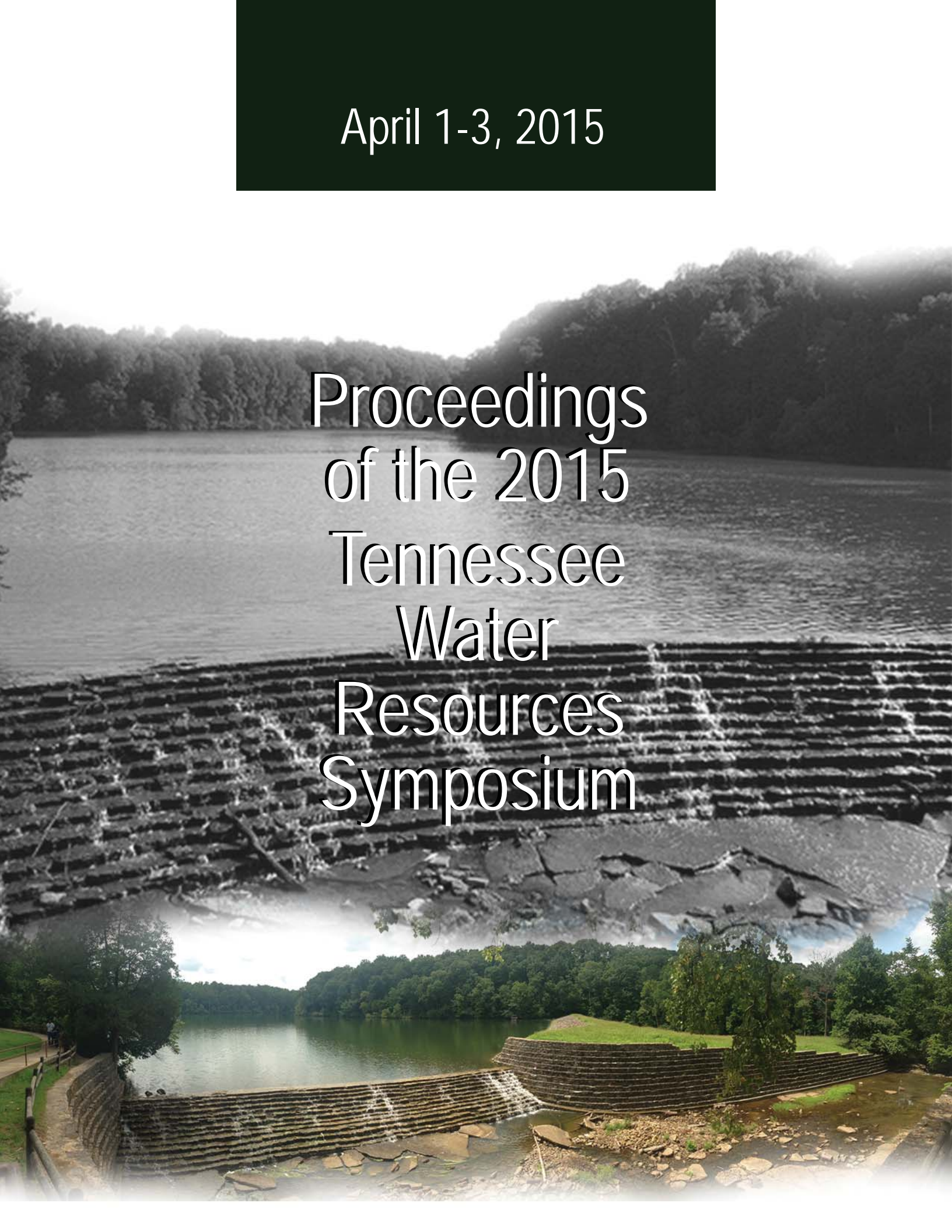


April 1-3, 2015

Proceedings
of the 2015
Tennessee
Water
Resources
Symposium



Proceedings from the

2015 Tennessee Water Resources Symposium

Montgomery Bell State Park
Burns, Tennessee

April 1-3, 2015

Sponsored by

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PREFACE

Welcome once again to the Tennessee Section of the American Water Resources Association annual symposium at Montgomery Bell State Park. It has not been since 2012 that we have had this symposium during the early spring, after a meeting in the fall of 2013 and one-day symposium last summer in Nashville. I trust all will enjoy getting back to our regular season for the symposium. Take time to learn the latest from our talks, re-new old friendships, make new acquaintances and enjoy the opportunities to socialize, visit with our vendors and enjoy the beauty of spring at Montgomery Bell State Park

This year we will be welcoming Michelle Perez of the World Resources Institute, Washington DC, to be our keynote speaker. We also will be welcoming back Dave Feldman of UC Irvine to be our lunchtime speaker. Both will be talking about water trading issues as a way to improve water quality locally, nationally and globally. This year we are trying something new by hosting an education outreach program for local 4th to 6th graders – it is never too soon to look for the next generation of AWRA members!

As always the success of this meeting is due to a small army of volunteers, many who have been involved with organizing the meeting for many years. As always, Lori Weir is the corner-stone of the meeting. She always does a great job in bringing the organizing committee together and keeping them on task. This year our secretary has been Andrea Ludwig and David Duhl has continued to serve as our treasurer. Other members of the conference committee include Sherry Wang, Adrian Ward, Amy Knox, Daniel Saint, Deedee Kathmon, Don Green, George Garden, Ken Barry, Marion Keith, Michael Hunt, Patrick Massey, Patrick McManhon, Paul Davis, Rodney Knight, Scott Schoefernacker, Shannon Quinn, Tom Allen, and Tom Lawrence.

On behalf of the organizing committee I wish you a great symposium!

Best wishes

Forbes Walker

President, Tennessee Section, AWRA, 2015 Conference Chair

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12:00 – 1:30 p.m.

Wednesday, April 1

Keynote Address by Michelle Perez, World Resources Institute

**“NUTRIENT TRADING AND TARGETED WATERSHED PROJECTS:
POTENTIAL FOR IMPROVING WATER QUALITY LOCALLY
AND IN THE GULF OF MEXICO”**

12:00 – 1:30 p.m.

Thursday, April 2

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**“WATER POLLUTANT TRADING—LOCAL CHALLENGES, GLOBAL
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SESSION 1A

HEADWATERS

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Chattanooga WPA Ditch Program
Patrick Dobbs

The Redevelopment of Pond Creek
Adrian Ward

A Hole in Our Bucket: How and Why Tennessee Needs to Improve Headwater Protection
Paul E. Davis

FRESHWATER ECOLOGY

3:30 p.m. – 5:00 p.m.

Ecological Limit Functions and Hydrologic Accounting: An OASIS on the Cumberland Plateau
Rodney R. Knight

*Determining the Chronic Toxicity of Boron to the Freshwater Mussel (*Lampsilis siliquoidea*) and the Aquatic Worm (*Lumbriculus variegatus*) in Whole-Sediment Exposures*
Scott Hall, Rick Lockwood, and Mike Harrass

Sediment Quality and Freshwater Mussels—One Piece of the Puzzle
Greg Johnson

CHATTANOOGA WPA DITCH PROGRAM

Patrick Dobbs¹

Between the years of 1936 and 1941, the Works Progress Administration (WPA) constructed a system of concrete- bottom rock-lined ditches within ten major neighborhoods in the City of Chattanooga: St. Elmo, South East Lake, East Lake, Highland Park, Orchard Knob, Bushtown, Avondale, East Chattanooga, Brainerd, and North Chattanooga. In the 70-plus years since these ditches were constructed, they have been slowly degraded by elements both natural and anthropogenic. In 1975, attempts were made to rehabilitate these ditches by covering most in a two- inch thick layer of new concrete, but this started to deteriorate over time. Since 1975, there has not been a comprehensive inventory and assessment of the integrity of the WPA drainage ditches. The City of Chattanooga and AMEC Foster Wheeler have begun a WPA Ditch program to prepare a Condition Assessment Report, Ranking System, and Rehabilitation Plan for the WPA Ditch system. The system has been assessed using innovative mobile data collection methods and hydrologic and hydraulic modeling, which can be seamlessly integrated into the City of Chattanooga's existing GIS datasets. Based on the condition assessment, a three pronged scoring system was developed to provide objective information for the City to rank WPA ditches for rehabilitation projects. The three pronged scoring system is based on flood risk, ditch deterioration, and ecological conditions. The scores will be used to develop a suite of rehabilitation alternatives tailored to each WPA ditch ranging from restoration to natural conditions to off-channel storage to resurfacing. This presentation will focus on WPA history, hydraulic modeling, and scoring the WPA ditches for rehabilitation planning.

¹ PE, Water Resources Engineer, AMEC Environment & Infrastructure, Inc., 3800 Ezell Road Suite 100 Nashville, TN 37211, 615-333-0630, Patrick.dobbs@amecfw.com, amecfw.com

THE REDEVELOPMENT OF POND CREEK

Adrian Ward

Tennessee Valley Authority (TVA) Muscle Shoals Reservation has had a long history of service which includes producing munitions during the early part of the 19th century and conducting extensive fertilizer research. The Reservation is split by Pond Creek, which is a tributary to the Tennessee River. Pond Creek has been modified throughout the history of the site. Originally, Pond Creek drained to a large sinkhole located in the middle of the town of Muscle Shoals, Alabama. In the early 1900's, the creek was relocated to drain through TVA's Muscle Shoals Reservation directly to the Tennessee River. Recent concerns due to legacy environmental and flooding issues have created the need to modify Pond Creek once again. This presentation will look at the history of Pond Creek and describe the recent flood studies and stream relocation and levee work conducted at the site.

A HOLE IN OUR BUCKET: HOW AND WHY TENNESSEE NEEDS TO IMPROVE HEADWATER PROTECTION

Paul E. Davis, P.E.

Tennessee waters are protected under both federal and state law. For years, the state program regulating physical alterations (called “ARAP” for “Aquatic Resource Alteration Permit”) under the Tennessee Water Quality Control Act was more protective than the Corps of Engineers program operated under Section 404 of the Federal Water Pollution Control Act (commonly referred to as the “Clean Water Act”). Although the federal law has not changed, recent rulings of the Supreme Court have given new direction on the extent to which headwaters and wetlands are subject to Clean Water Act jurisdiction and protection. Now the Corps protects more of our state’s small headwaters than does Tennessee, whose law and rules identify as “Wet Weather Conveyances” some watercourses that meet the court’s tests for federal jurisdiction. The Corps regulates discharges of dredge or fill material in jurisdictional waters, requiring mitigation for lost aquatic resource function. In contrast, Tennessee allows wet weather conveyances to be eliminated without mitigation or even notice to the state.

A growing body of science supports the position that headwaters, including portions of those small watercourses that Tennessee calls wet weather conveyances, are important and necessary elements of freshwater aquatic systems. For a state that has some of the most diverse aquatic ecology on the planet, that’s reason enough to review and revise our law. Increasing complaints about inconsistency between the agencies add to that. And finally, Tennessee law is arguably in conflict with Section 303 of the Clean Water Act, requiring states to set protective standards for all surface waters.

References: State and federal law and rules will be cited, along with reports and studies of the importance of headwaters in aquatic systems.

ECOLOGICAL LIMIT FUNCTIONS AND HYDROLOGIC ACCOUNTING: AN OASIS ON THE CUMBERLAND PLATEAU

Rodney R. Knight¹

Much has been accomplished in terms of environmental flow research in the Tennessee River basin over the last 7 years. Starting in 2007, a research program was initiated to empirically define the response of fish communities to changes in the annual flow regime. This research defined ecological limit functions using methods that were both unique in approach and spatial scale. While the publications from this research program advanced both the conceptual and empirical understanding of ecological limit functions, one component remains outstanding: the extension of research findings to resource management.

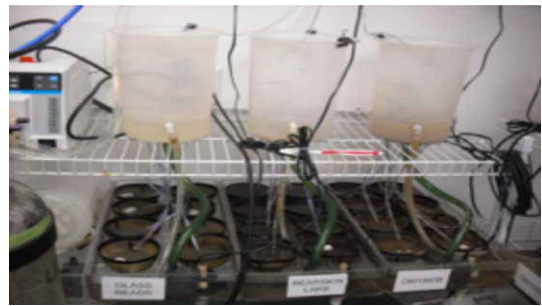
In 2014, the USGS, TWRA, and NPS funded an effort to apply the methods developed for the TN River Basin to the Cumberland Plateau. This effort provides the opportunity to evaluate the transferability of published methods used to develop ecological limit functions to a different geographic area. Importantly, this effort also provides an opportunity to create a scenario-based model linking environmental flow research to resource management – a seldom made connection. The OASIS hydrologic routing and accounting model will serve an important role in this process. This presentation summarizes the current status of ecological limit function development on the Cumberland Plateau and integration of these functions to an OASIS model developed to support decision making in the Obed River basin.

¹ USGS Lower Mississippi – Gulf Water Science Center

DETERMINING THE CHRONIC TOXICITY OF BORON TO THE FRESHWATER MUSSEL (*LAMPSILIS SILIQUOIDEA*) AND THE AQUATIC WORM *LUMBRICULUS VARIEGATUS* IN WHOLE-SEDIMENT EXPOSURES

Scott Hall, Rick Lockwood¹ and Mike Harrass²

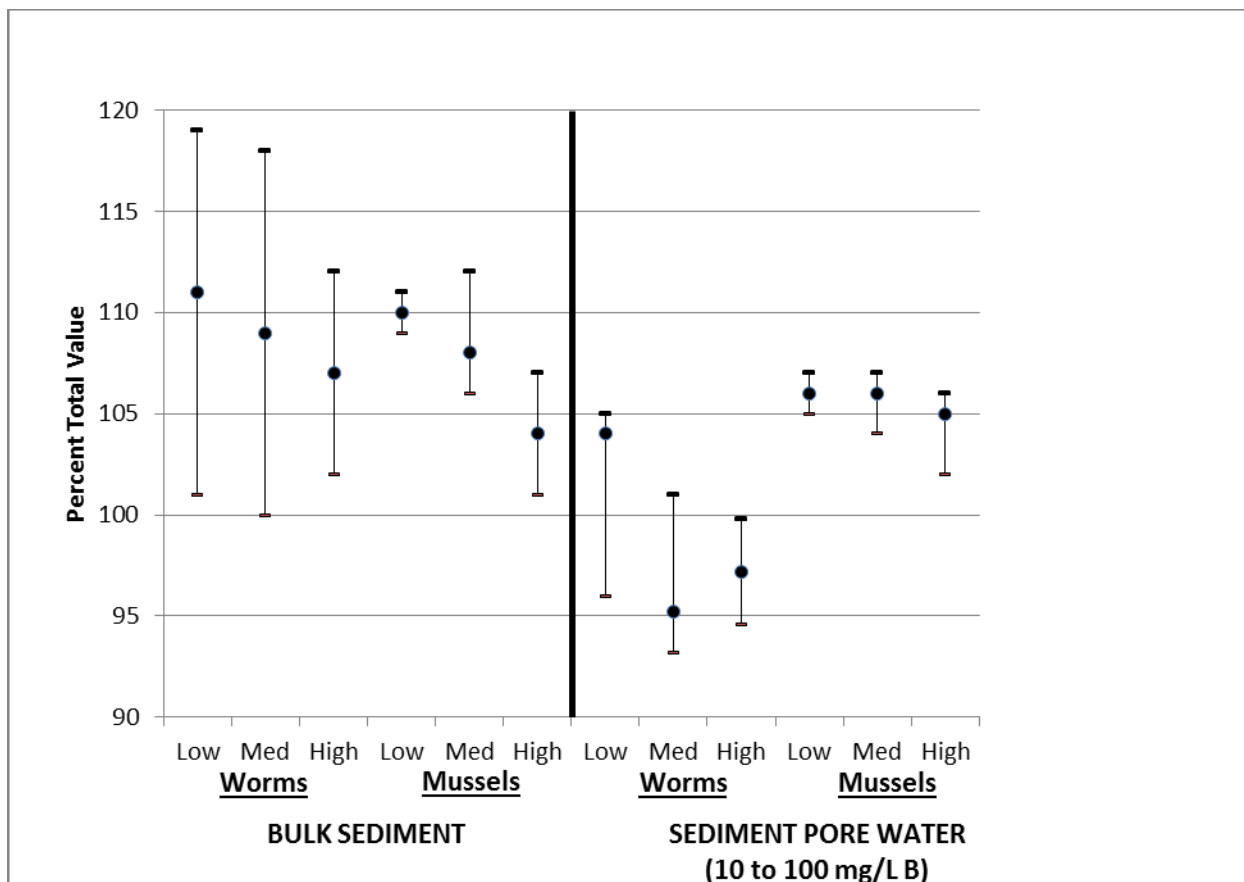
Freshwater mussels are becoming increasingly imperiled in the Tennessee Valley. The sensitivity of freshwater mussels to constituents such as copper and ammonia is becoming increasingly known. However, mussel sensitivity to materials such as boron, which is of relatively low toxicity to other aquatic organisms, is unknown. The chronic toxicity of boron (as boric acid) to the freshwater benthic worm *Lumbriculus variegatus* and Unionid mussel *Lampsilis siliquoidea* was evaluated in 21-day and 28-day tests with natural sediment. Testing was conducted in a flow-through test system.



Initial “range-finding” tests indicated that boron dosed into whole-sediment test substrate was rapidly lost from the flow-through test system due to the high water solubility of boric acid. Boron was therefore added to overlying test waters in concentrations equal to the whole-sediment exposures. This approach resulted in excellent agreement (generally within 10 percent) between nominal and measured total boron concentrations for the three routes of exposure assessed: overlying water, sediment pore-water, and whole-sediment, as illustrated below:

¹ ENVIRON

² Elevance

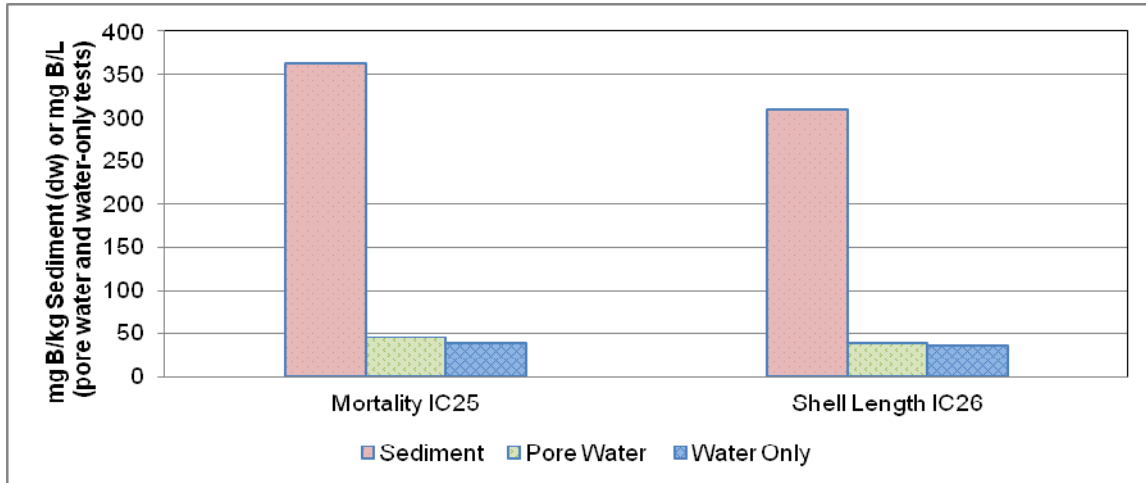


Lethal and sub-lethal (growth) test endpoints were determined for all three exposure routes. The 21-d mussel and 28-d worm IC25 values for growth are summarized below (total B concentrations):

<u>Exposure Basis</u>	<u>IC25 Value</u>	
	<u>Worm</u>	<u>Mussel</u>
Whole Sediment (mg/kg dw)	235	311
Porewater (mg/L)	26	39
Water Only (mg/L)	NA	35

The mussel and worm were of similar sensitivity to boron based on chronic, sub-lethal endpoints.

These results for the mussel are summarized below.



Key conclusions from this study are:

- The mussel and worm are of similar sensitivity to boron
- Lethal and sub-lethal endpoints were similar for mussels
- Water-only exposure's toxicity endpoints and porewater endpoints very similar for mussel
- Flow-through testing of water-soluble materials in sediment is feasible if test compound is added to overlying water

The results of this work, which were developed in accordance with Good Laboratory Practices, were published in the *Archives of Environmental Contamination and Toxicology*, as follows: Hall, W.S., R. Lockwood, and M.C. Harrass, Application of a Unique Test Design to Determine the Chronic Toxicity of Boron to the Aquatic Worm *Lumbriculus variegatus* and Fatmucket Mussel *Lampsilis siliquoidea*, *Arch Environ Contam. Toxicol.* (2014) 66:58-68, 2014.

SEDIMENT QUALITY AND FRESHWATER MUSSELS - ONE PIECE OF THE PUZZLE

Greg Johnson¹

Freshwater mussel declines have been attributed to numerous potential factors including hydrologic alteration, habitat loss, acute and chronic exposures to contaminants in water or streambed sediment. Different species of mussels are susceptible to different stressors, but the mussel declines in streams in Appalachia probably reflect multiple factors. In this study the USGS compared streambed-sediment chemistry and texture to mussel-population status at 21 sites with varying degrees of coal mining influence in the Clinch and Big South Fork of the Cumberland River basins in Tennessee, Virginia and Kentucky. In general the following interrelated patterns were observed:

- 1) The greatest concentrations of metals and organic compounds in streambed sediment were associated with relatively high proportions of silt and clay, and greater amounts of coal in the streambed sediment.
- 2) High mussel-metric values occur with low proportions of silt and clay in the streambed sediment, less coal in the streambed sediment, and lower streambed-sediment concentrations of metals and organic compounds.
- 3) Sites downstream from more intensively coal-mined areas (active or historic) had greater amounts of silt and clay, more coal in the streambed sediment, higher streambed sediment metals and organic compound concentrations, and lower mussel metric values.

A subsequent study of Clinch River sites found elevated water-column concentrations of major ions and metals correlated to areas experiencing mussel declines, but no relation between streambed-sediment concentrations of metals or organic compounds and the areas experiencing mussel declines. The range of streambed-sediment concentrations of metals or organic compounds in the Clinch River study was smaller than the range of concentrations observed with this study (Clinch and Big South Fork of the Cumberland Rivers and tributaries), for which the set of sites encompassed a greater range of watershed and site conditions. The results from both studies will be discussed in context of their relations to mussel population indices and potential future research directions will be outlined.

¹ USGS Lower Mississippi-Gulf Water Science Center

SESSION 1B

HYDRAULICS

1:30 p.m. – 3:00 p.m.

Continuous Flow Simulation for Ungauged Watershed to Calculate Stream Power for Cohesive Soil Erosion Studies

Badal Mahalder, John Schwartz, and Jon Zirkle

Operating Dams for Downstream Water Temperature Change and Water Quality Management: Two Case Studies (Elk and Cumberland Rivers)

Colleen R. Montgomery

Reelfoot Lake Hydrologic Controls and Spillway Operation: Then and Now

Brandon Cobb

TVA FLOOD SYSTEMS

3:30 p.m. – 5:00 p.m.

The Benefits of a Well Managed Reservoir System Using as an Example the Tennessee Valley Authority's Management of the Tennessee River Basin

Daniel P. Saint

Implementing Delft-FEWS at the Tennessee Valley Authority: The Evolution from a Unique, Model-Centric System to an Industry-Standard, Data-Centric System

N. Barber

Flood Control Operations Overview at the Tennessee Valley Authority

Gregory D. Mueller

CONTINUOUS FLOW SIMULATION FOR UNGAUGED WATERSHED TO CALCULATE STREAM POWER FOR COHESIVE SOIL EROSION STUDIES

Badal Mahalder, John Schwartz, and Jon Zirkle

Stream power defines the capability of a stream to keep sediments in suspension and carry through the stream channel. Construction of hydraulic structures on a stream makes the flow path narrower as the structure intervenes the actual flow path significantly. Hence, during peak flow after a large storm event, the flow velocity increases significantly and it makes the infrastructure foundations vulnerable to scour. The erosion rate behavior of cohesive soils is time dependent, thus estimate scour potential requires knowledge of duration of bed shear stress above a critical threshold using cumulative stream power as a surrogate for shear duration. The cumulative stream power can be easily calculated from long term flow data if available from gauged sites; however most stream sites will be ungauged. Henceforth, these circumstances rely on long term hydrologic flow simulation using available hydrologic models, and model calibration and validation are necessary by the hydrologic modeler. In this paper, validating the simulated continuous flows of ungauged streams used flood frequency curves per TDOT regression equations for the modeled urban/rural watersheds. Then using HEC-HMS model, flood frequency curves were generated and results compared. Finally, the continuous simulation was conducted using HEC-HMS model based on a gauged watershed's parameters similar to that of ungauged watersheds. The simulated flow was used for flood frequency curves construction using Gumbel distribution, and the results were compared with the previous two methods. Cumulative stream power was calculated from the simulated flows of ungauged watershed, and compared with bridge scour measurements at cohesive bed/bank sites.

OPERATING DAMS FOR DOWNSTREAM WATER TEMPERATURE CHANGE AND WATER QUALITY MANAGEMENT: TWO CASE STUDIES (ELK AND CUMBERLAND RIVERS)

Colleen R Montgomery, M.S., P.E¹

Water temperatures have been altered on two Middle Tennessee rivers by changes to releases at two dams; one by choice, and one to facilitate dam repairs. Although neither situation was pleasant for the managing utilities, both provided the opportunity gain operational knowledge from releasing water from the dams in novel ways, and to ultimately benefit downstream habitat.

This “tale” of two rivers contrasts how the altered dam releases over the past seven years have changed the water temperature, water quality and fish populations downstream of Tims Ford and Wolf Creek Dams. Both are large, tall dams but their situations and desired outcomes were completely opposite. The Tims Ford tailwater reach had very cold water temperatures that threatened and endangered fish species. These were warmed to more tolerable levels with unique operational changes.

The middle Cumberland River reach during the Wolf Creek dam rehabilitation project had warmer than normal water temperatures, decreased dissolved oxygen levels, decreased fish diversity, and significantly reduced power generation. These things were partially mitigated by altered operations from downstream dams to cool the river temperatures and improve water quality.

Numerical modeling, field data collection and analysis, and field trials of different dam release scenarios have all provided valuable insight into the best ways to mitigate the water temperature extremes for both the “too cold” and the “too warm” summertime river situations, yielding operational lessons and possible solutions for future flow and water temperature management challenges while still following prescribed reservoir operating guides and without significant capital expenditure on new outlet structures.

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REELFOOT LAKE HYDROLOGIC CONTROLS AND SPILLWAY OPERATION: THEN AND NOW

Brandon Cobb¹

Reelfoot Lake, located in Obion and Lake Counties, Tennessee, is a shallow natural lake that was formed by the New Madrid Earthquakes of 1811 and 1812. Water levels in this 19,000 acre lake have historically been regulated by a stop-log control structure. Stop-logs measuring 10 feet long by 15 inches tall were added or removed to control water levels to meet multiple management goals, including flood mitigation, wildlife management, and recreation and tourism. Water levels of Reelfoot Lake reflect the balance between streamflow entering the lake from Reelfoot Creek, Indian Creek, and Bayou du Chien and discharge through the control structure into Running Reelfoot Bayou. In 2013, the stop-log control structure was replaced by a series of computer-controlled lift gates measuring 20 feet long by 12 feet tall. These gates require a new set of operational guidelines to maintain target water levels in, and discharge from, the lake. The U.S. Geological Survey, in cooperation with Tennessee Wildlife Resources Agency, is analyzing interactions among tributary inflows, discharge through the new control structure, and water levels in the lake. A comparison between the operations of the old and new spillways establishes a basis for managing the new structure to replicate historical operation or meet revised management targets in the future. A description will be presented of how the new structure will be operated in response to changing lake levels.

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THE BENEFITS OF A WELL MANAGED RESERVOIR SYSTEM USING AS AN EXAMPLE THE TENNESSEE VALLEY AUTHORITY'S MANAGEMENT OF THE TENNESSEE RIVER BASIN

Daniel P. Saint¹

INTRODUCTION

The Tennessee Valley Authority was formed in 1933; since then it has been successfully managing the Tennessee River Basin. Throughout the years the TVA has learned many lessons and had to adapt to changing conditions in order to properly manage the 49 reservoirs that it manages. In recent years the impacts of a man-made reservoir has been questioned and challenged; although there are many valid reasons to re-evaluate the impact of a reservoir, the necessity and benefits of the Tennessee River System needs not to be forgotten. Perhaps evaluating the benefits of the man-made reservoirs within the Tennessee River Basin would help others as they evaluate reservoirs on an individual basis.

APPROACH

Since its formation in 1933, the Tennessee Valley Authority has recorded insurmountable amounts of information which can be retrieved, analyzed and interpreted. This historical data offers an understandable interpretation to the value of the reservoirs within the Tennessee Valley River Basin. For this analysis, the basin will be looked at holistically and the reservoirs will not be addressed individually, as this would be an impossible feat for the amount of time allotted. One could interpret the records to prove that a particular reservoir possibly has more “value” or “benefit” than another, but that was not done for this study.

RESULTS AND DISCUSSION

Among the benefits provided by the dams in the Tennessee River Basin are: navigation, flood-damage reduction, power generation, water supply, recreation, and water quality. On average, \$260 million of flood damages are averted annually as a result of the optimization of the reservoir system. Annual saving to shippers are estimated to be in excess of \$500 million from the navigation system, as well as providing passage for some 18,000 recreational vessels. The dams equipped with hydropower generators have the capacity to generate 3,538 megawatts of clean, renewable, cheap, on demand power which has vast benefits to the rate payers within the Tennessee Valley. Approximately 4.5 million people depend on the Tennessee River and its tributaries for drinking water as well as countless industries along the shores of the Rivers. The reservoirs are also operated to provide numerous recreational opportunities on the waters throughout the Tennessee River Basin. In order to operate a reservoir system the size of the Tennessee River Basin, there are locations where water quality needs to be monitored and improved in order to support aquatic life. TVA works hard to balance the competing demands of power generation, recreation, water supply, flood control, and water quality.

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IMPLEMENTING DELFT-FEWS AT THE TENNESSEE VALLEY AUTHORITY: THE EVOLUTION FROM A UNIQUE, MODEL-CENTRIC SYSTEM TO AN INDUSTRY- STANDARD, DATA-CENTRIC SYSTEM

N. Barber

Like most water-related agencies around the world, computer modeling drives decision making, research, and planning for the future. At the Tennessee Valley Authority (TVA), this dependence on computer modeling is not any different. TVA currently models river levels, discharge, water temperature, and several other parameters to ensure its large portfolio of power plants (hydro, nuclear, coal, natural gas, etc.) provide the necessary amount of power to the grid, while actively mitigating anthropogenic effects that can disrupt the natural system. This important balance requires a robust system that can manage large quantities of real-time data, promptly update decision-making models, allow users and autonomous processes to quality control that data, and swiftly deliver model results to end-users. While sections of this workflow have existed for some time, the current system lacks cohesion, long-term stability, and the dynamics required to improve modeling into the future. To achieve these goals, TVA is currently implementing Delft-FEWS, a data-centric, hydrologic, modeling system now used in over 50 countries. Delft-FEWS (Delft-Flood Early Warning System) will aggregate numerous TVA-developed models with several, proven third-party models such as the NOAA National Weather Service's Sacramento Soil Moisture Accounting Model, into one centrally-managed system. FEWS will allow forecasters and users to logically step through model input and output, allowing them to better understand the underlying model physics. FEWS will significantly improve troubleshooting procedures, given that the data and models are all managed by a central database with a real-time java messaging service. With an industry-standard infrastructure, FEWS will also allow TVA to partner with outside agencies, domestic and abroad, to further its mission of leading the Tennessee Valley region and the nation toward a cleaner and more secure energy future.

FLOOD CONTROL OPERATIONS OVERVIEW AT THE TENNESSEE VALLEY AUTHORITY

Gregory D Mueller¹

The TVA flood control mission is clearly stated in the TVA Act. Section 4j says that TVA “shall have the power to construct such dams, and reservoirs... to promote navigation on the Tennessee River and its tributaries and control destructive flood waters in the Tennessee and Mississippi River drainage areas.” River Management at TVA also has the responsibility of balancing flood control with other competing operating objectives such as water quality, water supply, navigation, hydropower production, and recreation.

TVA uses a simple hydrologic principle to manage the reservoir system for flood control. Available reservoir flood storage space is temporarily utilized to store excess river flows and reduce the downstream river flows and stages to non-damaging levels to the maximum extent possible. This simple principle gets complicated by the nature of the river system itself: Rainfall, and thus runoff, can vary greatly over the entire basin; the response time of the TVA river system is very rapid; each reservoir is different, and not all reservoirs were built to provide flood control; most reservoirs are multi-purpose, so there are competing objectives; and flood control reservoirs have a limited capacity. And because many public constituents are unaware of the limitations to TVA’s flood control capabilities, many have unrealistic expectations of what TVA can do to minimize flooding.

Fifteen flood damage centers are located throughout the Tennessee River Valley. Before TVA commenced flood operation activities, the narrow mountain passes below the City of Chattanooga would cause flooding within Chattanooga during major storms since flows through the gorge were severely limited. Historically, water backed up into the City of Chattanooga about once per year. This is part of the reason that approximately 90% of the potential flood damages in the Tennessee River Valley are averted at Chattanooga.

During flood damage reduction operations, river forecasts are updated up to four times a day. Because the River Forecast Center is staffed 24 hours a day, 365-days a year, continual adjustments to the forecasts and operations can be made in response to changing weather conditions. RiverWare and other hydrologic models are used to predict crest elevations at the various flood damage centers and at other locations downstream of TVA dams. As the accuracy of the inflows and crest forecasts are so critical to how TVA utilizes its flood storage space, we are currently upgrading our Forecast System to utilize Delft-FEWS, and HEC-RAS models to further refine our flood forecasting abilities. Delft-FEWS will allow us to better manage and process the data we use, while the new, hourly HEC-RAS models will allow us to improve the crest forecasts.

While the TVA reservoir system prevents millions of dollars in flood damages in an average year, the reservoir system will never prevent all flooding. Despite this, The River Forecast center can

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maximize the flood damages averted by the quick response to storms within the basin as a result of continual improvements to the tools being utilized and the around-the-clock staffing of the River Forecast Center.

REFERENCES

Tennessee Valley Authority. 2014. TVA: Flood Damage Reduction. [ONLINE] Available at: <http://www.tva.com/river/flood/index.htm>. [Accessed 23 February 15].

SESSION 1C

REMOTE SENSING APPLICATIONS

1:30 p.m. – 3:00 p.m.

Automated Identification of Sediment Sources and Sinks: Tool Development to Support Water Quality Planning

Jennifer Cartwright

Comparative Flood Consequence Assessment for Different Digital Elevation Data Over Cumberland River Near Nashville

Md N.M. Bhuyian

Using GIS Techniques and Terrain Analysis to Develop a Dataset of Karst Features for Tennessee

David E. Ladd

SEDIMENT

3:30 p.m. – 5:00 p.m.

Evaluating the Impacts on Runoff of Landscape-Based Best Management Practices in Intensively Managed Watersheds

A.N. Thanos Papanicolaou, Mohamed Elhakeem, Christopher G. Wilson, and Benjamin K.B. Abban

Characteristics of Fine Sediment Transport Along Hillslope Concentrated Flow Pathways Caused by Cattle Traffic

Zachariah T. Seiden, John S. Schwartz, Daniel Yoder, and Forbes Walker

Suspended-Sediment Concentrations at Six Highway-Construction Outfalls

T. Diehl

AUTOMATED IDENTIFICATION OF SEDIMENT SOURCES AND SINKS: TOOL DEVELOPMENT TO SUPPORT WATER QUALITY PLANNING

Jennifer Cartwright^{1*}

Water-quality improvement practices, including sediment retention and channel restoration projects, are commonly hampered by incomplete knowledge of sediment-source locations and transport networks within watersheds. In particular, gully systems can undermine infrastructure and pose public safety hazards through active bed and bank erosion and excessive sedimentation near their outlets. High-resolution digital elevation models (DEMs) from Light Detection and Ranging (LiDAR) are a newly-available data source useful for investigating geomorphology of stream channels and gullies. Channel and gully networks derived from these DEMs offer much higher resolution than currently available topographic maps or map-derived stream networks. The U.S. Geological Survey is working in cooperation with the Tennessee Department of Transportation and the Southwest Tennessee Development District to develop automated tools to identify locations of erosion, sediment transport, and deposition within channel and gully networks, based on landscape characteristics derived from high-resolution DEMs. By automating the identification of hotspots of channel erosion (for example incised channels and gully heads) and sedimentation (for example over-widened shallow channels and valley plugs) this project will provide a tools for local and regional efforts related to water quality, channel restoration, infrastructure protection, and storm-water management.

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COMPARATIVE FLOOD CONSEQUENCE ASSESSMENT FOR DIFFERENT DIGITAL ELEVATION DATA OVER CUMBERLAND RIVER NEAR NASHVILLE

Md N M Bhuyian¹

Flood modeling and damage assessment requires extensive surveyed data which are often cost prohibitive and time consuming. To offset the use of *in situ* data several methods are in practice to derive data from alternate sources. Topographic data is one of primary input in flood modeling, which can be collected through either field survey or via remote sensing. Digital Elevation Model (DEM) is commonly used as a substitute for surveyed topographic data. DEM varies by source, acquisition technique and spatial resolution which in turns influence their applicability. Selection of suitable DEM and optimum spatial resolution is thus a key for achieving expected accuracy within sufficient simulation time. This study will compare DEM from different sources (i.e. SRTM, ASTER, NED and LiDAR) with various spatial resolutions for a 35 mile long stretch of Cumberland River downstream of Old Hickory dam in Tennessee. The study period is considered as 2010 Nashville Flood to estimate flood losses in downstream especially in urban areas. Objective of this study is to quantify the comparative deviation of model accuracy for each specific set of topographic data. Hydrodynamic model will furnish input for flood damage assessment. Hydrologic Engineering Centers Flood Impact Analysis (HEC FIA) will be employed to estimate flood damage for each scenario. It is expected that this analysis will assist decision managers for selecting the appropriate DEM for flood damage assessment and get reasonable result within convenient time. It is also expected that this study will indicate possible range of uncertainty that may arise if global DEMs (i.e., SRTM, ASTER) is used which then can be referred for their application in remote and less developing areas.

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METHODOLOGY

The study compares performance of model setups generated from LiDAR, NED, SRTM and ASTER DEM. By performance it means error in simulated hydraulic parameters and flood consequence assessments. The study follows the following workflow as shown in Figure 1. The study comprises of four major steps.

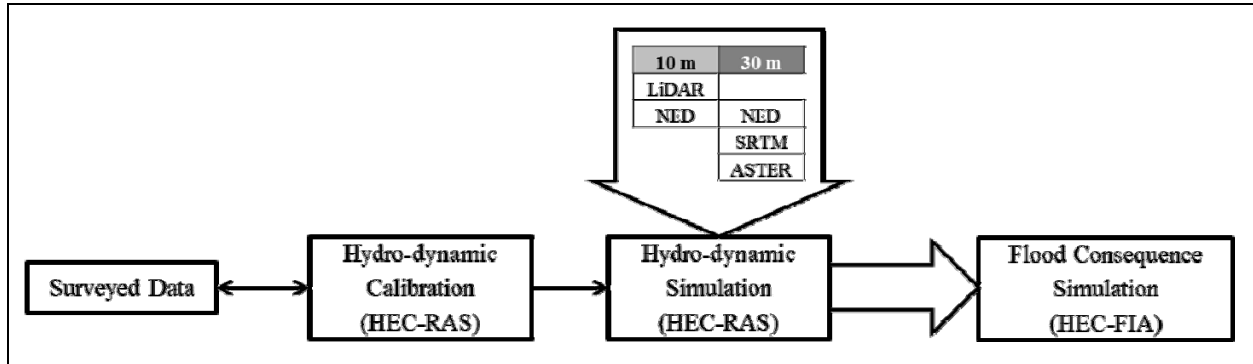


Figure 1. Methodology Flow chart.

1.1. Model Setup: River centerline, bankline were drawn using Google Earth image and cross sections were same as surveyed ones. Longitudinal slope of the river was drawn using the depth at approximate centerline at each cross section. Longitudinal slope for DEM correction algorithm was calculated using the trend line (linear) slope. A model using surveyed cross section was used to calibration simulation and five separate models were set for other digital topographic data sets. The study tests 10 m spatial resolution LiDAR, NED and 30 m NED, SRTM and ASTER digital elevation data. The model consisted of 68 cross sections but no structure across the channel was considered. The simulation event is 2010 Nashville flood.

1.2. Model Setup: River centerline, bankline were drawn using Google Earth image and cross sections were same as surveyed ones. Longitudinal slope of the river was drawn using the depth at approximate centerline at each cross section. Longitudinal slope for DEM correction algorithm was calculated using the trend line (linear) slope. A model using surveyed cross section was used to calibration simulation and five separate models were set for other digital topographic data sets. The study tests 10 m spatial resolution LiDAR, NED and 30 m NED, SRTM and ASTER digital elevation data. The model consisted of 68 cross sections but no structure across the channel was considered. The simulation event is 2010 Nashville flood.

1.3. Hydro-dynamic Calibration (HEC-RAS): The model that uses surveyed data as its sources is considered as “Control” scenario and will be used to estimate errors in other five scenarios. This model is here after named as Surveyed. The model was calibrated using the surveyed cross sections. Manning’s roughness factor was selected as calibration parameter. The simulated flood extent was also compared with actual flood inundation map to validate assure the performance of the control scenario.

1.4. Hydro-dynamic Simulation (HEC-RAS): The model was simulated in 1D HEC-RAS platform for five different topographic data sources. The calibration parameters are kept same for

all the simulations. Corresponding flood parameters (i.e. stage, flow, inundation extent) were generated to be used in impact assessment simulation.

1.5. Flood Consequence Simulation: HEC FIA was used to estimate flood loss for the study event. The simulated event using Surveyed elevation was considered as “Control” event. The rationale for selecting this as control scenario is that it is mostly derived from observed data and hence expected to have best agreement with the actual field condition. Local inventory such as structures, administrative area, agriculture were generated from Hazus 2010 database. The hydraulic parameters of the event were either generated using results from HEC-RAS or geometric files as used for each specific scenario.

PRELIMINARY RESULTS

Calibrated model setup was simulated for 30 m NED, SRTM and ASTER to simulate them for same 2010 event. Figure 2 shows the hydrographs derived from all three simulations along with observed flow at Nashville. It is noticeable that NED is able to flow the phase of flow raising and recession although the variation of flow is very high. SRTM and ASTER could not follow the flow phases. This indicates that these models actually went unstable and producing unreasonable values. Table 1 shows the simulation performance of 30 m NED and SRTM. Figure 2 shows the flood consequence assessment for these two simulations. Complete study will include similar results for 10 m LiDAR and NED and 30 m ASTER.

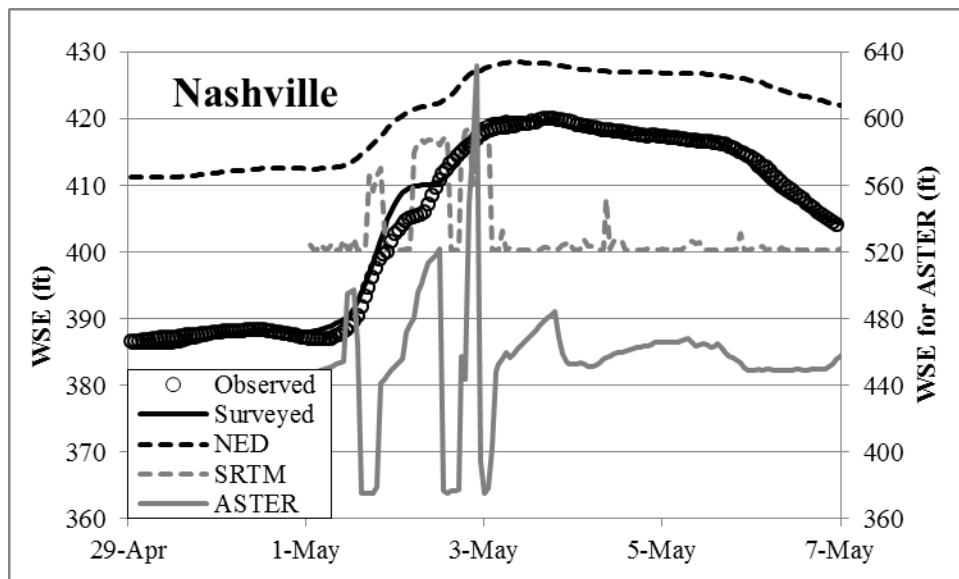


Figure 2. Hydrographs derived from preliminary simulations along with observed flow at Nashville.

Table 2. Performance of the Simulated Flood Stages and Inundation Extent.

Parameter	Topography	Observed	Surveyed	NED	SRTM
Inundated Area	Cell Size	-	-	30 m	30 m
	Sq. Miles	16.2	16.2	21.8	33.4
WSE	Error	-	0.1%	34.4%	105.8%
	Mean Error (ft)	-	-0.37	-16.1	7.6
	RMSE (ft)	-	1.53	17.3	13.6

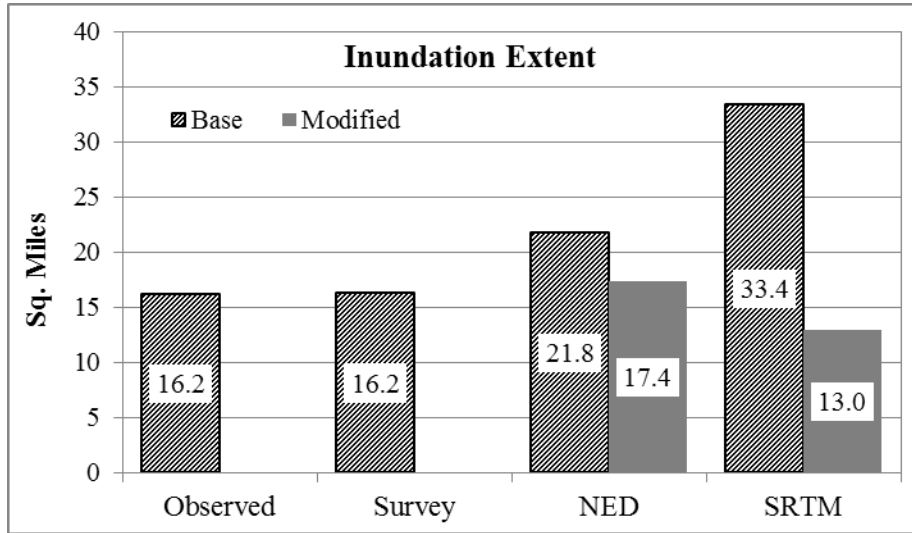


Figure 2. Total loss in billion USD for different scenarios.

USING GIS TECHNIQUES AND TERRAIN ANALYSIS TO DEVELOP A DATASET OF KARST FEATURES FOR TENNESSEE

David E. Ladd¹

Closed karst depressions (sinkholes), in areas underlain by carbonate rocks, present a number of challenges to the planning and construction of roads and other public works, natural-resources management, and topographic analysis. Spills along roadways and other types of contamination that enter karst-feature drainage areas have the potential to rapidly and adversely affect groundwater quality. The identification and delineation of karst features and their drainage areas are crucial to water-resources protection in karst areas. Identifying and delineating sinkholes from topographic maps is a tedious process. Digital Elevation Models (DEMs) provide a means to automate the identification of closed depressions on local and regional scales, but success of such efforts depends on the accuracy and resolution of the source elevation data. The simple mathematical analysis of DEMs to delineate closed depressions typically misidentifies a substantial number of features. In addition to simple mathematical analysis, numerical error propagation tests can be used to assess the identification of karst features, and digital filters can be applied to reduce the uncertainty in identification. Geographic Information System (GIS) techniques for identifying karst features and their drainage areas using DEMs have been tested on limited areas, but these techniques have not been thoroughly tested across Tennessee. The U.S. Geological Survey, in cooperation with the Tennessee Department of Transportation, is applying GIS techniques to identify karst features using DEMs on a regional scale, assess the identified features, and produce a karst GIS dataset for the State of Tennessee.

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EVALUATING THE IMPACTS ON RUNOFF OF LANDSCAPE-BASED BEST MANAGEMENT PRACTICES IN INTENSIVELY MANAGED WATERSHEDS

A.N. Thanos Papanicolaou^{1*}, Mohamed Elhakeem², Christopher G. Wilson³,
and Benjamin K.B. Abban⁴

Conversion of natural prairie or forested landscapes in the U.S. to intensively managed landscapes has altered runoff and stream hydrology by creating more dynamic surface water flow regimes and increasing the likelihood of severe floods. Flooding and the associated water quality issues adversely affect downstream ecosystem health and water availability. In response to these concerns, Best Management Practices (BMPs) have been adopted to increase runoff retention and reduce sediment delivery. Common BMPs, such as grassed waterways and other vegetative buffers, have been found to reduce effectively runoff/sediment conveyance by slowing water flow and increasing infiltration rates. This study examined the storm-event based efficiency of these buffers at reducing runoff using the Water Erosion Prediction Project (WEPP) model. Buffer efficiency was governed by the hydrology, expressed as Q_{peak} . The buffers were more efficient during events with smaller Q_{peak} values, while the efficiency decreased during larger events. Building on these simulations for a single hillslope, a standardized hydrologic analysis was conducted using established hydrologic modeling techniques (i.e., WIN TR-20) to quantify and mitigate potential flooding impacts for the entire watershed. The results suggested that the landscape changes are best used as secondary efforts, since a high level of land use conversion was needed to produce significant runoff reductions. Average reductions in runoff volumes of about 15% were observed for a 50% conversion of agricultural land to grasslands. However, these land conversions will likely decrease sediment and contaminant loads in the streams, which has other significant benefits.

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CHARACTERISTICS OF FINE SEDIMENT TRANSPORT ALONG HILLSLOPE CONCENTRATED FLOW PATHWAYS CAUSED BY CATTLE TRAFFIC

Zachariah T. Seiden¹, John S. Schwartz², Daniel Yoder³ and Forbes Walker⁴

In agricultural watersheds, one dominant contributor to water quality pollutants stems from the presence of livestock through unmanaged pasture land and physical degradation of stream banks. These impacts introduce excessive nutrient and bacterial contaminants related to cattle manure, and fine sediments to streams resulting from erosion on bare soil surfaces. Though best management practices by fencing livestock out of the stream riparian corridor and good rotation management have been shown to reduce these impacts, little is known about pollutant transport from the hillslope along livestock-created, concentrated flow pathways (cow paths). Cattle have a tendency to travel along linear pathways that traverse the side of the hill. This terracing results in linear corridors that can transport and discharge runoff and hillslope pollutants directly into a stream. To characterize the extent to which these linear corridors influence runoff and pollutant transport on the hillslope, Pinson bucket samplers were installed to collect the runoff and sediment transport from cattle paths and from unaltered control sites along the same hillslope. Runoff and pollutant transport were characterized in relation to storm intensity and total discharge. To verify that the impacts from the cattle paths are not localized to a single hillslope, two different cattle farms were monitored. In addition, one farm had samplers on parallel cow paths in order to determine if there is a threshold intensity where flow will move across the cow path. This research will result in a better understanding of concentrated flow and pollutant transport on pasture hillslopes within a watershed, and thus support development of improved watershed management practices.

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SUSPENDED-SEDIMENT CONCENTRATIONS AT SIX HIGHWAY-CONSTRUCTION OUTFALLS

T. Diehl

Highway construction activities contribute sediment to streams, including exceptionally clean streams little affected by other sources. Various methods of erosion protection and sediment controls (EPSCs) are used to reduce the turbidity and suspended-sediment concentration (SSC) of water leaving construction sites. During the construction of State Route 840 (SR840) in 2008 to 2012, enhanced EPSCs were applied with the intent of decreasing SSC and turbidity leaving the construction area to the lowest practical levels. In this study, turbidity and SSC were monitored at two outfalls on the SR840 project, and at one outfall at each of four other highway-construction projects where the primary EPSCs were blown straw cover and silt fences around the perimeters of disturbed areas.

One outfall at SR840 was monitored using a flume, which allowed observation of low flows not sampled at the other sites. At this site, following a four-day period during active construction in which runoff water was turbid even during low flows, turbidity and SSC returned to pre-construction levels after permanent stabilization of the disturbed areas. At the other SR840 outfall, turbidity and SSC during active construction were comparable to pre-construction turbidity at the site with the flume.

Water at the four non-SR840 outfall sites had much higher maximum SSC and turbidity, and turbidity was high for a larger percentage of the time over which monitoring occurred. Maximum turbidities exceeded the ranges of continuous turbidity monitors, and the two types of turbidimeter deployed gave inconsistent results. Deficiencies in the continuous turbidity data suggest that pumped samples are needed for defining EPSC performance. While observations at these few sites can't be used to define average performance of typical EPSCs, the departure of SSC and turbidity from reference conditions were dramatically greater than those observed at SR840.

SESSION 2A

NUTRIENTS

8:30 a.m. – 10:00 a.m.

Development of the Algae Trophic Index: A New Tool to Evaluate the Impacts of Aquatic Nutrient Pollution

Jefferson G. Lebkuecher, Elizabeth N. Tuttle, Jessica L. Johnson, and Nickolas K.S. Willis

Nitrogen and Phosphorus Removal Using Existing Wastewater Treatment Equipment: The Tennessee Experience

Grant Weaver and Karina Bynum

Progress in Understanding Sulfur Nutrient Cycling in the Great Smoky Mountains National Park

Adrian Gonzalez, John S. Schwartz, and Matt A. Kulp

MS4

10:30 a.m. – 12:00 p.m.

Water Quality Volume Trading

Mounir Minkara

Going Digital: The Visual Stream Assessment for Unincorporated Shelby County, Tennessee

Eric Goddard and Scott Schoefernacker

Three Tasks, One Tablet: Condition Assessments Go Mobile in Chattanooga

Bradley Heilwagen, Whitney Fuquay and Robert Berger

STORMWATER CONTROL MEASURE

1:30 p.m. – 3:00 p.m.

Predictive Performance Scaling of Hydrodynamic Separators Using the Peclet Number

Mark Miller

Estimating Load Reduction Costs for Assessing Stormwater Best Management Practice (BMP) Feasibility: A Case Study of James Lane Allen Elementary

Russ Turpin

Lessons Learned from Metro Nashville's Stormwater Control Measure (SCM) Oversight Program

Anneli Terry Nelson

WATER RESOURCES

3:30 p.m. – 5:00 p.m.

The Effects of Roadway Construction on Benthic Invertebrates in Two Middle Tennessee Streams
R. Deedee Kathman and Todd W. Askegaard

Effects of Extreme Flooding on a Flatrock Stream and Subsequent Recovery
William J. Wolfe, Timothy H. Diehl, and Greg E. Hileman

A Comparison of Three Thermoelectric Water-Use Data Sets in the Southeastern United States
Melissa A. Harris

DEVELOPMENT OF THE ALGAE TROPHIC INDEX: A NEW TOOL TO EVALUATE THE IMPACTS OF AQUATIC NUTRIENT POLLUTION

Jefferson G. Lebkuecher¹, Elizabeth N. Tuttle, Jessica L. Johnson, and Nickolas K. S. Willis

Knowledge of the effects of nutrient concentration on the composition and structure of photoautotrophic periphyton is essential to understand the impact of eutrophication on shallow lotic systems. Reaches of Sulphur Fork Creek upstream and downstream of effluent from Springfield Wastewater Treatment Plant in Middle Tennessee were sampled to assess the effects of trophic state on characteristics of photoautotrophic periphyton including composition of diatom and soft-algae assemblages. Pearson's correlation coefficient (r) for \log_{10} -transformed concentrations of soluble reactive phosphorus (\log_{10} [SRP]) to percent composition was significant for 4 of 63 soft-algae taxa sampled from cobbles. Five algae trophic indices (ATI) to assess the effects of trophic state on soft-algae assemblages were developed using different taxon-trophic indicators which included: (1) r values for \log_{10} [SRP] to percent composition (ATI_r), (2) abundance-weighted averages of [SRP] (ATI_{A-WA} [SRP]), (3) abundance-weighted averages of \log_{10} [SRP] (ATI_{A-WA} \log [SRP]), (4) weighted averages of \log_{10} [SRP] where the taxa occur, and (5) abundance-weighted ranks to phosphorus tolerance listed by the National Water-Quality Assessment Program. Eutrophication-induced impairment of Sulphur Fork Creek downstream of the effluent from the wastewater treatment plant was indicated by: (1) high concentrations of photoautotrophic periphyton, (2) low values for the Pollution Tolerance Index of diatom assemblages, (3) positive values for the ATI_r , and (4) high values for both the ATI_{A-WA} [SRP] and ATI_{A-WA} \log [SRP]. Of the indices using soft-algae taxa evaluated, the ATI_r exhibits the strongest and significant correlations to [SRP], [$NO_2 + NO_3$ nitrogen], and the Pollution Tolerance Index of diatom assemblages. The ATI_r accurately reflects the trophic state of the sites studied and provides a novel additional tool to evaluate the effects of nutrient concentration on the structure of photoautotrophic-periphyton assemblages.

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NITROGEN AND PHOSPHORUS REMOVAL USING EXISTING WASTEWATER TREATMENT EQUIPMENT: THE TENNESSEE EXPERIENCE

Grant Weaver¹ and Karina Bynum²

The implementation of Tennessee's Nutrient Reduction Framework encompasses best management practice strategy for non-point sources as well as point source nutrient reduction strategy through performance standards, policy and permitting within the watershed.

As a first step in the point source nutrient strategy, wastewater treatment plants are encouraged to evaluate and operate existing equipment differently in order to determine and utilize their current capability for nitrogen and phosphorus removal. Fine-tuning wastewater treatment processes to optimize the use of the existing capacity requires the creation of optimal biological habitats for nutrient removal. Using targeted monitoring of key operational parameters, wastewater operators are able to combine the new information with their knowledge of wastewater treatment. Motivated and informed wastewater operators equipped with timely, in-plant data are able to achieve notable results.

Survey of wastewater systems participating in a one day training show the level of engagement and interest of wastewater operators in biological nutrient removal. Three wastewater systems used a direct technical assistance through a 604b EPA watershed planning grant for an extensive in-plant training and optimization of treatment for biological nutrient removal. The early results and lessons learned are presented.

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² MSCE, P.E., TDEC Division of Water Resources

PROGRESS IN UNDERSTANDING SULFUR NUTRIENT CYCLING IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

Adrian M. Gonzalez¹, John S. Schwartz^{1*}, and Matt A. Kulp²

Availability of the essential nutrient sulfur is regulated by a system of biogeochemical processes. Source terms in the sulfur cycle equation include atmospheric deposition and sulfidic mineral components in bedrock geology. Both are germane to forested watersheds in the GRSM. Air-emissions data from large, regional point-sources, combined with long-term monitoring data of GRSM precipitation, have demonstrated a striking relevance of atmospheric deposition to the GRSM sulfur cycle. However, data from concurrent monitoring of stream water sulfate have shown a curious uniformity in the flux of inorganic sulfur exported from these same forested watersheds. Data from watersheds underlain by bedrock with an appreciable sulfidic mineral component have shown a strong spatial influence of pyritic weathering when compared to watersheds lacking a sulfidic mineral component, but no clear temporal correlation to changes in the atmospheric input rates were evident. Current understanding the GRSM sulfur cycle suffers from knowledge gaps of sulfur *storage* within GRSM. In response, a research study is planned to investigate how sulfur is stored, processed (transformed) and released to export in the GRSM.

Traditional physical/chemical methods and stable isotope ($\delta^{34}\text{S}$ and $\delta^{18}\text{O}$) analyses will provide information on sulfur speciation, and data for calculating sulfur mass budgets within and among environmental compartments (precipitation, bedrock, soil, water and biota). Relative sulfur mass contributions from atmospheric deposition and bedrock will be quantified through their unique stable isotope signatures. Study results will contribute to understanding biogeochemical cycling of GRSM sulfur and the cumulative influence of atmospheric deposition on GRSM ecosystems.

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WATER QUALITY VOLUME TRADING

Dr. Mounir Minkara¹

The City of Chattanooga's NPDES Permit is the state's first permit to require a 1" runoff reduction standard. To comply with this standard, Chattanooga passed a new stormwater ordinance on _____ requiring all new and redevelopment sites to utilize the City's Rainwater Management Guide (RMG) when designing for their projects' capture volume, or Stay-on-Volume (SOV). Jointly addressed in the ordinance was the mandate to provide an incentive program to increase the use of green infrastructure. Chattanooga developed a new program framework based on a system of incentives, fees, and credits for property owners and developers. The new program expands the applicability of incentives over the existing credit program and incorporates consistent performance standards and metrics. One of the more innovative credits developed is the use of water quality volume trading. The City of Chattanooga is establishing an open market for the sell, trade, and use of Credit Coupons that are earned in units of cubic feet through the exceedance of a baseline SOV. Earned or purchased coupons can be used to meet the runoff reduction volume of a site that cannot fully meet the standard onsite. Credit Coupons serve to: 1) encourage development in areas that better accommodate green infrastructure practices; 2) provide a market-based approach that facilitates trading of credits; 3) facilitate and encourage redevelopment and retrofit; and 4) provide a counterbalance to off-site mitigation and mitigation fees.

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GOING DIGITAL: THE VISUAL STREAM ASSESSMENT FOR UNINCORPORATED SHELBY COUNTY, TENNESSEE

Eric Goddard and Scott Schoefernacker

INTRODUCTION

The University of Memphis' Center for Partnerships in GIS and the Ground Water Institute in conjunction with CDM Smith and Powers Hill Design performed a visual stream assessment of approximately 160 miles of stream to identify impairments and general stream characteristics within unincorporated Shelby County using a custom Android application for data collection. The custom application streamlined data collection with attachments and synced with an ArcGIS geodatabase, which allowed for instantaneous data review once back at the office. On the backend, linear referencing was implemented to improve the accuracy and presentation of the linear impairments (channel alteration, erosion site, inadequate buffer, and stream construction). As well, Python scripts were developed and applied to assist in data QA/QC and the export of data to regulatory spreadsheets. The project resulted in a comprehensive geodatabase of inventoried stream impairments with the ability to be queried and updated in a digital format.

APPLICATION CREATION

Instead of using the traditional pen-and-paper data collection methodology, a custom Android application was created using the ArcGIS for Android Application Programming Interface (API) for inexpensive off-the-shelf Android tablets. The application allows users to create and update impairments using forms based on Yetman's (2001) Stream Corridor Assessment Survey. Using tablets for field data collection improved the speed and accuracy of the survey by using pre-populated options whenever possible on the application's forms, making use of the sensors and cameras that are built into the tablet, and eliminating the transcription step that is necessary to move paper-based surveys into a Geographic Information System (GIS).

TOWARDS A DIGITAL DATA COLLECTION METHODOLOGY

When performing digital data collection, some adjustments must be made for working in remote areas. Because of the remote locations, a data connection over cellular is not always guaranteed during survey, so a disconnected approach was used. The tablets contained high resolution aerial imagery for the entire stream footprint and also had the database containing the schema, or structure in which the impairment information was to be collected, which allowed the field teams to collect data without a cellular signal. When they returned to the University at the end of each workday, the tablets and geodatabase were synchronized, pushing new edits to the server and pulling in edits from the other tables.

While capturing information about point-based impairments such as fish barriers or exposed pipes is straight forward, digitizing a half-mile long stretch of erosion is not so simple. To streamline the collection of linear impairments, a Linear Reference System (LRS) was implemented on the back-end, essentially allowing the field teams to create rough sketches of linear features in the field. The LRS associates an impairment to a specified length of the stream network. As long as the start and end locations are accurate, the linear impairment can be adjusted to follow the stream. LRS systems provide other data management benefits as well, such as being able to keep a history of impairments so that the state of the stream network can be tracked over time.

FIELD TEAMS AND SURVEY ACTIVITIES

Prior to field investigation, field teams participated in training sessions conducted by CDM Smith to learn the basic mechanics of the local stream system (e.g., geomorphology), how to identify human impacts including channel alterations, erosion, exposed pipes, pipe outfalls, fish barriers, inadequate buffers, in/near stream construction, and illegal dumping. At the end of the training, team members were able to identify healthy versus impaired streams and evaluate impairment severity, correctability, and accessibility.

Field teams consisted of two to three members each, with up to four teams going out each day. Each team had a Field Team Leader who was responsible for collecting data according to established protocols (Barbour et al, 1999; Yetman, 2001; NRCS, 2009).

FINAL CLEANUP AND CONCLUSIONS

At the conclusion of fieldwork, data and images captured were checked for accuracy through a combination of automated and manual processes, and the severity and correctability ratings were checked by CDM Smith. Impairments were converted to the LRS through an automated process using Python. Due to some restrictions in the ArcGIS software, some minor modifications were necessary to how the LRS data and images were integrated and stored. ArcMap templates were created for use by the Shelby County Public Works Division and all of the data were merged and exported as a Microsoft Excel Spreadsheet, using Python as well.

Going digital with data collection projects has many benefits over traditional methods, especially with regard to efficiency and accuracy. The largest hurdle for this project was creating a custom application to use for the data collection process. While custom applications have many advantages for large projects, they are overkill for others. The good news is digital data collection continues to get easier with new tools designed for consumer tablets such as Esri's Collector for ArcGIS, Geopaparazzi, or QField, which allow for the creation of customized data collection forms with a spatial component without necessarily having to build a new application from the ground up.

REFERENCES

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- Natural Resources Conservation Service (2009), National Biology Handbook, Subpart B-Conservation Planning, Part 614-Stream Visual Assessment Protocol Version 2, Washington, D.C.
- Yetman, K.T (2001), Stream Corridor Assessment Survey – Survey Protocols, Maryland Department of Natural Resources, Annapolis.

THREE TASKS, ONE TABLET: CONDITION ASSESSMENTS THREE TASKS, ONE TABLET: CONDITION ASSESSMENTS GO MOBILE IN CHATTANOOGA

Bradley Heilwagen¹, Whitney Fuquay^{2*}, and Robert Berger

Between the years of 1936 and 1941, the Works Progress Administration (WPA) constructed a system of concrete-bottom, rock-lined ditches within 10 major neighborhoods of the City of Chattanooga, Tennessee: St. Elmo, South East Lake, East Lake, Highland Park, Orchard Knob, Bushtown, Avondale, East Chattanooga, Brainerd, and North Chattanooga. In the 70-plus years since these ditches were constructed, they have been slowly degraded by elements both natural and anthropogenic. Grass, weeds, bushes, and trees have grown relatively unchecked through the cracks in the joints, and stormwater from routine rainfall events and major flooding events has eroded the grout between the rock linings and undermined the concrete bottom. Sections of the ditches have been replaced by culverts, pipes, and bridges over the years, and some sections were completely enclosed and buildings and parking lots built on top of them. In 1975, attempts were made to rehabilitate these ditches by covering most in a two-inch thick layer of new concrete, but even that has started to deteriorate over time. There has not been a comprehensive inventory and assessment of the integrity of the WPA drainage ditches since 1975.

In late 2013, the City of Chattanooga selected AMEC to assist with development of a long-term rehabilitation plan for this aging, 22-mile network of concrete and rock-lined ditches. Having a long-term plan will allow the City to prioritize future projects with the purpose of preventing further deterioration and alleviating flooding problems. Of the 22 linear miles, approximately 17 are open channel, while the remaining miles are comprised of closed channel or pipe. As part of Phase 1, AMEC was tasked with developing a ranking system for current ditch conditions and identifying specific areas of concern, such as adverse hydrologic or hydraulic conditions, geomorphic deterioration, and threatened vegetation communities and aquatic habitat, as well as establishing viable alternatives to rehabilitate and/or improve those ditches identified as having the poorest conditions or most critical areas of concern, that can be implemented in subsequent phases of the program. To develop this ranking system would require a substantial amount of data collection, including a full cross-sectional survey of the network for use in hydraulic modeling, a physical condition assessment, as well as photographic and video documentation of technical and ecological areas of interest, all in a format that could be integrated seamlessly into their existing GIS datasets.

Although at first glance the cross-section survey, physical condition assessment, and collection of photographic and video documentation looked like a time-intensive and expensive task, AMEC took an innovative approach and combined the three efforts into a single field collection.

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While field crews were out performing the cross-section survey, they were also able to collect pertinent condition assessment data and take photographs and video using a customized version of our standard stormwater mobile application installed on an Android tablet. The Android platform was chosen for its ability to deploy quickly and update easily without requiring use of an app store.

To ensure that field crews had accurate, reliable basemap layers to reference while collecting data, tile package files (.tpk), also known as a tile cache, were developed and preloaded onto the Android tablet. The projection of the .tpk file was defined to match that of the back end geodatabase so that Collection Points marked annually on the preloaded imagery are automatically given an accurate spatial reference. In addition to allowing data to be collected in a disconnected mode (no cellular service or GPS availability), cached sets of tiles typically display more quickly. Although GPS is still active on disconnected devices, this particular application allows the user to choose whether to use the GPS location provided by the device or to manually select a location by touching the map. Given Chattanooga's unique topography, data network and GPS coverage is often spotty so this capability allows workflow to continue through periods when the GPS signal is weak or the accuracy is not sufficient.

The City of Chattanooga provided AMEC with catchment and conveyance inventory database, and the fields from that database were used to build the data collection form specific for this project. At each data collection location, the field technician is prompted with a number of dropdown menus to identify and assess the WPA ditch ID, material, condition, obstruction, debris type, and maintenance required. The technician is then prompted to take photographs and video in the upstream and downstream directions, as well as the left and right banks. All data collected in the field is stored on the device. Once back in range of a wireless network, the data is synchronized to a centralized server, secured by credentials, in a format that mimics the City's existing conveyance inventory, and is immediately available for review and editing.

To put the collected data to use, AMEC created a Feature Service and customized a web map using arcgisonline. By logging in to the secured account, AMEC GIS Specialists are able to use the point data collected in the field to update the catchment and conveyance inventory for the City. Once updated, AMEC engineers will utilize the inventory to score each ditch segment based on its probability and consequences of flooding, level of deterioration, and ecological instability, ultimately compiling a prioritized list of ditch segments in need rehabilitation.

By combining the data collection efforts into one field trip, AMEC was able to save the City a substantial amount of money, nearly \$60,000, which can be applied to potential future efforts to rehabilitate the WPA ditch system. The success of the Chattanooga WPA data collection application is a true testament to how implementing a mobile solution not only enhances paper-based processes, but also increase client satisfaction, reduces inspection errors, enhances information flow and improves in-field productivity and data quality.

This presentation will provide a brief overview of the overall Chattanooga WPA Program, including its motivation and goals. The majority of the presentation will be spent describing the

innovative techniques that AMEC has used to make the data collection and condition assessments that will support the comprehensive rehabilitation plan as cost-effective as possible.

PREDICTIVE PERFORMANCE SCALING OF HYDRODYNAMIC SEPARATORS USING THE PECLET NUMBER

Mark Miller¹

This presentation explores a predictive performance scaling (sizing) method for stormwater hydrodynamic separation (HDS) technology using the Peclet Number. HDSs utilize gravitational and inertial forces for suspended sediment removal, whereby HDS performance is a function of suspended solids removal efficiency, surface area loading rate and particle size distributions of the same specific gravity. This sizing approach provides an effective means to scale the performance of an HDS between various influent particulate gradations. The unitless Peclet Number (Pe) is expressed as $Pe = (D \cdot h \cdot V_s) / Q$, such that the parameters of Flow Rate (Q in cfs), Horizontal Flow Dimension (D in ft), Vertical Flow Dimension (h in ft) and Particle Settling Velocity (Vs in ft/sec) are considered. The Pe scaling method includes a vertical depth component instead of a conventional single horizontal surface area component when scaling an HDS device. Particle settling velocities are based on Stoke's Law values. The Peclet Number method allows a theoretical performance curve based on a given median (d50) particle size to be compared to a laboratory test-derived performance curve based on a different particle size. Predictive performance curves for d50 particle sizes including 45, 50, 67, 90 and 125 microns are compared to an independently verified HDS laboratory test having a d50 particle size 110 microns. This scaling method can be used for both net annual and 80% per storm event sediment removal efficiency. HDS sizing charts are derived for both annual and instantaneous treatment goals.

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ESTIMATING LOAD REDUCTION COSTS FOR ASSESSING STORMWATER BEST MANAGEMENT PRACTICE (BMP) FEASIBILITY: A CASE STUDY OF JAMES LANE ALLEN ELEMENTARY

Russ Turpin¹

This work is based on a stormwater BMP feasibility study of James Lane Allen elementary school in Lexington, Kentucky. The purpose of this presentation is to demonstrate how evaluating BMP life-cycle costs and estimated treatment capability can be used to appraise and prioritize the use of different practices. The goal was to identify which stormwater BMPs would have greater cost-effective potential. This study was funded by an LFUCG Stormwater Quality Projects Incentive Grant.

What is the most cost-effective way to improve your watershed? For many Kentuckians, this question may seem difficult to answer because of a lack of familiarity with stormwater Best Management Practices (BMPs). A challenge across our Commonwealth is how to select and implement the measures needed to restore the health and function of our watersheds. A variety of financial resources have been enacted statewide to assess stream conditions, to identify pollutants and support educational or community outreach programs. More intensive studies, such as Total Maximum Daily Loads (TMDLs), have been undertaken to establish a target for pollutant reductions. The next step is to attain our water quality goals, whether it is by fines, fees, credits or other incentives. One way or another, Kentuckians will be obligated to address the cost for clean water. Developing strategic plans with consideration for cost-effective BMPs selected to meet (or exceed) our water quality targets with limited funding can be an extraordinary endeavor, but not impossible. It can be done.

From across the nation, research is emerging on the effectiveness and pollutant reduction capacities of stormwater quality BMPs. Case studies from communities across the nation in the forefront of water quality (such as Portland, Seattle, Chesapeake Bay, etc.) offer insight and innovation in design, but do not always represent weather patterns, pollutant loads and applicability in Kentucky. Despite their growing popularity, many BMPs have not been in service long enough to develop a record of their operational lives and what long-term maintenance costs are to be anticipated. Developing installation cost estimates for these measures may also be difficult to predict because unit rate costs will vary with the scale, size or quantities of the practice. A better understanding of BMPs operating in our region is desperately needed.

The purpose of this presentation is to demonstrate how evaluating BMP life-cycle costs and estimated treatment capability can be used to appraise and prioritize the use of different practices. This presentation is based on a stormwater BMP feasibility study of James Lane Allen elementary school in Lexington, Kentucky. This study is funded by an LFUCG Stormwater Quality Projects Incentive Grant. Information from local projects was used to support realistic cost estimates. The first step was to generate a conceptual plan to identify potential BMP

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locations and designate drainage surfaces. Predicted annual pollutant loads from each drainage area and anticipated BMP pollutant treatment capacities were used to calculate estimated load reduction from each drainage area. The second phase of this process was to develop a total life-cycle BMP cost based on estimated costs for design, construction/installation, maintenance and operation over a predicted service life. By coupling a prorated annual BMP cost with the estimated annual load reduction, an estimated load reduction cost was developed.

The goal of this process was to identify which stormwater BMPs would have greater cost-effective potential at James Lane Allen elementary school. By developing estimated load reduction costs for each BMP we can re-evaluate and adjust the BMP conceptual plan to favor the use of more valuable BMPs. As a result of this feasibility study, demonstrating the treatment capabilities and life-cycle costs will foster better decisions for selecting and prioritizing the use of stormwater BMPs. Having estimated load reduction costs could offer financial savings by identifying expensive practices that are assumed to be highly effective. Identifying measures with the greatest performance value will produce more efficient watershed strategies to meet water quality targets at a lower cost.

LESSONS LEARNED FROM METRO NASHVILLE'S STORMWATER CONTROL MEASURE (SCM) OVERSIGHT PROGRAM

Anneli Terry Nelson¹

New and redeveloped sites are required to address stormwater onsite by way of an approved Stormwater Control Measure (SCM). Per Metro regulations and the Stormwater Detention Agreement, owners must maintain their stormwater practices in perpetuity. How does Metro Nashville provide effective oversight for the 2400+ sites with SCMs? 2013-2014 was a pilot study for a new ramped-up SCM Oversight Program, providing valuable lessons that will have increasing relevance as SCMs become a required practice in more communities. This presentation will share some of those lessons, and provide a time to discuss effective strategies for ensuring compliance.

¹ Metro Nashville Water Services

THE EFFECTS OF ROADWAY CONSTRUCTION ON BENTHIC INVERTEBRATES IN TWO MIDDLE TENNESSEE STREAMS

R. Deedee Kathman¹ and Todd W. Askegaard²

Since their construction, Columbia and Snake River hydroelectric dams were required to incorporate measures for adult and juvenile anadromous fish passage. The U.S. Army Corps of Engineers' Walla Walla District encompasses four (4) Snake River and one (1) Columbia River high-head dams, making it the epicenter for fish passage biology and engineering. While fish passage has been an integral part of many Pacific Northwest impoundments, it is a relatively new consideration for Southeastern hydraulic structures. This presentation will cover some of the general concerns in a fish passage system design, how they have been handled historically, and how these design parameters may be incorporated into the Southeast.

A general discussion of biological factors and ichthyomechanics (fish swimming capabilities and migration habits) will lead into the hydraulic assessment, analysis, and design tools that have been used to ensure proper and reliable function of a fish passage system. Examples of computational fluid dynamics (CFD) models, physical models, and state-of-the-art field data collection will be presented along with how these tools were utilized to assess man-made fish passage structures as well as the river itself. These engineering tools and their approach provide a scalable and transportable tool box that can be used for fish passage projects in the Southeast, as well as any riverine engineering project.

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EFFECTS OF EXTREME FLOODING ON A FLATROCK STREAM AND SUBSEQUENT RECOVERY

William J. Wolfe¹, Timothy H. Diehl¹, and Greg E. Hileman¹

Geomorphic channel units along a 10,000-foot section of Copperas Branch (drainage area 1.6 square miles), in Williamson County, Tennessee, were surveyed in 2006,2007,2008,2010, and 2014. The surveys conducted from 2006 through 2008 show stability in both distribution of channel units and in the location, length, and character of individual units. Most year-to-year changes that were observed during this period can be attributed to variations in streamflow or seasonal conditions, such as presence or absence of ice or leaf packs. A near-stationary storm front in May 2010 dropped about 20 inches of rain in the course of 2 days, producing extreme flooding across much of Middle Tennessee. The May 2010 flood mobilized practically all coarse-sediment bed material along the surveyed section of Copperas Branch, fundamentally altering the character of the channel. Several hundred feet of cobble riffle were scoured to bedrock. Much of this material was washed past the mouth of Copperas Branch and deposited in and along Kelley Creek below its confluence with Copperas Branch. A 180-foot long reach of Copperas Branch that had remained a stable bedrock riffle through nearly 5 years of observations became a depositional site for cobbles backed up behind a debris pile of fallen trees and limestone slabs. A survey in 2014 shows partial recovery toward pre-2010 conditions. Many former cobble riffles have become reestablished and the largest coarse-sediment deposits formed in 2010 have since been scoured back to bedrock.

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A COMPARISON OF THREE THERMOELECTRIC WATER-USE DATA SETS IN THE SOUTHEASTERN UNITED STATES

Melissa A. Harris¹

The need for reliable estimates of the amount of water withdrawn and consumed by thermoelectric plants is garnering increased attention due to the Nation's growing demand for water and energy. Water withdrawals for thermoelectric power generation are the largest category of withdrawals in the United States. Thermoelectric withdrawals were 58 percent of total water withdrawals in nine southeastern States in 2010. Although much smaller than withdrawal, thermoelectric water consumption is substantial and can be larger than other types of consumption at a local scale.

National sources of thermoelectric water-use data sets include the U.S. Geological Survey (USGS) and the Department of Energy – Energy Information Administration (EIA). The USGS has published national thermoelectric water-use estimates every five years since 1950, as part of a larger national water-use compilation. However, after 1995, reporting water consumption was suspended and only water withdrawals have consequently been published. Recently the USGS developed methods for estimating withdrawal and consumption at thermoelectric plants based on heat-and-water budgets, and estimated thermoelectric water-use for 2010. The EIA publishes annual reports on power plant operations that include plant-reported thermoelectric water withdrawal and consumption. There are, however, discrepancies among the three data sets. Depending on the data source, 2010 thermoelectric withdrawals in the southeast ranged from the USGS-model estimate of 35 billion gallons per day (BGD) to the USGS-compilation estimate of 47 BGD, a 27 percent difference; plants reported 44 BGD to EIA. USGS-modeled and EIA-reported consumption for 2010 were similar at 943 million gallons per day (MGD) and 1,077 MGD, respectively, although USGS estimated consumption at 62 plants not required to report to EIA because of a generation-capacity reporting threshold.

A more detailed plant-level analysis of the data for the southeastern States highlights the differences in methodologies, definitions, and quality of data among the sources. Comparisons of the data sets are important for trend analysis, policy decisions, and for understanding the uncertainty in each method. A comparison of the data and methods will allow users to determine if reported data are reasonable for certain types of cooling systems or generation technologies, and if the differences in methodology and/or definitions have an impact on the discrepancies in thermoelectric water withdrawal and consumption estimates.

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SESSION 2B

MODELING I

8:30 a.m. – 10:00 a.m.

Evaluating the Impact of Wetlands on Targeting and Integrating Conservation Practice in Watershed Systems

Henrique Momm, Amy Giley, and Ronald L. Bingner

Modeling Karst Hydrology

David Anderson Solomon

Reservoir Modeling for Development of TVA Emergency Action Plan Maps

Patrick Massey, Brett Connell, Keil Neff, and Curt Jawdy

MODELING II

10:30 a.m. – 12:00 p.m.

A Risk and Reliability Analysis Approach to Investigate the Impact of Reservoir Inflow Change on Dam Overtopping Risk

Ebrahim Ahmadisharaf and Alfred J. Kalyanapu

Updating Probable Maximum Precipitation and Precipitation Frequency Estimates in the Tennessee River Watershed

Bill Kappel, Mel Schaefer, Curt Jawdy, and Keil Neff

Predictions of Saturated Hydraulic Conductivity Dynamics in Intensively Managed Watersheds

A.N. Thanos Papanicolaou, Mohamed Elhakeem, and Christopher G. Wilson

MODELING III

1:30 p.m. – 3:00 p.m.

Modeling Climate Change Impacts on Bioretention Performance

J.M. Hathaway, R.A. Brown, J.S. Fu, and W.F. Hunt

Comparing Modeled Runoff Water Quality from Bioenergy Crop Land Conversions of Switchgrass and Short-Rotation Wood Crop in the Southeastern USA

Zachariah T. Seiden, Latha M. Baskaran, John S. Schwartz, Virginia H. Dale, Esther S. Parish, and Timothy G. Rials

TVA's New Rainfall-Runoff Model: Development and Use of the Sacramento Soil Moisture Accounting Model

Shaun Carney, Phil Burkhalter, Curt Jawdy, and Keil Neff

THE TENNESSEE PERMANENT STORMWATER MANAGEMENT PROGRAM
3:30 p.m. – 5:00 p.m.

Tennessee Permanent Stormwater Management: Requirements and Guidance
Robert Karesh

The Tennessee Runoff Reduction Assessment Tool (TNRRAT): A Tool for Permanent Stormwater Management System Design
Daniel Yoder

Tennessee Permanent Stormwater Management Design Training Program
Andrea Ludwig, John Buchanan, Tim Gangaware, John Tyner, and Daniel Yoder

EVALUATING THE IMPACT OF WETLANDS ON TARGETING AND INTEGRATING CONSERVATION PRACTICES IN WATERSHED SYSTEMS

Henrique Momm,^{1*} Amy Giley¹, and Ronald L. Bingner²

Constructed wetlands have been recognized as an efficient and cost-effective conservation practice to protect water quality through reducing the transport of sediments and nutrients from upstream croplands to downstream water bodies. The challenge resides on targeting the strategic location of wetlands within agricultural watersheds to maximize the reduction in nutrient loads while minimizing their impact on crop production. Furthermore, agricultural watersheds involve complex interrelated processes requiring a systems approach to evaluating the inherent relationship between wetlands with multiple sediment/nutrient sources (sheet, rill, ephemeral gully, channels) and other conservation practices (filter strips). This study describes the capabilities of the USDA's Annualized Agricultural Non-Point Source pollutant loading model, AnnAGNPS, to simulate and evaluate the contribution of constructed wetlands to reducing sediment/nutrient loads at the watershed scale. A newly developed AGNPS GIS-based wetland component is introduced to identify and characterize individual constructed or natural wetlands at a watershed scale. The impact of management practices on the function and capability of constructed wetlands individually or in a series to reduce sediment and nutrient loads within a watershed are evaluated through several scenarios involving targeting, the spatial location of wetlands, various conservation practices producing multiple pollutant load sources into wetlands, and buffer filter strips encompassing the wetlands. The AGNPS wetland component provides a simplified, semi-automated, and spatially distributed approach to quantitatively evaluating conservation management alternatives based on constructed wetlands (possible sites and potential sediment/nutrient load reduction). This technology provides conservationists the capability for improved management of watershed systems and support for nutrient credit trading programs.

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MODELING KARST HYDROLOGY

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Wetlands and karst aquifers both have non-ideal flow patterns and cannot be easily described using Darcian models. The TSU research team of Byl, Painter & Sharpe have approached these two systems using methods more commonly used by chemical engineers to describe chemical residence time in a non-ideal reactor. Recently, a pool was discussed in Mammoth Cave that has mystified hydro-geologists because it appears to be stagnant. However, there is no sign of evaporate minerals around the edge of the pool, no visible sign of flow in or out; yet the water appears to be fresh. This pool, referred to as Stagnant Pool, was the subject of this investigation. This study was divided into two phases. The objective in the first phase was to calibrate the model by calculating the salt (NaCl) required to raise the specific conductance by 50 uS/cm (going from 340 uS/cm to 350 uS/cm) evenly throughout the pool using a salt tracer study which determined the turn-over rate, i.e., residence time, in this pool using the residence-time distribution (RTD) and continuous stirred tanks-in-series reactor (CSTR) models. The objective of the second phase was to generate a computer model of Stagnant Pool using FlexPDE software using boundary conditions accumulated from phase 1.

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RESERVOIR MODELING FOR DEVELOPMENT OF TVA EMERGENCY ACTION PLAN MAPS

Patrick Massey¹, Brett Connell, Keil Neff², and Curt Jawdy

The Tennessee Valley Authority (TVA) maintains Emergency Action Plans (EAPs) for TVA dams throughout the Tennessee Valley and recently updated the flood mapping component of the EAPs. Historic floodplain maps were largely based on older models, assumptions and floodplain mapping techniques. Data from multiple sources including cross-section and silt range data and historic model geometry were integrated into a single hydraulic model. HEC-RAS (US Army Corps of Engineers) was chosen as the hydraulic model platform to facilitate production of updated EAP flood maps. During early stages of model development, some data gaps were identified which required additional bathymetric cross-sections data to be collected in reaches of several tributaries. The bathymetry data collection was completed utilizing acoustic Doppler profiler and RTK-GPS technology which was then merged with the Digital Elevation Model (DEM) for cross-section development. After the integration of a single geo-referenced HEC-RAS model of the TVA system was completed, model simulations of three flood-type scenarios were conducted for 10 main-stem reservoirs and 28 tributary reservoirs. Model results were used to create updated inundation maps to be incorporated into EAPs. In addition, the integrated HEC-RAS model will provide a starting point for future development of an operational hydraulic model for use over the full range of flows for TVA River Operations.

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A RISK AND RELIABILITY ANALYSIS APPROACH TO INVESTIGATE THE IMPACT OF RESERVOIR INFLOW CHANGE ON DAM OVERTOPPING RISK

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INTRODUCTION

Dam overtopping is the primary reason of dam failure worldwide (Wu et al., 2011). Various reasons such as large inflow may trigger this type of failure. Global changes including climate variability and urbanization have increased the risk of extreme hydrologic events such as floods (Hirabayashi et al., 2013), which is likely to alter the overtopping risk. It is most likely that hydraulic structures such as dams being affected by climate variability due to their long lifetime and therefore overlooking nonstationarity may yield failure risk underestimation and serious safety issues (Kunkel et al., 2013). However, in spite of the extensive research on dam failure, the impacts of nonstationarity has not been received sufficient attention yet. To our knowledge, the only research in this context is the study by Lee and You (2013), in which the impacts of climate variability and reservoir sedimentation on overtopping risk were analyzed for a dam in Taiwan. The case study results showed that the overtopping risk is increasing significantly.

With this research gap in the body of literature, *this study aims to investigate the temporal variation in annual overtopping risk using a risk and reliability analysis approach*. This investigation is conducted on the Burnett Dam located in Swannanoa River watershed, North Carolina. The presented framework is versatile and can be employed in similar studies and different locations.

APPROACH

A four-step dam overtopping risk assessment framework is used in this study, which encompasses the following sections: 1) statistical flow analysis; 2) channel flow routing; 3) dam overtopping risk assessment; and 4) Trend analysis. The framework is employed to assess dam overtopping risk in different years of a period. Here's the description of each section:

- i. *Statistical Flow Analysis*: Instantaneous streamflow data of a gaging station in the dam upstream is statistically analyzed and the annual peak streamflow in each year is determined.
- ii. *Channel Flow Routing*: Annual peak flow is routed through the upstream channel using a flow routing model in each year. The routing model employs Muskingum channel routing technique.
- iii. *Dam Overtopping Risk Assessment*: Routed flows into the reservoir are employed in order to determine the overtopping risk. This risk is defined as the probability of inflow exceeding the spillway capacity, here. A simple performance function is used to estimate overtopping risk following Lee and You (2013). Spillway capacity and annual peak inflow are used as input to

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this function. The performance function is assumed to be normally distributed (Kuo et al. 2007).

- iv. *Trend Analysis*: Temporal change in the annual overtopping risk is finally investigated using the nonparametric Mann-Kendall test (Mann, 1945). The test generally determines whether a time series tend to increase or decrease with time.

CASE STUDY

The framework is demonstrated on hypothetical failure of a high-hazard dam, Burnett, located in Buncombe County, state of North Carolina. The dam is located in the Swannanoa River watershed, which is a part of the larger French Broad River Basin. Constructed in 1954, the dam is 40.7 m high, crest of 399.0 m long and 7.6 m wide, maximum storage of 25.5 million m³ at top of dam elevation and drains total area of 52.1 km². The dam is classified as “large” based on the International Commission on Large Dams (ICOLD).

With more than 1200 high-hazard dams, state of North Carolina ranks second among the US states. Burnett Dam is one of these dams, which is located in upstream of the city of Asheville. An inspection report on 1980 showed that the dam cannot pass the Probable Maximum Flood (PMF) without overtopping due to insufficient spillway capacity. At that time, maximum peak flood of 40 cms at dam location was reported, which is during the November 1977 flood event.

RESULTS AND DISCUSSION

The framework, which was discussed in the approach section, is followed here to determine temporal variation of annual overtopping risk in the case study. First, streamflow data of a USGS station (USGS 0344894205), located in the dam upstream is analyzed to determine the annual peak flow. Flow records, which are available since 1989, are used to determine the annual peak flow. The peak flows are used as inputs to a calibrated channel routing model and the reservoir inflow is determined in the entire time span of 1989-2013, which is presented in Figure 1. The highest reservoir inflow is 228.7 cms and occurs in 2004 during Hurricane Ivan and Frances. Comparing to the highest recorded inflow before 1980, a greater flood magnitude occurred in more than one-third of the 1989-2013 period. The increase is significant in most of the years, in which peak streamflow of nearly 6 times larger than 1977 event can be observed.

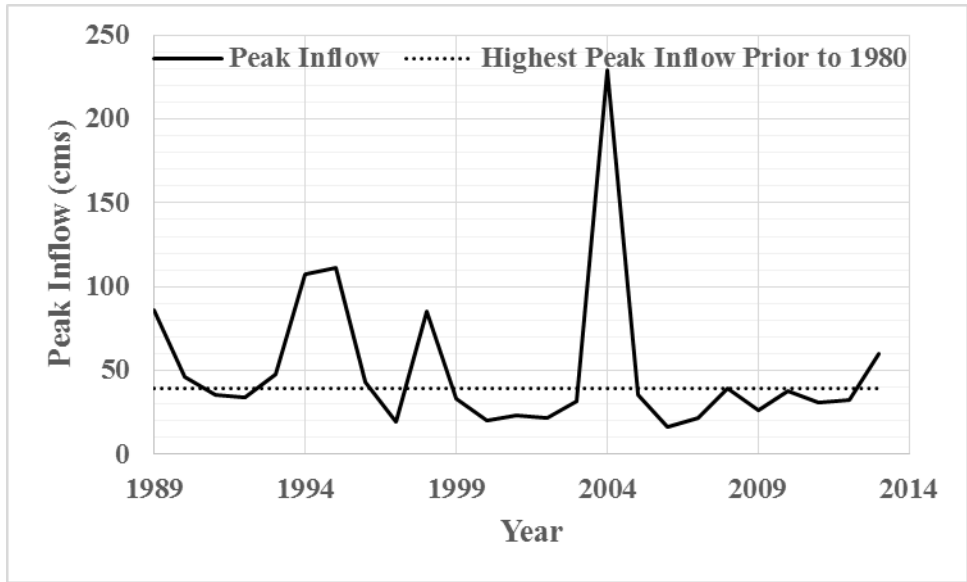


Figure 1. Reservoir annual peak inflow in the period of interest.

Taking the values of annual peak inflow, overtopping risk is determined in each year. The values of annual overtopping risk in 1989-2013 period are presented in Figure 2. The highest overtopping risk is 11.4% and occurs in 2004 during Hurricane Ivan and Frances. Comparing to the highest recorded inflow before 1980, a greater overtopping risk occurred in more than one-third of the 1989-2013 period. The increase is significant in most of the years, in which a risk of nearly 74 times higher than 1977 event can be observed. The significant increase in overtopping risk increases the downstream flood risk and potential consequences.

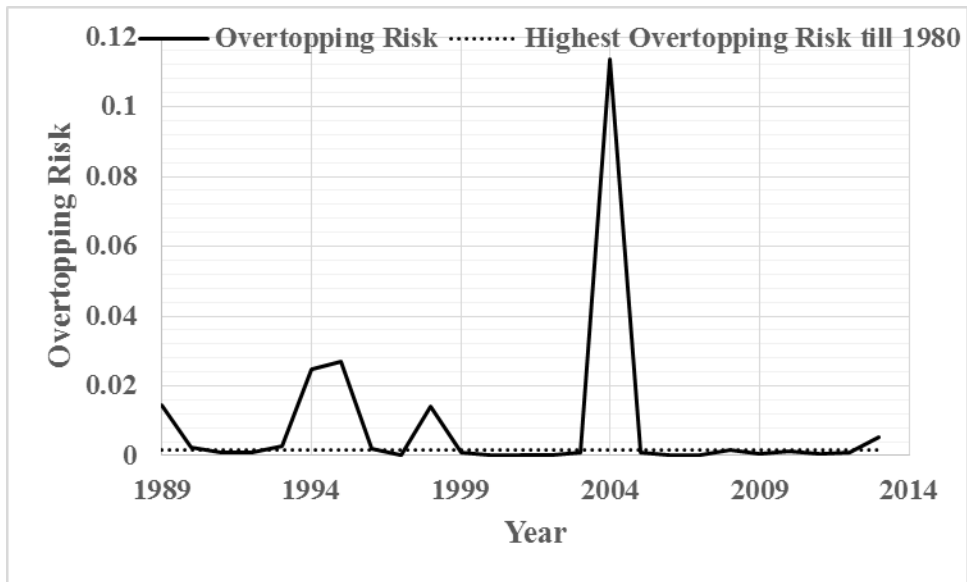


Figure 2. Annual overtopping risk in the period of interest.

Ultimately, temporal trend of annual overtopping risk is analyzed by using the Mann-Kendall test. As a result, a monotonic increasing trend in annual overtopping risk is found at 95% confidence level.

Considering the increasing trend in both annual peak inflow and overtopping risk, revisiting of the current dam operation policy is highly recommended. A cost-effective study to evaluate the dam efficiency based on failure risk and operational benefits is likewise helpful. Performing similar studies for other dams with different size and purpose, in different climatic and hydrologic regimes, will be helpful to draw more general conclusions. The methodology can be adopted for other dams such as one of those 300 high-hazard dams in Tennessee in order to help dam managers better understand the potential change in overtopping risk.

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UPDATING PROBABLE MAXIMUM PRECIPITATION AND PRECIPITATION FREQUENCY ESTIMATES IN THE TENNESSEE RIVER WATERSHED

Bill Kappel¹, Mel Schaefer², Curt Jawdy³, and Keil Neff^{4*}

The Tennessee Valley Authority (TVA) is currently improving estimates of Probable Maximum Precipitation (PMP) values and point precipitation-frequencies by using more extensive datasets and advanced. The PMP is defined in the most recently published Hydrometeorological Report (HMR) by the National Weather Service (NWS) as "theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of the year". Applied Weather Associates (AWA) has recently performed calculations to update PMP values for locations within the Tennessee Valley Watershed. In coordination, MGS Engineering Consultants (MGS) has performed analyses to develop point precipitation-frequency relationships for various storm types.

The TVA domain contains many diverse topographic and climatological regions. These include the West Tennessee Uplands, the Highland Rim, the Cumberland Plateau, and the Unaka Mountains. In between are several areas which are sheltered from major inflow of moisture and exhibit rain shadow effects compared to the surrounding higher elevations. Because of the distinctive climate regions and significant topography, the development of PMP values must account for the complexity of the meteorology and terrain throughout the region.

PMP values calculated in this study supersede historic PMP values reported in the four HMRS (41, 45, 47, and 56) published in 1965, 1969, 1973, and 1986 respectively. Several major issues were identified with the procedures used in the HMRS to developed PMP values. Important among these were the limited number of analyzed storm events, no inclusion of storms that have occurred since their publication, inadequate processes used to address orographic effects, inconsistent data and procedures used among the HMRS, and outdated procedures used to derive PMP.

TVA's current PMP project incorporates the latest methods, technology, and data to address the climate and topography complexities in the Tennessee Valley. Calculated PMP values are valid for specific seasons based on storm type, which is the time of the year when 100% of the PMP rainfall could occur, and subsequently are applied for computation of the Probable Maximum Flood (PMF). This study determines reliable and reproducible estimates of PMP values for use in computing the PMF for various watersheds in the within the overall project domain. This includes all area sizes from as small as 1/3rd-square mile through the total project domain and for durations ranging from 1-hour through 120-hours. The most reliable methods and data

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available were used and updates to methods and data used in HMRs were applied where appropriate.

The point precipitation-frequency analysis is Phase 1 of a three-phase program for developing precipitation-frequency relationships and scalable storm templates for watersheds in the Tennessee Valley. This analysis used a storm typing approach coupled with regional precipitation-frequency analysis, which is a major advancement over traditional precipitation-frequency methods. This approach provides for a direct link between watershed precipitation-frequency and the storm spatial, temporal and seasonal characteristics for each of the four storm types. This is critically important when the precipitation-frequency information is to be used for rainfall-runoff modeling for development of flood-frequency relationships. The ultimate goal is to conduct stochastic modeling for floods generated by the various storm types and to develop hydrologic hazard curves for dams and nuclear plants operated by the TVA.

Regional precipitation-frequency analyses were conducted for point precipitation for locations within the Tennessee Valley watershed. This included defining thirteen (13) climatic regions to depict the spatial variation of precipitation maxima in the complex topographic study area. A major component of the study was the development of precipitation data series that were comprised of precipitation maxima produced by specific storm types. This was accomplished by using meteorological criteria to identify the storm type for each rainy day in the period from 1881 through mid-2014 and using this database in assembling precipitation annual maxima data series for precipitation stations for each of four storm types. The storm types included Local Storms (LS), Mesoscale Storms with Embedded Convection (MEC), and synoptic-scale Mid-Latitude Cyclones (MLC) and Tropical Storm Remnants (TSR). There were 1,250 precipitation measurement stations and 60,096 station-years of record available for the synoptic-scale MLC and TSR storm types, 393 stations and 13,516 station-years of record for the MEC storm type, and 221 stations and 9,160 station-years of record for the LS storm type.

Separate regional precipitation-frequency analyses were conducted for precipitation annual maxima data series for key durations for each of the four storm types. The key durations were 48-hours for the synoptic scale MLC and TSR storm types, 6-hours for the mesoscale MEC storm type, and 1-hour for the LS storm type. Findings from the regional analyses provided for spatial mapping of statistical measures used to develop the point precipitation-frequency relationships. This included spatial mapping of the at-site means, regional L-moment ratio statistics $L-C_v$ and $L-Skewness$, and identification of the regional probability distribution. This information provided for development of point precipitation-frequency relationships for locations throughout the study area. Isopluvial maps were prepared for point precipitation maxima for annual exceedance probabilities of 10^{-1} , 10^{-2} , 10^{-3} , 10^{-4} and 10^{-5} for the key durations for each of the four storm types.

Equivalent Independent Record Length (EIRL) analyses were conducted for each storm type to provide a measure of the effective record length of the statistical information for the storms contained in the regional datasets. This information will be used in future uncertainty analyses to develop uncertainty bounds for watershed-specific precipitation-frequency relationships. Seasonality analyses were also conducted for the four storm types that provide a probabilistic

description of the likelihood for storms to occur at various times throughout the year. This information is important for stochastic modeling of floods for the four storm types.

The storm typing approach applied to the study area has allowed greater insight into the statistical characteristics of the various storm types. This has provided increased reliability in the precipitation-frequency relationships for the MLC, MEC and LS storm types. This occurs because the L-moment ratio statistics were found to have only minor variation across the domain based on very large regional datasets. In the case of the TSR storm type, the storm typing approach allowed for precipitation-frequency analysis of TSR precipitation which would not have been possible with a traditional approach. In particular, the spatial pattern and site-specific precipitation-frequency characteristics for the synoptic scale TSR storm type are quite dissimilar to the other synoptic scale MLC storm type. This is an important finding for application in modeling of floods generated by TSR events.

This presentation will provide an overview of work performed and results of recent PMP and point precipitation-frequency studies. This will include describing the process, data, and methods used to analyze storms and develop PMP values. Results will be shown in context of background data, and comparisons to previous PMP work in the region will be incorporated. Findings of the point precipitation-frequency analyses for the four storm types will be presented in the context of developing watershed-specific precipitation-frequency relationships and use in future stochastic flood modeling.

PREDICTIONS OF SATURATED HYDRAULIC CONDUCTIVITY DYNAMICS IN INTENSIVELY MANAGED WATERSHEDS

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In this study, a physically-based, modeling framework was developed to predict saturated hydraulic conductivity (K_{sat}) dynamics in an intensively managed landscape. The modeling framework integrated selected pedotransfer functions (PTFs) and watershed models with geospatial tools. Models selection was based on statistical measures of the models' errors compared to K_{sat} field measurements under different soil, climatic and land use conditions. The study has shown that the combined Rosetta and the Water Erosion Prediction Project (WEPP) models provided the best agreement to the measured K_{sat} values compared to the other tested models. These results were integrated with the Geographic Information System (GIS) tools by developing a program for data registries. The modeling framework allowed for visualization of the data in forms of geospatial maps and prediction of K_{sat} variability in an intensively managed landscape due to the seasonal changes in climate and land use activities. Except for the ungrazed grassland areas, effective K_{sat} that accounts for land cover only did not change significantly with season, exhibiting the lowest values at the forest and urbanized areas. The effects of rainfall on effective K_{sat} were demonstrated for single storm events and showed it was linearly proportional to rainfall depth.

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MODELING CLIMATE CHANGE IMPACTS ON BIORETENTION PERFORMANCE

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INTRODUCTION

Climate change remains an ongoing threat to global water resources. Variations in rainfall patterns and temperature have the potential to substantially strain urban water systems (Willems and Vrac, 2011). Climate change may exacerbate the adverse effects of urbanization on the hydrologic cycle, by overwhelming infrastructure and directing additional runoff to streams and rivers. Urban Stormwater Control Measures (also known as SCMs, Water Sensitive Urban Designs, and WSUDs) are commonly implemented to reduce the effects of urbanization. One such practice is the bioretention area (or biofilter) which promotes infiltration, evapotranspiration, and treatment of stormwater runoff.

Bioretention areas are typically designed to receive and treat some defined water quality event based on local rainfall patterns. For instance, in central North Carolina, USA, the runoff associated with a precipitation depth of 2.54 cm is targeted for capture and treatment. As climate change affects rainfall and temperature patterns, bioretention areas designed based on the water quality event may experience reduced effectiveness.

METHODS

Brown et al. (2013) utilized DRAINMOD, a continuous drainage simulation model, to explore bioretention functionality at multiple locations in central North Carolina, USA. The models were calibrated and validated based on field collected hydrologic data. One of the sites (Nashville, North Carolina, USA) contained bioretention cells with varied soil media depths, 0.6 and 0.9 m, respectively. Modeling of these systems was largely successful based on the Nash-Sutcliffe coefficients for the calibration and validation periods (Brown et al. 2013).

The calibrated DRAINMOD models for the Nashville sites were utilized to explore the impact of climate change on bioretention function in this region. Climate data were obtained from two sources. Data from the National Climatic Data Center (NCDC) from 2001 to 2004 were used to establish functionality under current climate conditions (“Base”). Climate change predictions described by Gao et al. (2012) were used to model function under future scenarios (2055 to 2058). Data from two Representative Concentration Pathways (“RCP 4.5” and “RCP 8.5”) were utilized, representing a moderate and severe usage of fossil fuels in the future. The data were generated by dynamic downscaling using the Weather Research and Forecasting (WRF) model, with the Community Earth System Model version 1.0 (CESM v1.0) serving to establish

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boundary conditions for the WRF model. See Gao et al. (2012) for further details. Modeling was performed on an hourly basis to allow a robust analysis of bioretention function.

RESULTS AND CONCLUSIONS

The estimated water balances from DRAINMOD for the Nashville bioretention areas, Nashville-0.6 and Nashville-0.9, are presented in Table 1. The percentage of drainage, overflow, and exfiltration/evapotranspiration (ET) varied slightly from the base scenario to the climate change scenarios. Most notably, the amount of runoff entering the system that left as overflow increased under both climate scenarios for both sites. Specifically, considering both climate change scenarios, the amount of overflow increased from 22 to 42% over the Base scenario. This is concerning considering the additional uncontrolled stormwater runoff that will be directed to surface waters. In comparing the two media depths, only minor differences in function due to climate change are present. The effects of climate change appear less influential than the difference in performance due simply to media depths. The differences in performance based on media depth are apparent even under the Base scenario.

These results suggest that climate change will have an influence on the overall quantity of overflow from bioretention areas in central North Carolina, USA. It should be noted that the magnitude of climate change varies spatially. These results are likely to vary in other locations globally.

Table 1. DRAINMOD results for the Nashville bioretention areas.

Site	Climate Scenario	Runoff		Drainage		Overflow			Exfiltration and ET		
		Depth (mm)	Depth (mm)	% of Runoff	% diff ¹	Depth (mm)	% of Runoff	% diff	Depth (mm)	% of Runoff	% diff
Nashville – 0.6 m	Base	2226	1079	48	-	411	18	-	737	33	-
	RCP 4.5	2435	1096	45	2	566	23	38	774	32	5
	RCP 8.5	2472	1175	48	9	502	20	22	795	32	8
Nashville – 0.9 m	Base	2088	876	42	-	316	15	-	897	43	-
	RCP 4.5	2272	897	39	2	450	20	42	926	41	3
	RCP 8.5	2314	961	42	10	391	17	24	962	42	7

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COMPARING MODELED RUNOFF WATER QUALITY FROM BIOENERGY CROP LAND CONVERSIONS OF SWITCHGRASS AND SHORT-ROTATION WOOD CROP IN THE SOUTHEASTERN USA

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Conditions supporting sustainable bioenergy crop production vary across climatic regions with existing studies showing that the southeastern United States is well-suited to provide needed feedstock supplies. Market demands for the feedstock crop type are currently in flux as the bioenergy industry continues to grow. Two promising bioenergy crops for the Southeastern region are switchgrass and short-rotation woody crops (SRWCs). Sustainability assessment for feedstock production not only includes economic feasibility but also environmental feasibility; this includes the potential alteration of water quality conditions in the region's watersheds. Using the Soil and Water Assessment Tool (SWAT), this study projected relative differences of watershed export of total nitrogen, total phosphorus, and total suspended sediment under varying degrees of land-use conversions from hay to switchgrass and hay to SRWCs. Modeling was completed for three East Tennessee watersheds with different drainage area sizes and physiographic characteristics. Compared to land managed for hay pasture, land managed for bioenergy crops appeared to improve water quality in all three watersheds as bioenergy crop cover increased; however, no statistically significant differences were observed in the water quality improvements realized by switchgrass versus SRWCs. Model results also indicated that watershed characteristics of drainage area size and slope influenced all three water quality parameters. Thus, more empirical data are needed to determine whether one feedstock can ultimately improve water quality more than the other in this complex terrain.

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TVA'S NEW RAINFALL-RUNOFF MODEL: DEVELOPMENT AND USE OF THE SACRAMENTO SOIL MOISTURE ACCOUNTING MODEL

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As part of the larger River Forecast Center Modernization Project, TVA created a new hydrologic model for the Tennessee and Lower Cumberland River watersheds. After researching several available models, the Community Hydrologic Prediction System (CHPS) was chosen as the modelling suite. TVA partnered with the Lower Mississippi River Forecast Center (LMRFC) on the project. The LMRFC already had a CHPS hydrology model for the basin, but it was largely un-calibrated. TVA and LMRFC have different missions, and had different forecast points prior to this project. Staff from the two organizations agreed on a common set of sub-basins and boundaries for the sub-basins were created using GIS tools. LMRFC then used those basin boundaries to derive 6-hourly rainfalls per sub-basin back to 1950.

In addition to rainfall, TVA prepared input time series for a wide range of inputs including streamflow, pool elevation, tailwater elevation, turbine flow and spill flow. Observed local inflows were then calculated for each forecast point using reverse routing techniques, along with stage-storage curves for each reservoir. These observed local inflows were used as the target time series for the calibration.

The unit operations used for the model included the Sacramento Soil Moisture Accounting (SAC-SMA), unit hydrograph (UNIT-HG) and Lag and K (LAG-K) operations. An iterative procedure was used to calibrate each sub-basin, progressing downstream. The SAC-SMA parameters were adjusted starting with the slow baseflow parameters, and progressing to the upper zone interflow parameters. Once a reasonable fit was obtained, unit hydrograph deconvolution techniques were used to create unit hydrographs for each reach. Finally, routing parameters in the LAG-K model were adjusted to move the flow downstream to the next location as accurately as possible.

After calibrating each of the sub-basins, several rounds of senior review were performed to improve the simulation while using regionally-consistent values for each parameter. A final round of edits was performed to remove the last bit of volume bias by adjusting the monthly potential evapotranspiration curves for each sub-basin.

Comparisons between the older TVA model and the new model showed improvement over the whole range of flows, but demonstrated significant improvement in representing baseflows. TVA has implemented the new model in the RFC Modernization project, and it has proven to be a significant improvement over the older model. The much richer conceptual model of CHPS has shown to have considerably more “model memory” and provides much better forecasts for days

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beyond one day. The focus on bias removal will allow TVA to run medium term (30-day) forecasts with the hydrology model and ensembles of forecast rainfall, rather than relying on ensembles of historic inflows. This improvement will allow much improved medium-term forecasts.

TVA plans to use the new model not just in the RFC, but also in future planning studies. The first use will be in a new stochastic hydrologic hazard program as detailed in a successive presentation. We are committed to getting the maximum value from this effort by opening up the model to interested parties for research and policy purposes.

Most of the calibration for this project was performed by Riverside Technology and AMEC Earth & Environmental. Our thanks go out to their talented and dedicated staff.

TENNESSEE PERMANENT STORMWATER MANAGEMENT: REQUIREMENTS AND GUIDANCE

Robert Karesh¹

Tennessee's local stormwater programs will soon require new development to include runoff reduction practices that manage permanent (post-construction) stormwater runoff with infiltration or reuse. Runoff reduction practices protect water quality by maintaining natural site hydrology and removing stormwater pollutants. This presentation will summarize minimum requirements, as well as the recently available TN Permanent Stormwater Management Design and Guidance Manual, Runoff Reduction Assessment Tool and related training.

¹ Statewide Stormwater Coordinator, Tennessee Division of Water Resources

THE TENNESSEE RUNOFF REDUCTION ASSESSMENT TOOL (TNRRAT): A TOOL FOR PERMANENT STORMWATER MANAGEMENT SYSTEM DESIGN

Daniel Yoder¹

This presentation builds on the session's previous presentation, which describes the requirements of the Tennessee Permanent Stormwater Permit and the implications of those for planners and system designers. This presentation describes the tool that determines to what degree a proposed specific site design meets those requirements. It will briefly cover the science used in the tool, the fundamental approach in applying that science to the site, and conclude using the tool on a range of examples.

¹ PhD, P.E., Biosystems Engineering & Soil Science Department, University of Tennessee, Knoxville (UT)

TENNESSEE PERMANENT STORMWATER MANAGEMENT DESIGN TRAINING PROGRAM

Andrea Ludwig¹, John Buchanan¹, Tim Gangaware², John Tyner¹, and Daniel Yoder¹

The Stormwater Management Assistance Research & Training (SMART) Center at the University of Tennessee offers designers and plan reviewers a suite of training resources on how to use the Tennessee Runoff Reduction Assessment Tool (RRAT). The RRAT was developed to provide end users with a transparent and quantitative evaluation tool to determine whether their design meets the requirements of the Tennessee general municipal separate storm sewer system permit under the unique site combination of climate, soil, flow patterns, land uses, and special site conditions. Informative basic videos available online provide a user the minimum basis for use of the program. A follow-up one-day design workshop has been developed with the following learning objectives: 1) Be able to apply permanent stormwater performance standards as delineated in the Phase II MS4 General Permit, 2) Be able to incorporate site designs that avoid, minimize, and manage stormwater runoff, 3) Be able to use the Design Manual to select and design stormwater control systems, and 4) Be able to use the RRAT to model on a proposed project to determine whether it meets site requirements. The design tool and training program are dynamic in that end user and participant feedback is quickly integrated to maximize robustness and practicality for the designers and municipal professionals who will use these tools on a daily basis. This presentation will summarize the training program and give excerpts of program materials, such as RRAT design examples and discussion of key Design Manual elements.

¹ Biosystems Engineering & Soil Science Department, University of Tennessee Institute of Agriculture

² Tennessee Water Resources Research Center, University of Tennessee Knoxville

SESSION 2C

WATER QUALITY

8:30 a.m. – 10:00 a.m.

A Collaborative Effort Towards Real-Time Water Quality Equipment Demonstration at Falling Water River, Tennessee

Alfred Kalyanapu, Tania Datta, Daniel Dodson, Karina Bynum, and Bill Harrington

Evaluation of Trace Metal Monitoring Results Near Landfill Contamination Plumes in Tennessee

Randy M. Curtis

Conceptual Models of the Formation of Acid-Rock Drainage at Road Cuts in Tennessee

Michael Bradley, Tom Byl, And Scott Worland

OUTREACH EDUCATION

10:30 a.m. – 12:00 p.m.

Collaborative Watershed Stewardship in the Cumberland River Basin

Jed Grubbs

How Many Drops of Water Fit on a Penny?

Lena Beth Reynolds

ArcGIS Online as a Tool to Teach Global, Regional and Local Water Resource Issues to Middle and High School Teachers and Students

R. Hanahan

AGRICULTURE

1:30 p.m. – 3:00 p.m.

Evaluating Agricultural Best Management Practices in the Mississippi Delta: Preliminary Findings

Jenny Murphy and Matt Hicks

Impact of Cropland Manure Application on Water Quality in Surface Water, Drain Tile Discharge and Groundwater at the UT Little River Dairy Farm

Larry McKay, D. Street, A. Layton, R.W. Hunter, D. Williams, and A. Ludwig

Alternative Tile Intake Design for Intensively Managed Ecosystems

A.N. Thanos Papanicolaou, William D. Ettema, Christopher G. Wilson, and Benjamin K.B. Abban

MEMPHIS AQUIFER

3:30 p.m. – 5:00 p.m.

Groundwater Geochemistry and Age Along Two Flow Paths in the Memphis Aquifer in the Memphis Area, Tennessee

James A. Kingsbury and Jeannie R.B. Barlow

For Better or for Worse: The State of the Former Shelby County Landfill

Scott Schoefnacker, Daniel Larsen, and Brian Waldron

*Fifteen Years of Age-Dating Groundwater from Production Wells in Shelby County, TN:
Summary of Results*

Daniel Larsen, Brian Waldron, and Scott Schoefnacker

A COLLABORATIVE EFFORT TOWARDS REAL-TIME WATER QUALITY EQUIPMENT DEMONSTRATION AT FALLING WATER RIVER, TENNESSEE

Alfred Kalyanapu¹, Tania Datta², Daniel Dodson³, Karina Bynum⁴, and Bill Harrington⁵

Continuous and real-time water quality monitoring of surface water bodies can have several benefits over conventional sampling and analysis techniques. However, an effective implementation of such monitoring often requires a collaborative effort between the local and state agencies along with academia and industry. During Fall 2014, the Tennessee Department of Environment Conservation in collaboration with Tennessee Technological University (TTU), City of Cookeville, HACH Company and Sea-Bird Scientific, conducted an in-stream water quality equipment demonstration study on the Falling Water River near Cookeville, TN. During its course, scientists and engineers from Sea-Bird Scientific, HACH and TTU installed in-situ analyzers to monitor nutrients (nitrates and phosphorus) along with stream flow and other relevant water quality data. This paper presents the data obtained from the one-month demonstration, effectiveness of real-time water quality monitoring equipment, and most importantly the *lessons-learned* on building collaborations and partnerships towards conserving and protecting watersheds.

INTRODUCTION

Conventional approaches to water quality sampling, laboratory analysis and data collection can be time and labor intensive and can pose significant financial burden. Moreover, it is unlikely, that traditional grab sampling methods will provide a reasonable estimate of the true temporal variability for a particular physicochemical parameter in a water body. In comparison, continuous real-time monitoring and data acquisition methods are beneficial, as they give an accurate idea of the changing environmental condition and complex water quality in real time. Over the past several years, instrument manufactures have developed sensors and analyzers for in-situ monitoring of a realm of water quality parameters. These analyzers can be deployed for extended periods of time for continuous monitoring, and the data can be uploaded over mobile devices for real-time access. Real-time nitrate and phosphate monitoring analyzers are also becoming available these days. The major supplier of these analyzers is Sea-bird Coastal. This company manufactures a nitrate analyzer (SUNA V2 <http://sea-birdcoastal.com/suna>) and a phosphate analyzer (Cycle PO4 <http://sea-birdcoastal.com/cycle-po4>).

Ms. Karina Bynum at the Tennessee Department of Environment and Conservation's (TDEC) Cookeville Field Office coordinated a 30-day demonstration of the capability of these analyzers

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⁴ Watershed Management Engineer, TDEC Division of Water Resources

⁵ Regional Manager, HACH Hydromet

with Sea-bird Coastal and HACH Company for a site on the Falling Water River. Tennessee Technological University (TTU) participated in the demonstration by collection of flow data of the stream, and performing data analysis of the monitoring data. This paper presents the data obtained from the one-month demonstration, effectiveness of real-time water quality monitoring equipment, and most importantly the *lessons-learned* on building collaborations and partnerships towards conserving and protecting watersheds.

APPROACH

Sea-Bird Coastal's field application engineers installed the in-situ analyzers on Falling Water River at the intersection of Burgess Mill Rd and Randolph Mill Rd. The analyzers were installed approximately 20 yards upstream of the bridge. The analyzers initially installed were Hydrolab datasonde DS5, SUNA V2 nitrate analyzer and Cycle PO4 phosphate analyzer. The nitrate analyzer (SUNA V2) utilizes a photo-spectrometric sensor to determine concentration of dissolved nitrate in water. The detection range of the instrument covers nitrate concentrations normally found in surface waters. The phosphate analyzer methodology is based on US EPA standard methods and combines precision fluidics with state-of-the-art optics to provide unparalleled precision and accuracy. Ideally suited for unattended monitoring the Cycle PO4 includes pre-mixed onboard reagent cartridges and onboard calibration standards. The Hydrolab DS5 is a multiprobe instrument configured to analyze for dissolved oxygen, conductivity, pH, temperature, and turbidity. The Global FL16 Flow logger captured stream depth data.

The analyzers were mounted in a cage and anchored in place mid-stream of the river. Analyzers were connected to the power supply and data logger located on the river bank via cables. Data collection was started on August 6th, 2014 and continued through September 9th, 2014. Analyzers were off-line from 9/2/2014-9/4/2014. The Cycle PO4 analyzer was removed from service after 24 hours of operation because the phosphate concentration of the river was beyond the specified upper concentration limit for the instrument. The TTU Water Center installed a Global Flow logger at the site on 8/6/2014, and collected data for the duration of the study. Analyzer readings were recorded at 30 minute intervals for the duration of the study except for the time period when analyzers were off-line. The parameters analyzed were temperature, dissolved oxygen, conductivity, pH, turbidity, nitrate and stream depth.

Grab samples were also collected for cross-referencing the nitrate analyzer data with laboratory analytical methods.

The TTU Water Center used a hand held velocity meter to obtain a stream velocity profile and calculate stream flow. This was performed at two stream depths in order to correlate stream depth and stream flow.

RESULTS AND DISCUSSION

All data collected for the Falling Water River project are presented graphically and discussed in this section. Figure 1 presents temperature, pH and dissolved oxygen data. pH is plotted on secondary axis. These physical parameters are considered normal for surface water bodies and have minimal influence on nitrate analyses.

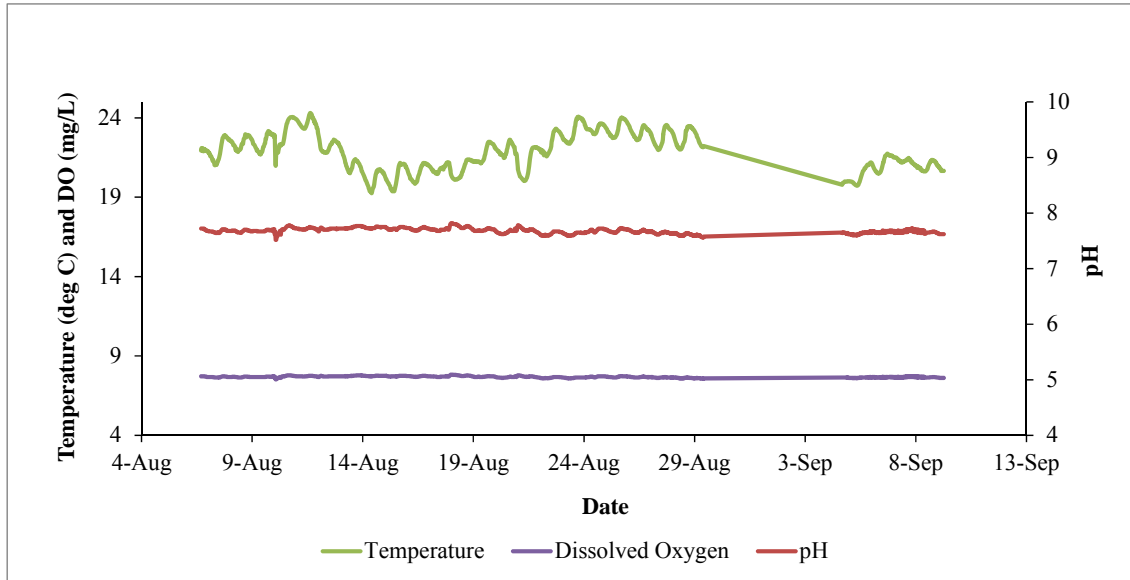


Figure 1. Temperature, pH and Dissolved Oxygen data from Falling Water River.

Figure 2 shows nitrate, turbidity and conductivity data. From the graphs, it is observed that nitrate concentration tracks conductivity. It is also observed that spikes in nitrate, conductivity and turbidity occur with significant spikes in stream flow.

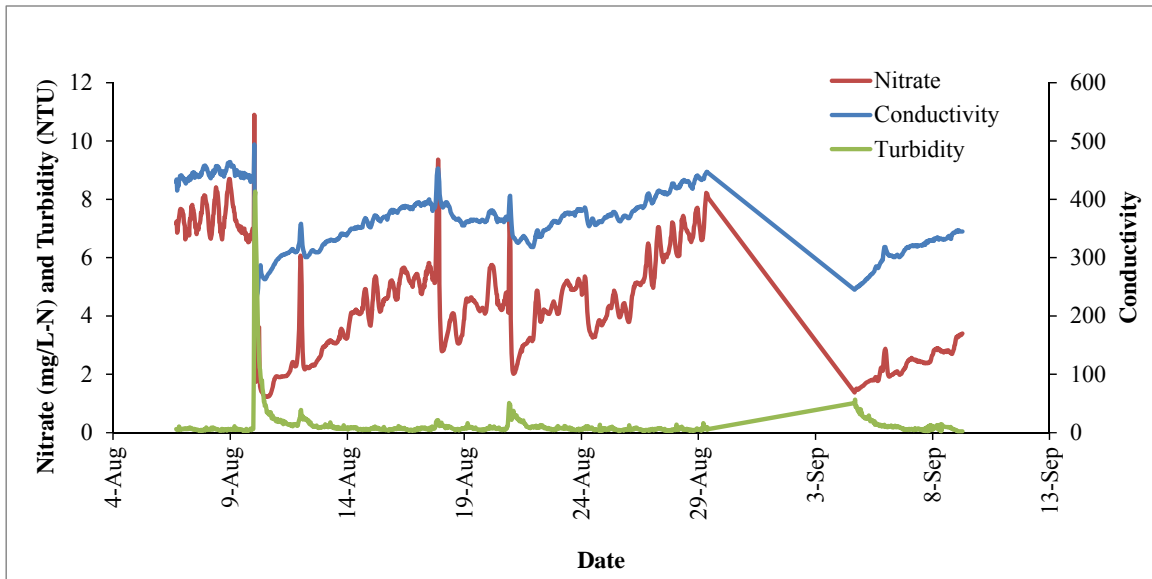


Figure 2. Nitrate, Turbidity and Conductivity data from Falling Water River.

Figure 3 shows the relationship between flow and conductivity data. Note that flow is plotted on an inverted axis. Flow is inversely related to conductivity except when significant flow spikes occur caused by rainfall in the watershed. The conductivity spikes may be associated with the ‘first flush’ phenomenon in which ionic species are initially flushed from the watershed during the first run-off of a rainfall event. Discreet samples would need to be collected during rainfall events to further define the nature of the constituents in these spikes.

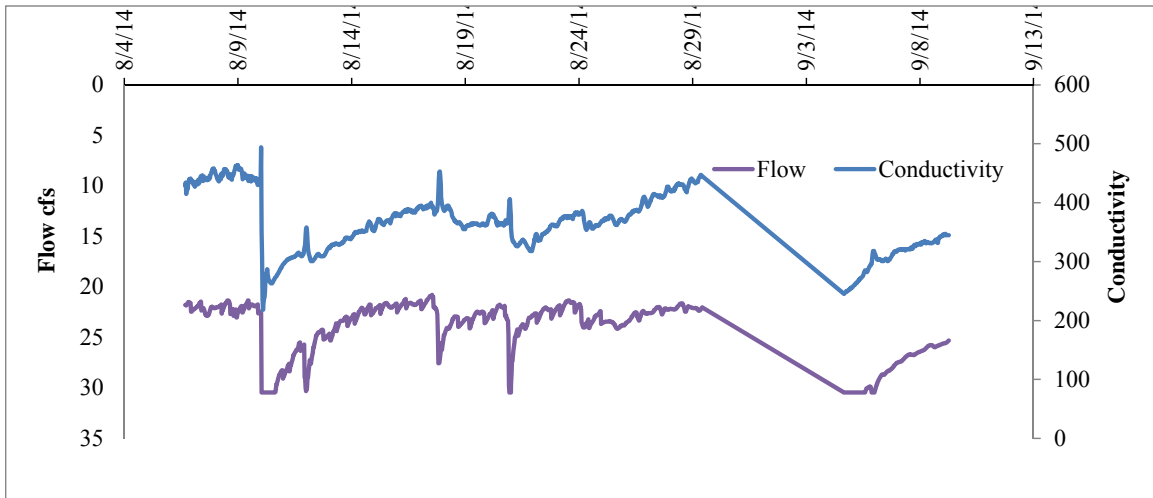


Figure 3. Flow and Conductivity data from Falling Water River.

Figure 4 shows nitrate and turbidity data. From this data, it is observed that spikes in nitrate correspond with spikes in turbidity and also with spikes in flow. Discreet samples during the spike events are needed to further define the relationship between increased flow and nitrate concentration. It is possible that increased turbidity during flow spikes result in increased absorbance of the SUNA V2 analyzer and account for the nitrate spikes.

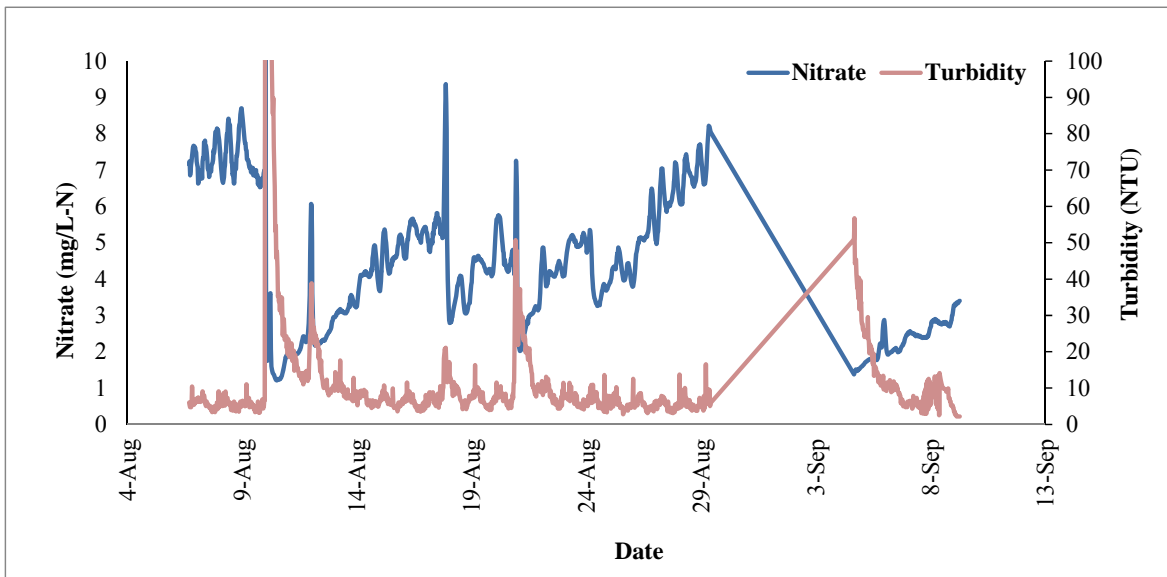


Figure 4. Nitrate and Turbidity data from Falling Water River.

Figure 5 shows flow and turbidity data. The correspondence between flow spikes and turbidity spikes are better demonstrated in this graph.

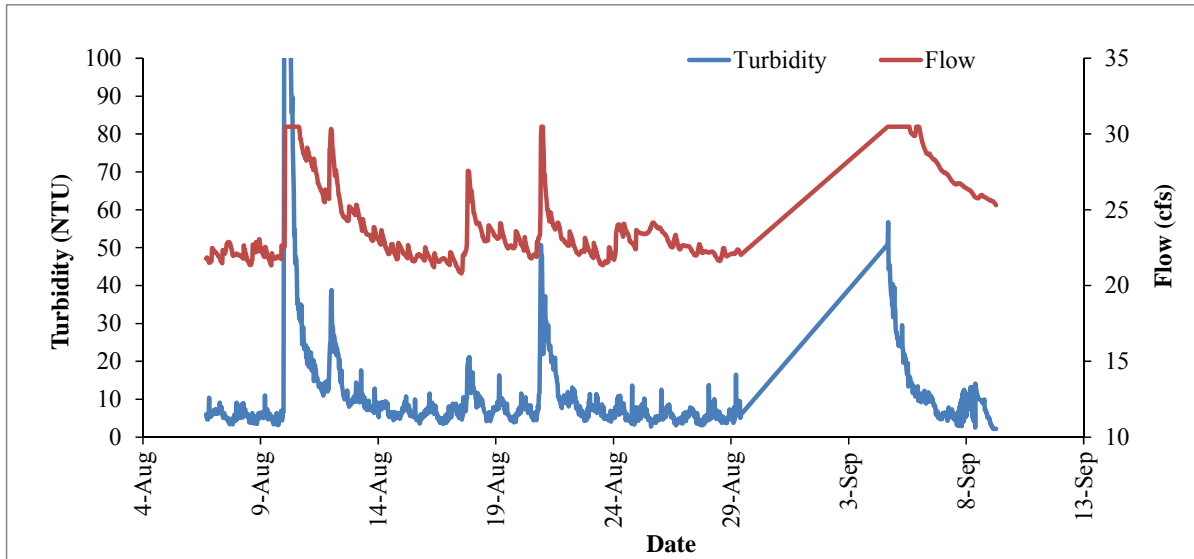


Figure 5. Flow and Turbidity data from Falling Water River.

The accuracy of the SUNA on-line nitrate analyzer was confirmed by collecting grab samples and analyzing by conventional nitrate analyses methods. The results of the cross-referenced grab samples are presented in Table 1 below. Results from the City of Cookeville, EFO and the SUNA are in good agreement.

Table 1. Comparison of Grab Samples with On-Line Nitrate Analyzer.

Date	Nitrate + Nitrite Analysis using SM 4500 Method		Nitrate UV Spec.	Nitrate by IC	Nitrite by IC	TKN		TON	TN [(NO ₂ +NO ₃)+TKN]	
	mg/L		mg/L	mg/L	mg/L	mg/L		mg/L	calc.	mg/L
	EFO	CKVL	SUNA	EFO	EFO	EFO	CKVL	EFO	EFO	CKVL
11-Aug-14	1.9	1.84	1.93	1.8	0.030J	0.64	1.40	0.61	2.54	3.24
12-Aug-14	2.2		2.25	2.1	0.028J	0.39J		0.37J	2.59	
18-Aug-14	3.3	3.35	3.28	3.2	0.029J	0.38J	0.65	0.54	3.68	4.00
19-Aug-14	4.4		4.54	4.4	0.033J	0.31J		0.81	4.71	
25-Aug-14	4.1	4.49	4.30	4.2	0.034J	0.40J	0.09	0.34J	4.5	4.58
26-Aug-14	4.9		5.13	5.0	0.039J	0.41J		0.33J	5.31	
1-Sep-14	1.3	1.33	*	1.3	0.024J	0.34	0.30	0.32J	1.64	1.63
02-Sep-14	1.7			1.7	0.026J	0.30J		0.28J	2.00	

CONCLUSIONS

Nitrate concentration in the Falling Water River was successfully monitored using the SUNA V2 analyzer, for a little over a 30-day period at 30-minute intervals. Continuous in-situ monitoring is much more cost effective than manual collection of individual samples and transporting these samples to the laboratory for analysis. The frequency of data collection also ensures that the analyses are much more representative of the stream than manual grab sample methodology. The continuous in-situ analyzer captures the variation in nitrate concentration associated with rainfall events and makes it much more possible to differentiate point and non-point source input to the receiving streams. The instrumentation also has the capability when connected to an Autosampler, to initiate sampling in spike events. This capability makes it viable to determine the constituent composition of ‘first flush’ runoff associated with rainfall events or other spikes that may occur. The continuous collection of data over an extended time period builds the necessary database to evaluate natural variations that occur in receiving streams.

EVALUATION OF TRACE METAL MONITORING RESULTS NEAR LANDFILL CONTAMINATION PLUMES IN TENNESSEE

Randy M. Curtis^{1*}

The Tennessee Solid Waste Regulations enacted in 1991 standardized monitoring procedures at permitted landfill sites in Tennessee to emphasize metals and volatile organic compounds in evaluation of groundwater samples. Leaching of metals from the solid wastes into groundwater was assumed to be one of the primary threats to human health and the environment so monitoring, so each facility was committed to monitoring for Antimony, Arsenic, Barium, Beryllium, Cadmium, Chromium, Cobalt, Copper, Lead, Mercury, Nickel, Selenium, Silver, Thallium, Vanadium, and Zinc. While no specific definition of what constitutes a plume of contamination is contained within the regulations, it is generally accepted as a volume of contaminated groundwater that extends downward and outward from a specific source. Examination of the upgradient, downgradient, and cross-gradient groundwater monitoring data from landfill sites in Tennessee indicates that unsaturated zone conditions, aquifer geologic materials, soil chemistry, microbial activities in the subsurface environment, and landfill gases resulting from degradation of organic wastes may all have some bearing on the number and quantities of trace metals contaminating groundwater. This complicates the task of defining the edge of the contaminant plume in that the edge of the zone of affected groundwater may not coincide with contaminants that leached directly from waste materials. Further, the monitoring requirements for landfill gas monitoring focus on explosive limits and do not account for potential effects of carbon dioxide on groundwater cross-gradient or upgradient over the water table.

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CONCEPTUAL MODELS OF THE FORMATION OF ACID-ROCK DRAINAGE AT ROAD CUTS IN TENNESSEE

Michael Bradley^{1*}, Tom Byl¹, and Scott Worland¹

Pyrite and other minerals containing sulfur and trace metals occur in several rock formations throughout Middle and East Tennessee. Pyrite (FeS₂) weathers in the presence of oxygen and water to form iron hydroxides and sulfuric acid. The weathering and interaction of the acid on the rocks and other minerals at road cuts can result in drainage with low pH (< 4) and high concentrations of trace metals.

Acid-rock drainage can cause environmental problems and damage transportation infrastructure. The formation and remediation of acid-drainage from roads cuts has not been researched as thoroughly as acid-mine drainage. The U.S Geological Survey, in cooperation with the Tennessee Department of Transportation, is conducting an investigation to better understand the geologic, hydrologic, and biogeochemical factors that control acid formation at road cuts.

Road cuts with the potential for acid-rock drainage were identified and evaluated in Middle and East Tennessee. The pyrite-bearing formations evaluated were the Chattanooga Shale (Devonian black shale), the Fentress Formation (coal-bearing), and the Precambrian Anakeesta Formation and similar Precambrian rocks. Conceptual models of the formation and transport of acid-rock drainage (ARD) from road cuts were developed based on the results of a literature review, site reconnaissance, and the initial rock and water sampling. The formation of ARD requires a combination of hydrologic, geochemical, and microbial interactions which affect drainage from the site, acidity of the water, and trace metal concentrations. The basic modes of ARD formation from road cuts are;

- 1 - seeps and springs from pyrite-bearing formations and
- 2 - runoff over the face of a road cut in a pyrite-bearing formation.

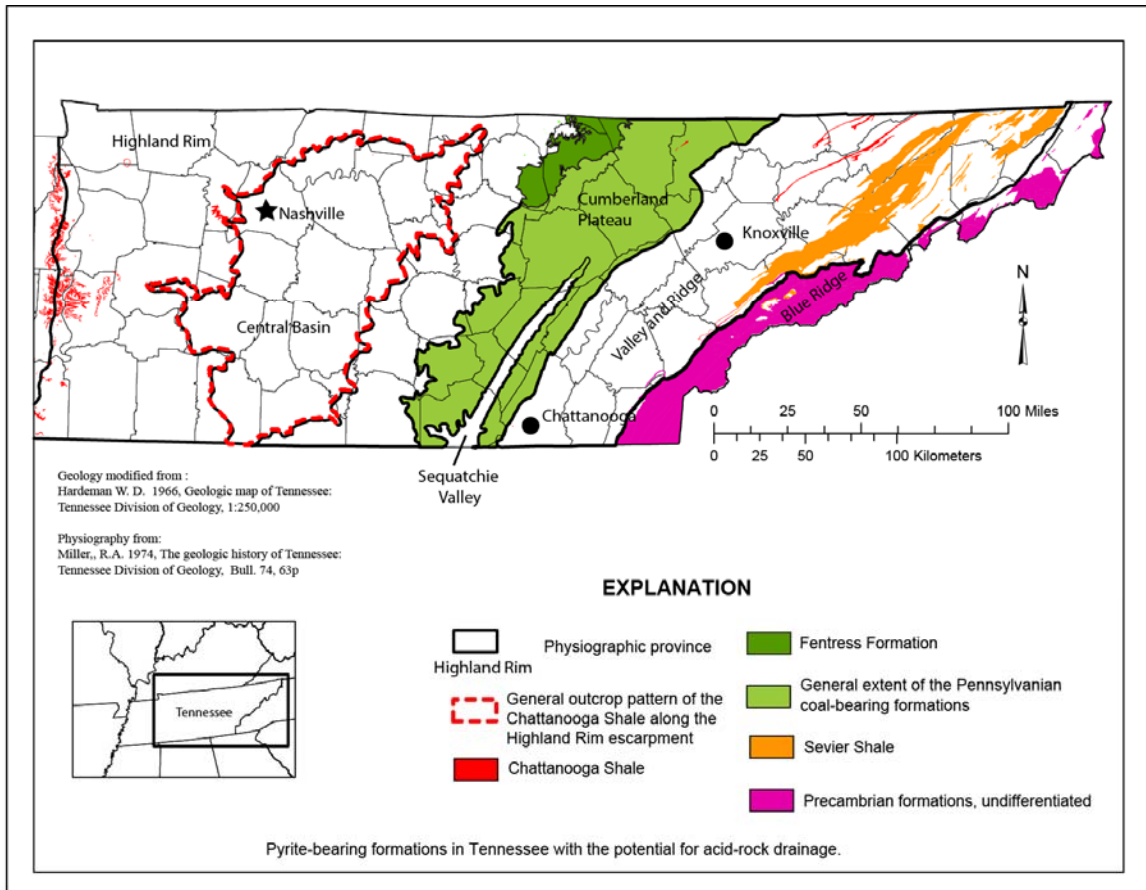
Depending on site conditions at road cuts, the basic modes of ARD formation can be altered and the additional modes of ARD formation are;

- 3 - runoff over and through piles of pyrite-bearing material, either from construction or breakdown material weathered from shale, and
- 4 - the deposition of secondary-sulfate minerals can store trace metals and, during rainfall, result in increased acidity and higher concentrations of trace metals in storm runoff.

Understanding the factors that control ARD formation and transport are key to addressing the problems associated with the movement of ARD from the road cuts to the environment. The investigation will provide the Tennessee Department of Transportation with a regional

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characterization of ARD and provide insights into the geochemical and biochemical attributes for the control and remediation of ARD from road cuts.



COLLABORATIVE WATERSHED STEWARDSHIP IN THE CUMBERLAND RIVER BASIN

Jed Grubbs^{1*}

Recognizing our basin's extraordinary value, the Cumberland River Compact (CRC) and The Nature Conservancy of Tennessee (TNC) have collaboratively developed regionally focused, introductory profiles of the Cumberland River Basin. The aim of these profiles is to characterize and celebrate the Cumberland Basin and to encourage stakeholders across the basin to join together and develop a more comprehensive and action oriented *State of the Basin* report. Such a report will explain in greater detail critical issues in the Cumberland Basin, identify opportunities for resource stewardship, and prioritize shared watershed stewardship strategies. The *State of the Basin* will also provide a platform for annually updated "report cards," which will establish health indices, benchmarks and goals for these indices, and track progress or decline in these indices over time.

We believe this work will significantly deepen our understanding of the basin, from the Cumberland's headwaters in eastern Kentucky to its confluence with the Ohio, and will allow the many stakeholders and agencies working in the basin to collectively make strategic decisions that target implementation efforts on those that will have the greatest impact for the greatest good. Working together, we can make great strides in improving water quality. As a result, our region will be a healthier place for our people, economy, and environment.

We hope to speak to attendees of the Tennessee Water Resources Symposium, sharing what we have learned in the development of regional basin profiles, and inviting attendees to join our larger State of the Basin effort.

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HOW MANY DROPS OF WATER FIT ON A PENNY? (YOUTH WATER EDUCATION)

Lena Beth Reynolds¹

In order for the public to be educated about the environment in the future, we must start with education of our youth today. Concerns about water quantity and water quality will be more common in the future. In Tennessee schools today, information presented by classroom teachers, as well as others, such as 4-H Agents, must be directed to fulfill requirements set by the state. 4-H Agents must be prepared to present factual science curriculum in order to continue to be allowed to meet clubs in the public school classrooms.

Hands-on experiment and activities are enjoyed, as well as remembered by students and teachers. The 4-H Motto learned decades ago was: Learn by Doing. Furthermore, professional demonstrations catch the attention of youth and can present more in-depth concepts.

University of Tennessee Extension has presented classroom activities, camp classes, and Farm Day demonstrations on water properties and water quality to thousands of youth in the past few years. Samples of these will be shown in this presentation. Photos will be shown of outdoor activities.

In the next few years, UT Extension will be studying existing water quality curriculum for youth. An outline of these plans will also be included.

¹ University of Tennessee Extension, Athens, TN

ARCGIS ONLINE AS A TOOL TO TEACH GLOBAL, REGIONAL AND LOCAL WATER RESOURCE ISSUES TO MIDDLE AND HIGH SCHOOL TEACHERS AND STUDENTS

Joanne Logan* and Ruth Anne Hanahan

The Water Quality Forum in Knoxville/Knox County, TN sponsors an Americorps Water Quality team each year. These volunteers are assigned to middle and high schools across Knox County to teach and lead active learning experiences about water resources issues, especially those related to their local communities. In June 2013, President Obama announced the ConnectED initiative, designed to enrich K-12 education for every student in America. ConnectED empowers teachers with the best technology and the training to make the most of it, and empowers students through individualized learning and rich, digital content (<http://www.whitehouse.gov>). As part of this initiative, ESRI has agreed to provide free access to ArcGIS Online Organization accounts – the same Geographic Information Systems mapping technology used by government and business – to every K-12 school in America to allow teachers and students to map and analyze data. We have developed an ArcGIS Online workshop using hydrology, topography, land use, and demographic information to teach engaging case studies about water resource issues at the global, regional, and local levels to the Americorps volunteers, students, teachers, parents, school administrators, and local community. Participants use both the public and organizational versions of online mapping to compare the potential of each for their own programs. Assessments are used to measure the success of the workshop and the future adaptation of ArcGIS online in the classroom. ArcGIS Online is a sophisticated yet easy to use tool for teachers and students to better understand water resource issues.

EVALUATING AGRICULTURAL BEST MANAGEMENT PRACTICES IN THE MISSISSIPPI DELTA: PRELIMINARY FINDINGS

Jenny Murphy and Matt Hicks

Located in northwestern Mississippi, Bee Lake and Lake Washington drain watersheds that have been extensively farmed for row crops. The U.S. Department of Agriculture Natural Resources Conservation Service, Mississippi Department of Environmental Quality and Delta Farmers Advocating Resource Management (Delta FARM) began installing best management practices (BMPs) in these watersheds around 2008. These installations were a part of the State of Mississippi's Nutrient Reduction Strategy, which strives to reduce nutrient and sediment contributions to receiving waters. The U.S. Geological Survey began conducting event-based monitoring in these watersheds around the time the BMPs were installed. The collected data, along with information about farming practices and climate, were used to evaluate the effectiveness of the BMPs. Flow-adjusted concentrations and loads were computed prior to a three-step data analysis. Statistical trends were explored to identify changes in water quality likely associated with BMP implementation. Structural-equation modeling was used to determine the likely causes of variability in nutrient concentration and load. A comparative analysis of hysteresis relationships was used to identify changes in the sources of nutrients and hypothesize potential mixing-models for these watersheds.

IMPACT OF CROPLAND MANURE APPLICATION ON WATER QUALITY IN SURFACE WATER, DRAIN TILE DISCHARGE AND GROUNDWATER AT THE UT LITTLE RIVER DAIRY FARM

Larry D. McKay, D. Street, A. Layton, R.W. Hunter, D. Williams, and A. Ludwig

The problem of assessing and limiting agricultural impacts on water quality is compounded by high variability associated with soil/sub-soil type, hydrology, climate and farming/livestock practices. Thus, it is important to develop a variety of research sites in different locations to investigate transport pathways, water quality impacts and test the effectiveness of management practices. This talk focuses on investigations at a small research dairy (<250 milking cows) operated by the University of Tennessee. The site includes approximately 100 hectares of low-relief cropland underlain by 3 to 9 m of floodplain deposits (silt and sand, with some gravel layers), which is bounded on two sides by a 4th order stream (the Little River) and on another side by a state-designated impaired 3rd order stream (Ellejoy Creek). This talk focuses on the surface water quality response to seasonal applications of liquid manure in the central portion of the floodplain, where a drainage ditch collects surface runoff, drainage tile discharge and groundwater discharge from an area of about 40 hectares of rotational cropland. Water samples were collected from the ditch at 3 locations, from 4 proximate wells and 6 drainage tile discharge locations before and after application of liquid manure. Monitoring began prior to commencement of dairy operations in 2011 and increased in frequency beginning in April 2013. The data set includes 4 manure application events (May 2013, November 2013, May 2014 and November 2014), each of approximately 2 million liters. The May 2013 application, which occurred during a rainy period, resulted in small, but statistically significant increases in *E. coli*, *Bacteroides* and nitrates above background levels in many sampling points. Applications in November 2013 and May 2014, under relatively dry conditions, did not lead to significant increases in these parameters. The November 2014 manure application was delayed due to heavy rains prior to the planned application date. During the period of background monitoring, levels of *E. coli* increased substantially in the drainage tiles and ditch, reaching a peak just as manure was starting to be applied to the fields. Concentrations then declined over the next 3 weeks. This strongly suggests that rainfall was mobilizing *E. coli* in the soils prior to manure application and confirms that rainfall rate is an important factor at this site. Monitoring is continuing to assess the importance of rainfall events on microbial indicators in surface water and drain tiles during periods between manure applications.

ALTERNATIVE TILE INTAKE DESIGN FOR INTENSIVELY MANAGED ECOSYSTEMS

A.N. Thanos Papanicolaou^{1*}, William D. Ettema², Christopher G. Wilson³, and Benjamin K.B. Abban⁴

The overall goal of this study was to demonstrate the effectiveness of an alternative tile intake (ATI) at reducing runoff and sediment loads in intensively managed landscapes. An ATI consists of a 3-foot gravel layer atop a 1-foot layer of wood chips. Gravel intakes are highly efficient at trapping sediment and sediment-bound particulates, like phosphorus, by enhancing settling through ponding and filtration, while the wood chips facilitate denitrification. Additionally, these intakes help reduce the runoff flow rate into subsurface tile drains or drop-pipe structures relative to conventional intakes. In this study a physical model was established in the laboratory to quantify the saturated hydraulic conductivity and filter efficiency of different combinations of gravel and wood chips. To complement the experimental study, the Water Erosion Prediction Project (WEPP) model was used to simulate the field conditions at a test site for calculating runoff volumes and sediment loads to an intake for rainfall events of different magnitudes. A significant goal of this study was to decompose the key mechanisms that affect the migration of flow and sediment through the gravel-wood chips matrix under a fixed head and incoming concentration. This study shows that intrusion occurs and the depth of intrusion can be captured by the change in the hydraulic gradient that occurs during an event and during a sequence of events. A secondary goal of this research is to understand the cycles of sediment migration during a sequence of different events.

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GROUNDWATER GEOCHEMISTRY AND AGE ALONG TWO FLOW PATHS IN THE MEMPHIS AQUIFER IN THE MEMPHIS AREA, TENNESSEE

James A. Kingsbury¹ and Jeannie R.B. Barlow²

To better understand the sources of groundwater to drinking-water wells in the Memphis area, Tennessee, twenty-two existing wells along two inferred east to west flow paths in the Memphis aquifer were sampled in August 2013 for a broad range of inorganic and organic constituents and groundwater age-dating tracers. A regional groundwater flow model was used to backtrack particles from two production wells to the recharge area of the Memphis aquifer to delineate the flow paths. In addition to the water-supply wells that defined the flow paths in the Memphis aquifer, 5 monitoring wells screened in the fluvial (terrace) deposits aquifer or the upper part of the Memphis aquifer in eastern Shelby County. These wells were sampled to characterize the water quality and age of water that may move downward into the Memphis aquifer in areas where the upper confining unit is thin or absent. The Memphis Sand, which makes up the Memphis aquifer, is composed of predominantly quartz sand which dissolves slowly and does not contribute high concentrations of solutes to groundwater. As a result, the observed changes in basic groundwater chemistry along the flow paths were relatively small with specific conductance increasing from about 40 to 120 microsiemens per centimeter at the end of the flow paths. Groundwater in the Memphis aquifer progresses from oxic conditions at upgradient locations to anoxic-sulfate reducing conditions in downgradient locations where the aquifer is confined. Age-date tracers indicate that groundwater age increases along the flow paths and the presence of low-level concentrations for volatile organic compounds suggests that some recent water is present in the Memphis aquifer at the locations of all of the sampled wells.

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FOR BETTER OR FOR WORSE: THE STATE OF THE FORMER SHELBY COUNTY LANDFILL

Scott Schoefernacker^{1,2}, Daniel Larsen^{1,2}, and Brian Waldron¹

INTRODUCTION

The unlined Shelby County landfill at Shelby Farms in Memphis, Tennessee, lies in the flood plain of the Wolf River and is known to be the source of low-level contamination in the underlying alluvial and Memphis aquifers. Prior to closure, discovery of a hydrogeologic “window” in the upper Claiborne confining unit overlying the Memphis aquifer 0.2 km north of the landfill led to several groundwater investigations by the U.S. Geological Survey (USGS) to evaluate the threat posed to the Memphis aquifer, the regional source for municipal water supplies (Bradley, 1988; Bradley, 1991; Parks and Mirecki, 1992). Later studies by The University of Memphis Ground Water Institute investigated recharge rates and window geometry at the landfill (Ng, 1993; Gentry *et al.*, 2006; Waldron *et al.*, 2009). This study reviewed historical groundwater sampling events (comprehensive and semiannual regulatory monitoring events) and conducted a comprehensive groundwater sampling event in 2011 and subsequent resistivity survey in 2012. These data provide a series of snapshots of the leachate plumes’ migration and its impact to the shallow and Memphis aquifers, which may have implications regarding the effectiveness of post-closure monitoring.

APPROACH

Groundwater quality data collected since the initial USGS studies, including available post-closure semi-annual sampling events to July 2011, were assimilated into a single database. The 2011 sampling event served as a benchmark for the overall water quality in the shallow and Memphis aquifers in the vicinity of the former Shelby County Landfill. The area north of the landfill near the “window” is the main area of concern and was the focus of the resistivity survey. Seven resistivity lines were completed north of the SCL using an AGI SuperSting R8/IP. Each array consisted of 28 stainless-steel electrodes at 10 meter spacing for a total length of 270 meters. Efforts were made to tie resistivity lines in with well locations and known groundwater data to aid in interpretation of resistivity data.

RESULTS AND DISCUSSION

The impairment of shallow and Memphis aquifer well water relative to the background well waters is primarily due to higher concentrations of metals, particularly barium, and common anions as well as nitrogen species. Specific conductance concentrations in shallow wells along the northern landfill boundary were 9 to 12 times the values of background concentrations. These wells also exhibited strong odors and a visible sheen on the purge water during the

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sampling event. Specific conductance values significantly declined in the shallow aquifer well in the hydrogeologic window. However, elevated specific conductance values are present in two Memphis aquifer wells in the hydrogeologic window; these values are 5 to 7 times higher than background values for the Memphis aquifer.

Exceedances of nitrate and arsenic appear to be spatially limited. Elevated nitrate concentrations are present in areas of cultivated farmland and likely attributed to agricultural fertilizer use, not the landfill. Elevated arsenic concentrations are most likely from the landfill; however, the impacts are spatially limited due to sorption and precipitation.

Volatile organic compounds (VOCs) detected in the shallow and Memphis aquifers are attributed to the landfill since none are detected in background wells and no other known sources are in the vicinity of the landfill; however, no VOC concentrations exceeded their respective maximum contaminant level. The bulk of VOC detections are in wells on the northern landfill boundary and within the Memphis aquifer portion of the hydraulic window at the unconfined cluster and include benzene, chlorobenzene, cis-1,2-dichloroethene, 1,4 dichlorobenzene, toluene, and naphthalene. Dichlorodifluoromethane and tetrachloroethene are detected in Memphis aquifer downgradient from the hydrogeologic window.

Difficulties arose during the spatial and temporal analysis of the groundwater data due to the limited number of wells and lack of basic groundwater quality parameters sampled during the post-closure monitoring, which included only two shallow and two Memphis aquifer wells. These difficulties may stem from regulatory “at minimum” requirements to sample Appendix I list metals and volatile organic compounds and one upgradient and two downgradient wells (TDEC 0400-11-01, March 2013). The issue at this landfill is that there are two aquifers impacted by leachate, not just one. In addition to the groundwater analysis, resistivity inversion models and interpretations will be briefly discussed to determine the effectiveness of the survey and its application at landfill sites.

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FIFTEEN YEARS OF AGE-DATING GROUNDWATER FROM PRODUCTION WELLS IN SHELBY COUNTY, TN: SUMMARY OF RESULTS

Daniel Larsen^{1,2}, Brian Waldron², and Scott Schoefernacker^{1,2}

The Ground Water Institute has conducted sampling and age-dating analysis of production waters from Memphis, Light Gas and Water and other municipal wells in Shelby County since 1999 in order to better understand where Memphis aquifer water resources are most vulnerable to degradation. Much of the sampling during 1999 to 2004 focused on establishing the presence of modern water (<60 years old) in wells using ^3H analysis. The use of $^3\text{H}/^3\text{He}$ to determine groundwater age began in 2000 and was supplemented with SF_6 following 2009. The results of our study confirm the following: (1) Modern water is present in many municipal well fields within Shelby County. Current data indicate $^3\text{H}/^3\text{He}$ ages of 11 to 50+ years in production waters in MLGW Allen, Davis, Lichterman, and McCord, Sheahan, and Shaw well fields, and at least one well field each in Bartlett, Collierville, and Germantown. (2) Mixing percentages of modern groundwater in production wells range from 0 to 76%. The proportion of modern water in the production well waters generally decreases with increasing depth of screen and distance from a window in the upper Claiborne confining unit to the production well. The age dating results collected over the past 15 years indicate considerable vulnerability of the Memphis aquifer to recharge of modern water and potential contamination. The results from the current piecemeal sampling approach argue for the need to establish more comprehensive monitoring, particularly of vulnerable production wells or wells that are likely to become more vulnerable through time.

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SESSION 3A

LID

8:30 a.m. – 10:00 a.m.

Maintenance and Cleaning of Pervious Concrete Systems
Alan Sparkman

LID Design Competition
Don Green

*Nashville's Voluntary Post Development LID Stormwater Treatment Program—Trial Period
Results and Lessons Learned*
R. Dohn

TDEC/EPA

10:30 a.m. – 12:00 p.m.

*A Long-Term Vision for Assessment, Restoration, and Protection Under the Clean Water Act
Section 303(d) Program*
Amy Feingold

The New Recovery Potential Screening Tool
Regan W. McGahen, David M. Duhl, and Sherry H. Wang

Using EPA Region 4's 5R Approach as Alternatives to TMDLS
David M. Duhl and Sherry H. Wang

MAINTENANCE AND CLEANING OF PERVIOUS CONCRETE SYSTEMS

Alan Sparkman^{1*}

INTRODUCTION

Pervious concrete is often utilized as an integral part of a stormwater management system. Pervious concrete systems reduce the quantity of stormwater runoff and properly designed systems can infiltrate large volumes of stormwater thus lowering the quantity of stormwater that leaves a given site as well improving the quality of stormwater due to filtering action by the pervious concrete as well as the underlying soil.

For pervious concrete to function effectively it needs to be maintained, primarily to retain adequate rates of infiltration for the entire system. In cases where maintenance is not performed on a regular basis, or where pervious concrete may be subjected to extraordinary events, cleaning of the pavement to restore infiltration may be necessary.

APPROACH

This presentation will give a brief overview of both maintenance and cleaning techniques that have proven to be effective for pervious concrete. Results from the actual cleaning of Tennessee pervious concrete installations will be shared, along with information on maintenance and cleaning from other projects around the US. Guidelines from the new (2015) NRMCA Pervious Concrete Operations manual will also be presented and discussed.

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LID DESIGN COMPETITION

Don Green, LEED AP
Water Quality Supervisor

ABSTRACT

The objective of this project was to develop a *Low Impact Development (LID)/Green Infrastructure (GI) Design Competition*. The Design Competition challenged teams of development professionals to demonstrate cost-effective approaches to implement LID/GI design on selected development sites.

Each entry was comprised of an integrated design team consisting of at least a *Professional Engineer, and a Registered Landscape Architect*. The inclusion of team members from the Land Planning, development community, homebuilding and construction disciplines, including students, was strongly encouraged. Teams were required to have at least one member who was based in Chattanooga.

The four properties in Chattanooga were selected for the design: Broad Street, Cherokee Blvd, a multi-use property off Bonny Oaks Drive and Northgate Mall.

NEW DEVELOPMENT STANDARDS

The City of Chattanooga has developed new runoff reduction/GI design standards along with a LID manual that the participants in the Design Competition use. The Competition was used to test the effectiveness of the new standards or other requirements set forth by the Criteria Committee.

The LID/GI Design Competition was a unique and powerful tool to drive and widely spread the adoption and implementation of LID/GI in the development community in Southeast Tennessee. We hoped this competition could later be duplicated by other regions in Tennessee.

We had hoped that it would demonstrate to the statewide design professionals, and to the development and civic communities, the economic, environmental and marketing benefits that are available to those developers and local governmental entities who adopt and innovate with respect to sustainable site development.

We developed a Technical Committee that developed the criteria of the completion and served as judges and conducted the first round of judging.

A Technical Committee was selected from the environmental, building and design community, and state and federal regulatory agencies, to conduct the judging at the night of the competition. They selected the first, second and third place winners, but the public's help was sought to select the People's Choice Award.

This project was funded through a grant from Lyndhurst Foundation and River City Company along with sponsorship from AquaShield and Belgard. Green|spaces, out of Chattanooga, was indispensable with help on implementing this project.

NASHVILLE'S VOLUNTARY POST DEVELOPMENT LID STORMWATER TREATMENT PROGRAM – TRIAL PERIOD RESULTS & LESSONS LEARNED

R. Dohn

Metro Nashville released their Low Impact Development (LID) Manual to the development community three years before the one inch runoff reduction standard becomes mandatory. They are using this period to assess the effectiveness of the Manual and fix any problems prior to it becoming a requirement. Approximately 25% of the plans currently submitted use the LID Manual methodology. Metro Nashville has already made some changes to the Manual based on problems discovered while reviewing projects and plans to make additional changes in the next year. They are also developing the standards that site designers will use to prove a project cannot meet the one inch requirement. This presentation will discuss what Nashville has learned during the LID implementation process.

A LONG-TERM VISION FOR ASSESSMENT, RESTORATION, AND PROTECTION UNDER THE CLEAN WATER ACT SECTION 303(D) PROGRAM

Amy Feingold

The Clean Water Act Section 303(d) Program provides for effective integration of implementation efforts to restore and protect the nation's aquatic resources, where the nation's waters are assessed, restoration and protection objectives are systematically prioritized, and Total Maximum Daily Loads and alternative approaches are adaptively implemented to achieve water quality goals with the collaboration of States, Federal agencies, tribes, stakeholders, and the public

In 2013, EPA released a new collaborative framework for implementing the Clean Water Act (CWA) Section 303(d) Program with States — *A Long-Term Vision for Assessment, Restoration, and Protection under the Clean Water Act Section 303(d) Program*. The Vision is the result of the experience gained by states and EPA over the past two decades in assessing and reporting on water quality and in developing approximately 65,000 TMDLs, and is a product of a collaborative process between the states and EPA that began in 2011.

The Long-Term Vision focuses on six goals for efficient and effective implementation of the CWA 303(d) program, each with milestones leading up to 2022:

- Systematic **prioritization** for the location and timing of water quality restoration plans;
- **integration** and partnership between local, state and federal offices and multiple water programs;
- targeted **protection** of existing uses and high quality waters;
- consideration of **alternative** restoration approaches where these may be more immediately beneficial or practicable than a TMDL to achieve water quality standards;
- facilitating meaningful **engagement** with the public and stakeholders; and
- monitoring and **assessment** to acquire a comprehensive understanding of the water quality status and program effectiveness in priority areas.

While the Vision provides a new framework for implementing the CWA 303(d) Program, it does not alter State and EPA responsibilities or authorities under the CWA 303(d) regulations.

To support the Prioritization Goal, EPA Region 4 states are providing Prioritization Framework documents, which detail how the states will determine what waters they will focus on between 2016 and 2022. These documents, along with the actual priorities selected, will be referenced or included with the states' 2016 Integrated Report.

In addition to developing TMDLs for impaired waters, the Long-Term Vision encourages states to identify, evaluate, and promote alternative restoration approaches, when these approaches may be more immediately beneficial or practicable to achieving applicable water quality standards. Impaired waters that are being addressed by an alternative restoration approach would remain on the 303(d) List (i.e., Integrated Report Category 5) until water quality standards are achieved, and may require TMDL development if sufficient progress does not occur.

THE NEW RECOVERY POTENTIAL SCREENING TOOL

Regan W. McGahen¹, David M. Duhl¹, and Sherry H. Wang¹

Recovery potential is the likelihood of an impaired water to re-attain a desired condition, given its ecological capacity, exposure to stressors, and the social context affecting efforts to improve its condition. Tennessee is developing a Recovery Potential Screening Tool that will help Tennessee compare restorability across all watersheds in a systematic but flexible way. This science-based process to rank and prioritize watersheds has many applications including restoration prioritization, watershed protection, TMDL development and plan implementation, nonpoint source project prioritization, and water quality monitoring prioritization.

The Tennessee Department of Environment and Conservation has been collaborating with the Environmental Protection Agency and its contractor to develop a Tennessee-specific tool. The tool considers ecological capacity, exposure to stressors, and social context to make an integrated priority score that allows for the prioritization and ranking of Tennessee watersheds and a means to communicate the findings. Each of these parameters is supported by multiple data sets that can be combined to meet query-specific needs. Results can be expressed as a rank order, a GIS interpretation, or a four-variable bubble plot. Tennessee has been using the tool with partner agencies: TVA to identify HUC-12 subwatersheds for restoration in the Elk River Watershed and NRCS to identify HUC-12 subwatersheds for the National Water Quality Initiative (NWQI).

Since the release of the original tool, Tennessee has been working with EPA and its contractor to develop and test a newer tool that includes nutrient-specific indicators and uses a systematic, comparative method for identifying differences among watersheds that may influence their relative likelihood to be successfully restored or protected.

The recovery Potential Screening Tool has applications for prioritizing development of TMDLs and alternatives as part of EPA's new 303(d)/TMDL Vision and for EPA's Healthy Watershed Initiative. More information is available at:

<http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/recovery/tools.cfm>

¹ Tennessee Department of Environment and Conservation, Division of Water Resources

USING EPA REGION 4'S 5R APPROACH AS ALTERNATIVES TO TMDLS

David M. Duhl¹ and Sherry H. Wang¹

As part of EPA's new 303(d)/TMDL Vision, Tennessee has been working with EPA Region 4 to develop alternatives to TMDLs that are designed to meet water quality standards. One alternative, integrated reporting sub-category 5R, is being offered by EPA Region 4. The voluntary 5R approach recognizes the importance of partnerships with stakeholders to implement water quality restoration activities prior to TMDL development and provides a framework to document those activities. States may defer TMDL development for those waterbodies and pollutants while they remain on the 303(d) List. If waterbodies are not showing water quality improvements within a reasonable period of time, the waterbody may be removed from the 5R category and reprioritized for TMDL development.

The Tennessee Department of Environment and Conservation has begun to identify 5R candidates where the influence of adjacent land use drives the impairment of water quality. 5R Plans recognize limitations in development of implementable TMDLs and the importance of sustainable water quality restoration plans that are developed through stakeholder collaboration.

Components of a sample 5R report and examples of stakeholder collaborations will be presented.

¹ Tennessee Department of Environment and Conservation, Division of Water Resources

SESSION 3B

STREAM RESTORATION I

8:30 a.m. – 10:00 a.m.

Divining the Pitfalls of Urban Stream Restoration Design
Patrick McMahon and Ken Barry

Application of the High Definition Stream Survey on the Paint Rock Creek and Bear Creek Watersheds
Brett Connell

Assessing Spatial Relationships of Distributed Urban Land Cover Composition and In-Stream Flow Regime in Knoxville, TN
Thom Epps and Jon Hathaway

STREAM RESTORATION II

10:30 a.m. – 12:00 p.m.

A Monitoring and Assessment Framework to Evaluate Stream Restoration Needs in Urbanizing Watersheds
John S. Schwartz

The May Prairie Stream Restoration Project: Functional Improvement at a Valuable State Natural Area
Adam Spiller

The Removal of a Lowhead Dam at McCabe Golf Course on Richland Creek in Nashville, TN
Gary Mryncza

DIVINING THE PITFALLS OF URBAN STREAM RESTORATION DESIGN

Patrick McMahon¹ and Ken Barry²

The Natural Channel Design (NCD) approach promoted by the U.S. Environmental Protection Agency and others is strongly dependent on the quantification of the bank full flow rate and associated channel geometries of a given stream. In an urban setting, the determination of bank full flows is often a difficult prospect given the complex nature of urban hydrology, the highly modified morphology and hydrology of urban streams, and the often subjective indicators of bank full stage that can be observed in the field. This presentation will describe the application of continuous simulation modeling (CSM) to supplement bank full flow interpretations on urban streams. CSM involves the application of a continuous record of historical precipitation data to hydrologic and hydraulic models for a given watershed. This technique is useful for the estimation of the frequency of flows of a given magnitude, such as the bank full flow, as well as the evaluation of the potential impact of future hydromodification within a watershed. Another difficulty that arises in the use of NCD in urban settings is the need for reference reach data. Reference reach data are intended in part, as a means to evaluate the long term dynamic stability of the restored reach. Given the degree of anthropogenic impacts to urban watersheds and their receiving streams, a suitable reference reach may be difficult to identify. This presentation describes the application of 2D modeling techniques to supplement the use of any available reference reach data.

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APPLICATION OF THE HIGH DEFINITION STREAM SURVEY ON THE PAINT ROCK CREEK AND BEAR CREEK WATERSHEDS

Brett Connell¹

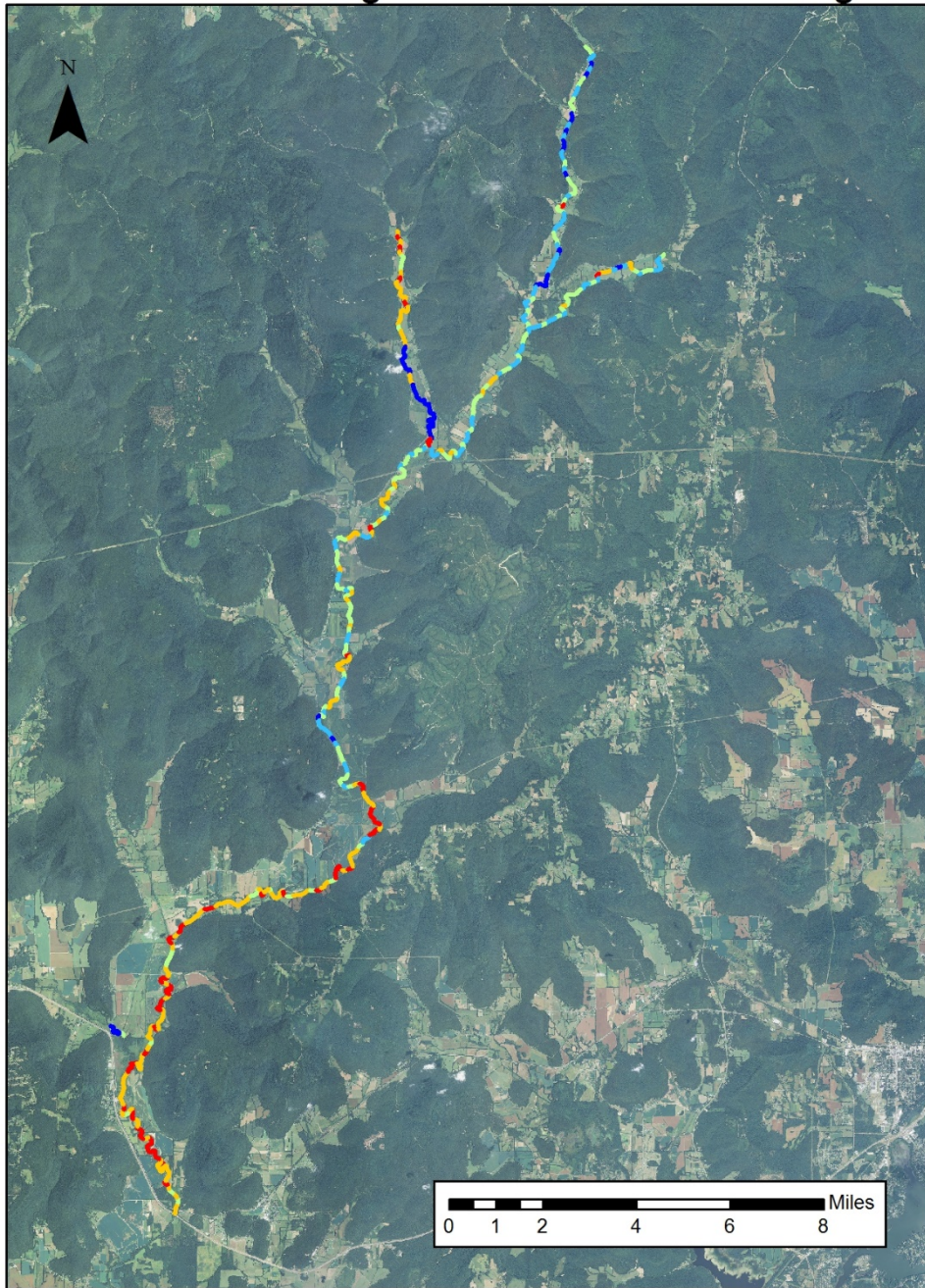
Traditional stream survey methods are often spatially limited due to access, time consuming, expensive, and done with a specific set of parameters. The novel HDSS (High Definition Stream Survey) approach was created to integrate GPS, video, and depth sensors to gather continuous geo-referenced data on substrate and both streambanks in a single pass. Data gathered can be used to assess countless habitat parameters and locate areas that contribute to poor stream conditions or even locate optimal habitat for reintroduction of threatened and endangered species.

Two recent surveys of Bear Creek and the Paint Rock River provide an example of the HDSS application. Using the HDSS, 63 continuous miles of river in the Bear Creek Watershed were surveyed in 4 days and 53 continuous miles of the Paint Rock River and its tributaries were surveyed in 3 days. Each GPS point had associated bank condition and habitat scores and was used to develop geo-referenced video and GIS habitat quality maps. The survey results will be used in three ways; 1) As a tool for monitoring the results of previous restoration activities; 2) a tool to prioritize future restoration efforts and action areas; and 3) baseline characterization of river bank conditions in 2014 for future review.

¹ Trutta Consulting, truttaconsulting@gmail.com, 419-215-7897

Paint Rock River Watershed

200 m Stream Segment Combination Rating



Colors range from Blue for good bank condition to Red for bad bank condition scores.
The 200 m Stream Segment Combination Rating includes the 200 m stream segment scores for both right and left bank weighted equally.

ASSESSING SPATIAL RELATIONSHIPS OF DISTRIBUTED URBAN LAND COVER COMPOSITION AND IN-STREAM FLOW REGIME IN KNOXVILLE, TN

Thom Epps^{1*} and Dr. Jon Hathaway²

The impacts of urban land cover on hydrology in highly developed watersheds are known to contribute to the urban stream syndrome, limiting the ability of these resources to meet their designated uses. Impervious surfaces and efficient stormwater drainage networks work in concert to collect and convey rainfall quickly to urban stream systems with greater volume, higher pollutant loading, and higher energies than previously experienced in predeveloped conditions. This has a negative impact on stream ecology, channel morphology, and water quality. Green infrastructure has emerged as a way to retrofit urban drainage systems to promote more natural hydrologic pathways in an effort to suppress peak stormflows and provide natural pollutant removal through infiltration. Impervious surfaces that are directly connected to the stream (effective impervious) can be disconnected by intercepting runoff along urban flowpaths with green infrastructure. However, stormwater retrofitting can be expensive in highly developed areas. If a systematic strategy of dispersed green infrastructure is sought to restore more natural flows throughout an urban catchment, greater knowledge of the drainage network and areas contributing surface runoff are necessary. Three urban watersheds in Knoxville, TN, representing different development patterns will be assessed using high-resolution land cover and drainage network data to identify the determining variables contributing to altered flow regimes. Spatial distribution of impervious land cover with respect to area, proximity to the stream, relationship to neighboring land cover, and connection to streamflow will be measured to assess the effects on flashiness, peak stormflow, and baseflows. This information will better inform how runoff is produced in urban catchments, how the distributed mosaic of pervious and impervious surfaces impacts the flow regime, and how surface runoff flowpaths might be altered to contribute to more natural drainage characteristics. The overall goal of this study is to develop methods which can be utilized to more rapidly assess effective imperviousness in urban watersheds and thus provide more targeted approaches to green infrastructure placement with greater knowledge of dispersed runoff production mechanisms.

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² University of Tennessee Knoxville Water Resources Engineering, Assistant Professor

A MONITORING AND ASSESSMENT FRAMEWORK TO EVALUATE STREAM RESTORATION NEEDS IN URBANIZING WATERSHEDS

John S. Schwartz¹

Urbanization has a significant impact on rivers and streams, modifying flows, sediment loads, channel morphology, water quality and nutrient processing, and aquatic biota. Because of these impacts, a majority of the streams in urban and urbanizing watersheds are reported on §303(d) state lists as impaired from siltation, habitat alteration, nutrients, bacteria, and other stressors. States are required to develop total maximum daily loads (TMDLs) under 40 CFR 130, and watershed-scale implementation plans are produced to rehabilitate impaired streams by achieving target TMDL allocations. Stream restoration practices are commonly used as corrective measures to meet TMDLs, particularly for siltation and habitat alteration. However for various reasons, urban stream restoration typically consists of reach-scale projects that may not be well integrated into a watershed corrective plan. Project scope and location are commonly determined by local perceptions of need and accessibility rather than a geomorphic, hydrologic, and ecological assessment of potential watershed recovery. Potential recovery is dependent on a changing system hydrology and sediment yields as development continues to occur over time until ultimate build-out, and on how infrastructure constrains channel planform stability. In order to achieve heightened ecological and water quality benefits from restoration projects, projects must be planned within a watershed context where assessments are integrated with stormwater management practices. The objective of this paper is to present a framework for monitoring and assessment protocols for urban and urbanizing watersheds, with the aim to better support planning of stream restoration projects and improve restoration outcomes. This is the product of a joint task committee by the Urban Stream Committee of the Urban Water Resources Research Council and the River Restoration Committee of the Hydraulics and Waterways Council of the American Society of Civil Engineers.

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THE MAY PRAIRIE STREAM RESTORATION PROJECT: FUNCTIONAL IMPROVEMENT AT A VALUABLE STATE NATURAL AREA

Adam Spiller, CPESC¹

Stream restoration projects are traditionally implemented in agricultural or urban landscapes in order to stabilize streams that are actively destabilizing and contributing sediment and other pollutants to an impaired watershed. In this respect, the May Prairie Stream Restoration Project in Manchester, Tennessee, a Tennessee Stream Mitigation Program project, was an atypical project. The pre-restoration stream was not suffering erosion and was not systematically unstable; however, it had been significantly altered from its natural state and lacked many basic stream functions. The pre-existing stream had been straightened and a portion of it was acting as a roadside ditch along US-41. To improve the functions of this stream system, three distinct reaches had to be designed, each with multiple constraints. Some of the design constraints included: stream relocation where large trees were a consideration, having set elevations at the up and downstream limits of the project, and not being able to fill portions of the old channel along US-41. In addition to these design constraints there were considerations that had to be taken for working in one of the most floristically diverse natural areas in the state and beginning construction in the winter at a site with shallow groundwater. This presentation will focus on the constraints, considerations, design approach, and lessons learned working on this project.

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THE REMOVAL OF A LOWHEAD DAM AT MCCABE GOLF COURSE ON RICHLAND CREEK IN NASHVILLE, TN

Gary Mryncza, PE¹, and Adam Spiller, CPESC²

Lowhead dam removals have been going on throughout the country for years, but very few have been occurring within the southeast and even fewer in Tennessee. This project highlights how effective partnerships, and a streamlined design, permitting, and construction process can successfully remove a dam and create significant functional uplift in an urban stream. The impetus for this project was the ARAP permit for water withdrawal from Richland Creek by McCabe Golf Course, a public golf course in Nashville managed by Metro Parks. A condition of this permit was the removal of the dam that had been constructed in the early 1970s to create a ponded area for this water withdrawal. The Nashville Metro government worked with the Cumberland River Compact and the Nature Conservancy to have this dam removed. This was implemented through an initial feasibility study and then a design-build process. This dam created ponded conditions for 700' to 800' upstream of the dam and had accumulated sediment behind the dam. The design was able to make use of this sediment by reusing it within the riffle/constrictor structure that was built. This structure allows for a small standing pool for continued water withdrawal and mimics the natural riffles within Richland Creek, allowing for unimpeded aquatic organism passage and sediment transport through the stream system.

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SESSION 3C

ENVIRONMENTAL MICROBIOLOGY I

8:30 a.m. – 10:00 a.m.

Sublethal Concentrations of Particular Antibiotics Stimulate Bacteria from Mammoth Cave Streams

Thomas D. Byl, Petra K. Byl, Shannon Trimboli, and Rickard Toomey, III

An Approach Towards Linking Diversity of Polyphosphate Accumulating Organisms to Improved Functional Stability of the Enhanced Biological Phosphorus Removal Process

Grace McClellan and Tania Datta

Effectiveness of Wastewater Treatment Processes in the Removal of Pathogenic Microorganisms

Si Chen and Qiang He

ENVIRONMENTAL MICROBIOLOGY II

10:30 a.m. – 12:00 p.m.

Patterns of Microbial Indicators in Stormwater Runoff as Revealed by Cultivation-Independent High-Throughput Sequencing

Kristen Wyckoff, Andrew Steinman, Si Chen, and Qieng He

Sediment-Microbial Source Tracking (MST) for Oostanaula Creek Watershed

Yanchong Huangfu, Shawn Hawkins, Alice Layton, Dan Williams, and Forbes Walker

Effects of Seasonal and Abiotic Factors on E. coli and Bacteroides Species at a Watershed Scale in Central Tennessee

Megan Stallard, Michelle Barbero, Mary Bruce, Steve Winesett, Alice Layton, and Frank Bailey

SUBLETHAL CONCENTRATIONS OF PARTICULAR ANTIBIOTICS STIMULATE BACTERIA FROM MAMMOTH CAVE STREAMS

Thomas D. Byl¹, Petra K. Byl^{1*}, Shannon Trimboli², Rickard Toomey, III²

Mammoth Cave National Park in central Kentucky attracts over 500,000 tourists per year. The high volume of tourists contribute to incidental surface releases of soaps and disinfectants at the waste-transfer station for recreational vehicles and at the biosecurity mats used to reduce spread of *Pseudogymnoascus destructans* spores on footwear. *P. destructans* is the fungus that causes white nose syndrome in bats. Multi-antibiotic resistant bacteria were reported in high numbers around the recreational vehicle waste-transfer station and white nose syndrome disinfection stations. Additionally, some disinfectants were observed in the cave streams after storms such as quaternary ammonia compounds (generally less than 30 mg/L), linear alkylbenzene sulfonates (less than 20 mg/L) and trace amounts of azithromycin and ciprofloxacin. The potential problems identified by these observations led to a study by the U.S. Geological Survey, in partnership with Mammoth Cave National Park, to determine antibiotic resistance of microbial communities associated with cave streams at different passage levels in the historic section of Mammoth Cave.

The cave streams within Mammoth Cave represent a hydrologic connection between land surface and the cave system. Storm water runoff carries suspended and dissolved constituents from the surface or near surface into the cave. The transported constituents can either be toxic, inconsequential, or serve as food for microbes that live in the subsurface streams. However, very little is known about the microbial community in cave streams, or their response to sublethal concentrations of antibiotic compounds. Twenty water samples were collected at seven cave-stream sites in the summer of 2012 through the fall of 2014. The cave-stream sampling sites had continuous flow and were sampled during and between storms. The cave-stream sampling sites were located on different vertical levels of the cave system; three sites in the upper-mid cave levels, two in the lower mid-level passages, and two in the deeper levels. All microbial tests, quaternary ammonia compounds (QAC) and linear alkybenzene sulfonates (LAS) analyses were conducted at the environmental lab at Tennessee State University (Nashville, Tennessee). Water samples for antibiotic analysis were collected from four cave-stream locations on three sampling dates and shipped to the Organic Geochemistry Research Laboratory in Lawrence, Kansas.

Bacterial sensitivity to antibiotics was quantified using a dose-response approach, with concentrations ranging from sublethal to medicinally relevant concentrations. Agar plates with 10 percent trypticase soy agar were augmented with antibiotic dose concentrations of 0.00 (control), 0.01, 0.1, 1.0, and 10.0 mg/L. The antibiotics included were erythromycin, kanamycin, gentamicin, tetracycline, LAS or QAC. Agar plates supplemented with the highest concentration of antibiotics (10 mg/L) had 98 percent fewer colonies than the control plates with no antibiotics.

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There was one exception; LAS stimulated bacteria growth with increasing concentrations. It was surmised from our observations and the literature that LAS is a food for many indigenous soil and water bacteria. The number of colony forming units on the plates generally decreased in response to the increased gentamicin, kanamycin and QAC dosage, but not with low concentrations of tetracycline and erythromycin. The number of bacteria colonies increased significantly ($p < 0.05$) on agar plates supplemented with 0.1 mg/L to plates supplemented with 1.0 mg/L erythromycin or tetracycline. The pattern of increasing colonies with increased erythromycin concentration was more common in samples collected from the upper-levels (Lee's Cistern, Shaler's Brook) and mid-level passages in the cave (Charlotte's Dome). Sublethal concentrations of tetracycline (less than 1.0 mg/L) stimulated colony growth in samples collected from the upper cave passage levels (Shaler's Brook, Devil's Cooling Tub, Stagnant Pool). The microbial growth response to increasing dosages of tetracycline and erythromycin can be classified as a hormesis response. Hormesis refers to growth stimulation at increasing sublethal concentrations until a critical threshold is attained; at which point, growth is stunted. Hormesis is a common biological response to chemical messenger molecules.

AN APPROACH TOWARDS LINKING DIVERSITY OF POLYPHOSPHATE ACCUMULATING ORGANISMS TO IMPROVED FUNCTIONAL STABILITY OF THE ENHANCED BIOLOGICAL PHOSPHORUS REMOVAL PROCESS

Grace McClellan¹ and Tania Datta²

Excess discharge of nutrients (nitrogen and phosphorus) from point and nonpoint sources is known to cause eutrophication and loss of biodiversity in surface-water bodies. Phosphorus (P) is of particular concern because it is often considered to be the primary limiting nutrient in aquatic ecosystems. Recognizing this, state and federal regulatory agencies are establishing stringent criteria to reduce P discharges, especially from point sources, such as wastewater treatment facilities (WWTFs). In the Upper Cumberland area of Tennessee (specifically Cookeville, Livingston, and Crossville), WWTFs are in the process of upgrading their systems to meet stricter nutrient effluent levels.

Both chemical and biological processes can be implemented for P removal, but the biological process, known as Enhanced Biological Phosphorus Removal (EBPR), is considered more sustainable and economical. EBPR relies on the selection of a unique microbial community known as polyphosphate accumulating organisms (PAOs) through sequential anaerobic-aerobic cycling of the activated sludge. Currently this process suffers from unpredictable and often unexplained failures, mainly due to gaps in microbiological understanding. This study hypothesizes that PAOs may be phylogenetically and functionally more diverse than currently understood and that by simulating environmental conditions that encourage a more ecologically diverse PAO community, reliability of EBPR will be enhanced. This will be tested in a lab-scale system using substrates other than acetate and propionate that can sustain a PAO community. The resulting community's structure and function will be investigated and diversity will be correlated to EBPR process stability. Preliminary results from the study will be presented at the conference.

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EFFECTIVENESS OF WASTEWATER TREATMENT PROCESSES IN THE REMOVAL OF PATHOGENIC MICROORGANISMS

Si Chen and Qiang He

Discharges from wastewater treatment plants have been considered as potential sources of pollutants to receiving waterbodies and watersheds. While the effectiveness of current wastewater treatment technologies has been proven for the removal of oxygen demanding organic pollutants, the efficiency in the removal of pathogenic organisms from domestic wastewater is less understood. Traditionally, pathogenic organisms are quantified as indicator microorganisms that are specifically enumerated by cultivation-based methods using selective media. However, cultivation-based methods are known to have inherited biases toward different microbial populations in wastewater. Thus, cultivation-independent methods may be more ideal for the comprehensive representation of microbial communities in wastewater treatment processes. In this study, next-generation sequencing technology was applied to characterize the changes in the microbial compositions throughout different activated sludge wastewater treatment processes, such as oxidation ditch (OD) and membrane bioreactor (MBR), to evaluate the removal of pathogenic microorganisms during treatment. Our results show that the activated sludge processes were very effective in eliminating pathogenic microorganisms and preventing fecal contamination from impacting receiving streams. Specifically, sequences of *Enterobacteriaceae* were reduced from 2% in the influent to less than 0.1% following treatment, which was also consistent with results from cultivation-based methods. With the application of cultivation-independent genomic sequencing in this study, we were able to gain a more complete depiction of the microbial populations in wastewater treatment processes, providing a unique tool for the risk assessment of pathogenic microorganisms from wastewater discharges.

PATTERNS OF MICROBIAL INDICATORS IN STORMWATER RUNOFF AS REVEALED BY CULTIVATION-INDEPENDENT HIGH-THROUGHPUT SEQUENCING

Kristen Wyckoff, Andrew Steinman, Si Chen, Qiang He

INTRODUCTION

Non-point source pollution caused by stormwater runoff is of major concern for improving water quality in impaired watersheds. A primary pollutant in stormwater runoff is pathogenic microorganisms, which are historically represented by groups of indicator microorganisms (Geldreich, Best, Kenner, & Donsel, 1968), (McCarthy, Deletic, Mitchell, Fletcher, & Diaper, 2008). Total coliforms generally account for bacteria classified as *Citrobacter*, *Enterobacter*, *Escherichia*, *Hafnia*, *Klebsiella*, *Serratia*, and *Yersinia*. Fecal coliforms are considered to comprise only a subset of total coliform organisms, including *Enterobacter* (*Enterococci* in particular), *Escherichia coli*, *Hafnia alvei*, and *Klebsiella oxytoca* (Environment Agency, 2002). Traditionally indicator microorganisms in environmental samples are specifically enumerated by cultivation-based assays with selective media. Cultivation-based enumeration methods are known to have inherited biases in the cultivation of diverse microorganisms with the same growth medium. Therefore cultivation-independent methods may be more ideal for the comprehensive representation of microbial communities (Staley & Konopka, 1985).

APPROACH

In this study, we used next-generation sequencing technology to characterize the complete microbial community composition in stormwater runoff samples collected from two separate storm events in late August and early September, 2014. pH, total suspended solids (APHA, AWWA, & WEF, 2005a), total coliform, fecal coliform, and *Escherichia coli* (*E. coli*) (APHA, AWWA, & WEF, 2005b) were analyzed within six hours of sample arrival in the lab. 50 mL of each sample were centrifuged and stored at -80°C until nucleic acid extraction could be performed. Nucleic acid extraction was executed using the FastDNA Spin Kit for Soil. Sequencing results were retrieved and analyzed by utilizing an Illumina MiSeq Sequencer, the RDP Pyrosequencing Pipeline, and Mothur. The MiSeq uses 16S rRNA Amplicons to deliver paired 300-basepair reads. The fastq pairs from the MiSeq are run through Mothur to provide fasta files which can be run through the RDP Pipeline. This allows for the determination of sequences in the metagenome as well as relative abundances of the detected sequences. Further analysis is possible with a continuation of the Mothur MiSeq Standard Operating Procedure.

RESULTS AND DISCUSSION

Our results suggest that total and fecal coliform bacteria constitute a very minor fraction of the entire microbial populations in stormwater runoff, as sequences of total coliform organisms were well below 1% of the total sequences. Neither *Hafnia* nor *Klebsiella* were detected in any of the stormwater runoff samples. *Citrobacter* and *Serratia* were only detected at very low relative abundance. Sequencing results report fecal coliform organism sequences represent over 90% of total coliform organism sequences. For all samples, *Proteobacteria* was the predominant phylum, which embodies all total coliform species. Other notable phyla include *Actinobacteria*,

Bacteroidetes, *Verrucomicrobia*, and *Firmicutes*. The majority of the top families from these phyla are believed to thrive in both water and soil environments, but twelve families with over 0.5% relative abundance contain potentially pathogenic microorganisms. Families with potential pathogenic sequences include *Burkholderiaceae*, *Moraxellaceae*, *Pseudomonadaceae*, *Xanthomonadaceae*, *Enterobacteriaceae*, and *Coxiellaceae* from *Proteobacteria*, *Nocardiaceae*, and *Mycobacteriaceae* from the *Actinobacteria* phylum, *Staphylococcaceae*, and *Clostridiaceae* 1 from the *Firmicutes* phylum, and *Cytophagaceae*, and *Flavobacteriaceae* from the *Bacteroidetes* phylum. Common pathogens associated with these families may not be the dominant present genus. This is prominent in the *Enterobacteriaceae* family which contains the species relevant to total and fecal coliform sampling. The primary genus is *Pantoea*, which is commonly found in soil and water environments. Results from this study provide information needed to develop guidelines for accurate monitoring of microbial contamination of stormwater runoff.

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SEDIMENT-MICROBIAL SOURCE TRACKING (MST) FOR OOSTANAULA CREEK WATERSHED

Yanchong Huangfu, Shawn Hawkins, Alice Layton, Dan Williams, and Forbes Walker

Removal of Oostanaula Creek from the Tennessee 303(d) list will require too much effort in reducing concentration of pathogen indicator (*E. coli*), Sedimentation, and phosphate. The current restoration plan focuses on promoting Best Management Practice (BMP) to reduce sediments caused by fecal pollution from the activities associated with cattle. However, to effectively implement BMPs, it is critical to identify the sediments caused in specific locations of non-point source pollution problems in the Oostanaula Creek Watershed (OCW). This research focuses on the identification of the sources of suspended and deposited sediment in OCW by Sediment-Microbial Source Tracking (MST) tool. Totally, 70 sediment samples, originating from pasture soils, cattle walkways and creek banks, were collected throughout the upstream and downstream of OCW at the city of Athens. The hypothesis of this study is that the microbial communities among different types of sediment samples are different. After DNA extractions and purification of the sediment samples, 16S rRNA gene amplicons were produced, purified and sequenced on a MiSeq sequencer for high-throughput sequencing analysis. The image data are further analyzed and categorized according to different types of soils by QIIME, MGRAST and R package. In addition, statistical analysis, like alpha diversity and beta diversity, are currently performed to support the characterization of sediments in OCW. A total 7,565,516 Illumina sequencing reads, comprised of 72,980 OTUs, were generated from the 30 samples of Oostanaula sediment, cattle manure and poultry litter. The median and the mean sequencing reads for all of the samples are 160,529 and 252,183. In summary, anticipated results will indicate Sediment MST technology can help matching the consortium of bacteria in sediment materials and contaminating sediment to suggest the origin of sediment pollution.

EFFECTS OF SEASONAL AND ABIOTIC FACTORS ON *E. COLI* AND *BACTEROIDES* SPP. AT A WATERSHED SCALE IN CENTRAL TENNESSEE

Megan Stallard^{1,3}, Michelle Barbero¹, Mary Bruce¹, Steve Winesett¹, Alice Layton²,
and Frank Bailey³

Escherichia coli (*E. coli*) are frequently used fecal indicator bacteria (FIB) the Environmental Protection Agency (EPA) uses to assess water quality in recreational waterbodies. *Bacteroides* spp., an alternative FIB, has been shown to be highly host specific for human, equine, and bovine 16S rRNA gene targets (Layton et al., 2007) which could have implications in appropriate watershed management strategies. Inasmuch, the real-time quantitative polymerase chain reaction (qPCR) technique for detecting *Bacteroides* gene target leads to faster turnaround times for assessing water quality. Before regulators select surrogates for impairment or source tracking methods, it is imperative to compare how seasonal and abiotic factors influence FIB presence. Stream samples were collected during seasonal baseflow in impaired watersheds from Davidson County, Tennessee. The Colilert method and real-time PCR were used for detection of *E. coli* and *Bacteroides* spp. concentrations, respectively. Summer *E. coli* concentrations were significant higher ($p < 0.05$) than in winter months for Browns, Richland, and Mill watershed. *Bacteroides* concentrations were significantly higher ($p < 0.05$) in Browns and Richland, but not Mill. For *E. coli*, a positive and negative correlation ($p < 0.05$) was found for temperature and dissolved oxygen, respectively. This was similar for *Bacteroides*, except in the case of Mill. It is evident the presence of fecal bacteria are influenced by seasonality and abiotic factors in the field. These results may supplement EPA's water quality criteria development in the future and prompt watershed stakeholders to understand the possible natural patterns that could exist in the field from abiotic influences.

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PROFESSIONAL POSTERS

Optimal Allocation of Agricultural Water Use in the Humid Southeastern U.S. Using Hydro-Economic Modeling

Lixia He, Christopher D. Clark, Dayton M. Lambert, Chris Boyer, Burton C. English, and A.N. Thanos Papanicolaou

Rain Gardens for Tennessee

Andrea Ludwig and Ruth Anne Hannahan

OPTIMAL ALLOCATION OF AGRICULTURAL WATER USE IN THE HUMID SOUTHEASTERN U.S USING HYDRO-ECONOMIC MODELING

Lixia He, Christopher D. Clark, Dayton M. Lambert, Chris Boyer, Burton C. English,
and A.N. Thanos Papanicolaou

The stress on Southeastern water resources is increasing due to expansions in irrigated acres, urbanization, population growth and economic development, coupled with a relatively limited storage capacity, an aging urban infrastructure, and reliance of large inland population centers on relatively small watersheds with limited water supplies. Climate change threatens to exacerbate this stress, with uncertain rainfall patterns and the amplified risk of extreme weather events, including both droughts and high rainfall events. These changes also imperil the resiliency of agricultural and forestry economies and the jobs and businesses that depend on these sectors since they are the major consumptive water users. Cost-effective adaptation to these changes and mitigation of their adverse impacts requires a deeper understanding by researchers, policymakers, educators and agricultural producers of the complexity characterizing the dynamics of land use and water availability for agriculture and competing uses under changing climatic conditions.

A partial equilibrium (PE) model is developed to estimate the economic value of water in the poultry, row crop, beef cattle, goat, and dairy sectors operating in the study region. The PE model developed in this proposal will induce the economic value of supplying limited water resources in different geographic locations and to analyze different water management strategies that may mitigate the stress of water shortages on the economic performance of these enterprises. The hydrological model Variable Infiltration Capacity (VIC) will be used to simulate water scarcity scenarios. The output of VIC will be used as water resource constraints of each agricultural sector to determine changes in gross sector income, changes in input use, crop mix, and livestock production, and changes in the economic value of water attributable to these shocks. The model output directly relevant to producers is examples of proactive, cost-effective measurements that can be implemented on their operations to moderate the impact of prolonged water scarcity or acute inundations.

RAIN GARDENS FOR TENNESSEE

Andrea Ludwig¹ and Ruth Anne Hannahan²

Building rain gardens creates a unique opportunity for citizens to come together to do their part to protect water quality in both a physical and existential manner. Rain Gardens for Tennessee is an effort presented by the team at Tennessee Smart Yards (TNSY) and funded through a grant from the 319 Nonpoint Program, Tennessee Department of Agriculture. Since 2012, the TNSY team has been hosting trainer workshops for educators interested in raising awareness of the impacts of land development on aquatic ecosystems and providing tools to empower citizens to use rain gardens effectively on their private property. We have built 10 new rain gardens across the state in public spaces as demonstrations as well as developed a tool kit for educators to use in programs at these locations. New regulations protect natural waterways from urban runoff, but the damage that is done consistently every time it rains from existing development is significant. To improve water quality in developing watersheds, retrofitted green infrastructure is needed, and rain gardens are an easy way to get the general public on board and get that inch of runoff back into the ground.

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STUDENT POSTERS

Illustrating Chemicals [Kool Aid] Leaching and Adsorption by Alfisols and Mollisols Soils Found on Flood Plain, Stream Terrace and Upland Landscapes in Middle Tennessee
Lindsey Andreasen

Karst Aquifer Properties and Water Levels at the TSU Research Farm, Nashville, Tennessee
Renas Barzanji, Lonnie Sharpe, and Tom Byl

Quantitative Tracer Studies at Mammoth Cave National Park with Implications for Contaminant Transport
JeTara Brown, Rick Olson, D. Solomon, Lonnie Sharpe, Rickard Toomey, and
Acknowledgment Tom Byl

Recharge to the Memphis Aquifer in Southwestern Tennessee, An Example of a Sand-Dominated Coastal Plain Aquifer in a Humid Region
John Bursi, D. Larsen, B. Waldron, S. Schoefernacker, J. Eason, and S. Girdner

Seasonal Aquatic Metabolism in an Agricultural Stormwater Treatment Wetland
Bing Cao and Andrea Ludwig

Calibration of Levee Breach: A Case Study on New-Madrid Floodway, Illinois, USA
Tigfsu T. Dullo and Alfred J. Kalyanapu

Groundwater Source Assessment of the Rock House Springshed, Carter County, TN
Zachary T. Fridell, Ingrid Luffman, and Michael Whitelaw

Associations Between Agricultural Land Use and Fish Assemblages in the Nolichucky River Watershed
Hayley Gotwald and J. Brian Alford

Knoxville Microclimates: Spatial Variability in Air and Water Temperature Across Four Urban Neighborhoods
David A. Howe, Jon Hathaway, and Kelsey Ellis

Investigation of Fecal Bacteria and Nutrient Levels in Lees Spring Branch, Rutherford County, TN
Lara Jarnagin, Euvelisse Jusino-DeValle, An Nguyen, Victoria Kremer, Gale Beaubien, Megan Stallard, and Frank Bailey

Linking Complex Organic Feedstock Characteristics to Microbial Metabolic Activities in Anaerobic Codigesters
Juliet Ohemeng-Ntiamoah and Tania Datta

Attenuating Acid-Rock Drainage by Stimulating Sulfur-Reducing Bacteria
Ronald Oniszczak, Diarra Fall, Andrew Hart, Lonnie Sharpe, and Tom Byl

Establishing Performance and Design Thresholds for Regenerative Stormwater Conveyances Through Modeling and Monitoring
Jessica M. Thompson, Jon M. Hathaway, and John S. Schwartz

LiDAR Compared to NED and Surveyed Data in HEC-RAS
Joseph C. Thornton, Alfred Kalyanapu, and Nowfel Mahmud

Spatial Distribution of Sediment and Microbes Across Streams in Eastern Tennessee
Michael Walton, John S. Schwartz, and Jon M. Hathaway

Sediment Source Potential in Small Urbanizing Stream Systems
Robert R. Woockman and John S. Schwartz

**ILLUSTRATING CHEMICALS [KOOL AID] LEACHING AND ADSORPTION
BY ALFISOLS AND MOLLISOLS SOILS FOUND ON
FLOOD PLAIN, STREAM TERRACE AND UPLAND LANDSCAPES
IN MIDDLE TENNESSEE**

Lindsey Andreasen

This undergraduate study illustrated leaching and adsorption of chemicals by soil materials. The undergraduates prepare four soil columns. They used four soil materials, two columns were filled with sub-soils of a Talbott and Armour soil series. The third column was filled with the topsoil of an Egam soil series. The final column was filled with sand.

The Talbott and Armour are classified as Alfisols. The Egam is classified as a Mollisol. Horizons sampled from the Talbott was the **Bt**; yellowish red (5YR 5/6) clay; from the Armour the **Bt**; brown (7.5YR 4/4) silty clay loam and from the Egam the **Ap**; dark brown (10YR 3/3) silty clay loam.

Cherry and grape Kool Aid packages were dissolved in distilled water. The % T of the mixture was measure with a spectrophotometer at 550nm. Three quarters of monthly precipitation (300 ml) were percolated through each soil columns. Percent T of the Pre and post percolation Kool Aid solutions were measured. The grams of Kool Aid adsorbed were calculated. The class attempted to improve adsorption by adding activated charcoal reagent to each column. The grams of Kool Aid adsorbed were calculated and compared. The charcoal was added to simulate Terra Preta soils of the Amazon Basin.

KARST AQUIFER PROPERTIES AND WATER LEVELS AT THE TSU RESEARCH FARM, NASHVILLE, TENNESSEE

Renas Barzanji¹, Lonnie Sharpe¹, and Tom Byl^{1,2}

Nashville, Tennessee is underlain by limestone geology and the terrain is referred to as karst. The term karst refers to a landscape with carbonate bedrock with fractures, caves, sinkholes and complex hydrology. Karst aquifers are extremely vulnerable to contaminants entering from the surface. Karst aquifers also serve as an important source of water for drinking and irrigation. The objective of this study was to characterize the hydrogeology of the limestone aquifer at Tennessee State University (TSU) research farm in Nashville, Tennessee. Six wells are located on the 350-acre farm and are drilled into carbonate bedrock (depth ranging from 175 to 250 feet below ground surface). The direction of groundwater flow was calculated from water level measurements and using the triangulation method. The transmissivity (T) and storage capacity (S) of the bedrock aquifer were also evaluated from an aquifer pump test. (T = 317 square feet per day; S = 0.0002 to 0.0003 gallons per cubic foot) During the same aquifer pump test, water levels were measured and indicated that the cone-of-depression radiating from the pumping well extended approximately 350 meters from the pumping well. The TSU College of Agriculture is upgrading their farm research facility and plans to install a groundwater irrigation system. The results of this study can be used in helping to design the irrigation system.

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QUANTITATIVE TRACER STUDIES AT MAMMOTH CAVE NATIONAL PARK WITH IMPLICATIONS FOR CONTAMINANT TRANSPORT

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and Dr. Tom Byl^{1,3}

Mammoth Cave National Park was designated an International Biosphere Reserve in 1990. The ecosystem in the cave is linked to the surface through groundwater recharge. The cave was formed over hundreds of thousands of years through erosion and dissolution of limestone by the groundwater. Water still plays a vital role with regards to the continued geomorphic processes that form the cave and to the ecosystem within the cave. The objective of this study was to conduct quantitative tracer studies to understand transport mechanisms from the surface into the caves. The study included tracer studies originating from potential sources of contamination on the surface, along the water flow path and into the cave system. A known amount of Rhodamine-WT20 dye was released during storms. Monitoring included portable fluorometers in the cave at different locations. The result of placing 2 small check dams along the surface flowpath resulted in lengthening the time-of-travel from 2 hours to 16 hours. Running the tracer study several times with and without the small check dams showed that the storm pulse delivered approximately 90% less dye when the dams were in place. We believe that the dye that did not make it into the cave sorbed to organic carbon on the forest floor or percolated into the vadose zone. This research will help provide options to emergency responders of spills.

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**RECHARGE TO THE MEMPHIS AQUIFER IN SOUTHWESTERN TENNESSEE,
AN EXAMPLE OF A SAND-DOMINATED COASTAL PLAIN AQUIFER
IN A HUMID REGION**

J. Bursi^{1,2}, D. Larsen^{1,2}, B. Waldron², S. Schoefnacker^{1,2}, J. Eason²,
and S. Girdner²

The Memphis aquifer is the most important source of groundwater in the state of Tennessee. Although the rate of production of water from this aquifer is monitored, the rates and distribution of recharge to the Memphis aquifer are poorly constrained. Previous studies indicate that recharge takes place primarily in the outcrop and subcrop region of the Eocene Memphis Sand, an 800-ft thick Coastal plain sand unit in the northern Mississippi Embayment. Studies of recharge processes in the outcrop belt in western Tennessee indicate that infiltration follows a complicated path prior to recharging the aquifer and the travel time from the upland surfaces to the water table could be as much as 100 years. In our current studies, ground water levels, stream flow, and climatic conditions are being monitored in an upland watershed to test hypotheses regarding heterogeneous recharge pathways and rates to the Memphis aquifer. In addition, the chemistry of precipitation, soil water, and both surface and subsurface water, are being used to track the geochemical evolution of water through the infiltration and recharge process.

Stratigraphic analysis, tensiometer measurements, and lysimeter soil-water yield data suggesting that recharge is fastest and most direct along the hillslopes and upland gully systems. Upland surfaces are mantled by loess and one or more paleosols, retarding vertical recharge, whereas the hillslopes and upland gully systems have sandy sediment allowing infiltration. Preliminary results show a seasonal shift in water levels and a profound response to large rain events. Present efforts focus on using geochemistry and SF₆ to trace potential recharge from the upper soil horizons to the water table, both spatially and temporally. Monitoring of precipitation, evapo-transpiration, run-off, and soil storage capacity will be used to obtain a water balance-based estimate of recharge in the watershed.

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SEASONAL AQUATIC METABOLISM IN AN AGRICULTURAL STORMWATER TREATMENT WETLAND

Bing Cao¹ and Andrea Ludwig²

Aquatic metabolism, as an indicator of wetland ecosystems health, provides a useful tool to understand biological activities in water system. Measuring oxygen consumption rates in aquatic media is the major practical method for determining the metabolic rates of aquatic ecosystems. Oxygen consumption is an indicator of respiration and is represented by gross primary productivity (GPP) and community respiration (CR). While previous research has recorded influential parameters of aquatic metabolism on surface stream and lake system, this information is limited for stormwater treatment wetlands.

The objective of this research is to determine the effect of hydraulic and nutrient loading on ecological metabolism in a stormwater treatment wetland. In-situ dissolved oxygen (DO) measurements as well as weather data were collected at the Little River Animal & Environmental Unit (Walland, TN) between Oct. 2012 to Jan. 2014. Statistical analysis will be used to detect seasonal metabolism rate variability and to qualify the effect of environmental predictors including temperature, discharge, pH and input nutrient mass. It is expected that GPP and CR will be a function of predominantly water temperature and discharge flowrate, and that nutrient mass inputs will stimulate oxygen consumption rates.

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CALIBRATION OF LEVEE BREACH: A CASE STUDY ON NEW-MADRID FLOODWAY, ILLINOIS, USA

Tigstu T. Dullo¹ and Alfred J. Kalyanapu¹

The simulation of levee breach requires the use of numerical model to approximate the complex flow dynamics during the flood event. Due to catastrophic flood events in the early nineties, Mississippi River and Tributary (MR&T) project adopts several measures along the lower Mississippi River to ensure sustainable flood management. The Bird's Point-New Madrid Floodway is a part of the MR&T project along the West bank of the Mississippi River below the confluence area. Following an unprecedented flooding event in the Mississippi and Ohio Rivers, the U.S. Army Corps of Engineers (USACE) detonated the birds point levee at the upper crevasse on May,02, 2011, to mitigate possible levee failure and flooding of Cairo, Illinois. However, the adopted measure has resulted in a prolonged disagreement with resident living in the flood plain areas. Taking this into consideration and for better understanding of levee breaching, the U.S. Geological Survey (USGS) collected hydrodynamic data before, after and during the activation of the flood way. In this case study, a numerical model is used to reconstruct the flood event of Cairo Illinois levee breaching. The observed flood hydrograph at the breaching location and 30m resolution Digital Elevation Model data are used as an input for the model. The calibration involves use of different Manning's roughness value to reproduce the observed outflow hydrograph with an acceptable accuracy. The output from the simulation is expected to provide a better understanding of flood occurrence. In addition, it can also be used as a tool to adopt an optimum measure to meet the interest of both upstream and downstream residents in the future.

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GROUNDWATER SOURCE ASSESSMENT OF THE ROCK HOUSE SPRINGSHED, CARTER COUNTY, TN

Zachery T. Fridell^{1*}, Ingrid Luffman¹, and Michael Whitelaw¹

INTRODUCTION

Karst landscapes occupy 10 to 20% of the earth's surface and supply 25% of the world's population with drinking water (Ford and Williams, 1989). In East Tennessee, carbonate aquifers are found in the Valley and Ridge Province. High precipitation and steep terrain result in high runoff rates which feed many springs in the area. In Carter County, the estimated groundwater withdrawal, in 2005, was 1.0 - 9.99 Mgal/d; with no withdrawal from surface water systems (Robinson and Brooks, 2010). In 2005, the Elizabethton Water Department served nearly 25,000 customers with clean drinking water drawn from springs in Cambro-Ordovician aquifers (Robinson and Brooks, 2010). These aquifers occur in highly fractured limestones, dolostones, shales, and sandstones and are unconfined towards the surface and confined at depth. Common yields from these aquifers range from 5 - 200 Mgal/d, but they can provide up to 2,000 Mgal/d after heavy precipitation events (Robinson and Brooks, 2010). The Elizabethton Water Department depends on Cambro-Ordovician aquifers for public water supply and the integrity of these systems must be maintained. Because of the hydrologic connections with surface streams karst aquifers can be easily compromised where accidental fuel spills, fertilizer, or other contaminated runoff enter streams. In these situations, it is vital to understand how surface water and groundwater are connected when mitigation has to be done quickly. This research describes a hydrologic evaluation of a multi-cave system, herein referred to as the Rock House Springshed that is an at-risk groundwater supply. A supplemental structural geologic analysis was completed in the spring of 2014 to determine possible bedrock controls on groundwater flow paths in the springshed.

STUDY AREA

The Rock House Springshed is located south of Johnson City and Elizabethton in Carter County, Tennessee (Figure 1). It occupies an area approximately 6 km² (2.3 mi²) and is centered on Rock House Cave, but also includes Carter Saltpeter Cave, and Cave Springs Cave. The area is bordered by Dry Creek to the east and Buffalo Creek to the west. Both creeks flow to the north, but water loss in channelized fractures along Dry Creek feed the Rock House Springshed, and flow west-northwest, against topography, from Dry Creek into the cave system. Other water systems include an unnamed sinking stream located south of Rock House Cave, herein designated Anderson Spring, and sinkholes that feed surface water to the subsurface. Rock House Cave, Carter Saltpeter Cave, and Cave Springs Cave are known to be hydrologic connections from Dry Creek to Buffalo Creek from previous experiments (Gao et al., 2006). For this project, the groundwater flow path from Anderson Spring was evaluated using fluorescent dyes to test for possible hydrologic connectivity within the Rock House Springshed. Previously identified connections from Dry Creek to Carter Saltpeter Cave (Gao et al., 2006) were restudied to recover flow velocity data and test for additional flow paths.

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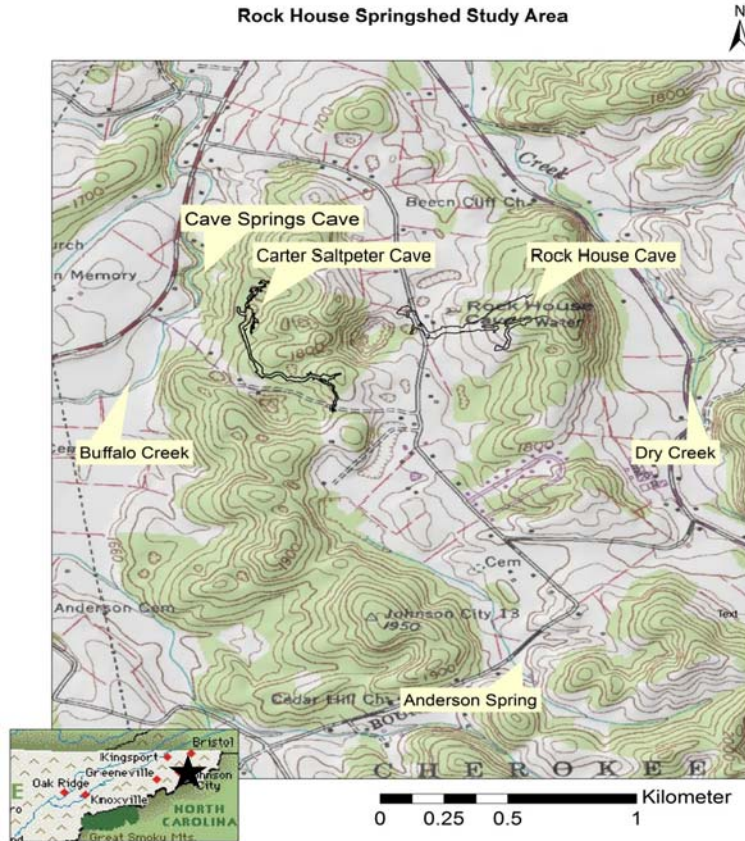


Figure 3. Study Area Location.

APPROACH

Dye injection sites were selected as likely locations of groundwater recharge, and were identified through field reconnaissance, map and aerial photography analysis, and by interviewing local residents to identify undocumented locations where groundwater was observed entering the system (Figure 2). On May 15, 2014, three Teledyne ISCO automated water samplers were placed in the study area (Figure 2); one at Cave Springs Cave, the spring exit for the Rock House Springshed, one in Rock House Cave, and one in the back of Carter Saltpeter Cave. The ISCOs were programmed to collect 24 samples at pre-determined time intervals. Along with the ISCOs, nine activated carbon charcoal samplers (BUGs) were deployed at surface and subsurface locations (Figure 2). Salt trace experiments were also carried out to measure discharge from the Rock House Springshed for the duration of the experiment.

This experiment employed three fluorescent tracing dyes; Fluorescein, Eosin, and Rhodamine WT. Standards for each dye were created as 1 ppb solutions and intensities derived from the standards were then used to estimate the mass of dye recovered by the ISCO samplers. Rhodamine WT (328.3 grams) was injected into the forward section of Carter Saltpeter Cave to assess hydrological connections to Cave Springs Cave. Eosin (577.5 grams) was injected into Dry Creek to evaluate hydrologic connections between Rock House Cave and Dry Creek. Fluorescein (103.6 grams) was injected into Anderson Spring to determine if the spring contributed to the cave system.

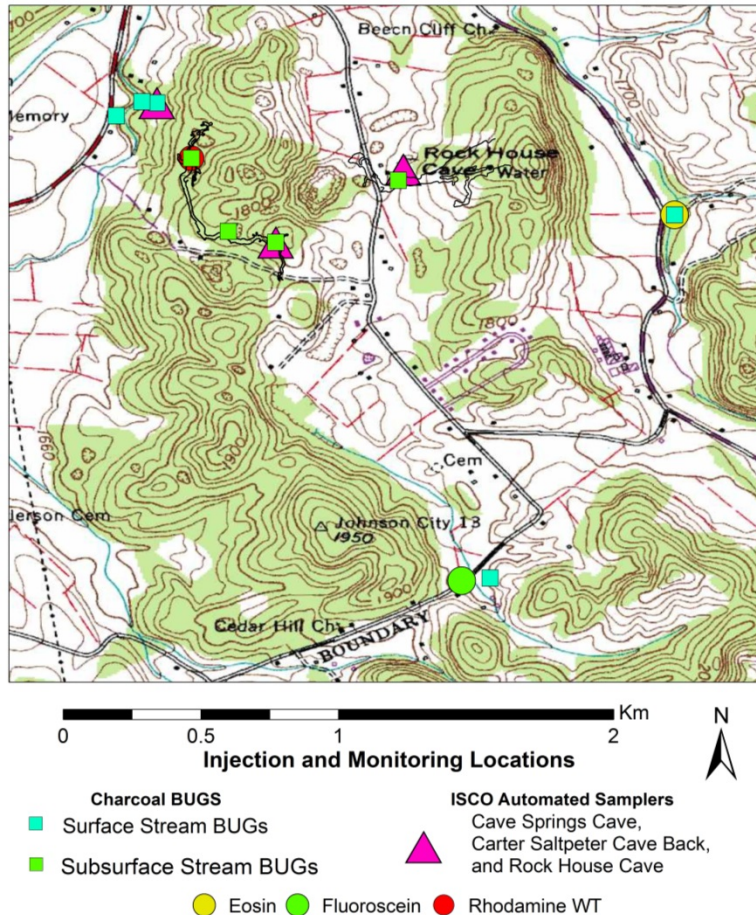


Figure 2. Dye Trace Overview.

RESULTS AND DISCUSSION

Dye Recovery

All three dyes injected into the system were recovered by at least one ISCO. Over a 2 week period nineteen rounds of samples were collected (N=451) and analyzed using a Shimadzu spectrofluorophotometer at the ETSU Hydrology Laboratory. Samples that recorded the first arrival and peak dye concentration were selected, identified, and used to calculate dye travel time. Peak arrival times were used to estimate flow velocity for each flow path from injection site to ISCO (Table 1).

Of the 9 BUGs deployed 8 adsorbed dye (or dyes) in the first round of sampling, but most recovered only one dye. A BUG placed in the stream at the back of Carter Saltpeter Cave was the only BUG to detect Fluorescein in the springshed. A BUG in the forward stream of Carter Saltpeter Cave detected Eosin thus confirming a groundwater flow path from Dry Creek, through Rock House Cave, the front of Carter Saltpeter Cave, Cave Springs Cave, and exiting into Buffalo Creek.

Table 1. ISCO Dye Trace Results.

ISCO	Dye (s)	Initial Arrival Time (hours)	Peak Arrival Time (hours)	Velocity (m/sec)	Dye Recovered (g/ %)
Cave Springs Cave	Rhodamine WT	0.92	1.12	0.0535	0.989/ 0.301
	Eosin	33	53	0.00442	3.434/ 0.594
Rock House Cave	Eosin	29	45	0.00395	4.326/ 0.749
Carter Saltpeter Cave	Fluorescein	49	71	0.00633	1.006/ 0.971

Salt Trace Experiment

Eight salt trace experiments were completed at Cave Springs Cave and documented a decreasing discharge rate trend for the Rock House Springshed over the duration of the experiment (Figure 3). Cave Springs Cave is the hydraulic toe for the Rock House Cave Springshed and this discharge calculation is related to most major channelized, open flow paths in the springshed. Discharge in fissures or fractures will be lower because of isolated flow segments. Thus, this discharge value cannot be assumed for areas of low or isolated flow.

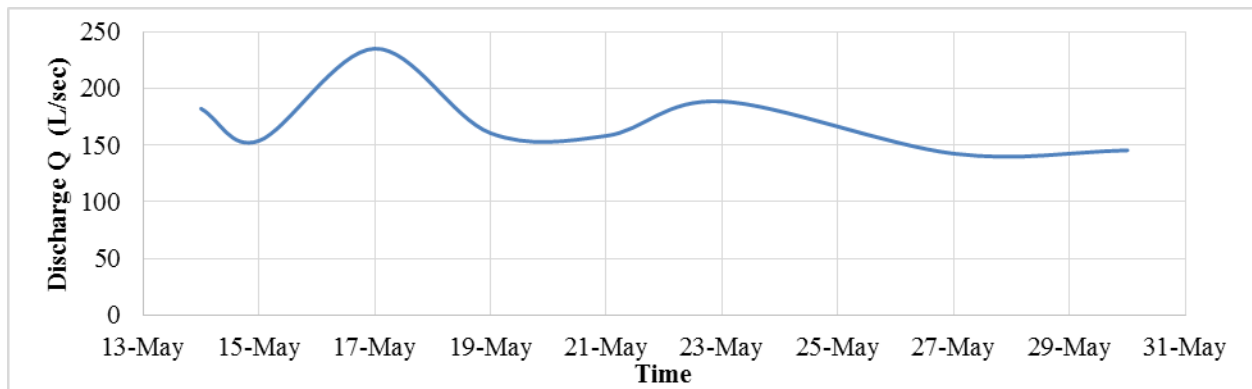


Figure 3. Discharge (Q) at Cave Springs Cave.

Groundwater Flow Paths

This dye trace experiment established the existence of hydrologic connections between Anderson Spring and the back stream of Carter Saltpeter Cave, and between Dry Creek and the Rock House Springshed. This information enables a groundwater flow map to be produced that models hydrologic connections in the Rock House Springshed (Figure 4).



Groundwater Flow Paths Within the Rock House Springshed

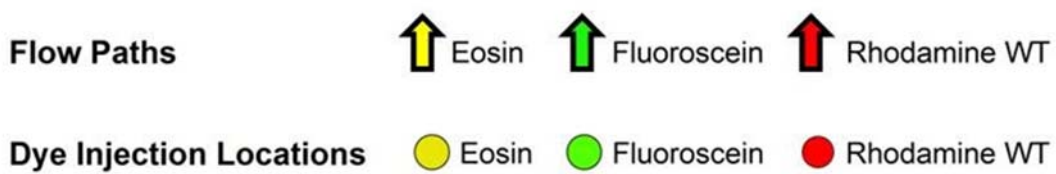
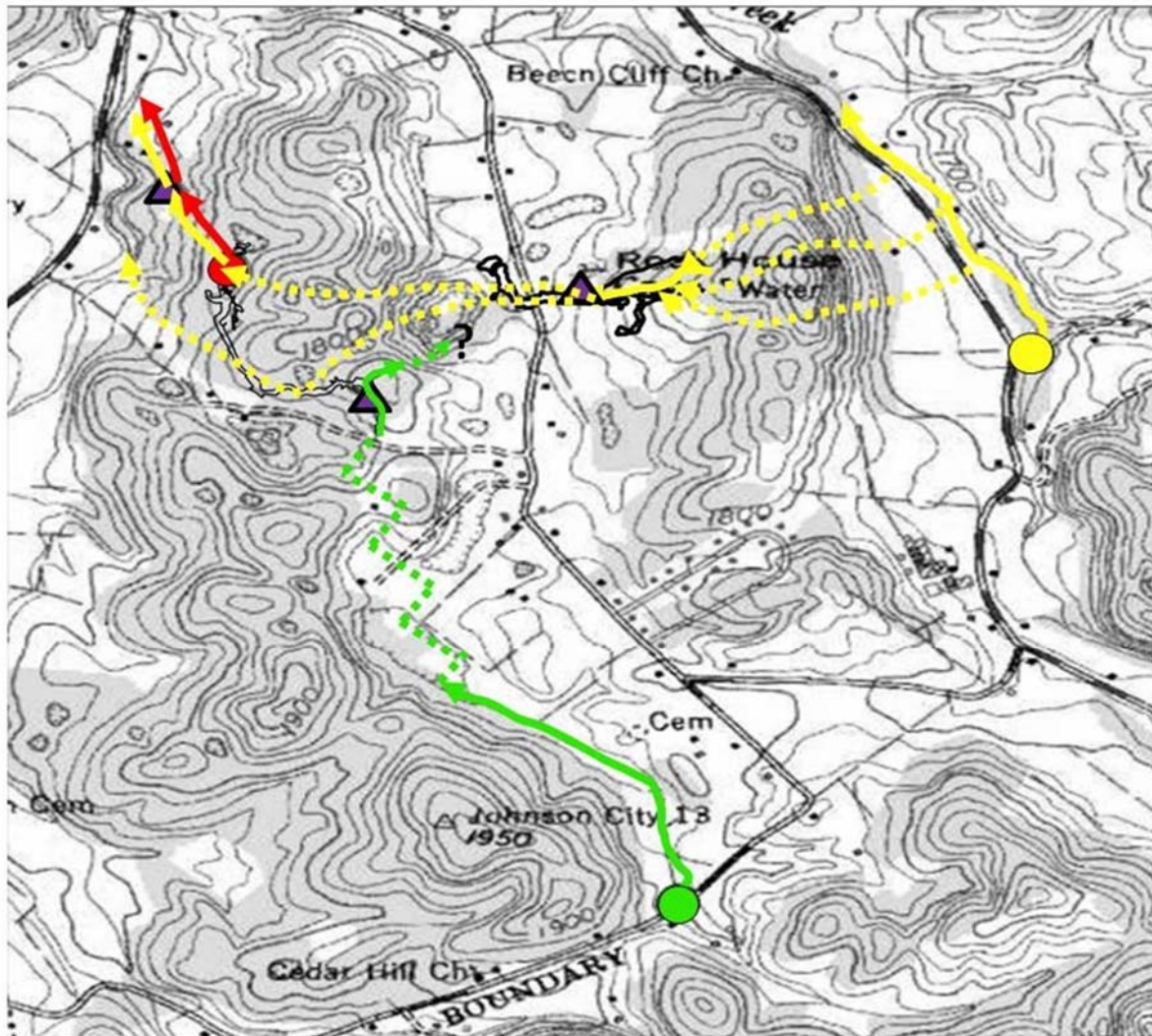


Figure 4. Interpretive Groundwater Flow Model.

Surface water in Dry Creek enters the groundwater system through fractures and sinks in the limestone bedrock and flows to Rock House Cave. Groundwater then travels east, emerges as a stream in the forward section of Carter Saltpeter Cave, and exits the springshed at Cave Springs Cave, discharging into Buffalo Creek.

Surface water in Anderson Spring enters a sinkhole, travels along joints and emerges in the back of Carter Saltpeter Cave, then exits the system via a sump in the back section of Carter Saltpeter Cave. This flow path was traced with Fluorescein, which was not recovered elsewhere in the study area, indicating a possible isolated, channelized flow of groundwater water through joint systems south of the cave.

Velocities for groundwater flow paths were calculated using straight line distance from injection site to ISCO location. The flow rate depends on the type of channel they are following. For instance, groundwater flowing from the forward section of Carter Saltpeter Cave to Cave Springs Cave has a relatively high flow velocity (0.0535 m/sec) because flow paths are more channelized than the flow paths from Dry Creek to Rock House Cave. From Dry Creek, groundwater enters the springshed through fissures and fractures, indicated by a low flow velocity (0.00395 m/sec). The mixture of different types of groundwater flow paths creates a complex hydrologic system in the Rock House Springshed which makes mitigation of contamination difficult. Using the groundwater flow map provided, remediating pollutants becomes less challenging and more feasible.

CONCLUSION

The results of this experiment illustrate the complexity of groundwater flow paths that can be present in karst aquifers. Groundwater flow paths within karst environments are uniquely controlled by the regional geologic setting. The Rock House Springshed is a hydrologically linked matrix of caves, conduits, and fissures which flow against areal topography to connect separated watersheds (Dry Creek and Buffalo Creek). Groundwater flow velocity is dependent on the type of flow path the groundwater is taking. Because of the interconnected network of flow paths, interception of potential contamination becomes a challenge. Using the groundwater flow model provided mitigation efforts can be deployed downstream to capture the pollutant.

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ASSOCIATIONS BETWEEN AGRICULTURAL LAND USE AND FISH ASSEMBLAGES IN THE NOLICHUCKY RIVER WATERSHED

Hayley Gotwald¹ and J. Brian Alford²

The Nolichucky watershed straddles the border of Tennessee and North Carolina. The Tennessee portion is where nearly all agricultural land use occurs. In recent years there has been a conversion of pasture to truck crops, predominantly tomatoes, on the TN side of the watershed, but soybean, corn, tobacco and other crops are prevalent. The management of these crops is threatening to the Nolichucky River fauna, because these fields require high amounts of fertilizer and pesticides during the growing season. The runoff from these types of crops has already been connected to a large fish kill in Washington County in 2012. For this study, a preliminary image classification of satellite photos was done in ArcGIS. The percentages of urban, forest, and agricultural land cover in the watershed and at varying buffer sizes along the river channel were calculated. To quantify the association between agriculture land use in the watershed, land use intensity (e.g., field size, shape, and proximity to channel) was compared to data from fish sampling conducted upstream and downstream of agricultural fields in the watershed during summer 2014.

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KNOXVILLE MICROCLIMATES: SPATIAL VARIABILITY IN AIR AND WATER TEMPERATURE ACROSS FOUR URBAN NEIGHBORHOODS

David Howe, Dr. Jon Hathaway, Dr. Kelsey Ellis

The main focus of this project is to observe spatial and temporal patterns of various metrological data across four urban neighborhoods in Knoxville, Tennessee. The preliminary findings will give us a snapshot of resiliency and environmental sustainability of individual urban neighborhood development and help us better understand human-environment interactions at a neighborhood scale. For this conference, the analysis will center on ambient air temperature and water temperature variability.

Our team installed 10 weather stations in July of 2014. Two weather stations were installed in each of 4 urban neighborhoods, along with one on a main street downtown and one within a nature center. Water temperature analysis will use data published by the City of Knoxville for five different urban streams.

Initial Tmax, Tmin, and diurnal temperature range (DTR) results show significant variability within a neighborhood as well as between neighborhoods. The presence of an urban heat island is also evident. Adding more stations within a single neighborhood will help determine if small-scale decisions play a significant role in mitigating urban heat. Water temperature analysis is currently underway. GIS (geographic information systems) software will help determine what factors (and at what scale) control increased temperatures in an urban environment. Of specific interest is how land cover, canopy cover, population density, and spatial pattern of green space effect the UHI as well as thermal pollution in urban streams.

INVESTIGATION OF FECAL BACTERIA AND NUTRIENT LEVELS IN LEES SPRING BRANCH, RUTHERFORD COUNTY, TN

Lara Jarnagin¹, Euvelisse Jusino-DelValle¹, An Nguyen¹, Victoria Kremer¹, Gale Beaubien¹, Megan Stallard¹, and Frank Bailey¹

Murfreesboro's Lees Spring Branch is fed by several springs that appear to have underground connections with groundwater that could be coming from many sources including urbanized areas and agricultural land. Lees Spring Branch is known to be contaminated with fecal pathogens/*Escherichia coli* and listed on the 303d list for nutrients from unknown sources. Nutrient and *E. coli* sampling was undertaken to help with TMDL development and to gather baseline data before future planned development in the area. Polymerase chain reaction (PCR) was used with the host-specific fecal bacteria, *Bacteroides* spp., to determine if fecal sources in Lees Spring Branch were human in origin. Lees Spring Branch was monitored seasonally at base flow (i.e. summer, winter, spring, and fall) for one year with arithmetic and geometric means calculated for *Bacteroides* and *E. coli*, respectively. Wet weather samples were taken once each season. Nitrate, range nitrite, orthophosphate, TSS, DO, pH and conductivity were collected with each sample. Only a small fraction of the fecal bacteria present were found to be from human sources. *Escherichia coli* and nutrient values were highly variable by season and weather conditions.

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LINKING COMPLEX ORGANIC FEEDSTOCK CHARACTERISTICS TO MICROBIAL METABOLIC ACTIVITIES IN ANAEROBIC CODIGESTERS

Juliet Ohemeng-Ntiamoah¹ and Tania Datta^{1,2}

Anaerobic codigestion is the process of adding supplemental feedstocks to an anaerobic digestion system to augment biogas production. Though codigestion results in higher biogas yields, complex and variable feedstock characteristics often inhibit key microbial communities from functioning effectively, resulting in operational problems and decreased biogas production. This is one of the main barriers to this technology. In spite of this, very few studies have delved into investigating the metabolic pathways upon which this biotechnology depends. ***The overall goal of the study is to understand the effects of feedstock characteristics on “healthy” metabolic pathways of key microbial communities in lab-scale anaerobic codigesters.*** More specifically, the study will: **a)** characterize three organic wastes as feedstocks for a series of lab-scale codigesters; **b)** determine if certain feedstock compositions and characteristics are more inhibitory than others; **c)** identify and monitor shifts in key microbial communities (acidogens and methanogens) under “healthy” and “poor” operating conditions using DNA sequencing; **d)** Determine metabolic pathways and inhibition mechanisms using metaproteomic data.

Some preliminary results from the study will be presented at the conference. It is anticipated that at the end of the research the relationship between feedstock characteristics and microbial metabolic pathways will be well established and the knowledge will enhance the optimum operation of anaerobic digesters. This will go a long way to help build a sustainable environment through viable renewable energy technologies such as anaerobic digestion which has desirable benefits as electricity generation, waste diversion from landfills, landfill space reduction and climate change mitigation.

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ATTENUATING ACID-ROCK DRAINAGE BY STIMULATING SULFUR-REDUCING BACTERIA

Ronald Oniszcak¹, Diarra Fall¹, Andrew Hart¹, Lonnie Sharpe¹, Tom Byl^{1,2}

In Middle and East Tennessee pyrite-bearing formations are exposed during road construction, leading to acid-rock drainage (ARD). As the pyrite (FeS_2) is exposed to oxygen, water and sulfur-oxidizing bacteria, it decomposes, forming sulfuric acid from sulfur oxides. The ARD subsequently leads to water-quality problems and potential damage to headwater streams. The objective of this research was to reverse the sulfur-oxidation process by stimulating sulfur-reducing bacteria. The scope of the research included use of flow-through microcosms in the laboratory. The half-liter microcosms were prepared with 450 grams of pyrite-rich Chattanooga Shale fragments (2- to 20-millimeter sieve size) and flushed with 500 milliliters of water containing indigenous bacteria collected from an ARD site in Middle Tennessee. Water was circulated using a peristaltic pump that ran for 8 hours a day at an approximate flow rate of 1 mL per minute. Deionized water (20 microsiemens per centimeter) was used to simulate percolating rain water. Several supplements expected to stimulate anaerobic, sulfur-reducing bacteria or raise the pH were evaluated, including NaOH (1.5 grams), NaOCl (1.5 milliliters), K_2HPO_4 (10.8 milliliters of 1 molar buffer), and sodium lactate (0.75 milliliter) and soy infant-formula (1.5 grams). When no supplements were added (control microcosm), the pH of the microcosm discharge waters remained acidic (pH 2-3.5). Soy infant-formula and lactate stimulated sulfur-reducing conditions, but the pH remained 5 units or less, and $\text{Fe}^{2+}_{\text{aq}}$ increased to unacceptable levels (50-60 mg/L). Supplementing the microcosms with K_2HPO_4 led to a neutral pH and low $\text{Fe}^{2+}_{\text{aq}}$ (less than 4 milligrams per liter), but increased levels of phosphate in the discharge waters from less than 1 to greater than 20 milligrams per liter as phosphorus. Adding a small dose of NaOH prior to injecting soy and sodium lactate helped the sulfur-reducing bacteria gain a foothold, allowing the bacteria to raise the pH to 6.2 and reduce $\text{Fe}^{2+}_{\text{aq}}$ to less than 10 milligrams per liter. The supplement mix of NaOH followed by soy infant-formula and sodium lactate holds promise for ARD mitigation by reversing the bio-geochemical processes responsible for acid production.

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ESTABLISHING PERFORMANCE AND DESIGN THRESHOLDS FOR REGENERATIVE STORMWATER CONVEYANCES THROUGH MODELING AND MONITORING

Jessica M. Thompson^{1*}, Jon M. Hathaway¹, and John S. Schwartz¹

As stormwater runoff is increasingly degraded due to growing trends in urbanization, it has become a priority to manage the quantity and quality of runoff that enters streams. Regenerative Stormwater Conveyances (RSCs) are an innovative approach to repairing bank erosion from stormwater outfalls while treating stormwater runoff through filtration, infiltration, microbial action, and sedimentation. RSCs have a dual function, allowing small storms to infiltrate and travel through the system as shallow groundwater flow, and large storms to travel through a series of step pools to dissipate energy and reduce erosive flows. RSC systems have become an important tool for restoring the Chesapeake Bay; however, they are less common outside the mid-Atlantic region. Furthermore, design specifications for other regions are not currently available. The intent of this study is to design, install, and monitor two RSCs to establish performance thresholds. During the design process, the computational fluid dynamics (CFD) software program, Flow3D, was utilized. Flow3D will allow an investigation into the most efficient design that will minimize bed and bank scour while simultaneously maximizing system performance. Initial model simulations indicate that modifications in system design will improve system performance. Once installed, the RSCs will act as educational and demonstration sites, serve as retrofit restoration projects for two degraded watersheds, and will be utilized for monitoring and research.

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LIDAR COMPARED TO NED AND SURVEYED DATA IN HEC-RAS

Joseph (JJ) Thornton, Alfred Kalyanapu,
and Nowfel Mahmud

Floods are the #1 natural disaster in the United States. They cause more damage, cost more, and occur more widespread than any other natural disaster. The U.S. founded the Hydrologic Engineering Center and they began developing computer programs that could simulate flooding. Their latest program is HEC-RAS.

For HEC-RAS to model floods, it requires input data of the land topography. Inputting accurate elevations, slopes, etc. is critical to getting accurate results. Lidar, or light detection and ranging, is a way of obtaining this data very accurately. This research project investigates how Lidar data input into HEC-RAS compares with other sources of data available through United States Geological Survey or NASA. The project involves exploring which data sources are more accurate and easier to work with as well as exploring options to increase the accuracy of Lidar data in the program. Three models of the Cumberland River that flooded during the May 2010 floods in Nashville were built, each model using different input data, Lidar being one. Then the models were used to analyze and compare the accuracy of each input data. The Lidar data was expected to be most accurate, but turned out to be less accurate than other input.

SPATIAL DISTRIBUTION OF SEDIMENT AND MICROBES ACROSS STREAMS IN EASTERN TENNESSEE

Michael Walton*¹, John S. Schwartz¹, and Jon M. Hathaway¹

Understanding how sediment and microbes are spatially distributed across stream cross sections has important implications for understanding transport processes, determining monitoring uncertainty, and exploring sediment/microbe interactions. Characterization of sediment transport within small headwater streams should vary more than that of large open channels, due to the decreased level of flow resistance affected by boundary roughness. While some modeling approaches focus on a logarithmic relationship of the flow profile due to effects of the viscous sublayer and shear velocity to predict suspended sediment transport within streams, the bed geometry and turbulence structures are likely key variables that must be considered. By gathering 10 samples simultaneously across a reach using a unique collection procedure, it will be possible to establish whether sediment transport can be characterized the same way for all open channels. Relationships between suspended sediment and microbial transport will also be explored in this study as to whether suspended sediment is a fundamental driver for microbial transport in streams. Due to the prevalent contamination of surface waters by indicator bacteria, it is important to further understand microbial transport to provide more accurate models for TMDL development. By evaluating the fecal coliform concentrations within these samples, it will be possible to evaluate the existence of a correlation between microbial and sediment transport and explore which particle size to which indicator bacteria are most associated. By refining our understanding of these transport variables, future modeling and monitoring efforts can be better developed and evaluated.

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SEDIMENT SOURCE POTENTIAL IN SMALL URBANIZING STREAM SYSTEMS

Robert R. Woockman^{1*} and John S. Schwartz²

Cost effectively mitigating excess energy in stream systems, caused by decreases in initial abstraction or modifications to channel erosive resistance, requires linking planning of stormwater control measure suites with stream rehabilitation needs. Integrated management plans can be accomplished through fluvial audits that observe surrogate measures of a channel's erosive versus resisting forces and continuous simulation modeling (CSM) to identify potential response trajectories. Surrogate measures of channel resistance and stream power in ER67 stream systems are explored to identify influence on developmental states and identify potential grouping. Calibrated CSMs of hillslope processes and in- channel processes are used to validate exploratory field data analysis and explore effective mitigation practices. Ultimately, this research is expected to support stream system rehabilitation in ER67 through adaptation of mitigation practices relative to channel resistance properties.

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Barge, Waggoner, Sumner & Cannon, Inc. is a professional services firm in Nashville, Tennessee, with offices in Ohio, Tennessee, Alabama and Georgia. The staff of BWSC offers a wide range of water resource services, focused on water supply and treatment, groundwater, storm water, municipal and industrial wastewater, utility management, feasibility studies, watershed management and rehabilitation, and river and impoundment hydrology and hydraulics.

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

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The Center for the Management, Utilization and Protection of Water Resources is an established Center of Excellence and is recognized for research on *Legionella* and *Legionella*-like bacteria; pesticide fate and transport in the environment; native and stocked fish habitat and survival; endangered mussels; and water and wastewater treatment using constructed wetlands. Its vision is enhancing education through research, and the Center accomplishes this through its world-renowned teams of interdisciplinary professionals.

Civil & Environmental Consultants, Inc.

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Civil & Environmental Consultants, Inc.

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.

Neel-Schaffer, Inc.

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Providing solutions that its clients can build upon is the essence of Neel-Schaffer, Inc. Made up of engineers, planners, environmental scientists, landscape architects and surveyors, Neel-Schaffer is an employee-owned firm. Since 1983, it has grown from a company of 20 individuals to a 320-member-strong multi-disciplined firm. With offices located across the South, it services public and private clients, including federal, state, and local governmental agencies.

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The University of Memphis Ground Water Institute and Center for Partnerships in GIS combined their expertise to form the Center for Applied Earth Science and Engineering Research (CAESER). This new center will continue the efforts of its former institutes, while broadening its areas of expertise to help build smarter, stronger communities through research and education.

Exhibitors

HydroLogics

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HydroLogics has over 25 years of experience in modeling and managing water resources in river basins throughout the United States. The firm's OASIS software is used to support water allocation decisions, develop drought management plans, and evaluate the benefits of water efficiency and conservation measures.



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**Suntree Technologies Inc.**

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Water Quality Matters!**Thomas B. Lawrence, PE**

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Water Quality Matters!

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. <http://www.waterqualitymatters.com>

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Tennessee Section
American Water Resources Association

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