitation (in natural logs), the percent of a watershed included in a hydrological landscape region (HLR) (five HLR regions cover the SAGT area), and the percent of a watershed included in an ecoregion (six ecoregions define the SAGT basin). Physical stream attributes are measured by (1) the segment travel time for small streams (mean flow < 2.8 m^3 sec^{-1}), and (2) the segment travel time for larger streams (2.8 m^3 $sec^{-1} \leq$ mean flow < 28 m^3 sec^{-1}). Loss rate coefficients were estimated for small (< 2.8 $m^3 s^{-1}$) and intermediate (2.8-280 $m^3 s^{-1}$) streams, and are expected to be positive but lower in magnitude as stream sizes increase (Alexander et al., 2000). Land-to-water delivery factors ($D_m(Z_i^D; \theta_D)$) are modeled with an exponential kernel; $\exp(\theta'_D Z^D)$. Reach attenuation factors ($A(Z_i^S, Z_i^R; \theta_S, \theta_R)$) are modeled as an exponential decay; $\exp(-\theta'_S Z^S)$. The estimated reservoir loss coefficient summarizing the mean water column length from which N is removed annually is expected to be positive (Schwarz et al., 2006).

Fertilizer emission sources ($S_{m,i}$) include; (1) fertilizer mass permitted in wastewater discharge, (2) inorganic nutrient deposition, (3) impervious surface area, (4) commercial fertilizer applied to agricultural land, and (5) fertilizer mass from livestock manure (Hoos and McMahon, 2009). These variables are of interest to policymakers and analysts because they are anthropogenic sources of pollutants. In this application, changes in the contribution of fertilizer from applied agricultural fertilizer ($S_{FERT,i}$) are simulated, holding contributions from the other sources constant. The source variable for fertilizer applied to agricultural land used to calibrate the baseline SAGT-SPARROW model was calculated using 2002 county-level fertilizer expenditure data and 2001 USGS National Land Cover Database (NLCD) land cover classifications by Ruddy et al. (2006). This variable is an aggregate of fertilizer applied to all types of agricultural land, including dominant row crops, orchards, agroforestry, vegetables, hay and pasture, vineyards, row crops, small grains, and cereals. The changes in fertilizer applied in each watershed and the changes in fertilizer emissions due to changes in emissions from agriculture (i.e., fertilizer use) are approximated by adjusting $S_{FERT,i}$ to reflect the conversion of agricultural land to the production of canola. The statistical relationship between observed agricultural fertilizer applications, nutrient emissions, and nutrient concentrations in streams is estimated and then used to forecast nutrient emissions into each watershed.

Rewriting the non-linear model of equation 1 as a generalized function, the predicted values of the baseline regression are,

(2) $$\hat{y}_{0i} = g\left(S_{FERT,i} \cdot \hat{\beta}_{FERT}; S_{m-1,i}\hat{\beta}_{m-1}, Z_i\hat{\theta}\right),$$

where $\hat{y}_{0i}$ is the baseline predicted value for stream nutrient emission in watershed i = 1,…8,321; $g(\cdot)$ is the function of equation 1; $S_{FERT,i}$ is the applied fertilizer to agriculture in watershed i used in the calibration step of SPARROW; $\hat{\beta}_{FERT}$ is the estimated regression coefficient for fertilizer applied to agricultural land; $S_{m-1,}$ are all other source variables excluding applied fertilizer; $\hat{\beta}_{m-1}$ are the coefficients of all other nutrient sources; and Z_i are all other covariates with corresponding parameters $\hat{\theta}$.

To simulate the level of feedstock production needed to meet the RFS mandate for the SE of 10.5 BGY with biodiesel, BioFLAME was used to project the associated spatial distribution of barley, corn, cotton, hay/pastureland, oats, sorghum, soybeans, and wheat converted to the production of canola assuming differences in the extent to which the RFS mandate is achieved. Target levels of T = 22%, 31% and 50% production of 10.5 BGY of biodiesel were considered by the facility sitting model.

Using the land use changes generated by BioFLAME, published N and P application rates, and regional crop budgets from POLYSYS (Ray and de la Torre Ugarte, 1998), the watershed-level quantity of N and P applied under each production target was calculated in the SAGT Basin. Land use changes driven by industry demand for biomass feedstock enter the calibrated SPARROW model as changes in $S_{FERT,i}$ to simulate impacts on N and P emission sources. Aggregate fertilizer applied by the agricultural sector ($S_{FERT,i}$) is composed of fertilizer applied to the key field crops analyzed here ($S_{FERT,i}^{FldCrop}$), plus nitrogen applied by all other agricultural activities ($S_{FERT,i}^{OthAct}$):

(4) $$S_{FERT,i} = S_{FERT,i}^{OthAct} + S_{FERT,i}^{FldCrop}.$$

Changes in the baseline aggregate agricultural fertilizer source variable ($S_{FERT,i}$) are a function of the baseline field crop N and P demands and the new crop demand for N and P following policy implementation. Deviations from the baseline aggregate are simulated holding $S_{FERT,i}^{OthAct}$ constant and perturbing $S_{FERT,i}^{FldCrop}$. For example, define $S_{FERT,i}^{T}$ as the quantity of fertilizer applied in watershed i under target production level *T* (= 22%, 31%, 50%), noting that *T* = 0 indicates the baseline kilograms of nitrogen applied in the initial equilibrium. A relative change in aggregate fertilizer applied is:

(5) $$S_{FERT,i}^{T>0} = S_{FERT,i}^{OthAct} + (1 + \epsilon_i) \cdot S_{FERT,i}^{FldCrop},$$

where:

(6) $$\epsilon = \left[\frac{(F_i^{T>0} - F_i^{T=0})/N_i^{T=0}}{\left(NF_i^{T>0} - S_{FERT,i}^{FldCrop}\right)/S_{FERT,i}^{FldCrop}}\right],$$

and F_i^T is the total nitrogen applied in watershed *i* to the field crops estimated with the 2009 USDA cropland data layer used in BioFLAME (e.g., $F_i^T = \sum_{k=1}^{9} F_{i,k}^T$, with *k* indexing the eight conventional crops plus switchgrass). The components of the applied fertilizer variable ($S_{FERT,i}^{OthAct}$ and $S_{FERT,i}^{FldCrop}$) were unavailable in the SAGT data base. Therefore, NASS 2002 county level crop production data was used as a proxy such that $S_{FERT,i}^{FldCrop} = \sum_{k=1}^{8} F_{i,k}^{2002}$, where $F_{i,k}^{2002}$ are the applied nitrogen from the POLYSYS budgets containing region-specific fertilizer rates and the county level crop production data. In 22% percent of the watersheds, $S_{FERT,i} < S_{FERT,i}^{FldCrop}$. In these cases, we set $S_{FERT,i}^{OthAct} = 0$ and $S_{FERT,i} = S_{FERT,i}^{FldCrop}$. This provided a benchmark from which to compare changes in land use generated by the site locator model with the initial state documented by the 2002 USGS fertilizer use data. The denominator of ϵ adjusts for differences in the time periods the fertilizer data was compiled by Ruddy et al. (2006) for SPARROW and BioFLAME (2009 data). The factor is a decimal percent change when divided by 100. When *T* = 0, ϵ = 0, and $S_{FERT,i}^{T>0}$ = $S_{FERT,i}$ (the baseline applied nitrogen level). When $\epsilon > 0$ ($\epsilon < 0$), applied fertilizer increases (or decreases) following changes in the agricultural landscape due to feedstock demand by biorefineries during the simulation.

Incorporating the revised quantities of N and P applied under each production target into the SPARROW model, predictions for stream level N and P concentration and agricultural N and P source share were generated for each of the 8,321 sub- watersheds in the SAGT Basin. For the present study, N and P application rate for canola were taken to be 180 lbs/acre and 90 lbs/acre.

<u>Principal Findings and Results:</u>

Nitrogen Emissions and Canola/bio-diesel Production

Producing 2.31 BGY (or 22% of 10.5 BGY) of advanced biofuel in the Southeastern US, would result in the conversion of 1.97 million hectares of cropland in the SAGT region to canola production (Table 4). The primary source for the land needed to produce canola is land currently devoted to cotton, soybean and wheat production, accounting for around 94% of the converted land. Soybeans receive very little or no nitrogen and nitrogen application rates for cotton and wheat are less than for canola (Table 3). Phosphorous application rates for soybeans and wheat are less than for canola, while the rate for cotton is about the same as that for canola (Table 3). At this level of feedstock production, SPARROW predicts an increase in the mean level of N application in the region's watersheds of 14.25% (from 28,039.73 to 32,037.5 kg yr^{-1}) compared to the baseline and an increase in the agricultural source share of 12.79% (from 3.83% to 4.32%) from the baseline (Table 6). However, this increase is not enough to change the mean concentration in the SAGT region, which remains 1.09 mgL^{-1} (Table 6). This level of feedstock production results in an increase in the mean level of P application in the region's watersheds of 2.19% (from 16,562.6 to 16,926.61), an increase in the agricultural source share of 1.24% (from 15.28% to 15.47%), and an increase in the mean P concentration from 1.50 to 1.51 mgL^{-1} from the baseline (Table 7).

Producing 3.255 BGY (or 31% of 10.5 BGY) of advanced biofuel in the Southeastern US would require converting 2.37 million hectares of cropland in the SAGT region to canola production (Table 4). Land devoted to cotton, corn and soybean production remain the primary source of the land converted to canola production, accounting for around 94% of the converted hectares. At this level of production, SPARROW predicts an increase in the mean level of N application in the region's watersheds of 16.89% (from 28,039.73 to 32,775.69), and an increase in the agricultural source share of 10.18% (form 3.83% to 4.22%) from the baseline (Table 6). This increase is still not enough to alter the mean N concentration in the region (Table 6). At this level of production, there is an increase in the mean level of P application in the region's watersheds of 1.95% (from 16562.6 to 16886.97), the agricultural source share increases by 1.7% (from 15.28% to 15.54%), and the mean P concentration increases from 1.50 to 1.51 mgL^{-1} relative to the baseline (Table 7).

Producing 5.25 BGY (or 50% of 10.5 BGY) of advanced biofuel in the Southeastern US would require the conversion of 3.71 million hectares of land in the SAGT region to canola production (Table 3). Land devoted to either cotton, corn or soybean production comprises 94% of the land converted to canola production. At this production level, SPARROW predicts an increase in the mean level of N application in the region's watersheds of 26.71% (from 28039.73 to 35530.8) compared to baseline and an increase in the agricultural source share of 8.87% (form 3.83% to 4.17%) from the baseline (Table 6). This increase is still not enough to alter the mean N concentration in the SAGT region (Table 6). At this level of production, the agricultural source share of P applications increases by 3.59% (from 15.28% to 15.83%), and the mean P concentration increases from 1.50 to 1.51 mgL^{-1} relative to the baseline (Table 7). At this level of production, there is an increase in the mean level of P application in the region's watersheds of 3.67% (from 16562.6 to 17170.56) compared to baseline.

Conclusions and Further Research

The goals of this project were to 1) modify the USGS/SAGT database to include data that reflected land use change driven by the 2007 RFS mandate for the development of second-generation feedstock sources for biofuels, and 2) estimate the impacts land use change would have on nutrient loading into the SAGT basin with SPARROW. Two feedstock were considered – short rotation woody crops and canola. Each feedstock required the development of production costs, which were subsequently used to determine changes in applied nutrient levels, in particular, N and P. Findings suggest that, while agricultural land uses would clearly be impacted by the introduction of alternative feedstock sources such as canola or SRWC, the impact on water quality (in terms of nutrient loading into the SAGT system) in broad geographic terms would not differ from current nutrient levels.

Our research developed a procedure whereby crop production data generated by NASS could be used to proxy changes in applied fertilizer, given the displacement of conventional crops by dedicated energy crops. The research addressed two key challenges. The first was the dearth of information for canola and short rotation woody crop budgets. This information is critical for determining the opportunity costs of producing conventional crops (given economic impetus to develop feedstock), and therefore changes in land use. The second challenge was harmonizing the NASS cropland data layers (recorded in 2009) with the USGS/SAGT database (recorded in 2002). Addressing the second challenge required an imputation procedure that accommodated differences in spatial resolution and temporal scale.

There are caveats to this research. First, we did not model intensification of traditional crop production, assuming there would be no expansion of traditional crop production coincident to the conversion of agricultural land to feedstock production. Indirect land use changes resulting from intensified crop production could affect water quality in the SAGT basin and elsewhere. Second, nitrogen fixation by soybeans was not modeled, therefore underestimating changes in N loadings associated with conversion of soybean area to feedstock production. Third, livestock N sources were modeled, but no effort was made to determine the effects of hay and pasture land to feedstock production on livestock production. Fourth, we assumed pastureland and land cultivated in hay receive the same quantity of fertilizer N and P, and that 100% of their respective acres were treated. This assumption may be untenable. The 2009 USDA Census of Agriculture did not distinguish land in hay and pastureland, which therefore precluded calculating the quantity of N and P applied to each land use separately. The relative contributions of hay and pastureland to emissions therefore represent an upper-bound estimate since less N or P is usually applied on pastureland. Lastly, the counterfactual scenario depends on the assumption that fertilizer N and P expenditures were similar between 2002 and 2009. That high-resolution cropland data layers were unavailable until 2009 precluded generating a comparable data surface for 2002.

With these limitations in mind, our research extends the empirical methodology of integrating economic-driven land use change models with a mass-balance hydrologic model. The integration of these systems provides a gateway through which the interaction between economic variables affecting land use change and water quality can be analyzed. The combined system facilitates the examination of ceteris paribus effects of policy on water quality indicators at a macro-regional scale. Other water quality models, such as the Soil and Water Assessment Tool (SWAT), could possibly be modified to accommodate the simulation procedures outlined by this research.

Table 1. Per-acre production cost estimates for canola by state

State	Region	Total Variable Costs	Total Fixed Costs	Total Costs
Georgia*	Southern Seaboard	280.13	96.88	377.01
Idaho	Basin and Range	279.23	48.63	327.86
Kentucky*	Eastern Uplands	252.51	74.82	327.33
Montana	Northern Great Plains	327.98	-	327.98
North Carolina*	Southern Seaboard	436.34	112.10	548.45
North Dakota	Northern Great Plains	203.71	41.83	245.54
Oklahoma	Prairie Gateway	226.16	18.54	244.71
Oregon	Basin and Range	324.78	89.90	414.68
Pennsylvania	Northern Crescent	224.51	20.08	244.60
South Carolina*	Southern Seaboard	254.95	7.46	262.42
Tennessee*	Eastern Uplands	400.59	94.11	494.70
Texas	Prairie Gateway	168.75	12.86	181.61
Virginia*	Eastern Uplands	311.65	116.22	427.87
Washington	Basin and Range	156.17	25.36	181.53

* States used in the Southeastern Interpolation

Table 2. Mean Squared Error of Prediction

	Mean Squared Error	
	Radial Basis Function	Inverse Distance Weighting
Net Returns @ $8/bushel	29.79	32.92
Net Returns @ $10/bushel	32.46	37.93
Net Returns @ $12/bushel	38.28	45.00

Table 3. Mean level Nitrogen and Phosphorus applied in SAGT region

Crop	Mean Nitrogen applied (lbs/ac)	Mean Phosphorus applied (lbs/ac)
Canola	82.8	39.6
Barley	90.25 (10.68)	30.58 (7.46)
Corn	101.66 (13.57)	38.18 (8.21)
Cotton	60.19 (6.59)	40.44 (2.00)
Hay	14.99 (6.00)	35.99 (7.41)
Oats	35.37 (14.77)	17.23 (3.76)
Sorghum	45.61 (21.10)	26.10 (3.06)
Soybean	5.43 (5.92)	27.32 (13.17)
Wheat	59.81 (5.18)	32.25 (1.83)

Notes: N = 8,321 hydrologic units. Standard deviations of the means are in parentheses.

Table 4: Aggregate area and nitrogen applied under baseline and policy simulations

	Canola			
		Percent change from base		
Crop	Base (000's ha)	22%	31%	50%
Barley	2.15	0.00	-0.11	-7.35
Corn	2717.35	-2.88	-6.63	-14.68
Cotton	2767.43	-40.26	-54.58	-71.25
Oats	20.04	-34.87	-36.82	-41.37
Sorghum	89.77	-23.40	-27.38	-65.36
Soybean	2055.79	-31.61	-36.50	-65.62
Wheat	231.52	-44.40	-48.72	-63.58
Hay/Pasture	26693.34	0.00	0.00	0.00
Canola(ha)	0.00	1972.98	2585.84	3934.13
		Percent change from base		
Crop	Base (KgN '000)	22%	31%	50%
Barley	104.96	0.00	-0.12	-7.56
Corn	142889.75	-2.55	-6.01	-14.06
Cotton	80375.78	-39.63	-53.62	-70.40
Oats	300.94	-25.07	-26.80	-32.50
Sorghum	1750.01	-18.73	-23.01	-65.95
Soybean	2930.08	-45.05	-53.21	-77.65
Wheat	7126.13	-46.42	-50.84	-64.98
Hay/Pasture	0	0	0	0
Canola (kg N)	0	74099.13	97116.178	147753.6123
Total N applied (000's kg)				
Field Crops	282344.89	281598.84	281548.51	280816.25
All other Crops	402261.53	402261.53	402261.53	402261.53
All Agriculture	684606.42	683860.37	683810.04	683077.78

Table 5: Aggregate area and phosphorus applied under baseline and policy simulations

	Canola			
		Percent Change from the base		
Crop	Base(000's ha)	22%	31%	50%
Barley	2.15	0.00	-0.11	-7.35
Corn	2717.35	-2.88	-6.63	-14.68
Cotton	2767.43	-40.26	-54.58	-71.25
Oats	20.04	-34.87	-36.82	-41.37
Sorghum	89.77	-23.40	-27.38	-65.36
Soybean	2055.79	-31.61	-36.50	-65.62
Wheat	231.52	-44.40	-48.72	-63.58
Hay/Pasture	26693.34	0.00	0.00	0.00
Canola(ha)	0.00	1972.98	2585.84	3934.13
		Percent change from the base		
Crop	Base(KgP'000)	22%	31%	50%
Barley	39.22	0.00	-0.11	-7.32
Corn	53295.83	-2.53	-5.95	-13.79
Cotton	55597.00	-40.19	-54.43	-71.11
Oat	169.64	-30.24	-32.18	-38.50
Sorghum	1193.66	-21.87	-26.03	-65.33
Soybean	24926.22	-26.75	-32.32	-61.67
Wheat	3871.16	-43.97	-48.24	-63.22
HayPasture	0.00	0.00	0.00	0.00
Canola (kg P)	0.00	35434.72	46441.64	70656.81
Total P applied (000's kg)				
Field Crops	128070.85	127805.00	127765.98	127723.60
All other Crops	34933.36	34933.36	34933.36	34921.29
All Agriculture	163004.2183	162738.36	162699.34	162644.89

Table 6: Nitrogen loading yield and source shares means for the SAGT region; baseline and post-policy simulations

	Baseline	Targets 22%	31%	50%
N yield and loading concentration				
Upstream yield (kg $ha^{-1}yr^{-1}$)	4.23 (2.95)	4.24 (2.96)	4.24 (2.95)	4.23 (2.96)
Incremental yield (kg $ha^{-1}yr^{-1}$)	8.56 (216.53)	8.57 (216.57)	8.57 (216.62)	8.57 (216.52)
Flow concentration (mg L^{-1})	1.09 (3.44)	1.09 (3.46)	1.09 (3.45)	1.09 (3.43)
Source Shares (%)				
Wastewater discharge	3.49 (13.25)	3.48 (13.24)	3.48 (13.24)	3.48 (13.24)
Atmospheric N	65.36 (21.65)	64.91 (21.70)	64.98 (21.70)	65.12 (21.64)
Impermeable surfaces	8.46 (12.41)	8.42 (12.39)	8.41 (12.38)	8.43 (12.40)
Commercial fertilizer	3.83 (6.64)	4.32 (7.29)	4.22 (7.18)	4.17 (6.94)
Manure	18.86 (16.53)	18.86 (16.54)	18.89 (16.56)	18.77 (16.48)

Notes: N = 8,321 hydrologic units. Standard deviations of the means are in parentheses.

Table 7: Phosphorus loading yield and source shares means for the SAGT region; baseline and post-policy simulations

	Baseline	Targets 22%	31%	50%
P yield and loading concentration				
Upstream yield (kg $ha^{-1}yr^{-1}$)	6.08 (6.93)	6.09 (6.91)	6.09 (6.91)	6.11 (6.92)
Incremental yield (kg $ha^{-1}yr^{-1}$)	7.09 (38.93)	7.10 (38.51)	7.10 (38.51)	7.12 (38.54)
Flow concentration (mg L^{-1})	1.50 (4.24)	1.51 (4.30)	1.51 (4.30)	1.51 (4.30)
Source Shares (%)				
Wastewater discharge	1.82 (8.88)	1.80 (8.84)	1.80 (8.80)	1.80 (8.84)
Impermeable surfaces	35.89 (28.74)	35.76 (28.72)	35.76 (28.73)	35.74 (28.75)
Commercial fertilizer	15.28 (21.27)	15.47 (21.24)	15.54 (21.27)	15.83 (21.45)
Manure	47.00 (28.49)	46.95 (28.43)	46.88 (28.41)	46.61 (28.31)

Notes: N = 8,321 hydrologic units. Standard deviations of the means are in parentheses.

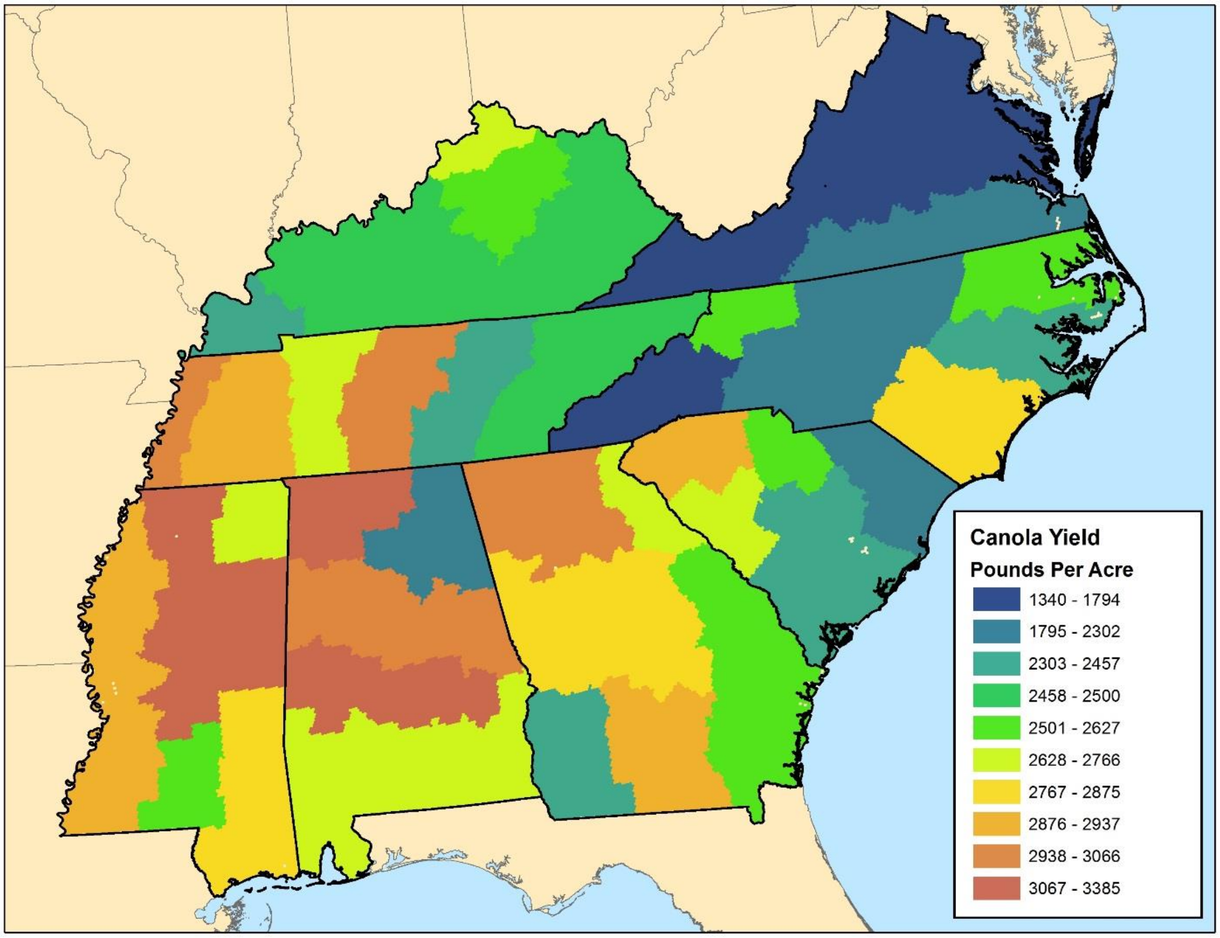


Figure 1. Canola yields generated by EPIC, aggregated t the Crop Reporting District level.

Figure 2: Predicted Net Returns when Canola is $8/bushel

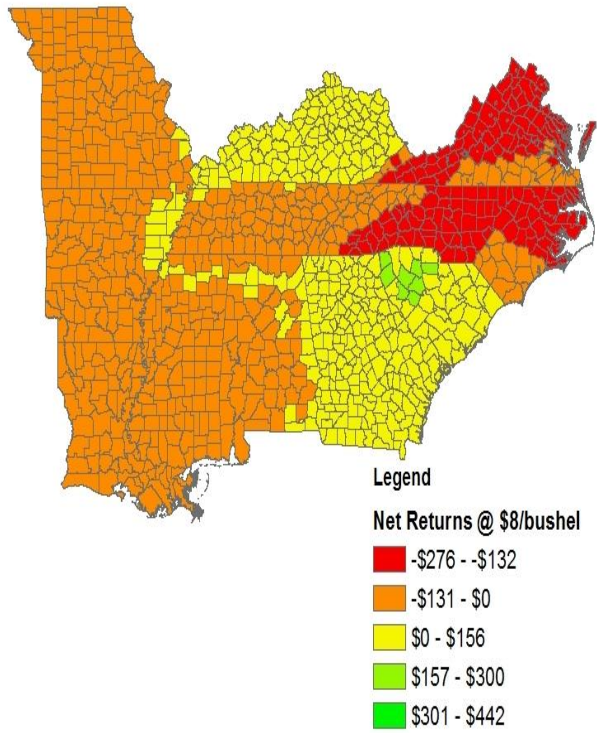


Figure 3: Predicted Net Returns when Canola is $10/bushel

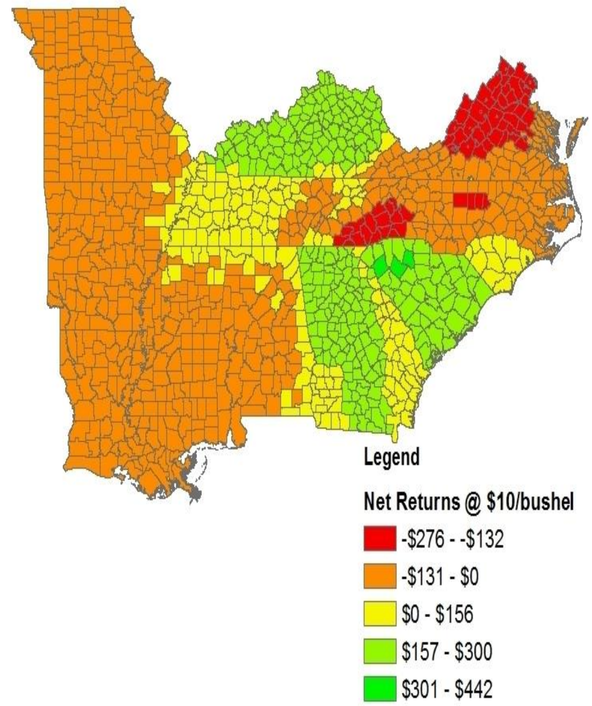
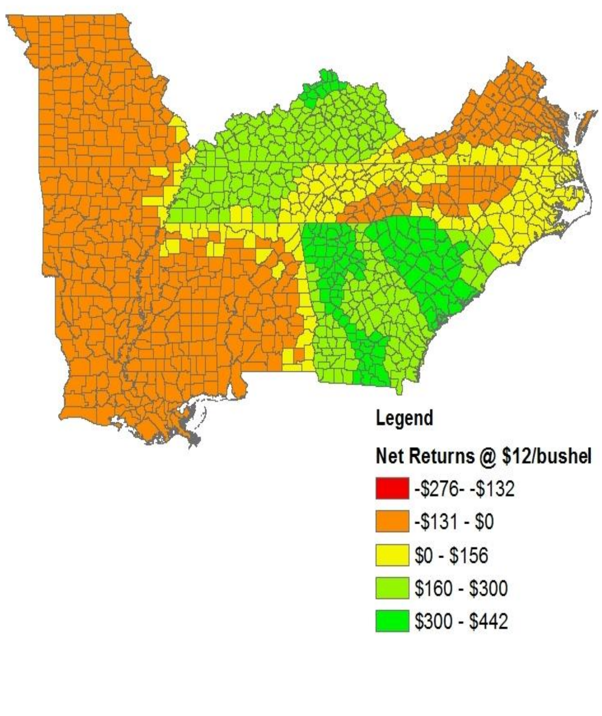


Figure 4: Predicted Net Returns when Canola is $12/bushel



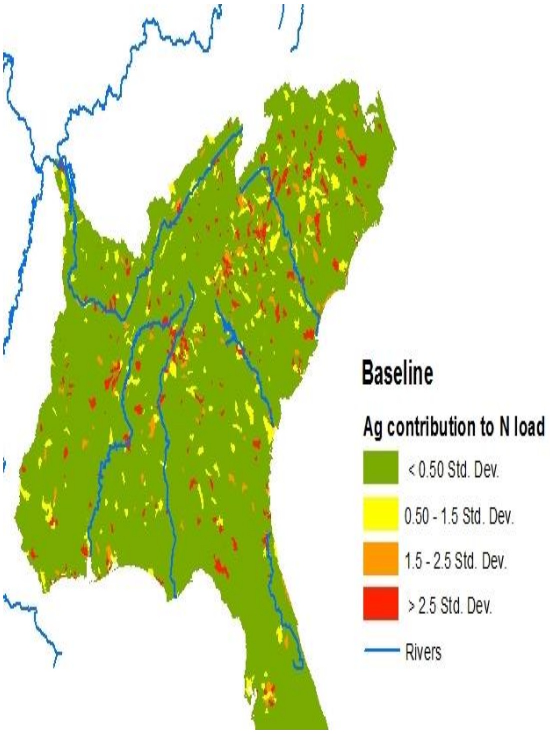


Figure 5: Agricultural N source share at baseline

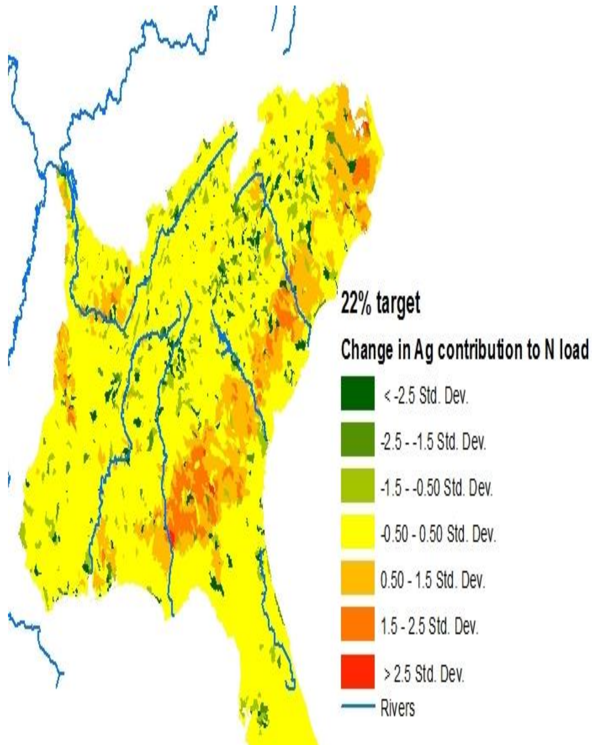


Figure 6: Agricultural N source share at 22% target

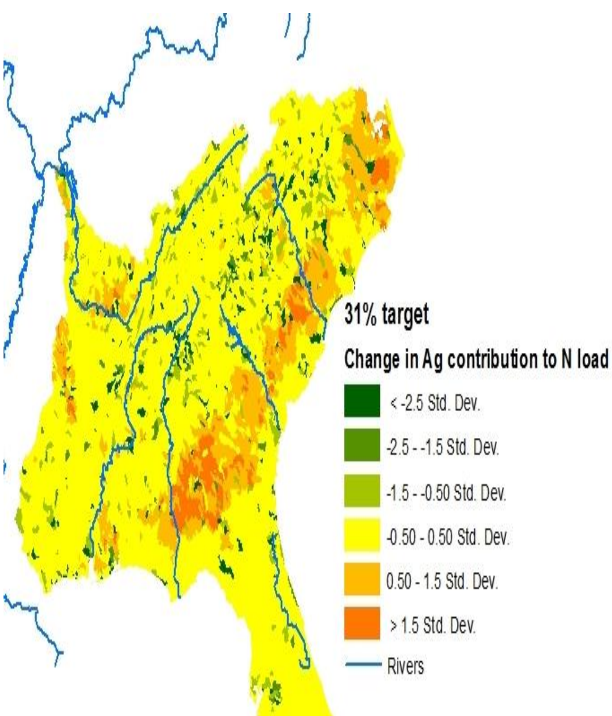


Figure 7: Agricultural N source share at 31% target

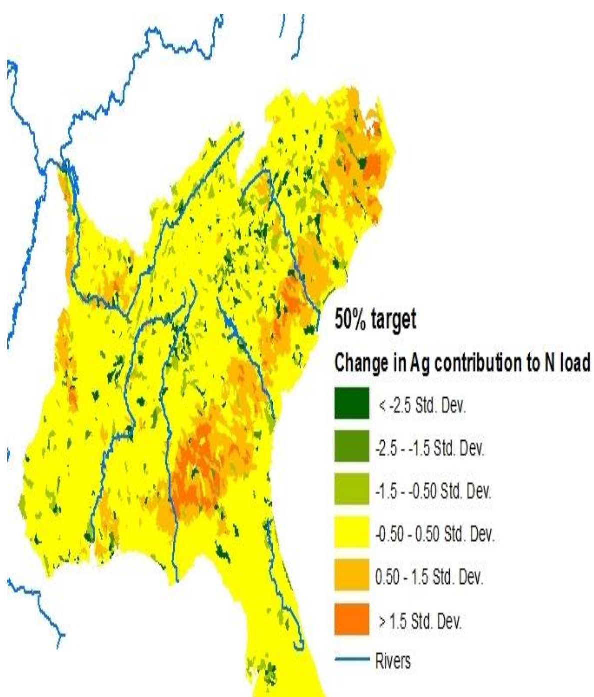
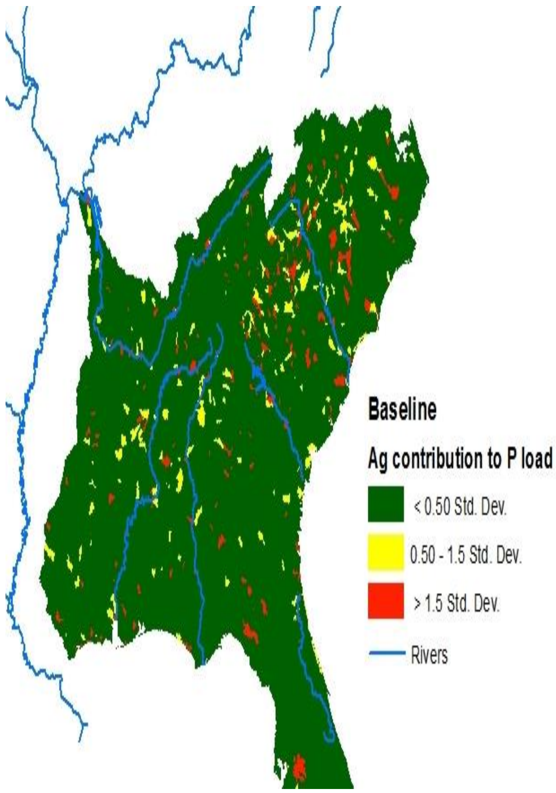


Figure 8: Agricultural N source share at 50% target



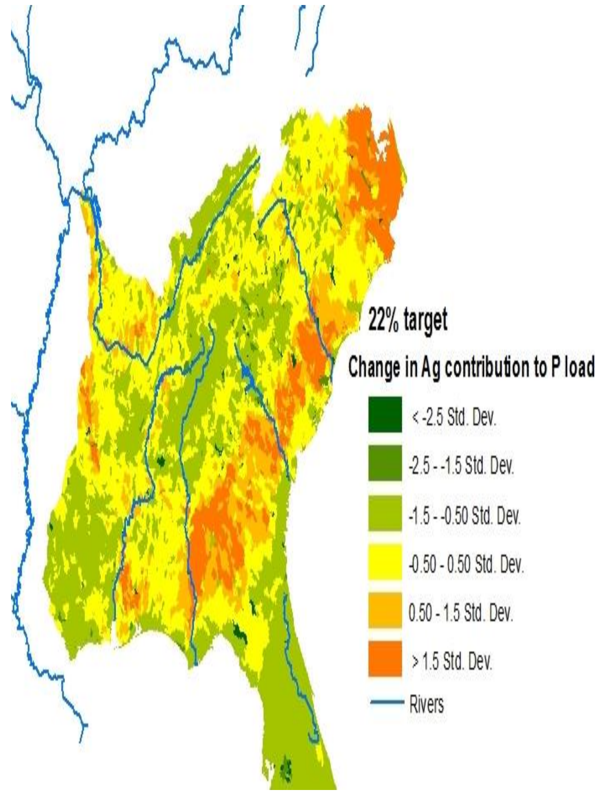
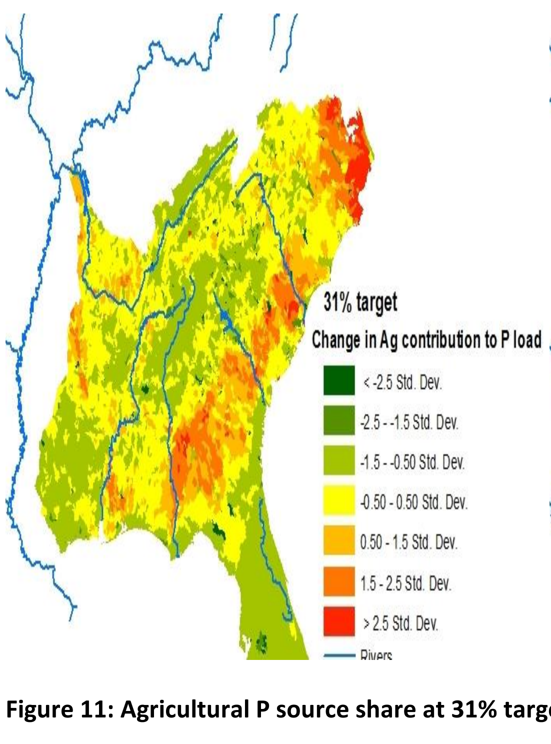


Figure 9: Agricultural P source share at base line

Figure 10: Agricultural P source share at 22% target



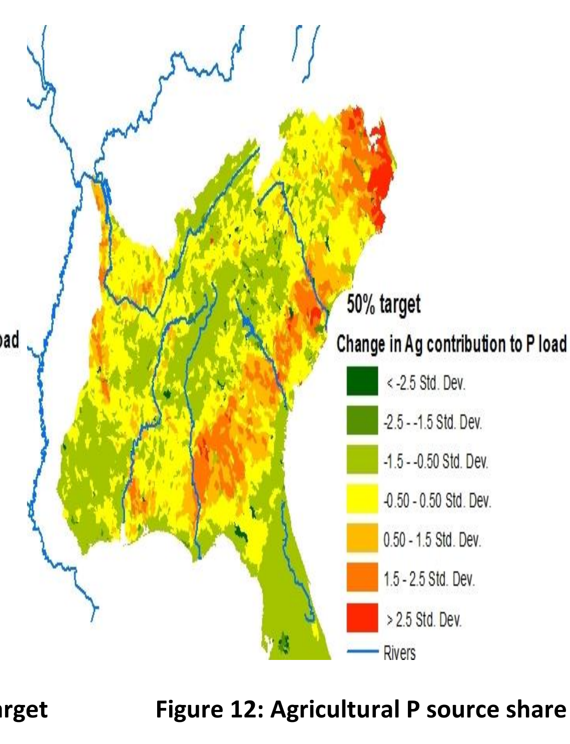


Figure 11: Agricultural P source share at 31% target

Figure 12: Agricultural P source share at 50% target

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Information Transfer Program Introduction

INFORMATION TRANSFER PROGRAM

The major emphasis of the information transfer program during the FY 2014 grant period focused on technical publication support, conference planning/development, and improvement in the information transfer network. The primary purpose of the program was to support the objectives of the technical research performed under the FY 2014 Water Resources Research Institute Program.

The primary objectives, as in previous years, of the Information Transfer Activities are: To provide technical and structural support to water researchers performing research under the WRRIP.

To deliver timely water-resources related information to water researchers, agency administrators, government officials, students and the general public.

To coordinate with various federal, state, and local agencies and other academic institutions on program objectives and research opportunities.

To increase the general public's awareness and appreciation of the water resources problems in the state.

To promote and develop conferences, seminars and workshops for local and state officials and the general public which address a wide range of issues relating to the protection and management of the state's water resources

During the FY 2014 grant period, a major focus of the information transfer activities was on the participation of the Center staff in the planning and implementation of several statewide conferences and training workshops

TNWRRC and the University of Tennessee, Agriculture Extension Service partnered with faculty from Auburn University, the University of Georgia, North Carolina State University and Clemson University to host Ecological Design in the Southeast: A workshop and Design Charrette. The three day workshop was sponsored by the American Ecological Engineering Society as part of the Certified Ecological Designer program which is sanctioned by AEES. The workshop targeted s engineers, landscape architects, planners, ecologists and other scientist to work in a collaborative, interactive team setting to develop a multidisciplinary ecological design for a local project, The French Broad riverfront Redevelopment Project. Over 35 persons attended the workshop in Asheville, NC. on April 23-15, 2014.

TNWRRC was a co-sponsor of the Annual Tennessee Stormwater Association Conference, Rockin' the Regs., held on September 23-25, 2014 at Henry Horton State Park. Over 210 attendees including staff from MS4 communities, state agencies, and engineering consulting companies from across the State participated in the 3 day event which included over 40 presentations, 4 hands-on workshops and several social networking sessions. The Tennessee Smart Yards program, which is co-directed by TNWRRC, coordinated a community service project which involved the design and installation of a rain garden to handle stormwater runoff form the Henry Horton Lodge. Over 100 persons participated in the one day service project.

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TNWRRC was a co-sponsor of the 2014 East Tennessee Development Symposium held on Nov. 4-5, 2014 at the Knoxville Convention Center. This tow day event provides a powerful platform for networking with hundreds of professionals and to share knowledge, lessons learned and best practices in the development field. Attendees include land developers, civil and environmental engineers, landscape architects, and consultants, professionals from the real estate and banking sectors, land use planners state and local government staff and policy makers from all level s of government. Last year over 350 persons attended the 2014 Symposium

The Center also participated in several meetings and workshops across the state that were held to address water related problems and issues such as stormwater management, water quality monitoring, non-point source pollution, water supply planning, TMDL development, watershed management and restoration, multiobjective river basin management and lake management issues and environmental education in Tennessee. The following is a brief listing of formal meetings, seminars and workshops that the Center actively hosted, supported and participated in during FY 2014:

East Tennessee MS4 Stormwater Management Working Group, July 24, 2014, October 27, 2014, January 23, 2015 at Knox County Stormwater Department, Knoxville, TN. TNWRRC and the Tennessee Department of Environment and Conservation sponsored a quarterly meeting of local government officials responsible of implementing local stormwater programs under the MS4 Phase II permit. These meeting are designed to provide local officials with information that will add them in development of their local stormwater management programs.

Tennessee Wetlands Technical Advisory Task Force meeting, May 1-2, 2014, Nashville, Tennessee. Meeting of government agency staff and technical experts to advise to the State on issues related to the Tennessee Wetlands Management Plan.

WaterFest, May 12, 2014, Knoxville, TN. An annual community-wide event sponsored by the Water Quality Forum that highlights the importance of our water resources and the activities of the WQF partners to protect and manage those resources. Over 850 elementary school age students from the Knox County school systems and schools from the surrounding region attended.

Fundamentals of Erosion Prevention and Sediment Control for Construction Sites- Level I Training and Certification course, sponsored by the Tennessee Department of Environment and Conservation and the Tennessee Water Resources Research Center. A one day course for developers, contractors, road builders and others involved with construction activities across the State. The course was offered on the following dates in FY 2014: March 6, 2014, Knoxville, TN.; March 21, 2014, TN Professional Land Surveyors Conference, Murfreesboro, TN.; March 26, 2914, Chattanooga, TN.; April 2, 2014, Memphis, TN.; April 30, 2014, Johnson City, TN.; May 6, 2014, Nashville, TN.; May 8, 2014, Knoxville, TN.; July 30, 2014, Nashville, TN.; September, 9, 2014, Nashville, TN.; September 11, 2014, Chattanooga, TN.; October 8, 2014, Knoxville, TN.; October 22, 2014, Jackson, TN.; November 6, 2014, Johnson City, TN.; November 20, 2014, Nashville, TN.; February 17, 2015, Nashville, TN. For this time period over 1,968 persons obtained Level I certification.

Design Principles for Erosion Prevention and Sediment Controls for Construction Sites Level II Certification course sponsored by the Tennessee Department of Environment and Conservation and the Tennessee Water Resources Research Center. A two day training course for engineers and other design professionals responsible for the development of Storm Water Pollution Prevention Plans for construction activities. The course was offered on the following dates in FY 2014: May 14-15, 2014, Nashville, TN.; June 4-5, 2014, Knoxville, TN.; October 29-30, 2014, Nashville, TN.; December 4-5, 2014, Knoxville, TN.; December 17-18, 2014, Chattanooga, TN.; February 4-5, 2015, Ft. Campbell Army Base. For this time period over 338 persons obtained Level II certification.

Construction Site Inspection as Required by Tennessee s Construction Stormwater General Permit - Level I Recertification course sponsored by the Tennessee Department of Environment and Conservation and the Tennessee Water Resources Research Center. This is a half day course which focuses on inspection requirement under the current TNCGP. This course is required for all inspectors of construction sites that have coverage under the TNCGP and serves as a recertification course for those that have completed the Level I Fundamentals course. The course was offered on the following dates: May 16, 2014, Nashville, TN.; May 22, 2014, Knoxville, TN.; June 10, 2014, Memphis, TN.; June 12, 2014, Knoxville Utilities Board, Knoxville, TN.; TN.; September 4, 2014, Cleveland, TN.; September 17, 2014, Nashville, TN.; September 23, 2014, Knoxville, TN.; October, 8, 2014, Knoxville, TN.; October 15, 2014, Chattanooga, TN.; October 16, 2014, Cookeville, TN.; October 23, 2014, Jackson, TN.; November 7, 2014, Johnson City, TN.; November 13, 2014, Memphis, TN.; November 17, 2014, Chattanooga, TN.; November 25, 2014, Knoxville, TN.; December 9, 2014, Nashville, TN.; December 10, 2014, Chattanooga, TN.; January 27, 2015 Nashville, TN. (two sessions) For this time period over 2,529 persons obtained Level I Recertification.

Tennessee Hydrologic Determination Training (TN-HDT) program. This new training program was developed and is being offered to meet the requirements of Tennessee Code Annotated, Section 69-3-105 which establish standard procedures for making stream and wet weather conveyance determinations in Tennessee. The three day course was developed by staff from the Tennessee Department of Environment and Conservation (TDEC) and faculty from the University of Tennessee and Tennessee Technological University. TNWRRC is responsible for administration of the TN-HDT program and works with TDEC and university faculty to deliver the course three to four times each year at selection location across the State. The course was offered on August 10-12, 2014, at Montgomery Bell State Park in Burns, TN. Those that successfully complete the course and meet the other minimum qualifications at certified as Tennessee Qualified Hydrologic Professionals (TN-QHPs). The TN-QHP certification is good for three years. Every three years all TN-QHPs or TN-QHP In-Training must attended a one day Refresher course to maintain their certification. The first round of Refresher courses were offered in 2014 on the following dates and locations: March 20, 2014, Murfreesboro, TN.; March 25, 2014, Knoxville, TN.; July 22, 2014, Knoxville, TN.; July 31, 2014, Nashville, TN.; November 3, 2014, Knoxville, TN.; November 18, 2014, Nashville, TN.

Adopt-A-Watershed teacher training workshop held on June 18-20 2014, Knoxville, TN. This four day workshop sponsored by TNWRRC and partners of the Water Quality Forum trains middle and high school science teachers on how to work with their students to conduct watershed investigations and develop watershed improvement service projects and part of their classroom curriculum. Ten new teachers completed the training course in 2014.

Knoxville Water Quality Forum, Quarterly meetings, May, July and October 2014 and January 2015. Meeting of government agencies and other organizations to share information and discuss water quality issues in the Tennessee River and it's tributaries in Knox County.

Little River , Lower Clinch River, Bull Run Creek, Beaver Creek Stock Creek and Emory River Watershed Associations, monthly meetings of agency staff and community leaders working towards protection of the Little River, Lower Clinch, the Emory/Obed and smaller tributaries watersheds.

Other principal information transfer activities which were carried out during the FY 2014 grant period focused on the dissemination of technical reports and other water resources related reports published by the Center as well as other types of information concerning water resources issues and problems. A majority of the requests for reports and information have come from federal and state government agencies, university faculty and students, and private citizens within the state. The Center also responded to numerous requests from across the nation and around the world.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	18	0	0	0	18
Masters	11	0	0	0	11
Ph.D.	3	0	0	0	3
Post-Doc.	0	0	0	0	0
Total	32	0	0	0	32

Notable Awards and Achievements

Publications from Prior Years

1. 2004TN13B ("An Investigation of Surface-Ground Water Connections at Nonconnah Creek: A Source of Recharge and Potential Contamination for the Memphis Aquifer in Shelby County Tennessee") - Articles in Refereed Scientific Journals - Larsen, Daniel, Jason, Morat, Brian Waldron, Stephanie Ivey and Jerry Anderson, 2013, Stream Loss Contributions to a Municipal Water Supply Aquifer in Memphis, Tennessee, Environmental & Engineering Geoscience, Vol. XIX, No. 3, pp. 265-287.
2. 2010TN71B ("Development of GIS Data Management System for Water Resources and Climate Research in Tennessee") - Articles in Refereed Scientific Journals - Jones, J.R.; J.S. Schwartz; K.N. Ellis; J.M. Hathaway; and C.M. Jawdy, 2014, Temporal Variability of Precipitation in the Upper Tennessee Valley. Journal of Hydrology-Regional Studies. DOI 10.1016/j.ejrh.2014.10.006.