Conference Proceedings

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Plenary Sessions

Key Water Challenges and Opportunities Facing the Southeast

Jim Giattina, Director of Water Protection Division, EPA Region 4

BIO: Jim Giattina is the Director of the Water Protection Division of the U. S. Environmental Protection Agency's Southeastern Regional Office in Atlanta, Georgia. He is responsible for administering all Regional EPA water programs related to the Clean Water Act, the Safe Drinking Water Act, and the Marine Protection, Research and Sanctuaries Act.

Jim has been working in the environmental protection arena for 37 years and he has been with EPA for 32 years. The last 14 years, he has served the Agency in his current capacity in Atlanta.

Jim is a native of Birmingham, Alabama. He received his Bachelor of Science in Biology from the University of Alabama and his Master of Science in Biology from the Center for Environmental Studies at the Virginia Polytechnic Institute and State University.

The Importance of Regional Collaboration

Laura Bowie, Executive Director, Gulf of Mexico Alliance

BIO: Laura Bowie serves as the Executive Director for the Gulf of Mexico Alliance, a partnership of the five Gulf States with the goal to significantly increase regional collaboration to enhance the ecological and economic health of the Gulf of Mexico.

Laura began her career in Houston, Texas, at Texas Eastern Pipeline Company as a remediation specialist on their PCB Task Force. Later, she served Continental Airlines as a Senior Manager in the Environmental Affairs Department. Since moving to Mississippi, she has supported local non-profits spear-heading watershed and grant programs. In 2010, Laura was the first employee hired by the Gulf of Mexico Alliance to take the loose network of partnerships into a formal not-for-profit organization.

Laura holds a bachelor's degree in chemistry from Mississippi State University and a master's degree in environmental management from the University of Houston. She is active in local civic and education organizations. Laura and her husband John have been married 16 years and have two sons, Andrew and Mitchell.

Research Encounters and Lessons Learned

Norman Whittlesey, UCOWR Warren A. Hall Medal Award Recipient
Professor (Emeritus) of Agricultural Economics, Washington State University

BIO: Norman Whittlesey is Professor (Emeritus) of Agricultural Economics at Washington State University, where he has been since 1964. During his tenure at Washington State University he has been heavily involved in research and teaching related to production agriculture, irrigation development, water policy, and environmental economics throughout the West. Studies of water value, allocation, and conservation have been central to research and policy development activities during the past two decades. He has authored over two hundred publications related to these fields. In 1987 he won the prestigious Award for Professional Excellence from the American Agricultural Economics Association in recognition of his distinguished policy contribution for work in water policy related to irrigation development in the West. In 1998 he was honored as a Fellow of the American Agricultural Economics Association in recognition for years of path breaking research in water policy and irrigation management. He served as vice president and president of the Western Agricultural Economics Association, and in 2004 he received the Distinguished Scholar award from the WAEA. In 2014 he received the Legacy of Excellence award for emeritus faculty from Washington State University. In 2015 he was appointed to the Hall of Fame for alumni in the Department of Agriculture and Resource Economics, Colorado State University. He has been involved in many consulting efforts. These include three (U.S. Supreme) Court cases involving disputes between states over allocation of cross border rivers. He has served on numerous regional and national committees and task forces engaged in policy development for solving problems of natural resource management and the environment.

Plenary Sessions

Water Demand Management and Cuban Infrastructure: A brief history of my time as a University of Florida graduate student

Miguel Morales, UCOWR Ph.D. Dissertation Award Recipient, University of Florida

BIO: Miguel Morales was born in Caracas, Venezuela to a Cuban father and Venezuelan mother. He received his Ph.D. from the Department of Environmental Engineering Sciences at the University of Florida under the advisement of Dr. James Heaney. Miguel has co-authored twelve peer-reviewed journal publications focusing on methodologies to estimate water use and data-drive optimization approaches to target customers for water demand management practices. He has worked with utilities across the state of Florida, water management districts, and regional planning agencies during his time with the Conserve Florida Water Clearinghouse. He has also been a co-investigator on studies for the Water Research Foundation, City of Sanford and St. Johns River Water Management District, and Florida Energy Systems Consortium. Miguel is a founding member and past president of the Association of Cuban Student Engineers, a student organization that provides engineering students with the opportunity to conduct research on Cuba's infrastructure. He is also a partner at WaterAIM, a consulting firm which provides data-driven analyses and planning services for water demand management and water.

The Potential and Need for Desalination

David Warsinger, UCOWR Ph.D. Dissertation Award Recipient, Massachusetts Institute of Technology

BIO: David Warsinger completed his B.S. and M.Eng at Cornell, and his Ph.D. in Mechanical Engineering at MIT. He completed his graduate studies in a combined three years. Prior to starting his Ph.D., David designed heating and cooling systems and performed energy and sustainability analysis at the engineering consulting firm Arup. David is a coauthor of 18 published and 6 submitted conference or journal papers and a co-inventor on 13 filed or awarded patents. David cofounded Coolify, a startup providing cold storage for farmers in developing economies, which won the national competition for the $100k Ag Innovation Prize. Recently, David received the Institute Award for Best Research Mentor for Undergraduate Students at MIT. He has also received awards for the highest GPA in his class (M.Eng.), numerous grants, and 8 presenter awards at conferences.

ABSTRACT: Global water use has been rapidly increasing due to economic growth, increasing population, urbanization, and industrialization. Meanwhile freshwater supply has changed little and even decreased, as climate change causes desertification, reservoirs are drained, and groundwater resources are depleted unsustainably. Today, over half the world's population lives in regions consuming nearly all of the local renewable water: the local net rainfall. To meet this intensifying scarcity, many are turning to desalinating seawater, brackish water, and wastewater. Many countries, especially in the Middle East, provide the majority of their water from desalination of seawater. Groundwater provides about 1/3 of the consumed water in the US, and is saline enough to need desalination in many regions in the US and globally. Desalinating marginally saline sources can provides other benefits, including substantial increases in agriculture yields, a decrease in soil salinization, and removing toxins that other modern processes do not remove. Costs for desalination have decreased significantly, and are often near, or within a factor of two of the conventional costs of river water. Global installed desalination capacity is more than doubling every 10 years, and will play an important role in combating the world's growing water crises.

Session 1, Impact of Irrigation Strategies to Reduce Overdraft of MS Alluvial Aquifer

Agronomic and economic impacts of cover crops and tillage in a continuous soybean system in the Mid-South

Corey Bryant, Extension Associate, Mississippi State University
(co-authors: L.J. Krutz, M. Locke, W. Steinriede)

Many of the world's soils are prone to structural degradation which results in surface sealing. In the Mid-South surface sealing is most prominent on silt loam soils. These soils experience limited infiltration, increased runoff and irrigation application efficiencies of approximately 36% in furrow irrigation systems. Chemical treatments applied to the soil have shown increased infiltration while delaying crust development. These treatments must be reapplied at the beginning of each growing season and many must be applied multiple times within a single growing season. An optimal approach will remediate long-term soil structural issues through organic matter additions while slowing furrow flow rates. Two practices gaining renewed interest are conservation tillage and cover crops. Our study seeks to determine the effects of varying tillage practices, and tillage combined with a rye (*Secale cereale* L.) cover crop on irrigation application efficiency and infiltration in the Mississippi River Delta, under furrow irrigated continuous soybean production. Year one treatments include conventional spring tillage without cover crop as a control, minimum fall tillage without cover crop, fall tillage with rye cover crop, and minimum tillage – irrigation tillage without cover crop. Plots are 153 m long by 8.16 m wide and separated by levees. Asgrow 4632 soybeans were planted twin row on 1.02 m beds with a seeding rate of 345,940 seeds ha^{-1}. All irrigation events are metered onto plots, and each plot is equipped with flow meters on the down-slope end to measure runoff. Single ring infiltrometers were used to directly measure infiltration rates for each treatment. Year one results observed and analyzed include infiltration rates, irrigation application efficiency, yield and economic return.

Irrigation water management from the pump to the tail ditch

Christopher Henry, Assistant Professor & Water Management Engineer, University of Arkansas Division of Agriculture
(co-authors: P. Horton, J. Gaspar, L.J. Krutz)

On-farm furrow irrigation demonstrations in Arkansas found a 27 % reduction ($p<0.001$) in water use while maintaining crop yields ($p=0.864$). In Arkansas groundwater withdraws from the alluvial aquifers are only about 42 % sustainable and 54.6 % sustainable from the Sparta/Memphis aquifer. Twenty-six on-farm demonstrations were conducted to compare Irrigation Water Management (IWM) Practices to farmer managed irrigation practices. Flow meters were installed on paired fields of furrow irrigated corn, soybeans, cotton and peanut fields. IWM fields consisted of computerized hole selection, surge irrigation, ET-based scheduling with an Atmometer, and soil moisture monitoring. Agents and producers followed Extension recommendations for termination. Cost of water was determined for the irrigation pumps at each demonstration and cost reductions on average of $511 per irrigation pump were found by optimizing operation.

Session 1, Impact of Irrigation Strategies to Reduce Overdraft of MS Alluvial Aquifer

Irrigation water management strategies that improve crop yield and/or on-farm profitability

Jason Krutz, Associate Extension / Research Professor - Irrigation Specialist, Mississippi State University
(co-authors: D. Pickelmann, L. Atwill, S. Leininger, C. Bryant, J. McNeal, W. Wood, M. Henry, D. Roach)

The Row-crop Irrigation Science Extension and Research (RISER) program has demonstrated how Irrigation Water Management (IWM) practices including computerized hole selection, surge irrigation, soil moisture sensor (SMS) technology, and alternate wetting and drying (AWD) reduces irrigation water use up to 40 % while improving profitability by $40/acre. However, very few Mid-South irrigators are using IWM practices. The objectives of this session are to 1) illustrate how computerized hole selection and surge irrigation improves irrigation application efficiency; 2) describe how SMS technology improves irrigation scheduling decision for initiation and termination; 3) inform practitioners how AWD impacts water use, yield, weed control, and N uptake; and 4) examine on-farm case studies where IWM practices significantly improved corn, soybean and rice yield/profitability.

Impact of planting date and maturity group on Mid-South soybean production

Wilks Wood, Graduate Student, Mississippi State University
(co-authors: L.J. Krutz, T. Irby)

The Mississippi Alluvial River Valley aquifer is being depleted at distressing rates due to irrigation withdrawal for cotton, corn, soybeans and rice. Current soybean production strategies consist of planting a majority of acres with maturity group IV and V soybean varieties. However, it is believed that transitioning more planted acres to maturity group III or IV soybean varieties could allow for an earlier harvest and the potential for less irrigation events when compared to maturity group V soybean varieties. An experiment was conducted at the Delta Research and Extension Center located in Stoneville, Mississippi in 2015 to determine the impact that planting date and soybean maturity group has on yield, water use and harvest date. Maturity group III, IV, and V soybean varieties were planted within three separate planting dates, which ranged from 20-April to 2-June. Irrometer Watermark moisture sensors were used to determine when irrigation events should be initiated. Each individual maturity group within a planting date was irrigated based upon the water use needs of the plants within the plot. Water use, date of harvest, and yield results from each individual maturity group by planting date will be discussed. Results from this study will provide insight into maturity group selection, optimum planting date and water management strategies for Mid-South soybean production

Session 2, Transdisciplinary Bridges to Watershed Science and Human Systems in Texas

Transdisciplinary approaches to bridging lateral and vertical dimensions in the structure and function of watershed science and human systems: Overview

Tom Arsuffi, Director, Texas Tech University Llano River Field Station
(co-authors: T. Broad, K. Wagner)

As water resource problems increase in complexity, the present state of having uncoordinated and mission-driven water resources agendas within and between federal and state agencies, within and between components of universities, and within and between companies and industries in the private sector, will have to be changed in order to: 1) improve science and management; 2) surmount future water problems; and 3) address the many and complicated water supply and demand issues associated with climate change, population growth, and the energy/water nexus. The institutional barriers to problem solution is often encapsulated in the term "silos," and the way to bridge "silos" is through trans/interdisciplinary approaches. However, silos exist at many levels in hierarchical scales and have vertical and horizontal components of complexity. Addressing water resource complexity often involves reactive and proactive solutions. At the federal level for example, the Environmental Protection Agency has launched a new initiative, Healthy Watersheds, a proactive approach involving a variety of stakeholders. At a state level, the 80th Texas Legislature (2007) established the Senate Bill 3 process to determine environmental flow standards for all of the major river basins and bay systems in Texas. Senate Bill 3 was designed as an accelerated, stakeholder-driven, scientific and consensus-based process to establish environmental flow recommendations. This special session will focus on cross cutting case studies and programs that are bridging the complexity among institutional science, human and regulatory disciplines, but also assist in guiding the development of policy and engaging the public. The session will be an opportunity to share the ongoing work at the academic, federal, state and local levels that are embracing new and novel paradigms for managing complexity and bridging silos in which multiple water resource areas are brought together to balance the competing and complementary goals of ecosystem health, productivity, economic and social well-being.

Healthy watershed approach to managing streams : Role of science, stakeholders, education and partnerships

Tyson Broad, Watershed Coordinator, Texas Tech University Llano River Field Station
(co-authors: T. Arsuffi, K. Wagner)

Addressing issues at the watershed scale is a natural approach for bridging silos in both the water and land management arena, especially in rural areas where traditional training focuses primarily on land management. To proactively manage and maintain the ecological health of the Upper Llano River, Texas, the Texas Tech University Llano River Field Station and Texas A&M Water Resources Institute are working with the Llano River Watershed Alliance and other stakeholders to develop and implement a Healthy Watershed Protection Plan (WPP) through a federal Clean Water Act 319(h) grant from the Texas State Soil and Water Conservation Board and U.S. Environmental Protection Agency. The WPP uses a stakeholder process for decision-making based on watershed science, modeling, landowner concerns, types, and scale of treatment measures needed; and economics and feasibility of Best Management Practices (BMP) implementation. Holistic BMP strategies include brush control for water supply enhancement, upland grazing management, feral hog trapping, and riparian and stream bank restoration. Agency partnerships, stakeholder/landowner involvement, and watershed education are critical components to successful implementation of the WPP.

Session 2, Transdisciplinary Bridges to Watershed Science and Human Systems in Texas

Bringing stakeholders together - Examples of bridging the gaps in knowledge, participation, and coordination with partner organizations and landowners

Rachael Ranft, Director, Northern Hill Country River Projects, The Nature Conservancy

The Nature Conservancy, an international conservation non-profit and land trust, has been active in the Blanco River watershed in Central Texas for the past 13 years. This case study will focus on methods we've used on our Blanco River Project to overcome obstacles and achieve meaningful conservation results. The Blanco River Project has grown from a handful of landowner participants to over 500 individuals and an ever-increasing number of partnering agencies. Conservation disasters, such as a record-breaking drought and multiple record-breaking floods, have been used to educate and engage partners and landowners. Several coalitions have also been formed; bringing partners together to develop long-term planning strategies which will allow for a rapid response mechanism as new needs arise. Success has been achieved by recognizing the strengths and limitations of each participating organization, allowing needs to be identified and plans developed to fit the organizational strengths. Sharing responsibility for these projects has allowed the partnering organizations to accomplish larger objectives together than would be possible for the individual entities acting alone.

Synergistic approach to water quality protection and restoration in Texas

Kevin Wagner, Deputy Director of Engagement & Professor, Texas Water Resources Institute, Texas A&M AgriLife Research
(co-authors: N. Dictson, L. Gregory, A. Berthold)

The Clean Water Act set a national goal of achieving water quality levels that are fishable and swimmable. However, despite efforts over the last four decades, a majority of US waterbodies do not meet water quality standards. Over half of river miles, two-thirds of lake acres, and almost three-quarters of the bay and estuary areas are impaired. To restore these waterbodies, watershed plans (i.e. total maximum daily loads, etc.) are required. The key to developing watershed plans and achieving water quality protection and restoration is through sustained efforts by local watershed groups and partnerships; however, public involvement can be challenging. For over a decade, the Texas Water Resources Institute (TWRI) has been leading watershed efforts in Texas using a multi-prong approach of assisting stakeholders with planning, training watershed coordinators, and educating the public on water quality protection. (1) To holistically address local water quality concerns, TWRI helps facilitate stakeholder efforts to identify, develop, and implement successful management strategies. Throughout Texas, TWRI is assisting communities with water quality evaluations, watershed assessments, and watershed plans. TWRI partners with Extension, researchers, other universities, river authorities, and others to educate stakeholders, engage the public in identifying and implementing effective strategies, demonstrate and evaluate innovative best management practices, and assess watershed conditions using modeling and monitoring. (2) To support statewide watershed efforts, TWRI provides training courses, professional development and networking opportunities, to help watershed coordinators better work with stakeholders to develop and implement scientifically defensible strategies that will lead to measurable water quality improvement and address stakeholders' watershed concerns. (3) To educate stakeholders, TWRI has worked with Extension to develop training programs on well head protection, livestock management, riparian protection, and feral hog control and supported delivery of others. This synergistic approach is now paying off. This approach and lessons learned will be discussed.

Session 3, Finding Wetland Ecosystem Services Within Existing Drainage Ditch Networks I

Drainage ditch mitigation strategies: The past, present, and future of water quality improvement

Matt Moore, Research Ecologist, USDA Agricultural Research Service
(co-authors: J. Taylor, M. Locke, J. Farris, E. Bennett, R. Kroger)

To the casual observer, agricultural drainage ditches serve only to move water from the field to nearby streams, rivers, or lakes. A closer look, however, indicates these unique structures are capable of providing vital ecosystem services such as contaminant mitigation. For the last two decades, core groups of scientists from across the country have evaluated the physical, chemical, and biological processes in drainage ditches in order to elucidate their value and benefit to both agricultural and downstream aquatic ecosystems. Early studies on vegetated drainage ditches in the Mississippi Delta demonstrated their substantial ability to sorb pesticides and transfer them out of the water column. These studies led to further confirmation across the United States, culminating in the Natural Resource Conservation Service's California state office recognizing vegetated agricultural drainage ditches as a modified conservation practice (607A). Simultaneously, researchers in the Midwest were evaluating engineering designs of two-stage ditches to address nutrient mitigation needs from agricultural runoff. These initial efforts further launched more recent, in-depth evaluations of the ditch denitrification process, carbon sequestration, and ditch metabolism as a measure of nutrient mitigation. This presentation will not only highlight the successes of past ditch mitigation research, but it will also address the current and future challenges of "ditch science" in order to address regional, national, and global water quality improvement.

Investigation of denitrifying microbial communities within an agricultural drainage ditch fitted with low-grade weirs

Beth Baker, Assistant Extension Professor, Mississippi State University
(co-authors: R. Kroger, J. Brooks)

Enhancing wetland characteristics in agricultural drainage ditches using low-grade weirs, has been identified as a best management practice (BMP) to mitigate nutrient runoff from agriculture landscapes. A major objective of utilizing low-grade weirs as a BMP includes fostering environments for the biogeochemical removal of nitrogen via denitrification. This study examined the spatial resolution of microbial communities involved in denitrification in agricultural drainage ditches fitted with low-grade weirs. Sampling scales of microbial communities were investigated using 16S rRNA and denitrification functional genes nosZ, nirS, and nirK via quantitative polymerase chain reaction (qPCR) and terminal-restriction fragment length polymorphism (T-RFLP) analysis. Genes 16S rRNA, nosZ, and nirS were successfully detected in soil samples, while nirK was below the detection limit throughout the study. Utilizing three sampling regimes in concert (management, reach, catchment) was found to be effective in capturing microbial community patterns, as ANOVA results revealed nosZ gene abundance was significantly greater at the management rather than reach scale ($p=0.045$; $F=3.311$), although no significant differences were observed in 16S rRNA or nirS between sampling scales ($p>0.05$). A Pearson correlation matrix confirmed that 16S rRNA and nosZ gene abundances were positively correlated with soil carbon (C), nitrogen (N), and moisture, while nirS abundance was positively correlated with soil C and soil moisture only. Results highlight the potential for wetland-like characteristics to be recovered in agricultural drainage systems, as weir proximity is observed to enhance soil moisture and conditions for N remediation. This study provides the foundation for additional investigations of these unique environments in the Mississippi Alluvial Valley and a starting point for adaptive management to enhance agricultural drainage ditches for microbial communities towards nutrient remediation goals.

Session 3, Finding Wetland Ecosystem Services Within Existing Drainage Ditch Networks I

Seasonal patterns in denitrification rates as a function of nitrate availability in vegetated agricultural ditch sediments

Shannon Speir, Graduate Assistant, University of Arkansas
(co-authors: J. Taylor, *T. Scott)
*Presenter - Thad Scott, Associate Professor, University of Arkansas

Application of external nitrogen (N) inputs to agricultural systems has increased food production to meet growing demands worldwide. However, excess N inputs also contribute to significant environmental impacts including eutrophication of fresh and coastal waters. Widespread implementation of best management practices (BMPs) that reduce N inputs to aquatic ecosystems are needed. Denitrification is a biologically-mediated removal mechanism that decreases nitrate transport to downstream waterbodies. Recent work demonstrated that ditch sediments planted with *Leersia oryzoides* have significantly higher denitrification potential than bare sediments or those planted with *Typha latifolia*. Seasonal factors including temperature, oxygen concentrations, nitrate availability, and organic matter content also influence denitrification rates. In this study, we explored the seasonal effects of nitrate availability on denitrification in agricultural ditch sediments from mesocosms vegetated with *L. oryzoides*. Denitrification rates were measured as N_2 production from intact vegetated sediment cores using Membrane Inlet Mass Spectrometry. We will present denitrification rates as a function of nitrate concentration and temperature in experimental cores across four seasons. This study will contribute to future models that predict denitrification rates associated with vegetated ditch BMPs.

Balancing summer nutrient mitigation potential with winter organic matter breakdown and release: Nutrient source-sink dynamics in vegetated ditch mesocosms

Jason Taylor, Research Ecologist, USDA-ARS, Water Quality & Ecology Research Unit, National Sedimentation Laboratory
(co-authors: M. Moore, S. Testa)

Success of vegetated ditch systems as nutrient sinks in agricultural landscapes is linked to factors that control nutrient uptake, storage, and microbial-mediated transformations. Additionally, the overall nutrient mitigation potential of vegetated ditch environments depends on factors that control breakdown of senescent plant material and release of nutrients back into ditch environments during winter months. We investigated the influence of phosphorus (P) enrichment on dissolved inorganic nitrogen (DIN) uptake and retention in ditch mesocosms planted with rice cutgrass (*Leersia oryzoides*) over three experimental runoff events conducted during the growing season. Additionally, we measured breakdown rates of cutgrass and nutrient export from ditch mesocosms across 14 winter rain events. Phosphorus retention increased with P enrichment but no effect was observed on DIN retention. Winter breakdown rates were low and not effected by P enrichment, with less than 10 % loss of organic matter over the three month period. Phosphorus export during winter was not related to summer P enrichment. We only observed one significant pulse of dissolved P during the first winter rain event, after which very little P was exported from mesocosms in dissolved or total forms. Ditch mesocosms continued to serve as significant dissolved (DIN) sinks during the winter with all atmospheric deposition of DIN in rain being retained in ditch mesocosms. We estimate that approximately 1500 g/m^2 of DIN was retained by ditch sediments planted with cutgrass during the summer. Mesocosms also retained between 60 and 360 g/m^2 of dissolved P during summer runoff events depending on P enrichment treatment. Less than 1 % of retained N and P was exported from mesocosms over a three month winter period. These results contradict previous reports suggesting that senescent rice cutgrass may serve as a significant source of previously retained nutrients in vegetated ditch environments.

Hydrologic monitoring and water balance modeling in West and Seven Palm Lake Drainages in the Florida Everglades

Joshua Allen, Research Assistant, Florida International University
(co-authors: D. Whitman, R. Price)

In the Florida Everglades, sea level rise and reduced freshwater inputs have altered the hydrologic and chemical conditions in coastal estuaries. Brackish coastal groundwater discharge, an inland intrusion of submarine groundwater discharge, has been shown to occur seasonally along the coastal wetlands of the Everglades. This brackish groundwater is enriched in total phosphorus, the limiting nutrient in the Everglades. A major component of the Comprehensive Everglades Restoration Plan is to increase freshwater delivery to the southern coastal Everglades and adjacent bays, in an effort to restore a salinity and nutrient regime conducive for the development of submerged aquatic vegetation. This study is being conducted in the estuarine lakes of the Everglades that are connected to Florida Bay. Water quality in these lakes has diminished over time, potentially due to increased nutrient deliveries from coastal groundwater discharge.

Current hydrologic and chemical conditions are being established within the lakes in order to gain a better understanding of the effects of restoration efforts through time. Water budgets are being constructed on daily, monthly and annual time steps to estimate the groundwater-surface water interaction term. In addition, hydrologic and topographic data from the Everglades Depth Estimation Network is being utilized in order to calculate water budgets for the lakes region spanning ten years prior to the study period. Water chemistry in the lakes and groundwater is also being monitored to determine the influence of groundwater-surface water exchange on salinity and nutrient conditions in the lakes. The results of this study can be used to assess the influence of restoration efforts on the hydrochemical conditions of downstream coastal areas affected by coastal groundwater discharge and sea level rise.

Stormwater retrofits for water quality restoration in the Lower White Oak River

Eban Bean, Assistant Professor, East Carolina University
(co-authors: C. Humphrey, M. O'Driscoll, R. Bond, N. Lyons)

Most of the Lower White Oak River, located along the North Carolina coast, is sensitive to nutrient inputs and has been closed to shellfish harvesting over the past decade due elevated fecal indicator bacteria counts. Residential development and improved drainage in surrounding watersheds have increased stormwater runoff and exports of pathogens and nutrients. This study seeks to implement and evaluate stormwater retrofits for reducing bacteria and nutrient exports to a tributary, Boathouse Creek. Flow monitoring, water quality monitoring, and sampling of existing conditions began in May 2015 to identify sources of pollutants. Monthly measurements of temperature, conductivity, pH, oxidation reduction potential, dissolved oxygen, turbidity, and stream flow were recorded from eight sites. Quarterly baseflow samples and two stormflow samples were collected at these sites and analyzed for nitrogen species, phosphate, chloride, dissolved organic carbon, *E. coli*, total coliform, and enterococci. Preliminary data indicate that stormflow bacteria counts were elevated relative to baseflow concentrations for each location. Baseflow concentrations of total dissolved nitrogen (0.72 - 0.82 mg/L) and phosphate (most < 0.03 mg/L) were relatively low, with human or animal waste as the dominant source of NO_3, based on isotopic analysis of NO_3. Retrofits, including flash-board structures in swales, disconnection of impervious areas, rain gardens, and cisterns, will begin installation during summer 2016. Monitoring will continue after implementation of the BMPs evaluation of runoff and pollutant load reduction.

Session 4, Emerging Issues in Coastal Water Resources Management I

Release and delivery of phosphorus from a carbonate aquifer affected by seawater intrusion to adjacent coastal areas

Rene Price, Professor and Chair, Florida International University

Phosphorus is often a limited nutrient in coastal settings and identifying all sources, both natural and anthropogenic, is important for assessing the overall water quality and ecosystem health of coastal areas. This paper summarizes the results of both laboratory experiments and field investigations of phosphorus concentrations in coastal carbonate aquifers affected by seawater intrusion. As seawater intrudes into a coastal carbonate aquifer and mixes with the fresh groundwater, phosphorus has been found to be released into the resulting mixing zone groundwater. At low to moderate salinities (30 psu) phosphate desorption occurs as bicarbonate ions in the intruding seawater compete for adsorption sites. Concentrations of phosphorus in mixing zone groundwater has been found to range from 1 to 8 µmol/L compared to values of less than 1 µmol/L in either the fresh groundwater or the intruding seawater. The high concentrations of phosphorus in the brackish groundwater has been found to associate with the extent and biomass of coastal mangroves as well as phosphorus concentrations of seagrasses. Furthermore, phosphorus concentrations as well as ecosystem metabolism were observed to spike in the surface water during times of groundwater discharge. In summary, seawater intrusion into coastal carbonate aquifers and its associated brackish groundwater discharge can affect both groundwater and surface water chemistry as well as ecosystem function in the coastal zone. As global sea levels continue to rise, seawater intrusion is expected to further intrude into coastal aquifers, further releasing phosphorus as the freshwater portion of the aquifer becomes brackish.

Saltwater intrusion mitigation strategies for Baton Rouge Multi-Aquifer System, southeast Louisiana

Frank Tsai, Professor, Louisiana State University
(co-author: *J. Yin)
*Presenter - Jina Yin, Graduate Student, Louisiana State University

Due to excessive groundwater withdrawals, many water wells in Baton Rouge, Louisiana experience undesirable chloride concentration because of saltwater intrusion. The study goal is to develop a management framework that takes advantage of the Baton Rouge multi-aquifer system to mitigate saltwater intrusion. The management framework utilizes several hydraulic control techniques to mitigate saltwater encroachment. These hydraulic control approaches include pumping well relocation, freshwater injection, saltwater scavenging, and their combinations. Specific objectives of the study are: (1) constructing scientific geologic architectures of the “800-foot” sand, the “1,000-foot” sand, the “1,200-foot” sand, the “1,500-foot” sand, the “1,700-foot” sand, and the “2,000-foot” sand; (2) developing scientific saltwater intrusion models for these sands; (3) using connector wells to draw native groundwater from one sand and inject to another sand to create hydraulic barriers to halt saltwater intrusion; (4) using scavenger wells or well couples to impede saltwater intrusion progress and reduce chloride concentration in pumping wells; and (5) reducing cones of depression by relocating and dispersing pumping wells to different sands. The study utilizes optimization techniques and newest LSU high performance computing (HPC) facilities to derive solutions. The management framework serves as a scientific tool to assist policy makers to solve the urgent saltwater encroachment issue in the Baton Rouge area. The research results will help water companies as well as industries in East Baton Rouge Parish and neighboring parishes by reducing their saltwater intrusion threats, which in turn would sustain Capital Area economic development.

Session 5, Sea Grant and Water Institutes: Research and Partnerships Investigating the Land Sea Interface

A collaborative, comprehensive approach to nutrient load reduction in the Midwest

Anjanette Riley, Communication Specialist, Illinois Water Resources Center
(co-author: E. Brown)

High nutrient loading in the Great Lakes and Mississippi River basins lowers water quality, harms commercially-significant fisheries, and increases water treatment costs. State and local efforts to control nutrients have yielded positive results over the decades, but nitrogen and phosphorus losses remain primary threats to water quality. Since 2012, the Illinois Water Resources Center (IWRC) and Illinois-Indiana Sea Grant (IISG) have worked with local and federal partners to expand research on nutrient loading and develop tools and outreach programs that help watershed planners, communities, farmers, and sewage districts reduce nutrient losses and restore aquatic ecosystems. IWRC and IISG managed the development of the Illinois Nutrient Loss Reduction Strategy, which included the first comprehensive scientific assessment of phosphorus and nitrogen loading in the state. To monitor progress towards nutrient reduction goals, IWRC and IISG have also collaborated with University of Illinois researchers and computer engineers to develop Great Lakes Monitoring and the Great Lakes to Gulf Virtual Observatory. These cutting-edge web applications make it possible for researchers, agencies, communities, and watershed planners to view and analyze decades of nutrient, water characteristic, and land use data from university, state, and federal monitoring programs, including U.S. Geological Survey super stations. Much of this data, along with original water quality research funded by IWRC and IISG, have also been integrated into the Tipping Points Planner, an interactive web tool that helps watershed planners identify how close a watershed is to known environmental tipping points and recommends ordinances, policies, and outreach efforts to prevent further environmental degradation. Although nutrient loading is currently addressed in this tool, an integrated assessment funded by IISG will lead to more effective recommended strategies. Together, these and other research and outreach efforts led by IWRC and IISG represent the most comprehensive approach to nutrients in the region to date.

Microplastics: The story from rivers to lakes

Laura Kammin, Program Leader, Illinois-Indiana Sea Grant
(co-author: A. Riley)

While the effects of plastic contamination in the oceans are well documented, much less is known about the abundance and impacts of microplastics in freshwater systems. In fact, researchers in the United States only began searching for microplastics in the open waters of the Great Lakes in 2012, sampling lakes Huron, Superior, and Erie. To help close this research gap, Illinois-Indiana Sea Grant (IISG) and the Illinois Water Resources Center (IWRC) have conducted original research and funded additional projects in the Great Lakes region. In August 2013, IISG and its partners conducted a three-day survey of southern Lake Michigan to document the abundance of microplastics. Samples were sorted into three size classes and divided into five categories: fragment, pellet, line, film, and polystyrene foam. Results from the survey showed surprisingly high numbers of microfibers and microbeads. The next year, IWRC awarded funds for the first-ever study into the source, quantity, and fate of plastic pollution, including microplastics, in riverine ecosystems. This study confirmed the theory that rivers are a primary source of plastic pollution in lakes and oceans. Results also showed that disease-carrying bacteria are surviving the wastewater treatment process by binding to microplastics. New research being funded by IISG will quantify and characterize microplastic inputs from major tributaries into Lake Michigan, assess the impacts of watershed land use on microplastic inputs, track their transport through three tributaries that feed into Lake Michigan, and characterize microplastic interactions with biota in the tributaries. To educate the public on the results of these and other investigations into plastic debris, IISG and IWRC highlight on-going research in the co-produced interview series UpClose, describe project results in newsletters and blog posts, and serve as a resource for local, national, and international media outlets.

Session 5, Sea Grant and Water Institutes: Research and Partnerships Investigating the Land Sea Interface

Cities, oysters, and groundwater - Current interstate water disputes in the Southeastern U.S.: FL v. GA and MS v. TN

Catherine Janasie, Research Counsel, National Sea Grant Law Center at The University of Mississippi School of Law

We all know that water is one of the most essential natural resources. However, in the United States, the management of water resources is increasingly becoming contested, including on an interstate level. While states can, and do, work together to share interstate water resources, the Supreme Court of the United States must preside over cases where states disagree. And while the eastern portion of the United States has always been considered water-rich, there are two current interstate disputes from this region of the country. This talk will provide an overview of the water laws and policies throughout the United States, including the regional differences in management between the wet eastern and dry western states. The talk will also cover the differences in the regulation of surface water and groundwater, which is becoming increasingly important in water law and policy. The talk will then focus in on the interstate water disputes currently before the Supreme Court in the Southeastern United States: Florida v. Georgia and Mississippi v. Tennessee. Both cases dispute the use of water by large cities in the region, as neighboring states are challenging the use of water by Atlanta and Memphis. Further, each case has interesting factual aspects. Florida v. Georgia places Florida's oyster industry and overall ecological health against Atlanta's need for water. In Mississippi v. Tennessee, the Supreme Court will consider an interstate dispute over groundwater for the first time. This talk will provide an overview of each case and how interstate water disputes have traditionally been treated by the Supreme Court. In conclusion, the talk will discuss the relevance of the cases and their possible future implications for water law and policy.

Water resources fellowships at the local level: Using the Knauss Sea Grant Fellows Program as a template

James Hurley, Aquatic Sciences Center Director, University of Wisconsin-Madison
(co-authors: J. Hauxwell, N. Garber, J. Galkiewicz, J. Eckman)

The national Sea Grant Knauss Fellowship program, developed in 1979, has placed 1,060 highly qualified graduate students with "hosts" in Washington, D.C. legislative and executive branch offices for a one year paid fellowship. The competitive program places students who have an interest in ocean, coastal and Great Lakes resources, and in the national policy decisions, in offices through a pairing process that matches the strengths of the student with government office needs. The model for the program has been used in state Sea Grant programs, most notably in California. California Sea Grant leads a State Fellows Program allowing successful applicants "on the job" experience in the planning and implementation of marine and/or coastal resource policies and programs in the state. Importantly, this program began as a cost-share between Sea Grant and the offices and has expanded (22 state programs interested in 2016) with decreasing reliance on Sea Grant-dedicated funding. In Wisconsin, a similar program began in 2015 with positions cost-shared with both the state Sea Grant and Water Resources Institutes. With increasing demands at the state and federal level to attract highly-skilled scientists to the workforce, these programs enable fellows to have direct practical experience and allows the hosts an opportunity to benefit from the technical expertise of postdoctoral and post Master's graduates and generally maximize their "bang for the buck" in making progress on complex water challenges, as well as having access to some of the state's best candidates for longer term recruiting.

Session 6, Agricultural Irrigation Practices

Improving irrigation water use efficiency in Louisiana crop production: Challenges and opportunities

Naveen Adusumilli, Extension Economist, LSU AgCenter
(co-author: S. Davis)

Irrigation efficiency is the primary resource concern in Louisiana. Investment in on farm irrigation management practices have often resulted in higher costs per acre without fully gaining the benefits of the technology. Farmers lack adequate information on irrigation application techniques, crop yield response to water use, and actual water use, resulting in not achieving irrigation efficiency. Farmers are interested in improving their on farm efficiency, gaining economic advantage, and providing on-site and off-site benefits in terms of reduced sediment and nutrient runoff into water bodies; however, strategies that focus on improvement in current efficiency of agricultural water management are still in its infancy. Conservation strategies in agricultural water management and scope for improvement for Louisiana farmers are discussed from an economic and environmental perspective. Strategic options as simple as measuring water use on farms and incorporating management practices that enhance conservation, wherever possible are essential. These options can serve as building blocks for future agricultural growth and can enhance resiliency of production systems in the face of climate challenges. Current policies that provide incentives for adoption of efficient practices complement the discussion. A robust knowledge base of such strategies and policies is necessary to support adoption of practices that provide environmental benefits with economic advantage to farmers.

Evaluation of alternate wetting and drying irrigation practices for mid-south rice production

Richard Atwill, Extension Associate, Mississippi State University
(co-author: L.J. Krutz)

Rice irrigation currently accounts for the greatest amount of irrigation water applied per hectare over corn, soybeans, and cotton in the mid-southern U.S. The alluvial aquifer serves as the major source of irrigation water for rice production in Mississippi; however, it is declining at a rate of 37,000 hectare meters per year and has done so for 35 years. An experiment was conducted at the Delta Research and Extension Center in Stoneville, MS to evaluate the yield and physiological response of rice to several alternate wetting and drying (AWD) irrigation regimes. Three rice cultivars were evaluated in six different rice irrigation treatments. Irrigation treatments included: a continuous flood, allowing the flood to recede to the soil surface, 10 cm below, 20 cm below, 30 cm below, and 40 cm below the soil surface. Water level in each paddy was monitored and irrigation events were triggered at each respective threshold back to a 10 cm flood, then allowed to subside until threshold was reached. Rice grain yield response of two AWD treatments were equal to rice grown with a continuous flood. A 200 kg grain yield increase was observed when the flood within a paddy was allowed to recede to the soil surface compared to a continuous flood. Grain yield for continuous flood was equal to rice grown with flood receding to 10 cm below soil surface. Reduction of grain yield was observed when the flood receded past 20 cm below the soil surface as compared to a continuous flood. Data from this experiment in 2015 suggest that allowing flood to subside to 10 cm below the soil surface does not result in yield loss compared to a continuous flooded system. Water management practices that reduce groundwater withdrawals are a viable option for rice producers in the mid-south.

Deep rooted crop options to sustain Ogallala Aquifer in the Southern High Plains

Sangu Angadi, Associate Professor, New Mexico State University
(co-authors: S.Singh, S. Begna, K. Grover, D. Auld)

Irrigation water from the Ogallala Aquifer has converted Southern Great Plains from "Dust Bowl of the 1930s" into a highly productive agriculture region in the country. Center Pivot Irrigation was invented in the region to improve irrigation application efficiency and reduce energy costs. The system is used extensively. However, continued decline of well outputs and pumping restrictions from the irrigation districts have compelled to look for deep rooted alternative crops, which can be grown with less water. With the current practice of irrigation, water is frequently applied to a shallower depth and deeper soil profiles are less frequently used. A multiyear study using the deep rooted safflower crop was conducted to assess effects of storing water in the deep soil profile using pre-season irrigation, varying in-season irrigation levels and critical growth stage based irrigation management on safflower stress physiology, seed yield formation and productivity. Safflower responded to water stress with multiple strategies. It ranged from morphological adjustment of plant size and leaf area to physiological response of stomatal and photosynthesis regulation. Lack of water in deep profile in no-pre-irrigation treatment limited water extraction by safflower. Regardless of the irrigation treatments, depth of rooting depth was at least 1.6 m in safflower. If water stress was early in the growing season, safflower relied less on water extraction to relieve stress at later stages. In contrast, if the stress was later in the growing season, safflower improved water extraction, especially from lower depths. Although the amount of water extracted from depth was relatively small, the efficiency of using that water in yield formation was much higher. As a result, reproductive stage was not more sensitive to water stress compared vegetative stage.

Session 7, International River Modeling

Spatio-temporal characteristics and trends of hydro-climatological variables in the semi-arid Southern Africa

Esther Mosase, Graduate Student, South Dakota State University
(co-author: *L. Ahiablame)
*Presenter - Laurent Ahiablame, Assistant Professor, South Dakota State University

Spatio-temporal characteristics and trends of the five key hydro-climatological variables (rainfall, temperature, streamflow, evapotranspiration, and soil moisture) were evaluated for the semi-arid Limpopo River Basin (LRB) in Southern Africa. Characterization of these variables included annual mean, maximum and minimum values, coefficient of variation, standard deviation and wetness coefficient, while the modified Mann-Kendall, Theil-Sen's slope estimator, and Hurst tests were used to quantify trends, magnitudes of trend and long-term persistence. The analysis showed varying results, but depicted statistically significant increasing trends for most of the variables within the watershed, except temperature which showed less significant trends. Abrupt changes as well as long-term persistence were observed in some pilot datasets. The findings of this study are anticipated to assist water managers in better planning and management of water resources under accelerated human activities and climate variability in the watershed.

Quantification of blue and green water in the Limpopo River Basin in Southern Africa using Earth Observation data and SWAT model

Esther Mosase, Graduate Student, South Dakota State University
(co-authors: L. Ahiablame, A. Rajib)

Adequate supplies of potable water is important to sustain agriculture, industry and domestic uses, particularly in semi-arid regions such as the Limpopo River Basin (LRB), Southern Africa where physical water scarcity is prominent. Effective planning and management of water resources in the region are hampered by scarcity of data due to limited hydro-meteorological stations thus limiting simulation modelling of water resources in the watershed. Earth Observation (EO) data is ingested, in lieu of ground-based data, into the Soil and Water Assessment Tool (SWAT) to quantify availability and changes in blue and green water footprints and drivers for agricultural and domestic uses in the LRB. Since reliable simulations are only possible when the hydrological model is soundly calibrated and tested, the LRB model is spatially calibrated using evapotranspiration (ET) data from MODIS and soil moisture (SM) from ASMR-E data. Even though calibration with ET and SM is selected due to the lack of reliable streamflow data in the watershed, it is anticipated that this study will test accuracy of the spatial and multi-parameter calibration procedure. The outcomes of this study will not only be beneficial for operational and planning purposes of water resources in Botswana and the LRB, but will also continue to demonstrate the use of remotely sensed observations as viable alternative input data for hydrological modelling in ungauged and poorly gauged watersheds.

The design and application of a hydro-economic modeling tool and its use in Southeast Asian watersheds

Brian Hurd, Professor, New Mexico State University

Watershed assessment using hydro-economic models is a widely supported approach and is an appropriate tool for many applications where estimates of economic welfare effects are desired. Training on the design and application of these methods has been the subject of recent UNDP efforts at technical capacity building in their program, Economics of Climate Change Adaptation (ECCA), for watershed managers across many Southeast Asian nations. This presentation will demonstrate how an Excel-based spreadsheet model can and has been used in training, educational, and outreach settings to improve understanding of the theory underlying hydro-economic models and to demonstrate their application in watershed assessments.

Session 8, Finding Wetland Ecosystem Services Within Existing Drainage Ditch Networks II

Canal sediment characteristics in the Everglades Agricultural Area and potential for P mitigation

Samira Daroub, Professor, University of Florida
(co-author: T. Lang)

Phosphorus (P) transported from farming and other sources to downstream water bodies have been identified as the primary cause of trophic imbalances within the Florida Everglades. Canals used for irrigation, drainage, and transport of water are loaded with sediments that can act as a potential sink or source to the water column. Sediments from the Everglades Agricultural Area (EAA) main and farm canals were sampled to determine their physicochemical characteristics, P fractions, clay mineralogy, and potential for P release. Phosphorus fractions associated with Ca and Mg compounds and recalcitrant P were dominant forms stored in EAA canals. Minerals found in main canals of the EAA included calcite, aragonite, dolomite, and palygorskite, which are similar to what is found in Lake Okeechobee. Flux studies conducted indicate some canal sediments are a source of P to the water column, while other canal sediments are in equilibrium with P in water column. Although the majority of P in canal sediments was found in stable forms, labile P, Fe-bound P and organic bound P may be susceptible to being released depending on redox potential in sediments as well as water column P concentrations. A current study is investigating the role of controlling floating aquatic vegetation, such as water lettuce (*Pistia stratiotes*), on the formation of denser inorganic sediments and recalcitrant P forms in canal sediments. A recently initiated project has the goal of demonstrating that EAA farm P loads can be reduced through the use of solar-powered water pumps that circulate farm canal water through aquatic vegetation-seeded field ditches at optimum flows that provide sufficient residence time for P removal.

Can floodplain restoration achieved with the two-stage ditch alter nutrient export from agricultural watersheds?

Jennifer Tank, Galla Professor, University of Notre Dame
(co-authors: S. Christopher, U. Mahl)

Excess fertilizer nutrients entering Midwestern agricultural streams degrade both local and downstream water quality, resulting in algal blooms and subsequent hypoxic “dead zones” often far from the nutrient source. We are quantifying the benefits of conservation practices that may reduce nutrient runoff from agricultural catchments. Specifically, research is lacking on whether restoring floodplains in streams and ditches, through implementation of the two-stage ditch practice, can reduce export of excess fertilizer nutrients to sensitive downstream ecosystems. We found that floodplain restoration increased reach-scale nitrate-N removal via denitrification and reduced sediment export, but impacts on surface water concentrations of nitrate-N and inorganic P were negligible, due to very high loading and relatively short floodplain reaches (~ 600 m). In contrast, modeling efforts using a common watershed model, the Soil and Water Assessment Tool (SWAT) suggested that longer two-stage implementations could achieve significant reductions in nutrient and sediment export from agricultural watersheds, showing promise for improved water quality in agricultural landscapes at larger spatial scales. For example, using SWAT, we evaluated several management scenarios within the highly-agricultural Western Lake Erie Basin. When the two-stage ditch was implemented in 100 % of the length of all possible ditches, > 75 % of the headwater streams showed nitrate-N reductions of at least 1 mg N/L, while 20 % of streams decreased nitrate-N by 3 mg N/L. In summary, successful outcomes highlighted through reach-scale demonstration projects can facilitate widespread adoption, while watershed-scale modeling efforts can forecast potential water quality outcomes. This paired approach may be an agent of change for advancing novel drainage management and conservation success in the agricultural Midwest.

Session 8, Finding Wetland Ecosystem Services Within Existing Drainage Ditch Networks II

Considerations for scaling investigative designs of mitigation efficiency in agricultural drainage ditches: Manipulating landscape properties and hydrology

Jerry L. Farris, Professor, Arkansas State University
(co-authors: T. Hudson, O.O. Iseyemi, M.T. Moore, R. Kroger)

Understanding the ecological, chemical, and hydrological processes operating within agricultural drainage ditches has been linked to a realization of ecosystem services at work to improve water quality in receiving systems. A historical overview of investigations conducted within an elaborate experimental drainage system illustrates the design challenges for evaluating nutrient removal efficiency within replicated experimental conventional and controlled (with weirs) agricultural drainage ditches during simulated seasonal runoff events. Study objectives will be presented across sequential investigations that examined the influence of routine mowing of vegetated ditches on nutrient mitigation and to assess spatial transformation of nutrients along ditch lengths and their influence upon ecosystem metabolism. Both mowed and unmowed ditch treatments decreased NO_3-N by 79 and 94 % and PO_4^{3-} by 95 and 98 %, respectively, with no significant difference in reduction capacities between treatments. This suggests occasional ditch mowing as a management practice would not be expected to undermine nutrient mitigation capacity of vegetated drainage ditches. Outcomes from these studies have indicated that a proper understanding and manipulation of agricultural ditch properties is vital to realize and improve ditch capacity in mitigating nutrient loads from intensive agricultural production.

Evaluation of package treatment plants on North Carolina's coast: Influence of seasonal dynamics on nutrient and pathogen treatment performance

Eban Bean, Assistant Professor, East Carolina University
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Effective treatment and disposal of wastewater is fundamental to protecting sensitive coastal water resources. Coarse sandy soils and shallow surficial aquifers provide little opportunity for mitigation of nutrients and pathogens introduced at or near the land surface. While onsite septic and centralized municipal wastewater systems are prevalent in coastal areas of North Carolina, Package Treatment Plants (PTPs) are also in use and relatively few studies have been conducted on these systems. PTPs are essentially small scale municipal plants typically located in settings where septic treatment and connection to a sanitary collection system are infeasible. PTPs treat wastewater using the same treatment processes and discharge treated effluent onsite. This study focused on evaluating the treatment efficiencies of seven PTPs using one of three treatment processes. All systems were located on Bogue Banks, one of North Carolina's barrier islands and a tourist destination that experiences seasonal population fluxes. Influent and effluent samples were collected monthly for one year beginning in February 2014 and analyzed for nitrogen species, phosphorous species, indicator bacteria, and other water quality parameters. All seven PTPs have shown the capability of effectively reducing total nitrogen concentrations to below 20 mg/L. While removal of particulate phosphorus is nearly complete, reduction of ortho-phosphate concentrations has been limited. All seven PTPs have also demonstrated effective disinfection with effluent *Escherichia coli* levels below 100 MPN/100 mL, although not consistently.

Geophysical approaches to improve the understanding of subsurface wastewater migration in coastal watersheds

Michael O'Driscoll, Director, Coastal Water Resources Center, East Carolina University
(co-authors: C. Humphrey, D. Mallinson, S. Hardison, M. Smith)

Currently, there are approximately 2 million onsite wastewater treatment systems (OWTS) in North Carolina with approximately half in coastal watersheds. However, there is limited monitoring data to evaluate the risk of water quality impairment to adjacent surface waters. We studied eight OWTS sites in coastal North Carolina to evaluate the use of capacitively-coupled resistivity (CCR) and ground penetrating radar (GPR) techniques to quantify the location and extent of subsurface wastewater migration (2009-2014). Groundwater measurements taken at the sites included depth to groundwater, pH, specific conductivity, temperature, dissolved nitrogen, and dissolved oxygen. Water samples were collected from septic tanks, groundwater beneath the drainfield, groundwater up- and down-gradient from the onsite wastewater systems, and from nearby surface waters. A comparison between the OWTS permits and GPR survey data confirmed that GPR surveys could identify drainlines and the extent of the drainfield. We compared electrical resistivity, groundwater specific conductivity, and groundwater dissolved nitrogen concentrations adjacent to OWTS. Our CCR survey results indicated that in areas with shallow water tables (200 uS/cm) and when surficial aquifer sediments were predominantly sand. The greatest contrasts in specific conductivity between the wastewater-affected groundwater and background groundwater were found at two large-scale, non-residential sites that had maximum design flows > 9,000 gallons/day. One of the large-scale sites had a grass lot downgradient and was instrumented for intensive monitoring of the wastewater plume. At this location, there was an inverse relationship between resistivity and groundwater nitrogen concentrations. This suggests that CCR surveys may be useful for screening for OWTS sites with elevated groundwater nitrogen concentrations.

Impact of harbor expansion on water resources

Ke Li, Assistant Professor, University of Georgia
(co-authors: B. Woodson, C. Meile, W. Savidge, F. Zeng)

Engineered infrastructures are backbones of municipal activities and economic development. Without adequate supporting infrastructure, the expected economic benefit of port expansion will not be feasible, especially with the competition among ports in the region. The growth of economic activities in the region will also lead to increasing population and industries, both of which require infrastructure expansion. To ensure we build asset instead of liability, it is important to understand the interaction among engineered system and the socio-economic and ecological environment. This understanding can be obtained with improved predictability of the system dynamics and long-term complexity of system evolvement. One important element within the coastal system in consideration is the water resources. It has been reported that economic growth and urban expansion will result in degraded eco-environments and declined condition for the water resources, especially on groundwater. A multi-factor modeling framework was built to assess the direct and indirect impacts of planned expansion of Savannah Harbor on local economy and water resources.

Harbor expansion is assumed to result in local industry growth, thus create more jobs. The estimation of the employment growth is modeled by the labor productivity (i.e. value added per man-hour/man-year) constants according to the United Nations demographic manuals, given the planned industry development as the input. The increased economic activities lead to the increase of both municipal (through population increase) and industrial infrastructures. These infrastructures affect water resource both directly and indirectly. The direct impacts are determined by the type of residential buildings and industrial categories which can be estimated based on the Georgia regional water plan. The indirect impacts are mainly due to the reduction of impervious surface which alternate the hydrological recharge cycles. The hydrological changes are modeled by the increased runoff to the surface water and the decreased recharge to groundwater from precipitation recharges.

Session 10, Panel Discussion, Sea Grant and Water Institutes: Research and Partnerships Investigating the Land Sea Interface

Darren Lerner, University of Hawaii, Director, Sea Grant College Program & Interim Director, Water Resources Research Center
Earl Greene, Chief of External Research, USGS

NOAA Sea Grant College Program (Sea Grant) and the USGS Water Resources Research Institutes (WRRI) through the National Institutes for Water Resources (NIWR) are both Federal-State partnerships federally mandated to address the Nation's oceans, coastal, Great Lakes, and water resources issues. Sea Grant is working on integrated research, education and outreach including water issues to assist coastal communities. The Institutes focus research and student training to address water issues related to resource availability, infrastructure and ecosystem services in watersheds. These programs intersect at the land-sea interface and in some locations over entire watersheds, but no coordinated effort to explore and exploit synergistic capacity between the Federal Agencies has occurred to date. Focusing on the significant aspect of the connection between coastal waters and the fresh water inputs they receive, we will discuss the intersecting foci described above and/or where Sea Grant and NIWR have partnered on research, education and/or outreach efforts.

Irrigation aquifer depletion: Challenges of sustaining this resource

Daniel Devlin, Director, Kansas Water Resources Institute, Kansas State University
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Demand for agriculturally produced food and feed is increasing and will continue to rise as populations expand and global economics improve. Irrigation is disproportionately supporting agricultural production compared to dry land management approaches; this production is critical in meeting the rising food demand. Irrigation results in about 40 % of global food production, and it occupies only about 18 % of the agricultural landscape. Irrigation from groundwater aquifers is paramount in critical food production regions of the world and a variety of these aquifers are highly stressed; their water recharge rates are well below extraction rates. Life expectancy of multiple irrigation aquifers, including selected aquifers in the United States, is decades or less with current management practices. Case examples from Kansas, Colorado and California are used to address the question: "Are existing irrigation management approaches preferentially focused on sustaining existing economies or sustaining the longevity of the irrigation aquifers?" Generally, irrigation aquifer depletion and water conservation needs are recognized by most stakeholders. The need for producers to maintain short-term financial integrity, which requires continued status quo use of irrigation water, is seriously challenging local water management policy development and delaying critical action. Relatively small areas of progressive thinking plans and even action are developing, but these areas must grow, and grow rapidly, to avoid major negative social and financial consequences.

Fields of action for IWRM for Colorado irrigated agriculture

John Wiener, Research Associate, University of Colorado

Integrated Water Resource Management (IWRM) has been embraced by leading organizations (e.g. American Water Resources Association). Consideration of city-periphery-rural interrelations, began with Von Thunen in 1881 and is emerging in climate adaptation. Climate change, land and soil quality loss should stimulate development of a mature form of IWRM to better align public interests and private adaptation capacity and needs. The Ditch and Reservoir Company Alliance held workshops on ditch company planning and alternative water transfer mechanisms (ATMs in Colorado's water discourse), to learn about irrigator needs. These efforts were stimulated by the first Colorado Water Plan, which calls for substantial ATM transfers in order to permanent avoid dry-up of lands from which irrigation water has been sold, threatening a substantial part of Colorado's agriculture. In the Western U.S., agriculture still accounts for more than 80 % of consumptive use of water and irrigation accounts for most of that, making irrigation water distribution and use critical in water re-allocation as well as maintenance of agricultural capacity. But, high financial vulnerability threatens remaining peri-urban agriculture, despite its values in amenity, recreation, real estate values, and ecosystem services. The higher values for water in urban use makes the most senior water rights vulnerable all over the West. This is aggravated by Colorado water law.

Argument to be made: The case for municipal water provider involvement in a mature IWRM approach is stronger than ever, but there are also perceived gaps in knowledge needed for irrigator decision-making. This presentation will outline the needs shown in Colorado and argue the virtues of a mature Integrated Resource Management approach concerned with the interrelations of city-peri-urban-rural activities and development of resilience to climate and rapid economic changes. It is time to consider fields of action – literally as well as metaphorically, needed in public interests, utility operations, and to respond to the needs of farmers who own critical land and water.

Monitoring the impacts of Sheridan County 6 Local Enhanced Management Area

Bill Golden, Research Assistant Professor, Kansas State University
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Current levels of groundwater consumption in northwest Kansas raise concerns relative to the long-term feasibility of irrigated agriculture in the area. In order to extend the economic life of the aquifer and maintain the economic base of the region groundwater water use reductions need to be considered. Past efforts to slow the decline and insure the future economic viability of the region have been largely unsuccessful. The 2012 Kansas Legislature passed SB 310 making Local Enhanced Management Areas (LEMAs) a part of Kansas water law. This law gives groundwater management districts (GMDs) the authority to initiate a voluntary public hearing process to consider a specific conservation plan to meet local goals. LEMAs are proactive, locally designed, and initiated water management strategies for a specific geographic area. Once approved by the Chief Engineer the LEMA becomes law, effectively modifying prior appropriation regulations. The stated purpose of the LEMA legislation was to reduce groundwater consumption in order to conserve the state's water supply and extend the life of the Ogallala Aquifer.

On December 31, 2012, the chief engineer issued his Order of Decision accepting the LEMA proposed by GMD #4 producers for the Sheridan #6 high priority area. This LEMA imposed a fixed-quantity-per-right groundwater use restriction on local irrigators, which on average is approximately 20 % less than historic use. Producers within the boundaries of the LEMA were assigned a five year allocation of 55 inches per acre.

Golden, Peterson, and O'Brien (2008) provided the initial economic analysis associated with the LEMA water use restriction. This static analysis yielded net economic losses associated with reduced groundwater use. Applying dynamic case study techniques, Golden and Leatherman (2010) suggested that, in the Wet Walnut Creek IGUCA, producers were able to mitigate the initial economic losses through innovation. This was accomplished by maintaining/expanding the production of higher valued crops and by adopting efficient irrigation technologies and practices. With these alternate research results in mind it is important that we monitor the economic outcomes associated with the water use restriction and disseminate the information to stakeholders.

This research documents the findings from monitoring the Sheridan #6 Local Enhanced Management Area (LEMA) in real time and observing producer innovation aimed at maintaining revenues. The knowledge of how irrigated crop producers react to conservation policies will provide guidance on what is expected to happen in the future as groundwater supplies are diminished and/or conservation policies are implemented.

Adaptive water planning and resilience

Tony Arnold, Boehl Chair in Property and Land Use, University of Louisville

Water planning is difficult under conditions of uncertainty and instability. Conventional planning methods produce top-down, static, up-front plans that are ineffective or maladaptive as conditions change. Adaptive management methods, on the other hand, provide flexibility for on-the-ground water management actions, but are ill-suited to resolving social goals and public policy choices over complex "wicked" problems, which are better addressed through planning processes. Moreover, legal systems often require that governance entities engage in planning before acting. Increasingly, water governance organizations are using adaptive planning methods for a variety of planning needs: water supply, conservation, watershed/basin, stormwater runoff, pollution control, restoration, flood, drought, and adaptation to climate change. Adaptive planning is an alternative to conventional planning. It is a tool to increase resilience in ecosystems, social systems, and institutions. Adaptive planning uses flexibility, continuous iterative processes, diverse participation, and feedback loops, and focuses on building adaptive capacity. It is ideal for goal-setting and strategy-development under conditions of unprecedented change, surprise disturbances, or cross-system complexity. Until recently, the theory and practice of adaptive planning were promising, yet relatively under-developed. This presentation discusses a new, deeper conceptualization of adaptive planning and the specific elements and methods that characterize adaptive planning. It integrates insights from four sources: 1) the existing and now growing literature on adaptive planning (and related concepts, such as collaborative planning and swarm planning); 2) resilience science (complex social-ecological-institutional systems); 3) planning theory and practice; and 4) lessons learned from seven diverse basins using adaptive planning to some degree: a) Anacostia (DC/MD); b) Blackfoot (MT); c) Great Lakes Restoration Initiative; d) Los Angeles River Restoration (CA); e) Santa Ana (CA); f) Santa Fe (NM); and g) implementation of the State of Washington Watershed Planning Act. The presentation discusses the roles of adaptive water planning in building social-ecological-institutional resilience in water systems.

Designing rivers, redesigning institutions: The U.S. Army Corps of Engineers' 308 reports

Jeffrey Brideau, Research Associate, Institute for Water Resources, USACE

This presentation focuses on a largely forgotten, unimaginatively named program to survey the nation's rivers – the Army Corps of Engineers' 308 Reports. Initiated by House Document 308 (69th Congress, 1st Session, April 12, 1926), the Corps produced 176 surveys over the following two decades, aimed at formulating general plans for multipurpose river basin development. Propelled by a desire for more efficient production of hydroelectricity – i.e. coordinated with alternative uses – federal lawmakers authorized the program. However, the Corps confronted cultural, political, and institutional forces that, like the rivers under their gaze, existed in flux. The abstraction of rivers to cost-benefit ratios and legislatively prescribed activities collided with turbid social, political, and environmental realities, including the Great Depression and New Deal response. Using the 308s as an aperture, this presentation explores two topics of particular interest to the water resources community: the long-range value of a national strategic vision for water resources, and the process of institutional transformation. Finally, a more fundamental challenge is embedded in this presentation – how to marshal the past to inform present policy and future activity.

Accordingly, I argue that the 308s mark a turning point in Corps' history and practice. A belated manifestation of Progressive Conservationism, the program reflects a transformation of the Corps' perception of rivers – from improvable, local transportation arteries to multipurpose national resources whose efficient use(s) should be maximized. This reversal of the Corps' vocal opposition to Conservation allows us to unpack the array of forces that conspired to incite organizational and ideological revision. The 308s also reveal the Corps' expanding role as a complex systems builder; the reports provided early blueprints for a torrent of unprecedented technological interventions into the nation's rivers – known as the "Big Dam Era." Collectively, the 308s embody an ad hoc nation-wide water resources development plan, and offer a glimpse into the value and limitations of a national strategic vision.

Development of a sustainable water management plan for the ACF River Basin

Martin Kistenmacher, Research Engineer, Associate Director, Georgia Water Resources Institute, Georgia Tech
(co-author: A. Georgakakos)

The ACF Stakeholders (ACFS) is a 503(c) nonprofit organization with membership from 56 river basin stakeholder groups in Georgia, Alabama, and Florida. For the past few years, ACFS has been undergoing a comprehensive consensus building process to reconcile the various special water-related interests in the Apalachicola-Chattahoochee-Flint river basin and develop a shared vision plan. The Georgia Water Resources Institute (GWRI) has been engaged to develop various modeling tools, carry out comprehensive assessments, and inform the planning process toward developing a consensus management plan.

This article describes the technical process and tools developed to support the stakeholder information needs. These activities included comprehensive surveys of individual stakeholders' interests and performance evaluation metrics, development of different modeling tools (e.g., ACF-DSS, ResSim, hydrologic models, hydro-dynamic models) to evaluate a host of water management alternatives (WMAs), development of post-processing tools to interpret complex technical information into stakeholder-meaningful findings and conclusions, and multiple workshops with each stakeholder caucus and the ACFS as a whole.

The technical assessments considered many potentially promising water management alternatives including making adjustments to in-stream and off-stream water uses; power generation management policies, reservoir coordination strategies, and modifications to the existing water infrastructure. Throughout this process, model results were analyzed and presented to highlight the effects of different WMAs on a wide range of performance metrics representing individual stakeholder preferences. Several rounds of modeling were conducted to help stakeholders appreciate the implications of the current operations, evaluate trade-offs among several key water uses, and identify the most promising WMAs included in the ACFS recommendations to the United States Army Corps of Engineers and the riparian states.

Nutrient removal in subsurface drainage using denitrification bioreactors and filter materials for phosphate adsorption

Laurent Ahiablame, Assistant Professor, South Dakota State University
(co-authors: G. Hua, C. Hay, J. Kjaersgaard, T. Trooien)

Subsurface drainage on agricultural land with poor natural drainage allows timelier field operations and contributes to improved crop yields. While properly designed and installed subsurface drainage typically reduces sediment and particulate-bound phosphate losses, studies showed that subsurface drainage may enhance exports of nitrate and dissolved phosphorus to surface waters. Elevated levels of nitrogen and phosphorus in natural waters can lead to eutrophication and harmful algal blooms, which will negatively affect aquatic ecosystems and human health. This study uses laboratory experiments, field installations, and field measurements to demonstrate the utility of using woodchip denitrification bioreactors and phosphorus adsorption beds as conservation drainage practices to remove nitrate and dissolved phosphorus from tile drain water. We expect that the project will lead to improved recommendations for conservation drainage practices in South Dakota to maximize the economic benefits of tile drainage and minimize potential negative environmental impacts from crop production systems.

Landscape irritation: Estimating use, conservation potential, and response to price

Miguel Morales, University of Florida
(co-authors: K. Friedman, S. Knight, J. Heaney)

Landscape irrigation is a major component of urban water use within most utilities. In order to facilitate quantitative evaluations of water demand options, the urban water resources group at the University of Florida (UF) has developed data-driven methodologies. Through the use of property appraiser, U.S. Census, and utility water billing databases, water use relationships have been developed and incorporated into a web-based model known as EZ Guide. EZ Guide utilizes data on each of the nine million parcels in the state of Florida and estimates water use at the parcel-level. This fine spatial unit of analysis allows for evaluations of water demand options from the sub-utility to the regional scale. EZ Guide estimates residential indoor and landscape irrigation water use, and commercial, industrial, and institutional water use, and incorporates an optimizer to identify which water demand best management practices and customers a utility should target based on cost effectiveness. This talk will focus on the UF methodologies to estimate irrigation water use, quantify conservation potential, optimally target customers and irrigation best management practices, and quantify the effect of water pricing on landscape irrigation use.

The impacts of cover crops and tillage on nitrate-N leaching in southern Illinois row crop agriculture

Brooke Hagarty, Graduate Student, Southern Illinois University Carbondale

Nitrate as a water contaminant has many detrimental effects on ecosystem and human health. The need for optimizing agriculture production while decreasing the impacts of nitrate leaching becomes more critical as the world population grows. The purpose of this research is to find effective methods to reduce nitrate leaching without reducing corn and soybean yields. Reductions of nitrate leaching have been documented from the incorporation of cover crops into field rotations, but more research is needed to understand what cover crops (legume vs. non legume) along with what tillage system (conventional-till vs. no-till) are the most effective at reducing nitrate losses. The four treatments for this two-year study are as follows: cover crop/no-till, no cover crop/no-till, cover crop/till, and no cover crop/till. The crop rotations for year 1 are cereal rye followed by soybean and no cover crop followed by soybean. The crop rotations for year 2 are hairy vetch followed by corn, tillage radish and spring oat mix followed by corn, and no cover crop followed by corn. Two tension lysimeters were installed in spring 2015 in each of the 18 treatment/sub treatment plots at 46 cm deep and 91 cm deep. Lysimeters are sampled every two weeks throughout the year except January and February, where they were only sampled once a month. Preliminary results show that mean nitrate-N leaching in the hairy vetch/tilled treatment is the highest (11.69 mg/L), with the no cover crop/no-till treatment the lowest (6.72 mg/L). The mass water balance equation is used to estimate the amount of water draining below the root zone. Soil nitrate-N concentrations are used with volume measurements to report flow-weighted nitrate-N concentrations. Grain yield is measured to assess impacts of cover crops and tillage on corn and soybeans. These data will provide useful information to farmers and land managers on optimal practices to reduce environmental impacts without changing yield.

Protecting public groundwater supplies using the Michigan Groundwater Management Tool (MGMT)

Ruth Kline-Robach, Outreach Specialist, Michigan State University Institute of Water Research

Michigan has more than 12,000 public water supplies. This includes municipal community water supplies such as villages, townships and cities; non-municipal community supplies such as condominiums, manufactured housing communities and apartment complexes; and noncommunity public water supplies such as schools, restaurants, gas stations and other small public facilities. In addition, nearly half of Michigan's residents rely on groundwater as their sole source of drinking water. Michigan State University (MSU) is working collaboratively with the Michigan Department of Environmental Quality (MDEQ) to provide public groundwater supplies with the information and tools needed to protect public groundwater supplies. Under a jointly-funded agreement between MSU and the MDEQ, the Michigan Groundwater Management Tool (MGMT) was developed. It is being used to generate source water protection areas for public water supplies. Using a variety of existing hydrogeological data, drinking water recharge areas are delineated and mapped, and then provided to local water supply operators along with susceptibility assessments unique to each supply and other training materials. The ultimate goal of the project is to help water supply operators understand changes that can be made to protect their drinking water supplies. Training workshops have been held to distribute the provisional source water protection area maps and associated drinking water protection materials. This presentation will summarize the MGMT project and discuss follow up activities that are underway.

Simulating conjunctive use of surface water and groundwater RiverWare Model: A case study in Urumqi River Basin, China

Shalamu Abudu, Postdoctoral Research Associate, Texas AgriLife Research & Extension Center at El Paso
(co-authors: Z. Sheng, A. Michelsen, C. Cui)

A RiverWare model was developed to simulate interaction between surface water and groundwater in Qingnian Irrigation District in the upper valley of Urumqi River, Xinjiang in far northwest China. The hydrologic effects of different water management alternatives were evaluated by considering irrigation and drainage system, crop water use, and diversion rules at the diversion dams into a RiverWare model developed both in daily and monthly time steps in the irrigation district. Water demands for crop consumptive uses were estimated by using crop acreage, crop patterns, and crop ET coefficients to generate a more accurate assessment, which in turn allows the model to simulate diversion requests and diversions more accurately. Groundwater objects were used to simulate seepage losses from the canals and the river, groundwater pumping, and return flows from the drains. The daily and monthly data from 2005 to 2012 were used to calibrate the model for Wulabo Reservoir inflow at the lower end of the irrigation district. The interaction of groundwater and surface water was further evaluated under different future water supply scenarios by coupling of the predictions of upstream runoffs by snowmelt runoff models into the developed the RiverWare model in the Basin. The results indicated that the model adequately reproduced the historic reservoir inflows for the Wulabo Reservoir for the period studied. Water operation policies from the RiverWare model simulation provide guidelines for conjunctive uses of groundwater and surface water resources within the basin under different water supply scenarios in the future. It is also recommended that the model performance can be further improved by acquiring more accurate crop data, groundwater data and parameters, improving return flow estimation, and calibrating and validating the model with extended historic data.

How can a gaining river become a losing stream in an arid region?

Zhuping Sheng, Professor, Texas AgriLife Research & Extension Center at El Paso
(co-authors: A. Michelsen, S. Abudu, P. King)

In an arid region both surface water and groundwater have been stressed by droughts and human activities, including urban development and agricultural irrigation. In some areas groundwater stresses become so great that it depletes the flow in the river overlying the aquifer. Therefore understanding such relationship between surface water and groundwater becomes more important in regional water resources planning and management. In an arid region such as the Rio Grande Project area in southern New Mexico and Far West Texas, stream flows are highly regulated by the upstream reservoirs during the irrigation season (March through October) and greatly influenced by return flows during non-irrigation season (November through February). At the same time, groundwater pumping further complicates the surface water and groundwater interaction. In this paper the authors will use observation data and results of numerical models to characterize and quantify hydrological exchange fluxes between groundwater in the aquifers and surface water (the Rio Grande, canals and drains) as well as impacts of groundwater pumping. In general, unlined canals and laterals recharge the shallow aquifer by the seepage, while drains collect water from the irrigated land through the shallow aquifer and return it to the river. Groundwater has been pumped for municipal supplies and agricultural irrigation, which has imposed stresses toward both stream flows and aquifer storage. The results show that historic groundwater pumping has caused some reaches of the river change from gaining stream to losing stream. Beyond the exchange between surface water and groundwater, groundwater pumping in a deep aquifer could also enhance the exchanges between different aquifers through leaky confining layers. In the earlier history of pumping, pumping from the shallow aquifer is compensated by depletion of surface water, while deep aquifer tends to use the aquifer storage. With continued pumping, the cumulative stresses from deeper aquifers migrate upward, resulting in additional depletion of surface water. Eventually such impacts turn some reaches of a gaining river into a losing stream.

Session 15, Water Integration Sustainable Design Strategies

Water integration sustainable design strategies

Omar Youssef, Adjunct Lecturer, University of Arizona
*Presenter - Sandy Bernal, University of Arizona

Water and energy are fundamental components of our 21st century life, but they can no longer be considered separated. Just as the fact of producing energy consumes water, the pumping, treating and distributing of water in turn requires energy. In other words, water is an energy issue and energy is a water issue. Water communication is one of the most challenging discussion topics within most of the environment and natural resources. There is a substantial gap between the science being produced whether its through academia, or actual preservation strategies such as harvesting, reusing, reducing or even generation and the process of decision making by managers, planners, and policy makers. Communication is key to avoid potentially useful science that may never make it beyond the scientific world. Establishing a common language of environment(al) conservation is a phenomenal idea. Not only does it become specific and descriptive, it also becomes extremely useful as it encourages the public's interaction and involvement with strategic scientific decisions.

Climate change is a major threat to the water supply, but there are several steps that are being adopted to avoid the projection of drought, through renewable and finite water supplies. Some of the steps that are taken towards adapting for this change. The plan and goal of this "special session" is to disseminate the possibility of securing water resources to adapt to change, through conservation, reclaiming, storing, and generating. Securing water resources to adapt to future changes and climate change is not an easy process, but students have accepted this challenge and will present possibilities by utilizing science to reduce uncertainty.

Categorizing water into three segments of reliability, resilience, and redundancy is important for the building sector to realize their full growth potential and their strategic vision. Through academic efforts architecture design and professional practice have been merged to provide the opportunity to overcome current high consumption of energy through integrating sustainable smart water strategies.

Four-legged water curriculum for architecture education

Nader Chalfoun, Chair, Masters of Science in Architecture, University of Arizona
*Presenter - Sandy Bernal, University of Arizona

The earth holds about eight million cubic miles of freshwater, most of it is stored in underground reservoirs, permanent ice, snow covers, lakes, and rivers. Although this statement implies availability of large quantities of water sources, many current desert communities are in jeopardy from lack or diminishing of water supplies for survivorship. Water and energy are fundamental components of our 21st century life, but they can no longer be considered separated. Just as the fact of producing energy consumes water, the pumping, treating and distributing of water in turn requires energy. In other words, water is an energy issue and energy is a water issue. Until today, in Architecture Education water efficiency principles have not been taught in tandem with energy conservation though strongly related. This paper describes the development of an innovative Architecture education curricula that focuses on the effective use of water in desert communities and its impact on energy consumption and building performance. The education curriculum approaches the issue of water/energy nexus through a proposed four-legged body of knowledge addressing: 1) Water Harvesting; 2) Water Reduction; 3) Water Reuse; and 4) Water Energy Generation technologies. Although water harvesting and water reduction have recently become common methods in building design, water reuse and water energy generation are relatively newer technologies that demonstrates greater promise to contribute to the affordability of water and its use as alternative energy sources. The curriculum includes the environmental benefits from integrating water saving strategies to modify thermal conditions inside spaces. The modified environments would otherwise use energy to be achieved while the saved water will facilitate techniques for exterior landscape development. All technologies will include calculative methods, use of computer simulation, design monographs, and hands on inquiry based learning through laboratory sessions.

Estimation of household willingness to pay for water conserving landscape design

Ryan Williams, Assistant Professor, Texas Tech University
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*Presenter - Blessing Ugwuanyi, Graduate Research Assistant, Texas Tech University

Fresh water resources in the western United States are increasingly scarce, therefore a need exists for improved allocation efficiency of water resources to ensure the sustainability of municipalities. Landscape irrigation, as one of the largest users of residential water (approximately 30 %), is the lowest hanging fruit for achieving efficient municipal water use. In fact, according to the EPA, in dry climates such as that of West Texas, outdoor water use can account for up to 60 % of total household water use. Furthermore, up to 50 % of that water may be wasted due to inefficient irrigation (EPA 2013). While some water conservation may be achieved either through municipal water policy (e.g. restrictions) or educational efforts, a shift in the norm for residential landscape design may be more effective.

An online survey targeted residents of Lubbock, TX, a community in a semi-arid region that has recently experienced persistent drought. We assess household willingness to pay for water conserving landscape design through a choice experiment. The survey respondents were presented with pictures of the same home with a traditional landscaping design and a water conserving design. The features of the home were described as would be common in a flyer for a home listed for sale, including prices. The respondents were asked to pick the home that they would prefer. Treatments for this portion of the survey include varying price differentials between the homes and the inclusion of suggested water use and cost of that water use for the landscaping. The household willingness to pay is estimated via discrete choice modeling.

We find that households are willing to pay a premium for water-conserving residential landscapes, but not a sufficient premium so as to cover the cost of installation unless the buyer is informed of the financial benefits of the water conservation.

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Session 16, Unintended Consequences of Projects and Policies

Impacts of Texas legislation on water treatment technology adoption

Ron Lacewell, Assistant Vice Chancellor, Texas A&M AgriLife
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The population of Texas is expected to double between the years 2000 to 2060. The Texas Lower Rio Grande Valley is one of the fastest-growing areas in Texas forcing community leaders to explore alternative water sources and potable treatment methods. An emerging and promising approach to expanding potable water supplies is brackish groundwater desalination. Due to recent technology developments in desalination membranes and increasing prices of surface water rights, the economics of desalination have become competitive with conventional water purchase and treatment methods. The apparent competitive relationship between conventional and desalination treatments was impacted, however, by Floor Amendment 60 of Texas Senate Bill 3, which was a legislative attempt to meet the increased demand for municipal water. This legislation established the price at which irrigation water in the Valley can convert to municipal water, as a result of urban/residential development of agricultural land, at 68 percent of the market price. The economic and financial implications, both intended and unintended, of Floor Amendment 60 on the Valley water market, and the resulting incentives impacting adoption of alternative technologies for producing potable water are identified and analyzed. Conclusions include a cost advantage for the use of conventional surface water treatment after implementation of Floor Amendment 60, an increase in the supply of potable water produced by this method, and providing benefits to consumers and municipalities, while adversely affecting irrigation districts selling converted municipal rights.

Will farmers save water? A theoretical analysis of groundwater conservation policies

Tong Wang, Assistant Professor, South Dakota State University
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*Presenter - Seong Park, Associate Professor, Texas A&M AgriLife Research

The development of agricultural irrigation systems has generated significant increases in food production and farm income. However, unplanned and unconstrained groundwater use could also cause serious consequences. To extend the economic life of groundwater, water conservation issues have become the main focus for the policy makers. Taking Ogallala aquifer in U.S. Southern Great Plains as an example, this paper analyzes whether current and potential groundwater conservation policies provide profit-driven farmers with incentives to save water. We adopt a theoretical approach to analyze farmer's optimal response when facing following policy alternatives, including: 1) irrigation technology subsidy; 2) increased water cost; 3) unit subsidies for water saving; and 4) subsidies on water-conservative crop. Our findings suggest that the effects of water conservation policies vary by region. Specifically, the switching to higher efficiency technology should occur in a preventative stage for the water saving to occur. Similarly, an increase in water cost promotes water saving only when water resource is relatively abundant. In regions where groundwater already poses a constraint, the unit subsidy for actual water saved and price subsidy for water-conservative crops are more effective in achieving the water conservation goal.

Session 16, Unintended Consequences of Projects and Policies

Unintended and paradoxical aggregate economic and environmental effects

Robert Taylor, Alfa Eminent Scholar & Professor, Emeritus, Auburn University
(co-author: R. Lacewell)

Unintended and unexpected consequences of policy are often manifested or evident only after implementation. Sometimes the unintended consequences are positive, sometimes negative. Sometimes the consequences are manifested quickly, sometimes it takes years, decades, or centuries for unintended consequences to be manifested or recognized. Unintended consequences come about for a variety of reasons. First, policy is often implemented in a rush with a narrow focus, such as economic efficiency. Some claim that the first law of ecology is "everything is connected to everything else." This is also a law of economics, but it is difficult to consider all possible ripple effects of policy proposals given the rush to implement and narrow compartmentalization of economic and ecological analysis. Second, there is a tendency to think about how an individual or small area is affected, thereby overlooking aggregate consequences that may be counter to that based on micro reasoning and analysis. In economics, this is called a micro-macro paradox because micro effects, when aggregated to the macro level may have an effect opposite that what is expected at the micro level. Such paradoxical effects also occur with environmental and water utilization dimensions of policy. However, if analysts chased every possible indirect effect, nothing might be done, thus preserving the status quo (which may be undesirable). Third, it must be recognized that some policy advocates are not interested in the policy itself, but desire to produce the unintended consequence while keeping their motive masked in hyperbola and numbers produced by economic hit men. Unintended consequences will be highlighted with examples of ethanol, water, and pesticide policy.

Unintended consequences of programs subsidizing irrigation water conservation programs

Frank Ward, Professor, New Mexico State University

Growing evidence of increased water scarcity as well as rising population in many parts of the world continue to place pressure on the discovery and development of measures to reduce water use in irrigated agriculture, the world's largest water consumer. According to the FAO, only 16 percent of the world's croplands are irrigated, but those lands produce about 36 percent of the world's harvest. In the developing world, irrigation increases yields for most crops by 100 to 400 percent. Numerous donor organization programs encourage adoption of modern irrigation technology like drip irrigation, motivated by a desire to promote water conservation in agriculture. Policy choices that promote on-farm conversions to modern irrigation technology are typically believed to free up water users for growing urban and environmental uses. Nevertheless, few peer reviewed investigations have been conducted to test this assumption. This work applies a hydroeconomic model originally developed for the Rio Grande Basin in Colorado, New Mexico, and Texas to assess the effectiveness of conversions to drip irrigation. Results assess crop yields, water applied, water consumed, water saved, and farm income. The difficulty of separating water applied from water consumed has proven to be an important barrier for economic investigations of the real conservation effectiveness associated with conversions from flood to drip irrigation. Conversions to drip irrigation can be expected to reduce water applied per acre, but can also reduce aquifer recharge and reduce valuable return flow into river systems. An unexpected result of our work is that adoption of more technically efficient irrigation technologies can actually increase water depletions. We found that securing real water savings requires assembling institutional, technical, legal, and water accounting methods that accurately track and economically reward water depletion reductions. Water laws and other water shortage sharing institutions could productively target and track water depletions rather than water applications to distinguish reduced water applications from true water saved. Such institutional innovations can guide the path towards discovery of policy measures to save water and protection food security and key ecological assets in the face of growing increases in water demands.

Drought early warning systems in the United States

Courtney Black, Regional Drought Information Coordinator, NIDIS/NOAA
(co-authors: V. Deheza, A. Marrs, C. McNutt)

The National Oceanic and Atmospheric Administration's (NOAA) National Integrated Drought Information System (NIDIS) program was authorized by Congress in 2006 (Public Law 109- 430) with an interagency mandate to coordinate and integrate drought research, building upon existing federal, tribal, state, and local partnerships in support of creating a national drought early warning information system (DEWS). Currently nine DEWS have been established to serve the following regions in the United States: Pacific Northwest, California and Nevada, Southern Plains, Missouri Basin, Midwest, Apalachicola-Chattahoochee-Flint Basin, Four Corners Tribal Lands, Coastal Carolinas and the upper Colorado River Basin.

These DEWS utilize new and existing partner networks to optimize the expertise of a wide range of federal, tribal, state, local and academic partners in order to make climate and drought science readily available, easily understandable and usable for decision makers; and to improve the capacity of stakeholders to better monitor, forecast, plan for and cope with the impacts of drought. Each of the DEWS is customized to best meet the needs of the stakeholders in the region. This presentation provides information on the DEWS research, monitoring, and outreach actions along with discussion of the benefits and lessons learned from these regional programs.

Improving water supply planning and operations by using climate science: The Florida Water and Climate Alliance

Christopher Martinez, Associate Professor, University of Florida
(co-authors: T. Asefa, J. Bolson, T. Irani, V. Misra, L. Staal)
*Presenter - Kevin Morris, Science and Technology Officer, Peace River Manasota Regional Water Supply Authority

The Florida Water and Climate Alliance (FloridaWCA) is a stakeholder-scientist working group focused on increasing the relevance of climate information for water supply planning and operations in Florida. Formed in 2009, the FloridaWCA has 1) developed a collaborative working group comprised of public water utilities, water resource managers, local governments, climate scientists, hydrologic scientists, and social scientists focused on understanding how climate variability and change may impact water supply planning and operations in Florida; 2) downscaled seasonal climate forecasts and climate change projections of hydrologically-relevant variables beyond precipitation and mean temperature at desired spatio-temporal scales to drive end-users' water supply and demand models; 3) developed customized statistical and physical hydrologic forecast models using climate information; and 4) increased the climate-literacy and water supply planning/operations-literacy of both practitioners and scientists, respectively. This presentation will highlight some of the technical products that have been cooperatively developed by the FloridaWCA and how they have aided in planning and operations. In addition, this presentation will provide insights on the success of the group, how it has maintained sustained participation, lessons learned that can help others in creating similar collaborative working groups, and future directions.

Using short-term climate forecasts to mitigate the effects of drought

Puneet Srivastava, Water Resources Center Director, Auburn University

In recent years, great advances have been made in weather forecasting. Because of this, skill in forecasting precipitation and temperature with up to two-week lead time has greatly improved, and the use of weather information for water resources decision-making has become ubiquitous. In addition to weather data, water resources community greatly relies on historical climate data for decision-making related to water supply, designing civil infrastructure, flood protection, and water quality protection. However, although we are greatly influenced by seasonal-to-interannual (SI) climate variability, the water resources community has not yet embraced the use of SI climate forecasts in decision-making. In the southeastern United States, large SI climate variability, caused mainly by the La Niña phase of the El Niño Southern Oscillation (ENSO), frequently results in low water availability and droughts. Because La Niña typically returns every two to seven years, drought is a recurring phenomenon and greatly affects the availability and quality of water in the Southeast. In recent years, advances have also been made to improve SI climate forecast skill. This is especially truly for the regions of the country (e.g., the Southeast) that are greatly affected by ENSO. In this seminar, I will present a number of examples from my recent research on how SI climate forecasts can be used to mitigate the effects of drought in the Southeast. Examples include (1) using SI climate forecast to better manage water supply and demand in small- to mid-size communities of the Southeast during drought, (2) using climate forecasts for National Point Source Discharge Elimination System (NPDES) permitting to protect surface water quality, and (3) ecologically-sustainable surface water withdrawal for cropland irrigation using climate forecasts. My research is an integral part of the National Integrated Drought Information System (NIDIS) effort to mitigate the effects of drought in the Southeast. Therefore, I will also talk about NIDIS drought mitigation efforts in the Southeast.

The NC Urban Water Consortium: Supporting decisions through collaborative funding for applied research

Nicole Wilkinson, Coordinator for Research and Outreach, NC Water Resources Research Institute

The pressures on drinking water and wastewater utilities to provide safe and reliable access to services for growing populations are compounded by issues such as climate change and related weather events. In 1985, North Carolina utilities came together to form the Urban Water Consortium in partnership with the North Carolina Water Resources Research Institute (WRRI). Their model of collaboratively funding research has enabled them to address priority research questions that directly feed into management decisions about topics such as capacity use planning, treatment, and pricing structures. This presentation will illustrate this successful model of collaboration, and highlight several applied research projects and how utilities are using the results to better inform decisions about water utility management.

Mysterious no more - The importance of demonstration projects
Case studies in watershed education and engagement

Eve Brantley, Water Resources Specialist & Associate Professor, Alabama Cooperative Extension System, Auburn University
(co-author: A. James)

Taking a watershed approach to improve water resources includes science-based planning, design, implementation, maintenance, and education. Each step of the process is critical to success, especially education and engagement. Building community support and willingness to implement new technologies often encounters obstacles related to lack of technical knowledge, concerns of costs, and uncertainties of maintenance. One of the first steps in transitioning to new or innovative approaches is removing the mystery of an unfamiliar practice, behavior, or technology. Demonstration projects can be powerful influences in raising awareness of innovative practices and increasing knowledge of where practices may be most successful. Arguably, the most important component of a demonstration project is improving stakeholder understanding of WHY the projects are needed. Case studies will be used to review lessons learned from a network of partners that have planned, implemented, and evaluated watershed improvement practices. The target audiences of these case studies includes K-12 students, natural resource professionals, and local government representatives. The demonstration practices include stormwater management, stream restoration, and community engagement. Flexibility in message delivery and building trust are critical to implementing projects that protect, conserve, or restore water resources. Without the correct message and watershed relationships, the ability to transfer technology and radiate projects is difficult and ineffective.

Enhancing water quality education and community services through a nationally accredited laboratory

Tolessa Deksissa, Director, Water Resources Research Institute, University of the District of Columbia

When strong environmental policies and active public engagement are required to protect and manage our precious fresh water resources, the availability of accredited water quality testing laboratory is crucial for not only for the water quality testing and management, but also to enhance water quality education and community services. Accredited lab generates documented and certified quality data in order to monitor and predict the changes in the quality of our water system. The purpose of this paper is to present the impact of newly established and nationally accredited Environmental Quality Testing Laboratory at the University of the District of Columbia in training future water quality scientist and engineers while providing laboratory testing service to the residents of the District of Columbia and beyond. Accredited by the National Environmental Laboratory Accredited Program with NELAC standard, the UDC's Environmental Quality Testing Laboratory has demonstrated impact on student's learning outcome through hands-on experience. It has enhanced faculty research capacity and extramural funding, increased visibility of water and environmental programs at the University, created new graduate and undergraduate degree programs, and created new laboratory testing services to DC residents and beyond. The lab also created an important niche for the District of Columbia as there is no such lab in the region. The laboratory service integrates research, teaching, training, and community services. All students enrolled in the water quality courses both in graduate and undergraduate programs are required to be trained in the accredited testing lab. Furthermore, the lab is in the process of building a model that the student runs the lab service as an entrepreneurial opportunity to increase enrollment and retention. This study successfully integrated entrepreneurship, teaching and learning, training faculty and researchers, and community services. This approach can be replicated in other places as a model to enhance water quality degree programs, community services, and marketability of the graduates.

A web-based module for hydrology and water resources education: A case study from a coastal basin

Matthew Deshotel, Research Assistant, University of Louisiana at Lafayette
(co-author: E. Habib)

This study presents the development of a student-centered, web-based data and model-driven educational-module that supports active learning in hydrology and water resources. The target audience of the module is undergraduate university students in water resources engineering and earth science programs. The module is based on a real-world case study of hydrologic restoration in south Louisiana (Pecan Island). The overall objective of the module is to introduce students to coastal restoration projects and the use of numerical models and data analysis to: (a) assess the feasibility of a proposed restoration project, and (b) perform hydraulic design analysis. Through utilizing this real-world case study, the intent is to provide students with practical experience to motivate and engage them and to provide them with an understanding of the social and technical complexities of water problems. The module is composed of two phases: "Feasibility Analysis", where students develop and apply a salt and water masa-balance model; and "Hydraulic Design" where students develop and use one-dimensional hydraulic unsteady flow model to design a proposed conveyance channel. The module is designed in such a way that the instructor can assign the module to be independently implemented by the students. The module is available online as part of the HydroViz system (www.hydroviz.org). The module has been implemented in two undergraduate water-related courses and an evaluation study was conducted to improve the design of the module and assess its impact on student learning.

Introducing the Mississippi Water Security Institute (MSWSI)

Clifford Ochs, Professor, University of Mississippi
(co-authors: D. Sullivan-González, D. Brown Young)

Through a generous grant from the Robert M. Hearin Foundation, The University of Mississippi Sally McDonnell Barksdale Honors College has established the Mississippi Water Security Institute (MSWSI). MSWSI is developing an intensive two-week workshop on water security issues in the state, which will be offered to a select group of undergraduate students in honors programs in Mississippi. With abundant natural resources and a growing population, Mississippi is an increasingly favorable place to invest, start a business, and raise a family. MSWSI recognizes that with population and economic growth there will be increasing demand on our freshwater resources. The term "water security" refers to challenges inherent in promoting and linking strong business development with community health with natural resource protection. Clearly, this is a challenge requiring communication among multiple fields and interests - the business community, agriculture, law and public policy, urban planning, engineering, and conservation. Reflecting this complex mosaic of water security concerns, the workshop will facilitate interdisciplinary study and problem solving, and include travel, guest speakers, and independent research. Students in the workshop will become knowledgeable in the availability and quality of freshwater resources in Mississippi, learn to assess how these resources can be used wisely in support of business and community development, and environmental stewardship, and work on skills to effectively communicate what we learn to a broad constituency. In this talk, we will present the framework of our first workshop in May, 2016.

New frontiers in urban water demand management

James Heaney, Professor, University of Florida
(co-author: M. Morales)

Our group at the Conserve Florida Water Clearinghouse has been developing new methods for water demand management for the past decade. Water demand management is a relatively new research area that has made significant advances due to emerging new technologies in high frequency data monitoring and analysis to isolate individual water use events, and linking customer billing data with property appraiser data to provide the basis for end use inventories of water across dozens of water use sectors. The following outputs of our research will be described in this presentation:

- EZ Guide software for Florida utilities that provides an online method for doing a detailed water budget for a utility and finding the most cost-effective way to meet target water conservation targets.
- New methods for estimating commercial, industrial, and institutional water use across 55 sectors based on customer billing data in benchmark utilities in Florida and Austin, Texas.
- Data driven methods for estimating the impact of metering irrigation water use when it is free and when a commodity charge is assessed.
- Evaluating the probability distributions of outdoor water use application rates and irrigated areas including associated trends.

Membrane technologies for potable water reuse

David Warsinger, Massachusetts Institute of Technology

Conventional water resources are significantly stressed in certain regions of the globe, and meeting the water needs of population growth is becoming increasingly difficult. Every city produces wastewater, and recent advancements in membrane technologies have allowed for the reclamation of this resource for the production of drinking water (i.e., potable reuse). Potable reuse is the most sustainable and least energy-intensive way to provide new water for water stressed regions. It requires less energy than desalination, and avoids the environmental impacts of diverting and consuming rivers.

A multi-institution international review effort presented here summarizes recent membrane advancements and research needs for this purpose. Research needs include reducing energy and capital costs, improving performance for the removal of a variety of constituents, and providing flexibility to treat different source waters. As engineered filters, polymeric membranes have been developed that can remove a variety of substances ranging from dissolved salts, particles, pathogens, organic compounds, and other constituents. Typically, these membrane processes include microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis desalination (RO) although other established technologies such as electrodialysis may be used for more targeted removal needs. This review highlights key trends in these membrane applications, including novel configurations, materials, manufacturing methods, and fouling-prevention techniques. It also covers continued challenges, including insufficient rejection of some key pollutants.

Using advanced metering infrastructure data to assist homeowners in conserving water

Allen Berthold, Research Scientist, Texas Water Resources Institute, Texas A&M AgriLife Research
(co-authors: K. Brumbelow, K. Wagner)

Household water conservation initiatives are perennially popular in Texas metropolitan areas, and urban water utility managers are continually on the lookout for new, innovative, and effective methodologies that reduce household water use. Increasingly, utilities are adopting advanced metering infrastructure systems, which include water meters that provide real-time data. A potential conservation measure involves providing users with their own real-time metering data in an accessible, easy-to-read format; this provides users with an accurate representation of how their personal habits directly affect their water bills. In this research, citizens of Arlington were given the option of enrolling in a web portal to view their metered usage. Web portal users' water data was collected and analyzed compared to a control group of similar customers who did not use the web portal. The before and after usage of both the control and treatment groups were tested to determine whether access to the portal had a significant impact on consumer habits. Results showed that there were statistically significant differences between the groups, and that portal users used on average 8 % less water in the winter and 17 % less water in the summer than non-users. Additionally, usage patterns were highly dependent upon local weather events. Further, supplementary research has included qualitative interviews of utilities in an effort to identify water related challenges and needs.

Session 20, Edge of Field Runoff Monitoring to Evaluate AG BMPs

Development of best management practices for the reuse of agricultural runoff as irrigation water in rice-soybean production systems

Ernest Girouard, Coordinator, Louisiana Master Farmer Program, Louisiana State University
(co-author: C. Jeong)

Water resources for irrigation purposes have been recognized for increasing efficiencies in crop management and yields. Surface runoff water and effluents are reused for irrigation purposes in many countries around the world including United States. Although a number of countries have developed guidelines on effluent quality criteria and on how effluents should be reused for irrigation purposes, there is little information on the reuse of surface runoff in terms of water use efficiency and management. In reuse of surface runoff as an irrigation source, water once drained from rice paddies or runoff from agricultural fields after rain events, is collected in a constructed pond, and then used again to irrigate rice fields and soybeans as a rotational crop. In addition, reuse water from runoff can be used as an additional nutrient source, and rice paddies can act as bio-filters through a combination of various physical, chemical, and biological functions and are capable of removing excess nutrients and sediments from irrigated water. The main goal of this study was to develop best management practice for re-using field runoff water collected from the constructed pond to provide an additional irrigation water supply to agricultural fields including rice and soybean fields. The research site was located in a farmer's rice and soybean fields northwest of Kaplan, Louisiana. The constructed pond for runoff water collection was located at the edge of the 523 acre farm. Results of this study provided a more complete understanding of the efficiency in reuse of agricultural runoff as irrigation water for rice and soybean fields as a best management practice to recycle nutrients and save fresh water from aquifers, as well as, reduce nonpoint source pollution in watersheds.

Edge of field study on phosphorus runoff losses from sugarcane fields under different management practices

Changyoon Jeong, Assistant Professor, LSU AgCenter
(co-author: E. Girouard)

Phosphorus losses in runoff from sugarcane fields can contribute to non-point source pollution of surface and subsurface waters. The objective of this study was to evaluate the effects of three different management practices on P losses in surface runoff and subsurface leaching from sugarcane (*Saccharum officinarum* L.) fields. Field experiments with treatments including conventional burning (CB), compost application with burning (COMB), and remaining green cane trash blanketing (GCTB) treatments were carried out to assess these management practice effects on P losses from sugarcane fields. In the CB treatment, sugarcane residue was burned after harvest. The COMB treatment consisted of compost applied at "off bar" with sugarcane residue burned immediately after harvest. Compost was applied in the amount of 13.4 Mg ha^{-1} annually, 8 weeks before planting. In the GCTB treatment, sugarcane residue was raked off from the row tops and remained in the wheel furrow after harvest. Surface runoff was collected with automatic refrigerated samplers, and subsurface leachate was collected with pan lysimeters over a period of 3 years. Measured concentrations of total P (TP), dissolved reactive P (DRP), and particulate P (PP) in surface runoff from the COMB treatment were significantly higher than concentrations from the CB and GCTB treatments. The mean losses of P (TP and DRP) after burning (postharvest, years 2 and 3) were significantly greater than the no-burn treatment (preharvest, year 1) in the CB, COMB, and CB/COMB/GCTB combined options. Additionally, the mean losses of total suspended solid and total combustible solids in residue burning were, on average, 2.7 and 2.2 times higher than the no-burn practices, respectively (preharvest and GCTB treatment). Annual P losses from surface runoff in the third year of study were 12.90 %, 6.86 %, and 10.23 % of applied P in CB, COMB, and GCTB treatments, respectively. However, the percent of annual DRP losses from applied P in COMB and GCTB treatments was similar magnitude, and their values were less than 50 % compared to the value from CB treatment. In the leaching study, percent of monthly mean TP and DRP losses in the COMB and GCTB treatments were greatly reduced. Based on these results, the COMB and GCTB procedures were equally recommended as sugarcane management practices that improve water quality in both surface runoff and subsurface leachate.

Impacts of concentrated flow paths on crops and water quality in southern Illinois row crop agriculture

Matthew Enger, Graduate Research Assistant, Southern Illinois University Carbondale
(co-authors: *J.E. Schoonover, K.W.J. Williard, R. Cook)
*Presenter - Jon E. Schoonover, Professor, Southern Illinois University Carbondale

Sediment and nutrient loss from agricultural landscapes contributes to water quality impairment and has the potential to impact crop yield. Concentrated flow paths (CFPs) contribute to this loss and are often overlooked in agricultural fields. Conventional management of CFPs is to fill and grade them; however, this provides only a short term solution leading to their reformation and increased sediment loss. The objectives of this study were to determine if the filling of CFPs (treatment) were advantageous to no-fill (control) and whether there were differences among three topographic positions. Using ArcGIS and LiDAR data, six small agricultural catchments, CFPs, and topographic positions (i.e., depositional, backslope, and shoulder) were delineated. In each catchment, six 4 m^2 plots were established along CFPs where crop biomass and crop yield were measured. Additionally, six plots with no influence from CFPs were established as reference plots. Water quality was also assessed by taking edge-of-field grab samples during significant rain events (i.e., precipitation exceeding 2.5 cm). Samples were analyzed for total suspended solids (TSS), dissolved reactive phosphorus (DRP), total phosphorus (TP), and nitrate-nitrogen (NO_3-N). Preliminary analysis of crop biomass and yield suggest that the depositional and backslope positions were similar regardless of treatment, but were lower than the reference plots and shoulder position. Median values for NO_3-N and TSS in the treatment catchment (1.85 and 140 mgL^{-1}) were higher than the control catchments (0.77 and 35.5 mgL^{-1}), while DRP and TP concentrations were higher in the control catchments (1.31 and 2.37 mgL^{-1}) compared to the treatment catchments (0.91 and 1.83 mgL^{-1}) over the growing season. Preliminary results from this study show that filling of CFPs was not advantageous to no-fill and filling may lead to increased sediment loss. Farmers and land managers may consider implementing stabilization measures in CFPs; since crop yields are lower, there is increased cost to maintain these areas, and accelerated sediment loss can exacerbate the crop yield losses and impact water quality.

Session 21, Multi-disciplinary Perspectives on Water Quantity and Quality in the MS Delta I

Do climate risks affect the use of irrigation technologies and water management practices? Evidence from Arkansas

Qiuqiong Huang, Associate Professor, University of Arkansas
(co-authors: Y. Xu, G. West)

Water shortage has become a major concern of producers in many parts of the world. Switching to more efficient irrigation technologies has often been proposed as a solution to water shortage problems. In addition to more efficient irrigation technology, a wide range of Water Management Practices (WMPs) could also play a substantial role in water conservation because many could improve the performance of existing irrigation systems. Among the factors that could influence irrigation technology choices, climatic factors have received increasing but still rather limited attention. In addition, most often only average climate conditions such as average temperature and total precipitation are analyzed.

This study investigates how climate risks affect producers' use of irrigation technologies and/or WMPs. Our contributions are twofold. First, we model the joint choices of irrigation technologies and/or WMPs. By providing a relatively more complete picture of irrigation practices, this paper is a significant addition to the existing literature that focuses mostly on more efficient irrigation technologies. Such knowledge is indispensable in helping policy makers design policies that consider all available tools to conserve water. Only a few studies (e.g., Negri and Brooks; 1990) have done so. Second, this paper captures the full range of the impacts of climate change on irrigated agriculture. In addition to average climate conditions such as mean daily temperature and total precipitation, a moment-based approach is used to measure expected climate risks including both the extent of volatility and the likelihood of extreme events. In an alternative specification, specific outcomes of climate changes such as the frequency of drought as well as the share of intensive rainfall are used. These measures enable us to study producers' responses to different aspects of the impacts of climate change.

Role of freshwater sediments in the survival and transport of human pathogens in the environment

Kristen Gibson, Assistant Professor, University of Arkansas

The potential contamination of fresh produce with pathogens of human health concern via irrigation water has long been recognized. The variety of irrigation water sources—groundwater wells, ponds, rivers, streams, municipal water, and reclaimed (treated wastewater) water—combined with the diversity of potential waste stream inputs have resulted in a complex issue when trying to understand and address the fate and transport of both fecal indicator bacteria (FIB) and pathogens in agricultural water resources. An area of uncertainty involves the transport of pathogens in fresh water sediments. A summary of 20 published studies estimate sediment densities of Escherichia coli ranging from 1 to 500,000 CFU or MPN per gram of dry weight sediment. In the end, microbial settling and resuspension are really the essential processes controlling pathogen and indicator bacteria in fresh water including water sources used for irrigation purposes. As stated by Droppo et al. (2008), "the lack of understanding around pathogen/sediment associations may lead to an inaccurate estimate of public health risk, and, as such, possible modification of sampling strategies to reflect this association may be warranted."

Session 21, Multi-disciplinary Perspectives on Water Quantity and Quality in the MS Delta I

Impact of on-farm water conservation practices on groundwater use in Arkansas

Qiuqiong Huang, Associate Professor, University of Arkansas
(co-author: Y. Xu)

Agriculture in Arkansas relies heavily on irrigation water. In the Arkansas Delta, various on-farm water conservation practices such as on-farm reservoir, center pivot irrigation and multiple inlet irrigation for rice production have been promoted but only used by a small number of farm managers. Furthermore, not many studies have evaluated the potential of on-farm water conservation practices to help growers deal with declining future water availability.

This study quantifies the effect of on-farm water conservation practices on water use. The main data set used in the paper is the Farm and Ranch Irrigation survey (FRIS) data collected by U.S. Department of Agriculture over years (2008, 2003, 1998, 1994, 1988), which is arguably the most comprehensive data on irrigation. County level climate and soil data are also gathered. Statistical methods such as county fixed effects with instrumental variable estimation are used to analyze the repeated cross-sectional data from FRIS. Shares of land allocated to various irrigation practices (flood irrigation, flood irrigation and water management practices such as tailwater recovery, sprinkler irrigation) are used to measure farmers' use of water conservation practices. The first part examines their impacts on farm level variables including total irrigated acreage, crop mix, and total water use. The second part examines their impacts on crop specific water use per acre.

Session 22, Education II

Tools & support for integrating real data in classroom environments

Jonathan Pollak, Program Manager, CUAHSI
(co-authors: E. Clark, *L. Brazil, L. Tran)
*Presenter - Liza Brazil, Community Support Specialist, CUAHSI

The Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) is a non-profit organization funded by the National Science Foundation to support water science research and education. Over the last few years, CUAHSI has developed and implemented a new suite of education support services that complement traditional classroom methods. Our newest initiative encourages and enables place-based, data-driven education lessons that utilize CUAHSI's Water Data Center program to integrate real-world data into classroom environments. This program uses the Science Education Resource Center (SERC) at Carleton College to share activities developed by CUAHSI staff and the broader CUAHSI community. Many of the activities on the newly developed Data and Model Driven Hydrology Education SERC website feature the free tools developed by CUAHSI for publication, access, and analysis of environmental time series data, which will be highlighted in this presentation.

ThinkWater: A case study in innovation and success in systems-thinking based water education

Jeremy Solin, Wisconsin ThinkWater Coordinator and National Program Manager, University of Wisconsin-Extension
(co-authors: D. Cabrera, J. Kushner, L. Cabrera)
*Presenter - Doug Parker, Director of California Institute for Water Resources, University of California

ThinkWater is a national movement of educators, students, managers, stewards, scientists, and citizens who think and care deeply about water. They know that future water security and sustainability starts with deeper learning, understanding, and caring, and that true understanding and behavior change requires more than new information. That's where systems thinking comes in. Systems thinking is a discipline based on four simple rules—making distinctions and recognizing systems, relationships, and perspectives (DSRP). These rules are useful for everyone from the aspiring water learner to the advanced water scientist to understand and solve complex water problems involving environmental, economic, social, and political stakes. As we say, the next big thing in water education, research, and extension isn't water, it's thinking. ThinkWater has generated a host of resources including online trainings, concepts and paradigms, instructional materials, software, and a community forum for water thinkers.

ThinkWater is a USDA NIFA funded campaign based at University of Wisconsin Extension in partnership with Cabrera Research Lab. ThinkWater has developed extensive resources for youth water education and is now developing and implementing resources and programs for adult and community education. ThinkWater also has an extensive research and evaluation agenda to determine the effectiveness of programmatic efforts.

During the presentation, we'll highlight the systems thinking framework on which ThinkWater is built and share key strategies and resources ThinkWater is using to build the movement of water thinkers. Findings of research exploring effective strategies to deliver systems thinking education and research will be highlighted. Participants will gain new tools and resources to enhance their water and other natural resources-based education and research programs. Participants will also learn about ways to engage with ThinkWater.

A survey of public perceptions and attitudes about water following an exceptional drought in Texas

Drew Gholson, Program Specialist - Water Resources, Texas A&M AgriLife Extension Service
(co-authors: D. Boellstorff, S. Cumming)

Texas A&M AgriLife Extension Service facilitated two random sample surveys of Texans to evaluate citizen awareness, attitudes, and willingness to act on water issues. The first survey was conducted in 2008 at the beginning of a relatively mild drought. The drought intensified through 2009-2012 when much of the state endured exceptional drought. The original survey was re-issued to another random sample of Texans in 2014 and represents an opportunity to investigate changes in public attitudes following extended exposure to municipal drought contingency plans and restrictions, water conservation educational programs and genuine concern, in some cases, that some communities would lose access to their water supply. From 2008 to 2014, the percentage of Texans living within city limits and ones living outside the city limits, not engaged in farming replied that 1) water quantity was an issue in their area increased, 2) that their area would suffer from prolonged drought increased, and 3) that there was a high chance that there would be an adequate water supply to meet area demands in 10 years decreased; conversely, there was no significant change in the responses of farming or ranching Texans. However, both farming and ranching Texans and those living within city limits replied that global warming would result in changing precipitation levels. Moreover, the percentage of farming Texans replying “I don’t know” (if the amount of rainfall will change as a result of global warming) decreased from 53 % in 2008 to 15 % in 2014, but was steady (29 % in 2008 and 31 % in 2014) for those living within city limits. For the 2014 survey alone, there is a significant difference of water-conserving actions between farmers and those living in the city. Seventy-eight percent of city dwellers changed the way they watered their yard with only 57 % for farmers ($p < .022$).

Value of adaptive drought management for the ACF river basin

Aris Georgakakos, Professor and Director, Georgia Water Resources Institute, Georgia Tech
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In recent times, severe droughts in the southeast US occur every 6 to 10 years and last for up to 4 years. During such drought episodes, the ACF river basin supplies decline up to 50 % of their normal levels, and water stresses increase rather markedly, exacerbating stakeholder anxiety and conflicts. As part of the ACF Stakeholder planning process, GWRI has developed new tools and carried out comprehensive assessments to provide quantitative answers to several important questions related to drought prediction and management:
(i) Can drought and other climatic periods be reliably anticipated? What drought indices can support reliable, skillful and long-lead forecasts?
(ii) What management objectives can drought/non-drought forecasts benefit? How should benefits/impacts be shared?
(iii) What operational adjustments are likely to mitigate stakeholder impacts or increase benefits consistent with stakeholder expectations?

Regarding drought prediction, a large number of indices were defined and tested at different basin locations and lag times. These included local/cumulative unimpaired flows (UIFs) at 10 river nodes; Mean Areal Precipitation (MAP); Standard Precipitation Index (SPI); Palmer Drought Severity Index; Palmer Modified Drought Index; Palmer Z-Index; Palmer Hydrologic Drought Severity Index; and Soil Moisture—GWRI watershed model. Our findings show that all ACF sub-basins exhibit good forecast skill throughout the year and with sufficient lead time. Index variables with high explanatory value include: previous UIFs, soil moisture states (generated by the GWRI watershed model), and PDSI.

Regarding drought management, assessments with coupled forecast-management schemes demonstrate that the use of adaptive forecast-management procedures improves reservoir operations and meets basin demands more reliably. Such improvements can support better management of lake levels, higher environmental and navigation flows, higher dependable power generation hours, and better management of consumptive uses without adverse impacts on other stakeholder interests. However, realizing these improvements requires (1) usage of adaptive reservoir management procedures (incorporating forecasts), and (2) stakeholder agreement on equitable benefit sharing.

Session 23, Water Planning and Governance I

Diverse public participation in watershed governance

Tony Arnold, Boehl Chair in Property and Land Use, University of Louisville
(co-authors: A. Chase, J .Ewa)

The effectiveness and perceived legitimacy of watershed governance depend on the participation of many diverse stakeholders. This study examines the barriers to, and best methods for, engaging underrepresented groups in governance by conducting in-depth semi-structured interviews of 43 individuals in two watersheds: the small urban Beargrass Creek watershed in Louisville, Kentucky, and the large rural Green River watershed in south-central and western Kentucky. Interviewees live, work, or recreate in either watershed (both governance participants and non-participants), with 50% from groups traditionally under-represented in Kentucky watershed governance: low-income persons, racial/ethnic minorities, and farmers. Two different researchers independently coded interview responses and analyzed results for patterns, with reliability test of > 90 % overlap. Citizens of watersheds overwhelmingly want to participate in watershed governance (95 %) and perceive many benefits from watershed governance. Their preferred methods of participating (e.g., formal meetings, deliberative workshops, informal networks, restoration/cleanup activities, monitoring/enforcement) vary greatly. Nearly all identified barriers to participation. Frequently mentioned barriers include the timing and location of meetings and perceptions that meetings are superficial, not addressing critical issues. Most respondents stated that the current governance in watershed institutions is not as effective as it could be, but the suggested mechanisms to effect change in the watershed varied from increased and better enforcement of regulation, more monitoring, and improved community involvement. The study supports growing evidence that often-used hierarchical participatory models (e.g., Arnstein's Ladder of Citizen Participation) do not match public preferences. Watershed governance systems should use diverse methods of participation, instead of trying to select a single "optimal" method, in order to engage a diverse range of participants. Several policy recommendations for public participation are discussed. The study was supported by USGS Section 104(b) Student Research Enhancement Grant G11AP20081, KWRRI Subaward UKFR#3048108119-14-152.

Adaptive water governance for transformational adaptation to climate change

Kofi Akamani, Assistant Professor, Southern Illinois University Carbondale

Climate change is increasingly recognized as one of the greatest threats to the sustainable governance of water resources and the attainment of sustainable development. In recent decades, growing realization of the inadequate progress in global climate change mitigation efforts has generated interest in climate change adaptation policies among scientists and policy makers. Climate change adaptation refers to the processes, actions, and outcomes associated with how households, communities, and societies learn and adjust to climate change impacts in order to reduce harm and take advantage of opportunities. However, conventional adaptation policies have been critiqued for their top-down, expert-driven and narrow sectoral approach that often lead to maladaptive outcomes. Adaptation policies also tend to adopt an incremental approach aimed at avoiding disruptions of systems rather than promoting fundamental changes toward new trajectories in response to severe climate change impacts. Recent insights into thresholds and tipping points associated with climate change highlight the need to build the capacity for transformation, i.e. the capacity to enable a shift from one regime to another when existing social and ecological conditions become undesirable. However, the institutional requirements for social-ecological transformation have not been adequately explored in the literature on the governance of climate change adaptation. This paper explores the potential roles of adaptive water governance in enhancing transformational adaptation to climate change. The paper discusses four ways in which the key attributes of adaptive water governance could contribute to social-ecological transformation in water resource systems: (1) creating awareness about climate change through social learning and the integration of diverse sources of knowledge; (2) generating interest for policy change through the provision of economic and non-economic incentives; (3) creating opportunities for change through the promotion of vertical and horizontal interactions among actors; and (4) building capacities for change through enhanced access to relevant institutions and resources.

Session 24, Multi-disciplinary Perspectives on Water Quantity and Quality in the MS Delta II

Sustaining agricultural economic returns and a shallow aquifer on a landscape using conjunctive water management

Kent Kovacs, Assistant Professor, University of Arkansas
(co-author: M. Mancini)

We examine the economic effectiveness of conjunctive water management with on-farm reservoirs and tail-water recovery to address this scarcity in the Lower Mississippi River Region of Arkansas, USA. An economic model of the landscape is used because groundwater use by one producer affects the groundwater available for other producers. The present value of farm net returns over thirty years on the agricultural landscape depends on the crop mix, reservoir adoption, and the groundwater depletion that are optimal using a spatial-dynamic programming problem. We find that reservoirs should be built when the depth to the aquifer exceeds 60 feet, and the average share of productive land in a reservoir should be about 2 %. Rice intensive areas use reservoirs to replace groundwater with reservoir surface water when the depth to groundwater increases. Soybean intensive areas use reservoirs sparingly to support shallow groundwater pumping depths, but groundwater remains the primary source of irrigation.

Monitoring of on-farm water storage systems for water reuse and nutrient reduction

Joel Paz, Associate Professor, Mississippi State University
(co-authors: M.L. Tagert, J. Pérez-Gutiérrez, R. Karki)

The declining groundwater levels in the Mississippi Delta Shallow Alluvial Aquifer and nutrient loads into the Mississippi River and the Gulf of Mexico are the two most important issues affecting the sustainability of agroecosystems in the Mississippi Delta region. On-farm water storage (OFWS) systems, which include a tailwater recovery canal and storage pond, offer farmers the benefits of providing irrigation water and capturing nutrient-rich tailwater from irrigated fields. Numerous OFWS systems have been recently installed across the region, with funding primarily through the Mississippi River Basin Healthy Watersheds Initiative and other state and federal assistance programs. The placement of these systems throughout a watershed can be better targeted if we can quantify the downstream nutrient reduction and water quantity effects of the technology. This presentation will give an update on the project, which has monitored water savings and nutrient levels at two OFWS systems, one each at Metcalf Farm and at Pitts Farm, in the Porter Bayou Watershed, Mississippi.

Session 24, Multi-disciplinary Perspectives on Water Quantity and Quality in the MS Delta II

Irrigation scheduling with soil moisture sensors and the Mississippi Irrigation Scheduling Tool (MIST)

Mary Love Tagert, Assistant Extension Professor, Mississippi State University
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As the number of irrigated acres and the demand for water in the Mississippi Delta has continually grown since the 1970's, groundwater levels in the Mississippi Alluvial Aquifer have experienced a corresponding decrease. Today, there are roughly 18,000 permitted irrigation wells dependent on water from the Mississippi Alluvial Aquifer. There has also been an increasing interest in irrigation in Northeast Mississippi, where surface water is the main source for irrigation. As concern has grown over groundwater declines in the Mississippi Delta and producers across the state work to ensure a sustainable water supply for future generations, farmers have been implementing more irrigation conservation measures, such as the use of surge valves and computerized hole selection, which improve irrigation application methods. Some farmers are also using soil moisture sensors to improve irrigation timing, although this can be cumbersome, especially if irrigating a large number of fields. The Mississippi Irrigation Scheduling Tool (MIST) is a web-based irrigation scheduling tool designed to help farmers manage and schedule irrigation in a humid climate. The tool provides an estimate of crop water use based on a "checkbook" approach that determines the water balance of the soil, plus usable water from rainfall or irrigation, minus water that is used by the crop, lost through runoff, or evaporated from the soil. Daily evapotranspiration is calculated using the modified Penman-Monteith equation. The system automatically notifies the farmer if irrigation is required when the available soil moisture balance falls below a set threshold. MIST, which is being tested on several production fields in the Mississippi Delta region, has a web interface that allows producers to access their information from any internet-accessible location through tablet computers or smart phones. This presentation will give an update on the MIST project and progress to date.

Session 25, Panel: Legal Developments in Agricultural Nutrient Management and Implications for Water Quality

Peggy Kirk Hall, Director, Ohio State University Extension Agricultural & Resource Law Program
Catherine Janasie, Research Counsel, National Sea Grant Law Center at The University of Mississippi School of Law
Alexandra Chase, Ocean and Coastal Law Fellow, National Sea Grant Law Center at The University of Mississippi School of Law

The surface application of fertilizer and manure onto agricultural land has raised concerns about the impact of agricultural nutrients on water quality. Science points to runoff from agricultural fields as a cause of elevated levels of nitrogen and phosphorous in our nation's waterways, which in turn can lead to Harmful Algal Blooms, hypoxia, and other water quality issues. As the Clean Water Act (CWA) generally exempts agricultural runoff from federal permitting requirements, the regulation of agricultural nutrients falls primarily to the states. State approaches to agricultural nutrients vary tremendously, with some states developing mandatory requirements or comprehensive programs and others choosing voluntary, cost-share, or targeted programs. While states are determining how to address agricultural nutrient runoff, other interests are utilizing federal courts to demand changes in agricultural nutrient management and regulation, as evidenced by an increasing number of enforcement petitions and lawsuits under the CWA, Resource Conservation and Recovery Act (RCRA), and Safe Drinking Water Act.

This panel will review current legal developments in agricultural nutrient management. Panelists will present a compilation and analysis of state approaches to agricultural nutrients, highlighting the most recent and innovative state-based efforts to reduce agricultural nutrient runoff. Panelists will also discuss recent and ongoing litigation in federal courts, as well as recent enforcement petitions under federal environmental laws. The panel will conclude with a discussion of regulatory and case driven implications for the future of agricultural nutrient management and its impact on water quality.

The effect of the development and growth of vegetation on floodplains

William Rahmeyer, Professor of Civil and Environmental Engineering, Utah State University

This paper presents an improved methodology and set of equations for predicting the effect of vegetation on flow resistance in floodplains and levees. The methods and equations are revisions from the previous methodology published in the USACE manual on "Determination of Resistance Due to Shrubs and Woody Vegetation", ERDC/CHL TR-00-25. The improved methodology considerably contributes to flood control procedures such as the USACE "Guidelines for Landscape Planting for Floodwalls, Levees, and Embankment Dams", EM 1110-2-301.

The methods and equations presented in this paper are based on over 220 experiments conducted with 27 different plant types, combinations of plant types, and plant ecosystems. Tests included variations of flow depth, flow velocity, effect of dormant plants without leaves, variation in the submergence of plants, varying plant size and growth, densities and combinations of plants, distortion and bending of plants and lead mass in flow. The equations consider the flexible stems and varying shapes of the plant's leaf mass which greatly complicate the understanding of resistance.

The deformation of plant shape with flow precludes the use of a constant blockage or plant density typically assumed in other publications, but is considered by the methods in this paper. Additional field tests were later conducted to verify the methodology and used in this paper. Of particular importance for this paper, is the ability of the methodology to predict the effect of growth and development of vegetation. Growth of vegetation, purposely introduced in a flow channel or unwanted, is a significant problem for floodplain managers. The problem becomes even more complicated with procedural difficulties in maintaining and or regulating growth of vegetation. An example is presented of using HEC-RAS to calculate the flow depth in a flood channel with varying age or growth of vegetation in a compound channel.

Culvert design for flood routing considering sediment transport

William Rahmeyer, Professor of Civil and Environmental Engineering, Utah State University
(co-author: W. Goodridge)

Flood control and flood routing often involve road crossings that utilize culverts to transport flood flows without overtopping the roadways. However, most floodplain managers and engineers can discuss numerous examples of culverts failing due to partial or full blockage by sediment that could not be transported through the culverts. Culverts transporting sediment experience additional energy loss that cause upstream flow depths to increase, upstream flow velocities to decrease, and then produce upstream sediment deposits that further increase flow depth and the potential for increased flooding. Current flood routing methodologies do not consider sediment bed-load transport through the culverts of road crossings. Many practitioners either ignore the transport of sediment through a culvert or assume that sediment is transported in suspension with little effect on the flow capacity of the culverts. While fine sand and silt can be transported though a culvert as a homogeneous suspension, larger sand sizes and gravels are transported as a slow moving bed-load along the bottom of the culvert. The presence of bed-load is then a major contributor of culverts plugging with sediment. This paper discusses laboratory testing and observations of sediment bed-load transport through culverts, and presents a methodology for calculating transport rates of bed-load in culverts. This paper further discusses incipient motion of sediment in culverts, the formation of bed forms in culverts, and a threshold or limit of sediment transport that causes plugging of culverts. Several of the sediment transport methods used in HEC-RAS are discussed for application to calculate sediment transport capacity in culverts, and a method for sizing culverts for sediment transport is presented. Both the understanding of the observed bed-load transport phenomena and of the methodology in this paper provide vital design considerations that enhance the design procedures in the FHWA-HIF-12-026, Hydraulic Design of Highway Culverts (Third Edition) 2012.

Adaptive water governance, social-ecological resilience, and climate change: Transdisciplinary synthesis

Tony Arnold, Boehl Chair in Property and Land Use, University of Louisville

The Adaptive Water Governance Project (AWG Project) is a synthesis project with the National Socio-Environmental Synthesis Center, funded by the National Science Foundation DBI-1052875. It explores the role of institutions, including law, in achieving governance that enhances rather than undermines the resilience and adaptability of water basins as society responds to climate change. The AWG Project Team conducted resilience and governance assessments of six major North American water basins as prototypical heavily regulated and developed social-ecological systems: Anacostia (DC/MD), Columbia (ID/WA/OR/BC/NV/UT/WY), Everglades (FL), Klamath (OR/CA), Middle Rio Grande (NM), Platte (CO/NE). These resilience assessments were conducted by interdisciplinary teams of interdisciplinary researchers, totaling 25 researchers from over a dozen universities in a broad range of ecological sciences, social sciences, policy sciences, engineering, and law. Each individual researcher uses three to five different disciplines in his/her work. Thus, the collection of six resilience assessments, published in an Idaho Law Review special issue, represents substantial cross-disciplinary synthesis of ideas and data about adaptive governance. This presentation is a synthesis of these syntheses through systematic textual analyses of the six assessments using NVivo software, for 3 major factors: 1) governance system features facilitating systemic resilience; 2) governance system features inhibiting systemic resilience; and 3) significant drivers of systemic change. Two separate coding and analysis processes are used: a top-down process to code for concepts in a predictive framework developed by the AWG Project Team, and a bottom-up grounded-theory process to code based on the concepts as developed in each resilience assessment. The two are compared to identify the common elements of new transdisciplinary knowledge about water governance systems emerging from this synthesis project. The AWG Project provides new understandings about how water governance institutions, including law, facilitate or inhibit social-ecological-institutional systemic trajectories of recovery, adaptation, and transformation in the face of climate change.

Adaptive water governance and evolving planning theories

Kofi Akamani, Assistant Professor, Southern Illinois University Carbondale

Shortfalls in the conventional command and control paradigm of water resource management that dominated 20th century water policy have led to the search for alternative water governance regimes with the potential to address the wicked conflicts and uncertainties in water resource governance. In this regard, the concept of adaptive water governance has been receiving attention among researchers and policy-makers. Contrary to the command and control paradigm, adaptive water governance relies on polycentric institutions for connecting individuals, institutions, and organizations across multiple levels in promoting a flexible, collaborative, and learning-based approach to water resource governance in the face of uncertainties. Polycentric institutions are composed of multiple nested centers of decision-making authority with some degree of diversity and autonomy at each level. Through these multi-level institutions, adaptive governance addresses the social and institutional shortfalls that have served as impediments to the implementation of adaptive management. While the institutional structures of adaptive governance have received significant research interest, the decision-making processes needed to operationalize adaptive governance have not received much attention. As part of an effort to enhance the policy relevance of discussions on adaptive governance, this paper explores the evolving theoretical approaches in the field of planning and their suitability as foundations for adaptive water governance. The paper argues that communicative action planning offers opportunities for enhancing the analytic-deliberation processes through which value conflicts and knowledge uncertainties are managed in adaptive governance regimes. There's risk of adaptive water governance being co-opted into a business as usual approach when implemented using the expert-driven, rational-comprehensive planning processes that constitute an integral component of the command and control paradigm. Overcoming the path-dependent effects of rational-comprehensive planning is needed to enhance the transition toward adaptive water governance for conflict management, adaptation and transformation in social-ecological systems.

Assessing conserved consumptive use of agricultural water for a potential Colorado Western Slope Water Bank

Amandeep Vashisht, Graduate Research Assistant, Colorado State University
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Irrigated agriculture in Colorado River Basin controls the highest percentage of water than any other sector; therefore, agricultural water is a likely supply for water conservation and sharing in such an environment. A more precise understanding of the quantities that can be conserved without jeopardizing the underlying agricultural and rural economies is required. A Colorado Western Slope Water Bank, under which agricultural water users could enter into voluntary, compensated short-term split-season leases to temporarily forego diversions by reducing irrigation, is one approach being evaluated to address water demand and supply issues. In order for the market underlying the water bank to develop, it is crucial to accurately assess the conserved consumptive use (CU) that maybe credited to agricultural water users on a split-season scale. The conserved CU credit serves as the fundamental basis for compensation for the foregone diversion. To assess conserved CU under a water bank, the "Potential CU" (PCU) must be estimated. The PCU is the amount of water historically put to beneficial use under the terms of the water right. The conserved CU credit is then the difference between PCU and the "Actual CU" (ACU), which is the amount of water being consumed beneficially under the terms of water bank. Remote sensing techniques have a potential in estimating both historic PCU and current, as well as future ACU. This potentially improved remote sensing assessment may help contend with specific situations like inaccurate or missing historic diversion records, water subbing due to shallow groundwater, and unaccounted return flows. Remote sensing approach is evaluated on a split-season scale, and new crop water use information for the water resource inventory potentially available to a Western Slope Water Bank is developed.

Are water indices co-integrated with the world water markets? ARDL bounds testing approach

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This study focuses on cointegration and causality approaches between four water indices (S-Net, WOWAX, S&P and MSCI ACWI) and four water markets (Asia, Europe, Latin America and US) using a unique daily dataset, from January 2004 to October 2014, we examine the possibility of cointegration between the water indices and water markets using the VECM Johansen methodology in different periods (full, pre-GFC, GFC and post-GFC period). The results show that when the water indices and the water market indices are combined, a linear relationship forces these indices into a long-run equilibrium relationship. In order to confirm our empirical results, we test Autoregressive Distributed Lag (ARDL)-based bounds testing approach for robust test, which was developed by Pesaran and Shin (1999) and Pesaran et al. (2001). ARDL bounds testing results confirm that the estimated parameters are statistically significant in the different periods. Importantly, the error correction coefficient carries the expected negative sign and are highly significant in both cases. Further, we examine the stability (short run and long run coefficient) of the estimated model by the CUSUM and CUSUMQ tests which indicate that the estimated model are stable in different periods.

Keywords: Cointegration; Water indices; Water markets; VECM Johansen methodology; ARDL approach

Importance of concentrated flow paths in agricultural watersheds in southern Illinois

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Best management practices such as riparian buffer zones have been recommended to trap nutrients and sediment from agricultural runoff. However, sediment deposited in buffers can eventually form berms that can contribute to concentrated flow path (CFP) formation. Subsequent CFPs have shown to limit the effectiveness of riparian buffers. The primary objective of this study was to determine the percentage of row crop agricultural fields drained by CFPs. A second objective was to assess the effects of field characteristics, soil texture and slope, on the frequency of CFPs. The research is being conducted in Jackson County, Illinois using cropland polygons from 2006 from the Natural Resources Conservation Service that were verified using ortho-imagery from 2011. Digital Elevation Models (DEMs) created using Laser Detection and Ranging (LiDAR) point data was used to identify and map CFPs. Watershed delineation at each CFP was used to estimate the percentage of agricultural fields drained by the CFPs. DEMs were also used to calculate slope of the field. Data on soil texture, soil erodibility factor, and hydraulic conductivity were acquired from the SURRGO database. Watershed delineation results showed that 35.6 - 99.8 % of the fields were drained by CFPs, with 373 of 387 fields being above 50 % drained. This finding supports the result from a previous survey-based study of ten fields that showed 82.5 to 100 % of drainage by CFPs. The results demonstrate that current static width riparian buffer designs may need to be revised to better handle CFPs. Further, preliminary statistical analysis showed that average field slope was negatively associated ($p=0.0137$) while organic matter ($p<0.0001$) and percent sand ($p=0.0393$) were positively associated with CFP length. CFP drainage area was found to be negatively associated with percent clay ($p=0.0008$) but positively associated with organic matter ($p<0.0001$). In addition, drainage density was found to be negatively associated with slope length factor ($p=0.0051$), but positively associated with slope ($p = 0.0318$) and organic matter ($p<0.0001$). The results from this study is expected to identify the key landscape and soil factors that influence CFP formation. This understanding can be helpful in designing riparian buffers based on the field characteristics to increase its effectiveness in addressing non-point source agricultural pollution.

Energetic benefits of staged reverse osmosis

Quantum Wei, Research Assistant, Massachusetts Institute of Technology
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For today's typical flux and permeability, moving to two-stage reverse osmosis (RO) makes sense around 68 % recovery for a seawater feed (20 % reduction in energy consumption). It has previously been shown that staged RO has potential for significant energy savings at recoveries higher than 50 %. However, those studies assume zero system flux (infinite membrane area) or confound the benefits of staging with the benefits of added membrane area. We sought to evaluate staged RO at a realistic system flux and isolate the benefits of staging. Therefore, system membrane area is kept constant throughout this paper. We compare the energy consumption of a single-stage RO system with eight total elements to two-stage RO systems with eight total elements. There are seven possible two-stage configurations: one element in the first stage, two elements in the first stage, and so on. In addition, each configuration can be operated in different ways by adjusting each stage's share of total permeate production. The choice of system operation has a significant effect on energetic performance. We implemented a model of spiral wound reverse osmosis element in MATLAB in order to assess the energetic benefits of staged RO. For a given system recovery and flux, we evaluated the energetic performance of two-stage RO at the ideal system configuration and operation. We compare these results to the energetic performance of a single-stage RO at the same recovery and flux. We also investigate the potential of staged RO at high salinity feed or with higher permeability membranes. This study is unique in that it evaluates staged RO at realistic system flux and fixed area, and at all possible system configurations and operations.

Impacts of woody biomass biofuel production on sustainable river basin management

Michael Barber, Professor, University of Utah
(co-authors: M. Hasan, J. Petrie, R. Goel)

Renewable sources of bioenergy are needed to meet future world-wide energy demands while helping to offset the global impacts of increased carbon dioxide from traditional fossil fuels. Options for producing bioenergy without adversely impacting food, water, and other environmental resources include using woody biomass residuals as feedstock. While linkages between land use alterations and runoff and erosion processes in river basins are widely known, little is known about how land use changes impact the entire ecological function of watersheds. Key issues include soil, water quality and loss of biodiversity as collecting small-diameter woody biomass may alter post-timber harvesting landscapes. This project explored using changes in microbial soil populations as a function of woody biomass removal treatment scenarios to determine potential changes in water export and nutrient ecology. This will help us understand the impacts of biomass removal in the production of jet fuel and be the start of holistic river basin management strategies focused on hydrologic implications of the entire food web.

Applications of statistical techniques to analyze temperature data trends for the State of Florida, U.S.A., for period 1895-2014

Hector Quevedo, Professor and Researcher of Environmental Engineering, Universidad Autonoma de Ciudad Juarez

The objective of this study was the application of statistical analyses to a 118 year sample data of atmospheric temperatures of the State of Florida, U. S. A., to assess temperature trends. The revision included the following statements:
1. A summary of descriptive statistics of the mean annual temperature sample data. The results showed a mean annual temperature of 70.25 ^{o}F, a median value 70.2 ^{o}F and a variance of 0.897, a skewness value of .0231 and a 95 % confidence interval for the population mean of 70.073 96.
3. The study involved the calculation of annual cumulative and density values and their graphical analysis to estimate temperature probabilities.
4. The methodology included a box plot diagram to identify outliers. The results showed there were no outlying observations, thus little experimental error.
5. The method built time-series graphical analyses and its subjectivist validation, so to assess annual temperature trends for state-wide Florida. The results showed an upward trend for the annual temperature data for the period under study.
8. It is concluded that this study is a distinctive educational style, because it first identifies the most appropriate probability distribution function, thus minimizing the background experimental error, therefore yielding more reliable temperature results to evaluate global warming trends and their consequential climatic distortion effects. Also, the study's findings can be used by researchers interested in meteorology, environmental engineering, hydrology, civil engineering, agriculture, statistics, and so on.

In-reservoir management reduces phosphorus flux from sediments and [maybe] cyanobacteria occurrence

Brian Haggard, Director, Arkansas Water Resources Center
(co-authors: T. Scott, S. Patterson)

Lake Wister is a water supply reservoir in east-central Oklahoma, which has violated state water quality standards and experienced cyanobacteria blooms. A previous hydrodynamic and water-quality modeling effort of the reservoir suggested that the source of phosphorus was internal not external. However, a set of lab experiments suggested that the phosphorus release rates from sediment was important but an order of magnitude less than that used in the model. The Poteau Valley Utility Authority (PVIA) made a series of decisions to address the water quality issues, ranging from water-quality monitoring of the inflows to Lake Wister to the in-reservoir management. The PVIA decided to use aluminum sulfate [plus sodium aluminate] treatment in the isolated cove where raw water is pulled into the drinking water treatment plant. Sediment cores were collected prior to the cove treatment and one week afterwards, and routine water-quality monitoring within the cove and reservoir continued. The sediment cores were used to evaluate both sediment phosphorus release rates, equilibrium phosphorus concentrations, sediment phosphorus pools, as well as sediment phosphorus with depth. Water samples were collected from the surface water (epilimnion) and near the sediment-water interface (hypolimnion), where analysis included physico-chemical properties, nitrogen, phosphorus, sediment, chlorophyll-a, and cyanobacteria numbers. The influence of the in-cove aluminum sulfate (plus sodium aluminate) treatment was confirmed both experimentally and in the routine water-quality monitoring - phosphorus release rates, equilibrium concentrations, and hypolimnetic concentrations all decreased following chemical treatment. The chemical treatment may have also influenced the numbers of cyanobacteria, although these organism are also influenced by climatic factors as well. The PVIA plans to treat the cove again to further improve water quality.

Removal of sulfamethoxazole, trimethoprim, and triclosan by a green alga *Nannochloropsis*

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The pharmaceutical and personal care products sulfamethoxazole (SMX), trimethoprim (TMP), and triclosan (TCS), are widely used and continuously released into the aquatic environment and may cause adverse effects to aquatic wildlife via direct exposure and/or food web transfer. The present research applied a series of incubation studies to investigate the removal of SMX, TMP, and TCS by a green alga *Nannochloropsis*. The results showed that the hydrophilic antibiotics TMP and SMX were not significantly removed by the alga, which were measured at 100% and 70% in the medium after 14 d of incubation, respectively. However, the lipophilic antimicrobial TCS was strongly removed from the medium, where 70% of TCS dissipated immediately after the incubation began and 100% of TCS was removed after 7 d of incubation. The removal mechanisms are found different for SMX and TCS. For SMX, algae-mediated uptake was insignificant; however, algae-mediated photolysis might play a role. In contrast, algae-mediated uptake was a primary process for the removal of TCS. The results demonstrate that the presence of *Nannochloropsis* could eliminate the lipophilic antimicrobial TCS, but could not remove the hydrophilic antibiotics TMP and SMX significantly in an aquatic ecosystem.

Effects of cover cropping and tillage on nutrient leaching in a corn/soybean rotation

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Agricultural practices like tillage and excessive fertilization can increase nutrient leaching especially nitrogen (N) leaching to ground water, in turn making it a major environmental concern. Tillage during autumn and early spring can stimulate N mineralization too early and increase the risk for nitrate leaching before subsequent crops have a chance to take up the nitrogen released by microbial activity. Cover crop establishment could provide an alternative measure to reduce potential nutrient leaching, nutrient loss via runoff, and soil profile accumulation of nutrients. The overall objective of this research is to evaluate the influence of cover crops and tillage on nutrient leaching from a corn/soybean cropping sequence. The specific objectives included are: (a) to quantify the influence of cover crops on soil solution chemistry and soil nutrient content in corn/soybean rotation, (b) to evaluate nutrient leaching due to the interactions with tillage and cover crops, and (c) to evaluate the influence of cover crops on yield and biomass accumulation of corn and soybean. Soil samples collected after corn/soybean harvest and after cover crop termination were used for analysis of standard soil fertility parameters. Soil solution nutrient concentration were measured through pan lysimeters installed below the 'A' horizon. Soil solution samples were collected weekly or biweekly depending on the amount of precipitation and were analyzed for pH, EC, anions (Br^-, Cl^-, F^-, NO_2^- , NO_3-, SO_4^{2-}, and PO_4^{3-}), dissolved reactive phosphorus, total nitrogen and dissolved organic carbon. Preliminary results indicate higher concentrations of nitrate-N leaching in treatments planted with hairy vetch (*Vicia villosa*) till and hairy vetch no till compared to all other treatments (no cover crop till, no cover crop no till, radish/oats till and radish/oats no till). Long term soil solution monitoring is needed to discover temporal changes in nutrient leaching under these treatments. This research will help to better understand the interaction of cover crops with tillage and will help in decision making on selection of an appropriate cropping sequence for agricultural producers.

Effectiveness of vegetated treatment areas as a BMP for small swine operations

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*Presenter - Kevin Wagner, Deputy Director of Engagement & Professor, Texas Water Resources Institute, Texas A&M AgriLife Research

Over 70 % of swine operations in the United States are considered small with less than 100 head. These small operations need practical, low-cost waste management options to protect water quality and avoid regulation. Vegetated Treatment Areas (VTAs) are an inexpensive alternative best management practice (BMP) to standard waste management systems (i.e. lagoon systems) required of larger operations and by current government standards to help reduce soil, nutrient, and bacteria runoff. VTAs are areas of perennial grasses which are used to improve runoff water quality from livestock, poultry, and other agricultural operations. VTAs are usually a component of a vegetative treatment system (VTS) which includes additional components to remove solids, such as a settling or vegetative infiltration basin. Numerous modeling and field studies have been conducted to evaluate the design and effectiveness of VTSs for treating animal feeding operation (AFO) runoff; however, none of these studies have evaluated the effectiveness of VTAs receiving direct runoff from small swine operations during natural rainfall events as a stand-alone practice. This study determined whether a sufficiently sized VTA alone could effectively remediate direct runoff from small swine operations (< 100 animals). Three study locations were established, and sampling sites were installed to measure runoff water quantity and quality at VTA inlets and outlets, as well as nearby control sites. Results showed that VTAs reduced runoff volumes by over 17 %, nutrient concentrations by more than 23 %, and nutrient loads over 50 %. Based on these results, VTAs appear to be a practical, environmentally-friendly waste management alternative for small swine operations if they are properly designed and managed.

Use of retention pond for storm runoff control - A modeling approach

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*Presenter - Laurent Ahiablame, Assistant Professor, South Dakota State University

Urbanization result in increases of impervious surfaces, changes of the natural hydrologic conditions and watershed's response to stormwater runoff. The application of Best Management Practice (BMP) measures can provide a potentially cost-effective solution for on-site management of post-construction stormwater runoff. A current study conducted at Southern Illinois University Edwardsville investigates the effectiveness and cost-benefit of various BMP alternatives for retaining the first inch of runoff from highways and roads in various locations of Illinois. This proposed presentation will report the modeling approach of use of retention pond for stromwater runoff control. The modeling incorporated various tools offered in ArcGIS and Personal Computer Stormwater Management Model (PCSWMM). Stormwater runoffs from 24 hours rainfalls were considered. Information from the National Land Cover Database (NLCD), Digital Elevation Model (DEM) National Elevation Dataset (NED) 1/3 ar c-second (~10 meter), contour map, transportation data, Hydrologic Unit Code (HUC), and soil data were collected and used. Sub-catchment areas were created through delineation process process in ArcGIS using ArcHydro tool. An existing stormwater detention pond in Madison County, Illinois, was selected for model validation. The modeling considered two scenarios: the pre-construction scenario using the post-development land cover when there is no BMP installed, and the post-construction with BMP scenario using post-development land cover when BMP is installed in the selected area. This presentation will report method of model development, the results obtained from scenario analysis, technical issues and solution through the modeling and analysis process.

Geologic and seismic effects of large-scale groundwater withdrawal from northeastern Nevada basins

Brian Anderson, Graduate Research Assistant, Desert Research Institute
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Several studies have shown a relationship between crustal unloading of a surficial mass and the response of nearby faults. Melting of glaciers, regression of large lakes, seasonal hydrologic loading, and even groundwater pumping from basin aquifers can affect slip-rates or modulate seismicity. Motivated by the potential for large scale pumping and inter-basin transfer of groundwater from eastern Nevada to southern Nevada, Spring Valley in eastern Nevada is used as a sample study area to determine the effect of large-scale groundwater transfer on Great Basin faults. Finite difference numerical simulations (MODFLOW) of pumping drawdown in Spring Valley are used to determine potential unloading over the study area. Using the modeled unloading estimates, both the normal and shear stress changes in the subsurface can be modeled to resolve the change in Coulomb stress on nearby faults. Change in Coulomb stress results are then compared with the same parameter in similar incidents in which groundwater pumping has been implicated in triggering rupture or modulating seismicity such as Lorca, Spain (Gonzalez et al., 2012), California's Central Valley (Amos et al., 2014), or the Cerro Prieto geothermal field (Trugman et al., 2014). This study aims to find an estimate of an inter-basin transfer threshold for groundwater in Spring Valley at which seismic hazard is significantly increased.

Changes in annual climate among the southeastern United States and potential impacts on water quality and quantity

Chance Bentley, Research Assistant/Graduate Student, Florida Agriculture and Mechanical University
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From the Appalachian mountain range in the north to the Florida Keys in the south, the southeastern region of the United States (SEUS) is home to a dynamic structure of social, economic, political, and environmental systems. In the midst of an ever changing climate, the systems present in this diverse region will be subject to change over the course of the 21st century. As the reality of climate change becomes more prominent, it becomes pivotal that the impacts to water quality and quantity in SEUS are assessed and quantified in order to assure proper strategies and policies be implemented. The objective of the study is to analyze 21st century annual climactic changes present for the SEUS on a 1°X1° longitude latitude scale. The change is studied using outputs from ~30 CMIP5 Global Climate Models (GCMs) projections for an array of future scenarios (RCP). These are used to show multiple pathways the climate could take in the future. Our preliminary analysis of annual precipitation and temperature changes demonstrate the large variability that exists within GCMs with regards to predicting the changes in precipitation. Furthermore, GCMs are in more agreement to the changes that could occur in temperature change compared to precipitation change. It is important that these changes be properly addressed at a finer scale in order to bring the out the potential issues to water quality and quantity to adapt to the positive implications of change and mitigate the negative implications that may coincide with a change in climate.

Vegetative best management practices for controlling roadway runoff

Alex Boger, Student, South Dakota State University
(co-authors: L. Ahiablame, D. Beck)

Roadside ditches are an integral part of the drainage network in many locations of the United States; as such the quality of water leaving these ditches would necessarily affect downstream waters. Vegetative best management practices (BMPs) such as vegetative filter strips and grassed swales are often used to manage roadside ditches for water quality conservation. The objective of this study is to (1) summarize the current state literature and document future research needs; and (2) provide recommendations for vegetative BMP implementation. Data on pollutant concentration level and removal were compiled in order to gain insight on the effectiveness of roadway vegetative BMPs. This information was used in this study to make inferences and explore factors that affect pollutant removal in roadside ditches.

An interactive web map for the assessment of the anthropogenic wastewater generation in the Southern High Plains

Erick Butler, Assistant Professor of Environmental Engineering, West Texas A&M University
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The Tierra Blanca watershed consists of five counties in the Texas Panhandle and one in Eastern New Mexico. Situated in the Southern High Plains, the High Plains Aquifer is the major supplier of water for the region that includes users from the agricultural, domestic, industry, and energy sectors. It has been estimated that 90 % of this water is for agricultural purposes and water availability in the region is decreasing dramatically in danger of not being able to meet the needs of its users. As a result, water users in the region might want to consider alternative sources of water which may include, but are not limited to evaluating anthropogenic wastewater generation in the region. Wastewater generation in the watershed is primarily produced by beef cattle feed yards. Secondary sources of generation include two ethanol plants, a processing plant, and a packing plant. The three largest municipalities within the region have a population less than 20,000. With limited resources available, there is a need to identify alternative water sources to satisfy the needs of the region.

The purpose of this study is to spatially assess the quality and quantity of anthropogenic wastewater generated within the region. Known wastewater quality and quantity data has been collected from the local state environmental agency combined with other spatial features from other agencies and potentially some field sampling data to generate an interactive web map that provides an overall picture of wastewater found in the region. Understanding this data will assist in determining possible future water uses provided appropriate treatment measures are made.

A multi-objective particle swarm optimization based on Pareto-adaptive ε-dominance and orthogonal design for reservoir flood control operation

Chen Chen, Student, Huazhong University of Science and Technology

Reservoir flood control operation (RFCO) is a complex multi-objective optimization problem (MOP) with interdependent decision variables. Traditionally, RFCO is modeled as a single optimization problem by using a certain scalar method. This study, we present an improved multi-objective particle swarm optimization algorithm(ε- MOOPSO) to solve the RFCO problem. It is characterized by (a) employing the orthogonal design method with quantization technique to generate the initial population, (b) adopting an archive to store the nondominated solutions and employing the new Pareto adaptive ε-dominance method to update the archive at each generation, and (c) incorporating the mechanism of crowding distance computation in the external archive. It can get evenly distributed individual in the whole search space, and these individuals improve the utilization of the algorithm in the subsequent evolution process, which can accelerate the convergence of the algorithm. In order to obtain the quality of the approximation of the Pareto-optimal front with less computational complexity and meet the diversity of individual, we combine with an external archive of nondominated solutions and update strategy based on crowding distance. So we can get a more optimal solution in the Reservoir flood control operation. Experimental studies on a typical multi-objective flood control operation problems of Three Gorges reservoir with flood data of Yangtze River in China (1981) have indicated that the proposedε- MOOPSO performs as well as or superior to the other three competitive multi-objective optimization. ε- MOOPSO algorithms is suitable for solving MO-RFCO problems.

LSU Irrigation and Leaching Control System: Development and Implementation

Stacia Davis, Assistant Professor, LSU AgCenter
(co-authors: D. Smith, J. Beasley, S. Hall, M. Thiessen, D. Bordelon)

Standard irrigation practices of containerized horticultural plant material include a daily time-based irrigation application that results in leaching estimated as 40-60 % of the applied volume as well as increased nutrient losses. When vigorous growing plant material is established within a relatively short period in containers, leaching can be minimized without resulting in plant degradation from harmful salt buildup. Therefore, the objective of this study was to develop and evaluate a technological alternative to a time-based irrigation schedule to minimize irrigation volumes and leachate while allowing proper plant growth and development. The LSU Irrigation and Leaching Control System was designed as a three tipping bucket system connected wirelessly to a logic controller. Each tipping bucket consists of a cylindrical catchment dome located directly under 3 representative plants. Leachate was funneled from the catchment dome into a receiving tray where leachate initiation and volume were measured. When two of the three buckets recorded the initiation of leachate, the system terminated irrigation. Two irrigation treatments, one utilizing the LSU Control System and the other acting as the standard time-based practice, were implemented using 36 lantana grown in 1 gallon trade pot containers over an 8 week period under glass house conditions. Both treatments were programmed to irrigate once daily. The LSU Control System terminated irrigation when two of the three buckets recorded leachate initiation. The time-based method was programmed to run for 5 minutes. Preliminary results showed an average decrease > 40 % in irrigation volume compared to the time-based irrigation treatment that is representative of current commercial practices. Lantana growth did not differ between treatments suggesting large leaching fractions associated with the time-based irrigation treatment were unnecessary. Results also indicated irrigation volumes, as determined by the control system, fluctuated daily suggesting a dynamic system such as this may be worthwhile in commercial applications for long-term water use efficiency.

Influence of amendment of biochars on soil water properties

Syam Dodla, Assistant Professor, Louisiana State University
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Use of biochar (BC) as a soil amendment has gained attention to increase carbon sequestration and enhance fertility of agricultural soils. In addition to improving C sequestration and soil fertility, BC soil amendment reported to improve soil water holding capacity (SWHC). However, the improvement in SWHC from BC amendment may vary significantly with the source materials and production temperatures of BC, which influence its chemical and physical properties. Thus, information of how BCs from different source materials and production temperatures effect SWHC is important. In addition, understanding how BC effect the soil water potential (SWP), hydraulic conductivity (HC), and evaporation is crucial for optimizing the crop irrigation. At present, not much information is available on how BCs from different source materials and production temperatures influence SWHC, SWP, evaporation losses, and HC. In the present study, BCs produced at four different temperatures (400°C, 500°C, 600°C and 700°C) and three source materials (pine wood, paper pulp and rice husk) were evaluated for their effect on a very fine sandy loam soil's SWHC, SWP, HC, and evaporation. Initial results using the pinewood BC produced at 500°C showed that its amendment had improved SWHC; however, due to the increased SWP there was minimal difference in the amount of plant available water content. Amendment of BC didn't show significant influence on water loss by evaporation while there was a decrease in both saturated and unsaturated hydraulic conductivity..

The impact of changing storm properties on water fluxes and solute transport in arid area under future climate change

Peng Jiang, Postdoctoral Fellow, Desert Research Institute, Las Vegas
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Changes in climate are likely to induce changes in precipitation characteristics including intensity, frequency, duration, and patterns of events. Previous study has indicated that projected precipitation will exhibit more consistent changes in storm duration, interstorm period, and storm intensity than in total precipitation. These changes in precipitation storm properties may have profound impacts on surface water fluxes and solute transport in arid area. In this study, changes of storm properties will be investigated based on multiple regional climate model/global climate model pairs in North American Regional Climate Change Assessment Program (NARCCAP) in Las Vegas Valley, then future precipitation time series will be generated by incorporating the changes in the storm properties, finally the generated precipitation will be used to driven the HYRDUS-1D for the simulation of water flow and chloride transport in selected soil texture and root density to examine the impacts of changing storm properties on water fluxes and solute transport in Las Vegas Valley. The responses of water flow and chloride transport to changes in storm properties will be presented for the impact studies in the study region.

Regional climate simulation of orographic precipitation in interior western USA: Comparisons with gauge and high-resolution

Xiaoqin Jing, Ph.D. Student, University of Wyoming
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There are several high-resolution (4 km) precipitation datasets covering the interior western US: the National Centers for Environmental Prediction (NCEP) National Hourly Multisensor Precipitation Analysis Stage IV dataset, which uses the NEXRAD network and precipitation gauges, is challenged over mountains because of lack of low-level radar coverage. The Precipitation-Elevation Regressions on Independent Slopes Model (PRISM) dataset does better over complex terrain, but has a poor time resolution (1 month), since it is a statistically-based dataset mainly using terrain and gauge data. Here a 10-year Weather Research and Forecasting Model (WRF) simulation is used to study precipitation patterns in interior western US. The simulated precipitation is compared with data from Snow Telemetry (SNOTEL) gauges (located in tree-covered mountains) and the two high-resolution datasets (NCEP IV and PRISM). The results show WRF compares well against SNOTEL, especially for wintertime precipitation, as well as against NCEP IV and PRISM in the plains and valleys in the vicinity of NEXRAD radars. NCEP IV significantly underestimates orographic precipitation. PRISM is good in areas near SNOTEL sites, but questionable in areas without gauges, especially in areas above the treeline. Statistical analysis of wintertime precipitation suggests the bias and correlation between PRISM and WRF depend on gauge density and elevation.

Optimal hydrothermal operation using linear programming with special ordered sets

Chuanxiong Kang, Student, Huazhong University of Science and Technology

The optimization of reservoir operation is a widely concerned problem. The optimization models always turn out to be nonlinear and nonconvex, which cause difficulties in solving the optimization models. This study uses Linear Programming (LP) with Special Ordered Sets of Type Two (SOS2) to solve a short-term hydrothermal scheduling problem with 4 cascaded hydroplants and 3 thermal plants. As the thermal power cost function and hydropower output function are nonlinear, previous studies on this problem mainly concentrated on heuristic search algorithms, and showed that the minimal thermal cost that could be achieved was $40179. To make this nonlinear optimization problem solvable using LP, SOS2 is used to approximate the nonlinear functions. In this study, each of the thermal power cost function is discretized to 50 points, and each of the hydropower output function is discretized to a 30×15 table. This optimization model is solved on MATLAB platform using Gurobi solver, which transforms the original model into a Mixed Integer Linear Programming (MILP) one. Solving the problem takes 80 seconds, and gives the minimal objective of $39568, which is much better than those reported in previous studies. The deviation caused by SOS2 is 0.12 %, which is very small. This study demonstrates that LP with SOS2 is useful and efficient in solving the nonlinear and nonconvex reservoir operation problems.

Applying Bayesian Inference to River Forecast Center river flow forecast for its better accuracy

Dong Ha Kim, Modeler, Georgia Environmental Protection Division

Among many tasks, the National Weather Service River Forecast Center (NWS RFC) provides river flow forecasts for five days ahead in six hours step. The forecast is made through multilayered hydrologic or climate models where the output of a lower layered model becomes input for an upper layered model. In this hierarchical structure, systematic errors might be a dominant source over random errors in mismatching forecasts to its true values evolved over time. This is because the final model outcome is a product after multiple runs of different models through many levels and this interconnected calculation process causes propagation of errors stemmed mainly from imperfectly calibrated parameters of each model. Systematic errors tend to be consistent in magnitude and/or direction so if the magnitude and direction of the error can be estimated by looking at underlying relations between historical forecasts and actual observations in hindcasting, the accuracy of the forecast can be improved by reducing systematic errors. Needless to say, random errors from measuring or forecasting hydrologic or climate field data are also significant due to, especially, uncertainty in foreseeing future values so that the errors cannot be ignored in investigating the accuracy. Unlike systematic errors, random errors vary in magnitude and direction inconsistently as its name suggests. However, the error can be reduced when an average is taken out of field data. This study searches for a way to lessen the uncertainty of RFC's river flow forecast. Normal Quantile Transform and Normal-Linear Model are drawn upon in Bayesian inference for computing analytical posterior distributions and hence efficient predictive distributions. Embodying historical forecast-observation functions, the predictive distribution probabilistically measures the combined effect of both systematic and random errors of river flow forecast evolved over time, thus improving the accuracy and efficiency of the forecast.

An introduction to water reallocation and barriers to its implementation

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The growing number of areas facing water scarcity necessitates adaptive water management strategies beyond traditional water supply and demand management approaches, which are becoming increasingly difficult in many regions. Many researchers and practitioners have endorsed water reallocation as a flexible water management approach to mitigate water scarcity under changing socioeconomic, climatic, and environmental conditions. In spite of the numerous benefits of reallocating water between users, examples of water reallocation are relatively sparse and the expected benefits are rarely met in full. This presentation provides an introduction to water reallocation and its various forms and details the primary impediments to its wide application. Several examples of water transfers from around the world are used to illustrate both the benefits and challenges associated with reallocation, as well as to identify measures to overcome some of the major difficulties when transferring water rights. This presentation will also highlight pressing interdisciplinary research needs in order for water reallocation to become a more viable tool for water planners and managers around the world.

E. coli transport in South Dakota streams

Rachel McDaniel, Assistant Professor / Water Resource Engineer, South Dakota State University, South Dakota Water Resources Institute

Nearly 60 % of South Dakota's streams are currently listed as impaired and two out of the top three causes for impairment are bacteria. *Escherichia coli* are the number one cause of impairment in the state. South Dakota Water Resources Institute personnel are conducting two projects to further understanding of bacteria transport in South Dakota's waters. The first project will assess the stability of *E. coli* concentrations in stream sediments over time including the impact of stormflow, shear stress, and sediment particle sizes. Stream sediments can be a major source of *E. coli* concentrations in the water column, particularly during high flows. In addition, sediment particle size can influence the survival of the bacteria. The second project focuses on what is occurring in the water column during high flows. It will evaluate *E. coli* attachment to particles of different sizes and estimate the impact of attachment on *E. coli* transport in streams during high flows. *E. coli* can attach themselves to a variety of particles; attachment and particle size can influence transport into the water column as well as transport downstream. Conducting these studies will allow state personnel to better address the issue of high bacteria concentrations in South Dakota's waterways.

The effects of hydro-sediment operation on future environmental non-stationary changing

Guo Min, Lecturer, Huazhong University of Science and Technology
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The paper assesses the nonstationarity of the storage capacity and the volume vs water level relationship attributable to sediment deposition, and take advantage of silting status to improve scheduling effect of reservoir operation strategy. Thus far, previous research works derive reservoir operation policies mostly based upon an assumption of geomorphological and hydrological from year to year, and seldom take into account their yearly nonstationarity. However, with the aggravation of human activities and their impacts, as well as due to the natural evolution itself, the nonstationarity is a reality and probably is increasing in magnitude. This work will start with the traditional reservoir operating strategies, analyze and quantify the nonstationarities, and then obtain operating policies adaptable to nonstationary states by improving or reforming the stochastic optimal models for reservoir operation. Then using the model to conduct many years simulation scheduler, develop to take advantage of sediment deposition status to improve scheduling effect of reservoir operation strategy. The model and procedure are applied to deal with the Yunnan provincial hydropower system. It has important theoretical and practical significance of the project.

Assessing the reliability of water test kits for use in pond aquaculture

Shamim Naigaga, Research Assistant, Auburn University
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Water analysis kits are useful for practical aquaculture only if they provide equivalent decision making as those obtained by standard water analysis methods. This study used weighted Cohen's Kappa statistics to compare management decisions made by farmers that used water analysis kits (e.g. Seneye slide kit, Tetra Easy Strips, API test strips, Seachem Ammonia Alert, Salifert Profi test kit and Hach DO and alkalinity kit) and those that used standard methods. The decisions made by farmers were similar for water analysis kits and standard methods except for Tetra and API test strips when measuring nitrate concentrations. The highest conformity between the two methods (Kappa value = 1.0, $p < 0.0001$) was obtained with the Hach and Salifert Profi test kits (for measuring DO) and the API test strip (for measuring total hardness). The rapid, simple measurements by the kits appear suitable for use by farmers if they are properly maintained and manufacturer's instructions are followed.

Effect of cover crops on soil and water quality parameters at the watershed scale

Gurbir Singh, Graduate Research Assistant, Southern Illinois University Carbondale
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Corn (*Zea mays* L.) and soybean (*Glycine max* L.) production in the Upper Midwest is a major contributor of nitrate leaching to groundwater. Contamination of water through nutrient leaching poses an environmental threat such as eutrophication and hypoxia in Gulf of Mexico. The interval between crop harvest in fall and planting in spring is a critical time for leaching of nutrients, especially in areas with high precipitation. A promising strategy to control nitrate leaching and sediment runoff loss during winter fallow periods is use of cover crops. Cover crops can not only improve crop productivity and soil quality, but also benefit efficiency of nutrient cycling. Some cover crops can scavenge residual nitrogen, while other leguminous cover crops can increase soil N content through fixation of atmospheric dinitrogen. Therefore, the overall goal of this study is to evaluate the influence of cover crops on nutrient dynamics and leaching in a corn/soybean rotation. This research includes the interaction of cover crop with topographic positions (shoulder, hillslope, and foot slope) on a watershed scale. The specific objective of this research is to evaluate nutrient leaching with and without cover crops on various slope positions delineated using topographical position index in ArcGIS on watershed scale. Soil samples collected after corn/soybean harvest and after cover crop burning were used for analysis of standard soil fertility parameters. Soil solution nutrient concentration were measured through suction lysimeters. Soil solution samples were collected weekly or biweekly depending on the amount of precipitation and were analyzed for pH, EC, anions (Br^-, Cl^-, F^-, NO_2^- , NO_3^-, SO_4^{2-}, and PO_4^{3-}), dissolved reactive phosphorus, total nitrogen, and dissolved organic carbon. Volumetric water content and electrical conductivity were also measured. Results from this study will help in understanding how cover cropping on watershed scale contributes to nutrient leaching. The research results can be used by the agricultural community, including growers, industry, and the scientific community to evaluate whether cover cropping could be an alternative means to reduce potential nutrient leaching from agricultural fields. This knowledge will enable us to better minimize environmental impact, optimize harvest yields, and maximize nutrient utilization from the fertilized field under typical corn/soybean rotation.

Developing an experiential learning mapping activity to enhance watershed education

Lisa Swanger, Coastal Waccamaw Watershed Education Programs Coordinator, Coastal Carolina University
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The Coastal Waccamaw Stormwater Education Consortium (CWSEC) was established in 2004 for the primary purpose of assisting local governments to meet federal requirements for stormwater education and public involvement under the National Pollutant Discharge Elimination System Phase II Permit Program of the Clean Water Act. This includes the development and delivery of effective, outcome-based stormwater and watershed education programs for diverse audiences within the Waccamaw River Basin and coastal watersheds along South Carolina's northern coast. In an effort to promote increased watershed exploration and stormwater literacy among community members and visitors, CWSEC plans to pilot an interactive watershed mapping program during spring 2016. This will be developed by a Coastal Carolina University undergraduate student as an independent study project under the direct supervision of the CWSEC coordinator. One goal for the proposed watershed mapping program is to help reinforce CWSEC educational programs and messaging through a guided exploration of a selected watershed within the Waccamaw River Basin. Therefore, the program is intended to serve as an experiential learning tool to be used by diverse target groups including local schools, clubs and interest groups, families, and individuals. The program will be modeled after an existing activity called "geocaching" and will include the use of Global Positioning System (GPS). Participants will be introduced to watershed and stormwater facts as they journey through the mapping activity. Through this interactive program, CWSEC hopes to provide an opportunity for participants to engage in a unique learning experience within a local watershed, reflect on their experience and build meaningful connections between watersheds and their daily activities that impact it.

Assessment of satellite precipitation products through hydrologic simulation

Peixin Xu, California State University Los Angeles
(co-author: J. Li)

Precipitation plays a dominant role in weather and climate. A great deal of efforts has been devoted to the development of satellite precipitation products. Such products can provide precipitation estimates with high spatial and temporal resolution that are suitable for hydrologic modeling, flood monitoring, and water resource management, especially in remote area where the ground-based rain gauges are distributed sparsely or even absent. Although providing unprecedented possibilities to hydrological studies, satellite precipitation products still need to be evaluated in terms of accuracy for further applications. In this study, two satellite precipitation products, which include Tropical Rainfall Measurement Mission (TRMM) Multi-Satellite Precipitation Analysis (TMPA) and Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN), are assessed through their hydrologic performances in the streamflow simulation. Such hydrologic evaluations are conducted at Illinois River in Arkansas the time period of 2009 to 2014. A spatially lumped continuous model, Sacramento Soil Moisture Accounting (SAC-SMA) model, is used for streamflow simulation in this study.