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PROCEEDINGS

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TENNESSEE WATER RESOURCES SYMPOSIUM

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28th Tennessee Water Resources Symposium

Montgomery Bell State Park
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April 10-12, 2019

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Tennessee Section of the American Water Resources Association

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PREFACE

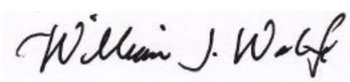
Welcome to the 28th (2019) Tennessee Water-Resources Symposium. We have a great lineup of speakers, presentations, and abstracts representing the breadth of issues, perspectives, and communities concerned with Tennessee's water resources. Between the pre-session workshop and the final panel discussion, the planning committee has organized a meeting as diverse as our membership.

Our keynote speaker, Dr. James P. Dobrowolski of USDA's National Institute of Food and Agriculture, will kick off the meeting with a timely presentation on our nation's dilemma of securing adequate water to sustain food production as water demands other non-agricultural sectors intensify. In addition, we are privileged this year to have as our Luncheon Speaker Commissioner David Salyers of the Tennessee Department of Environment and Conservation, who will speak to Tennessee's water-infrastructure needs.

We will continue our practice of the last several years of wrapping up our meeting with a panel discussion. This year's panel will include truly distinguished representatives of Tennessee diverse water-resources stakeholders, including local governments, public and private water utilities, hydroelectric power generators, state regulators, and the conservation community. They will be discussing the TNH2O initiative, a bold effort to establish a statewide water-resources planning framework. We expect a lively discussion with opportunities for active audience participation!

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

Thanks for being a part of the 2019 symposium.



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TIPS AND TRICKS WITH OPEN SOURCE TOOLS FOR WATERSHEDS
PRE-SYMPOSIUM WORKSHOP
8:30 a.m., Wednesday, April 10

12:00 – 1:30 p.m.
Wednesday, April 10
Keynote Address *by* James P. Dobrowolski, National Program Leader for Water and Rangeland and Grassland Ecosystems, USDA-National Institute of Flood and Agriculture (NIFA)

THE PLIGHT OF AGRICULTURE'S ADOPTION OF RECYCLED WATER FOR IRRIGATION

Is agriculture a valued customer or not? More than ten years ago, centralized municipal waste treatment plants were excited about delivering recycled water along dual "purple pipe" systems to alleviate treated water storage or additional treatment required to discharge. The City of Santa Rosa, CA uses over a third of its tertiary-treated water to irrigate approximately 6,400 acres of farmlands, vineyards, and public and private urban landscaping. Due in part to the City's success in reducing drinking water demands and water conservation practices, the City has determined that it is not cost effective to expand the recycled water distribution system to additional irrigated agriculture. However, the City continues to evaluate other potentially more cost-effective water supply sources for future water supply needs. Thus, irrigated agriculture is in a *Catch-22*—expected to reduce its water footprint while simultaneously accelerating the production of food to meet the demands of 10 billion inhabitants in 2050. Agriculture remains the greatest manager of freshwater across the U.S. at 88%. Competition for use of these freshwater sources resulting from demand by urban, urbanizing and peri-urban areas; industry, mining and energy extraction/production could in time force agriculture to relinquish that water, thereby reducing the potential to grow more food in some areas. What are agriculture's alternatives? Designing new crops through genomics and breeding; instilling drought tolerance in rain-fed crops such as rice, maize, barley, durum wheat, winter wheat, chickpea, cotton, sorghum and sweet peppers (SNP genotyping, breeding and selection in the field, QTL mapping or genome wide association study (GWAS), comparative transcriptome, precise high-throughput phenotyping, and characterization of the drought-resistance genes). Despite all the recent technological breakthroughs, the overall contribution of genomics-assisted breeding to the release of drought-resilient cultivars has so far been marginal. The successful application of genomics to elevate drought tolerance in food crops will only be possible within a coherent, multidisciplinary context delivering an understanding of the characteristics restricting crop yields in droughty environments. Other solutions focus on substituting nontraditional water sources (treated with low energy MABRs for example) for freshwater irrigation by designing small, efficient wastewater treatment plants located in "lobes" of newly urbanizing communities or within existing rural towns with short-distance deliverability exclusively to irrigated agriculture. Alternatively, portable wastewater treatment systems can be designed to deliver high quality water to irrigated agriculture from oil/gas/mining production wells. Critical issues associated with recycled water for agriculture involve 1) human health, 2) cost, 3) water availability, 4) social acceptance, 5) salinity and 6) storage. Because industrial agriculture relies on finite water resources, it has the responsibility to seek alternative methods of irrigation to reduce its water footprint. While irrigation strategies and techniques can help reduce water footprints without much added cost (e.g., deficit irrigation, irrigation scheduling, organic mulching), water reuse will be the most responsible and effective solution to sustain farming needs over the long-term.

12:00 – 1:30 p.m.
Thursday, April 11
Lunch Presentation *by* David Salyers, TDEC Commissioner

INFRASTRUCTURE: CRITICAL TO TENNESSEE'S WATER FUTURE

Tennessee's abundant, clean water has been critical to our economy, agriculture, transportation, tourism, recreation and our overall quality of life that distinguishes us from other places. However, this essential natural resource is under stress from the reality of today: we're experiencing strong population growth, intermittent drought, aging infrastructure, and nagging interstate conflicts over water rights and access.

My friends at the Farm Bureau are fond of saying, "You can't predict the future, but you can prepare for it." Part of this preparation must include investment in our infrastructure – both our physical capacity to produce, carry, treat, navigate and conserve Tennessee's water and also our workforce capacity to provide the people and skills necessary to create an abundant water future for all Tennessee communities. Making smart investments in this essential infrastructure and designing the future we want for Tennessee will make it possible for us to ensure reliable water and our distinctive quality of life.

I welcome the sustained involvement of front-line professionals as we raise public awareness on these issues and pursue a common goal of strengthening our state's infrastructure for the benefit of both our citizens and water resources.

SESSION 1A

GROUNDWATER
(Moderator: Ingrid Luffman, ETSU)

GW/SUBSURFACE MONITORING
(Moderator: Scott Schoefernacker, CAESAR)

SESSION 1B

STREAM RESTORATION FUNCTIONAL LIFT
(Moderator: Forbes Walker, UT)

STREAM RESTORATION
(Moderator: John Schwartz, UT)

SESSION 1C

GIS/MODELS
(Moderator: Richard Cochran, TDEC-DWR)

WATER QUALITY
(Moderator: Anne Hoos, USGS)

SESSION 2A

STREAM RESTORATION/MITIGATION
(Moderator: Angel Fowler, Mitigation Management)

STORMWATER
(Moderator: Paul Davis, P.E.)

STORMWATER/WATER QUALITY
(Moderator: Alfred Kalyanapu, TTU)

STAKEHOLDER PARTNERSHIPS
(Moderator: Regan McGahen, TDEC-DWR)

SESSION 2B

MODELS I
(Moderator: Dennis Borders, TDEC-DWR)

MODELS II
(Moderator: Rodney Knight, USGS)

FLOODS/FLOODING
(Moderator: Adrian Ward, Barge Design Solutions, Inc.)

FLOODING AND EROSION

(Moderator: David Ladd, USGS)

SESSION 2C

ECOLOGY-THURSDAY

(Moderator: Bill Wolfe, USGS)

ALGAL STUDIES-THURSDAY

(Moderator: Sherry Wang, TDEC-DWR)

H_2O
(Moderator: Scott Gain, USGS)

SESSION 3B

GREEN INFRASTRUCTURE
(Moderator: Andrea Ludwig, UT)

SESSION 3C

ANALYTICAL PARTICLE TECHNIQUES
(Moderator: Anne Choquette, USGS)

STUDENT POSTERS

High School

Doctoral

PROFESSIONAL POSTER

SESSION 1A

GROUNDWATER (Moderator: Ingrid Luffman, ETSU)
1:30 p.m. – 3:00 p.m.

Karst Hydrology of the Western Great Smoky Mountains
Benjamin Miller and Michael Bradley

Age-Tracer and Groundwater Flow-Model Age Distributions for Aquifers in the Mississippi-Embayment Aquifer System
James Kingsbury, Connor Haugh, and Katherine J. Knierim

Groundwater Resources and Regulations in Tennessee
Brian Hamm

GW/SUBSURFACE MONITORING (Moderator: Scott Schoefernacker, CAESAR)
3:30 p.m. – 5:00 p.m.

Alabama Groundwater Monitoring Using NGWMN
Ann Compton Arnold

The State of Groundwater Assessment in Alabama
Gregory M. Guthrie

Subsurface Temperature Variation Near a Closed Landfill, Jackson, Tennessee
Randy M. Curtis

KARST HYDROLOGY OF THE WESTERN GREAT SMOKY MOUNTAINS

Benjamin V. Miller[1]* and Michael Bradley[2]

The geology of Great Smoky Mountains National Park (GRSM) in Tennessee and North Carolina is dominated by siliciclastics and metamorphic strata. However, in the western portion of the Park a series of fensters (windows) expose lower Ordovician carbonates of the Knox Group. The fensters create the opportunity for allogenic recharge to occur at points along the contact of the surrounding insoluble strata with the underlying carbonates. The combination of chemically aggressive recharge and vertical relief has resulted in the formation of deep caves, many of which have active streams and other water resources. Though the karst is limited in extent and the number of caves is fairly low, the significance of the resources within the caves is substantial-several of the caves in the area are over 150 m in depth and two of the caves are major bat hibernacula . Cades Cove, a large carbonate fenster, is one of the National Park Service's most-visited sites. In 2017, the U.S. Geological Survey began a study to better understand the hydrologic behavior of these karst systems through hydrologic and geochemical monitoring, dye tracing, and seepage runs. Stage and water-quality instrumentation was placed in the main stream of Bull Cave and in a sump pool in White Oak Blowhole, at 173 m and 70 m below land surface respectively. Following setup of the cave sites, dye injections were conducted to determine discharge points for four of the deep cave systems on Rich Mountain and Turkeypen Ridge. Results show that tracers injected into streams in these systems to have an extremely rapid travel time, with tracers detected from caves to springs in less than 24 hours. To characterize streamflow, a real-time surface water gage was installed in May 2017 along Abrams Creek, the main stream in Cades Cove. Analysis of seepage run data along the tributaries and main stem of Abrams Creek quantified losses and gains as streams flow off of the insoluble strata and sink at the carbonate contact. The karst of GRSM provides an opportunity to study a unique landscape characterized by complex geology, high stream gradients, and deep caves. The investigation was conducted in cooperation with Tennessee Wildlife Resources Agency, GRSM, and Tallassee Fund.

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AGE-TRACER AND GROUNDWATER FLOW-MODEL AGE DISTRIBUTIONS FOR AQUIFERS IN THE MISSISSIPPI EMBAYMENT AQUIFER SYSTEM

James Kingsbury[1], Connor Haugh[1], Katherine J. Knierim[2]

As part of a regional assessment of groundwater quality in the Mississippi embayment aquifer system by the U.S. Geological Survey National Water-Quality Program, a substantial amount of data have been collected to characterize groundwater quality and groundwater ages. In this aquifer system and other regional aquifers across the country, groundwater age has been identified as an important factor affecting water quality. Generally, the probability of detecting anthropogenic constituents (such as organic compounds and high concentrations of nitrate) is greater if young groundwater is present in an aquifer. Conversely, the probability of anthropogenic constituent occurrence typically is lower in deep and confined aquifers with longer groundwater flow paths and residence times and where young groundwater typically is not present. Naturally-occurring constituents such as trace metals are often detected more frequently and in greater concentrations when groundwater residence times are long and groundwater chemistry evolves over time.

Groundwater in the Mississippi embayment aquifer system and the overlying Mississippi River Valley alluvial aquifer are important sources of water for public and domestic supply, as well as industrial and agricultural uses. Regional confining units in the Mississippi embayment aquifer system result in confined groundwater conditions throughout much of its extent. As a result, groundwater flow paths and residence times typically are long and much of the water withdrawn from these aquifers for public supply is pre-modern (tritium concentrations < 0.5 Tritium Units) in areas where the aquifers are confined. Age-tracer (tritium, sulfur hexafluoride, carbon-14) sample results from regional well networks and age-distributions derived from a regional groundwater-flow model were used to characterize water quality and recharge. Mean ages based on age-date tracers are comparable to groundwater-age estimates derived from particle-track runs using the regional groundwater-flow model. Tracer data indicate that mixtures of young and old water are prevalent, but the presence of waters with mixed ages is most common where long-term pumping has caused shallow, young water to move into the Claiborne aquifer of the Mississippi embayment aquifer system. The occurrence of anthropogenic contaminants in this aquifer is correlated to the fraction of young water estimated from age-tracer analysis.

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GROUNDWATER RESOURCES AND REGULATIONS IN TENNESSEE

Brian Ham[1]*

INTRODUCTION

Groundwater in Tennessee is a highly valued environmental resource and is an important part of the public water supply. This presentation will highlight the different types and spatial distribution of aquifers in Tennessee and how groundwater resources are being protected in the state. The regulatory framework for protecting these resources includes establishing Wellhead Protection Areas around public water supplies utilizing groundwater sources. Additional regulations are established within the Underground Injection Control (UIC) program to prevent sources of pollution from entering these aquifers. These regulatory mechanisms are designed to preserve and protect groundwater for the citizens of Tennessee. The presentation will include an overview of these regulatory programs, an evaluation of the current data for each, and discussion of the challenges encountered for managing these programs.

BACKGROUND

Over 450 pubilc water systems (58% of total) in Tennessee use groundwater as a source to supply the system. These systems are estimated to serve over 1.6 million people in the state. The value of groundwater is further emphasized by the quantity that is withdrawn by private entities (e.g., residential, agricultural and commercial/industrial wells). Public Water Systems using a groundwater source are required to implement a Wellhead Protection Plan which involves delineation of a Wellhead Protection Area and identifying any significant potential contaminant sources. These plans are updated every three years and submitted to Tennessee Department of Environment and Conservation, Division of Water Resources for review.

The UIC Program, as mentioned above, is another regulatory mechanism for protection of groundwater. The framework for these regulations were built around a more traditional sense of aquifer protection from emplacing fluids into drilled wells. The regulations also include storm water drainage to wells and "improved sinkholes," which creates a unique regulatory challenge for establishing a set of guidelines or thresholds for intentional utilization of a feature that also supports natural processes.

DISCUSSION

Tennessee citizens continue to rely on groundwater for drinking water (public and private), agriculture (irrigation/livestock), and industrial purposes. The protection of these resources is an important part to ensuring the quanitity and quality of groundwater for future use. Regulatory mechanisms such as Wellhead Protection and UIC rules are an integral part of protection, along with outreach and education for the public. Establishing partnerships with stakeholders during the development of Wellhead Protection Plans is a great example of how communication and

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outreach can create effective management strategies to prevent groundwater pollution and prepare for potential emergency scenarios.

Further engagement with the public and regulated community regarding UIC program rules helps establish a better understanding of the requirements and creates a platform for improved program implementation. The presentation will discuss the different classes of UIC wells, statistics regarding these wells in Tennessee, and the rules and regulations that are unique to each type.

REFERENCES

TDEC Drinking Water Annual Compliance Report, 2018, Tennessee Department of Environment and Conservation, Division of Water Resources.

Webbers, Ank, 2003, Public Water-Supply Systems and Associated Water Use in Tennessee, 2000, Water Resources Investigations Report 03-4264, United States Geological Survey in cooperation with TDEC, Division of Water Supply.

ALABAMA GROUNDWATER MONITORING USING NGWMN

Ann Compton Arnold[1]

Using the USGS National Groundwater Monitoring Network (NGWMN) framework document, Geological Survey of Alabama (GSA) staff are currently evaluating observation wells throughout the State to place them into subnetworks of *background*, *suspected* or *documented changes* in water-level elevations. The NGWMN's primary mission is to provide a national online map/data interface to address regional groundwater questions focused on principal aquifers. The GSA staff measure static water levels in observation wells bi-annually. These April and October measurements represent seasonal variation of wet and dry conditions. Many GSA observation wells have recorded water-level elevations for over forty years. The overall approach is to define areas with clusters of high-volume pumping wells. Groundwater use data supplied by the Alabama Office of Water Resources (OWR) provides locations for wells extracting >100,000 gallons per day, chiefly for municipal, agricultural and industrial uses. Within areas of significant groundwater use, GSA will evaluate the observation well network for potential aquifer drawdown. Five areas have tentatively been identified as *background* that are not affected by intensive groundwater withdrawal. Background areas are situated in low-yielding aquifers of the Cumberland Plateau or Piedmont region, with few major supply wells. The primary areas being evaluated for *suspected changes* due to groundwater withdrawal are Gulf Coastal Plain, Valley and Ridge, and Highland Rim aquifers. No areas have been classified as *documented changes*. Future studies will include analyses of available pump test data and delineation of water-level trends in major Alabama aquifers within these areas.

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THE STATE OF GROUNDWATER ASSESSMENT IN ALABAMA

Gregory M. Guthrie[1]

The Geological Survey of Alabama (GSA) Groundwater Assessment Program has two priorities in support of the development of a state-wide water management plan. The first priority is to monitor the state's groundwaters by: (1) conducting bi-yearly water level sampling, (2) expanding the real-time and continuously monitored well network, and (3) developing a GIS-based well database. The second priority is to utilize information from the initial assessment report entitled "Assessment of Groundwater Resources in Alabama 2010-2016," published as GSA Bulletin 186 in 2018, in conjunction with new data to develop a comprehensive integrated and calibrated water model for the state that will incorporate groundwater, surface water, land use, water use, and climatic data. Alabama's water resources are distributed in diverse settings, so the model will be a composite of subareas defined by HUC-8 boundaries rather than a singular state-wide model. The modeling process will utilize pilot projects representative of the state's aquifers to develop procedures that will be used in subsequent modeling of comparable aquifer environments. Two pilot projects have been initiated: the north Alabama Wheeler Lake HUC-8 and the west Alabama Middle Tombigbee-Choctaw HUC-8, representing the Appalachian Plateau and Gulf Coastal Plain aquifers, respectively. Future pilot projects will focus on basins located in the Valley and Ridge and Piedmont areas of the state. The model is being developed to allow responsible parties to make water-related and policy decisions in response to changing water stresses.

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SUBSURFACE TEMPERATURE VARIATION NEAR A CLOSED LANDFILL, JACKSON, TENNESSEE

Randy M. Curtis[1]*

Temperature dataloggers were deployed in methane monitors, gas vents, and monitoring wells as part of an environmental assessment of current conditons near a landfill that was closed in the late 1990's. The dataloggers recorded temperatures every 15 minutes in ambient air, water at the landfill surface, subsurface soil atmoshpere, shallow perched groundwater, and regional aquifer groundwater. The temperature recoring units were deployed from 11/16/2017 to 01/08/2018 with follow-up observations from 10/26/2018 to 11/17/2018 2018. The data was compared to the mean annual air temperature data from the Jackson McKellar-Sipes Regional Airport. The shallow groundwater temperatures in the monitor well nearest the buried waste has an average temperature nearly 12°F higher than expected based on the annual average temperature, and all groundwater monitors except the shallow upgradient well had temperatures slightly higer than expected. Data loggers placed in screened monitor well intervals from 50 to 175 feet below ground surface, but above the water table, recored average temperatures two to six degrees higher than expected in the deep soil atmosphere, with noticeable variation around the mean. This indicates that the local unsaturated porosity in the sands underlying this area are capable of carrying some heat via the soil atmosphere to depth. Two of the data loggers were capable of recording barometric pressures as well as temperatures, and this data indicated a lag of from 58 to 91 hours at depth compared to the surface hourly barometric reading from the airport.

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SESSION 1B

STREAM RESTORATION FUNCTIONAL LIFT (Moderator: Forbes Walker, UT)
1:30 p.m. – 3:00 p.m.

Evaluating the Functional Lift Provided by Habitat Rehabilitation in Urban Streams of the Ridge and Valley Province, TN
Grant Fisher

Use of Geomorphic Metrics in Functional Traits Analysis for Urban Streams
Jeremy Melton and John Schwartz

Assessing Functional Lift Through Improved Monitoring and Assessment Techniques for Urban Stream Restoration Projects
John Schwartz and Brian Alford

STREAM RESTORATION (Moderator: John Schwartz, UT)
3:30 p.m. – 5:00 p.m.

Two Dimensional Modeling Use in Stream Restoration Design
Patrick McMahon and Ken Barry

Stabilization Techniques for West Tennessee Streams
Trevor Cropp

PYFLUV: A Python Module for Fluvial Analysis and Design
Sky Jones

EVALUATING THE FUNCTIONAL LIFT PROVIDED BY HABITAT REHABILITATION IN URBAN STREAMS OF THE RIDGE AND VALLEY PROVINCE, TENNESSEE

Grant Fisher[1]

The business of stream restoration is a billion dollar industry today. Funds are used to correct anthropogenic damage to enable natural ecological processes to return. Unfortunately, ecological improvement from stream restoration projects, particularly in urban watersheds, have had mixed results. A critical need exists for a better understanding of ecological responses to restoration in order to improve on design strategies, and to assign mitigation credits. For our study, fish and benthic macroinvertebrate data were collected and indices of biotic integrity (IBI) were calculated for four urban restored, four urban unrestored, and four reference stream reaches in the Ridge and Valley physiographic province of east Tennessee. Benthic macroinvertebrates were sampled in riffles bimonthly in 2017-2018 using semi-quantitative kicknets and in pools using D-frame dipnets following the Tennessee Department of Environment and Conservation's standard operating procedure. Fishes were sampled biannually in 2017-2018 with a backpacker electroshocker and seine following standard operating procedures for the Tennessee Valley Authority's IBI monitoring program. The streams' functional lift will be analyzed and compared using the stream quantification tool (SQT) to better understand ecological recovery potential in urban streams following physical habitat restoration. Secondly, we will conduct a functional traits analysis to assess the degree to which ecological design criteria for stream restoration, particularly in urban watersheds, can be used to improve the ecosystem functioning of restored streams. Results will be presented comparing IBI metrics and scores among treatments to determine the effect size that can be gained from stream restoration in this region.

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USE OF GEOMORPHIC METRICS IN FUNCTIONAL TRAITS ANALYSIS FOR URBAN STREAMS

Jeremy Melton[1*] and John Schwartz[2]

Urban watersheds experience a variety of ecosystem stressors including hydromodification and impaired water quality. Impacts of hydromodification include rapid geomorphic adjustment to the channel and degraded habitat which potentially can affect detrimentally benthic macroinvertebrate and fish communities. Stream restoration is commonly implemented to resolute damage to these communities. Because geomorphic metrics define habitat structure they are a necessary component to stream condition and restoration design. Compensatory mitigation is required by the Clean Water Act for aquatic resource loss, and to ensure mitigation is obtained a functional lift analysis is conducted between the existing condition and the proposed restoration project. The existing tool used in Tennessee is the Stream Quantification Tool (SQT) and was based on the restoration of non-urban streams relying on geomorphic reference benchmarks. Unknown to date is the potential functional lift that may be achieved in urban streams. Our research explores the what functional lift is possible in restored urban streams by comparing three site classified streams: urban impaired, urban restored, and reference sites. All study sites were located in the Ridge and Valley Ecoregion (ER67) located in the eastern portion of Tennessee. Geomorphic and habitat data will be assessed to quantify the departure from impaired and restored streams from the reference streams. In doing so, a quantitative measure of the potential functional lift from geomorphic metrics will be achieved. This analysis is part of a broader study that also examined the biological communities and their relations among the three stream classifications – also quantifying the ecological departure from a reference condition.

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ASSESSING FUNCTIONAL LIFT THROUGH IMPROVED MONITORING AND ASSESSMENT TECHNIQUES FOR URBAN STREAM RESTORATION PROJECTS

John Schwartz and Brian Alford

Ecological improvement from stream restoration projects particularly in urban watersheds have had mixed results. There are several possible reasons for the limited improvements including 1) inadequate ecological design criteria based on recolonization potential and habitat requirements determined by functional traits expression 2) pre- and post-monitoring assessment methods, 3) the biological assemblage chosen for the bioassessment, and 4) lack of a watershed-scale stressor analysis and adequate project scoping and prioritization. The 2015 document Tennessee Integrated Assessment of Watershed Health (TIAWH): A Report on the Status and Vulnerability of Watershed Health provides the watershed-scale analysis for project prioritization; however for stream restoration design additional ecological information is needed particularly in urban streams. In addition, there is a critical need to better understand ecological responses to restoration in order to improve on design strategies, and assign mitigation credits. Two research study goals are proposed: 1) collect biological data urban restoration projects, and urban unrestored and reference stream sites, and analyze and compare *functional lift* per the quantification tool to better understand ecological impairment processes in urban streams; and 2) integrate a functional traits analysis methodology with the TIAWH Report to improve ecological design criteria for stream restoration particularly in urban watersheds.

TWO DIMENSIONAL MODELING USE IN STREAM RESTORATION DESIGN

Patrick McMahon[1] and Ken Barry[2]

The two dimensional (2D) modeling capabilities of HEC RAS 5 are finding wider application in stream restoration design although questions as to what constitutes an adequate model and how to interpret the results and integrate them into the design remain. This presentation examines the use of HEC RAS 5 2D in the design of an urban stream enhancement project. Techniques for generating the model surface to properly represent the planned features are presented. Also presented are the results of sensitivity analysis of varying the mesh size. Finally, the results are compared to the results of a one dimensional (1D) HEC RAS analysis with a discussion of the utility vs. cost of the 1D vs. 2D analysis with various mesh sizes.

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STABILIZATION TECHNIQUES FOR WEST TENNESSEE STREAMS

Trevor Cropp[1]

Streambed material in and around Shelby County is well known for being highly erosive and movable. Over the years, development around these erosive streams has increased the amount of impervious areas and changed the channel geometry through the installation of road and utility crossings. These changes have increased the potential for soil movement by increasing the amount and velocity of runoff entering the channels and reducing the amount of available channel conveyance area through the filling of floodplains and installation culverts and utility crossings that restrict flow.

There is no “one size fits all” solution to stream stabilization since the root cause of stream erosion can vary so much. This presentation will discuss various stream stabilization projects designed to prevent soil erosion in channel beds and banks depending on various design factors including velocities, locations of utilities, proximity to structures, etc. Various techniques such as armoring with rip-rap and concrete as well as proprietary materials will be explored. Scour holes and drop structures are options to control highly erosive and concentrated flows. Permitting requirements are always an issue. Requirements for complying with both the Tennessee Department of Environment and Conservation (TDEC) Aquatic Resource Alteration Permit (ARAP) and the US Army Corps of Engineers (USACE) 404/401 Permit will discussed as well. These requirements limit how much water can be impounded and the length of stream impacts and provided guidance on baseflow requirements.

Following the discussion of various stream stabilization case studies, the attendees will leave with a toolbox of best management concepts and techniques to consider in their next stream stabilization project.

[1] PE, Barge Design Solutions

PYFLUV: A PYTHON MODULE FOR FLUVIAL ANALYSIS AND DESIGN

Sky Jones[1]

ABSTRACT

The free and open source Python module *pyfluv* provides the stream restoration community with a powerful programming library that programmatically addresses analyses common in the field. Basic analysis of cross section, planform and profile data such as cross-sectional and bedform diversity statistics are possible as well as more complicated algorithms such as floodplain identification and reach segmentation. The module also can read, clean, validate and repair raw survey data, automatically formatting it so the output is comprehensible to *pyfluv*. Due to the prevalence of Dave Rosgen's methodologies in field restoration, much of *pyfluv*'s design is influenced by his work.

This extended abstract aims to give a brief overview of *pyfluv*'s functionality rather than how to use it or the specifics of its implementation. For documents that cover these purposes, please see the documentation referenced in the project's readme at https://github.com/rsjones94/pyfluv.

1. INTRODUCTION

Many restoration practitioners analyze geomorphic data using paid programs such as RIVERMorph or spreadsheets systems like the Ohio DNR's STREAM modules. These programs work well, but are limited in terms of the ability for a user to interact with them programmatically. The *pyfluv* module provides practitioners and researchers with a high level programming interface that facilitates the analysis of geomorphic data without the need to implement low level calculations and data processing. Because many common calculations are implemented out of the box, many stream analyses written with *pyfluv* are succinct and simple to understand even for those unfamiliar with Python. However, the package is also highly modular, allowing practitioners with some programming experience to quickly implement custom analyses. Consider the following code:

```
import pyfluv
mySurvey=
pyfluv.StreamSurvey(r'C:\Users\rsjon_000\Desktop\Pyfluv_Testing\wpr_myr5_adjusted.
csv')
pros = mySurvey.get_profile_objects()
crosses = mySurvey.get_cross_objects()
```

These four lines of code import a total station stream survey and parse it for streams and cross sections using the survey description field. The StreamSurvey object also identifies bankfull, water surface, top of bank, and other special calls (if specified in the survey description) and appropriately passes them to the Profile and CrossSection objects. These objects can be

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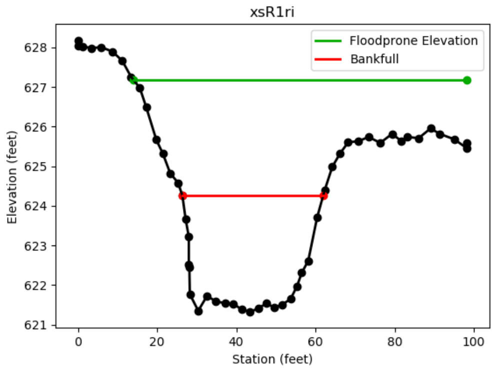
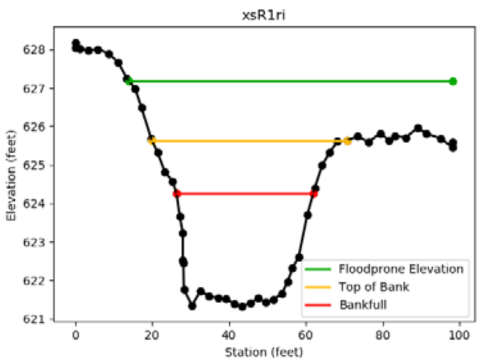
immediately inspected for information such as bankfull area and entrenchment ratios (for cross sections) and pool-to-pool spacing (for profiles). Quick plots can be made with the qplot() method:

```
crosses[5].qplot(ve=10)
```



The above cross section was plotted with 10x vertical exaggeration. No top of bank was called in the original survey so a top of bank elevation was not plotted. However, *pyfluv* can programmatically identify this elevation:

```
crosses[5].tobEl = crosses[5].find_floodplain_elevation()
crosses[5].qplot(ve=10)
```



If the user is interested in the area-to-mean depth ratio as a function of max bankfull depth, this can be implemented in a few lines of code.

```
crosses[5].bkfEl = min(crosses[5].elevations) + 0.1
bankfullElevation,areaToDepth = [],[]
while crosses[5].bkfEl <= max(crosses[5].elevations):
        bankfullElevation.append(crosses[5].bkfEl)
        areaToDepth.append(crosses[5].calculate_area() / crosses[5].calculate_mean_depth())
        crosses[5].bkfEl += 0.1
```

Note that this is just one way to produce the desired result and is relatively verbose for clarity's sake. The data can be plotted over a quick plot or otherwise analyzed further. The Profile and CrossSection objects included in *pyfluv* are very powerful; demonstrated here is just a very small portion of the package.

2. USES

Pyfluv was written with stream restoration in mind. Total station surveys can be easily imported and evaluated, and common stream analysis methodologies are already implemented. With this it is possible to create custom reporting programs that can quickly calculate and write out desired parameters with little manual inspection of the data. Additionally, *pyfluv* contains methods that automatically clean and validate imported data, preventing from reporting being done on faulty data. This allows rapid and confident analysis of geomorphic surveys that is repeatable and comprehensible to independent investigators, an important facet of both scientific research and commercial stream restoration projects.

Pyluv can also be used to analyze geomorphic data collected via remote sensing. A number of predictive algorithms help simplify large-scale studies since features such as top of bank elevations and substrate morphology can be extracted without manual inspection of the data. Thus, entire watersheds can be analyzed with only a few lines of code, and without ever leaving the desktop. These algorithms are currently experimental, but they serve to demonstrate the power of algorithmic analysis of geomorphic data in the context of stream restoration.

3. FUTURE WORK AND CONCLUSION

Pyfluv is currently in its pre-alpha release, meaning many new exploratory and experimental features are being added and significant unannounced changes may be made. Thus, *pyfluv* may not be suitable for commercial use at this time. However, a stable beta release is expected within a few months from the time of this writing. Most additions to the codebase center around predictive algorithms intended to facilitate hands-off/no-knowledge analysis of unclassified geomorphic data (primarily remotely sensed), so code not making use of these features can be expected to be somewhat stable.

This package is not intended to be a complete replacement for software and methodologies currently available, and its predictive algorithms are not a replacement for fieldwork. Rather *pyfluv* seeks to provide investigators in the field of stream restoration with another set of tools to augment their analysis of fluvial geomorphology. Practitioners and academics involved in stream restoration are encouraged to pip install pyfluv and experiment with its functionality as any feedback will be taken into consideration by the author.

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SESSION 1C

GIS/MODELS (Moderator: Richard Cochran, TDEC-DWR)
1:30 p.m. – 3:00 p.m.

Configuring Mobile GIS Applications for Field Inventory and Applications
Amanda O'Shea

Development of HEC-HMS Model for the Cane Creek Watershed
Godson Ebenezer Adjovu and Rex Gamble

River Temperature Forecasting for Wheeler Reservoir, Alabama
T. Matthew Boyington

WATER QUALITY (Moderator: Anne Hoos, USGS)
3:30 p.m. – 5:00 p.m.

Drinking Water Quality in Premise Plumbing: Impact of Stagnation
Clifford Swanson and Qiang He

Trends in Addressing Taste and Odor Issues Using PAC-A Case Study Look at Water Treatment in Nashville, TN
Pamela A. Hoover and Janey V. Camp

Collateral Benefits of Air Quality Regulations: Improving Water Quality
Victor L. Roland II, Anne B. Hoos, Richard B. Moore, W. Bryan Milstead, Jesse O. Bash, and Michael D. Woodside

CONFIGURING MOBILE GIS APPLICATIONS FOR FIELD INVENTORY AND APPLICATIONS

Amanda O'Shea[1]

Mobile GIS solutions leverage the latest capabilities in communication as well as database management to streamline field inventory, inspection, and reporting business processes. KCI's information session will outline the steps necessary for creating an application that allows field crews to complete a full suite of data management. The application's functionality would be designed to include such processes as identifying the spatial location of an asset, collecting attribute information, conducting physical inspections, and capturing relevant photos. After field activities are completed and enterprise information is updated as appropriate, the latest data and documentation are accessible via a web application and used for analysis.

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DEVELOPMENT OF HEC-HMS MODEL FOR THE CANE CREEK WATERSHED

Godson Ebenezer Adjovu[1] and Rex Gamble[2]

INTRODUCTION

The Cane Creek Watershed is located in the western part of the City of Cookeville, Tennessee, and is part of the Falling Water River Watershed (HUC 10-0513010807). Cane Creek gathers stormwater and surface runoff from the City of Cookeville and flows south crossing the Interstate I-40 near Exit 283. It reaches Window Cliffs State Natural Area and finally, through a series of Karst features, joins the Falling Water River near Burgess Falls State Natural Area. Local rivers around Cookeville have been shown to frequently flood due to the city's urbanization, endangering the public especially in state parks. Such a situation was exemplified by a flooding in Cummins Falls State Park on August 5, 2017. The flooding event led to the death of two individuals at Cummins Falls and highlights the need to understanding local watersheds and their hydrology (Alund, 2017). Cane Creek runs through Window Cliffs State Parks and discharges near Burgess Falls State Park. It is one of these local watersheds.

The objective of this project is therefore to develop a Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) model for the Cane Creek Watershed in order to understand its watershed hydrology and potentially be used in an early flash flood warning system.

APPROACH

The data needed for the execution of the project were land-use/land-cover data (LULC), digital elevation models (DEM), light detection and ranging (LIDAR), historic precipitation depth data, and soil data. These data were all respectively retrieved from Tennessee Geographic Information System (TNGIS), United States Geological Survey (USGS) National Maps TNM Download, TNGIS again, Weather Underground, and the Soil Survey Geographic Database (SSURGO). Data were preprocessed in ArcMap using HEC-geoHMS. Delineation of the watershed, subbasins, and stream was performed following the HEC-geoHMS User's Manual (2013). Each subbasin used the SCS Curve Number method as the loss method and the SCS Unit Hydrograph method as a transform method. CN value and percent impervious area for the loss method, and lag time in minutes for the transform method and other subbasin parameters were computed following the HEC-geoHMS user's manual. The HEC-HMS model file were subsequently generated in HEC-geoHMS and imported into HEC-HMS. The cumulative area of the watershed was approximately 24.32 square miles.

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Basin Model, Meteorological Model, Control specification and Time series data components were created in HEC-HMS. The subbasins within the Basin Model were populated with parameters obtained from HEC-geoHMS. Each reach used the Muskingum routing method. The parameters required for this were Muskingum K, Muskingum X, and number of subreaches. K represents the travel time through the reach (US Army Corp, 2016). This is estimated using the cross-sectional profiles of the reaches. The X value is the weighing between the inflow and outflow influence. The values of X ranges from 0.1 to 0.5 inclusive. A value of 0 results in maximum attenuation and 0.5 results in no attenuation (US Army Corps HEC-HMS user's Manual, 2016). A mid-value of 0.2 was used. The number of subreaches was computed using equation (1) HEC-HMS User's Manual (2016) and equation (2) Murty, (2018) written below.

$$\text{Number of subreaches} = \frac{Reach\ Length(L)}{CelerityxTime-step} \quad (1)$$

$$\text{Celerity} = \sqrt{gy} \quad (2)$$

Where g is the acceleration due to gravity and y is the depth of water in the reach.

For the Meteorological Model, Rainfall data was obtained from Weather Underground (2018) using four working stations close to the Cane Creek Watershed. These stations were: KTNCOOKE24, KTNCOOKE12, KTNCOOKE42, and KTNSPART4. Each precipitation event used 30 minutes intervals recording cumulative depth. The rain events recorded were October 23rd, 2017, May 31st, 2018, June 26th, 2018, and July 21st, 2018, since these events represent high, medium and low flows. Control specification time was set to 00:00 on the day the storm event started until several days after the storm event. The step-time used was 20 minutes, which was the largest time interval possible while maintaining the step-time had to be less than the smallest Muskingum K value as specified by HEC-HMS when running the model *Figure 1* shows Cane Creek Watershed with eleven subbasins, five reaches, five junctions and an outlet.

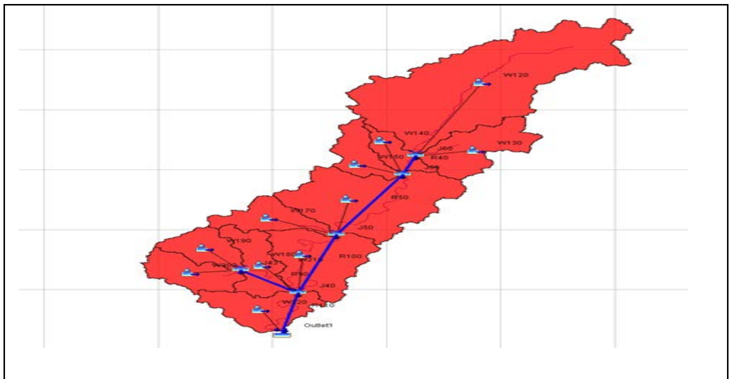

Figure 1: Cane Creek watershed in HEC-HMS

To calibrate and validate the model, observed data is needed. Depth data in combination with cross-sectional data were recorded at Window Cliffs State Park Creek Crossing 1 (CC1). This data was transformed into discharge through NRCS Cross-Section Hydraulic Analyzer (2011). These discharge data served as observation data for calibration and validation. The discharge data were input into discharge gages in the Time-Series component of the HEC-HMS. Model calibration was done by using the Automatic, numerical parameter optimization approach since it is quicker and almost everything was done by HEC-HMS.

RESULTS AND DISCUSSION

Runoff hydrographs of the uncalibrated model for all four rain events analyzed are attached in *Figure 2*. From a visual inspection it appears the peak flows of the model are near the observed flows, but the time-to-peak are variable. Calibration was done by using rainfall events for October 23rd, 2017, and June 27th, 2018. The optimized function for October 23rd, 2017, was used to validate the May 31st, 2018 and July 21st, 2018 events. Results for the calibration and validation model is shown *Figure 3*. A statistical analysis of the data was performed employing the Nash–Sutcliffe Efficiency (NSE), Root Mean Square Error (RMSE), Percent Bias (PBIAS), Coefficient of determination (R^2), and Ratio of the RMSE to Standard Deviation (RSR) as the statistical methods using their respective equations as presented in Moriasi et al (2007).

Simulations were made for different storm events with different recurrence intervals using Type II SCS storms and precipitation design storm depth from National Oceanic and Atmospheric Administration (NOAA) Precipitation Frequency Data Server (PFDS) (2017). Depths for 10-yr, 50-yr, 100-yr, and 500-yr 24-hr design storms were 5.10-in, 6.68-in, 7.39-in, and 9.14-in respectively. The runoff hydrographs for 10-yr, 50-yr, 100-yr, and 500-yr design storms were calculated using the calibrated and validated models. Peak flows for each respective event were 2538-cfs, 3942-cfs, 4744-cfs, and 6285-cfs.

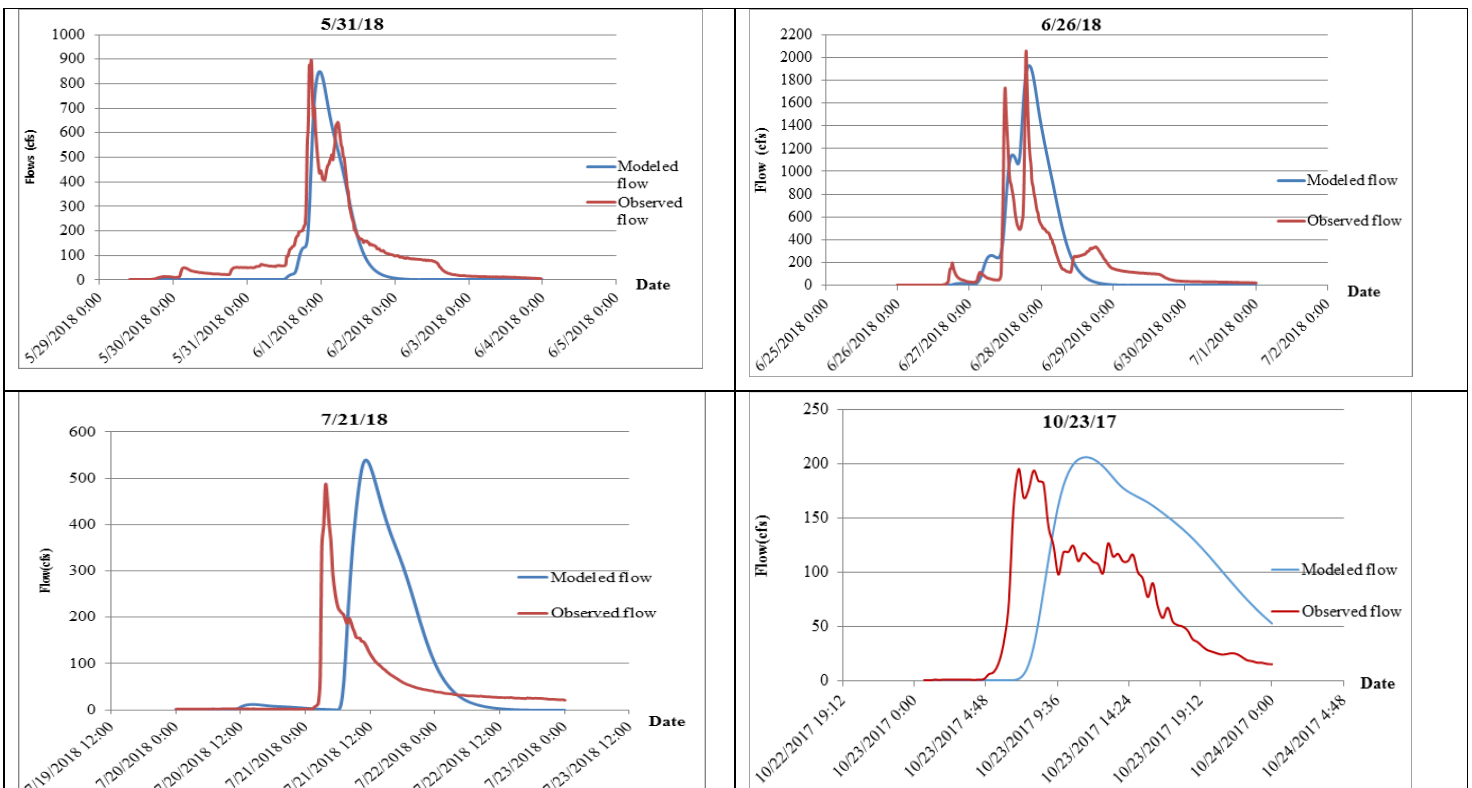

Figure 2: Uncalibrated Model Runoff Hydrograph

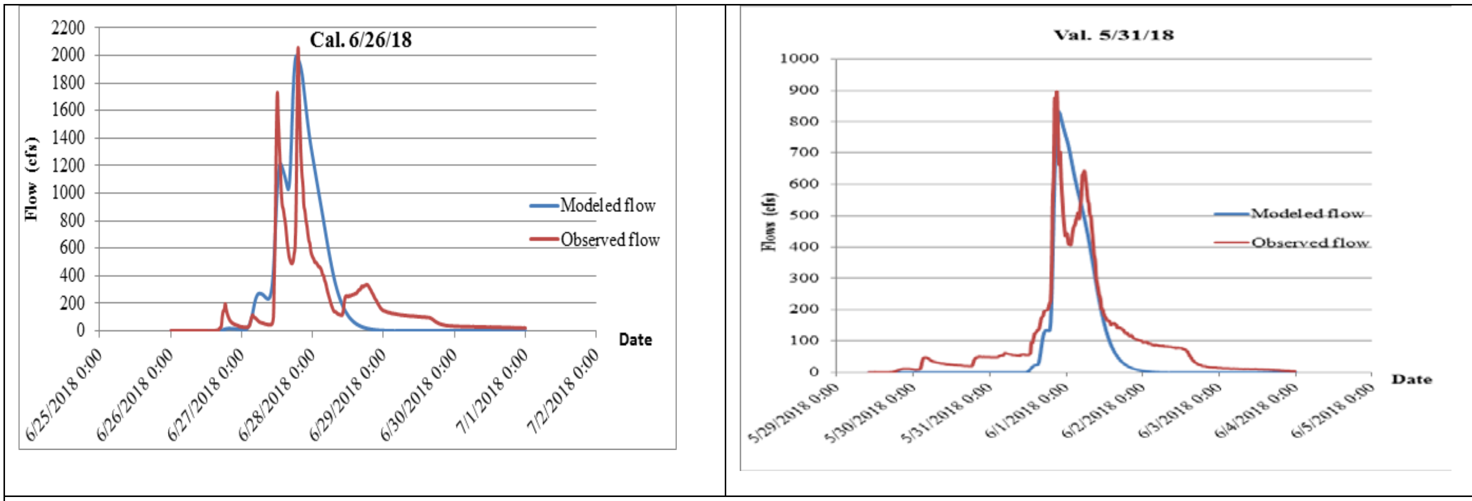

Figure 3: Calibrated (L) and Validated (R) Model Runoff Hydrograph

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RIVER TEMPERATURE FORECASTING FOR WHEELER RESERVOIR, ALABAMA

T. Matthew Boyington[1]

As part of the ongoing effort to maintain the aquatic habitats of the Tennessee River, the Tennessee Valley Authority (TVA) actively monitors and manages the thermal discharge from its power plants. A key element in the management of reservoir temperatures has been the development and application of numerical river models. These tools assist in the optimization of cooling equipment, operation of power plants, and scheduling the river in order to maintain downstream thermal compliance. As part of a multi-year project, TVA River Management has transitioned from an internally developed, one-dimensional hydraulic model to a coupled model framework that includes a three-dimensional hydrodynamic model (Delft3D). This presentation will describe the new system along with the benefits of using a three-dimensional river model in the management of river temperatures for Wheeler Reservoir, Alabama.

[1] Tennessee Valley Authority

DRINKING WATER QUALITY IN PREMISE PLUMBING: IMPACT OF STAGNATION

Clifford Swanson[1]* and Qiang He[1]

The supply of clean drinking water is a major, and relatively recent, public health milestone. While finished water produced by water utilities is required to meet stringent drinking water quality standards, substantial changes can occur to finished water during its delivery from a centralized treatment plant to consumers' taps. It is thus important to control microbial contamination in distribution systems, particularly in premise plumbing, which is characterized by longer residence times, more stagnation, lower flow conditions, and elevated temperatures compared to the main distribution system. The aim of this study was focused on the microbiological quality of drinking water in premise plumbing after prolonged stagnation. Several premise plumbing sites in commercial and residential buildings were monitored for up to a year with various water quality parameters, including chlorine residue, pH, TOC, and heterotrophic plate count. Samples were collected with various extent of stagnation at these locations in order to determine the impact of stagnation on water quality and microbial contamination. The results of this study confirmed that a major impact on water quality from stagnation was the decay of residual chlorine, leading to complete loss of chlorine residua in scenarios of prolonged stagnation. The levels of microbial contamination increased significantly as the premise plumbing system became more stagnant, increasing by more than 250% and even as high as 6,000%. While the level of microbial contamination differed considerably between locations, significant increases in microbiological contamination were observed at all sampling sites when prolonged stagnation occurred. Ongoing efforts are focusing on the identification of microbial populations that positively responded to stagnation in order for further assessment of public health risks.

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TRENDS IN ADDRESSING TASTE AND ODOR ISSUES USING PAC - A CASE STUDY LOOK AT WATER TREATMENT IN NASHVILLE, TN

Pamela A. Hoover, P.E.[1]* and Janey V. Camp, Ph.D., P.E., GISP, CFM[2]

Source water availability and quality for municipal drinking water is impacted by weather conditions, resulting in impacts on water treatment plant (WTP) processes. The impacts can be physical/chemical in the plant and distribution system. Ultimately, the use of chemicals is dependent on intake water parameters. The infrastructure and processes utilized are typically based upon norms and historic information. In today's world, it has become imperative to evaluate conditions outside the ranges, or on the edges, of historical data. To sustain a robust water treatment system for public health and quality of life, WTPs are faced with the challenge of planning for a wide range of weather conditions and implementing appropriate response. Further research on the relationship between source water quality, weather parameters, and water treatment is necessary to help predict and prepare for future infrastructure and supply chain needs. An example can be found in the use of powdered activated carbon (PAC) usage to treat taste and odors. Although taste and odors are not health concerns, they are the cause of complaints to WTPs and, also, are an indicator of water health issues for the public. We will present the results of an analysis of 10-years of local and plant-specific data to describe and quantify relationships between water quality, weather conditions, and PAC usage. The Nashville Omohundro WTP is used as a case study. The findings of this analysis are intended to inform future development of models to help predict chemical needs and improve decision support for WTP operators.

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COLLATERAL BENEFITS OF AIR QUALITY REGULATIONS: IMPROVING WATER QUALITY

Victor L. Roland II[1], Anne B. Hoos, Richard B. Moore, W. Bryan Milstead, Jesse O. Bash, and Michael D. Woodside

The SPAtially Referenced Regression on Watershed attributes (SPARROW) model was used to create two static simulations of total nitrogen (N) transport in surface-water bodies located in the United States: one using 2002 (baseline) levels of atmospheric N deposition, and the other using projected atmospheric N deposition for the year 2025. We show that a decrease in atmospheric levels of oxidized N anticipated from implementing air-quality regulations through 2025 could potentially reduce transport and delivery of N in streams by more than 10 percent (compared to 2002 levels), in 82 percent of lakes, and 30 percent of Eastern estuaries. Stream N levels were projected to decrease by 20-30 percent in the Northeast and by less than 20 percent for streams in the Southeast and mid-Atlantic. Large decreases (>=20 percent) in lake N loading were projected for most Northeastern lakes when compared to more moderate improvements (<20 percent) for most lakes in the South. In many North Atlantic, South Atlantic, and Gulf of Mexico estuaries, N loading was projected to decrease by more than 20 percent, but less than 10 percent for most mid-Atlantic estuaries. Changes in ecosystem health were evaluated by translating projected decreases in stream and lake N loading to projected shifts in the trophic state of a sample of modeled lakes. Six percent of lakes in the eastern U.S. were projected to have a change in trophic state. The results of our study provide evidence that improved water quality is a potential collateral benefit of air quality regulations.

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SESSION 2A

STREAM RESTORATION/MITIGATION **(Moderator: Angel Fowler, Mitigation Management)**
8:30 a.m. – 10:00 a.m.

An Overview of the Cumberland River Compact and Its In-Lieu Fee Program
Jacob Byers and Mekayle Houghton

Evaluating Fish Trait Responses to Channel Construction in Valley-Plugged Streams: Merging Hydrogeomorphic Design with Ecological Theory
Jeffrey D. Fore, Amy B. Alford, David C. Blackwood, and Tom A. Blanchard

Mud Creek Stream Mitigation Bank
Nick Carmean and Alec Sheaff

STORMWATER **(Moderator: Paul Davis, P.E.)**
10:30 a.m. – 12:00 p.m.

Introducing a Centralized Guidance Resource for Stormwater Best Management Practices Performance Evaluations
Mark Miller

Metro Nashville's Evolving Stormwater Control Measure (SCM) Program and the Importance of Post-Construction Maintenance
Kalee Hotchkiss

Persistence of Environmental E. coli *Strains from Stormwater Runoff*
Songyi Liu and Qiang He

STORMWATER/WATER QUALITY **(Moderator: Alfred Kalyanapu, TTU)**
1:30 p.m. – 3:00 p.m.

A Review of Wet Weather Sampling in Metro Nashville
Mary Bruce

Design Implications of Findings from a Nashville-Area Bioretention Field Survey
A. Ludwig, B. Curry, J. Hayes, and R. Dohne

Accreditation of the Water Quality Core Facility, University of Tennessee, Knoxville
Adrian Gonzalez, Chris Cox, John Schwartz, and Matt Kulp

STAKEHOLDER PARTNERSHIPS **(Moderator: Regan McGahen, TDEC-DWR)**
3:30 p.m. – 5:00 p.m.

The Importance of Community Partnerships: How to Build Public Education into Research Grants
Sarah Woolley Houston

The 4-H Water Project (You'll Wish You Were a Kid Again!)
Lena Beth Reynolds

Citizen Scientist Participation in Flood Study, Johnson City, TN
Ingrid Luffman, Daniel Connors, Timothy Muncy, and Chelsie Perkins

AN OVERVIEW OF THE CUMBERLAND RIVER COMPACT AND ITS IN-LIEU FEE PROGRAM

Jacob Byers, P.E.[1], Mekayle Houghton[2]

INTRODUCTION

The Cumberland River Compact (CRC), established in 1998, is a 501(c)(3) nonprofit organization with the mission of enhancing the health and enjoyment of the Cumberland River and its tributaries through education, collaboration and action. The Cumberland River Basin (CRB) is one of the top three most biodiverse regions in the world encompassing both rural and highly urbanized landscapes. Over three million people and thousands of species depend on the clean and abundant water from the Cumberland River Basin. The CRC focuses on education and conservation by partnering with advocacy groups promoting sustainability and green infrastructure.

In February 2018, CRC gained approval from the USACE for the CRB In-Lieu Fee Program. This program is being used to satisfy compensatory mitigation requirements for permits issued under Section 404 and 401 of the Clean Water Act, within the Tennessee portion of the CRB. Program Objectives include:

- Implement effective stream mitigation projects to compensate for the loss of ecological functions affected by permitted activities;
- Provide a watershed-level alternative to permittee-responsible mitigation;
- Meet the current and expected mitigation credit demand in the service area; and
- Provide a mechanism and source of revenue for stream restoration projects in the CRB in Tennessee.

The CRC has sold approximately 10,000 credits (as of early 2019) and is moving restoration projects through the approval process. Projects include the Sam Davis Memorial Home Dam Removal Project, and the Warner Park and Stephens Valley Stream Restoration Projects.

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EVALUATING FISH TRAIT RESPONSES TO CHANNEL CONSTRUCTION IN VALLEY-PLUGGED STREAMS: MERGING HYDROGEOMORPHIC DESIGN WITH ECOLOGICAL THEORY

Jeffrey D. Fore[1], **Amy B. Alford[2*]**, David C. Blackwood[2], and Tom A. Blanchard[3]

Valley plugs are a consequence of legacy stream channelization in West Tennessee wherein localized stream aggradation has resulted in reduced stream power and sand-clogged channels. To alleviate flooding and land use conflicts associated with valley plugs, the West Tennessee River Basin Authority began restoring valley-plugged downstream reaches of Obion, Hatchie, and Forked Deer River system tributaries in 2013 via channel construction. Whereas hydrogeomorphic objectives appear to have been met, uncertainties surrounding ecological benefits of stream restoration globally motivated a cross-collaboration between engineers and ecologists to improve future channel construction in West Tennessee. Fish trait responses to in-stream habitat conditions were monitored in channelized, recently restored, and reference stream reaches. Interestingly, in-stream habitat in newly constructed reaches most similarly resembled their upstream, channelized counterparts compared to reference reaches. These similarities were reflected in fish trait-habitat organization. Restored reaches were ecologically similar to channelized reaches, having higher proportions of individuals such as nest-guarding omnivores associated with poorer quality in-stream habitat conditions whereas reference reaches had higher proportions of fast-water dwelling, pollution intolerant, specialized insectivores. Organization of fish traits along in-stream habitat gradients appears to be driven by lower width:depth ratios used during the restoration process that likely promoted the formation pool habitats in restored reaches. These observations provide a foundation for testable hypotheses regarding how manipulations of width:depth ratios and channel slope may improve in-stream habitat conditions while meeting hydrogeomorphic objectives. This research highlights the progress of improving restoration science that can be made by incorporating ecological theory in channel construction design.

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MUD CREEK STREAM MITIGATION BANK

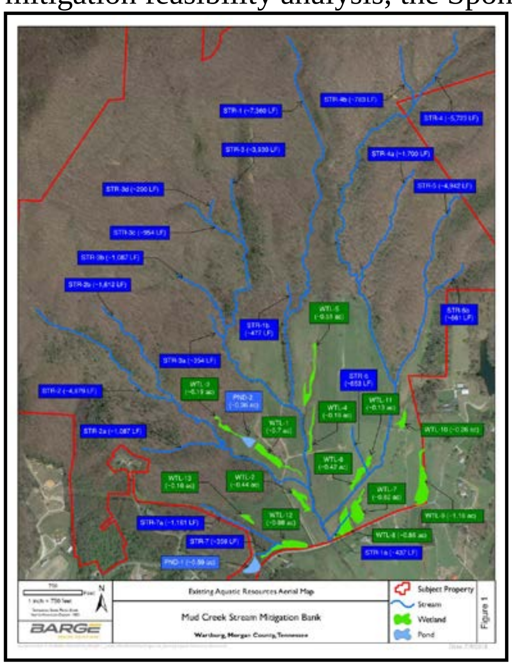
Nick Carmean[1] and Alec Sheaff[2]

INTRODUCTION

The lack of available stream mitigation credits in Tennessee has limited both private developers as well as public entities in the completion of desired construction projects. The Tennessee Department of Transportation (TDOT) has been specifically hampered as the majority of its projects impact stream features. These impacts commonly exceed the Tennessee Department of Environment and Conservation's (TDEC) General Aquatic Resource Alteration Permit (ARAP) limitations and require TDOT to comply with an Individual ARAP and its mitigation language. With few mitigation options available, the installation of transportation improvement projects has been slowed.

PROJECT OVERVIEW

Barge Design Solutions (Barge) and Resource Environmental Solutions (RES) teamed up on proposing to establish a stream mitigation bank on a 960-acre agricultural parcel of property near Wartburg, Morgan County, TN to help mitigate for TDOT's unavoidable impacts to streams in the Emory River watershed. The Bank site will incorporate approximately 6.9 miles (36,234 LF) of headwater ephemeral, intermittent and perennial stream channels along the main channel and several unnamed tributaries to Mud Creek. The project was evaluated using the State's new stream mitigation guidelines and Stream Quantification Tool (SQT). Based on a preliminary mitigation feasibility analysis, the Sponsor estimates that the stream re-establishment, restoration, preservation, and riparian buffer enhancement measures necessary to restore the ecological function of the aquatic resources on this site will generate approximately 20,607 stream mitigation credits. The site is currently used for agricultural purposes which includes beef cattle operations and hay production. Due to these land use practices, on-site streams have experienced severe degradation, loss of bedform diversity, loss of riparian buffers, and direct livestock access to stream channels. In addition to the agricultural impacts, there is also evidence (old logging roads, spoil piles, etc.) that the site was logged in the past, which has degraded the streams in the forested area of the proposed Bank site. Streams chosen for restoration are characterized by bank erosion, loss of floodplain connection, loss of riparian area, and general instability caused by ongoing channel evolution.



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SITE INVESTIGATION

Barge performed a wetland delineation on the subject property which followed the United States Army Corps of Engineers (USACE) Wetlands Delineation Manual (1987), as well as the regional supplement for the Eastern Mountain and Piedmont Region (2012). In addition, streams were characterized by the Regulatory Guidance Letter No. 05-05 (2005) and TDECs Guidance for Making Hydrologic Determinations (2011). During this investigation, thirteen (13) wetlands and seven (7) streams, and their unnamed tributaries were identified.

In addition, Barge performed a Phase I Environmental Site Assessment in conformance with the scope and limitations of ASTM Standard Practice E2247-16, of the subject property.

MITIGATION APPROACH

Restoration of the main channel and unnamed tributaries to Mud Creek will consist of establishing natural channel dimensions, patterns, and profiles that will promote a more defined meandering channel with proper pool-to-pool spacing and natural riffle-pool and step-pool sequences. The proposed mitigation approach will reconnect the stream reaches to a more functional floodplain, restore natural channel geomorphology (dimension, pattern, profile), restore natural velocities, improve sediment transport, and reduce stream bank erosion. In-stream structures (i.e. wood and rock) will be introduced to increase lateral stability, aquatic habitat, and grade control. Increasing re-oxygenation zones, reducing sediment input, and providing shade will improve the overall water quality of the stream reaches. The natural hydrology of the project area will be restored by removing existing culverts and impoundments along applicable reaches, and also by relocating the channels that have been relocated for agricultural purposes back to their relic floodplains. In the areas where impoundment removal is proposed, aquatic species will have access to move freely throughout the system and reclaim the biological integrity of the watershed. Defined channels with a properly sized bed and bank will be established where livestock grazing has destroyed the existing channel structure and form. Native riparian zones will provide shade, nutrient filtration, and wildlife habitat, and will be established throughout all reaches of the project. Livestock exclusion fences will also be installed throughout all project reaches to reduce nonpoint source pollution. All of the aforementioned measures will restore and protect the entire headwater system of Mud Creek, producing water quality and ecological benefits that extend to the downstream receiving service area.

INTRODUCING A CENTRALIZED GUIDANCE RESOURCE FOR STORMWATER BEST MANAGEMENT PRACTICES PERFORMANCE EVALUATIONS

Mark Miller[1]

The Interstate Technology and Regulatory Council (ITRC), a subcommittee of the Environmental Council of States (ECOS), recently published a web-based and centralized resource for information on post-construction stormwater BMP effectiveness (water quality treatment). Comprehensive guidance is provided on how to use and implement that information. The guidance document, a BMP screening tool, and four short "explainer videos" are available at https://stormwater-1.itrcweb.org/. This presentation explains the framework and objectives of the guidance document to assist stakeholders with BMP lifecycle processes including:

- Screening,
- Selection,
- Installation,
- Operation,
- Monitoring, and
- Maintenance.

National verification programs and public domain data repositories are featured to provide reliable, vetted data sources to the user for evaluating their BMP needs. The document provides applicable lifecycle considerations including contracting and generalized qualitative costs. Installation factors are detailed from construction challenges to inspection checklists, quality control factors and record drawings. It goes on to address long-term technology- and performance-based operational strategies, including aspects such as routine and non-routine maintenance. Data and information from existing publicly available BMP performance programs has been incorporated into an online BMP Screening Tool. Using site-specific pollutant treatment requirements and installation considerations, the screening Tool can assist the user by narrowing BMP options to a list that is appropriate for a given set of site conditions. The Tool also provides users with summarized information on the treatment efficiencies, installation requirements and maintenance issues regarding the identified BMPs, with links that connect the user with detailed data and fast links to information from across the nation.

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METRO NASHVILLE'S EVOLVING STORMWATER CONTROL MEASURE (SCM) PROGRAM AND THE IMPORTANCE OF POST-CONSTRUCTION MAINTENANCE

Kalee Hotchkiss[1]

Metro Water Services in Nashville, TN has almost **5000** stormwater control measures (SCMs) currently installed and are adding 30-40 new SCMs each month. Over **1900** of these SCMS are located within 303(d) listed watersheds. Nashville had previously depended on owner-submitted inspections, but, due to incomplete/inaccurate reports, variable enforcement results, and low ownership participation awareness, efforts have been reallocated to develop a more comprehensive oversight program. While owner-submitted reports are still required, Metro Nashville has dedicated more resources for MS4 employees to do post construction inspections and follow up coordination with owners on their inspections and maintenance responsibilities regarding SCMs.

The post construction SCM program outlines the importance of the property owners' responsibilities to maintain the stormwater control measure annually to help ensure functionality of these systems and a maintenance plan is being followed. Different types of structures have various maintenance needs which need to be identified for long term or short term maintenance planning. Since our post construction SCM program began, we have successfully seen 344 individual SCMs restored, which improves functionality in these systems and helps prevents pollution from directly impacting our stormwater systems. By using our comprehensive program to the fullest benefit, we are able to strengthen the health of our water ways, increase public education, and also build a relationship with our community.

Key Words: stormwater control measures, inspections, Metro Water Services, maintenance

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PERSISTENCE OF ENVIRONMENTAL *E. COLI* STRAINS FROM STORMWATER RUNOFF

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Escherichia coli has been used as an indicator for fecal contamination, based on the assumption that *E. coli* could not survive for a prolonged period of time once discharged into the environment. Therefore, the presence of live *E. coli* would be indicative of recent fecal contamination. However, it has recently been reported that *E. coli* populations were found in environments with no recent exposure to fecal materials, suggesting the capability of certain *E. coli* populations to survive for a prolonged period of time in the environment. The objective of this study was to evaluate the survival of three *E. coli* strains isolated from stormwater runoff under environmentally relevant conditions. One laboratory *E. coli* strain (MG1655) was tested as a control. The *E. coli* strains were exposed to four environmental factors: (i) presence or absence of sunlight; (ii) solid surface versus liquid media for growth; (iii) different temperatures, including 4 ℃, 20 ℃, and 35 ℃; (iv) different levels of relative humidity, i.e. 13%, 50%, and 100%. All environmental strains isolated from stormwater runoff persisted for a longer period of time than the lab strain under all environmental conditions tested. As expected, all *E. coli* strains survived longer at lower temperature. On the solid surface, the lab strain completely lost viability in less than 3 hours at the relative humidity of 13% or 50%. In comparison, the environmental strains were able to remain viable for a prolonged period with the maximum T_{90} of 6 days, which could be attributable to the persistence of these strains in natural environments. Additionally, it was found that sunlight exposure resulted in the rapid inactivation of all strains tested in this study. Findings from this study could provide insight into the interpretation of environmental monitoring data using *E. coli* as the fecal indicator.

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A REVIEW OF WET WEATHER SAMPLING IN METRO NASHVILLE

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Wet weather sampling has been a component of Metro's NPDES monitoring program since the late 90's. The most recent sampling protocol focused on differences between runoff samples from varying land use classifications. Sites were categorized as residential, commercial, industrial, transportation or open space. During each event, 2 samples were collected: first flush grab and a 1-hour grab. This was different than in previous years when samples were collected from 3 designated outfalls with mixed land uses. These samples consisted of a first flush sample and a 3 hour flow-weighted composite sample. Logistically, wet weather samples can be very difficult to obtain and many hours of monitoring weather are involved. In many instances, potential rain events do not qualify for sampling (too little rain) or the anticipated rain does not occur at all. Additionally, differences in storm events and length of time between rain events increases variability of the sampling data such that there are limited or no trends that can be gathered from the data. This presentation analyses Metro's wet weather sampling dataset and additionally compares it to the National Urban Runoff Program (NURP) study that was conducted in the early '80s.

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DESIGN IMPLICATIONS OF FINDINGS FROM A NASHVILLE-AREA BIORETENTION FIELD SURVEY

A. Ludwig[1], B. Curry, J. Hayes, and R. Dohne

Bioretention practice failures have led to costly renovations and repairs in Tennessee cities, creating uncertainty in the future of these practices as part of effective green infrastructure systems for stormwater runoff management. Modifications, such as using river rock surface cover in place of a plant-based mulch cover and minimizing species diversity of plantings, have been implemented by designers and practice owners in an attempt to limit potential for maintenance-related failures. A field survey of fifty-two bioretention practices was conducted in Davidson County, Tennessee, to determine functional status and common failures in order to support maintenance recommendations for property owners and municipal governments. Specific research questions included: 1) Does surface cover affect media bulk density? 2) What is the organic matter content in bioretention media and does it change with practice age? 3) Does media bulk density affect plant canopy establishment? 4) What plants are successful? and 5) What conclusions can be drawn regarding media characteristics related to practice maturation and what maintenance recommendations can be made to address common failures. A suite of site conditions were documented in the field, such as practice dimensions, signs of erosion, and dominant surface cover. A 1-foot soil core was collected from the surface of the engineered media layer for analyses of loss on ignition (e.g., organic matter content) and bulk density. Dominant plant species present were photographed and identified. A digital mobile device application was used to measure plant canopy percentage. Results indicate that media bulk density under rock surface cover was significantly higher than that under plant-based mulch cover ($p<0.01$); that media bulk density levels known to affect plant establishment in sandy loams ($p> 1.6$) were reached at a faster rate in rock covered applications as compared to plant-based mulch applications; that media bulk density was consistently above 1.6 g/cm^3 when organic matter content was below 4%; that plant canopy never surpassed 60% in practices with bulk densities above 1.55 g/cm^3; and that organic matter content below 4% was recorded in practices five years old and older. These results suggest that consideration should be made regarding the tradeoff between ease of maintenance with rock coverings and potential for plant establishment impacts. A suite of maintenance recommendations and plant replacement suggestions were created based on these findings. This presentation will share a summary of the status of the practices involved in the survey and detailed maintenance recommendations resulting from this work.

Key words: bioretention monitoring, maintenance implications, stormwater

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ACCREDITATION OF THE WATER QUALITY CORE FACILITY, UNIVERSITY OF TENNESSEE, KNOXVILLE

Adrian Gonzalez[1]*, Chris Cox[1], John Schwartz[1], and Matt Kulp[2]

Data quality (DQ) has always been a critical topic for environmental professionals and regulators. USEPA and USGS, and state agencies, have worked hard to define, and establish consistent methods for evaluating, DQ. In 1995, USEPA established the National Environmental Laboratory Accreditation Conference (NELAC) to address inconsistencies in DQ approaches in existence. In 2006, the NELAC Institute (TNI) was chartered to further advance environmental DQ. The UTK's Civil and Environmental Engineering (CEE) Department has been providing water analysis services to the Great Smoky Mountains National Park (GRSM) water quality monitoring program since the early 1990s. On 11 January 2018, the US DOI issued a policy requiring programs under its jurisdiction generate water quality data using accredited labs. Thus, research-level DQ is no longer acceptable to GRSM and other IMD participants. In response, the UTK CEE "volunteered" to seek accreditation to the current 2016 TNI Standard, and created the Water Quality Core Facility (WQCF) in April 2018 to house the accredited water quality lab. Lab director and technical manager positions were filled in May, newly renovated lab space was acquired in August, and the WQCF lab was fully furnished, supplied and operational within 6 weeks. Multiple activities have been proceeding in parallel: continued analysis of monitoring samples, recruitment of new clients, relocation and requalification of instruments, learning the 2016 TNI Standard's requirements, quality management plan and SOPs drafted and validated, analytical methods optimized and validated, and Proficiency Test (PT) studies initiated. Details of activities in progress toward accreditation will be presented.

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THE IMPORTANCE OF COMMUNITY PARTNERSHIPS: HOW TO BUILD PUBLIC EDUCATION INTO RESEARCH GRANTS

Sarah Woolley Houston

INTRODUCTION

Applied research plays an important role for policymakers to make informed decisions and improve current community conditions. This presentation addresses how researchers can increase the likelihood that research outcomes and recommendations are utilized by decision makers. Memphis, Tennessee lies with the Mississippi embayment aquifer system, a complex system that deserves thorough research and sensible management. From 2016-2018, a high-profile contamination site came to light and instilled "fear is that those toxins could permeate the Memphis Aquifer" (Arnold, 2018). The water quality issues spurred greater interest in addressing the integrity of the upper Claiborne confining unit (UCCU) which overlies the Memphis aquifer, the primary drinking water source for Shelby County, Tennessee. After an initial study, it was determined that there was an inter-aquifer water exchange near an old coal power plant that increases the likelihood of arsenic and lead contamination of the Memphis aquifer (Carmichael *et al.*, 2018). This set the stage to further characterize the UCCU through a multi-year research study. The Center for Applied Earth Science and Engineering Research (CAESER) at the University of Memphis, under the Herff College of Engineering, was awarded $1 million per year over the next five years to conduct research to identify and characterize breaches within the Memphis Light, Gas and Water (MLGW) service area and their impact on the Memphis aquifer. This grant is funded through a 1.05% water rate increase, approved by the Memphis City Council and MLGW Board.

APPROACH

Community awareness of contamination threats to the Memphis aquifer were heightened during this time. By utilizing the crisis and increased awareness of water issues, CAESER leveraged previously established relationships to persuade Memphis decision makers that the public had a vested interest in the long-term sustainability of the Memphis aquifer and were willing to pay for the research.

Working with partners at Protect Our Aquifer, Sierra Club, and others, allowed for a communal approach to educating Memphis city council members to pass the water rate increase. Including education and outreach in the scope of work to the grant proposal positions us to continue educating city council members, partner organizations and the general public so they understand the findings of our research efforts. This in turn, could result to continued funding on aquifer research and utilization of the findings for informed decision making.

RESULTS & DISCUSSION

CAESER included an education program in the deliverables of the contract to fill a major gap in how the public is informed and to work with elected officials and decision makers that will act on the information we will be producing. Before arriving at this step, CAESER had cultivate community relationships for years. Before education is built into grants, researchers can begin developing a set of best practices to disseminate scientific knowledge to broad, multi-generational audiences to advance efforts towards grant acceptance.

First, take the time to identify advocates and partners in the community. While these groups and individuals may seem inflammatory, identifying professionals that have aligned missions can prove to be advocates for your findings when advocacy is not part of our work. After partners have been identified, reach out to them, but confirm boundaries and a clear understanding of the information you can offer. Keep these contacts fresh with monthly emails.

Second, gather useful graphics and resources, then build out fact sheets that can serve as worthwhile responses when community members and advocacy groups reach out for information. This will encourage consistent messaging, and reduce time needed to answer back thoughtfully.

Third, identify what type of communication and education is necessary for your research grant proposal. Do you need to engage in capacity building? This will take a larger effort to build skills and informed citizens. Is this purely informative? This can be taken as one-way communication, purely delivering the facts. We have taken an approach to build capacity through stakeholder engagement, using the aforementioned graphics and resources, but also hosting two public forums per year. This allows for two-way communication and a formal learning opportunity (Water Outreach Self-Assessment).

Finally, hire outside your comfort zone. As funds become available, look for candidates that have a passion for communication and community involvement. While the science background is important for disseminating the correct information, the aforementioned skillset with prove crucial in building relationships and formalizing decisions and improve current community conditions.

By including public education in your research grants, you will position yourself to demonstrate how individual citizens can make a marked difference in water conservation and sustainability.

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Keywords:

1. Management Issues
2. Water Supply
3. Public Forum
4. Education
5. Partnership
6. Research funding

THE 4-H WATER PROJECT
(YOU'LL WISH YOU WERE A KID AGAIN!)

Lena Beth Reynolds

4-H Club members study and compete in subject matter "projects". Because everyone is affected by water, a curriculum is being developed to teach information about water to young people in 5^{th} – 12^{th} grades. Members may learn in classroom settings or by individual study, with an organized curriculum and established goals of accomplishment.

Project Outcomes were written to organize topics with the Beginner, Intermediate, and Advanced levels of study, containing concepts to understand, and activities to master. Project Lessons and Activities are now flowing through the approval process in the Institute for Agriculture on topics such as Watersheds, Surface Water, Groundwater, Wetlands, Water Cycle, Water Use & Conservation, and Water in the News. Twenty-nine agencies, organizations, and universities consented for TN 4-H to use their materials, with proper credit given.

Lesson plans have been piloted in 4-H Clubs in McMinn County, TN for three school years. 4-H members were asked to evaluate their knowledge level of five topics before the lesson, and after the lesson. With several open-ended questions, they could fill in what else they would like to learn, whether they have internet access at home, and suggestions far improvement.
The Search is underway to locate sponsors to underwrite the costs of 4-H junior high members learning about water during the summer at Academic Conference at UT-Knoxville, and high school students at 4-H Round-up. Will you and your organization be a sponsor?

CITIZEN SCIENTIST PARTICIPATION IN FLOOD STUDY, JOHNSON CITY, TN

Ingrid Luffman[1]*, Daniel Connors[2], Timothy Muncy[3], and Chelsie Perkins[3]

Johnson City, TN has an extended history of flooding in its downtown core, due to development along the margins of Brush Creek, a 20 mile long stream that flows through and underneath the city. Recent downtown redevelopment of two land parcels has created new city parks that mitigate flooding through floodwater storage, additional channel capacity, and reduced impervious surfaces that reduce runoff and encourage infiltration. Community buy-in for efforts to control flooding is important, and a citizen science project was developed in collaboration with East Tennessee State University (ETSU), the City of Johnson City, and the Boone Watershed Partnership to increase public awareness and collect stream stage data along Brush Creek. Citizen science projects such as this are an increasingly popular tool to collect scientific data, involve the community in scientific research, and provide information and education about an important issue (Buytaert et al. 2014; Kosmala et al. 2016). The use of citizen scientists in hydrology has generally been limited to measurement of water quality parameters (Buytaert et al. 2014, Little et al. 2016) although new applications of social media and Apps show promise (Robson, 2012). In this project, citizens read the water level from a staff gauge installed under a bridge abutment in one of the parks, and contribute the data via text message (Figure 1).

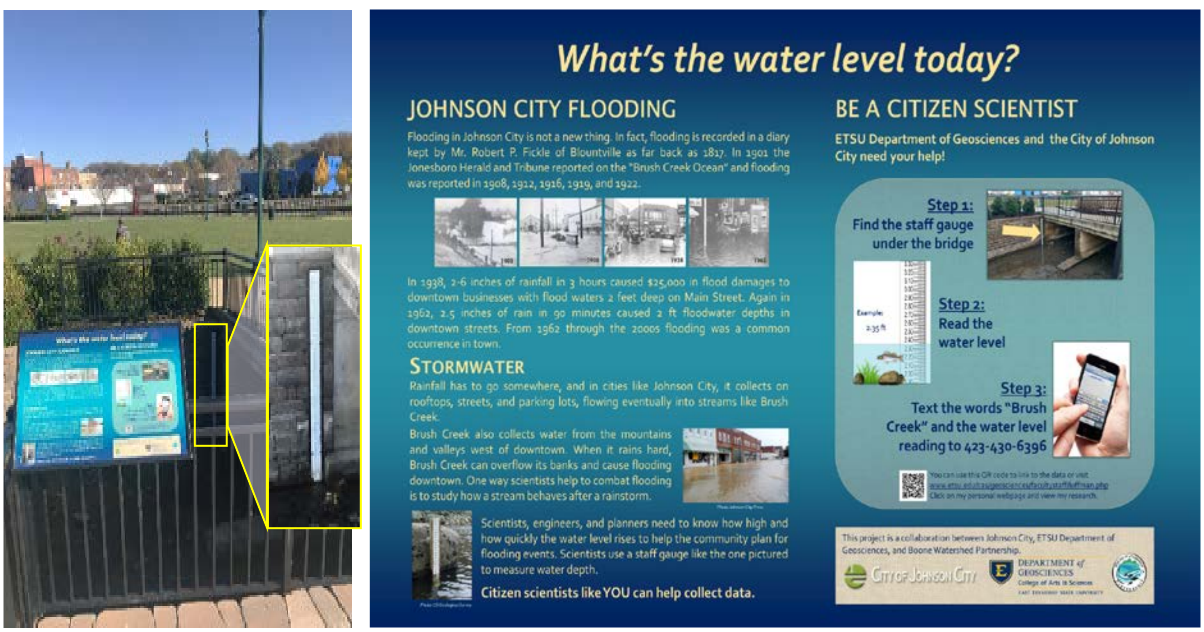

Figure 1. Brush Creek Citizen Science project field setup.

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DATA PROCESSING

Contributed stage data are parsed, written to a database, and merged with local precipitation data using the message timestamp. Python scripts automate the process using the workflow presented in Figure 2.

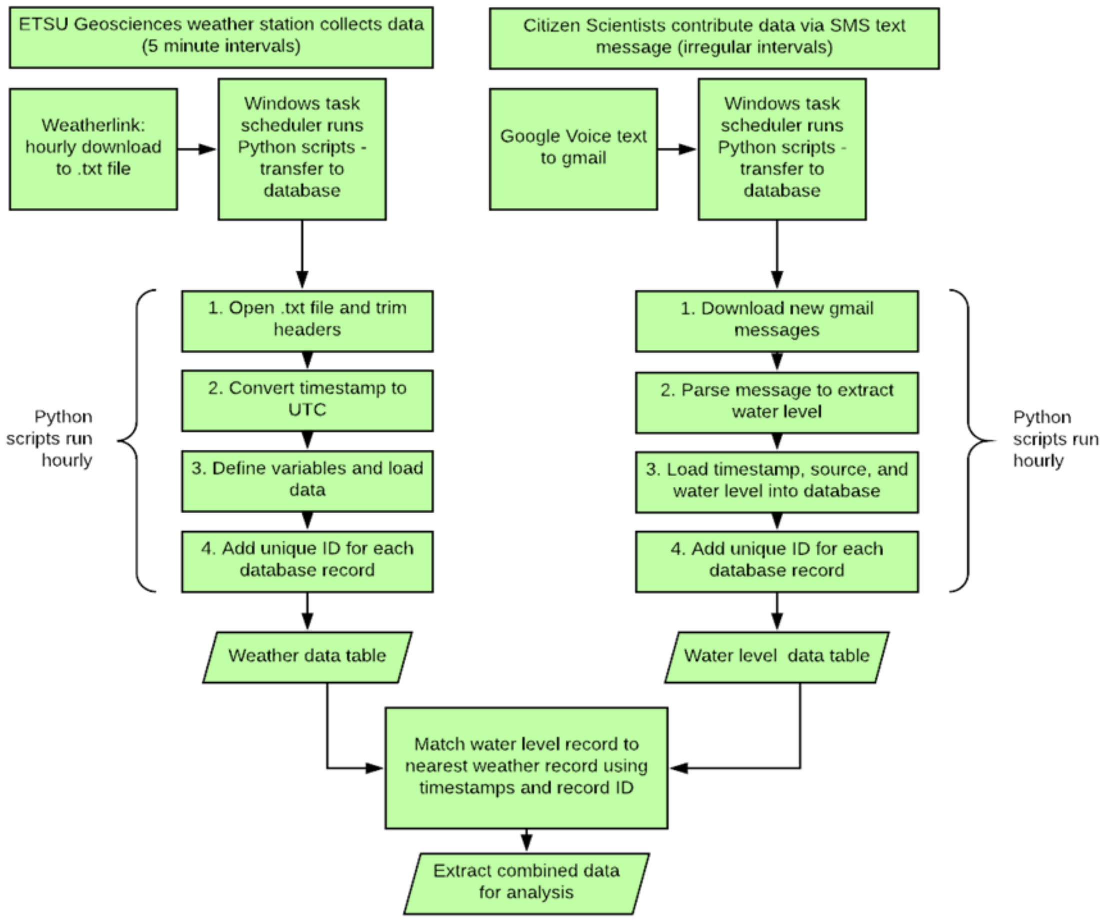

Figure 2. Fully automated workflow to extract water level data from text messages and combine with precipitation data in a database.

PUBLIC PARTICIPATION

From April 2017 through January 2019, we received 536 stage measurements from 283 different participants. These data were matched to precipitation data (collected using a weather station on the ETSU campus). The combined data may be used to assess the stream's response to precipitation, which will be successful only if appropriate stage data are contributed at representative times. Unfortunately, stage data for some major precipitation events may go unrecorded due to lack of reporting during times of inclement weather. It is apparent from a plot of contributed stage data and precipitation data that some rain events with the potential to produce flooding are not associated with any reported stage data, and conversely, some reports of high stage are not associated with significant rainfall measured at the ETSU campus weather station (Figure 3).

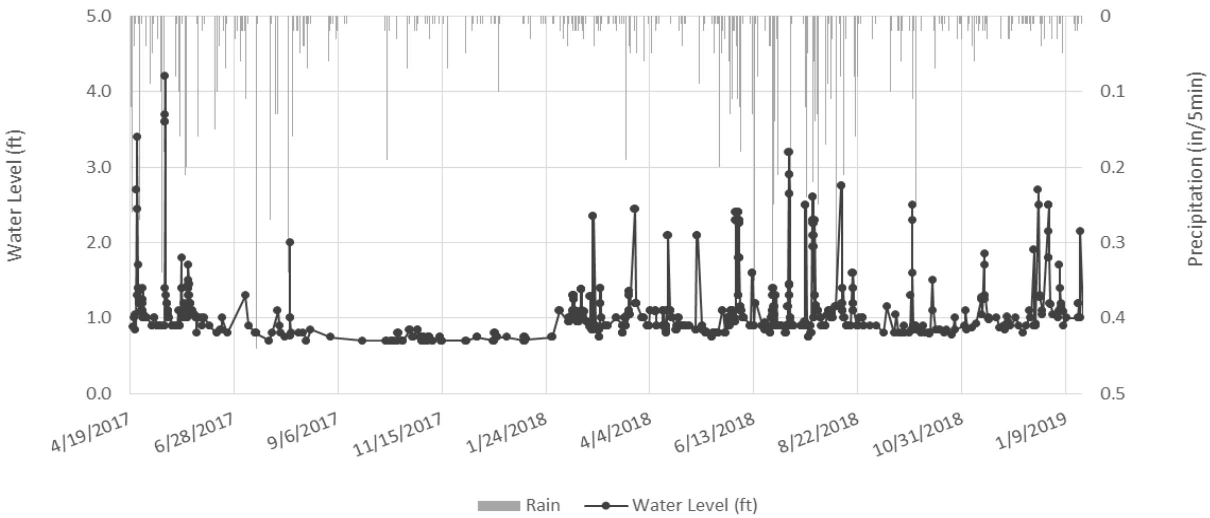

Figure 3. Reported water level (primary y-axis) compared to 5-minute precipitation (secondary y-axis).

We encountered several challenges using contributed stage data for analysis of the stream's response to precipitation: 1) data gaps during inclement weather and overnight, 2) difficulty extracting useful data from some text messages, and 3) lack of a reliable quality assurance/quality control process to assess accuracy of contributed data.

Challenge 1) Data gaps during inclement weather and overnight One challenge in relying on citizen scientists for data collection is that data are contributed only when citizens are present, which tends to be when weather is fair and during normal waking hours. Rainfall occurs at any time of day or night, yet citizens tend to contribute data more during daily peak times between 7-9 AM, 1-3 PM, and 6-9 PM (Figure 4). Only 12 observations (2%) were received between 11 PM and 7 AM, a pattern that is consistent throughout week and weekend nights. Moreover, while data are needed during all conditions, stream stage during rainy and stormy weather is not well represented in the contributed data. Only 7.5% of contributed data were received when there was rain in the prior 15 minutes and 12% received with rain in prior 30 minutes.

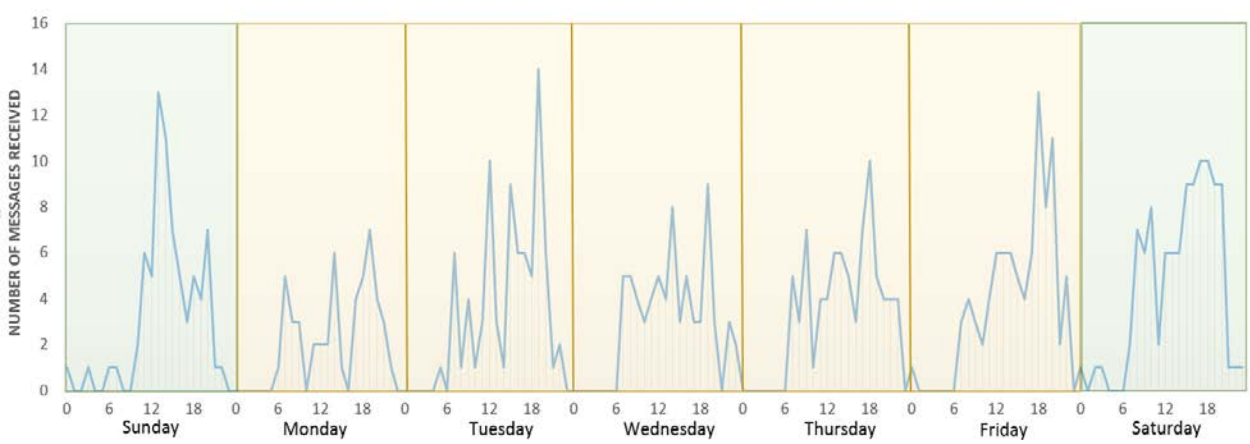

Figure 4. Frequency of incoming text messages by hour of day and day of week.

Challenge 2) Difficulty extracting useful data from some text messages Successful data collection by Citizen Scientists requires context and clear unambiguous instructions. Junk data, missing data, and use of Emoji's can result in false positives (wrong data extracted) and false negatives (parser unable to extract data even though usable data were reported). Of 536 text messages received, the parser extracted correct data for 527 (98%) of messages. Less than 2% of text messages were parser failures; false positives accounted for 1.3% of messages while false negatives accounted for 0.4% (Figure 5).

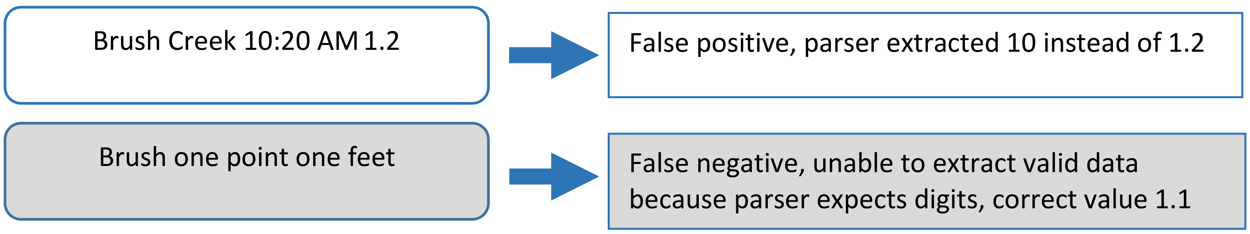

Figure 5. Examples of parser failures (false positive and false negative).

Challenge 3) Lack of reliable quality assurance/quality control Citizen Science literature indicates that data quality improves if study protocol takes citizen scientists into account. Processes for volunteer training, testing, replication of data, and validation are important (Kosmala et al. 2016). Data collected by citizen scientists should be specific, limited, and carefully scrutinized for accuracy. Researchers must be prepared to discard data that appear suspect (Cohn 2009). In our research, we have encountered stage data contributions that are improbable, including values of zero (we have no record of Brush Creek running dry during the course of this study) and values in excess of 7.1 ft (which is the limit of the staff gauge). These data may be discarded, however other data falling within a reasonable range are accepted as reliable data. A validation method for these data is needed.

FUTURE DIRECTIONS

To resolve these challenges, we have implemented strategies to recruit new participants and increase public participation.

- A 2018 interview on the local public radio station's "Community Forum" program re-airs periodically.
- Brush Creek flood field trips are periodically held for the community and university.
- Freshman geology students at ETSU are encouraged to participate in the project by opting in for credit.
- A Girl Scouts STEM day in Feb 2019 encouraged scouts to participate in the Brush Creek project as a required follow-up activity for badge completion.
- We plan targeted outreach to homeschoolers, high school environmental science clubs, and the community through data blast events.
- We plan to incentivize participation by acknowledging data contributions by return text message and providing links to a live data feed so that users can see their data in near real time.

To maximize utility of the contributed data and to reduce false negatives, we have examined the messages resulting in parser failures and identified the most common reasons for false negatives.

These include reporting the water level as a range, reporting time of day, and using qualifiers such as “a little below” or “a little higher than”. Incoming messages containing certain text strings will be flagged for review. These text strings may include numbers as text, “PM”, “AM”, “less than”, “below”, “between”, “above”, or “greater than”.

Last, to address QA/QC concerns, our next steps include implementation of an automated system to collect water level data at regular intervals. This will assist in data validation, which is an important component of a sound citizen science project (Kosmala et al., 2016).

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SESSION 2B

MODELS I (Moderator: Dennis Borders, TDEC-DWR)
8:30 a.m. – 10:00 a.m.

Modeling Methanogenic Processes: Conversion of Short-Chain Fatty Acids by Syntrophy
Liu Cao, Chris D. Cox, and Qiang He

Assessing DEM Error in Major River Basins of the World
Md N.M. Bhuyian and Alfred Kalyanapu

Two-Dimensional (2-D) Modeling: When, Why, and How?
Bradley Heilwagen

MODELS II (Moderator: Rodney Knight, USGS)
10:30 a.m. – 12:00 p.m.

Using ArcGIS Pro to Automate Bridge and Culvert Identification for NCDOT
Justine Hart

Development of a Numerical Multi-Layered Groundwater Model to Simulate Inter-Aquifer Water Exchange in Shelby County, Tennessee
Rodrigo Villalpando-Vizcaino, Brian Waldron, Daniel Larsen, Claudio Meier, and Scott Schoefernacker

Going Both Ways with 2D Modeling in East Chattanooga
Felipe Santanna Dias

FLOODS/FLOODING (Moderator: Adrian Ward, Barge Design Solutions, Inc.)
1:30 p.m. – 3:00 p.m.

Georeferenced Floodplain Mapping in HEC-RAS with Terrain Modification for Increased Mitigation
Justin Corbitt

Evaluating Effects of Proposed Levee Extension Along Yazoo River Watershed Plan and Environmental Assessment: Lower Mississippi River Basin—Upper Yazoo Watershed
Scott Taylor and Dana Waits

Two-Dimensional Modeling for Wilson County State Industrial Access Serving Project Delorean
Lina Khoury, Wesley Peck, and Ken Elrod

FLOODING AND EROSION (Moderator: David Ladd, USGS)
3:30 p.m. – 5:30 p.m.

Assessing the Validity of Sediment Fingerprinting Using Artificial Sediment Source Mixtures
Yanchong Huangfu, Michael E. Essington, Shawn A. Hawkins, Forbes R. Walker, John S. Schwartz, and Alice C. Layton

Analysis of the July 5, 2017, Flash Flood at Cummins Falls State Park and Proposal of a Flash Flood Warning System
Evan Hart

Understanding Flood Risk to Prioritize Infrastructure Improvements
Ben Zoeller

MODELING METHANOGENIC PROCESSES: CONVERSION OF SHORT-CHAIN FATTY ACIDS BY SYNTROPHY

Liu Cao[1]*, Chris D Cox[1], Qiang He[1]

Various engineering systems exploit methanogenic processes, including the anaerobic digestion of concentrated organic wastewater and landfill gas production. Methanogenic processes carry out the degradation of organic matter with a network of complex metabolic pathways by diverse microbial trophic groups under anaerobic conditions. It is of great significance to understand the underlying mechanisms of this process in order for process modeling and simulation. Short-chain fatty acids, including acetic acid, propionic acid, and butyric acid, are the most important intermediates during microbial decomposition of more complex substrates in methanogenic processes and act as the immediate precursors for methanogenesis. Therefore, this study aimed to identify the microbial populations specifically responsible for the conversion of acetate, propionate, and butyrate to methane using enrichments configured with one of these compounds as the sole substrate. Microbial community structures were evaluated by 16S rRNA gene amplicon library sequencing and PICRUSt functional gene prediction to understand the role of methanogens and associated bacterial populations in methanogenic conversion. The acetate enrichments were dominated by *Methanosaeta* and the acetoclastic methanogenesis pathway, while the propionate and butyrate enrichments were dominated by hydrogenotrophic methanogens and their syntrophic partners. By profiling the microbial community structures, an anaerobic food web was proposed to represent the anaerobic conversion of short-chain fatty acids, including both acetoclastic and hydrogenotrophic methanogens and syntrophic bacterial populations.

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ASSESSING DEM ERROR IN MAJOR RIVER BASINS OF THE WORLD

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

Digital Elevation Models (DEM) are static datasets that represent the earth surface as it was during data acquisition. Therefore, it is important to acknowledge this uncertainty while using DEM for geospatial analysis especially in hydrology. The implication of assuming earth surface as static for DEM-based flood risk management is significant because the waterbodies are among the most active systems in nature. While many rivers in the developed countries are engineered to improve the livelihood of the people, many rivers in the developing countries have remained dynamic and untamed. Therefore, the objective of this research is to contrast the dynamics of riverine waterbodies at a global-scale and assess its demographic impact. To perform this analysis five major river basins in the world are selected. The basins are (a) Amazon, (b) Danube, (c) Ganges-Brahmaputra-Meghna (GBM), (d) Mississippi and (e) Yangtze. The planform change between 2000 and 2015 of these river basins are analyzed and overlaid on remote sensing based global population data for determining the demographic impact. The findings of this study can be utilized for identifying priority areas for which DEMs need to be updated at a shorter time interval.

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TWO-DIMENSIONAL (2-D) MODELING: WHEN, WHY, AND HOW?

Bradley Heilwagen[1], PE, CFM

Whether for the purpose of creating flood insurance rate maps, flood mitigation strategies, bridge analysis, stream restoration, or emergency action plans, engineers have been developing different kinds of hydraulic models to simulate the flow of water over land for many years. The size and complexity of these models has always been limited by the technology available at the time. Modeling was typically performed in one dimension, assuming that all water at a certain point in a stream channel and floodplain was flowing downhill in the same direction and at the same speed. The most popular modeling software has always been the U.S. Army Corps of Engineers' HEC-RAS software, as it is freely available for download and requires very little computing power.

As computer processing power has increased, we've seen a surge in the availability of two-dimensional models. Established proprietary modeling systems, such as SRH, ICPR, and SWMM have been released with two-dimensional components, allowing engineers to better understand the flow of water, especially when that water is flowing in different directions. Recently, the Corps released a freely available two-dimensional version of HEC-RAS, making two-dimensional modeling a fast, easy, and relatively inexpensive endeavor.

This presentation will provide the listener with an introduction to two-dimensional hydraulic modeling. It will compare and contrast some of the basic hydraulic modeling methodologies, both one- and two-dimensional. It will discuss general situations where two-dimensional modeling should be used, and explain ways to modeling a two-dimensional scenario within a HEC-RAS model. The listener will get to see several examples of real-world results from some recent two-dimensional modeling efforts.

Keywords: hydraulic models, two-dimensional, HEC-RAS

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USING ARCGIS PRO TO AUTOMATE BRIDGE & CULVERT IDENTIFICATION FOR NCDOT

Justine Hart

The North Carolina Department of Transportation (NCDOT) is responsible for inspecting and maintaining upwards of 13,500 bridges and 4,500 culverts over 20 feet in length statewide, as well as ensuring routine inspection and maintenance of numerous culverts and pipes shorter than 20 feet in length that fall under local jurisdiction. As part of their progressive initiative to improve infrastructure statewide, NCDOT has set a target of having at least 70 percent of bridges rated to be in good condition or better.

An undertaking of this magnitude requires NCDOT to have an accurate inventory of all bridges, culverts, dams, levees, and other man-made structures that disrupt or alter natural flow near roadways. In the past, this inventory has been maintained by having road crews travel every road, mile-by-mile, collecting data on these structures. With only around 4,000 full time road workers statewide, all of whom share many other roadway responsibilities such as responding to citizen action requests, filling pot holes, etc. it was difficult to keep this inventory up-to-date.

To help speed along the inventory process, Wood Environment & Infrastructure Solutions, Inc. staff developed an ArcGIS tool to automate the identification of "hydroconnectors", a term used to summarize the man-made features described above. The tool analyzes natural topography and drainage patterns on each side of a roadway to determine locations of potential connectivity beneath the roadway. Leveraging the multi-threaded processing capabilities of recently released ArcGIS Pro, Wood was able to develop a fast-running tool that utilized a minimal amount of data. The tool only requires input of a digital elevation model and a roadway network. In addition to automating the identification of potential structures, the tool also has the capability to automate many of the hydrologic calculations necessary to assess the size and capacity of the structure.

The hydroconnector tool has been a great time- and cost-saving tool for NCDOT, successfully delivering GIS data that will be used for future road maintenance and repair projects. Given the simple design of the tool, its can easily be leveraged by transportation departments at the state and local levels outside of North Carolina to identify and assess bridges and culverts on a large scale.

This presentation will outline the hydroconnector tool, as well as its inputs, execution, and outputs. It will detail each phase of the NCDOT project and explain how the tool and its associated QAQC resulted in a spatially accurate representation of culverts in North Carolina. Finally, it will discuss potential enhancements for use in watershed modeling in North Carolina, as well as other potential applications for the tool for roadway and railroad applications across the United States.

DEVELOPMENT OF A NUMERICAL MULTI-LAYERED GROUNDWATER MODEL TO SIMULATE INTER-AQUIFER WATER EXCHANGE IN SHELBY COUNTY, TENNESSEE

Rodrigo Villalpando-Vizcaíno, Brian Waldron, Daniel Larsen, Claudio Meier, and Scott Schoefernacker

INTRODUCTION

Water exchange and leakage in groundwater systems comprised of alternating layers of aquifers and confining units can influence conditions and pose a contamination threat due to the downward transference of shallower waters of lesser quality, especially in urban areas where groundwater degradation is common, as is the case in Shelby County, Tennessee (Parks, 1990; Robinson *et al.*, 1997; Larsen *et al.*, 2003; Waldron, *et al.*, 2009; Barlow *et al.*, 2012). Due to inter-aquifer water exchange, the Memphis aquifer is experiencing localized water quality degradation and contamination (Bradley, 1991; Parks and Mirecki, 1992; Doudrick, 2008; Waldron *et al.*, 2011; Carmichael *et al.*, 2018).

Groundwater modelling of water resources in the Mississippi embayment has been used to assist with water management and to understand flow through the system under pre-development and modern conditions, mainly focusing in the Mississippi River Valley Alluvial aquifer (MRVA) in Arkansas. Although models have been used extensively, evaluation of inter-aquifer water exchange and flow in Shelby County has not been widely assessed except for a handful of models.

The purpose of this study is to develop a detailed multilayer, three-dimensional numerical groundwater-flow model that simulates the actual hydrogeologic conditions of water exchange between and external stressors to the shallow, Memphis, and Fort Pillow aquifers and their respective intervening confining units in Shelby County.

APPROACH

To simulate the complex groundwater flow beneath Shelby County, a conceptual model was assembled based on geological, geophysical, hydrological, hydrogeochemical, and other ancillary information (e.g., Anderson *et al.*, 2015). Boundary conditions conformed with observed historic water levels around Shelby County. Additionally, an extensive effort was taken to accurately represent the dynamic pumping regime employed by the five utilities in Shelby County and those in Mississippi, as well as surface water-groundwater exchange stressors, and selected water-demanding industrial and recreational users.

The United States Geological Survey (USGS) MODFLOW-NWT program (Niswonger *et al.*, 2011) was chosen to simulate groundwater conditions beneath Shelby County. The transformation of the conceptual model into a MODFLOW-NWT model was performed using the pre- and post-processing software GMS (Groundwater Modelling System, v.10.3), developed by Aquaveo. The model was calibrated using automated Parameter ESTimation (PEST) with a pre-process, manual trial-and-error analysis to ensure convergence. The model was parametrized at discrete locations with the use of pilot points.

RESULTS AND DISCUSSION

Modelled hydraulic conductivity values for the shallow aquifer (20.0 m/day) have a slightly higher average than the ones in the Memphis aquifer (18.4 m/day). The Fort Pillow aquifer has a lower average hydraulic conductivity at 9.8 m/day. Both the upper Claiborne confining unit (UCCU) and Flour Island confining unit have median hydraulic conductivities around 5.5×10^{-5} m/day. Higher values in the UCCU suggest the presence of areas with high conductance not previously identified as a breach location, that may warrant further investigation to determine their plausible role in inter-aquifer water exchange. Using a total of 74 monitoring wells, the Root-Mean-Square Error (RMSE) for the shallow aquifer is 2.2 m, 1.8 m for the Memphis aquifer, and 2.3 m for the Fort Pillow.

The simulated multi-layer aquifer system in Shelby County can be examined through the flow budget computed by MODFLOW. The main inflow component of the shallow aquifer is the water released from storage that gets into the system, accounting for 57.6% of its total inflows, followed by recharge and constant head inflows. Groundwater from the shallow aquifer going into the rivers accounts for over 52% of the overall outflows, and approximately 36 m^3/min or 10.5% of the flow will contribute in a little over 57% of the total inflows to the UCCU.

Due to the inter-aquifer connection of the shallow and Memphis aquifers through the UCCU, pumping in the Memphis aquifer induces downward flow and results in water-level changes, and a corresponding loss of storage in the UCCU and the shallow aquifer. An outflow of 61.1 m^3/min from the UCCU is discharged and exchanged with the Memphis aquifer. The Memphis aquifer inflows come mainly from lateral contributions, and vertical exchange with the UCCU represents an overall contribution of a little over 10% or 61.1 m^3/min of the total inflows of the Memphis aquifer in Shelby County. The main outflow and stressor to the Memphis aquifer is generated by pumping, accounting for 85.3% of the total extractions with 500 m^3/min; layer apportioning shows that the upper and middle areas are more stressed (i.e., 117 and 256 m^3/min), concentrating around 70% of the extractions. Water exchange with the Fort Pillow was found to be negligible.

Spatially discrete water exchange analysis using quadrants shows that leakage is mostly concentrated in areas with previously mapped breaches in the UCCU and water-table anomalies in the shallow aquifer, although comparison between the breach and quadrant water exchange suggests that the breaches mapped by Parks (1990) are not sufficient to account for all the flow through the UCCU.

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GOING BOTH WAYS WITH 2D MODELING IN EAST CHATTANOOGA

Felipe Santanna Dias[1]

Following substantial completion of Phase 1 of Chattanooga's Works Progress Administration (WPA) Ditch Program in 2016 and publication of the Condition Assessment, Scoring System, and Rehabilitation Plan for the Chattanooga WPA Ditch System in 2017, Wood Environment & Infrastructure Solutions, Inc. (Wood) and City of Chattanooga Staff identified six priority areas for flood reduction, deterioration repair, or ecological enhancement projects, as well as a number of short- and long-term measures necessary to begin rehabilitation of the entire WPA Ditch System. In order to begin implementation of the overall rehabilitation plan, known as Phase 2, Wood has begun developing drainage improvement plans for the Glass Street area of East Chattanooga.

The Glass Street area of Chattanooga has documented flooding problems during more frequent rain events that have potential to cause significant impacts on residential and commercial properties around Crutchfield St., Dodson Ave., Taylor St. and Daisy St. Major transportation routes within the City are routinely flooded, including one State Highway. The watershed is comprised of steep slopes in its headwaters and a flat downstream basin, which is a perfect recipe for overland flooding. The flooding impacts are exacerbated by heavy development in the downstream basin, in some cases right up against the ditch. During Phase 1 of the WPA Ditch Program, scoring systems were developed to measure and compare flooding potential in various neighborhoods. The East Chattanooga neighborhood scored the highest, with a high number of impacts in the Glass Street area.

With the intent of precisely quantifying the risk of flooding in this vicinity and developing conceptual design drainage improvements plans, an integrated 1-dimensional (1D) and 2-dimensional (2D) hydrologic and hydraulic model framework was developed. As mentioned above, much of the flooding in the downstream basin around the WPA ditch is overland in nature, which is difficult to accurately model with traditional 1D methods. The hydrologic and hydraulic modeling were performed using PCSWMM-2D software. PCSWMM-2D is a FEMA-approved dynamic rainfall-runoff modeling software that uses the open source US EPA SWMM5 algorithm engine to perform both 1-dimensional and 2-dimensional modeling.

A total contributing drainage area of 867 acres was modeled using a combined rain on grid 2D mesh and a 1D underground storm drainage system network. The models include detailed topographic information obtained from 3-foot LiDAR data; soil and landcover data for the NRCS (SCS) Curve Number (CN) and detailed surveyed field data, such as manholes, catch basins, junction boxes, inlets, pipes, and culverts. The rainfall data, total precipitation depth and rainfall distribution, was provided by the city stormwater management manual. Various conceptual flood mitigation measures were input into the model, including channel expansion, green infrastructure, and regional detention. Numerous combinations of these measures were input into the PCSWMM-2D model and outputs were compared to the existing conditions run.

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This presentation will cover the methodology used to develop the combined 1D and 2D hydrologic and hydraulic models and the existing and proposed conditions results. It will include displays of dynamic flood maps and animations that can be exported from the PCSWMM-2D software, and will discuss the conceptual plans to reduce flood impacts.

GEOREFERENCED FLOODPLAIN MAPPING IN HEC-RAS WITH TERRAIN MODIFICATIONS FOR INCREASED MITIGATION

Justin Corbitt, E.I.[1]

INTRODUCTION

With flood related incidents increasing at an alarming rate, more and more consideration is being given to the analysis of hydraulic and hydrologically influenced projects. With updated technology and software, having higher accuracy models is becoming a reality opposed to a hypothetical. By utilizing georeferenced projects in Hydraulic Engineering Center - River Analysis System (HEC-RAS) understanding and realizing the boundaries for impacted areas can help further mitigate for flooding disasters.

APPROACH

Using survey data for a project, along with LiDAR when necessary, a georeferenced terrain can be created in HEC-RAS. By assigning a specific terrain to a plan and geometry file a flood map can be created for the project. In one scenario, a new alignment was being designed through the middle of a floodplain with several feet of fill. A model was created to identify the impacted areas and mitigate early on for potential issues. Another example is a project that is in a designated FEMA zone AE and floodway. For this particular case, a new retaining wall was modeled opposed to additional lanes along the lateral encroachment to see the impacts of each design.

RESULTS AND DISCUSSION

Each of the two cases modeled had specific issues that could have been more difficult to identify without a good visual representation. By having the terrain created along with the georeferenced point, the extent of the impacts can be visually analyzed along with the model calculations to better understand the total impact for new designs.

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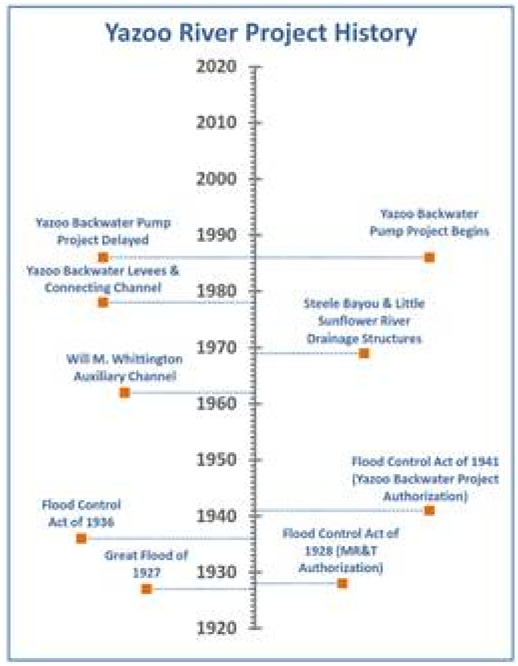
EVALUATING EFFECTS OF PROPOSED LEVEE EXTENSION ALONG YAZOO RIVER WATERSHED PLAN AND ENVIRONMENTAL ASSESSMENT LOWER MISSISSIPPI RIVER BASIN - UPPER YAZOO WATERSHED

Scott Taylor, P.E. and Dana Waits

PROJECT HISTORY

Following the Great Flood of 1927, Congress passed the Flood Control Act of 1928 which recognized that flooding due to the Mississippi River is a federal responsibility because 41% of the continental United States drains down the Mississippi River to the Gulf of Mexico. This Act authorized the Mississippi River & Tributaries Project (MR&T) which called for levees and floodwalls, floodways, channel improvement and stabilization, and tributary basin improvements. In 1936, Congress recognized that some of the levee construction work cut off drainage outlets for interior basins, therefore Congress passed the Flood Control Act of 1936 which extends federal responsibility to many river basins that feed into the Mississippi River, including the Yazoo Basin.



In 1941, Congress, at the request of the Arkansas delegation, removed the Eudora Floodway from the MR&T Project. At the same time, the Mississippi delegation recognized that this action would result in higher stages on the Mississippi River at the mouth of the Yazoo River and cause flooding in areas previously safe from floods in the Delta Region of Mississippi. The Flood Control Act of 1941 authorized the Yazoo Backwater Project to protect the Delta area of Mississippi from these increased stages. This project included a combination of levees, drainage structures and pumps.

The Yazoo Backwater Area generally covers that portion of the Yazoo Basin below the latitude of Yazoo City. The projects authorized in 1941 included a levee extension that runs generally along the west bank of the Yazoo River, to connect with the Yazoo River levee near Yazoo City, Mississippi. The 1941 Act also authorized construction of the Rocky Bayou and Carter Area elements. These levee segments were never constructed and are included in the current proposed action.

The Carter Area includes approximately 161 square miles of alluvial lands located east of the Will M. Whittington Auxiliary Channel and west of the Yazoo River. The Rocky Bayou Area includes approximately 22 square miles of alluvial lands east of the Yazoo River between the latitude of Yazoo City and Satartia.

PURPOSE

The purpose of the project is to reduce backwater flooding, and subsequent damage to agricultural crops, from the Mississippi River and Yazoo River within the Rocky Bayou and Carter Areas. NRCS proposes to accomplish this by:

- Constructing new levee along the Yazoo River in project area

PROJECT NEED

The Rocky Bayou and Carter Areas located along the Yazoo River are not protected due to the lack of levees along the Yazoo River in this area. During some Mississippi River flood events, water backs up into the Yazoo River and inundates vast areas on both sides of the Yazoo River from Silver City to the Satartia vicinity. When this happens, much of the agricultural lands within the Rocky Bayou and Carter Areas experience significant flooding, causing damages to crop yields as well as infrastructure, commercial and residential structures, and various other farming operations. Although there are exceptions, most crops in fields inundated with floodwater for a week or more will likely die. An evaluation of past flood events within the Carter and Rocky Bayou areas of Yazoo County demonstrate the need for adequate levee protection for residents, employers, catfish processing facilities, and extremely valuable cropland throughout this unprotected area of the Yazoo basin.

TWO-DIMENSIONAL MODELING FOR WILSON COUNTY STATE INDUSTRIAL ACCESS SERVING PROJECT DELOREAN

Lina Khoury, P. E[1], Wesley Peck, P. E[2], Ken Elrod[3]

INTRODUCTION

With the arising number of flood complaints that TDOT is continuously dealing with, there has been more emphasis on focusing on prevention measures instead of maintenance. The use of advanced hydraulic modeling is allowing the hydraulic designer to spot potential off-site flooding issues during the planning and design phases. Wilson County State Industrial Access serving project Delorean is a great example on how two -dimensional analysis raised questions and concerns even before finalizing roadway plans. As FEMA zone X is usually ignored or misinterpreted by most of roadway designers and developments, more flooding problems are occurring in this zone. Preventing legal complication for TDOT and avoiding potential off-site property loss to flood damages were the main two goals for this study.

APPROACH

TDOT State Industrial Access projects are usually on limited budget and fast schedule. The alignment was picked by TDOT roadway design and sent to hydraulics for approval. Due to the location of the alignment, HEC-RAS one dimensional model showed that the floodplain will be split leading to potential flooding issues for the future development and the properties downstream. This is considered not only a roadway/hydraulics complication but also a ROW and legal problem. Therefore, two-dimensional modeling was recommended. SMS-SRH2D, an Aquaveo software that is also used by FHWA, was used to model multiple scenarios.

RESULTS AND DISCUSSION

The used modeling technique helped ROW engineers in discussing alternatives with the development and property owners. It also helped in selecting a proper and cost-effective structure. As for the flooding downstream of the alignment, multiple alternatives were discussed and studied for the site. Due to the cost factor, development plans at that location, schedule, and commitments, a berm was the scenario that got approved as a best solution. A simple solution like this prevented future flood complaints and loss of property due to flood damages. Although the project is not in zone AE, the hydraulic designer made sure to satisfy the legal requirements while maintaining schedule and cost.

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ASSESSING THE VALIDITY OF SEDIMENT FINGERPRINTING USING ARTIFICIAL SEDIMENT SOURCE MIXTURES

Yanchong Huangfu[1]*, Michael E. Essington[1], Shawn A. Hawkins[1], Forbes R. Walker[1], John S. Schwartz[2], and Alice C. Layton[3]

The accurate identification of primary sediment sources in a watershed is necessary to implement targeted management practices that will reduce erosion and restore water quality. Sediment fingerprinting is a commonly-used tool to accomplish this task. However, the accuracy and precision of different procedures to select tracers for un-mixing sediment sources is still a largely uninvestigated area in relation to sediment fingerprinting. The goal of this research was to validate a sediment fingerprinting methodology by applying it to the Oostanaula Creek watershed in southeast Tennessee. We assessed three method protocols (soil digestion procedure, objective source grouping, and tracer selection) that are utilized for assessing the performance of fingerprinting in terms of apportionment outputs. The major and trace elemental composition of sediment source and suspended sediment were determined by total dissolution and nitric acid extraction followed by analysis with inductively coupled plasma - optical emission spectrometry (ICP-OES). The Kruskal-Wallis (KW) test as well as stepwise discriminant function analysis (DFA) were utilized during tracer selection. The source un-mixing model utilized was a Bayesian mathematical model within Stable Isotope Analysis in R (SIAR). Sediment fingerprinting in the Oostanaula watershed proved to be difficult due to the chemical and mineralogical similarities of the potentially erodible source material. Upon analysis, it was found that the sediment tracers identified as those with low misclassification during cluster analysis wouldn't guarantee a high degree of accuracy during source apportionment. However, there are certain outputs with low errors as compared with the real proportional contributions in artificial mixtures, for example findings showed that bank erosion is a primary source of suspended sediment in the Oostanaula Creek. Further, it was concluded that source apportionment from sediment fingerprinting were sensitive to the digestion procedure, objective source groupings, and the tracer selection. Our research provides a quantitative approach for assessing the validity of the sediment fingerprinting technique.

Keywords: Sediment fingerprinting, artificial sediment source mixtures, stream sediment source group classification, un-mixing model, bank erosion.

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ANALYSIS OF THE JULY 5, 2017, FLASH FLOOD AT CUMMINS FALLS STATE PARK AND PROPOSAL OF A FLASH FLOOD WARNING SYSTEM

Evan Hart[1]

On July 5, 2017 flash flooding occurred at Cummins Falls State Park and at Window Cliffs State Natural Area, in Jackson and Putnam Counties, Tennessee. The flooding at Cummins Falls resulted in 2 fatalities and required water and air rescues from a narrow canyon. At Window Cliffs, no fatalities occurred, but several people required assistance to escape rising floodwaters. These floods were caused by brief, exceptionally heavy rainfall centered directly over the affected watersheds. The rainfall was generated by deep convective thunderstorms and occurred after several days of antecedent rainfall that resulted in pre-storm saturation of soils. Base reflectivity images from the National Weather Service RADAR at Old Hickory (OHX) indicate that the majority of storm rainfall fell between 11:03 and 11:34 Central Daylight Time (CDT). Moving ENE, the heaviest rainfall was concentrated over the West Blackburn Fork watershed at 11:09 CDT, then covered the entire watershed at 11:16 CDT, and finally was concentrated over the East Blackburn Fork at 11:22 CDT. All of this rainfall was occurring mostly upstream from Cummins Falls, thus giving little warning to park visitors who were swimming directly beneath the falls. The direction of storm movement, the unusual intensity of the rainfall, and the nearly complete rainfall coverage over the watershed, all led to the “perfect” timing for a flash flood. It appears that the flood peaks from the West and East Blackburn Forks arrived nearly simultaneously at their confluence, 1 km above Cummins Falls, creating the “wall” of water that eye-witnesses described. Cell phone images taken during the flood show that water levels began to rise at approximately 13:20 CDT and rose approximately 3 feet by about 13:40 CDT. This 20-minute window left little time for visitors to escape the rocky, confined canyon below the falls. More importantly, despite the 2-hour time window between the onset of heavy rainfall and the arrival of the flood at Cummins Falls, no warning was issued to park visitors at the base of the falls. NWS officials did notify State Park officials at Cummins Falls that intense rainfall was falling in the region creating the threat of flash floods. However, since rainfall was occurring upstream from the Park, and not at the Park itself, and since no stream gauges exist upstream from the Park, there was no basis for Park officials to issue an evacuation for the falls area. The resulting wall of water caught everyone by surprise. Stream gauges upstream from the Park would have given officials crucial information about the timing of the flash flood and its arrival at Cummins Falls. While we suspect that the extremely rapid rise of water seen on July 5, 2017 was a rare event, other floods have hit the area over the last few decades. The NOAA Storm Events Database indicates that a total of 28 flood events occurred in Putnam and Jackson Counties between 1996 and 2017. Of these 28 flood events, 6 of them occurred in the Blackburn Fork watershed upstream from Cummins Falls. The largest of these floods occurred on August 18, 2010, when the Blackburn Fork below Cummins Falls rose to a height approximately 10 feet higher than the level reached on July 5, 2017. The 2010 flood occurred before the establishment of Cummins Falls State Park and there were no fatalities or injuries. However, the 2010 flood did result in $35 million of damages in Jackson and Putnam Counties. Despite these past floods, no stream gages have ever been established on Blackburn Fork (Cummins Falls) or Cane Creek

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(Window Cliffs). We propose that a network of stream gages be permanently established on these streams in order to reduce the risk of flash flooding for state park visitors. When fully operational, the flash flood warning system should provide 1 to 2 hours of advanced warning of an impending flash flood. This time window can be used by park officials to enact safety measures (evacuation, shelter in place, get to high ground, etc.).

Key Words: flash flood, stream gauges, warning system, Cummins Falls

UNDERSTANDING FLOOD RISK TO PRIORITIZE INFRASTRUCTURE IMPROVEMENTS

Ben Zoeller[1]

Two hot topics are regularly showing up on the news cycle that directly impact engineers and floodplain managers: aging infrastructure and increased vulnerability to flooding.

The American Society of Civil Engineers gave the U.S. infrastructure a grade of D+ in 2017. In response to that grade, the White House unveiled an outline for rebuilding infrastructure in America highlighted by 200 billion dollars in infrastructure funding.

National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) reports show an upward trend in frequency of intense rainfall events and damage caused by flooding. This trend is supported by recent historic hurricanes Matthew, Harvey and Irma, and recent historic flooding on the Ohio and Mississippi rivers.

As these two issues converge attention turns to the engineering and floodplain management community for answers. We should take this opportunity to improve our capital investment plans by using our understanding of flood risk to prioritize infrastructure improvement projects and improve flood resilience.
FEMA Flood Insurance Rate Maps, NWS precipitation and flood forecasting data, and U.S. Geological Survey stream gage data all help the public understand flooding hazards along streams and rivers, but that information does not truly inform flood risk… without help. That help comes from a process that uses a combination of published flood risk tools and modeling to estimate flooding risk for infrastructure and other flood-prone property to prioritize infrastructure improvement projects.

Attendees of this presentation will learn how to use existing FEMA tools to rate flood risk in their community and how the right approach to modeling can improve understanding of flood risk allowing a community to develop more informed capital investment plans and become more flood resilient.

Key Words: aging infrastructure, flooding, management, tools, models

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SESSION 2C

ECOLOGY-THURSDAY (Moderator: Bill Wolfe, USGS)
8:30 a.m. – 10:00 a.m.

Estimating Biomass and Ideal Sampling Period for a Cryptic, Stream-Breeding Salamander (Ambystoma barbouri) *Using Environmental DNA*
Nicole Witzel and William B. Sutton

Using a Standardized Bioassessment to Characterize Louisiana Waterthrush Habitat Use in an Agriculturally Dominated Landscape
Nicole Santoyo and Steven W. Hamilton

Seasonal Variation in the Invertebrate Community of Richland Creek
Lucia Berkey, Hannah Hitchcock, and Anissa Jayathilake

ALGAL STUDIES-THURSDAY (Moderator: Sherry Wang, TDEC-DWR)
10:30 a.m. – 12:00 p.m.

Impact of Eutrophication of Pigeon Roost Creek on the Composition of Algal Assemblages
Jefferson Lebkuecher, Tsvetan M. Tsokov, Austin L. Shackelford, Olivia N. Patrick, and James M. Mauney

Potential Techniques for Improving Analysis of and Response to Harmful Algal Blooms
Gerald Burnette

How Do You Measure a Year in the Life? Examining Ecosystem-Wide Responses to Annual Senescence of Invasive Hydrilla in Upland Streams of the Cumberland Plateau
Sandra Bojić

WASTEWATER TREATMENT I (Moderator: Karina Bynum, TDEC-DWR)
1:30 p.m. – 3:00 p.m.

Development of an Anaerobic Membrane Bioreactor for the Treatment of Recalcitrant Biofuel Process Wastewater
Lu Yang, Young Chul Choi, Gyu Dong Kim, and Qiang He

Microbial Community Structure and Stability During Optimization of a Full-Scale Biological Nutrient Removal Process
Grace McClellan and Tania Datta

Exploring Renewable Energy Recovery for Sustainable Wastewater Treatment
Juliet Ohemeng-Ntiamoah and Tania Datta

WASTEWATER TREATMENT II (Moderator: Ariel Wessel-Fuss, TDEC-DWR)
3:30 p.m. – 5:00 p.m.

Methylotrophic Methanogenesis in the Anaerobic Treatment of Animal Wastewater
Yabing Li, Si Chen, and Qiang He

Phosphorus Recovery from Animal Wastewater with Bauxite Residue in Anaerobic Treatment
Yongfeng Wang and Qiang He

Enhancing Biodegradation of PAHs in the Aqueous Phase: Effects of Biodemulsifiers
Ning Hou, Yanfei Dai, Tingting Jia, Dapeng Li, and Qiang He

ESTIMATING BIOMASS AND IDEAL SAMPLING PERIOD FOR A CRYPTIC, STREAM-BREEDING SALAMANDER (*Ambystoma barbouri*) USING ENVIRONMENTAL DNA

Nicole A. Witzel[1]* and William B. Sutton[2]

Cryptic species present significant challenges when attempting to create range maps and conservation plans and are often overlooked in comprehensive traditional surveys. This is specifically true for the Streamside Salamander (*Ambystoma barbouri*), which is listed as endangered in Tennessee. This species is only surface-active when they emerge to breed in low-order, ephemeral streams during the winter months and can be difficult to detect using traditional survey methods. Surveys that target DNA that the salamanders shed into their aquatic environment may provide an effective method for detecting this species. From December 2016 to May 2017, 17 ephemeral streams were sampled four times for environmental DNA (eDNA) and salamander biomass within a 50-meter stretch. Our objectives were 1) to determine if there was a relationship between salamander biomass and eDNA copies and 2) identify the best time during this period to sample for eDNA. Using a linear mixed-effects model, we examined the relationship between streamflow, biomass, and eDNA copies per sample, using site as a random effect. Environmental DNA copy number was logarithmically related to salamander biomass found in the stream after ~1,000 copies, but became less accurate as copy number increased. The best time to survey for *Ambystoma barbouri* eDNA occurred during the month of February, which coincided with the greatest period of larvae emerging from eggs. This information provides an efficient, accurate method which can be utilized by wildlife agencies to identify species presence and roughly estimate the population status of this cryptic, and locally rare amphibian in ephemeral streams.

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USING A STANDARDIZED BIOASSESSMENT TO CHARACTERIZE LOUISIANA WATERTHRUSH HABITAT USE IN AN AGRICULTURALLY DOMINATED LANDSCAPE

Nicole Santoyo[1]* and Steven W. Hamilton[2]

INTRODUCTION

Aquatic macroinvertebrates are widely used to determine instream biotic integrity by state and federal governments. The Louisiana Waterthrush (*Parkesia motacilla*), a riparian-obligate songbird (family Parulidae), may also serve as a bioindicator of both instream and riparian habitat quality of the streams it occupies, as it preys upon both terrestrial and aquatic invertebrates. Agricultural land use can affect biotic integrity of streams via sedimentation, excess nutrient input, and destruction or reduction of the riparian zone, impacting the macroinvertebrate communities on which the waterthrush feed. In the Western Pennyroyal Karst Plain (USEPA Ecoregion 71e), located in northern Tennessee and southcentral Kentucky, much of the historically described "mosaic" of hardwood forest and prairie found in this ecoregion has been replaced by farmland. As the karstic bedrock allows water to flow through its many cavities, surface water is sparse. Widespread farming and karst topography together result in a landscape with relatively few surface streams of varying degrees of agricultural disturbance. This research aims to characterize the habitat of the waterthrush in this heavily farmed ecoregion as well as investigate correlations between waterthrush occupation and habitat variables measured by standardized assessments. To do so, I attempted to determine their presence via a visual and aural search, conducted a macroinvertebrate survey according to Tennessee Department of the Environment and Conservation protocols (TDEC, 2017), and performed a forested riparian buffer width analysis at seven sites with a range of habitat degradation.

APPROACH

Seven stream reaches within the Western Pennyroyal Karst Plain (Passenger Creek, 4 Elk Fork Creek sites designated S1-S4, Buzzard Creek, and Calebs Creek) were selected for bioassessment, waterthrush survey, and riparian buffer width analysis. To perform the standardized macroinvertebrate survey, organisms were collected from two riffle sections within a ~100m reach of stream using a 500µm mesh, $1m^2$ kick net. Macroinvertebrates and associated debris were preserved in 70% isopropanol. Canopy cover, pH, conductivity, dissolved oxygen, and turbidity were measured. Habitat quality was scored by consensus between N.S. and colleagues assisting with the bioassessment. A subsample of 160-240 organisms were obtained from each sample to calculate biometrics (Taxa Richness, EPT [Ephemeroptera, Trichoptera, and Plecoptera] Richness, Percentage of EPTs minus *Cheumatopsyche*, Percentage of Oligochaetes and Chironomids, Percentage of Clingers minus *Cheumatopsyche*, and North Carolina Biotic Index) used to assess habitat quality.

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Waterthrush presence was determined concurrently or before the date of fieldwork. Presence was determined if waterthrush were seen or heard singing or calling adjacent to or along the ~100m reach used for sampling. If no waterthrush were observed, a second survey period was conducted. A single site (Elk Fork S4) where no waterthrush were detected during either the first or second observation attempt will be re-surveyed in March/April 2019.

Buffer analyses for each reach were performed in ArcMap. A 500m-radius circle was created approximately at the midpoint of macroinvertebrate sampling points to encompass at least one waterthrush territory, and habitat therein was used for analyses. Studies examining the size of a forested riparian buffer needed for riparian-associated songbirds vary from 25m (Chapman, Courter, Rothrock, and Reber, 2015) to >100m (Perry et al., 2011). Percentage of forest coverage was calculated for stream buffers 30, 50, and 100m wide.

PRELIMINARY RESULTS AND DISCUSSION

Waterthrush presence was observed on 6 sites out of 7, with waterthrush not detected on Elk Fork S4, the furthest downstream of the Elk Fork sites. On Elk Fork S1, a nest with young was found during macroinvertebrate sampling along a tributary confluent with the main stem of Elk Fork. Locations with similar conditions may also have the habitat characteristics necessary to support nesting and fledging. While waterthrush presence can indicate a site is suitable for an adult bird to occupy, further research is needed to investigate whether these or similar sections of habitat are suitable for rearing young, in addition to the importance of stream morphology in influencing habitat suitability for waterthrush. While macroinvertebrate and habitat quality results are pending, I predict to find that waterthrush presence will be positively associated with relatively high macroinvertebrate taxa richness and largely unimpacted habitat conditions.

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SEASONAL VARIATION IN THE INVERTEBRATE COMMUNITY OF RICHLAND CREEK

Lucia Berkey, Hannah Hitchcock, Anissa Jayathilake

Streams are a vital part of many ecosystems because they provide wildlife with habitats, act as a natural rain drain, and carry nutrients across different regions. Studying abiotic and biotic factors reveals the conditions and time of year in which certain organisms flourish as well as increasing understanding the health of the river. The abiotic factors (temperature, pH, illumination, nitrate, flow rate, dissolved oxygen, turbidity, and salinity) and invertebrate communities (e.g. flies, snails, crawfish, etc.) of Richland Creek (Nashville, Tennessee) were examined by collecting water samples and counting organisms every other week from January 31st to April 11th of 2018. A kick net was used to collect aquatic invertebrates, and a fly trap was used to attract and catch insects. A Principal Component Analysis (PCA) showed a correlation between the seasonal variation in abiotic factors and the abundance and variety of certain invertebrates in Richland Creek. The water quality samples collected in March showed the strongest relationship with biodiversity, with a correlation between worm counts and increased dissolved oxygen, pH, and turbidity while mollusk counts were positively associated with temperature. Caddisfly and crane fly counts served as the clearest indicator of seasonality as larvae stopped appearing in the stream, and began appearing in the fly trap as adults in later weeks. Understanding how seasonal changes affect the abundance and diversity of different invertebrates can help to better understand the health of ecosystems during varying seasons.

IMPACT OF EUTROPHICATION OF PIGEON ROOST CREEK ON THE COMPOSITION OF ALGAL ASSEMBLAGES

Jefferson G. Lebkuecher[1], Tsvetan M. Tsokov, Austin L. Shackelford,
Olivia N. Patrick, and James M. Mauney

ABSTRACT

Two stream sites were sampled in Pigeon Roost Creek which originates in Cookeville, Tennessee. One site was located upstream of the Cookeville Wastewater Treatment Facility and the other downstream. One stream site was sampled in Post Oak Creek which drains an agricultural region south of Cookeville. The concentration of total phosphorus of water from the Pigeon Roost Creek site downstream of the wastewater treatment facility was substantially greater relative to the concentration at the Pigeon Roost Creek site upstream of the facility and the Post Oak Creek site. The greater concentration of total phosphorus relative to total nitrogen at the Pigeon Roost Creek site downstream of the treatment facility resulted in a total nitrogen to total phosphorus ratio of 9.8, a value below the threshold hypothesized to result in nitrogen limitation of algae growth. Concentrations of benthic chlorophyll *a* at the Pigeon Roost Creek sites upstream and downstream of the treatment facility (61.7 ± 8.5 mg·m^{-2} and 58.9 ± 14.1 mg·m^{-2}, respectively), did not differ significantly, and were significantly greater than the concentration of chlorophyll *a* at the Post Oak Creek site (13 ± 1.1 mg·m^{-2}). Percent composition of 133 algae taxa were documented: 49 taxa of soft-bodied algae and 84 taxa of diatoms. Values for the algae trophic index for soft-bodied algal assemblages and values for the pollution tolerance index for diatom assemblages indicate that eutrophication of Pigeon Roost Creek between the upper and lower Pigeon Roost sites sampled changes the composition of both soft-bodied algal and diatom assemblages.

INTRODUCTION

Bioassessments that characterize and quantify the impacts of eutrophication are prerequisites to monitoring the efficacy of management practices designed to improve the integrity of nutrient-impaired waters (Smucker and Vis 2009). Algae are a major component of the trophic base of most shallow lotic systems and assemblage composition reflects habitat quality (Stancheva and Sheath 2016). The composition of algae assemblages of the majority of streams in the Interior Plateau Level III Ecoregion is unknown (Grimmett and Lebkuecher 2017). This lack of knowledge limits the ability of watershed managers to monitor changes of habitat quality. This work documents the composition of algal assemblages in Pigeon Roost and Post Oak creeks and is used to assess the impacts of eutrophication on habitat quality.

Pigeon Roost and Post Oak creeks are located in the Falling Water River Watershed which drains 49,496 ha of primarily the Eastern Highland Rim Level IV geologic base of the ecoregion is limestone and includes some chert, shale, siltstone, Ecoregion in the southeastern portion of the Interior Plateau Level III Ecoregion. The

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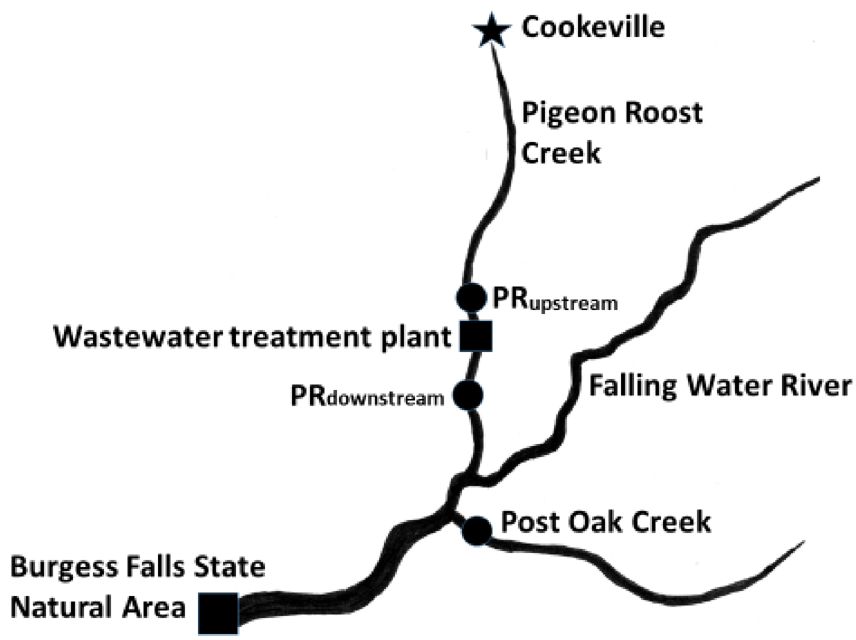
sandstone, and dolomite (Griffith et al. 1997). Mesophytic forest surrounds the watershed, much of which has been converted to row crops and cleared for livestock (TDEC 2017).

Pigeon Roost Creek originates in Cookeville, Tennessee, flows south approximately 18 km, drains 5,700 ha (TDEC 2017), and empties into the Falling Water River (Figure 1). The Cookeville Wastewater Treatment Facility discharges treated wastewater into the creek approximately 11 km south of the creek origin. The creek traverses residential areas in the upper portion of the watershed and agricultural areas below the wastewater treatment facility.

Post Oak Creek originates approximately 15 km southwest of Cookeville and flows west approximately 14 km. The creek drains 6,553 ha of mostly agricultural areas and empties into the Falling Water River approximately 2 km downstream of the confluence of Falling Water River and Pigeon Roost Creek.

Figure 1. Sites sampled (dark circles) in Pigeon Roost Creek upstream of the wastewater treatment plant ($PR_{upstream}$), Pigeon Roost Creek downstream of the wastewater treatment plant ($PR_{downstream}$), and Post Oak Creek.



APPROACH

Sampling date and site locations.

Three sites were sampled on July 12, 2018 (Figure 1). Two sites were sampled in Pigeon Roost Creek, one upstream of the Cookeville Wastewater Treatment Plant (WWTP) and one downstream. The Pigeon Roost Creek site upstream of the WWTP ($PR_{upstream}$) is located 1 km upstream of the WWTP at the end of Sliger Road (36.0686 latitude, -85.5014 longitude). The

Pigeon Roost Creek site downstream of the WWTP ($PR_{downstream}$) is located 2 km downstream of the WWTP, 0.2 km upstream of the bridge on Lovelady Road (36.0883 latitude, -85.5074 longitude), and approximately 2 km upstream of where the creek empties into Falling Water River. The Post Oak Creek site is located 0.1 km downstream of where Old Cookeville Lane crosses the creek (36.0683 latitude, -85.5094 longitude) approximately 1 km upstream of where the creek converges with the Falling Water River.

Field methods.

Reach morphological characteristics were determined as described by Lebkuecher et al. (2015) to provide a depiction of the abiotic characteristics of the sites sampled (Appendix 1). Water samples were collected at mid-stream 5 cm below the surface for determinations of nutrient concentrations. Cobble sampling to determine periphyton characteristics occurred in runs with velocities between 0.29 $m \cdot s^{-1}$ and 0.46 $m \cdot s^{-1}$ and at depths between 0.11 m and 0.42 m. Four plots at each of the three sites sampled were established with 0.25 m^2 wire frames placed approximately 1.25 m apart at midstream. Two cobbles nearest to the plot center between 12-cm and 18-cm diameter with most of the surface area for periphyton growth parallel to flow were removed. If a plot did not contain two cobbles appropriate for sampling, cobbles closest to the plot were removed. One cobble from each plot was used to determine the percent composition of soft-bodied algal and diatom taxa. Algae were removed from cobbles in the field using a single-edge razor blade and scrub brush. Algae removed from the four cobbles per site were combined, preserved in 1 % glutaraldehyde adjusted to pH 7.0 with NaOH. One cobble from each plot was used to determine pigment concentrations of algae and ash-free dry mass of benthic organic matter (AFDM). These cobbles were placed in self-sealable plastic bags and transported to the lab on ice in darkness. A multi-habitat sampling followed the methods described by Grimmett and Lebkuecher (2017) to identify additional algal taxa not found associated with the cobbles sampled to determine percent composition.

Laboratory methods and calculation of metrics and indices.

Concentrations of total phosphorus and total nitrogen of water samples were determined as described by Lebkuecher et al (2018). Methods to determine periphyton pigment concentrations and ash-free dry mass of benthic organic matter (AFDM) followed those described in Lebkuecher et al. (2015). Means for concentrations of chl *a* and AFDM were compared using Tukey-Kramer Honestly Significant Difference Tests preceded by Analysis of Variance Tests. Assay means were considered significantly different if they differed at the experimentwise-error rate of $\alpha = 0.05$.

Identification and enumeration of soft-bodied taxa and diatoms followed the methods described by Grimmett and Lebkuecher (2017). Shannon diversity index (H’) and evenness (J) of soft-algae and diatom assemblages were calculated by the equations of Shannon and Weaver (1949): Pairwise percent similarities of diatom and soft-algae assemblages associated with cobble were calculated as the sum of the smaller of the two percent-composition values for all taxa common to two sites (Whittaker and Fairbanks 1958). A percent-similarity value of 0 indicates that the two assemblages compared do not have a single taxon in common. A percent-similarity value of 100 indicates that the two assemblages compared have the exact same percent composition of taxa.

The Pollution tolerance index for diatom assemblages (PTI; KDOW 2008) was calculated as:

$$PTI = [\Sigma_{j=1\ sp.}\ n_j\ t_j]/N$$

where: n_j = number of individuals of taxon j, t_j = eutrophication-tolerance value (one to four; KDOW 2008) of taxon j, and N = total number of individuals assigned a eutrophication-tolerance value and tallied to calculate the index. The PTI ranges from one (all taxa very tolerant to eutrophic conditions) to four (all taxa very intolerant of eutrophic conditions). A value for the PTI $\leq$ 2.6 indicates an assemblage is impaired by eutrophic conditions as determined by comparisons of PTI values of stream sites with different trophic states in Middle Tennessee (Lebkuecher et al. 2011, Lebkuecher et al 2015, Grimmett and Lebkuecher 2017, Lebkuecher et al. 2018).

The organic pollution index (OPI) is the percentage of diatoms tolerant of organic Pollution listed in Kelly (1998). OPI values of $\geq$ 20 imply organic pollution impacts the composition of diatom assemblages and values > 40 imply the habitat is severely impaired by an excessive concentration of organic matter (Kelly 1998). The SI values range from 0 to 100. High SI values signify that sediments impact the structure of diatom assemblages. Belton et al. (2005) suggested that SI values near 40 indicate an impact of sediments on diatom assemblages.

The algae trophic index of soft algae assemblages (ATI) was calculated as:

$$ATI = [\Sigma_{j\ =\ 1\ taxon}\ n_j\ ti_j]/N$$

where: n_j = number of taxon units j sampled at a site, ti_j = trophic-indicator value for taxon j, and N = total number of taxon units at the sampling site used to calculate the index (Grimmett and Lebkuecher 2017). The trophic-indicator values are the abundance-weighted average of the concentration of benthic chl *a*, listed in Grimmett and Lebkuecher (2017). Taxa not identified to species were excluded from index calculations and included less than 10 % of the algae observed. ATI values for stream reaches studied by Grimmett and Lebkuecher (2017) were very similar to and significantly correlated with concentrations of benthic chl *a* ($mg{\cdot}m^{-2}$). Therefore, ATI values correspond with Dodds et al. (1998) suggested classification of temperate streams with chl-*a* concentrations $\leq$ 20 $mg{\cdot}m^{-2}$ as oligotrophic and concentrations $\geq$ 70 $mg{\cdot}m^{-2}$ as eutrophic.

RESULTS

Nutrient concentrations and periphyton biomass.

The concentration of TP of water from the Pigeon Roost Creek site downstream of the wastewater treatment plant ($PR_{downstream}$) was substantially greater relative to the concentration of TP of water from both the Pigeon Roost Creek site upstream of the wastewater treatment plant ($PR_{upstream}$) and the Post Oak Creek (PO) site (Table 1). Only the TP and TN concentrations at the $PR_{downstream}$ site were above the threshold used to designate stream sites as eutrophic as suggested by Dodds et al. (1998). The TN:TP ratio was lowest at the $PR_{downstream}$ site as a result of the much greater concentration of TP relative to TN compared to the $PR_{upstream}$ and PO sites.

Table 1. Concentration of total phosphorus (TP) and total nitrogen (TN) of water and periphyton characteristics from Pigeon Roost Creek upstream of the wastewater treatment plant ($PR_{upstream}$), Pigeon Roost Creek downstream of the wastewater treatment plant ($PR_{downstream}$), and Post Oak Creek. Means ± standard error for concentrations of chlorophyll *a* and ash-free dry mass of benthic organic matter represent four replicates and are not significantly different if they share the same letter at the experiment-wise error rate of alpha = 0.05.

Characteristic	$PR_{upstream}$	$PR_{downstream}$	Post Oak
TP ($\mu g \cdot L^{-1}$)	20	193	27
TN ($\mu g \cdot L^{-1}$)	1318	1900	1685
TN:TP ratio	65.9	9.8	62.4
Benthic chlorophyll *a* ($mg \cdot m^{-2}$)	61.7 ± 8.5 A	58.9 ± 14.1 A	13.1 ± 1.1 B
Ash-free dry mass of benthic organic matter($g \cdot m^{-2}$)	11.2 ± 2.7 A	5.7 ± 2.0 AB	2.6 + 0.5 B

Concentrations of benthic chlorophyll (chl) *a* were significantly lower at the PO site relative to the $PR_{upstream}$ and $PR_{downstream}$ sites (Table 1). The PO site was the only site which had chl *a* concentrations in the range used to designate streams as oligotrophic by Dodds et al. (1998). Although the $PR_{upstream}$ and $PR_{downstream}$ sites had > 2-fold concentrations of ash-free dry mass of benthic organics (AFDM) relative to the PO site, only the concentration of AFDM at the $PR_{upstream}$ site was significantly greater than the concentration at the PO site.

Composition of algal assemblages.

One hundred and thirty-three taxa of algae were identified: 49 taxa of soft-bodied algae (Appendix 2) and 84 taxa of diatoms (Appendix 3). The most abundant soft-bodied algae sampled (Table 2) was the filamentous Rhodophyta *Audouinella hermannii* (Roth) Duby (50.9 %) followed by the filamentous cyanobacterium *Leptolyngbya foveolarum* (Mont.) Anagn. and Komárek (15.0%) and the colonial Chlorophyta *Gloeocapsopsis pleurocapsoides* (Novacek) Komárek and Anagn. (8.2 %). The most abundant diatom sampled (Table 3) was *Achnanthidium rivulare* Potapova and Ponader (24.6 %) followed by *Psammothidium curtissimum* (Carter) Aboal. (7.5 %), and *Psammothidium* sp. (5.7 %).

All three sites had a much greater abundance of soft-bodied algal units relative to diatoms with the $PR_{downstream}$ site having the lowest percent of soft-bodied algal units (Table 4). Rhodophyta were the most abundant soft-bodied algal group at both Pigeon Roost sites, whereas Cyanobacteria were the most abundant soft-bodied algal group at the PO site (Table 5). Composition of soft-bodied algal and diatom assemblages differed dramatically between sites (Table 6). The most dissimilar assemblages of soft-bodied algae and diatoms were the assemblages at the $PR_{downstream}$ and PO sites.

Table 2. Most abundant soft-bodied algal taxa removed from cobbles in Pigeon Roost Creek upstream of the wastewater treatment plant ($PR_{upstream}$), Pigeon Roost Creek downstream of the wastewater treatment plant ($PR_{downstream}$), and Post Oak Creek. Numbers in parentheses represent percent composition.

$PR_{upstream}$	$PR_{downstream}$	Post Oak
Audouinella hermannii (51.2)	*Audouinella hermannii* (57.5)	*Audouinella hermannii* (44.1)
Leptolyngbya foveolarum (34.4)	*Phormidium articulatum* (10.7)	*Gloeocapsopsis pleurocapsoides* (20.7)
Gloeocapsopsis pleurocapsoides (3.5)	*Leptolyngbya foveolarum* (8.7)	*Heteroleibleinia kossinskajae* (11.2)
Lyngbya martensiana (2.4)	*Phormidium aerugineo-caeruleum* (3.8)	*Leptolynbya notatum* (10.9)
Oscillatoria subbrevis (1.7)	*Oedogonium* sp. (3.7)	*Leptolyngbya angustissimum* (4.0)

Table 3. Most abundant diatom taxa removed from cobbles in Pigeon Roost Creek upstream of the wastewater treatment plant ($PR_{upstream}$), Pigeon Roost Creek downstream of the wastewater treatment plant ($PR_{downstream}$), and Post Oak Creek. Numbers in parentheses represent percent composition.

$PR_{upstream}$	$PR_{downstream}$	Post Oak
Achnanthidium rivulare (38.9)	*Psammothidium curtissimum* (12.0)	*Achnanthidium rivulare* (23.8)
Amphora perpusilla (9.1)	*Achnanthidium rivulare* (11.2)	*Gomphonema brasiliense* (13.4)
Amphora veneta (7.8)	*Psammothidium* sp. (8.9)	*Cocconeis placentula* (9.9)
Psammothidium curtissimum (6.2)	*Platessa conspicua* (8.6)	*Achnanthidium minutissimum* (6.4)
Psammothidium sp. (5.2)	*Navicula minima* (7.2)	*Psammothidium curtissimum* (4.3)

Table 4. Percent total soft-bodied algal units and diatoms removed from cobbles in Pigeon Roost Creek upstream of the wastewater treatment plant ($PR_{upstream}$), Pigeon Roost Creek downstream of the wastewater treatment plant ($PR_{downstream}$), and Post Oak Creek.

	$PR_{upstream}$	$PR_{downstream}$	Post Oak
Soft-bodied algae	95.6	69.6	86.6
Bacillariophyceae (diatoms)	4.4	30.4	13.4

Table 5. Percent composition of soft-bodied algae groups removed from cobbles in Pigeon Roost Creek upstream of the wastewater treatment plant ($PR_{upstream}$), Pigeon Roost Creek downstream of the wastewater treatment plant ($PR_{downstream}$), and Post Oak Creek.

	$PR_{upstream}$	$PR_{downstream}$	Post Oak
Cyanobacteria	47.9	36.6	51.0
Chlorophyta	1.2	5.0	11.7
Rhodophyta	51.2	57.5	44.1

Table 6. Percent similarity of soft-bodied algae and diatom assemblages between sites in Pigeon Roost Creek upstream of the wastewater treatment plant ($PR_{upstream}$), Pigeon Roost Creek downstream of the wastewater treatment plant ($PR_{downstream}$), and Post Oak Creek.

	$PR_{downstream}$	Post Oak
Soft-bodied algae		
$PR_{upstream}$	65.9	52.0
$PR_{downstream}$		50.3
Diatoms		
$PR_{upstream}$	51.2	55.4
$PR_{downstream}$		47.4

Taxon richness of soft-bodied algal taxa associated with cobbles was greatest at the $PR_{downstream}$ site (Table 7). The $PR_{upstream}$ site had the lowest Shannon Diversity Index and evenness values. The low values for the Shannon diversity index for all of the soft-algal assemblages were due partially to low evenness values. The high values for the algae trophic index (ATI) suggest that the composition of soft-bodied assemblages at all the sites were affected by nutrient enrichment. The greatest value for the ATI at the $PR_{downstream}$ site indicates that this soft-bodied algal assemblage was most affected by eutrophication.

Taxon richness of diatoms associated with cobbles was greatest at the $PR_{downstream}$ site (Table 8). The $PR_{downstream}$ site had the greatest Shannon Diversity Index and evenness values. Greater values for the Shannon diversity index for the diatom assemblages relative to the soft-algae assemblages at the same sites (Table 7) are due largely to the greater evenness of the diatom assemblages. Values for the Pollution tolerance index for diatom assemblages (PTI) at the $PR_{upstream}$ and $PR_{downstream}$ sites were ≤ 2.6, which indicate eutrophic conditions, while the PTI value for the PO site indicates mesotrophic conditions. The lowest value for the PTI at the $PR_{downstream}$ site indicates that this diatom assemblage was most affected by eutrophication.

The low values for the organic Pollution index (OPI) for the diatom assemblages at all the sites were below the threshold values used to designate assemblages as impacted by organic pollution or siltation.

Table 7. Metrics and indices for soft-bodied algal assemblages at sites sampled in Pigeon Roost Creek upstream of the wastewater treatment plant ($PR_{upstream}$), Pigeon Roost Creek downstream of the wastewater treatment plant ($PR_{downstream}$), and Post Oak Creek.

	$PR_{upstream}$	$PR_{downstream}$	Post Oak
Taxon richness	22	24	18
Genus richness	14	12	12
Shannon diversity index	1.47	1.76	1.71
Evenness	0.48	0.55	0.59
Algae trophic index	99	115	95

Table 8. Metrics and indices for diatom assemblages associated with cobbles in Pigeon Roost Creek upstream of the wastewater treatment plant ($PR_{upstream}$), Pigeon Roost Creek downstream of the wastewater treatment plant ($PR_{downstream}$), and Post Oak Creek.

	$PR_{upstream}$	$PR_{downstream}$	Post Oak
Taxon richness	34	49	45
Genus richness	14	19	21
Shannon diversity index	2.48	3.14	2.90
Evenness	0.70	0.81	0.76
Pollution tolerance index	2.6	2.2	2.8
Organic Pollution index	4.1	10.0	2.9

DISCUSSION

Changes of natural concentrations of nutrients and TN:TP ratios as a result of anthropogenic activities may result in unnatural changes of algae composition and growth (Gobler et al. 2016). Values for the Algae Trophic Index (ATI) for soft-algae assemblages and the Pollution Tolerance Index for diatom assemblages (PTI) at the $PR_{downstream}$ site indicate the much greater concentration of TP at this site impacts the composition of algae assemblages. These index values indicate that eutrophication of Pigeon Roost Creek increases the relative abundance of taxa tolerant of eutrophic conditions.

The TN:TP ratio at the $PR_{downstream}$ site is just below the threshold value hypothesized to result in N limitation of algae growth. For example, N may be considered limiting when the TN:TP ratio is < 10 and by P when the TN:TP ratio is > 17 (Dodds 2003). The low TN:TP ratio at the $PR_{downstream}$ site may have precluded the potential for a significant increase of concentrations of benthic chl *a* at the $PR_{downstream}$ site. Of course environmental heterogeneity typical of streams, and thus variation in benthic concentrations of chl *a*, may have contributed to the absence of significant differences between sites.

The greater value for the ATI at the $PR_{downstream}$ site was due partially to the greater abundance of the filamentous Rhodophyte *Audouinella hermannii* and the filamentous Cyanobacterium *Phormidium articulatum*. Both *A. hermannii* and *P. articulatum* are assigned high trophic-indicator values for the ATI which indicate these taxa are abundant at eutrophic sites (Grimmett and Lebkuecher 2017). The lower values for the ATI at the $PR_{upstream}$ and PO sites are due partially to the lower abundances of *A. hermannii* and *P. articulatum* and the greater abundances of filamentous cyanobacterium *Leptolyngbya foveolarum* and the colonial cyanobacterium *Gloeocapsopsis pleurocapsoides*. Both *L. fovularum* and *G. pleurocapsoides* have relatively low trophic-indicator values for the ATI which indicate these taxa are abundant at mesotrophic and oligotrophic sites (Grimmett and Lebkuecher 2017).

The most abundant diatom taxa at each of the three sites, *Achnanthidium rivulare*, *Psammothidium curtissimum*, *Amphora perpusilla* Grun., and *Gomphonema brasilinense* Grun. are assigned eutrophication-tolerance values of 3 or 4 given they are common in oligotrophic and mesotrophic lotic systems (KDOW 2008). The lower abundance of *Achnanthidium* taxa at the $PR_{downstream}$ site is consistent with lower abundances of *Achnanthidium* taxa in other Middle Tennessee streams substantially impacted by nutrient enrichment and the characterization of this genus as less common in streams with poor quality water (Grimmett and Lebkuecher 2017)

The $\leq$ 2.6 values for the Pollution tolerance index (PTI) for diatom assemblages at the $PR_{downstream}$ and $PR_{upstream}$ sites are due partially to the high percentage of taxa tolerant of eutrophication which are not listed as the four most abundant including *Navicula minima* Grun., *Amphora veneta* **Kütz.**, and several *Nitzschia* sp. (Appendix 3). The low PTI values for the diatom assemblages at the $PR_{upstream}$ and $PR_{downstream}$ sites are similar to those of other stream sites in predominately agricultural and urban regions impaired by nutrient enrichment in Middle Tennessee. PTI values for stream sites in Middle Tennessee considered some of the most nutrient impaired range from 2.3 to 2.0, whereas PTI values for stream sites in Middle Tennessee considered reference sites with good water quality range from 2.8 to 3.0 (Lebkuecher et al. 2011, Lebkuecher et al. 2015, Grimmett and Lebkuecher 2017). The organic pollution index (OPI) values $\leq$ 20 for the diatom assemblages at the three sites are typical for most sites studied to date in Middle Tennessee (Lebkuecher et al. 2011, Lebkuecher et al. 2015, Grimmett and Lebkuecher 2017). However, OPI values well above 40 are common in reaches with very high concentrations of organics such as Elk Fork Creek in the Red River Watershed in northern Middle Tennessee (Lebkuecher et al. 2011) and Jones Creek downstream of the Jones Creek Wastewater Treatment Plant near Dickson, Tennessee (Grimmett and Lebkuecher 2017).

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Appendix 1. Morphological characteristics (mean ± SE) of reaches sampled in Pigeon Roost Creek upstream of the wastewater treatment plant ($PR_{upstream}$), Pigeon Roost Creek downstream of the wastewater treatment plant ($PR_{downstream}$), and Post Oak Creek.

Characteristic	$PR_{upstream}$	$PR_{downstream}$	Post Oak
Discharge ($m^3 \cdot s^{-1}$)	0.44 ± 0.02	0.70 ± 0.02	0.31 ± 0.02
Width (m)	6.2 ± 0.2	6.9 ± 0.1	5.3 ± 0.2
Depth (m)	0.2 ± 0.6	0.3 ± 0.1	0.2 ± 0.1
Velocity ($m \cdot s^{-1}$)	0.37 ± 0.01	0.44 ± 0.2	0.31 ± 0.02
Benthic substrate < 64 mm (%)	36 ± 2	19 ± 2	30 ± 4
Canopy angle (degrees)	90	90	80

Appendix 2. Percent composition of soft-bodied algal taxa removed from cobbles in Pigeon Roost Creek upstream of the wastewater treatment plant ($PR_{upstream}$), Pigeon Roost Creek downstream of the wastewater treatment plant ($PR_{downstream}$), and Post Oak Creek. Additional taxa identified by multi-habitat sampling are listed as present (P).

	$PR_{upstream}$	$PR_{downstream}$	Post Oak
Chlorophyta			
Chlamydomonas gloeogama Korschikov			P
Cladophora glomerata (L.) Kütz.		P	2.4
Gloeocystis vesiculosa Nägeli	0.8	0.4	2.2
Oedogonium sp.		3.7	
Ulothrix aequalis Kütz.		0.9	
Ulothrix sp.	0.4		0.5
Cyanobacteria			
Borzia trilocularis Cohn.			P
Chamaesiphon incrustans Grunrow		1.8	P
Chroococcus minor (Kütz.) Nägeli	0.6		
Chroococcus sp.	0.1		

Dactylococcopsis raphidioides Hansg.			0.1
Entophysalis rivularis			
Gloeocapsa aeruginosa (Carm.) Kuetzing	0.2		
Gloeocapsopsis cyanea (Krieg) Komárek and Anagn.	0.6	0.2	
Gloeocapsopsis pleurocapsoides (Novacek) Komárek and Anagn.	3.5	0.5	20.7
Heteroleibleinia kossinskajae (*Elenkin*) *Anagn. and Komárek*	0.1	1.0	11.2
Hydrococcus rivularis Kütz	0.1		
Komvophoron munitum (Skuja) Anagn. and *Komárek*	0.4		
Komvophoron **schmidlei (Jaag.) Anagn. and Komárek**		P	
*Leptolyngbya angustissimum (*West and West) Anagn. and Komárek	0.5	1.1	4.0
Leptolyngbya foveolarum (Mont.) Anagn. and Komárek	34.4	8.7	1.9
Leptolyngbya nostocorum (Bomont.) Anagn. and Komárek	P	1.6	0.4
Leptolynbya notatum (Schmidle) Anagn. and Komárek	P	P	10.9
Leptolyngbya sp.	P	P	P
Lyngbya major Menegh.	P		
Lyngbya martensiana Menegh.	2.4		
Microcystis incerta Lemmerm.		0.5	0.3
Oscillatoria angusta Koppe			0.3
Oscillatoria sp.	P	0.4	
Oscillatoria subbrevis Schmidle	1.7	0.5	
Oscillatoria subtilissima Kütz. and De Toni		0.4	
Oscillatoria tenuis var. *natans* Gomont			0.1
Phormidium aerugineo-caeruleum (Gomont) Anagn. and Komárek		3.8	
Phormidium articulatum (Gardner) Anagn. and Komárek	1.4	10.7	0.3
Phormidium autumnale Gomont		1.8	
*Phormidium formosum (*Bory) Anagn. and Komárek		0.8	
Phormidium fragile Gomont	0.5	0.5	
Phormidium incrustatum Gomont		0.9	
Phormidium retzii (C. Agardh) Gomont	0.2		
Phormidium sp.	0.5	1.3	0.1
Phormidium tenue (C. Agardh) Anagn. and Komárek	0.5	1.0	0.2
Spirulina sp.			P
Synechococcus aeruginosus Nägeli	0.1	0.1	
Synechococcus sp.	0.1	P	0.5
Synechocystis sp.	P	P	P
Cryptophyta			
Cryptomonas erosa Ehrenb.	P		
Euglenophyta			

Euglena sp.	P		
Ochrophyta			
Vaucheria sp.	P		
Rhodophyta			
Audouinella hermannii (Roth) Duby	51.2	57.5	44.1
Compsopogon coeruleus (Balbis) Montagne		P	

Appendix 3. Percent composition of diatom taxa removed from cobbles in Pigeon Roost Creek upstream of the wastewater treatment plant ($PR_{upstream}$), Pigeon Roost Creek downstream of the wastewater treatment plant ($PR_{downstream}$), and Post Oak Creek. Additional taxa identified by multi-habitat sampling are listed as present (P).

	$PR_{upstream}$	$PR_{downstream}$	Post Oak
Achnanthidium deflexa Reimer	2.6	0.5	0.3
Achnanthidium eutrophilum Lange-Bert.			0.3
Achnanthidium exiguum (Grun.) Czarnecki			0.5
Achnanthidium latecephalum Kobayasi		2.2	
Achnanthidium minutissimum (Kütz.) Czarn.	2.6	3.3	6.4
Achnanthidium rivulare Potapova and Ponader	38.9	11.2	23.8
Achnanthidium sp.	3.4	5.5	4.3
Amphora normanii Rabenh.			P
Amphora perpusilla Grun.	9.1	1.7	2.4
Amphora sp.		0.2	
Amphora veneta **Kütz.**	7.8	6.2	2.9
Anomoeonesis sphaerophora (Ehrenb.) Pfitzer		0.2	
Anomoeonesis sp.		0.2	
Cocconeis placentula Ehrenb.	0.5	1.0	9.9
Cocconeis placentula var. lineata Ehrenb.	0.5	P	0.3
Craticula halophila (Grun.) G. D. Mann		P	
Cymatopleura solea (Bréb. and Godey) W. Sm.	0.5		0.3
Cymbella affinis Kütz.			0.3
Cymbella ancyli Cleve			0.3
Encyonema appalachianum Potapova	1.0	1.0	0.3
Encyonema silesiacum (Bleisch) Mann			0.3
Facallia subhamulata (Grun.) D. G. Mann		0.2	
Frustulia vulgaris (Thwaites) De Toni			0.3
Gomphoneis olivacea (Horn.) Daws.	0.5		
Gomphonema angustatum (Kütz.) Rabenh.	P	0.2	
Gomphonema brasiliense Grun.	1.6	1.0	13.4
Gomphonema gracile Ehrenb.	0.3		
Gomphonema minutum Ag.	0.8	0.2	1.1
Gomphonema parvulum (Kütz.) Kütz.		0.2	
Gomphonema pumilum (Grun.) Reich.			

and Lange-Bert.		0.2	0.3
Gomphonema sphaerophorum Ehrenb.	P		0.3
Gyrosigma acuminatum (Kütz.) Rabenh.	P		
Gyrosigma scalproides (Rabenh.) Cleve		1.0	
Halamphora montana (Krasske) Levkov		P	
Karayeva clevei (Grun.)	0.3		
Karayeva clevei var*. rostrata* Hust.			0.3
Melosira varians Ag.		1.4	1.1
Navicula capitatoradiata Germ.	0.3	0.2	0.8
Navicula cryptotenella Lange-Bert.	2.6	2.2	3.2
Navicula gregaria Donk.		P	
Navicula lanceolata (Ag.) Ehrenb.			0.3
Navicula menisculus Schum.		0.2	0.5
Navicula menisculus var*. upsaliensis* (Grun.) Grun.	0.3		
Navicula minima Grun.	2.6	7.2	2.7
Navicula radiosa var. *tenella* (Breb.) Grun.		0.2	
Navicula reichardtiana Lange-Bert.	0.3		P
Navicula rhynchocephala Kütz.	0.3	0.2	
Navicula sp. (< 12 µm length)	0.8		
Navicula sp. (> 12 µm length)		1.0	1.1
Navicula symmetrica Patr.		0.2	
Navicula tenelloides Hust.			
Navicula tripunctata (O. F. Müll.) Bory	3.4	0.5	1.6
Navicula trivialis Lange-Bert.			0.3
Navicula veneta **Kütz.**	0.3		
Navicula viridula (Kütz.) Ehrenb.	P	1.2	0.8
Neidium binode (Ehren.) Hust.			P
Nitzschia capitellata Hust.		0.5	1.3
Nitzschia constricta Kütz.		0.7	
Nitzschia dissipata (Kütz.) Grun.		4.5	0.5
Nitzschia frustulum (Kütz.) Grun.	0.5		
Nitzschia inconspicua Grun.		0.7	
Nitzschia minuta Bleisch		0.7	
Nitzschia palea (Kütz.) W. Sm.	0.3	1.2	P
Nitzschia perminuta (Grun.) M. Perag.	0.5		
Nitzschia sociabilis Hust.		1.4	
Nitzschia sp.		2.9	1.3
Nitzschia tubicola Grun.			P
Planothidium haynaldii (Schaarschmidt) Lange-Bert.		P	
Planothidium lanceolatum Bréb.			1.6
Planothidium lanceolatum var*. dubia* Grun.		0.5	2.9
Platessa conspicua (A. Mayer) Lange-Bert.	1.3	8.6	
Psammothidium curtissimum (Carter) Aboal	6.2	12.0	4.3
Psammothidium levanderi (Hust.) L. Bukht. and Round	1.0	0.2	
Psammothidium subatomoides Hust.	0.3		
Psammothidium sp*.*	5.2	8.9	3.2
Pseudostaurosira trainorii Morales		0.7	1.6

Reimeria sinuata (Greg.) Kociolek and Stoermer			0.5
Rhoicosphenia abbreviata (C. Agardh) Lange-Bert.	2.3	2.4	0.3
Rossithidium lineare (Smith) Round and Bukhtiyarova			0.3
Sellaphora seminulum (Grun.) D. G. Mann.	1.8	1.7	1.3
Stephanodiscus parvus Stoermer and Hakansson		0.2	
Surirella angusta Kütz.			P
Surirella brebissonii Lange-Bert. and Krammer	P	0.5	
Surirella sp.		0.2	
Ulnaria sp.			0.3
Ulnaria ulna (Nitzsch) Compère			0.3

POTENTIAL TECHNIQUES FOR IMPROVING ANALYSIS OF AND RESPONSE TO HARMFUL ALGAL BLOOMS

Gerald A. Burnette[1]

Harmful Algal Blooms (HABs) are increasing in both frequency and intensity. Because of this, organizations that manage reservoirs face new pressures to address identification and notification of HAB occurrences. The desire to improve responses to these requirements is driving some organizations to revisit their procedures related to algal testing. Proper analysis of and response to HABs may require approaches that are different from those used for traditional phytoplankton analysis. The time-critical nature of HAB response means faster and more efficient analytical techniques become essential to meeting the new constraints. The US Army Corps of Engineers (USACE) manages many reservoirs, and in this context is evaluating best practices related to HAB management. A primary objective is to identify those techniques that show the most promise, and incorporate these into existing programs and projects that involve potential HABs. An additional objective is to incorporate these practices into existing software used for managing water quality data. This paper will present the direction and initial results of this investigation.

BACKGROUND

The missions of many USACE Districts include monitoring of water quality in reservoirs. For those Districts, HABs have become an increasingly important concern. Some of these Districts have joined with other government agencies (both federal and state) and/or universities in projects that attempt to better understand the causes of HABs and develop new approaches to algal monitoring that may improve HAB responses. Within USACE, an informal group has organized to share and discuss results of these projects and other research information. A primary goal of the group is to create a catalog of best practices and establish a common set of tools and techniques for HAB management. Another goal – albeit an ambitious one – is to strive for the ability to recognize conditions favorable for HABs in order to improve assessment and response.

Participants in this informal group all use the Data Management and Analysis System for Lakes, Estuaries, and Rivers (DASLER) for managing water quality data. Any data pertinent to algal monitoring is already stored in DASLER, so any tools and techniques identified by the group may be incorporated into DASLER so that all Districts gain from the group's experience.

SPECTRAL ANALYSIS

USACE participated with the University of Cincinnati, the US Environmental Protection Agency (EPA), and other agencies in a study to assess methods of using satellite and other spectral imagery to determine the presence of certain algae. The study used concurrent satellite and fly-over data to generate composite hyperspectral images. Simultaneously collected grab samples

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were used for validation and comparison, and laboratory water quality analysis results were used for method calibration. Several avenues for use of spectral analysis were explored, including

$ estimating chlorophyll-a values,
$ estimating turbidity,
$ estimating cyanobacteria concentrations,
$ estimating phycocyanin values, and
$ estimating cyanobacteria total biovolume.

The project involved two USACE-managed reservoirs in Ohio: William Harsha Lake, and Taylorsville Lake. The study examined several established algorithms for estimating various pertinent algal measures from imagery. Estimates derived from computation were compared to in situ observations in order to assess algorithm performance. A number of algorithms performed well. This suggests that computational methods for algal presence and concentration based on increasingly available imagery may provide acceptable screening-level assessments without the need for intensive physical monitoring.

USE OF MULTI-PARAMETER PROBE DATA

Another idea being discussed is the use of multiparameter probe data for algal analysis. Many such devices include the option to report algal concentrations in cells/ml. These results are generally calculated in the device by measuring relative fluorescence (in RFUs) and then using a conversion factor. The most common conversion factor in use is for *Microcystis aeruginosa*. A suggested better approach, however, is to use only the raw relative fluorescence readings and organism-specific conversion factors. This approach requires site-specific algal sample collection and analysis to determine dominant organisms for calibration. Organism-specific factors have been determined for conversion from RFUs to concentration. After calibration, probe data may then be used as a screening-level assessment for organism-specific estimates of concentration.

IMPROVING HISTORIC DATA

Much can be learned by examining results from past phytoplankton sampling events, but concerns have been expressed over the reliability of techniques previously used to calculate algal biovolume. Some laboratories have in the past provided biovolume results by applying standard, organism-specific conversion factors to density results. Density results, however, are inherently tied to the process of counting cells. Human factors associated with cell counting techniques may lead to observational biases, particularly for colonial or filamental species. Determining the number of actual cells in a colony, filament, or fragment may be as much art as science. As the body of research on algal communities expands, statistical measures of organism-specific aggregation characteristics are becoming more widely available and accepted. An interest is developing in applying probablistic techniques to conversion factors to assess the likelihood of biovolume determination errors in past results. Analysis that includes comparing a range of new determinations to previously-reported values may provide insight into improving estimates.

PREDICTIVE “MODELING”

It may never be possible to predict HABs. There is much we do not yet know or understand about the interaction of factors that produce a bloom. One goal that seems achievable, however, is comparison of conditions to those that produced HABs in the past. Cataloging the occurrence of past HABs in a reservoir and combining that with observed water quality conditions in the same time frame should give us the ability to at least generate preliminary warnings. Such warnings should not claim that a HAB is imminent, but rather should only signify that current conditions in the reservoir show similarities to conditions in the past that produced a HAB. This results in a very basic analysis similar to those provided by more complex water quality or biological community models. Like those models, some degree of calibration would be required. Once implemented, though, this could offer a tool that at least provides anticipatory feedback.

HOW DO YOU MEASURE A YEAR IN THE LIFE? EXAMINING ECOSYSTEM-WIDE RESPONSES TO ANNUAL SENESCENCE OF INVASIVE HYDRILLA IN UPLAND STREAMS OF THE CUMBERLAND PLATEAU

Sandra Bojić[1]*

INTRODUCTION

Aquatic macrophytes are essential to the structure and function of freshwater ecosystems. In addition to creating a heterogenous habitat, macrophytes with annual growth generally influence nutrient availability in the water between periods of growth when they act as nutrient sinks and senescence when they act as nutrient sources[1]. This natural process can have profound effects on native communities where a non-native macrophyte has invaded and successfully colonized as no evolutionary relationship exists between a native community and its exotic invader. Monoecious hydrilla (*Hydrilla verticillata*) is a submerged aquatic macrophyte native to the Eastern Hemisphere. It is among the most aggressive non-native species as it grows quickly and profusely, successfully smothering the benthos of both lentic and lotic systems. In contrast to the dioecious biotype which occurs as a perennial, monoecious hydrilla (m-hydrilla) experiences annual growth characterized by winter senescence of shoots, giving it the potential to alter algal and associated invertebrate communities in response to nutrient and detritus influx. M-hydrilla was discovered growing in tributaries and the mainstem of the Emory River, a relatively high-quality stream system of eastern Tennessee, in 2004[2].The establishment of the species in this stream system is unique as it normally occurs in lentic and lower quaility habitats. The Emory River system features high diversity of aquatic biota, including many endemics, and is partially protected federally by its designation as a Wild and Scenic River. Considering the extent of diversity in this region, the invasion of m-hydrilla is a serious concern, and understanding its spatial and temporal effects on river biota is crucial. This study examines the effects of growing and senescent seasons on dissolved nutrients, algal colonization, and macroinvertebrate communities.

APPROACH

Study sites were chosen based on status of m-hydrilla for a total of seven sites: four hydrilla and three non-hydrilla sites. Field sampling took place during the peak in m-hydrilla's growing season in late-summer and immediately following senescence of shoots in late-fall[3]. Water samples of 100 mL were collected in duplicate from each site and during each season and analyzed for soluble reactive phosphorous (SRP) and nitrates/nitrites. Randomly chosen cobbles were collected from each site and sampled for periphytic growth via fluorometry. Macroinvertebrates were collected via kicknet, preserved in isopropanol, identified in the lab to genus-level or lowest possible taxonomic unit, and categorized into functional feeding groups (FFG). Genera and FFGs were analyzed for richness, Shannon's diversity, %EPT, %OC, biotic integrity, and Morisita's Index of Community Similarity.

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RESULTS AND DISCUSSION

The growing season showed a trend of higher SRP concentrations at all sites, while the senescent season showed a trend for higher nitrate/nitrite concentrations for all sites but one (Rhea Road; non-hydrillla site); however, these concentrations were not significantly different between hydrilla and non-hydrilla sites. Chlorophyll *a* concentrations representing periphytic algal growth followed phosphorous trends and were significantly higher at hydrilla sites during the growing season than during the senescent season or during either season at non-hydrilla sites. Processing of macroinvertebrate samples is ongoing.

We propose that the seasonal fluctuations of water levels in this river system shift the normal process of nutrient release and absorption from an annual occurrence to one dependent on water level fluctuations. The Obed River system is characterized by higher water levels during the winter senescent season than the summer growing season, with a high degree of interseasonal fluctation as well. Hydrilla growing in the littoral zone may become removed from the water upon water level retreat, causing dessication and senescence during the growing season and becoming a nutrient source following rewetting after a rain event. This is seen in the literature[4] but is not extensively studied, and its implications for river biota is still unknown. Once completed, FFG analysis will contribute to our understanding of effects to aquatic macroinvertebrates. Future studies may investigate nutrient concentrations before and after rain events as well as changes to community assemblages of both periphyton and phytoplankton during these river upsets.

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DEVELOPMENT OF AN ANAEROBIC MEMBRANE BIOREACTOR FOR THE TREATMENT OF RECALCITRANT BIOFUEL PROCESS WASTEWATER

Lu Yang[1*], Young Chul Choi[2], Gyu Dong Kim[2], Qiang He[1,3]

Pyrolysis of lignocellulosic biomass is one of the options to produce biofuel as a renewable source of energy. The process wastewater from the catalytic pyrolysis of biomass contains a significant amount of soluble organic carbon, with the COD of such wastewater frequently exceeding 15,000 mg/L. The high organic content of the process wastewater presents an opportunity to recover energy using technologies such as anaerobic digestion. However, microbial activities underlying the anaerobic digestion processes could be hindered by the toxicity of certain wastewater constituents, including heterocycles, phenolics, and cycloalkane, as well as the high acidity of this type of wastewater. A laboratory-scale anaerobic membrane bioreactor (AnMBR) was developed to enrich microbial biomass both resistant to the toxicity and capable of converting the organics into methane. With the gradual increase in organic loading of the process wastewater, the AnMBR was able to remove >99% of COD loading with stable biogas production, which coincided with the dominance of *Methanobacterium*, suggesting the functional importance of hydrogenotrophic methanogenesis in the anaerobic metabolism of the wastewater organics. Other methanogen populations, including *Methanosaeta* and *Methanomassiliicoccus*, were also found at significant levels in the AnMBR, indicative of the need for functional diversity to support the degradation of diverse organic constituents in the process wastewater. More importantly, the prevalence of multiple syntrophic bacteria (*Syntrophaceticus*, *Syntrophobacter*, *Syntrophomonas*, *Syntrophorhabdus*, and *Syntrophus*) demonstrates the importance of syntrophic interactions in anaerobic treatment.

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MICROBIAL COMMUNITY STRUCTURE AND STABILITY DURING OPTIMIZATION OF A FULL-SCALE BIOLOGICAL NUTRIENT REMOVAL PROCESS

Grace McClellan[1] and Tania Datta[2]

Introduction

As regulatory limits on nutrient discharge from wastewater treatment plants (WWTP) become more stringent, optimizing the secondary treatment process, rather than building new infrastructure, is gaining popularity as being more cost-effective (USEPA, 2015). This is especially true for facilities operating oxidation ditches. Biological nutrient removal (BNR) is commonly the focus of such optimizations. While a conventional BNR process is typically accomplished through multiple reactors, unconventional implementations of BNR, such as modifying the aeration pattern of a single oxidation ditch to incorporate a dissolved oxygen (DO) gradient that enables simultaneous nitrification, denitrification, and enhanced biological phosphorus removal (EBPR), have emerged. As an emerging practice, not many studies have investigated the process stability and associated microbiology of an optimized oxidation ditch. Therefore, factors leading to long-term stability have yet to be established. Investigating these factors that contribute to the structure, function, and stability of the BNR microbial community could contribute to reliable optimizations. Furthermore, there is a knowledge gap in the understanding of microbial structure and function in unconventional BNR processes, especially with regards to polyphosphate accumulating organisms (PAOs) and other novel microorganisms who perform BNR (Camejo et al., 2016; Stokholm-Bjerregaard et al., 2017). For example, current knowledge states that PAOs are typically found in high abundance in WWTPs designed for EBPR with separate anaerobic, anoxic and aerobic reactors. Very few studies have investigated their role in a full-scale, non-EBPR facility, even when found in relatively high abundance (Mehlig et al., 2013). Therefore, this study aims to elucidate how BNR-relevant microbial community structure and function adapt to optimizations in oxidation ditches, and if and how this influences the process stability over time.

METHODOLOGY

In 2015, the City of Cookeville, Tennessee’s WWTP began optimizing its secondary treatment process to determine the extent of effluent nutrient limits that were achievable without the addition of chemicals or building new infrastructure. Originally designed for BOD_5 and ammonia removal, the WWTP aimed to integrate simultaneous nitrification, denitrification, and phosphorus removal (SNDP) into its existing process. In order to accommodate SNDP, modifications were made to alter the brush aeration patterns of the WWTP’s oxidation ditches to generate a DO gradient both laterally and vertically, resulting in anaerobic, anoxic, and oxic environments within a single ditch. This was done by alternating between pairs of brush aerators every four hours, instead of operating all six brush aerators concurrently (Figure 1).

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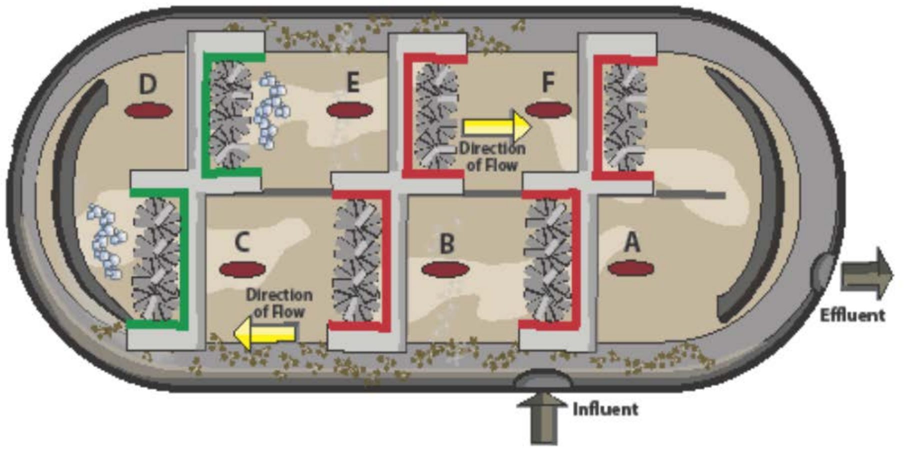

Figure 4 - Aerial schematic of an oxidation ditch at City of Cookeville's WWTP during sampling events. The green lines indicate the pair of brush aerators in operation during sampling, while the red lines indicate those that were not in operation. Red dots ( ) represent sampling locations. Samples were collected from the surface and the bottom of the ditch.

We investigated the stability of the aforementioned process optimization by monitoring the microbial community and wastewater characteristics over a course of three years. Samples were collected from the same oxidation ditch every summer and winter since microbial activity can shift in response to temperature changes. Dissolved oxygen was measured in order to determine sampling locations within the ditch. Due to the DO gradient, samples were collected from various locations throughout the ditch, including different depths (Figure 1). Samples were analyzed for ammonia, nitrate, total nitrogen, orthophosphorus, total phosphorus, COD, VFA, MLSS and MLVSS. Nutrients and COD were measured using HACH Test N Tube kits and VFA concentrations were measured by gas chromatography. Solids were measured following Standard Methods (APHA et al., 2012). Batch tests were also performed to determine phosphorus release and uptake rates of the microbial community in the activated sludge.

Whole genomic DNA was extracted from all unfiltered samples collected from the oxidation ditch. Amplicon sequencing of the v4 region of the 16s rRNA gene was carried out on Illumina's MiSeq platform. Amplicon processing was performed using the bioinformatics tool, Mothur, and taxonomy was assigned using the Microbial Database for Activated Sludge (MiDAS). Primer-E and IBM-SPSS were utilized for statistical and diversity-based analyses.

RESULTS AND DISCUSSION

The DO gradient generated from City of Cookeville's process optimization was successful in creating anaerobic, anoxic, and oxic environments in a single oxidation ditch. As seen in Figure 2, the wastewater characteristics during a single sampling event varied throughout the ditch. In sampling locations with lower DO concentrations, ammonia and orthophosphorus concentrations were elevated and nitrate concentrations decreased, while the inverse occurred for the locations with higher DO concentrations. The wastewater characteristics for the overall facility, depicted in Figure 2, also indicate successful SND.

A.)

	WWTP Influent	WWTP Effluent	% Removal
Total COD	261	21	92.0
Soluble COD	54	20	63.0
Ortho P	3.2	1.7	46.9
Total P	4.3	1.8	57.7
Ammonia	8.7	0.3	96.6
Nitrate	3.2	0.5	84.4
Total N	28.0	1.3	95.4

B.)

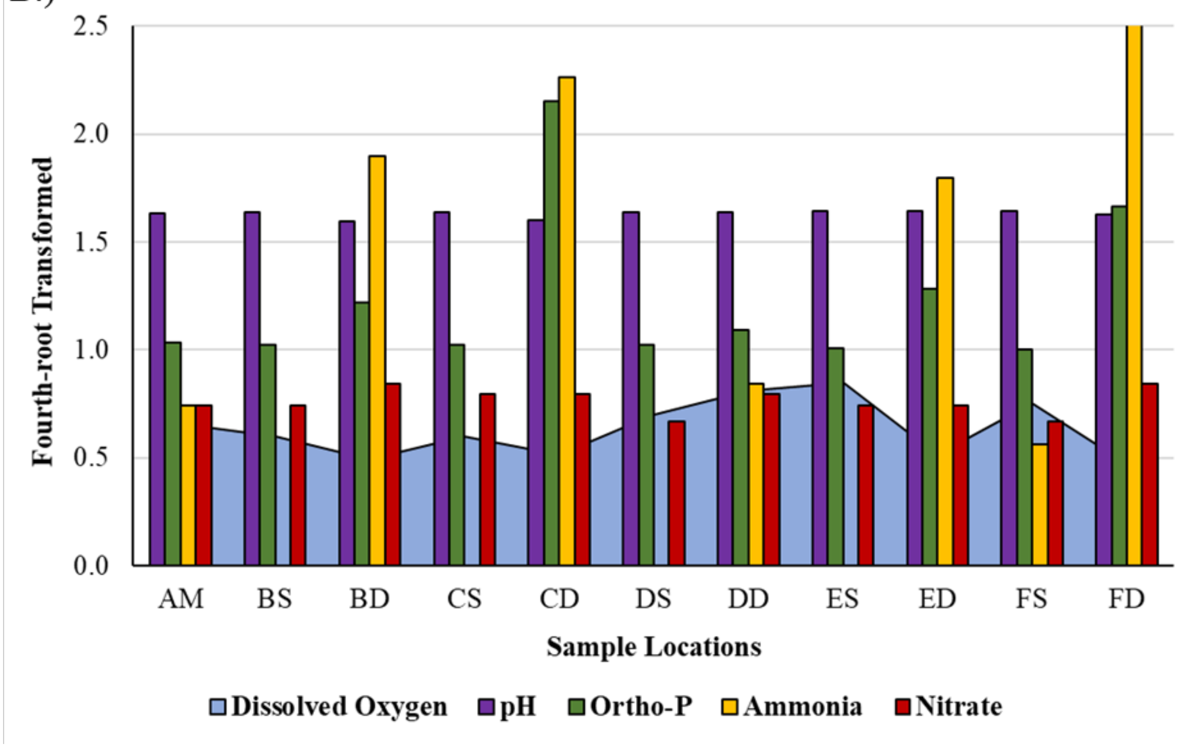

Figure 5 – Wastewater characteristics for a summer sampling event post-optimization: a.) the facility's influent and effluent and b.) the oxidation ditch.

The BNR-relevant microbial community was comprised of roughly 70% denitrifiers and PAOs both before and after optimization. In addition, we observed around 50% total nitrogen removal during winter sampling events, and around 90% during the summer. This could indicate that activated sludge employed for BOD_5 and nitrification can be exploited for BNR and that the microorganisms necessary for nutrient removal may naturally reside in the activated sludge but require the proper environment to perform BNR functions. Furthermore, the denitrifiers showed a significant increase in diversity over time, suggesting optimization resulted in a more resilient denitrifying community. As seen in Figure 3, prior to optimization, the denitrifying community was mostly comprised of three genera. Over the course of sampling, the relative abundance of the rarer genera increased, especially during Summer 2016 and Summer 2017, which is noteworthy because the summer months were also when we observed the highest total nitrogen removal. Interestingly, a relatively high abundance of PAOs were also detected, even prior to optimization. More specifically, *Candidatus* Accumulibacter phosphatis were ranked among the top ten genera of the activated sludge community, which is intriguing considering Cookeville WWTP is not designed for EBPR. The detection of PAOs before and after process modification suggests this group may have a larger role in the activated sludge community than removing phosphorus.

The microbial community composition between sampling events was distinct, for both the total community and the BNR-relevant community. As seen in Figure 4, the green circles indicate samples that are significantly similar in community membership; most samples were grouped together by event. However, the figure also depicts the Summer 2016 and Summer 2017 sampling events as overlapping, meaning the BNR-relevant communities shared similarities in regards to membership, a trend that may indicate stabilization of community structure. If the BNR community structure has stabilized, this could support optimization to possibly be a reliable practice. Results from additional sampling of Cookeville's WWTP will be presented at conference. Furthermore, two other WWTPs in TN that did not undergo optimization were investigated for comparison. Results comparing all three WWTPs will also be presented at conference.

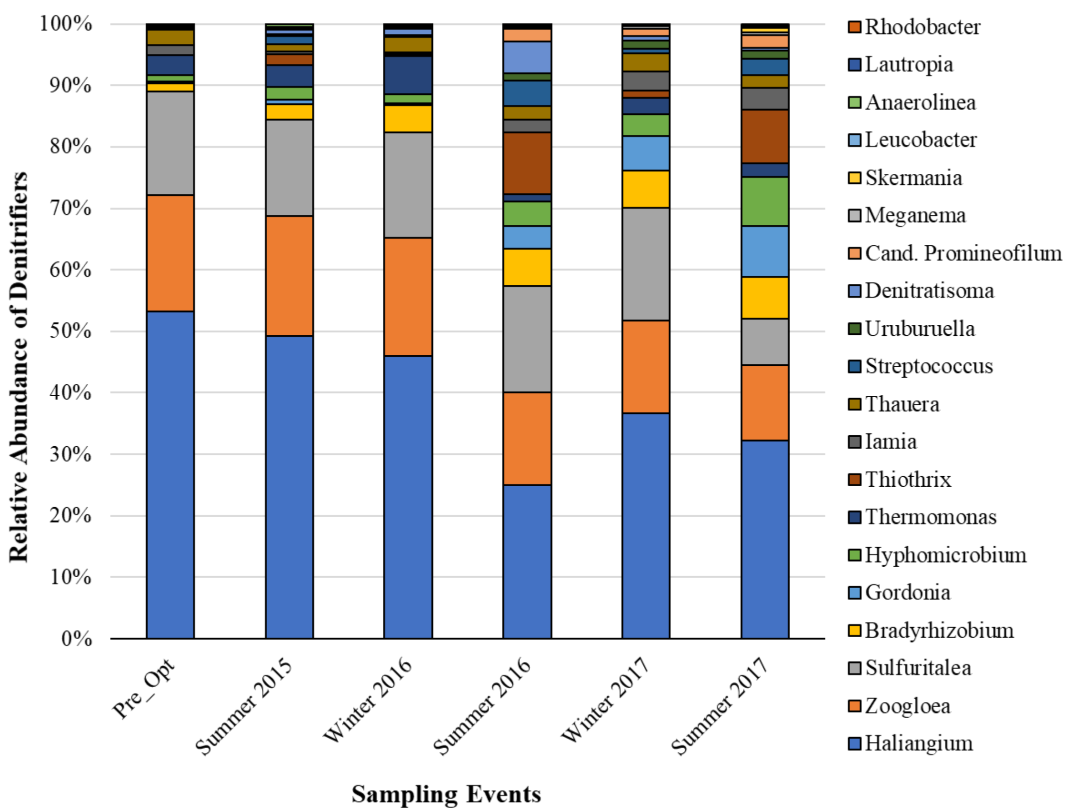

Figure 3 - Relative abundance of denitrifying genera for each sampling event

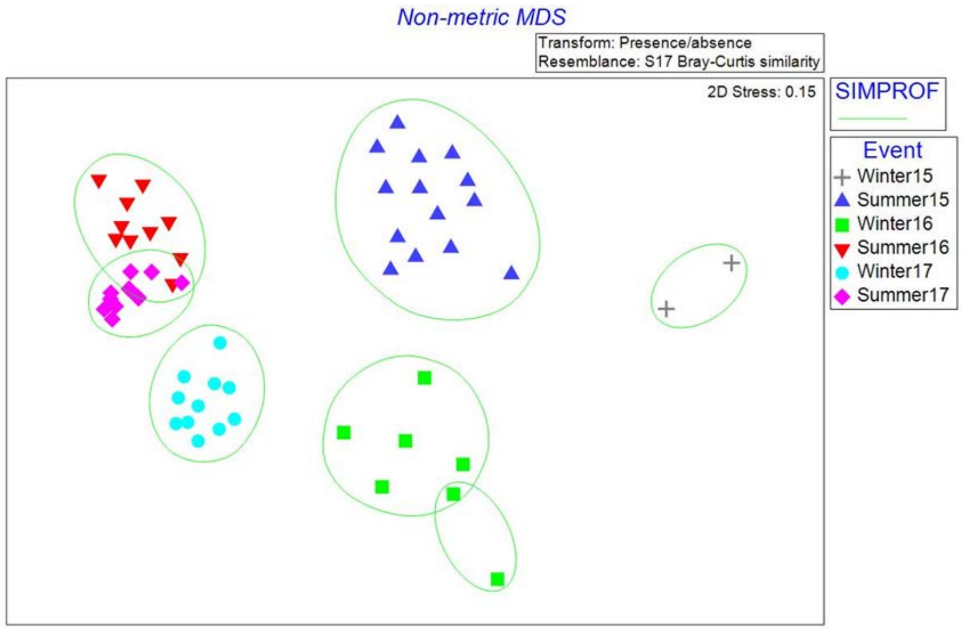

Figure 4 – NMDS of the BNR-relevant microbial community (Jaccard Transformed)

CONCLUSION

The WWTP of Cookeville, TN has shown that an oxidation ditch can be modified to achieve unconventional BNR. However, the long-term process stability of this optimization needs to be thoroughly investigated and compared to the stability of other designed treatment processes. This research emerged from a unique opportunity to study the microbial communities of a common secondary treatment process as it underwent modifications to be operated in an atypical way and the results could contribute to establishing process stability. Therefore, the information gathered could further validate optimization as a potential sustainable practice, which could afford small to medium-sized WWTPs operating oxidation ditches the convenience to treat their wastewater in a manner previously thought could only be achieved through complex designs.

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EXPLORING RENEWABLE ENERGY RECOVERY FOR SUSTAINABLE WASTEWATER TREATMENT

Juliet Ohemeng-Ntiamoah[1] and Tania Datta[1,2]

INTRODUCTION

In the United States, wastewater treatment plants (WWTPs) are currently burdened with treating approximately 34.5 billion gallons of wastewater per day, generating over 13.8 million tons of wastewater sludge annually. About 50% of the produced sludge end up in landfills (Seiple et al., 2017). Therefore, it has become necessary for WWTPs to find more sustainable ways of sludge management. Anaerobic digestion remains a well-established and viable technology employed by WWTPs to transform sludge into renewable energy in the form of biogas, while stabilizing it. Some studies have shown that the mono-digestion of wastewater sludge yields low amounts of biogas, which makes it economically unattractive for small to medium size WWTPs to adopt. However, through anaerobic co-digestion, a process of adding supplemental high-strength organic substrates to an anaerobic digester to augment biogas production, WWTPs can improve energy recovery. Co-digestion, although a viable process for harnessing the maximum potential of the anaerobic digestion technology, suffers some challenges. This is because the complexity and variable characteristics of co-substrates can potentially inhibit the microorganisms that drive this biotechnology.

Many studies have looked into operational parameters, such as organic loading rates, different types of co-substrates and co-substrate mix ratios that can cause inhibition (Fitamo et al., 2017; Wang et al., 2013). However, they have mostly reported the effects of operational parameters on digester performance in terms of biogas production, volatile solids (VS) removal and microbial community structure, without assessing possible strategies of overcoming inhibition by enhancing the key microbial communities' resilience and/or functional redundancy during co-digestion. The goal of this study was to 1) investigate the anaerobic co-digestibility of waste activated sludge (WAS) with food waste and fats, oils and grease (FOG) in various co-substrate mix ratios using long-term lab-scale reactors, and 2) examine key microbial communities' resilience and/or functional redundancy during anaerobic co-digestion, as a strategy to overcome inhibition.

METHODOLOGY

Lab-scale anaerobic co-digester design and operation: The anaerobic co-digestion study was carried out for a total of 368 days using three identical 10 L continuous-stirred lab-scale reactors (R1, R2 and R3) with a working volume of 6 L, operated at 35°C. Inoculum was obtained from an active anaerobic digester at Nashville Metro Biosolids WWTP. During the startup phase, all

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the reactors were fed with 100% WAS obtained from City of Cookeville's WWTP until they reached steady state. Following the startup, five experimental phases were carried out. R1 was a designated control reactor fed with only WAS throughout all experimental phases, while R2 and R3 were test reactors receiving various proportions of food waste and FOG as co-substrates mixed with WAS, respectively. Phases I-III were conducted at volatile solids loading rate (VSLR) of 2 g-VS/L/d and involved co-digestion of 25%, 50% and 75% (VS basis) of the co-substrates, respectively. Phase IV comprised of co-digestion of 75% co-substrate at an increased VSLR of 4 g-VS/L/d to assess if the system is able to build resilience to handle a higher VS load due to prior microbial adaptation. Phase V involved the co-digestion of 75% co-substrate at higher VSLR of 4 g-VS/L/d without prior exposure to the co-substrate, and therefore without prior microbial adaptation. Reactors were operated at 20 days solids retention time (SRT), and each experimental phase was run for 3 SRTs.

Substrate characterization: Total solids (TS) and volatile solids (VS) of all substrates were determined according to the Standard Methods (APHA, 2012). Chemical oxygen demand (COD) and total nitrogen (TN) were analyzed using Test N Tube kits (HACH Company, Loveland, CO). The pH was measured using a probe (Accumet AE150, Fisher Scientific). Total lipids content was estimated using the Bligh and Dyer method (Bligh EG and Dyer W J, 1959). Total carbohydrates content were determined with slightly modified anthrone method (Morris, 1948; Ohemeng-Ntiamoah and Datta, 2018). Protein content was estimated to be 16% of the TN concentration (Jones, 1941).

Monitoring of co-digester performance: The digesters were monitored weekly by measuring average daily biogas production, biogas composition, pH, and VS removal. Other parameters such as ammonia, Total nitrogen and total phosphorous were also measured. Volatile fatty acids concentration was analyzed using gas chromatography (Model 6890N; Agilent, Santa Clara, CA). Deoxyribonucleic acids (DNA) was extracted from digestate samples using DNeasy Powersoil kit (Qiagen, Valencia, CA).

Microbial community analysis through high-throughput sequencing: DNA library preparation was performed on Illumina Miseq platform according to manufacturer's protocol (Illumina, San Diego, CA, USA). It involved PCR reactions that amplified the v4 variable region of the 16s rRNA gene using universal primers 515f and 806r (Integrated DNA Technologies, Coralville, IA, USA). The resulting sequences were processed using Mothur v1.39.5 (Schloss et al., 2009) and following the Miseq SOP (Kozich et al., 2013). The sequences were aligned with the SILVA reference database (Quast et al., 2013). Sequences within two nucleotide of each other were merged and taxonomy was assigned using MiDas Database (McIlroy et al., 2017). Shannon and Simpson diversity metrics were used to assess the alpha diversity of the microbial community, while Bray-Curtis similarity matrix was used to analyze the beta diversity among the test samples.

RESULTS & DISCUSSION

Generally, phases I & II demonstrated that co-digestion of WAS with food waste and FOG improved biogas production in all the test reactors. During phase III, the co-digestion of WAS with 75% food waste at VSLR 2 gVS/L/d recorded the highest methane yield of 372.8±18 mL/g-

VS, which was about 15 times higher than the mono-digestion of WAS as seen in Figure 1. However, the co-digestion of WAS with 75% FOG at 2 g-VS/L/d resulted in inhibition and digester failure ,due to accumulation of VFAs. This drastically decreased the pH in the system. The total VFA concentrations in all reactors remained below 10 mg/L during phases I-III except in R3, where an accumulation of 2,154 mg/L total VFA was observed on day 216.

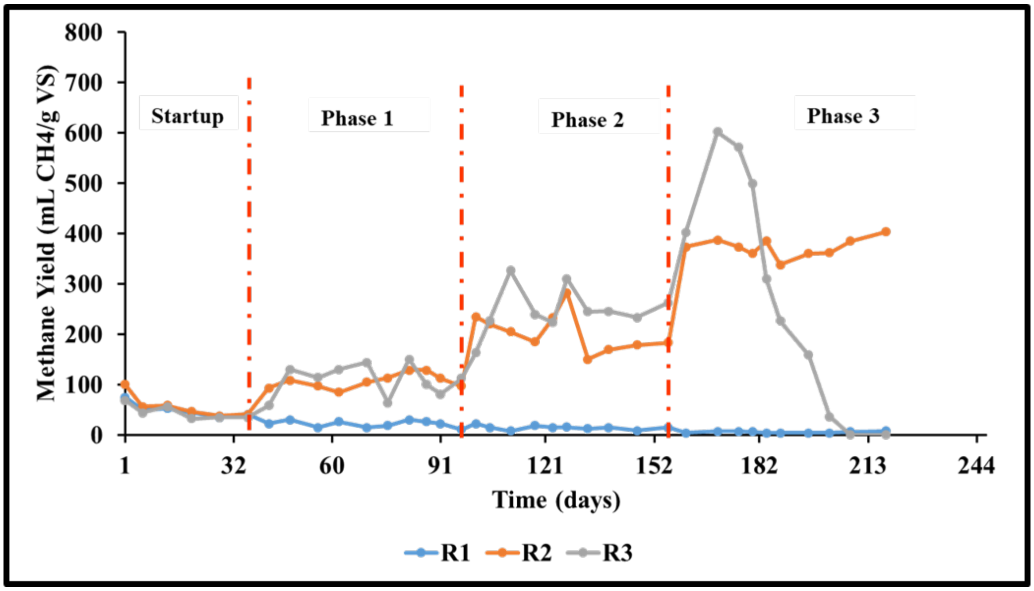

Figure 1. Specific methane yield observed in phase I (25% co-substrate), phase II (50% co-substrate) and phase III (75% co-substrate).

As seen in Figure 2, results from phase V showed that direct co-digestion of WAS with 75% food waste at a higher VSLR of 4gVS/L/d is not feasible due to organic overload and consequent accumulation of VFAs. However, as observed in phase IV, stepwise increment of food waste enabled the microbial communities to build some form of resilience and/or acclimation, which ensured digester stability during higher loads.

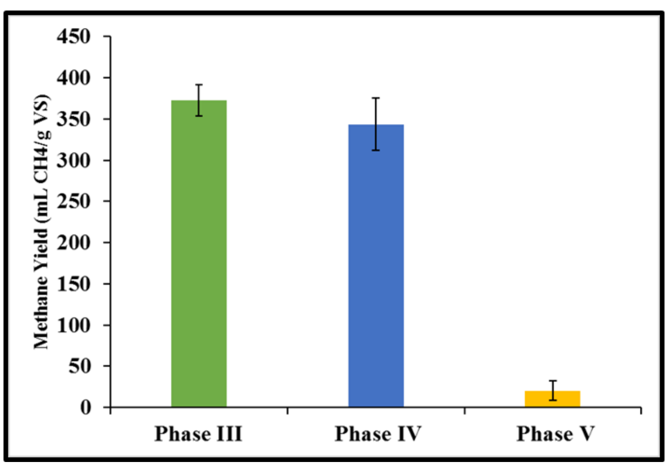

Figure 2. Specific methane yield of 75% food waste observed in phases III-V of R2.

The bacterial community under phase I and II were similar in all the reactors and was dominated by phyla Bacteroidetes, Proteobacteria, Firmicutes and Spirochaetae. However, in phase III, R2 hosted unique bacterial composition with the emergence of Fusobacteria and Chloroflexi whereas R3 was dominated by Firmicutes in phase III. The archaeal community consisted of methanogens which belonged to the phylum Euryarchaeota which was prevalent under 'healthy' conditions but was absent during inhibited conditions. The microbial community structure in the various experimental phases revealed that prior microbial acclimation ensures resilience of key functional microorganisms, which averts inhibition. An in-depth microbial community analysis is still ongoing and detailed findings will be presented at the conference.

CONCLUSION

Anaerobic co-digestion of WAS with 75% food waste has the potential to increase biogas production by 15 fold, however, co-digestion of WAS with FOG should be operated at a maximum of 50% FOG to avoid digester failure. Acclimation of anaerobic co-digestion systems with gradual increment of co-substrates enables the system to handle higher volatile solids loading rates.

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METHYLOTROPHIC METHANOGENESIS IN THE ANAEROBIC TREATMENT OF ANIMAL WASTEWATER

Yabing Li[1*], Si Chen[1], Qiang He[1,2]

Hydrolysis, acidogenesis, acetogenesis and methanogenesis are four major metabolic steps in the anaerobic catabolism of organic matter to methane and carbon dioxide. Methanogenesis traditionally includes three pathways, i.e. acetoclastic, hydrogenotrophic, and methylotrophic methanogenesis, using acetate, hydrogen plus CO_2, and methylated compounds as the intermediate substrate, respectively. While extensive efforts have been devoted to studying acetoclastic and hydrogenotrophic methanogenesis pathways, relatively little is known about the microbial populations involved in methylotrophic methanogenesis. In this study, methanol was added as a model methylated compound to anaerobic reactors treating animal wastewater. It was hypothesized that the methanogen populations positively responding to methanol addition would be associated with methylotrophic methanogenesis. Results of microbial community analysis show that *vadinCA11*, which belongs to the methanogen order *Methanomassiliicoccales*, increased its relative abundance in the archaeal community from 1.84% to 43.13%. A second addition of methanol was able to reproduce the same positive response of *vadinCA11*, suggesting the importance of methanogens associated with *Methanomassiliicoccales* in methylotrophic methanogenesis. Surprisingly, other known methylotrophic methanogen groups were not detected at significant abundance levels. Given that *Methanomassiliicoccales* represents a novel group of methanogens with unique anaerobic metabolism, it is likely that the catabolism of methanol might involve novel features in the anaerobic reactors of this study. In contrast, responses of the bacterial communities to the addition of methanol were minimal, indicating that the catabolism of methanol might not involve bacterial partners. Findings in this study are useful for delineating the complex anaerobic food web in various anaerobic treatment processes.

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PHOSPHORUS RECOVERY FROM ANIMAL WASTEWATER WITH BAUXITE RESIDUE IN ANAEROBIC TREATMENT

Yongfeng Wang[1,2]*and Qiang He[1]

Input of excess nutrient, particularly phosphorus, to surface water is a major cause of eutrophication and toxic algal blooms. One source of excess nutrient is animal waste, which is considered as a concentrated source of phosphorus suitable for recovery and reuse. Anaerobic digestion is a proven technology for the treatment of animal waste and production of biogas as a renewable energy source. Challenges to the broad application of anaerobic digestion include the need to improve treatment efficiency and management of nutrients in the digestate, e.g. phosphorus (P). In this study, bauxite residue as an industrial waste was evaluated for its potential as a sorbent for phosphorus in the anaerobic digestion treatment process. Specifically, we investigated the effect of bauxite residue as an additive on P bioavailability and biogas production as the indicator of process efficiency in anaerobic digestion of animal wastewater. The dosage of bauxite residue was shown to be critical for biogas production. Addition of a bauxite residue with high iron content at lower dosages (0.5%, 2% and 4%) improved biogas production, while higher dosages did not. It was also found that the addition of bauxite residue increased iron (Fe) concentration in the digestion liquor, which likely contributed to improved methane production and subsequent H_2S control. Moreover, the addition of bauxite residue increased the relative abundance of non-apatite inorganic phosphorus (NAIP), indicative of enhanced bioavailability of recovered P in the digestate. Therefore, the addition of bauxite residue at proper dosages could simultaneously enhance the treatment efficiency and P bioavailability in the anaerobic digestion of animal wastewater, providing an innovative strategy for the reuse of bauxite residue in animal waste treatment and nutrient management.

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ENHANCING BIODEGRADATION OF PAHS IN THE AQUEOUS PHASE: EFFECTS OF BIODEMULSIFIERS

Ning Hou[1,2*], Yanfei Dai[1], Tingting Jia[1], Dapeng Li[1,2], Qiang He[2,3]

Polycyclic aromatic hydrocarbons (PAHs) are a group of hydrophobic compounds with low aqueous solubility, and therefore difficult to be biodegraded. PAHs are present at high concentrations in process wastewater generated from the oil and gas industry. One potential strategy to enhance the biodegradation of PAHs is to increase the aqueous solubility of these compounds. Biodemulsifiers are novel biosurfactants with excellent surface activities, capable of considerably improving the solubility of PAHs in water. In this study, a biodemulsifier-producing bacterium, *Achromobacter sp.* LH-1, was isolated and characterized. It was revealed that this bacterium could efficiently utilize phenanthrene (PHE), a model PAH compound, as the sole carbon source for growth. Further, the biodemulsifier generated by LH-1 was shown to increase the biodegradation of PHE, likely by increasing the solubility of PHE. It was observed that the permeability of the cell membrane of strain LH-1 increased significantly with the presence of biodemulsifiers. TEM monitoring of the cell morphology of strain LH-1 indicated that the biodemulsifier concentration was positively correlated with the contact area between LH-1 and PHE, and the biodegradation of PHE. Findings in this study support the potential of microbial biodemulsifers in enhancing the biodegradation of PAHs in aqueous environments.

Keywords：PAHs; phenanthrene; biodemulsifier; biodegradation

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SESSION 3A

CLIMATE CHANGE (Moderator: David Duhl, TDEC-DWR)
8:30 a.m. – 10:00 a.m.

Adapting to Climate Change in Tennessee—What Technologies Should We Be Looking At?
Forbes Walker

Water Budgets for Agriculture: A Tennessean Approach Across Three Eco-Regions
Thomas Papanicolaou, Benjamin Abban, Christopher Wilson, Jon Hathaway, John Schwartz, Christopher Clark, Alfred Kalyanapu, and Brian Waldron

Potential Effects of Pasture Conversion from Cool Season to Warm Season Grasses on Water Quality in the Oostanaula River Watershed
Bahareh Shoghli, John Schwartz, Shawn Hawkins, Forbes Walker, Chris Clark, and Dayton Lambert

H_2O (Moderator: Scott Gain, USGS)
10:30 a.m. – 12:00 p.m.

ADAPTING TO CLIMATE CHANGE IN TENNESSEE – WHAT TECHNOLOGIES SHOULD WE BE LOOKING AT?

Forbes Walker[1]

Under predicted climate change scenarios Tennessee and the southeastern USA will experience more floods and more droughts. Researchers and extension personnel at the University of Tennessee Institute of Agriculture in collaboration with Tennessee Technological University, University of Memphis, Middle Tennessee State University and the University of Tennessee at Martin are working closely with landowners, farmers and other stakeholders across the state to provide practical and cost-effective strategies for both crop and livestock producers to manage their agricultural operations during times of rainfall deficient and droughts.

A diverse team of UT Extension personnel is identifying and evaluating the best agricultural practices such as the use of no-till systems, cover crops and irrigation to increase soil resilience in row-crop systems, use of biochar to rehabilitate sandy deposits left after floods and the adoption of native warm season grasses for pasture based livestock systems for Tennessee agriculture to adapt to climate-related changes in water availability. This paper will give an overview of the on-going applied research and extension efforts to provide pasture-based livestock with adequate forages during the summer months, extend the grazing season, improve hay-use efficiency, improve irrigation efficiency for field crops (corn, soybean and cotton) and nursery crop agriculture. This work is in part supported by a USDA NIFA Water for Agriculture grant awarded to study the effects that climate change may have on agricultural production in the Tennessee and Cumberland River Basins in the coming decades.

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WATER BUDGETS FOR AGRICULTURE: A TENNESSEAN APPROACH ACROSS THREE ECO-REGIONS

Thanos Papanicolaou, Benjamin Abban, Christopher Wilson, Jon Hathaway, John Schwartz, Christopher Clark, Alfred Kalyanapu, and Brian Waldron

Tennessee consists of three eco-regions with distinct geological history, land use, topographic characteristics and micro-climates. To address water budgets across the state, therefore, we had to develop an integrative modeling framework that couples remote and in-situ observational data with parsimonious modeling schemes to provide hydrologic time sequence data for infiltration, runoff, soil moisture, and evapotranspiration while accounting for climate non-stationarity. The modeling scheme consists of the VIC model, which accounts for vertical heterogeneity in soil layering and can predict groundwater recharge and streamflow by routing runoff on an hourly timestep at a 1-km^2 resolution. The model has been trained for fragipan soils, karst regions, and regions with unconsolidated sediment layers. Using the framework, hydropedologic functions, and roughness features from 30-m DEMs, we downscale the hydrological data to the sub-meter resolution to allow use of an enhanced WEPP model that incorporates micro-roughness representation, downslope curvature, management, and crop growth routines to simulate different crop rotations. The model was used to predict crop yields for future climate scenarios under different management scenarios pertaining to irrigation, fertilizer, and pesticide application. The considered climate scenarios represent moderate and extreme representative concentration pathways. The model outputs are used to predict the system water use efficiency, as well as soil health indicators such as the soil aggregate stability, carbon to nitrogen ratio, carbon management index, and soil wetness index. Furthermore, fluxes from the framework serve as inputs for two-dimensional modeling of flood inundation and implications to crop yields, as well as monitoring of storage behind impoundments.

POTENTIAL EFFECTS OF PASTURE CONVERSION FROM COOL SEASON TO WARM SEASON GRASSES ON WATER QUALITY IN THE OOSTANAULA RIVER WATERSHED

Bahareh Shoghli, John Schwartz, Shawn Hawkins, Forbes Walker, Chris Clark, and Dayton Lambert

Agricultural lands with pasture grasses may be more sustainable and profitable by a farm allocating a portion of existing cool season grasses to warm season grasses. Warm season grasses are characterized by higher biomass yields annually, and relatively lower nutrient and management requirements therefore improving water quality. In this study, the effects of pasture conversion from cool season to warm season grasses were assessed using the USDA Soil and Water Assessment Tool (SWAT) in the Oostanaula Creek watershed of East Tennessee. The model output variables to be assessed included biomass yields, water yields, and water quality (nutrient loadings). Model output included long-term simulations for current land uses (0% conversion), and two potential conversion projections at 25% and 40% from existing cool-season grass pastures to warm season grasses (switchgrass). In addition, model outcomes were assessed for differences in climate conditions (wet/normal/dry years) and seasons. The general hypothesis is during drought years, cattle farms with a portion of warm season grasses will be more resilient hydrologically and biomass productive.

SESSION 3B

GREEN INFRASTRUCTURE (Moderator: Andrea Ludwig, UT)
8:30 a.m. – 10:00 a.m.

A "Value-Added" Approach to Stream Buffers and Green Infrastructure
Russ Turpin

From Design to Construction: The Valuable Lessons Learned in the Implementation of an RSC
Michael Underwood

Field Survey and Evaluation of Nashville-Area Bioretention Function
Blue Curry and Andrea Ludwig

A “VALUE-ADDED” APPROACH TO STREAM BUFFERS AND GREEN INFRASTRUCTURE

Russ Turpin[1]

One inherent advantage of green infrastructure is that it can provide multiple ecosystem functions, services and benefits. In addition to meeting water quality standards, green infrastructure can be adjusted to meet multiple community needs. “Value-added” projects are those that deliver qualities that are greater than the costs to provide similar goods or services. Rather than assessing only costs, a “value-added” project includes considerations for outcomes as well as user experiences that have some perceived worth. This approach produces characteristics or features that make a particular project more desirable or beneficial. When applied to stream buffers, green infrastructure and greenspaces, the “value-added” approach can help address: cost/benefit comparisons of management programs, user experiences and perceptions, cultural or social significance, integration with complimentary efforts and exemplify the identity and values of a place or community. This presentation will address ways to identify and communicate “value-added” options during design and management of green projects.

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FROM DESIGN TO CONSTRUCTION: THE VALUABLE LESSONS LEARNED IN THE IMPLEMENTATION OF AN RSC

Michael Underwood[1]

INTRODUCTION

A regenerative stormwater conveyance (RSC) was designed and built to address severe erosion of a wet weather conveyance located at Holliday Park, a city park in Indianapolis, Indiana. Sedimentation from the erosion had already filled in a downstream pond and was endangering a wetland. The eroded conveyance was around 600 feet and had two five-food headcuts with near vertical banks. The first headcut is located approximately 75 feet downstream of the outlet pipe and the second headcut is approximately 350 feet downstream of the first one. Both headcuts are prevented from moving upstream because of large trees roots grown into the channel.

The City of Indianapolis hired KCI Technologies to design the RSC to stabilize the stream bed and banks, dissipate the energy of the flow, improve water quality by increasing retention time, reduce total suspended solids, and improve habitat for amphibians and invertebrates. The surrounding watershed consists of residential lots approximately one-fourth to one-half of an acre and mostly flat terrain until the project begins. The project is located within a mature hardwood forest and the terrain begins to steepen as the stream transitions to the confluence with the White River.

APPROACH

The RSC was designed using the guidelines established by Anne Arundel County, Maryland in their manual, “Regenerative Step Pool Storm Conveyance (SPSC) – Design Guidelines.” The horizontal alignment of the RSC is 598.5 feet long and follows the existing channel starting 53 feet downstream of an outlet pipe. The bottom of the channel was raised to connect the stream with the existing floodplain in most areas. This was accomplished using a mix of sand and mulch to fill in the channel, and also by using three different stream features: pools, riffles, and cascades, which were built on top of the sand medium. A riffle/pool sequence was designed to have a slope of no more than five percent. These structures, including the cascades, were designed in series to dissipate the energy of the flow and to treat the quality of the water entering the channel. Each riffle is less than eight feet long and the pools are designed to be at least twice as long as the riffles. A cascade is a structure built with boulders to drop the elevation of the stream quickly in a stabilized manner when the overall slope of the stream exceeds five percent. Since the overall slope of the channel is 5.5 percent, three cascades were used to drop the RSC back to existing grade at the end of the project.

Each riffle and cascade was designed to convey the 100-year storm discharge without supercritical flow occurring. This was calculated using Manning’s Equation and Froude Number to check the flow condition. The 100-year discharge was calculated using the NRCS TR-55/TR-

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20 methods. The d_{50} of the cobble installed in the riffles along with the depth of the structure were used to calculate Manning's roughness coefficient. The maximum allowable velocity in the riffles were based on the d50. A HEC-RAS model was created that compared the existing and the proposed conditions and determined that the channel will be stable during the 100-year storm event. The 100-year water surface elevation was also fully contained within the valley.
The design of the RSC presented many challenges because of the steep terrain and working in a forested area. The profile and the cross-sections of the RSC had to be designed to reduce the quantity of excavation which was difficult because of the narrow valley and the incised existing channel. The proposed channel elevation could not decrease too quickly to follow the existing profile which included the headcuts because significant grading would be needed to tie the banks back into the existing ground. Large trees were also present near the existing channel that were to be saved if possible. These included a 36" DBH cottonwood (*Populus deltoides*) and a 27" DBH sycamore (*Platanus occidentalis*). In order to design around these trees, a pool was extended to include these trees.

CONSTRUCTION

The construction of the design plans also taught many valuable lessons that will be implemented in future RSC design projects. The type of rock designed for the riffles and the boulders were too similar in size and prevented a noticeable separation and function between the two structures in the field. Boulders are used at the end of each riffle and in the construction of the cascades. The boulders were on the smaller side and the contractor had a hard time stacking the boulders. The boulders were originally specified to be bigger, but the cost of the bigger boulders increased the cost of the project significantly, so the length was reduced from 48" to 36". Another reason for the difficulty in stacking the stone is because most of the supplied boulders from the quarry were not the right shape. The riffles were made of INDOT Class I Riprap which has a range of 6" to 24". For future project, if the riffle stone and the boulders are close in size, the riffle stone sizes may need to be reduced below the design standard to create a size difference between the riffle and cascades. The riffle stone would be anchored in placed by the boulders at the end of each riffle. If possible, the boulder sizes should be larger so that they can stack easier and provide more stability. Another thing that could help is to show the Contractor pictures of example riffles and cascades to give them an idea of the final product. Also, an increase in the amount of time needed for construction oversight may be needed so that the Contractor can be shown how to build the initial structures.

Groundwater was also encountered in places during construction, which changed the design of the RSC as it was difficult to install the sand/mulch mixture below the structure. The purpose of the sand/mulch mix is to filter out stormwater before it enters the groundwater. Since the channel already was at groundwater level, the sand/mulch mix was not needed. The correct installation of the geotextile placement behind the weir boulders at each cascade and at the end of each riffle is necessary for a successful project. After construction was complete, eroded flow paths appeared in the bottom of the pools which showed that water did not back up in the pools, but instead flowed through the pools into the bottom of the riffles. The function of the RSC and the stability of the pools were in question because of the placement of the geotextile. The difficult situations encountered in the design and construction of the RSC provided many learning opportunities and will allow for successful upcoming projects.

FIELD SURVEY AND EVALUATION OF NASHVILLE-AREA BIORETENTION FUNCTION

Blue Curry[1] and Andrea Ludwig[2]

Continuous urban growth has led to increased stormwater runoff and subsequent stream pollution. To mitigate this environmental degradation, rain gardens have been identified as a viable solution for removing pollutants from stormwater runoff through infiltration. Rain garden popularity has risen considerably over the last decade, yet due to variability in local geography, regional native plant species, and bioretention media characteristics, much uncertainty exists between each current and potential rain garden site in terms of overall function. These variabilities have led to frequent dissatisfaction and failure of rain garden projects, leaving private homeowners, city planners, and research institutes to pay upwards of $30,000 in renovations per rain garden.

To reduce the rate of failure of rain gardens, a researched response has been developed to identify and address variables negatively impacting these facilities which lead to costly renovations. Fifty-two randomly selected rain gardens that aligned with a previous field study conducted by Metro Water Services were observed. Rain garden function was evaluated with specific concern for components of successful plant selections, surface cover impacts, and presence of soil organic matter. A short list of successfully functioning plant species was compiled. Selection of surface cover was found to have impacts on soil infiltration properties. Organic matter, which is critical to a highly functioning rain garden, was also investigated at sites that ranged in age from two to nine years. Based on this work, guidance will be developed to make renovations more effective. Ultimately, even if this effort will reduce renovation extent on half of all rain gardens in Nashville, this will **save property owners approximately one million dollars in annual expenses** in engineered soil replacement alone.

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SESSION 3C

ANALYTICAL PARTICLE TECHNIQUES (Moderator: Anne Choquette, USGS)
8:30 a.m. – 10:00 a.m.

Major Ion Toxicity and Emerging Toxics Standards
Scott Hall

Detection and Treatability of Nanomaterials in Surface Waters
Jejal Bathi

MAJOR ION TOXICITY AND EMERGING TOXICS STANDARDS

Scott Hall[1]

INTRODUCTION

"Major Ions" such as calcium, chloride, potassium, sodium, and sulfate are increasingly recognized as aquatic life concerns due to their presence in municipal and industrial effluents and road runoff. Although not as toxic as many other pollutants, potassium and bicarbonate are relatively toxic whereas calcium and sulfate are much less toxic to aquatic life. The toxicity of any major ion is highly dependent on the concentrations and ratios of other major ions, with water hardness increasingly recognized as a parameter altering major ion toxicity. Illinois and Iowa have recently published hardness-dependent water quality standards for sulfate and chloride, respectively. This presentation focuses on the toxicity of major ions, factors altering their toxicity, and recently published state aquatic life water quality standards for major ions. An update on EPA's consideration of water quality criteria for major ions, nanoparticles, and endocrine disruptors will also be presented.

OVERVIEW

In addition to calcium, chloride, potassium, sodium, and sulfate, ions such as magnesium, carbonate, bicarbonate, nitrite/nitrate, and to a lesser extent phosphorous, iron, and aluminum can all contribute substantially to the total dissolved solids (TDS) concentration of water. Due to its interference with osmoregulation in aquatic life, TDS is increasingly recognized as a factor impacting the health of freshwater ecosystems. Because of their inability to actively regulate ions, freshwater invertebrates are much more sensitive to TDS and its component ions than freshwater fish.

Although the regulation of much more toxic constituents such as heavy metals, pesticides, ammonia, cyanide, etc. is well established and supported by USEPA water quality criteria with relatively extensive data on the toxicity of such constituents, states are increasingly recognizing the need to regulate the less toxic component ions and/or TDS as a whole. For example, the individual TDS ions could be regulated much like better-known toxic materials such as those on USEPA's Priority Pollutant List. With the increasing recognition that many major ions' toxicity is influenced by water hardness (increased hardness generally decreases major ion toxicity) and the concentrations of other ions, it would be necessary to develop criteria or standards based on the water quality components influencing major ion toxicity as has been done for decades for the hardness-dependent metals. Illinois and Iowa have taken such an approach. Although TDS could be used as a surrogate parameter to account for major ion toxicity, such an approach would have the shortcoming of a given TDS concentration having highly variable effects based on the make-up of the component ions. Another approach would be to account for the effects of TDS through the use of whole effluent toxicity (WET) tests of effluents and ambient waters. To date, regulation of the chemical constituent in a way that considers the role of other water quality

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parameters has been the general approach. Such an approach is consistent with USEPA's development of biotic ligand models that consider numerous water quality parameters influencing metal toxicity.

DISCUSSION

Examples of the differences in freshwater invertebrates' and freshwater fishes' sensitivity to individual major ions are present throughout the literature, with the best-documented examples being for members of the family Daphniidae (e.g., *Daphnia magna*, *D. pulex*, *Ceriodaphnia dubia*) and the fathead minnow (*Pimephales promelas*) for toxicants such as sodium chloride and potassium chloride. Sodium chloride is commonly used as a reference toxicant in WET testing. As listed by Mount et al. (1997), the acute (48 hour) toxicity (expressed as the median lethal concentration or LC50 value) of sodium chloride to *C. dubia* and *D. magna* is 1,960 mg/L and 4,770 mg/L, respectively in moderately hard synthetic water. By comparison, the fathead minnow 48 hour LC50 for sodium chloride is 6,510 mg/L. The higher toxicity of potassium chloride is evidenced by the *C. dubia* 48 hour LC50 value of 630 mg/L. As a general rule, the order of toxicity of the most common major ions is:

Cations	$K>Na>Mg>Ca$
Anions	$HCO_3>Cl>SO_4$

A valuable tool in determining the toxicity of a mixture of major ions is the Salinity Toxicity Relationship (STR) model developed as a result of the testing done by Mount et al. (1997).

An example of regulation of major ions by various states includes that of the Iowa Department of Natural Resources, which sets criteria for chloride and regulates chloride on the basis of the influence of water hardness and sulfate on chloride toxicity. The water quality parameter-dependent equation to set ambient chloride criteria in Iowa is:

Acute Criterion (mg/L) = $287.7(\text{hardness})^{0.205797}(\text{sulfate})^{-0.07452}$

Chronic Criterion (mg/L) $177.87(\text{hardness})^{0.205797}(\text{sulfate})^{-0.07452}$

Other emerging contaminants and/or new approaches to their regulation includes the use of Biotic Ligand Models (BLM) to regulate metals and set metals criteria. The BLM is a metals bioavailability model that considers receiving water characteristics to develop water quality criteria most applicable to a given site. The USEPA aquatic life criteria for copper (2007) are based on the copper BLM. In order to calculate the copper criteria for a given site, water quality data must be available for temperature, pH, dissolved organic carbon, calcium, magnesium, sodium, potassium, sulfate, chloride, alkalinity, and sulfide. Emerging contaminants USEPA has considered for the development of national water quality criteria include various endocrine disrupting chemicals (EDCs) and pharmaceuticals (e.g., ethynylestradiol, a synthetic estrogen), as well as metal- and carbon-based nanoparticles. Due to the unique chemistry and analytical challenges of nanoparticles and the long-term sub-lethal toxic effects of EDCs, the 1985 USEPA methodologies for development of water quality criteria may not be suitable for criteria derivation of such constituents. For further discussion of this topic, see EPA's White Paper *Aquatic Life Criteria for Contaminants of Emerging Concern* and the Science Advisory Board's review of that work. EPA has also recently published tissue-based aquatic life criteria for selenium.

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DETECTION AND TREATABILITY OF NANOMATERIALS IN SURFACE WATERS

Jejal Bathi

Engineered nanomaterials (ENMs) are characterized by nanoscale dimensions (0 to 100 nm), making it difficult to detect and treat them using classic techniques. Considering an increasing use of ENMs in commercial products, we can expect an increase in an uncontrolled discharge of large quantities of ENMs into our water bodies. Literature now suggests scientific evidence of detectable levels of silver dioxide, zinc dioxide, titanium dioxide, and graphene ENMs in sewage, wastewater, and surface water. Also, advancing in technology has now helping to characterize nanoparticles in the aquatic environment. For example, our earlier research has confirmed that polycyclic aromatic hydrocarbons (PAHs) predominately associated with less than 100 um. However, their association with nanosized particles is yet to be explored in detail. A goal of our ongoing research is to develop a treatment train for tracking, treating, and capturing ENMs in surface waters. This presentation will review an array of modern analytical techniques for quantifying ENMs in pristine and impure waters. The presentation will also discuss the current understanding of ENM treatment in water infrastructure.

STUDENT POSTERS

High School

Comparing Water Quality of the Two Sides of Dams
Marcus A. Hollo

Using Camera Traps to Analyze Relative Abundance of Basking Turtles in Wetland Ecosystems
Elizabeth G. Riddle

Investigating the Safety of Metro Nashville Water Pipes by Testing Drinking Water
Zhoobin Mohammadabadi, Anthony Onaghinor and Clifford Thompson

Undergraduate

Analysis of Lag Time for Flash Floods on the Blackburn Fork River, Cummins Falls State Park, Tennessee
Bailey Carter and Evan A. Hart

Determination of Irrigated vs. Rainfed Agricultural Fields Using NDVI Time Series and Daily Water Balance in the Upper Sunflower River Watershed, MS
Abigail Choisser and Henrique Momm

Presence of Fecal Indicator Bacteria, Alternative Fecal Indicators, and Pathogens in Sand at Freshwater Recreational Beaches in Tennessee
Andrew Todd, Robin Dixon, and Frank C. Bailey

Engineered Nanoparticles: Microscopic Miracle or Pint-Sized Pollutant?
Steven Sawyer, Patrick M. Craig, and Jejal Bathi

Water Quality Characteristics of the Boils Springs in Jackson County, Tennessee
Eric D. Frye, Anna Foster, and Joseph Asante

Groundwater Geochemistry and Geomicrobiology of a Karst Aquifer Underlying the Research Farm at Tennessee State University
Darrius Lawson, Dafeng Hui, De'Etra Young, Jessica Oster, and Thomas Byl

Terrestrial Cyanobacteria of Mammoth Cave National Park Produce Microcystin Toxin
Shakarah Nelson, De'Etra Young, Rickard Toomey, and Thomas Byl

Harmful Algal Blooms: Microcystin Toxin and Nutrient Analysis in the Tennessee State University Wetland
Rodney Blackwell Jr., De'Etra Young, and Thomas Byl

Graduate

Trends in Forest Throughfall Deposition in the Great Smoky Mountains National Park

Taylor Blackstone

A Comparison of the HGM Approach to the RBP Method of Evaluating Reconstructed Streams on Surface Coal Mines
Michelle L. Caudill-Osborne

Developing an Early Warning System for Floods for Window Cliffs State Natural Area, Putnam County, TN
Alexander J. Davis and Alfred J. Kalyanapu

Monitoring E. coli *Levels in Beaver Creek, Northeast Tennessee*
Jacob L. Hansen, Tosin James, and Ingrid Luffman

The Use of Fluorescence Probe to Characterize Lampenflora in Mammoth Cave National Park
Brittany Hogan, Rickard Toomey, De'Etra Young, and Thomas Byl

Reservoir Routing Model for Cane Creek Lake, Cookeville, TN
Minhazul Islam, Tristen Cunningham, Nusrat Jannah Snigdha, and Alfred Jayakar Kalyanapu

Beaver Creek, Northeast Tennessee and Southwest Virginia Hydrological Modeling Using ArcGIS SWAT
Tosin James and Ingrid Luffman

Examining the Response of Agricultural Watersheds to the Presence of Pesticides
Miranda D. McBride and Racha El Kadiri

What Impacts Do Hurricanes Have on Water Quality?
Andrew D. Osborne and Racha El Kadiri

Procedural Planning for Stream Embeddedness Study
Nicholas Pettit and John S. Schwartz

Characterizing Response of Soil and Stream Chemistry from the Chimney Tops 2 Fire in the Great Smoky Mountains National Park
Salley A. Reamer, John S. Schwartz, and Qiang He

Decision Supporting Hydrodynamic Modeling of Tennessee River
Shuvashish Roy

Characterization of Nano Contamination: Challenges and Findings
Syed M. Tareq

Comparison of Parametric Rainfall Models of Tropical Cyclone Rainfall for Flood Risk Studies
John T. Brackins and Alfred J. Kalyanapu

Doctoral
High-Resolution Modeling of Hurricane Harvey Flooding for Harris County, TX, Using a Calibrated GPU-Accelerated 2D Flood
Tigstu Dullo, Alfred J. Kalyanapu, Sudershan Gangrade, Md Bulbul Sharif, Thomas Hines, Shih-Chieh Kao, Sheikh Ghafoor, and Katherine Evans

PROFESSIONAL POSTER

Estimated Groundwater Withdrawals for Irrigation and Aquaculture in the Mississippi Delta
John A. Robinson and Jeannie R. Barlow

Shallow Groundwater Geothermal Energy: Modeling and Simulation
Nan Wang, Qiang Zhou, and Qiang He

COMPARING WATER QUALITY OF THE TWO SIDES OF DAMS

Marcus Hollo[1]

Research shows that dams have an effect on surrounding water by altering the contents and temperature of the water, interfering with the ecosystem. This makes it important to perform regular tests on the water that surrounds dams to ensure its safety.[2] The water quality of upstream and downstream sites at Old Hickory and J. Percy Priest Dams was assessed once a week for four weeks. HACH water quality field testing kits were used to measure free chlorine, total chlorine, dissolved oxygen, temperature, and pH on-site. Water samples from all sites were brought back to the lab where orthophosphates and nitrates tests were also conducted. Of the tests conducted, the majority of results were within Tennessee's safety regulations. However, there were higher amounts of chlorine found on the upper side of the J. Percy Priest Dam. Chlorine is used to disinfect drinking water for human consumption and to keep swimming pools clean. If it finds its way into natural water sources, it can kill some of the essential bacteria that help the ecosystem thrive.[4] One potential source of the chlorine pollution is Nashville Shores Water Park. This hypothesis must be further assessed by confirming the presence of elevated chlorine levels and testing sites closer to the water park. Should Nashville Shores be ruled out as the cause of the chlorine pollution, additional testing would be needed to identify the source.

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USING CAMERA TRAPS TO ANALYZE RELATIVE ABUNDANCE OF BASKING TURTLES IN WETLAND ECOSYSTEMS

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Wetland degradation threatens many aquatic turtle species, which link terrestrial and aquatic habitats, and are important species in many ecosystems. Aquatic turtles are ectotherms that must sun themselves to thermoregulate in a behavior known as basking. This research evaluates the applicability of camera traps, a new innovation in ecology, for monitoring basking relative abundance of red-eared sliders (*Trachemys scripta elegans*) in three wetland ecosystems in Tennessee during summer 2018. Cameras took pictures of basking sites every hour from sunrise until sunset utilizing time-lapse technology. Temperature was recorded with a data logger, and solar irradiance was calculated using a solar calculator. Basking use was significantly different during three times of day (morning, afternoon, and night) and significantly greater during the afternoon (P-values < 0.001). Compared to temperature (P-value $= 0.039$), solar irradiance had a more significant effect on basking use (P-value < 0.001). Basking during the afternoon (12:00 – 17:00) allows turtles to make considerable energy gains, while leaving the rest of the day for foraging and other activities. Future directions include utilizing camera traps to assess a variety of ecological measures (i.e. range, occupancy). Modifying the technology to be applicable to more organisms will increase the opportunities for researchers to identify and conserve populations.

Key words: biological clocks, habitat degradation, invasive species, physiological responses, thermoregulation

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INVESTIGATING THE SAFETY OF METRO NASHVILLE WATER PIPES BY TESTING DRINKING WATER

Zhoobin Mohammadabadi, Anthony Onaghinor, and Clifford Thompson

Clean and potable drinking water is an essential piece to the survival of all human beings. Therefore, when Nashville's water supply was deemed dangerous due to chemical and biological contamination by things such as silt and cholera, Nashville's health department urged the city to build a filtering gallery on a nearby island to combat the recent cholera outbreak. From this point forward, further improvements were added to Nashville's filtration system, starting with the addition of alum as a purification chemical in 1908 to allow large amounts of mud and particles to clump together and sink out of water. As the years went on, Nashville added hypochlorite of lime in the process of cleansing water in 1909, eventually switching to chlorine in 1920. Nashville eventually began to follow EPA standards in order to make sure that the water sent out was safe for consumption. Congress passed the Safe Drinking Water Act (SDWA) in 1974 to protect public health, including by regulating public water systems. The Safe Drinking Water Act requires EPA to establish and enforce standards that public drinking water systems must follow. This would include public libraries, since public libraries are state regulated. It is expected that the water is safe for use when it is sent out. However, the question stands in regards to the safety of the water for consumption and use once it reaches any property owned by Metro Nashville. Considering this, the purpose of the project was to investigate if drinking water meets EPA standards when it reaches any Nashville public source. This is to ensure that the pipes are not damaged in a way to cause contaminants to leak in or for water to leak out. The libraries that were tested were are all a part of the Metro Nashville Public Library system. The tests that were conducted in order to evaluate the safety of the water were chlorine, nitrate, and orthophosphate tests. These were done due to the fact that they are the most accessible to test, as well as the fact of them being some extremely important chemicals that can be found in water. For example, as previously stated, chlorine is a disinfectant. However, it needs to be kept at a moderated level as to not cause irritation of the throat and lungs. Nitrates need to be kept at a low level as well due to how it can cause blue baby syndrome when ingested by children and infants, causing death by asphyxiation. Orthophosphates also needs to be moderated. Since it is used as a corrosion inhibitor, there needs to be enough in the water to bind to lead and copper to make it sink. By examining the levels present in water samples, the safety of the water can be easily determined.

Specific Aims:

1. **Evaluate the state of Metro's water transport pipes by testing retrieved water samples.**
    a. Gather water samples from various Nashville Public Libraries.
    b. Test water samples and compare results to EPA standards.

ANALYSIS OF LAG TIME FOR FLASH FLOODS ON THE BLACKBURN FORK RIVER, CUMMINS FALLS STATE PARK, TENNESSEE

Bailey R. Carter[1] and Evan A. Hart[1]

The Blackburn Fork River is situated on the Highland Rim in Putnam and Jackson Counties. The river has a history of flash flood events. There have been two notable flash flood events in recent times: one in August of 2010, and the latest being in July 5, 2017. The flood of 2010 was a higher magnitude flood, but occurred before the creation of Cummins Falls State Park. The flood of 2017 was not as large a flood, but claimed the lives of two individuals at Cummins Falls State Park (est. 2011). During the summer, thousands of people visit Cummins Falls State Park on weekends and gather at the base of the waterfall to enjoy the geologic masterpiece. Park visitors near the waterfall are at great risk from flash floods because there are no easy escape routes and the base of the waterfall is surrounded by steep cliffs. Rainfall that led to the July 5, 2017 flood occurred upstream of Cummins Falls, with the falls area experiencing little if any rain, thus there was little warning for people congregated below the falls.

The goal of this research project is to use precipitation radar and stream gauge data to calculate the lag time for recent floods on the Blackburn Fork in the area of Cummins Falls. In March 2018, one HOBO water level and temperature logger was installed 700 m upstream from the falls on the main stem of the Blackburn Fork. Further upstream, in September 2018 two more gauges were installed on the East and West Blackburn Forks, the main sub-watersheds above the falls. Since then, data have been collected and graphed to observe the rising water levels and water temperature response related to storm rainfall events. Data from three separate rainfall events were collected: September 24-25, 2018; September 25-27, 2018; and September 27-28, 2018. The response time of these three events to reach their hydrograph peaks ranged from 2.45 hours to 5.15 hours. At all three stream gauges, an increase in stream water temperature occurred after each rainfall event. This increase in water temperature suggests the importance of springs in contributing flow along Blackburn Fork. Of the three rain events studied, the peak lag time between the upstream and downstream gauges averaged 1.25 hours. The East Fork averaged 55 minutes and the West Fork averaged 1.05 hours. Some of the variables that control the lag time in this study are the precipitation movement direction and the antecedent moisture. Lag time for the fatal 2017 flood was much shorter than the storm events studied here, probably on the order of 15 to 30 minutes, according to time stamped pictures taken during the flood. Results from this study will be important in the future development of a flash flood warning system for the safety of those who visit Cummins Falls State Park.

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DETERMINATION OF IRRIGATED VS. RAINFED AGRICULTURAL FIELDS USING NDVI TIME SERIES AND DAILY WATER BALANCE IN THE UPPER SUNFLOWER RIVER WATERSHED, MS

Abigail Choisser and Henrique Momm

Crop conversion in the Mississippi River alluvial floodplain has resulted in noteworthy increase in irrigation practices made possible by pumping water from the shallow Mississippi River Valley Alluvial aquifer. Crops like soybeans and corn rely on these irrigation practices to meet yield expectations. The Upper Sunflower River watershed was selected an appropriate proxy for studies of rainfed versus irrigation practices, as the region is under environmental stress from over-pumping. This project focuses on developing methods to discern between irrigated and rainfed crops through use of Landsat-derived NDVI time series combined with daily water balance analysis generated by the AnnAGNPS hydrological model. Time series of NDVI values at field scale during the growing season were used to estimate individual crop phenology curves. This information was contrasted with daily water balance information (precipitation/evapotranspiration/infiltration), and maps of fields with active irrigation permits. Determining impacts of excessive irrigation on the water table, watershed capacity, and runoff intensity during both on and off seasons for agriculture are of primary concerns in this region.

PRESENCE OF FECAL INDICATOR BACTERIA, ALTERNATIVE FECAL INDICATORS, AND PATHOGENS IN SAND AT FRESHWATER RECREATIONAL BEACHES IN TENNESSEE

Andrew Todd*[1], Robin Dixon*[1], and Frank C. Bailey[1]

There are many human-made freshwater recreational beaches in TN. Water at these beaches is sometimes monitored for fecal indicator bacteria (FIB), such as *Escherichia coli*, as an indication of potential pathogen presence and human health risk. Though beach sand has been shown to harbor high concentrations of FIB in some studies, sand is not typically monitored, and neither the sources of fecal contamination (e.g. human, cattle, geese, etc) nor the presence of actual human pathogens is usually investigated. The objective of this study is to assess the abundance of standard FIB, alternative FIB, and pathogens in sand and water at two central Tennessee recreational beaches. Sand core and water samples were taken during nine sampling events in summer 2018. Water and PBS extracts of sand samples were analyzed for *S. aureus* and MRSA (Methicillin Resistant *Staphylococcus aureus*) using selective agars, *E. coli* by Colilert®, coliphages by EPA Method 1602, and human-specific Bacteroidales genetic markers by qPCR. *S. aureus* was present in all sand samples (range - 100 CFU/100g – TNTC (too numerous to count)). MRSA was found in all but 3 sand samples (range - 0 CFU/100g – 124,000 CFU/100g). Each sand and water sample contained *E. coli* (range - 10 MPN/100g – 57,940 MPN/100g for sand and 3 MPN/100mL – 365.4 MPN/100mL for water). Initial sampling results show male-specific (F+) coliphage concentrations in sand ranging from 0 PFU/100g – 18 PFU/100g and somatic coliphages from 0 PFU/100g – 16 PFU/100g. These results indicate potential human exposure to fecal contamination at recreational beaches in TN.

Key words: Beach, Sand, Fecal Indicators, Bacteria, Pathogens

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ENGINEERED NANOPARTICLES: MICROSCOPIC MIRACLE OR PINT-SIZED POLLUTANT?

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Engineered nanoparticles (ENMs) are an emerging issue in today's world. With modern production methods advancing and becoming more sophisticated; the technological ramifications are not always understood before putting into practice. Inability to regulate the NMs in environment may lead to effects on public health and aquatic organisms. Relatively little is yet known about amenability of ENMs to conventional coagulation and filtration systems for treatment. Our ongoing research hypothesizes that the degree and kinetics of ENM deposition are a function of the surface characteristics of carbonaceous adsorbents, metal coagulants, or filtration media. Our research is combining the state-of-the-art spectroscopic, microscopic, and surface characterization techniques to extend current knowledge of adsorption-based treatment systems with an ultimate goal of developing next-generation adsorption technologies for ENMs. There are no in-depth studies that investigated the fate and transport of ENMs in a bioretention configured for treating stormwater runoff, specifically from a surface chemistry perspective. We are instigating bioretention treatment of ENMs using prototypes of a bioretention media adsorption column for treating ENMs in stormwater runoff. Our poster will present column test protocols and versatile analytical techniques to correlate the surface properties and concentration levels of ENMs (nano-scale) in surface runoff waters with the performance parameters of adsorption units (macro-scale).

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WATER QUALITY CHARACTERISTICS OF THE BOILS SPRINGS IN JACKSON COUNTY, TENNESSEE

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We are investigating the water quality of the Boils Spring, a large karst spring draining the East Highland Rim region. The Boils Spring flows into the Roaring River—a State scenic river. A previous study conducted by Gardner et al. (2017), found that the average annual discharge of the Boils spring is 2.1 m^3/s, with storm discharge reaching 14 m^3/s. Although information about water quality of the Boils is of interest to the public and for scientific research, detailed water quality information is hard to find. The objectives of this research are to summarize the water quality of the Boils Spring, collected before and after precipitation events, and to compare the constituent chemical levels to the US EPA water quality standards. These data will help to determine the suitability of different uses for the spring water including water dependent ecosystems. This research is interesting and important because the rapid changes in discharge can cause water quality problems. Total dissolved solids range from 74 to 137 below the MCL of 500mg/L. The spring is moderately hard with hardness ranging from 124 to 149 mg/L. Maximum Fe and Mn concentrations were approximately equal to the MCL. Concentrations of trace (Cu, Zn) elements and nutrients (NO_3, PO_4) were well below the MCL. The results indicate that the spring water quality is good, non-toxic and can be a source for drinking water supply and agriculture. We conclude that although the spring discharge varies rapidly, the variations do not appear to affect the water quality.

GROUNDWATER GEOCHEMISTRY AND GEOMICROBIOLOGY OF A KARST AQUIFER UNDERLYING THE RESEARCH FARM AT TENNESSEE STATE UNIVERSITY

Darrius Lawson[1]*, Dafeng Hui[2], De'Etra Young[2], Jessica Oster[3], Thomas Byl[1,4]

ABSTRACT

Five irrigation and four research wells screened in a karst aquifer system underly the Research Farm located at Tennessee State University in Nashville, Tennessee. The wells extend 250 feet below land surface and have approximately 200 to 230 feet of open borehole in the limestone. Water-quality in the wells range from aerobic freshwater to anaerobic, sulfide waters, and the close proximity of the differing water-quality conditions in nearby wells is puzzling. The objective of this research was to characterize the geochemistry and microbiology of the groundwater to determine if the sulfide waters and freshwater are interconnected. Sulfide concentrations ranged from 3 to 127 mg/L in 4 of the 5 anaerobic wells and pH ranged from 6.6 to 7.8 in the 9 sampled wells. Actively growing bacteria were measured using specific Biological Activity Reaction tests (BART). Sulfur-reducing and sulfur-oxidizing bacteria were plentiful in the anaerobic waters. Heterotrophic aerobic bacteria dominated the microbial community in the freshwater system. Sulfur-oxidizing bacteria in the sulfur groundwater oxidized the sulfide into a yellow sulfur compound, and subsequently into a white calcium sulfate precipitate when incubated at room temperatures for 24 hours. Understanding the geochemistry and microbiology of the two systems provides useful information about nutrient cycling and water quality in the karst aquifer below the TSU Research Farm.

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TERRESTRIAL CYANOBACTERIA OF MAMMOTH CAVE NATIONAL PARK PRODUCE MICROCYSTIN TOXIN

Shakarah Nelson[1]*, De'Etra Young[2], Rickard Toomey[3], Thomas Byl[1,4]

ABSTRACT

Cyanobacteria are prokaryotes with photosynthetic capabilities commonly found in marine and freshwater environments. Fossil evidence indicates they were prolific in the Precambrian oceans 3.5 billion years ago and helped to give rise to the oxygen-rich atmosphere. Microcystis, Oscillitoria, Leptolyngbya, Planktothrix, Nostoc, Dolichospermum and Hapalosiphon are types of cyanobacteria that have continued to thrive and have adapted to grow near lights used for tours in the cave passages at Mammoth Cave National Park. During preliminary cyanotoxin testing, 10 out of 11 cave sites with visible algal growth tested positive for microcystin (total concentration range was 0.154 to 2.59 µg/L analyzed using Enzyme Linked Immuno-Sorbent Assays). No microcystins were detected at control sites in Mammoth Cave where algae were not visible. Another common terrestrial cyanobacterium, *Nostoc commune*, found growing along the surface of gravel paths had microcystin concentrations ranging from 0.0 to 16.6 µg/L. The difference in toxin concentrations between the cyanobacteria growing near the lights and the growth along the gravel paths may be due to differences in algal community structure, light intensity, subtle geochemical variances, moisture, or some other environmental factor. These preliminary findings raise interesting questions, such as: what percent of the terrestrial cyanobacteria are capable of producing toxins, what toxins are they capable of producing, and, what are the environmental signals that trigger the production of toxins in this environment?

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HARMFUL ALGAL BLOOMS: MICROCYSTIN TOXIN AND NUTRIENT ANALYSIS IN THE TENNESSEE STATE UNIVERSITY WETLAND

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ABSTRACT

Cyanobacteria capable of producing microcystin toxins flourish in the wetland at the Tennessee State University (TSU) research farm in Nashville, Tennessee.and the cyanobacteria pose a danger to livestock and wildlife. The objective of this research was to measure microcystin and water chemistry to determine trends through time. Samples were collected at four locations in the TSU wetland between the summer of 2017 through early winter of 2019 and analyzed for nitrogen, phosphorous, iron, sulfur, Secchi depth, type of algae present, and microcystin. Continuous water-quality instruments were also installed at the inlet and outlet of the wetland to document dissolved oxygen, pH, temperature, specific conductance and turbidity. Seven cyanobacteria genera capable of producing microcystins were identified in the wetland. Microcystin concentrations ranged from less than 0.15 to 25.1 µg/L.The peak microcystin concentrations were well above the U.S. Environmental Protection Agency's health advisory concentration of 0.3 µg/L. The highest microcystin concentrations were located near a livestock access point. Additional work includes correlations between water chemistry parameters and microcystin concentrations.

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TRENDS IN FOREST THROUGHFALL DEPOSITION IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

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Abstract: Atmospheric deposition of acid pollutants have declined substantially in the past decade and is reflected in the trends in throughfall chemistry. Limited data exists for throughfall chemistry in the Great Smoky Mountains National Park (GRSM), and there is a need to character the changes that have occurred. Of particular interest in the GRSM is the combined effects of forest vegetation structure and elevation on deposition chemistry. This study examines the long-term changes in deposition chemistry that has occurred at Noland Divide, a high-elevation research monitoring station. In addition, this site will be compared with a low-elevation NADP monitoring site at Elkmont in the GRSM.

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A COMPARISON OF THE HGM APPROACH TO THE RBP METHOD OF EVALUATING RECONSTRUCTED STREAMS ON SURFACE COAL MINES

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A review of annual monitoring reports for stream restoration projects on surface coal mines in the central Appalachian Mountains found that the criteria used for judging the success of the projects was generally based on visual assessments of habitat structure which were evaluated using the Rapid Bioassessment Protocol (RBP) (Palmer and Hondula, 2014). In recent years the Hydrogeomorphic Approach (HGM), which was originally developed to evaluate wetlands, has been adapted for stream evaluations as well (Summers, et al., 2017). Both of these methods are primarily a means to determine if suitable habitat structure and riparian growth are present to support aquatic life. It is assumed that if habitat structure is suitable then macroinvertebrate and other life will be present. However, each of these two methods place emphasis on different aspects of habitat and riparian structure. The primary purpose of this project is to compare and contrast how effective these two methods are at evaluating reconstructed streams on surface coal mines. A secondary objective is to determine if macroinvertebrate assemblages in reconstructed streams is significantly different from that of reference streams not impacted by mining. Research on benthic community structure downstream of coal mining activities suggests that even after many decades taxa richness and abundance still have not recovered from indirect impacts (Petty, et al., 2010). Information on reconstructed streams directly impacted is lacking. This project evaluates streams that were reconstructed five years prior using the RBP and HGM methods, and compares them to local reference streams that have minimal to no mining impacts. Multiple benthic metrics are also used to evaluate community structure.

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DEVLOPING AN EARLY WARNING SYSTEM FOR FLOODS FOR WINDOW CLIFFS STATE NATURAL AREA, PUTNAM COUNTY, TN

Alexander J. Davis[1] and Alfred J. Kalyanapu[2]

Putnam County has a large amount of karst features such as sinking streams, sink holes, caves and more. This adds difficulty when it comes to understanding the pathways water will drain throughout the area. This is especially true in Window Cliffs State Natural Area where Cane Creek meanders through and crosses the hiking trail on 9 different occasions. Within the park, it has been observed that the stream can dissapear for stretches of the creek as well incur severe flash flooding, water levels raising several feet within a 15 minute window. Between the flash flooding potential and other local occasions of devestation due to flooding, a flood warning system was determined to be needed to assist the Burgass Falls Park Rangers ensure the safety of park vistors. Therefore, the objective of this research is to *develop an early warning system for floods at Window Cliffs State Natural Area*. The complexities that arise with the karst features adds great dificulty to modeling and therefore predicted the water level/velocity. To help combat this, a data-driven model was used. This allows for a lesser understanding of the drainage area and its flowpaths and accordingly less time and money in developing a flood model. This model, coupled with some judgement, will help assist the park rangers predict when the creek is not safe to cross and the park should be closed.

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MONITORING *E. COLI* LEVELS IN BEAVER CREEK, NORTHEAST TENNESSEE

Jacob L. Hansen[1]*, Tosin James[1], and Ingrid Luffman[1]

Beaver Creek, part of the South Fork Holston River watershed (HUC06010102), is located in southwest Virginia and Northeast Tennessee (Figure 1). The creek runs through the city of Bristol, TN/VA and into Tennessee – the reach from the state line to the confluence with the South Holston River is 303(d) listed due to: alteration in stream-side or littoral vegetation cover, excessive nitrate and nitrite inflow, loss of biological integrity due to siltation and an elevated presence of *Escherichia coli* (*E. coli*) (Tennessee Department of Environment and Conservation (TDEC), 2006). Several tributaries are also impaired (Table 1).

Water quality criteria for *E. coli* in Tennessee waterways is established by the State of Tennessee such that "the concentration of *E. coli* should not exceed 126 colony forming units per 100 mL (CFU/100mL) as a geometric mean based on a minimum of 5 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples collected at intervals of not less than 12 hours." (TDEC 2006) This process is commonly referred to as 5-in-30 sampling. Several restoration projects have been implemented along the Tennessee portion since 2013 (Luffman, Barrigar, & Scheuerman, 2016). The objective of the study was to assess the impact of recent implementations of Best Management Practices (BMPs) on *E. coli* loads in Beaver Creek, and test whether standards for healthy waterways are being met at this time.

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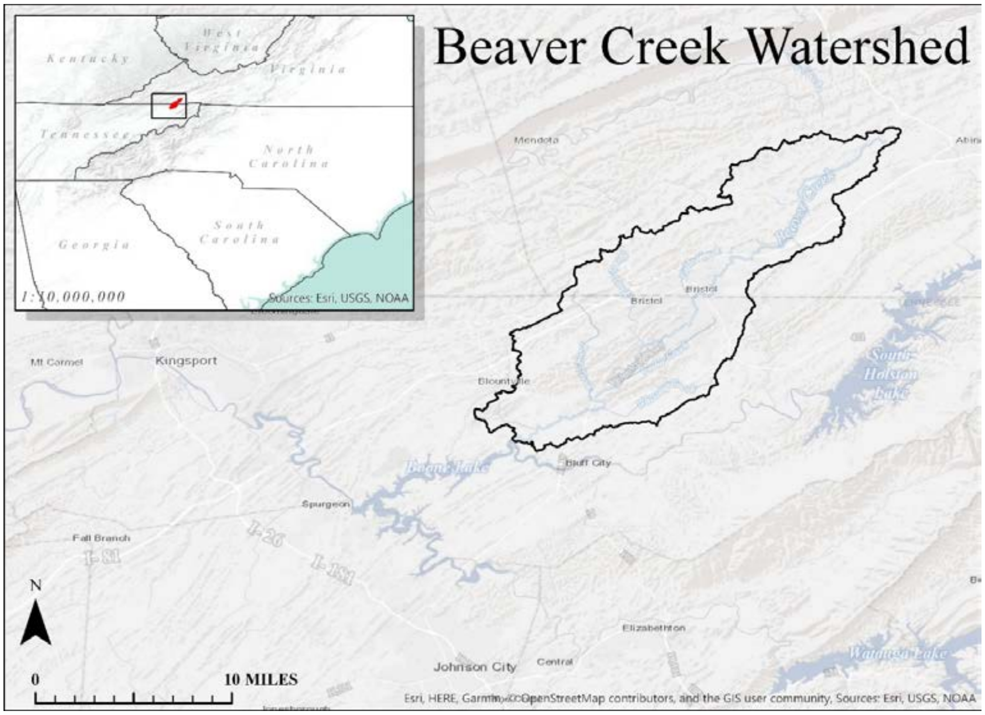

Figure 1. Beaver Creek watershed.

Table 1. 303(d) listed impairments for Beaver Creek and three tributaries (TDEC, 2006).

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	Cause (Pollutant)	Pollutant Source
TN06010102042 – 0200	BACK CREEK (from Beaver Crk to headwaters; not incl. Unnamed trib)	14.1	Nitrates Loss of biological integrity due to siltation Physical Substrate Habitat Alterations Escherichia coli	Unrestricted Cattle Access Grazing in Riparian or Shoreline Zones
TN06010102042 – 0400	LITTLE CREEK	0.3	Escherichia coli	Discharges from MS4 area Sources Outside of State
TN06010102042 – 0500	CEDAR CREEK	11.8	Nitrates Loss of biological integrity due to saltation Other anthropogenic Habitat Alterations Escherichia coli	Discharges from MS4 area
TN06010102042 – 1000	BEAVER CREEK (from S. Fork Holston to Cedar Creek)	11.1	Escherichia coli	Discharges from MS4 area Grazing in Riparian or Shoreline Zones
TN06010102042 – 2000	BEAVER CREEK (from Cedar Creek to Virginia stateline)	10.5	Habitat loss due to alteration in stream-side or littoral vegetative cover Nitrates Loss of biological integrity due to siltation Escherichia coli	Discharges from MS4 area Grazing in Riparian or Shoreline Zones Sources Outside of State

METHODS

Three sampling sites were selected from prior Tennessee Department of Environment and Conservation (TDEC) sampling sites on Beaver Creek in Tennessee, based on the availability of historical data. Sites were located at stream miles 1.0, 11.0, and 15.3, between S. Holston River and the TN/VA state line in Bristol, TN (Figure 2).

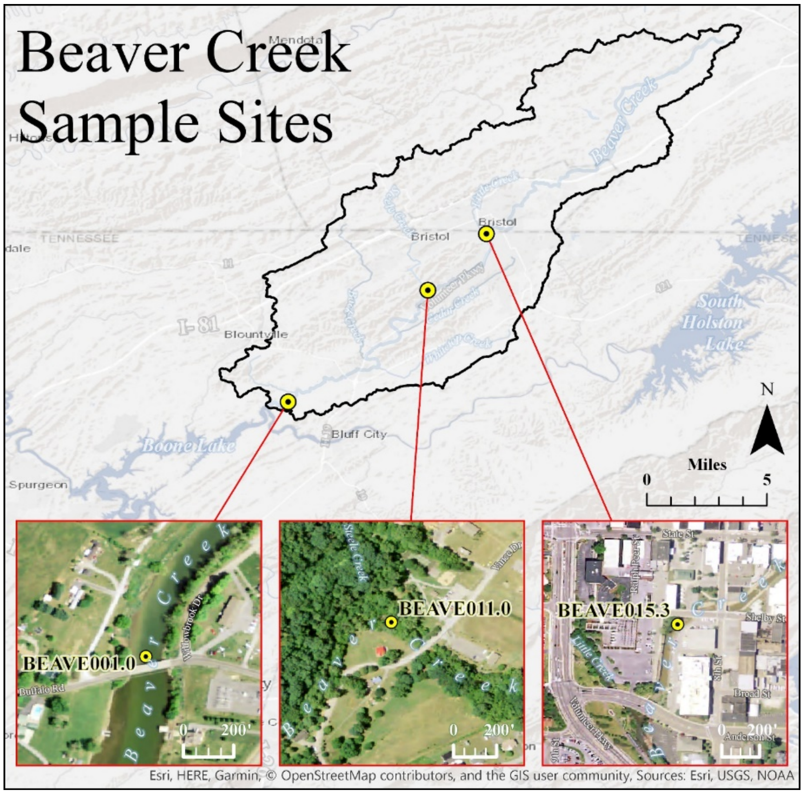

Figure 2. Three sample sites with historical data, which were used in this study.

BEAVE001.0 is located 1 mile upstream of the confluence with S. Holston River, at Buffalo Rd, BEAVE011.0 is 11 miles upstream of the confluence with S. Holston River, at Rooster Front Park (upstream of the confluence with Steele Creek), and BEAVE015.3 is 15.3 miles upstream of the confluence with S. Holston River, at the municipal lot in downtown Bristol, TN.

Sampling for *E. coli* was done using 5-in-30 sampling methods. Each site was sampled in triplicate at each visit and the daily arithmetic average for each site was treated as an individual sample during data analysis. Water was collected using a dipper, and poured into sterile 100 mL sample bottles which were capped, bagged separately for each site, and stored on ice in a cooler for transport to the lab. The dipper was sanitized by spraying with Liquinox and rinsing with deionized water at each site immediately prior to sampling.

Samples were processed immediately upon return to the lab (within 6 hours) using the Colilert Quanti-Tray 2000 procedure. Trays were left to incubate at 35° C for 24-30 hours and then compared to a comparator for color and fluorescence, testing *Fecal coliform* and *E. coli* loads, respectively. Field equipment blanks of deionized water were collected using the dipper, immediately after sanitizing. Additionally, trip blanks of deionized water were prepared in the lab prior to field collection and carried in the sample cooler while in the field. Blanks were used as quality assurance/quality control for the sampling methods.

Daily arithmetic means were used to calculate a geometric mean of the 5-in-30 samples, which was compared to the standard of 126 CFU/100mL (Figure 3). The five *E. coli* measurements taken at each site during this study were compiled with historical data provided by TDEC and split into two groups for each site: one group prior to restorative work ($\leq$ 2013), and the other group subsequent to restorative efforts (> 2013) (Luffman, Barrigar, & Scheuerman, 2016). The groups were analyzed via Mann-Whitney tests to identify statistically significant differences in measured *E. coli* loads pre- and post-restoration (Table 2). Some of the historical *E. coli* data for site 15.3 had values that were out of range for the Colilert Quanti-tray method (a maximum value of 1,011.2 CFU/100 mL). Therefore, a second Mann-Whitney test was performed for site 15.3 data after limiting the highest values in the historical data to 1,011.2 CFU/100 mL to assess differences between a more conservative historic dataset and the data collected post-restoration (Table 2).

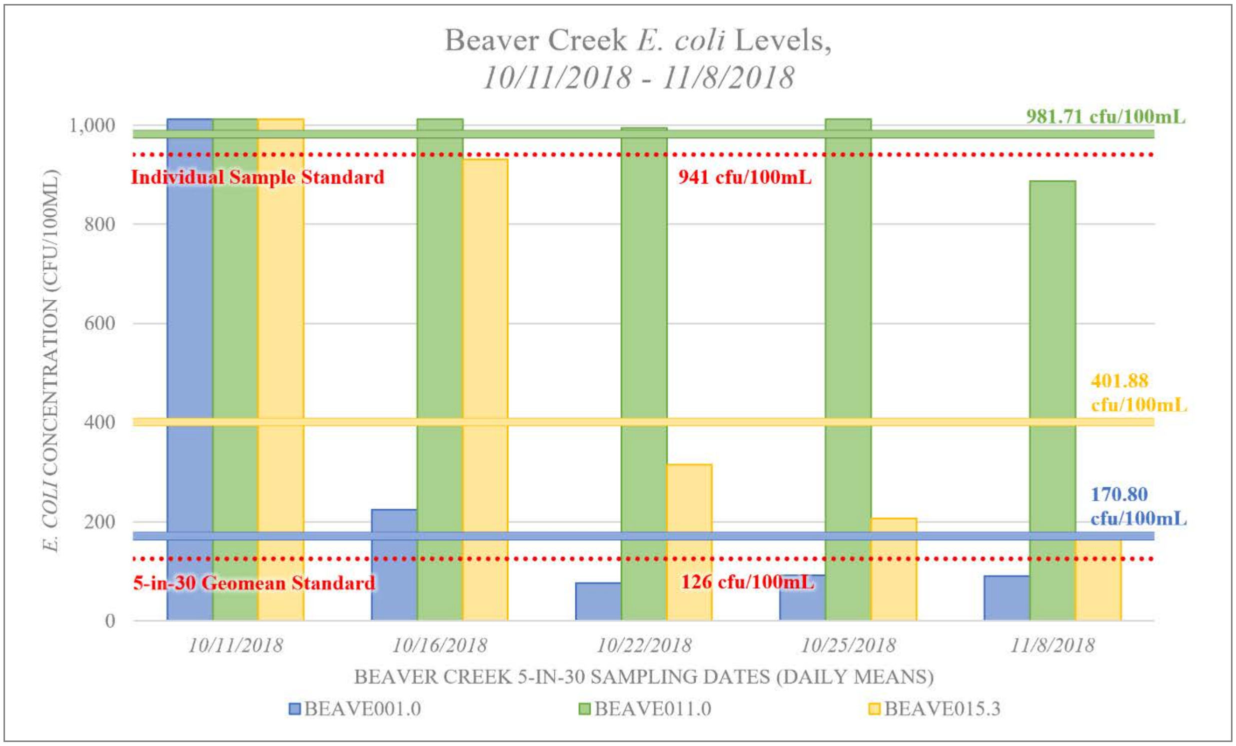

Figure 3. Daily means of *E. coli* loads at each site, collected 10/11/2018-11/8/2018, with 5-in-30 geometric mean values shown with horizontal bars. Total Maximum Daily Load (TMDL) individual and geometric mean standards (TDEC, 2006) are shown with dotted-lines.

RESULTS AND DISCUSSION

All three sites produced at least one individual sample exceeding the individual sample standard of 941 CFU/100mL (Figure 3). Sites 1.0 and 15.3 each produced only one sample exceeding the individual standard, while site 11.0 produced only one sample that did not exceed the standard (Figure 3). Geometric means from the 5-in-30 sampling continue to exceed the standard of 126 colony forming units per 100mL (CFU/100mL) (Figure 3). Site 1.0 had the overall lowest *E. coli* loads, with a geometric mean of 170.82 CFU/100mL for this study. Site 11.0 displayed the highest count – 981.71 CFU/100mL – and *E. coli* loads at site 15.3 were 401.88 CFU/100mL for this study period (Figure 3).

Qualitatively, all three sites show decreased *E. coli* since BMP implementation, however, only the most upstream site (mile 15.3 in Bristol) showed a statistically significant difference between pre- and post-restoration *E. coli* loads (p=0.000). Substantial high-value outliers are likely skewing the historical data, and small sample size for sites 1.0 and 11.0 may be a limiting factor. Additionally, the testing methods utilized by TDEC provide significantly higher possible values (as high as 46,110 CFU/100mL for site 11.0). Using conservative values (by enforcing upper limits of 1,011.2 CFU/100 mL for historical data at site 15.3 to match upper limits of the Quanti-Tray method) also demonstrated significant reduction in *E. coli* at mile 15.3 between the two time periods (p=0.002) (Table 2).

Table 2. Comparison of *E. coli* load (in CFU/100 mL) through 2013 to *E. coli* load since 2013.

		BEAVE001.0	**BEAVE011.0**	**BEAVE015.3**	**BEAVE015.3** *adjusted max*
Pre-restoration (≤ 2013)	Mean	**763.73**	**5,319.40**	**2,294.70**	**821.73**
	Number of Samples	*53*	*45*	*65*	*65*
Post-restoration (> 2013)	Mean	**283.80**	**982.97**	**482.06**	**474.66**
	Number of Samples	*8*	*5*	*12*	*12*
Percent decrease		--	--	79%	42%
Mann-Whitney U-test	p-value	0.146	0.950	**0.000**	**0.002**

Minor QA/QC concerns arose during sampling where *Fecal coliform* was present in 5 of 7 field-equipment blanks although *E. coli* was present in none. Cross-contamination of the sampling dipper is a concern and in future, more liberal use of cleaning agents and scrubbing of the dipper are recommended.

Although *E. coli* levels are still above the standard at each site, the site located furthest upstream showed a significant decrease in *E. coli* over time. This result may be related to restoration efforts in Virginia completed between 2000 and 2010 that may have had a positive effect on *E. coli* loads. It is likely that the more recent restoration efforts on the Tennessee portion of Beaver Creek are so recent that the stream has not yet adjusted. Flood mitigation work by the US Army Corps of Engineers to reduce channel constriction and enhance downtown drainage may also have an impact on water quality at the two downstream sites (mile 11.0 and 1.0) in the short term. More time may be needed to see the effects of restoration efforts on water quality. Rain during the first collection date (10/11/2018, Figure 3) likely caused a spike in *E. coli* loads at each site due to stormwater runoff. A second phase of restoration work is planned and annual sampling of these sites is recommended to continue to monitor progress.

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THE USE OF A FLUORESCENCE PROBE TO CHARACTERIZE LAMPENFLORA IN MAMMOTH CAVE NATIONAL PARK

Brittaney Hogan[1]*, Rickard Toomey[2], De'Etra Young[3], Thomas Byl[1,4]

ABSTRACT

Algae have adapted to live in a variety of terrestrial environments, even in the cave passages at Mammoth Cave National Park. Cyanobacteria (blue-green algae) and chlorophyta (green algae) are the two main algae that grow close to the tour lights installed along the cave passages. These cave-adapted algal growths are called lampenflora. The lampenflora are considered a nuisance because they are not a natural cave flora and can detract from a natural cave experience. Additionally, it is unknown how the presence of lampenflora affects cave biota. Some cyanobacteria have been shown to produce cyanotoxins such as microcystin that present a danger to cave fauna and tourists. The objective of this research was to develop quick, reliable tools that could be used to characterize the lampenflora, provide an estimate of biomass and differentiate between cyanobacteria and chlorophyta. Lampenflora sites that represented communities of cyanobacteria and chlorophyta were characterized using a dual-channel fluorescence-based sensor (sensors for chlorophyll a and phycocyanin). The ratio of chlorophyll a to phycocyanin provided a quick method to estimate if the algal community is dominated by cyanobacteria or chlorophyta. The intensity of the reading provided some indication of lampenflora coverage on the rock but maxed out when the cave wall was above 60% covered with lampenflora. Additional research will look at the correlation between cyanotoxin and pigment concentrations to determine if the chlorophyll a or phycocyanin is an indicator of toxin levels.

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RESERVOIR ROUTING MODEL FOR CANE CREEK LAKE, COOKEVILLE, TN

Minhazul Islam[1], Tristan Cunningham[2], Nusrat Jannah Snigdha[3], and Alfred Jayakar Kalyanapu[4]

INTRODUCTION

Cane Creek Lake is an artificial impounded lake (earthen dam) built by the "Civilian Conservation Corps" located in the western part of Cookeville. It is a significant recreational area and also one of the crucial lakes as it carries runoff from stormwater discharges. The main objective of this project is to build a reservoir routing model for Cane Creek Lake in HEC-HMS to analyze its hydrology for different design storms. A sonar boat was used to collect the lake bathymetry and used as input into the hydrologic model. Various design storms including 10yr, 50yr, 100yr and 500yr events were used for the reservoir routing model. Finally, various lake inundation scenarios were simulated in ArcGIS and the flooded areas were estimated. This model has the potential to help engineers and planners to determine the water level attained in the reservoir, spillway flow and the time lag between inflows and outflows (Goff, 2012). This assessment from the model will help to forecast the probable timing of flood and also it will also help to regulate the spillway valve more efficiently.

APPROACH

On 6th October 2018, a bathymetry survey was done on the Cane Creek Lake in order to get the bottom profile of the reservoir. A sonar boat was used to collect the depth at various points of the lake area. More than 70,000 data points were collected through the survey. A hand-held GPS unit was used to collect lake water level around the lake and an average water surface elevation was determined. Using these datasets, lake bottom elevations for all points from the sonar boat were calculated by subtracting the sonar boat depth data from the average water surface elevation. These elevations were spatially interpolated in ArcGIS to generate the lake bottom profile. Using this lake bottom profile, a stage-storage relationship was developed for the HEC-HMS model input. A watershed was delineated in the upstream of the lake area to estimate the inflow from various design rainfall events. DEM (Digital Elevation Model) data was collected from the USGS National Map website. Land Cover data (NLCD, 2011) was collected from the USGS National Map data platform (TNM Download V1.0: https://viewer.nationalmap.gov/basic/) and SSURGO soil data was used to estimate the watershed parameters for the hydrologic model. Rainfall data for different return period was collected from the NOAA Precipitation Frequency Data Server (PFDS). "Outlet Structure" method was used in the HEC-HMS model. For this method, a clear idea of the outlet structure information was necessary. The main design plan of the cane creek dam was collected and necessary inputs were made in the hydrologic model.

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RESULTS & DISCUSSION

The Cane Creek lake bottom profile (Figure 6) was made from the sonar boat data. Using the lake bottom profile the reservoir routing model was created. The model was simulated for two different conditions. One of them is “Empty Reservoir Condition” and the other condition is “Reservoir Pool Condition”. In the “Empty Reservoir Condition”, the reservoir was assumed empty at the beginning of the simulation. In “Reservoir Pool Condition”, the lake was assumed to be filled up to the pool water level which is 1026.7 feet. The model was simulated for 8 days as it was observed that the highest storm event took 7-8 days to be washed out from the lake completely. One-minute time step was used for the simulation. Along with the flow, HEC-HMS model was also estimating the storage and water level change in the lake. Using the water level estimation from the hydrologic model, a lake inundation map was made to estimate the flooding extent of the storm events for each initial condition.

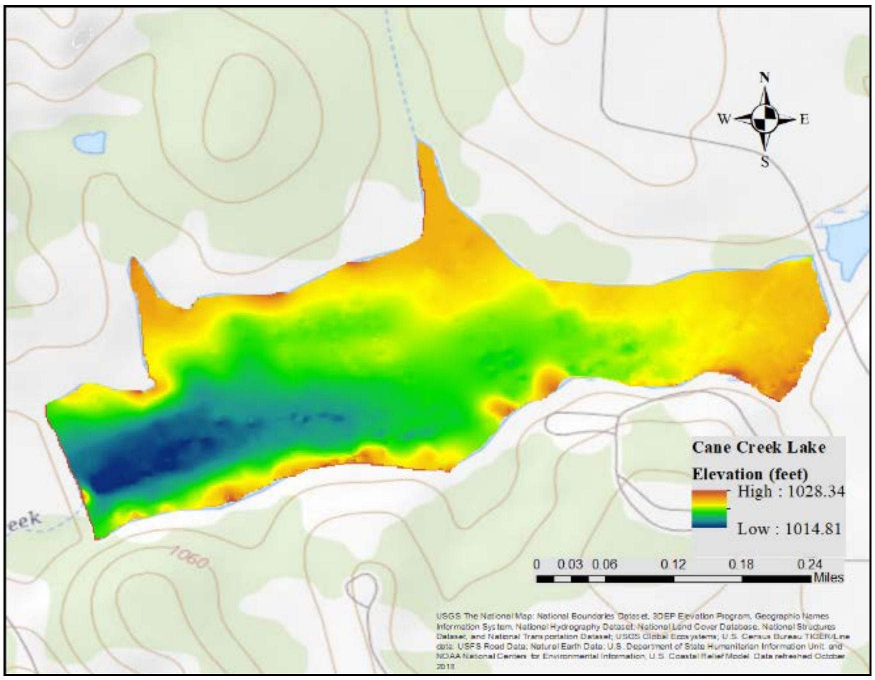

Figure 6: Lake Bottom Profile

This preliminary model can be well calibrated in the future to help the planners and engineers to simulate different flooding scenarios in order to take the necessary steps in severe flooding conditions.

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BEAVER CREEK, NORTHEAST TENNESSEE AND SOUTHWEST VIRGINIA HYDROLOGICAL MODELLING USING ArcGIS-SWAT

Tosin James[1] and Ingrid Luffman[1]

Beaver Creek is a 40.9 km long stream draining a 284 km^2 EPA Level IV Ecoregion watershed in southwest Virginia and northeast Tennessee. Approximately 52% (148.4 km^2) of the watershed is in Sullivan County, Tennessee and 48% (130 km^2) is in Washington County, Virginia. Within the South Fork Holston River watershed (HUC06010102), Beaver Creek has a history of flooding in Bristol TN/VA. The largest recorded flood in 1977 had peak flows of 1600 cfs, and high water marks 49 inches above street level in downtown Bristol TN/VA (Jorns, 2004). For comparison, normal daily flow at a US Geological Survey (USGS) gauge located near the top of the watershed ranges from 20 – 10 cfs. Moreover, from 1958 – 2018, annual peak flows exceeded 500 cfs in 20 of 60 years and exceeded 1000 cfs in only 4 of 60 years at this gauge.

Land Use Land Cover (LULC) in the Beaver Creek watershed, according to National Land Cover Database (NLCD) 2011 data, is forest (36.0%) and agriculture (32.8%), followed by developed areas which represent approximately 29.4% of the total drainage area of the watershed (Homer et al. 2011). LULC change in the watershed between 2001 and 2011 resulted in the conversion of planted/cultivated and forest land to developed land, which may increase stormwater runoff and impair water quality.

Beaver Creek, is listed on the 2016 303(d) as impaired (not supporting its designated use for recreation) for *Escherichia coli* (*E. coli*), siltation, nitrates, and habitat loss (Tennessee Department of Environment and Conservation, 2017). *E. Coli* are either point sourced (untreated sanitary waste) or non-point sourced (livestock, urban, and failed septic systems). Sediment is non-point sourced (agricultural activities, roadways, and urban sources). Both *E. coli* and excess sediment have been shown to increase with precipitation and discharge (McLellan et al., 2007). In order to address sediment and pathogens through modeling, a necessary first step is to first develop a calibrated model for discharge.

The objective of this study is therefore to develop a calibrated hydrologic model for discharge on Beaver Creek. ArcGIS-SWAT, a geodata model and geographic information system interface for the Soil and Water Assessment Tool (SWAT) was selected to model runoff and SWAT-CUP was used for calibration and validation (Arnold et al., 2012).

SWAT is a river basin scale model that operates on a daily time step that models the impact of land use and management on water, sediment, and agricultural chemical yields in ungauged watersheds. The model is process-based, computationally efficient, and capable of continuous simulation over long periods. Major model components may include weather, hydrology, soil temperature and properties, plant growth, nutrients, pesticides, bacteria and pathogens, and land

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management. In SWAT, a watershed is divided into multiple sub-watersheds, which are then further subdivided into Hydrologic Response Units (HRUs) that consist of homogeneous land use, management, topographic, and soil characteristics. The HRUs are represented as a percentage of the sub-watershed area and may not be contiguous or spatially identified within a SWAT simulation.

APPROACH

Monthly discharge station data for Beaver Creek (USGS station ID USW00013877 at 36.6318, -82.13369) were gathered from USGS Stream Stats version 4 (Ries et al., 2017). This gaging station is near the top of the watershed and has a drainage area of 8.8 $km^{2,}$ and the predominant LULC is cropland (hay). Stage and discharge data are available from 1958-present and were used for model calibration and validation. The 10-meter Digital Elevation Model (DEM) (USGS 2016) for the study area was uploaded to ArcSWAT, sinks were filled, and a stream network was delineated. Two outlet points were placed (Figure 1): Outlet 1 was located at the existing USGS gaging station and Outlet 2 where Beaver Creek empties into the South Fork Holston River. HRUs were delineated using STATSGO soil data (Soil Survey Staff, n.d.), NLCD land use data (Homer et al. 2015), and slope reclassifications. Precipitation and temperature data for the Tri-Cities Regional Airport, located outside the watershed, were used because there was no NOAA weather station located in the watershed. Relative humidity, solar radiation, and wind speed were simulated in ArcSWAT with Climate Forecast System Reanalysis (CFSR) data.

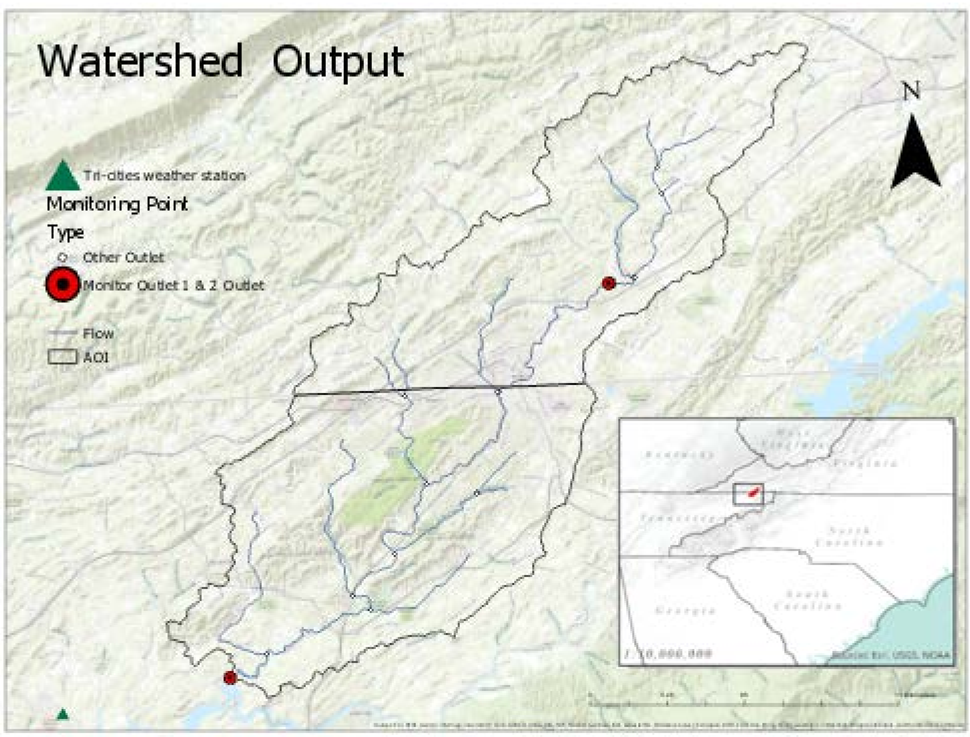

Figure 1: Beaver Creek watershed outline with flow paths. Two outlets are marked in red and Tri-cities weather station in green triangle

The model was run for 30 years (1/1/2001 to 12/31/2031). The first three years of the simulation were a stabilisation period to establish appropriate initial conditions for the period of interest

(1998 to 2000). The simulated output was then calibrated in SWAT-CUP with ten years of observed monthly discharge for Beaver Creek at the USGS gauge. Finally, observed and simulated discharge were compared visually using time series graphs and statistically using model diagnostics and correlation coefficients calculated using SPSS Version 25 (IBM 2017).

FINDINGS AND DISCUSSION

Forest (deciduous) and hay were the two predominant LULC (Figure 2A); developed land covered 30% of the total watershed. Elevation (Figure 2B), slope (Figure 2C), and soil (Figure 2D) were reclassified and overlain to delineate HRUs. In general, soil types were classified as loamy. Soil TN237 and Soil VA003 were labeled differently in each state, but represent the same soil. Together, they were the dominant soil class covering more than 63% of the watershed.

Twenty-four (24) sub-basins were created (Figure 3) for the watershed. These watersheds contain the hydrologic response units (HRUs) that consist of homogeneous land use, management, topographical, and soil characteristics. The largest sub-watershed covers 11.9% of the total watershed, and the predominant LULC is forest-deciduous which is 53.6% of the sub-watershed. The dominant soil is TN143 (loam), covering 53.4% of the subwatershed. The most common slope class is 10-20%.

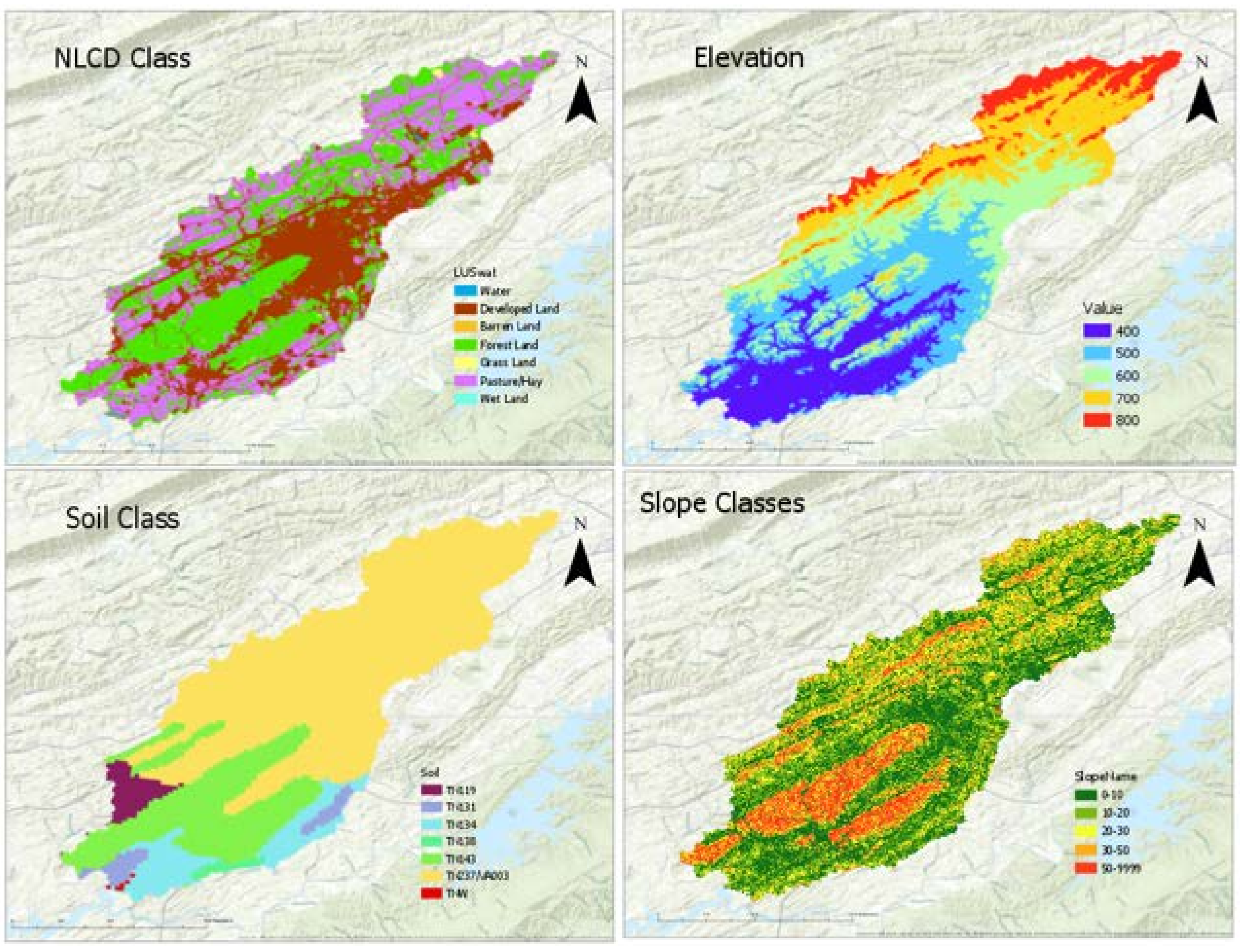

Figure 2: A) Land Use Land Cover (NLCD). B) Elevation in meters. C) Soil classification (STATSGO). D) Slope classes (NED)

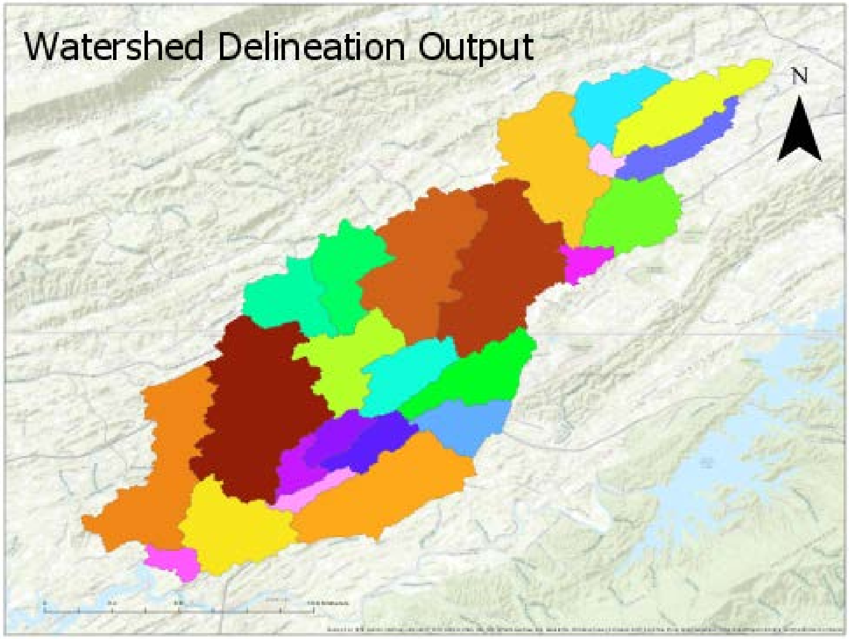

Figure 3: Sub-watershed delineation showing 24 different sub-watersheds

A time series comparison of observed vs. simulated discharge from Outlet 1 (at the USGS gauge) showed good agreement, although the simulated discharge generally underpredicts during most high flow events (Figure 4). Overlay of observed precipitation shows increased discharge associated with precipitation events (model $R^2 = 0.64$). Spearman correlation of observed to simulated discharge was moderate and positive ($r=0.47$, $p= 0.00$). Simulated discharge at Outlet 2 shows a good fit with observed precipitation (Figure 5).

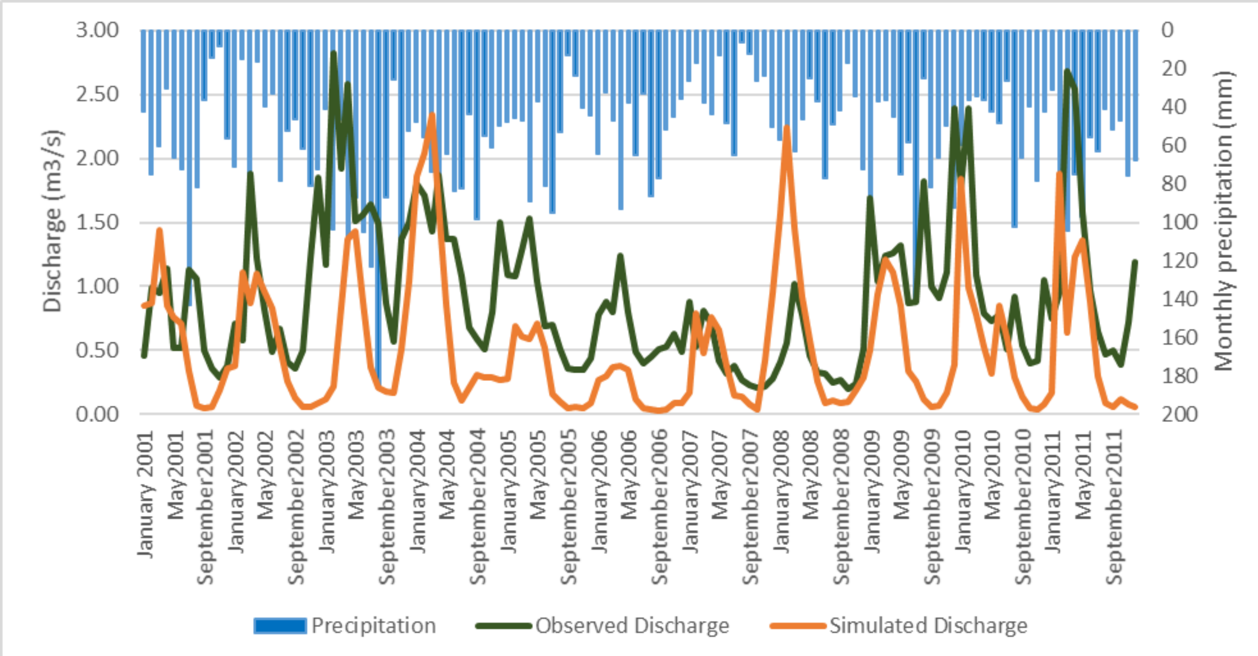

Figure 4: Comparison of observed to simulated discharge at Outlet 1 (USGS gaging station). Precipitation is shown on the secondary axis.

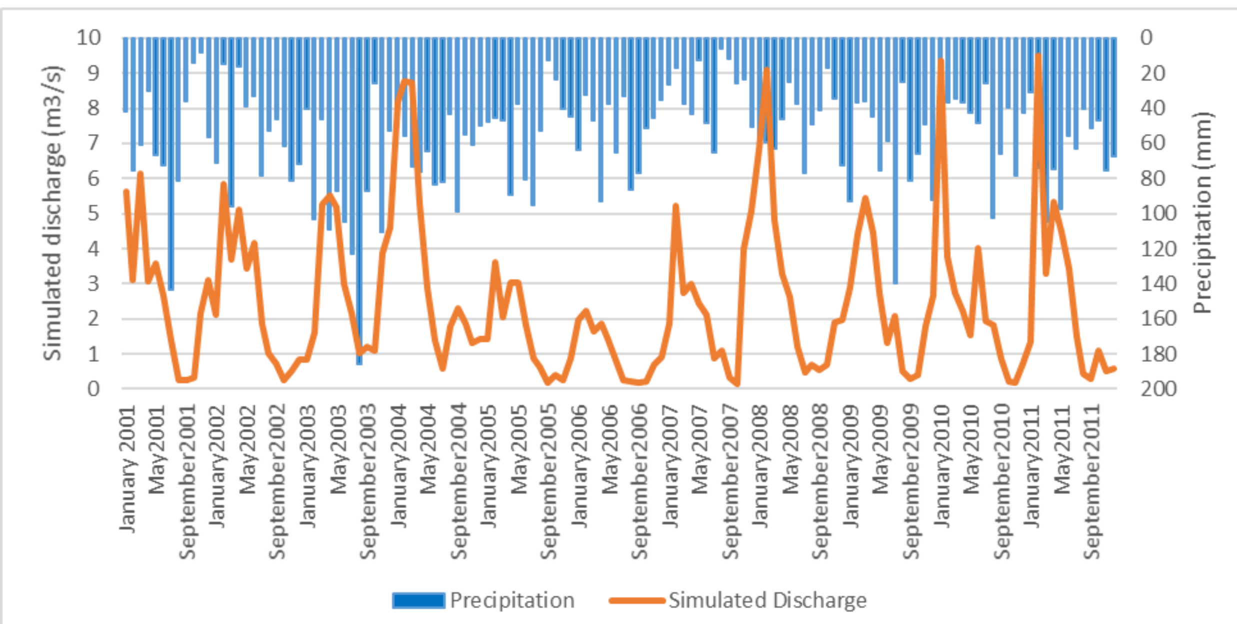

Figure 5: Comparison of simulated discharge at Outlet 2 (watershed outlet) with precipitation recorded at Tri-Cities airport shown on secondary y-axis.

Monthly simulated discharge at both outlets do not correlate well with precipitation. This is likely an artefact of the monthly timestep. Beaver Creek is prone to flash flooding in response to precipitation, and the monthly time step is too large to capture this behavior. Future work will include re-running the model at a daily time step. Descriptive statistics derived from SWAT-

CUP showed good coverage with R^2 (0.63) but a discrepancy between the mean discharge for observed (0.92 m^3/s) and simulated (0.52 m^3/s) discharge was noted. Also, the Nash-Sutcliffe efficiency (NS=-2.44) was exceedingly low and indicates that use of the mean value is a better estimate of discharge than the simulated data. This diagnostic is in opposition to the R^2 and correlation coefficients that show good agreement. Limitations exist for all modelling tools as they are solely dependent on input data.

CONCLUSIONS

Thirty years of monthly runoff in the Beaver Creek watershed was simulated with ArcGIS-SWAT and twenty-four sub-basins were delineated. Observed and simulated discharges were compared visually using time series graphs and statistically using correlation coefficients and model diagnostics. Observed discharge and simulated discharge show good agreement.

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EXAMINING THE RESPONSE OF AGRICULTURAL WATERSHEDS TO THE PRESENCE OF PESTICIDES

Miranda D. McBride[1] and Racha El Kadiri[1]

Nonpoint source pollution (NPS) is the nation's largest source of water quality problems. A major NPS type originates from fertilizers, herbicides and pesticides that flow from agricultural fields after rain events into neighboring water bodies. In Tennessee (TN), agricultural watersheds are predominately concentrated in the western region of the state in the Mississippi River Basin with a few exceptions in the eastern region of the state, each draining into numerous rivers and lakes. For this study, a total of five watersheds were selected as pilot zones to assess the response of agricultural watersheds to the presence of pesticides. The selected basins have an average area of 900 square miles, an average agricultural landuse of roughly 60 percent, and all of their outlets are monitored by active USGS gages. To reach our objective we first collected water quality data from the USGS Water Quality Data Portal and Water-Quality Watch database including nitrogen and phosphate; second we acquired pesticide use data in the pilot watersheds from TN Department of Environment & Conservation, third we correlated the pesticide presence and water quality datasets in the selected outlets to infer spatial and temporal trends in the pilot watersheds. This study is a step toward better management of water quality in Tennessee and agricultural watersheds nationwide.

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WHAT IMPACTS DO HURRICANES HAVE ON WATER QUALITY?

Andrew Osborne[1] and Dr. Racha El Kadiri[1]

Hurricanes have affected the Southeast United States throughout the region's history, causing disruption and damage to its coastal areas. One of the effects of hurricanes is to generate storm surges and rainfall that contribute to both localized and regional flooding during and immediately after the hurricane. As developed and urbanized areas have become more prevalent, the opportunities for contamination of water resources during these events have grown. In this study we investigated the effect of hurricanes (i.e. Harvey, Irma, Katrina, and Sandy) on water quality in the impacted fresh water bodies. To reach our goal, we collected water quality data (i.e. turbidity, dissolved O2, and pH) from the USGS's Water-Quality Historical Instantaneous Data for the Nation database. Then, we conducted statistical analysis to measure the correlation (i.e. pearson correlation coefficient, determination factor) between the hurricane-related change in water quality parameters and storm characteristics (i.e. storm surge height, area affected, precipitation amount, and hurricane strength on the Saffir–Simpson hurricane wind scale). In addition, we analyzed the spatial patterns of water quality changes post hurricane and we conducted time series analyses for the time period from one-year pre-hurricane (i.e. reference period) to one-year post-hurricane. These efforts will allow better predictions of the effects hurricanes have on water quality, contributing toward a better management of water resources in hurricane prone areas.

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PROCEDURAL PLANNING FOR STREAM EMBEDDEDNESS STUDY

Nicholas Pettit and John Schwartz

Who: Dr. John Schwartz & M.S. Candidate Nicholas Pettit

When: January 2019- adequate data collection or May 2019

Where: Second Creek riffles and various other locations as need arises (first 2 miles upstream from creek exit into Tennessee River)

What: Sediment embeddedness testing

How: Sediment will be collected through two methods. One is a standard passive sampler which is essentially a post staked into the streambed with bottles at various levels. The top of these collection bottles will have two holes in each of them. One hole will be open to the stream while the other will be connected to tubing placed above the post to allow for air being replaced in the bottles to gas off to the environment. The second method is a creation which Dr. Schwartz and I have discussed. It will consist of plastic tubs (surrounded by a wooden barrier to prevent bed collapse during sample collection) being embedded at bed height in the stream and filled with "stream rocks" which have no sediment in the gravel matrix at time of placement. The tubs and bottles will be collected, examined, and replaced after several major rainfall events. From the data collected by the bottles (passive), we should be able to determine both total suspended solids (TSS) during major events and an estimate for increase in stream power during the events. From the data collected by the tubs, we should be able to determine a sediment diffusion rate into the bed as well as estimates for erosion and deposition rates in the stream during baseflow conditions and major rainfall events.

Materials: Passive samplers are available at the university (I think…). If not, we will need to get posts at least 4' high with some sort of handle which will hold the passive sample bottles (3 per post, 1' apart), tubing to fit the bottlecap holes, and the sample bottles themselves. Zip ties could be used to strengthen connections and could be cut off every sample collection and replaced.

The tubs for the second method would be the extra deep version 12x8x18 (L,W,D) plastic tubs from Lowe's or Walmart. Ideally, I'd like to have sampling at least every 400' of stream which would equate to 13 sites/mile or 26 total sites. At minimum, the wood required per site would be 16x16x18 without capped ends and no back frame. This would be roughly 2496" or 208' of 2x6 wood. 3" wood screws should be sufficient to fasten the wood together, however, brackets could be used for additional strength. If 6 were used per frame, this would bring us to 156 wood brackets. River rock fill would be required as well. Using the 26-site idea, this would be roughly 44,928 cubic inches or 26 cubic feet of river rock fill.

*These are rough estimates, and I can draw these out for you when you get back to the office, but this is what it sounded like we were planning for at last meeting. Let me know if this seems over the top or too light in materials, and we can meet at some point before class starts back. Also, this document is only prepared for you, but when writing up the experiment will be more in-depth.

CHARACTERIZING RESPONSE OF SOIL AND STREAM CHEMISTRY FROM THE CHIMNEY TOPS 2 FIRE IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

Salley Reamer[1], John S. Schwartz[1], and Qiang He[1]

The Chimney Top 2 (CT2) fire began in November 2016 and burned a total of nearly 18,000 acres, with roughly 11,000 being in the Great Smoky Mountains National Park (GRSM). The fire spread due to strong, dry winds in the area and extreme drought conditions. Within the burn area, 55 stream miles were affected and soil and water quality impacts due to the fire are unknown. Here we have a unique opportunity to analyze these effects from the CT2 fire as a result of continuous monitoring efforts in the park including site characterization at 15 to 20 sites in and near the burn area before the fire. Data collected at these sites will be compared to post burn analysis of the same parameters. A soil and water characterization of the burn area will be produced. Soil parameters tested will include: pH, moisture content, organic matter content, exchangeable base cations, exchangeable aluminum and iron, exchangeable sulfate, nitrate and chloride, exchangeable acidity, cation exchange capacity, anion exchange capacity, total base saturation, total and amorphous metal oxides, total sulfur, total carbon and total nitrogen. These parameters will be tested on soils collected in 2018 and 2019, at locations in both levels of burn: low/medium and high burn. Additionally, samples will be collected at sites near the burn, that were not impacted as a control. We hypothesize that the GRSM will experience increased concentrations of nutrient cations (calcium, magnesium, potassium) on the soil exchange and in stream water due to fire ash, serving to increase pH and acid neutralizing capacity. We expect that the changes in stream water quality will be short lived but will exhibit elevated stream nutrient losses due to increases in runoff and soil availability. Sites will be selected away from major roads in the park to avoid contamination from sources such as road chat applied in the winter and exhaust from vehicles.

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DECISION SUPPORTING HYDRODYNAMIC MODELING OF TENNESSEE RIVER

Shuvashish Roy

Faculty Advisor: Jejal Reddy Bathi, Ph.D., P.E.

In this poster, we will present the results of the development and calibration of a fine-scaled 3D hydrodynamic model (EFDC) for the Tennessee River in the urban stretch of Chattanooga, below Chickamauga Reservoir, as the model domain. We are using this model domain as a case study to highlight the uses of hydrodynamic models as well the need for further investment in hydrodynamic modeling at scales relevant to the decisions facing water resource managers and planners. The development of the hydrodynamic model is timely, as the significance of water resources management becoming more critical with frequent flooding events as well stress on water sources during drought conditions. The model is calibrated using existing data from a low flood year and high flood year, including dry season and wet season flows. However, issues with available data and its quality and key data gaps that are being challenged to be addressed before the model can be further refined, validated and then used for decision making. Our calibrated model not only help understand the river flows under extreme dry and wet conditions but also be useful in the analysis of the integrity of floodway infrastructure (example, overpass bridge piers) and inundation potential of critical infrastructure (example, hospitals, utilities, etc.) in the floodplain.

CHARACTERIZATION OF NANO CONTAMINATION: CHALLENGES AND FINDINGS

Syed M Tareq
Faculty Advisor: Jejal Reddy Bathi, Ph.D., P.E.

Nano contamination (particulate contaminants of <100 nm) in surface waters is a growing concern worldwide. It is estimated that there are more than 1800 consumers products found in the environment, containing nano particles. Due to their ultrafine invisible nature, it is very difficult and highly technical to detect them in the aquatic environment. With difficulty, micron level (< 1µm) particle such as colloids and others can be traced. But for nano contaminants, sample collection, processing and analysis are highly challenging and standard procedure are still evolving. Often, the detection of nano particles in surface water requires the use of multiple technologies in tandem including ultrafiltration, centrifugation and ionization techniques to identify the nano elements. We have conducted a systematic review of the procedures and techniques that researchers are currently using and developed a methodology of characterization of the nano contaminates in surface waters. We are currently applying the newly developed characterization techniques to quantify the nano contamination in surface waters from different urban source areas. Our poster will present the details of the nanomaterial characterization procedures as well our current findings of the source area specific nano contamination.

COMPARISON OF PARAMETRIC RAINFALL MODELS OF TROPICAL CYCLONE RAINFALL FOR FLOOD RISK STUDIES

John T. Brackins[1]* and Alfred J. Kalyanapu[2]

Tropical cyclones (TCs) are responsible for 2,544 deaths in the United States from 1963-2012, with 27% occurring due to TC rainfall-induced freshwater flooding and mudslides (Rappaport 2014). Furthermore, from 1960 through as recent as 2018, TCs have produced greater than 1000-year rainfalls over time periods ranging from 1 to 5 days for the states in Federal Emergency Management Agency Region IV (except Kentucky, where the TC rainfall of record produced between a 200- and 500-year rainfall event). Clearly, TC rainfall events have the potential to affect the tail of flood risk statistical distributions, even for inland states. Given the paucity of historical data for TCs, especially inland, it is important to be able to simulate expected TC rainfall from a joint distribution of parameters like TC track, size, and intensity. Four existing parametric models already attempt to predict rainfall patterns from these variables. The objective of the current study is *to compare precipitation fields produced by the four existing parametric TC rainfall models and then to select the most appropriate model for inclusion in future flooding studies*. The standard meteorological skill metrics of critical success index, equitable threat score, and frequency bias were used to evaluate rainfall models for 70 Atlantic TCs affecting the United States from 2004 through 2017. While orographic effects play an important role for watersheds with steep elevation gradients, of the four models evaluated, the highly simplified IPET (2006) rainfall model demonstrates the most skill at reproducing storm-total precipitation for thresholds above 75 millimeters (3 inches).

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HIGH-RESOLUTION MODELING OF HURRICANE HARVEY FLOODING FOR HARRIS COUNTY, TX USING A CALIBRATED GPU-ACCELERATED 2D FLOOD MODEL

Tigstu Dullo[1], Alfred J. Kalyanapu,[2] Sudershan Gangrade[3] Md Bulbul Sharif [4],Thomas Hines[5], Shih-Chieh Kao[6], Sheikh Ghafoor[7], and Katherine Evans[8]

With advancement in computational power, reconstruction of historic flood events through high-resolution hydrodynamic model has become more affordable in the recent decade. Hurricane Harvey that made landfall in the southern Texas was one of the most destructive hurricanes in U.S. history. The downpour from Hurricane Harvey has caused significant flooding resulting in about 77 casualties, displacing more than 30,000 people, and causing more than $70 billion in direct damage. Harris County, which covers over two HUC-8 drainage basins (~2702 mi^2), has experienced more than 80% of its annual average rainfall during this event. The objective of this case study is to reconstruct flooding caused by Hurricane Harvey in Harris County, Texas using a calibrated model. The flood simulation was performed at 10m and 30-m spatial resolution using a graphic processing unit (GPU) accelerated 2D flood model (Flood2D-GPU) at through high performance computing (HPC). The hourly radar-based rainfall estimates from the National Center for Environmental Prediction Stage IV Quantitative Precipitation Estimate (Stage IV QPE) were fed into a calibrated Variable Infiltration Capacity (VIC) hydrologic model to generate runoff estimates which were then routed through the Routing Application for Parallel computation of Discharge (RAPID) to obtain streamflow hydrographs at 69 locations for Flood2D-GPU simulation. Preliminary results indicate that the maximum flood extent from Hurricane Harvey has resulted 453mi^2 of flooded area just in Harris County alone, which is 60 mi^2 more than the FEMA derived floodplain. A calibrated model run will help in revising these estimates. This study will include model calibration and validation for this event, and ultimately demonstration of the capability of the modeling framework.

Key Words: Flood Modeling; Flood2D-GPU; HPC; Hurricane Harvey

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ESTIMATED GROUNDWATER WITHDRAWALS FOR IRRIGATION AND AQUACULTURE IN THE MISSISSIPPI DELTA

John A. Robinson[1], Hydrologist, and Jeannie R. Barlow[2], Hydrologist
U.S. Geological Survey, Lower Mississippi-Gulf Water Science Center

The Mississippi Delta region of the Mississippi Alluvial Plain (MAP) is one of the most productive agricultural regions in the Nation and depends largely on groundwater for irrigation. To provide stakeholders with information and tools to better understand and manage the water resources in the region, the U.S. Geological Survey (USGS), through cooperative studies with the Mississippi Department of Environmental Quality (MDEQ) and the USGS MAP Water Availability Project, is developing a common hydrologic framework for describing and predicting highly variable interactions among surface and groundwater systems within the MAP area.

Water use is one of largest components of the overall water availability budget and is often the most uncertain. In February of 2013, MDEQ, with the support of the Delta Sustainable Water Resources Task Force, implemented a voluntary metering program. Under MDEQ's voluntary metering program, ten percent of the irrigation wells screened in the Mississippi River Valley alluvial aquifer in each county are metered, and annual reports of metered water use for these wells are submitted to MDEQ. Irrigation withdrawals can then be estimated at a 1-square mile resolution across the Mississippi Delta using the voluntary metering dataset to determine representative groundwater withdrawal rates by beneficial use (crop or aquaculture), north, central, and south region, and precipitation range.

For the MAP water budget, water use in each 1-square mile cell was determined for each crop by multiplying the acreage irrigated by groundwater by the representative withdrawal rate for that crop based on its respective region and precipitation range. Total water use for each 1-square mile cell was computed by adding water use for each crop. Improving the monitoring and mapping of water use within the Mississippi Delta will help provide accurate local data on groundwater use, support broader efforts to assess regional water use, and improve the management of the groundwater resource.

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SHALLOW GROUNDWATER GEOTHERMAL ENERGY: MODELING & SIMULATION

Nan Wang[1,2*], Qiang Zhou[1,2], and Qiang He[2]

Geothermal energy, particularly shallow geothermal energy, has great potential as a clean energy for broad applications. This study aims to 1) model the availability and distribution of shallow geothermal energy in an urban area; and 2) optimize the configuration of groundwater pumping and recharge wells for geothermal energy applications with numerical simulation. Based on geotechnical and hydrogeological characteristics of the study area, three different lithological types were modeled to develop the shallow geothermal reservoir temperature field distribution using the thermal coupling simulation model TOUGH2, validated by field temperature and pressure data. Modeling results indicate that thermal capacity was much greater in areas of groundwater than areas consisting of mostly soil and rock layers. Numerical simulation was used to optimize the design of shallow ground geothermal systems with regard to the configuration and spacing of pumping and recharge wells. This study provides much needed information for the assessment of shallow groundwater geothermal energy and its applications such as shallow geothermal heat pump systems as clean energy sources.

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LIDAR USA (a Fagerman Technologies company) manufactures car and UAV-ready LIDAR and image mapping systems using a variety of scanners (single and multiple line, multi-return), cameras (non-metric, metrick, RGB, multispectral) and INS (OEM & name-brand). Systems can be fixed to a drone platform or to any other vehicle (car, boat, rail). At the moment we are the only vendor offering a lidar solution for the DJI M200/M210. We build systems to suit your needs and make you successful. Visit us at https://www.lidarusa.com.

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Founded in 2007, RES is the largest dedicated provider of ecological solutions in the United States. With nearly 400 devoted staff across the nation, RES works directly with clients to provide high-quality, client-centric solutions. RES helps clients manage risk from operations in environmentally sensitive areas by providing proactive project impact analyses, streamlining permitting processes, and limiting liability and regulatory exposure.

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Skytec is a leader in Unmanned Aerial System (UAS), remote sensing and Geographic Information Systems (GIS) technologies. Skytec provides competitive data capture, analysis and information delivery services with a commitment to safety, innovation and achieving our client's objectives through high quality work and expertise.

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At Water & Land Solutions, we are dedicated to restoring, enhancing, and protecting our precious natural resources with the intent of leaving this Earth better than we found it. We place equal value in growing personal relationships and positively impacting PEOPLE throughout the process. Whether you want to restore ecological functions, conserve land for future generations, navigate regulatory processes, or maximize yields, Water & Land Solutions can help. We strive to put PEOPLE first and think you will find our expertise, work ethic, and focus on your needs to be invaluable.

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Van Essen Instruments offers a complete portfolio of Diver technology and services in the field of groundwater and surface-water monitoring networks. Reliable and accurate sensors combined with the latest developments in the field of wireless communication and data visualization, Van Essen Instruments offers effective and efficient data and water management solutions. www.vanessen.com.

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