2022 UCOWR/NIWR Annual Water Resources Conference
Greenville, SC, June 14-16, 2022
Book of Abstracts

Sustainability of Water Resources in the Southern High Plains: A Case Study of the Dockum Aquifer

Donna McCallister, Texas Tech University (N. Howell)

As water resources from the Ogallala Aquifer continue to decline, alternative sources of water resources should be considered to extend the life of irrigated agriculture in the Southern High Plains. The Dockum Aquifer may be a suitable water source for irrigation supplementation; however, the cost to pump from the Dockum may not be economically profitable due to deep pumping depths, poor water quality, and low well yields. An economic analysis will be performed to determine the costs associated with supplemental pumping from the Dockum. The costs of development and pumping from the Dockum will be estimated and an optimization model will be used to estimate the impact of irrigation from the Dockum on water availability, crop mix, crop yields and producer net returns over time.

A Spatiotemporal Economic Analysis of Crop Production in the Texas High Plains

Lal Almas, West Texas A&M University (A. Naher, B. Guerrero, S. Shaheen)

The Texas High Plains is one of the most prolific crop-producing areas in the United States. Due to extreme weather conditions and climate change, crop production in the region is facing a severe threat due to declining irrigation water availability from the Ogallala Aquifer. A survey of the literature shows that few studies have investigated the cropping pattern for a specific crop production for this region. The main objective of this research is to visualize the historical change of cropping patterns in the Texas High Plains from the standpoint of geographical concentration and spatial autocorrelation. Historical county-level agricultural census data source include National Agricultural Statistical Services (NASS) from 1978 to 2017. Exploratory data analysis (EDA) techniques were applied to examine the geographical concentration and the spatial dependence of crop production among nearby locations. Results of temporal changes indicate that harvested acres and the number of farms trend downward through the study period. To show temporal changes in cropland acres maps were developed. The Gini coefficient and the quantiles of size were also computed to analyze the change in geographical distribution. Irrigated harvested cropland acres were concentrated in a smaller number of counties that indicates change in geographical concentration in the Texas High Plains. Both total and irrigated harvested corn, cotton, sorghum grain, and wheat acreages were concentrated in a smaller number of counties over time while wheat production was mostly concentrated in the northern part of the region. The percentage of acres of irrigated relative to total harvested cropland acreage has decreased over time. The Moran's I test statistics suggest that there was spatial dependence among the neighboring counties in the production of crops in this region. In summary, there was a spatiotemporal change in cropping patterns in the Texas High Plains over the study period.

Producer-initiated Groundwater Conservation in Northwest Kansas

Bridget Guerrero, West Texas A&M University (B. Golden)

Groundwater consumption rates in northwest Kansas have raised concerns about the long-term feasibility of irrigated agriculture in the area. The amount of water pumped from the Ogallala Aquifer will need to be reduced in order to extend the economic life of the aquifer and maintain the economic base of the region, which is largely agricultural. Monitoring the Sheridan #6 Local Enhanced Management Area (LEMA) in real time has allowed the observation of producer innovation aimed at maintaining revenues while facing water restrictions. The LEMA initially began in December of 2012 and has since been extended and expanded, increasing the overall effects of the producer-driven policy over time. Results indicate that during the study period, irrigated crop producers within the boundary of the LEMA relative to outside the boundary reduced total groundwater use by 24.9%, average groundwater use per acre by 17.0%, irrigated crop acreage by 11.8%, irrigated corn acreage by 25.2% (which later returned to normal), and increased irrigated grain sorghum acreage by 338.4%. Additionally, they reduced water use on corn and soybeans by 17.8% and 19.3%, respectively. Overall, the LEMA was found to be successful in reducing groundwater use and helping the aquifer approach sustainability. The producer-supplied economic data implies that cash flow has not suffered, and importantly, the producers are satisfied with the economic consequences, as they have maintained their water use reductions even when given the option to ease them. The experiences of producers within the Sheridan #6 LEMA have provided the motivation and confidence necessary to expand the LEMA concept to all of GMD#4. The knowledge of how irrigated crop producers reacted to conservation policies in this case scenario can be helpful to producers, stakeholders, and researchers in other areas faced with diminishing supplies who are considering implementing conservation measures.

Updating the Historical Records of the Carrizo-Wilcox Aquifer Groundwater Availability Model for Improved Model Predictions

Michael Ramos, Texas A&M University - Kingsville (J. Saenz, J. Amaya, M. Alexander)

The Winter Garden region of the Carrizo-Wilcox aquifer is historically known for its agricultural production of irrigated winter vegetable crops in southwest Texas. The groundwater supplies of the Carrizo-Wilcox aquifer are monitored by the Texas Water Development Board (TWDB) through direct measurements of water wells or predictions generated by their groundwater availability model (GAM). Over the last 20 years, well records from TWDB indicate consistent water level decline while the GAM generates overly optimistic predictions for water levels after the year 2000, denoted as the start of the predictive period of the model, contrary to the measured well water levels. As the GAM is based on historic pumping and precipitation data from 1975 to 1999, denoted as the historical period of the model, it is evident the GAM is significantly outdated for the prediction of today's groundwater levels. In this study, the inputs of the groundwater availability model, such as well pumpage and water levels, were extracted for comparison between model predictions and current TWDB well records to highlight changes required to prepare an update for the current model. An updated historical period was formulated using TWDB well pumpage and water level data from 1975 to 2018 for the possibility of improved model predictions. This study highlights the data formulation and analysis procedures used to generate the updated historical period.

Methodology for Sustainable River Mining in Alluvial Rivers: A Case Study using Puerto Rico Guidelines

Walter Silva-Araya, University of Puerto Rico at Mayaguez

The Puerto Rico Department of Natural Resources adopted new guidelines for the preparation of sediment transport studies for the extraction of riverbed material. The document aims at minimizing the environmental impact and increasing the sustainability of river resources while allowing the use of alluvial materials for construction. To this abstract, a river mining operation is considered sustainable if, the affected reach approaches its natural condition with materials from the river and its watershed in a reasonable time after the dredging operation ended. Dredging must be done at a rate not exceeding the threshold beyond which the replacement of materials will not be possible. This presentation describes the application of the Puerto Rico guidelines to a reach of Rio Majada in the municipality of Salinas, Puerto Rico. The methodology includes:

1) A geomorphological and vertical stability analysis of the bed to determine if the formation of an armor layer is possible and to compare the present riverbed slope with the equilibrium slope.
2) A monthly sediment volume analysis under the quasi-equilibrium assumption to examine if the river supplies recoverable material.
3) A sediment transport model with the simulation of dredging scenarios using daily flows from USGS gaging stations, Yang's sediment transport function, and different scenarios of mass removal based on weekly dredging operations.

The study computed the amount of dredged material under different scenarios, riverbed changes in elevation during several years, including two years of weekly dredging, and recommendations about where and how to proceed with the extraction operation to obtain a significant recovery of the river characteristics after the cease of operations. Decision-makers used this methodology to approve a sustainable river mining operation.

Water Reuse System Design by Reusing Existing Pipeline: An Analysis with WaterCAD Model
Hafiz Ahmad, Florida State University - Panama City (J.W. Miller, R.D. George)

This study presents a hydraulic model developed for the hydraulic analysis and design of a water reuse system using WaterCAD program. The new design uses/modifies an existing system, which pumped secondary treated effluent from the wastewater treatment plant through a 4000 ft 12-inch transmission line to a “constructed wetland” system. The tertiary treated water was then re-pumped more than 5 miles through another 12-inch transmission line to a natural (jurisdictional) wetland. The new design involves conveying the treated effluent from the same treatment plant to a new pump-station (and wet weather storage pond), bypassing the constructed wetlands. The secondary treated water is then pumped from the new pump-station to a local nursery using the existing (12-inch 5-miles long) transmission line for reuse as irrigation. The main design challenge was to evaluate the hydraulics of the transmission system, the effect of the new pump-station location, and select new pumps that would convey the reclaimed water more than 5 miles to the new destination with adequate pressure and flow rate. To address the challenge, first, a hydraulic model is developed for the existing system. Then this model (of the existing system) was used for calibration of the model developed for the new design. The results of the hydraulic model for the new design confirmed that new pumps and piping system will work and convey the reclaimed water to the nursery with adequate flow and pressure.

Modular Convection-Enhanced Evaporation (CEE) System for Brine Management

Mustafa Kaddoura, University of Minnesota, Twin Cities (N. Wright)

Brine is a byproduct of desalination plants and several industrial processes which can have an adverse impact on the environment if not properly managed. Conventional brine concentrating technologies are limited by high energy consumption and cost. This study proposes a novel convection-enhanced evaporation (CEE) system as a modular, cost-effective brine management and on-site treatment device for decentralized desalination and industries. CEE is comprised of a set of horizontally packed evaporation surfaces at uniform vertical spacing. Liquid (brine) is uniformly released along the width of each evaporation surface forming a thin film. A fan fixed at the opposite side of the liquid injection acts as a driving force for air flow. As air flows over the liquid film, the difference in vapor pressure between the air and liquid surfaces induces evaporation. We present mathematical modeling of CEE based on conservation of mass and energy, along with cost modeling and cost optimization framework. Capital and operating costs were normalized to generalize the results to applications with varying material and energy (electric and thermal) prices. Brine injection rate, temperature and air flow speed are found to be the primary factors affecting CEE performance and cost, and therefore, were selected as optimization design variables to investigates the trade-off between the operating (energy) cost, capital cost, and footprint area. The optimization reveals two distinct operation modes, "all-electric mode" and "heating mode". The "all-electric mode" corresponds to a lower total specific cost, ranging from 1.4 to 5 $\$/m^3$, and higher footprint area, ranging from 0.5 to 1.8 m^2 per m^3 of evaporated volume. The "heating mode" corresponds to a higher total specific cost, up to 6.5 $\$/m^3$; at low energy cost ratios, a compact footprint area ranging from 0.072 to 0.5 m^2 per m^3 of evaporated volume is achieved.

Effect of Cover Crops on Nitrate Leaching in Continuous Corn-Soybean Rotation in Southern Illinois

Ashani Thilakarathne, Southern Illinois University (K. Williard, G. Singh, J. Schoonover, J. Gillespie, J. Snyder)

Winter fallow season and spring are critical times for nutrient management as precipitation has great potential to flush available nutrients from the soil profile in row-crop agricultural fields. Cover Crops (CC) are a promising strategy to reduce nutrient leaching during these time periods. In 2014, a replicated plot study was established to monitor nutrient leaching with pan lysimeters at the Southern Illinois University Carbondale Research Farm. The research layout includes a complete randomized design with two tillage practices reduced tillage (RT) and no tillage (NT)] and three different crop rotation treatments [corn-noCC-soybean-noCC (CncSnc), corn-cereal rye-soybean-hairy vetch (CcrShv), and corn-cereal rye-soybean-oats+radish (CcrSor)]. Pan lysimeters were installed below the A horizon (~22-30 cm in depth) in each plot. Soil solution was sampled weekly or biweekly depending on precipitation and analyzed for nitrate-N. During the CC season in spring 2015/2016, cereal rye in CcrShv and CcrSor significantly reduced nitrate-N leaching by 76% and 74% compared to noCC treatment. In 2017/2018, nitrate-N leaching was 79% (CcrShv) and 65% (CcrSor) lower compared to noCC treatment. The last season of cereal rye 2019/2021 had significantly greater nitrate -N leaching in CC treatment than in noCC treatment, possibly caused by the delayed planting of cereal rye in 2019. Hairy vetch CC seasons always had greater nitrate -N leaching in CC treatments, likely because of the significant N fixing by the legume and rapid decomposition of low C:N ratio biomass. This induce the rapid mineralization of nitrogen. However, it was not significant for the last season 2020/2021. The greatest corn yield was observed in CcrShv with RT, which likely resulted by N credit of vetch. More research is needed on timely cultivation and termination of CCs for improved assessment of the effects of CCs on water quality.

Impacts of Cover Crops on Nutrient Loading in Streams on a Paired Watershed Scale

Steven Bachleda, Southern Illinois University Carbondale

The impact of agricultural runoff and its influence on nutrient loading in nearby streams has been well documented. Many best management practices (BMP's) have been adopted to mitigate these issues, one being cover crops. In 2007, a paired watershed study was established at Southern Illinois University farms to examine the impacts of cover crops in no-till corn (*Zea may*) and soybean (*Glycine max*) on phosphorus, nitrogen, and sediment runoff. Results presented are based on 2020-2021. Water samples were collected from outlets in watershed with cover crops (CC) and one that was used as a control, non-cover crop field watershed (non-CC). Using ISCO automated water samplers, water samples were collected after significant rain events where the stream stage exceeded 0.35 ft. Water samples were then tested for concentrations of ammonium (NH^{-4}-N), nitrate (NO^{-3}-N), dissolved reactive phosphorus (PO_4^{-3}-P) referred to as DRP, and total suspended solids (TSS). Results showed that ammonium event mean concentrations (EMCs) were 38.39% lower than predicted; however, differences in loading of ammonium was not significant ($p=0.965$, $F=0.0019$) for CC and non-CC, 0.135 kg/ha/yr and 0.132 kg/ha/yr, respectively. The EMC of DRP between the CC and non-CC watershed was not significant ($p=0.075$, $F= 3.205$). However, the DRP loading from the CC watershed was significantly lower than non-CC, 4.904 kg/ha/yr and 11.95 kg/ha/yr, respectively ($p=3.512e^{-9}$, $F=38.412$). TSS EMC was 37.1% less than predicted. Nitrate loading for CC and non-CC was significant at 8.6 kg/ha/yr and 28.31 kg/ha/yr, respectively ($p= 0.01424$, $F=6.1333$). This long-term study illustrates that cover crops have positive impacts on reducing nutrient runoff from agricultural fields at the watershed scale. Data suggest that cover crops have the potential to reduce fertilizing costs for farmers and to help achieve environmental goals of the Illinois Nutrient Loss Reduction Strategy.

Integrating Watershed Modeling and Paleolimnological Techniques to Understand the Role of Geographically Isolated Wetlands in Mitigating Non-point Source Pollution in Agricultural Landscapes

Frances O'Donnell, Auburn University (C. Barrie, C. Eggert, S. Brantley, M. Waters, S. Gollday)

Geographically isolated wetlands (GIWs) are widespread in many agricultural regions and represent preferential flow paths to groundwater. Their role in mitigating non-point source water pollution is poorly understood, but it is likely that healthy GIWs store and process nitrogen and phosphorus, reducing impacts on groundwater quality. We are investigating these issues in an ongoing study in southwest Georgia, a karstic region with numerous GIWs and intensive irrigated row crop agriculture. The agricultural GIWs in the study are on working farms and are compared to reference wetlands with forested watersheds. Rain gauges, water level loggers, and sediment traps were installed in each wetland and samples are collected regularly for water quality analysis. We are using these data to develop a watershed model of the contributing area of each wetland based on the model mechanics of the Soil Water Assessment Tool (SWAT) to simulate water, sediment, and nutrient transport. To understand wetland function, we are analyzing organic matter and nutrient content of surface sediments. We also collected a long core from each wetland, which will be analyzed using paleolimnological techniques to quantitatively reconstruct sediment biogeochemical dynamics throughout the 50- to 100-year period of agricultural expansion in the study area. Preliminary results from the analysis of one agricultural wetland demonstrate that estimated sedimentation rates are similar for the three methods (sediment traps, long-cores, modeling). Future work will integrate modeling and sediment core analysis to gain a process-level understanding of the temporal changes observed in the cores. Inter-site comparisons will allow us to explore how vegetated buffers and the design and construction of berms influence wetland function. We are also working with partners in the local agricultural community to understand farmers' perspectives on wetland management and water quality protection.

Virtual Fencing for Improved Grazingland Water Quality

Kevin Wagner, Oklahoma State University (R. Reuter, L. Goodman, B. Murray, A. Phillippe)

Grazinglands are of particular importance in Oklahoma, comprising 50% of the state's surface area. Unfortunately, current grazing practices are oftentimes found to be impacting water quality, wildlife, ranch productivity, and long-term sustainability of livestock production in many regions. Overgrazing near waterbodies can increase streambank erosion, contributing sediment and other contaminants to streams and impacting aquatic life, habitat, and recreation. In Oklahoma, riparian and rangeland grazing is estimated to impact over 15,000 river miles and over 40,000 lake acres according to a 2014 Oklahoma Department of Environmental Quality report. Producers need new tools to improve grazingland management. New technologies offer the opportunity to overcome many challenges faced by grazing operations. Virtual fencing, in particular, is anticipated to allow better management of grazing distribution and protection of sensitive areas (e.g. riparian zones). Such new tools will allow ranchers to actively manage remote grazing sites, increase grazing efficiency, reduce infrastructure costs and labor, and improve animal welfare. However, the range of benefits of such practices needs to be understood to support adoption by landowners and funding by natural resource agencies. Oklahoma State University has partnered with a U.S. based virtual fencing company to evaluate the use of new virtual fencing technology, which employs GPS-enabled collars on individual cattle to provide auditory and electric stimulus, to improve the management of livestock grazing. Preliminary data found that virtual fencing is 60% effective on average (and as high as 99% effective) in reducing cattle presence in protected areas. It is important to understand the effectiveness of virtual fencing and if the level of protection afforded by it provides sufficient riparian and stream health, along with runoff and in-stream water quality, improvements to warrant its use as a recommended conservation practice. We will review preliminary findings and discuss future plans for evaluating virtual fencing.

Quantifying Conservation Practice Effectiveness Statewide: Balancing Variability with Usability
Katy Mazer, Purdue University (J. Frankenberger)

Agricultural runoff and drainage are leading contributors to excess nutrient concentrations in waterways, that can lead to algal blooms and decreased ecosystem function. In an effort to reduce these nutrient loss rates from agriculture, government organizations, non-profits, and scientists alike have been promoting the implementation of best management practices to treat water before it enters waterways. In recent years, states like Iowa, Minnesota and Illinois, have created science assessments in an effort to estimate the nutrient reduction impacts of these practices statewide and within the larger watershed. These science assessments for nutrient reduction strategies can help to capture present and future endeavors within a watershed that positively impact water quality, as well as gauge the progress of conservation and soil health practice adoption. They can also be used to provide direction for future nutrient reduction efforts and enhance collaboration in conservation implementation, in part by showcasing the impacts of conservation practices. Conservation practices are promoted and implemented to reduce excess nutrient concentrations in waterways, yet the effectiveness of these practices is difficult to assess and compare. Researchers and agency staff across Indiana are developing a method to quantify expected nutrient reductions from conservation practices, to be used statewide. The vision is that this process will lead to (1) improved documentation of statewide progress towards nutrient reduction goals, (2) prioritization of the most effective conservation practices based on Indiana conditions to improve program implementation, (3) more accurate assessment of Indiana's contributions to downstream water quality issues, and (4) alignment of communication by researchers, agencies, and others throughout Indiana about conservation practices effectiveness. Quantifying the nutrient load reductions from individual conservation practices relies on analysis of many variables that account for differences in nutrient reduction, all while being balanced with the usability of such an assessment. In this presentation, we will describe the on-going science assessment based in Indiana to create a nutrient reduction estimation tool that is functional, while also accounting for the spatial variability and design differences that can affect practice effectiveness. A team of scientists, agency representatives, and practitioner groups have come together to identify the most important factors needed to make a tool that can accurately assess practice effectiveness, while still being easy and functional to use for the thousands of practices implemented in the state annually. We will highlight factors that we have considered important enough to include in the assessment as well as discuss tactics we have utilized to achieve collaborative, ultimately improving accuracy and usability of this nutrient reduction tool.

Cover Crops, Soil Moisture, and Precipitation Affect Nutrient Loss of Spring Applied Phosphorus Fertilizer

Harpreet Kaur, University of Missouri Columbia (K. Nelson, G. Singh)

Cover crops (CC) have been found to reduce particulate phosphorus (P) by reducing soil erosion; however, there are increasing concerns regarding increased risk of dissolved reactive phosphorus (DRP) in surface water runoff. Effectiveness of CCs in reducing runoff and nutrient losses may vary within soils during a freeze-thaw cycle. Winter applied nutrient losses are associated with soil moisture and temperature conditions as well as runoff hydrology. Therefore, the objective was to evaluate the effect of variable spring precipitation and soil conditions on fertilizer loss and the impact of cover crops on fertilizer loss in a no-till field. Soil samples were collected before P fertilizer application and after CC termination. In this research, P and K fertilizers were spring applied as a BMP to reduce nutrient loss since CC growth would be greater than in the fall which should limit loss. Variable spring precipitation and soil conditions can affect fertilizer loss. We were able to evaluate these differences and the interaction with cover crop establishment from 2019 to 2022. Results on P budget analysis from cover crop management practice will be presented.

SmartPath: A Grower Directed Tool Box to Protect Human Health Through Advanced Irrigation Water Quality Management

Lucas Gregory, Texas A&M University, Texas Water Resources Institute

Agricultural water shortage problems arise from deteriorating quality, groundwater depletion, uncertainties in precipitation associated with climate change, and unsustainable freshwater usage. One approach to reduce water shortage problems is to utilize water sources that have traditionally been viewed as unsuitable for edible crop irrigation. This project focuses developing new smart irrigation systems emphasizing the quality of alternative water sources (treated domestic wastewater, brackish, low quality surface water) with potential pathogen contamination (SmartPath). Using grower feedback as a guide, this project will develop innovative software and hardware solutions for on-farm water management, enabling small farmers that do not have access to a nearby analytical lab service to meet the Food Safety Modernization Act (FSMA) requirements for testing water quality within eight hours of sampling. Treatment systems will be coupled with sensing systems for measuring physical, chemical and biological constituents including: temperature, pH, salinity (ions), dissolved oxygen, nitrate and phosphate, and fecal bacteria, and integrated into an internet of things wireless decision support system. Economic feasibility and social viability will be evaluated across various spatial scales (from individual farms to regions) for growers in 4 key regions of the US (Florida, Texas, Iowa and Maryland). Through laboratory testing and field case studies, SmartPath will develop and validate water treatment systems and increase the use of alternative water for irrigation of fresh produce, decreasing freshwater withdrawals and closing basin water gaps.

QMRA of Recreational Beaches Impacted by Dog, Gull, and Human Fecal Sources

Anna Gitter, University of Texas Health Science Center at Houston School of Public Health-El Paso (M. Gidley, H. Solo-Gabriele, K. Mena)

Microbial contamination of recreational waters continues to be a significant public health concern, affecting beach closures and health advisories. For recreational waters impacted by both human and non-human fecal sources, evaluating the health risks associated with fecal pathogens from these different sources is imperative to not only improve water quality, but also inform effective management. Water samples were collected from two Miami, FL beaches - Crandon and Haulover in the summer of 2018 - and molecular source tracking techniques were used to identify the concentrations of the following fecal markers, human (HF183), gull (Gull2), and dog (DogBact). These marker concentrations were analyzed using a quantitative microbial risk assessment (QMRA) approach to estimate the human health risks for a gastrointestinal infection and illness following ingestion of seawater while swimming for adults and children. Source-specific and cumulative health risks for all fecal sources were estimated and found to not exceed the U.S. EPA risk threshold of 0.036 for primary contact recreation. Among the fecal sources evaluated, human presented the greatest risk for an illness. The two non-human fecal sources had comparable risk of illness estimates and were at least one order of magnitude lower than the risks posed by the human fecal source. Overall, children were identified to have a slightly higher risk for a GI illness than adults, which may be due to the greater assumed ingestion volume of water while recreating. This study supports using environmental molecular marker data in a QMRA to better inform site-specific beach management practices that may influence advisories.

The Role of Environmental Buffers in Potable Water Reuse

Olya Keen, University of North Carolina - Charlotte (X. Brown)

With a large percentage of US population residing in arid areas, potable water reuse is becoming a widespread practice. Due to general public opposition to direct potable reuse, an environmental buffer (river, aquifer or reservoir) is frequently in place to mitigate the "toilet-to-tap" perception. The goal of this study was to evaluate the effectiveness of the environmental buffers for water quality improvement. This project used case studies to evaluate the ability of different types of environmental buffers (groundwater recharge, riverbank filtration, wetland treatment, river and lake discharge) to attenuate contaminants representative of different classes and different environmental fate mechanisms by measuring conventional water quality parameters as well as unregulated constituents of concern. Multiple contaminant classes were analyzed (salts, metals, pharmaceuticals, antibiotic resistance genes, pesticides/herbicides, nutrients, microorganisms, suspended solids and organic carbon) to determine whether different types of environmental buffers reduce or increase the contaminant load at the drinking water treatment facility. Overall, some environmental buffers may be of benefit if treated wastewater in a water reuse scenario is released into the environmental buffer without advanced treatment. The buffers with the most advantage in such scenario were wetlands, riverbank filtration, and aquifer recharge. The benefits achieved in advanced treatment may be partially reversed by the release of purified water into the environment.

There's Something in the Water: Mental and Physical Health Consequences Associated with Tap Water Contamination in Six Nations of the Grand River First Nation

Sarah Duignan, McMaster University (D. Martin Hill)

In collaboration with Six Nations First Nation, we investigate household-level tap and drinking water sources and uses, and examine the associations between household water contaminations, treatments and self-reported household health conditions related to the ongoing water quality crisis within the reserve. Water was tested from 66 household taps for heavy metals (including mercury) and *E. coli* contaminants. A co-created survey collected reported household health conditions, water sources, uses and treatments, and drinking water sources for these households. Logistic regression models analyzed associations between reported health conditions and demographics, contaminants, and water treatment variables. *E. coli* was present in 21.2% (n=14) of household tap samples, and mercury was found in 25.4% (n=17) of samples in levels exceeding the provincial drinking water guidelines. Households with *E. coli* contamination or purchasing bottled water were significantly more likely to report mental health conditions, and those using bleach/chlorine treatments were more likely to report gastroenteritis. 57% of households with contaminated tap water were still using it for activities that may heighten exposure risks (such as making beverages with unboiled water). **Conclusions**: Investigating household tap water uses beyond drinking water demonstrates alternative pathways for contaminant exposures. Mental health was found to be associated with the presence of *E. coli* in tap water, as well as the reliance on purchasing bottled drinking water, and presence of gastroenteritis were associated with bleach treatments. As Six Nations Peoples have deep cultural relationships with water, these results inform experiences of colonially imposed environmental racism.

Accomplishing Common Goals Through a Regional Stormwater Partnership

Regina Guyer, Rising Solutions, PLLC /Regional Stormwater Partnership of the Carolinas, & Marissa Meltzer, City of Mooresville

The Regional Stormwater Partnership of the Carolinas (RSPC) is a 501c(3) non-profit which provides a forum for 21 municipal and county entities to achieve common goals. The RSPC is committed to the improvement of water quality and takes an active leadership role in achieving that vision. Our vision states, "We seek to educate and bring awareness to the public, local businesses and education centers of our region about stormwater issues and their impact on our water quality and our environment. We further aim to unite local stormwater professionals and programs by sharing information and ideas in order to collaborate, discuss and address similar stormwater issues on a regional level." The RSPC has a board comprised of representatives from member municipalities that make key decisions, set goals, and determine priorities. Members meet quarterly to provide further input on their programs' needs and to collaborate on how to meet those needs through the partnership. Initial activities included public education and outreach to meet MS4 permit requirements but grew to include many other activities including municipal staff training, elected officials workshops, a grant project, semi-annual technical presentations, and many other activities. The experiences of RSPC members will be provided in the presentation to highlight MS4 permit compliance initiatives and methodologies for a variety of municipality/county entity sizes. As compliance is not a one-size-fits-all strategy, engaging and learning from other stormwater professionals has provided valuable insight. The presentation will share this insight and provide discussion points and examples for stormwater management and permit compliance.

Staggered Volunteering: An Approach to Managing Public Participation in Water Quality Restoration During a Pandemic

Jake Mowrer, Texas A&M AgriLife Extension Service (E. Spears, M. Kuitu)

Volunteering is an essential component of water quality restoration and outreach education in the U.S., and yet Covid-19 guidelines have sidelined many public gatherings. This has substantially constrained the use and organization of group volunteer labor to facilitate restoration of water quality. Volunteering makes possible a multitude of projects that could not happen without it, including riparian revegetation, stream cleanup, biodiversity conservation and cataloguing, watershed protection, and more. In return, volunteers receive benefits such as improvements to individual mental and physical health, self-fulfillment of social responsibility, strengthening of community relationships, and collective resilience to disasters and emergencies. Volunteering must continue in spite of the current and future constraints on large public gatherings in order to maintain all of its associated benefits. Staggered volunteering is an approach to arranging volunteering in a spatial and temporal way that retains all benefits while observing social distancing and other CDC guidelines for public health. Details on this approach and a case study of the Geronimo and Alligator Creeks Cleanup Event in 2021 will be featured in the presentation.

Engaging the Earth Science Community for Developing a River Morphology Information System (RIMORPHIS)

Amanda Cox, Saint Louis University (M. Muste, V. Merwade, I. Demir, T. Minear)

River morphology data are critical for understanding and studying river processes (e.g., hydrodynamics and sediment and nutrient transport) and for managing rivers with their multiple socio-economic uses (e.g., navigation, water abstractions, and aquatic habitat). While such data have been acquired extensively over time, several issues hinder their use for river morphology studies such as data accessibility, variety of data formats, lack of data models for data storage, and lack of processing tools to assemble the data in products readily usable for research, management, and education. With recent funding from the National Science Foundation, a multi-university research team aims to prototype a web-based river morphology data platform (RIMORPHIS) for hosting and creating new information and tools to be shared with the broader earth science community. The RIMORPHIS design principles include: (i) broad access via a publicly and freely available platform-independent system; (ii) flexibility in handling existing and future data types; (iii) user-friendly and interactive interfaces to encourage contributions and execution of workflows from a wide variety of stakeholders with diverse technical backgrounds; and (iv) interoperability and scalability to sustain the platform usage beyond the project duration. Development of such an ambitious community resource is only possible by continuously engaging stakeholders from the inception of the project. This presentation will highlight the research team strategy and initial activities to connect and engage with morphology data producers and potential users from academia, research, and practice. Engagement activities to-date include identification of community partners, hosting the first annual project workshop, and one-on-one in-depth discussions with relevant data partners. The presentation will also detail outcomes of stakeholder engagement and illustrate how these interactions are shaping RIMORPHIS development.

Stakeholder Engagement in Watershed Management: Lessons from Two Texas Watersheds
Evgenia Spears, Texas A&M AgriLife Extension Service (J. Mowrer, M. Kuitu)

Watershed protection plans (WPPs) are locally developed voluntary strategies designed to restore and protect water bodies within a watershed from point source and nonpoint source pollution. Inherently a community-driven effort, a WPP heavily relies on public participation to address local water quality concerns through voluntary behavior change. Stakeholder engagement is critical to successful implementation of WPPs. If conducted effectively, stakeholder outreach can increase public awareness of water quality issues, promote support for watershed management initiatives, and ultimately, enhance the social capital of the watershed community essential to achieve water quality goals. This presentation will focus on the public outreach strategies implemented in two WPPs in Texas – Mill Creek WPP and Geronimo and Alligator Creeks WPP. In particular, stakeholder profiling, specific communication tools, and practical approaches to building trust and sustaining long-term collaboration will be discussed. Based on the outreach experience in these watersheds, recommendations for water resource practitioners will further be provided.

On-campus Stream Restoration as Interdisciplinary Senior Capstone
Chelsea Peters, Roanoke College

Senior capstones and practicum courses can provide environmental studies majors with real-world skill sets and pride towards environmental engagements. This study presents a capstone project that connected students with on- and off-campus communities and produced measurable environmental change through the restoration of Snyder Branch Creek. Stream restoration requires advanced ecological and hydrological understanding of the aquatic habitat and watershed function, but it also entails community support and engagement. A Roanoke College class of 12 undergraduate seniors achieved these goals through a student-led project in Fall 2021. The Environmental Studies majors (1) researched ecological and historical aspects of the land, (2) developed stream awareness, (3) created a restoration plan, and (4) conducted a community cleanup of the stream. Ultimately, student planted over 120 riparian plants, removed 900 gallons of invasive species, and stabilized 200 linear feet of stream bank. They educated the community on the ecological importance of the area through the creation of signs and social media, and they crafted a restoration plan for the remaining stream channel. Students reported increased pride in the program and campus, and demonstrated improvement in career readiness. The stream restoration project was an engaging and inclusive learning experience allow students to develop socially-responsible leadership skills. This project framework could achieve sought after project-based and service learning outcomes for other undergraduate programs.

A Collaborative Research Framework for Co-Producing Knowledge to Enhance Climate Resilience

Loretta Singletary, University of Nevada, Reno (E. Koebele, W. Evans, C. Copp, S. Hockaday, J.J. Rego)

In snow-fed river basins in the arid intermountain western U.S., water allocation institutions are fundamental to agricultural production. Most river systems are fully allocated, and irrigated agriculture accounts for approximately 80-90% of freshwater withdrawals. Climate change is reducing snowpack, shifting snowmelt timing and runoff volume, and impacting food security. Moreover, municipal and environmental stakeholders are experiencing water security challenges and look to agriculture for additional water supplies. Using the Walker River Basin in Nevada-California as a representative study area, we describe and evaluate a collaborative research framework for knowledge co-production grounded in participation theory, including engagement intensity, modalities, and processes, to enhance the climate resiliency of basin food systems. Results indicate that, based on engagement experiences to date, stakeholders understand and recognize the importance of research goals; demonstrate positive attitudes towards collaborative research and partnerships with researchers; view their contribution of knowledge and expertise as critical to project success; and perceive researchers as eager to use their expertise. Stakeholders' goals for collaborative research include new information to efficiently address increased competition for more variable water supplies. For these goals to be achieved, stakeholders believe researchers must learn about their basin, including its water allocation history and agricultural practices. Our findings suggest that context, process design, power dynamics management, participation culture, and scalar fit each contribute to explaining the outcomes of stakeholder engagement leading to knowledge co-production. Results underline the importance of formative evaluation to structure, monitor, and adapt engagement modalities and intensity as needed to achieve collaborative research goals.

Is There a New Era of Flood Risk? A Rapid Assessment and Improved Perspective on a County-wide Scale

JC Hollingsworth, Davis & Floyd

Large scale flood risk assessments are paramount for capital project planning. However, for a county or government entity, the path is often unclear, and funds are limited. Herein, we adopt and present a unique and efficient first-ever approach to develop a comprehensive flood risk model for Florence County. The aim of the study was to develop a set of tools to identify potential flood risk and evaluate damages to assist Florence County, SC in evaluating current (and updated) conditions flood risk and assessing capital improvement needs. In this case study, a 2-D rain-on-grid hydrologic and hydraulic model of Florence County was constructed and calibrated using available USGS gauge data and FEMA cross sections. Simulation results were post-processed to obtain county-wide flood depth grids with the inclusion of major stream and river crossings. Next, the study area was divided into approximately 1,000 sub-watersheds for capital improvement prioritization. A unique user-defined weighted overlay algorithm was developed to assign flood risk and vulnerability indices based on the analytic hierarchy process. Flood vulnerability metrics coupled with a monetary FEMA HAZUS model provided sub-watershed prioritization based on their underlying potential flood risk. These tools and models provided Florence County with its first-ever holistic flood risk assessment and can be routinely updated and expanded upon to provide high-resolution and realistic flood risk in the near future.

Barriers and Opportunities for Ecosystem-based Adaptation to Climate Change Impacts in the Cache River Watershed of Southern Illinois

Kofi Akamani, Southern Illinois University Carbondale (M. Lood)

In recent decades, the impacts of climate change on water resources have been receiving research and policy attention. Changes in temperature and precipitation patterns are expected to result in changes in the hydrologic cycle, with adverse implications for food, energy, and water security, as well as ecosystem health. Whereas past policies on climate change largely focused on mitigation policies aimed at reducing the anthropogenic causes of climate change, a shift has been occurring towards adaptation policies that focus on the mechanisms by which societies learn and respond to the impacts of climate change in order to take advantage of opportunities and minimize the adverse impacts. One form of adaptation that has been gaining popularity among scientists and decision-makers is ecosystem-based adaptation. Ecosystem-based adaptation refers to adaptation policies that take into account the role of ecosystems in reducing vulnerability and building the resilience of social and ecological systems to climate change impacts and other drivers of change. The key features of ecosystem-based adaptation include: embracing complexity and the need for adaptive management; pursuing multi-sectoral goals; utilizing integrated knowledge systems; and relying on adaptive governance institutions. In spite of its promise, the transition towards ecosystem-based adaptation has been slow, and evidence on its successful implementation are limited. Drawing from qualitative data generated through interviews and the review of documents, this presentation provides an assessment of the current status of ecosystem restoration efforts in the Cache River watershed of southern Illinois from an ecosystem-based adaptation perspective. Barriers and opportunities for the successful implementation of ecosystem-based adaptation in the watershed are also analyzed. The presentation concludes with policy recommendations for enhancing the transition toward ecosystem-based adaptation in the Cache River watershed and elsewhere.

Integrating Data Sets to Understand Climate Change Vulnerability for Aquatic Fauna in West Virginia Watersheds

Joseph Molina, West Virginia University (C. Chaves-Arantes, B. Murry, J. Anderson, W. Veselka)

Climate adaptation planning is becoming more common in natural resource management, but supporting information is disperse or at inappropriate spatial scales. Our project utilizes unassociated data from the West Virginia DNR, West Virginia DEP, and scientific literature to conduct assessments of species', communities', and habitats' vulnerability to climate change. Integrating these three levels of assessment, we develop a watershed-scale decision support tool, the Watershed-Based Aquatic Fauna Ecological Risk Index (WB-AFE). We assess species-specific vulnerability using the methodologies from NatureServe's Species-Specific Climate Change Vulnerability Index (CCVI) which categorize vulnerability ranging from Not Vulnerable/Increase Likely to Extremely Vulnerable . A community level sub-index is then derived from the presence/absence of the categories within a watershed. We evaluate and update the number of habitats within West Virginia that have currently been classified into climate change vulnerability categories that range from Least Vulnerable to Critically Vulnerable. The community subindex and habitat vulnerability index are combined to allow managers the ability to view each index individually and as a holistic watershed-level index. Managers are supplied with raw data and GIS layers to be viewed in conjunction with their system. Here we demonstrate the ability to acquire and utilize unassociated data from several sources to develop a simple static decision-support tool that can assist managers in the implementation of conservation and recovery strategies.

Eclipsing Problems Embedded in Composite Drought Indices

Mohammad Hadi Bazrkar, Texas A&M AgriLife (H. Han, S. Park, T. Abitew, C.H.M. Green, J. Jeong)

Composite drought indices have been increasingly used for drought identification. However, selection of hydroclimatic variables and aggregation process cause final outputs (values of drought indices) to hide the true nature of anomalies in water sources (i.e., eclipsing). This study aims to examine, quantify, and compare eclipsing nature of composite drought indices. The eclipsing problems in composite drought indices such as hydroclimatic aggregate drought index (HADI), snow-based hydroclimatic aggregate drought index (SHADI), standardized precipitation and evapotranspiration index (SPEI), and standardized melt and rain index (SMRI) were quantified and compared with univariate standardized drought indices, standardized precipitation index (SPI), standardized runoff index (SRI), and standardized soil moisture index (SSI). In applying to the Upper Colorado River Basin (UCRB), the Global Land Data Assimilation System (GLDAS) data in 1950-2014 were used for drought monitoring. The results indicated that the composite drought indices, HADI and SHADI, show relatively more eclipsing issues than the standardized bivariate indices, SPEI and SMRI, and the standardized univariate indices, SPI, SRI, and SSI. HADI and SHADI demonstrate higher sensitivity to the aggregation process due to the application of principal component analysis for their derivation. SPEI and SMRI show fewer eclipsing issues than multivariate indices due to their simple additive aggregation process. This study defines and quantifies the term eclipsing in composite drought indices and discusses the negative impacts of eclipsing on drought identification.

Extreme Flooding: A Non-Stationary Hydrologic Assessment of Seasonal Floods in South Carolina

Ryne C. Phillips, Davis & Floyd, Inc. (S.Z. Samadi, M.E. Meadows)

Non-stationarity has emerged as a prevailing issue for the design of engineering infrastructure given the potential for peak flood discharge to increase with climate change, thereby underscoring the need to better characterize the statistical assumptions underlying hydrological frequency analysis. The focus of this study is on developing and evaluating non-stationary probabilistic flood frequency curves for the major catchments in South Carolina (SC) where the October 02-05, 2015 floods caused infrastructure damages and several lives to be lost. Continuous to discrete probability distributions, including the generalized extreme value (GEV), Generalized Pareto (GP), log-normal, log-Pearson type III, beta-K, and beta-P, were fitted to the seasonal annual peak flood events in stationary and non-stationary settings. Global climate indices and physical watershed characteristics were implemented as potential explanatory variables to evaluate the hypothesis of improved flood frequency estimates in the non-stationary setting. Results of the study suggested that the GP and beta-type distributions serve as seasonal parent distributions. Implementation of non-stationary modeling improved goodness-of-fits of standardized quantile estimates in all cases. Watershed characteristics as explanatory variables outweighed global climate factors in smaller catchments, while larger catchments exhibited better fits with a blend of climate and physical factors. Design implications of the non-stationary models were investigated by considering two popular non-stationary return level models: expected waiting time and expected number of events. Overall, return level estimates did not significantly vary between stationary and non-stationary models. However, Monte-Carlo based confidence intervals of design return levels did reveal increased model uncertainty in the non-stationary setting. The results of this study do not conclusively dismiss the use of non-stationary modeling in South Carolina but rather highlight the need for a better understanding and analysis of major flood driving factors to reduce uncertainty and improve accuracy in non-stationary flood modeling.

Mississippi Water Stewards: Building Capacity for Watershed Protection Through Community-based Monitoring

Beth Baker, Mississippi State University (E. Sparks, M. Dominguez, S. Ruiz-Cordova, A. Braman)

To advance the protection of Mississippi's freshwater resources and coastal waters of the Gulf of Mexico, Mississippi State University Extension Service personnel have partnered with the Alabama Water Watch (AWW) Program and the Pearl Riverkeeper program, with funding from the U.S. Environmental Protection Agency to develop the first statewide citizen water monitoring and education program. The Auburn University AWW and Global Water Watch (GWW) programs have been successfully applying and refining their model of community-based watershed stewardship for more than 25 years. The Mississippi Water Stewards (MSWS) program adapts the AWW model to implement EPA-approved quality assurance plans for water chemistry and bacteriological monitoring, as well as develop plans for biomonitoring and a youth education program in three pilot watersheds. Development and piloting of the MSWS program includes adaptation of an administrative infrastructure, development of online instructional courses, facilitation citizen monitor certification workshops, development of a trainer manual and implementation of a train-the-trainer program. Additionally, training citizens in water science & monitoring techniques utilizing quality assured protocols affords greater capacity for monitoring watersheds where conservation and restoration have been implemented to restore water quality for specific designated uses. Too often, grant-funded monitoring timelines are too short to document water quality benefits and monitoring approaches are too costly to support sustained monitoring efforts. Mississippi Water Stewards also utilizes a publicly available data platform, Water Rangers, as a data submission interface. Utilizing a publicly available online platform streamlines data logging, management, conducting quality assurance and quality control reviews, and visualizing data more efficient for small organizations with limited capacity. Protection of water resources through education, outreach, and citizen science builds transparency and public participation in the protection of the states' unique water resources and ecosystems, thereby protecting the GOM, fostering community involvement, and water resource protection.

Watershed Watch in Kentucky: A Case-Study of a Nonprofit-Based Community Science Organization

Steven Evans and Malissa McAlister, Kentucky Water Resources Research Institute

Watershed Watch in Kentucky (WWKY) is a statewide volunteer monitoring program whose mission is to support water quality monitoring that informs, connects, and empowers volunteers and their communities for the improvement and protection of Kentucky's water resources. Its origins began in the mid-1990s out of Kentucky Division of Water's interest in generating interest and support for water issues and the participation in the Kentucky Watershed Management Framework approach to managing water quality. Since inception, monitoring has included field testing, laboratory samples, habitat assessment, and biological assessment with consistent methods statewide. However, the parameters sampled and the approaches to volunteer engagement differed by regional focus. WWKY is a nonprofit with membership consisting of independent river basin organizations, Kentucky Division of Water, Kentucky Waterways Alliance, and the Sierra Club. It also relies heavily on voluntary technical and logistical support from universities and community colleges across the state. The unique evolution and structure of the Watershed Watch program have created various sustainability challenges and identity crises over the years due to competing partner visions. Recent strategic planning efforts have refined the organization's purpose and approach to meeting the current landscape of data quality objectives, database management, partner support, volunteer enthusiasm, and funding interest. After 25 years, WWKY has achieved numerous successes, including training over 4,500 volunteers, maintaining a network of nearly 1,000 active samplers, and sampling more than 3,700 stream monitoring sites. It boasts some unique partnerships including collaboration with a Phase 1 MS4 permit community on monitoring requirements, a lake monitoring program used in tandem with remote sensing to identify harmful algal blooms, and a 4H Stream Team program to involve youth. The organizational leadership hopes to continue to build on these successes and evolve in a way that best engages its sampling network for mutual benefits to participants and Kentucky's waterways.

Challenges, Growth, and Future Objectives of the South Carolina Adopt-a-Stream Program
Katie Callahan, Clemson University (E. Anderson, H. Bird, S. Hylton)

Citizen science water quality monitoring programs can be organized by several characteristics, including leadership and agency responsibilities; program integrity, data use, and purpose; data access; experience and/or training requirements; funding and more. The citizen science water quality and ecosystem monitoring program, South Carolina Adopt-a-Stream (SC AAS), began in 2017 after a year of research and development funded by the US Environmental Protection Agency and learning from model programs across the country and most especially our neighboring Georgia Adopt A Stream program. The program is co-lead by our state's delegated water quality authority, the SC Department of Health and Environmental Control (DHEC) and the Center for Watershed Excellence at Clemson University. In this way, leadership is committed to training and data integrity, utility of data for research and outreach purposes, and engaging all people of South Carolina in improving their connections with our waterways. Data collected by certified volunteers is baseline, non-regulatory data that can lead to expedited actions to concerns identified by the volunteer. Through a train-the-trainer partnership, volunteers are certified amongst three protocols – Freshwater, Macroinvertebrate, and Tidal Saltwater – and required to recertify annually. The database created by leadership and maintained at Clemson University is the backbone of the program, providing data transparency and immediate utility for local watershed planning, student engagement, and research. SC AAS has been conducting an annual motivations survey for certified volunteers from 2019 – 2021. Using these results, leadership can identify program weaknesses, such as geographic distribution and volunteer retention, as well as speculate on motivations for long- term engagement of volunteers and program growth interests. Using this feedback, we can better reach programmatic goals of engaging more residents in an aware conversation about the impacts of growth and climate change, offering a greater number of trainings in areas of historic environmental injustice, and developing stable funding.

Georgia Adopt-A-Stream

Harold Harbert, Georgia Environmental Protection Division (B. Sauls, C. Nachtmann)

Georgia Adopt-A-Stream has engaged in volunteer water quality monitoring since 1992. A program of the Georgia Environmental Protection Division, state staff began conducting outreach training events in the 1980s and earlier. After the Adopt-A-Stream program was created, it grew to incorporate water education for the K-12 audience and river cleanups. At its core, the Adopt-A-Stream citizen science, or community-based program, has continued to grow, now supporting over 200 active groups monitoring over 700 sites. Program success is a result of our focus on data integrity, partnerships, and a robust database. Through this 3 pillared approached, we have been able to educate an involved citizenry in the protection of our water resources, whether in Georgia or any place where streams flow and water is deemed important. There's more work to be done, and our challenge is the collective challenge of all programs in the southeast and throughout the nation. We look forward to sharing some of what we learned and gain knowledge from the experiences of others.

Addressing Reach, Recruitment, and Retention of Volunteer Water Quality Monitors with Alabama Water Watch

Rachel McGuire and Mona Dominguez, Auburn University Water Resources Center

Alabama Water Watch (AWW) is a statewide volunteer water monitoring program that was established in 1992 and is based at the Auburn University Water Resources Center. Citizen science, water monitoring programs share many challenges including those related to reach, recruitment, and retention of volunteers. To thrive, programs must creatively address these challenges. The solutions must also readily integrate into current cultural and technological landscapes among other conditions. In 2018, AWW was approached by USDA Forest Service (USFS), more specifically, National Forests in Alabama (NFAL) staff, with interests in engaging citizen scientists through data collection on the NFALs. Together, USFS and AWW are implementing the project, "Developing a Citizen Volunteer Water Quality Monitoring Program in Alabama's National Forests", funded, in part, by the USDA CitSci Fund. This project provided AWW with a valuable opportunity to experiment with new ways of addressing these shared challenges. Some of these new strategies included pre-establishing monitoring sites for prospective monitors, a hybrid (online and in-person) training model, and a monitoring materials check-out system housed at the USFS District Ranger Offices. Most notably, this project demonstrated the potential for increased partnership with agencies and organizations focused on public lands. During the session, AWW will highlight the most successful strategies that have emerged from the project as well as some of the project's deficiencies. AWW will share how they plan to improve future projects and plans to implement this project model on a larger scale, thereby reaching and monitoring more public lands in Alabama.

A Vision for Building Trust and Reciprocity in Watershed-Scale Community-Based Science through Interconnected Science Participation Programs

Stephen Moysey, East Carolina University (P. Arora, J. Petersen-Perlman, M. O'Driscoll, V. Lakshmi, N. Bell, M. Hale, C. Zarzar, C.A. Grace-McCaskey, K.S. Hagge, J. Best, A. Stevenson, S. Radel, J. Webb, T.J. Mulrooney, D. Hitchcock, A. Mishra, A.L. Peralta, V. Gould, G. Howard, R. Malhotra, S. Mosier, J. Hoven, S. Strickland, T. Van Niekerk, C.K. Harris, R.G. Asch, J.R. Etheridge, G. Vlahovic)

Communities in the coastal plain of North Carolina are increasingly impacted by natural hazards, ranging from floods to harmful algal blooms. These problems generally do not result from the actions of a single actor, but rather emerge from the cumulative behavior occurring across a watershed or driven by regional-to-global processes, such as sea level rise. Enhancing community resilience through adoption of adaptation measures to mitigate these hazards should therefore not be as a viewed as a burden to be borne by individual communities. Instead, the interdependencies between communities should be considered to assess collaborative opportunities to enhance resiliency at a watershed level. There are many challenges to building effective networks between communities, however, that includes the need for communities to develop an understanding of their own region, the creation of trust and effective communication between communities to identify and foster mutually supportive arrangements, and the inclusion of voices from community members that might often be neglected in resilience planning activities. A vision for overcoming these challenges through local science participation programs that are interconnected across the watershed is described. The approach focuses on increasing the capacity of community members, especially youth, to participate with community leadership, academics, and other local stakeholders in the ideation, implementation, and reporting of community-relevant science driven by and created for the broader community. By explicitly embedding opportunities for interaction between program teams across the watershed and encouraging participation of their broader familial networks across communities, we seek to build relationships and understanding that can shift community attitudes toward enhanced modes of dialogue and collaboration.

Indigenous Communities' Prioritized Information and Data Needs to Enhance the Climate Resilience of Water Resources on Reservation Lands: A Participatory Research Approach in the Arid Southwestern U.S

Loretta Singletary, University of Nevada, Reno (H. Fillmore)

Indigenous communities across the United States are actively engaged in climate adaptation initiatives making them experienced witnesses to community-based adaptation. This USDA-NIFA funded participatory research involves a regional survey of climate information and data needed to enhance the climate resiliency of water resources on reservation lands in the arid southwestern United States. Study participants include tribal government employees, agriculturalists, researchers, and outreach professionals actively engaged in climate adaptation and resiliency efforts on reservation lands. Study respondents prioritize climate information and data that serve to assess local climate change impacts, enhance food security, and integrate the traditional knowledge of their communities into reservation-wide climate adaptation initiatives. In this arid and predominantly rural region, respondents prioritize water quality data as their highest need followed by streamflow data and air temperature data. They most frequently access their respective Tribal sources of climate information and data. This participatory research identifies needs unique to reservation lands in the southwestern United States while illuminating the critical role of Indigenous sovereignty in enhancing climate resiliency. As such, it assesses and reports the climate information and data needs of Indigenous communities in the Southwest through the lens of individuals engaged in or interested in climate adaptation. Statistical analyses of primary data collected through this survey produce a hierarchy of climate data and information priorities that highlight the unique needs of survey participants which have been shared with Tribal nations who participated in this research. The persistence of Indigenous communities in a region characterized by historical climate extremes and water scarcity implies that climate resilience is an inherent part of the culture and economies of these communities. Integrating traditional knowledge and values into adaptation strategies may be particularly advantageous, and perhaps a continuance of sustainable practices that have persisted and endured for thousands of years.

Factors Affecting United States Geological Survey Freshwater Irrigation Withdrawal Estimates in Utah

Jason Manley, Utah Water Research Laboratory

The primary aim of this study was to validate factors used within the United States Geological Survey's (USGS) statewide, sub-state region, and county-level irrigation withdrawal estimates in Utah. This included investigating how those factors relate to irrigated acreages in the state and which acreages form the foundation of irrigation withdrawal estimates since 2000 in Utah. Irrigation is the dominant freshwater use in Utah. Utah is, on average, the second driest state in the U.S., with drier conditions projected in the coming decades. Prior studies have identified factors related to irrigation withdrawals, including total irrigated acreages, on-farm irrigation technology, and weather variability/freshwater availability. Understanding how these key indicators relate to irrigation withdrawals can inform more sustainable future decisions. Few studies have focused on Utah, no recent studies evaluate USGS irrigation data at the county-level, and no studies have considered relating factors directly with irrigated acres. Using a non-parametric Kendall Tau-b correlation test, this study assessed factors of irrigation withdrawals and acreages at state, sub-state, and county levels. Freshwater availability key indicators in this study included unimpaired stream flows, reservoir levels, precipitation, and air temperatures. The results indicate that at the state-level, irrigation withdrawals and irrigated acres or sprinkler irrigated acres do not have a strong positive correlation, indicating strategies such as fallowing fields or conversion to sprinkler systems may not reduce freshwater withdrawals. There were relatively few correlations with water-year analyses, indicating that our current infrastructure and practices may have been adequate at handling annual weather variability. Individual areas' results vary widely, showing the importance of finer scales of analysis, and closer inspection of the specific results from areas of interest is recommended.

Efficacy and Design of Saturated Riparian Buffers (SRBs) in Central Illinois

Emma Eldridge, Southern Illinois University Carbondale (J.E. Schoonover, K.W.J. Williard, J.C. Gillespie, J.C. Snyder)

Saturated riparian buffers (SRBs) are an edge-of-field best management practice (BMP) that have been adopted to reduce nutrient loads reaching a water body in tile drained, row crop agriculture fields. SRBs function by intercepting existing tile lines at a control structure designed to artificially raise the water table to redirect flow into a vegetated riparian buffer. To date, SRB studies have used the same standard design with one dispersion line extending laterally in a vegetated buffer. In 2018 a "pitchfork" SRB equipped with a backflow check valve was implemented that utilized three dispersion lines extending into a vegetated buffer. The pitchfork SRB was installed adjacent to a standard SRB design buffer on the same field in Moultrie County, Illinois. The objectives of this study were to monitor and compare water quality and quantity of groundwater and tile outlets within the two SRB systems. The pitchfork design redirects 17% of base flow and nutrients into the buffer zone; while the standard buffer experienced backflow even during low flow conditions, contributing 182% more water and nutrients to the stream than entered the control structure from the field. During high flow events the influx of water from the field and backflow generated from rising groundwater in the buffer caused turbulence in the control structures, which resulted in inaccurate pressure transducer readings and therefore erroneous discharge calculations. These data indicate that neither buffer is performing as well as expected, especially during higher flows. While both buffers experience backflow, presumably due to site conditions, our results show nutrients are attenuated as water moves through the buffers, so nutrient loads are being reduced. Future studies and designs in this region should focus hydrologic characteristics—like buffer width, saturated hydraulic conductivity, and difference in hydraulic head in the buffer—and understanding how those characteristics influence SRB performance.

A Comparison of the Denitrifying Capabilities of Bioreactors Comprised of Woodchips, Pine Bark, and Peanut Hulls Paired with Expanded Slate as a Phosphate Adsorbent at High Flow Rates

Ann Marie Lindley, East Carolina University (N. Bell, M. O'Driscoll, G. Iverson, C. Humphrey, J. Hoben)

Denitrifying bioreactors are commonly utilized as a best management practice in agricultural systems to reduce nitrate in drainage waters. The USDA recommends the use of bioreactors with hydraulic retention times (HRTs) of 4+ hours and commonly recommends utilization of woodchips as a carbonaceous substrate. This study compares the nitrate-reducing capabilities of pilot-scale bioreactors comprised of locally-sourced woodchips, pine bark, and peanut shells (a regional agricultural waste product) utilizing low HRTs (30 minutes, 1 hour and 2 hours), corresponding to higher flow rates that are often observed in first order, sub-urban streams that are affected by non-point source nutrient inputs. The phosphate desorption rate of expanded slate paired downstream of the denitrifying bioreactors is also being explored. The bioreactors have been operating under antecedent saturated conditions (ASCs) since June 2021, during which nutrient-amended water from a rainwater-fed pond is pumped through the bioreactors once per week. Preliminary data suggests that a) high flow rates, such as those that correspond with HRTs as low as 30 minutes, still promote nitrate removal; b) pine bark is the most effective substate for nitrate removal at all tested flow rates; and c) peanut hulls serve as an ammonium source. These data suggest that denitrifying bioreactors can be effective tools for reducing nitrate under high flow conditions, such as those in first order sub-urban streams. Preliminary conclusions suggest that carbonaceous substrates (e.g., pine bark) other than woodchips could be effective at promoting denitrification, thus more research is warranted on quantifying denitrification from various carbonaceous media.

Impacts of Flue Gas Desulfurization Gypsum Application on Surface Runoff Water Quality in Southern Illinois

Kevin Turnbow, Southern Illinois University Carbondale (D. Poudel (1st author), H. Kaur, K. Turnbow, K. Williard, J. Schoonover, A. Sadeghpour, J. Snyder, J. Gillespie)

The agricultural community is seeking to minimize nutrient losses while ensuring high crop yields. The primary objective was to evaluate different application rates of flue gas desulfurization (FGD) gypsum (calcium sulfate dihydrate) for reducing phosphorus (P) losses in surface runoff. Research also aims to assess the impact of FGD Gypsum, calcium and sulfur additions on corn and soybean yield as well as the impact of gypsum application on soil physical and chemical properties. Four treatments including: control and gypsum at 1, 2, and 6 tons/acre were applied to assess the effect of gypsum applications on runoff water quality. DRP (Dissolved Reactive Phosphorus), TP (Total Phosphorus), TSS (Total Suspended Solids) and Sulfate loads were assessed on surface-runoff samples. A total of 64 events were collected since Dec. 2, 2018, until Dec. 18, 2021. Results showed that DRP, TP, and TSS concentrations and loads lowered in treated samples compared to control. Regarding the DRP and TP loads, treatment Gypsum 1 ton/acre showed 11% and 15% reduction, Gypsum 2 tons/acre showed 31% and 29% reduction, and Gypsum 6 tons/acre showed 25% and 27% reduction, respectively compared to control. Regarding TSS, Gypsum 1 ton/acre had 46% reduction, Gypsum 2 tons/acre had 58% reduction, and Gypsum 6 tons/acre had 66% reduction compared to control. Sulfate values were higher in all the treatments compared to control, indicating that sulfur dissociated from calcium and likely formed $Ca_3(PO_4)_2$ in the soil. Post-treatment samples did not show any increases in heavy metals or trace elements compared to control. Overall, gypsum application appears to be a tool farmers can use to reduce P leaching and improve water quality.

Using Remote Sensing Techniques to Identify Concentrated Pockets of Coal Ash within a Recreational Lake

Joni Backstrom, UNC Wilmington (K. Burdette)

Coal ash, or coal combustion residuals (CCRS), is produced at coal-fired power plants. Coal ash has been stored in unlined waste storage ponds, commonly known as coal ash ponds, for decades at many locations across the United States. Coal ash contains numerous contaminants, including arsenic, mercury, selenium, chromium, cadmium, lead, boron, manganese, thallium, vanadium, and others. Coal ash is one of the largest types of industrial waste generated in the US and, importantly, poses serious risks to surface waters like lakes and rivers, human health, coastal ecosystems, groundwater and air quality. The North Carolina Department of Environmental Quality (NCDEQ) has required that all coal ash ponds in North Carolina be cleaned up, and cleanup activities at some locations are close to completion. A significant amount of work has been done over the last ten years to clean up legacy of coal ash pollution and much will be happening in the coming years as closure plans continue to be implemented. This pilot project tested the feasibility of using sidescan sonar as a tool to identify concentrated pockets of coal ash within Sutton Lake, North Carolina, a recreational water body which also provided cooling water for the now retired coal fired power plant. Differences in acoustic reflectivity and water depths confirmed the existence of old deep channel systems comprising muddy sediments surrounded by shallower sandbank areas. A chemical analysis of sediment samples from within the channel deposits confirmed elevated heavy metal concentrations, especially selenium, often exceeding safety threshold limits set by the EPA. The ability to accurately delineate and map areas of concentrated coal ash deposits will prove valuable and cost-effective when clean-up operations are undertaken in the future. This innovative survey method can be used as a model for other coal ash clean-up activities nationwide.

Assessing Indicators of Soil Quality and Forest Productivity across a Chronosequence of Afforested Cropland in Cypress Creek National Wildlife Refuge

Maggie Herrmann, Southern Illinois University Carbondale (K. Williard, J. Schoonover, E. Holzmueller, C. Ruffner, E. Holzmueller)

Afforestation, the planting of trees on land not in forest cover, is a sustainable forest management practice increasing in prevalence worldwide. In addition to storing carbon, replanting native forests can increase plant diversity, improve soil and water quality, and decrease annual water yield. Long-term farming of land can compact the soil and deplete soil nutrients like nitrogen and phosphorus which are essential for plant growth. Additionally, nutrient laden runoff from fertilizers often creates eutrophic conditions in nearby lakes, rivers, and streams. As a result, many governmental agencies and private organizations have begun replanting native forests worldwide to restore the function of native soils and promote a wide diversity of plant growth and re-establishment of native bottomland forests and wetlands. Since 1982, the state of Illinois has afforested over 100,000 acres of abandoned or marginal cropland. One such replanting effort, and the site of our study, occurred at Cypress Creek National Wildlife Refuge (CCNWR), in southern Illinois. To assess forest restoration success in terms of ecological function, seven ecological indicators were measured across a chronosequence of 50 afforested sites and 25 mature forested sites. Soil indicators: bulk density, aggregate stability, total nitrogen, total carbon, and labile carbon, and vegetation indicators: forest productivity and stand density were assessed for each site. Additional sampling was completed on 25 nearby agriculture fields for each of the five soil indicators. The objectives of this project are to quantify the extent of alterations to indicators of ecological function immediately following afforestation efforts up until present day sampling, and to develop soil and vegetation indicator values of restored ecological function for afforested sites. Study results will be presented at the conference.

The Hybrid Training Model: Effective, In-Depth Water Resource Management Education

Kim Morganello, Clemson University (S. O'Shields, G. Wallover, D. Hitchcock, A. Scaroni, C. Sawyer)

A dynamic teaching strategy is required to provide information on diverse water management needs and the associated design practices, considerations, and stressors. Audiences in need of water resource education include technical, professional, and residential, varying in knowledge level, time commitment, and priorities. To address this need, Clemson University Cooperative Extension has developed a hybrid approach to water resource management training that uses a combination of online and field-based instruction. Since 2015, three certification courses (Master Pond Manager, Post-Construction BMP Inspector, and Master Rain Gardener) have been offered regularly and there are plans to develop additional courses in 2022. The hybrid training model delivers in-depth information and application through multi-week online training courses with an associated field day(s). The overall objective of these courses is to empower participants to design, manage, and maintain stormwater best management practices in South Carolina communities and beyond. Effective implementation of these practices (stormwater pond management, bioretention, permeable pavement, dry detention basins, rainwater harvesting, and more) can help to make the built environment more resilient and more closely mimic pre-development hydrology. The participation, feedback, and knowledge gained from past hybrid course participants have improved pedagogy that leads to practical outcomes. The Extension process has evolved to incorporate this hybrid approach. Lessons learned include development timeline, resources required for long-term success, effective partnership, engagement, and more. In the face of COVID, the hybrid training programs were well suited to deliver in-depth information conveniently and efficiently. This presentation will highlight the hybrid model with a focus on development, implementation, challenges, and successes.

Community Cloud Computing Services to Support Water Science Education and Research
Anthony Castronova, Consortium of Universities for the Advancement of Hydrologic Science, Inc.

The use of research and educationally focused cloud computing environments has become ubiquitous in the earth sciences. For several years, the Consortium of Universities for the Advancement of Hydrologic Science, Inc (CUAHSI) has been adopting and extending research-grade cloud computing tools to provide powerful, free, and accessible capabilities to the water science community. While, similar initiatives are widespread across U.S. research universities, our efforts focus primarily on providing scientifically configurable environments for virtual events such as conference workshops, interactive presentations, and educational lectures. To address this broad range of use cases, CUAHSI hosts multiple cloud computing technologies including JupyterHub, BinderHub, and MATLAB Online. Since 2020, we leveraged our experience in this field to support a number of educational events, including an international virtual hydrological modeling course hosted at the University of Saskatchewan, which consisted of approximately 90 concurrent users investigating and executing hydrologic models. This presentation highlights CUAHSI's cloud computing cyberinfrastructure within the context of this large international event. We provide an overview of existing capabilities and how they have been used to successfully support community activities, as well as opportunities for leveraging our services in future events.

Evaluating the Efficacy of Targeted Educational Interventions to Improve Residential Outdoor Water-Use Efficiency

Rosa Garcia, Texas A&M University (A. Lewis (1st author), P. Khedun, R. Kaiser)

Water utilities use a variety of communication strategies to encourage their customers to conserve water. Targeted interventions, such as providing personalized information, hosting educational seminars, conducting water audits, or creating nudge messaging services increase the likelihood that consumers will adopt conservation-oriented behaviors and use water more efficiently. Intervention programs, thus, help build resilience into municipal water distribution systems by creating a more responsible consumer base. However, very few studies have examined their efficacy at the consumer level. In this study, we examine the individual and combined impacts of four targeted interventions on single-family residential outdoor water use in College Station, Texas, for the period 2011 to 2020. These interventions include sprinkler irrigation system checkups by irrigation specialists, letters mailed to residents with tailored water budgets, weekly watering recommendations administered via email, and neighborhood seminars to educate consumers about efficient landscape management practices. Monthly billing data and landscape water budgets, which were estimated using neighborhood-level evapotranspiration and precipitation data, were used to identify customers who were overwatering. Our analysis shows that the conservation programs have led 6,500 households to save over 660 million gallons of water—equivalent to more than two months of the city-wide total water use during the winter. Preliminary results suggest that irrigation checkups are the most effective intervention, with recipients conserving the most water at the customer level and significantly reducing their over-irrigation for up to three years after the intervention. Lessons learned from this study can help water utilities conserve water by implementing similar interventions in their water service areas.

Direct Mailing Educational Campaign Impacts on the Adoption of Grazing Management Practices

Allen Berthold, Texas A&M AgriLife, TWRI (T. Olsovsky, M. Schramm)

Watershed-based plans are developed by local communities, where management measures and numeric targets are identified with the intent of protecting water quality. In watersheds where agricultural production is present, it is common to include a management measure regarding the adoption of agricultural best management practices through existing government programs. These programs offer both technical and financial assistance for eligible landowners; however, many landowners are not aware that this assistance is available. One major role for watershed coordinators is to encourage adoption through newsletters, newspaper articles, public meetings, social in-person educational programs, and other methods of reaching the target audience. These outreach methods are often limited to an email list that has been developed over the years, followers on social media, and the ability for people to attend an in-person event, all of which have a limited reach. To expand our reach as watershed coordinators, we have conducted a mass mailing campaign where every landowner who owns 10 acres of land or more, making them eligible for an agricultural exemption, was reached. The mailing campaign consisted of a single educational flyer that focused on encouraging proper stocking rates for beef cattle where key messages included: indicators of overstocking, implications of overstocking, advantages of proper stocking rates, practices to help improve stocking rates, and sources of technical and financial assistance. The flyer was mailed to landowners four times, over a six-month period, to 4,921 landowners and resulted in a modeled increase in the adoption of practices by 300%.

Innovating Water Conservation Strategies through North Carolina's Agricultural Water Resources Assistance Program (AgWRAP)

Sydney Mucha, North Carolina Department of Agriculture and Consumer Services Division of Soil and Water Conservation

North Carolina's Department of Agriculture and Consumer Services Division of Soil and Water Conservation offers a unique cost share program—Agricultural Water Resources Assistance Program or AgWRAP—that provides financial assistance to farmers to implement best management practices (BMPs) to conserve water resources through water quantity storage and efficiency. One of the 8 BMPs offered through AgWRAP is Conservation Irrigation Conversion. This BMP allows for the modification of an existing irrigation system to be converted into a more efficient system to allow for water savings and uniformity of irrigation water application. Examples of this BMP include conversion from hand watering to drip or micro irrigation, center-pivots and lateral move irrigation systems to drop nozzles or low-pressure spray nozzles. These conversions have saved thousands of gallons of water, increased crop production, led to less erosion on farm fields, and helped produce farmers better comply with new produce safety regulations. This presentation by Sydney Mucha, AgWRAP Coordinator for the Division, will showcase AgWRAP's sustainable irrigation solutions through two case studies. The first case study will feature a Guilford Soil and Water Conservation District Conservation Irrigation Conversion project that allowed the cooperator to see a return on investment and water savings more quickly on his row crop farm by using AgWRAP. The second will feature a Durham Soil and Water Conservation Agricultural Water Storage and Collection System and Micro-Irrigation project that was undertaken by Durham Greens Farm, a minority owned urban farm, that was able to collect rainwater runoff from their greenhouses and water their produce through micro irrigation.

The Hybrid Training Model: Effective, In-Depth Water Resource Management Education

Kim Morganello, Clemson University (S. O'Shields, G. Wallover, D. Hitchcock, A. Scaroni, C. Sawyer)

A dynamic teaching strategy is required to provide information on diverse water management needs and the associated design practices, considerations, and stressors. Audiences in need of water resource education include technical, professional, and residential, varying in knowledge level, time commitment, and priorities. To address this need, Clemson University Cooperative Extension has developed a hybrid approach to water resource management training that uses a combination of online and field-based instruction. Since 2015, three certification courses (Master Pond Manager, Post-Construction BMP Inspector, and Master Rain Gardener) have been offered regularly and there are plans to develop additional courses in 2022. The hybrid training model delivers in-depth information and application through multi-week online training courses with an associated field day(s). The overall objective of these courses is to empower participants to design, manage, and maintain stormwater best management practices in South Carolina communities and beyond. Effective implementation of these practices (stormwater pond management, bioretention, permeable pavement, dry detention basins, rainwater harvesting, and more) can help to make the built environment more resilient and more closely mimic pre-development hydrology. The participation, feedback, and knowledge gained from past hybrid course participants have improved pedagogy that leads to practical outcomes. The Extension process has evolved to incorporate this hybrid approach. Lessons learned include development timeline, resources required for long-term success, effective partnership, engagement, and more. In the face of COVID, the hybrid training programs were well suited to deliver in-depth information conveniently and efficiently. This presentation will highlight the hybrid model with a focus on development, implementation, challenges, and successes.

Community Cloud Computing Services to Support Water Science Education and Research
Anthony Castronova, Consortium of Universities for the Advancement of Hydrologic Science, Inc.

The use of research and educationally focused cloud computing environments has become ubiquitous in the earth sciences. For several years, the Consortium of Universities for the Advancement of Hydrologic Science, Inc (CUAHSI) has been adopting and extending research-grade cloud computing tools to provide powerful, free, and accessible capabilities to the water science community. While, similar initiatives are widespread across U.S. research universities, our efforts focus primarily on providing scientifically configurable environments for virtual events such as conference workshops, interactive presentations, and educational lectures. To address this broad range of use cases, CUAHSI hosts multiple cloud computing technologies including JupyterHub, BinderHub, and MATLAB Online. Since 2020, we leveraged our experience in this field to support a number of educational events, including an international virtual hydrological modeling course hosted at the University of Saskatchewan, which consisted of approximately 90 concurrent users investigating and executing hydrologic models. This presentation highlights CUAHSI's cloud computing cyberinfrastructure within the context of this large international event. We provide an overview of existing capabilities and how they have been used to successfully support community activities, as well as opportunities for leveraging our services in future events.

Evaluating the Efficacy of Targeted Educational Interventions to Improve Residential Outdoor Water-Use Efficiency

Rosa Garcia, Texas A&M University (A. Lewis (1st author), P. Khedun, R. Kaiser)

Water utilities use a variety of communication strategies to encourage their customers to conserve water. Targeted interventions, such as providing personalized information, hosting educational seminars, conducting water audits, or creating nudge messaging services increase the likelihood that consumers will adopt conservation-oriented behaviors and use water more efficiently. Intervention programs, thus, help build resilience into municipal water distribution systems by creating a more responsible consumer base. However, very few studies have examined their efficacy at the consumer level. In this study, we examine the individual and combined impacts of four targeted interventions on single-family residential outdoor water use in College Station, Texas, for the period 2011 to 2020. These interventions include sprinkler irrigation system checkups by irrigation specialists, letters mailed to residents with tailored water budgets, weekly watering recommendations administered via email, and neighborhood seminars to educate consumers about efficient landscape management practices. Monthly billing data and landscape water budgets, which were estimated using neighborhood-level evapotranspiration and precipitation data, were used to identify customers who were overwatering. Our analysis shows that the conservation programs have led 6,500 households to save over 660 million gallons of water—equivalent to more than two months of the city-wide total water use during the winter. Preliminary results suggest that irrigation checkups are the most effective intervention, with recipients conserving the most water at the customer level and significantly reducing their over-irrigation for up to three years after the intervention. Lessons learned from this study can help water utilities conserve water by implementing similar interventions in their water service areas.

Direct Mailing Educational Campaign Impacts on the Adoption of Grazing Management Practices

Allen Berthold, Texas A&M AgriLife, TWRI (T. Olsovsky, M. Schramm)

Watershed-based plans are developed by local communities, where management measures and numeric targets are identified with the intent of protecting water quality. In watersheds where agricultural production is present, it is common to include a management measure regarding the adoption of agricultural best management practices through existing government programs. These programs offer both technical and financial assistance for eligible landowners; however, many landowners are not aware that this assistance is available. One major role for watershed coordinators is to encourage adoption through newsletters, newspaper articles, public meetings, social in-person educational programs, and other methods of reaching the target audience. These outreach methods are often limited to an email list that has been developed over the years, followers on social media, and the ability for people to attend an in-person event, all of which have a limited reach. To expand our reach as watershed coordinators, we have conducted a mass mailing campaign where every landowner who owns 10 acres of land or more, making them eligible for an agricultural exemption, was reached. The mailing campaign consisted of a single educational flyer that focused on encouraging proper stocking rates for beef cattle where key messages included: indicators of overstocking, implications of overstocking, advantages of proper stocking rates, practices to help improve stocking rates, and sources of technical and financial assistance. The flyer was mailed to landowners four times, over a six-month period, to 4,921 landowners and resulted in a modeled increase in the adoption of practices by 300%.

Innovating Water Conservation Strategies through North Carolina's Agricultural Water Resources Assistance Program (AgWRAP)

Sydney Mucha, North Carolina Department of Agriculture and Consumer Services Division of Soil and Water Conservation

North Carolina's Department of Agriculture and Consumer Services Division of Soil and Water Conservation offers a unique cost share program—Agricultural Water Resources Assistance Program or AgWRAP—that provides financial assistance to farmers to implement best management practices (BMPs) to conserve water resources through water quantity storage and efficiency. One of the 8 BMPs offered through AgWRAP is Conservation Irrigation Conversion. This BMP allows for the modification of an existing irrigation system to be converted into a more efficient system to allow for water savings and uniformity of irrigation water application. Examples of this BMP include conversion from hand watering to drip or micro irrigation, center-pivots and lateral move irrigation systems to drop nozzles or low-pressure spray nozzles. These conversions have saved thousands of gallons of water, increased crop production, led to less erosion on farm fields, and helped produce farmers better comply with new produce safety regulations. This presentation by Sydney Mucha, AgWRAP Coordinator for the Division, will showcase AgWRAP's sustainable irrigation solutions through two case studies. The first case study will feature a Guilford Soil and Water Conservation District Conservation Irrigation Conversion project that allowed the cooperator to see a return on investment and water savings more quickly on his row crop farm by using AgWRAP. The second will feature a Durham Soil and Water Conservation Agricultural Water Storage and Collection System and Micro-Irrigation project that was undertaken by Durham Greens Farm, a minority owned urban farm, that was able to collect rainwater runoff from their greenhouses and water their produce through micro irrigation.

Irrigation Best Management Practices: Influencing Factors in Arkansas, Louisiana, and Mississippi

Merri Day, Kansas State University (Q. Huang, C. Henry, J. Krutz)

This study uses the 2016 Irrigation Survey data from Arkansas, Louisiana, and Mississippi to investigate factors that influence producers' decisions regarding irrigation best management practices (IBMPs). IBMPs included in the survey can be grouped as: field management practices (zero or precision-grade leveling, end blocking, warped surface, and deep tillage), water flow control practices (computerized pipe-hole selection, multiple-inlet irrigation, surge irrigation, alternate wetting and drying, cutback irrigation, flow meters, and pump timers), water recovery/storage practices (tail-water recovery system and on-farm storage reservoir), and advanced irrigation scheduling practices (soil moisture sensors, ET or atmometers, computerized scheduling, and Woodruff charts). Multivariate probit models are used to estimate producer choices among the four groups of IBMPs, as well as producer choices among individual IBMPs. Ordered logit models are used to estimate the number of groups of IBMPs, the total number of individual IBMPs used by producers, and the number of IBMPs used from each group. Explanatory variables include producer characteristics (being a landowner, education, years of farming experience, income), farm characteristics (total irrigated acres, percent of irrigated acres under gravity irrigation, percent of irrigation from ground water, farm location), and conservation variables (participation in conservation programs within the last five years), and producer perception of groundwater shortage on his or her own farm. We find strong correlations between higher irrigated acres and water flow meters, and the use of many IBMPs. Our results indicate that more years of farming experience is negatively associated with use of advanced irrigation scheduling practices, and participation in conservation programs such as EQIP is associated with use of water recovery and storage practices, as well as land leveling practices. Being located in a critical groundwater area did not have any statistically significant effect on producers' decisions concerning IBMPs in this study.

Role of Sponsored Conservation Programs on Adoption of Irrigation Water Best Management Practices in the Lower Mississippi River Basin

Nicolas Quintana, Mississippi State University (D. M Gholson, G. Kaur, G. Singh, J. Massey, J. Krutz, M. Reba, C. Henry, T. Cooke, III, M. Locke)

The Mississippi River Valley Alluvial Aquifer (MRVAA) underlies and sustains highly productive agricultural areas in the Lower Mississippi River Basin (LMRB) that include portions of Arkansas, Louisiana, Mississippi and Missouri. Depletion of the MRVAA presents a complex conservation problem that requires careful irrigation and drainage management because despite abundant annual rainfall, only a small fraction of total precipitation occurs during the growing season; and when it does, it tends to be intense and rapid—which reduces precipitation effectiveness. Regulatory intervention to curtail groundwater use is unlikely in the region. Furthermore, any curtailment could have severe impacts on regional agricultural production and the economies and societies it supports. In this context, farmer adoption of irrigation best management practices (BMPs) emerge as a viable avenue to slowdown the rate of aquifer depletion while expanding the productivity of groundwater used in agriculture. Various public and private initiatives have established programs to provide incentives for farmers to adopt such conservation practices. We apply a Poisson empirical count model with data from a survey of producers across the LMRB to identify how participation in sponsored conservation programs influence the number of irrigation BMPs adopted by farmers. We find that farmer participation in these programs is associated with 1.4 more practices adopted on average. Furthermore, we compare and validate the empirical results comparing NRCS administrative data for the Mississippi Delta with the implicit irrigation BMP adoption curve for that survey sub-group. The regression analysis indicates that the number of years of farmer experience is negatively correlated with the number irrigation BMPs while perceiving groundwater problems at the farm or state level increase the number of irrigation BMPs adopted.

Tile Drainage, Sub-Irrigation and Furrow Irrigation for Soybean Production in Mid-South Mississippi Delta

Gurpreet Kaur, Mississippi State University (G. Singh, N. Quintana, D. Gholson, J. Krutz, D. Dodds)

Mississippi State receives annual average precipitation of 1372 mm. More than 60% of the annual total precipitation is received during late winter or early spring (December to March). Low temperatures along with greater precipitation results in drainage issues in the Mississippi Delta Region. In this region land under row crop production is land-formed to 0.05 to 0.1% slope to help with better surface drainage. Surface and subsurface drainage has been a long-term issue that growers face during every growing season. Due to inadequate subsurface drainage planting, corn and soybean are often delayed in this region. Delayed planting combined with lower precipitation and higher temperatures during summers often results in yield drags. Therefore, supplemental irrigation as furrow irrigation is a common practice among the Mississippi growers. Tile drainage and sub-irrigation are new concepts in the Mid-South US. Sub-surface drainage using tile can be a potential game-changer for the Mississippi growers. Early planting windows for row crops in Mississippi are narrow. Tile drainage can help to drain the subsoil and can help with widening the planting windows. The overall objective of this study was to evaluate tile drainage plus subirrigation system in the Mississippi Delta. The specific objectives were to evaluate soybean production on non-tile drained non-irrigated, non-tile drained furrow irrigated, tile-drained furrow irrigated, and tile-drained sub-irrigation treatment plots and to evaluate the effect of the tile drainage on the drying and wetting of the soil profile for two different tile spacings. This research project was established in summer 2021 on a Sharkey clay soil series having more than 70% clay content with two tile spacings 15’ and 20’. The year 2022 will be the first year to evaluate the effect of drainage treatments on soybean production. Sentek soil moisture sensors were installed in Jan. 2022 to a depth of 91 cm to monitor soil moisture changes from non-tile drained and tile-drainage treatments. Tile drainage installation design and preliminary data on soil and soil moisture will be presented at the conference.

Economic Value of Irrigation Water in Oklahoma Panhandle Counties

Lixia Lambert, Oklahoma State University (H. Shear, J. Warren)

The Oklahoma Panhandle region is semi-arid and is dominated by row crop production systems. Agriculturalists working on the region's land have a long history of managing its fragile soils and limited water resources. The region's producers rely on the Ogallala Aquifer for irrigation. Of the total arable land in the Oklahoma Panhandle, nearly 51% is cultivated with wheat, about 25% to grain sorghum, and about 21% to corn. Continued reliance on the aquifer for water-intensive crops and unsustainable water extraction rates has reduced the water table and well capacity. A recent survey of producers who participated in Oklahoma's Master Irrigator Program found that 13 of the 15 farm managers acknowledged declining well capacities on their operations. These producers and water managers would like to increase water use efficiency, and maximize profit levels while reducing water withdrawals during the growing season. However, achieving this goal can be challenging without an understanding of economic (marginal) value of irrigation water. We developed a partial equilibrium (PE) model to estimate the marginal value of irrigation water for Oklahoma Panhandle three counties. The analysis will focus on cropping pattern changes that are expected to mitigate the inter-temporal stress of water shortages on the economic performance of agricultural enterprises. Given data on costs, prices, and production levels observed from 2020, along with inputs including water, land, other variable costs, we proceed by benchmarking the PE model using Positive Mathematical Programming (PMP). The PE model allows for decision-making at the county level in a given growing season. The model allocates expected irrigation withdrawals to maximize producers' gross margins, subject to economic, social, physical, technological, and water availability constraints. The marginal (economic) values of productive factors, such as land and water, are determined by incrementally changing resource availability constraints.

Impact of Low Energy Precision Application (LEPA) Adoption on Irrigation Decisions and Water Saving in High Plains Aquifer Kansas

Amer Al-Sudani, Mississippi State University (N. Quintana)

The High Plains aquifer (HPA) is the source of irrigation water for 98% of all irrigated fields in Kansas (Hendricks and Peterson, 2012). Prolonged pumping from this aquifer has led to declining water levels, especially in the southwestern part of the state where depletion ranged from 5 feet to more than 80 feet between 2000 and 2017 (Buchanan et. al., 2001). To prolong the life of the aquifer and sustain the levels of agricultural productivity, producers and policy makers look for ways to improve water management at the farm and district levels by reducing the rates of groundwater pumping (water conservation) and increasing the benefits obtained for a given amount of irrigation water applied (irrigation efficiency). Various governmental conservation agencies at the state and federal levels promote the adoption of agricultural practices associated with increased irrigation water use efficiency under the assumption that increased irrigation water use efficiency results in reduced water use. This assumption has been examined in the literature with contrasting results. Notably, Pfeiffer and Lin (2014) found that conversion from conventional center pivot to more efficient Low Energy Precision Application (LEPA) technology does not reduce overall water use. In this research, we apply the approach in Pfeiffer and Lin (2014) to updated data and confirm their findings under those methods. We use an inverse probability-weighted estimator with regression-adjustment (IPWRA) to further expand the analysis by controlling for heterogeneity of climate and pumping cost that can impact irrigation decisions. When we account for the heterogeneity in climate and pumping cost, our results indicate that there is a decrease in water applied per acre when farmers adopt LEPA.

Surface water use for irrigation in two Mississippi agricultural regions

Mary Love Tagert, Mississippi State University (M.L. Brock, Z. Green)

Surface water is being used for irrigation in two agricultural regions of Mississippi – the Mississippi Delta region and northeast Mississippi. Producers in both areas rely on supplemental irrigation to meet crop water demands and reduce risk during the summer growing season. In the Mississippi Delta, groundwater from the Mississippi River Valley Alluvial Aquifer (MRVAA), a shallow subsurface aquifer, serves as the main source of water for irrigation. The MRVAA experiences the second highest daily pumping rate in the United States at 45,803 million liters per day. Over 60% of cropland in the Mississippi Delta is irrigated with groundwater from the MRVAA, and the continued increase in irrigation over the past few decades has resulted in declining MRVAA groundwater levels in the central Delta. As a result, more producers in the Mississippi Delta are using surface water for irrigation. In northeast Mississippi, it is both difficult and expensive to access groundwater for irrigation, so surface water is the main source of water for irrigation in this region of the state. In both agricultural areas, surface water is obtained from both nearby rivers and streams and by capturing runoff from precipitation and irrigation in on-farm water storage (OFWS) ponds. Although there are differences in how OFWS systems are constructed in the Mississippi Delta and the northeast region of the state, systems in both regions provide the dual benefit of providing water for irrigation and reducing downstream nutrient runoff. Thus, there is an ongoing need to quantify the use of these systems to better measure their benefits on a watershed scale. From 2007 to 2020, a geospatial inventory showed that 794.5 hectares of land have been converted to surface water storage in OFWS systems in the Big Sunflower River Watershed (HUC 08030207) in the Mississippi Delta. A similar geospatial inventory is in progress for northeast Mississippi.

Resources and Lessons Learned from the WBP Development Process

Kathryn Ellis, McCormick Taylor

There are many challenges to develop a watershed-based plan (WBP) that incorporates the mandatory EPA 9 elements. Although time and budget are constraints with every WBP, every watershed is unique, so there is no cookie cutter method for getting the work done. How do we identify areas that are sources of pollutants and determine their causes? How do we collaborate with stakeholders to plan out a vision for the watershed, including valuable opportunities for public input and educational outreach? How should we model pollutant loads and estimate the benefits of structural and non-structural practices? How do we assess funding needs and opportunities to implement the plan? In addition to these baseline requirements, many communities are also including recommendations for source water protection and climate change adaptation into WBPs. In this talk I will share how I have leveraged partnerships within the consulting, regulatory, and academic fields to develop several successful WBPs across South Carolina. I will share case study examples from Gills Creek (Columbia, SC), Middle Horse Creek (Aiken, SC), May River (Bluffton, SC), Three Rivers Watershed (Columbia, SC), Goose Creek (Hanahan, SC), and the Lower Caw Caw Swamp (Orangeburg, SC) to illustrate lessons learned and useful strategies for compiling, analyzing, and sharing information in a watershed-based plan.

Watershed Modeling to Improve Water Quality: Lessons Learned as a Professional Engineer
Debabrata Sahoo, Clemson University

The availability of clean water in various aquatic ecosystems such as streams, rivers, and lakes is essential for maintaining a healthy ecosystem. Watershed models are important decision-support systems that aid local agencies such as cities, counties and municipalities in the decision-making process to help understand and achieve the required ecosystem health objectives. In many parts of the US, these watershed water quality models are often developed and delivered by the regulatory agencies following a top-down approach. Frequently, the topdown approach takes little input from the stakeholders. This results in the unsuccessful implementation of the model, particularly on the occasions where the model outputs could potentially have regulatory implications. Further complicating the issue, water quality models are often developed utilizing sparse datasets, which brings into question their applicability when it comes to regulatory decisions. In a recent effort, a bottom-up approach was successfully utilized to improve the water quality in Boyd Millpond, a downstream lake located in the Reedy River watershed in upstate South Carolina. The approach brought together the involvement of multiple stakeholders in the watershed to develop a consensus-driven water quality model. This presentation will highlight some of the interesting experiences over 20 years and critical challenges faced while implementing the bottom-up watershed water quality modeling approach in the Reedy River watershed in general, and Boyd Millpond in particular.

Quantifying Ecosystem Services to Aid in Watershed Management and Planning

Lucas Clay, Clemson University (M. Motallebi, T. O'Halloran)

In South Carolina, the Edisto River Basin (ERB) encompasses one of the longest free-flowing blackwater river systems in the United States. The ERB is approximately 3,120 square miles and encompasses about 10% of the state's land area. This watershed is an area of rich biodiversity and ecosystem services, which are benefits provided by the environment for people. The ERB provides myriad ecosystem services due to its rich habitat, water resources, and longstanding protected areas. The bottomland hardwood forests often sequester the most carbon per unit area, providing benefits for climate change mitigation. The ERB also provides significant ecosystem services in the form of water yield and sediment retention. The Edisto River and surrounding wetlands provide a buffer for flooding events and provides water to an estimated 770,000 people. To understand and protect the sustainability of a system, it is vital to quantify the ecosystem services that exist. To quantify ecosystem services in the ERB, we utilized the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) model for three major ecosystem services: water yield, sediment retention, and carbon stocks. This model utilizes a variety of ecological function datasets to calculate a supply of ecosystem services by 30 meter by 30 meter pixel. Two datasets were produced to assess any change in ecosystem services over time. The outputs provide a scale of the relative benefits for each ecosystem service. The models showed that land use, such as agriculture and urban areas, was large driver in decreasing ecosystem services compared to forested lands and wetlands. Furthermore, the model identified that much of the sediment and water yield occurs in the upper ERB. This type of analysis is important to developing watershed plans and providing the underlying quantification for conservation programs by providing priority areas for ecosystem service protection and restoration.

A Road Map to Restoration: Community Driven Watershed Planning on Edisto Island, SC
Amy Scaroni, Clemson University (G. Wallover, C. Greenthaler)

Edisto Island, a Lowcountry sea island within the ACE Basin Watershed, encompasses three sub-watersheds classified as outstanding resource waters. While Edisto Island is largely considered rural and agricultural, it is also home to the Town of Edisto Beach, a suburban beach-front community with a large, seasonal part-time population. These Edisto Island subwatersheds include 25 monitored sites listed as impaired for one or more pollutants, and two Total Maximum Daily Loads (TMDLs). Like many coastal watersheds across South Carolina, the waterways on and around Edisto Island are affected by pollution from a variety of sources, with fecal bacteria being the primary pollutant of concern. High levels of bacteria have resulted in the closure of shellfish beds to commercial and recreational harvest, which affects both the economy and the deep historic and cultural traditions of the island. Creating a community-driven watershed plan for the area was a first step towards reducing pollution and improving water quality for the Edisto community. However, creating a watershed plan was only the initial step; implementing recommendations requires community buy-in, so the project team worked closely with community leaders and sought input from residents at each stage of plan development. We'll share our perspective on how we combined existing water quality data and GIS data layers with local community knowledge of the watershed to pinpoint key sources of pollution across the watershed. This prioritization effort identified several key areas across the watershed to target for best management practices that could most effectively lead to pollutant load reductions. We'll also share our lessons learned and highlight key communication recommendations to keep residents engaged and informed as implementation of the plan begins. The completed plan serves as a framework to address pollution sources and sets the stage for protecting the valuable shellfish resources at the heart of the community.

An Adaptive Management Case Study of the May River Watershed Action Plan Implementation in Bluffton, SC

Kimberly Jones, Town of Bluffton

The May River watershed in Bluffton, SC is designated a priority watershed by both EPA and SC Department of Health and Environmental Control (SCDHEC). The river is also recognized by SCDHEC as an Outstanding Resource Water due to its exceptional recreational, ecological, and economic resources and value. Due to these characteristics, the May River is considered the heart of the fast-growing, coastal community of Bluffton and influences all aspects of the residents' quality of life. Thus, when one-third of the river was closed to shellfish harvesting in 2009 due to high fecal coliform concentrations, the community demanded action from the Town of Bluffton to restore and protect this historic use. The ensuing year-long watershed-based planning effort produced the May River Watershed Action Plan (Action Plan). The Action Plan was adopted in 2011 and the Town began to implement its many policy, program, and project recommendations in partnership with stakeholders. Instituting an adaptive management approach has been essential to assess the Action Plan's efficacy to achieve its dual goal of shellfish harvesting restoration and protection within the May River. Additionally, the adaptive management approach has guided decision-making efforts by elected officials on how best to allocate limited resources most effectively. After a decade of implementation and assessment, an updated Action Plan was adopted in 2021 to guide the next phase of watershed-based protection and restoration efforts for the Town. A crucial component of the updated Action Plan is continuing to employ an adaptive management framework.

Stakeholder-Driven Modeling in Support of Groundwater Sustainability: The Floridan Aquifer Collaborative Engagement for Sustainability (FACETS) Project

Wendy Graham, University of Florida, Water Institute (D. Adams, K. Athearn, W.L. Bartels, P. Carton de Grammont, C. Court, M. Dukes, R. Hochmuth, D. Kaplan, J. Lai, J. Love, M. Monroe, K. Schlatter, G. Cowie, M. Masters, K. Rowles, P. Dwivedi, C. Furman, X. Lui, W. Porter, A. Smith, G. Vellidis, L. Kalin)

The Upper Floridan Aquifer (UFA) is among the largest, most productive aquifers in the world and is a vital regional resource shared between Florida, Georgia, and Alabama. The UFA supports agricultural activities worth >$7.5 billion and supplies drinking water to more than 10 million people, but faces significant threats to water quality and quantity which could potentially harm food security, fiber production, and vital ecosystem services. The USDA-NIFA funded Floridan Aquifer Collaborative Engagement for Sustainability (FACETS) project is bringing scientists and a diverse group of stakeholders together in a Participatory Modeling Process to understand the economic-environmental tradeoffs associated with alternative climate, land use, and Best Management Practice (BMP) adoption scenarios, with the ultimate goal of understanding changes needed to achieve agricultural water security and environmental protection. This session will highlight successes, challenges and outcomes of this five-year project including field experiments to measure yields as well as water and nutrient balances of alternative cropping systems and BMPS; co-developed biophysical and economic models to simulate agricultural/silvicultural production, water quality and quantity, and economics for current conditions and alternative future scenarios; optimization modeling to maximize aggregate landowner profit via alternative land use choices subject to environmental flow and water quality restrictions; and use of social learning research to shape the design of the Participatory Modeling Process.

Agronomic and Nitrogen Dynamics of a Corn-Carrot-Peanut Crop Rotation

Michael Dukes, University of Florida (J. Merrick, M. Zamora Re)

There are more first magnitude springs in Florida than anywhere else in the world. Many of these springs are in the northern part of the state which is an area dominated by agricultural land use. This body of work describes a three year field research project that monitored irrigation scheduling strategies and nitrogen (N) rates on a corn-carrot-peanut crop rotation. Monitoring data from this project was used in complementary crop and hydrologic modeling studies. Irrigation scheduling generally consisted of the following: (i) CAL, mimicking grower's practices of a calendar based schedule, (ii) SWB or APP, using a theoretical soil water balance separately or within a smartphone app, (iii) SMS, monitoring volumetric water content measured by soil moisture sensors and triggered using maximum allowable depletion (MAD) and field capacity (FC) as thresholds to refill the soil profile, (iv) NON: non-irrigated plots. For corn and carrot, three N rates were used on each irrigation treatment as follows: 112, 224, 336 kg N/ha relative to the IFAS recommendation of 241 kg/ha. Peanut had no N applied and all crops had similar irrigation treatments. Advanced irrigation scheduling such as SWB or SMS reduced corn irrigation by as much as 40% while maintaining yield. In addition, in these more efficient irrigation methods the 224 kg N/ha was sufficient to maintain maximum yield. Similarly, 224 kg N/ha was sufficient to produce peak carrot yield. The advanced irrigation scheduling reduced irrigation application on carrot and peanut as well.

Large Scale Implementation of Soil Moisture Sensors in Georgia: What Did We Learn?
Wesley Porter, University of Georgia

Multiple research studies have shown that the proper incorporation of soil moisture sensors into a row crop production operation has the ability to not only increase water use efficiency of the crop, but in most cases, it increases yield and profitability of the crop. However, even with these studies and this information the overall adoption of soil moisture sensing systems into production agriculture is low, as documented by a USDA NASS survey which shows that adoption of soil moisture sensors across the U.S. is around 10%. This is alarmingly low considering the benefits that these systems can provide at the farm level. The main goal of this study was to educate and increase the comfort level of utilizing soil moisture sensors for both Extension Agents and Farmers. Over the past 5 years we have been conducting a large on-farm study at the University of Georgia which has focused on increasing the education and adoption levels of soil moisture sensors across the state of Georgia. Through this study we have worked with over forty farmers, and around 20 UGA Extension Agents in over 15 counties across the southern portion of Georgia. The implications of this study have helped us to better understand the associated benefits and issues with adopting soil moisture sensor systems at the farm level. In addition, through this study we have increased educational awareness for our UGA Extension Agents on the usage and implications of implementing soil moisture sensors at the farm level. Due to the implementation of the project we now have many agents that are comfortable installing, using, making decisions from, and uninstalling soil moisture sensor systems. This greatly helps increase our Extension and in-field education capabilities on using soil moisture sensor systems.

Quantifying Environmental and Economic Tradeoffs for Agricultural and Silvicultural Practices in the Floridan Aquifer Region

Nathan Reaver, University of Florida (D. Lee, S. Rath, U. Koirala, F. He, H. Haas, R. De Rooij, T. Borisova, D. Adams, L. Kalin, A. Smith, D. Kaplan, W. Graham)

Agriculture and silviculture are economically and culturally important to the region overlaying the Floridan Aquifer. However, these systems consume water and can be nonpoint sources of nitrate, affecting water quantity and quality in the Floridan Aquifer and associated ecosystems. Specific management practices (MP) applied at the farm- and forest-scale substantially influence aquifer recharge and nitrate leaching, and improved MP can reduce environmental impacts of production while also potentially improving yields. However, such MP typically require new equipment/technologies, often with high costs, potentially prohibiting adoption by producers or reducing economic viability. Quantifying the environmental and economic tradeoffs of MP is important for supporting their adoption and incentivizing environmentally favorable, but potentially economically unattractive, practices. In this study, we engaged with stakeholders in a participatory modeling process to develop and assess a range of MP and enterprise budgets for corn, peanut, carrot, hay, pasture-raised cattle, loblolly pine, slash pine, and longleaf pine in the Floridan Aquifer region. We used the Soil and Water Assessment Tool (SWAT) to simulate groundwater recharge, nitrate leaching load, and crop/forest yields. Economic analyses used enterprise budgets informed by SWAT outputs to compute net returns to the producer. Results were compared within a 3-dimensional tradeoff space (recharge-nitrate load-net returns). Results indicated clear tradeoffs between production systems, with row crops having the highest economic benefit and largest environmental impacts, while forest and forage had smaller economic benefit and lower environmental impacts. Importantly, improved MP dramatically reduced environmental impacts while maintaining similar or higher net returns. These observations suggest that improved MP can improve both the environmental and economic sustainability of agricultural and silvicultural production in the Floridan Aquifer region.

Assessing the Complex Processes that Drive Coastal Flooding in Northeastern South Carolina
Tom Williams, Clemson University (T. O'Halloran, D. Hitchcock)

Georgetown County, SC is prone to a variety of flooding problems. Winyah Bay is a tidal estuary that receives freshwater flow from five separate rivers draining the Pee Dee basin, which extends from the eastern continental divide across central North Carolina and northeastern South Carolina. Drainage in the county is limited by very flat terrain and large areas of soil with limited internal drainage. The region is subject to frequent tropical cyclones bringing heavy rain, tidal surge, and river flooding. We have examined the interaction of river and tidal flows in the complex estuary/tidal river system that enters the ocean through Winyah Bay. The alluvial tidal system produced complex interaction with river floods that varied as hurricanes impacted the various river systems in ways that were unique to an individual river system as well as individual hurricanes. Understanding the tidal stagnation point, how that point moves with variation in river flow, and how water level is determined by differing drivers above and below the stagnation point, is vital to making predictions of flood levels. Understanding of tidal effects is greatly hampered by a lack of data collection infrastructure, although a number of USGS gauges have been added in recent years. USGS gauge data can be used to approximate mean higher high water (MHHW) and mean lower low water (MLLW) levels, given the differences in collection interval between NOAA tidal data and USGS gauges. All tidal datum information relates to the 1983-2001 epoch and excludes the period of enhanced sea level rise noted in the coastal SC data during the last decade. Winyah Bay charting data does not include the complex channels connection the Pee Dee River to the bay and has not been updated since the early 2000's.

Recent Trends in Sea-level Rise Vulnerability and Adaptation Modeling Methodologies

Janardan Mainali, Stetson University (M. James, J.M. Evans)

Increased greenhouse gases are forecasted to further increase global temperature and raise sea levels, impacting people and ecosystems in coastal areas. There are various modeling tools available to anticipate impacts from sea-level rise and explore possible adaptation options that may mitigate future damages. There, however, is a need for more comprehensively understanding similarities, differences, trends, and gaps in how such models are conceptualized and operationalized. Towards this purpose, we performed a systematic review covering approximately the past twenty years of sea-level rise vulnerability and adaptation literature, as listed within Web of Science. We categorized reviewed articles in terms of the adaptation and vulnerability models they developed/used, spatial and temporal coverage of those models, types of systems being modeled, the published accuracy of the model, and how various social and environmental datasets were utilized. Our review shows that the vast majority of published modeling research uses a quantitative approach for assessing vulnerability and adaptive capacity. Among them, Dynamic Interactive Vulnerability Assessment (DIVA) is most used in socio-environmental adaptation, while the Sea Level Rise Affecting Marshes Model (SLAMM) is most used in natural ecosystem modeling along with several other models. Most of the analyses are performed at the country scale followed by cities and provinces. There does appear to be a need for more robust consideration of geographic and temporal scaling when assessing both vulnerability and adaptive capacity. Frequent use of property-based valuations in vulnerability assessments and adaptation-based decision support also may pose substantial justice issues, especially in terms of prioritizing actions that primarily benefit wealthy coastal landowners over other affected citizens. The insights derived from this review can help decide the model to be used in site-specific adaptation modeling and can direct future development of accurate, comprehensive, and useful vulnerability and adaptation models.

Flood Prediction Using an Artificial Recurrent Neural Network

Rishav Karanjit, Clemson University (V. Samadi)

Floods are a major natural threat to critical infrastructure, communities, and populations worldwide, causing thousands of fatalities and resulting in large economic damages annually. Recent advances in data-driven and machine learning methods have offered faster and more intelligent solutions to predict flooding events as core drivers and mechanisms for many floods prediction challenges. The goal of this research was to develop an intelligent surrogate model to predict flood stage across large, gauged rivers in coastal South Carolina. We developed an artificial recurrent neural network, i.e., Long Short-Term Memory (LSTM) architecture, coupled with data engineering and inundation approaches to compute inundation extent and depth. Results revealed that LSTM is capable of modeling stage records with the accuracy metrics of >0.70. Our proposed approaches provided a machine-learning alternative to flood hydrograph and hydraulic modeling of inundation extent. Current and future work on the system includes extending coverage to additional flood-prone locations, as well as improving LSTM modeling capabilities and accuracy. This research is funded by the National Science Foundation.

Developing an Improved Compound Flood Modeling Using Fully Coupled, Distributed Hydrologic Model

Ahad Hasan Tanim, University of South Carolina (E. Goharian, F. McKinnie)

Compound flood modeling long been practiced by developing one-way or two way coupled model integrating the hydrologic and hydraulic models. The compound flood has severe impact in the coastal urban areas, but one-way or two-way coupling cannot resolve the full physics of compound flood in coastal urban area. This study aims to develop a fully coupled model of compound flood modeling in Charleston peninsula using Interconnected Channel and Pond Routing (ICPR). High resolution (0.5m) Digital Elevation model (DEM) and Digital Surface Model (DSM) derived from the LiDAR cloud points are engaged to model the compound flood. The finite volume element-based ICPR model physics in a node-link-basin network resolved the compound flood dynamics in a single model framework and simultaneous hydrologic and hydraulic model processing. High resolution spatial maps for curve number and soil zone incorporated for characterizing the basin properties in urban area and Manning's roughness coefficients based on the land use maps are engaged for overland flow modeling in an integrated interwoven model configuration using three distinct mesh configurations: triangular irregular network for links, diamond layer for overland flow area, and honeycomb meshes for basin. The fully coupled model is engaged to simulate the coastal urban flood in Charleston peninsula. The 2015 South Carolina major flood events are calibrated and validated to test the compound flood performance using the USGS high water marks and SCDOT road closure data. Moreover, one nuisance flood during Nov 2021 is also tested to validate the model capability. Result shows high accuracy to simulate compound flood dynamics in urban area at precise resolution. Therefore, it is expected that the model can be extensively use for modeling the compound flood in coastal urban area.

Compound Hazards in Coastal Regions of the Southeast USA in the Present and Climate Change Conditions

Ramprasad Yaddanapudi, Clemson University (A. Mishra)

Nearly 40% of the population lives on the coast, which is expected to increase in the next few decades. The Southeast USA coast is vulnerable to compound floods due to weather systems that impact this region. Different weather systems such as tropical cyclones, storms, and extratropical cyclones can cause coastal hazards. The coastal events impacting vulnerable communities are often multi-hazard; combinations such as river flood, excess rainfall, and wind or storm surge originate from a single weather system. For example, three recent tropical cyclones in 2017, Harvey, Maria, and Irma, caused a combined economic loss of over $275 billion. The coastal infrastructure has higher exposure to increased risk of such events; therefore, hazard quantification is essential under present and future climate change scenarios. Thus, our study investigated such multi-hazard (compound) events based on the joint return periods of historical events in select locations of the southeast USA. Our study analyzed various combinations such as fluvial flood-storm surges and pluvial flood-storm surges under historical conditions. We also evaluate the historical and future scenarios for compound wind and precipitation (CWP) events using CMIP6 models. Our study analyzes the magnitude of precipitation and wind variables individually under historical and future shared socio-economic pathways. We identify the percentage of locations with a higher likelihood of CWP events under future scenarios in our study area. Our results reveal that a substantial percentage of locations show an increased likelihood of compound events in the future. For specific joint return periods (50- and 100-year), we identified an increase in the frequency of future CWP events under various climate change scenarios.

Occurrence and Characteristics of Microplastics in a Wastewater Stabilization Pond and an Oxidation Ditch Wastewater Treatment Plant at the University of Mississippi

James Cizdziel, University of Mississippi (Z. Gao)

Microplastics (MPs) are a diverse suite of contaminants commonly found in wastewater. However, wastewater treatment plants (WWTPs) were not designed to remove MPs. Further, MP pollution has not been examined in wastewater stabilization ponds (WSPs), which serve rural and small communities worldwide, and in WWTPs that serve universities where sudden and drastic changes in on-campus populations occur. Here, we characterized MPs in a WSP serving ~500 houses and in an adjacent lake as well as in a modern oxidation ditch WWTP. In the pond, MPs were most abundant in duckweed (*Lemna minor*) and sludge (75 ± 22 and 12.8 ± 3.1 particles/g, respectively). In the water, average concentrations (particles/L) were highest in the WSP (4.1 ± 0.6), followed by WSP effluent (3.9 ± 0.5) and the lake (2.6 ± 0.6). Polyester and polyethylene were the predominant types, followed by polyethylene terephthalate, polyacrylate, PVC, and polystyrene. Morphologies consisted of fibers (62–71%), fragments (28–37%), and beads (1–6%). Potential sources include synthetic textiles from laundry and plastics washed down household drains. With >500,000 MPs/day released from the pond and with duckweed a source of food for waterfowl, WSPs can be MP point sources to both aquatic and terrestrial ecosystems. At the University WWTP, we observed the highest abundance of MPs after a football game (62.3 ± 7.6 particles/L), followed by 46.3 ± 9.5 during a typical school week, and 22.8 ± 4.5 with little on-campus activity. Over 90% of the MPs were removed in the primary treatment. MPs were most abundant in the oxidation ditch (>1000 particles/L). Concentrations in secondary clarifier and final effluent were <4 particles/L during high-flow and 16-39 particles/L during low flow. MPs were mainly composed of polyester, PVC, polyethylene, polypropylene and polyurethane. Most MPs in the effluent were fibers (61%), fragments (21%), and films (13%).

Mount Pleasant Waterworks Explores Direct Potable Reuse (DPR) as a Source Water Sustainability Option

Jestine Deepe, Mount Pleasant Waterworks (A. Clum, D. MacNevin)

In 2019, Mount Pleasant Waterworks (MPW) a coastal community in Mount Pleasant, South Carolina commissioned a study by CDM Smith to evaluate the feasibility of direct potable reuse (DPR) of highly treated wastewater as a supplemental water supply option to one of MPW's four RO WTPs. MPW currently relies on several groundwater wells in the Charleston Aquifer as the source of supply for the RO WTPs. Recently, MPW's groundwater withdrawal permit was susceptible to a nearly 50% reduction due to the State's concern over saltwater intrusion and land subsidence. In the search for a sustainable water supply solution, MPW will be the first in the state of South Carolina to investigate DPR as an additional water source to meet Mount Pleasant's current and future water demand. The presentation will include a history of MPW's water source, current and future challenges. Highlights from several elements of the DPR feasibility study including a regulatory review; treatment alternatives evaluation; benchtop treatability testing; demonstration facility recommendations; public acceptance challenges and approaches; and program funding opportunities. The benchtop tests simulated a DPR treatment train of ultrafiltration, reverse osmosis, and UV-chlorine advanced oxidation. The multibarrier treatment train produced purified water meeting all primary drinking water standards, while also removing measured CECs and PFAS below detection levels. Based upon the results of the DPR feasibility study, this could be a timely solution to secure future water supplies. MPW is investigating the opportunity to construct a pilot-scale DPR demonstration facility to showcase the approach to the public and continue the conversation with regulators.

Heteroatom Doping Modulating the Physicochemical Properties of Waste Derived Carbon: A Potential Candidate for Lead and Arsenic Capturing from Wastewater

Hafiz Muhammad Aamir, Texas A&M University-Kingsville (M. Alexander)

Lead and arsenic are most commonly hazardous heavy metals in agriculture soil and industrial wastewater. It's a dire need of a society to remove lead and arsenic from wastewater via facile and cost-effective route, highly needed to improve the water quality. The objective of this research is to rationally design the cost-effective metal free carbon-based material for lead and arsenic removal from wastewater. Here we obtain Boron(B) doped porous carbon (BC) via thermal and chemical treatment of waste rubber/plastic, as it is a promising raw material. The coordination chemistry, physicochemical properties, and surface structure of carbon are further modulated by introducing porosity and B doping. The degree of graphitization, boron content and pore size distribution of BC can be easily controlled by thermal and chemical treatment. The specific surface area, surface functionality, absorption coefficient, surface topography, and elemental composition of synthesized materials are thoroughly characterized by BET, FTIR, UV/Vis, SEM, EDS before and after treatment. Benefiting from the structural disorder, high specific surface area, least coordinated exposed carbon, the BC has the potential to substantially remove the lead and arsenic from wastewater.

Nitrogen and Phosphorus Remediation in Mesocosm-Scale Floating Treatment Wetlands for Wastewater Treatment

Matthew Barnes, East Carolina University (N. Bell)

Human-introduced eutrophication poses serious threats to water quality throughout the world. Agricultural processes, including aquaculture, and municipal wastewater can contribute to these issues by introducing nutrients like nitrogen and phosphorus into receiving waters. Floating treatment wetlands (FTWs) have been proposed as a cost-effective approach to remediate nutrients from a variety of sources. These systems can be implemented in substantial number due to their low cost and ease of installation. The goal of this research project is to implement pilot-scale mesocosm FTWs focused on the remediation of nitrogen and phosphorus from municipal and marine aquaculture wastewater. The municipal wastewater treatment FTW system will be installed at the Greenville Utilities Commission wastewater treatment plant in Greenville, NC, and will receive a high-strength wastewater side stream. The aquaculture FTW system will be installed at North Carolina State University's Marine Aquaculture Research Center (MARC) in Smyrna, NC, which contains saltwater recirculating aquaculture systems. The research project will be conducted from late March through September of 2022. Floating treatment wetland experimental units will consist of 150-gallon troughs that will each contain a floating mat made of 1-cm thick foam material (BeeMats, New Smyrna Beach, FL) as well as multiple plants. Both research sites will contain a series of eight treatments with three replicates per treatment. One trough will serve as a control, three troughs will contain monocultures, three troughs will contain two plant species, and one trough will contain all three plant species. The plant species chosen for the municipal wastewater site are *Juncus effusus* (common rush), *Carex stricta* (tussock sedge), and *Pontederia cordata* (pickerel weed). The plant species chosen for the marine aquaculture wastewater generated by recirculating systems are *Juncus roemerianus* (black needlerush), *Distichlis spicata* (saltgrass), and *Spartina alterniflora* (smooth cordgrass). Preliminary nutrient remediation results will be presented.

Modeling the Impacts of Agricultural Practices on Nitrate Loads, Streamflow and Crop Yields in the Santa Fe River Basin

Dogil Lee, Department of Agricultural and Biological Engineering, University of Florida (N. Reaver, S. Rath, R. De Rooij, D. Kaplan, W. Graham)

Aquifers throughout the world are threatened by over-pumping and nutrient enrichment. In particular, the Floridan Aquifer of the southeastern U.S. has experienced increasing agricultural and urban water withdrawals and nutrient load from human activities. Agriculture has been identified as a large groundwater user and a primary source of nutrients in groundwater, springs and streams in the Santa Fe River Basin, which overlies the Floridan Aquifer in North Florida. Grazed pasture, row crops, and hay fields are the major agricultural land uses, occupying approximately 12%, 4% and 5% of the basin area, respectively. Quantifying the impacts of alternative water and nutrient management practices for these land uses is important for understanding the potential changes needed to improve surface and groundwater quantity and quality in the region. The main objectives of this study are to model the hydrologic system in Santa Fe River Basin using the Soil and Water Assessment Tool (SWAT) and to evaluate groundwater recharge, streamflow, nitrate load and crop yield from row crops, hay fields and grazed pasture. Farm-scale management practices in SWAT were calibrated using available data from corn-peanut rotation, corn-carrot-peanut rotation, and Bermuda grass cultivation experiments, while basin-scale SWAT parameters were calibrated using streamflow and spring and stream water quality data. Alternative scenarios were established with stakeholders to analyze the impact of changes in agricultural cropping system and management practices on the quality and quantity of groundwater, springs and surface water in the Santa Fe River Basin. The results of this study will be useful for incentivizing growers to adopt management practices with lower water and nutrient footprints, and for estimating the land use and land management changes required to achieve aquifer, springs and rivers protection in the Santa Fe River Basin.

Simulating Nitrate Loading and Nitrate Transport to the Devil's Springs Complex in the Santa Fe River Basin, FL using SWAT-MODFLOW and MODPATH

Rob De Rooij, University of Florida, Water Institute (S. Rath, N. Reaver, D. Lee, W. Graham, D. Kaplan)

We have developed a SWAT-MODFLOW model for the Santa Fe River Basin, Florida. This model was constructed within the framework of the USDA-NIFA funded Florida Aquifer Collaborative Engagement for Sustainability (FACETS) project. The overall objective of this project to gain insights into the tradeoffs between the regional agricultural economy and environmental quality. The SWAT-MODFLOW code is well-suited for our objective as it is able to simulate crop growth, coupled surface-subsurface flow processes in watersheds as well as nitrate loadings. To simulate nitrate transport through the subsurface the model code SWAT-MODFLOW-RT3D can be used. However, SWAT-MODFLOW-RT3D only provides the spatiotemporal variations in nitrate concentrations and does not provide direct information about source areas or travel times. In this study we provide an alternative approach to simulate nitrate transport in the subsurface based on backwards particle-tracking using MODPATH. Using this approach we can extract useful information from SWAT-MODFLOW models in terms of source areas, pathlines and travel times. Here, we track particles backwards starting from the discharge zones associated with the Devil's Springs Complex in the Santa Fe River. When we simulate changes in land use and land management with our SWAT-MODFLOW model, we can use the particle-tracking results to compute the change in spring nitrate concentrations over time and the time at which we start to observe more desirable spring nitrate concentrations. This information can help in setting realistic expectations on how much time it takes for a change in nitrate loading to have the desired effect at the spring. Moreover, our simulation results can be used to design a monitoring program. Namely, we can compute targets for spring nitrate concentrations over time that would indicate that we are on track to reach a certain spring nitrate concentrations at some time in the future.

Evaluating the Water Quantity and Environmental Benefits of Sustainable Agricultural Management Practices in the Lower Apalachicola-Chattahoochee-Flint River Basin, USA

Ritesh Karki, University of Maryland (L. Kalin, P. Srivastava)

Agriculture, which is critical to the economy of the lower Apalachicola-Chattahoochee-Flint (ACF) River Basin of southeastern United States (U.S.) generating more than $2billion in revenue annually, is heavily reliant on the underlying Upper Floridan Aquifer (UFA) for irrigation. Recurring drought conditions and subsequent increases in groundwater use for irrigation have, however, stressed the surface- and groundwater resources threatening the long-term agricultural and environmental sustainability in the region. Identifying and evaluating the benefits of sustainable management practices for the major row crops in the region is, therefore, critical for mitigating the threats of near-future droughts as well as long-term climate change. This study developed a range of management practices/scenarios that are currently applied for corn, cotton, and peanut in the region based on intensity for irrigation water use, fertilizer application and tillage. The management practices were then evaluated under historical as well as projected climate conditions using a coupled SWAT-MODFLOW model developed for the lower ACF River Basin and the underlying aquifer system that can adequately simulate the surface- and groundwater resources as well as the intrinsic connection between these resources in the region. Streamflow evaluation after calibration at six locations from 2007 to 2013 showed that the model can adequately replicate streamflow in the region. The model also satisfactorily simulated the spatial and temporal variability of groundwater levels along with crop yield and water use for the three major crops. Evaluation, as well as comparison of the developed management scenarios using the calibrated model for crop yield, irrigation water use, streamflow, recharge, and groundwater levels, helped understand the environmental benefits of the management scenarios. The study also helped identify stream sections as well as aquifer regions that are most sensitive to the changes in management scenarios, especially under historical as well as predicted drought conditions.

A Stochastic Dynamic Optimization Approach for Understanding Expected Land Use Changes to Meet Potential Water Quality Regulations: A Case Study from Georgia, United States

Yu-Kai Huang, University of Georgia Warnell School of Forestry and Natural Resources (R. Bawa, P. Dwivedi)

The objective of this study is to investigate the tradeoff between agriculture and potential water quality regulations at the watershed level for developing insights into the role of forestry in meeting water quality standards. Specifically, we applied a dynamic stochastic mathematical programming approach to evaluate the impact of land use changes on profits under uncertain water quality regulations and crop yields. We selected the Little River Experimental Watershed located in South Georgia as a case study. Seven potential water pollution (phosphorus concentration) reduction trajectories were developed, and the proposed model applied a chance-constraint technique to allow some degree of uncertainty in meeting the water quality standard. The result shows that profits decrease when uncertainties are considered at the watershed level. The findings further show that uncertainties of meeting the water quality standard facilitate the speed of the land use transition from croplands to forestlands and magnify the share of forestlands, highlighting the crucial role of forests in managing water pollution in the selected watershed. The results also indicate that in a moderate pollution reduction scenario, it will lead to $18 million in agricultural losses to achieve the phosphorus reduction of 17%. In a more ambitious pollution mitigation scenario, it will lose $67 million to have a 53% decrease in phosphorus. Our study provides a platform for analyzing policy options for assessing tradeoffs between profits and water quality standards relative to land use changes across the world.

Evaluating Economic Impacts due to Storm-based and Tidal Flooding in the Coastal Southeastern U.S.

Robert Carey, Clemson University (D. Hitchcock)

Coastal riverine and estuarine areas of the Southeastern U.S. are prone to flooding – not only from regionally-based tropical storm events, but also due to flash rain events and tidal high tide "sunny day" flooding. This presentation highlights ongoing analyses to examine the potential economic impacts that flooding may have on local communities – including residents, businesses, and public service activities. Focus is placed on Georgetown County, South Carolina. Similar analyses will be run for New Hanover and Craven counties in North Carolina and Chatham County in Georgia. Geographic Information System (GIS) data are being used to isolate areas vulnerable to storm and/or tidal flooding and to identify transportation routes and businesses affected. The impact to these businesses will then be quantified and the impact on the broader economy will be estimated using the REMI PI^{+}® modeling engine. Our team has formed an expert panel to guide us in surveying local residents and businesses, as well as forming focus groups to work with specific affected local communities, targeting those that are underserved and underrepresented. The survey work provides a critical link between the hydrological analyses and the economic data available via GIS Business Analyst and REMI® information.

Exploring Landscapes of Unequal Exposure to Risk: Mapping Poverty Clusters in Relation to Pluvial Flooding

Narcisa Pricope, University of North Carolina Wilmington (J. Halls, G. Shivers, C. Hidalgo)

Among global floods, tidal and pluvial flooding are least studied, both from the perspective of physical impacts and occurrence prediction, but especially from a socio-economic impact assessment perspective. Floods are also recognized as the costliest natural hazard worldwide and in the United States and are projected to increase in frequency and magnitude amid a warming global climate. Referencing the impacts of Hurricane Florence, a 1000-yr storm event that affected the state of North Carolina in September 2018, we identified communities at the Census Block Group level of geography most vulnerable to flooding and which demographic and socio-economic variables from the U.S. Census Bureau best explain vulnerability to flooding for an eight-county region in NC most affected by recurrent flooding. Using PlanetScope high resolution imagery, approximately 44% of residential structures were classified as flooded and were located outside of the 100-year floodplain, which has serious implications for the resiliency of local residents, many of whom do not have flood insurance policies. Demographically, the population that was most impacted from Hurricane Florence flooding families with children; families who are white, Asian and other; African American families with dependents adult white females; and elderly white individuals. These findings show that capturing social vulnerability to flooding, with the goal of executing effective outreach to at-risk populations needing assistance, would require the inclusion, or exclusion, of variables that would lead to a comprehensive and accurate model within the eight-county study area. The implication of this study is that measures to mitigate disaster through outreach to at-risk communities needs to vary based on local demographics and context, as the social and economic makeup of these vulnerable communities differ and require tailored approaches.

Planning, Modeling, and Monitoring of Green Infrastructure Interventions for Flood Mitigation in the East Central Florida Coastal Zone

Jason Evans, Stetson University (E. Niederman, J. Mainali, C. de Bodisco, L. Nieves-Ruiz, C. Abbatantuono, T. McCue)

The coastal zone of East Central Florida is a rapidly growing, largely urbanized region contained within Brevard and Volusia counties. These two counties stretch across ~150 linear miles of Atlantic beachfront, have extensive estuarine resources within the greater Indian River Lagoon system, and consist of several moderately sized metropolitan centers (e.g., Daytona Beach, Melbourne, and Titusville) with sprawling suburbs. A high proportion of urban development in the immediate coastal zone of this region originally dates to the 1950s-1970s, largely in response to the rapidly growing U.S. space program. Because stormwater engineering practices from this era were almost uniformly focused on rapid drainage and conveyance of runoff from urbanized areas into receiving waters, local jurisdictions are faced with the significant challenge of managing a large inventory of legacy infrastructure that has increasingly antiquated functionality. Green infrastructure interventions such as rain gardens, stormwater wetlands, vegetated ponds, permeable pavement, cisterns, and infiltration basins have been implemented on a limited project-by-project basis within the urban matrix, mostly for the purpose of reducing non-point nutrient loads into impaired waterways. However, hydrologic changes associated with both sea-level rise and increased precipitation event intensity in this region are prompting interest in more widespread use of distributed green infrastructure as a primary flood mitigation approach. Using case studies in several partnering municipalities, we have developed a framework for identifying and assessing candidate locations for operationalizing specific types of green infrastructure interventions within the built environment. A key lesson of this work is that such suitability modeling can effectively support effective implementation of green infrastructure interventions at a municipal level in East Central Florida. However, there remains a critical need for more cost-effective micro-basin hydrological studies, associated post-intervention performance monitoring, and clear maintenance protocols to provide local officials with the confidence to move toward broader implementation.

Intersection of Hybrid Infrastructure and Perceptions of Risk

Jon Calabria, University of Georgia (C. Landry, B. Nick, D. Hitchcock, J. Evans)

We evaluated how respondents (n=225) perceived risk, property protection and environmental quality. Respondents from three coastal counties in GA self-reported they (63%) intend to continue living at the coast despite that the majority of respondents acknowledging that flooding and erosion will worsen and housing, insurance and taxes will increase. To meet this challenge, respondents agree measures are necessary to protect against environmental risk and were most accepting of hybrid infrastructure that offered higher levels of flood protection and wildlife habitat as opposed to only green (close second) or grey infrastructure. For example, hybrid infrastructure could include a bulkhead with a living shoreline to provide protection and ecological benefits. Respondents shared data that suggested more than half suffered damage from previous storms and received flood insurance claims (μ=$3,334), which also displaced them for an average of five days. However, if respondents were offered rentback contracts, then more than a half were not interested. Interestingly, willingness to pay models suggest they would pay $676 per household annually for good coastal habitat if they were to participate in a special local sales tax option.

Egypt Food Security Research Project: Can the Desert Help Meet Egypt Food Demand?

Lal Almas, West Texas A&M University (S. Burian, M. El-Sayed, M. Hazman, M. McFarland, A. Shams El-Din)

Egypt, like many other developing countries, is facing a severe crisis in water resources sustainability and management. Its water scarcity is due to increasing demands and poor management practices particularly in irrigated agriculture. Egypt imports more than half of its food grains. The logical step in water management is to examine water demand and to identify ways to reduce the demand. Egypt will face even more shortage of water supply from the Nile River after the construction of the Grand Ethiopian Renaissance Dam. Wheat is one of the most widely cultivated cereal crops and consumable food globally. Production efforts are essential to reduce the gap between production and consumption of wheat in Egypt. The production-consumption gap can be reduced through advanced agriculture, innovative wheat varieties, land expansion, bio-saline agriculture, and other water management practices. This research aims to investigate the determinants of wheat consumption in Egypt, find the price, income, and cross price demand elasticities of wheat. For empirical analysis, the time series data from 1961 through 2020 was collected from different sources and was analyzed to investigate the demand determinants of wheat in Egypt. The results indicated the presence of a relationship among determinants of wheat consumption. The results of own price, GDP per capita, and population reveal that wheat is a necessity food. The estimates of rice price, corn and barley consumption indicate that such commodities are substitutes for wheat in Egypt. Based on these estimates, the policy makers in the Egyptian government and all other stakeholders need to concentrate on a comprehensive policy for parallel consumption of wheat, rice, corn, and barley. The Egyptian government must focus on exploring ways including bio-saline agriculture to increase domestic wheat production to reduce wheat imports, save valuable foreign exchange, and overcome some of the food security challenges in Egypt.

The Art of Building International Higher Education Partnerships in Pakistan to Advance Water Security and Resilience

Steven Burian, University of Alabama Water Institute (M. Chaudhry, B. Lashari, R. Mahar, M. Ward, T. Banuri, S. Ahmad, T. Gates, J. Ullman, M. Barber)

At the heart of Pakistan's sustainable development agenda is, *inter-alia*, access to clean water and sanitation, protected water quality and ecosystems, and sustainable water resources management and use. Making progress towards this end requires a concerted cross-sector effort and strengthened interface between scientific, policy, and social aspects. In this later context, the key is to create the local communities of practice that are able to home grow adaptable and resilient solutions. Higher education is uniquely positioned to develop the workforce and deliver the research to strengthen these local communities of practice and deliver practical solutions through community-engaged research. One key step in this direction was the creation of the U.S.-Pakistan Center for Advanced Studies in Water (USPCASW). Established at the Mehran University of Engineering and Technology with technical assistance from the University of Utah and team of partners, including Colorado State University and the University of Nevada at Las Vegas, the Center was launched in 2014 with financial support from USAID, and guidance from the Higher Education Commission of Pakistan. The project established the governance structure of USPCASW, introduced critical interdisciplinary educational programs together with innovative teaching and learning approaches, established facilities and environment for learning and research, built the capacity of the Center's faculty and leaders, and strengthened networks supporting the research-policy-practice interface. Throughout the delivery of the project, the team used a combination of art and science, applying creativity and imagination to overcome challenges and benefit from potential opportunities. Ultimately, the use of an integrated framework and multi-tiered partnerships were found to be the most instrumental in gaining traction leading to step-change successes. This presentation will describe the USPCASW partnership, present the success stories, and offer recommendations for fostering international higher education collaboration supporting advances in water security and water management for sustainable development.

Multiscale Coastal Vulnerability Analysis of South Carolina Coast Integrating Socio-environmental Geospatial Dataset

Ahad Hasan Tanim, University of South Carolina (E. Goharian)

Multi-dimensional and multifactorial spatially distributed geophysical and hydroclimate data is required in coastal hazard vulnerability assessment. Moreover, in vulnerability assessments, the representation of coupled socio-environmental elements, particularly hazard adaptive capacity, is frequently overlooked. These call for development of a novel and inclusive vulnerability assessment framework, which comprises various hydroclimatic, physical, socio-economic, and ecological factors. This research conducted developing a novel coastal vulnerability index (CVI) by considering more than 20 factors of South Carolina coast. The probabilistic and deterministic approach is employed in this study combining the socio-economic and hydroclimate datasets at a spatial resolution from 30m to census block scale. The concerning factors are developed harnessing historical datasets of hydroclimate, physical and social, ecological, and shoreline information covering 20-150 years of natural hazard activities in the SC coast. The deterministic method employed in this study, developed by aggregating fuzzy logic-based factor scaling, objective weighting, uncertainty optimization and vulnerability information maximizing novel concept in factor aggregation framework. The probabilistic CVI is developed using copula based joint probability analysis considering the vulnerability of biophysical factors (hydroclimate and physical) and socioeconomic factors. Each method has good agreement with observed hazard information of SC coast. The sensitivity analysis of CVIs shows that the Charleston County is more sensitive to socio-economic factors and highly vulnerable, whereas the physical factors contribute to higher degree of vulnerability in Horry County. The outcome from multiscale probabilistic/deterministic method shows the coastal vulnerability at precise resolution which can detail a priority-based coastal management information in South Carolina coast.

Finding stable middle ground in stream improvement practices - Panel Discussion

Panelists:
Katie Collins, Clemson Extension
Eve Brantley, Auburn University
Amanda Gumbert, University of Kentucky Cooperative Extension Service
Mitch Woodward, North Carolina State University

Increased development, more severe storm events, and removal of riparian areas have all resulted in degraded waterways requiring repair or restoration in the channel, along the riparian area, or both. Since 1990, it is estimated that $1 billion have been spent annually on stream restoration projects. Individual projects may cost anywhere from $30 to hundreds of dollars per linear foot. In addition to being expensive, stream restoration also requires heavy machinery, permitting at the federal and state level, and extensive knowledge of stream processes. Restoration efforts are vitally important for restoring natural processes and ecosystem benefits in moderately to severely degraded streams, but intermediate actions can be utilized to enhance the function of impacted streams, in some cases. Landowners and landscape professionals managing properties containing waterways face daunting financial and logistic barriers to stream restoration, which may result in taking no action at all. There is a need for manageable, intermediate options to address eroding streambanks and enhance riparian areas, leading to improved water quality and in-stream habitat. The panel will discuss efforts being made in the Southeastern US to provide education and technical training about intermediate stream solutions.

Preparing for, Responding to, and Mitigating Compound Coastal Water Hazards for Resilient Rural Communities

Scott Curtis, The Citadel (J. Kruse, A. Mukherji, A. Ghosh, K. De Polt, N. Adeniji)

Compound flooding is a complex hazard with higher risk in the rural, coastal Southeastern U.S. due to (i) the confluence of fluvial, pluvial, and tidal flooding, (ii) outdated and insufficient drainage infrastructure, (iii) poorly drained soils in a flat open landscape, and (iv) sea level rise. As compound flooding frequency increases with climate change, rural regions with underdeveloped roadways and communication networks and limited emergency resources will become even more vulnerable. Since 2019, we have examined these issues in eastern North Carolina through a NOAA-funded grant. A workshop in February 2020 consisting of in-depth focus group discussions with hazard management and planning professionals indicated that the threat of compound flooding is pervasive and constant and that rural communities are often still struggling to recover from one flood when another one occurs. To reduce the impact of flood events, communities seek funding to maintain and repair infrastructure, clear waterways, and implement buyouts and elevation projects. This workshop identified two overarching issues with respect to external funding requests: (i) the funding process for mitigation and recovery is very slow and (ii) the processes for applying for funding often do not align with current programs and may not accommodate differences across coastal and non-coastal areas or urban and rural areas. Following the workshop, we investigated the physical nature and risks of what we have termed: compound coastal water events (CCWE). Trivariate copulas were used to quantify the probability and return periods of CCWE components: pluvial, fluvial, and tidal flooding for three locations in eastern North Carolina. The “CCWE nature” of Hurricanes Matthew and Florence were also explored. A concluding workshop, which is being held in February 2022, will close the loop by re-thinking policies and tools that may help rural communities proactively and strategically seek mitigation projects for responding to CCWE.

Conceptual Decision Support Tool for Climate-Resilient Infrastructure in Adapting to Climate Change and Sea Level Rise

Xixi Wang, Old Dominion University

In the past decades, a variety of best management practices (BMPs) have been constructed to treat agricultural runoff and urban stormwater. Although those BMPs were initially designed to improve water quality by trapping sediments, nutrients, and other contaminants, they are also being expected to mitigate floods and/or droughts in the wake of changing climate and environments. That is, the BMPs are hypothesized to play important roles in adapting to climate change and sea level rise and thus increasing community resilience. However, the informative knowledge in supporting such a hypothesis is incomplete or barely available in existing literature. To fill the knowledge gap, using the Chesapeake Bay Watershed as the testbed, this presentation puts forward a conceptual decision support tool that can be used to improve the climate resilience of coastal communities. This tool consists of five interrelated components, namely: 1) a database; 2) a module for generating next-generation rainfall intensity-duration-frequency curves; 3) a module for evaluating vulnerability, reliability, stability, and resilience; 4) a module for scaling up from specific sites to communities to river basins; and 5) a module for formulating adaptation measures in accordance with a resilience target. For a given infrastructure system, its resilience is computed as a function of the reliability, stability, and vulnerability, which in turn are determined as functions of historical or future climate, rising sea level, physiography, and characteristics of civic and hydraulic structures. The scaling-up module executes algorithms for spatiotemporal clustering and aggregation, whereas the module for formulating adaptation measures uses artificial intelligence and machine learning techniques to formulate optimal adaptation measures, subject to various constrains. In practice, such a tool is needed but lacking for communities to plan, design, construct, and manage hydrology-influenced infrastructure in changing climate and environments in guarding against over- or under-committing resources.

Moving Beyond Resilience: Antifragility Assessment and Design of Flood Control Systems
Farboud Khatami, University of South Carolina (E. Goharian)

Historically, flood control structures have been designed based on reliability of the system, and more recently resilience has also been used to design and operate flood systems. However, traditional approaches, due to their reliance on deterministic and stationary data, do not provide sufficient information on the performance of the system over the uncertain future conditions, such as climate change. Further, traditional approaches do not offer any suggestions for improving the state of the system after each failure. To solve such deficits, this research proposes an improved design criteria for flood control systems based on the principles of Antifragility. Antifragile systems, instead of suffering from shocks, improve under them and build more tolerance after each extreme event. Antifragile systems are fundamentally different from reliable and resilient systems due to their ever-improving nature. As such, this research seeks to answer how antifragile previously built systems are, how antifragile will they be under unlikely but high impact cases (known as Black Swans), and how can a system be designed to not only be reliable and resilient, but improve after each shock. To achieve this, a sample coastal water drainage network was chosen and its performance in controlling flooding was studied under sets of extreme historic rainfall distributions as well as perturbed ones so as to mimic future conditions. As such, the performance of the system under Black Swans was evaluated. The results show that the design based on average conditions is inadequate both for the case of extreme unlikely conditions, as well as climate change. In the end, these findings were used in conjunction with the currently in use National Risk Index to create a new Antifragility-based metric which better reflects the system's performance under extreme conditions and help provide a measure of its self-improvement.

Assessing General and Specified Resilience in Resource-dependent Communities: A Case Study of the Cache River Watershed of Southern Illinois

Raymond Bieri, Southern Illinois University Carbondale (K. Akamani)

The field of water resources governance is increasingly rejecting the conventional command-and-control water management paradigm in favor of alternatives that rely on flexible and adaptable institutional mechanisms to manage uncertainties and change. The shift toward embracing uncertainty is based on the recognition that water resource systems are constantly exposed to multiple drivers of change across multiple scales from the local to the global. Rural resource-dependent communities are particularly vulnerable to the simultaneous impacts of climate change and other drivers of change. Enhancing the sustainability of communities in this context requires building community resilience – the ability of communities to adapt to change while maintaining or enhancing their well-being. The resilience of communities is often associated with the availability of capital assets (e.g. social capital, natural capital, economic capital, human capital, and social capital), as well as the presence of effective institutions (public, private, and civic). However, the exact mechanisms by which capital assets and institutions interact to shape the process and outcomes of community resilience have not been adequately explored. Moreover, while the focus on capital assets and institutions deal with the contextual factors that influence general resilience, i.e. the ability to adapt to all kinds of drivers of change, the influence of these contextual factors on specified resilience, i.e. the ability to adapt to specific shock events, has not received enough attention in the literature. To address these knowledge gaps, this presentation proposes a synthesized conceptual model for analyzing general and specified resilience in resource-dependent communities. The model describes how community contextual factors, such as capital assets and institutions interact to shape the awareness, motivation, capacity, and opportunities that influence the process and outcomes of community responses to specific drivers of change across scales. The Cache River watershed in southern Illinois is used as an illustrative case study.

Rising Coastal Groundwater Levels and Their Effects on Decentralized Wastewater Infrastructure: Examples from Dare County, NC

Michael O'Driscoll, East Carolina University (C. Humphrey, G. Iverson, J. Harrison, J. Bowden, L. Voorhees)

Rising groundwater levels can have a major influence on community resilience and infrastructure. Recent research along the Atlantic coast has documented rising groundwater levels in numerous coastal communities. These changes have been attributed to factors such as: sea level rise; coastal storms; wastewater disposal; and land-use change. In North Carolina, there are approximately 1 million onsite wastewater treatment systems (OWTSs) draining to the coast. These systems rely on unsaturated soils to treat waste and reduce the impacts to surrounding waters. Rising groundwater tables can reduce a system's capability to effectively treat waste. Groundwater level data (1983-2021) from 8 surficial aquifer wells maintained by the NC Department of Environmental Quality were analyzed to evaluate the temporal variations in groundwater levels. Five additional wells were instrumented to evaluate groundwater interactions with OWTSs in 2019-2020. Groundwater level data was compared with sea level rise data collected at Duck, North Carolina, where NOAA has been monitoring tidal levels since the 1970s. The results revealed that groundwater level rise is occurring and positively correlated with sea level rise. Overall, groundwater levels have increased by approximately 30 cm since the 1980s. This change in groundwater levels in the surficial aquifer has resulted in a decline in the unsaturated soils available for onsite wastewater treatment. Based on the relationship between land surface elevation and groundwater levels, the data suggested that conventional OWTS at elevations of < 6-7 ft. above sea level were likely to experience reduced vertical separation and potential groundwater inundation that would reduce the effectiveness of the onsite wastewater treatment systems. There is a growing need for coastal communities to evaluate how rising coastal groundwater levels affect their onsite wastewater infrastructure and to develop adaptation strategies to ensure adequate wastewater treatment and protection of public health.

Regulatory Frameworks for Addressing Climate Impacts to Onsite Wastewater Systems: Existing Barriers and Potential Paths Forward

Katie Hill, University of Georgia Institute of Government

Climate change, and particularly sea level rise, will have significant impacts on onsite wastewater treatment systems in the United States. In coastal areas, impacts to these systems from rising groundwater tables, storm events, increased incidence of flooding, and other factors will threaten public and environmental health. Unfortunately, existing regulatory frameworks for managing onsite systems were not developed with climate change and sea level rise in mind, and states have been slow to amend their statutes, regulations, and other policies to address this ever-increasing threat. Indeed, in many states there is confusion concerning the basic issue of who has the authority to regulate onsite systems to address the impacts of climate change, with local governments eager to act but wary of preemption by state law. In this talk, we will first provide an overview of the way that onsite systems are typically regulated. We will then discuss the short fallings of this approach for managing impacts from climate change (focusing on sea level rise), followed by a brief summary of ways that these regulatory regimes could be amended going forward to address this threat. Our talk will focus on the southeastern U.S., but the lessons therein are widely applicable nationwide.

Climate Change and Rainfall Extremes within Eastern North Carolina and the Implications for Onsite Wastewater Treatment Systems

Jared Bowden, North Carolina State University

Understanding the past climate is no longer a reliable predictor of the future. It is imperative that climate scientists provide better insight into components about climate change that will have significant impacts on the natural and built environment. One feature that has implications for onsite wastewater treatment is changing rainfall, especially extreme rainfall. Downscaled climate model data and idealized climate model experiments provide insight into how rainfall characteristics associated with hurricanes like Matthew & Florence are projected to change as the climate warms. Results indicate anticipate large increases in the average rainfall intensity, maximum rainfall amount, and area total rainfall. For instance, projections indicate the plausibility of rainfall totals rivaling that of Hurricane Harvey are possible within eastern North Carolina. Changing rainfall characteristics associated with hurricanes as well as other storms poses an increasing threat to onsite wastewater treatment within the Carolinas and will be discussed.

Inflow and Infiltration (I&I) in a Coastal Central Sewage Collection System: Effects of Climate Variability

Lawrence Cahoon, UNC Wilmington (G. Alexander)

Inflow and Infiltration ('I&I') represent extraneous flows into central wastewater treatment plants (WWTPs) that can degrade system performance and cause sanitary system overflows (SSOs). This study looked at I&I over three multi-year periods (2005-2008, 2010-2011, and 2019-2021) in the Wilmington 'Northside' WWTP collection system, which serves major portions of the City of Wilmington and northern New Hanover County, in coastal North Carolina. We examined three factors that can affect daily I&I either directly or through effects on groundwater levels: rainfall (same-day and cumulative), average daily temperature (seasonality), and sea level (daily high-high tide in this coastal service area). Multiple regression analyses demonstrated that all three factors had significant effects, as demonstrated in previous studies of I&I in coastal North Carolina central sewage systems. These results were interpreted with respect to changes in the three factors over time, notably sea level at Wilmington, which rose ~17 cm in the decade 2010-2020. Management and maintenance of the Northside WWTP and its collection system changed during the study period, with transfer of responsibility from the City of Wilmington and New Hanover County to the Cape Fear Public Utility Authority (CFPUA) in July, 2008, so these results were also interpreted with respect to changes in the management and maintenance of the system.

Using a Wireless Sensor Network to Automate Irrigation of Cotton using a Lateral Move Irrigation System

Jose Payero, Clemson University (U. Sekaran, D. Turner)

In South Carolina, overhead sprinkler systems (mostly center pivots and a few lateral move systems) are typically used to irrigate row crops, which cover much of the state's irrigated land. Although farmers in South Carolina have adopted efficient irrigation systems (i.e., center pivot and drip), managing these systems to achieve their full potential is still challenging. This project's overall goal was to create and field-test an affordable system to help cotton farmers increase water use efficiency by automating irrigation based on real-time soil moisture data using a wireless sensor network. The specific objectives were to: (1) develop a wireless sensor network to automate irrigation scheduling of cotton, based on real-time soil moisture using a lateral move irrigation system and, (2) field-test the irrigation automation system by evaluating the response of cotton to three irrigation trigger points. A wireless soil moisture sensor network prototype created in 2019 to automate irrigation of cotton using a subsurface drip irrigation (SDI) system was modified and adapted to a lateral move irrigation system. A field experiment was conducted at the Edisto Research and Education Center in 2021 to field-test the irrigation automation system. In this experiment, three irrigation treatments were evaluated in which irrigation was automatically applied to cotton when the weighted-average soil moisture reached either 30, 40, or 50 kPa using four replications. Soil moisture was measured using Watermark moisture sensors installed at three depths in each plot. The electronics and software for the automation system were developed and installed in the field. Field tests conducted in 2020 and 2021 showed that the new automation system performed as expected.

Less is More: Eco-Intensification using Recycled Drainage Water for Fertigation
Laura Bowling, Purdue University

Rainfall has traditionally been sufficient in the Eastern Corn Belt to support agriculture and replenish groundwater, but increasingly producers are considering supplemental irrigation as a method to buffer risk associated with water shortages. Despite increasing annual precipitation, short-term droughts are projected to increase due to shifting seasonality. More winter and spring precipitation may potentially overwhelm agricultural drainage systems and increase nutrient contributions to the Gulf of Mexico without alleviating drought stress during growth periods. Drainage water recycling (DWR) is the practice of capturing and storing water drained from fields in a pond, reservoir, or wetland, and using the stored water to irrigate crops when there is a water deficit. At its most basic this seems like a very simple solution to help farmers to increase production while minimizing downstream impacts. Although there are many benefits in implementing DWR, several barriers exist that may hinder adoption. Creating storage ponds is expensive and the yield benefit of supplemental irrigation in the portions of the Corn Belt with sufficient subsurface drainage to support DWR may not be sufficient to recover the costs. In addition, navigating the permitting process and cost-share programs can be confusing and overwhelming. This presentation will describe on-going research to evaluate the feasibility of ecologically intensifying corn and soybean management using existing depressional storage of drainage water for irrigation and fertigation to maximize crop production and profitability while enhancing nutrient use efficiency and minimizing downstream impacts. This will be accomplished through an in-field demonstration experiment at the Agronomy Center for Research and Education in West Lafayette, IN to quantify the effectiveness of drip fertigation using DWR, the water quality benefits of enhanced wetland storage and the economic feasibility of using DWR for supplemental fertigation.

Understanding Irrigation Patterns of Public Parks and Recreational Landscapes in College Station, TX

Rosa Garcia, Texas A&M University (A. Lewis, P. Khedun, R. Kaiser)

Outdoor water use, and particularly landscape irrigation, has the potential to account for a significant portion of total urban water demand, including high levels of waste. Conservation programs are often used by water utilities looking to encourage their customers to save water. However little research has explored the extent to which municipalities respond to their own cries for water conservation by using water more efficiently. In this study we analyzed monthly irrigation patterns for various parks in the city of College Station, Texas, for 2015-2020. Estimates of over-irrigation (waste) were made by comparing data from designated outdoor water meters to an irrigation budget based on plant water requirements and remotely sensed landscape area measurements. We developed and applied irrigation efficiency ratios for parks to further investigate patterns of efficiency in relation to seasonality, park typology, and irrigation area. This study also examines the capacity of rain sensors to increase water-use efficiency on irrigated large landscapes.

Willingness to Pay for Aquatic Invasive Species Management

Lucia Levers, Sustainable Ag Water Systems, USDA-ARS Davis (A. Pradhananga)

We estimate willingness to pay for statewide aquatic invasive species lake management in the form of a property tax increase by conducting contingent valuation surveys in Minnesota, USA of both general residents (mail surveys) and lakeshore property owners (emailed surveys) in Summer and Fall of 2021. We also examine respondents' general knowledge of invasive species, perceived risk and awareness of problem, as well as socio-demographic factors and physical lake visitation. We estimate the impact of these additional parameters on willingness to pay and compare and contrast general resident results vs those of lakeshore owners and comment on the relationship to recreationists' willingness to pay from past work (Levers and Pradhananga, 2019). The results of these surveys have implications for aquatic invasive species policy and management, particularly for regions with large numbers of waterbodies and extensive aquatic invasive species transmission risk.

Economic Analysis of Sand Sources on the Lowermost Mississippi River for Coastal Restoration Projects

Hua Wang, LSU AgCenter (R. Caffey, M. Miner, A. Courtois, B. McMann)

Demand for dedicated dredging in U.S. waters has more than doubled in the past decade, with particular growth in coastal Louisiana, where an estimated 90 million yd^3 of sediment will be needed for wetland restoration over the next 50 years. The Lowermost Mississippi River (LMR) is a nationally significant, multiple-use resource, and Mississippi River sediment resources are critical for restoration, most importantly because they are renewable. This study examines the beneficial use of dredged sediment from the LMR for coastal restoration projects in Louisiana, focusing on whether maintenance dredged sand is economically efficient for restoration. Detailed cost data were collected for historical and recent maintenance- and dedicated-dredging efforts on the Mississippi River from the U.S. Army Corps of Engineers. These data inform the development of statistical models of cost-efficacy for examining the relative efficiency of current and alternative dredging practices along the study corridor. Under the status quo scenario, the project looks at 50-year projections of Mississippi River management (cost of sediment dredging and transport). The status quo scenario examines the physical and economic forecasts for relative sea-level rise plus land loss projections and diversion operations under conditions of uncertainty. A trajectory economics approach (i.e., cost-efficacy) is used for comparing proactive versus reactive management with riverine versus offshore-based dredging. The economic analysis deal with physical and economic data at the aggregate and system level. The results indicate that the scenario of cut across displays some minor cost-advantages at shorter distances, while the advantages are lost beyond 36 miles versus the scenario of round the horn. The study supports the evaluation of various proposed river management strategies, such as a detailed economic comparing current beneficial use practices with alternative strategies for sediment dredged in the lower Mississippi River.

Breakeven Price to Incentivize Agricultural Water Rights Leasing

Rajendra Khanal, Department of Civil and Environmental Engineering, University of Utah (C. Stöckle, M. Barber)

Many watersheds around the world are facing chronic water shortages due to increased demands, overallocation, drought, and climate change. Water markets are a possible solution to reduce the impacts of water shortage by reallocating the water resources to where and when it is most needed. The determination and the fair and equitable breakeven price is critical for the flourishing of water trading. The lack of knowledge regarding how much price is required for possible leasing/trading has repercussions in responding to climate change and water shortages. This is because the implementation of agricultural water rights leasing will result in loss of crop production. If we have an acceptable means to estimate the breakeven price covering the loss in crop production due to water leasing, it opens up the possibility of facilitating not only full-year leasing but also part-year leasing – something that does not currently exist in many watersheds around the world. Thus, using CropSyst, a process-based agricultural yield model, in the Walla Walla River basin we predicted the loss in crop production due to both full-year leases and part-year leases on two crops(winter wheat and grain corn). Finally, we predicted the breakeven price that would cover the loss in crop yield for both full year and partial leasing strategies fixing the price at different times throughout the growing season. With this, farmers will be benefitted by knowing the minimum amount required for potential full and partial leasing of their agricultural water rights based on the time of the growing season. This information will be extremely valuable to the watershed managers trying to plan and conduct water trading projects. Our findings will also further highlight the possibility of using CropSyst as a supporting tool for agricultural water leasing.

A Hydro-Economic Optimization Model of Agriculture under California's Sustainable Groundwater Management Act

Lucia Levers, Sustainable Ag Water Systems, USDA-ARS Davis (G. Yao)

California's landmark Sustainable Groundwater Management Act (SGMA) was enacted to stop overdraft of groundwater basins by bringing withdrawals and recharge into balance. The biggest user of groundwater in perpetually overdrawn basins in California is agriculture, as such the biggest impacts of SGMA will fall to agriculture as well. Land fallowing is one management tool that can reduce reliance on groundwater resources, as can managed aquifer recharge. We developed a regional hydro-economic programming model of representative crops in multiple groundwater basins in California's San Joaquin Valley—the agricultural heart of California and home to substantially overdrawn aquifers. We model the impacts of sustainable groundwater use under SGMA and estimate land fallowing under different climate scenarios. We also model managed aquifer recharge as a response to reduced water supplies. The outcomes of this model will help policy makers better understand the implications of this groundbreaking law.

Thermal Variability and Patterns in a Karst Mixed Land-use Basin of Central Pennsylvania
Lexie Orr, Pennsylvania State University (J. Duncan, E. Boyer)

Water temperature is a critical physical property of stream ecosystems that influences nearly all in-stream biochemical processes. Atmospheric, physical, and hydrologic conditions all influence a stream's thermal regime, and anthropogenic effects on any of these factors, such as changes in land-use or natural flow patterns, can greatly impact stream temperature and ecosystem processes. The Spring Creek Watershed in Centre County, Pennsylvania is a karst, mixed land-use watershed that has undergone steady development over the last century. This study identified the most influential environmental and anthropogenic factors controlling stream temperature in stream reaches of the watershed. We analyzed 20 years of stream temperature data with a mixed effect, stream network model. Results suggest that streams with less groundwater contribution and higher levels of impervious cover exhibit the highest average and maximum summer temperatures respectively. Further, impervious cover can cause thermal surges following summer storm events that can increase stream temperatures rapidly to temperatures unsuitable for certain aquatic species. Identifying streams that may experience temperatures outside critical ecological habitat ranges can help prioritize planning for streambank restoration, stormwater management and other innovative strategies.

Soil Disturbance Assessment Through Comparative TDS Emissions from Headwaters

Fernando Rojano, West Virginia State University (R. Cantrell, A. Hass)

Total dissolved solids (TDS) in water from a small headwater (<0.5km^2) runoff reveal soil disturbance. The precipitation regime together with evapotranspiration and soil moisture, however, drives flow alterations inducing changes in TDS. These field conditions cause unique TDS temporal patterns from headwaters. Yet, one approach under field conditions evaluating soil disturbance is feasible by conducting comparative TDS studies between similar headwater characteristics and climate conditions. This study focuses on the analysis of two small headwaters, a reforested mining area and an adjacent native forest area with the aim to assess soil disturbance. Each of the two headwaters were monitored during 2020 measuring local climate (precipitation, air temperature and relative humidity), flow and electrical conductivity (EC) with a time step of 15min. In particular, EC was used as a proxy to estimate TDS being calibrated by means of periodic water sampling. These data served to identify concentration-discharge relationship through hysteresis and the influence of the last 30 days by means of the antecedent precipitation index(API_{30}). The hysteresis followed a counterclockwise path for a reforested mining area and clockwise path for a native forest area when observing an API_{30}≥32mm. Furthermore, the hysteresis responses were split in a wet and dry sections, revealing the capability of dilution during wet periods and subsurface flow reaching runoff during dry periods. The wet periods identified that TDS are undergoing an average twofold dilution in the reforested mining area with respect to the native forest area. On the other hand, runoff during dry periods identified that TDS linearly increased as API_{30} decreased for both headwaters; however, mean TDS were six times higher in the reforested mining area. This approach proved that hysteresis and wet-dry periods served as an adequate assessment of soil disturbance for reforested mining areas using comparative field data.

Hydrogeophysical Investigation of Agricultural Soil Salinization in the Eastern North Carolina Coastal Plain

Stephen Moysey, East Carolina University (A. Manda, E. Pezeshki, M. Sirianni)

Soils in low-lying coastal environments are at increasing risk of salinization as a result of multiple processes, including sea level rise, flooding produced by coastal storm surge, and the intrusion of saline waters into aquifers. Understanding how these processes might impact sites differently is important for making climate adaptation plans and determining what the long-term consequences might be for agriculture and ecosystems in these regions. Frequency-domain EM and electrical resistivity imaging methods are combined with soil and groundwater sensors to evaluate the patterns of salinity observed in three fields located in different areas of eastern North Carolina. Preliminary imaging results suggest that at the most inland field site salinity is likely impacted by vadose zone processes controlling the hydraulic connectivity of groundwater to the soil surface. In contrast, at sites closer to the Pamlico Sound the salinity is impacted by connectivity to the estuary produced by natural channels and extensive ditch networks created by people to support agriculture during the last century. Given this connection to flooding, the sensitivity of soils to salinization may then depend on how soil structure, such as macropores, affects flow and transport of salt in soils. While soil salinization is often considered to be a local problem, it is known that salt can enhance the displacement of nutrients and agricultural legacy chemicals, contribute to the loss of productive agriculture lands, and create ghost forests that all contribute to degrading environmental quality and economic impacts for eastern North Carolina.

Volunteer Monitoring in the Upper White River Basin, Arkansas: What Can We Learn?
Erin Grantz, University of Arkansas Division of Agriculture (B. Haggard)

The Arkansas Water Resources Center has partnered with the StreamSmart volunteer monitoring program since 2013, analyzing samples collected from across the Upper White River Basin (UWRB) for total nitrogen and phosphorus concentrations, alkalinity, conductivity, pH, total dissolved and suspended solids, and turbidity. The monitored streams are tributaries to Beaver Reservoir, the drinking water source for more than half a million Arkansans. In addition to quarterly water sampling, volunteers also complete habitat assessments on each site visit and sample for macroinvertebrates twice annually (May and August). The goal of this study was to use StreamSmart data (2013 – 2020) to gain insight into water quality conditions, land use-land cover (LULC) relationships, and trends in the UWRB, as well as assess the utility of volunteer monitoring datasets for answering these type of questions. The Mann-Kendall test was used to detect potential trends in water quality variables over time at each site. Site medians were calculated for all water quality, habitat, and macroinvertebrate variables and were input to linear regression analysis and non-parametric changepoint analysis (nCPA) to detect stressor-response relationships between water quality variables and LULC categories. Median macroinvertebrate index scores were also examined for stressor-response relationships with water quality variables and habitat assessment scores using nCPA. Study findings suggested change in one or more variables at 17 sites, most notably increasing TN concentrations at five sites, in-line with other watershed-scale analyses. Observed linear relationships with LULC were in-line with well-known patterns, as well as thresholds in %forest ranging from 30 to 68% and in %pasture+urban ranging from 28 to 53%. Threshold relationships were identified between macroinvertebrate metrics and habitat assessment components, but not the overall habitat index. Further investigation is necessary to understand if these components are better predictors, or if they are more accessible for volunteers to reliably quantify.

Agriculture Nutrition Effects of Increased Oil and Gas Activity from the Carrizo-Wilcox Aquifer in the Winter Garden Region of Southwest Texas

Ysenia Granados, Texas A&M University Kingsville (M. Coronado, M. Alexander, J. Amaya, J. Hernandez)

The Carrizo-Wilcox aquifer in southwest Texas encompasses the Winter Garden region, known for its year-round production of vegetables by irrigation. The area of interest includes Dimmit, Frio, La Salle, and Zavala counties, where there has been an increase in human and industrial activities, which have led to increased water contaminants in aquifers. The water quality effects of increased oil and gas production are the key interest in determining the suitability of agriculture nutrition levels in the area. Spatial analysis of the crop data is displayed by pixel-based images and the location of oil and gas wells in the region is displayed utilizing ArcGIS. Historic and recent data of total dissolved solids, specific conductivity, and sodium absorption rate was collected from groundwater well records maintained by the Texas Water Development Board. The mapping indicated a slight increase in total dissolved solids in the southernmost counties, Dimmit and La Salle, with a minimal decrease and steady level of total dissolved solids in the northernmost counties, Zavala and Frio. Additionally, most of the oil and gas activity occurred in the southern portion, compared to the agriculture areas primarily in the northern part of the region. The purpose of this study is to analyze the effects of increased oil and gas activity in the area to determine whether the crops are benefited or harmed by the increased salinity levels.

GastonWaterMap: A Web GIS for Informing Residents of Groundwater Contamination in Gaston County, NC

Zachery Slocum, University of North Carolina at Charlotte (E. Delmelle, D. Shoemaker, M. Serre, S. Dye)

The GastonWaterMap is a web-based GIS that provides timely information of groundwater quality and analyses to both individuals and County health officials. Over 42% of homes in Gaston County (NC) currently use private well water as their primary source of drinking water. The groundwater resources that feed these wells may be degraded by a range of contaminant sources. Based on findings from our ongoing CDC-funded "Healthy Wells" project, only a fraction of these households regularly test their drinking water, placing them at risk. Further, few public health regulatory instruments are available to inform well users as to the quality of their water. Needed are tools that 1) provide timely information and analyses to both individuals and County health officials to support decision-making and 2) educate well users as to the best practices to manage their water. To close this information gap, we propose an interactive geospatial approach that can focus and direct public health, testing, and monitoring efforts for specific contaminants. This project consists of three objectives. First, we estimated and mapped groundwater quality using our Healthy Wells database and geostatistical methods developed at UNC Charlotte and UNC Chapel Hill. Second, we developed an interactive, opt-in "alert" system to improve the visibility of ongoing water quality findings. Third, we implemented advanced modeling techniques that estimate the impact of geology, point, and nonpoint sources of pollution on groundwater quality. Findings from the third objective will be shared to health officials to increase awareness of risks posed by these sources of pollution, and facilitate property owners' decisions to conduct well testing.

Developing a Decision Tree-based model for Reoperation of California's Reservoir Systems and Flood Waters Managed Aquifer Recharge

Mahdi Erfani, University of South Carolina Mahdi Erfani, University of South Carolina (E. Goharian, J. Medellín-Azuara, M. Maskey, D. Lettenmaier, Q. Cao)

Recent changes in the climate, including frequency and duration of droughts, and changes in inter-annual patterns of water availability has put extra pressure on California's already limited water resources. This study introduces a novel integrated and multi-component framework for optimization and reoperation of the Folsom Reservoir, where there is potential for whole-watershed management. An integrated simulation-optimization model, which links FOLSim model with a hybrid multi-objective and linear optimization model, has been developed for reoperation of Folsom, groundwater recharge and flood managed aquifer recharge (Flood-MAR) considering also economic feasibility. The economic module consists of three elements namely: recharge, reservoir storage and hydropower production, and has been developed by tailoring the CALVIN model. Furthermore, in order to explore the effects of climate change and modify the long term operation rule, the NOAA-MP land surface model is configured for the American River and coupled with a hydrologic model to forecast discharge in the American River, to be employed in the FOLSim simulation-optimization model. Finally, a decision-tree based model has been developed to surrogate and accelerate systemwide modeling and water allocation. The results suggest that the proposed integrated watershed management framework has the potential to improve the operation of the Folsom reservoir and the downstream demand sites, mitigate the groundwater depletion through FloodMAR and regulating the river flow during the flood season and wet years in an economically effective manner.

Nitrogen Treatment Efficiency of Onsite Wastewater Systems in the Coastal Carolinas
Charles Humphrey, East Carolina University (M. O'Driscoll, G. Iverson)

Onsite wastewater systems (OWS) are a common means of wastewater treatment in the coastal Carolinas. OWS use a septic tank for separation of raw waste into solids and liquids, anaerobic digestion of organic matter, and retention of solids. Liquid wastewater is piped from the tank to drainfield trenches where it infiltrates the soil. After an initial permitting process that includes an evaluation of soil/site characteristics, most OWS are not monitored for their effectiveness in reducing concentrations of environmental pollutants such as nitrogen. This presentation will provide an overview of the nitrogen treatment efficiency of more than 30 OWS that were monitored in coastal regions of the Carolinas. Wastewater samples were collected from the septic tanks and groundwater samples were collected from monitoring wells installed near the OWS. Samples were analyzed for total dissolved nitrogen, nitrate, ammonium, and various physicochemical properties including pH and specific conductance. The differences in nitrogen concentrations between wastewater and groundwater samples were used to determine the treatment efficiency of each OWS. There was great variability in the concentration of nitrogen in wastewater from the septic tanks and in groundwater near the systems. Treatment efficiencies ranged from less than 10% to greater than 90%. OWS that had less than 45 cm of separation distance from drainfield trenches to the water table typically had higher ammonium and lower nitrate concentrations in groundwater relative to OWS with larger (> 45 cm) separation distances. Therefore, nitrification (conversion of ammonium to nitrate) was inhibited at those sites with shallow groundwater, and nitrogen removal via conversion of nitrate to N2 gas was also negatively affected. These data suggest that OWS in coastal areas may become less efficient at treating nitrogen as sea level rises and there is a corresponding increase in groundwater level and reduced thickness of unsaturated soil beneath drainfield trenches.

Attenuating Decentralized Wastewater Nitrogen using Nature-based Features

Guy Iverson, East Carolina University (C. Humphrey, C. Sanderford, M. O'Driscoll, E. Bean, S. Pradhan)

Non-point sources can discharge substantial concentrations and/or masses of nitrogen to water resources. Recent work has shown that septic systems have potential to be a significant source of nitrogen to surface waters, especially in nutrient-sensitive watersheds with a high density of septic systems. Additional research on retrofit best management practices (BMPs) designed to curtail septic-derived nitrogen inputs are needed. The goal of this study was to quantify concentration and mass reductions of total dissolved nitrogen (TDN) in water passing through an in-stream bioreactor (IBR) and a natural wetland (NW). The IBR was constructed in March 2017 and consists of a bed of carbon-rich and absorptive media installed in the hyporheic zone of a drainageway downgradient of septic drainfields. Water samples were collected upgradient, within, and downgradient of the IBR approximately monthly from March 2017 to June 2018. The NW was not engineered or modified during this study and samples were collected from inflow and outflow approximately monthly from November 2016 to June 2018. Results indicated that both BMPs were effective at reducing nitrogen. Concentrations of TDN and nitrate were reduced by 23% and 78%, respectively, after passing through the IBR. Mass removal of TDN and nitrate was greater at 31% and 86%, respectively. Concentrations of TDN and nitrate were 48% and 58%, respectively, lower after passing through the NW. Mass reductions were substantially greater for TDN and nitrate at 81% and 92%, respectively. Based on these results, future work focusing on the efficacy of BMPs adapted for wastewater treatment may be helpful to aid efforts to manage nitrogen, especially in nutrient-sensitive watersheds with high densities of septic systems. Additionally, watershed-scale attenuation features (e.g., wetlands, riparian buffers, etc.) should be considered when assessing nutrient transport from wastewater sources to water resources.

Spotlighting the Hawai'i Cesspool Hazard Assessment & Prioritization Tool

Christopher Shuler, University of Hawaii Water Resources Research Center (M. Mezzacapo)

Cesspools are a substandard sewage disposal method and are widely recognized to harm human health and the environment. The state of Hawai'i has an estimated 82,000 cesspools. To address pollution concerns, the Hawai'i State Legislature mandated replacement of all cesspools by 2050. A major step in achieving this goal is to categorize cesspools based on potential or realized harm to humans and the environment. This presentation will showcase the development and key features of The Hawai'i Cesspool Prioritization Tool (HCPT), a web-based framework designed for this purpose and funded by the Hawaii Department of Health. The tool incorporates a comprehensive list of datasets that met the needs of state government, cultural values, and environmental sensitivities including fifteen risk-factors that either control or relate to how cesspool impacts are distributed across communities and the environment. These factors were processed with a Weighted Risk Scoring Model to calculate a prioritization score for every cesspool in Hawai'i. Results from the HCPT prioritization were validated through comparison with a statewide assessment of nearshore wastewater impacts. All data used in the HCPT is at the statewide scale, normalized, and based on regulatory rules or modeling outputs. The HCPT was designed to be as objective as possible with prioritization based solely on the relationships between datasets, thereby reducing human bias as much as possible. The total number of cesspools in the state categorized as Priority Level 1 was 13,885, with 13,482 and 54,058 as Priority Level 2 and Priority Level 3, respectively. Approximately 35%, 7%, 21%, and 37% of cesspools in the Priority Level 1 group are located on O'ahu, Maui, Kaua'i, and Hawai'i Island respectively. Future data, organized within census area frameworks, can be layered onto the results to address equity and outreach challenges.

Hybrid Constructed Wetlands for Aquacultural and Municipal Wastewater Treatment in the Coastal Plain

Natasha Bell, East Carolina University (S. Hall, R. Etheridge, E. Hvastkovs, J. Hoben)

Coastal communities are facing many challenges related to climate change. These challenges, which include saltwater intrusion on cropland and damage from extreme weather events, are threatening important sectors of the economy and valuable coastal ecosystems. This project aims to help coastal communities adapt to these challenges by (1) overcoming barriers to the expansion of recirculating aquaculture systems (RASs) as an alternative agricultural land use for areas affected by sea level rise and (2) increasing the resiliency of infrastructure used for treatment of wastewater from aquaculture and municipal sources. A key barrier that must be overcome for growth and expansion into lucrative saltwater aquaculture production is treatment of nutrient-rich waste from saltwater species. Municipal wastewater treatment plants (WWTPs) are facing hydrologic and climatic challenges, and are contending with aging infrastructure and increasingly stringent effluent regulatory limits. To reduce downstream negative impacts of nutrients, including nitrogen (N) and phosphorus (P), from both the aquaculture and municipal WWTP sectors, resilient and affordable wastewater treatment options are needed. One such approach is the implementation of novel ecological engineered water treatment technologies. Our team is in the process of designing and testing on-site hybrid constructed wetlands (CWs) specifically for (1) marine aquaculture production in RASs at North Carolina State University's Marine Aquaculture Research Center; and (2) as an add-on technology for a municipal WWTP located in Greenville, North Carolina. We have partnered with an advanced technology-enabled manufacturing small business to produce 3D-printed nutrient adsorbent ecomodules to include in hybrid CW installations. We are also developing biosensors and automated controls systems to monitor biogeochemical and hydrological parameters in real-time and adapt amidst changing conditions. Data from these installations will inform our development of decision-making process-based models and guidance for hybrid CWs design, operations, and maintenance. During this presentation, we will report our preliminary findings.

Empowering Citizens with "Our Voice Our Water" in Municipal Stormwater to Build Resilience and Two-Way Communications

Regina Guyer, Rising Solutions, PLLC / Regional Stormwater Partnership of the Carolinas; Bryan Patterson, Johnson C. Smith University; Kari Raburn, Rising Solutions, PLLC

There is a need to acquire an understanding of the unique challenges and interests of the constituents within underserved, marginalized, and/or low- or fixed- income neighborhoods while developing applied methodologies for building two-way communications and trust. "Our Voice Our Water" research was conducted within three communities in Charlotte, NC to address the linkages between stormwater and trash, litter, and/or illicit discharges. The neighborhoods selected are historically underserved communities of Historic Washington Heights, Lincoln Heights, and Northwood Estates. Primary research objectives included: 1) Implementing applied research techniques by Johnson C. Smith University faculty, Rising Solutions, PLLC staff, and an AmeriCorps Member to access the behaviors and knowledge of stormwater issues with community citizens. Community members were encouraged to "Be Heard" by sharing their knowledge and perspectives. Research techniques included focus groups, surveys, and stream indexing. 2) The 3-1-1 Call Center Data was evaluated to gain a historic understanding of the citizens' concerns and follow up actions by Charlotte Mecklenburg. There were over 10,000 calls to the Charlotte/Mecklenburg 3-1-1 call center from community members of our target neighborhoods from January 2018- March 2020 assessed to understand the types of issues occurring within the communities. 3) Engagement with neighborhood leaders and citizens to build community trust and understanding through education and outreach opportunities as well as community meetings and a "3-1-1 Having a Voice" Workshop. This research was conducted through Johnson C. Smith University in collaboration with the Regional Stormwater Partnership of the Carolinas (comprised of 22 municipalities) on a grant through the Water Resources Research Institute - Stormwater Consortium. This presentation will highlight the research findings to enable municipalities to increase understanding while reviewing methodologies and strategies for the engagement of citizens.

Documenting Water Quality, Access, and Associated Water Coping Behaviors in Central Appalachia

Leigh-Anne Krometis, Virginia Tech (A. Cohen, H. Patton)

Recent high profile outbreaks and emergencies (e.g. Flint, MI; Martin County, KY) have demonstrated that significant vulnerabilities in water infrastructure exist in the United States. Systematic analyses of American Community Survey (ACS) census data suggest these infrastructure inequities disproportionately fall on native communities, rural regions of the south, and Appalachia. Though helpful in assessing infrastructure needs at a macro level, analyses of aggregate data documenting household water access do not capture measures of water quality at the point of use, and likely underestimate lack of access to services like safe water in lower-income and more remote rural regions. To examine trends in water access and quality at a more granular level, and document the use of supplemental or alternative sources, we conducted a walking water census of communities in McDowell County, WV beginning in the Fall of 2021. McDowell County is the 8th poorest county in the nation, and its "water crisis" is nationally recognized in popular media. Accompanied by community liaisons from local nonprofits, we offered free home water testing and asked residents to complete a short survey, including questions from the Multidimensional Poverty Assessment Tool, to better document water usage. Sample collection will continue throughout Spring 2022; initial results suggest that in-home water quality can be poor, and is often associated with significant household burdens. To date, over 60% (22/35) of household water samples collected were positive for total coliform, and 29% of samples were positive for *E. coli*. Two-thirds of samples exceeded the USEPA guidance level of 20 ppm sodium, with concentrations as high as 685 ppm observed. This may be of concern given elevated incidence of chronic health conditions requiring low salt diets in the area. Notably, 44% of respondents drink bottled water exclusively; half of these homes also only use bottled water for cooking.

New Dimensions of a Famous Water Conflict: Public Interest, Indigenous Rights, and the Los Angeles Aqueduct

Sophia Borgias, Boise State University

This presentation provides a critical reassessment of the emblematic water conflict over the Los Angeles Aqueduct, one of the first large rural-to-urban water transfers in the American West. Drawing on three years of in-depth archival, ethnographic, and collaborative research, I discuss how public, private, and tribal interests have been weighed in decision-making about this transfer over time amid social, regulatory, and environmental change. I address gaps in the history of the water conflict, demonstrating how Indigenous rights were impacted by the transfer, and discuss how that history continues to shape the ongoing water conflicts in California's Owens and Mono basins, as well as growing movements for water justice across the West.

Building Resilience into International Water Resources Collaborations (Participatory Session)

Facilitators:

- Katy Mazer, Purdue University
- Laura Bowling, Purdue University
- Anna Erwin, University of Texas Rio Grande Valley

In a world that is more connected than ever, threats like global environmental change and the COVID pandemic are increasingly becoming issues that require cooperation and resilience from many different countries. Also, while the impacts of these changes are felt in every corner of the globe, countries in the Global North have an increased capacity to face them through research, discovery, and often, financial resources. Many of these crises are expected to have worse effects on vulnerable countries with a projected increase in poverty, loss of available clean water, and many other issues. There is a need for increased resilience and capacity for facing these global issues, and one avenue that has emerged to solve these problems is through international water resources collaborations. The number of international research collaborations between universities or other institutions has increased in recent years, partially as an attempt to support countries that may be underequipped to address looming global changes. Although the initiation of many of these collaborations has been popular, there is little information on the longevity of these partnerships or literature on measures of success. In this participatory session, we will review the collaboration principles for international water research from Mazer et al. 2020 and discuss how to bolster vulnerabilities to create more resilient partnerships. We will discuss best practices for supporting host countries and building a pathways for sustainably achieving collaboration goals.

Bridging the Digital Water Divide - Improved Integration of Emerging Technologies

Panelists:

- Debabrata Sahoo, Clemson University
- Cal Sawyer, Clemson University
- Eve Brantley, Auburn University
- Paul Dow, City of Greenville, SC

The Internet revolution has created an inseparable digital aspect to our society. This digital world includes electronic devices, sensors and systems that help in collecting, compiling, computing, correcting, and communicating critical data. These datasets help in understanding and informing the world around us. They enable us to predict the future purely based on evidence. The world of water is no exception to the digital revolution. While numerous business applications have been created utilizing these datasets, the digital space around water remains fragmented. Although many water datasets are aggregated by various agencies such as the USDA, USEPA, USGS and potentially made available to the public, because they are not assembled and communicated in a structured way, the data are often not easy to access. If water data relevant to a state such as South Carolina is consolidated to a single repository for example, it could become the "Google of SC Water". Many such connected networks would aid in the development of a regional network – "Google of Southeast Water". Such integrated networks could facilitate development of water-related applications such as "Regional Real-Time Flood Predictions", "Regional Real-Time Drought Predictions", "Regional Real-Time Water Quality", "Live-Modeling", "SMART Stormwater Management", "Near-Realtime Event Detection" and more. Information and output would strengthen economic sectors that rely on such predictions: transportation, healthcare, retail, horticulture, agriculture, fisheries, etc. Newly established infrastructure would likely also spur growth in future industries surrounding "Digital Water".

The session will focus on some of the early adoptions and applications of digital data for hydrologic assets around data-collection, correction, compilation, computation, and consulting. Panelists will also address emerging technologies such as machine learning, cloud computing, Internet of Things, blockchains and their integration in solving some of the challenges around Digital Water.

Demand Management in the Upper Colorado River Basin: Economic Considerations
Kristi Hansen, University of Wyoming

Policymakers in the Upper Colorado River Basin states of Colorado, New Mexico, Utah, and Wyoming) are evaluating the feasibility of a water conservation program, called Demand Management (DM). Under a DM program, water users would be compensated for reducing their consumptive use of water on a temporary and voluntary basis. The conserved water would be stored in one of several large reservoirs in the Upper Basin (including Lake Powell) and released as needed to help these four states meet their obligations to downstream states under the Colorado River Compact of 1922. One of the issues that policymakers, water users, and other stakeholders in the Upper Basin must consider is the economic impacts to local and state communities resulting from water conservation. Results of three economic analyses already undertaken in Colorado and Wyoming will be compared. Analysis will be extended to New Mexico and Utah, with an eye towards understanding some of the institutional, geographic, and human considerations that drive differences in responses across states to the idea of a DM program. An additional consideration is how the states are differently situated with respect to "curtailment," which would involve involuntary and uncompensated reductions in water use in these four Upper Basin states, to ensure Compact obligations are met. (A robust DM program would reduce the risk of curtailment.) Further, a DM program would be just one of several strategies employed by the Upper Basin states to address Compact obligations in light of the region's persistently dry hydrology. The relative ability of a DM program vis-à-vis these other strategies to deal with uncertainty of future water supply will also be discussed.

Measurement and Modeling of Consumptive Use in the Upper Green River Basin; Important Information to Inform Management Strategies in the Upper Colorado River Basin

Ginger Paige, University Of Wyoming (S. Miller)

The Colorado River Basin has been experiencing drought for about two decades. The Upper Division States of the Colorado River Basin, Colorado, New Mexico, Utah and Wyoming, are collaborating with the Department of the Interior and stakeholders throughout the Upper Basin to evaluate proactive options for protecting critical elevations at Lake Powell. A Demand Management (DM) Program, a temporary, voluntary and compensated program for the reduction in consumptive use is one of the options being evaluated by the Upper Division States. Determining the feasibility of an Upper Basin DM program requires assessment of many outstanding issues. Critical to a DM program is the ability to measure and/or model consumptive use and the potential change in consumptive use. Many of the Upper Division states are implementing field investigations to assess our ability to measure and model these processes. In Wyoming, we have initiated a measurement intensive study with the primary objectives to 1) quantify consumptive use under “normal” irrigation practices, 2) quantify changes in consumptive uses under fallow conditions, and 3) document any changes in vegetation characteristics (e.g., species composition) due to fallowing. We present details on the methods and approaches we are using to measure and model consumptive use and results and key findings to date. In addition, we discuss these efforts in relationship to other ongoing studies in the Upper Division States.

Lessons from Synchronously Modeling Flex Accounts in a Combined Lake Powell-Lake Mead System with 26 Colorado River Managers and Experts

David E. Rosenberg, Utah State University

As Upper and Lower Colorado River Basin supplies declined in 2021, I introduced flex accounts in a combined Lake Powell-Lake Mead system as an alternative to interim operations that expire in 2026. Upper Basin, Lower Basin, Mexico, Colorado River Delta, and First Nations parties consumed and conserved within their account balance independent of other parties. Synchronous modeling with 26 Colorado River managers and experts (Figure 1) provoked discussion and 36 improvements. Participants said share this modeling activity with others and flex accounts were too far from current operations. I synthesized 10 lessons to improve model process, further river management, build trust, and produce more actionable insights. I posted a draft manuscript and a Github repository provides directions to download and use the synchronous model with colleagues.

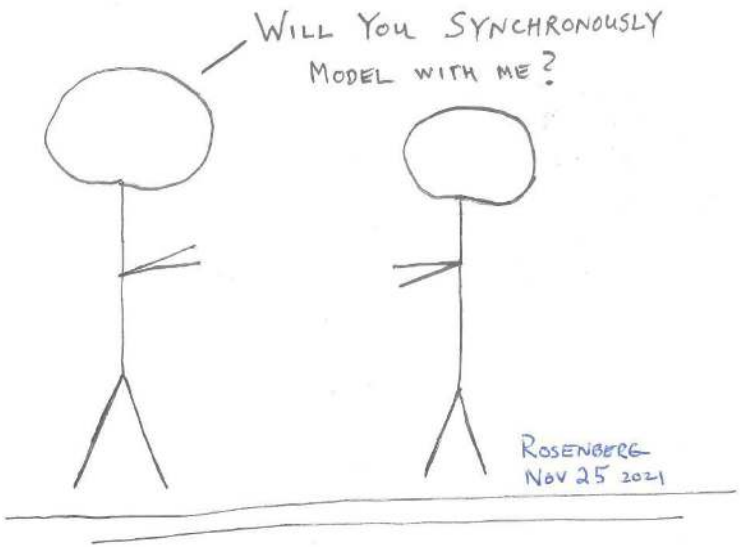

Figure 1. Start a digital adventure in a combined Lake Powell-Lake Mead system.

Getting to the Heart of Science Communication (Water Communication Workshop)

Facilitator: Faith Kearns, California Institute for Water Resources

Working on emotional and contentious issues like water, drought, climate change, and disasters that have direct impact in people's lives can be challenging for scientists and science communicators. This is particularly true for practitioners working and living in places where they are directly accountable to communities. Although this can feel like a weighty responsibility, it is also an area of potential insight, much in the way that a successfully allied therapeutic relationship can lead to profound transformation. However, it also invites practitioners to move away from the intellectually distanced stance that is common in the sciences and place themselves "in the work," which is no small task. This workshop will feature a presentation on increasing relational capacity for successful science communication. Workshop participants will then practice communication as a relationship-driven process, focusing on listening as at least as important as speaking, and how to work with the conflict that comes up when listening well.

Links for more information: https://islandpress.org/author/faith-kearns https://islandpress.org/books/getting-heart-science-communication

Developing Flow-ecology Relationships for SC Streams using Biotic Communities and Modeled Flow Metrics

Brandon Peoples, Clemson University (L. Bower)

South Carolina is experiencing sustained levels of increasing human population growth, which will present new challenges of protecting the quality and quantity of water in the state. Monitoring ecosystem health is a critical component of aquatic conservation; the predictable relationship between aquatic organisms and their environment forms the foundation of freshwater 'bioassessment'—using aquatic organisms as indicators of freshwater ecosystem integrity. Bioassessment based on stream fish and invertebrate communities can inform about human impacts to ecosystem health, such as land use change, poor water quality, and instream flow alteration. During this time of unprecedented growth, maintaining instream flow for both human use and ecological integrity is becoming a topic of increasing interest. An important first step is to quantify "flow-ecology relationships" between instream flow metrics and aquatic biota. The South Carolina departments of Natural Resources and Health and Environmental Control monitor stream fish and invertebrate communities, respectively, across the state. Coupling these data with modeled instream flow metrics produced by hydrologists from the Research Triangle Institute, we developed spatial flow-ecology relationships across ecoregions and hydrologic classes in South Carolina. Our results provide a robust, region-specific framework for informing decision makers seeking to develop instream flow standards and guidances. These relationships can also be used to inform potential biodiversity change under various future hydrologic scenarios. We anticipate this work can be used to help guide the water planning process at both basin-specific and statewide scales.

Quantifying Flow-ecology Relationships to Inform Flow Management in South Carolina

Luke Bower, Clemson University (B. Peoples, M. Eddy, M. Scott)

The natural flow regime (i.e. magnitude, frequency, duration, timing and rate of change of flow events) is crucial for maintaining freshwater biodiversity and ecosystem services. Protecting instream flow from anthropogenic alterations first requires an understanding of the relationship between aquatic organisms and the flow regime. In this study, we used a unique framework based on random forest modeling to quantify effects of natural flow regime metrics on fish and macroinvertebrate assemblages across ecoregions and flow regime types in the state of South Carolina, USA. We found that all components of the natural flow regime affected both fish and benthic macroinvertebrate assemblages, suggesting that maintaining natural aspects of all flow regime components is critical for protecting freshwater diversity. We identified hydrologic metrics and flow regime components such as magnitude, frequency, and duration of flow events, that were associated with the greatest ecological responses for individual stream classes to help managers prioritize hydrologic and biological metrics of interest during environmental flow standard development. The response of aquatic organisms to hydrologic metrics varied across stream classifications and ecoregions, highlighting the importance of accounting for differences in flow regime and ecoregion when designing environmental flow standards. We provide a flexible framework based on statistical flow-ecology relationships that can be used to inform instream flow management and assess effects of flow alteration on riverine assemblages.

Biological Standards for Water Withdrawal Management: Application in the Edisto River, South Carolina

Eric Krueger, The Nature Conservancy (South Carolina)

Water withdrawal management is an emerging issue as human populations expand. Existing water quantity projections and water withdrawal agreements are becoming more tenuous as climate change affects the hydrologic cycle and water demands increase. These forces are motivating water managers to develop or refine new and existing scenarios and agreements. A common question in these endeavors is: can we retain our ecosystem health and ecosystem services with increasing water use, and how can we measure or project this? By linking water withdrawal modeling to biological standards based on ecosystem field data, we can answer this very question. Typically grounded in fish and macroinvertebrate data, biological standards make explicit connections between water quantity and the health of these communities. Using sufficient data and machine learning concepts, biological standards can be used to project the degree to which stream flow quantity is affecting community health over other variables like water quality and land use. In this presentation, I describe an application of biological standards to various water withdrawal scenarios developed for the Edisto River of South Carolina, a free-flowing river composed of various stream types. The standards reveal the relative risks to stream health from varying levels of potential water withdrawal from the River, and show the variation of risk across the component stream types.

The Value of Freshwater Interventions: SC Residents' Willingness-To-Pay for Improved Water Quality

Carl Ureta, Clemson University (M. Motallebi, L. Bower, B. Peoples)

Environmental benefits known as Ecosystem Services (ES) are the direct linkage between human well-being and the ecosystems. Hence, changes in the ecosystem quality eventually affect the society's welfare. Particularly for rivers and streams, the increasing urbanization and industrialized agricultural practices change its water quality characteristics. Therefore, interventions for improvement are employed to monitor and manage rivers and streams' water quality. However, these interventions are typically based on technical indicators that are not easily comprehensible and appreciated by the public. This creates some resistance in implementing interventions, particularly when weighing its potential benefits to society. This study explores the idea that clear and concise communication of these indicators will increase the public's understanding and acceptability of possible interventions by eliciting their willingness-to-pay (WTP) for water quality improvement. Using a stated preference approach, we elicited South Carolina residents' WTP for improving water quality characteristics such as index of biotic integrity (IBI), flow quality, species richness, and abundance of catch. Results estimated that residents' mean WTP for improving these characteristics ranges from $3.00 to $4.50 per month per household. This approximates to around $60 million to $90 million welfare benefits annually. Furthermore, households with high water consumption and in higher income bracket revealed to have higher willingness to pay. The results indicate the economic value of river and streams' water quality as it contributes to an increase in society's welfare. The result could be used in a benefit-cost ratio assessment of potential interventions to identify which would be the best strategic program for an area.

South Carolina River Basin Planning – Balancing Social, Economic, and Environmental Needs
Scott Harder, SCDNR

Economic development, environmental protection and public health are critical quality of life issues that depend on a reliable supply of water. Increased water demand and climate variability (drought) are two major factors that have the potential to limit future water availability in the State of South Carolina. The development of comprehensive water-resources management plans for the State is vital for ensuring that an adequate and reliable supply of water will be available to sustain all future uses. To that end, the South Carolina Department of Natural Resources (SCDNR) published the *South Carolina State Water Planning Framework* (Planning Framework) in October 2019 under the guidance of the South Carolina Planning Process Advisory Committee. The Planning Framework describes the process for developing a stakeholder-driven water supply plan (River Basin Plan), and the content of such a plan, for each of the State's eight planning basins to ensure current and future water demands can be met over a 50-year planning horizon. A major component of the Planning Framework is the convening, by the SCDNR, of a River Basin Council (RBC) consisting of a diverse group of stakeholders in each of the eight planning basins. One of the key guiding principles for RBCs in the development of a River Basin Plan is that plans should balance social, economic, and environmental needs. Historically, South Carolina has lacked sound scientific information from which to adequately address the environmental or ecological flow needs in the states' river basins. A recent study completed by Clemson University on quantifying streamflow-ecology relationships fills an important information gap, and results from the study may be used by RBCs to inform river basin planning. We will present an overview of South Carolina's state and river basin planning process and the importance of integrating flow-ecology relationships into the RBC decision-making process.

Vulnerability and Recommended Mitigations Concerning Water Resilience to Cyber-based, Malevolent Acts on Community Water Systems

Michael Kuitu, Texas A&M AgriLife Extension Service (J. Mowrer)

Water management practices include the application of multiple professions to meet water-related needs of farms, cities, and wildlife while overcoming legal and logistical challenges associated with water ownership, movement, treatment, and disposition. While such needs and challenges are faced each day by water resource professionals, Section 2013 of "America's Water Infrastructure Act of 2018" (§ 2013) addresses a requirement to consider the less common scenario: "…malevolent acts and natural hazards…". In regards malevolent acts, cyber threats to each practice of water management have garnered growing attention by regulatory, law enforcement, and national security agencies of the federal government. This has occurred as public utilities and private companies across the United States have increasingly reported cyberattacks in recent years, affecting the management of their physical infrastructure. As a result, the role of cybersecurity as a professional discipline is paramount to both the present and future of water resiliency. In response, amendments to existing law and established regulations have taken place to protect water resources against an otherwise invisible threat. This oral presentation focuses on vulnerabilities of community water systems to cyber-based, malevolent acts and the preventative measures for those vulnerabilities. Historical context, requirements resulting from § 2013, examples of recent cyber breaches, and recommended mitigations to enhance resiliency will be detailed.

Per- and Polyfluorinated Substances Legal and Regulatory Update

Catherine Janasie, University of Mississippi School of Law/National Sea Grant Law Center (O. Deans)

Per- and polyfluorinated substances (PFAS) are an emerging contaminant with known human health effects. PFAS do not break down easily and have been found to accumulate in soil and water throughout the country. For example, in early 2022 the Wisconsin Department of Natural Resources issued a fish-consumption advisory for Green Bay due to PFAS contamination. Understanding the PFAS regulatory framework is important for scientists, industry, and decision-makers, and it helps to identify where more information is needed and how scientific studies can better inform the regulatory process. The past year saw many updates to the legal framework for PFAS. With the passage of the Federal Infrastructure Package, Congress provided $10 billion for projects aimed at reducing the risk of PFAS exposure. The U.S Environmental Protection Agency (EPA) also finalized the fifth Unregulated Contaminant Monitoring Rule, which will require sample collection for 29 PFAS between 2023 and 2025 to help identify PFAS contamination in drinking water. On January 24, 2022, the EPA added 4 PFAS to the agency's Toxic Release Inventory List. There has also been activity on the state level. Some states continue to regulate PFAS more robustly than the federal government, and the regulatory impacts contain important lessons for future studies and legislation. Along with regulatory changes, lawsuits concerning PFAS continue to be filed and make their way through the court system. Several groups recently sued the EPA for exceptions to its PFAS reporting requirements, and industry members have challenged the PFAS clean-up requirements in Wisconsin. This presentation will explain the PFAS regulatory approaches of the federal and state governments, as well as highlight some of the current PFAS-related lawsuits.

The Effect of Management Agency on Reservoir Recreation Participation

Mary Mena Boateng, North Dakota State University (R. Hearne)

Dams and reservoirs are created to provide flood control, water storage for irrigation and water supply, recreation, and hydroelectric generation. Most US reservoirs provide recreation in some form. However, there are concerns that certain reservoir/dam managers do a better job in providing recreation than others. Some agencies that manage land riparian to US reservoirs, such as the National Park Service (NPS), are dedicated to recreation development. Other agencies such as the Army Corps of Engineers (USACE) might not be interested in catering to the additional demands of recreators as a stakeholder group. Management actions such as boat access, waterfront land and campsite management, safety, aesthetics, and water levels have direct and indirect effects on anglers, swimmers, boaters, and other recreators. The objective of this study is to analyze recreation participation for different reservoirs based different management agencies due to the fact these agencies have different institutional objectives. Therefore, the analysis aims to compare the recreation participation rates of these two agencies, namely the NPS and the USACE, at the national level. A dataset of visitor data for the years 2011 - 2020 from 11 NPS managed reservoir National Recreation Areas and 42 USACE managed reservoirs has been developed. Explanatory variables will include: reservoir size and weather; water levels and water quality; local economy and population; distance to major metropolitan areas; number of agency-managed and non-agency managed campsites, marinas and boat launches: and management agency. Results of this study would demonstrate if agencies with a clear mandate to promote recreation are better in attracting visitors. If this is the case then policy-makers could adjust agency mandates or alter the management of reservoir riparian land in order to better suit recreation demand.

Efficient Management of Water Resources in the Eastern US

Nataly Medina, Clemson University (M. Rad)

Unlike the western United States, the eastern half has historically benefited from abundant water supplies. However, demand for water has increased over time due to population growth and an increase in irrigated agricultural production and energy generation. The supply of water has also been affected in some states by climate change and saltwater intrusion. Increasing demand for water resources in the eastern US along with decreasing supplies have raised concerns regarding water availability in the future. To address future water scarcity issues, there is a need to establish an efficient management strategy for the eastern US, which historically follows the riparian doctrine. So far, most changes in water management in these states have focused on reducing the demand for water. In this article, we have two main goals. First, we provide a comprehensive review of water management approaches across the eastern US. Our analysis shows that an increasing number of eastern states are adopting a regulated riparian doctrine. Second, we discuss the limitations of current water management approaches and provide suggestions for future changes in water resources management across the eastern states. In particular, we argue for a transition away from the riparian water rights system and adopting a water rights system that allows for trading between water users. We provide examples of successful changes in water rights systems from Texas and Australia.

Monitoring Infiltration Rates of Coastal Low Impact Development Practices in Georgia
Jessica Brown, University of Georgia (R. Brown)

Bioinfiltration practices to manage nonpoint source pollution from stormwater rely on specific hydrologic and microbial processes to achieve their expected pollutant load reductions. Studies have shown that water quality benefits and corresponding pollutant removal efficiencies attributed to bioinfiltration practices, such as bioretention, are linked with hydrologic performance, namely runoff reduction because of infiltration. Unique coastal conditions and associated factors such as fluctuations of ten (10) feet in the daily diurnal tide, shallow groundwater, and local soil properties and soil characteristics impact the performance of bioinfiltration practices. As weather patterns change, monitoring of the integrity of existing infrastructure has been identified as an adaptation strategy to protect against the impact of climate variability and build resiliency in local stormwater conveyance systems. In addition, pollutant load reduction estimates are based on a very limited amount of data and should be verified using independently reviewed performance monitoring data and calculations. Monitoring of rainfall and water levels was conducted in 2020 and 2021 to establish infiltration and exfiltration rates of the infiltration media. The data will contribute to hydrologic performance models (volume and flow) of bioinfiltration practices that have been modified to accommodate coastal conditions: reduced depths to groundwater, without underdrains, and with other design allowances. The record of hydrologic performance will be compared with the efficiency standards and design guidance in Georgia's Coastal Stormwater Supplement. This information will determine functionality and effectiveness of bioinfiltration in a coastal setting and help improve future design and maintenance recommendations for coastal GI/LID BMPs. The presentation will share project data and provide opportunities to discuss data trends and how this research will inform regulatory guidance.

Regenerative Stormwater Conveyance: From Research to Application

Gillian Palino, University of Tennessee - Knoxville (J. Thompson, J. Schwartz, J. Hathaway)

In natural systems, stormwater moves to streams and river networks by way of wetlands, floodplains, and riparian forests which offer treatment and runoff detention. As watersheds are urbanized, these natural flow paths are short circuited by storm drains and pipes that bypass these ecosystem services. This causes increased peak flows in receiving waters with subsequent erosion, volume control, and pollutant problems. Regenerative stormwater conveyances (RSCs) are an emerging design solution to decrease runoff flow energy, increase infiltration rates, and improve water quality. Positioned at the stormwater outfall, RSCs are comprised of an open channel step-pool system lined with native vegetation and are sized to fully contain the 100-year storm. With storms predicted to continue increasing due to climate change, management strategies to safely convey stormwater will also continue to become more critical. Scientifically informed RSC design guidance is limited and prevents more widespread application to protect these receiving waters and surrounding urban areas. In Knoxville, TN, modeling techniques were employed to optimize RSC pool dimensions and hydraulic performance. Preliminary results found that the number of pools did not impact hydraulic performance and instead pool/riffle geometry should be prioritized. The main objectives of the project are to better optimize and streamline the RSC design process thereby improving stormwater quality, preventing erosion, and increasing flood resilience.

Breaking Down LID+GSI Barriers: A Code Audit Tool for Florida Communities

Eban Bean, University of Florida (L. Bertolotti, L. Jarrett)

Outdated, conflicting, and poorly constructed local ordinances are a common barrier to the implementation of Low-Impact Development (LID) designs and Green Stormwater Infrastructure (GSI; LID+GSI). These codes often directly or indirectly prevent or restrict the use of these practices. The state of Florida is considering including a requirement in the revision of the MS4 permit to require permittees to review their local codes to identify these barriers. Ordinance Audit tools are intended to facilitate the process of reviewing local codes following a structured, methodical approach. Building largely on work of Wisconsin Sea Grant, the Center for Watershed Protection, we integrated and adapted code review elements into a state-specific tool for Florida municipalities and counties. The tool includes of a community scoping exercise intended to assess the extent of GSI implementation, community support and resistance, and to identify a core group of local government liaisons to provide experience and perspective on the process from varying departments. The second part is the Audit Workbook, which is includes nearly 200 questions divided into 16 sections aligned with typical code sections. Each question includes audit tips and is scored on a scale from zero to four, with positive a positive response receiving a higher score. Sections with lower percent of possible points may indicate sections of code that could be revised. The workbook is comprehensive but scalable, such that communities (external parties) may conduct as complete, or as limited, of a review as deemed necessary. The tool is set to be piloted in early 2022.

Building Community Infrastructure

Eve Brantley, Water Resources Center, Department of Crop, Soil and Environmental Sciences, Auburn University

Successful green infrastructure includes science-based planning, design, implementation, maintenance and community education. Each of these steps is critical, but often the community education piece is overlooked. Building community support and willingness to implement new technologies often encounters obstacles related to lack of technical knowledge, concerns of costs, hesitancy of aesthetic appeal, and uncertainties of maintenance. A first step to building community infrastructure involves listening to concerns and identifying opportunities for education and collaboration. Partnerships on demonstration projects provide shared responsibility to try a new approach with the expectation of learning lessons to refine and improve green infrastructure.

Advancing Green Stormwater Infrastructure: A Land Grant Mission Success Story

Andrea Ludwig, University of Tennessee, Biosystems Engineering and Soil Science (J. Hathaway)

As an increasingly clear picture has developed of the repercussions of unchecked land development and urbanization, there has been a shift in expectation for responsible stormwater runoff management as to not impact downstream communities as well as protect against degradation of water quality and aquatic ecosystem health. Universities, in particular Land Grant institutions, have played a seminal role advancing the science, application, and adoption of green stormwater infrastructure (GSI) to protect urban water quality. A wide range of university-led activities, from research to technical assistance and outreach education, support efforts at state and local levels to increase understanding and the prevalence of GSI in communities. Specific examples from Tennessee are representative of how university products and partnerships across the country are advancing GSI, carrying out the land grant mission of providing technical and practical education that makes a difference in everyday lives.

How Interactive Biotic and Abiotic Factors Drive Cyanobacteria Bloom Dynamics: Synthesizing 14 Years of Ecological Research in Vancouver Lake, WA, USA

Gretchen Rollwagen-Bollens, Washington State University

The frequency and magnitude of freshwater harmful cyanobacterial blooms (CHABs) are expected to accelerate under future climate change, thus understanding the driving mechanisms for CHABs is a pressing need. Over a 14-year period (2006 – 2020) we studied the effects of multiple biotic and abiotic factors on the timing, magnitude, and composition of summertime CHABs in Vancouver Lake, a shallow urban lake in Washington state, USA. Studies included high frequency water quality sampling, multiple series of microzooplankton grazing (dilution) experiments, rotifer and copepod feeding experiments, and incubation experiments testing the interactive effects of enhanced [PO_4] and copepod grazing on phytoplankton growth. Our synthesis of these results demonstrates a consistent year-to-year pattern of CHAB dynamics occurring in four overlapping phases. 1) Early Summer: low [PO4] and moderate [NO3], strong copepod predation on microzooplankton (ciliates, dinoflagellates), high diatom growth; 2) Mid- to Late-Summer: Wind-driven PO_4 resuspension, copepods and microzooplankton shift diet to diatoms, cyanobacteria bloom; 3) Late Summer: [PO4] decreases, copepods stop grazing, microzooplankton (including small rotifers) consume cyanobacteria, bloom diminishes; 4) Early Autumn: Large predatory rotifers consume microzooplankton, diatoms increase, copepods resume grazing. Our overall results have important implications for bloom management in Vancouver Lake and other shallow lakes, and suggest solutions will come from considering several factors acting in concert.

Microcystin Thresholds and Response to Nutrient Additions at Lake Fayetteville, Arkansas

Brian Haggard, Arkansas Water Resources Center (L. Haddock, A. Ferri, B. Austin, E. Grantz, N. Wagner, and T. Scott)

Recently, cyanobacterial harmful algal blooms (HABs) have been increasingly documented and studied in freshwater systems across the USA. Lake Fayetteville in northwest Arkansas had its first documented cycanbacterial HAB in 2019, and we have been collecting water samples on a near weekly basis during the growing season since 2019 at this small (<1 km^2 surface area) recreational impoundment. We measured total microcystin concentrations, dissolved and total nutrients, phycocyanin and chlorophyll raw fluorescence units (RFUs) and pigments, and general physico-chemical properties in each sample. In 2021, we completed 21 bioassays from April through November to evaluate the response (i.e., growth and microcystin) of the cyanobacterial HABs to nutrient (nitrate and phosphate additions). The microcytin results from the bioassays were fascinating, where nutrient addition did not increase toxin concentrations at first, but then shifted to a response to increasing nutrients, then to only an increase with nitrate addition, and finally back to an increase only with phosphate additions; this clearly showed the seasonal influence that nutrient supply or additions have on increasing toxin concentrations in cyanobacterial HABs. We took the data from the lake and built regression trees, which showed significant thresholds and hierarchical structure between microcystin and nutrients, algal parameters, water temperature and categorical variables like season and year; these regression trees varied each year and with all data lumped together. These data show how variable the response of cyanobacterial HABs and toxin production can be to nutrients and environmental conditions, highlighting the importance of site specific studies in the management of this pressing water quality issue.

Chlorophyll-A Estimation in Lakes Using Multi-parameter Sonde Data

Xiaofeng Liu, Georgia Water Resources Institute, Georgia Tech (A.P. Georgakakos)

Algae blooms are of considerable concern in freshwater lakes and reservoirs worldwide. Chlorophyll *a* (Chl-*a*), the major photosynthetic pigment in algae, is typically used as a proxy indicator to assess lake trophic status and algal bloom extent and severity (USEPA, 2000). Chl-*a* can reliably be determined through laboratory analysis of lake water samples, but this process is time-consuming and costly and requires experienced analysts to produce consistent and accurate results. Alternatively, in situ Chlorophyll a (Chl-*a*) fluorometers are used widely to provide rapid Chl-*a* assessments over large lake areas. However, accurate conversion of Chl-*a* fluorescence data to equivalent laboratory-extracted concentrations is challenging due to various environmental and biological factors, including non-photochemical quenching (NPQ). This article describes an effective bias correction method for converting Chl-*a* fluorometer data to equivalent laboratory-extracted concentrations. The study is based on Chl-*a* fluorometer measurements taken monthly from October 2018 to December 2020 using a YSI EXO2 sonde at several locations in Lake Lanier (in Georgia) from surface to bottom at depth spacings of 0.5 meters. Water samples at the same locations and depths were also obtained and analyzed through traditional laboratory methods. The new bias correction method estimates Chl-*a* concentrations through a multivariate nonlinear model of several concurrently measured sonde parameters. NPQ effects are also identified and corrected in the mixed surface layer through association with the dissolved oxygen profile. Extensive validation tests demonstrate that Chl-*a* estimation accuracy is significantly improved with a root mean square error (RMSE) less than 0.8 µg/L. The new method effectively addresses various biases of in situ fluorometer measurements, rendering them suitable for use in algal bloom and regulatory compliance assessments.

Prediction of Chlorophyll-A Concentrations in a Piedmont Lake in South Carolina using Continuous Water Quality Data and a Machine Learning Algorithm

Ibrahim Busari, Clemson University (D. Sahoo)

Understanding the complex interrelationships between ecosystem and environmental factors triggering harmful algal blooms (HABs) in freshwater systems is an essential step towards their proper management. Chlorophyll-a concentrations are often used as an index of rapid algae proliferation. Although commercial sensors are available to measure chlorophyll-a concentrations based on fluorescence, these commercial sensors are expensive to maintain. Additionally, the conversion of raw fluorescence in the sensors to chlorophyll concentrations is sensitive to environmental factors too. As an alternate to chlorophyll-a measurements, predictions of chlorophyll-a concentrations using traditional continuous water quality datasets (e.g., temp, pH, dissolved oxygen) are getting attention due to the breakthrough in data acquisition systems and sensing technologies. In this study, machine learning algorithms such as random forest model was explored to predict chlorophyll-a concentrations utilizing several water quality parameters continuously measured from 2014 till 2021 at Boyd Millpond. The model parameters were optimized using the Grid Search cross-validation technique. The study used the Permutation Variable Importance (PVI) algorithm to rank the importance of the predictors and obtain parameters that highly influences chlorophyll-a prediction. The study further investigated the impact of splitting criteria on the performance of the chosen model. The result from this study indicated that the best model performance was obtained when all input parameters were used and the training set was randomly chosen. R^2, correlation and RMSE values of 0.86, 0.93 and 0.00013 respectively were obtained. These performances reduced when the data was considered as time dependent. This study provides an efficient way to observe chlorophyll-a concentrations using fewer water quality parameters. These chlorophyll predictions are an important requisite of a better HABs event detection systems upon which regulatory advisories can be based.

An Analysis of Environmental Conditions Impacting Cyanobacterial Algal Blooms in Drinking Water Sources in Upstate South Carolina

Gregory Langlois, Clemson University

Maintaining water quality in reservoirs used for drinking water has been an issue in recent years due to the presence of algal blooms. Algal blooms are a perennially recurring problem that can have negative impacts on tourism, recreation, and overall water quality. Additionally, algal blooms will often produce an assortment of chemicals, some of which are hazardous to the health of humans, and some of which that, while relatively innocuous, result in unpleasant tastes and odors in water. Geosmin and 2-methylisoborneol are two taste and odor compounds that are notoriously difficult to treat out of drinking water sources by traditional methods like flocculation and screening. It is important to establish the time frame that odor causing algal blooms occur, and to determine the environmental conditions that drive excessive algal growth. Four freshwater lakes in Upstate South Carolina, Lake Whelchel, Lake Bowen, Lake Greenwood, and Lake Rabon, have had problems with cyanobacterial taste and odor compound causing blooms in recent years. Subsequently the goal of this research was to 1) establish any seasonal peaks in algal growth 2) establish any relationships between total algal growth and the presence of cyanobacteria 3) determine what, if any, environmental conditions influenced the growth of said blooms in each lake. The fourth and final project objective was to develop an ultraperformance liquid chromatography method for determining total geosmin and 2-methylisoborneol in environmental samples. While phosphorus is typically identified as the limiting nutrient in algal bloom growth, it was determined that Nitrogen, specifically ammonium and nitrates, were the primary drivers of algal blooms in sites with substantial algal growth, providing insight into how potentially harmful blooms can be managed in these drinking water sources in the future.

Satellite-based Assessment of Lake Lanier Chlorophyll-A

Husayn El Sharif, Georgia Water Resources Institute, Georgia Tech (X. Liu, A.P. Georgakakos)

Fine spatio-temporal resolution estimates of Chl-*a* concentrations are critical for monitoring the water quality of inland lakes which typically provide many important services including drinking water, farm irrigation, industrial water supply, and recreation. Multispectral remote sensing data from the European Space Agency (ESA) Sentinel-2A/B satellite mission provide an opportunity to infer Chl-*a* concentrations. In this study, a new procedure to assess Chl-*a* over Lake Lanier at 30-meter spatial resolution from Sentinel-2A/B remote-sensing data is developed and tested. The new procedure is based on multivariate nonlinear associations of multi-band satellite and in-situ Chl-*a* data, and aims to estimate the photic-zone depth-averaged Chl-*a*. Model accuracy (measured by the root mean square error, RMSE) with respect to in-situ measurements ranges from 0.5 ug/L to 1.3 ug/L, with the model performing well in all seasons. This model has been operationalized and is hosted on the Google Earth Engine (GEE) web-based platform. The GWRI SatTool facilitates convenient and fast calculation of Chl-*a* concentration maps as well as seasonal and interannual assessments. The results suggest that model relationships are regionalizable and can provide useful assessments for similar inland water bodies throughout the southeast U.S. The GWRI SatTool is designed to support several useful applications including (i) *Monitoring of lake eutrophication over time*; (ii) *Hotspot identification and nutrient source attribution;* and (iii) *Early warning of harmful algal blooms.*

Low-Cost Reliable Water Resource Monitoring Using the Intelligent River® System

Christopher Post, Clemson University (M. Mayyan, J. Merritt, C. Cook, D. Sammeta, A. Isaac, V. Modi, P. Minerva, J. Allen, M. Bolick, E. Mikhailova)

Understanding how streams and watersheds function in times of drought and extreme precipitation events requires more spatially dense monitoring of our water resources. The Clemson University Intelligent River® project has developed technologies to monitor water resources using internet-connected devices that can stream data in near real-time. These sensor systems can increase water measurements density in both streams and connected stormwater pipes to help understand storm and drought response. These Intelligent River® sensor nodes include low-cost integrated sensors, embedded computers, and metadata management and visualization systems. This system can integrate newly developed sensors as well as the best commercial sensor solutions while storing the data and metadata in an open format that can be securely shared with stakeholders and state agencies. These technologies have the potential to significantly improve how water can be monitored in a range of situations and environments. Recent advances in cellular Internet-of-Things (IoT) and Low Power Wide Area Network (LPWAN) technologies have increased communication reliability while reducing system power requirements. We will discuss the Intelligent River® low-cost IoT system with near-real-time hydrologic reporting that can be replicated to scale to thousands of monitoring locations and does not have limitations inherent in many closed commercial systems.

Developing Temporal Convolutional Neural Networks and Application of Transfer Learning for Hydrologic Modeling in Ungauged Basins

Mahdi Erfani, University of South Carolina (E. Goharian, J. Imran)

The application of data-driven models in hydrologic modeling has been growing as a result of advances in big data analysis and machine learning. Temporal Convolutional Neural Networks (TCNNs), a 1-d variation of convolutional neural networks developed for sequential modeling tasks, take advantage of deep network structures, dilatation, and causal convolution, to increase the network's receptive field and learn long-term dependencies in the data. Consequently, TCNNs have great potential for hydrologic modeling rainfall-runoff and outperform Recursive Neural Networks (RNNs) for streamflow prediction. In this study, the ability of TCNNs in rainfall-runoff modeling is explored by developing a regional TCNN model for South Atlantic Gulf region and the TCNN model capability has been compared with an LSTM model. The model is trained using the Catchment Attributes and Meteorology for Large-sample Studies (CAMELS) dataset, an extensive dataset with meteorological forcing and streamflow data for many large basins in the United States. Furthermore, a transfer learning approach has been used to incorporate statistical hydroclimate and physical watershed attributes into the modeling to evaluate the performance of TCNN for prediction in ungauged basins (PUB). The results of this study show that TCNN performs satisfactorily for streamflow prediction, learns from, and predicts long-term patterns in hydrological data. Moreover, the accuracy of the regional model in predicting the streamflow in a hypothetical ungauged basin in South Carolina, suggests that TCNN application can be extended to PUB tasks since they can learn the general patterns in hydrologic data and therefore perform well for basins with no streamflow data available to train the model.

Catawba-Wateree Integrated Water Resources Plan: Developing Long-term Water Quantity and Quality Resilience for Drinking Water Supply

Sara Yeh, HDR Engineering, Inc. and Jimmy Bagley, City of Rock Hill (M. Eddy)

Eighteen drinking water suppliers and a hydropower operator have joined efforts within the Catawba-Wateree River Basin to develop a long-term plan to secure water quantity and quality for the Basin. Following a severe drought in 2006, this group of water managers across North and South Carolina, known as the Catawba-Wateree Water Management Group (CWWMG), recognized the strain that the changing environment and regional population and economic growth may have on the long-term use of the Basin's water resources. In 2014, these efforts culminated in a basin-wide Water Supply Master Plan, which modeled future scenarios to allow partners to plan and implement sustainable water resource management strategies, including raw water intake contingency planning and water loss audits. The CWWMG recognizes the importance of resilient resources to meet not only water quantity needs, but also water quality protective of human and ecological concerns. Given this understanding and a 10-year revision requirement resulting from a US Supreme Court settlement decision, the CWWMG embarked in late 2020 on a 5-year planning process for an updated Integrated Water Resources Plan (IWRP). The group has developed the IWRP planning framework, is updating probabilistic water demand forecasts, and extending the geographical planning area to include 76 additional river miles downstream of Lake Wateree. The IWRP update will explore a range of water quality concerns within the Basin rivers and reservoirs using methods ranging from state of the science summaries to quantitative empirical and/or process-based modeling depending on the level of concern, data availability, and ability to define actionable outcomes for stakeholders. As part of both the hydrologic and water quality assessments, the IWRP team will complete coupled watershed (WaterFALL®) and reservoir (CHEOPS) models to examine the daily changes in water availability and quality throughout the Basin under current conditions and a series of future projections.

Stormwater Quality Treatment with Bioretention Cell: Is It a Filter or Sponge?
Tolessa Deksissa, University of the District of Columbia (S. Rose, S. Tefera)

Stormwater pollution is one of the challenges of modern water pollution control in the urban areas. To address this challenge, bioretention cell is one of the most popular best management practices, collectively known as green infrastructures (GIs), implemented by the cities. Bioretention cells are designed to slowdown the peak surface flow while removing contaminants from stormwater runoff, however there is limited field data that shows the effectiveness of bioretention cells as a filter or sponge media in removing priority pollutants. Lack of field data is the major challenge in advancing stormwater quality mitigation measures as well as in exploring the potential use of treated stormwater. The purpose of this work is to address the knowledge gap in the effectiveness of bioretention in treating stormwater quality while assessing the potential use of treated stormwater runoff for urban gardening. The composite sample of each storm event was analyzed for key water quality parameters including the sixteen-priority polycyclic aromatic hydrocarbons (PAHs), trace metals, and basic water quality parameters such as total suspended solid, total nitrogen and total phosphorous, nitrate plus nitrite and orthophosphate. The performance of bioretention in treating stormwater was analyzed based on the event mean concentration of these water quality parameters. The findings of this research work will contribute to the advancement of triple bottom line benefits of bioretention cell as stormwater GIs in various ways including the advancement of bioretention design and potential use of treated stormwater.

The River Basins Research Initiative: Three Decades of Undergraduate Research in the South Carolina Piedmont

Gregory Lewis, Furman University (D. Haney, M. Liao, S. Muthukrishnan, B. Andersen)

Since 1997, faculty at Furman University have involved well over 200 undergraduate students in interdisciplinary studies of streams, rivers, and watersheds in the Broad and Savannah River basins in northwestern South Carolina. Given the rapid increases in human population and expansion of urban land cover in the region, the overarching goal of our research has been to develop a better understanding of the influence of human activities and land use on stream habitats, fish and bacterial communities, geomorphology, and biogeochemistry. Early research showed a strong positive relationship between watershed urban land cover and stream nitrate concentrations, especially urban headwaters. Large changes in nutrient concentrations in streams and rivers are associated with release of effluents from wastewater treatment plants. In contrast, artificial ponds and lakes act as nutrient sinks, but also, along with golf courses, influence steam water temperature. In rural areas, elevated stream nitrate concentrations are also associated with row crop agriculture. Both pasture and poultry farms appear to influence the frequencies of various phylogroups of *E. coli* in stream water. At larger scales, stream solute concentrations and abundance of suspended microbes in forested headwaters vary along an elevation gradient within the Piedmont and Blue Ridge provinces. However, our research also has identified important challenges to understanding impacts of current land cover and land use on streams in the region. For example, we have found that both urban and rural streams typically have similar and poor fish community diversity and are often deeply incised, suggesting lasting changes associated with past agricultural activity. Thus, efforts to understand influences of urban or agricultural land covers on stream water quality and biogeochemistry are complicated by legacy land use conditions and topographic variations. Current research at Furman University is focusing on teasing apart these anthropogenic and natural variations in stream characteristics.

Determining Runoff Quantity and Quality from Differing Land use and Land Cover Types in the Cross Timbers Ecoregion

Austin Phillippe, Oklahoma State University (K. Wagner, C. Zou, R. Will)

Nonpoint source pollution is the leading cause of pollution in the U.S. This is even more pronounced in Oklahoma where the top three potential sources of contamination for river and stream miles is grazing, wildlife, or unknown. Differing land uses and land covers can positively or negatively influence contaminant loading, but the manner in which the landscape changes water quality is not clearly understood. At the Cross Timbers Experimental Range Station we addressed this problem by monitoring the water quantity and quality (sediment, bacteria, nutrients) of runoff from small watersheds (5-10 acres) that differed in dominant vegetative cover (oak forest, eastern redcedar encroached grassland, switchgrass, and native prairie) and grazing treatment (17 acres per head or not grazed) from March 2020 through October 2021. Consistent with findings in other ecosystems, the watersheds dominated by woody species had significantly less runoff compared to grassland watersheds (p value = <.0001). The volume of runoff from oak forests and redcedar encroached grasslands did not differ significantly from one another (p value = 0.99). There were no significant differences in bacterial concentration in surface runoff for any of the treatments used in the study. However, eastern redcedar encroached watersheds had significantly higher concentrations of total Kjeldahl nitrogen compared with all other vegetation cover types (p value = 0.09). The impact of grazing at the intensity of this study did not significantly impact any of the water quality metrics examined. The results from this study will act as baseline/control data for comparing to future projects on runoff water quality in this ecoregion.

Assessing Water Quality Conditions at the Buffalo National River over the Last 20 Years
Erin Grantz, University of Arkansas Division of Agriculture (B. Haggard)

The Buffalo National River is America's first National River, established in 1972, and protects miles of Outstanding National Resource Waters in the Boston Mountains and Ozark Highlands regions of Arkansas. The National Park Service has historically invested in extensive monitoring programs to support assessment of water quality conditions in the Buffalo River, its primary tributaries, and adjacent springs. The present study focused on the last 20 years (2000 – 2019) of data including twelve water quality variables: ammonia-nitrogen, conductivity, dissolved oxygen (DO), Escherichia coli and fecal coliform bacteria (FCB), nitrate+nitrite-nitrogen, pH, orthophosphate, total nitrogen (TN), total phosphorus (TP), turbidity, and water temperature. These data were analyzed for directional change over time using linear regression, the Mann-Kendall test, and the seasonal Kendall test for sites and variables meeting data requirements. For all sites with an available flow record (31 of 33 sites), trend analysis was conducted on flow-adjusted values (FAVs), or the residuals of the locally estimated scatterplot smoothing (LOESS) relationship between log-transformed values of water quality variables and streamflow. Focusing on the last five years (2015 – 2019), summary statistics were calculated for all variables, using methods adapted for datasets with non-detections for nutrient variables. A park-scale synthesis of trend analysis results and frequency distribution of water quality variable medians will be presented to show where water quality is stable in the park and/or where values suggest low risk for ecological change, as well as potential hotspot locations for changing water quality.

Educating and Engaging Communities to Enhance Water Quality Knowledge and Build Community Resilience - An Interactive Session with the Watershed Game

Karen Bareford, University of Alabama and Mississippi-Alabama Sea Grant Consortium
Jessica Brown, UGA Marine Extension and Georgia Sea Grant
Mark Risse, UGA Marine Extension and Georgia Sea Grant

The Watershed Game has been used for over a decade in more than 20 states across the country as a highly effective tool to help Extension Educators facilitate conversations with diverse watershed communities on how they can adapt practices, policies and plans to improve water quality and to be more resilient. Originally developed by Minnesota Sea Grant, the Game is designed to shift the conversation on watershed management and planning by using a relaxed role-playing environment. This setting helps break down barriers, encourage dialogue and mutual respect, and foster cooperation - all while enhancing the learning process through hands on activity. Colleagues from across the country use the Game to help individuals understand the connection between land use and water quality. The Game includes two versions: Local Leader and Classroom. The Local Leader Version of the Watershed Game is designed for use with community leaders and comes in four models (stream, lake, river, coast), while the Classroom Version is designed for middle school-aged youth and is intended for use by formal and informal educators. The Minnesota Sea Grant and Minnesota Extension recently teamed up with the University of Alabama, Mississippi-Alabama Sea Grant Consortium, and NOAA to develop the new Coast Model of the Game which helps participants learn how land uses impact water quality, natural resources, and community resilience in coastal areas. A comprehensive evaluation of the Game revealed communities that have used the Local Leader Version of the Game as a water education and engagement tool had positive results in facilitating critical conversations around sustainable water and land use planning. This session will include an introduction to the Watershed Game, provide information on how the tool can be used to help connect with local communities and students, and allow for a demonstration play of the game.