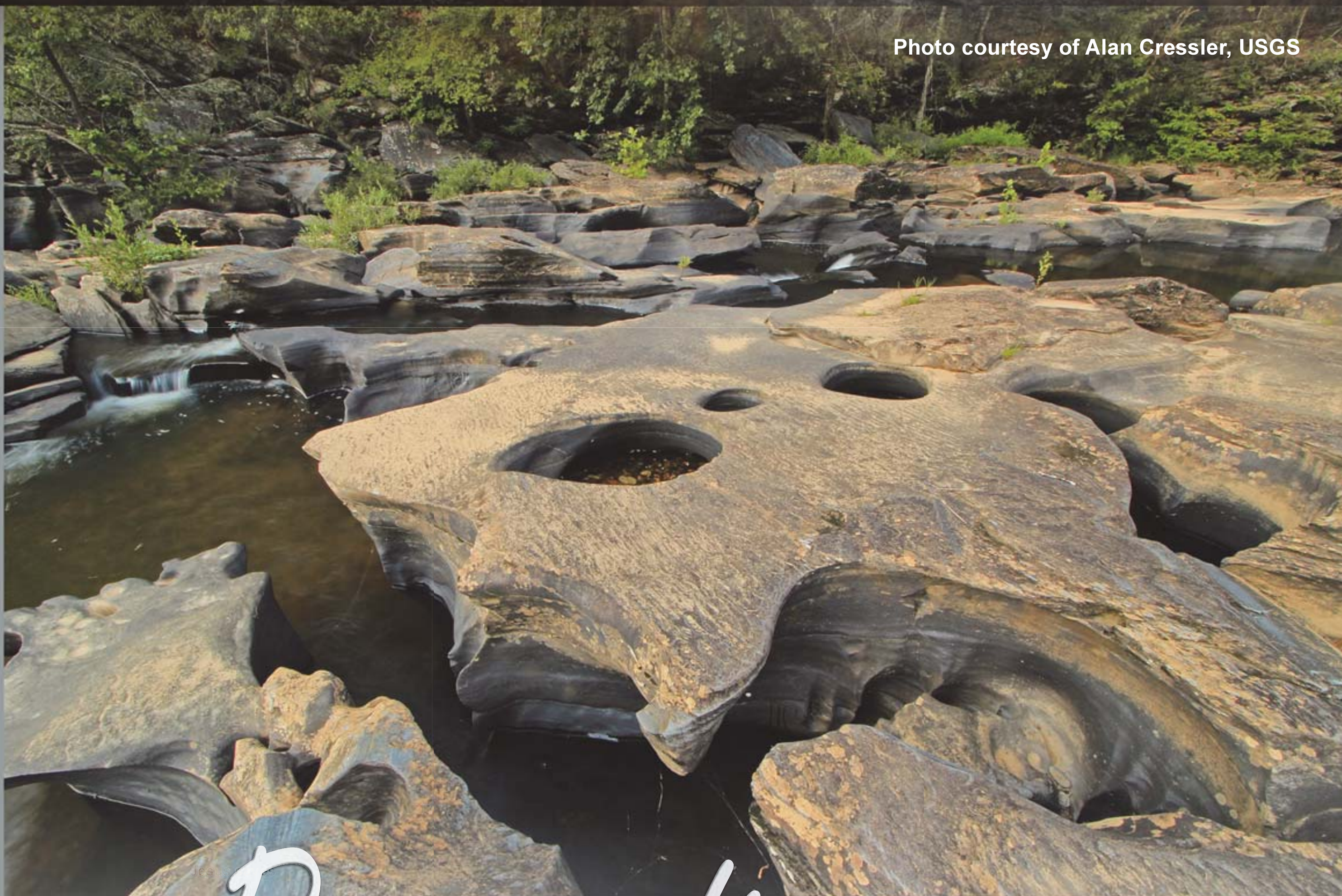
APRIL 11-13, 2018



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Proceedings of the 2018 Tennessee Water Resources Symposium

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Proceedings from the

27^{th} Tennessee Water Resources Symposium

Montgomery Bell State Park
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April 11-13, 2018

Sponsored by

Tennessee Section of the American Water Resources Association

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PREFACE

Welcome to the 2018 TN-AWRA annual meeting. I think you will find the proceedings full of interesting presentations, and I trust you will agree there is a good variety of subject matter worthy of your consideration. Between the pre-session workshop and the final panel discussion, the planning committee has organized a meeting as diverse as our membership.

This year we have chosen, *adapting to hydrologic extremes*, as our symposium theme. Our keynote speaker, Dr. Sam Brody, will kick off the meeting by presenting his work related to addressing the national challenges on flood mitigation and adapting to extreme water events, thereby planting a seed in our minds as we listen to the technical talks. And we'll wrap it up with a panel discussion that will close the loop by asking panel members from agencies and local governments they see as the future of adapting to hydrologic extremes in Tennessee.

We will also hear from Dr. Jay Lund, Director of the Center for Watershed Sciences and Distinguished Professor of Civil and Environmental Engineering, at University of California, Davis, who will deliver his lecture on how the state of California manages water and how they adapt to variety of hydrologic stressors.

I encourage you to take full advantage of the symposium: the talks, the vendor demonstrations, and the closing panel discussion. And please don't overlook the value of informal networking, especially in the evenings when new partnerships and collaborations are forged.

Thanks for being a part of the 2018 symposium.

Alfred J. Kalyanapu, Ph.D.
2018 President, TN-AWRA

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DELFT 3D MODEL PRE-SYMPOSIUM WORKSHOP
8 a.m., Wednesday, April 11

12:00 – 1:30 p.m.
Wednesday, April 11
Keynote Address ***by*** **Sam Brody,** Center for Texas Beaches and Shores, Department of Marine Science, Texas A&M

THE FLOODED LANDSCAPE: ADAPTING TO THE NEW REALITY OF EXTREME WATER EVENTS

Floods continue to be the costliest and most disruptive natural hazard worldwide. Increasing physical risk combined with rapid land use change and development in flood-prone areas has amplified the adverse economic and human impacts in recent years. Never before have the repercussions from storm events driven by both surge and rainfall been so damaging to local communities. Losses from both acute and chronic flood events are especially problematic in the United States (U.S.), where development in low-lying areas has accelerated over the last several decades. Given the far-reaching impacts of recent major storms, such as Hurricanes Katrina (2005), Ike (2008), Sandy (2012), and Harvey (2017), it has become clear that the rising cost of floods is not solely a function of changing weather patterns or a problem that can be solved through engineering solutions alone. Rather, flood risk and associated losses can only be mitigated through multiple strategies working synergistically across jurisdictional boundaries.

This presentation traces the causes, consequences, and policy implications of flood losses in the United States. Special attention is paid to the increasing amount of losses occurring in areas not previously considered flood-prone. Based on recent research findings, a framework is presented on how local communities can reduce the tide of growing flood losses in the future. Emphasis is given to flood impact and mitigation issues in the Nashville, TN area.

12:00 – 1:30 p.m.
Thursday, April 12
Lunch Presentation *by* Jay Lund, Center for Watershed Sciences, University of California-Davis

MANAGING WATER IN CALIFORNIA, A LAND OF EXTREMES

California is a state of water extremes. With its Mediterranean climate, every year California has a worse drought than most of the country has ever seen. Some of our storms also have hurricane rates of local precipitation. The talk examines how water management infrastructure, laws, technology, and social institutions have adapted to this climate prosperously. Challenges of environmental declines and resource allocation conflicts remain. Although new infrastructure continues to be developed, changes in operation and the use of water markets, trades, groundwater banking, and water conservation have proven to be economical for most of the state. As a dry place with a highly variable climate, California will always have to manage for extremes.

SESSION 1A

STREAM RESTORATION
(Moderator: John Schwartz, UT)

WETLANDS AND BIORETENTION
(Moderator: Mike Williams, Stantec)

SESSION 1B

FLOOD PROTECTION
(Moderator: Tom Palko, Metro Water Services)

FLOOD MODELING
(Moderator: Roger Lindsey, Metro Water Services)

SESSION 1C

FIELD SURVEY AND MAPPING
(Moderator: Richard Cochran, TDEC)

EPSC ON CONSTRUCTION SITES
(Moderator: Tom Lawrence, Water Quality Matters!)

SESSION 2A

SUBSURFACE HYDROLOGY
(Moderator: Alfred Kalyanapu, TTU)

FLUVIAL GEOMORPHOLOGY
(Moderator: Bill Wolfe, USGS)

STREAM RESTORATION EDUCATION AND CERTIFICATION
(Moderator: Jimmy Smith, TDEC-DWR)

NUTRIENT REDUCTION FRAMEWORK
(Moderator: Victor Roland, USGS)

SESSION 2B

FLOOD
(Moderator: Adrian Ward, Barge Design Solutions)

WASTEWATER TREATMENT
(Moderator: Tania Datta, TTU)

STORMWATER MANAGEMENT
(Moderator: Andrea Ludwig, UT)

AQUATIC ECOLOGY
(Moderator: Deedee Kathman)

AQUATIC HABITAT
(Moderator: Justin Murdock, TTU)

SESSION 3A

HARMFUL ALGAL BLOOMS (HABS)
(Moderator: Paul Davis, PE)

PROFESSIONAL POSTER

SESSION 1A

STREAM RESTORATION **(Moderator: John Schwartz, UT)**
1:30 p.m. – 3:00 p.m.

Spatial Distribution and Habitat Use of Trout in Hatchery Creek at the Wolf Creek National Fish Hatchery
Brady McPherson

Harpeth River Bank Stabilization
Jeffrey B. Shaver

On-Site Stream Mitigation Design and Construction for an Over Widened Bedrock Channel
Brent Wood, Michael Pannell, and Ken Barry

WETLANDS AND BIORETENTION **(Moderator: Mike Williams, Stantec)**
3:30 p.m. – 5:00 p.m.

Experiences and Applications of IRIS Tubes
Cole Liggett

Occurrence of Cyanotoxins in a Nashville Wetland
Taylor Ribeiro, April Falconer, Thomas Byl, and De'Etra Young

Examining the Role of Trees in Bioretention Using Laboratory and Field Scale Methods
Andrew Tirpak and Jon Hathaway

SPATIAL DISTRIBUTION AND HABITAT USE OF TROUT IN HATCHERY CREEK AT THE WOLF CREEK NATIONAL FISH HATCHERY

Brady McPherson[1]*

INTRODUCTION

The Hatchery Creek Stream and Wetland Mitigation Project in Russell County, KY was funded by the Kentucky Wetland and Stream Mitigation Program. The purpose of the project was to offset unavoidable impacts to aquatic resources while also creating a self-sustaining trout fishery for the public to enjoy at Wolf Creek National Fish Hatchery campground along the Cumberland River. The project encompassed 6,162 feet of trout habitat focused natural channel design. Various types of bio-engineered large woody debris and rock structures were used to optimize habitat in the constructed channel. Refugia, spawning, and rearing habitats were also constructed to encourage sustained reproduction of trout in the constructed channel.

Backpack shocking was conducted during year one and two monitoring to inventory trout presence in the constructed channel. Year one data indicated that trout were migrating from the stocking location at the tailwater of the Wolf Creek Dam into Hatchery Creek. During year one it was also observed that trout were evenly distributed throughout Hatchery Creek. Year two data indicated that trout of select maturities were potentially occupying particular reaches and habitat types. Specifically, larger trout were occupying reaches that provided more macro and micro pool habitat, whereas younger trout were occupying reaches with less pool habitat and a greater frequency of riffle and run habitat.

In dynamic stream systems, biochemical parameters such as temperature and dissolved oxygen can significantly affect the spatial distribution of trout. In Hatchery Creek these parameters are relatively consistent across the reaches selected for study due to flow being provided by the discharge from the Wolf Creek National Fish Hatchery. Food availability is also consistent among the reaches. The relative consistency among reaches should allow for a more direct comparison of physical habitat availability and use preference to explain the spatial distribution of trout in Hatchery Creek. The goal of the study will be to validate designed macro and micro habitat types through two-dimensional (ecohydraulic) modeling and to support the visually observed habitat use preference of resident trout in Hatchery Creek.

APPROACH

To enable ecohydraulic modeling of habitat types and spatial representation of trout in the newly constructed channel including detailed topographic data collection and georeferenced fish sampling and large woody debris data. Survey grade GPS will be used to collect topographic data in the study reaches in order to create a detailed surface model of the bed and habitat features to be used in the ecohydraulic model. Survey grade GPS will also be used to record the location of significant large woody debris structures that may contribute to micro habitat.

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Backpack shocking will be completed in the study reaches to identify the primary size of trout occupying the micro habitats and reaches. Additionally, high-resolution georeferenced drone imagery will be gathered during the sampling in attempt to document the location of trout as they are stunned so that individual sizes can be more closely tied to the available habitat types. The georeferenced large woody debris data and fish sampling data will be paired with the results of the ecohydraulic model to support the visually observed habitat use preferences of resident trout.

HARPETH RIVER BANK STABILIZATION

Jeffrey B. Shaver[1]

INTRODUCTION

The City of Franklin Waste Water Treatment Plant had infrastructure along the left descending bank of the Harpeth River being threatened due to severe bank erosion. This segment is 303(d) listed by TDEC for loss of biological integrity due to siltation. It has an average bank height of 23 feet and regularly experiences bank full flows, which contribute to the bank erosion. The goal of the design was to stabilize the eroded streambank to protect the infrastructure.

APPROACH

Based on the existing conditions of the left descending bank and other site constraints Longitudinal Stone Toe Protection (LSTP), locked logs, grading, and native vegetation were incorporated in the final design.

The LSTP was included to stabilize the toe of the bank by "self-launching" stone into scour holes that develop during higher flow events and to aid in arresting future bank sloughing that may occur. Locked logs were incorporated in the LSTP to further protect the bank by increasing the roughness, redirecting flow, and decrease the velocity along the toe of the bank. A bench was also graded into bank to compensate for the reduction in flow conveyance due to the LSTP. The bank was also revegetated with native seeds, live branch cuttings, and live stakes.

RESULTS AND DISCUSSION

During construction, after installation of the LSTP and locked logs, this segment of the Harpeth River experienced a bank full flow event. The LSTP and locked logs performed as expected in stabilizing the toe of the bank and reducing bank erosion. Construction was completed in December 2017.

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ON-SITE STREAM MITIGATION DESIGN AND CONSTRUCTION FOR AN OVER WIDENED BEDROCK CHANNEL

Brent Wood[1], Michael Pannell[2], Ken Barry[3]

Many stream mitigation projects in Tennessee use the natural channel design methodology. But this approach is not always applicable, particularly when performing on-site mitigation, where the constraints of the site often dictate what is possible. This presentation provides a look at the challenges of designing and constructing an on-site stream mitigation project comprising the enhancement of 850 feet of perennial stream channel lying on bedrock with adjacent fringe wetlands. Because the stream profile follows existing bedrock and the fringe wetlands were not to be disturbed, neither plan form realignment nor profile modification were proposed. For this reason, a reference reach was not considered in the final design.

The project challenges included design and construction of an appropriately dimensioned channel on bedrock while minimizing impacts to the adjacent wetlands. Baseline data for the existing stream were collected and used to establish a bankfull discharge for the proposed design. The existing channel dimension values were compared with published regional curve data for Ecoregion 71i to calibrate bankfull for the observed cross sections. Following calibration to the observed bankfull discharge, the slope was calculated based on the length of the existing alignment, and a new riffle cross section was developed. This restoration design implements a novel approach for using coir blocks to form the new channel cross section on the bedrock surface.

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EXPERIENCES AND APPLICATIONS OF IRIS TUBES

Cole Liggett[1]

INTRODUCTION

IRIS tubes are indicators of reduction in soil, which are field tests that detect sufficiently reducing conditions for iron reduction. Recent wetland mitigation projects have indicated an adoption of this technology by regulatory agencies, as IRIS tube studies are being incorporated into performance standards to verify hydric soil conditions.

APPROACH

IRIS tubes are pieces of PVC pipe coated in an iron oxide paint typically installed in the upper 12 inches of the soil profile. When reducing conditions are present, the iron oxide paint is removed from the tube. The tubes are analyzed and percent removal is calculated through a digital image analysis program to determine if reducing conditions are present. Studies and research are conducted following the *Protocol for Using and Interpreting IRIS Tubes*, as well as guidance issued by the U.S. Army Corps of Engineers and requirements set by the National Technical Committee for Hydric Soils.

RESULTS AND DISCUSSION

Recent project experiences and ranges of application will be presented, as well as data interpretation and influencing factors of IRIS tube studies. Additional research evaluating IRIS tubes to verify wetland hydrology is currently underway and will also be discussed.

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OCCURRENCE OF CYANOTOXINS IN A NASHVILLE WETLAND

Taylor Ribeiro[1], April Falconer [2], Thomas Byl [3] and De'Etra Young[4]

Tennessee State University's main campus, located in Nashville, Tennessee, is home to an agriculture research facility containing a 26-acre wetland. The wetland was established by beavers in 1996 and has doubled in size every 5 years. For the past 5 years, every May and June, the wetland becomes eutrophic and choked with algae. Research livestock and wildlife have access to the wetland for water, so there was growing concern that the eutrophic conditions could transform into a harmful algal bloom (HAB) and release cyanotoxins. In cooperation with the Tennessee Dept. of Health, the Tennessee Dept. of Environment and Conservation, and the U.S. Geological, a study was conducted in the summer and fall of 2017 to determine if cyanotoxins were present in the wetland. Water samples were collected at different locations within the wetland to measure nutrients (nitrogen, phosphorous, iron, sulfur), Secchi disk depth, type of algae present, and various cyanotoxins. Continuous water-quality instruments were also installed at the upper end of the wetland, mid-wetland and below the wetland to document dissolved oxygen, pH, temperature, specific conductance and turbidity. Several cyanobacteria genera capable of producing cyanotoxin were present in the wetland during the sampling period, including *Dolichospermum*, *Chrysosporum*, *Aphanizomenon, Anabaena, Oscillatoria, Pseudoanabaena,* and *Lyngba.* Low levels of microcystin and saxitoxin were found in the wetland waters during July through October. The microcystin concentrations ranged from below detection to 0.26 µg/L. The saxitoxin concentrations ranged from below detection to 0.07 µg/L. The highest concentrations of toxin were located in the mid-wetland, near to the livestock access point. The peak microcystin concentrations were just below the US EPA's health advisory concentration. Additional work is being done to determine if there are correlations between various water chemistry parameters and cyanotoxin concentrations. A positive correlation would provide an early and inexpensive indictor for the presence of cyanotoxins.

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EXAMINING THE ROLE OF TREES IN BIORETENTION USING LABORATORY AND FIELD SCALE METHODS

Andrew Tirpak and Jon Hathaway

Bioretention is a stormwater control measure (SCM) implemented to ameliorate pollution and reduce runoff volume generated from impervious surfaces. Plants have been shown to improve the overall performance of these systems; however, vegetation is predominately selected based on its ability to survive the environmental conditions found in bioretention practices. Further, systems are preferentially planted with native grasses, sedges, and shrubs. Although the numerous benefits of trees in urban areas are understood (i.e. heat island mitigation, air quality improvements, noise attenuation, etc.), knowledge of their potential contributions to stormwater management as integral components of bioretention is minimal. This presentation reports on a series of studies designed to better understand the natural treatment mechanisms trees can provide to bioretention systems. Results will be discussed from a controlled mesocosm experiment conducted to characterize the treatment contributions of three native tree species and a field study of two tree-specific stormwater treatment devices monitored for pollutant removal and hydrologic performance. Ultimately, this research will culminate in the development of specifications and guidance for designers that will explain how to best integrate trees in bioretention practices.

SESSION 1B

FLOOD PROTECTION (Moderator: Tom Palko, Metro Water Services)
1:30 p.m. – 3:00 p.m.

Flood Protection for Critical Facilities
Adrian Ward

Estimating Basin Discharge Using 2D Hydraulic Model
Trevor Cropp

Baffle Step Weir to Protect Sewer Crossing on Lateral D Germantown, Tennessee
Robert L. Hunt and Tim Bierdz

FLOOD MODELING (Moderator: Roger Lindsey, Metro Water Services)
3:30 p.m. – 5:00 p.m.

The Vulnerability of Critical Energy Infrastructures to Climate Change Induced Flooding: A Case Study for the Conasauga River Basin
Tigstu Dullo, Sudershan Gangrade, Ryan Marshall, Sheikh R. Islam, Sheikh Ghafoor, Shih-Chieh Kao, and Alfred Kalyanapu

Reconstruction of Hurricane Harvey Flooding for Harris County, TX Using a GPU-Accelerated 2D Flood Model for Post-Flood Hazard Analysis
Alfred J. Kalyanapu, Tigstu Dullo, Sudershan Gangrade, Shih-Chieh Kao, Ryan Marshall, Sheikh R. Islam, and Sheikh Ghafoor

ALCAL – Nashville SAFE's Quick and Easy Flood Prediction Model
Bradley Heilwagen and Amec Foster Wheeler

FLOOD PROTECTION FOR CRITICAL FACILITIES

Adrian Ward, PE, CFM

ABSTRACT

Background and Study Area

A major regional hospital in southern Mississippi has experienced repeated flooding issues over the years from adjacent waterways, as well as from hurricanes approaching from the coast. The facility is bordered on the west by Flat Branch which has a drainage area of approximately 12 square miles and is located six miles from the coast. In 2005, the hospital took on water from Hurricane Katrina when flood levels exceeded the hospital's finished floor elevation (FFE) by two to three feet. Given that the facility is deemed a critical facility, in 2013, hospital ownership decided to perform a study to determine the best flood mitigation alternative to protect the facility and allow it to remain fully functional during a flood event.

Study and Alternative Analysis

The study and alternative analysis included the following tasks:

- Collection of all readily-available historic and site data to evaluate past and future flooding potential at the site from Flat Branch and the coast, including critical elevations of the hospital.
- Development of mitigation alternatives that provided varying levels of flood protection. Options varied from engineering and operational controls to constructed site systems. Items considered ranged from floodproofing doorways and elevating critical equipment to installing floodwalls and a stormwater pump station.
- Presentation of alternatives to ownership and selection of an alternative that best fit the mission and associated needs of the critical facility.

Site Improvements

In 2016, hospital ownership decided to move forward with design and construction of a floodwall and stormwater pump station to provide flood protection for this facility. Various site constraints and challenges had to be evaluated and addressed when developing the design.

- An existing FEMA floodway runs along Flat Branch which is on the west side of the site and the creek frequently floods. A No-Rise study was prepared to ensure that adjacent property owners would not be impacted by installation of the floodwall along the creek bank. Multiple wetlands and streams exist on-site. The final design avoided any impacts to natural resources to forgo the lengthy Federal permitting process.
- To fully address localized flooding issues, a 48-inch RCP storm sewer system was designed to convey stormwater around the hospital.
- The facility was constructed on a layer of peat causing geotechnical concerns. To provide adequate stability and prevent floodwater from seeping under the floodwall, sheetpile cut-off walls had to be installed four times as deep in the ground than was above the ground surface.

A pump station with approximately 40,000 GPM pumping capacity was installed to evacuate floodwaters and prevent the site from flooding during a coincidently 100-year rainfall event. In addition, 2800 linear feet of floodwall was installed around the perimeter of the site that extended between two and seven feet above the ground. Four removable sections were also designed to allow for access into the site.

Construction

The flood protection project was bid at approximately $6,300,000 in 2017. Despite various changes resulting from unexpected utility conflicts, construction is scheduled to be finished in early 2018 before the hurricane season.

ESTIMATING BASIN DISCHARGE USING 2D HYDRAULIC MODEL

Trevor Cropp, PE, CFM

ABSTRACT

Lake County resides in Northwest Tennessee along the Mississippi River. The U.S. census shows that over 42% of the county's population live in poverty. The area, primarily used for agriculture, has been protected for years from devastating floods from the Mississippi River by a levee located along the west side of the county. The county seat is Tiptonville with a population of just over 4,000 residents. It, too, is protected by the Mississippi River levee. Localized drainage on the "dry side" of the levee drains through the levee via an existing pipe located just to the north of Tiptonville. When the Mississippi River stage gets high enough, a sluice gate is shut and localized stormwater is allowed to pond on the landward side of the levee. Frequently, the sluice gate is required to be closed during a Mississippi River flood event and a coincidental storm event occurs on the landward side of the levee and floods the agricultural land along with 21 low- to moderate-income households. Given the limited resources of the community, the town did not have the funding to install a permanent drainage solution. There is a dependence on the local levee board and the West Tennessee River Basin Authority (WTRBA) to secure several portable pumps to evacuate flood water on the landward side of the levee. This option has been ineffective since the pumps do not have the capacity to discharge water fast enough to prevent flood waters from impacting residents and downtown Tiptonville.

In 2016, the State of Tennessee was awarded a grant from the US Department of Housing and Urban Development to install a permanent pumping solution. The WTRBA moved forward with selecting an engineering firm and the design process is currently underway. The major challenge being addressed is the development of an accurate inflow hydrograph from the upstream drainage area. Accurate discharge estimates are critical in the sizing of the large pump station. Given the flat topography, even a small miscalculation in stormwater inflow will result in a very large increase in inundation area and impact many residential structures. Traditional hydrology methods were first used and yielded a peak inflow of approximately 1,100 cfs during the 100-year rainfall event. This large peak flow is due largely to the poorly draining soils. The projected inundation elevations seemed to exceed those of the existing conditions. In an effort to produce a more realistic hydrologic response, the engineering staff chose to use the new HEC-RAS 5.0 2D modeling software to more accurately represent the discharge of this very flat drainage basin. 2D models are relatively new and generally used for very flat terrain and areas where large amounts of overland flow are expected. New Lidar GIS data was used to build a 2D computational mesh and excess rainfall amounts were applied to that mesh. As excess rainfall is applied to individual cells within the mesh, water accumulates and is conveyed downstream from one cell to the next until it reaches the outfall. Each cell has its own set of hydraulic properties and allows the software to compute a combined discharge hydrograph based on the response of each individual cell. The results showed that the existing flat topography has a large attenuation effect on the discharge hydrograph. By using this complex 2D model, anticipated pumping costs have been cut in half and freed up funds to be utilized for additional improvements.

BAFFLE STEP WEIR TO PROTECT SEWER CROSSING ON LATERAL D GERMANTOWN, TENNESSEE

Robert L. Hunt[1] and Tim Bierdz[2]

The City of Germantown, Tennessee and the Memphis District Corps of Engineers designed and built a grade control structure on Lateral D, an urbanized, channelized, and incised tributary of the Wolf River. The structure contract bid price was $1,384,333.00 and construction was completed in September, 2017. Lateral D has a drainage area of approximately 1.3 square miles and a 100-year flow of 2,300 cubic feet per second at the structure site, which is 2,000 feet upstream of the confluence with the Wolf River. The structure is located immediately downstream of a multi-pipe inverted siphon crossing for a 36-inch diameter sanitary sewer line and protects the siphon from the damage that would occur if the channel were to degrade further and expose the siphon. The grade control structure is made of reinforced concrete and sheet pile and attaches to a sheet pile weir the City installed as a grade control structure. The structure will dissipate energy by means of baffle blocks when the Wolf River is low and will convey flow without energy loss when the weir is submerged by backwater. The design of the structure can be adapted to other sites where severe land rights restrictions, a wide range of tailwater elevation, and severe consequences of failure justify a concrete and steel structure.

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THE VULNERABILITY OF CRITICAL ENERGY INFRASTRUCTURES TO CLIMATE CHANGE INDUCED FLOODING: A CASE STUDY FOR THE CONASAUGA RIVER BASIN

Tigstu Dullo[1], Sudershan Gangrade[2], Ryan Marshall[3], Sheikh R. Islam[4], Sheikh Ghafoor[5], Shih-Chieh Kao[6], and Alfred J. Kalyanapu[7]

INTRODUCTION

The U.S. energy infrastructure is considered as uniquely critical because it fuels the economy by providing required sources of energy to all infrastructure sectors that are essential to the growth and production (Energy-SSP 2015). However, the electric infrastructures are becoming more and more vulnerable due to frequent extreme weather conditions, cyberterrorism, infrastructure aging, man-made accidents, and other natural disasters (Energy-SSP 2015; Gilstrap et al. 2015; Zamuda et al. 2015; Forzieri et al. 2016). Extreme weather events have shown increase in frequency, intensity, spatial extent, and duration due to climate change and variability (Khedun and Singh 2014; Chandramowli and Felder 2014; Vale et al. 2014). Energy infrastructures that lie in areas vulnerable to flooding can be affected through changes in their energy production and consumption or through damages from floodwater (Chernin 2013; Morgan 2013; Tan 2013; Chandramowli and Felder 2014; Bollinger and Dijkema 2016). The effects of flooding on the critical electrical infrastructures are mainly attributed to the damages on electrical components due to the floodwater, which can rust metals, destroy insulation, and damage interruption capabilities (Farber-DeAnda et al. 2010; Vale et al. 2014; Bollinger and Dijkema 2016). Because the most common cause of damage to substation is flooding, some states recommend water-sensitive elements to be set above the Base Flood Elevation (BFE). Critical electric infrastructures can also be mitigated from extreme weather damages by changing the infrastructures physically to make them less vulnerable, which is also known as hardening (Farber-DeAnda et al. 2010; Gilstrap et al. 2015). However, due to the high cost of hardening and inadequate flood protection measures electric infrastructures are becoming more and more vulnerable. As Magill (2014) indicated, *"It does not take rising seas for electric power plants and other energy infrastructure in the U.S. to flood. Major 100-year floods can do that without the help of climate change.*" Therefore, the objective of this study is to assess the impact of

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climate change induced flooding on critical electric infrastructures inside the Conasauga river basin using a GPU+MPI-accelerated 2D flood model (Flood2D-GPU).

APPROACH

Taking the Conasauga river basin as a test bed, hydrologic simulation is conducted using a 90m resolution DHSVM hydrologic model driven by observed precipitation and simulated meteorology from Weather Research Forecasting (WRF) model. The DHSVM hydrograph along with a 30m resolution digital elevation model and estimated bed roughness are then used to conduct high resolution flood simulation using an accelerated Flood2D-GPU model. To perform the flood simulation, the largest flood events were identified from the three sets of hydrologic simulations (Control, Baseline and Future). The control case was driven be the 1981-2012 observed meteorology while the baseline was driven by the 1966-2005 bias-corrected input climate data. The future case is the same as the baseline but driven by the 2011-2050 downscaled meteorological data. The flow hydrographs for the baseline and future scenarios were prepared using 11-climate models. Selecting one flood event (the largest flood event from three consecutive days) per-scenario and per-climate model, a total of 23-flood simulations were performed for this case study. Because the flood simulations were not calibrated, model verification was done at three selected river segments. Finally, the vulnerability of critical electric infrastructure will be conducted by extracting the maximum flood depths at each substations and power plants.

RESULTS AND DISCUSSION

Preliminary results indicated that, the model verifications for the Flood2D-GPU show satisfactory agreement with NSE above 0.8. Moreover, the future simulations overall indicate wetter trend than the baseline simulations. This result is supported by the comparison of flood inundation extents between baseline and future simulations. The comparison revealed that seven of the eleven climate models show larger inundation extent in the future. Future efforts will focus on identifying some of the most vulnerable energy infrastructure locations in the Conasauga river basin and illustrate how they might be affected by climate change induced flooding.

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RECONSTRUCTION OF HURRICANE HARVEY FLOODING FOR HARRIS COUNTY, TX USING A GPU-ACCELERATED 2D FLOOD MODEL FOR POST-FLOOD HAZARD ANALYSIS

Alfred J. Kalyanapu[1], Tigstu Dullo[2], Sudershan Gangrade[3], Shih-Chieh Kao[4], Ryan Marshall[5], Sheikh R. Islam[6] and Sheikh Ghafoor[7]

Hurricane Harvey that made landfall in the southern Texas this August is one of the most destructive hurricanes during the 2017 hurricane season. During its active period, many areas in coastal Texas region received more than 40 inches of rain. This downpour caused significant flooding resulting in about 77 casualties, displacing more than 30,000 people, inundating hundreds of thousands homes and is currently estimated to have caused more than $70 billion in direct damage. One of the significantly affected areas is Harris County where the city of Houston, TX is located. Covering over two HUC-8 drainage basins (~2702 mi^2), this county experienced more than 80% of its annual average rainfall during this event. This study presents an effort to reconstruct flooding caused by extreme rainfall due to Hurricane Harvey in Harris County, Texas. This computationally intensive task was performed at a 30-m spatial resolution using a rapid flood model called Flood2D-GPU, a graphics processing unit (GPU) accelerated model, on Oak Ridge National Laboratory's (ORNL) Titan Supercomputer. For this task, the hourly rainfall estimates from the National Center for Environmental Prediction Stage IV Quantitative Precipitation Estimate were fed into the Variable Infiltration Capacity (VIC) hydrologic model and Routing Application for Parallel computation of Discharge (RAPID) routing model to estimate flow hydrographs at 69 locations for Flood2D-GPU simulation. Preliminary results of the simulation including flood inundation extents, maps of flood depths and inundation duration will be presented. Future efforts will focus on calibrating and validating the simulation results and assessing the flood damage for better understanding the impacts made by Hurricane Harvey.

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ALCAL – NASHVILLE SAFE'S QUICK AND EASY FLOOD PREDICTION MODEL

Bradley Heilwagen and Amec Foster Wheeler

Originally published in the NHWC Transmission, May 2017

ABSTRACT

The Nashville SAFE (Situational Awareness for Flooding Events) Program is a partnership formed between Metro Water Services and other agencies following the flooding that occurred in May 2010 in Nashville, Tennessee. From the beginning, the mission of Nashville SAFE was to better prepare the city for future floods by improving coordination between responding agencies, developing more and better data for analysis during a flood event, and training more personnel to make informed decisions during a flood event.

Early in the program, the U.S. Army Corps of Engineers (USACE) modeled 11 precipitation scenarios, 24 hours in duration, with an SCS Type II distribution, with total rainfall depths of one inch through 11 inches, in one-inch intervals. The resulting water surface elevations and mapping serve as the basis for an Action Level approach to flood prediction, with Action Levels lettered A through K, which represent the resulting 11 flood scenarios.

In addition, Metro Water Services created the role of Watershed Advisor within their ranks to support Emergency Management by providing scientifically-based impact assessments and decision recommendations to their Situation Management Team. During the first two years, it became clear that Watershed Advisors needed a way to quickly and easily determine an anticipated Action Level(s), given current and predicted rainfall. A pilot project to develop HEC-RTS (a real-time H&H modeling system developed by USACE) modeling was initiated, and will eventually result in implementation across all watersheds in the Metro Nashville area over several years.

In the meantime, to help Watershed Advisors quickly determine a current and predicted Action Level in the watersheds of Metro Nashville, Amec Foster Wheeler (AmecFW) developed a rudimentary flood model that would eventually be called the Action Level Calculator (ALCAL).

The 11 precipitation scenarios modeled by USACE serve as the technical basis for the calculations within ALCAL. They assume that a shorter duration event with a similar rainfall depth as the most intense two-hours of a longer duration event will have the same or similar net result. Input data includes recent rainfall at USGS gages and NWS precipitation forecasts in 6-hour increments for the next 24 hours. The calculation involves assigning an Action Level to the quantity of rainfall observed in the last 2-, 4-, and 6-hours, the predicted rainfall over the next 24 hours, and variations of predicted incremental rainfall in 6-, 12-, and 18- hour increments. The result is a range and average of potential current and future Action Levels. Calculations were originally performed manually, but have been incorporated into a Microsoft Excel macro for automation.

This presentation will explain how using readily available data, the project team created a user-friendly automated decision support tool for Nashville SAFE. It will also discuss the shortcomings of the calculation process, as well as future developments being planned, which include a mapping component and automated data retrieval.

SESSION 1C

FIELD SURVEY AND MAPPING (Moderator: Richard Cochran, TDEC)
1:30 p.m. – 3:00 p.m.

UAS-Based LiDAR Data Collection for Water Quality and Environmental Site Management Applications
Andrew Carroll

Using the High Definition Stream Survey of the Duck River to Prioritize Areas for Streambank Restoration
Brett Connell and James Parham

Implementation of Statewide Best Management Practices (BMPs) During Forest Harvesting in Tennessee: A Statewide Evaluation
Wayne K. Clatterbuck and Katelyn Rimmer

EPSC ON CONSTRUCTION SITES (Moderator: Tom Lawrence, Water Quality Matters!)
3:30 p.m. – 5:00 p.m.

Review of USEPA/ASCE National Database on Performance of Erosion Prevention and Sediment Control Devices at Construction Sites
John S. Schwartz and Ali Hangul

In-Service Performance Evaluation of Erosion Prevention and Sediment Control Devices
Ali R. Hangul

Engineering Design Guidance on Highway Construction Sediment Basins
Payton Smith and John Schwartz

UAS-BASED LiDAR DATA COLLECTION FOR WATER QUALITY AND ENVIRONMENTAL SITE MANAGEMENT APPLICATIONS

Andrew Carroll[1]

ABSTRACT

Light Detection and Ranging (LiDAR) data sets are commonly used in geospatial data analysis for water quality and environmental site management. LiDAR sensors are fully capable of vegetation and ground cover penetration for accurate terrain surface measurement. LiDAR data can deliver accurate representations of both terrain and above-ground returns from structures, canopy, or cover. This ability, as compared to typical single-surface only capture results from passive imaging sensors used in photogrammetric methods, makes LiDAR a leading technology for documentation, tracking, and measurement of complex environmental and ecological sites.

Traditionally, LiDAR sensors require manned aircraft operation, ground-based mobile, or static ground scan capture solutions. These approaches, while effective, often introduce time and costs increases to project management budgets, when operating on the scale and variety of conditions at typical environmental or ecological/natural resource project sites. However, recent advances for inertial measurement unit devices, global navigation satellite system receivers, and regulatory authorizations have increased the capability of unmanned aerial systems (UASs) to host LiDAR hardware. Additionally, commercially manufactured LiDAR sensor payloads are available in smaller form factors and weights. These innovations have led to increasing deployment of LiDAR enabled unmanned systems.

UAS based LiDAR technology is well suited for water quality and environmental site management. Results from UAS field mapping missions and LiDAR sensor evaluations, indicate increased mobility, reduction of safety hazards, and acquisition of very accurate, high resolution data. Through the integration of ground control and best practices for UAS based LiDAR capture, USGS Quality Level 1 or Quality Level 0 Digital Terrain Models and derivative elevation products can be produced. The spatial resolutions of dense UAS-based point clouds allow for unparalleled surface and flow analysis. High resolution stream profile and channel characterization is possible from point cloud alone. As a result, these systems offer real potential time and cost savings by reducing the need for a complete traditional field survey or manned aircraft data acquisition.

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USING THE HIGH DEFINITION STREAM SURVEY OF THE DUCK RIVER TO PRIORITIZE AREAS FOR STREAMBANK RESTORATION

Brett Connell[1] and Dr. James Parham[2]

The High Definition Stream Survey (HDSS) approach was created to rapidly gather continuous geo-referenced data in a single pass for a broad range of stream and streambank conditions by integrating GPS, video, depth, water quality and other sensors. Once the data are collected, the videos are combined to create a virtual tour with four simultaneous views of the river survey (front, left bank, right bank and underwater). Other information such as side-scan sonar and a dynamic overhead map are also included when applicable. Because each second of video is linked to a specific GPS point, this allows for the identification, selection and prioritization of streambanks for restoration. The results can also be used to monitor restoration results, determine the extent and distribution of instream habitat, define the geomorphic condition for the stream, identify infrastructure impacts, and provide a powerful "virtual tour" experience.

The HDSS method is fast, we surveyed 120 miles of the Duck River, TN in eight days with just two people. HDSS provides better data, we collected continuous data on streambank condition, water depth, water quality, habitat type, substrate, and channel capacity at approximately 1m resolution. HDSS is cost-effective, fewer people and less time in the field means less costs to the overall project with funding left over to properly monitor restoration reaches.

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IMPLEMENTATION OF STATEWIDE BEST MANAGEMENT PRACTICES (BMPS) DURING FOREST HARVESTING IN TENNESSEE: A STATEWIDE EVALUATION

Wayne K. Clatterbuck[1] and Katelyn Rimmer[2]

An evaluation of forestry BMP implementation in Tennessee was conducted by the University of Tennessee, Dept. of Forestry, Wildlife & Fisheries and the Tennessee Dept. of Agriculture, Division of Forestry in 2017. A total of 213 harvest sites stratified among five regions statewide were evaluated in terms of haul roads, skid trails, log landings, streamside management zones (SMZs), stream crossings and wetlands, a total of 5,463 observations. The statewide BMP implementation rate was 88.5% with 13 of the 213 sampled harvests (6.1%) having observations that were or could lead to significant threats to water quality. The West region had the lowest rate of BMP implementation at 82.9% while the Plateau region had the greatest at 96.1%. Stream crossings and skid trails were the greatest sources of potential water quality threats although stream crossings only occurred on 34% of the sampled harvests. Stream crossings either were avoided or not present on two-thirds of the sampled harvest sites indicating that loggers were making an effort to avoid waterways. Based on this survey, logger continuing education programs will emphasize proper BMP practices on stream crossing approaches, seeding to stabilize disturbed ground surfaces and water control points on skid trails. Implementation of forestry BMPs through a non-regulatory educational program appears effective in protecting water quality during forest harvest operations.

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REVIEW OF USEPA/ASCE NATIONAL DATABASE ON PERFORMANCE OF EROSION PREVENTION AND SEDIMENT CONTROL DEVICES AT CONSTRUCTION SITES

Dr. John S. Schwartz[1] and Ali Hangul[2]

A joint effort in the 1990s by the US Environmental Protection Agency (USEPA) and the American Society of Civil Engineers (ASCE) created a national database for stormwater best management practices (BMP). This database includes data from NPDES municipal storm sewer systems (MS4s), federal and state agencies, and others on BMP performance. Data has been summarized on specific BMPs related to erosion prevention and sediment control (EPSC), and will be presented.

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IN-SERVICE PERFORMANCE EVALUATION OF EROSION PREVENTION AND SEDIMENT CONTROL DEVICES

Ali R. Hangul[1]

Erosion prevention and sediment control (EPSC) devices are widely used during construction projects by departments of transportation (DOTs) nationally to prevent or reduce the movement of sediment that is carried into lakes, streams, and rivers by stormwater runoff from a site during construction and are required by state water quality and stormwater regulations. Erosion prevention reduces the amount of nutrient and pollutant-laden sediment that leaves a construction site and degrades water resources and harms aquatic wildlife. Proper planning of construction site activities greatly reduces the impact of soil disturbance on nearby resources (Minnesota Stormwater Manual 2017). Although erosion on construction sites often affects only a relatively small acreage of land in a watershed, it is a major source of sediment because the potential for erosion on highly disturbed land is commonly 100 times greater than on agricultural land. Department of transportations in every state have developed standard drawings per state water quality and stormwater regulations and drainage manuals to provide guidance to roadway designers in order to develop erosion control plans to protect natural water resources during temporary roadway construction activities.

It is evident that more information is required to better asses the amounts of sediment lost during the temporary construction actives. In addition, there is a need for observation of field performance of EPSC devices and improvement of design and implementation of EPSC devices based on past experiences. This need has been elevated not only by design professionals who are directly involved in the development of erosion plans, but also operations professionals and other agencies and research institutions. Since the US Environmental Protection Agency first published guidance (1972), other research has provided additional design guidance to improve practices (NCHRP Project 1976). Currently every state department provides specific EPSC guidance that serves best for their state needs.

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ENGINEERING DESIGN GUIDANCE ON HIGHWAY CONSTRUCTION SEDIMENT BASINS

Payton Smith[1] and Dr. John Schwartz[1]

Regulations set in place by the US Environmental Protection Agency and Tennessee Department of Environment and Conservation require performance standards that often affect existing design criteria for current stormwater control measures (SCM). Specifically, resulting in the Tennessee Department of Transportation's (TDOT) need for a revised engineering design criteria for sediment basins at highway construction sites. The nature of highway sites being corridor-like in shape and often having fully exposed and highly trafficked soil reflects the need to assess whether current design criteria are adequate to meet the state's performance standards. Therefore, it was decided that the monitoring of the influent and effluent of three separate sites with varying land slopes, soil types, and drainage areas would be required, which would assess a prior modeling effort for site sediment yields estimates and basin sizing as a function of these three key site conditions. Through engineering assessment, the monitoring devices used at each site were specially chosen for the constraints of the individual location; at each location the following were collected for ten storms: inlet and outlet water samples, soil samples from flume deposits, full weather data, and volumetric flow data. The resulting particle size analysis and suspended sediment concentration data can then be used to calibrate the hydraulic and sediment model in order to get a firm grasp on sediment basin design. This data will ensure that TDOT has a functioning and usable design for various sized sediment basins, minimizing cost and inconvenience, ensuring their use when the best possible stormwater practice.

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SESSION 2A

SUBSURFACE HYDROLOGY (Moderator: Alfred Kalyanapu, TTU)
8:30 a.m. – 10:00 a.m.

Stimulation of Plant Growth by Groundwater Naturally Rich in Sulfide and Calcium
Danelle Solomon and De'Etra Young (Acknowledgement Tom Byl)

Basic Temperature Variation in Karst Microenvironments in the Lost Creek State Natural Area, White County, Tennessee
Randy M. Curtis

Evaluating Modern Recharge to the Memphis Aquifer at the Lichterman Well Field, Memphis, TN
Michael R. Smith, Daniel Larsen and Scott Schoefernacker

FLUVIAL GEOMORPHOLOGY (Moderator: Bill Wolfe, USGS)
10:30 a.m. – 12:00 p.m.

Instability in Relocated and Restored Channels
Tim Diehl

Remote Sensing Applications to Measure Geomorphic Properties of West Tennessee Watersheds
David Blackwood

Geomorphic Implications of River Conservation Practices in the Coastal Plains
Jeff Fore and David Blackwood

STREAM RESTORATION EDUCATION AND CERTIFICATION
(Moderator: Jimmy Smith, TDEC-DWR)
1:30 p.m. – 3:00 p.m.

Stream Restoration Education and Certification
John Schwartz, Karina Bynum and Ken Barry

NUTRIENT REDUCTION FRAMEWORK (Moderator: Victor Roland, USGS)
3:30 p.m. – 5:00 p.m.

Applying a Regional-Scale Water-Quality Model to Tennessee Watersheds
Anne B. Hoos and Sherry H. Wang

Tennessee's 2018 Nutrient Reduction Framework: Development and Progress in Implementation
Jenny Dodd

The Tennessee Nutrient Reduction Framework: Development and Progress in Implementation
Forbes Walker

STIMULATION OF PLANT GROWTH BY GROUNDWATER NATURALLY RICH IN SULFIDE AND CALCIUM

Danelle Solomon[1] and De'Etra Young[1] (Acknowledgement – Tom Byl[2])

Previous research found sterile water artificially enriched with sulfide stimulated plant biomass. This study's objective was to determine if groundwater from Tennessee State University's farm wells, naturally rich in sulfide, stimulated plant growth. Lettuce, radish and oat raised using waters from a well containing high sulfide (65-115 mg/L) were compared to groundwater with no sulfide. Seeds were germinated in tissue soaked in the experimental waters and raised in a growth chamber at 20ºC. The oat plants raised in sulfur-water had 3x more lateral roots and 18% greater biomass than plants raised in fresh-water. Lettuce and radish plants raised in sulfur-water were 35% and 13% larger than those raised in fresh-water, respectively. Plant peroxidase activity significantly ($p < 0.05$) increased in plants exposed to sulfide, giving them stronger, more compact cell. Oat plants raised in sulfide-water had more efficient photosynthesis capacity as compared to oat plants raised in freshwater. There was 10% more chlorophyll and 3x greater uptake of CO_2 in the sulfide-raised oats as compared to those raised in aerobic water without sulfide.

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BASIC TEMPERATURE VARIATION IN KARST MICROENVIRONMENTS IN THE LOST CREEK STATE NATURAL AREA, WHITE COUNTY, TENNESSEE

Randy M. Curtis[1]*

ABSTRACT

Temperature dataloggers were deployed in sink, cave, and karst water settings in the Lost Creek State Natural area on the edge of the western Cumberland Escaprment in the Caney Fork River surface water basin near Sparta, Tennessee. The dataloggers recorded ambient temperatures every quarter-hour for several weeks in late summer to provide baseline information on temperature variation. Units were placed in the Lost Creek resurgence, the upper Lost Creek Cave, the Lost Creek sink floor, the entrance, twilight zone, dark zone, and floor water of the main bore of Lost Creek Cave (a.k.a. Dodson Cave), and the ceiling and floor channel water of Merry Branch Cave. Late summer temperatures indicate air flow into the Dodson Cave entrance produces condensation water sufficient to provide some recharge water into the main cave, that the Merry Branch Cave floor fractures contain water at equilibrium temperature with the surrounding bedrock, and that the upper Lost Creek Cave resurgence responds to late summer storm events with slight peaks in water temperature followed by gradual return to a nearly uniform baseflow temperature condition.

BACKGROUND

Lost Creek State Natural Area is situated on the western flank of the Cumberland Plateau where the surface drainage transitions to Wester Highland Rim physiography. The area features Lost Creek Falls, formed from a large spring resurgence at the base of the Bangor Limestone on the west side of a very large sink. This water flows as a stream for about a hundred yards untill it drops over the Hartselle Formation in a 40' fall into a plunge pool where normal flow volume disappears underground again. This water forms another waterfall in the very bottom portion of Dodson Cave. High rainfall rates in the area activate stormflow from cave passages immediately upslope of the spring resurgences. Very high flow volumes overwhelm the plunge pool swallet and an overland flow channel across the bottom of the sink carries water directly into the very large cave opening. This is the main entrance to Dodson Cave, also known as the Lost Creek Cave. Lost Creek Cave is one of the larger caves in Tennessee, with four other entrances and seven miles of mapped passages. The lower limits of exploration are near a sump that takes water from an underground waterfall, the destination of some of the water from the surface water plunge pool swallet.

The floor of the sink is at an elevation of about 1020' above mean sea level, with about 60' of vertical relief to the upper edge of the topographic sinkhole. There is typically a marked daytime temperature contrast in summer between the lower levels of the sink and the surrounding

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hillslopes. Cool air seems to spread from the base of the waterfall into the main cave entrance. Onset HOBO® U22-001 Underwater Data Loggers were deployed in the sink, cave, and spring environments under a research permit granted by the Tennessee Division of Natural Areas in the late summer of 2016 and 2017 to continuously record air and water temperatures in this area. The loggers were set to record temperatures at 5 to 15-minute intervals for several weeks to check basic assumptions regarding expected cave and water temperatures in a karst setting.

The impetus of the original research permit request in 2016 was to evaluate the Powell and Vermette Equation used for calculating american cave temperatures (Powell and Vermette, 2014). Cave environments may be conviently divided into three zones; light, twilight, and dark representing the cave entrance area, the transition zone where ambient light intensity gradually decreases, and the area where no natural light reaches. The dark zone typically is assumed to maintain a stable temperature reflecting the average annual surface temperature of an area; this is because the country rock from which the cave is formed acts as a heat source. Most caves are at or above the regional water table which acts as a buffer from geothermal heat gradients from below. The Powell and Vermette equation is written as T = 44- (0.8*L) - (0.0018*A), where T is temperature in degrees Celsius, L is degrees in Latitude of the cave's location, and A is the altitude of the cave in meters above mean sea level. The Lost Creek Cave entrance is roughly latitude N 35.84177 (about 8.2 miles southeast of Sparta, Tennessee) and an estimated 310 meters above sea level, yielding a calculated cave temperature of 14.76884°C, or about 58.58°F. This is slightly warmer than the average annual temperature from the nearest regional climate data center in Sparta, TN, which is 58.25°F (www.usclimatedata.com).

AIR TEMPERATURE READINGS

From August 5, 2016 until September 9, 2016, data loggers set to record temperature in 5 minute intervals were deployed on the hillside above the Lost Creek sink, outside the closed contours of the sink, in the bottom of the sink at the main Dodson Cave entrance, in the twilight zone near the entrance, in the dark zone of the main cave bore near the end of the first breakdown rubble pile, in the water supply in the floor of the cave near the base of the first rubble pile, and in the dark zone at the end of the main bore. The devices were generally deployed in rock crevices out of sight to the casual observer at foot to shoulder height. The following table compares the average readings of all but the water supply loggers:

Table Comparing Powell / Vermette Equation to Lost Creek Air Temperatures

Powell Vermette = 58.58 °F	Avg. Data °F	Median Data °F
Hillside Air	75.98	75.33
Sink Bottom	59.22	59.27
Cave Twilight	54.59	54.58
Front Cave Dark Zone	51.93	51.90
Back Main Cave Dark Zone	51.14	51.11

It appears that the effects of airborne mist entrained with air entering the large entrance of the cave in summer, coupled with condensation of mositure from the air as it moves downward inside the large open bore of the cave, are cooling the cave sidewalls to temperatures lower than would ordinarily be expected. Obvious condensation was present on all the black plastic dataloggers inside the cave at the time of retreival.

From August 3, 2017 to August 27, 2017 several dataloggers were again deployed to try and determine whether there could have been a bias in the original sample design because the loggers were in physical contact with the rock inside the cave. The hillside slope background air logger was suspended in the shade of a young beech tree at the same location used in 2016. The dark zone Dodson Cave point at the rear of the main bore was replicated by a data logger suspended from a fishing line attached to a tent peg wedged into the sidewall near the 2016 dark zone location. Another datalogger was placed in the dark zone of the upper cave above the falls, a much smaller but easily accessible cave passage above the springs at the base of the Bangor Limestone. A third cave air sample was suspended from the roof of Merrybranch Cave several hundred feet back from the main entrance. Merrybranch Cave is also in the base of the Bangor Limestone just outside the southern boundary of the Lost Creek Natural Area. The higher altitude of the Bangor Caves would dictate a minor adjustment of the Powell / Vermette Equation, yielding an estimated temperature of 58.48 °F. The following table lists the air temperature data recorded at 15 minute intervals in August of 2017:

Table Comparing Powell / Vermette Equation to Lost Creek Area Air Temperatures

Pow. /Verm. 58.58-58.48°F	Average °F	Median °F
Hillsope Air	71.77	71.75
Dodson Cave Dark Zone	52.21	52.20
Upper Lost Creek Cave	65.96	66.04
Merrybranch Cave	56.54	56.56

The Upper Cave air temperature at Lost Creek is warmer than expected, on average, while the main bore cave passage air on the other side of the sink from the waterfall was again several degrees cooler than would be expected. The air sampler in the Merrybranch Cave bore's ceiling was suspended about five feet directly over flowing water in a fissure in the floor of the cave. The median temperature recorded by the dataloggers in Merrybranch Cave ceiling air and floor water were 56.599°F and 56.556°F, respectively.

WATER TEMPERATURE READINGS

The following table contains the data from the periods in August 2016 and 2017, where overlapping days of data from loggers submerged in water are available. Extra data from 2016 from the 5 minute interval 2016 data set was not used in order to match the 15 minute recording interval from 2017. Expected groundwater temperature for the region would be near 58.25°F if the water were in equilibrium with the shallow subsurface heat flow.

Lost Creek Area Water Temperatures, Aug. 5th to Aug. 27th, 2016-17, 15 min. intervals

Point	Average	Median	Variance
Waterfall Source	62.725	62.330	.629
Merrybranch Cave	56.599	56.599	.005
Dodson Cave Floor	51.718	51.785	.000

The larger variance and warmer temperatures of the Lost Creek Cave sink waterfall source are in accord with the theory that this water flows underground from the Lost Creek / Dog Cove swallet along the Bangor Limestone / Hartselle Sandstone geologic contact to the resurgence above the falls (Matthews, 2016). The slight variance in the resurgence water reflects the mix of surface and groundwater temperatures. The increase in variance in the resurgence water occured within a few hours of heavy rainfall shown on radar records that tracked the presence of thunderstorms in the area.

The Merrybranch Cave system is considered an overflow conduit for the same Lost Creek / Dog Cove Swallet, and although there were indications of increased flow in Merrybranch Cave, the fissure flow groundwater did not reflect any significant temperature increases at the time of the Lost Creek area thunderstorm events. The fissure system's lower water temperature and lower viscoisity may have acted as a buffer against mixing with warmer overflow water.

The trickle of water in the floor of Dodson Cave flows from the rubble / breakdown rock debris about 150 yards down the main bore from the cave entrance. That water changed temperature by only a couple of tenths of a degree over the sample period in 2016, and the water temperature rise was in accord with the gradual increase in the air / wall temperature in the same area, indicating this flor water in the main cave passage is associated with deposition of suspended water droplets from the waterfall as well as temperature variation related condensation.

SUMMARY

The waterfall appears to be the main source of the cool air creating the summer season micrometerological niche in the bottom of the Lost Creek Natural Area sink. The same temperature contrast appears to drive at least some of the water balance for the upper portions of the main cave in the same sink, owing to the large entrance size and orientation of Dodson Cave.

Cool air from the subsurface vadose zone over the Hartselle / Bangor contact could also be issueing from the same conduits as the resurgence water feeding the falls. The large sink in the bottom of the southern end of Dog Cove, north of the Lost Creek Natural Area, would be cooled by the shade of the surrounding plateau in the late afternoon during the summer. While the Lost Creek bed is ordinarily dry of surface water in late summer, any cool air collecting in the creek botttom in the shade could be traveling from the Lost Creek / Dog Cove swallet to the spring / resurgence openings above the falls in the Lost Creek Natural Area. Winter season precipitation events show that the Lost Creek / Dog Cove swallet is capable of deliveing sufficient stormwater to migrate upward into the floor of the ipper cave and to spread laterally along the contact and place enough water into the head of the falls to surcharge the plunge pool. Surface water then flows overland across the sink bottom and into the rubble at the main entrance on the floor of the Dodson Cave. In summer the same resurgence conduits may provide unsaturated pathways for an air density gradient from the large shaded sinkhole in the bottom of the south end of Dog Cove to travel underground, in contact with the cool water of the base flow water table, all the way to the outlets at the head of the falls.

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EVALUATING MODERN RECHARGE TO THE MEMPHIS AQUIFER AT THE LICHTERMAN WELL FIELD, MEMPHIS, TN

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CAESER and Department of Earth Sciences
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INTRODUCTION

The Lichterman well field is a municipal water plant in south-central Shelby County, Tennessee, that is vulnerable to vertical seepage of modern (<60 years) groundwater into the underlying semiconfined Memphis aquifer. Regional recharge of the Memphis aquifer originates to the east and southeast of Shelby County; by the time these waters reach the Lichterman well field they are hundreds to thousands of years old. Near the Lichterman well field, local recharge of modern water to the shallow aquifer occurs through infiltration and loss of Nonconnah Creek stream water into the underlying shallow aquifer (Larsen et al., 2003; Larsen et al., 2013). Once in the shallow aquifer, modern water is suspected of leaking through nearby hydrologic windows in the upper Claiborne confining unit to the Memphis aquifer. Pumping of the Memphis aquifer at the Lichterman wellfield has created a cone of depression in the potentiometric surface of the Memphis aquifer and a downward hydrologic gradient from the shallow aquifer to the Memphis aquifer (Nyman 1965, Parks and Carmichael 1990, Parks and Mirecki, 1992; Kingsbury, 1996). Modern waters represent a potential contaminant source as studies in the Memphis area have found declining water quality in the shallow aquifer due to the introduction of nitrates, volatile organic compounds, and pesticides (Coupe, 2000; Gonthier, 2002; Barlow et al., 2012). Previous investigations of local recharge of modern water to the Memphis aquifer have used geochemical data and isotopic environmental tracers to model the sources, age, and relative contributions of modern waters to production waters of MLGW well fields (Parks et al., 1995; Larsen, 2003; Koban et al., 2011; Larsen et al., 2013; Gallo, 2015; Larsen et al., 2016). The purpose of this study is to assess the contribution of modern water to the Lichterman well field, likely recharge pathways, and areas vulnerable to contamination in order to develop a new conceptual model for leakage from the shallow aquifer to the well field.

APPROACH

In order to identify likely recharge pathways and sources of modern water in Lichterman well field, production water from 11 production wells and 1 shallow monitoring well were sampled for major solute chemistry, ^{3}H, ^{3}H/^{3}He, SF_6, and noble gases. Additionally, water quality and environmental tracer data from 10 monitoring wells in the shallow and Memphis aquifer near Nonconnah Creek was used (Gonthier, 2002). Inverse geochemical modelling, performed using PHREEQCi, was used to estimate mixing proportions of recent water, from the shallow aquifer, and older Memphis aquifer water, from regional recharge. ^{3}H/^{3}He and SF_6 groundwater concentrations were used to date modern waters produced from production and monitoring wells. Additionally, ^{3}H/^{3}He and SF_6 data were used in lumped parameter models (LPMs) in TracerLPM, a USGS lumped parameter modeling spreadsheet (Jurgens et al., 2014). Hydrostratigraphic cross sections of the study area, developed from geophysical logs, driller's logs, potentiometric surface maps, and water table maps were used to investigate the location of hydrologic windows near the wellfield and likely recharge pathways from the shallow aquifer. The conceptual model of recharge developed from the hydrostratigraphic analysis was then evaluated along with inverse geochemical mixing models and lumped parameter modelling of environmental tracer data to determine the most likely sources and pathways of modern recharge to the well field.

RESULTS AND DISCUSSION

Geochemical modelling revealed distinct deep Memphis aquifer and shallow aquifer end members, representing deep Memphis aquifer water and shallow aquifer waters, respectively. The modern component of production waters was dated to between 22 and 36 years since last exposure to the atmosphere for $^{3}H/^{3}He$ dating, compared to 28 to 51 years for SF_6 dating. Inverse geochemical modelling mixing proportions of shallow water in production well waters ranged from 3 to 19% were estimated. LPMs of MLGW production wells 324 and 304, using an exponential piston flow and dispersion model, estimated mixing proportions of modern water at 41% and 11%, respectively. Hydrostratigraphic cross sections identified hydrologic windows in the Upper Claiborne confining layer at USGS observation wells UR-13, UR-22 and UR24, to the northeast and northwest of the Lichterman well field. Additionally, hydrostratigraphic cross sections and water level data reveal a downward hydrologic gradient from the shallow to the Memphis aquifer, and water table conditions for the Memphis aquifer throughout much of the study area. These results indicate that perched water in the shallow aquifer to the north and east of the wellfield is most likely leaking through confining unit windows to the Memphis aquifer. However, in order to contribute significant percentages of modern water to the well field a direct connection between surface water, which recharges the shallow aquifer, and the Memphis aquifer would need to be present somewhere near the wellfield.

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INSTABILITY IN RELOCATED AND RESTORED CHANNELS

Tim Diehl[1]

The U.S. Geological Survey, in cooperation with the Tennessee Department of Transportation, recently observed post-construction changes in channel relocation and channel restoration projects in Tennessee.

Most channel relocations are designed as threshold channels, which rely on a non-eroding channel lining such as riprap, synthetic fabric, or grass to protect the surrounding material. Stream restorations, by contrast, are intended to undergo gradual erosion and deposition while preserving their designed dimensions and profile in dynamic equilibrium. Many stream relocations include stone structures such as bank revetments and rock riffles intended to stabilize the channel until maturing trees reinforce the banks.

In threshold channels, movement or removal of the channel lining constitutes instability, and can take the form of erosion of the nominally non-erodible lining, or erosion of cohesive materials where the lining is damaged or absent. In stream restorations, erosion of and around stone structures is acceptable where growth of vegetation prevents downcutting and the development of high, bare eroding banks.

Erosion of cohesive materials around riprap structures, or erosion of the riprap, is part of the naturalization of the channel if bank vegetation grows to take the place of the eroding structures, but represents instability if the channel profile degrades or the area of bare, steep cohesive banks increases. Observed instability includes development of expanding areas of bare bank above, below, or within riprap revetments, or in cohesive material at the upstream and downstream ends of revetments, erosion of channels in cohesive material adjacent to profile control structures, and development of bare, downcutting channels in the cohesive material of the floodplain. Locations where flow has moved the riprap or eroded cohesive material from around a structure can be recognized in the field and documented with photographs. Where these changes have compromised the function of the structure, the development of erosional features such as mass movements and toppled trees, head cuts, or sharp bends with steep bare banks may also be observed.

In addition to the local effects of flowing water on channel boundaries, channels can be destabilized by unanticipated inflows of bedload and large woody debris, direct human disturbance (e.g. clearing of channel banks), beaver activity, and the toppling of trees growing on the banks.

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REMOTE SENSING APPLICATIONS TO MEASURE GEOMORPHIC PROPERTIES OF WEST TENNESSEE WATERSHEDS

David Blackwood[1]

An overview of work by the West Tennessee River Basin Authority to determine channel geometry relationships for river systems in west Tennessee by using high resolution LIDAR in ArcGIS. Alluvial systems present unique challenges to the standard regional curve methods. Drastic swings in channel and valley conditions happen throughout our systems and there isn't a base set of information that accurately represents trends and geomorphic relationships. This presentation explores the methods and ideas behind collecting large datasets using high resolution remote sensed surfaces; including the challenges, opportunities, and hopes for the future.

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GEOMORPHIC IMPLICATIONS OF RIVER CONSERVATION PRACTICES IN THE COASTAL PLAINS

Jeff Fore[1] and David Blackwood[2]

Channelization and landuse changes have caused widespread alterations to stream processes in the Gulf Coastal Plains region of Tennessee. Generally, watershed hydrology has become flashier with increases in flood magnitude and frequency since the widespread drainage of wetlands and channelization projects that were designed to quickly convey water from the landscape. Unintentionally, these changes have also exacerbated sediment supply (particularly from instream sources) which causes channel aggradation and results in valley plugging in many instances. The sources for much of these instream sediments are degradational areas in the watershed where active gully erosion and headcutting processes occur. Often, stream restoration activities are proposed as the major solution to reversing the negative effects of channelization. We propose that when restoring stream channels, one must view the proposed projects and actions in the appropriate watershed context and that conservation practices should be depend on whether working in a degradational, aggradational, or transport (neither aggrading nor degrading) zone. We will discuss relevant stream conservation goals and techniques when working in these watersheds and identify key areas of future research need.

[1] The Nature Conservancy
[2] West TN River Basin Authority

STREAM RESTORATION EDUCATION AND CERTIFICATION

John Schwartz, Karina Bynum, Ken Barry

Practitioners of stream restoration have a wide range of educational backgrounds including biologist, geologist, environmental scientists, and engineers. Individuals have received training from various venues. The most common training is through Wildlands Hydrology Inc. offered by Dave Rosgen. Other courses are offered through the University of California with Utah State University, and the University of Minnesota. North Carolina State University offers several courses related to stream restoration through their agricultural extension program. Many other universities and departments offer a course or two and content varies more focused on assessment to courses specially orientated towards design. In 2014 led by Sue Niezgoda, an American Society of Civil Engineers (ASCE) Task Committee completed a survey and publication on educational needs and suggested for a national certification program. Last year a new ASCE Task Committee was formed to explore what national certification and the supporting course would look like for engineers with an existing professional engineering (PE) license. The basic rationale for the course specialization is that if a PE must stamp a stream restoration design what should he/she absolutely need to know to meet some ‘standard of care’ for approving design and contract documents? This presentation will review some of the existing courses offered nationally, the previous findings form the 2014 ASCE Task Committee, and recent information from the new 2017 Task Committee.

APPLYING A REGIONAL-SCALE WATER-QUALITY MODEL TO TENNESSEE WATERSHEDS

Anne B. Hoos[1] and Sherry H. Wang[2]

Implementation of Tennessee's statewide Nutrient Reduction Framework requires estimates of nutrient load for each 10-digit hydrologic unit code (HUC10) watershed in the State. Also needed are watershed estimates of the relative contribution of nutrient inputs from different sources and a tool for predicting changes in stream loads due to changes in nutrient inputs. The U.S. Geological Survey (USGS) published a set of regional statistical models to provide estimates of stream nutrient loads and relative contributions of sources, for both nitrogen and phosphorus, for all watersheds in the South Atlantic Gulf Drainages and Tennessee River Basin (SAGT). We applied the SAGT models to estimate stream loads and source shares for streams in the Tennessee River Basin and developed: (1) a web-based tool to map and chart this information for HUC10 watersheds; and (2) a spreadsheet tool based on model input and coefficients to allow users to quickly evaluate nutrient delivery at pre-set points in the stream network under different scenarios of nutrient management.

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TENNESSEE'S 2018 NUTRIENT REDUCTION FRAMEWORK: DEVELOPMENT AND PROGRESS IN IMPLEMENTATION

Jenny Dodd

The Tennessee Nutrient Reduction Framework consists of nutrient reduction strategies for both point and nonpoint sources. The Division of Water Resources plans to use the USGS SPARROW model to help determine the relative percentage of source contributions in HUC 10 watersheds. This along with other information will help the division develop nutrient limits for direct dischargers.

The division decided to start with West Tennessee for the nonpoint section of the Nutrient Reduction Framework, and thus has worked with TDA and UT to develop an agricultural nonpoint source nutrient reduction plan in West Tennessee watersheds. The West Tennessee agricultural nutrient load reduction plan focuses on a process that is results-oriented and promotes stakeholder involvement by building upon proven land stewardship practices that are known to improve water quality. It uses a farmer-led approach by using voluntary, economic-based incentives that enable landowners to make wise land use decisions that maintain profitability and reduce environmental impacts from farming. Methods detailed in the plan can be applied across the state to achieve reductions in agricultural sources of nutrient load.

The Nutrient Reduction Framework uses an adaptive management approach for long-term corrective actions. As a part of this approach, the division is beginning to revise the framework and expects the process will involve multiple stakeholders. This presentation will go over the basics of the current framework and some of the challenges they hope to address with the revisions.

THE TENNESSEE NUTRIENT REDUCTION FRAMEWORK: DEVELOPMENT AND PROGRESS IN IMPLEMENTATION

Forbes Walker[1]

Recent efforts by the Gulf of Mexico Hypoxia task force have included collaboration with the Land Grant Universities in the Mississippi River Basin to develop and implement nutrient loss reduction strategies for each state. Tennessee's nutrient loss reduction strategy was developed by a multi-agency consortium of the Tennessee Department of Environment and Conservation, the University of Tennessee Extension and the Tennessee Department of Agriculture. The Tennessee framework emphasizes voluntary, research and extension based approaches to reducing nutrient losses by encouraging the adoption of University of Tennessee Extension soil fertility recommendations, the continued use of no-tillage technologies, the increased use of winter cover crops and precision practices for row crop agriculture. This presentation will summarize progress in implementing the current nutrient loss reduction framework, as well as other multi-state collaborative efforts across the Mississippi River Basin.

[1] Extension Soil Specialist, Dept. of Biosystems Engineering and Soil Science, University of Tennessee Knoxville

SESSION 2B

FLOOD (Moderator: Adrian Ward, Barge Design Solutions)
8:30 a.m. – 10:00 a.m.

Predicting Future Flood Risk in a Morphologically Active River: A Case Study in the Obion River
MD N M Bhuyian and Alfred Kalyanapu

Hydrologic Warning Systems
Bradley Heilwagen

TVA River Management Flood Control Using FEWS
James H. Everett

WASTEWATER TREATMENT (Moderator: Tania Datta, TTU)
10:30 a.m. – 12:00 p.m.

Feasibility of Bauxite Residue for the Removal of Aqueous Antibiotics
Yongfeng Wang and Qiang He

Major Microbial Community Shift in Sucrose-Fed Anaerobic Digesters Despite Stable Performance
Liu Cao and Qiang He

Microbial Responses to Substrate Change in an Anaerobic Treatment Process
Yabing Li, Liu Cao, and Qiang He

STORMWATER MANAGEMENT (Moderator: Andrea Ludwig, UT)
1:30 p.m. – 3:00 p.m.

Using Impervious Surface Connectivity to Guide Stormwater Retrofit Siting
Thomas Epps and Jon Hathaway

The Importance of Regular Upkeep of a Stormwater Utility Impervious Area Database in Relation to Flooding Extremes and Stormwater Infrastructure Maintenance
Justine Hart

Promoting Successful Urban Watershed Restoration Through Enhanced Bioretention Cell Modeling
Whitney A. Lisenbee

STORMWATER CONTROL MEASURES **(Moderator: Karina Bynum, TDEC)**
3:30 p.m. – 5:30 p.m.

Metro Nashville's Evolving Stormwater Control Measure (SCM) Oversight Program
Michael Hunt

Navigating the New Jersey and Washington State Stormwater Programs as Models for Approving Manufactured Treatment Devices
Mark B. Miller

Storm Water Quality Study on Christian Brothers University's Detention Pond
L. Yu Lin and Chee Chew

The Cutting Edge of SCM O&M
Thomas B. Lawrence

PREDICTING FUTURE FLOOD RISK IN A MORPHOLOGICALLY ACTIVE RIVER - A CASE STUDY IN THE OBION RIVER

MD N M Bhuyian[1] and Alfred Kalyanapu[2]

The Obion River located in North-West Tennessee was channelized in the 1960s and is currently protected by levees to reduce flooding. Historic trend analysis (1980 – 2015) of dry season low water level (LWL) on the streamflow gages showed declining trend on the upper reaches while opposite on the lower reaches of the Obion River watershed. Additionally, at Rives, the 5-year average LWL from 1980 to 1985 were below the mean bed level elevation of 2016 indicating a bed level aggradation. Time-series Satellite image (1977 – 2015) analysis for months of August also revealed increasing Normalized Difference Vegetation Index (NDVI) within the watershed indicating a positive trend towards agricultural land use. Hence, we hypothesize that changes in watershed characteristics along with the obstruction of sediment movement by the levees are primarily responsible for the bed level adjustment (aggradation-degradation) and subsequent trend of LWL. Therefore, the objectives of this study are (a) to determine a watershed character based regression model to predict future bed level and corresponding bed level (b) to predict future flood risk in the Obion River for floods of different probability of exceedance (design scenarios). A 30-km reach of the Obion River from Rives to Trimble would be used as the study area. Time-series watershed characteristics (i.e., soil moisture, vegetation, water body size, land use etc.) would be analyzed to develop the regression model and a two-dimensional hydrodynamic model would be employed to analyze flood risk for design scenarios.

Keywords: flood risk, DEM, satellite image, river morphology, Obion River

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HYDROLOGIC WARNING SYSTEMS

Bradley Heilwagen[1]

Hydrologic disasters are those events that are caused by an alteration to the hydrologic cycle that result in significant loss of life, property, or damage to the environment. An alteration of the hydrologic cycle is a change in the normal hydrology of a watershed through natural or man-made means. Examples of natural alterations are floods, droughts, and hurricanes. Man-made examples include the construction of communities in areas susceptible to floods, droughts, hurricanes, and other hydrologic threats.

Although the phrase "hydrologic warning" is not commonplace, it has a broad, diverse meaning to those familiar with it. Hydrologic Warning is the ability to warn of imminent danger to life, property, and the environment from hydrologic events through the use of real-time, automated remote data collection networks, modeling and analyses, and integrated forecast and warning systems.

The National Hydrologic Warning Council (NHWC), with membership across the United States and around the world, is a non-profit organization with a vision for all communities to effectively use hydrologic information and warnings to protect lives, property, and the environment. We are dedicated to providing education, training, and standards for the generation, delivery, and use of timely, reliable hydrologic information. We assist managers and operators with the design, implementation, operation, and use of these systems, forming partnerships and integrating networks for maximum benefit.

This presentation will serve two purposes. It will give a brief summary of the NHWC, including its governing board, membership, and mission. It will also provide a general overview of the different types of hydrologic warning systems currently in use around the world, and will walk attendees through the process of planning, design, operations, and maintenance of the system. It will promote the benefits of implementation of a hydrologic warning system at a regional or local level, including how hydrologic warning systems saved lives during recent floods in Colorado, Texas, Louisiana, and Florida.

[1] Secretary, Board of Directors, National Hydrologic Warning Council

TVA RIVER MANAGEMENT & FLOOD CONTROL USING FEWS

James H. Everett[1]

The Tennessee Valley Authority (TVA) River Forecast Center (RFC) is responsible for scheduling the day-to-day, integrated operation of the Tennessee River system and balancing the competing demands on the system and the overall value to the public. Operating plans are developed 365 days a year and monitored around-the-clock from the RFC in Knoxville. The RFC balances operating plans in order to meet system demands for flood-risk reduction, navigation, hydroelectric generation, water quality, water supply, and recreation.

The RFC also coordinates daily operating plans with the U. S. Army Corps of Engineers. This inter-agency collaboration plays an essential role in maintaining successful operation of the nation's entire inland waterway system, as well as reducing flood damages on the Lower Ohio and Mississippi Rivers. Weather conditions, rain data, reservoir inflows and outflows, and reservoir elevations are monitored in real-time through satellite and hard-lined communication equipment. Continuous monitoring of reservoir information allows the RFC to quickly respond to system demands during critical periods.

This presentation will serve two purposes. It will give a brief summary of the TVA's mission as it relates to providing flood control and flood damage reduction for the nearly 42,000 square mile Tennessee River Valley which also provides extended protection to the Lower Ohio and Mississippi River Valleys. It will also provide a general overview of TVA's development and implementation of the Flood Early Warning System (FEWS). The TVA River Forecasting System was built on the Delft-FEWS platform, providing an open shell system for managing forecasting processes and/or handling time series data. The FEWS system is highly configurable and has allowed TVA to migrate from in-house highly customized software applications to a more broadly supported user-based application while still maintain a high degree of customization.

A brief review of the performance and application of TVA's River Forecasting system during a recent high inflow event will also be provided in order to bridge the theme of TVA's historic mission of flood damage reduction and our utilization of modern software to aid in the effect management of the Tennessee River system.

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FEASIBILITY OF BAUXITE RESIDUE FOR THE REMOVAL OF AQUEOUS ANTIBIOTICS

Yongfeng Wang[1]* and Qiang He

Bauxite residue as an alkaline waste stream generated from the alumina refining industry has been for applications in pollution mitigation. In this study, two types of neutralized bauxite residue were tested for the ability to remove ciprofloxacin (CIP), which is an antibiotic frequently detected in aquatic environments as an emerging contaminant. CIP removal from the aqueous phase was found to be related to the sodium content of bauxite residue, which was representative of cation exchange sites. The parallel-first-order model showed that CIP removal followed the two-phase adsorption model. Fast adsorption and slow adsorption were attributed to cation exchange and complexation or bridging with metal oxides, respectively. CIP removal exhibited a strong dependence on pH and ionic strength, indicating that a combined mechanism of cation exchange and complexation was responsible for CIP removal. The applicability of the Freundlich model suggested that CIP removal capacity was controlled by adsorption sites on the heterogeneous surfaces of bauxite residue. In conclusion, bauxite residue could serve as an effective sorbent for the removal of CIP from the aqueous phase.

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MAJOR MICROBIAL COMMUNITY SHIFT IN SUCROSE-FED ANAEROBIC DIGESTERS DESPITE STABLE PERFORMANCE

Liu Cao and Qiang He

Anaerobic digestion is considered as a sustainable option for the treatment of biodegradable organics in wastewater and generation of biogas as a renewable source of energy. As a microbial process, it is important to understand the microbial communities underlying anaerobic digestion process, which remains unclear. It is of particular significance to treatment performance how the shift of major microbial populations is connected to substrate characteristics, operational conditions, as well as digester performance. In this study, triplicate laboratory-scale semi-continuous anaerobic reactors were established and maintained with sucrose as the sole substrate for a year. Methane production was measured daily while COD, concentration of volatile fatty acids, and pH were monitored weekly. To analyze the microbial community dynamics, digestate samples taken during stable performance (Day 96, 120, 149, 172, 194, 215, 234, 253, 266, 298, 310, 325, and 343 respectively) was used for DNA extraction, PCR amplification, and 16S rRNA gene amplicon library sequencing. Despite the stable pH, CH_4, COD and acetate concentration, shifts in overall microbial community structure were observed over time. While the archaeal microbial community structure remained unchanged, the bacterial microbial community experienced major changes with increases in the relative abundance of *Kosmotogaceae* (*Thermotagae*) and decreases in the abundance of *Carnobacteriaceae (Firmicutes*). These findings provide more insight into the potential mechanisms, such as stochastic drifting, contributing to microbial community dynamics in anaerobic digestion processes.

MICROBIAL RESPONSES TO SUBSTRATE CHANGE IN AN ANAEROBIC TREATMENT PROCESS

Yabing Li[1], Liu Cao[1], and Qiang He[1,2]

Anaerobic digestion is a microbial process capable of both waste treatment and recovery of biogas as a renewable source of energy. However, the dynamics of microbial populations underlying the anaerobic treatment process remains undefined. Substrate type has been suggested as an important determinant of the microbial communities in anaerobic digestion processes.

In this study, we compared microbial community structure before and after a change in the substrate fed to anaerobic digesters, i.e. a shift from dairy manure to wastewater sludge. High-throughput sequencing and a suite of bioinformatics tools were used to analyze the responsiveness of three methanogenesis pathways known to be functional in anaerobic treatment processes. *Methanosaeta* remained as the dominant archaeal population in the anaerobic digesters before and after substrate shift. *Methanoregula* (Relative abundance before the shift was lower than 0.01 %; after the shift was 4.24 %), a hydrogenotrophic methanogens, thrived after substrate shift from diary manure to wastewater sludge. Among the bacterial populations, the dominant phyla belonged to *Firmicutes*, *Bacteroidetes* and *Proteobacteria*, with relative abundances before substrate shift averaging 20.74%, 21.97% and 9.96%, respectively. Following the substrate shift, the relative abundance of *Firmicutes*, *Bacteroidetes* and *Proteobacteria* changed to 22.26%, 14.85% and 14.09%, respectively. Beta diversity analysis with unweighted unifrac method showed that microbial compositions varied to some degree. Further analyses with the gene prediction tool, PICRUSt, indicated that the most abundant metabolic functions in digesters before and after substrate shift were involved in carbohydrate metabolism and amino acid metabolism, as expected in anaerobic digestion processes. Based on the relative abundance of functional genes involved in three methanogenesis pathways before and after the substrate shift, acetoclastic methanogenesis remained to be the dominant pathway. The hydrogenotrophic pathway became more active after the substrate shift, consistent with the increased abundance of hydrogenotrophic *Methanoregula* populations following the substrate shift. Findings from this work provide much needed insight into the microbial processes in response to changes in substrate in anaerobic treatment processes, which are frequently encountered in practice.

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USING IMPERVIOUS SURFACE CONNECTIVITY TO GUIDE STORMWATER RETROFIT SITING

Thomas Epps and Jon Hathaway

Research has identified the effective impervious areas (EIA), a subset of the total impervious area (TIA) more closely connected to the stream network, as a greater determinant of stream conditions than TIA. Early EIA measurements used geographic analysis and/or a binary classification of connectivity based on topography, surface cover, and infrastructure maps. However, these methods do not account well for spatial and temporal variability in factors influencing runoff connectivity. The advancements to these approaches utilized herein involve the combination of high-resolution datasets and geospatial analysis to measure connectivity along a continuum. This study focuses on watersheds in Knoxville, TN, where impervious surface connectivity has been measured both graphically and geospatially and parameterized according to observed rainfall-runoff data. Watersheds ranged in size from 5,200 ha (First Creek) to 700 ha (Williams Creek), and from 36% TIA (Second Creek) to 18% TIA (First Creek). Results help identify the dynamic nature of EIA and how to best allocate stormwater retrofits within a watershed to impart meaningful changes to stream hydrology. The data generated from these methods can also be applied to readily utilized models such as SWMM to better parameterize watershed models and generate representative results.

Keywords: effective impervious, connectivity, stormwater, geospatial, green infrastructure

THE IMPORTANCE OF REGULAR UPKEEP OF A STORMWATER UTILITY IMPERVIOUS AREA DATABASE IN RELATION TO FLOODING EXTREMES AND STORMWATER INFRASTRUCTURE MAINTENANCE

Justine Hart

As stormwater management programs in growing cities across the U.S. continue to evolve and adapt to changing times, it is apparent that regular updates and improvements to a stormwater utility database to manage flooding extremes in a city are key to keeping the city's stormwater infrastructure well- funded. By performing a full impervious area update of a city approximately every 5 years, or 6-10 years for smaller municipalities, the city can accurately track the amount of impervious area development, which directly correlates to the intensity of flooding events. Most stormwater professionals know that as the impervious area in a city goes up, the resulting runoff most likely will increase. If billing is adjusted accordingly, these increases in urban runoff can more easily be controlled. As development continues, credits will also provide businesses with an incentive to incorporate green infrastructure – green roofs, rainwater harvesting, rain gardens, etc. – into their construction. This is a win-win situation, both reducing their stormwater fee and the amount of urban runoff their parcels create. Finally, by accurately assigning responsibility to each city-owned parcel within a well-managed database, each department within a municipality can take responsibility for parcels they might have otherwise overlooked. This added financial responsibility might incentivize, for example, destruction of an otherwise forgotten parking lot, thereby decreasing impervious area. Each of these best practices are important in maintaining a stormwater user fee and decreasing the risk of extreme flooding events as a city grows.

This presentation will explain the reasoning behind some of the best practices described above, and provide examples of successful application from across the U.S. It will emphasize the importance of regularly updating impervious area databases and stormwater utility billing structures. The presentation will relate a number of these best practices back to the established stormwater utilities in Tennessee, Georgia, and other southeastern states in the hopes that those communities can continue to successfully manage flooding extremes and stormwater infrastructure maintenance.

PROMOTING SUCCESSFUL URBAN WATERSHED RESTORATION THROUGH ENHANCED BIORETENTION CELL MODELING

Whitney A. Lisenbee[1]

Urban runoff and stormwater is one of the top ten leading causes of water quality impairment in lakes, estuaries and streams in the United States (USEPA 2004). Over the last decade, bioretention systems have become a leading stormwater control measure that contributes to restoration of urban streams and watersheds. Bioretention cells increase infiltration of stormwater thereby reducing urban runoff volumes and peak flows which alter the hydrology of local waterways. Modeling of bioretention allows designers to better optimize the function of bioretention cells, provide guidance for design standards, and scale local impacts to the larger watershed. However, current hydrologic models with bioretention capabilities consist of lumped parameters and simplifications that do not fully account for fundamental hydrologic processes. DRAINMOD is an agricultural drainage model that has shown promise when applied to bioretention systems. It has the capability of using the soil-water characteristic curve to obtain detailed water balances over a continuous time period (both advances over other models for bioretention). However, because DRAINMOD was designed for agricultural purposes, it cannot currently accommodate the rapid response time of an urban runoff hydrograph, instead aggregating data to a daily timeframe. For this study, DRAINMOD has been recoded to allow high temporal resolution inputs and outputs, more closely matching the travel times of urban systems. DRAINMOD simulations were conducted both with and without the time scale modifications (original vs. bioretention-specific model) to determine if improvements in site-scale modeling were realized. Future work will compare these results to those of simplistic, lumped-parameter bioretention modeling.

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METRO NASHVILLE'S EVOLVING STORMWATER CONTROL MEASURE (SCM) OVERSIGHT PROGRAM

Michael Hunt[1]

Metro Nashville Stormwater (Metro) continues to expand and refine its ongoing Stormwater Control Measure (CSM) Oversight Program. Via continuing process evaluations and staffing enhancements, Metro is endeavoring to more effectively track and insure the functionality of the almost 5,000 SCMs that have been installed over time within Metro Nashville in association with Metro Grading Permit requirements. While these SCMs are the responsibility of respective property owners to inspect and maintain, Metro has the regulatory role of insuring such oversight is being performed. From the dry detention ponds installed beginning in the 1980's for flood protection through more recent stormwater quality SCMs such as proprietary treatment units, bioretention cells, etc., the need to inventory and evaluate the functionality of SCMs is paramount for the community to be afforded the protections these controls were designed to provide. There have been and continue to be many "lessons learned" by staff that are being incorporated into Metro's ever-evolving SCM Oversight Program. This presentation outlines recent Program improvements as well as the current overall status of Metro's SCM Oversight Program.

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NAVIGATING THE NEW JERSEY AND WASHINGTON STATE STORMWATER PROGRAMS AS MODELS FOR APPROVING MANUFACTURED TREATMENT DEVICES

Mark B. Miller[1]

Many state and local municipalities administer stormwater programs that approve the use of proprietary post-construction manufactured treatment devices (MTDs) to provide water quality treatment by means of hydrodynamic separation (HDS) and filtration technologies. However, there is often a lack of resources for regulators, design engineers or other stakeholders to dedicate efforts to evaluate MTD pollutant removal (performance) claims and sizing criteria that are based on laboratory and/or field testing programs. Instead, MTD approvals and/or specifications may rely on an existing widely recognized stormwater program(s). The New Jersey Department of Environmental Protection (NJDEP) and the Washington State Department of Ecology (Ecology) administer robust stormwater programs which can serve as models for MTD performance evaluations and sizing methodologies. This presentation identifies both significant and subtle aspects of both programs given their complex regulatory processes and testing protocols. The merits and pitfalls of the laboratory testing and field testing protocols are compared since each setting provides a unique set of data upon which an approval can be based. Having a fundamental understanding of these programs will increase confidence in a stakeholder's approval and/or specification of an MTD.

New Jersey stormwater rules require that prior to an MTD's entrance to the NJDEP process; the MTD must obtain "Verification" through the New Jersey Corporation for Advanced Technology (NJCAT). The verification report includes the device's performance claim for total suspended solids (TSS) removal that was obtained solely under laboratory protocols (January, 2013). Essential elements of the HDS and filtration testing protocols will be explained. The verification process includes peer review via a public comment period to enhance the vetting process. Only those NJCAT verifications issued in full compliance with the protocol are then eligible for NJDEP "Certification" to allow for in-state installation. It is important to recognize that a certification is specific to New Jersey stormwater rules and does not necessarily convey a higher level of performance scrutiny beyond that of the NJCAT verification. NJDEP certifies the use of HDS and filtration systems to be sized for annual TSS removal rates of 50% and 80%, respectively, regardless of whether a performance claim is verified at a higher removal rate. The often-cited and field test-based Technology Acceptance Reciprocity Partnership Protocol for Stormwater BMP Demonstrations (TARP) is no longer applicable to the current verification or certification processes. Not all verifications are eligible for certification. For example, if an MTD test followed the protocol in every aspect but used coarser test sediment than the protocol's specification, presumably resulting in more favorable performance, a test-specific verification can still be issued but that verification would not be eligible for certification. MTD sizing and marketplace implications for this example are explained.

The Washington State Technology Acceptance Protocol – Ecology (TAPE) program provides a peer-reviewed regulatory certification process for MTDs (August 2011). This presentation also

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outlines TAPE specifications for acceptable test site influent pollutant concentration ranges, target effluent concentrations and pollutant removal rates. Essential elements, merits, pitfalls and challenges of the field testing protocol are described. An MTD is initially issued either a Pilot Use Level Designation (PULD) or a Conditional ULD (CULD). PULDs are typically issued when there is sufficient laboratory data to indicate that an MTD may meet the TAPE performance goals. CULDs are typically issued when both laboratory and field data indicates that an MTD would indicate an even greater likelihood of meeting TAPE performance goals. The final General ULD (GULD) can only be obtained via a TAPE-compliant field test in the Pacific Northwest. A device is then sized on a per storm event basis based on field performance exhibited at peak loading rates. Local jurisdictions can allow MTD installations that hold PULD or CULD with limitations to facilitate the GULD process, but there are no limitations for retrofits. There are no installation limitations for those devices holding GULD. TAPE includes pollutant-specific ULDs for Basic Treatment (TSS), Dissolved Metals Treatment (copper and zinc), Phosphorus Treatment (total), Oil Treatment and Pretreatment (TSS).

STORM WATER QUALITY STUDY ON CHRISTIAN BROTHERS UNIVERSITY'S DETENTION POND

L. Yu Lin[1] and Chee Chew[2]

ABSTRACT

A five-year storm water quality monitory program was studied on Christian Brothers University (CBU) Soccer field, in which a detention pond was built. One hundred and five storm events during 2011-2016 were collected and studied. For each storm water event, nine major constituent pollutants in the storm water samples were tested, including total solid, total suspended solids, total nitrogen, nitrate, ammonia, total phosphorus, BOD/COD, pH, and Total-Coliform. The results showed low concentrations of BOD/COD in the samples, indicating that there are no bio-activities and low oil/grease containments in the study area although the samples being collected is close to the CBU main parking lot. In addition, low concentrations of total nitrogen, ammonia, nitrate, and total phosphorus were found in the samples which may reveal less gardening and yard fertilizing activities on campus. Among the water quality parameters, only a relatively high concentration of total solids and total suspended solids ranging from 100 mg/l to 200 mg/l were found in the water samples, which is higher than typical storm water in the urban area. More than twenty percent of suspended solids and five percent of nutrients can be removed in the detention basin. It conclude that CBU detention facility, one of the best storm water management practices (BMPs) for storm water management, can handle not only flood control, but also water quality control.

INTRODUCTION

Christian Brothers University is located on the upstream of the Lenox Bayou Watershed, which receives storm water runoff from two adjacent sub-areas with a total area of 61.5 acres. The basic watershed characteristics are composed of the time of concentration of 23.5 minutes, the average of slope of 2.8%, and the average peak discharge of approximately 100 cfs according to the 25-year frequency design storm. Because of frequent flooding in the watershed, the City of Memphis decided to use CBU's soccer field as a detention basin in order to attenuate the peak flow (discharge) and to prevent flooding in the downstream watershed on Lick Creek Watershed. In 2011, the City of Memphis completed the construction phase of the detention facility and granted this monitoring program. The original objectives of this project were to: (1) develop a storm water monitor system for the detention basin located on CBU's soccer field; (2) monitor the storm water quantity for the drainage basin; (3) determine the storm water quality of those storms; and (4) provide results and information to the City for future improvement.

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The designed drainage system at CBU's soccer field as shown in Figure 1 consists of one 54-inch diameter RCP sewer pipe, one 72-inch diameter RCP sewer pipe, one 5' (height) x 4' (width) box culvert, a 164'-long concrete board-crest weir, four 8-inch PVC French drainage pipes, one 42-inch diameter RCP sewer pipe, and an inlet/outlet control manhole. During extreme storms, the CBU soccer field has the capacity to hold a maximum of 16.9 ac-ft. of runoff (in Table 1).

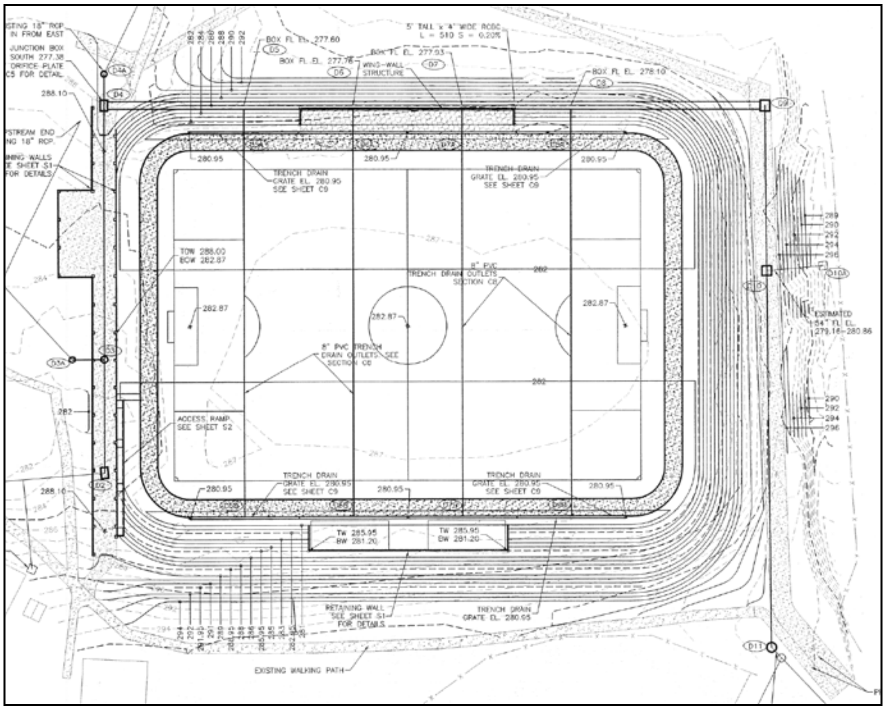

Figure 1: Drainage System on CBU's Soccer Field

Table 1. Storage-Storage-Discharge of CBU Detention

Stage (msl)	Depth (ft)	Storage (ac-ft)	Discharge (cfs)
277.38	0	0	0
278.38	1.0	0.02	6.3
280.38	3.0	0.11	22.7
282.38	5.0	2.41	32.8
284.38	6.0	5.57	37.1
286.38	8.0	12.45	39.2
286.61	9.23	16.89	46.3

The City of Memphis, like other cities in the United States, is required to have a National Pollutant Discharge Elimination System (NPDES) permit to discharge storm water from the municipal separate storm sewer system (MS4). To accomplish this requirement, the City and County have ordinances and standards that require the Best Management Practices (BMP's) for storm water implementation. The inspections as part of land development activities have also become the major activities associated with the storm water BMP's. One of the purposes of this storm water monitoring program was to provide the MS4 with information to verify the effectiveness of various facets of the storm water management program, data to aid in the identification of problematic areas, as well as water quality data to be used in evaluating the MS4's overall effectiveness.

Storm water runoff from urban areas can contain significant concentrations of harmful pollutants that contribute to adverse water quality impacts in receiving waters. The most comprehensive study of urban runoff was NURP, conducted by the EPA between 1978 and 1983. NURP was conducted in order to examine the characteristics of urban runoff and similarities or differences between urban land uses, the extent to which urban runoff is a significant contributor to water quality problems nationwide, and the performance characteristics and effectiveness of management practices to control pollution loads from urban runoff (US EPA, 1983). Sampling was collected for 28 NURP projects, including 81 specific sites and more than 2,300 separate storm events. NURP examined both the soluble and the particulate fraction of pollutants, since the water quality impacts can depend greatly on the form that the contaminant is present. NURP also examined coliform bacteria and priority pollutants at a subset of sites. Ten constituent pollutants were found in the water sampling. These are: Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Phosphorus (TP), Soluble Phosphorus (SP), Total Kjeldahl Nitrogen (TKN), Nitrate + Nitrite (N), Total Copper (Cu), Total Lead (Pb), and Total Zinc (Zn). Median event mean concentrations (EMCs) for urban land uses are listed in Table 2.

Table 2: Typical Storm Water Quality in Urban Area

Pollutants	Range (mg/l)	Typical (mg/l)
COD	200-275	75
TSS	20-2890	150
Total-P	0.02 – 4.30	0.36
Total-N	0.4 – 20.0	2
Lead	0.01 – 1.20	0.18
Cooper	0.01 – 0.04	0.05
Zinc	0.01 – 2.90	0.02

Reference: EAP national Urban Runoff Program (EPA, 1983)

MATERIAL AND METHOD

Two storm water samples from the drainage inlet where is close to the CBU main parking lot and inside the box culvert were collected. Samples were collected from 2011 to 2016. Based on the storm water magnitude, twenty to twenty five typical storm water samples in each year were selected. Two liters of water sample from each sampling location were collected using the grab method. The samples were immediately preserved and sent to the Bio-Environmental Engineering Laboratory in the Department of Civil and Environmental Engineering at CBU for examination. Nine major constituent pollutants in the storm water samples were tested, including Total Solid, Total Suspended Solids, Total Nitrogen, Total Phosphorus, Nitrate, Ammonia, BOD/COD, and pH. Since High concentration of suspended solids and total solids were observed in the water sample, sediment samples were collected inside the box culvert. The sample was sent to the Geotechnical and Soil Mechanical Laboratory for the D_{60}, D_{10}, and the uniformity coefficient analyses.

BioPaddles® was selected to test E-coliform in the water sample. BioPaddles® is flexible dual-agar paddle which contains microbe-specific media enclosed in a sterile vial. It can identify and quantify microbes in air, soil, water, or any surface. BioPaddles do not require any other testing equipment – only a magnifier and warm place are needed. There are 16 species of total coliform. This group of organisms is aerobic or facultative anaerobic, Gram negative, non-spore-forming, rod-shaped bacteria that can ferment lactose at 35 – 37°C with the production of acid and gas within 24 – 48 hours. Total coliforms include species that may occur naturally in soil, vegetation, or water. These species may also inhabit the intestines of warm-blooded animals. They are usually found in feces-polluted waters and are often associated with disease outbreaks. Although they are not usually pathogenic themselves, their presence in water indicates the possible presence of pathogens.

RESULTS AND DISCUSSION

The result of a typical water quality sample analysis is shown in Table 3. Among the water quality parameters, only a relatively high concentration of total solids and total suspended solids were found in the water samples, ranging from 100 mg/l to 200 mg/l, which is higher than typical storm water in the urban area listed in Table 1. Particularly the sediment was in the box culvert (in Figure 2). The storm water quality study and field study suggested that some field construction activities in the Lenox Drainage District may contribute significant suspended solids to the drainage system. Based on the Stormwater Best Management Practices and Ordinances, a local remediation should take place in order to reduce Total Suspended Solid concentrations in the storm water. Sediment sample study showed that the majority of sediment is composed of sand. From the sieve analysis (in Figure 3), it was found that the D_{60}, D_{10}, and the uniformity coefficients are 0.85 mm, 0.25 mm, and 3.4, respectively.

The removal of TSS to be effective requires either a filter system or a physical gravity type of sedimentation which is a direct function of the rate of flow through a system. Since the effectiveness of a rainfall treatment works best by removing the first flush of water and the pollutants, an approach that accomplishes that should be promoted. In order to determine if 80% of pollutants were removed, it needs to define the characteristics of the influent to the proposed treatment system. Using the same poundage loading of TSS will manifest itself as having varying concentrations because the pounds of TSS theoretically remains constant. However, the amount of liquid in which it is suspended varies for each rainfall category. An assumption was based on the TDEC standards specification that an 80% removal of 1 inch rainfall on the basin was collected. One pound per acre of TSS load has accumulated and directly washed off into the outlet of the watershed. The TSS concentration would be 110.00 mg/l. The TSS data collected from CBU'S soccer were less than this assumption. The results in Table 3 showed the TSS ranges from 100 mg/l to 180 mg/l.

Table 3. Result of Typical Stormwater Sample Analysis

Date	01/25/16	02/15/16	03/09/16	03/31/16	04/11/16	04/29/16	05/10/16	05/20/16	05/26/16	06/15/16	06/27/16	07/04/16
TS (mg/l)	180	250	320	300	280	370	320	350	280	300	280	310
TSS(mg/l)	100	125	150	140	130	160	150	170	130	160	140	160
Total-N_{org} (mg/l)	0.4	0.6	0.8	0.6	0.7	0.8	0.5	0.8	0.9	0.7	0.9	1
Total-PO_4^- (mg/l)	0.5	0.8	0.7	0.6	0.7	0.6	0.5	0.7	0.5	0.6	0.7	0.6
NO_3^-(mg/l)	0.01	0.05	0.05	0.08	0.08	0.06	0.08	0.1	0.08	0.1	0.15	0.1
NH_3(mg/l)	0.1	0.2	0.1	0.3	0.2	0.3	0.2	0.3	0.2	0.2	0.3	0.4
COD(mg/l)	100	120	150	130	140	150	120	130	140	150	120	130
pH	6.3	6.5	6.3	6.4	6.2	6.3	6.4	6.3	6.5	6.2	6.3	6.4
E-Coli	300	500	500	500	500	500	500	200	200	500	200	500

Figure 2: Sediment in 5’ x 4’ Box Culvert

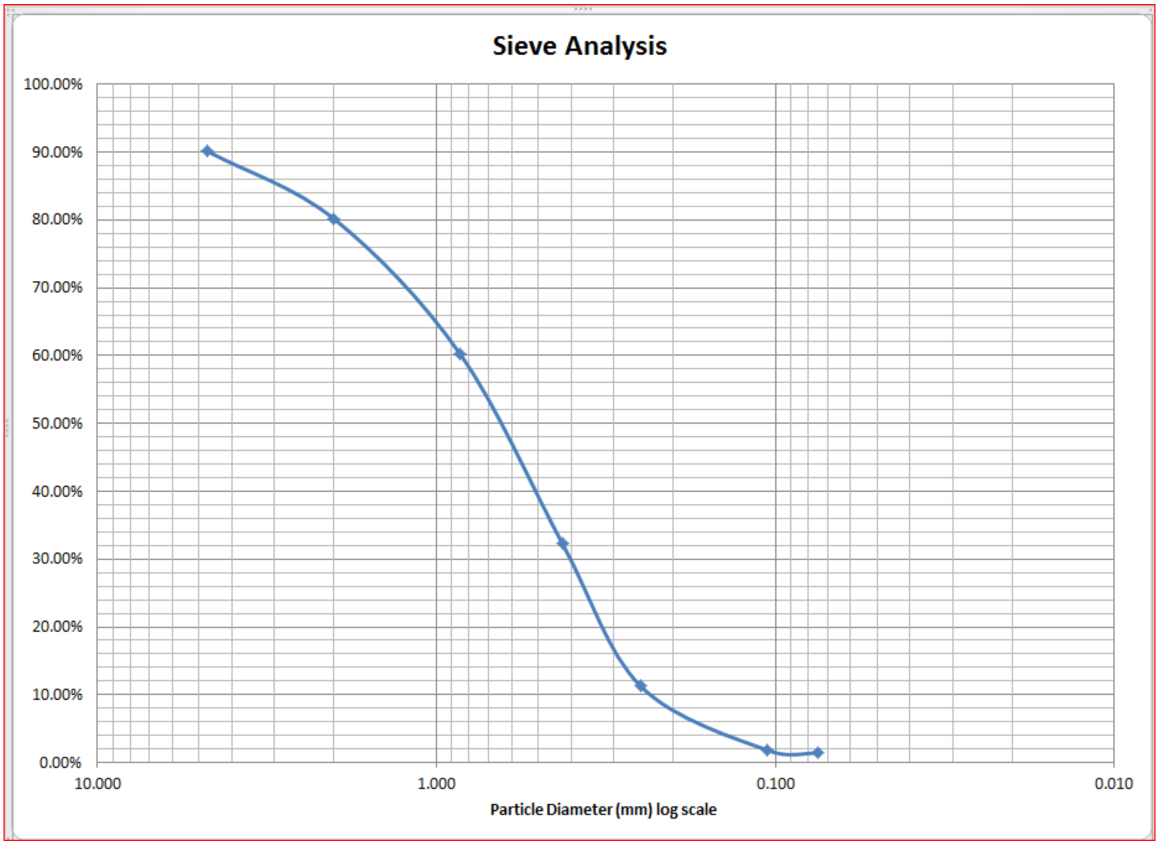

Figure 3: Sieve Analysis

The term "total coliform" refers to a large group of Gram negative, rod-shaped bacteria that share several characteristics. The group includes thermos-tolerant coliforms and bacteria of fecal origin, as well as some bacteria that may be isolated from environmental sources. Thus, the presence of total coliform may or may not indicate fecal contamination. In extreme cases, a high count for the total coliform group may be associated with a low, or even zero, count for thermos-tolerant coliforms. Such a result would not necessarily indicate the presence of fecal contamination. It might be caused by entry of soil or organic matter into the water or by conditions suitable for the growth of other types of coliform. In the laboratory, total coliform are grown in or on a medium containing lactose, at a temperature of 35 or 37°C. They are provisionally identified by the production of acid and gas from the fermentation of lactose.

Samples collected from the field were tested for Total Colony Count. After the incubation period, samples were tested and examined (in Figure 4). The results showed very light to little total colony counts in the sample, ranging from 100 – 1000 count/100 ml of water sample. This count is an indicator of the number of viable aerobic mesophilic microorganisms, including bacteria, yeasts and molds that are insignificant in the water samples.

To examine the potential water quality improvement through the soccer field, water samples from the storm water inlet close to CBU's main parking lot and the 5' x 4' box culvert or overflow on the CBU soccer field were collected and tested. A typical water sample collected from both locations is shown in Figure 5. From the appearance, it clearly identifies the difference between two samples. From the water sample analysis, it indicated that 15-25% of suspended solids and less than 8% of nutrients, including $N0_3^-$, P, NH_4, can be removed. The majority of suspended solids could have settled rapidly and remained in the box culvert due to the back water effect of the 24 inch outlet drainage pipe.

Figure 4. Total Coliform Study

CONCLUSIONS

This project was granted in 2011 and completed in 2017. The monitoring program has proved that the detention has enough capacity to handle a 100-year design storm. The storm water quality was also consistent with other monitoring year showing that storm water contains a high concentration of suspended solids. The majority of suspended solids were in sand range according to the sieve analysis. It was also of concern that the 8-inch PVC drainage under the soccer field carried a significant amount of debris and grass waste which come from the backwash of storm water after heavy storm events. It concludes that the detention facility on CBU's soccer field is the best management practice in storm water management. More than twenty percent of suspended solids and five percent of nutrients can be removed in the detention basin. However, very little total coliform can be removed in the detention basin. It conclude that CBU detention facility, one of the best storm water management practices (BMPs) for storm water management, can handle not only flood control, but also water quality control.

Figure 5: Water Sample

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THE CUTTING EDGE OF SCM O&M

Thomas B. Lawrence[1]

ABSTRACT

Mr. Lawrence's presentation shares important information from the ASCE EWRI SCM O&M conference held in Denver in November of 2017 by highlighting the speakers for the sessions he attended and important points from each that are applicable to SCM O&M in the Southeast. Additionally, the presentation weaves Mr. Lawrence's own experience with SCM O&M from both the regulator and consulting engineer viewpoints.

ASCE - American Society of Civil Engineers
EWRI - Environmental and Water Resources Institute
O&M - Operation and Maintenance
SCM - Stormwater Control Measure

TOPICS

Green Infrastructure
Unique Approaches to Stormwater System Maintenance
Level and extent of maintenance policies

BIO

Thomas B. Lawrence, PE is a consulting engineer specializing in water quality protection and restoration, including projects as varied as underground tank remediation, Industrial SWPPP and SPCC development, construction site erosion prevention and sediment control design and implementation, and municipal storm water pollution prevention. He is an experienced and well-received speaker and instructor, having spoken at professional conferences throughout the country.

He is past President of the Engineer's Club of Memphis, the TN Section of ASCE, the Environmental and Water Resources Institute Tennessee Chapter, the West TN ASCE Branch and the Memphis Chapter of TSPE.

He is a registered Professional Engineer in CA, IL and TN and has been working as a Civil Engineer for over 25 years.

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SESSION 2C

WATER AVAILABILITY (Moderator: Mike Bradley, USGS)
8:30 a.m. – 10:00 a.m.

Surface Water Quantity Can Regulate Aquatic Agroecosystem Water Quality and Nutrient Retention
Justin N. Murdock, Martin A. Locke, Richard E. Lizotte Jr., and Jason M. Taylor

Estimated Use of Water in Tennessee in 2015
Melissa A. Harris

Summer 2017: Making the Most of Limited Resources: An Investigation of Harmful Algal Blooms and Cyanotoxins
Judy Manners (Acknowledgement Tom Byl) and David Money

WATER AVAILABILITY: USDA UPDATE (Moderator: Melissa Harris, USGS)
10:30 a.m. – 12:00 p.m.

Educational Enhancements at UT Martin Associated with the Joint Water for Agriculture Project
Paula M. Gale and Gregory H. Nail

Adapting to Climate Change, Improving the Sustainability of Grazing Systems and Improving Water Quality in Tennessee
Forbes Walker and Pat Keyser

Estimating the Water and Nutrient Footprint of the New Poultry Complex in Humboldt Tennessee
Shawn Hawkins

AQUATIC ECOLOGY (Moderator: Deedee Kathman)
1:30 p.m. – 3:00 p.m.

Ecological Flow Analysis of Surface Water-Withdrawal Scenarios in the Cumberland and Tennessee River Basins
Lucas Driver, Rodney Knight and Jennifer Cartwright

Impacts of Trophic State on the Composition of Algae Assemblages of the Harpeth River in Middle Tennessee
Jefferson Lebkuecher, Sandra Bojic, Cooper Breeden, Samantha Childs, Matthew Evans, Bailey Hauskins, Zach Irick, Josh Kraft, Jonathan Krausfeldt, Nicole Santoyo, Tsvetan Tsokov, and Tiffanie Kelly

Aquatic Ecology Research in Oak Ridge, Tennessee
Mark Peterson

AQUATIC HABITAT (Moderator: Justin Murdock, TTU)
3:30 p.m. – 5:00 p.m.

Owen Spring Improvement Project at Sequatchie Cave State Natural Area
Adam Spiller

The Use of Environmental DNA and Occupancy Modeling to Evaluate the Distribution of the Hellbender Salamander (Cryptobranchus alleganiensis) in Tennessee, U.S.A.
Jeronimo Da Silva Neto, William Sutton, Stephen Spear, and Michael Freake

Detecting the Presence and Abundance of the Streamside Salamanders (Ambystoma barbouri) in Middle Tennessee Using Environmental DNA
Nicole Witzel, Ali Taheri, and William B. Sutton

SURFACE WATER QUANTITY CAN REGULATE AQUATIC AGROECOSYSTEM WATER QUALITY AND NUTRIENT RETENTION

Justin N. Murdock[1], Martin A. Locke[2], Richard E. Lizotte, Jr.[2], and Jason M. Taylor[2]

The amount and movement of water across agricultural landscapes is largely influenced by agricultural practices, climate, and regional geomorphology. Changing rainfall and evapotranspiration patterns along with increases in water demand are altering surface water availability in the southeastern United States. Understanding if and how water quality and pollutant (i.e., sediment and nutrients) removal rates change relative to surface water volume will help managers to improve water use practices that optimize crop production while maintaining aquatic agroecosystem health. Long-term monitoring data and controlled experiments in shallow lakes and streams in the lower Mississippi River alluvial plain were used to assess how water depth interacts with the major agricultural pollutants to influence water quality and ecosystem services. Processes that reduce hypoxia and increase nitrogen and phosphorus retention were a specific focus. Results indicated that deeper lakes had more stable but lower average oxygen concentrations, along with lower water nutrient concentrations. Phytoplankton were a major driver of oxygen production and nutrient removal, but growth was co-limited by both nutrients and light in these hypereutrophic, highly turbid systems. With light limited to approximately the top 0.5 m, increasing water depth creates more zones of oxygen consumption, and in turn greater denitrification potential for nitrogen removal. Thus, as long as these systems maintain high nutrient and sediment inputs, a tradeoff with increasing water depth will be experienced; with increased nutrient removal and retention in deeper systems, but potentially greater hypoxic stress for organisms.

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ESTIMATED USE OF WATER IN TENNESSEE IN 2015

Melissa A. Harris[1]

Every five years, the U.S. Geological Survey (USGS) compiles data and estimates the Nation's use of water for eight categories: public supply, domestic, irrigation, thermoelectric power, industry, mining, livestock, and aquaculture. In the State of Tennessee, the USGS works in cooperation with the Tennessee Department of Environment and Conservation to compile water-use data. In 2015, total water withdrawals for Tennessee were approximately 6,440 million gallons per day (Mgal/d), a 16 percent decrease from 2010, although the population of the state increased four percent during the same time period.

A large majority (93 percent) of water withdrawals in 2015 were from surface-water sources. The greatest percentage of withdrawals occurred at thermoelectric power plants which accounted for 4,620 Mgal/d (72 percent) of total withdrawals. Public supply (850 Mgal/d) and industry (734 Mgal/d) accounted for 13 percent and 11 percent, respectively, of total withdrawals, while the other categories of use accounted for about one percent or less each.

Withdrawals for thermoelectric power in 2015 were 20 percent less than in 2010. The decrease in withdrawals coincided with a decrease in power production (14 percent) and a change from once-through cooling to recirculating cooling towers at the John Sevier plant in Hawkins County. Public supply and industrial withdrawals were 7.5 percent and 5.5 percent less, respectively, compared to 2010. Withdrawals for the other categories of use increased during the same time period except for livestock which decreased 15 percent.

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SUMMER 2017: MAKING THE MOST OF LIMITED RESOURCES: AN INVESTIGATION OF HARMFUL ALGAL BLOOMS AND CYANOTOXINS

Judy Manners[1] (Acknowledgement - Tom Byl[2]) and David Money[3]

With common goals, a small budget and limited resources we explored public drinking water sources, recreational lakes, livestock ponds and the TSU wetland to understand nuisances of Harmful Algal Bloom (HAB) occurrence and cyanotoxins of emerging concern to humans and animals.

Beginning at last year's Water Resources Symposium discussions among USGS, MTSU, ETSU, TSU and TDEC representatives revealed common objectives. A limited, intense investigation was undertaken through collaborative efforts in planning, sampling; including sharing of funding and staffing resources.

The US EPA National Aquatic Resource Survey Program conducted national lake assessment monitoring in 2007 and 2012. From these results, the Tennessee Department of Environment and Conservation (TDEC) Division of Water Resources identified 32 water bodies in Tennessee that may be vulnerable to harmful algal blooms (HABs) based on known algal occurrence. In June 17, 2015, the EPA announced the release of Ten-Day Drinking Water Health Advisories (HAs) for two cyanobacterial toxins, microcystins and cylindrospermopsin. Currently, there are no drinking water standards for cyanotoxins and no requirement for public water systems to monitor or report occurrence.

The confirmation and presence of cyanotoxins in Tennessee water bodies along with historical taste and odor occurrence in drinking water systems is concerning and indicates the need for awareness, monitoring, preparedness and appropriate response in the event of a harmful algal bloom.

[1] Tennessee Department of Health
[2] TSU/USGS
[3] TDEC Division of Water Resources

EDUCATIONAL ENHANCEMENTS AT UT MARTIN ASSOCIATED WITH THE JOINT WATER FOR AGRICULTURE PROJECT

Paula M. Gale[1] and Gregory H. Nail[1]

As part of the Water for Agriculture project "Increasing the Resilience of Agriculture Production in the Tennessee and Cumberland River Basins through more Efficient Water Resource Use" the University of Tennessee at Martin has developed new and has improved existing courses in agriculture and engineering. Students in courses such as soil and water conservation and environmental regulation have had enhanced opportunities outside of the classroom through field work and site visits. In engineering a new course has been developed in Computational Hydraulic and Computational Hydrologic Modeling. We will discuss how these efforts have enhanced the student experience at UT Martin and what other opportunities we see for the future.

[1] University of Tennessee at Martin

ADAPTING TO CLIMATE CHANGE, IMPROVING THE SUSTAINABILITY OF GRAZING SYSTEMS AND IMPROVING WATER QUALITY IN TENNESSEE

Forbes Walker[1] and Pat Keyser[1]

The livestock industry is very valuable to Tennessee agriculture and the rural economy. Beef cattle production has historically been the backbone of this industry with a most, if not all, production on pastures. Pastures have a significant impact on the agricultural landscape in Tennessee and water quality. Traditionally the forage base has been dominated by cool-season grasses such tall fescue and orchard grass. In recent years, Tennessee has been experiencing more variable rain distribution patterns, with more floods and periodic dry periods, or even droughts during the summer months. This has impacted the beef industry in many ways. The University of Tennessee (UT) Extension and other partners are working to diversify the forage-base of our pasture systems in Tennessee. Work at the University of Tennessee has demonstrated that the inclusion of native warm season grasses (NWSG), such as Eastern gamma grass, Big Blue Stem, Little Blue stem and Indian grass into our forage systems, not only will provide livestock with a valuable forage during the warm summer months, but also be an effective tool in managing forages during periodic dry periods and even drought. During intense summer rainfall events, the greater infiltration rates observed under NWSG systems greatly reduces the amount of runoff and thus soil erosion, the potential for local floods, and is another best management practice (BMP) for improving water quality and mitigating against the potential harmful effects of climate change in Tennessee. This presentation will summarize some of the on-going work at UT on promoting these systems in Tennessee. This work is in part supported by a USDA NIFA Water for Agriculture grant awarded to the University of Tennessee in collaboration with Tennessee Technological University, University of Memphis, Middle Tennessee State University and the University of Tennessee at Martin to study the effects that climate change may have on agricultural production in the Tennessee and Cumberland River Basins in the coming decades.

[1] University of Tennessee

ESTIMATING THE WATER AND NUTRIENT FOOTPRINT OF THE NEW POULTRY COMPLEX IN HUMBOLDT TENNESSEE

Shawn Hawkins, University of Tennessee

Poultry farm water use and litter management has been comprehensively evaluated on an 8 house broiler farm in Bradley County, Tennessee (54x500 ft houses). Water use was placed into three main categories: drinking water, evaporative cooling pad consumption, and for cleaning. Drinker water use varied seasonally and was affected by the size of the bird produced. Production of large birds, with growouts lasting approximately 45 days and yielding a 5.2 lb bird, required approximately 2 gallons of water per bird produced. Production of smaller birds, with growouts lasting approximately 35 days and yielding a 4.2 lb bird, required approximately 1.5 gallons per bird produced. Purely consumptive use in the evaporative cooling pads used to regulate production house temperature peaked in July and August at 25,000 per growout and peaked at 6-7 gallons per minute during peak cooling. Cleaning water use was low, typically less than 1% of total water use. These water use data, as well as poultry farm nutrient production data, will be formulated to present a water use and nutrient production footprint of the new poultry complex under construction in Humboldt Tennessee.

ECOLOGICAL FLOW ANALYSIS OF SURFACE WATER-WITHDRAWAL SCENARIOS IN THE CUMBERLAND AND TENNESSEE RIVER BASINS

Lucas Driver[1], Rodney Knight[1], and Jennifer Cartwright[1]

Water management and conservation efforts can benefit from scientifically-sound guidelines for the permitting of water withdrawals at a rate that maintains ecological health in streams while maximizing water availability for multiple human uses. In 2016, the U.S. Geological Survey (USGS), in cooperation with Tennessee Department of Environment and Conservation (TDEC), began a study to investigate the effects of different withdrawal scenarios on fish species richness at more than 150 surface-water sites within four ecoregions of the Tennessee and Cumberland River drainage basins (Interior Plateau, Cumberland Plateau, Ridge and Valley, and Blue Ridge). Published ecological limited functions from the four ecoregions were used to predict changes in species richness under different withdrawal scenarios (percent-of-flow rates and constant withdrawal rates) and minimum flow levels (MFLs) and identify potential withdrawal thresholds.

Withdrawal thresholds that maintained species richness within 5% of original (unaltered) conditions were calculated for each stream site, stream size class, and ecoregion. Results indicate that stream flow characteristics vary in their sensitivity both within and among the different withdrawal scenarios and MFLs resulting in variable patterns in predicted species richness. Importantly, within constant rate withdrawal scenarios, increasing the MFL appeared to increase or even eliminate withdrawal thresholds in many streams across multiple fish groups and ecoregions. This suggests that a more conservative MFL may provide more protection to ecological communities, especially during low flow periods, and allow for greater withdrawals during higher flows.

[1] U.S. Geological Survey, Lower Mississippi-Gulf Water Science Center

IMPACTS OF TROPHIC STATE ON THE COMPOSITION OF ALGAE ASSEMBLAGES OF THE HARPETH RIVER IN MIDDLE TENNESSEE

Jefferson Lebkuecher[1*], Sandra Bojic, Cooper Breeden, Samantha Childs, Matthew Evans, Bailey Hauskins, Zach Irick, Josh Kraft, Jonathan Krausfeldt, Nicole Santoyo, Tsvetan Tsokov, and Tiffanie Kelly

ABSTRACT

The concentration of total phosphorus of water samples, biomass of periphyton, and composition of soft-algae and diatom assemblages in the Harpeth River at two sites upstream and two sites downstream of Franklin, Tennessee were evaluated to assess the impact of water quality on the integrity of photoautotrophic periphyton. Nutrient impairment of all four sites was indicated by eutrophic concentrations of total phosphorus of water samples and periphyton biomass. Percent composition of 186 taxa of algae were documented; 92 taxa of soft algae and 94 taxa of diatoms. Analyses of algae composition by indices including the algae trophic index for soft-algae assemblages and the pollution tolerance index for diatom assemblages indicate biotic impairment by nutrient enrichment was greatest at the river site located immediately downstream of Franklin. The results indicate that degradation of water quality as the Harpeth River flows through Franklin alters the composition of photoautotrophic periphyton.

INTRODUCTION

The Harpeth River flows northwest 185 km from its source near Eagleville, Tennessee in rural Middle Tennessee to where it enters the Cumberland River approximately 25 km northwest of Nashville, Tennessee. The middle reaches flow through Franklin, Tennessee, a large suburb of Nashville, with a population of 75,000 as of 2015 (USCB, 2015). The river serves as the region's water supply and sewage disposal. The lower portion is designated as a scenic river under the Tennessee Scenic Rivers Act and is popular for swimming, canoeing, and fishing (TDEC 2017).

APPROACH

Four sites were sampled in the Harpeth River on September 30, 2017 from river mile 106 (site 1; uppermost river site sampled) to river mile 62.4 (site 4; lowermost river site sampled). The uppermost site is located 12 km east-southeast of Franklin, Tennessee in a rural, agricultural region. Site two (river mile 90.5) and site three (river mile 80) are located in densely populated, urban areas of Franklin, Tennessee, 3 km east-southeast of downtown and 5 km northwest of downtown, respectively. Effluent from the Franklin Water Treatment Facility enters the river at

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river mile 85.2, 5 km upstream of site 3. Site 4 is located 15 km north-northwest of Franklin and 20 km southeast of downtown Nashville. Concentrations of total phosphorous of water samples, cobble sampling, and determinations of periphyton characteristics followed the methods described in Grimmett and Lebkuecher (2017).

RESULTS AND DISCUSSION

Concentrations of total phosphorus (TP) of water of the 4 sites sampled (Table 1) were well above 75 µg $TP \cdot L^{-1}$, the value suggested by Dodds et al. (1998) to designate lotic systems as eutrophic. Concentrations of TP were substantially greater at site 3 (river mile 80), 5 km downstream of the Franklin Wastewater Treatment Facility. The high concentrations of TP of water at all four sites likely reflect the heavy anthropogenic activities in the watershed and high concentrations of phosphorus in the limestone bedrock (USGS 1999). The concentrations of chlorophyll (chl) *a* (Table 1) were > 70 $mg \cdot m^{-2}$, the value suggested by Dodds et al. (1998) to designate lotic systems as eutrophic. Concentrations of ash-free dry mass of benthic organics (AFDM) were > 10 $g \cdot m^{-2}$, a value we consider indicative of eutrophic environments based on earlier studies (O'Brian and Wehr 2010, Lebkuecher et al. 2015, Grimmett and Lebkuecher 2017).

Table 1. Concentrations of total phosphorus of water and periphyton characteristics at the sites sampled. Means ± standard error (SE) represent four replicates are not significantly different at the experiment-wise error rate of alpha = 0.05.

Characteristic/Site	Site 1. River mile 106	Site 2. River mile 90.5	Site 3. River mile 80.0	Site 4. River mile 62.4
Total phosphorus (µg $\cdot$ L^{-1})	310	360	1035	515
Chlorophyll *a* (mg $\cdot$ m^{-2})	135 ± 33	103 ± 11	151 ± 13	134 ± 47
Ash-free dry mass of benthic organic matter (g $\cdot$ m^{-2})	20.6 ± 5.7	15.1 ± 1.4	12.9 ± 1.6	20.3 ± 6.3

We identified 186 taxa of algae; 92 taxa of soft algae (Appendix 1) and 94 taxa of diatoms (Appendix 2). The most abundant soft taxon sampled was the filamentous Rhodophyta *Audouinella hermannii* (16.0 %) due to its high abundance at the three lowermost sites. The high value for the algae trophic index (ATI) for the assemblage at site 3 indicates that this assemblage is most impacted by eutrophication (Table 2). The low ATI value for the uppermost site results largely from the high abundance of *Phormidium diguetii* which is assigned a low trophic-indicator value for the ATI given this taxon is most abundant at sites which are not eutrophic (Grimmett and Lebkuecher 2017). The higher values for the ATI at the lower 3 sites are due largely to the abundance of *Cladophora glomerata* and *Audouinella hermannii* which are indicators of eutrophic conditions (Grimmett and Lebkuecher 2017).

Table 2. Indices for algae assemblages.

	Site 1. River mile 106	Site 2. River mile 90.5	Site 3. River mile 80.0	Site 4. River mile 62.4
Algae trophic index	37	71	107	91
Pollution tolerance index	2.64	2.55	2.20	2.41

The most abundant diatom taxa sampled was *Achnanthidium rivulare* (10.4 %) due largely to its high abundance at sites other than site 3 (Appendix 2). Values for the pollution tolerance index for diatom assemblages (PTI) at the sites studied are $\leq$ 2.6 (Table 2), which indicate eutrophic conditions (Lebkuecher et al. 2011). The greatest PTI value for the assemblage at site 1 is due largely from the abundance of *Achnanthidium* taxa (52 %) and *Cymbella affinis* (17 %) which are assigned pollution tolerance values for the PTI of 3 or 4 (KDOW 2002). The lowest PTI value for the assemblage at site 3 is due largely from the high abundance of *Navicula minima* (11.0 %), designated as an indicator of poor water quality by a trophic-indicator value for the PTI of 1 (KDOW 2002).

CONCLUSIONS

This study documents the composition of soft-algae and diatom assemblages necessary to monitor the integrity of photoautotrophic periphyton in the upper and middle reaches of the Harpeth River. Superfluous biotic impairment by eutrophication of the river sites downstream of Franklin, Tennessee is illustrated by the values for the algae trophic index for soft-algae assemblages and the pollution tolerance index for diatom assemblages.

ACKNOWLEDGMENTS

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Appendix 1. Percent composition of soft-algae taxa associated with cobble listed in alphabetical order. Additional soft-algae taxa identified from multi-habitat sampling are listed as present (P).

	Site 1. River mile 106	Site 2. River mile 90.5	Site 3. River mile 80.0	Site 4. River mile 62.4
Chlorophyta				
Characium ambiguum H. Jaeger				0.1
Chlamydomonas angulosa Dill				0.1
Chlamydomonas globosa Snow			0.3	0.1
Chlamydomonas gloeogama Korschikov				0.1
Chlamydomonas patellaria Whitford	0.1			0.5
Chlamydomonas sp.	0.1		0.3	0.4
Cladophora glomerata (L.) Kütz.	P	P	19.7	P
Closterium acerosum (Schrank) Ehrenb.			0.9	
Closterium ehrenbergii Menegh				0.1
Closterium leibleinni Kütz.		0.1		
Closterium moniliferum (Bory) Ehrenb.		0.2	0.1	
Closterium sp.			P	0.1
Coleochaete obicularis Pringsh				P
Cosmarium botrytis Menegh.			0.1	1.2
Entransia sp.				1.2
Gloeocystis vesiculosa Nägeli		0.5	1.3	1.0
Oedogonium sp.	2.4	P	9.5	2.4
Pandorina morum (Müller) Bory				0.1
Pediastrum simplex Meyen			0.1	
Rhizoclonium hieroglyphicum (C. Agardh) Kütz.	P			
Scenedesmus abundans (G. Kirchn.) Chodat	0.1			
Scenedesmus acuminatus (Lagerh.) Chodat		0.1		
Scenedesmus quadricauda (Turp.) Bréb.			0.4	
Selenastrum capricornutum Printz		0.1		

Spirogyra sp.		2.0		
Stigeoclonium tenue (C. A. Ag.) Kütz.				3.7
Tetraedron sp.				0.5
Ulothrix sp.				0.7
Ulothrix zonata (Weber & Mohr) Kütz.	P			
Cyanobacteria				
Aphanothece nidulans Richter			0.1	0.6
Aphanothece sp.				0.1
Arthrospira jenneri (Kütz.) Stitz.		0.2		
Borzia trilocularis Cohn.			0.6	
Calothrix sp.		0.5		0.4
Callothrix stellaris Bornet & Flahault				0.2
Chamaesiphon incrustans Grunrow		P	1.3	
Chroococcus minimus (Keissler) Lemmerm.				0.1
Chroococcus minor (Kütz.) Nägeli		0.3		0.1
Chroococcus minutus Kütz.		0.1		
Chroococcus pallidus Nägeli				0.1
Chroococcus turgidus (Kütz.) Nägeli	0.1			
Dactylococcopsis raphidioides Hansg.				0.1
Entophysalis rivularis Kuetz.			0.1	
Gloeocapsopsis cyanea (Krieg) Komárek & Anagn.	1.8	1.7	8.9	2.0
Gloeocapsopsis pleuroccapsoides (Novacek) Komárek & Anagn.	0.2			0.6
Heteroleibleinia kossinskajae (Elenkin) Anagn. & Komárek	0.1			
*Homeothrix juliana (*Bornet & Flahault) Kirchner	4.3	4.0		
Komvophoron constrictum (Szafer) Anagn. & Komarek		0.6	0.6	
Komvophoron munitum (Skuja) Anagn. & Komarek		0.3		1.6
Komvophoron **schmidlei (Jaag.) Anagn. & Komárek**		3.3		3.0
Leibeinia sp.		P		
*Leptolyngbya angustissimum (*West and West) Anagn. & Komárek			2.5	24.4
Leptolyngbya foveolarum (Mont.) Anagn. & Komárek	10.5	25.4	1.3	8.2
Leptolyngbya sp.		0.6		
Lyngbya major Menegh.	3.0	2.4		
Lyngbya martensiana Menegh.	4.4	2.5	3.2	
Merismopedia punctata Meyen	0.1			
Microcystis incerta Lemmerm.	0.1	0.1	1.5	1.1
Microcystis sp.				0.4
Oscillatoria agardhii Gomont		1.9	2.5	
Oscillatoria rubescens DeCandoll		3.0		
Oscillatoria sp.	0.6	1.3	1.4	4.8
Oscillatoria subbrevis Schmidle	1.3	0.8	1.5	0.5
Oscillatoria subtilissima Kütz. & De Toni		1.2	0.6	
Phormidium articulatum (Gardner) Anagn. & Komárek	3.2	2.1	0.8	1.7
Phormidium autumnale Gomont	3.0			
Phormidium diguetii (Gomont) Anagn. & Komárek	28.8	12.9		0.2
*Phormidium formosum (*Bory) Anagn. & Komárek	2.4	2.0		
Phormidium fragile Gomont	16.1	5.1	1.1	

Phormidium indundatum Kütz			0.9	
Phormidium retzii (C. Agardh) Gomont	10.8	1.0		
Phormidium sp.	0.6	1.0	5.7	2.7
Phormidium tenue (C. Agardh & Gomont) Anagn. & Komárek	2.5		1.6	
Phormidium terebriforme (C. Agardh & Gomont) Anagn. & Komárek	1.7	0.4	8.2	0.2
Spirulina major Kütz.				1.8
Spirulina nordstedtii Gomont				1.8
Spirulina princeps (W. West and G.S. West) G. S. West	1.2			
Spirulina sp.		0.3		
Spirulina temerrima Kutz.		0.2		
Synechococcus aeruginosus Nägeli	0.2		0.3	0.4
Synechococcus sp.			0.1	
Synechocystis sp.			0.1	0.2
Cryptophyta				
Chilomonas sp.		0.1		
Chroomonas sp.				0.1
Dinophyta				
Ceratium hirundinella (O.F.M.) Schrank				P
Euglenophyta				
Euglena minuta Prescott			0.1	
Euglena proxima P.J.L. Dang.	0.1			
Euglena sp.			0.1	
Phacus sp.			0.1	
Ochrophyta				
Vaucheria sp.			2.5	7.2
Rhodophyta				
Audouinella hermannii (Roth) Duby		22.0	19.3	22.7
Compsopogon coeruleus (Balbis) Montagne			P	
Cercozoa				
Paulinella chromatophora Lauterborn		P		

Appendix 2. Percent composition of diatom taxa associated with cobble listed in alphabetical order.

	Site 1. River mile 106	Site 2. River mile 90.5	Site 3. River mile 80.0	Site 4. River mile 62.4
Achnanthes pinnata Hust.	2.0	0.5	0.5	
Achnanthidium deflexa Reimer	8.0		0.5	
Achnanthidium eutrophilum Lange-Bert.				0.5
Achnanthidium exiguum var. *constrictum* (Grun.) Anderson				0.5
Achnanthidium latecephalum Kobayasi			0.5	0.5
Achnanthidium minutissimum (Kütz.) Czarn.	11.0	7.3	1.8	5.7
Achnanthidium rivulare Potapova & Ponander	16.5	15.0	2.3	7.6
Achnanthidium sp.	4.0	1.9	2.7	3.3
Amphora minutissima W. Sm.	0.5		0.5	
Amphora perpusilla Grun.	2.0	4.4	3.2	3.8
Amphora sp.		1.0		

Amphora veneta **Kütz.**		1.0		
Bacillaria paradoxa Gmelin	1.5	1.5	2.3	4.8
Cocconeis pediculus Ehrenb.			0.5	1.4
Cocconeis placentula Ehrenb.	3.0	4.8	4.5	4.8
Cocconeis placentula var. *euglypta* Ehrenb.				1.0
Craticula halophila (Grun.) G. D. Mann		0.5		
Cyclotella meneghiniana Kütz.			0.5	1.0
Cymatopleura elliptica (Bréb.)W. Sm.	0.5			
Cymatopleura solea (Bréb. & Godey) W. Sm.				0.5
Cymbella affinis Kütz.	16.5	5.8	3.6	1.4
Cymbella sp.			0.5	
Cymbella tumida (Bréb.) Van Heurck			0.9	
Diatoma vulgaris Bory				0.5
Encyonema appalachianum Potapova	4.5	1.9	5.0	2.4
Encyonema prostratum (Berk.) Kütz.			0.5	
Gomphoneis olivacea (Horn.) Daws.			0.9	0.5
Gomphonema brasiliense Grun.	0.5			
Gomphonema minutum Ag.		0.5		1.0
Gomphonema parvulum (Kütz.) Kütz.	0.5		0.5	1.4
Gomphonema pumilum (Grun.) Reich. & Lange-Bert.				0.5
Gomphonema sp.			0.5	0.5
Gyrosigma acuminatum (Kütz.) Rabenh.	0.5	1.5	1.8	2.4
Gyrosigma obtusatum (Sull. & Wormley) Boyer				0.5
Gyrosigma scalproides (Rabenh.) Cleve		0.5	1.8	1.0
Karayeva clevei (Grun.)				
Karayeva clevei var. *rostrata* Hust.		0.5		
Luticola goeppertiana (Bleish) D.G. Mann		0.5	0.5	
Melosira varians Ag.			5.9	
Navicula atomus (Kütz.) Grun.	1.0			
Navicula capitatoradiata Germ.	2.0	1.9	0.9	1.9
Navicula cari Ehrenb.			0.5	
Navicula cryptocephala Kutz.			0.5	
Navicula cryptotenella Lange-Bert.			8.6	5.2
Navicula decussis Østrup	0.5	0.5		
Navicula gregaria Donk.		1.0	0.5	
Navicula lanceolata (Ag.) Ehrenb.		0.5		0.5
Navicula menisculus Schum.	0.5		2.7	1.4
Navicula menisculus var. *upsaliensis* (Grun.) Grun.		0.5		
Navicula minima Grun.	8.0	5.4	5.4	11.4
Navicula reichardtiana Lange-Bert.	0.5	1.9	0.9	
Navicula reinhardii Grun.	0.5		0.5	
Navicula rhynchocephala Kütz.	0.5	1.9	0.9	
Navicula sp. (< 12 µm length)		1.0	4.5	2.9
Navicula sp. (> 12 µm length)		1.5	5.0	2.9
Navicula subminuscula Mang.		1.0		
Navicula subrotundata Hust.				0.5
Navicula symmetrica Patr.		0.5	0.5	
Navicula tenelloides Hust.				0.5
Navicula veneta **Kütz.**			0.9	1.0
Navicula viridula (Kütz.) Ehrenb.	1.0	1.0	3.6	0.5
Navicula viridula var. *linearis* Hust.				1.4
Neidium alpinum Hust.				0.5
Nitzschia acicularis (Kütz.) W. Sm.		3.4		

Nitzschia amphibia Grun.				2.4
Nitzschia capitellata Hust.	1.0	1.0		
Nitzschia constricta (Kütz.)			0.9	1.0
Nitzschia disputata (Kütz.)		0.5		
Nitzschia dissipata (Kütz.) Grun.		1.5	0.5	1.9
Nitzschia dissipata var. *media* (Hantz.) Grun.				0.5
Nitzschia flexa Schum.	0.5		0.9	1.0
Nitzschia frustulum (Kütz.) Grun.	0.5		0.5	
Nitzschia inconspicua Grun.			0.5	1.4
Nitzschia linearis (Ag.) W. Sm.		0.5	0.9	
Nitzschia microcephala Grun.				0.5
Nitzschia minuta Bleisch		0.5		
Nitzschia palea (Kütz.) W. Sm.	2.0	1.0		2.0
Nitzschia sociabilis Hust.			5.0	
Nitzschia sp.	1.0	2.4	1.8	2.0
Nitzschia sublinearis Hust		0.5		0.5
Pinnularia sp.	1.0			
Planothidium lanceolatum var. *dubia* Grun.		0.5	0.5	1.0
Psammothidium curtissimum (Carter) Aboal	4.0	6.9		
Psammothidium sp.		7.4	0.5	
Reimeria sinuata (Greg.) Kociolek & Stoermer		1.0	0.9	
Rhoicosphenia curvata (Kütz.) Grun.		1.5	3.6	2.9
Sellaphora seminulum (Grun.) D. G. Mann.	2.5	1.5	1.8	5.0
Stephanodiscus parvus Stoermer & Hakansson	0.5			
Stephanodiscus sp.		0.5		
Surirella brebissonii Lange-Bert. & Krammer		0.5		0.5
Surirella linearis W. Sm.	0.5			
Surirella ovalis Breb.	0.5			
Surirella ovata var. *pinnata* (W. Sm.) Brun.	0.5	1.9	0.5	
Synedra rumpens Kütz.				0.5
Synedra ulna (Nitz.) Ehrenb.			0.5	

AQUATIC ECOLOGY RESEARCH IN OAK RIDGE, TENNESSEE

Mark Peterson

Oak Ridge, the "secret city" during the Manhattan Project in the 1940s, is celebrating in 2018 its 75th Anniversary. Although Oak Ridge and Oak Ridge National Laboratory (ORNL) in particular is well known for its reactors, neutron sciences, and powerful computers, less well known is that ORNL has a long and rich history in aquatic ecology research. Organisms in Oak Ridge streams and impoundments were first monitored by health physicists in the late 1940s. In the 1950s ORNL's "Ecology Program" began and included a field station on the Clinch River, where pioneering use of radionuclides as tracers helped lead to the development of the field of radioecology. The ability to use tracers led to National Science Foundation-supported studies of the Walker Branch Watershed in the 1960s, with a focus on terrestrial-aquatic ecosystem processes and nitrogen cycling. Walker Branch Watershed is one of the longest continually studied stream systems in the world, with over 60 years of research and expectations of decades-long future research as part of the NSF's National Ecological Observatory Network (NEON). Ecological studies at ORNL expanded significantly with the creation of the Environmental Science Division in 1972, and fisheries related work was a significant part of the division's research portfolio. The Aquatic Ecology Laboratory was built in 1977 primarily to support assessments of fish responses to warm water discharges from coal and nuclear plants. Investigations of fisheries effects from another energy alternative, hydropower, also began in the 1970s with multiple field investigations in the northwest US. By the 1980s ORNL scientists were expanding investigations of Oak Ridge area streams and conducting aquatic toxicity experiments that contributed to the development of the field of ecological risk assessment. Mercury-related research at ORNL started to grow in the 1990s and 2000s, in part due to local mercury issues and also because mercury in many aquatic environments is linked to energy alternatives like fossil fuel combustion and hydropower operations. Today, aquatic ecologists in Oak Ridge strive to provide the scientific knowledge and technical innovation to address some of the country's most complex and multi-faceted water-energy resource challenges.

OWEN SPRING IMPROVEMENT PROJECT AT SEQUATCHIE CAVE STATE NATURAL AREA

Adam Spiller[1]

The smallest State Natural Area, at only 10 acres, Sequatchie Cave is home to one of the state's smallest endangered species, the royal snail (*Pyrgulopsis ogmorhaphe*). This site is also home to other rare species. This unique site is centered around the Sequatchie Cave, from which flows Owen Spring Branch, a cold water spring that originates from multiple sources in the surrounding vicinity. This site, in unincorporated Sequatchie in Marion County, has gone through a transformation over the past 20 years. Once a local gathering point for the community, the site became a TDOT roadside park and then a state natural area in 2001. Since then, the site has been the subject of multiple efforts to conserve and protect the site and the species that make the cave and spring their home. This presentation will focus on these efforts over the years and the latest project, which has improved the site with a new bioretention cell to manage stormwater and a bank stabilization. This project is unique in that it focuses on an ecologically important site in an underserved community that brought together mutiple stakeholders including the state, the county, the local community, and a private engineering firm all contributing to make this project successful. Other components of this presentation will discuss the cave mapping efforts that are underway, the dye tracing that occurred to discover the sources of the spring, and other ongoing efforts to improve this valuable resource.

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THE USE OF ENVIRONMENTAL DNA AND OCCUPANCY MODELING TO EVALUATE THE DISTRIBUTION OF THE HELLBENDER SALAMANDER (*CRYPTOBRANCHUS ALLEGANIENSIS*) IN TENNESSEE, U.S.A.

Jeronimo Da Silva Neto[1], William Sutton[1], Stephen Spear[2], and Michael Freake[3]

The Hellbender salamander (*Cryptobranchus alleganiensis*) is a long-lived, fully-aquatic salamander that inhabits cool, well-oxygenated streams and rivers in the eastern United States. Although once abundant, *C. alleganiensis* populations have experienced major declines across the historical range. Habitat degradation, siltation, aquatic contaminants, and infectious diseases are commonly suggested contributors to these declines. Although Tennessee provides areas of high-quality habitat for *C. alleganiensis*, standardized state-wide distribution assessments have been limited to known populations, and status of other *C. a. alleganiensis* populations remains unknown. We used environmental DNA (presence/absence) data to identify important conservation areas with potential remaining *C. alleganiensis* populations, and estimate site occupancy at 292 sites across Tennessee. Site occupancy was estimated to be 0.45 (130 sites), and the detection probability was 0.55. The overarching goals of this project is to encourage efficient use of time and resources to effectively manage and conserve the few remaining hellbender populations throughout the state of Tennessee.

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[2] The wilds, Cumberland, OH 43732
[3] Department of Natural Sciences and Mathematics, Lee University, Cleveland, TN 37311

DETECTING THE PRESENCE AND ABUNDANCE OF STREAMSIDE SALAMANDERS (*AMBYSTOMA BARBOURI*) IN MIDDLE TENNESSEE USING ENVIRONMENTAL DNA

Nicole Witzel[1]*, Ali Taheri[1], and William B. Sutton[1]

Amphibians represent the vertebrate taxa that has experienced the greatest declines globally. Declines tend to occur in species with geographically-isolated and/or fragmented populations. This is specifically true for the Streamside Salamander (*Ambystoma barbouri*), an Ambystomatid salamander that occurs in Middle Tennessee. This salamander species emerges to breed in low-order, ephemeral streams during the winter and spring months. As these animals are cryptic and only surface-active for several months, they can be difficult to detect using traditional survey methods. Surveys that target environmental DNA (eDNA) in the form of DNA sloughed into their aquatic environment could provide an effective method for detecting the presence of this species. Water samples were collected at 50 meter stretches of 17 streams across the *A. barbouri* range four times over 6 months (December – May 2017). Stream segments were searched for all life-stages of salamanders using rock-turning and visual surveys. We used real-time PCR to quantify DNA amounts using an *A. barbouri* species-specific primer. We used Generalized Linear Mixed Models to evaluate relationships between *A. barbouri* adult, larval, and egg counts and biomass at each site. In addition, we evaluated the change in eDNA amounts across the active season of *A. barbouri*. Primary outputs from this study include a replicable eDNA approach to identify *A. barbouri* populations in Tennessee and sampling guidelines for appropriate times to collect eDNA survey data for *A. barbouri*. This information will provide a method which can be used by wildlife agencies to further the knowledge and conservation of this species.

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SESSION 3A

HARMFUL ALGAL BLOOMS (HABS) (Moderator: Paul Davis, PE)
8:30 a.m. – 10:00 a.m.

An Introduction to Harmful Algal Blooms and Review of Conditions that Influence Toxin Production
Thomas Byl and De'Etra Young

Reservoir Aging—A New Paradigm for Water-Quality Management: Are Our Reservoirs Promoting Cyanobacterial Harmful Algal Blooms?
W. Reed Green

The Use of Molecular Techniques to Identify Cyanobacteria and Better Understand HAB Dynamics
Frank C. Bailey and Jordan Jatko

HYDROLOGIC EXTREMES (Moderator: Paul Davis, PE)
10:30 a.m. – 12:00 p.m.

Speakers: Roger Lindsey, Metro Water Service; Ben Rohrbach, U.S. Army Corps of Engineers; Scott Gain, U.S. Geological Survey; Jay Lund, University of California, Davis (Abstracts Not Available)

AN INTRODUCTION TO HARMFUL ALGAL BLOOMS AND REVIEW OF CONDITIONS THAT INFLUENCE TOXIN PRODUCTION

Thomas Byl[1,2] and De'Etra Young[3]

Harmful algal blooms (HABs), often caused by cyanobacteria (blue-green algae), are increasingly a water quality-concern across the United States due to their production of cyanotoxins. Toxin-producing cyanobacteria were found in 74% of the 79 Southeastern United States streams and rivers surveyed by the US Geological Survey in 2015; cyanotoxins were found in about 35% of the 79 rivers. Middle-and-east Tennessee depend on surface-water for water supply and irrigation and the surface-water resources are vulnerable to HABs. However, very little is known about the spatial and temporal occurrence of HABs in middle and east Tennessee. This presentation will provide an introduction and overview of the different environmental variables reported in the literature that influence HAB dynamics.

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RESERVOIR AGING – A NEW PARADIGM FOR WATER-QUALITY MANAGEMENT: ARE OUR RESERVOIRS PROMOTING CYANOBACTERIAL HARMFUL ALGAL BLOOMS?

W. Reed Green[1]

Reservoir research in fisheries and water-quality management peaked in the 1970s and early 1980s. Relative to 1970, these reservoirs ranged in age from newly constructed to around 30 years old. The process of Internal phosphorus loading was recognized, but was ‘decimal dust’ when compared to the magnitude of external phosphorus loads. Most reservoirs today are around 40 to 80 years old. Considering the efficiency of reservoir sediment trapping, reservoir bed sediments today contain much larger stores of phosphorus than these same reservoirs in the 1970s and 1980s. Under hypoxic conditions in the bottom water, large quantities of phosphorus are released from the bed sediments into the overlying water. Mixing events during the summer thermal stratification season can deliver large quantities of this phosphorus into the photic zone which can promote episodic cyanobacterial harmful algal blooms. The question now becomes, how do we manage our reservoirs when internal phosphorus loading during the thermal stratification season may be as critical or more so than external phosphorus loading?

[1] Hydrologist, U.S. Geological Survey, Lower Mississippi-Gulf Water Science Center, 401 Hardin Road, Little Rock, AR 72211

THE USE OF MOLECULAR TECHNIQUES TO IDENTIFY CYANOBACTERIA AND BETTER UNDERSTAND HAB DYNAMICS

Frank C. Bailey[1]* and Jordan Jatko[1]

Harmful Algal Blooms (HABs) are a frequent occurrence in some freshwater systems, and due to the production of toxins such as microcystin and saxitoxin by the cyanobacteria involved, they may pose a significant public and environmental health threat. In order to understand the population dynamics of toxin-producing and non-toxin producing cyanobacteria before, during and after a bloom, it is necessary to be able to identify both the organisms involved and the toxin producing genes within some of them. Assorted techniques have been investigated for this purpose with varying amount of success. In this talk, an introduction to the use of molecular methods to better understand population, community and toxin dynamics associated with HABs will be presented. Techniques to be discussed include the use of quantitative real time PCR (qPCR) for identification and quantification of cyanobacteria (16s rRNA genes) and toxin producing genes (e.g. mcyB gene), next generation sequencing for microbial community analysis, fluorescent *in situ* hybridization, and enzyme linked immunosorbent assays (ELISA).

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SESSION 3B

WATER QUALITY MANAGEMENT **(Moderator: Daniel Saint, TVA)**
8:30 a.m. – 10:00 a.m.

River Temperature Forecasting for Wheeler Reservoir, Alabama
T. Boyington

Predictive Environmental and Hydropower Modeling for Scheduling Multipurpose Reservoir Systems
Boualem Hadjerioua

Toward Development of a Framework and Watershed Quality Index Tool for Karst Watershed Management
Christine Guy-Baker, Samantha Allen, Tania Datta, and Alfred Kalyanapu

RIVER TEMPERATURE FORECASTING FOR WHEELER RESERVOIR, ALABAMA

T. Boyington

As part of the ongoing effort to maintain the aquatic habitats of the Tennessee River, the Tennessee Valley Authority (TVA) actively monitors and manages the thermal discharge from its power plants. A key element in the management of reservoir temperatures has been the development and application of numerical river models. These tools are used to assist in the operation of cooling equipment, power generating facilities, and river scheduling to maintain downstream thermal compliance. As part of a multi-year project, TVA River Management has transitioned from an internally developed one-dimensional model to a vendor-supported three-dimensional model (Delft3D). This presentation will describe the integration of the new model into TVA's existing forecasting framework as well as the benefits of using a three-dimensional river model in the management of river temperatures for Wheeler Reservoir, Alabama.

PREDICTIVE ENVIRONMENTAL AND HYDROPOWER MODELING FOR SCHEDULING MULTIPURPOSE RESERVOIR SYSTEMS

Dr. Boualem Hadjerioua[1]

The Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) funded UT-Battelle LLC, Oak Ridge National Laboratory (ORNL), to develop a state-of-the-art decision support system for optimal hydropower generation subject to environmental constraints for a multiple reservoir system. The work, which involves the modeling of the Cumberland River system was executed in close collaboration with Vanderbilt University and the U.S. Army Corps of Engineers (USACE).

Increasing generation capacity at hydropower facilities is normally obtained through the optimization of a number of variables, including reservoir release patterns, settings of individual generation units, and operational controls of multiple generation units. This optimization can be further complicated by the common use of hydropower to supplement peak power requirements of thermal electric plants. However, this "peaking" operation has the potential to result in adverse environmental impacts through changes in temperature, dissolved oxygen, and sediment loads, which can adversely impact downstream aquatic ecosystems as flow regimes represent the key driving variables for such systems. As such, optimization of hydropower operations represents now more a multiple objective function, balancing maximization of hydropower generation while minimizing environmental impacts. Realization of a well-optimized hydropower system thus requires a fully integrated approach with the goal to achieve energy production and environmental quality. The goal of this research initiative directly addresses the objectives of developing new tools for hydropower units and plants to improve water use efficiency, operations optimization, and mitigate environmental impacts of hydropower operation.

This work illustrates a framework by which simulations of a high-fidelity two-dimensional hydrodynamic and water quality model, CE-QUAL-W2 (W2), can be exploited in a computationally efficient manner to optimize hydroelectric power generation subject to constraints on water quality. Models such as W2 allow operators to gain additional knowledge about the behavior of reservoirs and make operating decisions. The computational expense of W2, however, limits its usefulness in real-time scheduling schemes. This work addressed this challenge by presenting a framework to employ much less data-intensive W2-based surrogate models in an optimization scheme to maximize hydroelectric power generation subject to hydrodynamic and water quality constraints.

Author Biography:
Dr. Boualem Hadjerioua is a Sr. research engineer, leading the water power technology team at Oak Ridge National Laboratory (ORNL), and an adjunct professor at Vanderbilt University. Before joining ORNL in January of 2010, Dr. Hadjerioua worked for 18 years balancing the

[1] Water Power Technology Team Lead, Oak Ridge National Laboratory; Adjunct Professor, Vanderbilt University

many stakeholder demands for the Tennessee Valley Authority (TVA). Currently, Dr. Hadjerioua manages projects for the Department of Energy (DOE), focusing on developing technologies, decision-support tools, and methods of analysis that enable holistic management of water-dependent energy infrastructure and natural resources. He holds a PhD from the University of Arizona, has authored 141 technical publications. Dr. Hadjerioua can be reached at Hadjeriouab@ornl.gov and 865-574-5191.

TOWARD DEVELOPMENT OF A FRAMEWORK AND WATERSHED QUALITY INDEX TOOL FOR KARST WATERSHED MANAGEMENT

Christine Guy-Baker[1], Samantha Allen[2], Tania Datta[3], and Alfred Kalyanapu[4]

As cities and communities grow, and land use patterns change, the water quality within a watershed is impacted by increased point, non-point source discharges and altered hydrology. Therefore, decision-makers are always attempting to determine the best choices for sustaining economic growth while protecting the environment. A new framework for conserving and restoring watershed health that is gaining traction lately, focuses on identifying and addressing water quality impairments in collaboration with state and local stakeholders. This framework is deemed the "**watershed approach".** However, implementing this approach can be challenging, especially for watersheds that are largely karst. Our study presents the development of ***a framework and watershed quality index tool to illustrate the benefits of a watershed approach to water quality improvement, for a karst watershed***. The goal is accomplished by characterizing the hydrological and water quality processes of a watershed through the selection, calibration, and validation of a holistic hydrological model and developing an easy-to-use **Watershed Quality Index (WQI)** tool that will integrate the water quality data and allow a robust evaluation of various watershed management alternatives. The WQI tool can be used to illustrate the impacts, whether positive or negative, of land use changes, and can be developed to utilize existing Geographic Information Systems (GIS) data from a variety of sources. This tool may provide a way to enhance decision-making capabilities, leading to efficient management of watersheds while meeting the needs of urban development.

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SESSION 3C

WATERSHED MANAGEMENT (Moderator: Amy Feingold, EPA)
8:30 a.m. – 10:00 a.m.

Developing a Web-Based Geodatabase for Data Sharing and Collaboration within the Falling Water River Watershed
Samantha Allen, Christine Guy-Baker, Tania Datta and Alfred Kalyanapu

Stakeholder-Led Restoration Projects: Beaver Creek as Example
David Duhl and Roy Arthur

Improving Water Resources Management with Pasture Management in Tennessee
Forbes Walker and Lena Beth Reynolds

DEVELOPING A WEB-BASED GEODATABASE FOR DATA SHARING AND COLLABORATION WITHIN THE FALLING WATER RIVER WATERSHED

Samantha Allen[1], Christine Guy-Baker[2], Tania Datta[3], and Alfred Kalyanapu[4]

The Falling Water River Watershed is a HUC10 watershed located in Middle Tennessee. It is characterized by karst hydrology, resulting in springs, sinkholes and sinking streams. Within the watershed, there is an increase in urban development, ongoing recreational activity, and growth in industrial and commercial entities. The uniqueness of the watershed and its uses make the watershed an area of interest to a variety of stakeholders to determine the effects these anthropogenic activities may have on the water quality and watershed hydrology. To allow for an effective way to characterize the watershed using existing data, this project aimed to bring stakeholders together for the purpose of streamlining data collection efforts and decreasing duplication of work, as well as facilitated data sharing and encouraged collaboration among stakeholders. Geographic Information System (GIS) technology allows for data visualization and analysis at the watershed level, facilitating a deeper understanding of the spatial relationships that exist between water quality, land-use, and the karst hydrology. Therefore, a database and GIS geodatabase was developed to house data collected from stakeholders and provide the ability for online data sharing among stakeholders. Descriptive statistics were used to determine the spatio-temporal variability of water quality at 5 year intervals. As a result, informed watershed management is facilitated. Results from the project will be shared during the presentation.

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STAKEHOLDER-LED RESTORATION PROJECTS: BEAVER CREEK AS EXAMPLE

David M. Duhl[1] and Roy A. Arthur[2]

In the current 303(d) program vision, EPA encourages states to work with local stakeholders in designing restoration plans in advance of a Total maximum daily Load (TMDL). The accompanying report, called a 5-alt report after the Integrated Report use support category, acknowledges the valuable work done by local stakeholders in identifying and addressing restoration strategies that target water quality impairments. Statutory and regulatory obligations to develop TMDLs for waters identified on States' Clean water Act 303(d) lists remain unchanged. Nevertheless, EPA and states recognize that under certain circumstances there are alternative restoration approaches that may be more immediately beneficial or practicable in achieving WQS than pursuing the TMDL approach. An alternative restoration approach is a near-term plan, or description of actions, with a schedule and milestones, that is more immediately beneficial or practicable to achieving Water Quality Standards.

Local stakeholders are often the most knowledgeable about water quality problems in their area and have the most insight about what needs to be done to restore water quality. In addition, local stakeholders have the advantage of leveraging local businesses and citizens to perform the tasks necessary to restore water quality. Stakeholder and public support for the alternative restoration approach is important for achieving timely progress in implementing the alternative.

In the Beaver Creek subwatershed of the Lower Clinch River Watershed, stakeholders—led by the Beaver Creek Task Force—envisioned paths to restoring water quality and to involve local stakeholders to execute this vision. Through a combination of federal, state, and local grants, and in-kind services, the Task Force installed best management practices and conducted a public awareness campaign to address sediment, pathogen, and nutrient water quality impairments of Beaver Creek.

This presentation will describe the efforts of the Task Force, and how the efforts were recognized by EPA through a 5-alt report.

[1] TDEC/Division of Water Resources
[2] Knox County Watershed Coordinator/Knox County Stormwater Management

IMPROVING WATER RESOURCES MANAGEMENT WITH PASTURE MANAGEMENT IN TENNESSEE

Forbes Walker[1] and Lena Beth Reynolds[2]

In 2014, the Tennessee Department of Environment and Conservation (TDEC) estimated that 44 percent of all water quality impairments in Tennessee came from agriculture, and of that 63 percent were related to grazing systems. Agricultural landscapes in middle and east Tennessee are dominated by cool season pastures, such as tall fescue and orchard grass. Poorly managed pastures can be a significant source of non-point source water quality impairments from erosion, nutrients and pathogens. Since 2001, the University of Tennessee (UT) Extension has been working intensively in the Pond Creek and Oostanaula Creek watersheds in East Tennessee to improve water quality. Efforts to model the sources of sediments identified over-grazed and less well managed pastures as significant sources of pollutants in these watersheds. Based on this information UT Extension focused on improved pasture management as a best management practice (BMP) not only for increasing cattle performance but also for improving water quality. By 2010 several miles of streams were removed by TDEC from the 303 d list of impaired waters. Given the similarities in the geology, soils and land-use in the region improvements in pasture management are a viable win-win option for both improving livestock performance and water quality.

[1] Extension Soil Specialist, Dept. of Biosystems Engineering and Soil Science, University of Tennessee Knoxville
[2] Extension Area Specialist, Athens, Tennessee

STUDENT POSTERS

High School

Bacterial Antibiotic Resistance in Three Wells with Different Geochemistry, Nashville, TN
Ethan Moore (Acknowledgement Tom Byl)

Seasonal Ecology of Invertebrate Taxa in an Urban Stream Ecosystem, 2017
Mina H. Aziz, Sean E. Pak, and Elizabeth Riddle

Undergraduate

Groundwater Flow and Benzene Biodegradation in a Karst Aquifer Well, Nashville, TN
Chris Alexander and Renas Barzanji (Acknowledgement Thomas Byl)

Retrofitting Based Campus Stormwater Masterplan
Avery Cowan, Matthew Shields, Austin Ethridge, Christy Ziesme, Will Khomtchenko, Elliot Ziebart, and Jejal Bathi

Assessing Freshwater Cyanobacterial Bloom Dynamics and Toxin Production in a Lentic Ecosystem
Jordan Jatko, Menglian Zhang, and Frank C. Bailey

Landowner Demographics in the Application of Best Management Practices (BMPs) in Tennessee
Katelyn Rimmer and Wayne K. Clatterbuck

Graduate

Occurrence and Fate of Nanomaterial in Surface Water Environment
Avery Cowan, Breana Harvell, and Jejal Bathi

Comparison of HEC-RAS 1-D to HEC-RAS 2-D Model for Breedings Mill Branch Creek, Putnam County, Tennessee
John T. Brackins, Alexander J. Davis, Christine L. Guy-Baker, and Alfred J. Kalyanapu

Is Water Quality in Boone Lake a DAM Problem? An Assessment of Water Quality Pre- and Post-Drawdown
Annie Grant and Ingrid Luffman

Assessment of Biodiversity and Seasonal Patterns of Leech (Hirudinea) Parasitism of Semi-Aquatic Turtles in an Urbanized Wetland System
Laura Horton, Nicole Witzel, Brittany Hogan, Shawn Snyder, and William Sutton

Cover Crops to Mitigate Water Contamination in the Mississippi River
Manuel Sabbagh, Sindhu Jagadamma, and Forbes Walker

Mapping Impervious Areas of the Sandy Creek Watershed in Jackson Tennessee Using Land Cover Data
S. Smith, D. Larsen, B. Waldron, S. Schoefernacker, and W. Wimco

PROFESSIONAL POSTERS

Irrigated Acreage in Tennessee Counties, 1934 to 2012
John Robinson

BACTERIAL ANTIBIOTIC RESISTENCE IN THREE WELLS WITH DIFFERENT GEOCHEMISTRY, NASHVILLE, TN

Ethan Moore[1], acknowledgement – Thomas Byl[2]

Previous studies have shown that high concentrations of metals will select for antibiotic resistance in soils and water. There was a lack of articles on other aqueous geochemical parameters that might influence the selection of antibiotic resistance. The main objective of this study is to determine the relationship between water geochemistry of 3 distinct wells and antibiotic resistance of culturable bacteria isolated from the three wells at Tennessee State University research farm. The three wells represent three distinct geochemical conditions in a karst aquifer. One well is high in dissolved iron (>10 mg/L), the second well is high in sulfide (>60 mg/L), and the third well is aerobic and has moderately high sulfate (>150 mg/L) and alkalinity. Each of the three wells has between 500,000 and 1-million bacteria per milliliter as determined using most probably number technique. Antibiotic resistance tests will be conducted using 10% Tryptic Soy Agar made using well water and amended with an increasing dose of antibiotic (tetracycline, erythromycin, quaternary ammonia compounds). Patterns of antibiotic resistance and geochemical parameters will be used to determine if certain water chemistry selects for particular antibiotic resistance.

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SEASONAL ECOLOGY OF INVERTEBRATE TAXA IN AN URBAN STREAM ECOSYSTEM, 2017

Mina H. Aziz, Sean E. Pak, Elizabeth G. Riddle

Within an ecosystem, the interplay between organism counts and seasonally-changing environmental parameters reveals information about phenological adaptations and community behaviors. Increased urbanization around freshwater habitats can interfere with the phenology of local invertebrates. This study documents the seasonal ecology of flying and aquatic invertebrates in an urban stream environment (Richland Creek, Tennessee), where information on seasonal population sizes and life histories was previously lacking. Data on invertebrate counts and environmental parameters were collected every two weeks from January to June 2017. On seven visits, count data were obtained using traps and kick-net sampling of the streambed at two stations. Environmental parameters recorded included temperature, pH, dissolved oxygen, turbidity, and conductivity. Gastropods, the most commonly observed invertebrates, comprised 80% of the total mollusk counts and were more abundant than bivalves on all dates. Bivalves increased in percentage relative to gastropods on each visit from mid-January to mid-March (4-48%) before declining in early June (11%). Although total insect counts appeared to decrease from winter to summer, diversity of insects generally increased. Principal Component Analyses revealed positive correlations between several environmental parameters and taxon counts. The correlations suggest sensitivities in gastropods and moths to seasonal changes in dissolved oxygen, pH, and temperature. These changes could affect the numbers of gastropod predators on a seasonal basis. Shallower waters contained less bivalves, possibly due to changes in food availability or feeding opportunities. Future studies would track invertebrate phenology over a full yearly cycle, and investigate responses to other seasonally-changing environmental parameters such as chemical composition.

GROUNDWATER FLOW AND BENZENE BIODEGRADATION IN A KARST AQUIFER WELL, NASHVILLE, TN

Chris Alexander[1], Renas Barzanji[2], and (Acknowledgement - Thomas Byl[3])

Karst aquifers are susceptible to contamination from surface sources due to rapid infiltration at sinkholes and underground conduits. Karst refers to carbonate bedrock with fractures, caves, sinkholes and complex hydrology. The objectives of this project are to characterize the groundwater flow direction around a contaminated well at Tennessee State University (TSU); and, to evaluate the potential for biodegradation of benzene. The 250-foot deep well used in this study is located on the TSU Agriculture Research farm in Nashville, TN, between a truck fueling station and a tank storage facility. The well has extremely high levels of dissolved iron (>10 mg/L) and tested positive for the gasoline additive called diisopropyl ether (DIPE) after a heavy storm (1.5 inches). It is suspected that the DIPE originated from one of the two adjacent fuel facilities. Triangulation tests to determine the flow direction used water elevations in TSU wells to the south of the contaminated well. Results of those calculations indicate a gradient flowing toward the west. However, these results used data collected under non-storm conditions and should be revisited during heavy storms to determine if there is change in flow direction due to rapid recharge due to a sinkhole or stormwater retention. The high iron in the well may be due to geobacteria breaking down organic compounds and using iron as the terminal electron acceptor process, transforming $Fe^{3+}_{(ppt)}$ to $Fe^{2+}_{(aq)}$. Since DIPE is a recalcitrant fuel additive, one might expect benzene, toluene, ethyl-benzene and xylenes (BTEX) to also be present in the contaminated well. Additional studies will be done to determine if the bacteria present in the well are efficient at biodegrading toluenee. This information will help determine the potential for intrinsic bioremediation of BTEX.

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RETROFITTING BASED CAMPUS STORMWATER MASTERPLAN

Avery Cowan[1]; Mathew Shields[1]; Austin Ethridge[1]; Christy Ziesme[1]; Will Khomtchenko[1]; Elliot Ziebart[1]; Jejal Bathi[2]

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In alignment with the City of Chattanooga's pollution mitigation efforts and the University of Tennessee at Chattanooga's (UTC) suitability efforts, our team has developed a campus-wide stormwater management master plan for UTC campus. The plan primarily focuses on retrofitting gray infrastructure with green infrastructure to help mitigate pressing issues with stormwater on campus and also aids in implementing the UTC's existing master plan. For the master plan development, we assembled relevant data through: field surveys, public domains, interacting with the city engineers, the Tennessee Department of Environmental Conservation (TDEC), and from the UTC Department of Facilities. All identified projects were evaluated using a computer simulation program for hydrological and water quality control. Projects are ranked and prioritized based on described criteria for their implementation. The proposed controls are expected to reduce 14,042 ac-ft./yr of runoff and its associated pollutant loads.

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ASSESSING FRESHWATER CYANOBACTERIAL BLOOM DYNAMICS AND TOXIN PRODUCTION IN A LENTIC ECOSYSTEM

Jordan Jatko[1]*, Mengliang Zhang[2] and Frank C. Bailey[1]

Harmful Algal Blooms (HABs) are an increasing problem in freshwater ecosystems, and pose significant public health threats, including the safety of our water resources. The most common contributors to HAB formation in freshwater environments are cyanobacteria, in particular, *Microcystis*, *Anabaena*, and *Oscillatoria spp*. We are conducting a year-long study that assesses seasonal variation in algal species composition and algal toxin concentrations at J. Percy Priest Reservoir, Tennessee, which is known to experience HAB activity. In doing so, we hope to achieve a better understanding of when and under what conditions specific algal species are present, and factors influencing toxin production/availability. We have selected four sampling locations on J. Percy Priest Reservoir, all located upstream of water treatment facilities. The study will consist of four sampling events, one for each season, with each event consisting of 5 samples taken no less than 24 hours apart, all within a 30 day period. The samples will be averaged and analyzed by ANOVA/MANOVA. We will additionally sample water treatment plant effluent to determine whether algal toxins are effectively removed through water treatment. Algal species composition will be analyzed using quantitative real-time PCR. Algal toxins will be analyzed using coupled liquid chromatography and mass spectrometry. We will also take a variety of environmental measurements to better inform seasonal algal bloom dynamics and toxin production, including water temperature, Phosphorous, Nitrogen, flow, conductivity, dissolved oxygen, pH, and chlorophyll a.

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LANDOWNER DEMOGRAPHICS IN THE APPLICATION OF BEST MANAGEMENT PRACTICES (BMPs) IN TENNESSEE

Katelyn Rimmer[1] and Wayne K. Clatterbuck [2]

An evaluation of forestry BMP implementation in Tennessee was conducted by the University of Tennessee, Dept. of Forestry, Wildlife & Fisheries and the Tennessee Dept. of Agriculture, Division of Forestry in 2017. A total of 213 harvest sites stratified among five regions statewide were evaluated. Demographic information about the harvest sites was collected to determine trends in the BMP implementation. The demographic categories included landowner type (private, public, industry/corporate), trained loggers from the Tennessee Master Logger Program or a untrained logger, whether a written timber sales contract was used, whether a professional forester was involved with the harvest, and the wood dealer purchasing the timber. These data are sometimes difficult to collect for some harvest sites, especially if the landowner does not want to convey the particular information about their timber sale or a landowner, absentee or otherwise could not be contacted. Thus, information for every harvest site may be totally missing or incomplete. Preliminary results suggest that BMPs were implemented correctly if a professional forester or a Master Logger was involved with the harvest and vice versa, harvest sites without trained loggers or professional foresters were more likely to have BMPs implemented incorrectly or without BMPs applied at all which could lead to water quality risks. BMPs were correctly applied on public and industry/corporate harvest sites because these sites have involvement of both professional foresters and Master Loggers based on organizational policy. Forests on private lands had the greatest non-conformity of BMP implementation.

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OCCURRENCE AND FATE OF NANOMATERIAL IN SURFACE WATER ENVIRONMENT

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Manufactured nanomaterial (NM) are increasing globally in terms of production and use. NM have diverse applications in the modern world and can be found in many electronics, plastics, cosmetics, and other household items, as well as being used in industrial production for vehicles and textiles. The medical field has also found many uses for these materials. Their increased production and use also comes with increased potential for their contamination in environment, especially their entry into surface water and air systems. There is a wide variety of NMs, each with unique physical and chemical properties and hence their transport and fate mechanism in natural environment. However, since the NMs use is consider still as very early stage, there is no significant information of their occurrence in surface water systems. Our proposed poster presentation will describe our research that focused on identify common nanomaterial with the highest contamination potential in surface water systems, their physical and chemical properties, along with their prevalence in non-point source runoff. We present our research findings of NM fate and transport behavior that could provide insight in designing controls for their treatment.

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COMPARISON OF HEC-RAS 1-D TO HEC-RAS 2-D MODEL FOR BREEDINGS MILL BRANCH CREEK, PUTNAM COUNTY, TENNESSEE

John T. Brackins[1]*, Alexander J. Davis[2]*, Christine L. Guy-Baker[3]*, and Alfred J. Kalyanapu[4]

The city of Cookeville is largely drained by karst features such as sinkholes and caves, with a substantial amount of manmade channelized streams designed to direct floodwaters into these features. One example is the Breedings Mill Branch (BMB) Creek which runs parallel to Willow Avenue and drains to Ensor Sink in Cookeville, Tennessee. The flood impacts of this area are well familiar to local residents, but the Federal Emergency Management Agency (FEMA) has not undergone detailed hydraulic studies of the extents and depths of inundation experienced in a 100-year flood. However, some of the project area is classified as a Special Flood Hazard Area Zone A for which base flood elevations are not determined. Several techniques are available for evaluating the features of these floods in detail, including the Hydrologic Engineering Center's River Analysis System (HEC-RAS), which is capable of solving the governing hydraulic equations in both one-dimensional and two-dimensional flow. The objective of this study is *to explore the differences between a HEC-RAS 1D model and a HEC-RAS 2D model for Breedings Mill Branch Creek in Cookeville, Tennesee, and to simulate the 100-year flood for this area since it has not been formally mapped previously by FEMA.* In order to accomplish this objective, the project team collected information on past floods, channel geometry, culvert properties, and other model parameters. This information, along with a previous Hydrologic Modeling System (HEC-HMS) model created by Hart et al. (2009), was used to create both a 1D and 2D HEC-RAS model for the study area. Both the 100-year base flood and past events were evaluated using various boundary conditions, and the model results were compared with the existing Zone A extents. Differences between the model formulations were explored, and recommendations for future study and potential flood map updates were made.

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*This research is done entirely independently by the first three authors. Dr. Kalyanapu serves as the research advisor for the project.

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IS WATER QUALITY IN BOONE LAKE A DAM PROBLEM? AN ASSESSMENT OF WATER QUALITY PRE- AND POST-DRAWDOWN

Annie Grant[1]* and Ingrid Luffman

INTRODUCTION AND BACKGROUND

Boone Lake was formed in 1952 by the impoundment of the South Fork Holston River in Sullivan and Washington counties, northeast TN. The “V” shaped lake spans 6.88 square miles; it consists of two primary tributaries of approximately equal-length which meet just above the dam. South Fork Holston River (HUC 06010102) makes up the northern arm and Watauga River (HUC 06010103) feeds the southern arm. In October 2014, the discovery of a sinkhole led to detection of sediment-laden seepage under the earthen part of the dam. As a safety precaution, the reservoir was immediately lowered to an elevation of 1,352.5 feet, 10 feet below operational “winter” levels (Figure 1). It will remain there until the anticipated dam repair completion date of 2022 (Tennessee Valley Authority, 2016).

Figure 1. Boone Reservoir before (2012, left) and after (2015, right) drawdown showing water level. Pictured: Devault Bridge and Boone Marina. Source: Google Earth.

Boone Reservoir has a history of elevated metal and excessive nutrient concentrations in sediment dating back to the 1960s (Nicholas, 1973). It has been 303(d) listed for PCB and Chlordane contamination since 1992 (TDEC, 1992). TVA categorized the overall ecological health of the lake as “poor” from 1994-2011 basing its categorization on low Dissolved Oxygen concentrations and presence of metals and organic contaminants in the lake’s sediment (Tennessee Valley Authority, 2010).

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This study compares reservoir water quality data collected before seepage detection to data collected since drawdown (1998-2013 versus 2015-2017) to determine the impact of drawdown on water quality in the reservoir. Parameters analyzed were Dissolved Oxygen (DO), turbidity, conductivity (EC), Total Dissolved Solids (TDS), pH, temperature, and *Escherichia Coli* (*E. coli*).

METHODS

Water quality data were compiled from two sources: TDEC routine and grab samples collected in the spring and summer months from 1998 to 2017 and grab samples collected between November and December 2017. Data were gathered from 22 locations dispersed throughout each arm of the reservoir (Figure 2). A pre/post analysis was conducted using independent samples t-tests and Mann-Whitney tests as appropriate.

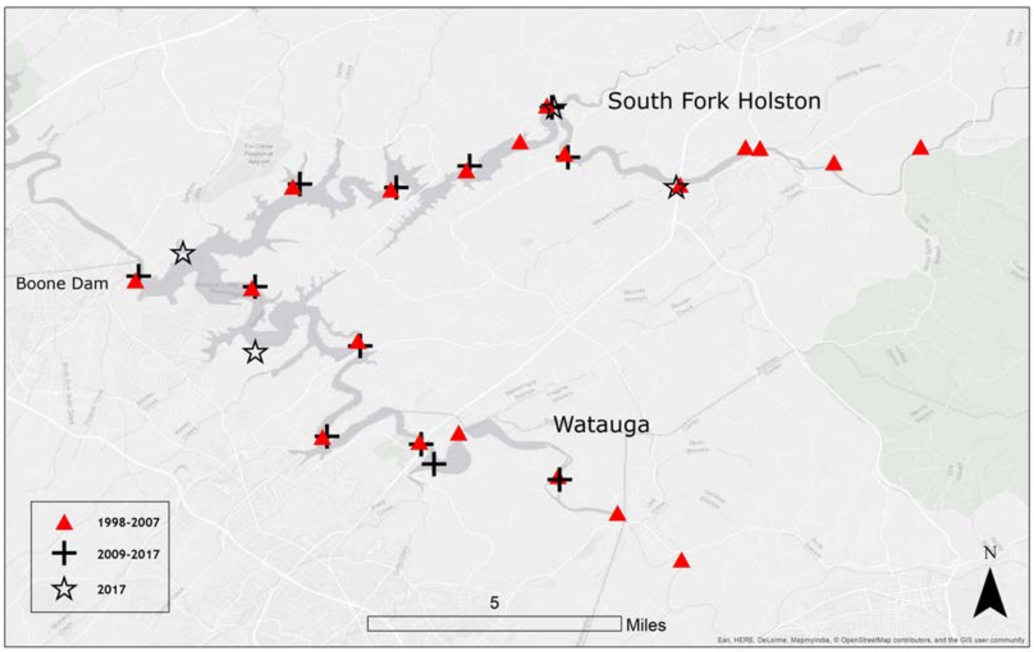

Figure 2. Sampling locations within Boone Reservoir labeled by time frame. Clustered sampling sites indicate areas near known, historically-polluted tributaries and/or state-confirmed point sources of pollution.

RESULTS AND DISCUSSION

Statistical analysis of pre/post-drawdown water quality parameters within the reservoir as a whole indicates the reservoir drawdown has had a significant "flushing" effect on the reservoir. Significant decreases in pH, conductivity, TDS, and *E. coli*, and a significant increase in temperature were observed post-drawdown ($p \leq .05$) (Table 1). *E. coli* samples in particular showed high variance, especially among "pre" data; three outliers above 10,000 cfu/100mL were excluded from analysis. High variation in *E. coli* values is to be expected given that lakes are dynamic systems whose water quality parameters vary naturally by season (USEPA 2016).

Damming and other anthropogenic activities add to this complexity. In the case of Boone Lake, water quality monitoring and management encompasses additional challenges due to dam repairs and elevated pollutant concentrations.

Table 1. Means and standard deviations (in brackets) of water quality parameters pre- and post- drawdown.

Parameter measured	**Pre-drawdown (before 2014)**	**Post-drawdown (after 2014)**	**Direction**	**Sample size (Pre/post)**
pH	7.7 (.32)	7.3 (.83)	-	107/48
Conductivity (mu)	227.5 (147)	141.3 (19.9)	-	110/28
TDS (ppm)	105.9 (50.9)	50.9 (53.3)	-	291/26
Temperature (◦C)	10.6 (4.3)	12.3 (3.2)	+	104/28
E. coli (cfu/100mL)	273.4 (1,111)	101.6 (120)	-	432/30

Averages measured for pH fall within "healthy" range for freshwater lakes (between 6.5- 9) (TDEC 2016). Average temperature does not exceed normal range for the region, however it is increasing significantly (USEPA 2016). Time series analysis of temperature and pH data show significant trends overtime ($p \leq .05$) (Figure 3). Increasing temperature and acidity are indicators of metal solubility and have been shown to expedite release of metals and organic nutrients contained in sediments (Haiyan 2013 and USEPA 2016). The observed significant decrease in pH coupled with a significant increase in temperature could have an exacerbating effect on heavy metal concentrations in the reservoir. For decades, legacy pollution from metals has largely remained trapped within Boone Lake's sediments making metal concentrations easy to miss when testing water quality alone (TVA, 2016). Because contaminated sediment has for the most part remained immobilized, its potency and quantitative impact if released, is difficult to predict. Not only does metal dissolution increase with pH, but research has indicated "flushing" due to dam failure increases sediment mobilization in the water column (Deonarine, 2013). This combination of relationships is enough to warrant increased monitoring of lake sediments and vigilance to further fluctuations in temperature and pH.

Regardless of cause, changing water quality warrants continued monitoring throughout the timespan of the dam repair and after its completion. It is recommended that water quality data be collected regularly at consistent time intervals using a paired samples approach. A more regulated methodology would result in a more thorough understanding of the dam's role in lake health and aid in minimizing error due to sample size and uncontrolled variables. Additionally, based on pH and temperature findings, it is recommended that water quality testing include testing for presence of metals. Water quality parameters tend to be strongly connected; a change in one value can lead to a change in another, resulting in a domino effect impacting an entire limnological system as well as the humans that live and play near it.

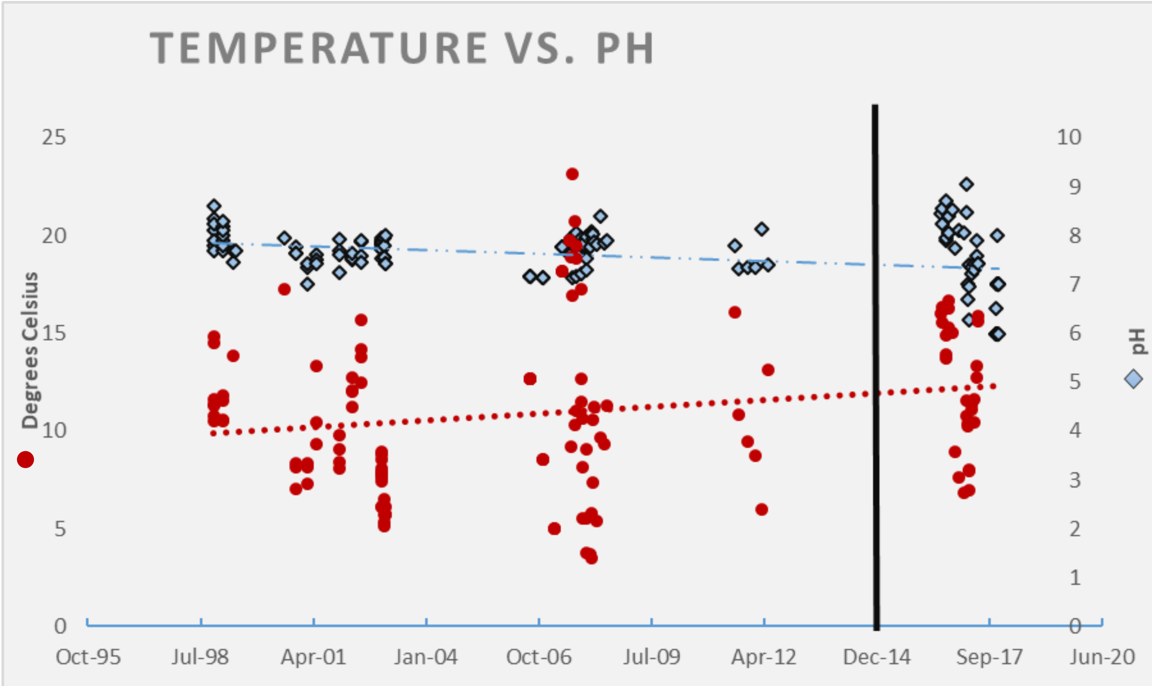

Figure 3. Decrease in pH (R^2= .12) and an increase in temperature (R^2 = .035) in Boone Lake has occurred over the study period. Best fit lines project similar trends in the future, however R^2 values are low due to high variability in data. The solid line indicates date of drawdown.

CONCLUSIONS

Results of this study indicate water quality in Boone Lake has changed significantly since water levels were lowered. This change is likely due to flushing of the reservoir as a result of ongoing dam repair. Conductivity, TDS, and *E. coli* levels have decreased, showing improvements in water quality. Temperature has increased, and pH has decreased, which may indicate the potential for future water quality problems as heavy metals trapped in sediments are remobilized.

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ASSESSMENT OF BIODIVERSITY AND SEASONAL PATTERNS OF LEECH (HIRUDINEA) PARASITISM OF SEMI-AQUATIC TURTLES IN AN URBANIZED WETLAND SYSTEM

Laura Horton[1]*, Nicole Witzel[1], Brittany Hogan[1], Shawn Snyder[1], and William Sutton[1]

Aquatic turtles inhabiting a palustrine emergent wetland adjacent to Tennessee State University in Nashville, Tennessee were examined for leeches as a component of a multi-year mark and recapture study. Leeches serve as bioindicators in aquatic environments, and are useful in determining the biological condition of aquatic ecosystems based upon various evaluations such as species richness indices between parasite and host. This study investigated seasonal fluctuations in leech species diversity, abundance, and severity of infestation on hosts over a four-month period. Aquatic funnel traps were baited and deployed weekly from June – October 2016 to sample the turtles. Each captured turtle was weighed, measured, sexed, marked, and examined for external leeches. All located leeches were removed and preserved for later identification. Turtle species captured during this study, included the Common Snapping Turtle (*Chelydra serpentina)*, Stinkpot (*Sternotherus odoratus*), Spiny Softshell Turtle **(***Apalone spinifera*), and the Red-eared Slider (*Trachemys scripta elegans*). The leeches that were collected from the turtles represented 3 different genera under phylum Hirudinea, including Batracobdella, Placobdella, and Helobdella, and 7 different species. Collectively, the interpretation of these data can be used to understand parasite-host relationships and how patterns in leech parasitism vary throughout the active season in a wetland system.

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COVER CROPS TO MITIGATE WATER CONTAMINATION IN THE MISSISSIPPI RIVER

Manuel Sabbagh[1], Sindhu Jagadamma[2], and Forbes Walker[3]

Cover crops (CC) are popular amongst farmers due to their ability to decrease soil erosion, increase weed suppression and soil physical properties. However, there are various other ecosystem services that CC perform that get overlooked when evaluating the merits from incorporating CC. Nitrogen is the most important macronutrient crops need to increase productivity. Much of this N comes from synthetic fertilizer inputs with a lot of it lost by leaching and volatilization processes. The N leaching that is sourced from the Corn Belt has created a gargantuan dead zone in the Gulf of Mexico. Our study is aimed to investigate the role CC have on N dynamics in soil and the potential to apply N credits to agroecosystems to improve water quality in the surrounding environments. Our study is leveraging a study started in 2013 at the University of Tennessee's Research and Education Center in Milan, TN which include single-, double-, and a multi-species CC mixture along with a control (no CC). Soil samples were taken from 0-5, 5-10, and 10-20 cm depths from 6 treatments during October 2017. Our CC treatments include nitrogen fixing legumes, nitrogen mining cereals, and a deep tap rooted Brassica species. Preliminary results show higher mineral N and gravimetric soil water content in the CC treatments compared to the control. A detailed examination will be conducted to understand the seasonal effect on N availability for successive cash crops from incorporating CC in the agroecosystem. This research is expected to provide valuable information for farmers on the advantages of CC to improve yield and broadly to improve water quality in the adjacent water reservoirs.

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MAPPING IMPERVIOUS AREAS OF THE SANDY CREEK WATERSHED IN JACKSON TENNESSEE USING LAND COVER DATA

S. Smith, D. Larsen, B. Waldron, S. Schoefernacker, and W. Simco

The Memphis aquifer is the most important source for groundwater in western Tennessee; however, recharge processes to the aquifer are poorly understood. Previous studies have shown that in rural areas recharge occurs more efficiently in stream gullies with sand bottoms than in upland terraces. The same is expected in urban streams where the Memphis Sand is exposed. Water balance research in the Sandy Creek watershed in Jackson, Tennessee, provides information regarding infiltration and potential recharge to the Memphis aquifer that may be typical of urban streams where the aquifer materials are exposed.

Sandy Creek is within an urban environment, which adds impervious surfaces that decrease infiltration rates and increase evaporation rates. The magnitude, location, geometry, spatial pattern of impervious surfaces, and the pervious-impervious ratio in a watershed have hydrological impacts. Watersheds with large amounts of impervious cover may experience an overall decrease of groundwater recharge and baseflow discharge in urban streams and an increase of stormflow and flood frequency. Data from the National Land Cover Database were divided into 16 different categories, but for this project only areas with impervious surfaces are taken into account. GIS and remote sensing techniques were used to classify the land cover data into classes of impervious surface coverage and non-impervious surface coverage using unsupervised classification. The data were reclassified based on predetermined criteria; the area of each class was weighted against the total watershed area to determine the percentage of imperviousness in the watershed. Using the impervious surface data, it will be possible to more accurately compare recharge processes between urban and rural watersheds within the exposure belt of the Memphis Sand.

IRRIGATED ACREAGE IN TENNESSEE COUNTIES, 1934 TO 2012

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Water use for irrigation in Tennessee has substantially increased since 2000. Published water-use data from the U.S. Geological Survey's National Water-Use Science Program show that during 1985 through 2000, water withdrawals for irrigation ranged from 2 to 15 million gallons per day (MGD) and averaged about 9 MGD. Furthermore, water withdrawals for irrigation have increased from 7 MGD in 2000 to 33 MGD in 2005 and 44 MGD in 2010. To assess the possible impact of irrigation on water resources, accurate estimates of water withdrawals for irrigated lands and an understanding of how factors driving water-use needs are likely to change in the future are needed. In 2015, the U.S. Geological Survey, in cooperation with the Tennessee Department of Environment and Conservation, evaluated past water use and irrigation data to understand the effect of irrigation on groundwater resources in Tennessee counties. Irrigation data were obtained from the U.S. Department of Agriculture and the U.S. Census Bureau and used to determine irrigation withdrawals by county, and recent temporal patterns of withdrawals. The data cover the period 1934 to 2012 and were published every 4 to 5 years. From 1934 through 2012, reported irrigated acreage in Tennessee increased from 57 to 142,992 acres. Since 2000, the largest increases in reported irrigated acreage have occurred in counties located primarily in West Tennessee. During 2012, the top ten irrigated counties were in West and Middle Tennessee and, in descending order, include Dyer, Lake, Haywood, Lauderdale, Madison, Obion, Tipton, Warren, Fayette, and Gibson Counties. These 10 Tennessee counties accounted for 94,689 acres or 65 percent of the irrigated acreage in Tennessee during 2012. Warren County, the only county located outside of West Tennessee, has been in the top ten irrigated counties in Tennessee ten times since 1949.

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Please come by our booth to see the New SDI-12 SMART PT water level and temperature sensor. Steven's SMART PT is a ceramic membrane pressure and temperature sensor that delivers accurate results for a wide range of fluid level measurement applications. In addition to simple instantaneous measurements, this smart sensor features the ability to capture peak crest levels and to automatically sample and report basic statistics on a configurable time interval.

Tennessee Water Resources Research Center
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The Tennessee Water Resources Research Center (TNWRRC) is the formal water resources research entities under the Institute for a Secure and Sustainable Environment (ISSE) at The University of Tennessee. The two organizations work synergistically together to address water resources research needs to the broad regional community.

The TNWRRC is a federally designated research institute headquartered at the University of Tennessee, Knoxville. The Center was established in 1964 by Governor Clement following the enactment of the Water Resources Research Act of 1964 (PL 88-379) by Congress. TNWRRC's missions include: (1) to assist and support all academic institutions of the state, public and private, in pursuing water resources research programs that address problem areas of concern to the state; (2) to promote education in fields related to water resources and to provide training opportunities for students and professionals in water resources related fields; and (3) to provide information dissemination and technology transfer services to state and local governments, academic institutions, professional groups, businesses and industries, environmental organizations, and others that have an interest in solving water resources problems.

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Trutta Environmental Solutions provides stream channel and aquatic habitat surveying and assessment services for the energy, transportation, and industrial sectors, as well as federal and state agencies, and nonprofit organizations. We have developed and use the High Definition Stream Survey (HDSS). HDSS is a stream survey system that integrates GPS, video, depth, side-scan sonar, and water chemistry sensors to allow many miles of stream (typically 15 miles) to be surveyed in a single day, with data collected approximately every meter. By using this multi-attribute data collection technique, we have the ability to change from guesses and broad extrapolations about the condition of the study area, to high-resolution (1m) maps of the stream and stream channel. The range of data collected is highly useful for GIS mapping, hydrologic modeling, and habitat identification applications.

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Wood, PLC (formerly Amec Foster Wheeler) is a recognized leader in providing a comprehensive set of municipal stormwater management services to local governments throughout North America and internationally. These include both water quality and quantity services, and range from being site-specific to watershed-wide solutions. With offices in Chattanooga, Knoxville, and Nashville, Wood services cover both institutional and technical needs for clients throughout the State of Tennessee.

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ASCE Tennessee Section/Environmental and Water Resources Institute
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http://sections.asce.org/tennessee/

The Tennessee Section of the American Society of Civil Engineers (ASCE) represents more than 2,000 members of the civil engineering profession in Tennessee. ASCE is America's oldest national engineering society with more than 147,000 members worldwide. ASCE's vision is to position engineers as local, national and global leaders building a better quality of life. The Environmental and Water Resources Institute (EWRI) is ASCE's technical source for environmental and water-related issues. EWRI is one of nine ASCE technical institutes.

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Barge Design Solutions, Inc. is a professional services firm that includes engineers, architects, landscape architects, surveyors, planners, and scientists. Barge has 15 offices located throughout Tennessee, Alabama, Georgia, Texas, and Ohio. The staff of Barge uses their experience in planning, design and permitting to provide environmental services that will aid in conservation of our water resources and protect our natural communities. Our team offers comprehensive knowledge that incorporates modeling, mapping, engineering, and regulatory compliance to support integration of the natural resources component into engineering projects.

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Since 1945, BH's experienced, interdisciplinary teams have provided our clients with cost-effective, advanced solutions. Our expertise includes Stormwater Analysis, Green Infrastructure, Stream Restoration, Sewage Facilities Planning, Treatment Facility and Pump Station Design, Biosolids Handling, Collection Systems and Modeling, Transmission and Distribution Systems, Water Storage, and Permitting.

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At CAESER, we're rooted in academia, but not limited by it. Our center is comprised of industry professionals, University faculty and highly-motivated students—all working together to provide the best service possible. We give students hands-on experience within a diverse, multi-disciplinary environment that makes them much more marketable upon graduation.

We consider our clients to be partners and work closely with them to develop a detailed scope of work. And because we're a nonprofit institution, we're also deeply committed to offering the most cost-effective solution available.

Center for the Management, Utilization and Protection of Water Resources
Tennessee Technological University

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The mission of the Center for the Management, Utilization and Protection of Water Resources (Water Center) is to support state and federal agencies, communities, and industry in solving water quality, biodiversity, and water security problems and advancing scientific understanding of all aspects of water science and engineering through basic and applied research. Center researchers study aquatic biodiversity and ecology from genes to ecosystems; address water quality challenges and develop better treatment technologies; and implement state-of-the-art technologies and tools for watershed sciences, modeling and simulation, data acquisition and geospatial analysis. The Center provides a strong water resources research infrastructure at Tennessee Tech by supporting faculty research, training and mentoring of future water professionals, and serving the citizens of the state of Tennessee.

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CEC, with offices in Franklin and Knoxville, is a full-service engineering and environmental consulting firm, specializing in ecosystem restoration, biological assessments, water resource engineering, EPSC and stormwater BMP design, MS4 compliance, wetland ecology, survey, infrastructure, and solid waste. Our staff is comprised of engineers, biologists, geologists, and environmental scientists.

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EnviroScience is a nationally recognized ecological consulting firm with over 100 biologists, environmental scientists, environmental engineers, and commercial divers. Since 1989, EnviroScience has completed ecological work throughout the United States with a focus on the Midwest and Southeast. EnviroScience provides expert technical services to help our clients meet their environmental design and regulatory requirements.

KCI Technologies
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KCI Technologies is a multi-disciplined engineering firm with offices in Middle Tennessee. KCI offers many services throughout the water market. We specialize in natural resources mitigation, stream and wetland restoration, dam removal, stormwater management, and watershed planning. Our experience also covers Geospatial and GIS services, including asset management and MS4 compliance. KCI is also a licensed construction contractor in Tennessee, specifically focused on ecological restoration and stormwater construction projects.

Exhibitors

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We manufacture, sell, support, service, and repair water quality monitoring equipment worldwide. We are leaders in innovation of new products and services that enable our customers to collect water quality data with ease and confidence. Our objective is to provide you with the most reliable equipment and the best service at the lowest price possible.

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Integrated Technologies specializes in NPDES stormwater solutions by partnering with industry leaders for answers to both quality and quantity challenges. AquaShield has long been the leader in industry approved, cost effective treatment solutions and we have added Lane pipe and Cultec chambers for storage solutions giving us the most options for challenging designs. Our team stands ready to assist in providing you the best design choices for your project.

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K. S. Ware and Associates, LLC (KSWA) is a Woman-Owned Small Business (WOSB) engineering firm that provides environmental, geotechnical and construction engineering and inspection (CEI) services to Federal, State and Local governments as well as private clients. KSWA has extensive experience in environmental assessments, investigation, and restoration services. Our staff is also experienced in providing assistance with NEPA, natural resource assessments, permitting and stormwater management as well as indoor air quality, asbestos and lead inspection and abatement services.

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The program is designed for students with a bachelor degree to get solid and rigorous training in GIS, business management and statistics. Students are required to take an internship opportunity to work for a company. With such training, students would be able to get real-world and problem-solving skills in addition to learning from the classroom. The program is open to anyone with a strong learning desire and ambition to be a great professional leader in managing natural resources with computer-based analytical and critical methods.

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Founded in 1933, Ragan-Smith Associates, Inc. is a multi-disciplined consulting firm with expertise in land planning, civil, transportation, and environmental engineering, landscape architecture, construction services, water services, surveying, and sustainable design. Our professional focus is to provide the best use of the land and efficiency of service infrastructure appropriate for the environment, the use, and the client.

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S&ME was formed in 1973 in Raleigh, North Carolina. Over the ensuing 45 years, we have grown to 36 offices in Tennessee, South Carolina, North Carolina, Georgia, Kentucky, Ohio, Pennsylvania, Louisiana, Virginia, Alabama, and Florida. We are an employee owned firm with over 1,200 professional and support staff in civil, environmental, and geotechnical engineering; planning and landscape architecture; environmental, natural resources, and industrial hygiene services; and exploration and materials testing. Because we are employee-owned, we realize that our success is dependent on the professional execution of our clients' projects. Our employees are highly motivated to assist our clients to succeed. S&ME is a leader in its field, having won 80 Engineering Excellence Awards from state chapters of the American Council of Engineering Companies for "achievements which demonstrate the highest degree of merit and ingenuity." S&ME currently ranks 89th on Engineering News-Record magazine's list of Top 500 Design Firms and 156th in the Top 200 Environmental Firms.

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Thomas B. Lawrence, PE provides water quality services, including MS4 compliance, NPDES permitting and compliance, public education, SPCC plans, EPSC planning and inspections, training and SWPPP preparation.
