2014
S.C. Water Resources Conference

Informing Strategic Water Planning to Address Natural Resource, Community and Economic Challenges

P R O G R A M

October 15-16, 2014
Columbia Metropolitan Convention Center
Columbia, SC

Sponsored and Organized by

Clemson University Public Service and Agriculture
Institute of Computational Ecology
Center for Watershed Excellence

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CONFERENCE EVALUATION FORM

Your input is very important for planning future conferences. Please complete the evaluation, remove at the perforated edge and submit at the registration desk. Thank you for your comments.

	STRONGLY AGREE	SOMEWHAT AGREE	SOMEWHAT DISAGREE	STRONGLY DISAGREE
The conference advances water resources sciences	1	2	3	4
The conference was useful to me professionally	1	2	3	4
The plenary sessions were informational	1	2	3	4
The convention center was an adequate venue	1	2	3	4
Columbia is a good location for the conference	1	2	3	4
I would recommend this conference to colleagues	1	2	3	4

What kinds of sessions would you like to see included at future conferences?

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What did you like most about the conference?

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What did you like least about the conference?

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Comments/Suggestions for Improvement:

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S.C. Water Resources Conference

Informing Strategic Water Planning to Address Natural Resource, Community and Economic Challenges

2014 Program
October 15-16, 2014

www.scwaterconference.org

Conference Co-Chairs

Gene W. Eidson, Ph.D., Clemson University Institute of Computational Ecology

Calvin B. Sawyer, Ph.D., Clemson University Center for Watershed Excellence

Conference Coordinator

Dawn Anticole White, M.M.C., Clemson University Institute of Computational Ecology

Technical Support – Clemson University

Debbie Dalhouse, Public Service and Agriculture

Peter Kent, Public Service and Agriculture

Charlene Mayfield, Public Service and Agriculture

Walker Massey, Public Service and Agriculture

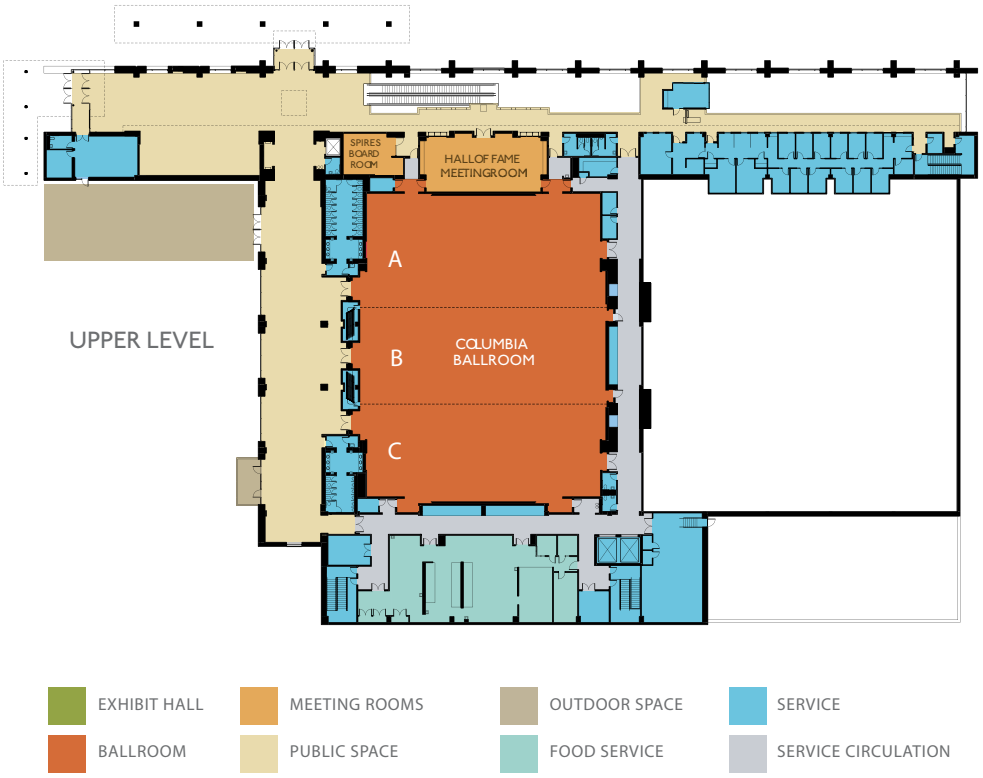
Contents

Cover photo: *ACE Basin, S.C. - Courtesy of Kim Counts, Clemson University Water Resources Agent*

Columbia Metropolitan Convention Center

Wireless Internet connection is available throughout the main public areas of the building.

Convention Center Floorplans



Schedule is subject to change

S.C. Water Resources Conference Schedule - (Day 1) Wednesday, October 15

7:30 a.m.	**Registration Opens**					
8:30-10:30	*(Ballroom A)* **Welcome & Opening Remarks** **PLENARY SESSION - Informing Strategic Water Planning to Address Natural Resource, Community and Economic Challenges: Legislative and Business Viewpoints** *Moderated by Senator Paul Campbell, Jr.* Senator Daniel Verdin, Senator Robert Hayes, Representative Nelson Hardwick, Representative David Hiott Daniel Kassis/SCE&G, Jeffrey Lineberger/Duke Energy, Geoff Penland/Santee Cooper, Dyke Spencer/Past Chairman SCAWWA Water Utility Council, David Winkles/S.C. Farm Bureau					
10:30-11:00	**Morning Break** ***(Lower Level)***					
	TRACK 1 **Water Policy & Planning** *Lexington Room A*	**TRACK 2** **River Basin & Stream Systems** *Lexington Room B*	**TRACK 3** **Stormwater** *Richland Room A*	***TRACK 4*** **Water Quality & Monitoring** *Richland Room B*	**TRACK 5** **Coastal & Estuarine Systems** *Richland Room C*	***TRACK 4*** **Water Quality & Monitoring** *Ballroom A*
TRACK CHAIR	***Jeff Allen*** ***Clemson University***	***Tim Callahan*** ***College of Charleston***	***Calvin Sawyer*** ***Clemson University***	***Colton Bowles*** ***USACE***	***Rick DeVoe*** ***S.C. Sea Grant Consortium***	***Colton Bowles*** ***USACE***
11:00-12:30 **SESSION 1**	**Session 1** **Watershed Partnerships**	**Session 1** **Infrastructure**	**Session 1** **From the Bottom Up - Green Infrastructure Considerations**	***Session 1A*** **Tools I**	**Session 1** **Saltwater Intrusion**	***Session 1B*** **Partnerships in Integrative Monitoring**
Moderator	Jeff Allen Clemson University	Noel Hurley U.S. Geological Survey	Amy Scaroni Clemson University	Colt Bowles USACE	Rheta DiNovo SCDHEC	Rick DeVoe S.C. Sea Grant Consortium
Presenter 1	**Ronald Walker** **S&ME Inc.** The Big Generostee Creek Mitigation Bank: A Case Study in Planned Watershed Management	**Andral Caldwell** **U.S. Geological Survey** A Guidance Manual for Assessing Scour Potential Using the South Carolina Bridge-Scour Envelope Curves	**Daniel Hitchcock** **Clemson University** Evaluating the Role of Evapotranspirative Processes for Stormwater Management in Coastal South Carolina Watersheds with Shallow Groundwater	**Natalia Shim** **University of Georgia** Application of Recurrent Neural Networks for Predicting Water Quality Constituents of Collected Runoff From Windrow Composting Pad	**Anand Jayakaran** **Clemson University** Monitoring Water Quality Changes in a Forested Freshwater Wetland Threatened By Salinity	**Frank Henning** **Congaree National Park** Integrating Multiple Dimensions of Stream Monitoring to Improve Water Resources Protection at Congaree National Park
Presenter 2	**Robert Osborne** **Black & Veatch** Apalachicola-Chattahoochee-Flint Stakeholders: Working Together to Share a Common Resource	**Stephen Benedict** **U.S. Geological Survey** Assessment of the NCHRP Abutment Scour Prediction Equations with Laboratory and Field Data	**Erik Smith** **University of South Carolina** Stormwater Hydrology and Material Transport in Urbanized Watersheds of the Grand Strand, South Carolina	**John Shelton** **U.S. Geological Survey** Beyond the Streamgage	**Rachael Kassabian** **College of Charleston** Water Budget of a Surficial Aquifer in the Lower Coastal Plain: ACE Basin, South Carolina	**Cheryl Carmack** **Charleston Waterkeeper** Development of a Regulatory Level Water Quality Monitoring Program for Enterococci in Recreational Waters of Charleston
Presenter 3	**Maryanne McGowan** **Duke Energy** Partnering For Sustainability	**William Rector** **AMEC Environment & Infrastructure, Inc.** Protecting Critical Infrastructure Along Eroding Streams Using Bioegineering Techiniques and Stream Restoration Methodology	**Nigel Kaye** **Clemson University** A Proposal for Standard Reporting of Extensive Modular Green Roof Hydraulic Performance Parameters	**Edward Rabon** **S.C. Department of Health & Environmental Control** South Carolina DHEC Use of R	**Jamie Duberstein** **Clemson University** Monitoring Marsh Vegetation and Soil Salinity During the Savannah Harbor Expansion Project Pre-development Phase	**E.V. Bell** **S.C. Sea Grant Consortium** From Seeds to Shoreline: Engaging Students in Salt Marsh Restoration
12:30-1:30 **LUNCH**	**Lunch** ***(Ballroom B/C)***					

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S.C. Water Resources Conference Schedule - (Day 1) Wednesday, October 15

	TRACK 1 Water Policy & Planning *Lexington Room A*	TRACK 2 River Basin & Stream Systems *Lexington Room B*	TRACK 3 Stormwater *Richland Room A*	TRACK 4 Water Quality & Monitoring *Richland Room B*	TRACK 5 Coastal & Estuarine Systems *Richland Room C*	SPECIAL SESSION *Ballroom A*
1:45-3:15 SESSION 2	**Session 2 Water Policy & Modeling**	**Session 2 Restoration**	**Session 2 Low Impact Development: Modeling to Maintenance**	**Session 2 Tools II**	**Session 2 Processes**	**Session 2 Development of a Watershed-Based Plan for Murrells Inlet**
Moderators	Lori Dickes Clemson University	Gene Eidson Clemson University	Brandon Stutts SCANA	Heather Preston SCDHEC	Chris Ellis NOAA	Amy Bennett SCDHEC
Presenter 1	**Scott Gregory Wildlands Engineering, Inc.** How Drivers and Data Affect Watershed Planning at Various Scales	**Zachary Smoot Woolpert, Inc.** Hydraulic Geometry Curves and Bankfull Recurrence in the Pee Dee River Basin	**Lauren Owen Clemson University** Using GIS to Prioritize Green Infrastructure Installation Strategies in an Urbanized Watershed	**Kimberly Ryan College of Charleston** Using Ocean Color Remote Sensing to Monitor Phytoplankton in Coastal Waters: A Case Study in Long Bay	**Thomas Williams Clemson University** Role of Hurricanes and Drought in Mortality of Tidal Forested Wetlands Using Historical Aerial Photography	**Delaney Faircloth - SCDHEC** SCDHEC Section 319 Grant Program: Community-Based Watershed Planning and Implementation **Daniel Newquist - Waccamaw Regional Council of Governments** Murrells Inlet Watershed: Positive Outcomes from a Multi-stakeholder Planning Process **Stephen Williams The EARTHWORKS Group** Watershed Management Planning for the Murrells Inlet Estuary using GIS: Delineation, Assessment, Identification, & Solutions for Fecal Coliform Loading **Heather Young Coastal Carolina University** Water Quality Stewardship Informs Management Directions
Presenter 2	**Ken Rentiers S.C. Department of Natural Resources** Development of Basinwide Surface-Water Quantity Models in South Carolina - A Status Report	**Charles Oligee S&ME, Inc.** The Genetta Restoration Project	**William Martin Clemson University** Characterization of the Hydraulic Behavior of Porous Pavements	**Matthew Neet University of South Carolina** Model Performance Results in Myrtle Beach, SC Using Virtual Beach and R Regression Software	**Devendra Amatya USDA Forest Service** Comparison of Potential Evapotranspiration (PET) Using Three Methods for a Grass Reference and a Natural Forest in Coastal Plain of South Carolina	
Presenter 3	**Ryne Phillips Clemson University** A Comparison of Remote Sensing Estimates of Lake Evaporation with Pan Evaporation Measurements Along the Savannah River Basin	**Calvin Sawyer Clemson University** Restoring Hunnicutt Creek: Perspectives and Preliminary Results from a University Campus Project	**Brad Putman Clemson University** Evaluation of Low-Cost Retrofit Solutions for Sealed Porous Pavements	**Alan Johnson Clemson University** A Decision-Analytical Approach to Monitoring and Managing Freshwater Algal Blooms	**Alicia Wilson University of South Carolina** Tidally-Driven Groundwater Flow and Intertidal Wetlands	
3:15-3:45	**Afternoon Break *(Lower Level)***					

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3:45-5:15 SESSION 3	**Session 3** **Water Monitoring for Policy**	**Session 3** **Processes**	**Session 3** **Stormwater Monitoring: Making Data Work for You**	**Session 3** **Groundwater - Big Picture**	**Session 3** **Modeling**	**Session 3** **Development of a Watershed-Based Plan for Murrells Inlet** *(cont)*
Moderator	Chris Ellis NOAA	Devendra Amatya USDA Forest Service	Katie Giacalone Clemson University	Mike Harrelson Santee Cooper	Eric Strom U.S. Geological Survey	Amy Bennett SCDHEC
Presenter 1	**Jonathan L. Hodges** **Clemson University** Improving Satellite Measurements of Reservoir Surface Temperature Via a Thermal Model of Lake Surface Temperature for Improved Evaporation Estimates	**Devendra Amatya** **USDA Forest Service** Pre- and Post-Hugo Event Hydrograph and Flow Characteristics of Paired First Order Forested Watersheds in Atlantic Coastal Plain	**Kimberly Jones** **Town of Bluffton** From Planning to Management & Assessment: The May River Watershed Action Plan in Bluffton	**Joseph Gellici** **S.C. Department of Natural Resources** Revisions to the Hydrogeologic Framework of the South Carolina Coastal Plain	**Paul Conrads** **U.S. Geological Survey** Assessing the Past and Potential Future Impacts of Saltwater Intrusion on Tidal Swamp Habitat Along the South Atlantic Coast	**Susan Libes** **Coastal Carolina University** Watershed-based Planning for Murrells Inlet: Source Assessment of Fecal Bacteria Using Volunteer and Shellfish Sanitation Program Data
Presenter 2	**Kimberly A. Counts** **Clemson University** Rainwater Harvesting: A Community-Based Program Approach as a Vehicle for Increasing Stormwater Awareness	**Tim Callahan** **College of Charleston** Tracking Stream Flow Response to Storm Events in Low-Gradient Watersheds: Application of Stable Isotopes for Hydrograph Separation	**Melanie Ruhlman** **The Friends of the Reedy River** Addressing Water Quality through Stormwater Retrofit in the Reedy River Watershed, Greenville, South Carolina	**Chenille Williams** **University of South Carolina** Groundwater Recharge Rates in Isolated and Riverine Wetlands: Influencing Factors	**James Greenfield** **Tetra Tech** Simulation of Hydrodynamics and Water Quality in the Bushy Park Reservoir, Charleston, SC	**Amanda Sturgeon** **Coastal Carolina University** Building Local Capacity for Microbial Source Tracking in the Myrtle Beach Urbanized Area
Presenter 3	**Paula Reidhaar** **Winyah Rivers Foundation** Volunteer Water Monitoring: Educating and Building Relationships to Manage Our Watershed	**Andrew Tweel** **S.C. Department of Natural Resources** Volume Sensitive Waters in Tidal Creeks of Beaufort County, SC	**Robert Schroeder** **Coastal Carolina University** Assessment of Water Quality Benefits from Stormwater Treatment Train and Ocean Outfall for the Main Street Drainage Basin in N. Myrtle Beach	**Joe Harrigan** **AECOM** Analysis Techniques to Improve Development of Fractured Bedrock Groundwater Resources	**Chris Mack** **AECOM** Numerical Modeling Elements of a FEMA Coastal Flood Study	**Dave Fuss** **Horry County Stormwater Management** Watershed Plan Implementation Challenges for SMS4s in Murrells Inlet **Extended Panel Discussion**
5:30-7:00	**Reception & Poster Session** ***(Lower Level)***					

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S.C. Water Resources Conference Schedule - (Day 2) - Thursday, October 16

7:30 a.m.	**Registration Opens**					
8:15-8:30	*(Ballroom A)* **Welcome & Conference Remarks**					
8:30-10:30	**PLENARY SESSION - Informing Strategic Water Planning to Address Natural Resource, Community and Economic Challenges: Regulatory Agency and Nonprofit Viewpoints** *Moderated by Dr. Gene Eidson* Chris Thomas/U.S. EPA Region 4, Ken Rentiers/SCDNR, David Wilson/SCDHEC Dana Beach/Coastal Conservation League, Hamilton Davis/Coastal Conservation League, Mark Robertson/The Nature Conservancy, Eric Krueger/The Nature Conservancy, Heather Nix/Upstate Forever					
10:30-11:00	**Morning Break** ***(Lower Level)***					
	TRACK 1 **Water Policy & Planning** *Lexington Room A*	**TRACK 2** **River Basin & Stream Systems** *Lexington Room B*	**TRACK 3** **Stormwater** *Richland Room A*	***TRACK 4*** **Water Quality & Monitoring** *Richland Room B*	**TRACK 5** **Coastal & Esturine Systems** *Richland Room C*	***TRACK 4*** **Water Quality & Monitoring** *Ballroom A*
TRACK CHAIR	***Jeff Allen*** ***Clemson University***	***Tim Callahan*** ***College of Charleston***	***Calvin Sawyer*** ***Clemson University***	***Colton Bowles*** ***USACE***	***Rick DeVoe*** ***S.C. Sea Grant Consortium***	***Colton Bowles*** ***USACE***
11:00-12:30 **SESSION 4**	**Session 4** **Economic Opportunities in Water Resources**	**Session 4** **Modeling I**	**Session 4** **Tools for Better Management**	***Session 4A*** **Groundwater Case Studies**	**Session 4** **Climate**	***Session 4B*** **Biomarkers**
Moderators	Rob Carey Clemson University	Tim Callahan College of Charleston	Robert Osborne Black & Veatch	Mike Harrelson Santee Cooper	Rick DeVoe S.C. Sea Grant Consortium	Michael Paller Savannah River National Laboratory
Presenter 1	**Colt Bowles** **U.S. Army Corps of Engineers** I'm From the Federal Government and Am Here to Help: Extending Local Resources through Partnering with the Corps in Addressing Water Resource Concerns	**Seyedehzahra Samadi** **University of South Carolina** Toward a Reliable Prediction of Streamflow Uncertainty: Characterizing and Optimization of Uncertainty Using MCMC Bayesian Framework	**Jeremy Ritchie** **Town of Bluffton** Building a Stormwater Toolbox: Learning What to Expect from Your Stormwater BMPs	**Bruce Campbell** **U.S. Geological Survey** Groundwater Availability in the Crouch Branch and McQueen Branch Aquifers, Chesterfield County, SC, 1900-2012	**Michael Childress** **Clemson University** Going With the Flow: Forecasting the Impact of Climate Change on Blue Crabs	**Paul Bradley** **U.S. Geological Survey** Hormones, Pharmaceuticals and Other Contaminants of Emerging Concern in Water and Sediment from Congaree National Park
Presenter 2	**Cindy Roper** **Clemson University** Interstate Water Compacts: Partnerships for Transboundary Water Resource Management	**Toby Feaster** **U.S. Geological Survey** Estimating the Magnitude and Frequency of Floods for Urban and Small, Rural Streams in Georgia, South Carolina and North Carolina	**Kelli Resler** **AMEC Environment & Infrastructure, Inc.** Water Quality Design Criteria for Post Construction: Striking a Balance Between Performance and Simplicity	**James Landmeyer** **U.S. Geological Survey** Occurrence of Ethylene Dibromide (EDB), Dibromochloropropane (DBCP), Volatile Organic Compounds, Radium Isotopes, and Radon in Groundwater from the Upper Coastal Plain Aquifers Near McBee	**Kirsten Lackstrom** **University of South Carolina** Drought and Coastal Ecosystems: Identifying Impacts and Opportunities to Inform Management	**Peter Van den Hurk** **Clemson University** Biomarkers as a Tool for Biomonitoring of Water Quality in the Savannah River
Presenter 3	**Eric Krueger** **The Nature Conservancy** Water Funds: Shared Investments Now for Treatment Savings Later	**Ed Dickson** **AECOM** Modeling the Congaree River and its Levee(s)	**Tanya Strickland** **City of North Augusta** Transitioning a Community to Natural Water Resource Management, A City Perspective of NPDES MS4 Permitting	**Francis Chapelle** **U.S. Geological Survey** Modeling Long-term Trends of Chlorinated Ethene Contamination at a Public Supply Well	**Paul Conrads** **U.S. Geological Survey** Development of a Real-time Salinity Drought Index	**David Graves** **S.C. Department of Health & Environmental Control** Microbial Source Tracking to Assess Human Contributions of Fecal Bacteria to a Freshwater Receiving Stream
12:30-1:30 **LUNCH**	**Lunch** ***(Ballroom B/C)***					

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S.C. Water Resources Conference Schedule - (Day 2) - Thursday, October 16

	TRACK 1 Water Policy & Planning *Lexington Room A*	TRACK 2 River Basin & Stream Systems *Lexington Room B*	TRACK 3 Stormwater *Richland Room A*	TRACK 4 Water Quality & Monitoring *Richland Room B*	TRACK 5 Coastal & Estuarine Systems *Richland Room C*
1:45-3:15 SESSION 5	**Session 5 Drought Management Planning**	**Session 5 Modeling II**	**Session 5 Stakeholder Engagement in Better Management**	**Session 5 Water Use & Management I**	**Session 5 Water Quality**
Moderators	Jeff Allen Clemson University	Noel Hurley U.S. Geological Survey	Cal Sawyer Clemson University	David Graves SCDHEC	Susan Libes Coastal Carolina University
Presenter 1	**Ekaterina Altman** **University of South Carolina** Analysis of Drought Indices and Drought Status Declarations: Example of South Carolina Drought Management Program	**Michael Meadows** **University of South Carolina** Examining the Robustness of the SWAT Distributed Model Using PSO and GLUE Uncertainty Frameworks	**C. Guinn Garrett** **Clemson University** A 6,000 Stormwater Pond Task: Meeting the Needs of Diverse Audiences for Stormwater Pond Management Outreach in the Berkeley, Charleston and Dorchester Communities	**Ruth Albright** **SynTerra** PCBs: Old Chemicals Present New Challenges	**Dianne Greenfield** **University of South Carolina / SCDNR** Linking Phytoplankton Community Composition with Incidences of Vibrio in Stormwater Detention Ponds
Presenter 2	**Edwin Roehl** **ADMi** Optimally Managing Water Resources in Large River Basins for an Uncertain Future	**Ryne Phillips** **Clemson University** The Effect of Uncertainty in Evaporation Rate on Predictions of Water Availability in the Savannah River Basin	**Katie Giacalone** **Clemson University** 2014 Update on the Perceptions of Nonpoint Source Pollution in South Carolina	**Porter Rivers** **URS Corporation** Evaluation of Water Supply Options: Catching Two Fish with One Worm	**Daniel Tufford** **University of South Carolina** Indicators of the Occurrence of Vibrio in the Winyah Bay, South Carolina Estuary
Presenter 3	**Eleanor Jenkins** **Clemson University** Optimization of a Managed Aquifer Recharge Network	**Seyedehzahra Samadi** **University of South Carolina** Improving the Robustness of Uncertainty Algorithms in Quantification of Uncertainty in Water Balance Forecasting	**M. Richard DeVoe** **S.C. Sea Grant Consortium** Stormwater Management Ponds in SC: Formulating An Integrated Research and Outreach Collaborative to Enhance Pond Ecology, Functionality, Efficiency, Effectiveness, and Management	**José Payero** **Clemson University** Demonstrating Subsurface Drip Irrigation as a Climate Adaptation Strategy for Sustainable Crop Production in South Carolina	**Jillian Phillips** **College of Charleston** Applications of Source-tracking and Site-specifc Models for Water Quality Assessment of Tidal Waters: Upper Inlet Creek, Mount Pleasant, SC
3:15 - 3:45	**Afternoon Break** ***(Lower Level)***				

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S.C. Water Resources Conference Schedule - (Day 2) - Thursday, October 16

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3:45-5:15 SESSION 6	**Session 6 Sustainable Water Planning**	**Session 6 Modeling III**	**Session 6 Hydromodeling & Influences on Decision-Making**	**Session 6 Water Use & Management II**	**Session 6 EcoHydrology**
Moderators	Rob Carey Clemson University	Devendra Amatya USDA Forest Service	Chuck Jarman Clemson University	John J. Mayer Savannah River National Laboratory	David Graves SCDHEC
Presenter 1	**Graham W. Rich** **Central Arkansas Water** Watershed Management – Holistic Policies and Practices That Achieve Sustainable Water Quality Solutions	**Charles Pellett** **Clemson University** Storm Water Damage Risk Assessment Along the South Carolina Heritage Trail	**Kevin Conlon** **U.S. Geological Survey** Characterization of Stormwater At Selected SC Department of Transportation Maintenance Yards and Section Shed Facilities In Ballentine, Conway, and North Charleston, 2010-12	**Jimmy Clark** **U.S. Geological Survey** Bathymetry and Water Quality in Table Rock and North Saluda Reservoirs Utilizing an Autonomous Underwater Vehicle	**Tim Dunleavy** **U.S. Geological Survey** Real-Time Tracking of Atlantic and Short-nose Sturgeon Using Existing USGS Streamgage Network Infrastructure
Presenter 2	**Rocky Nation** **Southern Wesleyan** Use of a Volunteer Monitoring Program to Assess Water Quality in a TMDL Watershed Utilized for Recreational Use, Pickens County, South Carolina	**Toby Feaster** **U.S. Geological Survey** Scaling Up Watershed Model Parameters: Flow and Load Simulations of the Edisto River Basin	**Michael Meadows** **University of South Carolina** Adjusting NRCS Curve Number for Rainfall Durations Less Than 24 Hours	**Matthew Petkewich** **U.S. Geological Survey** Investigation of Flow Patterns, Water–Quantity, and Water-Quality Conditions in the Bushy Park Reservoir, Charleston	**Nathaniel Weaver** **Clemson University** The Long-Term Effects of Exurbanization on Stream Health and Salamander Communities in the Southeastern Appalachian Mountains
Presenter 3	**Jonathan Williams** **HDR Engineering** Catawba-Wateree River Basin Water Supply Master Plan - Providing a Sustainable Water Supply for Future Generations	**Celeste Journey** **U.S. Geological Survey** Publically Accessible Decision Support System of the SPAtially Referenced Regressions on Watershed Attributes (SPARROW) Model and Model Enhancements in South Carolina	**Derek Hutton** **Clemson University** Analysis of the Impact of Climate Change on Stormwater Design Storms for the State of South Carolina	**Tim Lanier** **U.S. Geological Survey** Real-time Flow Monitoring of the Edisto River and Bushy Park Reservoir Water-Supply Tunnels in Charleston	**Paul Bradley** **U.S. Geological Survey** Effects of Treated Wastewater Effluent on Water-Quality, Sediment-Quality, and Biological Condition in Spirit Creek, Fort Gordon, Georgia
5:15	**Conference Closes**				

Letter from the Conference Co-Chairs

Welcome to the fourth biennial S.C. Water Resources Conference. The conference theme, "*Informing Strategic Water Planning to Address Natural Resource, Community and Economic Challenges*," represents a collaborative focus on the need for development of a statewide water plan for South Carolina. The morning plenary sessions on both days have been expanded to present panels encapsulating statewide viewpoints about water resources planning. The opening keynote plenary on the first day features legislative and business leaders, and the second day plenary welcomes state and federal regulatory and nonprofit agency directors.

Papers and posters have been actively solicited from colleges and universities; municipal water authorities and entities; environmental engineering, consulting and law firms; state and federal agencies; nonprofit organizations; economic development associations; utility companies and land trusts. This year's conference features 103 oral and 39 poster presentations. The presentations during these two days highlight the great care that must be taken with understanding and conserving the state's valuable natural resources. Discussions will focus on South Carolina's water policies, research and water management issues.

The past three conferences each brought together more than 300 participants to address statewide and regional water challenges. This year's conference will continue to advance water science and management in the state and region by again providing a neutral and open forum for diverse perspectives, which in turn will foster discussion for solutions to watershed management. The S.C. Water Resources Conference is coordinated by Clemson University's Institute of Computational Ecology, in conjunction with the Center for Watershed Excellence, and planned with a statewide committee of water resources professionals representing the major state universities, agencies and private groups in notable sectors. The conference represents a major collaboration by a wide-ranging group of organizations throughout South Carolina.

On behalf of the conference planning committee, we thank you for your involvement in, and support of, this year's conference.

Gene W. Eidson, Ph.D.
Conference Co-Chair

Calvin B. Sawyer, Ph.D.
Conference Co-Chair

Conference Dates and Proceedings

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Savannah River National Laboratory, *John J. Mayer, Michael Paller*
USDA Forest Service, *Devendra Amatya*
U.S. Army Corps of Engineers, *Colton Bowles*
U.S. Geological Survey, *Noel Hurley, Eric Strom*
University of South Carolina, *Gwendelyn Geidel*

Wednesday Reception and Poster Session

Where: Lower Level
When: 5:30 – 7:00 p.m.

Plenary Sessions

Wednesday 8:30 a.m.
"Informing Strategic Water Planning to Address Natural Resource, Community and Economic Challenges: *Legislative and Business Viewpoints"*
Moderator: Senator Paul G. Campbell, Jr. - Senate Agriculture and Natural Resources Committee Member

Legislative Panel:
Senator Daniel Verdin - Senate Agriculture and Natural Resources Committee Chairman
Senator Robert W. Hayes, Jr. - Senate Banking and Insurance Committee Chairman
Representative Nelson L. Hardwick - House Agriculture, Natural Resources and Environmental Affairs Committee Chairman
Representative David R. Hiott - Agriculture, Natural Resources and Environmental Affairs Committee Member

Business Panel:
Daniel F. Kassis - SCE&G, Vice President of Customer Relations and Renewables
Jeffrey G. Lineberger - Duke Energy, Director of Water Strategy and Hydro Licensing
Geoff Penland - Santee Cooper, Senior Attorney, State and Federal Government Affairs
Dyke Spencer - Powdersville Water District, Executive Director; SCAWWA Water Utility Council Past Chairman
David Winkles - S.C. Farm Bureau, President / CEO

Thursday 8:30 a.m.
"Informing Strategic Water Planning to Address Natural Resource, Community and Economic Challenges: *Regulatory and Nonprofit Viewpoints"*
Moderator: Gene W. Eidson, Ph.D. - SCWRC Co-Chair; Clemson University Institute of Computational Ecology and Urban Ecology Center Director

Regulatory Agency Panel:
Chris Thomas - U.S. EPA Region 4, Pollution Control and Implementation Branch Chief, Water Protection Division
Ken Rentiers - SCDNR, Deputy Director for Land, Water and Conservation
David Wilson - SCDHEC, Bureau of Water Chief

Nonprofit Panel:
Dana Beach - Coastal Conservation League, Executive Director
Hamilton Davis - Coastal Conservation League, Energy and Climate Director
Eric Krueger - The Nature Conservancy, South Carolina, Director of Science and Stewardship
Mark Robertson - The Nature Conservancy, South Carolina, Director
Heather Nix - Upstate Forever, Director of Clean Air and Water Program

Poster Presentations

The Poster Session is Wednesday, October 15 from 5:30 p.m. to 7:00 p.m. on the Lower Level. Posters will be displayed in assigned order as numbered below.

(* Denotes student posters.)

1. ***Afrin, Tanjina**, A.A. Khan, N.B. Kaye, F.Y. Testik
   Clemson University
   Numerical Model for Hydraulic Performance of Under-drained Perforated Pipe Surrounded by Loose Aggregate

2. ***Altman, Ekaterina**
   University of South Carolina
   Drought Indices in Decision-making Process of Drought Management

3. **Amatya, Devendra**, Charles R. Harrison, Carl C. Trettin
   USDA Forest Service
   Watershed Scale Effects on Water Quality Monitoring at Santee Experimental Forest, Coastal, SC

4. **Barley, Jeffrey**, Ryan Winston, Bill Hunt, Susan Libes
   Coastal Carolina University
   Bacteria Removal Efficiency of a Bioswale Located in Lockwood Folly, A Coastal Watershed in North Carolina

5. **Beckingham, Barbara**, Peter Grathwohl, Hermann Ruegner, Marc Schwientek, Bertram Kuch
   College of Charleston
   Integrated Monitoring of Particle-associated Transport of Persistent Organic Pollutants (PAHs as case study) in Contrasting Catchments in Southwest Germany

6. **Caflisch, Mary**, Chenille Williams
   Clemson University
   Celebrating Water by Hosting a Water Quality Festival

7. **Caldwell, Andral**, Kevin J. Conlon, Celeste A, Journey, William F. Falls
   U.S. Geological Survey
   Determination of Changes in Water Quality, Streambed Sediment, and Benthic Macroinvertebrates as a Result of Stormwater Runoff from Selected Bridges in South Carolina

8. **Caldwell, Andral**, Paul Conrads, John Shelton, Sara Brown
   U.S. Geological Survey
   Updates to the South Carolina Hurricane Storm-Tide Network - 2014

9. **Dillard, William C.**, H. Freeman Belser
   Belser & Belser, PA
   The Relationship Between Regulatory Protections and Common Law Water Rights in South Carolina

10. ***Drennan, Kathryn**, Dhanuska Wijesinghe, Dara Park, Sarah White, David White
    Clemson University
    Soil Temperature and Moisture Differentials from Concrete Sidewalks

11. ***Ellis, Kathryn**, Blaik Keppler, Greg Hoffmann, Sadie Drescher, April Turner
    North Inlet - Winyah Bay NERR
    Low Impact Development in Coastal South Carolina: A Planning and Design Guide

12. ***Evans, Tyler**, Alicia M. Wilson, Willard S. Moore
    University of South Carolina
    Groundwater Transport and the Freshwater-Saltwater Interface Below Beaches

13. ***Feng, Wenpeng**, Wenwu Tang, Charles Harrison, Devendra Amatya, Julie Arnold, Carl C. Trettin
    University of North Carolina at Charlotte
    The Development of an Advanced Web GIS Portal of Santee Experimental Forest

14. ***Ferons, Daniel P.**, Jane L. Guentzel, Andrew Heyes
    Coastal Carolina University
    A Comparison of Whole Body Mercury Concentrations of Mummichogs (Fundulus heteroclitus) and Atlantic Silversides (Menidia menidia) from Dunn Sound, S.C.

15. **Fuss, Karen**, Rich Viso, Paul Gayes
    Coastal Carolina University
    School of Coastal and Marine Systems Science at Coastal Carolina University: A Systems Science Approach to Resource Management

16. **Gellici, Joseph A.**, C.W. Clendenin, Jr., Robin L. Banner, Kyle J. Mohr
    S.C. Department of Natural Resources
    Establishment of a Permanent Groundwater Monitoring Site in Calhoun County, South Carolina

17. **Gregory, Scott**
Wildlands Engineering, Inc.
Neuse River Regional Watershed Plan

18. ***Gunning, Kristin**, Karen Fuss
Coastal Carolina University
New Assessment Tool for Bioretention Practices

19. **Harmon, Michele**, A. E. Bodie, K.A. Fettro, J.R. Yates
University of South Carolina Aiken
Tracking Fecal Pollution Sources in Sand River in the Upper Reaches of the Horse Creek Watershed in Aiken County, SC

20. ***Harrington, Jon**, K. Adem Ali
College of Charleston
Using Hyperspectral Remote Sensing Data to Determine Phytoplankton Density in the Coastal Waters of Long Bay, South Carolina

21. **Heintz, Melissa**
North Inlet - Winyah Bay NERR
Educating the adjacent communities of the North Inlet - Winyah Bay National Estuarine Research Reserve

22. ***Hughes, Andrea L. H.**, Alicia M. Wilson
University of South Carolina
Improving Radium-Based Tracer Techniques: Hydrologic Controls on Porewater Radium Activity

23. ***Kang, Yi**
University of South Carolina
Feasibility Study: Treatment of Poultry Processing Wastewater using Mitton Valve Cavitation Reactor Technology

24. **Kelly, Brian**, Sudhanshu Panda, Carl Trettin, Devendra Amatya
University of North Georgia
Assessment of the Reach and Ecological Condition of Freshwater Tidal Creeks in the Lower Coastal Plain, Charleston County, South Carolina with Advanced Geospatial Technology Application

25. ***LaPlaca, Stephanie**, Daniel Tufford, Warren Hankinson
University of South Carolina
Assessing the Spatial and Temporal Aspects of Buffer Capacity in Lake Wateree, South Carolina

26. ***Mhatre, Snehal**, Alan Johnson
Clemson University
Water for Electricity: Impacts of Habitat Degradation and Fragmentation on Freshwater Mussels

27. **Murphy, Patrick**, Nigel Kaye, Abdul Khan
Clemson University
Hydraulic Performance of Full Flowing Perforated Pipe Underdrains Surrounded by Loose Laid Aggregate

28. ***Pellett, Charles A**, David White, Nakisha Fouch
Clemson University
Digital Elevation Model (DEM) Error Propagation in Watershed Delineation

29. ***Qiao, Xin**, Ahmad Khalilian, Charles Privette, Young Han, Jose Payero
Clemson University
Soil Moisture Mapping Utilizing Space-Based GPS Technology Developed by NASA

30. ***Robinson, Reggie**, Mary Caflisch
University of South Carolina
LID: A survey and Assessment of BMP's for Richland County Developers

31. **Samadi, Seyedehzahra**, D. L. Tufford, G. J. Carbone
University of South Carolina
Improving Hydrologic Predictions of Distributed Watershed Model via Uncertainty Quantification of Evapotranspiration Methods

32. ***Sassard, Andrea**, Richard DeVoe, Susannah Sheldon, Timothy Callahan, Dianne Greenfield, Daniel Hitchcock, Richard Peterson, Erick Smith, April Turner, John Weinstein, Denise Sanger, Jeff Allen
South Carolina Sea Grant Consortium/
The Graduate School at the College of Charleston
Facilitating Stormwater Pond Research through Collaboration

33. ***Senn, Lauren**, Timothy J. Callahan, David C. Shelley, Joel Gramling, Courtney Murren
College of Charleston
Ecohydrology of a Floodplain Forest: Relationships between Evapotranspiration, Vegetation, and Topography at Congaree National Park, South Carolina

34. *__Thepaut, Benjami__n, John M. Shelton, Susan M. Libes
U.S. Geological Survey
The Tidal Reach and Distribution of Tidal Freshwater Forested Wetlands in the Waccamaw River, South Carolina

35. **Tufford, Daniel**, Setsen Altan-Ochir
University of South Carolina
Hydrogeomorphic and Landscape Influecnes on Dissolved Organic Matter in Streams and Rivers on the S.C. Coastal Plain

36. ***Vaughn, Sara**
College of Charleston
Measuring the Impact of Restored Shoreline from a Student-Driven Salt Marsh Restoration Program in South Carolina

37. **Wachob, Andrew**, Brenda L. Hockensmith, C. Scott Howard, Erin Koch
S.C. Department of Natural Resources
Potentiometric Surface Maps of the Middendorf, Black Creek, and Floridan Aquifers of South Carolina

38. **Werth, David**
Savannah River Nuclear Solutions
Climate Change Projection for the Department of Energy's Savannah River Site

39. ***Wijesinghe, Dhanuska**, C. Alex Pellett, Holly Garrett, David White, Dara M. Park
Clemson University
Defining Cover Management (C) and Length Slope (LS) Factors of RUSLE to Model Soil Erosion in Urban Landscapes

Exhibitors

Exhibits open Wednesday morning and end Thursday evening on the Lower Level outside the session break-out rooms (Lexington and Richland meeting rooms).

AMEC Environment and Infrastructure
Carolina Clear
Clemson University Center for Watershed Excellence
Clemson University Institute of Computational Ecology
Clemson University Strom Thurmond Institute – S.C. Water Resources Center
Coastal Carolina University's Waccamaw Watershed Academy
College of Charleston, Graduate Program in Environmental Studies
Duke Energy
Greenville Water
Normandeau Associates
S.C. Department of Natural Resources
S.C. Mitigation Association
S.C. Sea Grant Consortium
Santee Cooper
Sutron Corporation
Water Missions International (Hosted by Charleston Water System)
YSI, Inc.

Abstracts

* Denotes Student Presenters

***Afrin, Tanjina**, A.A. Khan, N.B. Kaye, F.Y. Testik
Clemson University

NUMERICAL MODEL FOR HYDRAULIC PERFORMANCE OF UNDER-DRAINED PERFORATED PIPE SURROUNDED BY LOOSE AGGREGATE (Poster)

Urbanization significantly alters the hydrological cycle, leading to reduced infiltration, increased flooding, and reduced water quality. Proper management of storm-water runoff is necessary to mitigate these undesired impacts, and the use of Best Management Practices (BMP) and Low impact development (LID) has become a common practice. Many LID strategies and BMPs use perforated pipes in various scenarios, for example, Porous Landscaping Detention Basin, rain-garden, bio-retention filter, porous pavements and sand filter. Increased use of such pipes in LID/BMP applications has led to higher interest in their hydraulic behavior. An experimental investigation was undertaken in a previous study to determine the relationship between the heights of water above the pipe and the resulting discharge for a trench under saturated subsurface flow i.e. where water surface level is higher than the top of the aggregate layer. For this setup, provided the pipe ran full, the system behaved like an orifice. However, that previous experimental work was limited in the range of parameters investigated due to experimental constraints. These parameter space limitations can be overcome by CFD modeling, and it is possible to come up with a complete stage-discharge relationship for the saturated scenario which should be applicable for all practical ranges of trench lengths and pipe diameters. This paper presents the result of a Computations Fluid Dynamics (CFD) study of the hydraulics of porous pipe under-drains. The study was conducted using a 3-D CFD model built in ANSYS FLUENT v14.5. The paper includes a model validation study and a broader parametric study. The CFD model was validated by replicating the previous experimental results of saturated flow for a 4 inch perforated pipe. The CFD model consistently over predicted the flow rate for a given head and aggregate depth. However, for most of the cases the difference between the CFD model and experimental results were less than 10%. Following the validation study, a parametric study was undertaken to examine the impact of pipe length, trench width, pipe diameter, and pipe wall inlet area on the hydraulic performance. Results indicate that for a given pipe and trench width the discharge increases linearly with pipe length up to a critical length. Beyond this critical length, simulation results did not indicate an increase in the flow rate with further increase in the pipe length. This result has practical applications in the design and analysis of LID porous pipe underdrains.

Albright, Ruth, Heather H. Smith, George M. Huddleston III
SynTerra

PCBS: OLD CHEMICALS PRESENT NEW CHALLENGES

Polychlorinated biphenyls (PCBs) were first developed in the U.S. in 1929 and used extensively in the manufacture of transformers, capacitors, and other heat transfer devices through the late 1970s. Because of mounting concern over potential toxicity to humans and wildlife, PCBs were banned from production in 1979. With the possible exception of known PCB waste sites such as Twelve Mile River on Lake Hartwell in Pickens County, South Carolina and the Upper Hudson River in New York, PCBs have largely faded from public consciousness as a contaminant of concern. This was largely true until stories starting breaking in late summer 2013 about the millions of dollars local wastewater treatment utilities were going to have to spend to clean up from unauthorized disposal of PCBs into upstate South Carolina sewer systems. What does this recent spate of illegal activity teach us about environmental risk and liability? Should managers of water resources consider changes in management of the resources they protect to address this activity or was it an isolated event? This presentation will provide a summary of the publicly available background information regarding the incidents and how the utilities in Upstate South Carolina have responded. Revisions made to public sewer ordinances in the wake of these events will be discussed, as well as the impact to private businesses that were targets of the unauthorized disposal. Potential implications for future economic impacts and considerations that water resources managers can incorporate into future plans and procedures will be addressed. Finally, consideration will be given of how this information may apply to a broader perspective of the possibility of other contaminants entering sewer systems and the subsequent implications.

***Altman, Ekaterina**
University of South Carolina

ANALYSIS OF DROUGHT INDICES AND DROUGHT STATUS DECLARATIONS: EXAMPLE OF SOUTH CAROLINA DROUGHT MANAGEMENT PROGRAM

Drought indices are one of the most important elements of an effective drought monitoring and early warning system that guide appropriate response in water management. Drought indicators are more useful than raw data in decision-making process, even though each index has specific applications and limited by its strengths and weaknesses. The literature review showed the evaluation of drought conditions by decision-makers as an important issue, but so far no research has been done to understand how decision-makers use diverse and often conflicting values of drought indices to make drought declarations. This research studies how drought declarations by decision-makers relate to drought indices to measure past two droughts in South Carolina, USA. The South Carolina Drought Response Committee (DRC), the state's major drought decision-making body, evaluates climate data and drought indices to issue drought status declarations for each county of the state. The state has one of the largest number of drought indicators among other state-level programs in the nation. This research analyses similarities and differences in measures of drought between the DRC and multiple drought indices, such as Palmer Drought Severity Index (PDSI), Palmer Hydrological Drought Index (PHDI), Z-index, Standardized Precipitation Index (SPI), Crop Moisture Index (CMI), Keetch-Byrum Drought Index (KBDI) and the U.S. Drought Monitor (USDM). Nine years of monthly values for each index are compared with the DRC declarations in a sample of five South Carolina counties in measuring drought onset, duration, severity and recovery. This research aims to benefit the

decision-making process for drought and water management as it informs drought assessment in the use of major drought indices. Effective use of drought indices in decision-making process enhances proactive drought management policies (risk management approaches) and assists in reduction of drought impacts with an ultimate goal of creating drought resilient societies.

***Altman, Ekaterina**
University of South Carolina

DROUGHT INDICES IN DECISION-MAKING PROCESS OF DROUGHT MANAGEMENT (Poster)

Drought indices are one of the most important elements of an effective drought monitoring and early warning system that guide appropriate response in water management. Drought indicators are more useful than raw data in decision-making process, even though each index has specific applications and limited by its strengths and weaknesses. The literature review showed the evaluation of drought conditions by decision-makers as an important issue, but so far no research has been done to understand how decision-makers use diverse and often conflicting values of drought indices to make drought declarations. This research studies how drought declarations by decision-makers relate to drought indices to measure past two droughts in South Carolina, USA. The South Carolina Drought Response Committee (DRC), the state's major drought decision-making body, evaluates climate data and drought indices to issue drought status declarations for each county of the state. The state has one of the largest number of drought indicators among other state-level programs in the nation. This research analyses similarities and differences in measures of drought between the DRC and multiple drought indices, such as Palmer Drought Severity Index (PDSI), Palmer Hydrological Drought Index (PHDI), Z-index, Standardized Precipitation Index (SPI), Crop Moisture Index (CMI), Keetch-Byrum Drought Index (KBDI) and the U.S. Drought Monitor (USDM). Nine years of monthly values for each index are compared with the DRC declarations in a sample of five South Carolina counties in measuring drought onset, duration, severity and recovery. This research aims to benefit the decision-making process for drought and water management as it informs drought assessment in the use of major drought indices. Effective use of drought indices in decision-making process enhances proactive drought management policies (risk management approaches) and assists in reduction of drought impacts with an ultimate goal of creating drought resilient societies.

Amatya, Devendra, Charles A. Harrison, Carl C. Trettin
USDA Forest Service

COMPARISON OF POTENTIAL EVAPOTRANSPIRATION (PET) USING THREE METHODS FOR A GRASS REFERENCE AND A NATURAL FOREST IN COASTAL PLAIN OF SOUTH CAROLINA

Potential evapotranspiration (PET) is a driving factor behind the estimates of ecosystem evapotranspiration (ET). Most of the PET methods with varying levels of complexity have been developed for a standard grass reference with unlimited soil moisture. There is only limited information examining the difference between the PET for a standard grass reference (REF-ET) and for a forest vegetation and their potential effects in water balance. Data being measured at three long-term complete weather stations located within < 10 km distance from each other on the USDA Forest Service Santee Experimental Forest (SEF) in coastal South Carolina are used in this study. The first two stations on grass reference are located at SEF headquarters (SHQ) and on Turkey Creek watershed (TC), and a third one is on a 27-m tall tower above the canopy of a pine/mixed hardwood forest on a control watershed (WS 80). In this study we evaluated (a) the observed micro-climatic conditions at those three stations and (b) the monthly and annual PET estimated by three methods with varying complexities (Penman-Monteith (P-M), Turc, and Thornthwaite (THORN)) using daily climatic data for a recent two-year (2011-2012) period. Average daily wind speed was observed to vary substantially (as much as 3 times) among the three locations, and average daily net radiation (Rn) on the WS 80 forest canopy was ~ 14% higher than the nearby SEF grass site. The effects of these differences were reflected in the PET results by the P-M method with much higher PET for the forest than the nearby grass site where the Turc method provided similar results with another grass site. Where possible and data were available, the results from these three methods were compared with pan evaporation estimates at SHQ. Results indicated that the PET estimates derived by these three methods for a single site and/or the estimates for nearby sites using a single method can vary greatly because of differences in their complexity of describing PET process, climatic factors and their interaction with site vegetation types. These differences should be considered when selecting a PET method and interpreting the results in hydrologic and water balance studies, especially for forested sites with much taller vegetation than the grass reference assumed in most PET methods in the literature.

Amatya, Devendra[1], Herbert Ssegane[2], Charles A. Harrison[1], Carl C. Trettin[1]
[1]USDA Forest Service, [2]Argonne National Laboratory

PRE- AND POST-HUGO EVENT HYDROGRAPH AND FLOW CHARACTERISTICS OF PAIRED FIRST ORDER FORESTED WATERSHEDS IN ATLANTIC COASTAL PLAIN

Coastal forests of the southern US have developed over time with hurricanes and tropical storms occurring as natural episodic events. Wind damage associated with hurricanes can alter the landscape by changing the vegetation canopy and reducing live biomass. These changes can lead to increased streamflow potentially due to decreased evapotranspiration (ET) thereby altering the water and chemistry budgets, including the streamflow dynamics. Using over 30 years of monthly rainfall and streamflow data linked with vegetation dynamics from a pair of 1st order coastal watersheds at the USDA Forest Service Santee Experimental Forest in South Carolina, a recently published study showed a significant transformation in the hydrologic character of the two watersheds soon after the passage of Hurricane Hugo in September 1989. The authors linked the change in this transformation to a catastrophic change in forest vegetation resulting in selective hurricane damage, and one of the watersheds was able to return to pre-hurricane levels of streamflow. There are limited data, however, on hurricane effects on streamflow dynamics in general. In this study

we identified 27 storm hydrographs from the 1969-1978 period before Hugo and 30 events from 2003-2010 post-Hugo period when the vegetation stands impacted by Hugo were regenerated on the paired watersheds, for the analysis of their peak flow rates, times to peak, event durations, event flow to rainfall ratios, initial flow rates, and water table depth in order to test the hypotheses that the event streamflow characteristics for each watershed and between the watersheds have returned back to pre-Hugo levels in this resilient coastal forest ecosystem. We also analyzed the daily flow duration curves using the 10 years (1969-1978) of pre-Hugo and 10 years (2004-2013) of post-Hugo data for the same paired watersheds to test for the return of flow magnitude of various frequencies and durations to pre-Hugo levels. Our preliminary results for the control watershed indicated that the Post-Hugo average time to peak of 15.9 hrs, peak flow rate of 0.46 m3 s-1, event duration of 187.5 hrs, and event outflow of 25.1 mm were also not significantly different from corresponding Pre-Hugo values of 17.1 hrs, 0.50 m3 s1, 204.1 hrs, and 22.9 mm, respectively, potentially indicating its flow dynamics returning to baseline levels. Additional analyses are being conducted to test these hypotheses. This type of information is necessary to accurately estimate fluxes and pollutant transport into receiving waters, for stormwater management, designing best management practices, and for ecosystem restoration in this region of the Atlantic Coastal Plain.

Amatya, Devendra, Charles R. Harrison, Carl C. Trettin
USDA Forest Service

WATERSHED SCALE EFFECTS ON WATER QUALITY MONITORING AT SANTEE EXPERIMENTAL FOREST, COASTAL, SC (Poster)

Understanding hydro-biogeochemical linkages between freshwater terrestrial and marine environment including tidal estuaries is fundamental to sustainable management of coastal plain forests and for addressing the water quantity and quality issues of the rapidly expanding wildland-urban interface. Long-term spatial and temporal data on both water quantity and quality are needed for understanding such linkages, assessing the health of waterbodies, habitat assessments, setting standards/criteria including the TMDL, ecosystem restoration, and trend analysis. Hydrologic monitoring on the 1st and 2nd order watersheds at USDA Forest Service Santee Experimental Forest and portions of the adjoining Francis Marion National Forest was established in the 1960's, and represent the only long-term hydrological database for relatively undisturbed forested wetland watersheds on southeastern Atlantic coastal plain. The 2004 revitalization of an adjacent 5,240 ha Turkey Creek watershed draining a 3rd order stream completed the development of a multi-scale monitoring framework The vegetation on these lowland watersheds represents the matured pine mixed hardwood forest stands regenerated since its impact by Hurricane Hugo in 1989. The minimal silvicultural treatments, except on the control watershed, include prescribed burning of understory biomass and whole tree thinning of selected stands for reducing fire hazard and habitat restoration.
In this study we summarize chemical and physical water quality parameters measured from 2006 until 2013 on four long-term experimental watersheds (WS 77 -treatment and WS 80 –control, both1st order, WS 79 – 2nd order, and WS 78 – 3rd order). The chemical parameters include TN, NH4-N, NO3 +NO2-N, TP, PO4, Cl, Ca, K, Mg, Na, DOC, Br, Si, and SO4 and stream temperature, pH, specific conductance, salinity, DO concentration and saturation as physical. All these and other related data can be accessed at http://www.srs.fs.usda.gov/charleston/santee/data.html. Chemical parameters were obtained from the laboratory analysis of the flow-proportional samples collected by ISCO 3700 samplers triggered by the Teledyne ISCO 4210 flow dataloggers at WS77, WS79, and WS80 gauging stations, and by Sutron 8210 datalogger at WS78 where flow is being monitored in collaboration with U.S. Geological Survey and College of Charleston. We computed the exploratory statistics including the seasonal variability and trends for these parameters. Statistical analyses were also conducted to test the differences, if any, among the means of each of the critical parameters on four watersheds. When used together with measured streamflow for calculating loadings, these information may serve as important resources for advancing the understanding of eco-hydrological linkages, management decisions and monitoring assessments on the coastal forest lands; they should also serve as reference data for comparison with more intensively managed forests, as well as for the protection and restoration of waterbodies/habitat and assessing allowable loading for receiving waters from similar lowland watersheds.

Barley, Jeffrey[1], Ryan Winston[2], Bill Hunt[2], Susan Libes[1]
[1]*Coastal Carolina University,* [2]*North Carolina State University*

BACTERIA REMOVAL EFFICIENCY OF A BIOSWALE LOCATED IN LOCKWOOD FOLLY, A COASTAL WATERSHED IN NORTH CAROLINA (Poster)

NC Department of Transportation (NCDOT) has obtained, through partnerships with the private sector, an engineered soil to enhance removal of fecal bacteria when used in conjunction with stormwater Best Management Practices, such as bioretention cells. The efficacy of this media is being tested at a site in Lockwood Folly, NC where a TMDL for fecal coliforms was approved by the NC Department of Natural Resources in 2010 to address shellfish harvesting impairments in the nearby estuary. Mechanisms for bacterial removal are attributed to: (1) retention of particles to which microbes adsorb and (2) mortality due to grazing by protozoans harbored by the soils. Funding is being provided by NC DOT as part of a program to evaluate pollutant removal efficiencies of various BMPs for road runoff treatment. NCDOT's NPDES permit requires the retrofit of 50 stormwater BMPs in each 5 year cycle; they optimize their retrofits through results of research. The results of this assessment work are of much interest to South Carolina due to the large number of monitoring sites with fecal bacteria impairments that are located in settings similar to the Lockwood Folly watershed, the relatively low cost of the media, and the option of retrofitting existing BMP's to enhance bacteria removal.
The test site at Lockwood Folly was constructed in 2012 by installing a 200-ft linear strip of media, 3-ft deep in a pre-existing stormwater swale that runs parallel to a secondary state road maintained by NCDOT. The removal efficiency of this bioswale is being evaluated by measuring bacteria transport into and out of the media during 18 storm events. For each event, flow-weighted samples are being collected

at the inlet and outlet of the bioswale using autosamplers outfitted with water-level sensors. The upstream autosampler is triggered by rainfall and downstream by a volumetric discharge threshold. The samples are being analyzed for two fecal indicator bacteria, Enterococcus and Fecal coliform, and for turbidity, total suspended solids, volatile suspended solids, and conductivity. Sample collection and processing is being performed by Coastal Carolina University's Environmental Quality Laboratory.

Beckingham, Barbara[1], Peter Grathwohl[2,3], Hermann Ruegner[3], Marc Schwientek[3], Bertram Kuch[3,4]
[1]College of Charleston, [2]Center for Applied Geoscience University of Tuebingen Germany, [3]Water Earth Systems Science Cluster Tuebingen Germany, [4]University of Stuttgart Germany

INTEGRATED MONITORING OF PARTICLE-ASSOCIATED TRANSPORT OF PERSISTENT ORGANIC POLLUTANTS (PAHS AS CASE STUDY) IN CONTRASTING CATCHMENTS IN SOUTHWEST GERMANY (Poster)

Strongly sorbing hydrophobic pollutants such as polycylic aromatic hydrocarbons (PAHs) are primarily subjected to particle-associated transport and thus are mobilized especially during high flow conditions when soils and sediments undergo erosion and urban runoff is intensified. Whereas soil pollutants reach rivers only slowly by erosion, untreated surface runoff from sealed urban space and stormwater releases are major immediate sources of particle-bound pollutants. Chemical loads to rivers in general may increase with increasing population density or urban development of watersheds due to abundance of sources and impervious surface. By monitoring monthly grab samples at locations within 5 neighboring river catchments we demonstrate strong linear correlations between total water concentrations of PAHs and total suspended solids, which indicates that TSS (or turbidity) could be a convenient measure for assessing particle associated fluxes of pollutants. We also find that loading of PAHs on particles is proportional to the urban pressure exerted on the catchment as represented by the catchment population normalized to particle mass flux. This relationship should be tested in catchments with more varied land use, geology and climate characteristics.

Bell, E.V.[1], Kimberly Counts Morganello[2]
[1]South Carolina Sea Grant Consortium, [2]Clemson University Cooperative Extension Service

FROM SEEDS TO SHORELINE: ENGAGING STUDENTS IN SALT MARSH RESTORATION

South Carolina is home to 2,876 miles of coastline and an estimated 350,000 acres of salt marsh. The salt marsh is one of the most productive ecosystems in the world providing a range of benefits including water quality improvement, storm surge protection, and a nursery ground for numerous marine species. As the human population continues to increase along the South Carolina coast, negative impacts to this critical ecosystem occur largely as a result of stormwater runoff associated with increased urban area. In order to protect the health of the salt marsh, there is a need to address sources of pollution found in stormwater runoff through targeted community education and involvement opportunities. From Seeds to Shoreline (S2S) is a South Carolina-based youth wetland restoration initiative that teaches stewardship of the salt marsh ecosystem through seed collection, germination, cultivation and transplantation of Spartina alterniflora, the dominant plant in southeastern salt marshes. As a pre-requisite to participation in the S2S program, summer teacher workshops provide the tools necessary to execute S2S effectively and autonomously during the upcoming school year. Teachers receive starter kits, educational resources, renewal credits and assistance in developing an implementation plan unique to their individual school needs. S2S spans the length of the school year, is aligned with state science standards, encourages student-driven science investigations, and culminates in a Restoration Day where students transplant their young Spartina altnerniflora seedlings to areas along South Carolina's coastline. S2S is the first student-driven wetland restoration project in South Carolina, providing an opportunity for community service-learning with emphasis on environmental stewardship and is coordinated by the South Carolina Sea Grant Consortium in partnership with Clemson Cooperative Extension Service and the South Carolina Department of Natural Resources. Since the piloting of the program in 2011, S2S has grown from 16 teachers, 8 schools, and 700 students to 27 schools, 18 schools, and more than 1200 students.

Benedict, Stephen, Andral Caldwell, Toby D. Feaster
U.S. Geological Survey

A GUIDANCE MANUAL FOR ASSESSING SCOUR POTENTIAL USING THE SOUTH CAROLINA BRIDGE-SCOUR ENVELOPE CURVES

The U.S. Geological Survey, in cooperation with the South Carolina Department of Transportation, conducted a series of three field investigations of bridge scour in order to better understand regional trends of scour within South Carolina. The studies collected historic-scour data at approximately 200 riverine bridges including measurements of clear-water abutment, contraction, and pier scour, as well as live-bed contraction and pier scour. These investigations provided valuable insights for regional scour trends and yielded bridge-scour envelope curves for assessing scour potential associated with all components of scour at riverine bridges in South Carolina. The application and limitations of these envelope curves were documented in three reports. Each report addresses different components of bridge scour and thus, there is a need to develop an integrated procedure for applying the South Carolina bridge-scour envelope curves. To address this need, the U.S. Geological Survey and the South Carolina Department of Transportation initiated a cooperative effort to develop an integrated procedure and document the method in a guidance manual. In addition to developing the integrated procedure, field data from other investigations outside of South Carolina were used to verify the South Carolina bridge-scour envelope curves.

Benedict, Stephen
U.S. Geological Survey

ASSESSMENT OF THE NCHRP ABUTMENT-SCOUR PREDICTION EQUATIONS WITH LABORATORY AND FIELD DATA

The U.S. Geological Survey, in cooperation with the National Cooperative Highway Research Program (NCHRP) is assessing the performance of several abutment-scour prediction equations developed in NCHRP Project 24-15(2) and NCHRP Project 24-20. To accomplish this assessment, 516 laboratory and 329 field measurements of abutment scour were compiled from selected sources and applied to the new equations. Results will be used to identify strengths, weaknesses, and limitations of the NCHRP abutment-scour equations, providing practical insights for applying the equations. This paper presents some preliminary findings from the investigation.

Bowles, Colt, Dudley Patrick
U.S. Army Corps of Engineers

I'M FROM THE FEDERAL GOVERNMENT AND AM HERE TO HELP: EXTENDING LOCAL RESOURCES THROUGH PARTNERING WITH THE CORPS IN ADDRESSING WATER RESOURCE CONCERNS

Partnering with the US Army Corps of Engineers through the Continuing Authorities Program (CAP), the Planning Assistance to States Program (PAS), or through a General Investigation (GI) study, are means to leverage existing resources into federal cost share to address water related issues through planning efforts, feasibility studies, and implementation efforts. Corps of Engineer projects usually requires a non-Federal partner who will cost share in the project. Through cost sharing, the Corps will match local resource contribution, thus doubling the amount of funds available for a particular project. This presentation will detail the Corps Civil Works Mission, what is allowed through specific authorities, cost sharing options, and how to request Corps assistance to address local water related issues. Examples of South Carolina projects will also be discussed.

Bradley, Paul, Celeste A. Journey
U.S. Geological Survey

EFFECTS OF TREATED WASTEWATER EFFLUENT ON WATER-QUALITY, SEDIMENT-QUALITY, AND BIOLOGICAL CONDITION IN SPIRIT CREEK, FORT GORDON, GEORGIA, USA

The USGS is conducting a combined pre/post-closure assessment at a long-term wastewater treatment facility (WWTP) site at Fort Gordon near Augusta, Georgia. Here we assess select endocrine active chemicals and benthic macroinvertebrate community structure prior to closure of the WWTP. Substantial downstream transport and limited in-stream attenuation of endocrine-disrupting-chemicals (EDC) was observed in Spirit Creek over a 2.2-km stream segment downstream of the WWTP outfall. A modest decline (less than 20% in all cases) in surface-water detections was observed with increasing distance downstream of the WWTP and attributed to partitioning to the sediment. Estrogens detected in surface-water in this study included estrone (E1), 17β-estradiol (E2), and estriol (E3). The 5 ng/L and higher mean estrogen concentrations observed in downstream locations indicated that the potential for endocrine disruption was substantial. Concentrations of alkylphenol ethoxylate (APE) metabolite EDC also remained statistically elevated above levels observed at the upstream control site. Wastewater-derived pharmaceutical and APE metabolites were detected in the outflow of Spirit Lake, indicating the potential for EDC transport to aquatic ecosystems downstream of Fort Gordon. The results indicate substantial EDC occurrence, downstream transport, and persistence under continuous supply conditions and provide a baseline for a rare evaluation of ecosystem response to WWTP closure. The post-closure ecosystem response will be presented.

Bradley, Paul[1], Bill A. Battaglin[1], Luke Iwanowicz[1], William T. Foreman[1], Edward T. Furlong[1], Frank Henning[2], Terry Hogan[2], Celeste A. Journey[1], Dana W. Kolpin[1], David Shelley[2]
[1]U.S. Geological Survey, [2]U.S. National Park Service

HORMONES, PHARMACEUTICALS AND OTHER CONTAMINANTS OF EMERGING CONCERN IN WATER AND SEDIMENT FROM CONGAREE NATIONAL PARK

The U.S. National Park Service (USNPS) is tasked with protecting parklands to "…leave them unimpaired for the enjoyment of future generations." Contaminants of emerging concern (CEC), in general, and endocrine disrupting chemicals (EDC), in particular, have been identified as USNPS environmental priorities. EDC threaten the reproductive success and long-term survival of sensitive aquatic populations. For example, environmental release of EDC can induce male vitellogenin (egg yolk protein) expression, skewed sex ratios and intersex characteristics, degraded predator avoidance behavior, as well as reproductive failure and population collapse in sensitive fish species at concentrations that have previously been documented in wastewater effluent and effluent-impacted surface water systems. The USGS Toxic Substances Hydrology Program's Emerging Contaminants Project is working with the USNPS to assess EDC risk in individual Parks and in Park Monitoring Networks. Congaree National Park (CONG, http://www.nps.gov/cong/index.htm) was designated the nation's 57th National Park in 2003 and is part of the International Biosphere Reserve network. CONG protects nearly 10,900 ha of forested floodplain, including the largest contiguous tract of old-growth bottomland forest remaining in North America. CONG is composed almost entirely of floodplain and aquatic environments (greater than 90 percent riparian wetlands coverage) and is located downstream of several major metropolitan areas and associated wastewater treatment plants. Wastewater EDC pose particular threats to aquatic ecosystems due to widespread releases of treated wastewater to surface water either directly or indirectly via bank filtration systems and episodic releases of untreated wastewater via surface runoff or combined sewer overflows. USGS-USNPS reconnaissance sampling conducted in 2010, documented the presence of wastewater compounds in primary surface-water sources to CONG, indicating that wastewater contaminant compounds are reaching Park aquatic habitats from external sources. In 2013, water and sediment samples were collected from 15 sites throughout the Park. Water samples were analyzed for total estrogenic activity (BLYES), 19 hormones, 110 pharmaceutical compounds, and 69 wastewater

indicator compounds. Sediment samples were analyzed for 19 hormones and 57 wastewater indicator compounds. Preliminary results indicate a wide range of CEC, including EDC, are present in water and sediment in high visitation, front country locations as well as in remote locations in the Park, suggesting multiple contaminant sources.

Caflisch, Mary[1], Chenille Williams[2]
[1]Clemson Extension, [2]Richland County Stormwater Management
CELEBRATING WATER BY HOSTING A WATER QUALITY FESTIVAL (Poster)
Capturing the attention of people across a wide age range can be challenging, even on a topic as important as water quality. How do you bring together a diverse crowd and have them leaving with more awareness of local water quality issues than when they arrived? With a water quality festival! Festivals are a useful mechanism for disseminating information to the broader public. They educate participants about local water quality while fostering an improved relationship with waterways and building stewardship. Hosting a festival presents many challenges, but lessons learned from Summer Celebration of Water ensure the return of a more aware and more active public. Annually, Richland County, City of Columbia and Lexington County host Summer Celebration of Water, a festival that encourages stewardship by building appreciation and understanding of local water resources. Held in Columbia, S.C. in August - National Water Quality Month - Summer Celebration of Water attracts guests from across the Midlands who come to learn about local watersheds and the importance of conserving and protecting water resources. Although the primary target audience is families with children, the activity-filled festival attracts people of all ages. Attendees not only enjoy entertainment and interactive activities from a variety of local exhibitors, but they also have the opportunity to participate in a variety of water activities including kayaking, tubing, and stand-up paddle boarding—many for the first time. The festival is now in its fifth year of implementation and its size and success brings stories and lessons to share. The proposed poster will address planning the festival, its community impact, building partnerships across government agencies, creating interactive and educational attractions, recruiting volunteers, and advertising. The poster will also address evaluation—another important element of a successful education and outreach effort. At Summer Celebration of Water, written and online surveys are used as indicators of knowledge gained, anticipated behavior change, and which activities and messages were effective. Experiences and survey data from each year's festival shape the following year's event.

Caldwell, Andral, Kevin J. Conlon, Celeste A, Journey, William F. Falls
U.S. Geological Survey
DETERMINATION OF CHANGES IN WATER QUALITY, STREAMBED SEDIMENT, AND BENTHIC MACROINVERTEBRATES AS A RESULT OF STORMWATER RUNOFF FROM SELECTED BRIDGES IN SOUTH CAROLINA (Poster)
In South Carolina, stormwater runoff from highways may be treated by structural or non-structural systems. Some stormwater may enter receiving waters without treatment such as from bridge deck scuppers. The impact of this discharge, if any, may be driven by the daily traffic volume or atmospheric deposition from surrounding industry. Even though numerous studies have been conducted to analyze the impacts of stormwater from highways and, to a lesser extent, bridges to receiving waters, no specific studies have been conducted in South Carolina. In June 2013, the U.S. Geological Survey (USGS), in cooperation with the South Carolina Department of Transportation, began a 4.75-year investigation in South Carolina to quantify the downstream changes in receiving water-quality conditions during periods of observable stormwater runoff from six selected bridge deck locations in South Carolina. The information collected might help to estimate or predict changes in water quality at bridge crossings with similar characteristics. Additionally, comparison of sediment-quality conditions and benthic macroinvertebrate community structure at upstream and downstream locations from selected bridge decks will assess cumulative impact of bridge deck runoff effects on receiving water. Data collection began in January 2014. Data will be collected from two bridges during calendar years 2014, 2015, and 2016. Data analysis will be ongoing throughout the data-collection phase and during part of calendar year 2017, and a USGS Scientific Investigations Report is scheduled to be published in 2018. Preliminary findings to date will be provided in the conference poster.

Caldwell, Andral[1], Paul Conrads[1], John Shelton[1], Sara Brown[2]
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UPDATES TO THE SOUTH CAROLINA HURRICANE STORM-TIDE NETWORK – 2014 (Poster)
Preventing flood hazards, such as the hurricane induced storm-tide, from becoming human disasters requires an understanding of the relative risks that floods pose to specific communities, and knowledge of the processes by which flood waters rise, converge, and abate. It is critical that the timing, magnitude, and duration of hurricane storm tide are accurately measured. The U.S. Geological Survey - South Carolina Water Science Center (USGS-SCWSC), in cooperation with various municipal, state, and Federal cooperators, uses three monitoring approaches for measuring hurricane storm-tide dynamics. The USGS currently (2014) maintains a network of 47 real-time water-level and water-quality gages along the South Carolina coast. The gages record water level, specific conductance, temperature, and (or) dissolved oxygen at 15-minute intervals, and are available on the web with a maximum of a 1-hour time delay. The real-time network is maintained to monitor a large range of hydrologic conditions from droughts to floods, and provide the data on the web for a broad base of stakeholders. In addition to the real-time network, the USGS-SCWSC, in cooperation with the U.S. Army Corps of Engineers - Charleston District and the South Carolina Department of Transportation, established a hurricane storm-tide monitoring network for South Carolina. The network is designed for a cost-effective and time-efficient monitoring of hurricane storm-tide. Currently (2014), the hurricane storm-tide network consists of 63 sites distributed along the South Carolina coast. At each site, a bracket for a water-level sensor has been attached to a permanent structure, such as a bridge pier. The elevation of the bracket has been determined by

differential surveying to a benchmark of known elevation. In the event of a storm, the sensors are attached to the bracket and the timing, duration, and magnitude of the storm tide is recorded. Upon retrieval of the sensors, there is minimal delay in disseminating the storm-tide elevation data to interested agencies and coastal resource managers because the water-level data are easily adjusted to mean sea level. These two fixed networks can be augmented with real-time rapid deployment gages and the temporary deployment of pressure transducers attached to bridge piers or other substantial structures to provide more spatially dense monitoring of hurricane storm tide. For example, temporary deployment of sensors in the projected hurricane path can be placed to monitor the attenuation of the hurricane storm tide along coastal rivers and across barrier islands, low-lying areas, and wetlands. After the passing of a storm, the locations of the temporarily deployed sensors must be surveyed to a known elevation. The USGS has successfully deployed temporary storm-tide networks for Hurricanes Rita (2005), Wilma (2005), Gustav (2008), Ike (2008), Irene (2011), Isaac (2012), Sandy (2013) and Tropical Storm Ernesto (2006). The 110 monitoring sites for the two fixed networks, with the addition of temporarily deployed sites, provide a cost-effective hurricane storm-tide monitoring network for South Carolina. The combined networks effectively leverage resources of over 10 cooperative funding agencies in South Carolina for monitoring hurricane storm tide.

Campbell, Bruce, James E. Landmeyer
U.S. Geological Survey

GROUNDWATER AVAILABILITY IN THE CROUCH BRANCH AND MCQUEEN BRANCH AQUIFERS, CHESTERFIELD COUNTY, SOUTH CAROLINA, 1900-2012

Chesterfield County is located in the northeastern part of South Carolina along the southern border of North Carolina and is primarily underlain by unconsolidated sediments of Late Cretaceous age and younger of the Atlantic Coastal Plain. Approximately 20 percent of Chesterfield County is in the Piedmont Physiographic Province, and this area of the county is not included in this study. These Atlantic Coastal Plain sediments compose two productive aquifers: the Crouch Branch aquifer that is present at land surface across most of the county and the deeper, semi-confined McQueen Branch aquifer. Most of the potable water supplied to residents of Chesterfield County is produced from the Crouch Branch and McQueen Branch aquifers by a well field located near McBee, South Carolina, in the southwestern part of the county. The primary purpose of this study was to determine groundwater-flow rates, flow directions, and changes in water budgets over time for the Crouch Branch and McQueen Branch aquifers in the Chesterfield County area. This goal was accomplished by using the U.S. Geological Survey finite-difference MODFLOW groundwater-flow code to construct and calibrate a groundwater-flow model of the Atlantic Coastal Plain of Chesterfield County. The model was created with a uniform grid size of 300 by 300 feet to facilitate a more accurate simulation of groundwater-surface-water interactions.
The calibrated groundwater-flow model was then used to calculate groundwater budgets for the entire study area and for two sub-areas. The sub-areas are the Alligator Rural Water and Sewer Company well field near McBee, South Carolina, and the Carolina Sandhills National Wildlife Refuge acquisition boundary area. For the overall model area, recharge rates vary from 56 to 1,679 million gallons per day (Mgal/d) with a mean of 737 Mgal/d over the simulation period (1900-2012). The simulated water budget for the streams and rivers varies from 653 to 1,127 Mgal/d with a mean of 944 Mgal/d. The simulated "storage-in term" ranges from 0 to 565 Mgal/d with a mean of 276 Mgal/d. The simulated "storage-out term" has a range of 0 to 552 Mgal/d with a mean of 77 Mgal/d. Groundwater budgets for the McBee, South Carolina, area and the Carolina Sandhills National Wildlife Refuge acquisition area had similar results. An analysis of the effects of past and current groundwater withdrawals on base flows in the McBee area indicated a negligible effect of pumping from the Alligator Rural Water and Sewer well field on local stream base flows. Simulated base flows for 2012 for selected streams in and around the McBee area were similar with and without simulated groundwater withdrawals from the well field. Removing all pumping from the model for the entire simulation period (1900-2012) produces a negligible difference in increased base flow for the selected streams. This abstract presents the partial findings of a multi-year study of the groundwater resources and groundwater quality of the Atlantic Coastal Plain aquifers of Chesterfield County, South Carolina.

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DEVELOPMENT OF A REGULATORY LEVEL WATER QUALITY MONITORING PROGRAM FOR ENTEROCOCCI IN RECREATIONAL WATERS OF CHARLESTON, SOUTH CAROLINA

Recreation in waters contaminated with fecal pollution poses a public health risk. Routine monitoring of fecal pollution is resource intensive and development of new water quality monitoring programs is a complex process. The South Carolina Department of Health and Environmental Control (DHEC) routinely monitors beaches for levels of enterococci pursuant to the Beaches Environmental Assessment and Coastal Health Act and notifies the public accordingly. The Cooper River Basin's tidal creeks and rivers are also frequently used for primary contact recreation by residents and visitors who may be unaware of fecal pollution. Charleston Waterkeeper, an environmental nonprofit organization in Charleston, South Carolina, sought to establish a regulatory level Recreational Water Quality Monitoring Program (RWQMP) to monitor enterococci at multiples sites in the Cooper River Basin. Accordingly, the RWQMP was designed to produce high quality data used to 1) inform the public concerning the quality of waterways for primary contact recreation, and 2) assist in formulation of the South Carolina 303(d) list of impaired waters. To ensure quality of the data produced from this program, two critical components needed establishment: a DHEC approved quality assurance project plan (QAPP) and a laboratory certified for analyzing enterococci. The QAPP is an official document outlining the entire scope of a project and serves as both a training manual and a reference for project personnel. Charleston Waterkeeper partnered with the College of Charleston's Department of Geology to certify the Hydrochemistry Laboratory. The lab was outfitted with the necessary equipment, materials, and methodologies in adherence with DHEC certification standards. The RWQMP began officially in July 2013 with DHEC approval, and

the Hydrochemistry Laboratory obtained certification in September 2013. RWQMP data are submitted to DHEC annually to be used in formulation of the subsequent biennial 303(d) list. The detailed report of RWQMP development aims to serve as an example for other environmental organizations attempting to produce similar programs.

Chapelle, Francis[1], Mark A. Widdowson[2]
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MODELING LONG-TERM TRENDS OF CHLORINATED ETHENE CONTAMINATION AT A PUBLIC SUPPLY WELL

A mass-balance solute-transport modeling approach was used to investigate the effects of dense non-aqueous phase liquid (DNAPL) volume, composition, and generation of daughter products on simulated and measured long-term trends of chlorinated ethene concentrations at a public supply well. The model was built by telescoping a calibrated regional three-dimensional MODFLOW model to the capture zone of a public supply well that has a history of chlorinated ethene contamination. The local model was then used to simulate the interactions between naturally-occurring organic carbon that acts as an electron donor, and dissolved oxygen (DO), chlorinated ethenes (CEs), ferric iron, and sulfate that act as electron acceptors using the Sequential Electron Acceptor Model in three dimensions (SEAM3D) code. The modeling results indicate that asymmetry between rapidly rising and more gradual falling concentration trends over time suggests a DNAPL rather than a dissolved source of CEs. Peak concentrations of CEs are proportional to the volume and composition of the DNAPL source. The persistence of contamination, which can vary from a few years to centuries, is proportional to DNAPL volume but is unaffected by DNAPL composition. These results show that monitoring CE concentrations in raw water produced by impacted public supply wells over time can provide useful information concerning the nature of contaminant sources and the likely future persistence of contamination.

Childress, Michael
Clemson University

GOING WITH THE FLOW - FORECASTING THE IMPACT OF CLIMATE CHANGE ON BLUE CRABS

Blue crabs are one of the most important commercial fisheries in South Carolina, but landings have declined during recent droughts. Climate forecast models suggest that in the Southeastern US, we can expect our future climate to be wetter, hotter and more variable than in the past, with a net decrease in freshwater surface flow. To better understand the complex interaction of climate change on river flow and blue crab abundance, we used a spatially-explicit, individual-based population model (ACE-SCBCRABS) parameterized from field observations of water quality, crab abundance, predation, disease, and fishing effort collected in the ACE Basin National Estuarine Research Reserve. In this study, we explored how changes in river flow under future scenarios of climate change might impact blue crabs landings over the next 75 years. We examined how the rate of freshwater flow decrease and the degree of inter-annual flow variability might interact to influence crab abundance, commercial landings, and disease. Models were run for 150 years beginning with flow rates observed in 1940 and projecting forward in time to the year 2090. Decreasing freshwater flow and increasing inter-annual variability both caused a significant decrease in crab landings. Models run under 1940 conditions of flow decline and variability show crab landings at our current harvest level. Models run under 1975 conditions of flow decline and variability show a reduction in crab landings of 30%. Models run under 2010 conditions of flow decline and variability show a reduction in crab landings of 76%. These results suggest that current levels of freshwater decline and inter-annual variability there is a 29% risk of collapse for the South Carolina blue crab fishery by the year 2090.

Clark, Jimmy
U.S. Geological Survey

BATHYMETRY AND WATER QUALITY IN TABLE ROCK AND NORTH SALUDA RESERVOIRS UTILIZING AN AUTONOMOUS UNDERWATER VEHICLE

Greenville Water provides drinking water to more than 450,000 residents in the Upstate region of South Carolina. The water authority obtains its drinking water from three surface water supplies: Table Rock Reservoir, North Saluda (Poinsett) Reservoir, and Lake Keowee. Detailed assessments of bathymetry for the Table Rock and North Saluda Reservoirs to determine the current storage capacities of the reservoirs are important for management/planning of the drinking water supply. The U.S. Geological Survey (USGS) South Carolina Water Science Center, in cooperation with Greenville Water, conducted bathymetric, water quality, and imaging surveys of Table Rock and North Saluda Reservoirs utilizing the EcomapperTM Autonomous Underwater Vehicle. In addition, digital echo-sounding equipment with differential global positioning system techniques were used for quality control at specified transects and along the shoreline where the Ecomapper Autonomous Underwater Vehicle could not efficiently obtain data. The datasets were used to produce digital bathymetric maps and water-quality analysis. Bathymetric maps for both reservoirs will be published as USGS Scientific Investigations Maps.

Conlon, Kevin, Celeste Journey
U.S. Geological Survey

CHARACTERIZATION OF STORMWATER AT SELECTED SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION MAINTENANCE YARDS AND SECTION SHED FACILITIES IN BALLENTINE, CONWAY, AND NORTH CHARLESTON, SOUTH CAROLINA, 2010-12

The South Carolina Department of Transportation operates section shed and maintenance yard facilities throughout the State of South Carolina. Prior to this investigation, the South Carolina Department of Transportation had no data to define the quality of stormwater leaving these facilities. To provide these data, the U.S. Geological Survey (USGS), in cooperation with the South Carolina Department of Transportation, conducted an investigation to identify and quantify constituents that are transported in stormwater runoff from two maintenance yards and a section shed in three different areas of South Carolina. The two maintenance yards, located in North Charleston and Conway, South Carolina, represent facilities where equipment and road maintenance materials are stored and complete equipment

repair operations are conducted. The section shed, located in Ballentine, South Carolina, is a facility that stores equipment and road maintenance material. Flow measurements and storm samples for water-quality analysis were collected at these sites over a 23-month period (from March 2010 to January 2012) that represented a range of seasons and rainfall intensities. A total of 44 sample sets were collected as flow-weighted composites to provide event-mean concentrations. In addition, each set included grab samples that were collected to provide the "first-flush" concentrations of volatile organic compounds, 5-day biochemical oxygen demand, and fecal indicator bacteria. Over the 23-month sampling period, sample collection targeted one sample per season (winter, spring, summer, and fall) at each site as a flow-weighted composite until a total of eight samples were collected at each location. Sample-collection methods are described in the U.S. Geological Survey and U.S. Environmental Protection Agency Environmental Technology Verification (ETV) protocols. Samples were collected from runoff events resulting from rainfall exceeding 0.10 inch and at least 72 hours after the previously measurable (greater than 0.10 inch of rainfall) storm event recorded at each site. These samples were analyzed for selected constituents including suspended sediment, total suspended solids, turbidity, 5-day biochemical oxygen demand, chemical oxygen demand, selected metals, nutrients, volatile organic compounds, pesticides, herbicides, and polyaromatic hydrocarbons. Flow measurements were made at the time of sampling in order to composite the samples and compute the constituent load leaving the sites for each event. Rainfall data were collected with a tipping bucket raingage at each site and transmitted by satellite. In addition to providing information on instrumentation and data-collection procedures, this presentation will include discussion of laboratory results that are provided in the recently released USGS Scientific Investigations Report titled, "Characterization of stormwater at selected South Carolina Department of Transportation maintenance yard and section shed facilities in Ballentine, Conway, and North Charleston, South Carolina, 2010-2012," which can be accessed at <http://pubs.usgs.gov/sir/2013/5175/>.

Conrads, Paul[1], Donald DeAngelis[2], Thomas J. Smith, III[2], Marshall C. Sasser[3]
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ASSESSING THE PAST AND POTENTIAL FUTURE IMPACTS OF SALTWATER INTRUSION ON TIDAL SWAMP HABITAT ALONG THE SOUTH ATLANTIC COAST

Coastal habitat mosaics distributed across salinity gradients are susceptible to saltwater intrusion caused by sea-level rise (SLR), land surface subsidence, and decreased freshwater flow to the coast. Sea-level rise and storm-surge overwash could have acute and long-term effects on vegetation and on soil and groundwater salinities, posing risks of habitat loss critical to native species. Tidal freshwater swamps along the southeast Atlantic Coast are particularly vulnerable to these stressors, with implications for local wildlife populations and value of the ecosystem services that they provide. A multi-disciplinary approach is needed to accurately predict changes in tidal freshwater swamps and other components of coastal habitat mosaics that may occur in this region due to a changing climate, human developmental pressures and SLR. This project seeks to develop a widely applicable methodology for predicting changes in coastal habitat that utilizes investigations of past changes in habitat, hydrologic simulations, and process-based models of ecotonal responses to fluctuating salinity and water levels. The work will focus on the Waccamaw National Wildlife Refuge (WNWR). The primary objectives of the study are: 1) to investigate past changes in the aerial extent of tidal freshwater swamps utilizing historical aerial photogrammetry, satellite imagery, and (or) recent vegetation mapping efforts; 2) to develop a coupled hydro-dynamic and vegetation model at representative locations within the WNWR; 3) to model salinity and water levels at gaging stations located within and around the WNWR using Artificial Neural Network (ANN) techniques; and 4) to develop a methodology for forecasting potential changes in ecotonal boundaries between tidal swamps and herbaceous oligohaline marshes utilizing predictions of SLR and changing freshwater inflows. To predict habitat effects from a set of possible precipitation and SLR scenarios, two U.S. Geological Survey (USGS) spatially explicit models; a model of vegetation community dynamics along coastal salinity gradients (Mangrove-hammock-marsh interactions model, MANHAM), and a USGS groundwater model (Saturate-Unsaturated Transport, SUTRA) will be used. MANHAM simulates the competition of vegetation types on an N by N grid of spatial cells at cell resolutions of 1 to 10 meters. It simulates interaction of vegetation with hydrology and salinity dynamics in the vadose zone. The environmental factors of precipitation, groundwater salinity, and tides are external drivers on daily time steps. The MANHAM has been used to examine the impact of SLR on coastal vegetation of southern Florida. The presentation will describe the applications and preliminary results of the SUTRA and MANHAM models to the wetlands of the WNWR, integration of the ANN simulation of water levels and salinity, and long-term vegetative analysis using historical aerial photogrammetry.

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DEVELOPMENT OF A REAL-TIME SALINITY DROUGHT INDEX

The location of the freshwater-saltwater interface in surface water bodies along the coast is an important factor in the ecological and socio-economic dynamics of coastal communities. Salinity is a critical coastal response variable that integrates hydrologic and coastal dynamics including streamflow, precipitation, sea level, tidal cycles, winds, and tropical storms. The position of the interface determines the freshwater and saltwater aquatic communities and the freshwater availability for municipal and industrial water intakes. Freshwater tidal marshes support larger biodiversity than brackish and saltwater tidal marshes. Many definitions of drought have been proposed, with most describing a decline in precipitation having negative impacts on water supply and agriculture. Four general types of drought are recognized: hydrological, agricultural, meteorological, and socio-economic. Indices have been developed for these drought types incorporating data such as rainfall, streamflow, soil moisture, groundwater levels, and snow pack. These drought indices were developed for upland areas and may not be appropriate indices for characterizing drought in coastal

areas. Because of the uniqueness of drought impacts on coastal ecosystems, a need exists to develop a coastal drought index. The availability of many real-time and historical salinity datasets provides an opportunity to leverage these datasets for the development of a salinity-based coastal drought index. The challenge for the salinity data analysis is to characterize the salinity dynamics in response to drought while excluding responses attributable to the occasional saltwater intrusion event. Determining the best analytical approach was a discovery process of applying various statistical and numerical techniques to evaluate which techniques are most appropriate to developing salinity drought indices. The presentation will provide an overview of the development of a coastal drought index and present results for selected sites along the South Carolina coast.

Counts, Kimberly A.[1], C. Guinn Garrett[1], Leslie Wooten[2]
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RAINWATER HARVESTING: A COMMUNITY-BASED PROGRAM APPROACH AS A VEHICLE FOR INCREASING STORMWATER AWARENESS

To encourage audience engagement in stormwater best management practices, the Ashley Cooper Stormwater Education Consortium (ACSEC) and Clemson Cooperative Extension's Carolina Clear program have implemented a diverse outreach campaign with a focus in rainwater harvesting. Rainwater harvesting is considered a unique vehicle to engage audiences with a larger message about stormwater runoff pollution, especially with respect to stormwater quality and quantity impacts from impervious surfaces. Since 2008, multiple education methods have been employed to help improve awareness of rainwater harvesting and overcome known barriers. These efforts were made possible through partner collaboration involving nonprofit organizations, universities, state government and the private sector. Numerous permanent exhibits have been installed in public spaces throughout the focus region and include rainwater harvesting demonstrations varying from a single rain barrel to larger cisterns with site capacity upwards of 3,300 gallons. Rain barrel sales were hosted to provide the opportunity for the public to purchase a rain barrel at a discounted price. Rainwater harvesting presentations and trainings occur throughout the year and provided an opportunity to distribute print resources and establish long-term communication via internet-based mediums. The combined result of public survey data, a rainwater harvesting program evaluation and lessons learned from diverse outreach strategies has provided context for future community-based stormwater outreach efforts.

DeVoe, M. Richard[1], Timothy Callahan[2], Dianne Greenfield[3,4], Daniel Hitchcock[5], Richard Peterson[6], Denise Sanger[4], April Turner[1], John Weinstein[7], Erik Smith[3]
[1]S.C. Sea Grant Consortium, [2]College of Charleston, [3]University of South Carolina, [4]S.C. Department of Natural Resources, [5]Clemson University, [6]Coastal Carolina University, [7]The Citadel

STORMWATER MANAGEMENT PONDS IN SOUTH CAROLINA: FORMULATING AN INTEGRATED RESEARCH AND OUTREACH COLLABORATIVE TO ENHANCE POND ECOLOGY, FUNCTIONALITY, EFFICIENCY, EFFECTIVENESS, AND MANAGEMENT

The S.C. Sea Grant Consortium has established the South Carolina Stormwater Ponds Research and Management Collaborative to address the pressures on the state's communities, infrastructure, and natural and human resources from the increasing use of ponds for stormwater management. Stormwater ponds, especially detention ponds, are by far the most common best management practice (BMP) for controlling stormwater runoff from developed landscapes in coastal South Carolina. There are some 14,000 ponds associated with commercial, residential, golf course, and other developments in the coastal counties alone, but very little information exists about their effectiveness, long-term functionality, and potential impacts on the adjoining ecosystem. Intended and designed primarily as water quantity control structures to minimize localized flooding, they are increasingly expected to serve as a means of controlling water quality impacts to adjacent receiving waters through the removal/retention of pollutants (nutrients, organic matter, sediments, bacterial pathogens, etc). They are also known to harbor contaminated sediments, and are the primary sites along the coast of South Carolina for harmful algae. A quantitative assessment of what hydrologic and water quality control services ponds provide, and which management practices may maximize these services, is therefore essential to assist coastal communities in better managing their stormwater to preserve vital water quality and aquatic resources. The collaborative seeks to (1) develop an integrated, sustainable, economic and natural resource strategy for the construction, use, and maintenance of stormwater ponds serving existing and future South Carolina communities; (2) satisfy the information needs and concerns of existing local communities, homeowners' associations (HOAs), businesses, and industries surrounding stormwater pond design, ecology, efficiency, effectiveness, and management; (3) characterize coastal stormwater ponds to understand their functionality, durability, benefits, and costs, and (4) ultimately develop new and innovative engineering and construction practices to ensure that current and future stormwater ponds function without concerns about possible ecological impacts or additional economic costs associated with their management and maintenance. While research on stormwater ponds in South Carolina has been conducted, this Collaborative will serve to integrate these efforts through a holistic approach.

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MODELING THE CONGAREE RIVER AND ITS LEVEE(S)

The Congaree River drains over 7,800 square miles and is formed in Columbia, SC by the confluence of the Saluda and Broad Rivers near the Piedmont fall line. It is being restudied by SCDNR through FEMA as part of the Richland County Flood Insurance Study initiated in 2010. The Manning Levee is a 5.5 mile man-made earthen embankment that runs along the east side of the Congaree River from just south of Rosewood Drive to near Beckam Swamp Road. This, up to 25 foot high, embankment was originally constructed in the 1960's as a farm levee to protect crops and has since been modified, fortified, and rectified, but it is still not certified. This presentation will review the hydrology and hydraulic methods used to model this large and diverse river through the City of Columbia downstream to below I-77. The hydrologic modeling included detailed gage analysis and the base hydraulic model is an unsteady HEC-RAS model. The unsteady RAS model was supplemented with some rudimentary two-dimensional modeling in order to quantify the storage expanse associated with the vast floodplains in this area.

Dillard, William C., H. Freeman Belser
Belser and Belser, PA

THE RELATIONSHIP BETWEEN REGULATORY PROTECTIONS AND COMMON LAW WATER RIGHTS IN SOUTH CAROLINA (Poster)

This poster presentation will focus on a graphical representation illustrating the qualitative relationship between two categories of legal rules protecting water resource owners from harmful effects of activities by other parties. Specifically, the graph will compare the relative scope of regulatory restrictions, on the one hand, and common law water and property rights, on the other. For some categorically prohibited activities (e.g., discharge of certain toxic pollutants), government regulations provide protections commensurate with common law property rights. Other activities (e.g., discharge of turbid storm water) are largely unregulated but can nonetheless invoke common law nuisance and trespass remedies. Still other activities (e.g., discharges of sediment and permitted pollutants) are allowed within certain regulatory limits but can result, even where regulatory requirements are met, in violations of enforceable common law property rights. The poster will provide a qualitative area graph visualization of the relationship between these common law water rights and the varying degrees of protection provided by regulation of different activities affecting water resources. This visualization will be based on South Carolina property and water rights law and the various state and federal regulations governing impacts on water resources. The poster will also include, as a secondary element, arrow diagram visualizations of the nature and limits of key common law and constitutional property rights (e.g., the right to exclusive possession, the right of use and enjoyment, and the right to just compensation for governmental "takings") and corresponding legal mechanisms for enforcement of these rights (e.g., trespass, nuisance, and inverse condemnation causes of action). The purpose of this element of the presentation is to provide context for the primary diagram illustrating of the relationship between common law and regulatory protections.

***Drennan, Kathryn**, Dhanuska Wijesinghe, Dara Park, Sarah White, David White
Clemson University

SOIL TEMPERATURE AND MOISTURE DIFFERENTIALS FROM CONCRETE SIDEWALKS (Poster)

Anecdotal observations suggest that impervious surfaces influence water content and temperature in adjacent soil and subsequently may affect plant quality. Soil moisture and temperature sensors are used to assist in irrigation management in greenhouse and nursery crop production, sports fields, golf courses, and residential landscapes. Previous research suggests that many plant species do not perform well close to concrete sidewalks. It is often assumed that heat from the sidewalk results in warmer and drier soil environments not optimal for plant growth. A study was conducted using GS3 soil sensors (Decagon Devices) in the Sustainable Demonstration Garden at Clemson University to measure the effect of sidewalks on soil water content and temperature. Soil sensors were installed in three replicate locations within the garden at 15, 30, 45 and 60 cm increments from sidewalks, at a depth of 10 cm into the soil on August 9, 2013, and moved in two-month intervals on October 17, 2013 and January 23, 2014, for a total of three timed intervals. Measurements are logged every 30 minutes using EM50G data loggers (Decagon Devices). Weather data was organized from the Clemson University Entomology Weather Station to determine the correlation between soil conditions and air conditions. Data analysis calculating the Local Correlation (LoCo) Score, reveal the correlation among the three replicates. Further analyses of data were performed using a one-way ANOVA. It is hypothesized that soil moisture and temperature near the sidewalk will fluctuate more than sensors placed at increasing distances. The findings from this study will help landscape contractors manage landscapes in a more sustainable manner by improving irrigation practices (sprinkler placement) and plant placement. Future research needs include: investigating greater distance distributions, varied impervious surfaces, the role of compaction, and identification of optimal plants. Results of the three monitoring periods will be presented at the conference.

Duberstein, Jamie
Clemson University

MONITORING MARSH VEGETATION AND SOIL SALINITY DURING THE SAVANNAH HARBOR EXPANSION PROJECT PRE-DEVELOPMENT PHASE

Marsh vegetation and soil salinity monitoring in the Savannah River estuary has been re-initiated based on plans associated with the Savannah Harbor Expansion Project (SHEP), organized by the US Army Corp of Engineers, Savannah District. A summary of historic studies will be presented, including distinguishing species and the associated soil salinities. The scope and intensity of the monitoring was increased, so several new marsh areas were established and three tidal freshwater forest sites will be added in summer 2014. An update will be given regarding cursory results of marsh communities and soil salinities found during the 2014 sampling events.

Dunleavy, Tim[1], Paul Conrads[1], Bill Post[2], Mike Randall[3]
[1]U.S. Geological Survey SCWSC, [2]SCDNR, [3]USFS SESC

REAL-TIME TRACKING OF ATLANTIC AND SHORT-NOSE STURGEON USING EXISTING USGS STREAMGAGE NETWORK INFRASTRUCTURE

Short-nose and Atlantic sturgeon, which are protected under the Endangered Species Act, populate the rivers and estuaries along the U.S. East coast from Northern Florida to Maine. Historically, there has been limited data available on specific habits of sturgeon, such as foraging areas, spawning behaviors, and transfer between river systems. New technologies have greatly increased the feasibility of tracking aquatic animals. Uniquely coded acoustic transmitters are implanted into an animal. These transmitters "ping" on a regular interval, sending out a data string that can be decoded by an autonomous passive receiver (APR). These receivers log, by date and time, the ID number sent in each "ping" when a tagged animal is within acoustic range. While transmitters' numbers are unique, all transmitters broadcast on a common frequency; therefore, an APR array can be used to track many different species simultaneously. The National Marine Fisheries Service funded a three-year sturgeon telemetry study in 2010, collaborating with the South Carolina Department of Natural Resources (SCDNR) and other state agencies and universities to implant sturgeon with transmitters and to deploy 600 APRs throughout the Southeast. While acoustic tagging technology has greatly improved the understanding of aquatic life behavior, the data collected are still historical in nature. Data must be downloaded from the in-situ APRs; therefore, researchers know where the fish were at a particular time, but not necessarily where they are currently. Real-time data collection via satellite or wireless telemetry solves this problem and it precludes the possibility of data loss due to theft, vandalism, electronic failure and flooding. The U.S. Geological Survey South Carolina Water Science Center (USGS) and the SCDNR realized that tagged sturgeon were swimming by existing USGS streamgages, and that existing USGS gaging station infrastructure, if retrofitted with a new class of APRs, could be used to supply real-time locations of individually tagged animals in addition to river conditions. This pilot study demonstrates how upgraded streamgages, along with an Internet mapping application, can be used to view historic and real-time movement of sonic tagged animals. The project retrofitted a new class of APRs to two existing streamgages on the Santee and Congaree Rivers. This presentation will describe preliminary results of the data collection effort and challenges to integrating APRs with the USGS real-time gages.

***Ellis, Kathryn**[1], Blaik Keppler[2], Greg Hoffmann[3], Sadie Drescher[4], April Turner[5]
[1]North Inlet-Winyah Bay NERR, [2]ACE Basin NERR/SCDNR, [3]Center for Watershed Protection, [4]S.C. Sea Grant Consortium

LOW IMPACT DEVELOPMENT IN COASTAL SOUTH CAROLINA: A PLANNING AND DESIGN GUIDE (Poster)

Development along South Carolina's coast is growing rapidly. Conventional development practices increase stormwater runoff pollution significantly and alter coastal hydrology. These negative impacts from changes in stormwater runoff are well-documented. In coastal South Carolina, the impacts include decreased tidal creek and estuary health, reduced tourism and resource-related industries, as well as increased flooding and property damage. Often, low impact development (LID) practices are touted as a solution to these problems and an opportunity to create more sustainable, resilient environmental systems. However, progress on LID implementation in many coastal communities is hindered by a lack of engineering and planning guidance among other barriers. During the past two years, the Coastal Training Programs (CTPs) at the Ashepoo-Combahee-Edisto (ACE) Basin and North Inlet-Winyah Bay National Estuarine Research Reserves (NERRs) have collaborated with the SC SeaGrant Consortium and the Center for Watershed Protection, Inc. to develop an LID manual for Coastal South Carolina. There are two main goals for the manual. First, the manual will be a resource that meets the needs of engineers, landscape architects, planners, stormwater managers, and other coastal decision makers. In order to address these needs, the project team used surveys, informal discussions, and facilitated meetings with a diverse group of stakeholders to identify and understand barriers to LID implementation and present potential solutions. One of the biggest obstacles identified through the stakeholder interaction was that the different groups each require different types of information to overcome LID implementation barriers. Therefore, the LID Manual has been divided into sections that target specific stakeholder groups, such as planning guidance and technical specifications. The second goal was to tailor content to the conditions in coastal South Carolina. To accomplish this, the project team facilitated a series of collaborative focus group meetings with applied science researchers and engineers. In these meetings the team learned about the unique challenges and opportunities for stormwater management in coastal South Carolina, including the potential impacts of climate change. Based on these interactions, the existing guidance, specifications, and design tools from other states and regions were modified, adjusted, or replaced so that the manual addressed the South Carolina coastal conditions. The resulting document, Low Impact Development in Coastal South Carolina: a Planning and Design Guide, will be an important tool to expedite the implementation of LID practices. Planners will have the information they need to facilitate LID through ordinance and regulation changes; designers will have the design tools they need to develop effective practices; and regulators will have the specifications they need to ensure that LID efforts are implemented successfully and sustainably to protect residents and receiving waterways.

***Evans, Tyler**, Alicia M. Wilson, Willard S. Moore
University of South Carolina

GROUNDWATER TRANSPORT AND THE FRESHWATER-SALTWATER INTERFACE BELOW BEACHES (Poster)

High rates of exchange between seawater and fresh groundwater in beach sediments drive significant chemical reactions, but the groundwater flow that controls this is poorly understood. Current conceptual models for groundwater flow in beaches highlight an upper saline plume, which is separated from the classic Ghyben-Herzberg salt-wedge by a zone of brackish to fresh groundwater discharge. The lack of an upper saline plume at our study site led us to ask whether the plume exists in all beaches and what controls its formation. We used variable-density, saturated-unsaturated, transient groundwater flow models to investigate the

geometry of the freshwater-saltwater interface in beaches with slopes varying from 0.1 to 0.01. We also varied hydraulic conductivity, dispersivity, tidal amplitude and inflow of fresh groundwater. All models showed that a freshwater-saltwater interface developed in the intertidal zone, but the width and morphology of this interface was variable. No upper saline plumes formed in any beach with hydraulic conductivities less than or equal to 1 m/d. The slope of the beach was also a significant control. Steeper beach faces allowed more significant upper saline plumes to develop. Prior studies of groundwater flow and salinity in beaches have used small dispersivities, and we found that the upper saline plume became less distinct when larger, potentially more realistic dispersivities were used. Our results suggest that upper saline plumes do not form in all beaches and may be less common than previously considered.

Faircloth, Delaney, Amy M. Bennett
South Carolina Department of Health and Environmental Control

SCDHEC SECTION 319 GRANT PROGRAM: COMMUNITY-BASED WATERSHED PLANNING AND IMPLEMENTATION

Section 319 of the Clean Water Act authorizes EPA to award annual grants to states to implement nonpoint source management programs designed to reduce nonpoint source pollution across the state. Approximately half of these funds are to be used to implement watershed-based plans. The goal of watershed-based planning is to identify all potential sources of a specific pollutant and outline the methods needed to reduce or eliminate those sources. In South Carolina, SCDHEC staff calculate Total Maximum Daily Loads (TMDLs) and work with local organizations to develop watershed-based plans, and then provide funding through competitive 319 grants for their implementation to ultimately improve water quality. SCDHEC has been implementing watershed-based plans since 2003 and has documented resulting water quality improvements. Because this program is entirely voluntary, the most successful planning and implementation efforts include significant community involvement and strong partnerships. Further, community involvement in plan development is essential since local groups are most familiar with their watershed and ownership of the watershed-based plan leads to better implementation projects. As one of SCDHEC's values is "Local Solutions to Local Problems," and as it is critical that all key stakeholders within a watershed are involved, SCDHEC Watershed Managers work to bring all groups together and help facilitate their participation. The wide array of stakeholders often includes organizations such as homeowners associations, soil and water conservation districts, universities, planning organizations such as Councils of Government, county and municipal governments, conservation groups, and other state and federal agencies.

Feaster, Toby, Athony Gotvald, Curtis Weaver
U.S. Geological Survey

ESTIMATING THE MAGNITUDE AND FREQUENCY OF FLOODS FOR URBAN AND SMALL, RURAL STREAMS IN GEORGIA, SOUTH CAROLINA, AND NORTH CAROLINA

Reliable estimates of the magnitude and frequency of floods are essential for such things as the design of transportation and water-conveyance structures, Flood Insurance Studies, and flood-plain management. The flood-frequency estimates are particularly important in densely populated urban areas. A multistate approach was used to update methods for determining the magnitude and frequency of floods in urban and small, rural streams that are not substantially affected by regulation or tidal fluctuations in Georgia, South Carolina, and North Carolina. The multistate approach has the advantage over a single state approach of increasing the number of stations available for analysis, expanding the geographical coverage that would allow for application of regional regression equations across state boundaries, and building on a previous flood-frequency investigation of rural streamflow-gaging stations (streamgages) in the Southeastern United States. In addition, streamgages from the inner Coastal Plain of New Jersey were included in the analysis. Generalized least-squares regression techniques were used to generate predictive equations for estimating the 50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent annual exceedance probability flows for urban and small, rural ungaged basins for three hydrologic regions; the Piedmont-Ridge and Valley, Sand Hills, and Coastal Plain. Incorporation of urban streamgages from New Jersey also allowed for the expansion of the applicability of the predictive equations in the Coastal Plain from 2.1 to 53.5 square miles. Explanatory variables in the regression equations included drainage area (DA) and percent of impervious area (IA) for the Piedmont-Ridge and Valley region; DA and percent of developed land for the Sand Hills; and DA, IA, and 24-hour, 50-year maximum precipitation for the Coastal Plain. An application spreadsheet also was developed that can be used to compute the flood-frequency estimates along with the 95-percent prediction intervals for an ungaged location.

Feaster, Toby, Stephen Benedict, Jimmy Clark, Paul Bradley, Paul Conrads
U.S. Geological Survey

SCALING UP WATERSHED MODEL PARAMETERS - FLOW AND LOAD SIMULATIONS OF THE EDISTO RIVER BASIN

The Edisto River is the longest and largest river system completely contained in South Carolina and is one of the longest free flowing blackwater rivers in the United States. The Edisto River basin also has fish-tissue mercury concentrations that are among the highest recorded in the United States. As part of an ongoing effort by the U.S. Geological Survey to expand the understanding of relations among hydrologic, geochemical, and ecological processes that affect fish-tissue mercury concentrations within the Edisto River basin, analyses and simulations of the hydrology of the Edisto River basin were made using the topography-based hydrological model (TOPMODEL). The potential for scaling up a previous application of TOPMODEL for the McTier Creek watershed, which is a small headwater catchment to the Edisto River basin, was assessed. Scaling up was done in a step-wise process beginning with applying the calibration parameters, meteorological data, and topographic wetness index data from the McTier Creek TOPMODEL to the Edisto River TOPMODEL. Additional changes were made with subsequent simulations culminating in the best simulation, which included meteorological and topographic wetness index data from the Edisto River basin and updated calibration parameters for some of the TOPMODEL calibration parameters. Comparison of goodness-of-fit statistics between measured

and simulated daily mean streamflow for the two models showed that with calibration, the Edisto River TOPMODEL produced slightly better results than the McTier Creek model, despite the significant difference in the drainage-area size at the outlet locations for the two models (30.7 and 2,725 square miles, respectively). Along with the TOPMODEL hydrologic simulations, a visualization tool (the Edisto River Data Viewer) was developed to help assess trends and influencing variables in the stream ecosystem. Incorporated into the visualization tool were the water-quality load models TOPLOAD, TOPLOAD-H, and LOADEST. Because the focus of this investigation was on scaling up the models from McTier Creek, water-quality concentrations that were previously collected in the McTier Creek basin were used in the water-quality load models.

***Feng, Wenpeng**[1], Wenwu Tang[1], Charles Harrison[2], Devendra Amatya[2], Julie Arnold[2], Carl C. Trettin[2]
[1]University of North Carolina at Charlotte, [2]Center for Forested Wetlands Research, USDA Forest Service

THE DEVELOPMENT OF AN ADVANCED WEB GIS PORTAL OF SANTEE EXPERIMENTAL FOREST (Poster)

We present an advanced Web GIS (Geographic Information Systems) portal that integrates cutting-edge web technologies and geospatial capabilities to better organize, maintain, and disseminate spatiotemporal data associated with Santee Experimental Forest. Long-term climate, hydrology and ecological records are fundamental to assessing complex questions associated with climate change or sustainability of ecosystem services. Accordingly, long-term, hydrologic, space-time series of climatic, and land use data from the Santee Experimental Forest can provide important insights if it is available to a broad audience. Therefore, developing the capabilities to avail long-term records is key to realizing the value from monitoring activities. This Web GIS portal is built on advanced spatial database and Web GIS to organize these geospatial data characterized by high update frequency and various attributes. The implementation of the Web GIS server allows for the deployment of geospatial web services to mash up and visualize alternative GIS data of the Santee Experimental Forest. We use cloud computing capabilities to support automatic update of data into online spatial database in a decentralized manner. Internet-based access, query, and analysis of these spatiotemporal data for the Santee Experimental Forest are implemented to support online operations, which will greatly facilitate collaboration among various stakeholders. This application is particularly important to utilize empirical data in model development and validation.

***Ferons, Daniel P.**[1], Jane L. Guentzel[1], Andrew Heyes[2]
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A COMPARISON OF WHOLE BODY MERCURY CONCENTRATIONS OF MUMMICHOGS (FUNDULUS HETEROCLITUS) AND ATLANTIC SILVERSIDES (MENIDIA MENIDIA) FROM DUNN SOUND, SOUTH CAROLINA (Poster)

Inorganic mercury (Hg2+) enters waterways throughout South Carolina by wet and dry atmospheric deposition. Before mercury can begin to bioaccumulate in fish it must to be transformed into methylmercury (CH3Hg+). The process of transforming inorganic mercury into methylmercury is mediated by iron and sulfate reducing bacteria that are present in low oxygen environments. These are usually sediments within wetlands, estuarine tidal creeks and salt marshes. After inorganic mercury is transformed into methylmercury, it becomes suspended in the water column. Phytoplankton, such as diatoms, accumulate the available methylmercury through passive diffusion across the cell membrane. When the phytoplankton are eaten by other organisms, such as zooplankton, methylmercury is incorporated into the tissues of zooplankton. When the zooplankton are consumed by forage fish the mercury within the zooplankton is assimilated into the tissues of the forage fish. As trophic level increase, this results in an increase in fish mercury concentrations. Scientific studies of mercury cycling in fish populations have primarily occurred in freshwater and open ocean environments. Relatively few studies have focused on mercury cycling within estuaries and the majority of these studies were conducted using laboratory conditions. Estuaries provide a unique environment that serve as an interface between freshwater systems and the open ocean. Additionally, they serve as a nursery for commercial fishes such as tilefish (Lopholatilus chamaeleonticeps), cobia (Rachycentron canadum), and king mackerel (Scomberomorus cavalla), which have been known to contain high levels of mercury. Mummichogs (Fundulus heteroclitus) and Atlantic silversides (Menidia menidia) are year round residents of South Carolina salt marshes and are important species in the transport of energy and nutrients from the salt marsh to the coastal ocean. Although mummichogs and silversides are both tertiary consumers feeding on herbivores, secondary consumers, and detritivivores, they differ in their food web interactions. Mummichogs are opportunistic feeders that eat prey based on the size of their mouth. They will feed from the benthos, off of the shoots of Spartina alterniflora during high tide, and from the water column. Silversides are planktivorous feeders and prey upon zooplankton that are in the water column above oyster reefs and mudflats during high tide. Both species are prey to commercially important fish including cobia, summer flounder (Paralichthys dentatus), and king mackerel as well as birds, such as the Great Egret (Ardea alba) and the Double-crested Cormorant (Phalacrocorax auritus). This study will compare total and methyl mercury concentrations in mummichogs and Atlantic silversides to determine the potential of each species to contribute to bioaccumulation of mercury in higher trophic level fish and birds.

Fuss, Dave[1], Dan Newquist[2], Sue Sledz[3], Tracy Jones[4], Dan Hitchcock[5]
[1]Horry County Stormwater Management, [2]Waccamaw Regional Council of Governments, [3]Murrells Inlet 2020, [4]Georgetown County Stormwater Management, [5]Clemson University

WATERSHED PLAN IMPLEMENTATION CHALLENGES FOR SMS4S IN MURRELLS INLET

The Murrells Inlet Watershed Plan (WRCOG, 2014) was crafted by a group of key stakeholders with community support and guidance to address fecal coliform bacteria loading in shellfish harvesting waters. While at times the planning process was both confusing and contentious, stakeholders debated the interpretation of the data analysis and ultimately concluded that the primary pollutant sources were wildlife

and domestic animals. Stakeholders also concluded that the loads from these sources were being delivered to the estuary via a landscape that includes a network of surface drainage ditches and subsurface pipes so that water detention on the landscape has been largely short-circuited. Armed with this information, plan participants devised management measures that considered several strategies, including: 1) utilize an end-of-pipe/ditch solution that addresses pollution nearest the discharge point; 2) generally reduce volume and flow and/or increase retention/detention across the landscape to reduce the pollutant load; and 3) use education and outreach such as pet waste cleanup campaigns. With geographic constraints, limited opportunities exist to incorporate detention basins into the landscape. Besides the construction of stormwater wetlands as a detention basin in one location, the existing conditions pushed the stakeholders towards the concept of intercepting and reducing pollutant loads with devices not initially designed for use in high-flow drainage pathways. Other strategies include incentivizing the use of low impact development devices and employing education and outreach campaigns. As implementation progresses, the steering committee must track plan implementation and evaluate the effectiveness of management measures. Local funding must also be leveraged against grant funds to enable implementation.

Fuss, Karen, Rich Viso, Paul Gayes
Coastal Carolina University

SCHOOL OF COASTAL AND MARINE SYSTEMS SCIENCE AT COASTAL CAROLINA UNIVERSITY: A SYSTEMS SCIENCE APPROACH TO RESOURCE MANAGEMENT (Poster)

The newly created School of Coastal and Marine Systems Science (SCMSS) at Coastal Carolina University houses both Ph.D. and M.S. programs. SCMSS realizes the increasing need to better understand coastal systems through the dynamic and complex interaction of the earth, ocean, atmosphere and society thus conveying the best science available to support effective resource management. The mission of the School is to:

• advance the understanding of the complex interconnected environmental processes within the coastal zone through basic and applied research,
• train the next generation of coastal scientists to apply this knowledge to predict coastal environmental behavior and aid in addressing environmental issues important to society, and
• communicate the best science available to help society effectively manage critical coastal natural resources and the economies dependent upon them.

The main research arm of the School is the Burroughs and Chapin Center for Marine and Wetland Studies (BCCMWS) which was established in 1988 to facilitate basic and applied research of the marine and wetland environments and promote the application of Center expertise and technology to help understand and address regional environmental issues. Through its activities the Center actively partners with federal and state agencies, local communities and the private sector to enhance natural resource management benefiting the public. By providing direct opportunity to participate in real-world studies, access to state-of-the-art instrumentation and applications and diverse professionals within the Center and partnering agencies and universities, the Center greatly advances the training and professional and academic development of Coastal Carolina students in the area of marine and wetland sciences, management and policy. This poster will show the interplay between various scientific disciplines and provide several recent examples of how SCMSS is bringing these disciplines together in order to accomplish a systems science approach, including: hurricane modeling to forecast probabilities of storms making landfall along the US Atlantic and Gulf Coasts; Arctic exploration to study past abrupt climate shifts and relating those to present and future climate changes; subglacial discharge and freshwater inputs in Antarctica; and hypoxia monitoring using water quality and biological monitoring in Long Bay on the Grand Strand in coastal South Carolina. To enhance and expand research being conducted at BCCMWS, SCMSS recently added a newly designed 50 foot aluminum research vessel to its vessel operations. R/V Coastal Explorer is equipped with state of the art sea floor mapping/geophysical survey systems, 6 research workstations, a hydraulic A-frame (3-ton lift capacity) and dive platform. The vessel accommodates up to 22 passengers and has a cruising range of 500 miles. This wide array of research enables graduate students and undergraduate marine science students to become active participants.

Garrett, C. Guinn[1], Kimberly A. Counts[1], Blaik Keppler[2], April Turner[3]
[1]Clemson University Cooperative Extension Service, [2]S.C. Department of Natural Resources, [3]S.C. Sea Grant Extension Program

A 6,000 STORMWATER POND TASK: MEETING THE NEEDS OF DIVERSE AUDIENCES FOR STORMWATER POND MANAGEMENT OUTREACH IN THE BERKELEY, CHARLESTON AND DORCHESTER COMMUNITIES

Stormwater ponds are one of the most highly used flood management and water quality control practices in South Carolina, with an estimated 6,000 ponds in Berkeley, Charleston and Dorchester (BCD) counties alone. Poorly managed ponds can play a role in water resource degradation that threatens ecological and human health. State, county and local governments require regular maintenance of these ponds systems to ensure proper function and performance. In addition, input from BCD-area municipal and county level stormwater managers indicates a need for outreach that encourages proper pond maintenance for improved pond function and downstream waterway protection. To assist meeting both regulatory and community needs, Carolina Clear and the Ashley Cooper Stormwater Education Consortium (ACSEC) partnered with the South Carolina Ashepoo, Combahee and Edisto River Basin Coastal Training Program and the South Carolina Sea Grant Consortium to host the biannual Charleston Area Stormwater Pond Management Conference in March 2012 and May 2014. The objectives of the conference were: 1) to increase awareness of the purpose of stormwater ponds and need for regular maintenance for function; 2) to provide participants the information needed to overcome common challenges in pond management; and 3) to integrate communities with service providers to assist in inspection and management actions. Management content was provided by local and regional researchers and experts in the pond management field. Target audiences included community associations, property and

pond management companies, and county and municipal employees. To accommodate these diverse audiences, the conference format included concurrent sessions as well as plenary lectures and vendor exhibition areas. A comparison between the 2012 and 2014 conferences offered a tool to evaluate the effectiveness of this outreach method in encouraging stakeholder awareness and implementation of stormwater pond best management practices. Feedback from the 2012 conference indicated that a majority of residents benefited from knowledge learned and would implement many of the recommended management practices into their pond maintenance protocol. Lessons learned and evaluation feedback from 2012 were used in formatting the 2014 conference offering, resulting in adjustments in conference promotion, plenary and session content, format and pricing. The Charleston Area Stormwater Pond Management Conference offers a national model of outreach for communities tasked with providing impactful stormwater pond content-area knowledge to residential, commercial and government target groups. Lessons learned and priorities in content identified from the 2012 and 2014 conferences will be used to help shape the future direction of stormwater outreach for water resource protection in the South Carolina.

Gellici, Joseph A.
S.C. Department of Natural Resources

REVISIONS TO THE HYDROGEOLOGIC FRAMEWORK OF THE SOUTH CAROLINA COASTAL PLAIN

In the 27 years since Aucott, Davis, and Speiran released "Geohydrologic Framework of the Coastal Plain Aquifers of South Carolina" (U.S. Geological Survey Water-Resources Investigations Report 85-4271), a vast amount of additional groundwater and stratigraphic data have become available, mainly from coreholes, well-cluster sites, and water wells. Of significance are the "P-well" series of coreholes and well clusters drilled at SRS during the mid-to-late 1980's (Bledsoe 1984, 1987, and 1988; Bledsoe and others, 1990); the "C-well" series of coreholes and well clusters drilled just outside the boundaries of SRS during the late 1980's and early 1990's (Logan, 1987; Kuntz and Griffin, 1988; Simones, 1992; Gellici and others, 1995); sidewall cores collected from two deep test holes in Jasper County (2,900 ft) (Self-Trail and Bybell, 1997) and Beaufort County (3,833 ft) (Temples and Engelhardt, 1997); five coreholes drilled in Sumter County in the late 1980's to study a landfill near Pinewood, S.C. (Prowell, 1993; Vroblesky, 1994); a corehole drilled for an aquifer storage-and-recovery project at Myrtle Beach (Castro and others, 1995); two coreholes drilled in Darlington and Florence Counties that were used for developing a ground-water flow model (Falls, 1994; Rodriguez and others, 1994); two coreholes drilled in the Breezy Hill area of Aiken County (Krambis, 2000; Harrelson and others, 2002; Gellici, 2007); two coreholes drilled in Charleston County for an aquifer storage-and-recovery project at Charleston (Campbell and others, 1997; Petkewich and others, 2004); a corehole drilled in the city of Charleston (Bybell and others, 1998); two coreholes at Orangeburg, S.C. (Gellici, 2007); a shallow corehole at the type locality of the Peedee Formation at Burches Ferry in Florence County (Self-Trail and others, 2002); two coreholes in Richland County (unpublished); and a single corehole in each of the following counties: Berkeley, Charleston, Chesterfield, Colleton, Darlington, Dillon, Horry, Lee, Lexington, and Sumter (all unpublished). Deep water wells, too numerous to list here, were also drilled during the past 27 years. Also of significance are early cores that were used by Aucott and others (1987) that have since been re-sampled for paleontological analysis and stratigraphically revised. These include the USGS-Clubhouse Crossroads #1 core in Dorchester County (Gohn, 1992); the USGS-St. George No. 1 core in Dorchester County (Self-Trail and Gohn, 1996); and the USGS-Pregnall No. 1 core in Dorchester County (Edwards and others, 1997). A revised hydrogeologic framework of the South Carolina Coastal Plain is presented. It incorporates new data from the coreholes, well clusters, and water wells as described above. In addition, it extends the hydrostratigraphic nomenclature and classification scheme that was developed at SRS by Aadland and others (1995) to the entire Coastal Plain.

Gellici, Joseph A.[1], C.W. Clendenin, Jr.[1], Robin L. Banner[2], Kyle J. Mohr[1]
[1]*S.C. Department of Natural Resources,* [2]*College of Charleston*

ESTABLISHMENT OF A PERMANENT GROUNDWATER MONITORING SITE IN CALHOUN COUNTY, SOUTH CAROLINA (Poster)

Increased groundwater use in Calhoun County, South Carolina for crop irrigation has raised concern among several citizen groups that the increase may be affecting water levels in aquifers that are used for domestic supplies. Irrigation use increased from 85 MGY (million gallons per year) in 2004 to 4,602 MGY in 2011 (S.C. Department of Health and Environmental Control). Acting on this concern, the South Carolina Department of Natural Resources (DNR), in collaboration with Calhoun County, drilled a test hole at the Town of Creston in south-central Calhoun County during the summer of 2013. The test hole was continuously cored to a depth of 1,058 ft (feet) using a wireline coring system and drill rig operated by the U.S. Geological Survey. A suite of geophysical logs was obtained from the hole after the cores were collected. The logs and core were used to delineate local aquifer zones and to correlate them to regionally defined aquifers. Sieve analyses were made to determine grain size and sorting. Four aquifers were delineated and are listed in descending order: 1) surficial, 2) Gordon (Tertiary sand), 3) Crouch Branch (Black Creek), and 4) McQueen Branch (Middendorf). The surficial aquifer occurs from land surface to 43 ft bls (below land surface). It consists of gravelly, poorly sorted, fine to very coarse quartz sand, interbedded with 0.5-2 ft clay layers towards the top of the aquifer. Gravels compose up to 20 percent of some samples. The Gordon occurs from 80 to 130 ft bls and consists of interbedded quartz sand and clay. Sand beds are moderately sorted and medium to very coarse grained and contain trace to minor amounts of lignite and muscovite. The Crouch Branch occurs from 193 to 385 ft bls and consists of interbedded quartz sand and clay. The sand fraction is moderately sorted and medium to coarse grained. Muscovite, pyrite, feldspar, and heavy minerals are present in trace to minor amounts. The lowermost McQueen Branch occurs from 660 to 850 ft bls and consists of interbedded quartz sand and clay. Sand beds consist of moderately to poorly sorted, fine to very coarse sand and gravel. Trace to minor amounts of lignite, muscovite, pyrite, and heavy minerals occur and gravels compose up to 34 percent of some

samples. Four monitoring wells were completed—one in both the surficial and Gordon, and two in the Crouch Branch. Future work will include the installation of a well in the McQueen Branch aquifer. Automated water-level recorders installed in each well indicate water levels are about 20 ft bls in the surficial, 60 ft bls in the Gordon, and 80 ft bls in the Crouch Branch. The site will serve as a long-term groundwater monitoring site.

Giacalone, Katie, Catherine Mobley, Ph.D., James Witte, Calvin Sawyer
Clemson University

2014 UPDATE ON THE PERCEPTIONS OF NONPOINT SOURCE POLLUTION IN SOUTH CAROLINA

In the fall and winter of 2013-2014, 2000 South Carolina residents from five regions across the state were surveyed as to their knowledge attitudes, behaviors and intentions, as these relate to stormwater and watershed management. The following questions guided the study's purpose:

• What is the level of concern for environmental health and waterway quality?
• What is the level of understanding of stormwater, watersheds, and nonpoint source pollution across the state?
• How do people perceive their own actions as possibly having an impact on water quality?
• Where are the residents of this state finding guidance in regards to their own actions that may impact water quality?
• What is the level of involvement in pollution prevention in South Carolina, and what outreach considerations need to be made to increase this level of involvement?

Previously, this survey effort was conducted in 2009, collecting 1600 responses from South Carolina adult residents. Data from this survey served to direct the efforts of regional stormwater outreach programs conducted or participated in by Clemson's Carolina Clear program and create a baseline for which to judge program efforts over time. Many survey questions were also culled from previous surveys conducted by the South Carolina Department of Health and Environmental Control, the U.S. Environmental Protection Agency and other entities. Lessons learned from the 2009 survey and usability of data towards program measurement and direction were considered in the instrumentation of this 2013 survey and will be shared in this presentation. Results of the survey will direct pollution prevention and watershed protection programming across the state, as the stakeholder input in this process will increase the likelihood of knowledge gain and sustainable changes in behavior that may affect water quality. Examples of how data will be used in the implementation of regional stormwater outreach and involvement include the following:

• Modification of messaging and vocabulary used to describe and inform on environmental topics.
• Measure of interest in homeowner-scale best management practices such as rainwater harvesting and rain gardens.
• Information to local, regional and state decision-makers on the concern for environmental quality and acknowledgement of the link between healthy waterways and local economy.
• Evaluation of the impact of specific programming over time and across regions.

The survey was conducted with the survey lab at George Mason University. Data has been cleaned and weighted against 2010 U.S. Census data. Information gained from the survey will help Clemson Carolina Clear develop strategies for education and increased involvement in these regions. In addition, the presentation will look to increase awareness of the availability of this data to increase collaboration opportunities and water resource protection in South Carolina.

Graves, David[1], D. E. Chestnut[1], E. B. Rabon[1], W. J. Jones[2], J. G. Moore[3], C. Johnston[3], C. K. West[1]
[1]South Carolina Department of Health and Environmental Control, Bureau of Water, [2]University of South Carolina, Selah Genomics Facility, [3]NOAA, National Ocean Service, Center for Coastal Environmental Health and Biomolecular Research

MICROBIAL SOURCE TRACKING TO ASSESS HUMAN CONTRIBUTIONS OF FECAL BACTERIA TO A FRESHWATER RECEIVING STREAM

The State of South Carolina, Department of Health and Environmental Control (SCDHEC) is charged with the responsibility to ensure that waters of the State support classified uses and are free from pollutants in excess of State standards. Crucial to any plan to achieve compliance with E. coli standards is an understanding of the probable sources of fecal bacteria (i.e., human vs. animal). Metagenomics (sequencing and analysis of DNA from environmental samples) and quantitative polymerase chain reaction (qPCR) are genetic methodologies that can be used for microbial source tracking: the identification of microbial organisms specific to potential sources of fecal bacteria pollution. Metagenomic methods were used first to sequence DNA present in receiving stream water samples. The 16S rRNA amplicon was analyzed using BLAST, Greengenes, etc., to derive and contrast the microbial community composition. Then, qPCR methodology was used to quantify the presence of known genetic markers to substantiate and confirm the presence of potential human sources of fecal bacteria pollution. This assessment strategy was employed on an urban freshwater stream system, the Lower Saluda River, from its "origination" from a major impoundment, to its confluence with the Congaree River. A comprehensive study conducted July – September 2012 included eight Lower Saluda River sites, 10 sites on tributary streams with municipal wastewater treatment plant discharges and two sites on tributaries without discharges. A generally increasing trend in human markers downstream in the Lower Saluda River was noted. The most specific human marker, M. smithii, was seen immediately downstream of two municipal wastewater treatment plants and also from an impoundment outfall. Community structure between tributaries appeared to be substantially different. The extent of these differences and their influence on the Lower Saluda River are being evaluated.

Greenfield, Dianne[1, 2], Chuck Keppler[2], Elizabeth Hilborn[3], Janet Gooch Moore[4], Paul Sandifer[4]
[1]USC, [2]SCDNR, [3]USEPA, [4]NOAA,

LINKING PHYTOPLANKTON COMMUNITY COMPOSITION WITH INCIDENCES OF VIBRIO IN STORMWATER DETENTION PONDS

Occurrence and distribution of harmful algal blooms (HABs) and pathogenic Vibrio bacteria have often been assessed as separate endeavors. However, emerging evidence suggests possible linkages. This collaborative research effort

investigates whether pathogenic Vibrios may proliferate in association with algal blooms in coastal South Carolina stormwater detention ponds and receiving tidal creeks. Specifically, this project explores linkages between water temperature, nutrient concentrations, algal blooms, and other factors that may be useful for forecasting human health risks from marine-derived pathogens. During 2008-2009, water samples were collected twice per month from two stormwater detention ponds and receiving tidal creeks at mid-ebb tide. Samples were evaluated for basic water quality, nutrients, chlorophyll a, Vibrio (V. vulnificus and V. parahemolyticus), HABs, and others. Results confirmed the presence of one or both Vibrio species in approximately 28% of samples, and algal blooms (HABs and non-HAB blooms) were recorded in several samples as well. Here we report on correlations between water quality, Vibrio, and phytoplankton observed during this 1.5 year field study.

Greenfield, James[1], Paul Conrads[2], Matthew Petkewich[2], Andrew Fairey[3]
[1]Tetra Tech, [2]USGS SCWSC, [3]Charleston Water System

SIMULATION OF HYDRODYNAMICS AND WATER QUALITY IN THE BUSHY PARK RESERVOIR, CHARLESTON, SOUTH CAROLINA

The Bushy Park Reservoir is a relatively shallow impoundment in a semi-tropical climate and is the principal water supply for the 400,000 people of the City of Charleston and the surrounding areas including the industries in the Bushy Park Industrial Complex. Although there is an adequate supply of freshwater in the reservoir, there are taste-and-odor water-quality concerns. To evaluate the effects of potential changes in reservoir operations on water quality, Charleston Water System is cooperating with Tetra-Tech and the U.S. Geological Survey, on the application of a three-dimension (3D) hydrodynamic and water-quality model to Bushy Park Reservoir. A Total Maximum Daily Load (TMDL) for dissolved oxygen for the Cooper, Ashley, and Wando Rivers and Charleston Harbor was established using the 3D Environmental Fluid Dynamics Code (EFDC) model for both hydrodynamics and water quality (Hamrick, 1992). Bushy Park Reservoir is simulated in the Charleston Harbor EFDC model. The model has received technical review by the U.S. Environmental Protection Agency, the S.C. Department of Health and Environmental Control, and accepted by the permitted dischargers and other stakeholders. The EFDC model is being used by the U.S. Army Corps of Engineers to evaluate potential effects of the proposed deepening of Charleston Harbor from 45 feet to 50 feet on hydrodynamics and water quality. The Charleston Harbor EFDC model was modified to create a separate standalone Bushy Park Reservoir model. The objectives for creating a separate reservoir model were to increase the resolution of the representation of the Bushy Park Reservoir in the model, while decreasing run times for the model. These objectives were met by reducing the model domain to include only the Cooper River and reservoir and increasing the horizontal layers and number of cells in the reservoir. Overall the number of cells in the model was reduced from 1,512 in the Charleston Harbor model to 322 in the Bushy Park Reservoir model. Run times were decreased over twenty-fold from 4.6 hours to simulate a year in the TMDL EFDC model to 12 minutes in the Bushy Park Reservoir model. The reduced runtime and increased resolution allowed for better calibration of the hydrodynamics and water quality dynamics as compared to the Charleston Harbor EFDC model. The calibrated Bushy Park Reservoir model is being used to evaluate the effect of various reservoir management options on water quality. These management scenarios affect the circulation patterns in the reservoir that could have substantial effects on improving the water quality of the reservoir. Some of the management scenarios include changing the location and magnitude of major withdrawals from the reservoir. The presentation will describe the development and calibration of the Bushy Park Reservoir model and preliminary results of the reservoir management scenarios.

Gregory, Scott, Jake McLean
Wildlands Engineering, Inc.

HOW DRIVERS AND DATA AFFECT WATERSHED PLANNING AT VARIOUS SCALES

The Neuse River Basin drains a land area of over 6,200 square miles from the central piedmont of North Carolina to the Pamlico Sound located off the coast. The headwaters of this basin includes the Raleigh-Durham-Cary combined statistical area (the Triangle) which is among the most highly developed and fastest growing areas in the state. Population growth and associated rapid development within the basin has consistently created a significant need for stream and wetland mitigation projects as well as nutrient offset projects to satisfy required load reduction targets of various impaired waters. Multiple watershed and water quality improvement plans are underway within the heavily urbanized headwaters of the Neuse basin to identify and prioritize mitigation and nutrient offset project opportunities in an effort to streamline the implementation of such projects. One of these watershed plans, the Neuse River Regional Watershed Plan (RWP), encompasses a drainage area of approximately 580 square miles, which is at least 4 times larger in area to those local watershed plans previously conducted by the NC Ecosystem Enhancement Program; the Neuse River RWP heavily relies upon the use of GIS data and remote sensing to support such a broad scale study. Future phases, already underway, involve more detailed reconnaissance of digital and on-the-ground condition. The Little Lick Creek Watershed Improvement Plan (WIP) is another active water quality study within the Neuse basin headwaters, but is operating at a much narrower scale. The Little Lick Creek WIP involves leveraging various sources of existing water quality data by combining the data into a more uniform platform that will allow the data and scoped modeling efforts to be the basis for allocation of funds towards water quality improvements. The Neuse River RWP and Little Lick Creek WIP are good examples of watershed planning at various scales, incorporating innovative data management and modeling approaches to assess water quality, to identify and prioritize mitigation projects, and to develop documents to help leverage funding for the implementation of these projects. The studies are looking at planning efforts in the Chesapeake Bay Watershed to determine what existing tools and approaches can be repurposed to address southeastern watershed issues.

Gregory, Scott
Wildlands Engineering, Inc.
NEUSE RIVER REGIONAL WATERSHED PLAN (Poster)
The Neuse River Basin drains a land area of over 6,200 square miles from the central piedmont of North Carolina to the Pamlico Sound located off the coast. The headwaters of this basin includes the Raleigh-Durham-Cary combined statistical area (the Triangle) which is among the most highly developed and fastest growing areas in the state. Population growth and associated rapid development within the basin has consistently created a significant need for stream and wetland mitigation projects as well as nutrient offset projects to satisfy required load reduction targets of various impaired waters. Multiple watershed and water quality improvement plans are underway within the heavily urbanized headwaters of the Neuse basin to identify and prioritize mitigation and nutrient offset project opportunities in an effort to streamline the implementation of such projects. One of these watershed plans, the Neuse River Regional Watershed Plan (RWP), encompasses a drainage area of approximately 580 square miles, which is at least 4 times larger in area to those local watershed plans previously conducted by the NC Ecosystem Enhancement Program; the Neuse River RWP heavily relies upon the use of GIS data and remote sensing to support such a broad scale study. Future phases, already underway, involve more detailed reconnaissance of digital and on-the-ground condition.

***Gunning, Kristin**, Karen Fuss
Coastal Carolina University
NEW ASSESSMENT TOOL FOR BIORETENTION PRACTICES (Poster)
Since December 2007, the Coastal Waccamaw Stormwater Education Consortium (CWSEC) has assisted local storm water departments to install rain gardens at schools throughout Horry and Georgetown Counties, South Carolina. After installation, limited records have been kept on whether or not these rain gardens are being maintained and are functioning properly. Working in conjunction with Horry County Stormwater Management, an undergraduate marine science student at Coastal Carolina University (CCU) has developed a rain garden assessment as an easy, user-friendly tool that can be used to determine if maintenance is required on a rain garden. This rain garden assessment is a pilot program that was developed by modifying an assessment of bioretention practices (including rain gardens) developed by the University of Minnesota. The assessment consists of a series of questions grouped into six categories that are designed to address common maintenance issues of rain gardens. The categories include:
•Access -Is access and drainage to the Rain Garden is clear?
•Inlets and Drainage - Are inlet structures in need of maintenance? Has it rained in the last 48 hours? Is there standing water?
•Vegetation - Are the plants healthy and placed in the proper locations? Does any maintenance need to be done (weeding, pruning, etc.) on the Rain Garden?
•Sediment and Erosion- Is there any source of erosion or sediment deposition into the Rain Garden?
•Other – Is there any debris (trash, yard waste, pet waste) within or around the Rain Garden? Is mosquito larvae present within the Rain Garden?
•Maintenance Recommendations – What service needs to be done on the Rain Garden to ensure it functions properly?
Responses to the questions in each category should clearly highlight what maintenance needs to be done on the rain garden. Utilizing the rain garden assessment, the inspector (CCU student) will summarize the required maintenance in a report that will be given to the school/business. A maintenance calendar will also be provided with the report to give quick tips on seasonal care of the garden in order to keep it functioning properly. This calendar also addresses the need for a visual inspection after a large rain event to ensure the following: water is properly moving through the practice; an inspection of inlet structures to prevent clogging; removal of debris and trash; weeding; pruning of trees, shrubs and grasses; mulching; watering; replanting; and sediment addition/erosion. This rain garden assessment and maintenance calendar can be a valuable tool in ensuring rain gardens and other bioretention practices are properly functioning so that they can continue to filter stormwater and prevent harmful pollutants from getting into our waterways. After initial piloting at public facilities, these tools will be modified for use by homeowners and businesses.

Harmon, Michele, A.E. Bodie, K.A. Fettro, J.R. Yates
University of South Carolina Aiken
TRACKING FECAL POLLUTION SOURCES IN SAND RIVER IN THE UPPER REACHES OF THE HORSE CREEK WATERSHED IN AIKEN COUNTY, SC (Poster)
The Horse Creek watershed in Aiken County, SC, is known for its history of high coliform pollution. Previous studies have identified one particular tributary, Sand River, as being a high bacterial contributor to the upper portions of the watershed, but the source(s) remain unknown. Sand River drains Hitchcock Woods, an urban forest that is heavily used by equestrians; is transected by both old and new sewer lines; and is surrounded by older homes, some of which depend upon aging septic systems. In addition, Sand River in Hitchcock Woods receives an enormous volume of stormflow from the downtown area during rain events. This study focused on fecal pollution in two of Sand River's smaller tributaries, Calico Creek and Cuthbert Branch. Both steams were monitored bi-weekly using sterile sampling techniques and 3M Petrifilm Plates to obtain fecal coliform counts. Calico Creek contained the highest concentrations of fecal coliforms, with an average of 195 cfu/mL. We further hypothesized that horses were the main source of this fecal pollution, and microbial source tracking (MST) techniques were used to test this hypothesis. The MST involved a phenotypic method that compares the antibiotic resistance profiles of the unknown coliforms from Calico Creek to the resistance profiles of fecal coliforms isolated from known sources. Potential source species included horses, waterfowl, canines, and untreated sewage. An array of antibiotics (Kanamycin, Streptomycin, Tetracycline, Apramycin, Trimethoprim, Rifampicin), in a range of differing concentrations, was used to determine the antibiotic resistance profiles for each of these known sources. Once the profiles were established, fecal coliforms isolated from Calico Creek were tested using the same array of antibiotic exposures. A discriminant function analysis was used to statistically compare each unknown fecal isolate to the library of known species in order to determine its probable source.

Harrigan, Joe
AECOM
ANALYSIS TECHNIQUES TO IMPROVE DEVELOPMENT OF FRACTURED BEDROCK GROUNDWATER RESOURCES
Successful development of the groundwater resource in fractured bedrock requires the development of an accurate subsurface conceptual site model (CSM). The CSM is needed for all fractured bedrock sites to characterize the geology and hydrogeology to guide understanding and interpreting subsurface conditions. Without a good CSM to define the subsurface architecture data interpretation and planning additional investigation for water resource development can be seriously flawed and can result in inefficient field efforts and use of project budget. Several investigative and interpretative tools are available to better characterize the subsurface and improve the interpretation of existing and newly acquired subsurface data. Borehole data coupled with both surface and borehole geophysical data can yield a much-improved visualization of the subsurface structure and improved interpretation of the occurrence and dynamics of the groundwater. As an example of this evaluation process suite of borehole geophysical logs, core data (including core photos), and surface geophysics (VLF-EM WADI) were used to improve the subsurface characterization and guide future well drilling and installation efforts in the California desert. A 250 foot deep corehole was advanced in granitic rock at Edwards AFB to add a deeper well at an existing well pair location. The core was photographed and the corehole was geophysically logged with a suite of tools including caliper, gamma, electric (short-normal and long-normal), induction, temperature, fluid resistivity, and acoustic televiewer (ATV). The ATV log data was processed by the contractor to provide interpretation of open and closed fractures, the fracture dip angle, and the fracture dip azimuth. At the same time a surface geophysical survey was conducted with the VLF-EM WADI to identify dipping fracture zones. The WADI survey line stations were geo-referenced with a GPS instrument. The survey data, coupled with the GPS data, were processed and interpreted and then converted to a three-dimensional rendering. This interpretative subsurface data rendering allowed correlation of bedrock structure elements, the fracture zones, identified by the two geophysical and provided a tool to guide future well drilling activities.

***Harrington, Jon**, K. Adem Ali
College of Charleston
USING HYPERSPECTRAL REMOTE SENSING DATA TO DETERMINE PHYTOPLANKTON DENSITY IN THE COASTAL WATERS OF LONG BAY, S.C. (Poster)
The southeastern coastal region has become one of the fastest growing regions in the United States, and the increasing utilization of open water bodies has led to the deterioration of water quality and aquatic ecology, placing the future of these resources at risk. In coastal zones, a primary indicator that can be used to assess the stress on the environment is the water quality. Water quality is heavily influenced by multiple biogeochemical constituents or color producing agents (CPAs) such as phytoplankton, suspended matter, dissolved organic carbon, and also the interaction of chemical, biological, and physical components. This gives rise to the optical complexity observed in coastal waters of South Carolina (SC) such as in Long Bay - an open ocean, shallow embayment on the South Atlantic Bight of the USA that produces turbid waters. Ecological stress on these environments is reflected by the increase in the frequency and severity of Harmful Algal Blooms (HABs) - a prime agent of water quality deterioration that includes foul odors and tastes, de-oxygenation of bottom waters (hypoxia and anoxia), toxicity, fish kills, and food web alterations. To support the sustainability and to better manage the water resources, managers need enhanced capabilities of near real-time monitoring to understand the state of the conditions to protect, manage, and address the question of how various natural and anthropogenic factors affect the health of these environments. Obtaining these observations through conventional in-situ methods is challenging for these open water systems, such as the coastal waters of S.C. Remote sensing has become very promising in providing temporal and spatial information regarding bio-geodynamics in large and open coastal water bodies. In this study, a suite of exiting blue-green and NIR-red bio-optical algorithms is applied to the observed data from the ASD spectro-radiometer sensor to predict chlorophyll a in the Long Bay waters. The pigment is the primary light harvesting pigment in all phytoplankton and is used as an index for the estimation of phytoplankton density concentrations. Satellite-based inclusive measurements using hyper and multi spectral sensors (HICO, VIIRS, and MODIS) produce substantial spatial and temporal resolution but depend upon bio-optical algorithms to show the correlation between the spectral reflectance and the absorption of the water quality parameters that are attributed to these color producing agents.

Heintz, Melissa
North Inlet - Winyah Bay National Estuarine Research Reserve
EDUCATING THE ADJACENT COMMUNITIES OF THE NORTH INLET - WINYAH BAY NATIONAL ESTUARINE RESEARCH RESERVE (Poster)
The North Inlet - Winyah Bay National Estuarine Research Reserve promotes healthy estuaries, watershed preservation, resilient coastal communities, and thriving ecosystems through education, research, stewardship and training. The Reserve, located in Georgetown, SC, is one of 28 reserves around the coastal United States that form the National Estuarine Research Reserve System (NERRS). Each Reserve is supported by a partnership between the National Oceanic and Atmospheric Administration (NOAA) and a host state agency. Reserves are responsible for conducting year-round research and monitoring, stewardship, and education programs. Part of the North Inlet-Winyah Bay (NI-WB) Reserve's mission is "to enhance public awareness and understanding of estuarine areas and to provide suitable opportunities for public education and interpretation". The local residents in the Georgetown area directly impact NI-WB estuaries, with many living along the waterways and/or using them year-round for commercial or recreational purposes. Despite the extensive use, residents have demonstrated a significant deficiency in knowledge and appreciation for these important water systems. The NI-WB Reserve has developed a series of public education programs targeting Georgetown residents. The program series is to be held in honor of "National Estuaries Day" and consist of hands-on exhibits, demonstrations, and seminars on topics including water quality, salt marsh biology

and ecology, and stormwater pollution. The goal of these programs is to gauge the current knowledge of residents and identify specific topics where education is lacking. Based on the programs' outcomes, more effective education programs can be conducted in the Georgetown area. Educated residents will be more apt to make behavioral changes and environmentally conscious decisions around their community.

Henning, Frank[1], Brian Gregory[2], David Shelley[3]
[1]National Park Service/Congaree National Park, [2]National Park Service/Southeast Coast Inventory and Monitoring Network, [3]National Park Service/ Old-Growth Bottomland Forest Research and Education Center

INTEGRATING MULTIPLE DIMENSIONS OF STREAM MONITORING TO IMPROVE WATER RESOURCES PROTECTION AT CONGAREE NATIONAL PARK

Congaree National Park (CONG) was established to protect for the enjoyment, education, and inspiration of this and future generations, the nation's largest remaining tract of southern old-growth bottomland forest as well as a significant expanse of associated floodplain, resource waters, and upland ecosystem. Serving this multidimensional mission requires an integrated approach that incorporates monitoring, data management, research and education components. Threats from pollutant loads and hydrologic alteration are expected to expand as Southeast Richland County Develops. The 2014 South Carolina List of Impaired Waters includes E. coli impairment in sections of Cedar Creek and Tom's Creek that are located inside the park's boundaries. The 2008 Southeast/ Lower Richland Sub-Area Transportation Study predicts that Southeast Richland County areas that drain towards CONG will grow by 42.9% between 2000 and 2035. This area includes the Bluff/Shop Road area of Columbia that is expected to experience continued growth with additional University of South Carolina oriented residential development and new industrial, office development (DHEC, 2010). In order to establish monitoring protocols that will inform resource management decisions, the Southeast Coast Inventory and Monitoring Network (SECN) partnered with CONG to develop a stream habitat monitoring protocol. In addition to data collection, this protocol includes guidance for long-term data management that will provide insight into the status of and trends in stream and riparian habitat conditions. This protocol includes (1) status and trends of upstream watershed or drainage basin characteristics that are known to affect stream habitat; (2) classification of stream reaches based on channel features and geomorphic dimensions; and (3) status and trends of benthic and riparian habitat features. Additional assessment tools were needed to support the park's education mission and encourage sound water resource management in CONG's expansive (14,000 mi2) watershed. In cooperation with local, state and federal partners, CONG staff developed a South Carolina Volunteer Stream Assessment Tool (SVAT). This simple tool was designed to supplement monitoring and expand water resource education in upstream communities. SVAT encourages students and citizen scientists to expand their water resources knowledge as they assess the physical and biological integrity of freshwater streams. CONG stream monitoring programs support and integrate multiple dimensions of stream assessment. Stream Monitoring programs: 1) identify stream segments that may need protection, restoration or further assessment; 2) develop datasets that provide early warnings of changing conditions and inform park mitigation decisions; 3) increases public awareness, community engagement and citizen science capacity in local watershed management.

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EVALUATING THE ROLE OF EVAPOTRANSPIRATIVE PROCESSES FOR STORMWATER MANAGEMENT IN COASTAL SOUTH CAROLINA WATERSHEDS WITH SHALLOW GROUNDWATER

In the face of dual pressures in coastal South Carolina - residential and commercial development along with potential climate change impacts - water resource management becomes a formidable challenge. Hydrologic processes in coastal forested watersheds with shallow groundwater are typically driven seasonally by evapotranspiration. As a response to increasing urbanization, low impact development (LID) practices that are designed to decrease stormwater runoff and volumes by mimicking natural hydrology via infiltration and/or evapotranspiration are being investigated. This presentation focuses on ecohydrological criteria being developed for sustainable land and water resource guidance in coastal South Carolina, specifically in upland forested and freshwater wetland areas. Forest and wetland water budgets in watersheds with flat topography and shallow groundwater with the goal of defining pre-development conditions are being refined, including the seasonal influence of evapotranspiration on water table elevation as it drives highly variable watershed outflow and thus runoff throughout the year. Stormwater control measures, specifically engineered wetland and bioretention systems, are being investigated to determine hydraulic and water quality performance based on the influence of groundwater. An assessment of the evapotranspirative processes for both existing vegetation and installed practices (green infrastructure) - as well as their benefits via ecohydrological services at various scales - can provide useful guidance toward resource protection with the goal of creating resilient communities, whether via conservation or restoration efforts or better site design. These landscape elements are complex within and between these varying scales. Results have implications for watershed planning and site engineering, including stormwater management and design. These results also have implications for guidance toward the prioritization of conservation and restoration efforts. With a better understanding of evapotranspirative rates and process, sustaining coastal water resources may be achieved to protect from flooding, water quality impairment, and degraded ecological health of downstream receiving waters.

Hodges, Jonathan L., John R. Saylor, Nigel B. Kaye, Ryne C. Phillips
Clemson University

IMPROVING SATELLITE MEASUREMENTS OF RESERVOIR SURFACE TEMPERATURE VIA A THERMAL MODEL OF LAKE SURFACE TEMPERATURE FOR IMPROVED EVAPORATION ESTIMATES

Estimates of evaporation rates from large lakes and reservoirs can be significantly improved using satellite measurements of water surface temperature. Because of limitations on the temporal resolution of such measurements, a model of the diurnal variation in surface temperature could further improve evaporation estimates. Herein, a one-dimensional model of a lake is used in combination with surface temperature measurements from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument aboard the satellites Aqua and Terra, and ambient atmospheric conditions from local Automated Surface Observing System (ASOS) weather stations to compute the diurnal surface temperature variation. The computed solutions were parametrized and used to obtain a functional form of the diurnal surface temperature variation. In addition to its use in the application of evaporation estimates, this functional form is of fundamental limnological significance.

***Hughes, Andrea L. H.**, Alicia M. Wilson
University of South Carolina, Department of Earth and Ocean Sciences

IMPROVING RADIUM-BASED TRACER TECHNIQUES: HYDROLOGIC CONTROLS ON POREWATER RADIUM ACTIVITY (Poster)

Radium isotopes (223Ra, t1/2=11.1 d; 224Ra, t1/2=3.66 d; 226Ra, t1/2=1600 y; and 228Ra, t1/2=5.75 y) are considered excellent tracers of groundwater movement and discharge in coastal systems. The accuracy of these tracers has been hindered, however, by both spatial and temporal variability in porewater radium activity. This variability can be as much as two orders of magnitude in coastal aquifers with a distinct and mobile fresh water/salt water transition zone and creates a proportionally large uncertainty in radium-based estimates of coastal groundwater discharge. To better understand the factors affecting radium variability in coastal systems, measurements of porewater (piezometers screened at 1, 2, and 4 m depth) and nearby surface water radium activity were made at an island within North Inlet Salt Marsh in Georgetown, South Carolina from November 2009 to February 2011. Water salinity, temperature, pH, and redox were also recorded, and sediment samples were collected for analysis of bulk 228Ra and 226Ra activity. Vertical and lateral variability in porewater radium activity reflects varying porewater residence times due to contrasting sediment grain size and permeability with depth, and tidal flushing differences between the marsh edge and interior. Temporal variability in porewater radium was controlled by variations in marsh groundwater dynamics due to changes in mean water level. Higher mean water resulted in less groundwater discharge, longer porewater residence times, and greater porewater radium activity. Comparisons of the 228Ra/226Ra activity ratio between porewater and surface water indicated that a primary source of radium to the surface water was the confined aquifer (4 m) at locations nearest the creek banks. In addition, the activities of 228Ra and 226Ra at these same locations were relatively constant through time. Temporal variations in surface water radium activity did not correspond to increases and decreases in hydrology-based estimates of groundwater discharge. This result is contrary to the theory behind radium-based discharge estimates in which changes in surface water activity reflect increases or decreases in groundwater discharge. Our results highlight the importance of understanding the hydrology of any coastal system when interpreting radium results, of identifying and measuring the correct porewater end-member(s) when calculating a radium budget, and of consistently measuring porewater radium activity from source aquifers in conjunction with any radium surface water measurements to account for temporal porewater radium variability.

***Hutton, Derek**, Nigel B. Kaye, William Martin
Clemson University

ANALYSIS OF THE IMPACT OF CLIMATE CHANGE ON STORMWATER DESIGN STORMS FOR THE STATE OF SOUTH CAROLINA

A warming climate leads to a moister atmosphere and a more rapid hydrologic cycle. As such, many parts of the country are predicted to become wetter with more extreme rainfall events. This paper analyzes rainfall forecasts across the state of South Carolina through 2099 using the data from 134 global climate models. Results show that there is an increasing tendency in both total annual rainfall and design storm intensity. Across the state, the total annual rainfall increase ranged from approximately 1.5-3.3 inches over the forecast period while the 100-year design storm increased by 0.5- 1.2 inches depending on location.

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MONITORING WATER QUALITY CHANGES IN A FORESTED FRESHWATER WETLAND THREATENED BY SALINITY

Coastal forested wetland swamps are sentinel sites for salinity intrusions associated with large tidally-influenced or storm-driven incursions of estuarine waters that may also indicate rising sea levels associated with climate change. A coastal freshwater forested wetland in coastal South Carolina has experienced dieback of freshwater forested wetland trees due to increased salinity within the wetland. Vegetation in the wetland is transitioning from a closed canopy of common freshwater wetland trees such as bald cypress, water tupelo and swamp tupelo, to a more open canopy due to the establishment of salt tolerant grasses. The swamp is prime habitat for several wildlife species as evidenced by game cameras and amphibian recorders installed within the swamp. A team of researchers at the Baruch Institute examined a series of historical aerial images to track changes in vegetation through the years. In June 2013, several water level and conductivity sensors were installed along the salinity gradient to measure temporal variations in water level and salinity within the swamp. Microclimatic conditions were also measured and water flux at the tidally influenced watershed outlet logged. The data reveal that there is a pronounced

salinity gradient from the upper reaches of the swamp to its lowest tidally influenced section. Upper reaches of the swamp are influenced primarily by incident rainfall within the watershed, while at the outlet there appears to be a complex dynamic driven by tides, local rainfall, and estuarine backwater effects.

Jenkins, Eleanor[1], John Chrispell[2], Sourav Dutta[3], Kathleen Fowler[4], Matthew Farthing[5], Stacy Howington[5]
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OPTIMIZATION OF A MANAGED AQUIFER RECHARGE NETWORK

Over the last few decades, groundwater resources in many regions have been depleted at a faster rate than the underlying aquifers have been replenished. This imbalance has led water management agencies to consider managed aquifer recharge networks, where infiltration basins are used to replenish the aquifers using previously un-captured storm water runoff. In this work, we utilize optimization to evaluate the costs associated with constructing such a network and the ability of the network to meet demands placed on the aquifer. Our objective function incorporates land and construction costs, along with rewards for effective aquifer recharge. We enforce capture of a minimum volume of storm water runoff by penalizing the cost. We present results for two basin networks, one based on results from the literature and another based on a study of the Pajaro Valley region in California. The Pajaro Valley example is used as our realistic test case, and we use the analysis to suggest the viability of a managed aquifer recharge network in a particular sub-watershed associated with the area.

Johnson, Alan
Clemson University

A DECISION-ANALYTICAL APPROACH TO MONITORING AND MANAGING FRESHWATER ALGAL BLOOMS

Many lakes and reservoirs in South Carolina experience episodic blooms of harmful or nuisance algal species. Factors controlling these blooms are complex, and may involve nutrient loading, water temperature, light regime, turbidity, vertical mixing, flushing rates, biological competition, and trophic interactions. Since blooms can arise relatively quickly, and prediction of their occurrence is difficult, managers often must rely upon an adaptive approach of periodic monitoring coupled with management decisions based on the imperfect information afforded by monitoring. Development of an adaptive monitoring and management strategy must consider certain inherent tradeoffs. More frequent sampling is valuable in terms of the information provided and the increased probability of detecting an incipient bloom before it reaches harmful or nuisance proportions. However, frequent sampling is also costly in terms of the need for materials and human resources. Based on monitoring results, the manager will periodically face a choice of various options, which may include: (1) no action (beyond continued monitoring), (2) restriction of human access or activities in the water body, or (3) management intervention, such as chemical treatment, to control algal population growth. Decisions regarding which action to implement may affect the subsequent course of algal population dynamics, and will lead to outcomes that differ in associated ecological, economic and societal values. The repeated monitoring and management decisions can be cast in the mathematical framework of a Markov Decision Process (MDP), in which algal dynamics are represented as transitions between different system states which are affected by internal system processes as well as management actions. Utilities are assigned to represent the costs and benefits associated with various outcomes, and optimization approaches can be used to find a policy consisting of an algorithmic procedure for selecting an optimal sequence of management actions. Decision theory typically seeks to maximize the expected utility associated with the resulting sequence of outcomes and actions. However, in cases of complex ecological dynamics typical of algal blooms, the relevant probabilities for some outcomes may be deeply uncertain, due perhaps to insufficient data, disagreement among experts, or inadequate theoretical understanding. Ambiguity is used as a technical term to refer to situations with uncertain outcomes for which precise probability estimates are unavailable. A variety of alternative decision criteria have been proposed for decisions under ambiguity. These criteria can be regarded as precautionary in the sense that they give extra weight to worst-case outcomes over some set of plausible scenarios. It is possible to adapt the Markov Decision Process framework to use such alternative criteria is selecting an optimal or robust policy.

Jones, Kimberly
Town of Bluffton

FROM PLANNING TO MANAGEMENT & ASSESSMENT: THE MAY RIVER WATERSHED ACTION PLAN IN BLUFFTON, S.C.

Prior to exponential growth in the early to mid-2000s, shellfish harvesting was possible throughout the length of the May River located in Bluffton, SC. However, in 2007, SC Department of Health and Environmental Control reported rising fecal coliform levels in the May River headwaters, resulting in a shellfish harvesting classification down-grade to nearly one-third of the river's length in 2009. In response to this down-grade, the Town of Bluffton with its community partners committed to take action to restore shellfish harvesting and to prevent further degradation to the river by developing a watershed management plan based upon the EPA's methodology (EPA, 2008). The resulting May River Watershed Action Plan (AMEC, 2011) was adopted by Town Council in November 2011 as a guiding document for stormwater management and May River watershed restoration and protection. Now that the May River Watershed Action Plan (Action Plan) has been implemented for nearly three (3) years, a number of activities, programs and projects have been accomplished and are on-going throughout the watershed including, but not limited to,

- creating a May River Watershed Action Plan Advisory Committee,
- increasing social marketing efforts via social media and continued watershed branding,
- completing targeted outreach,
- encouraging alternative development patterns via Low Impact Development (LID) design alternative incentives and by designating intended growth areas,

• completing a stormwater Best Management Practice (BMP) project in an undeveloped area,
• initiating a stormwater BMP retrofit project in a densely developed area,
• continuing a stormwater management program, and
• assessing the potential water quality improvement impact of a habitat restoration project.

Following the EPA template, the Action Plan was always intended to be a "living document" that not only allows for the incorporation of new information and technology, but also assesses the impact of completed projects and on-going programs to further refine the plan if needed. As the Town continues with the implementation of the Action Plan, it has also entered a concurrent phase of the plan's life – adaptive management and holistic watershed assessment by evaluating the individual and combined impact of these projects and programs on water quality improvements within the May River. Continuous analysis of the success of any watershed management plan is crucial to keeping a plan current with ever-changing technical knowledge and a variable physical environment. This assessment of the Action Plan serves as an example of adaptive watershed management and shares the knowledge gained to date with others who face the task of stormwater, watershed or water quality management for consideration in their programs to manage natural resources.

Journey, Celeste, Anne B. Hoos, David E. Ladd, John W. Brakebill, Richard A. Smith
U.S. Geological Survey

PUBLICLY ACCESSIBLE DECISION SUPPORT SYSTEM OF THE SPATIALLY REFERENCED REGRESSIONS ON WATERSHED ATTRIBUTES (SPARROW) MODEL AND MODEL ENHANCEMENTS IN SOUTH CAROLINA

The U.S. Geological Survey (USGS) National Water Quality Assessment program has developed a web-based decision support system (DSS) to provide free public access to the steady-state SPAtially Referenced Regressions On Watershed attributes (SPARROW) model simulation results on nutrient conditions in streams and rivers and to offer scenario testing capabilities for research and water-quality planning. Access to the decision support system is through a graphical user interface available online at http://cida.usgs.gov/sparrow. Nationally, the SPARROW models are based on the modified digital versions of the 1:500,000-scale River Reach File and 1:100,000-scale National Hydrography Dataset stream networks. For South Carolina, the DSS has total nitrogen and total phosphorus models for the South Atlantic-Gulf and Tennessee Region based on the Enhanced River Reach File 2.0. The system can be used to estimate nutrient conditions in unmonitored streams in South Carolina and to produce estimates of yield, flow-weighted concentration, or load of nutrients in water under various land-use conditions, changes, or resource management scenarios. This model divides larger river basins into multiple stream catchments and models nutrient contributions by source inputs and land use within each of those catchments. The model information, reported by stream reach and catchment, provides contrasting views of the spatial patterns of nutrient source contributions, including those from urban (wastewater effluent and diffuse runoff from developed land), agricultural (farm fertilizers and animal manure), and specific background sources (atmospheric nitrogen deposition, soil phosphorus, forest nitrogen fixation, and channel erosion). However, the large scale and static nature of the model (modeled only for the 2002 water year) have produced some limitations on the application of the decision support system on the state level. To address those limitations, the USGS is working cooperatively with the Resources For the Future program to adapt the steady-state model for South Carolina to a dynamic model that will simulate seasonal-average loads, yields, and concentrations during the period 2001-2003. Temperature and an Enhanced Vegetation Index from Moderate Resolution Imaging Spectroradiometer (MODIS), a National Aeronautics and Space Administration Terra-satellite-borne sensor, will be used as input to the dynamic model to characterize seasonal uptake and release of nitrogen during land-to-water transport.

***Kang, Yi**
University of South Carolina

FEASIBILITY STUDY: TREATMENT OF POULTRY PROCESSING WASTEWATER USING MITTON VALVE CAVITATION REACTOR TECHNOLOGY (Poster)

In this project, I will work with Cav-Energy and Shealy Electric to do a pilot economic feasibility study for implementation of Mitten Valve wastewater treatment at Columbia Farms, a local poultry processing plant. Mitton Valve claims to be an improved version of a cavitation reactor that could be economical for use in industrial settings. Columbia Farms is located within the West Columbia City limits, with very limited space for wastewater treatment using traditional methods. Columbia Farms has been sending its post-processing wastewater to the City of Columbia Wastewater Management authority for treatment, but the high amount of fat, grease, nitrogen, phosphorus, and organic matter dissolved in the water makes treatment difficult and costly. The City of Columbia therefore requires that Columbia Farms reduce a significant amount of fat in its output wastewater by 2015, or pay heavy financial penalties. Because of its small size, Mitton Valve is a potential candidate for providing an economical on-site treatment solution for Columbia Farms. The fat, nitrogen, phosphors and other organic matters dissolved in Columbia Farm's output water have high enough post-separation resale value that it may offset the implementation cost.

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WATER BUDGET OF A SURFICIAL AQUIFER IN THE LOWER COASTAL PLAIN: ACE BASIN, SOUTH CAROLINA

South Carolina has the most extensive acreage of marshes than any other state on the East Coast. Salt marshes, in particular, support a collection of unique and sensitive ecosystems providing environmental and economic value to the coastal community. However, the ecological viability may be threatened due to sea level rise and land use stressors. Sea level rise has impacted groundwater resources in confined aquifers, but what is not well understood is the impact on freshwater resources of the surficial aquifers in the coastal zone. Furthermore, advancement landward of the marsh will follow sea level rise as the salt marsh system attempts

to accrete sediment and transition previous maritime forest and other upland locations into coastal marsh. Sea level rise, coupled with topographic barriers between marsh and uplands as well as increased demand for shoreline development limits the space available for natural marsh retreat resulting in the issue of "shoreline squeeze". This research seeks to identify the current state of an undeveloped tidal salt marsh located on Edisto Island, SC by analyzing the groundwater dynamics along the marsh transition unit (MTU). The marsh transition unit is located between the marsh and upland maritime forest and is generally characterized by an elevation gradient. There is currently a limited amount of information on hydrological processes occurring across the MTU, although this narrow strip of transitional land is significant for the future preservation of salt marshes. This research seeks to expand knowledge on the groundwater dynamics of the MTU and its interaction with the upland maritime forest. It is hypothesized that the resiliency of surficial groundwater resources is a function of topography and soil drainage (permeability and depth to water table) groundwater dynamics will vary on water budget as well as topographic position and distance to the tidally dominant saltwater creek. The objectives of this study are to (A) determine the budget of fresh water at the site and (B) identify the groundwater dynamics as a function of season and response to storm events. We will present results of groundwater and runoff dynamics from a network of shallow wells in the upland and fringing salt marsh at Big Bay Creek behind Edisto Island. This project makes use of data collected for the National Estuarine Research Reserve System System-Wide Monitoring Program (SWMP). The results of this study will assist in determining how sea level rise may affect tidal salt marshes as well as marsh migration or transition of upland habitat. Furthermore, this research will be useful for coastal resource managers to identify pathways of future marsh relocation.

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A PROPOSAL FOR STANDARD REPORTING OF EXTENSIVE MODULAR GREEN ROOF HYDRAULIC PERFORMANCE PARAMETERS

Green roofs are becoming increasingly popular due to their reported benefits with regard to building thermal performance, urban heat island mitigation, improved local air quality, improved stormwater runoff water quality, and reduction in total runoff. They are also a component of some green scoring systems such as the LEED program. However, there is still a great deal of uncertainty in how to model the hydraulic performance of green roofs. This is particularly important when green roofs are part of a broader low impact development (LID) stormwater design. The inclusion of green roofs in performance based stormwater designs can only be achieved if a reliable method for routing flow through a green roof is achieved. Unfortunately, this is currently very hard to achieve, as there is little in the way of standardized data on their hydraulic performance. In this paper we propose a simple routing model for extensive modular green roof systems with high porosity engineered soil. We also propose a standard set of data that should be provided to the stormwater design engineer by green roof vendors. The model assumes that, after an initial abstraction due to moisture absorption into the soil, the green roof module behaves as a detention pond with a series of orifice outlets at the base of the soil layer and a weir outlet at the top of the module. Standard pond routing equations can then be used with the stage storage relationship being modified to account for the soil porosity. The model would require green roof vendors to publish data on the volume of rainfall retained by the soil, the soil porosity, the effective area of the basal orifice outlets, and the effective weir length. Examples of the application of this model will be presented showing the potential efficacy of green roofs in stormwater quantity management.

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ASSESSMENT OF THE REACH AND ECOLOGICAL CONDITION OF FRESHWATER TIDAL CREEKS IN THE LOWER COASTAL PLAIN, CHARLESTON COUNTY, SOUTH CAROLINA WITH ADVANCED GEOSPATIAL TECHNOLOGY APPLICATION (Poster)

Tidal freshwater wetlands are the interface between marine and terrestrial ecosystems; hence they are directly impacted by sea level rise and climate change. Little is known about the hydro-ecological functions and ecosystem services provided by these important and widely-distributed ecosystems. These wetlands are common in the rapidly urbanizing landscape of the southeastern Atlantic coastal plain, as well as other coastal areas. Tidal freshwater forested wetlands (TFFW) occur in floodplains situated near the coastal zone along freshwater rivers that are subject to tides. They are most prominent along the Southeastern Atlantic lower Coastal Plain, where it is estimated that over 200,000 ha of TFFW exist. TTFW in the lower coastal plain, Charleston County, South Carolina was used as our study area. The objectives of this study were to: i) Acquire and process the high resolution LiDAR data to develop latest and high resolution DEM for the study area; ii) Use Soil Water Assessment Tool (SWAT) hydrologic model to delineate the watershed and the stream network using the up-to-date DEM developed with LiDAR; iii) Use the average climate change related high tidal surge heights to develop land topography model showing the area affected by salt water intrusion and use soil properties to exact delineate the area with salt water ecosystem; and finally, iv) Use advanced object based image analysis (OBIA) image segmentation algorithm to classify/differentiate the saltwater and freshwater ecosystems in the study watersheds with other land uses. Charleston County mosaicked high resolution (3m) DEM was downloaded from USDA-NRCS Geospatial Data Gateway. Initial watershed (Cooper Basin) delineation was conducted using the SWAT model with the confluence point of Tidal Creek to Charleston Bay considered as the end point for the analysis. Then the same 3 m DEM was used to delineate the area under 2 m (high estimated tidal height in recent years in Atlantic Ocean) ground elevation showing that these coastal ecosystem will be under submergence in high tide period. Another study was conducted on these areas under 2 m elevation with the use of SSURGO soil data. Hydrologic Group (HG) and Available Water Storage/Capacity (AWS) characteristics of the soil were used

to determine the upper elevation area that will be affected by tidal surge, thus ultimately help the research team in delineating fresh and brackish water ecosystem delineation. High resolution (30 cm) LiDAR tiles were obtained from SC DNR and mosaicked for the study area. The mosaicked LiDAR was then processed to develop the nDSM and subsequent ground elevation raster (DEM), shrub raster, and short tree raster, and tall tree raster using different returns of the raster. The DEM created from the LiDAR was later used to delineate the watershed again using SWAT and the process also helped us to delineate the 4th order reaches (streams) in the watershed. Then, same process was followed using LiDAR based DEM and SSURGO soil data to delineate the area under 2 m ground elevation and soil characteristics of HG and AWS for salt water intrusion ecosystems. Finally, we used 1 m resolution National Agricultural Imagery Program (NAIP) imagery for the watershed to perform image segmentation with OBIA to differentiate plant species, and other land uses in the watershed. We took the help of training sample development with pre-ground verification of land uses, shrub raster, short tree raster, tall tree raster, and other height raster created from LiDAR data for OBIA. Supervised training samples helped us delineating brackish and freshwater ecosystem plant species also. The final product obtained from this study was i) a new freshwater and saltwater dividing line in the Charleston coast and that was compared with the one acquired from DNR; ii) a 4th order stream (reaches) network which was not available with NHD or was inaccurate as they were developed with old DEMs and the land topography changes very quickly in coastal areas due to eroded soil coming from upper catchment; and iii) A distinct fresh and salt water ecosystem delineation for the watershed. This study will help for future intense analysis of this TFFW for ecosystems change analysis and the high-end geospatial technology based protocol developed for the study can be used in other TFFW in fresh and salt water ecosystem analysis.

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WATER FUNDS: SHARED INVESTMENTS NOW FOR TREATMENT SAVINGS LATER

Water Funds are voluntary programs where water users fund the conservation and / or management of watershed lands. The purpose is to prevent or delay water quality degradation, or to improve water quality over current conditions. The Funds are set upon a long, deep scientific history supporting the water-cleansing functions of natural lands, particularly in temperate areas with multiple strata of vegetation and soil organic layers. Fund structures and activities vary according to participants, watershed conditions, and many other factors. However, all share the same concept of a substantial user-pay funding method. Typically, user funds are matched or leveraged by other funding sources, many which prioritize requests that include a drinking water protection purpose. Water funds are typically only successful when subject areas of underlying science, conservation priorities, funding flows, and governance of activities are concurrently addressed. In this presentation, we present a water fund development case in the Savannah River watershed, South Carolina and Georgia, USA that has addressed all of these critical areas. Now titled the Savannah River Clean Water Fund, this presentation will detail the development process, and provide lessons learned and future visions that may be applied elsewhere.

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DROUGHT AND COASTAL ECOSYSTEMS: IDENTIFYING IMPACTS AND OPPORTUNITIES TO INFORM MANAGEMENT

The National Integrated Drought Information System (NIDIS) is in the process of developing drought early warning systems in areas of the U.S. where the development and coordination of drought information is needed. In summer 2012, NIDIS launched a pilot program in North and South Carolina, addressing the uniqueness of drought impacts on coastal ecosystems. The monitoring and management of drought in coastal regions presents several challenges. While commonly used drought indices incorporate data such as rainfall, streamflow, soil moisture, groundwater levels, and snow pack, such indices were developed for upland areas and may not be appropriate indices for characterizing coastal drought. Furthermore, current systems of drought management focus primarily on agricultural impacts, fire risks, and maintaining water supplies for municipal and industrial use, energy production, and navigation. Understanding of drought impacts on other interests and sectors (e.g. environmental resources, public health, and water quality) remains limited. In addition, these impacts are currently not well integrated into existing planning and response processes at national, regional, state, and local levels. The NIDIS-Carolinas pilot currently focuses on 1) developing and testing a new drought index for coastal regions based on USGS real-time salinity measurements, 2) conducting a needs assessment regarding drought information for coastal ecosystems, and 3) increasing observations of coastal drought impacts through citizen science and the Community Collaborative Rain, Hail & Snow Network (CoCoRaHS). This paper will provide an overview of the pilot program, explain how stakeholder needs and input are incorporated into the projects, and report on results from two of the pilot projects investigating the impacts of drought on coastal ecosystems in the Carolinas. The first project entailed approximately 40 interviews with fishermen, recreationalists, and land managers in Beaufort County, SC, and Carteret County, NC, to document and assess local impacts and experiences with drought. While drought can reduced landings, thereby directly and adversely affecting shrimpers and crabbers because of the inherent salinity sensitivity of these fisheries, other interviewees highlighted the ways in which drought can amplify stressors related to broader economic conditions, government regulation, and land use change. A second, ongoing, project involves working with citizen scientists to improve the documentation of drought impacts in the coastal areas of the Carolinas. In addition to generating useful drought impacts information, this project will evaluate how citizen science and volunteer engagement can contribute to broader drought management efforts. Findings and information obtained through both projects will help inform other components of the NIDIS-Carolinas pilot program and be shared with drought planners and managers in ongoing efforts to enhance drought monitoring and communications in the Carolinas.

Landmeyer, James, Bruce G. Campbell
U.S. Geological Survey

OCCURRENCE OF ETHYLENE DIBROMIDE (EDB), DIBROMOCHLOROPROPANE (DBCP), VOLATILE ORGANIC COMPOUNDS, RADIUM ISOTOPES, AND RADON IN GROUNDWATER FROM THE UPPER COASTAL PLAIN AQUIFERS NEAR MCBEE, SOUTH CAROLINA

Between 2010 and 2012, samples were collected from several public-supply, irrigation, and monitoring wells and springs in the upper Coastal Plain Crouch Branch and McQueen Branch aquifers near the small town of McBee in northeastern South Carolina. Water samples were collected and analyzed for volatile organic compounds, including ethylene dibromide (EDB) and dibromochloropropane (DBCP), total radium (as 226Radium and 228Radium), and radon. The study was commenced because EDB, DBCP, and total radium had been previously detected above U.S. Environmental Protection Agency maximum contaminant levels in groundwater samples collected by DHEC. During our investigation, EDB and DBCP were detected above their maximum contaminant levels in groundwater samples from some public supply and irrigation wells, and in some springs. Multiple volatile organic compounds, the fuel oxygenate methyl tert-butyl ether (MTBE), and carbon disulfide were detected at concentrations near or below method reporting levels in some wells, and the solvent trichloroethylene was detected in one public-supply well. Total radium and radon were detected in most groundwater samples, but at levels below the maximum contaminant levels of 5 picoCuries per liter for total radium and the proposed level for radon. Finally, concentrations of chlorofluorocarbons (CFCs) measured in groundwater samples from public-supply wells sampled in 2010 indicate an average recharge age of about 40 years for groundwater being pumped by these wells, confirming the relatively recent (decadal) release history of the contaminants. The CFC-based recharge ages were used with a MODLFOW model to identify recharge locations and potential contaminant source areas.

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REAL-TIME FLOW MONITORING OF THE EDISTO RIVER AND BUSHY PARK RESERVOIR WATER-SUPPLY TUNNELS IN CHARLESTON

Charleston Water System (CWS) has been a leader in water-resource planning for the low country of South Carolina since its inception as Charleston Light and Water Company in 1917. To increase the water supply to meet the demands of new industries, a 23-mile tunnel from the Edisto River to the Hanahan Water Treatment Plant was started in 1928. The hand-dug tunnel was completed in 1937. Looking for an alternative water supply to the Goose Creek Reservoir and the Edisto River, CWS contributed to the construction of the Bushy Park Reservoir in the 1950s and a 7-mile tunnel was constructed from the reservoir to the Hanahan Treatment Plant. Historically, there were no direct measurements of velocity or flow in the tunnels and the amount of diverted water was determined indirectly. The South Carolina Surface Water Withdrawal Act of 2010 requires accurate accounting of the volume of diverted water in the tunnels. To measure the flow in the water tunnels, CWS collaborated with the U.S. Geological Survey (USGS) to establish real-time flow monitoring stations for the Edisto and Bushy Park water-supply tunnels. The installation of the velocity meters required the close coordination of the Hanahan Water Treatment Plant staff, commercial divers, and USGS personnel. Due to the depth of the dive of approximately 70 feet, dive times were limited to 48 minutes. For safety concerns, raw water and process pumps were turned off while the divers were in the tunnel. Only two dives a day were planned to minimize disruptions of water-plant operations. To install the velocity meters, divers descended down access shafts, entered the tunnels, and attached the meter to the tunnel ceiling. A communication cable from the velocity meter was run to the telemetry equipment in the gage house at the land surface. The presentation will describe the technical approach for measuring velocity and computing flow, the logistics of coordinating the meter installation, and an underwater video of the meter installation in the tunnel.

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University of South Carolina

ASSESSING THE SPATIAL AND TEMPORAL ASPECTS OF BUFFER CAPACITY IN LAKE WATEREE, SOUTH CAROLINA

(Poster)

Lake Wateree is in the Piedmont region of South Carolina located about 30 miles from Columbia. Lake Wateree is on the 303(d) list of impaired and threatened waters for the state of South Carolina. The University of South Carolina and the Lake Wateree Water Watch volunteer committee (WW) currently conduct bi-monthly water quality analysis tests measuring field parameters including dissolved oxygen, pH, and turbidity. Three times per year during the growing season of phytoplankton, they take water samples to analyze for nutrients and chlorophyll A (ChlA). The goal of my project is to expand upon historical knowledge on the water quality of Lake Wateree by measuring how buffer capacity changes spatially and temporally. The study involves two sites, Taylor Creek embayment and Singleton Creek embayment. Past sampling has shown the Singleton Creek embayment often had pH values that exceeded the state standard. The Taylor Creek embayment was selected for comparison. Each month from June to August, a YSI multiparameter sonde was deployed for 24-hours at each location, collecting surface water data in 15-minute intervals. Surface water samples were also collected at the two sites in 8-hour intervals over the 24-hour deployment. The water samples were analyzed for ChlA, ammonium, phosphate, and alkalinity in the lab. The combination of YSI data and water sample analysis allow us to measure the buffer capacity in the two locations and how it changes in space and time. My hypothesis is that the site with historically high pH values during the growing season will have low alkalinity and that buffer capacity will be lowest during times of high sunlight during the day. If correct, the data will show that the buffer capacity is low, making it susceptible to large variability in pH during the growing season. Knowledge of the buffer capacity will provide the lake associations and resource managers with additional environmental context for interpreting sampling results.

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[1]Coastal Carolina University, [2]Waccamaw Council of Government, [3]Murrells Inlet 2020

WATERSHED-BASED PLANNING FOR MURRELLS INLET: SOURCE ASSESSMENT OF FECAL BACTERIA USING VOLUNTEER AND SHELLFISH SANITATION PROGRAM DATA

A watershed-based plan was recently developed for Murrells Inlet, a moderately tidal, euhaline estuary located on the northern coast of South Carolina. The adjacent saltmarshes are managed for oyster and clam harvesting. A Total Maximum Daily Load (TMDL) had been approved in 2005 to address long-standing fecal coliform impairments observed by SC DHEC under the National Shellfish Sanitation Program. Various efforts have been undertaken to better understand the sources and transport pathways of the fecal bacteria to enable implementation of the TMDL. This included an effort to develop an OCRM-funded Special Area Management Plan (2003-2005), volunteer water quality monitoring initiated in 2006, and the performance of spatial surveys conducted by SC DHEC, Georgetown County and Coastal Carolina University. The latter included measurement of fecal bacteria in sediments. In 2012, work began on a watershed-based plan supported by US EPA 319 program funding provided by SC DHEC. One of the goals of this planning effort was to collate and analyze existing data to refine source assessments. Coastal Carolina University's Waccamaw Watershed Academy (WWA) was engaged to lead this data analysis effort. Data from the state shellfish and volunteer monitoring programs were used to elucidate spatial and temporal trends in bacteria levels and their causative drivers, including rain, tidal flushing, and land-use change. The US EPA 319 project's steering committee participated in selection of appropriate statistical tests, reasonable assumptions, and modes of data presentation including GIS mapping. A technical advisory committee provided peer review. Additional data collection has included efforts by the volunteers to track upstream sources and by the WWA to identify host animal sources using genotypic and chemical markers. These efforts were funded by Georgetown and Horry County, respectively. The most important bacterial sources identified were urbanized wildlife and canines. Results from the data analyses were used to prioritize subwatersheds for remediation. This has led to proposed treatment strategies that focus on volume reduction of stormwater runoff, dredging of tidal creek sediments, and outreach education for pet waste control.

Mack, Chris, Maria Cox Lamm
AECOM

NUMERICAL MODELING ELEMENTS OF A FEMA COASTAL FLOOD STUDY

This presentation presents the numerical models, tools, and technologies used for conducting FEMA coastal flood insurance studies. This includes and overview of storm surge modeling, joint probability methods, overland wave modeling using WHAFIS (Wave Height Analysis for Flood Insurance Studies), and flood hazard mapping. Examples from the current South Carolina statewide coastal flood study will be provided.

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Clemson University

CHARACTERIZATION OF THE HYDRAULIC BEHAVIOR OF POROUS PAVEMENTS

We present two models for the characterization of the hydraulic behavior of porous pavements. The first model is based on the widely used curve number parameterization for relating rainfall depth to runoff depth. For undrained pavements the pavement's effective curve number (ECN) is shown to be a function of the pavement storage capacity and infiltration capacity, and the local rainfall IDF curve and SCS rainfall type. For underdrained pavements the ECN is independent of the local rainfall IDF curve, though is dependent of the type and size of underdrain used. The ECN can be used in preliminary design calculations for estimating the reduction in runoff that results from using a porous as opposed to impermeable pavement. While the ECN provides a familiar, simple to use single number to characterize porous pavement performance, the actual behavior of porous pavements does not match the curve number behavior for undrained pavements, particularly for rainfall depths close to the pavement storage capacity. Improved characterization for these undrained pavements is achieved by using a broken-line model that characterizes the pavement in terms of an initial abstraction and a linear relationship between rainfall depth and run off depth for rainfall depths greater than the initial abstraction. For this model, the initial abstraction and line slope are independent of the local IDF curve and, therefore, universal characterization curves can be calculated that are applicable for a given SCS rainfall distribution. Examples of the use of both characterization models will be presented.

McGowan, Maryanne
Duke Energy

PARTNERING FOR SUSTAINABILITY

The water and wastewater industry uses almost 4% of all energy capacity in the US. Population growth and increasingly stringent environmental requirements are expected to raise electricity demand in the US water and wastewater treatment plants by 20% by 2023. This issue, coupled with increasing customer concerns about water quality, is expected to give raise to the demand in seeking a balance in the water-energy balance. The idea of providing services in an Energy Efficient manner is gaining strength - especially in the forms of more efficient pumps and motors - but all remains secondary to compliance with state and federal regulations and public health and safety. The water and wastewater industry is seeking creative solutions to their challenges and the Energy industry want to partner with them to be part of those solutions. A review of Opportunities and Constraints for Energy Management will be provided:

- Describe an assessment of how the mix of treatment plants and their associated energy use characteristics have evolved because of more stringent regulations and more energy intensive technologies.
- Strategic Energy Management Practices
- Data Monitoring and Controls
- Energy Efficiency Improvements in Equipment & Process
- Peak Load Management Strategies

Conclude with an example of the collaboration that is developing between the water and energy industry.

Meadows, Michael E.
University of South Carolina, Dept of Civil & Environmental Engineering

ADJUSTING NRCS CURVE NUMBER FOR RAINFALL DURATIONS LESS THAN 24 HOURS

The primary use of the NRCS curve number (CN) is to compute total storm runoff based on total rainfall. During development of this method, CN values were determined using daily rainfall and runoff data, which is the implicit duration for values input to the curve number runoff model. Duration is not factored into the calculation. As explained by William Merkel, Hydraulic Engineer, USDA-Natural Resources Conservation Service, Beltsville, MD, you cannot use the standard curve number for any duration other than 24 hours. If you do, you need to increase it for durations less than 24 hours and decrease it for durations longer than 24 hours. A basic hydrologic principle is that after initial abstractions have been satisfied, water infiltrates into the soil at nearly a steady rate. For a given rainfall depth, if the event duration is extended over a longer period of time, more rainfall will infiltrate. If the storm occurs over a shorter duration, less rainfall will infiltrate and more will go to runoff. This concept was explained by Merkel as follows. At a watershed with CN value of 80, for 4 inches of rainfall, the runoff is 2.04 inches. For rainfall duration of 1 hour, the runoff would be 2.04 inches and for 24 hours rainfall duration, the runoff also would be 2.04 inches. If you use the standard curve number for a 60-minute storm, it assumes that you have 24 hours of infiltration in just 60 minutes. This concept is technically invalid. The curve number should be increased for rainfall events with duration less than 24 hours. Assume the same initial abstraction occurs for all durations. This obviously would not work for short durations, but probably is practical for durations of 1 through 24 hours. The second part of the analysis is to assume the relationship of time and infiltration can be related to the value of S (maximum retention). This allows variation of the infiltrated amount based on storm duration and estimation of how much the CN would increase from the 24-hour base value. The following table shows steps to compute the adjusted CN value for storm duration less than 24 hours. For this example, the standard CN is 75 and storm duration D is 3 hours. Standard CN refers to the CN obtained from the published NRCS CN table based on land use and soils information. This value is labeled 24-Hour CN. The objective of the following calculations is to compute the 3-Hour CN. As described above, this value will be higher than the standard 24-hour CN.

24-hr CN = 75
24-hr S = 3.33
24-hr Ia = 0.67
D -hr = 3 Hour
D-hr P = 2.50
Assume D-hr P occurs in 24 hours and compute 24-hr QCN = 0.65
24 hr F = D-hr P-24-hr Ia-24-hr QCN = 1.18
24-hr Infiltration Rate (in/hr) = 24-hr F/24 = 0.05
24-hr Infiltration Rate multiplied by D hours = D-hr Infiltration (inches) = 0.15
D-hr Infiltration plus Ia = 0.81
D-hr P - D-hr Infiltration plus Ia = D-hr Runoff (inches) = 1.69
Use D-hr P and D-hr Runoff to compute D-hr CN = 91.9

Mhatre, Snehal, Alan Johnson
Clemson University

WATER FOR ELECTRICITY: IMPACTS OF HABITAT DEGRADATION AND FRAGMENTATION ON FRESHWATER MUSSELS (Poster)

The use of water resources for electricity production and the associated impact on reservoir levels, streamflows, and thermal regimes is in conflict with the requirements of in-stream biota particularly freshwater mussels. Populations of unionid species have experienced significant declines and extirpations in the recent times due to habitat fragmentation, hydrologic alterations due to impoundments, changing thermal regimes and lack of connectivity. These long-lived species reproduce by producing larval glochidia, which are parasitic on fish gills, making availability of suitable host fish species crucial for dispersal. These freshwater mussel populations have potentially limited connectivity in situations where host fish are not available or their movements are restricted by dispersal barriers such as large dams. We used metapopulation models to simulate the dynamics of spatially fragmented populations representing typical freshwater mussels. Habitat degradation had the most significant impact on metapopulation abundance and persistence of local populations. The loss of connectivity due to dams acting as dispersal barriers had much less immediate effect however may cause long-term species decline. The development of such simulation models will aid in assessing the impact of water use on native freshwater bivalves and provide assistance in managing water resources for future energy use scenarios.

Mosteller, Kevin[1], Jeff Lineberger[2]
[1]HDR, [2]Duke Energy

CATAWBA-WATEREE RIVER BASIN WATER SUPPLY MASTER PLAN - PROVIDING A SUSTAINABLE WATER SUPPLY FOR FUTURE GENERATIONS

The Catawba-Wateree Water Management Group (CWWMG) is completing a Water Supply Master Plan (Master Plan) for the Catawba-Wateree River Basin (Basin). The Master Plan is anticipated to be complete and published in May 2014, coinciding with Drinking Water Week. The purpose of this Master Plan is to protect, preserve, and extend the available water supply in this Basin that extends from the foothills of North Carolina through the piedmont area of South Carolina. Previous water supply studies have indicated the potential for this water supply source to reach its safe yield by mid-century (i.e. 2050). As such, the CWWMG has commissioned this effort to update future water demand projections, evaluate options to conserve and extend the available water supply, and establish an implementation plan for accomplishing these objectives. The work effort was guided by the CWWMG membership, a water supply modeling team comprised of regulatory officials from both NC and SC, as well as an outside stakeholder team. The outside stakeholder team includes representatives from interested non-governmental organizations, regulatory agencies, marine commissions, regional council of governments, and others. The results and recommendations of the Master Plan include the following:

• Secured $850,000 of outside funding (>71% of total project cost).
• Secured 20-25 member Stakeholder Advisory Team (SAT) support.

• Tasked SAT with broad communication of Master Plan.
• Enhanced GIS database planning tool with water use information.
• Completed approved Environmental Management Commission (EMC) hydrologic model of the Catawba-Wateree River Basin with stakeholder input.
• Constructed a more robust CHEOPS model with additional tools, flexibility, and faster processing.
• Made 11 specific recommendations for updating, revising the Low Inflow Protocol (LIP).
• Reviewed water quality initiatives in the Basin, shortlisted applicable models for the CWWMG, and identified a strategy for moving forward with water quality modeling.
• Updated/developed future projections for water use in the Basin to 2065.
• Updated the CHEOPS model for the new Drought of Record, and other operations considerations.
• Integrated climate change into water supply planning for the Basin.
• Evaluated population growth sensitivity into water yield analysis.
• Evaluated climate change sensitivity into water yield analysis.
• Modeled 26 individual scenarios and 10 integrated scenarios for water yield analysis, including 'book end' Best Case and Worst Case outlooks.
• Established a Planning Case scenario that extends water yield 40+ years into the next century.
• Developed project decision criteria matrix.
• Identified public and private sector future funding support opportunities for future projects.
• Recommended 6 specific actions for the CWWMG to gain/maintain regulatory and legislative leverage.
• Explored regionalization opportunities and identified successes.
• Identified goals for each user (and basin-wide) to reduce residential water use by 17.8% in the planning period (11.6% total usage).
• Identified Lake James storage as 'emergency contingency' plan.
• Identified vulnerabilities and prioritized systems for Raw Water Intake Contingency Plans.
• Recommended 7 specific public outreach activities for the CWWMG to enhance communication/collaboration.
• Endorsed 5-year self-assessment recommendations for organizational enhancement of CWWMG.
• Provided timetable for implementing items in the project decision criteria matrix.

This paper provides an update on the final development and publication of the Master Plan. The results and recommendations will be discussed, including revised future 50-year projections, key elements of water quantity modeling and the impacts of variables including climate change and new droughts of record. Input and leadership from the outside stakeholder team, NC DENR and SC DNR will also be discussed.

Murphy, Patrick, Nigel Kaye, Abdul Khan
Clemson University

HYDRAULIC PERFORMANCE OF FULL FLOWING PERFORATED PIPE UNDERDRAINS SURROUNDED BY LOOSE LAID AGGREGATE (Poster)

Results are presented from an experimental study of the hydraulic performance of a porous pipe buried under loose laid aggregate. A series of experiments were performed in which the depth of flow over the pipe was measured for a constant pipe discharge. The stage-discharge relationship for the pipe is well described by an orifice equation provided that the water surface in the aggregate trench is horizontal and the pipe is running full at the outlet. Analysis of the system using the integral form of the energy equation shows that the dominant energy losses are due to flow through the small side wall orifices into the pipe and from friction losses along the pipe. Friction losses in the aggregate bed are negligible which again supports the orifice equation model. We report discharge coefficients for three commonly available porous pipes. These results can be used in the sizing and placement of sub-surface drains in aggregate filled stormwater infiltration practices such as infiltration trenches and porous pavements.

Nation, Rocky, Leah Johnson
Southern Wesleyan University

USE OF A VOLUNTEER MONITORING PROGRAM TO ASSESS WATER QUALITY IN A TMDL WATERSHED UTILIZED FOR RECREATIONAL USE, PICKENS COUNTY, SOUTH CAROLINA

Municipalities, regulatory agencies, and resource advocacy organizations are often tasked with the enormous responsibility of monitoring water quality and implementing management strategies for vast areas within their jurisdictions. A potential means for addressing this sampling shortfall is the use of volunteer monitoring programs. The project reported herein demonstrates the use of QA/QC protocols developed by Georgia Adopt-a-Stream (AAS) to monitor water quality issues for Twelve Mile Creek located in Pickens County, SC. The Twelve Mile watershed has a storied past as an EPA Superfund site due to industrial PCB contamination. Recent mitigation efforts involving the removal of two concrete dams have resulted in the creation of a nearly two-mile section of whitewater which is used by the local paddling community and is being marketed as a recreational destination. However, the Twelve Mile watershed also has a TMDL Implementation Plan in place due to chronic impairment from fecal coliform bacteria. Using sampling and monitoring methods developed by AAS, this project determined that E. coli levels increase significantly during high-flow discharges due to storm events and there were no significant differences in E. coli concentrations among sites located along a longitudinal gradient following the proposed Twelve Mile Creek Blueway. Ironically, the popularity of this area for paddling increases during periods of high discharge, thus recreational users are likely exposed to unhealthy levels of bacteria under these "desirable" conditions. Volunteer monitoring programs like AAS exhibit tremendous potential for gathering water quality data that may not be possible if left solely up to other stakeholders. Appropriately managed volunteer monitoring programs have the capability to increase the resolution, reach, and efficiency of existing monitoring programs and serve to benefit a variety of stakeholders.

***Neet, Matthew**[1], Heath Kelsey[2], Dwayne Porter[1], Dan Ramage[1], Adrian Jones[2]
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MODEL PERFORMANCE RESULTS IN MYRTLE BEACH, SC USING VIRTUAL BEACH AND R REGRESSION SOFTWARE

Daily forecasts of beach water bacteria levels have been developed and automated by a beach water quality forecast team. With support from the Southeast Coast Ocean Observing Regional Association (SECOORA), R software and a variety of data sources were used to model daily bacteria levels. Modeled (predicted) water quality results are then shown at beach locations via a website and mobile phone app. While R provides a robust set of tools for use in forecast modeling, the software has an extensive learning curve and requires skilled statistical interpretation of model results. To address some of these concerns, the Environmental Protection Agency (EPA) created a software package called "Virtual Beach." Virtual Beach was developed to allow robust predictive models to be created without a long learning period. As both the forecast team and EPA were interested in comparing R and Virtual Beach outputs, predictive models were created and analyzed. Recommendations were made based on ease of use and model robustness. Model results indicate the two software packages yield comparable outputs in terms of performance. However, Virtual Beach tends to create better predictions with more robust model forecasts, while R tends to produce more flexible model options and outputs.

Newquist, Daniel[1], Sue Sledz[2], Susan Libes[3], Stephen Williams[4], Dave Fuss[5], Tracy Jones[6], Daniel Hitchcock[7]
[1]Waccamaw Regional Council of Governments, [2]CMurrells Inlet, [3]Coastal Carolina University, [4]Earthworks Group Inc, [5]Horry County Stormwater Management, [6]Georgetown County Stormwater Management, [7]Baruch Institute of Coastal Ecology and Forest Science, Clemson University

MURRELLS INLET WATERSHED: POSITIVE OUTCOMES FROM A MULTI-STAKEHOLDER PLANNING PROCESS

Murrells Inlet is a coastal community with strong economic and cultural ties to the salt marsh estuary that bears its name. Recognized throughout the region as the Seafood Capital of South Carolina, Murrells Inlet attracts thousands of visitors every year to the numerous restaurants and abundant outdoor recreational opportunities including boating, fishing, swimming, birdwatching, and shellfish harvesting. Protecting the long-term health of the estuary is a paramount goal of the community. With the support of a SC DHEC 319 grant, the Waccamaw Regional Council of Governments facilitated a watershed-based planning process to evaluate the existing water quality conditions in Murrells Inlet and identify opportunities to improve water quality through structural and non-structural Best Management Practices (BMPs). The main parameter of focus for this watershed plan is fecal coliform. The watershed plan is organized to follow the 9 element format recommended by EPA's Handbook for Developing Watershed Plans to Restore and Protect our Waters. This case study outlines the importance of long-term partnerships in watershed management, the value of a watershed plan as a guiding document resource, and the lessons learned throughout the planning process.

***Nickolas, Lydia,** T.J. Callahan, V.M. Vulava, A.E. Morrison
College of Charleston

TRACKING STREAM FLOW RESPONSE TO STORM EVENTS IN LOW-GRADIENT WATERSHEDS: APPLICATION OF STABLE ISOTOPES FOR HYDROGRAPH SEPARATION

The southeastern coast is among the fastest growing communities in the United States. From 2010-2012, Charleston, South Carolina experienced a 2.1% increase in population growth, ranking it as the 12th fastest growing metropolitan area in the US. The resulting urbanization and increased land use has led to significant alteration of coastal watersheds and degradation of associated fresh and estuarine water body health. Compounding this problem are the many effects of global change-related extreme weather patterns - e.g., large floods caused by moderate storms - that could have grave consequences for the ecology and people that live here. The overarching goal of our research project is to provide scientific guidance about how storm events affect stormwater runoff response in coastal watersheds in order to better manage stormwater in areas undergoing land use change. The main objective of this study is to delineate sources of water to streams in low-gradient coastal watersheds using stable isotopes of water. Precipitation, surface water, and groundwater samples were collected from multiple sites within the Francis Marion National Forest and analyzed for stable isotopes of water (18-O/16-O and deuterium/hydrogen). End-member mixing analysis was performed to estimate the source contributions to Turkey Creek (US Geological Survey gage ID 02172035), a third order stream which serves as a model for streams found in low-gradient watersheds of the southeastern coast. Previous results indicated that precipitation experiences some seasonal variability (depending on storm origin and timing), surface water closely-tracks precipitation in the winter months, and groundwater follows seasonal trends of depletion in the cold months and enrichment in the warm months. Data also suggest that, on average, stream flow consists of about 40: 60% groundwater: precipitation in Turkey Creek yet there is a large variability in stream flow behavior. With continued studies we have focused on a more targeted period of time during February-May 2014; the transition from the dormant to growing season in which evapotranspiration increases, thus affecting both the antecedent water-table position and in turn the runoff response to storm events. This time period also experienced above-average rainfall, providing several substantial storms for us to better test our mixing model. We will present results that provide a more precise view on stream flow response as a guide for watershed managers and land planners to know what possible stormwater conditions to expect in areas of low relief and shallow water table conditions. Stormwater managers and decision-makers in this rapidly urbanizing region need region-specific data to design and implement best management practices to mitigate stormwater runoff.

Oligee, Charles, Ken Barry
S&ME, Inc.

THE GENETTA RESTORATION PROJECT

The Genetta Stream watershed in Montgomery, Alabama encompasses approximately 7.7 square miles, the majority of which is highly urbanized and densely developed. The upper reaches of the watershed are characterized by impervious surfaces, concrete lined channels, and piped conveyances. Research has shown the downstream reach has also been significantly altered through channelization and straightening as well as by increased peak storm flows and durations due to urbanization. The net effect of the highly developed watershed is the loss of natural stream habitat, increased urban pollution, and "flashy" hydrology. The Genetta Restoration Project represents a multi-phased plan to restore many of the natural features and functions of Genetta Stream through; introduction of green infrastructure elements, development of constructed wetland complexes, day-lighting of culverted portions of the stream, naturalization of hard engineered stream segments, and restoration of previously altered stream reaches. Phase 1 of the project includes day-lighting approximately 500 feet of the stream into a constructed wetland complex. Phase 2 of the project includes introduction of green infrastructure elements low impact development techniques to reduce non-point source pollution and restore surface water infiltration in formerly hard surfaced areas. Phase 3 of the project includes naturalization of approximately 2,500 feet of Genetta Stream currently contained in a trapezoidal concrete-lined channel. Future Phases of the project include restoration of the channelized and straightened portion of the stream and incorporation of storm water treatment wetlands for tributaries along the reach.

Osborne, Robert[1], Brad Moore[2], Stephen Simpson[1]
[1]*Black & Veatch,* [2]*ACFS*

APALACHICOLA-CHATTAHOOCHEE-FLINT STAKEHOLDERS: WORKING TOGETHER TO SHARE A COMMON RESOURCE

The Apalachicola-Chattahoochee-Flint (ACF) watershed begins in Georgia, with the headwaters of the Chattahoochee near Unicoi and the headwaters of the Flint near Atlanta Hartsfield Airport. These rivers flow south to join at Lake Seminole, forming the Apalachicola, which flows south through Florida towards the Apalachicola Bay in the Gulf of Mexico. Sustainable management of water resources in the ACF Basin is an urgent need; demands on the system are escalating, as is the need to protect the natural systems. For over 30 years, the states of Alabama, Florida, and Georgia and numerous interests within these states have sought a comprehensive and equitable management program for the ACF Basin. Water use in the basin has been litigated for more than two decades. Recognizing that litigation and politics have been unable to resolve the issues, a grassroots effort was launched by the individuals and groups most impacted by the situation - the stakeholders themselves. The ACF Stakeholders brought together a diverse group representing all water use sectors, organized by geographical basin caucuses. The ACF Stakeholders was incorporated as a 501(c)3 nonprofit in late 2009, and has since begun working together to achieve a common goal: the development of a sustainable water management plan. The ACFS's mission is to recommend equitable water-sharing solutions among stakeholders that balance economic, ecological and social values while ensuring sustainability for current and future generations. The ACFS has raised over $1.3 million dollars for the development of this historic plan through scientific modeling and a shared vision process. This plan involves the identification of performance indicators for modeling of the basin, compilation of the latest water use and other input data, development of water management alternatives, and iterative modeling to evaluate alternatives against the performance metrics. This stakeholder-driven planning process is a unique example of empowerment of impacted water users seeking to develop consensus around water management priorities. The ACFS' democratic, collaborative approach is distinctly different from other efforts in the watershed, and it offers an unprecedented opportunity to reach a long-term solution. This presentation will present the progress to date and some of the challenges of multi-discipline planning aimed at developing consensus solutions in a complex environment in the Apalachicola-Chattahoochee-Flint basin. The presentation will also include lessons learned that would be applicable to South Carolina's growing interest in a stakeholder-based, statewide water planning effort.

***Owen, Lauren**, Daniel R. Hitchcock, David L. White, Gene W. Eidson
Clemson University

USING GIS TO PRIORITIZE GREEN INFRASTRUCTURE INSTALLATION STRATEGIES IN AN URBANIZED WATERSHED

A Geographic Information System (GIS) was utilized to create a digital elevation model (DEM) and a stormwater systems map in order to perform spatial hydrologic analyses on watershed discharges from urban Aiken, SC. Arc Hydro® was used to create and analyze hydro networks, to determine flow accumulation, and for subwatershed delineation. The HEC-HMS preprocessor HEC-GeoHMS was then used to transform the ArcMap model into a format that can be imported into watershed model HEC-HMS to create hydrographs for peak flow and runoff in 10 subwatersheds within the entire urban watershed. Model calibration is underway based on isolated storm event data to determine stormwater flow and volume contributions from respective subwatersheds. By modeling storm events, hydrologically informed decisions can be made related to the addition of green infrastructure-based stormwater control measures (SCMs) in specific subwatersheds. This modeling effort is also essential for understanding the infrastructure connections within the existing city stormwater system.

Payero, José, Rebecca Davis, Ahmad Khalilian
Clemson University

DEMONSTRATING SUBSURFACE DRIP IRRIGATION AS A CLIMATE ADAPTATION STRATEGY FOR SUSTAINABLE CROP PRODUCTION IN SOUTH CAROLINA

There is strong evidence that the climate is changing, which has been linked to anthropogenic increases in concentration of greenhouse gases in the atmosphere. Predictions are that in the future we are to expect a hotter climate with more frequent climate extreme events such as droughts and floods. Farmers in South Carolina have a high exposure to climate risk since most row crops in the state are traditionally produced

under dryland conditions. Dryland production, however, is risky because it can severely limit yields and farm profits during drought periods. Adoption of irrigation, on the other hand, stabilizes yields from year to year and can significantly increase yields and profits. Farmers in South Carolina are rapidly adopting irrigation and irrigated acreage doubled from 1997 to 2011, increasing considerably since 2002 at a rate of 9,184 ac/year. However, most row-crop farmers who irrigate use Center Pivot systems, which require large and square fields and do not adapt well to small or odd-shaped fields. Most fields in the state, however, are small and odd-shaped, which has limited the adoption of irrigation by many farmers. An option for these farmers is to use Subsurface Drip Irrigation, which is even more efficient than center pivots and adapts well to this type of fields. This presentation will focus on work that is currently underway at the Edisto Research and Education Center of Clemson University to evaluate and demonstrate the technical and economic feasibility of using Subsurface Drip Irrigation for row crop production in South Carolina.

***Pellett, Charles A**, David White, Nakisha Fouch
Clemson University

DIGITAL ELEVATION MODEL (DEM) ERROR PROPAGATION IN WATERSHED DELINEATION (Poster)

A typical stream and watershed delineation workflow in GIS starts with a DEM grid and proceeds to fill any extraneous sinks and subsequently determine the flow direction and flow accumulation of each cell. Pour points are snapped to cells of high flow accumulation, and all cells which flow towards that pour point are included in the watershed. Where underground storm drains are present, either the DEM or the flow direction and flow accumulation derivatives should be modified accordingly. Even without underground storm drains, DEM error is propagated through the derivatives and can introduce uncertainty into the delineated watershed. DEM error varies according to the source of the elevation data. Furthermore, there is often spatial autocorrelation in the error. Slope is one spatial condition which increases DEM error. DEMs derived from contour maps may be affected by 'ghost contours,' a form of systematic error. Especially in the case of LiDAR derived DEMs, there is uncertainty as to the value being measured – ranging from the soil surface to plant canopy or rooftops. A Monte Carlo simulation of DEM iterations, conditioned for slope, and adjusted for underground storm drains, will be used to generate fuzzy watershed delineations. This output can be used to guide field observations for efficient verification.

***Pellett, Charles**, David White, Dhanuska Wijesinghe, Dara Park
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STORM WATER DAMAGE RISK ASSESSMENT ALONG THE SOUTH CAROLINA HERITAGE TRAIL

Storm water damage in the form of rill formation across the South Carolina Botanic Gardens (SCBG) Heritage Trail has been modeled as a function of contributing area using D8 and D-infinity flow direction algorithms on a preprocessed LiDAR-derived elevation raster grid. D8 was also applied over a set of stochastic Monte Carlo simulations (n=500) representing elevation error. The mean simulated, D8, and D-infinity contributing area was calculated for each 5'x5' cell along the trail. Model outputs are calibrated against observed rill formation, and the receiver operating characteristic (ROC) is compared for each of the three outputs. Appropriate preprocessing and flow direction algorithms can be applied to digital elevation models to predict areas at high risk of damage from storm water runoff. These low-cost methods may inform storm water infrastructure design.

Petkewich, Matthew, Timothy A. Lanier, Celeste A. Journey, John M. Shelton, Paul A. Conrads
U.S. Geological Survey

INVESTIGATION OF FLOW PATTERNS, WATER–QUANTITY, AND WATER-QUALITY CONDITIONS IN THE BUSHY PARK RESERVOIR, CHARLESTON, SOUTH CAROLINA

The U.S. Geological Survey, in cooperation with Charleston Water System (CWS), is evaluating the hydrodynamics of the Bushy Park Reservoir to determine the effects on water-quality conditions. Specifically, the CWS has four areas of concern that this investigation will address: (1) hydrologic monitoring of the reservoir to establish a water budget, (2) water-quality sampling, profiling, and continuous monitoring to evaluate the causes of taste-and-odor occurrence, (3) flow monitoring in the tunnels to compute flow from Bushy Park Reservoir and at critical distribution junctions; and (4) technical evaluation of appropriate hydrodynamic and water-quality simulation models for the reservoir. Data collection will include real-time continuous monitoring, discrete water-quality sampling, and vertical and longitudinal profiling by using an Autonomous Underwater Vehicle. The data-collection effort will help to identify probable "hot spots" of elevated chlorophyll and blue-green algae (BGA) concentrations within the reservoir and give insight to the principal causes of the Bushy Park Reservoir taste-and-odor episodes. Periods of elevated trans-1, 10-dimethyl-trans-decalol (geosmin) and 2-methylisoborneol (MIB) concentrations have occurred in the Bushy Park Reservoir including an extreme case during the spring of 2012. Occurrence of geosmin and MIB, which produce musty, earthy tastes and odors, are one of the primary causes of taste-and-odor episodes in drinking water. Although not a human health problem, geosmin and MIB are problematic because the human taste-and-odor detection threshold for these compounds is extremely low and conventional water-treatment procedures such as particle separation, oxidation, and adsorption typically do not reduce concentrations below the threshold level. Geosmin- and MIB-producing BGA blooms are attributed to a range of environmental factors, including nutrient concentrations and ratios, light availability, water temperatures, water-column stability, and reservoir flushing rates. Remediation efforts of reservoir conditions where cyanobacteria dominance occurred has hinged upon a strong scientific understanding of the mechanisms controlling the algal community. Evaluating the physical and chemical conditions within the Bushy Park Reservoir with respect to changes in cyanobacteria concentration may provide CWS a basis to further modify management strategies to reduce taste-and-odor occurrence. Management strategies can be implemented long-term to prevent conditions under which cyanobacteria dominate and additional treatment technologies, like the powdered activated carbon that CWS currently utilizes, can be implemented short-term to reduce or remove the taste-and-odor compounds.

***Phillips, Jillian**[1], Timothy J. Callahan[1], Vijay M. Vulava[1], Geoffrey I. Scott[2], Andrew J. Wunderley[3], Jestine deWerdt[4]
[1]College of Charleston, [2]NOAA, [3]Charleston Waterkeeper, [4]Mount Pleasant Waterworks

APPLICATIONS OF SOURCE-TRACKING AND SITE-SPECIFC MODELS FOR WATER QUALITY ASSESSMENT OF TIDAL WATERS: UPPER INLET CREEK, MOUNT PLEASANT, SOUTH CAROLINA

In South Carolina, there are 504 water bodies identified as impaired for recreation or shellfishing activities and 78% of those impairments are due to pathogen levels above regulatory limits. Upper Inlet Creek, located in a tidal basin along the Atlantic Intracoastal Waterway in Mount Pleasant, SC, is an important habitat for a variety of estuarine life and supports local molluscan shellfish operations. According to the South Carolina 303(d) list for impaired waterways, Upper Inlet Creek is impaired for shellfishing activities due to high levels of fecal coliform, a type of bacteria indicator. However, it is unknown whether this impairment is due to human fecal contamination (i.e. sewage or septic) or due to non-point sources such as stormwater runoff, pets and/or wildlife. The goal of this study was to determine possible causes and sources of fecal coliform contamination by using various inexpensive source-tracking methods. Methods included the use of targeted sampling for fecal indicator bacteria fecal coliform and enterococci, optical brightener measurements, and water quality monitoring and analysis for pH, temperature, turbidity and conductivity. Objectives of this study were to (1) provide monthly water quality and bacteria monitoring for the impaired waterway for a 12 month period, and (2) identify potential bacterial sources and (3) provide data for best management practices (BMPs) that could be implemented to reduce bacteria loading in coastal streams similar to Upper Inlet Creek. Results show that optical brighteners were adequate screening tools in determining whether human waste from impaired sewer or septic systems was present, and combined with microbiological data and site-specific models, ruled out human waste streams as the primary source of fecal coliform pollution in Upper Inlet Creek. Results from site-specific models for stormwater and potential fecal coliform loading identified stormwater, pets, and wildlife as the largest potential contributors of fecal coliform bacteria loading to Upper Inlet Creek. The impact of development on stormwater runoff and bacteria loading was found to be significant and recommendations for future remediation include the maintenance of on-site BMPs and the use of predictive modeling to understand how land use change will affect fecal coliform loading in a tidal basin.

Phillips, Ryne C.[1], John R. Saylor[1], Nigel B. Kaye[1], James M. Gibert[2]
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A COMPARISON OF REMOTE SENSING ESTIMATES OF LAKE EVAPORATION WITH PAN EVAPORATION MEASUREMENTS ALONG THE SAVANNAH RIVER BASIN

Lake evaporation significantly affects water availability in many river basins. As water resources are strained from droughts or population and industry growth, water management plans are paramount. However, without a proper understanding and accurate estimate of lake evaporation, such plans may be subject to failure. Within this paper, two methods for estimating lake evaporation are considered. The first is a satellite-based method where mass transfer models (three are investigated) that incorporate high resolution satellite measurements of water surface temperature from the MODIS sensor. The second method is the traditional pan method using monthly derived pan coefficients. These models are used to estimate the historical lake evaporation within the five major lakes encompassing the Savannah River Basin. This comparative study clearly reveals differences between the two methods on a daily, monthly, and yearly time scale. Results show significant variation in the seasonal evaporation trends between the mass transfer method and the pan method. There are also differences in the seasonal evaporation variation from lake to lake.

Philips, Ryne, N. B. Kaye, J. R. Saylor
Clemson University

THE EFFECT OF UNCERTAINTY IN EVAPORATION RATE ON PREDICTIONS OF WATER AVAILABILITY IN THE SAVANNAH RIVER BASIN

We examine the impact of uncertainty in estimates of lake evaporation on the uncertainty in water availability estimates in the Savanah River Basin. Remotely sensed lake surface temperature measurements were used as inputs to three mass transfer models to estimate daily evaporation rates. These estimates along with traditional pan based measurements were used to generate four water availability estimates of the Savannah River Basin. The four models were implemented within the USACE HEC-ResSim water availability simulation tool. Historical water availability simulations were run for 57 years of data and future availability estimates based on water use growth scenarios were simulated 70 years into the future. The simulations were run using extant water management and drought plans. The total available water, defined as the volume of water above the lake critical intake, was used as a comparative measure and was computed for drought and normal flow conditions. Results show significant variability in the predicted available water during periods of drought. Return periods were calculated for an event where the lake and basin storage volumes went below 50% of capacity. The calculated return periods indicate that the variability in predicted water availability is greater than the overall estimates of availability of individual models for both historical and future water use scenarios. For example, the estimates of return period for a basin wide 50% full event ranged from 9 to 31 years depending on the choice of evaporation parameterization.

Putman, Brad[1], Gregory Bunting[2]
[1]Clemson University, [2]Purdue University

EVALUATION OF LOW-COST RETROFIT SOLUTIONS FOR SEALED POROUS PAVEMENTS

Porous pavements have become a popular stormwater best management practice across the US, including South Carolina and as a result, a great deal has been learned about how to properly design and construct these pavements to ensure that they function as intended. However, what happens when the porous pavement does not function as intended (i.e., it does not have adequate infiltration)? When clogging occurs in a porous pavement that initially had adequate infiltration capacity, a large portion of the initial infiltration rate can be

restored using a variety of maintenance practices such as vacuuming, pressure washing, or even just using a leaf blower in some cases. However, field surveys have shown that some pavements had limited, or no infiltration capabilities from the onset. This failure is often due to poor construction practices when placing the "porous" pavement. When this occurs, property owners sometimes find themselves in a situation where they have invested a significant amount of money on a porous pavement system to handle the stormwater on their property, but that system does not work sufficiently - or at all. Often times, the situation is left as is, which leads to ponding of water on the pavement, routing to adjacent property, erosion, and other unintended consequences. The objective of this research was to evaluate low-cost retrofit methods for porous pavements with limited or no infiltration resulting from poor construction practices. This study was conducted on a pervious concrete pavement that was sealed at the surface due to over consolidation of pavement during construction, which resulted in an infiltration rate of 0 in/hr throughout the entire property. Core samples from this location revealed that the sealing of the pervious concrete was only limited to the upper 1 to 1.5 inch of the 6 inch pervious concrete thickness. Below this sealed layer, the porosity of the concrete was as designed and the porous reservoir course was also intact. Based on this finding, the retrofit strategy was to cut into the pervious concrete to a depth below the sealed portion to expose the interconnected pore structure of the pervious concrete. These retrofit cuts were made using different size core bits and using a circular saw to evaluate the influence of cut geometry on the effectiveness of the retrofit. Results showed that the techniques were effective at increasing the infiltration rate of the pavement from 0 in/hr to as high as 800 in/hr. Based on the results of this study, a method was developed to plan retrofit solutions for large areas. Retrofit solutions, such as this have the potential to save property owners a significant amount of money while restoring the intended functionality of the porous pavement structure to handle the stormwater as designed.

***Qiao, Xin,** Ahmad Khalilian, Charles Privette, Young Han, Jose Payero
Clemson University

SOIL MOISTURE MAPPING UTILIZING SPACE-BASED GPS TECHNOLOGY DEVELOPED BY NASA (Poster)

Soil moisture at the land surface is a key variable for weather and climate prediction, flood forecasting, irrigation management, and the determination of groundwater recharge. Currently, only in situ data from ground based soil moisture measurements are available. However, interpolating these data to surrounding areas for large-scale characterization is still problematic due to inherent heterogeneity of soil properties and land surface attributes. Alternatively, remote sensing techniques could be used for mapping soil moisture for large regions, which would be very beneficial for disciplines such as hydrology, climatology, and agriculture. NASA scientists have recently developed a modified GPS Delay Mapping Receiver (DMR), which could potentially be used to estimate changes in surface soil moisture. The DMR system records the GPS signal reflected from the earth's surface, which relates to soil dielectric properties. Our overall objective is to investigate the feasibility of utilizing the reflected GPS satellite signal recorded by a DMR to determine soil moisture content. Over the last four years we have conducted replicated tests at the Edisto Research & Education Center to determine correlations between measured soil moisture contents and GPS reflectivity values under a variety of soil textures, soil compactions, and ground cover conditions. Our results have shown that this space-based technology has great potential for determining soil moisture contents. For example, we found strong positive correlations between soil moisture and reflected GPS signal at various soil depths; although, the good relationship tended to degrade with soil depth. Soil compaction and soil texture did not significantly affect reflectivity, while surface roughness and vegetation cover showed attenuation effects on GPS reflectivity.

Rabon, Edward
SCDHEC

SOUTH CAROLINA DHEC USE OF R

South Carolina DHEC is using R for analyzing data from its surface water monitoring program. R is a very robust statistical tool that is free and has allowed the agency to develop some sophisticated programs to aid in the analysis of its data. It has been used in water quality trend assessment, in a statewide pathogen indicator study, in the state water quality survey, and finally in the state wide 303 (d) assessment. The trend assessment tool calculates Seasonal Kendall's Tau for data supplied on a monthly time series. For the pathogen study R was used to find the best regression and fit it to the data. This allowed TMDLs to be converted from Fecal Coliform to E. coli without major data analysis. The statewide survey of water quality is done completely in R. This tool gives an overall assessment of state water quality and gives an estimation of the state's waters that are, or are not, meeting designated uses. The statewide assessment is built from the experience gained from the other three projects. The main piece of this assessment is the comparison of the data collected to the states water quality standards. It also includes a trend assessment on the data. From this analysis further work is done and the 303d list of impaired waters is created.

Rector, William
AMEC

PROTECTING CRITICAL UTILITY INFRASTRUCTURE ALONG ERODING STREAMS USING BIOEGINEERING TECHINIQUES AND STREAM RESTORATION METHODOLOGY

As land development continues and our waterways experience increased stormwater runoff, erosion within our streams and river systems has caused significant problems as it relates to existing critical utility infrastructure. Sanitary sewer, stormwater, natural gas, potable water, and electrical infrastructure all interact with these stressed stream corridors. Stream erosion within these utility rights-of-way has caused exposure of this critical infrastructure, which can be exposed to threats such as impacts from floating debris and hydraulic pressure during significant storm events. Potential failures or significant damage to the utility infrastructure can cause releases, which have the potential to threaten human life and the environment, inhibit product delivery, create expensive repair and clean-up expenses, and result in extensive

regulatory oversight and potential fines. Typically, stream channels within maintained rights-of-way tend to be more severely impacted by erosion than forested/naturalized reaches usually found upstream and downstream of the right-of-way. Exposed pipelines along an eroded stream channel often reveal a lack of woody vegetation within the right-of-way with incised beds, widened channel banks, lateral migration, and sloughing. The purpose of this presentation is to explore and provide alternatives for the maintenance and installation protocols currently used by government and private entities responsible for maintaining these rights-of-way that reside parallel and/or perpendicular to these ailing stream systems. This presentation will also look at providing alternative methodology for repairing these eroding stream channels around exposed and/or endangered critical infrastructure using bioengineered techniques and stream restoration methodology. A recent engineering evaluation of a current natural gas line exposure in the Carolinas will be used to demonstrate this comprehensive approach.

Reidhaar, Paula[1], Susan Libes[2], Christine Ellis[3], Heather Young[4], Tom Garigen[5], Tracy D. Jones, P.E.[6], Kevin Chestnut[7]
[1]Winyah Rivers Foundation, [2]Coastal Carolina University, [3]Waccamaw Riverkeeper, [4]Coastal Carolina University, [5]Horry County Stormwater, [6]Georgetown County Stormwater, [7]City of Conway

VOLUNTEER WATER MONITORING: EDUCATING AND BUILDING RELATIONSHIPS TO MANAGE OUR WATERSHED

The Waccamaw RIVERKEEPER® Program began in 2001 as a "neighborhood watch" program of Winyah Rivers Foundation, a 501(c)(3) not for profit organization whose mission is to protect, preserve, monitor and revitalize the health of the lands and waters of the greater Winyah Bay watershed. As a licensed member of the WATERKEEPER® ALLIANCE, a grassroots advocacy organization with over 200 local Waterkeeper programs and growing, we are dedicated to preserving and protecting YOUR water. Our work includes educating the public; recruiting, training and maintaining a motivated volunteer network to serve as the "eyes and ears" of their local communities; maintaining an on-the-river presence to investigate pollution sources and support monitoring efforts; and coordinating with volunteers and other organizations to stay abreast of actions affecting the watershed. One of the program's major ongoing projects is volunteer water monitoring along the Waccamaw River. Monitoring takes place at 12 sites in South Carolina and 6 sites in North Carolina twice per month throughout the year. Funding for the program is a combination of monies from city and county governments, along with pro bono contributions from the Waccamaw RIVERKEEPER® Program and Coastal Carolina University's Waccamaw Watershed Academy. Local governments providing funding include the City of Conway, Horry, and Georgetown Counties. The duration and stability of this program has led to implementation of multiple sister monitoring programs. Additional programs include benthic macroinvertebrate sampling, bacteriophage monitoring, and water monitoring on campus at CCU.
The benthic macroinvertebrate program is a joint effort of Winyah Master Naturalists, the Waccamaw Riverkeeper, SC DHEC, and Clemson University. Bacteriophage monitoring is a student project being conducted by CCU undergraduate student Joe Cannon and supervised by Dr. Paul Richardson. Monitoring on CCU campus follows the same protocols as the Waccamaw River monitoring at multiple sites on campus. Work is now being done to integrate with other monitoring data such as local CoCoRaHS information as well as making our data available through the Water Quality Exchange. Data is publicly available on the Waccamaw Watershed Academy website and can be exported by site, by date, or by parameter type. The combination of the water quality monitoring, sister monitoring projects, integration with other data sources, and data sharing has increased the value of this work to the public and decision makers.

Rentiers, Ken[1], David G. Baize[2], Joseph A. Gellici[1]
[1]S.C. Department of Natural Resources, [2]S.C. Department of Health and Environmental Control

DEVELOPMENT OF BASINWIDE SURFACE-WATER QUANTITY MODELS IN SOUTH CAROLINA - A STATUS REPORT

Effective water planning and management requires an accurate assessment of the location and quantity of the water resources of the State, and one of the most useful tools for evaluating management strategies is a computer model that can simulate the surface water system throughout an entire watershed. To that end, the South Carolina Department of Natural Resources (SCDNR), in cooperation with the South Carolina Department of Health and Environmental Control (SCDHEC), has initiated a program to develop surface-water models for each of the State's eight major river basins. The models will simulate water levels of the major reservoirs and flows in the major and minor rivers and stream in each basin, and they will quantify water availability at withdrawal and discharge sites. These models will be used as decision-support tools for SCDHEC's surface-water permitting program and SCDNR's water policy and water planning work. Additionally, these models will provide resource managers with the ability to anticipate future water shortages or other water problems that might result from new or increased water withdrawals, droughts, or other changes in physical conditions. Identifying these problems before they occur allows time to develop and objectively evaluate potential solutions before the problems become critical. Unforeseen problems with existing drought plans also may be identified before the drought plans have to be activated. Earlier this year, a consultant was hired to begin developing these eight surface-water models. This work involves collecting and compiling historic streamflow and water use data, as well as characterizing the hydrologic properties of each of the each watersheds, and developing an unimpaired flow data set that extends back about 70 years. The initial modeling development work is expected to be completed by the middle of 2016.

Resler, Kelli, William F. Lamb
AMEC Environment & Infrastructure

WATER QUALITY DESIGN CRITERIA FOR POST CONSTRUCTION: STRIKING A BALANCE BETWEEN PERFORMANCE AND SIMPLICITY

For many years, construction activities and development have been recognized to cause significant impacts on the environment. This environmental concern has led to strict laws

concerning both water quantity and water quality control for construction and development activities. For the State of South Carolina, stormwater management and sediment reduction regulations stem from the State's Construction NPDES General Permit (CGP) and State Regulation 72-300. Although the CGP has recently been updated, the stormwater design standards in State Regulation 72-300 date back to early 1990s. During this time when the stormwater design regulations were being written, with flooding issues in mind, water quantity was the primary focus for design, and thus water quality design was not the main emphasis for regulatory purposes. Since the writing of State Regulation 72-300, significant amounts of research have greatly improved our understanding and methods for post-construction water quality design standards. As land development continues and the number of impaired water bodies in South Carolina rises, it is increasingly important that future land development be designed to protect and improve not only water quantity, but water quality as well. However, it is critical that tightening local and state stormwater regulations provide a sufficient framework of design criteria to give engineers and developers the tools to create cost-effective and environmentally-friendly developments.

Rich, Graham W.
Central Arkansas Water

WATERSHED MANAGEMENT - HOLISTIC POLICIES AND PRACTICES THAT ACHIEVE SUSTAINABLE WATER QUALITY SOLUTIONS

Water utilities throughout the country are facing uncertainties concerning source water supply quality and quantity. Historically, emphasis on protection of water sources was not a priority with water providers; the prevailing industry wisdom centered on the treatment process to act as the initial and final barrier of pollutant removal. Today, utilities throughout the country are placing a heightened focus on source water protection due to a number of factors such as limited availability, impaired water quality, and unpredictable climate issues. Central Arkansas Water (CAW) is a regional water provider in the greater Little Rock metropolitan area serving over 400,000 customers. CAW's largest water supply reservoir, Lake Maumelle is located less than five miles from the western edge of the Little Rock city limits with much of the land within the watershed being owned by a company specializing in timber management and real estate development. Ten years ago, development plans by this company were announced and the location of the development was less than a quarter mile from CAW's water intake on Lake Maumelle. This caused a significant outcry from concerned citizens and local environmental groups prompting the development of a comprehensive watershed management plan aimed at protecting Lake Maumelle. The Lake Maumelle Watershed Management Plan was a collaborative effort between CAW, an independent contractor (Tetra Tech, Inc.), and over seventy community stakeholders representing a variety of interests. The emphasis of the plan centered on mitigating impacts of new development along with a list of watershed stewardship recommendations aimed at producing sustainable solutions for protection of water quality. Although much work and expense went in to developing the watershed management plan, implementation proved to be far more difficult and controversial than the original plan development. This was primarily due to the fact that CAW had to rely on other governmental entities to actually administer and enforce program elements that dealt with new development through land use zoning. However, today CAW has a comprehensive watershed management plan in place that protects and in many cases improves water quality in Lake Maumelle. In summary, lessons learned from CAW's ten year process of developing and implementing a comprehensive watershed management plan can easily be applied to water utilities throughout the country, especially in the Southeast. Today, CAW's active management of the watershed integrates resource protection, recreation, research, and storm water management.

Riekerk, George[1], Denise Sanger[1], John Leffler[1], Eric Montie[2], Anne Blair[3], April Turner[4], Jeff Brunson[1], Kevin Pitts[1]
[1]S.C. Department of Natural Resources, [2]University of South Carolina Beaufort, [3]NOAA HML, [4]S.C. Sea Grant Consortium

VOLUME SENSITIVE WATERS IN TIDAL CREEKS OF BEAUFORT COUNTY, SOUTH CAROLINA

Non-point source pollution from stormwater runoff associated with rapid coastal human population growth and large-scale land use changes threaten the integrity of ecologically and economically valuable estuarine ecosystems worldwide. The headwater tidal creeks of these estuaries serve as the primary hydrologic link between the uplands and the deeper tidal creeks and rivers, and because of that connection are especially sensitive to stormwater inputs. The threat comes from both the volume of stormwater draining into estuarine systems as well as the chemical and biological contaminants carried in the stormwater. Beaufort County, S.C. has implemented some of the toughest stormwater runoff regulations in the country to control both volume and contamination of tidal creeks. The county continues to be cautious and is interested in understanding what portions of their tidal creeks are most sensitive to freshwater stormwater runoff. Using both local and national funding sources, scientists and managers have been working together to identify and implement research with the goal of developing this science-based information for Beaufort County. Through a collaborative process, five watersheds of critical interest to the county and municipalities have been instrumented with rain gauges and salinity sensor arrays to understand the movement of freshwater down the length of these five systems. Sampling sites in each creek system have been established from the volume "sensitive" headwaters to the downstream volume "insensitive" waters. The primary goal of the project is to define the area along the continuum where the impact of the freshwater is reduced to biologically irrelevant variations. In addition, the stormwater runoff is being modeled with the Stormwater Runoff Modeling System (SWARM) to estimate the expected watershed runoff based on existing land cover and to estimate the impacts of severe weather events, and retrofits to stormwater management infrastructure to reduce runoff into headwater tidal creeks. This information will permit Beaufort County to rank its watersheds in terms of volume sensitive areas and to focus policy and regulatory decisions on those regions of headwater tidal creeks that are most sensitive to stormwater inputs.

Ritchie, Jeremy
Town of Bluffton

BUILDING A STORMWATER TOOLBOX - LEARNING WHAT TO EXPECT FROM YOUR STORMWATER BMPS

The May River in Bluffton, SC is designated an Outstanding Resource Water by the SC Department of Health and Environmental Control (SCDHEC, 2012) for its valued natural resources, particularly for its oyster production and aesthetic views. However, due to the rapid development within the watershed, rising fecal coliform levels in the river's headwaters resulted in closing portions of the river to shellfish harvesting. Rising fecal coliform levels are a clear indicator of the deterioration of the health of a watershed.

Research, studies and countless staff-hours have been used to identify where and why increased pollutant loading occurs within the watershed. The indications from those efforts are that increased stormwater runoff volume from development is a key contributor to pollutant loading downstream. This knowledge resulted in the Town of Bluffton adopting a volume-based stormwater ordinance in 2010 and the May River Watershed Action Plan (AMEC, 2011) in 2011. These two documents provide preventative and restorative measures aimed at improving water quality within the May River. The May River Watershed Action Plan (Action Plan) lists multiple project recommendations at fecal coliform "hot spots," which were identified through the Town's water quality monitoring program. The Town's priority is implementing those projects and refining our understanding of what can be expected. Recently completing an EPA 319 Grant-funded New Riverside Stormwater Lagoon at one of the hot spots represents the start of on-the-ground solutions, demonstrating real action toward restoring the health of the May River. Equally important is the knowledge gained by comparing post-construction water quality monitoring data of the lagoon to pre-development monitoring data to determine its efficacy. Using the Action Plan for guidance the Town applied for, and was awarded, a second 319 Grant for a stormwater Best Management Practice (BMP) project. The project will retrofit an existing stormwater system, permitted before the current volume-based ordinance, with volume control through stormwater reuse for irrigation. This is the most common volume reduction technique used by the development community to meet the Town's ordinance. Currently there are no design guidelines for these systems. One of the expected outcomes of the project is creating a design strategy that optimizes the amount of runoff infiltrated by the system. Flow monitoring for both pre- and post-project conditions will help determine its efficacy. In addition to the water quality benefits, valuable information will be gained from this BMP that will aid the Town in offering design guidance to the public that will maximize this particular type of BMP's volume control potential. Both projects contribute to a better understanding of the true impact of a particular BMP to improve water quality. The Town expects to continue this methodology for different BMP technologies in the future. Thus, every project will help the Town build a stormwater toolbox tailored to its specific needs and conditions and provide a template for use by other communities or watershed managers.

Rivers, Porter, Will Huggins, Jane Gan
URS Corporation

EVALUATION OF WATER SUPPLY OPTIONS: CATCHING TWO FISH WITH ONE WORM

Quality and quantity of water supply are imperative for a drinking water utility to be successful. Finding feasible water supply solutions that optimize both of these parameters can be challenging. Recent events motivated the City of North Augusta, South Carolina (SC) to evaluate options for addressing concerns about each. The City draws raw water for its water treatment plant (WTP) from the Savannah River, which serves as the border between South Carolina and Georgia.

While the Savannah River is an abundant source, the City had concerns regarding both the short term and long term reliability of the supply from the Savannah. These concerns were derived from the following:

- Ongoing negotiations between South Carolina and Georgia regarding the allocation of the Savannah River for both wastewater discharge and drinking water supply.
- New regulations implemented by South Carolina for surface water withdrawal permits.
- Aging water treatment infrastructure which requires balancing compliance with the Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2) with control of taste and odor as well as manganese during periodic poor water quality episodes in the Savannah River.
- Recent spills in the watershed upstream of the City's intake which resulted in closing of intakes for some local utilities

Options available for the City to address these concerns included securing a secondary, independent water source with or without new treatment facilities, upgrading and adding a new treatment process to the existing WTP for Stage 2 compliance, and constructing off stream storage facilities to provide emergency supply during poor water quality / contamination events. Factors considered during the evaluation of these options include current and future demands, capital costs, operating and maintenance costs, frequency and occurrence of poor water quality events, ability to secure sufficient quantity under new withdrawal permitting requirements, and ability to comply with water quality regulations. Based upon findings from the feasibility study, the City elected to implement the following:

- Upgrade the existing WTP to enhance treatment capacity and safety (liquid disinfection processes).
- Install a 30 million gallon, concrete, off stream storage reservoir that allows for blending or bypassing during periods of poor water quality in the Savannah River. This presentation will review the proposed solutions (based upon the available options), discuss the analysis and evaluation process (including the statistical analysis and proposed operating schemes used to size the off stream storage), and the iterative process used to select the final recommended solution.

***Robinson, Reggie**[1], Mary Caflisch[2]
[1]*University of South Carolina,* [2]*Clemson University*

LID: A SURVEY AND ASSESSMENT OF BMP'S FOR RICHLAND COUNTY DEVELOPERS (Poster)

I will work with the Mary Caflisch of Clemson Extension Carolina Clear Program to encourage developers to utilize Low Impact Development (LID) techniques in their plans

and drawings, in order to better manage stormwater runoff. Following a thorough literature review of LID and LID techniques, I will perform an analysis of rain garden pollution removal rates to assess evidence for the benefits of LID technology. I will evaluate developers' understanding of LID techniques, and identify ways to promote their use of LID, barriers to implementation, appropriate incentives, and resources required. This evaluation may include surveys, one-on-one interviews, group meetings, and panel discussions. From that evaluation, I will help these builders identify ways to incorporate more LID techniques within their plans and drawings. I will prepare a written summary of recommendations on needs for training, written materials, websites, and other options for providing information and encouragement on the use of LID. Lastly, I will design and produce an outreach package or training workshop based on these recommendations.

Roehl, Edwin[1], Paul Conrads[2]
[1]ADMi, [2]U.S. Geological Survey

OPTIMALLY MANAGING WATER RESOURCES IN LARGE RIVER BASINS FOR AN UNCERTAIN FUTURE

Managers of large river basins face conflicting needs for water resources such as wildlife habitat, water supply, wastewater assimilative capacity, flood control, hydroelectricity, and recreation. The Savannah River Basin for example, has experienced three major droughts since 2000 that resulted in record low water levels in its reservoirs, impacting local economies for years. The Savannah River Basin's coastal area contains municipal water intakes and the ecologically sensitive freshwater tidal marshes of the Savannah National Wildlife Refuge. The Port of Savannah is the fourth busiest in the United States, and modifications to the harbor have caused saltwater to migrate upstream, reducing the freshwater marsh's acreage more than 50 percent since the 1970s. There is a planned deepening of the harbor that includes flow-alteration features to minimize further migration of salinity. The effectiveness of the flow-alteration features will only be known after they are constructed.

One of the challenges of basin management is the optimization of water use through ongoing development, droughts, and climate change. This paper describes a model of the Savannah River Basin designed to continuously optimize regulated flow to meet prioritized objectives set by resource managers and stakeholders. The model was developed from historical data by using machine learning, making it more accurate and adaptable to changing conditions than traditional models. The model is coupled to an optimization routine that computes the daily flow needed to most efficiently meet the water-resource management objectives. The model and optimization routine are packaged in a decision support system that makes it easy for managers and stakeholders to use. Simulation results show that flow can be regulated to substantially reduce salinity intrusions in the Savannah National Wildlife Refuge while conserving more water in the reservoirs. A method for using the model to assess the effectiveness of the flow-alteration features after the deepening also is demonstrated.

Roper, Cindy
Clemson University

INTERSTATE WATER COMPACTS: PARTNERSHIPS FOR TRANSBOUNDARY WATER RESOURCE MANAGEMENT

While there are both successes and challenges related to the use of interstate water compacts, in their most effective forms, they allow states to take a comprehensive, holistic approach to water management. Successful compacts tend to encompass the natural hydrologic boundaries of the water basin. They are more likely to utilize a commission type governance structure with sufficient authority to carry out the mission and goals of the compacting agreement. Successful compacts are flexible and allow for future developments (including climate change) while being cognizant of the need to protect and enhance the environment. They are also sensitive to the needs and desires of various stakeholders, including federal, state, and local governments as well as non-governmental organizations. Water compacts also face a variety of challenges. They must answer to a wide and diverse constituent base, often with conflicting interests. Stronger states can and do attempt to "bully" other states, severely limiting or eliminating altogether the usefulness of the compact. Governance structures that fail to integrate the interests of both states into a single body simply make the compact into an arena where small scale water wars can be fought.

Ruhlman, Melanie[1], Nikki Grumbine[1], Jeff Beacham[2], John Darrohn[2], Rick Huffman[2], Jesse McClung[3], Matt Johnson[2], Eric Potts[1]
[1]Friends of the Reedy River, [2]The Greenfields Consortium, [3]Earth Design

ADDRESSING WATER QUALITY THROUGH STORMWATER RETROFITS IN THE REEDY RIVER WATERSHED - GREENVILLE, SOUTH CAROLINA

The Reedy River is situated in one of the most rapidly urbanizing areas in the country. Changes in historic and modern land use have adversely affected hydrology and water quality in the watershed. While the Reedy River has exhibited the capacity for long-term recovery, water quality in urban areas remains poor and hydrology is altered due to increases in impervious area. The Friends of the Reedy River (FoRR) have identified stormwater as a major threat to the river. Along with various partners, they have developed plans for a stormwater retrofit project along a highly utilized recreational corridor to serve as a demonstration for improved stormwater management for an existing development in a highly urbanized area. The project will be funded through grants and participation in the local stormwater utility fee credit program. New developments are subject to local stormwater ordinance requirements that address quantity and quality control to varying degrees. Many older developments predate existing stormwater requirements and lack adequate stormwater controls. A combination of effective policy and incentive-based land management tools are needed for long-term watershed protection. As urban and suburban areas continue to expand, creative stormwater management solutions are needed particularly for existing developed areas to help protect, sustain, and improve the quantity and quality of surface waters. Public-private partnerships can capitalize on effective use of resources to achieve common watershed protection goals in these challenging areas.

***Ryan, Kimberly, K.**, Adem Ali
College of Charleston

USING OCEAN COLOR REMOTE SENSING TO MONITOR PHYTOPLANKTON IN COASTAL WATERS: A CASE STUDY IN LONG BAY, SOUTH CAROLINA

Remote sensing of water color for the monitoring of water quality has been in practice for decades. The deduction that higher concentrations of chlorophyll-a (CHLa), a pigment found in all algal species, causes a shift in water color from blue to green has led to the use of CHLa as an indicator for water quality. Traditional modeling techniques for the prediction of CHLa fail to remove the influence of other color-producing agents (CPAs) in the water (e.g. suspended sediments and dissolved organic matter). This is a particular challenge of inland and coastal waters that contain high levels of non-algal CPAs, and many traditional models subsequently fail. A novel approach to predictive water quality modeling is introduced that employs partial least-squares regression (PLSR), a two-step multivariate statistical method that reduces the multidimensionality and colinearity characteristic of large, hyperspectral remote sensing data sets. Data used in model development was collected from each of 13 study stations in Long Bay, South Carolina for five research cruises during the months of May-July, 2013. Field-retrieved radiometric data and laboratory-analyzed CHLa concentrations from each station were used to train the model. Due to a limited sample size (n = 53) a leave-one-out validation technique was applied. The model resulted in an R-squared= 0.80 and root-mean square error of 2.03 µg/L. These results suggest that this technique may be applied to other coastal regions in an effort to increase the efficacy of water quality predictive modeling. Due to the broad scale of this monitoring tool, it may be useful for both coastal managers and research scientists in the identification of problem areas that are contributing to the decline of water quality in a coastal system.

Samadi, Seyedehzahra, Michael E. Meadows
University of South Carolina, Dept of Civil & Environmental Engineering

EXAMINING THE ROBUSTNESS OF THE SWAT DISTRIBUTED MODEL USING PSO AND GLUE UNCERTAINTY FRAMEWORKS

Simulating the hydrology of a watershed system is a challenging task due to biases in input data and measurements, and mismatches in spatial and temporal scales between model representation and the physical system. Modeling difficulty increases for watershed systems with low-storage shallow soils, a large number of riparian floodplain alluvials, and non-uniform rainfall distributions. A simulation study was performed to assess feedback effects associated with uncertainty propagation in the Soil and Water Assessment Tool (SWAT) using the Generalized Likelihood Uncertainty Estimation (GLUE) and Particle Swarm Optimization (PSO) algorithms at the Waccamaw River watershed, a low-gradient forested wetland Coastal Plain watershed in the SE region. Optimization of both algorithms indicated the evapotranspiration rate typically exceeded the combination of shallow aquifer, surface flow, and lateral flow contributions during dry periods. It was also shown that shallow aquifer contribution to the total water yield during wet spells may raise the shallow water table and increase the risk of groundwater flooding due to rapid water table responses during storm events.

Samadi, Seyedehzahra, D. L. Tufford, G. J. Carbone
University of South Carolina

IMPROVING THE ROBUSTNESS OF UNCERTAINTY ALGORITHMS IN QUANTIFICATION OF UNCERTAINTY IN WATER BALANCE FORECASTING

Recent studies have highlighted the potential challenges in US southeastern (SE) watersheds from climate variability. There may be shifts in water balance due to complexity of the flow generation processes that determine how water is partitioned in these landscapes. The main objective of this study was to capture the feedback relationships among the water balance components using the Soil & Water Assessment Tool (SWAT) watershed-scale streamflow model linked with the Sequential Uncertainty Fitting (SUFI-2) and Particle Swarm Optimization (PSO) parameter uncertainty algorithms in the Waccamaw River watershed, a low-gradient forested watershed on the coastal plain of the southeastern United States. Water balance uncertainty analysis suggested close correspondence of the model with the physical behavior and system dynamics during different hydroclimatological periods in the 2003-2007 calibration interval. SUFI-2 water balance analysis revealed that surface runoff, ground water, and lateral flow contributed 22.2%, 3.9% and 0.4% of the total water yield during simulation period while PSO analysis indicated 16.7%, 13.2% and 0.3% of their contributions respectively. Both uncertainty methods found that 71.1% of the total rainfall was lost by evapotranspiration during the simulation interval. The total water yields using both algorithms were over predicted by up to 14.0% of the annual rainfall inputs during the dry period (2007); this was related to the extra contribution of shallow aquifer flow to the river system. Both algorithms also specified that surface flow and ground water runoff dominated the water balance during October and December respectively. The distribution of predictive uncertainty was least in the wet year (2006) and was greatest towards the end of dry period, particularly within alluvial riparian floodplains. Water balance estimation with uncertainty quantification can be a useful step in understanding the dynamic nature of a coastal plain landscape, and it may lead to more useful solutions of analytical flow processes through the watershed system.

Samadi, Seyedehzahra
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TOWARD A RELIABLE PREDICTION OF STREAMFLOW UNCERTAINTY: CHARACTERIZING AND OPTIMIZATION OF UNCERTAINTY USING MCMC BAYESIAN FRAMEWORK

Streamflow quantification in the southeastern landscape is subject to a range of uncertainties due to spatially heterogeneous and complex nature of Coastal Plain hydrological system. This paper aims to address the question of how the parameter and total uncertainty quantification in the Soil & Water Assessment Tool (SWAT) model can effectively influence on streamflow prediction in the Waccamaw River watershed, a low-gradient forested wetland dominated Coastal Plain landscape, in North and South Carolina. In this study a Markov Chain Monte Carlo (MCMC) Differential Evolution Adaptive Metropolis (DREAM) algorithm for

Bayesian inference implemented to SWAT in R to capture the uncertainty propagation of daily streamflow dynamics during calibration period (2003-2005). The marginal posterior distributions of eighteen important streamflow parameters values are well identified by DREAM within their prior ranges. In this study a Gelman Rubin diagnostic of <1.2 was achieved for all parameters after about 40000 iterations, indicating that DREAM algorithm well sampled the posteriors. Using a parallelized MCMC algorithm in R identified appropriate likelihood functions and reduced the error in the hydrologic quantity estimation. Further the degree to which all uncertainties are accounted for is quantified and bracketed 72% and 70% of daily measured flow by the 95% prediction uncertainty (95PPU) in the upstream and downstream outlets respectively. The results also indicated that low flow value has high impact on the parametric uncertainty while the variation of uncertainty propagation narrows in the case of high flow events. The posterior distributions of output values also indicated that flow parameters in upstream and downstream portions have non-unique posterior distributions and the corresponding model processes appear to be sensitive to a nonlinear function of the shallow soil properties and river hydraulic characteristics. In particular, DREAM algorithm showed flexibility for parallel implementation on distributed watershed model; efficiently estimates the posterior probability density function and can be therefore practice as a basic approach for a data assimilation framework under hydrological dynamics.

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IMPROVING HYDROLOGIC PREDICTIONS OF DISTRIBUTED WATERSHED MODEL VIA UNCERTAINTY QUANTIFICATION OF EVAPOTRANSPIRATION METHODS (Poster)

Successful initialization and accurate estimation of evapotranspiration (ET) in Coastal Plain landscapes is crucial for the prediction of hydrologic processes including streamflow, surficial aquifer lost and infiltration. The aim of this study is to examine the ability of Soil and Water Assessment Tool (SWAT) to accurately represent the characterization of three potential ET methods (Priestley-Taylor (P-T), Penman–Monteith (P-M) and Hargreaves (HG)) using the Sequential Uncertainty FItting (SUFI-2) algorithm during 2003-2005 and 2006-2007 as calibration and validation intervals. The study area was the Waccamaw River watershed, a low-gradient Coastal Plain watershed in the southeastern US. The results indicated that in estimating ET for a Coastal Plain landscape, P-T method bracketed more than 75% of daily streamflow during calibration period while P-M and HG bracketed 57% and 69% of measured streamflow during calibration period, respectively. Model daily performance using P-T method was "very good" (calibration NSE = 0.77; validation NSE=0.90) but only "satisfactory" (P-M calibration NSE = 0.55; HG calibration NSE =0.61) to "good" (P-M validation NSE=0.75; HG validation NSE=0.70) in P-M and HG methods. The prediction mean square error (MSE) for P-T method was comparably low (57.88 and 325.68) compared to P-M (68.34 and 635.95) and HG (69.99 and 551.99) methods at upstream and downstream outlets, respectively. This suggests that radiation based ET method performed significant results in forested wetland dominated ecosystem with wet and humid surfaces. Based on the water balance analysis, only about 21.2% of flow loss was consumed via stream evaporation and floodplains evapotranspiration, indicating that 78.8% of the loss within the entire study area represented land ET and shallow aquifer recharge. Furthermore, uncertainty quantification revealed that low flows are sensitive to the changes in ET process in dry period and at the beginning of the wet season, but insensitive at the end of the wet season due to nonlinear control of Coastal Plain soil on water movement. In particular, under conditions of so-called "deep uncertainty" in Coastal Plain landscapes, uncertainty quantification of ET methods can lead to the identification of optimal land and water management strategies in southeastern ecosystems.

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FACILITATING STORMWATER POND RESEARCH THROUGH COLLABORATION (Poster)

Stormwater ponds are now permanent features of the coastal South Carolina landscape; over 14,000 ponds are located in the coastal region. Ponds are by far the most common best management practice (BMP) implemented to control stormwater runoff quantity and are increasingly relied upon to improve quality. Examples of the research challenges posed by ponds include design and long-term functionality of ponds, pond interaction with the surrounding hydrology and ecosystem, and risks to human health and the environment created by ponds, especially the accumulation of pollutants including nutrients, organic compounds, and pathogens. Research challenges are coupled with stakeholder needs for information concerning pond ecology, efficiency, effectiveness, design, and management. The South Carolina Sea Grant Consortium has responded to these information needs through support of a number of stormwater pond-related research projects. The Consortium is now fostering the development of an integrated plan to enhance multi-disciplinary research, involving hydrologists, geologists, social scientists, toxicologists, ecologists, and engineers. This network will represent members of multiple universities and government agencies in the state. The potential benefits of collaboration are three fold. First, collaboration facilitates the leveraging of funding from multiple sources. Second, collaboration allows for an interdisciplinary approach in outreach to stakeholders. Most importantly, collaboration highlights research strengths and knowledge gaps allowing for more efficient allocation of resources. Ultimately, a collaborative effort will support the development of an ecological characterization of stormwater ponds to aid in the creation of an integrated and sustainable economic and natural resource strategy for continued construction and use of stormwater ponds as a BMP in South Carolina and the southeastern region.

Sawyer, Calvin, Jeremy Pike, Don Hagan, Charles Privette, Jason Hallstrom, Gene Eidson
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RESTORING HUNNICUTT CREEK: PERSPECTIVES AND PRELIMINARY RESULTS FROM A UNIVERSITY CAMPUS PROJECT

Clemson University has a longstanding, fundamental commitment to environmental sustainability. However, several reaches within the campus stream network illustrate conversion of natural fluvial ecosystems into largely unstable and simplified aquatic environments that require continuing maintenance and provide only marginal value to the surrounding landscape or to the university. Conducting a stream restoration and wetland enhancement project within the physical campus supports multi-disciplinary research, creates opportunities for student engagement, demonstrates critical innovation in restoration monitoring and provides the platform for real-time monitoring and analysis of surface and groundwater resources. In 2013 and 2014, the Hunnicutt Creek Restoration Project established an ecological monitoring and assessment framework for the lower Hunnicutt Creek watershed located on Clemson University Experiment Station property. The permittee-responsible mitigation plan includes hydraulic modification to approximately 4 acres of emergent wetland area and channel restoration to approximately 300 linear feet of perennial stream. Research objectives build on the Clemson University Riparian Corridor Master Plan and align with priority PSA funding areas of enhancing natural resource remote data collection and improving forested watershed management. Work was conducted as offsite compensation for a commercial development project located in the town of Clemson for which no other suitable mitigation credits could be found. Though the project was only installed several months ago, there are data being collected to address several research objectives: 1) Permanently deploy proven, robust sensors and instrumentation within the proposed wetland enhancement and stream restoration project to collect ecological data for use in evaluating project success; 2) Engage university faculty and students in exploring opportunities for advancement of interdisciplinary curricula, research, and public service; and 3) Disseminate results to a variety of audiences, including the broader university community and the general public. Preliminary research results (physical, chemical and biological parameters) collected up until the point of the 2014 SC Water Resources Conference will be included in the oral project report.

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ASSESSMENT OF WATER QUALITY BENEFITS FROM STORMWATER TREATMENT TRAIN AND OCEAN OUTFALL FOR THE MAIN STREET DRAINAGE BASIN IN NORTH MYRTLE BEACH, SOUTH CAROLINA

The city of North Myrtle Beach is located along the northern coast of South Carolina. It is part of the Grand Strand, which annually hosts 15 million visitors drawn to its famous beaches. In Spring 2014, the city of North Myrtle Beach (NMB) completed Phase I of an enhanced drainage system designed to help reduce loading of fecal bacteria into the recreational waters of the surf zone and thereby reduce beach advisories. The system will also improve drainage characteristics and reduce flooding. From the water quality perspective, this system employs a series of best management practices (BMP's) terminating in an offshore outfall that discharges treated stormwater runoff 1200 feet seaward of the OCRM setback line. This stormwater had been previously discharging through multiple pipes directly onto the beachface, which was a relict drainage system designed to carry runoff from state-maintained roads. The BMP's include Snouts® with Bio-Skirts®, catch basin inserts, settling and mixing boxes. Nonstructural BMP's include street sweeping, routine cleaning of the Bio-Skirts®, and removal of debris from the other structural BMPs. The outfall pipe is located at the foot of Main Street. Its upstream BMP system collects water from a 100-acre catchment, aka the Main Street Drainage Basin, whose impervious coverage is on the order of 70% of the surface area of this urban municipality. The associated construction work required a critical area permit from SC DHEC OCRM. The permit stipulated that an assessment be performed to evaluate localized and cumulative effects on water quality and benthic communities under wet and dry conditions. This assessment work is being conducted by Coastal Carolina University's Environmental Quality Lab. The results will also be used by the city of NMB to help meet some of the requirements of its NPDES Phase II Stormwater permit coverage. The following assessment strategies are being employed to address these multiple regulatory needs: (1) An increased frequency of surf zone sampling for Enterococcus, (2) Characterization of chemical and microbiological concentrations in dry and wet weather flows from the Main Street Drainage Basin, (3) Quantification of associated mass transport of chemical and microbial constituents into the ocean under dry and wet weather conditions, and (4) Quantification of the load reductions achieved by the BMP treatment trains. The chemical characterization focuses on issues of eutrophication and hypoxia, including measurement of nutrients (nitrogen and phosphorus), total and volatile suspended sediments, BOD5, and dissolved oxygen concentrations. Microbial measurements include Enterococcus to address the recreational impairments and fecal coliforms to address National Shellfish Sanitation program requirements. The results will be compared to data from SC DHEC's beach and shellfish programs and real-time information collected by the Long Bay Hypoxia Monitoring Consortium, to evaluate impacts to local marine waters.

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ECOHYDROLOGY OF A FLOODPLAIN FOREST: RELATIONSHIPS BETWEEN EVAPOTRANSPIRATION, VEGETATION, AND TOPOGRAPHY AT CONGAREE NATIONAL PARK, SOUTH CAROLINA (Poster)

Congaree National Park supports high biodiversity and provides ecosystem services for the surrounding area in the floodplain wetland system, especially in the bottomland hardwood forests which contain some of the last remaining old-growth stands in the eastern U.S. Maintaining the hydraulic functions of this ecosystem is essential not only for the conservation of biodiversity, but also for the ecosystem services it provides, such as nitrification, denitrification,

decomposition, removal of organic carbon, and phosphorous uptake and sorption. Because management practices of the park depend on understanding the area's hydrology, past research has been performed to analyze the flooding of Congaree River. However, not much has been done to better understand groundwater movement through the floodplain sediments in the Congaree River Valley. The goal of this project is to quantify interactions between the surficial aquifer and local vegetation surrounding eight piezometers in the Congaree Observation Well Network at Congaree National Park through calculating and comparing evapotranspiration rates, specific yield, vegetation diversity and basal area, and microtopography. Data on groundwater response to storm events, diurnal signals caused by evaporation and transpiration in the forest, vegetation community structure, and local topography are being analyzed to better understand the role of these factors on vegetation water demand in this wetland-dominated system.

Shelton, John
U.S. Geological Survey SCWRC

BEYOND THE STREAMGAGE

Since 1889, the U.S. Geological Survey (USGS) has been monitoring the streamflow of the United States to assist and ensure proper water resources management. In South Carolina, the USGS has operated monitoring stations (streamgages) since the late 19th century. (Station 02169000, Catawba River near Rock Hill, SC, has been in operation since October 1895.) In cooperation with more than 40 Federal, State, and local agencies, the USGS South Carolina Water Science Center currently (2014) operates more than 200 continuous real-time monitoring stations across the state. In the 1980's, the USGS in South Carolina pioneered the use of satellite telemetry to provide hydrologic data from the streamgage to the public in real time. The implementation of real-time monitoring has led to the development of a vast array of analytical and visualization tools available to all data users through the USGS's National Water Information System Web Interface (NWISWeb) as well as other analysis portals. Additionally, because of advancements in technology, new hydrologic investigations are being conducted that take the traditional streamgaging network to the "next level." This presentation will provide an overview of the USGS analytical and visualization tools available through NWISWeb, and discuss how the USGS is implementing the use of new technology to expand hydrologic monitoring and investigations beyond the streamgage. The overview will include: (1) StreamStats, a web-based geographic information system application for the computation of streamflow statistics in South Carolina; (2) Flood Inundation Mapping (FIM), a real-time operational tool that visually relates USGS streamgage readings and National Weather Service forecasts to flood risk for the primary purpose of public safety; and (3) the integration and deployment of an acoustic fish tracking system with the existing real-time streamflow monitoring network for the purpose of monitoring the presence and migratory habits of Atlantic and Shortnose Sturgeon.

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APPLICATION OF RECURRENT NEURAL NETWORKS FOR PREDICTING WATER QUALITY CONSTITUENTS OF COLLECTED RUNOFF FROM WINDROW COMPOSTING PAD

Continuous industrialization and ever-increasing population all over the world are resulting in many water quality problems. Majority of organic waste originates from municipalities in the form of yard waste and municipal biosolids. One of the effective methods of organic material decomposition is the composting process. Windrow composting sites are usually open field areas exposed to rainfall. Typically, windrow composting systems are located in remote areas and runoff cannot be directly treated in a wastewater treatment plant. The runoff from these facilities is contaminated and highly regulated due to pollution potential. Land application system (LAS) is an approved approach for discharging effluent of a pond. Therefore, water quality constituents of collected runoff must be considered when designing a pond and collecting runoff in order to prevent the discharge of organic pollutants. The central question in this research is to determine if trends in the water quality time series can indicate likelihood of approaching exceedance of selected pollution measures. Initially, we used Principal Component Analysis (PCA) to transform correlated variables into uncorrelated ones (Principal Components) and to reduce dimensionality of the data. By examining PCs, we observed that temperature associates with water quality constituents such as biological oxygen demand (BOD) in influent and effluent. Also, we found out that temperature associates with total suspended solids (TSS) and nitrogen concentration in effluent. In addition, the number of days between rainfall events associates with TSS concentration in influent. Based on this information, we used commonly used method, Multiple Regression Analysis for predicting TSS and BOD in effluent. The best subset of predictors included precipitation, waste volume and pond level. We selected this subset based on step-wise selection procedure which gave us $R2=0.56$ only. The main objective of this study is to apply state-of-the-art method, recurrent neural networks for better prediction of water quality constituents of stored runoff from windrow compost pad located at UGA Bioconversion center, Athens, USA. We used existing observation data of precipitation, temperature, pond level, total suspended solids, biological oxygen demand and nitrogen concentration levels recorded for the past twelve years (from April 2000). We obtained the best validation performance of recurrent neural network with $R2=0.97$ and Mean Squared Error of 15.6995. This is equal to error in terms of concentration $\pm$ 3.962 mg/L. Models such as this should be helpful as we assess strategies to minimize future potential exceedance in critical water quality parameters.

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STORMWATER HYDROLOGY AND MATERIAL TRANSPORT IN URBANIZED WATERSHEDS OF THE GRAND STRAND, SOUTH CAROLINA

Land use and land cover changes associated with urbanization have been shown to have substantial effects on watershed hydrology and stormwater constituent concentrations. The nature of these effects can often be site-specific, depending on the local geological and hydrological setting, as well as the type of development and adopted stormwater management practices. In particular, information on stormwater hydrography and material export from urbanized headwater catchments specific to the southeastern lower coastal plain is relatively scarce. As part of a larger study aimed at quantifying material loadings from stormwater runoff and groundwater inputs to Long Bay, South Carolina, an intensive base-flow and rainfall-runoff event sampling effort was conducted in three urbanized headwater sub-basins within two major drainages ("swashes") in the Grand Strand region of South Carolina. From July of 2011 to October of 2013, 18 base-flow and 18 rainfall-runoff events were sampled at each site to characterize hydrography (total volume export and rainfall-runoff coefficient, the amount of runoff as a proportion of total rainfall over the catchment) and concentrations of nutrients (nitrogen and phosphorus, in both total and dissolved inorganic and organic forms), suspended sediments, and dissolved and particulate organic carbon in both surface runoff and shallow groundwater flows. Despite differences in land use and percent impervious cover among catchments, mean rainfall-runoff coefficients were generally similar among catchments and, in contrast to forested streams of the lower coastal plain, showed little clear seasonality. Concentrations of most nutrients, sediments, and organic carbon sampled during base flow conditions generally showed little significant variability among the catchments. In contrast, all variables showed significant differences among catchments for rain event samples. There was little to no significant seasonal variability in rain event concentrations for any parameter, however. In addition, there was little relationship between event mean concentrations of nutrients, sediments or organic carbon and total runoff amount across all rain events. In general, concentrations in surface water samples tended to be significantly greater than corresponding concentrations in groundwater samples, although the degree to which this held true varied by specific parameter and site. Similar to many previous studies, differences in broad land use categories or percent impervious cover among the catchments was not generally reflected in corresponding differences in hydrography or the magnitude and forms of material export from these catchments. Therefore, developing appropriate management strategies and designs for controlling stormwater pollution requires site-specific knowledge of the magnitude and variability in contaminant discharge from urban areas in the lower coastal plain.

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HYDRAULIC GEOMETRY CURVES AND BANKFULL RECURRENCE IN THE PEE DEE RIVER BASIN

Streams and tributaries within the lower Pee Dee watershed Hydraulic bankfull geometry or regional curves are a useful metric for evaluating stream stability and plan stream restoration projects. Streams and tributaries within the middle Pee Dee watershed in South Carolina drain a highly productive landscape that is characterized by forest and agricultural practices. While streams in the region are generally stable, pockets of this landscape are beginning to face increasing pressure from changing land development practices and showing signs of stream instability. In order to provide a foundation for potential stream restoration projects in the area, we selected sixteen sites in the watershed on the basis of catchment area, in categories of small (<50 km2), small-medium (50-500 km2), medium (500-1000 km2), and large (>1000 km2). Bankfull geometries, channel substrate, flow and temperature were measured at all the sites, and a set of regional hydraulic geometry curves developed. We also estimated the frequency of bankfull flows that occurred over the period of sampling to document floodplain connectivity. Bankfull dimensions in the middle Pee Dee River watershed were well correlated with bankfull discharge and drainage area. The results showed that hydraulic geometry in the region were similar to those measured in a similar physiographic region in North Carolina.

Strickland, Tanya
City of North Augusta

TRANSITIONING A COMMUNITY TO NATURAL WATER RESOURCE MANAGEMENT, A CITY PERSPECTIVE OF NPDES MS4 PERMITTING

South Carolina communities have differences in ecosystems, topography, wildlife and hydrology based on whether they are in the uplands, midlands or lowlands, river swamps, sand hills, coastal or urban centers. Greater than that though, communities have different philosophies about these things. Many residents never think of them, especially if there are few recreational opportunities to utilize the natural features of a community. People move through their towns coming and going never considering the streams they cross over or their streets storm sewer outfall locations. Other communities thrive solely on the recreation that their natural resources provide and are the base of their economic engines, making them highly important considerations. Some fall in the middle of these two extremes in philosophy about water quality of their streams and creeks. What happens when you add a required common goal in the various types of communities in SC? When the small municipal separate storm sewer permits (small MS4s) became a requirement under the Clean Water Act for many communities in SC, that common goal was set. Now, seemingly out of the blue to many, there is this permit that cities and towns are required to implement (at a community level) to help them protect their natural resources or be fined. This presentation will take a close look at the program that North Augusta has created to meet the small MS4 permit requirements including a look at water quality data collected in the community.
In North Augusta, a baseline assessment of water quality

was conducted and then tracked over time in high density neighborhoods, business districts and in less populated areas. There will be a discussion as to how the numbers compare to other communities, what programs are ongoing to address stormwater pollution and the innovative use of natural features to clean up the water. The information gathered through the program has focused attention on natural resources in the city and created a better decision-making process regarding development and future growth. The stormwater program has created a vehicle for citizens, visitors and leaders in the community to transition from "Stormwater goes where?" thinkers to water resource managers in 10 years.

Sturgeon, Amanda, Susan M. Libes, Erin J. Burge, J. Michael Trapp
Coastal Carolina University

BUILDING LOCAL CAPACITY FOR MICROBIAL SOURCE TRACKING IN THE MYRTLE BEACH URBANIZED AREA

Over 80 sites in Horry and Georgetown counties have fecal bacteria impairments that have resulted in 303(d) listings or Total Maximum Daily Loads. To formulate cost-effective strategies for remediation of these water quality issues requires knowledge of the fecal bacteria sources, both from the perspective of their geographic locations and the host animals. The USACOE and municipalities of the Myrtle Beach Urbanized Area (City of Myrtle Beach, City of North Myrtle Beach, Horry and Georgetown Counties) joined into a partnership with Coastal Carolina University's Environmental Quality Lab to develop local capacity for performing microbial source tracking that relies on a two-fold approach: (1) a watershed-based investigation to identify sources spatially and (2) the use of genotypic assays and chemical tracers to distinguish host animal sources. This microbial source tracking protocol has been used in several watersheds in Horry County with another pending in Georgetown County.

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THE TIDAL REACH AND DISTRIBUTION OF TIDAL FRESHWATER FORESTED WETLANDS IN THE WACCAMAW RIVER, SOUTH CAROLINA (Poster)

The Waccamaw River Basin (HUC 03040206), is located on the coastal plain and meanders from North Carolina to South Carolina. This tidal black-water river flows parallel to the coast past the cities of Conway and Georgetown, terminating in Winyah Bay. The river is also hydrologically connected to the Atlantic Intracoastal Waterway (AIW) with net discharge occurring during periods of high freshwater flows. The tides are semi-diurnal with an amplitude classified as meso-tidal (2-4 meters). The semi-diurnal tidal amplitude in the Waccamaw River declines with increasing distance upstream from Winyah Bay and the AIW. Temporal variations in this longitudinal gradient reflect varying effects of astronomical tides, weather, river and river discharge. This poster documents a new record for the upstream extent of a tidal signature in the Waccamaw River. Streamflow data collected at a new USGS gauging station (02110550) located on the Waccamaw River at river mile 63.0, upstream of Winyah Bay is used in the analysis. Station 02110550, Waccamaw River above Conway, SC, became operational in June 2013, just prior to a significant flood event. When water levels receded in early September, a semidaily tidal amplitude of 0.4 to 1.0 feet was observed, in addition to upstream flows during flood tides. The overall hydrograph represents patterns of non-tidal and tidal oscillation. This observation suggests that the aerial extent of tidal freshwater forested wetlands (TFFW) in the Waccamaw River basin has been underestimated. Prior evaluations did not consider the possibility of tidal signatures above river mile 60.0. These wetlands represent unique habitats, enhance flood storage, provide valuable biogeochemical ecosystem services, and are also prone to anthropogenic alteration. Improved knowledge of their areal extent would provide valuable information for land-use planning and management. It is hypothesized that 1) the tidal reach is a function of upstream and downstream forces at different temporal and spatial magnitudes; 2) TFFW exist at and beyond the tidal reach based on the frequency and duration of tidal influence; 3) Water- Quality trends at the tidal reach differ than upstream and downstream river continuums. Predictors of the tidal reach, as well as biological distribution, chemical phenomena, and physical processes that occur at the tidal reach were examined statistically and descriptively. An Auto Regressive Integrative Moving Average (ARIMA, SPSS) was used in the analysis of the tidal reach based upon quarter-hourly observations from 06/21/2013 to 09/11/2014. Initial results show that tidal reach significantly influenced water-level a majority of the observations. Tidal predictors were significant (<0.00 at p=0.05) in predicting water-level (ft) at USGS 02110550. Additionally, water quality events upstream occur and lag downstream showed a significant (<0.00 at p=0.05) relationship to discharge (ft3/s). This information aims to benefit local scientists and highlight the importance of USGS long-term gauging stations.

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HYDROGEOMORPHIC AND LANDSCAPE INFLUENCES ON DISSOLVED ORGANIC MATTER IN STREAMS AND RIVERS ON THE SC COASTAL PLAIN (Poster)

Dissolved organic matter (DOM) is recognized as a major component in the global carbon cycle and is an important driver of numerous biogeochemical processes in aquatic ecosystems, both in-stream and downstream in estuaries. This study sought to characterize chromophoric DOM (CDOM) in major rivers and their tributaries of South Carolina Coastal Plain to assess the impact of land use and other factors on water quality. During eight trips from June 11 to July 9 of 2014 throughout the South Carolina Coastal Plain, we visited 54 sites, where we measured field parameters (temperature, dissolved oxygen, pH, and specific conductance) and collected water samples for laboratory analysis. All sampling was done during baseflow conditions. The water samples were filtered and analyzed for dissolved organic carbon (DOC) and dissolved nutrients. Sample sites included headwater wetlands and springs, streams and rivers, and water table monitoring wells. We measured stream discharge at stream sites where there was not a US Geological Survey (USGS) gaging station. We used the discharge measurements to make point estimates of fluxes of the nutrients and DOC during baseflow. Spectral analysis of the filtered water samples was done from 200-800 nm using a Shimadzu UV-1700 spectrophotometer. We

calculated absorption coefficients, spectral slope coefficients, and related metrics to facilitate broad characterizations of the nature of the CDOM in the water based on source and other landscape factors. This poster will summarize the results of those analyses.

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INDICATORS OF THE OCCURRENCE OF VIBRIO IN THE WINYAH BAY, SOUTH CAROLINA ESTUARY

There are several studies on the distribution of Vibrio vulnificus and Vibrio parahaemolyticus in estuarine waters around the world, but little information on the distribution of both organisms in South Carolina waters. Monthly sampling of surface and bottom water from 9 sites in Winyah Bay and the Waccamaw River was conducted over the period April-October 2012. Both organisms were enumerated on CHROMagar Vibrio media. The V. vulnificus counts were highest when salinity ranged between 5 ppt and 20 ppt. V. parahaemolyticus did not show a clear pattern with salinity, suggesting other factors that interact to control its occurrence and abundance. Turbidity showed a positive association with both V. vulnificus and V. parahaemolyticus. In this study were particularly interested in the relation between Vibrio and conductivity in order to couple this relation with future climate scenarios calculated by the Pee Dee River and Atlantic Intracoastal Waterway Salinity Intrusion Model 2 (PRISM2). PRISM2 integrates predictions of future streamflow and sea level in an artificial neural network model that predicts specific conductance at several locations in the Winyah Bay estuary. Based on the model results, increasing sea level will results in expanded range of occurrence for V. vulnificus in the Winyah Bay estuary due to increased specific conductance. The model was tested by predicting for post hurricane Sandy sampling date (29OCT2012). The V. vulnificus counts fell within the predictive interval of the model. Thus, the conservative model is able to predict for V. vulnificus under normal and post low impact storm events. In the future the increased relative risks of optimum Vibrio growth based on specific conductance will increase up to 36X depending on location and sea level predictions. These increased periods of optimal growth conditions for Vibrios may result in increased risk for swimmers and shellfish consumers.

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BIOMARKERS AS TOOL FOR BIOMONITORING OF WATER QUALITY IN THE SAVANNAH RIVER

The Savannah River is subject to a variety of anthropogenic influences that have a profound effect on the river ecosystem. The watershed also provides a number of services to communities and states bordering the river. All these uses of the river ecosystem require a balanced management approach, which secures the sustainable use of the river and protects the natural environment as much as possible. One of the services the river provides is discharge of industrial and urban wastewater. Despite regulation of these point sources, accidental discharges and release of unregulated or unknown contaminants may have severe effects on aquatic organisms. In addition, non-point sources may also contribute to the overall contaminant load the river receives. A powerful method to detect and monitor the presence of these contaminants and their biological effects is through a biomarker approach. Biomarkers are biochemical changes in resident organisms that are induced by exposure to environmental pollutants. Biomarker responses are specific for classes of pollutants, and as such are useful tools to identify what contaminants organisms are exposed to. Because biomarkers provide a time integrated picture of these environmental stressors, they can be used not only in environmental assessment studies, but also in monitoring programs that are intended to evaluate the effects of management decisions. We performed an initial biomarker study in the middle section of the Savannah River in 2012. Sunfish species (Lepomis) and largemouth bass (Micropterus) were collected on 14 sites, ranging from just below Lake Strom Thurmond to Allandale, SC. Fish were collected through electrofishing, and blood and tissue samples were harvested for biomarker analysis. Among the biomarkers measured were bile fluorescence and cytochrome P450-1A induction as markers for exposure to polynuclear aromatic hydrocarbons, glutathione-S-transferase activity as general oxidative stress marker, acetylcholinesterase activity in blood plasma as marker for pesticide exposure, and bile estrogens and plasma vitellogenin as markers for exposure to estrogenic compounds. The results show that fish from a variety of locations have significantly changed biomarker responses. In a number of cases, these responses can be linked to discharges directly upstream of the sampling location. Overall the study demonstrates that biomarkers are a useful tool for measuring biological effects in aquatic organisms in the Savannah River, and that they can be applied in future biomonitoring programs in the river.

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MEASURING THE IMPACT OF RESTORED SHORELINE FROM A STUDENT-DRIVEN SALT MARSH RESTORATION PROGRAM IN SOUTH CAROLINA, U.S.A. (Poster)

Tidal salt marshes are routinely described as critical, semi-inundated ecosystems that provide habitat for numerous coastal species, protection from wave action and erosion and improvement in nutrient productivity. Additionally, salt marshes are unique in their ability to filter excess nutrient runoff in the surrounding water through various chemical processes. Because of these benefits, wetland restoration, and more specifically marsh restoration, is a priority in coastal areas around the United States, where aggressive destruction of the ecosystem occurs. Coastal restoration projects vary in techniques used, with the majority focusing on regrowth of natural vegetation. In South Carolina, native vegetation establishment and growth is used as the prominent method to restore salt marshes to their natural functioning state. The South Carolina Sea Grant Consortium (SCSGC)'s From Seeds to Shoreline Program provides K-12 students and teachers with opportunities to engage in salt marsh restoration projects through the cultivation and transplantation of Spartina alterniflora (smooth cordgrass), the dominant plant in South Carolina coastal salt marshes. The direct effect and success

of this student-driven program has not been evaluated for shoreline impact. This thesis study will determine the success of the program with regard to shoreline impact at three selected locations in Charleston County, SC, using specific pre-determined variables. Stem height, stem density, and total vegetation cover of planted S. alterniflora will be measured bimonthly for 12 consecutive months. The results from this study will gauge the impact of student-driven restoration efforts in South Carolina salt marshes as well as investigate potential monitoring protocol that could be incorporated into projects for the future.

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POTENTIOMETRIC SURFACE MAPS OF THE MIDDENDORF, BLACK CREEK, AND FLORIDAN AQUIFERS OF SOUTH CAROLINA (Poster)

The Middendorf, Black Creek, and Floridan aquifers are the three major aquifers of the Coastal Plain of South Carolina and are important sources of water for many public, industrial, and agricultural supplies. In an effort to assess groundwater conditions in these three aquifers and to identify areas where declining water levels may be a concern, the South Carolina Department of Natural Resources (SCDNR) maintains a program to regularly map the potentiometric surface of each aquifer. Presented here are the most recent potentiometric maps developed by SCDNR for each of South Carolina's three major aquifers. The potentiometric map of the Middendorf aquifer presented here was constructed by using water levels measured in 136 wells in late 2011. The potentiometric surface shows that the generally southeastward groundwater flow is affected by several potentiometric lows. These cones of depression have developed because of groundwater pumping in Florence and Williamsburg Counties and Berkeley and Charleston Counties. The potentiometric map of the Black Creek aquifer was constructed by using water levels measured in 100 wells in late 2012. The potentiometric surface shows that the generally southeastward groundwater flow is affected by several potentiometric lows. These cones of depression have developed because of groundwater pumping in Georgetown, Florence, and Williamsburg Counties. The potentiometric map of the Floridan aquifer and its updip clastic equivalent, the Tertiary sand aquifer, was constructed by using water levels measured in more than 200 wells in late 2013. The potentiometric surface shows a generally southeastward groundwater flow affected by several potentiometric depressions. These cones of depression have developed because of groundwater pumping in Colleton and Dorchester Counties. Water levels in Jasper and Beaufort Counties continue to be affected by pumping in the Savannah, Georgia area.

Walker, Ronald, Jacob Foose
S&ME Inc

THE BIG GENEROSTEE CREEK MITIGATION BANK: A CASE STUDY IN PLANNED WATERSHED MANAGEMENT

The availability of adequate mitigation sites is a key consideration in water planning. If permitting is properly implemented, and mitigation adequately implemented, mitigation should contribute to improvements in water quality. Planners should consider the availability and nature of mitigation within a watershed as part of any strategic water planning process. Mitigation Banks will typically improve stream and wetland water quality primarily within the Bank boundary and secondarily to the water quality downstream from the bank. For this reason Planners should have a working knowledge of what mitigation banking projects are currently operational as well as what mitigation banks are proposed within a watershed. As of April 8, 2014 the Big Generostee Creek Mitigation Bank (BGCMB) received its initial credit release after being approved by the US Amy Corps of Engineers and the Interagency Review Team. The Bank will provide compensatory mitigation for unavoidable adverse impacts to Waters of the United States that result from activities authorized under Sections 401 and 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act, provided such activities have met all applicable requirements and are authorized by the appropriate authority.

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THE LONG-TERM EFFECTS OF EXURBANIZATION ON STREAM HEALTH AND SALAMANDER COMMUNITIES IN THE SOUTHEASTERN APPALACHIAN MOUNTAINS

The southern Appalachian Mountains have experienced large population growth over the past 30 years. Land use practices are shifting and forests are being converted into residential land. The majority of development has been low density, suburban land, especially in the Southeast (Mcdonald et al. 2010) and is often near highly biodiverse areas. Lotic Systems and riparian areas are severely degraded by conversion of rural land to urban land. The long-term effects of urbanization in the southeastern Appalachian Mountains are not well known (Price and Leigh 2006, and even less is known with respect to stream salamander response to urbanization. We seek to determine if streams disturbed for exurban housing will eventually rehabilitate to conditions more similar to the undisturbed sites, or if they will remain degraded in the long-term.

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CLIMATE CHANGE PROJECTION FOR THE DEPARTMENT OF ENERGY'S SAVANNAH RIVER SITE (Poster)

As per recent Department of Energy (DOE) requirements for long-term operational sustainability, the Savannah River National Laboratory (SRNL) is developing a climate projection for the DOE's Savannah River Site (SRS) in Aiken, SC. This will comprise data from both a statistical and a dynamic downscaling process, each interpolated to the site. Numerous activities at the site (energy and water resource needs, fire and forest ecology, and facility and worker safety) are strongly dependent on weather and climate conditions, and long-term mitigation strategies are needed to maintain these operations in the face of climate change. For example, the DOE is responsible for maintaining adequate habitat on site for various aquatic amphibians and reptiles, and site production operations are dependent on adequate water supplies. For the statistical downscaling, we use global climate

model (GCM) data from the Climate Model Intercomparison Project, version 5 (CMIP-5), which was used in the IPCC Fifth Assessment Report (AR5). GCM data from five research groups was selected, and two climate change scenarios – RCP 4.5 and RCP 8.5 – are used with observed data from site instruments and other databases to produce the downscaled projections. We apply a quantile regression downscaling method, which involves the use of the observed cumulative distribution function to correct that of the GCM. This produces a downscaled projection with an interannual variability closer to that of the observed data and allows for more extreme values in the projections, which are often absent in GCM data. We also collected data from an existing database of statistically-downscaled climate data that was generated with GCM data from the older CMIP-3 database. This is interpolated to the SRS, and the results compared to those calculated with the newer GCM data. The statistically downscaled data is complemented with dynamically downscaled data from the North American Regional Climate Change Assessment Program (NARCCAP) database, which comprises output from regional climate models forced with GCM data from the CMIP-3 database of GCM simulations. The methods used suggest that a major concern at SRS is the projection of more hot and humid days, which could impede outdoor work on site. The models were generally in agreement that temperatures will rise, and specific humidity will naturally rise along with it. There is less agreement with regards to changes in precipitation, with the overall trend towards greater rainfall at SRS. Extremely dry periods occurred in the future simulations with about the same frequency as exists in the past records, making future drought less of an issue. Using the downscaled meteorology, streamflow modeling will be performed to estimate the effect of precipitation changes on site operations.

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USE OF FACTORS OF THE REVISED UNIVERSAL SOIL LOSS EQUATION (RUSLE) TO MODEL SOIL EROSION IN THE SOUTH CAROLINA BOTANICAL GARDEN (Poster)

The South Carolina Botanical Garden (SCBG) is one of the most important natural heritage sites in the state. Heavy rain events of July 2013 caused unprecedented damage to the SCBG, including the Natural Heritage Trail (NHT). Erosive storm runoff washed out many endemic species and structures in the garden including bridges. Soil deposition from upland areas to the valley of the NHT was appreciable but not uniform. Predicting soil erosion will assist in determining strategies to reduce potential erosion to occur from future storm events. The Revised Universal Soil Loss Equation (RUSLE) is an empirical equation used to estimate soil loss in agricultural fields. It consists of five factors: rainfall and runoff (R), soil erodibility (K), length slope (LS), crop management (C) and support practice (P). However, the application of RUSLE can be problematic in undulating landscapes with complex topography and a variety of land cover types. While R and K factors are relatively uniform throughout the SCBG, C and LS factors are more variable, with the LS factor as the most sensitive in soil loss prediction. Therefore, identification of the input parameters and appropriate use of the C and LS factors must be determined. Field assessment and ArcGIS software was used to estimate C and LS factor for each analysis unit at three different scales: sub-catchment (large scale), land use area (medium scale) and raster cell of the Digital Elevation Model (small scale). The LS factor algorithm developed by Arnhold et al. (2014) was used by identifying all possible flow paths within each analysis unit and subsequently calculating the mean slope length and slope angle. Similarly, spatial statistics are used to estimate mean C values for each analysis unit. R programming language was used to compare the three soil loss estimation models. Model development and comparison in soil loss estimations will be presented.

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GROUNDWATER RECHARGE RATES IN ISOLATED AND RIVERINE WETLANDS: INFLUENCING FACTORS

Several studies have indicated that isolated wetlands (IW) and riverine wetlands (RW) have similar groundwater hydrology despite their difference in topography and surface water hydrology. To further measure the impact of topography and surface water hydrology on the hydrologic behavior of these two systems, a comparative analysis of the groundwater recharge rates of IW's and RW's was conducted. In the study it was observed that the frequency of precipitation and the saturated zone soil type had a significant impact on mean recharge rates. The study sites were located in the Coastal Plain of the Carolinas where water tables are shallow and soils are often sandy with a rapid response to precipitation. Each of the four study sites contained an isolated wetland, an adjacent upland, and a riverine wetland with a surface water connection. There were no immediately observable surface water connections between the isolated and riverine wetlands, but assessments have shown a subsurface hydrologic connection. Soil characteristics, water table fluctuations, and precipitation data from January 2012-September 2012 were evaluated and from that data mean recharge rates were calculated. A qualitative analysis of the hydrographs indicated a change in water table behavior as precipitation frequency increased throughout the study period. This observation was reinforced by a statistically significant difference in the mean rates of the "wet" and "dry" periods. However, there was not a statistically significant difference in the mean rates of the IW, RW, and upland, indicating that precipitation frequency and sub-surface soil type were more impactful on water table movement than topography and surface water hydrology. The infrequent precipitation during the dry period resulted in unfilled soil pores and provided freedom for groundwater to move, whereas, soils were saturated throughout the soil profile during the wet period and the water table's ability to receive water and fluctuate was dampened. Despite different surface soil textures, a similar soil texture was observed throughout the saturated zone of the IW, upland, and RW at each site—and soil texture can be a driving force for groundwater movement in the unsaturated zone when saturated soils are similarly drained. Throughout the sites the amount of precipitation in a given amount of time—and in turn, soil type and soil moisture in the saturated zone—affected mean recharge rates and dictated groundwater movement in the

unsaturated zone. In detecting factors that affect recharge, natural resource managers and permit regulators can make the appropriate considerations for groundwater supply and surface water quality.

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WATERSHED MANAGEMENT PLANNING FOR THE MURRELLS INLET ESTUARY USING GIS: DELINEATION, ASSESSMENT, IDENTIFICATION, AND SOLUTIONS FOR FECAL COLIFORM LOADING

Nonpoint source impacts from fecal coliform bacteria and the resulting closures of shellfish harvesting grounds has increased the awareness and concern in the Murrells Inlet community. The Murrells Inlet watershed, which extends from the Huntington Beach State Park in Georgetown County to the southern end of Surfside Beach in Horry County, is an elongated watershed with no major incoming freshwater tributary. The watershed is approximately 14.5 square miles. SCDHEC approved a TMDL in 2005 to assess fecal coliform impairment within the inlet. In 2008, the community group Murrells Inlet 2020 (MI2020) sponsored a volunteer water monitoring program in partnership with Coastal Carolina University (CCU), Horry, and Georgetown County. When SCDHEC released the 2011 Shellfish report it resulted in the closure of approximately 241 acres of shellfish harvesting grounds on the south end of the inlet. This prompted MI2020 to endorse the development of a watershed-based plan that was funded in part by EPA Section 319 and 604(b) grants provided by SCDHEC. The EARTHWORKS Group was a major contributor of services as part of the local grant funding match. Our role included the application of engineering and GIS to address fecal coliform loading within the estuary. Our GIS centric approach included assessing several key areas. First was the development of a LiDAR surface model which was used to define the overall watershed. These data were supplemented by stormwater infrastructure information provided by both counties to further define 51 subwatersheds ranging in size from 632.9 to 4.7 acres. There are 25 subwatersheds situated along the Murrells Inlet shoreline with runoff entering the inlet via overland sheet flow. Subwatersheds where analyzed using the SCS Runoff Curve Number (CN) method with a 2 year storm event and Time of Concentration (Tc) flow paths. To generate curve numbers a localized Land Use Land Cover (LULC) data layer was created and integrated with USDA NRCS Soils data for the watershed to provide a curve number data layer. This process was also replicated using almost 20 year old historic NAPP color infrared aerial photography. The final application of these data were to prioritize subwatersheds based upon the location of their outfalls in relation to SCDHEC monitoring stations within the inlet with the goal of identifying areas of concern for Best Management Practice implementation. This watershed-based planning effort will provide the framework for water quality solutions within the Murrells Inlet estuary that are likely to aid in reducing fecal coliform loading from subwatersheds that discharge near the higher priority SCDHEC monitoring stations. Suggested improvements which could easily be implemented watershed-wide that would quickly begin benefiting the estuary include pet waste stations and educational outreach. The plan also provides engineered solutions that could be implemented with additional funding.

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ROLE OF HURRICANES AND DROUGHT IN MORTALITY OF TIDAL FORESTED WETLANDS USING HISTORICAL AERIAL PHOTOGRAPHY

The Belle W. Baruch Foundation has managed the Hobcaw Barony near Georgetown for the last fifty years for research of coastal ecology in partnership with South Carolina colleges and universities in accordance with Miss Baruch's wishes. Researchers from Clemson University have studied various aspects of forestry under a long-term agreement with the Foundation since 1967. Aerial photography has been an integral part of forest management and research during that period. Such a long-term-photographic history can be examined to determine forest mortality. Hobcaw barony is at the tip of the Waccamaw Neck Peninsula and has forested wetlands adjacent to saline salt marsh on the east, brackish tidal marsh on the south, and slightly brackish to fresh marshes along the western side. With 60 years of aerial photographic analysis on a small wetland along the western side it was found that wetland forest mortality and marsh expansion could be explained primarily (R2 = 0.95)by sea level rise and topographic gradient. Hurricane Hugo produced the greatest tidal surge into the forest over that period. There have also been several dry periods prior to and after Hurricane Hugo. In this presentation we will compare the mortality of cypress-gum stands that have been subjected to both; hurricane induced salt mortality, and mortality due to drought induced lowering of freshwater inputs. On the eastern side of the property, direct tidal surge mortality was evident by 1991 but there has been regeneration of cypress-gum since then on some sites. On the western side, tidal surge of the hurricane had much smaller effect, with increased mortality associated more with low flows of freshwater into Winyah Bay. On the southern side, both processes have occurred and mortality and recovery there is more complex.

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TIDALLY-DRIVEN GROUNDWATER FLOW AND INTERTIDAL WETLANDS

The South Carolina coastline is dominated by highly productive salt marsh ecosystems, and the ability of these key ecosystems to withstand stresses associated with development and sea level rise is poorly understood. Groundwater hydrology is an important yet commonly overlooked factor in salt marsh systems. Groundwater discharging from salt marshes carries nutrients and other important dissolved constituents to estuaries and the coastal ocean, and recent studies show that variations in tidal amplitude and mean sea level can create variations of up to a factor of 10 in the volume of water that discharges from salt marshes. These studies also show that rises in sea level are likely to cause groundwater discharge to decrease

unless marshes are able to keep up with sea level rise. Recent work also shows the importance of groundwater flow for plant zonation in salt marshes. Whereas previous studies of ecological zonation in salt marshes have largely focused on elevation and hydroperiod, new results indicate that this zonation is strongly influenced by groundwater flow, including discharge from adjacent freshwater uplands. The migration of plant zones during sea level rise will in turn influence the rate of salt marsh accretion, and hence the ability of salt marshes to keep up with sea level rise. Ecological zonation and SGD from salt marshes can be altered significantly by trenching, causeways, and other modifications that affect the size of freshwater uplands or sever the connection between uplands and marshes.

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WATER QUALITY STEWARDSHIP INFORMS MANAGEMENT DIRECTIONS IN MURRELLS INLET, SC

In 2008, a volunteer water quality monitoring program was implemented by Horry County, Georgetown County, Murrells Inlet 2020 and Coastal Carolina University, sampling at 8 locations throughout the Murrells Inlet watershed. The volunteer water quality monitoring program has enabled the volunteers to take ownership of their data and understand the connections of the water quality in tributaries to the estuary as a whole. The resulting partnership has provided a platform to voice their concerns to the local decision makers. Due to the collaborative nature of the volunteer water quality monitoring program, the volunteers have been able to have significant input on the future management of Murrells Inlet and have encouraged managers to put funding towards efforts to protect or enhance the water quality throughout Murrells Inlet.

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