Georgia Water Resources Institute
Annual Technical Report
FY 2017

Introduction

MISSION STATEMENT

GWRI strives to improve the science and practice of water resources planning and management in ways that balance quality of life, environmental sustainability, and economic growth. GWRI pursues this mission through its education, research, information dissemination, and technology/knowledge transfer programs at the state, national, and international levels.

Organizational Structure: The GWRI organizational structure includes a Director, Associate Director, Assistant Director, Advisory Board, and technical support staff. The technical support staff comprises several Ph.D. graduate students who work on GWRI projects while carrying out doctoral research, and information technology support staff. The Advisory Board includes representatives from major state and federal water agencies as well as environmental and citizen groups. At Georgia Tech, GWRI reports to the Senior Vice-Provost for Research under the Office of the Provost.

Research Program Sponsorship and Administration: GWRI activities are sponsored by (i) the Department of the Interior/USGS as part of the state and national research programs, and (ii) other national and international funding agencies and organizations supporting research in water related areas. Through its annual state and national competitive programs, GWRI provides research awards to Georgia Universities. The award process includes submission of technical proposals, technical peer reviews, and reviews for relevance to Georgia needs by the State Environmental Protection Division (Georgia EPD).

Other External Funding: In addition to the 104B and 104G programs, GWRI generates additional funding through participation in competitive national and international research programs. Recent funding has been provided by the California Energy Commission, the California Department of Water Resources, NOAA, the Gwinnett County Department of Water Resources, and the ACF Stakeholders. GWRI involvement in national and international research activities is crucial to maintaining the expert capacity and funding portfolio necessary to provide quality services to the state of Georgia and all other sponsors.

FY2017 RESEARCH PROJECTS THROUGH 104B PROGRAM

(1) Quantifying the relative contributions of the physical mechanisms responsible for the Atlanta 2009 flood; Shepherd, Marshall and Debbage, Neil; University of Georgia.

(2) Developing real time sensor networks for monitoring stream water quality to improve water resource management; Wenger, Seth, Rosemond, Amy, Dowd, John, and Bumpers, Phillip M.; University of Georgia.

(3) Estimation of irrigation withdrawals in the Apalachicola Chattahoochee Flint (ACF) River Basin; Luo, Jian; Georgia Institute of Technology.

Additionally, GWRI provided funds to support the 2017 Georgia Water Resources Conference held at the University of Georgia on April 19 20, 2017.

OTHER RESEARCH PROJECTS AND ACCOMPLISHMENTS

Climate Change Assessment and Adaptation Planning for River Basins with Estuarine Resources, Aris Georgakakos PI, Georgia Institute of Technology, sponsored by NOAA.

Integrated Forecast and Reservoir Management (INFORM) for Northern California, Aris Georgakakos PI, Georgia Institute of Technology (Project Partners: Hydrologic Research Center), sponsored by the California Department of Water Resources.

Septic System Impact Study (SSIS) for Lake Lanier, Aris Georgakakos PI, Georgia Institute of Technology, (Project Partners: University of Georgia, New York State Water Resources Institute at Cornell University) sponsored by Gwinnett County Department of Water Resources.

RECENT PUBLICATIONS

DiVittorio, C.A., A.P. Georgakakos, 2018. Land Cover Classification and Wetland Inundation Mapping using MODIS. Remote Sensing of Environment, 204(1), pp 1-17.

Dettinger, M., B. Udall, and A.P. Georgakakos, 2015: Western Water and Climate Change. Ecological Applications, 25(8), pp. 2069–2093 (Ecol. Soc. of America Centennial Paper).

Sharif, H.E., J. Wang, and A.P. Georgakakos, 2015: Modeling Regional Crop Yield and Irrigation Demand Using SMAP Type of Soil Moisture Data. Journal of Hydrometeorology, 16, pp. 904–916. Available at http://journals.ametsoc.org/doi/pdf/10.1175/JHM-D-14-0034.1.

Kistenmacher, M., and A.P. Georgakakos, 2015: Assessment of Reservoir System Variable Forecasts, Water Resources Research, 51, pp. 3437–3458 (doi:10.1002/2014WR016564).

Chen, C.-J., and A.P. Georgakakos, 2015: Seasonal Prediction of East African Rainfall. International Journal of Climatology, 35, pp. 2698–2723 (doi:10.1002/joc.4165).

Georgakakos, A.P., P. Fleming, M. Dettinger, C. Peters-Lidard, T.C. Richmond, K. Reckhow, K. White, and D. Yates: Water Resources Chapter, 2014 National Climate Assessment Draft, http://ncadac.globalchange.gov, 2014.

Georgakakos, A.P., H. Yao, and K.P. Georgakakos, "Ensemble streamflow prediction adjustment for upstream water use and regulation", Journal of Hydrology, doi: 10.1016/j.jhydrol.2014.06.044, 2014.

Kim, D.H., and A.P. Georgakakos, "Hydrologic River Routing using Nonlinear Cascaded Reservoirs," Water Resources Research, doi: 10.1002/2014WR015662, 2014.

Chen, C-J., and A.P. Georgakakos, "Seasonal Prediction of East African Rainfall," International Journal of Climatology, doi: 10.1002/joc.4165, 2014. Climate of the Southeast United States: Variability, Change, Impacts, and Vulnerability, co-author of Chapter 10, "Impacts of Climate Change and Variability on Water Resources in the Southeast USA," Island Press, Washington DC, 341p, 2013.

Chen, C-J., and A.P. Georgakakos, "Hydro-Climatic Forecasting Using Sea Surface Temperatures—Methodology and Application for the Southeast U.S.," Journal of Climate Dynamics, doi:10.1007/s00382-013-1908-4, 2013.

RECENT REPORTS

Georgakakos, A.P., and M. Kistenmacher (2015): Water Management Scenario Assessments for the ACF River Basin. Technical Report, Georgia Water Resources Institute, Georgia Institute of Technology, Atlanta, Georgia, 41p.

Georgakakos, A.P., and M. Kistenmacher (2015): Value of Drought Prediction for the Management of the ACF River Basin. Technical Report, Georgia Water Resources Institute, Georgia Institute of Technology, Atlanta, Georgia, 34p.

Georgakakos, A.P., and M. Kistenmacher (2012): Unimpaired Flow Assessment for the Apalachicola Chattahoochee-Flint River Basin. Technical Report, Georgia Water Resources Institute, Georgia Institute of Technology, Atlanta, Georgia, 211p.

RECENT CONFERENCE PRESENTATIONS

DiVittorio, C, and A.P. Georgakakos, "Improved Management of the Nile River Basin Through Modeling the Sudd, a Wetland with Vital Socioeconomic and Environmental Services", 2017 AGU Fall Meeting, San Francisco, December 2017.

Kistenmacher, M. and A.P. Georgakakos, "Value of Adaptive Drought Management for the ACF River Basin", 2017 Georgia Water Resources Conference, April 2017.

DiVittorio, C, and A.P. Georgakakos, "A Satellite-Based Method for Wetland Inundation Mapping", 2017 Georgia Water Resources Conference, April 2017.

Divittorio, C, and A.P. Georgakakos, "Integrated Water, Energy, and Environmental Management: Experience from Tanzanian River Basins", 2017 Georgia Water Resources Conference, April 2017.

Georgakakos, A.P., "Integrated Water, Energy, and Environmental Planning in the Rufiji River and Lake Rukwa Basins, Tanzania", 2016 AGU Fall Meeting, San Francisco, December 15, 2016.

Dettinger, M., B.H. Udall, A.P. Georgakakos, "Western Water and Climate Change--An Overview", 2016 AGU Fall Meeting, San Francisco, December 12, 2016.

Kistenmacher, M. and A.P. Georgakakos, "Value of Adaptive Drought Forecasting and Management for the ACF River Basin in the Southeast U.S", 2016 AGU Fall Meeting (Poster), San Francisco, December 13, 2016.

DiVittorio, C. and A.P. Georgakakos, "A Satellite Based Method for Wetland Inundation Mapping", 2016 AGU Fall Meeting, San Francisco, December 15, 2016.

Kistenmacher, M., and A.P. Georgakakos, "Development of a sustainable water management plan for the ACF River Basin", 2016 UCOWR/NIWR Annual Water Resources Conference, Pensacola Beach, June 21-23, 2016.

Kistenmacher, M., and A.P. Georgakakos, "Value of adaptive drought management for the ACF river basin", 2016 UCOWR/NIWR Annual Water Resources Conference, Pensacola Beach, June 21-23, 2016.

Research Program Introduction

Three research projects were funded through the 104B Program (each at $18,000) in FY2016:

(1) Quantifying the relative contributions of the physical mechanisms responsible for the Atlanta 2009 flood; Shepherd, Marshall and Debbage, Neil; University of Georgia.

(2) Developing real time sensor networks for monitoring stream water quality to improve water resource management; Wenger, Seth, Rosemond, Amy, Dowd, John, and Bumpers, Phillip M.; University of Georgia.
(3) Estimation of irrigation withdrawals in the Apalachicola Chattahoochee Flint (ACF) River Basin; Luo, Jian; Georgia Institute of Technology.

Additionally, GWRI provided funds to support the 2017 Georgia Water Resources Conference held at the University of Georgia on April 19 20, 2017.

The Georgia Water Resources Institute asked for and received permission to extend the deadline of project (1) and (2) into FY2018.

Fecal bacteria source tracking, nutrient analysis, and modeling of an urban TMDL watershed

Basic Information

Title:	Fecal bacteria source tracking, nutrient analysis, and modeling of an urban TMDL watershed
Project Number:	2016GA366B
Start Date:	4/1/2016
End Date:	7/31/2017
Funding Source:	104B
Congressional District:	GA-10
Research Category:	Water Quality
Focus Categories:	Non Point Pollution, Surface Water, Models
Descriptors:	None
Principal Investigators:	David Radcliffe, Mussie Ykeallo Habteselassie

Publications

There are no publications.

Title

Fecal bacteria source tracking, nutrient analysis, and modeling of an urban TMDL watershed

State:	GA
Project Number:	2016GA366B
Title:	Fecal bacteria source tracking, nutrient analysis, and modeling of an urban TMDL watershed
Project Type:	Research
Focus Category:	Non Point Pollution, Surface Water, Models
Keywords:	Fecal bacteria, nitrogen , source tracking, urban watershed, stormwater management model.
Start Date:	
End Date:	
Congressional District:	GA-10
PI:	Radcliffe, David email: dradclif@uga.edu phone: (706) 542-0897
Co-PI(s):	Habteselassie, Mussie Ykeallo email: mussieh@uga.edu phone: (770) 229-3336

Abstract

Pathogens are one of the leading causes of stream and river impairment in the State of Georgia. The presence of fecal bacteria is driven by several factors including rapid population growth stressing infrastructure, increased percent imperviousness, urban runoff, municipal discharges, sewer leaks, animal waste and failing septic systems. Understanding the sources, fate and transport of pathogenic bacteria at the watershed scale is difficult given the complexity of the land cover, landuse, soils and weather conditions. The United States Environmental Protection Agency (USEPA) recommends the use of *E. coli* because they are highly correlated with pathogenic organisms. However, it is difficult to estimate the exact sources of fecal contamination because human and certain animal species contain *E. coli* in their waste. Certain strains of *E. coli* are also able to survive outside of their hosts. As a result, microbial source tracking (MST) studies use gene specific markers to identify the contributors whether human or animal. Trail Creek, a second-order stream located in Athens-Clarke County, GA, is listed on the TMDL list for violating *E. coli* standards. Synoptic sampling events were conducted during baseflow condition. Storm sampling events (> 8 mm) were captured using automated samplers equipped with pressure transducers. The samples were analyzed for total coliform and *E. Coli*. Nitrogen and Phosphorus forms were also measured. Water quality parameters including temperature, specific conductance, dissolved oxygen, pH, and turbidity were also recorded. Factor Analysis confirmed relationships between parameters and *E. coli*. Using quantitative PCR and MST techniques, the human specific marker

HF183, ruminant marker *Rum2Bac* and dog marker *DogBac* were used to identify the fecal sources during baseflow and stromflow. The Soil and Water Assessment Tool (SWAT) modeling software was used to predict *E. coli* bacteria concentrations. SWAT bacteria inputs varied from deer, dog, cattle waste and potential sewer leaks in high-risk locations. Census data from the County was used for human and animal population estimates and the Fecal Indicator Tool to generate the number of colony forming units of *E. Coli* for each source. The model was calibrated at a daily time step with one year of monitored streamflow and *E. coli* bacteria data using SWAT-CUP and the SUFI2 algorithm.

We found that storm samples had higher concentrations of *E. coli* (>1000 MPN/100 ml) compared to baseflow which implied that the sources of bacteria were runoff or resuspension of bed sediments during high flows. Human markers were prevalent in the lower East Fork of Trail Creek, especially during storms. At a small tributary draining a low-income neighborhood area (site 3), we found evidence of a sewer leak since only human markers were detected. Low correlation between human marker and culturable *E. coli* indicated that *E. coli* may be coming from different sources within the watershed (site 3 was the only site having a significant relationship during both baseflow and stormflow). A SWAT model was successfully calibrated for flow but the bacteria module needs to be improved to better represent baseline conditions.

Background

The Trail Creek watershed is one of the 17 watersheds located within the Athens-Clarke County (ACC) boundary. The watershed is approximately 64% forests, 18% pastures and 16% residential. It covers 33 km^2 in the Upper Oconee River Basin. The reaches of Trail Creek are listed on the 303 (d) list for violating TMDL levels for fecal coliform (Figure 1-1).

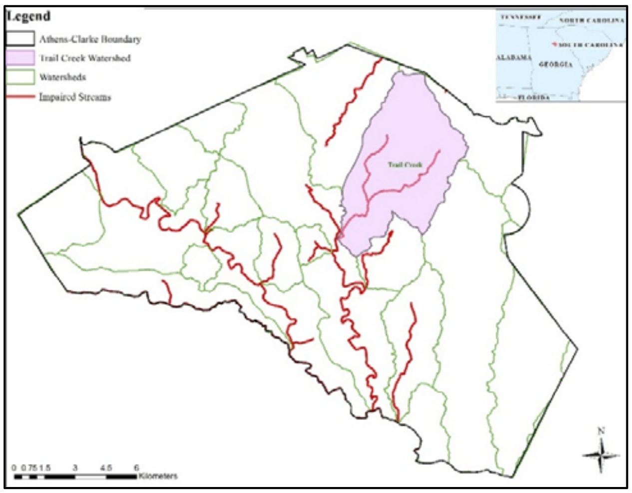


Figure 1-1 Athens-Clarke County boundary, impaired streams, and watersheds including Trail Creek

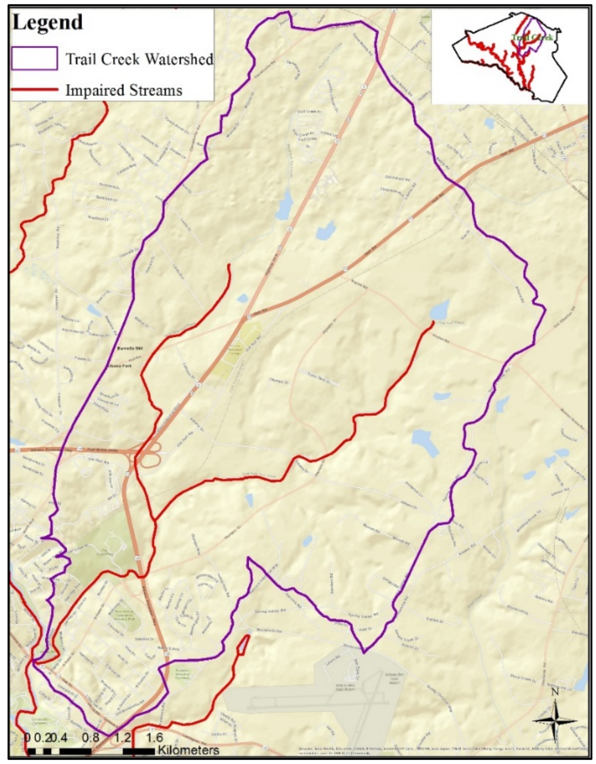


Figure 1-2 Location of the Trail Creek watershed

Trail Creek is an urban second-order stream. It is comprised of an East Fork and a West Fork tributary, which converge to form the main stem that extends to the North Oconee River (Figure 1-2). Sections of streams within both Forks are listed on the 2014 Integrated 305(b)/303(d) List and on the draft 2016 Integrated 305(b)/303(d) List for exceeding the Georgia Standard for fecal coliform (GAEPD, 2014, 2016) .

There are sewer line networks throughout the City with a higher density going towards downtown Athens, and clusters of septic systems on the upper and at the outskirts of the watershed (Figure 1-3).

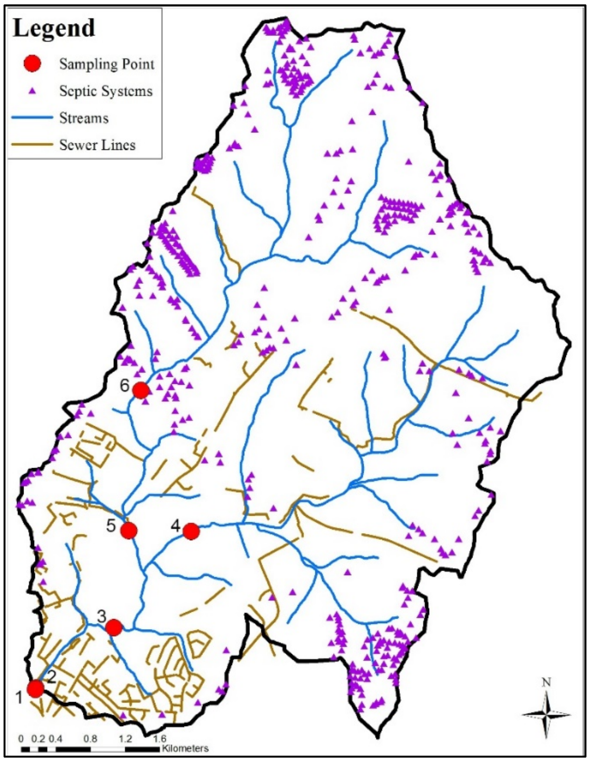


Figure 1-3 Trail Creek wastewater infrastructure and sampling locations.

Nature, scope and objectives of the project

The specific objectives of this study are:

- To use water quality parameters, nutrient analysis and bacterial methods of source tracking to determine the sources of *E. coli* in the Trail Creek watershed, and
- To develop a watershed-scale model using the Soil and Water Assessment Tool (SWAT) using flow and *E. coli* data.

Sample Collection and Analysis

- Sampling sites were selected based on accessibility and within close proximity to sewer lines and septic systems.
- Samples were collected at six locations (1-6) (Figure 1-3). Synoptic samples were collected at all locations and storm samples (> 8mm) were collected at two locations (site 1: watershed outlet; site 3: Trail Creek bridge).
- ISCO automated samplers equipped with pressure transducers were installed at two monitoring locations to continuously monitor for stream water level at a 30-min interval. Stage data at both locations were used to estimate discharge following the rating curve approach. Back-up ODYSSEY water level loggers were also installed to avoid data gaps due to equipment failure or malfunction.
- A QUANTA multi-parameter probe was used to record temperature, specific conductance, pH, turbidity, and dissolved oxygen during synoptic sampling. Specific conductance and turbidity were only measured for composite storm samples.
- A YSI multi-parameter probe was used to record conductivity and turbidity real-time (15-min interval) at the outlet of the watershed and later in a tributary above the Trail Creek Bridge where a sewer leak was suspected to be located.
- E. coli samples were analyzed 4 hours after collection using IDEXX Colilert-18 kits. Then, the samples were filtered through a 47-micron Isopore hydrophilic membrane for DNA extraction using Mo Bio kits. Three Fast Taqman qPCR assays were performed at the local EPA laboratory using *HF183MGB*, *Rum2Bac* and *DogBac* markers. The remaining samples were frozen and later analyzed for Nitrogen and Phosphorus forms at the UGA Isotope Laboratory.

Discussion

Stage data at the outlet of the watershed was recorded from July to December 2017. The first part of the data from July to December 2016 was during a drought. Flow varied from 0.1 cms – 3cms. However, in 2017 flow regimes were higher with frequent rain events. Flow varied from 0.1 cms – 12 cms. At the Trail Creek Bridge, stage data was recorded from January to December 2017. The flow regimes were lower compared to the outlet of the watershed varying from 0.1 cms to less than 1 cms (Figure 1-4). The outlet of the watershed is surrounded by impervious cover (parking lots, buildings etc...). Therefore, as expected storm events presented flashy hydrographs with short lag time and high peak discharge. This is a main characteristic to identify stream ecosystems affected by urbanization.

A statistical factor analysis was performed with the different water quality parameters collected at the 6 synoptic sampling locations (1a) and the composite storm samples (1b) (Figure 1-5). Correlation matrices and Eigen values were generated using coding in Matlab. Factors 1 & 2 explained more than 60 percent of the data. During baseflow conditions, sites 1 and 3-6 were more correlated with turbidity and *E. coli* compared to site 2 highly correlated with conductivity. This indicated that turbidity is a better indicator of fecal contamination during baseflow. Other observations were that turbidity is inversely correlated with conductivity; temperature and pH are inversely correlated to dissolved oxygen. During storms, again *E. coli* and total coliform are highly correlated to turbidity which is explained by the turbid runoff entering streams. Furthermore, to have a better understanding of water quality parameters real-time, observations from the YSI sonde were analyzed by comparing conductivity to turbidity (Figure 1-6, 1-8). Three patterns indicating pollution sources were noticed in the data: (1) high turbidity and low conductivity, (2) low turbidity and high conductivity and (3) low turbidity and low conductivity. (1) happens during storms while turbidity is increasing, conductivity decreases. (2) happens during baseflow possibility indicating a sewer leak. (3) happens after the first flush when runoff is coming from impervious surfaces with lower sediments.

We compared *E. coli* during baseflow and stormflow for all the synoptic baseflow and composite storm samples collected during the project (Figure 1-10). There was a clear difference between the storm and baseflow samples. The storm samples (1b) violated the U.S. EPA standard of 235 cfu/ 100 mL at all times (Table 1). The baseflow samples (1a) went over this threshold by more than 50% at sites 1, 4 and 6 (Table 1). The descriptive statistics were informative about which sites were mostly affected by *E. coli*, however, it didn't necessarily mean that site 1,4,and 6 are contaminated with pathogenic strains of *E. coli* especially coming from human and animal sources. Finally, the baseflow data was highly variable, fluctuating on a daily basis.

To explore the sources of elevated *E. coli* at the six sites, we narrowed the potential *E. coli* contributors to ruminants, dogs and humans based on a watershed assessment. Microbial Source Tracking (MST) techniques using the human HF183MGB, ruminant Rum2Bac and dog DogBac were performed for a subset of baseflow and stormflow samples (Figure 1-11). The percent presence of gene specific markers in the samples was calculated to reflect the degree of contamination by each markers. All sites except 2 contained ruminant markers with sites 3,5 and 6 having 90% - 100 % presence. Sites 1-5 contained human markers with sites 1,2 and 5 having 40% - 60% presence. Dog markers were observed at sites 1, 4 and 5 having 10% - 20% presence. During storms, all three markers were present in the composite samples from 70% - 90%. Although there are no standards to compare the quantification data to, we were able to notice differences in the number of gene copies. For Rum2Bac (1a), mean gene copies during baseflow were approximately 3.2 - 4.2 log gene copies and 4.5 - 4.7 log gene copies during storms (Figure 1-12). For HF183MGB (1b), mean gene copies during baseflow were approximately 0.8 -2.9 log gene copies whereas during storms 3.1 -3.2 log gene copies (Figure 1-12). For DogBac (1c), mean gene copies during baseflow were close to the detection limit with occasional spikes. However, storm samples were significantly higher with mean values of 3.8 log gene copies (Figure 1-12).

Then, we ran Pearson correlations to make inferences about *E. coli* gene copies and *E. coli* colony forming units (Tables 1), HF183MGB gene copies and *E. coli* colony forming units (Table 2), Rum2Bac gene copies and *E. coli* colony forming units (Table 3), and DogBac gene copies and *E. coli* colony forming units (Table 4). There were no significant relationship at all sites except 3 and 5 during baseflow between *E. coli* gene copies and *E. coli* colony forming units. However, there was a significant relationship at site 3 during storms (r= 0.79, p-value= 0.00). There were no significant relationship at all sites between HF183MGB gene copies and *E. coli* colony forming units. However, again there was a significant relationship at site 3 during storms (r= 0.67, p-value= 0.02). There were no significant relationship at all sites between Rum2Bac gene copies and *E. coli* colony forming units. However, there was a significant relationship at site 3 during storms (r= 0.72, p-value= 0.01). There were no significant relationship at all sites between DogBac gene copies and *E. coli* colony forming units. However, there was a significant relationship at sites 1 and 3 during storms. Low correlation between the different markers and culturable *E. coli* indicates that the *E. coli* may be coming from different sources within the watershed. Sites with significant relationships between different markers and culturable *E. coli* indicates that the source may be nearby.

Nutrient analysis for nitrogen and phosphorus forms indicated that inorganic forms of nitrogen were more dominant than organic forms. On the contrary, recalcitrant forms of phosphorus were more dominant than dissolved forms. Site 2 had the highest concentration of nitrate and particulate phosphorus compared to other sites (Figure 1-13; 1-14). This might be because site 2 is draining from a residential area and that part of the stream is in a culvert with limited biota to process nutrients.

We calibrated and validated a SWAT model for discharge using a jackknifing method because we had only one year of collected flow data. The model was successfully calibrated and validated with NSE values exceeding the 0.5 threshold (Figure 1-15; 1-16). The model was calibrated manually for bacteria, although baseflow samples were not well captured in the model compared to storm samples (Figure 1-17).

Summary

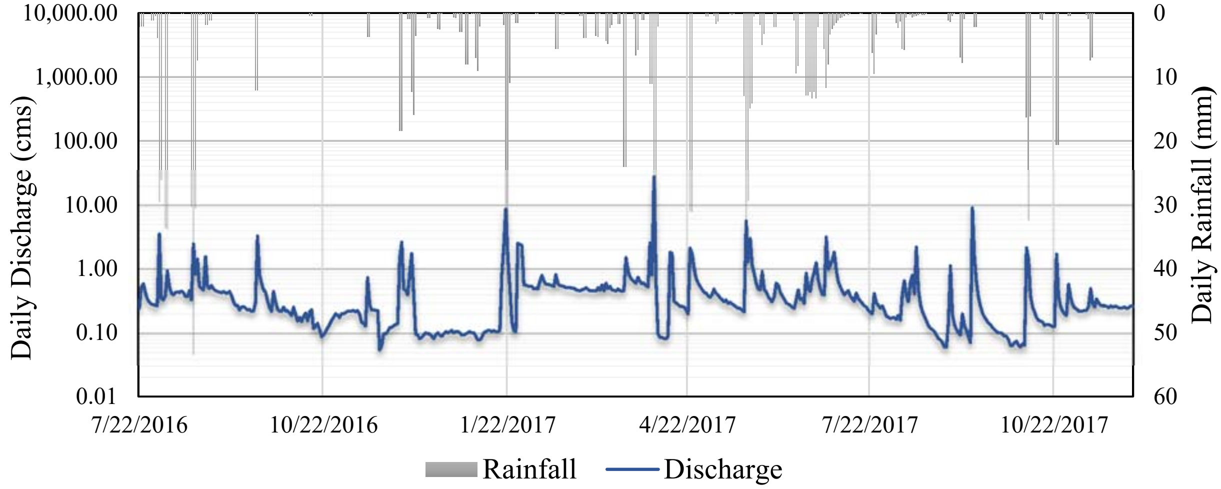
- Water quality parameters are good indicators of overall water quality. With factor analysis, we were able to determine site behavior and interesting grouping of variables. Turbidity seems to be the best indicator of *E. coli*.
- Storm samples have higher concentrations of *E. coli* (>1000 MPN/100 ml) compared to baseflow. This might be due to wash-off from land surface or resuspension of bed sediments during high flows (Bradshaw et al., 2016) .
- Sites 1, 4 and 6 violated the standard the most. However, site 6 had zero human influence and was only contaminated with deer manure. This shows the importance of microbial source tracking because human sources pose a higher risk than others (Soller et al., 2010).
- Prevalence of human markers across sites 1-4 indicates that the lower East Fork of Trail Creek has high levels of human impact especially during storms.
- Site 2, a small tributary crossing a low-income neighborhood area, may be located near a sewer leak because only human markers were detected.
- Most polluted sites (1-3) are located in low to medium density urban areas whereas site 4 is located in a forested area draining from high density urban.
- Low correlation between human marker and culturable *E. coli* indicates that *E. coli* may be coming from different sources within the watershed (site 3 was the only site having a significant relationship during both baseflow and stormflow, indicating that it may be near a point source).
- SWAT model was successfully calibrated for flow but bacteria module needs to be improved to better represent baseline conditions. Next steps will be to use the LID module to determine the effectiveness of LID features at reducing bacteria.

Supplemental Material

Results (Graphs, Figures, Statistical Analysis)

Discharge

Site 1: Watershed Outlet



Site 3: Trail Creek Bridge

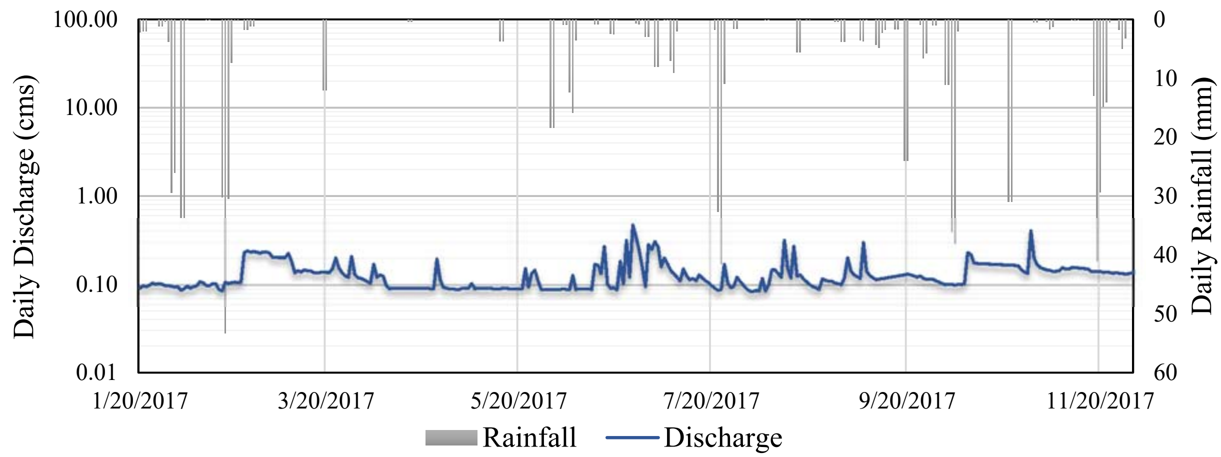


Figure 1-4 Daily Discharge at storm monitoring locations

Water Quality Parameters: Synoptic baseflow and composite storm samples

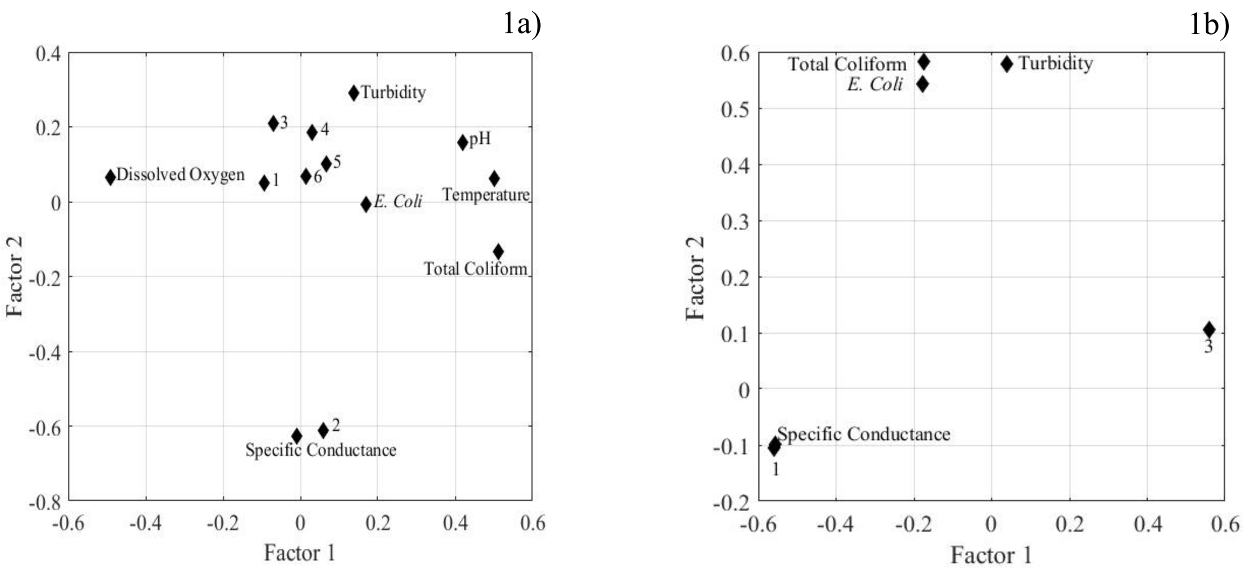


Fig 1-5 Factor Analysis baseflow (1a), stormflow (1b)

Water Quality Parameters: Real Time Data

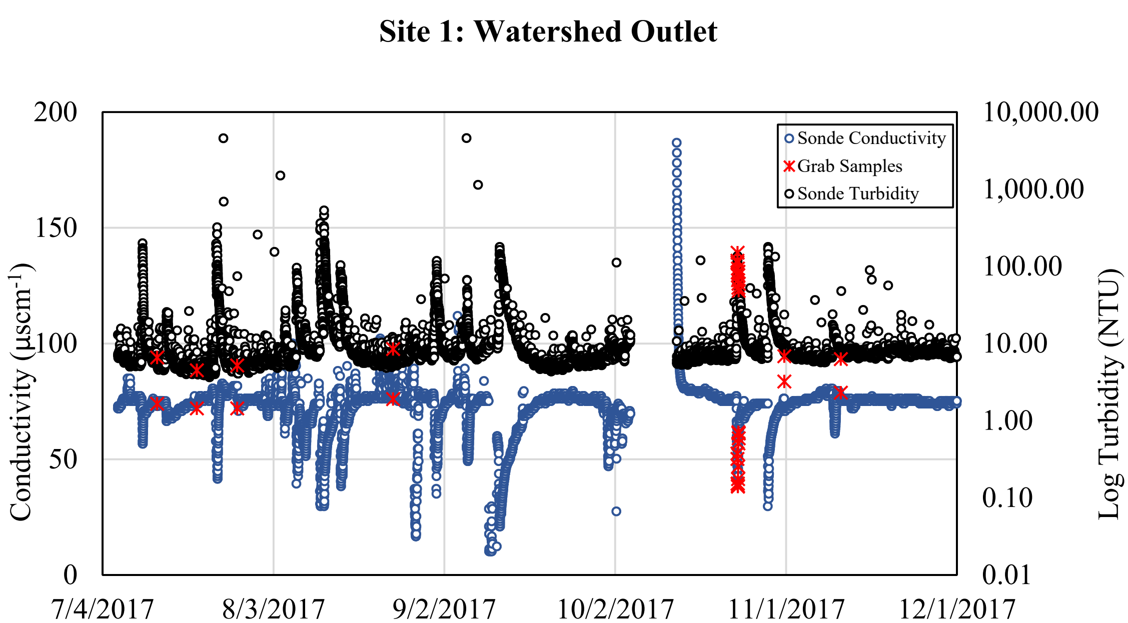


Fig 1-6 Real-time Conductivity and Turbidity at a 15-min interval

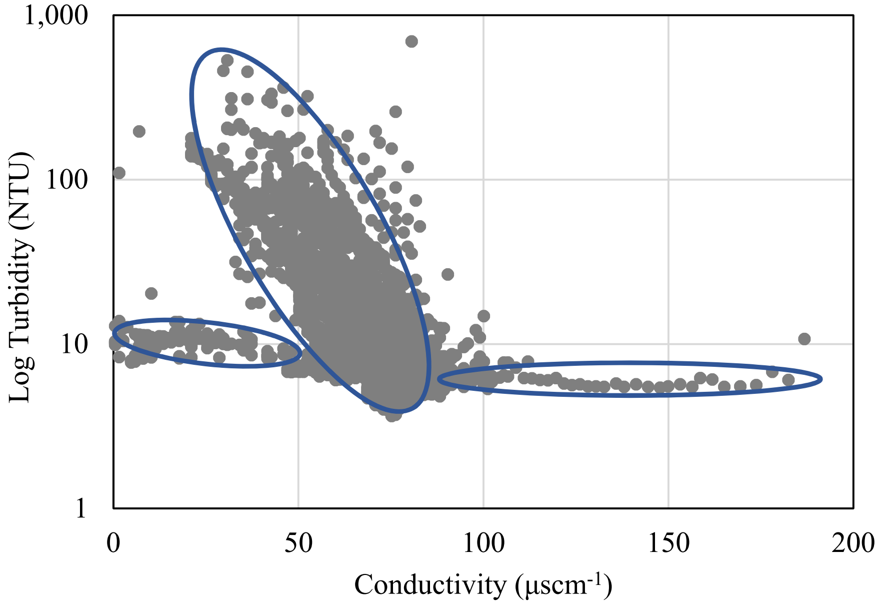


Fig 1-7 Turbidity and Conductivity Patterns indicating pollution sources

Tributary above site 3: Trail Creek Bridge

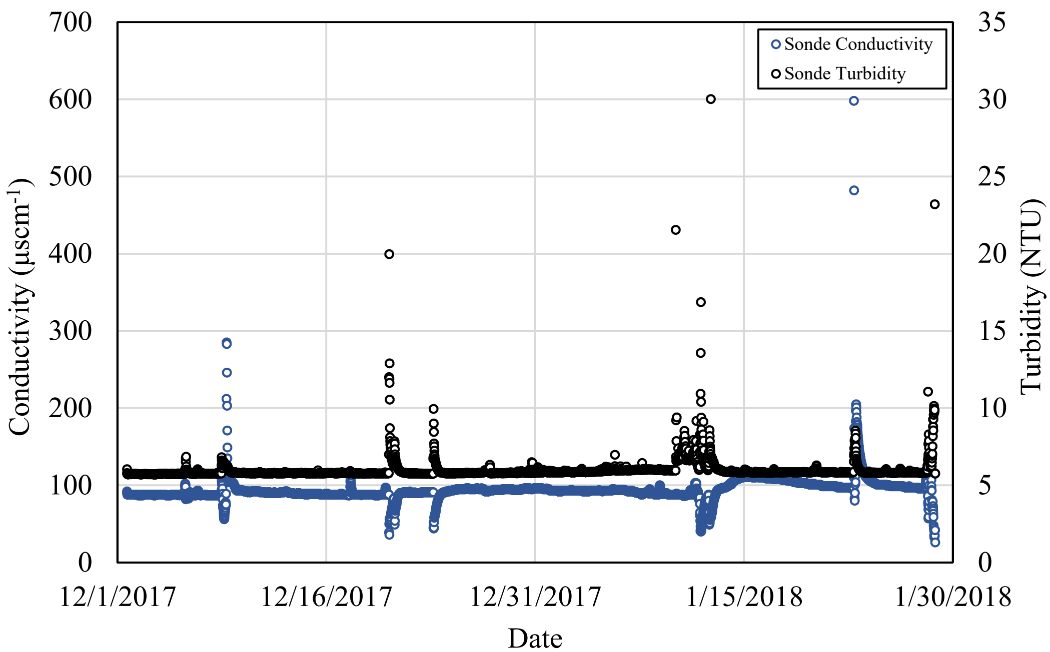


Fig 1-8 Real-time Conductivity and Turbidity at a 15-min interval

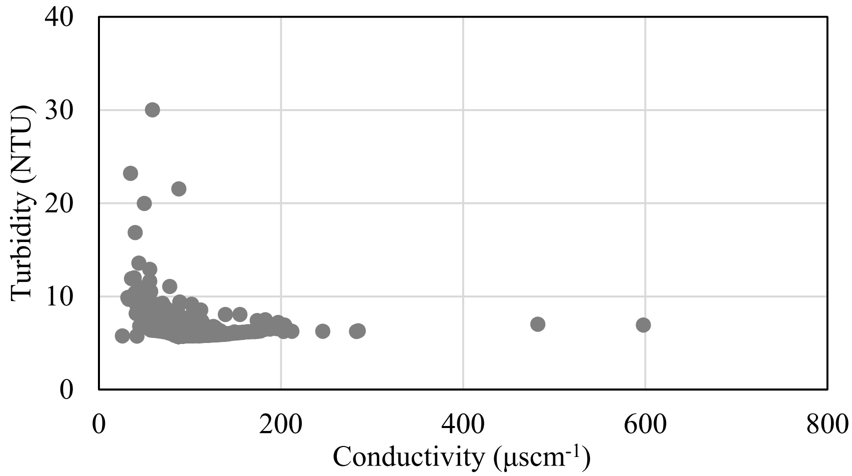


Fig 1-9 Turbidity and Conductivity Patterns indicating pollution sources

E. Coli during baseflow and stormflow

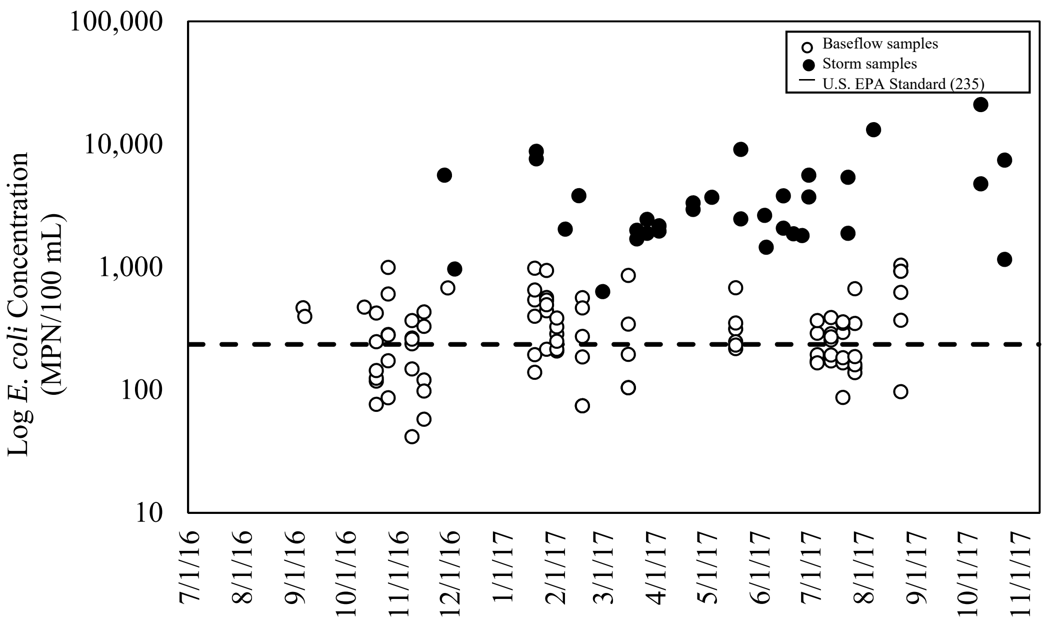


Fig 1-10 Daily *E. coli* concentrations comparison

1a)

Sites	*n*	*Mean*	*Min*	*25th*	*50th*	*75th*	*Max*	*%>235*
1	18	383	86	226	369	556	677	72
2	13	670	76	172	214	272	366	38
3	14	308	42	131	189	306	975	36
4	14	366	98	241	337	453	852	79
5	14	229	74	148	188	311	440	43
6	14	325	74	197	259	389	991	64

1b)

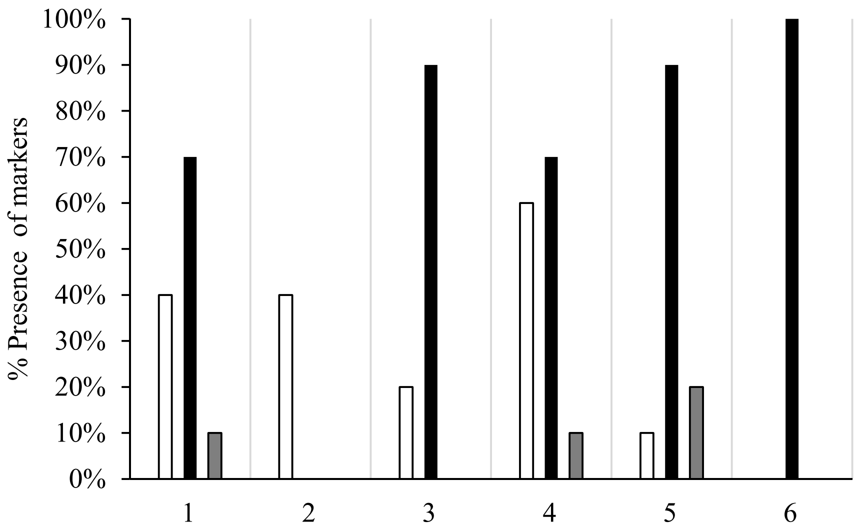
Sites	*n*	*Mean*	*Min*	*25th*	*50th*	*75th*	*Max*	*%>235*
1	18	3427	960	1904	2393	3781	9060	100
3	10	3133	630	1900	2448	3670	7580	100

n = # of samples

Table 1 Descriptive Statistics (baseflow) (1a), (stormflow) (1b)

Microbial Source Tracking: Detection

1a)



1b)

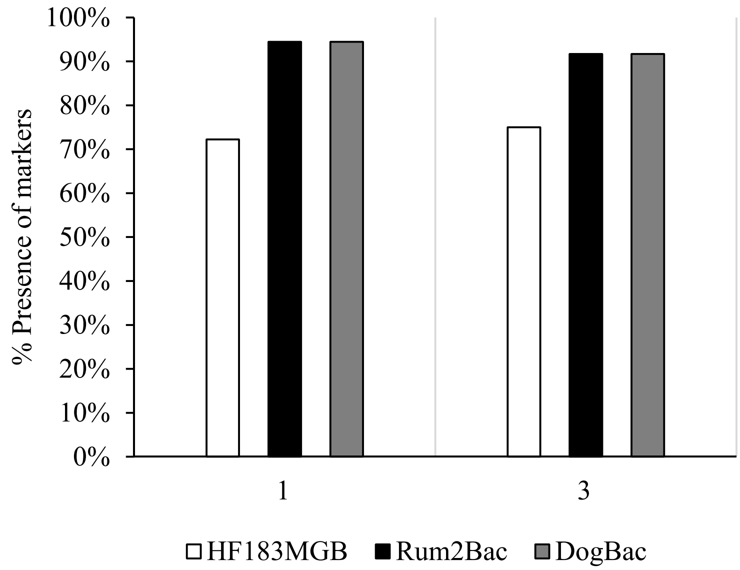
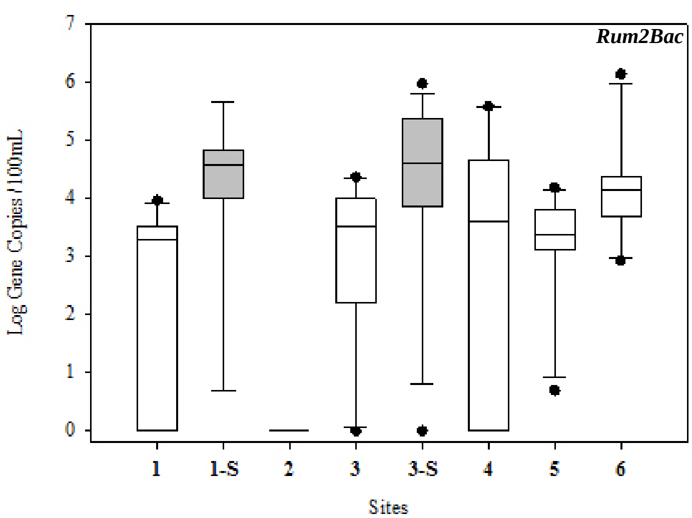


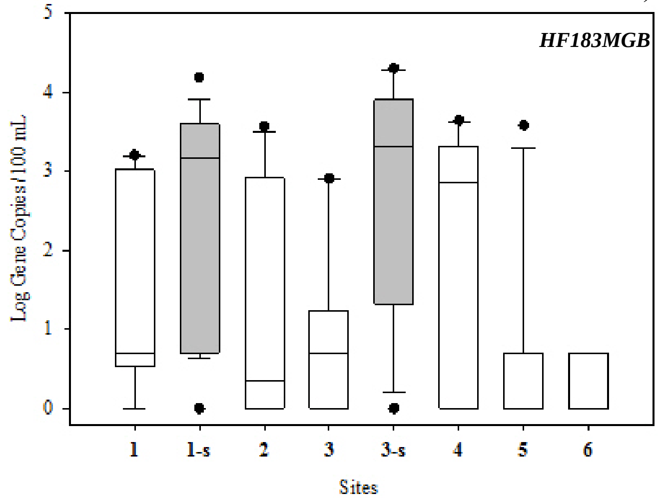
Fig 1-11 Percentage markers detection baseflow (1a), stormflow (1b)

Microbial Source Tracking: Quantification

1a)



1b)



1c)

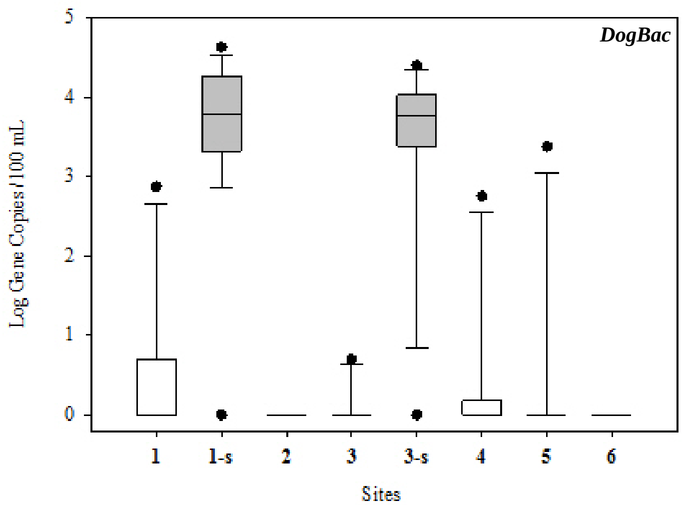


Fig 1-12 Distribution of Rum2Bac (1a), HF183MGB (1b), and DogBac (1c) gene copies

Microbial Source Tracking: Person Correlation

Site Names	# Observations	Pearson correlation	P-value (p<0.05)
Baseflow			
All sites	60	0.48	0.00
1	10	0.45	0.19
2	10	0.10	0.70
3	10	0.80	0.01
4	10	0.55	0.10
5	10	0.69	0.03
6	10	0.51	0.13
Stormflow			
1	18	0.01	0.95
3	12	0.79	0.00

Table 2 *E. coli* GC vs. *E. coli* CFU

Site Names	# Observations	Pearson correlation	P-value (p<0.05)
Baseflow			
All sites	60	0.46	0.00
1	10	0.35	0.32
2	10	0.33	0.35
3	10	0.05	0.90
4	10	0.55	0.09
5	10	0.12	0.73
6	10	0.11	0.77
Stormflow			
1	18	0.18	0.46
3	12	0.67	0.02

Table 3 HF183MGB GC vs. *E. coli* CFU

Site Names	# Observations	Pearson correlation	P-value (p<0.05)
Baseflow			
All sites	60	0.42	0.00
1	10	0.31	0.38
2	10	-	-

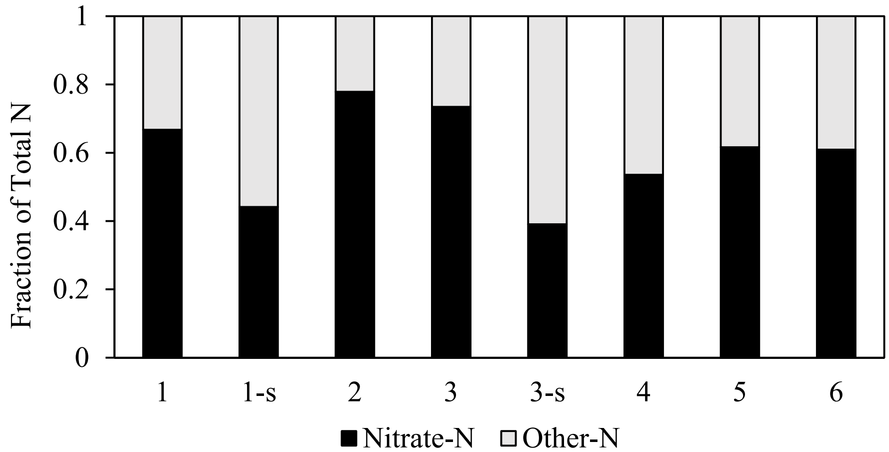
3	10	0.24	0.50
4	10	0.39	0.26
5	10	0.37	0.29
6	10	0.22	0.53
Stormflow			
1	18	0.26	0.28
3	12	0.72	0.01

Table 4 Rum2Bac GC vs. *E. coli* CFU

Site Names	**# Observations**	**Pearson correlation**	**P-value (p<0.05)**
Baseflow			
All sites	60	0.79	0.00
1	10	0.36	0.29
2	10	-	-
3	10	0.24	0.50
4	10	0.29	0.40
5	10	0.28	0.43
6	10	-	-
Stormflow			
1	18	0.49	0.04
3	12	0.84	0.0005

Table 5 DogBac GC vs. *E. coli* CFU

Nutrient Analysis: Nitrogen



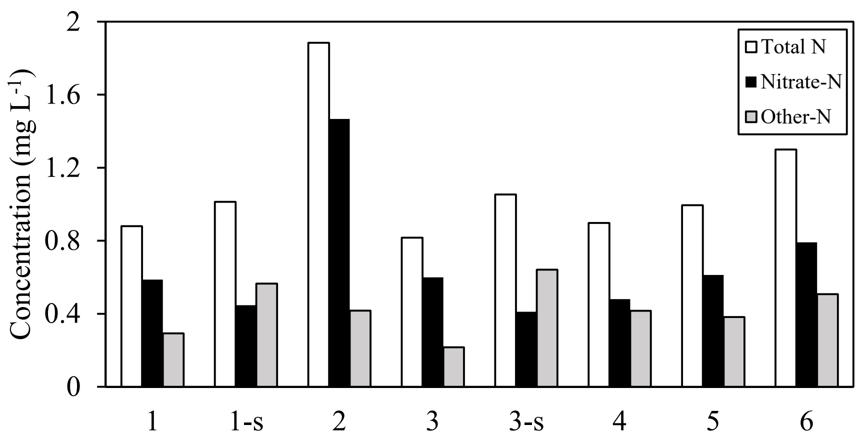
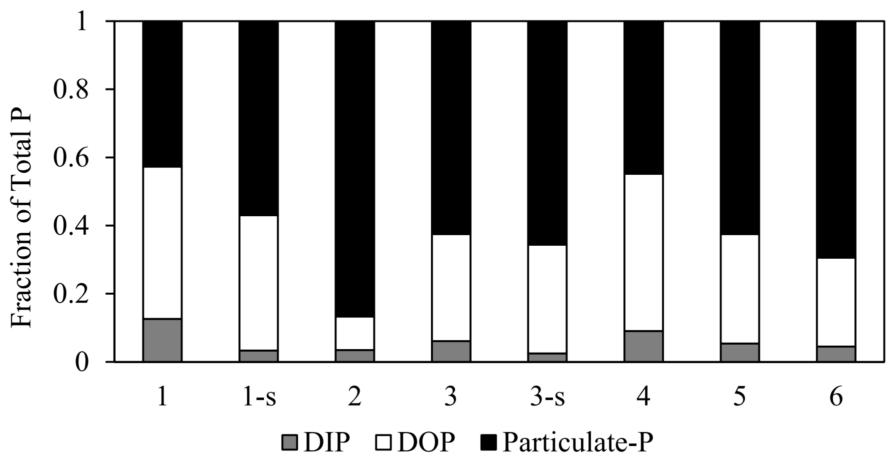


Fig 1-13 Representation of fractions of Total N followed by the concentrations of N forms at all sites based on the means.

Nutrient Analysis: Phosphorus



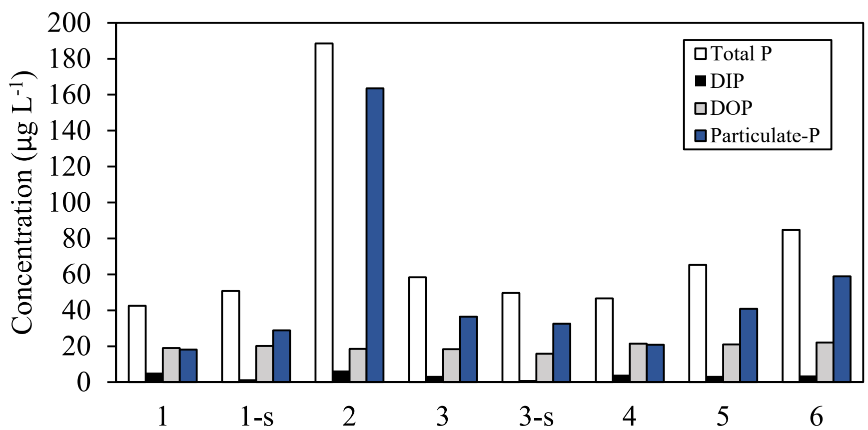
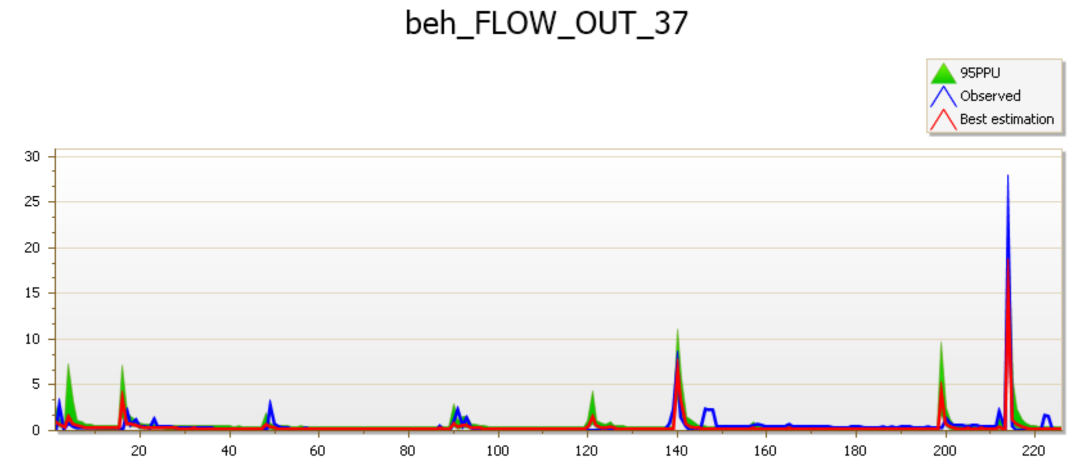


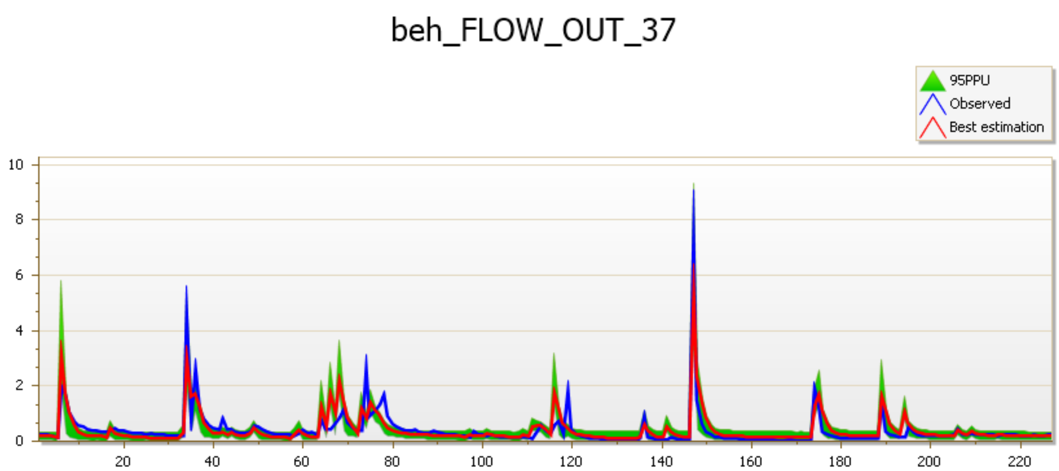
Fig 1-14 Representation of fractions of Total P followed by the concentrations of P forms (Dissolved Inorganic Phosphorus (DIP), Dissolved Organic Phosphorus (DOP) and Particulate Phosphorus) at all sites based on the means.

Soil and Water Assessment Tool

Flow Calibration (Jackknifing Method)



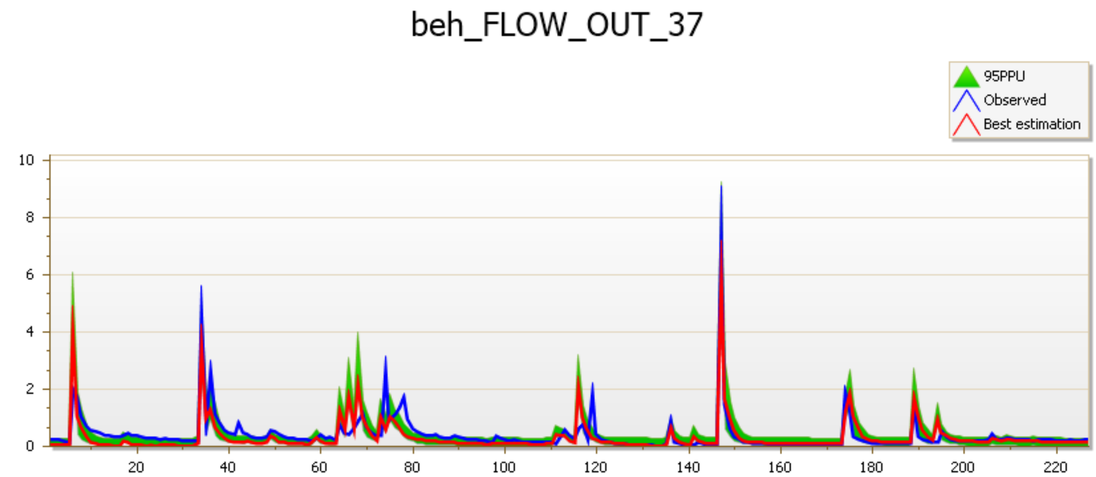
# of behavioral runs: 433
P-factor = 0.60
R-factor = 0.38
R^2 = 0.82
NSE = 0.78



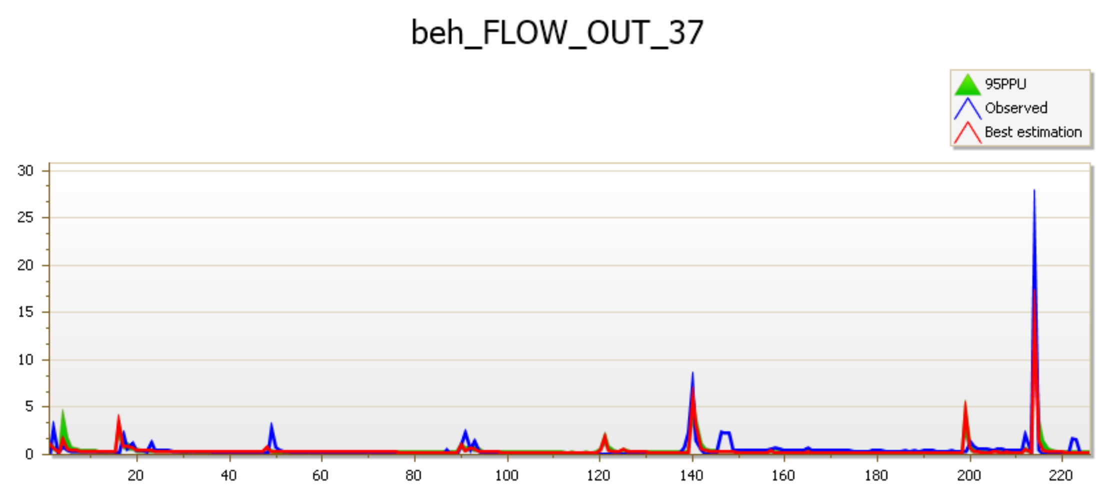
# of behavioral runs: 276
P-factor = 0.86
R-factor = 0.63
R^2 = 0.71
NSE = 0.71

Fig 1-15 Flow Calibration (Jackknifing method)

Flow Validation (Jackknifing Method)



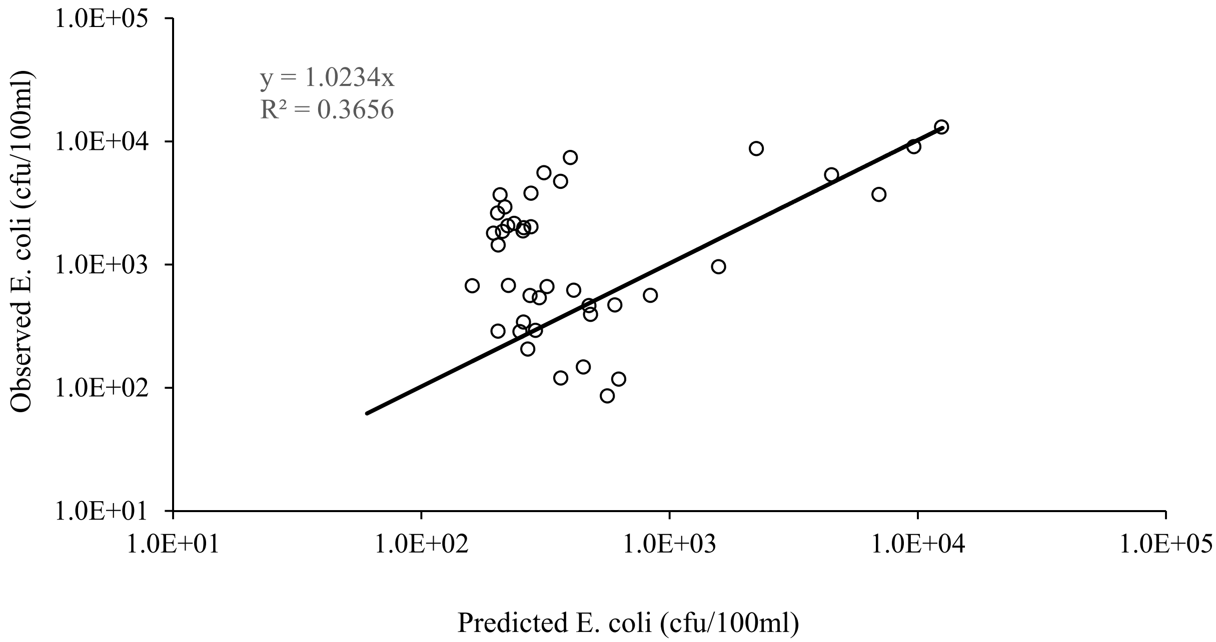
# of behavioral runs: 30
P-factor = 0.77
R-factor = 0.56
R^2 = 0.69
NSE = 0.68



# of behavioral runs: 433
P-factor = 0.52
R-factor = 0.26
R^2 = 0.80
NSE = 0.75

Fig 1-16 Flow Validation (Jackknifing method)

Bacteria Manual Calibration



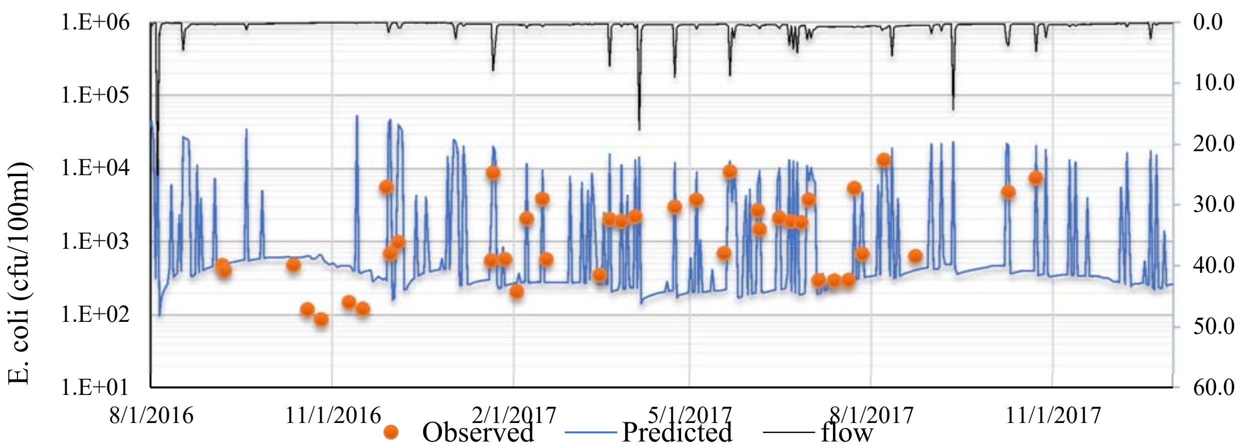


Fig 1-17 Bacteria Manual Calibration

Bradshaw, J. K., B. J. Snyder, A. Oladeinde, D. Spidle, M. E. Berrang, R. J. Meinersmann, B. Oakley, R. C. Sidle, K. Sullivan, and M. Molina. 2016. Characterizing relationships among fecal indicator bacteria, microbial source tracking markers, and associated waterborne pathogen occurrence in stream water and sediments in a mixed land use watershed. Water Research 101: 498-509.

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GAEPD. 2016. Draft 2016 Intergrated 305 (b)/ 303 (d) List - streams. Georgia Environmental Protection Division. https://epd.georgia.gov/sites/epd.georgia.gov/files/related_files/site_page/303d_Draft_Streams_Y2016.pdf (accessed on 1 Sept. 2017)

Soller, J. A., M. E. Schoen, T. Bartrand, J. E. Ravenscroft, and N. J. Ashbolt. 2010. Estimated human health risks from exposure to recreational waters impacted by human and non-human sources of faecal contamination. Water Research 44: 4674-4691.

Quantifying the relative contributions of the physical mechanisms responsible for the Atlanta 2009 flood

Basic Information

Title:	Quantifying the relative contributions of the physical mechanisms responsible for the Atlanta 2009 flood
Project Number:	2017GA373B
Start Date:	3/1/2017
End Date:	8/31/2018
Funding Source:	104B
Congressional District:	10
Research Category:	Climate and Hydrologic Processes
Focus Categories:	Floods, Climatological Processes, Management and Planning
Descriptors:	None
Principal Investigators:	Marshall Shepherd, Neil Debbage

Publications

There are no publications.

The Georgia Water Resources Institute asked for and received permission to extend the deadline of the following research project into FY2018. The final project report will be included in the FY2018 Annual Report.

Quantifying the relative contributions of the physical mechanisms responsible for the Atlanta 2009 flood; Shepherd, Marshall and Debbage, Neil; University of Georgia.

Developing real-time sensor networks for monitoring stream water quality to improve water resource management

Basic Information

Title:	Developing real-time sensor networks for monitoring stream water quality to improve water resource management
Project Number:	2017GA374B
Start Date:	3/1/2017
End Date:	7/31/2018
Funding Source:	104B
Congressional District:	GA-10
Research Category:	Water Quality
Focus Categories:	Water Quality, Non Point Pollution, Management and Planning
Descriptors:	None
Principal Investigators:	Seth Wenger, Amy Rosemond, John Dowd, Phillip M Bumpers

Publications

There are no publications.

The Georgia Water Resources Institute asked for and received permission to extend the deadline of the following research project into FY2018. The final project report will be included in the FY2018 Annual Report.

Developing real-time sensor networks for monitoring stream water quality to improve water resource management; Wenger, Seth, Rosemond, Amy, Dowd, John, and Bumpers, Phillip M.; University of Georgia.

Estimation of irrigation withdrawals in the Apalachicola-Chattahoochee-Flint (ACF) River Basin

Basic Information

Title:	Estimation of irrigation withdrawals in the Apalachicola-Chattahoochee-Flint (ACF) River Basin
Project Number:	2017GA377B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	5
Research Category:	Ground-water Flow and Transport
Focus Categories:	Groundwater, Irrigation, Models
Descriptors:	None
Principal Investigators:	Jian Luo

Publications

There are no publications.

FINAL REPORT

Estimation of Irrigation Withdrawals in the Apalachicola-Chattahoochee-Flint (ACF) River Basin

JIAN LUO

School of Civil and Environmental Engineering

Georgia Institute of Technology

April, 2018

Abstract

This study is a continuation of our previous work to analyze the random fields with multiple spatial correlations. The main objective of this study is to enhance the accuracy of the kriging estimates by separating random fields and performing kriging using multiple correlation structures that are prevail in the measurements of groundwater usage and levels in the ACF River Basin. It was found that the estimates using constituent random fields gives much more accurate kriging predictions compared to using single mixed random field. The novel cutting edge technique based on the variogram deviation was developed to identify and separate the different correlation structures in a potential mixture of fields. The proposed clustering technique was applied to analyze the flowmeter measurements in the ACF River Basin and led to a significant improvement in the studies of optimizing the pumping well monitoring network and estimating the groundwater withdrawals for irrigation in the ACF River Basin.

1. Introduction:

Groundwater is the major source of water in the lower Apalachicola-Chattahoochee-Flint (ACF) River basin in the south-western part of Georgia (Albertson & Torak, 2002; Fanning, 1997; Fanning, 2003; Mosner, 2002; Warner & Lawrence, 2005). High demand of water for the irrigation in the region leads to large-scale groundwater withdrawals and therefore, it becomes extremely important to continuously monitor the pumping from the wells in order to get a reliable estimate of the amount of water pumped and its spatial and temporal patterns. These estimates are critical for the development of long-term sustainable water resource management plan for ACF basin. To achieve these goals, Georgia Soil and Water Conservation Commission (GSWCC), following a state legislature in June 2003, installed more than 10,000 annually read water meters and around 200 daily reporting telemetry sites on irrigation systems primarily in southern Georgia (2004 to 2010) to monitor groundwater pumping (Torak & Painter, 2011). Fig. 1 shows the locations of permitted unmetered and metered agricultural water-use sites and metered and telemetered sites located in middle-and-lower Chattahoochee and Flint River basin by year-end 2009. However, due to a large number of pumping wells and budget constraints, it is not feasible to install meters at each well. Furthermore, due to budget cuts, it is getting difficult to operate and maintain even the existing monitoring network. Therefore, there is a pressing need to optimize the existing monitoring network in order to get the required spatial pumping information through minimum monitoring efforts. In addition to it, there is also a need to develop a comprehensive and robust technique for the indirect estimation of the irrigation withdrawals using the data from the metered sites. In 2009, National Water Census was established by U.S. Geological Survey (USGS) with the objective of providing water resource managers and policy makers comprehensive and reliable information about the water consumptions, losses and transfers (Painter et al., 2015).

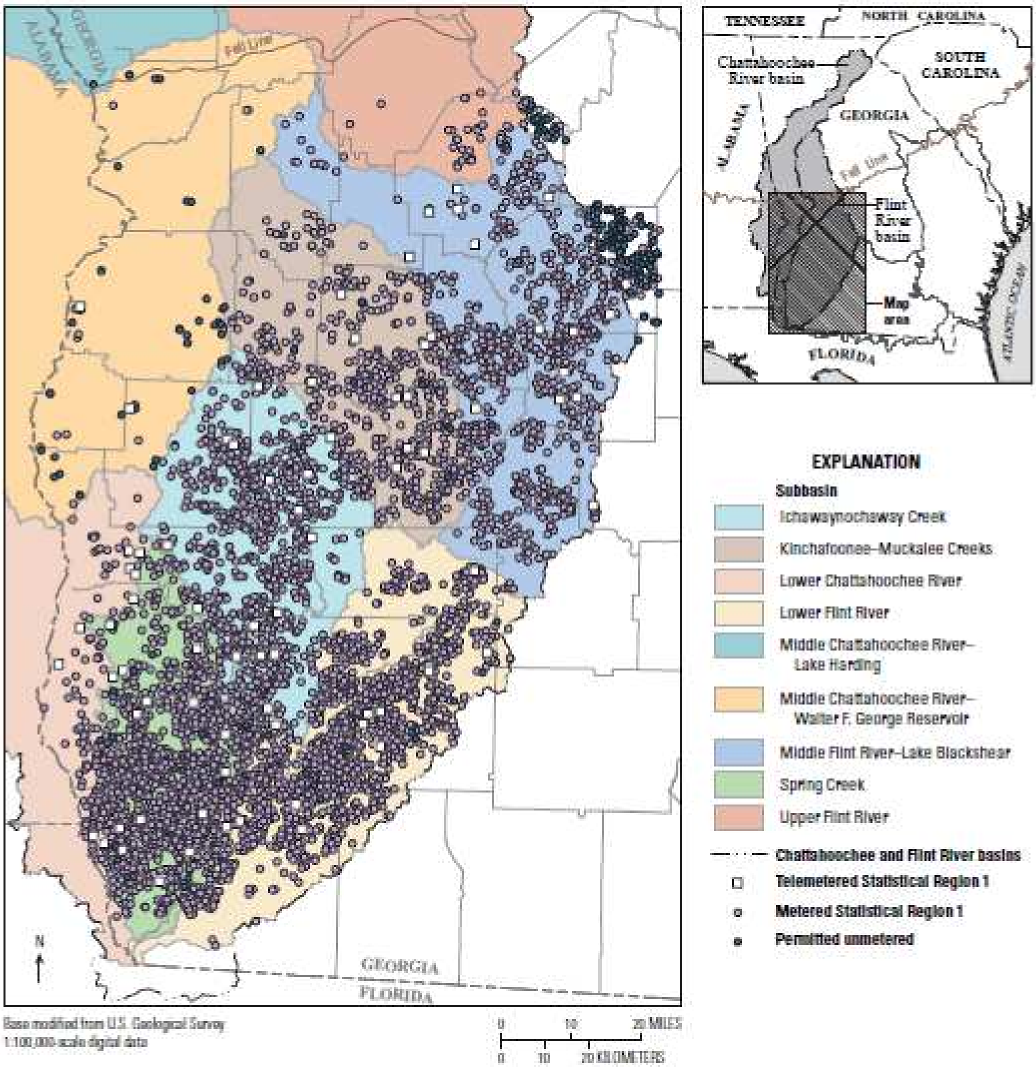


Figure 1: Status of the Georgia Agricultural Water Conservation and Metering Program in southern Georgia by year-end 2009; locations of permitted unmetered and metered agricultural water-use sites; and metered and telemetered sites located in middle-and-lower Chattahoochee and Flint River basin (Torak & Painter, 2011)

Painter et al. (2015) compared three different techniques– crop-demand method, geostatistical method, and image analyses, to estimate the total agricultural groundwater withdrawal in the ACF focus area. They found that none of the three techniques is a turnkey method to estimate the irrigation withdrawals. The crop-demand method requires data parameterization of soil, crop and meteorological data which undermines the local conditions and affect the accuracy of the estimation. Painter et al. (2015) suggested that geostatistical can potentially provide most reliable and consistent estimates with minimum parameterization. However, the accuracy of the geostatistical estimates largely depends on the accuracy of the meter readings of the irrigated-water volumes, associated irrigation area and how well we can capture the underlying correlation structures. Both crop-demand model and geostatistical techniques suffer due to the inaccuracies in the irrigation area estimates, which turns out to be the most critical parameter for the accuracy of the irrigation withdrawals. Image analysis which is primarily aimed at getting monthly estimates of the irrigated areas proves to be inadequate due to inconsistencies in the satellite images caused by atmospheric interference (Painter et al., 2015).

Geostatistical Technique, despite heavy dependence on the accuracy of the metered data, turns out to be a very attractive and viable method as it requires minimal parameters (data driven) and has a higher regard for the local conditions compared to the crop-demand model. Availability of the rich dataset obtained from the metering program in which significant amount of resources are invested further favors geostatistical techniques. Torak and Painter (2011) used geostatistical techniques which include variogram analysis, kriging, monitoring network optimization and cross-validation using the annually reported meter data. Their specific objective was to evaluate the spatial correlation structure and employing it to revise the spatial distribution of the telemetry meters, thus reducing the errors associated with estimating the annually reported meter data using the telemetry network. They carefully selected distance class to obtain experimental variogram with a strong spatial correlation. The exponential variogram model fitted showed a very good fit with an R-squared value equal to 0.998. However, it is important to recognize that fitting a variogram model to the experimental variogram is not same as fitting the estimation model to the known data. Therefore, the goodness of the fit between variogram model and the experimental variogram does not imply good estimation of the data points. Additionally, Torak and Painter (2011) considered the whole dataset as the realization of the single random field with one correlation structure, however, it is very much possible that there are multiple overlapping random fields, which can be better characterized with more than one correlation structures. The factors that can cause multiple correlation structures include different aquifer layers from which water is pumped, different crop types and other local and regional factors. In such cases, considering the single random field and using the whole dataset to obtain variogram model can significantly hamper the performance of the geostatistical analysis and lead to higher cross-validation and estimation errors. We demonstrate this using numerical experiments in the later sections. Therefore, there is a need to identify and separate overlapping random fields form the mixed field. Random fields with significantly different constant means or fields which are spatially isolated can be separated using K-means clusters or other similar conventional techniques. However, if the means of the constituent fields are not significantly different and there is an overlap in their range of data values, they become indistinguishable for the conventional clustering or classification techniques, suggesting a need for a more robust method that can separate overlapping random fields based on the difference in their correlation structure.

In this study, we first provide a framework to conceptualize two overlapping random fields and relations between the variogram features of the mixed fields and constituent fields. Based on that, we develop a novel technique to identify and separate constituent random fields from the mixed field. The technique is then tested over a wide range of scenarios using synthetically generated mixed random fields. The success in the separation of the constituent random fields is measured by the purity of the final clusters, and its advantages are demonstrated using cross-validation and an application for optimizing monitoring network.

2. Theoretical Framework:

Spatial data in the real world is often not unimodal and is governed by more than one correlation structures not necessarily spatially contiguous. Geostatistics practitioners often assume single correlation structure, thus perform geostatistical analysis and kriging using a single variogram model. However, the estimate using single variogram model for the dataset representing overlapping fields might not be the best estimate. In this study, we demonstrate using theoretical analysis and numerical experiments that in case of a mixed field, separating the fields and using their respective correlation structures will give much better results in geostatistical applications compared to using all the available data as a single random field.

We use the framework provided by Rubin (1995) to analyze mixed field with two constituent random fields (RF). The adopted model for an attribute value Y at a location x is given as:

$$Y(x) = I(x)Y_1(x) + [1 - I(x)]Y_2(x) \tag{1}$$

where I is an indicator function which is either 1 with probability P if $Y = Y_1$, or 0 with probability $(1 - P)$ if $Y = Y_2$. Y_1 and Y_2 denote the same attribute, but come from different RFs and display distinct correlation structures, which coexist in the same spatial domain. $I(x)$ also is a random spatial variable which essentially represents the geometry of the distributions of the Y_1 and Y_2 in space. $I(x)$ can be either spatially correlated or uncorrelated, implications of each case are discussed in the later section. It is assumed that there is no correlation among Y_1, Y_2 and $I(x)$ (Rubin, 1995).

Desbarats used this model to evaluate effective permeability (Desbarats, 1987) and analyze macrodispersion (Desbarats, 1990) in sand-shale formations. They modeled Y as a binary random variable which could take only two values, i.e., constant hydraulic conductivities of sand and shale formations, and I as a random variable. Johnson and Dreiss (1989) used indicator kriging specifically to distinguish the geometries of the spatial distribution of two different fields.

First- and second-order spatial moments of $I(x)$ can be given as follows (Desbarats, 1987):

$$E[I(x)] = P \tag{2}$$

$$Var[I(x)] = C_I(0) = P(1 - P) \tag{3}$$

$$Cov[I(x), I(x + \mathrm{h})] = C_I(\mathrm{h}) = P(1 - P)\rho_I(h) \tag{4}$$

$$\gamma_I(\mathrm{h}) = C_I(0) - C_I(\mathrm{h}) = P(1 - P)[1 - \rho_I(h)] \tag{5}$$

where $\gamma_I(h)$ and $\rho_I(h)$ are the variogram and correlation function, respectively, of the random function $I(x)$. Y_1 and Y_2 represents the data points from random field 1 (RF1) and random field 2 (RF2) with means as μ_1 and μ_2, variances as σ_1^2 and σ_2^2, covariograms as C_1(h) and $C_2(h)$, respectively. The spatial moments of the data points from mixed field, $Y(x)$, can be given as:

$$\mu_y = P\mu_1 + (1-P)\mu_2 \tag{6}$$

$$\sigma_Y^2 = P\sigma_1^2 + (1-P)\sigma_2^2 + P(1-P)(m_1 - m_2)^2 \tag{7}$$

$$C_y(\mathrm{h}) = [C_I(\mathrm{h}) + P^2]C_1(\mathrm{h}) + [(1-P)^2 + C_I(\mathrm{h})]C_2(\mathrm{h}) + (m_1 - m_2)^2 C_I(\mathrm{h}) \tag{8}$$

The variogram for $Y(x)$, that we are especially interested in, can be obtained from $\gamma_Y(h) = \sigma_Y^2 - C_y(\mathrm{h})$, and making following substitutions: $C_1(\mathrm{h}) = \sigma_1^2 - \gamma_1(\mathrm{h})$, $C_2(\mathrm{h}) = \sigma_2^2 - \gamma_2(\mathrm{h})$, $C_I(\mathrm{h}) = \sigma_I^2 - \gamma_I(\mathrm{h})$, $\sigma_I^2 = P(1-P)$, where $\gamma_1(h)$ and $\gamma_2(h)$ are the variograms of RF1 and RF2.

$$\gamma_Y(h) = [P - \gamma_I(h)]\,\gamma_1(h) + [(1-P) - \gamma_I(h)]\,\gamma_2(h) + [(m_1 - m_2)^2 + (\sigma_1^2 + \sigma_2^2)]\,\gamma_I(h)$$

(9)

Eq. (9) presents the variogram of the mixed field as a function of variograms of the constituent fields, the proportion of the number of points from each field (an unbiased estimate for P), variances of each field, means of each field and variogram of indicator function $I(x)$.

The mixed fields can be broadly categorized into two different categories: 1) $I(x)$ is spatially correlated, or 2) $I(x)$ is spatially uncorrelated. This categorization have implications on the conceptualization of mixed field problems, techniques to separate the constituent random fields, and eventually geostatistical analysis and kriging.

2.1. Mixed fields with spatially correlated $I(x)$:

In case of mixed fields with spatially correlated $I(x)$, similar $I(x)$ values tend to realize in spatially contiguous regions. There will be a group of Y_1 realizations clustered together and governed by correlation structure of RF1, and similar groupings for Y_2 can be expected. This category covers the scenarios, where, at one spatial location, we can have data-point from only one random field (either Y_1 or Y_2), such as, mineral-ore grade, rainfall data, hydraulic conductivity (sand-shale formations), etc. However, this study is limited to the cases with uncorrelated $I(x)$, discussed in the next section.

2.2. Mixed field with spatially uncorrelated $I(x)$:

In case of mixed fields with spatially uncorrelated $I(x)$, the realization of I at one location is independent of its realizations at locations around it, i.e. whether a Y realization is from Y_1 or Y_2 is not dependent on from which field the nearby realizations are. Conceptually, one scenario of such occurrence is two completely overlapping random fields. Which means both Y_1 and Y_2 exist in the whole spatial domain, however, are separated by some other attribute which could be time, third spatial coordinate (height or depth), sampling technique, etc. A sample Y at any location can be from any of the two fields, independent of the field of previously sampled values.

The variogram of Y can be obtained for the case of uncorrelated I using Eq. (9), with $\gamma_I(h) = \sigma_I^2 = P(1-P)$:

$$\gamma_Y(h) = P^2\,\gamma_1(h) + (1-P)^2\,\gamma_2(h) + [(m_1 - m_2)^2 + (\sigma_1^2 + \sigma_2^2)]P(1-P) \quad (10)$$

The nugget and sill are two prominent features of the variogram. The sill of the mixed field is independent of the fact whether I is correlated or not (Eq. (7)). Nugget for the Y (Nug_Y) in mixed field with uncorrelated I case is given as:

$$Nug_Y = [(m_1 - m_2)^2 + (\sigma_1^2 + \sigma_2^2)]P(1-P) \tag{11}$$

For given two fields, Nug_Y is maximum at $P = 0.5$, i.e., when the number of data points from both the RFs are almost equal. When $P = 0$ or 1, we get $Nug_Y = 0$.

A special case of mixed field with uncorrelated I is when two RF's have same correlation structure, i.e., $\gamma_1(h) = \gamma_2(h)$, $\sigma_1^2 = \sigma_2^2$, and $\mu_1 = \mu_2$. It can be understood as two-different realizations of the same field. Sill and nugget for this case can be obtained as:

$$\sigma_y^2 = (2P^2 + 1 - 2P)\sigma_1^2 + 2\sigma_1^2(P - P^2) = \sigma_1^2 \tag{12}$$

$$Nug_Y = 2\sigma_1^2 \, P\,(1 - P) \tag{13}$$

From the above analysis, we can say that a non-zero nugget is a strong indication of the existence of two random fields. There are other reasons attributed to nugget in the literature (Cressie, 1993; Matheron, 1963) which includes white noise in the data, or small-scale variability which cannot be resolved through adopted sampling technique. In this study, the focus is on the fields with the same means, for which there is no technique discussed in the literature to separate them. However, for different means, there have been several techniques discussed, K-means is one of the common ones. We will demonstrate later, our algorithm does not rely on the difference of the means, however, if the means are different, gives excellent results.

3. Numerical validation of the framework

We numerically validate the above-described framework by comparing the statistical moments of the mixed field, estimated using the equations described above, and numerically using the synthetic data. Most of the geostatistical analyses were performed using gstat package in R (Pebesma, 2004).

First, we consider a case of two-overlapping fields generated from two different correlation models with the parameters described in Table 1. We generate a grid of dimension 50 by 100 and resolution 1 by 1 unit. From these 5000 grid points, two sets of 1500 locations are picked randomly and unconditional realizations, Y_1 and Y_2, were generated at these locations. I is assumed to be spatially uncorrelated. In case 1 constituent fields, Y_1 and Y_2, have different correlation structures, and in case 2, they have same correlation structure.

Table 1: Cases considered to numerically validate the framework

		Model	Mean	Sill	Range	P
Case 1	Field 1	Exponential	10	0.20	28	0.5
	Field 2	Exponential	10	0.47	14	0.5
Case 2	Field 1	Exponential	10	0.38	10	0.5
	Field 2	Exponential	10	0.38	10	0.5

Table 2 summarizes the comparison between the theoretical $\gamma_Y(h)$ and Nug_Y (Eq. 10 and 11, respectively) and numerically obtained using experimental variogram for the mixed field. Fig. 2 shows the experimental variograms for case 1 and case 2. The framework discussed above is able to capture the geostatistics of the mixed field well, and hence used as a base for the geostatistical analysis of the mixed fields in the next sections.

Table 2: Theoretical vs experimental, $\gamma_Y(h)$ and Nug_Y, for the mixed field in case 1 and 2

		$\boldsymbol{\gamma_Y(h)}$	$\boldsymbol{Nug_Y}$
Case 1	Theoretical	0.335	0.168
	Numerical	0.343	0.170
Case 2	Theoretical	0.384	0.192
	Numerical	0.386	0.186

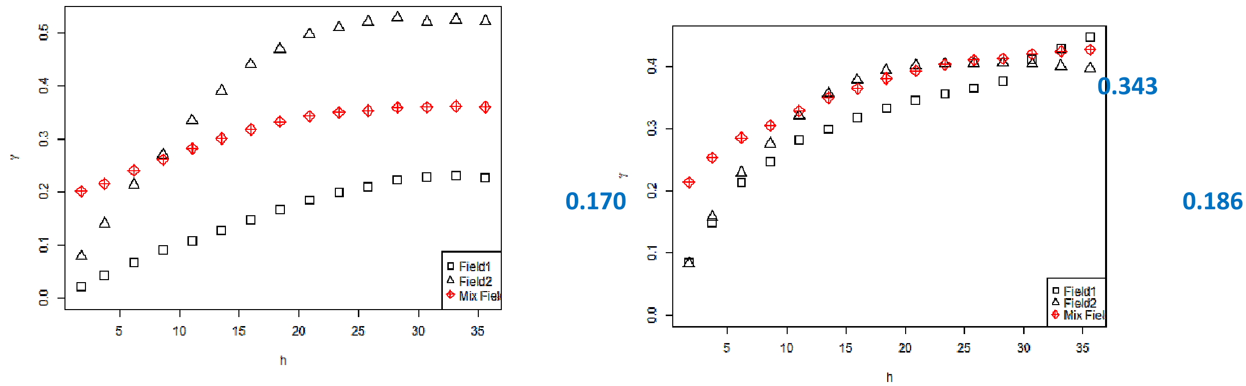


Figure 2: Experimental variograms of two constituent fields and mixed field in case 1 (left) and 2 (right)

4. Separating overlapping fields

We believe that using individual fields in any geostatistical application will give us a better result in any compared to using all the data points of the mixed field together. We can check this proposition by simply comparing the kriging cross-validation (CV) results in the cases when we perform CV separately for RF1 and RF2 using their respective variogram model and when we perform CV over the mixed field by fitting a variogram model over whole the dataset. For the case 1 discussed in the previous section with two fields RF1 and RF2, each having 1500 points, the CV results in terms of mean absolute error (MAE) and root mean square error (RMSE) are summarized in Table 3. Using the mixed field to perform kriging CV leads to a significant loss in the accuracy of the kriging estimates compared to using individual fields. which demonstrates that in other geostatistical applications also like monitoring network optimization, kriging, etc., using individual fields will give better results because two separate variograms for two sets of points characterize the existing spatial correlation structures better compared to using single variogram (fitted) for the whole dataset which essentially distorts the individual spatial correlation structures. Therefore, there is a strong incentive in separating the constituent random fields from the mixed field.

Table 3: Comparison of the CV results: Individual random fields vs Mixed field

	MAE	**RMSE**
Individual fields	0.1384	0.1834
Mixed field	0.4473	0.5407

4.1 Approach

We first analyze the effect on variogram when a point from the different random field is added. We consider 1500 points each from two overlapping random fields with 1) exponential variogram model with mean 10, sill 0.50 and range 10; 2) exponential variogram with mean 10, sill 0.25 and range 20, as shown in Fig. 3. Experimental variograms for individual fields and mixed field are shown in Fig. 4.

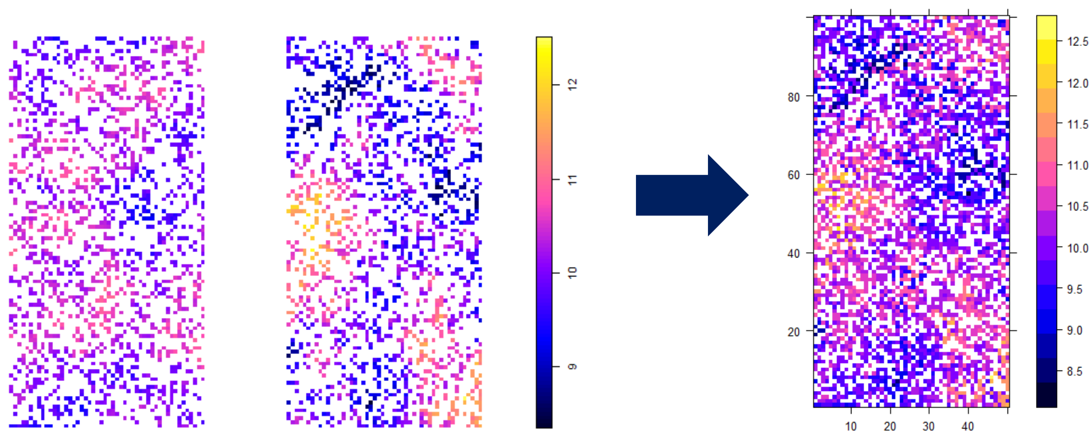


Figure 3: Two fields mixed. Field 1: Exponential variogram with mean 10, sill 0.50 and range 10. Field 2: Exponential variogram with mean 10, sill 0.25 and range 20.

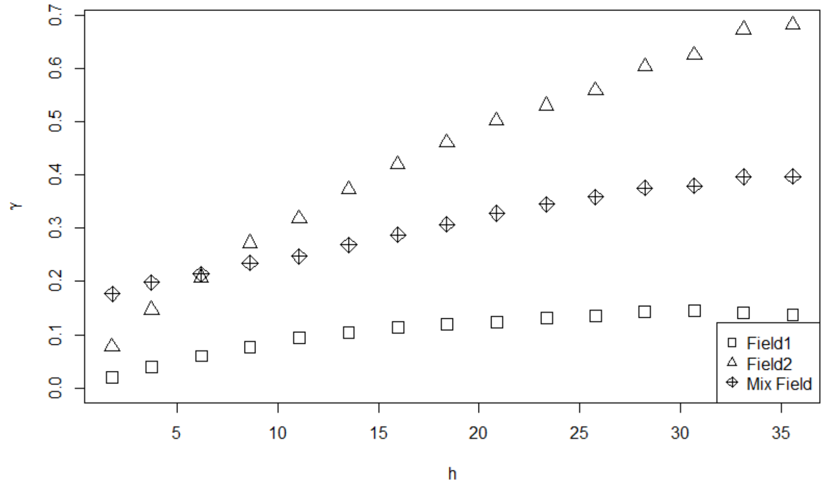


Figure 4: Experimental variograms of the individual fields and mixed fields

We start with a sample of 500 randomly selected points from each field which we shall refer as pure initial clusters. We make these clusters increasingly impure by adding points from the remaining points of the other field, one at a time, and observe the movement of the variograms with the increasing impurity. Fig. 5 shows the variograms of two clusters after adding 50, 250, 400 and 500 points. As the number of points from the other field increases, two variogram move closes to each other and eventually almost overlap (approaching the variogram described by Eq. (10)) when both the clusters have an equal number of points from both the fields (50% purity). Hence, we can expect variogram to shift significantly if the added point is from a different field, and remain fairly unmoved if the added point is from the same field. In order to further explore this shifting and obtain a qualitative range of this shift, we create two bands of variograms by adding with replacement points from the same field and different field. We perform this analysis separately for different sill and different range cases.

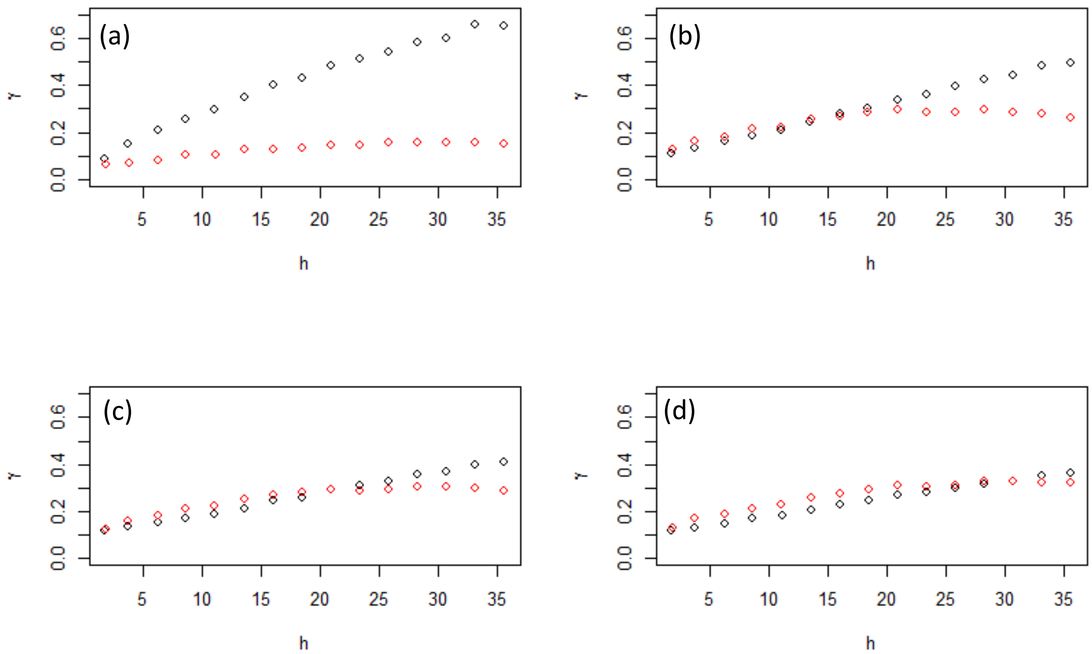


Figure 5: Variograms after (a) 50, (b) 250, (c) 400, (d) 500 points from the other fields are added to the initial pure clusters, continuously decreasing the purity from 100% to 50%

The two fields with different sills 0.15 and 0.50, same mean 10 and same range 10 are considered. Fig. 6 - (a) and (b) shows pixelated data values of two fields and their corresponding variograms, respectively.

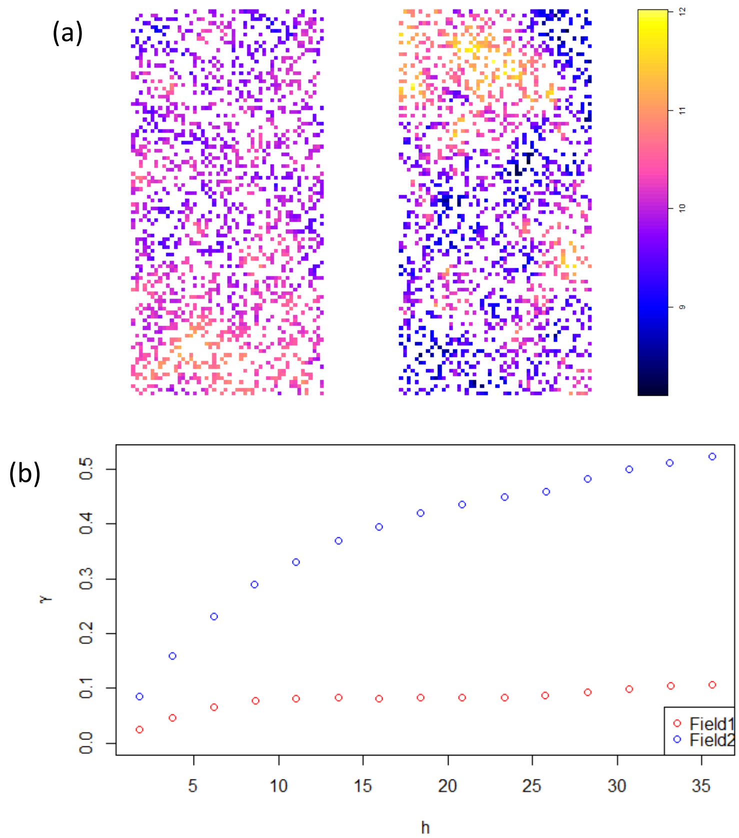


Figure 6: Random fields with different sill but same mean and range (a) pixelated data values in space; (b) experimental variograms of random fields

We take samples of 400 points from each field that we will refer as 'pure clusters' and plot their variograms in Fig. 7. We select one point at random from the field 1 and add it to both pure clusters and obtain new variograms. We replace the added point with another random point from field 1 and repeat this 100 times to obtain a band of variograms as show in in Fig. 8. We get similar bands of variograms by adding points from field 2.

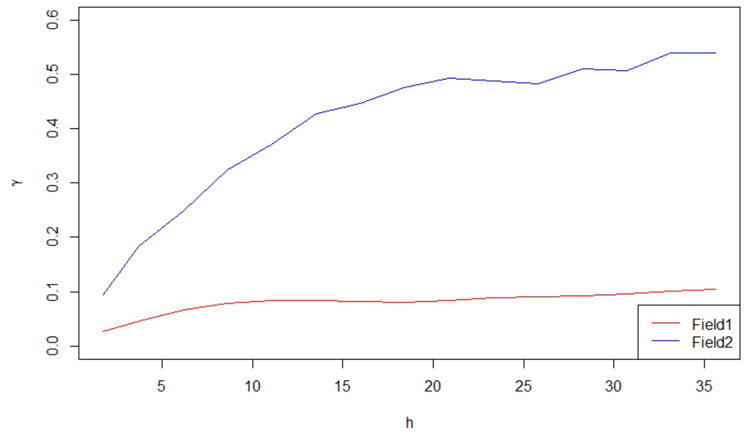


Figure 7: Variograms of initial pure clusters with 400 points each

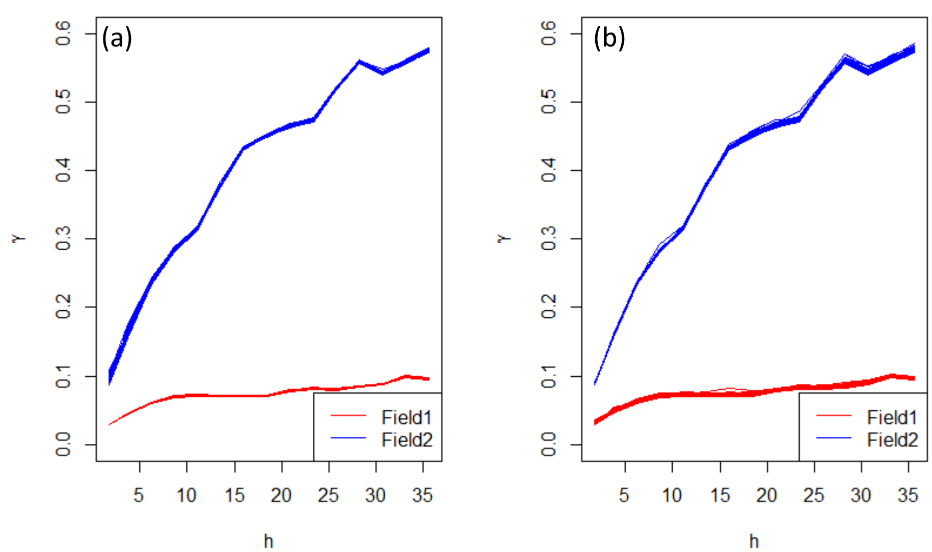


Figure 8: Band of variograms when points were added from (a) Field 1; (b) Field 2 We repeat this exercise for the random fields with different ranges. We consider random fields with range 5 and 25, and same mean and sill, 10 and 0.25, respectively. The variogram for the pure clusters and bands of variograms after adding points are shown in Fig. 8 and 9, respectively.

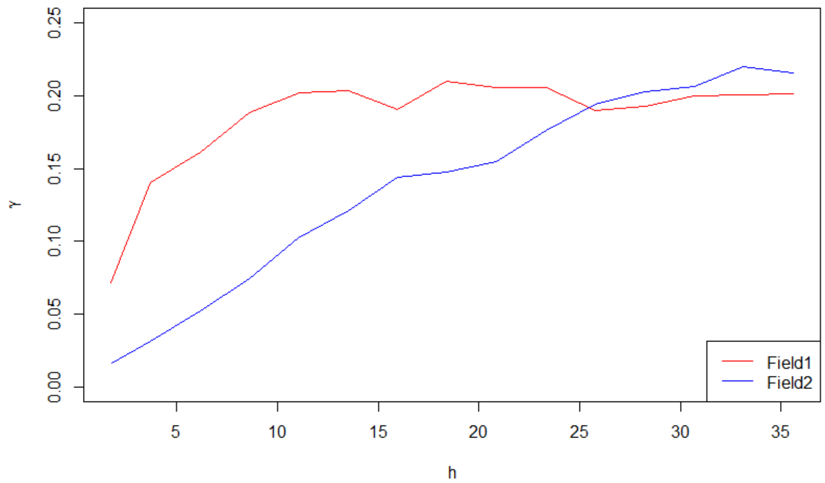


Figure 9: Variograms of pure clusters with 400 points each

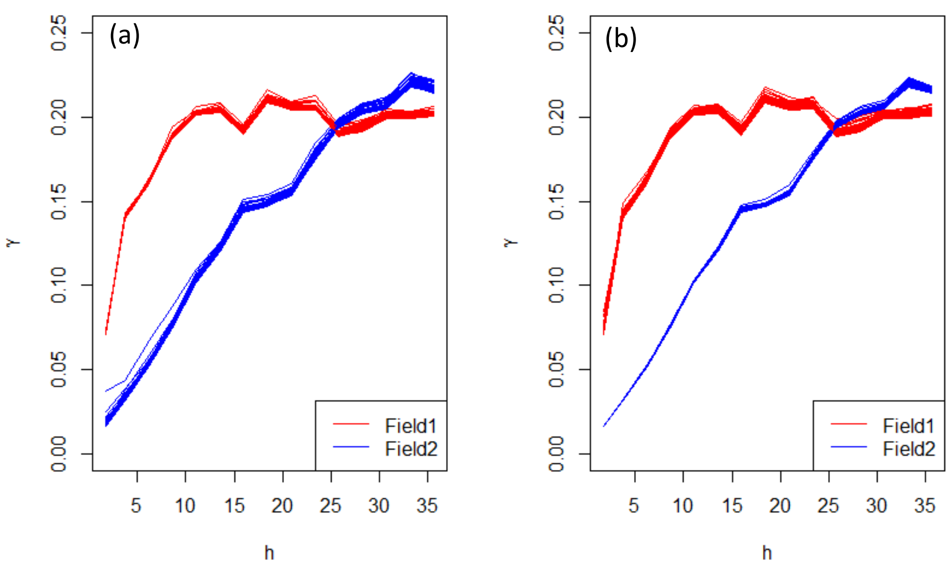


Figure 10: Band of variograms when points were added from (a) Field 1; (b) Field 2

As we can see in Fig. 7 - 10, the variogram-band of the cluster receiving points from the different field is thicker compared to the one receiving from the same field. This variogram behavior can be exploited to assign the points to the cluster representing the correlation structure the data point is better represented by. Building on this, we propose a novel algorithm - 'least-variogram-shift/stable-variogram algorithm' to separated points from the mixed fields into two clusters.

Proposed variogram algorithm assigns the point to the cluster whose variogram shifts least when the point is added. Please note that this algorithm is applicable when we already have initial clusters and is essentially a supervised classification technique where we have a dataset with known classification i.e. our initial clusters and we perform classify remaining points from the mixed fields based on known data.

4.2 Application of the least-variogram-shift algorithm with initial clusters on the synthetic data:

We test the proposed algorithm on the synthetic data to allocate points from the mixed field based on given initial clusters. We consider two constituent random fields with properties**:** 1) exponential variogram model with mean 10, sill 0.50 and range 10; 2) exponential variogram with mean 10, sill 0.25 and range 20. We have 3000 data point in total, 1500 from each field. To apply the least-variogram-shift algorithm, we consider 600 points from both the field as perfect initial clusters (100% percent purity). After assigning the remaining 1800 points from the mixed field to clusters using the proposed algorithm, the purity of the final clusters excluding the initial pure clusters was found to be 80%. Fig. 11 shows the excellent match between the experimental variograms represented by the clustered fields and original constituent fields of the dataset.

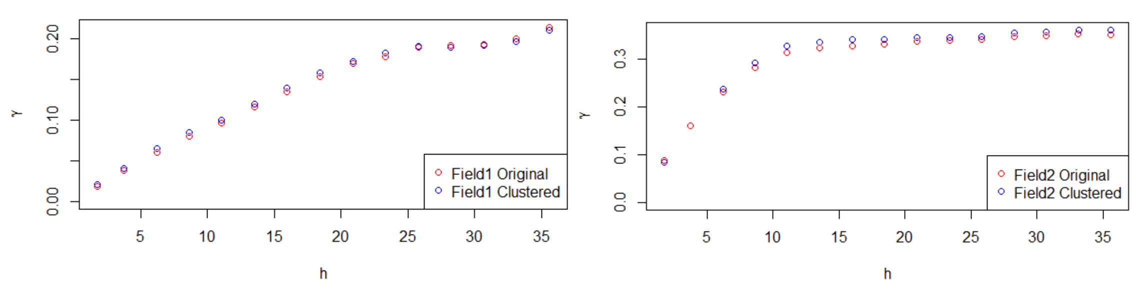


Figure 11: Comparison of experimental variograms of final clusters and original fields; 600 points in initial clusters

It is also important to assess the sensitivity of the effectiveness of the algorithm to the size of the initial cluster. Table 4 presents the purity of the final clusters (excluding the initial pure clusters) for different sizes of the initial clusters. To put in perspective, if we have initial clusters of size 100 points each, the remaining 2800 points can be assigned to the clustered with the accuracy of

72%. It is also important to note that, as we decrease the size of the initial clusters from 600 to 100 with decrements of 100 points, the first significant drop in the final cluster purity was observed at 300 size i.e., a size equal to the 10% of the total dataset size. Figure 12 shows the comparison of variograms of final clusters (72% purity) obtained using the least variogram deviation technique with 100 points each in initial clusters.

Table 4: Sensitivity of the least variogram deviation algorithm results to the initial cluster size.

Initial Cluster Size	Final Clusters Purity
(600,600)	80%
(500,500)	79%
(400,400)	80%
(300,300)	76%
(200,200)	74%
(100,100)	72%

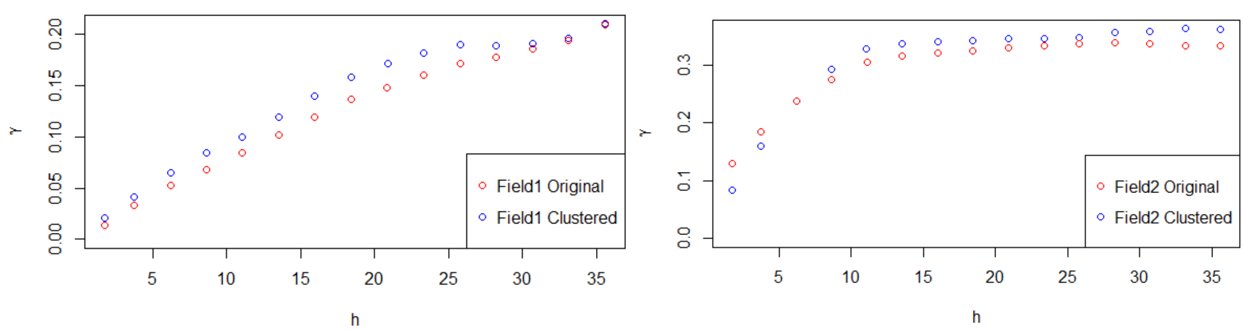


Figure 12: Comparison of experimental variograms of final clusters and original fields; 100 points in initial clusters

We also assessed the sensitivity of the algorithm to the difference in variogram model parameters of the constituent fields. Taking 400 points in each initial pure cluster, we assigned the remaining 2200 points using the least-variogram-shift algorithm. Because of the stochastic nature of the experiments, we repeated each experiment 4 times. Table 5 and Table 6 presents the final cluster purities for different sill differences and range differences, respectively. As we can see from the Table 5 and 6, as far as the variograms are fairly different, there is no significant improvement in the performance with increasing difference in the variogram model parameters.

Table 5: Sensitivity of algorithm performance to sill difference of constituent fields with range as 10 and mean as 10 for both fields

Sills	**Final Clusters Purity**			
(0.40, 0.50)	69%	80%	71%	73%
(0.25, 0.50)	79%	77%	72%	78%
(0.10, 0.50)	72%	74%	75%	72%

Table 6: Sensitivity of algorithm performance to range difference of constituent fields with sill as 0.5 and mean as 10 for both fields

Ranges	**Final Clusters Purity**			
(5, 10)	71%	65%	72%	72%
(5, 20)	72%	75%	75%	77%
(5, 30)	76%	72%	74%	71%

We analyzed the misclassified points and found that these points are statistically same for the spatial correlation structures represented by both clusters, and hence they affect both the variograms similarly. Since we know the constituent fields of the misclassified points, we add these points to the variograms of constituent fields and assess the difference it makes. As we can see in Figure 13, these points satisfy both correlation structures equally well as they shift both variograms similarly. Since these points do not distort the correlation structure of original fields, their misclassification is not expected to affect the kriging results.

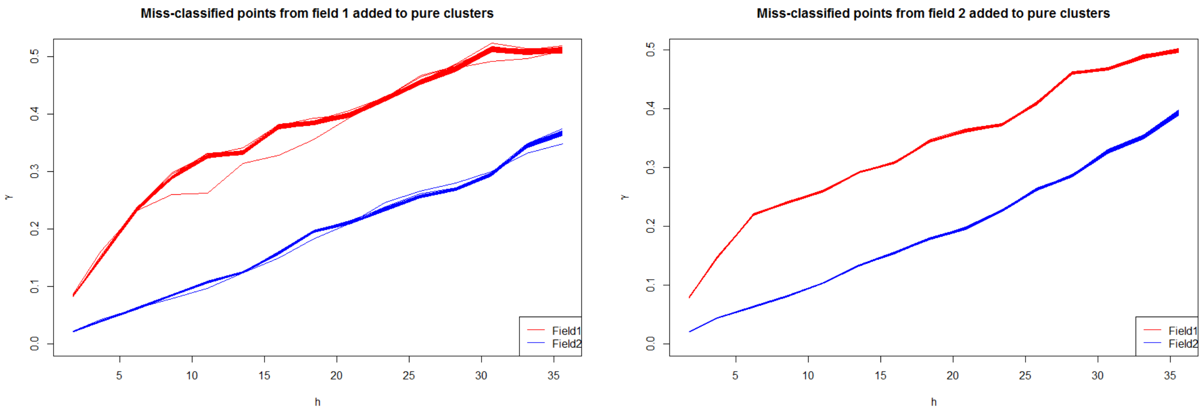


Figure 13: Bands of variograms obtained by adding misclassified points to the variograms of the constituent fields

5. Obtaining initial clusters

Often we will not have initial clusters, thus a problem, in this case, will be of unsupervised classification in nature. Therefore, we need to develop a technique that can provide us with initial clusters, based on which we can allocate remaining points from the mixed field using the least-variogram-shift algorithm. To begin with, in this case, we just have a mixed field, which makes this task very challenging, especially when we have a very similar mean value for two constituent fields. After developing and trying multiple techniques, the most effective technique is based on the nugget effect that we observe in the experimental variogram of the mixed field. We define $\gamma'(h)$ which, similar to variogram, average squared pairwise difference, but between two separate group of points, where points in the data-pair are not from the same group. The mathematical expression is as follows:

$$\gamma'(h) = 0.5 * E[(z_1(x) - z_2(x+h))^2] = \sum_{i=1}^{N} 0.5 * \frac{(z_{1i} - z_{2i})^2}{N}$$

(14)

where $z_1(x)$ and $z_2(x)$ are data points from group 1 and group 2, respectively, a N is the total number of data pairs with one point from group1 and another points from group 2, separated by distance h. We analyze the behavior of pseudo-variogram under different scenarios. We consider two constituent random fields: 1) exponential variogram model with mean 10, sill 0.50 and range 10; 2) exponential variogram with mean 10, sill 0.25 and range 20. Experimental variograms of the constituent fields and mixed field are shown in Fig. 14.

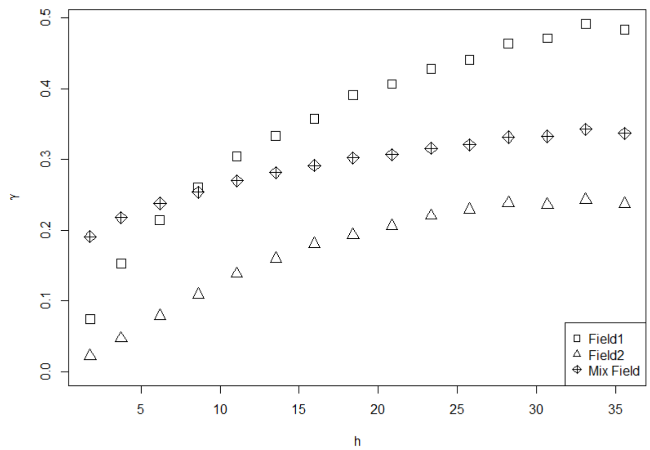
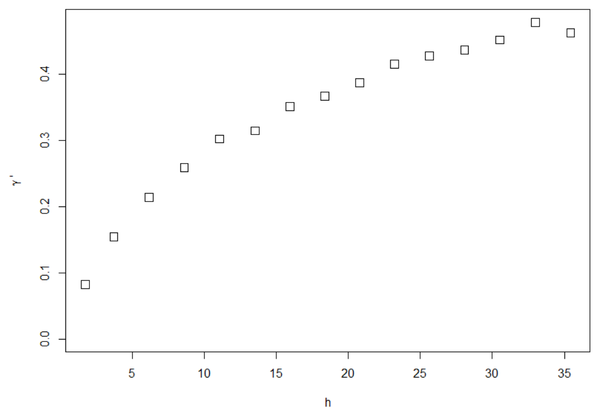
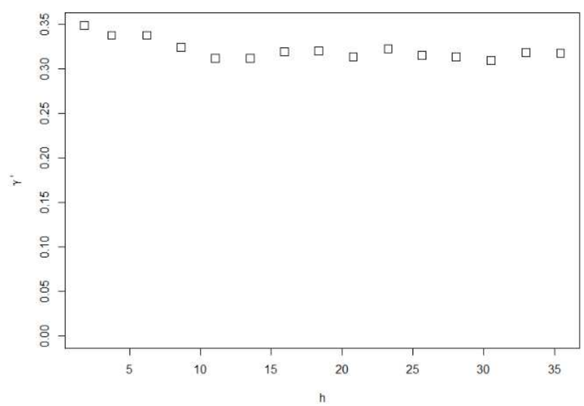


Figure 14: Experimental variograms of the considered constituent fields and mixed field

We plotted experimental pseudo-variograms by taking samples of 600 points as group 1 and group 2, under three different scenarios: 1) Group 1 and Group 2 are from the same constituent field; 2) Group 1 and Group 2 are from different constituent field (hence uncorrelated); 3) Group 1 and Group 2 are both from the mixed field. The experimental pseudo-variograms for each of the three scenarios are presented in Fig. 15.


γ'
h


γ'
h

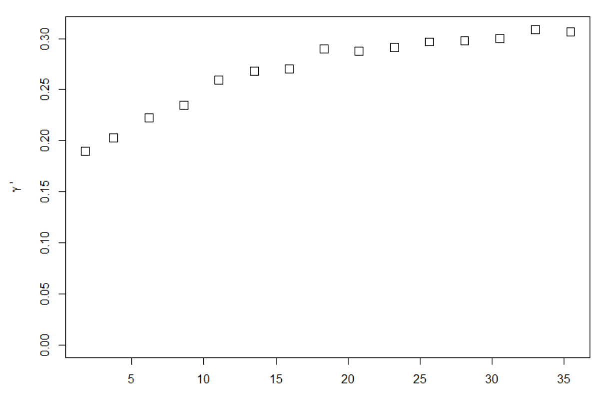
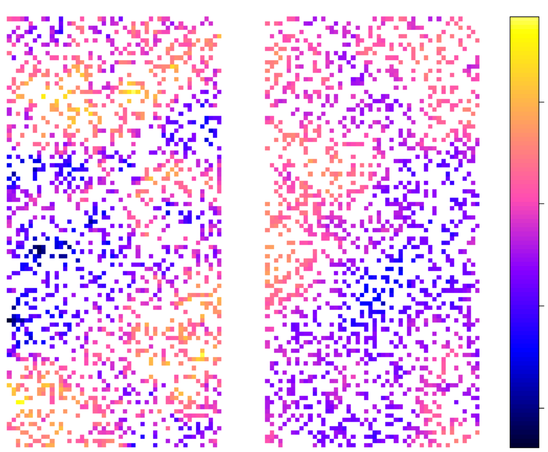

γ'
h

Figure 15: Experimental pseudo-variograms in scenario 1 (top), 2 (middle) and 3 (bottom)

As we can see in Fig. 15, when group1 and group 2 are from the mixed field, pseudo-variogram is similarly mixed field variogram, and when group 1 and group 2 are from different constituent fields, hence uncorrelated, pseudo-variogram is flat with the values equal to the sill of the mixed variogram. We capitalize on this difference and develop another novel technique to come up with initial clusters. Starting with two randomly sampled set of points from the mixed field as group 1 and group 2 which will have pseudo-variogram as scenario 3, we continuously swap points between groups we get flat pseudo-variogram as in scenario 2, therefore getting groups with high purity. We will refer this algorithm as ‘pseudo-variogram algorithm’. This algorithm is highly computationally intensive which limits the size of group 1 and group 2.

6. Application of the complete unsupervised technique on the synthetic data

Starting with just the mixed field, we apply both the algorithms sequentially; 1) pseudo-variogram algorithm to obtain initial clusters; 2) least-variogram-shift algorithm to allocate remaining points from the mixed field. We consider two constituent random fields: 1) exponential variogram model with mean 10, sill 0.50 and range 10; 2) exponential variogram with mean 10, sill 0.25 and range 20. Pixelated data values are shown in Fig, 16, experimental variograms of the constituent fields and mixed field are shown in Fig. 17, and a histogram of the mixed field is shown in Fig. 18.



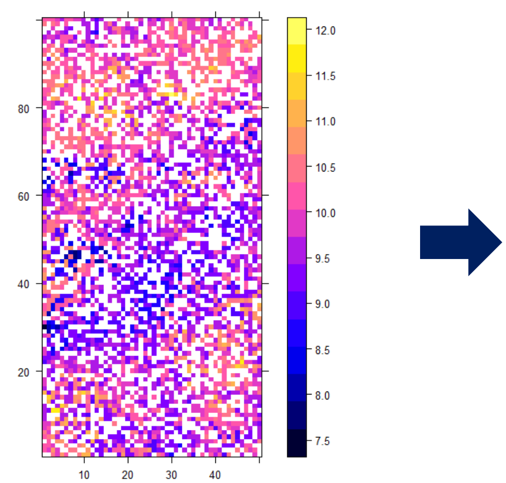


Figure 16: Pixelated constituent fields and mixed field data points

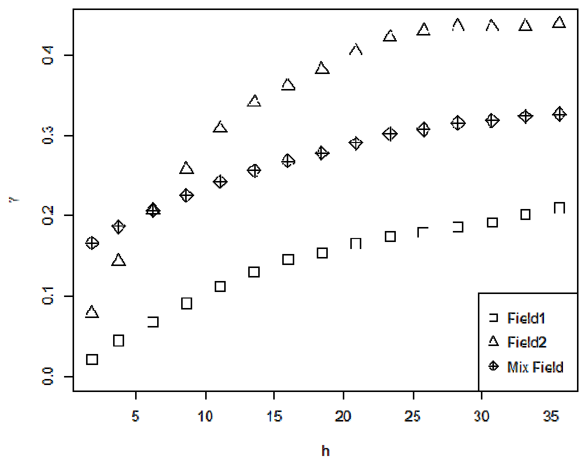


Figure 17: Experimental variograms of the considered constituent fields and mixed field

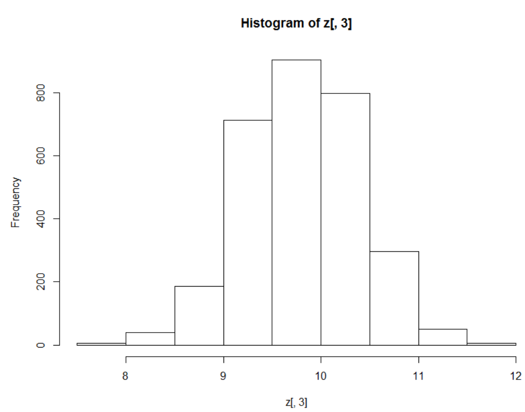


Figure 18: Histogram of the mixed field data values

After applying the complete technique we get purity of the final clusters as 75%, which means under the unsupervised condition we are able to separate 75% of the points correctly. After stage

1 of the algorithm (pseudo-variogram algorithm), we get initial clusters with 65% purity. The experiment variograms of cluster 1 and cluster 2 and constituent fields are shown in Fig. 19, and a number of points in each cluster from each constituent fields are shown in Table 7.

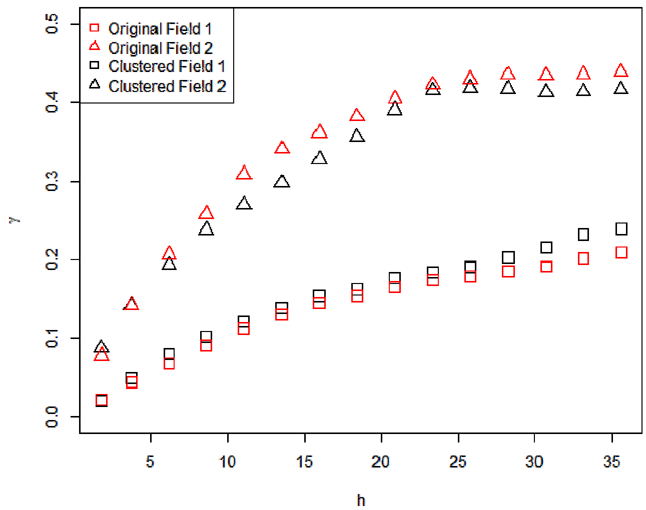


Figure 19: Comparison of the experimental variogram of the constituent fields and clustered fields

Table 7: Composition of the clustered fields

	Actual field 1	**Actual field 2**	**Purity**
Classified field 1	1151	411	74%
Classified field 2	349	1089	76%

5. 1 Cross-validation on the synthetic data

We perform cross-validation to demonstrate compared to mixed field how points within each clustered field have higher spatial with the points from the same clustered field and experiment variograms fitted to clustered fields are able to characterize the spatial correlation structure of dataset between single variogram for the mixed field. Table 8 shows the CV results, where we compare MAE and RMSE of the constituent fields which is our a baseline, with mixed field and clustered field. We also present percent difference in errors relative to the constituent fields. CV results demonstrate that clustering offers a huge potential to reduce prediction errors.

Table 8: Cross validation results

Fields	MAE	% increase in MAE	RMSE	% increase in RMSE
Constituent fields	0.1443	-	0.1921	-
Mixed field	0.3855	167%	0.4781	149%
Clustered fields	0.1621	12%	0.2124	11%

5. 2 Monitoring network optimization

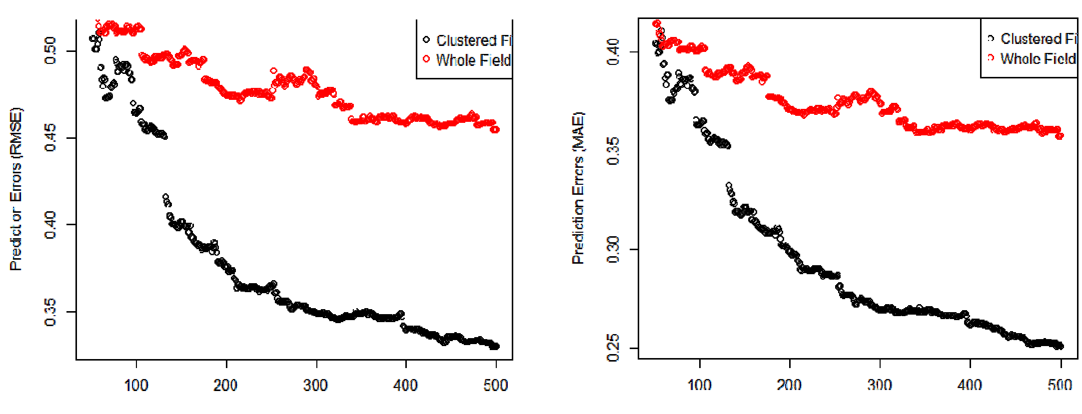
Since we demonstrated that clustered fields capture correlation structures better than the mixed field, we expect to have better and efficient monitoring networks if we used clustered fields instead of a single mixed field. Monitoring networks cost money, and often need to be evaluated, enlarged or shrunken. The main challenge in finding optimal network design is the absence of a priori quantitative criterion (Mateu & Müller, 2012). We adopt a simple approach suggested by Bivand et al. (2008) i.e. to find the point whose removal leads to the smallest increase in mean kriging variance. Depending on the problem, the target could be the size of the monitoring network or the error of CV. We keep on removing the points base on the mentioned criteria till be reach the target.

We apply obtain two sets of monitoring network: 1) Monitoring network for the mixed field (MN); 2) Monitoring network for the clustered fields (MN1 and MN2). For the field considered above, with the target size of 400 data points we obtain motoring networks, and then use these monitoring networks to predict the remaining points. The process is repeated with the target size of 200 points. The size of Mn1 and MN2 are proportional to the sizes of two clusters. The prediction errors for both the cases are presented in Table 9.

Table 9: Errors of prediction using monitoring network

Case	MAE	RMSE
Errors of prediction using Monitoring Networks of size 400 points		
Case	MAE	RMSE
Mixed field	0.36	0.46
Clustered field	0.26	0.34
Errors of prediction using Monitoring Networks of size 200 points		
Case	MAE	RMSE
Mixed field	0.37	0.48
Clustered field	0.30	0.38

A more practical approach would be to set error as a target and find the size of monitoring network needed to achieve that level of error. With the target MAE of 0.40, we need 100 points in the monitoring network and 55 points (25 in MN1 and 30 in MN2) after clustering. As we can see, clustering reduces the requirement of the size of the monitoring network as variograms after clustering is a better representation of the spatial correlation structure of the corresponding data



points. Fig. 20 shows the how prediction error varies with monitoring network size, for both mixed field and clustered field.

Figure 20: Prediction error vs monitoring network size

7. Application of the complete unsupervised clustering technique on the real data

The proposed technique is applied to the ACF basin pumping data. We consider irrigation depth is our primary data. We remove the data points with a depth higher than 50 inches are potential outliers. The total number of remaining data points is 3,352. The empirical CDF of the resulting data is shown in Fig 21.

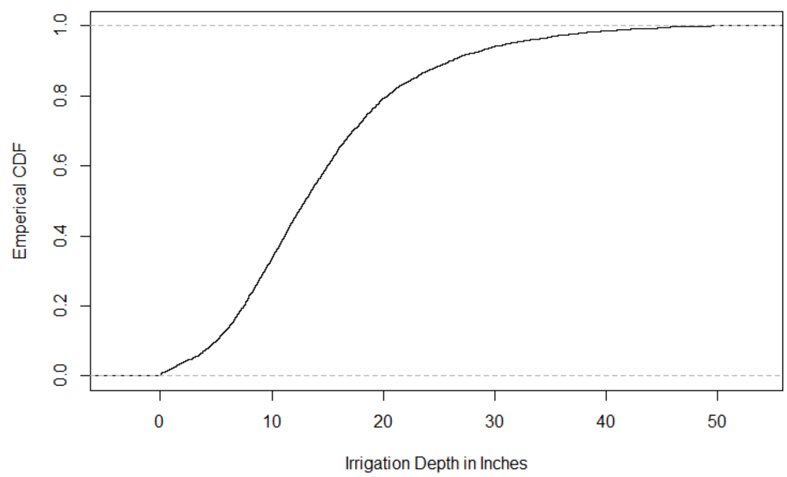


Figure 21: Empirical CDF after removing potential outliers

The variogram cloud and experimental variogram for the remaining data points are shown in Fig. 22.

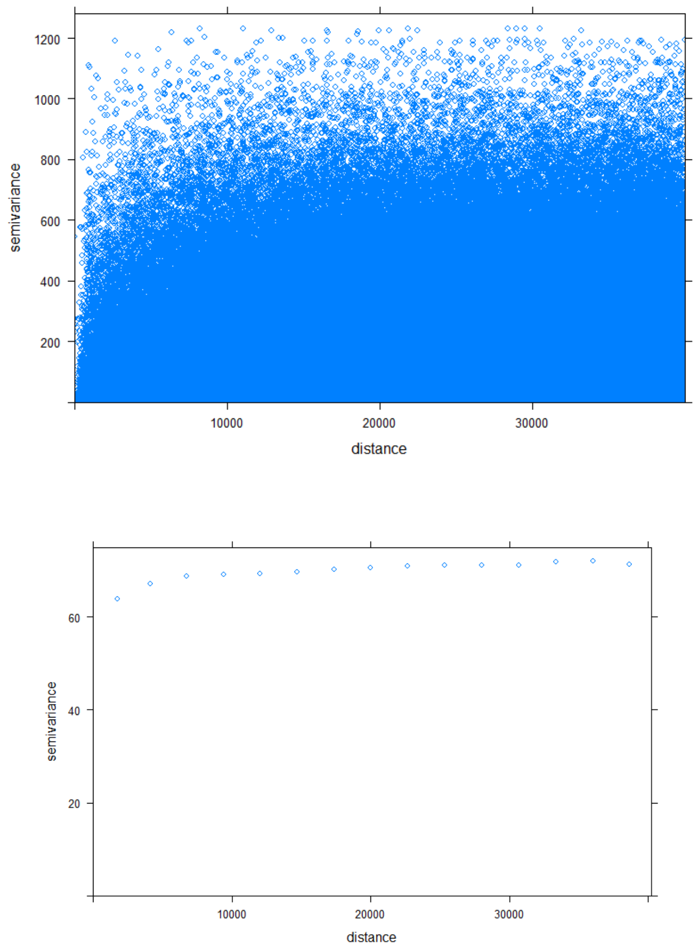


Figure 22: Variogram cloud (upper) and empirical variogram (lower)

We apply our clustering technique and obtained two clusters of size 1467 and 1885. The experimental variograms of the clustered field and mixed field are shown in Fig. 23. As we can see, we get higher spatial correlation compared to the mixed field. The spatial distribution of the clusters is shown in Fig. 24.

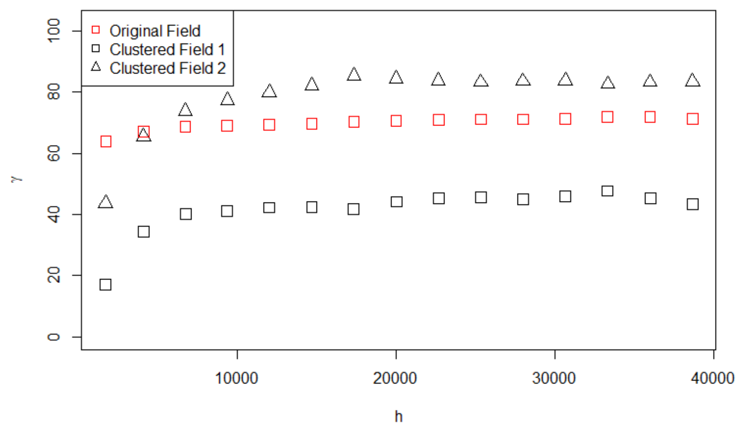


Figure 23: Experimental variograms of the clustered fields and mixed field

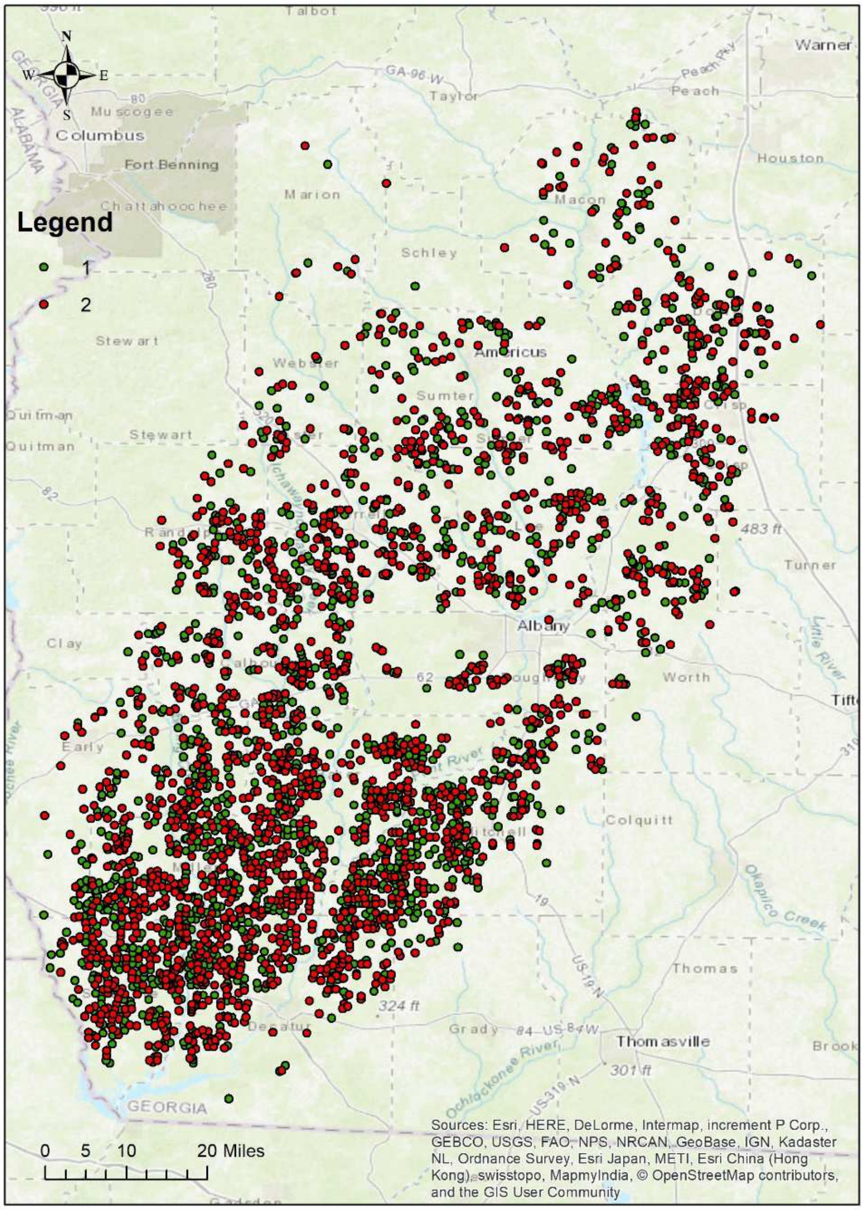


Figure 24: Spatial distribution of clusters

We fit the variogram models to the clustered field and mixed field. Model plots are shown in Fig. 25 and model parameters in Table 10.

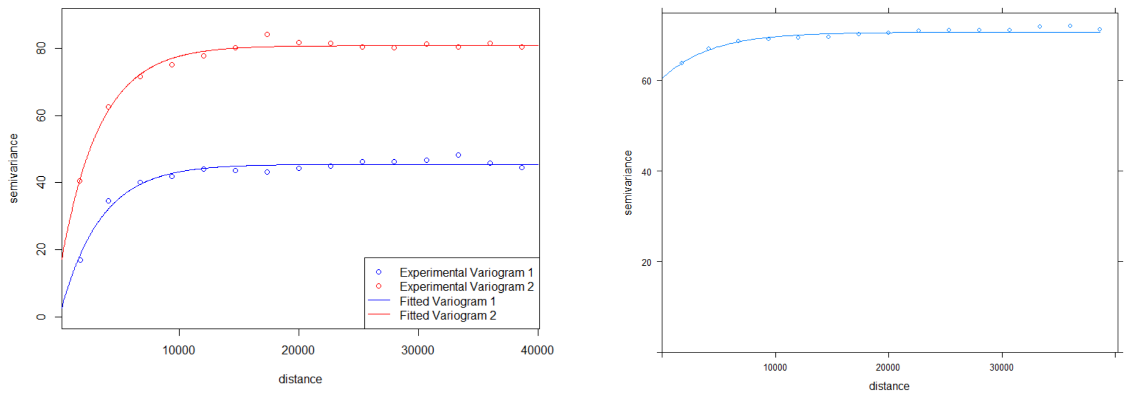


Figure 25: Experimental and fitted variograms for clustered fields (left) and mixed field (right)

Table 10: Fitted variogram model parameters for the clustered and mixed field

Model Parameters	Cluster 1	Cluster 2	Mixed Field
Model Type	Exponential	Exponential	Exponential
Nugget	0	13.23	60.43
Sill	45.47	80.87	70.63
Range	3335	3264	4283

We performed CV and results showed a reduction in the CV errors after clustering. In the mixed field MAE and RMSE in the mixed field were 5.83 and 7.87, respectively and in the clustered field were 4.85 and 6.39, respectively. This shows, clustered field represent spatial correlation structure better than the mixed field.

We used the clustered fields to obtain monitoring network and compared it with the mixed field. We set a somewhat random target MAE of 6.8. After using the monitoring network optimization technique discussed above, the sizes of the monitoring network to achieve the target accuracy are 405 wells in the mixed field and 70 wells in the clustered field (MN1: 25 wells and MN2: 45 wells). As we can see, clustering offers a huge advantage in optimizing the monitoring network because of a better representation of the underlying correlation structures.

8. Summary and Conclusion

It is very common in geohydrology to perform variogram analysis considering single random field for the whole dataset. In previous studies for optimizing monitoring network and estimation of groundwater withdrawals for the irrigation in the ACF river basin, single variogram model was used to represent the correlation structure of the whole dataset. However, there was a strong reason provided regarding why single correlation structure is suitable for such studies. In the field, more often than not, there are multiple correlation structures present. In this study, we demonstrated using synthetic data, how using single variogram in the case when there are multiple correlation structures, lead to higher prediction errors compared to using multiple variograms. However, given only mixed field, it is indeed challenging to identify and separate underlying random fields, especially if the random fields have similar mean value. In this study we proposed a novel clustering technique involving two algorithms: 1) Pseudo-variogram algorithm to obtain initial clusters; 2) Least-variogram-shift algorithm which allocates remaining points from the mixed field given we have initial clusters. We applied these algorithms on real and synthetic data and demonstrated how clustering provides huge benefits in terms of reducing CV errors, and significantly reducing the size of the monitoring network required to achieve the desired accuracy in terms of prediction error. This improvement in results is essentially because, mixing different random fields distorts correlation structure if we use single variogram, however after clustering, we observe higher spatial correlation within each cluster, corresponding experimental variograms explain the underlying correlation structure better than a single variogram for the mixed field.

9. Future work

This study revealed the huge potential of clustering before performing any geostatistical analysis in case of overlapping random fields. Next, we plan:

1) To extend the clustering algorithm for more than two constituent fields
2) To use the advantages of clustering in kriging to estimate the total irrigation withdrawals in ACF river basin.

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Information Transfer Program Introduction

GWRI provided funds to support the 2017 Georgia Water Resources Conference held at the University of Georgia on April 19 20, 2017.

The 2017 Biennial Georgia Water Resources Conference

Basic Information

Title:	The 2017 Biennial Georgia Water Resources Conference
Project Number:	2017GA381B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	GA 10th
Research Category:	Social Sciences
Focus Categories:	None, None, None
Descriptors:	None
Principal Investigators:	Laurie Fowler, Duncan Elkins

Publications

There are no publications.

FINAL REPORT
US Department of the Interior/Geological Survey
Research Grant RG692-G3

Award Amount: $15,000

The 2017 Biennial Georgia Water Resources Conference

Duncan C. Elkins and Laurie A. Fowler

UGA River Basin Center
203 D.W. Brooks Drive
Athens, GA 30602-5017

Abstract: The Georgia Water Resources Conference (GWRC) has been held every other year since 1989 at the University of Georgia. It has traditionally been a high-profile event attracting a wide range of water researchers and professionals from Georgia and the southeastern U.S., policy makers from across the US, university students, and the general public. The 2017 conference continued the success of the 2015 conference in recovering the meeting's attendance, breadth, and prominence after administrative changes and economic conditions conspired to jeopardize the conference in 2011 and 2013.

Objectives

The objectives for which the conference sought funding in 2017 were:

1) Creation and coordination of a Conference Technical Planning Committee consisting primarily of faculty from University System of Georgia schools.

2) Creation and coordination of a Conference Steering Committee consisting of representatives of state agencies, non-government organizations, and significant private sector water users.

3) Regular meetings of both committees to develop technical sessions and conference tracks, selection of keynote speakers and invitation of other speakers, promotion of the conference through their personal and professional contacts, including social media.

4) Solicitation of abstracts from a wide range of scientists, engineers, and other water professionals across Georgia and surrounding states.

5) Public outreach to identify conference topics and invited speakers that reflect current and emerging water resources issues at the state level and attract new constituencies to present at the conference.

6) Distribution of conference flyers, posters, and other notifications to maintain a high level of knowledge about, and interest in, the 2017 GWRC.

7) Regular communication with the Technical Planning and Steering Committees and water experts assigned to review abstracts and manuscripts.

8) Coordination and editing of GWRC proceedings, including formatting and publishing of CD-ROMS or other appropriate formats.

9) Close collaboration with the UGA Center for Continuing Education, a conference facility on the campus of the University of Georgia where the 2017 GWRC will be held. This collaboration will include determining conference registration fees, assigning rooms and halls to technical sessions, arranging for conference registration, lunches, and refreshments, and other activities related to conference planning and execution.

10) Assembly of GWRC abstracts and manuscripts into digital conference proceedings.

Results

All objectives were met; the conference was a success relative to previous financial and attendance metrics and the numbers of contributed panel discussions and presentations increased by 57% and 10%, respectively (Table 1).

Table 1: Breakdown of 2015 and 2017 GWRC attendance and program metrics

	2015	2017
Attendees	258	295
Program		
Panel Discussions	7	11
Talks	110	121
Posters	35	35
Novel Program Items	2 documentary films screened	Undergraduate poster session

Details of the presentation tracks and speakers can be found in the 2017 program (Attachment 1 and http://georgiawaterconference.org/wp-content/uploads/2017/04/2017_GWRC_Program_wCover.pdf) but we would like to highlight activities pursuant to objective 5, which may not be obvious in the printed program. In addition to an online survey of current and emerging environmental issues sent to the GWRC email list of previous attendees, we held two "listening sessions" and invited leaders from across the state to attend and reflect on the water-related issues that currently occupy their attention and identify any topics they felt were growing in importance. The first of these was held on Jekyll Island, GA, in coordination with the Georgia Environmental Conference in August. The second was held in Atlanta. Both the online and in-person efforts elicited topics that because conference sessions, including panels on the Savannah River Clean Water Fund, collaborative approaches to managing drought in the Upper Flint River basin, and Strategies for reducing impacts of coal-fired power plants on Georgia's water resources. Finally, the feedback from these sessions was instrumental in the committee's discussions on the selection of keynote speakers.

Attachment:
2017 Conference Program

P R O G R A M

2017 GEORGIA WATER RESOURCES CONFERENCE

April 19 & 20, 2017 • The University of Georgia • Athens, Georgia

EDITED BY

Duncan Elkins

River Basin Center, Odum School of Ecology

Jill Qi & Todd Rasmussen

Warnell School of Forestry and Natural Resources

2017 GEORGIA WATER RESOURCES CONFERENCE

April 19-20, 2017

- Conference Website -

http://www.georgiawaterconference.org/

Conference Organizer
- Duncan Elkins, UGA River Basin Center

Steering Committee
- William Hughes, US Geological Survey
- Eric Somerville, US Environmental Protection Agency
- Margaret Mackintosh, US Army Corps of Engineers
- Gary Hawkins, UGA Crop and Soil Science
- Jason Bodwell, CH2M
- Katherine Bowen, ACCG
- Aris Georgakakos, Georgia Tech
- Elizabeth Sudduth, Georgia Gwinnett College
- Bennett Weinstein, GA Environmental Protection Division
- Pam Burnett, Georgia Association of Water Professionals
- Doug Oetter, Georgia College
- Larry Kleitsches, Georgia State University
- Bill Bailey, US Army Corps of Engineers
- Gil Rogers, Southern Environmental Law Center

Technical Planning Committee
- Mark Risse, Georgia Marine Extension Service
- Chuck Hopkinson, UGA Marine Science
- Seth Wenger, UGA River Basin Center

Link to Full Proceedings
http://georgiawaterconference.org/index.php/2017-proceedings/

Conference Advisors
- Laurie Fowler, UGA River Basin Center
- Todd Rasmussen, UGA Warnell School

Conference Staff
- Katie Hill, UGA River Basin Center
- Jill Qi, UGA Graduate Student
- Ellie Duffy, UGA Student

Conference Student Assistants
- Abigail Knapp
- Ashwini Kannan
- Caitlin Conn
- Claire Webster
- Cody Matteson
- Edward Stowe
- Ellie Duffy
- Greg Jacobs
- Holly Hutcheson
- Jessica Chappell
- Jon Skaggs
- Kayleigh Hall
- Lauren Gill
- Madeline McDonald
- Philipp Nussbaum
- Rachel Rotz
- Sage Maher
- Sarah Hensey
- Seth Younger
- Thalika Saintil

2017 Underwriters

2017 Advocates

2017 Supporters

The organizers would like to thank these institutional and corporate sponsors for their generous support of the 2017 Georgia Water Resources Conference.

History of the Georgia Water Resources Conference

The Georgia Water Resources Conference has been held biennially since May 1989. The inaugural conference included 76 oral presentations and nine posters with an increasing number of participants and attendees at every succeeding conference; this year's conference had 11 contributed sessions, 126 submissions for oral presentations, and 35 poster submissions. Each conference has also seen new opportunities for workshops and training sessions. The steering committee includes representatives of the conference sponsors: U.S. Geological Survey Georgia Department of Natural Resources Natural Resources Conservation Service University of Georgia and Georgia Institute of Technology - Georgia Water Resources Institute (GWRI). The co-sponsors include federal and state agencies professional associations and citizen organizations.

The idea for the first Georgia Water Resources Conference came from discussions of Dr. Robert Pierce Alec Little and Kathy Hatcher and stemmed from an initial statewide water conference led by Dr. Ram Arora (GSU) in 1984. The steering committee for that first conference was composed of Jeffrey Armbruster (USGS) Kathy Hatcher (UGA) Vernon Henry (GSU) Jim Kundell (UGA) Alec Little (UGA) Bob Pierce (USGS) Harold Reheis (GA EPD) and Bernd Kahn (GaTech-GWRI). The GWRI through USGS provided grants for the first and subsequent conferences to prepare the proceedings which were edited by Kathy Hatcher. The complete set of conference proceedings (1989-2007) is available online at www.gwri.gatech.edu.

Since its inception the goal of the Georgia Water Resources Conference has been to provide an open forum for the discussion of current water policies research projects and water management in Georgia. Papers on topics related to water policies legislation research on-going studies technical innovations issues and concerns current situation and trends new approaches management programs data and information education public participation institutional and financial arrangements history culture future needs and solutions and other topics related to water management have been encouraged and actively solicited.

This collaborative effort by water professionals has led to the advancement of water science and management in the state by providing a neutral and open forum for diverse perspectives to be presented and discussed.

Conference Dates and Proceedings

Hatcher K.J. (ed.) Proceedings of the 1989 Georgia Water Resources Conference ISBN: 0-935835-01-6 LOC## 89-84389 245 pages May 16-17 1989.

Hatcher K.J. (ed.) Proceedings of the 1991 Georgia Water Resources Conference ISBN: 0-935835-02-4 LOC# 91-70247 356 pages March 19-20 1991.

Hatcher K.J. (ed.) Proceedings of the 1993 Georgia Water Resources Conference ISBN: 0-935835-03-2 LOC# 92-76060 412 pages April 20-21 1993.

Hatcher K.J. (ed.) Proceedings of the 1995 Georgia Water Resources Conference ISBN: 0-935835-04-0 LOC# 95-68015 412 pages April 11-12 1995.

Hatcher K.J. (ed.) Proceedings of the 1997 Georgia Water Resources Conference ISBN: 0-935835-05-9 LOC# 97-71355 550 pages March 20-22 1997.

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Hatcher K.J. (ed.) Proceedings of the 2005 Georgia Water Resources Conference ISBN: 0-935835-09-1 LOC# 2005926249 931 pages April 25-27 2005.

Rasmussen T.C. G.D. Carroll and A.P. Georgakakos (eds.) Proceedings of the 2007 Georgia Water Resources Conference ISBN: 0-9794100-0-2 633 pages March 27-29 2007.

Carroll G.D. (ed.) Proceedings of the 2009 Georgia Water Resources Conference ISBN: 0-9794100-1-0 636 pages April 27-29 2009.

Carroll G.D. (ed.) Proceedings of the 2011 Georgia Water Resources Conference ISBN: 0-9794100-2-9 April 11-13 2011.

GWRC 2013-2017 Proceedings http://www.gwri.gatech.edu/conferences

Table of Contents

Schedule at a Glance:

Wednesday, April 19

Registration: 7:30 – 9:30 am

Concurrent Session 1: 8:30 – 10:00 am

***Session 2 Plenary*:** 10:30 – 12:00 pm Masters Hall

“**Building Resilience at the Water’s Edge**”
Rebecca Wodder Fellow Center for Humans and Nature
“The Challenges of Stream Health”
Stephen W. Golladay Associate Scientist J.W. Jones Ecological Research Center at Ichauway
Moderator: Dr. Laurie Fowler

***Luncheon Speaker*:** 12:00 – 1:15 pm

“2017 Georgia Legislative Update"
Russ Pennington *Vice President McGuireWoods Consulting*

Concurrent Session 3: 1:30 – 3:00 pm

Session 4 Poster Session: 3:30 – 5:00 pm Pecan Tree Galleria

Special Session for Undergraduate Posters Room K

***Evening Social Event*:** 5:30 – 7:30 pm

Reception at Creature Comforts Brewery — see map on page 6

Thursday, April 20

Registration: 7:30 – 9:30 am

Concurrent Session 5 8:30 – 10:00 pm

Concurrent Session 6: 10:30 – 12:00 pm

***Luncheon Speaker*:** 12:00 – 1:15 pm

“Water in the Southeast”
Mary Walker *Director Water Protection Division Region 4 U.S. Environmental Protection Agency*

Concurrent Session 7: 1:30 – 3:00 pm

Concurrent Session 8: 3:30 – 5:00 pm

Time	Track 1 Water Law Planning & Management Room Q (2nd Floor)	Track 2 Coastal Water Issues Master's Hall (1st Floor)	Track 3 Agriculture Forestry and Aquifers Room F/G (2nd Floor)	Track 4 Hydrologic Conditions Room L (2nd Floor)	Track 5 Green and Urban Infrastructure Room R (2nd Floor)	Track 6 Ecology and Water Quality Room K (2nd Floor)
DAY 1 Wednesday April 19 2017						
7:30 – 9:30	**Conference Registration**					
Morning Session 1 8:30 – 10:00	**1.1 Georgia Water Planning Update**	**2.1 Water and Drought**	**3.1 Agricultural Water**	**4.1 Flood Risk Mapping**	**5.1 Green Infrastructure**	**6.1 Stream Ecology**
	Glen Behrend	Jacque L. Kelly	Vasileios Liakos	Georgia flood risk Mapping Assessment and Planning (MAP)	R. Alfred Vick	Jacob M McDonald
	Danielle Jensen-Ryan	James S. Reichard	Craig Druden		Christopher Cameron	Edward Stowe
	Leigh Elkins	Lauren Rouen	Jeffrey Mullen		Kevin Samples	Caitlin Conn
	Martin Kistenmacher	Bruce Campbell	Stefanie Gugolz		Cory Rayburn	Stephen Shivers
	Adriana Bustillos	Christopher P. Foldesi	Lynn Torak		Cory Rayburn	Nicholas Marzolf
10:00-10:30	Morning Break					
Plenary 10:30-noon	**Session 2: Plenary in Masters Hall:** **Rebecca Wodder, Fellow Center for Humans and Nature** *"Building Resilience at the Water's Edge"* **Stephen W. Golladay, Associate Scientist J.W. Jones Ecological Research Center at Ichauway** *"The Challenges of Stream Health"*					
Lunch 12:00 – 1:15	**Lunch Keynote Speaker: Russ Pennington, McGuireWoods Consulting** *"2017 Georgia Legislative Update"*					
Afternoon Session 3 1:30 – 3:00	**1.3 Water Law & Litigation**	**2.3 Coastal Ecology & Management**	**3.3 Groundwater**	**4.3 Hydrologic Hazards**	**5.3A Savannah River Clean Water Fund**	**6.3 Water as Education K-12 & Undergrad**
	Panel: Water law and litigation Update Doug Henderson Hutton Brown Lewis Jones Laura Benz	John Schmidt	Debbie Gordon	Brian McCallum	Panel: Identifying Intersections & Partnerships for Source Water Protection Brae Boardman Hazel Cook Sharon Holbrooks Eric Krueger Laura Walker	Shawn Musengo
		Thomas Bliss	Gerard J. Gonthier	Eric Frantz		Mallika Dinesh
		Mark Risse	L. Elliott Jones	Todd Hamil		MacKenzie Duffy
		Frank Henning	Edward Rooks	Christopher Schaffer		Sudhanshu Panda
		Mona Behl	Calvin Perry	Wei Zeng		Gary L. Hawkins
3:00 – 3:30	Afternoon Break					
3:30 – 5:00	**Session 4: Posters – Pecan Tree Galleria**				Campus streams and Lake Herrick: Highlighting undergraduate volunteer research and watershed education	
5:30 – 7:00	**Reception at the Creature Comforts Brewery, Downtown Athens**					

Wednesday Continued

	Track 5 Green and Urban Infrastructure Room T/U
Afternoon Session 3 1:30 – 3:00	**5.3B Innovative Approaches** Panel: **Utilizing Rainwater, Groundwater and Condensate at EVERY Commercial Building?** Richard Hanson Stanton Stafford

DAY 2 Thursday April 20 2017

Time	Track 1 Water Law Planning & Management Room Q (2nd Floor)	Track 2 Coastal Water Issues Master's Hall (1st Floor)	Track 3 Agriculture Forestry and Aquifers Room F/G (2nd Floor)	Track 4 Hydrologic Conditions Room L (2nd Floor)	Track 5 Green and Urban Infrastructure Room R (2nd Floor)	Track 6 Ecology and Water Quality Room K (2nd Floor)
7:30 – 9:30	**Conference Registration**					
Morning Session 5 8:30 – 10:00	**1.5 Upper Flint River Basin**	**2.5 Savannah Harbor**	**3.5 Wetlands**	**4.5 Hydrologic Statistics**	**5.5**	**6.5 Stormwater**
	Panel: New perspectives on drought and water management in the Upper Flint River Basin Ben Emanuel Lee Pope Gordon Rogers Mike Thomas	William Bailey	Phillipp Nussbaum	Jaime A. Painter	Panel Rescheduled Now 5.3B	Ali Alnahit
		Nathan Dayan	Courtney Divittorio	Tim Stephens		Tien Yee
		Bryan N. Riggs	John Paul Schmidt	Phillip Bumpers		Stacey Isaac Berahzer
		Jamie A. Duberstein	Bryana Bush	Anthony J. Gotvald		
		Stephen Ramos	Matt Carroll	Reed Palmer		
10:00 - 10:30	Morning Break					
Morning Session 6 10:30 – 12:00	**1.6 EPA Watershed Registry I**	**2.6 Coastal Development**	**3.6 Agricultural Wetlands I**	**4.6 Spatial Mapping**	**5.6 Urban Case Study: Alpharetta**	**6.6 Water Quality & Modeling**
	Panel: EPA Watershed Registry I (Introduction) Ralph Spagnolo Michael Herzberger	Madeleine Russell	Darold Batzer	Todd Rasmussen	Panel: Meeting Georgia's New Recommended Runoff Reduction Performance Standard: One Metro-Atlanta City's Approach	Krista Capps
		Jessica Alcorn	Stephen Golladay	Jennifer Miller		Erin Lincoln
		Robert A. Brown	Lora L. Smith	Huidae Cho		Brian Avant
		Warren Kriesel	Chelsea Smith	Bruce A. Pruitt		Edwin A. Roehl Jr
		Jessica T. R. Brown	Brittany Clark	Sudhanshu Sekhar Panda		Karina Walls
Lunch Noon-1:15	**Luncheon Keynote Speaker: Mary Walker *USEPA*** *"Water in the Southeast"*					
Afternoon Session 7 1:30 – 3:00	**1.7 EPA Watershed Registry II**	**2.7 Coastal Resiliency**	**3.7 Wetlands II & ACF Studies**	**4.7 Hydrologic Connectivity I**	**5.7 Urban Streams**	**6.7 Coal Impacts**
	Panel: EPA Watershed Registry II (Georgia Applications)	Michael Roberts	Cody Matteson	Panel: Aquatic Connectivity in Georgia I Sara Gottlieb Ben Emanuel Nate Nibbelink Robert Hines Eric Harris	Celeste Journey	Panel: "Strategies for reducing impacts of coal-fired power plants on Georgia's water resources" Jen Hilburn April Lipscomb Jennette Gayer
		Scott Pippin	Susan Bennett Wilde		Daniel Calhoun	
		Kelly Hill	*Ag Wetlands Q&A*		Paul M. Bradley	
		Shana Jones	Jacob H. LaFontaine		Blake Snyder	
		Elizabeth Kramer	Scott Cole		Emily M. Johnson	
3:00 – 3:30	Afternoon Break					

DAY 2 Thursday April 20 2017						
Time	**Track 1 Water Law Planning & Management Room Q** (2nd Floor)	**Track 2 Coastal Water Issues Master's Hall** (1st Floor)	**Track 3 Agriculture Forestry and Aquifers Room F/G** (2nd Floor)	**Track 4 Hydrologic Conditions Room L** (2nd Floor)	**Track 5 Green and Urban Infrastructure Room R** (2nd Floor)	**Track 6 Ecology and Water Quality Room K** (2nd Floor)
Afternoon Session Session 8 3:30 - 5:00	**1.8 Water Management**	**2.8 Coastal Changes**	**3.8 Forests & Water**	**4.8 Hydrologic Connectivity II**	**5.8 Urban & Green Infrastructure**	**6.8 Mitigation**
	Veronica Craw	Kelly Murray	Kitty Weisman	Panel: Aquatic Connectivity in Georgia II Doug Peterson Vance Crain Katie Owens Jay Shelton	Elizabeth B. Sudduth	Katie Hill
	Aris P. Georgakakos	Joan E. Sheldon	Carrie McCarty		David Bell	Matt Peevy
	Puneet Dwivedi	Charles Hopkinson	C. Rhett Jackson		Lisa Casanova	Alex Robertson
	Marshall Shepherd	Annette M. Hynes	Brent T. Aulenbach		Devyn Quick	Sean Miller
	Daniel F. Wallace	William Savidge	James B. Deemy		Robert Sowah	*Mitigation Q&A*

Tuesday Special Events

Plenary Session
Where: Masters Hall **When:** 10:30 – 12:00 AM

Topic: "**Building Resilience at the Water's Edge**"
Speaker: Rebecca Wodder *Fellow Center for Humans and Nature*

Topic: "The Challenges of Stream Health"
Speaker: Stephen W. Golladay *Associate Scientist J.W. Jones Ecological Research Center at Ichauway*

Luncheon Keynote Speaker:

Topic: "2017 Georgia Legislative Update"
Speaker: Russ Pennington, *Vice President McGuireWoods Consulting,*

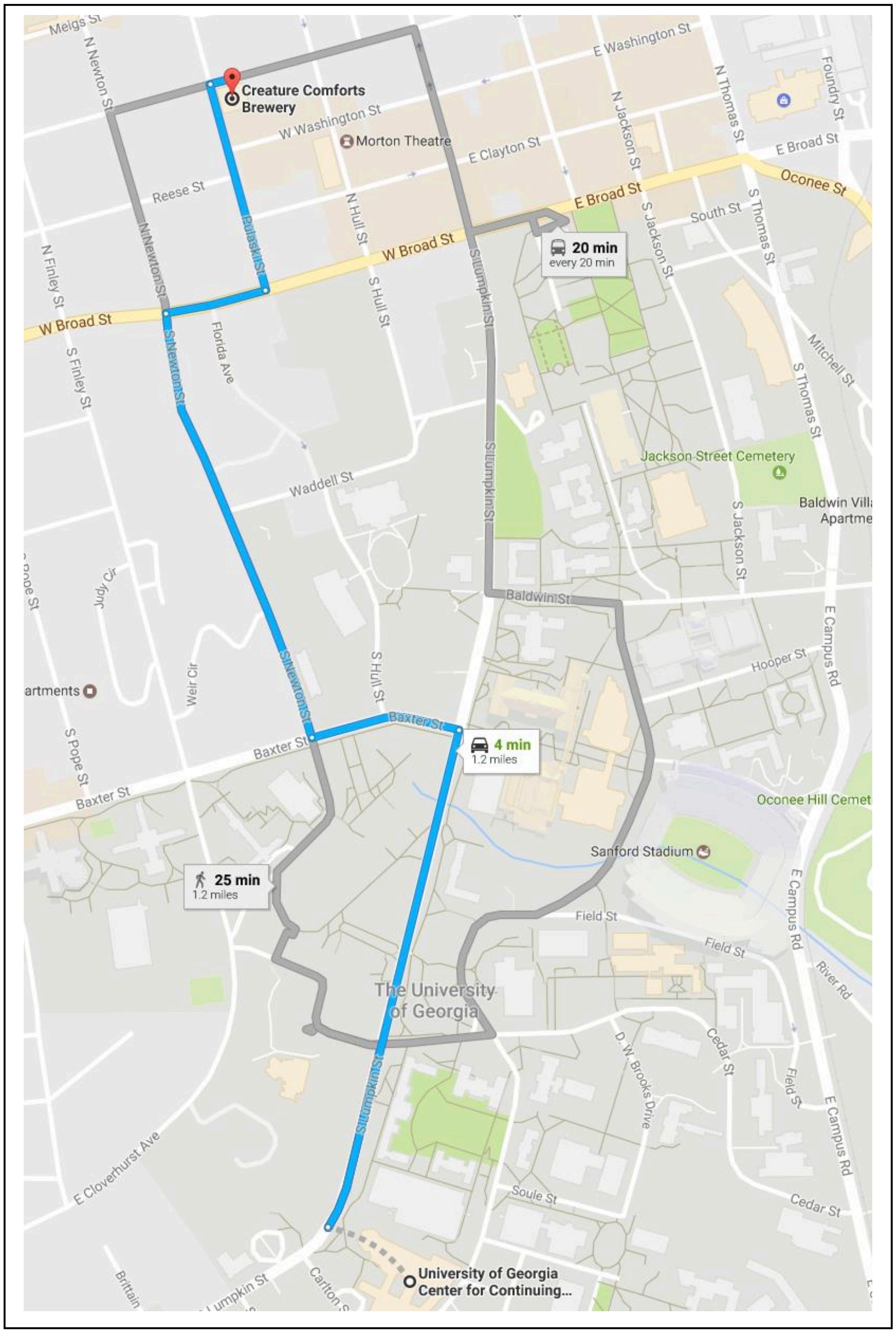
Poster & Exhibitor Session
Where: Pecan Tree Galleria **When:** 3:30 – 5:00 PM

Evening Social
Where: Creature Comforts Brewery (See Map Below) **When:** 5:30 – 7:30 PM

Wednesday Special Events

Luncheon Keynote Speaker:

Topic: *"Water in the Southeast"*
Speaker*:* Mary Walker**,** *Director Water Protection Division Region 4 U.S. Environmental Protection Agency*,



Creature Comforts

Social Details

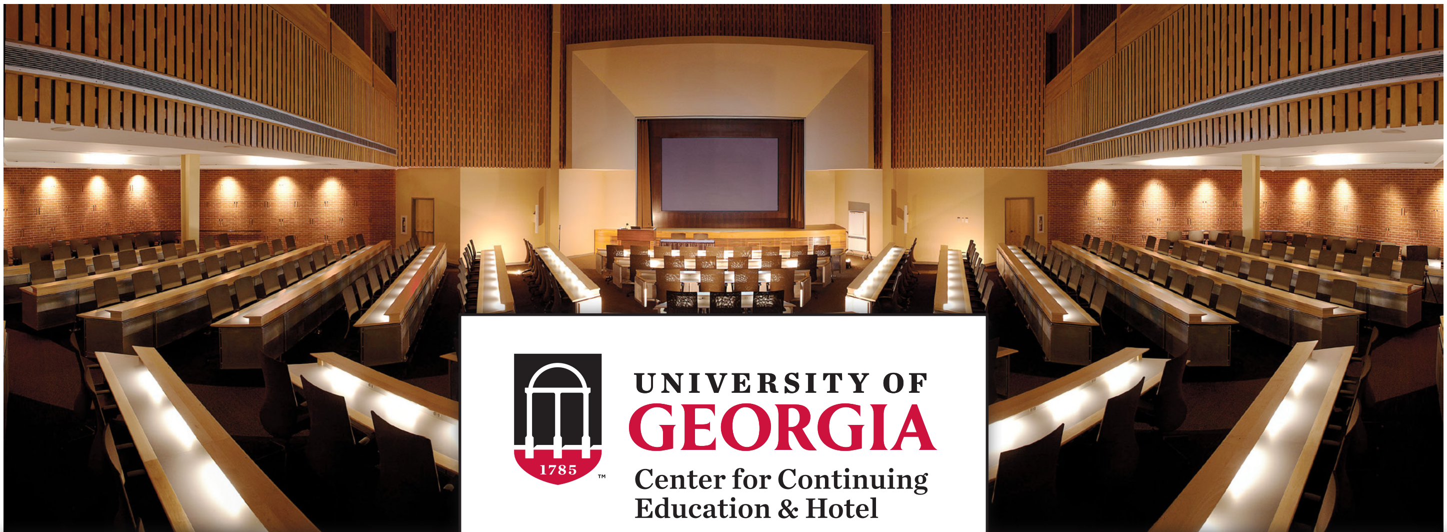
GWRC guests can present their ticket stubs (received at registration) for $2 off a tour and tasting on Wednesday between 5 and 8pm. (Note, you must be 21 to taste.)

Creature Comforts hosts the Athens Farmers Market on Wednesday evenings. This market features fresh produce, baked goods, and at least one food cart.

The brewery is located 1.2 miles from the Georgia Center at the corner of Hancock and Pulaski, near the northwest edge of downtown Athens. This area also hosts a variety of restaurants, some of which offer discounts when you present your Creature Comforts wristband. Ask who's currently running this special at the brewery.

The brewery address is

271 W HANCOCK AVE.
ATHENS, GEORGIA 30601



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The Georgia Center

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- Complimentary local shuttle service
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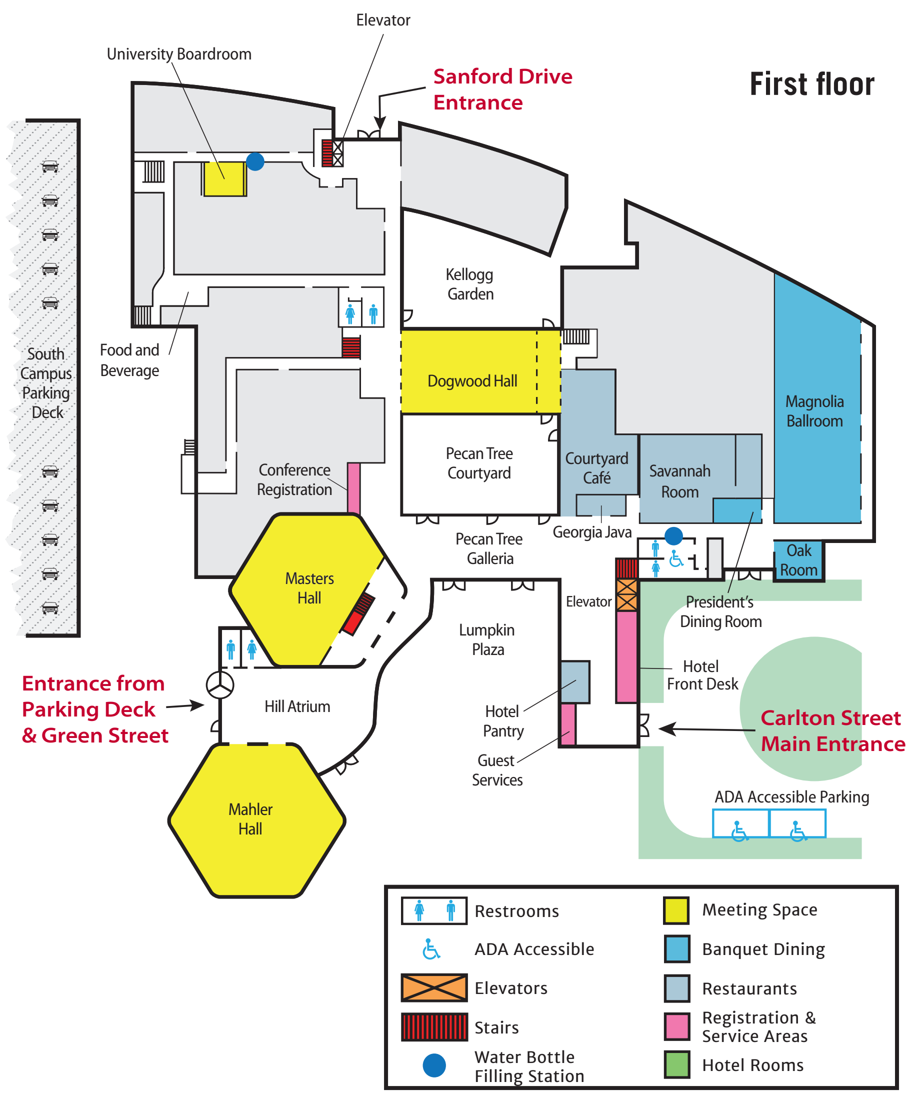
On-Site Dining

Georgia Java serves locally-roasted Jittery Joe's coffee, specialty drinks, homemade pastries, and snacks. Opens daily at 6:30am.

Courtyard Café offers quick and casual breakfast and lunch.

Savannah Room provides a relaxed atmosphere for lunch, dinner, and weekend brunch, with full bar service in the evenings.

Hotel Pantry has a selection of snacks and drinks for guests on the go.



Connecting to Wi-Fi

eduroam Access (including UGA MyID accounts)

- Join your device to the wireless network named "eduroam".
- If prompted, accept the connection security certificate.
- Enter your eduroam username (i.e. *myid@uga.edu*, *user@clemson.edu*) and password when prompted.

Access for All Other Guests

- Join your device to the wireless network named "UGA."
- Open your Internet browser (Safari, Explorer, Mozilla, Google Chrome) and browse to any website.
- Click on the "Accept and Continue" button on the Terms of Use page that appears.

Business Center

The Business Center is located on the second floor across from Room J. It is open 7am until 7pm for guests attending events. Hotel guests have 24-hour access with their hotel keycard.

Printing

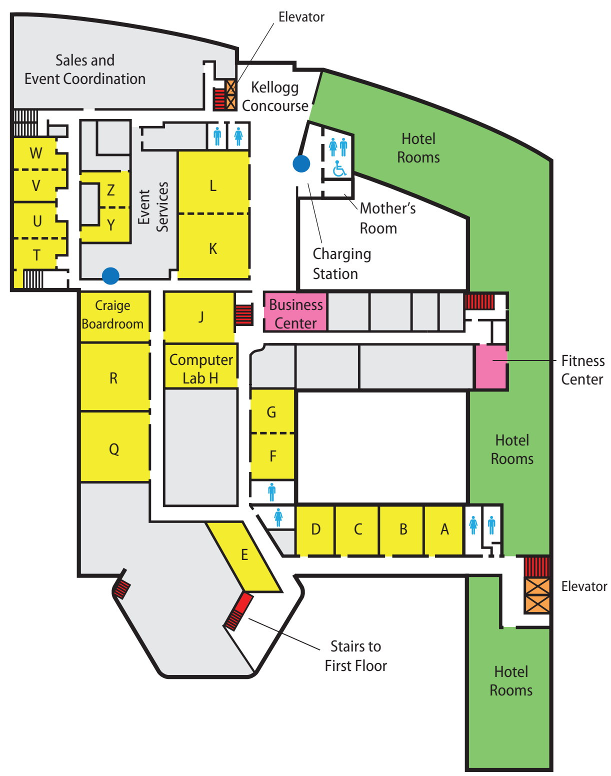
Print from your smartphone, laptop, or tablet by sending an email to *366016982@printspots.com* or by visiting *www.printeron.net/ricoh/512114*

Your release code will be emailed to you. Take that code to the Hotel Front Desk where you will pay and receive your documents. You will be charged 15 cents per side copied.

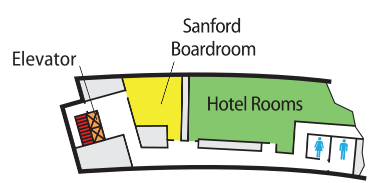
Plan an Event

To plan an event at the Georgia Center, stop by the Sales Department in suite 298, call 706-542-2654, or e-mail *sales@georgiacenter.uga.edu*

Second floor



Fifth floor



Transportation

Complimentary shuttles are available on request to transport our hotel guests anywhere within a 3-mile radius. They depart from the Carlton St. entrance next to Guest Services. Additionally, guests are welcome to use the university bus system, which has a stop just outside our Sanford Drive entrance.

3-17/152212

About Our Invited Speakers

Rebecca Wodder is a nationally known environmental leader whose career in conservation began with the first Earth Day. As president of the national river advocacy organization American Rivers from 1995 to 2011 she led the development of community-based solutions to freshwater challenges. From 2011 to 2013 she served as Senior Advisor to Secretary of the Interior Ken Salazar. Previously Rebecca was a Vice President at The Wilderness Society and a Legislative Assistant to Senator Gaylord Nelson. In 2010 she was named a Top 25 Outstanding Conservationists by Outdoor Life Magazine. In 2014 she received the James Compton Award from River Network. As a Fellow with the Center for Humans and Nature Rebecca explores how communities enhance their resilience to climate impacts via sustainable approaches to rivers and freshwater resources. She serves on the boards of River Network the Potomac Conservancy and the Nelson Institute for Environmental Studies at the University of Wisconsin-Madison.

Stephen Golladay's interests include the ecology of streams and wetlands the impact of human land use on water quality and aquatic invertebrates and the impact of variation in hydrology on ecological processes and aquatic communities. Recently he has developed an interest in the ecology and conservation of rare and endangered freshwater mussel species. Dr. Golladay has served as a technical advisor to the Sand County Foundation Georgia EPD DNR and Water Management districts in Florida. He has developed training activities for resource professionals in partnership with the U.S. Fish and Wildlife Service. Dr. Golladay also has assisted in the development of programs to enhance the natural resource awareness of regional educators in cooperation with regional Georgia Youth Science and Technology Centers.

Russ Pennington is a Vice President at McGuireWoods Consulting where he specializes in environmental issues regulatory affairs and government affairs. His consulting experience includes helping public and private clients with navigating the complex federal state and local regulatory framework for both strategic planning as well as in active response to compliance measures. Additionally Russ provides strategic consultation to secure water supplies and infrastructure capacity to support economic stability. Prior to joining McGuireWoods Consulting Pennington served in State Government as the Director of the Governor's Water Supply Program an appointed position within the Office of Interagency Coordination and Management of Water Resources which was created by Governor Nathan Deal in response to the State's litigation over water. He was appointed to that position from the GA Environmental Protection Division where he was Director of Policy and Public Affairs. Russ' past experience also includes Associate Vice President at HDR Engineering. Russ is a professional engineer and is a graduate of the University of Georgia with degrees in Biological Engineering and a Masters of Business Administration.

Mary Salmon Walker is the Director of the Water Protection Division in the United States Environmental Protection Agency Region 4. In this role she oversees the water programs of the eight Southeastern states. Mrs. Walker previously served as Assistant Director and COO for the Georgia Environmental Protection Division where she oversaw policy development compliance programs and general agency operations. Her state government career also includes work at the Georgia Governor's Office of Planning and Budget and the Georgia Department of Community Affairs. Mrs. Walker is a graduate of the Institute for Georgia Environmental Leaders and has served as a state representative on the joint EPA/State E-Enterprise for the Environment Leadership Council and the Southern States Energy Board. She earned an undergraduate degree from Tulane University and a master's degree in Public Administration from the University of Georgia.

Exhibitors & Conference Supporters

XYLEM/YSI Incorporated

YSI is a developer and manufacturer of sensors instruments software and data collection platforms for environmental water quality monitoring and testing. Reaching beyond our products we build relationships with our customers through our dedicated customer service including technical applications and service support.

Tetra Tech

Tetra Tech is a leading provider of consulting engineering program management construction management and technical services. The Company supports government and commercial clients by providing innovative solutions focused on water environment infrastructure resource management energy and international development. With 16000 associates worldwide Tetra Tech's capabilities span the entire project life cycle.

Geosyntec

Geosyntec Consultants is a specialized consulting and engineering firm that works with private and public sector clients to address new ventures and complex problems involving our environment natural resources and civil infrastructure. We deliver solutions through Geosyntec and our wholly-owned divisions (MMI Engineering SiREM Savron Green Harbor Energy Geosyntec Asia and Geosyntec Europe) with a combined staff exceeding 1200 engineers scientists and related technical and project support personnel. We serve our clients from more than 80 offices in the United States Canada the United Kingdom Ireland Australia and Malaysia. At the center of Geosyntec's Water and Natural Resources practice is a collaborative group of nationally recognized scientists and engineers dedicated to achieving the balance between the built and natural environments. Their practice specialties represent a diverse array of disciplines including geomorphology ecology biology statistics construction management computer science and engineering. Our practitioners are at the forefront of policy analyses regulatory compliance and technology applications that promote sustainable water resources management and ecosystem restoration. Geosyntec has built its Water and Natural Resources practice to address our clients' most challenging regulatory sustainability and restoration issues.

Georgia Water Tanks LLC

Based in Atlanta Georgia Water Tanks LLC provides a range of installation services and products for Rainwater Collection

Stormwater Control Fire Protection Drinking Water Municipal Water Treated Wastewater Agriculture Thermal Storage and

Breweries & Wineries. Founded by Georgia Tech graduate Richard Hanson Georgia Water Tanks also contributes a portion of its monthly sales to Water for People an international non-profit dedicated to eradicating water poverty.

Eureka Water Probes

Eureka was formed in 2002 by industry veterans who believed there was considerable room in the multiprobe market for improvements in technology and customer service. Eureka an employee-owned partnership includes the company's founder along with partners from both Europe and Asia with extensive history in the water quality industry. Eureka Water Probes continues to provide innovative reliable mulitprobes backed by market-leading customer service. Playing a part in helping to protect the world's water resources by designing and manufacturing the world's best mulitprobes remains our sole focus.

US. Geological Survey South Atlantic Water Science Center - Georgia

The South Atlantic Water Science Center - Georgia (WSC) is one of 48 Water Science Centers in the Water Resources Discipline of the U.S. Geological Survey (USGS). The Water Science Center's mission is to collect analyze and disseminate the impartial hydrologic data and information needed to wisely manage water resources for the people of the United States and the State of Georgia. USGS:

- Operates local and statewide networks to collect high-quality data that define natural and human-induced hydrologic conditions.
- Analyzes hydrologic processes through investigations and research to increase understanding of important water-resource issues and to promote informed decision making.
- Maintains real-time and historical data bases and publish peer-reviewed interpretive and data reports to disseminate unbiased hydrologic information.

Upper Oconee Watershed Network

The Upper Oconee Watershed Network is dedicated to protecting water resources and improving stream health in our watershed through community-based advocacy monitoring education and recreation. The Upper Oconee Watershed Network (UOWN) was formed in January 2000 in response to citizen concern about the region's rapid growth and its impact to local streams and rivers. UOWN members actively engage in various advocacy education and stream monitoring initiatives in an effort to raise community awareness about local water resource issues and to facilitate a cooperative spirit for long-term watershed protection.

Oconee Rivers Greenway Commission

The Oconee Rivers Greenway Commission (ORGC) is a chartered citizen committee that advises the Athens-Clarke County Mayor & Commission on matters related to the Oconee Rivers Greenway system. The general responsibility of ORGC is to develop a plan for a river-oriented greenway system in Athens-Clarke County and to recommend measures to protect the resources of the Oconee Rivers and their tributaries. The 2016 Greenway Network Plan describes the current funded and proposed sections of the greenway trail network.

Open Source Data Logging - *John Dowd and Stephanie Fulton*

Open source hardware and software have made it possible to build complex environmental data logging systems for a reasonable cost. Microprocessors such as Arduinos can be integrated with a large number of sensors to record real-time conditions. Both the hardware and the programming of the supporting software will be described, using the system at the inflow stream (Birdsong) to Lake Herrick as an example. This system measures flow every second and averages these values over five minutes, while measuring air temperature, barometric pressure, relative humidity, and water temperature once a minute and averaging these values over five minutes. Once every five minutes electrical conductivity of the water, the solar charged battery voltage and current are also measured. On the dam at the other end of Lake Herrick a tipping bucket rain gauge records rainfall, and sends the time of each tip and the cumulative count to the Birdsong box via wireless radio. All data measured plus the five minute rainfall is sent via cellular modem to the Geology Department server every five minutes, in addition to being stored on a micro SD card.

SESSION 1 ABSTRACTS: WEDNESDAY 8:30-10:00 AM

Track 1.1 - Room Q: Georgia Water Planning Update

(1.1.1) **Welte, Jennifer H.**, and Glen R. Behrend
Georgia Environmental Protection Division, Watershed Protection Branch

UPDATES ON REGIONAL WATER PLANNING IN GEORGIA

The Regional Water Plans that were completed and adopted by Georgia EPD in 2011 are currently undergoing their first 5-year review and update. The 10 Regional Water Planning Councils around the state have been meeting to review and consider updates to the data and technical information that inform the Regional Water Plans, and that information will inform the Councils' updates to their Plans, which are scheduled to be completed in June 2017. The data and technical information includes updates to statewide population projections, municipal water and wastewater demands, thermoelectric water demands, and agricultural irrigation water demands through 2050. Updates in the surface water availability, groundwater availability, and water quality (assimilative capacity) resource assessments have also been completed and reflect improvements in both the data that is used in those assessments, as well as the modeling tools used to perform them. As the 10 Regional Water Planning Councils are reviewing and updating their Plans, the Metropolitan North Georgia Water Planning District ("Metro District") is also updating their 2009 plans into a single Water Resource Management Plan to be completed in 2017. The Councils and the Metro District now have the opportunity to inform and better align their respective Plans during a coordinated update schedule that will be carried forward into future 5-year cycles.

(1.1.2) **Jensen-Ryan**, Danielle, and Laura German
UGA

THE POLICY PROCESS: A CRITICAL ASSESSMENT OF WATER POLICY MAKING IN THE STATE OF GEORGIA

The policy process is often discussed as a means to alleviate "wicked problems," particularly those focused on environmental issues. Yet, attempts to address "wicked problems" often leads to different conclusions and dissension, rather than agreement. In an effort to clarify the differences that occur during policy processes, scholars have advanced alternative policy theories explaining the political process. Competing theories focus on instrumental, political, and critical conceptions of policy processes. The instrumental (or means-end) conception stems from the notion of rationality while political-based policy theories seek to understand political struggles occurring during the policy process. Critical policy theories investigate both the rational and the political through a focus on actors and wider interests involved in political spheres. In an effort to advance our understanding of the political processes at play during "wicked problems," we utilized a critical-based policy assessment to examine how water policy was made in Georgia and which contextual factors and stakeholders (rational) as well as wider influences (political) significantly influenced policy trajectories. The state of Georgia presented an ideal setting to explore "wicked problems." A water paradox, Georgia receives 50 inches of annual precipitation and is located amid 14 major river systems and seven highly productive groundwater aquifers. Yet, despite abundant water resources, Georgia's supply is pressured by population growth, and agricultural and economic water use. This paper utilized a year-long ethnographic approach to provide an in-depth analysis of three water policy case studies in the state: the 2008 Comprehensive Statewide Water Plan, the 2012 Moratorium on Groundwater Withdrawals, and ongoing riparian protection debates. Findings indicate that established systems of informal relationships provided the greatest influence for each water policy case study in Georgia. The emergence of social structures as significant in determining water policy efforts in Georgia ultimately provides evidence for a more critical model of policy making in the state—a model which focuses on policy as a social construction through which informal stakeholder ties determine much of what happens in formal democratic structures and policy processes.

(1.1.3) **Elkins, Leigh**
Carl Vinson Institute of Government, University of Georgia

REGIONAL WATER PLANNING: FUNDING IMPLEMENTATION

When Georgia launched its Regional Water Planning efforts in 2009, the work of the each Council was supported by state funds and federal grants. The plans for each region, now being updated, include myriad recommendations to address water quality and quantity issues (and opportunities) but have little to no funding explicitly dedicated to their implementation. A number of Councils and Council members have developed their own ideas for funding their efforts. This presentation will provide a brief review of the past and current mechanisms to fund water planning and explore those proposals have been introduced to support plan implementation.

(1.1.4) **Kistenmacher, Martin**, and Aris P. Georgakakos
Georgia Water Resources Institute, Georgia Tech

VALUE OF ADAPTIVE DROUGHT MANAGEMENT FOR THE ACF RIVER BASIN

In recent times, severe droughts in the southeast US occur every 6 to 10 years and last for up to 4 years. During such drought episodes, the ACF river basin supplies decline up to 50% of their normal levels, and water stresses increase rather markedly, exacerbating stakeholder anxiety and conflicts. As part of the ACF Stakeholder planning process, GWRI has developed new tools and carried out comprehensive assessments to provide quantitative answers to several important questions related to drought prediction and management: (i) Can drought and other climatic periods be reliably anticipated? What drought indices can support reliable, skillful and long-lead forecasts?(ii) What management objectives can drought/non-drought forecasts benefit? How should benefits/impacts be shared? (iii) What operational adjustments are likely to mitigate stakeholder impacts or increase benefits consistent with stakeholder expectations? Regarding drought prediction, a large number of indices were defined and tested at different basin locations and lag times. These included local/cumulative unimpaired flows (UIFs) at 10 river nodes; Mean Areal Precipitation (MAP); Standard Precipitation Index (SPI); Palmer Drought Severity Index; Palmer Modified Drought Index; Palmer Z-Index; Palmer Hydrologic Drought Severity Index; and Soil Moisture—GWRI watershed model. Our findings show that all ACF sub-basins exhibit good forecast skill throughout the year and with sufficient lead time. Index variables with high explanatory value include: previous UIFs, soil moisture states (generated by the GWRI watershed model), and PDSI.

(1.1.5) **Bustillos, Adriana**
Georgia Environmental Protection Division, 2 Martin Luther King Jr. Drive, Suite 1362 East, Atlanta, GA 30334

2016/2017 GA EPD DROUGHT RESPONSE UPDATE

During the summer of 2016 portions of the southeast were included in the cluster of cities that saw the warmest July on record. Not only was July a historical month in regards to temperatures, it was also the driest month on record for some locations. Due to the persistent and extremely dry conditions in the State of Georgia, and after continuous monitoring of climatic indicators and water supply conditions, the Georgia EPD implemented drought response strategies under the State's Drought Management Rule adopted in 2015 for many counties throughout the state. Subsequently, EPD made two drought response level declarations. The first declaration was made on September 9th for a Drought Response Level 1 in 53 counties in northwest Georgia. Faced with worsening drought conditions in about three-fourths of the state, along with water supply concerns in some areas, EPD made a second drought declaration on November 17th, raising the drought response to Level 2 in 52 counties including Atlanta metro area and much of North Georgia, while imposing a Level 1 Drought Response in an additional 58 counties in the northeastern part of the State and central Georgia (110 of 159 counties). According to the drought rule, there are three levels of drought responses (levels 1, 2 and 3) that can be declared by the EPD Director. Drought response level 1, a first stage early warning, requires increased education on drought and voluntary conservation. Levels 2 and 3 contain mandatory measures that are designed to reduce water demands. Public water systems who want to impose outdoor water use restrictions more or less stringent than the state requirements must request and be granted a variance from the state's current drought response.

SESSION 1 ABSTRACTS: WEDNESDAY 8:30-10:00 AM

Track 2.1 – Masters Hall: Water and Drought

(2.1.1) **Kelly, Jacque L**., and Cody E. Mahaffey
Department of Geology and Geography, Georgia Southern University, Statesboro, GA 30460

STREAM CHANNEL MORPHOLOGY IMPACTS NATURAL SUBMARINE GROUNDWATER DISCHARGE TO OYSTER CREEK, GEORGIA

Submarine groundwater discharge (SGD) is a natural process that transports groundwater and dissolved constituents to proximal coastal zones. SGD represents a major but inadequately constrained piece of coastal marine water and chemical budgets because it is spatially and temporally heterogeneous and is difficult to identify without using chemical or temperature tracers. We conducted a surface water survey via boat to detect and quantify groundwater discharge to the Oyster Creek area, which is a brackish tidal estuary near Savannah, GA that winds through extensive intertidal marshes of Spartina alterniflora and mud flats lined by eastern oysters (Crassostrea virginica). We used radon-222, which is a well-established tracer to detect and quantify groundwater discharge to surface water bodies. The data show the radon signature was everywhere we surveyed, suggesting that groundwater discharge is prevalent in the area and that the groundwater rapidly mixes with the surface water. Furthermore, most of the discharging water (94 and 99%) was recirculated seawater with the small remainder likely sourced from infiltrated precipitation. The spatial distribution of the discharge was heterogeneous, consistent with observations from numerous researchers working sites worldwide. However, we found that stream channel morphology exerted a strong control on the spatial distribution and magnitude of groundwater fluxes to the area. We hypothesize that groundwater discharge to brackish tidal estuaries is common in the southeast and that the discharge is dominated by recirculated seawater. In the future, a more thorough investigation of how ebb and flood tides interact with stream channel morphology to control groundwater discharge locations and fluxes is necessary as this is the first investigation, to our knowledge, to recognize the morphologic control of tidal streams on groundwater discharge.

(2.1.2) **Reichard, James S**.[1], R. Kelly Vance1, Jacque L. Kelly1, and Brian K. Meyer2
[1]Department of Geology and Geography, Georgia Southern University, Statesboro, GA 30460 [2]Department of Geosciences, Georgia State University, Atlanta, GA 30302

SALTWATER INTRUSION IN THE SURFICIAL AQUIFER ON ST. CATHERINES ISLAND, GEORGIA

St. Catherines Island is located along the Georgia coast and consists of a Pleistocene core surrounded by Holocene salt marsh and ridge and swale deposits. Since 2011, hydraulic head and chemical data have been collected from the surficial aquifer along an E-W transect of six monitoring wells ranging in depth from 5-8 meters. Two additional transects were added in 2016, creating a network of 18 wells. Data from the original 6-wells reveal that unusually high tides periodically drive saltwater into the surficial aquifer. The pulses of saltwater intrusion are much more pronounced on the marsh-side of the island relative to the ocean side, indicating the presence of permeable pathways within the shallow aquifer. Preliminary data from the new wells installed in 2016 show anomalously high chloride concentrations at select locations within the island, supporting the hypothesis that saltwater is intruding along preferred pathways. Analysis of old topographic maps of the island show a linear alignment of former freshwater ponds and marshes that coincide with regional joint trends. Historical records indicate these former freshwater bodies were fed by artesian springs whose source was the regional carbonate aquifer. In addition, ground penetrating radar and electrical resistivity profiles reveal sag structures in the surficial aquifer. Prior to major pumping withdrawals from the regional aquifer, artesian water flowed upward along joint and fault traces, creating artesian springs at the surface. Solution cavities eventually developed in the carbonate aquifer, some of which collapsed causing sag structures in the overlying layers. It is hypothesized that the observed saltwater intrusion events on St. Catherines are driven by unusually high tides, allowing saltwater to flow into the surficial aquifer through solution collapse features that have propagated to the surface. In the future, vertical well nests will be installed to help delineate the saltwater movement within the aquifer.

(2.1.3) **Rouen, Lauren**[1], and Paul Conrads[2]
1U.S. Geological Survey, Columbia, SC, 2Carolinas Integrated Sciences & Assessments (CISA), Columbia, SC

USING THE COASTAL SALINITY INDEX FOR MONITORING DROUGHT IN THE CAROLINAS

A number of activities are currently (2017) underway to further utilize the Coastal Salinity Index (CSI) for monitoring drought in the Carolinas. Scientists have recognized the necessity of defining drought within a coastal context where an ecological drought represents the influence of increased salinity stress on the structure and function of ecological habitats. To address the need for a unique coastal drought index and the importance of salinity as a coastal ecological stressor, a CSI was developed by using an approach similar to the Standardized Precipitation Index (SPI). Similar to the SPI, the CSI is computed for unique time intervals (for example 1-, 6-, 12-, and 24- month intervals) that can characterize the onset and recovery of short- and long-term drought. Evaluation of the CSI indicates that the index can be used for different estuary types (for example: brackish, oligohaline, or mesohaline), for regional comparison between estuaries, and as an index of wet conditions (high freshwater inflow) in addition to drought (saline) conditions. Three activities are planned that will increase the use of the CSI. One, a software package is being developed for the consistent computation of the CSI that includes preprocessing of salinity data, filling missing data, computing the CSI, post-processing, and generating the supporting metadata. Two, the CSI is being computed at more sites along the Gulf of Mexico and the Southeastern Atlantic Ocean. Three, by using a real-time salinity data stream, the real-time computation and dissemination of the index at a number of sites in the Carolinas is being prototyped.

(2.1.4) **Campbell, Bruce**
USGS South Atlantic Water Science Center

EASTERN GEORGIA, SOUTH CAROLINA, AND SOUTHERN NORTH CAROLINA ATLANTIC COASTAL PLAIN GROUNDWATER AVAILABILITY MODEL

The Atlantic Coastal Plain aquifers and confining units of South Carolina are composed of crystalline carbonate rocks, sand, clay, silt, and gravel and contain large volumes of high-quality groundwater. The aquifers have a long history of use dating back to the earliest days of European settlement in the late 1600s. Although extensive areas of some of the aquifers have or currently (2016) are experiencing groundwater level declines from large-scale, concentrated pumping centers, large areas of the South Carolina (SC) Atlantic Coastal Plain contain substantial quantities of high-quality groundwater that currently are unused. Groundwater use from the Atlantic Coastal Plain aquifers in South Carolina has increased during the past 70 years as the population has increased along with demands for municipal, industrial, and agricultural water needs. While South Carolina works to increase development of water supplies in response to the rapid population growth, the State is facing a number of unanswered questions regarding availability of groundwater supplies and the best methods to manage these important supplies. Overall, groundwater use in the SC Coastal Plain from 2004-2013 has increased slightly from about 202 million gallons per day (Mgal/d) in 2004 to an average of 209 Mgal/d from 2005 to 2013. There has been a significant increase in irrigated agriculture in SC, with much of this new water demand met by groundwater use. In SC this trend is likely to continue. Potential adverse effects of the continued increase in groundwater withdrawals include groundwater level declines and reduced baseflow to streams and other surface-water bodies. The SC Agriculture Commission is actively recruiting industrial-scale farms to locate in the Coastal Plain counties of SC. These new farms will most likely use groundwater for their primary source of irrigation water and are likely to be clustered in areas with suitable soils, transportation, and labor. The South Carolina Water Plan, 2nd Edition states: “A comprehensive groundwater flow model of the Coastal Plain should be developed and used to predict the effects of future pumping and to determine optimal well spacing’s”. The update to the existing SC Coastal Plain groundwater-flow model will provide the model described in the SC Water Plan. An updated groundwater flow model of the South Carolina Coastal Plain will benefit the State by providing a tool that can be used by water-resource managers to estimate current available water resources and to assess the effects of future water-use development and climate variability on available water resources. The USGS is working cooperatively with the SC Department of Natural Resources, SC Department of Health and Environmental Control, and SC Department of Agriculture to develop an updated groundwater-flow model of the South Carolina Coastal Plain.

(2.1.5) **Foldesi, Christopher P**.[1], David K. Huff[1], and R. David G. Pyne[2]
[1]Nutter and Associates, Inc., Athens, GA 30606; [2]President, ASR Systems LLC, Gainesville, FL 32601

UTILIZING AQUIFER STORAGE AND RECOVERY TECHNOLOGY TO MANAGE GEORGIA'S WATER RESOURCE CHALLENGES

The State of Georgia is faced with multiple water resource challenges, as agricultural, industrial, and public users compete for water from the major river basins and principal aquifer systems. Competition for these resources is also an interstate issue involving legal challenges with Alabama and Florida over surface water allocations in the Apalachicola-Chattahoochee-Flint watershed and long standing negotiations with South Carolina over unsustainable withdrawals and saltwater intrusion in the Upper Floridan Aquifer. Aquifer Storage Recovery (ASR) can address many of Georgia’s water resource challenges. The technology is becoming an increasingly important water management tool in the Atlantic Coastal Plain. Groundwater in the coastal aquifers of Georgia is the predominant source of water supply and its sustainability is threatened by increasing demand, saltwater intrusion, and limited freshwater recharge. Despite its internationally-recognized success, ASR has been prohibited in some counties of Georgia in the past and continues to be challenged by some environmentalists. ASR is a low-impact technology that utilizes a small footprint within an aquifer, usually within a 500-foot radius of an ASR well. ASR provides the opportunity for water users to store treated drinking water and manage water resources seasonally. ASR has many other benefits, including disinfection by-product reduction, improvement in regional groundwater levels, and reduction of saltwater intrusion effects. The local hydrogeology is a major consideration for the implementation of ASR projects. The development of aquifers as storage zones requires great care to avoid potential well-plugging. Local aquifer geochemistry can affect recovered water quality after storage, and treatment or other operational measures may be required to make the project successful. We present the results of a few successful ASR projects in the Coastal Plain of South Carolina and review two attempted ASR projects in Georgia.

SESSION 1 ABSTRACTS: WEDNESDAY 8:30-10:00 AM

Track 3.1 – Room F/G: Agricultural Water

(3.1.1) **Liakos, Vasileios**, Timothy Coolong, Kati Migliaccio, Kelly Morgan, Wesley Porter, Calvin Perry, Erick Smith, and George Vellidis
UGA

SMARTPHONE APPS FOR SCHEDULING IRRIGATION

Proper irrigation scheduling provides many benefits to growers including optimal crop growth, better utilization of nutrients, higher yields, and reduced susceptibility to pathogens. Irrigation scheduling based on crop water needs has not been widely adopted in Georgia because reliable and easy-to-use scheduling tools are not available. Smartphone Apps are an emerging technology with great potential for helping growers improve water management efficiency as well as the overall profitability of the farm operation. Our project's goal is to make irrigation scheduling Apps available to growers to ensure that they benefit from the competitive advantage that this technology offers. The project has developed or is in the process of developing easy-to-use and engaging irrigation scheduling tools for cotton, blueberry, cotton, soybean, and three vegetables (cabbage, tomato, watermelon) as well as residential turf which operate on a smartphone platform. The Apps use interactive ET-based models, meteorological data from weather station networks or national gridded data sets, soil parameters, crop phenology, crop coefficients, and irrigation applications to develop irrigation scheduling recommendations. The Apps send notifications to the user when irrigation is needed, when phenological changes occur, and when rain is recorded. They operate on both iOS and Android operating systems. The Cotton, Turf, and Vegetable SmartIrrigation Apps have been released while the Blueberry and Soybean Apps are in beta testing. This presentation will describe how the Apps work and present data on their performance.

(3.1.2) **Druden, Craig**, and Sudhanshu Panda
University of North Georgia, Gainesville, GA

GEOSPATIAL ANALYSIS FOR SWINE CAFOS AND STREAM WATER QUALITY CORRELATION STUDY

Concentrated Animal Feeding Operations (CAFOs) are the confinements of animals for more than 45 days during a growing season with no vegetation. There are close to 15,500 CAFOs around the United States with an astounding 2,514 located in North Carolina (NC) alone and most of them being swine CAFOs. Most of the swine CAFOs within NC are in Duplin and Sampson County. Very nature of a CAFO is harmful to the immediate environment as well as organisms higher up the food chain and especially, the low gradient topography creates serious environmental issues like stream water contamination. The waste from CAFOs are periodically applied to "spray fields" of Bermuda grass or feed crops and washed away to streams to contaminate it. Two contrasting watersheds were chosen based on the presence of swine lagoons. These watersheds have the USGS gauging stations at their exit points. Grove Creek watershed in Duplin County with 23 swine lagoons, six of which are within 100m of a stream. The watershed in Durham County has only one swine lagoon. A soil analysis of both watershed suggested that the watershed with only one CAFO has large percentage (77%) of well-drained soils making it more vulnerable for contaminant transportation to the streams. Grove Creek watershed with more CAFOs has a better soil types, i.e., 38% well-drained and 36% poorly drained soil. Water quality data was downloaded from the USGS gauging stations and averaged for 5 years period, and were spatially compared for both watersheds. It was observed that watershed in Durham County was more impaired for DO, TN, TP, Nitrate, Nitrite, and CO2, explaining that the presence of swine CAFOs may not be responsible for this impairments in the nearby streams. However, the watershed with more CAFOs were impaired for pH, organic nitrogen, ammonia, , and especially, fecal coliform. As the fecal coliform is a bigger water quality concern and it is directly related to CAFO outputs, our spatial analysis confirmed that presence of swine lagoons closer to streams if not managed properly might create water quality issues in the stream. Higher impairment in the watershed with only one CAFO was attributed to comparatively higher slope gradient, higher percentage of well-drained soil, and more urban land cover. This study is being intensified with the inclusion of more spatial data. A Soil and water Assessment Tool (SWAT) models are being developed for water quality analysis.

(3.1.3) **Mullen, Jeffrey**, and Niyun Chen
UGA

PREDICTING IRRIGATION WATER USE IN GEORGIA WITH CROP GROWTH SIMULATION MODELS AND REGRESSION ANALYSIS: A COMPARATIVE ANALYSIS

Regression analysis is the predominate method used by economists to estimate the effects of weather, agronomic and economic variables on water withdrawals for crop irrigation. Weather variables typically include measures of precipitation and a proxy for temperature, e.g., growing degree days. Precipitation is often included either at the seasonal or monthly scale. In contrast, crop growth simulation models can investigate the effects of daily precipitation and weather events. Using the data set compiled for the Georgia Agricultural Water Pumping study, we estimate three regression models of total irrigated water applied for three crops: corn, cotton, and peanuts. The models differ based on the time scale of the precipitation variable (bi-weekly, monthly, seasonal). We then use DSSAT to simulate irrigation applications under a series of irrigation management strategies based on soil moisture conditions. Finally, we compare the out-of-sample prediction errors across the regression models and the DSSAT models. Our results show that the DSSAT models based on daily soil moisture conditions are better predictors of total irrigated water use than any of the regression models we estimated.

(3.1.4) **Gugolz, Stefanie**, and Valentine Nzengung
UGA Dept. of Geology

EVALUATION OF A BIOCHAR ENHANCED CONSTRUCTED TREATMENT WETLAND FOR THE REMOVAL OF CONTAMINANTS FROM AGRICULTURAL WASTEWATER

Nutrient-rich wastewater runoff from concentrated animal feeding operations (CAFO's) is one of the largest sources of contamination of surface waters in the US. This study evaluated biochar as a media in vegetated constructed treatment wetlands (CTWs) for treatment of CAFO wastewater. A wood biochar, pyrolyzed at 500°C was characterized for its adsorption of ammonia (NH3), nitrate (NO3) and phosphate (PO43-). A greenhouse experiment was conducted with four 140 L simulated constructed wetland tanks as follows: R1 – 100% biochar planted with cattails, soft rush, parrots feather and knotweed; R2 - 50% biochar, 50% pea gravel and plants; R3 - 100% biochar and no plants; and R4 - pea gravel and plants. Diluted swine waste was applied to each tank and the influent and effluent were analyzed for total solids (TS), PO43-, chemical oxygen demand (COD), total Kjedahl nitrogen (TKN), NH4+-N, NO3--N and total minerals (Al, B, Ca, Cu, Fe, K, Mg, Mn, Na, P, S, Zn). Plant growth was monitored. Diluted swine wastewater (2x) used in test 1 resulted in the death of all of the plants in R4, ~ half in R2, and only a few in R1. Follow-up 2nd and 3rd tests were conducted using the more dilute wastewater. Overall, there were no statistical differences between the mass of pollutants removed by R1 and R2, but for almost all parameters they outperformed R3 and R4. Cattail growth was the greatest in R1 and the least in R4. These findings show that incorporation of biochar into the substrate of constructed wetlands media can significantly increase their treatment of agricultural wastewater. Additional studies using other types of biochar could yield even better results.

(3.1.5) **Torak, Lynn**
USGS

ASSESSING AQUIFER DEPLETION AND AGRICULTURAL WATER WITHDRAWAL WITH REMOTELY SENSED AIRBORNE AND SATELLITE EARTH OBSERVATIONS

Remotely sensed Earth observations from National Aeronautics and Space Administration (NASA) satellites and unmanned aircraft systems (UAS) can provide timely information to enhance security and sustainability of water, energy, and food supplies. Scientific and resource-management applications involving remote-sensing technology can 1) define aquifer depletion caused by drought and over-pumping; 2) assess patterns and amounts of basin-wide agricultural water withdrawal during the growing season; and, 3) direct precision-irrigation techniques to conserve water and energy, increase agricultural production, and improve farming economy. Observations of Earth's gravitational field measured by NASA's Gravity Recovery and Climate Experiment (GRACE) satellite can detect regional anomalies resulting from variations in water stored as soil moisture and in water-table and shallow-confined aquifers. Commensurate with GRACE gravity observations, NASA's soil moisture active passive (SMAP) satellite can detect soil-moisture variations, allowing quantification of the groundwater-level-change component of GRACE gravity anomalies to combine with geohydrology data for calculating aquifer depletion. Multiple-level Earth observations from high-altitude long-endurance (HALE) aircraft or pseudo-satellites (HAPS) and low altitude UAS platforms can identify near real-term irrigation patterns during the growing season that are crucial to 1) assess and manage agricultural water withdrawal, and 2) direct precision irrigation to enhance agricultural production and the Nation's food supply. Solar-powered HALE aircraft or HAPS, flying above the troposphere at altitudes of 60,000 feet, can linger from weeks to months collecting and transmitting thermal and hyperspectral imagery daily over areas of interest, such as agricultural regions of Georgia. Together with contemporaneous irrigation-meter data, irrigated acres identified using HALE imagery constitute critical components for assessing basin-wide agricultural water withdrawal. Complementary imagery acquired from UAS flights over specific agricultural fields can downscale HALE imagery to identify over- or under-irrigated cropland—soil-moisture conditions detrimental to agricultural production—and can direct precision- irrigation techniques to inform water and energy management at the farm scale.

SESSION 1 ABSTRACTS: WEDNESDAY 8:30-10:00 AM

Track 4.1 – Room L: Georgia Flood Risk Mapping Assessment and Planning (MAP) Workshop

Session Organizer: **Haydn Blaize**
Georgia Floodplain Management Unit, 2 MLK, Jr., Dr., Suite 1152 E, Atlanta, GA 30334

The intent of this workshop session is to provide information to participants on the Georgia Flood Risk Mapping Assessment and Planning (MAP) program and how the program promotes flood risk awareness and use of available Flood Risk Products in planning and implementing flood related mitigation strategies. This floodplain mapping workshop session will allow participants to gain a more comprehensive understanding of available Flood Risk products and how to use these products to regulate development within special flood hazard areas. Incentives that accompany participation in the Community Rating System will also be presented in the context of regulatory development and improved hazard mitigation planning and actions.

The Georgia Department of Natural Resources has developed a tool that helps homeowners quickly determine their flood risk using a web-based mapping tool; www.georgiadfirm.com. Residents and business owners can use the maps to obtain reliable information about their flood risk on a property-by-property basis. The maps also provide flood zone and elevation data to help community planners, engineers, builders and others decide where and how new structures, developments, and remodeling projects should be built. Users can quickly locate a property, either using a known address or by clicking the map, to identify the flood risk status, the effective Flood Insurance Rate Map, and even create a flood hazard report that captures all of this information in an attractive and shareable format. The vision for Georgia Flood MAP has been to develop a statewide program that not only delivers more accurate and complete flood hazard information for counties and municipalities within the state, but also provides information and tools to assist communities in developing more comprehensive mitigation plans that will reduce losses from flooding.

Other Presenters:
Haydn Blaize, M.S. Eng.
Thomas Tkacs, PE, CFM
Joseph Martinenza, P.E. CFM
Brian Shoun, P.E., CFM
Alan Giles, CFM

SESSION 1 ABSTRACTS: WEDNESDAY 8:30-10:00 AM

Track 5.1 – Room R: Green Infrastructure

(5.1.1) **Vick, R. Alfred**[1], Jon Calabria[1], and Jenny Hoffner[2]
[1]University of Georgia; [2]University of Georgia; [3]American Rivers
THE I-20/I-85/I-20 INTERCHANGE GREEN STORMWATER INFRASTRUCTURE PILOT PROJECT
Impervious surfaces in the vicinity of Turner Field generate a significant volume of stormwater runoff that contributes to recurring flooding of downstream communities. As part of the Turner Field Neighborhoods Livable Centers Initiative, American Rivers completed a feasibility study in July 2016 that identified several opportunities to implement green stormwater Infrastructure (GSI) within Georgia Department of Transportation (GDOT) rights-of-way at the I-20/I-75/I-85 Interchange. Once implemented, these projects will reduce runoff, improve water quality, help alleviate downstream flooding and serve as visible demonstration projects. American Rivers, GDOT, the Atlanta Downtown Improvement District and other project partners have collaborated to develop plans for a demonstration green infrastructure project located within the GDOT right-of-way at the I-20/I-75/I-85 interchange. The proposed green infrastructure practices include bioretention and enhanced swales designed to capture and treat the 95th percentile storm event. The project also includes plans to incorporate interpretive features to engage the public, as well as future research and monitoring of the green infrastructure performance and maintenance requirements. This demonstration project will create a beautiful and functional stormwater management feature that establishes a precedent for GDOT's commitment to green infrastructure and will help reduce stormwater impacts in the Turner Field neighborhoods.

(5.1.2) **Cameron, Christopher**[1], and Natalia Bhattacharjee[2]
[1]NASA DEVELOP National Program, [2]UGA College of Engineering
IDENTIFYING KEY URBAN AREAS TO REDUCE STORMWATER RUNOFF AND MAXIMIZE CONSERVATION EFFORTS IN METROPOLITAN ATLANTA
Residents of metropolitan Atlanta pay the highest rates in the nation for municipal water and sewer, due to massive recent investments in infrastructure to manage stormwater runoff. As development continues at a rapid pace in Atlanta and its suburbs, expanding areas of impervious surface will continue to exacerbate this problem. Forested land is known to slow runoff during storms, allowing water to infiltrate, and the soil to absorb particles and contaminants before entering the surface water. Protecting existing green infrastructure and strategically planting more trees to intercept stormwater runoff will help reduce sediment and nutrient-laden stormwater runoff in local watersheds and, ultimately, limit the need for future city infrastructure. The DEVELOP team at the UGA partnered with The Nature Conservancy to identify conservation targets in the Atlanta region to improve existing green infrastructure and locate additional areas suitable for expansion of reforestation efforts using NASA data from Landsat 8 and Terra satellites. This was accomplished through a combined, watershed-scale assessment of metropolitan Atlanta using the Land-Use Conflict Identification Strategy (LUCIS) and Soil and Water Assessment Tool (SWAT) models. The LUCIS model was employed in this project to identify areas of land use prioritization as it relates to existing and future conservation areas in Atlanta. The SWAT model produced an analysis of streamflow and runoff within the study area. Together, these model results provided project partners with an integrated understanding of water resource issues in metropolitan Atlanta that emphasized land use scenarios.

(5.1.3) **Samples, Kevin**, and Elizabeth Kramer
Natural Resources Spatial Analysis Laboratory, College of Agricultural and Environmental Sciences, University of Georgia, Athens, GA
PRIORIZING THE LOCATION OF GREEN INFRASTRUCTURE TO MAXIMIZE EFFECTIVENESS OF STORMWATER MITIGATION, FOR THE CITY OF SANDY SPRINGS
Cities across the Metro-Atlanta region are experiencing a renaissance as market demand for urban live, work, and play, is driving infill development. As these cities transform from lower density suburban architecture to denser walkable communities, their stormwater infrastructure becomes challenged to support increases runoff due to impervious surfaces and changes in intensity of rainfall events. Green infrastructure and low impact development approaches which include better planning and site design practices can reduce the potential for flooding and further degradation of stream water quality. Our objective was to identify and prioritize the locations for stormwater interventions that can be used to minimize stormwater impacts to already TMDL-listed streams within the boundaries of the City of Sandy Springs. A high resolution model of impervious surface, topography and land use was derived from LIDAR and integrated with the existing stormwater infrastructure to identify areas which receive high surface flows. These areas were then ranked and prioritized to provide a new roadmap for stormwater management within the boundaries of the City. We will report the results of our modeling effort and discuss how these results can be used to identify restoration opportunities in flood prone areas and describe how these alternatives provide cost effective solutions to stormwater management on public and private owned properties.

(5.1.4) **Rayburn, Cory**
City of Atlanta Department of Watershed Management
BUILDING GREEN: ATLANTA'S GREEN INFRASTRUCTURE STRATEGY
Through strong leadership, a commitment to sustainability, and collaborative partnerships, the City of Atlanta is implementing an approach to green infrastructure to address both combined sewer overflows and surface water management. In February of 2013, Atlanta adopted one of the most far-reaching stormwater management ordinances in the country, laying the groundwork for a robust green infrastructure program for both private development as well as capital public projects. Without a direct source of funding from a stormwater utility fee, Atlanta has

implemented this program through an extensive coordination approach which relies on multiple city departments, non-profit organizations, and the private development community. Early phases focused on establishing baselines and goals, producing guidance material to simplify compliance, and training and outreach efforts for the development community and city staff to help ensure consistency. To date, the City has permitted nearly 3,000 construction projects that utilize green infrastructure, equating to the removal of approximately 650 million gallons of polluted runoff from our streams and combined sewer infrastructure annually. To leverage the success of the stormwater ordinance, the City created the Green Infrastructure Task Force composed of municipal departments and non-profit organizations to fully integrate green infrastructure into City processes and community development. The Task Force recently released a Strategic Action Plan to formalize this approach and create the organizational infrastructure needed to accomplish this task. In addition, the City has completed the installation of the world's largest permeable paver roadway retrofit project to help alleviate flooding in neighborhoods served by the City's combined sewer infrastructure. This presentation serves to summarize these efforts as well as the lessons learned of implementing green infrastructure on a city-wide scale.

(5.1.5) **Rayburn, Cory**
City of Atlanta Department of Watershed Management
ADDRESSING NEIGHBORHOOD FLOODING WITH GREEN INFRASTRUCTURE
In July 2012, several neighborhoods in southeast Atlanta experienced catastrophic flooding after a 10-yr and 25-yr storm event occurred within a three-day period. Atlanta Mayor Kasim Reed met residents who were affected by these storms to assure them that appropriate action would be taken to make long-term infrastructure improvements. The Peoplestown, Summerhill, and Mechanicsville neighborhoods are served by the City's combined sewer system that drains the heart of Atlanta, including the Capitol, I-20 and the Downtown Connector, and Turner Field. In an effort to increase combined sewer capacity in this highly urbanized watershed, the City of Atlanta implemented a strategy which utilized both gray and green infrastructure. To date, a 5.9M gallon storage vault adjacent to Turner Field and 7 bioretention cells have been constructed. In addition, four miles of permeable paver roadways in combination with stormwater planters have been installed throughout the watershed to delay peak flow rates and remove a certain portion of stormwater runoff from entering the combined sewer system. This is the largest application of retrofitted roadways using permeable pavers known. This presentation will highlight the steps leading up to construction and lessons learned throughout the first year, including design hurdles, aging infrastructure, sedimentation, and community outreach. Learn how this regional green infrastructure approach has improved drainage while providing an aesthetically pleasing solution for the community. Future phases of the Southeast Atlanta Green Infrastructure Initiative (SAGII) will be discussed, including additional paver roadways, large-scale bioretention, garden-themed stormwater retention ponds, and potential retrofit incentives to promote the use of green roofs within the combined sewer area.

SESSION 1 ABSTRACTS: WEDNESDAY 8:30-10:00 AM

Track 6.1 – Room K: Stream Ecology

(6.1.1) **McDonald, Jacob M**[1,2], Eric N. Starkey[2], and M. Brian Gregory[2]
[1]The University of Georgia – Warnell School of Forestry; [2]National Park Service – Southeast Coast Network

WADEABLE STREAM MONITORING IN SOUTHEASTERN NATIONAL PARK UNITS

The National Park Service Inventory and Monitoring Division's Southeast Coast Network (SECN) has initiated a monitoring effort to assess habitat conditions in wadeable streams at parks, battle fields, and monuments in Alabama, Georgia, and South Carolina. These parks include Chattahoochee River National Recreation Area, Kennesaw Mountain National Battlefield Park, Congaree National Park, Horseshoe Bend National Military Park, and Ocmulgee National Monument. The purpose of this monitoring program is to provide relevant data to assess the types of streams within each park and determine their physical conditions with respect to the aquatic and riparian habitats that are present. The methods used in this monitoring program rely on standard data collection methods currently in use by other government agencies (e.g., the USGS) and have been modified to better meet the needs of NPS managers. The objectives of this protocol are to: 1) determine the status of and trends in watershed characteristics that are known to affect stream habitat; 2) accurately describe the geomorphic dimensions of wadeable streams so that changes over time can be determined; and 3) determine the status of and trends in benthic and riparian habitat, including the size, type, and distribution of bed sediments and large woody debris as well as the amount of canopy cover. Data collected under this protocol will allow the wadeable stream resources within SECN parks to be compared to streams surveyed by other organizations, highlighting similarities and differences in these resources as they relate to general stream habitat and geomorphic conditions. The streams selected for survey highlight known issues related to stream habitats in SECN parks, highlighting important linkages between the physical condition of streams and park resources. Most importantly, this protocol will provide early warnings of changing conditions that will inform managers of appropriate site mitigation procedures that may be needed.

(6.1.2) **Stowe, Edward**[1,2], Mary C. Freeman[2,3], and Seth J. Wenger[1,2]
[1]Odum School of Ecology, University of Georgia; 2River Basin Center, University of Georgia; 3U.S. Geological Survey, Patuxent Wildlife Research Center

ASSESSING FISH MICROHABITAT USAGE TO UNDERSTAND PATTERNS IN SPECIES DECLINES IN THE CONASAUGA RIVER, GA

The Conasauga and Etowah rivers of north Georgia support high levels of fish biodiversity and endemism, but this fauna is also imperiled by land use changes, hydrologic alterations, and industrial inputs. Sampling of fish communities in the upper Conasauga River from 1995 to 2014 documented dramatic declines for four species—Tricolor Shiner (Cyprinella trichroistia), Coosa Chub (Macrhybopsis sp. cf M. aestivalis), Coosa Madtom (Noturus sp. cf. N. munitus), and Amber Darter (Percina antesella). However, no such declines are evident from monitoring data for the same taxa within the Etowah River, and causes for declines in the Conasauga River are not known. For this study, we performed two analyses to assess whether there are patterns in microhabitat usage common to these four declining taxa that may suggest possible causes for declines. First, we performed pair-wise co-occurrence analyses to assess whether these four taxa occur together in microhabitats with greater frequency than would be expected by chance. Second, we used logistic regression models to assess the relationship between the presence of each of the declining taxa at a microhabitat scale and microhabitat characteristics. We also conducted both analyses for non-declining species representing the same or similar genera as the declining species for comparison with patterns of co-occurrence and microhabitat usage for the declining fish. Results of these analyses indicate the extent to which processes at the microhabitat level may affect species responses to environmental change, and may provide a framework for analyzing fish declines in other freshwater environments.

(6.1.3) **Conn, Caitlin**[1], Seth Wenger[1,2], Amy Rosemond[1], Phillip Bumpers[1,2], Mary Freeman[3], and Kyle McKay[4]
[1]Odum School of Ecology, University of Georgia, Athens, GA 30602 2River Basin Center, University of Georgia, Athens, GA 30602 [3]Patuxent Wildlife Research Center, US Geological Survey, Athens, GA 30602 [4]US Army Corps of Engineers, New York, NY 10278

QUANTIFYING PRODUCER RESPONSES TO ANTECEDENT FLOW CONDITIONS IN THE MIDDLE OCONEE RIVER, GA

Stream flow has a major influence on ecosystem structures, functions and the corresponding services provided to us by rivers. Because river biota are adapted to a specific set of flow conditions in unmanaged rivers, alterations to land use, climate, and river management can affect hydrologic variability in ways that degrade – or perhaps enhance – ecological characteristics. While there are decades of well-supported research on how flow variability impacts ecosystem structure, there is relatively little known about how these changes affect ecological functions. Nevertheless, scientists have proposed that these functions be considered as management objectives alongside ecosystem structural attributes due to their importance in maintaining ecosystem services. With funding from the US Army Corps of Engineers, we are studying the effects of different flow conditions on primary productivity in the Middle Oconee River. We measure biomass of different primary producers monthly, and are measuring biomass-specific primary productivity rates through chamber studies. By modeling productivity in response to biomass changes and antecedent flow conditions, we aim to quantify the effects of different flow conditions, and thus different management strategies and climate scenarios, on important ecosystem functions.

(6.1.4) **Covich, Alan**[1], Stephen D. Shivers[1,2], Stephen W. Golladay[2], Matthew N. Waters[4], and Susan B. Wilde[3]
[1]UGA Odum School of Ecology, [2]Joseph W. Jones Ecological Research Center, [3]UGA Warnell School of Forestry & Natural Resourc, [4]Auburn University, Dept. of Crop, Soil, and Environmental Sciences

RIVERS TO RESERVOIRS: HYDROLOGICAL DRIVERS CONTROL RESERVOIR FUNCTION BY AFFECTING SUBMERGED AQUATIC VEGETATION COVERAGE

Freshwater ecosystems, including lakes and reservoirs, are important sites for biogeochemical cycling on a regional scale. Reservoirs affect nutrient storage and transformation as water moves through a watershed from the land to the sea. Reservoirs can also facilitate the spread of invasive species because of heavy anthropogenic use. Invasive species, particularly submerged aquatic vegetation (SAV) such as Hydrilla verticillata, affect nutrient transformation and storage within a reservoir, which can affect downstream water quality. The goal of this study was to investigate how hydrology affected SAV coverage and how changes in coverage affected in-reservoir nutrient processing. To assess these effects, annual vegetation surveys were completed during the peak of the SAV growing season, and a comprehensive water quality monitoring program quantified nutrient concentrations in the inflows and outflows. Greater areal precipitation in the spring of 2013 and 2014 caused increased river flow (208 m3/s and 192 m3/s in 2013 and 2014, respectively compared to 74 m3/s in 2012), which created turbid conditions within the lake. Consequently, SAV decreased from 35.5 km2 in 2012 to 18.3 km2 in 2014. Increased NO3-N concentrations were also observed as SAV coverage declined. These results indicate that hydrological variation was driving changes in SAV coverage, and that changes in coverage altered nutrient processing at the reservoir scale. Water resource and invasive species management plans should consider effects of SAV on in-reservoir processing to ensure downstream water quality is maintained.

(6.1.5) **Marzolf, Nick**[1,2], Stephen Shivers[1,2], Brian Clayton[2], and Stephen Golladay[2]
[1]UGA Odum School of Ecology, [2]Joseph W. Jones Ecological Research Center

INTRA-AND INTER-ANNUAL APPLE SNAIL POPULATION DYNAMICS IN LAKE SEMINOLE

The introduction of the island apple snail, Pomacea maculata, across tropical and sub-tropical freshwaters is one of the most concerning species' introduction. As a cryptic species, observing and quantifying adults has proved challenging, leading to alternative methods to estimate populations. Pomacea spp. snails deposit egg masses above the water line, and can be identified to species and quantified as a proxy for adult abundance. In Lake Seminole, a reservoir in the Apalachicola-Chattahoochee-Flint (ACF) watershed, P. maculata were first observed in 2003, and subsequent dispersal was noted in 2009. To understand the distribution of P. maculata within Lake Seminole, shoreline surveys during 2013-2016 identified and quantified egg masses across the reservoir and nearby small ponds. Additionally, monthly surveys during 2016 identified peak egg mass production and whether egg mass deposition ceased during the winter. Egg masses of P. maculata and P. paludosa were observed in Lake Seminole each year and during winter months. The extent of P. maculata distribution increased in each survey year, including expansion into arms of the lake not present during previous surveys. We document dispersal of P. maculata from the Flint River arm of the lake to the Spring Creek and Chattahoochee arms of the lake by 2016. Monthly surveys indicated peak production during summer months, and production through December, where previous work suggested no egg masses produced during winter months. We hypothesize that continued dispersal of P. maculata, a voracious herbivore, will potentially alter submerged aquatic vegetation and aquatic food webs within Lake Seminole, among other unknown ecological consequences.

SESSION 3 ABSTRACTS: WEDNESDAY 1:30-3:00 PM

Track 1.3 – Room Q: Water Law and Litigation

Session Organizer: **Douglas Henderson**
Troutman Sanders, 600 Peachtree Street, NE Suite 5200, Atlanta, GA 30308

At no time in Georgia's history have there been more disputes over water quality and water quantity. The State of Florida is suing the State of Georgia over water consumption. The State of Alabama is suing the U.S. Corps of Engineers over flows in the Chattahoochee. And citizen suits by environmental groups are now the norm to enforce the Clean Water Act. Even disputes over surface water runoff are at an all-time high.

This panel, composed of lawyers and scientists, will summarize and analyze the top water law and litigation developments in the state over the past several two years. Each speaker will offer relatively a short observation or a point or two, followed by a structured panel discussion on common themes and continuing disputes

Douglas Henderson, Troutman Sanders, *Chair and Moderator*

Panelists
Hutton Brown, GreenLaw, *Recent Georgia Water and Wastewater Lawsuits*
Lewis Jones, King & Spalding, *Water Wars Involving the State and the Corps*
Laura Benz, Laura Benz Law LLP, *The Role of Reservoirs in Georgia's Water Future*

SESSION 3 ABSTRACTS: WEDNESDAY 1:30-3:00 PM

Track 2.3 – Master's Hall: Coastal Ecology and Management

(2.3.1) **Schmidt, John**[1], Ian Blaylock[1], Daniel Zangari[2], Michelle Smith[2], Shannon Jenkins[3], and David Glenn[4]
[1]National Weather Service-Southeast River Forecast Center, [2]Florida Dept. of Agriculture and Consumer Services-Division of Aquaculture, [3]North Carolina Dept. of Environmental Quality-Division of Marine Fisheries-Shellfish Sanitation and Recreational, [4]National Weather Service-Newport/Morehead City, NC Weather Forecast Office

THE APPLICATION OF OPERATIONAL NATIONAL WEATHER SERVICE PRECIPITATION DATA TO SHELLFISH HARVESTING MANAGEMENT

The National Oceanic and Atmospheric Administration's Southeast River Forecast Center (SERFC), a field office of the National Weather Service, monitors hydrometeorological conditions and prepares streamflow and level forecasts for rivers in the Southeast U.S. and Puerto Rico. To accomplish this primary mission, SERFC hydrometeorologists continually process hourly Multi-sensor Precipitation Estimate (MPE) data, a program that combines weather radar rainfall estimates and rain gauge data to produce calibrated precipitation estimates for use in river forecasting. Recently, the SERFC has been working with the Division of Aquaculture, Florida Department of Agriculture and Consumer Services, and the Shellfish Sanitation and Recreational Water Quality Section in the North Carolina Department of Environmental Quality, agencies who are charged with monitoring and closing shellfish harvest areas in their respective states for the protection of public health. Precipitation data is a key variable in making harvest area closure decisions and this collaborative effort is leveraging SERFC's continuously calibrated precipitation estimates to provide more reliable 24-hour rainfall totals, an indicator of the potential for pollution runoff, to decide if shellfish harvesting waters should remain open or be closed. This presentation will describe the production of MPE data, the variety of formats that MPE data is packaged in, and how MPE is applied operationally in harvest area closure decisions. Additionally, topical forecast data will be described that may be applicable for future shellfish closure decision and resource management.

(2.3.2) **Bliss, Thomas**[1], Scott Pippin[2], Melanie Biersmith[3], and Mark Risse[4]
[1]Shellfish Research Laboratory, Marine Extension and Georgia Sea Grant, University of Georgia, Savannah, GA 31411; [2]Carl Vinson Institute of Government, University of Georgia, Athens, GA 30602; [3]UGA Extension - Georgia 4-H, University of Georgia, Eatonton; [4]The Georgia Sea Grant College Program, The University of Georgia

THE CREATION OF A LIVING SHORELINE USING RECYCLED OYSTER SHELL AND NATIVE PLANTINGS TO CONTROL EROSION ON TYBEE ISLAND, GEORGIA

Estuaries are a vital component of the coastal ecosystem and provide numerous ecosystem services and habitat for ecologically and commercially important species. Shoreline hardening to control erosion or protect vulnerable upland areas is increasing and have traditionally been stabilized using bulkheads which break the connection of the estuaries to the upland. An alternative to traditional shoreline hardening that is being examined for use in Georgia are living shorelines. In the spring and summer 2015 a living shoreline was created at the Burton 4-H center on Tybee Island to control erosion that was threatening existing structures. To evaluate the ecosystem response to the living shoreline we examined the amount of oyster habitat pre and one year post construction. This analysis will be presented. In addition to the habitat value, the living shoreline has become an outdoor classroom and invaluable teaching tool.

(2.3.3) **Risse, Mark**
The Georgia Sea Grant College Program, The University of Georgia

A BLUEPRINT FOR OYSTER AQUACULTURE IN GEORGIA

Georgia is launching a new industry in aquaculture, cultivating oysters for the lucrative half-shell market. Na-tionally, consumer demand for high-quality, raw-bar-grade oysters is rising. At the same time, the regions tradition-ally sourcing this product have experienced a decline in supply, resulting in an increase in price and profit margin. This has created a prime opportunity for Georgia to enter the aquaculture market. The University of Georgia, Georgia Department of Natural Resources and Georgia Department of Agriculture are partnering to expand the Georgia aquaculture industry, with the goal of gaining enough growers to sustain a pri-vate, commercial oyster hatchery. By working together and leveraging resources, this part-nership seeks to follow the example of Virginia, who has shown what state investment in the single oyster market can produce. In just 10 years, Virginia expanded their oyster harvest value from $196,125 in 2004 to $27.96 million in 2014. We have developed a blueprint for Georgia Oyster Aquaculture that outlines critical needs to grow the industry from its current state of 10 permitted growers to 50 in the next 5 years. Using both state and federal investment, the University of Georgia Oyster Hatchery opened in 2015 at the UGA Shellfish Research Laboratory on Skidaway Island, Georgia. At full capacity, the hatchery will produce 15 million oyster spat with an estimated harvest value of $3- 5.25 million. Additional investment in oyster research, training for shell-fish growers, resource management and consumer safety is needed to sustain continued growth and realize the goals and actions outlined in this collaborative Blueprint for Georgia Oyster Aquaculture. In addition to the impacts on economic development, it is expected that expansion in this industry will lead to water quality improvements through education and restoration.

(2.3.4) **Henning, Frank**, Jon Calabria, John Fry, and Alton Anderson
National Park Service

ASSESSING PLANT STRESSES ASSOCIATED WITH THE APPLICATION OF BRACKISH WATER FOR WILDLAND FIRE MANAGEMENT ON CUMBERLAND ISLAND, GA

Cumberland Island National Seashore (CUIS) manages over 19,000 acres of upland habitat with vegetation communities that are primarily either fire-adapted or fire-dependent. Along with fire ecology, land managers have other considerations that periodically require fire suppression. During peak fire periods, fresh water on the island is typically insufficient or unavailable for fire suppression, and mainland sources are not practical. Helicopters can effectively suppress fires by delivering brackish water from Cumberland Sound, but park managers need additional information to understand impacts on vegetation. A RCBD study with four replicates was initiated on July 7, 2016 to monitor changes in soil pore water electrical conductivity (EC), photosynthetic stress, and soil sodium concerns associated with CUIS wildfire suppression activities. Dielectric probes were installed to monitor pore water EC throughout the study. On Aug 16, brackish water with a salinity of 35.35 psu was collected from Cumberland Sound and applied as spot dump, line holding, trail drop, and control treatments (3, 1, 0.5 and 0 gal ft-2 respectively). An EC value of 3.125 dS m-1 (2 psu) was selected a conservative threshold indicative of saline soils that impair tree growth in southeastern forests. Excluding the untreated control, time required for EC to return below this threshold was 34.9 days, and no treatment differences were found. Quantum yield of photosystem II (Fv/Fm) of leaf tissue in each trt*rep combination was measured on Aug. 16 prior to fire suppression treatments and at the end of the study on Nov.14. No treatment differences were found, and mean Fv/Fm values were 0.72 and 0.71 for Aug and Nov. respectively. Similarly, neither differences in soil sodium concentration, nor sodium adsorption ratio were detected in the 0-15 cm depth for soils sampled on Nov. 14. Future research will investigate long term impacts of brackish water applications on plant communities.

(2.3.5) **Behl, Mona**
The Georgia Sea Grant College Program, The University of Georgia

SCIENCE SERVING GEORGIA'S COAST: THE GEORGIA SEA GRANT COLLEGE PROGRAM

The Georgia Sea Grant College Program is a unique partnership that unites the resources of the federal government, the state of Georgia and universities across the state to create knowledge, tools, products and services that benefit the economy, environment and citizens of Georgia. Georgia Sea Grant is administered through the National Oceanic and Atmospheric Administration (NOAA) and is one of 33 university-based Sea Grant Programs around the country. Georgia Sea Grant activities began in 1971 under the leadership of Edward Chin. In 1980, the Department of Commerce, under section 207 of the National Sea Grant Program Act, designated UGA as the nation's 15th Sea Grant College Program. Today, Georgia Sea Grant along with its education and outreach arm, UGA Marine Extension, works to improve public resource policy, encourage far-sighted economic and fisheries decisions, anticipate vulnerabilities to change and educate citizens to be wise stewards of coastal ecosystems.

SESSION 3 ABSTRACTS: WEDNESDAY 1:30-3:00 PM

Track 3.3A – Room F/G: Groundwater

(3.3.1) **Gordon, Debbie W**, and Gerard J Gonthier
U.S. Geological Survey, South Atlantic Water Science Center, 1770 Corporate Drive, Suite 500, Norcross, GA 30093

HYDROLOGY OF THE CLAIBORNE AQUIFER IN SOUTHWESTERN GEORGIA

The USGS, in cooperation with the Georgia Environmental Protection Division, conducted a study to define the hydrologic properties of the Claiborne aquifer and to evaluate its connection with the Upper Floridan aquifer in the lower Apalachicola-Chattahoochee-Flint River Basin in southwestern Georgia. Borehole geophysical logs were collected from seven wells throughout the study area and two 72-hour aquifer tests were conducted in Mitchell and Early Counties, Georgia. The data collected from the wells and the aquifer tests, along with pre-existing data, were used to determine extent and properties of the Claiborne aquifer. The top of the Claiborne aquifer extends from an altitude of about 200 feet above the North American Vertical Datum of 1988 (NAVD 88) in Terrell County, Georgia to 402 feet below NAVD 88 in Decatur County, Georgia. The base of the aquifer extends from an altitude of about 60 feet above NAVD 88 in eastern Sumter County, Georgia to about 750 feet below NAVD 88 in Decatur County, Georgia. Aquifer thickness ranges from about 70 feet to 400 feet in the study area. Transmissivity estimates of the Claiborne aquifer range from about 700 to 4,700 square feet per day in the study area. These values are based on three previous aquifer-test analyses, analyses of the two aquifer tests conducted for this study, and five transmissivities estimated from specific capacity tests. Aquifer-test data from Mitchell County, Georgia indicate a small amount of leakage; however, no drawdown was measured in the overlying Upper Floridan aquifer as a result of pumping. This leakage was assumed to be coming into the Claiborne aquifer from the underlying Clayton aquifer, however the Clayton aquifer was not directly assessed as a part of this study.

(3.3.2) **Gonthier, Gerard J**., and Debbie W Gordon
USGS

CLAIBORNE AQUIFER HYDRAULIC PROPERTIES, BASED ON TWO AQUIFER TESTS, SOUTHWESTERN GEORGIA, 2015–2016

Two 72-hour constant-discharge aquifer tests were performed in southwestern Georgia as part of a study in cooperation with the Georgia Environmental Protection Division to determine the hydraulic properties of the Claiborne aquifer and the degree of its connection with the overlying Upper Floridan aquifer. At each site, one Claiborne aquifer well was pumped while water-levels were monitored in the Claiborne and Upper Floridan aquifers. The two sites are 23 miles apart. Both showed no indication of leakage between the Upper Floridan and Claiborne aquifers. The aquifer-tests indicated quite different groundwater and geohydrologic conditions within the Claiborne aquifer at each site, however.

One aquifer test was performed at the University of Georgia, Stripling Irrigation Research Park, located in Mitchell County, Georgia, during December 15–18, 2015. Here the Claiborne aquifer is 260-feet (ft) thick, and the well was pumped at 579 gallons per minute (gal/min). Water-level decline in the Claiborne aquifer monitor well (drawdown) indicated wellbore-storage effects and leakage into the Claiborne aquifer, likely from the underlying Clayton aquifer, based on model calibration. A two-dimensional, axisymmetric, transient groundwater-flow model (MODFLOW-2005) simulated this drawdown and estimated aquifer transmissivity and storage coefficient at 1,500 feet squared per day (ft2/d) and 0.0006, respectively.

Another aquifer test was performed at the Newberry site, located in northeastern Early County, Georgia, during March 14–17, 2016, where the Claiborne aquifer is 55-ft thick and was pumped at 291 gal/min. Drawdown indicated the presence of a restricted- or no-flow boundary and recorded water-levels indicated very slow recovery from previous pumping events. Transmissivity and storage coefficient of the Claiborne aquifer were estimated at 700 ft2/d and 0.0004, respectively, using Theis concepts and temporal superposition.

(3.3.3) **Jones, L. Elliott**
U.S. Geological Survey, 1770 Corporate Drive, Suite 500, Norcross, GA 30093

SIMULATION OF THE GROUNDWATER BUDGET IN SOUTHWESTERN GEORGIA AND PARTS OF ALABAMA AND FLORIDA, 2008-12

In the lower part of the Apalachicola–Chattahoochee–Flint River (ACF) basin, groundwater in the Upper Floridan aquifer is the primary source for agricultural irrigation and public supply, and is vital to the regional economy. The primary goal of the ACF Basin Focus Area Study of the USGS Water Census is to evaluate water availability in the watershed in as fine detail as possible. A MODFLOW groundwater model is being developed to better understand the dynamics of the groundwater-flow system and to assess the flow of water in the Upper Floridan aquifer to and from streams and to pumped wells. The groundwater model will simulate aquifer-stream flow to and from the main-stem rivers and to 118 tributary streams represented as flow boundaries. Monthly estimates of recharge to the Upper Floridan aquifer in the lower ACF will be obtained from a PRMS (Precipitation-Runoff Modeling System) watershed model of the entire ACF basin. Groundwater-withdrawal rates for irrigation in Georgia will be estimated using an extensive network of agricultural water meters. Agricultural groundwater use in Florida and Alabama will be estimated using available meter data and user-supplied records. Monthly groundwater budget components for 2008–12 will be simulated for the entire model area and for six subbasins within the ACF. Groundwater storage loss and inflows from recharge, surface waters (rivers and lakes), and regional boundaries will be balanced with groundwater storage gain and outflows to surface waters (rivers, streams, swamps, and lakes), wells, and regional boundaries. Preliminary results of the groundwater model will be presented.

(3.3.4) **Rooks, Edward**
Georgia Environmental Protection Division, 2 Martin Luther King Jr. Dr. S.E., Suite 1362 East Tower, Atlanta, Georgia 30334

THE ROADMAP TO WELL PERMITTING

Wells can be constructed for a variety of purposes. Most require some type of permission in order to be installed or to be utilized. While there is no single "one-size-fits-all" document that explains the requirements are for all situations, this presentation provides a roadmap to assist with the permitting process.

(3.3.5) **Perry, Calvin**, Vasileios Liakos, Xi Liang, Wesley Porter, Michael Tucker, and George Vellidis
UGA

A DYNAMIC VARIABLE RATE IRRIGATION CONTROL SYSTEM

Currently variable rate irrigation (VRI) prescription maps used to apply water differentially to irrigation management zones (IMZs) are static. They are developed once and used thereafter and thus do not respond to environmental variables which affect soil moisture conditions. Our approach for creating dynamic prescription maps is to use soil moisture sensors to estimate the amount of irrigation water needed to return each IMZ to an ideal soil moisture condition. The UGA Smart Sensor Array (UGA SSA) is an inexpensive wireless soil moisture sensing system which allows for a high density of sensor probes. Each probe includes three Watermark sensors. We use a modified van Genuchten model and soil matric potential data from each probe to estimate the volume of irrigation water needed to bring the soil profile of each IMZ back to 75% of field capacity. These estimates are converted into daily prescription maps which we downloaded remotely to a VRI controller thus creating a dynamic VRI control system. During 2016, we conducted an on-farm experiment to assess our system. We worked with a producer in a 330ac field in southwestern Georgia. The field was divided into alternating conventional irrigation and dynamic VRI strips with each strip 162 rows wide. The conventional strips were irrigated uniformly based on the producer's recommendations. We divided the VRI strips into IMZs and after planting we installed UGA SSA probes in each of the IMZs. The data from the probes were used to develop daily irrigation scheduling recommendations for each IMZ. The recommendations were converted into a daily prescription map and downloaded remotely to the pivot VRI controller. When an irrigation event was initiated, the VRI-enabled pivot responded dynamically to soil moisture conditions. We will present the design of our dynamic VRI control system and the results from the 2016 study.

SESSION 3 ABSTRACTS: WEDNESDAY 8:30-10:00 AM

Track 3.3B – Room T/U: Innovative Approaches: Utilizing Rainwater, Groundwater and Condensate at EVERY Commercial Building?

Session Organizer: **Richard Hanson** - *Georgia Water Tanks, LLC, 3577 Chamblee Tucker Rd., Suite A 223, Atlanta, GA 30340*

Most commercial buildings with more than 1 basement level have to collect and dump groundwater into the storm drain or sewer, in order to prevent moisture problems. Cousins Properties decided to use that water, estimated to be over 2,000,000 gallons per year at the Spring @ 8th building, instead of wasting it. By utilizing groundwater, rainwater, and condensate, Cousins expects to reduce operating costs by over $50,000/year. This presentation describes the design changes used to build "LEED Platinum Class A Office Space at Market Rates." Furthermore, many graywater treatment systems are abandoned within 5 years of commissioning, because the operations staff don't want to maintain and tweak them. NSF has created a performance standard that forces manufacturers to create a product that works without the constant attention. Now that several manufacturers have been certified, it's time to reconsider graywater treatment. The presenters discuss lessons learned and current design standards for both residential and commercial buildings.

Panelists:

Richard Hanson – *Georgia Water Tanks, Atlanta, GA*
A 1989 graduate of Georgia Tech, Richard has worked in the field of water pressure control his entire career. First as a manufacturer's rep for SyncroFlo, Watts Regulator, and other control valve companies, covering southeast Georgia and portions of Atlanta. Then 20 years at SyncroFlo, in every department: Production, Purchasing, Engineering, Marketing, Sales, IT, Finance, Accounting, Field Service, Commissioning, etc. It was there that he discovered rainwater harvesting, starting in the the late 90's with Gwinnett County Schools' use of alternative water supplies for turf irrigation, cisterns in Puerto Rico, and culminating in offering treatment and pumping skids. After a friendly parting, now moving back into the rep business for Georgia, eager to find new ways to serve the water control needs in the commercial, industrial, and residential markets. His goal is for rainwater harvesting to be part of the design of most projects, in areas where stormwater management is required.

Stanton Stafford - *Integral Consulting Engineering, Atlanta, GA*
Stanton Stafford is the Managing Principal of Integral Consulting Engineering, the Atlanta, Georgia Studio of Integral Group. Recognized as a green building and sustainability expert, Stanton brings over 15 years of experience designing, modeling and commissioning mechanical systems for higher education, healthcare, science & technology, government and commercial facilities. With a goal of maximizing the potential of every building, Stanton's passion is working with clients from IDEAS-to-IMPLEMENTATION-to-IMPACT to drive value through high performance design and operations solutions.

Nationally, Stanton is Chair-elect of ASHRAE Technical Committee 2.8 – Building Environmental Impacts and Sustainability where he is currently co-authoring the Fifth Edition of ASHRAE's Green Guide. Locally, he serves as the Immediate Past Chair of the Board of Directors of the Lifecycle Building Center of Greater Atlanta, an entrepreneurial non-profit focused on building material salvage and reuse. Stanton is also a Charter Member of the University of Georgia's Mechanical Engineering Advisory Board and has been recognized as a member of Engineering News Record Southeast's Top 20 Under 40 (2015), the Atlanta Business Chronicle's 40 Under 40 (2015) and Georgia Trend Magazine's 40 Under 40 (2016). Stanton also served on the Board of Directors for the USGBC-Georgia Chapter from 2012 to 2016.

SESSION 3 ABSTRACTS: WEDNESDAY 1:30-3:00 PM

Track 4.3 – Room L: Hydrologic Hazards

(4.3.1) **McCallum, Brian**[1], Jeanne C. Robbins[2], and John M. Shelton[3]
[1]USGS South Atlantic Water Science Center (SAWSC), Norcross, Georgia 30093; [2]USGS South Atlantic Water Science Center (SAWSC), Raleigh, North Carolina, 27607; [3]USGS South Atlantic Water Science Center (SAWSC), Columbia, South Carolina, 29210

USGS MONITORING FOR REGIONAL STUDIES AND CRITICAL EVENTS

The USGS (USGS) has collected high-quality streamflow, groundwater, and water-quality data according to nationally-consistent protocols for many decades. Historically, the effort behind these datasets were managed in a state-based organizational approach with sharing of resources between states on an as-needed basis. Recently, with the merger of the North Carolina, South Carolina, and Georgia USGS offices into the new USGS South Atlantic Water Science Center (SAWSC), the increased ability to share resources across state lines has greatly enhanced the ability of USGS to support larger regional studies and to respond to large-scale natural disasters, including our recent responses to Hurricanes Joaquin and Matthew. This provides enhanced support to our federal and state partners by controlling future costs and providing large-scale datasets that cross political boundaries. In addition to the more than 780 real-time streamgages in the 3-state region, SAWSC operates a number of unique networks including river cameras to view streamflow levels in real-time, real-time water-quality monitoring sites with a BacteriAlert program and selected sites equipped with real-time anadromous fish tracking capability. Additionally, the national applications to receive email and text-message user defined notifications via WaterAlert and WaterNow were developed in the South Atlantic Water Science Center. The SAWSC is constantly investigating new technologies to improve monitoring capabilities. Some examples of these technologies include the operation of an autonomous underwater vehicle for the collection of a wide-range of hydrologic parameters and the development of a real-time bridge-pier scour monitoring program. The goal of this presentation is to provide a current assessment of the SAWSC monitoring networks, explore the future directions of hydrologic monitoring in the three-state region, and demonstrate some examples of how streamlining the organizational structure has benefitted the data products and partners of the USGS.

(4.3.2) **Frantz, Eric**[1], Michael Byrne[2], Andral Caldwell[3], and Stephen Harden[4]
1USGS South Atlantic Water Science Center; 2USGS Caribbean – Florida Water Science Center; 3USGS South Atlantic Water Science Center; 4USGS South Atlantic Water Science Center

USGS MONITORING STORM TIDE AND FLOODING FROM HURRICANE MATTHEW

The USGS (USGS) deployed a temporary monitoring network of water-level and barometric pressure sensors at 288 locations along the Atlantic coast from Florida to North Carolina to record the timing, areal extent, and magnitude of hurricane storm tide and coastal flooding generated by Hurricane Matthew in October 2016. During the storm, real-time water level data collected at both the temporary rapid deployment gages and long-term USGS streamgages were relayed immediately for display on the USGS Flood Event Viewer webpage to provide emergency managers and responders with critical information for tracking flood-impacted areas and directing assistance to impacted communities. In the days immediately following Hurricane Matthew, storm-tide data collected with non-real-time water-level and wave-height sensors were retrieved and processed for subsequent dissemination on the Flood Event Viewer. Along with the sensor retrieval, 543 high water marks were surveyed in the impacted areas. The high water mark information is also available on the Flood Event Viewer. Data collected from this event can be used to evaluate the performance of storm-tide models for maximum and incremental water level and flood extent as well as the site-specific effects of storm tide on natural and anthropogenic features of the environment. This presentation will describe the factors for selecting the temporary sites, the equipment used, methods for obtaining the peak water level, and usage of the USGS Flood Event Viewer. It will also discuss the various ways these data are used by forecasters and emergency management officials during the event and researchers after the event.

(4.3.3) **Hamill, Todd**
NWS - Southeast River Forecast Center

SOUTHEAST RIVER FORECAST CENTER FORECASTS AND THE IMPORTANC OF PARTNERSHIPS IN THE SOUTHEAST

Decision Support Services in the National Weather Service (NWS) have become an integral part of the work that is done in this agency. The river forecast center's role has become more prominent in the last 20 years. Through numerous droughts and floods, communications with our general user groups and key partners has become essential to making effective river forecasts. Partners like the USGS and the Corps of Engineers provide vital data to produce these forecasts. This presentation will describe Southeast River Forecast Center operations and the importance of the partnerships to produce accurate forecasts.

(4.3.4) **Schaffer, Christopher**
Southeast River Forecast Center/NWS/NOAA, Peachtree City, GA, 30269

QUANTITATIVE PRECIPITATION ESTIMATES OF THE SOUTHEAST RIVER FORECAST CENTER

The Southeast River Forecast Center (SERFC) creates hourly multisensor precipitation estimates, which are used as input to a hydrologic model. These estimates have a variety of users outside of SERFC, both in the private and public sector. The estimates are frequently considered by water resource professionals when evaluating drought conditions across the Southeast U.S. This presentation will describe how the precipitation estimates are created at SERFC and where they can be accessed online.

(4.3.5) **Jiang, Feng**, Hailian Liang, Menghong Wen, Jeffrey Regan, Dongha Kim, Inchul Kim, and Wei Zeng
Georgia Environmental Protection Division, 2 Martin Luther King Jr. Dr. S.E., Suite 1352 East Tower, Atlanta, Georgia 30334

HYDROLOGIC VARIATIONS RENDERED BY MOTHER NATURE

Declines in the magnitude of regulatory flows have been noticed in technical evaluations of hydrologic records as well as in reviews of permit applications. Anthropogenic impacts such as human consumptive use of water and reservoir regulations cannot fully explain such declines. The magnitude of the former is dwarfed by the magnitude of flow declines, while the latter can be removed by only looking at runoff materialized in unregulated drainage areas (i.e. incremental flows). Precipitation records have been carefully reviewed from the beginning of instrumentation measurement to 2013. A demarcation of pre-development and post-development has been set at 1975. Substantial deviations of monthly precipitation have been identified in the post-development period in comparison to the re-development one. Higher winter precipitations and lower spring and summer precipitations are characteristic of the post-development period in comparison to the pre-development one. Lower low flows in the modern period can at least be partially explained by such deviation of monthly precipitation patterns.

SESSION 3 ABSTRACTS: WEDNESDAY 1:30-3:00 PM

Track 5.3 – Room R: Savannah River Clean Water Fund

Session Organizer: Braye Boardman, *Savannah River Clean Water Fund*

Background: The Savannah River Clean Water Fund got started in 2009 with a South Low Country (SOLO) Task Force comprised of state and federal government agencies, local environmental non-profit organizations, landowners, businesses and private interests, with the agreement that there was an explicit connection between the land resources of the Savannah River Basin and the impact on raw water supplies. Shortly thereafter, a Special Steering Committee was formed with the addition of key stakeholders: water utilities and state regulatory agencies with the mission of protecting the river corridor and watershed. As a result, the Savannah River Clean Water Fund (the Fund) was formed in August 2014 to support conservation, protection and enhancement of the water quality in the Savannah River Basin including the streams, creeks tributaries and lands adjacent to the basin.

This session will start with a 25 min. presentation on the SRCWF and the work being done in the basin. After that, the panelist will each give a 8-10 min. (50 min.) presentation on their work and the intersection with the SRCWF. The rest of the time we be devoted to questions.

Panelists:

Braye Boardman - *Executive Director, Savannah River Clean Water Fund*
Braye Boardman is the executive director of the Savannah River Clean Water Fund – a source-water protection fund that is focused on land conservation, land management, and science/research to benefit water quality in the 2.8 million-acre lower portion of the Savannah River Basin.

Braye has had a love for the outdoors since he was a child, and has been an active conservationist in the southeast region for the last 18 years. He has been involved in leadership roles with numerous organizations including the Nature Conservancy, Georgia Conservancy, and was one of the founding members of the Central Savannah River Land Trust. Braye was appointed by Governor Sonny Purdue to the Governor's Committee on the Savannah River and by Lieutenant Governor Casey Cagle to the Savannah-Upper Ogeechee Regional Water Council.

Braye Boardman is a native of Augusta, Georgia, and graduated from the College of Charleston. Braye and his wife, Tori, have been married for over twenty-three years and have two children - a 18-year-old son and a 19-year-old daughter.

Eric Krueger - *Director of Science and Stewardship, The Nature Conservancy – South Carolina*
Eric Krueger is the Director of Science and Stewardship for The Nature Conservancy's South Carolina Chapter., and has 22 years of experience in river management, and wetland and forest management and restoration. He currently manages Chapter programs in freshwater conservation, forest management and restoration, and marine restoration. Eric's project experience includes 14 years on managed rivers in South Carolina to produce environmentally compatible flows through major hydropower facility re-operation, and targeting land conservation to protect water quality and stream function.

Eric received a Master's degree in Geosciences from the University of Wisconsin in 1996. His research studied the relationships of groundwater to wetland vegetation patterns. While completing his degree, Eric was employed for two years by the US Forest Service in Michigan analyzing stream habitat quality. After graduation, Eric worked for the Coeur d'Alene Tribe of Idaho as a hydrologist, and later as the Water Resource Program Manager. Eric also worked three years in for the Idaho Transportation Department implementing wetland mitigation and protection activities. Eric joined the South Carolina Chapter in September, 2002.

Sharon Holbrooks - *Conservation Easement Specialist, U.S. Department of Agriculture - Natural Resources Conservation Service*
Sharon has been the Conservation Easement Specialist with the USDA Natural Resources Conservation Service in Athens, Georgia for 7 years. Her main role is in statewide implementation of the Agricultural Conservation Easement Program (ACEP), which purchases easements on wetlands and surrounding uplands (Wetlands Reserve Easement (WRE) program), as well as agricultural land (Agricultural Land Easement (ALE) program), for permanent protection, enhancement, and restoration. Sharon also works on all of NRCS Georgia's other conservation easement programs, and serves as the main point of contact for the Regional Conservation Partnership Program (RCPP). Prior to this job, she worked as a Private Lands Biologist for the Georgia Department of Natural Resources (GA DNR), Wildlife Resources Division, Nongame Conservation Section. Sharon graduated from the University of Georgia Warnell School of Forestry and Natural Resources with a bachelors and master's degree in wildlife management in 2004 and 2007 respectively. Sharon currently serves as Board Member At Large on the Georgia Chapter of The Wildlife Society, as a member of the University of Georgia Warnell School of Forestry and Natural Resources Alumni Steering Committee, and is an alum of the Institute for Georgia Environmental Leaders (IGEL) class of 2015.

Hazel Cook - *Executive Director, The Central Savannah River Land Trust*
Hazel has over 15 years of experience in public policy, conservation and environmental law, grant writing, graphic design, and business administration. She holds a Bachelors of Arts in Political Science from Penn State University's Schreyer Honors College, and a Masters of Arts in

International Environmental Policy from the Middlebury Institute of International Studies at Monterey. Hazel has been a part of the Land Trust since 2004, and is honored to have watched the organization grow from its humble beginnings into a nationally-accredited land trust with over 7,000 acres of preserved land in twelve Georgia and South Carolina counties. Outside of her role at the Land Trust, Hazel's hobbies include outdoor adventure sports, international travel, organic gardening, ballroom dancing, and performing aerial silks in the circus. She and her husband, Taylor, also run Piccolina Farm, a small organic farm that supplies fresh healthy vegetables to local farmer's markets.

Glen R. Behrend, P.E. - *Manager, Nonpoint Source Program, Watershed Protection Branch, Georgia Environmental Protection Division*
Glen Behrend is the manager for the Nonpoint Source Control Program of the Georgia Environmental Protection Division. Responsibilities include stormwater, erosion and sediment control, floodplain management, water quality grants (319), and outreach. Glen has also served EPD as Water Quality Monitoring Manager, Technical Manager for the State-wide Water Plan, and a wastewater engineer. Glen has a Bachelors from Mercer University in Environmental Engineering and a Masters from the University of Florida in Systems Ecology.

Laura Walker - *Water Resources Environmental Administrator, Public Works and Water Resources Bureau, City of Savannah*
Laura Walker is a "water first" person who just reached her 10-year anniversary with the City of Savannah Water Resources Department. Most of her career has been spent protecting the water resources of the May River, SC, the Vernon River, GA and now the Savannah River. She has a degree in Biology and has studied Civil Engineering Technology and Public Administration. As a Master Naturalist, she works very hard preventing nature deficit disorder. She has a 10-year-old son and they both really drink tap water every day.

SESSION 3 ABSTRACTS: WEDNESDAY 1:30-3:00 PM

Track 6.3 – Room K: Water As Education - K-12 & Undergraduate

(6.3.1) **Musengo, Shawn**, and Sudhanshu Sekhar Panda
University of North Georgia, Gainesville, GA

WETLAND LOSS - AN ARTIFICIAL ENVIRONMENTAL DISASTER: A CASE STUDY OF OKEFENOKEE SWAMP

The Okefenokee Swamp, located in the southeastern corner of Georgia, encompassing most of Charlton and Ware counties and parts of Brantley and Clinch counties, is the largest swamp in North America, and covers about 700 square miles. The swamp has more than 1,400 square miles of watershed, and about "85 percent of the water leaving the Okefenokee is carried by the Suwannee River to the Gulf Coast of Florida. The St. Mary's River, which flows into the Atlantic, drains the remainder of the swamp. Eroded soil moving out of the catchment area is deposited in the swamp converting the wetland into uplands. As wetlands are considered the kidney of the earth, its shrinking size is alarming for the earth's sustainable management. The Okefenokee Swamp's wetland has been receding in size over the past forty years. As a consequence of this lowland to upland conversion, several major fires have broken out in the swamp recently. In 2002, three fires collectively known as the Blackjack Bay Complex Fires burned more than 95,000 acres. The fire started by lightning and was allowed to burn in order to revitalize the swamp. Again, in 2007 a massive fire known as The Big Turnaround was raging in the swamp. The goal of the study was to analyze the wetland loss of the swamp over the years, determine the land cover changes inside the study area, and decipher the reasoning behind such dramatic changes to the wetland. Georgia GLUT and NLCD classified imageries were obtained for the years 1974, 1985, 1992, 2001, 2005, and 2011. The images were extracted to the study area mask. They were reclassified to obtained the wetland, agriculture, forest, water, and pasture classes. National Agricultural Imagery Program (NAIP) image tiles were obtained, mosaicked, masked to study area, and classified using unsupervised classification process. Reclassification and Plus tool of ArcGIS was used to complete multi-temporal change analysis of the study area over the years. The spatial land cover changes were mathematically calculated. It was observed that over the last 41 years, the swamp has lost more than 20% of its wetland. Most of them were converted to upland forest or pasture. Therefore, lighting induced wildfire has become a norm in the swamp. We also analyzed the total soil being eroded to the swamp through the development of a RUSLE based soil erosion model. It was found that the wetland conversion to upland is the consequence of severe soil erosion in the agricultural watershed that drains water into it. It became clear that human-induced cause along with some natural activities is diminishing the wetland coverage in this largest swamp in North America. This study would be a warning for environmental managers who deals with the swamp up-keeping.

(6.3.2) **Dinesh, Mallika**[1], and Sudhanshu Sekhar Panda[2]
[1]University of Georgia, Athens, GA; [2]University of North Georgia, Gainesville, GA

FARM SCALE SUSTAINABLE WATER MANAGEMENT DECISION SUPPORT SYSTEM DEVELOPMENT THROUGH GEOHYDROLOGIC MODELS

Erratic weather pattern is a consequence of global warming and climate change. This El Nino and La-Nina based effect is being encountered often over all parts of globe including California. Last year, California entered the fourth year of a record-breaking drought creating an extremely parched landscape forcing strict conservation measures statewide. Very recently, Georgia also encountered such scenario. Therefore sustainable water use is a bigger requirement in today's time, especially in agricultural farms. It could be achieved through site-specific water management (SSWM). Almonds, a major component of farming in California, use up some 10 percent of the state's water reserves according to federal estimates. Iyer farms, spans 1800 acres between the cities of Gustine and Newman in California, needs a steady source of waters supply. The goal of the study was to develop two geohydrologic models to i) determine efficient irrigation scheduling on plot-scale basis through the spatial analysis of soil, hydrology and hydrography of the farm and ii) suggest effective site-specific fertilizer/pesticide application with irrigation water based on the groundwater contamination vulnerability analysis in the farm on plot-scale. An automated geospatial model was developed in ArcGIS ModelBuilder using several characteristics, such as hydrologic group, texture, available water content, drainage, and soil erodibility factors of the soil (gSSURGO) spatial data available for the farm on parcel basis. Geologic data (shallow aquifer availability) of the farm also supported in our decision support on the orchard management, i.e., suggesting type of horticultural plants to grow in which part of the farm. An automated DRASTIC (D = Depth of Water, R = Net Recharge, A = Aquifer Media, S = Soils, T = Topography, I = Impact of Vadose Zone, and C = Hydraulic Conductivity) model was developed in ArcGIS ModelBuilder for the study farm using USGS data for groundwater and hydrology, well points data obtained from California GIS department, gSSURGO soil, geology, hydrography, and precipitation raster data from USDA-NRCS Geospatial Data Gateway. Finally, based on the results obtained from this study, we established the following decision support on the line of sustainable water management in the horticultural farm. They are such as i) grow horticultural crops in appropriate parcels according as their rate of irrigation requirement and water availability in each parcel, ii) improve soils in parcels that are vulnerable to soil erosion and excessive drainage using organic matter amendments so that it would decrease water requirement, and iii) in-stead of using, fertilizers or pesticides mixed with irrigation water, organically improve the soil in parcels that are more susceptible to ground water contamination. This comprehensive geohydrologic model based results were groundtruthed in the farm and shared with the farm owners to uptake the suggested sustainable water management decision support in the farm for efficient fruits and nuts crop production.

(6.3.3) **Duffy, MacKenzie**, and Sudhanshu Sekhar Panda
University of North Georgia, Gainesville, GA

SUSTAINABLE MANAGEMENT DECISION SUPPORT SYSTEM DEVELOPMENT FOR BARROW COUNTY, GA THROUGH FLOOD POTENTIAL ANALYSIS

Since 2002, the National Weather Service uses Flash Flood Monitoring Program (FFMP) and Flash Flood Guidance (FFG) to predict flash flood events. However, these programs contain several deficiencies for several forecast areas in the nation. Developing a GIS based model that incorporates basin physiographic characteristics will allow the hydrologist to better predict flash flood events and the area being affected by such flooding. These flash flood events are very common in recent times. Therefore, a sustainable management decision support to tackle such disaster is a necessity for any county, state, or federal authorities. The goal of this study was to develop a comprehensive sustainable management decision support for county managers of Barrow County, GA, to be able to manage flash flood scenarios in the county in an efficient manner. In this study, we have developed an automated geospatial model to determine the flooding potential (five different scale: very high, high, moderate, low, and very low) in the county. The dynamic GIS model parameters used in the model development are: Year 2011 NLCD land cover map (30 cm resolution) to obtain vegetation spatial dynamics; slope- developed from 10 m DEM for topographic distribution; flow accumulation, derived from the 10 m DEM using the Flow Accumulation tool available with 100-years storm distribution spatial data and annual precipitation spatial distribution data of the state using 1981 – 2010 precipitation record along with mean monthly precipitation spatial data for rainy months (April to October ; and soil texture, hydrologic group, permeability, and drainage attributes, derived from gSSURGO soil data of the state. All these layers were transformed to raster datasets of same resolution (10 m for all) if they were not in raster form using the essential attribute field responsible for flooding potential analysis. The prepared individual raster were reclassified with different assigned weights based on their flood potential ranking, i.e., least flood potential [1] to most flood potential (9). Finally, each individual layers were overlayed with a weighted overlay analysis using 'Weighted Sum' tool of ArcGIS 10.3. For the weighted overlay analysis, each spatial data layer was given certain weights, judged by their influence in flooding potential. Final output obtained was raster cells with value between 1 (least potential) to 9 (most potential) and classified to above mentioned five categories of potential. County parcel data was obtained from the QPublic site. The flood potential map and the parcel map of the county were analyzed using Zonal Statistics feature of ArcGIS. Thus, a flood potential condition for each parcel were obtained. The parcels with high value (buildings, roads, and other costly features) were selected to provide decision support on a proactive sustainable management, in case of a flash flood occur in the county. Other soil, topographic, hydrologic, and landuse management scenarios were developed for county managers so that they would efficiently manage the county in case of such geohazards.

(6.3.4) **Miklas, Kristen**, and Sudhanshu Sekhar Panda
University of North Georgia, Gainesville, GA

MANGROVE CHANGE ANALYSIS IN THE EVERGLADES NATIONAL PARK OF FLORIDA IN THE GLOBAL WARMING AND CLIMATE CHANGE CONTEXT

Because of global warming and climate change, sea-level rise and subsequent changes to the freshwater-forested wetlands along the coast are biggest concern to sustainable environmental managers. It is observed that a 2m tidal surge is probable in the coastal areas submerging the low-lying areas and converting the fresh water forested wetlands to brackish water forested wetlands, thus increasing the coverage of the mangroves in those areas. We tested this hypothesis of increase in coastal mangroves in the Everglades National Park in Florida analyzing temporal imageries and ground trothing. The goal of the study was to analyze and examine the increase or decrease of mangroves in the said study area through the years of 1990, 2000, and 2016. The Everglades National Park is an International Biosphere Reserve, World Heritage Site (UNESCO) and a Wetland of International Importance (RAMSAR Wetland), which spreads over more than 1.5 million acres. Landsat 5 TM (YR-1990), Landsat 7 ETM+ (YR-2000), and Landsat 8 (YR-2016) comprising of the study area were downloaded from USGS Earth Explorer site and processed (mosaicked, extracted to the masked AOI, and developed Soil Adjusted Vegetation Index (SAVI) raster using band 3 and 4) in ArcMap for classification in IDRISI Taiga. ISODATA classification algorithm was used in IDRISI to obtain three main classes- water, mangroves (brackish water forest species), and non-mangrove plants (freshwater forest species) and reclassified again in ArcMap to obtain two (mangrove and rest) land covers. Stratified Random Sampling, Sample, Layer to KML tools were used to verify (ground truth) the classified mangrove pixels for all three dates on Google Earth, which refers to a very high-resolution imagery and even clearing showing the mangrove plant species' absence or presence. In all three (years) cases, more than 90% overall accuracies were obtained in classifying mangroves. Instantly, a tremendous increase in mangroves were observed visually on classified images. We also completed a statistical analysis on the mangroves coverage increase in the study area. It was more than 30% increase over the years from 1990 – 2000 and 2000 - 2016. This increase in mangroves in the Everglades could be attributed to the Everglades National Park Protection and Expansion Act- Dec 13, 1989, the Comprehensive Everglades Restoration Plan (CERP) authorized by Congress in 2000, and above all due to the increase in sea-water inundation in the park due to sea-level rise. Although, the study results provided a positive picture for environmental conservationists but this increase in mangroves may be alarming to the ecosystems in the other low-lying coastal areas, where instant adaptation to such brackish water ecosystems modification may be a challenge.

(6.3.5) **Hawkins, Gary L**., Laura Goss, Jennifer Grogan, Katie Hammond, Brenda, Jackson, and Sonya Jones
UGA

WATER EDUCATION FOR ALL AGES USING HANDS-ON ACTIVITIES

Educating any age person on water quality issues is not limited to classroom type education. Within the UGA College of Agricultural and Environmental Sciences (CAES) the Water Resources Team provides education to different groups in Georgia ranging from the K-12 student to adults. Education for elementary school aged students involves the use of an 8X10 foot water cycle to the Enviroscape Model. Erosion and sediment control are concepts in middle school where we have worked with teachers to educate students. This education has included presentations on the causes and results of erosion and sedimentation. Erosion and sedimentation is also demonstrated to farmers and other groups through the use of rainfall simulators. Teachers are provided educational materials through work with the regional educational service agency (RESA) to conduct water resource trainings which includes hands-on activities to take back to the classroom and help meet STEM concepts. Adult education ranges from festivals to structured classes on various water related issues. Overall, UGA Extension across the state and the Water Resources Team help educate the citizens of Georgia through classes and hands-on educational programs. This presentation will show how UGA Extension uses hand-held tools and other teaching aids to educate citizens of Georgia from K-12 to adults on the importance of water resources.

SESSION 5 ABSTRACTS: THURSDAY 8:30-10:00 AM

Track 1.5 – Room Q: New Perspectives on Drought and Water Management in the Upper Flint River Basin

Session Organizer: **Ben Emanuel**, *American Rivers, Decatur, GA 30030*

After managing through three multi-year droughts since the year 2000, water providers in the Piedmont portion of the Flint River basin met new challenges once again with the severe drought of 2016. The 2016 drought was climatically noteworthy on a variety of fronts. For instance, it developed rapidly following wet conditions, and was associated with extended high-temperature periods. These and other characteristics had implications for reservoir management and municipal drought response which have provided new "lessons learned" even to highly drought-experienced public water systems.
Independent of the 2016 drought per se, multiple water systems in the basin are engaged in planning exercises that are likely to have beneficial impacts on water resources and environmental flows in the basin in both drought and non-drought conditions. Fayette County Water System is reforming some of its reservoir management regimes and developing new customer water conservation efforts that may have impacts on streamflow especially during dry seasons and dry years. Clayton County Water Authority is engaged in system-wide long-range master planning regarding its complex water infrastructure, which includes six treatment plants and constructed wetlands in two river basins. The City of Griffin water system, a regional water provider, is implementing changes to reservoir management and drought response reflective of conditions during the 2016 drought, in addition to studying potential changes to reservoir management to improve basin streamflow.

Meanwhile, through the Upper Flint River Working Group, American Rivers and non-profit conservation partners have developed collaborative approaches with water utilities to address altered hydrology and severe drought impacts in the basin. Examples include a new basin-scale forum for information-sharing among water providers regarding drought response planning and actions, collaboration on proactive new water demand management and stormwater management efforts, and dialogue on the outlook for future water infrastructure planning and environmental health in the river basin.

Moderator:
Ben Emanuel, *American Rivers, Decatur, GA 30030*

Panelists:
Lee Pope *Director, Fayette County Water System, Fayetteville, GA 30214*
Gordon Rogers *Executive Director and Riverkeeper, Flint Riverkeeper, Albany, GA 31701*
Mike Thomas *General Manager, Clayton County Water Authority, Morrow, GA 30260*

SESSION 5 ABSTRACTS: THURSDAY 8:30-10:00 AM

Track 2.5 – Master's Hall: Savannah Harbor

(2.5.1) **Bailey, William**
U.S. Army Corps of Engineers, Savannah District, 100 West Oglethorpe Avenue, Savannah, GA 31401
ENVIRONMENTAL MONITORING DURING CONSTRUCTION OF THE SAVANNAH HARBOR EXPANSION PROJECT
The U.S. Army Corps of Engineers, Savannah District is working with the State of Georgia to deepen Savannah Harbor. The project was approved in 2012 and construction began in 2015. A comprehensive environmental monitoring program is being conducted to [1] provide a baseline to document project impacts, [2] ensure the construction is performed as approved, [3] identify whether the completed project produces more environmental impacts than expected, and [4] ensure the mitigation features perform as intended. This project has nearly 20 components, some of which are nearly 200-miles apart, and will take several years to complete. This paper describes the various components of the monitoring program and the status of the ongoing work.

(2.5.2) **Dayan, Nathan**, and William Bailey
U.S. Army Corps of Engineers, Savannah District, 100 West Oglethorpe Avenue, Savannah, GA 31401
ENVIRONMENTAL CHALLENGES IN THE SAVANNAH HARBOR EXPANSION PROJECT
The U.S. Army Corps of Engineers, Savannah District is working with the State of Georgia to deepen Savannah Harbor. The project was approved in 2012 and construction began in 2015. The project includes several project features which will be constructed over a number of years. As plans and specifications were developed for those features, the designs were refined, sometimes requiring new environmental approvals. This paper describes the changes sought in two major project features – the raw water impoundment and the dredging and placement of cadmium-laden sediments.

(2.5.3) **Riggs, Bryan N**., and Francisco Cubas
Civil Engineering and Construction Management Department, Georgia Southern University, Statesboro, GA
MORPHOLOGY AND TIDAL EFFECTS ON SALINITY PROFILES IN THE SAVANNAH RIVER: PORT WENTWORTH TO I-95
The Savannah Estuary is a unique system which sits at the termination point of the Savannah River and flows into the mouth of the Atlantic Ocean. The estuary is subject to semi-diurnal tides and has been classified as a well-mixed estuary. Additionally, the estuary is subject to low freshwater flow from the upper river basin measured at Clyo, Georgia, and its salinity is vertically uniform, gradually decreasing further up the estuary. The Savannah Harbor Expansion Project (SHEP) will deepen the lower portion of the estuary from its current depth of 42 to a new depth of 48 ft. below mean low lever water. This poses a potential risk to the fresh water intake of the city, located at Abercorn Creek, two miles from the confluence of Abercorn Creek and the Savannah River. Salinity-levels recorded daily at several USGS (USGS) gauging stations along the Savannah Estuary confirmed a gradual decrease in salinity throughout the entire study area as expected. However, a sharp non-gradual decrease in salinity of 188% parts per thousand was observed between Port Went Worth, located near GA 25, and the gauging station at the I-95 Bridge. A review of bathymetry data from the USACE suggested that deep horizontal channels located throughout that stretch of the estuary acted as a salinity trap preventing the advection of chlorides in the salt water further north. Observed changes in salinity profiles further suggested that this unique channel geometries affected the salinity mixing and distribution in this section of the estuary. From an engineering-management perspective this natural phenomenon presented an interesting natural way to control salinity transport, which may be exploited to prevent the advection of salinity further north into the municipal fresh water intake.

(2.5.4) **Duberstein, Jamie A**
Baruch Institute of Costal Ecology and Forest Science, Clemson University, PO Box 596, Georgetown, SC 29442
MONITORING VARIABILITY IN MARSH VEGETATION AND SALINITY PRIOR TO DREDGING THE SAVANNAH RIVER INNER HARBOR
The Savannah Harbor Expansion Project (SHEP) was implemented to allow better traffic flow for large-draft ships, primarily obtained through dredging the shipping channel, which will affect the estuarine dynamics within the Savannah National Wildlife Refuge and adjacent landholdings. Agreed upon in 2013 and moving forward on-the-ground in 2015, SHEP is nearly poised to dredge the inner harbor that extends from the mouth of the river up to the ports. Clemson University has been monitoring surface and sub-surface salinities, as well as seasonal marsh vegetation characteristics and tidal forest tree growth since 2014. Marsh vegetation communities have undergone change unrelated to SHEP, generally reflecting lower salinity conditions that have existed through the pre-construction monitoring; abundant rain in the upstate was sufficient to allow relatively high discharge further into the historically dry months at the three dams that govern flow into the estuary. Water levels and salinity impacts from Hurricane Matthew were captured throughout the monitoring area. Maximum surface salinities reached 16.89 psu at one monitoring station in the estuary, and maximum salinities recorded throughout the monitoring area were interesting spatially. Our monitoring will go forward as SHEP progresses. Major SHEP construction aspects currently underway include two oxygen injection systems and removal of pre-SHEP river tide gate artifacts. Future construction aspects of SHEP include increased flow through the Back River, part of the Savannah 3-river braided network at this point in the estuary. Anticipated effects of flow diversion include a decrease in site salinity and corresponding response in the marsh vegetation along the Back River, and is expected to ameliorate the anticipated loss of freshwater marsh communities along the main stem of the Savannah River upstream of the harbor.

(2.5.5) **Ramos, Stephen**
College of Environment and Design. University of Georgia. 285 S. Jackson St. Athens, GA 30602

THE DEVELOPMENTAL PORT REGION: A KIND OF PLANNING

On June 10, 2014, President Obama signed the Water Resources Reform and Development Act of 2014, which authorized $2 billion federal funds for port projects, including Savannah, GA Harbor expansion. The $706 million Savannah Harbor Expansion Project (SHEP) will dredge 32 miles of the Savannah River navigation channel from 42 to 47 ft: 14 miles of Atlantic Ocean entrance channel and 18 miles of the river upstream to Garden City Terminal. On September 10, 2015, the Dredge Alaska barge began SHEP offshore work after 16 years of litigation. The Port of Savannah is the 4th busiest U.S. container port, and since 2001, the fastest-growing U.S. container port. Its Garden City Terminal is the largest single container terminal in North America, with 9,700 ft of continuous berth space, with Class 1 CSX and Norfolk Southern rail service directly onsite. With SHEP, freight container truck traffic and rail movement is predicted to increase for the metropolitan region from 3.73 million TEU to 6.5 million TEU by 2030. The Colliers International's 2016 2nd Quarter Savannah Industrial Market report includes Information for Chatham, Effingham, Bryan, Liberty counties, GA, and Jasper County, SC, with a total of 47,955,950 sq ft, 2,282,000 sq ft under construction, and a 1.93% vacancy rate (among the lowest in the U.S). Key national industrial land developers in the region include Duke Realty, Panattoni, ID Gazely, Prologis, TPA Group, and Stratford Land. By using Christopher C.M. Lee's criteria for the "developmental city," the paper focuses on the impact of port expansion on regional industrial land-use markets as a way to explore relationships among private sector agents and the various levels of government in the determination of coastal and riparian land management.

SESSION 5 ABSTRACTS: THURSDAY 8:30-10:00 AM

Track 3.5 – Room F/G: Wetlands

(3.5.1) **Nussbaum, Philipp**[1], Laurie Fowler[1], Deborah McGrath[2], and Scott Torreano[2]
[1]UGA, [2]University of the South

BUILDING PUBLIC CONFIDENCE IN WASTEWATER TREATMENT THROUGH CONSTRUCTED WETLANDS

In collaboration with the Odum School of Ecology, the University of the South, located in Sewanee, Tennessee, is undertaking a pilot constructed wastewater treatment wetland project. The primary goal of this project is to determine whether constructed wetlands are cost-effective in removing pharmaceuticals and endocrine disruptors that are incompletely and expensively treated by most conventional wastewater systems and are likely to be regulated pursuant to the federal Clean Water Act in the future. The second major goal is to build public confidence in and awareness of constructed wetlands through a comprehensive community engagement campaign. We conducted a survey in fall 2015 and focus groups in spring 2016 to understand the Sewanee community's current knowledge and perceptions of water issues as well as the means they rely on for this information. The data we collected has, among other things, helped us to develop a project website; the first public event at the wetlands was held in October 2016. Overall, we believe that this project has the potential to encourage other communities throughout the southeastern US as well as internationally to adopt constructed wetlands to treat wastewater more effectively and inexpensively.

(3.5.2) **Divittorio, Courtney**, and Aris P. Georgakakos
Georgia Water Resources Institute, Georgia Tech

A SATELLITE-BASED METHOD FOR WETLAND INUNDATION MAPPING

Hydrologic models of wetlands enable hydrologists and water resources managers to appreciate the environmental and societal roles of wetlands and manage them in ways that preserve their integrity and sustain their valuable services. However, wetland model reliability and accuracy are often unsatisfactory due to the complexity of the underlying processes and the lack of adequate in-situ data. In this research, we demonstrate how MODIS satellite imagery can be used to characterize wetland flooding over time and to support the development of more reliable wetland models. We apply this method to the Sudd, a seasonal wetland in South Sudan that is part of the Nile River Basin. The database consists of 16 years of 8-day composite ground surface reflectance data with a 500 m spatial resolution downloaded from Earth Explorer. After masking poor quality pixels, monthly mean NDWI and NDVI values were extracted. Based on literature and personal accounts describing the Sudd as well as Google Earth imagery, a set of ground truth locations were identified for each land class and monthly distributions of the indices were derived. The indices were then combined in a unique way and statistics of the new distributions were used to classify land types present in the full area of interest. Subsequently, annual statistics were derived from the same indices and used to identify pixels that undergo flooding as well as the timing and duration of flooding for each year (2000–2015). An independent set of ground truth locations were selected for method validation. The combined indices demonstrate high land classification accuracy and outperform the individual indices as well as other existing land classification algorithms. The derived monthly inundation series agrees well with upstream flow records and anecdotal observations. This information is currently being used to develop wetland models as part of a comprehensive modeling system for the Nile River Basin. The new method is general and can be used in Georgia and other regions, such as the Florida Everglades, to develop improved wetland models and support better river basin management. Other potential applications of the method include flood mapping in data scarce areas, snow cover mapping, and satellite-based estimation of hydrologic and water quality variables.

(3.5.3) **Schmidt, John Paul**[1,2]
[1]Odum School of Ecology, University of Georgia, Athens, GA 30602; [2]River Basin Center, University of Georgia

FORESTED WETLAND CONSERVATION ON THE COASTAL PLAIN IN GEORGIA

As a result of federal, state and private efforts, 17.8% of all forested wetlands in Georgia's Atlantic Coastal Plain are in some form of conservation management – 56% as public land and 28% as private land under conservation easement. These impressive sums represent the dedicated efforts of many individuals, organizations, and agencies, yet it is striking that most of the conserved land is public and that only 7.8% of private lands enjoy some measure of protection. In the absence of a continued, but vastly increased land acquisition campaign, most forested wetlands will remain in private hands. An imperative, therefore, is to promote the management of these lands for important environmental benefits including critical wildlife habitat, flood protection, removal of nutrients and pollution from urban and agricultural runoff, water storage that moderates droughts, and carbon sequestration. Importantly, 476,000 acres of forest in the 11 coastal counties are enrolled in either FLPA or CUVA, which require lands to be maintained in forest production – indicating the potential of incentive programs. And yet, within the 38 counties making up Georgia's Atlantic Coastal Plain, zero acres are enrolled under the Environmentally Sensitive category of CUVA/FLPA that requires maintaining land in a natural condition. A key conclusion, therefore, is that the current range of programs available to landowners, as well as existing incentive structures and outreach associated with these programs are clearly not engaging private landowners to conserve mature wetland forests to a degree that protects the valuable portfolio of ecosystem services they provide. As a first step toward developing policy tools that can shift the management of forested wetlands by private landowners toward conservation, we present a series of maps summarizing the extent, condition, and conservation status of forested wetlands on Georgia's Coastal Plain.

(3.5.4) **Bush, Bryana**, and Darold P. Batzer
Department of Entomology, University of Georgia, Athens, GA 30602

SUCCESSION IN INVERTEBRATE COMMUNITIES IN SOUTHEASTERN BEAVER-CREATED WETLANDS

Southeastern US beaver-created wetlands are typically unstable transitory systems due to a history of extreme sedimentation resulting in unstable stream beds and regional weather patterns. The Southeastern US receives high annual precipitation (1300+ mm per year) as well as strong tropical and winter storms that create large stream surges. Dams are frequently breached, rebuilt, relocated, or abandoned which results in complexes of newly-created, mature, and abandoned beaver wetlands. Abandoned beaver wetlands typically retain parts of the original stream channel as well as developing secondary channels and usually fill with some seasonal standing water. To compare invertebrate communities of beaver wetlands among three basic stages of habitat succession, invertebrates were sampled in newly formed (created within 2 years; n = 4), mature (established for >15 years; n = 4), and abandoned wetlands (breached dams; n = 3) in October 2013 and May 2014 in Oconee National Forest in Georgia, USA. There were a relatively high number of taxa (>60 families) in each wetland type, with strong seasonal variation in invertebrate communities. In October, invertebrate communities differed among all successional stages, while in May only the mature beaver wetland communities differed from newly formed or abandoned ponds. This seasonal difference suggests that both seasonal change and longer- term succession strongly control invertebrate community structures in these beaver wetlands. Beaver wetlands are typically found in complexes of clustered wetlands frequently comprised of several successional stages. Variation in invertebrate community structure among successional stages may increase invertebrate diversity at the watershed (or Beta-diversity) scale which could be important in the face of wetland loss, fragmentation, and the impacts of climate change.

(3.5.5) **Carroll, Matt**
University of Georgia, Odum School of Ecology – River Basin Center, Athens, GA

DO INTRODUCED MOSQUITOFISH AFFECT THE FUNCTION OF CONSTRUCTED WETLANDS?

Constructed wetlands used for wastewater treatment emulate the appearance and function of natural wetlands. Diverse assemblages of birds, amphibians, reptiles, and mammals may be attracted to these systems, but disease vectoring organisms, such as mosquitos, may also colonize. To mitigate this issue, many constructed wetlands have introduced fish as a biocontrol of mosquito populations. The most commonly introduced fish, Gambusia sp., is known to prey indiscriminately on macroinvertebrates and small vertebrates. Trophic cascades caused by fish predation on invertebrates have been shown to slow litter breakdown rates in streams. Slower decomposition rates in constructed wetlands may inhibit the wastewater treatment process. I designed an experiment that assessed the impact Gambusia predation has on macroinvertebrate communities and litter breakdown rates at a wastewater treatment wetland in Clayton County, Georgia. Results showed that Gambusia did not significantly affect invertebrate populations or litter breakdown rates and are likely not affecting the wastewater treatment process. Water nutrient levels and the presence of predatory macroinvertebrates appear to be more accurate predictors of invertebrate assemblages; while litter breakdown rates are likely determined by bacteria and fungi colonization.

SESSION 5 ABSTRACTS: THURSDAY 8:30-10:00 AM

Track 4.5 – Room L: Hydrologic Statistics

(4.5.1) **Painter, Jaime A.**
U.S. Geological Survey, South Atlantic Water Science Center, 1770 Corporate Drive, Suite 500 Norcross, GA 30093
THIRTY-FIVE YEARS OF GEORGIA WATER USE INFORMATION: WHAT DO WE KNOW FROM THE DATA AND ITS TRENDS?
Understanding the movement of water from its natural source, through its interaction with human activity, and the quantities of water consumed or returned back to the natural water system is paramount to resource sustainability and societal prosperity. Knowledge of the amounts withdrawn by source, surface water and ground water, and the amounts consumed or returned for further use, is necessary to effectively manage the water resources of Georgia to ensure that all water users have sufficient water supply to meet current and future needs. Water use information, including water withdrawals, deliveries, consumptive use, return flows and losses, have been collected and compiled in Georgia since 1980 as part of an ongoing cooperative agreement between the USGS, South Atlantic Water Science Center and the Georgia Department of Natural Resources, Environmental Protection Division. Statewide, annual water withdrawal totals have averaged 5.6 billion gallons per day since 1980 and showed a decrease from year 2000. During the 35-year history of the Georgia water-use program, natural and human-induced alterations have resulted in observed changes in water use. Driving forces behind the observed water-use changes include 1) population changes in number and location; 2) Five periods of major drought 3)Water conservation efforts and education programs initiated by state and local governments and water utilities, and; 4) changing water needs for power generation, industry, and agriculture activities. Page Break M. Harris comments: I know there are a lot of mark-ups and comments, but all in all I think it's a good abstract. The material you are covering will be of interest to multiple audiences. Keep this presentation in your repertoire; there will probably requests/opportunities for you to present it at other conferences. It's fitting (and maybe ironic) that my WSC, the LMG, was reminded a few days ago about the basic guidelines for the content of conference abstracts. Apparently, supervisors have reviewed a few abstracts that don't follow USGS fundamental science practices. Here's what they sent out to us in brief: 1. Data that are published in approved reports, data releases, or databases can be included without reservation; 2. Interpretive statements drawn from approved reports can be included without reservation; 3. Provisional, unpublished data may be included with appropriate qualifiers--"Preliminary analysis shows an increase of about 7 percent in nitrate concentrations between 2008 and 2012."; 4. Interpretive statements attributing cause and effect should NOT be included UNLESS they appear in an approved interpretive report. The basic principle is that we should never use abstracts as the sole publication for important interpretive results. This reminder refocused my review of your abstract. And I have a couple of concerns with the interpretive statements in your abstract. My concern with the statements of "natural and human-induced changes…resulted in observed changes in water use" and "driving forces behind water-use changes in GA include…" are that they are interpretive statements based on water-use data that were published for 1980 – 2010, but 2015 data have yet to be published (right? I may be wrong). Also, these statements appear to me to be cause and effect statements (because of natural and human-induced changes, we observed water-use changes and they are due to 1 – 5 driving forces), or are the results correlation rather than causation? They will have to be backed up with explicit methodology and citations where necessary. I think you will be able to do that with driving forces 1 – 4. I am concerned about driving force #5, though. How do you make the connection between how water saving technologies and water efficiency measures effect changes in water use (I'm assuming decreases in withdrawals and consumption)? I'm sure you explain that in your presentation, I just want to make sure the connection between more efficient technologies/measures and decrease water use is either clearly expressed or that the results are worded in a way that doesn't imply "water saving technologies and water efficiency measures resulted in decreased water use" without any backup evidence. I've seen that in multiple water-use reports and presentations and the science program wants to move away from blanket statements like that. Please be vigilant in your interpretations.

(4.5.2) **Stephens, Timothy1**, Brian Bledsoe[1], Wei Cui[1], Tyler Cromey[2], and Benjamin Gallagher[2]
[1]Institute for Resilient Infrastructure Systems, University of Georgia, Athens, GA 30605; [2]Southern Company, Birmingham, AL 35203
LOW FLOW TRENDS AT SOUTHEAST U.S. STREAMFLOW GAGES
The southeast U.S. is widely perceived as a water rich region, yet recent droughts, highly variable streamflows, and rapidly growing demands for water have revealed vulnerabilities and the potential for widespread water scarcity. Recent studies have shown decreasing trends in low flows at many stream gages across the region, but have failed to identify the causal mechanisms underlying these trends. We describe low flow trend analyses of regional stream gage records in the southeast U.S. to assess water availability for multiple uses including thermoelectric power production. Low flows in gage records are quantified as the annual minimum 7-day mean streamflow. Statistical analyses, including the Mann-Kendall, Pettitt, and Ljung-Box tests are used to assess monotonic trends, the presence of abrupt shifts in data, and autocorrelation, respectively. We compare our results with other studies assessing trends in low flows and perform type II error analysis to quantify the likelihood of erroneously declaring stationarity in low flows. A type II error analysis is of particular importance when the consequence of missing an effect in the presence of one, results in under-preparedness for future changes in water availability. Further, we present preliminary findings of an investigation into potential drivers of trends in low flows across varying spatial and temporal scales. Trends in streamflow reflect interactions among climatic cycles, land use, flow regulation, and groundwater withdrawals.

(4.5.3) **Bumpers, Phillip**[1], David W.P. Manning[1], Amy Rosemond[2], and Bruno Giri[1]
[1]Upper Oconee Watershed Network, Athens, GA; [2]Odum School of Ecology, University of Georgia, Athens, GA

LONG-TERM TRENDS IN THE UPPER OCONEE WATERSHED USING THE UPPER OCONEE WATERSHED NETWORK'S CITIZEN-SCIENCE DATA

The Upper Oconee Watershed Network (UOWN) is an all-volunteer citizen-science organization that has monitored streams in the greater Athens, GA area for over 16 years. We measure a suite of chemical and biological parameters at up to 100 sites at least annually. In an effort to detect acute and chronic effects of stressors from development/urbanization we measure fecal coliform abundance (i.e. E. coli; acute stressors) and macroinvertebrate assemblages (chronic stressors) at a subset of these sites. Using data from 2001 to 2015, we assessed the trajectories and current status of biological integrity of streams in the Upper Oconee watershed. We evaluated potential long-term changes of a biotic index through time. In addition, we related chemical parameters that may be associated with observed changes in biotic indices for nine streams with varying degrees of impact from development throughout the Upper Oconee watershed. Overall, declines in the biotic index were evident for both the Middle Oconee and North Oconee watersheds. Six of the streams exhibited declining integrity scores; the remaining three streams exhibited slightly positive trajectories to no change over time. Poor biotic index scores were correlated with elevated nitrate and E. coli concentrations and specific conductance. Specific conductance was most strongly associated with declines in biotic index scores, suggesting that chemical pollution associated with urban environments is an important stressor of stream ecosystems. Streamwater pH was positively related to biotic index scores, indicating that lowered pH could negatively affect biotic communities. The trends in macroinvertebrate index scores suggest that stream health in the Upper Oconee watershed has generally declined since 2001. Though inferring the specific mechanisms driving decreased stream health with UOWN data is not possible, the patterns we found with nitrate, specific conductance, and E. coli suggest that chemical pollution is likely an important driver of these declines.

(4.5.4) **Gotvald, Anthony J**, and Chad Wagner
U.S. Geological Survey South Atlantic Water Science Center

ESTIMATING SELECTED LOW-FLOW FREQUENCY STATISTICS AND MEAN ANNUAL FLOW FOR UNGAGED LOCATIONS ON STREAMS IN NORTH GEORGIA

The USGS (USGS), in cooperation with the Georgia Department of Natural Resources, Environmental Protection Division, developed regional regression equations for estimating selected low-flow frequency and mean annual flow statistics for ungaged streams in north Georgia that are not substantially affected by regulation, diversions, or urbanization. Selected low-flow frequency statistics and basin characteristics for 56 streamgage locations within north Georgia and 75 miles beyond the State's borders in Alabama, Tennessee, North Carolina, and South Carolina were combined to form the final dataset used in the regional regression analysis. Because some of the streamgages in the study recorded zero flow, the final regression equations were developed using weighted left-censored regression analysis to analyze the flow data in an unbiased manner, with weights based on the number of years of record. The set of equations includes the annual minimum 1- and 7-day average streamflow with the 10-year recurrence interval (referred to as 1Q10 and 7Q10), monthly 7Q10, and mean annual flow. The final regional regression equations are functions of drainage area, mean annual precipitation, and relief ratio for the selected low-flow frequency statistics and drainage area and mean annual precipitation for mean annual flow. The final regression equations developed from this study are planned to be incorporated into the USGS StreamStats program. StreamStats is a Web-based geographic information system that provides users with access to an assortment of analytical tools useful for water-resources planning and management, and for engineering design applications, such as the design of bridges. The StreamStats program provides streamflow statistics and basin characteristics for USGS streamgage sites and ungaged locations. StreamStats also allows the user to compute estimates of streamflow statistics for ungaged sites for a location at any stream in Georgia

(4.5.5) **Palmer, Reed**[1], Casey Caldwell[2], and Kenneth Waldroup[3]
[1]Hazen and Sawyer, Raleigh, NC; [2]HydroLogics Inc., Denver, CO; [3]City of Raleigh Public Utilities Department, Raleigh, NC

WHEN SHOULD YOU CUT BACK? USING WATER SUPPLY FORECASTS AND WATER SHORTAGE TRIGGERS TO MANAGE DROUGHTS

The City of Raleigh, NC is one of the fastest growing cities in the US, and like many growing cities in the southeast, is located in a region subject to increasing water scarcity. This presentation describes the evolution of Raleigh's drought preparedness over the last decade. Following the 2007-08 drought, the NC legislature passed a statute requiring each utility to prepare and submit a Water Shortage Response Plan (WSRP). The law stipulates that each utility's WSRP be set up with quantifiable triggers defining the conditions for implementation. Concurrent to these events, the NC Division of Water Resources (DWR) developed sophisticated water basin models that provide stakeholders like Raleigh with new planning and forecasting tools. When the City's WSRP was put into practice over 3 consecutive dry years from 2010-2012 it became evident that the conservation triggers in the WSRP were sub-optimal. The short-term solution was to generate a water supply forecast with DWR's basin model that better informed the decision to enact mandatory conservation measures. The longer-term solution was to improve the drought triggers in the WSRP. Effective drought response triggers facilitate a utility's ability to manage emerging droughts promptly while simultaneously minimizing false alerts. False alerts (mandating conservation when unnecessary) aggravate customers, erode conservation compliance during future droughts, and disrupt the utility's revenue stream. Creating effective triggering mechanisms for a WSRP requires an understanding of the dynamics that distinguish normal hydrologic cycles from droughts as well as the demand reduction achievable at each WSRP stage. By incorporating this information in the basin models, a new set of triggers was developed that are expected to reduce the frequency of WSRP activation by 40-50% without increasing the risk of exhausting the City's water supply during the worst droughts on record.

SESSION 5 ABSTRACTS: THURSDAY 8:30-10:00 AM

Track 6.5 – Room K: Stormwater

(6.5.1) **Alnahit, Ali**[1], Abdul Khan[2], and Tom Owino[1]
[1]Department of Civil Engineering, [2]Department of Environmental Engineering & Earth Science, Clemson University, Clemson, SC 29630
IMPACTS OF INTERPOLATION SCHEMES ON CRITICAL SOURCE AREAS IDENTIFICATION FOR NON-POINT SOURCE POLLUTION CONTROL BASED ON SWAT MODEL
The Critical Source Areas (CSAs) have been widely recognized as priority locations for the control of NPS pollution and implementation of best management practices (BNPs). In previous studies, CSAs were identified based on factors such as pollutant concentration, load, and yield at the levels of subwatered and/or hydrologic response unit (HRU); however, the previous studies did not consider the impact of the temporal and spatial uncertainties of precipitation data, which propels most of the NPS pollution. The objective of this study was to assess the impact of using different interpolation schemes on identifying CSAs. This study used five different methods; Thiessen polygons, statistical, geostatistical approaches to incorporate spatially variable of rainfall into the Soil and Water Assessment Tool (SWAT). The study also identified the impacts of five different gauge-density scenarios. The scenarios were evaluated by finding the best performing parameter set and their associated uncertainty ranges using the Sequential Uncertainty Fitting Procedure. By applying different interpolation schemes in SWAT model, the maps of CSAs at the subwatered level for controlling total nitrogen (TN) and total phosphorus (TP) were produced. While the CSAs identified using different interpolation methods were the same, some CSAs were different. This study concludes that using different interpolation methods will affect the location of some CSAs and further investigation on using the interpolation methods is needed.

(6.5.2) **Yee, Tien**, and Huidae Cho
Department of Civil and Construction Engineering, Kennesaw State University, Marietta, GA 30060
FLOODWAY OPTIMIZATION ALGORITHM FOR STREAMS IN GEORGIA
Floodway boundaries are essential limits within a floodplain used to outline the area in which encroachment should be severely restricted. This boundary is important to regulating agencies and engineers as it provide valuable information to help in decision making, planning and management of floodplain development activities. An ideal floodway is constructed from a set of left and right encroachment extents that cause surcharges equal to or less than a permissible limit, usually 1-ft in the state of Georgia, at every cross section within the reach. Additionally, encroachment should not be applied partial to just one side of a waterways. HECRAS is the standard software accepted by FEMA for flood modeling and therefore many effective floodway boundaries are created using HECRAS. Typically, floodway boundaries are produced manually through iterative trial and error procedure where the left and right encroachment limits are varied within HECRAS to produce the target surcharge of 1-ft or less in all cross sections along a reach. The quality of the encroachment limits obtained through the trial and error process varies between modelers and is dependent upon a modeler's experience level, engineering judgements and is thus bound to subjectivity and sometimes subconscious preferences and biases. Further, optimal floodways are not required for flood mapping purposes and therefore some effective floodways may have been left unoptimized. This work introduces a computer model that automates the production of HEC-RAS encroachment limits and is therefore able to mitigate biases and subjectivity from a modeler. In addition, the algorithm outputs floodway footprint that are reach-wide minima. The algorithm will be applied to two different streams in Gwinnett County, Georgia. Results obtained from the floodway optimizer will be presented and the potential of the model for future applications will be discussed.

(6.5.3) **Berahzer, Stacey Isaac**
UNC Environmental Finance Center
FINANCING WATER QUALITY IMPROVEMENT - STORMWATER UTILITY MANAGEMENT IN GEORGIA
This presentation will provide an overview of the 2016 Georgia Stormwater Survey. Funded by the Georgia Environmental Finance Authority (GEFA), the Environmental Finance Center (EFC) is conducted this research to assist local governments in developing and managing stormwater utilities across the state. Participants will learn how to use the use the free, interactive, computer-based Stormwater Dashboard that allows users to compare fees among utilities according to multiple factors including geographic region, MS4 Permit type, river basin, 50-mile radius, and median household income. Initial results show that there are several more stormwater utilities now in Georgia compared to the last time the survey was conducted in 2012. During this presentation, participants will learn how Georgia's stormwater utilities are structured. There will be a focus on how utility fees are designed, the method used for billing, as well as other financial management aspects of running a stormwater utility.

SESSION 6 ABSTRACTS: THURSDAY 10:30-NOON

Track 1.6 – Room Q: EPA Watershed Registry I

Session Organizer: **Laurie Fowler** – River Basin Center, University of Georgia, Athens, GA

The Watershed Resources Registry (WRR) is an interactive GIS-based screening tool that incorporates data from various organizations to reveal a comprehensive picture of watershed conditions and identify opportunities for aquatic and terrestrial creation, restoration, enhancement and preservation. The WRR is a product of the Green Highways partnership and the Maryland State Highway Administration to improve resource planning and mitigation decision-making using a watershed approach, by integrating regulatory and non-regulatory programs. The WRR currently identifies ecological opportunity areas throughout the state of Maryland and scores each opportunity area w/ a score from one to five stars. Agencies are using it for an array of activities such as identifying strategies for TMDL implementation and CWA Section 404 determinations, targeting ecological opportunities for preservation and restoration and supporting MD's In-lieu Fee program for tidal and non-tidal wetland permitting activities. EPA uses it to gather info prior to conducting site visits and to provide supportive materials for briefings and other projects. Other states—such as Delaware and Pennsylvania are considering using it as well.

This first session will provide an overview of the program and web tool.

Presenters:
Ralph Spagnolo – *Watershed Program Manager*, *US Environmental Protection Agency, Region III, 1650 Arch Street, Philadelphia, PA 19103*
Ralph Spagnolo is Watershed Program Manager at U.S. Environmental Protection Agency Region III

Michael S. Herzberger, GISP, CFM - *Section Chief, GeoSpatial and Engineering Services, Maryland Environmental Service, 259 Najoles Road, Millersville, MD 21108*
Michael Herzberger is Chief of the GeoSpatial and Engineering Services group of the Maryland Environmental Service (MES). MES is a not-for-profit Independent State agency. The organization focuses on working with both governmental and private sector clients to find innovative solutions to some of the most complex environmental challenges. He is responsible for oversight of various technical services for numerous entities within the public sector. Michael has a Bachelor of Science degree in Geography and Environmental Planning from Towson University (2005).

SESSION 6 ABSTRACTS: THURSDAY 10:30-NOON

Track 2.6 – Master's Hall: Coastal Development

(2.6.1) **Russell, Madeleine**
UGA Marine Extension & Georgia Sea Grant
COASTAL GEORGIA USES A COLLABORATIVE APPROACH TO REDUCE FLOOD INSURANCE RATES
Unlike dissolved chemicals which use equilibrium partition coefficients, heteroaggregation consists of a particle collision rate and an attachment efficiency (ahet) that generally acts as a one direction process. To demonstrate, we used a derived ahet value from sediment attachment studies to parameterize WASP for simulation of multiwalled carbon nanotube (MWCNT) transport in Brier Creek, a coastal plain river located in central eastern Georgia, USA and a tributary to the Savannah River. Simulations using a constant MWCNT load of 0.1 kg d-1 in the uppermost Brier Creek water segment showed that MWCNTs were present predominantly in the Brier Creek water column, while MWCNTs accumulated in sediments attached to different naturally occurring particulates. Distribution of MWCNTs in the sediment layer followed the distribution of sediment particles. Downstream MWCNT surface sediment concentrations exhibited a general increase with time and distance from source. With the increasing production of nanomaterials, the development of WASP8 for nanomaterials provides a powerful tool for investigating ecological exposure to these emerging contaminants.

(2.6.2) **Alcorn, Jessica**[1], and Doug Atkinson[2]
[1]*UGA Carl Vinson Institute of Government,* [2]*UGA Marine Extension*
GEORGIA'S COASTAL SEPTIC TANK INVENTORY: MAPPING WASTEWATER SYSTEMS TO ENHANCE CLIMATE READINESS
The US Environmental Protection Agency estimates that more than one in five homes are served by decentralized wastewater treatment systems—commonly known as septic tanks. In coastal areas where it is impossible to extend sewer service due to either financial or hydrogeological constraints, septic tanks are an integral part of wastewater treatment. When maintained adequately and installed under appropriate conditions, septic tanks remove excess nutrients and dangerous pathogens from wastewater. When not appropriately maintained, septic tanks pose a threat to human and environmental health. Further, changing climactic conditions increase the likelihood of septic tank failure. Due to increasing incidences of recurrent flooding and extreme weather events and future inundation from sea level rise, areas where septic tanks could function adequately in the past might not be able to rely on this method of wastewater treatment in the future. Through funding from the Coastal Resource Division of the Department of Natural Resources, UGA's Marine Extension has completed digitization and mapping of historic septic tank records in five coastal Georgia counties. This presentation will focus on the data management processes used to comprehensively catalog septic tanks and discuss the advantages and limitations of the completed data products. We will also highlight the challenges that we faced in creating a standardized dataset from county-level records based on variable data recording and inspection processes. The septic tank inventory offers two primary benefits. First, digitization of septic records increases the efficiency of local public health departments in fulfilling information requests. Second, mapping septic tanks allows for identification of areas in the county where septic tanks might be at the highest risk of failure or where targeted water sampling might be beneficial. By presenting this data resource, we intend to increase awareness and stimulate more research using the septic tank inventory data.

(2.6.3) **Brown, Robert A**., and Courtney Reich
Ecological Planning Group, 35 Abercorn St., Suite 210, Savannah, GA 31401
RED ZONE WATER SUPPLY MANAGEMENT PLAN FOR CHATHAM AND EFFINGHAM COUNTIES
Saltwater intrusion into the Floridan aquifer has occurred in Hilton Head Island area. Modeling studies show that the saltwater plume is migrating towards the Savannah area because of historic groundwater pumping from this aquifer. In 1995, the first Chatham County Water Supply Management Plan was written to identify strategies for reducing groundwater withdrawals and hopefully slow the migration. This Plan was updated in 2000 and 2006, but it has been dormant since. Recently, the Chatham County-Savannah Metropolitan Planning Commission received a Coastal Incentive Grant from GA DNR's Coastal Resources Division to revisit and update this plan for the "Red Zone," which includes Chatham County and southeastern Effingham County. There is a need for an update because continued action is necessary to ensure continued access to water supplies while still supporting future economic growth in this region. Goals for this project include: [1] evaluating the effects of the 28 management strategies identified in the 2006 Plan and [2] developing new strategies (tools and policies) to meet new groundwater withdrawal permit reductions by 2025 (typically 22% reductions from 2015 permit levels). As with previous plans, this plan uses a Task Force comprised of large water users (e.g. municipalities and industries), local environmental and civic groups, and GA DNR's Environmental Protection Division to provide program guidance and technical assistance throughout the planning process. This presentation will highlight the progress that Chatham County has had with its original plan and subsequent revisions, as well as highlight strategies moving forward based on research and discussion with the Project Task Force. During the first decade of the Chatham County Plan, groundwater withdrawal rates in Chatham County for domestic/commercial and industry combined were reduced by 16.6 MGD, and withdrawal rates from 2004 to 2015 have been further reduced by 11.7 MGD to 46.9 MGD.

(2.6.4) **Kriesel, Warren**

UGA Ag & Applied Economics, Athens, GA

RESULTS OF RESEARCH INTO GEORGIA'S COASTAL REAL ESTATE MARKET

The natural amenity that dominates Georgia's coastal real estate market is the saltwater marshes. It is well known that homebuyers pay a premium for properties that have a view of the marsh. However, a related issue is the value of planned open space/ commons area inside a subdivision. We found that homebuyers also paid more for homes with access to more open space, and that their desire for these outweighed their desire for larger lot sizes. Future developers of residential subdivision therefore have a market incentive to provide open space even though nature also provides it in the form of marshlands. Other research demonstrated that the marshland price premium actually increased during the housing bust of 2008-11. This reaction of homebuyers was similar to the price of gold: both increased as people invested in the things that stood a lower chance of losing value. Finally, other research is investigating the benefits and costs of elevation retrofitting houses against flood damage. Preliminary results indicate that the price premium for an elevated house is between $20-$30, 000. The costs are lower for houses with a smaller footprint, those without masonry or brick and houses that weren't built on a concrete slab.

(2.6.5) **Brown, Jessica T.R**.

UGA Marine Extension and Georgia Sea Grant

LOW IMPACT DEVELOPMENT BEST MANAGEMENT PRACTICE INVENTORY FOR COASTAL GEORGIA

Stormwater Low Impact Development Best Management Practices (LID BMPs) are a means of accomplishing integrated water management through mimicking natural hydrology. This approach incorporates both the natural environment and engineered systems to improve water quality, reduce water quantity (i.e. flooding), protect ecosystems, and provide benefits to people and wildlife, and it can be applied at a variety of scales. LID BMPs are science-based strategies, to treat polluted runoff. As part of a Georgia Department of Natural Resources, Coastal Resources Division Coastal Zone Management Administration Award from the National Oceanographic and Atmospheric Administration, Marine Extension and Georgia Sea Grant, along with partners from Ecological Planning Group, the Georgia Department of Natural Resources, Coastal Resources Division, and the Center for Watershed Protection are creating a database for LID best management practices installed in Georgia's 11 coastal counties. The project team is working with local environmental and design professionals, municipal stormwater administrators, and local municipalities to identify these practices and are conducting a field assessment of condition and physical characteristics for the following structural LID practices: bioretention, permeable pavement, green roofs, bioswales, cisterns, and stormwater wetlands. The data collected as part of this project will be used to populate the Georgia LID Atlas and the National LID Atlas. In addition to providing information to assist future LID project development, the inventory is identifying on-the-ground examples to use as demonstration and educational resources for practitioners, local governments, and the water resources community. This presentation will highlight the progress made on the Inventory, as well as some of the initial data trends. To date, there have been approximately 200 LID practices identified in Georgia's 11 coastal counties, and field assessments have been conducted for 25.

SESSION 6 ABSTRACTS: THURSDAY 10:30-NOON

Track 3.6 – Room F/G: Agricultural Wetlands I

(3.6.1) **Batzer, Darold**[1], Joseph McHugh[1], C. Rhett Jackson[3], Dennis Hancock[2], Mark Risse[2], and Susan Wilde[3]
Departments of [1]Entomology and [2]Crop and Soil Sciences, and [3]Warnell School of Forestry; University of Georgia

INTEGRATING WETLAND ECOSYSTEM SERVICES INTO AGRICULTURE: A UGA DEMONSTRATION PROJECT

Showing how wetland ecosystem services can be profitably integrated into agricultural practice would be a powerful way to induce farmers to conserve wetland habitats. We have developed a project to demonstrate this concept at the Iron Horse research farm, UGA, a place where croplands interact with an extensive complex of floodplain wetlands. In terms of research, we intend to: 1) Establish hydrologic and ecological linkages between croplands and wetlands; and 2) Show how agricultural floodplain wetlands can be managed to simultaneously maintain wetland ecosystem services and cropland productivity. In terms of public outreach, we intend to: 1) Develop the farm as resource for education on sustainable agriculture and wetland ecology; 2) Conduct outreach events for public school teachers, farmers, and students. This effort is being funding by the USEPA, and the research phase of the project will continue for the next three years.

(3.6.2) **Golladay, Stephen**, Chelsea R. Smith, and Nathalie D. Smith
J.W. Jones Ecological Research Center

WATER QUALITY IN GEOGRAPHICALLY ISOLATED WETLANDS IN AGRICULTURAL LANDS AND SECOND GROWTH LONGLEAF PINE FOREST

Geographically isolated wetlands (GIWs) are common aquatic features throughout the southeastern Coastal Plain. They are referred to as 'isolated' because they are surrounded by uplands and lack connection to perennial surface waters. In southwestern Georgia, these wetlands are referred to as 'limesinks' reflecting their geologic origins in a karst landscape. The lack of connection to surface waters or 'Waters of the US' means that regulatory authority is ambiguous. Most GIWs lack protection under Clean Water Act and its associated rules and provisions, making them vulnerable to alteration in human- dominated landscapes. In the southeastern US, GIWs occupy a small portion of the landscape (<3%) but are noted for their contribution to regional biotic richness. They also tend to be small (80% < 4 ha) and region-wide about 50% show signs of impairment. From 2010 through 2016, we sampled water quality in reference (second growth longleaf pine savanna) and intensively managed areas (agriculture and forestry). Replicate samples were taken early, mid-, and late hydroperiod at Ichauway (reference) and surrounding private farms with management practices typical of the region. Analyses included suspended solids, pH, alkalinity, dissolved organic carbon (DOC), NO3-N, NH4-N, and soluble reactive phosphorus (SRP). We also compared water column planktonic microbial communities during a single hydroperiod. During each hydroperiod sampled, wetlands in intensively managed areas had consistent and significantly greater concentrations of suspended solids, NO3-N, NH4-N, and SRP compared to reference sites. Wetland water column pH was also greater in managed areas. In managed areas, elevated suspended solids and nutrients reflect soil disturbance and subsequent runoff from fields, pastures, and pine plantations. Elevated pH reflected leaching of lime (a common crop amendment) and residual from irrigation water withdrawn from the carbonate-rich upper Floridan aquifer. Wetland water column microbial communities were dominated by small (<4µm) heterotrophic bacterial cells in both wetland types. Wetlands in intensively managed landscapes had greater microbial abundance. Wetland microbial communities respond to runoff from adjacent areas and likely play an important role in its processing or remediation. Geographically isolated wetlands clearly show altered water quality from adjacent land use. The potential for isolated wetlands to remediate runoff is l

(3.6.3) **Smith, Lora L.**[1], Cara McElroy[2], Anna M. McKee[2], Rachel King[3], and Camille Herteux[4]
[1]Joseph W. Jones Ecological Research Center, [2]USGS, [3]Florida Fish and Wildlife Conservation Commission, [4]Dept. of Biological Sciences, Florida Atlantic University

WILDLIFE USE OF GEOGRAPHICALLY ISOLATED WETLANDS IN FORESTED VERSUS AGRICULTURAL LANDSCAPES

Geographically isolated wetlands (GIWs) embedded southeastern longleaf pine forests provide important ecosystem services including water storage, nutrient processing and sequestration, and wildlife habitat. Although there is increasing recognition of these services, many GIWs are not afforded regulatory protection at the state or federal level and it has been estimated that more than 50% of GIWs in the southeastern U.S. have been altered by agricultural and urban land uses. Despite large scale alterations of wetlands and surrounding forests, many GIWs persist within agricultural landscapes and a basic understanding of the role of these wetlands as wildlife habitat is of interest. We examined the effects of landscape variables on wetland use and connectivity for a broad suite of fauna (amphibians, reptiles, and wading birds) in southwestern Georgia. Among amphibians species richness, diversity and abundance was highest in GIWs with more surrounding forest and wetland land use. Likewise, genetic data indicated that connectivity among populations of some amphibian species (southern cricket frog and dwarf salamander) was positively related to the amount of forest and wetlands in the surrounding landscape. However, populations of another amphibian species (southern leopard frog) showed little genetic differentiation even at the largest spatial scale (>20 km) and in agricultural landscapes. Wading bird use of GIWs was highest in wetlands in agricultural landscapes during breeding season, but increased in GIWs in forested landscapes late in the hydroperiod. During overland movements between wetlands, freshwater turtles moved through natural pine forests rather than agricultural lands or pine plantations.

(3.6.4) **Smith, Chelsea**, Nathalie D. Smith, and Stephen W. Golladay
J.W. Jones Ecological Research Center

LARVAL MOSQUITO USE OF AGRICULTURAL AND REFERENCE WETLANDS WITHIN SOUTHWEST GEORGIA

The southeastern Coastal Plain contains many geographically isolated wetlands that contribute greatly to regional biodiversity. Because they lack any connection to a permanent water body, geographically isolated wetlands are often not recognized under federal or state statutes. In southwestern Georgia, disturbance of these systems has often occurred as a result of agriculture, altering habitat availability and water quality. We examined mosquito larval abundance and water quality among 10 reference wetlands (5 grass-sedge marsh and 5 cypress-gum swamp) and 10 agricultural wetlands (4 pasture, 3 adjacent to fields and 3 within fields) in southwestern Georgia monthly from September 2009 to May 2016, to assess the suitability of these habitats for mosquito breeding. Across these wetland types, 35 mosquito species were identified, with nine of those species being unique to reference wetlands. Agricultural wetlands had no unique species, though indicator species analysis revealed that Psorophora columbiae was indicative of pasture wetlands, and sites adjacent to fields were indicated by Anopholes quadrimaculatus. Indicators of cypress-gum swamps included 4 species (Culiseta melanura, Ochlerotatus canadencis, Culex territans, Ps. ferox), as did grass-sedge marshes (Uranotaenia sapphirina, An. crucians, An. spp, Cx. pilosus). The most abundant species across all wetlands types was Aedes vexans, comprising 33% of mosquitoes identified during the study, followed by Cx. territans (24%). The majority of Ae. vexans sampled were within the first three months of wetland inundation following a drying event, and none were observed if wetlands contained water for more than 7 months. This species is an important vector for many arboviruses in the area including West Nile encephalitis and eastern equine encephalitis. Ae. vexans also transmits the nematode that causes heartworms. Because many of the species within this system are known vectors of arboviruses, understanding factors that influence habitat suitability and reproductive success will be important as climate change and land use continue to alter the hydrology of wetlands and available habitat.

(3.6.5) **Clark, Brittany**, Joseph McHugh, and Darold Batzer
Department of Entomology, University of Georgia, Athens, GA 30602

MIGRATIONS OF INSECT NATURAL ENEMIES FROM WETLANDS INTO AGRICULTURAL FIELDS

Illustrating how wetland ecosystem services can be profitably integrated into agricultural practice is a powerful way to induce farmers to conserve wetland habitats. This project aims to elucidate the ecological linkages between wetlands and croplands by monitoring distributions of wetland arthropods and crop pests through utilization of pitfall traps, sticky traps, and sweep netting. Sample sites included row crop/wetland and pasture/wetland complexes that were sampled along four transects with six replicates. Traps and samples were collected monthly during the growing season to monitor movements of ground-dwelling wetland invertebrates, as well as pollinators and other flying insects, within the two complexes. Analysis of natural enemy population trends over the growing season will indicate patterns of pest-suppressing predatory insect movement from wetlands into crop complexes, thus revealing potential roles of wetlands acting as refugia for natural enemies and other beneficial insects in agroecosystems.

SESSION 6 ABSTRACTS: THURSDAY 10:30-NOON

Track 4.6 – Room L: Spatial Mapping

(4.6.1) **Rasmussen, Todd C**
UGA Warnell School of Forestry & Natural Resources

BIG DATA IN HYDROLOGY: INFORMATION MANAGEMENT FROM HILLSLOPE TO CONTINENTAL SCALES

Hydrologic data, information, and knowledge resolve differently depending upon the spatial and temporal scales of interest. A multi-scale hydrologic information system (HIS) is presented that can be designed and populated for a broad range of spatial (e.g., hillslope, local, regional, continental) and temporal (e.g., current, recent, historic, geologic) scales. Surface and subsurface hydrologic and transport processes are assumed to be scale-dependent, requiring unique governing equations and parameters at each scale. This robust and flexible framework is designed to meet the inventory, monitoring, and management needs of multiple federal agencies (Forest Service, National Park Service, Fish & Wildlife Service, National Wildlife Reserves). Multi-scale HIS examples are provided using Geographic Information Systems (GIS) for the Southeastern US.

(4.6.2) **Miller, Jennifer**[1], Eric Byrne[2], Nick Jokay[2], and Kyle Dalton[3]
[1]Arcadis, [2]Tetra Tech, [3] Athens-Clarke County, Georgia

INTEGRATING GIS TOOLS WITH FIELD ASSESSMENTS TO SAVE TIME AND MONEY WITHOUT COMPROMISING DATA QUALITY

In support of developing watershed management plans for Athens-Clarke County, field personnel conducted stream health assessments of over 80 stream miles throughout 8 watersheds in a span of 9 weeks. These typically time-intensive field assessments or "streamwalks" were expedited by using progressive GIS tools and data integration technologies, which resulted in significant cost savings for Athens Clarke County. The streamwalk assessments provide critical information on stream geomorphology and biological habitat that is used, in part, to characterize current watershed conditions, and ultimately identify and prioritize areas and management strategies to improve water quality. The field assessments produce indispensable high quality data on current conditions, yet are typically labor-, time- and cost-intensive. However, using progressive GIS tools and technologies, such as electronic data collection using digital smart tablets equipped with the Esri Collector applications, the time and cost of such field assessments can be dramatically reduced. For example, for this project it is estimated that $32,800 or 33% was saved by employing advanced data collection technologies. This cost saving considers the approximately two weeks of work for 2 field personnel that were eliminated from the project schedule as well as 16 days of work saved on data post-processing and quality assurance/quality control checks. While field efforts are often plagued by issues that can affect data quantity and quality, the use of the digital data collection technologies helped assure data quality without sacrificing the quantity of data collected. Device customization and wireless data plans also can eliminate device data storage and database integration issues often associated with such field efforts. Data upload speed and visualization options allowed field personnel to adapt daily work plans to real time conditions such as site access constraints and weather conditions.

(4.6.3) **Cho, Huidae**[1,2]
[1]Department of Civil and Construction Engineering, Kennesaw State University, Marietta, GA 30060; [2]Dewberry, Atlanta, GA 30341

WEB-BASED HYDROLOGIC MODELING SYSTEM FOR TEXAS

The author introduces the Web-based Hydrologic Modeling System (WHydroMod). The primary objective of this research is to create a web-based system that can generate model files for a physically based, distributed watershed model called the Topography Model (TOPMODEL), with a single mouse click in the web browser. The traditional process of hydrologic modeling includes collecting and pre-processing input data, creating model files, running the model, and finally post-processing model outputs. All these tasks for hydrologic simulation require quite a lot of effort and time if manually done, but most of those modeling efforts can be automated by using and integrating the right tools into a well-thought-out modeling system. This new web-based modeling system lets the researcher spend more time on analyzing the modeling results rather than on mechanically manipulating data just to create a hydrologic model. At the same time, since this system is based on an Open Source stack, the inner working of the system is transparent to the user, which makes the system easier to fix and improve when compared to proprietary modeling software. The current version of WHydroMod was developed for Texas as a proof-of-concept implementation and the author plans to implement this system for Georgia soon. Future research includes the integration of parameter optimization in a Bayesian manner and uncertainty estimation of the modeling results with forecasting capabilities.

(4.6.4**) Bruce A. Pruitt**[1], K. Jack Killgore[2], W. Todd Slack[2], Leandro E. Miranda[3] and Carson A. Pruitt[4]
[1]U.S Army Corps of Engineers, Engineer Research and Development Center, 960 College Station Rd., Athens, GA 30605; [2]U.S. Army Corps of Engineers, Engineer Research and Development Center, 3909 Halls Ferry Rd., Vicksburg, MS 39180-6199; [3]U.S. Geological Survey, Mississippi Cooperative Fish and Wildlife Research Unit, Mississippi State University, Mississippi State, MS 39762; [4]Graduate Student, University of Georgia, School of Geography, Athens, GA 30605

WATERSHED ASSESSMENT: A MULTI-SCALE APPROACH USING ECOLOGICAL MODELING

Pursuant to the Water Resources Development Act of 1986 (as amended), a Watershed Assessment Plan was developed for the Duck River watershed located in the Interior Plateau, Tennessee. The objectives of the Duck Watershed Plan were to evaluate the stream corridors in regards to establish current (baseline) conditions and identify water resource problems, needs and opportunities. The study area, which is

within the Tennessee River Drainage Basin, included the Duck and Buffalo River watersheds, approximately 1,545 and 1,085, respectively. A knowledge base was developed by compiling and analyzing biological and geomorphological data across HUC 12 watersheds from existing databases of fishes, mussels, aquatic habitats, and benthic macroinvertebrates. Additional stream data were collected from low altitude high resolution video resulting in a final subset of eleven of 18 stream geospatial test variables compiled on 213 stream segments and subjected to statistical analysis. An ecological model, stream condition index (SCI), was formulated based on the degree of statistical correlation (dependency) between the variables. Forty-six of the 64 watersheds were experiencing major to severe ecological disturbance compared to 18 watersheds exhibiting minimal to minor ecological disturbance. Only three watersheds were considered relatively undisturbed (i.e., attainable reference conditions). In addition to the analysis of geospatial data, fish Index of Biotic Integrity (IBI) scores were evaluated based on twelve metrics which addressed species richness and composition, trophic structure, fish abundance, and fish condition. By comparing the SCI to IBI scores, aquatic biota impairment was predominantly due to loss of streamside canopy, reduction of in-stream cover, and impacts to channel stability, all of which were considered to be limiting factors in regards to sustaining a healthy aquatic ecosystem in the Duck River watershed. The findings of this study can be utilized to prioritize watersheds for restoration, enhancement and conservation, and conduct intensive ecosystem studies.

(4.6.5) **Panda, Sudhanshu Sekhar**[1], Norman Worthington[1], and Devendra Amatya [2]
[1]Institute of Environmental Spatial Analysis, University of North Georgia, Oakwood, GA; [2]Center for Forested Wetland Research, USDA Forest Service, Cordesville, SC

AUTOMATED GEOSPATIAL MODEL DEVELOPMENT FOR STREAM BANK EROSION SPATIAL VULNERABILITY DETERMINATION

Remote prediction of spatial vulnerability due to stream bank erosion, one of the four types of water erosion, is yet to be ascertained accurately. Universal Soil Loss Equation (USLE) or RUSLE models are able to quantify the erosion rate on spatial basis very precisely but not able to locate the vulnerable locations of the stream for stream bank erosion. Geomorphological characteristics of the stream valley and the watershed such as overbank floodplain level, drainage area, stream channel capacity, channel slope, and soils are some of the factors that influence the frequency, duration, and intensity of flooding and subsequent soil erosion on the channel banks. Riparian areas along the stream banks also support soil stabilization along the stream reducing stream bank erosion. Studies of inexpensive and efficient use of geospatial technology (GIS, remote sensing, and GPS) to predict spatial vulnerable locations of stream bank erosion are rare. The goal of our study is to develop an automated geospatial model in ArcGIS ModelBuilder using spatial data like landuse, Digital Elevation Models (DEM), soil, and design flood discharges of various frequencies to determine vulnerable spatial locations on the streams of interest. The study is completed in the 12-digit HUC watersheds covering the Upper Chattahoochee River and the exit point is south of city of Helena, GA. The two HUC12 watersheds used as study area are 031300010101 and 031300010102, the top two watersheds of HUC 8 Upper Chattahoochee watershed. Comprehensive ground truth was conducted to ascertain the accuracy of the results. 10m resolution DEM and high-resolution multispectral imagery (Y2015 - 1m NAIP Imagery) were obtained. The R- and NIR- bands of NAIP imagery were used to develop the Soil Adjusted Vegetation Index (SAVI) raster and the SAVI rasters were classified with self-organizing map (SOM) neural segmentation process to obtain the landuse features of the study watershed that embedded the streams. The same classified landuse raster provided the accurate riparian cover along the stream. High-resolution gSSURGO (10m resolution) soil data was processed and used for the model development. Slope map was created from the DEM and classified into different class ranges based on the stream bank erosion vulnerability range. These ranges were ascertained based on literature review and our own knowledge of the landscape dynamics. Soils of the study watersheds were reclassified to flood frequency, hydrologic group, soil erodibility (K-factor) rasters. Weighted Sum tool of ArcGIS was introduced in the model to provide specific weightage to individual stream bank erosion vulnerability parameters discussed above. The weight scale was developed with expert knowledge and group scoring. The resultant raster was overlayed with weight based riparian zone rasters and the slope rasters along the stream (1 ft) as the riparian zone cover and the topographic slope adjacent to the stream bank has higher impact for stream bank erosion. The final weighted summed raster was clipped to 1 m buffered stream polygon and classified into five different classes (Very Low – Very High) of vulnerability to erosion along the stream. As mentioned above in-field groundtruthing were completed and accuracy assessment matrixes were developed. This automated geospatial model can be replicated to determine the highest vulnerable spots for stream bank erosion and provide decision support for its control, which in turn improve stream water quality.

SESSION 6 ABSTRACTS: THURSDAY 10:30-NOON

Track 5.6 – Room R: Urban Case Study: Alpharetta

Meeting Georgia's New Recommended Runoff Reduction Performance Standard: One Metro-Atlanta City's Approach

Session Organizer: **Eric Byrne** - *Tetra Tech, 1165 Sanctuary Pkwy., Ste. 270, Alpharetta, GA 30004*
This session will include short presentations followed by discussion. The presentations will highlight projects that have been implemented in the City of Alpharetta that promote smarter stormwater design and watershed management with emphasis on the new recommended runoff reduction performance standard. The following projects will be presented:

- An Introduction to Alpharetta's Stormwater Management Program: Provides an overview of Alpharetta's stormwater challenges and their approach to solving those problems.

- Code Barrier Report - Advancing Smart Stormwater Design in Alpharetta: Alpharetta has experienced and is continuing to experience revitalization in the Downtown area and new development in other areas of the City. As part of a modern approach to managing stormwater, the City wanted to ensure that its ordinances, stormwater regulations, and policies support and encourage the use of smart stormwater design, and other specific practices that are performance driven and economically advantageous. The purpose of the Code Barrier Report is to propose clear and effective policies and standards that Council, staff, citizens, businesses, and the development community can support and use in implementing smart stormwater design, including onsite stormwater runoff reduction measures and offsite stormwater mitigation techniques, and that can be considered in future updates of the Unified Development Code (UDC) and policies.

- Smarter Stormwater Design in Wills Park: We designed several stormwater projects for the City of Alpharetta in Wills Park, a very important resource for the community. The projects include a Regenerative Stormwater Conveyance System (RSC), very large scale Cistern system that captures rainwater runoff from the covered equestrian arena for reuse in watering the fields and providing dust control, bioretention, and waste containment to reduce fecal coliform pollution. These projects were designed in consideration of the recommended runoff reduction standard while balancing costs and site constraints.

- Bacteria Source Tracking (BST) in the Foe Killer Creek watershed: The City of Alpharetta (City) has implemented bacteria source tracking (BST) sampling and analysis throughout the Foe Killer Creek watershed along with baseline water quality sampling and analysis in Wills Park. The BST sampling and analysis will be used to help identify sources of fecal coliform bacteria in the watershed. The Wills Park water quality tests will be performed to develop a baseline for comparison after water quality measures are implemented.

Presentations:
Jill Bazinet - *City of Alpharetta*, Senior Stormwater Engineer
Julie Kaplan - *Tetra Tech*, ordinance review
Eric Byrne - *Tetra Tech*, Wills Park design projects
Eric Byrne, Julie Kaplan & Jamie Childers - *Tetra Tech*, water quality and bacteria source tracking projects

SESSION 6 ABSTRACTS: THURSDAY 10:30-NOON

Track 6.6 – Room K: Water Quality And Threats

(6.6.1) **Capps, Krista**[1], Brian Bledsoe[2], Daniel Capps[3], Laurie Fowler[4], Marirosa Molina[5], S. Kyle McKay[6], J. Scott Pippin[6], Amy Rosemond[1], Jennifer Rice[6], and Seth Wenger[4]
[1]UGA Odum School of Ecology, [2]UGA Institute for Resilient Infrastructure Systems, [3]UGA Mathematics and Science Education, [4]UGA River Basin Center, [5]United States Environmental Protection Agency, Office of Research and Development, National Exposure Research Laboratory, [6]U.S. Army Corps of Engineers, Engineer Research and Development Center, [7]UGA Carl Vinson Institute of Government, [8]UGA Geography

DECISION-MAKING UNDER DURESS - PRIORITIZING MANAGEMENT ACTIVITIES TO PRESERVE THE INTEGRITY OF FRESH WATERS, PROMOTE HUMAN HEALTH, AND PROTECT WATER SUPPLIES

Globally, local resource managers and policy-makers are tasked to address environmental and human-health concerns associated with aging and obsolete water infrastructure using limited financial resources. Though many issues associated with aging and obsolete water infrastructure can have large economic and ecological impacts, failing wastewater treatment infrastructure (WWTI) presents a globally pervasive threat to the integrity of freshwater ecosystems. Nevertheless, there is limited information describing how waste streams vary in their pollutant load or explaining the heterogeneous effects of waste on ecosystem structure and function through space and time. Consequently, as more aging wastewater systems degrade, local resource managers and policy makers are forced to develop watershed management strategies to deal with increasing effluent discharge (e.g., leaky pipes, failing septic tanks, and obsolete wastewater treatment systems) without the information needed to understand how their decisions will influence local ecological processes or the structural and functional integrity of downstream habitats. Here, we will present ideas generated by a new collaboration between Athens-Clarke County, the UGA, the Environmental Protection Agency, and the Army Corps of Engineers to address this challenge. We propose to generate a greater understanding of the dynamic feedbacks between WWTI management decisions and the socio-ecological condition of fresh waters by addressing three objectives. Initially, the proposed work will elucidate how environmental, regulatory, and social information has informed infrastructure and environmental management decisions made by local officials. We propose to create a set of possible WWTI management scenarios under variable governance conditions and predict how and when reactive (e.g., reaction to infrastructure failure) and proactive (e.g., enhanced operational procedures) management decisions will influence in the biophysical system. Furthermore, we aim to study interactions among WWTI, variations in wastewater streams, and the biological response of aquatic systems.

(6.6.2) **Lincoln, Erin**, Rene Camacho, and Brian Watson
Tetra Tech, Inc., Atlanta, GA 30339

COMPUTATIONAL FLUID DYNAMICS (CFD) MODELS: CASE STUDIES IN WATER RESOURCES MANAGEMENT

Computational fluid dynamics (CFD) models are powerful tools that solve complex fluid flow problems described by Navier-Stokes equations. The computational-intensive models provide accurate and detailed hydraulic information similar to results obtained from physical models, and can be used to predict and optimize design performance. CFD models are used by Tetra Tech for a wide variety of hydrology and hydraulic studies, including restoration designs, fish bypasses, contaminant plumes, settling tanks, and dam failures. Three case studies will be presented. Stream Restoration Design: The City of San Antonio is restoring a concrete channel back to natural conditions at Lackland Airforce Base. A CFD model was developed to evaluate flow velocities and shear stresses under different flow conditions to support and improve the design of a stable channel configuration. Fish Passage Design: The U.S. Army Corps of Engineers (USACE), Savannah District, designed a fish passage at the New Savannah Bluff Lock and Dam in support of the Savannah Harbor Expansion Project (SHEP). A CFD model was developed to ensure that the fish passage design met USACE's required criteria for minimum depths and maximum velocities to allow for movement of a wide variety of fish species. Using CFD model results, the fish passage channel was optimized to ensure proper velocities for a range of flows. Mixing Zone Analysis: As part of SHEP, the Savannah River navigational channel is being deepened, which is expected to decrease dissolved oxygen (DO) in the system. In order to maintain current DO levels, DO injection systems will inject high-oxygenated water back into the river at three locations using Speece Cones. CFD models were developed to investigate the evolution of the solute plumes, both in location and concentration, in the river under various flow and tidal conditions. Preliminary CFD model results will be presented.

(6.6.3) **Avant, Brian**[1], Christopher Knightes[2], Dermont Bouchard[2], Xiaojun Chang[3], W. Matthew Henderson[2], Sharon Martin[1], and Richard Zepp[2]
[1]Oak Ridge Institute for Science & Education; [2]USEPA Office of Research and Development, National Exposure Research Laboratory; [3]National Research Council Research Associate, Athens, Georgia 30605

MODELING ENGINEERED NANOMATERIALS (ENMS) FATE AND TRANSPORT IN AQUATIC ECOSYSTEMS

Under the Toxic Substances Control Act (TSCA), the Environmental Protection Agency (EPA) is required to perform new chemical reviews of nanomaterials identified in pre-manufacture notices. However, environmental fate models developed for traditional contaminants are limited in their ability to simulate the environmental behavior of nanomaterials due to incomplete understanding and representation of the processes governing nanomaterial distribution in the environment and by scarce empirical data quantifying the interaction of nanomaterials with environmental surfaces. We have updated the Water quality Analysis Simulation Program (WASP), version 8, to incorporate nanomaterials as an explicitly simulated state variable. WASP8 now has the capability to simulate nanomaterial fate and transport in surface waters and sediments using heteroaggregation, the kinetic process governing the attachment of nanomaterials to particles and the dominant process of nanomaterials in an aquatic system.

(6.6.4) **Roehl Jr., Edwin A.**
Advanced Data Mining Int'l, Greenville, SC
EMPIRICAL MODELING OF A REVERSE OSMOSIS SYSTEM
Reverse osmosis systems (RO) play an increasing role in supplying potable water through direct and indirect reuse, and treating low quality sources. The Orange County Water District, California operates a 75 MGD RO that treats secondary WWTP effluent for its Groundwater Replenishment System. The RO comprises 45 membranes in 15 parallel 3-stage units, and requires periodic chemical cleanings to restore permeability due to fouling that occurs in two phases. Phase 1 fouling is caused by initial particle deposition, whereupon Phase 2 brings long-term biofilm and inorganic scale growth. OCWD wants to increase the duration of "runs" between cleanings to reduce costs, and supplied a six-year process dataset to be mined for useful information. The dataset comprised 179 runs and 62 hydraulic and water chemistry parameters. The investigative approach involved developing dynamic models of membrane fouling using multilayer perceptron artificial neural network models (ANN), with the goal of quantifying causes and effects among foulants, anti-foulants, and fouling indicators. Data for specific flux, the traditional fouling indicator, was sparse and exhibited extensive superposed hydraulic disturbances unrelated to fouling. An alternative fouling indicator (P[Symbol]) was calculated from five RO pressures. P[Symbol] is the portion of the feed pressure that modulates the permeate (cleaned water) flow rate. An ANN with only two inputs, P[Symbol] and the feed flow rate, accounted for 97% of permeate flow variability. Modeling P[Symbol] behavior caused predominantly by fouling required filtering the dataset to remove hydraulically-induced variability. P[Symbol] was then modeled using ensembles of water quality parameters represented as spectral signal components. Sensitivity analyses identified the most predictive components. Runs were divided into Phases 1 and 2, and the phases were modeled separately. The strongest predictors of P[Symbol] during Phase 1 were total chlorine, ammonia, TDS, electrical conductance, and boron; and total chlorine, ammonia, turbidity, and TOC during Phase 2.

(6.6.5) **Kleitches, Larry**[1], and Karina Walls[2]
[1]Rural Geography Specialty Group, American Association of Geographers, Alamosa, CO [2]Dept. of Geosciences, Georgia State University
HIDING IN PLAIN SIGHT - PIPELINES AND WATER RESOURCES IN NORTHERN GEORGIA
The world has been literally been watching for some time the events transpiring at Standing Rock Reservation in North Dakota. After months of turmoil, they had achieved a provisional victory in their fight against the Dakota Access Pipeline. However, that victory would soon be washed away by two executive orders by President Donald Trump reviving the Keystone XL and Dakota Access pipelines. The Bureau of Indian Affairs is now sending agents to help clear Dakota Access dissenters from the area. How are these actions even remotely related to water resources in Georgia? Georgia is not as pockmarked with oil and natural gas pipelines as numerous states in the southeastern U.S. However, the issue in Georgia is not necessarily number, but siting. Several gas transmission and hazardous liquid pipelines traverse through Fulton County and the counties in the Lake Lanier basin. Leakages similar to those in Alabama and Pennsylvania could potentially wreak havoc on the water supply for Atlanta and localities downstream. The 2016 drought, and its connected measures, underscored the fragility of water sources in northern Georgia. While there is currently a state moratorium on new pipeline construction, it is within the realm of possibility that "the good of interstate commerce" could be invoked to supersede any state efforts to block such construction.

SESSION 7 ABSTRACTS: THURSDAY 1:30-3:00 PM

Track 1.7 – Room Q: EPA Watershed Registry II

Special Session continues from 1.6 with more detailed usage, small group discussion, and exploration of Georgia applications.

SESSION 7 ABSTRACTS: THURSDAY 1:30-3:00 PM

Track 2.7 – Master's Hall: Coastal Resiliency

(2.7.1) **Roberts, Michael**
Community Consultants, LLC

IMPLEMENTATION OF COMMUNITY ASSET BASED STORMWATER MANAGEMENT TO ENHANCE RESILIENCY AND PRESERVE CHARACTER AND ENVIRONMENT OF COASTAL CITIES

The South Atlantic Bight is an area of the Atlantic Ocean that stretches from Winyah Bay down to Cape Canaveral. Its center is located near the Altamaha River Delta. The curvature of the coastline funnels tides and surges towards the center of the arc, causing higher tides here than in other areas of the Atlantic coast. The areas affected most range from Brunswick to Beaufort, SC. Greater resilience is required of cities along this portion of Atlantic coastline. On October 8, 2016, Hurricane Matthew made landfall near McClellanville, SC after closely paralleling this entire portion of the coast. At any point, a slight track to the Northwest would have meant a devastating impact. A fortuitous eleventh hour and fifty-ninth minute turn to the North from the North-Northwest spared the Savannah area from a direct impact. The water level at Fort Pulaski still rose to an all-time high of 12.57 feet above normal low tide, even two hours after high tide. This presentation will discuss how coastal cities can prepare themselves to withstand the impact of a major hurricane while creating community assets. Integrated stormwater management allows a city to embrace and integrate water and the natural environment while protecting infrastructure and the built environment from the ocean's inherent dangers. Comprehensive planning allows a city to accommodate future population growth while preserving the area's history and character and enhancing water quality and resiliency. If the environment and scenic beauty of the coast is degraded, quality of life will suffer as one of the most unique, pristine, and important landscapes on Earth will disappear. I will discuss how cities can implement projects and management strategies to protect the environment, preserve green space, promote economic development, improve runoff water quality, enhance wildlife habitat, lower flood insurance premiums, and develop and leverage funding sources.

(2.7.2) **Pippin, Scott**[1], Shana Jones[2], and Amble Jones[2]
[1]Carl Vinson Institute of Government at the University of Georgia; [2]Georgia Sea Grant Program Legal Fellow

ASSESSING THE BARRIERS AND VALUE OF ACQUIRING OR ELEVATING PROPERTY AT RISK OF FLOODING: A CASE STUDY OF THE CITY OF TYBEE ISLAND, GEORGIA

As sea levels rise and flooding damage in coastal communities becomes more frequent and severe, there is an increasing need to understand the costs and benefits and different adaptation options. Government acquisition or incentivizing renovation of flood prone properties are two of the primary tools local governments are expected to use to adapt to increasing flood risks. FEMA's Community Rating System (CRS) is probably the most significant federal program promoting local adaptation and increased community resilience to flood damage. The CRS rewards local governments that engage in enhanced floodplain management practices with discounts in local flood insurance rates. Public service faculty from the UGA's Carl Vinson Institute of Government and a student with Georgia Sea Grant Legal Fellows Program conducted a two-year study funded by Georgia's Coastal Incentive Grant Program on the costs and benefits to local governments of promoting acquisition, renovation, or relocation of residences exposed to significant flood risk based on the incentive structure of the CRS. This study is looking at the up-front and long-term costs of acquiring, renovating, or relocating these threatened properties to evaluate whether the CRS provides a meaningful incentive for local governments to engage in these adaption activities.

(2.7.3) **Hill, Kelly**
GA DNR Coastal Resources Division

ENHANCING COASTAL RESILIENCE WITH GREEN INFRASTRUCTURE

The Georgia Coastal Management Program (GCMP) works with coastal communities to foster awareness and understanding of the role of natural resources in protecting communities and citizens from the effects of natural disasters such as tropical storms/hurricanes, riverine flooding events and long-term hazards including sea level rise. The GCMP has developed a 5 year project to demonstrate how Low Impact Development and nature-based infrastructure practices, collectively referred to as "green infrastructure (GI)," can reduce a coastal community's vulnerability to flooding from major weather events or long-term climate events. This project began in 2017 and will utilize Liberty County as the Pilot Community to demonstrate the practicality and cost-effectiveness of replacing traditional storm water management practices, such as retention ponds and pipes, with GI approaches that utilize or mimic natural land processes. Computer models (HAZUS) will provide risk assessments and damage cost estimates from extreme precipitation-based and coastal storm surge based flooding using present-day stormwater management scenarios and idealized scenarios with GI practices. The results will be used to evaluate GI versus traditional stormwater practices. Workflow guidance for the modeling and analyses will be generated so that other communities in coastal Georgia and beyond can conduct their own evaluations of GI versus traditional designs in the future. Partners with the UGA Carl Vincent Institute of Government will develop model ordinances and a guidance document to accompany the results and training opportunities. Ongoing watershed based tools and resources that will accompany this project will also be discussed.

(2.7.4) **Jones, Shana**[1], and Mandi Moroz[2], Paul Wildes[2]
[1]UGA Carl Vinson Institute of Government, [2]UGA School of Law

COASTAL RESILIENCE: LEGAL ISSUES FOR LOCAL ADAPTATION

Since Hurricanes Katrina and Rita in 2005 and Superstorm Sandy in 2012, the concept of coastal “resilience” has transfixed the American public and gained increased importance across a variety of disciplines. While there has been increased interest in coastal resilience as a concept, however, many barriers to implementing resilience measures at the local level exist, including a need for greater understanding of the legal issues and potential solutions to these issues. Incorporating resilience measures into local decision-making raises questions about legal liability, legal duties, property rights, risk, economic and social equity, and fairness. In addition, every community is different and must balance competing interests such as encouraging economic development, promoting a secure tax base, and planning for long-term community prosperity, safety, and vitality. This session will provide an overview and introduction to two emerging legal and policy issues that are arising as coastal communities address increased flooding: “negligent takings” claims and “environmentally-compromised road segments.” With respect to “negligent takings,” recent court rulings indicate a growing trend of courts holding government liable for failing to protect their citizens from flooding disasters. Flood-control projects usually enjoy immunity from liability, but several recent cases have concluded that the government's negligence resulted in an unconstitutional "taking" of citizens' property. We will provide an overview of “takings” law and then will discuss how the law may be changing to allow for claims that have traditionally been barred by the doctrine of sovereign immunity. With respect to “environmentally-compromised road segments,” a recurring question is how should local governments balance their interests in protecting property rights and access to property with fiscal responsibility for maintaining frequently flooded roads? We will discuss Georgia law related to local government duties to maintain roads as well the process for abandoning roads.

(2.7.5) **Kramer, Elizabeth**, and Kevin Samples
Natural Resources Spatial Analysis Laboratory, College of Agricultural and Environmental Sciences, University of Georgia, Athens, GA

ADDING DYNAMIC INFORMATION TO RESILENCY PLANNING: IDENTIFYING AND REDUCING FUTURE CONFLICTS DUE TO SEA LEVEL RISE AND PROJECTED LAND USE CHANGE

Coastal marshes and barrier islands are, by nature, highly dynamic, and the forces that degrade them on the seaward side tend to transfer them in a landward direction. It is this transference that can be impeded by human development, often resulting in the reduction in the ability of marshes and sediments to migrate and thereby inhibiting the potential for natural resiliency of coastal communities to storm surge and wave action. In addition, sea level rise puts additional inland areas at risk to flooding as surficial water tables rise over time. Activities such as infrastructure planning often ignores the dynamic nature of our coasts. Public financing of infrastructure works on 30 year cycles, and therefore, locating new now infrastructure would benefit from including these future dynamics in the decision making. The overall goal of this project is to identify and prioritize the best sites for wetland protection, mitigation, restoration, and migration along the Georgia Coast, taking account of potential future land use change and the impacts of sea level rise. We identified and prioritize wetlands sites that could be restored, created, or protected based upon their location and condition 30 years from now. Our analysis shows that approximately 125,000 acres along the Georgia coast will be converted to wetlands by 2045 due to sea level rise; of those, 12,774 acres currently in urban land use and 507 miles of roadways will be impacted in the next 30 years. An additional 5,800 acres of additional lands are highly likely to be developed in the future, will also potentially be at risk due to sea level rise. It is hoped that this information will be used to support resiliency planning for coastal counties.

SESSION 7 ABSTRACTS: THURSDAY 1:30-3:00 PM

Track 3.7 – Room F/G: Agricultural Wetlands II and ACF Studies

(3.7.1) **Matteson, Cody**, Darold Batzer, Steve Golladay, Lora Smith, Chelsea Smith, Susan Wilde, Cody Matteson, C. Rhett Jackson, and Brittany Clark
University of Georgia, Warnell School of Forestry and Natural Resources

HYDROLOGIC LINKAGES BETWEEN FLOODPLAIN WETLANDS AND ADJACENT AGRICULTURAL LANDS

Wetland areas, and riparian zones, can be very important components in the nitrogen cycle and transport process, depending on their hydrologic conditions and flow paths (Denver et al., 2014). Runoff from these agricultural areas typically contain forms of nitrogen and phosphorus (Dupas et al., 2015) due to various activities that are typical on a farm. Depending on where these activities are located in the landscape, stormwater and irrigation runoff flowing into a riparian zone can significantly reduce the nutrient load being discharged to an adjacent stream (Secoges, Aust, Seiler, Dolloff, & Lakel, 2013). The specific objectives of this research are 1) to assess the connectivity of wild hog wallows and former feed lots to elevated phosphorus and nitrogen levels, through water and soil, 2) to establish a connectivity with nutrient levels in runoff from agriculture, to nutrient levels in adjacent streams, 3) assess the correlation between the levels of nitrogen and phosphorus and the abundance of micro biota and micro fauna in order to better predict locations of harmful algal blooms, 4) correlate nutrient levels with water table levels over time, to assist farmers in determining the most efficient time to apply fertilizers, and 5) investigate the effects of riparian buffers on nutrient reduction and uptake by comparing different types and sizes of riparian zones which would ultimately assist in future riparian buffer implementation. During this study, 23 piezometers and 22 surface water locations will be sampled for pH, specific conductivity, dissolved oxygen, and temperature, as well as total nitrogen and total phosphorus. Sampling events will be conducted bimonthly during annual dry periods, and monthly during annual wet periods. This research project is located in the piedmont region of Georgia, known for sediment laden streams (Jackson, Martin, Leigh, & West, 2005) and reddish-brown sandy loam soil (Payne, 1976).

References

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(3.7.2) **Wilde, Susan Bennett**, Cody Matteson, and Johnson Jeffers
UGA

ALGAL AND PERIPHYTON BIO-ASSESSMENT OF AGRICULTURAL WETLAND, STREAM AND RIVER

Biological assessments allow for integration in space and time of the anthropogenic alterations on the landscape. We screened algal samples collected from an agricultural site with wetland, stream and river system. A monitoring well network is in place to target likely areas of surface and subsurface flow, transitions between croplands and floodplains, floodplain, any jurisdictional wetlands. Monitoring and wells helped to identify existing hydrologic nutrient plumes from past activities (former feed lot and pasture, row crop agriculture) into and through floodplain wetlands. We also monitored surface waters at the site (n = 15; wetlands, Rose Creek, Oconee River, drainage ditches). Besides flows, water quality measures monitored in wells and surface waters will including nitrate-nitrite, phosphate, total nitrogen and phosphorus. Surface waters with elevated levels of nutrients supported harmful cyanobacteria, and low diversity of tolerant macroinvertebrates and fish. We also assessed the biotic integrity of the surface water by characterizing the periphyton, benthic macroinvertebrates, and fish communities in the individual catchments. Because the study site is split into one catchment dominated by pasture and an abandoned feed-lot that slopes towards the natural floodplain wetlands of Rose Creek, and a second catchment dominated by intensive row crop agriculture that slopes towards agricultural floodplain wetlands of the Oconee River, we anticipate unique hydrologic and run-off chemical relationships between agricultural uplands and wetlands in each catchment.

(3.7.4) **LaFontaine, Jacob H.**
U.S. Geological Survey South Atlantic Water Science Center, Norcross, GA 30093

WATER BUDGET SIMULATION IN THE APALACHICOLA-CHATTAHOOCHEE-FLINT RIVER BASIN AS PART OF THE USGS NATIONAL WATER CENSUS

The Apalachicola-Chattahoochee-Flint River Basin (ACFB), which is home to multiple fish and wildlife species of conservation concern, is regionally important for water supply and has been a recent focus of complementary water-resources, ecological, and climate-change research. As part of the USGS (USGS) National Water Census, a water-availability study of the ACFB was conducted for the period 2008-2012. This study combined monthly estimates of water use with linked surface water and groundwater models to assess the effects of climate, land cover, and water use on the hydrologic behavior of the ACFB. Seven hydrologic models were developed for the ACFB using the USGS Precipitation Runoff

Modeling System (PRMS); one coarse resolution model of the entire ACFB and six fine-resolution models in various watersheds across the basin (Upper Chattahoochee, Chestatee, and Chipola Rivers; and Ichawaynochaway, Potato, and Spring Creeks). As part of this effort, new modeling capabilities were developed for PRMS to incorporate various types of water-use information. In addition, four of the PRMS hydrologic models were loosely coupled with a MODFLOW groundwater model of the lower ACFB where the Upper Floridan Aquifer is at or near land surface. This coupling was needed to better understand surface-water/groundwater interactions in the lower ACFB and the impact of water use, primarily agricultural pumping, on streamflow. Water budget components from the coarse resolution model were summarized to the 12-digit Hydrologic Unit Code spatial resolution for inclusion in the National Water Census Data Portal (https://cida.usgs.gov/nwc/). Statistics of daily streamflow were computed for each stream segment in the fine-resolution model simulations for use in ecological response models.

(3.7.5) **Cole, Dargan "Scott**", and William Bradly Carver
Hall Booth Smith, PC, 191 Peachtree Street; Suite 2900, Atlanta, GA 30303-1775

AUGMENTATION OF FLOWS IN THE ACF

What happens if the Special Master requires Georgia to augment flows in the ACF during droughts? Several options are available for consideration if the Special Master rules this way. First, while not producing any "new" water, above ground storage (reservoirs) or below ground storage (aquifer storage and recovery) of water during high flow events for use during lower flows must be considered. Each option has its benefits and challenges including cost, environmental impacts and benefits, and practicability. Second, Georgia should consider interbasin transfers of water from [1] the Ocmulgee River basin to the Flint River, which would "return" the net transfer of about 50 mgd from the Chattahoochee basin, and [2] the Tennessee River, which has the potential to a "game changer" because of (x) its size, between 250 to 500 mgd is available depending on competing uses, (y) its location "at the top" of Georgia's water use network permits flexibility to directly or indirectly benefit multiple river basins. Finally, Georgia should consider the creation of "new" water via a gulf coast desalination plant feeding the Apalachicola River. This solution is becoming more cost effective with improved technology and addresses the main concerns expressed by Florida and Georgia in the trial before the special Master. We will provide a high level exploration of the benefits and challenges of each option.

SESSION 7 ABSTRACTS: THURSDAY 1:30-3:00 PM

Track 4.7 – Room L: Hydrologic Connectivity I

Session Organizer: **Sara Gottlieb** – Director of Freshwater Science & Strategy, *The Nature Conservancy, 100 Peachtree St. NW, Suite 2250 ·Atlanta, GA 30303*

This session will pick up where a 2015 GWRC panel left off in planning for the future for fish passage in Georgia. Since then, the Georgia Aquatic Connectivity Team has formed, with over 80 members from all the major state and federal agencies, many NGOs, recreation advocates, and private citizens participating toward the goal of accelerating dam removal and culvert replacement across the state. Several recent policy changes may make the permitting process for dam removal easier, and a revision by the U.S. Army Corps of Engineers to the Water Control Manual for the ACF Basin directs the Corps to operate the lock Jim Woodruff Lock and Dam to allow fish passage for Alabama shad and other anadromous fish during critical times in their life history. The Nature Conservancy is pursuing a dam removal project in the Raccoon Creek watershed, where a great deal of watershed restoration and culvert removal has already taken place. The University of Georgia is investigating improved aquatic connectivity at Whitehall Dam on the Middle Oconee River. Thousands of dams have been assessed in the ACF Basin and addressing connectivity concerns there is part of a larger initiative to preserve the native black bass species in the southeastern US. Additional topics relevant to aquatic connectivity in Georgia will be discussed, as will opportunities for attendees to become involved in this important initiative, which will have lasting impact on Georgia's water resources.

Panel part I: Statewide issues, modeling efforts, prioritizing maintenance and removal

Sara Gottlieb – *The Nature Conservancy*, Introductions, including background on SEACAP – 10 mins
Ben Emanuel - *American Rivers*, regulatory issues around dam removal in GA – 15 mins
Nate Nibbelink – *University of Georgia*, culvert prioritization modeling – 15 mins
Robert Hines - *University of Georgia*, Dam Safety and flood mapping – 15 mins
Eric Harris - USDA *Natural Resources Conservation Service*, NRCS dam maintenance and rehabilitation - 15 mins
Questions and discussion – 20 mins

Selected Abstracts:

Nibbelink, Nathan[1], Thomas Prebyl[1], Evan Collins[2], and Duncan Elkins[3]
[1]*University of Georgia - Warnell School of Forestry & Natural Resources, Athens, GA 30602; [2]US Fish & Wildlife Service - Alabama Ecological Services Field Office, Daphne, AL 36526; [3]University of Georgia - Odum School of Ecology, Athens, GA 30602*

HOW TO AVOID DEATH BY 10,000 CULVERTS: SPATIALLY-EXPLICIT TOOLS FOR MULTI-SCALE PRIORITIZATION TO RESTORE AQUATIC CONNECTIVITY

Fragmentation of hydrologic connectivity is one of many threats to aquatic biodiversity. Increasingly, culverts installed at road-stream crossings are known to be significant contributors to fragmentation. Culverts present a unique challenge in that they are often only partial barriers to fish passage, but are incredibly numerous on the landscape. The dendritic connectivity index (DCI) has been used to calculate overall network connectivity at the watershed scale, and the contribution of one or more potential barriers to the DCI score can be calculated by removing those barriers one at a time and recalculating the DCI. Because 8-digit hydrologic units in the southeastern U.S. can have between 3,000 and 13,000 road-stream crossings, the prioritization of one or more crossings for remediation quickly becomes a computationally impossible problem. Furthermore, the DCI requires a passability score for each potential barrier, and while databases containing passability information at each of these points on the landscape are growing, we still lack sufficient data for landscape-level planning efforts. In order to address these challenges, we created a comprehensive set of spatially-explicit tools for multi-scale prioritization. First, we use a random forest algorithm to estimate passability at road-stream crossings as a function of local and regional environmental gradients (e.g., stream slope, % forest cover, basin relief). Second, we apply a heuristic algorithm in a graph-theoretic framework to prioritize potential barriers for remediation or removal. Predictive models appear useful for prioritizing areas with passability problems at a subwatershed level, but prediction success for individual barriers are more variable. Within a hydrologic unit, heuristic prioritization algorithms improve computation times by several orders of magnitude, and exactly match exhaustive solution priority rankings for more than 350 barrier removal options. Scenarios also indicate the relative effect of culverts vs. dams alone, and show variation in prioritization based on species life history characteristics.

Hines, Robert
UGA Carl Vinson Institute of Government

SHORING UP DAM SAFETY: ASSESSING THE FUTURE THREAT LEVEL OF GEORGIA'S DAMS AND REVIEWING THE APPLICABILITY OF SIMPLIFIED INUNDATION MAPS FOR EMERGENCY PLANNING

Adequate strategic and emergency planning is essential to protect Georgia's expanding communities from aging dam infrastructure. This project accessed the National Inventory of Dams to produce summary statistics describing the state of Georgia's dams. Georgia's dams are aging, mostly privately owned, primarily earthen, and variable in size. Communities will be increasingly threatened as they continue to expand into dam break floodplains. In the event of a dam break, emergency action plans (EAP) can prepare local emergency responders to quickly issue

warnings, plan for efficient emergency service delivery, and identify at-risk infrastructure. While the high cost of complex dam break inundation mapping studies has prevented EAP development across the United States, new Environmental Protection Division (EPD) rules now require all category one dams that, by definition, may cause a loss of life upon breaking to have EAPs. However, given a situation in which full dam break studies are unavailable, simplified inundation maps may be able to fill the gap in dam break emergency action planning. To explore simplified mapping reliability this project reviewed engineering recommendations and created a simplified mapping methodology that utilizes Arc GIS mapping and HEC RAS steady state modeling. Federal Emergency Management Agency Recommendations for EAP development were assessed to produce road crossings and threatened structures as the most relevant and practical points of comparison between simplified and formal maps. Two qualitative case studies were developed comparing simplified maps against formal, unsteady state maps provided by the Georgia Soil and Water Commission. Ultimately, the simplified mapping methodology either over or underpredicted flooding as compared to formal mapping. However, these qualitative case studies were not able to formally measure risk or create perfect steady state models. Emergency managers must ultimately determine if simplified methodologies produce maps that are better than nothing for EAP development.

Harris, Eric, George Skovran
USDA, Natural Resources Conservation Service, Athens, GA

GEORGIA NRCS WATERSHED MAINTENANCE & REHABILITATION

Local communities in Georgia, with USDA Natural Resources Conservation Service (NRCS) assistance, have constructed over 350 dams since 1953. Many of these dams are nearing the end of their 50-year design life. Maintenance and rehabilitation of these dams is needed to address critical public health and safety issues in these communities. The following presentation will provide background and case studies of maintenance and rehabilitation needs of watershed dams across Georgia as well as progress toward rehabilitation accomplishments.

SESSION 7 ABSTRACTS: THURSDAY 1:30-3:00 PM

Track 5.7 – Room R: Urban Streams

(5.7.1**) Journey, Celeste**[1], Paul M. Bradley[2], and Peter VanMetre[3]
[1]U.S. Geological Survey South Atlantic Water Science Center, 720 Gracern Road, Suite 129, Columbia, SC 29210; [2]U.S. Geological Survey South Atlantic Water Science Center, 720 Gracern Road, Suite 129, Columbia, SC 29210; [3]U.S. Geological Survey Texas Water Science Center, 1505 Ferguson Lane, Austin, TX 78754

NUTRIENTS IN WADEABLE STREAMS IN THE PIEDMONT AREA OF THE SOUTHEASTERN UNITED STATES

During the spring and summer of 2014, the USGS National Water-Quality Assessment Program assessed stream quality across the Piedmont and southern Appalachian Mountain region in the southeastern United States. The goal of the Southeast Stream Quality Assessment (SESQA) is to characterize multiple water-quality factors that are stressors to aquatic life – contaminants, nutrients, sediment, and streamflow alteration – and the relation of these stressors to ecological conditions in streams throughout the region. Two important anthropogenic factors affecting water quality in the region are urbanization and streamflow alteration; therefore, these factors were targeted in the assessment. Findings from the assessment will provide communities and policymakers with information about which human and environmental factors are the most critical in controlling stream quality, and, thus, provide insight about possible approaches to protect and improve stream quality. The targeted design of the assessment used streamflow and land-use data to identify and select sites that reflected a range in the amount of urbanization and streamflow alteration. Seventy-eight multi-stressor sites were selected and sampled across the region for as many as 10 weeks during April, May, and June 2014 for contaminants, nutrients, and sediment. This water-quality "index" period culminated with an ecological survey of habitat, periphyton, benthic macroinvertebrates, and fish at all sites. Fifty-nine sites were on streams in watersheds with varying degrees of urban land use, 5 were on streams with numerous confined feeding operations (CAFOs), and 13 were reference sites with little or no development in their watersheds. This presentation will provide preliminary findings from the SESQA study and focus on spatial distribution of nutrients and related watershed characteristics of selected streams that drained a gradient of urbanized, animal-feeding-operation-dominated, and reference conditions. The data were assessed regionally and by urban center that included Atlanta, Ga., Greenville-Spartanburg, S.C., Charlotte, N.C., Raleigh-Durham-Greensboro, N.C., and Washington, D.C.

(5.7.2) **Calhoun, Daniel**
U.S. Geological Survey, South Atlantic Water Science Center, 1770 Corporate Drive, Suite 500, Norcross, GA 30093

EVALUATING TEMPORAL CHANGES IN AQUATIC MACROINVERTEBRATE AND STREAM FISH ASSEMBLAGES AT LONG-TERM MONITORING SITES IN THE SOUTHEASTERN US

The southeastern United States has undergone large scale historic land use change as a result of agriculture and urbanization. The USGS investigated temporal changes in aquatic macroinvertebrate and stream fish assemblages at long-term monitoring sites that were established to determine the status and trends of stream conditions in the United States based on specific indicators of current land use. This study assessed trends in the macroinvertebrate and fish assemblages of stream segments of four urban, six agricultural, and two minimally-altered watersheds as well as at two large river sites with integrated multiple land uses. The time periods of data collection varied across the sites beginning in 1993 and ending in 2008. All locations had a minimum of five years and a maximum of nine years of annual ecological community composition. A multivariate seriation test on the ecological time series for each site was used to identify significant trends in the macroinvertebrate and fish communities. The time series was then compared to assemblage metrics to determine potential structural and functional attributes of the changing communities. The responding metrics were then linked to indicators of water chemistry, hydrology, climatic factors, or stream habitat. Significant temporal changes in macroinvertebrate and fish assemblages were found at four and five of the thirteen sites, respectively. Two of these sites showed temporal change in both assemblages. Macroinvertebrate and stream fish metrics were found to be sensitive to changes in stream chemistry, stream habitat, and to a lesser extent, hydrologic indices. Progressive change in biotic assemblage structure can be identified in these locations highlighting the potential benefit of long-term biomonitoring and trends assessment to evaluate the effectiveness of land management activities.

(5.7.3) **Bradley, Paul M.**[1], Keith A. Loftin[2], Jimmy M. Clark[1], Celeste A. Journey[1], Dana W. Kolpin[3], and Peter C. Van Metre[4]
[1]U.S. Geological Survey, South Carolina Water Science Center, 720 Gracern, Columbia, SC, 29210; [2]U.S. Geological Survey, Organic Geochemistry Research Laboratory, Kansas Water Science Center, 4821 Quail Crest Place, Lawrence, KS 66049; [3]U.S. Geological Survey, Iowa Water Science Center, 400 S. Clinton St., Iowa City, IA 52240; [4]U.S. Geological Survey, Texas Water Science Center, 1505 Ferguson Lane Austin TX 78754

MICROCYSTINS OCCURRENCE IN WADEABLE STREAMS IN THE SOUTHEASTERN UNITED STATES

The presence of potential toxin-producing cyanobacteria has been documented in multiple stream assessments conducted by the USGS throughout the Southeastern US during 1993-2011. However, fluvial cyanotoxin occurrence has not been assessed systematically in the region. To begin to address this gap, the USGS Toxic Substances Hydrology and National Water Quality Assessment Programs conducted a spatial reconnaissance of fluvial microcystin concentrations in 75 wadeable streams during June 2014. Microcystins were detected (ELISA; MDL = 0.10 µg/L) throughout the region. The persistence and temporal variability of microcystins were assessed monthly through October 2014 in five of the streams where microcystins were observed in June and in one reference location. Microcystins were repeatedly detected in all but the reference stream. The widespread occurrence of microcystins observed in this reconnaissance demonstrates the need for further investigation throughout the Southeastern US and in fluvial systems, in general.

(5.7.4) **Snyder, Blake**[1], Marirosa Molina[2], and Ourania Georgacopoulos[3]
[1]Oak Ridge Institute for Science and Education, Oak Ridge, Tennessee; [2]US Environmental Protection Agency, Office of Research and Development, Athens, Georgia; [3]Student Services Contractor at the Environmental Protection Agency, Athens, Georgia

RELATIONSHIPS AND TRENDS OF E. COLI, HUMAN-ASSOCIATED BACTEROIDES, AND PATHOGENS IN THE PROCTOR CREEK WATERSHED

Urban surface waters can be impacted by anthropogenic sources such as impervious surfaces, sanitary and storm sewers, and failing infrastructure. Fecal indicator bacteria (FIB) and microbial source tracking (MST) markers are common gauges of stream water quality, however, little is known about their relationship with public health. In this study, we measured culturable and molecular concentrations of E. coli, a human-associated Bacteroides marker (HF183MGB), and selected waterborne pathogens and toxins (Salmonella sp. and Shiga-toxin (Stx2)) in surface water throughout a highly urbanized watershed near downtown Atlanta, GA to determine if any relationships exist between these parameters. The Proctor Creek watershed, a tributary to the Chattahoochee River, consistently fails fecal coliform standards and is therefore, listed on the Environmental Protection Agency's (EPA) 303(d) impaired waters list. Water grab samples were taken at 12 locations throughout the watershed every two weeks for one year. Culturable E. coli concentrations varied greatly throughout the watershed (24 to 101,330 MPN/100 mL). The human associated marker was widespread throughout the watershed and correlated highly with molecular E. coli (r2 = 0.63). Salmonella was present at all mainstem and half of the tributary sites, whereas Stx-2 was widespread throughout the entire watershed but was most frequently found at headwater locations where storm water inlets and outfalls were more prevalent. Based on their high correlation, E. coli could be a useful parameter in predicting human-associated Bacteroides in this watershed. Our results also indicate that major and consistent human sources of fecal contamination are present throughout the watershed suggesting that sanitary sewer leaks could be widespread across the region.

(5.7.5**) Johnson, Emily M.**, Seth J. Wenger, Amy D. Rosemond, and Phillip M. Bumpers
Odum School of Ecology, University of Georgia, Athens, GA 30606

CONDUCTIVITY AS AN INDICATOR OF DISTURBANCE AND TOOL FOR WATERSHED MANAGEMENT

Increased conductivity of streams is a common symptom of watershed urbanization and is often highly correlated with degraded water quality and impaired biotic assemblages. Stormwater runoff, sewage effluent, and sediment inputs have all been cited as sources of ions that drive conductivity. However, it is often difficult to identify these sources of pollution and distinguish them from one another. In order to better understand the spatial and temporal patterns of conductivity we continuously monitored specific conductance (SpC), stage height, and temperature from October 2016 – April 2017 in seven streams in Athens, GA. Baseflow SpC was consistent in time but variable among streams, suggesting chronic sources of ions in some urban streams. In addition, our study revealed distinct patterns of high conductivity that may be diagnostic of specific stressors and events. For example, we saw clear "first flush" phenomena in the most urbanized watersheds, as well as potential evidence of sewer leaks and sedimentation events. Thus, the continuous monitoring of conductivity may be an effective management tool for identifying specific sources of pollution. Ongoing work will synthesize results and test the application of these monitoring techniques as a tool for watershed management. Additionally, we will explore relationships between macroinvertebrate assemblage characteristics and drivers of conductivity to allow us to better understand how pollution is altering biological communities in Athens streams.

SESSION 7 ABSTRACTS: THURSDAY 1:30-3:00 PM

Track 6.7 – Room K: Coal Impacts

STRATEGIES FOR REDUCING IMPACTS OF COAL-FIRED POWER PLANTS ON GEORGIA'S WATER RESOURCES

Session Organizer: **Amelia Shenstone** - *Southern Alliance for Clean Energy, 250 Arizona Ave., NE, Atlanta, GA 30307*
Coal-fired power plants dot Georgia's landscape along rivers, lakes, and streams in the Altamaha, Chattahoochee, Coosa, and Savannah River basins. Georgians rely on these water resources for drinking water, fishing, swimming, and recreation. Georgia's electricity sector is the largest water use sector in Georgia and power plants represent one of the greatest sources of pollution.

The Southern Alliance for Clean Energy (SACE) has organized a session comprised of 3 short presentations followed by a moderated discussion.

The presentations will cover:

- Georgia Environmental Protection Division's (EPD) out-of-date National Pollutant Discharge Elimination System (NPDES) permits for Georgia Power's coal-fired power plant fleet
- Thermal pollution impacts and solutions at Plant Hammond and other power plants
- Proposed coal ash storage plans and pollution concerns at landfill and power plant sites

Presenters:
Jen Hilburn, *Executive Director, Altamaha Riverkeeper*: The Altamaha Riverkeeper is a grassroots organization dedicated to the protection, defense and restoration of Georgia's biggest river – the Altamaha – including its tributaries the Ocmulgee, the Oconee and the Ohoopee.

April Lipscomb, *Associate Attorney, Southern Environmental Law Center*: The Southern Environmental Law Center has represented environmental non-profits and citizens in successful cases that have achieved thorough cleanup of coal ash storage impoundments. Jill Kysor is an expert on Georgia's current coal ash regulations. We are currently discussing her potential role.

Jennette Gayer, *Director, Environment Georgia*. Ms. Gayer coordinates policy development, research, and legislative advocacy for Environment Georgia. She is based in Atlanta and organizes around a number of issues to bring cleaner air, water and open spaces to Georgia. She serves on the board of Citizens for Progressive Transit, a statewide group dedicated to increasing public transportation, and is a member of the Beltline Tax Assessment District Advisory Council. Previously, she directed field campaigns to build a million solar roofs and cap global warming for Environment Georgia's sister organization, Environment California. She also worked as a Consumer Advocate with CALPIRG, where she sat on the state of California's Bureau of Automotive Repair and helped to found Angelenos for Equitable Access to Technology a media reform community group.

SESSION 8 ABSTRACTS: THURSDAY 3:30-5:00 PM

Track 1.8 – Room Q: Water Management

(1.8.1) **Craw, Veronica**
Georgia Environmental Protection Division, 2 Martin Luther King Jr. Drive, Suite 1462 East, Atlanta, GA 30334

WHERE THE NPDES ENDS: WATERSHED IMPROVEMENT BEYOND THE PERMIT

The Federal Clean Water Act National Pollutant Discharge Elimination System (NPDES) permitting program regulates discharges of pollutants from point sources, which includes stormwater discharge and wastewater discharges from pipes, outlets and other discrete conveyances. The NPDES permitting program does not address nonpoint sources of pollution which transports sediment, nutrients, bacteria, metals, pesticides, organic compounds and other forms of pollution into rivers, lakes, estuaries and wetlands. The wide range of nonpoint sources (e.g., agriculture, mining, silviculture, urban runoff) and the variety of pollutants generated by them create a challenge for their effective control. The U.S. Environmental Protection Agency (USEPA) awards a Nonpoint Source (NPS) Implementation Grant to the Georgia Environmental Protection Division (GAEPD). The grant is used to fund eligible projects as described in Section 319(h) of the Clean Water Act which support Georgia's NPS Management Program goals and objectives of prevention, control, and/or abatement of nonpoint sources of pollution. USEPA awards the grant annually, which GAEPD uses to administer the program and make funds available to public agencies in Georgia (e.g. cities, counties, regional development centers, local school systems, State colleges and universities, and State agencies). Historically, Georgia has received approximately $3.5 million each year to address NPS pollution and implement its NPS Management Program. Local governments and project partners have annually contributed approximately $2.3 million in matching funds to these efforts. During the 2016 calendar year, GAEPD continued to implement statewide water quality improvement projects by administering 49 active Section 319(h) grant contracts that totaled over $10.8 million in federal funds and $8.1 million in matching funds or in-kind services. Thirty-six of these projects were funded to external sub-grantees. Project components included Best Management Practice implementation, water quality monitoring, septic repair, Green Infrastructure/Low Impact Development, stream restoration, educational outreach, and watershed planning.

(1.8.2) **Georgakakos, Aris P.**
Georgia Water Resources Institute, Georgia Tech

INTEGRATED WATER, ENERGY, AND ENVIRONMENTAL MANAGEMENT: EXPERIENCE FROM TANZANIAN RIVER BASINS

In recent decades sharply rising populations, economic development pressures, and myopic environmental management practices have been escalating the use and pollution of water resources worldwide. Tanzania is also witnessing its share of environmental degradation as large swaths of woodlands and savannahs are rapidly cleared to make way for farmland and pastures; forests are cut for timber, charcoal, and firewood; wetlands are drained for agricultural use; river banks and hill slopes are cultivated intensely; and water withdrawals from rivers, lakes, and aquifers are increased to meet the rising demands for irrigation and other water uses. Climate change is causing more severe and more frequent droughts and floods and exacerbates environmental stresses and socio-economic vulnerabilities, especially for the poor. The Rufiji River and Lake Rukwa Basins are well-endowed with environmental resources and hold great promise of socio-economic prosperity for their communities and Tanzania as a whole. In many watersheds comprising these basins, this promise remains intact, but in others, the lack of good management practices has allowed water and environmental stresses to become unsustainable, threatening to reverse economic development and bring about societal and environmental crises. This article reports on the hydro-climatic, water resources, and socio-economic assessments, findings, and recommendations of Integrated Water Resources Development and Management (IWRMD) Plans recently prepared to address the above concerns and harness the considerable basin water and natural resources. The single most important message of the plans is that the Rufiji River and Lake Rukwa River Basins can indeed deliver their full societal and environmental promise to their communities and Tanzania, but for this to occur, there must be a systemic change in the way water and environmental resources are managed by government institutions (at all levels) and by the stakeholders themselves. The Rufiji River and Lake Rukwa IWRM Plans have successfully been ratified and legally adopted by the Government of Tanzania.

(1.8.3) **Dwivedi, Puneet**
Warnell School of Forestry and Natural Resources, University of Georgia,180 E Green St Athens GA 30602

NEXUS BETWEEN BIOENERGY DEVELOPMENT, LAND USE CHANGE, AND CLIMATE CHANGE ON WATER AVAILABILITY: A CASE STUDY FROM OCONEE WATERSHED

The export of wood pellets from the SE United States to the European Union is continuously increasing. It is quite likely that the area under forestry cover will increase to meet the rising demand for wood pellets at the expense of other competitive land uses in SE states. This research analyzes the impact of an increase in forestlands coupled with changing climatic inputs (temperature and precipitation) on the hydrology of a local watershed located in the Northeastern Oconee River Basin in the Piedmont region of Georgia. Using spatial modeling, suitable sites for loblolly pine (Pinus taeda) were determined. The outputs of suitability analysis were merged with historical land use change records to project an increase in area under loblolly pine for 2016, 2021, and 2026. Then, SWAT hydrological model was used to predict any changes in water discharge until 2028 for 14 scenarios in the presence of evolving land cover changes and changing climatic inputs. Results suggest that changes in land use in conjunction with variable climatic conditions could decrease or increase streamflow by up to 27% and 31% and evapotranspiration by up to 3% and 4%, respectively. Impact of changing climate on streamflow was much higher than any changes in land use. Results of this study improve our understanding of sustainability of transatlantic wood pellet trade.

(1.8.4) **Shepherd, Marshall**[1], and Chuntao Liu[2]
[1]UGA, [2]Texas A&M Corpus Christi
PRECIPITATION METRICS AND THE ENERGY-FOOD-WATER NEXUS: CHALLENGES AND OPPORTUNITIES
In a 2011 Global Risk report, the World Economic Forum (WEF) explicitly stated that natural resources were among the top 3 global risk clusters facing society. The report stated clearly that: "Food production requires water and energy; water extraction and distribution requires energy; and energy production requires water. Food prices are highly sensitive to the cost of energy inputs through fertilizers, irrigation, transport and processing." Many frameworks have been used to study the Energy-Water-Food-Network (EWFN), however, there has been very little attention to the hydroclimate implications and interactions. Much of the attention has focused on greenhouse gas emission, landuse, resource management efficiency, or societal facets. The complicated interconnections of Energy-Water-Food systems have emerged as critical areas of research. We present our ongoing efforts to link satellite based precipitation data and other NASA data to support the EWFN nexus related to urban transitions and interconnections to agriculture. As a part of our broader research portfolio, satellite-based precipitation estimates are being exploited to develop scientifically rigorous but stakeholder accessible metrics. The basic questions guiding the research are: Can precipitation per urban capita or per individual be quantified using PMM datasets? If so, can spatio-temporal trends in the metric be useful in the assessment of the EWFN capacities and vulnerabilities?

(1.8.5) **Wallace, Daniel F.**
USDA-NRCS
GEORGIA'S LAND: ITS USE AND CONDITION FOURTH EDITION
This presentation reports 30 years of results from USDA's National Resources Inventory (NRI) program in Georgia and introduces the recently published 4th Edition of Georgia's Land: Its Use and Condition. The publication shows that Georgia's largest land uses in 2012 were forest, developed land, cropland, and pasture. Surface water is an important category which saw an increase over the inventory period. Details on all land uses, their condition, their distribution and trends over time are presented in the publication and summarized in this presentation. Change detection is one of the NRI's biggest strengths - from 1982 to 2012, the equivalent of 20% of Georgia's area has been involved in change. Identifying such trends should prove useful in guiding the future direction of conservation efforts. Data from the inventory such as a significant reduction in cultivated cropland and the doubling of developed land acreage in 30 years displays the vast scale and dramatic speed of land use change affecting our land and water resources.

SESSION 8 ABSTRACTS: THURSDAY 3:30-5:00 PM

Track 2.8 – Master's Hall: Coastal Changes

(2.8.1) **Murray, Kelly**, Darold Batzer, and Joseph McHugh
Department of Entomology, University of Georgia, Athens, GA 30602

ASSESSING LONG-TERM ECOLOGICAL CHANGE IN THE OGEECHEE RIVER USING AQUATIC INVERTEBRATE COMMUNITIES

Biodiversity is decreasing rapidly, and nearly all types of organisms and environments are placed at risk due to land-use and global climate change. One strategy for researchers studying these changes and attempting to understand how they manifest in the natural world is to utilize reservoirs of natural history museum collections and make comparisons between characteristics of past and present organisms and populations. In the 1980s, an extensive collection of aquatic invertebrates from the Ogeechee River (Georgia, USA) was produced from systematic sampling of submerged woody debris. Since this collection, there has been considerable change both on a global and local scale, including a chemical spill in the Ogeechee that was linked to a significant fish-kill. Currently, we are repeating the sampling scheme of the previous project and using the preserved specimens donated to the Georgia Museum of Natural History to compare aquatic invertebrate communities between the past and present. Analyses will be based on ordinations such as Non-Metric Multidimensional Scaling, and aspects of functional trait diversity will be compared between time periods. Our aim is to understand: [1] whether changes in community structure and trait diversity have occurred, [2] what trends appear to dominate in these invertebrate assemblages, and [3] what might be the source of such changes. By revisiting the original collection and making this addition to it, our goal is to provide a basis for continued study in light of global change and other anthropogenic effects on aquatic invertebrate biodiversity in the Southeast.

(2.8.2) **Sheldon, Joan E.**, and Merryl Alber
Department of Marine Sciences, University of Georgia, Athens, GA 30602

CLIMATE SIGNALS AFFECT FRESHWATER INFLOW, SALINITY AND TEMPERATURE IN GEORGIA ESTUARIES

Variability in watershed precipitation, river discharge, salinity, and temperature for the Ogeechee, Satilla, and St. Marys estuaries was related to indices of four climate signals. Variability in watershed precipitation (not shown in detail here) was analyzed using empirical orthogonal functions (EOFs) and results were similar to those for the Altamaha River watershed (Sheldon and Burd 2014), showing alternating seasonal correlations with the Bermuda High Index (BHI) in summer-fall and the El Niño/Southern Oscillation Index (ENSO/SOI) in late fall-winter. The Atlantic Multidecadal Oscillation (AMO) imposes a long-term seasonality modulation that is weaker in the Ogeechee and St. Marys than in the Satilla and Altamaha watersheds, although these effects could be due to data limitations. Climate signal-precipitation patterns all propagated (with some signal attenuation) to lower watershed river discharge 0-1 month later and to estuarine salinity 0-2 months later, consistent with residence time estimates for each estuary. The BHI and SOI had only brief seasonal correlations with estuarine water temperatures. The North Atlantic Oscillation (NAO) was correlated with January-April temperatures but not with any of the flow variables. These patterns agree broadly with regional-scale analyses but are likely to be different from those outside the region. In the southeast US, fundamental estuarine characteristics such as freshwater inflow, salinity and temperature are influenced seasonally and interannually by a complex interplay among at least four climate signals.

(2.8.3) **Hopkinson, Charles**[1], J. Morris[2], S. Fagherazzi[3], and P. Raymond[4]
[1]UGA, [2]University of South Carolina, [3]Boston University, [4]Yale University

HAS THE 10,000 YEAR PERIOD OF BAY INFILLING PASSED? IF SO, WHAT ROLE WILL BAY EDGE EROSION PLAY IN HELPING TO MEET PLATFORM SALT MARSH SEDIMENT NEEDS?

Observations of ancient (>1000 yrs) fine organic material in marsh surface sediments has led us to examine the source and importance of this material in maintaining marsh elevation relative to sea-level rise. We find very low inputs of sediments from the watershed to the Plum Island Sound estuary, less than 10% of that needed to sustain marsh elevation relative to SLR. An imbalance between SLR and allochthonous sediment inputs to the estuary is contributing to the expansion of tidal waterways through lateral erosion of marsh creekbanks. Based on an analysis of 2005 and 2011 LiDAR imagery, we estimate annual erosion of about 42,000 m2, and a daily input of about 27 MT of sediment. 14C dating of suspended POC along the length of the estuary shows that ancient blue carbon peat can make up over a third of the total load on occasion, confirming that eroded creekbank sediment is being resuspended and transported via tidal currents. If all this material is deposited on the marsh platform during inundating tides, it could provide 33% of the sediment required to maintain elevation of all salt marshes in the Plum Island system.

(2.8.4**) Hynes, Annette M.**[1], Brian M. Hopkinson[1], Joan E. Sheldon[1], Joseph J. Vallino[2], and Charles S. Hopkinson[1]
[1]Department of Marine Sciences, University of Georgia, Athens, GA 30602; [2]Ecosystems Center, Marine Biological Laboratory, Woods Hole, MA 02050

MODELLING ECOSYSTEM METABOLISM IN COASTAL ESTUARIES

Concentrations of dissolved oxygen (DO) result from the combined effects of photosynthetic production, respiration, and air-water gas exchange, and time series of DO can be used to calculate ecosystem metabolism. We are adapting a nonlinear inverse model to estimate spatially explicit ecosystem metabolism in the Sapelo Island Estuary (Duplin River, GA) using DO measurements from high-speed transects along the river. This work in progress modifies a model developed to measure gross primary production (GPP), community respiration (CR), and net ecosystem production (NEP) in the Plum Island Estuary, MA. We are also using harmonic analysis of long-term DO time series from

stationary sondes to calculate temporal estimates of GPP, CR, and NEP. These long-term studies can examine the effects of nutrient loading, sediment loading, river discharge, sea level rise, and temperature on estuarine community metabolism.

(2.8.5) **Savidge, William**, and Kate Doyle
Skidaway Institute of Oceanography

SEASONAL NUTRIENT DISTRIBUTIONS AND INVENTORIES IN THE OGEECHEE RIVER ESTUARY

Seasonal distribution and inventories of nutrients (organic and inorganic N & P), DOC, chlorophyll, and oxygen were obtained from nine seasonal survey transects of the Ogeechee River in 2015-2016. Riverine freshwater residence times ranged from ~45 days in the late summer to ~5 days in the winter. Long summer residence times, low river discharge, and high river endmember concentrations led to high inventories of nitrate and phosphate in the estuary during the summer. Distributions and estimated residence times of nutrients and DOC indicated that they usually behaved conservatively during estuarine transit, especially during higher flow portions of the year. There were some exceptions to the general pattern. Large inventories and long residence times relative to fresh water of nitrite and phosphate in the Ogeechee during the summer and early fall transects imply an estuarine source for these nutrients. High nitrite concentrations are likely a result of partial denitrification within estuarine sediments. The ~conservative behavior of nitrate, however, implies that denitrification must be supported primarily by coupled nitrification-denitrification of organic nitrogen sources rather than by direct denitrification of riverine nitrate. The conservative behavior of nutrients in the estuary suggests that most terrestrial/riverine nutrient removal must occur on the inner shelf.

SESSION 8 ABSTRACTS: THURSDAY 3:30-5:00 PM

Track 3.8 – Room F/G: Forests and Water

(3.8.1**) Weisman, Kitty**[1], and Scott Thackston[2]
[1]SE Partnership for Forests and Water; [2]Watershed Coordinator, Georgia Forestry Commission
SOUTHEASTERN PARTNERSHIP FOR FORESTS & WATER - GEORGIA SUCCESSES
The Southeastern Partnership for Forests and Water (Partnership), funded by the US Forest Service and the US Endowment for Forestry and Communities, brings the drinking water, forestry, and conservation sectors together to collaborate on watershed protection throughout the southeastern United States. Partnership goals include: • Maintain and expand healthy forests in drinking water watersheds • Initiate and develop working relationships between state and local agencies, Rural Water Associations, forestry interests and conservation groups • Identify watersheds and initiatives that have high potential for cooperative forest conservation, sound management and restoration • Explore pilot projects to implement creative watershed protection strategies such as Payment for Watershed Services and forestry best management practices, demonstrating the interdependence of healthy forests and drinking water In Georgia, the Partnership has identified three key watersheds for collaboration – Athens/Oconee River, Columbus/Middle Chattahoochee, and Savannah River Watershed. This presentation will detail collaborative projects in these three watersheds with a variety of partners at the local, state, and regional levels. Projects focus on forest landowner outreach and fundraising to achieve best management practices and forest land conservation to directly benefit drinking water.

(3.8.2) **Carrie McCarty**, James Shelton, and Brian Davis
UGA Warnell School of Forestry & Natural Resources
THE EFFECT OF RIPARIAN CANOPY GAPS ON MACROINVERTEBRATE AND PERIPHYTON COMMUNITY STRUCTURE IN STREAMS IN THE SOUTHERN APPALACHIAN MOUNTAINS
Small man-made disruptions in forest cover are common in riparian zones of most streams, even in heavily forested areas. Power line easements, logging road clearings, bridge clearings, and private property clearings are numerous throughout southeastern headwaters. This two-part study investigates the within-gap and downstream effects that small riparian canopy disruption may have on periphyton and benthic macroinvertebrate communities in streams within the Little Tennessee River basin of the Southern Appalachian Mountains. This study was conducted in conjunction with a project evaluating the effects of riparian canopy gaps on stream water temperature. We collected periphyton and benthic macroinvertebrate samples from ten streams within the Little Tennessee River basin of North Carolina and Georgia. Samples were taken within, above and below gaps in riparian forest cover. Periphyton sampling locations were allocated based on substrate composition (sand, rock, leaves and woody debris). Periphyton were identified, enumerated and grouped for analysis (diatoms, cyanobacteria and chlorophytes). We then compared periphyton community composition for samples from above gaps to samples within and below gaps. Benthic macroinvertebrate sampling locations were taken proportional to substrate types present at each site (cobble, sand/fines, leaf packs, submerged aquatic macrophytes, and woody debris). We then compared benthic macroinvertebrate community composition for samples from above gaps to samples within and below gaps. We then compared findings on the effects of riparian canopy gaps on stream temperature to the biological response of periphyton and benthic macroinvertebrate community composition.

(3.8.3) **Jackson, C. Rhett**, and W. Alan Coats
UGA Warnell School of Forestry & Natural Resources
DO OPEN-CANOPY MOUNTAIN STREAMS COOL DOWN AFTER RETURNING TO FORESTED CONDITIONS?
Summer maximum stream temperatures are a primary determinant of stream habitat suitability for cold-water species like trout. In the Southern Appalachian Mountains, trout are limited to small headwater streams due to temperature constraints. Sunlight and longwave radiation are the dominant drivers of spatial and temporal variability in stream temperatures. Consequently, the removal of riparian forest cover causes stream temperatures to rise until the outgoing longwave radiation (proportional to Tabs^4) matches the incoming shortwave. We have observed both rapid increases of daytime stream temperatures within riparian gaps and rapid declines of daytime stream temperatures after the stream returns to forested riparian conditions. Previous case studies have found very different rates of cooling below gaps. To quantify and better understand cooling downstream of gaps, we measured temperatures above, within, and below 12 riparian gaps near Franklin, North Carolina. Temperature responses to riparian cover changes varied widely. After returning to forested conditions, some streams cooled rapidly, some cooled slowly, and some continued to warm. The data suggest that smaller streams are more sensitive to riparian gaps and also cool more rapidly below riparian gaps. Understanding downstream cooling is critical for the development of riparian management policies for cold-water species.

(3.8.4) Aulenbach, Brent T.[1], and Norman E. Peters[2]
[1]U.S. Geological Survey, South Atlantic Water Science Center, Norcross, GA 30093; [2]University of Georgia, Athens, GA 30602
THE ROLES OF SHALLOW AND DEEP STORAGE ON DROUGHT AT A SMALL FORESTED, WATER-LIMITED WATERSHED NEAR ATLANTA, GEORGIA
Southeastern U.S. experiences recurring hydrological droughts, which can reduce water availability needed for human consumption and aquatic ecosystems and can result in water-limiting conditions that can reduce plant growth and health. Long-term monitoring at Panola Mountain Research Watershed, a small 41-hectare forested watershed in the Piedmont near Atlanta, Georgia, was used to study and quantify the roles of shallow and deep storage on drought. Watershed storage (WS) was estimated monthly from 1985 through 2015 using a water

budget approach combined with a baseflow-WS relationship. Shallow storage (SS) was assessed using data from a soil moisture profile for 2005 and 2007–2015. Water-limiting conditions occurred by the end of summer in most years as SS was depleted by evapotranspiration (ET) while deeper storage was unavailable for ET during dry conditions. The majority of deeper storage recharge occurred during the winter and required SS to first be recharged to a wetted state. Low WS at the end of the previous fall and low winter precipitation (P) resulted in low WS at the beginning of the growing season that almost always resulted in low stream base flows and drought conditions during the summer—as little recharge occurred in the summer. Summer recharge required wet SS conditions and exceptionally high P that exceeded high potential ET. A hydrologic persistence analysis was performed to assess the importance of past hydrologic conditions on WS, Monthly-standardized WS was significantly correlated (p-value <0.05) with past monthly-standardized WS for the previous 19 months and with past monthly P for the previous 11 months. These results are in contrast to a recent study of five nearby non-water-limited watersheds that indicated P was a more important control than WS on WS persistence. These differences likely result from summer P rarely contributing to increases in WS in the water-limited watershed.

(3.8.5) **Deemy, James B.**[1], Jeffrey Hepinstall-Cymerman[1], L. Katherine Kirkman[2], and Todd C. Rasmussen[1]
[1]UGA Warnell School of Forestry & Natural Resources, [2]Joseph W. Jones Ecological Research Center

PREDICTING EPISODIC STORM FLOWS THROUGH A LONGLEAF-PINE / WIRE-GRASS FOREST ON THE DOUGHERTY PLAIN, SOUTHWEST GEORGIA

On the Dougherty Plain, episodic storm runoff driven flows are observed in response to intense storms. Flows can be observed during most months of the year, but may be linked to seasonal factors or long term drought cycles. A challenge in managing water resources for these storm flows and the materials/energy that they transport is predicting when they will occur. Another challenge centers on few events being officially documented. Accordingly, our goal was to use physical data from known, documented events and then compare hindcast predictions to and calculated indices or data that can provide indicators or proxy data showing likely events in historic records. Our objectives were 1) derive the necessary antecedent physical conditions that produce episodic surface flows from antecedent conditions during known events, 2) correlate these flows with proxy data to determine when flows occurred outside of known events, and 3) evaluate predicted flow dates using convolution and deconvolution methods with proxy data that strongly correlate with conditions that produced known recent events. Soil moisture between 25% and 30% was identified as the most important condition required to produce flows observed. Other parameters identified were intense precipitation (approximately 50.8 mm/d) and wetlands at nearly at high stage (~75% of max stage). Flows also appear to happen slightly more often during winter when evapotranspiration is low but can occur in result from spring storms or late season tropical storm associated precipitation events. Palmer Drought Severity Index, Ichawaynochaway stage, evapotranspiration (Thornthawaite's), and day of the year were correlated with parameters. In our preliminary analysis Ichawaynochaway at high stage (top 10% of stages) appears to be a suitable proxy for direct observation of events. Identification of the combination of the environmental conditions that predict episodic flows will allow hindcasting of historic conditions to estimate frequency of such events.

SESSION 8 ABSTRACTS: THURSDAY 3:30-5:00 PM

Track 4.8 – Room L: Hydrologic Connectivity II

(Session Continues from 4.7)

Panel part II: Case studies of connectivity projects completed and in progress

Sara Gottlieb – *The Nature Conservancy*, Introductions, Set up Discussion– 10 mins
Doug Peterson – *University of Georgia,* Fish passage and conservation locking at Jim Woodruff Lock and Dam – 15 mins
Vance Crain - *Southeast Aquatic Resources Partnership*, Native Black Bass Initiative – 15 mins
Katie Owens - *The Nature Conservancy*, dam removal and culvert replacement case studies – 15 mins
Jay Shelton - *University of Georgia*, Whitehall Dam Removal Update – 15 mins
Questions and discussion – 20 mins

SESSION 8 ABSTRACTS: THURSDAY 3:30-5:00 PM

Track 5.8 – Room R: Urban and Green Infrastructure

(5.8.1) **Sudduth, Elizabeth B.**, Courtney Dobash, Alyssa Boudreau, Mikayla Oglesby, Marie Leavitt, and Annalise Reagan
School of Science and Technology, Georgia Gwinnett College, Lawrenceville, GA 30043

ECOLOGICAL RESTORATION OF A DRAINED URBAN STREAM-WETLAND SYSTEM THROUGH BEAVER ACTIVITY

In 2002, a developer illegally rerouted a small tributary of Nancy Creek in Buckhead to drain a wetland. As mitigation for these impacts, the city of Atlanta ultimately acquired the land. Many different restoration alternatives were considered by Blue Heron Nature Preserve until the arrival of beavers a few years later began to transform the site, possibly beginning the recovery of the stream-wetland system. In conjunction with the land managers, we monitored physical, chemical, and biological data at the site, looking for indications of recovery of the ecosystem. Strong positive trends were seen in the groundwater levels and the amphibian community in the wetland. However, the site remains a net exporter of sediment to the watershed, likely due to high erosion rates in the constructed channel. Although downstream reductions in conductivity and ammonium and fecal coliform concentrations were seen at times, the site is as yet having little overall effect on downstream water quality. If beaver activity at the site continues, this ongoing monitoring project could demonstrate the potential for restoration and management of urban streams and wetlands without the high costs and impacts of major construction projects. We also hope to expand this pilot project to the greater Atlanta area to examine the broader potential for water quality benefits of beaver activity in urban watersheds.

(5.8.2) **Bell, David**
CH2M, 6600 Peachtree Dunwoody Road, Atlanta, GA 30328

LONG-TERM MONITORING RESULTS OF BENTHIC MACROINVERTEBRATE COMMUNITIES IN GWINNETT COUNTY, GEORGIA

Since 2004, the Gwinnett County Department of Water Resources (GCDWR) has implemented a long-term monitoring program as a part of the County's Watershed Protection Plan (WPP). As part of the Plan, GCDWR conducted annual monitoring of benthic macroinvertebrates, using the latest Georgia Department of Natural Resources (GADNR) Standard Operating Procedures (SOPs), to assess ecological trends. From 2004 through 2015, GCDWR collected 348 individual samples from up to 34 long term monitoring stations, on an annual basis. Additionally, GCDWR collected pre- and post-construction macroinvertebrate data from Watershed Improvement Projects (WIP), including 36 individual samples from seven stream restoration projects, to evaluate the effects of restoration on the benthic community. GCDWR evaluated the benthic community using the GADNR Multi-metric Index (MMI) as well as other ecological metrics. Overall, benthic macroinvertebrate data for most long-term sampling locations indicated some level of environmental degradation compared to reference locations with fewer environmental stressors. Nonetheless, over the past 11 years, MMI scores indicated a statistically significant ($p < 0.05$) increase in the mean distribution of scores between 2005 through 2010 and 2011 through 2015, 33.89 and 39.07, respectively. Although some year to year variability was noted during this period, particularly due to climactic conditions such as drought, this was a favorable trend given that development continued to occur across the County. Benthic macroinvertebrate data collected at WIP locations demonstrated notable shifts in community composition associated with improved channel bed and bank conditions and increased habitat diversity. Among the seven WIP locations monitored before and after restoration, Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa, demonstrated a statistically significant increase (median pre = 2.0; median post = 5.0) while other functional feeding groups (FFG) demonstrated statistically significant shifts as well; collector/gatherer taxa decreased (median pre = 41.89%; median post = 16.51%) and filterer taxa increased (median pre = 7.51%; median post = 35.08%). These results along with other notable trends from the study will help to inform future watershed management decisions by Gwinnett County.

(5.8.3) **Casanova, Lisa**[1], Charity Perkins[1], Dominique Smith[1], Darian Morgan[1], and Jason Ulseth[2]
[1]School of Public Health, Georgia State University, 140 Decatur St. Atlanta, GA 30302; [2]Chattachoochee Riverkeeper, 916 Joseph E Lowery Blvd NW #3, Atlanta, GA 30318

WATER QUALITY IN AN URBAN STRETCH OF THE CHATTAHOOCHEE RIVER

The Chattahoochee River, a major Georgia waterway, is both a drinking water source for nearly 3 million people and a surface water discharge point for 100 public and private wastewater treatment plants serving metro Atlanta and the surrounding areas, as well as being a major recreation site. This project measured water quality over 6 months during two separate years at 15 sampling points along a 15-mile stretch of river that runs past the City of Atlanta. This stretch includes multiple discharge points for wastewater treatment plants serving the greater Atlanta area, and receives stormwater runoff from local communities. Water samples from the river were analyzed for human fecal indicators, including E. coli and male-specific coliphage. Water samples were collected at 1-mile intervals from the middle of the river at a depth of 6 inches. Samples were analyzed for E. coli using membrane filtration and male-specific coliphages using EPA method 1601 and two-step enrichment procedure and single agar layer. Mean E. coli concentrations across sampling sites on each sampling date ranged from 1.5-2.7 log10 CFU/100mL, with no clear trend over time. Mean E. coli concentrations at each sampling point across 2 years ranged from 1.9-2.2 log10 CFU/100mL, with no significant differences between sites. There was no significant difference in E. coli levels upstream and downstream of two wastewater treatment plant effluent discharge sites in the 15 mile stretch. All sites were positive for male-specific coliphage over the course of sampling. The presence of fecal indicator organisms in the river suggests that the waterway is vulnerable to fecal contamination from numerous sources; given the multiple uses of the river by the surrounding population, effective monitoring and watershed protection is vital for protecting water quality.

(5.8.4) **Quick, Devyn**, Jon Calabria, and Tom Breedlove
College of Environment + Design, University of Georgia, 285 S Jackson St, Athens, GA 30602

IMPROVING WATER QUALITY FROM ROGERS ROAD FAMILY AND GRADUATE HOUSING RUNOFF

This multi-disciplinary project focused on improving the water quality for UGA's Family and Graduate Housing located on Rogers Road, which flows unchecked into Lake Herrick. The site is among the most developed areas within the Lake Herrick watershed. This study investigated 1) conceptual stormwater control measures to treat runoff and 2) explored residents' attitudes and behaviors toward water quality. Then, findings were integrated and guided program and design development for stormwater retrofits that would slow, treat, and cool runoff. First, an inventory of existing site conditions and identification of likely constituents contributing to poor water quality shaped opportunities to improve water quality. Conceptual Stormwater Control Measures (SCMs) were sized and presented to residents to solicit input. Residents were also asked to respond to a national questionnaire about water quality attitudes and behavior. Questionnaire results from the residents were compared to previous findings and guided design alternatives. Once a preferred alternative was chosen, then a final design was developed. It focused on improving water quality, enhancing aesthetics, and increasing ecosystem services in the hopes of improving Lake Herrick's water quality. The project is an extension of Watershed UGA program and is supported by the Office of University Architects and UGA Student Affairs.* *This research was supported in part by a grant funded by the UGA Office of Academic Partnerships & Initiatives in the Office of the Vice President for Student Affairs.

(5.8.5) **Sowah, Robert**[1], Mussie Habteselassie[2], David Radcliffe[2], and Marirosa Molina[3]
[1]Oak Ridge Institute for Science and Education; [2]Crop and Soil Sciences, The University of Georgia Griffin Campus; [3] Crop and Soil Sciences, The University of Georgia; [4] U.S. Environmental Protection Agency, ORD, NERL/MEB

MODELING THE INFLUENCE OF SEPTIC SYSTEMS ON FECAL BACTERIA LOAD IN A SUBURBAN WATERSHED IN GEORGIA

Watershed scale models such as the soil and water assessment tool (SWAT) are promising tools for studying the impacts of septic systems on water quality and quantity. In this study, SWAT was used to model the influence of high density septic systems on bacterial loads in a suburban watershed. The model was first calibrated and validated for flow in the Big Haynes Creek watershed located in Gwinnett County, GA. The model performed satisfactorily for flow predictions at the watershed level with Nash Sutcliffe Efficiency (NSE) values of 0.67 and 0.70 for calibration and validation periods, respectively. Flow predictions in the study area shows that on average septic systems contributed approximately 7% to the total water yield annually. This observation is significant and contradicts suggestions that septic systems are 100% consumptive use. Although NSE values for bacterial predictions were low in this study, estimates of percent bias (PBIAS) and p-factor show acceptable model predictions compared to the observed data. Model results suggest that the distance of septic systems to streams in the study area can influence bacterial loads in streams. Bacterial source analysis points to septic systems contribution to microbial water quality when septic systems are less than 10 m from streams. This result suggests that the current mandated minimum distance of 15 m between septic system drainfields and streams in the state of Georgia may be adequate to protect water resources. However, the results from this study also indicate that there are still local areas with septic systems within the minimum separation threshold which could present a risk to water quality. The findings of this study provide tools that can be used at the watershed level to assess critical areas to support septic system management.

SESSION 8 ABSTRACTS: THURSDAY 3:30-5:00 PM

Track 6.8 – Room K: Mitigation

(6.8.1) **Hill, Katie**, Jon Skaggs, and Hunter Jones**,** *UGA River Basin Center, Athens, Georgia*

NO NET LOSS IN GEORGIA: ASSESSING THE U.S. ARMY CORPS SAVANNAH DISTRICT'S ACHIEVEMENT OF A NATIONAL MITIGATION POLICY

Implementation of stream and wetland impact permitting under Section 404 of the Clean Water Act is guided by the national policy of "no net loss." Established by George H.W. Bush in 1989 and supported by every subsequent administration, the goal of no net loss is to replace aquatic resource functions that are lost when streams, wetlands, and other waters are damaged or destroyed via § 404 permits. This replacement of function ostensibly occurs through mitigation requirements for permits that are established by each of the 38 U.S. Army Corps Districts across the country. Mitigation is typically achieved through restoration and other projects that are supposed to offset permitted impacts through a net increase in aquatic function. In this recently completed analysis, the UGA River Basin Center analyzed the mitigation standards of the U.S. Army Corps Savannah District, which regulates § 404 permitting across all of Georgia, to determine whether these standards are in fact achieving the national policy of no net loss. Through national and District-level regulatory and policy assessments, GIS analysis, and permit and database review, we determined that the Savannah District is likely achieving no net loss for wetlands, but is not doing so for streams. In this presentation, we will present our findings and methods and detail specific recommendations for the Savannah District that, if implemented, would remedy some issues in its existing mitigation standards and support achievement of the critical national policy of no net loss.

(6.8.2) **Peevy, Matt**, and Trey Evans**,** *Georgia Environmental Restoration Association*

MITIGATION BANKING TRENDS IN GEORGIA

An overview of mitigation banking, marker trends (Supply and Demand), history of pricing, market challenges, solutions and future opportunities.

(6.8.3) **Robertson, Alex,** *Georgia-Alabama Land Trust, Inc.*

A LAND TRUST'S EXPERIENCE WITH MITIGATION MARKETS: CONSERVATION EASEMENTS, IN-LIEU FEE, AND LONG-TERM SITE PROTECTION

Streamflow in urban watersheds is characterized by transient, dramatic increases in response to large storm events, and similarly abrupt recessions. Previous research has highlighted the stark differences in the timing and magnitude of streamflow response between urbanized versus non-urbanized watersheds, though notably these differing short-term dynamics may not always lead to differences in overall partitioning of rainfall to streamflow at monthly to annual time scales. Far less is known about the relative contributions to streamflow of water from different sources: specifically, surface runoff from current rainfall, versus groundwater discharge, versus possible leakages from water-supply infrastructure. We are currently developing a study in the Proctor Creek Watershed of Atlanta, GA aimed at elucidating these source contributions to streamflow. We are recording hydrometric measurements of precipitation and streamflow at multiple locations, along with temporally-resolved measurements of stable-isotope ratios and ion concentrations within each of the noted sources. We will utilize these data within 2- and 3-component mixing models in an attempt to evalute relative contributions to flow from each source, and how those contributions vary under differing short-term weather conditions, and longer-term seasonal changes. In this contributed poster we report on our study design and preliminary conclusions drawn from our initial analyses of these data. The overall outcome of this work will be an improved understanding of spatially-variable hydrological processes within the Proctor Creek Basin, and sub-basins, which may also aid in understanding water-quality dynamics within the observed stream channels.

(6.8.4) **Miller, Sean,** *Mitigation Management, Athens, GA 30601*

ENHANCING AQUATIC MACROINVERTEBRATE COMMUNITIES THROUGH GEOMORPHIC STREAM RESTORATION

Stream restoration has become a valuable tool in the field of conservation. The majority of stream restoration that occurs in Georgia is done through the commercial mitigation banking process regulated by the US Army Corps of Engineers. Much of the focus of these restoration activities has been on creating channels with stable patterns, profiles, and dimensions. Very little focus is placed on creating biological habitat necessary for creating, in many instances, the proposed macroinvertebrate community lift. The purpose of this study was to determine what relationships existed between geomorphic variables and macroinvertebrate communities in order to incorporate a greater level of biological habitat creation in natural channel design methodology. The primary study was conducted in north Georgia along 12 stream reachers. A host of geomorphic variables were collected along each stream reach. Additionally, macroinvertebrate community samples were collected along these reaches using Georgia Department of Natural Resources, Environmental Protection Division methodology. Based on the results of this study, shear stress, shear velocity, and riffle D50 have a strong correlation with macroinvertebrate abundance. The incorporation of geomorphic parameters suitable for increased macroinvertebrate abundance. The incorporation of geomorphic parameters suitable for increased macroinvertebrate abundance may decrease the primary performance standard of the overall level of physical stability in the channel, but would lead to an overall higher level of ecological restoration. Preliminary results of a more contemporary study conducted within the Ochlockonee Basin have shown that based on the GA EPD biotic indices, that baseflow conditions, and therefore certain geomorphic variable, may influence macroinvertebrate community structure. When taken in conjunction with the study above, this shows that future stream restoration projects must take into limiting factors of achievable macroinvertebrate community lift and that geomorphic variables effects on the communities are most likely highly dependent on ecoregion scale factors.

POSTER SESSION ABSTRACTS - WEDNESDAY 3:30-5:00 PM
(SEE ALSO SESSION 6.4 – UNDERGRADUATE POSTERS)

(1.4.01) **Diederich, G Ryan**, Jacque L. Kelly, R. Kelly Vance, and Anne M. Delua
Department of Geology and Geography, Georgia Southern University, Statesboro, GA 30460

GEOPHYSICAL INVESTIGATION OF ST. CATHERINES ISLAND USING ELECTRICAL RESISTIVITY AND GROUND PENETRATING RADAR

St. Catherines Island is a barrier island experiencing saltwater intrusion via structural pathways that may include joints, faults, or sag structures. This study used geophysical methods of electrical resistivity (ER) and ground penetrating radar (GPR) to locate and determine the modes of transportation of the saltwater. The geophysical study was conducted in November of 2016 near a shallow (6-7 m deep) aquifer well traverse that has shown recent spikes in chloride concentration. Three geophysical transects where collected using ER and GPR. The ER data were collected using 56 electrodes with either 2 m or 3 m spacing. A dipole-dipole array with a strong gradient was used for data collection and then inverted using EarthImager 2D (Advanced Geosciences, Inc.). The GPR data were collected along the same transects as the ER data using a 100 MHz shielded antenna set at a shallow time window and a 250 MHz shielded antenna set at a deep time window. The GPR profiles were processed using Object Mapper (MALA). The ER data show a low resistivity layer at 1-6 m depth that correlates with the sandy surficial aquifer, a higher resistivity layer at 6-13 m depth that may represent a clay aquitard, and a low resistivity layer from 13-26 m depth that may represent a deeper aquifer. The GPR data suggest lateral and vertical variation in water saturated porosity of the sandy surficial aquifer and a sharp reflector below the aquifer that is interpreted as the top of the clay aquitard. The geophysical data correlate and will be combined to investigate structures causing the saltwater intrusion. This research will allow us to gain a better understanding of the hydrogeology of St. Catherines Island and how it may be impacted by rising sea level, along with the other barrier islands along the Georgia coast.

(1.4.02) **Wakefield, Katherine**
Department of Biology and Department of Geology and Geography, Georgia Southern University, Statesboro, Ga 30458

SHORELINE CHANGE AND VEGETATION COVER ADJACENT TO BACK-BARRIER SHORELINE STABILIZATION STRUCTURES IN GEORGIA ESTUARIES

Anthropogenic stabilization of erosional shorelines by hard-armoring structures (including bulkheads and riprap structures) is used for protection of property, especially if buildings, historical monuments, cultural resources, or other infrastructure are present. The post-installation effects of shoreline stabilization structures on adjacent shorelines in the back-barrier marshes of coastal Georgia are a concern, and interest in living shorelines (soft-armoring structures) as erosion control devices has increased because of their use of natural materials and vegetation. AMBUR shoreline analysis software was used to calculate pre-and post-installation shoreline change rates of shorelines adjacent to riprap and bulkhead structures There was no significant difference between the post-installation shoreline change rates of the structures, but individually there is post-installation erosion immediately adjacent to four of the structures (the end-around effect). The shoreline change rates adjacent to riprap structures showed site-specific accretion adjacent to the structure and needs more study to determine if this is a representative trend for this structure type. Analysis of vegetation percent cover, stem height, and stem densities showed similarities between shorelines adjacent to living shorelines and control sites. There are significant differences in vegetation cover between riprap structures and the control sites, and these results showed that installation of riprap structures significantly changes the vegetation cover of the adjacent, unprotected shorelines. These results provide novel methodologies and initial data for determining the influence of erosion control structures on back-barrier shorelines, but it is unclear how much influence historical anthropogenic activities such as boat traffic have played a role with shoreline erosion in the study sites. The researcher identified limitations with available data sets so they may be changed moving forward to improve future research on back-barrier shoreline study. The results from these studies may allow for better informed decision making about the effects of shoreline stabilization structures on adjacent shorelines.

(1.4.03) **Wang, Yu**[1], Kai Ziervogel[2], and Christof D. Meile[1]
[1]Department of Marine Sciences, University of Georgia, Athens, GA 30602; [2]Ocean Process and Analysis Laboratory, University of New Hampshire, Durham, NH 03824.

A MODEL STUDY OF NEAR-SEABOTTOM FLOW AND ITS EFFECT ON SEDIMENT RESUSPENSION

Sediment resuspension occurs when sediment that has been deposited at the seafloor is moved back into the benthic boundary layer, resulting in lateral transport of particulate and dissolved matter. Resuspension can be caused by strong flow fields, hurricanes, storms, etc. Here, we focus on an area in the northern Gulf of Mexico at a water depth of ~1250m. In order to assess whether sediments get resuspended, we quantify near-sediment flow, and then compare the flow velocity with experimental critical shear velocity. Thus, in situ ADCP data (measuring near-seabottom flow velocity) and bathymetry data are combined to simulate a near bottom flow field across a larger spatial domain (about 400m * 500m * 50m). Based on the ADCP time series data characterizing the flow 15 – 30m above the bottom, we simulate the near seafloor flow field in the study domain over time. The equations solved in the model are the Navier-Stokes equations for conservation of momentum and the continuity equation for conservation of mass. Turbulence effects are modeled using standard two-equation k-ε model. To estimate resuspension, we extract the simulated flow velocities of the lowest layer in the mesh. We then analyze these velocities and calculate the percentage of time when the simulated flow velocity is higher than an experimentally determined critical shear velocity, to assess the probability of resuspension for each point in the model mesh. Comparing modeled velocities at the ocean bottom with this threshold indicates zones where resuspension is likely to happen.

(1.4.04) **Miklesh, David**, and Christof Meile
Department of Marine Sciences, University of Georgia, Athens, GA 30602

HYDROLOGIC PROCESSES DETERMINING POREWATER SALINITY IN A SOUTHEASTERN SALT MARSH

Coastal wetlands provide many important ecosystem services, which include carbon and nitrogen sequestration and transformations, the provision of habitats, and the reduction of erosion by the vegetation. In coastal marsh ecosystems, porewater salinity strongly determines vegetation distribution and productivity. Therefore, as part of the Georgia Coastal Ecosystems Long Term Ecological Research project, an integrated modeling approach has been developed and applied to the Duplin River marsh, Sapelo Island, Georgia, which simulates porewater salinity and water content distributions in surface sediments across the entire Duplin River marsh domain. The development of the soil model is presented, which is based on mass conservation for water and salt and links physical, hydrological, and biological processes that determine porewater salinity, including precipitation, evapotranspiration, salt exchange between surface and subsurface, groundwater exchange, and tidal inundation, with the lateral exchange controlled by marsh topography. Model validation is performed by comparing model-estimated salinities to porewater salinity measurements of the same vegetation class and marsh elevation. To identify the environmental factors that control marsh salinities, a sensitivity analysis was carried out that assesses the effect of precipitation intensity, evapotranspiration, hydraulic conductivity, salt exchange, tidal salinity, and marsh elevation have on porewater salinities. Also, model-derived variability in porewater salinities was quantified over seasonal and interannual time scales, accounting for drought, normal conditions and years with excess rain. Annual simulations and the sensitivity analysis reveal that vegetation classes can be split up into two groups, low marsh plants—short, medium, and tall Spartina alterniflora—and high marsh plants—Borrichia frutescens, Batis maritima, Juncus roemerianus, and Sarcocornia spp. Initial results show that low marsh porewater salinity in our study region is sensitive to changes in the salinity of the flooding tide, which is strongly correlated with Altamaha River flow, whereas the high marsh is sensitive to changes in precipitation and evapotranspiration.

(1.4.05) **Thorson, Scott D.**, and Jacque L. Kelly
Georgia Southern University, Statesboro, GA 30460

ESTIMATING SUBMARINE GROUNDWATER DISCHARGE ON ST. CATHERINE'S ISLAND, GA VIA RADON-222

Submarine Groundwater discharge (SGD) is an important pathway for material transport and one of the most accurate approaches for measuring SGD fluxes is using the natural radioactive tracer radon. Radon-222 exists in high concentrations in groundwater and low concentrations in seawater and forms from the decay of heavier elements which are more prevalent in immature sediments. The goal of this study was to understand the spatial distribution and fluxes of groundwater discharge around the southwestern part of St. Catherine's Island using radon-222. We hypothesized that there were several areas of groundwater discharge coming from the island, and that the fluxes would be comparable to fluxes from similar study areas. In December 2016 we conducted our radon survey by boat around the southwestern part of the island and measured radon concentrations in surface waters using a RAD-7 continuous radon monitor. Our collection took place during low tide, because the outgoing tide draws more groundwater to the surface than during high tide. During the survey we also took several discrete groundwater samples from areas along the shore that showed active groundwater discharge. We created a standard mass-balance mixing model to quantify the groundwater discharge. We identified several areas of SGD around the southwestern part of the island with groundwater fluxes comparable to previous studies. A more extensive investigation of the site can help determine if the rate of groundwater discharge correlates with seasonal changes and varying tidal conditions.

(1.4.06) Cherry, Gregory S., Michael D. Hamrick, and Michael F. Peck
U.S. Geological Survey South Atlantic Water Science Center, 1770 Corporate Drive, Suite 500, Norcross, GA 30093

SALTWATER INTRUSION IN THE FLORIDAN AQUIFER SYSTEM NEAR DOWNTOWN BRUNSWICK, GEORGIA, 2016

Since 1959, the USGS (USGS) has led a cooperative water program (CWP) with Brunswick, Georgia, to assess the effect of groundwater development on saltwater intrusion within the Floridan aquifer system (FAS). Saltwater was first detected in wells completed in the Upper Floridan aquifer (UFA) near the southern part of the city in late 1957. By the 1960s, a plume of saltwater had migrated northward toward two major industrial pumping centers, and since 1965, chloride concentrations have steadily increased in the northern part of the city. In 1978, data obtained from a 2,720-foot-deep test well drilled south of Brunswick indicate the source of saltwater was located below the UFA in the Fernandina permeable zone of the Lower Floridan aquifer. During calendar year 2016, the CWP data collection included continuous water-level recording at 10 wells completed in either the Floridan or Brunswick aquifer systems, or surficial aquifer; synoptic water-level measurements in 56 wells to map the potentiometric surface of the UFA in the Brunswick/Glynn County area during October 2016; and sampling 59 wells completed in the FAS for chloride concentrations. Results from thirty-one of the wells sampled indicate the shape of the chloride plume in the UFA near downtown Brunswick has remained relatively unchanged over the past several years. Results from eight of the wells collected at industrial sites near the northern part of the chloride plume indicate upward migration of chlorides between the upper and lower water-bearing zones of the UFA.

(1.4.07) **Truitt, Zamara Ruby Garcia**, Brennan K. Poon-Kwong, and Dave S. Bachoon
Department of Biological and Environmental Sciences, Georgia College and State University, Campus Box 81, Milledgeville, GA 31061-0490

ASSESSMENT OF THE IMPACT OF FECAL POLLUTION ON COASTAL AREAS OF PUERTO RICO

Water quality of 32 freshwater sites located across streams and rivers of coastal locations across Puerto Rico in Puerto Rico was assessed using IDEXX's Colilert assay to enumerate fecal indicator bacteria (FIB). Improper wastewater treatment is a threat to public health and aquatic resources, as human pathogens and nutrient pollution are detected alongside FIB's. Detection of fecal contamination exceeding the U.S. EPA's recommended threshold for recreational water quality at eleven of the sites, called for the use of quantitative PCR to identify the source of fecal contamination through molecular source tracking (MST) techniques. Probe based Taqman qPCR assays were utilized in the targeting of

Bacteroides human-specific (HF183) marker, and a cow-specific (BacCowP) Bacteriodales 16S rRNA gene. The human-specific HF183 assay detected the presence of human fecal contamination in 34% of the sampled locations, whereas the cow-specific assay confirmed cow fecal contamination in 22% of the locations sampled. Assays to detect the presence of pathogenic genes associated with enterohemorrhagic Escherichia coli O157:H7, Campylobacter jejuni, and Helicobacter pylori, are currently being developed and results will be added to the final presentation of collected data.

(1.4.08) **Nicolette, Travis William**, and Francisco J. Cubas
Civil Engineering and Construction Management Department, Georgia Southern University, Statesboro, GA
METHYLMERCURY PRODUCTION POTENTIAL ASSESSMENT IN SEDIMENTS FROM THE BRUNSWICK, GA ESTUARY
Mercury is potentially toxic to the environment. Mercury sorbed to anaerobic sediments of surface waters may be converted to methylmercury, which is the toxic form of mercury that bio-accumulates in aquatic biota. Sources of mercury to the environment vary, but the production of methylmercury is common in sulfur-rich sediments containing mercury. In such environments, sulfur reducing bacteria (SRB) produce methylmercury as a by-product of the metabolic process used to extract energy from the reduction of sulfate to sulfide. This study focuses on determining the methylmercury production and release potential from sulfur-rich sediments extracted from different areas of the Brunswick Estuary. Previous studies note of historical considerable levels of mercury in the Brunswick estuary due to waters draining areas of a local super fund site for mercury. Water and sediment samples were collected from six different sites to seed microcosms designed to measure the sediments' potential for methylmercury production. Microcosms were operated under anaerobic conditions to determine if sediments produced methylmercury under extreme conditions (e.g. low dissolved oxygen, low oxidation-reduction potential, and highly productive environment) that may seasonally exist in different zones of the estuary. Results revealed that sediments have the potential to reduce sulfate under anaerobic conditions. In the microcosms, sulfate concentrations rapidly decreased from values as high as 290 mg/L to practically 0 mg/L, suggesting that sediments provide an adequate environment to support SRB activity, which may result in methylmercury production. Further, results revealed that methylmercury production potential varies across different zones of the estuary. Precise methylmercury concentrations collected from the different sites are currently being evaluated. Due to the environmental conditions that prevail in the estuary, its proximity to a mercury super fund site, and its accessibility for fishing activities, it is crucial to further assess the methylmercury formation in this area.

(1.4.09) **Hensey, Sarah**
UGA Warnell School of Forestry and Natural Resources
ASSESSING TOXICITY AND CONTAMINATION LEVELS IN LAKE HERRICK
Located on the UGA campus, Lake Herrick serves as a valuable recreational and institutional resource. In recent years, use of the lake by the public has been restricted due to declining water quality. High nutrient levels in storm water runoff have been linked to seasonal toxic algal blooms. This study aimed to monitor these seasonal algal blooms and assess the present levels of contamination and toxicity in Lake Herrick in comparison to previously collected data. Weekly water parameters of temperature, dissolved oxygen, and pH were recorded and water samples were screened microscopically for potentially toxic cyanobacterial species. Fecal coliform were assessed from the water samples using petrifilm E. coli/ coliform count plates to evaluate contamination levels. In addition, toxicity was assessed through chronic and acute reproduction and survival tests of Ceriodaphnia dubia. We anticipated the presence of a toxic algal bloom in the warmer months of August through October but there was no persistent bloom due to a lack of rainfall events. We recorded a small-scale bloom of Aphanizomenon cyanobacteria, of which most forms are toxic, during October of 2016. A frozen water sample from an Anabaena planctonica bloom (157,000 cells/mL) during a similar time in 2015 resulted in significant reductions in Ceriodaphnia dubia reproduction and survival in both acute and chronic tests ($p<0.05$). Our current results suggest that Lake Herrick is continuing to experience infrequent seasonal algal blooms resulting in harmful levels of toxicity. The water quality data from this study can help guide future remediation plans, such as our newly funded project to install floating wetlands in Lake Herrick to aid in improving inflow dynamics.

(1.4.10) **Kannan, Ashwini**[1], Thalika Saintil[2], David Radcliffe[2], and [3]Todd Rasmussen
[1]College of Engineering; [2]Crop and Soil Sciences Department, College of Agriculture and Environmental Sciences; [3]Warnell School of Forestry and Natural Resources; University of Georgia, Athens, GA 30602
WATER QUALITY MONITORING TO RESTORE AND ENHANCE LAKE HERRICK
Lake Allyn M. Herrick is about 1.5 km2 and covers portions of the UGA's East campus, the Oconee Forest, residential and commercial landuse. Lake Herrick, a recreational site on the UGA's campus was closed in 2002 due to fecal contamination. Subsequent monitoring confirmed persistent contamination which led to permanent closure to swimming, boating and fishing. However, no studies have been done on the streams entering and leaving the lake. This study emphasizes on quantifying lake influent/effluent bacteria and nutrient loads. Two inflow tributaries and the outlet stream were monitored for discharge, fecal coliform, forms of nitrogen and phosphorus and other water quality parameters including dissolved oxygen, turbidity, pH and conductivity during base flow and storm conditions. The results indicated that urban runoff is the most severe contributor of nonpoint source pollution, and the leading cause of lake impairment. Preliminary results confirm high concentrations of E. Coli and Enterococci above the State's limit during baseflow and stormflow at the inflow streams compared to the outlet. This may suggest that the Lake acts as a retention pond. The total and soluble forms of nutrients are low at all sites (below 1-2 ppm) which explains that nutrients are not coming from runoff but rather from accumulated bed sediments in the Lake. The samples were also analyzed for microbial source tracking using human, ruminant and dog genetic markers. However, more source tracking data is needed to identify which markers are most prevalent at each site. Statistical analysis will be used to establish relationships between the nutrients data, the fecal contamination, and the gene-specific makers.

(1.4.11) **Spidle, David**, Marirosa Molina, and Mike Cyterski
United States Environmental Protection Agency, Office of Research and Development, National Exposure Research Laboratory
PREDICTING E. COLI AND ENTEROCOCCI CONCENTRATIONS IN THE SOUTH FORK BROAD RIVER WATERSHED USING VIRTUAL BEACH
Virtual Beach (VB) is a decision support tool that constructs site-specific statistical models to predict fecal indicator bacteria (FIB) at locations of exposure. Although primarily designed for making decisions regarding beach closures or issuance of swimming advisories based on exceedance to the FIB criteria, VB can also be used for studying relationships between any water quality indicator and ambient environmental conditions. Our objective was to evaluate the effectiveness of statistical models developed using VB for predicting the impairment of inland rivers and streams. From 2012-2015, water samples were collected during rainfall events and base flow conditions from two sites on the South Fork Broad River watershed located in Madison and Oglethorpe Counties in Northeast Georgia. Samples were analyzed for E. coli and Enterococci along with other water quality parameters. Data collected during the study were divided into two groups: one for model development and another for model prediction at each site. Approximately 75% of the data points were randomly selected to develop a multiple linear regression (MLR) model describing the relationship between E. coli and Enterococci and a set of independent variables (IVs): turbidity, total suspended solids (TSS), rainfall and water temperature. R-squared values for the MLR models developed by VB were 0.73 for E. coli and 0.69 for Enterococci at the Clouds Creek site (N=270). For the Carlton site, R-squared values were 0.81 for E. coli and 0.80 for Enterococci (N=188). Model accuracy (i.e., model prediction agrees with the observed FIB concentration being above or below the regulatory level) ranged from 96-98% for E. coli and 99% for Enterococci. Accuracy using data not included in model development (approximately 25%) was 99% for E. coli and Enterococci. Our results show statistical models developed with VB can be effective for predicting the impairment of inland rivers and streams.

(1.4.12) **Deocampo, Dan**[1], Gary Keller[2], Clarisse Croteau-Chonka[2], and Joel Rosenfield[3]
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H2OTECH: AN EPA-AFFILIATED WATER TECHNOLOGY INNOVATION CLUSTER IN ATLANTA SERVING THE SOUTHEAST US, FOCUSED ON WATER AND HUMAN HEALTH
H2OTECH is a 501(c)3 nonprofit based in the CollabTech Incubator at Georgia State University in Downtown Atlanta, serving the Southeast US, a region of 60 million people using 65 billion gallons of water per day. H2OTECH began in 2015, partnering with academics, water industry, agriculture, tech startups, other technologists, and other stakeholders. H2OTECH's goal is to promote technology-led economic development. Like other EPA-affiliated Water Clusters, H2OTECH supports commercialization of tech innovations, with a unique focus on water and human health. Examples include collaborations to finance early stage proof of concept research (e.g. SBIR/STTR funding), market research and business acceleration, and networking in the water tech sector. At the 2016 White House Water Summit, H2OTECH committed to 2020 goals of doubling federal SBIR/STTR in the regional water economy to $5M/year, and growing the regional water workforce by 5,000 jobs. H2OTECH is enhancing tech commercialization through partnerships with startups, mid-size companies, and industry leaders in the region, including startups with innovative nano-technologies and water treatment technologies. H2OTECH is pursuing discussions to develop a local demonstration site in Downtown Atlanta to highlight innovative technologies. H2OTECH is also partnering with Georgia State University to support SBIR, STTR, and other funding efforts by a number of other local startups. H2OTECH continues to seek partnerships stakeholders with an interest in water technology commercialization. The Southeast US has a robust water community, with strong science and policy groups addressing regional water challenges. H2OTECH complements those efforts by coordinating water tech commercialization to increase the rate at which innovations in the lab are brought to market to provide solutions to priority problems. These advances will not only address serious issues of water quality and quantity in the region, but will also contribute to technology-led economic development.

(1.4.13) **Georgacopoulos, Ourania**[1], Brad Acrey[2], and Marirosa Molina[3]
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INACTIVATION RATES OF COLIPHAGES ISOLATED FROM WASTE WATER TREATMENT PLANT EFFLUENTS IN GEORGIA
Coliphages are a type of host-specific bacteriophages that infect E. coli and are found abundantly in the gut of animals, including humans. Coliphages share many structural similarities with viruses and are being evaluated as indicators for the presence of enteric viral contamination of water sources. Many studies have looked at solar inactivation rates of coliphages as one of the most significant factors affecting their fate in surface waters. Direct inactivation by solar irradiation of MS2 (an fRNA, male-specific coliphage) and Phi-X 174 (a somatic coliphage) have been well-documented; however, these surrogate indicators are not always present in all sources of fecal contamination or may not behave the same as a mixed community. The objective of our study is to obtain accurate inactivation rates for community coliphages to be able to model the transport of these alternative indicators from point sources into surface waters. Community somatic and fRNA coliphages were isolated from primary waste water treatment plant (WWTP) effluents discharging in a tributary of the South Fork Broad River in Comer, Georgia and irradiated using a full sun solar simulator. Photoinactivation was described using first order rate constants that were calculated using the enumerated phage decay rates (Log Ct/C0). MS2, Phi-X 174, community somatic and fRNA coliphage decayed at -0.88, -4.57, -3.90, and -3.06 logs/hour, respectively. Phi-X 174 exhibited the greatest rate of decay, with community somatic exhibiting a similar decay rate ($p = 0.009$). Community fRNA decayed approximately 3 times as fast as MS2 in the solar simulator, indicating that MS2 may not be a good surrogate indicator ($p<0.001$) for this community. Samples from Comer WWTP contained 720 PFU/mL somatic and 166 PFU/mL fRNA community coliphage, with respective die off of 0.73 hours and 0.85 hours at the surface. Although both community somatic and fRNA show similar inactivation rates, fRNA coliphages are more resistant to solar inactivation indicating the potential for longer survival times in rivers impacted by WWTP effluents.

(1.4.14) **Knaak, Andrew**
USGS
FECAL COLIFORM BACTERIA SAMPLING PROGRAM BY THE USGS IN COOPERATION WITH THE DEKALB COUNTY DEPARTMENT OF WATERSHED MANAGEMENT, GEORGIA
None submitted

(1.4.15) **Saintil, Thalika**[1], David Radcliffe[1], Todd Rasmussen[2], and Ashwini Kannan[3]
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WATER QUALITY ASSESSMENT OF STREAMS IN THE TRAIL CREEK WATERSHED
The Trail Creek watershed covers about 33 km2 in the Upper Oconee River Basin located in Athens, Georgia. The watershed is comprised of an East Fork and a West Fork tributary, which converge to form a branch that extends to the North Oconee River. The upper reaches of East and West Forks are in forest and agriculture landuse. The lower reaches are located in a mixed residential and industrial zone. Stream segments within the Trail Creek watershed are listed impaired due to high levels of fecal coliform concentrations exceeding the Georgia Standard. While fecal coliform abundance is a standard metric for determining human health risks, Geldreich (1970) showed that fecal abundance does not necessarily correlate with the presence of pathogens. Nor does it identify pollution sources, which are needed to mitigate health risks. A microbial source tracking analysis will also be performed to identify the sources of fecal contamination using human, ruminant and dog genetic markers. Three grab sampling sites are selected in the upper watershed on the East and West forks and three others in the lower watershed. All sites are monitored during baseflow conditions and two sites during storms where discharge is estimated using the rating curve approach. The samples are analyzed for fecal coliform, E. Coli and Enterococci. Water quality parameters including temperature, specific conductance, dissolved oxygen, pH, and turbidity are recorded at all sites. Additional velocity measurements during various conditions are needed to estimate a more accurate rating curve equation. Turbidity seems to be the strongest indicator of bacterial contamination. Finally, further sampling and monitoring should provide an understanding of the bacteria dynamics based on seasonal change and spatial variation within the watershed. Preliminary results will be discussed.

(1.4.16) **Maher, Sage**, Adam Milewski, William Miller, and Rachel Rotz
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URBANIZATION-DRIVEN HYDRAULIC EROSION IN THE GEORGIA PIEDMONT
Urbanization transforms natural landscapes into cultivated earth and urban concrete cover to support the demands of urban populations. These land use changes cause shifts in ground cover dynamics. Soils with poor physical buffers are subject to higher runoff and erosion rates, while sites with well-developed physical buffers demonstrate antithetical results. A three-phase approach was undertaken in Athens, GA to examine the effects of urbanization on erosion susceptibility for a representative Piedmont soil. First, four field plots were established on a moderate slope in a grassy forest gap. Each of the four plots represented a unique ground cover found in the Athens area: bare, vegetated, mulched, and manured. These plots were left exposed to natural conditions for four months in summer 2016. Second, soil from each of the sites was gathered, dried, and packed into erosion pans. These pans were exposed to rainfall simulations at a precipitation rate of 5 cm/hr to obtain erosion and runoff values. Third, the erosion rates for each ground cover were assigned to their representative area within Athens to produce a total erosion rate for each ground cover. These rates were compared to the natural vegetated rate to establish the extent of relative change in erosion. Compared to the vegetated control rates, runoff and erosion rates were hypothesized to greatly increase in the bare ground cover, marginally increase in the manured ground cover, and match the mulched ground cover. Results confirmed the hypotheses regarding the bare and mulched ground covers at erosion rates of 0.03 cm and 2.58x104 cm respectively; however, the manured plot revealed the highest runoff rates at 24.01 cm and the highest erosion rates at 0.08 cm. These data support the claim that transforming the natural forested landscape into urban environments or associated land uses increases the erosion susceptibility of Athens, Georgia.

(1.4.17) **Pruitt, Carson A**.[1], David S. Leigh[1], Todd C. Rasmussen[1], and Oscar P. Flite III[2]
[1]University of Georgia, Athens, GA;[2]Phinizy Center for Water Sciences, Augusta, GA
A SEDIMENT YIELD INVESTIGATION IN AN URBAN STREAM
Even though urban streams have been sampled extensively for conventional water quality parameters, very little attention has been focused on sediment transport. A sediment yield study was conducted on Rock Creek which is an urban stream located along the falline in Augusta-Richmond County, Georgia. The stream was sampled for suspended load and bedload at three stations over two storm hydrographs during January 2017. Land use within the Rock Creek watershed, which is approximately 0.5 square miles, is predominantly medium density residential, resulting in 25 percent impervious surfaces. The objective of the sediment yield study was to determine the sediment-discharge relationship and develop the correlation between turbidity and total suspended solids (TSS). Bedload was collected using a handheld Helly-Smith sampler with a 6-inch orifice, and suspended sediment was sampled via grab samples at the three stations and automated sampling on 30-minute intervals at one of the stations. A direct relationship was observed between bedload and TSS (by weight) and stage and discharge. TSS was higher in the first hydrograph even though the second hydrograph was of higher magnitude. Sediment particle size class distribution collected in the bedload sampler was higher in the downstream stations. The linear relationship between turbidity and TSS (r2 = 0.85) was noteworthy in that, it can be used accurately by stream watch organizations to monitor suspended sediment indirectly at a significantly reduced cost and effort. Overall, the results of the study can be utilized by the City of Augusta in planning and maintainence in regards to identification of sediment sources, sediment removal and stream restoration, and establishing best management practices.

(1.4.18) **McKee, Anna**
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MICROBIAL SOURCE TRACKING IN THE CHATTAHOOCHEE RIVER NATIONAL RECREATION AREA
The BacteriALERT program is a public-private partnership among the USGS, the National Park Service, and the Chattahoochee Riverkeeper. The BacteriALERT program monitors fecal indicator bacteria, including Escherichia coli, levels at two sites on the Chattahoochee River within the Chattahoochee River National Recreation Area (CRNRA), in the Atlanta metro area. When E. coli counts at either site exceed the U.S. Environmental Protection Agency (USEPA) Beach Action Value for primary contact, a health advisory is posted for designated swimming areas downstream of that site. While E. coli is commonly found in the gastrointestinal tract and feces of warm-blooded animals, the human health risk of exposure to human fecal contamination is greater than the risk of exposure to non-human fecal contamination. As E. coli is general to warm-blooded animals, E. coli counts are not always an accurate predictor of the risk of exposure to pathogens. Additionally, the presence of E. coli does not provide information about the sources of contamination, which is critical for remediation efforts. In Winter and Summer 2016 we collected water samples from the two BacteriALERT sites on the Chattahoochee River with the addition of 13 other locations within the CRNRA watershed, and used microbial source tracking as a means for assessing the presence and source locations of human fecal contamination and pathogenic bacteria that may cause gastrointestinal infections. We present these results and discuss implications for addressing sources of fecal contamination in the Chattahoochee River National Recreation Area.

(1.4.19) **Dinesh, Mallika**, and Jon Calabria
American Rivers
INCREASING WATER QUALITY AND INFILTRATION IN THE CITY OF NEWNAN, GA
This project will be conducted in conjunction with American Rivers, a non-profit organization, Coweta county and the city of Newnan. The project is intended to be carried out under the guidance of Dr. Jon Calabria. This city has recently undergone a lot of development and is home to many new subdivisions, settlements, businesses and even a golf course. In order to plan effectively for the future of the city (which includes the placement of various light industrial and retail within its perimeter) it is essential to perform a coarse scale hydrologic assessment of the city in relation to the White Oak watershed and also to Coweta county. To do so, first, suitability analysis will be generated from the landcover, runoff analysis, digital elevation model and the existing storm water control measures in the city. After creating the suitability study, the Soil and Water Assessment Tool in ArcGIS will be used to model the runoff of from the city into the watershed and the model will then be recalibrated based on the suitability study in order to evaluate the necessary modifications to the model in order to maximize infiltration and increase water quality. Possibilities for retrofitting existing buildings and structures will also be outlined. This project is intended to provide the city of Newnan with a guide to better their storm water control measures based on existing conditions and the near future (to reduce their impact on the Upper White Oak watershed).

(1.4.20) **Knapp, Abigail S**., Adam M. Milewski, and Rachel R. Rotz
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TEMPORAL RELATIONSHIP BETWEEN DROUGHT-PRECIPITATION PATTERNS AND THE CYANOBACTERIAL HARMFUL ALGAL BLOOMS IN LAKE ALLATOONA, GA
Harmful algal blooms (HABs) increasingly threaten the freshwater supply through contamination and fish kill. These blooms occur annually in the eutrophic Lake Allatoona, and are affected by a number of interconnected biological, chemical, and hydrogeological mechanisms. This study investigated the effect of precipitation and drought dynamics on HAB onset, durations, and severity through the integration of remote sensing and in situ datasets and statistical analysis. Precipitation and streamflow data were obtained from USGS stations at Lake Allatoona for the years 2008-2014. Chlorophyll-a fluorescence data measured by the Georgia Environmental Planning Division in Allatoona were collected for the same time span to calculate algal biomass. Phycocyanin concentrations were modelled using geometrically, radiometrically, and atmospherically corrected data from the Landsat ETM+ and OLI/TIRS satellite sensors. Statistical analyses including a Standardized Precipitation Index and Flow Duration Curves were conducted to determine the relationship between precipitation intensity, duration, and frequency and HAB growth. Landsat scenes were corrected and processed using a phycocyanin concentration detection algorithm to verify the presence of HABs associated with Chlorophyll-a data. These data suggest that the relationship between HAB growth and precipitation dynamics during the wet season may be a function of bloom location within the lake. Blooms near the river inflow are disrupted by destratifying discharge events throughout the year and therefore can show reduced growth due to the increased wet season inflow. HABs in stable waters will be more likely to have increased growth correlating to wet season precipitation intensity. Improved understanding of the relationship between precipitation and HAB growth will allow for greater prediction and remediation of freshwater resources.

(1.4.21) **Johnson, Katie M.**[1], Kelsey Laymon[1], Damon Mullis[1], Alyssa Thomson[2], Dr. Oscar P. Flite[1], and Dr. John Hains[3]
[1]Phinizy Center for Water Sciences, Augusta, GA 30906; [2]Georgia College and State University, Milledgeville, GA 31061; [3]Clemson University, Clemson, SC 29634
A PRELIMINARY STUDY ON BIOLOGICAL INDICATORS AND WATER QUALITY OF OXBOW LAKES IN THE MIDDLE AND LOWER SAVANNAH RIVER BASIN
Studies have shown that oxbows are important to riverine ecosystem biodiversity, stability, and productivity. Over time oxbows become disconnected from the main river channel resulting in prolonged periods of poor water quality. In this preliminary investigation we sampled two disconnected Savannah River oxbows (Conyers Lake, Possum Eddy), and one connected oxbow (Whirligig) during Fall 2015 for biological, physical and chemical parameters to understand oxbow ecosystems and water quality. We assessed the following: temperature (°C), specific conductance (uS/cm), pH, dissolved oxygen (DO)(mg/L), chlorophyll a (ug chl a/L), and biological indicators such as diatoms and

macroinvertabrates. We found that Conyers Lake had the highest Hilsenhoff biotic index (HBI=8.15), the lowest average temperature (M=22.49, SD=5.83), specific conductance (M=72.9, SD= 2.28), chlorophyll a concentrations (M=27.79, SD=2.28) and no diatom species indicative of eutrophic conditions. Whirligig had the lowest HBI (7.44), average DO (M=4.41, SD= 2.09); 51.27% saturation, and average pH (M=7.29, SD=1.34), but the highest mean specific conductance (M=94.43, SD=2.92), and diatom species indicative of eutrophic conditions (Nitzschia amphibia and Discostella stelligera). Possum Eddy had the highest average temperature (M=26.26, SD=5.22), pH (M=9.31, SD= 1.29), DO (M=7.25, SD= 2.60 mg/L); 89.07% saturation, chlorophyll a concentrations (M=84.35, SD= 2.11) and the most abundant diatoms indicative of eutrophic conditions (Aulacoseira ambigua, A. granulata, and A. granulata var. angustissima). Because chlorophyll a concentrations and eutrophic diatom species were not reflected in the HBI values and low DO values were found in the oxbow with the lowest HBI values, the HBI may not be the best index for measuring water quality when investigating nutrients in oxbow habitats. Given the HBI is traditionally used for evaluating streams and rivers, and the data in this study were taken from one sampling event close to the end of a flood, a more extensive study is recommended to draw conclusions about correlations between biota and nutrients.

(1.4.22) **Webster, Claire**[1], Adam Milewski[1], Todd Rasmussen[1], John Dowd[1], and Rachel Rotz[1]
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IMMEDIATE AND LONG TERM THREATS TO WATER RESOURCE AVAILABILITY AT FELSENTHAL NATIONAL WILDLIFE REFUGE

The alteration of hydrologic conditions due to human and natural causes affect water availability to U.S. Fish and Wildlife Service (USFWS) facilities, and may also lead to adverse environmental impacts at National Wildlife Refuges (NWR). The management and protection of NWRs requires an accurate reconnaissance-level Water Resources Inventory and Assessment (WRIA) on NWR lands to identify threats and needs and provide a foundation for planning and prioritization of needed management actions. A WRIA requires local and regional inventories and assessments for the biological, physical, chemical, and hydrologic resources of each refuge to study and ensure the quality and the availability of useable water resources at a specific site. We are currently conducting WRIAs for the Southeast region based on inventory data and identifying and providing recommendations to address perceived threats, needs, or concerns (immediate and long-term) on the refuge related to water resources for a subset of refuges. Information is being compiled from publicly available reports (e.g., published research), databases (e.g., governmental websites), and geospatial datasets from federal, state, and local sources. Here we present the assessment of Felsenthal NWR, one of the refuge sites in the southeastern region of the USFWS. This site is located in southern Arkansas and is a part of the Lower Ouachita-Bayou De Loutre watershed. Recently, over-pumping in the area has caused widespread groundwater level declines. Global climate change also poses a threat to the water resources at Felsenthal NWR. There is also an increased statistical likelihood of extreme precipitation events in the area. We examined the change in current and projected water resources using an integrated approach involving field data, satellite remote sensing, existing inventories, and statistical analyses. Results highlight the impact of diminishing water resources as current climate projections project wetter, milder winters and hotter, dryer summers.

(1.4.23) **Laymon, Kelsey A**., Damon L. Mullis, Oscar P. Flite III, and John J. Hains
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MACROINVERTEBRATE SUCCESSIONAL RESPONSE TO HYDROLOGIC CONNECTIVITY OF OXBOW LAKES DURING A FLOOD PULSE

Floodplains contain a unique and diverse array of habitats that rely on the activity of the river. In particular, oxbow lakes contain a high level of biodiversity, and are considered hotspots in coastal plain floodplains. These lentic systems are often considered important in the flux of nutrients and organic material during high levels of hydrologic connectivity. The level of this connectivity can contribute to the heterogeneity of the floodplain. Floodplain inundation also has the potential to displace certain species, and can lead to oxygen deficiency through bacterial respiration. The main objective of this study was to assess the macroinvertebrate assemblages during varying levels of hydrologic connectedness within oxbow lakes along the Savannah River to further understand community response to a flood pulse. Four lakes along the Savannah River were analyzed seasonally for macroinvertebrate assemblages between July 2015 and June 2016 (N=24). Two lakes were always connected and two were connected only during floodplain inundation. Macroinvertebrate assemblages were assessed for differences in: Composition (%EPT, %Trichoptera), Tolerance (Hilsenhoff Biotic Index) and Functional Feeding Group Structure. Bray-Curtis similarity matrix and permutational ANOVA/MANOVA were used to assess differences between the benthic community structure at various levels of flooding. In addition, a similarity percentage analysis (SIMPER) test was performed to determine which taxa were responsible for differences between macroinvertebrate assemblages at different stages of flooding. Results indicated there were significant differences in Functional Feeding Group Structure with shedders increased linearly from 29% of the community before flooding to 41% after flooding receded (P=0.021) and collector-filters decreased from 59% to 7% during flooding, then increased to 33% after flooding (P=0.029). PerMANOVA results indicated significant differences between flood stages (P=0.005) and SIMPER results showed Polypedilum spp. of Chironomidae increased from 11% to 56% during flooding, and subsequently decreased to 20% after flooding receded (P=0.002). Overall results indicate of oxbow connectedness be a significant driver of change in macroinvertebrate assemblages and functional feeding group structure. Additional sampling is needed to account for macroinvertebrate drift and natural seasonal variation.

(1.4.24) **Quinn, Matthew**
UGA Geology Dept.

APPLICATIONS TO PROLONGING DATA COLLECTION EFFICIENCY IN STREAM CHANNELS

Within small first and second order streams, such as tributaries of the North Oconee River watershed, the response time to precipitation is fast. This response makes repetitive measurement of discharge and water chemistry necessary. Continual data collection in streams can be more efficiently measured with an automated system. The discharge of a stream is easily determined by a pressure transducer, but water chemistry

proves to be more problematic. Probe calibration is prone to drift if continually left in the water. Three electrical conductivity systems are compared in this study. They are tested in Birdsong Creek of the North Oconee River watershed. One system is a conductivity probe that remains in the stream taking measurements every five minutes. The second system is driven by peristaltic pumps that draw water from the stream in order to fill a reservoir for measurement. This system measures conductivity every hour. The last system is a track that lowers a probe into the water on the hour and then raises it. The anticipated result is that the peristaltic pump apparatus will be the most efficient system due to more isolated measurement and greater protection from the stream. However, early failures have occurred when the air temperature drops below freezing or the intake is buried under shifting sands of the channel. The submerged probe has also failed from burial. When operating properly both systems have shown similar results, however the probe that stays submerged displays more drift in calibration over time. This research exhibits how reliable chemical data can be collected in remote areas where field visits are infrequent.

(1.4.25) **Painter, Jaime**, Michael F. Peck, and Debbie W. Gordon
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CONTINUOUS GROUNDWATER-LEVEL MONITORING AND WATER-LEVEL TRENDS IN THE PRINCIPAL AQUIFERS OF GEORGIA

Groundwater-level data in Georgia are collected by the USGS, South Atlantic Water Science Center in cooperation with local, State, and other Federal agencies. The principal aquifers monitored in Georgia are the surficial aquifer, the Brunswick and Floridian Aquifer systems, Claiborne aquifer, Clayton aquifer, Cretaceous aquifer system, Paleozoic-rock aquifers, and the crystalline rock aquifers. Long term continuous water-level data from wells are necessary to monitor seasonal fluctuations, determine long-term trends, and establish relations between hydrologic stress and groundwater-level changes. For example, groundwater withdrawal influences water levels which affects aquifer storage and water availability. Water levels were monitored continuously at 158 groundwater wells during calendar year 2015. One hundred and eighteen wells were equipped with electronic data recorders that recorded water levels at 60-minute intervals and stored the data for bimonthly retrieval. Forty wells had real-time satellite telemetry that recorded water levels at 60-minute intervals. Real-time groundwater level data are transmitted hourly via satellite telemetry and available at http://waterdata.usgs.gov/ga/nwis/current/?type=gw. To illustrate long-term (period of record) water-level changes, selected hydrographs showing monthly mean water levels with trend lines are presented from the principal aquifers in Georgia.

(1.4.26) **Musser, Jonathan**
USGS

FLOOD INUNDATION MAPPING IN GEORGIA

The USGS (USGS) has been modeling and mapping flood inundation in Georgia since 1994. Links to the flood-inundation maps and publications for six stream reaches can be found on the Georgia Flood Inundation Web site (http://ga.water.usgs.gov/fim/). These include the Flint River at Albany (Musser and Dyar, 2007), Peachtree Creek at Atlanta (Musser, 2012a), Suwanee Creek at Suwanee (Musser, 2012b), Sweetwater Creek near Austell (Musser, 2012c), Big Creek in Alpharetta and Roswell (Musser, 2015a), and South Fork Peachtree Creek in DeKalb County (Musser, 2015b). The inundation maps, which are available through the USGS Flood Inundation Mapping Science Web site at http://water.usgs.gov/osw/flood_inundation/, depict estimates of the areal extent and depth of flooding corresponding to selected water levels (stages) at each USGS streamgage. Current stage at each USGS streamgage may be obtained at http://waterdata.usgs.gov/ and can be used in conjunction with these maps to estimate near real-time flooding extent. The National Weather Service (NWS) forecasts flood hydrographs at many places that commonly are collocated at USGS streamgages. The forecasted peak-stage information for a USGS streamgage, which is available through the National Weather Service River Forecast Center, Southeast RFC Web site (http://www.srh.noaa.gov/serfc/), may be used in conjunction with these maps to show predicted areas of flood inundation. The availability of these maps, when combined with real-time stage from USGS streamgages and forecasted stream stages from the NWS, provides emergency management personnel and residents with critical information for flood-response activities, such as evacuations and road closures, as well as for post-flood recovery efforts. In addition, USGS is currently developing flood-inundation maps for the Withlacoochee River in Valdosta and Lowndes County. Musser, J.W., and Dyar, T.R., 2007, Two-dimensional flood-inundation model of the Flint River at Albany, Georgia: USGS Scientific Investigations Report 2007–5107, 49 p., http://pubs.usgs.gov/sir/2007/5107. Musser, J.W., 2012a, Flood-inundation maps for Peachtree Creek from the Norfolk Southern Railway bridge to the Moores Mill Road NW bridge, Atlanta, Georgia: USGS Scientific Investigations Map 3189, 9 p., 50 sheets; available online at http://pubs.usgs.gov/sim/3189/. Musser, J.W., 2012b, Flood-inundation maps for Suwanee Creek from the confluence of Ivy Creek to the Noblin Ridge Drive bridge, Gwinnett County, Georgia: USGS Scientific Investigations Map 3226, 8 p. pamphlet, 19 sheets; available online at http://pubs.usgs.gov/sim/3226/. Musser, J.W., 2012c, Flood-inundation maps for Sweetwater Creek from above the confluence of Powder Springs Creek to the Interstate 20 bridge, Cobb and Douglas Counties, Georgia: USGS Scientific Investigations Map 3220, 10 p. pamphlet, 21 sheets, available online at http://pubs.usgs.gov/sim/3220/. Musser, J.W., 2015a, Flood-inundation maps for Big Creek from the McGinnis Ferry Road bridge to the confluence of Hog Wallow, Alpharetta and Roswell, Georgia: USGS Scientific Investigations Map 3338, 19 sheets, 10-p. pamphlet, http://dx.doi.org/10.3133/sim3338. Musser, J.W., 2015b, Flood-inundation maps for South Fork Peachtree Creek from the Brockett Road bridge to the Willivee Drive bridge, DeKalb County, Georgia: USGS Scientific Investigations Map 3347, 13 sheets, 10-p. pamphlet, http://dx.doi.org/10.3133/sim3347.

(1.4.27) **Straw, Chase**, and Gerald Henry
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UNIFORMITY AND SPATIAL VARIABILITY OF SOIL MOISTURE AND IRRIGATION DISTRIBUTION ON NATURAL TURFGRASS SPORTS FIELDS

Sports field irrigation systems are a common management tool that aid in maintaining turfgrass growth during dry periods. A uniform application of water is desired to promote water conservation and homogeneous playing conditions. The catch can (CC) method to calculate the lower quarter distribution uniformity (DUlq) is the most widely used method of evaluating irrigation system performance in turfgrass. However, this technique provides no indication of water infiltration and redistribution following application. Emerging technology that couples spatial irrigation distribution data with spatial plant and soil property data may provide a more robust assessment of system performance. Research was conducted on a native soil and sand capped sports field to 1) compare the DUlq and spatial variability of soil moisture (volumetric water content; VWC) and irrigation distribution (using the CC method), 2) investigate the influence of CC amount, soil compaction (penetration resistance), and turfgrass vigor (normalized difference vegetative index; NDVI) on VWC, and 3) delineate and compare site-specific management units (SSMUs) for VWC and CC amount in order to generate more informed irrigation-based management decisions. VWC DUlq was much higher than CC DUlq on the native soil field. Spatial maps of VWC and CC amount indicated that the spatial variability of VWC was not reflected in the spatial variability of CC amount on either field. Penetration resistance and NDVI were significant at predicting VWC on the native soil field ($P < 0.001$ and 0.01, respectively), and their spatial maps resembled the VWC map. Only CC amount was significant at predicting VWC on the sand capped field ($P < 0.001$), but their spatial maps were dissimilar. In conclusion, CC amount SSMUs would be useful to visually identify deficiencies in an irrigation system. VWC SSMUs would be useful for site-specific irrigation applications, soil moisture sensor placement, or aerification to improve irrigation efficiency.

(1.4.28) **Ryland, Rachel**[1], Daniel Markewitz[2], and Aaron Thompson[1]
[1]University of Georgia, College of Agriculture and Environmental Science, Crop and Soil Science; [2]University of Georgia, Warnell School of Forestry

HYDRUS 2D MODEL INTERFLOW COMPARISON, CHANGES IN LAND USE WITH A LOW PERMEABLE LAYER.

Current numerical models of hillslope and watershed hydrology often use characteristics from soil classification maps to parameterize subsurface hydrologic flow paths. These soil maps, however, may lack sufficient spatial detail and may not accurately represent landscapes that have been eroded from historical farming (De Alba et al., 2004). Therefore, a spatially explicit model of eroded landscapes, particularly in the Piedmont region of GA, could be valuable. Hillslope hydrology of the Piedmont typically involves an argillic horizon with low permeability causing high lateral flow in periods of high precipitation (Derps, 2011). In hillslope models this layer of low permeability is generally parallel to the soil surface creating different zones of interflow along the hillslope (Jackson et al. 2014). Highly eroded landscapes, such as those within South Carolina's Calhoun Critical Zone Observatory, have a redistribution of soil from higher to lower landscape positions. This redistribution has led to a low permeable layer that is not consistently parallel to the soil surface, creating zones of interflow that are different than current estimates. This study used extensive soil sampling within highly eroded and undisturbed watersheds to map spatial variations in depth to the argillic horizon. These spatially explicit hillslope data were used to parameterize a HYDRUS 2-D model and outflows at the lower slope were compared to the conventional parallel depth model.

(1.4.29) **Andrews, Josh**, Zack Sanders, David Radcliffe, and Nicholas Hill
Department of Crop and Soil Sciences, University of Georgia, Athens, GA 30602

COMPARING WATER AND NITRATE MOVEMENT IN THREE DIFFERENT CORN PRODUCTION SYSTEMS USING HYDRUS-1D

A HYDRUS-1D model was used to evaluate water and nitrate movement in three different corn production systems. Corn grown in the southern Piedmont requires 200 to 250 kg ha-1 of nitrogen annually (Raun et al., 1999) and can require up to 0.87 cm (Lee et al., 2015) of water per day, making groundwater systems susceptible to nitrate pollution due to high nitrogen and water demands by the corn crop. Three different cover cropping and fertilization treatments were simulated for 2015 and 2016: annual cereal ryegrass with 150 kg ha-1 N, annual crimson clover with 100 kg ha-1 N, and a white clover living mulch with 50 kg ha-1 N. Water content was measured at 16 and 30-cm depths below the corn row using time domain reflectometers (TDRs) and soil nitrate samples were taken at 0-16 and 75-cm depts. 2015 and 2016 were considered model calibration and validation periods, respectively. A water and nitrate flux model was created for each treatment and were evaluated using root mean square error (RMSE), mean error (ME), and R-squared (R2). Water uptake and flow models (RMSE 0.049 - 0.070) show small variations in total crop uptake among treatments in the same year, but larger differences between years, supporting research conducted by Sanders et al. (unpublished). Water flux below the root zone (>1 m) varies among treatments due to differences in initial water contents at planting. NO3--N leaching models (RMSE 0.120 – 0.767) show greater leaching in 2015 than in 2016 for all treatments due to greater rainfall and irrigation. The models also show a difference in nitrate leached below the root zone due to differences in timing of N application, with the crimson clover cover crop with 100 kg ha-1 N generally leaching the greatest amount of NO3--N below the root zone.

(1.4.30) **Miller, Luke**[1], George Vellidis[2], Timothy Coolong[2], Erick Smith[1], and Welsey Porter[1]
[1]2360 Rainwater Road, Department of Horticulture, University of Georgia, Tifton, GA 31793; [2]2360 Rainwater Road, Crop and Soil Sciences Department, University of Georgia, Tifton, GA 31793

ALTERNATIVE IRRIGATION SCHEDULING: PERFORMANCE OF THE SMART IRRIGATION APP FOR VEGETABLE PRODUCTION

Numerous tools have been developed to improve irrigation scheduling in vegetables. Recently, smartphone applications have been developed that schedule irrigation based on crop coefficients and real-time weather data. Called the Smartirrigation™ application (smartirrigationapps.org), these tools have the potential to aid farmers in conserving water and nutrients for crops. The parameters to determine irrigation in each application are based on crop-specific evapotranspiration (Et) curves that have been linked to weather stations in Georgia and Florida. This new application has the ability to use weather forecasting tools to predict Et for several days in advance, allowing irrigation to be scheduled proactively. To determine the efficacy of a new Smartirrigation™ application for tomatoes (Solanum lycopersicum), a trial was conducted comparing it to a water-balance method and an automated soil moisture based irrigation system. Tomatoes 'Red Bounty' were planted into raised beds of black plastic mulch. The trial was a randomized complete block design with four replications of each treatment. Total water use, soil moisture at depths of 15, 25, and 36 cm, as well as yield, brix, titratable acidity and internal pH were recorded.

Our results indicated that the Vegetable App and the soil moisture-based irrigation system reduced water use 14% and 50%, respectively, compared to the water-balance method while maintaining similar yields. Internal quality parameters did not significantly differ among the irrigation scheduling treatments, suggesting that water usage may be reduced, while not affecting quality. Data from this trial will be used to demonstrate the overall utility of the Smartirrigation™ application for vegetable growers.

(1.4.31) **Troast, Hannah**, and Luke Pangle
Georgia State University

PARTITIONING METEORIC, SUBSURFACE, AND ANTHROPOGENIC SOURCES OF WATER THAT CONTRIBUTE TO STREAMFLOW GENERATION IN THE PROCTOR CREEK WATERSHED, ATLANTA, GA

Streamflow in urban watersheds is characterized by transient, dramatic increases in response to large storm events, and similarly abrupt recessions. Previous research has highlighted the stark differences in the timing and magnitude of streamflow response between urbanized versus non-urbanized watersheds, though notably these differing short-term dynamics may not always lead to differences in overall partitioning of rainfall to streamflow at monthly to annual time scales. Far less is known about the relative contributions to streamflow of water from different sources: specifically, surface runoff from current rainfall, versus groundwater discharge, versus possible leakages from water-supply infrastructure. We are currently developing a study in the Proctor Creek Watershed of Atlanta, GA aimed at elucidating these source contributions to streamflow. We are recording hydrometric measurements of precipitation and streamflow at multiple locations, along with temporally-resolved measurements of stable-isotope ratios and ion concentrations within each of the noted sources. We will utilize these data within 2- and 3-component mixing models in an attempt to evalute relative contributions to flow from each source, and how those contributions vary under differing short-term weather conditions, and longer-term seasonal changes. In this contributed poster we report on our study design and preliminary conclusions drawn from our initial analyses of these data. The overall outcome of this work will be an improved understanding of spatially-variable hydrological processes within the Proctor Creek Basin, and sub-basins, which may also aid in understanding water-quality dynamics within the observed stream channels.

(1.4.32) **Rainey, Donald**, Laurie Trenholm, CJ Bain, John Bossart, and Esen Momol
University of Florida - IFAS Extension

A STATEWIDE BEST MANAGEMENT PRACTICES TRAINING PROGRAM THAT PROMOTES URBAN ENVIRONMENTAL STEWARDSHIP IN FLORIDA

To help minimize the potential nonpoint source loading from inappropriate water, fertilizer and pesticide use in the urban landscape, the UF/IFAS Extension Florida-Friendly Landscaping™ Program, in partnership with the Florida Department of Environmental Protection (FDEP), trains thousands of landscaping professionals statewide through the Green Industries Best Management Practices (GI-BMP) Training Program. The state of Florida requires this training for all landscaping professionals who apply fertilizers. The training program has four main program goals: reducing off-site transport of sediment, nutrients, and pesticides to surface water or groundwater; promoting appropriate site design and plant selection; using appropriate rates and methods for irrigation and fertilizer application; and promoting integrated pest management (IPM) practices. The GI-BMP training includes six learning modules covering efficient use of water and fertilizer, integrated pest management, fertilizer application, and pollution-minimizing lawn and landscape cultural practices. Course delivery is available through several formats, including in-person classes, online and DVD. Courses are available in English and Spanish, with Haitian Creole available through in-person classes. During 2016, a network of some 250 instructors offered 162 in-person classes and, including all teaching formats, 4,051 persons were certified. Since the program's start in 2006, over 48,000 persons received training, with 39,000 of these trainees receiving their GI-BMP certification. Surveys conducted 6 months after each training class assess the extent to which trainees have changed their landscaping behaviors and practices to conserve water and reduce pollutants. These surveys found that, post-training, 93-98% of the attendees used the GI-BMPs on a regular basis and that there was a 26% increase in those who always use the following practices: apply no more than 0.5-0.75 inches (1.27-1.91 cm) water per irrigation event (for water savings of 25-50%); avoid mulching around tree trunks and shrub bases; reset irrigation controls/timers seasonally; reduce fertilizer application; and use integrated pest management.

(1.4.33) **Colon-Gaud, Checo**, Candace Moon, Aubrie Goodson, Ashley Deal, V. Byron Collins, Jamie Roberts, and Alan Harvey
Georgia Southern University, Department of Biology, Statesboro, GA 30458

EDUCATION, OUTREACH, AND MONITORING AT BEAUTIFUL EAGLE CREEK IN THE CAMPUS OF GEORGIA SOUTHERN UNIVERSITY

Beautiful Eagle Creek on the campus of Georgia Southern University has been a symbol of pride and tradition since legendary football coach, Erk Russell, mentioned its magical waters during The Eagles' championship run in 1985. Historically, Beautiful Eagle Creek has been envisioned as a symbolic staple of the successful program that practices near its banks, as well as inspired the name of business entities within the Statesboro community. Realistically, Beautiful Eagle Creek's near 500m stretch has remained no more than a drainage ditch with little to no aesthetic appeal, much less ecological health and biological integrity. As part of an interdisciplinary effort, the Georgia Southern University Freshwater Ecology Lab, the Center for Sustainability, and the Facilities Services division, in collaboration with several Biology courses (e.g., Aquatic Ecology, Fisheries Biology, Ichthyology, and Field Biology), have been working since 2015 to transform Beautiful Eagle Creek into a venue for K-20 education, community outreach, and monitoring programs that promote environmental sustainability, as well the ecological health and integrity of freshwater ecosystems in the region. To date, over 100 students have participated in education/outreach activities at the site and several courses have become certified in chemical monitoring procedures through a partnership with the Ogeechee Riverkeeper. Furthermore, Beautiful Eagle Creek is now registered as an active monitoring site through the Georgia Adopt-A-Stream network. In this presentation, we'll highlight the findings from our efforts at Beautiful Eagle Creek and one other nearby creek with a less disturbed surrounding riparian area (Lotts Creek). We will also discuss the progress made since the implementation of the monitoring program and registering the site with Georgia Adopt-A-Stream.

(1.4.34) **Cross, Denzell A.**[1], Chelsea R. Smith[1], and Stephen W. Golladay[12]
[1]Joseph W. Jones Ecological Research Center, Newton, GA 39870 , [2]Odum School of Ecology, University of Georgia, Athens, GA 30602

STATE CITIZEN SCIENCE BIOMONITORING PROTOCOLS AND THEIR COMPARABILITY TO NATIONAL INVERTEBRATE METRICS

Citizen Science biomonitoring programs are an effective tool for assessing the condition of local and regional streams, rivers, and lakes. Macroinvertebrate indices within assessments provided by Georgia Adopt-A-Stream and Alabama Water Watch are designed to inform landowners and government agencies on potential problems in streams and rivers. We applied both Georgia Adopt-A-Stream and Alabama Water Watch macroinvertebrate metrics to assemblages collected seasonally in wadeable stream reaches within the lower Flint River basin quarterly between September 2013 and May 2014 to determine applicability to metrics used under EPA stream monitoring (Hilsenhoff Biotic Index (HBI), taxon richness, %EPT, and % clingers). Overall water quality ratings from state indices were consistently ranked between 'fair' (11-16) to 'excellent' (>22) condition. Published literature was used to obtain available species tolerance values for HBI determination, revealing rankings of 'fair' to 'fairly poor' over the sampling period, which is consistent with previous published national findings categorizing streams in the coastal plain based on macroinvertebrate assemblages. While taxon richness and %EPT varied seasonally within these streams, # of clingers remained low in all but one stream. Because these streams lie within the coastal plain, # clingers is likely not a good indicator as most streams lack riffles that would support the importance of such taxa. Additionally, lack of known tolerance values within the southeast for certain species likely skewed HBI determinations as many of the more sensitive taxa that occur lacked values. Understanding the applicability of volunteer-state indices to nationally used metrics can help strengthen the contribution of these volunteer programs to a larger network of data.

(1.4.35) **Vick, R. Alfred**, Cam Berglund, Jiaxin Di, Li Fu, Ming Guan, Ashwini Kannan, Chen Qu, Devyn Quick, Henry Ricks, Danielle Schwartz, Arianne Wolfe, Landon Woodward, Yuwen Yang, Alex Yuan, and Ran Zhang
UGA

EAST GEORGIA STATE COLLEGE GREEN INFRASTRUCTURE PLANS

Students in LAND 6030: Sustainability Studio in the fall of 2016 developed green infrastructure master plans for East Georgia State College. The plans were submitted to the EPA Campus Rainworks Competition.

Special Poster Session (6.4) UGA Campus Streams and Lake Herrick

Highlighting Undergraduate Volunteer Research and Watershed Education

Session Organizer: **James B. Deemy,** *Warnell School of Forestry and Natural Resources, 180 E Green Street • Athens, GA 30602-2152*

Session Coordinators: **James B. Deemy, Jordan N. Francis, Todd C. Rasmussen**

Experiential learning programs that are now becoming mainstream in higher education aim to increase opportunities for students to get experience in their fields during their undergraduate education. Another objective of these programs is to enable students to experience fields outside of their own so that they may become more informed citizens. Campus streams and Lake Herrick have provided an excellent outdoor laboratory for providing experiential learning opportunities to both science major and non-major undergraduates at the University of Georgia.

This poster session highlights the efforts of students doing volunteer water quality research on campus and the perspectives of students experiencing campus watersheds through their coursework. The first poster will present an overarching conceptual model of how volunteer research, experiential learning and watershed education are being integrated by the Warnell Aquatic Resources Group (WARG). Three posters will present the results of student volunteer led research. Three posters will present the student perspectives from experiential learning during courses that visit Lake Herrick or campus streams. One poster will present on participation in volunteer research as an experiential learning opportunity. Lastly, one poster will present watershed education data from a study on the efficacy of a lesson module created to provide basic concepts about watersheds to students in non-science majors.

This session will provide a concise sampling of water resources education and research opportunities for both science majors and non-majors at the University of Georgia. One of our goals is to provide water resources education context to professionals outside of academia and to spark a conversation about how we can integrate their needs into curriculum at UGA. Additionally it is hoped that this session will stimulate a conversation that will inform the future of water resources education at UGA and other institutions.

Presenters:

Jordan N. Francis

Lewis J. Craghead

Wesley C. Sparks

V. Ruth Pannil

Christine L. Roberts

Andrea Conety

Kelsey E. Morton

Taylor W. Faulk

James B. Deemy

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	0	0	0	0	0
Masters	2	0	0	0	2
Ph.D.	2	0	0	0	2
Post-Doc.	3	0	0	0	3
Total	7	0	0	0	7

Notable Awards and Achievements

Septic System Impact Study for Lake Lanier (SSIS)

The Georgia Water Resources Institute is leading a multi-year, $2.3 million study to assess the historical and current septic system impacts on water quality in Lake Lanier within and outside Gwinnett County, assess the lake water quality restoration expected from progressive removal of septic systems in lakeshore areas within and outside Gwinnett County, and provide environmental lakeshore management recommendations for Gwinnett and other Lake Lanier counties. The project objectives will be met through a combination of interlinked monitoring, modeling, assessment, and outreach activities.

Projects results will be shared with several stakeholders, including Georgia state agencies and other counties/cities facing similar issues.

The project will be implemented by a team of engineers, scientists, and outreach experts from Georgia Tech, the University of Georgia, and New York State Water Resources Institute (Cornell University). The project team will be led and coordinated by the Georgia Water Resources Institute (GWRI) at Georgia Tech.

The project team includes the following individuals encompassing expertise over a broad range of disciplines.

Georgia Tech/GWRI:

Dr. Aris P. Georgakakos; Professor and Director, GWRI; Integrated Water Resources Mgt.

Dr. Phillip W. Roberts; Professor, School of Civ. and Env. Eng.; Environmental Fluid Mechanics.

Dr. Martin Kistenmacher; GWRI Principle Engineer and Deputy Director; DSS Expert.

Dr. Nicholas Azza; GWRI Research Associate; Water Quality and Limnology Expert.

Mr. Wilton Rooks; GWRI Associate Director for Outreach Activities.

Ms. Beatriz Villegas; Water Quality Modeler.

Ms. Leslie Blythe; Environmental Engineer, Internal Technical Review and Quality Control.

Graduate Research Assistants (3).

University of Georgia:

Dr. David Radcliffe; Professor; Soil Physics, Environmental Transport Processes.

Dr. Garry L. Hawkins; Assistant Professor; Biological and Agricultural Engineering.

Dr. Susan B. Wilde; Associate Professor; Ecology of Freshwater and Marine Systems.

Graduate Research Assistants (2).

Cornell University:

Dr. M. Todd Walter; Associate Professor and Director, Cornell Water Resources Institute; Hydrology, Ecology, and Biogeochemistry.

Graduate Research Assistant (1).