July 2016 - June 2017
Annual Report

and

July 2018 - June 2019
Appropriation Request

to the

Tennessee Higher
Education Commission

October 2017

311 Conference Center Building, Knoxville, Tennessee 37996-4134
(865) 974-4251 Fax (865) 974-1838 email: isse@utk.edu http://isse.utk.edu

ISSE MISSION STATEMENT

The University of Tennessee's Institute for a Secure and Sustainable Environment (ISSE) seeks to promote the development of policies, technologies, and educational programs that cut across multiple disciplines, engage the university's research faculty and staff, and grow in response to pressing environmental and security issues facing the state, the nation, and the globe.

Executive Summary

Dr. Terry Hazen, ISSE Director

During 2016-17, ISSE continued to expand its research and outreach, and the pages of this report provide an update of the activities carried out by ISSE staff, students, and ISSE-affiliated faculty. Here is a summary of ISSE activity this year:

- ISSE has supported more than a dozen externally funded research projects, and continued to co-support two research initiatives with the UT Office of Research and Engagement.
- In addition to its seven on-going internally funded, faculty-led seed projects, ISSE awarded six new seed projects at the end of FY16.

  ISSE seed grant funding resulted in the submission of ten new proposals, four of which were funded and three are still pending.
- ISSE-related faculty, staff, and students received several awards during the year, as shown on page 62 of this report. Along with numerous presentations made to a wide range of audiences, several articles were published, most in peer-reviewed journals (see list of publications below).
- ISSE research projects have engaged more than 60 UT faculty members, six post-docs, 38 graduate students, and 30 undergraduate students.
- ISSE's Tennessee Water Resources Research Center (TNWRRC), under the leadership of Director Thanos Papanicolaou and Assistant Director Timothy Gangaware, continued supporting six on-going water resource projects funded through the USGS 104(b) program and awarded five new projects under this program, one of which was Graduate Research Assistant Supplemental Research Award.

  TNWRRC continued to conduct training programs in erosion prevention and sediment control around the state. Its Level 1 course (fundamentals) was conducted 15 times and attended by 1,221 people. Its Level 2 course (design principles) was conducted four times and 210 persons attended. The Level 1 one-day recertification course was held 16 times and attended by 1,312 people. The hydrologic determination training program had approximately 50 attendees and the refresher course had 41 attendees.

Executive Summary (cont)

TNWRRC supported the Knox County Adopt-A-Watershed Program, which involved 1500 students from 14 middle and high schools in East Tennessee. This program is managed by TNWRRC and sponsored by Knox County Stormwater and the Water Quality Forum. Assistance to the Tennessee Smart Yards program (jointly supported by TNWRRC and UT Extension) included management of the program's communications and marketing, including maintenance of their website, native plant database, social media platforms, and producing a quarterly newsletter.

- In addition to other projects, the East Tennessee Clean Fuels Coalition managed the annual allotment of State EPA Diesel Emissions Reductions Act (DERA) funding, assisted new fleets across the State, and partnered to develop and designate alternative fuel corridors in Tennessee.
- ISSE's Worker Health and Safety Training Program facilitated training of 1,500 DOE workers at sites around the country. An online course option was approved and will increase accessibility for workers.

In 2016, ISSE developed a Basic Ordering Agreement (BOA) to enable ISSE researchers to easily contract with communities and municipalities to offer technical assistance and expertise in areas such as recycling, solid waste management, bioenergy, solar energy use, alternative fuel use, water quality and supply issues, sustainable growth plans, tourism and business development, and other topics that fall under the broad umbrella of sustainability. The City of Farragut, Tennessee took advantage of this BOA to fund a project (starting in August 2017) to identify, locate, and assess the different stormwater structures that are owned by the Town.

Assistance was provided to ISSE Researchers Timothy Ezzell and Catherine Wilt to promote economic development in rural West Virginia by creating a "Dark Skies" park to accommodate tourists drawn to the increasingly rare dark night sky. A 2016-17 ISSE seed grant furthered their efforts.

ISSE also supported a conference on People and Climate Change at Washington University in St. Louis and made a financial contribution to UT Knoxville's iGEM team 2017. iGEM stands for international genetically engineered machine, and is a team of undergraduate students in chemical engineering. Their current project focuses on developing microorganisms that are capable of producing chemical products from hazardous chemicals; specifically, the synthesis of benzaldehydes through degradation of the water pollutant toluene.

A new initiative ISSE began to develop in FY2016 is the Methane Center, whose vision is to integrate across science, engineering, and business models to create a broad conceptual understanding of CH_4 as a driver of ecosystem processes and services, and to use this understanding to create a lifecycle assessment framework for environmentally sustainable generation, management, and utilization of CH_4. The mission of the Methane Center is to provide a continuum of fundamental and technological research advances and training in CH_4 environmental science leading to a cohort of young engineers and scientists dedicated to effective communication of meaningful scientific findings to inform and stimulate the public, and provide structured rationale for economic and environmental policy decisions and regulations. The methane center supported one graduate student and was linked to a new seed project funded this year. Director of the Methane Center is Terry Hazen, who has published two papers related to fracking effects and has two more under review.

In the next fiscal year, ISSE will continue to expand its research and outreach. The ISSE Advisory Committee met for the first time in December 2016 and is helping to develop a strategic plan for ISSE, with an additional meeting planned for December 2017.

Table of Contents

Summary of Faculty and Student Particpation

Faculty/Staff Actively Engaged in ISSE Research

Name	Affiliation
Paul Armsworth	Ecology & Evolutionary Biology
Anton Astner	Center for Renewable Carbon
Abjijeet Borole	Chemical Engineering
Barry Bruce	Biochemistry and Cellular and Molecular Biology
John Buchanan	Biosystems Engineering and Soil Science
Kimberly Carter	Civil and Environmental Engineering
Jiangang Chen	Public Health
Rachel Chen	Retail, Hospitality and Tourism Management
Christopher Cherry	Civil and Environmental Engineering
Christopher Clark	Agricultural Economics
Daniel Costinett	Electrical Engineering & Computer Science
Chris Cox	Civil and Environmental Engineering
Virginia Dale	Ecology and Evolutionary Biology
Jennifer DeBruyn	Biosystems Engineering and Soil Science
Islam El-Adaway	Civil and Environmental Engineering
Kelsey Ellis	Geography
Michael Essington	Biosystems Engineering and Soil Science
Barbara Evans	Mechanical, Aerospace, and Biomedical Engineering
Timothy Ezzell	Political Science
Paul Frymier	Chemical and Biomolecular Engineering
Joshua Fu	Civil and Environmental Engineering
Timothy Gangaware	ISSE, Tennessee Water Resources Research Center
Melissa Goldberg	ISSE, East Tennessee Clean Fuels
Chris Graves	Forestry, Wildlife and Fisheries
Sue Hamilton	Plant Sciences
Ruth Anne Hanahan	ISSE, Tennessee Water Resources Research Center
Jon Hathaway	Civil and Environmental Engineering
Shawn Hawkins	Biosystems Engineering and Soil Sciences
Douglas Hayes	Biosystems Engineering and Soil Sciences
Terry Hazen	Civil and Environmental Engineering; Earth and Planetary Sciences; Microbiology; ISSE
Qiang He	Civil and Environmental Engineering
Don Hodges	UTIA Forestry, Wildlife and Fisheries
Baoshan Huang	Civil and Environmental Engineering
Becky Jacobs	Law
Mingzhou Jin	Industrial and Systems Engineering
Anahita Khohandi	Industrial and Systems Engineering
Ungtae Kim	Civil and Environmental Engineering, Cleveland State
Alice Layton	Earth and Planetary Sciences
Sarah Lebeis	Microbiology
Xueping Li	Industrial and Systems Engineering
Brian Long	Chemistry
Andrea Ludwig	Biosystems Engineering and Soil Sciences
Lisa Reyes Mason	Social Work
Hugh O'Neill	Biochemistry and Cellular and Molecular Biology
Jim Ostrowski	Industrial and Systems Engineering

Faculty/Staff Actively Engaged in ISSE Research

Name	Affiliation
Jonathan Overly	ISSE, East Tennessee Clean Fuels
Angelica Palomino	Civil and Environmental Engineering
Thanos Papanicolaou	Civil and Environmental Engineering
Hector Pulgar	Electrical Engineering and Computer Science
Todd Reynolds	Microbiology
Gary Sayler	Microbiology
John Schwartz	Civil and Environmental Engineering
Sean Schaeffer	Biosystems Engineering and Soil Science
Charles Sims	Economics
Anna Szynkiewicz	Earth and Planetary Sciences
Forbes Walker	Biosystems Engineering and Soil Science
Sheila Webster	ISSE (retired)
Christopher Wilson	Civil and Environmental Engineering
Catherine Wilt	Institute for a Secure & Sustainable Environment
Janet Wu	Electrical Engineering & Computer Science
TingTing Xu	Center for Environmental Biotechnology

Post Docs and Graduate Students Involved in ISSE Research

Graduate Students	Department
Abban, Benjamin	Ph.D., Civil & Environmental Engineering
AzadDisfany, Mojdeh	Ph.D., Civil & Environmental Engineering
Brown, Vincent	MS, Geography
Campa-Ayala, Maria	Ph.D., Civil & Environmental Engineering
Cecil, Alisha	MBA, Finance
Chen, Tian	Ph.D., Microbiology
Dhakal, Niebesh	MS, Civil & Environmental Engineering
Eichler-Inwood, Sarah	Bredesen Center
Ende, Jessica	Ph.D., Earth & Planetary Sciences
Epps, Thomas	MS, Civil & Environmental Engineering
Erwin, Jennifer	Ph.D., Social Work
Fritz, Bridgett	MS, Earth & Planetary Science
Gathongo, Njoroge	MS, Geography
Gonzalez, Adrian	Ph.D., Civil & Environmental Engineering
Hicks, Jordan	MS, Civil and Environmental Engineering
Jalapout, Mojtaba	MS, Electrical Engineering and Computer Science
Knueven, Bernard	Ph.D., Industrial and Systems Engineering
Ling, Ziwen	Ph.D., Civil & Environmental Engineering
Love, Austin	Ph.D., Industrial and Systems Engineering
Manz, Katherine	Ph.D., Bredesen Center
Matzek, Laura	Ph.D, Civil and Environmental Engineering
McBride, Kathryn	MS, Microbiology
McIlvenna, Amelia	Ph.D., Industrial and Systems Engineering
Mitchell, Nolan	Chemistry
Rabby, Yasin	MS, Geography
Ramsey, Ashley	Ph.D., Earth & Planetary Sciences
Ramshani, Mohammad	MS, Industrial and Systems Engineering
Sanchez, Diego	MS, Earth & Planetary Sciences
Sawyer, Nevin	MS, Industrial and Systems Engineering
Scruggs, Phillip	MS, Industrial and Systems Engineering
Seiden, Zachariah	MS, Civil & Environmental Engineering
Sun, Jian	Ph.D., Civil & Environmental Engineering
Tan, Jiani	Ph.D., Civil & Environmental Engineering
Tansakul, Varisara	MS, Industrial and Systems Engineering
Tsakiris, Achilleas	Ph.D. Civil & Environmental Engineering
Veeneman, Andrew	Ph.D. Civil & Environmental Engineering
Woockman, Robert	MS, Civil & Environmental Engineering
Yang, Cheng-en	Ph.D., Civil & Environmental Engineering
Yang, Lu	Ph.D., Civil & Environmental Engineering
Zhang,Zhihou	Ph.D., Civil & Environmental Engineering
Zhu, Qingzhao	Ph.D., Civil & Environmental Engineering
Post-Docs	
Dong, Xinyi	Civil and Environmental Engineering
Ghaneeizad, Seyed	Civil and Environmental Engineering

Undergraduate Students Involved in ISSE Research

Undergraduate or Hourly	Department
Alcala, Aliyah	Biochemistry & Molecular and Cellular Biology
Arnholt, Kelly	Biochemistry & Molecular and Cellular Biology
Barnette, Lauren	Civil and Environmental Engineering
Beeler, Brett	Civil and Environmental Engineering
Benavidez, Joshua	Civil and Environmental Engineering
Brewer, Sheridan	Civil and Environmental Engineering
Burchett, Julianna	Environmental Science
Cecil, Alisha	Center for Transportation Research
Delalla, Jacob	Biological Sciences
Gipson, Amie	Civil and Environmental Engineering
Goldfarb, Phillip	Civil and Environmental Engineering
Harrison, Taylor	Social Work
Huang, Vicki	Civil and Environmental Engineering
Humphrey, Laura	Political Science and Sustainability
Keckler, Amy	Social Work
Keyser, John	Civil and Environmental Engineering
Manka, Brandy	Civil and Environmental Engineering
Mann, Joseph	Electrical Engineering & Computer Science
Marr, Enolia	Microbiology
Mohler, Roderick	Civil and Environmental Engineering
Muir, Christopher	Industrial & Systems Engineering
Myers, Kalie	Business Administration
Patel, Bindiya	Food Science and Technology
Nicole Pearlman	Civil and Environmental Engineering
Quistorff, Cassidy	Civil and Environmental Engineering
Sherwin, Erin	Biochemistry & Molecular and Cellular Biology
Shires, Mary	Social Work
Smith, Payton	Civil and Environmental Engineering
Young, Anna	Biomedical Engineering

2016-17 Programmatic Report

Tennessee Water Resources Research Center (TNWRRC)

(Team: Thanos Papanicolaou, Timothy Gangaware, Ruth Anne Hanahan, and Roy Arthur)

A note from the TNWRRC Director, Thanos Papanicolaou—

Currently, Tennessee is fortunate to have what many consider an abundance of good quality water. However, this may not always be the case. The U.S. Global Change Research Program in a recent report has projected less frequent precipitation and higher temperatures. As a result, we will see increased evapotranspiration (ET) and more frequent drying-and-wetting cycles. These changes will lead to deficits in both soil moisture and surface/ground water stores, and hence more droughts, like in 2007.

The increased drying-and-wetting cycles will also weaken soil aggregates through repeated shrinking and swelling. Then higher intensity rains will cause extreme erosion events, washing away soil nutrients and contaminants. The subsequent degradation of our water quality will further limit the availability of clean water.

In addition to the effects of climate variability on water availability, there will be an increased demand from a rising population and growing cities. These changes in demand are especially significant in adjoining urban and agricultural areas around Tennessee.

With more and more people migrating to cities needing drinking water and electricity, as well as more farms needing to irrigate, this escalating demand may lead to a water crisis. The shifting water demands may lead to complex natural-human interactions that have not been encountered before in the southeastern U.S.

Providing an adequate supply of quality water for agricultural, industrial, commercial, and domestic uses, while protecting our surface and groundwater resources are major concerns in the whole state and vital to Tennessee's economic development and growth. However, the level of knowledge necessary to understand the underlying hydrological, biogeochemical, and social processes that control the availability of water in the state, as well as their interactions and feedbacks, is beyond the capacity of one group or agency to handle. This necessitates collaboration among academia, governmental agencies, and industry to collect and analyze information for water quality and quantity (WQ^2) at any scale and at all times.

To address management issues of Tennessee's water resources, a truly interdisciplinary and well-coordinated effort is needed. The Tennessee Water Resources Research Center (TNWRRC) has the right mixture of leadership, outreach, and interdisciplinary research and can unite the different groups and work towards a statewide adaptive governance plan managing the state's water resources to the benefit of all. It is a primary goal of the TNWRRC to assist the state in developing and implementing programs for sustaining high quality water, serving as a link between the academic community, federal and state government water-related organizations, the private sector, and local communities.

During this past year, the TNWRRC staff have worked with our newly developed Advisory Board to bridge the gaps across the state. We have focused on growing the 104B seed grant program.

Building on the input of the Advisory Board, this year's 104B seed grants focused on the impact of water, soil, and nutrient management decisions on Tennessee's water resources. Excess runoff and soil erosion, resulting from our management choices affect soil health and productivity, as well as WQ2 across the state. Public awareness of nutrient-related water quality issues is rising and putting pressure on the state government to regulate these issues.

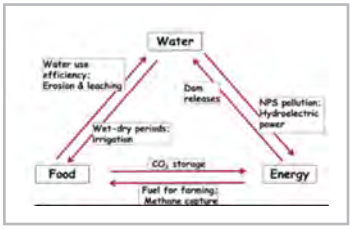
The 104B program was also enhanced to include student stipends with funding of up to $5,000. This stipend program is to help students complete additional research objectives or products beyond the scope of their current water-related funded project. With these funds, the students are encouraged to use the money for publication costs, so

2016-2017 Programmatic Report

that they can submit their research to top-tier, peer-reviewed journals.

Projecting forward to upcoming years, TNWRRC staff are targeting five initiatives. The initiatives include applying a new perspective to Tennessee by viewing it as a coupled natural-human system. As our cities continue to grow and infringe on agriculture lands, we must explore how human interactions will alter the natural processes we sometimes take for granted. As we change the landscape to fit our growing numbers, we are essentially re-plumbing how water moves through the soil. By constructing artificial flow pathways, water now moves more quickly, with little time to experience the natural remediation processes that the soil and its microbes perform. This is just one example of new natural-human interactions are reshaping our lives.

One outcome of this system re-plumbing will be a lack of sufficient soil moisture, which would lead to a decline in crop yields in those agriculture lands adjacent to the cities. This may necessitate increased fertilizer use and irrigation to offset the yield losses. Increased fertilization and irrigation will translate to excess fluxes of non-point source nutrient loads into the dams, ultimately affecting dam operations to produce hydropower, especially the controlled water releases to meet optimal energy production.



In response, we have coalesced like-minded researchers from the different departments on campus, as well as from the Tennessee Valley Authority and Oak Ridge National Laboratory into an Initiative for Food, Water, and Energy, (IFWE). All research in IFWE is question-driven and aimed at developing a system dynamics model to address food-water-energy concerns in the southeast.

Additionally, there is growing evidence that much of the sediment load in Tennessee streams comes from the banks rather than the adjoining upland areas, as channels adjust to altered flow regimes. Very few studies have systematically examined the relationship between bank soil properties and flow regimes along a bank profile and in different parts of the river to determine the most appropriate bank stabilization method. Past channel restoration activities have relied heavily on riprap and other highly engineered structures without accounting for ecological context and natural stream processes. However, riprap may not be the best response in all cases. Targeted bio-based bank stabilization structures may be better suited.

Left: Severe bank erosion; Right: A bio-based bank stabilization structure.

On March 3, 2017, the TNWRRC staff, along with the Tennessee Department of Agriculture, met with various state agencies during a daylong workshop to address bank erosion and stream restoration concerns in Tennessee. More than 50 participants from the Tennessee Department of Environment and Conservation, the Tennessee Department of Transportation, the Natural Resources Conservation Service, the Nature Conservancy, the West Tennessee Basin Authority, and local consulting firms were present. The goal of the workshop is to develop a classification scheme for the state that identifies the most appropriate bank stabilization technique for a particular stream reach.

The TNWRRC is also working with other water resources research centers to form a Mississippi River Basin Network Initiative that will transform research in the MRB through new infrastructure investments. The infrastructure will facilitate

studies that cannot be done under current single-investigator or collaborative projects. Amplifying the impact of existing research investments starts with a system of integrated nested measurements to examine watershed nutrient dynamics; agricultural and decentralized treatment (e.g., bioswales) practices for nutrient losses; long-term changes in hydrology and climate; economic and social impacts of hypoxia; and institutional interactions from catchment to basin scale and across policy domains. To do so we are establishing partnerships that include the Environmental Protection Agency and Corps of Engineers, along with our parent agency, the USGS.

Finally, the TNWRRC is expanding into the local communities to help them with water related issues. The latest effort is with the Town of Farragut. The TNWRRC and the Town are working together to identify, locate, and assess the different stormwater structures that are owned by the Town. The project is a multi-year, phased effort that will canvas the different residential communities in Farragut. The team of Thanos Papanicolaou, Christopher Wilson, Tim Gangaware, Roy Arthur, and student intern Sean Ryan are canvassing the neighborhoods of Farragut, mapping the different assets and assessing their condition. They will compile GIS maps for the Town and provide a detailed report. Not only is this work mandated for maintaining the Town's MS4 permits, but also it will lead to the development of a stormwater infrastructure improvement plan.

TNWRRC Intern Sean Ryan and Lori Saal, the Farragut Stormwater Manager, are reviewing the attributes needed to describe the stormwater grates.

2016-2017 Programmatic Report

USGS Projects

The TNWRRC is one of 54 state-level Water Resource Research Institutes of the US Geological Survey (USGS) and administers several state-level grants through the 104(b) program. Active projects during this reporting period are discussed below.

Using UV/Peroxyacetic Acid to Remove Pharmaceuticals from Reclaimed Wastewater

(PI: John Buchanan, Biosystems Engineering and Soil Science, UTIA)

Methods, Procedures, and Facilities: A near-collimated beam UV light device was built such that light can only strike the sample at a right angle to the water surface. This procedure allows for consistent and repeatable UV intensity and exposure. Additionally, this device prevents the laboratory staff from inadvertently looking at the UV lamp. The light source is a low-pressure mercury arc lamp that produces most of its light energy in the 254 nm wavelength. The intensity of exposure can be adjusted by moving the sample closer or further from the light source. UV dosage is the product of intensity multiplied by time of exposure. Intensity has units of mW cm-2. If the exposure is measured in seconds, then the UV dosage becomes mW s cm-2 or mJ cm^{-2}.

Water samples containing various concentrations of pharmaceuticals and personal care products (PPCPs) are placed in a 10 mL beaker with a small stir bar. The beaker is placed on a stir plate that is positioned under the near-collimated beam device. The distance between the lamp and the sample water surface is held constant for a given UV intensity. To date, we have used two intensities – 0.060 mW cm^{-2} and 0.094 mW cm^{-2}. Ten minutes of exposure at the lower intensity is equivalent to 36 mW s cm^{-2}. The UV light industry typically reports dosage values in terms of µW s cm^{-2}, thus this dosage would be 36,000 µW s cm^{-2}.

For each PPCP, a 100 mg L^{-1} standard solution was assembled. 100 µL of this solution is put in a 10 mL glass beaker and diluted to a final concentration of 1 ppm of the selected PPCP. A small square of sheet metal (10 cm by 10 cm) is placed over the beaker (used as an aperture to block UV light) until the test begins. The PAA was sourced from SaniDate® 12 (BioSafe Systems, East Hartford, CT). This formulation is 12% peracetic acid (PAA), 18.5% hydrogen peroxide, 20% acetic acid and water. The PAA dosages are based on the peracetic acid content (e.g., 1 ppm PAA as peracetic acid). Using a 10 mL sample, 0.075 µL of Sanidate® 12 was added to achieve 1 ppm of PAA.

Each test was conducted in triplicate and the AOP process (PAA/UV) was conducted for 10, 20 and 30 minutes. At the end of each test, a two molar excess (as compared to PAA and H_2O_2 addition) of sodium thiosulfate was added to quench the oxidation reactions, and the beaker was re-covered to prevent additional UV exposure.

Analyses for PPCP removal was conducted with a HPLC using a C18 column (150 mm long by 4.6 mm dia.), an 80/20 methanol/water mobile phase operated at 1 ml min^{-1}.

Results and Findings: It was proposed to specifically evaluate the removal of 17α-ethinylestradiol, sulfamethoxazole, triclosan, and diclofenac. Two PAA concentrations and two UV dosages are being evaluated for removal effectiveness. At this time, we have evaluated triclosan.

The AOP process seems to increase the overall remove efficiency and the removal rates as compared to PAA alone and UV alone.

Precipitation Prediction in a Climate Model in the Obion River

(Team: Joshua Fu and Xinyi Dong, Civil and Environmental Engineering, UTK)

Introduction: Precipitation is the water released from the atmosphere to the Earth. It is an important component in the water cycle and provides the input to the hydrology. Long-term shortage of precipitation will lead to drought while extreme precipitation in a short period of time could cause the flooding issue, both of which are severe environmental concerns and bring tremendous loss to the water resource, agriculture and human life. Although the precipitation over the conterminous US (CONUS) is monitored and assessed by more

2016-2017 Programmatic Report

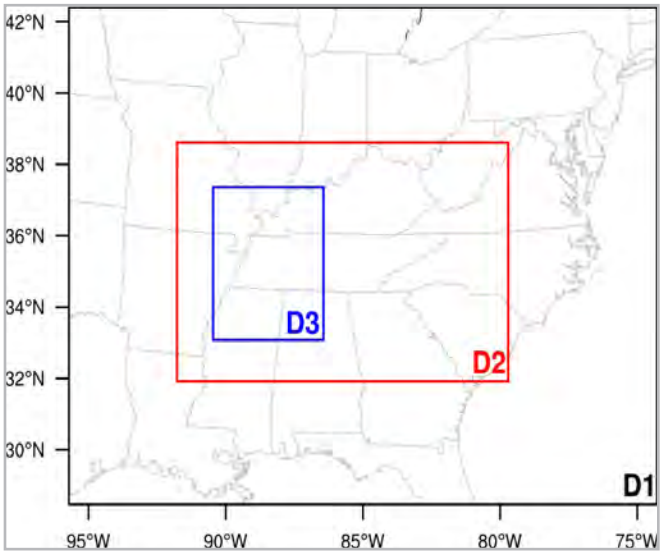
than a thousand observation sites from NOAA's National Climatic Data Center (NCDC), they are not evenly distributed and there could exist lots of missing data for precipitation of a specific region. Therefore, model simulation is a good alternative to provide continuous information about the spatial distribution and magnitude of precipitation.

This research proposes to investigate the frequency and intensity of precipitation at the Obion region, a county in the Western Tennessee. We run the global climate model, the Community Earth System Model (CESM), to generate the necessary initial and boundary input for the regional weather model, the Weather Research and Forecasting (WRF) model. A 10-year simulation (2001 to 2010) is done to provide a long-term result of precipitation and reduce the interannual variability from the global climate model. We evaluate the model prediction ability by comparing the simulated precipitation with the observations from two sites at the Obion region. We evaluate both the bias of monthly mean precipitation and the probability distribution (PDF) of precipitation, which is a common way to examine how well the model can capture the extreme precipitation. If the model results agree well with the observational data, we can use it to provide the necessary input for the hydrologic model for a further study of hydrology.

Results: We compare the simulated 10-year precipitation with two observational sites from NCDC at the Obion region (site1: 36.3925°N, 89.0317°W; site2: 36.4527°N, 89.3027°W). It shows that CESM overpredicts the frequency of light rain (days with precipitation higher than 1mm) from 2001 to 2010 while WRF clearly reduces this bias. Considering the total amount of precipitation for the days with precipitation higher than 1mm, the WRF results are also close to the observation data, especially for site1. With respect to the frequency of extreme precipitation (e.g., days with precipitation higher than 30mm), strong underestimation is observed from CESM output while WRF again reduces the bias significantly. A similar improvement of the intensity of extreme precipitation (e.g., total amount of precipitation for the days with precipitation higher than 30mm) is also achieved by WRF simulation.

In addition, we also use the site2 as an example to visualize the probability distributions of daily precipitation. It shows that when the daily precipitation is less than 10mm, CESM and WRF predicts a higher probability than the observation. When the daily precipitation is higher than 30mm, CESM almost loses the whole information about the extreme precipitation while WRF generally captures the probability distribution of observation. We further compare the WRF results to our previous WRF results for the whole Eastern US. It turns out that the WRF results yield certain improvement over the CESM results but don't perform as well as the WRF results from this study, which highlights the importance of doing sensitivity analysis of physics schemes for a particular region and using a newer land-use dataset.

We also show the scatter plots of 10-year averaged monthly total precipitation for all the observation sites (~200) inside the WRF D3 domain. It seems that for most sites, the WRF results agree well within ±50% of the observational data. There is certain underestimation of monthly total precipitation for WRF during the winter (December-January-February) but overestimation during the spring (March-April-May), which is probably related to the water evaporation from the soil.



WRF simulation domain for the Obion region: D1 (36 km x 36 km); D2 (12km x 12 km); and D3 (4 km x 4 sm)

2016-2017 Programmatic Report

Measuring Water Table Fluctuations under Different Irrigation Regimes in Western Tennessee Agroecosystems

(Team: Christopher Wilson and Jon M Hathaway, Civil and Environmental Engineering, UTK; Shawn Hawkins, Biosystems Engineering and Soil Sciences, UTIA)

Research objectives: In this study, we planned to address the above critical gap by establishing a nest of piezometers for measuring the movement and rate of change in the water table elevation under a field in western Tennessee supplied with different rates of irrigation. In addition to the piezometer nest, we planned to make simultaneous measurements of soil moisture, infiltration, and evapotranspiration (ET) to help close the water budget for the field. The instrumented farms at the Milan Research and Education Center (REC) run by the University of Tennessee Institute of Agriculture allow for pilot-scale studies to isolate the dominant hydropedologic factors affecting infiltration and percolation of irrigated water to help close the water budget of the field. These measurements would allow us to identify how ambient soil moisture conditions and soil characteristics, as well as vegetation coverage, affect the upward and downward movement of water in the soil column. This knowledge would provide improved predictive ability of water table fluctuations in response to changing weather conditions and irrigation rates by incorporating the "memory effects of soil". The measurements also provide ground-truthing of satellite-derived estimates of field moisture levels. This provides the ability to scale up results using remotely sensed data and Geographical Information Systems (GIS) software using kriging interpolation techniques based on in-situ property cross correlation functions developed by the matrix of the proposed experiments. This effort can help decision-makers enact sound water resource policies that are science-based.

The nature of our proposed study encompassed three main objectives. Objective (1) included the development and testing of the sensors. Objective (2) involved data collection of water table fluctuations, as well as changes in soil moisture, infiltration, and ET in a field plot under a center pivot. Finally, Objective (3) involved the comparison of these data with soils data and remote sensing images from MODIS as a form of ground-truthing. These three objectives are initial stepping stones to closing the hydrologic budgets for the different ecosystems in Tennessee.

Methodology: This project is a seed instrumentation grant, with its whole purpose being to design/acquire the appropriate equipment to conduct current and future research that is beyond the short term lifespan of the seed grant. It also builds from existing USDA efforts that are looking at water availability issues in Tennessee and the U.S. Southeast. The findings of this study will help address the critical gap in our current monitoring and modeling capabilities, which is the lack of understanding about the interactions of soil moisture, infiltration, and pedology at different spatial and temporal resolutions and under different management practices.

Initially, after we reviewed the literature pertinent to in soil moisture, infiltration, and ET in the Southeast, we collected satellite imagery in advance to identify ranges of variability and bounds of uncertainty. Combinations of MODIS ET images and SMAP soil images were used to identify locations in western Tennessee where we see potential deficits in available water.

At these locations modeling simulations using VIC and WEPP were used to project potential water stresses under the different land-uses in the area. The simulations showed that the critical times of water stress occur in early spring and late summer, when ET exceeds precipitation. We targeted our monitoring these time periods Once that was done, we began developing a monitoring protocol that included all the necessary instruments of the monitoring array and the different irrigation regimes to be tested.

The monitoring protocol included ET array, double ring infiltrometers, moisture sensors, and piezometers. The protocol also included a LP-80 Ceptometer to measure Photosynthetically Active Radiation (PAR) in real time and Leaf Area Index

(LAI). The LAI data can estimate total biomass production without destroying the crop and other canopy processes, which can be used to convert ET0 to actual ET.

However, difficulties were met when planning the installation of the piezometer nest. The persistent presence of a clay fragipan in the region limited our ability to collect usable readings with the piezometers these measurements. Continued searching found a useable location however, we had missed to optimal window to measure water stress determined by the modeling exercises.

Principal findings: A one-year, no cost extension was received for this project to finish additional field work. The plan was to measure water table fluctuations, soil moisture changes, infiltration, and ET under different irrigation rates. We were going to install a piezometer nest to understand the influence of irrigation on the water table but the persistent presence of a clay fragipan in the region limited our ability to collect usable readings with the piezometers these measurements. Once a suitable location was found, it was too late in the season to obtain measurements under the active irrigation period. With a suitable location now available, the measurements can be made during this upcoming season with a no-cost extension.

During the extension, the PIs will perform the tasks mentioned above. The additional field work is designed to provide more data for calibrating and validating the top-down, bottomup modeling framework. Our plans include correlated measurements of infiltration, actual evapotranspiration, and soil moisture, as well as runoff and erosion. Understanding the complex connection between climate and management requires ample data. We are also examining the role of adaptive management, namely cover crops and the different effects of planting date and crop type.

Urban Stream Restoration Planning: Towards Cost-Effective Mitigation of the Effects of Hydromodification

(Team: Robert R Woockman and John S. Schwartz, Civil and Environmental Engineering, UTK)

Introduction: Urbanization causes widespread changes to watershed hydrology and channel geomorphic processes, where increased impervious surfaces cause hydromodification mostly observed as greater peak stormflows and longer durations. Hydromodification leads to channel bed and bank erosion increasing fine sediment loads to stream. These increases in fine sediment loads result in degradation of aquatic habitat and impairment of biotic integrity. Impacted streams are identified on federal/state 303(d) list requiring a total daily maximum loads (TMDLs) for suspended sediment to be produced, in addition to an implementation plan to achieve loading targets. In urban watersheds, the potential generation of fine sediment loads from geomorphic incision cannot be separated from uplands stormwater management practices. Although stormwater control measures improve water quality from local sites, a key question remains as to what levels of treated stormwater discharges are acceptable to maintain in-stream geomorphic stability, termed channel protection flows. However, the linkages between urbanization, stormwater management policy, and stream channel response are still poorly understood over the range of watershed settings. Therefore, a critical need exists for state and local agencies charged with the water quality protection of streams to have geomorphic field assessment tools that can prioritize streams reaches most vulnerable to in-channel bank/bed erosion. This research proposes to clarify interrelationships between hydromodification from urbanization, fluvial geomorphological processes, and stormwater management and policy. It is proposed that classification of urban stream reaches by trajectory of response to hydromodification allows an approximation of impacts of land-use modifications, development of effective regulation to avoid or minimize externalities, and prioritization of mitigation efforts between stormwater control measures and stream rehabilitation. The classification scheme will be based on in improved geomorphic field assessment protocol for urban streams. Ultimately, this research is expected to support stream system rehabilitation in Ecoregion 67 through adaptation of mitigation

2016-2017 Programmatic Report

practices relative to channel erosive resistance properties and adapted for use in channel protection efforts throughout the nation.

Methods, Procedures, and Facilities:
Task 1 - Site Selection: In order to accomplish the objectives listed above, fluvial audits will be performed at both reference condition and urban-impacted sites. Representative reaches within small stream systems will be selected from 2nd and 3rd order streams in ER67. Reference conditions sites will be determined as those having similar environmental controls but either limited anthropogenic disturbance or have reached a new stable state following disturbance. Stable state can be broadly defined as those reaches which exhibit no apparent signs of incision and our lateral retreat. Reference sites will be validated through Rapid Geomorphic Assessments (RGA) and Channel Evolution Model (CEM) stage. It is expected reference sites will provide benchmarks with respect to processes and form and discriminate potential thresholds and magnitudes of response. Reference states will be distinguished as CEM stage one and six. Reference sites will be compared to urban stream reaches destabilized by hydromodification and will be distinguished by CEM stages two thru five. Initial site selection will be determined based on categorizing watershed scale variables, stream system, and stream segment variables through GIS analysis and identifying logical extremes of response. Initial site selection will then be screened based on site accessibility, GIS analysis of reservoir controls, potential legacy impacts not associated with hydrologic alteration, and availability of flow data with ultimate intent of conducting fluvial audits of roughly 15 streams. As well, site selection will favor those streams systems that offer multiple reaches meeting the criteria above. Geomorphological impacts are not independent, but are known to interact with both upstream and downstream systems from the point of disturbance through process-form feedback mechanisms relevant to the fluvial system.

Progress to Date: The site selection process was started in October 2014 through desktop analysis of relevant GIS databases and conducted by Robert Woockman. After the potential candidate list was generated on-site visits were conducted to confirm there were no access issues or other potential issues that would affect the sites relevance in the study. Final site selection included an attempt to have a generally equal dispersion of stable (qausi-equilibrium) and unstable reaches distributed across the entire study domain (Ecoregion 67 bounded by the state of Tennessee). Further selection criteria were based on sites representing variations in watershed and reach characteristics. The site selection process was finalized in fall of 2015.

Task 2 - Fluvial Audits: A host of variables representing critical components that may influence channel response to hydromodification will be considered for observation/analysis. Candidate variables will be selected based on their ability to directly or indirectly describe relevant environmental controls, processes, and form. The candidate variables will be utilized to potentially explain some portion of the variance in potential candidate response variables and identify elements of a stream system that describe a stream reaches erosive resistance. Variables under consideration will be selected at three hierarchical scales. These scales indirectly represent both spatial and time scales of response and ultimately predict the potential capacity of a reach in question. The stream system spatial scale will be defined by the downstream point of the reach in question. The stream segment scale will be delineated by tributary junctions equal to or one order lower than the stream segment of interest and should have a uniform process domain. The reach scale will be delineated as a channel section at a minimum of 5 to 7 channel unit widths, but could exceed this length if channel resistance properties remain consistent.

Progress to Date: Fluvial audits were performed at both reference condition sites (stable) and sites that experienced land-use changes resulting in increased impervious surface cover. Topographical surveys were completed from December 2014 thru December 2015. Longitudinal profiles included

a reach slope conducted from riffle crests above and below the reach itself and utilizing the water surface elevation as reference points. Additional fluvial features included head and toe of all riffle features and deepest point in all pools within the surveyed reach itself. In conjunction with the longitudinal profile, survey cross sectional data was sampled. The cross sections were sampled in the upper portion of riffles. Recorded points were intended to characterize cross-sectional area, bank height and angle, relevant terraces, and floodplain connection for 1-D hydraulic modeling methods. Fluvial audits were performed in conjunction with the topographical surveys. Fluvial audits included vegetation audits, soil characterization, sample of bed material distribution, assessment of influencing grade control, and RGAs. Both audits and surveys were managed by Robert Woockman (graduate student) and conducted with the support of Jackson Mohler (graduate student) and Brandy Manka (undergraduate student). This task was completed fall of 2015.

Task 3 - Analysis: In order to meet the formerly mentioned objectives statistical analysis will be performed on data provided through fluvial audits and desktop analysis. Statistical analysis will include exploratory analysis, correlation analysis, and probability analysis. Variable selection for the fluvial audits has been carefully selected to insure that controls, processes, and form are all thoroughly described. This allows for a detailed analysis of the drivers of susceptibility to hydromodification. Ultimately, the goal of data analysis will be to utilize the representative data set, provided by the fluvial audits as foundational evidence for classification of reach sediment source potential. It is expected that classification could ultimately be utilized to inform the degree of reach susceptibility to hydromodification and improve effectiveness of mitigation efforts. Improved clarity of response should provide better understanding of the appropriate hillslope and channel mitigation practices necessary to reduce external costs. A reduction in external costs would be expected through improved effectiveness of invested mitigation funds when compared to non-segregated uniform prescriptions.

Progress to Date: Analysis of desktop and field collected data was completed by Robert Woockman, leading to a draft manuscript that was completed in fall of 2016. The manuscript has been revised and will be submitted for journal review during the summer of 2017.

Development of a Robust Model for Cross-Scale Prediction of Flow and Sediment Transport

(Team: Benjamin Abban and Thanos N Papanicolaou, Civil and Environmental Engineering)

Overview: Field work was performed in the summer of 2016 in headwaters of the Upper Sangamon River Basin (USRB), Illinois (see Figure 1).

SRB is a U.S. National Science Foundation Intensively Managed Landscape Critical Zone Observatory (IML-CZO). The purpose was to determine the relative contribution of terrestrial and instream sediment sources for storm events over the growing season. In IMLs like the USRB, the terrestrial and instream sediment contributions have been observed to vary over the course of a season in response to changing hydrologic forcing and LULC. The USRB is a low-relief hillslope characterized by mild gradients. The land use is predominantly row-crop agriculture with two-year corn-soybean rotations, and the dominant soil texture is silty clay loam.

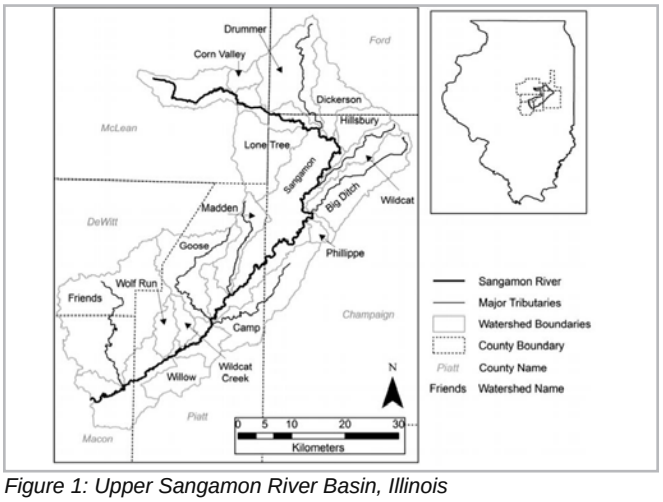


Figure 1: Upper Sangamon River Basin, Illinois

2016-2017 Programmatic Report

Methods and Procedures: Sampling of soils/sediments and transported eroded material was done during three consecutive time periods, each approximately one month long, from May to July, 2016. Land cover over the study period was obtained concurrently from Enhanced Thematic Mapper natural color satellite imagery for USRB, downloaded from the United States Geological Survey EarthExplorer repository. Rainfall data for the study period were obtained from a digital rain gauge situated within the sub-watershed. The purpose of all these data was for use in an un-mixing model, along with the signatures of the sampled soils/sediment for determining the sediment contributions from the various land use sources.

Several watershed sources and processes were identified during the field campaign based on the following considerations: 1) the total organic material collected at the outlet of USRB is a mixture of material from terrestrial and instream sources; and 2) source areas in the watershed that promote soil/sediment deposition and re-suspension affect sediment travel times with potential impacts on time-integrated source tracer signatures. Terrestrial soil samples were collected from five fields distributed within the watershed that were considered to be representative of the land uses, soil types, and topography in USRB. In each field, surface soil samples (0-5 cm and 5-10 cm) were collected along 75- to 100-m long planar transects located on the downslope to capture planar and downslope heterogeneity from the summit to the backslope, toeslope, and floodplain (Figure 2). Figure 3 illustrates the transect locations for two of the fields with No Till Bean – Spring Till Corn (NTB-STC) and Fall Till Bean – Spring Till Corn (FTB-STC) rotations and their underlying soil series. In the first field, Transects 1, 2, and 3 were located on the summit, backslope and toeslope, respectively, whilst Transects 4 and 5 were located on the floodplain. Similarly, for the second field, Transects 10, 9, and 8 were located on the summit, backslope and toeslope, respectively, whilst Transects 6 and 7 were on the floodplain. As shown in Figure 3 with dots, there were approximately eight sampling locations per transect to capture

Figure 2: Terrestrial Soil Sampling

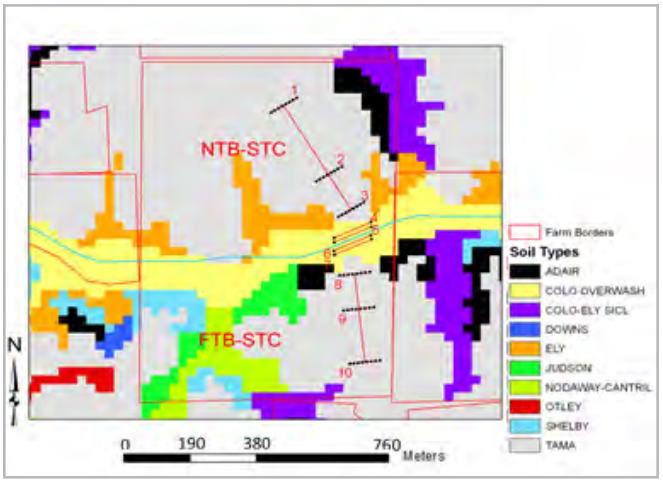


Figure 3: Sampling locations, transcets, and soil series

the planar heterogeneity. At each dot location, samples were taken at two depths, since previous studies had shown that tracer signatures of the active layer (usually the top 10-20 cm depending on plowing depth) could vary with depth. To characterize instream sediment sources, discrete samples were collected during non-flood flows using Sigma suspended sediment samplers following the Olley [2002] approach. Sampling of the total transported eroded material at the USRB outlet

was done using stream tubes. For each of the three sampling periods, two to four stream tubes were placed close to the bed of the stream outlet to continuously capture suspended sediments over the period. Stream conditions were such that the tubes primarily captured sediment contributions from the storms that occurred during the period.

After the samples were collected, the $\delta^{13}C$ and $\delta^{15}N$ signatures of the fine grained portion (<53 μm) of each sample were quantified using mass spectrometry. The samples were initially dried at 60°C, then the coarse particulate organic matter (diameter >250 μm) was removed. Sub-samples between 15-30 g were disaggregated in 50 mL of 0.5 mol/L Na-hexametaphosphate and gently washed through a 53 μm sieve. Material passing through the 53 μm sieve was allowed to settle at 4°C, the overlying water was decanted, and then dried again at 60°C. The material was then ground on an orbital ball-mill for the mass spectrometry analysis to determine the $\delta^{13}C$ and $\delta^{15}N$ signatures. Hotelling's T^2 tests were performed on the signatures from different landuse sources to confirm that they were significantly different from each other ($p < 0.05$) and, thus, could be used to distinguish the sources. The differences in isotopic signatures between the 0-5 and 5-10 cm samples were found to be insignificant ($p > 0.05$) and so differentiation of contributions with depth was ignored in this study.

Key Findings: The tracer signatures were input into a Bayesian un-mixing model to determine the sediment contributions from the various sources. The analyses predicted mean terrestrial soil contributions to be larger than mean instream sediment contributions during both Periods 1(May) and 2 (June) – a trend consistent with observations from previous studies in the watershed by Abaci and Papanicolaou [2009]. This was attributed, for the most part, to less land cover and more bare soil. In addition, the mean instream sediment contribution in June was greater than the mean instream sediment contributions in May. This was due to greater amount of runoff generated resulting in more instream erosion and the slightly greater cover in the period resulting in relatively less terrestrial erosion. In Period 3 (August) the mean terrestrial soil contributions were less than mean instream sediment contributions. The smaller terrestrial contributions was attributed to the establishment of extensive surface cover, which has been shown to minimize rain drop impact and reduce erosion by both sheet and concentrated flow. The trends observed are in agreement with similar previous studies by Abaci and Papanicolaou [2009] and Wilson et al. [2012]. Scientific advances from the study include the accounting of sediment delivery and travel times in the sediment sourcing analysis, as well as the determination of the seasonal nature of source partitioning in intensively managed landscapes. The study thus accounts for critical processes such as material availability, exhaustion of material supply, flow power, and rainfall intensity.

On-going work: The predicted mean sediment source contributions from terrestrial and instream sources, predicted with the aforementioned sediment sourcing analyses, will be used to validate a state-of-the-art numerical model that simulates dynamic flow processes on landscapes exhibiting heterogeneity in land use/land cover. The numerical model has been designed to run on in parallel mode on GPU threads and will be implemented on a workstation with GPU capabilities. Although the study results thus far are useful for partitioning terrestrial and instream contributions over the growing season, they are not sufficient for further sub-partitioning the contributions the wide range of terrestrial land uses and sediment fluxes noted in the basin. Such sub-partitioning data which will be beneficial for validating the numerical model's ability to capture landscape heterogeneity. As such, the work is being extended in the summer of 2017 to collect more terrestrial samples iin the Upper Sangamon, and the analyses repeated in the Clear Creek Watershed, to validate under a wider range of conditions.

2016-2017 Programmatic Report

Environmental Impacts of Coal Ash Spill on Nutrient Cycling and Surface Water Quality in Eastern Tennessee

(PI: Anna Szynkiewicz, Earth and Planetary Sciences, UTK)

Introduction: Coal ash is a waste product of coal burning in power plants to produce electricity. It contains verity of toxic metals (Ag, Al, As, B, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se, V, Zn) that may contaminate locally surface water and groundwater used for drinking. Currently, there are 8 contaminated sites with coal ash disposal and 1 coal ash spill into surface water in Tennessee. However, research about environmental impacts of coal ash spills on the aquatic environment is still limited. Few studies exist targeting this problem, and most are focused on general characterization of pollutants and their concentrations in surface water and sediments. Conversely, studies on disturbance of nutrient cycling and microbial biodegradation of coal ash spill pollutants in aquatic system are limited or nonexistent.

Using multiple chemical and isotopic tracers, this study has investigated impacts of the recent coal ash spill on three rivers: Emory, Clinch and Tennessee that took place in December 2008 in Kingston, Eastern Tennessee. Current contamination levels by toxic metals were determined in the light of new field and geochemical measurements.

The toxic remains of coal ash spills may cause cancer, developmental disorders and reproductive problems. Additionally, they can decrease water quality, kill fish and wildlife, and disturb cycling of sulfur (S) and carbon (C) during microbial decomposition of organic matter in freshwater sediments. The latter is crucial in releasing nutrients for aquatic life in riverine systems. Therefore, this project has the potential to provide new, inexpensive, and relatively simple environmental tracers (e.g., water chemistry, S-O-C isotopes) for state agencies and stakeholders in Tennessee and nationwide to evaluate the impacts of coal ash spills on surface water quality, nutrient cycling and metal bioremediation in contaminated sites.

Nature, Scope and Objectives of Project: Major objectives of this project were:

- To determine if nutrient cycling via microbial sulfate reduction in the river bottom sediments can effectively immobilize toxic metals from coal ash spill due to formation of insoluble sulfides.
- To determine changes of nutrient cycling (sulfur, carbon) in water column and sediments due to coal ash spill.
- To evaluate water quality of Emory, Clinch and Tennessee rivers 8 years after the coal ash spill.

The study field area for this project is located in Kingston area of Eastern Tennessee (~65 km west from Knoxville). Water and sediment samples were collected from the portions of Emory River, Clinch River, and Tennessee River that had been polluted by coal ash spill in December 2008. For comparison, water and sediment samples were also collected from upstream locations that did not show contamination by the spill. For collecting water and sediment samples, a pontoon boat was rented from a Caney Creek Marina located off of the Watts Bar Reservoir. In total, 10 different locations were sampled. All sediments and water samples were collected near the midpoint of the rivers in order to provide the most unbiased results.

Methods, Procedures and Facilities: Water sample collection took place on April 28, 2016. The water column (at 0, 4 and 6 m depth) was sampled using a Wilco sampler. In-situ measurements included: temperature, pH, and dissolved oxygen (DO) using a YSI ProDSS Multiparameter Meter. Additionally, alkalinity was determined using a Lamotte Titration Kit. Water samples for major ion, trace metal and isotope analyses were filtered using 0.45 μm nylon filters, stored in Nalgene bottles, and kept on ice until frozen at the end of the day. Water samples for S and O isotope analysis of dissolved sulfate (SO4) were filtered using Whatman glass microfiber filters. The samples collected included the following: 1 L of water for S and O isotope analysis of dissolved

SO4, 60 mL of water for major anion and isotope composition of NO3 analyses, 60 mL of water acidified with 2% HNO3 for major cation and trace metal analyses, 1 mL of water injected into a GasBench vial, with He gas headspace and 100 µL phosphoric acid, for C isotope analysis of DIC and DOC.

The sediment sampling of riverbeds took place on June 15 and 16, 2016. The sediment samples consisted of 26-30 cm long cores, which accounted for ~16 cm sediment accumulation in the past 8 years. In order to obtain the cores, two scuba divers hammered a 30 cm PVC pipe into the riverbed sediment, capped off the cores, and brought them back to the surface. These cores were stored on ice until frozen at the end of each day.

Major chemical (cations, anions, DOC, DIC) and isotope analyses (δ34S, δ18O, δ13C) were performed in the PI's Stable Isotope Laboratory at the Department of Earth and Planetary Sciences (EPS) of University of Tennessee, Knoxville (UTK) using a Finnigan Delta Plus XL mass spectrometer and Dionex ion chromatography. Trace metal composition of water samples and sediments (e.g., Ag, Al, As, B, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se, V, Zn) were analyzed via inductively coupled plasma optical emission spectrometry (ICP-OES) available on campus at UTK.

In order to determine the effects of metal immobilization by microbial sulfate reduction, a sulfur sequential extraction was performed on the riverine core sediments (4 cm intervals). This method allowed for separation of various sulfur species (acid-soluble SO4, elemental sulfur, biogenic sulfides) for δ34S analysis. The obtained results will be used for assessing the role of microbial sulfate reduction during decomposition of organic matter in freshwater settings (including riverine sediments) and remediation of toxic metals from coal ash spill. In addition, the sediment samples will be analyzed using x-ray diffraction (XRD) methods, and if necessary scanning electron microscope (SEM), to characterize mineralogical composition of biogenic sulfides formed during microbial sulfate reduction and bioremediation of river sediments.

Results and Findings: In the water column, the concentrations of trace metals such as Al, As, Cd, Cu, Cr, Be, Li, Ni, and Pb were below the detection limit of 0.002 mg/L. Only a few water samples showed slightly higher concentrations of B (0.02-0.04 mg/L), Se (0.03 mg/L) and Zn (0.03 mg/L). However, the measured concentrations were within a maximum contamination level determined by Environmental Protection Agency. In contrast, the elevated concentrations of As, B, Se, Cd, Cr, Pb and Zn were measured in the riverine sediments, particularly in close proximity to the Kingston power plant. This suggests that higher quantities of toxic metals are still present in the shallow riverine sediments. Among the studied metals, As appears to be of major concern. Using carbon-oxygen-sulfur-nitrogen-hydrogen isotope compositions of dissolved organic/inorganic carbon, sulfate, and nitrate in the water column and carbon-nitrogen-sulfur isotope compositions of the sediments, the conceptual model will be proposed to characterize major processes responsible for element cycling within the water column, sediment-water interface, and sediments. Consequently, this knowledge will be used to determine how the elevated metal toxicity in the sediments, resulted from the coal ash spill, might currently affect the water quality, people, and aquatic organisms in the studied area.

The negative bulk δ34S values of -5.4 to -0.5 ‰ are indicative of active microbial sulfate reduction and the presence of biogenic metal sulfides in the studied riverine sediments. However, the content of metal sulfides appears to be low (<0.1 wt. %). Relatively low sulfate concentrations observed in the water column (2-17 mg/L) and sediments (<0.01 wt. %) might be limiting factor inhibiting microbial sulfate reduction and formation of biogenic sulfides. This, in turn, decreases the overall capability for microbial bioremediation of toxic metals introduced by the 2008 coal ash spill to the studied river systems. The results of sulfur sequential extractions and mineralogical analysis

2016-2017 Programmatic Report

will be used to propose conceptual models of main processes leading to metal storage and potential releases in the studied river systems.

New USGS projects (March 1, 2017-February 28, 2018) awarded this reporting period:

- 2017TN129B—Evaluation of Fecal Indicators and Pathogens at Recreational Beaches in Central Tennessee, Dr. Frank Bailey and Megan Stallard, Department of Biology, Middle Tennessee State University
- 2017TN130B—Sediment Source Tracking in Urban Watersheds: An Application in the Second Creek Observatory, Dr. John Hathaway, Dr. Thanos Papanicolaou, and Dr. Chris Wilson, Department of Civil & Environmental Engineering, University of Tennessee, Knoxville
- 2017TN131B—Characteristics of Fine Sediment Embeddedness: Towards Understanding Drainage Network Transports Lags, Dr. John Schwartz, Department of Civil & Environmental Engineering, University of Tennessee, Knoxville
- 2017TN132B—Examining Sediment Rating Curves Hysteresis with State-of-the-Art Sensors, Dr. Achilleas Tsakiris, Dr. Thanos Papanicolaou, and Dr. Jon Hathaway, Department of Civil & Environmental Engineering, University of Tennessee, Knoxville.
- 2017TN133B—Combined Field Study of Turbulence and Bed Morphology in Mountainous Boulder Arrayed Streams, Michah Wyssmann and Dr. Thanos Papanicolaou, Department of Civil & Environmental Engineering, University of Tennessee, Knoxville (Graduate Student Supplemental Research Award)

Training Activities

TNWRRC coordinates two statewide training and certification programs for the Tennessee Department of Environment and Conservation (TDEC). The ***Tennessee Erosion Prevention and Sediment Control Training and Certification*** program (TNEPSC) is comprised of three basic courses:

- The Level I Fundamentals of Erosion Prevention and Sediment Control for Construction Sites is a one-day foundation-building course for individuals involved in all aspects of land disturbing activities. It was offered 15 times in nine communities with 1221 people attending.
- The Level II Design Principles for Erosion Prevention & Sediment Control for Construction Sites is an intensive two-day course for engineers and other design professionals focused on engineering technology needed to plan and design practices and controls for preventing erosion and managing sediment and other stormwater pollutants on construction sites. It was offered four times in three communities with 210 professionals attending.
- The Level I Recertification is a half-day course for those who have successfully completed the Level I course and need to renew their Level I certification. Recertification is required every three years. It was offered 16 times in 11 communities with 1312 people attending.

The ***Tennessee Hydrologic Determination Training Program*** (TN-HDT) is the second training program coordinated by TNWRRC for TDEC. The TN-HDT program consists of a three-day course designed to provided participants with a basic understanding of the underlying scientific principles, the legal ramifications, and the practical investigative techniques surrounding the determination of wet weather conveyances versus streams and other surface water features. The course was offered twice with a total of 50 people attending. The state regulations that established the TN-HDT certification program require those that successfully complete the TN-HDT course attend a one day Refresher course every three years to maintain their certification. The one day Refresher course were offered in four times 2016, twice in both Knoxville and Nashville, with 41 persons attending.

Low Impact Development Stormwater Manual and Training Courses—The TNWRRC, including faculty and graduate students from the Department of Civil and Environmental

Engineering (CEE) and the Department of Biosystems Engineering and Soil Science (BESS) are working with staff from TDEC Division of Water Resources to develop the first edition of the Tennessee Permanent Stormwater Management and Design Guidance Manual. TDEC has established stormwater runoff reduction as the primary treatment objective for new development and redevelopment projects across Tennessee. This new manual will provide detailed design guidelines for permanent stormwater control measures that meet this treatment objective. The primary purpose of this manual is to serve as a technical design reference for designated and non-designated (unregulated) MS4 (municipal separate storm sewer system) communities in Tennessee. It is intended to provide the information necessary to properly meet the minimum permanent stormwater management requirements as specified in MS4 permits. The UT team has also developed the Runoff Reduction Assessment Tool (RRAT) to be used in conjunction with the Manual. The RRAT will assist professional engineers and other design professionals to ensure that the stormwater management plans they have prepared meet the permanent stormwater performance standards for new or redevelopment sites. The first edition of the Manual was released in December 2014. The Manual and the RRAT model may be down loaded from the new Tennessee Stormwater Training Program website, http://tnstormwatertraining.org/index.asp.

In addition, TNWRRC, with support from faculty the Department of Civil and Environmental Engineering (CEE) and the Department of Biosystems Engineering and Soil Science (BESS), has developed and delivered new training courses that will inform local officials, administrators, design professionals and consultants, and private sector companies on the use of the manual to develop, implement, and maintain the permanent stormwater control measures and practices described in the manual. The Permanent Stormwater Management Design course is a one-day course designed for engineers, landscape architects; stormwater plans preparers and local government plan reviewers. The course describes how to create stormwater management systems using green infrastructure and evaluate performance with the Tennessee Runoff Reduction Assessment Tool (TNRRAT) so that stormwater management plans for new and redevelopment projects meet the requirements of the TN MS4 permit. The PSW Design course was not offered in 2016-2017.

The two day Stormwater Control Measure Inspection and Maintenance course was held four times with 52 persons attending. Course information and registration for both courses can be found on the Tennessee Stormwater Training program website.

Outreach Activities

Knox County Adopt-A-Watershed Program

The 2016/17 Adopt-A-Watershed (AAW) Program got started in June 2016 when TNWRRC coordinated its annual AAW teacher training, bringing seven new teachers into the program along with training Office of Surface Mining staff who are supporting the program's implementation at the L&N STEM Academy. In addition, the 2016-2017 CAC AmeriCorps members completed their month-long "watershed boot camp" training and are mapping out service learning projects with the teachers.The program is being conducted in Knox County, Oak Ridge, and Farragut with the support of six CAC/Knox County Stormwater members, two CAC/Oak Ridge Stormwater members, and one CAC/Farragut Stormwater member. Two AmeriCorps members are being supported by the Regional Office of Surface Mining Program, and will be conducting the program at the L&N STEM Academy. Other participating schools include: Halls High, North Knox Technology, Powell High, Career Magnet Academy, Farragut High, West Valley Middle, Bearden High, Central High, Fulton High, West High, South Doyle Middle, Holston Middle, and Grace Christian Academy. The AAW Program is managed by ISSE's TNWRRC and is sponsored by Knox County Stormwater and the Water Quality Forum.

The Adopt-A-Watershed Program hosted about 1500 students participating in projects that result-

2016-2017 Programmatic Report

ed in outcomes that further educated our community on how we can protect our natural resources and/or directly improved a watershed through on-the-ground projects. Approximately two-thirds of the classes participated in five or more hands-on 60- to 90-minute lessons, with some classes having participated in 10 plus in-class and field activities. Nearly all the students (96%) responded on a post survey that as a result of their participation in AAW they intended to change their living habits in ways that would help improve our waterways. This later statistic is gathered on behalf of the CAC AmeriCorps Program that seeks to influence environmental behavior through education and community involvement.

Baker Creek Watershed, **South Doyle Middle School** AAW Club students:

- Installed native plants in the UT Regenerative Stormwater Conveyance demonstration site
- Stabilized exposed soil to start a campus garden
- Participated in the Adopt-A-Stream program, helping to remove trash from in and around the stream.

North Knox Career Technical Education (CTE) & **Halls High School**—Ms. Keep's fall semester CTE AgriScience 4th block class refurbished two rain barrels for the Halls Outdoor Classroom (HOC) pavilion and installed two on the school's greenhouse.

The 1st block AgriScience class focused on the HOC invasive plant problem, removing 140 lbs of invasive species and planting select native species for additional habitat and beautification. Ms. Keep's spring AgriScience students assisted the LRE (special needs) class in planting annuals in the HOC raised bed ("quilt garden") as well as removing invasive plants.

Mrs. Coley's year-long Environmental Science "Watershed" class' primary service involved preparing for the recertification of the HOC Tennessee Urban Forest Certification (TUFC) Level 1 Arboretum due this fall. This included updating the tree inventory data including both the tree locations and their species, using the ESRI program Survey123. The students were aided by a PhD candidate from the UT Forestry Department. Using this information, the class developed an ArcGIS Online StoryMap for the HOC Arboretum. This on-line interactive application includes the locations of the trees along with tree profile sheets created by the students that can be publically downloaded. Mrs. Coley's class also planted roughly 15 native shrubs and trees in the HOC Arboretum, while pulling out invasive plants in the process. This class also assisted with the children's activities conducted at the HOC Celebration.

Karns High School—After learning about the impacts of household hazardous wastes, Mr. Brem's spring Marine Ecology students educated their parents on the local Hazardous Waste Facility.

Beaver Creek Watershed,**Grace Christian Academy**—Mrs. Walker's two year-long Environmental Science classes mentored 50 4th grade students, involving them in hands-on activities that introduced the 4th graders to the Beaver Creek Watershed, it impacts, and how the students could help mitigate these impacts.

Conner Creek Watershed, **Hardin Valley Academy**—Mr. Paquette and Ms. Elton/Ms. Halvorson's spring Botany/Zoo and Ecology classes focused on improving the health of Conner Creek

2016-2017 Programmatic Report

flowing through their campus by both conducting trash clean-ups and riparian plantings. They also drafted "No Mow" signs for the Conner Creek riparian zone upon the completion of the middle school construction.

First Creek Watershed, **Fulton High School**—Ms. Davis's fall Biology class educated school staff on impacts on First Creek through a poster campaign, with campaign effectiveness measured through on-line staff pre- and post-surveys.Ms. Davis and Ms. Neff's spring Biology classes participated in an Instagram contest where students were challenged with taking on-campus photos that made the connection between their natural environment and what that they learned through AAW activities. Students had to not only take a great photo, but include a relevant caption to accompany it. Contest judging criteria included number of likes on their Instagram posts.

Central High School—Ms. Jill Strating's AP Environmental class built a prototype for a Floating Wetland Habitat for the Fountain City Lake that was recently launched in the Lake for a trial run. This project is being conducted in partnership with the City of Knoxville Stormwater Department in conjunction with LDA Engineering and the Fountain City Lion's Club. A primary purpose of the 4 ft by 4 ft Floating Habitat that contains wetland plants is to absorb excess nutrients from the Lake.

Love Creek Watershed, **Holston Middle School**—Ms. Keeler's 7th grade Honors Science class' primary focus was to educate parents about the rain barrel concept through an online drawing of a rain barrel. In addition, the barrel was designed and painted with a watershed theme by the students. Outreach for this drawing included creating advertisements and for those parents who participated in the drawing to take a stormwater pledge.

Swan Pond Creek Watershed, **Career Magnet Academy**—Mr. Blankenship's Agriculture Science class created custom hand fans (aka "Fans of Sustainability") that conveyed watershed health concepts through student artwork and slogans. They were disseminated at the 2017 EarthFest and, since it was a particularly warm day, were extremely well received.

Mrs. Brown's Chemistry classes conducted the Swanpond Watershed Stream Assessment. This involved conducting split sampling with KUB, with samples being tested by both the KUB Lab as well as in-class by the students. Data from these analyses were incorporated into two student SASEF Science Fair projects. One entry won the SASEF Certificate of Excellence and the other entry won the following awards: SASEF Certificate of Excellence; ASU Walton Sustainability Award; and the US Stockholm Junior Water Prize Regional Award.

Ms. Brown's Chemistry and Ms. Shinlever's Biology students planted 42 native trees in the riparian zone of Swan Pond Creek at the Forks of the River Park. Both classes also educated family members on watershed concepts, seeking pledges that they would help to protect our local waterways.

Ten Mile Creek Watershed, **West Valley Middle School**—The 8th grade Science classes conducted a range of projects that improved the environmental health and aesthetics of the and/or educated their parents on actions they could take to improve our local watersheds. These projects included:

- Stabilizing an area of eroding soil in a highly trafficked area of campus by applying a fabric and overlaying with mulch; adding stepping

2016-2017 Programmatic Report

stones for functionality and appearance; and removing 550 pounds of invasive species.

- Building three three benches for the campus outdoor classroom.

- Learning about the importance of native species to share with their parents and then putting this knowledge into action by creating native plant "seed bombs" to be planted in their home landscape.
- Participating in a "Can the Grease" initiative, creating cans to take home and teach their families about the importance of proper grease disposal.

Bearden High School—Ms. Turner's two fall Marine Ecology classes created and distributed educational brochures with watershed-related concepts and personal action steps to improve water quality, obtaining signatures from family and friends showing intent to change practices to keep the watershed clean. Ms. Turner's spring Marine Ecology classes removed 200 lbs of trash along Ten Mile Creek at the Walker Springs Park in conjunction with field educational activities that included working with professional biologists in collecting and analyzing fish and benthic macroinvertebrate populations and conducting chemical analysis on creek water. Her classes also created preliminary designs for an educational mural to be painted along Ten Mile Creek Greenway next year that is being planned by Knox County Stormwater.

Third Creek Watershed, **West High School**—Ms. Nanney's Botany/Zoology classes conducted a multi-prong riparian buffer initiative along Third Creek Greenway that included:

- creating a map of invasive and native species in a select area along the Third Creek Greenway using Survey 123 for ArcGIS;
- removing invasive plant species; and
- drafting designs for "No Mow" signs that are to be replicated and installed by the City of Knoxville Stormwater Program.

Mr. Reed's IB Environmental Science class installed a 10 ft by 17 ft rain garden by hand on the West High's campus. This project is a component of Dr. Jon Hathway's NSF CAREER grant being coordinated by graduate student, Whitney Lisenbee. A subsurface monitoring well was installed in the garden for students to continue to participate in this data sharing project with other schools over the next three years.The Environmental Club assisted UT Engineering graduate student Andrew Tirpak with rainfall data collection and watering of tree bioretention columns in an experimental station located on the West High campus as a part of the US Forest Service grant. The Environmental Club also took a lead role in organizing one of the Tennessee Environmental Council's 100K Tree Day distribution sites and plantings along Third Creek near Sutherland Avenue.

Tennessee Smart Yards

Tennessee Smart Yards (TNSY) program is jointly conducted by UT Extension and TNWRRC. Its mission is to support homeowners across the state in applying sustainable landscaping practices that are protective of Tennessee's waterways. In 2017, TNWRRC managed the program's communications and marketing. This

2016-2017 Programmatic Report

included maintaining the TNSY's website, native plant database, and social media platforms; producing quarterly newsletters; updating marketing materials; and managing its office. In addition, TNWRRC provided fall and spring TNSY trainings for the Knoxville Habitat for Humanity Habitat Urban Gardening Program.

Screenshot of 2017 summer newsletter

Watershed Symposium

The Watershed Faculty at the University of Tennessee and TNWRRC hosted the 5th Annual Watershed Symposium on September 13, 2016, at Hollingsworth Auditorium on the UT Agriculture Campus. The primary purpose of the annual Symposium is to highlight the latest research in water-related fields and share insights from state and federal experts and to expose undergraduate and graduate students to water related careers opportunities. This year the Watershed faulty decided to take a different approach from the past. The Symposium started off with a half day Careers in Water Expo with over eighteen government agencies, utilities and private consulting companies hosting booth to discuss job opportunities with UT students. The career expo was followed by the Keynote address by Andy Reese, PE, Vice President, Amec Foster Wheeler, Inc. Next faculty from the different colleges at UT offered career focused presentations followed by student zip talks. Finally, University of Tennessee students had a technical poster session. Over 120 students and 65 government and private water resources professional attended the 5th Annual Watershed Symposium.

East Tennessee Clean Fuels Coalition (ETCF)

(PIs: Jonathan Overly, Executive Director; Melissa Goldberg, Project Manager)

Managing State EPA DERA Funding—Through collaborative discussions that started in 2015, the East Tennessee Clean Fuels Coalition (ETCF) began managing the annual allotment of State EPA "DERA" (Diesel Emissions Reductions Act) funding that the Tennessee Department of Environment & Conservation (TDEC) oversees in mid-2016. We developed the "Reducing Diesel Emissions for a Healthier Tennessee" grant program and quickly released two years of this funding to fleets across Tennessee. The funding program provides up to 100 percent of incremental cost of new alternative fuel vehicles (AFVs), up to $16,700 per vehicle. Five fleets applied in the first round and eight fleets in the second, with seven fleets ultimately winning funding. The winners vary from school districts like Clarksville-Montgomery County School System who received funds to acquire 15 new propane powered school buses; Waste Management who are acquiring 18 new CNG (compressed natural gas) powered refuse trucks and roll-offs for use in Nashville and Jackson, Tennessee; and Clean Sweep, Inc. who is purchasing several new propane-powered street sweepers in Chattanooga. All of these projects help protect Tennesseans—including children—from the dangers of particulate matter and other harmful pollutants generated by diesel-powered vehicles.

Assisting & Reaching New Fleets across Tennessee—During the year, we held coalition meetings in several cities where we had either never held a meeting, or where we had not in nearly a decade. These locations included Greeneville, Jackson and Sevierville, Tennessee. Each meeting included either a tour of a facility (like Sevier County Utility District's CNG station and natural gas vehicle maintenance facility in Sevierville) and/or alt-fuel vehicle showcases like were held in Jackson and Greeneville.

In April 2017, ETCF wrapped up helping the Great Smoky Mountains National Park complete a second phase of a grant through the "Clean Cities National Parks Initiative." In Phase 2, the park added propane fueling stations at both its Tennessee and North Carolina main facility maintenance districts and purchased and put into service five propane F-250 work trucks. These vehicles added to what was implemented in the first phase which included five propane lawn mowers, three low-speed electric vehicles (EVs), and installing electric vehicle charging equipment at both Park main Visitor Centers near Gatlinburg, TN and Cherokee, NC. All of these initiatives are helping improve air quality in and around on of the crown jewels in America's National Park System.

ETCF joined Central States Bus Sales, Blue Bird buses and ROUSH CleanTech on a propane school bus tour that took place in January 2017. That tour visited two sites and introduced propane school buses to about 10 school systems across the state. This type of fleet meetings and introductions are an excellent way to continue ETCF's outreach to meet new fleets where we can work on a) reducing petroleum use and b) improving air quality around distinct groups of Tennesseans (i.e., children) who are at greater risk from air pollution issues than other populations.

Partnering to Develop, Designate Alternative Fuel Corridors in Tennessee—In fall 2016, ETCFC worked with TDEC, the TN Department of Transportation (TDOT), the TN EV Advisory Committee (TEVAC) and several other interested parties to help craft a response to an FHWA

2016-2017 Programmatic Report

solicitation. That request asked individual states to voluntarily submit corridors in their state along which different alternative fuels are available, or are expected to become available. CNG, propane and electricity for EVs were the main fuels of interest, and TDOT submitted the information for the group. I-40, the interstate that has the largest distance in Tennessee (452 miles), was the only corridor applied for in the application and LNG (liquified natural gas) and idle reduction sites that provide electricity for long-haul tractor trailers were added to the other fuels in Tennessee's application. You can learn more about and see the corridors that are "Signage-Ready" and "Signage-Pending" on this FHWA website, https://www.fhwa.dot.gov/environment/alternative_fuel_corridors/.

In addition to this effort, ETCF has been working with TEVAC (which includes ORNL and the Office of Energy Programs within TDEC) to develop a master plan for the best way (and best places to) add electric vehicle supply equipment, or EVSE, that is the EV recharging/refueling equipment that is used to "refuel" EVs with electricity. This plan takes many factors into account but a significant portion of that plan was hatched in 2016-2017 and the group is looking to complete the plan soon and began using the plan to assist in the decision-making for where EVSE sites will be placed in the near future, especially for DCFC equipment, which is the quick-fill infrastructure that can refuel most EVs in under 25 minutes.

Assisting & Celebrating the Opening of New CNG Stations in Tennessee—Throughout the year we've supported and celebrated the opening of several new public CNG fueling stations in Tennessee. This is particularly important due to the cost and scale of building such infrastructure and the need to enable a faster transition to using more of this otherwise ubiquitous fuel (natural gas and its wide availability in the U.S.). Knoxville Utilities Board spent a number of years formulating their plan to build a public CNG station in Knoxville, and that culminated in the opening of the station earlier this year - Knoxville's first public CNG station. It fills a critical hole along I-75 and I-40 for truck traffic. Also, we partnered with Frito-Lay, a division of Pepsico, to open a new CNG station in Fayetteville that will serve their fleet of roughly 20 CNG-powered class 8 trucks (tractor trailers) and open up a new market in that south-central Tennessee city. Additionally, the Metropolitan Nashville Airport Authority opened a private CNG station for their new fleet of 20 various size shuttles that move riders to and amongst their parking areas. They are an example of growing fleets in well-known places that are helping elevate this fuel in the state.

Future Goals & Plans

- Implement a comprehensive Constituent Relationship Management (CRM) database to improve coalition operations and efficiency
- Increase the overall total gasoline-gallon equivalents (GGEs) and reduce greenhouse gas (GHG) emissions across all of Tennessee over our calendar year 2016 amounts
- Hire 1-2 University of Tennessee students for internship opportunities during the scholastic year
- Support the State of Tennessee's distribution of its allocation of Volkswagen Environmental Mitigation Trust settlement funds, particularly advocating for funds to be allotted to AFV purchases and infrastructure for private and public fleets across the state

Other Projects and Initiatives

A Practical Approach for Remediation Performance Assessment and Optimization at DNAPL Sites for Early Identification and Correction of Problems Considering Uncertainty

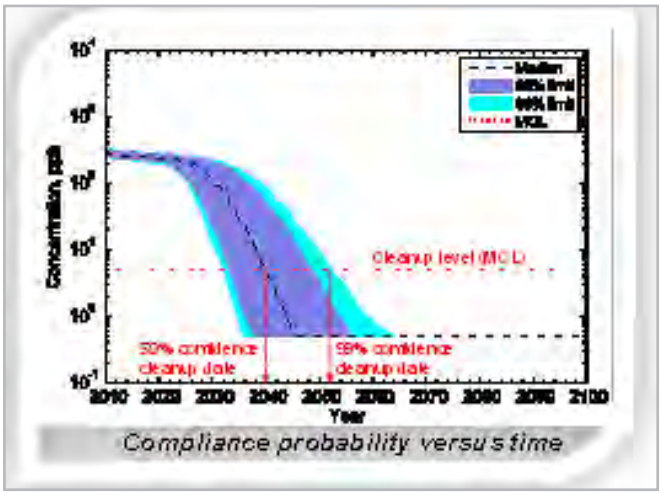
(Team: Jack Parker, UT; and Ungtae Kim, Cleveland State University)

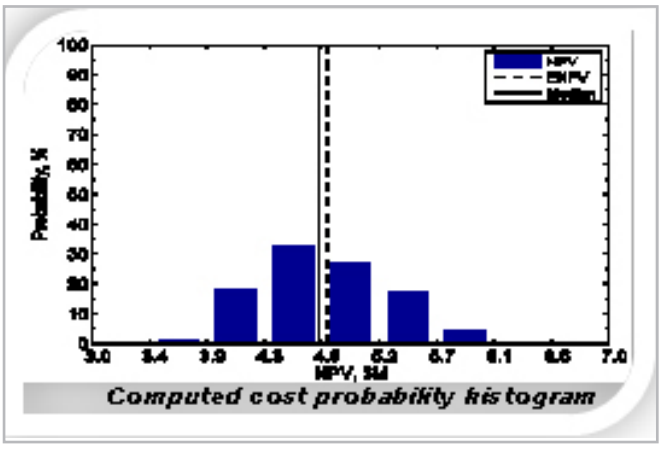
The objective of this project is to develop and test a methodology to periodically assess and optimize groundwater remediation systems at DoD sites contaminated with chlorinated solvents (e.g., TCE, PCE) and other dense nonaqueous phase liquids (DNAPLs). A computer program designated the Stochastic Cost Optimization Toolkit (SCOToolkit) have been developed with modules for (1) contaminant fate and transport in groundwater with multiple DNAPL sources, (2) cost-performance models for commonly used remediation technologies coupled with the transport model, (3) an inverse solution to calibrate model parameters from available site data, (4) a Monte Carlo model to compute the probability-weighted costs for a given remediation strategy, (5) an optimization algorithm to determine design variables that will minimize life cycle expected net present value cost to reach remediation objectives, and (6) a graphical user interface to simplify field applications.

The transport module employs an efficient 3-D semi-analytical solution that accounts for natural and engineered source reduction and diffusion-limited mass transfer between high and low permeability zones. Remediation technologies considered include thermal source reduction, continuous and pulsed in situ chemical oxidation, electron donor enhanced reductive dechlorination, and plume containment.

An interesting finding from SCOToolkit optimization studies, that is contrary to current practice, is that decreasing monitoring frequency and/or number of samples per sampling event does not necessarily reduce expected life cycle cost. While less intensive monitoring reduces direct monitoring costs, fewer samples yield wider confidence limits which can increase the duration of long term monitoring to achieve cleanup objectives with the same level of confidence.

Performance monitoring protocols were developed to track remediation system performance at various space scales (e.g., system-wide, in individual monitoring zones MZ), and multiple treatment zones (TZ) that consist of several MZs. A statistical protocol was developed to terminate treatment system-wide or for individual TZs or MZs with equal reliability that enables significant cost savings.





Results from test problems and limited field site testing indicate that SCOToolkit can significantly increase the probability of meeting remediation objectives within a specified period and decrease expected cost based for one-time calibration and optimization analyses. Additional cost savings can be realized by periodic recalibration using new

2016-2017 Programmatic Report

data and reoptimization to keep remediation progress on track. Results indicate average cost savings across all DoD sites of 10% to 30% or more can be realized, which can translate to hundreds of millions of dollars in cumulative savings to DoD, other public agencies and private entities.

Cooperative Agreement between National Park Service and University of Tennessee: Impacts of Acid Deposition on Water Quality and Aquatic Biota

(PI: John Schwartz, Civil and Environmental Engineering)

Long-term research continues in the Great Smoky Mountains National Park (GRSM) investigating the impacts of acid deposition from atmospheric pollution due to various sources including coal-fired power plants, vehicle exhaust, and agriculture. Various research projects are active within the cooperative agreement. A high-elevation monitoring station at Noland Divide is maintained, which includes a deposition collector, full weather station, soil lysimeter pit with vacuum pump collection system for three horizons, soil moisture and air temperature probes, throughfall collectors, flow recorders at two 3-ft H flumes and water quality data sondes. Streamlet water samples are collected biweekly along with water samples collected from the other devices. This research is specifically to enhance our understanding of the biogeochemical processes within high elevation watersheds exposed to acid deposition. Watershed budgets for acid anions and base cations examining mass net export has provided key information on the fate and transport of acid pollutants. At the station, we reported the rapid drop in sulfate deposition immediately following the installation of air pollution equipment at TVA's Bull Run and Kingston Power Plants. Our team also assists in the routine bimonthly Park-wide stream water collections, in which our Water Quality (WQ) Laboratory at the University of Tennessee conducts the chemical analyses. This effort is part of a broader National Park Service (NPS) Initiative called the Vital Sign Program. This program is a 20-year research effort to ensure water, air, soil, and vegetation surveys are coordinated in space and time nationally. We have two special on-going studies, Masters' student Andrew Veeneman is revising the throughfall deposition map, which is over 15 years dated since the last published park-wide characterization of acid deposition in the GRSM. Doctoral student Adrian Gonzalez is investigating sulfate dynamics in the GRSM, which includes the use of isotopes for source tracking of atmospheric (meteoric) and pyrite geology contributions of sulfate to streams. This research includes soil biogeochemical processes for retention potential and the environmental factors influencing export from small catchments.

Photo of Andrew Veeneman sampling water on Palmer Creek in the Great Smoky Mountains.

Photos from the Great Smoky Mountains National Park, long-term high elevation atmospheric, soil, and water monitoring station at Noland Divide.

Our cooperative agreement for water quality analysis is expanding, which now includes the Appalachians Highlands Network. The goal for this year is to officially accredit our Water Quality Laboratory and hire a full-time lab manager. The Carolina-Florida Coastal Vital Signs Program plans to use our water quality facilities with spe-

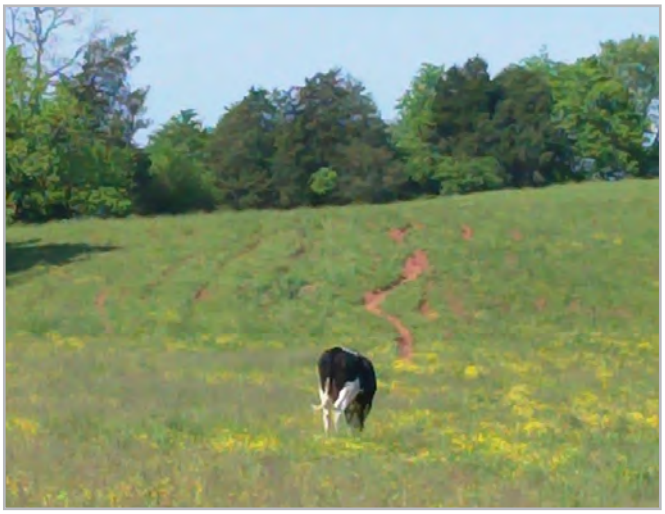
cific research goals in 2018. Other NPS programs have expressed interest in our water quality analytical and research capabilities. With our WQ laboratory accreditation and program expansion, research opportunities among UTK faculty are expected to grow.

Integrated watershed management in Oostanaula Creek Watershed, Tennessee: Stakeholder education, improving targeting and understanding stakeholder behavior to improve implementation of best management practices for water quality

(PI: John Schwartz, Civil and Environmental Engineering)

Research on the Oostanaula Creek watershed was a team effort among several PIs led by Dr. Forbes Walker to improve watershed management practices by agricultural producers with a focus on reducing in-stream suspended sediment and fecal bacteria pollution. Other PIs on this USDA funded project included Drs. Shawn Hawkins, Michael Essington, Alice Layton, Chris Clark, and Andrea Ludwig. The research by Dr. Schwartz included improving our understanding of geomorphic processes associated with bank stability. Extensive fieldwork was conducted on Cedar Branch, a tributary to the Oostanaula Creek that has land use impacts from both agricultural and urban development. Specific findings of the research identified the importance of natural hydraulic grade controls, riparian vegetation, and soil cohesion on predicting whether a bank will be stable or not over time. The research expanded into applications of the CONCEPTS model, a sediment transport and channel adjustment model to test the data analysis from the fieldwork investigations noted above. Robby Woockman, the PhD candidate on the project plans to defend his dissertation that includes this research. His dissertation, which couples the CONCEPTS model with the USEPA Stormwater Management Model (SWMM), enhances our understanding of watershed placement of green infrastructure and other stormwater control measures (i.e., detention ponds, grassy swales) on channel erosion. Essential, his research provides a new tool to quantify what constitutes "channel protection flows" from urbanization.

A second task project worked on MS student Zachariah Seiden consisted of monitoring sediment transported from concentrated flows in cow paths. Cows will walk the same path to their watering hole forming an eroded dirt path from the pasture hillslope to the creek (photo shown below). A unique monitoring system was constructed of Pinson et al (2003) weir divider buckets in series (photo shown below). This project quantified the mass of fine sediment transported in cow path runoff and identified environmental factors that affect transport such as time between rainfall events, rainfall intensity and event depths. As one would expect, sediment from cow paths are a major contributor of suspended sediment to receiving streams.



A typical cow path prone to greater erosion compared with pasture land.

Pinson et al. (2003) flow divider buckets monitoring sediment from cow paths.

2016-2017 Programmatic Report

Seed Grant Projects from Prior Years

Microenvironments, Vulnerability, and Resilience in the City of Knoxville: A Comparative Study of Four Urban Neighborhoods—Final Report

(Team: Kelsey Ellis, Geography; Jon Hathaway, Civil and Environmental Engineering; and Lisa Reyes Mason, Social Work)

Project Summary: As urbanization escalates, understanding the impact of expanding cities is of extreme importance to human and environmental well-being. This study used a multidisciplinary approach to monitor urban environmental conditions and understand their impact on diverse populations in the City of Knoxville. To launch the study, 10 sensor-based monitoring stations were mounted in four neighborhoods (West Hills, Burlington, Vestal, and Lonsdale), with control stations in Downtown Knoxville and Ijams Nature Center. Study neighborhoods were chosen for geographic and topographic reasons, as well as for social and economic diversity. West Hills is a predominantly White and middle to upper income neighborhood. Burlington, Vestal, and Lonsdale are more racially and ethnically diverse, and in general house more lower to middle income residents. From July 2014 to May 2016, stations recorded temperature, humidity, and wind data in five-minute increments. Simultaneously, social research examined people's perspectives and experiences with environmental conditions—such as temperature extremes, air quality, and urban green space—and considered their interests and preferences for accessing more localized environmental data.

The study's primary significance derived from its emphasis on human and environmental data and implications at the neighborhood-scale, where people live, raise families, and build communities together. New sensor technologies allow monitoring of urban environments at finer scales than in the past, yet analyses of neighborhood-scale data and integration of that data with social concerns is still limited. Significant findings from the Knoxville Urban Observatory's (KUO) research are that neighborhoods experienced statistically significant temperature and heat index differences, supporting the existence of an urban heat island effect even in a medium-sized and relatively green-covered city such as Knoxville. Social research points to important differences among neighborhoods, particularly around themes of social and economic effects of weather extremes, air quality concerns, unequal green space access, and distinct attitudes and resources for environmental action. Finally, study participants expressed high interest in receiving environmental information specific to their neighborhoods, not just to the city or county as a whole. For developing smartphone applications or websites that would provide such information, KUO's research points to the importance of having integrated and reputable data, clear and intuitive design features and color schemes (e.g., green-to-red for warnings), simple and effective behavioral change messages, and one-click tools for civic engagement on environmental action.

Outcomes: We have produced a number of deliverables from this work, including publications (five accepted), presentations (seven delivered), outreach, media interviews, and proposal submissions.

National and International Recognition: In addition to dissemination of the team's work in widely recognized national and international journals (see ISSE Publications/Presentations below), presentations about KUO's work have been sought out by the social work profession's Grand Challenges for Social Work initiative. One of the 12 grand challenges identified by the American Academy of Social Work and Social Welfare is create social responses to a changing environment. At the most recent Society for Social Work Research annual conference (January 2017), two refereed roundtables included Lisa Reyes Mason as a panelist about how the grand challenges can advance through community-engaged, collaborative, and multidisciplinary research, drawing explicitly on KUO as an example: Building social work's environmental research capacity and advancing a community-engaged research agenda to address the

grand challenge of creating social responses to a changing environment. As the grand challenge initiative is in its 2nd of 10 years of implementation, the national recognition and influence of KUO's work in this area is only expected to increase.

Funded "Spin-off" Grants: While no funded proposals were generated specifically on the topic of urban microclimates, this work has promoted broader multidisciplinary research across the campus and generated numerous new collaborations. As such, funded research was gained through these "spin-off" collaborations, including:

- Tornado warning response in the Southeast: Advancing knowledge for action in Tennessee. Submitted to National Oceanic and Atmospheric Administration, $248,217, 10/1/15 – 9/30/17. PIs: Ellis, Mason.
- Convective mode and Tennessee tornadoes: Climatology, warning procedures, and false alarm rates. Submitted to National Oceanic and Atmospheric Administration, $83,714, 1/1/17 – 6/30/18. PIs: Ellis, Mason.
- Engaging the community and creating young scientists to restore nutrient-impacted Baker Creek. Submitted to U.S. Environmental Protection Agency, $59,995, 10/1/16 – 9/30/18. PI: Hathaway, Co-PIs: Mason, with three faculty in Geography (Li, Sharma, Washington-Allen)

Toxicity profiling of dioxin-like pollutants and other aryl hydrocarbon receptor agonists using a high-throughput yeast bioassay—Final Report

(Team: Tingting Xu & Gary Sayler, Microbiology)

Project Description: Dioxin and dioxin-like compounds (DLCs), a group of structurally related halogenated aromatic hydrocarbons, account for a quarter of the 'dirty dozen" Persistent Organic Pollutants internationally recognized as chemical pollutants with a high priority for environmental cleanup, reduction of release, and restricted production. While the commercial production and use of some DLCs is banned in the United States, other DLCs continue to be generated as unintentional byproducts of municipal, medical, and industrial waste incinerations, forest fires, cremations, oil spills, and many industrial manufacturing processes. This is especially troublesome because these compounds are extremely stable, highly resistant to degradation and metabolism, and persistent in the global environment. They are also prone to accumulation in animals, and therefore biomagnify along the food chain towards human consumption. Despite their structural variations, DLCs are of toxicological concern to human health because they induce a common pattern of biological and toxicological responses via their interaction with a crucial signaling protein, the aryl hydrocarbon receptor (AhR). Perturbations of this signaling protein have been linked to a variety of adverse health effects, including deficiencies in reproduction and development, disruption of the endocrine system, neurotoxicity, immunotoxicity, cancer, and metabolic diseases. Due to their stability in the environment, ability to bioaccumulate, and substantial toxicological effects, it is critical to monitor and quickly detect DLCs in the environment and provide a rapid tier 1 toxicity evaluation for environmental security and public health risk assessment. The current gold standard for DLC detection is an analytical chemical approach which offers superior sensitivity but with significant cost and complexity. Meanwhile, although the analytical chemical method can identify individual compounds based on their structures, it is complicated and often difficult to determine the overall biological impacts. To facilitate faster, easier, more economical, and higher-throughput tier 1 sample analysis for safeguarding environmental security and public health, the goal of this project is to develop an improved low cost tier 1 bioassay for reagent-free DLC detection using humanized yeast bioreporters that autonomously generate a high resolution optical signal in response to bioavailable DLCs. Using the robust yeast as the host organism also offers a convenient and rapid assay format while still maintaining the toxicological relationships with human exposure endpoints. This new assay, by virtue of its autonomous reporting capabilities, will also be amenable

2016-2017 Programmatic Report

to automation and high-throughput sample analysis, making it a vastly improved candidate for large scale use for not only environmental monitoring and risk assessment but also food supply biosurveillance and high-throughput toxicological screening of DLCs for protection of human and animal health. This autobioluminescent reporter system will also serve as a proof-of-concept 'plug-and-play' platform that can be expanded to a suite of high-throughput bioassays using both yeast and human cells as hosts to profile the impact of a wide range of environmental pollutants.

Technical Report:

1. Development of a novel autonomously bioluminescent yeast dioxin reporter—During the project period, we have successfully engineered an autonomously bioluminescent *Saccharomyces cerevisiae* strain that produces a detectable light signal upon exposure to DLCs and AhR agonists in a dose-responsive manner. This reporter strain was constructed by expressing the bacterial bioluminescence gene cassette (*luxCDABEfrp*) under the control of a synthetic promoter consisting of aryl hydrocarbon response elements (XREs) and an enhancer-less yeast *MEL1* core promoter. To facilitate the expression of the multigene pathway of bacterial origin in a eukaryotic cellular background, we optimized the bacterial luciferase gene cassette to match the codon usage pattern in *S. cerevisiae* and strategically linked the genes using viral 2A elements to mimic polycistronic expression of multiple genes from a single promoter. These strategies allowed efficient expression and streamlined integration of the reporter construct in the *S. cerevisiae* host. We additionally evaluated the effect of promoter organization on reporter gene expression and signal responsiveness to DLC exposure. Our results suggested that a single copy of XRE, rather than five copies as previously hypothesized, coupled with a truncated *MEL1* core promoter, produced the lowest background expression as well as the highest signal induction when exposed to the known DLC benzo-a-pyrene. Therefore, this particular promoter variant was chosen for the final reporter construct. The fully assembled reporter plasmid was transformed into a *S. cerevisiae* strain harboring chromosomally integrated human hydrocarbon receptor (*AHR*) and aryl hydrocarbon nuclear translocator (*ARNT*) genes, whose protein products are essential signaling components of AhR-mediated gene regulation. The resulting reporter strain was designated as BLYAhS and subjected to further validation as described below.

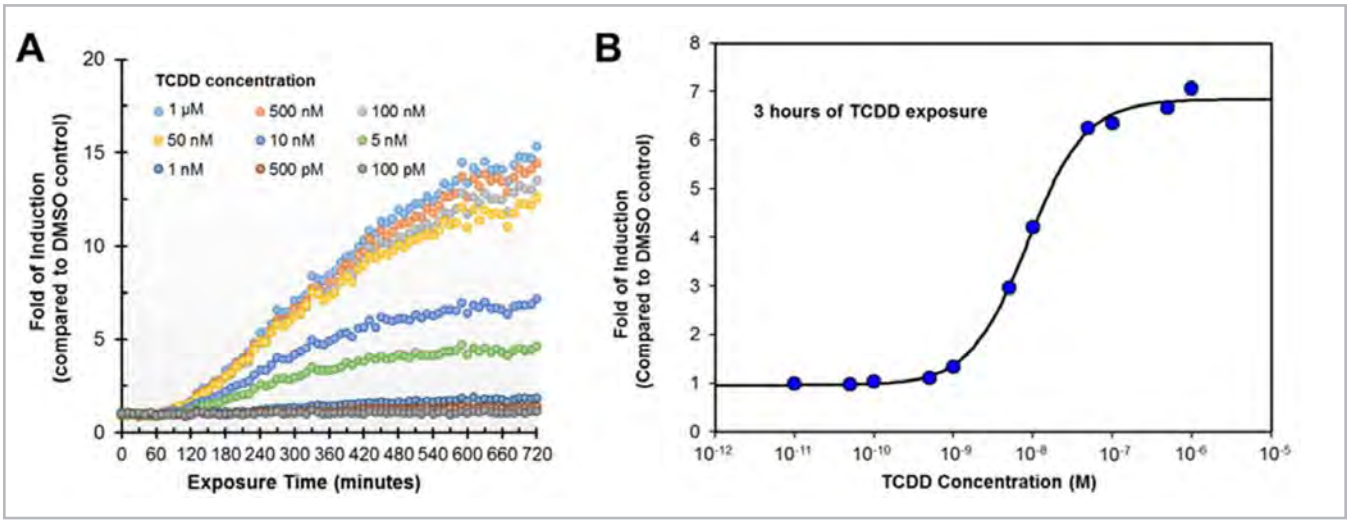


Figure 1. (A) The S. cerevisiae BLYAhS reporter cells are capable of producing a light signal upon exposure to DLCs without cell lysis or any external manipulation, allowing for continuous and uninterrupted data acquisition to capture response kinetics without additional hands-on time.

(B) Exposure to TCDD resulted in a dose-dependent response in the bioluminescent output of BLYAhS cells. Within a 3-hour assay time, the BLYAhS reporter was capable of detecting as low as 500 pM TCDD with an EC50 concentration of ~ 8.5 nM.

2. Characterization of the yeast dioxin reporter with DLCs—Following successful reporter strain development, we proceeded to characterize the performance and effectiveness of the BLYAhS reporter cells against a suite of DLCs. To date we have developed and optimized a standard operating procedure for a 96-well microtiter plate-based highthroughput yeast bioassay. Because the yeast reporter cells produce a light signal continuously without cell lysis or any other external manipulation, the assay is readily automated in a compatible plate reader to automatically collect signal kinetics data hands-free (Figure 1A). Using the model dioxin 2,3,7,8-tetrachlorodibenzodioxin (TCDD) as an assay standard, we determined the dynamic range of detection, minimal response time for each concentration, and the concentration capable of triggering half maximum bioluminescence (EC_{50}). Our results showed that the BLYAhS reporter was capable of detecting as low as 500 pM TCDD with an EC_{50} concentration of ~ 8.5 nM within 3 hours of exposure (Figure 1B). We have additionally characterized the *S. cerevisiae* BLYAhS reporter cells against known DLCs, including the polycyclic aromatic hydrocarbon benzo-*a*-pyrene, the polychlorinated biphenyl (PCB) congeners PCB-126 and PCB-169, and alternative polychlorinated dibenzo-*p*-dioxins such as 1,2,3,6,7,8-HxCDD and OCDD. These alternative DLCs induced dose-dependent sigmoidal responses in the BLYAhS signal output with detection limits and EC50 values higher than those of TCDD, suggesting that TCDD was the most potent inducer of the BLYAhS strain.

Publications and Presentations: This research project has to date generated one publication, four conference/symposium presentations, three of which include an undergraduate co-author. A manuscript resulting from this project is currently being prepared with an anticipated submission date of Spring 2017.

Outreach Activities: This research project has to date trained five high school interns from local and neighboring high schools and eight undergraduate research assistants, including two participants funded through the university's Educational Advancement Program (EAP) Annual Summer Institute whose mission is to promote academic and personal success of first generation, low income or disabled students.

In June 2016, this project was also selected as a research demonstration for 70 high school students from East Tennessee during a three-day visit as part of the inaugural Possibilities in Postsecondary Education & Science (PiPES) summer program.

External Funding Activities: With the generous support from ISSE seed funding, we have successfully accomplished our goal of developing a novel autonomously bioluminescent yeast assay for rapid screening of dioxin and dioxin-like compounds. During this project period, we have conducted comprehensive characterization of the novel yeast assay against a suite of DLCs that are of environmental and public health concern. Data obtained from this study provides a solid foundation for seeking external funding opportunities and will be leveraged as strong preliminary data for research proposals that we are preparing for submission to the NIH National Institute of Environmental Health Sciences for a prospective project centered on toxicological profiling of environmental endocrine disruptors and to the NSF Chemical, Bioengineering Environment, and Transport Systems Program with a focus on monitoring environmental transport and fate of DLCs in Spring/Summer 2017.

Investigation of Crown Ether-Modified Diatoms for the Removal of Alkali Metals from Aqueous Solutions

(Team: Angelica Palomino and Kimberly Carter; Civil and Environmental Engineering; Brian Long, Department of Chemistry)

Introduction and Background: Providing access to clean water is one of the National Academy of Engineering's Grand Challenges. In order to do so, treatment technologies should be environmentally sound, non-energy intensive and economical for the removal of bacteria, suspended solids and metal species. Metals such as arsenic and mercury

2016-2017 Programmatic Report

are toxic to human health, harmful environmental pollutants and are difficult to remove from solution, especially at low concentrations. Technologies such as reverse osmosis membranes and ion exchange resins are used to remove salts and metal ions from solution; however, these technologies can be expensive and energy intensive to use, especially in remote areas where little infrastructure for water treatment plants exists.

The purpose of this proof-of-concept study was to investigate the use of crown-ether modified diatoms for the removal of alkali metal ions, in particular K^+ and Na^+ ions, from aqueous solutions. The techniques and materials developed here were anticipated to be further modified to address the removal of other species such as arsenic.

Crown ethers are polycyclic ethers that have found tremendous utility due to their remarkable ability to bind cationic metal salts. Previous studies have investigated the use of silica surfaces for immobilizing crown ethers to provide a substrate to aid in the removal of metals from solution.

Diatoms are the skeletal remains of algae and plankton and are typically found in lakes, rivers, and other large bodies of natural waters. The skeletons are microscopic in size (~10-100 μm) and primarily composed of biogenic silica. The advantages of using diatoms in environmental applications are that (1) the cost of the material is low, (2) silica is relatively chemically inert, and (3) diatoms have a high specific surface area of up to 100 m2/g due to their size, shape and topography.

While the immobilization of crown ethers on silica surfaces has been thoroughly studied and surface modification of silica using other surface treatments methods have also been studied for the removal of metal ions, the objective of this study was to demonstrate that a simpler, more environmentally-friendly approach can be achieved by the use of surface immobilized crown ethers on a less costly silica material, i.e. diatoms.

Results: Task 1—Diatom Characterization. Surface and material characterizations of the diatoms prior to and after functionalization were conducted.

Imaging. Scanning Electron Microscopy (SEM) was used to image the diatoms before and after surface modification with the crown ethers. Surface elemental microanalysis was conducted using the attached energy dispersive x-ray spectrometer (EDS). SEM/EDS was conducted at the JIAM Microscopy Center. A SEM of the untreated diatoms is shown in Figure 1.

A comparison was made using SEM/EDS between the untreated and functionalized diatom material. As shown in Figure 2, no observable differences can be made between the two materials either visually (Figures 2(a) and 2(b)) or chemically using EDS (Figures 2(c) and 2(d)).

Determination of Crystallographic Structure. X-ray diffraction (XRD) was used to characterize the crystallographic structure of the diatoms. As shown in Figure 3, the untreated and functionalized material have almost identical diffraction patterns, except for a peak appearing at 20~ 28°.

Specific Surface. The measured specific surface of the untreated diatoms is 26.2 m2/g. The surface area per unit mass was determined using the Brunauer-Emmett-Teller (BET), i.e. gas adsorption, method. A BET specific surface device is housed within the Department of Civil and Environmental Engineering, and the measurement was obtained by Aashish Sharma (Graduate Research Assistant).

Characterization of Silica Surface Bond Groups. Fourier Transform Infrared (FTIR) Spectroscopy was used to determine the presence of –Si-OH, –Si-H, and –Si-O-Si bond types at silica and diatom surfaces. These end groups are needed in order to bond the crown ether molecules.

Task 2—Immobilization of Crown Ethers to Diatom Surfaces. Surface treatments are routinely encountered in the literature, and are well-known to dramatically increase the number and/or density of free surface hydroxyl groups, which are essential for subsequent surface immobilization reactions. Toward this goal, the crown ether

2015-2016 Programmatic Report

modified diatoms were synthesized in good yield following a simple synthetic procedure starting with native diatoms and ending with a fully activated crown ether-modified product. Therein, the raw diatoms were activated through a two-step process; first the diatoms were stirred in a mixture of methanol and concentrated hydrochloric acid before being subsequently filtered and washed. Next, the off-white powder was re-suspended in a solution of water and ammonium hydroxide, followed by addition of hydrogen peroxide over a 30-minute time period. This activation process was necessary to ensure the diatom surfaces were fully hydroxylated, which is critical for the subsequent crown ether immobilization.

The now "activated", or hydroxylated, diatoms were suspended in a toluene solution and 3-glycidoxypropyl-trimethyloxysilane was added. This mixture was refluxed over-night to yield the epoxy-functionalized diatoms as an off-white powder in overall good yield. The epoxy-substituted diatoms were then suspended in toluene and the appropriate amine-functionalized crown ether was added. After the reaction reached completion, the solution was filtered, washed, and dried to produce the crown ether functionalized materials as light purple solids in good yield.

Task 3—Adsorption-Desorption of Alkali Metal Ions from Crown Ether Enhanced Diatoms.

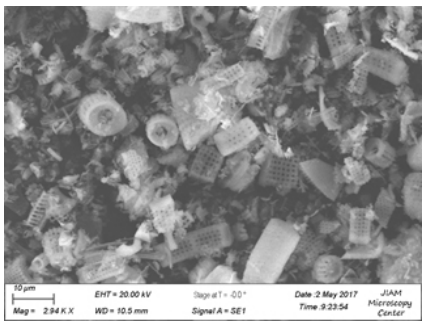
The purpose of this task was to determine if crown ether-modified diatoms can remove/capture cations (and associated anions) from brine solutions. Equilibrium adsorption studies were performed in order to ascertain the maximum adsorption capacity of the modified diatoms for the removal of sodium, lithium, and calcium salts from solution. The solutions were allowed to equilibrate at room temperature. Samples were analyzed using ion chromatography (IC) and inductively coupled plasma–optical emission spectrometry (ICP-OES) to measure the equilibrium concentrations of the salts. Mass balances were performed to determine the amount of salt that has been removed from the water solutions. Langmuir and Freundlich isotherm models were applied to determine the affinity of the salts to the modified diatoms.

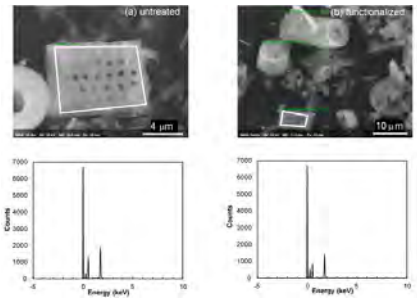
Experimental Method—Adsorption. 1 g L-1 of functionalized diatoms were placed into the solutions and samples taken with time. The total starting weight of the diatoms in each experiment was nominally 0.2 g and the starting solution volume was 200 mL. Each sample volume was 2.5 mL. Stirring was maintained at 350 rpm.

Key findings:

When functionalized diatoms were placed in the indicated solutions, cation concentrations increased. It was expected that the concentrations would either remain the same if there was no absorption, or decrease if the cations were taken up by the functionalized diatoms.

The same increasing Na^+ concentration was seen with untreated diatoms in a $CaCl_2$ solution. Note, no NaCl was added to the solution. The concentration of $Ca2^+$ also appeared to increase.





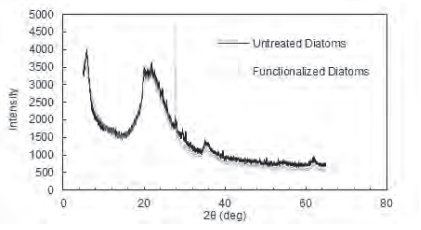


Figure 1. Scanning electron micrograph of untreated diatoms. Figure 2. Scanning electron micrographs and corresponding EDS analysis of untreated diatoms (a) and (c), and functionalized diatoms (b) and (d). The EDS analysis area is outlined by the white quadrilaterals in (a) and (b). Figure 3. X-ray diffractograms for untreated and functionalized diatom material.

2016-2017 Programmatic Report

Given the apparent leaching of excess Na^+, Li^+, and $Ca2^+$ ions into solution by the diatoms, additional studies are required to better understand why the concentrations of these ions seem to be increasing with time.

International Center for Air Pollution and Energy Studies (iCAPES)

(PI: Joshua Fu, Civil and Environmental Engineering)

(1) *Uncertainty quantifications of Extratropical Forest Biomass in CMIP5 Models over the Northern Hemisphere*—Simplified representations of processes influencing forest biomass in Earth system models (ESMs) contribute to large uncertainty and variability among projections. We evaluate forest biomass from eight historical simulations in the Coupled Model Intercomparison Project Phase 5 archive produced by ESMs from four modeling centers, using a data product synthesized from radar remote sensing and ground-based observations across northern extratropical latitudes. Our results show ESMs overestimate carbon mass in the wood pool, causing overprediction of global total forest biomass, likely as a result of allocating too much carbon to wood.

(2) *Modeling Cold Soak Evaporative Vapor Emissions from Gasoline-powered Automobiles Using a Newly Developed Method*—In this study, we developed a new method to representatively model canister capacity and emissions during parking events based on semi-empirical functions derived from real-world activity data and laboratory measurements. The study highlights the importance for considering the complete anthropogenic evaporative emission inventory and tightened the related regulatory standards.

(3) *The Task Force on Hemispheric Transport of Air Pollution (TF HTAP) phase II*—The HTAP II is a joint effect of international scientists for a better understanding of the hemispheric transport of air pollutants.

(4) *Implementation of computationally efficient chemical solver into global chemistry-climate model (CAM4-Chem)*—The global chemistry-climate model (CAM4-Chem) overestimates the surface ozone concentration over the conterminous US (CONUS). Reasons for this positive bias include emission, meteorology, chemical mechanism and solver. In this study, we explore the last possibility by examining the sensitivity to the numerical methods for solving the chemistry equations.

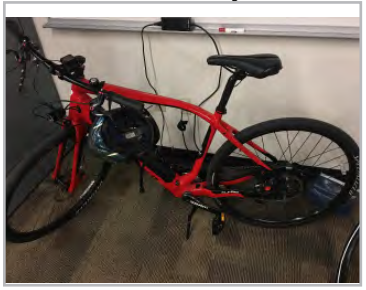
(5) *Climate-driven critical load exceedance*—Nitrogen (N) and sulfur (S) deposition are much mitigated over the conterminous US (CONUS) but deposition exceedance still exists on forest soil. In addition, the empirical approach is usually used but only provides a spatially constant critical load (CL). Therefore, the CL derived from steady-state mass balance equation is used to study the CL exceedance on forest soil over the CONUS.

(6) *ABaCAS for China air benefit and cost and attainment system funded by Energy Foundation*—The International Center for Air Pollution and Energy Studies (iCAPES) conducted further development of the Streamlined Edition of Air Benefit and Cost Analysis and Attainment Assessment System (ABaCAS-SE).

Sustainable E-bikes: Naturalistic Behavior Approaches to Assess Sustainability

(Team: Christopher Cherry, Civil and Environmental Engineering; Daniel Costinett, Electrical Engineering and Computer Science; Paul Frymier, Chemical and Biomolecular Engineering)

Naturalistic behavior analysis involves the collection of "real-world" use data. Naturalistic methods can be simple (e.g., active or passive GPS, smartphone tracking) or advanced (fully instrumented vehicles). For the purposes of this and future research in this area we intend to develop an instrumentation system for four different e-bike types, from standard e-bikes to the newest cutting edge technology (e.g., Bosch drive systems and Speed Pedelecs).



Instrumented bike

During the project period, two papers

were published and six presentations were made by the project team (see "Publications and Presentations" below).

In addition, outreach was conducted with academic researchers, manufacturers, and companies, summarized below:

- Engaged Bosch USA on developing a proposal for National Science Foundation (NSF).
- Collaborated with researchers from Electronic Engineering and Chemical Engineering to work on system requirements for an app-based data acquisition system.
- Collaborated with identified programmer from Computer Science for iOS app development to interface with bike for data logging.
- Engaged with sensor providers to establish data collection processes.
- Contacted StagesCycling to explore methods to get user-power data and motor power data from Bosch driven e-bike.
- Mounted a power meter on the specialized e-bike successfully, allowing a calculation of force, and ultimately power.
- Met with industrial partners from Bewegen Company to explore future collaboration and research opportunities, building a research team that includes faculty from Portland State University, University of Alabama Birmingham, Johns Hopkins, and UT.
- Led effort to develop and pass state legislation (SB 1705 – HB 1711) to allow e-bikes on the road, necessary to enable field research. This effort included interfacing with national advocacy organizations, industry, statewide organizations, personal testimony to senate the transportation committee and relevant educational outreach efforts. This law was signed by the governor in May 2016.
- Built an interdisciplinary, two-institution collaborative team including researchers from computer science, electrical engineering, and chemical engineering to submit a NSF proposal, which was funded.
- Joined the STEMpunk event as community outreach activity, gave e-bike and sustainability education to over 70 ninth grade students and their parents.

During the project period, the research team submited seven proposals, of which five were funded ($552,652 total) and two were rejected. Also, the research team are working on one proposal targeting NIH.

2015-2016 Baker Center Energy and Environment Forum

(Team: Paul Armsworth, Ecology and Evolutionary Biology; Jacob LaRiviere, Economics; Becky Jacobs, Law; Donald Hodges, Forestry, Wildlife and Fisheries; and Charles Sims, Economics and the Baker Center)

Dr. Gary Parker, W.H. Johnson Professor of Geology from the University of Illinois at Urbana-Champaign.gave a seminar on February 23, 2017 on "Bankfull Characteristics of Alluvial Rivers."

Appalachian Dark Skies Network

(Team: Tim Ezzell, Political Science/ISSE; and Catherine Wilt, ISSE)

Over the past year the project team has completed the following tasks:

Appalachian Dark Skies Database—Team members have compiled a database of dark sky destinations and stakeholders across the twelve state ARC region. The database includes contact information for a wide range of stakeholders, including astronomy clubs, planetariums, observatories, and state, local, and national parks. The current list includes over 550 regional groups and destinations.

Appalachian Dark Skies Survey—After compiling the database, team members developed and delivered a survey to better understand the travel habits and economic potential of dark skies visitors. The survey also measured awareness of various dark sky destinations in the region and compiled demographic information related to the market sector. The survey was distributed among astronomy clubs across the region and was posted on a popular astronomy message board. To date,

2016-2017 Programmatic Report

the survey has received almost 100 responses. The survey has also increased dialog with regional groups and enthusiasm for the project is high. The survey has generated interest from other researchers and the UT team has been in contact with researchers conducting parallel projects in the UK and Australia.

Presentations—

- Dr. Ezzell presented preliminary findings from the study before the staff of the Appalachian Regional Commission in Washington on December 1, 2016. The staff and leadership of the agency expressed interest and support for the work and additional funding from the agency appears likely.
- Dr. Ezzell led a panel on dark skies development at the Appalachian Studies Conference at Virginia Tech in March 2017.

Events—Dr. Ezzell and Ms. Wilt helped host Calhoun Stargaze 2017 on May 19th-21st 2017. The event was well attended, with almost 40 paid registrants and an additional 20-25 local participants in attendance.

Findings—The database and survey, perhaps the first of their kind in the US, have greatly expanded our understanding of the region's dark skies landscape and the amateur astronomy tourism market. Among our findings are the following:

Taken (by Steven Ganzler) at star party in November (cold, clear skies).

- The astronomy landscape is more complex than originally thought. While a small number of high profile destinations dominate the landscape, a significantly larger number of sites also exist that serve local or subregional audiences. Some of these sites have the potential to become regional or even national destinations.
- State parks appear to form the backbone of the dark skies landscape and park managers and staff may emerge as lead proponents of any regional network.
- Survey trends among astronomers are fairly constant and, to a degree, confirm prior demographic assumptions related to gender, race, educational attainment, and income. In general, astronomers tend to be white middle-aged men with higher than average incomes and levels of educational attainment.
- Travel and spending habits appear to be promising, as astronomers appear eager to travel and willing to spend. Interestingly, a majority of participants also expressed interest in owning or co-owning a vacation home in a dark sky community.
- The growth of this sector may create a demand for new technologies to better serve these visitors. Global demand for specialized lighting and power and data distribution systems could become a niche industry in the region.

Other Developments—

- Calhoun County Park has applied for a $300,000 state ARC grant to begin implementation of recommendations in the UT strategic plan. The county has also created a planning commission and will soon adopt a lighting ordinance to protect local dark skies resources.
- Dr. Ezzell and Ms. Wilt met with officials from Pickett CCC State Park near Jamestown Tennessee to discuss UT assistance with their dark skies programming and facilities. Dr. Ezzell's Fall Appalachian Teaching Project class will assist in exploring possible outreach activities during the Fall Semester.

External Funding Opportunities—Dr. Ezzell has submitted a notice of intent for an NSF AISL grant and is working with project partners to develop a submission for an internal competition related to the opportunity. The proposed pilot program would team academic scientists with citizen scientists (regional astronomy clubs) to conduct outreach activities and teacher training sessions at Calhoun County Park and Pickett CCC State Park.

Socially Responsible Stormwater Management in the Face of Climate Change Uncertainty

(Team: Anahita Khojandi and Xueping Li, Industrial & Systems Engineering; Lisa Reyes Mason, Social Work; Kelsey Ellis, Geography; and Jon Hathaway, Civil & Environmental Engineering)

Project Summary: This study is an interdisciplinary analysis of urban system resiliency to climate change that integrates methods from the social, hydrologic, and systems sciences. Specifically, this study focuses on urban flooding, a common occurrence that will be exacerbated by climate change, and the benefits of green infrastructure for flood abatement. Instead of traditional designs that aim to merely mitigate excess runoff or its associated economic costs, this study aims to incorporate the disproportionate effect of weather events and their associated hazards on communities with less social and economic advantages, highlighting the need to integrate these communities in flood abatement and resiliency planning.

Outcomes: We have produced a number of deliverables incorporating this work in 2016-2017, including peer-reviewed conference papers, presentations, proposal development, and media interviews. The project has also supported five graduate students.

Outreach: Discussions of research with neighborhood associations to facilitate community engagement ; and discussions with TVA on potential collaborations on research of flood warning systems and the interconnectivities among different critical infrastructure sectors.

Media attention: "Cities enlist nature to tame rising flood risks." *Christian Science Monitor* 20, December 2016.

Progress:

- IRB application to conduct phone surveys, neighborhood research meetings, and interviews submitted and partially approved.
- Focus group conducted with Edgewood Park Neighborhood Association.
- Interviews conducted with residents of Edgewood Park and Fairmont/Emoriland.
- Phone survey revised and IRB revisions under preparation for approval of SWORPS/CARE to collect survey data.
- Social vulnerability mapping of Knoxville census tracts completed.

Sustainable Treatment of Wastewaters Generated during Unconventional Oil and Gas Production with Production of Renewable Hydrogen

(Team: Abhijeet Borole, Chemical and Biomolecular Engineering/ORNL; and Terry Hazen, Civil & Environmental Engineering/ISSE)

Produced and flow-back water were acquired directly from either an exploration and production company or oilfield services company. These samples were used for enrichment of electroactive organisms to enable hydrogen production from the organics in the fracking waters. The task of initial development of an electroactive microbial community to produce hydrogen from flow-water was successfully completed. The salt and organic content of produced water obtained from several oil wells in Texas were quantified. The salt concentration was very high as exhibited by the high conductivity (> 100 mS/cm) and the organic content for the different samples ranged from 2.2 to 18.6 g COD/L. Targeted evolution of the microbial community was conducted via process control of the microbial electrochemical reactors achieving a current density > 1 A/m^2 and a hydrogen productivity > 1 L-H_2/L of anode volume-day. Microbial characterization of the produced water was also done identifying *Paenibacillus* genus in the raw

2016-2017 Programmatic Report

water. Samples of the microbial consortia from the bioelectrochemical reactors were collected and saved for future microbial characterization. The configuration of the reactors and their operation had to be redesigned and reconfigured to allow processing high salt concentrations in the reactor. This required dilution of the incoming stream in recycle water, which can potentially be generated via desalination methods such as capacitive deionization, etc. in the field.

Successful demonstration of the proof of principle of microbial electrochemical technology for treatment of produced water has potential to develop practical, sustainable solutions for managing the large volumes of produced water generated via hydraulic fracturing. Funding to continue the research and develop the technology further will be sought from NSF, USBR and DOE. A manuscript is also planned for completion before end of 2017 using the experimental work initiated during this project.

Conclusion—The two primary objectives proposed for this study have been completed. Enrichment of a microbial consortium capable of using produced water or flow-back water organics as the sole source of energy for electron generation was accomplished by demonstrating current production using these conditions. Secondly, production of hydrogen was demonstrated in the MECs with examination of the effect of salts on MEC performance. The work conducted to date has resulted in elimination of a major limitation of the system design by changing the membrane from CEM to AEM. Future work will include characterization of the anode microbial consortium and biofilm growth to improve the hydrogen productivity further.

Proposal Development Activity—A proposal was submitted to the US Bureau of Reclamation (USBR) in the first quarter of 2017. This was a collaboration between Dr. Borole, Dr. Hazen and Dr. Quinn from Lawrence Berkeley National Laboratory. It was focused on treatment of salt and selenium contaminated water. Discussions with the USBR Program Manager and the staff at the pilot plant at Panoche Water District treating contaminated waters revealed that there is interest in removal of salts from the water. This indicates scope for direct application of the work being done under ISSE project. The USBR proposal was not funded, however, the reviewers recommended conducting lab-scale studies to develop the method further. The results obtained since the last submission will allow demonstration of the treatment of saline waters, so the chances of funding will be higher next time. We plan to resubmit the proposal with these data to demonstrate that the salt removal can be supported by energy generated from wastes, thus reducing the cost of treatment, which was indicated to be of interest to USBR by the Program Manager.

A second proposal will be submitted to NSF targeting salt removal from produced water in September 2017. The preliminary data obtained in this study will be useful for additional proposals to DOE Fossil Energy Office as well as EPA, which is interested in treatment of produced water. A manuscript is also planned for completion before end of 2017 using the experimental work initiated during this project.

Understanding Formation, Structural Changes, and Ultimate Fate of Terrestrial Microplastics

(Team: Doug Hayes, Biosystems Engineering & Soil Science; Barbara Evans, ORNL (Adjunct Professor in Mechanical, Aerospace and Biomedical Engineering); Hugh M. O'Neill, ORNL (Adjunct Professor of Cellular & Molecular Biochemistry and Biology)

The objectives for our ISSE seed project consist of:

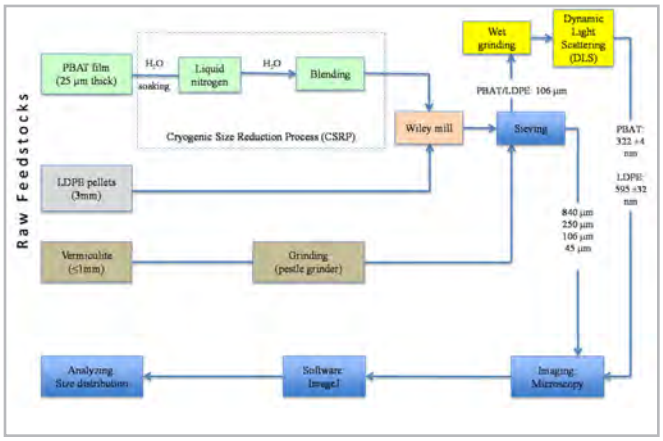
- Understand the formation of micro-(and nano-) plastics (abbreviated as MPs in this report) and artificial (simulated) soil
- Structural analysis of NPs in simulated soil by small-angle neutron scattering (SANS)
- Prepare proposal draft(s)

Motivation for our project—Weathering and fragmentation of plastics in the environment producesmicroplastics (MPs; <5 mm) and nano-

plastics (NPs; <100 nm). The literature has shown many examples of pollution and bio-accumulation in watersheds and fish and shellfish. The MPs and NPs are commonly composed of polyethylene, polyethylene terephthalate and other plastics that are poorly biodegradable, and therefore may persist in the environment for many months and years. The scientific community is learning of the harm of MPs and NPs to all organisms through their persistence in watersheds. But very little is known about the fate and impact of MPs and NPs in terrestrial environments, except that agricultural plastics (e.g., plastic mulch films) do lead to the formation of terrestrial MPs and NPs. The goal of this project is to provide seed data related to this topic, to allow us to pursue this area more deeply through major funding.

Progress report—For Objective 1, Mr. Anton Astner, Research Associate, has developed a robust technique for preparing MPs and NP from polyethylene (PE) and biodegradable plastic: a film of Mater-Bi®, a blend of poly(butylene-dipate)-co-(butylene-terephthalate) and thermoplastic starch (referred to herein as PBAT, as sold as "BioAgri,", a product from BioBag Americas, Palm Harbor, FL). Employment of Image J software analysis of SEM images, to obtain sizes of MPs. MP formation was achieved. The 106-46 mm fraction of PBAT MPs was further size-reduced by the use of wet-grinding with a "supermass colloider" in the UT Center for Renewable Carbon (CRC). NPs were formed. A similar extent of size reduction was also achieved for LDPE pellets.

The goal of Objective 2 is to demonstrate that NPs can be isolated in the neutron beam for a mixture of NPs and soil via neutron contrast matching through SANS analysis. We obtained 1 day of instrument time at the Bio-SANS instrument (High-Flux Isotope Reactor, ORNL) in each of February and July of 2017, and from SANS analysis of vermiculite/water slurries at different H_2O/D_2O ratios using well-stirred tumbler cells as the sample environment, we determined that 66% D_2O / 33% H_2O serves as the contrast match point for vermiculite. We prepared slurries NPs of PBAT and LDPE (prepared as described above) in 66% D_2O/33% H_2O. Results show that the neutron scattering is mainly from the NPs. For the LDPE NPs, we see a peak maximum at low-Q, near 0.004 $Å^{-1}$, suggesting the average size of the NPs is approximately ($2\pi/Q_{max}$) 1570 Å (157 nm). We wrote a SANS "user proposal" that was placed on the "alternate list" for the current instrument cycle for 3 days of instrument time. The instrument scientist for Bio-SANS, Dr. Venky Pingali, has indicated it is likely that we will have 3 days of instrument time in August, 2017. We will repeat the SANS experiments depicted below for vermiculite/NP slurries, but for a more precisely determined contrast match point (i.e., the size-reduced vermiculite used in the July beam time gave a contrast match point slightly different from that obtained in our February beam time using a coarser grade of vermiculite, of 57% D_2O in water). We will prepare samples and evaluate the size of NPs subjected to stirring for several days in the presence of vermiculite prior to beam time, to determine if the NPs undergo size reduction.

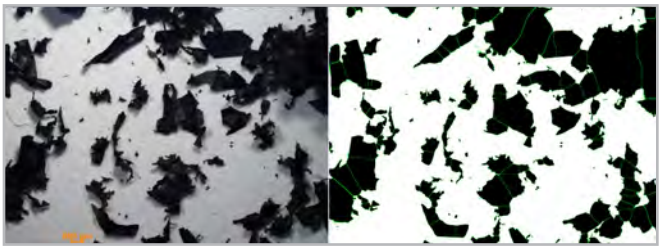


Flow diagram of size reduction process (from Astner et al., in preparation (J. Polym. Environ.)

Regarding Objective 3, Barbara Evans has been working on possible funding avenues to continue the project. An ORNL seed money proposal was prepared to extend the investigation to the specific role of soil humic substances on the degradation of plastics in the environment. Humic substances constitute as much as 10% dry weight of typical soils, yet their effect on fragmentation and degradation of plastics, including photocatalysis, has

2016-2017 Programmatic Report

not been examined, despite their known effects on polycyclic aromatics and alkanes. Although the proposal received positive feedback from the review committee, it was not accepted. We are considering ideas for the next cycle of seed proposal calls, including the effect of humic acid (as described above), "biocatalysts for plastic degradation", "microplastics and duckweed," and "uptake of nanoplastics and microplastics by root systems."



Use of Image J software to analyze SEM micrographs, via use of the 'watershedding" function of Image J.

Some ideas for future proposals:

- Hayes contacted the Dr. Hongda Chen, director of the USDA Nanotechnology Program. Dr. Chen indicated that our project did not fit strongly within the current RFA. Hayes will prepare a joint proposal to NSF (environmental sciences) this fall, after a more mature manuscript draft is prepared. (The first draft is under review, and follow-up experiments are being planned.) Hayes will continue to support Mr. Astner using an alternate research account to allow for the data collection and manuscript writing to be completed.
- DOE Office of Biological and Environmental Research announced a call for white papers from DOE national laboratories for research on the Energy-Water Nexus: Regional-Scale Data, Modeling, and Analysis (DMA) Test-Beds. The Department of Energy has released a new report, the Water-Energy Nexus: Challenges and Opportunities, that frames an integrated challenge and opportunity space around the water-energy nexus for the Department and its partners to pursue research, development, and deployment of key technologies; sharing of robust datasets; integration of models to inform decision-making; harmonization of policies where warranted; and enhanced public dialogue. Dr. Stan Wullshleger is coordinating the ORNL response.
- Recognition of the issues related to plastic waste by the U. S. Department of Defense has led to the inclusion of plastic materials with metals for in-field advanced manufacturing recycle/reuse in a recently released WPSON-18-C4, "Development of Novel Expeditionary Manufacturing Processes Using Recycled and Reclaimed Materials" from the Strategic Environmental Research and Development Program (SERDP). The focus of this Statement of Need was on portable fielddeployable manufacturing units and did not specify type of plastic or uses.

Enzymatic degradation of biodegradable plastic polymers by fungi and/or bacteria

(Team: Todd Reynolds, Microbiology; and Jennifer DeBruyn, Biosystems Engineering & Soil Science)

Background/Goals—The advent of man-made plastic polymers has revolutionized virtually every facet of modern life. With their malleability, hydrophobicity and resistance to desiccation, petroleum-based plastics have seen an exponential increase in production since their commercialization. However, many of the characteristics that make petro-polymers so comprehensive and useful also lead to a harmful environmental footprint. The energy needed to create plastics such as poly-ethylene and poly-propylene are approximately 70-85 MJ/kg. This does not include the environmental impact of petroleum extraction, which can have long-lasting detrimental effects on fragile ecosystems. Furthermore, man-made plastics resistant to natural weathering and degradation have led to a sharp increase in plastic pollution of both oceanic and terrestrial environments. One of the key reasons for their resistance to degradation is the monomeric linkages that create the polymers are seldom recognized by microbe synthesized extracellular enzymes.

2016-2017 Programmatic Report

The scarcity of extracellular enzymes that recognize petro-polymers is contrasted by biodegradable plastic polymers. Biodegradable plastics are polymers either created from organic, renewable materials such as corn, soybeans and sugarcane, or are petrochemically based polymers that have been altered to be more readily degraded. Although using crops as sources for the plastics may drive up food costs, the carbon footprint of collecting and producing the source materials is far lower than for petroleum based plastics. For polyhydroxyalkanoates (PHA), the current energy needed for production is estimated to be 50.4 MJ/kg. For Poly-lactic acid (PLA) the energy needed is currently around 55 MJ/kg. However, next generation plastic manufacturing facilities have reported creating a kg of PLA for as low as 27.2 MJ, with the hope of reducing that number to 16.6 MJ/kg. This reduction in energy production costs, coupled with less detrimental material extraction and product degradation, makes the shift in biodegradable polymers for certain uses attractive.

As previously stated, one of the reasons that plastics such as PLA and PHA are more easily degraded is their recognition by microbes as a source of carbon. Both bioplastics are created by coupling monomeric subunits together into long chains through ether linkages, which can be found in several lipid and protein molecules. The ability to depolymerize plastics into smaller oligomers and eventually monomers is the key step in utilizing the materials as an energy source. For energy recycling, the soil environment is rich with large organic molecules, which need to be degraded. Of the approximate 2700 Gigatons (Gt) of carbon found in the earths terrestrial environments, 1550 Gt are stored in organic carbon sources. This massive amount of carbon, coupled with large and complex carbon based molecules, makes the environment rife with microbes excreting extracellular enzymes capable of degrading molecules for a fitness advantage. Like the richness in production of antimicrobials in the soil environment, competition over resources is the driving factor that pushes microbial life to create unique structures for gathering energy.

Our goal in this project is to isolate and identify soil microbes that have the capability of degrading biodegradable polymers. Furthermore, we want to identify the mechanisms and pathways behind these processes and to attempt to alter them, to create more efficient polymer degrading systems. To accomplish this, soil samples from a field site here in Knoxville were taken and enriched in PLA/PHA polymer blends to isolate soil microbes. Two microbial species identified as members of the *Rhodococcus* (B12) and *Bacillus* (F27) genera have been shown quantitatively to degrade the polymer Poly-lactic acid (PLA). We hope to continue investigating the degradation phenomena of these microbes by utilizing molecular genetics and biochemical techniques. Furthermore, understanding how broad-ranging the phenomena is and how evolutionary pressure may change these soil isolates will also be explored.

Results—Section 1: Defining characteristics of plastic degradation by Bacillus and Rhodococcus isolates

Developing PLA Degradation Assay: We first attempted to measure the release of Poly-Lactic Acid monomer, L-lactate, in the presence of a known purified protease, Proteinase K. In a 96-well plate, a slurry of 5 mg/mL of PLA and NEB enzyme buffer 4 was made. Following overnight incubation, wells with the addition of Proteinase K had greater than 100μM of L-lactate released into the medium. L-lactate was also found to be released in low levels in control wells without the presence of Proteinase K; this was determined to be a result of the contents of the NEB buffer (most likely the disulfide breaker DTT). A series of assays were performed to determine the variability of assay efficacy at various time points and temperatures. Serial dilutions of Proteinase K from 6.4 units/μL to 1.6 units/μL showed no significant reduction in L-lactate release (Figure 1). Proteinase K yielded high levels of L-lactate release as quickly as an hour and persisted for the duration of the time course (12 hours). A time course showed Proteinse K saturates the detection limit of the L-lactate kit by 4 hours. Altering the temperature between

2016-2017 Programmatic Report

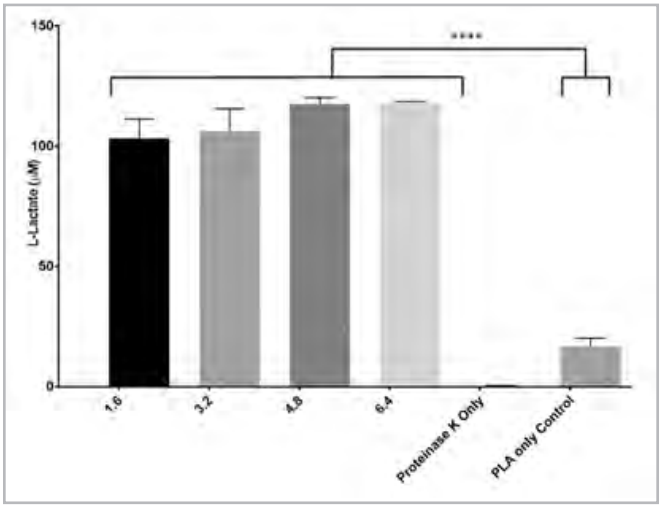


*Figure 1. Serial dilution in Proteinase K did not reduce efficacy of enzyme. Concentrations of Proteinase K from 6.4 units/µL to 1.6 units/µL were added to a PLA slurry for 4 hours. L-lactate was measured using a colormetric lactate detection kit. The control well was a PLA slurry with no addition of Proteinase K. ****=p≤.0001*

20°C and 37°C had no effect on the enzyme's ability to degrade PLA. We also checked to see if acidification of the media or an addition of a carbon source could alter the sensitivity of our L-lactate detection kit. No large differences were found between the release of L-lactate in more acidified media, and no differences were seen in lactate levels when glucose was added to the media. The results of these initial parametric assays gave us confidence in our positive control Proteinase K for measuring PLA degradation. Also, laboratory conditions that microbes would be exposed to did not significantly alter L-lactate detection by our assay and did not negatively affect Proteinase K efficacy.

Determining the Degradation of PLA by Rhodococcus *spp. and* Bacillus *spp. Isolates:* Members of the Debruyn lab collected soil samples from a field site in Knoxville for enrichment. These samples were enriched in minimal salt media (MSM) containing a Poly-lactic Acid/Polyhydroxyalkanoate (PLA/PHA) polymer blend. Enrichment was performed for six weeks and the polymer degradation was determined by measuring CO_2 release and polymer weight reduction. Two microbial colonies were isolated from the enrichment cultures and identified using 16s rRNA sequencing. The strains B12 and F27 had a high sequence identity to *Rhodococcus yunnanensis* and *Bacillus pumilus* respectively.

To quantify the level of PLA degradation by each of these soil microbes, three-week cultures in MSM and PLA were made. The levels of L-lactate detected in these cultures were in the low µM range and showed no increase over our negative controls. In cultures that had a supplemented carbon source in the form of glucose, eight to ten-fold increases in L-lactate release were detected for both isolates. This indicates that PLA can be degraded by both microbes, however it is a poor source of primary carbon for growth. We next shortened the incubation period to 72 hours in PLA+MSM slurry and measured the levels of L-lactate release. Although initial cultures gave us high levels of L-lactate release, our results using PLA+MSM slurry were inconsistent. To remedy this issue, we decided to create PLA films that evenly coat the surfaces of the 96-well plates and glass vials. Crystallized PLA was dissolved using chloroform and equal amounts of the PLA+chloroform paste was added to Polypropylene plates (which are resistant to the solvent). Next, chloroform was evaporated from the wells using nitrogen gas, leaving an even coating of PLA on the well or glass vial. A similar approach was used in flasks for larger volume experiments. Microbes incubated in PLA coated wells showed a ten to twenty-fold increase in L-lactate release compared to those incubated in a PLA+MSM slurry. To test whether L-lactate was produced by microbial respiration of glucose, microbes were grown in MSM+glucose with and without PLA. There was a 25X increase in L-lactate released in MSM+glucose with PLA compared to the same media without PLA for both microbes (Figure 2). These results indicate that the large increase in L-lactate is driven primarily by the microbial degradation of PLA.

Measuring the Effect of Carbon Sources on PLA Degradation: After observing the large increase in PLA degradation by these soil microbes in the presence of glucose, we decided to investigate the effect of altering the carbon source on priming

2016-2017 Programmatic Report

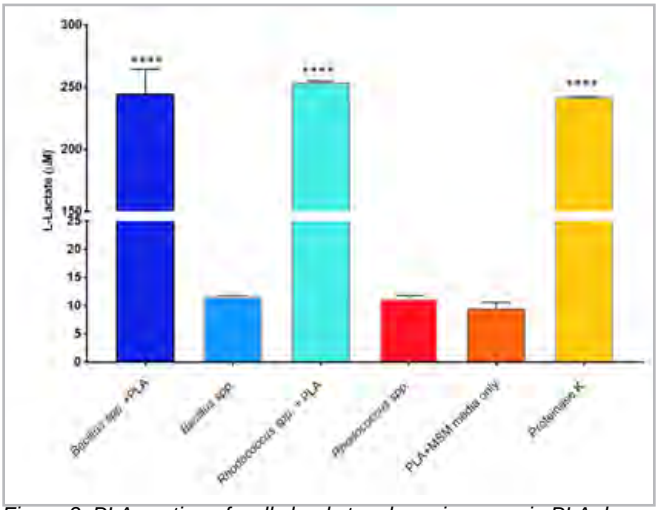


*Figure 2. PLA coating of wells leads to a large increase in PLA degradation by microbes. Glass vials were coated with 10 mg/mL of PLA and incubated with soil isolates. Proteinase K was used as a positive control, with our negative control being PLA in only MSM+glucose. ****=p≤.0001*

PLA degradation by F27 and B12. Our goal was to see if variations in L-lactate release were driven by increased efficiency of growth on certain carbon sources, or if altering the carbon source changes gene expression. To test this, we incubated our strains in MSM media with the addition of seven different fermentable and non-fermentable carbon sources in PLA coated wells. We observed large variations in L-lactate release after 48 hours in different carbon sources for both microbes. Furthermore, the variations in L-lactate release were not consistent between the two strains. The F27 strain had the most significant increases in L-lactate release in sucrose, starch and galactose while the B12 strain had the most significant increases in mannitol and maltose.

Next, we determined the growth rate and the cell concentrations for the B12 and F27 strains. In all carbon sources, stationary phase was reached by 48 hours with OD600 readings ranging from approximately 1.0 to 4.0. Next, we performed colony counts on both strains to determine the approximate CFU/mL corresponding to optical density. For the B12 strain, an optical density of 1.0 was equal to approximately 1.256*108 CFU/mL and for F26 it was approximately 1.837*108 CFU/mL. After determining the approximate cell concentrations for both strains in different carbon sources, a ratio of L-lactate production per cell was created. This was performed to rule out cell growth as the primary cause in changes of L-lactate release. We observed that on a per cell basis, several-fold more lactate was being produced when B12 was grown in both mannitol and maltose than in glucose. When grown in starch, the F26 strain showed a significant increase of L-lactate release per cell compared to glucose. This provides evidence for metabolic changes occurring within the microbial population that leads to an increase in PLA degradation for the B12 strain, and may be based on transcriptional changes.

I*nvestigating the Change in Mechanical Strength of PLA When Exposed to Soil Microbes:* As a follow-up measurement of PLA degradation, we investigated the alterations in plastic rigidity when exposed to microbial cultures. We utilized atomic force microscopy (AFM) to identify nano-scale changes in PLA topography and elasticity. Thicker films of 25 mg/mL were created and incubated for 48 hours with each of our soil isolates. After incubation, the films were removed, cleaned, dried and stored at -20°C. Dr. Sahar Hasim performed AFM at Oak Ridge National Lab (ORNL), and both material rigidity and topography were measured. PLA incubated with F27, B12 and proteinase K all showed significant reductions in rigidity compared to PLA incubated in MSM+glucose only. This indicates a loss of polymer strength, providing further evidence of microbial-based PLA degradation. In the future, AFM will be used as a collaborative measurement to our L-lactate assay for measuring the breakdown of PLA.

Results: Section 2—Identification of enzymes that degrade poly-lactic acid

Developing a High Throughput Assay for isolating strains with altered PLA Degradation: In order to identify genes necessary for degradation of PLA, transposon mutagenesis will be performed to create a mutant library. Because the cost of testing several thousand strains for L-lactate release is not economically viable, a primary screen must be developed to cut out superfluous strains. Our initial screen was measuring the change in growth

2016-2017 Programmatic Report

rate on PLA as the sole carbon source. The reasoning was a complete loss of growth would indicate an inability to utilize the PLA as a carbon source, whilst a large increase would identify strains more efficient at degrading and using PLA.

For our initial pilot screen, the B12 strain was mutagenized using ultraviolet light, until there was an approximately 50% survival rate. Next, a single colony was added to one well of a 384-well plate. The isolates were grown in MSM+glucose, washed and diluted to an optical density range of .0001 to .002 (2.56*104 CFU/mL to 5.12*105 CFU/mL) into 200 µL of MSM. AlamarBlue was added to 100 µL of the stock culture to get an initial cell viability value. The remaining 100 µL was placed in a 384-well plate with PLA coated wells. Strains were grown for seven days, after which final AlamarBlue readings were taken. To determine a relative fold change in growth, mutant strain growth values were divided by wildtype B12. A control plate of Wildtype only was also subjected to AlamarBlue measurement, with little variance detected between wells. Any mutant that had a two-fold increase in growth was selected as a "hit" for secondary screening using the L-lactate assay. Of the ten mutant strains chosen, four had a significant increase in L-lactate release in the presence of PLA compared to wildtype B12. This hit rate is too high to be the cresult of random mutation, but it may be caused by stress induced phase-variation. Whether mutation or phase-variation, it indicates that PLA degradation is a regulatable process, and we are in the postion to use transposon mutagenesis in the future to genetically dissect it. Furthermore, it is clear from this that using growth solely on PLA is a good primary screen for identifying increases in PLA degradation. The same pilot analysis will be performed for the F27 strain before we begin to look into transposon mutagenesis.

Genome sequences of bacterial isolates that degrade plastic: Whole genome sequences of *Bacillus pumulis* and *Rhodococcus* have been generated using Illumina platform sequencing, and are currently being assembled into draft assemblies using CLC Genomics Workbench. These sequences are being explored for the presence of genes with homologies to protease, lipase, or laccase genes, all of which have been associated with plastic degradation.

Isolation of secreted proteins during plastic degradation: Proteins have been isolated from the supernatant of the Bacillus isolate while it degrades PLA. B12 and F26 Cultures were incubated at 30°C for one week either with or without PLA coating. Protein in the supernatant was then concentrated from an initial volume of 100mL using acetone precipitation. After a 100-fold concentration of the media, protein was observable on SDS-page gels with silver staining. There are several prominent bands at a variety of molecular weights for both bacterial strains. Furthermore, bands can be observed both in the presence of PLA and without PLA added. We are currently in the process of using precipitated secreted proteins to identify the extracellular proteome by mass spectrometry and determining if priming the microbes with different carbon sources has an effect on the extracellular proteomic profile.

Future Directions—Exploring the Breadth of Polymer Degradation by Soil Microbes: Many plastic polymers used are blends consisting of two or more unique molecular moieties. This can change the material properties of the plastic, molding it to suit the desired purpose. Because of this, we will also investigate the soil isolates' abilities to degrade PLA blended with other polymers. Degradation of other purified polymers such as polyhydroxyalkanoates (PHA) and Polyethylene terephthalate (PET), will also be investigated to determine the range of degradation capacities of the isolates.

Genetic Characterization of PLA Degradation Phenomena: Another major goal of the project is to a) genetically characterize the pathways involved in PLA degradation and b) manipulate genes to more efficiently degrade PLA polymers. To accomplish this, the combination of transposon mutagenesis, proteomics, and the annotated genome will be used to identify pathways that

regulate PLA degradation. For the genome annotation approach, once it is annotated, putative enzymatic targets will be candidates for cloning, expression in E. coli, and testing for enzymatic degradation of PLA by release of L-lactate. Proteomics and reverse genetics will be further used to identify enzymes and these will confirmed as described for the genome annotation approach. Finally, mutageneis will be used to identify pathways that regulate expression of these enzymes that degrade PLA. , genes necessary for adhesion and metabolism may be investigated to understand their importance in PLA. Regulation of such genes, once identified can then be more precisely analyzed by qRT-PCR or even Western blotting with antibodies to the enzymes.

Multi-scale optimization methods for electric distribution systems with renewables

(Team: Jim Ostrowski, Industrial and Systems Engineering; and Hector Pulgar, Electrical Engineering & Computer Science)

There have been three main thrusts in the past year for this project. They are as follows:

Integrate a microgrid optimization model into ORNL's software for real time deployment:

- Ph.D. student Amelia McIlvenna is currently focusing on formulating a microgrid optimization component for a connected communities project in collaboration with Oak Ridge National Lab. The connected communities project has two major aspects: microgrid operation and individual house operation. Oak Ridge National Lab is partnering with Southern Company to run the connected communities system in two real-world communities, which will be built within the next year. Southern Company will help to facilitate the construction and operation of the microgrid for the homes in the communities. The first community, with about 60 homes, will be commissioned November 2017.
- We have completed an AC optimization framework for Oak Ridge National Lab which will return setpoints for the microgrid. For the first community being deployed, the setpoints component will take in load data, as well as parameters for a 330 kW PV unit, 100 kW and 200 kWh Li-ion batteries, and a 400 kW generator. We also take into account the network structure of the microgrid, with AC power. Because of this, the model has many non-linear constraints, which increase difficulty of the problem. Non-linear constraints were therefore linearized to decrease computational burden.
- The second optimization framework, which is in development, will decide the optimal three-phase balanced load for the system. Prices are decided for each phase, and sent to the homes. The homes can decide to adjust load or remain the same. If load is adjusted, price will be re-evaluated. Once the second framework is complete, the team will begin lab testing with the microgrid control system. The goal of lab testing is to ensure robustness in test cases, and adequate communication of the optimization with both the homes and the microgrid control system.
- ORNL has recently subcontracted $50,000 to UT (through ISSE) to continue this work.

Investigate the impact of uncertainty in microgrid optimization:

- Undergraduate researchers Ethan Deakins and Christopher Muir have been investigating the impact of uncertainty on the current optimization models. There are currently two issues related to uncertainty that need to be addressed. The first is how to even model uncertainty. Access to ORNL's project will give Chris and Ethan the data necessary to perform thorough statistical analysis and to identify the distribution of errors in PV and load forecasts. Knowledge of this uncertainty can then be used to create more robust schedules. In preparation for the data, Chris and Ethan have been developing robust mathematical formulations for microgrid optimization.

2016-2017 Programmatic Report

Identify better ways to model components in a microgrid:

- Gas generators have been components in all of the microgrids we have considered. The physics of such generators, however, presented some modeling challenges. In particular, the on/off nature adds nonconvexities into the mathematical optimization model that (a) increase computation time and (b) makes it more difficult to compute real-time prices. Ph.D. student Bernard Knueven has been working to identify improved formulations that mitigate these two concerns. We currently have a paper on this topic in the second round of revision for IEEE Transactions on Power Systems. Moreover, we have submitted a proposal to the NSF AMPS program (submitted through the ISSE) to continue this work. We expect to hear a funding decision in the next month or two.

Going Forward—The next 6 months will be focused on helping ORNL researchers implement the live test systems. When these are up and running, they produce data that will fuel future research (and proposals).

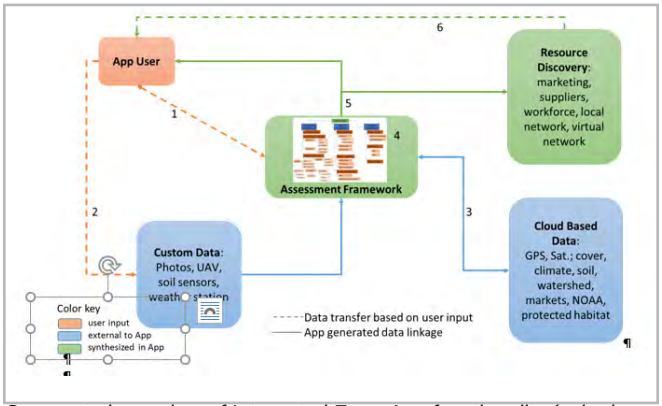
Evaluating sustainability and resilience in agricultural systems using an integrated, web-based app for on-farm self-assessment and resource discovery

(Team: Virginia Dale, Ecology and Evolutionary Biology/ORNL; and Don Hodges, UTIA Forestry, Wildlife and Fisheries)

The goal of this project is to do preliminary interdisciplinary work to design a sustainability assessment tool (an "App") for farmers and agriculturalists. Our project has made the following progress in 2016-17:

- Created a conceptual diagram and flow chart of App functionality (Figure 1).
- Identified interface design and related end-user survey tasks, pursued preliminary focus group information.
- Discussed likely data-sharing obstacles and began to identify persons knowledgeable on data resources that may advise us on these issues.
- Completed training on Institutional Review Board (IRB) human subjects research.
- Presented progress to The University of Tennessee's Institute for a Secure and Sustainable Environment (ISSE).
- Discussed functionality requirements with potential collaborators and future end-users.
- Presented the concept to relevant persons in IBM Corporation over a conference call.
- Prepared and presented a poster for the Southern Sustainable Agriculture Working Group – Lexington, KY, conference on Jan. 27, 2017.
- Presented the project to potential funders and collaborators at a Systems Analysis Workshop in Belgium on January 31 to February 2, 2017.
- Submitted a pre-proposal Concept Note to the International Maize and Wheat Improvement Center (CIMMYT) in anticipation of a potential opportunity for funding of first phase App development research along with possible Yaqui Valley, MX, participants.
- For a related project, we considered the indicator selection process portion of a novel agricultural assessment framework for potential use within the App, including possible modifications required in order to function in a real-time information setting.
- Discussed preliminary functionality and possible case study site data availability with database specialists a CIMMYT Headquarters in Texcoco, Mexico, on March 21, 2017.
- Discussed information needs and preferences with agricultural stakeholders in Yaqui Valley, Mexico, during site visit in Obregon, Mexico, on March 22-25, 2017.
- Submitted summary report from stakeholder interactions in Yaqui Valley to ISSE on June 5, 2017.
- Requested a no-cost extension from ISSE that was approved through December 31, 2017.

2016-2017 Programmatic Report



Conceptual overview of Integrated Farm App functionality (color key: orange=user input, blue=external to app; green=synthesized in app)

- Discussed information needs and agricultural improvement goals with agricultural stakeholders in the Guatemala highlands during a site visit on June 21-24, 2017 (forthcoming site visit summary report to be submitted to ISSE).

Remaining anticipated tasks under this funding include:

- Follow-up on submitted Concept Note for potential funding opportunity
- Determine suitable open-source platform options (e.g. Python, R, Shiny) for developing a user interface in English and Spanish (or other translations/ language versions)
- Compile input from interested farmers, researchers and extension agents and other stakeholders to gauge priorities for the tool's topics and design
- Final report

Note: Based on interactions with agricultural researchers and stakeholders, as well as data and software experts, we have concluded that creation of a prototype application is beyond the scope of the current funded project. While the conceptual overview diagram has received enthusiastic responses, especially related to the real need for a tool that provides so much information from "one-stop-shopping," many experts have also commented on the likely technical software engineering challenges in making the database connections in real-time. Therefore, the task of prototype development and user-interface design would be part of future funded work.

New 2017-18 Seed Grant Projects

(These new seed grant projects were awarded in June 2017 for one-year, July 2, 2017-June 30, 2018:

Nutrient and microbial community implications associated with the addition of duckweed to wastewater remediation

(Team: Sarah Lebeis, Microbiology Department and Graduate School of Genome Science and Technology (GST); and Barry D. Bruce, Department of Biochemistry and Cellular and Molecular Biology and GST Program)

In this project, we will use an experimental test platform to investigate how duckweed alters aquatic microbiomes using an authentic, municipal wastewater source (Hallsdale Powell Utility District). While companies such as, Lemna Technologies have been providing innovative wastewater treatment systems for municipal and industrial applications over the past 25 years, the dynamics and effect on a given microbial have not been well studied.

Green infrastructure project delivery performance evaluation and decision support tool for water/wastewater projects

(Team: Islam H. El-adaway, Department of Civil and Environmental Engineering; and Charles Sims, Department of Economics and the Howard H. Baker Jr. Center for Public Policy)

The goal of this project is to evaluate project delivery performance and develop an automated decision support tool for water/wastewater capital projects.

Hydraulic fracturing chemical effects on characterization of fractured shale particulates and their impact on hydraulic fracturing wastewater quality

(Team: Kim Carter and Angel Palomino, Civil and Environmental Engineering)

2016-2017 Programmatic Report

The goal of this work is to determine the effects of using oxidizing agents, acids, and organic additives on the chemical and physical characteristics of shale at ambient pressures and elevated temperatures to establish a better understanding of the impact of HF processes on water quality.

2017-18 Baker Center Energy and Environement Forum

(Team: Charles Sims, Economics Department and Baker Center; Paul Armsworth, Department of Ecology and Evolutionary Biology; Becky Jacobs, College of Law; Donald Hodges, UTIA Forestry, Wildlife and Fisheries)

The goal of the Energy and Environment Forum is to provide an intellectual meeting place for the many disparate researchers and students around the University interested in the interface of science and policy topics surrounding energy and the environment. The Forum aims to draw people out of home departments and to expose them to new perspectives on energy, environment, and sustainability topics and to stimulate interdisciplinary discussion and research teams that will be competitive for external funding.

Microbial contamination, biofilm development and lead release in drinking water and in premise plumbing

(Team: Jayne Wu, Department of Electrical Engineering and Computer Science; Qiang He, Civil and Environmental Engineering; and Jiangang Chen, Public Health)

The primary objective of this seed project to prevent public health risks associated with lead and microbial contamination of drinking water via the minimization of biofilm development and lead release from the water distribution system

Improving models of soil C stability by incorporating feedbacks between microbial C utilization, aggregate stability and agricultural management in response to simulated precipitation and drought

(Team: Sean Schaeffer, UTIA Biosystems Engineering and Soil Science; and Thanos Papanicolaou, Civil and Environmental Engineering)

The goal of this project is to collect preliminary data and provide a proof concept that feedbacks between microbial activity and soil moisture can affect the distribution of SOC on the landscape. Namely, we wish to set up experimental manipulations, under different agricultural management conditions, where we can impose dry-wet cycles and observe changes in microbial CUE, soil aggregation and erodibility.

We hypothesize that the coupled influences of changing tillage practices, and regional hydrology due to intensive agricultural management significantly modify soil aggregate structure evolution, landscape water holding capacity, and microbial CUE, as well as soil strength and erodibility. The interactions and feedbacks of these processes influence the turnover rates of SOC with potential significant implications on residence times, and storage and transport of organic matter across the landscape.

Instrumenting an outdoor laboratory at the UT Gardens constructed wetlands

(Team: Andrea Ludwig, UTIA Biosystems Engineering and Soil Science; Sue Hamilton, UTIA Plant Sciences; Chris Graves, UTIA Forestry, Wildlife & Fisheries)

The goal of this project is to provide real-time accessible data for use in university classrooms and multidisciplinary research on the function of constructed wetlands towards restoration of ecosystem services in the urban environment.

Other Activities

The Center for Sustainable Business and Development (CSBD)—CSBD is led by Dr. Rachel JC Chen. During 2016-2017, one undergraduate (majoring in accounting) and three graduate students (one from UT's MBA program and two from UT's Department of Civil and Environmental Engineering) were working on various projects under the direction of Dr. Chen. Two projects have been funded and are in progress:

- 25th Year Celebration: Economic Impacts of Tennessee Aquarium in Hamilton County and

Tennessee. Funded by Tennessee Aquarium, Tennessee ($13,299)

- Center for Sustainable Business and Tourism edu-cation, scholarship, and research efforts, $50,000 donation by Ruby Falls LLC., Chattanooga, Ten-nessee, in progress

In addition, Dr. Chen authored or co-authored four papers in referred journals (listed in "Publications," below), has submitted three additional articles that are still under review, has six extended abstracts published in conference proceedings, and was an invited speaker at the 2016 Tennessee Governor's Conference on Hospitality and Tourism in Chattanooga, Tennessee. Her topic was "You've got a friend in me! How Tennessee Welcome Centers can work for you."

Future Plans/Goals for CSBD:

- Engage interdisciplinary research and outreach—The current collaborators include: faculty members from the Tickle College of Engineering, Haslam College of Business, College of Education, Health, and Human Sciences, and UT Agriculture Extensions
- Promote and move beyond social/environmental responsibility and green activities—sustainable business and strategic development related projects have been one of the top focuses
- Engage sustainable development research and outreach collaborations on campus and among communities—*keep submitting proposals, obtaining external funding, and broadening collaborations across campus* (identified funding agencies include Appalachian Regional Commission, TN Department of Transportation [three full proposals to be submitted], TN Department of Tourist Development [one to be submitted], USDA [one working proposal], foundations [narrowing the identified ones], and NSF[RFP from Social, Behavioral, and Economic Sciences division]; *keep publishing refereed articles in SSCI*; and k*eep sustaining visibility for CSBD.*

Worker Health and Safety Training at Department of Energy (DOE) Facilities—In 2016-2017, Dr. Sheila Webster, Research Director and Rex Short, Senior Research Associate, facilitated training for approximately 1,500 DOE workers at Oak Ridge Operations, the Savannah River and the Portsmouth Sites. The training is funded by a grant from NIEHS and administered by the Partnership for Environmental Technology Education (PETE).

Training for workers included technicians, supervisors, and professionals who are required to complete 29CFR1910.120 certification or recertification, Radiation II, Practical Factors Training and various OSHA and EPA regulatory training courses.

An online course option, approved by the National Institute of Environmental Health and Sciences (NIEHS), was tailored to increase accessibility and maximize training options for increased worker health and safety training delivery.

We will evaluate and revise the course based on our scope of work in general, which includes online courses, classroom courses, and integrated courses with "hands on" activities. ISSE will collect and analyze data on student performance, course evaluation by students, and follow-up with students and employers to determine how HAZWOPER content was applied in the workplace.

The focus this year was to strengthen collaborative efforts with DOE facilities and to expand cooperation and training activities with educational institutions, small environmental businesses and community organizations. Because the online HAZWOPER was made available to a broader audience, the result was increased numbers of students and an increased awareness of HAZWOPER among employees and employers.

We assisted with planning and implementation of the yearly DOE Advisory Committee meeting in Portland, Maine in May 2017. Committee members from DOE facilities and educational institutions throughout the US were present. Representatives from NIEHS provided guidance on

2016-2017 Programmatic Report

goals and priorities. The University of Tennessee participated in a workshop conducted by Rutgers University in conjunction with Spring 2017 Awards meeting. The meeting explored use of technologies for HAZWOPER training along with other health and safety training. New technology in the environmental health and safety field was on display and demonstrated. UT joined educational institutions throughout the United States and US Territories.

Expanding the opportunity for training to colleges, environmental businesses, and community organizations is increasing the supply of workers eligible for employment. These workers will be prepared to improve health and safety culture through integrated safety awareness on DOE work sites.

China-US Joint Research Center for Ecosystem and Environmental Change (JRCEEC)—The China-US Joint Research Center for Ecosystem and Environmental Change (JRCEEC) was established in 2006 to enhance collaboration among Chinese and US scientists in environmental research and education. The center's partners include the University of Tennessee (UT), Oak Ridge National Laboratory (ORNL), Purdue University, the Chinese Academy of Sciences (CAS), and the University of Science and Technology of China (USTC). In 2011, the Center was accepted into the China-US EcoPartnership program, which was established by the US Department of State and the China National Development and Reform Commission.

The 2016 China-US Joint Annual Symposium was held October 26-29, 2016, in Yixin, Jiangsu Province, China. The theme of the workshop was "International Nexus of Food, Energy, Water, and Soil." This meeting marked the tenth anniversary of the China-US Joint Research Center (2006—Build and Explore—2016). The Keynote Speaker was Dr. Warren Washington, awarded the 2010 U.S. National Medal of Science.

ISSE continues to support the JRCEEC by supplying administrative support and support for its annual workshop through travel funds.

Awards

Faculty/Staff Awards

- Thanos Papanicolaou, Director of ISSE's Tennessee Water Resources Research Center, was named a Fellow of the American Society of Civil Engineers, a honor that is bestowed on only 1.2% of ASCE members.
- Bruce Tschantz, ISSE/TNWRRC Senior Research Fellow was recently honored in Philadelphia at the national ASDSO dam safety conference with a National Merit Award for his life-long contributions to dam safety. Bruce has led efforts to improve US dam safety since the 1970's, following the failure of the Teton Dam when he was asked by President Carter to coordinate development of federal dam safety guidelines.
- Jon Hathaway, ISSE/TNWRRC Researcher was interviewed by the Christian Science Monitor (December 2016) on urban storm runoff for their article "Cities enlist nature to tame rising flood risks."
- Jonathan Overly and ISSE's East Tennessee Clean Fuels were one of the recipients of the Governor's Environmental Stewardship Award. The award recognizes those whose efforts protect Tennessee's scenic beauty, promote environmental education, or improve the overall environment.
- Dr. Andrea Rocha (post-doc working with ISSE Director Terry Hazen) was selected from

21 outstanding women in East Tennessee to be the honoree in Technology, Research and Innovation at the 2016 YWCA Tribute to Women.

- ISSE's Jonathan Overly (Executive Director, ETCleanFuels) was one of UT's Center for Transportation Research (CTR) Faculty Fellows for 2016.

Student Awards

- Jian Sun, an ISSE graduate research assistant to Professor Joshua Fu, won best student paper at the 109th Annual Conference and Exhibition of the Air & Waste Management Association (AWMA) in New Orleans on June 20-23, 2016. Sun's paper was titled "Climate-driven exceedance of combined nitrogen and sulfur depositions at forested areas over continental U.S."
- Hannah Woo, CEE/ISSE Ph.D. student, just returned from her eight weeks in China for her NSF East Asia and Pacific Summer Institutes for US Graduate Students Award.

Goals/Future Plans

Goals/Future Plans

The Institute for a Secure and Sustainable Environment plans to continue funding seed grant proposals annually and to concentrate the funding awarded around the themes of natural and built systems sustainability with a focus on water and methane.

ISSE will also support a new initiative with UTIA to help develop a Research Coordination Network (RCN), designed to identify transdisciplinary research opportunities for scientists in the US and China focusing on the nexus of food, energy, and water systems (FEWS). This initiative, termed "Food-Energy-Water Systems Transdisciplinary Environmental Research Network (FEWSTERN)," will partner with three NSF-China awards to three teams of Chinese institutions, led by Nanjing University, South China University of Science and Technology, and Remin University of China, respectively, to develop research priorities transcending US and Chinese grand challenges.

Additionally, we will continue to work with the ISSE Advisory Committee to develop ISSE's strategic objectives.

Future plans for the centers housed by ISSE are below.

The primary goal of the **Tennessee Water Resources Research Center (TNWRRC)** is to assist the state of Tennessee and its entities in developing and implementing programs for sustaining high quality water, serving as a link between the academic community, federal and state government water-related organizations, the private sector, and local communities. The following are planned activities to help meet that goal:

- Continue to offer two statewide training and certification programs for the Tennessee Department of Environment and Conservation (TDEC) and develop new courses as the need arises;
- Focus on new initiatives, such as bank erosion, that relate to statewide issues of water quality and infrastructure;
- Focus on research themes pertinent to human decision making and water;
- Conduct workshops/webinars on a semi-annual basis to highlight best management practices for important water topics;
- Continue to work with the TNWRRC Advisory Board to fund USGS 104(b) research grants that meet the needs of state agencies

The **East Tennessee Clean Fuels Coalition's** future plans include:

- Implementation of a comprehensive Constituent Relationship Management (CRM) database to improve coalition operations and efficiency;
- Working to increase the overall total gasoline-gallon equivalents (GGEs) and reduce greenhouse gas (GHG) emissions across Tennessee over calendar year 2016 amounts;
- Hiring one or two UT students for internship opportunities during the academic year; and
- Supporting the State of Tennessee's distribution of its allocation of Volkswagen Environmental Mitigation Trust settlement fund, particularly advocating for funds to be allotted to AFV purchases and infrastructure for private and public fleets across the state.

The primary goal of the **Tennessee Methane Center** is to research sustainable methods to utilize methane for energy, water and agriculture in Tennessee, as Tennessee and the United States becomes a methane-based economy.

- Fund more students in this area to make sure Tennessee has the resources to be a major research and application center for Methane.
- Apply for major funding from NSF and DOE to further establish multidisplenary and multi-institutional research and training in Methane related technologies.
- Invite national and international methane experts to UTK to provide lectures and interactions with faculty and students.

Publications & Presentations

2016-2017 Publications & Presentations

ISSE Related Publications

Abban, B., A.N. Papanicolaou, M.K. Cowles, C.G. Wilson, O. Abaci, K. Wacha, K.E. Schilling, and D. Schnoebelen. 2016. An enhanced Bayesian fingerprinting framework for studying sediment source dynamics in intensively managed landscapes. *Water Resources Research* 52(6): 4646-4673 (doe: 10.1002/2015WR018030)

Bandeira, J., D. Carvalho, A. Khattak, N. Rouphail, P. Fernandes, T. Fontes, S. Pereira, & M. Coelho. 2015. Empirical assessment of route choice impact on emissions over different road types, traffic demands, and driving scenarios. *International Journal of Sustainable Transportation* (ID: 901447, doi:10.1080/15568318.2014.901447)

Chen, R.J.C. 2016. What can Rural Communities do to be Sustained? *Sustainability* 8(9): 930-941

Chen, R.J.C. and C. Barrows. 2015. Developing a Mystery Shopping Measure to Operate a Sustainable Restaurant Business: The Power of Integrating with Corporate Executive Members' Feedback. *Sustainability* 7(9): 12279-12294

Chen, R.J.C. 2015. From Sustainability to Customer loyalty: A Case of Full Service Hotels' Guests. *Journal of Retailing and Consumer Services* 22(1): 261-265

Chen, R.J.C. 2015. Beyond Sustainability: from Sustainable Consumer Services to Sustainable Business. *Journal of Retailing and Consumer Services* 22(1): 223-224

Chen, S., H. Cheng, K. N. Wyckoff, and Q. He. 2016. Linkages of Firmicutes and Bacteroidetes populations to methanogenic process performance. *J. Ind. Microbiol. Biotechnol* 43(6): 771-781 (doi: 10.1007/s10295-016-1760-8)

Dian, Ding, Yun Zhu, Carey Jang, Che-Jen Lin, Shuxiao Wang, Joshua S. Fu, Jian Gao, Shuang Deng, Junping Xie, Xuezhen Qiu. 2016. Evaluation of Health Benefit Using BenMAP-CE with an integrated scheme of Model and Monitor Data during Guangzhou Asian Games. *Journal of Environmental Sciences* 42: 9-18. (doi:10.1016/j.jes.2015.06.003)

Dong, X, J. S. Fu, K. Huang, D. Tong, G. Zhuang. 2016. Model development of dust emission and heterogeneous chemistry within the Community Multiscale Air Quality modeling system and it's application over East Asia. *Atmospheric Chemistry and Physics* 16: 8157–8180 (doi:10.5194/acp-16-8157-2016)

Dong, X. and J. S. Fu. 2015. Understanding biomass burning from Peninsular Southeast Asia, part I: model evaluation and analysis of systematic errors. *Atmospheric Environment* 116: 293-307. (doi:10.1016/j.atmosenv.2015.06.026)

Dong, X. and J. S. Fu. 2015. Understanding interannual variations of biomass burning from Peninsular Southeast Asia, part II: variability and different influences in lower and higher atmosphere levels. *Atmospheric Environment* 115: 9-18 (http://dx.doi.org/10.1016/j.atmosenv.2015.05.052)

Elhakeem, M., A.N. Papanicolaou, and C.G. Wilson. 2017. Implementing streambank erosion control measures in meandering streams: Design procedure enhanced with numerical modeling. *International Journal of River Basin Management* (doe: 10.1080/15715124.2017.1315816)

Elhakeem, M., A.N. Papanicolaou, and A.G. Tsakiris. 2016. A probabilistic model for sediment entrainment: The role of bed irregularity. I*nternational Journal of Sediment Research* 32(2): 137-148 (DOI:10.1016/j.ijsrc.2016.11.001)

Ellis, K. N., J. M. Hathaway, L. R. Mason, D. Howe, T. Epps, and V. M. Brown. 2015. Summer temperature variability across four urban neighborhoods in Knoxville, Tennessee, USA. *Theoretical and Applied Climatology (DOI:* 10.1007/s00704-015-1659-8)

Greene D., A. Khattak, J. Liu, X. Wang, J. Hopson, R. Goeltz. 2016. What is the Evidence Concerning the Gap between On-Road and Environmental Protection Agency Fuel Economy Ratings. Submitted for review: *Transport Policy*

Greene, D.L. and C.Z. Liu. 2015 (June 10). U.S. Oil Dependence 2014: Is Energy Independence in Sight? *Energy Policy* 85:126-137 (published on

2016-2017 Publications & Presentations

line at http://www.sciencedirect.com/science/article/pii/S0301421515002104)

Hass, A. L., K. N. Ellis, L. R. Mason, J. M. Hathaway and D. A. Howe. 2016. Heat and humidity in the city: Neighborhood heat index variability in a mid-sized city in the United States. *International Journal of Environmental Research and Public Health* 13: 117, (DOI: 10.3390/ijerph13010117)

Hazen, T. C. and G. S. Sayler. 2016. Environmental Systems Microbiology of Contaminated Environments, p 5.1.6-1-5.1.6-10. In Yates M, Nakatsu C, Miller R, Pillai S (ed), *Manual of Environmental Microbiology*, 4th Edition. ASM Press, Washington, DC. (doi: 10.1128/9781555818821.ch5.1.6)

Hazen, T. C., R. C. Prince, and N. Mahmoudi. 2016. Marine Oil Bioremediation. Feature Article. *Environ. Sci. Technol.* (doi: 10.1021/acs.est.5b03333)

Hernandez-Murcia, O.E., D.J. Schnoebelen, A.N. Papanicolaou, and B.K.B. Abban. 2017. Coupling flow with nutrient dynamics via BioChemFOAM in the Mississippi River. *Journal of Applied Water Engineering and Research* Feb 21:1-23.

Huang, K. J. S. Fu, V.Y. Prikhodko, J. M. Storey, A. Romanov, E. L. Hodson, J. Cresko, I. Morozova, Y. Ignatieva. 2015. Russian anthropogenic black carbon: Emission reconstruction and Arctic black carbon simulation. *Journal of Geophysical Research – Atmospheres* 120 (21): 11306-11333 (doi: 10.1002/2015JD023358)

Keel-Blackmon, Kristy, Scott Curran, and Melissa Lapsa. June 2016. Summary of OEM Idling Recommendations from Vehicle Owner's Manuals. Oak Ridge National Laboratory, ORNL/TM -2016/ 50.

Khatri, R., C. Cherry, S. Nambisan, L. Han. 2016.) Modeling route choice of bikeshare users with GPS data. T*ransportation Research Record: Journal of the Transportation Research Board* 2587 (doi: 10.3141/2587-17)

Liu C. and D.L. Greene. 2015. Consumer Choice of E85: Price Sensitivity and Cost of Limited Fuel Availability. *Journal of the Transportation Research Board* 2454: 20-27

Liu J., X. Wang, & A. Khattak. 2016. Customizing driving cycles to support vehicle purchase and use decisions: Fuel economy estimation for alternative fuel vehicle users. *Transportation Research* (Part C) 67: 280–298

Liu J., A. Khattak, X. Wang. 2016. The role of alternative fuel vehicles: Using behavioral and sensor data to model hierarchies in travel. *Transportation Research* (Part C) 55: 379-392

Liu, Y., T. Stoesser, H. Fang, A.N. Papanicolaou, and A.G. Tsakiris. 2017. Turbulent flow over an array of boulders placed on a rough permeable bed. *Computers & Fluids (*DOI: 10.1016/j.compfluid.2017.05.023)

Mason, L. R., K. N. Ellis, and J. M. Hathaway, 2016. Experiences of urban environmental conditions in socially and economically diverse neighborhoods. *Journal of Community Practice,* in press.

Minoura, H., J. C. Chow, J. G. Watson, J. S. Fu, X. Dong, and C-E Yang. 2016. Vertical circulation of atmospheric pollutants near mountains during a southern California ozone episode. *Aerosol and Air Quality Research* (doi:10.4209/aaqr.2015.09.0554)

Nie, Q., W. Hu, T. Ai, B. Huang, X. Shu, and Q. He. 2016. Strength properties of geopolymers derived from original and desulfurized red mud cured at ambient temperature. *Constr. Build. Mater.* 125: 905-911. (doi: 10.1016/j.conbuildmat.2016.08.144)

Papanicolaou, A. N. (T), K. M. Wacha, B. K. Abban, C. G. Wilson, J. L. Hatfield, C. O. Stanier, and T. R. Filley. 2015. From soilscapes to landscapes: A landscape-oriented approach to simulate soil organic carbon dynamics in intensively managed landscapes. *Journal of Geophysical Research Biogeosciences* 120: 2375–2401 (doi:10.1002/2015JG003078)

Papanicolaou, A.N. 2017. Following the Water Drop: 60 Years of the Journal of Hydraulic Engineering. *Journal of Hydraulic Engineer-*

2016-20176 Publicatons & Presentations

ing 143(5) (DOI.org/10.1061/(ASCE)HY.1943-7900.0001285)

Papanicolaou, A.N., and A.G. Tsakiris. 2017. Chapter 2: Boulder effects on turbulence and bedload transport. In: D. Tsutusmi and J.B. Laronne. *Gravel-Bed Rivers: Process and Disasters*. Wiley-Blackwell. pp. 33-71

Papanicolaou, A.N., C.G. Wilson, A.G. Tsakiris, T. Sutarto, F. Bertrand, M. Rinaldi, S. Dey, and E. Langendoen. 2017. Understanding mass fluvial erosion along a bank profile: using PEEP technology for quantifying retreat lengths and identifying event timing. *Earth Surface Processes and Landforms (*DOI: 10.1002/esp.4138)

Papanicolaou, A.N., and B.K.B. Abban. 2016. Chapter 65: Channel Erosion and Sediment Transport. In Chow, V.T. (ed.). H*andbook of Applied Hydrology*. McGraw-Hill.

Paradis, C.J., S. Jagadamma, D. B. Watson, L. D. McKay, T. C. Hazen, M. Park, and J. D. Istok. 2016. In situ mobility of uranium in the presence of nitrate following sulfate-reducing conditions. *J. Cont. Hydro.* (doi 10.1016/j.jconhyd.2016.02.002)

Parker, J. and U. Kim. 2015. An upscaled approach for transport in media with extended tailing due to back-diffusion using analytical and numerical solutions of the advection dispersion equation. *Journal of Contaminant Hydrology* 182: 157-172

Poisson, D.K. and R. J. C. Chen. 2017. Operating Sustainable Meal Plans and Food Places: Factors Influencing College Students' Dining Choices and Preferences. *Journal of Hospitality and Tourism* 15(1): 19-30

Qiu, X., Y. Zhu, C. Jang, C.-J. Lin, S.X. Wang, J. S. Fu, J. Xie, J. Wang, D. Ding, S. Long. 2015. Development of an integrated policy making tool for assessing air quality and human health benefits of air pollution control. *Front. Environ. Sci. Eng.* 9 (Issue 6): 1056-1065 (doi: 10.1007/s11783-015-0796-8)

Rocha, AM, Q. Yuan, D. Close, K. B. O'Dell, J. Fortney, J. Wu, and T. C. Hazen. 2016. Rapid Detection of Microbial Cell Abundance in Aquatic Systems. *Biosensors & Bioelectronics* 85:915-923 (http://dx.doi.org/10.1016/j.bios.2016.05.098)

Sarkar, S., A.N. Papanicolaou, and S. Dey. 2016. Turbulence in gravel-bed stream with an array of large gravel obstacles. *Journal of Hydraulic Engineering* (DOI: 10.1061/(ASCE)HY.1943-7900.0001191, 04016052)

Shi, Y., N. Yu, and R.J.C. Chen 2015. After 2008 Olympic Games: From a Glorious Mega-event to a Sustainable Destination Brand. *Journal of Hospitality and Tourism* 13(1): 48-57

Sun, J., J. S. Fu, K. Huang. 2016. Organic nitrates and other oxidized nitrogen compounds contribute significantly to the total nitrogen depositions in the United States. Proceedings of National Academy of Sciences 113(31): E4433–E4434 (doi: 10.1073/pnas.1608717113)

Uchida, T., S. Fukuoka, A.N. Papanicolaou, and A.G. Tsakiris. 2016. Non-hydrostatic, quasi 3D model coupled with dynamic rough wall law for simulating flow over rough bed with submerged boulders. *Journal of Hydraulic Engineering* (DOI: 10.1061/(ASCE)HY.1943-7900.0001198, 04016054)

Upreti, G., D.L. Greene, K.G. Duleep and R. Sawhney. 2016 (January 21). Impacts of the American Recovery and Reinvestment Act and the Investment Tax Credity on the North American non-automotive PEM fuel cell industry. I*nternational Journal of Hydrogen Energy* (published online at http://www.sciencedirect.com/science/article/pii/S0360319915313458

Wang, J., S. X. Wang, S. A. Voorhees, B. Zhao, C. Jang, J. Jiang, J. S. Fu, D. Dian, Y. Zhu, J. M. Hao. 2015. Assessment of short-term PM2.5-related mortality due to different emission sources in the Yangtze River Delta, China. *Atmospheric Environment* 123 (Part B): 440-448 (doi: 10.1016/j.atmosenv.2015.05.060)

Wang, Q., G. Zhuang, K. Huang, T. Liu, C. Deng, J. Xu, Z. Guo, Y. Chen, Q. Fu, J. S. Fu, J. Chen. 2015. Probing the severe haze pollution in three typical regions of China: characteristics,

2016-2017 Publications & Presentations

sources and regional impacts. *Atmospheric Environment* 120: 76-88 (doi:10.1016/j.atmosenv.2015.08.076)

Wang X, A. Khattak, J. Liu, G. Masghati-Amoli, and S. Son. 2015. What is the Level of Volatility in Instantaneous Driving Decisions? *Transportation Research* (Part C:) (DOI: 10.1016/j.trc.2014.12.014)

Wilson, C.G., K.M. Wacha, A.N. Papanicolaou, H.A. Sander, V.B. Freudenberg, B.K.B. Abban, and C. Zhao. 2016. Assessing sustainability of current management practices in an intensively managed landscape. *Journal of Contemporary Water Research & Education* 158: 148-171

Wu, L., Y. Yang, S. Chen, M. Zhao, Z. Zhu, S. Yang, Y. Qu, Q. Ma, Z. He, J. Zhou, and Q. He. 2016. Long-term successional dynamics of microbial association networks in anaerobic digestion processes. *Water Res.* 104: 1-10 (doi: 10.1016/j.watres.2016.07.072)

Xu T, *Marr E*, Sayler G, Ripp S. Monitoring endocrine disrupting contaminants using high-throughput bioluminescent yeast assays. *Methods in Molecular Biology*, in press.

Yoon, D.H. and R.J.C. Chen. 2016. A Green Shadow: the Influence of Hotel Customers' Environmental Concern, Knowledge, and Education Level on Green Marketing Skepticism and Behavioral Intentions. *Tourism Analysis* (in press)

Yu, N. and R.J.C. Chen. 2016. Hotel Guests' Preferences and Choices: Baby Boomer, X, and Y Generations. *Journal of Hospitality and Tourism* (in press)

Zhou, Q., C.T. Driscoll, S.E. Moore, M.A. Kulp, J.R. Renfro, J.S. Schwartz, M. Cai., and J.A. Lynch. 2015. Developing critical loads of nitrate and sulfate deposition in the Great Smoky Mountains National Park, United States. *Water, Air, and Soil Pollution* 226:255 (doi: 10.1007/s11270-015-2502-7.)

ISSE-Related Presentations

Brewer, S. S., M. F. Campa, A. Garcia de Matos Amaral, S. M. Techtmann, K. Fitzgerald, J. L. Fortney, and T. C. Hazen. Contributed. Isolation and Characterization of Anaerobic Microbial Communities from Hydraulic Fracturing Fluids. June 16, 2016, Boston, MA. ASM Microbe Annual Meeting

Brewer, S. S., M. F. Campa, A. Garcia de Matos Amaral, S. M. Techtmann, K. Fitzgerald, J. L. Fortney, and T. C. Hazen. Contributed. Isolation and Characterization of Anaerobic Microbial Communities from Hydraulic Fracturing Fluids. April 13-14, 2016, Knoxville, TN. University of Tennessee Exhibition of Undergraduate Research and Creative Achievement (EUReCA).

Brewer, S. S., M. F. Campa, A. Garcia de Matos Amaral, S. M. Techtmann, K. Fitzgerald, J. L. Fortney, and T. C. Hazen. Contributed. Isolation and Characterization of Anaerobic Microbial Communities from Hydraulic Fracturing Fluids. April 7, 2016, Asheville, NC. National Council Undergraduate Research Annual Meeting

Brewer, S. S., M. F. Campa, A. Garcia de Matos Amaral, S. M. Techtmann, K. Fitzgerald, J. L. Fortney, and T. C. Hazen. ontributed. Isolation and Characterization of Anaerobic Microbial Communities from Hydraulic Fracturing Fluids. March 12, 2016, Knoxville, TN. 3rd Annual Southeastern Biogeochemistry Symposium

Buchanan, J.R., B.N.Perez, and J.M.DeBruyn. 2015. Engineered Strategy to Remediate Trace Organic Contaminants using Recirculating Packed-Bed Media Biofilters at Decentralized Wastewater Treatment Systems. WEFTEC, Chicago, IL, September 26-30.2015

Burchett J, Xu T, Sayler G, Ripp S. 2016. Evaluating the cytotoxic effects of cellulose nanocrystals (CNCs) using autobioluminescent yeast and human cells. Society of Toxicology Annual Meeting, New Orleans, LA.

Campa, M. F., S. Techtmann, M. L. Patterson, A. Garcia de Matos Amaral, R. Lamendella, C. Grant, and T. C. Hazen. Contributed. Environmental microbial community tolerance and adaptation to biocides use in hydraulic fracturing operations. June 16, 2016, Boston, MA. ASM Microbe Annual Meeting

2016-2017 Publications & Presentations

Campa, M. F., S. Techtmann, M. L. Patterson, A. Garcia de Matos Amaral, R. Lamendella, C. Grant, and T. C. Hazen. ontributed. Evironmental microbial community tolerance and adaptation to biocides use in hydraulic fracturing operations. arch 15, 2016, San Diego, CA. ACS Annual Meeting

Campa, M. F., S. Techtmann, M. L. Patterson, A. Garcia de Matos Amaral, R. Lamendella, C. Grant, and T. C. Hazen. Contributed. Environmental microbial community tolerance and adaptation to biocides use in hydraulic fracturing operations. October 22-24, 2015, Lafayette, IN. Critical Zone Science, Sustainability, and Services in a Changing World. Purdue University

Chen, C., G. Pan, W. Shi, F. Xu, S. M. Techtmann, S. M. Pfiffner, and T. C. Hazen. Contributed. How does clay flocculation of harmful algal blooms affect microbial community composition in water and sediment. October 22-24, 2015, Lafayette, IN. Critical Zone Science, Sustainability, and Services in a Changing World. Purdue University

Chen, R.J.C. 2016. You've got a friend in me! How Tennessee Welcome Centers can work for you. 2016 Tennessee Governors's Conference on Hospitality and Tourism, Chattanooga, Tennessee

Chen, R.J.C., G. H. Parsa, M. Singal, and A. Sharma. 2016. Concurrent Research Topics, Methodologies, and Trends. International Council on Hotel, Restaurant and Institutional Education Proceedings, Dallas, Texas, July 20-22.

Chen, R.J.C., J. Katz, and F. Mayo. 2016. Concurrent Teaching Topics, Tips, and Trends. International Council on Hotel, Restaurant and Institutional Education Proceedings, Dallas, Texas, July 20-22.

Christian, L.E., J.M. Hathaway, and T.H. Epps. 2016. Exploring the Influence of Urban Watershed Characteristics and Antecedent Climate on In-stream Pollutant Dynamics. In Proceedings of the 16th Annual Meeting of the American Ecological Engineering Society, Knoxville, TN, June 7-9, 2016.

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

Epps, T.H., J.M. Hathaway. 2016. Runoff Uncertainty Related to Fine-Scale Spatial Variability in Urban Watersheds. In Proceedings of the 25th Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN, pp.1B-3

Epps, T.H., J.M. Hathaway. 2016. Refining Urban Hydrologic Models: Incorporating the Spatial Variability of Rainfall, Vegetation, and Soil Infiltration. In Proceedings of the World Environment and Water Resources Congress, West Palm Beach, FL.

Fu, J. & R.J.C. Chen. 2017. The Impacts of Wildfires on Air Quality and Communities. The 24th Recent Advances in Retailing & Services Science Conference, European Institute of Retailing and Services Studies (EIRASS) Proceedings, Canada, June 26-29.

Gonzalez, A., and J.S. Schwartz. 2016. Biogeochemical processes occurring in forested mountain catchments deduced from chemical and sulfur isotopic composition of drainage water. 7th SETAC World Congress/SETAC North America 37th Annual Meeting. Session title: Environmental Chemistry Perspectives from Around the Globe. Orlando, Florida. November 7-10, 2016.

Han, L., Zhang, Z. & R.J.C. Chen. 2017. A Comparative Analysis: Geographical Information System (GIS) Applications and Data Management in Transportation. The 24th Recent Advances in Retailing & Services Science Conference, European Institute of Retailing and Services Studies (EIRASS) Proceedings, Canada, June 26-29.

Harik, A-M. and T. C. Hazen. Contributed. Methanotrophically Mediated Bioaggregation to Control Sand Dust. June 16, 2016, Boston, MA. ASM Microbe Annual Meeting

2016-2017 Publications & Presentations

Hazen, T. C. Invited. Paradigm change? Predicting water geochemistry from microbial community structure. June 8, 2016, Knoxville, TN. American Ecological Engineering Society Annual Meeting

Hazen, T. C. Invited. Microbial Community Structure Predicts Groundwater and Marine Geochemistry. March 16, 2016, Houghton, MI. Department of Biological Sciences, Michigan Technological University

Hazen, T. C. Invited Seminar. Deepwater Horizon Oil Spill. February 19, 2016, Managua, Nicaragua. Seminar to 12th grade science classes at Lincoln International Academy

Hazen, T. C., Smith, M. B., Rocha, A. M., Smillie, C. S., Olesen, S. W., Paradis, C., Wu, L., Campbell, J. H., Fortney, J. L., Mehlhorn, T. L., Lowe, K. A., Earles, J. E., Phillips, J., Techtmann, S. M., Joyner, D. C., Elias, D. A., Bailey, K. L., Hurt, R. A., Preheim, S. P., Sanders, M. C., Yang, J., Mueller, M. A., Brooks, S., Watson, D. B., Zhang, P., He, Z., Dubinsky, E. A., Adams, P. D., Arkin, A. P., Fields, M. W., Zhou, J., and Alm, E. J. Keynote. Microbial Community Structure Predicts Groundwater Geochemistry. October 22-24, 2015, Lafayette, IN. Critical Zone Science, Sustainability, and Services in a Changing World. Purdue University

Hazen, T. C. Plenary. Phenotypic and Genomic Heterogeneity among Colwellia psychrerythraea Strains from Distant Deep-Sea Basins. September 11, 2015, Florence, Italy. 3rd Conference of Phenotype MicroArrays, University of Florence

Hazen, T. C. International Scientific Advisory. 3rd Conference of Phenotype MicroArrays. September 10-12, 2015, Florence, Italy, University of Florence.

Hazen, T. C. Section Chair. Genotype/Phenotype 3rd Conference of Phenotype MicroArrays. September 11, 2015, Florence, Italy, University of Florence.

Hazen, T. C. Invited Seminar. Deepwater Horizon Oil Spill: Do Microbial Communities at other Deep Water Drilling Sites around the World Respond the Same? July 16, 2015, Nanjing, China. Nanjing University.

Hazen, T. C. Invited Seminar. Methane: the Good, the Bad and the Ugly. July 15, 2015, Shenyang, China. China Agriculture Institute.

Hazen, T. C. Invited Seminar. Methane: the Good, the Bad and the Ugly. July 13, 2015, Beijing, China. China Agriculture Institute.

Hazen, T. C. Plenary. Deepwater Horizon Oil Spill: Do Microbial Communities at other Deep Water Drilling Sites around the World Respond the Same? July 1, 2015, Chania, Crete, Greece. European Bioremediation Conference VI

Kim, U., J.C. Parker, and R.C. Borden. 2015. Cost and Performance Assessment of In-situ Chemical Oxidation for Intermittent and Continuous Oxidant Injection. 2015 American Geophysical Union Fall Meeting

Liu, J., J. L. Fortney, S. M. Techtmann, D. C. Joyner, and T. C. Hazen. Contributed. Microbial Community changes and Crude Oil Biodegradation and Microbial Community Changes in Deep Oceans. October 22-24, 2015, Lafayette, IN. Critical Zone Science, Sustainability, and Services in a Changing World. Purdue University

Papanicolaou, A.N., K. Basnet, B. Abban, C. Giannopoulos, J. Schwartz, J. Hathaway, S. Hawkins, and C.G. Wilson. 2016. Assessing water availability in the Hiwassee River basin using a hydrologic budget. 2016 Tennessee Water Resources Symposium, Burns, TN, April 11-16, 2016

Pelle, A., A.N. Papanicolaou, B. Abban, C. Giannopolous, and C.G. Wilson. 2016. Investigating Non-stationarity in the Obion Watershed. 16th Annual Meeting of the American Ecological Engineering Society, Knoxville, TN, June 7-9, 2016

Perez, Brittani, 2015.Removal of Trace Organic Compounds in Domestic Wastewater using Recirculating Packed-Bed Media Filters. MS Dissertation, Department of Biosystems Engineering and Soil Science, College of Agriculture and Natural Resources, the University of Tennessee, Knoxville, TN. pp.137

2016-2017 Publications & Presentations

Ripp S, Xu T, Close D, Sayler G. 2016. The toolbox of bioreporter and biosensor technologies - from environmental monitoring to the protection of human health, China-US Joint Workshop on Environmental Remediation and Watershed Restoration, Changchun, China.

Schwartz, J., R. Woockman, and C. Clark. 2016. World Environmental & Water Resources Congress. "Urban Stream Restoration Planning: Towards Cost-Effective Mitigation of the Effects of Hydromodification," West Palm Beach, Florida

Schwartz, J.S., and P.V. Simmons. 2016. Spatial analysis of streambank structural heterogeneity and its contribution to bank stability in eastern Tennessee. ASCE/ EWRI World Water & Environmental Resources Congress; West Palm Beach; May23-26, 2016

Seiden, Z.T, and J.S. Schwartz. 2015. Characteristics of fine sediment transport along hillslope concentrated flow pathways caused by cattle traffic. ASCE/EWRI Watershed Management Symposium; Reston, Virginia; August 5-7, 2015

Shi, Y., N. Yu, S. Ha, and R.J.C. Chen. 2016. The Effectiveness of Using Sina Weibo in China by Five Top Origin Counties' DMOs: A Qualitative Approach. International Council on Hotel, Restaurant and Institutional Education Proceedings, Dallas, Texas, July 20-22.

Veeneman, A. J.S. Schwartz, and M.A. Kulp. 2016. Throughfall chemistry study in the Great Smoky Mountains National Park. TN AWRA 25thTennessee Water Resources Symposium, Burns, Tennessee; April 2016.

Walker, F.R., C.D. Clark, J. DeBruyn, M. Essington, S. Hawkins, D.M. Lambert, A. Layton, A Ludwig, J.S. Schwartz, and L. Reynolds. 2015. Watershed scale project in Oostanaula Creek, East Tennessee. USDA NIFA Soil Water Conference, Greensboro, NC. July 27-29, 2015.

Woo, H. L. and T. C. Hazen. Contributed. Using high throughput sequencing methods to identify keystone bacterial species in recalcitrant terrestrial organic matter transformation. October 22-24, 2015, Lafayette, IN. Critical Zone Science, Sustainability, and Services in a Changing World. Purdue University

Woockman, R., and J. Schwartz. 2015. ASCE/ EWRI Watershed Management Symposium. "Excess stream power management in small urban stream systems of the ridge and Valley province in Tennessee, "Reston, Virginia

Woockman, R., and J. Schwartz. 2016. 25th Tennessee Water Resources Symposium. "Reach Scale Sediment Source Potential in Small Urbanizing Stream Systems," Burns, Tennessee.

Woockman, R., and J. Schwartz. 2016. American Ecological Engineering Society. "Channel Protection: Surplus Stream Power, Channel Erosive Resistance Elements, and Sediment Source Potential," Knoxville, Tennessee.

Xu T, Marr E, Sayler G, Ripp S. Monitoring endocrine disrupting contaminants using high-throughput bioluminescent yeast assays. *Methods in Molecular Biology*, in press.

Yoon, D.H. Y. Kim and R.J.C. Chen. 2016. Green Hotels and Implementations. Asia Pacific Council on Hotel, Restaurant and Institutional Education Proceedings, Bangkok, Thailand, May 11-13.

Contacts

Dr. Terry Hazen, ISSE Director
311 Conference Center Building
Knoxville, TN 37996-4138
Office: 865-974-1843
Office: 865-974-7709
Email: tchazen@utk.edu

Ms. Tina McConnell, ISSE Business Manager
311 Conference Center Building
Knoxville, TN 37996-4138
Office: 865-974-3866
Email: tmcconne@utk.edu

Sherry Redus, ISSE Program Manager
311 Conference Center Building
Knoxville, TN 37996-4138
Office: 865-974-0721
Email: sredus@utk.edu