Georgia Water Resources Institute
Annual Technical Report
FY 2015

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, 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.

FY2015 RESEARCH PROJECTS THROUGH 104B PROGRAM

1. Water supply and its potential impact on economic development along the Macon-Hawkinsville reach of the Ocmulgee River; E. Tollner, A. Mandall, and T. Rasmussen; University of Georgia.

2. Market-based approaches to resolve water conflicts in the Apalachicola-Chattahoochee-Flint River Basin; L. Fowler; University of Georgia.

3. Overland flow-sourced water quality impairment and targeted restoration of natural flow regimes in Proctor Creek, Atlanta, GA; K. Price and DM Deocampo; Georgia States University.

4. The 2015 Biennial Georgia Water Resources Conference; R. McDowell and T. Rasmussen; University of Georgia.

EXTENDED FY2014 RESEARCH PROJECTS THROUGH 104B PROGRAM

1. Baseline Conservation Analysis for Agricultural Irrigation in Priority Watersheds of the Lower Flint River Basin; M. Masters; Albany State University.

2. Validation of Oysters as Biomonitors of Pharmaceutical Pollution in Georgia; M. Black; University of Georgia.

OTHER RESEARCH PROJECTS AND ACCOMPLISHMENTS

Technical Support for the Development of a Sustainable Water Management Plan for the Apalachicola-Chattahoochee-Flint (ACF) River Basin, Aris Georgakakos PI, Georgia Institute of Technology, sponsored by the ACF Stakeholders.

RECENT PUBLICATIONS

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

Georgakakos, A.P., and H. Yao, "Value of Adaptive Drought Management for the ACF River Basin," Georgia Water Resources Conference, University of Georgia, Athens, April 28–29, 2015. (http://www.gwri.gatech.edu/conferences)

Kistenmacher, M., and A.P. Georgakakos, "Informing the Development of a Sustainable Water Management Plan for the ACF River Basin," Georgia Water Resources Conference, University of Georgia, Athens, April 28–29, 2015. (http://www.gwri.gatech.edu/conferences)

Villegas, B., P. Roberts, and A.P. Georgakakos, "A Mathematical Model of Apalachicola Bay Salinity and Its Effects on Oyster Harvesting," Georgia Water Resources Conference, University of Georgia, Athens, April 28–29, 2015. (http://www.gwri.gatech.edu/conferences)

Research Program Introduction

Four research projects were funded through the 104B Program (each at $18,000) in FY2015:

1. Water supply and its potential impact on economic development along the Macon-Hawkinsville reach of the Ocmulgee River; E. Tollner, A. Mandall, and T. Rasmussen; University of Georgia.

2. Market-based approaches to resolve water conflicts in the Apalachicola-Chattahoochee-Flint River Basin; L. Fowler; University of Georgia.

3. Overland flow-sourced water quality impairment and targeted restoration of natural flow regimes in Proctor Creek, Atlanta, GA; K. Price and DM Deocampo; Georgia States University.

4. The 2015 Biennial Georgia Water Resources Conference; R. McDowell and T. Rasmussen; University of Georgia.

Another two projects initiated in FY2014 received extensions and were completed in FY2015:

1. Baseline Conservation Analysis for Agricultural Irrigation in Priority Watersheds of the Lower Flint River Basin; M. Masters; Albany State University.

2. Validation of Oysters as Biomonitors of Pharmaceutical Pollution in Georgia; M. Black; University of Georgia.

Validation of Oysters as Biomonitors of Pharmaceutical Pollution in Georgia

Basic Information

Title:	Validation of Oysters as Biomonitors of Pharmaceutical Pollution in Georgia
Project Number:	2014GA341B
Start Date:	3/1/2014
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	Georgia 10th
Research Category:	Water Quality
Focus Category:	Water Quality, Non Point Pollution, Sediments
Descriptors:	None
Principal Investigators:	Marsha Carolyn Black

Publications

There are no publications.

Validation of Eastern Oysters as Biomonitors of Pharmaceutical Pollution in the Georgia Estuarine Environment

PI: Marsha C. Black; Co-PI: David W. Brew (PhD student)
Department of Environmental Health Science
University of Georgia, Athens GA 30602-2102

Final Report

The objectives of the study were to:

(1) Conduct chemical analysis of pharmaceuticals in oysters, suspended particles and sediments sampled bimonthly from estuarine environments of coastal Georgia that are susceptible to pharmaceutical pollution;

(2) Determine age-related pharmaceutical deposition in oyster tissues to evaluate the use of native oysters as pharmaceutical biomonitors;

(3) Develop a pharmaceutical pollution index and an oyster condition index for each of the sampling areas within each estuary as measures of environmental and biological (oyster) health in these areas related to pharmaceutical pollution;

(4) Calculate a pharmaceutical risk quotient for each of the pharmaceuticals analyzed in the study;

(5) Model environmental fate of pharmaceuticals in the estuarine environment, based on partitioning within oysters and environmental media (water, suspended particles and sediment)

Because of an invaluable partnership with Dr. Matthew Henderson (US EPA Region IV ORD, Athens, GA) we have expanded our original analyte list from 8 pharmaceuticals to include 19 contaminants of emerging concern, including pharmaceuticals, personal care products and pesticides. In February 2015 we were granted a no-cost extension of this GA Water Resources Grant to extend our sampling dates through April 2015 and accommodate the additional analytical workload generated by these additional samples. Through an in-kind collaboration with the Georgia Department of Natural Resources we were able to sample through October 2015, but this report only includes data collected through April 2015.

***Study Sites**:* Four study sites were chosen along the Brunswick River (Figure 1) to coordinate with an ongoing UGA Marine Extension study examining the effects of land use and septic tank densities on water quality. These sites are affected by a medium-sized city (population of metropolitan area ~100,000) and include sites with *C. virginica* beds subjected to effluents (via tidal influences) from two local wastewater treatment plants (WWTP) and from septic fields in local housing areas (Figure 2). Three of the Brunswick sites are located along a continuous stretch of the river and are influenced by septic fields and a WWTP. Plantation Creek was the presumed reference site due to its location away from the main river channel; however tides may still carry contaminants to this site. Our second study location is Sapelo Island, a small island with controlled (ferry) access and a small population (60-100 people, including island visitors) that is entirely serviced by septic tanks. On Sapelo Island we sampled three sites located on separate small tidal creeks (Figure 1, right panel): Oak Dale Creek, South End Creek (located adjacent to the UGA Marine Institute), and Cabretta Creek. Pharmaceuticals have been detected in oysters from Oak

Dale Creek in a previous study (Fuller 2012). Cabretta Creek was the presumed reference site as it had the lowest density of septic tanks among the three sites (Figure 2).

Sampling Regimen: Oysters and Environmental Media

Eastern oysters (*Crassostrea virginica*) were sampled from natural oyster beds at Brunswick and Sapelo Island, Georgia bimonthly from October 2013 through October 2015. Fifteen oysters were collected from each site. From these 15 oysters, equal portions of 5 oysters were composited, yielding three composited samples per site for each sampling date. Dispositional sediment samples, two 1-liter water samples and filtered suspended sediment particles were collected at each sample site from October 2014 through October 2015 (data shown through June 2015). The water samples were filtered to remove particulate matter (> 45 µm).

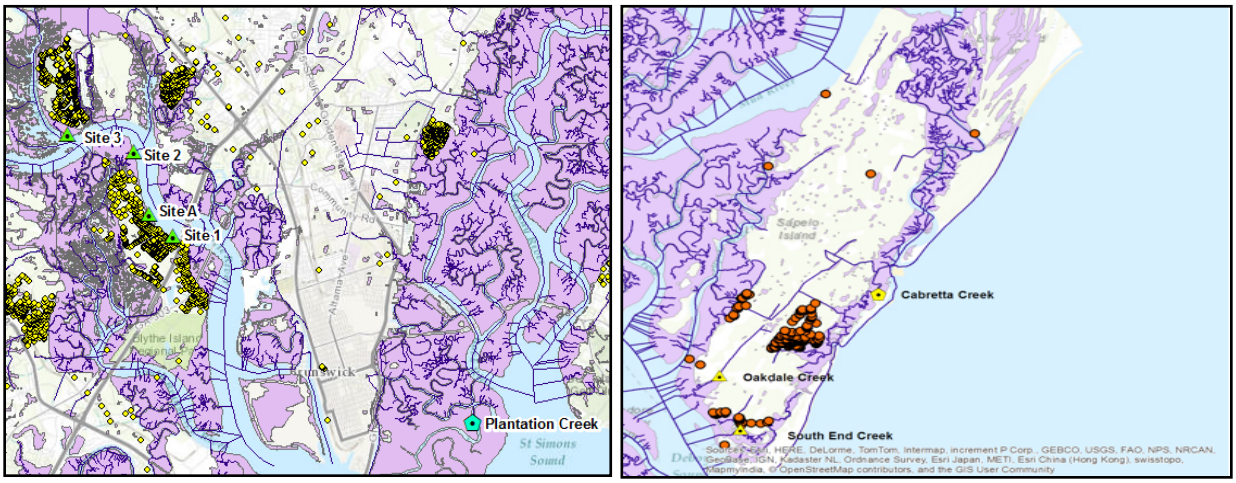

Figure 1. Map of sample site locations at Brunswick, Georgia (left) and Sapelo Island, Georgia (right). Triangles represent sample sites; pentagrams represent presumed reference sites. Colored circles represent individual septic fields, the purple background identifies tidal marshes and red stars indicate a wastewater treatment plant. Site 1 was only sampled from October 2013 – February 2014, prior to the death of the oyster bed. Brunswick has approximately 100,000 residents, while Sapelo Island has approximately 50 residents and is located approximately 42 kilometers north of Brunswick.

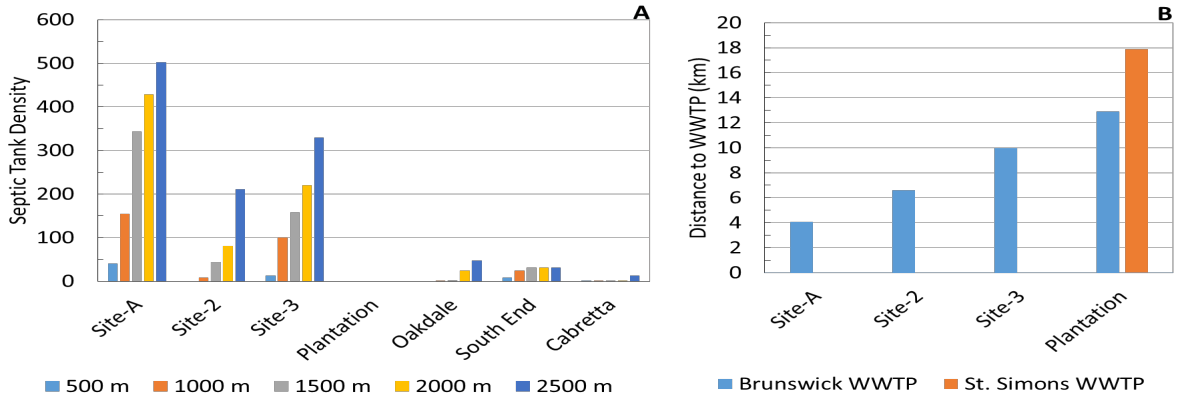

Figure 2. (A) Septic tank densities at specified distances (meters) from each sample site. (B) Distance (km) to local wastewater treatment plants (WWTP) from each sample site in Brunswick, Georgia. There is not a WWTP in McIntosh County that would impact sites at Sapelo Island.

Analysis of CECs in Water, Sediment and Oysters

Water samples were filtered (0.45 µm) to remove particulate matter. Analytes in water were separated via 6 cc Oasis HLB cartridges (Waters Corp.) <48 hours post-collection, eluted with 6 mL methanol, blown to dryness and reconstituted in 10% acetonitrile for LC-MS/MS analysis (EPA, 2007). Sediment samples were homogenized, placed in an ultrasonic bath (30 minutes) and diluted with 20 mL HPLC grade-water prior to separation via 6 cc Oasis HLB cartridges (Waters Corp.). Samples were then eluted with 6 mL methanol, blown to dryness and reconstituted in 10% acetonitrile for LC-MS/MS analysis (Lara-Martín et al., 2014). Oysters were freeze-dried and composited into three samples per sampling site for each sampling event. Tissue analytes were solvent extracted with a mixture of acetonitrile, methanol and MTBE, separated via florisil Sep-Pak cartridges, eluted with 6 mL methanol, blown to dryness and reconstituted in 10% acetonitrile for LC-MS/MS analysis (modified from Fuller 2012). Analyte concentrations for all media were quantified with an Accela HPLC coupled with a TSQ Quantum Ultra mass spectrometer (Thermo Scientific, Bellefonte, PA). Chromatographic separation was achieved with a Kinetex 3 µm C18 HPLC column (150 x 2.1 mm, Phenomenex, Torrance, CA) using a gradient of deionized water and acetonitrile supplemented with 0.1 % formic acid. All chemical analyses were conducted at the US EPA ORD facility at Athens, GA.

Water Quality Data

During each sample event, water quality parameters (pH, dissolved oxygen (mg/L), salinity (ppt) and conductivity (µm/cm)) were measured at each site. Bimonthly data were assigned to seasons based on mean monthly temperatures for each study location (https://www.ncdc.noaa.gov/cdo-web/) (Table 1).

Table 1: Water quality parameters measured *in situ* at Brunswick and Sapelo Island, Georgia

		pH		Temperature (°C)		Dissolved Oxygen (mg/L)		Salinity (ppt)		Conductivity (µs/cm)	
Season	Estuary	mean	range	mean	range	mean	range	mean	range	mean	range
Fall 2013	Brunswick	7.70	7.61 - 7.86	21.46	21.03 - 21.97	6.02	5.75 - 6.18	26.37	25.0 - 27.6	38700	36900 - 43200
	Sapelo Island	7.60	7.59 - 7.62	22.30	22.00 - 22.70	3.93	3.80 - 4.02	29.50	26.5 - 32.0	31909	18114 - 41411
Winter 2013 - 2014	Brunswick	7.69	7.48 - 7.95	18.83	12.40 - 17.52	5.88	5.76 - 11.18	26.21	19.69 - 27.14	39250	23480 - 42900
	Sapelo Island	8.02	7.32 - 8.87	12.10	10.80 - 14.50	7.92	7.07 - 8.75	26.00	7.0 - 35.0	26506	7223 - 33872
Spring 2014	Brunswick	7.00	6.84 - 7.16	22.85	21.40 - 23.70	5.54	4.71 - 5.90	10.75	8.0 - 15.0	17533	13938 - 22300
	Sapelo Island	7.23	6.66 - 7.60	23.63	22.50 - 25.10	4.50	3.42 - 5.15	14.33	0.0 - 28.0	22017	2603 - 38097
Summer 2014	Brunswick	7.29	7.11 - 7.58	29.90	28.09 - 31.06	4.26	2.82 - 5.27	25.93	20.54 - 30.52	40288	32700 - 46700
	Sapelo Island	7.49	7.22 - 7.80	30.83	28.80 - 33.30	4.57	3.05 - 7.29	25.67	20.0 - 30.0	44414	36567 - 49068
Fall 2014	Brunswick	7.40	7.36 - 7.43	24.33	23.56 - 25.13	4.59	4.13 - 4.91	27.28	26.38 - 28.83	42575	41400 - 44700
	Sapelo Island	7.40	7.17 - 7.68	22.50	22.20 - 22.70	4.40	2.68 - 6.29	28.00	20.0 - 34.0	36257	27270 - 43000
Winter 2014 - 2015	Brunswick	7.58	7.36 - 7.83	12.33	11.12 - 13.46	7.81	6.65 - 7.69	23.23	17.81 - 27.33	37350	29300 - 43400
	Sapelo Island	7.53	7.19 - 8.03	10.85	8.10 - 13.20	8.11	6.87 - 9.32	29.50	20.0 - 35.0	26801	15375 - 35533
Spring 2015	Brunswick	7.28	7.19 - 7.40	24.39	23.11 - 25.37	4.72	4.46 - 4.94	21.51	19.44 - 24.46	34225	31300 - 38400
	Sapelo Island	7.55	7.54 - 7.56	25.20	24.90 - 25.40	5.42	3.97 - 6.40	27.50	25.0 - 30.0	29915	17068 - 41250

Analyte Concentration Results – Oyster tissues

Analyte extraction and LC/MS/MS analyses have been completed for oysters collected bimonthly from October 2013 through April 2015 and for ease of interpretation, individual months were grouped by season based upon similar mean temperature readings (Fall 2013 = October 2013; Winter 2013 = December 2013 + February 2014; Spring 2014 = April 2014; Summer 2014 = June 2014 + August 2014; Fall 2014 = October 2014; Winter 2014 = December 2014 + February 2015; and Spring 2015 = April 2015). Analytes were selected to represent a broad spectrum of contaminants of emerging concern (CECs) that could be entering Georgia's estuarine environment. Target analytes included: sertraline and fluoxetine (selective serotonin reuptake inhibitors); norethindrone, norgestrel, and medroxyprogesterone (progestins); carbamazepine (anti-convulsant), methylphenidate (stimulant to treat ADHD); caffeine (stimulant); diphenhydramine (antihistamine), naproxen and acetaminophen (analgesics), atenolol and

propranolol and valsartan (blood pressure regulators), gemfibrozil (cholesterol lowering); *N,N*-diethyl-meta-toluamide (DEET) (insect repellent), atrazine (herbicide); imidacloprid and thiacloprid (neonicotinoid pesticides). While atrazine, imidacloprid and thiacloprid are not pharmaceuticals or personal care products, they were selected to provide an estimate of compounds that enter the marine environment from sources other than wastewater treatment plants (WWTPs) or septic tank inputs. These compounds are predicted to primarily enter tidal rivers and estuaries from freshwater inputs and from residential and agricultural runoff (Moreau et al., 2015 and Loos et al, 2013).

The analyte most frequently detected in oysters was DEET, which was detected in nearly 100% of the oyster samples across all seasons and in both study locations. Sertraline, diphenhydramine, atrazine and atenolol were detected in ≥ 75% of samples in five out of seven seasons at both study locations. Concentrations of analytes and their detection frequencies in oysters varied greatly between seasons and sampling sites and all analytes were detected at least once over the course of the study at each site. Overall, no statistically significant differences in detections of CECs were observed between the two study locations (Brunswick versus Sapelo Island) (Table 2). We compared the mean ±95% confidence intervals for each analyte at Brunswick and Sapelo for each season and found that the only statistically significant difference among sites was diphenhydramine during fall 2014 (Brunswick: mean 0.13 ng/g [95% CI 0-0.27]; Sapelo: mean 1.36 ng/g [95% CI 0.56-2.15]). Both estuaries exhibited higher CEC detection frequencies (≥ 75% of samples within a specific season) and higher concentrations during warmer seasons in 2013 and 2014 (fall 2013, spring, summer, fall 2014) (Table 2). The exception to this pattern was spring 2015. During that season, oyster tissue samples had both lower detection frequencies and lower analyte concentrations, except for DEET, which had the highest measured concentration of the entire study. Lower analyte concentrations and detections compared to the previous spring (2014) were not related to rainfall, as our sampling event during spring 2015 had less rainfall (2.27 inches compared to 4.83 inches) and fewer rainy days (four compared to six) in the two-weeks prior to our sampling date, compared to the spring 2014 sample event. Water quality parameters (pH, temperature and salinity) also varied markedly between these two seasons (Table 1) and it is likely that this plays some role in the differences detected.

Analyte Concentrations – Water & Sediment Samples

Water: Although detection frequencies and analyte concentrations in water varied between seasons (fall 2014, winter 2014 and spring 2015) and estuaries, all analytes were detected at least once over the course of the study (Table 3). At Brunswick, 7 of 19 analytes (valsartan, diphenhydramine, imidacloprid, naproxen, carbamazepine, atrazine and DEET) were detected in 100% of the samples during all seasons; while at Sapelo, only 5 of 19 analytes (valsartan, diphenhydramine, carbamazepine, DEET and caffeine) were detected in all samples during all seasons. Of the remaining analytes, only caffeine and acetaminophen were detected in over 75% of the samples at Brunswick; while at Sapelo, imidacloprid, naproxen, acetaminophen, methylphenidate and atrazine were detected in over 75% of the water samples. Analyte concentrations in water were generally lower than those detected in oysters, with the exception of acetaminophen and DEET, and several of the analytes (naproxen, acetaminophen, caffeine and DEET – Sapelo) predicted to pose medium and high (DEET – Brunswick) ecological risk to aquatic organisms were also the most frequently detected compounds in water.

Table 2. Seasonal concentrations of contaminants of emerging concern in oyster tissues (ng/g dry weight) collected from Brunswick, GA and Sapelo Island, GA. (ND = not detected)

		Brunswick, Georgia			Sapelo Island, Georgia		
Season	Compound	Mean (ng/g)	Range (ng/g)	Frequency of Detection	Mean (ng/g)	Range (ng/g)	Frequency of Detection
Fall 2013	Atenolol	1.20	0.01 - 3.06	83%	1.64	0.46 - 2.59	78%
	Propanolol	1.88	0.05 - 12.99	100%	0.92	0.14 - 2.25	89%
	Valsartan	0.13	0.01 - 0.28	100%	0.15	0.04 - 0.48	89%
	Gemfibrozil	19.65	0.88 - 92.26	100%	37.41	2.99 - 156.62	89%
	Diphenhydramine	1.20	0.01 - 3.06	83%	1.64	0.46 - 2.59	78%
	Caffeine	1.01	0.02 - 6.06	100%	1.22	0.25 - 1.80	89%
	Imidicloprid	1.20	0.01 - 3.06	83%	1.64	0.46 - 2.59	78%
	Thiacloprid	1.88	0.05 - 12.99	100%	0.92	0.14 - 2.25	89%
	Fluoxetine	2.70	0.18 - 18.03	100%	1.57	0.24 - 5.28	89%
	Sertraline	95.02	7.20 - 187.44	100%	108.49	4.28 - 482.13	78%
	Naproxen	75.84	11.37 – 507.7	100%	55.56	11.37 - 98.53	89%
	Acetaminophen	0.73	0.29 - 1.54	100%	0.82	0.41 - 1.35	89%
	Carbamazepine	0.06	0.02 - 0.18	100%	0.05	0.02 - 0.13	89%
	Methylphenidate	1.21	0.34 - 2.08	17%	0.12	0.12	11%
	Atrazine	0.13	0.03 - 0.37	100%	0.12	0.02 - 0.23	89%
	DEET	14.01	4.25 - 21.01	100%	22.21	1.47 - 62.96	89%
	Norethindrone	2.07	0.72 - 5.32	100%	1.62	0.59 - 2.84	89%
	Norgestrel	20.10	10.97 - 32.46	100%	14.71	4.01 - 33.99	89%
	Medoxyprogesterone	1.26	0.20 - 2.03	91%	2.38	0.41 - 5.67	89%
Winter 2013-2014	Atenolol	0.61	0.10 - 1.41	83%	0.42	0.06 - 1.76	100%
	Propanolol	0.13	0.05 - 0.42	92%	0.08	0.03 - 0.16	67%
	Valsartan	0.50	0.21 - 1.25	50%	0.25	0.11 - 0.54	67%
	Gemfibrozil	ND	ND		1.69	1.37 - 2.17	44%
	Diphenhydramine	0.27	0.06 - 1.52	100%	0.57	0.06 - 6.34	89%
	Caffeine	4.42	0.90 - 11.80	42%	4.01	1.15 - 13.56	44%
	Imidicloprid	0.27	0.09 - 0.99	75%	0.16	0.07 - 0.49	56%
	Thiacloprid	0.15	0.04 - 0.32	83%	0.11	0.02 - 0.23	78%
	Fluoxetine	0.12	0.01 - 0.21	67%	0.13	0.12 - 0.15	33%
	Sertraline	0.92	0.15 - 5.37	100%	0.46	0.03 - 1.34	89%
	Naproxen	0.62	0.62	8%	0.47	0.34 - 0.61	22%
	Acetaminophen	4.84	0.88 - 12.16	25%	2.06	1.29 - 3.09	33%
	Carbamazepine	0.24	0.04 - 0.76	100%	0.04	0.02 - 0.07	89%
	Methylphenidate	0.09	0.01 - 0.48	100%	0.19	0.04 - 0.53	89%
	Atrazine	0.39	0.04 - 1.78	100%	0.18	0.05 - 0.66	89%
	DEET	19.94	4.61 - 51.76	100%	26.60	5.06 - 91.27	89%
	Norethindrone	2.45	0.96 - 5.66	67%	2.17	1.56 - 3.20	22%
	Norgestrel	17.10	8.46 - 44.28	83%	17.29	6.62 - 33.92	89%
	Medoxyprogesterone	ND	ND		1.35	1.35	11%

Table 2 (continued)

Season	Compound	Brunswick, Georgia			Sapelo Island, Georgia		
		Mean (ng/g)	Range (ng/g)	Frequency of Detection	Mean (ng/g)	Range (ng/g)	Frequency of Detection
Spring 2014	Atenolol	2.13	0.60 - 5.12	100%	1.00	0.27 - 2.12	100%
	Propanolol	0.31	0.07 - 0.71	25%	4.70	0.01 - 11.45	33%
	Valsartan	1.59	0.35 - 4.89	100%	2.19	0.56 - 4.84	100%
	Gemfibrozil	25.12	2.99 - 111.26	100%	15.96	3.24 - 67.00	100%
	Diphenhydramine	0.39	0.04 - 1.64	100%	1.68	0.02 - 10.26	100%
	Caffeine	0.60	0.13 - 1.73	100%	0.85	0.17 - 2.09	100%
	Imidicloprid	0.91	0.41 - 1.63	100%	1.50	0.23 - 3.05	100%
	Thiacloprid	0.69	0.19 - 2.47	83%	0.95	0.19 - 2.44	89%
	Fluoxetine	6.11	0.27 - 62.04	100%	1.48	0.19 - 4.64	100%
	Sertraline	2.02	0.45 - 5.75	100%	3.07	0.50 - 7.80	100%
	Naproxen	14.96	3.53 - 56.72	100%	44.53	5.70 - 144.00	100%
	Acetaminophen	1.51	0.32 - 3.67	100%	0.92	0.39 - 1.61	100%
	Carbamazepine	ND	ND		ND	ND	
	Methylphenidate	ND	ND		1.11	1.11	11%
	Atrazine	0.70	0.13 - 1.75	100%	0.63	0.13 - 2.21	100%
	DEET	5.74	0.09 - 15.84	100%	14.52	4.94 - 31.38	100%
	Norethindrone	5.58	0.39 -18.67	100%	6.92	1.36 - 36.89	100%
	Norgestrel	21.91	1.71 - 79.91	100%	15.53	2.10 - 66.79	100%
	Medoxyprogesterone	2.30	0.60 - 8.44	100%	8.43	1.80 - 22.67	100%
Summer 2014	Atenolol	1.39	0.05 - 6.29	100%	1.01	0.04 - 5.23	100%
	Aropanolol	3.06	0.05 - 22.11	100%	8.56	0.04 - 118.45	100%
	Valsartan	0.69	0.01 - 3.04	100%	0.34	0.01 - 1.37	100%
	Gemfibrozil	10.45	1.85 - 29.75	100%	23.95	4.55 - 69.18	100%
	Diphenhydramine	4.40	0.17 - 47.22	100%	6.52	0.42 - 58.47	100%
	Caffeine	2.45	0.02 - 27.50	100%	1.42	0.23 - 5.42	100%
	Imidicloprid	0.42	0.09 - 1.00	100%	0.28	0.10 - 0.60	100%
	Thiacloprid	0.14	0.02 - 0.32	83%	0.09	0.01 - 0.23	78%
	Fluoxetine	39.44	0.57 - 746.27	100%	78.08	0.18 - 1017.89	100%
	Sertraline	14.30	0.03 - 264.74	100%	40.36	0.04 - 566.33	100%
	Naproxen	39.47	1.54 - 268.10	100%	108.11	3.26 - 777.04	100%
	Acetaminophen	0.43.	0.04 - 1.20	100%	0.57	0.07 - 1.58	100%
	Carbamazepine	0.76	0.04 - 3.05	100%	0.54	0.13 - 1.37	100%
	Methylphenidate	0.46	0.01 - 3.27	100%	3.05	0.01 - 14.62	100%
	Atrazine	0.24	0.01 - 2.42	100%	0.05	0.02 - 0.23	100%
	DEET	12.26	0.47 - 38.48	100%	24.06	4.25 - 126.99	100%
	Norethindrone	3.92	0.21 - 14.74	100%	3.43	0.36 - 12.95	100%
	Norgestrel	7.54	0.20 - 50.40	100%	6.69	0.10 - 21.49	100%
	Medoxyprogesterone	1.95	0.26 - 12.20	100%	4.20	0.36 - 9.54	100%

Table 2 (continued)

Season	Compound	Brunswick, Georgia			Sapelo Island, Georgia		
		Mean (ng/g)	Range (ng/g)	Frequency of Detection	Mean (ng/g)	Range (ng/g)	Frequency of Detection
Fall 2014	Atenolol	1.40	0.05 - 6.64	100%	1.90	0.21 - 9.77	89%
	Propanolol	0.11	0.02 - 0.38	75%	0.06	0.03 - 0.09	44%
	Valsartan	0.22	0.06 - 0.46	58%	0.54	0.20 - 1.05	44%
	Gemfibrozil	3.53	3.53	17%	1.08	0.16 - 1.99	22%
	Diphenhydramine	0.31	0.14 - 0.86	50%	1.75	0.66 - 3.50	78%
	Caffeine	5.12	1.48 - 10.96	33%	55.41	2.25 - 215.16	56%
	Imidicloprid	0.25	0.04 - 0.64	67%	0.19	0.06 - 0.36	67%
	Thiacloprid	0.20	0.01 - 0.37	41%	0.10	0.04 - 0.19	67%
	Fluoxetine	0.32	0.07 - 0.65	33%	0.08	0.06 - 0.09	33%
	Sertraline	0.43	0.04 - 1.65	83%	0.61	0.19 - 1.76	100%
	Naproxen	ND	ND		0.82	0.82	11%
	Acetaminophen	0.64	0.15 - 1.06	33%	3.66	1.98 - 6.08	33%
	Carbamazepine	0.29	0.11 - 0.62	50%	0.42	0.10 - 1.03	44%
	Methylphenidate	0.16	0.02 - 0.42	100%	0.38	0.08 - 1.61	100%
	Atrazine	0.70	0.13 - 1.60	92%	0.60	0.05 - 1.12	100%
	DEET	9.49	2.48 - 16.56	100%	18.06	4.25 - 33.78	100%
	Norethindrone	1.01	0.52 - 1.36	33%	0.41	0.41	11%
	Norgestrel	12.68	4.08 -27.99	83%	7.17	1.40 - 23.85	78%
	Medoxyprogesterone	1.09	0.20 - 2.04	33%	2.07	1.01 - 3.13	22%
Winter 2014-15	Atenolol	1.53	0.08 - 2.98	17%	0.36	0.21 - 0.49	67%
	Propanolol	0.12	0.01 - 0.42	58%	0.08	0.03 - 0.15	67%
	Valsartan	0.52	0.29 - 0.86	25%	0.26	0.23 - 0.29	22%
	Gemfibrozil	ND	ND		1.61	1.03 - 2.14	33%
	Diphenhydramine	0.27	0.02 - 0.85	100%	0.20	0.06 - 0.48	100%
	Caffeine	3.79	2.47 - 5.52	25%	5.63	2.63 - 9.87	44%
	Imidicloprid	0.25	0.08 - 0.53	56%	0.17	0.09 - 0.24	56%
	Thiacloprid	0.07	0.03 - 0.09	41%	0.19	0.05 - 0.27	78%
	Fluoxetine	0.19	0.03 - 0.62	41%	0.13	0.07 - 0.19	22%
	Sertraline	0.44	0.02 - 0.97	91%	0.22	0.05 - 0.42	67%
	Naproxen	ND	ND		ND	ND	
	Acetaminophen	6.52	0.88 - 12.16	17%	2.27	1.45 - 3.09	22%
	Carbamazepine	6.20	2.99 - 9.41	17%	ND	ND	
	Methylphenidate	0.13	0.02 - 0.42	100%	0.11	0.03 - 0.29	89%
	Atrazine	0.19	0.03 - 0.62	33%	0.07	0.07	22%
	DEET	26.15	0.26 - 146.93	100%	16.47	0.06 - 98.06	89%
	Norethindrone	3.91	3.91	8%	2.11	2.11	11%
	Norgestrel	26.15	6.10 - 57.53	33%	22.68	3.09 - 70.69	33%
	Medoxyprogesterone	ND	ND	0%	ND	ND	

Table 2. (continued)

Season	Compound	Brunswick, Georgia			Sapelo Island, Georgia		
		Mean (ng/g)	Range (ng/g)	Frequency of Detection	Mean (ng/g)	Range (ng/g)	Frequency of Detection
Spring 2015	Atenolol	0.63	0.63	8%	ND	ND	
	Propanolol	2.09	0.63 - 5.75	58%	0.53	0.11 - 1.31	56%
	Valsartan	ND	ND		ND	ND	
	Gemfibrozil	ND	ND		ND	ND	
	Diphenhydramine	13.49	2.12 - 19.91	75%	5.08	2.04 - 9.45	56%
	Caffeine	ND	ND		ND	ND	
	Imidicloprid	ND	ND		ND	ND	
	Thiacloprid	ND	ND		ND	ND	
	Fluoxetine	ND	ND		ND	ND	
	Sertraline	0.36	0.03 - 0.68	17%	0.09	0.02 - 0.17	33%
	Naproxen	ND	ND		ND	ND	
	Acetaminophen	ND	ND		ND	ND	
	Carbamazepine	ND	ND		11.72	0.08 - 34.34	33%
	Methylphenidate	ND	ND		ND	ND	
	Atrazine	0.75	0.39 - 1.28	33%	1.95	1.95	11%
	DEET	2778	50- 11426	83%	52	4 - 184	78%
	Norethindrone	0.06	0.06	8%	ND	ND	
	Norgestrel	ND	ND		ND	ND	
	Medoxyprogesterone	ND	ND		ND	ND	

Table 3. Seasonal concentrations of contaminants of emerging concern in water (ng/L) and sediment (ng/kg dry weight) collected from Brunswick, GA and Sapelo Island, GA. (ND = not detected)

		Environmental Media - Brunswick, Georgia				Environmental Media - Sapelo Island, Georgia			
Season	**Compound**	**Sample Media**	**Mean (ng/L or ng/kg)**	**Range (ng/L or ng/kg)**	**Frequency of Detection**	**Sample Media**	**Mean (ng/L or ng/kg)**	**Range (ng/L or ng/kg)**	**Frequency of Detection**
Fall 2014	**Atenolol**	Water	ND	ND		Water	ND	ND	
		Sediment	0.06	0.06 - 0.07	50%	Sediment	0.07	0.06 - 0.08	100%
	Propanolol	Water	0.03	0.01 - 0.05	75%	Water	0.08	0.08 - 0.08	67%
		Sediment	0.45	0.38 - 0.62	75%	Sediment	0.02	0.01 - 0.02	67%
	Valsartan	Water	1.02	0.71 - 1.40	100%	Water	1.48	0.29 - 2.64	100%
		Sediment	ND	ND		Sediment	ND	0.00	
	Gemfibrozil	Water	ND	ND		Water	ND	ND	
		Sediment	ND	ND		Sediment	ND	ND	
	Diphenhydramine	Water	0.91	0.32 - 1.68	100%	Water	0.57	0.19 - 1.19	100%
		Sediment	0.03	0.03 - 0.04	100%	Sediment	0.03	0.03	33%
	Caffeine	Water	2.53	2.22 - 3.0	75%	Water	1.61	0.77 - 2.90	100%
		Sediment	1.00	0.70 - 1.30	50%	Sediment	0.75	0.54 - 0.99	67%
	Imidicloprid	Water	0.59	0.30 - 0.78	100%	Water	2.35	0.59 - 3.92	100%
		Sediment	ND	ND		Sediment	ND	ND	
	Thiacloprid	Water	ND	ND		Water	0.13	0.13	33%
		Sediment	ND	ND		Sediment	ND	ND	
	Fluoxetine	Water	0.08	0.04 - 0.12	50%	Water	0.01	0.01	33%
		Sediment	0.32	0.32	25%	Sediment	ND	ND	
	Sertraline	Water	0.09	0.09 - 0.10	50%	Water	0.21	0.21	33%
		Sediment	ND	ND		Sediment	ND	ND	
	Naproxen	Water	1.51	0.53 - 2.26	100%	Water	1.74	0.46 - 2.02	67%
		Sediment	ND	ND		Sediment	ND	ND	
	Acetaminophen	Water	76.39	64.59 - 88.02	100%	Water	74.07	67.77 - 83.96	100%
		Sediment	ND	ND		Sediment	ND	ND	
	Carbamazepine	Water	0.64	0.52 - 0.77	100%	Water	0.27	0.20 - 0.38	100%
		Sediment	0.01	0.01 - 0.02	100%	Sediment	0.01	0.01 - 0.01	67%
	Methylphenidate	Water	ND	ND		Water	1.79	1.79 - 1.79	67%
		Sediment	ND	ND		Sediment	ND	ND	
	Atrazine	Water	0.16	0.12 - 0.19	100%	Water	0.17	0.13 - 0.20	67%
		Sediment	0.01	0.01	25%	Sediment	0.05	0.05	33%
	DEET	Water	113.14	92.41 - 143.09	100%	Water	39.38	20.12 - 65.48	100%
		Sediment	1.30	0.95 - 1.90	100%	Sediment	1.57	1.00 - 2.64	100%
	Norethindrone	Water	ND	ND		Water	1.13	1.13	33%
		Sediment	ND	ND		Sediment	ND	ND	
	Norgestrel	Water	ND	ND		Water	ND	ND	
		Sediment	ND	ND		Sediment	ND	ND	
	Medoxyprogesterone	Water	4.28	0.42 - 7.45	75%	Water	2.18	0.56 - 3.79	67%
		Sediment	ND	ND		Sediment	ND	ND	

Table 3 (continued)

		Environmental Media - Brunswick, Georgia				Environmental Media - Sapelo Island, Georgia			
Season	**Compound**	**Sample Media**	**Mean (ng/L or ng/kg)**	**Range (ng/L or ng/kg)**	**Frequency of Detection**	**Sample Media**	**Mean (ng/L or ng/kg)**	**Range (ng/L or ng/kg)**	**Frequency of Detection**
Winter 2014 - 2015	**Atenolol**	Water	0.34	0.19 - 0.49	50%	Water	0.35	0.17 - 0.48	100%
		Sediment	ND	ND		Sediment	0.02	0.02	33%
	Propanolol	Water	0.09	0.06 - 0.12	100%	Water	0.13	0.05 - 0.22	100%
		Sediment	0.01	0.01	50%	Sediment	0.01	0.01 - 0.01	67%
	Valsartan	Water	3.21	1.25 - 4.37	100%	Water	0.63	0.55 - 0.78	100%
		Sediment	ND	ND		Sediment	0.04	0.04	33%
	Gemfibrozil	Water	0.20	0.05 - 0.36	50%	Water	0.13	0.13	33%
		Sediment	ND	ND		Sediment	ND	ND	
	Diphenhydramine	Water	1.96	0.71 - 4.19	100%	Water	2.06	1.68 - 2.35	100%
		Sediment	0.03	0.03 - 0.04	100%	Sediment	0.03	0.03 - 0.03	100%
	Caffeine	Water	5.32	2.26 - 7.44	100%	Water	9.38	4.46 - 12.58	100%
		Sediment	0.16	0.13 - 0.20	50%	Sediment	ND	ND	
	Imidicloprid	Water	0.58	0.35 - 0.76	100%	Water	0.45	0.44 - 0.47	100%
		Sediment	1.23	1.23	25%	Sediment	ND	ND	
	Thiacloprid	Water	0.08	0.06 - 0.11	75%	Water	0.15	0.14 - 0.36	100%
		Sediment	ND	ND		Sediment	ND	ND	
	Fluoxetine	Water	0.09	0.04 - 0.13	100%	Water	0.13	0.06 - 0.23	100%
		Sediment	ND	ND		Sediment	ND	ND	
	Sertraline	Water	0.06	0.05 - 0.07	50%	Water	0.09	0.04 - 0.11	100%
		Sediment	ND	ND		Sediment	ND	ND	
	Naproxen	Water	1.16	0.84 - 1.59	100%	Water	0.64	0.48 - 0.97	100%
		Sediment	ND	ND		Sediment	ND	ND	
	Acetaminophen	Water	83.89	82.44 - 85.33	50%	Water	82.23	81.56 - 82.90	67%
		Sediment	ND	ND		Sediment	0.00	0.00	0%
	Carbamazepine	Water	0.65	0.47 - 0.87	100%	Water	1.54	0.72 - 2.35	100%
		Sediment	0.02	0.02 - 0.03	100%	Sediment	0.01	0.01 - 0.01	67%
	Methylphenidate	Water	0.25	0.24 - 0.26	50%	Water	0.87	0.47 - 1.27	67%
		Sediment	ND	ND		Sediment	ND	ND	
	Atrazine	Water	4.47	3.77 - 5.40	100%	Water	2.85	2.32 - 3.27	100%
		Sediment	0.00	0.00	0%	Sediment	0.02	0.02	33%
	DEET	Water	61.22	53.55 - 78.56	100%	Water	42.83	24.19 - 60.57	100%
		Sediment	1.08	0.81 - 1.23	100%	Sediment	0.70	0.63 - 0.75	100%
	Norethindrone	Water	ND	ND		Water	0.85	0.47 - 1.22	100%
		Sediment	ND	ND		Sediment	ND	ND	
	Norgestrel	Water	ND	ND		Water	1.37	1.37	33%
		Sediment	ND	ND		Sediment	ND	ND	
	Medoxyprogesterone	Water	0.00	0.00	0%	Water	0.40	0.40	33%
		Sediment	0.00	0.00	0%	Sediment	0.15	0.10 - 0.20	67%

Table 3 (continued)

		Environmental Media - Brunswick, Georgia				Environmental Media - Sapelo Island, Georgia			
Season	Compound	Sample Media	Mean (ng/L or ng/kg)	Range (ng/L or ng/kg)	Frequency of Detection	Sample Media	Mean (ng/L or ng/kg)	Range (ng/L or ng/kg)	Frequency of Detection
Spring 2015	Atenolol	Water	0.46	0.39 - 0.51	75%	Water	ND	ND	
		Sediment	0.02	0.02	25%	Sediment	ND	ND	
	Propanolol	Water	0.08	0.08	25%	Water	ND	ND	
		Sediment	0.01	0.01 - 0.02	50%	Sediment	0.01	0.01 - 0.01	0%
	Valsartan	Water	2.98	1.29 - 4.59	100%	Water	0.47	0.43 - 0.55	100%
		Sediment	ND	ND		Sediment	ND	ND	
	Gemfibrozil	Water	ND	ND		Water	ND	ND	
		Sediment	ND	ND		Sediment	ND	ND	
	Diphenhydramine	Water	1.28	0.83 - 2.35	100%	Water	1.40	0.77 - 2.39	100%
		Sediment	0.07	0.03 - 0.15	100%	Sediment	0.03	0.03 - 0.03	100%
	Caffeine	Water	18.88	2.55 - 34.10	100%	Water	51.54	27.39 - 72.70	100%
		Sediment	0.00	0.00	0%	Sediment	0.49	0.49	33%
	Imidicloprid	Water	1.04	0.76 - 1.37	100%	Water	0.56	0.32 - 0.81	67%
		Sediment	ND	ND		Sediment	0.03	0.03	33%
	Thiacloprid	Water	ND	ND		Water	0.03	0.03	33%
		Sediment	ND	ND		Sediment	ND	ND	
	Fluoxetine	Water	ND	ND		Water	ND	ND	
		Sediment	ND	ND		Sediment	ND	ND	
	Sertraline	Water	ND	ND		Water	0.12	0.08 - 0.15	67%
		Sediment	ND	ND		Sediment	0.04	0.04	33%
	Naproxen	Water	1.42	0.75 - 1.91	100%	Water	1.37	0.90 - 2.25	100%
		Sediment	ND	ND		Sediment	ND	ND	
	Acetaminophen	Water	71.57	62.93 - 84.26	75%	Water	69.85	67.26 - 72.44	67%
		Sediment	0.00	0.00	0%	Sediment	ND	ND	
	Carbamazepine	Water	0.59	0.50 - 0.68	100%	Water	0.33	0.27 - 0.42	100%
		Sediment	0.01	0.01 - 0.02	75%	Sediment	0.01	0.01 - 0.01	67%
	Methylphenidate	Water	2.09	1.92 - 2.26	50%	Water	12.72	3.20 - 23.31	100%
		Sediment	ND	ND		Sediment	ND	ND	
	Atrazine	Water	9.18	6.47 - 12.98	100%	Water	3.77	2.91 - 4.60	100%
		Sediment	0.01	0.01	25%	Sediment	ND	ND	
	DEET	Water	4273.19	315.96 - 5546.2	100%	Water	2720.70	473.08 - 3613.7	100%
		Sediment	1.44	0.56 - 1.82	100%	Sediment	3.28	1.82 - 5.67	100%
	Norethindrone	Water	0.50	0.29 - 1.01	100%	Water	0.56	0.56	33%
		Sediment	ND	ND		Sediment	ND	ND	
	Norgestrel	Water	2.73	2.73	25%	Water	ND	ND	
		Sediment	ND	ND		Sediment	ND	ND	
	Medoxyprogesterone	Water	0.37	0.16 - 0.81	100%	Water	ND	ND	
		Sediment	0.08	0.08	25%	Sediment	ND	ND	

To analyze differences between the two study locations we compared the mean ±95% confidence intervals for each analyte at Brunswick and Sapelo at each sample season. There were statistically significant differences between locations for atenolol (spring 2015), propranolol (Fall 2014 and winter 2014), valsartan (winter 2014 and spring 2015), fluoxetine (fall 2014), sertraline (fall 2014), atrazine (winter 2014 and spring 2015) and DEET (fall 2014). Surprisingly, analyte detection frequencies increased during the winter season (Brunswick: 84.2%; Sapelo 100%) and decreased during the fall (Brunswick: 68.4%; Sapelo 84.2%) and spring seasons (Brunswick: 78.9%; Sapelo 68.4%), which was the opposite trend observed in the oysters. We hypothesize that this is due to two co-occurring phenomena. Higher CEC detection in the winter months may result from reduced

CEC degradation in water and WWTP effluents (Hedgesperth et al., 2012), yet oysters may accumulate less of the available CECs because of a combined effect of slower metabolism and slower water filtration rates during the colder months.

Sediment: Detection frequencies and concentrations of CEC concentrations in sediment varied between seasons (fall 2014, winter 2014 and spring 2015) and study locations and only 10 of 19 analytes (atenolol, propranolol, diphenhydramine, caffeine, imidacloprid, fluoxetine, carbamazepine, atrazine, DEET and medroxyprogesterone) were detected in sediments at Brunswick and 11 of 19 (atenolol, propranolol, valsartan, diphenhydramine, caffeine, imidacloprid, sertraline, carbamazepine, atrazine, DEET and medroxyprogesterone) were detected in sediments at Sapelo (Table 3). Diphenhydramine and DEET were detected in 100% of the samples at bot locations during all seasons. Of the remaining analytes, only carbamazepine was detected in over 75% of the sediment samples from Brunswick and at Sapelo, only propranolol was detected in over 75% of the samples.

Analyte concentrations in sediment were generally the lowest detected across all sample types and seasons (Figure 3). We compared the mean +/- 95% confidence intervals (CI) for each analyte at Brunswick and Sapelo at each sample season and there were statistically significant differences between estuaries for propranolol (spring 2015), caffeine (winter 2014), carbamazepine (winter 2014), DEET (winter 2014) and medroxyprogesterone (winter 2014). Interestingly, the analyte detection frequencies at Brunswick were opposite what was observed for the water samples. The percent detections of analytes in sediments were higher during the warmer months (fall 2014 – 42.1%; spring 2015 – 36.8%) and lower during the winter (31.6%). At Sapelo, this trend was reversed, as the winter season had the highest detection frequency (42.1%), and fall and spring had the lowest number of detections (both at 36.8%).

Biota-sediment Accumulation and Bioconcentration Factors for CECs

Biota-sediment accumulation factors (BSAF) and bioconcentration factors (BCF) were calculated for the ten most detected analytes from fall 2014 through spring 2015. Analytes included in this analysis include: atenolol, propranolol, diphenhydramine, caffeine, fluoxetine, sertraline, carbamazepine, atrazine, DEET and norgestrel. These metrics provide a ratio of the concentrations of each analyte within oysters to concentrations in the environment. The BCF is calculated as the analyte concentration in oysters (ng/g dry weight) divided by the analyte concentration in water (ng/mL). The BSAF is calculated as the analyte concentration in oysters (ng/g dry weight) divided by the analyte concentration in sediments (ng/g dry weight). For BSAFs, a ratio >2 indicates that the organism is a macro-concentrator (Granek et al., 2016), while a BCF ratio > 1000 indicates that the compound is readily accumulated from water and that uptake of the chemical exceeds metabolism and elimination. Diphenhydramine and DEET were consistently macro-concentrated (BSAF>2) at both estuaries across all sample seasons. None of the analytes had a BCF > 1000 that remained consistent over time. (Table 4). However, during spring 2015, BCFs >1000 were calculated for DEET (Brunswick; BCF = 1929) and carbamazepine (Sapelo; BCF = 1172). There is a paucity of research about the environmental fate and degradation of CECs in marine waters and this needs to be remedied in order to better characterize the risk they pose to aquatic organisms.

Table 4: Calculated BSAFs and BCFs for Brunswick, GA (left panel) and Sapelo Island, GA (right panel) by season.

Brunswick BSAF & BCF				
		Fall 2014	Winter 2014	Spring 2015
Atenolol	BSAF	23.3	0.0	31.5
	BCF	0.0	4.5	1.4
Propanolol	BSAF	0.2	12.0	209.0
	BCF	3.7	1.3	26.1
diphenhydramine	BSAF	10.3	9.0	192.7
	BCF	0.3	0.1	10.5
caffeine	BSAF	5.1	23.7	0.0
	BCF	2.0	0.7	0.0
fluoxtine	BSAF	1.0	0.0	0.0
	BCF	4.0	2.1	0.0
sertraline	BSAF	0.0	0.0	0.0
	BCF	4.8	7.3	0.0
carbamazepine	BSAF	29.0	310.0	0.0
	BCF	0.5	9.5	0.0
atrazine	BSAF	70.0	0.0	75.0
	BCF	4.4	0.0	0.1
DEET	BSAF	7.3	24.2	1929.8
	BCF	0.1	0.4	0.7
norgestrel	BSAF	0.0	0.0	0.0
	BCF	0.0	0.0	0.0

Sapelo BSAF & BCF				
		Fall 2014	Winter 2014	Spring 2015
Atenolol	BSAF	27.1	18.0	0.0
	BCF	0.0	1.0	0.0
Propanolol	BSAF	3.0	8.0	53.0
	BCF	0.8	0.6	0.0
diphenhydramine	BSAF	58.3	6.6	169.3
	BCF	3.1	0.1	3.6
caffeine	BSAF	73.9	0.0	0.0
	BCF	34.4	0.6	0.0
fluoxtine	BSAF	0.0	0.0	0.0
	BCF	8.0	1.0	0.0
sertraline	BSAF	0.0	0.0	2.3
	BCF	2.9	2.4	0.8
carbamazepine	BSAF	45.0	0.0	1172.0
	BCF	1.6	0.0	35.5
atrazine	BSAF	12.0	3.5	0.0
	BCF	3.5	0.0	0.5
DEET	BSAF	11.5	23.5	16.1
	BCF	0.5	0.4	0.0
norgestrel	BSAF	0.0	0.0	0.0
	BCF	0.0	16.6	0.0

Condition Index

The condition index is a measure of the overall fitness of organisms and is calculated per Manley and Walker (2011): dry tissue weight (g) x 100/ [whole oyster weight (g) – shell weight (g)]. Mean condition indices [confidence intervals] for oysters collected on Sapelo Island were 7.33 [6.89, 7.77]), compared to mean condition indices at Brunswick, mean = 5.98 [5.62, 6.34]. Significantly higher condition indices in oysters from Sapelo Island (based on non-overlapping 95% confidence intervals) suggest that overall the oyster populations on Sapelo Island are a more robust population, despite the finding that oysters in Brunswick and Sapelo Island have similar body burdens of emerging contaminants. This result suggests that other factors (environmental, other contaminant classes) are adversely affecting the health of oysters at Brunswick, resulting in an overall reduced condition. Brunswick has a major port, four NPL-listed superfund sites and numerous brownfield sites, many of which are located along or in close proximity to the Brunswick River. These sites likely contributed to the decline in oyster condition and health in Brunswick.

Site Contamination Rankings Based on CECs

The sample sites were ranked based upon the frequency of detects for each analyte in each season and were ranked 1-4 at Brunswick and 1-3 at Sapelo Island, with lower numbers indicating higher CEC contamination and considered the most contaminated sites. It should be noted that this method of site ranking does not include any information about the toxicity or physiochemical characteristics of the analytes or their mixtures or the presence of chemicals not analyzed in the current study.

Plantation Creek at Brunswick and Cabretta Creek at Sapelo Island were consistently ranked as the most CEC-contaminated sites across all seasons sampled (Table 5). It was unexpected that these particular sites would be ranked as the most contaminated as they have the lowest density of septic sites and are farthest away from nearby wastewater treatment plants (WWTPs) (Figures 1

and 2). Both of these sites were initially selected to be reference sites for their respective locations, which is not supported by the analyte data. However, based on our study results CECs are widely distributed in aquatic organisms and environmental media throughout both study locations, indicating insufficient degradation of CECs associated with septic and WWTP inputs throughout both study locations.

Table 5: Calculated site contamination rankings for Brunswick and Sapelo Island, Georgia by season.

		Sample Season							
Estuary	Site	Fall 2013	Winter 2013	Spring 2014	Summer 2014	Fall 2014	Winter 2014	Spring 2015	Sum of Rankings
Brunswick	Site-1	1	3	1	2	4	2	1	14
	Site-2	2	1	3	1	3	3	4	17
	Site-3	3	1	2	2	2	4	3	17
	Plantation	2	2	1	1	1	1	2	10
Sapelo Island	Oakdale	3	2	2	2	1	3	1	14
	South End	2	1	2	2	2	2	2	13
	Cabretta	1	3	1	1	1	1	2	10

One of our hypotheses was that sample sites farther away from human sewage inputs would have lower concentrations of CECs, which was also not supported. At Brunswick the daily tidal cycles appear to mix the water-borne contaminants, providing a semi-homogenous distribution of contaminants within the areas of the Brunswick River that we sampled. This study provides preliminary evidence of this mixing by detection of no statistically significant differences (mean ±95% confidence intervals) between percent detection frequencies and concentrations of analytes between the sample sites within each study location. These findings are also supported by Zhao et al., 2015, who found that the fate of pharmaceuticals in the Yangtze River (China) was linked with the tidal cycle, and that pharmaceutical concentrations increased as the tides were receding. This observation is in direct contrast to a freshwater riverine system, where, the river flows only in one direction, creating defined upstream and downstream sites and where contaminant concentrations are expected to increase immediately downstream of an effluent discharge. Although sampling sites on Sapelo Island were not continuous along a single gradient, it is likely that CEC concentrations there were highly influenced by ground water, the likely source of septic-borne CECs to the tidal creeks. Barrier islands have very shallow water tables, which readily exchange with island surface waters, including tidal creeks. If there is only one major groundwater plume at Sapelo, it is logical that the different tidal creeks would have similar concentrations of CECS originating from septic sources. Future studies should examine the groundwater at Sapelo Island as a potential conduit of pharmaceuticals and other septic-related CECs to tidal creeks and a potential route of exposure to human populations on the island.

CEC Risk Quotients

Risk quotients (RQ) for the CECs detected at Brunswick and Sapelo Island were calculated by the methods outlined in Minguez et al. (2016). The predicted no effect concentration (PNEC) for each of the target analytes (derived from Minguez et al., 2016 or the ECOTOX database, was https://cfpub.epa.gov/ecotox/) was divided by the highest measured oyster concentration for each season. An RQ score of < 0.01 indicates that the analyte has no predicted ecological risk, analytes with 0.01 ≤ RQ ≤ 0.1 have low risk, analytes with 0.1 ≤ RQ ≤ 1 have medium risk and a RQ score ≥ 1 is indicative of high predicted ecological risk (Hernando et al., 2006) (Table 6).

Table 6: Calculated risk quotients (RQ) for analytes at Brunswick, GA (top panel) and Sapelo Island, GA (bottom panel) by season. Yellow = low risk; orange = medium risk; red = high risk.

	Brunswick, GA CECs Risk Quotients						
compound	Fall 2013	Winter 2013	Spring 2014	Summer 2014	Fall 2014	Winter 2014	Spring 2015
atenolol	0.0003	0.0001	0.0005	0.0006	0.0007	0.0003	0.0001
valsartan	0.0000	0.0001	0.0005	0.0003	0.0000	0.0001	0.0000
diphenhydramine	0.0003	0.0002	0.0002	0.0047	0.0001	0.0001	0.0020
caffeine	0.0006	0.0012	0.0002	0.0028	0.0011	0.0006	0.0000
imidicloprid	0.0003	0.0001	0.0002	0.0001	0.0001	0.0001	0.0000
thiacloprid	0.0032	0.0001	0.0006	0.0001	0.0001	0.0000	0.0000
carbamazepine	0.0000	0.0001	0.0000	0.0003	0.0001	0.0009	0.0000
methylphenidate	0.0002	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000
atrazine	0.0000	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001
norethindrone	0.0005	0.0006	0.0019	0.0015	0.0001	0.0004	0.0000
norgestrel	0.0032	0.0044	0.0080	0.0050	0.0028	0.0058	0.0000
medroxyprogesterone	0.0002	0.0000	0.0008	0.0012	0.0002	0.0000	0.0000
propanolol	0.0663	0.0021	0.0036	0.1128	0.0019	0.0021	0.0293
gemfibrozil	0.1318	0.0000	0.1589	0.0425	0.0050	0.0000	0.0000
naproxen	0.0015	0.0001	0.0057	0.0268	0.0000	0.0000	0.0000
acetaminophen	0.0189	0.1494	0.0451	0.0147	0.0130	0.1494	0.0000
fluoxetine	4.1930	0.0488	14.4279	173.5512	0.1512	0.1442	0.0000
sertraline	27.9761	0.8015	0.8582	39.5134	0.2463	0.1448	0.1015
DEET	0.0021	0.0052	0.0016	0.0038	0.0017	0.0147	1.1427

	Sapelo Island, GA CECs Risk Quotients						
compound	Fall 2013	Winter 2013	Spring 2014	Summer 2014	Fall 2014	Winter 2014	Spring 2015
atenolol	0.0003	0.0002	0.0002	0.0005	0.0010	0.0000	0.0000
valsartan	0.0000	0.0001	0.0005	0.0001	0.0001	0.0000	0.0000
diphenhydramine	0.0003	0.0006	0.0010	0.0058	0.0004	0.0000	0.0009
imidicloprid	0.0003	0.0000	0.0003	0.0001	0.0000	0.0000	0.0000
thiacloprid	0.0006	0.0001	0.0006	0.0001	0.0000	0.0001	0.0000
carbamazepine	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0034
methylphenidate	0.0000	0.0001	0.0001	0.0015	0.0002	0.0000	0.0000
atrazine	0.0000	0.0001	0.0002	0.0000	0.0001	0.0000	0.0002
norethindrone	0.0003	0.0003	0.0037	0.0013	0.0000	0.0002	0.0000
norgestrel	0.0034	0.0034	0.0067	0.0021	0.0024	0.0071	0.0000
medroxyprogesterone	0.0006	0.0001	0.0023	0.0010	0.0003	0.0000	0.0000
propanolol	0.0115	0.0008	0.0584	0.6043	0.0005	0.0008	0.0067
gemfibrozil	0.2237	0.0031	0.0957	0.0988	0.0028	0.0031	0.0000
caffeine	0.0002	0.0014	0.0002	0.0005	0.0215	0.0010	0.0000
naproxen	0.0099	0.0001	0.0144	0.0777	0.0001	0.0000	0.0000
acetaminophen	0.0166	0.0380	0.0198	0.0194	0.0747	0.0380	0.0000
DEET	0.0063	0.0091	0.0032	0.0127	0.0098	0.0185	0.0185
fluoxetine	1.2279	0.0349	1.0791	236.7186	0.0209	0.0442	0.0000
sertraline	71.9597	0.2000	1.1642	84.5269	0.2627	0.0627	0.0254

Based on detected levels the majority of compounds were considered to have no to low ecological risks, depicted in yellow (Brunswick – 63% of detected compounds; Sapelo – 58% of detected compounds), followed by medium risk (Brunswick – 21% of detected compounds; Sapelo – 32% of detected compounds) and high risk (Brunswick – 16% of detected compounds; Sapelo – 11% of detected compounds). Sapelo Island had two more compounds in the medium risk category versus Brunswick. Caffeine was detected at Sapelo in Fall 2014 at a much higher RQ score than at Brunswick at any sampling time. The antidepressants, fluoxetine and sertraline, which were classified as high risk in both study locations, could have health implications for resident organisms. These compounds alter spawning times of bivalves, suppress metabolism rates and growth and affect key neurological functions of many aquatic and marine organisms (reviewed in Ford and Fong, 2016).

There was a strong seasonal trend in overall RQ scores, with higher mean RQ scores in warmer months (fall, spring and summer) versus colder months (winter) at both Brunswick and Sapelo, except for the spring 2015 score at Sapelo, which was lower than both of the winter RQ scores. Seasonal variability in compound use, changes in precipitation levels and changes in the physiological status of oysters over the course of a year could have influenced higher RQ scores during warmer seasons. These findings provide a basis for future research into identifying critical exposure windows when oyster populations could be increasingly susceptible to the effects of CEC exposures.

Discussion and Conclusions

Analyte concentrations and detection frequencies in oysters were similar between Brunswick and Sapelo (Table 3) and followed similar trends across the seasons sampled. Both estuaries exhibited higher oyster CEC detection frequencies (≥ 75% of samples within a specific season) and higher concentrations during warmer seasons (fall 2013, spring, summer, fall 2014), than they did over during the winter sample seasons. In comparison, fewer analytes were detected in the water (7/19 Brunswick; 5/19 Sapelo) and sediment (10/19 Brunswick; 11/19 Sapelo) samples, but there were more statistically significant differences (mean +/- 95% confidence intervals) between the estuaries. Interestingly, the trends in detection frequencies were different between oyster, sediment and water samples. Trends with the sediment samples were similar to the oyster samples (higher concentrations during the warmer months), but the water samples had the opposite trend. Water samples had higher analyte detection frequencies during the winter season (Brunswick: 84.2%; Sapelo 100%) and lower detection frequencies during the fall (Brunswick: 68.4%; Sapelo 84.2%) and spring seasons (Brunswick: 78.9%; Sapelo 68.4%). We hypothesize that the difference between the trends of oyster and water concentrations during the winter season is due to two co-occurring phenomena: (1) an oyster's metabolism slows down during the colder months, resulting in a slower filtering rate and likely lower contaminant exposures, which could explain in part, their low concentrations during winter months; and (2) degradation of compounds in WWTPs and surface waters is slower in colder months (Hedgesperth et al., 2012), which could in part explain the higher concentrations of CECs detected in water during the winter months.

We hypothesized that CEC concentrations would be higher at urban sample sites (Brunswick) that have high septic densities and WWTP inputs, compared to the more rural sites (Sapelo) with significantly lower numbers of septic sites (Figure 2). Initially, our hypothesis appears to not be supported by the data. However, the two study sites differed greatly in the size of the sampled

estuarine water bodies. The sample sites on Sapelo Island were small estuarine tidal creeks with shallow depths. Mean ebb and flood discharges ranged up to 10 m^3/s on South End Creek (Gilroy et al., 2005), a Sapelo Island sample site. In comparison, the Brunswick River is a much larger system that is also tidally influenced with multiple tributaries that contribute to overall water discharge. Actual discharge information is not available as there are no UGGS monitoring stations along the stretch that we sampled for CECs. However due to the overall size of the river, discharges should be much greater than those measured in tidal creeks at Sapleo Island. Thus to achieve similar CEC concentrations in water from the Brunswick River versus the small tidal creeks at Sapelo Island, CEC inputs must be increased by many fold due to the increased dilution (caused by the assumed increased discharge) at Brunswick. Conversely smaller inputs of CECs would be concentrated in the small tidal creeks at Sapelo Island. To better understand this phenomena, we propose that future studies in estuaries that vary greatly in size by use water samplers (i.e. POCIS) in conjunction with aquatic organisms to provide a better baseline understanding of contaminant concentrations and that each study system's hydrology be fully characterized over the duration of the study.

We also hypothesized that sample sites farther away from human sewage inputs would have lower concentrations of CECs, which the data did not support. The site contamination index ranked the Plantation Creek at Brunswick and the Cabretta Creek at Sapelo island as being the most contaminated sites across all seasons sampled. It was unexpected that these particular sites would be ranked as the most contaminated because they have the lowest density of septic sites and are farthest away from nearby wastewater treatment plants (WWTPs) (Figures 1 and 2). It is likely that the diurnal tidal cycles in the Brunswick River and comment groundwater sources for Sapleo Island sites sufficiently mixed the water, resulting in a semi-homogenous distribution of contaminants within each site.

The calculated risk quotients (RQ) for CECs can be used to better understand the risks that exposure to individual CECs poses to oysters over the seasons sampled. There was a strong seasonal trend in RQ scores, with warmer months (fall, spring and summer) having a higher mean RQ score than colder months (winter) at both Brunswick and Sapelo Island, except during the spring 2015 mean score at Sapelo, which was lower than both of the winter RQ scores (Tables 5 and 6). These higher RQ scores during warmer seasons indicate increased risks to aquatic organisms during warmer months, which may include times of increased activity and growth of many organisms and may overlap reproductive seasons for ecologically-important fish and invertebrate species. Further studies are needed to understand more about CEC inputs from septic and sewage origins and their potential for toxic responses in Georgia's estuarine organisms.

CITATIONS

Banerjee, B. D., Koner, B. C., & Ray, A. (1996). Immunotoxicity of pesticides: perspectives and trends. *Indian Journal of Experimental Biology*, 34(8), 723-733.

Ford, A. & Fong, P. P. The effects of antidepressants appear to be rapid and at environmentally relevant concentrations. *Environmental Toxicology and Chemistry* 35: 794-798.

Fuller, S. L. (2012). Effectiveness of Oyster Spat Stick Communities in Removing Pharmaceutical Contaminants from Tidal Creeks. Masters Thesis, University of Georgia. 81 pp

Gilroy, D.J., Lottig, N.R., Preston N.D., & S.N. Schmidt. 2005. Long-term analysis of stream biogeochemical characteristics in a salt marsh tidal creek on Sapelo Island, Georgia, USA. http://limnology.wisc.edu/Library/LimnologyLibrary/Sapelo%20Island.html

Granek, E. F., Conn, K. E., Nilsen, E. B., Pillsbury, L., Strecker, A. L., Rumrill, S. S., & Fish, W. (2016). Spatial and temporal variability of contaminants within estuarine sediments and native Olympia oysters: A contrast between a developed and an undeveloped estuary. *Science of The Total Environment*, 557, 869-879.Hedgesperth et al., 2012

Hedgespeth, M. L., Sapozhnikova, Y., Pennington, P., Clum, A., Fairey, A., & Wirth, E. (2012). Pharmaceuticals and personal care products (PPCPs) in treated wastewater discharges into Charleston Harbor, South Carolina. *Science of the Total Environment*, 437, 1-9.

Lara-Martín, P. A., González-Mazo, E., Petrovic, M., Barceló, D., & Brownawell, B. J. (2014). Occurrence, distribution and partitioning of nonionic surfactants and pharmaceuticals in the urbanized Long Island Sound Estuary (NY). *Marine Pollution Bulletin*, 85(2), 710-719.

Loos, R., Carvalho, R., Antonio, D. C., Comero, S., Locoro, G., Tavazzi, S., ... & Jarosova, B. (2013). EU-wide monitoring survey on emerging polar organic contaminants in wastewater treatment plant effluents. *Water Research*, 47(17), 6475-6487.

Manley, J. & Walker, R. Condition index for Georgia oyesters (2011) Occasional Papers of the Marine Extension Service, University of Georgla 12:9

Minguez, L., Pedelucq, J., Farcy, E., Ballandonne, C., Budzinski, H., & Halm-Lemeille, M. P. (2016). Toxicities of 48 pharmaceuticals and their freshwater and marine environmental assessment in northwestern France. *Environmental Science and Pollution Research*, 1-10.

Moreau, P., Faury, N., Burgeot, T., & Renault, T. (2015). Pesticides and Ostreid Herpesvirus 1 Infection in the Pacific Oyster, *Crassostrea gigas*. PloS one, 10(6), e0130628.

Zhao, H., Zhou, J. L., & Zhang, J. (2015). Tidal impact on the dynamic behavior of dissolved pharmaceuticals in the Yangtze Estuary, China. *Science of The Total Environment*, 536, 946-954.

USEPA (2007). Method 1694: Pharmaceuticals and Personal Care Products in Water, Soil, Sediment, and Biosolids by HPLC/MS/MS.

Baseline Conservation Analysis for Agricultural Irrigation in Priority Watersheds of the Lower Flint River Basin

Basic Information

Title:	Baseline Conservation Analysis for Agricultural Irrigation in Priority Watersheds of the Lower Flint River Basin
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There are no publications.

Project Report for State Water Resources Research Institute Program FY 2014 (104b) from Albany State University Georgia Water Planning and Policy Center – Project # RB665-G6

Baseline Agricultural Irrigation and Conservation Mapping in Priority Watersheds of the Suwannee-Satilla Water Planning Region

Project Rationale

Effective management of water resources requires a solid information base on which to make decisions. In recent years, the State of Georgia has begun to collect data on agricultural water use in the State, but for management purposes, the State is largely dependent on annual readings from meters and estimates made by academic researchers. A lack of information hampers management, and especially lacking is information on the use of agricultural water use and conservation practices.

Agricultural producers are highly dependent on access to freshwater resources to support irrigation. Irrigation greatly increases crop yields, quality, diversity, and returns, as well as land values. Without irrigation, agriculture in the region would be only a small fraction of what it is today. Irrigated agriculture is critical to the State's economy, and Georgia farmers have made an enormous investment in irrigation infrastructure.

In South Georgia, recent droughts have resulted in low flows and heightened concern over water scarcity for in-stream and off-stream needs. Agricultural water use for irrigation is critical to supporting the region's economy. Low flows create substantial economic and environmental concerns. Environmentally, low flows compromise the habitat of important aquatic species, including some federally-listed endangered and threatened freshwater mussels. Low flows also can create significantly degraded water quality conditions that are often not captured by existing water quality sampling programs. Sustainable use and careful management of water resources is central to ensuring a sustainable environment and economy for the region. Agricultural water use management is a critical part of the solution.

This project focused on agricultural water use in high priority watersheds in the Suwannee-Satilla Water Planning Region, which is one of eleven water planning regions in the State of Georgia. In the Suwannee-Satilla region, agriculture is a dominant economic sector. In 2012, the region reported $30.6 million in farm receipts (USDA Census of Agriculture, 2012). Based on recent agricultural metering data, agricultural irrigation used 89 MGD in 2013 (wet year) and 172 MGD of groundwater in 2011 (dry year), and it used 31 MGD in 2013 and 59 MGD in 2011 of surface water. Agricultural irrigation is the dominant use of both surface water and groundwater in the region.

Conservation practices are widely used by farmers in Georgia. The State lacks a comprehensive database on where, and to what extent, conservation practices are in place for agricultural operations, and without that information, it is unknown what levels of efficiency improvement can be attained, what

practices should be prioritized, and where improvements should be targeted. A baseline survey on conservation implementation in irrigation systems is needed to support decision making about future conservation investments and to estimate expected benefits.

In 2012, the Albany State University Georgia Water Planning and Policy Center (the Center) initiated an effort to establish baseline information on conservation practices implementation. Through various projects, the Center has collected this information on high priority watersheds in South Georgia. In this project, the Center collected such information on agricultural water conservation practices in high priority watersheds in the Suwannee Satilla region.

Project Description

This project included the following components:

a. Complete a full survey of conservation practices associated with agricultural withdrawals (greater than 100,000 gallons per day) in priority watersheds of the project area (selected in consultation with the Georgia Environmental Protection Division - GAEPD).

b. Compile collected data in the Center's GIS database.

c. Analyze collected data to support reporting and recommendations for water resource management.

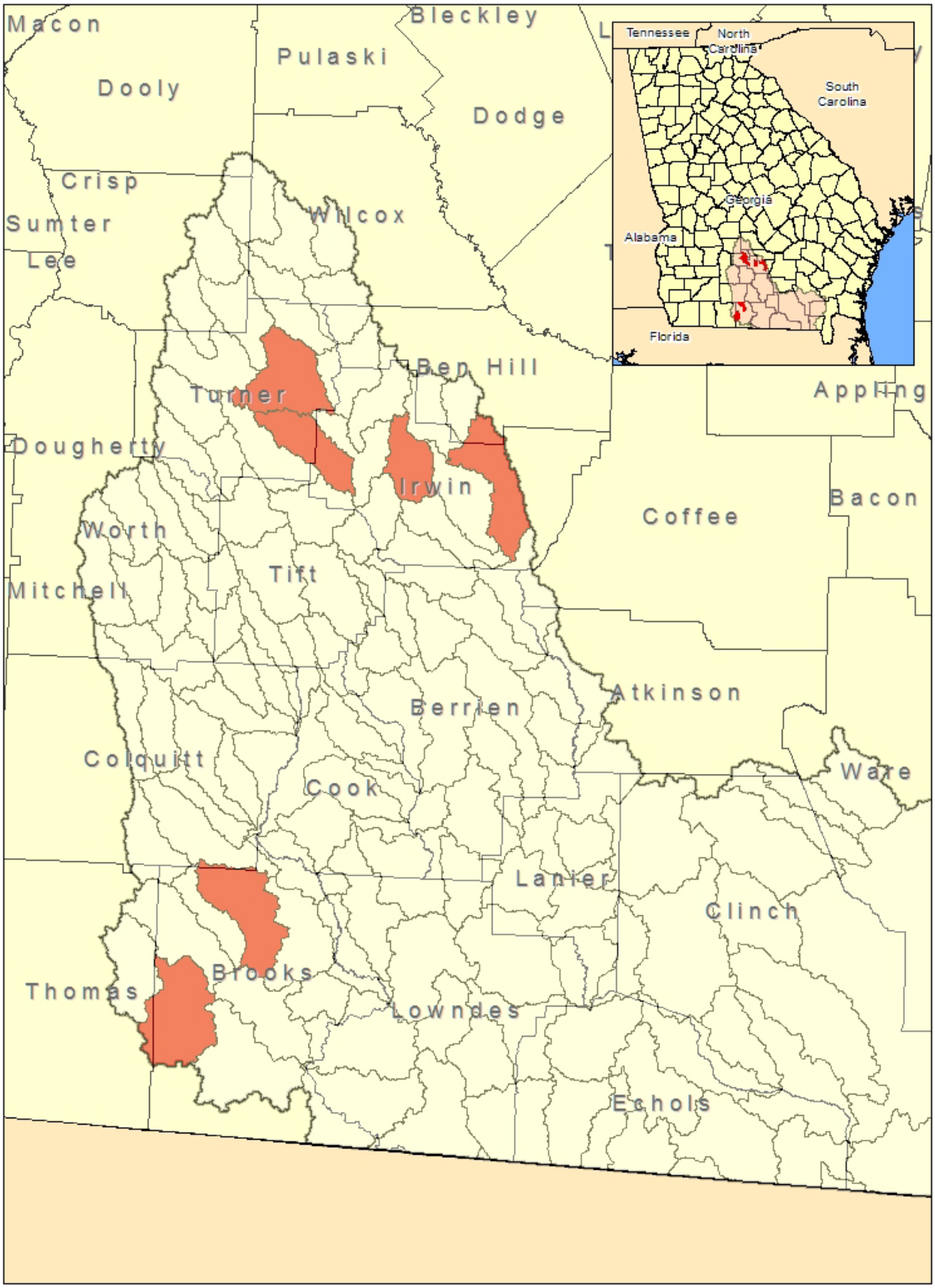
Project funding was used to complete field surveys, build the database, and conduct basic analyses of the collected information (summary statistics, geographic sub-totals, etc.). The project was initiated in 2015, and this report marks the conclusion of the project in April 2016.

The priority watersheds that were surveyed in the project include those listed in Table 1. These watersheds were selected in consultation with GAEPD in an effort to identify where the new information could have the greatest impact in improving the information base for management. A map of the priority watersheds is provided in Figure 1.

Table 1. Project HUC-12 Watersheds

HUC-12 Number	HUC-12 Name	River Basin
031102020205	Deep Creek 3	Suwannee
031102030702	Piscola Creek 2	Suwannee
031102030504	Okapilco Creek Upper 3	Suwannee
031102020303	Sand Creek	Suwannee
031102020601	Reedy Creek 1	Suwannee
031102020503	Willacoochee River 1	Suwannee

Figure 1. Map of Project Area



Project Approach

Implementation of the project involved the following activities:

- Field visits – Center personnel made field visits to 820 withdrawal locations in the priority watersheds. On the field visits, the following information was recorded:
    - GIS data on irrigation systems, water source(s), meter location, pump type, etc.
    - Assignment and/or confirmation of wetted acreage of irrigation withdrawals based on GIS data collected
    - Meter readings
    - Crop data, as available
    - Conservation assessment, including hardware used, age of system, existing conservation measures in place such as low pressure drops and other relevant information, as available, that may be used by the Georgia Soil and Water Conservation Commission or their partners (i.e. USDA Natural Resource Conservation Service) in prioritizing future conservation programs
- Data Review: Collected data was checked in by GWPPC personnel and stored in the Center's GIS database. Data on sources, pumps, meters, and wetted areas were stored in the geographic database. The Center has several format storage capabilities including but not limited to SQL, MS Access, and ESRI shapefile formats. The Center has state-of-the-art network facilities for data access and management.
- Data Analysis: Center personnel with expertise in GIS analysis, agricultural water use, and water resources planning and policy analyzed collected data and calculated summary statistics on a geographic basis.

Project Methods

The following sections detail the mapping activities.

Field Visits

Each agricultural irrigation site was mapped using a global positioning system equipped with ESRI ArcPad software. This software contained a mapping package that depicted known existing water withdrawal points and wetted areas. The package also contained feature collection database that had feature classes for sources, pumps, meters, and field description features. Each feature class was equipped with a set of attributes considered necessary to describe each irrigation site. Many attributes contained a list of possible values that was used to describe the configuration of the site.

Included in the mapping package was a file to describe the wetted areas. There were two basic feature types that could be collected, an irregularly shaped polygon and a center pivot system. Most irregularly shaped polygons were noted in the field with a single point. This point also contained the required attributes that describe the field, including but not limited to an identification number, the sequence number of the field within the ID number, the irrigation system type, crop, and location of the meter (if

any). If the field did not match the field in the supplied map book the mapper would collect the corners of the field.

The second feature type was center pivot systems. These were mapped with a single point at the center of the pivot and the point at the end of the hardware boom. This provided the radius of the pivot circle from which the circle was drawn. Information about the pivot was entered with the center point of the systems. The information was the same as with the irregularly shaped polygons with the addition of system mobility, conservation measures, power source, end gun presents, presents of a variable rate irrigation system, and meter location. In addition, the stops or travel limits of the boom were also collected.

Field mappers were assigned an area to be mapped normally described by a hydrologic unit sub-watershed or HUC-12. The intention was to discover and map all irrigation within the assigned area. The GAEPD Agricultural Water Withdrawal database was provided as a reference for known source points. These points, however, were not the targets, but rather, an aid to assign identification numbers and locate known sources. Many unknown points not in the database were also mapped. These were given a different type of identification number.

Data Review

These data were checked in to the master database at the GWPPC office. The data were placed in four feature classes: one for each source, pump, meter, and wetted area in the master database. The attributes were checked for consistency with other data. The wetted areas were drawn and attributed according to the field data. With pivot systems, the throw of the end gun was drawn with each pivot in those cases where it was visible on supporting imagery.

The final data form resides in a geographic information data format known as a personal database. This format is consistent with a MS Access format. The additional geographic positioning data are part of this MS Access database and can be read and manipulated in any GIS software. These data are referred to the master database from which transformations to other formats can be made.

Project Results

The primary end product of this initiative is a database of irrigated acres and conservation practices in the targeted watersheds of the project area. A total of 820 potential agricultural water withdrawal sites in the project area were mapped. The new geographic database that describes these irrigation sites is a part of the Center's larger geographic database of agricultural irrigation in the State. The new data from this project is now linked to data on water use from the annual meter readings, irrigated acreage maps developed by the Center, geographic data on withdrawal locations, and various hydrologic data on the aquifers and streams in these watersheds. The database can support up-to-date evaluation of water use at the field level. The following sections summarize the data collected in the project.

Sources – Type and Status

The sources were mapped with descriptors of source type, source status, metering status, and primary use. It should be noted that not all sources mapped were active or used for agricultural purposes. The

reason for these discrepancies is beyond the scope of this document. Table 2 summarizes the types of sources observed for the 820 withdrawal points. Figure 2 is a map of the sources (at end of report).

Table 2. Source Type

Source Type	Count
Ground	323
Stream	15
Pond	413
Ground to pond	67
Stream to pond	1
Pond to pond	1
Total	**820**

Table 3 summaries the status for the withdrawal points. Source status reflects the current use of the source. Active sources are in use, and inactive sources are not. Inactive status does not indicate that a source is permanently inactive; it could be activated in the future. In most cases, inactive sources had no hardware at the site. A lack of hardware could be because the pump and pipe are mobile. In most cases in this project, inactive sources were those where the operator indicated that the source was no longer used. Usually, however, the fields assigned to the inactive source by the GAEPD database were actually wetted by another active source. Some fields with inactive sources were dryland operations.

"No source" is different inactive as these sites cannot be used as a source given their condition when mapped. Most of these are sites are groundwater sources where no well or hardware were found. "Non-Agricultural" use was most often observed to be domestic wells or other uses such as wildlife habitat.

Table 3. Source Status

Source Status	Count
Active	646
Inactive	146
No source	25
Non-agricultural use	3
Total	**820**

Meter Status

Meter status required evaluation of the site after the data was checked in at the Center. The evaluation was made based upon all data collected for each site. "Fully metered" indicates that all of the water from that source flows through a meter. "Partially metered" indicates that not all fields wetted by the source are metered. This usually is observed where there is not a meter at the source but where a meter

may be installed on the actual irrigation hardware (e.g. one source serves multiple center pivots but only one pivot is metered). For these sites, each field would need to have an onsite meter for the source to be considered "fully metered," and otherwise, it is "partially metered."

"Not metered" indicates that none of the water from the source flows through a meter. "Incomplete systems" are those that were under construction and a metering status evaluation was not completed at that time. "Non-agricultural" refers to sites that were in the GAEPD agricultural withdrawal database but onsite inspection revealed that the sites were not used for agricultural purposes. "Unknown" systems are those that could not be mapped due to difficulties in accessing the site or meter.

Table 4. Meter Status

Meter Status	Count
Fully metered	336
Partially metered	12
Not metered	428
No source	25
Incomplete systems	5
Non-agricultural use	13
Unknown	1
Total	**820**

Primary Use of Source

Table 5 lists the primary uses observed for the 820 withdrawal sites. Not all of the sources found in the GAEPD database were actually used for agricultural purposes. Some withdrawal sites have been changed in use over time, and others were never actually used for agricultural purposes. Within agricultural purposes, there are the sub-classes of livestock and mixing sites. These sub-classes do not have any field associated wetted areas.

As noted above, inactive sources were observed in the field visits. Most of these sites had no evidence of hardware but might have been used with portable pump units. Most of these sites were on surface ponds and have been replaced with ground or more viable surface sources. "No source" refers mostly to well sources where no well or hardware were found.

Table 5. Primary Use of Source

Source Primary Use	Count
Irrigation	634
Livestock	4
Mixing site	3
Non-agricultural use	21
No source	25

Not used	133
Total	**820**

Analysis of Active Sites

A more refined evaluation can be made of those sites that are active. Of the 820 total withdrawal sites, 646 were active. Tables 6 through 8 summarize the above data for the active sites, and Figure 3 is a map of the meter status data for active sites in Table 8.

Table 6. Primary Use of Active Sites

Primary Use of Active Sites	Count
Domestic	3
Habitat	3
Irrigation	628
Livestock	4
Mixing site	3
Managed turf	1
Well to pond, no irrigation	4
Total	**646**

Table 7. Source Type of Active Sites

Active Site Source Type	Count
Ground	300
Stream	2
Pond	280
Ground to pond	63
Pond to pond	1
Total	**646**

Table 8. Meter Status of Active Sites

Active Site Metering Status	Count
Fully metered	333
Partially metered	12
Not metered	297
Non-agricultural use	3
Meter not mapped	1
Total	**646**

Water Pump Statistics

In general, if a source is active, it has a pump. In most instances, this is a one to one relationship. However, there can be more than one source and pump per permitted withdrawal. Both sources and pumps are tagged with matching sequence numbers depicting their position in a permit. Most surface water pumps are centrifugal while groundwater sources can have either a submersible or vertical turbine pump. The pumps can be powered by either electricity or a diesel motor. Pumps with a motor are more likely to be mobile. A source can be considered active if it has a pump.

A total of 654 pumps were mapped in association with active sources. Most active sources had pumps at the location but some did not have pumps as they were mobile. Most inactive sites did not have pumps but a few did.

Table 9. Pump Type

Pump Type	Count
Centrifugal	281
Submersible	246
Vertical Turbine	122
Other	5
Total	**654**

Table 10. Pump Power Source Type

Pump Power Type	Count
Diesel	220
Electric	434
Total	**654**

Table 11. Pump Mobility

Pump Mobility	Count
Fixed	412
Mobile	242
Total	**654**

Meter Hardware

Meters can be matched with either a source or a wetted area. It is common to find meters at the pivot as opposed to the source. In the project area, most meters were located at the source. This is the most economical method for metering because one meter is necessary. However, it limits the usefulness of the meter as a best management practice tool because the meter includes water use for multiple fields. Individual field use measurements are useful to farmers for water use versus yield evaluations.

A total of 337 meters were mapped in the project area. These meters are mostly mechanical meters, with a smaller quantity being electrical meters.

Tables 12 and 13 list the units of measure and the multipliers for the meters that were observed. Meter readings are usually a six digit number indicating water use. This reading is adjusted by a multiplier that is displayed on the meter. This is necessary as it helps keep the number of digits to a minimum. Without the multiplier, the number registered by the meter could be misinterpreted. In the case of meter units of measure, most acre inch meters and will have a multiplier of 0.01, while meters that register in gallons can be 10, 100, or 1000. With respect to gallons, the lower the multiplier, the more likely the meter will turnover between readings if installed on a relatively active irrigation site.

The 12 "unknown" meters in Tables 12 and 13 include three meters that were not accessible because of flooding or animals and nine meters that were electronic and observed to be not functional (see below).

Table 12. Observed Meters – Units of Measure

Meter Units of Measure	Count
Acre Inch	250
Gallons	75
Unknown	12
Total	**337**

Table 13. Observed Meters -- Multiplication Factors

Multiplication Factor	Count
0.001	8
0.01	242
0.1	1
1	0
10	5
100	65
1000	4
Unknown	12
Total	**337**

The meter status was collected at the time of mapping and reflects only the outward appearance of the meter. A number of problems were observed with meters in the field including: meter disconnection, meter not found, meter damaged, meter top sealed shut, meter with fogged lens, and meter full of water. In all these cases, the meter was flagged as "not functional." Electronic meters require a battery to record and maintain water use data. Most of the electronic meters encountered during this project were classified as "not functional" because the batteries were depleted.

There were occasions where meters could not be evaluated or read due to flooding, animals in the field, and wasp nests in the meter cap. These were marked as "unknown." "Needs maintenance" was marked for meters that may be functioning but need attention based on the limited evaluation of GWPPC personnel. The readings of these meters may or may not be affected by their need for maintenance.

Table 24. Observed Meters - Status

Meter Status	Count
Fully functional	321
Not functional	12
Needs maintenance (or replacement)	1
Unknown	3
Total	**337**

Meter locations are described in Table 15. Meter location is important because the placement can determine whether a source is fully or partially metered. If the meter is at the source, the source and all the wetted fields were considered "fully metered." If the meter is located at some, but not all of the irrigated fields, the source was considered "partially metered," not to be confused with a *field* that is partially metered, discussed later. The "Other" classification refers to those meters that are at neither position. This occurs where the meter is on a mobile pump or a manifold away from the source (e.g. on a portable pump that may be in storage).

Table 3. Meter Location.

Meter Location	Count
Source	307
Pivot	28
Other	2
Total	**337**

Wetted Areas

This section provides a summary of the observed characteristics of the wetted acreage associated with the withdrawal sites described above. The wetted areas feature class has the largest number of

attributes. Among these are attributes that link each wetted area back to the source, pump, and meter. The data collected includes the system type, conservation, mobility, crop at the time of mapping, metering status, supplying meters, irrigation status, land use, land cover, and supplying water sources. As with the sources, the wetted areas were mapped using the GAEPD database as a reference. These data were provided to the mapper on the GPS and in the form of a map book that the mapper could use for markup. Thus, like the sources, not all GAEPD mapped areas were irrigated. The mapped fields included areas in the GAEPD database that were dryland at the time of mapping. In order to obtain a more accurate assessment of irrigation, the "dryland" and "non-agricultural" areas can be excluded from analysis using the land use and irrigation status attributes collected.

Table 16 summarizes the data on mapped wetted areas in the project area. Figure 4 is a map of these areas by irrigation system type (at end of report). A total of 1,604 fields were mapped with 42,217.9 wetted acres. Subtracting the end gun throw areas from the total acres yields 996 total fields with 35,361.5 wetted acres. Wetted acres totals in Table 16 include all mapped areas. This includes areas that were a part of the GAEPD wetted acreage database but that were observed to be in dryland in this project. Some of these areas fall into the categories of "non-agricultural" use and "no hardware." In very few instances, there were risers (source pipes) in the field, yet, the sources were not active. These were also classified as "dryland" in Table 19.

Table 46. Distribution of Irrigation Systems of Mapped Areas

Irrigation System Type	Count	Acres
Drip	52	1,360.5
Pivot	661	27,445.4
Risers	105	3,098.2
Traveler	7	108.9
Solid set	77	1,731.7
Golf course	5	95.5
No hardware	81	1,352.4
Non-agricultural use	7	127.1
No source	1	41.8
Sub-total	*996*	*35,361.5*
End Gun Throw	608	6,856.4
Total	**1,604**	**42,217.9**

The metering status of all fields required an evaluation of all sources supplying each field. Table 17 summarizes the meter status for mapped fields in the project. This data is shown as a map in Figure 5 (at end of report). It is possible that a field can receive water from more than one source. Such is the case of pond withdrawals supplemented by a groundwater source or a "well to pond." "Fully metered" indicates that all sources supplying a field are metered. This status is best achieved by placing a meter at the field, but, depending on the location, it can be a more costly configuration. "Not metered" indicates

that all sources supplying a field are not metered. There can be a variety of configurations mixing groundwater and surface water sources. In cases where the primary source and all supplemental sources are metered, the field was classified as "fully metered". If water from any source for a field fails to pass through a meter, then the field was classified as "partially metered."

Table 5. Meter Status of Mapped Wetted Areas

Metering Status (all actively irrigated fields)	Count	Acres
Fully metered	937	25,721.1
Partially metered	104	2,871.2
Not metered	556	13,470.9
Not mapped	7	154.7
Total	**1,604**	**42,217.9**

Table 18 lists corrections to the mapping database based on a comparison of the GAEPD wetted areas database with more recent imagery. The latest version of the GAEPD wetted areas database was compiled by drawing new or modifying existing wetted areas from a collection of imagery ranging from 2013 to 2015. The majority of the imagery was from 2014.

While checking in the mapped project data, changes could be noted on the 2015 imagery. Table 18 provides the noted changes. Please note that the provided acres are not indicative of the total amount of change but rather the total acres of the newly mapped areas. The dates between the GAEPD database and the mapped data encompass only a year in time, and therefore the number of changes needed was minor. The corrected areas are mostly irregularly shaped polygons that were taken from the older GAEPD data but not confirmed. These features were redrawn on the more recent imagery. Most of the 335 areas that were subject to corrections were these redrawn irregularly shaped features.

Table 18. Wetted Area Mapping Corrections

Corrections	System Class	Count	Acres
Area added	Non pivot areas	6	311.7
Area loss	Non pivot areas	2	14.7
Converted to pivot	Pivot	3	52.3
Pivot converted to full circle	Pivot	6	201.4
New field not previously recorded	Pivot	104	2,869.4
Pivot reconfigured adding area	Pivot	3	171.2
Pivot reconfigured loosing area	Pivot	2	43.3
Stop moved adding area	Pivot	2	33.2
System moved	Pivot	2	45.5
System removed	Pivot	2	39.6
No change	All areas	1,137	30,587.8

Area drawing corrected	All areas	335	7,847.8
Total		1,604	42,217.9

Tables 19, 20, and 21 list the irrigation status, land use, and land cover for all mapped areas, based on field observations in this project. As previously noted "dryland" can refer to fields with sources and hardware that are not wetted as confirmed by the mapping conducted via this project.

Table 6. Irrigation Status of All Mapped Fields

Irrigation Status	Count	Acres
Irrigated	1,513	40,650.5
Dryland	87	1,465.8
Non-agricultural land use	4	101.6
Total	**1,604**	**42,217.9**

Table 7. Primary Land Use of All Mapped Fields

Primary Land Use	Count	Acres
Agricultural	1,595	42,065.4
Other	9	152.5
Total	1,604	42,217.9

Table 81. Land Cover of All Mapped Fields

Land Cover	Count	Acres
Row crop	1,507	40,054.0
Pine	2	93.4
Orchard and vineyard	44	1,154.1
Grass	51	916.4
Total	1,604	42,217.9

Wetted Areas for Center Pivot Systems

When evaluating irrigation, there is some value in focusing on large pivot systems. In particular, this analysis includes data collected on conservation practices for center pivot systems. Moreover, the data on wetted acreage is slightly more reliable than that from other types of irrigation systems, which often have irregular shaped fields. Tables 22 through 26 summarize data collected for the center pivot systems observed in the project area. In this analysis, end gun throw areas are separated from the hardware acres.

The total number of pivot systems in the project area was 661 accounting for 27,445.4 acres. End gun throw totaled 608 areas with 6,856.4 acres. Three observed pivot systems were not able to be mapped and thus excluded from this analysis. In addition, two systems under construction were also excluded

from this analysis as the exact acres and metering status were not known or observable. With these exclusions, the total number of pivot systems summarized in the tables and observed in the project areas was 656 totaling 27,256.0 acres. As a result of the exclusions, the end gun throw acres changed to 605 areas covering 6,831.6 acres. Table 23 summarizes the eater delivery hardware installed on the mapped center pivot systems. In general, systems with high pressure impact sprinklers are 10-15% less efficient than systems with low pressure nozzles on top of the hardware or installed on "drops" designed to deliver water closer to the ground. No variable-rate irrigation (VRI) systems were observed in the project area. Figure 6 is a map of conservation measures for mapped center pivot systems.

Table 92. Center Pivot System Mobility

Pivot System Mobility	Count	Acres
Fixed	652	27,180.4
Towable	4	75.6
Total	**656**	**27,256.0**

Table 23. Center Pivot Hardware – Indication of Efficiency

Pivot System Nozzle Type	Count	Acres
High pressure impact on top	104	4,001.2
Low pressure sprinkler on top	94	3,994.0
Low pressure sprinkler on drops	458	19,260.8
Total	**656**	**27,256.0**

Table 24. Power Sources of Center Pivot Systems

Power Source Type	Count	Acres
Electric	649	26,937.2
Hydraulic	7	318.8
Total	**656**	**27,256.0**

Table 10. Wetted Area Mapping Corrections for Center Pivots

Changes From Previous Mapping	Count
Converted from other area	2
Converted to full circle coverage	3
New pivot area	24
Reconfigure adding area	2
Stop moved adding area	1
System moved	1
No change	577
Drawing corrected	46
Total	**656**

Table 116. Metering Status of Center Pivot Systems

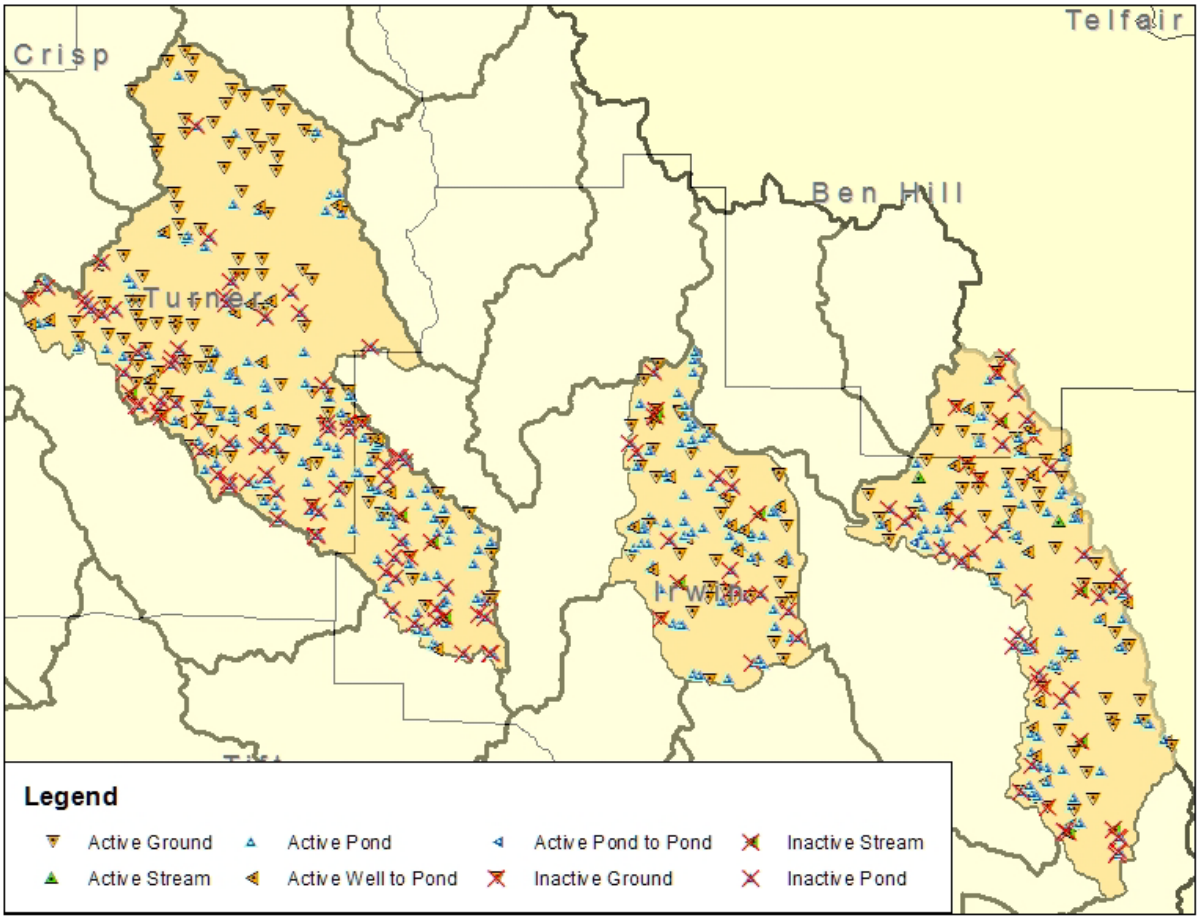
Pivot System Metering Status	Count	Acres
Fully metered	435	18,662.4
Partially metered	51	2,146.5
Not metered	170	6,447.1
Total	**656**	**27,256.0**

Project Impact

The new database created by this project expands the information base for water resource management in the Suwannee-Satilla Water Planning Region. This information can be used by State water policy makers, regional water planning councils, and federally-funded agricultural conservation incentive programs with the ability to enhance their management and planning related to agricultural water use. As a part of the Center's GIS database on agricultural water use, it extends the Center's ability to analyze agricultural water use and conservation policy in support of water resource management planning and policy development.

This new information can support estimation of the levels of efficiency improvement that can be attained, prioritization of what conservation practices are needed and where, and the targeting of conservation improvements. With this information, the State water managers and federally-funded conservation incentive programs will be able to ensure that conservation practices are effectively implemented and that conservation investments are directed toward the greatest benefits. Additionally, farmers can benefit from the establishment of this baseline as it will enable the agricultural sector to demonstrate its commitment to wise water use and document conservation practices.

Figure 2. Sources Mapped



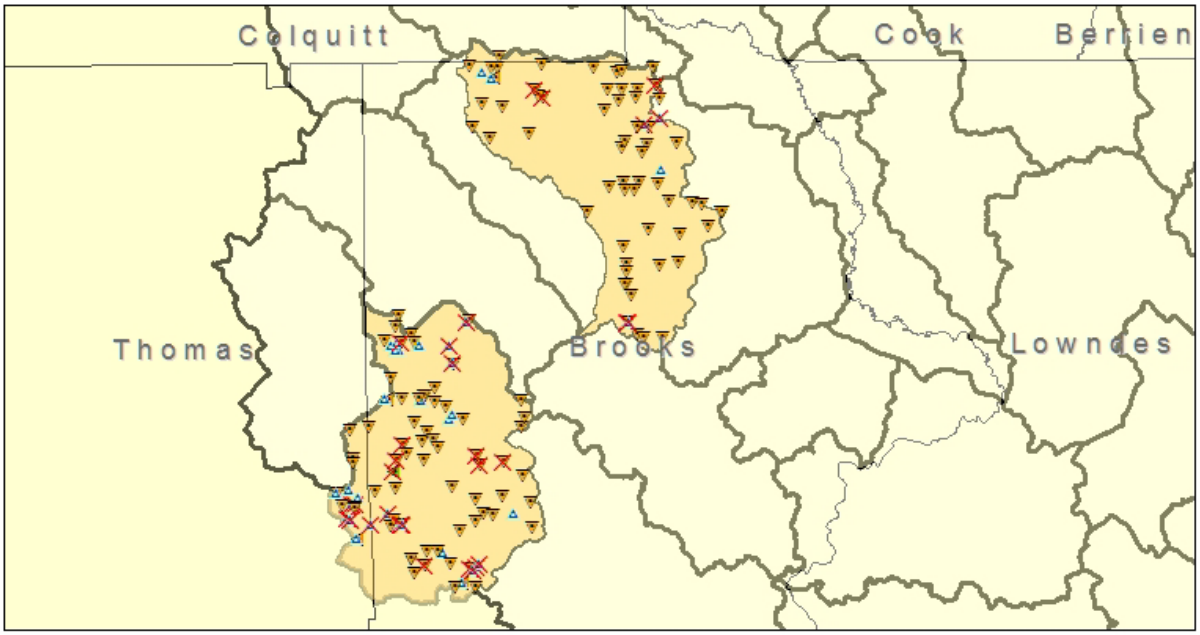
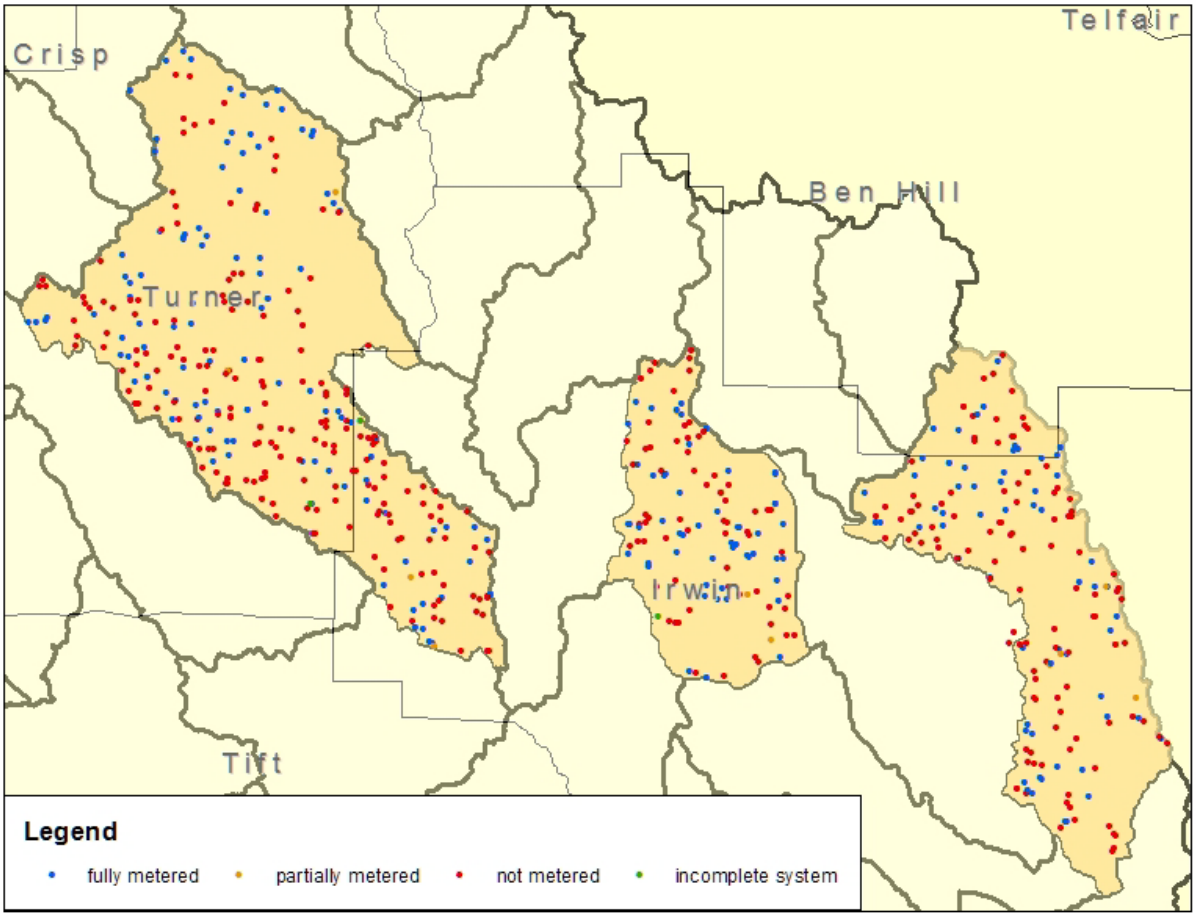


Figure 3. Meter Status of Active Sites



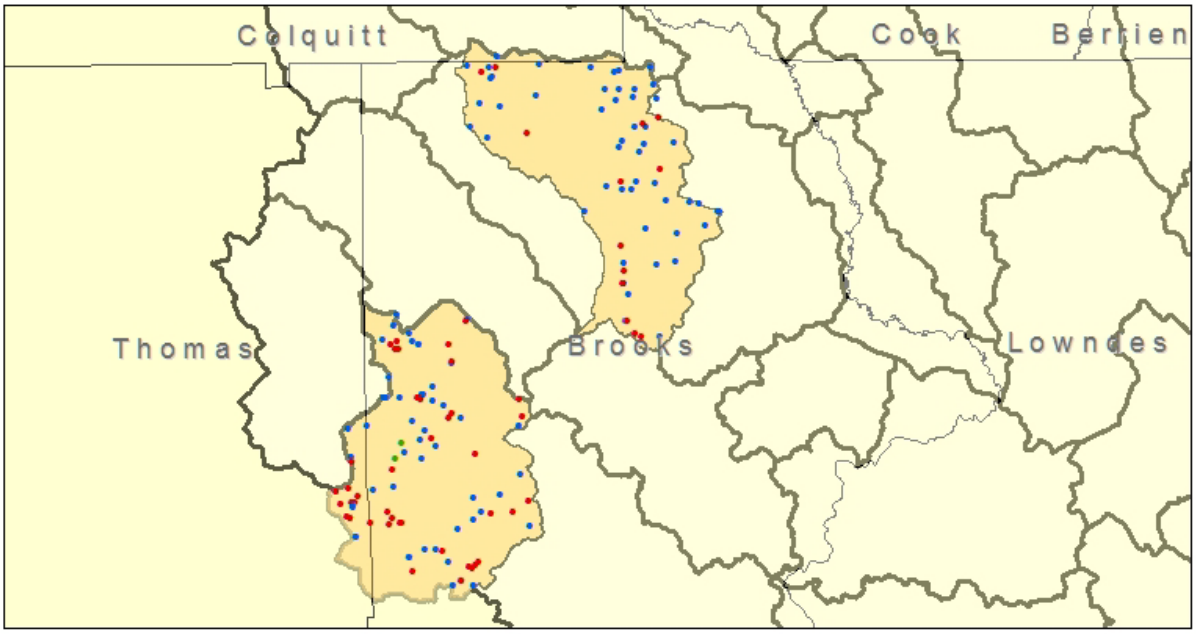
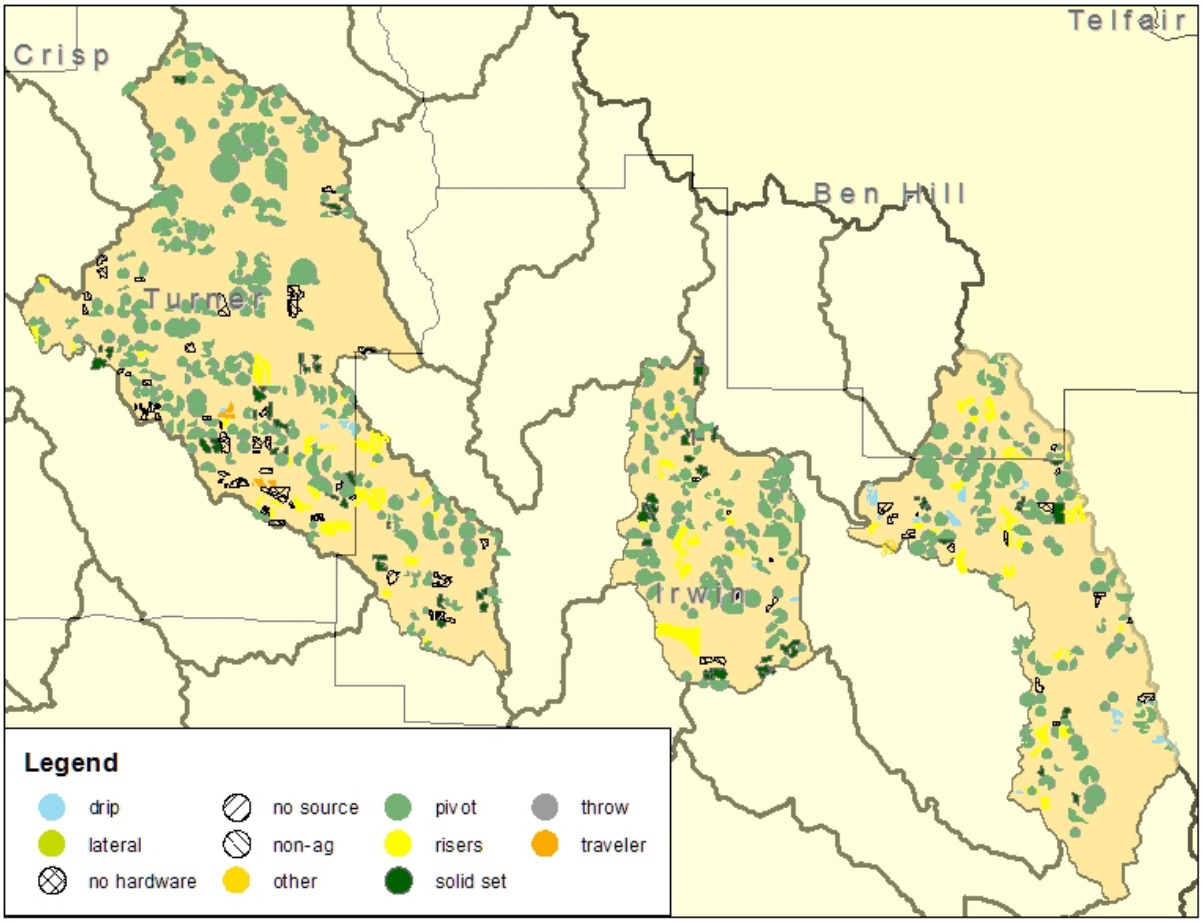


Figure 4. Irrigation Systems of Mapped Areas



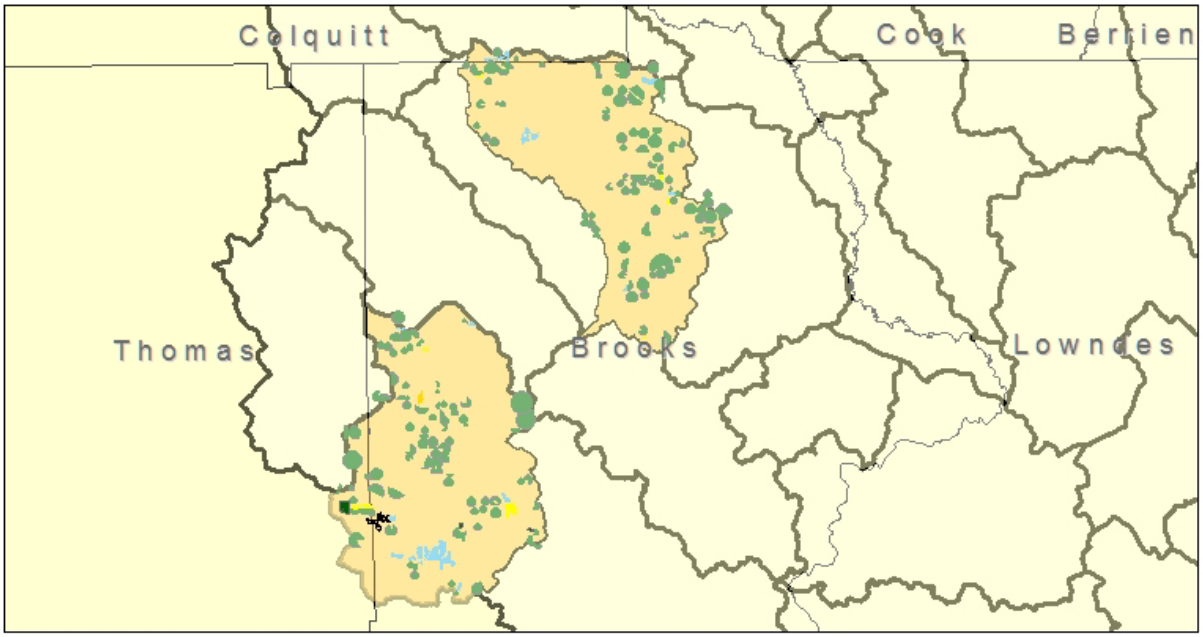
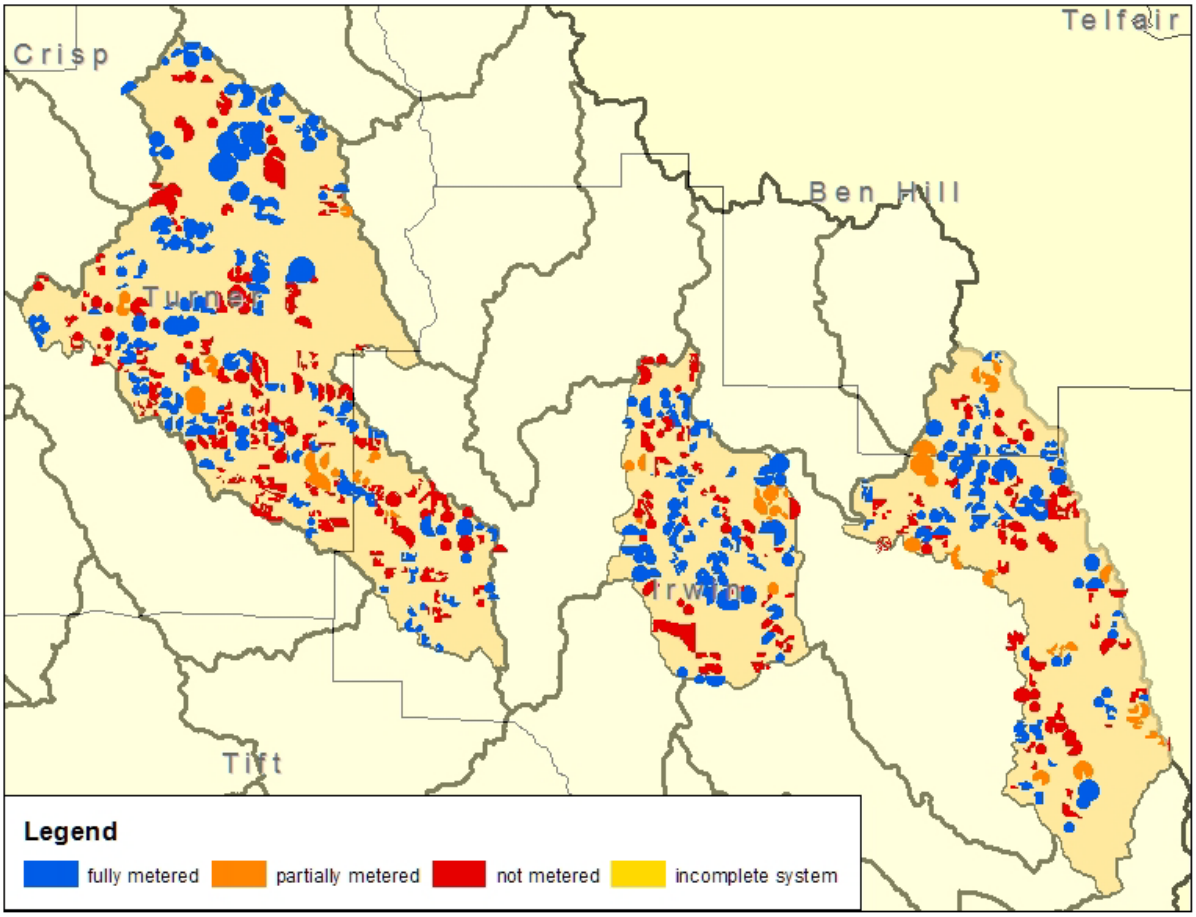


Figure 5. Meter Status of Mapped Wetted Areas



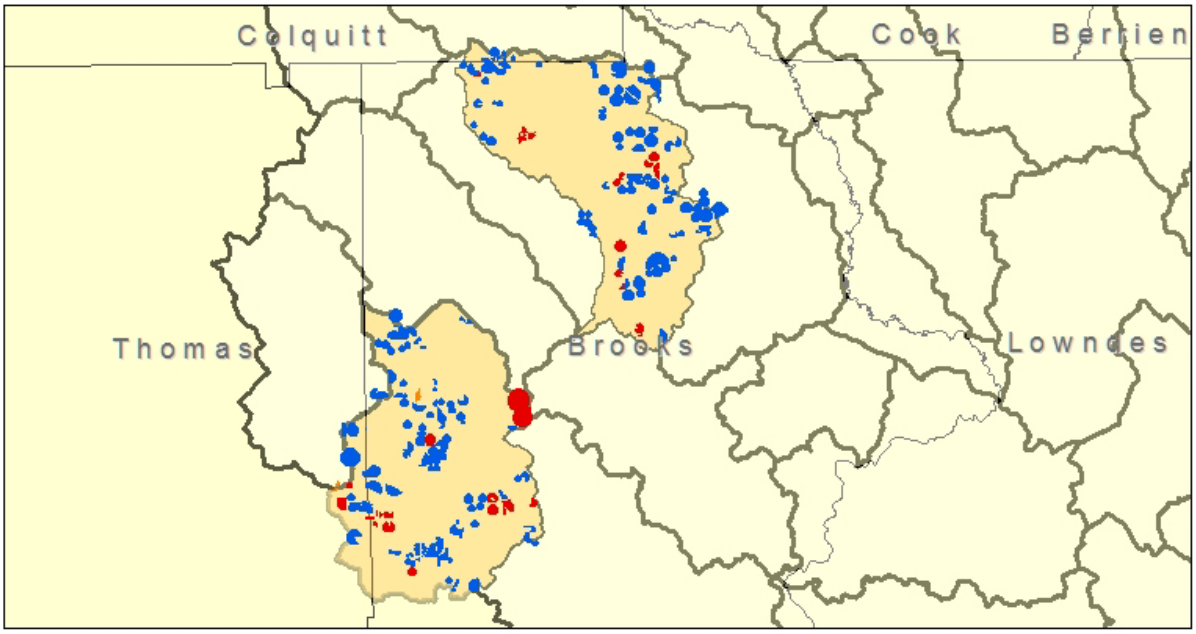
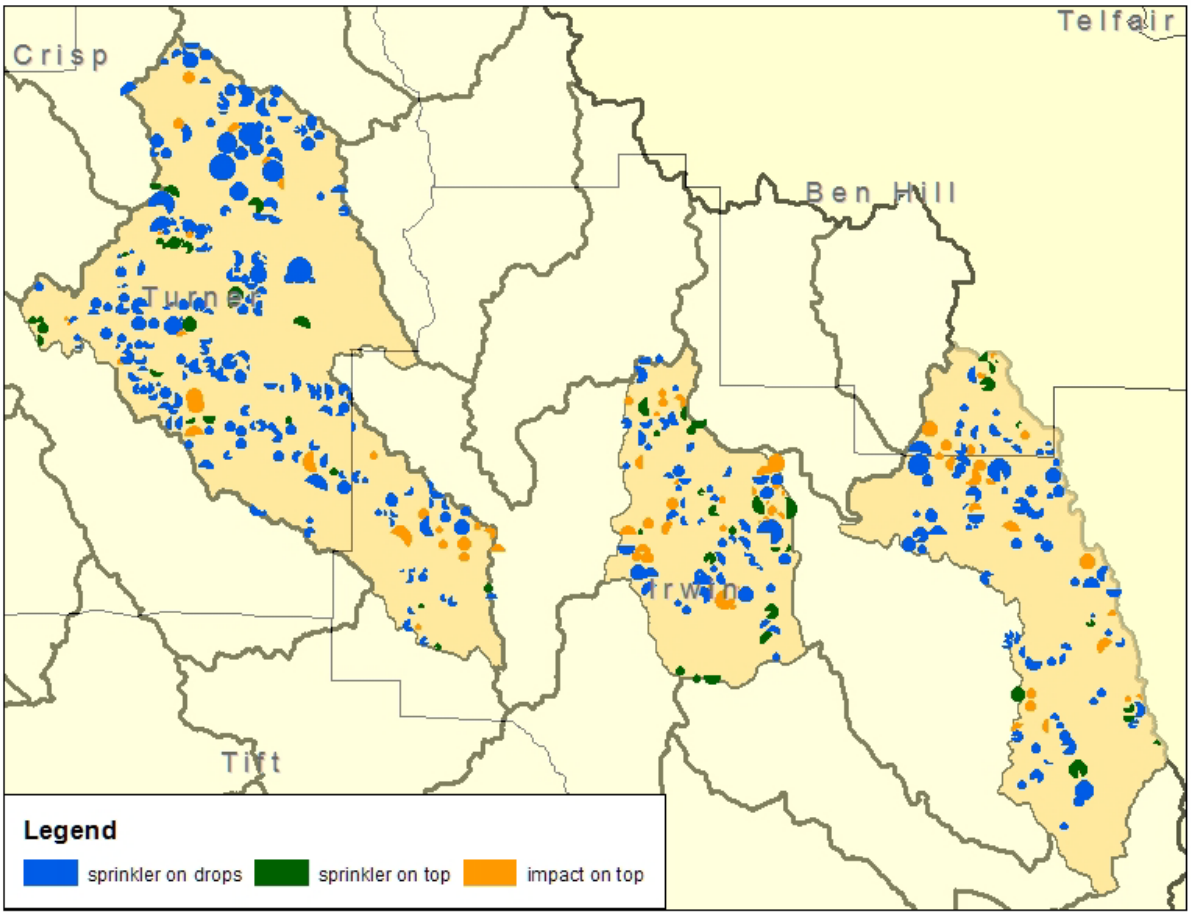
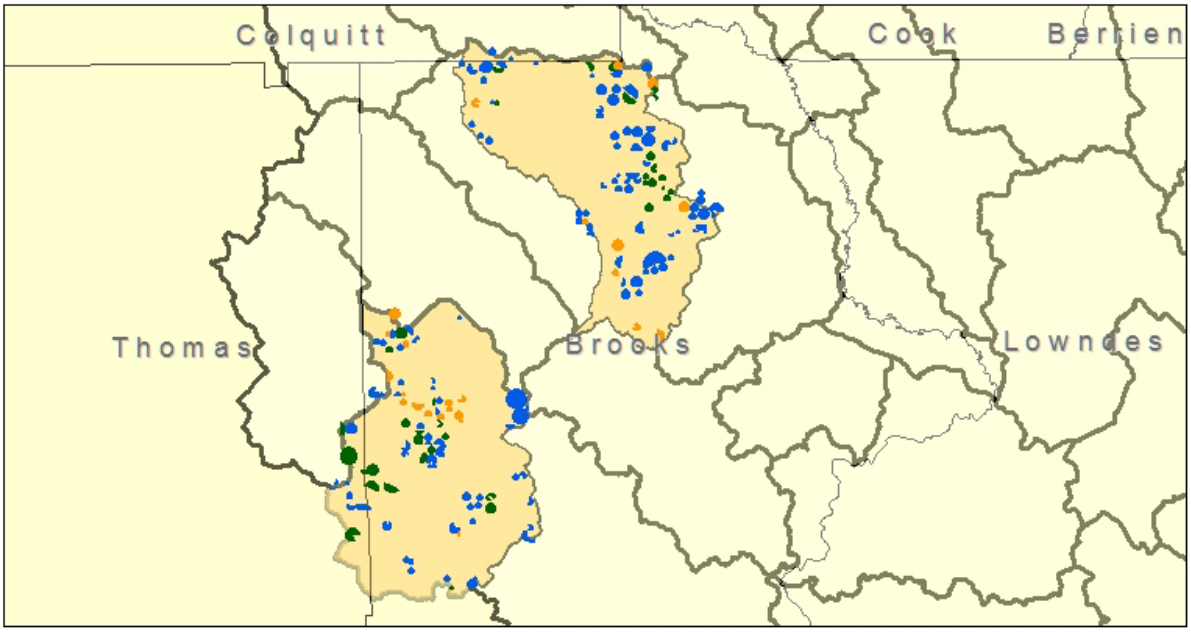


Figure 6. Center Pivots by Conservation Measure Status





Water supply and its potential impact on economic development along the Macon-Hawkinsville reach of the Ocmulgee River

Basic Information

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Publications

There are no publications.

Water supply and its potential impact on economic development along the Macon-Hawkinsville reach of the Ocmulgee River

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According to the Middle Ocmulgee Regional Water Plan, the population in the region is projected to double by 2050 which will involve water demand increase by 38% and wastewater generation by 62% by 2050 [1]. Therefore, it is important to examine trade-offs in water management in order to support sustainable ecosystem of the region. In Georgia, trade-offs study for water management strategies along the Oconee River has been conducted by S. K. McKay, 2014 [2]. In his study, S. K. McKay examined environmental flow and constructed a decision making framework for the Middle Oconee River near Athens, Georgia [3]. Furthermore, C. A. Gibson et al., 2005 conducted a study for two river basins (Cle Elum River, Washington and Chattahoochee-Apalachicola River Basin, Georgia and Florida) in order to investigate impact of future climate scenarios on river ecosystem. They demonstrated significant changes in flow regimes and aquatic habitat under various climate scenarios [4]. Additionally, a comparison study of two rivers in Northern Michigan (Carp Lake River and Little Black River) was conducted by J. Dillon in order to examine ecological effects of agricultural development on stream habitat and nutrient input [5]. In Alabama, study of Tulotoma snail habitat was performed along the Coosa River by Swinson, 2014. The main focus of his study was contour generation using HEC-RAS software based on geo-referenced bathymetry of Coosa River [6]. Moreover, Yao and Georgakakos, 2001 introduced a concept of adaptive water resources management in their study of Folsom Lake, California. Adaptive system demonstrated reliable forecasts for better reservoir performance when compared to traditional one [7, 8]. Also, A. Chen et al, 2015 addressed trade-offs for better water management of Jordan River in the Middle East and Colorado River in the western United States [9]. They addressed similarities and differences of the two river basins by considering various factors, such as increasing water demand and supply and environmental flow demand.

- Deterministic Model development for the Ocmulgee river

We obtained discharge records of time series from January 2008 to December 2014 via website of the U.S. Geological Survey (USGS) water resources which operates several stream flow monitoring stations along the Ocmulgee River [10]. Additionally, we obtained river depth data from Georgia Department of Natural Resources (DNR) Division office for Hawkinsville fisheries management [11]. LiDAR data was provided by Macon-Bibb County Planning and Zoning Comission [12]. We used Geographic Information System (Arc-GIS) and HEC-GeoRAS in order to obtain cross-section profile of the Ocmulgee River (Figure 1).

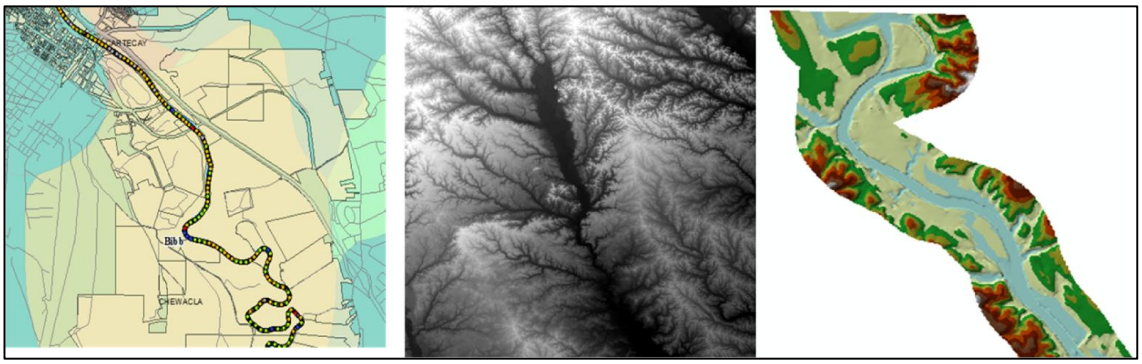

Figure 1. HEC-RAS Model development for the Ocmulgee river [19]

We then pass this information into HEC-EFM along the known hydrology-ecology relationships obtained from habitat models. We used Habitat Suitability Index (HSI) modeling approach to compare fish habitat upstream and downstream of Ocmulgee River. We focused on bluegill, largemouth bass and redbreast sunfish species and compared their HSI models for Macon and Hawkinsville. For example, for largemouth bass, we observed lower HSI values upstream when compared to downstream. The study showed the influence of power plant operation on the river flow and fish habitat [13].

In our future studies, we will build HEC-RAS model for the Oconee river as well in order to provide hydrologic similarities and differences between the Oconee and Ocmulgee river basins.

- Probabilistic Model Development for the Ocmulgee River

Currently, in one part of the study, we took Bayesian approach for solving inverse problem when our goal was to identify the space of input parameters of deterministic model. We performed uncertainty analysis using History Matching approach that uses iterative succession of emulators [14]. Figure 2 demonstrates performance of the History Matching (HM) algorithm given a deterministic model. We compared this method with True Simulation (TS) and Sequential Experiment Design (SED) methods [15]. The results demonstrated that both SED and HM lead to a more accurate solution of the inverse problem than the TS in terms of Root Mean Square Error (RMSE). Besides that, HM uses less number of function evaluations than TS and SED methods in order to find the common solution of the inverse problems [16]. Therefore, History Matching algorithm is less computationally expensive and less time-consuming.

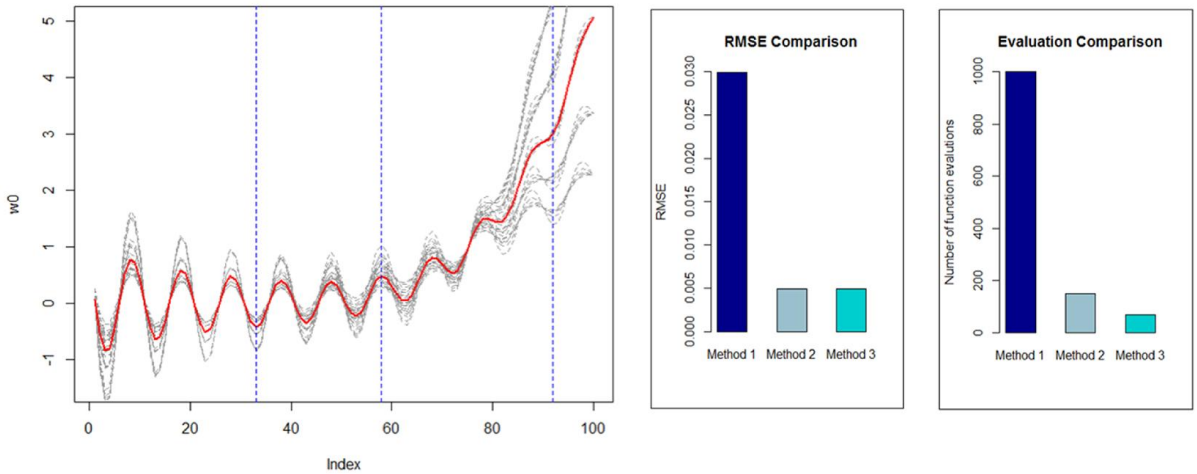

Figure 2. History Matching Algorithm Performance [22]

Constructing emulator and solving the inverse problems help us to gain more insights into the system. Therefore, History Matching algorithm can be used to match the data points (observed) with the deterministic model in order to integrate the deterministic and probabilistic approaches.

In this modeling approach, our next step will be to implement Bayesian techniques to capture bias of deterministic model for the Oconee River. In order to take into account the model uncertainty, we will emulate, calibrate and validate the model using R package SAVE. SAVE package will help us to overcome challenges of computationally expensive models.

- Ocmulgee Water Trail Initiative

In support of the Ocmulgee Water Trail Initiative, we evaluated existing landings and worked on specific recommendations for new landings that can improve recreational access and tourism between Macon and Hawkinsville. We used Arc-GIS software and, as a result, developed the following new site evaluation criteria:

- Paddling distance of 6-10 miles,
- Proximity to existing road,
- Contour (elevation and grade),
- Distance from a population center,
- River depth,
- Ownership and property licensing,
- Soil type.

We examined these 7 criteria (listed above) for the purpose of assisting the Ocmulgee Water Trail Partnership in identifying the best sites for future growth. At the conclusion of the project, we identified 8 high potential locations for future improvements, and provided the group with data that we collected for future use (Figure 3).

As our future research, we will extend this work by including archaeological information about Indian artifacts along the river reach in order to stimulate further economic development of the region.

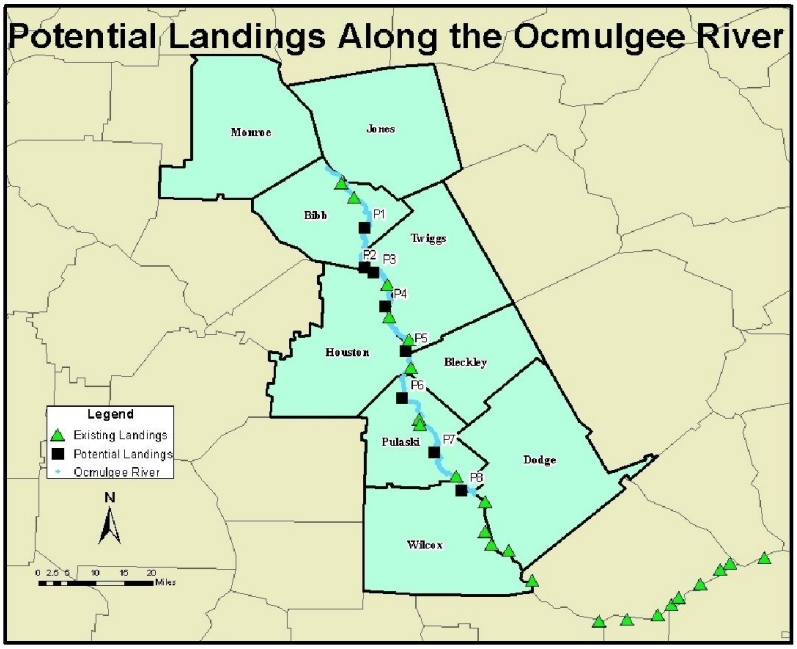

Figure 3. Existing and Potential Landings along the Ocmulgee River [7].

- Bathymetric data collection for the Oconee River

LiDAR data from the Athens-Clarke County Planning Department were retrieved for the Oconee river basins and for the surrounding banks and floodplain areas. In order to augment the LiDAR data set with more detailed information of the river and surrounding land, a Leica total station was used to collect bathymetric and on-land topographic data. A real-time kinematic (RTK) unit was utilized to set up control on the eastern bank of the river within Ben Burton Park. Six control points were staked and flagged with coordinate measurements taken within the NAD GA State Plane coordinate system. The total station was then placed within a sightline of the cross-sectional bathymetric points and onland topographic points to be collected near the upstream portion of the reach. A Carlson data logger was connected to the total station and used to perform a “resection” on the control points. After performing a resection, rebar was driven partially in the ground on each side of the bank where cross-sectional bathymetric data was desired. All in all, a total of 10 cross-sections were measured as well as surrounding bank and floodplain features. If funding is available, we will try more efficient way of collecting bathymetric data (for example, using GPS echo sounder mounted to the boat).

Our future work will include development of deterministic and probabilistic models for the Oconee River as well as comparison and integration study for the Ocmulgee and Oconee River basins. As a final result of the proposed project, we will prepare and submit the manuscript to a peer-reviewed journal for possible publication.

Publications

- N. V. Shim and E. W. Tollner, "Developing tools for modeling selected ecological changes induced by upstream reservoir management along a small river using HEC-RAS, HEC-EFM and additional spatial statistical tools", *2015 American Society of Agricultural and Biological Engineers (ASABE) Annual International Meeting, 26-29 July 2015, New Orleans, Louisiana, USA.*
- N. V. Shim, E. W. Tollner, J. W. Willis and S. K. McKay, "Comparison of Oconee and Ocmulgee river basins for water management improvement", *2016 American Society of Agricultural and Biological Engineers (ASABE) Annual International Meeting, 17-20 July, 2016, Orlando, Florida, USA.*
- N. V. Shim and E. W. Tollner, "Recurrent neural network for forecasting water quality parameters: Sensitivity Analysis" *under review.*
- N. V. Shim, E. W. Tollner, J. W. Willis and S. K. McKay, "Habitat provision associated with environmental flows" *under preparation.*

References

1. *Middle Ocmulgee, Regional Water Plan*. 2011; Available from: http://middleocmulgee.org/documents/MOC_Adopted_RWP.pdf.
2. McKay, S.K., *Quantifying Tradeoffs Associated with Hydrologic Environmental Flow Methods.* JAWRA Journal of the American Water Resources Association, 2015.
3. McKay, S.K., *Informing flow management decisions in the Middle Oconee River*. 2014.
4. Gibson, C., et al., *Flow regime alterations under changing climate in two river basins: implications for freshwater ecosystems.* River Research and Applications, 2005. **21**(8): p. 849-864.
5. Dillon, J. *Comparison of two rivers in Northern Michigan for determination of differential effects of development*. 2013; Available from: http://deepblue.lib.umich.edu/bitstream/handle/2027.42/101886/Dillon_Jeff_2013.PDF?sequence=1&isAllowed=y.
6. Swinson, K. *Contour Generation to Support Calculation of Exposed Snail Habitat in the Coosa River, Alabama*. in *American Water Resources Association Conference*. 3-6 November 2014. Tysons Corner, VA, USA.
7. Yao, H. and A. Georgakakos, *Assessment of Folsom Lake response to historical and potential future climate scenarios: 2. Reservoir management.* Journal of Hydrology, 2001. **249**(1): p. 176-196.
8. Georgakakos, A., et al., *Value of adaptive water resources management in Northern California under climatic variability and change: Reservoir management.* Journal of hydrology, 2012. **412**: p. 34-46.
9. Chen, A., et al., *A tale of two rivers: Pathways for improving water management in the Jordan and Colorado River basins.* Journal of Arid Environments, 2015. **112**: p. 109-123.
10. *U.S. Geological Survey Water Resources*. Available from: http://www.usgs.gov/water/.
11. *Georgia DNR Wildlife Resources Division*. Available from: http://www.georgiawildlife.org/about/contact.
12. *Macon - Bibb County Planning and Zoning Commission.*

13. Shim, N.V. and E.W. Tollner. *Developing tools for modeling selected ecological changes induced by upstream reservoir management along a small river using HEC-RAS, HEC-EFM and additional spatial statistical tools*. in *2015 American Society of Agricultural and Biological Engineers (ASABE) Annual International Meeting*. 26-29 July 2015. New Orleans, LA, USA.
14. Vernon, I., M. Goldstein, and R.G. Bower, *Galaxy formation: a Bayesian uncertainty analysis.* Bayesian Analysis, 2010. **5**(4): p. 619-669.
15. Ranjan, P., D. Bingham, and G. Michailidis, *Sequential experiment design for contour estimation from complex computer codes.* Technometrics, 2008. **50**(4).
16. Shim, N.V., P. Ranjan, and A. Mandal. *Bayesian Linear Approach for Solving Inverse Problem: Uncertainty Analysis*. in *2015 Design and Analysis of Experiments (DAE) Conference*. 4-6 March 2015. Cary, NC, USA.

Market-based approaches to resolve water conflicts in the Apalachicola-Chattahoochee-Flint River Basin

Basic Information

Title:	Market-based approaches to resolve water conflicts in the Apalachicola-Chattahoochee-Flint River Basin
Project Number:	2015GA355B
Start Date:	3/1/2015
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	GA-10
Research Category:	Social Sciences
Focus Category:	Law, Institutions, and Policy, Water Use, Economics
Descriptors:	None
Principal Investigators:	Laurie Fowler

Publications

There are no publications.

Market-based approaches to resolve water conflicts in the Apalachicola-Chattahoochee-Flint River Basin

Main Author: Shannon Bonney. PI: Laurie Fowler. With contributions by: Katie Sheehan, Laura Early, Dan Read, Brian Easley, and Torre Lavelle.

Final Report
February 2016

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Executive Summary

Georgia, Alabama, and Florida have been entrenched in a dispute over the waters of the ACF River Basin for decades. In recent years the debate has become ever more serious because there is insufficient water to meet environmental and public water demands during droughts. A variety of approaches have been employed in attempts to resolve this dispute, including political negotiations and litigation, but have been unsuccessful to date because they do not ensure the benefits derived from water and burdens borne by lack thereof are shared equitably amongst water users. Market-based instruments (MBIs), typically divided into four major types: instream buybacks, trading and offsets, beneficiary-pays fund, and bilateral agreements, offer a way to resolve water disputes by redistributing benefits and burdens experienced by water users, in lieu of litigation and politics. However, MBIs, found to be particularly effective for solving interstate water allocation disputes in other basins, have largely been ignored.

While an irrigation reduction auction program was established in the Flint River sub-basin to meet shortfalls in environmental water during droughts by paying farmers to temporarily suspend irrigation, this program has no permanent funding source, design flaws that limit its effectiveness. The program has only been implemented twice and it is no longer active. No auction programs or other MBIs are currently employed at a basin-wide scale, which excludes several important potential beneficiaries and providers (such as the Florida seafood industry and metropolitan Atlanta water suppliers). Moreover, while a number of MBIs are used successfully in other regions, there remains scarce literature that is easily understood and readily usable by those with the authority to implement MBIs.

Report Contents:

1. Database of all U.S. interstate water quantity disputes occurring since 1990
2. Case studies on emerging and well-established MBIs utilized in U.S. river basins experiencing water scarcity
3. Discussion of select topics important for consideration while evaluating the potential of MBIs to resolve interstate water quantity conflicts
4. Outreach materials

Interstate Water Quantity Dispute Database

BASIN	Apalachicola-Chattahoochee-Flint
CITATION	229 F.R.D. 669
CASE	State of ALABAMA, Plaintiff, and State of Florida, Intervenor-Plaintiff v. UNITED STATES ARMY CORPS OF ENGINEERS, et al., Defendants.
COURT LEVEL	US Federal Courts
COURT TYPE	US District Courts
COURT DESCRIPTION	Eleventh Circuit (Alabama Northern District, Eastern Division)
DATE FILED	6/28/90
HISTORY	no direct history
RELATED CASES	357 F.Supp.2d 1313, (vacated and remanded by) 424 F .3d 1117, (certiorari denied by) 547 U.S. 1192; 382 F .Supp.2d 1301; 2006 WL 6080869 (appears procedural); 2006 WL 6091450 (appears procedural); 441 F .Supp.2d 1123
PARTY NAMES	State of Alabama (plaintiff); Water Works and Sanitary Sewer Board of the City of Montgomery (intervenor plaintiff); State of Florida (intervenor plaintiff); Alabama Power Company (intervenor plaintiff); The Board of Water and Sewer Commissioners of the City of Mobile (intervenor plaintiff); United States Army Corps of Engineers (defendant); Michael F. Thuss Colonel, in his capacity as District Engineer, Mobile District, U.S. Army Corps of Engineers (defendant); Robert M. Bunker Major General, in his capacity as Division Engineer, South Atlantic Division, U.S. Army Corps of Engineers (defendant); Henry J. Hatch Lt. General, in his capacity as the Chief of Engineers, U.S. Army Corps of Engineers (defendant); United States Fish and Wildlife Service (defendant); Gail Carmody (U.S. Fish and Wildlife Service) (defendant); State of Florida (defendant); State of Georgia, in its individual capacity as trustee of its natural resources and in its representative capacity as parens patriae for the citizens of the state of Georgia (intervenor defendant); Cobb County-Marietta Water Authority (intervenor defendant); Atlanta Regional Commission Water Supply Intervenor (intervenor defendant); Lake Lanier Association (intervenor defendant); Sierra Club (amicus). [Additional parties from GPO]: Alabama Conservancy (movant); Alabama Wildlife Federation (movant); City of Atlanta, Georgia (movant); City of Cartersville, Georgia (movant); Coosa-Alabama River Improvement Association, Inc. (movant); DeKalb County, Georgia (movant); Fulton County, Georgia (movant); Gwinnett County, Georgia (movant); Industrial Water Board of the City of Birmingham, Alabama (movant); Water Works & Sewer Board of the City of Gadsden (movant); Water Works and Sewer Board of the City of Selma (movant)
PARTY DESCRIPTION	? local government ? ; state government; federal government; utilities; water user groups; businesses; environmental groups; ? recreation interests ? ; regional governments
COMPETING	upstream vs. downstream water uses; municipal and industrial supply (along with associated storage in federal reservoirs)

FEDERAL AGENCY PARTY?	yes
STATE AGENCY PARTY?	? yes ?
WATER RIGHTS DOCTRINE	riparian rights
COMPACT	
ISSUES	The original complaint was filed by the State of Alabama against the U.S. Army Corps of Engineers (Corps) and several Corps' officers, which challenged numerous activities, plain, and actions regarding the management of 3 reservoirs in Georgia: 2 in the Alabama-Coosa-Tallapoosa (ACT) Basin (Carters Lake and Lake Allatoona) and 1 in the Apalachicola-Chattahoochee-Flint (ACF) Basin (Lake Lanier). The original complaint was based on the following alleged Corps activities: entering into water withdrawal contracts with various Georgia municipalities to allow withdrawal from Lake Lanier, entering into contracts for water supply storage at Lake Allatoona, submitting a final Reallocation Report and Environmental Assessment reviewing impacts of reallocating water in Carters Lake without considering Alabama's objections, planning to issue a draft Reallocation Report and draft Environmental Assessment for Lake Allatoona without basin-wide study, releasing for review a draft Post Authorization Change Notification Report and draft Environmental Assessment proposing increased withdrawals from Lake Lanier, issuing interim water supply contracts to Georgia municipalities authorizing withdrawals from Lake Lanier before finalizing reports and obtaining Congressional approval, proposing a two-phased Comprehensive Studies Plain to Congress that prevents Alabama form later remedying any damage caused by phase one, failing to consider already-authorized future reservoirs to be constructed in Georgia when allocating water withdrawals, failing to consider potential impact resulting from Atlanta's petition for an increase in amount of pollution released into ACF Basin when considering increases in water withdrawals from Lake Lanier, and failing to prepare Environmental Impact Statements entirely or doing so inadequately when preparing reports for various ACF and ACT reservoirs. Georgia and the Corps claimed none of the contracts referenced in the complaint have ever been finalized and all of those contracts had been withdrawn. SUMMARY OF MAJOR ACTIVITIES ASSOCIATED WITH THIS CASE: Soon after the suit was filed, multiple entities moved to intervene; including Florida, Georgia, and the Atlanta Regional Commission. In 1990 Alabama and the Federal defendants filed a Joint Motion to Stay Proceedings, to foster settlement negotiations, where they agreed to not enter into any contracts or agreements relating to the complaints of this court case unless all parties to the case expressly agreed to in writing. In 1992 they stay Order was renewed and the court denied the pending motions to intervene, but allowed for them to refile once stay was lifted. In 2003 the Corps and Georgia entered into a settlement agreement ("the DC agreement") in a related case in the DC District Court ("DC Case"); however they didn't first comply with the termination provisions of the 1990 Stay. As a response to the DC agreement, in 2003 Alabama filed a motion for temporary restraining order and preliminary injunction against the Corps. Limited litigation activities and numerous stay orders followed. Later in 2003 Florida and Georgia were allowed to intervene. Later in 2003 court decided Corps had violated 1990 Stay and entered a preliminary injunction prohibiting Corps from implementing the DC agreement or entering into any new storage or withdrawal contracts effecting

	the ACF Basin, until this case resolved on its own merits. The court then stayed the case until the DC Case was resolved and the validity of the proposed settlement determined. In 2004 the DC District court declared that the DC agreement was valid and could be implemented once the preliminary injunction was vacated. Later in 2004 action was stayed because of an appeal taken by the Defendants of the 2003 Preliminary Injunction Order (424 F .3d 1117 "Alabama I"). In April 2004 the 11th Circuit stayed the appeal to allow this court time to decide on whether to dissolve or modify the injunction (424 F .3d 1117 "Alabama I"). In 2005 court denied motions to lift injunction (357 F .Supp.2d 1313) and later in 2005 that order was appealed (424 F .3d 1117 "Alabama II"). The plaintiff states then tried to amend complaint (382 F .Supp.2d 1301). The final activities associated with this case (before all ACF related cases were consolidated, with the exception of the DC case, under Judge Magnusen) were motions to intervene by a city water board and power company. INTERESTS OF PARTIES: Montgomery Water Works Board wants adequate quantities and quality of water supplies to operate its water treatment and wastewater facilities in the ACT Basin; Alabama Power wants adequate water supplies to operate its dams, reservoirs, and hydroelectric, steam, and nuclear power plants in the ACT and ACF basins, and to get eventual Corps' approval for one of its plans for development that was withheld because of preliminary injunction; Alabama's interests are general and concern management of all the water resources of the ACF and ACT basins (see overview of original complaint); Georgia wants to maintain current and protect potential future contracts for municipal and industrial water supply from reservoirs of the ACF and ACT basins; Florida wants more water to reach the downstream (i.e. Florida) portions of the ACF Basin and believes the past, present, and continuing provision of storage in Lake Lanier and the provision to the water supply providers of water from such storage for municipal and industrial purposes has and will adversely affect the existing Congressionally-authorized purposes of Lake Lanier, as well as Florida's existing lawful uses of the waters of the ACF Basin; Florida also wants limits to withdrawals from Lake Lanier for municipal and industrial purposes because it believes current withdrawals are impacting the quality of the environment and are jeopardizing the continued existence of endangered or threatened species.
DATE RESOLVED	8/10/05
RESOLUTION DESCRIPTION	The motions to intervene were granted (see related cases, DC case, and consolidated cases for more substantial rulings). For a time, the case was stayed for party negotiations and an interstate compact. This interstate compact (the "ACF River Basin Compact"), and associated compact commission, lasted from 1997-2003; during which time the states attempted to come up with a mutually agreed-upon allocation formula to divvy up the waters of the ACF Basin. No consensus was reached on an allocation formula and the compact was dissolved in 2003.
RESOLUTION TYPE	court order
HOLDINGS	1) parties' intervention as of right was proper and 2) parties' permissive intervention was proper
RESEARCHER	Shannon Bonney
REFERENCE	Westlaw; GPO
NOTES	

BASIN	Apalachicola-Chattahoochee-Flint
CITATION	223 F.R.D. 691
CASE	The State of GEORGIA, Plaintiff, and Lake Lanier Association, Intervenor-Plaintiff, v. The UNITED STATES ARMY CORPS OF ENGINEERS, et al., Defendants, and The State of Florida and Southeastern Federal Power Customers, Inc., Intervenor-Defendants.
COURT LEVEL	US Federal Courts
COURT TYPE	US District Courts
COURT DESCRIPTION	Eleventh District (Northern District of Georgia, Gainesville Division)
DATE FILED	2/7/01
HISTORY	(remanded from) 302 F .3d 1242; (rehearing and rehearing en banc for 302 F .3d 1242 denied by) 54 Fed.Appx. 935; (affirmed by) 144 Fed.Appx. 850
RELATED CASES	
PARTY NAMES	State of Georgia (plaintiff); Lake Lanier Association (intervenor plaintiff); U.S. Army Corps of Engineers (defendant); Gregory R. Dahlberry in his official capacity as acting secretary of the United States Army (defendant); JOSEPH W. WESTPHAL IN HIS OFFICIAL CAPACITY AS ASSISTANT SECRETARY OF THE UNITED STATES ARMY FOR CIVIL WORKS (defendant); LIEUTENANT GENERAL ROBERT W. FLOWERS IN HIS OFFICIAL CAPACITY AS COMMANDER AND CHIEF OF ENGINEERS, UNITED STATES ARMY CORPS OF ENGINEERS (defendant); MAJOR GENERAL PHILLIP R. ANDERSON IN HIS OFFICIAL CAPACITY AS DIVISION COMMANDER, SOUTH ATLANTIC DIVISION, UNITED STATES ARMY CORPS OF ENGINEERS (defendant); COLONEL J. DAVID NORWOOD IN HIS OFFICIAL CAPACITY AS DISTRICT COMMANDER, MOBILE DISTRICT, UNITED STATES ARMY CORPS OF ENGINEERS (defendant); SOUTHEASTERN FEDERAL POWER CUSTOMERS, INC. (intervenor defendant); State of Florida (intervenor); Atlanta Regional Commission (intervenor); CITY OF GAINESVILLE, GEORGIA (intervenor); GWINNETT COUNTY, GEORGIA (intervenor); STATE OF ALABAMA (intervenor); STATE OF FLORIDA (intervenor); STATE OF FLORIDA (intervenor)
PARTY DESCRIPTION	local government; state government; federal government; utilities; water user groups; businesses; ? recreation interests ?; regional governments
COMPETING USES	Municipal and industrial water supply demands, are competing with water demands downstream in Apalachicola River and Bay (including seafood industry), and with hydropower production.
FEDERAL AGENCY PARTY?	yes
STATE AGENCY PARTY?	? Yes ?
WATER RIGHTS DOCTRINE	riparian rights
COMPACT	

ISSUES	"The Governor of Georgia made a written water supply request asking the Corps to commit to making increased releases of water from the Buford Dam until the year 2030 in order to assure a reliable municipal and industrial water supply to the Atlanta region. Specifically, Georgia requested that the Army Corps take the following actions: 1. Allow municipal and industrial withdrawals from Lake Lanier to increase as necessary to the projected annual need of 297 mgd in 2030; 2. Increase the water released from the Buford Dam sufficiently to permit municipal and industrial withdrawals in the Chattahoochee River south of the dam to be increased as necessary to the projected annual need of 408 mgd in 2030; 3. Enter into long-term contracts with Georgia or municipal and industrial water users in order to provide certainty for the requested releases; 4. Ensure that sufficient flow is maintained south of the Buford Dam to provide the requisite environmental quality—that is, assimilate discharged wastewater; and 5. Assess fees on the municipal and industrial water users in order to recoup any losses incurred by a reduction in the amount of hydropower generated by the dam as a result of *1248 the increased withdrawals or releases. After approximately nine months without a response from the Corps, Georgia filed suit seeking (1) an order compelling the Corps to grant its water supply request; (2) a declaration that the Corps has the authority, without additional Congressional authorization, to grant its request; (3) a declaration that the Corps is subject to state law insofar as it does not conflict with federal law and that state law mandates that the Corps grant the request; and (4) a declaration that, if applicable federal law prohibits the Corps from granting Georgia's request, then such federal law is unconstitutional on its face or as applied by the Corps." [p. 1247-1248; in 302 F .3d 1242] "The state of Florida filed a motion to intervene as of right or permissively as a defendant in the suit and simultaneously filed a motion to dismiss, or, in the alternative, to abate proceedings. Florida argued, as it does on appeal, that Georgia was seeking to effect a de facto partial apportionment of the water in the ACF Basin in violation of the ACF Compact. Florida asserted that if Georgia's water supply request is granted, more water will be consumed upstream in the ACF Basin and less will be available for uses in Florida because the flow in the Apalachicola River, located completely within Florida's borders, depends almost entirely on the amount of water flowing in the Chattahoochee. Florida asserts that the Compact is designed to be the exclusive mechanism to resolve disputes involving the ACF Basin, and that this litigation improperly contravenes the ACF Compact." [p. 1248; in 302 F .3d 1242] "Six months after Georgia filed suit, SeFPC also filed a motion to intervene as of right or permissively as a defendant, along with a proposed answer to Georgia's complaint. SeFPC's members are “preference customers” of the Buford Project, which means they are entitled to purchase surplus hydropower from the Southeastern Power Marketing Administration (“SEPA”), a power marketing agency of the Energy Department.3 SeFPC argued that, unlike hydropower, municipal and industrial water supply is not an established purpose of the Buford Project, and that granting Georgia's water supply request would reduce the availability of hydropower to SeFPC's members." [p. 1248; in 302 F .3d 1242]
DATE RESOLVED	7/20/04

RESOLUTION DESCRIPTION	Motions to intervene by various parties (inc. Florida, Alabama, association hydropower preference customers, and local governments) were granted. However, action was abated pending resolution of a parallel case in Alabama.
RESOLUTION TYPE	court order
HOLDINGS	"The District Court, Story, J., held that: 1 Alabama was entitled to intervene as of right; 2 local governments were entitled to permissively intervene; and 3 action would be abated pending resolution of parallel Alabama case" ["Synopsis"]
RESEARCHER	Shannon Bonney
REFERENCE	Westlaw
NOTES	

BASIN	Apalachicola-Chattahoochee-Flint
CITATION	514 F.3d 1316
CASE	SOUTHEASTERN FEDERAL POWER CUSTOMERS, INC., Appellee v. Peter GEREN, Secretary of the United States Department of the Army, et al., Appellees. State of Florida, Appellant
COURT LEVEL	US Federal Courts
COURT TYPE	US District Courts
COURT DESCRIPTION	District of Columbia Circuit
DATE FILED	12/12/2000 [original filing for 301 F .Supp.2d 26]; 3/24/2006 [this case]
HISTORY	301 F .Supp.2d 26, (appeal dismissed by) 400 F .3d 1; (and reversed by) 514 F .3d 1316; (certiorari denied by) 555 U.S. 1097
RELATED CASES	2006 WL 6608801 [appears procedural]

PARTY NAMES	SOUTHEASTERN FEDERAL POWER CUSTOMERS, INC. (PLAINTIFF - APPELLEE); FRANCIS J. HARVEY, SECRETARY OF THE U.S. DEPARTMENT OF THE ARMY (DEFENDANT - APPELLEE); JOSEPH W. WESTPHAL, IN HIS OFFICIAL CAPACITY AS THE ASSISTANT SECRETARY OF THE ARMY (DEFENDANT - APPELLEE); ROBERT B. FLOWERS, LT. GENERAL IN HIS OFFICIAL CAPACITY AS THE COMMANDER, UNITED STATES ARMY CORP OF ENGINEERS (DEFENDANT - APPELLEE); PHILLIP R. ANDERSON, MAJ. GENERAL IN HIS OFFICIAL CAPACITY AS THE SOUTH ATLANTIC DIVISION COMMANDER, UNITED STATES ARMY CORPS OF ENGINEERS (DEFENDANT - APPELLEE); JOHN D. NORWOOD, COL. IN HIS OFFICIAL CAPACITY AS THE MOBILE DISTRICT COMMANDER, UNITED STATES ARMY CORPS OF ENGINEERS (DEFENDANT - APPELLEE); CITY OF GAINSVILLE (INTERVENOR - APPELLEE); STATE OF GEORGIA (INTERVENOR - APPELLEE); COBB COUNTY MARIETTA WATER AUTHORITY (INTERVENOR - APPELLEE); DEKALB COUNTY (INTERVENOR - APPELLEE); GWINNETT COUNTY (INTERVENOR - APPELLEE); ATLANTA REGIONAL COMMISSION (INTERVENOR - APPELLEE); STATE OF FLORIDA (INTERVENOR - APPELLENT); STATE OF ALABAMA (INTERVENOR - APPELLEE); AMERICAN PUBLIC POWER ASSOCIATION (AMICUS CURIAE FOR APPELLEE); NATIONAL RURAL ELECTRIC COOPERATIVE ASSOCIATION (AMICUS CURIAE FOR APPELLEE); ALABAMA RIVERS ALLIANCE (AMICUS CURIAE FOR APPELLANT); APALACHICOLA BAY & RIVERKEEPER, INC. (AMICUS CURIAE FOR APPELLANT); BLACK WARRIOR RIVERKEEPER, INC. (AMICUS CURIAE FOR APPELLANT); CHATTAHOOCHEE RIVERKEEPER (AMICUS CURIAE FOR APPELLANT); COALITION OF ASSOCIATIONS AT LAKE MARTIN (C.A.L.M.) (AMICUS CURIAE FOR APPELLANT); COOSA RIVER BASIN INITIATIVE (AMICUS CURIAE FOR APPELLANT); LAKE WATCH OF LAKE MARTIN (AMICUS CURIAE FOR APPELLANT); UPPER CHATTAHOOCHEE RIVERKEEPER FUND, INC. (AMICUS CURIAE FOR APPELLANT)
PARTY DESCRIPTION	local government; state government; federal government; ? private citizens ? ; utilities; water user groups; businesses; environmental groups; ? recreation interests ? ; regional governments
COMPETING USES	
FEDERAL AGENCY PARTY?	yes
STATE AGENCY PARTY?	? yes ?
WATER RIGHTS DOCTRINE	regulated riparianism
COMPACT	

ISSUES	"This case arises out of the requirements of three States for water stored in a federal reservoir. The States of Alabama and Florida appeal the order of the district court approving a Settlement Agreement between Southeastern Federal Power Customers, Inc. (“Southeastern”), a group of Georgia water supply providers (“Water Supply Providers”), the U.S. Army Corps of Engineers (the “Corps”), and the State of Georgia." [p. 1318, in 514 F .3d 1316]. In the original case (301 F.Supp.2d 26) the Southeastern Federal Power Customers ("Southeastern") sought to "enjoin the Corps from permitting the increased water withdrawals which, Southeastern alleged, impaired the hydropower capacity of the Buford Dam project to Southeastern's financial detriment." "Georgia and the Water Supply Providers moved to intervene in February 2001. On January 9, 2003, after lengthy mediation, Southeastern, the Corps, Georgia and the Water Supply Providers concluded a settlement agreement, which provided for interim ten-year contracts allocating water storage space in Lake Lanier to the Water Supply Providers that, in turn, were to pay higher fees for the storage to compensate Southeastern for lost hydropower. Each interim contract was renewable for an additional ten years and was to “roll-over” into a permanent contract if such were authorized by the Congress or by court order. On January 16, 2003 the parties filed the settlement agreement with the D.C. district court. In February 2003 Florida and Alabama moved to intervene in this action and the motions were granted on October 9, 2003...Florida and Alabama had filed a motion in the Alabama action to enjoin and declare void the settlement agreement, alleging that it violated the 1990 stay of that action...the D.C. district court rejected Florida's and Alabama's challenge and directed that the settlement agreement “is hereby declared valid and approved"...and the court issued an order dismissing the action as moot in light of its approval of the settlement agreement...Florida and Alabama then filed these appeals [400 F.3d 1] challenging the district court's approval of the agreement." [p. 3; in 400 F.3d 1] Then it was ordered that "the district court's February 12, 2004 dismissal order is vacated, the appeals of the November 7, 2003 and February 10, 2004 orders are dismissed for lack of jurisdiction and the case is remanded to the district court." [p. 5; in 400 F.3d 1]. The district court however re-confirmed the validity of the agreement. Alabama and Florida again appealed the validity of the agreement in this current case (514 F .3d 1316)" [p. 1318; in 514 F .3d 1316].
DATE RESOLVED	2/5/08
RESOLUTION DESCRIPTION	This case reverses previous rulings affirming the validity of the DC Agreement in saying the "Agreement provides for a ten or twenty year “temporary” reallocation of over twenty percent (20%) of the water storage in the Lake Lanier reservoir" and "because the Agreement's reallocation of Lake Lanier's storage space constitutes a major operational change on its face and has not been authorized by Congress, we reverse the district court's approval of the Agreement." [p. 1318; in 514 F .3d 1316]
RESOLUTION TYPE	? court order ?
HOLDINGS	"The Court of Appeals, Rogers, Circuit Judge, held that: 1 Alabama and Florida had standing, and 2 settlement agreement constituted “major operational change” under Water Supply Act (WSA), and thus required prior congressional approval." ["Synopsis"]
RESEARCHER	Shannon Bonney
REFERENCE	Westlaw

NOTES	

BASIN	Apalachicola-Chattahoochee-Flint
CITATION	644 F.3d 1160
CASE	In Re: MDL–1824 TRI–STATE WATER RIGHTS LITIGATION. State of Alabama, Alabama Power Company, State of Florida, Plaintiffs–Appellees, v. United States Army Corps of Engineers, John M. McHugh, Secretary of the Army, et al., Defendants–Appellees, Cross–Appellants. State of Georgia, Gwinnett County, Georgia, et al., Plaintiffs–Appellants Cross–Appellees, v. United States Army Corps of Engineers, John M. McHugh, in his official capacity as Secretary of the United States Army, et al., Defendants–Appellees, Cross–Appellants. City of Apalachicola, Florida, Plaintiff–Appellee, v. United States Army Corps of Engineers, John M. McHugh, Secretary of the Army, et al., Defendants–Appellees, Cross–Appellants. Southeast Federal Power Customers, Inc., City of Apalachicola, Florida, Plaintiffs–Appellees, v. United States Army Corps of Engineers, John M. McHugh, Secretary of the Army, et al., Defendants–Appellees Cross–Appellants.
COURT LEVEL	US Federal Courts
COURT TYPE	US Federal Court of Appeals
COURT DESCRIPTION	Eleventh Circuit (Middle District of Florida)
DATE FILED	9/26/09
HISTORY	(reversed and vacated judgment of) 639 F .Supp.2d 1308; (rehearing and rehearing en banc denied by) 451 Fed.Appx. 908; (certiorari denied by) 133 S.Ct. 25 "FL v. GA"; (and certiorari denied by) 133 S.Ct. 25 "AL v. GA"; (and certiorari denied by) 133 S.Ct. 25 "SE Fed Pow v. GA"
RELATED CASES	

PARTY NAMES	THE STATE OF GEORGIA (APPELLANT); THE ATLANTA REGIONAL COMMISSION (APPELLANT); CITY OF ATLANTA, GEORGIA (APPELLANT); FULTON COUNTY (APPELLANT); DEKALB COUNTY (APPELLANT); THE COBB COUNTY-MARIETTA WATER AUTHORITY (APPELLANT); CITY OF GAINESVILLE, GA (APPELLANT); THE LAKE LANIER ASSOCIATION (APPELLANT); GWINNETT COUNTY, GA (APPELLANT); THE UNITED STATES ARMY CORPS OF ENGINEERS (APPELLEE); STATE OF ALABAMA (APPELLEE); STATE OF FLORIDA (APPELLEE); ALABAMA POWER COMPANY (APPELLEE); SOUTHEASTERN FEDERAL POWER CUSTOMERS, INC. (APPELLEE); THURBERT BAKER (INITIAL SERVICE); ANDREW MCFEE THOMPSON (INITIAL SERVICE); C. GRADY MOORE, III (INITIAL SERVICE); CHARLES T. DUMARS (INITIAL SERVICE); CHARLES A. ZDEBSKI (INITIAL SERVICE); CHRISTOPHER HOOD (INITIAL SERVICE); CLAY C. LONG (INITIAL SERVICE); DAVID ACTON FITZGERALD (INITIAL SERVICE); DAVID M. MOORE (INITIAL SERVICE); DEBORAH SHOEMAKE (INITIAL SERVICE); EDDIE LEITMAN (INITIAL SERVICE); EDWARD S. ALLEN (INITIAL SERVICE); EDWARD J. MCGRATH (INITIAL SERVICE); ERIC J. FRISCH (INITIAL SERVICE); GREGORY W. BLOUNT (INITIAL SERVICE); ISAAC BYRD (INITIAL SERVICE); JOHN GREGORY ALLEN (INITIAL SERVICE); J. BARRINGTON VAUGHT (INITIAL SERVICE); JACKSON R. SHARMAN, III (INITIAL SERVICE); JAMES ANTHONY MAYSONETT (INITIAL SERVICE); RUTH ANN STOREY (INITIAL SERVICE); JOHN C. CRUDEN (INITIAL SERVICE); JONATHAN ALAN GLOGAU (INITIAL SERVICE)
PARTY DESCRIPTION	local government; state government; federal government; ? private citizens ? ; utilities; water user groups; businesses; ? recreation interests ? ; regional governments
COMPETING USES	municipal and industrial water supply in Atlanta metropolitan region, v. hydroelectric power production and downstream water needs (Alabama mainly thermoelectric power production and commercial navigation, Florida mainly seafood industry and endangered species and river-based recreation)
FEDERAL AGENCY PARTY?	yes
STATE AGENCY PARTY?	? yes ?
WATER RIGHTS DOCTRINE	riparianism
COMPACT	

ISSUES	(See "issues" for 229 F.R.D. 669, 223 F.R.D. 691, and 514 F .3d 1316 for more complete description of issues leading up to this consolidated case). In this case "the Georgia Parties, Gwinnett County, Georgia, and the United States Army Corps of Engineers (“the Corps”) appeal from the Middle District of Florida's grant of summary judgment in this consolidated suit. The appeal arises from more than 20 years of litigation involving the above parties as well as the States of Alabama and Florida, Alabama Power Company, the City of Apalachicola, Florida, and Southeastern Federal Power Customers, Inc. (“SeFPC”), a consortium of companies that purchase power from the federal government. All of the underlying cases relate to the Corps' authority to operate the Buford Dam and Lake Lanier, the reservoir it created, for local water supply. In its order, the district court found that the Corps' current operation of the Buford Project—Buford Dam and Lake Lanier collectively—had allocated more than 21% of Lake Lanier's storage space to water supply. The court determined that such an allocation exceeded the Corps' statutory authority and ordered the Corps to drastically reduce the quantity of water that it made available for water supply. The court's summary judgment order also affirmed the Corps' rejection of Georgia's 2000 request for additional water supply allocations to meet the needs of the localities through 2030. The court stayed its order for three years to give the parties time to reach a settlement or to approach Congress for additional water supply authority."
DATE RESOLVED	6/26/11
RESOLUTION DESCRIPTION	Previous district court judgment was reversed, all four cases were vacated and remanded to Corps for "further proceedings not consistent with this opinion" [p. 1205]. Subsequent requests for rehearing were denied (however the ACF debate was eventually taken up by the US Supreme Court (135 S.Ct. 701).
RESOLUTION TYPE	? Court order ?
HOLDINGS	"The Court of Appeals held that: 1 Court of Appeals had pendent appellate jurisdiction over other three cases; 2 district court lacked jurisdiction to review claims challenging water withdrawals from reservoir; 3 Corps was authorized to allocate storage in reservoir for water supply; and 4 Corps' denial of Georgia's water supply request was based on clear error of law." ["Synopsis"]
RESEARCHER	Shannon Bonney
REFERENCE	Westlaw
NOTES	

BASIN	Apalachicola-Chattahoochee-Flint
CITATION	135 S.Ct. 701
CASE	State of FLORIDA, plaintiff, v. State of GEORGIA.
COURT LEVEL	US Federal Courts

COURT TYPE	US Supreme Court
COURT DESCRIPTION	
DATE FILED	Nov. 19, 2014
HISTORY	
RELATED CASES	134 S.Ct. 1509; 135 S.Ct. 471
PARTY NAMES	State of Florida (plaintiff); State of Georgia
PARTY DESCRIPTION	state government
COMPETING USES	upstream vs. downstream water uses; municipal and industrial supply (along with associated storage in federal reservoirs) upstream in Atlanta metropolitan region, vs. current and future demands for various water uses downstream in Florida (including water needed by endangered species, water-based recreation businesses, and seafood industry)
FEDERAL AGENCY PARTY?	n/a
STATE AGENCY PARTY?	n/a
WATER RIGHTS DOCTRINE	riparian rights
COMPACT	
ISSUES	It is ordered that Ralph I. Lancaster, Esquire, of Portland, Maine, is appointed *702 Special Master in this case with authority to fix the time and conditions for the filing of additional pleadings, to direct subsequent proceedings, to summon witnesses, to issue subpoenas, and to take such evidence as may be introduced and such as he may deem it necessary to call for. The Special Master is directed to submit Reports as he may deem appropriate. The compensation of the Special Master, the allowances to him, the compensation paid to his legal, technical, stenographic, and clerical assistants, the cost of printing his Reports, and all other proper expenses, including travel expenses, shall be charged against and be borne by the parties in such proportion as the Court may hereafter direct.
DATE RESOLVED	n/a
RESOLUTION DESCRIPTION	n/a
RESOLUTION TYPE	n/a
HOLDINGS	n/a
RESEARCHER	Shannon Bonney
REFERENCE	Westlaw

NOTES	

BASIN	Arkansas River
CITATION	115 S.Ct.1733
CASE	State of Kansas, Plaintiff, v. State of Colorado
COURT LEVEL	Federal
COURT TYPE	Supreme Court
COURT DESCRIPTION	
DATE FILED	
HISTORY	N/A
RELATED CASES	N/A
PARTY NAMES	PLAINTIFFS (State of Kansas), DEFENDANTS (State of Colorado)
PARTY DESCRIPTION	State governments
COMPETING USES	The use of Arkansas river water in conjunction with the rules of the Arkansas River Compact
FEDERAL AGENCY PARTY?	medium
STATE AGENCY PARTY?	High
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	Kansas sued Colorado over what it thought were violations of the Arkansas River Compact, established in 1949. It argued (1) that groundwater well pumping in Colorado significantly lowered the water level; (2) that a reservoir project (Winter Water Storage Program) in Colorado violated the compact; and (3) Colorado's failure to abide by the Trinidad Reservoir Operating Principles Violated the compact. A Special Master found that Colorado's well pumping had materially depleted the water in the river, while suggesting that Kansas had failed to show the effect of the reservoir program, and that the third complaint be dismissed. Both parties filed exceptions to the Special Master's findings. The Supreme Court overruled all exceptions.
DATE RESOLVED	5/15/95

RESOLUTION DESCRIPTION	All exceptions are overruled
RESOLUTION TYPE	
HOLDINGS	
RESEARCHER	Dan Read
REFERENCE	Westlaw
NOTES	

BASIN	Arkansas River
CITATION	121 S.Ct. 2023
CASE	State of Kansas, Plaintiff, v. State of Colorado
COURT LEVEL	Federal
COURT TYPE	Supreme Court
COURT DESCRIPTION	
DATE FILED	Argued 3/19/01
HISTORY	N/A
RELATED CASES	
PARTY NAMES	PLAINTIFFS (State of Kansas), Defendants (State of Colorado)
PARTY DESCRIPTION	State governments
COMPETING USES	The issue is over damages in Kansas due to loss in water resulting from groundwater welling in Colorado
FEDERAL AGENCY PARTY?	med
STATE AGENCY PARTY?	high
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	

ISSUES	Kansas sued Colorado for violations of the Arkansas River Compact, related to groundwater welling. Three Special Master reports ended with the recommendation that damages be measured by Kansas' losses, rather than Colorado's profits, that damages be paid in money rather than water, and that the damages should include prejudgment interest from 1969. Colorado filed four objections: (1) that the recommended award of damages would violate the 11th Amendment, (2) that the damages award should not include prejudgment interest, (3) that the amount of interest awarded is excessive, and (4) that the Special Master improperly credited flawed expert testimony, with the result that Kansas' crop production losses were improperly calculated. Kansas filed an objection submitting that prejudgment interest should be paid from 1950, rather than 1969. All objections are overruled.
DATE RESOLVED	6/11/01
RESOLUTION DESCRIPTION	All objections are overruled
RESOLUTION TYPE	
HOLDINGS	
RESEARCHER	Dan Read
REFERENCE	Westlaw
NOTES	

BASIN	Blue River
CITATION	935 F.2d 1143
CASE	CITY AND COUNTY OF DENVER v. UNITED STATES of America; Trans Mountain Hydro Corporation
COURT LEVEL	Federal
COURT TYPE	United States Court of Appeals
COURT DESCRIPTION	Tenth Circuit
DATE FILED	
HISTORY	1989 WL 128576 (District Court judgment)
RELATED CASES	
PARTY NAMES	CITY AND COUNTY OF DENVER (Appellant) v. UNITED STATES of America; Trans Mountain Hydro Corporation (Appellees)
PARTY DESCRIPTION	federal government; local government; utilities
COMPETING USES	Water reservoir access v. water protection

FEDERAL AGENCY PARTY?	yes (Department of Interior)
STATE AGENCY PARTY?	no
WATER RIGHTS DOCTRINE	
COMPACT	
ISSUES	The City and County of Denver looked to exchange water from reservoirs to be constructed on “western slope” of continental divide for additional water from Colorado River. After the Colorado District Court dismissed the application and the city and county appealed, the Court of Appeals determined that Denver's application was properly dismissed. The responsibility for any loss of priority lies squarely with Denver for failing to obtain the consent of the Secretary of the Interior before filing its application.
DATE RESOLVED	6/10/91
RESOLUTION DESCRIPTION	District Court ruling affirmed
RESOLUTION TYPE	Court of Appeals ruling
HOLDINGS	(1) application by city and county did not seek modification of earlier consent decrees, and therefore abuse of discretion standard of review was inapplicable; (2) consent decree required city and county to obtain consent of Secretary of the Interior before it applied for state adjudication of its exchange rights; and (3) requiring consent of Secretary as precondition to adjudication of exchange rights did not violate Colorado water law.
RESEARCHER	Torre Lavelle
REFERENCE	Westlaw
NOTES	

BASIN	Catawba-Wateree Rivers
CITATION	130 S.Ct. 854
CASE	SOUTH CAROLINA v. NORTH CAROLINA
COURT LEVEL	US Federal Courts
COURT TYPE	US Supreme Court
COURT DESCRIPTION	US Supreme Court

DATE FILED	6/8/07
HISTORY	128 S.Ct. 1117 (Special Master appointed), 128 S.Ct. 1694 (procedural)
RELATED CASES	128 S.Ct. 349 (procedural); 129 S.Ct. 895 (report of Special Master received); 129 S.Ct. 1691 (procedural); 129 S.Ct. 2039 (procedural); 131 S.Ct. 855 (complaint dismissed); 131 S.Ct. 975 (procedural)
PARTY NAMES	PLAINTIFF (South Carolina); RESPONDENT (North Carolina); OTHER (Duke Energy Carolinas, LLC; Catawba River Water Supply Project; City of Charlotte, North Carolina)
PARTY DESCRIPTION	state government; local government; utilities;
COMPETING USES	hydroelectric power; municipal water supply
FEDERAL AGENCY PARTY?	no
STATE AGENCY PARTY?	yes;
WATER RIGHTS DOCTRINE	riparian rights
COMPACT	
ISSUES	South Carolina seeks to attain equitable apportionment of the interstate waters of the Catawba River through a decree. SC claims that NC Environmental Management Commission has issued permits for upstream withdrawals that exceed NC's equitable share to the river. NC wished to add Duke Energy, CRWSP, and City of Charlotte as defendant parties. Special Master granted Duke and CRWSP, but not Charlotte. CRWSP supplies residents of both states with water that is withdrawn from the Catawba in SC.
DATE RESOLVED	decided on 1/20/10
RESOLUTION DESCRIPTION	For this individual case, the Court upheld the Special Master's recommendation to allow Duke Energy and CRWSP to intervene, and deny intervention by City of Charlotte. However, this issue was eventually settled outside of court.
RESOLUTION TYPE	
HOLDINGS	"1 municipal entity which was established as joint venture with encouragement of regulatory authorities in both North and South Carolina, and which was designed to serve water needs of counties in both states, would be allowed to intervene; 2 energy company whose operations had direct effect on flow of water in interstate river that was the subject of equitable apportionment action would also be allowed to intervene; but 3 municipality which, while one of the largest users on whose behalf North Carolina was diverting waters of interstate stream, was not entity from which downstream state was seeking any direct relief in its cause of action to compel equitable apportionment of waters of stream would not be allowed to intervene." [Synopsis]

RESEARCHER	Laura Early
REFERENCE	Westlaw
NOTES	

BASIN	Colorado River
CITATION	WL 16189353
CASE	State of Kansas v. State of Colorado
COURT LEVEL	Federal
COURT TYPE	United States Supreme Court
COURT DESCRIPTION	United States Supreme Court
DATE FILED	
HISTORY	64 S.Ct. 176 (Supreme Court river apportionment five-sixths to Colorado and one-sixth to Kansas)
RELATED CASES	
PARTY NAMES	State of Kansas (Plaintiff); State of Colorado (Defendant)
PARTY DESCRIPTION	State governments; federal government
COMPETING USES	State water interests of Kansas v. Colorado
FEDERAL AGENCY PARTY?	no
STATE AGENCY PARTY?	yes (Arkansas River Compact Administration)
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	Extensive well pumping in Colorado has depleted water resources in Kansas. Through the 1970s Kansas chose not to complain due to the developing Colorado regulatory system that showed promise. It was therefore determined that Kansas had not made an inexcusable delay in making its well claim and therefore Kansas should not be barred from obtaining relief based on its well claim.
DATE RESOLVED	10/3/94

RESOLUTION DESCRIPTION	
RESOLUTION TYPE	Supreme Court ruling
HOLDINGS	(1) Kansas has not been guilty of inexcusable delay in making its well claim, and Colorado has not been prejudiced by Kansas' failure to press its claim earlier. (2) Kansas should not be barred by laches or any other equitable defense, including acquiescence, from obtaining relief based on its well claim.
RESEARCHER	Torre Lavelle
REFERENCE	Westlaw
NOTES	

BASIN	Colorado River
CITATION	244 F.3d 1164
CASE	MOHAVE VALLEY IRRIGATION & DRAINAGE DISTRICT v. Secretary of Interior
COURT LEVEL	Federal
COURT TYPE	United States Court of Appeals
COURT DESCRIPTION	Court of Appeals Ninth Circuit
DATE FILED	
HISTORY	District Court judgment
RELATED CASES	
PARTY NAMES	MOHAVE VALLEY IRRIGATION & DRAINAGE DISTRICT (Plaintiff); Secretary of Interior (Defendant)
PARTY DESCRIPTION	Federal department (Department of the Interior); Regional irrigation and drainage district
COMPETING USES	The interests of a Colorado irrigation district and Department of Interior under the present perfected rights (“PPRs”) to the Colorado River
FEDERAL AGENCY PARTY?	yes (Department of Interior)
STATE AGENCY PARTY?	no
WATER RIGHTS DOCTRINE	
COMPACT	

ISSUES	Mohave Valley Irrigation & Drainage District sued the Secretary of the Department of the Interior for allegedly breaching a contract, which allotted districts annual portions of water from the Colorado River. After the United States District Court for the District of Arizona granted summary judgment to the secretary, the district appealed.
DATE RESOLVED	4/11/01
RESOLUTION DESCRIPTION	District Court ruling affirmed
RESOLUTION TYPE	Court of Appeals ruling
HOLDINGS	Under contract, water delivered to private landowners in district who held present perfected rights (PPRs) to Colorado River water was properly considered in determining whether district was receiving its annual allotment.
RESEARCHER	Torre Lavelle
REFERENCE	Westlaw
NOTES	

BASIN	Gila River
CITATION	920 F.Supp. 1444
CASE	UNITED STATES of America, Plaintiff, and Gila River Indian Community, Plaintiff in Intervention, San Carlos Apache Tribe, Plaintiff in Intervention, and GILA VALLEY IRRIGATION DISTRICT, et al., Defendants.
COURT LEVEL	US Federal Courts
COURT TYPE	US District Courts
COURT DESCRIPTION	Ninth District
DATE FILED	9/18/92
HISTORY	The District Court, 804 F.Supp. 1 (R; Order Affirmed in Part, Vacated in Part by U.S. v. Gila Valley Irr. Dist); 31 F.3d 1428 United States Court of Appeals (Affirmed in part and vacated in part)
RELATED CASES	The District Court, 804 F.Supp. 1 (R; Order Affirmed in Part, Vacated in Part by U.S. v. Gila Valley Irr. Dist); 31 F.3d 1428 United States Court of Appeals (Affirmed in part and vacated in part)
PARTY NAMES	UNITED STATES of America (Plaintiff); Gila River Indian Community (Plaintiff in Intervention); San Carlos Apache Tribe (Plaintiff in Intervention); and GILA VALLEY IRRIGATION DISTRICT, et al. (Defendants)
PARTY DESCRIPTION	federal government; water user groups; regional governments
COMPETING USES	San Carlos Apache Tribe and Gila River Indian Community water use, v. upper valley irrigators

FEDERAL AGENCY PARTY?	no
STATE AGENCY PARTY?	no
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	The San Carlos Apache Tribe and Gila River Indian Community brought complaint surrounding enforcement of water diversion from Gila River. After an appeal was taken that interpreted decree on diversion issues but failed to rule on water quality issues, the District Court then ruled that the Apache Tribe was entitled to injunction to protect its water access against upper valley water degraders. Additionally, the court held that the agreement allowing for upper valley river diversion transfer right unless diverted without regard for rights of Tribe. Lower valley diverters in Gila Crossing District were not given priority call against upstream diverters.
DATE RESOLVED	3/23/96
RESOLUTION DESCRIPTION	Previous district court judgment was affirmed in part and vacated in part on remand. Water apportionment agreements were upheld and enforced accordingly.
RESOLUTION TYPE	Judgment
HOLDINGS	"The District Court held that: (1) Apache Tribe was entitled to injunction to protect its water right against material degradation by upper valley irrigators; (2) Tribe's 1846 priority right was not subject to upper valley irrigators' apportionments but immemorial priority right of Gila River Indian Community was forfeited as to apportioned water; (3) upper valley irrigators were not required to exhaust their apportionments before making priority call; (4) agreement providing for transfer of diversion rights among upper valley irrigators above and below dry river crossing did not violate consent decree unless apportioned water was diverted in disregard of rights of Tribe; (5) upper valley irrigators could divert on an available apportionment even if stored water was not available for release to Community; and (6) lower valley diverters in Gila Crossing District were not entitled to priority call as against upstream diverters."
RESEARCHER	Torre Lavelle
REFERENCE	Westlaw
NOTES	

BASIN	Gunnison River
CITATION	14 P.3d 325

CASE	The BOARD OF the COUNTY COMMISSIONERS OF the COUNTY OF ARAPAHOE, and Union Park Water Authority v. CRYSTAL CREEK HOMEOWNERS' ASSOCIATION; Milton Graves, Charles Hubbard, and Nancy Williams, Trustees
COURT LEVEL	State Court
COURT TYPE	Colorado Supreme Court
COURT DESCRIPTION	Supreme Court of Colorado
DATE FILED	
HISTORY	891 P.2d 952 (Supreme Court affirms in part, reverses in part, and remanded with directions); On remand, the District Court again dismissed the applications. County again appealed, and parties opposed to the application cross-appealed.
RELATED CASES	
PARTY NAMES	The BOARD OF the COUNTY COMMISSIONERS OF the COUNTY OF ARAPAHOE, and Union Park Water Authority, Applicants–Appellants/Cross-Appellees v. The BOARD OF the COUNTY COMMISSIONERS OF the COUNTY OF ARAPAHOE, and Union Park Water Authority, (Applicants–Appellants/Cross-Appellees) v. CRYSTAL CREEK HOMEOWNERS' ASSOCIATION; Milton Graves, Charles Hubbard, and Nancy Williams, Trustees, Objectors (Appellees/Cross–Appellants)
PARTY DESCRIPTION	local government; private citizens; developers
COMPETING USES	County water rights v. Colorado River Storage Protection Act
FEDERAL AGENCY PARTY?	no
STATE AGENCY PARTY?	no
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	Arapahoe County applied for conditional water right decrees in Gunnison River Basin. After the District Court, Water Division No. 4 dismissed the application, the Colorado Supreme Court remanded with directions and the District Court again dismissed the application. The county appealed and the counter parties cross-appealed. The Supreme Court affirmed that those waters were not available for appropriation for junior conditional rights.
DATE RESOLVED	11/20/00
RESOLUTION DESCRIPTION	District Court ruling affirmed

RESOLUTION TYPE	Court of Appeals ruling affirmed
HOLDINGS	(1) the United States had an absolute decree for Colorado River Storage Project Act (CRSPA) reservoirs, and a right to use the water for the decreed purposes, such that those waters were not available for appropriation for junior conditional rights; (2) Bureau of Reclamation's (BUREC) agreement to subordinate 60,000 acre-feet of water in CRSPA reservoirs made such water available only to users within the river basin; (3) BUREC's acknowledgment that it could accommodate a loss of 240,000 acre-feet established a marketable pool that was available for use by in-basin or trans-basin users, but only by contract; (4) challenge to accounting conditions regarding a reservoir was barred by collateral estoppel and res judicata; (5) county failed to prove that it can and will obtain a permit to pump water from a reservoir; and (6) county failed to prove prejudice from water court's allowing a witness to testify as an expert.
RESEARCHER	Torre Lavelle
REFERENCE	Westlaw
NOTES	

BASIN	Gunnison River
CITATION	493 Fed.Appx. 944
CASE	TROUT RANCH, LLC v. COMMISSIONER of INTERNAL REVENUE
COURT LEVEL	US Federal Court of Appeals
COURT TYPE	US Federal Courts
COURT DESCRIPTION	United States Court of Appeals, Tenth Circuit
DATE FILED	
HISTORY	2010 WL 5395108 (District Court judgment)
RELATED CASES	
PARTY NAMES	TROUT RANCH, LLC; Michael D. Wilson, Tax Matters Partner (Appellant); COMMISSIONER of INTERNAL REVENUE (Appellee)
PARTY DESCRIPTION	IRS (Federal agency); Taxpayer
COMPETING USES	The interests of taxpayers in conservation easements v. IRS charitable deduction tax
FEDERAL AGENCY PARTY?	yes (IRS)
STATE AGENCY PARTY?	no

WATER RIGHTS DOCTRINE	
COMPACT	
ISSUES	In 2010, a taxpayer challenged the IRS' denial of claimed charitable deduction for a conservation easement. The taxpayer appealed the decision after the U.S. Tax Court valued the easement at $560,000 rather than the taxpayer offer of $2.2 million. On appeal, the decision was upheld.
DATE RESOLVED	8/16/12
RESOLUTION DESCRIPTION	District Court ruling affirmed
RESOLUTION TYPE	Court of Appeals ruling
HOLDINGS	"In valuing conservation easement, expert appraisers properly overlooked comparable sales and based their finding on the difference in the fair market value of the property before and after the easement was donated."
RESEARCHER	Torre Lavelle
REFERENCE	Westlaw
NOTES	

BASIN	Klamath River
CITATION	64 Fed.Cl.328
CASE	Klamath Irrigation District vs. United States
COURT LEVEL	Federal
COURT TYPE	Court of Federal Claims
COURT DESCRIPTION	Court of Federal Claims
DATE FILED	10/11/01
HISTORY	N/A
RELATED CASES	See other tabs
PARTY NAMES	PLAINTIFFS (Klamath Irrigation District, et al.), DEFENDANTS (the United States), Defendant-Intervenor-Applicants (Pacific Coast Federation of Fishermen's Associations, Institute for Fisheries Resources, the Wilderness Society, Klamath Forest Alliance, Oregon Natural Resources Council, Water Watch of Oregon, Northcoast Environmental Center, and Sierra Club)
PARTY DESCRIPTION	Federal government, environmental groups, water user groups

COMPETING USES	Fishermen benefitting from salmon runs, water districts and farmers needing to irrigate crops
FEDERAL AGENCY PARTY?	high
STATE AGENCY PARTY?	low
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	Water districts and individual farmers brought suit against the United States seeking just compensation under the Fifth Amendment, as well as damages for breach of contract, owing to restrictions placed by the Bureau of Reclamation on the use, for irrigation purposes, of the water resources of the Klamath Basin of southern Oregon and northern California. Fishing and environmental organizations moved to intervene.
DATE RESOLVED	2/28/05
RESOLUTION DESCRIPTION	Fishermen's organizations representing commercial fishermen deriving income from Pacific salmon that spawn in the waters of the Klamath Basin are entitled to intervene as defendant.
RESOLUTION TYPE	
HOLDINGS	
RESEARCHER	Dan Read
REFERENCE	Westlaw
NOTES	

BASIN	Klamath River
CITATION	348 Or. 15
CASE	Klamath Irrigation District, et al., Plaintiffs, v. United States of American and Pacific Coast Federation of Fishermen's Associations, Defendants and State of Oregon, by and through the Oregon Water Resources Department, Intervenor
COURT LEVEL	State Courts
COURT TYPE	Oregon Supreme Court
COURT DESCRIPTION	
DATE FILED	5/8/05

HISTORY	532 F.3d 1376; 75 Fed.Cl. 677
RELATED CASES	64 Fed.Cl. 328; 67 Fed.Cl. 504; 68 Fed.Cl. 119; 69 Fed.Cl. 160; 113 Fed.Cl. 688; 116 Fed.Cl. 117
PARTY NAMES	Klamath irrigation District, Tulelake Irrigation District, Klamath Drainage District, Poe Valley Improvement District, Sunnyside Irrigation District, Klamath Hills District Improvement Co., Midland District Improvement Co., Malin Irrigation District, Enterprise Irrigation District, Pine Grove Irrigation District, Westside Improvement District No. 4, Shasta View Irrigation District, Van Brimmer Ditch Co., Fred A. Robison, Albert J. Robison, Lonny E. Baley, Mark R. Trotman, Baley Trotmann Farms, James L. Moore, Cheryl L. Moore, Daniel G. Chin, Deloris D. Chin, Wong Potatoes, Inc., Michael J. Byrne, Daniel W. Byrne, and Byrne Brothers (Plaintiffs), United States and Pacific Coast Federation of Fisherman's Associations (Defendant), State of Oregon, by and through the Oregon Water Resources Department (Intervenor)
PARTY DESCRIPTION	Federal government, state government, water user groups
COMPETING USES	Water for agriculture vs. endangered species
FEDERAL AGENCY PARTY?	Yes
STATE AGENCY PARTY?	High
WATER RIGHTS DOCTRINE	Prior appropriation
COMPACT	
ISSUES	Irrigation districts and agricultural landowners sued the US for breach of contract and violation of the Taking clause. Oregon Supreme Court took up questions certified by the Federal Court of Appeals, which ask whether or not irrigation districts that use water from a federal reclamation project have an equitable property interest in a water right to which the US holds legal title by state law.
DATE RESOLVED	3/11/10
RESOLUTION DESCRIPTION	Districts and landowners can acquire property interest in water rights acquired by the US. Beneficial use is necessary but not sufficient for groups to acquire water rights. State law recognizes districts' and landowners' property interest in right to use water from the basin.
RESOLUTION TYPE	
HOLDINGS	
RESEARCHER	Dan Read
REFERENCE	Westlaw

NOTES	

BASIN	Klamath River
CITATION	532 F.3d 1376
CASE	Klamath Irrigation District, et al. Plaintiffs-Appellants, v. United States, Defendant-Appelle, and Pacific Coast Federation of Fishermen's Associations, Defendant-Appelle
COURT LEVEL	US Federal Courts
COURT TYPE	United States Court of Appeals
COURT DESCRIPTION	Federal Circuit
DATE FILED	5/8/07
HISTORY	
RELATED CASES	
PARTY NAMES	Klamath irrigation District, Tulelake Irrigation District, Klamath Drainage District, Poe Valley Improvement District, Sunnyside Irrigation District, Klamath Hills District Improvement Co., Midland District Improvement Co., Malin Irrigation District, Enterprise Irrigation District, Pine Grove Irrigation District, Westside Improvement District No. 4, Shasta View Irrigation District, Van Brimmer Ditch Co., Fred A. Robison, Albert J. Robison, Lonny E. Baley, Mark R. Trotman, Baley Trotmann Farms, James L. Moore, Cheryl L. Moore, Daniel G. Chin, Deloris D. Chin, Wong Potatoes, Inc., Michael J. Byrne, Daniel W. Byrne, and Byrne Brothers (Plaintiffs-Appellants), United States (Defendant-Appelle), Pacific Coast Federation of Fisherman's Associations (Defendant-Appelle)
PARTY DESCRIPTION	Federal government, water user groups
COMPETING USES	Water for agriculture vs. endangered species
FEDERAL AGENCY PARTY?	yes
STATE AGENCY PARTY?	low
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	Irrigation districts and agricultural landowners sued the US claiming that a temporary reduction in water available for irrigation was a breach of contract and a violation of the Taking Clause. Appeal of 75 Fed.Cl. 677 was taken.

DATE RESOLVED	7/17/08
RESOLUTION DESCRIPTION	Questions of Oregon property law should be dealt with in Oregon.
RESOLUTION TYPE	
HOLDINGS	
RESEARCHER	Dan Read
REFERENCE	Westlaw
NOTES	

BASIN	Klamath River
CITATION	67 Fed.Cl. 504
CASE	Klamath Irrigation District, et al., Plaintiffs, v The United States, Defendant, Pacific Coast Federation of Fishermen's Associations, Defendant-Intervenor
COURT LEVEL	Federal Courts
COURT TYPE	US Court of Federal Claims
COURT DESCRIPTION	
DATE FILED	10/11/01
HISTORY	No direct history
RELATED CASES	68 Fed.Cl. 119; 69 Fed.Cl.160; 64 Fed.Cl. 677; 75 Fed.Cl.677; 532 F.3d 1376; 345 Or. 638; 348; Or. 15, Or.; 635 F.3d 505; 75 Fed.Cl 677; 635 F.3d 505; 113 Fed.Cl. 688; 116 Fed.Cl. 117
PARTY NAMES	Klamath Irrigation District, et al., (Plaintiffs) The United States, (Defendant) Pacific Coast Federation of Fishermen's Associations (Defendant-Intervenor)
PARTY DESCRIPTION	Federal Government, water user groups
COMPETING USES	A reclamation project reduced the amount of water available for irrigation
FEDERAL AGENCY PARTY?	Yes
STATE AGENCY PARTY?	No

WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	Irrigation water users from the Klamath Basin reclamation project sued the United States because of temporary reductions in the amount of water available for irrigation in 2001. The water available was reduced because the low levels in the river threatened Coho salmon, which are listed on the endangered species act. Water users sought just compensation and damages for breach of the Klamath River Compact, and for just compensation under the 5th amendment eminent domain clause.
DATE RESOLVED	8/31/05
RESOLUTION DESCRIPTION	The United States has property rights to unappropriated water in the Klamath Basin and tributaries, proper remedy for the alleged infringement was in a breach of contract and was unrelated to the taking claim. Because of this, claims by individual farmers are also related to the contract, not the taking clause. Motion granted in part and denied in part.
RESOLUTION TYPE	
HOLDINGS	
RESEARCHER	Dan Read
REFERENCE	Westlaw
NOTES	

BASIN	Klamath River
CITATION	75 Fed.Cl. 677
CASE	Klamath Irrigation District, et al., Plaintiffs, v. The United States, Defendant, Pacific Coast Federation of Fishermen's Associations, Defendant-Intervenor
COURT LEVEL	US Federal Courts
COURT TYPE	US Court of Federal Claims
COURT DESCRIPTION	
DATE FILED	4/21/05
HISTORY	67 Fed.Cl.504; 532 F.3d 1376; 345 Or. 638; 348 Or. 15; 635 F.3d 505; 75 Fed.Cl.677
RELATED CASES	64 Fed.Cl.328; 67 Fed.Cl.504; 68 Fed.Cl. 119; 69 Fed.Cl.160; 113 Fed.Cl.688; 116 Fed.Cl.117
PARTY NAMES	Klamath Irrigation District, et al., (Plaintiffs); The United States, (Defendant) Pacific Coast Federation of Fishermen's Associations, (Defendant-Intervenor)

PARTY DESCRIPTION	Federal Government, water user groups
COMPETING USES	Water available for irrigation, water for endangered species
FEDERAL AGENCY PARTY?	Yes
STATE AGENCY PARTY?	low
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	Irrigation districts and agricultural landowners sued the United States for breach of contract over amount of water available for irrigation, after the Bureau of Reclamation reduced the amount of water available to farmers.
DATE RESOLVED	3/16/07
RESOLUTION DESCRIPTION	Bureau of Reclamation was within its legal bounds because it reduced amount of available water under the ESA for the public good
RESOLUTION TYPE	
HOLDINGS	
RESEARCHER	Dan Read
REFERENCE	Westlaw
NOTES	

BASIN	Klamath River
CITATION	2014 WL 4946996
CASE	Klamath Irrigation District, et al. Plaintiffs, v. The United States, Defendant
COURT LEVEL	US Federal Courts
COURT TYPE	US Court of Federal Claims
COURT DESCRIPTION	
DATE FILED	5/8/07
HISTORY	635 F.3d 505; 348 Or. 15; 532 F.3d 1376; 75 Fed.Cl. 677

RELATED CASES	64 Fed.Cl. 328; 67 Fed.Cl. 504; 68 Fed.Cl. 119; 69 Fed.Cl. 160; 113 Fed.Cl. 688; 116 Fed.Cl. 117
PARTY NAMES	Klamath Irrigation District, et al. (Plaintiffs), The United States (Defendant)
PARTY DESCRIPTION	Federal government, water user groups
COMPETING USES	Water for agriculture vs. endangered species
FEDERAL AGENCY PARTY?	Yes
STATE AGENCY PARTY?	low
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	Irrigation districts and agricultural landowners sued the US for breach of contract and violation of the Taking clause. Individual plaintiffs wanted certification as a class of plaintiffs, including all agricultural landowners who did not get water in 2001.
DATE RESOLVED	10/2/14
RESOLUTION DESCRIPTION	Court ordered that individual plaintiffs cannot form a class
RESOLUTION TYPE	
HOLDINGS	
RESEARCHER	Dan Read
REFERENCE	Westlaw
NOTES	

BASIN	Memphis Sand Aquifer
CITATION	135 S.Ct. 425
CASE	State of MISSISSIPPI, plaintiff, v. State of TENNESSEE, City of Memphis, Tennessee, and Memphis Light, Gas & Water Division.
COURT LEVEL	US Federal Courts
COURT TYPE	Supreme Court

COURT DESCRIPTION	Supreme Court of the United States
DATE FILED	6/6/14
HISTORY	
RELATED CASES	
PARTY NAMES	Mississippi (Plaintiff); Memphis Light, Gas & Water Division (Respondent); City of Memphis, Tennessee (Respondent); Tennessee (Respondent)
PARTY DESCRIPTION	local government; state government; utilities
COMPETING USES	ground water use for municipal supply in Tennessee (i.e. Memphis) v. ground water use for all purposes desired by Mississippi
FEDERAL AGENCY PARTY?	unknown
STATE AGENCY PARTY?	unknown
WATER RIGHTS DOCTRINE	riparian rights (modified)
COMPACT	
ISSUES	Mississippi is suing Tennessee over withdrawals from the Memphis Sands Aquifer, which allegedly deplete ground water in sections of aquifer underlying Mississippi. If this case is heard, the Supreme Court of the United States will have to determine if the doctrine of equitable apportionment is to be applied to interstate aquifers (as it's only been applied to surface waters previously).
DATE RESOLVED	n/a
RESOLUTION DESCRIPTION	n/a
RESOLUTION TYPE	n/a
HOLDINGS	n/a
RESEARCHER	Shannon Bonney
REFERENCE	Westlaw; Docket (online at SCOTUS website: http://www.supremecourt.gov/Search.aspx?FileName=/docketfiles/22o143.htm)
NOTES	

BASIN	Memphis Sand Aquifer
CITATION	570 F.3d 625
CASE	Jim HOOD, Attorney General, ex rel. State of MISSISSIPPI, Acting for Itself and Parens Patriae for and on behalf of the People of the State of Mississippi, Plaintiffs–Appellants, v. The CITY OF MEMPHIS, TENNESSEE; Memphis Light Gas & Water Division, Defendants–Appellees.
COURT LEVEL	US Federal Courts
COURT TYPE	US Federal Court of Appeals
COURT DESCRIPTION	Fifth Circuit
DATE FILED	2/1/05
HISTORY	(affirmed judgment of) 533 F.Supp.2d 646; (certiorari denied by) 130 S.Ct. 1319
RELATED CASES	
PARTY NAMES	Jim HOOD, Attorney General, ex rel. State of MISSISSIPPI, Acting for Itself and Parens Patriae for and on behalf of the People of the State of Mississippi (Plaintiffs–Appellants); The CITY OF MEMPHIS, TENNESSEE (Defendants–Appellees.); Memphis Light Gas & Water Division (Defendants–Appellees)
PARTY DESCRIPTION	local government; state government; utilities
COMPETING USES	water for municipal supply in Memphis, Tennessee v. water use in De Soto County, Mississippi
FEDERAL AGENCY PARTY?	no
STATE AGENCY PARTY?	? No ? (none specified)
WATER RIGHTS DOCTRINE	riparian rights (modified)
COMPACT	

ISSUES	"In this lawsuit, the state of Mississippi seeks damages from the City of Memphis and Memphis Light, Gas and Water (“MLGW”) (collectively, “Memphis”), for the alleged conversion of groundwater in the Memphis Sands Aquifer (the “Aquifer”). The district court dismissed Mississippi's lawsuit without prejudice, holding that Tennessee is an indispensable party to the suit and that the court was without power to join Tennessee...The Aquifer is located beneath portions of Tennessee, Mississippi, and Arkansas. There is no interstate compact governing use of the Aquifer's water, and thus no specific volumes of groundwater from the Aquifer have been apportioned to Mississippi, Tennessee, or Arkansas...The Aquifer is the primary water source for both DeSoto County, Mississippi, and the city of Memphis, Tennessee, which lies just across the state line from DeSoto County. Mississippi seeks past and future damages, as well as equitable relief, related to Memphis's allegedly wrongful appropriation of groundwater from the Aquifer.1 Mississippi alleges that part of the groundwater that Memphis pumps from the Aquifer is Mississippi's sovereign property and that the state must therefore be compensated...MLGW, a division of the City of Memphis, owns and operates one of the largest artesian water systems in the world. It is responsible for providing gas, electricity, and water to its residential, business, governmental, and other customers, who are primarily citizens of Memphis. Although three of its groundwater well fields are located near the Tennessee border, all of MLGW's wells are located within Tennessee, and Memphis and Tennessee contend that this municipal water program operates under the direction and control of Tennessee law...Mississippi asserts that MLGW's groundwater pumping has created an underground “cone of depression” centered under Memphis and extending into Mississippi. Mississippi states that this cone of depression causes groundwater that would otherwise lie beneath Mississippi to flow across the border and into the cone under Tennessee, and thus become available to be pumped by Memphis. Mississippi argues that due to the growth of Memphis's water system the Aquifer is being drawn down at a higher rate than it is being replenished, thus causing water levels to drop...Mississippi filed its first complaint against Memphis in February 2005. In June 2007, Memphis moved for judgment on the pleadings, again arguing that Tennessee was an indispensable party to the suit. Memphis also moved for partial summary judgment on several of Mississippi's claims. In September 2007, the court denied the motions. In late January 2008, shortly before the bench trial was to start, the district court announced that it had decided sue sponte to revisit the issue of Tennessee's possible status as an indispensable party and thus the court's subject-matter jurisdiction. After briefing from the parties and oral argument, the district court dismissed the suit for failure to include Tennessee, an indispensable party. Mississippi appeals." [627-628]
DATE RESOLVED	6/5/09
RESOLUTION DESCRIPTION	The previous district court decision was affirmed (see holdings), which essentially meant that this case was interstate in nature and as such fell under the jurisdiction of the Supreme Court of the United States.
RESOLUTION TYPE	judgment
HOLDINGS	The Court of Appeals, Carl E. Stewart, Circuit Judge, held that: 1 Tennessee was necessary and indispensable party, and 2 suit fell within original and exclusive jurisdiction of United States Supreme Court. Affirmed.
RESEARCHER	Shannon Bonney

REFERENCE	Westlaw
NOTES	

BASIN	Missouri River
CITATION	330 F.3d 1014
CASE	South Dakota v. Ubbelohde
COURT LEVEL	United States Federal Court
COURT TYPE	Court of Appeals
COURT DESCRIPTION	Eighth Circuit
DATE FILED	
HISTORY	Cert. Denied 541 U.S. 987
RELATED CASES	
PARTY NAMES	State of South Dakota; State of North Dakota; State of Iowa; State of Nebraska; US Army Corps of Engineers; MO-ARK Association
PARTY DESCRIPTION	State Governments, Federal Agency, Non-governmental entity representing interests in the Basin, various private parties
COMPETING USES	Withholding water in reservoirs for the benefit of the states in which those reservoirs are located during drought times; maintaining downstream flows for the benefit of states downstream of the reservoirs.
FEDERAL AGENCY PARTY?	yes [xxx]
STATE AGENCY PARTY?	yes [xxx]
WATER RIGHTS DOCTRINE	Prior Appropriation
COMPACT	

ISSUES	Review of the decisions of three district courts involving the authority of the USACE to release water from reservoirs in the Missouri River Basin during drought times. Both the North Dakota and South District Courts issued injunctions prohibiting the Corps from releasing water from reservoirs within those states. The Nebraska District Court issued an order requiring the Corps to maintain downstream flows. This appeal followed in order to resolve the conflict between the district court opinions. The Eighth Circuit held that the Corps' decision to release from the reservoirs was within its discretion because it was authorized under the Flood Control Act of 1944, was consistent with the Corps' Master Manual for the Main Stem of the Missouri River, and was not arbitrary and capricious. In addition the Eighth Circuit held that the Nebraska Court did not err when it held that the Master Manual was binding as to the Corps, but the Court explicitly avoided the question whether unforeseen circumstances permit the Corps to deviate from the Master Manual.
DATE RESOLVED	6/4/03
RESOLUTION DESCRIPTION	North Dakota and South Dakota District Courts Reversed. Nebraska District Court Affirmed. Remanded for proceedings consistent with the opinion.
RESOLUTION TYPE	
HOLDINGS	
RESEARCHER	Brian Easley
REFERENCE	Westlaw
NOTES	

BASIN	Platte River
CITATION	69 P.3d 50
CASE	SIMPSON v. BIJOU IRRIGATION CO.
COURT LEVEL	State Courts
COURT TYPE	State Supreme Court
COURT DESCRIPTION	Colorado Supreme Court
DATE FILED	
HISTORY	
RELATED CASES	235 P.3d 1061, Colo.(distinguished by, energy and utilities)

PARTY NAMES	APPELLANTS (Hal D. SIMPSON, State Engineer), APPELLEES (BIJOU IRRIGATION CO.; Bijou Irrigation District; Ducommun Business Trust; Farmers Highline Canal & Reservoir Company; City of Lafayette; Mountain Mutual Reservoir Co; City of Westminster; Varra Companies, Inc.; Sand Land Inc.; Pasquale Varra; Centennial Water and Sanitation District; City of Boulder; Center of Colorado Water Conservancy District; Peterson Ditch Co.; City of Brighton; City of Aurora; City of Englewood; Magness Land Holdings, LLC.; Magness Platteville, LLC; Platteville LLC; South Reservation Ditch Co.; Central Colorado Water Conservancy District and the Ground Water Management Subdistrict of the Central Water Conservancy District; Lower South Platte Water Conservancy District; City of Greeley; Fort Morgan Reservoir & Irrigation Co.; North Sterling Irrigation District; the Harmony Ditch Co.; Jackson Lake Reservoir and Irrigation Co.; Anderson Ditch Co.; Fort Morgan Water Co., Ltd; Liddle Ditch Co; City and County of Denver; Farmers Reservoir & Irrigation Co; Henrylyn Irrigation District; Groundwater Appropriators of the South Platte River Basin, Inc.; Riverside Irrigation District; Riverside Reservoir and Land Company; Lower Platte & Beaver Canal Company; Highland Ditch Company; Water Users Association of District No. 6; City of Sterling; Bruce Gerk and Donald Sellman Shareholders In Petersen Ditch Company and Julesburg Irrigation District; City of Thornton; City of Blackhawk)
PARTY DESCRIPTION	local government; state government; private citizens; utilities; water user groups; businesses; agriculture groups; conservation districts
COMPETING USES	groundwater withdrawals and surface flows
FEDERAL AGENCY PARTY?	no
STATE AGENCY PARTY?	yes, State Engineer
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	The State Engineer proposed rules and regulations to uphold The South Platte River Compact, but this case questions whether State Engineer has the authority to do this. (Seems slightly procedural, but about authority to allocate water.) The State Engineer's proposed rules regarded replacement of groundwater depletion to protect senior water rights and ensure adequate flow in the South Platte River to uphold the South Platte River Compact.
DATE RESOLVED	4/30/03
RESOLUTION DESCRIPTION	The court found that the State Engineer did not have full authority through the South Platte River Compact to enforce the proposed regulations. The case was remanded back to the trial courts.
RESOLUTION TYPE	

HOLDINGS	"After granting expedited review, the Supreme Court, Rice, J., held that: (1) State Engineer exceeded his water rule power in promulgating the rules, to the extent the rules exceeded statutory limitations on State Engineer's authority to grant temporary approval of replacement plans; (2) State Engineer had authority to promulgate rules to enforce terms of the South Platte River Compact, but State Engineer was still constrained by statutory restrictions imposed on his water rule power; and (3) State Engineer's proposed rules could not take effect until all protests were judicially heard and resolved."
RESEARCHER	Laura Early
REFERENCE	Westlaw
NOTES	

BASIN	Platte River
CITATION	974 F.Supp.2d 1264
CASE	FRENCHMAN CAMBRIDGE IRRIGATION DISTRICT v. HEINEMAN
COURT LEVEL	US Federal Courts
COURT TYPE	US District Courts
COURT DESCRIPTION	DISTRICT OF NEBRASKA (OMAHA)
DATE FILED	12/28/12
HISTORY	
RELATED CASES	
PARTY NAMES	PLAINTIFFS (FRENCHMAN CAMBRIDGE IRRIGATION DISTRICT, a Nebraska Political Subdivision; Bostwick Irrigation District in Nebraska, a Nebraska Political Subdivision; Dale Cramer, Jay Schilling, Steve Henry); DEFENDANTS (Dave HEINEMAN, Governor of Nebraska; Brian Dunnigan, Director, Nebraska Dept. of Natural Resources; Upper Republican Natural Resources District, A Nebraska Political Subdivision; N–Corpe, An Interlocal Cooperative; United States Of America, United States Department of Interior, Bureau of Reclamation; Kenneth Salazar, Secretary of Interior; Michael Connor, Commissioner of Bureau of Reclamation; and Michael Ryan, Director, Great Plains Region, Bureau of Reclamation)
PARTY DESCRIPTION	state government; federal government; private citizens; water user groups
COMPETING USES	irrigation and groundwater pumping to satisfy interstate water allocation compact
FEDERAL AGENCY PARTY?	yes, US Department of Interior- Bureau of Reclamation
STATE AGENCY PARTY?	yes, Nebraska Department of Natural Resources

WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	Plaintiffs allege that defendants plan to pump groundwater to streams to satisfy interstate compact allocation requirements. Plaintiffs wish to stop this action because of potential disruptions of inflows of groundwater within the irrigation district.
DATE RESOLVED	9/24/13
RESOLUTION DESCRIPTION	The action was dismissed for procedural reasons.
RESOLUTION TYPE	
HOLDINGS	"1 McCarran Act did not provide waiver of sovereign immunity for action;2 statute that provided jurisdiction over quiet title claims against United States did not provide waiver of sovereign immunity for action;3 federal government was not obligated to prevent Upper Republican River Natural Resources District (NRD) from over pumping water to detriment of Middle and Lower Republican River NRDs;4 Tucker Act could not provide basis for jurisdiction for action;5 Administrative Procedure Act did not provide basis for jurisdiction for action; and6 prudence counseled court to decline to exercise supplemental jurisdiction over State and Natural Resources District (NRD) defendants." [Synopsis]
RESEARCHER	Laura Early
REFERENCE	Westlaw
NOTES	

BASIN	Platte River
CITATION	113 S.Ct. 1689
CASE	NEBRASKA v. WYOMING
COURT LEVEL	US Federal Courts
COURT TYPE	US Supreme Court
COURT DESCRIPTION	US Supreme Court
DATE FILED	argued on 1/13/93
HISTORY	115 S.Ct. 1933 (appears to be procedural)
RELATED CASES	73 S.Ct. 1041, 122 S.Ct. 420, 124 S.Ct. 598 (distinguished by; Potomac)

PARTY NAMES	PLAINTIFF(State of Nebraska), DEFENDANT(States of Wyoming and Colorado)
PARTY DESCRIPTION	state government
COMPETING USES	development projects (reservoir/municipal supply/electric plant and irrigation system) upstream v. water storage in Inland Lakes for agricultural use
FEDERAL AGENCY PARTY?	yes
STATE AGENCY PARTY?	yes
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	In 1945, decree was created to implement Court's mandate for water allocation between Colorado, Wyoming, and Nebraska. "Initiating this original action in 1986, Nebraska petitioned the Court for an enforcement order and injunctive relief under the decree's “reopener” provision, alleging that Wyoming was violating or threatening to violate the decree by virtue of developments on two North Platte tributaries, Deer Creek and the Laramie River, and objecting to certain of Wyoming's actions with respect to the Inland Lakes in Nebraska. Wyoming answered and counterclaimed, arguing, essentially, that Nebraska was circumventing the decree by demanding and diverting water from above the Tri-State Dam for uses below Tri-State that are not recognized in the decree."[1691, 584] Special Master appointed.
DATE RESOLVED	decided on 4/20/93
RESOLUTION DESCRIPTION	Special Master's recommendations partially granted: Inland Lakes priority date was not changed and canal diversion limitations were no 'absolute ceilings' and Nebraska could divert its allocation as it wishes
RESOLUTION TYPE	
HOLDINGS	"1. No exceptions having been filed to the Master's recommendation that the Court deny the intervention motions, that recommendation is adopted." [1694] "2. The Master's recommended dispositions of the summary judgment motions are adopted, and the parties' exceptions are overruled." [1694-1701]
RESEARCHER	Laura Early
REFERENCE	Westlaw
NOTES	

BASIN	Platte River

CITATION	122 S.Ct. 420
CASE	NEBRASKA v. WYOMING and COLORADO
COURT LEVEL	US Federal Courts
COURT TYPE	US Supreme Court
COURT DESCRIPTION	US Supreme Court
DATE FILED	
HISTORY	73 S.Ct. 1041
RELATED CASES	115 S.Ct. 1933 (appears to be procedural), 113 S.Ct. 1689
PARTY NAMES	PLAINTIFF(State of Nebraska), DEFENDANT(States of Wyoming and Colorado)
PARTY DESCRIPTION	state government
COMPETING USES	development projects (reservoir/municipal supply/electric plant and irrigation system) upstream v. water storage in Inland Lakes for agricultural use
FEDERAL AGENCY PARTY?	yes
STATE AGENCY PARTY?	yes
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	Final Report from the Special Master received and ordered filed. Modified the Decree written in 1945 and amended in 1953 with limitations on water diverted and exported from the North Platte in Colorado, and with limitations on consumptive uses in Wyoming, and storage in inland lakes reservoirs. The Decree includes seasonal provisions, and includes provisions for allocation modifications 10 years in the future.
DATE RESOLVED	11/13/01
RESOLUTION DESCRIPTION	The original Decree from 1953 was modified.
RESOLUTION TYPE	
HOLDINGS	
RESEARCHER	Laura Early
REFERENCE	Westlaw

NOTES	

BASIN	Potomac River
CITATION	124 S.Ct. 598
CASE	Virginia v. Maryland
COURT LEVEL	US Federal Courts
COURT TYPE	US Supreme Court
COURT DESCRIPTION	US Supreme Court
DATE FILED	Argued on 10/7/03
HISTORY	none
RELATED CASES	(in regards to state boundaries, distinguished by) 128 S.Ct. 1410;
PARTY NAMES	PLAINTIFF (Commonwealth of Virginia), DEFENDANT (State of Maryland)
PARTY DESCRIPTION	state government
COMPETING USES	residential water use, state's authority to govern water withdrawals and waterway construction
FEDERAL AGENCY PARTY?	no
STATE AGENCY PARTY?	yes (Maryland Department of the Environment)
WATER RIGHTS DOCTRINE	riparian rights
COMPACT	
ISSUES	The interstate boundary between Virginia and Maryland is set at the low water mark on Virginia's shore of the Potomac River, per the Black-Jenkins Award. Virginia must obtain a permit for any water withdrawals or construction projects beyond that point from the Maryland Department of Environment (MDE). In 1996, MDE denied a permit to the Fairfax County, VA Water Authority for construction of a new water intake structure. Virginia then filed suit claiming that Maryland could not require permits for water withdrawal or waterway construction by Virginia.
DATE RESOLVED	Decided on 12/9/03

RESOLUTION DESCRIPTION	The Special Master recommended that the 1785 Compact regarding the Potomac River and the Black-Jenkins Award do not limit Virginia's regulated riparian rights, and Maryland cannot require a permit for Virginia to exercise their riparian rights for water withdrawal or waterway construction. Maryland's objections were overruled, and relief was granted to Virginia.
RESOLUTION TYPE	
HOLDINGS	"The Supreme Court, Chief Justice Rehnquist, held that: (1) Maryland lacked authority to regulate project, and (2) Virginia had not acquiesced in Maryland's regulation of project." ["Synopsis"]
RESEARCHER	Laura Early
REFERENCE	Westlaw
NOTES	

BASIN	Red River
CITATION	656 F.3d 1251
CASE	City of Hugo v. Nichols
COURT LEVEL	Federal
COURT TYPE	Court of Appeals
COURT DESCRIPTION	Tenth Circuit
DATE FILED	
HISTORY	(District Court Judgment) 2010 WL 1816345; (Appellate Court Decision) 656 F.3d 1251; (Cert. Denied) 132 S.Ct. 1744.
RELATED CASES	133 S.Ct. 2120; 545 F.3d 906
PARTY NAMES	City of Hugo, Hugo Municipal Authority, City of Irving, Jess Mark Nichols; Rudolf John Herrmann; Ed Fite; Ford Drummond; Jack W. Keeley; Kenneth W. Knowles; Linda Lambert; Lonnie Farmer; Richard Sevenoaks, in their official capacity as members of the Oklahoma Water Resources Board and the Oklahoma Water Conservation Storage Commission
PARTY DESCRIPTION	City Government, State Agency, Members of a State Agency in their individual capacities,
COMPETING USES	The interests of city governments in buying and selling water rights across state lines versus the ability of the Oklahoma legislature to prevent such a sale pursuant to its ability to regulate water rights within its state boundaries.
FEDERAL AGENCY PARTY?	no
STATE AGENCY PARTY?	yes

WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	The City of Hugo Oklahoma and the City of Irving Texas contracted for the sale of water Hugo possesses pursuant to permits issued by the Oklahoma Water Resources Board. Hugo and Irving brought suit to enjoin the enforcement of Oklahoma statutes prohibiting Hugo from selling its water to Irving. The Plaintiffs-Appellants alleged that the Oklahoma statutes violated the Dormant Commerce Clause of the Constitution.
DATE RESOLVED	9/7/11
RESOLUTION DESCRIPTION	District Court Judgment vacated and remanded for dismissal for lack of jurisdiction
RESOLUTION TYPE	Appeals Court Decision
HOLDINGS	1) City of Hugo cannot bring a Supremacy Clause claim against its parent state 2) Political Subdivision doctrine is not applicable when City is suing a state other than its parent state 3) Claim brought by City of Irvin was not redressable under the Dormant Commerce Clause
RESEARCHER	Brian Easley
REFERENCE	Westlaw
NOTES	

BASIN	Red River
CITATION	545 F.3d 906
CASE	Tarrant Regional Water District v. Sevenoaks
COURT LEVEL	Federal
COURT TYPE	Court of Appeals
COURT DESCRIPTION	Tenth Circuit
DATE FILED	
HISTORY	(District Court Judgment) 2007 WL 3226812; (Appeals Court Decision) 545 F.3d 906
RELATED CASES	113 S.Ct. 2120

PARTY NAMES	Tarrant Regional Water District (Plaintiff- Appellee); Richard Sevenoaks, Kenneth K. Knowles, Jack W. Keely, Ed Fite, Linda Lambert, Ford Drummond, Lonnie Farmer, Jess Mark Nichols, Rudolf John Herrmann, in their official capacities as members of the Oklahoma Water Resources Board (OWRB) and the Oklahoma Water Conservation Storage Commission (Defendants–Appellants).
PARTY DESCRIPTION	State Agencies, Members of the Oklahoma Water Resources Board in their individual capacities
COMPETING USES	The interests of Texas and Oklahoma under the Red River Compact
FEDERAL AGENCY PARTY?	no
STATE AGENCY PARTY?	yes
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	This case did not consider substantive issues of water law. "TRWD filed suit in federal district court, alleging that Oklahoma law unconstitutionally prevents TRWD from appropriating or purchasing water located in Oklahoma. The defendants filed a motion to dismiss, claiming in part that the matter was not a ripe 'case or controversy,' that the defendants were immune from suit under the Eleventh Amendment, and that the court should abstain under the doctrine of Younger v. Harris, 401 U.S. 37, 91 S.Ct. 746, 27 L.Ed.2d 669 (1971). The district court denied the motion, and the defendants now appeal."545 F.3d 908-909.
DATE RESOLVED	10/27/08
RESOLUTION DESCRIPTION	Affirmed in part, dismissed in part
RESOLUTION TYPE	Appeals Court Decision
HOLDINGS	1) The Plaintiff's challenge was ripe 2) OWRB board members are not protected from suit by the 11th Amendment 3) Denial of abstention was not reviewable
RESEARCHER	Brian Easley
REFERENCE	Westlaw
NOTES	

BASIN	Red River

CITATION	133 S.Ct. 2120
CASE	Tarrant Regional Water District v. Herrmann
COURT LEVEL	Federal
COURT TYPE	United States Supreme Court
COURT DESCRIPTION	United States Supreme Court
DATE FILED	
HISTORY	(District Court judgment) 2009 WL 3922803; (District Court Judgment) 2010 WL 2817220;(Affirming the District Court Judgment) 656 F.3d 1222; (Granting Cert.) 133 S.Ct. 831; (Affirming Appellate Court Ruling) 133 S.Ct. 2120
RELATED CASES	
PARTY NAMES	Tarrant Regional Water District (petitioner); Rudolf John Herrmann
PARTY DESCRIPTION	Regional Water District (state agency);
COMPETING USES	The interests of Texas and Oklahoma under the Red River Compact
FEDERAL AGENCY PARTY?	no
STATE AGENCY PARTY?	yes
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	Because of substantial growth in north central Texas, the Tarrant Regional Water District (a state agency) sought to negotiate with the Chickasaw and Choctaw Nations and the State of Oklahoma to purchase additional water. These negotiations failed, so Tarrant then decided to apply for a water resource permit from the Oklahoma Water Resources Board. Tarrant applied for the permit knowing that several Oklahoma statutes work together to effectively, though not explicitly, prevent the issuing of a permit to an out of state user. Accordingly Tarrant simultaneously filed suit in the Federal District Court. Tarrant contends that the statutes violate Federal law, specifically the congressionally approved Compact, and the Dormant Commerce Clause of the Constitution. Tarrant argues that under the Compact Texas has the right to take water from within Oklahoma's borders in order to meet its entitlement.
DATE RESOLVED	6/13/13
RESOLUTION DESCRIPTION	Court of Appeals ruling affirmed

RESOLUTION TYPE	Supreme Court ruling
HOLDINGS	1) The congressionally-approved Red River Compact did not give Texas the right to cross state lines in order to divert water from Oklahoma; 2) The Oklahoma water statutes did not violate the Dormant Commerce Clause
RESEARCHER	Brian Easley
REFERENCE	Westlaw
NOTES	

BASIN	Republican River
CITATION	135 S.Ct. 1042
CASE	State of Kansas, Plaintiff v. States of Nebraska and Colorado
COURT LEVEL	Federal
COURT TYPE	Supreme Court
COURT DESCRIPTION	
DATE FILED	Argued 10/14/14
HISTORY	N/A
RELATED CASES	
PARTY NAMES	Plaintiff (State of Kansas), Defendant (States of Nebraska and Colorado)
PARTY DESCRIPTION	State governments
COMPETING USES	The disagreement was originally over Nebraska's pumping of ground water, in violation of the Compact. It became an issue of adherence to the Compact and the procedures put in place to ensure such adherence.
FEDERAL AGENCY PARTY?	Med
STATE AGENCY PARTY?	High
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	

ISSUES	Kansas and Nebraska had entered into a settlement agreement to promote compliance with the Republican River Compact, but Kansas and Nebraska brought new claims against each other arising from the implementation of that settlement. The settlement established mechanisms to accurately measure water and promote compliance with the Compact. In 2007, Kansas petitioned the Supreme Court for monetary and injunctive relief, claiming that Nebraska had substantially exceeded its water allocation. Nebraska responded that the procedures for measuring water improperly charged the state for using imported water and requested that the procedures be modified. A special master concluded that Nebraska had knowingly failed to comply with the Compact, and recommended that Nebraska disgorge a portion of its gains and pay damages for Kansas's loss, while also recommending denying Kansas's request for an injunction, and reforming the procedures.
DATE RESOLVED	2/24/15
RESOLUTION DESCRIPTION	The Supreme Court held that Nebraska violated the Compact by exposing Kansas to a substantial risk of receiving less water, ordered Nebraska to disgorge $1.8 million, or its additional gain from its breach of the Compact through its consumption of 17% more water than its proper share, was a fair and equitable remedy, Kansas was not entitled to injunction ordering Nebraska to comply with the Compact and a related settlement, and the procedures, which inadvertently charged Nebraska for using water imported from outside the Republican River basin for irrigation in the basin, could be amended to ensure that Nebraska's consumption of such imported water would not count toward its allotment under the Compact.
RESOLUTION TYPE	
HOLDINGS	
RESEARCHER	Dan Read
REFERENCE	Westlaw
NOTES	

BASIN	Rio Grande
CITATION	115 N.M. 229
CASE	ELEPHANT BUTTE IRRIGATION DISTRICT, Plaintiff–Appellee, v. The REGENTS OF NEW MEXICO STATE UNIVERSITY, Intervenors–Defendants–Appellants, v. UNITED STATES of America, Defendant–Appellant, v. Eluid L. MARTINEZ, New Mexico State Engineer, The City of El Paso, and All Claimants, Known and Unknown, to Water of the Rio Grande Stream System Between Elephant Butte Reservoir and the Texas State Line, Defendants. ELEPHANT BUTTE IRRIGATION DISTRICT, Plaintiff–Appellant, v. Eluid L. MARTINEZ, New Mexico State Engineer, Defendant–Appellee, v. UNITED STATES of America, et al., Defendants.
COURT LEVEL	State Courts
COURT TYPE	Court of Appeals

COURT DESCRIPTION	New Mexico Court of Appeals
DATE FILED	9/12/86 [date original complaint filed]
HISTORY	(certiorari denied by) 115 N.M. 359
RELATED CASES	[later appealed by United States in 289 F.3d 1170]
PARTY NAMES	ELEPHANT BUTTE IRRIGATION DISTRICT (Plaintiff-Appellee); The REGENTS OF NEW MEXICO STATE UNIVERSITY (Intervenors-Defendants-Appellants); UNITED STATES of America (Defendant-Appellant); Eluid L. MARTINEZ, New Mexico State Engineer (defendant); The City of El Paso (defendant); All Claimants, Known and Unknown, to Water of the Rio Grande Stream System Between Elephant Butte Reservoir and the Texas State Line (defendant); ELEPHANT BUTTE IRRIGATION DISTRICT (Plaintiff-Appellant); Eluid L. MARTINEZ, New Mexico State Engineer (Defendant-Appellee); UNITED STATES of America, et al., (Defendants).
PARTY DESCRIPTION	local government; state government; federal government; ? Private citizens? (all unknown claimants); water user groups; agriculture groups; ? Other interest groups ? (The Regents of New Mexico State University)
COMPETING USES	The Elephant Butte Irrigation District wants to obtain a superior water right (which gives them priority to water during shortages) from Rio Grande and hydrologically connected aquifers for use by farmers in the District. It requested adjudication to distinguish its water rights as superior to competing demands from municipalities (e.g. El Paso) and other claimants in New Mexico and Texas (including farmers and municipalities). [UPDATE BECAUSE MEXICO OWES US WATER FROM RIO GRANDE IN EXCHANGE FOR WATER US PROVIDES MEXICO FROM COLORADO RIVER, and MEXICO IS BEHIND ON ITS WATER DELIVERIES]
FEDERAL AGENCY PARTY?	? Yes ? (doesn't name agency, but Bureau of Reclamation responsible for Rio Grande Project)
STATE AGENCY PARTY?	? Yes ? (Office of the State Engineer)
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	

ISSUES	"These three appeals arise out of an attempted water rights adjudication of the Rio Grande between Elephant Butte Dam and the New Mexico/Texas state line. The suit was initiated by Elephant Butte Irrigation District (EBID), who named as defendants the state engineer, the United States, the City of El Paso, and all known and unknown claimants to the disputed water. In Court of Appeals No. 13,371, appellant United States contends that the district court should have granted its motion to dismiss because the federal statute waiving sovereign immunity for state water adjudications, 43 U.S.C.S. § 666 (1980) (McCarran Amendment) does not permit joinder unless the entire main stem of the Rio Grande in New Mexico is adjudicated. The United States further argues that, even if joinder is permissible, the New Mexico stream adjudication statute, NMSA 1978, Section 72–4–17 (Repl.1985), and SCRA 1986, 1–019 (Repl.1992), require dismissal. In Court of Appeals No. 13,450, an interlocutory appeal, appellant EBID argues that the dismissal of the state engineer as a party was improper because the district court misinterpreted applicable venue statutes. Finally, in Court of Appeals No. 13,364, an interlocutory appeal, appellant Regents of New Mexico State University (NMSU) contends that the district court should have granted its motion to dismiss for lack of an indispensable party as a result of the dismissal of the state engineer. We hereby consolidate the three appeals, affirm the denial of the United States' motion to dismiss, and reverse the district court's dismissal of the state engineer. As a result of our disposition, it is not necessary to reach NMSU's appeal." [230]
DATE RESOLVED	1/14/93
RESOLUTION DESCRIPTION	"Affirmed in part and reversed in part and remanded" [Westlaw description]. "We affirm the district court's order denying the United States' motion to dismiss and reverse the district court's order dismissing the state engineer as a party" [236]
RESOLUTION TYPE	judgment
HOLDINGS	
RESEARCHER	Shannon Bonney
REFERENCE	Westlaw; Justia;
NOTES	

BASIN	Rio Grande
CITATION	141 N.M. 1
CASE	STATE of New Mexico ex rel. OFFICE OF the STATE ENGINEER and Pecos Valley Artesian Conservancy District, Plaintiffs–Appellees, v. L.T. LEWIS et al., Defendants–Appellants, and United States of America and Carlsbad Irrigation District, Defendants–Appellees.
COURT LEVEL	State Courts
COURT TYPE	Court of Appeals

COURT DESCRIPTION	Court of Appeals of New Mexico
DATE FILED	3/1/04
HISTORY	
RELATED CASES	Texas v. New Mexico, heard by Supreme Court in 1983 (462 U.S. 554), was over non-compliance with the Pecos River Compact
PARTY NAMES	STATE of New Mexico ex rel. OFFICE OF the STATE ENGINEER (Plaintiffs–Appellees); Pecos Valley Artesian Conservancy District (Plaintiffs–Appellees); L.T. LEWIS et al., (Defendants–Appellants); United States of America (Defendants–Appellees); Carlsbad Irrigation District (Defendants–Appellees)
PARTY DESCRIPTION	state government; federal government; private citizens; water user groups; agriculture groups; conservation districts
COMPETING USES	downstream senior water rights v. upstream junior water rights; New Mexico water claims v. Texas water claims [UPDATE BECAUSE MEXICO OWES US WATER FROM RIO GRANDE IN EXCHANGE FOR WATER US PROVIDES MEXICO FROM COLORADO RIVER, and MEXICO IS BEHIND ON ITS WATER DELIVERIES]
FEDERAL AGENCY PARTY?	? No ?
STATE AGENCY PARTY?	yes (New Mexico Office of the State Engineer)
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	

ISSUES	"In significant part, the Pecos River issues have revolved around: (1) the competing claims of downstream, senior surface water users in the Carlsbad, New Mexico area and upstream, junior groundwater users in New Mexico's Roswell Artesian Basin; and (2) the competing claims of New Mexico users and Texas users. The present case involves the attempt by the State of New Mexico, the United States, and irrigation entities through a settlement agreement to resolve difficult long-pending water rights issues through public funding, without offending New Mexico's bedrock doctrine of prior appropriation, and without resorting to a priority call. In this case, certain downstream, senior surface water users, specifically Tracy/Eddy Trusts and Farms (Tracy/Eddy), and Hope Community Ditch Association (Hope), who are the Appellants in this appeal, seek to abort that attempt and to require the doctrine of prior appropriation to be strictly enforced through senior against junior priority enforcement in order to assure adequate water for the downstream users and additionally to assure that the upstream, junior users and not the State's taxpayers bear the burden of providing adequate water. Appellees, who are Carlsbad Irrigation District (CID), Pecos Valley Artesian Conservancy District (PVACD), and the State of New Mexico, seek ratification of a settlement agreement among themselves and the United States establishing a managed water plan for *3 **377 the Pecos River, which recognizes prior appropriation rights but subsumes individual interests to collective and representative bodies." [2-3]
DATE RESOLVED	11/16/06
RESOLUTION DESCRIPTION	"We hold that the settlement agreement and decree do not violate Article XVI, Section 2 of the New Mexico Constitution or Article IX of the Compact." [15]
RESOLUTION TYPE	judgment
HOLDINGS	"The Court of Appeals, Sutin, J., held that: 1 settlement that did not require a priority call did not violate State Constitution provision regarding water appropriation; 2 State's purchase of upstream junior water rights as part settlement agreement did not violate anti-donation clause of the State Constitution; and 3 district court did not exceed its power in approving settlement agreement. Affirmed." [Westlaw, "Holdings"]
RESEARCHER	Shannon Bonney
REFERENCE	Westlaw
NOTES	

BASIN	Rio Grande
CITATION	181 P.3d 252

CASE	Concerning the Matter of the Rules Governing New Withdrawals of Ground Water in Water Division No. 3 Affecting the Rate or Direction of Movement of Water in the Confined Aquifer System a/k/a "confined Aquifer New Use Rules for Division 3." Hal D. SIMPSON, in his official capacity as State Engineer for the State of Colorado, Proponent–Appellee v. COTTON CREEK CIRCLES, LLC., Opposer–Appellant and Rio Grande Water Conservation District; Rio Grande Water Users Association; and Conejos Water Conservancy District, Appellees.
COURT LEVEL	State Courts
COURT TYPE	Supreme Court
COURT DESCRIPTION	Supreme Court of Colorado (En Banc)
DATE FILED	unknown (first oral argument in 2007)
HISTORY	
RELATED CASES	218 P.3d 1098 (appears procedural); see also 270 P.3d 927 (where first water management plan to regulate ground water in San Luis Valley was opposed, by those senior water rights, but upheld by the court)
PARTY NAMES	Hal D. SIMPSON, in his official capacity as State Engineer for the State of Colorado (Proponent–Appellee); COTTON CREEK CIRCLES, LLC. (Opposer–Appellant); Rio Grande Water Conservation District (Appellee); Rio Grande Water Users Association (Appellee); Conejos Water Conservancy District (Appellees)
PARTY DESCRIPTION	state government; water user groups; businesses; developers; conservation districts
COMPETING USES	ground water use v. surface water required by Rio Grande Compact and downstream senior water users; irrigated agriculture v. municipal supply [UPDATE BECAUSE MEXICO OWES US WATER FROM RIO GRANDE IN EXCHANGE FOR WATER US PROVIDES MEXICO FROM COLORADO RIVER, and MEXICO IS BEHIND ON ITS WATER DELIVERIES]
FEDERAL AGENCY PARTY?	no
STATE AGENCY PARTY?	yes (Colorado Division of Water Resources)
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	"This is an appeal from a water court's Findings of Fact, Conclusions of Law, Judgment and Decree ("judgment") upholding rules related to certain new withdrawals from the confined aquifer in Water Division Three ("the rules")1 . Appellant Cotton Creek Circles, LLC ("Opponent") asserts that the rules are invalid because they are contrary to statute and violate the Colorado Constitution. We disagree, and we affirm the water court's judgment upholding the rules...The rules at issue apply only to the confined aquifer in Water Division Three, which is generally coterminous with the San Luis Valley ("the Valley")...the unconfined aquifer, the confined aquifer, and the surface streams are hydraulically connected to varying

	degrees...Opponent argues that there is another source of water that should be taken into account in the rules. That water comes from the unconfined aquifer of an area known as the Closed Basin. A federal reclamation project called the Closed Basin Project has for decades “salvaged” shallow groundwater from the sump area of the Closed Basin that would have otherwise largely been lost to evaporation and evapotranspiration...Wells completed in the unconfined aquifer in that area provide the means to divert the salvaged water to the Rio Grande, which aids Colorado in meeting its obligations under the Rio Grande Compact...According to the water court's judgment, there were already 7500 flowing wells in the Valley by 1958. Construction of wells in both the confined and unconfined aquifers continued until 1972 when the state engineer imposed a moratorium on new well permits, with the exception of permits for the unconfined aquifer in the Closed Basin. In 1981, the moratorium was extended to include the Closed Basin as well. Administration of the water at issue is complicated by the existence of the Rio Grande Compact.3 The compact was a resolution of competing claims on water from the Rio Grande by Colorado, New Mexico, and Texas...The compact requires Colorado *256 to deliver water in the Rio Grande at the New Mexico border, though the precise amount varies according to schedules related to the natural supply of water at that time. Alamosa–La Jara, 674 P.2d at 918–19. The compact allows for accumulated debits of up to 100,000 acre-feet...the state engineer and water users took steps to address issues relating to the over appropriation of both aquifers, the protection of senior surface rights, and the Rio Grande Compact obligations...The Closed Basin Project promised some relief from the curtailed diversions. Two years after our decision in Alamosa–La Jara, certain water user groups in the Valley *257 4 entered into an agreement regarding the allocation of water from operation of the Closed Basin Project, called the Resolution Regarding the Allocation of the Yield of the Closed Basin Project (“the 60/40 agreement”)...The agreement provided that sixty percent of the usable yield from the project would go to the Rio Grande, and forty percent of that yield would go to the Conejos River. The parties to the agreement waived all claims against all existing wells located within the Rio Grande Water Conservation District for alleged effects on the flow of rivers resulting from the existing levels of production and use of those wells. In other words, the agreement was intended to allow existing well users to continue their existing use5 of groundwater. While their usage would otherwise need to be curtailed to ensure compliance with the Rio Grande Compact, the 60/40 agreement was intended to provide sufficient replacement water from the Closed Basin Project to allow existing users to maintain their current levels of production and usage without injuring senior users. Since the 60/40 agreement was executed in 1985, the state engineer has declined to take action to regulate historical use of existing wells, but he has opposed any form of expansion of use or appropriation...The yield of the Closed Basin Project declined, and the drought of 2002 strained the existing water supply. When the state legislature considered the issue,6 water users testified that the 60/40 agreement was an incomplete solution to groundwater problems in the valley, and it was insufficient on its own to protect senior vested water rights from injury caused by groundwater pumping." [253-257]
DATE RESOLVED	3/24/08
RESOLUTION DESCRIPTION	"we uphold the water court's judgment approving the rules as promulgated" [264]
RESOLUTION TYPE	judgment

HOLDINGS	"The Supreme Court, Rice, J., held that: 1 artesian pressure requirements did not violate the constitutional right to divert unappropriated waters; 2 rational basis existed for artesian pressure requirements; 3 use of the phrase, “unappropriated water is not made available and injury is not prevented as a result of the reduction of water consumption by non-irrigated native vegetation” in rules did not exceed the scope of statutory authority; 4 rational basis existed for rules regarding the reduction of water consumption by non-irrigated native vegetation; 5 rules did not violate statutory authority by regulating only new withdrawals from confined aquifer and failing to also regulate existing users; 6 rational basis existed for treating those who would make new withdrawals from unconfined aquifer differently from those who would make new withdrawals from confined aquifer; and 7 rules which regulated new diversions without regulating existing diversions did not violate equal protection. Affirmed." [Westlaw, "Holdings"]
RESEARCHER	Shannon Bonney
REFERENCE	Westlaw
NOTES	

BASIN	Rio Grande
CITATION	135 S.Ct. 474
CASE	State of TEXAS, plaintiff, v. State of NEW MEXICO and State of Colorado
COURT LEVEL	US Federal Courts
COURT TYPE	Supreme Court
COURT DESCRIPTION	Supreme Court of the United States
DATE FILED	1/8/13
HISTORY	
RELATED CASES	133 S.Ct. 1855 (appears procedural); 134 S.Ct. 1050 (appears procedural); 134 S.Ct. 1783 (appears procedural); Texas v. New Mexico, heard by Supreme Court in 1983 (462 U.S. 554), was over non-compliance with the Pecos River Compact
PARTY NAMES	Texas (Plaintiff); New Mexico (Respondent); Colorado (Respondent); Hudspeth County Conservation and Reclamation District No. 1 (Respondent); El Paso County Water Improvement District No. 1 (Respondent); City of El Paso, Texas (Respondent); City of Las Cruces (Respondent); United States (Respondent); Elephant Butte Irrigation District(Respondent)
PARTY DESCRIPTION	local government; state government; federal government; utilities; water user groups; agriculture groups; conservation districts

COMPETING USES	upstream water use (in Colorado and New Mexico) v. downstream water use (in Texas and Mexico); farmers in New Mexico receiving 'insufficient share' of surface water so withdrawing from hydrologically connected aquifers, as well as surface water diversions (both permitted and unpermitted), reducing Rio Grande flows to Texas; irrigated agriculture (in all 3 states) v. municipal water use (in all 3 states) v. water needed to comply with Rio Grande Compact, 1944 Water Treaty, and instream flow requirements [UPDATE BECAUSE MEXICO OWES US WATER FROM RIO GRANDE IN EXCHANGE FOR WATER US PROVIDES MEXICO FROM COLORADO RIVER, and MEXICO IS BEHIND ON ITS WATER DELIVERIES]
FEDERAL AGENCY PARTY?	unknown
STATE AGENCY PARTY?	unknown
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	"The Texas Commission on Environmental Quality, on behalf of the State of Texas [hereinafter Texas], sued the State of New Mexico in the U.S. Supreme Court over alleged Rio Grande Compact violations on January 8, 2013 in a case named Texas v. New Mexico and Colorado. Texas complained that as a result of New Mexico's actions and inaction, Texas does not receive its share of water apportioned by the 1938 Rio Grande Compact [hereinafter Compact] and allocated under the Rio Grande Project operations. According to Texas, this is an interstate disagreement about the interpretation of an interstate compact and the operations of an interstate irrigation project. It has asked the Court to hear the case, enjoin New Mexico's diversions and depletions that take Texas' portion of Rio Grande Project water, order New Mexico to pay for the water it has allegedly taken through groundwater pumping and unpermitted surface diversions since 1938, and specifically allocate Texas' portion of water under the Compact: in short to interpret and enforce the Rio Grande Compact." [Bushnell 2013, p. 1]
DATE RESOLVED	n/a
RESOLUTION DESCRIPTION	n/a
RESOLUTION TYPE	n/a
HOLDINGS	n/a
RESEARCHER	Shannon Bonney
REFERENCE	US Supreme Court Docket (online); Westlaw; article with the citation: Bushnell, Darcy S. (2013). "Texas v. New Mexico and Colorado". Utton Transboundary Resources Center, University of New Mexico, online at: http://uttoncenter.unm.edu/pdfs/2013-05-16_BushnellTx-NM-Final.pdf.
NOTES	

BASIN	Rio Grande
CITATION	2013 WL 1657355
CASE	State of NEW MEXICO, Plaintiff, City of Las Cruces, Plaintiff/Intervenor, v. UNITED STATES of America, Kenneth L. Salazar, Secretary of the Department of Interior, in his official capacity, Michael L. Connor, Commissioner of the Bureau of Reclamation, in his official capacity, Filiberto Cortez, Manager of the El Paso Field Division of the Bureau of Reclamation in El Paso, Texas, in his official capacity, U .S. Bureau of Reclamation, a federal agency, U.S. Department of Interior, a federal agency, Elephant Butte Irrigation District, a quasi-municipal corporation of New Mexico, and El Paso County Water Improvement District No. 1, a political subdivision of the State of Texas, Defendants.
COURT LEVEL	US Federal Courts
COURT TYPE	US District Courts
COURT DESCRIPTION	US District Court District of New Mexico
DATE FILED	8/8/11
HISTORY	
RELATED CASES	
PARTY NAMES	State of NEW MEXICO (Plaintiff); City of Las Cruces (Plaintiff/Intervenor); UNITED STATES of America (Defendant); Kenneth L. Salazar, Secretary of the Department of Interior, in his official capacity (Defendant); Michael L. Connor, Commissioner of the Bureau of Reclamation, in his official capacity (Defendant); Filiberto Cortez, Manager of the El Paso Field Division of the Bureau of Reclamation in El Paso, Texas, in his official capacity (Defendant); U .S. Bureau of Reclamation, a federal agency (Defendant); U.S. Department of Interior, a federal agency (Defendant); Elephant Butte Irrigation District, a quasi-municipal corporation of New Mexico (Defendant); El Paso County Water Improvement District No. 1, a political subdivision of the State of Texas (Defendant).
PARTY DESCRIPTION	local government; state government; federal government; ? Utilities ? (El Paso County Water Improvement District No. 1); water user groups; agriculture groups; ? Regional government ? (El Paso County Water Improvement District No. 1)
COMPETING USES	irrigated agriculture in New Mexico (relying mainly on ground water that's hydrologically connected to Rio Grande) v. municipal water use (especially in Las Cruces, NM and El Paso, TX) v. US obligations to deliver water to Mexico (vis a vis 1944 Water Treaty) v. New Mexico obligations to deliver water to Texas (vis a vis Rio Grande Compact); hydrologically connected ground water use v. surface water use [UPDATE BECAUSE MEXICO OWES US WATER FROM RIO GRANDE IN EXCHANGE FOR WATER US PROVIDES MEXICO FROM COLORADO RIVER, and MEXICO IS BEHIND ON ITS WATER DELIVERIES]
FEDERAL AGENCY PARTY?	yes (Bureau of Reclamation)

STATE AGENCY PARTY?	? No ?
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	"The primary issue is whether this case would become moot if the Supreme Court of the United States grants the State of Texas' motion for leave to file a complaint against the State of Colorado and Plaintiff State of New Mexico. For the reasons stated herein, the Court will stay litigation in this case until the Supreme Court decides whether to grant Texas' motion, and if the Supreme Court grants Texas' motion, the Court will continue the stay of litigation at least until the Supreme Court identifies all the parties and issues before the Supreme Court...New Mexico filed its First Amended Complaint on February 14, 2012. See Doc. 45. New Mexico alleges that the United States Bureau of Reclamation is improperly operating the Rio Grande Project1 in two ways. First, the Bureau of Reclamation reduced and released credit water from the Rio Grande Project in 2011...Second, the Bureau of Reclamation executed the 2008 Operating Agreement with Elephant Butte Irrigation District and El Paso County Water Improvement District No. 1, which significantly changed the Rio Grande Project's historical operation...New Mexico alleges that the Bureau of Reclamation's actions violated provisions in the Rio Grande Compact, N.M.S.A.1978 § 72–15–23, the Water Supply Act, 43 U.S.C. §§ 390, the Administrative Procedures Act, 5 U.S.C. §§ 701–706, the National Environmental Policy Act, 42 U.S.C. §§ 4331–4332, and Section 8 of the Reclamation Act of 1902, 43 U.S.C. § 383...The City of Las Cruces filed its Complaint in Intervention on February 29, 2012...Las Cruces alleges that the operational changes that the Bureau of Reclamation implemented under the 2008 Operating Agreement harm Las Cruces, because the principle results of the 2008 Operating Agreement "have been increased diversions of groundwater from the aquifer underlying the Lower Rio Grande Underground Water Basin," which is the source of Las Cruces' municipal water...Defendant and Cross–Claimant Elephant Butte Irrigation District filed its cross-claim against the Bureau of Reclamation on April 26, 2012...Elephant Butte alleges that the Bureau of Reclamation illegally released water from the Rio Grande Project to the Republic of Mexico on or about April 1, 2012...Elephant Butte alleges that the Bureau of Reclamation's release of water to the Republic of Mexico: (i) is a breach of the 2008 Operating Agreement; (ii) violated a federal treaty with Mexico, see Convention between the United States and Mexico providing for the equitable distribution of the waters of the Rio Grande for irrigation purposes, May 21, 1906, 34 Stat. 2953; and (iii) constitutes a taking of property which entitles Elephant Butte to just compensation...On January 8, 2013, El Paso County Water Improvement District No. 1 filed a notice that Texas filed a motion in the Supreme Court seeking leave to file a complaint against Colorado and New Mexico for violations of the Rio Grande Compact...Texas alleges that New Mexico allows surface water diversions and groundwater pumping in New Mexico, and in doing so, New Mexico breaches its obligations and responsibilities under the Rio Grande Compact...Texas' Proposed Complaint ¶ 20, at 11–12. Texas asks the Supreme Court to "[i]ssue its Decree commanding the State of New Mexico ... to ... cease and desist all actions which interfere with and impede the authority of the United States to operate the Rio Grande Project...On March 1, 2013, the Court requested that "the parties submit a letter to the Court stating their position as to whether this case would become moot if the Supreme Court of the United States grants the State of Texas' Motion for Leave

	to File Complaint."[1-3]
DATE RESOLVED	3/29/13
RESOLUTION DESCRIPTION	" the Court will stay litigation in this case until the Supreme Court decides whether to grant Texas' motion, and if the Supreme Court grants Texas' motion, the Court will continue the stay of litigation at least until the Supreme Court identifies all the parties and issues before the Supreme Court." [1]
RESOLUTION TYPE	judgment
HOLDINGS	
RESEARCHER	Shannon Bonney
REFERENCE	Westlaw
NOTES	

BASIN	Rio Grande
CITATION	289 F.3d 1170
CASE	UNITED STATES of America, Plaintiff–Counter–Defendant–Appellant, v. CITY OF LAS CRUCES; Hudspeth County Conservation and Reclamation District No. 1; City of El Paso; New Mexico State University; Stahmann Farms, a New Mexico corporation; State of New Mexico, ex rel. State Engineer, Defendants–Appellees, El Paso County Water Improvement District No. 1, Defendant–Counter–Claimant–Cross–Claimant, v. Elephant Butte Irrigation District of New Mexico, Defendant–Cross–Defendant–Appellee. State of Texas; Lower Valley Water District; Pueblo of Isleta Del Sur; State of Colorado; James Scott Boyd, Administrator of the Estate of Nathan Ellington Boyd, Intervenors. United States of America, Plaintiff–Counter–Defendant, v. City of Las Cruces; Hudspeth County Conservation and Reclamation District No. 1; New Mexico State University; Stahmann Farms, a New Mexico corporation; State of New Mexico, ex rel. State Engineer, Defendants–Appellees, El Paso County Water Improvement District No. 1, Defendant–Counter–Claimant–Cross–Claimant, and City of El Paso, Defendant–Appellant, v. Elephant Butte Irrigation District of New Mexico, Defendant–Cross–Defendant–Appellee. State of Texas; Lower Valley Water; Pueblo of Isleta Del Sur; State of Colorado; James Scott Boyd, Administrator of the Estate of Nathan Ellington Boyd, Intervenors. United States of America, Plaintiff–Counter–Defendant, v. City of Las Cruces; Hudspeth County Conservation and Reclamation District No. 1; City of El Paso; New Mexico State University; Stahmann Farms, a New Mexico corporation; State of New Mexico, ex rel. State Engineer, Defendants–Appellees, and El Paso County Water Improvement District No. 1, Defendant–Counter–Claimant–Cross–Claimant–Appellant, v. Elephant Butte Irrigation District of New Mexico, Defendant–Cross–Defendant–Appellee. State of Texas; Lower Valley Water; Pueblo of Isleta Del Sur; State of Colorado; James Scott Boyd, Administrator of the Estate of Nathan Ellington Boyd, Intervenors.

COURT LEVEL	US Federal Courts
COURT TYPE	US Federal Court of Appeals
COURT DESCRIPTION	Tenth Circuit
DATE FILED	10/26/00
HISTORY	(Y; treated negatively in cases not related to water)
RELATED CASES	[originally argued in 115 N.M. 229 and (?)others?]
PARTY NAMES	United States Of America (Plaintiff-Counter- Defendant); City Of Las Cruces (Defendant – Appellee); Hudspeth County Conservation And Reclamation District No. 1 (Defendant – Appellee); City Of El Paso (Defendant – Appellee); New Mexico State University (Defendant – Appellee); Stahmann Farms, A New Mexico Corporation (Defendant – Appellee); State Of New Mexico, Ex Rel. State Of New Mexico, Ex Rel. State Engineer (Defendant – Appellee); El Paso County Water Improvement District No. 1 (Defendant-Counter- Claimant-Cross-Claimant – Appellant); Elephant Butte Irrigation District Of New Mexico (Defendant Cross-Defendant); State Of Texas (Intervenor); Lower Valley Water (Intervenor); Pueblo Of Isleta Del Sur (Intervenor); State Of Colorado (Intervenor); James Scott Boyd, Administrator Of The Estate Of Nathan Ellington Boyd (Intervenor)
PARTY DESCRIPTION	local government; state government; federal government; private citizens; utilities; water user groups; native American; businesses; agriculture groups; conservation districts
COMPETING USES	water use for irrigation in the Elephant Butte Irrigation District v. municipal water supply (especially in El Paso) v. water allocated by compact for delivery to Texas and Mexico [UPDATE BECAUSE MEXICO OWES US WATER FROM RIO GRANDE IN EXCHANGE FOR WATER US PROVIDES MEXICO FROM COLORADO RIVER, and MEXICO IS BEHIND ON ITS WATER DELIVERIES]
FEDERAL AGENCY PARTY?	? Yes (doesn't specify, but Bureau of Reclamation responsible for Rio Grande Project) ?
STATE AGENCY PARTY?	? Office of the State Engineer of New Mexico ?
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	

ISSUES	"This is an appeal from the district court's order dismissing the United States' suit to quiet title to water rights in a portion of the Rio Grande River." [1174] "In 1986, Elephant Butte Irrigation District (EBID) filed a complaint in New Mexico state court against the New Mexico State Engineer, the United States, the City of El Paso, and all known and unknown claimants to water rights in the Rio Grande from Elephant Butte Dam to the Texas state line. EBID claimed a right to appropriate water superior to all defendants. The complaint sought, among other things, a New Mexico stream adjudication and an injunction preventing the State Engineer from allowing appropriation of Rio Grande water until completion of the stream adjudication...Numerous parties attempted to dismiss the case, including the United States and the New Mexico State Engineer...an interested Texas party, the El Paso County Water Improvement District No. 1 ("El Paso Water District") moved to intervene in the stream adjudication...Pursuant to Texas Water Code §§ 11.304–.305, the TNRCC [Texas Natural Resources Conservation Commission] ordered an adjudication of the Rio Grande from the New Mexico border to Fort Quitman, Texas (corresponding to the extent of the Project within Texas)...Shortly following the denial of its third attempt to dismiss the New Mexico stream adjudication, the United States filed this federal civil action in the District Court for the District of New Mexico. The United States sued to quiet its title to Project water... The United States asserted that the named defendants had clouded its title to Project water...The district court dismissed the United States' suit...The district court found that the requested federal declaratory relief would not settle the entire controversy over water rights or even clarify the relative rights of the parties to Rio Grande water, because any declaration of the United States' rights to divert, impound, and store Project water would not be binding on parties not joined to the action...The district court was concerned that the United States engaged in procedural fencing because it had moved to dismiss the New Mexico case on jurisdictional grounds several times. The court found that the United States' jurisdictional argument was rejected by every court to consider it, including the New Mexico Court of Appeals, and that the United States brought the present federal action shortly after losing its third attempt to dismiss on jurisdictional grounds...The district court concluded that the state adjudications would provide a more effective remedy to the general controversy than the federal declaratory judgment action. The state proceedings would produce a "more comprehensive and cohesive" remedy, because the rights of all, including the parties to the federal action, would be decided...In arguing that the state proceedings are not the more effective remedies, the United States and Texas parties fail to acknowledge the reality of water rights disputes in the West. Thousands of individuals claim water rights that depend on the resolution of the claims of others. The situation has long been recognized as demanding a comprehensive adjudication of all users' claims." [1175-1194]]
DATE RESOLVED	5/7/02
RESOLUTION DESCRIPTION	"This court concludes that the district court's decision to apply Brillhart and withhold jurisdiction over this declaratory judgment action was not an abuse of discretion. It is thus unnecessary to resolve whether the district court erred in dismissing under the Colorado River doctrine. The district court, however, should consider whether the preferable remedy is to stay the federal proceedings. The judgment of the District Court for the District of New Mexico is therefore VACATED and the case is REMANDED for further proceedings consistent with this opinion."
RESOLUTION TYPE	judgment

HOLDINGS	"The Court of Appeals, Murphy, Circuit Judge, held that: (1) action was declaratory judgment action for purposes of district court's broad discretion to decline jurisdiction over declaratory judgment actions; (2) similarity between parallel state and federal proceedings was not threshold condition for district court's exercise of discretion to decline jurisdiction; (3) action did not involve issue of federal law that would render inappropriate district court's exercise of discretion to decline jurisdiction; (4) decision to decline jurisdiction over action was not abuse of discretion; and (5) remand was warranted to permit district court to determine whether stay, rather than dismissal, was appropriate remedy. Vacated and remanded with instructions." [Westlaw, summary]
RESEARCHER	Shannon Bonney
REFERENCE	Westlaw
NOTES	"This dispute centers around the Rio Grande Reclamation Project (the "Project"). In 1902, Congress passed the Reclamation Act...The purpose of the Reclamation Act was to facilitate irrigation of arid and semi-arid western territories and states by providing for the construction of large-scale irrigation works...The Project is one that grew out of the Act. It is expansive, running through New Mexico and Texas. The Project begins in the north at Elephant Butte Reservoir, near the town of Truth or Consequences, New Mexico. Just below Elephant Butte Reservoir is Caballo Reservoir. From the reservoirs, water is released into the Rio Grande riverbed. The water is then diverted by one of six diversion dams into canals running on either side of the river. From the canals, river water is further diverted into channels and ditches running to farmland. The water is used to irrigate crops. Other channels and ditches return both run-off from the farmland and groundwater back to the Rio Grande. The process is repeated several times over the length of the Project to irrigate land in both southeastern New Mexico and western Texas. Irrigation in the United States is not the sole use of Project water. The river runs *1176 through or near several towns and cities. At least one, El Paso, Texas, uses Project water to supplement its municipal water system. Project water is also used outside of the United States. Pursuant to a 1906 treaty with Mexico, the federal government is obligated to provide 60,000 acre-feet of water a year to Mexico...To fulfill its treaty obligations, the United States diverts Project water from the Rio Grande to Mexico at the International Diversion Dam, which is located approximately two miles northwest of El Paso. Several legal regimes govern the use of Project water. The Rio Grande Compact is an agreement entered into by the states of Colorado, New Mexico, and Texas and ratified by the United States Congress in 1939...The Compact is an attempt to equitably apportion Rio Grande water among the three states...State law governs the United States' acquisition of water rights...State law also governs the rights of individual water users in both New Mexico and Texas...The hierarchy is established through a state proceeding called a "stream adjudication."...Generally, the water rights of the federal government are also adjudicated in state proceedings such as a stream adjudication." [1175-1177]

BASIN	Rio Grande
CITATION	601 F.3d 1096

CASE	RIO GRANDE SILVERY MINNOW (Hybognathus amarus); Southwestern Willow Flycatcher (Empidonax trailii extimus); Defenders of Wildlife; Forest Guardians; National Audubon Society; New Mexico Audubon Council; Sierra Club; and Southwest Environmental Center, Plaintiffs–Appellees, v. BUREAU OF RECLAMATION, an agency of the United States; Robert L. Van Antwerp, Lt. Gen., Chief Engineer, Army Corps of Engineers; United States Army Corps of Engineers, an agency of the United States; United States of America; Ken Salazar, Secretary, Department of the Interior; Michael L. Connor, Commissioner, Bureau of Reclamation; Larry Walkoviak, Regional Director, Bureau of Reclamation; and Kimberly M. Colloton, Lt. Col., Albuquerque District Engineer, Defendants–Appellants, The Middle Rio Grande Conservancy District; State of New Mexico, Defendants–Intervenors–Appellants, Albuquerque–Bernalillo County Water Utility Authority, Defendant–Intervenor–Appellee, Rio De Chama Acequia Association, Defendant–Intervenor, City of Santa Fe, Intervenor. State of Arizona; Central Arizona Water Conservation District; Imperial Irrigation District; Metropolitan Water District of Southern California; and Arizona Power Authority, Amici Curiae.
COURT LEVEL	US Federal Courts
COURT TYPE	US Federal Court of Appeals
COURT DESCRIPTION	Tenth Circuit
DATE FILED	5/21/02 [original case]
HISTORY	469 F.Supp.2d 973; (appeal dismissed by) 46 Fed.Appx. 929; (and motion to vacate denied by) 469 F.Supp.2d 1003; (appeal dismissed by and remanded to vacate by) 601 F.3d 1096. [ALSO] 469 F.Supp.2d 973 (appeal dismissed by and remanded to vacate by) 601 F.3d 1096. [ALSO] 356 F.Supp.2d 1222; (appeal dismissed by) 355 F.3d 1215; (and motion to vacate denied by) 469 F.Supp.2d 1003; (appeal dismissed by and remanded to vacate by) 601 F.3d 1096. [ALSO] 356 F.Supp.2d 1222; (appeal dismissed by and remanded to vacate by) 601 F.3d 1096. [ALSO] 333 F.3d 1109; (opinion vacated by) 355 F.3d 1215.
RELATED CASES	599 F.3d 1165; 294 F.3d 1220; 206 F.Supp.2d 1156

PARTY NAMES	Rio Grande Silvery Minnow, Hybognathus Amarus (Plaintiff – Appellee); Southwestern Willow Flycatcher (Plaintiff – Appellee); Defenders Of Wildlife (Plaintiff – Appellee); Forest Guardians (Plaintiff – Appellee); National Audubon Society (Plaintiff – Appellee); New Mexico Audubon Council (Plaintiff – Appellee); Sierra Club (Plaintiff – Appellee); Southwest Environmental Center (Plaintiff – Appellee); Bureau Of Reclamation, An Agency Of The United States (Defendant); Joseph Ballard, General, Chief Engineer, Army Corps Of Engineers (Defendant); United States Army Corps Of Engineers, An Agency Of The United States (Defendant); United States (Defendant); Gale Norton, Secretary, Department Of Interior (Defendant); Eluid L. Martinez, Director, Bureau Of Reclamation (Defendant); Michael R. Gabaldon, Regional Director, Bureau Of Reclamation (Defendant); Tom Fallin, Lt. Col., Albuquerque District Engineer (Defendant); The Middle Rio Grande Conservancy District (Defendant-Intervenor); State Of New Mexico (Defendant-Intervenor – Appellant); Rio De Chama Acequia Association (Defendant-Intervenor); City Of Albuquerque (Defendant-Intervenor); Albuquerque-Bernalillo County Water Utility Authority City Of Santa Fe (Defendant-Intervenor - Appellee Intervenor); State Of Arizona (Amicus Curiae); Central Arizona Water Conservation District (Amicus Curiae); Imperial Irrigation District (Amicus Curiae); Metropolitan Water District Of Southern California (Amicus Curiae); Arizona Power Authority (Amicus Curiae)
PARTY DESCRIPTION	local government; state government; federal government; utilities; water user groups; environmental groups; agriculture groups; conservation districts; regional governments
COMPETING USES	instream water for endangered species v. irrigation water v. municipal water [UPDATE BECAUSE MEXICO OWES US WATER FROM RIO GRANDE IN EXCHANGE FOR WATER US PROVIDES MEXICO FROM COLORADO RIVER, and MEXICO IS BEHIND ON ITS WATER DELIVERIES]
FEDERAL AGENCY PARTY?	yes (Bureau of Reclamation; Army Corps of Engineers; Department of Interior)
STATE AGENCY PARTY?	yes (New Mexico Interstate Stream Commission)
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	

ISSUES	"This case involves one battle in a prolonged war over a finite and elemental resource—Rio Grande water. The needs of the plants and animals that depend upon this water for survival are in tension with the needs of the human inhabitants of the Middle Rio Grande Valley (the "Valley") who depend upon the water for daily living and commercial and agricultural activities. Alleging that the Bureau of Reclamation ("Reclamation") failed to properly maintain the delicate balance between these counterpoised needs to the detriment of several endangered species, Defenders of Wildlife, Forest Guardians, National Audubon Society, New Mexico Audubon Council, Sierra Club, and the Southwest Environmental Center (the "Environmental Groups") sought relief in federal court pursuant to the Endangered Species Act ("ESA").Directly at issue is whether Reclamation has discretion to reallocate water from agricultural and municipal contract users to maintain stream flows for the benefit of the Rio Grande Silvery Minnow ("Minnow"). The Environmental Groups claim that Reclamation does and that its failure to weigh that discretion in its consultations with the U.S. Fish and Wildlife Service (the "FWS") violated § 7 of the ESA." [1103]
DATE RESOLVED	4/21/10
RESOLUTION DESCRIPTION	"The Court of Appeals, Holmes, Circuit Judge, held that: 1 environmental groups' scope-of-consultation claim was mooted by FWS's issuance of superseding B.O.; 2 de novo standard of review was applicable to questions of Article III mootness; and 3 vacatur of District Court's prior orders was warranted. Appeal dismissed; remanded with directions. Henry, Chief Judge, filed a dissenting opinion." [Westlaw "Holdings"]
RESOLUTION TYPE	judgment
HOLDINGS	"The Court of Appeals, Holmes, Circuit Judge, held that: 1 environmental groups' scope-of-consultation claim was mooted by FWS's issuance of superseding B.O.; 2 de novo standard of review was applicable to questions of Article III mootness; and 3 vacatur of District Court's prior orders was warranted. Appeal dismissed; remanded with directions. Henry, Chief Judge, filed a dissenting opinion." [Westlaw "Holdings"]
RESEARCHER	Shannon Bonney
REFERENCE	Westlaw
NOTES	

BASIN	Stony Creek Watershed (Sacramento River)
CITATION	7 F.3d 891
CASE	Wackerman Dairy, Inc. v. Wilson
COURT LEVEL	Federal
COURT TYPE	Appeals Court

COURT DESCRIPTION	Ninth Circuit
DATE FILED	
HISTORY	(District Court ruling) 760 F.Supp. 1366; (Reversing District Court ruling) 7 F.3d 891
RELATED CASES	
PARTY NAMES	Wackerman Dairy, Inc.; Hollis Reimers (Plaintiffs- Appellants). George G. Wilson, Angle Decree Water Master; Orland Unit Water Users' Association, a California Corporation; United States of America (Defendants–Appellees).
PARTY DESCRIPTION	Business, Private Individual, Water Master, Water User's Association, Federal Government
COMPETING USES	Private water rights holder's claimed entitlement versus the United States Watermaster's interpretation of the controlling 1930 decree.
FEDERAL AGENCY PARTY?	Yes
STATE AGENCY PARTY?	No
WATER RIGHTS DOCTRINE	prior appropriation
COMPACT	
ISSUES	"This litigation arises out of watermaster Wilson's application of the 1930 'Angle Decree' which determines the rights of the United States and some six hundred landholders in the Stony Creek watershed. Reimers, successor in interest to members of the Scearce family who were among the original parties to the decree, seeks a declaration of her water rights under the decree. What is at issue is the water to which she is entitled without payment to the government." 7 F.3d 893. The Plaintiffs-Appellants contend that the proper method for calculating their water entitlement is set forth as a contractual right in the original Angle Decree. The Appellees claim that the method of calculation is modified by other provisions of the Decree, which support Watermaster Wilson's interpretation that the Appellants are entitled to a lesser amount.
DATE RESOLVED	10/21/93
RESOLUTION DESCRIPTION	District Court judgment reversed. Remanded for the District Court to recalculate the amount of water to which the landowner is entitled consistent with the Court of Appeals' decision.
RESOLUTION TYPE	Appellate court ruling
HOLDINGS	Watermaster Wilson's interpretation of the 1930 Angle Decree was incorrect. The Plaintiffs are entitled to an amount of water to be calculated by the district court on remand.
RESEARCHER	Brian Easley

REFERENCE	Westlaw
NOTES	

BASIN	Yellowstone River
CITATION	131 S.Ct. 1765
CASE	State of Montana v. State of Wyoming and State of North Dakota
COURT LEVEL	Federal
COURT TYPE	United States Supreme Court
COURT DESCRIPTION	United States Supreme Court
DATE FILED	
HISTORY	(Original Jurisdiction of Supreme Court) 131 S.Ct. 1765
RELATED CASES	
PARTY NAMES	State of Montana; State of Wyoming; State of North Dakota
PARTY DESCRIPTION	State Governments
COMPETING USES	Wyoming's entitlement to water for irrigation versus reduced flows in Montana, which is downstream of Wyoming
FEDERAL AGENCY PARTY?	no
STATE AGENCY PARTY?	yes
WATER RIGHTS DOCTRINE	Prior appropriation
COMPACT	
ISSUES	"Montana alleges that Wyoming has breached Article V(A) of the [Yellowstone River] Compact by allowing its pre–1950 water appropriators to increase their net water consumption by improving the efficiency of their irrigation systems. The new systems, Montana alleges, employ sprinklers that reduce the amount of wastewater returned to the river, thus depriving Montana's downstream pre–1950 appropriators of water to which they are entitled." 131 S.Ct. 1769.
DATE RESOLVED	5/2/11
RESOLUTION DESCRIPTION	The Supreme Court ruled on this case as a matter of original jurisdiction. The

RESOLUTION TYPE	Supreme Court ruling
HOLDINGS	The use of more efficient irrigation systems is permissible under the Yellowstone River Compact as long as the conserved water is used to irrigate the same acreage as in 1950, when the Compact originated.
RESEARCHER	Brian Easley
REFERENCE	Westlaw
NOTES	

Case Studies

BILATERAL AGREEMENTS

NAME_PROGRAM	Arkansas River Pilot Water Bank (inactive)
TYPE	Bilateral agreements
HYDRO_SERV_GOALS	Simplify and improve approval of leases, loans, an exchanges; reduce transaction costs, increase availability of water---related information; help farmers and ranchers to realize the value of their water rights assets without forcing severance from land; avoid material injury to other water rights users.
SCALE	Only on the Arkansas River in Colorado
ACTORS	Administered by the Southeastern Colorado Water Conservation District; nine cities, two landowners, and one irrigation company registered with the bank
BUYER	Municipalities buy the water rights of agricultural landowners.
INTERVENTION	Water rights of agricultural landowners
DRIVER	Colorado cities had experienced severe droughts and needed to secure water for their populations
EXCHANGE_ARRANGE	The Bank administers transactions in which agricultural landowners put their water rights up for auction and municipalities bid on them.
COMPENSATION	Money
COBENEFITS	Gives money to agricultural landowners
BARRIERS	The asking prices were too high, and despite people being registered, no transactions occurred in the first five years of the program.
EXT_EVALUATION	The timeframe for approval was too long. It took three months to get approved for an agreement that only lasted one year. Also, the cities wanted longer agreements.
BASIN	Arkansas River
STATE	Colorado
SW_GW	
RESEARCHER	Dan Read
REFERENCE	http://cwcb.state.co.us/LoansGrants/alternative---agricultural---water---transfer---methods---grants/Documents/BriefHistoryArkBasinWaterBankFeb21.pdf

NAME_PROGRAM	California water market (general)
TYPE	Bilateral agreements
HYDRO_SERV_GOALS	Water shortages across the state, especially during drought times.
SCALE	The market covers the entire state of California, but data indicates that most sales occur locally or regionally.
ACTORS	Sellers are persons or entities that have the right to use the water during the period of the sale, and the water to be sold must be "wet" in the sense that it is physical rather than "paper" water. Thus, sellers can be individuals, private companies, or local public agencies. Transfers involving changes of purpose, place of use, or point of diversion must be approved by the State Water Resources Control Board (SWRCB).
BUYER	Buyers are individuals or entities in need of additional water.
INTERVENTION	The buyer pays for the consumption of physical water not used by the seller. This water can come from four potential sources: excess water stored in surface reservoirs, excess amounts of surface water, conserved surface water that the seller obtained through more efficient use of water, and groundwater. Groundwater is available through groundwater banking and groundwater substitution transfers.
DRIVER	The buyer needs additional water beyond what it can obtain without the market. The seller has additional water and a lower value use than the buyer.
EXCHANGE_ARRANGE	The buyer and seller agree on the way payment is to be received. Water is transferred using whatever infrastructure is available.
COMPENSATION	The payments are made in the form agreed upon by the buyer and seller. A specific form of currency is not required.
COBENEFITS	
BARRIERS	Buyers must be able to get the physical water from the seller to their intended destination for use. Accordingly, the infrastructure available is a limitation on the market. Local ordinances, especially in rural counties can prevent transfers in the market. State and Federal Regulations can also hinder the growth of the market.
EXT_EVALUATION	Recent articles are calling for a revamping of the water market
BASIN	All Basins in California
STATE	California
SW_GW	Surface water and groundwater
RESEARCHER	Brian Easley
REFERENCE	http://www.ppic.org/content/pubs/report/r_1112ehr.pdf

NAME_PROGRAM	Colorado---Big Thompson Project
TYPE	Bilateral agreements
HYDRO_SERV_GOALS	The Colorado---Big Thompson project was designed to address the over---appropriation of water rights that had occurred by the late 1980s in northeastern Colorado. This project planned for the additional water supplies that were needed by farmers.
SCALE	Colorado only. West Slope mountain water collected from the headwaters of the Colorado River is diverted to Colorado's Front Range and plains.
ACTORS	Colorado Division of Water Resources; Bureau of Reclamation under the Department of the Interior; municipal and industrial supply, hydro---power generation, recreation, and fish and wildlife communities
BUYER	Landowners within the district
INTERVENTION	Proportional water rights [more details needed] (both rental water & regional water pool)
DRIVER	"Short---term rentals and permanent leases of water, and trades within the agricultural sector and between the agricultural and municipal and industrial sectors. Water rights are homogeneous and trades are in allotments of the use of 1 acre foot (for 1 year) of the 310,000 acre feet per year of water supplied by the Colorado---Big Thompson Project; each acre---foot is a tradable allotment. Conserved water can be transferred to another use, which is not the case in prior appropriation systems. Water can also be rented to users outside the district through exchanges and replacements." [1] The buyer can pay for short-term rentals and permanent leases of water, and participate in trades among the agricultural, municipal and industrial sectors. Conserved water can be put to another use, such as rented to users outside the district.
EXCHANGE_ARRANGE	There are market prices, brokers, short-term rentals and permanent leases of water in this system, and trades within the agricultural sector and between the agricultural and municipal and industrial sectors. Water rights are homogeneous and trades are in allotments of the use of 1 acre foot (for 1 year) of the 310,000 acre feet per year of water supplied by the CBT; and each acre---foot is a tradable allotment. [Quote from Wikipedia: http://en.wikipedia.org/wiki/Water_trading#United_States] Brokers are involved in organizing market prices, short term rentals and permanent leases of water. Each acre---foot is tradable.
COMPENSATION	All transactions use the fair market value of the water rights, and payment takes the form of a monetary transaction.
COBENEFITS	Address the over---commitment of water resources; encourage land, water, and cattle grazing management strategies
BARRIERS	
EXT_EVALUATION	
BASIN	Colorado River Basin; Upper Colorado River Basin; South Platte River basin; Blue River
STATE	Colorado
SW_GW	Surface water
RESEARCHER	Torre Lavelle
REFERENCE	[1] http://en.wikipedia.org/wiki/Water_trading#United_States ; [2] http://www.usbr.gov/gp/aop/cbt/02cbt.pdf ; [3] http://www.northernwater.org/docs/AllotteeInfo/RegionalPool_Factsheet.pdf [SB]

NAME_PROGRAM	PlatteFLEX
TYPE	Bilateral agreements
HYDRO_SERV_GOALS	The aim of this research project was to develop a water market model that would increase the use of alternative water transfer methods (as opposed to more traditional water markets), in order to enhance mechanisms for water---sharing between agricultural and municipal/industrial users.
SCALE	Flexible---based on participants
ACTORS	Project Collaborators: Colorado Water Conservation Board, Colorado Corn Growers Association, City of Aurora, Ducks Unlimited, Regenesis Management Group. Pilot Project Participants: Platte Valley Irrigation Company (PVIC), the Lower Latham Ditch Company (LLDC) and Lower Latham Reservoir Company (LLRC).
BUYER	Based on participants
	The FLEX Market Model created a flexible framework for multiple water users and rights holders to implement market---based solutions based on their individual needs. The framework is designed to allow rights holders to transfer portions of the rights at different times, rather than the entire water allotment. A FLEX Market is a "voluntary agreement between one or more municipal and industrial water users (M&I), one or more agricultural (Ag) water users, and one or more environmental/conservation (EC) water users to change the use of a senior irrigation right to include multiple end uses in addition to irrigation, and to establish a trading platform facilitating uses by all participants. The goal of the FLEX Market approach is to permit a portion of the senior right to be used for M&I and EC uses pursuant to voluntary contractual arrangements, to maintain the economic benefit of the senior water right in its region of origin, and to retain sufficient agricultural water supply to sustain commercially viable farming activities." [1, p. viii] Two demonstration projects were pursued as part of a FLEX Market study. The ditch companies taking part in these demonstration projects were the Platte Valley Irrigation Company and Lower Latham Ditch Company. [1]
DRIVER	Based on participants and services. The FLEX model itself attempts to overcome the barriers to alternative transfer methods outlined in multiple agency reports (including the one referenced for the "Alternative Agricultural Water Transfer Grant Program").
EXCHANGE_ARRANGE	Bilateral or multilateral agreements. Would involve voluntary contracts between parties.
COMPENSATION	Would depend on agreement between parties
COBENEFITS	Would depend on the services/actions paid for. But generally there are socioeconomic benefits to meeting municipal demands without taking agricultural land out of production; as well as environmental benefits to be derived from including conservation or restoration objectives as one of the multiple end uses of senior irrigation rights.
BARRIERS	Participants concerns for legal standards and processes regarding transfer of water rights has been a barrier to market---based instruments like this, but this study team created a model "terms and conditions" document that will hopefully alleviate some of these concerns.
EXT_EVALUATION	The report on the FLEX Market study [1] includes the following recommendations: “Water Transfers Should Preserve Economic Benefit in Local Economies”, keep It Simple”, “Promote Ditch Wide Changes in Use to Multiple End Users”, “Statutory Amendments”, “Standardized Approaches”, “Develop New Models of Ownership” including “Shared Ownership”, “Explore new models of shared ownership by separating the “sticks” in the water rights “bundle””, “Market Based Interventions preventing buy and dry”, “Distinguish between ATM Market Types” (such as ““Over the Counter” (“OTC”) Market: Water available on a “cash and carry” basis for a limited term”, “Permanent Supply: Water delivered to an end user perpetually”, and “Blended Market”), “Use Land Use and Policy Tools”, “Real Covenants”, “Prioritizing Food and Fiber Production Areas”, “Investigate Indexed Pricing Mechanisms”, and educate the public and water users. [1, p. 12---1 through 12---7]
BASIN	South Platte River Basin
STATE	Colorado
SW_GW	
RESEARCHER	Laura Early

REFERENCE	[1] FLEX Market Model Completion Report: http://cwcb.state.co.us/water---management/water---projects---programs/Documents/FallowLease/SterlingComments.pdf

NAME_PROGRAM	Texas water markets (general)
TYPE	Bilateral agreements
HYDRO_SERV_GOALS	Water shortages across the state, especially during drought times. The demand for water is generated both by agricultural and municipal use.
SCALE	Throughout the state of Texas
ACTORS	Providers: Sellers are persons or entities with water rights Beneficiaries: Buyers are persons or entities with a higher use value for the water Other stakeholders: Texas Commission on Environmental Quality (approves transfers involving change of place or purpose of water), Texas Water Bank (intermediary which provides voluntary service of connecting willing buyers and sellers, sales do not have to go through Bank), Texas Water Exchange (administers a groundwater exchange market and provides services as an intermediary)
BUYER	Buyers can be agricultural or municipal users.
INTERVENTION	The buyer pays for the use of the water to which the seller has a right. Transfers involving a change of place or purpose of the water must be approved by the Texas Commission on Environmental Quality (TCEQ). There is a statewide Texas Water Bank that provides an internet resource through which willing buyers and sellers can find one another. Since 2013 the Texas Water Exchange has been providing market for buyers and sellers of groundwater rights. The separate market for groundwater is a product of Texas' regulatory treatment of groundwater: there is no permit required for groundwater pumping. Groundwater is primarily governed by the rule of capture, meaning there is an incentive to be the first to pump groundwater. The Texas Water Exchange aims to unite buyers and sellers so that those with rights will transfer them to buyers who have a greater use value. Transfers are subject to statutory conditions requiring notice, hearing, and approval.
DRIVER	The buyer needs additional use for water and places a higher value on the water than the seller.
EXCHANGE_ARRANGE	The buyer and seller agree on the way payment is to be received. Water is transferred using whatever infrastructure is available.
COMPENSATION	The payments are made in the form agreed upon by the buyer and seller. A specific form of currency is not required.
COBENEFITS	
BARRIERS	Transfers are limited to the State of Texas. The infrastructure available to transfer water limits the volume that can be transferred and to where it can be transferred. In many Basins water rights are nearly entirely appropriated on paper and the rights are primarily held by water authorities or large water supply entities. Thus, often transfers are in bulk between these entities rather than between underlying individual buyers and sellers.
EXT_EVALUATION	The market is not as developed as California's market, but it is likely that transfers will become more widespread as growth increases and water supplies become more strained. The rule of capture makes for unrestrained water marketing that may threaten the sustainability of Texas' aquifers; pump limits may be advisable. Stream gauging may be needed to ensure that water rights are accurately enforced.
BASIN	All basins in Texas
STATE	Texas
SW_GW	Surface and groundwater
RESEARCHER	Brian Easley
REFERENCE	http://parulallc.com/wp---content/uploads/2010/10/Parula---Texas---Water---Marketing---in---Perspective.pdf; http://texaslivingwaters.org/wp---content/uploads/2013/04/powerful_thirst.pdf

COLLECTIVE ACTION FUNDS

NAME_PROGRAM	Catawba Wateree Water Management Group
TYPE	Collective action funds
HYDRO_SERV_GOALS	Insufficient water quantity in the future. Public water utilities intake from reservoirs and main river channel and Duke Energy is generating power from dams on reservoirs and using water to cool nuclear reactors.
SCALE	Catawba Wateree Water Management Group (CWWMG). Investments will occur in each public utility district that opts into the program, but the program spans the Catawba Basin across the NC/SC border.
ACTORS	The key actors of the members of CWWMG (18 public utilities and Duke Energy) and their respective customers.
BUYER	The members of CWWMG will pay for incentives for their respective regions.
INTERVENTION	The members will distribute incentives to their customers for the purchase of water---efficient and energy efficient appliances (i.e. washing machine, toilets, showerheads). This program will be available to both residential and commercial customers.
DRIVER	The public utilities want to increase water---efficiency in the region to secure their future business. With projected growth in the area and water demand, there is expected to be an inadequate supply of water by 2050.
EXCHANGE_ARRANGE	Public utilities will pay their customers to increase their efficiency/reduce their water use.
COMPENSATION	The Plan leaves it open---ended but the payment will be monetary in some form. (It could be a credit on the utility bill, cash, etc.). The incentive amount is also left up to the individual utilities to decide.
COBENEFITS	The incentives for water and energy efficient appliances could also reduce energy usage in the region. Incentives could also increase sales for retailers/manufacturers.
BARRIERS	Since the program is voluntary for the members of CWWMG, there may not be participation. Adequate incentives may not be offered to customers. This portion of the Plan is not set to be implemented until 2016.
EXT_EVALUATION	
BASIN	Catawba
STATE	North Carolina and South Carolina
SW_GW	Surface water
RESEARCHER	Laura Early
REFERENCE	[1] Water Use Efficiency Plan, April 2014. CWWMG. http://catawbawatereewmg.com/2014/2014.04_CWWMG_WaterUseEfficiencyPlan_April2014.pdf

NAME_PROGRAM	Colorado River System Conservation program
TYPE	Collective action funds
HYDRO_SERV_GOALS	Increase flows to Lake Powell (for use by in Lower Basin and in the cities of Denver, Phoenix, and southern California) by reducing the amount of water diverted for irrigation in the Upper Colorado River Basin.
SCALE	Basin. Includes all seven states of the Colorado River Basin
ACTORS	**Providers:** Existing water users that are willing to be compensated for voluntary reductions in water consumption through efficiency or foregoing usage, which are labeled as Entitlement Holders or Upper Colorado River Water Users. "Entitlement Holder means a person, or entity, within the Lower Division States or Mexico that: (i) has an existing authorization to divert or order Colorado River water, (ii) with the consent of (i) is located within the water service area of (i); or (iii) has control of state appropriated water rights on the Muddy and Virgin Rivers, all as reasonably required for beneficial uses." [2, p. 7] "Upper Basin Colorado River Water User means a person or entity within an Upper Division State that has an existing authorization under applicable state law to divert Colorado River System water as reasonably required for beneficial uses. [2, p. 9] "In the Upper Colorado River Basin, partners to the agreement so far include: The Colorado Cattlemen's Association, Colorado Farm Bureau, Colorado River District and the Southwestern Water Conservation District." [1] **Beneficiaries:** All users of the Colorado River system which benefit from sustained water availability; including municipal and hydropower users that would be threatened with interruptions from shortages. [2] This primarily means Local Funding Agencies and hydropower companies but also all other entities that benefit from System Conservation and agencies with mandates to reduce salinity or provide minimum flows. Local Funding Agencies are comprised of the Central Arizona Water Conservation District (includes Phoenix and Tucson), Metropolitan Water District of Southern California (MWD), Denver Water, and Southern Nevada Water Authority, "all of which are public entities that use water from the Colorado River Basin for municipal purposes." 2, p. 7] Upper Basin Contracting Entity means an entity to be agreed upon by the Parties, such as, by way of example, the Upper Colorado River Commission, the Colorado River Basin Salinity Control Forum, an Upper Division State or States, or Reclamation. [2, p. 9] **Other Stakeholders:** Bureau of Reclamation (administrator; funder; in Lower Basin states: processes and reviews proposal requests, enters into and administers agreements with Entitlement Holders, enters into project specific funding agreement with Local Funding Agencies, verifies and documents all consumptive use reductions associated with Program). Upper Basin Contracting Entity (a yet undecided entity, in Upper Basin states: enters into and administers agreements with Upper Basin Colorado River Water Users, enters into project specific funding agreement with Local Funding Agencies). Upper Colorado River Commission, Colorado River Basin Salinity Control Forum (along with Bureau of Reclamation and Upper Division State(s), are parties to consensus process for approving an Upper Basin Contracting Entity). [2]
BUYER	Beneficiaries (listed above) and public good payers (federal government via the Bureau of Reclamation)

INTERVENTION	OVERVIEW: A pilot program to fund System Conservation (i.e., "voluntary, measurable reduction of consumptive use of Colorado River water, including the elimination of system losses or reduction in demands through increased efficiency" [2, p. 8]) in the Colorado River Basin, which was established by an agreement between entities in all seven basin states [2]. PURPOSE: "The purpose of this Agreement is to initiate a Pilot Program for System Conservation to determine whether System Conservation is a sufficiently cost---effective, robust, and feasible method to partially mitigate the impacts of salinity and ongoing drought on the Colorado River System by managing water elevation levels in Lakes Mead and Powell above critically low elevations as a first priority, with the ancillary benefit of enhancing flows in areas upstream of storage reservoirs." [2, p. 9] PROCEDURES: A System Conservation Implementation Agreement is entered into between a current water user (i.e., Entitlement Holder, in Lower Basin, or Upper Basin Colorado River Water User, in Upper Basin), contracting entity (i.e., Reclamation, in Lower Basin, or Upper Basin Contracting Entity, in Upper Basin), and one or more Local Funding Agencies (third---party beneficiaries, which are afforded the right of enforcement). Before a project is initiated there must be unanimous approval of all effected parties and a funding agreement. SUNSET CLAUSE: It is important to note "the program is intended only as emergency short---term drought relief and would end if Colorado River flows increase to levels that can refill and sustain Lake Powell." [1]
DRIVER	DROUGHT: The basin is in a 14y year drought and "recent Colorado River System modeling projections show a serious neary term risk that water elevations in both Lakes Mead and Powell could decline to levels that would trigger shortages and could interrupt the ability of certain municipal users to draw or benefit from water from both lakes and certain hydropower users to benefit from hydroelectric energy generation" [2, p. 4]. COMPACT: Water stored in Lake Powell acts as a buffer against annual shortages in water guaranteed to lower basin states by the Colorado River Compact. However, the levels in Lake Powell have been very low. This may lead to a compact call in the next 3y 4 years (meaning upper basin states must curtail usage to provide the share of water apportioned to lower basins states by the Compact). This deal is an attempt to raise levels in Lake Powell without a compact call. [1] STUDY: Colorado River Basin Water Supply and Demand Study had "purpose of defining future imbalances in water supply and demand through the year 2060, and to develop and analyze options and strategies to resolve those imbalances" and "results from the Basin Study show that without further proactive steps, there may be a long term and potentially significant imbalance in future water supply and demand. Options to address these imbalances include increased agricultural and municipal water conservation" [2, p. 4] REGULATORY: The Colorado Basin Salinity Control Act of 1974 authorizes projects to reduce basin salinity and directs Secretary to conduct research on better methods to do so. PREVIOUS POLICY: There was a Bureau of Reclamation Policy Establishing a Demonstration Program for System Conservation of Colorado River Water ("Demonstration Policy"), active from 2006y 2010, which intended to "establish a demonstration or "pilot" program of voluntary agreements with eligible holders of Colorado River water entitlements to conserve a portion of their approved annual consumptive use of Colorado River water for the benefit of Colorado River system storage" [2, p. 3]. This current Program hopes to further both the research and system benefits of the Demonstration Policy.
EXCHANGE_ARRANGE	Bilateral or multilateral contracts, in the form of System Conservation Implementation Agreements.
COMPENSATION	Cash. "Compensation for System Conservation shall be paid by Reclamation or the Upper Basin Contracting Entity from the amounts contributed by the Local Funding Agencies and the funding available from Reclamation for the Pilot Program. Where feasible, Entitlement Holders and Upper Basin Colorado River Water Users shall be paid some or all of the required payments in arrears (after verification has occurred)." [2, p. 13] Program funding will be provided by the following entities: Bureau of Reclamation ($3 million for the initial pilot project), local funding agencies (up to $2 million each to go towards Pilot Program costs), and other entities such as nonprofit organizations (may contribute money via local funding agencies). [2]

COBENEFITS	Environmental. "Upper Colorado River Basin partners include major conservation groups, showing how the envisioned water reallocation will help protect native and recreational fisheries in the Upper Colorado Basin and maintain critical Lake Powell water levels at the same time." [1] Social: "Parties desire to cooperate with the users of water for agricultural purposes, avoid adverse economic and environmental impacts, and compensate voluntary reductions of consumptive use of water by fallowing agricultural lands only to the extent such reductions in consumptive use avoids injury to existing water rights." [2, p. 6]
BARRIERS	LEGALITY: According to one reviewer "agreements reached under the new program could violate state laws that govern water allocation" because "participants to voluntary agreements can bind each other legally with a water contract, but the new multi---state program doesn't address what happens if those deals affect other water users not party to the agreement" [1] FARMER PERCEPTIONS: "The deal doesn't include provisions for any direct water grabs that would transfer water directly from farms to cities. But the mere mention of agricultural water transfers — even if they're voluntary — is enough to send shock waves through some farming communities in Colorado. The concerns often center around loss of community and the traditional culture and way of life associated with farming and ranching." [1]
EXT_EVALUATION	Some "water law experts" say "the transfers envisioned under the agreement are probably more of a Band---Aid than the major surgery that may be required to equitably distribute Colorado River water during times of shortage" [1]
BASIN	Colorado River Basin
STATE	Arizona, California, N evada, N ew Mexico, Utah (Lower Basin); Colorado, Wyoming (Upper Basin)
SW_GW	Surface water and groundwater (if hydrologically connected to Colorado River System)
RESEARCHER	Shannon Bonney
REFERENCE	[1] Berwyn, B. (2014). "Water deal aims to keep city faucets flowing". *The Colorado Independent,* http://www.coloradoindependent.com/148506/water---deal---aims---to---keep---city---faucets---flowing ; [2] "Agreement Among the United States Of America, Through the Department Of The Interior, Bureau of Reclamation, the Central Arizona Water Conservation District, the Metropolitan Water District of Southern California, Denver Water, and the Southern Nevada Water Authority, for a Pilot Program for Funding the Creation of Colorado River System Water Through Voluntary Water Conservation and Reductions In Use"

NAME_PROGRAM	PlatteFire
TYPE	Collective action funds
HYDRO_SERV_GOALS	Watershed protection to prevent sedimentation and erosion (as a result of wildfires) into the reservoir that supplies municipal water to Denver and Aurora.
SCALE	Investments are occurring within the South Platte River Basin in Colorado, upstream of Denver and Strontia Springs Reservoir.
ACTORS	The main actors are the Forest Service and Denver Water, but all the customers of Denver Water are also stakeholders.
BUYER	Denver Water (public utility, cost absorbed by their customers) and the Forest Service (federal government)
INTERVENTION	The funds support forest restoration, thinning, and fuel reductions on National Forest Service lands upstream of the city's water supply reservoirs. [1]
DRIVER	The Buffalo Creek Fire (1996) and Hayman Fire (2002) caused over $10 million in damages to Denver Water's water supply. The costs included water quality treatments, sediment and debris removal, reclamation and infrastructure costs. Denver Water and The Forest Service are investing in watershed protection to prevent catastrophic and costly effects of wildfires on the water supply. [1]
EXCHANGE_ARRANGE	Denver Water will contribute $16.5 million over 5 years to match the Forest Service's contribution of $16.5 million, for a total of $33 million to go towards watershed protection on Forest Service Lands. [1] This translates to an additional $27 per year for Denver Water customers. [2]
COMPENSATION	Cash
COBENEFITS	This program also benefits wildfire prevention, and potentially terrestrial habitat restoration.
BARRIERS	
EXT_EVALUATION	
BASIN	South Platte
STATE	Colorado
SW_GW	Surface water
RESEARCHER	Laura Early
REFERENCE	[1] New York Times (2011) http://www.nytimes.com/gwire/2011/08/18/18greenwire---to---protect---tap---water---cities---sharing---costs---of---s---38859.html?pagewanted=all ; [2] High Country News (2012) https://www.hcn.org/issues/44.3/communities---help---pay---for---ecosystem---services---provided---by---forests

NAME_PROGRAM	Flint River Basin Partnership
TYPE	Collective action funds/ Public subsidies
HYDRO_SERV_GOALS	There are insufficient surface water flows for endangered and threatened aquatic species during droughts. Agricultural irrigation consumes the most water in the region, but also supports a very economically and socially important farm industry. A previous Irrigation Reduction Auction paid farmers to not irrigate during a drought; but this MBI gave farmers a choice between the environment and agriculture. A new approach was needed to find win---win solutions for both farmers and the environment. This solution would allow farmers to continue irrigating, but would reduce overall consumption of water for irrigation, so more water is left instream for endangered and threatened species. [1---4]
SCALE	Investments occur on a farm---by---farm (i.e. local) basis within the Flint River Basin (i.e. subbasin). [1]
ACTORS	**PROVIDERS:** farm owners using water for irrigation in the Flint River Basin that participate in the Partnership's program. **BENEFICIARIES:** endangered and threatened aquatic species that rely on sufficient surface water flows, additionally: NGOs and other stakeholders with conservation interests and government agencies responsible for protecting endangered and threatened species (e.g. USFWS and GA DEP), participating farmers also benefit by reduced water pumping costs. **OTHER STAKEHOLDERS**: the Partnership is administered and funded by the Flint River Soil and Water Conservation District (FRSWCD), USDA's N atural Resources Conservation Service (NRCS), and The Nature Conservancy (TNC)– Georgia. Research on variable rate irrigation (VRI) and other water saving technologies was conducted at the University of Georgia's C.M. Stripling Irrigation Research Park. [1---4]
BUYER	All funds are derived from public goods payers. The Partnership obtains funds from public sources (e.g. agency grants) and private contributions (i.e. donations to TNC). The FRSWCD obtains funds from NRCS grants such as EQIP and uses them as cost---shares for farmers to adopt water saving technology. The NRCS provides a number of grants for agricultural water conservation and technical assistance. [1---4]
INTERVENTION	Agricultural BMPs and irrigation infrastructure upgrades. The buyer pays for the adoption of water---saving practices and technologies by farmers, in order to reduce irrigation water consumption in the Flint River Basin. The 3 main water---saving practices and technologies paid for by this program are: 1) retrofitting center pivot irrigation systems to low---pressure nozzles that more efficiently spray water on crops, 2) rotating perennial grasses with cash crops and adopting conservation tillage practices, and 3) adopting variable rate irrigation technology to only put water where it's needed. It is assumed farmers will not consume the saved water by increasing the area of crops grown or switching to more water intensive crops. If this assumption holds true, the adopted practices and technologies are successful in reducing water consumption, another farmer does not consume additional water found in stream or in recharged aquifers, and no additional consumptive use permits are issued, then there will be more water left instream for endangered and threatened species. [1---4]
DRIVER	The buyers pay for various reasons, but primarily because water shortfalls during drought, caused or exacerbated by irrigation, have harmed federally protected endangered species (i.e. mussels). Water use permits have no cap on how much a farmer can pump from aquifers. Even at the current number of permits issued there are shortages of water during drought (implying the basin has been over---allocated). So there is a situation where there is potentially a 'taking' of endangered species (through habitat reduction and direct mortality) but no politically feasible way to permanently limit agricultural water use through regulatory means (new permits can be denied, but existing permits cannot be capped and the state would have to use its police powers to obtain permits through eminent domain, or impose temporary water---use restrictions during droughts). So therefore, there are many actors with incentives to provide or participate in incentives programs that fund voluntary reductions in irrigation water use. Moreover, the FRSWCD and NRCS pay for these water saving technologies and practices so farming can continue to be economically viable, while complying with Endangered Species Act. The Nature Conservancy pays because it is achieving ecological goals in the region, while also building partnerships with farming communities. [1---4]
EXCHANGE_ARRANGE	Bilateral or multilateral contracts between participating farmer and funder (unsure if contract between farmer and Partnership or directly with federal agency sponsors). [1]

COMPENSATION	Payment is in form of cost---share for adoption of technologies (#1 & #3). Non---monetary payments include in---kind donations of irrigation equipment. Indirect payment includes cost---savings from adopting water saving practices (#2) and access to research and technical assistance. [1---4]
COBENEFITS	The program also has socio---economic objectives (i.e. to ensure the economic sustainability of agriculture in the region in the face of water shortages, and to prevent the losses to the community that would come if agriculture were severely limited in the region). [1---4]
BARRIERS	According to Watson and Scarborough (2014, 5) "several farmers in the Flint River Basin were understandably skeptical of the sophistication and gadgetry. But when the “firstmovers” realized significant water savings, the skepticism eased". [1]
EXT_EVALUATION	One case study praises the project: "The water and cost saving results are impressive. Since the program began in 2003, farmers employing variable rate irrigation have saved more than 10 billion gallons of water. That’s enough to meet the water needs of Orlando, Florida, for an entire year! Additionally, irrigation costs have fallen by 15–30 percent on the 22 participating farms, due primarily to reductions in the amount of water and diesel required." (Watson and Scarborough 2014, 5) [1]
BASIN	Apalachicola---Chattahoochee---Flint River Basin; Flint River Sub---basin
STATE	Georgia (impacts Florida through increasing inflows to Lake Seminole)
SW_GW	Surface and groundwater
RESEARCHER	Shannon Bonney
REFERENCE	[1] Watson, R. and B. Scarborough (2014). Flint River Basin Irrigation: Wireless Water for Biodiversity. PERC Case Studies. L. Huggins. Bozeman, MT, Property and Environment Research Center,: 1---8. ; [2] http://striplingpark.org/collaborations/ ; [3] http://www.nature.org/ourinitiatives/habitats/riverslakes/explore/saving---millions---of---gallons---of---water---flint---river.xml ; [4] http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/georgia/explore/conservation---on---the---flint---river.xml

NAME_PROGRAM	The Freshwater Trust
TYPE	Collective actions funds/ Instream buybacks
HYDRO_SERV_GOALS	Restore river ecosystems through a strategically applied suite of approaches, including: planting trees, restoring river flows, removing invasive species, creating log jams, removing fish barriers, protecting streambanks, and implementing agricultural best management practices. [1]
SCALE	Multiple basins throughout the western US
ACTORS	**Providers:** For restoration of flows, those with water rights that are willing to sell, lease, or donate all or a portion of their share on a permanent or temporary basis. Additionally, farmers willing to improve irrigation efficiency or forgo irrigation during critical times (such as times when rivers are thermally stressed) in exchange for compensation. **Beneficiaries:** Entities with interests in (or legal obligations for) protecting or enhancing riverine ecosystems. **Other stakeholders**: governmental agencies and community organizations that collaborate with Freshwater Trust on specific projects.
BUYER	Multiple. There is a wide---array of entities that fund the Freshwater Trust, which include public donations, residential utility customers (taking part in Pacific Power's Blue Sky Program), and members of the Corporate Council for Freshwater. [1]
INTERVENTION	The full suite of restoration practices includes more than approaches flow restoration (including water quality trading and removing fish barriers). However, the tools employed by the Trust for restoring flows include those applied at parcel, watershed, and community scales. Parcel---scale approaches include: split season leasing, full season leasing, and point of diversion transfer. An example of a watershed scale approach is the Fifteenmile Creek, Oregon. In this watershed irrigators agreed to voluntarily suspend irrigation when water temperature would be lethal for an endangered fish species living in the creek, in exchange for limited liability under the Endangered Species Act. In the Lostine River watershed, Oregon, the Trust has an agreement with ditch companies to compensate irrigators for improvements to irrigation efficiency in order to provide more water for migrating salmon.
DRIVER	Lack of instream flows and degraded habitat has led to the decline of salmon populations and other indicators of ecosystem health.
EXCHANGE_ARRANGE	Bilateral or multilateral contracts.
COMPENSATION	Cash or in kind.
COBENEFITS	Environmental and socioeconomic. The interventions are designed to restore riverine health, while also benefiting farmers and their communities.
BARRIERS	
EXT_EVALUATION	
BASIN	Multiple in western US
STATE	Multiple in western US
SW_GW	Surface water
RESEARCHER	Shannon Bonney
REFERENCE	[1] http://www.thefreshwatertrust.org

INSTREAM BUYBACKS

NAME_PROGRAM	Colorado Water Conservation Board Instream Flow Program
TYPE	Instream buybacks
HYDRO_SERV_GOALS	"The CWCB acquires water, water rights and interests in water to preserve and improve the natural environment of streams and lakes in the state. " [1]
SCALE	Statewide
ACTORS	**Providers:** Water rights holders that wish to permanently or temporarily sell, lease, donate, or loan their water rights. **Beneficiaries:** State agencies and conservation groups that have an interest in protecting instream flows. **Other Stakeholders**: Department of Natural Resources Colorado Water Conservation Board (administers program). The Nature Conservancy (made significant water donations)
BUYER	Public goods payer. Department of Natural Resources Colorado Water Conservation Board
INTERVENTION	"The Water Acquisition Program is a voluntary program that allows water rights' owners to donate, sell, lease or loan existing decreed water rights to the CWCB on a permanent or temporary basis. The CWCB can acquire water by purchase, bequest, donation, lease, exchange or any other contractual agreement. The CWCB cannot acquire water rights by eminent domain or force an individual to convey a water right to the CWCB for instream flow purposes." [1] The CWCB currently receives several offers of water rights for ISF use via donation, purchase, lease or loan each year. Water acquisition proposals can be considered at any time during the year. Each water acquisition transaction is unique, and the particular terms and conditions are included in a separate agreement that is developed by the proponent and CWCB staff. The CWCB has 120 days to respond to the proposal. Individuals interested in learning more about the water acquisition process are encouraged to contact the CWCB staff." [1]
DRIVER	The CWCB appropriates water rights to instream flows purposes, which are considered new junior rights [2]. During low flow times there may not be enough water to fulfill these, and other, junior rights. The CWCB is also allowed to buy, lease, or be donated senior rights. These acquisitions increase the likelihood that instream flows will be protected during times of scarcity when the junior instream flow appropriations cannot be fulfilled.
EXCHANGE_ARRANGE	Bilateral or multilateral contracts
COMPENSATION **COBENEFITS**	Cash Environmental
BARRIERS	Limited information available on agency's website.
EXT_EVALUATION	A story by Aspen Journalism [3] points out that there is a relatively insignificant amount of money put into this program, the program is limited by only being able to appropriate instream flows as junior rights (however as newer development occurs over time these rights will become relatively more senior), the process of transferring senior rights is risky (upon inspection the right may be determined to be smaller than the permit originally stated) and time---consuming (as it requires being heard before water court). [3]
BASIN	Statewide
STATE	Colorado
SW_GW	Surface water
RESEARCHER	Shannon Bonney
REFERENCE	[1] http://cwcb.state.co.us/environment/instream---flow---program/Pages/CompletedTransactions.aspx ; [2] http://cwcb.state.co.us/Pages/InstreamFlowProgramFAQs.aspx ; [3] http://aspenjournalism.org/2014/01/21/state---of---colorados---instream---flow---program---is---lauded---challenged/

NAME_PROGRAM	Colorado Water Trust
TYPE	Instream buybacks
HYDRO_SERV_GOALS	Increase the quantity of instream flows through promoting and accelerating the transfer of water rights from consumptive uses to the Colorado Water Trust. "The passage of Senate Bill 97 created the State's Instream Flow Program and gave the Colorado Water Conservation Board the exclusive authority to appropriate instream flow water rights and to protect water in a reach of stream. The Colorado Water Trust (CWT) was formed in 2001 to partner with Colorado's Instream Flow Program and amplify its work by supporting and promoting voluntary, market---based efforts to protect and restore Colorado's streamflows. Today, CWT is the only non---profit organization working statewide to transact water deals for conservation benefits. We facilitate the transfer of decreed water rights into the Instream Flow Program. To do this, we work in close partnership with the Colorado Water Conservation Board. We also work on physical projects that restore streamflows, such as moving a headgate, establishing a low---flow channel, or installing a fish---ladder. And we provide technical assistance to the land trust community." [1]
SCALE	Multiple basins, including Colorado River, Rio Grande, and South Platte.
ACTORS	Providers: Entities water rights that are willing to temporarily or permanently sell or lease all or a portion of their water rights. These entities include farmers, as well as municipal and industrial water users. Beneficiaries: Entities with voluntary or mandatory interests in protecting or enhancing instream flows. Other stakeholders: Colorado Water Conservation Board (CWCB), watershed groups, and land trusts. Colorado Water Trust (is an intermediary between water users and CWCB for transfers to the Water Trust for instream purposes, also raises funds for said transfers and other interventions).
BUYER	Public good payers (Colorado Water Trust secures and utilizes funds for the protection of instream flows).

INTERVENTION	The CWT utilizes the following approaches to securing instream flows: Water Rights Sale: “permanent transfer of a water right for change to instream flow use. It typically requires separation of the water from the land and acceptance of the water by the CWCB. CWT fundraises to buy the water, conducts any necessary engineering and other studies, and completes the transaction with the CWCB.” Water Rights Donation: “similar to a sale. It, too, requires separation of the water from the land and acceptance of the water by the CWCB, and our [CWT] role remains the same as it does in a sale. The difference is that the donation may be a charitable contribution and, therefore, tax deductible.” Longs Term Lease: “allow for the CWCB to use water for instream flows on a temporary basis. Longs term leases under House Bill 08s 1280 must go through water court. Funds may be available for water users who enter into these leases, and we [CWT] are able to facilitate the lease transaction with the CWCB.” Shorts Term Lease: “allow the CWCB to utilize water for instream flow benefits in three of ten years. Typically, these leases need not go through water court. Funds may be available for water users who enter into these leases, and we [CWT] are able to facilitate the lease transaction with the CWCB." Drys Year Transactions: "transaction that allows the CWCB to use water rights when a certain event, such as water levels dropping below a certain point at a specific stream gage, is triggered. These can be shorts term, longs term or permanent arrangements. It will depend on the duration of the agreement as to whether water court must be involved. Funds may be available for water users who enter into these leases, and we [CWT] are able to facilitate the lease transaction with the CWCB." Structural and Alternative Use Solutions: "physical solutions such as headgate and delivery system upgrades that make more water available downstream. Other approaches include reservoir outlet structure upgrades, changes in points of diversion, creation of lows flow channels and fish ladders, and other creative physical projects that don’t involve buying or leasing water...may have to go through water court, depending upon the plan. Other approaches that can provide additional flows include innovative agricultural technology, storage releases, or changes in reservoir management." Water Rights Trust: "Under the right circumstances, water rights can be placed in a trust to be managed by the CWCB. The water rights owner maintains title to the water, but the CWCB can use the water in the Instream Flow Program. Funds may be available for water users interested in this type of arrangement, and we are able to facilitate the lease transaction with the CWCB." Conservation Easements: CWT "works closely with the land conservation community on water rights issues, from educational programs on water to model language that encourages smart, flexible, and effective inclusion of water rights in conservation easements." Creative Combinations: "hybrid of the solutions available." [4]
DRIVER	Inadequate flows throughout many basins in Colorado caused by over---appropriation and inefficient use.
EXCHANGE_ARRANGE	Bilateral or multilateral contracts.
COMPENSATION	Cash.
COBENEFITS	Environmental.
BARRIERS	
EXT_EVALUATION	
BASIN	Multiple basins, including Colorado River, Rio Grande, and South Platte.
STATE	Colorado
SW_GW	Surface water
RESEARCHER	Shannon Bonney
REFERENCE	[1] http://www.coloradowatertrust.org/about---us/ ; [2] http://www.coloradowatertrust.org/our---work/projects/peabody---no---1---ditch---blue---river/ ; [3] http://www.coloradowatertrust.org/newsroom/conservation---deal---will---boost---water---quantity---in---blue---river/ ; [4]

NAME_PROGRAM	Klamath Basin Rangeland Trust Water Transactions Program [no longer active]
TYPE	Instream buybacks
HYDRO_SERV_GOALS	The Klamath Basin Rangeland Trust works to achieve three objectives: "(1) Address the over---commitment of water resources by reducing water use above Upper Klamath Lake. This increases instream flows to provide critical fish habitat, as well as provides additional water to Upper Klamath Lake for the downstream benefit of fish, wildlife, ranching, and agriculture. (2) Encourage land, water, and cattle grazing management strategies that improve water quality in rivers and lakes while maintaining a viable ranching economy in the upper basin. (3) Restore and re---establish wetland areas to produce water quality improvements, natural water storage, and other wetland---related environmental benefits." [1]
SCALE	Upper Klamath Lake Drainage Basin. Local/sub---basin. Oregon only.
ACTORS	Oregon Water Resources Department, Natural Resources Conservation Service, "agricultural, tribal, fishing, and conservation communities." "Klamath Tribes, Oregon Department of Fish and Wildlife, US Forest Service, US Fish and Wildlife, Sustainable Northwest, Upper Klamath Water Users Association" [1]
BUYER	Klamath Basin Rangeland Trust
INTERVENTION	There are several interventions, including water rights leases and transfers. In the 'Standard Instream Lease' the water user leases their use rights for a period of one to five years, which protects them from forfeiture of their rights due to nonuse. In 'Split---season Instream Lease' the landowner may irrigate for part of the season, but convert their water right to instream use for the low flow period of the year. A 'Standard Instream Transfer' is similar to the 'Standard Instream Lease' but is permanent. A 'Time---Limited Transfer' allows a water right to be transferred instream for a specific period of time. A 'Point of Diversion Transfer' incentivizes relocating the point at which a landowner diverts water, say from a spring area to a main lake, in order to protect habitat. In 'Allocation of Conserved Water' allows a water user who conserves water to allocate the saved water to instream use. The Program also helped farmers achieve water conservation by supporting deficit irrigation & dryland farming; through planting native or drought tolerant grass species and compensating farmers for dedicating saved water to instream uses. [2]
DRIVER	Waters of the Klamath Basin have been over---allocated. This Program attempts to lower the water deficit (estimated to be 30,000 acre feet annually [1]) through water transactions.
EXCHANGE_ARRANGE	Bilateral or multilateral contracts.
COMPENSATION	Cash. All transactions use the fair market value of the water rights, and payment takes the form of a monetary transaction.
COBENEFITS	Environmental and social. See "Hydrological service goals"
BARRIERS	There are limitations imposed by Oregon Law; such as: the inability to protect diminishments (i.e. reductions in usage of a water right through technological or behavioral changes) for instream use and the inability to place water protected by behavioral changes (i.e. foregoing irrigation), rather than by technological changes (i.e. purchasing more efficient irrigation equipment) into the statewide Allocation of Conserved Water Program (which protects conserved water from forbearance, i.e. being taken from farmer and used for new appropriations). Additionally, Oregon Law does not require the monitoring or metering of water diversions. This makes it difficult and costly to protect an instream water right; as an individual representing the instream right must take on the task of measuring and report their findings to the water master in order for the instream right to be protected. Moreover, in Oregon, instream water rights cannot be protected if the stream is above the 'Estimated Average Natural Flow'; even if it occurs during a 'wet' year. The Federal appraisal process, necessary for the government to acquire real property, is burdensome.
EXT_EVALUATION	
BASIN	Klamath Basin, Upper Klamath Lake sub---basin
STATE	Oregon
SW_GW	Surface water
RESEARCHER	Dan Read and Shannon Bonney
REFERENCE	[1] http://www.oregon.gov/owrd/law/docs/GrantApp/GC0013_09_WTPFinal_June2011_OWRD.pdf ; [2] http://www.kbrt.org/water/

NAME_PROGRAM	Montana statewide legislation [needs more details]
TYPE	Instream buybacks
HYDRO_SERV_GOALS	The need for water for agricultural and environmental purposes. The leasing program allows for private leasing to increase instream flows.
SCALE	Statewide in Montana.
ACTORS	Trout Unlimited, Montana Water Trust, and Montana Fish, Wildlife, and Parks are the primary buyers (lessees) Individual buyers may also arrange for water rights leases through formal or informal means, but data on these types of transfers seems to be largely unavailable. Sellers are water rights holders who are willing to lease (temporarily transfer) their rights. Applications for transfers are submitted to the Department of N atural Resources and Conservation (DNRC) for review and approval.
BUYER	Groups or agencies wanting to protect environmental flows or individuals wanting to obtain more water for instream flows.
INTERVENTION	Increased instream flows; water leasing for other purposes is currently not available under Montana law. Montana has enacted following legislative tools to facilitate protection of instream flows: Murphy (water) Rights, reservations, leasing/converstions [sic], storage, and judicial determinations [1]. State law also allows for 'public recreational use' claims [1].
DRIVER	The buyers are groups or agencies interested in environmental conservation.
EXCHANGE_ARRANGE	The buyers negotiate prices and terms with the sellers.
COMPENSATION	The payment form is negotiated by the buyers and sellers.
COBENEFITS	Organizations wanting environmental benefits (for example Trout Unlimited) can purchase water rights in order to increase instream flows.
BARRIERS	Montana does not have water banks, which serve as middlemen in transfers, uniting buyers and sellers. Montana has very little infrastructure to support interbasin transfers.
EXT_EVALUATION	Montana may benefit from the development of water banks to facilitate transfers. Under the current circumstances formal leasing agreements may take several years to complete.
BASIN	All basins in Montana
STATE	Montana
SW_GW	Surface water
RESEARCHER	Brian Easley and Shannon Bonney (updates and details)
REFERENCE	http://leg.mt.gov/content/Committees/Interim/2007_2008/water_policy/staffmemos/watermarketing101.pdf; http://scholarship.law.umt.edu/cgi/viewcontent.cgi?article=1272&context=plrlr ; [1] http://fwp.mt.gov/fishAndWildlife/habitat/fish/waterManagement/instreamFlows.html

NAME_PROGRAM	Texas Water Trust
TYPE	Instream buybacks
HYDRO_SERV_GOALS	Addressing the insufficient surface water to meet environmental needs through increasing the amount of water left instream for the environment. The shortfall in environmental water is caused by a number of factors, including: 1) Texas not receiving its full share of water guaranteed to it by the Rio Grande and Pecos River Compacts, and 2) increases in consumptive use of water for irrigation and municipal needs in Texas. [1]
SCALE	Program is statewide, but only transactions to date have been on the Rio Grande (Hudspeth County) [1]
ACTORS	The Texas Water Trust is a subset of the Texas Water Bank, a clearinghouse for bilateral trades open to any willing seller and buyer, which has been set up to hold environmental water rights. **PROVIDERS:** To date the only seller has been a state agency (Parks and Wildlife Department). **BENEFICIARIES:** aquatic species and environmental services that rely on sufficient surface water flows, additionally: NGOs and other stakeholders with conservation interests and government agencies responsible for protecting endangered and threatened species. **OTHER STAKEHOLDERS**: The Texas Water Development Board administers the Trust. [1]
BUYER	The Trust may buy water rights from willing sellers (though no money has yet been appropriated to them for these purposes) or receive donated water. The fees charged for buyers and sellers to register with the Texas Water Bank are waived for Trust transactions (i.e. environmental water transactions). [1]
INTERVENTION	A transfer of water rights from consumptive use permit holders to the Texas Water Trust to be used for instream environmental purposes. [1]
DRIVER	The administrating agency is responsible for protecting endangered and threatened species. Buying or leasing water rights for environmental purposes helps to protect water dependent species. Additionally, there are minimum water flows that need to make it to the Texas---Mexico border defined in compacts. [1] [UPDATE BECAUSE MEXICO OWES US WATER FROM RIO GRANDE EXCHANGE FOR WATER US PROVIDES MEXICO FROM COLORADO RIVER, and MEXICO IS BEHIND ITS WATER DELIVERIES]
EXCHANGE_ARRANGE	Bilateral contracts which are facilitated by a market---place mechanism (i.e. the water trust). [1]
COMPENSATION	Cash or in---kind donation. Cash payments can be made on behalf of the Trust, but thus far there have been only in---kind donations of water rights to the Trust.
COBENEFITS	Environmental co---benefits include increases in: aquatic habitat, instream flows, and water quality. [1] There are also increases in water available for non---consumptive instream uses, such as water---based recreation and navigation.
BARRIERS	There have yet to be appropriations to the Trust in the Texas State budget. On account of this, transactions have been highly limited.
EXT_EVALUATION	
BASIN	State wide (Texas), but transactions thus far in Rio Grande Basin
STATE	Texas
SW_GW	Surface water
RESEARCHER	Shannon Bonney
REFERENCE	[1] Clifford, P., C. Landry and A. Larsen---Hayden (2004). Analysis of Water Banks In the Western States. Olympia, Washington, Washington Department of Ecology: 1---168.

NAME_PROGRAM	Washington Water Acquisition Program
TYPE	Instream buybacks
HYDRO_SERV_GOALS	Increase quantity of water left instream to meet flow needs of endangered and threatened fish species. Additionally, to focus on providing water during critical times necessary for fish survival. In this way the hydrologic service goals are related both to quantity and timing.
SCALE	Multiple watersheds. Sixteen watersheds that have critically low flows that may harm endangered or threatened fish species (primarily trout and salmon)
ACTORS	**Providers:** Generally agricultural water users that make withdrawals in priority areas, which are willing to sell or lease all or a portion of their water rights on a permanent or temporary basis (must be "wet" water and not "paper" water). **Beneficiaries:** State agencies and nonprofit organizations acting on behalf of endangered and threatened fish species eds. **Other stakeholders**: Washington State Department of Ecology (funder and administrator), Washington Water Trust (intermediary in all watersheds besides Dungeness that "outreach to water users, a safe point of contact for inquiries, a confidential initial review of the water right's validity, and valuation of the water right" [2, p.5]), Bonneville Power Administration, Dungeness Agricultural Water Users Association (intermediary between sellers and buyers in Dungeness watershed)
BUYER	Public goods payers.
INTERVENTION	Willing sellers or lessors transfer water to the Washington Trust Water Rights Program via the following mechanisms: Purchase: "permanently transfers all or a portion of the water right to the state's trust program". Lease: "temporary acquisition of the right. In practice, leases have been arranged for periods of 1, 3, 5, and 20 years. Longer term leases are preferred." Split season lease: "allows a portion of the water right to be used for irrigation early in the season, but returns the water to streams during the period of need for fish. In the Dungeness watershed, the water is leased for just six weeks per year, from August 1 to September 5." Dryad year lease: "allows a farmer to irrigate except in dry years, when water is not withdrawn." Donation: "Water right holders can donate all or part of a water right on a permanent or temporary basis, and they might be eligible for a tax deduction." [2, p. 3] The Water Acquisition Program utilizes the full portfolio of acquisition mechanisms and additional strategies in order to maximize benefits for environment and consumptive uses. [3] Additional strategies used to increase instream flows include: "irrigation efficiency projects, water auctions, water banking, changes in the point of diversion, changes in the source of water, water storage, aquifer recharge, and acquisition of farmland with water rights attached" [2, p. 3] While these activities fit into the overall Water Acquisition Program strategic framework, they are administered and funded by other entities (e.g., Irrigation Efficiencies Program is administered by Washington State Conservation Commission and local irrigation districts).
DRIVER	A large---scale effort to recover salmon populations was occurring statewide. As flows were considered to be a primary limiting factor in salmon population, this program was designed to increase instream flows needed for this effort. The basins selected were the result of a 1999 report by the Governor's Salmon Recovery Office, which labeled them as over---appropriated. Prior to the Water Acquisition Program, the state legislature established the Trust Water Rights Program (which allows water rights to be held for future use or transfer without relinquishment or loss in priority of water right). The Acquisition Program expands the capacity of the Trust Water Rights Program by establishing a strategic framework and specific mechanisms to maximize the amount of water transferred for instream purposes. [1,
EXCHANGE_ARRANGE	Marketplace mechanism
COMPENSATION	Cash. Multiple methods to value water are employed. In areas with an established water market, the value is based on past prices for similar transactions. Otherwise the value can reflect the lost revenues from forgone crops. Another valuation method is to compare the value of the land with and without the attached water right. Despite the method used, the value is modified by the type of transaction (with permanent sales being worth more than temporary leases) and the ecological importance of the water.

COBENEFITS	Environmental and socioeconomic co---benefits. Environmental: Strategic acquisition of instream water maximizes benefits to ecosystems and specifically to populations of endangered and threatened salmon and trout. Socioeconomic: Compensation for split season leases allows farmers to irrigate through the initial part of the season and forgo irrigation at the end of the season. This setup allows farmers to make multiple harvests early on, compensates for lost crops, and leaves open the potential to make a final harvest if crops persist without irrigation. The compensation adds flexibility to farming operations and is said to "substantially enhances the viability of agriculture in the area" [2, p.10]
BARRIERS	"After three years of effort, receptivity to the Water Acquisition Program has been mixed. The program has been well received in the Dungeness watershed, for example, but program uptake in other areas of the state has been significantly less than expected. The program has been controversial for a number of reasons, in part due to concerns that it will treat farmers unfairly or will be detrimental to farming communities and the viability of agricultural economies at the local and state level." [2, p. ii]
EXT_EVALUATION	[In a 2004 report, Lovrich et al. reviewed the Water Acquisition Program, in a process that included interviews with policy leaders and stakeholders located in three of the watersheds. More specific recommendations and valuable insights may be found in this report than are summarized here.] Main findings of the 2004 review include: 1) Mixed receptivity of the program based on local context and history with the administrating agency. 2) Perceived risks of participation in program: "loss of water rights", "leased water might not be returned", "loss of control over water and property", "loss of flexibility", "threat to the agricultural community", and "loss of agricultural economy and infrastructure". [2, p. 14---16]. 3) Slow processing of applications. 4) Potential competition with Irrigation Efficiencies Program (a program where 85% cost share is provided for installation of efficient irrigation and saved water is used for instream uses, without actual transfer of water right). [2]
BASIN	Multiple basins. Sixteen watersheds statewide
STATE	Washington
SW_GW	Surface water
RESEARCHER	Shannon Bonney
REFERENCE	[1] http://www.ecy.wa.gov/PROGRAMS/wr/instream---flows/wacq.html ; [2] Lovrich, .P., D. Siemann, J. Brock, R.M. Bireley, M.J. Gaffney, C. Kent and J. Huckabay (2004). Of Water and Trust: A Review of the Washington Water Acquisition Program.

PUBLIC SUBSIDIES

NAME_PROGRAM	New Mexico's Strategic Water Reserve
TYPE	Public subsidies
HYDRO_SERV_GOALS	Increase the amount of surface water flows leaving New Mexico to meet requirements of Rio Grande and Pecos River Compacts because currently there are insufficient flows to do so. [1---3]
SCALE	Statewide, but each year priority reaches are identified. The Middle Rio Grande, Lower Rio Grande, and Pecos River basins have all been identified as priorities reaches in the years since 2008. [1---2]
ACTORS	Program Administrator: Interstate Stream Commission. Suppliers: Water right holders; United States Bureau of Reclamation. Buyers: Interstate Stream Commission [2]
BUYER	Interstate Stream Commission [2]
INTERVENTION	Lease or permanent sale of surface or ground water rights [1---3]
DRIVER	There are obligations to deliver a specific quantity of water to the New Mexico/Texas state line required by both the Pecos River and Rio Grande Compacts. There have been shortfalls in both of these watersheds (both are in the larger Rio Grande River Basin), which have led to numerous court cases and settlement agreements. The water bank allows users with rights that are junior compared to the compact to continue pumping water during drier times, which will be replaced by water from the bank. [1---4]
EXCHANGE_ARRANGE	Water funds. The Water Fund was set up in 2005. It receives money from state appropriations (which have greatly varied over the years) and the Interstate Stream Commission is authorized to use this money to pay willing sellers. [1]
COMPENSATION	Cash (and in kind). The Interstate Stream Commission is authorized purchase or lease water rights by NM state law. The amount paid cannot exceed the appraised market value. The Commission may also receive donated water (i.e. in---kind donation). [3]
COBENEFITS	The water may be used to augment stream flows for the benefit of threatened and endangered species. There is a 2---mile long pipeline in the Fort Sumner area of the Lower Pecos River that may be used to deliver Reserve water to designated critical habitat for the threatened Pecos bluntnose shiner. [1]
BARRIERS	The Commission cannot purchase water from certain acequia or community ditch companies (i.e. irrigation districts) unless it obtains a contractual agreement with the district board of directors. The Commission can only purchase senior water rights proven to be put to beneficial use. This ensures the purchased water rights are secure even during droughts and will effectively move water out of beneficial use. [3] The Commission solicited stakeholder opinions on challenges to implementation of the Reserve and was told the main barriers were: water price and scarce water rights. [1] There have been significant declines in funding with the recession, with $0 appropriated in 2008 and $1.5 million de---authorized as well as $600,000 frozen in 2009. [1] One study (Clifford et al. 2004) cites significant opposition from irrigation districts, such as the New Mexico Acequia Association, to water banking legislation. [4]
EXT_EVALUATION	The Utton Transboundary Resources Center published a case study that generally praises program, but cites significant funding challenges. [1]
BASIN	Rio Grande River Basin/ Lower Rio Grande, Middle Rio Grande, and Pecos River Sub---basins/watersheds
STATE	New Mexico (impacts Texas through ensuring more surface water reaches state border)
SW_GW	Surface water and groundwater
RESEARCHER	Shannon Bonney
REFERENCE	[1] Buynak, B. (2009). Strategic Water Reserve. Water Matters! Utton Transboundary Resources Center. Albuquerque, M, University of New Mexico,: 1---3. ; [2] http://www.watershedconnect.com/programs/Strategic---Water---Reserve ; [3] N.M.S.A. 1978 §§ 72---1---2.2 --- 2.5. and .M.S.A. 1978 §§ 72---14---3.3 ; [4] Clifford, P., C. Landry and A. Larsen---Hayden (2004). Analysis of Water Banks In the Western States. Olympia, Washington, Washington Department of Ecology: 1---168.

NAME_PROGRAM	Alternative Agricultural Water Transfer Methods Grant Program
TYPE	Public subsidies/ Bilateral agreements
HYDRO_SERV_GOALS	Alternative Agricultural Water Transfer Methods--- The state is offering grants to incentivize development of water sharing programs between irrigators and municipal and industrial users.
SCALE	Statewide, Colorado
ACTORS	Universities, irrigators, public water utilities, ditch companies, state legislature
BUYER	Colorado State Legislature (public good)
INTERVENTION	The state is providing funding to study alternative methods of water---sharing, and the feasibility of implementation. It is a "competitive grant program to advance various agricultural transfer methods as alternatives to permanent agricultural dry---up, including interruptible water supply agreements, long---term agricultural land fallowing, water banks, reduced consumptive use through efficiency or cropping while maintaining historic return flows, and purchase by end users with leaseback under defined conditions" [2]
DRIVER	Current water supplies won't meet municipal demand of projected population growth.
EXCHANGE_ARRANGE	Bilateral or multilateral agreements. Competitive grants to fund projects utilizing alternative agricultural water transfer methods
COMPENSATION	Cash (grant funding)
COBENEFITS	Socioeconomic. Prevents socioeconomic impacts associated with taking agricultural land out of production. [3]
BARRIERS	"The barriers to implementation [of ATMs] have been identified as (1) potentially high transaction costs, (2) water rights administration issues, (3) water providers need permanence and certainty of long---term supply, and (4) infrastructure and water quality." [1]
EXT_EVALUATION	A 2011 agency report [3] states "combinations of ISAs [interruptible service agreements], shared water banking, and/or purchase and leaseback are likely to find success in Colorado. ISAs and rotational fallowing appear particularly suited to areas in the lower South Platte and Arkansas Basins, areas where there is extensive irrigated land and little pressure from urbanized development. Shared water banking may be viable at the interfaces of urban and rural areas." [3, p. 45]
BASIN	South Platte River Basin
STATE	Colorado
SW_GW	
RESEARCHER	Laura Early and Shannon Bonney
REFERENCE	[1] http://cwcb.state.co.us/about---us/about---the---ibcc---brts/Documents/RoundtableSummit2012/ATM%20Group%20---%20ATM%20Fact%20Sheet.pdf ; [2] http://cwcb.state.co.us/loansgrants/alternative---agricultural---water---transfer---methods---grants/documents/altaggrantprogramcriteriaguidelines.pdf ; [3] http://www.coagwater.colostate.edu/docs/ATM_Final_Report_5_3_11.pdf

TRADING & OFFSET MECHANISMS

NAME_PROGRAM	Danvers water use mitigation program
TYPE	Trading & offset mechanisms
HYDRO_SERV_GOALS	Allow for continued development while still complying with its Massachusetts Water Management Implementation Act Permit supply limitations.
SCALE	Local. Restricted to the town of Danvers, Massachusetts.
ACTORS	**Providers:** Residents that take part in the retrofit rebate program. **Beneficiaries:** Applicants able to receive a building permit for new development that requires water. **Other stakeholders**: Danvers Department of Public Works (administers rebates and mitigation program)
BUYER	Applicants for new building permits, such as developers, business owners, and homeowners (pays fees). Public Works buys water conservation through funding plumbing retrofit rebates.
INTERVENTION	Applicants of new building permits pay Public Works a fee to offset for new water demands. Public Works puts these fees into a fund that is used for demand reduction programs, such as the rebate program. [1] The fee is dependent on the type and size of development; for residential units the fees range from $1980---$7920 per unit and for commercial/industrial developments the fees are $9 per gallon per day. There is a 2:1 ratio, meaning the fee paid is for two times the amount of water proposed to be used. Currently there are rebates available for toilets, showerheads, faucets, washing machines, and rain sensors for already existing outdoor irrigation systems.
DRIVER	The Massachusetts Water Management Implementation Act requires Danvers to implement a water use mitigation program as part of its permit requirements.
EXCHANGE_ARRANGE	Bilateral or multilateral agreements.
COMPENSATION	Cash. The amount of the rebates depend on what was being replaced and how efficient the equipment is that replaces it; but range from $25---$200.
COBENEFITS	
BARRIERS	
EXT_EVALUATION	Christiansen (2015) points out that some of the rebates are to high. For instance the rebate for rain sensors ($100) is greater than the average cost of a new rain sensor. The author also says the $50 rebate for faucet and showerheads may be too high for a technology with difficult to quantify water savings. Finally, Christiansen (2015) points out that the rain sensors may be less effective at saving water than soil moisture sensors. 1]
BASIN	Ipswich Watershed (drains directly into Gulf of Maine)
STATE	Massachusetts
SW_GW	Surface water
RESEARCHER	Shannon Bonney
REFERENCE	[1] Christiansen, B. (2015). Water Offset Policies for Water---Neutral Community Growth: A Literature Review & Case Study Compilation. Chicago, Illinois, Alliance for Water Efficiency,: 1---62.

NAME_PROGRAM	Dungeness Water Exchange
TYPE	Trading & offset mechanisms
HYDRO_SERV_GOALS	Address chronic low flows that occur in the summer and fall, as well as a fully apportioned watershed, through closing certain areas to new surface water withdrawals and requiring mitigation for new groundwater withdrawals [1]. Mitigation requirements may be fulfilled through Dungeness Water Exchange or through individual mitigation plans approved by the Department of Ecology.
SCALE	Watershed (basin). Dungeness watershed, Washington state.
ACTORS	**Providers:** willing sellers of water rights **Beneficiaries:** new indoor and outdoor water users required to mitigate in order to be issued a new (building?) permit or to install a permit exempt well (includes developers, homeowners, and farmers with ungulate livestock not poultry) [5, **Other stakeholders:** Department of Ecology (administers program, is intermediary in transactions as they use the mitigation fees to purchase water rights, and funds program through providing the initial mitigation fees required of private homeowners). State Trust Water Rights Program (water held by state for mitigation and instream flows) [6]. The Water Exchange was created through a partnership between: "Clallam County, Department of Ecology, the Dungeness Water Users Association, the Jamestown S'Klallam Tribe, City of Sequim, Clallam PUD No.1, Clallam Conservation District, Washington Department of Fish and Wildlife, and Washington Water Trust, Clallam County, Department of Ecology, the Dungeness Water Users Association, the Jamestown S'Klallam Tribe, City of Sequim, Clallam PUD No.1, Clallam Conservation District, Washington Department of Fish and Wildlife, and Washington Water Trust" [5?]
BUYER	Homeowners or developers that wish to obtain building permits or install a permit exempt well. Farmers that wish to establish an ungulate livestock operation [6]. The Department of Ecology has been paying the mitigation fees required of private homeowners with a $100,000 grant that was supposed to last only the first year after the rule went into effect (2013), but lasted into 2014 [4].
INTERVENTION	Water rights that are obtained from willing sellers (through donations and market transactions) are transferred to state trust water program [1]. Landowners or developers applying for building permits can then buy the water rights, held by the state, in order to meet mitigation requirements [1].
DRIVER	The watershed is already fully apportioned and experiences chronic low flow conditions in summer and fall. This combined with an expanding population, which is occurring faster than many other areas of the state, and four federally endangered fish species creates the pressures on the system that led the Department of Ecology to pass instream flow requirements and a reserve system (for new indoor municipal use) as well as the mitigation requirements and water exchange (to meet the instream flow requirements). [2, 6]
EXCHANGE_ARRANGE	New groundwater users (including those looking for a permit or those installing a permit exempt well), required to mitigate new water usage before being issued a permit, pay a fee to the Dungeness Water Exchange in order to obtain a mitigation credit certificate that says they meet the mitigation requirements. The Department of Ecology uses this money to purchase water rights from willing sellers to place in the water bank. This mitigation water is put into the stream to serve as instream water (to offset the effects of the new groundwater withdrawal). There are a variety of "mitigation packages", based on the type and quantity of water use, which range from $1000---$3000 [5]. As of 2014, the Department of Ecology was using grant money in order to pay for the mitigation requirements of private homeowners. Those creating individual mitigation packages generally obtain senior water rights to transfer it to the state Trust Water Rights Program.
COMPENSATION	Cash. Providers of water rights are paid in cash by the Department of Ecology.
COBENEFITS	The mitigation requirements allow for new development while also meeting instream flow requirements of endangered species and ecosystems [1]. Moreover, mitigation offsets help to replenish water reserves, which provides a backup when mitigation water is not available in an area [1].
BARRIERS	As of 2014 the rule is under litigation, which is preventing its implementation (and also preventing new development in the areas which require mitigation) [3].
EXT_EVALUATION	

BASIN	North Olympic Peninsula Basin
STATE	Washington
SW_GW	Groundwater. Mitigation required for groundwater withdrawals but closure of certain areas to surface water withdrawals.
RESEARCHER	Shannon Bonney
REFERENCE	[1] "Overview of the Water Resources Management Program Rule for the Dungeness Watershed". State of Washington Department of Ecology ; [2] http://www.ecy.wa.gov/programs/wr/instream---flows/dungeness.html ; [3] http://www.peninsuladailynews.com/article/20140723/NEWS/307239985/state sen---jim---hargrove---warns---dungeness---water---rule---lawsuit---could ; [4] http://www.peninsuladailynews.com/article/20131209/news/312099982/ecology---to---pay---for---water---use---credits---in---dungeness---watershed ; [5] http://www.washingtonwatertrust.org/water---exchange ; [6] Final Dungeness Mitigation Guide

NAME_PROGRAM	Edwards Aquifer cap & trade program
TYPE	Trading & offset mechanisms
HYDRO_SERV_GOALS	Limit aquifer withdrawals to point where spring flows are still sufficient to meet the needs of endangered species (572,000 acre feet annually); as the overdraft of the aquifer led to insufficient spring flows. [3] All the while still allowing for sufficient water withdrawals to meet the municipal and industrial demands of San Antonio, which is reliant upon aquifer for approximately 90% of its water supply, and irrigated agriculture. [1] Edwards Aquifer Authority has the additional hydrologic service goals of promoting aquifer recharge and further limiting withdrawals during critical periods of low levels [3, 5].
SCALE	Aquifer (basin). Multi---jurisdictional aquifer that covers nine counties and serves 1.7 million people. [2]
ACTORS	**Providers:** Holders of nonexempt groundwater permits (as exempt groundwater users do not have permits with withdrawal limits), which they are willing to sell or lease. **Beneficiaries:** Entities wishing to permanently or temporarily obtain water for new or expanded uses, including municipal, industrial, and agricultural [4] **Other stakeholders**: Edwards Aquifer Authority (sets withdrawal limits, issues permits, posts lists of sellers and lessors on website)
BUYER	Entities wishing to obtain water for new or expanded uses; including municipal, industrial, and agricultural purposes. 4]
INTERVENTION	[1, 3] The Edwards Aquifer sets a cap on aquifer withdrawals and issues permits to nonexempt groundwater users with a specified withdrawal limit. Permit holders may sell or lease their permits to willing buyers. Entities wishing to permanently or temporarily obtain water for new or expanded uses (including municipal, industrial, and agricultural) must find a willing seller or lessor. The Authority posts a list of sellers and lessors on their web site; but is not directly a party to the market transactions. Permit holders pay a few to the Authority, in order to finance the Authority's aquifer management activities [3]. This fee is based on the withdrawal amount and water use; with a $2/acre---foot cap on agricultural uses and not such cap on municipal and industrial uses [3].
DRIVER	[6] Aquifer overdrafts led to declining spring levels and harm to endangered species reliant upon springs. Over the course of decades the region was embroiled in conflict over water rights, with much of the debate between San Antonio and rural agricultural interests. A historic drought, occurring in the 1950's, only exacerbated this already heated conflict. However, it was the endangered species act, and threat of federal intervention, which eventually provided the legislative force necessary to bring stakeholders to the table.
EXCHANGE_ARRANGE	Marketplace mechanism
COMPENSATION	Cash
COBENEFITS	Environmental co---benefits. Capping withdrawals through limiting the number of permits and requiring mandatory reductions in pumping during critical periods protects the aquifer levels, and consequently spring flows, necessary for the survival of flow---dependent endangered species.
BARRIERS	The authorizing legislation required changing the groundwater permit system from the rule of capture to those which are permitted (with withdrawal limits) and tradable [1]. Groundwater laws in ACF Basin may not be compatible with such a system (?--- check to see if this assumption is true). There is limited information on what the effects of changing where withdrawals occur in an aquifer that are the result of trading permits; but studies in Australia point to some potential challenges with such changes in points of withdrawal (such as the potential concentration of withdrawals and therefore impacts) [1].
EXT_EVALUATION	An article by Sugg (2013) gives a relatively positive evaluation of the Edwards Aquifer cap and trade program, but does cite some limitations in its general operation and in its transferability [1].
BASIN	Edwards Aquifer
STATE	Texas
SW_GW	Groundwater
RESEARCHER	Shannon Bonney

REFERENCE	[1] Sugg, Z.P. (2013). Market---based Groundwater Allocation: Consideration for Arizona from the Edwards Aquifer Cap and Trade System, University of Arizona School of Geography and Development. ; [2] http://edwardsaquifer.org/aquifer---data---and---maps/maps ; [3] http://edwardsaquifer.org/legislation---and---rules/the---eaa---act ; [4] http://edwardsaquifer.org/groundwater---permit---holders ; [5] http://edwardsaquifer.org/groundwater---permit---holders/critical---period---management---plan/ ; [6] http://www.therivardreport.com/oral---history---war---peace---edwards---aquifer/

NAME_PROGRAM	Lower Arkansas Water Management Association
TYPE	Trading & offset mechanisms
HYDRO_SERV_GOALS	Originally a "'membership' association for the primary purpose of providing replacement water to allow its members to operate their wells under the 1973 [State Engineer] Rules" but later took on purpose to "replace well depletions both to Colorado surface water rights and to usable flow at the Colorado---Kansas Stateline in compliance with Colorado law and the Arkansas River Compact" [1, p. 1]
SCALE	Basin.
ACTORS	**Providers:** Lower Arkansas Water Management Association (in that they've purchased direct flow water rights, which they use for augmentation), non---shareholders that dedicate water rights in exchange for the augmentation service. **Beneficiaries:** All shareholders and non---shareholders that are able to continue pumping groundwater because of the augmentation to Arkansas River flows. Some examples include: Five Rivers Ranches, Colorado Division of Wildlife (bought and dedicated 'ditch company' water shares and receives augmentation water for a hatchery and recreational facilities), City of Lamar, and other "commercial entities". [1] **Other stakeholders**: Lower Arkansas Water Management Association Board of Directors (Seven farmers that administer program), Division Engineer (coordinates with association on storage and releases of water and oversees program to make sure augmentation is sufficient to comply with Compact and other appropriations), and the Water Court (must approve many transactions, like changes to points of diversion).
BUYER	Beneficiaries and public good payers. Beneficiaries of the augmentation services buy shares or dedicate water rights to obtain these services (mostly farmers, but also municipalities and industrial users). A state agency participating in the program receives augmentation water for a hatchery and recreational facilities.
INTERVENTION	The LAWMA is a non-profit corporation that issues stocks to its members. Its purchases include "direct flow water rights and storage, leases of water rights, and operational agreements [that] have been pooled to allow its membership to continue use of their irrigation wells". [1, p. 2] Additionally, it "executed management agreements wherein members put up the water rights and LAWMA incorporates those water supplies with LAWMA's other water supplies to replace depletions caused by members' wells." [1, p. 1] The quantity of replacement water provided to shareholders is "directly proportional to the number of shares of common stock owned by the shareholder member which then converts to a volume of pumping by the shareholder's wells. Shares can be sold and transferred upon approval of the board of directors to different farm units or changed to a different use such as for wells used for industrial or municipal purposes. For non shareholder members, the rights and obligations relating directly to augmentation of the wells and other structures owned or operated by those members are established by written contract between the non shareholder members and LAWMA. To provide a permanent replacement supply, the non shareholder members will exchange water rights for shares issued by LAWMA according to a predetermined exchange formula." [1, p. 3] LAWMA purchased direct flow water rights in six irrigation ditches near the John Martin Reservoir, which stores water according to the Arkansas River Compact "during the non irrigation season and during times when the inflow exceeds downstream demands. The storage water is distributed into "Article II Accounts", 40 percent to Kansas water users and 60 percent among 9 Colorado ditches located downstream of John Martin Reservoir...Water from the accounts is released on demand of the owner to supplement the direct flow diversions during the irrigation season…[Account II water] provides carryover supplies to balance the yearly fluctuations in the water supplies available under the direct flow water rights." [1, p. 5] An Offset Account was "established to regulate replacement water delivered to John Martin Reservoir primarily for replacing depletions with respect to usable state line flow. Kansas can call for the water stored in the Offset Account at any time it is usable by Kansas. An annual charge of 500 acre feet of fully consumable water (paid annually by LAWMA) for the first 10,000 acre feet regulated in the account plus 5 percent of delivered water exceeding 10,000 acre feet is solely for Kansas' use. Monthly, LAWMA and the Division Engineer work together to coordinate the storage releases and transfers from LAWMA's storage water and to measure and record the direct flow deliveries so that the replacement water supplies match the stream depletions caused by LAWMA's members." [1, p. 9]

DRIVER	While established before the case, the purpose of the program was heavily influenced by the recommendations of Kansas v. Colorado; which were to establish a program that replaces the depletion caused by well withdrawals to surface water rights in Colorado and usable flow at the border of Kansas and Colorado, in order to maintain compliance with the Arkansas River Compact.
EXCHANGE_ARRANGE	Bilateral or multilateral contracts and water funds. Water fund: The Association augments supplies to the Arkansas River on behalf of their shareholders. The amount of water a shareholder may withdrawal from their groundwater wells for irrigation is determined by the number of shares the shareholder owns (a shareholder may only pump a predetermined amount of water, an amount which will deplete flows in the Arkansas River only as much as the Association is able to offset through augmentation using their storage in John Martin Reservoir and other acquired direct flow water rights). Bilateral or multilateral contracts: Non shareholders and the Association may enter into a contract where the non---shareholders dedicate water rights to the Association in exchange for the Association augmenting flows to the Arkansas River to offset the effects of their groundwater usage.
COMPENSATION	Cash and in kind. Shareholders originally buy into the Association with cash and receive the service of the Association offsetting their groundwater usage. Non---shareholders dedicate water rights to the Association to receive this same service.
COBENEFITS	Socioeconomic. This setup allows for continued groundwater pumping for irrigation during dry years, which buffers farmers from the potential restrictions on water usage caused by the Arkansas River Compact and Kansas v. Colorado.
BARRIERS	
EXT_EVALUATION	
BASIN	Arkansas River Basin
STATE	Colorado and Kansas
SW_GW	Surface water (to offset effects groundwater withdrawals)
RESEARCHER	Shannon Bonney
REFERENCE	[1] http://www.lawma.net/LAWMA%20INFO.pdf

NAME_PROGRAM	San Luis Obispo County Water Neutral New Development [proposed]
TYPE	Trading & offset mechanisms
HYDRO_SERV_GOALS	Prevent further exploitation of already severely taxed groundwater supplies, while still allowing for growth and development, by requiring an offset to mitigate for all new or expanded urban, rural, and in certain areas agricultural irrigation water usage [1]. This will be part of a larger Countywide Conservation Program, which has the additional goals of preventing water waste, requiring retrofits of inefficient toilets and showerheads before sale of existing structures, and requiring increased landscaping water---use efficiency [2].
SCALE	Local. Three areas in San Luis Obispo County, California that are labeled as Level of Severity III: Paso Robles Groundwater Basin, Los Osos Groundwater Basin, and Nipomo Mesa Management Area.
ACTORS	**Providers:** Property owners with inefficient toilets, shower---heads, turf grass that are willing to participate in either the Turf Removal Incentive Program or plumbing retrofits. The specific providers for the agricultural offset program are yet to be determined. **Beneficiaries:** All adjacent water users that would be harmed by additional groundwater pumping. Those wishing to establish new or expand urban, rural, or agricultural irrigation water usage, which would be unable to do so without the offset mechanism. **Other stakeholders**: Department of Planning and Building
BUYER	Those wishing to establish new or expand urban, rural, or agricultural irrigation water usage. This includes homeowners, developers, and farmers.
INTERVENTION	This legislation is proposed and as of May 2015 is undergoing the Environmental Review Process. In groundwater basins labeled as Level of Severity III, all new development, both urban and rural, has a minimum required offset of 1:1 for new water usage [1]. There are additional restrictions in the Paso Robles Groundwater Basin, which include a minimum offset of 1:1 for all new or increased intensity agricultural irrigation [1]. The urban and rural development offsets are to be achieved through a Turf Removal Incentive Program and plumbing retrofits. While the specifics of the agricultural offset program are yet to be determined, they are to include a "formal framework for the transfer of offset credits to/from agricultural operations within the Paso Robles Groundwater Basin only" [1]. A sunset provision on the agricultural offset program would allow it to expire if a Groundwater Sustainability Plan, which conforms to the Sustainable Groundwater Management Act, re passed.
DRIVER	The county is experiencing an "exceptional drought", with "exceptional and widespread crop and pasture losses, shortages of water in reservoirs, streams and wells creating water emergencies" [2]. Moreover, areas in the county labeled as Level of Severity III currently are experiencing a situation where "groundwater demand has met or exceeded the dependable supply" [2]. The legislative mandate is also there, as the Board of Supervisors allowed and encouraged the Department of Planning and Building to update both the County General Plan and County Codes, with a specific objective to find ways to prevent further exploitation of groundwater resources while still allowing for increased development and irrigation [2].
EXCHANGE_ARRANGE	Before receiving a building permit, or otherwise being authorized to expand water usage, an applicant must prove they are offsetting their proposed water usage by a minimum of a 1:1 ratio. The specifics are not yet available as this is proposed legislation.
COMPENSATION	The specifics are not yet available as this is proposed legislation.
COBENEFITS	
BARRIERS	This legislation is not yet passed, as it is still in the Environmental Review Process. The final Supplemental Environmental Impact Report is due to be released to the public in July 2015 [3].
EXT_EVALUATION	
BASIN	Multiple groundwater basins, including: Paso Robles Groundwater Basin, Los Osos Groundwater Basin, and Nipomo Mesa Management Area
STATE	California
SW_GW	Groundwater
RESEARCHER	Shannon Bonney

REFERENCE	[1] http://www.slocounty.ca.gov/planning/water---amendments/water---neutrality.htm ; [2] http://www.slocounty.ca.gov/planning/water---amendments.htm ; [3] http://www.slocounty.ca.gov/planning/water---amendments/environmental---review.htm

NAME_PROGRAM	Paso Robles Groundwater Basin Urgency Ordinance and Paso Robles Groundwater Basin Water Conservation Ordinance
TYPE	Trading & offset mechanisms
HYDRO_SERV_GOALS	Prevent further exploitation of already severely taxed groundwater supplies, while still allowing for growth and development, by requiring an offset to mitigate for all new or expanded urban, rural, and agricultural irrigation water usage [1, 3]. While the Urgency Ordinance is due to expire in late 2015, it will become part of a larger Countywide Conservation Program, which has the additional goals of preventing water waste, requiring retrofits of inefficient toilets and shower---heads before sale of existing structures, and requiring increased landscaping water---use efficiency [4]. Both the Urgency Ordinance and the Countywide Conservation Program provide additional restrictions on top of the Paso Robles Groundwater Basin Water Conservation Ordinance in the Paso Robles Groundwater Basin.
SCALE	Local. This is one of the Level of Severity III groundwater basins in San Luis Obispo County, California.
ACTORS	**Providers:** Property owners with inefficient toilets, shower---heads, turf grass that are willing to participate in either the Turf Removal Incentive Program or plumbing retrofits. Agricultural irrigators willing and able to conserve water through crop conversion or fallowed land [6]. **Beneficiaries:** All adjacent water users that would be harmed by additional groundwater pumping. Those wishing to establish new or expand urban, rural, or agricultural irrigation water usage, which would be unable to do so without the offset mechanism. **Other stakeholders**: Department of Planning and Building
BUYER	Those wishing to establish new or expand urban, rural, or agricultural irrigation water usage. This includes homeowners, developers, and farmers.
INTERVENTION	This is one of the Level of Severity III groundwater basins in San Luis Obispo County, California. There is already Paso Robles Groundwater Basin Water Conservation Ordinance in place that has a number of restrictions in place to protect the groundwater resources, which include: restrictions on land new divisions, limits on outdoor water use (i.e. discretionary permits) that include efficiency requirements and limits on irrigated landscaped acreage, and offset requirements at a 2:1 minimum for all new discretionary permits (excluding agricultural water usage). The offsets for the 2:1 Conservation Ordinance may be achieved through the following: retiring potential development plots by placing them in a land trust, retrofitting plumbing, purchasing supplemental water from a Paso Robles water supplier, participation in an approved conservation program, or reducing water demand in other approved ways. These offset requirements must be met before applications for discretionary permits are approved. [5] The Urgency Ordinance puts into place more rigorous requirements than the proposed, yet to be implemented, San Luis Obispo County Water Neutral N ew Development program as well as the Paso Robles Groundwater Basin Water Conservation Ordinance (as it includes agricultural and non---discretionary permits, i.e. indoor water usage). For ALL new development or expansion/intensification of irrigated agriculture, a 1:1 offset must be met before the required permits are granted. For ALL new development or expansion/intensification of irrigated agriculture, a 1:1 offset must be met before the required permits are granted. For new development offset credits must be purchased from the county (or alternatively an applicant can meet the offset requirements by hiring a licensed plumber to do retrofits and submitting proof of this work to the county). The offset credits are generated by the county's N ew Development Conservation Program, through willing customers retrofitting plumbing and receiving a rebate.
DRIVER	The county is experiencing an "exceptional drought", with "exceptional and widespread crop and pasture losses, shortages of water in reservoirs, streams and wells creating water emergencies" [2]. Moreover, areas in the county labeled as Level of Severity III currently are experiencing a situation where "groundwater demand has met or exceeded the dependable supply" [2]. The legislative mandate is also there, as the Board of Supervisors allowed and encouraged the Department of Planning and Building to update both the County General Plan and County Codes, with a specific objective to find ways to prevent further exploitation of groundwater resources while still allowing for increased development and irrigation [2].

EXCHANGE_ARRANGE	Bilateral or multilateral contracts (marketplace mechanisms? for the fees paid for offset credits?).
COMPENSATION	Cash and in---kind. Participants in the retrofit rebate programs receive a cash rebate in exchange for them completing the retrofits. These retrofits produce offset credits for the county. Those required to offset their new or expanded development pay cash to purchase the offset credits, or complete one of the offset activities approved by the Conservation Ordinance (such as placing potentially developable land into a land trust). In this way meeting the offset requirements may be accomplished through cash or in---kind payments.
COBENEFITS	
BARRIERS	The Urgency Ordinance is only a temporary ordinance and the more permanent San Luis Obispo County Water N eutral N ew Development legislation has yet to be passed.
EXT_EVALUATION	
BASIN	Paso Robles Groundwater Basin
STATE	California
SW_GW	Groundwater
RESEARCHER	Shannon Bonney
REFERENCE	[1] http://www.pasobasin.org/urgency---ordinance/ ; [2] http://www.sanluisobispo.com/2014/01/16/2880211/county---moves---ahead---on---plan---for.html ; [3] http://www.slocounty.ca.gov/planning/water---amendments/water---neutrality.htm ; [4] http://www.slocounty.ca.gov/planning/water---amendments.htm ; [5] "AN ORDINANCE AMENDING ARTICLE 9 OF TITLE 22 OF THE SAN LUIS OBISPO COUNTY CODE, THE LAND USE ORDINANCE, BY ADDING SECTIONS 22.92.020D, 22.94.020E, 22.98.030E, 22.100.020B, 22.102.020D, 22.104.020I, 22.110.030E, D 22.110.060A RELATING TO WATER CONSERVATION THE PASO ROBLES GROUNDWATER BASIN" ; [6] "Agricultural Water Offset Program" Powerpoint presentation found on www.pasobasin.org

NAME_PROGRAM	Santa Fe water neutral program (Water Development Offset Requirements, Development Water Budget, Water Conservation Credit Programs, Water Rights Transfer Program, and City Water Bank)
TYPE	Trading & offset mechanisms
HYDRO_SERV_GOALS	Allowing for new development when water supply system that is already fully (over?)allocated. The Offset Requirements essentially state the system is already fully allocated; while the Conservation Credit Programs, Water Rights Transfer Program, and City Water Bank provide the necessary tools for developers to obtain water needed for development through conservation, purchase of conservation credits, or water rights transfers. There is insufficient water to meet all current and future water demands for Santa Fe, while still complying with the Rio Grande Compact. Essentially all uses are competing because the basin is over---allocated. Historically many transfers have been from agriculture to municipal uses. There are a growing number of transfers within and between municipal and industrial sectors. There is also a concerted effort to replace aquifer withdrawals with surface water withdrawals in order to allow overtaxed aquifers to recharge.
SCALE	Local scale, but with potential impacts at interstate (sub)basin scale. [1] Water Development Offset Requirements cover all areas in City of Santa Fe and its annexed areas. These offset requirements are for all new development and renovations to existing development that will increase water demand. Conservation credits are only generated and used within the City water system. Water rights may be transferred from outside of City water system; but it must be feasible for them to be connected with the City water system. The Water Bank is used for all transactions. Santa Fe gets its water from three sources: surface water from Santa Fe River (a tributary to the Rio Grande River) and Rio Grande River (from the San Juan---Chama Project via the Buckman Direct Diversion), as well as ground water from the Tesuque Formation aquifer.
ACTORS	**Providers:** [1] Holders of preo 1907 water rights from the Middle Rio Grande and holders of water conservation credits (participants of Water Conservation Credit Programs, which may be customers of City water system or the City itself). **Beneficiaries:** [1] Developers, home owners, or other entities that wish to complete a new development or renovation, which will increase indoor or outdoor water usage. Entities applying for a residential, mixed use, or commercial building permit. **Other stakeholders**: [1] Water Budget Administrative Office (WBAO) of the Land Use Department Technical Review Division (reviews development applications and approves Development Water Budgets); Engineering Section of the Water Division (if additional review required the WBAO sends Development Water Budgets to Water Division for approval; the Water Division also approves alternative development water budgets and monitors compliance with all water budgets, administers the Water Conservation Credit Programs and Water Rights Transfer Program and City Water Bank); Office of the State Engineer (approves transfers of water rights). Water Conservation Office (helps administer the rebate program).
BUYER	New water users. Developers, homeowners, or other entities that wish to complete a new development or renovation, which will increase indoor or outdoor water usage. Entities applying for a residential, mixed---use, or commercial building permit.

INTERVENTION	[1] The buyer pays for the water required to meet the Water Development Offset Requirements*, an amount determined by the Development Water Budget**, in order to receive a building permit. This amount includes all water which will be required by the development, plus an additional 9.8% contingency. *Water Development Offset Requirements: All new construction, or renovation projects and land use changes that lead to increased water consumption, must be offset by an amount of water equal to its proposed water usage, plus an additional 9.8% contingency. Applicants must have an approved Development Water Budget and prove the offset requirements are, or are guaranteed to be, met before receiving a building permit. These offsets can be achieved through conserving water in existing development or obtaining water rights. An applicant may dedicate privately owned water conservation credits (they either generated through participation in the Water Conservation Credit Programs or purchased from other water conservation credit holders), purchase City owned water conservation credits, or dedicate water rights to the project (which are generally obtained through market transactions). Development Water Budget: A description of all indoor and outdoor water uses and quantification of proposed annual indoor and outdoor water usage for new/renovation development projects; either made by developer and approved by Water Division, or made by Water Division based on historical water use for similar development projects. Proposed annual water usage determines which programs developers can use to meet the offset requirements; with larger projects using the Water Rights Transfer Program and smaller projects using either the Water Conservation Credit Programs or Water Rights Transfer Program.
INTERVENTION (cont.)	Water Conservation Credit Programs (bilateral or multilateral contracts): There are two programs through which water conservation credits may be generated: 1) Water Conservation Contract Program and 2) Rebate Program. Water Conservation Contract Program: participants agree to reduce water consumption at their property, as compared to either the previous five years of recorded usage or an amount determined by an alternative development water budget, with a minimum of 0.02 acre---feet/year (AFY). The Water Conservation Office conducts water conservation audits at customers' requests, to estimate the potential for water savings. Once contract approved and executed, Water Division deposits the quantity of water the participant agreed to conserve as conservation credits into the participant's City Water Bank account. Water Division also monitors for compliance and has graduated penalties for noncompliance with the contract or alternative development water budget; these penalties range from surcharges, to mandatory transfer of additional water rights or water conservation credits, to disconnection of service. The following are conservation measures for commercial customers: "i) a change in the nature of the business; ii) a change in commercial process; iii) retrofit of older commercial appliances or fixtures with newer, more water efficient units; or iv) installation of new water conservation technology" and residential customers "i) retrofit of older appliances of fixtures with newer more water---efficient units [and] ii) installation of new water conservation technology" [[1], Section 2.2.4]. Water conservation credits may be held in a participant's City Water Bank account to be used for future development water offsets, sold to the city, donated to city for a public purpose specified by participant, or transferred to another person's City Water Bank account (generally in exchange for money, i.e. sold to another account holder).

INTERVENTION (cont.)	Rebate Program: participants are partially compensated for retrofitting older appliances with more efficient models. The City pays the participants that completed these retrofits a cash rebate. Through this rebate the City generates water conservation credits that are deposited into the City's account in the City Water Bank. The City may also install water saving devices at City facilities to generate water conservation credits for its City Water Bank account. Updated listings of approved water saving devices are posted to multiple City agency web sites and in City offices. The City reserves the right to inspect the site before, during, and after installation; as well as to prevent reo circulation of older devices by collecting and disposing of them. The amount of rebate money paid is determined by quantity of water to be saved and the price the City will pay for the water. The City may sell its water conservation credits to new water customers (to fulfill development water budget) or to existing water customers that exceed their Water Conservation Contract or alternative development water budget. There was a previous Toilet Rebate Program, in which participants generated retrofit credits through installing low flow toilets. While this Toilet Rebate Program is no longer in existence, retrofit credits generated through this program can still be applied towards a development water budget (but cannot be sold or marketed). In summer 2015 the City offered Summer Irrigation Efficiency Rebates, which will partially compensate a customer for an Irrigation Efficiency Evaluation by a certified landscaper ($50 residential/$75 commercial) and for an Irrigation Equipment Upgrade ($40o $750 depending on the irrigation hardware).
INTERVENTION (cont.)	Water Rights Transfer Program (marketplace mechanisms): For larger water development projects (greater than 5 AFY for commercial, 7.5 AFY for mixed use, and 10 AFY for residential) developers must transfer water rights to the City to meet the offset requirements determined by the Development Water Budget before building permits are approved. Water rights must be preo 1907 consumptive use water rights from the Middle Rio Grande Basin. Phased projects may include a mixture of water conservation credits and water rights transfers until the project meets the aforementioned requirements of a large water development project; upon this point the entire project's development water budget must be met by water rights transfers and the City will reimburse the developers for any previous water conservation credits applied to the project. Water rights must be approved by the City through a due diligence process, the cost of which the developer pays for (beginning with an upfront $1000 deposit). The City has the right to request more documentation or to not accept all or part of the water rights proposed for transfer. Water rights costs are determined by the developer and willing seller; the City is not a party to this market transaction. Once the water rights are approved developer creates a draft application, which will be submitted to the Office of the State Engineer (OSE) for the transfer of the water rights to the point of diversion designated by the City. The developer, seller, and City submit to the OSE the final application. The developer pays for all of the costs associated with the application to the OSE and subsequent litigation contesting the water rights if it may arise. In certain situations the developer may be issued a permit if a financial guarantee of the water rights is provided. This financial guarantee is in the form of escrow funds in the amount of the current fair market value of preo 1907 consumptive use water rights for the Middle Rio Grande Basin. Once the water rights transfer is complete the City will return all of the escrow funds and interest accrued. If fewer water rights were transferred than what was specified in the application, then the City keeps a proportionate amount of the escrow funds and the accrued interest (in order to purchase the needed rights from the City Water Bank). At any point in the process the water rights transferor may sell all or part of water rights to the City or any other party; for a fair market value negotiated by developer and purchaser.

INTERVENTION (cont.)	City Water Bank (water funds): The Water Division administers the City Water Bank. The following items may be deposited into the bank: water credits (from the Water Rights Transfer Program), water conservation credits (from the Water Conservation Credit Programs), and consumptive use water rights (obtained by the City through Retrofit Rebates, donations, water rights purchases, and water reuse infrastructure projects). All water credits are in consumptive---use acre---feet per year and represent the amount of water a holder of the water credit may be served by the City water system in a year. Holders of water credits may transfer them to another account holder or sell them at any time. Water credits may also be 'withdrawn' when they are dedicated to a development water budget. If circumstances change and less water is needed to meet the requirements of a development water budget, then a holder may sell the extra water credits to the City at the current fair market value. The City keeps a listing of all water rights held in deposit in the City Water Bank (information includes the holders name and quantity held, for all holders that agree to be listed).
DRIVER	The buyer pays because these are compulsory regulatory requirements that must be met before any proposed development is approved. Drivers leading to the Water Development Offset Requirements and associated programs are as follows: Inadequate supplies: Santa Fe's surface and ground water supplies are constrained by interstate compact water debts and competing within---state uses (leading to statewide adjudication), as well as insufficient runoff and overused aquifers. In general, there is insufficient runoff because runoff is dependent on snow pack melt, which is currently at historical lows, and sensitive to droughts, which have been widespread and severe. Compact: The Rio Grande Compact allocates surface water based on a percentage of runoff and not fixed quantities, and as such allocations are sensitive to climate change, drought, snow pack levels, and increased consumptive uses upstream (including withdrawals from connected aquifers). When a state cannot make its compact requirements it can accrue water debt and Colorado has accrued a water debt to New Mexico numerous times. However, when the Elephant Butte and Caballo Reservoirs fill the water debt is between Colorado and New Mexico is erased, but New Mexico still owes its water debt to Texas. This system of water debts, combined with high evaporation rates (causing much water to evaporate from reservoirs and before recharging aquifers) and alleged over---pumping of aquifers (see 'litigation' below) has led to a situation where New Mexico is short in meeting its water debt to Texas during dry years. Litigation: There has been a long history of water rights litigation in the region and currently the Supreme Court is hearing the case Texas v. New Mexico. In this case TX alleges NM is not providing TX with its fair share of water according to the Rio Grande Compact [check which compact]. Population and economic growth: A desire to accommodate for continued growth in population and economy, combined with already inadequate water supplies (discussed above), provides the pressure necessary to implement the comprehensive offset requirements.
EXCHANGE_ARRANGE	Bilateral or multilateral contracts; water funds; marketplace mechanisms. Water Conservation Credit Programs (bilateral or multilateral contracts). Water Rights Transfer Program (marketplace mechanisms). The City Water Bank (water funds)
COMPENSATION	In---kind or cash. [1] Water credits are applied to a person's account for conservation or water rights transfers (in---kind), which can be dedicated to a development water budget (in---kind) or sold for cash. Developers of smaller projects, eligible for offset through conservation, may pay a cash fee in lieu of generating conservation credits directly, in the amount of $1000 plus the consumptive---use water rights purchase price ($15,000/acre---foot in 2010). Participants of the Water Conservation Contract Program and Rebate Program receive water conservation credits, measured in consumptive---use acre---feet/year, which may be applied to new development projects, sold, donated to City Water Bank, or deposited in their City Water Bank account (for use or sale later). Participants in the Water Rights Transfer Program pay willing sellers cash for water rights. Participants in the 2015 Summer Outdoor Irrigation Rebate Programs will be partially compensated in cash for an Irrigation Efficiency Evaluation by a certified landscaper ($50 residential/$75 commercial) and for an Irrigation Equipment Upgrade ($40---$750 depending on the irrigation hardware).

COBENEFITS	[1] Water credits may be donated to the City for specified public purposes or to nonprofit organizations for in---stream purposes. Replacing lawns with native plants may increase biodiversity [rewrite]. Upgrading outdoor irrigation equipment may lower runoff, which will reduce the amount of sediments and nutrients that get exported to natural waterways. Utility customers that participate in conservation programs have smaller water bills. There are less offsets required of low---priced dwelling units part of the Housing Opportunity Program; this may provide an incentive (or at least remove disincentives) for providing housing for the poor.
BARRIERS	None listed in Administrative Procedures [1] or Harder (2014) [4], but perhaps an interview with the Water Division could illuminate the barriers.
EXT_EVALUATION	Harder (2014) gives a rather brief overview of this program, in which he generally seems to support the program [4]. There's also a review of Santa Fe's Water Conservation Program (Michael and Pushard 2014), which says the Rebate Program generates water through conservation more cheaply than the price would be to purchase additional water rights to meet new demand [5]. This review also cites some barriers, which include a time---consuming process required to modify the Rebate Program [5].
BASIN	Santa Fe River [tributary to Rio Grande]; Rio Grande River Basin; Tesuque Formation aquifer
STATE	New Mexico
SW_GW	Both surface and ground water
RESEARCHER	Shannon Bonney
REFERENCE	[1] Administrative Procedures 3---31---10 [finish] ; [2] http://bddproject.org/about---the---bdd/ ; [3] http://www.santafenm.gov/where_does_our_drinking_water_come_from ; [4] Harder 2014 [finish] ; [5] review article [finish]

Discussion of Select Topics[1]

I. **Summary**

This group has been exploring the use of market-based instruments (MBIs) in interstate river basins with the goal of determining the feasibility of their use in the Apalachicola-Chattahoochee-Flint (ACF) River Basin. This project focus on interstate water conflicts in the United States and MBIs used for water allocation. This report focuses on four issues that practitioners may encounter while pursuing MBIs in the ACF River Basin. First, we outline issues concerning instream flow, or the amount of water within a stream channel, and how they are at the center of ecological and economic concerns regarding MBIs for water uses. Second, we detail the potential for conservation easements to be used as a tool for protection of instream flows under Georgia's regulated riparian doctrine. Third, we further explore the legal constraints and framework that will govern the feasibility and implementation of MBIs for water allocation**.** Last, we highlight the issue of externalities and social justice, emphasizing that MBIs need to be integrated into a broader water management plan.

II. Instream Flow

Instream flow refers to the amount of water within a stream channel. Although a simple definition, there are competing interests for water among public supply, irrigation, hydropower, and aquatic habitat. Another difficulty is the variation in flow levels across wet and dry seasons and among variations in years. Determining best practices to meet and quantify instream flow needs for each of these uses is a challenge faced by natural resource program managers, and various rules and regulations have been enacted to assist in this process.

II. A. Instream Flow and Water Allocation Conflict Background

Conflicts over water allocation commonly occur in interstate river basins throughout the United States. Historically many of these conflicts occurred in the arid western United States; however, in recent years there have been an increasing number of water allocation conflicts in the humid southeast—the US Supreme Court is hearing five cases in this year alone that pertain to interstate water allocation. Georgia, Alabama, and Florida have been experiencing conflict over water allocation in the ACF Basin for decades. Recent droughts have strained the water supply in the ACF Basin, making it difficult to meet environmental needs, public water supply, and agricultural demands, stressing the debate even further. Over the course of the conflict, a variety of approaches have been employed in attempts to resolve this dispute. Although they have been attempted in the ACF Basin, interstate water disputes are difficult to resolve with political negotiations and litigation because they do not ensure the benefits derived from water and burdens borne by lack thereof are shared equitably amongst water users. Market-based instruments (MBIs) offer a way to resolve water disputes by redistributing benefits and burdens experienced by water users, in lieu of, or in addition to, litigation and politics.[2]

An instream flow recommendation is one of the first steps to take because it gives a quantifiable answer to the question of how much water should be in the river. The Instream Flow Council (IFC) provided this definition for instream flows:

> "The objective of an instream flow prescription should be to mimic the natural flow regime as closely as possible. Flow regimes must also address instream and out-of-stream needs and integrate biotic and abiotic processes. For these reasons, inter-and intra-annual instream flow prescriptions are needed to preserve the ecological health of a river."[3]

The National Environmental Policy Act (NEPA) of 1969 required planning activities to "create and maintain

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[1] Written by the following environmental practicum students: Laura Early, Torre Lavelle, Dan Read, and Brian Easley

[2] Bonney, S. et al. "Market-based approaches to resolve water conflicts in the Apalachicola-Chattahoochee-Flint River Basin." Georgia Water Resources Conference, 2015.

[3] "An Introduction to Instream Flow Science and Programs." The Science of Instream Flows: A Review of the Texas Instream Flow Program . Washington, DC: The National Academies Press, 2005.

conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations…" Trends and principles of instream flow science emerged in the late 1960s and 1970s, the years after NEPA was established, and continues to evolve today. Throughout this time, certain constants and concepts have remained present.

II. B. Instream Flow Trends

II. B. 1. Hydrology and Hydraulics

A single minimum, or flat-line, flow as the basis for instream flow science is changing to incorporate variability, namely in the range of flows from seasonal and inter-annual variation, magnitude, timing, and frequency of change. This hydrologic variation leads to different levels of flow, from subsistence and base flows to high flow pulses and over bank flows. Flow regime refers to this range of flows. Other important terms include:

1) Subsistence flow: minimum stream flow needed during critical drought periods to maintain tolerable water quality conditions and provide habitat for aquatic organisms
2) Base flow: "normal" flow conditions; support aquatic communities and groundwater level maintenance for adequate riparian vegetation
3) High flow pulses: short-duration, high flows within the stream channel that occur during or immediately following a storm event; restores normal water quality and provide connectivity for species movement along the river
4) Overbank flow: infrequent, high flow event that breach riverbanks; can restructure the stream channel and floodplain, recharge groundwater reservoirs, provide nutrients to riparian vegetation, and provide connectivity for species movement along the river[4]

[4] "Texas Instream Flow Studies: Technical Overview." Texas Water Development Board. Report 369, May 2008.

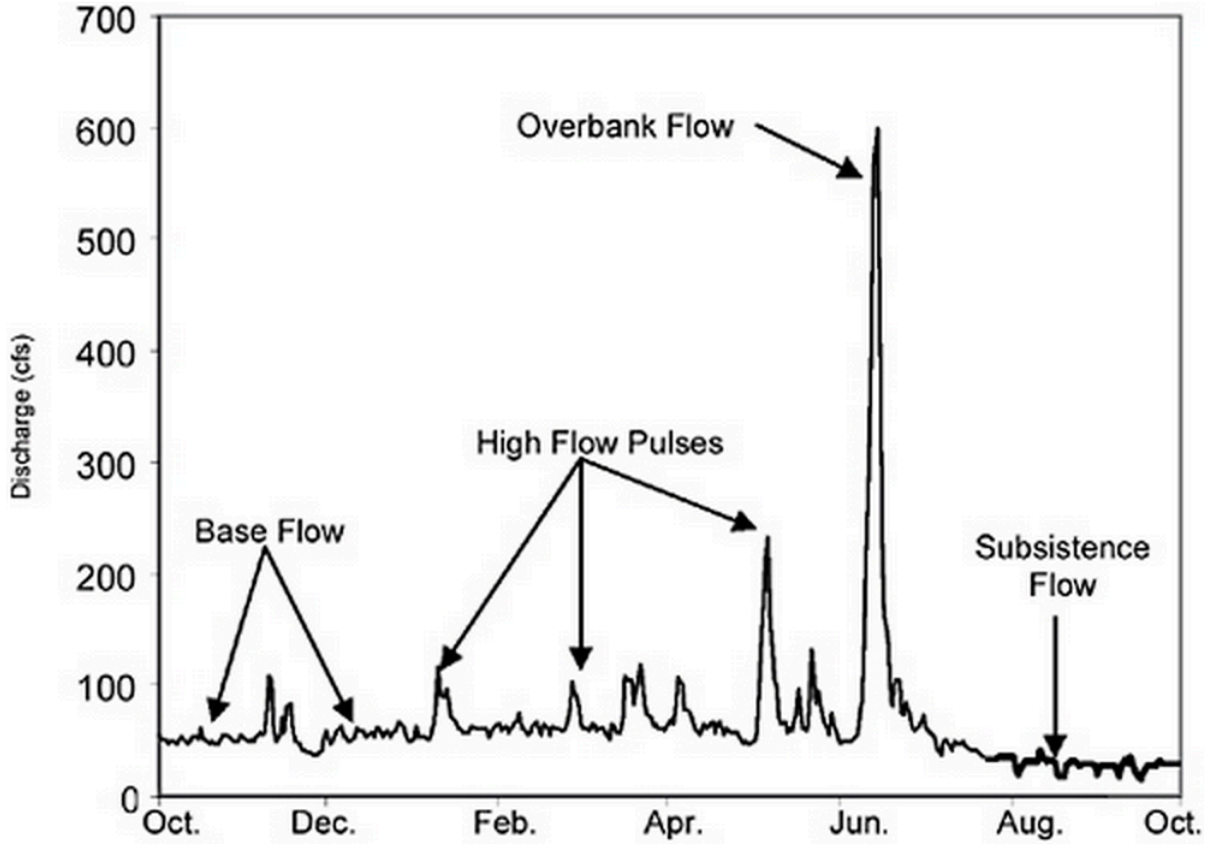

Figure 1. Figure taken from p. 34 of *An Introduction to Instream Flow Science and Programs* to chart the daily stream flow for the Guadalupe River in Victoria, Texas.[5]

II. B. 2. Biology & Functional Focus

Initially, instream flows focused solely on one species' survival, usually a species of fish. Although single species may be the basis for many river evaluations still, added emphasis on multiple ecosystem functions, adequate habitat, and sustainable aquatic and riparian communities are also important principles within the evaluation.[6]

A growing number of efforts to calculate instream flows have expanded to include physical processes in not only the stream channel, but also riparian and floodplain areas.[7] Hydrologists no longer solely decide instream flow recommendations. Within this field, interdisciplinary teams are now composed of scientists from biology, water quality and chemistry, and water law and policy. This partnership can most efficiently handle the competing interests from instream flow science, public opinion and legal mandates.[8]

These instream flow trends have allowed for a more comprehensive way to monitor flow regimes, but at the expense of more resource-intensive studies that are more difficult to conduct. Understaffed programs lacking the necessary financial support and time may further complicate matters. Additionally, a more comprehensive list of factors may make the goal of integrative results and recommendations less wholly achievable.[9]

II. C. Instream Flow Principles

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[5] An Introduction to Instream Flow Science and Programs." 2005.
[6] "An Introduction to Instream Flow Science and Programs." The National Academies Press, 2005
[7] Kondolf, G., D. Montgomery, H. Piégay, and L. Schmitt (2003) Geomorphic classification of rivers and streams. In Tools in Fluvial
[8] An Introduction to Instream Flow Science and Programs." 2005.
[9] Ibid.

Several principles are included in the IFC's *Resource Stewardship for Riverine Resource Stewardship* (2002).[10,11] The principles below draw from the trends of instream flow science and center around the idea of expanding the scope of flow studies both academically and in the field. On the ground, scientists are encouraged to include the whole functioning ecosystem, not simply the river channel or a single species. Additionally, an interdisciplinary approach should incorporate experts from public-private partnerships in a variety of fields and use adaptive management to constantly update plans as they are executed. Finally, stakeholders should be encouraged to participate in the process.

The first three of the IFC principles (preserve whole ecosystems, simulate natural flow regime, and include floodplain and riparian zones in instream flow considerations) stress actions that should be conducted, while the last four principles (take an inter- and multi-disciplinary approach, use a variety of tools, and practice adaptive management; and involve stakeholders) provide the methodology to accomplish the first three.

II. D. Instream Flow Methods

There are three main categories of flow assessment methods and the complementary methods for selecting minimum flow.

1) Historic flow regime: percentage of average annual flow; ecological goal is to sustain existing life forms, so food, water quality and temperature considered implicitly
2) Hydraulic: considers river width or perimeter because stream bed supports primary and secondary stream production; goal to keep main river channel 'full'
3) Habitat: to provide suitable physical habitat for aquatic organisms living in the river; focus on 'target' species[12]

Method	Historic flow	Hydraulic	Habitat
Data requirement	Flow record	Cross-section survey	Cross-section survey Habitat suitability criteria
Method of assessing flow requirement	% of average annual or monthly flow	% habitat retention	% habitat retention
	% exceedance	Inflection point	Inflection point Optimum Minimum habitat (exceedance or percentage)
Stream hydraulics	Effect on width, depth and velocity dependent on morphology	Effect on depth and velocity dependent on morphology	Prescribed depth and velocity
	Maintains 'character'	Maintains 'character' only in terms of variable considered (e.g. wetted perimeter)	Potential loss of 'character'
Ecological assumption	Close relationship between natural flows and existing ecology	Biological productivity related to wetted area	Close relationship between habitat and ecology
			Models consider ecological requirements, where known
Advantages and disadvantages	'Cook-book' flow assessment	Not necessarily a 'cook-book' flow assessment, some interpretation required	Not a 'cook-book' approach, application and interpretation critical
	Trade-off considerations not possible	Trade-off considerations not possible	Allows trade-offs
	Flow always less than, but related to natural	Flow dependent on channel shape	Flow assessment independent of natural flow
	Precludes enhancement	Levels of protection difficult to relate to ecological goals	Enhancement potential recognized

[10] IFC (Instream Flow Council) (2002) Instream Flows for Riverine Resources Stewardship: Revised Editon. United States: IFC.
[11] Knighton, D. (1998) Fluvial Forms and Processes. London: Arnold
[12] "Establishing Environmental Flow Requirements for Selected Streams in the Grand River Watershed." The Grand River Conservation Authority.

Table I. Figure taken from p. 124 of *Instream Flow Methods* to summarize the differences between different flow assessment methods.[13]

II. E. Instream Flow Conclusions

Instream flow methods are established to provide a certain level of protection to both the aquatic environment and all users interested in allocation rights. A sound water use management plan will determine how much water should be in the river through scientific and engineering studies, which determine flow conditions necessary to support a sound ecological environment. After establishing watershed-specific standards, instream flow programs generally focus on three main goals: mimicking the natural flow regime, addressing instream and out-of-stream needs, and integrating biotic and abiotic processes. Plans should outline each user's allocation of available water while keeping in mind an interdisciplinary approach that captures important aspects of instream flow studies.

III. Conservation Easements and Instream Flows

There are a myriad of MBIs used to apportion water rights in the United States. Through our investigation, we found that MBIs are concentrated in Western states that follow the prior appropriation doctrine. In order for market-based allocation instruments to be successful, the state's legal framework needs to support transferring of water rights or incentives for water conservation. This section discusses the potential for conservation easements to be used as a tool for protection of instream flows under the regulated riparian doctrine in Georgia.

III. A. Georgia Water Rights

[14] The landowner cannot divert the water from its ordinary course or degrade it in a way that would interfere with the reasonable use of the next riparian landowner.[8] These actions would constitute a trespass.[15] However, the code is not intended to prevent landowners from diverting the stream flow of non-navigable water through their own property.[16] For surface water withdrawals that exceed 100,000 gallons per day on a monthly average, a permit from the Director of Georgia's Environmental Protection Division (EPD) is required.[17]
Like most states in the eastern United States, Georgia follows a regulated riparian water rights doctrine, in which riparian land owners have the right to reasonable use of water that flows through or adjacent to their property. Georgia's statutes state that water belongs to the owner of the property through which it runs.

It was also found that landowners have "absolute dominion" over groundwater accessible from their property.[18] As with surface water, any withdrawal in excess of 100,000 gallons per day of groundwater requires a permit from EPD, and any withdrawals for purposes other than agriculture must include a water conservation plan in the permit application.[19] In fact, except in some areas of the Flint River Basin, agricultural uses are exempt from most of the permitting regulations for surface water withdrawals and groundwater withdrawals.[20]

This difference from Western water law that follows the prior appropriation doctrine explains in part why market-based instruments for voluntary trading of water rights are more common in the Western U.S. than in the Eastern U.S. [21] There are no statutes that allow for separating water rights and/or permits from the title to the land.

III. B. Payment for Watershed Services

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[13] Jowett, I.G. Instream Flow Methods: A Comparison of Approaches. (1997).
[14] OCGA § 44-8-1
[15] OCGA § 51-9-7
[16] OCGA § 44-8-9
[17] OCGA § 12-5-31
[18] 2 City of Atlanta v. Hodgins, 19 S.E.2d 508 (Ga. 1942); Saddler v. Lee, 66 Ga. 45 (1879)
[19] OCGA § 12-5-96
[20] OCGA § 51-9-7
[21] Dellapenna, J.W. Georgia Water Law: How to move forward now? Proceedings of the 2005 Georgia Water Resources Conference.

There are numerous Payment for Watershed Services (PWS) schemes across the country, but many address water quality issues as opposed to instream flows or water allocation. There are examples of PWS in states that follow the riparian rights doctrine that involve conservation easements or land acquisition in the watershed. Three of these cases are discussed below. Each of these case studies exhibits co-benefits of water quality protection, recreational use, and/or habitat protection.

III. B. 1. Mountain Island Lake, NC

Mountain Island Lake is a drinking water supply source for the City of Charlotte and Mecklenburg County. This lake and its tributaries are part of the Catawba River watershed, [22] Mecklenburg County Land & Park Bonds, City of Charlotte Funds, Mecklenburg County (and land donated to Mecklenburg County) funds were used to acquire about 6,000 acres in the watershed with an emphasis on lands adjacent to the lake or streams and creeks that feed directly into the lake. An additional 1,900 acres in Gaston and Lincoln Counties was also protected with the help of N.C. Clean Water Management Trust Fund Grant, the City of Gastonia Revenue Bond, and the Catawba Lands Conservancy. To date, 74% of Mountain Island Lake's shorelines are protected from development.[23]
which has experienced interstate water conflict heard in a Supreme Court Case in 2007.

III. B. 2. Carroll County, GA

With a voter-approved special-purpose local-option sales tax (SPLOST), Carroll County protected 500 acres along the Chattahoochee River and another 250 acres along the Little Tallapoosa River, both of which are drinking water sources for the municipalities in Carroll County. With additional funds from Trust for Public Lands and a national water quality program through EPA, they were able to acquire an additional 477 acres in these watersheds. The county is protecting green space to improve the quality of life in the community, but also acquiring properties that deliver watershed services when protected.[24]

III. B. 3. New York City and Catskill Watershed

To avoid constructing mandated filtration plants for their municipal water supply, New York City invested in conservation in the Catskills watershed upstream of the City. They initiated a three-pronged approach including the Watershed Agriculture Program, Watershed Forest Management Plan, and the Conservation Easement Program, which was a subset of a Land Acquisition Program. The agriculture and forest management initiatives were aimed at incorporating best management practices to protect stream water quality while maintaining the function of the land. The conservation easement and land acquisition programs were aimed at preventing development on land adjacent to streams and reservoirs. This program was funded by a 9% increase on water utilities, a $60 million trust fund, and additional funds from the City. The Conservation Easement Program is funded entirely by NYC Department of Environmental Protection.[25] As of 2011, about $1.5 billion has been spent on the project, compared to a $6-8 billion price tag estimated for the filtration facilities. Over 1 million acres in the watershed have been protected.[26]

III. C. Conservation Easements and Water Rights

As demonstrated in the above case studies, land conservation through easements and acquisition is a market-based mechanism being employed to protect water quality. Several land trusts and conservation organizations

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[22] South Carolina v. North Carolina (2007). 130 S.Ct. 854

[23] Charlotte-Mecklengurg Storm Water Services. Mountain Island Lake Watershed Protection Guidelines, 2005.

[24] Rasmussen, Patty. (2007) "Carroll County: Adding Greenspace." Georgia Trend.

[25] Smith, M., de Groot, D., Perrot-Maîte, D. and Bergkamp, G. (2006) Pay – Establishing payments for watershed services. Gland, Switzerland: IUCN. Reprint, Gland, Switzerland: IUCN, 2008. https://portals.iucn.org/library/efiles/edocs/2006-054.pdf

[26] Bennett, Genevieve, Nathaniel Carroll, and Katherine Hamilton. (2013) Charting New Waters: State of Watershed Payments 2012. Washington, DC: Forest Trends. Available online at http://www.ecosystemmarketplace.com/reports/sowp2012.

are using this mechanism across the country, and at least 29 states [27] However, especially in regulated riparian rights states, this mechanism may have the potential to be applied to protect instream flows in the long term, as well.
include water quality or water quantity as a reason for a conservation easement in their legislation.

Historically, there have been some issues with conservation easements where they were written in the "riparian mindset," meaning that they assumed the rights to the land coincided with water rights. In fact, this is not the case in most Western states. Colorado is a "prior appropriations" state, and in 2003, they amended their conservation easement legislation to allow conservation easements on water rights. In prior appropriation states, conservation easements can place restrictions on water rights to uphold the purpose of the easement. For example, the easement can require the landowner to maintain their water rights, or prevent them from selling or trading their water rights.[16]

Conservation easements that aim to preserve agricultural lands are inherently tied to water usage and water rights. In prior appropriation states, if an easement is not accompanied by water rights, it may be impossible to maintain the agricultural purpose identified in the easement. Also, in states where markets exist for water rights, keeping water rights connected to agricultural land inadvertently decreases opportunity for development in arid areas.[16] However, as in the Apalachicola-Chattahoochee-Flint River Basin, agricultural water demand represents one of the players in the interstate water conflict. Agricultural conservation easements may present an opportunity for landowners to voluntarily restrict or prevent increase in withdrawals in Georgia, both surface water and groundwater. It is within the scope of conservation easement to limit withdrawals in Georgia as long as it fits with the conservation purpose of the easement. Although it is not common, there have been instances where new piping or irrigation sources were limited through agricultural conservation easements.[28]

Water trusts, modeled after and operating similar to land trusts, are also being used to protect instream flows. These are present in several Western states where water rights can be traded and where instream uses are recognized as a beneficial use of the water right.[21] Water trusts are funded by state, federal, and/or charitable funds, and in some cases can lease water rights back to other consumptive users to generate revenue to continue to acquire water rights during high-flow periods.[29]

III. D. Tax Incentives

In order for the conservation easement to qualify for the income tax, it must meet at least two of the conservation objectives:[30] One of the benefits to the landowner of placing a conservation easement on their property is a substantial tax break. In Georgia, donors can receive an income tax credit of up to 25% of the fair market value of their land, up to $250,000 for individuals, or $500,000 for corporate landowners.

1) Water quality protection for streams, rivers, lakes, wetlands.
2) Protection of wildlife habitat as consistent with the Comprehensive Wildlife Conservation Strategy.
3) Protection of outdoor recreation areas.
4) Protection of important agriculture or forestry.
5) Protection of cultural, heritage, archeological, or historical sites.

Conservation Easement donations may qualify for 30%-50% of their income for Federal Income Taxes, as well. Qualifying easements for the IRS include lands that:[27]

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[27] King, M.A. and S.K. Fairfax (2005) Beyond the Bucks and Acres: Land Acquisition and Water. Texas Law Review. Vol. 83:1941-1984.
[28] Personal communication with Kat Nelson, Georgia Land Trust.
[29] Culp, P.W., R. Glennon, and G. Libecap (2014) Shopping for Water: How the Market Can Mitigate Water Shortages in the American West. http://islandpress.org/resources/9781610916745_optimized.pdf
[30] OCGA §48.7.29

1) Preserve outdoor recreation, education, or general use by the public.
2) Protect relatively natural habitat of fish, wildlife, plants, or ecosystems.
3) Preserve open space for the enjoyment of the general public.
4) Protect historical sites or structures.

Neither of the qualifications for state nor federal income tax deductions specifies criteria about water quantity or maintaining instream flows. If conservation easements become a tool for market-based instruments for water conservation, then the tax incentives should reflect that. Although, it is likely that if a tract of land were being conserved it would also meet some of the other qualifying criteria listed above. For example, in Georgia, protection of instream flows is likely to also be protecting aquatic habitat for threatened and endangered fish, mussels, or other species.

IV. Legal Limitations to Market-Based Instruments for Trading Water Rights

IV. A. State & Federal

The Supreme Court has consistently held that water rights are a matter of state law.[31] Outside of equitable apportionment and multistate compacts, each state controls intrastate water rights through its own regulatory framework. Yet many water conflicts span across state lines and interstate market-based approaches may be desirable. There are two primary Supreme Court cases that govern the ways in which state law may interfere with water transfers across state lines: *Sporhase v. Nebraska*[32] and *Tarrant Reg'l Water District v. Herrmann*.[33]

In *Sporhase* the Court considered whether a Nebraska statute banning commercial exportation of water violated the dormant Commerce Clause rooted in Article I of the U.S. Constitution.[34] The dormant Commerce Clause doctrine stands for the idea that because the Constitution grants Congress the power to regulate interstate commerce, there is a correlated prohibition that states cannot place improper burdens on interstate commerce. The Court in *Sporhase* held that the dormant Commerce Clause did prohibit the Nebraska statute.[35] The Court considered a similar question in *Tarrant* but arrived at a different result. Again the Court reviewed a state statute restricting the export of water under dormant Commerce Clause grounds.[36] But the Court held that the Red River Compact governing allocation in that Basin between Texas and Oklahoma made the question one of contractual interpretation.[37] The Court reasoned that because the Red River Compact left no water unallocated there could not be an interference with interstate water pertaining to any unallocated water.[38]

The Supreme Court's distinct treatment of interstate water allocations decided based upon the contractual interpretation of regional compacts suggests the potential power and permanency of such contractual arrangements. The *Tarrant* decision suggests that compacts will be given great deference outside of Commerce Clause and equitable apportionment jurisprudence. Thus, compacts can be used to implement interstate market based water allocation solutions. But the drawback to this deference is that future changes to the compact require modification through the means provided in the text of the agreement.

Constitutional limitations aside, incompatible state regulatory schemes present an obvious impediment to interstate water transfers. This difficulty is more pronounced in eastern states where the riparian rights doctrine

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[31] *United States v. Alaska*, 521 U.S. 1, 5 (1997); *Martin v. Lessee of Waddell*, 16 Pet. 347, 410 (1842).
[32] 458 U.S. 941 (1982).
[33] 133 S.Ct. 2120 (2013).
[34] 458 U.S. 943.
[35] *Id.* at 960.
[36] 133 S.Ct. 2125.
[37] *Id.* at 2137.
[38] *Id.*

is used.[39] Because the riparian rights doctrine defines withdrawals in terms of "reasonable use," it does not clearly adjudicate how much water a potential seller can market.[40] In the past, when water was plentiful in riparian states this was not a concern.[41] But today water scarcity is a threat in the east, and water markets may be a viable solution to meeting the demand. However, even current regulated riparian system may need to be modified to better define what water is for sale.[42]

While the *Sporhase* decision held that states cannot prohibit exportation, the difficulty of navigating state regulatory schemes can discourage efficient transfers. Accordingly, states wishing to facilitate interstate markets should view compacts as an effective means to explicitly set forth the framework for interstate transfers. Article I, Section 10 of the U.S. Constitution prevents any state from entering into a compact with another state without the consent of Congress. Interstate water compacts fall within this prohibition. This means that from a practical perspective creating a compact requires an agreement between states put into writing and then approved by Congress. A compact will not only make the process more accessible to a greater number of buyers and sellers, but it will also give the participating states an opportunity to negotiate how water transfers will be conducted.

Where compacts already exist it may be more difficult to implement market-based instruments because signees to a compact are legally bound to the compact's specific language about the allocation of water. To the extent that a desirable water market would conflict with the language of the compact, the compact would have to be amended. Amending the compact may be difficult depending on its terms for modification. In some cases it may be that a single signee state may block amendment if it wants to maintain the status quo.

IV. B. Local

Local governments can potentially use ordinances to impede the transfer of water in both interstate and intrastate water markets. For example, California has one of the largest intrastate water markets, but many rural counties have enacted ordinances that add restrictions to the export of groundwater to other counties.[43] California has a total of 58 counties, and 22 have enacted groundwater export ordinances.[44] These ordinances do not entirely outlaw groundwater exports, but they require environmental review before sellers can obtain an export permit.[45] The review is costly and carries a stigma that discourages sellers from entering the market.[46] While placing limits on water transfers is not an inherently bad local governmental action, it can stand in the way of implementing effective water markets on a larger scale, whether inter or intrastate. As the example in California suggests, markets created at the state level often need to be free of local protectionism. Implementing a successful regional market would likely require the action of each member-state to discourage or restrict local governments from enacting protectionist ordinances.

V. Social Equity in Water Markets

Establishing a water market in the ACF Basin may increase the efficiency and equitability of trading between direct partners, but there is strong potential for external influences on trading because water property rights are not clearly delimited by the Southeast's regulated riparian doctrine. Chong and Sunding[47] suggest water markets and trading "deviate from an ideal textbook market because of third-party effects and transaction costs,

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[39] Janet C. Neuman, *HAVE WE GOT A DEAL FOR YOU: CAN THE EAST BORROW FROM THE WESTERN WATER MARKETING EXPERIENCE?*, 21 Ga. St. U. L. Rev. 449, 450-451 (2004).
[40] *Id.*
[41] *Id.* at 454-455.
[42] *Id.*
[43] "Managing California's Water Market: Issues and Prospects," Research Brief, Public Policy Institute of California (Issue# 74, July 2003) http://www.ppic.org/content/pubs/rb/RB_703EHRB.pdf
[44] *Id.*
[45] *Id.*
[46] *Id.*
[47] Chong, Howard, and David Sunding (2006) Water Markets and Trading. Annual Review of Environment and Resources 31:239-264.

which arise out of water's unique properties." These externalities – third-party effects and transaction costs – carry dimensions of social equitability that cannot be addressed solely within a market system, but must be attended to under a broader integrated water management plan.[48]

The importance for social equitability in water markets can be summarized by three concerns: (1) the preference for urban uses, rather than agricultural, (2) effects on the area-of-origin, and (3) and the privatization of a public good. First, citing evidence from Los Angeles and the Rio Grande area, several scholars[49] suggest that water markets favor urban areas and uses at the expense of rural agriculture. Urban centers, which typically have a greater buying power, can more easily purchase water rights from agriculturalists than vice versa[50]. This concern can be limited by the lack of infrastructure and high conveyance costs[51]. Additionally, in the ACF Basin, there is little incentive for the Atlanta-metro area to purchase rural water rights, as the majority of agricultural production is downstream of the urban center. However, this concern does highlight the notion that agriculturalists may not be favored in a water market program, as they do not have the financial ability to purchase water rights from urban areas.

Second, area-of-origin and third-party effects call attention to how purchasing water rights from agricultural users, for example, can have a rippling effect throughout that community.[52] Farmers that earn money from selling water rights, rather than farming, have little need for farm hands or farm equipment, thus influencing the economy of the area. Chong and Sunding[53] acknowledge that these effects can depend on the response of water sellers, and how they choose to use funds from selling their water rights. Additionally, potential tools to overcome these area-of-origin effects are compensation, caps on traded volume, and state governments adjusting local funding to account for third-party effects. For the ACF Basin, this concern again highlights the importance of integrating water markets into a larger water management plan, taking into account the potential for third-party and area-of-origin effects, so that water markets avoid unintended social consequences.

Third, some scholars argue that water is a public good and should not be privatized and subjected to market forces[54]. These authors suggest that privatizing water creates values based on willingness to pay that are skewed against those lacking ability to pay, and that market mechanisms emphasize the need to reallocate to high-value uses, rather than providing clean water to all people. Orlove and Caton[55] voice concern over "the equity of access to safe drinking water for people of all classes, of all ethnic and racial groups, of all ages, and [all] genders." Conversely, Rogers et al.[56] suggest that high prices of water would benefit the poor because it would encourage water conservation amongst high volume water users and make more water available to poorer communities. However, the argument for privatization give inadequate attention to the lack of clarity in property rights surrounding water and the preconditions needed for effective water markets, like those Rogers et al. suggest. Under the Southeast's regulated riparian doctrine, achieving these preconditions for effective water markets would be near impossible. Lastly, in the privatization of water, even in integrated water resource

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[48] *Id.*
[49] Molle, François, and Jeremy Berkoff (2006) Cities versus agriculture: Revisiting intersectoral water transfers, potential gains and conflicts. Colombo, Sri Lanka: Comprehensive Assessment Secretariat. 73p. (Comprehensive Assessment Research Report 10).
[50] *Id.*
[51] Chong, Howard, and David Sunding (2006) Water Markets and Trading. Annual Review of Environment and Resources 31:239-264.
[52] *Id.*
[53] *Id.*
[54] Howe, Charles (2000) Protecting Public Values in a Water Market Setting: Improving Water Markets to Increase Economic Efficiency and Equity. 3 University of Denver Water Law Review 357.
Swyngedouw, Erik (2005) Dispossessing H_20: The Contested Terrain of Water Privatization. Capitalism Nature Socialism 16(1):81-98. doi: 10.1080/1045575052000335384
[55] Orlove, Ben, and Steven C. Caton (2010) Water Sustainability: Anthropological Approaches and Prospects. Annual Review of Anthropology 39:401-415. doi: 10.1146/annurev.anthro.012809.105045
[56] Rogers, Peter, Radhika de Silva, and Ramesh Bhatia (2002) Water is an economic good: How to use prices to promote equity, efficiency, and sustainability. Water Policy 4:1-17.

management, there is a tendency to slight the social equity of small farmers and tenant farmers who do not own water rights, in favor of economic efficiency and environmental concerns. Thus, an integrated water management plan in the ACF Basin would need to pay particular attention not only to the allocation of water through markets, but to water quality and the equitable distribution of clean water across users.

Because of these concerns over water markets, Chong and Sunding[57], in agreement with Howe[58], suggest water markets are not sufficient to address all problems of equity. Rather they suggest, once basic uses of water are met, water markets are an efficient mechanism for dealing with the scarcity of remaining elective uses of water. They conclude that "combined with water conservation on the demand side, water markets are an integral option for allocating scarce water." Because of water's unique properties, managers cannot rely solely on markets to promote equity or conservation. Rather, any water market mechanism in the ACF Basin will need to be nested within a broader conservation plan that addresses environmental and social concerns over access to water.

[57] Chong, Howard, and David Sunding (2006) Water Markets and Trading. Annual Review of Environment and Resources 31:239-264.

[58] Howe, Charles (2000) Protecting Public Values in a Water Market Setting: Improving Water Markets to Increase Economic Efficiency and Equity. 3 University of Denver Water Law Review 357.

Outreach Materials

Market-based approaches to resolve water conflicts in the Apalachicola-Chattahoochee-Flint River Basin

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Project Overview

This study explores the use of market-based instruments (MBIs) in interstate river basins and aims to determine the feasibility of their use in the Apalachicola-Chattahoochee-Flint (ACF) River Basin. The project is limited in scope to industrialized nations and MBIs used for water allocation.

Research Objectives

1) Identify all instances where interstate water allocation disputes were brought to state or federal courts in the United States
2) Categorize cases into a comprehensive list of interstate water allocation disputes
3) Derive from the comprehensive list of interstate water allocation disputes all cases where MBIs were utilized
4) Characterize emerging and well-established MBIs utilized in river basins of select industrialized nations

Market-Based Instruments (MBIs)

Market-based instruments (MBIs) are used to incentivize voluntary behavior, in contrast to regulations or court rulings. There are four main types of MBIs used to (re)allocate water:

1) Instream buyback: temporary lease or permanent purchase of water right for the purpose of leaving the water in the river.
2) Trading: water rights are bought and sold in a marketplace, either directly or via water bank
3) Beneficiary-pays fund: entities benefitting from watershed services contribute to a fund, which is used to protect or enhance watershed services.
4) Bilateral agreement: contract between entity willing to pay for a water-derived benefit and an entity able to provide the water-derived benefit.

Instream Flow Considerations

Instream flows are quantities of water left in the stream for the maintenance of environmental health, water quality, recreation, and other ecosystem services. The most basic protection afforded by all states is the minimum instream flow needed to ensure a stream's capacity for waste assimilation. This minimum is commonly based on the 7Q10 standard, or the "lowest continuous flow over a 7-day period that is expected to occur within a 10-year interval" (Beerely et al., 2006). Regardless of the method used to determine minimum, a state may protect instream flows by limiting the number of or placing conditions on withdrawal permits or augmenting flows. Scientific and engineering studies may be performed to determine flow conditions necessary to support a sound ecological environment.

Measure of level of protection

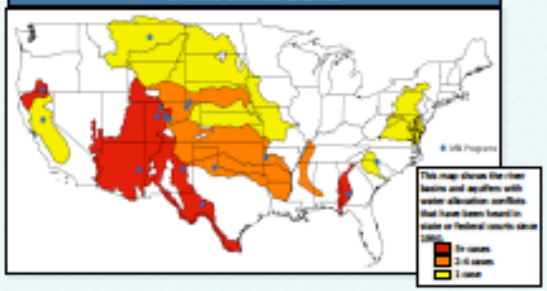
1) Historic flow regime: percentage of average annual flow; ecological goal is to sustain existing life forms, so food, water quality and temperature considered implicitly
2) Hydraulic: considers river width or perimeter because stream bed supports primary and secondary stream production; goal to keep main river channel "full"
3) Habitat: to provide suitable physical habitat for aquatic organisms living in the river; focus on "target" species

Establish watershed-specific standards

- Mimic natural flow regime
- Address instream and out-of-stream needs
- Integrate biotic and abiotic processes

- Conflicting minimum flow assessments from different environmental goals and protection
  - Small rivers more "at risk"

MBI Programs and Interstate Water Allocation Conflicts of the United States



Interstate Water Allocation Conflicts

Conflicts over water allocation commonly occur in interstate river basins throughout the United States. Historically many of these conflicts occurred in the arid western United States; however, in recent years there have been an increasing number of water allocation conflicts in the humid southeast. The US Supreme Court is hearing a whopping five cases this year that pertain to interstate water allocation! Three of these cases are in basins with previously established water compacts (i.e. binding agreements between states that specify the quantity of water that must reach one or more state boundaries). The other two cases are in areas with no previous water compacts, which include the ACF River Basin and the Memphis Sand Aquifer (the first dispute over groundwater heard by the US Supreme Court).

Apalachicola-Chattahoochee-Flint (ACF) River Basin

Georgia, Alabama, and Florida have been entrenched in a dispute over the waters of the ACF River Basin for decades. In recent years the debate has become ever more serious because there is insufficient water to meet environmental and public water demands during droughts. A variety of approaches have been employed in attempts to resolve this dispute, including political negotiations and litigation, but have been unsuccessful to date because they do not ensure the benefits derived from water and burdens borne by lack thereof are shared equitably amongst water users. Market-based instruments (MBIs) offer a way to resolve water disputes by redistributing benefits and burdens experienced by water users, in lieu of litigation and politics. However, MBIs, found to be particularly effective for solving interstate water allocation disputes in other basins, have largely been ignored.

Legal Consideration for use of MBIs in the ACF Basin

The possibility of implementing market-based instruments in the ACF falls against an existing legal backdrop stemming from legislation and litigation in other basins.

State and Federal Legal Limitations:

- Incompatible state regulatory schemes present a barrier to the transfer of water across state lines within a basin. Interstate compacts are enforceable contracts between states that allow the participating states to negotiate water allocations. A signee who violates the terms of the compact can be legally compelled to cease bad behaviors by other signees. Incorporating market-based instruments into any future compacts in the ACF may be an effective way to get water from sellers with excess to buyers in need.
- The Supreme Court has ruled that a state may not prohibit water exports due to the Commerce Clause of the U.S. Constitution. *Sporhase v. Nebraska*, 458 U.S. 941 (1982). But water allocated pursuant to an interstate compact does not raise Commerce Clause concerns. *Tarrant Reg'l Water District v. Herrmann*, 133 S.Ct. 2120 (2013).

Local Concerns:

Local ordinances can put limitations on water transfers that introduce inefficiencies to markets. For

Payment for Watershed Services and Land Considerations

Water markets are feasible in western states in part because water rights are not inherently linked to land ownership, and can be traded and transferred separately from the land itself. In exploring market-based instruments that may be applicable in Georgia's riparian rights system, it may be beneficial to consider land conservation as a tool for "netting" or limiting water withdrawals.

Georgia Riparian Rights Doctrine:

- The landowner has the right to "reasonable" use of water flowing through his property (OCGA § 46-8-1).
- Georgia law does not provide specifications for the transfer of water rights separately from title of the land.
- Landowners have "absolute dominion" over groundwater (2 City of Atlanta v. Hodgins, 195 S.E.2d 508 (Ga. 1942); Saddler v. Lee, 66 Ga. 45 (1879).

Land acquisition has been employed in several instances for watershed protection with a focus on water quality. Co-benefits of payment for watershed services listed below include recreation opportunities and habitat protection.

- Mountain Island Lake, NC
  Over 8,000 acres around Mountain Island Lake, a drinking water supply source, have been protected. Counties adjacent to the lake, City of Charlotte, and local land trusts contributed to land acquisition and protection. NC Clean Water Management Trust Fund distributes funds through grants for projects that protect or improve surface water quality. CWMTF is funded by the NC General Assembly.
- Carroll County, GA
  Voters approved a SPLOST tax increase that funded protection of 750 acres of riparian land to protect drinking water supply source. Funding from national EPA program for protection of water quality and Trust for Public Lands protected an additional 500 acres.
- New York City and Catskills-Delaware Watersheds
  To avoid constructing new filtration systems (at a cost of between $6 and 8 billion), the City of New York invested in a watershed protection program. This program has three components: an agricultural program, a forest management plan, and conservation easement program. The conservation easement program is funded entirely by the NYC Department of Environmental Protection. The city is also purchasing development rights around reservoirs and streams.

Water Withdrawal Permits and Conservation Easements

The IRS doesn't specifically identify water conservation as a tax-deductible purpose for a conservation easement, but it does include the protection of aquatic habitat. To work within Georgia's legal framework, conservation easements on riparian land may be used to protect future flows by writing in specifications about water use permits on the land, and setting up additional tax incentives for these types of easements.

Social Equitability

Third party effects and transaction costs, or the externalities that extend beyond the buyer-seller interactions, which result from unclear property rights, create three main concerns for promoting social equity.

1) Prioritizes urban uses over agricultural uses. This concern comes from the pattern of urban centers, which have relatively more buying power, purchasing water from agricultural sector. However, though this has occurred in Los Angeles and the Rio Grande area, lack of infrastructure and high transportation costs limit transfers of water to growing urban areas.
2) Area-of-origin effects. This concern recognizes that buying water from farm activity reduces farm employment and decreases sales for supporting businesses. In turn, this can erode the tax base and economy in the areas from which water is bought.
3) Privatization of a public good. This concern asserts that water is a public good that should not be subject to market forces. Doing so can privilege those with the ability to pay for water, slight small

Overland flow-sourced water quality impairment and targeted restoration of natural flow regimes in Proctor Creek, Atlanta, GA

Basic Information

Title:	Overland flow-sourced water quality impairment and targeted restoration of natural flow regimes in Proctor Creek, Atlanta, GA
Project Number:	2015GA356B
Start Date:	3/1/2015
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	5
Research Category:	Water Quality
Focus Category:	Hydrology, Non Point Pollution, Water Supply
Descriptors:	None
Principal Investigators:	Katie Price, Daniel M Deocampo

Publications

There are no publications.

Georgia Water Resources Institute Final Report

Katie Price and Daniel Deocampo, Department of Geosciences, Georgia State University

Overland flow-sourced water quality impairment and targeted restoration of natural flow regimes in Proctor Creek, Atlanta, GA

An important note on project status:

This GWRI project funded parts of one PhD and five MS student research projects. While this is a fantastic outcome for the Watershed Hydrology and Geomorphology Laboratory at GSU, as well as the training objective of the USGS 104b program, it has meant that the PIs' original timeline has been shifted substantially to accommodate student degree progress. Of the six student projects, one thesis has been defended, two will be defended Summer 2016, and the remainder will be completed by Spring 2017.

Furthermore, substantial delays have been introduced in search of landowner permissions for stream monitoring equipment, as well as our *a posteriori* inclusion of invaluable community stakeholder participation, discussed in the methods section.

While all necessary costs have been encumbered (stream monitoring equipment purchases, geochemical analyses, student funding, etc.), several aspects of this project will continue through the 2016-2017 academic year, and all results presented herein are preliminary.

Introduction:

Communities and ecosystems across the southeastern US face public health and environmental concerns relating to contamination from past and current industrial and urban land use. In addition to contaminants associated with roadways and active industrial sources (Deocampo 2012), abandoned industrial sites may continue to contaminate air and water resources long after activity has ceased (Suh 2011, Bradham 2014). Known as 'brownfields', areas of relic urban contamination, commonly laden with trace metals such as cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), and zinc (Zn), among others, are often located within densely populated areas of cities, posing ongoing public health threats (USEPA 2011, Bradham 2014). Contaminated soils may repeatedly introduce metals to stream systems during overland flow and flooding events, as many brownfield sites are located near stream channels, or even within active floodplains. Metals-laden surface waters are associated with decreased aquatic biodiversity, public health risks, and increased costs of water treatment for use downstream (Paul and Meyer 2001, Peters 2009, Bradham 2014).

As an additional stressor, the low permeability of many urban land cover types has been repeatedly shown to complicate hydrological flow regimes and pathways, leading to drastic increases in overland flow and flood peaks (Booth and Jackson 1997, Price 2011). This resulting exaggeration in flood peaks and low flow variability from normal flow conditions, known as stream 'flashiness', increases interactions between water and contaminated sites , greatly exacerbating nonpoint sources pollution loadings to stream systems (Paul and Meyer 2001, Fletcher *et al.* 2014). In recent years, awareness of these problems has grown, and there have

been large government, private sector, and scientific thrusts toward development of engineering strategies to mediate overland flow and restore streams to more natural hydrodynamic regimes. Often referred to as 'green infrastructure' or 'low impact development (LID)' (Bhaskar 2016), such efforts typically involve strategic location of natural or vegetated areas to reduce flood damage and contaminant transport (McKane 2012, Kousky *et al.* 2013). The combination of brownfield soil remediation and green infrastructure implementation may drastically reduce public and ecological health risks associated with legacy urban and industrial pollution.

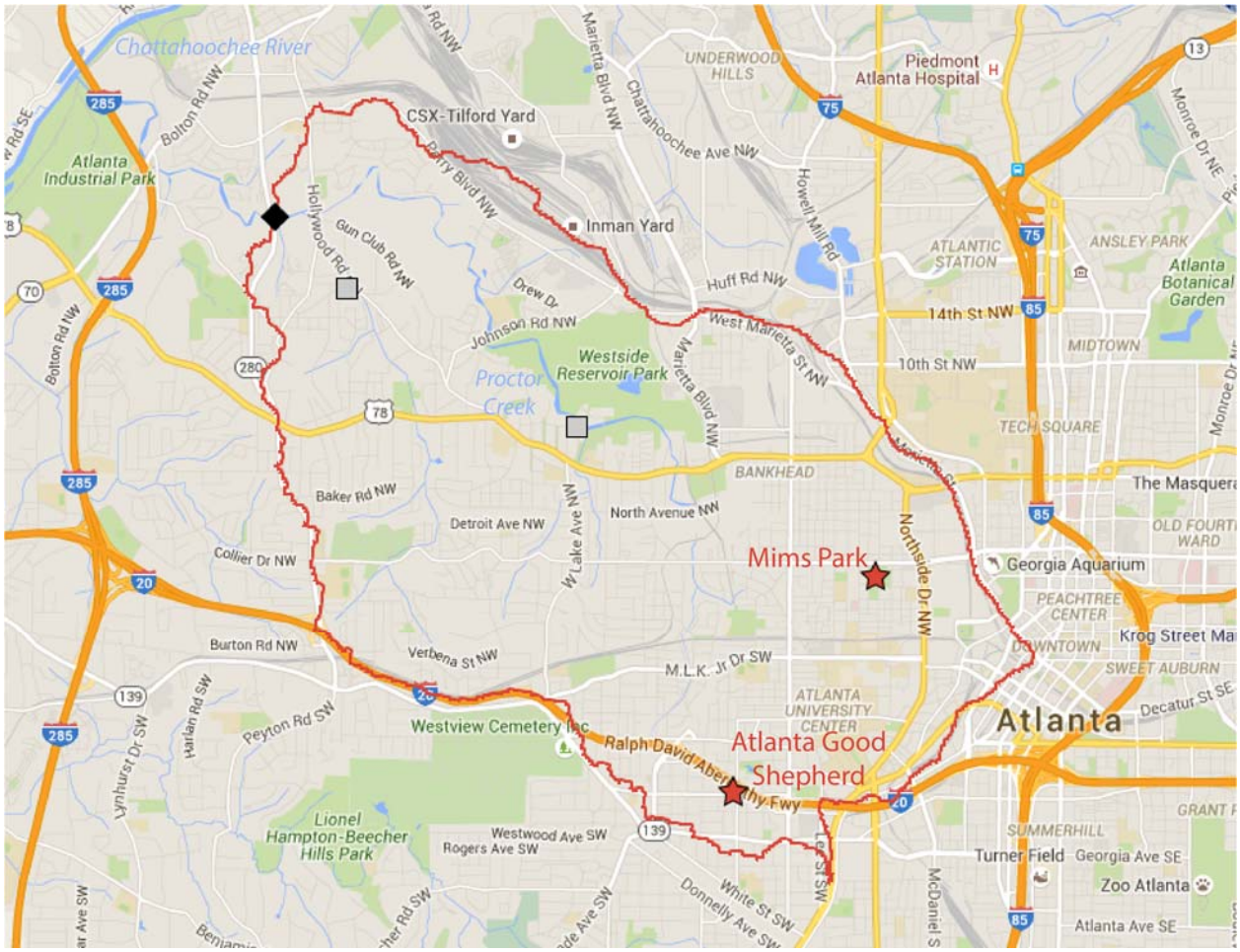


Figure 1 - Proctor Creek Watershed. The black diamond indicates the long term USGS gage at Jackson Parkway (USGS 02336526). Grey squares show new USGS gages (Active beginning Oct. 2015). Red stars show upland soil hydrology and geochemistry study areas.

The Proctor Creek watershed is approximately 41 km^2 and is located in the northwestern portion of the City of Atlanta (Figure 1). The headwaters of Proctor Creek are in the downtown core of the city, and the watershed as a whole has approximately 34% impervious surface cover (City of Atlanta 2014). The watershed has a storied land use and environmental exposure history involving numerous brownfields, pathogen contamination from wastewater treatment facilities and sewer systems, and drastically altered flood hydrology. Geochemical analyses from multiple studies have demonstrated trace metal concentrations in the dissolved, suspended,

	Georgia EPD Instream Limit		USEPA Aquatic Biota Limit		Proctor Creek Stormflow (McConnell 1980)	Proctor Creek Stormflow (Horowitz 2008)	LEA ICP-MS Detection Limit
	Acute	*Chronic*	*Acute*	*Chronic*			
Copper	7	5	-	-	85	76	0.01
Zinc	65	65	120	120	640	280	0.01
Cadmium	1	0.2	2	0.3	BDL*	0.7	0.01
Chromium	16	11	16	11	72	46	0.01
Nickel	260	29	470	52	NA	25	0.01
Lead	30	1	65	3	1700	110	< 0.001

Table 1. - Observed trace metal concentrations in Proctor Creek (µg/L). Sources: GAEPD 2005, USEPA 2014a, McConnell 1980, and Horowitz *et al.*,2008. BDL* indicates measurement below instrumentation detection limits

and bedload fractions of Proctor Creek sediments, well in excess of known biotic tolerances and regulatory limits (Table 1) (McConnell 1980, Horowitz 2008, Peters 2009). The problems associated with unremediated brownfields are worsened by the drastically altered flow regime, with Proctor Creek flashiness exceeding that even of other Atlanta urban watersheds (Figure 2). The myriad water quality, air quality, and environmental justice problems within the watershed have prevented any focused efforts on evaluating the spatial variability and possible remediation of water-borne trace metals. In addition to deleterious water quality and biotic health effects within the Proctor Creek watershed itself, as a tributary to the Chattahoochee River, water quality impairment in Proctor Creek propagates to water treatment and biotic integrity challenges elsewhere in the state of Georgia (Peters 2009). Given public budgetary constraints, it is critical that brownfield remediation and flow restoration efforts be strategically targeted, based on a system-wide spatial understanding of contaminant sourcing and flow dynamics (Kaushal *et al.* 2014).

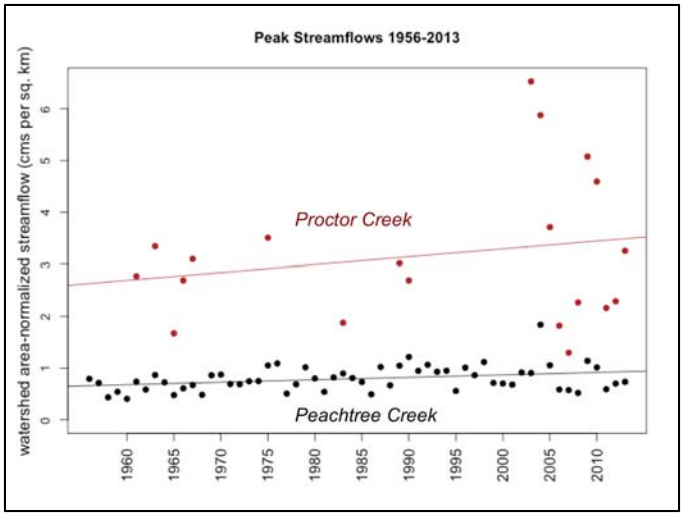


Figure 2 - Area-adjusted annual peak streamflow data from Proctor Creek (USGS 02336526) and Peachtree Creek (USGS 02336300)

Objectives:

This project aimed to evaluate the spatial variability of hydrodynamic flow alteration, as well as soil and water geochemical contamination throughout the Proctor Creek watershed. Final outcomes of this study will be used to optimize locations for LID, restoration, and cleanup efforts. As brownfields and altered flow regimes are a regional problem, affecting many areas beyond the Proctor Creek watershed, the results of this study will provide guidance for similar remediation and flow restoration efforts elsewhere in Georgia and the southeastern US.

Ongoing research objectives

This study was designed around three distinct but complementary objectives:

1) Use a system-wide approach to assess a) overland flow/flood flashiness and b) water- and sediment-borne metals throughout the Proctor Creek watershed.
2) Use statistical methods to identify hotspots of flow alteration and water quality impairment
3) Use watershed modeling to determine optimized areas for flow restoration efforts

Methods:

Soil hydrology assessment

A key element of the spatial analysis portion of this project is the linkage between watershed land management in Proctor Creek and overland flow occurrence. While impervious surface is a primary control on the partitioning of overland flow and infiltration, other altered land surfaces are often overlooked as contributors to urban and suburban runoff. Soils in urban settings, under residential lawns, parks, landscaping, etc., are often highly compacted and effectively impervious (Booth and Jackson 1997, Price *et al.* 2010). To address systematic spatial variability of soil infiltration capacity, we conducted *in situ* field measurements of saturated hydraulic conductivity (K_{sat}), across three scales of analysis, 1) single-meter, 2) multiple-meter and 3) kilometer. Sub-meter and ten-meter scale analyses were completed in Fall 2015 and Spring 2016, as part of a MS student thesis, which will be defended in July 2016. Kilometer-scale sampling is part of a separate, ongoing MS student thesis project, to be completed by Summer 2017.

Figure 3 – Soil K_{sat} sampling zones within Atlanta Good Shepherd. Each triangle represents three sampling points.

A mixed-use site within the Proctor Creek watershed, the Atlanta Good Shepherd, was identified for the single-meter and multiple-meter sampling designs. All sampling locations are mapped with "low-intensity developed" land use and "urban land (Ub)" soil in the 2011 NLCD and SSURGO databases, respectively. Within the Atlanta Good Shepherd property, 30 sampling zones were selected using the random point generator in ArcGIS 10.1 (Figure 3). Initially, 40 random points were generated. Points falling on roads, buildings, or other

inaccessible locations were discarded, leaving sites distributed across three land cover (LC) types: compacted fill, tilled soil, and lawn. In each sampling zone, three boreholes were augured in a triangle arrangement, 1 m apart, resulting in 90 total boreholes, summarized as 30 sampling zones (Figure 3). Each borehole was wire-brushed to remove any clay-smearing effects from the auger. The target depth for all boreholes was 25-30 cm to represent near-surface processes (Price *et al.*, 2010), and the exact depth and diameter of each

An Aardvark (Soil Moisture, Inc.) automated permeameter was used for collection of continuous infiltration rate data from each sample point (Theron *et al.* 2010), which were later converted to K_{sat} measurements using the Reynolds and Elrick Equation, which is ideal for the diameter of the boreholes required for this particular instrument (Elrick and Reynolds 1992). The Aardvark "constant head" permeameter is a constant head well permeameter that uses a down-hole float valve to maintain ponded water (Figure 4). Constant head refers to the condition that the water in the well is maintained at a constant depth as the test is conducted. Readings were collected every five seconds, until a steady state was reached, defined by three or more consecutive readings with negligible change in infiltration rate.

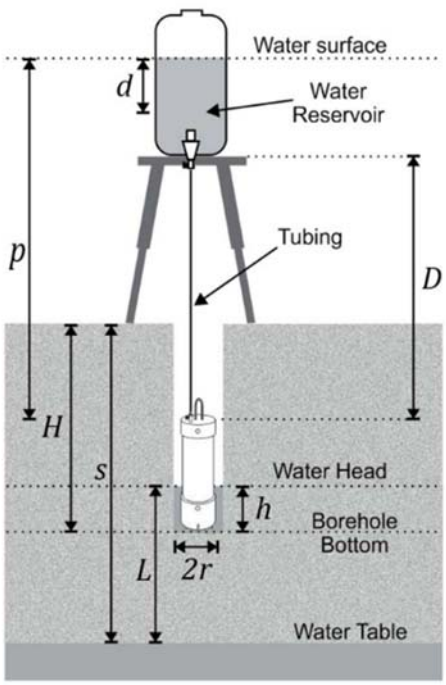


Figure 4 - Schematic of Aardvark Permeater standard setup: d=drop in reservoir water level, D = vertical distance between reservoir and permeameter, H = borehole depth, r = borehole radius, h = ponded water height

For multi-meter scale evaluation, the geometric mean of the three points at each sampling zone was calculated, as a representation of the entire zone (West *et al.* 2007). For kilometer-scale measurements, a stratified random sampling approach was applied to the Proctor Creek watershed as a whole, with stratification based on a) soil type, and b) land cover. Ongoing K_{sat} measurements at these sites occur, as part of a MS student thesis. Completion is anticipated by Fall 2016.

Brownfield soil geochemical assessment and biochar remediation potential

Mims Park was selected as the study area for a detailed geochemical assessment (Figure 1). Mims Park is administered by the City of Atlanta Department of Watershed Management and was reported to be contaminated. This land was reputedly filled using coal slag and presumed to contain byproducts of lead-based paints and plumbing from housing developments demolished onsite. Ten random samples were collected from the park property, in order to confirm contamination and identify possible "hot spots" of metals. Once these were identified, ten further samples were collected surrounding the hot spots. Bulk samples (~2 L) were collected using plastic tools, from the upper 25 cm, following removal of overlying vegetation. These samples were then homogenized, and a 250 mL subsample was analyzed for trace metal concentrations using inductively coupled plasma atomic emission spectroscopy (ICP-AES).

Sample grinding, sieving, *Aqua Regia* extraction, and ICP-AES analysis were performed by ALS Global.

Yellow pine biochar (sieved to <64 mm) was mixed with subsmaples of the contaminated soils, to test the remediation potential for protecting the quality of water reaching Proctor Creek. Soil samples were sieved through a 2 mm nylon mesh sieve and were split into two subsamples of 15 grams each and placed inside separate plastic vials (Uchimiya *et al.*, 2011). Synthetic rainwater was created by mixing ultrapure water and H_2SO_4 to a pH of 4.48, representative of local rain pH (Kieber *et al.*, 2004). To one subsample per location, 3 g of biochar was added, while the other subsample was left untreated. Both subsamples were saturated with 30 mL of synthetic rainwater and shaken in an orbital shaker for 24 hours. These slurries were then vacuum-filtered through 0.2 µm glass fiber filters, and 2 mL of filtrate from each sample were analyzed for As, Cd, Cr, Cu, Ni, Pb and Zn concentrations using inductively coupled plasma mass spectrometry (ICP-MS), performed by the University of Georgia's Center for Applied Isotope Studies. This process was repeated for all 20 soil samples, along with 6 replicates for error assessment.

Streamflow monitoring

Our original plan was to work with the City of Atlanta to obtain permission to install stream monitoring equipment in road rights-of-way, but all our efforts have been hitherto unsuccessful. Thus, we have invested a large amount of unplanned time developing working relationships with non-government stakeholders and landowners in the Proctor Creek watershed, to our great benefit. These efforts have included:

- Funding of a water policy graduate student to interface with community groups
- PI attendance at Proctor Creek nonprofit organization and community events, including those sponsored by Proctor Creek Stewardship Council, Eco-Action, and West Atlanta Watershed Alliance, and Chattahoochee Riverkeeper
- Development of working relationships with Park Pride and The Emerald Corridor Foundation

All stream monitoring equipment has been purchased, and installations are in progress. All stations will be active by August 2016. A positive, unexpected benefit to this project was that two additional USGS gages were installed in the Proctor Creek watershed during the funding period (Figure 1), underscoring the need for water monitoring in this locale, along with better intra- and inter-agency communication!

In order to evaluate flow dynamics from a system-wide perspective, (*i.e.*, from the headwaters to the outlet, streamflow will be monitored at a minimum of 20 locations distributed across the Proctor Creek watershed. Streamflow measurement will involve two main components: 1) water level (stage) monitoring, and 2) development of rating curves to convert stage measurements to discharge values (flow per unit time).

HOBO data-logging pressure transducers will be installed at each monitoring site that is not already gaged by the USGS. Where possible, loggers will be installed by suspending the probe

directly into the stream channel via PVC housing attached to bridge support or other pre-existing structures. Where no such structure exists, loggers will be installed in the stream bank, connected to the stream thalweg via lateral tubing (Price *et al*., 2011). Several such installations have been completed. Barometric pressure fluctuations will be adjusted, based on a single land-based pressure transducer installed centrally among the sites. Stage measurements will be collected every 15 minutes at each of the 20+ monitoring stations.
Discharge (streamflow) rating curves will be developed for conversion of stream stage values to streamflow. Episodic streamflow will be measured using the standard midsection method (Mosley and McKerchar, 1993), using a SonTek Accoustic Doppler Velocimeter at 60% water depth. A minimum of eight flow events will be measured at each site, at flows ranging from annual low flows to high stormflows. When high flows create non-wadeable conditions, biodegradable dye tracers will be used to estimate surface velocity with a 0.92 adjustment factor (Pelletier, 1989). Bankfull flow values will be estimated using the HEC-RAS program (USACE 2010). Simulated and empirical flow measurements will be linked to the current water level recorded at the given site, and rating curves will be established using Bayesian curve fitting methods of stage/discharge points for each site (Reitan and Petersen-Øverleir 2008, Price *et al*. 2011).

Watershed modeling
Two separate student research projects are exploring watershed modeling approaches for Proctor Creek. In the first, the VELMA (Visualizing Ecosystem Land Management Assessments), version 2.0, is being used to explore overland flow dynamics as a function of soil moisture distributions and shallow flowpaths (USEPA 2014b). In the second, low-impact development scenarios are being compared using an ensemble of VELMA and the USEPA's Storm Water Management Model (SWMM). VELMA 2.0 and SWMM 5.1.0 have been applied to green infrastructure/LID applications in the Pacific Northwest and Great Lakes regions.

Prior to scenario modeling, VELMA and SWMM will be calibrated against long-term observed flow data from the USGS flow gauges at Jackson Parkway. Model calibration will involve a simulation set, multi-objective approach to incorporate low flows, high flows, and flow variability (Price *et al*. 2012). Calibrations will be validated against an independent time series, using a standard split-sample approach (Andréassian *et al.* 2009), as well as by the short-term records available from the more recent USGS gages and all flow monitoring conducted as part of this study. LID infrastructure and other restoration scenarios will be developed based on the results of the geostatistical analyses, with guidance from previous strategic planning efforts (Park Pride 2010). Target flow dynamics for restoration will be based upon flow regimes known to be of greatest benefit to flood control, water supply, and aquatic habitat (Poff *et al.* 2010, Fletcher *et al*. 2014). Existing standard infrastructure, as a key control on watershed hydrodynamics, will be incorporated into VELMA and SWMM (Hopkins *et al.* 2014, Kaushal *et al.* 2014).

Results and Discussion:

Given the number of student projects involved and the delays introduced by landowner permissions, we emphasize that all results are preliminary and have not yet been scrutinized using rigorous quality assurance procedures.

Soil hydrology assessment

Land cover was shown to have a highly significant relationship to K_{sat} among the three LC classes observed at the single-meter and multiple-meter scales. Mean values by LC spanned four orders of magnitude (Figure 5). Unsurprisingly, tilled soils ("Farm") had by far the highest K_{sat} values, with a mean of 2.2 x 10^{-4} cm/s. Undifferentiated fill soils had the lowest K_{sat} values, with a mean of 7.5 x 10^{-7} cm/s, while the mean lawn K_{sat} value of 9.0 x 10^{-6} cm/s was higher than fill soils, but still far lower than the tilled soils. Non-parametric ANOVA (Kruskal-Wallis) results highly indicated statistically significant ($p < 0.001$) differences among all LC pairs in the single-meter spacings, and significant differences ($p < 0.05$) among all LC pairs in the multi-meter spacings. These drastic differences in Ksat are attributed to highly varied levels of compaction, with the "fill" soils assumed to have been mechanically compacted to the point that little vegetation is able to grow, the lawn soils slightly less so, and the farm soils actively loosened via tillage. These differences in K_{sat} have been observed to translate to differences in hydrologic behavior during storm events, with infiltration-excess overland flow occurring during frequent rainfall events on the fill and lawn areas, but not the tilled areas.

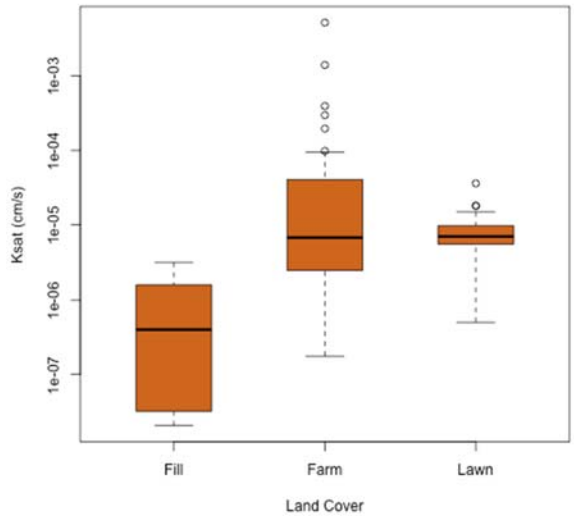


Figure 5 - Saturated hydraulic conductivity under different land covers at Atlanta Good Shepherd

Figure 6 - Infiltration-excess overland flow following a moderate rainfall event at Atlanta Good Shepherd (Photo by Hayden Hinton)

Table 2 - Mims Park soil metal concentrations (ppm)

SAMPLE	As	Cd	Co	Cr	Cu	Ni	Pb	Zn
6.1	9	<0.5	32	157	65	82	31	130
6.2	<5	<0.5	35	193	61	96	31	126
6.3	<5	<0.5	32	160	53	73	39	130
6.4	<5	<0.5	35	144	51	71	32	125
6.5	<5	<0.5	33	162	58	75	25	117
9.1	6	<0.5	11	53	60	12	176	278
9.2	7	<0.5	13	34	44	19	108	174
9.3	12	1.1	18	58	130	40	418	584
9.4	14	0.6	16	55	86	29	296	612
9.5	18	2.6	15	57	143	33	669	860
10.1	17	1.7	16	69	238	34	704	807
10.2	20	1.4	13	63	253	27	490	629
10.3	15	1.5	13	52	198	26	640	636
10.4	14	1.2	15	76	174	34	637	744
10.5	11	1.3	16	62	171	33	515	612

Brownfield soil geochemical assessment and biochar remediation potential

The ten reconnaissance samples collected from Mims Park were found to have elevated levels of many metals, but three samples. Subsequently, these areas were more densely sampled, and ten more samples were collected and analyzed (Table 2).

Yellow pine biochar had mixed results in sorbing metals from the Mims Park contaminated soils (Table 3). Tukey's range test results indicate that treatment with yellow pine biochar was shown to significantly reduce concentrations of filtrate Cd (Δ -0.61, $p = 0.033$), Cu (Δ -33.6, $p = 0.007$), Pb (Δ -0.62, $p = 0.033$), Zn (Δ -71.6, $p = 0.030$). However, the yellow pine biochar significantly *increased* Cr concentrations in the filtrate ((Δ +9.35, $p < 0.001$).

Conclusions:

Proctor Creek has a long history of exhibiting extreme flashiness and flooding, pathogen contamination, and presence of metals in stream water and sediments. This project seeks to mechanistically link watershed land cover and surface geochemistry to patterns of water quality and quantity observed in the stream. There are a number of targeted efforts to restore Proctor Creek and improve community conditions, but these cannot be successful without understanding the underlying causes and sources of flooding and contamination. While this project is still in progress, and all results presented are prelimary, it is clear that the trajectory is in place for of project to meet the research objectives with very interesting results.

- Multi-scale soil hydraulic results show that land cover, as potentially determined by aerial imagery at a finer scale than NLCD data, is significantly linked to soil hydraulic conductivities and infiltration-excess overland flow. Metal-contaminated soils have been identified within the watershed, and biochar methods have been demonstrated as a potential remediation strategy for preventing leaching of existing contamination to groundwater and streamflow.
- Community groups and local stakeholders are willing to accommodate scientific research on their private lands and participate in citizen science efforts.
- Further efforts, for which all funds have been encumbered from this funding, will provide a detailed network of flow data, as well as modeling analyses for targeted siting of low-impact development (LID)/green infrastructure efforts to optimize improvements in water quantity and quality in the Proctor Creek watershed.

Table 3 - Filtrate metals concentrations (ppb) among samples with (Y) and without (N) biochar treatment. Red = higher metal concentration in the treated sample, green = lower metal concentration in the treated sample, and yellow = no change.

Sample	Cr	Co	Ni	Cu	Zn	As	Cd	Pb	pH
9.5Y	22.67	0	6.458	6.249	32.41	2.047	0.112	0	7.1
9.5N	7.286	0	6.287	25.94	52.53	20.68	0.342	15.31	6.6
9.4Y	9.206	0	4.122	2.244	0	5.321	0.158	0	7.2
9.4N	9.185	0	7.746	5.26	54.21	3.895	0.632	0	6.6
9.3Y	24.78	0	7.155	6.14	0	1.443	0.231	0	6.9
9.3N	13.99	0	6.835	64.03	156.2	13.02	0.664	28.6	6.6
9.2Y	23.02	0	7.211	3.678	21.81	8.866	0.421	2.586	7
9.2N	13.04	2.466	10.79	88.91	207.5	10.43	1.709	77.77	6.5
9.1Y	19.82	0	9.461	50.32	20.49	6.293	0.679	0	7.3
9.1N	14.14	0	4.482	1.929	45.17	9.821	0.278	0	6.8
9.0Y	14.76	0	0	0.609	14.66	0.671	0.02	0	6.9
9.0N	12.58	0	8.253	44.95	57.67	5.369	0.465	0	6.3
8.0Y	19.53	0	6.824	11.65	46.78	12.99	1.115	0	6.9
8.0N	17.52	16.54	9.297	7.748	347.9	1.1	2.056	8.199	6.4
6.5Y	17.7	1.092	12.82	2.446	56.14	1.264	0.166	0	7.1
6.5N	2.72	0	5.404	58.53	19.67	8.372	1.036	3.406	5.9
6.4Y	22.41	1.387	7.055	30.67	101.3	3.814	0.76	12.91	6.7
6.4N	9.5	0	4.934	162.8	176.1	3.44	0.803	183	6.3
6.3Y	22.49	0	3.785	23.3	45.51	0.092	0.444	6.34	6.8
6.3N	11.43	1.173	8.3	86.19	233.8	11.01	1.665	54.28	6.2
6.2Y	23.15	0	7.025	7.169	89.17	6.285	0.382	0	6.9
6.2N	1.824	0	4.43	3.187	63.34	34.62	2.814	6.166	5.8
6.1Y	17.11	0	7.952	10.75	28.09	3.747	0.29	0	7.1
6.1N	3.939	0	13.12	46.5	51.55	6.843	0.541	3.954	6.1
6.0Y	11.6	0	7.24	7.466	46.79	34.96	0.758	0	7.2
6.0N	3.154	0	7.143	4.681	24.81	8.846	0.186	1.073	6.5
4.0Y	22.88	0	2.774	1.727	14.89	0.066	0.13	0	6.9
4.0N	6.818	6.872	8.499	13.16	91.45	38.93	0.284	56.75	5.6
10.5Y	22.25	0	6.932	12.37	0	13.3	0.251	1.099	7.1
10.5N	9.389	0	13.48	168.1	127.3	29.44	2.807	12.46	6.6
10.4Y	23.1	0	3.149	1.276	0	6.867	0.131	1.462	7.1
10.4N	10.79	0	4.797	10.53	35.58	5.082	0.135	5.049	6.5
10.3Y	3.507	0	3.469	11.54	0	13.93	0.134	3.388	7.1
10.3N	5.433	0	7.787	11.31	162.4	26.17	2.061	9.219	6.5
10.2Y	20.37	2.088	10.48	30	61.63	11.19	0.516	0	7
10.2N	16.57	0	8.086	10.95	10.68	13.83	0.271	4.327	6.5
10.1Y	19.35	0	0	0.391	0	0.001	0.04	0	7.3
10.1N	10.3	1.074	11.69	44.61	13.72	9.725	0.249	0	7
10.0Y	19.67	0	3.686	1.751	15.09	20.55	0.451	0	7.2
10.0N	12.71	0	9.115	34.91	94.66	2.652	0.497	3.302	6.5

References:

Andréassian, V, Perrin, C, Berthet, L, LeMoine, N, Lerat, J, Loumagne, C, Oudin, L, Mathevet, T, Ramos, M-H, and Valéry, A. 2009. Crash tests for a standardized evaluation of hydrologic models. Hydrologic and Earth System Science 13: 1757-1764.

Bhaskar, AS, Hogan, DM, and Archfield, SA. 2016. Urban base flow with low impact development. Hydrological Processes, published online, DOI: 10.1002/hyp10808.

Booth, DB and Jackson, CR. 1997. Urbanization of aquatic systems: Degradation thresholds, stormwater detection, and the limits of mitigation. Journal of the American Water Resources Assocation 33(5): 1077-1090.

Bradham, K, Laird, B, Rasmussen, P, Schoof, SS, Siciliano, S, and Hughes, M. 2014. Assessing the bioavailability and risk from metal-contaminated soils and dusts. International Journal of Human and Ecological Risk Assessment 20(1): 272-286.

City of Atlanta, 2014. Proctor Creek Watershed. <http://www.atlantawatershed.org/inside-dwm/offices/watershed-protection/atlantas-watersheds/the-proctor-creek-watershed/>

Deocampo, DM, Reed, JR, and Kaleniuk, AP. 2012. Road dust lead (Pb) in two neighborhoods of urban Atlanta (GA, USA). International Journal of Environmental Research and Public Health 9: 2020-2030.

Elrick, DE and Reynolds, WD. 1992. Methods for analyzing constant-head well permeameter data. Soil Science Society of America Journal 56: 320-323.

Fletcher, TD, Vietz, G, and Walsh, CJ. 2014. Protection of stream ecosystems from stormwater runoff: The multiple benefits of an ecohydrological approach. Progress in Physical Geography 38(5):543-555.

Georgia Environmental Protection Division (GA EPD), 2005. Rules and Regulations for Water Quality Control. <http://rules.sos.state.ga.us/docs/391/3/6/03.pdf>

Hopkins, KG, Bain, DJ, and Copeland, EM. 2014. Reconstruction of a century of landscape modification and hydrologic change in a small urban watershed in Pittsburgh, PA. Landscape Ecology 29: 413-424.

Horowitz, AJ, Elrick, KA, Smith, JJ. 2008. Monitoring urban impacts on suspended sediment, trace element, and nutrient fluxes within the City of Atlanta, Georgia, USA: program design, methodological considerations, and initial results. Hydrological Processes 22: 1473-1496.

Kaushal, SS, McDowell, WH, and Wollheim, WM. 2014. Tracking evolution of urban biogeochemical cycles: Past, present and future. Biogeochemistry 121: 1-21.

Kieber, RJ, Skrabal, SA, Smith, C, and Wiley, JD. 2004. Redox speciation of copper in rainwater: Temporal variability and atmospheric deposition. Environmental Science and Technology 38(13): 3587-3594.

Kousky, C, Olmstead, SM, Walls, MA, and Macauley, M. 2013. Strategically placing green infrastructure: cost-effective land conservation in the floodplain. Environmental Science and Technology 47: 3563-3570.

McConnell, JB. 1980. Impact of urban storm runoff on stream quality near Atlanta, Georgia. US Environmental Protection Agency EPA-600/2-80-094, 52 p.

McKane, RB. 2012. USEPA Sustainable and Healthy Communities Research: A Pacific Northwest Demonstration Study. US Environmental Protection Agency, EPA/600/F-12/005.

Mosley, MP, and McKerchar, AI. 1993. Streamflow, in Handbook of Hydrology, edited by DR Maidment, McGraw-Hill, p. 8.1-8.39.

Park Pride, 2010. Proctor Creek North Avenue Watershed Basin: A Green Infrastructure Vision. <http://www.parkpride.org/get-involved/community-programs/park-visioning/content/more-info/2010_pna_overview.pdf>

Paul, MJ and Meyer, JL. 2001. Streams in the Urban Landscape. Annual Review of Ecology and Systematics 32: 333-365.

Pelletier, P. 1989. Uncertainties in streamflow measurement under winter ice conditions a case study: The Red River at Emerson, Manitoba, Canada. Water Resources Research 25(8): 1857-1867.

Peters, NE. 2009. Effects of urbanization on stream water quality in the city of Atlanta, Georgia, USA. Hydrological Processes 23: 2860-2878

Poff, NL, Richter, BD, Arthington, AH, Bunn, SE, Naiman, RJ, Kendy, E, Acreman, M, Apse, C, Bledsoe, BP, Freeman, MC, Henriksen, J, Jacobson, RB, Kennen, JG, Merrit, DM, O'Keeffe, JH, Olden JD, Rogers, K, Tharme, RE, and Warner, A. 2010. The ecological limits of hydrological alteration (ELOHA): A new framework for developing regional environmental flow standards. Freshwater Biology 55: 147-170.

Price, K, Jackson, CR, and Parker AJ. 2010. Variation in surficial soil hydraulic properties across land uses in the southern Blue Ridge Mountains, North Carolina, USA. Journal of Hydrology 383: 256-268.

Price, K. 2011. Influence of watershed land use and geomorphology on stream baseflows: A review. Progress in Physical Geography 35(4): 465-492.

Price, K, Jackson, CR, Parker, AJ, Reitan, T, Dowd, J, and Cyterski, MC. 2011. Effects of watershed land use and geomorphology on stream low flows during severe drought conditions in the southern Blue Ridge Mountains, Georgia and North Carolina, United States. Water Resources Research 47: W02516.

Price, K, Purucker, ST, Kraemer, SR, and Babendreier JE. 2012. Tradeoffs among watershed model calibration targets for parameter estimation. Water Resources Research 48(10): W10542.

Reitan, T and Petersen-Øverleir, A. 2008. Bayesian power-law regression with a location parameter, with applications for construction of discharge rating curves. Stochastic Environmental Risk Assessment 22: 351-365.

Rienzner,

Suh, HH, Zanobetti, A, Schwartz, J, and Coull, BA. 2011. Chemical properties of air pollutants and cause-specific hospital admissions among the elderly in Atlanta, Georgia. Environmental Health Perspectives 119(10): 1421-1428.

Theron, E, LeRoux PA, Hensley, M. 2010. Evaluation of the Aardvark constant head soil permeameter to predict saturated hydraulic conductivity. Transactions on Ecology and the Environment 134: 153-162.

Uchimiya, M, Wartelle, LH, Klasson, KT, Fortier, CA, and Lima, IM. 2011. Influence of pyrolysis temperature on biochar property and function as a heavy metal sorbent in soil. Journal of Agricultural and Food Chemistry 59(6): 2501-2510.

USACE, 2010. HEC-RAS River Analysis System: hydraulic reference manual, version 4.1. US Army Corps of Engineers CPD-69. 3, 417 p.

USEPA, 2011. Air and Water Quality Impacts of Brownfields Redevelopment: A Study of Five Communities. US Environmental Protection Agency, EPA 560-F-10-232, 100 p.

USEPA, 2014a. Aquatic Life Criteria. http://water.epa.gov/scitech/swguidance/standards/criteria-/aqlife/index.cfm

USEPA, 2014b. Velma Eco-hydrological Model. < www.epa.gov/wed/pages/projects/VELMA_2014.pdf>

West, LT, Abreu, MA, and Bishop, JP. Saturated hydraulic conductivity of soils in the Southern Piedmont of Georgia, USA: Field evaluation and relation to horizon and landscape properties. Catena 73(2): 174-179.

Information Transfer Program Introduction

The Georgia Water Resources Institute provided funds ($18,000) for the 2015 Biennial Georgia Water Resources Conference held at the University of Georgia in April 2015. The conference fosters interactions and exchanges of ideas between a wide range of water researchers, professionals, private residents, students, and policy makers from Georgia and the southeastern U.S.

Conference proceedings from the 2015 conference, as well as previous conferences dating back to 1989, are made available to the general public for free at the Georgia Water Resources Institute website: http://gwri.gatech.edu/previousconferences

The 2015 Biennial Georgia Water Resources Conference

Basic Information

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Project Number:	2015GA357B
Start Date:	3/1/2015
End Date:	12/31/2015
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Focus Category:	Water Use, Water Supply, Water Quality
Descriptors:	None
Principal Investigators:	Robin John McDowell, Todd Rasmussen

Publications

There are no publications.

FINAL REPORT
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The 2015 Biennial Georgia Water Resources Conference

Todd C Rasmussen[1], Robin J McDowell,[2] and Carson A Pruitt[3]

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. Recent changes at the University of Georgia have diverted full-time faculty and staff away from organizing the GWRC in an effective manner. However, changes in management and the involvement of outside groups and individuals resulted in a successful 2015 Georgia Water Resources Conference.

Introduction

Since 1989, the University of Georgia has hosted the biennial Georgia Water Resources Conference (GWRC). In its heyday, the GWRC attracted researchers and policy makers from around the southeastern United States. Conference speakers included the Governor of Georgia, the Director of the U.S. Geological Survey, regional commanders from the U.S. Army Corps of Engineers, and a host of similarly high-profile individuals. Representatives of federal and state agencies from Georgia and adjacent states participated in panel discussions, technical sessions, and plenary sessions for as many as 400 conference attendees.

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The GWRC has always been an important forum for graduate students from Georgia and the southeastern United States to present their thesis and dissertation research. Additionally, many of the technical and plenary sessions have presented the latest hydrologic and ecological research into Georgia's water resource issues, and many others have focused on the complex legal and policy issues associated with water resource management in Georgia and the southeast. Conference attendees, especially students, are thus very well exposed to the latest thinking, research, and policy surrounding Georgia's water resources. This has always been one of the greatest assets of the GWRC. Also, many of the minor conference functions such as running projectors, performing head counts, answering questions and staffing information booths are traditionally performed by students whose conference registration fees are waived in return for their service.

Conference attendance grew rapidly until 2009, when the faculty member assigned to organize the conference retired. Since then, attendance has declined sharply due to the economy and tight travel budgets for potential conference presenters and attendees, but also because the Warnell School of Forestry and Natural Resources has only been able to provide *ad hoc* assistance in planning and execution of the conference. Full-time faculty and staff are typically too committed to other work to devote sufficient time needed to successfully perform the many tasks involved in conference planning. As a result of these factors, attendance at the 2013 GWRC dwindled to approximately 150 individuals, and the invited speakers consisted almost entirely of faculty from the University of Georgia and the Georgia Institute of Technology, a co-sponsor of the GWRC. A principal goal of this 104(b) grant was to support a dedicated faculty member at the University of Georgia to coordinate all aspects of the 2015 GWRC, and to halt or reverse the conference's decline.

In support of this goal, the Warnell School of Forestry and Natural Resources hired Dr. Robin John McDowell, P.G., to function as GWRC coordinator. Dr. McDowell is a former full-time faculty member of the University of Georgia; is a registered Professional Geologist in the State of Georgia; has 21 years of experience in water management, policy, regulation, and research; and was already a part-time Assistant Professor in the Odum School of Ecology at the University of Georgia. Additionally, he has broad experience

working with state government agencies, the Georgia General Assembly, several institutions within the University System of Georgia, and the private sector; and has long-established professional relationships with government officials, water science researchers, and stakeholders across Georgia.

Objectives

The primary objectives of this project were to prepare for the 2015 GWRC and repair the conference's reputation in Georgia. This included the following activities, which are principally administrative in nature:

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) Distribution of conference flyers, posters, and other notifications to maintain a high level of knowledge about, and interest in, the 2015 GWRC.
6) Regular communication with the Technical Planning and Steering Committees and water experts assigned to review abstracts and manuscripts.
7) Coordination and editing of GWRC proceedings, including formatting and publishing of CD-ROMS or other appropriate formats.
8) Close collaboration with the UGA Center for Continuing Education, a conference facility on the campus of the University of Georgia where the 2015 GWRC will be held. This collaboration will include determining conference registration fees, as-

signing rooms and halls to technical sessions, arranging for conference registration, lunches, and refreshments, and other activities related to conference planning and execution.

9) Assemblage of GWRC abstracts and manuscripts into digital conference proceedings.

Results

Dr. McDowell created and organized a Conference Technical Planning Committee consisting primarily of faculty from the University System of Georgia. The Technical Planning Committee meet frequently at the UGA River Basin Center, a research center housed in the Odum School of Ecology at the University of Georgia. This Technical Planning Committee consisted of the following individuals:

- Dr. Jason Christian, UGA College of Engineering
- Prof. Laurie Fowler, UGA Odum School of Ecology
- Dr. Seth Wenger, UGA River Basin Center
- Dr. Mark Risse, UGA Marine Extension
- Ms. Susan Varlamoff, UGA College of Agriculture and Environmental Sciences
- Dr. John Bergstrom, UGA College of Agriculture and Environmental Sciences
- Dr. David Radcliffe, UGA College of Agriculture and Environmental Sciences
- Dr. Todd Rasmussen, UGA Warnell School of Forestry and Natural Resources
- Dr. Aris Georgikakos, Georgia Institute of Technology
- Prof. Mark Masters, Albany State University
- Dr. Chuck Hopkinson, UGA Sea Grant Program
- Dr. Rob McDowell, UGA Warnell School of Forestry and Natural Resources

Dr. McDowell created and organized a Conference Steering Committee consisting of representatives of state agencies, non-government organizations, and significant private sector water users. The Steering Committee met twice on the campus of the Georgia Institute of Technology. These meetings were hosted by Dr. Aris

Georgikakos, Director of the Georgia Water Resources Institute at The Georgia Institute of Technology. This Steering Committee consisted of the following individuals:

- Mr. Ron Shipman, Georgia Power
- Ms. Pam Burnett, Georgia Association of Water Professionals
- Mr. Bennett Weinstein, Atlanta Regional Commission
- Dr. Rob Williams, Georgia State University
- Dr. Mark Risse, UGA Marine Extension
- Mr. John Ratke, Coca Cola Enterprises, North America
- Ms. Catherine Fleming, Georgia Municipal Association
- Mr. Brian Hughes, US Geological Survey
- Mr. Todd Edwards, Association County Commissioners of Georgia
- Dr. Rob McDowell, UGA Warnell School of Forestry and Natural Resources
- Dr. Aris Georgikakos, Georgia Institute of Technology

Both Committees began meeting in early Fall 2014. Members of both Committees provided invaluable counsel on organizing the GWRC, and members of the Steering Committee helped advertise the conference through their professional networks. The Technical Planning Committee was instrumental in developing conference tracks. Both Committees provided excellent suggestions for, and in some cases provided, outside keynote speakers.

A major problem with previous conferences was a lack of advertising and outreach in the year leading up to the conference. Indeed, in 2013 some faculty at the University of Georgia believed that the conference had been cancelled due to a near total lack of advertising. To rectify this, Dr. McDowell and his assistant Carson Pruitt developed revised contact lists of previous conference attendees and their professional affiliations will be used to begin building an email contact list. That list was greatly augmented with new contact information for additional water scientists and experts from across Georgia and neighboring states. Faculty from academic departments such as biology, chemistry,

ecology, geology, political science, public policy, and environmental science at USG institutions were notified and invited to attend and/or submit abstracts for the conference. Significantly, Dr. McDowell sent out bi-monthly emails to these individuals reminding them of the upcoming 2015 GWRC. This undoubtedly maintained the visibility of the Conference, and re-assured recipients that it was still going to be held.

Assisted by Ms. Jenny Yearwood form the Warnell School of Forestry and Natural Resources, Dr. McDowell and Mr. Pruitt distributed of conference flyers, posters, and other notifications to maintain a high level of knowledge about, and interest in, the 2015 GWRC. Beginning in Fall 2014, these flyers were mailed to academic departments around Georgia and the Southeast. They were mailed again in early Spring 2015.

Dr. McDowell and Mr. Pruitt, collaborated closely with the UGA Center for Continuing Education, a conference facility on the campus of the University of Georgia where the GWRC has been be held for many years. This collaboration included 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.

In February and March 2015, Dr. McDowell and his and administrative staff from the Warnell School of Forestry assembled the abstracts and generate conference proceedings. Mr. Pruitt was extremely helpful and industrious in this phase of the Conference. Unlike previous GWRCs, manuscripts accompanying abstracts were optional for the 2015 GWRC.

The 2015 Georgia Water Resources Conference

1. **Attendance:** More than 257 individuals attended the 2015 GWRC. Indeed, it was necessary to close registration because the reserved rooms were filled to capacity. To overcome this, an on-site registration was allowed that did not include lunch.

2. **Speakers and panelists:** The 2015 GWRC featured 30 technical and panel sessions, as well as 36 poster presentations. Conference Proceedings may be found at http://www.gwri.gatech.edu/node/4070.
3. **Budget:** Total expenses for the 2015 GWRC were approximately $36,222.82. Income was approximately $35, 770. A $3000 cash award from the J.W. Jones Ecological Research Center was deposited directly into an account at the Warnell School of Forestry and Natural Resources, resulting in a net surplus of $2527.18 for the 2015 GWRC. This surplus was applied to the salary and graduate student tuition of Mr. Pruitt. In contrast, the 2013 GWRC had a deficit of approximately $2200.

Summary

The 2015 GWRC was an unqualified success in terms of raising the visibility of the conference, attracting a wide range of participants, and reversing the decline of previous conferences. The most important factor in its success was the ability of UGA to hire a dedicated employee (Dr. McDowell) to coordinate all aspects of the Conference, and to be assisted by a dedicated and extremely able graduate assistant (Mr. Pruitt). In large part, the hiring of Dr. McDowell was made possible by funds obtained from this 104(b) grant.

Attachments

2015 Conference Budget Summary

"The Water Conference"

Nicholson retired, and was dead within a year.
Pritchard's words and simple talks are always crystal clear.
Colonel Hart could not attend because of sequestration.
The farmers are offended and resent the implication.

Dr. Chang got tenure, and is marrying the dean.
Ravi's in the field this year, and hardly ever seen.
Undergrads were always young, but now seem pre-pubescent.
The Congressman is schmoozing, and he's never really present.

No one's quite exactly sure what killed the oyster catch.
Low-flow toilets are the law, but hardly make a scratch.
Another state is suing and their lawyers are befuddled.
Dryer, wetter, warmer, what: the argument is muddled.

Paul got fat, Rebecca drowned, Enrique got divorced.
No one pays for all three days, but nothing is enforced.
Fresh young faces fill the seats, and new ideas are churning.
In two years' time, we'll all be back to keep the fires burning.

- Rob McDowell

2015 GEORGIA WATER RESOURCES CONFERENCE

April 28-29, 2015

- Conference Website -

http://www.gawrc.org/

Sponsors
- AWRA, UGA Student Chapter
- Joseph W. Jones Ecological Research Center
- Warnell School of Forestry and Natural Resources, UGA
- US Geological Survey
- GA Water Resources Institute, Georgia Instit. of Technology
- River Basin Center, Athens, GA

Steering Committee
- Deatre Denion, Georgia Dept. of Community Affairs
- Todd Edwards, Assoc. County Commissioners of Georgia
- Catherine Fleming, Georgia Municipal Association
- Carrie Fowler, GA Soil and Water Conservation Commission
- Steve Golladay, Jones Ecological Research Center
- Alice Keyes, One Hundred Miles
- Linda MacGregor, Georgia Environmental Finance Authority
- Russ Pennington, Georgia EPD
- Jon Radtke, Coca Cola North America
- Ron Shipman, Georgia Power
- Katherine Zitsch, Atlanta Regional Commission

Technical Planning Committee
- Clark Alexander, Skidaway Institute of Oceanography
- John Bergstrom, UGA Ag. and Applied Economics
- Jason Christian, UGA College of Engineering
- Laurie Fowler, UGA Odum School of Ecology
- Aris Georgakakos, Georgia Institute of Technology
- Chuck Hopkinson, Georgia Sea Grant Program
- Brian Hughes, US Geological Survey
- Mark Masters, Flint River Planning and Policy Center
- David Radcliffe, UGA Crop and Soil Sciences
- Todd Rasmussen, Warnell School of Forestry
- Mark Risse, Georgia Marine Extension Service
- Susan Varlamoff, UGA College of Ag. and Environmental Sci.
- Seth Wenger, UGA River Basin Center

Link to Full Proceedings
http://www.gawrc.org/2015proceedings.html

Conference Staff
- Rob McDowell, Warnell School of Forestry Resources, UGA
- Robert Bahn, Warnell School of Forestry Resources, UGA
- Jenny Yearwood, Warnell School of Forestry Resources, UGA
- Carson Pruitt, UGA Graduate Student

Conference Student Assistants
- Lauren Cameron
- Carson Pruitt
- Ridwan Bhuiyan
- Laura Marie Early
- Andrew Bailey
- Robert Sowah
- Tiffany Eberhard
- Kristin Kraseski
- Matt Cahalan
- Chandler Lipham
- Laura Keys
- Joel Martin
- Shannon Bonney
- Katie Brownson
- Randi Butler
- Matt Carroll
- Alan Coats
- James Deemy
- Stephanie Fulton
- Khalil Lezzaik
- Todd Miller
- Richard Milligan
- Rosemary Pearson-Clarke
- Rachel Rotz
- Sam Santoso
- Natalia Shim
- John Spencer
- Justin Vining
- Seth Younger

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 167 submissions for oral presentations and 32 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.

Hatcher, K.J. (ed.), Proceedings of the 1999 Georgia Water Resources Conference, ISBN: 0-935835-06-7, LOC# 99-61857, 604 pages, March 30-31, 1999.

Hatcher, K.J. (ed.), Proceedings of the 2001 Georgia Water Resources Conference, ISBN: 0-935835-07-5, LOC# 2001087837, 793 pages, March 26-27, 2001.

Hatcher, K.J. (ed.), Proceedings of the 2003 Georgia Water Resources Conference, ISBN: 0-935835-08-3, LOC# 2003104494, 900 pages, April 23-24, 2003.

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 Proceedings http://www.gwri.gatech.edu/conferences

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reduction goal set in ATL's Sustainability Management Plan. The plan includes a comprehensive water audit, a distribution system evaluation, and an overview of stormwater management plan. The water audit included a detailed survey and personnel interview that documented end-user water use and plumbing fixtures at each of the terminal and support facilities with the airport property boundary, including an audit of ATL's new rental car center with recycled cash wash system. A spreadsheet-based on model was developed to estimate water savings based on conservation strategies. In addition to the audit, a distribution system model was developed to evaluate the adequacy of the water distribution system to provide future supplies. The stormwater management overview focused on evaluating the potential to implement green infrastructure and to maximize the potential to recharge the Flint River basin. This presentation will discuss the audit and planning process, results, recommendations and various projects that are being implemented at ATL following the completion of the plan in 2013.

34. **Usher, R.**, J. Wood, A. Rosemond, and S. Wenger
Odum School of Ecology, University of Georgia, Athens, GA 30602

RESPONSE OF STREAM BIOFILMS ACROSS AN URBANIZATION GRADIENT

This study examined 30 sites from 2010-14 investigating stream biofilms response to urbanization in Athens-Clarke County, GA. Urbanization initiates cascading environmental stressors impacting stream systems altering abiotic factors including hydrology and water chemistry. Biofilm, the active biological surface on stream bottoms comprised of algae, bacteria, fungi and organic matter, integrates the effects of multiple stressors. Thus, biofilm characteristics including its biomass and nutrient content can indicate the effects of watershed land use on stream condition. We determined watershed land cover and used physical/chemical data provided by Athens-Clarke County to determine relationships with biofilms. We found a positive correlation between impervious surface cover (%ISC) and total nitrogen (TN), dissolved inorganic N, and temperature of stream water. An isotope of N, ^{15}N is typically found in higher quantities in streams with wastewater inputs. Total phosphorus was positively correlated with $\delta^{15}N$, suggesting sewage or wastewater input but surprisingly, there was a negative relationship between biofilm $\delta^{15}N$ and %ISC. The $\delta^{15}N$ response to forest cover yielded expected values (3-4) in heavily forested areas (>60%), increased values (4 – 9) in moderately forested areas (30-60%), and decreased values (>2.5) in reduced forest area (>15%). These findings suggest that land uses can differentially affect inputs and cycling of N in biofilms, resulting in non-linear relationships between potential source indicators (e.g., $\delta^{15}N$) with single types of land cover change.

35. **Williams, M.**
Dept. of Geography, University of Georgia, Athens, GA 30602

THE SPATIO-TEMPORAL EVOLUTION OF IRRIGATED AREAS IN THE GEORGIA COASTAL PLAIN

Agricultural landscapes are the most prevalent form of land cover globally and are likely to increase in the future due to the upward trend in population growth and demand for biofuels. By some estimates, agricultural landscapes comprise up to 40% of the global land cover. There has also been a growing trend towards irrigating agricultural land cover, especially in areas such as the Southeastern United States which has recently experienced periods of drought. Research has shown that irrigation alters temperature and precipitation patterns at various spatial scales and is a consumptive form of water use, thus it would be beneficial how this form of land-use change evolves over time. This study investigates the evolution of areas capable of irrigation in the Georgia Coastal Plains region by quantifying temporal and spatial changes in total acres irrigated primarily by using historical and current high resolution aerial photographs and satellite imagery. Irrigated areas are delineated through remote sensing data to map center pivot irrigation (CPI) systems. These systems irrigate circular, or arc like fields using a series of sprinklers mounted on a pipe supported by a row of mobile towers and rotate to distribute water supplied by a central well. Several Landsat band combinations are analyzed to produce the best contrast of existing CPI systems with the surrounding landscape and are readily identified using manual digitization techniques. Results will be presented that demonstrate a significant increase in the intensity of irrigation in terms of density and distribution within the Georgia Coastal Plain region during the 35-year period of analysis.

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Schedule at a Glance:

Tuesday, April 28

Registration: 7:30 – 9:30 am

Concurrent Sessions 1: 8:30 – 10:00 am

***Plenary Session*:** 10:30 – 12:00 pm, Masters Hall
"Water and Climate: Findings of the US National Climate Assessment"
Speaker: Kathy Jacobs, *Director, Center for Climate Adaptation Science and Solutions, University of Arizona*
Moderator: Dr. Laurie Fowler

***Luncheon Speaker*:** 12:00 – 1:15 pm
Adam Sowatzka, *King & Spalding*
"The Role of Environmental Law in the Protection of Water Resources - Current Issues and Trends"

Concurrent Sessions 2: 1:30 – 3:00 pm

Poster Session: 3:30 – 5:00 pm

***Evening Social Event*:** 5:30 – 7:30 pm
Reception at Odum School of Ecology — see map on page vii
Sponsored by: Nutter and Associates Environmental Consultants, the River Basin Center, & the Odum School of Ecology

Wednesday, April 29

Registration: 7:30 – 9:30 am

Concurrent Sessions 3 and 4: 8:30 – 12:00 pm

***Luncheon Speaker*:** 12:00 – 1:15 pm
Bruce Karas, Coca-Cola North America Group: *"Coca-Cola's Water Stewardship Journey"*

Concurrent Sessions 5: 1:30 – 3:00 pm

DAY 1, Tuesday April 28, 2015

Time	Track 1 Climate Change and Coastal Issues Masters Hall	Track 2 Urban Water Quality and NPS Room K (2nd Floor)	Track 3 Hydrologic Monitoring, Data, and Tools Press Box (5th Floor)	Track 4 Resilient Water Management Room L (2nd Floor)	Track 5 Floodplain and Flood Risk Assessment Room F/G (2nd Floor)	Track 6 Stream Habitat and Aquatic Chemistry Room R (2nd Floor)
7:30 – 9:30	**Conference Registration**					
Morning Session 8:30 – 10:00	**1.1 Climate**	**2.1 Green Infrastructure**	**3.1 Modeling & Tools I**	**4.1 Upper Flint drought resiliency**	**5.1**	**6.1 Habitat and in-stream conditions I**
	Panel Discussion: Stephanie Benfield, Laurie Fowler, Katharine Jacobs	Eric J. Byrne	D. Kim	**Panel Discussion:** Ben Emanuel, Lee Pope, Mike Thomas, Gordon Rogers	**Floodplain Mapping Workshop** **GaEPD Floodplain Mgmt. Program**	Nathalie Smith
		Duncan Hughes	Patrick McMahon			Paul McCormick
		Donald P. Rainey	David Manning			Matthew Waters
		Julie Kaplan	Kristin A. Kraseski			Courtney Holt
		Glen Behrend	Feng Jiang			Beatriz Villegas
10:00 – 10:30	Morning Break					
Plenary 10:30 – 12:00	**Plenary Session in Masters Hall: Water and Climate: Findings of the US National Climate Assessment Speaker: Kathy Jacobs, *Director, Center for Climate Adaptation Science and Solutions, University of Arizona* Moderated by Dr. Laurie Fowler**					
Lunch 12:00 – 1:15	**Lunch Keynote Speaker: Adam Sowatzka, *King & Spalding*** *"The Role of Environmental Law in the Protection of Water Resources - Current Issues and Trends"*					
Afternoon Session 1:30 – 3:00	**1.2 Climate change and water resources**	**2.2 Green Infrastructure**	**3.2 Modeling & Tools II**	**4.2 Water reclamation and re-use**	**5.2 Floodplain Risk Assessment**	**6.2 Habitat and in-stream conditions II**
	S. Sarmistha	**Panel Discussion:** Alfie Vick, Jon Calabria, Cory Rayburn, Polly Satler, Ben Emanuel	Anthony Gotvald	**Panel Discussion:** Jason Gregory, Brent Zern, Ben Liverman, Jonathan Lanciani	Toby D. Feaster	Jeffrey W. Riley
	Aris Georgakakos		Nancy L. Barber		Derek R. Hutton	Anna M. McKee
	J. Sheldon		Jacob LaFontaine		Young Kim	Laura L. Aycock
	B. T. Aulenbach		David C. Leeth		John Dees	Wei Zeng
	P. N. Knox		Kristen McSwain		Jerald B. Robinson	John K. Joiner
3:00 – 3:30	Afternoon Break					
3:30 – 5:00	**Poster Session – Pecan Tree Galleria**					
5:30 – 7:00	**Reception at the Odum School of Ecology (See map on page vii)** Sponsored by: Nutter and Associates Environmental Consultants, the River Basin Center, & the Odum School of Ecology					

ture water management planning must consider the contributions of reservoirs to water quality in order to maintain the integrity of the overall drainage basin.

30. **Sizemore, Daniel W.**

Graduate Student, College of Environment and Design, University of Georgia, Athens, GA 30602

USING PASSIVE INTERPRETIVE DESIGN STRATEGIES TO REMEDIATE BROWNFIELDS IN THE SOUTHEASTERN PIEDMONT

Many people are undertaking brownfield restoration and other bio-remediation projects, but the general public remains uneducated about these processes. The study was conducted to determine how landscape architects can use design to inform and educate the public about bio-remediation and ecosystem functions. First, a site was chosen. After determining which type of contaminants were on the site, proper remediation tactics were determined. These tactics were merged with passive interpretative design strategies and designed so that they actively repair the environment while also informing the public of their function. It is hypothesized the people will be more interested in learning about the site when the education process is more interactive. Through the use of these strategies, more people will be educated about the ecosystem and their surrounding environment. Future research includes conducting surveys given out at two different experimental sites, one using passive interpretation and one using active interpretation.

31. **Soliman, Mahmoud A.**

Mr., MSc. Student, Teaching and Research assistant at Faculty of Engineering, Cairo University

HYDRO-CLIMATE PROJECTIONS IN THE CORDEX MENA DOMAIN USING THE WEATHER RE-SEARCH FORECAST MODEL WITH FOCUS ON THE EASTERN NILE BASIN

Assessment of the future climate in the Eastern Nile Basin (ENB) is still lacking and the level of understanding of future climate behaviour is not yet clear to the different stakeholders in the ENB. This is mainly because of the complexity of the carrying representative climate studies, the wide range of uncertainties in the different General Circulation Models (GCM) results that cause the decision makers and stakeholders do not buy into the climate projections, the lack of established climate datasets in the basin and on top of that the scarcity of the qualified human resources with capacity to carry out climate studies. This study provides steps towards enhancing the understanding of the interactions between the climate and hydrology systems in the EN basin using WRFv3.5 as a numerical model to assess the impacts of climate change on the basin's water resources using ERA interim reanalysis data as boundary conditions. The output climatic fields may be used to force the calibrated Nile basin water balance model to assess the future impacts of the different emissions scenarios on the water resources in the basin. The objective is to improve the consideration of climate implications on the Nile Basin through building a dynamic climate downscaling model for the Nile using the state of the art regional climate models. The outcomes of the climate modeling will be used for the assessment of the impacts on the basin's water balance under climate change scenarios.

32. **Sowah, Robert**

Department of Crop and Soil Sciences, University of Georgia, Athens, GA 30602

TRACKING THE INFLUENCE OF SEPTIC SYSTEMS ON MICROBIAL WATER QUALITY IN SUBURBAN WATERSHEDS OF GEORGIA

Fecal pollution of surface waters is a critical public health concern, especially in areas where surface water serves as the primary source of drinking water. Non-point sources of fecal pollution such as septic systems, agricultural runoff and wildlife have come under scrutiny due to the widespread nature of pollution incidents and overall stricter controls over point sources. There is a growing urgency to identify significant sources of fecal inputs to streams to inform watershed management efforts. The goal of this study was to determine the contribution of septic systems to fecal pollution loads in urbanizing watersheds. Water samples, collected from 24 well characterized watersheds with varying septic system density, were analyzed for fecal indicator bacteria to quantify pollution levels and identify seasonal trends. Pollutant sources were then tracked using Bacteroides sp. genetic markers to isolate and quantify the contributions of septic systems (humans), livestock and wildlife to fecal pollution. Results indicate statistically significant interaction between septic density and season for enterococci count ($p = 0.005$) and stream yield ($p = 0.04$). In general, the frequency of detection of human specific marker, which represents inputs from septic systems, was significantly greater in high density septic impacted watershed than low density watershed. Also, human marker abundance was statistically different between high density and low density watershed, indicating the influence of septic systems in high density watershed. This study will aid efforts to account for the influence of septic systems at the watershed level.

33. **Su, Tai Yi**

Senior Project Manager, AECOM, Charles F. Marshall, CEM, CEA, CBCP, CLEP Utilities Manager, Asset Management and Sustainability Division, 1600 Peachtree Street NE, Suite 500, Atlanta, GA 30309

SUSTAINABLE WATER MANAGEMENT AT THE HARTSFIELD JACKSON ATLANTA INTERNATIONAL AIRPORT

The 2013 Water Management Plan for Hartsfield Jackson Atlanta International (ATL) Airport is the first comprehensive water management plan for the ATL Airport. Directed by City of Atlanta Department of Aviation's Asset Management and Sustainability (AMS) Division, the information obtained for this plan was used to develop water conservation strategies for reaching the potable water

ture runoff, etc.) and pollution receptor targets (e.g. drinking wells) to isolate at-risk areas. Groundwater analysis will be used to estimate the water table position across the landscape, and to relate this position to groundwater and surface-water risk. Risk ratings will be collaboratively developed that account for current and possible future sources of groundwater hazards, and the potential exposures to the public and critical ecosystems.

26. **Reeves, Tyler G.**

Student, Georgia Southern University, 1332 Southern Drive, Statesboro, Georgia 30458

LEAF DECOMPOSITION ALONG A LONGITUDINAL GRADIENT OF THE LOWER OGEECHEE RIVER

Leaf litter decomposition and macroinvertebrate colonization of leaf litter were examined along a longitudinal gradient of the Ogeechee River in southeast GA. Leaf litter packs of sweetgum (*Liquidambar styraciflua*) and oak (*Quercus sp.*) were placed at 4 sites along the Ogeechee River and retrieved at two week intervals for ~56 days. Litter materials remaining in leaf packs were dried and weighted to estimate decay rates (-k). In addition, macroinvertebrates collected from leaf packs were sorted, identified to the lowest taxonomic level practical, and classified into functional feeding groups. The mean number of macroinvertebrates found in leaf packs was 171±43.20 SD for oak leaves and 132±70.88 SD.

27. **Rozier, Ralph S.**

Student, Georgia College and State University, 231 W. Hancock St., Milledgeville, GA 31061

ASSESSING THE WATER QUALITY AND SOURCES OF FECAL POLLUTION IN SOUTHWESTERN PUERTO RICO

For a USEPA sponsored project, 24 monitoring stations were characterized for sources of contamination in the Lajas Valley and the lowlands of Rio Loco in southwestern Puerto Rico. Lying in regions categorized as urban, suburban, and agricultural, these stations had a defined basin delineation, different covers, varying land uses, and alternate methods of management. Two rounds of samples were collected from each station, and they were analyzed for nutrients, heavy metals, optical brighteners, pH, conductivity, temperature, DO, and fecal contamination (using enterococci). In the urban areas, the enterococci were highest, and the nutrient levels were highest in agricultural regions. Eleven of the 24 sites were above EPA limits for enterococci. QPCR was used for microbial source tracking (MST) of human and cattle specific Bacteroides markers. Two of the sites were positive for human fecal bacteria, and eight were positive for cow fecal bacteria.

28. **Seka, Ayalkibet Mekonnen**

IMPACTS OF LAND USE/ LAND COVER CHANGE ON CATCHMENT HYDROLOGY OF KULFO WA-TERSHED: AN ASSESSMENT USING HYDROLOGIC MODEL, SWAT

Rates of deforestation, agriculturalization, urbanization, wet land drainage, and several other types of land use change have accelerated as a function of the growth of human populations Soil erosion and related land degradation are considered as serious threats to development endeavors in many parts of Ethiopia. Particularly in Southern Nation, Nationalities and People Regional State (SNNPRS), situated on high and step-faulted western sides of the Ethiopian rift system, the issues of land degradation is becoming of vital concern. Kulfo River Basin, which is in the Southern part of Ethiopia, has been seriously affected by extreme soil erosion and land degradation since steep slopes have been cultivated for many centuries. Since the last few years there are many watershed based soil and water conservation activities practices in this sub-basin of the Ethiopian Rift Valley. These practice range from simple infiltration trenches to engineering structures such as check dams and rainwater harvesting structures. Kulfo River represents the major tributary to Chamo Lake, which is the largest lake in Ethiopia next to Abaya Lake. This study aims to assess the impacts of land use/ land cover change on catchment hydrology of Kulfo watershed. Hydrological models will be used for analyzing hydrological characteristics of the basin based with and without intervention of soil and water conservation practices.

29. **Shivers, Stephen**

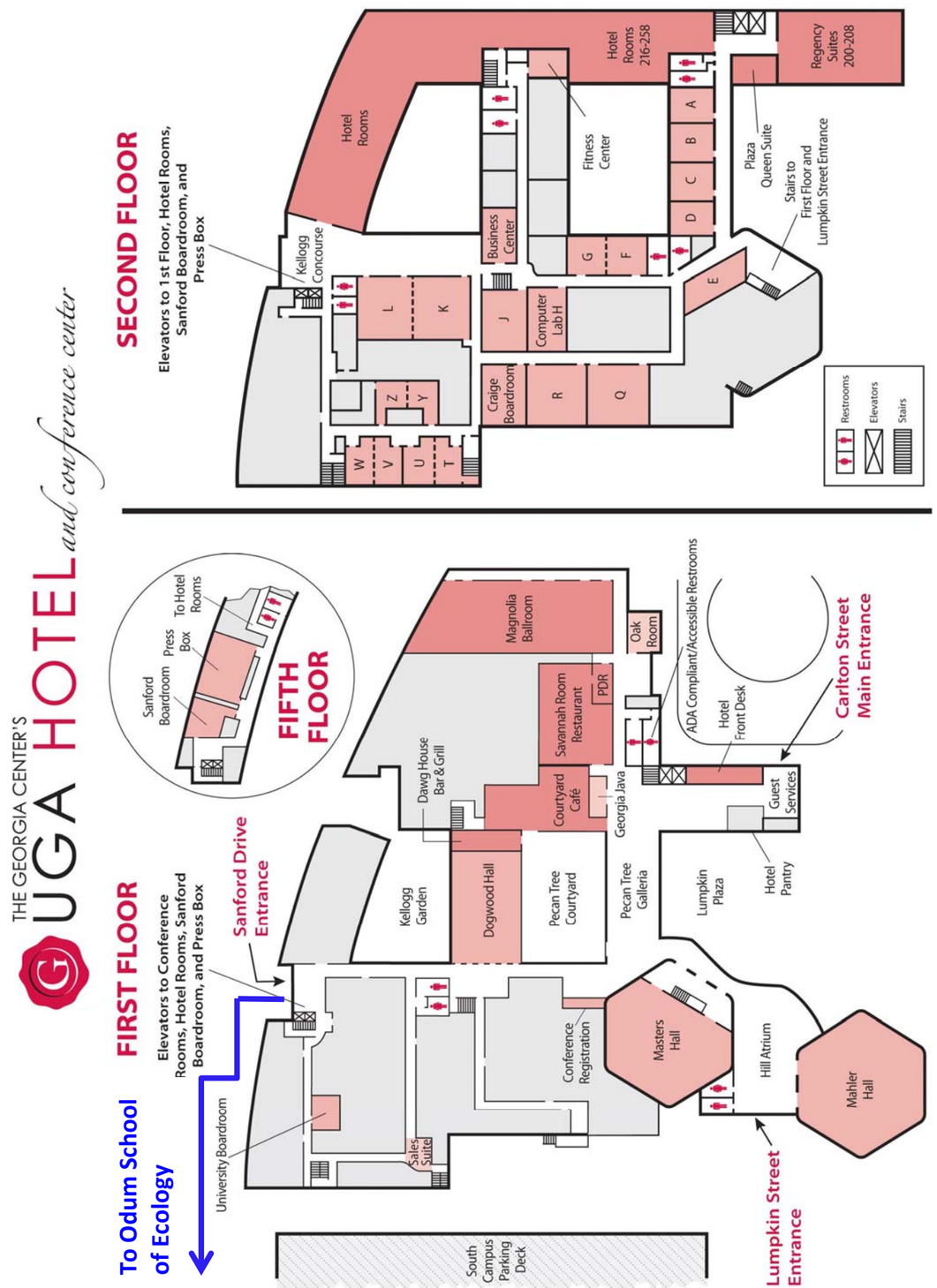
Graduate student, University of Georgia J. W. Jones Ecological Research Center, 3988 Jones Center Drive Newton, GA 39870

ANNUAL VARIATION IN SPATIAL COVERAGE OF AN INVASIVE MACROPHYTE WITHIN A SHALLOW, SUBTROPICAL RESERVOIR

Submerged aquatic vegetation (SAV) can affect overall productivity and biogeochemical cycling within aquatic ecosystems. Because SAV can cover large areas, changes in nutrient cycling can alter nutrient transformation and storage within reservoirs. Lake Seminole is a shallow reservoir formed by the Woodruff dam at the confluence of the Flint and Chattahoochee rivers in southwestern Georgia. The SAV community of the lake is dominated by an invasive macrophyte, *Hydrilla verticillata*, which was found in the early 1960s. In order to investigate the effects of SAV on a reservoir scale, SAV must be identified and quantified. During the peak growing seasons of 2012-2014, we used a visual survey by boat followed by post-processing in ArcMap to create vegetation maps and determine the spatial coverage of SAV on Lake Seminole. We found surprising variation in Hydrilla coverage during this three-year period. We are currently investigating the relationships between Hydrilla coverage and local hydrology as these years spanned both drought and flood conditions. It is important to understand these connections, as Lake Seminole is the last impoundment in the embattled ACF Basin. Downstream water quality within the Apalachicola River is dependent on nutrient transformations within the lake. Thus, fu-

DAY 2, Wednesday April 29, 2015

Time	Track 1 Climate Change and Coastal Issues Masters Hall	Track 2 Urban Water Quality and NPS Room R (2nd Floor)	Track 7 River Basin Management Room F/G (2nd Floor)	Track 4 Resilient Water Management Room Q (2nd Floor)	Track 8 Industry and Agriculture: Engines of Growth Press Box (5th Floor)	Track 6 Stream Habitat and Aquatic Chemistry Room D (2nd Floor)
7:30 – 9:30	**Conference Registration**					
Morning Session 1 8:30 – 10:00	**1.3 Shoreline Stabilization**	**2.3 Nutrient Management**	**7.1 Savannah River and Harbor**	**4.3 Understanding the state of our resources**	**8.1 Coordinating with Ag. on water stewardship**	**6.3 Habitat & Assessment I**
	Panel Discussion: Tom Bliss, Jan MacKinnon, Christi Lambert	Chad R. Wagner	Edwin Roehl, Jr.	Brian McCallum	**Panel Discussion:** Angela Bray, Chris Faulkner, Gary Hawkins	Damon L. Mullis
		Jeffrey D. Mullen	Susan C. Grams	John M. Shelton		Coral Thompson
		Rixiang Huang	Oscar P. Flite	M. Kistenmacher		Seirisse J. Baker
		D. Baughman	William Duncan	J. Bodwell		Harold L. Harbert
		B. Poon-Kwong	Jason D. O'Kane	C. Cameron		Larry Kleitches
10:00 – 10:30	Morning Break					
Morning Session 2 10:30 – 12:00	**1.4 Adapting to a changing coast I**	**2.4 North Georgia Water Planning**	**7.2 Savannah River Basin**	**4.4 Sustainability and Re-use I**	**8.2 Ag water use**	**6.4 Habitat & Assessment II**
	Paul Conrads	Daniel Johnson	**Panel Discussion:** Oscar Flite, Eric Krueger, Will Duncan, Rhett Jackson, Stan Simpson	J. A. Lanciani	W. G. Simmons, Jr.	Chelsea R. Smith
	C.R. Bodrey, Jr.	C. Faulkner		Joey McKinnon	Kitty Weisman	Thomas Forsberg
	Gregory S. Cherry	Nahal Hoghooghi		W. G. Simmons, Jr.	Jaime A. Painter	S. W. Golladay
	Mark B. Miller	Kirk Westphal		W. G. Simmons, Jr.	Aaron Bose	Vinay Kumar
	Ashley Grundtner	Robert A. Bahn		W. G. Simmons, Jr.	Peter J. Lasier	Robert Bringolf
Lunch 12:00 – 1:15	**Luncheon Keynote Speaker: Bruce Karas, *V.P. of Environment & Sustainability, Coca-Cola North America Group* "Coca-Cola's Water Stewardship Journey"**					
Afternoon Session 1:30 – 3:00	**1.5 Adapting to a changing coast II**	**2.5 Groundwater**	**7.3 Ogeechee River**	**4.5 Conservation & Augmentation**	**8.3 Industrial Water Mgmt.**	**6.5 Sustainability and Re-use II**
	James S. Reichard	Lynn J. Torak	Oscar P. Flite	M. Roberts	Tyler T. Cromey	Brent M. Zern
	Daniel L. Calhoun	David Radcliffe	Oscar P. Flite	J. Regan	Tim Echols	D. Henderson
	David W. Brew	Gerard Gonthier	V. Sittaramane	Sydney Bacchus	David Gipson	Candace Timpte
	Sudhanshu Panda	Debbie Gordon	Thomas C. Kuhn	G. Cowie	Ramesh Ghimire	H. Schurman
	C. S. Hopkinson	Robin McDowell	Checo Colon-Gaud	Hailian Liang	Tim Thoms	Amber Ignatius
3:00 – 3:30	Afternoon Break					
3:30 – 5:00	**Student Career Roundtable – Master's Hall**	**Documentary: "Chasing Ice"**	**Documentary: "Chattahoochee Unplugged"**			



and subsequent 1m DEM for the study area. Image segmentation was performed in eCognition software using Object based Image Analysis (OBIA) technology to develop the land use classification map of the study area. Different bands of NAIP imagery were used to develop NDVI and Dryness Index raster and DEM was used to develop slope, suppression, rate of spread, and sun aspect raster using proper algorithm. Biomass and urban fuel load raster were created using the classified land use map. Soil drainage raster was developed using the SSURGO soil data. A road buffer was created different buffer distances using the multi-ring buffer tool of ArcGIS and the vector file was converted to a raster using Polygon to Raster tool. Finally, a lighting strike raster was created by digitizing the hard copy file obtained from the USDA Forest Service for entire South Carolina and converting that to raster in ArcGIS. Once all the raster were obtained, they were all reclassified giving different 'weight values' developed by the team and other literature review according as the layer parameters' (e.g., a score of 300 for moderately drained soil, 500 for somewhat well-drained soil, and 700 for well-drained soil) wildfire susceptibility rate. Finally, the Weighted Sum tool was used with a different weight specification for individual wildfire susceptibility based reclassified layer (raster) to develop the final study area wildfire susceptibility map. The final map was classified into five different categories using Jenks algorithm to show the susceptible regions for wildfire. Above all, all the geospatial processes were completed through an automated geospatial model developed with ArcGIS ModelBuilder. As the last outcome, a decision support system was developed by the team to suggest wildfire hazard mitigation measures on spatial basis for the study area. This automated model can be replicated in any forest wildfire management.

23. **Peck, Michael F.**

U.S. Geological Survey, South Atlantic Water Science Center, 1770 Corporate Drive, Suite 500, Norcross, GA 30093

CONTINUOUS GROUNDWATER LEVEL MONITORING AND WATER LEVEL TRENDS IN THE PRINCIPAL AQUIFERS OF GEORGIA

Groundwater-level data in Georgia are collected by the U.S. Geological Survey, 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 aquifer system, the Floridan Aquifer system, 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 and determine long-term trends in groundwater levels. Often water levels are influenced by groundwater withdrawals from aquifers with declines reducing aquifer storage and changing water availability over time. Water levels were monitored continuously at 164 wells during calendar year 2014. One hundred and twenty five wells were equipped with electronic data recorders that recorded water levels at 60-minute intervals and stored the data for bimonthly retrieval. Thirty-nine wells had real-time satellite telemetry that recorded water levels at 60-minute intervals. Four of the real-time sites were equipped to monitor water levels and specific conductance, and at another site only specific conductance was monitored. Real-time satellite telemetry data are transmitted hourly 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.

24. **Pride, Carol J.**

Professor/Chair, Department of Marine and Environmental Sciences, Savannah State University, 3219 College St Savannah, GA 31404

THE COLLABORATIVE NSF EDGE PROGRAM AND UNDERGRADUATE RESEARCH ENGAGEMENT IN THE SAVANNAH RIVER ESTUARY

The EDGE Program at Savannah State University is in its final year of operation with the nearby University of Georgia Skidaway Institute of Oceanography. The strengths of the EDGE Program have been: early engagement in shipboard research; infusion of research in the classroom setting; and the award of both low- and high-commitment research internships. The program engaged high school, undergraduate and graduate students in bimonthly monitoring of the Savannah River estuary aboard the R/V Savannah from 2009 to 2014. On average, 40% of the scientific party aboard each research cruise was comprised of first-time participants who were largely trained by their peers or near-peers in shipboard operations. 62% of the participants were minority students and 47% were undergraduates. Samples and data from the Savannah River transects were used in internships, thesis projects, and class projects. In the first 5 years of implementation, 157 internships were awarded to develop competency in field work, lab work, and presentation formats for scientific research. Of the 79 individuals who have served as EDGE interns, 56% earned subsequent EDGE internships, 25% completed subsequent internships beyond the EDGE Program, and 52% have graduated. Interns have given at least 88 conference presentations, with most of them presenting on-campus before proceeding to an off-campus venue. Repeated participation in the shipboard and internship experiences allowed undergraduates to progress from being participants to serving as station leaders aboard the ship, while progressing from helpers to independent researchers in the laboratory.

25. **Pruitt[1], Carson A.**, Todd C. Rasmussen[2], and James Deemy[1]

[1]Graduate Student & Research Assistant, University of Georgia, [2]Professor, University of Georgia

USING THE DRASTIC PROTOCOL TO IDENTIFY VULNERABILITIES AND POTENTIAL RISKS ASSOCIATED WITH GROUNDWATER HAZARDS IN THE U.S. FOREST SERVICE SOUTHERN REGION

Groundwater is a major resource for municipalities, industries, and agricultural areas alike. Therefore, any potential vulnerability to pollutants is a concern to managing bodies. The DRASTIC protocol utilizes a number of ratings and weights along with several explanatory variables to create a vulnerability index that can be used in tandem with actual threats to the system (e.g. landfills, agricul-

The U.S. Geological Survey (USGS) has been modeling and mapping flood inundation in Georgia since 1994. Links to the flood-inundation maps and publications for four 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), and Sweetwater Creek near Austell (Musser, 2012c). 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 stream-gage, 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 Big Creek in Alpharetta and Roswell.

21. **Nguyen, Lan**
Undergraduate Student, Georgia Southern University, 1332 Southern Drive Statesboro, Georgia 30458

EFFECT OF TETRAKIS (HYDROMETHYL) PHOSPHONIUM CHLORIDE (THPC) ON ZEBRAFISH (*DANIO RERIO*)

Tetrakis (hydromethyl) phosphonium chloride (THPC) is a tetrakis (hydromethyl) phosphonium salt commonly used in commercial flame retardants. Mainly used by the textile industry, THPC is polymerized onto cotton fabrics to provide a flame-retardant finish. Traces of THPC were found in the Ogeechee River, a 294 mile-long black river in Georgia, and could have been a toxin contributing to the mass killing of aquatic animals in May 2011. Currently, there are no studies being conducted investigating how this chemical impacts water quality and the toxic effects THPC can have aquatic organisms following exposure. In this study, we used zebrafish (*Danio rerio*) embryos as a model to study the developmental and stressor effects THPC has on these fish. Zebrafish serve as excellent models because of their ease of manipulation, sensitivity to environmental stress, transparent embryos, and low cost of maintenance. Briefly, we exposed zebrafish embryos to varying concentrations of THPC for 5 continuous days. The embryos were observed everyday for critical endpoints such as development, hatching, mortality, morphology, heart rate etc. After 5 days, total RNA was extracted from the larvae and specific biomarker gene expressions were analyzed using Quantitative PCR. We have identified a Lethal Dose 50 for THPC that kills 50% of the exposed zebrafish embryos in one day. Further, we have identified that acute exposure of THPC results in severe retardation of zebrafish development producing developmental defects such as stunted growth, impaired vascular and neural development. We are currently evaluating the biomarker expression for resulting underlying molecular toxicity. Thus, zebrafish embryo is a valuable tool to evaluate the toxicity of commercially used chemicals in various local industries.

22. **Panda, Sudhanshu**
Associate Professor, Institute of Environmental Spatial Analysis, University of North Georgia, Gainesville Campus, 3820 Mundy Mill Rd., Oakwood, Ga. 30566

HYDROCLIMATOLOGY BASED WILDFIRE SUSCEPTIBILITY AUTOMATED GEOSPATIAL MODEL DEVELOPMENT FOR FOREST MANAGEMENT

Wildfire is one of the biggest natural hazards that United States faces every year and it is concentrated mostly in the western parts of the country. As a con-sequence of global warming and climate change, and the subsequent El-Nino and Na-Nina effects, wildfire vulnerability has increased in United States. Locations having good rainfall for few years are experiencing exceptional drought in next few years. Due to these drought conditions in previous years and following incessant rain next year with lightening is increasing the wildfire probability in USA. States that have not seen much of wildfire earlier are experiencing it in recent times. Southern states like Georgia and South Carolina have experienced increased wildfire in last 3-4 years. It is very difficult to fight wildfire without proper disaster management and planning. Information system is crucial to disaster management both for disaster prediction and relief. Most of the data requirements for such emergency management are of a spatial nature. Therefore, geospatial technology is one of the most important tools for this decision support system development. The goal of this study was to develop an automated geospatial model to predict the wildfire susceptibility in the Sumter National Forest in South Carolina. The objectives of the study to accomplish the goal is to: i) collect and process spatial data for wildfire vulnerability parameters; ii) develop an automated geospatial model in ArcGIS ModelBuilder using Map Algebra and advanced spatial analyst tools to locate most vulnerable locations in the study area, and iii) suggest wildfire hazard mitigation measures including post hazard management decision making. The geospatial data used for this study are 1m resolution, year 2013 four band (R, G, B, and NIR) National Agricultural Imagery Program (NAIP) image, 1 m DEM developed with 30 cm LiDAR, SSURGO soil, TIGER road, and most importantly a Lightning Strike data. Four-band NAIP images were obtained from Farm Service Agency (FSA) of USDA, mosaicked, clipped to the study area (Sumter NF), and band separated with ArcGIS 10.2 software. The LiDAR tiles for the study area were collected from SC DNR, mosaicked, and processed to develop nDSM

Tuesday Special Events

Floodplain Mapping Workshop — See page 9 for more details

Host: Tom Shillock & Georgia Environmental Protection Division
Where: Room F/G
When: 8:30 – 10:00 AM

This workshop will provide participants the opportunity to increase their flood risk awareness and knowledge of Flood Risk Map Products; whereby they will be better equipped to plan and implement flood related mitigation strategies. The floodplain mapping workshop session will allow attendees to gain a more complete understand all of the Flood Risk MAP products and the Community Rating System incentives, in order to make better regulatory decisions, and improve hazard mitigation plans and identified mitigation 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 that can be used 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; identify the flood risk status; see the effective Flood Insurance Rate Map, and even create a flood hazard report that captures all of this information in an attractive and sharable format.

Plenary Session

Where: Masters Hall
When: 10:30 – 12:00 AM
Topic: Water and Climate: Findings of the US National Climate Assessment
Speaker: Kathy Jacobs*, Director, Center for Climate Adaptation Science and Solutions, University of Arizona*

Luncheon Keynote Speaker:

Adam Sowatzka, *Partner, King & Spalding LLP*

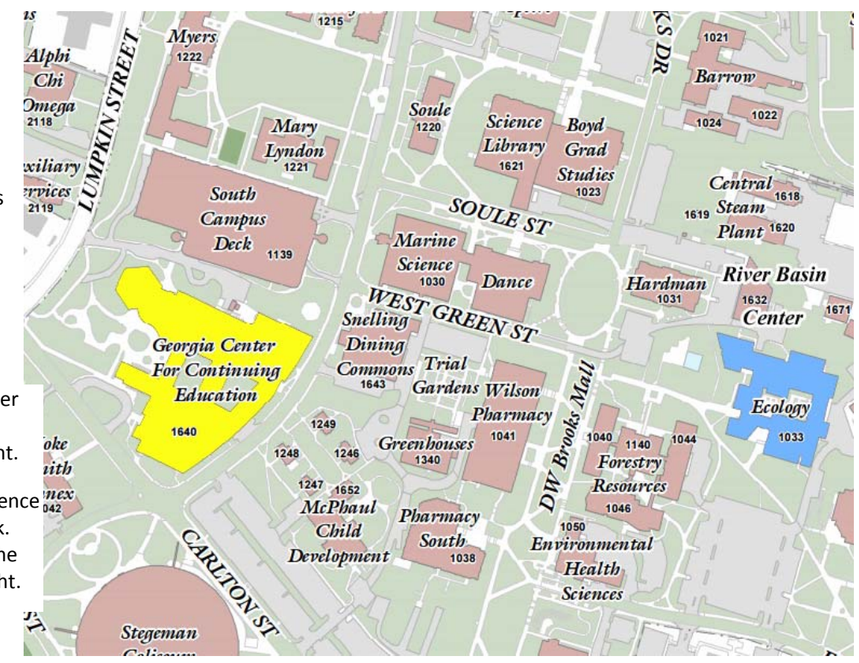
Poster & Exhibitor Session

Where: Pecan Tree Galleria
When: 3:30 – 5:00 PM

Evening Social

Where: Odum School of Ecology
When: 5:30 – 7:30 PM

Sponsored by: Nutter & Associates Environmental Consultants and the River Basin Center



Map from the Georgia Conference Center (yellow) to the Odum School of Ecology (blue) for the reception on Tuesday night.

Directions: Take a left out of the conference and stay along Sanford Dr. for one block. Turn right to follow West Green St. to the Ecology sidewalk, splitting off to the right.

Wednesday Special Events

Luncheon Keynote Speaker:

Bruce Karas
Vice President of Environment and Sustainability, Coca-Cola North America Group
"Coca-Cola's Water Stewardship Journey"

Career Roundtable for Students

Where: Master's Hall
When: 3:30 – 5:00 PM
A chance for graduate and undergraduate students to meet with water resource professionals of a diverse background to gain an understanding of what goes on outside of academia. Professionals will introduce themselves and answer a few questions from the session moderator. The floor will then be open to questions from student attendees.
Hosted by the University of Georgia Chapter of AWRA
Panelists to include:

Cody Hale, *Principal Hydrologist, Nutter & Associates, Inc., Athens, GA*
Erin Lincoln, *Project manager, Tetra Tech*
Marilyn Hall, *ACC Water Conservation Coordinator*
Kathryn Shepard, *ACC Stormwater Coordinator*
Brian Hughes, *USGS Georgia Water Science Center*

Documentary Showings:

Where: Room R & F/G
When: 3:30 – 5:00 PM

1.Chasing Ice — Room R

"In the spring of 2005, acclaimed environmental photographer James Balog headed to the Arctic on a tricky assignment for National Geographic: to capture images to help tell the story of the Earth's changing climate. Even with a scientific upbringing, Balog had been a skeptic about climate change. But that first trip north opened his eyes to the biggest story in human history and sparked a challenge within him that would put his career and his very well-being at risk.

Chasing Ice is the story of one man's mission to change the tide of history by gathering undeniable evidence of our changing planet. Within months of that first trip to Iceland, the photographer conceived the boldest expedition of his life: The Extreme Ice Survey. With a band of young adventurers in tow, Balog began deploying revolutionary time-lapse cameras across the brutal Arctic to capture a multi-year record of the world's changing glaciers.

As the debate polarizes America and the intensity of natural disasters ramps up globally, Balog finds himself at the end of his tether. Battling untested technology in subzero conditions, he comes face to face with his own mortality. It takes years for Balog to see the fruits of his labor. His hauntingly beautiful videos compress years into seconds and capture ancient mountains of ice in motion as they disappear at a breathtaking rate. Chasing Ice depicts a photographer trying to deliver evidence and hope to our carbon-powered planet." https://chasingice.com

2. Chattahoochee Unplugged — Room F/G

"More than 20 years ago canoe enthusiast and outdoor store owner, Neal Wickham, dreamed of running rapids in his own backyard on the Chattahoochee River. But there was a problem – those rapids lay submerged beneath the waters held back by two aging rock and masonry dams. The dams were built more than a century ago after the Civil War. They powered Columbus's booming textile business. Eventually that business moved elsewhere leaving behind a blighted riverfront, empty mills and disused dams in danger of failing. This Emmy Award-winning 1-hour documentary, filmed over the course of two years, explores how local businessman, John Turner and the civic organization, Uptown Columbus had to raise millions of dollars. They enlisted the services of Olympic white-water designer, Rick McLaughlin, the US Army Corps of Engineers and many other experts. The best environmental science converged with state-of-the-art engineering and construction to realize a much grander dream: to return a critical 2.5 mile stretch of the Chattahoochee, one of the largest rivers in the Southeast, to its natural state. At the same time it's creating a thrill ride for kayakers and rafters who can enjoy the world's the longest urban whitewater run through the heart of downtown Columbus and neighboring Phenix City, Alabama." http://chattahoocheeunplugged.org

we do have more wisely. Conservation and efficiency techniques are available and much cheaper than reservoirs or ASR - which could ultimately cost us more than just money but our health too.

17. **Marzolf, Nicholas S.[1,2],** Stephen W Golladay[2], Alan P Covich[1]
[1]Odum School of Ecology, University of Georgia, [2]Joseph W Jones Ecological Research Center, [3]Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA 30602
IS ENVIRONMENTAL CALCIUM AVAILABILITY LIMITING DISPERSAL OF AN INVASIVE SNAIL IN LAKE SEMINOLE AND ASSOCIATED SMALLER LAKES?
Since its introduction to the United States from South America in the mid 1990s, the spread of the invasive Apple snail, *Pomacea maculata*, continues to be of great interest because of its potential to affect ecosystem processes such as nutrient cycling. Physio-chemical parameters, such as pH and minimum annual winter temperature, have been used to predict spatial limits of *Pomacea* dispersal. Availability of calcium also influences gastropod distribution. In Lake Seminole, the availability of calcium is high due to inputs of mineralized groundwater. In contrast, depressional wetlands adjacent to the lake, which receive surface runoff and rainfall, exhibit much lower calcium concentrations. These depressional wetlands, previously thought to be within the predicted dispersal of *P. maculata* within the lake, may not fit the ecological requirements of the snail, particularly calcium and alkalinity, which are required for shell growth. Determining areas where *P. maculata* may not be able to establish has management implications for the spread of this voracious grazer among multiple lakes could reduce submerged aquatic vegetation. Submerged aquatic vegetation provides refuge for juvenile fishes, and can accumulate dissolved nutrients in their biomass. High *Pomacea* density and grazing rates could alter these key ecological conditions. Based on preliminary calcium sampling and *Pomacea* surveys completed in 2014, no *Pomacea* were found where calcium was below 10mg/L, but future surveys, continued sampling and bioassays will help determine the role of calcium in the spread of *P. maculata* within Lake Seminole.

18. **McDonald, Jacob M.**
Ph.D. Candidate, Department of Geography, University of Georgia, Athens, GA 30602
VIDEOGRAPHIC MONITORING OF NON-WADABLE STREAMS IN SOUTHEAST COAST NETWORK PARKS
The National Park Service Inventory and Monitoring Program was initiated to inventory natural resources, monitor ecosystems, and provide points of reference to understand the dynamic nature and condition of natural resources and ecosys-tems within their management units. The Southeast Coast Network (SECN) Non-Wadable Stream Habitat Monitoring Protocol was developed to provide data that will give park resource managers insight into the status of, and trends in, bank conditions and riparian habitats in their network. Non-wadable stream monitoring, currently implemented at five SECN parks, involves videographic documentation of the entire stretch of stream in each park using a GPS-enabled dual camera (Chase cam) system. Surveys will be repeated every three to five years to provide a long-term understanding of the condition of non-wadable streams in the SECN. Areas of interest (AOI), including bank erosion and illegal structures, will be identified in the field and upon review of the video, spatially documented, and disseminated to park managers. Additionally, stills extracted from the video record will be used to produce three-dimensional (3D) models using a photogrammetric range imaging approach called "structure from motion'". Secondary surveys near the AOI will provide a spatial reference (e.g. distance between two or more relative benchmarks) that will allow subsequent surveys and 3D models to provide a semi-quantitative measure of change. This protocol will help highlight known issues related to non-wadable streams in the SECN and provide early warnings of changing conditions, helping inform managers of appropriate techniques or procedures that may be required.

19. **Moak, Jason W.**
Senior Research Manager, Phinizy Center for Water Sciences, 1858 Lock and Dam Road, Augusta, GA 30906
PRELIMINARY RESULTS OF CONTINUOUS WATER QUALITY MONITORING IN THE OGEECHEE RIVER
In 2013, a Consent Decree between King America Finishing and Georgia Environmental Protection Division resulted in the funding of several Supplemental Environmental Projects (SEPs) aimed at benefitting the health of the Ogeechee River. As part of one of these SEPs, beginning in July 2014, we installed five continuous water quality monitoring stations within a 135-mile reach of the Ogeechee River mainstem that will be operated and maintained for a minimum of three years. Each of these monitoring stations provided web-accessible data on water temperature, specific conductance, pH, and dissolved oxygen levels as measured at 15-minute intervals. Based on data collected thus far, water temperature and conductivity generally increased in the downstream direction. Dissolved oxygen decreased in the downstream direction, with the lowest levels measured at the tidally-influenced site at US Highway 17.

20. **Musser, Jonathan W.**
Hydrologist, U.S. Geological Survey, South Atlantic Water Science Center, 1770 Corporate Drive, Suite 500, Norcross, GA 30093
FLOOD INUNDATION MAPPING IN GEORGIA

to characterize southeastern cities, investigation of these effects is increasingly important, especially in the expanding I-85 corridor of the Piedmont region. The concept that urban development has a significant effect on the hydrology of a watershed has been understood for quite some time, however the complexity of urban/suburban landscapes and the permeability of the different types of surfaces found within them makes it difficult to predict the exact effects. Additionally, actually defining what constitutes a flashy stream can also be ambiguous, as stream flashiness has no set definition. This paper explores how flashy the streams actually are, and to what extent the surrounding conditions (i.e. land-cover/impermeable surfaces) affect this. This was achieved by analyzing three aspects of flow regime that could be used to assess stream flashiness: magnitude, frequency, and rate of change. Preliminary results indicate that while several of our urbanized streams demonstrate increased stream flashiness than their more rural counterparts, it is clear that other factors have a large influence on streamflow dynamics. Examples of such factors may include connectivity of impervious surface or urban growth factors unique to individual cities.

14. **Lawrence, Stephen J.**
Hydrologist, U.S. Geological Survey, South Atlantic Water Science Center, 1770 Corporate Drive, Suite 500, Norcross, GA 30093
WATER USE IN GEORGIA BY COUNTY FOR 2010 AND WATER-USE TRENDS, 1985–2010
Estimated total water withdrawals in Georgia were about 4,697 million gallons per day (Mgal/d) in 2010. The largest withdrawals were for thermoelectric power generation (2,046 Mgal/d), public supply (1,141 Mgal/d), irrigation (802 Mgal/d), and self-supplied industrial uses (494 Mgal/d). Seventy-five percent of 2010 withdrawals were from surface-water sources. According to the U.S. Census Bureau, nearly 9.7 million people lived in Georgia in 2010. Public suppliers provided water to 85 percent of the population, 78 percent of that water was surface water. Surface water sources provided nearly 100 percent of the water withdrawn for thermoelectric-power generation (2,043 Mgal/d). About 75 percent of all groundwater withdrawn in 2010 was used for irrigation (579 Mgal/d). Withdrawals for 2010 were 14 percent lower than 2005 (5,471 Mgal/d) and 30 percent lower than the 1980 total of 6,725 Mgal/d. These declines were evident across all water-use categories. The total water use per capita in 1985 (total withdrawals divided by total population) was about 850 gallons per day (gal/d) and steadily decreased to 482 gal/d in 2010, a 43 percent decline. About 2,337 Mgal/d of water was returned to Georgia streams and lakes in 2010 under the National Pollutant Discharge Elimination System (NPDES) program administered by the Georgia Environmental Protection Division. This amount was about 50 percent of the total water withdrawn from all sources. Water returns declined 39 percent between 1995 and 2010, mirroring the decline in water withdrawals during that period. In addition, land applications of treated wastewater increased steadily between 1995 and 2010.

15. **Laymon, Kelsey A.**
Research Scientist, Phinizy Center for Water Science, 1858 Lock and Dam Road, Augusta, GA 30906
SUCCESSIONAL PATTERNS OF MOSQUITO ABUNDANCE IN RICHMOND COUNTY, GA
The dynamics, diversity and environmental driving forces influencing mosquito communities have been described by many researchers throughout the world. This study seeks to understand how extrinsic driving forces affect the urban mosquito communities in Richmond County, GA. Mosquitos were collected at fifteen sites biweekly by deploying light and gravid traps from January-December 2014. Cyclical successional trends were observed at several sites with possible exogenous and endogenous driving factors. To determine the factors behind the observed changes in abundances, we collaborated with the Richmond County Mosquito Control Program, using their data to determine the effects of mosquito control operations as well as, temperature and precipitation data from the Bush Field airport in Augusta, GA. We found that total abundance peaked at 6/22/14 at Site 1, and 5/12/14 at Site 2 with various highs and lows throughout the rest of the year, this trend generally coincided with higher and lower temperatures, respectively. Abundances of particular species correlated with rain events but correlations to mosquito control operations were confounded by non-synchronous sampling and control efforts, which can be improved in the future.

16. **Markesteyn., Emily J**
Riverkeeper and Executive Director for Ogeechee Riverkeeper, 202 W 44th St, Savannah, GA 31405
AQUIFER STORAGE AND RECOVERY: A BAD ALTERNATIVE
Aquifer Storage and Recovery (ASR) is the practice of injecting surface, ground or treated wastewater into an aquifer for storage and later recovery during times of high demand. ASR can be risky to public health through increases in arsenic contamination and/or the introduction of bacteria, pathogens and disinfection byproducts to the aquifer water. 59% of Florida's ASR sites have been abandoned or operations suspended for reasons including arsenic mobilization or the inability to recover the "stored" water. Some ASR projects in South Carolina have experienced well-clogging and bacterial growth. ASR can also be risky to taxpayers' wallets. There are many unanswered, potentially devastating questions as to the expense of ASR. Who pays for an ASR project in Georgia? What happens if it fails? Who's left with the debt? These projects can cost millions if not billions of dollars. Arguably the most troubling aspect of ASR involves the issue of water rights, property rights and the legality of the practice. Who owns water that is put into an aquifer? What happens if that water can't be recovered, or it moves/mixes with native ground water? As Georgia's leaders work to balance quality and quantity of our water resources, we shouldn't be looking to risky water supply schemes but instead to using the water

Exhibitors & Conference Supporters

OTT Hydromet

OTT Hydromet, a member of Hach Company, helps water resource professionals generate reliable data throughout the entire water cycle. We go beyond simply providing solutions by partnering with our customers in designing effective answers to the challenges they encounter in their vital role of monitoring the world's water. Formed from three separate companies (OTT, Hydrolab, and Adcon Telemetry), OTT Hydromet offers the combined strength and expertise of leaders in the water quality, quantity and telemetry fields and over 140 years of experience in environmental measurement.

Georgia Association of Water Professionals

The Georgia Association of Water Professionals (GAWP) is a not-for-profit association whose chief purpose is to educate and assist those who have an interest in the proper management and protection of Georgia's water resources. GAWP provides professional development and promotes sound public policy in the water resources and related environmental fields.
GAWP's membership is comprised of water and wastewater treatment plant operators and managers, municipal and industrial officials and environmental managers, civil and environmental engineers, scientists, manufacturers and their representatives, contractors, elected officials, and other's concerned with Georgia's water resources. GAWP membership also consists of the professionals who implement state and federal water supply, water protection, and water resource laws and regulations, and is a reliable source for information for the media and the public

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.

ADMi, LLC

Advanced Data Mining Intl is headquartered in Greenville, South Carolina and provides data mining and visualization software products and consulting services of unusual sophistication. ADMi delivers powerful solutions to problems of real-time monitoring, prediction, forecasting, anomaly detection, and decision support for water resource management, TMDLs, estuarine and groundwater salinity intrusion, climate change effects, and water plant and water distribution system optimization.

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.

Sustainable Water

Sustainable Water is a leading provider of water reclamation and reuse solutions. Utilizing the world's leading technologies, we recycle water for heating, cooling and irrigation, bringing customers annual savings on operations costs year after year.
Sustainable Water's ecologically-driven projects bring together teams of experts comprised of seasoned water industry veterans, world-class design engineers and award winning commercial contractors who have built hundreds of high-profile, first-of-their-kind, multi-million dollar projects. Our turnkey development services begin with comprehensive feasibility studies and continue through design, permitting, construction and operation.

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.

Georgia Forestry Association

As the leading advocate for Georgia's forestry community, the Georgia Forestry Association works to promote the value of Georgia's working forests and forest industries while educating business, environmental and political leaders about responsible forest management practices and landowner rights. Ninety-one percent of Georgia's forests, which cover two-thirds of the land area of the state, are privately owned. The majority of that land is owned by tens of thousands of private, non-industrial landowners whose stewardship serves to clean the state's water and air while providing valuable wildlife habitat and outdoor recreation. For more than a century, these working forests have turned the state's most plentiful, renewable, natural resource – trees – into jobs and tax dollars, while providing direct environmental benefits to Georgia citizens. Forest landowners and forest industries continue to face pressure from growing global competition, local property taxes and sprawling urban and suburban development. Georgia's forests have the capacity to meet increased demands for goods and services now and in the future. But the correct mix of stewardship, market opportunities and commitment to public policy must come together to support forest landowners, organizations and communities that hold these forests in trust for future generations.

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.

Saltwater intrusion in Brunswick, GA has impacted the Upper Floridan aquifer (UFA) in an approximately 2-square mile area limiting future groundwater use. Since the late-1950's the U.S. Geological Survey (USGS) in cooperation with local government has performed annual sampling of wells in and near the affected area. Previous studies and sampling results indicate saltwater has migrated upward from deep saline zones in the Fernandina permeable zone of the Lower Floridan aquifer. This migration occurs through breaches in confining units as a result of groundwater pumping that has reduced hydraulic head in water-bearing zones of the UFA. During 2014, 52 wells were sampled for chloride in the Brunswick/Glynn County area. Data from 31 of those wells was used to construct a map delineating the chloride plume in the UFA near downtown Brunswick. Currently, the USGS South Atlantic Water Science Center, in cooperation the Georgia Department of Natural Resources, Environmental Protection Division and the Brunswick-Glynn County Joint Water and Sewer Commission continuously monitor specific conductance in 5 wells equipped with satellite telemetry. Data are recorded and transmitted hourly and are available at http://ga.water.usgs.gov/projects/intrusion/brunswick.html. The specific conductance is used as a surrogate for chloride concentrations. The continuous data collected from the Brunswick Villa well (34H134) indicates a steady rise in specific conductance from near 500 microsiemens per centimeter at 25 degrees Celsius during late-2009 to values above 700 by the end of 2014.

11. **Jones, L. Elliott**
Hydrologist, U.S. Geological Survey, South Atlantic Water Science Center, 1770 Corporate Drive, Suite 500, Norcross, GA 30093

SIMULATION OF GROUNDWATER FLOW IN THE UPPER FLORIDAN AQUIFER IN THE LOWER APALACHICOLA–CHATTAHOOCHEE–FLINT RIVER BASIN, SOUTHWESTERN GEORGIA AND PARTS OF ALABAMA AND FLORIDA, 2008-2012

The primary goal of the Apalachicola–Chattahoochee–Flint River Basin (ACFB) Focus Area Study, part of the USGS National Water Census, was to evaluate water availability at the scale of a subwatershed (12-digit hydrologic unit, averaging about 31 square miles in the ACFB). Initially, a Precipitation-Runoff Modeling System (PRMS) watershed model of the entire basin was developed for this purpose. However, in the lower part of the ACFB, groundwater in the Upper Floridan aquifer is the primary source for agricultural irrigation and public supply and a major component of the hydrologic budget. A groundwater model was needed to better understand the dynamics of the groundwater-flow system and to assess the flow of water in the Upper Floridan aquifer to pumped wells and to and from streams in the lower ACFB. Groundwater-withdrawal rates for irrigation in Georgia were estimated using an extensive network of water meters, installed and maintained by the Georgia Soil and Water Conservation Commission. Groundwater use in Florida and Alabama was estimated using available meter data and other records. A MODFLOW groundwater model was developed for the lower ACFB to simulate comprehensively aquifer-stream flow in the main-stem rivers and in 94 tributary streams. Estimates of recharge to the Upper Floridan aquifer, another major component of the hydrologic budget, were obtained from the PRMS watershed model. Linking the PRMS and MODFLOW models into a unified modeling system to evaluate water availability in the lower part of the ACFB was a critical element of this study.

12. **Knaak, Andrew E.**
Hydrologist, U.S. Geological Survey, South Atlantic Water Science Center, 1770 Corporate Drive, Suite 500, Norcross, GA 30093

RETURN TO NORMAL STREAMFLOWS AND WATER LEVELS: SUMMARY OF HYDROLOGIC CONDITIONS IN GEORGIA, 2013

The U.S. Geological Survey (USGS) South Atlantic Water Science Center (SAWSC) maintains a long-term hydrologic monitoring network in Georgia that includes more than 350 real-time streamgages, 10 lake-level monitoring stations, 67 real-time water-quality monitors, and several water-quality sampling programs. Additionally, in Georgia the SAWSC monitors more than 180 groundwater wells, 39 of which are real-time. Changing hydrologic conditions emphasize the need for accurate, timely data to help make informed decisions regarding the management and conservation of Georgia's water resources. Hydrologic conditions during water year (WY) 2013 (October 2012–September 2013) were assessed by comparison with long-term historical data. The 2013 WY started out in persistent drought conditions, as portions of Georgia had been in extreme (D3) drought conditions since August 2010 as defined by the U.S. Drought Monitor. Several streamgages with 20 or more years of record were experiencing near record low flows and several lake and reservoir levels were below full pool. Groundwater levels in unconfined aquifers monitored by the Georgia Climate Response Network were experiencing near record low levels. In December 2012, Georgia began experiencing persistent heavy rainfall for extended periods. As a result Georgia was free of D3 drought conditions as of February 2013 and hydrologic conditions for streamgages, groundwater levels, and lake and reservoir levels improved. By February 2013 till the end of the water year, several streamgages returned to normal flow conditions, groundwater levels in unconfined aquifers increased above historic median levels, and lake and reservoir levels reached full pool.

13. **Koslofsky, Eli B.**
Master's Student, Dept. of Geosciences, Georgia State University, Atlanta GA 30303

EFFECTS OF URBANIZATION ON STREAM FLASHINESS IN THE 1-85 CORRIDOR OF THE SOUTHEASTERN PIEDMONT

Increased urbanization, and other changes in land-use, can have significant effects on stream hydrology within a watershed, including large fluctuations of flow in streams referred to as "stream flashiness". Increased stream flashiness has numerous consequences, including water quality degradation and destruction of aquatic habitats. With the sprawled out suburban landscape which has come

lated wetlands during episodic flows. The mechanisms producing these results are unclear but are probably attributed to a combination of dilution from soil water/upland runoff and biogeochemical activity/sedimentation.

7. **Diaz, David L.**
Master's Student, University of Georgia, conducting research at the Joseph W. Jones Ecological Research Center, 3988 Jones Center Drive Newton, GA 39870

INFLUENCE OF GROWING SEASON STREAM FLOWS ON PERIPHYTON GROWTH

Water extractions for irrigation in the lower Flint River Basin (LFRB) can reduce summertime stream flows below historic levels, particularly during droughts. Anecdotal evidence suggests that these low-flow conditions promote periphyton growth. We conducted controlled experiments to examine how flow conditions affect summertime periphyton growth, biomass, and composition in Ichawaynochaway Creek, a major tributary of the lower Flint River. Creek water was pumped through replicate artificial stream channels lined with clean ceramic tiles to achieve a 5 discharge treatments ranging from 0.25 to 5 gpm. Tiles were collected twice weekly for four weeks to quantify periphyton biomass (ash-free dry mass and chlorophyll a) and calculate growth rate. Noticeable growth occurred in all discharge treatments, but growth rates and final biomass increased with discharge and were approximately 3-fold greater at the highest as compared to the lowest discharge. Flow also affected periphyton taxonomic composition as higher discharge promoted development of thick diatom (Class: Bacillariophyceae) mats and lower discharge allowed dominance by unattached masses of filamentous green algae of the order Zygnematales. These treatment responses were consistent with observations of variation in periphyton assemblages across different flow conditions within the creek itself during the same time period. Additional ex-perimentation (to be reported in the conference manuscript) has examined whether nutrient limitation contributes to slower periphyton development at low flows and how stream herbivores respond to flow-related differences in periphyton growth and composition. These findings provide insight into how alterations to summertime flow regimes affect stream ecological conditions within the LFRB.

8. **Erickson, Matthew R.**
Research Scientist, Phinizy Center for Water Sciences, 1858 Lock and Dam Road, Augusta, GA 30906

LAGRANGIAN SAMPLING OF E. COLI IN AN URBAN STREAM

Rocky Creek, an urban stream in Augusta, Georgia, has been identified on Georgia's 1998 303(d) list of impaired water bodies due to concerns about fecal coliform bacteria. There are no widespread agricultural or animal farming operations in its watershed and a large portion of its area is impervious to water infiltration, so pollutant runoff is a major concern. Monitoring efforts thus far have shown the upper-middle stretch typically has the highest concentrations of fecal indicator bacteria, but source identification has been inconclusive. To further investigate possible causes or sources of impairment, a lagrangian sampling scheme was applied, and both surface and sediment water at six sites on the creek were sampled according to travel time. At each site, a rhodamine dye tracer was used to determine travel time, and discharge, pH, dissolved oxygen, specific conductance, and temperature was measured. We found that total load of E. coli increased linearly as a function of stream length from the first site. This study builds on the results of a previous lagrangian study in the same creek. Results from these studies support previous literature indicating stream sediments may be acting as a reservoir of E. coli. If bacterial loading during low flow conditions is a result of mobilization from sediment into the water column, source identification from bacterial monitoring, as well as control efforts, become increasingly difficult.

9. **Fitzpatrick[1], Stephan D.** and Darryl Haddock[2]
[1]Dept. of Life and Earth Sciences, Georgia Perimeter College, 555 North Indian Creek Drive, Clarkston, GA 30021-2361; [2]West Atlanta Watershed Alliance, Atlanta, GA 1442 Richland Road, Atlanta, GA 30310

GIS-BASED WATER QUALITY AND QUANTITATIVE ASSESSMENT OF HISTORIC PROCTOR CREEK, ATLANTA, GEORGIA

We utilized specifically targeted geographic information systems (GIS) along with field data to establish baseline evidence regarding various forms of contaminant issues in the Proctor Creek Watershed, Atlanta, Georgia. Urban watersheds experience significant pollutant loads, which cause environmental stress, reduction in ecological stability and public exposure due to toxic load. Evaluating these problems requires understanding the past and present hydrology, as well as socio-economic activities within the watershed. The Proctor Creek Watershed is considerably impacted by non-point source runoff and combined sewer overflows (CSO). These are the most likely influences on this urban ecosystem. However human health also been negatively influenced by socioeconomic conditions within this area especially in the western segment of Proctor Creek. The watershed is mainly populated by African American residents of modest means located in nearly 30 neighborhoods. With a history of degradation through development, transportation and disenfranchisement the Proctor Creek Watershed is a living laboratory of environmental justice issues.

10. **Hamrick, Michael D.**, Cherry, Gregory S.
Hydrologic Technician, U.S. Geological Survey, South Atlantic Water Science Center, 1770 Corporate Drive, Suite 500, Norcross, GA 30093

MONITORING SALTWATER CONTAMINATION IN THE UPPER FLORIDIAN AQUIFER, BRUNSWICK, GA

TRACK 1 ABSTRACTS: Tuesday 8:30 – 10:00 AM

Session 1.1 – Masters Hall

Panel Discussion: Climate and Public Policy

THE SCIENCE-POLICY INTERFACE: BRIDGING ENVIRONMENTAL SCIENCE AND POLICY IN THE TWENTY-FIRST CENTURY

Panel Description: Water management is a significant issue in the state of Georgia as drought, population growth, the Tri-state Water Wars, and growing concerns of global climate change engulf the region. These intractable environmental issues are characterized by high uncertainty, complexity, and swift change. How science is developed and applied to these issues is one major factor influencing "humanity's environmental future" (Caldwell 1990). Yet, science is currently underutilized in environmental policy despite the growing call for effective scientific engagement in public policy (NSF 2002). This panel explores how scientific evidence can be best applied to growing environmental pressures facing decision makers in the state of Georgia. The panelists vary in their approach with some synthesizing science-policy interface literatures to decipher best practices while others contribute original research through detailed ethnographic and social studies. Overall, the objectives of this panel are to enhance the theoretical understandings of the science-policy interface while informing efforts to bridge environmental science and policy, particularly in complex political arenas.

Panel Guests:

Stephanie Stuckey Benfield, *Esq. Executive Director, GreenLaw, Atlanta*

Laurie Fowler, *J.D. Associate Dean, UGA Odum School of Ecology*

Katharine Jacobs, *Director of the Center for Climate Adaptation Science and Solutions, University of Arizona*

Moderator: Dr. Rob McDowell, *UGA Warnell School of Forestry and Natural Resources*

TRACK 2 ABSTRACTS: Tuesday 8:30 – 10:00 AM

Session 2.1 – Room K: Green Infrastructure

Byrne, Eric J.
Water Resources Engineer, Tetra Tech, 2110 Powers Ferry Road, S.E. Atlanta, GA 30339

CLARKESVILLE GREEN INFRASTRUCTURE IMPLEMENTATION STRATEGY

The U.S. Environmental Protection Agency (USEPA) encourages using green infrastructure to help manage stormwater runoff. In October 2013 USEPA renewed its commitment to green infrastructure with a new release of the Strategic Agenda to Protect Waters and Build More Livable Communities through Green Infrastructure. The agenda identifies technical assistance as a key activity and Clarkesville, GA was one of the communities selected for the program in 2014. The Clarkesville Green Infrastructure Implementation Strategy provides the basic building blocks for the City to strengthen its efforts to improve stormwater management while benefiting from the environmental, economic, and social benefits of green infrastructure. Goals and objectives, based on the City's current and future needs, form the basis of the strategy. These goals and objectives led to a comprehensive prioritization of parcels throughout the City to identify opportunities for green infrastructure. The community and project team evaluated the highest priority parcels and identified the most promising and feasible opportunities from that list. Site-specific design recommendations, including illustrations and descriptions of potential green infrastructure practices, were created to aid the City in further evaluation and discussion among city staff, officials, local partners, and the public. A range of green infrastructure practices are recommended, including rain water harvesting, a green alley, bioretention, permeable pavement, a green roof, stormwater wetlands, and stormwater detention.

Hughes, Duncan L.
Headwaters Outreach Director, Chattahoochee Riverkeeper 615F Oak St., Suite 1000, Gainesville, GA 30501

GREEN INFRASTRUCTURE IN A SMALL UNREGULATED COMMUNITY: PROCESS AND LESSONS FROM CLARKESVILLE, GA

The City of Clarkesville is a small unregulated MS4 in Habersham County GA. The Soque River, the drinking water supply and waste receiving stream for the City, has documented water quality impairments attributed to non-point source pollution and urban runoff. The Soque is a major tributary to the Chattahoochee River, the primary drinking water supply for millions of people downstream. Clarkesville has demonstrated a strong commitment to water quality by serving as the lead organization for the Soque Partnership, a local stakeholder group implementing a series of Clean Water Act §319(h) grants since 2004. Additionally, the City is seeking the WaterFirst designation from the Georgia Department of Community Affairs, a voluntary program which acknowledges communities across the state who engage in a rigorous protocol including watershed assessment and stormwater master planning. In an effort to address the causes and sources of the known impairments, the City completed a stormwater inventory. The purpose of the inventory was to document existing stormwater infrastructure conditions and identify potential green infrastructure implementation opportunities. As a small city, Clarkesville does not have the in-house technical capability to design and implement the practices needed to best control stormwater using green infrastructure. EPA technical assistance, provided via contract by Tetra Tech, resulted in the development of Clarkesville's Green Infrastructure Implementation Strategy to guide prioritization of stormwater BMPs in and around the City center, an area high in impervious surfaces and with documented stormwater problems. This process may serve as a guide for other small, unregulated communities.

Rainey[1], Donald P., Esen A. Momol[2], Laurie E. Trenholm[2], Mike Thomas[3], and Alberto Chavez[4]
[1]University of Florida, IFAS, Sarasota County Cooperative Extension Service, Florida Friendly-Landscaping Program, 6700 Clark Road., Sarasota, FL 34241; [2]University of Florida, IFAS, Environmental Horticulture Department, P.O. Box 110675, Gainesville, FL 32611; [3]Florida Department of Environmental Protection, Nonpoint Source Management Section, 2600 Blair Stone Rd., Tallahassee, FL 32399; [4] Rookery Bay National Estuarine Research Reserve, 300 Tower Road, Naples, FL 34113

FLORIDA-FRIENDLY LANDSCAPING™ GREEN INDUSTRIES BEST MANAGEMENT PRACTICES: EDUCATION FOR THE PROTECTION OF FLORIDA'S WATERS AND NATURAL RESOURCES

The sustainability and protection of Florida's natural resources in the urban landscape is an important issue facing landscape maintenance providers. The Green Industries Best Management Practices (GI-BMP) Training Program is mandatory by Florida statute for those applying fertilizer commercially in the urban landscape. The GI-BMP Program is administered by Florida Department of Environmental Protection (FDEP) Nonpoint Source Management Section (NPSMS) and implemented by the UF/IFAS Florida-Friendly Landscaping™ (FFL) Program. The program has trained/certified over 30,000 industry professionals. The training is taught by Extension Agents and Green Industry volunteers. A combined 1,340 training classes have been provided in English, Spanish or Haitian Creole. Three training options are available: in-person, online and DVD. Classes are held at Extension offices and other locations around the state. The training consists of six GI-BMP learning modules covering: efficient use of water and fertilizer, integrated pest management (IPM), fertilizer application, and lawn and landscape cultural practices to reduce nonpoint source pollution. Passing rates for in-person training are: English 92%; Spanish 80%; Haitian Creole 72%. Knowledge gain results (18% average) are based on pre- and post-test scores. An end-of-training evaluation is given to in-person participants: 17,612 (84%) out of 21,026 indicated a willing-

4. **Bhuiyan, Ridwan A.**
Undergraduate Student, Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA 30602

A STUDY OF CHLORIDE AND RHODAMINE DYE TRACER MOVEMENT THROUGH AN URBAN STREAM AND RAINGARDEN

The University of Georgia main campus is dominated by impervious surfaces that produce stormwater runoff during rain events. The primary objective of this study is to observe and better understand the hydrology of stormwater within Lilly Branch, a UGA campus watershed. A mixture of sodium chloride and Rhodamine was used to characterize velocities and travel times through a section of Lilly Branch. A secondary objective is to evaluate stormwater movement through a raingarden that is tributary to Lilly Branch. Sodium chloride is also a potential contaminant that results from road salt application during icy weather. As such, the background and peak concentrations in local streams are of concern, as is the ability of raingardens to mitigate the adverse impacts of watershed salt loading. Data collected from tracer tests provide insight into the pathways of sodium chloride deicers and how contaminants travel through an urban stream and raingarden. Approximately 250 mL tracer cocktail was prepared that was composed of chloride combined with Rhodamine, a commonly used dye tracer. The tracer travel times were recorded at 10-m increments, along with the wetted width and the average depth based on three measurements across the width of the channel. The Lilly Branch raingarden buffers runoff from a parking lot and deck, which enters at high velocities. A weir is used to determine raingarden inflows and outflows. Water samples are collected upstream and downstream using ISCO automated samplers. Water samples were analyzed for chloride concentrations by the UGA Ecology Analytical Chemistry Laboratory using ion chromatography.

5. **Cahalan, Matthew D.**
Graduate Student, Department of Geology, University of Georgia, Athens, GA 30602

INTEGRATED APPROACH FOR SUBSIDENCE MONITORING AND SINKHOLE FORMATION IN THE KARST TERRAIN OF DOUGHERTY COUNTY, GEORGIA

The Upper Floridan Aquifer (UFA) is an important water source for agricultural and municipal purposes in Dougherty County. However, prolonged water demand, dissolution of the carbonate aquifer (Ocala Limestone), and short and long-term fluctuations in precipitation, surface water discharge, and groundwater levels have placed many areas at risk for sinkhole formation and broader scale land deformation (i.e., subsidence) in the covered karst terrain. Evaluating the causes of sinkhole formation and subsidence is essential for reducing risk within karst settings. We evaluate sinkhole development in Dougherty County by applying a sinkhole delineation and regression analysis procedure utilizing digital elevation models (DEMs) from 1979, 1999, 2010, and 2011. After sinkholes were accurately mapped, a regression analysis was utilized to determine the hydrogeologic (e.g. fracture traces, aquifer levels), climatic (e.g. precipitation), and land use variables that are most influential in sinkhole development. Preliminary regression results indicate aquifer levels and distance to fracture traces are the strongest explanatory variables for sinkhole formation (R2 = 0.74 for the 2010 DEM). Furthermore, DEM analysis results show a 77.2% ±5% increase in number of depressions from 1979 - 1999 and a 9.8% ±5% increase from 1999 - 2010. A 5% error was estimated due to variations in DEM resolution, source, and processing techniques. Persistent scatterer interferometry (PSI) will measure the temporal evolution of subsidence in Dougherty County using 125 ERS 1-2 satellite scenes from 1992 - 2010 within ENVI's SARscape program. These results will be compared with sinkhole location and development through time.

6. **Deemy, James B.**, Jeffrey Hepinstall-Cymerman, L. Katherine Kirkman, Todd C. Rasmussen
Ph.D. Student, Warnell School of Natural Resources, University of Georgia, Athens, GA 30602

WATER QUALITY OF EPISODIC FLOW THROUGH ISOLATED WETLANDS EMBEDDED IN A LONG LEAF PINE / WIREGRASS ECOSYSTEM

Isolated, depressional wetlands are common on the karstic Dougherty Plain in Southwest Georgia, where dissolution of the underlying limestone has resulted in a landscape that is largely devoid of headwater streams. Stormwater runoff collects in these wetlands, and occasionally spills into perennial streams following major storms. These episodic flows are known to transport elevated levels of sediments, nutrients, and pathogens into and through isolated wetlands, although the magnitude and fate of these constituents are unknown. In this study, we report water-quality data collected during a three-week stormflow event (Feb 15 to Mar 9, 2014) which resulted from over 203 mm of precipitation between February 13th and March 5th, 2014. Data were collected along two flowpaths at the Joseph W. Jones Ecological Research Center, a private, 11,700-ha property on the Dougherty Plain of southwest Georgia. Sampling of both flowpaths began where upstream agricultural stormflow first enters the site. Inflows plus additional onsite contributions were then monitored as they migrate across the forested site through and between normally isolated wetlands. Stage, field water-quality parameters (temperature, specific conductance, pH, dissolved oxygen), sediment (turbidity, total filterable solids), nutrients (dissolved organic carbon, dissolved inorganic carbon, dissolved total carbon, ammonium, nitrate plus nitrite, phosphate, total nitrogen, total phosphorus), and pathogen indicators (total coliform, *E. coli* were monitored daily at 5 sites along the first flowpath, and at 2 sites along the second flowpath. A general trend of decreasing sediment, nutrient, and pathogen concentrations was observed as water moved between and through isolated wetlands. The greatest reductions were observed within wetlands located directly below site inflows, indicating that agricultural inputs of sediments, nutrients, and pathogens are rapidly sequestered by iso-

Poster Presentations: Pecan Tree Galleria, Tuesday 3:30 – 5:00 PM

1. **Arnold[1], Ashton B.** and Carol J. Pride[2]
[1]Graduate Student, Marine Sciences Program, Dept. of Marine & Environmental Sciences, Savannah State University;
[2]Professor/Chair, Department of Marine and Environmental Sciences, Savannah State University, 3219 College St Savannah, GA 31404

DIATOM COMMUNITIES OF THE SAVANNAH AND ALTAMAHA RIVER ESTUARIES

The purpose of this study is to compare the diatom communities of the Savannah and Altamaha River estuaries during different seasons. These rivers are similar in size, but the Altamaha has fewer anthropogenic impacts and has a larger contribution from black water tributaries. A project completed in May 2010 suggested that estuarine diatom community diversity increases going southward from the Savannah area to the Altamaha River estuary. To test these results, surface water samples were collected in October 2011 from three lower estuary stations in both the Savannah and the Altamaha rivers. Diatoms were identified to the genus level in each sample from salinities of 30, 25, and 20 PSU. In the October 2011 samples, diatom standing stocks were similar in the two estuaries ranging from 2280 to 3640 cells/L at all except the outermost (30 PSU) Savannah River station where standing stocks were 7796 cells/L. Standing stocks may have been higher in this lower estuarine Savannah River sample due to higher nutrient concentrations and greater light penetration. Analyses of nutrient concentrations and PAR profiles are underway for the two estuaries. Unlike the May 2010 results, diversity of the Altamaha River diatom samples were not much higher than those in the Savannah River estuary with mean Shannon-Weiner indexes of 1.16 and 1.14, respectively. Coscinodiscus was the most common genus in both rivers. The study is being expanded upon with samples collected in July 2010, October 2011, and December 2013.

2. **Bailey, Andrew B.**
Master's Candidate, Environmental Planning and Design, University of Georgia, Athens, GA 30602

CONNECTING DATA, DISCIPLINES, AND DISTURBED HYDROLOGY

Green infrastructure (GI) planning at the busiest airport in the world requires an intimate and ongoing understanding of the complex systems that interact on the 4,700-acre site. An inventory of the hydrology of the area reveals that the headwaters of the impaired Flint River originate just north of the airport site and are then piped underneath the airport in a large concrete culvert. Vast impervious surfaces at the airport generate massive amounts of runoff that are currently handled through grey infrastructure systems and detention basins. Through the implementation of GI stormwater control measures (SCM) the airport can make significant improvements to water quality and subsurface return flows in the upper Flint River basin. This study utilized a land suitability analysis that integrates multi-criteria evaluation with GIS to determine optimum site locations for GI. The suitability analysis identified areas that are suitable for a broad variety of GI SCM given the analyzed criteria of land-cover, slope, FAA regulations, public visibility, and open drainage swales. The results of the analysis indicate 38% of the airport site as possessing high suitability values and an additional 24% as moderately suitable. Recommendations for future action are presented across spatial and temporal scales and include potential pilot sites for short, medium, and long-term action. Recommendations also indicate the importance of acquiring additional and updated soil and groundwater datasets as well as comprehensive runoff calculations to aid in planning and overall distributed system design. Overall, the study has demonstrated the relevance of a land suitability analysis as a spatial planning tool for GI and as a catalyst for interdisciplinary discourse.

3. **Bonney[1], Shannon**, Laurie Fowler[1], Laura Early[1], Brian Easley[2], Torre Lavelle[3], Daniel Read[4], and Katie Sheehan Hill[1]
[1]River Basin Center, Odum School of Ecology, University of Georgia, Athens, GA; [2]School of Law, University of Georgia; [3]Odum School of Ecology, University of Georgia; [4]Department of Ecological & Environmental Anthropology, University of Georgia

MARKET-BASED APPROACHES TO RESOLVE WATER CONFLICTS IN THE APALACHICOLA-CHATTAHOOCHEE-FLINT RIVER BASIN

Georgia, Alabama, and Florida have been entrenched in a dispute over the waters of the ACF River Basin for decades. In recent years the debate has become ever more serious because there is insufficient water to meet environmental and public water demands during droughts. A variety of approaches have been employed in attempts to resolve this dispute, including political negotiations and litigation, but have been unsuccessful to date, perhaps because they do not ensure the benefits derived from water and burdens borne by lack thereof are shared equitably amongst water users. Market-based instruments (MBIs), typically divided into four major types: instream buybacks, trading and offsets, beneficiary-pays fund, and bilateral agreements, offer a way to resolve water disputes by redistributing benefits and burdens experienced by water users, in lieu of litigation and politics. However, with the exception of irrigation reduction auctions twice held in the Flint River sub-basin, MBIs have largely been ignored. No auction programs or other MBIs are currently employed at a basin-wide scale, which excludes many potential beneficiaries and providers. This multi-year study explores MBIs for water allocation in transboundary river basins and aims to determine their feasibility for use in the ACF River Basin. To accomplish these ends we will: identify all cases where MBIs were used to resolve interstate water allocation disputes, characterize emerging and well-established MBIs utilized in river basins of select industrialized nations, and determine the institutional and political feasibility of different market-based instrument types and design elements in the ACF River Basin.

ness to adopt BMPs; 3,035 (14%) indicated they "Already Do" use the BMPs. 16,840 (79%) out of 21,302 responding said, "I will" use the recommended fertilization rates and methods presented in the BMP manual; 19% indicated they "Already Do". Annual follow-up survey results indicate at least 10 BMPs adopted based on before and after questions.

Kaplan, Julie
Water Resources Scientist, Tetra Tech, 2110 Powers Ferry Road, S.E. Atlanta, GA 30339

SELECTION AND IMPLEMENTATION OF A COMPREHENSIVE STORMWATER IMPROVEMENT PROJECT

The City of Griffin, Georgia (City) is constructing a comprehensive watershed improvement project adjacent to a county park and a middle school. The Kelsey Avenue Ecosystem Restoration project includes 970 feet of stream restoration, a dry detention pond, a bioretention area, and the replacement of two undersized culverts within the stream restoration reach. The design includes native vegetation, floodplain benches, natural channel structures, and properly sized culverts. These discrete improvement projects are being designed and constructed as a single ecosystem restoration project so that the individual elements can be fully integrated into a well-functioning system. The project will improve failing infrastructure, reduce pollutant loads entering an impaired stream, stabilize banks and improve habitat along a degraded stream reach, facilitate fish passage, and provide an improved environment and educational resource for the middle school. The stream restoration, dry detention, and bioretention components are improvement projects recommended in the City's Cabin Creek Watershed Protection Plan (Tetra Tech 2012). They were recommended based on a watershed assessment that identified management needs, and a BMP modeling effort that identified the most cost effective BMP projects for reducing nutrient and TSS loads. The close proximity of these projects to each other and to planned DOT culvert replacements allowed the projects to be integrated to achieve multiple objectives and significant cost savings. The project, which received a 319 grant, supports other initiatives in the watershed, including community revitalization efforts and the City's Green Infrastructure practices.

Behrend, Glen
Manager, Watershed Protection Branch, Georgia Environmental Protection Division, 2 MLK, Jr., Dr. NW, Atlanta, GA 30334

NONPOINT SOURCE CONTROL PRIORITIZATION

Georgia recently completed an update to its State-wide Nonpoint Source Management Plan. An important challenge the plan addresses is the effective targeting of projects and watersheds for nonpoint source pollution reduction efforts. Challenges focus on: 1) Quantifying the extent of septic tank impacts on impairments. There is disagreement among restoration professionals about the efficacy of such controls. What are the most effective practices and with what factors should they be selected? 2) Developing a prioritization scheme for competitive 319 project funding. Georgia EPD has developed a preliminary scheme making use of water quality modeling work, readily available GIS layers such as land use, and socioeconomic data from the Georgia Adopt-a-Stream database. What other factors could be considered? Are there methodology improvements? 3) Developing a prioritization scheme for wetland restoration efforts including both mitigation banking and other restoration efforts to benefit water quality. Georgia EPD has developed a preliminary scheme making use of readily available GIS layers such as land use, and wetland quality and restoration GIS layers developed by the Natural Resources Spatial Analysis Laboratory at the University of Georgia. What other factors could be considered? Are there methodology improvements?

TRACK 3 ABSTRACTS: Tuesday 8:30 – 10:00 AM

Session 3.1 – Press Box: Modeling & Tools I

Kim, D.
Georgia Environmental Protection Division, Watershed Protection Branch, 2 MLK, Jr., Dr. NW, Atlanta, GA 30334

SENSITIVITY OF STATISTICAL THRESHOLDS IN STREAM FLOWS

Instream Flow Protection Threshold (IFPT), such as monthly, annual 7Q10, 30% of annual average daily discharge (AAD), or site-specific conditions per Georgia DNR's Interim Instream Flow Protection Policy, plays an important role in deciding safe yield of water supply facilities including water supply reservoirs. IFPT is calculated using the historic time series data of "undisturbed" streamflow, generally defined as flow from a predominately rural basin minimally affected by direct human activities such as diversions, discharges, and dam regulations. When drought conditions take place in a natural stream network, as experienced in GA in periods including 1985-89, 1998-03, and 2007-08, the value of IFPT can be significantly lowered from extending the period of hydrologic record and including these drought years. Understanding how sensitive the values of IFPT to various low flow conditions should serve both regulated community and decision-makers in the regulatory review process. In this study, systematic analysis on the impact of low flow conditions in various regions of Georgia to the values of IFPT is performed and the results will be presented.

McMahon, Patrick L.
Project Engineer, S&ME Inc., 1413 Topside Road, Louisville, TN 37777

SUPPLEMENTAL TOOLS FOR NATURAL CHANNEL DESIGN

The Natural Channel Design (NCD) approach promoted by the U.S. Environmental Protection Agency and others is strongly dependent on the quantification of the bank full flow rate and associated channel geometries of a given stream. In an urban setting, the determination of bank full flows is often a difficult prospect given the complex nature of urban hydrology, the highly modified morphology and hydrology of urban streams, and the often subjective indicators of bank full stage that can be observed in the field. This presentation will describe the application of continuous simulation modeling (CSM) to supplement bank full flow interpretations on urban streams. CSM involves the application of a continuous record of historical precipitation data to hydrologic and hydraulic models for a given watershed. This technique is useful for the estimation of the frequency of flows of a given magnitude, such as the bank full flow, as well as the evaluation of the potential impact of future hydromodification within a watershed. Another difficulty that arises in the use of NCD in urban settings is the need for reference reach data. Reference reach data are intended in part, as a means to evaluate the long term dynamic stability of the restored reach. Given the degree of anthropogenic impacts to urban watersheds and their receiving streams, a suitable reference reach may be difficult to identify. This presentation describes the application of 2D modeling techniques to supplement the use of any available reference reach data.

Manning, David W. P.[1], Reid Brown[2], Phillip M. Bumpers[3], Bruno Giri,[4] and S. Kyle McKay[5]
Science and Monitoring Committee, Upper Oconee Watershed Network, PO Box 531, Athens, Georgia. USA 30603

LONG-TERM MONITORING DETECTS BIOLOGICAL RESPONSES TO AN ACUTE TOXICITY EVENT IN TRAIL CREEK, ATHENS, GA USA

Watershed urbanization often reduces water quality for aquatic organisms through chronic stress; however, acute stressors such as contaminant spills are also more likely in urbanized than undisturbed watersheds. Here, we examine the acute and long-term effects of a 2010 chemical spill on an urban stream (Trail Creek) in the Upper Oconee Watershed in Athens, Georgia. Two local watersheds are used to contrast acute effects of the spill; a relatively undisturbed stream (Bear Creek) and a highly impacted stream (Carr Creek). Using citizen-science data, we compared quarterly biological and chemical responses (Georgia Adopt-a-Stream's macroinvertebrate community index and conductivity, respectively) from 2001-2014 among these three sites. Bear and Carr Creeks showed relatively stable macroinvertebrate scores during the 13-yr study period. Following the spill in 2010, macroinvertebrate indices in Trail Creek (score in 2010 = 4.5, n = 2) declined below 95% confidence limits for the long-term mean score, representing a 13-yr low (mean score 2001-2014 = 13.2; 95% CI = 6 - 20.8, n = 37). After 2010, macroinvertebrate scores for Trail Creek increased to approximately pre-disturbance levels (score =12.5, n = 11). Paradoxically, during peak impact in 2010, Trail Creek had comparable macroinvertebrate scores to the highly impacted Carr Creek, even though conductivity remained more comparable to the less impacted Bear Creek. These results exemplify the importance of long-term data for detecting watershed responses to and recovery from acute stressor events. Adequate ecological baselines and impact would have been unavailable without these volunteer-collected watershed monitoring data.

opportunities, shorelines, and fish populations (including native shoal bass and recreationally important trout species) as a result of managed river flows. Our objective is to evaluate critical flow requirements for sustaining the ecological and cultural resources at CRNRA while ensuring ample flows to maintain lake and river management requirements. At the completion of our study, we will have 1) synthesized all available studies examining flow and its potential effects on CRNRA, 2) identified gaps in the knowledge base, and 3) developed a comprehensive conceptual model to assess how flow affects the various ecological and cultural resources of the river. Workshops involving academics, natural resource managers, government personnel, and other relevant scientists will help fill in information gaps and develop consensus on critical elements of the river flow regime. Data from the literature and experts will be synthesized into a conceptual model to determine optimum flow regimes for CRNRA while accommodating downstream flows and other stakeholder needs.

Ignatius [1], Amber R. and Todd C. Rasmussen[2]
[1]PhD Candidate Department of Geography, University of Georgia; [2]Professor of Hydrology & Water Resources, Warnell School of Forestry and Natural Resources, University of Georgia

SMALL RESERVOIR IMPACTS ON STREAM WATER QUALITY IN AGRICULTURAL, DEVELOPED, AND FORESTED WATERSHEDS: GEORGIA PIEDMONT, USA

Small reservoirs and ponds have become a prevalent landscape feature throughout the world, and are an important component of headwater hydrology. Tens of thousands of ponds, most less than one hectare, have been constructed over the past century within the United States. While remote-sensing and geographic-mapping technologies assist in quantifying these features, their influence on water quality is less well understood. This study reports the results of a year-long physicochemical study of nine ponds (0.15 - 2.17 ha) within the Oconee and Broad River watersheds in the Georgia Piedmont. Study sites were selected along an urban-to- rural gradient (i.e., three each of developed, agricultural, forested) and were sampled monthly for pond discharge as well as inflow and outflow water-quality parameters (pH, temperature, specific conductivity, dissolved oxygen, turbidity, alkalinity, total phosphorus, total nitrogen, nitrate, ammonium). While not representative of all ponds, this study provides reference conditions for pond water quality and examines downstream impacts within divergent land uses in the Georgia Piedmont.

TRACK 6 ABSTRACTS: Wednesday 1:30 – 3:00 PM

Session 6.5 – Room D: Sustainability and Re-use II

Zern, Brent M.
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EMORY UNIVERSITY'S WATER RECLAMATION SYSTEM EMBODIES THE TRIPLE-BOTTOM LINE

Over the last decade, sustainable water management has become a critical issue for the metro-Atlanta region, which has struggled with drought, legal disputes over supply, and EPA consent decrees on water quality issues. As a pioneer, community leader, and home of the renowned Center for Global Safe Water, Emory University is seeking to comprehensively address local and global water challenges. Wastewater reclamation and reuse helps extend the life cycle of water by turning a waste into a resource. It provides a number of environmental, social, and economic benefits, including cost savings, risk mitigation, pollution abatement, and a reduced dependence on community water infrastructure. Emory's on-campus facility, which relies on complex adaptive ecosystems to break down nutrients and pollutants in water, is one of the most sustainable forms of treatment available. The robust ecological treatment process produces a very high quality effluent that meets all federal, state and local regulations while consuming very little energy relative to traditional wastewater treatment systems. The recycled water will then replace potable water that is being used to heat and cool Emory's buildings as well as flush toilets. Flexible site integration, a compact footprint and a natural aesthetic also enable the facility to complement Emory's campus. This presentation will discuss the strategy behind Emory's water conservation efforts, how wastewater reclamation evolved from those efforts, and the multi-faceted benefits the facility will provide to many community stakeholders. The planning, permitting, design and construction logistics of the project will also be reviewed.

Henderson, Douglas A.
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THE CLEAN WATER ACT: RECENT CITIZEN SUITS FOR UNPERMITTED DISCHARGES

The Clean Water Act includes a "citizen suit" provision, which, under certain circumstances, permits environmental groups, individuals, and other organizations to enforce the Clean Water Act. Before the citizen suit provision can be used, the Act requires that several pre-notice conditions be met. This paper reviews the requirements of the citizen suit provision and analyzes the success of the citizen suit provision in the context of recent cases in Georgia. Based on this review of cases, the citizen suit is alive and well in Georgia, and it may have become the preferred—and most successful—route for clean water enforcement in the USA.

Timpte, Candace
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RAISING AWARENESS OF CRITICAL WATER ISSUES ON THE COLLEGE CAMPUS

Even as water management professionals meet and discuss water issues in Georgia, many actions are hampered by lack of financial and legislative support. Successful community water management flows through education and public awareness of local and global water issues. Three classes at Georgia Gwinnett College engaged in an interdisciplinary and collaborative effort to raise awareness of water issues both in these specific classes and to the campus community at large. Each class required a specific in-depth analysis of some water topic, for example, topics included waterborne diseases, tri-state water wars, and the Three Gorges dam, or students researched and discussed a water management issue with regard to local or global leadership as a major assignment. Students were required to develop an interactive demonstration to present at a campus event to raise water awareness to the greater College campus community. Students engaged other students in activities to raise awareness of the critical issues around water. Activities included discerning bottled water taste from tap water, fishing in garbage strewn oceans, considering water as a potential terrorist target. Through these efforts students gained a greater appreciation and awareness of water issues and the need to conserve and protect water resources. We will present outcomes data from this event and share resources that can be exported to other groups.

Schurman, H. and C. Anderson
Auburn University, Dept. of Forestry and Wildlife Services, Auburn Univ, AL 36849

EVALUATION OF STREAM FLOW AND ASSOCIATED ECOLOGICAL NEEDS AT CHATTAHOOCHEE RIVER NATIONAL RECREATION AREA IN THE CONTEXT OF UPSTREAM DAM OPERATION MODIFICATIONS

The Chattahoochee River National Recreation Area (CRNRA) consists of 48 miles of river and 16 land based park units adjacent to the Chattahoochee River north of Atlanta. CRNRA is an important ecological and cultural resource and provides 70% of metropolitan Atlanta's green space. Situated downriver from Lake Lanier, CRNRA is directly affected by dam release and resulting flow from Buford Dam. Severe flow alterations related to short-term and high-velocity dam releases can reduce ecological and cultural resources provided by rivers and adjacent lands. At CRNRA, numerous reports have documented declines in water quality, recreational

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ESTIMATING WATER TEMPERATURE CHANGES THOUGH HYPORHEIC FLOW PATHS: POSSIBLE IMPLICATIONS FOR STREAM TEMPERATURE MODELING

Stream temperature is an important aspect of water quality that can be affected in many ways. Although solar radiation has the largest influence, heat exchange also occurs at the streambed interface. Hyporheic exchange is the movement of channel water into and out of bed sediments caused mainly by pressure gradients, and while temperature averages will be comparable between hyporheic and surface waters in any stream, overall temperature patterns can be quite different. Although the scale of this exchange may not be large enough to influence total stream temperature, it may serve to increase thermal heterogeneity within the stream and therefore create cool water refuges for some freshwater species. A small-scale laboratory experiment demonstrated that conduction between water and bed sediments occurs very quickly, so as to be near-instantaneous, especially when hyporheic velocities are slow. A model was then developed that uses surface water temperature time series and adjusts them according to a "damping coefficient," calculated based on how long water is in contact with hyporheic sediments. Short hyporheic flow paths may have temperatures patterns that differ very little from channel water, but the longer the travel time through the hyporheic zone, the more changed the water will be. Model results found that if water's travel time within a hyporheic pathway is longer than about four days, the temperature pattern is almost indistinguishable from a line representing the temperature average. These results have implications for within-stream temperature modeling, where hyporheic exchange is often ignored due to its apparent complexity.

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DEVELOPING A HEC-RESSIM MODEL IN THE OCMULGEE-OCONEE-ALTAMAHA RIVER BASIN

In a large and complicated river basin, understanding the delicate balance between hydrologic conditions, water withdrawal and discharges of reclaimed water, and any substantial operations of storage facilities is essential in informing decision-makers in a regulatory review process. In river basins with substantial amount of storage and subsequent flow regulation, reservoir simulation models (e.g. HEC-ResSim) are used to obtain this understanding. The Ocmulgee-Oconee-Altamaha River Basin (OOA Basin) had not had a basin-wide water resources model before the State of Georgia's Regional Water Planning effort in 2009. In this study, a HEC-ResSim model was developed for the OOA Basin where three large Georgia Power hydropower projects are located. This model utilized unimpaired Flow (UIF), recorded water use data, other hydrologic data developed earlier, and project data provided by Georgia Power. Preliminary modeling results showed good verification with observed historical flow and lake elevation. Upon completion, this model can be used for cumulative impact analyses in the OOA Basin.

TRACK 4 ABSTRACTS: Tuesday 8:30 – 10:00 AM

Session 4.1 – Room L

Panel Discussion: Upper Flint River drought resiliency

Since 2011, American Rivers and Flint Riverkeeper have collaborated to assess low streamflow problems in the Piedmont portion of the Flint River basin and opportunities for restoring drought resilience and healthy flows in the basin. Since 2013, American Rivers has convened the Upper Flint River Working Group, a voluntary and collaborative venue for dialogue among water utilities, non-profit organizations and other stakeholders in water resource sustainability in the upper Flint basin. This session will review the low-flow issues in the basin, the 2014 Resiliency Action Plan charting a path to addressing these issues collaboratively, and other topics from the perspectives of both water utility and NGO participants in the Upper Flint River Working Group.

Moderator: Ben Emanuel, *Associate Director of Water Supply, American Rivers*

Panelists:

Ben Emanuel, American Rivers
Lee Pope, Fayette County Water System
Gordon Rogers, Flint Riverkeeper
Mike Thomas, Clayton County Water Authority

in. Visitors who participated in boating placed importance on size; visitors who participated in swimming placed importance on water-quality; and visitors who participated in fishing/bird/nature viewing placed importance on wildlife. Recreation resource managers could benefit from these findings to better understand the needs and expectations of their user groups and manage these attributes accordingly.

Thoms, Tim,
President and Founder, Thoms Trees and Plants, Inc., Fayetteville, Georgia 30215

WATER CONSERVATION EFFICIENCIES OF DROUGHT MANAGEMENT RULE EXEMPTION

An overview of the basis for conservation elements of the GA EPD Existing Outdoor Water Use Rules (Chapter 391-3-30) and the consideration of the exemptions listed therein becoming Drought Mitigation Strategies in the currently proposed EPD Drought Rules. This includes the intent behind the Water Stewardship Legislation of 2010 and the practical implications seen in the landscape and nursery industry to implement the conservation mindset of several of the exemptions since that legislation. Examples of changing plant palettes, Best Management Practices, hand watering emphasis, advances in irrigation capabilities and 30 day rule for new plant installations will be discussed. The emphasis will be on the conservation these exemptions/strategies provide in the overall use of water.

TRACK 8 ABSTRACTS: Wednesday 1:30 – 3:00 PM

Session 8.3 – Press Box: Industrial water management

Cromey, Tyler T.
Research Engineer with Southern Company Services, Inc., 241 Ralph McGill Blvd. NE, Atlanta, GA 30308

AN OVERVIEW OF THE ELECTRIC UTILITY'S WATER RESEARCH CENTER

This presentation provides an overview and status update of the Water Research Center (WRC) at Georgia Power's Plant Bowen. In partnership with the Electric Power Research Institute (EPRI) and the Southern Research Institute (SRI), Georgia Power announced the $12 million WRC in 2011. The WRC was designed to focus on current and anticipated future regulations to the power industry, such as the new EPA Effluent Limitation Guidelines. In addition, the facility focuses on 7 key areas of the Water Energy Nexus: overall power plant water management, wastewater treatment, Zero Liquid Discharge (ZLD) systems, solid landfill management issues created by water technologies, advanced and hybrid cooling systems, moisture recovery, and water issues associated with Carbon Capture and Storage (CCS.) The WRC began testing in 2012 and this presentation outlines how the facility was designed and provides details on what technologies are currently being tested or that will soon be tested at the facility.

Echols, Tim
Commissioner, Georgia Public Service Commission, Bogart, GA

THE CHANGING ENERGY PARADIGM IN GEORGIA AND ITS IMPACT ON OUR WATER RESOURCES

Georgia PSC Commissioner Tim Echols was elected to the Public Service Commission in the general election of November 2010. Tim's campaign focused on consumer protection, clean energy, and accountability. An advocate for solar, nuclear, and alternative energy, he has installed solar hot water heating to his home; purchased a natural gas car and an electric car; he created the Alternative Fueled Vehicle Roadshow, now in its fifth year, that travels Georgia helping cities, businesses and consumers evaluate alternative fuel and see if it will work for them. His priority is helping Georgia be prepared for rising energy prices for diversifying the way our electricity is generated. He has helped secure record amounts of solar and wind for Georgia--without a subsidy. He advocates for more nuclear power and advocates for recycling of nuclear waste. Tim and his wife put their home on a "time of use" rate to further conserve energy as he turns off his AC units during the peak summer cooling period.

Gipson, David
Georgia Environmental Finance Authority, Water Resources Division, 233 Peachtree Street NE, Harris Tower, Suite 900
Atlanta, Georgia 30303

STATUS OF THE GEORGIA CHARGE INITIATIVE

Georgia is currently the number two market in the nation for electric vehicles (EV's) and the number one market for the Nissan Leaf, with over 15,000 EV's registered. It is expected that nearly a quarter of the new car market in the United States will be EV's within a decade. In response to the rapid adoption of EV's in Georgia, the Georgia Environmental Finance Authority (GEFA) launched the Charge Georgia initiative to expand the public's access to charging stations across the state. Charge Georgia is a rebate program designed and administered by GEFA as an incentive to install alternating current (AC) Level II and direct current quick charging (DCQC) electric vehicle charging stations. The rebate is available to Georgia colleges and universities; technical colleges; state agencies and authorities; and cities and counties. Forty-four electric vehicle charging stations will be installed throughout the state as a result of the Charge Georgia program. Eighteen state and local organizations were awarded 33 rebates totaling $278,386 to install the new charging stations. As a result of the Charge Georgia program, GEFA expects an 18 percent increase in public charging infrastructure in Georgia to be installed by July 30, 2015.

Ghimire, Ramesh
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RECREATIONISTS' PREFERENCES FOR FRESHWATER AMENITY CHARACTERISTICS: IMPLICATIONS FROM THE U.S. HOUSEHOLD SURVEY

Studies have analyzed the importance of site amenities in the choice of recreation activities (e.g., Cutter et al. 2007; Paudel et al. 2011). Because of inherent heterogeneity, visitors may have different preferences on site amenities. However, studies have not examined what are the most important site amenities as ranked by visitors and is there any relation between activity participation and how visitors rank these amenity characteristics. Hence, we used U.S. national household survey data to understand visitors' rankings of freshwater amenity characteristics (size, quality, wildlife, and closeness). We employed spectral analysis to identify the most preferred site amenities and rank-ordered and multinomial logit analyses to identify the factors affecting those ranking choices. Results from spectral analyses indicated closeness and size were the two most important amenity characteristics in freshwater recreation. Results from ranked-ordered and multinomial logit analyses suggested visitors placed importance based on activity they participated

TRACK 5 ABSTRACTS: Tuesday 8:30 – 10:00 AM

Session 5.1 – Room F/G: Floodplain Mapping Workshop

GEORGIA FLOODPLAIN MANAGEMENT UNIT: Todd Harris, CFM; Tom Shillock, CFM; and Thomas Tkacs, PE, CFM
Georgia Environmental Protection Division, Watershed Protection Branch, 2 MLK, Jr., Dr. NW, Atlanta, GA 30334

The intent of this training is to provide participants the opportunity to increase their flood risk awareness and knowledge of Flood Risk Map Products; whereby they will be better equipped to plan and implement flood related mitigation strategies. The floodplain mapping workshop session will allow attendees to gain a more complete understand all of the Flood Risk MAP products and the Community Rating System incentives, in order to make better regulatory decisions, and improve hazard mitigation plans and identified mitigation 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 sharable format. The vision for Georgia Flood M.A.P. (Mapping, Planning, & Assessment) 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.

Ways Georgia Communities can benefit from the Georgia Flood Risk management Mapping products:

- The updated risk map study data will provide more accurate information for Georgia communities to help with design decisions when rebuilding after flood disasters, building new structures and infrastructure, and when retrofitting existing structures.
- FIRMs will more accurately depict flood risk information.
- Users will be able to make more precise flood risk determinations.
- Builders and developers can use the updated map data to determine where and how to build structures more safely and how high to build to reduce the risk of flood damage.
- Real estate agents will be better able to inform clients of the risk factors that may affect the property they are buying or selling as well as any flood insurance requirements.
- Insurance agents will know their clients' current flood risk and can provide more informed recommendations regarding flood insurance coverage options.
- Residents and business owners will understand their current flood risk and be able to make better decisions about insuring and protecting their property against floods.
- Community officials will be able to develop a more comprehensive approach to disaster mitigation planning, economic development and emergency response, resulting in a safer Georgia in which to live and work.

TRACK 6 ABSTRACTS: Tuesday 8:30 – 10:00 AM

Session 6.1 – Room R: Habitat and in-stream conditions I

Smith, Nathalie D., Stephen W. Golladay, David W. Hicks, and Brian Clayton
Joseph W. Jones Ecological Research Center, 3988 Jones Center Drive Newton, GA 39870

STREAM HABITAT AND MUSSEL POPULATIONS ADJACENT TO AAWCM SITES IN THE LOWER FLINT RIVER BASIN

Freshwater mussel communities of the Flint River Basin (FRB) in southwestern Georgia are among the richest mussel assemblages in the southeastern United States. Declines in these populations appear to be associated with periodic droughts along with increasing withdrawal for irrigation and other uses. Concerns about stream health and recognition of the need to manage water efficiently led to the development of Advanced Agricultural Water Conservation Measures (AAWCM). In 2012 and 2014, we examined the effects of AAWCM installed in operational settings on in stream habitat, flow, and mussel populations in two watersheds of the lower Flint River Basin: Spring Creek and Ichawaynochaway Creek. Mussel abundance was relatively low in the sites sampled during the 2012 field season (in comparison to historic 1999/2001 surveys). In 2014, Spring Creek mussel abundance increased at sites adjacent to AAWCM farms and at two of three downstream locations. In 2014, Ichawaynochaway Creek mussel abundance remained constant or decreased at all sites. Historic surveys noted 2-11 mussel species at sampling sites. In 2012, 1-10 species were noted and in 2014, 0-8 species were noted. Abundance also declined from 8-1028 individuals per 100m reach to 0-629 individuals. Endangered species were rare at all sites and surveys. Rapid declines or extirpation of species at many sites occurred during the 1999-2001 drought, followed by an ongoing decline of surviving individuals through 2014. It appears that long-term declines in freshwater mussels continue in the tributaries of the lower Flint River.

McCormick, Paul V.
Scientist, Joseph W. Jones Ecological Research Center, 3988 Jones Center Drive Newton, GA 39870

EFFECTS OF REDUCED SUMMERTIME STREAM FLOWS ON INSTREAM HABITAT IN THE LOWER FLINT RIVER BASIN, GEORGIA, USA

The Lower Flint River and its tributaries in southwestern Georgia have experienced diminished summertime flows in recent decades in response to increased water use for agricultural irrigation. We are conducting an instream flow assessment in one tributary watershed to predict effects of reduced stream discharge on the quantity and condition of instream habitat. Substrate elevation profiles were measured at several locations for two ecologically important habitats that are particularly susceptible to dewatering: shoals and coarse woody material. Analysis of these profiles in conjunction with water elevation-discharge relationships and historic discharge records dating back to the 1930s showed that reductions in summertime minimum flows below historic (pre-irrigation era) levels causes substantial habitat loss from dewatering; for example, most shoal habitat remained wet during extreme droughts in the past but dries under similar climate conditions today. Excessive shoal drying may also create temporary barriers to fish passage as thalweg depth can decrease to 15 cm or less. Habitat that remains inundated experiences reduced current velocity and increased temperature and periphyton cover. Studies are underway to assess biological responses to this habitat loss and change.

Waters, Matthew N.
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ALTERATIONS TO BIOGEOCHEMICAL PROCESSES AND SEDIMENT TRANSPORT BY THE INVASIVE MACROPHYTE, *HYDRILLA VERTICALLATA*, IN LAKE SEMINOLE

Invasive macrophytes are a particular management target in reservoir systems because they can outperform native aquatic plants, obstruct boating areas, and modify ecosystem services. Here, we use paleo-limnological techniques and sediment trap collections to establish the effects of the growth and die-off of a dominant (55% of SA) invasive macrophyte, *Hydrilla verticallata*, on biogeochemical processes in a large, shallow reservoir, Lake Seminole, GA, USA (152 km2, mean depth = 3 m). This system offers a unique hydrology with the mixing of the Chattahoochee River's industrialized watershed with the agricultural watershed of the Flint River. Our results show that the sediment characteristics reflect the Chattahoochee-side historically and the Flint-side seasonally. Hydrilla presence serves as a bio-filtration mechanism increasing material deposition to the benthic environment. Likewise, organic matter deposition in the dam area indicates that decaying Hydrilla is a source of organic carbon for downstream areas, but this organic carbon is temporarily deposited, rapidly removed, or degraded. These results establish the need to better understand carbon dynamics and biogeochemical processes related to invasive macrophytes prior to eradication monitoring efforts.

Cowie, G.
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STATE DIRECT INVESTMENT GROUND WATER PROJECTS

The Governor's Water Supply Program was initiated by Governor Deal in 2011 to assist in developing new sources of water supply to meet forecasted water demand. The program furthers the state's previous commitment to loan funds to local governments and utilities for water supply projects. In addition, it provides state direct investment (SDI) in water supply projects that are of state and regional significance but cannot or will not be funded by traditional water suppliers in Georgia. SDI funds are currently being used for two major groundwater projects. The first is an aquifer storage and recovery (ASR) demonstration project in Baker County. In this project, a well installed in the shallow Floridan aquifer will provide recharge water to an ASR well installed across the deeper Claiborne/Clayton aquifers. The demonstration project will test the feasibility of ASR, providing critical data on the potential for ASR's to help meet some of southwest Georgia's water needs. The second project is a deep well demonstration project on Tybee Island. This project is exploring technical, environmental, and cost implications of shifting some of the current use of the Floridan aquifer to the Cretaceous aquifer, thus helping to address issues associated with coastal salt water intrusion in the Floridan aquifer. The project will evaluate whether the Cretaceous aquifer can serve as a reliable drinking water supply alternative to the Floridan aquifer for communities on the Georgia coast. This presentation will provide an overview, status update, and description of the regional water management context for these projects.

Liang, Hailian
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DEVELOPING UNIMPAIRED FLOW (UIF) DATA IN THE SAVANNAH RIVER BASIN

Unimpaired flow (UIF) data are developed for the period of 2009 – 2013 in Savannah River basin. The basic hydrologic inputs include stream flow data, reservoir operational and meteorological data, and water use data. Reservoir precipitation data are developed using Inverse Distance Weight method and evaporation data are developed by combining the long-term average value and the potential evapotranspiration using the Hamon method. To reduce the uncertainty in the pump-back data for pump-back reservoir systems, the monthly total amounts of the impaired local incremental flow are redistributed into daily by the daily patterns that are constructed from the nearby tributary stream flow data. The verification shows the reservoir elevations computed from UIF are close to observed ones.

TRACK 4 ABSTRACTS: Wednesday 1:30 – 3:00 PM

Session 4.5 – Room Q: Conservation and Augmentation

Roberts, M.
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GEFA CONSERVATION INITIATIVES

GEFA administers both the Clean Water State Revolving Fund (CWSRF) and the Georgia Land Conservation Program. Loans and grants can be made through these programs to local governments and accredited land trusts to preserve Georgia's land resources and protect the quality of our state's waters. GEFA can offer loans for a variety of energy production and energy efficiency projects. Through the Drinking Water State Revolving Fund (DWSRF) and the CWSRF, GEFA is able to finance solar installations at water and wastewater treatment facilities. For many municipalities, the power bill is the largest single cost to the government. By producing energy through solar installations or other innovative projects, energy costs are reduced. Energy consumption by a utility is greatly reduced through sewer rehabilitation, and GEFA has extensive experience financing this type of project for municipalities. GEFA provides low-interest financing for local government water utilities to promote and sustain a culture of water conservation in the state of Georgia. Several of GEFA's loan programs can be used to finance a range of water conservation projects in the areas of water loss and end-use water efficiency. Water loss projects addressing address "real" losses include pipe replacement and other leak abatement activities. "Apparent" losses, such as metering inaccuracies and water theft are addressed through projects such as meter replacement and installation of automated metering and billing systems. End-use water efficiency projects include upgrading water fixtures (e.g., toilets, faucets, irrigation systems, etc.), encouraging water conservation by utility customers, and water reuse projects.

Regan, J.
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RESERVOIR SAFE YIELD SENSITIVITY ANALYSIS

This paper investigates the sensitivity of reservoir safe yield for various generic locations by performing sensitivity tests for all the parameters used in a typical reservoir yield simulation. A yield sensitivity tool will be developed using VBA and Excel with geographic and temporal input flexibility. The specific parameters that will be tested include the hydrologic time-series, minimum flow regime, pump capacity and reservoir net evaporation. Input hydrologic data includes the unimpaired flows (UIFs) and USGS Gage data. Various random locations in Georgia will be used to evaluate commonalities and differences with respected yields and their sensitivities. Results should indicate that certain input parameters can greatly affect the yield while others have very little effect. Finally this tool can be used as a starting platform for more detailed safe yield estimations of existing and potential reservoirs.

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WHAT GEORGIA CAN LEARN FROM ASR IN FLORIDA

Preferential groundwater flow through fractures has been documented in karst and non-karst aquifer systems, including regional aquifer systems of Florida and Georgia. This preferential flow is induced by groundwater withdrawals and aquifer injections of fluids. Most recently, evidence of preferential groundwater flow through fractures has been associated with aquifer injections of sewage effluent in south Florida and subsequent discharge of nitrogen contaminants in coastal waters associated with the Florida Keys, where harmful algal blooms and coral decline and death occurred. Large-scale aquifer injections and withdrawals as "aquifer storage and recovery" ("ASR") were proposed for south Florida by the U.S. Army Corps of Engineers' 2014 report. That report did not consider the dense network of fractures that were mapped by the Florida Department of Transportation's Remote Sensing office in 1971 or other mapped networks that have been published. A closer look at previously published ASR reports from Florida raises questions regarding claims of both "storage" and "recovery" and the role of fractures in these extremely low rates of actual recovery. The current work reports on our mapping and geospatial analysis of fracture distribution, extent and proximity to injection and withdrawal wells in southern Florida, including considerations regarding preferential flow of groundwater contaminants. The coastal plain of Georgia is underlain by the same regional karst Floridan aquifer system as Florida and could be expected to have similar ineffective ASR results as those documented in Florida. Mapped fracture networks in Georgia should be a prerequisite for consideration of ASR in Georgia.

Holt[1], Courtney R., Don Pfitzer[2], Chris Scalley[2], Broughton A. Caldwell[3], Paula I. Capece[4], Darold P. Batzer[5]
[1]Ph.D. Candidate, Department of Entomology, University of Georgia, Athens, GA; [2]Chattahoochee Coldwater Fishery Foundation, 710 Riverside Rd, Roswell, Georgia 30075; [3]Florida State Collection of Arthropods, Division of Plant Industry, P.O. Box 147100, Gainesville, Florida 32614; [4]Chattahoochee River National Recreation Area, 1978 Island Ford Pkwy, Sandy Springs, Georgia 30350; [5]Department of Entomology, University of Georgia, 413 Biological Sciences Bldg., Athens, Georgia 30602

MACROINVERTEBRATE TRENDS OVER 11 YEARS IN THE CHATTAHOOCHEE RIVER BELOW BUFORD DAM

The Chattahoochee River is one of the most important waterways in Georgia from economic, recreation, and biodiversity standpoints. However, research on the macroinvertebrate diversity has only recently begun. Since 2001, a citizen-led effort has been collecting quarterly macroinvertebrate samples in a 65-km stretch of the Chattahoochee River below Buford Dam within the Chattahoochee River National Recreation Area (CRNRA). The objective of this paper is to present a detailed taxa list from this long-term study. Samples were collected from 2001-2011 on a quarterly basis from six separate sites within the study area using two sampling mechanisms (Hester-Dendy plates and a Surber sampler). We present a complete taxa list of the study area along with information regarding each taxon's specific location within the study area and presence/absence of each taxon during each season. As one of the most urbanized river corridors in Georgia, long-term, continuous monitoring of the macroinvertebrate community in the CRNRA is imperative to maintaining regional biodiversity and a healthy fishery. In addition, macroinvertebrate diversity studies of large rivers in the Georgia Piedmont are rare, and this study contributes a significant amount of data to the study of large river ecology in Georgia.

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A MATHEMATICAL MODEL OF APALACHICOLA BAY SALINITY AND ITS EFFECTS ON OYSTER HARVESTING

Biological productivity in estuaries is strongly influenced by freshwater inflows that provide nutrients and determine salinity variations; in particular, oyster growth and mortality are directly related to salinity. The salinity in Apalachicola Bay, Florida, is heavily influenced by flows in the Apalachicola River, the lower part of the Apalachicola-Chattahoochee-Flint (ACF) river basin. The ACF is shared by Alabama, Florida, and Georgia, and is subject to on-going negotiations on competing water demands that may result in significant operational and flow regime changes. Apalachicola Bay is the most important ACF basin ecosystem. The bay is hydrodynamically complex. The river flow enters perpendicular to the main estuary axis as a surface buoyant jet. Its subsequent mixing in the bay is influenced by periodic tidal currents that are primarily diurnal and semi-diurnal. Winds, particularly those blowing along the long estuary axis, can significantly affect circulation and volume fluxes and therefore salinity and water quality. Although the bay is very shallow it can have strong vertical density stratification. The relative magnitudes of the various driving forces, wind, tide, and freshwater inflow, vary, resulting in significant temporal and spatial (i.e., horizontal and vertical) salinity variations. A three-dimensional hydrodynamic model of the bay was set up, calibrated and validated using Delft3D and existing data. The purpose of the model is to assess the impacts of upstream regulation and climatic changes on salinity. The modeling effort resulted in realistic simulations of the major estuary major hydrodynamic characteristics. The modeled water levels are in very good agreement in phase and magnitude with measured values at all available recording stations. Salinity results also follow reasonably well the general observational trends. Long term salinity variations were assessed through a 16-year simulation experiment, clearly showing the significant influence of river flow on salinity. Salinity in oyster bar regions exhibits considerable variability over intra-annual time scales, but its interannual and long term statistical distribution is consistent with previously identified ranges favorable to oysters. Salinity-based indicators for environmental change and oyster sustainability are proposed and used to identify the existence of possible trends. Such trends are indeed detected, with salinity conditions gradually shifting away from those favorable to oysters. The article discusses the likely sources contributing to these trends and makes adaptation recommendations.

TRACK 1 ABSTRACTS: Tuesday 1:30 – 3:00 PM

Session 1.2 – Masters Hall: Climate change and water resources

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BASEFLOW RESPONSE TO CLIMATE VARIABILITY INDUCED DROUGHTS IN THE APALACHICOLA-CHATTAHOOCHEE-FLINT RIVER BASIN

Climate variability induced droughts have been the source of the Tri-State Water Wars in the Southeastern United States. One of the major issues related to the conflict is the reduction in baseflow levels in the Flint River during droughts. This study was conducted to understand and quantify the impacts of climate variability cycles on baseflow levels in the Flint River. The individual and coupled impacts of the El Nino-Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), Atlantic Multidecadal Oscillation (AMO), and North Atlantic Oscillation (NAO) on baseflow were studied and quantified. A non-parametric Joint Rank Fit (JRFit) procedure was used to test the interaction between ENSO phase baseflows with PDO, AMO, and NAO phase baseflows. Further, simple-main effect comparisons were also performed using the JRFit model to estimate significant difference between the positive and negative phase baseflows of PDO, AMO and NAO associated with El Nino or La Nina phases. The results indicate that the phases of ENSO, AMO and NAO significantly affect baseflows in the Flint River. Interaction tests showed that the PDO and AMO phases modulate ENSO phase baseflows. La Nina associated with positive phase of PDO and AMO resulted in greater decrease in baseflow levels of approximately 30% and 35% respectively. However, La Nina associated with negative phase of AMO showed above normal baseflows. Results obtained from this study can be used by water managers in issuing severity-based water restrictions in the region.

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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. Drought management is the most critical piece of a sustainable water management plan that has eluded the region for more than two decades. 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 (Buford, West Point, George, Montezuma, Albany, Bainbridge, [Bfrd+WP], [Bfrd+WP+Grg], [Flint+Below Grg], ACF at Chattahoochee); Mean Areal Precipitation (MAP) over the previous 10 sub-basins; Standard Precipitation Index (SPI) over same 10 sub-basins; Palmer Drought Severity Index (10 sub-basins); Palmer Modified Drought Index (10 sub-basins); Palmer Z-Index (10 subbasins); Palmer Hydrologic Drought Severity Index (10 sub-basins); Total Soil Moisture – GWRI Watershed Model (10 sub-basins); Lower Soil Moisture – GWRI Watershed Model (10 sub-basins). Our findings show that all ACF sub-basins exhibit good forecast skill throughout the year and with sufficient lead time. Index variables with high explanatory value include: previous UIFs, soil moisture states (generated by the GWRI watershed model), and PDSI. Regarding drought management, assessments with coupled forecast-management schemes demonstrate that the use of adaptive forecast-management procedures improves reservoir operations and meets basin demands more reliably. Such improvements can support better management of lake levels, and/or higher environmental and navigation flows, and/or higher dependable power generation hours, and/or better management of consumptive uses without adverse impacts on other stakeholder interests. However, realizing these improvements requires (1) operationalization and usage of adaptive reservoir management procedures (that explicitly incorporate forecasts into operations), and (2) stakeholder agreement on equitable benefit sharing.

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EFFECTS OF CLIMATE SIGNALS ON FRESHWATER DELIVERY TO FOUR GEORGIA RIVERINE ESTUARIES

Freshwater delivery helps to determine estuarine characteristics and may be influenced by large-scale climate oscillations. Variability in precipitation and river discharge to the Ogeechee, Satilla, and St. Mary's River estuaries (GA) was examined in relation to several climate signal indices and compared to earlier results for the Altamaha River estuary. Empirical orthogonal function (EOF) analysis

ic carbon, extensive floodplains, variable discharge, and predominantly sandy substrate. These factors result in a set of distinct challenges to a fixed monitoring protocol that will be discussed. Monitoring ranges from assessments of potential stressors of the river to fish abundance and diversity measures. Fishes are being monitored quarterly at six sites, three above a textile processing plant discharging treated waste into the river and three below the textile plant. Fishes are sampled at each site in single-pass electrofishing transects. We will report fish assemblage metrics (richness, diversity, IBI) from the first quarterly samples.

Colon-Gaud, Checo
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BENTHIC MACROINVERTEBRATES COLONIZING LEAF PACKS IN THE OGEECHEE RIVER NEAR ROCKY FORD: CONTRASTING ASSEMBLAGES BETWEEN DROUGHT VS. WET YEARS

During the Fall of 2012 approximately 56% of the state of Georgia experienced moderate-to-exceptional drought conditions. During this time, the lower Ogeechee River exhibited abnormally low river stages and reduced flow conditions. During the same time period the following year (2013), river stages and discharge returned to average conditions in part due to a wet summer season. We used packs filled with oak (Quercus sp.) or maple (Acer sp.) leaves to collect colonizing invertebrates from September to November of 2012 and 2013 as a means for assessing the health and condition of a reach of the Ogeechee River near Rocky Ford (Screven county). We found significant differences in macroinvertebrate assemblages between study years ($p=0.001$). However, there were no differences in colonizing communities between leaf types ($p=0.05$). Pleurocerid snails and non-predatory chironomids (85% combined) contributed most to macroinvertebrate assemblages in 2012, while non-predatory chironomids, longhorned caddisflies, and flat-headed mayflies (83%) contributed most to assemblages in 2013. Macroinvertebrate functional feeding group composition also differed between study years with scraper-grazers (61%) and collector-gatherers (28%) being dominant in 2012 and collector-gatherers (79%) as the major contributors in 2013, suggesting differences in organic matter resources from year to year. Biotic index estimates (i.e., NCBI) yielded a slight increase from 2012 (4.81 ± 0.75) to 2013 (5.43 ± 0.61) indicating fairly substantial organic pollution likely at the site. However, %EPT taxa increased from 10% to 33% from 2012-2013. Our study supports a need for multi-year, continuous monitoring to accurately assess the health and biotic integrity of these systems.

TRACK 7 ABSTRACTS: Wednesday 1:30 – 3:00 PM

Session 7.3 – Room F/G: Ogeechee River

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PRELIMINARY ASSESSMENT OF ORGANIC MATERIAL FLUX IN THE OGEECHEE RIVER SYSTEM: A LAGRANGIAN PERSPECTIVE

In 2014, we developed a Lagrangian sampling (sampling according to travel time) program for the Ogeechee River to focus on the fate and transport of organic material in this system. We sampled the river at five locations on four separate sampling excursions from June to September and analyzed the water for total organic carbon (TOC) and dissolved organic carbon (DOC) and ash-free dry mass (AFDM). Results showed that TOC and DOC concentrations were equal 75% of the time. All samples with higher TOC occurred during the June sampling event only which coincided with the falling limb of an extended flood event within the basin. The flux of organic material increased steadily in the downstream direction for the June and September samplings, remained relatively steady during the August sampling, and increased significantly from River Mile 204 to River Mile 119, then decreased from River Mile 119 to River Mile 80 during the July sampling. Mass flux rate of the July sampling was nearly 5 times higher than all other sample excursions; this trend was most likely due to considerably higher flows during that time period; decreased flux during the last legs of this sample excursion were likely due to organic matter consumption in the floodplain. Compared with a Lagrangian sampling event in the Savannah River that coincided with the June sampling event in the Ogeechee, the Savannah River transported 14 times more DOC/s than the Ogeechee at four sites of equivalent distance from the ocean.

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SUMMARY AND COMPARISON OF CONTINUOUS SONDE DATA FROM THE OGEECHEE AND SAVANNAH RIVER BASINS

Continuous sonde data (temperature, pH, dissolved oxygen, and specific conductivity) is important for providing a baseline of parameters that help provide a short-term and long-term perspective of water quality conditions. In this study, we provide a summary of results on the first six months of sonde data from five permanent stations in the Ogeechee River Basin that span from River Mile 162 to RM 27. We also compare these data to continuous sonde data collected during the same time period from five locations within the Savannah River Basin that span from River Mile 214 to River Mile 27. Results show significant differences between these two adjacent river basins which likely lead to observed spatial differences in biological species composition and ecosystem processes.

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EVALUATION OF OGEECHEE RIVER WATER USING ZEBRAFISH AS A BIOMONITORING TOOL

Freshwater ecosystems are constantly subjected to environmental, natural or anthropogenic stressors that can have broad and lasting implications on the aquatic community such as abnormal developmental effects and mass kills. The ability to rapidly assess the health of a freshwater ecosystem using biomonitoring tools provides an early-stage opportunity to properly manage a potentially detrimental stressor. Recently, a major fish and organism kill caused by various environmental stressors, occurred in a local freshwater system, the Ogeechee River. This study evaluates the effects of stressors on Ogeechee river streams with acceptable and impaired GA EPD water quality standards using zebrafish larvae as biomonitoring tool. We have identified four streams within the Ogeechee River that fall under category 1-4: all acceptable levels, excess fecal coliforms counts, excess mercury levels, and impaired biological integrity. Briefly, we collected surface water and sediments samples from 5 different Ogeechee river sites and exposed zebrafish larvae in the samples for 5 continuous days. The larvae were observed everyday for critical endpoints such as development, hatching, mortality, morphology, heart rate etc. After 5 days, total RNA was extracted from the larvae and specific biomarker gene expressions were analyzed using Quantitative PCR. Our study has identified that sediments induce higher toxicity than surface water samples. Further, samples from site with both increased fecal coliform counts and mercury levels produce highest toxicity to zebrafish larvae as expected. This early detection of stressors and understanding the subsequent effects will contribute to a growing knowledge base in making appropriate system management decisions.

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POST FISH-KILL MONITORING ON THE OGEECHEE RIVER

In May of 2011, the Ogeechee River was the site of the largest fish kill in Georgia's history. In the wake of this event Georgia Southern University initiated a three-year monitoring project in June 2014 to better understand the ecology of the Ogeechee River in the coastal plain. The Ogeechee River basin is a blackwater system characterized by low gradient, low conductivity, high dissolved organ-

showed that monthly precipitation can be largely described by a temporal signal that is spatially uniform across each watershed (EOF 1), modulated by spatial patterns along (EOF 2) and across (EOF 3) the long axes of the watersheds, although analysis of three EOFs was not supported in all watersheds. The time series (principal components, PCs) associated with each precipitation EOF was best correlated with a different climate signal, and the dominance of climate signals changed seasonally: PC 1 with the Bermuda High Index in summer-fall, and PC 1 and PC 2 with El Nino/ Southern Oscillation in fall-winter. Atlantic Multidecadal Oscillation (AMO) correlation patterns differed across watersheds, in part due to data availability for discerning spatial patterns. In the Altamaha, the AMO was correlated with PC 3, altering the seasonality of freshwater delivery. In the other watersheds, PC 3 could not be evaluated but AMO was correlated with PC 1 in winter. No correlations were found with the North Atlantic Oscillation. Correlations between climate signals and river discharge mirrored those with precipitation, with additional lags. Seasonal switching of climate signal dominance could lead to differential propagation of climate signals through ecosystems depending on critical seasons for keystone species.

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MONTHLY WATER BUDGETS AT PANOLA MOUNTAIN RESEARCH WATERSHED, GEORGIA WITH SOME IMPLICATIONS FOR CLIMATIC CHANGE

Seasonal climatic variations have a pronounced effect on watershed water budgets in Georgia; in winter, a large portion of precipitation recharges ground-water while in summer, much is evapotranspired. Monthly water budgets were estimated at Panola Mountain Research Watershed, a small 41-hectare forested watershed near Atlanta, Georgia, from 1985 through 2011 to quantify the effects of climatic variability. A watershed storage-base flow relation was developed by combining a stream base flow-recession analysis with a watershed water budget. Through this, storage was calculated from base flow and actual evapotranspiration (ET) was estimated by differences in the remaining components of the water budget. Actual ET averaged 40 mm/month during the dormant season (November – February) and 88 mm/month during the growing season (April – September). Average monthly storage increased by 27 mm/month during the dormant season and declined by 14 mm/month during the growing season. Variation in baseflow storage ranged 430 mm over the study period, with an average interannual range of 247 mm. Annual water yields—the proportion of stream runoff to precipitation —ranged from 9.7–46%. Water limited conditions for vegetative growth were identified by periods when potential ET greatly exceeded actual ET and typically occurred during the late summer months when precipitation and storage were both low. Variability in precipitation and watershed storage led to large interannual fluctuations in water budgets, and demonstrate possible impacts of climatic changes in the seasonal quantity of precipitation and the frequency and duration of droughts on water budgets and water availability.

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TEMPORAL CHANGES IN DROUGHT IN GEORGIA: IMPLICATIONS FOR AGRICULTURE AND WATER SUPPLY IN THE FUTURE

In the last two decades, Georgia has gone through three major droughts as well as several minor dry spells. By comparison, drought in the state was almost nonexistent during the period from 1958 to 1980, although earlier decades included some of the worst droughts in Georgia's recorded history. Drought is caused by a number of interlocking factors, including the lack of tropical storms, La Nina occurrence, and increased evaporation from warmer temperatures. The impacts of each recent drought caused both physical and political changes that have affected Georgia's agriculture as well as its ability to supply water to its citizens. Changes in future climate due to global warming suggest a likely increase in drought conditions over time due to both increasing evaporation and evapotranspiration in higher temperatures and more high intensity rainfalls with longer dry periods between rain events. Water managers and agricultural producers will need to adapt to these conditions to supply sufficient water to meet the needs of their communities in future decades.

TRACK 2 ABSTRACTS: Tuesday 1:30 – 3:00 PM

Session 2.2 – Room K

Panel Discussion: Green Infrastructure

THE GREENING OF GEORGIA: LATEST INNOVATIONS IN GREEN INFRASTRUCTURE

A diverse panel of academicians, government staff and nongovernmental advocates will share the latest news about the "greening of Georgia". Jon Calabria and Alfie Vick at the UGA College of Environment and Design will discuss recent national and state shifts in stormwater management that emphasize runoff reduction using green infrastructure. They will present design details and performance expectations of recommended green infrastructure practices. Cory Rayburn from the City of Atlanta's Department of Watershed Management will talk about the approach Atlanta has taken to promote green infrastructure through city ordinances and other policies. Polly Sattler from Hartsfield/Jackson Atlanta Airport and Ben Emanuel from American Rivers will discuss efforts to restore water quality and hydrology in the Flint River headwaters through the implementation of green stormwater infrastructure at the world's busiest airport. They will present the recently completed Land Suitability Analysis for Green Infrastructure Stormwater Management at the Hartsfield-Jackson Atlanta International Airport which provides recommendations for implementation of green infrastructure at the airport and provides a framework for incorporating green infrastructure when planning new airport projects.

Moderator: TBA

Panel Guests:

Alfie Vick, *UGA College of Environment and Design*

Jon Calabria, *UGA College of Environment and Design*

Cory Rayburn, *City of Atlanta, Dept. of Watershed Management*

Ben Emanuel, *Associate Director of Water Supply, American Rivers*

Polly Sattler, *Hartsfield-Jackson Atlanta International Airport*

Gordon, Debbie W.
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RECHARGE ESTIMATES AND BASELINE HYDROLOGIC DATA FOR THE SURFICIAL AQUIFER, JEKYLL ISLAND, GEORGIA

The U.S. Geological Survey, in cooperation with the Jekyll Island Authority, conducted a study from October of 2012 through December 2013, investigating shallow groundwater flow, recharge, and water-quality on Jekyll Island. Twenty-six shallow, surficial-aquifer wells were installed to monitor fluctuations in water levels. Water-level and water-quality data were collected from a network of existing and newly constructed wells, continuous groundwater-level data, stage levels in two island ponds, and climatic data from three nearby sites were compiled. Seasonal groundwater recharge/discharge was estimated using these data. Rainfall during 2013 was approximately 5 inches above average which contributed to up to two feet of water-level rise in the surficial aquifer. Potentiometric-surface maps suggest that groundwater in the surficial aquifer flows from recharge areas primarily in the center of the island towards discharge areas at the coastline, the Jekyll River, and ponds on the island. Average estimated daily volume of loss (negative) or recharge (positive) to the surficial aquifer ranged from about −5.2 to 9.3 million gallons. The difference in the volume of available water in the surficial aquifer between wetter (November 8, 2012) and drier (April 17, 2013) periods was approximately 387,000 gallons per day. Water samples were collected from the surficial aquifer and analyzed for chlorides, total dissolved solids, and field parameters. Chloride concentrations ranged from 17 to 555 milligrams per liter. The relationship between chloride and specific conductance suggests that specific conductance could be used as a reasonable surrogate for chloride to monitor possible degradation of the fresh-water resources.

McDowell[1], Robin J. and Kathleen Rugel[2, 3]
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COMPARING INSTREAM AND UPLAND BEDROCK FRACTURING AND STREAM REACH ORIENTATION TO PREDICT GROUNDWATER/SURFACE WATER INTERACTION IN THE LOWER FLINT RIVER BASIN

To manage finite freshwater resources in the karst terrain of southwest Georgia, it is important to determine the degree of connectivity between surface water and groundwater. To do so, we compared instream and upland joint patterns, stream reach orientation, and stream reach chemistry in and adjacent to the Lower Flint River Basin (LFRB) to determine if these factors could predict groundwater/surface water interaction on a landscape scale. Stream reach orientations (n=37,134) in the LFRB show a strong N6W trend with lesser trends at ~N40W, and N85E. Bedrock joints measured in limestone exposures in the channel of Ichawaynochaway Creek (n=125) generally mimic the dominant N-S jointing trend and contain subsidiary sets at approximately ~N27W and N20E. One set of joints measured in a limestone near the divide between the LFRB and the Chattahoochee River Basin show a strong N36W orientation. Upland fracture patterns measured in Cretaceous and Miocene sandstones, and the Cretaceous Riley Formation show a significant regional change in fracture orientation, from approximately N50E east of the LFRB, to progressively more northerly trends closer to the LFRB. This trend is consistent with previous interpretations of regional tectonic stress regimes, and may reflect a change from Atlantic to Gulf-directed subsidence with a "hinge line" in the LFRB. Enhanced groundwater/surface water interaction (as increased specific conductance) is 33% more common in Ichawaynochaway Creek in reaches where the stream is oriented ~N40W. Interaction of these reaches with an orthogonal pattern (~N40E) may also be enhancing connectivity in the western and northern portions of the LFRB. Trends in upland fracture and stream orientation in the western and southwestern portions of the LFRB suggest connectivity may follow different patterns.

TRACK 2 ABSTRACTS: Wednesday 1:30 – 3:00 PM

Session 2.5 – Room R: Groundwater

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USE OF METERED IRRIGATION WATER USE AND LANDSAT IMAGERY TO ESTIMATE IRRIGATION RATES FOR SURFACE-WATER–GROUNDWATER AVAILABILITY MODELING IN THE APALACHICOLA-CHATTAHOOCHEE-FLINT RIVER BASIN, SOUTHWESTERN GEORGIA

Irrigated acres defined using Landsat imagery can be linked to metered irrigation in the southwestern Georgia part of the Apalachicola-Chattahoochee-Flint River Basin providing valuable ground truthing of inputs to water-availability models such as those used by the U.S. Geological Survey for the National Water Census. Since 2008, irrigation meter data have been provided to the USGS by the Georgia Soil and Water Conservation Commission under a cooperative agreement. Neither meter data nor Landsat imagery alone provides complete information on spatial and temporal variations of irrigation during the growing season. Robust geospatial modeling methods were used to first estimate irrigation depth and percent of total annual irrigation from a monthly network of 60-90 telemetry sites, and then estimate monthly percent of total irrigation at the nearly 4,000 annually read meter sites. Geospatial models of monthly irrigation depth based on annual meter data were validated by the high spatial correlation of monthly irrigation depth associated with the monthly percent models of telemetry; the latter telemetry models were applied to the annual meter data. Assignment of monthly irrigation depths to specific fields cannot be accomplished without ground truthing of actual wetted fields provided by Landsat imagery. The 16-day interval between successive Landsat images of the basin limits the imagery to identify all irrigation and wetted fields during the growing season; thus, a hybrid approach consisting of geospatial models of irrigation depth and remotely sensed evidence of irrigated acres using Landsat imagery can prove useful for developing monthly irrigation rates for input to water-availability models.

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ESTIMATING SOIL AND GROUNDWATER ATTENUATION FACTORS FOR NITROGEN FROM ONSITE WASTEWATER SYSTEMS IN THE CHESAPEAKE BAY TMDL

For the Chesapeake Bay TMDL, EPA assumes a percent reduction in the nitrogen (N) load within the drainfield of an onsite wastewater treatment system (OWTS) and between the drainfield and the receiving water body. These are referred to as "attenuation factors" and we will refer to these as the soil attenuation factor and the groundwater attenuation factor, respectively. The current assumption is that the drainfield attenuation factor is 20% and the groundwater attenuation factor is 60% for an overall attenuation factor of 68%. An expert panel has been established to refine these values and see if different values for major physiographic regions in the Chesapeake Bay watershed are appropriate by the summer of 2015. This paper will describe the progress the panel has made.

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GROUNDWATER SUSTAINABILITY IN THE AUGUSTA-RICHMOND COUNTY AREA, EASTERN GEORGIA

The U.S. Geological Survey, in cooperation with Augusta Utilities, is assessing groundwater sustainability of the Cretaceous aquifer system in the Augusta-Richmond County area, Georgia, where three well fields are operating. Unconsolidated sediments including the Cretaceous aquifers thicken southward at a rate of roughly 30 feet per mile from the Fall Line that trends east-west through Augusta. Well Fields 1, 2, and 3 are located about 3, 7, and 11 miles south of the Fall Line, respectively. Groundwater levels have been monitored for Augusta Utilities since 2007 using real-time continuous-recorders at four wells and annual synoptic water-level measurements at 56 wells. In addition, the Georgia Environmental Protection Division (GaEPD) has been monitoring groundwater levels at two wells located in Richmond County for a longer time period than since 2007. One well, 15 miles south of the Fall Line, provides a real-time continuous record of groundwater levels. Another well, 7 miles south of the Fall Line, contains a continuous-recorder, in which water-level data are downloaded about three times per year. Up-to-date groundwater levels are available on the groundwaterwatch.usgs.gov website at http://groundwaterwatch.usgs.gov/GAR/StateMaps/GAR.html. Since 2007, groundwater levels at Well Field 1 have responded to individual rain events while those at Well Fields 2 and 3 have responded to annual precipitation fluctuations. Water levels in the GaEPD well located about 15 miles south of the Fall Line have been declining since 1993. About 7 miles south of the Fall Line, groundwater levels in the other GaEPD well fluctuated about a constant level since 2000.

TRACK 3 ABSTRACTS: Tuesday 1:30 – 3:00 PM

Session 3.2 – Press Box: Modeling & Tools II

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STREAMSTATS—A WEB-BASED TOOL FOR ESTIMATING STREAMFLOW CHARACTERISTICS IN GEORGIA

StreamStats is a Web-based Geographic Information System (GIS) application that was created by the U.S. Geological Survey (USGS), in cooperation with the Environmental Systems Research Institute, Inc. (ESRI) that allows users to easily obtain streamflow statistics, basin characteristics, and descriptive information for USGS streamgages and user-selected ungaged locations on streams (Ries and others, 2008). StreamStats is being implemented on a state-by-state basis to allow for customization of the data development and underlying data sets to address state specific needs, issues, and objectives. The USGS, in cooperation with the Georgia Environmental Protection Division and Georgia Department of Transportation, have implemented StreamStats for Georgia. The Georgia StreamStats website is available through the national StreamStats web-page portal at http://streamstats.usgs.gov. Links are provided on this web page for individual state applications, instructions for using StreamStats, definitions of basin characteristics and streamflow statistics, and other supporting information. StreamStats can be used to obtain previously published basin characteristics and (or) streamflow statistics for over 700 USGS streamgages in Georgia. Currently (2014), 18 basin characteristics are available for a user-selected point on a stream. Streamflow statistics, such as flood magnitude and frequency, for a user-selected point on a stream are determined through the use of published USGS regional regression equations. Applications as diverse as planning for bridge and road construction, managing water-resources quality and quantity, characterizing drainage basins, or examining the effects of urbanization on streamflow can be implemented

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IMPLEMENTING A NETWORK-BASED WATER-USE DATA SYSTEM FOR GEORGIA

The U.S. Geological Survey, in cooperation with the Georgia Environmental Protection Division, has developed county water-use estimates for Georgia every five years since 1980. These estimates are based on reported water use compiled from regulatory programs, supplemented by estimates of uses not covered by permit reports. An effort is underway to integrate these compiled water-use reports into the USGS National Water Information System (NWIS) in the Site-Specific Water-Use Data System (SWUDS) subsystem. Public supply, industrial, thermoelectric and hydroelectric power, mining, and commercial sites are included; irrigation and livestock are not. Currently about 3,250 users are represented in the Georgia SWUDS, some with monthly and annual data from 1980 (or earlier) to 2012. SWUDS is a tracking database—measurements of water withdrawals, transfers, and return flows can be stored as a network of points (sites) with connections showing the direction of movement and other characteristics of water being used. For example, SWUDS may store individual well locations (with additional data in the NWIS groundwater subsystem), one site representing all wells for a single permit, or a surface-water intake. SWUDS can then track water from the source to a water distribution system; treated water can be tracked to customers or customer groups. If water use can be tracked from withdrawal point to return location, retrievals can summarize data for interbasin transfers and consumptive use. With the implementation of SWUDS in Georgia, water-use information can be retrieved in conjunction with sites for stream gages, water-quality sampling, and groundwater-level monitoring.

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SIMULATION OF STREAMFLOW 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 U.S. Geological Survey (USGS) National Water Census, a water-availability study of the ACFB was conducted for the period 2008-2012. This study combined improved 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. Hydrologic models of varying spatial extents and resolutions were required to provide varied local-to-regional water-resources information for use by water resource managers. 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 Flori-

dan 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.

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COMPUTING TOOLS FOR THE WATER PROFESSIONAL FROM THE U.S. GEOLOGICAL SURVEY

The U.S. Geological Survey (USGS) has numerous computing products however, those unfamiliar with USGS may find it hard to locate applicable tools and information. The National Map http://nationalmap.gov/ where current and historical topographic maps can be accessed; USGS publication warehouse http://pubs.er.usgs.gov/ and the National Water Information System http://waterdata.usgs.gov/nwis/, giving real-time access to groundwater, surface water and water-quality data, are well known and accessed millions of times annually. However, other important tools such as StreamStats http://water.usgs.gov/osw/streamstats/ WaterAlert http://water.usgs.gov/wateralert/ and WaterNow http://water.usgs.gov/waternow/ are less known. USGS water web services http://waterservices.usgs.gov/ use Representational State Transfer (REST), allowing quick and easy data retrieval for more than a million hydrologic sites in large batches through a web browser. Off line tools can be downloaded including modeling and statistical tools in worldwide use. MODFLOW is an international standard for simulating groundwater, with many additional tools for the model http://water.usgs.gov/ogw/modflow/. Water-quality applications for reactive and solute transport modeling of both surface- and groundwater vary from LOADEST http://water.usgs.gov/software/loadest/ for estimating constituent loads in streams, to NAS (Natural Attenuation Software), providing a decision-making framework for estimating time to clean up groundwater contamination. Surface-water tools http://water.usgs.gov/software/lists/surface_water/ including the deterministic, distributed-parameter, physical process based Precipitation-Runoff Modeling System (PRMS); and site specific tools like PeakFQ for implementing USGS standard methods for flood-frequency analysis. A number of statistical tools, using the open source R language are available including waterData—An R Package for retrieval, analysis, and anomaly calculation of daily time-series Data http://pubs.usgs.gov/of/2012/1168/ and RRAWFLOW http://sd.water.usgs.gov/projects/RRAWFLOW/RRAWFLOW.html, that simulates streamflow, springflow, groundwater level, solute transport, or cave drip in response to input of precipitation, recharge, or solute injection.

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FIBER OPTIC DISTRIBUTED TEMPERATURE SENSING: AN EMERGING GROUNDWATER MONITORING TECHNOLOGY

The exchange of water through the groundwater/surface water interface of waterbodies has been the subject of much research over the past twenty years. Despite intense study, adequately describing the temporal dynamics and spatial patterns of groundwater/surface water interactions continues to be a challenge. Groundwater discharge areas are not often readily discernable and may require a tracer to differentiate between groundwater and surface water. Temperature has been shown to be an excellent passive environmental tracer to infer areas of groundwater movement as it interacts with surface water. The relatively recent addition of fiber optic distributed temperature sensing (FO-DTS) networks into the hydrologist's data collection tool box has increased the spatial and temporal scale of temperature observations to extensions of 5 kilometers or more with resolution of less than 1 meter and temperature precision of 0.1 degree Celsius. In a March 2013 application of this technology, a 725 meter FO-DTS survey was conducted in an unnamed tributary to Hawe Creek at the Barite Hill/Nevada Goldfields Superfund Site near McCormick, South Carolina. The goal was to determine if groundwater discharge affected by acid mine drainage could be located in the tributary that bounds the abandoned mine. Four areas of groundwater discharge were identified on the basis of thermal differences. Synoptic measurements of pH and specific conductance in the surface water above and below the identified groundwater discharge sites suggest the groundwater has been adversely affected by acid mine drainage originating from the Main Pit Lake.

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CLIMATE CHANGE AND THE RESILIENCE OF TIDAL WETLAND CARBON SEQUESTRATION

C sequestration of plant-derived organic matter in sediments of coastal wetlands is about 70 – 220 Tg C/y. While the expanse of these systems is small globally, areal rates of C burial are among the highest of Earth's ecosystems. However, this globally relevant ecosystem service is highly vulnerable to climate and land use change. Sea-level rise (SLR) will likely increase rates of shoreline erosion, reversing a several thousand year trend in progradation. Transgression will likely slow as a result of coastal armoring to protect upland uses of higher local value. Increased rates of SLR may compromise the ability of tidal wetlands to accrete vertically, which would result in inundation, loss of area and decreased C sequestration. Simulation results suggest an optimal rate of SLR for a given tidal range and suspended sediment availability beyond which wetland survival is compromised. Differential warming effects on respiration relative to primary productivity will likely lead to reduced net ecosystem production and decreased C burial potential in the future. Considerable research is needed to better understand the relationships between wetland resilience and global change.

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ENVIRONMENTAL METABOLOMICS AND BIOMONITORING OF CONTAMINANTS OF EMERGING CONCERN IN WILD EASTERN OYSTERS FROM GEORGIA, USA ESTUARIES

Georgia has approximately one-third of the salt marshes in the eastern United States. Salt marshes provide essential habitats and nursery grounds for the majority of Georgia's economically vital fish and shellfish populations. As coastal zone populations increase, anthropogenic sources of pharmaceuticals and personal care products (PPCPs) will be an increasingly complex problem. PPCPs can exert adverse effects on physiological systems at ng to μg concentrations, putting organisms in these sensitive estuarine areas at risk from prolonged exposures. PPCPs were quantified in water, suspended solids, sediments and oysters (*Crassostrea virginica*) collected from native oyster beds near Brunswick and Sapelo Island, GA. Sample sites were selected based on their proximity to anthropogenic sources of PPCPs (wastewater treatment plants and/or septic sites) and included one reference site at each estuary. Target analytes included 25 PPCPs in the following classes: selective serotonin reuptake inhibitors, hormones, beta-blockers, angiotensin II receptor blockers, fibrates, antihistamines, stimulants, anti-epileptics, cancer medication, anti-inflammatories, analgesics, personal care products, illicit drugs and six pesticides. Analysis by LC-MS/MS detected analyte concentrations in the low ng/g to low µg/g range in oyster tissues. Chemical analysis of suspended solids, sediments and water samples and metabolomics analysis of tissues samples is ongoing. Metabolomic analyses will characterize the physiological responses of oysters to local anthropogenic inputs and environmental conditions. This research will create a more holistic picture of the presence, distribution and population level impacts of PPCPs in estuaries at Brunswick and Sapelo Island, Georgia.

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ASSESSMENT OF THE REACH AND ECOLOGICAL CONDITION DUE TO COASTAL FLOODING IN GEORGIA COAST WITH ADVANCED GEOSPATIAL TECHNOLOGY APPLICATION

Tidal freshwater wetlands are the interface between marine and terrestrial ecosystems. They are being directly impacted by sea level rise as a consequence of climate change. These wetlands are common in the rapidly urbanizing landscape of the southeastern Atlantic coastal plain, as well as other coastal areas. Coastal flooding has increased many folds recently including the Georgia coast. Tidal freshwater forested wetlands (TFFW) occur in floodplains situated near the coastal zone along freshwater rivers are subject to these coastal flooding related tidal surge. The brackish water intrusion to these TFFW is creating tremendous damage. The objectives of this study conducted in Georgia coast were to: i) acquire and process the LiDAR data to develop latest and ultrahigh resolution DEM for the study area; ii) use the average climate change related high tidal surge heights (presumably 2 m) to develop land topography model showing the TFFW area affected by salt water intrusion and use soil properties to exact delineate the area that will affect freshwater ecosystems; and finally, iii) use advanced object based image analysis (OBIA) image segmentation algorithm to classify/differentiate the saltwater and freshwater ecosystems in a selected county (Chatham County) with other land uses. LiDAR tiles (*.LAS files) of Georgia Coastal counties were downloaded from NOAA Digital Coast library. The LiDAR tiles were processed and mosaicked to develop DEM with ground returns. The DEM developed from the LiDAR data of 2010 is much updated and represents present and accurate topography of the area. Then the ultrahigh resolution (30 cm) DEM was used to delineate the area under 2 m (high estimated tidal height in recent years in Atlantic Ocean) ground elevation showing that these coastal ecosystem will be under submergence in high tide period. Another study was conducted on these areas under 2 m elevation with the use of SSURGO soil data. Soil Hydrologic Group (HG) and Available Water Storage/Capacity (AWS) characteristics provide insight about the saltwater percolation to the soil. Soil HG C, C/D, and D tend to help slow percolation and high (more than 18 cm) AWS also do the same. Spatial areas with Soil HG C, C/D, and D and AWS greater than 18 cm were overlayed with areas under 2 m elevation with the use of 'Weighted Sum' tool of ArcGIS 10.2 to obtain the exact spatial area that will be affected by tidal surge and altering/stressing the freshwater ecosystems. Finally, for the selected Chatham County, we used 1 m resolution National Agricultural Imagery Program (NAIP) imagery to per-form image segmentation with OBIA to differentiate plant species, and other land uses in the area affected by tidal surge. We took the help of training sample development with preground verification of land uses, shrub raster, short tree raster, tall tree raster, and other height raster created from LiDAR data, NAIP based NDVI and other image indices to develop rule sets for OBIA. The resultant data would provide coastal ecosystems management people to know the probable spatial and ecological extent of damage due to coastal flooding.

TRACK 4 ABSTRACTS: Tuesday 1:30 – 3:00 PM

Session 4.2 – Room L

Panel Discussion: Water reclamation and re-use

EXTENDING THE LIFECYCLE OF OUR WATER IN GEORGIA

Objectives: Understanding Risk Factors beyond Drought; Identifying Areas for Non Potable Demand and Water Footprint; Achieving Lofty Sustainability Goals in Water Reduction; Private Partnerships and Third Party Funds; and Setting in Motion an Action Plan. Proposed panel discussion with representatives from University of Georgia, Georgia Tech and Emory University and Moderator from Sustainable Water. Panelists will represent and discuss a water reclamation and reuse project at three phases – beginning, middle and end phase where facility is operational. Discussion will include working through identification of need after a risk assessment, feasibility studies, design, permitting, construction and operation. Experience with private financing will be presented to demonstrate how this resource can be utilized to find partners to achieve academic goals while maximizing economic efficiency of critical projects. The panel will also address the state of Georgia's deep commitment to the conservation of critical freshwater supplies and how this is impacted by current legislation. Their views on how this planning will sustainably meet the needs of economic development in both Georgia and its neighboring states will be explored.

Moderator: Bob Salvatelli, *Director of Sales, Sustainable Water*

Panel Guests:

Jason Gregory, *Sr. Educational Facilities Planner, Georgia Institute of Technology*

Brent Zern, *Assistant Director of Operational Compliance, Emory University*

Ben Liverman, *Space Management Coordinator, Architecture and Planning, UGA*

Jonathan Lanciani, *President and CEO, Sustainable Water*

TRACK 5 ABSTRACTS: Tuesday 1:30 – 3:00 PM

Session 5.2 – Room F/G: Floodplain Risk Assessment

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

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

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EFFECTIVENESS OF LID TECHNOLOGIES TO MITIGATE THE IMPACT OF CLIMATE CHANGE ON STORMWATER DESIGN STORMS

Current prediction models are showing an increase in intensity and frequency of rainfall events due to climate change's effects on atmospheric temperature. This increase in precipitation can result in increases in peak runoff as well as total runoff volume. Low Impact Development (LID) can be used to mitigate these increases in water runoff through the uses of various hydraulic detention or infiltration practices. Three different site designs (Small commercial, residential, and big-box store) will be used as case studies for three different locations (coastal, midlands, and piedmont) and will be modeled in HEC-HMS. The SCS rainfall distribution and infiltration rate are the only variables that change from the locations. Precipitation from 0.5 to 12 inches, in steps of 0.5 inch, is run for each scenario to obtain rainfall-sub basin response curves that compare the pre-development, standard post-development and LID post-development. These curves will illustrate the impact of LID technologies to reduce the peak runoff and runoff volume when compared to standard design, for a range of precipitation rates.

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GEORGIA AUTOMATED GEOSPATIAL FLOOD POTENTIAL MAP DEVELOPMENT AND ANALYSIS FOR DECISION SUPPORT

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. In this study, we have developed an automated geospatial model to determine the flooding potential (three different scale: high, moderate, and low) in the state of Georgia. We also developed in-depth flood spatial analysis of the three counties (Forsyth, Gwinnett, and Hall). 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 30 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 STATSGO soil data of the state. All these layers were transformed to raster datasets of same resolution 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., of least flood potential (1) to most flood potential (9). Finally, each individual layers were overlayed with a weighted overlay analysis using

TRACK 1 ABSTRACTS: Wednesday 1:30 – 3:00 PM

Session 1.5 – Masters Hall: Adapting to a changing coast II

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INTERPRETING RECENT GROUNDWATER CHEMISTRY RESULTS FROM ST. CATHERINE'S ISLAND, GEORGIA

Hydraulic head and chemical data have been collected regularly on St. Catherine's Island since 2011 to characterize the hydrogeology. An E-W transect of six wells was installed to monitor the surficial aquifer, and a N-S transect of six water-supply wells was used for the Upper Floridan aquifer (UFA). LiDAR data show that the core of the island is subdivided topographically along a N-S trending axis, with the eastern side being 2-3 meters higher. Results show that total dissolved solids (TDS) within the surficial aquifer average 50 mg/L on the crest of the island and 95 mg/L in topographically low areas. Piper diagrams reveal that surficial groundwater in low areas is a strong Na-Cl type water that plots close to modern seawater, but is a more mixed type water on the topographic high. When integrated with lithologic, ground-penetrating radar and radiocarbon data, it's hypothesized that the island core consists of Pleistocene marine units overlain by Holocene eolian and washover sands. Head data confirm that the UFA transect follows a S-N flowpath into the Savannah drawdown cone. UFA chloride concentrations average 14.5 mg/l at the upgradient end of the transect, decreasing to 9.0 mg/l at the downgradient end. Piper diagram analysis eliminates the surficial aquifer and modern sea water as possible mixing end members, whereas samples from the Lower Floridan plot upgradient of the mixing line. Saltwater intrusion into the UFA on St. Catherine's appears to be taking place by the upward movement of more saline water along vertical fractures or faults.

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SPATIAL AND TEMPORAL ASSESSMENT OF BACK-BARRIER EROSION ON CUMBERLAND ISLAND NATIONAL SEASHORE

Many studies have been conducted to better understand erosion and accretion processes for the seaward zones of coastal barrier islands. However, on Cumberland Island National Seashore, the greater management concern is the effect that erosion is having on the resources of the island's western shoreline, or back barrier. Catastrophic slumping and long-term erosion rates across large areas in excess of one meter (m) per year threaten important ecological habitats, historic and pre-historic resources, and modern infrastructure on the island. Prior research has helped the Park identify the most severe and vulnerable areas, however, in order to develop effective management actions, information is needed on the causes of the erosion and the conditions under which it is occurring. In February 2012, the U.S. Geological Survey (USGS) in cooperation with the National Park Service constructed monitoring stations at four locations that were identified as erosional hotspots. Innovative techniques such as continuous measures of erosion position and acoustic recordings of underwater sound were used to investigate under what conditions erosion occurred through May 2013. Further, the magnitude of erosion at each location was quantified to elucidate the relative influence of causative agents. Results indicate that erosion is, in general, highly variable within and among these locations. Observed erosion ranged from a maximum of 3 meters of bluff-line retreat to no net erosion for the entire study period. Three of the four sites displayed punctuated, mass wasting events that were coincident with above average high tides and storm events. The fourth site exhibited steady, low magnitude retreat throughout the study period. Boating activity was acoustically detected at all sites during the study and occasionally occurred prior to measured erosion, however ascribing a degree of causation was not possible. While it is difficult to precisely attribute certain amounts of erosion to specific agents, this study provides insight into the mode of erosion among sites and the interaction among factors that are leading to the alteration of the back barrier of Cumberland Island. Estimates of sea-level rise predicted to be in place by the end of the 21st century were incorporated into the monitoring data to forecast tidal position with respect to the current erosional margin.

during April through October over the past 30+ years. While specific biological responses are largely undocumented, enough is known to suggest that several important faunal groups including freshwater fishes, mussels, and crayfishes may be adversely affected. The Flint River appears at risk for moderate to severe ecological degradation due to flow alteration. Biota and ecological processes depending upon adequate summer flows appear to be at greatest risk. Sufficient technical information exists to guide initial management responses and a monitoring network is in place to provide feedback. The challenge lies with engaging diverse social and economic interests in a formal process leading to protection of stream flows that sustain ecological structure and function. Actions that could be taken include more rapid responses to drought early warning systems, already in place, and enhanced water conservation efforts.

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EARLY DETECTION TOOLS FOR CYANOBACTERIAL HARMFUL ALGAL BLOOMS IN GEORGIA'S INLAND WATERS

The effects of anthropogenic eutrophication are intensified in inland watersheds across southeastern United States (SEUS) due to increasing temperatures associated with frequent droughts and agricultural induced nutrient enrichment. These factors may ultimately lead to the formation of toxic Cyanobacterial Harmful Algal Blooms (CyanoHABs) in inland waters. Therefore, accurate, cost-effective, and targeted monitoring of these events is indispensable to sustainable management of the environment. The abundance of phycocyanin (PC), a phycobiliprotein, may be used as a proxy to assess the amount of cyanobacteria biomass that is present in a water body. This study presents two innovative approaches for monitoring CyanoHABs in these environments; community and satellite-based remote sensing. CyanoTRACKER is a project supported by NSF that encourages the community to provide their observations regarding the quality of their lakes by sending trustworthy, actionable information via online social media platforms such as Facebook and twitter. This community-as-sensors paradigm will act as the initial trigger for the traditional sensing infrastructure comprised of high-resolution cameras and multiple Raspberry PI integrated with OceanOptics "STS-VIS" hyperspectral spectroradiometers deployed at the study sites. Data collected by these sensors will be run through models that produce an estimation of cyanobacteria concentration within the water bodies. Meanwhile, an upscaling procedure demonstrated the feasibility of using Landsat-8 satellite imagery to detect cyanobacteria reflectance patterns. This model aimed to identify and delineate spatial and temporal distribution of CyanoHABs in order to rapidly monitor and respond to these systems thereby improving water quality management decision-making for inland Georgia reservoirs. The combination of these tools will enable early detection and timely implementation of preemptive measures to reduce the frequency and severity of future CyanoHABs.

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SOURCES AND EFFECTS OF ESTROGENS IN THE UPPER CONASAUGA RIVER

Declines of rare fish in the Upper Conasauga River (UCR) are well documented and our preliminary contaminant survey indicated high concentrations of estrogens in sediments throughout the watershed. The goal of this study was to determine the effects of estrogens on fish in the UCR and identify tributaries with the highest estrogen activity. Specific objectives were to: 1) determine the presence and bioavailability of estrogens in UCR tributary water and sediments, 2) determine incidence of intersex in a survey of multiple species of fish in the UCR, and 3) determine if exposure to estrogens altered the sexual development of male Western Mosquitofish (*Gambusia affinis*) in the UCR. Results from this study showed estrogens are present in water, but concentrations were substantially higher in sediment. However, male fathead minnows (*Pimephales promelas*) produced higher concentrations of Vtg when exposed to UCR water than when exposed to UCR sediments, suggesting estrogens in the water column were more bioavailable than those in the sediment. Of the 174 male fish (27 species) collected for the intersex survey, 13 (7.5%) were intersex. Gonopodia of Western Mosquitofish collected from a farm drainage ditch were significantly ($p = <0.0001$) shorter compared to Western Mosquitofish from reference sites in the UCR. Results indicate environmentally relevant concentrations of estrogenic compounds are present in UCR surface water and sediment, and these compounds may be linked to declines in fish populations. This approach facilitated identification of tributaries with the highest estrogen loads, where best management practices should be targeted for greatest impact.

'Weighted Sum' tool of ArcGIS 10.2. 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 of 1 (least potential) to 9 (most potential). The final flooding potential map was presented as colored map with scale from 1 to 9. This automated model can be easily replicated in any other watershed or state in the nation by changing the input parameters. The Flood potential map of Georgia was classified into three categories of potential, high, moderate, and low. As the size of the data was too large to be handled by the best of the computers, we analyzed the flood potential map of three metro Atlanta counties as mentioned earlier. Zonal Statistics tools were run on the final spatial product of these counties and statistical tables were developed to show the extent of flooding potential. Individual maps for low, moderate, and high flood potentials were created for these three states. These data were compared with the FEMA flood zone map and it showed some resemblance but many discrepancies.

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FLOOD ASSESSMENT AND EVACUATION PLAN DEVELOPMENT FOR HYPOTHETICAL DAM BREACH AT SINCLAIR DAM USING HAZUS-MH AND ARCGIS NETWORK ANALYST

Dams are an important part of United States' infrastructure, providing many advantages like flood control, water supply, irrigation, hydropower, navigation, and recreation benefits. Despite these benefits, dams also present risks to property and life due to their potential to fail causing catastrophic flooding. Most of the small and medium size dams in USA are old. It is essential for dams for which failure or misoperation probably will cause loss of human life, to develop an emergency action plan for possible evacuation and shelter by understanding the flooding extent downstream, probable loss of lives and properties, and infrastructure to support. Lake Sinclair, created with an earthen dam is a 15,330 acre water impoundment located in Putnam County and Baldwin County, just north and northeast of Milledgeville, Georgia. It is classified as High Hazard dam due to its proximity to populated areas and the damage potential associated with the quantity of water in the impoundment and the surrounding elevation. The objectives of this study are to: 1) approximate the flood extent of a catastrophic dam break at Sinclair Dam using FEMA HAZUS 2.1 soft-ware and 2) identify potential evacuation routes for moving affected populations to local shelters and hospitals in the possible affected areas using Network Analyst Extension for ArcGIS 10.1. HAZUS-MH is an add-on for ArcGIS 10.1. Most of the geospatial data used in this hypothetical dam break model building came with the HAZUS-MH program. It provides locations of facilities, roads, trees, surface roughness, topography, hydrography, and many more including the census data. Other data used in the model building were collected from outside sources. HAZUS modeling was conducted in four basic phases, 1) organize resources, 2) assess risks, 3) develop a mitigation plan, and 4) implement the plan and monitor progress. In this study, the floodplain is approximated using a 200,000 cfs (just less than half the maximum) steady flow. The results obtained from the analyses were the flood zone, number of people to be affected and need evacuation, amount of infrastructure like building, schools, roads will be affected, and many more. These results helped in our Network Analyst based evacuation route development for moving marooned population through unaffected roads to the unaffected schools or other shelter available in close proximity. The final map delineated as a result will support planning people and resource managers to draw up probable plan for safety. However, this project can be improved further with the application of non-steady state flow analysis with HEC-GeoRAS software with HAZUS.

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FLOOD INFORMATION AND NOTIFICATION SYSTEM, MECKLENBURG COUNTY, NC

The U.S. Geological Survey (USGS), in cooperation with Mecklenburg County and the City of Charlotte, NC, operates and maintains an automated and highly complex flood warning network known as the Flood Information and Notification System (FINS). Two primary purposes of FINS are to provide real-time hydrologic data to aid in the mitigation of loss of life and property due to flash flooding in a densely populated urban area, and to provide data for post event analysis. Given its importance, FINS is robustly designed with multiple redundant features to help ensure its operation. FINS consists of 72 raingages and 53 streamgages. All data are recorded in 5-minute intervals and transmitted in real-time using a combination of UHF radios (capable of both two-way polling and ALERT) and GOES satellite equipment. Additionally, there are 9 live web cameras located at strategically selected sites. Generally, sites equipped with UHF radios transmit data every 5 minutes, while sites equipped with GOES radios transmit data every hour. Once received by USGS base stations, data are automatically processed and loaded in the National Water Information System (NWIS), and are available to the public on the internet within 5-10 minutes of reception. During hydrologic events, the rate of data transmission is increased. GOES sites begin transmitting data every 5-15 minutes and UHF sites begin transmitting data every minute using the ALERT protocol. These data are immediately made available to emergency responders and are crucial to the development of a rapid, coordinated and effective response to potential flooding issues.

TRACK 6 ABSTRACTS: Tuesday 1:30 – 3:00 PM

Session 6.2 – Room R: Habitat and in-stream conditions II

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USING WETLAND MORPHOLOGY TO CLASSIFY HYDROLOGIC PERMANENCY AND HABITAT SUITABILITY OF ISOLATED WETLANDS AT ST. MARKS NATIONAL WILDLIFE REFUGE IN NORTHWEST FLORIDA, USA

Pond breeding amphibians require wetlands of various hydrologic permanency depending upon individual breeding phenologies. The reason is two-fold; water must be present long enough for larvae to mature and secondly, in many species, intermittent drying needs to occur to reduce or eliminate predators. The U.S. Geological Survey in cooperation with the U.S. Fish and Wildlife Service investigated the feasibility of a repatriation effort of the Striped Newt (*Notophthalmus perstriatus*), a candidate species for federal listing, within the St. Marks National Wildlife Refuge in northwest Florida. Potential breeding habitats for repatriation were delineated using a Light Detection and Ranging (LiDAR) derived digital elevation model and a topographic position index (TPI) classification to identify and classify isolated depressions. Determining threshold classification values was an iterative process that was informed by a calibration dataset of forty-five field-identified ponds, the perimeters of which were surveyed with a high precision Global Positioning System. Twenty-two of these ponds were instrumented with water-level recorders to investigate inundation dynamics across a wide range of hydrologic conditions. Relations between pond TPI characteristics and hydroperiod (HP) were then explored to extend hydrologic characterization to the unmonitored locations. The TPI procedure provided a reasonable means to extend hydrologic classifications. While results varied by hydrologic class, the permanent/long HP were more often classified correctly (80%) than short HP (43%). However, classification results were improved to 100% and 75% for permanent/long and short HP, respectively, by removing ponds occurring on an abrupt marine terrace that erroneously inflated pond topographic characteristics.

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SURVEYING ISOLATED WETLANDS FOR PRESENCE OF THREE IMPERILED AMPHIBIAN SPECIES USING ENVIRONMENTAL DNA AT FORT STEWART MILITARY BASE, GA

The loss of longleaf pine forests and associated wetlands has led to the decline in fauna dependent on these habitats. However, Fort Stewart contains numerous isolated wetlands that may provide habitat for three imperiled amphibian species: the frosted flatwoods salamander (*Ambystoma cingulatum*), gopher frog (*Lithobates capito*), and striped newt (*Notophthalmus perstriatus*). Because of the time-intensive nature of conducting dipnet surveys at all wetlands, only a fraction of these wetlands have been surveyed for amphibians. We recently developed environmental DNA (eDNA) assays to detect presence of the aforementioned amphibian species and used these assays to assess 287 water samples collected from 95 wetlands across the military base. No evidence of presence of frosted flatwoods salamanders was found at any of the wetlands. Due to evidence of gopher frog genomic DNA contamination in numerous water samples, there is limited confidence in the gopher frog results. Weak evidence of presence of striped newts was found in 11 samples from 7 wetlands. However, all positive samples were at extremely low concentrations, ranging from 2.7 x 10-8 to 9.3 x 10-10 ng/µL. These concentrations were well below the level at which eDNA quantity can be reliably estimated, and are near the lower limits of expected detection. While eDNA results for striped newts were not definitive, the seven wetlands that tested positive should be given higher priority among all wetlands on the base for physical surveys to verify presence.

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AN ASSESSMENT OF ALGAL COMMUNITIES AND THE IMPACT OF IONIC STRESS ON ALGAL CELLS FROM STREAMS IMPAIRED BY ACID MINE DRAINAGE

Algae are often bioindicators due to their wide range of habitats, high biodiversity, and sensitivity to anthropogenic influence. Streams impacted by acid mine drainage (AMD) are characterized by low alkalinity, high conductivity, low pH levels (e.g., <3) and a high concentration of dissolved metal ions, all of which can cause changes in the algal community composition. Samples were collected in a previous study of AMD impacts on diatom species composition. The samples were taken from streams located in the Western Allegheny Plateau of southeast Ohio that suffer from impairment caused by AMD. We studied the physiology of algal cells under ionic stress and other algal assemblages. A standard protocol was used to identify 300 live algal units to the lowest taxonomic level possible. Dead algal units and associated cells were not included in the 300 unit cell count. About 80% of algae in the samples were diatoms, followed by green algae. High nutrient representatives from genera like Gomphonema, Cymbella, and Navicula were

TRACK 6 ABSTRACTS: Wednesday 10:30 – 12:00 PM

Session 6.4 – Room D: Habitat and water quality assessment II

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IDENTIFYING INVERTEBRATE ASSEMBLAGE CHANGES INDICATIVE OF REDUCED FLOW IN AN AGRICULTURAL WATERSHED

Water extractions for agricultural irrigation have reduced stream baseflows in dry years and likely have increased the number of intermittent stream reaches within the lower Flint River basin. We characterized macroinvertebrate assemblages in stream reaches spanning a gradient of flow permanence to identify key taxa indicative of flow alteration within our watershed. We sampled monthly from September to December 2013 in stream reaches classified as: perennial, intermittent-wet (ceased flowing periodically with some pools maintained during drought); intermittent-dry (seasonally ceased flowing and dried completely); and intermittent-frequent (tend to dry multiple times a year). We examined rock and wood habitats at each site. We also collected monthly overnight drift samples at each of these sites when flow was present. This information was used to classify those taxa within our watershed as susceptible to, tolerant of and favorable to low flow conditions. In addition, we examined likely dispersal responses to reduced flow conditions such as drift and life history traits. Taxa indicative of moderate to high flow conditions included filterers (*Hydropsyche*, *Isonychia*, and *Simuliidae*) and those with univoltine life cycles (*Ancyronyx*, *Taeniopteryx*), while those in low flow conditions were more tolerant of low flow and drying (*Ostracoda*, *Copepoda*, *Macromia*). Determining which taxa are affected by increased frequency of drying and low flow will aid in understanding how changes in water availability affect biological diversity of streams at a regional scale.

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ASSESSMENT OF THE TEXAS BEST MANAGEMENT PRACTICE EVALUATION TOOL AS A QUANTITATIVE PREDICTOR OF FIELD-SCALE PHOSPHORUS LOSS

The United States Department of Agriculture and the United States Environmental Protection Agency require each state to adopt a management strategy for controlling non-point phosphorus (P) loading to public waters. The most common strategy is the P-index. Currently, 48 states use some form of the P-index as mandated by the Natural Resources Conservation Service 590 Nutrient Management Standard (NRCS 590). In spite of widespread adoption, the lack of evaluation against field runoff data and variations in implementation among states threaten the success of the P-index. As a result, the Southern Extension-Research Activity Group 17, established to review NRCS 590, advised using measured P loss data and predicted P loss from quantitative P loss models to improve P-indices. Therefore, this study assesses whether the Texas Best Management Practice Evaluation Tool (TBET), a field-scale version of the Soil and Water Assessment Tool, is able to sufficiently predict quantitative P loss. TBET was successfully calibrated and validated in Texas and Oklahoma as a qualitative tool for conservation planners. However, this study tests whether TBET can be successfully applied quantitatively to fields beyond the region of its original calibration and validation. Measured water quality data from three sites in the southern United States were used for our analysis. We present results for the baseline and site-specific calibrated performance of TBET as a quantitative P loss predictor. In addition, we test whether the soil moisture based curve number approach or the plant evapotranspiration based curve number approach produces more precise predictions with TBET.

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TESTING THE SUSTAINABLE BOUNDARY APPROACH (SBA) TO ASSESS AND DEVELOP FLOW GUIDELINES: FLINT RIVER GEORGIA

Recent droughts have elevated concerns about water security, i.e., the ability to provide for public supply and support in stream requirements for healthy biota and associated ecosystem services. These concerns are amplified in Georgia and the Southeastern US by projections of increasing population, temperatures, and water demand; and uncertain precipitation. Given these variables, there is a need for systematic assessment of hydrologic change and evaluation of biological responses. While generally acknowledged that stream flow is a master variable governing the structure and function of rivers, its characterization is complex and challenging to incorporate into management guidelines. Together, complexity of metrics and poor understanding of responses have limited the development of river management guidelines. We used the Sustainable Boundary Approach (SBA) to assess and develop flow guidelines using data from two long-term USGS gauging stations on the Flint River. The analysis showed substantial declines in daily flows

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AGRICULTURAL CHEMICALS IN SURFACE WATERS AND SEDIMENTS FROM THE UPPER CONASAUGA RIVER

Surface waters and sediments were collected from the upper Conasauga River in Georgia and Tennessee and analyzed for agricultural chemicals (nutrients, glyphosate, hormones, metals) that may be responsible for fish and mussel declines over the past decade. Surface-water samples were collected from the mainstem, major tributaries, and farm tributaries after major rain events. Depositional sediments were collected above and below major tributaries in 2010, 2012, and 2013 and from the major tributaries in 2012. In assessments of chronic toxicity using *Ceriodaphnia dubia*, *Hyalella azteca* and *Lampsilis siliquoidea*, few water or sediment samples were determined to be harmful. Concentrations of nitrate in surface waters often exceeded a level protective of sensitive invertebrates (2 mg NO3-N/L) while phosphorus concentrations in many samples were above levels that may alter the distribution of aquatic plants (0.1 mg P/L). Glyphosate was rarely observed in surface water, but its primary degradation product, aminomethyl phosphonic acid (AMPA), was detected in 77% of the samples. Water and sediment concentrations of glyphosate/AMPA (≤ 0.15 mg/L and ≤ 2.4 mg/Kg) were high compared to samples from other agricultural regions, but bioassays with *Ceriodaphnia dubia* and *Cyprinella trichroistia* exposed to a glyphosate-based herbicide indicated little toxicity at measured levels. Sediment-hormone concentrations ranged from 1 - 200 µg/Kg, which may be sufficient to disrupt endocrine functions in aquatic biota. Metal concentrations in water and sediment samples were low. Nutrients and hormones are potential causes of observed species declines. Probable sources include inorganic and organic fertilizer, livestock production, and domestic septic systems.

abundant. About 75% of algae in samples were alive. Morphological alterations in diatoms and chrysophyte spores were recorded and analyzed.

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POTENTIAL STURGEON HABITAT IN THE LOWER FLINT RIVER

In April 2013, investigators at the University of Georgia proposed to study pre- and post-spawning movements of Gulf sturgeon upstream of Jim Woodruff Dam. Since the Dam currently prevents Gulf sturgeon from moving upstream, the researchers planned to artificially relocate Gulf sturgeon upstream of Jim Woodruff Dam, and to tag and track their movements. What remains unclear is the amount of potential spawning habitat upstream of the Dam, particularly in the lower Flint River, and how the amount may change as a result of varying flow conditions. The authors utilized bathymetric survey data of the lower Flint River, obtained substrate information from the US Fish and Wildlife Service, and constructed an HEC-RAS model of the River. Using the most adverse hydrologic conditions in the most recent decade, the authors determined the extent of available potential habitat under various flow conditions.

Joiner, John K.[1], Brent T. Aulenbach[2], and Mark N. Landers[3]
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WATERSHED CHARACTERISTICS AND WATER-QUALITY TRENDS AND LOADS IN 12 WATERSHEDS IN GWINNETT COUNTY, GEORGIA

The U.S. Geological Survey, in cooperation with Gwinnett County Department of Water Resources, established a comprehensive Long-Term Trend Monitoring (LTTM) program in 1996 to monitor, analyze, and quantify the magnitudes of instream pollutants and the effects of urbanization on six watersheds. In 2001, six additional watersheds were added to the LTTM program. These 12 watersheds were continuously monitored for water level, streamflow, precipitation, and water-quality properties (water temperature, specific conductance, and turbidity). Discrete water-quality samples were collected during storm and base-flow conditions and analyzed for nutrients, trace metals, total dissolved solids, and total suspended sediment (total suspended solids and suspended sediment). This sampling schedule was designed to identify variations in water quality both hydrologically and seasonally. The 12 watersheds were characterized for basin slope, population density, land use, and impervious area. Seasonal patterns and long-term trends in flow-adjusted water-quality concentrations were identified for five constituents—total nitrogen, total phosphorus, total zinc, total dissolved solids, and total suspended solids. Seasonal patterns of all five constituents were fairly similar, with higher concentrations in the summer and lower concentrations in the winter. Surface water loads were computed for 10 water-quality constituents. These loads represent the cumulative effects of watershed characteristics, hydrologic processes, climatic variability, and human influences on watershed water quality. Variations in constituent yields, in load per unit area, between watersheds appeared to be related to basin slope and impervious area. Yields then were used to compare contaminant loads from watersheds of different sizes and constituent trends from 1997-2009.

TRACK 1 ABSTRACTS: Wednesday 8:30 – 10:00 AM

Session 1.3 – Masters Hall

Panel Discussion: Shoreline Stabilization and the changing face of Georgia's coast

SHORELINE STABILIZATION AND THE CHANGING FACE OF GEORGIA'S COAST

In the face of changing climate and sea level rise, the 100-mile coast of Georgia is changing. Some areas are accreting, and many areas are eroding. Shoreline stabilization is a land management tool designed to protect or reinforce shoreline areas with man-made structures. Traditional methods of shore stabilization, like bulkheads and sea walls, can slow erosion rates and may be suitable in developed areas. However, they alter shoreline and water dynamics and often lead to loss of beach and intertidal habitat. Softer techniques, such as living shorelines and plantings, utilize natural materials and can enhance intertidal habitats and promote vegetative growth. However, soft techniques may not be suitable in high-energy environments. This panel discussion will include a brief overview of the benefits and drawbacks of shoreline stabilization methods, a presentation of regulations and policies in place governing shore stabilization, a demonstration of soft shoreline techniques in practice along Georgia[1]s dynamic coastal communities, and a group discussion about options recognizing the need for various techniques for different situations. Panel members will include representatives from the scientific and legal communities, state agencies, research institutions, and non-profit organizations working to promote stable shorelines that enhance our natural resources and protect our communities.

Moderator: Keyes, Alice M., *Associate Director, One Hundred Miles, 301 Gloucester Street, Brunswick, GA 31520*

Panelists:

Tom Bliss, *UGA Marine Extension, Athens, GA 30602*

Jan MacKinnon, *GA Coastal Resources Division, One Conservation Way, Brunswick, GA 31520*

Christi Lambert, *The Nature Conservancy, P.O. Box 484Darien, GA 31305-0484*

TRACK 8 ABSTRACTS: Wednesday 10:30 – 12:00 PM

Session 8.2 – Press Box: Agricultural water use

Simmons Jr., William Gus

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IRRIGATION UNIFORMITY: ENSURING MAXIMUM SUSTAINABLE SITE LIFE AND COST EFFICIENCY

One of the most important characteristics of an efficient irrigation system is making sure it is designed and maintained to distribute water as uniformly as possible. Even distribution means uniform application of water and nutrients to soil and receiving crops. Over-irrigation may lead to costly remediation from localized ponding, soil saturation, anoxic root zones, plant “drowning” and die-back, compaction, etc. Well-designed systems using modern equipment shod have a distribution uniformity of 75-85%. Lower uniformity dramatically increases water usage, probability for disease, localized ponding, and runoff. Distribution Uniformity (DU) is the measure of how evenly the irrigation system applies water to the landscape. This presentation will identify the common causes for Poor DU, and identify calculations that can help to alleviate potential problems. Distribution Uniformity can lengthen the site life and provide cost efficient measures, while providing the best stewardship of our water resources.

Weisman, Catherine C., Steve McWilliams, and Jimmy Matthews

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EXPLORING THE CONNECTION BETWEEN GEORGIA'S FORESTS AND DRINKING WATER

This session will provide an overview of recent efforts to bring together the forestry and drinking water sectors in Georgia to enhance communication, seek common ground, explore creative watershed management solutions, and develop collaborative projects. We will discuss the ways that forests and drinking water are interrelated, give a summary of issues facing each sector, and review the collaborative actions listed in the recent Georgia Forests and Drinking Water Forum Final Report.

Painter[1], Jaime A. and Lynn J. Torak[2]

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APPLIED IRRIGATION DEMAND: A COMPARISON OF THEORETICAL CROP IRRIGATION DEMAND TO METERED IRRIGATION WATER USE

Spatial and temporal distribution of agricultural withdrawals is essential to understanding and managing water resources. For the Apalachicola-Chattahoochee-Flint (ACF) River basin pilot study of the National Water Census, methods to estimate agricultural water use were developed. One method estimates agricultural water use using a demand-based approach that assumes only enough water is pumped onto a crop to satisfy the deficit between evapotranspiration and precipitation (theoretical crop demand). This method uses nationally available datasets, which are transferable to other geographic regions of agricultural production. A dataset of metered agricultural water use in the southeast part of the ACF River Basin was provided by the Georgia Agricultural Metering Program, a cooperative study between the Georgia Soil and Water Conservation Commission and the U.S. Geological Survey, for testing the validity of the theoretical crop demand method. Applied irrigation demand is defined as the difference between the theoretical crop demand irrigation rate and water actually applied to a field which is recorded through the metering program. This value was developed for major crop types throughout the growing season in the southeast part of the ACF basin.

Bose, Aaron

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EXPANDING IRRIGATION IN ALABAMA: POTENTIAL IMPLICATIONS FOR GEORGIA'S WATERSHEDS

Irrigation has allowed for the expansion of agriculture worldwide; this has led to the need for greater management of water resources. Throughout the southeastern United States, there is considerable heterogeneity in irrigation adoption. Georgia and Florida lead the region in irrigated land. While Alabama lags behind, it has recently passed legislation providing tax incentives to growers who adopt irrigation systems. The success of this policy could have significant implications for the water resources of Alabama's neighbors, including Georgia. The primary objectives of this study are to 1) identify the economic and climatic conditions under which adopting irrigation is profitable in Alabama, and 2) estimate, at the watershed level, aggregate water use associated with the increase in irrigated acreage under those conditions.

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MANAGING SEASONAL SEWER FLOWS WITH A PLAN BASED ON AVERAGES

Most long-term plans that have been developed for sanitary sewer service, including collection, treatment, and disposal, are based on average daily flow projections for the various types of customers served by this infrastructure. Additionally, most local, state, and federal regulations and guidelines are based on an average daily flow projection for various types of wastewater generators, as is the case in the State of North Carolina. There are a number of cases, however, where the actual flows experienced do not follow the prescriptive rates stipulated in published texts and guidance documents. Although the "law of averages" holds true in the end, and volumetrically, average daily flow limits in permits can be maintained, seasonal peak flows affecting tourist-based infrastructure, such as at the beaches or mountains of North Carolina, can present real challenges in managing and operating sewer infrastructure. Such is the case for The Town of Surf City, North Carolina. Located on the coast in Pender County, North Carolina, approximately half of the Town's land mass is situated on Topsail Island. During the summer tourism season, much more than half of the Town's sewer flow is generated by the island-portion of the Town, which sees exponential flow increases as vacationers and tourist flock to the beaches during warmer weather. In the "off seasons'", however, the proportionate flows between the island and the mainland portions of the Town become much more balanced. This paper describes the manner in which the Town of Surf City has managed seasonality and growth, and the impacts both have to the sewer collection system and wastewater treatment system. Also discussed is how a water balance may be developed for the existing system and coupled with the plans for expanding and improving upon the existing system infrastructure to accommodate continued growth with seasonality in the future.

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REMOTE TELEMETRY: MANAGING REMOTE REUSE SITES

The Town of Surf City, an island town located in Coastal North Carolina, began the process of expanding their wastewater facilities to meet the demands of a growing population and increasing seasonal tourism. The Town's treated wastewater is designed and permitted to meet North Carolina Reclaimed Water standards. The Town owns and operates an 88-acre sprayfield that uses small impact sprinklers to irrigate a grass receiving crop. The existing fields operate at maximum capacity, which is less than half of the Town's 10-year flow projection capacity needs. This existing sprayfield site is also bound on all sides by properties that are either unusable or unattainable by the Town for use in expansion of the non-discharge irrigation system. After an extensive search for available and usable property, the Town acquired a 2,200-acre tract under managed pine that would serve the Town's long-term needs. However, this tract of land is eight miles from the Town's wastewater facilities, in a remote, rural area. The project has recently been constructed, and this paper describes the challenges presented in managing this remote site that has limited access and coverage by conventional telecommunications infrastructure, and the strategies implemented to overcome these challenges; including solar-powered radio controls system and custom-designed irrigation management system.

TRACK 2 ABSTRACTS: Wednesday 8:30 – 10:00 AM

Session 2.3 – Room R: Nutrient Management

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EFFECTS OF LAND-APPLIED BIOSOLIDS ON SURFACE-WATER NUTRIENT YIELDS AND GROUND-WATER QUALITY IN ORANGE COUNTY, NC

The practice of applying biosolids from municipal wastewater treatment plants to agriculture fields is becoming more commonplace across much of the Piedmont and Coastal Plain of North Carolina. The impact of land-applied municipal biosolids to agriculture fields on the delivery of nutrients, bacteria, metals and emerging contaminants to surface water and groundwater resources is largely unknown. The U.S. Geological Survey and North Carolina Division of Water Resources partnered through the Non-point Source Grant 319 Program on a study of paired agricultural watersheds in Orange County that is designed to better understand the transport of nutrients, metals, bacteria and emerging contaminants from biosolids application fields to groundwater and surface water. Results will be useful for developing and implementing Total Maximum Daily Loads (TMDLs) for nutrient-impaired watersheds and to provide a scientific basis for evaluating the effectiveness of current regulations. In order to characterize the impact of land-applied biosolids on groundwater and receiving surface water, the study addressed the following elements: 1) assess the offsite transport of nutrients and bacteria in groundwater and overland runoff from the biosolids application fields to receiving streams, 2) compute and compare surface water nutrient and bacteria yields for both a watershed with biosolids land application and a nearby watershed without biosolids application, 3) conduct chemical analysis of biosolids and soil from agriculture fields with and without biosolids application and 4) perform preliminary evaluation of organic wastewater compounds as potential indicators of constituents derived from wastewater treatment plant biosolids in surface water and groundwater.

Mullen, Jeffrey D.
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OPTIMAL POLICY DESIGN FOR UPGRADING ON-SITE RESIDENTIAL WASTEWATER TREATMENT: DOES THE BASELINE SCENARIO MATTER?

When exploring environmental policy options, sometimes neither the current state of the environmental good being analyzed nor the effectiveness of the proposed policy is known with certainty. The issue under consideration in this study is the current state of water quality in Gwinnett County, Georgia, and the effectiveness of a particular policy - in our case, upgrading septic systems in the county to reduce nutrient loads from septic drainage fields - on improving water quality. Current water quality, expressed in terms of the probability a stream will fail to meet its designated use under the status quo, is unknown. Also unknown is the efficacy of the upgrade in reducing the probability of failing to meet designated uses. In this paper, we present the results of a choice experiment designed to explore how preferences for several policy attributes (cost of the policy, which stakeholder groups pay for the policy, and how costs are shared across stakeholder groups) are affected by changes in the status quo probability of failing to meet water quality and the efficacy of the policy in reducing the probability of failure. Results indicate that a) the status quo probability of failure does impact both individual preferences and estimated welfare measures for a given policy; b) policies in which costs are shared equally across stakeholder groups are preferred to those with unequally shared costs.

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SPECIATION DYNAMICS OF NUTRIENTS AND HEAVY METALS DURING THERMAL AND HYDRO-THERMAL TREATMENT OF SEWAGE SLUDGE

Because of the intrinsic high water content and the presence of a wide range of contaminants such as microorganisms, heavy metals and hazardous organic substances in sewage sludge from wastewater treatment plant, the management of sewage sludge has been a challenging task for the wastewater industry. Thermal and hydrothermal treatments are emerging as promising treatment alternatives since the contamination hazards can be mitigated and the sludge can be efficiently converted into valuable products. In the present study, we systematically investigated the migration and speciation dynamics of phosphorus (P) and heavy metals during the pyrolysis and hydrothermal treatment of sewage sludge collected from a local wastewater treatment plant in Atlanta, in order to evaluate the potential application of chars derived from the sludge as soil amendments. P in the chars and liquid extracts were characterized by 31P solid-state and liquid nuclear magnetic resonance spectroscopy (NMR), respectively. Heavy metals (Zn and Cu) were characterized by synchrotron X-ray adsorption spectroscopy. Results showed that both P and the heavy metals in the chars were significantly altered depending on the treatment conditions, which was possibly responsible for the different acid extraction

behaviors between chars. Results from the present study provide guidance for safe handling of the chars and technique selection for P reclamation, ultimately the development of sustainable management techniques for sewage sludge.

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EVOLVING NUTRIENT MANAGEMENT STRATEGIES AND POTENTIAL APPLICATIONS IN GEORGIA

The focus on nutrient management issues has continued to increase across the country as more and more states have identified water bodies as not meeting their designated use due to nutrient impairments. High profile harmful algal blooms like the 2014 incident off Toledo, OH on Lake Erie, evidence of a large "dead zone" in Green Bay, WI, and the continued challenges in meeting the restoration goals for the Chesapeake Bay have further heightened the awareness of the public and water resource managers that more effective nutrient management is badly needed. Traditional regulatory strategies of focusing on the point source dischargers has proven to be only partially successful in meeting nutrient reduction goals. Federal and State water quality management agencies have known for years that nonpoint source pollutant runoff has been the dominate source of nutrient loadings. However, regulation of nonpoint sources has proven much more difficult than point sources. Regulators in other states are developing innovative frameworks to encourage collaboration between point and nonpoint sources to benefit each other and to achieve watershed goals. Watershed based permitting and water quality credit trading programs have been recommended by the US Environmental Protection Agency as approaches to help point source dischargers find more cost effect strategies for overall nutrient load reductions in impaired watersheds. Unfortunately, these methods have been used infrequently and in some cases have not led to the improvements in water quality that were anticipated. Water quality credit trading has been discussed in Georgia for several years but has not been broadly implemented despite being recommended in several of the regional water plans in 2012. Other regions of the country have moved forward with new strategies to provide point source discharges with additional tools for meeting nutrient load reductions and to provide flexibility for achieving additional nonpoint source load reductions from both agricultural and urban land uses. This paper provides two innovative approaches to nutrient compliance: one includes a wastewater utility partnering with agricultural communities and the other includes a municipality implementing urban retrofits. For wastewater and agricultural collaboration, the paper provides a summary of Wisconsin's Adaptive Management strategy being tested in a TMDL tributary watershed to Lake Michigan in the bay of Green Bay, WI. For innovative urban retrofits, the paper provides a summary of the Chesapeake Bay program to achieve urban nonpoint source nutrient loadings reductions. These innovative nutrient and sediment reduction options include stream restoration, shoreline restoration, and improvements to leaking sanitary sewers. Observations on these programs and their potential application in Georgia will be provided.

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FECAL COLIFORMS, E. COLI AND PCR BASED MICROBIAL SOURCE TRACKING IN STREAMS OF PUERTO RICO

Fecal pollution was assessed in a series of locations along streams and rivers in Puerto Rico, among which are Rio Culebrinas, Rio Añasco, Rio Yagüez, Quebrada Sábalos, Caño Boquilla, Rio Guanajibo in western Puerto Rico. Turbidity, dissolved oxygen, temperature, pH, specific conductivity and salinity measurements were collected in the field. Water samples were collected using 4 replicates, two of which were used for bacteriology and for water filtration for later analysis of DNA markers for MST. Microbial contamination was determined using IDEXX to enumerate the level of fecal bacteria (E. coli and Coliform) in the rivers and Microbial Source Tracking was used to identify human, cattle and pig source of the fecal pollution at each location. There were high levels of fecal bacteria (> 400 MPN/100 ml) in most of the river sites. The highest E. coli counts were at Río Matilde and Costa Azul. MST indicated that eight out of 32 sites were contained human fecal pollution but pig fecal bacteria were not detected in any of the rivers. We are continuing to monitor the water quality along these rivers in Puerto Rico.

TRACK 4 ABSTRACTS: Wednesday 10:30 – 12:00 PM

Session 4.4 – Room Q: Sustainability and Re-use I

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ON-CAMPUS WATER REUSE: RELIABILITY & READINESS

Water main breaks across the country highlight concerns about the safety of an aging water infrastructure. The current water needs in Atlanta rely on a system designed almost 140 years ago that has been cobbled together ever since. Atlanta's 1600+ miles of pipe is in need of constant repair, to minimize the loss of service associated with infrastructure failure. Atlanta is currently funding infrastructure upgrades with a $350 M program and on-campus water reuse can help augment these efforts. It takes a lot of water to create energy and energy systems on university, government and corporate campuses require resiliency and redundancy to guarantee uninterrupted service. Environmental and infrastructure challenges are forcing utilities to reconsider exposure to risk as it relates to water supply for HVAC and utilities. Many institutions are looking to secure their operations through innovative water reclamation systems, while maintaining industry leading treatment results. These institutions demonstrate how campus-wide wastewater reclamation provides cost savings, reliability and N+1 readiness in the midst of 21st century water stresses. This presentation will offer case studies of installations at major universities, illustrating the key characteristics of an innovative and impactful business model, including: Assessing appropriate water management solutions based on specific environmental, economic, and social conditions present on each campus; Minimizing dependence on an aging infrastructure through decentralized reclamation and reuse; De-risking operations, while helping to resolve collective municipal infrastructure and environmental issues; and Addressing regulatory and public relations issues associated with non-potable reuse.

McKinnon[1], Joey, S. Blankinship[2], J. Dowd[3]
[1] Local2Global, LLC, 5 West Forsyth Street, Suite 200, Jacksonville, Florida 32202; [2] St. Johns Riverkeeper, 2800 University Boulevard North, Jacksonville, Florida 32211; [3] Department of Geology, The University of Georgia, Athens, Georgia 30602.

NEW DIRECTIONS IN CONSERVATION DISTRICTS

Since the 1930's Dust Bowl era, conservation districts have existed as politically-elected or appointed local units of government throughout the United States, charged with coordinating voluntary soil and water conservation and resource management programs with landowners and agricultural operators. More than 3,000 conservation districts exist in the United States with nearly 17,000 Soil and Water District Supervisors. Georgia, for example, where agriculture is the top industry, consists of 40 conservation districts and 370 supervisors. Although widespread in geographical range, the effectiveness of the districts under contemporary conditions has been called into question, with many localized political movements advocating the dissolution of the boards. New directions in agriculture and politics may offer renewed purpose for conservation districts. As voters have become less connected to traditional agriculture, these political races have become low information campaigns. However, increased interest in areas such as urban agriculture, green infrastructure, and environmental protection provide new avenues for districts to recalibrate to today's challenges. The role of conservation districts has widely shifted to public outreach and education in recent decades. Advances in social media provide platforms for districts to connect with the public easily when many are seeing reductions in funding. Conservation districts create an intersection of agricultural, environmental science, and politics at the local level. With the visibility of recent high profile environmental issues in national politics, and the need for scientists as communicators and public policy makers, conservation districts may provide an unique opportunity to "build the bench" with new leadership for science in politics.

Simmons Jr., William Gus
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DESIGNING WASTEWATER IRRIGATION SYSTEMS: ENGINEERING DESIGN INPUTS

In order to complete a Surface Irrigation System Design, there are many factors that influence the best equipment choices. Quality of effluent and site specific conditions will drive the decision for equipment types that may be available for use. Once an instantaneous loading rate and a long-term application rate are established, the designer must select irrigation system components that match the requirements and abilities of the site. This includes Irrigation Equipment, Pumps Valves, System Controls, and Storage Facility. This presentation explores the different irrigation equipment types depending on area size and application rates, and carries the participants through the design process to create a functional system. Listeners will discover the primary design considerations, such as precipitation rate, loading rate, and how spatial considerations such as field shape and slope contribute to the design. Single or multiple zone requirements, pressure system capabilities, and coordinating with soils and hydrogeologic reports may influence the design, and will ultimately give operators the most flexibility in system operation and effectiveness.

TRACK 7 ABSTRACTS: Wednesday 10:30 – 12:00 PM

Session 7.2 –Room F/G

Panel Discussion: Maximizing Flow: restoring the Savannah River Basin's natural flood patterns

A pending study involving South Carolina, Georgia, The Nature Conservancy and the USACE will specifically address updates to the drought plan using the new drought of record. With revised ecosystem flow recommendations developed by a scientific panel, the study will model the effects of several alternatives of revised Thurmond Dam outflows.

Guest Panelists:

Eric Krueger, *Director of Science & Stewardship, SC Chapter of TNC*

Oscar Flite, *CEO & Senior Scientist at the Phinizy Center for Water Sciences*

Will Duncan, *Aquatic Ecologist, US Fish & Wildlife Service*

Dr. C. Rhett Jackson, *Professor of Hydrology, UGA*

Stan Simpson, *US Army Corps of Engineers*

TRACK 7 ABSTRACTS: Wednesday 8:30 – 10:00 AM

Session 7.1 – Room F/G: Savannah River and Savannah Harbor

Roehl Jr., Edwin A.
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MANAGING SAVANNAH RIVER BASIN WATERS TO OPTIMALLY MEET MULTIPLE OBJECTIVES

Managing the many, often conflicting needs for water in the Savannah River Basin is increasingly difficult. Three droughts since 2000 brought record low elevations in the upper Basin's reservoirs, negatively impacting local economies. Near the coast are two municipal water intakes and the important freshwater marshes of the Savannah National Wildlife Refuge. Modifications to Savannah Harbor have allowed saltwater to migrate into the Refuge, reducing its freshwater acreage more than 50 percent since the late 1970s. The currently planned harbor deepening includes flow alteration features to protect the Refuge, but their real effect is unknowable before implementation. The above describes a complex optimization problem - how to best manage the many water needs through droughts, sea-level rise, the deepening, and other concerns. The optimal solution is to conserve the available water by continuously controlling reservoir releases to the minimum that meets multiple objectives that have been prioritized by resource managers and stakeholders. This requires continuously gathering data that characterize changing needs and conditions, and an accurate model that predicts the best course of action. Extensive hydrologic and weather data are already being collected at critical sites. This paper describes an optimization model based on machine learning that leverages these data, with simulation results that indicate salinity intrusions can be reduced while also conserving water. The model can adapt to structural changes such as the deepening by fitting new data; and quantify the effect of the flow alteration features by comparing the pre- and post-deepening salinity responses to freshwater flows and tides.

Grams, Susan C.
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LONG-TERM HYDROLOGIC MONITORING BY THE U.S. GEOLOGICAL SURVEY (USGS)

The U.S. Geological Survey (USGS) operates a network of streamflow and water-quality monitoring stations along the Savannah River and in the Savannah River estuary in cooperation with the U.S. Army Corps of Engineers (USACE) to support the monitoring requirements for the USACE's Savannah Harbor Expansion Project (SHEP). The goal of the SHEP is to deepen the shipping channel to a new depth of 47 feet to allow larger ships to use the port. The primary concerns regarding the harbor deepening project are: (1) the consequent potential for increased upstream salinity encroachment which may damage fragile ecosystems in the Savannah Wildlife Refuge and threaten fresh-water intakes, and (2) the decrease in ambient dissolved-oxygen levels. The SHEP streamflow and water-quality monitoring network is comprised of 15 monitoring stations, 4 of which have been in operation since the mid-to-late 1980's. These stations are located upstream and downstream of Port of Savannah operations and represent Savannah Harbor model nodes, salinity-intrusion monitoring points, chloride monitoring locations in the upper estuary, and dissolved oxygen mixing-zone locations. The hydrologic-monitoring objectives of SHEP are designed to occur in three phases of channel construction: a 1-year pre-construction phase, a 4-year construction phase, and a 10-year post-construction phase. A subset of the current monitoring locations will continue to be operated well beyond the project timeframe. All data are available in real-time on the USGS National Water Information System Web Interface (NWIS-Web) at http://waterdata.usgs.gov, and are provided to the SHEP database (http://www.shep.uga.edu) managed by the USACE for frequent modeling updates.

Flite, Oscar P.
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BIOCHEMICAL OXYGEN DEMAND IN THE SAVANNAH RIVER BASIN: RESULTS FROM SIX YEARS OF RESEARCH

Biochemical oxygen demand (BOD) is a regulatory parameter that is used to determine how much oxygen will be consumed by a particular natural or manmade discharge to a water body. Over the past six years, we have assessed oxygen demand dynamics within this river system by applying multiple methods, experiments, and analysis approaches. By using a Lagrangian sampling approach (sampling according to travel time) from 2006-2008, we found that the river acts as a conduit for dissolved organic material in the winter but undergoes moderate organic matter loss in the summer. Using the EPA approved Long Term Biochemical Oxygen Demand method, we found large seasonal intra-site variability (20% to 90% coefficient of variation) for all sampled sites but also found that the oxygen consumption rate used in the Total Maximum Daily Load calculations for the Savannah Basin underestimates the fast kinetic rate and overestimates the slow kinetic rate used in the current modeling effort. Using a real-time, in-situ Lagrangian sampling effort, we found that the conventional LTBOD test likely underestimates actual river respiration rates downstream of in-

dustrial and municipal discharges. Results from this research show that current sampling, analysis, and modeling of biochemical oxygen demand in river systems can be improved to better characterize actual river processes.

Duncan, William W.
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A SCIENTIFIC BASIS FOR THE RECONNECTION OF SAVANNAH RIVER OXBOWS THROUGH FLOW RELEASES AND HARBOR DEEPENING MITIGATION

Navigation improvements to the Savannah River in the late 1950's included the removal of 40 river bends, amounting to a steeper, straighter main channel that is 13% shorter. Hydrologic connectivity between natural and artificial oxbows and the Savannah River frequently has been cited as a management concern for recreational fishing access, game fish production, rare mussel conservation, and wildlife management. Releases from Thurmond Dam have the potential to affect numerous natural oxbows, artificial meander cutoffs, and sloughs for nearly 200 river miles. To our knowledge, very little information has been generated to identify the hydrologic connectivity thresholds between the Savannah River and these habitats. Similarly, no information on recreational fishing access to these habitats exists. With the Corp's support, we developed relationships between river discharge and habitat connectivity, acreage connected to the river, and angler access. At a subset of sites, we evaluated water quality parameters in the mainstem river and artificial cutoffs. Results show that hydrologic connectivity, water chemistry, and angler access vary widely across oxbows. A classification of oxbows was developed to guide future re-connection efforts that are intended to mitigate for the Savannah Harbor deepening and other restoration initiatives. We also demonstrate how results provided in this study can be used to evaluate and develop flow management alternatives for the 220 miles of river below J. Strom Thurmond Dam.

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Savannah Harbor Expansion Project, Senior Project Manager, US Army Corps of Engineers, Savannah District, 100 W Oglethorpe Ave, Savannah, GA 31401

SAVANNAH HARBOR EXPANSION, DREDGING AND MITIGATION BEGIN

The study for the Savannah Harbor Expansion Project (SHEP) began in the 1990s and continued into 2012. With recent legislation and an October 8, 2014, Project Partnership Agreement with the State of Georgia, the Corps of Engineers is starting this long awaited project to deepen Savannah Harbor by 5 feet. The Port of Savannah is the fourth busiest container terminal in the nation, the second largest on the East Coast and the largest single container port in North America. Deepening Savannah Harbor from 42 to 47 feet is estimated to cost $706,000,000 and take at least 5 years. Large container vessels must await high tide or light load to reduce drafts in order to call at Savannah, reducing overall transportation efficiency. Once SHEP is completed, these delays will be reduced and the project will generate $174,000,000 in net benefits to the nation annually. The port is also located in an exceptionally environmentally sensitive area. For this reason, SHEP involves robust environmental monitoring that started in 2013 in addition to surface water, endangered species, wetlands, dissolved oxygen and cultural resources mitigation. Approximately half of project costs are for mitigation and demonstrates how the project balances human needs with the needs of the environment. SHEP is one of many infrastructure improvement projects around the world to help capture efficiencies as the world's container vessel fleets grow larger.

two were from high density and two from low density watersheds. All water samples were analyzed for nitrate, ammonium, and total Kjeldahl nitrogen. Base-flow yields were not significantly different in various seasons. The contribution from OWTS may be offsetting the lower yield expected due to increased impervious surface with urbanization. Total nitrogen and nitrate concentrations increased significantly with OWTS density above a threshold density of about 100 systems km-2 during base-flow conditions. On average, in storm flow condition 58% of total N load was in the form of TKN (failing OWTS, livestock, and leaves) and 42% was nitrate (fertilizer, OWTS, and livestock).

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UTILITY CLIMATE RESILIENCY STUDY FOR THE MNGWPD

CDM Smith is working with the Metropolitan North Georgia Water Planning District (MNGWPD) to assess the potential impacts of climate variability on water resources and infrastructure within the 15-county planning region. A series of future climate scenarios were developed that represent discrete plausible future conditions, but which are not considered to be forecasts. Utilizing a standard range of global climate model projection data sets, five discrete scenarios were developed representing the central tendency as well as outer quartiles categorized as: hot/dry, hot/wet, warm/wet, and warm/dry. Data from all the model projections residing within a given quartile were pooled to create the five scenarios. This provided a broad but practical number of scenarios for subsequent analysis while not requiring a subjective selection of a single model projection. The “hybrid delta ensemble” method was then utilized to adjust the historical climate records to reflect the five future climate scenarios. Using this method statistical adjustments were made to the historical observed data in a way that preserves the seasonal patterns of variability. A sixth future climate scenario was then developed by extending statistical trends observed in the historical data. Utilizing the developed climate scenarios, a vulnerability analysis was performed for impacts to water supply, water demand, water quality, watersheds, and infrastructure. Output from these various analyses included potential climate related impacts to firm and average yields of water supply reservoirs, water demand, regulatory low flows and implications for wastewater discharge permitting, flood frequency and stream peak flows, water quality, and infrastructure vulnerabilities. Following the identification of vulnerabilities, a suite of potential adaptive strategies will be identified as well as a high level assessment of both potential benefits and negative impacts from implementing the adaptation measures. The final component of the study includes development of a list of recommended future work tasks for the District or individual government/utilities to address climate resiliency.

Bahn, Robert A.
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EFFECTS OF EXURBANIZATION IN THE UPPER LITTLE TENNESSEE RIVER BASIN: SEDIMENTATION IS PREDICTABLE, FLOW AND SPECIFIC CONDUCTIVITY ARE NOT

From late summer 2010 through early fall 2011, hydrology and water chemistry were monitored in 12 watersheds varying in spatial distributions of human land use. Monitoring included continuous recording of water level and specific conductivity, regular baseflow sampling, and stormflow sampling with an automated sampler. Rating curves were developed to convert the stage time series into flow time series. The 12 watersheds included two fully forested watersheds, three watersheds with small farms and rural residences in the valleys (classic S. Appalachian land use), three watersheds with small farms and rural residences in the valleys but also with homes built on the hillslopes and ridges (mountainside development), one urbanized watershed draining the City of Franklin, NC, and three mainstem river sites. We analyzed these data to test the following hypotheses: 1) More developed streams would have higher peak flows and flashiness indices; 2) More developed streams would have higher TSS values and steeper TSS / discharge rating curves; and 3) More developed streams would yield more sediment on a per hectare basis and have higher specific conductivity values.

TRACK 2 ABSTRACTS: Wednesday 10:30 – 12:00 PM

Session 2.4 – Room R: North Metro Water District Planning

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UPDATE OF THE WATER RESOURCE MANAGEMENT PLANS FOR THE METROPOLITAN NORTH GEORGIA WATER PLANNING DISTRICT

The Metropolitan North Georgia Water Planning District ("the District") is currently in the development of a major update to the Water Resource Management Plan ("the plan") as required under O.C.G.A. §12-5-570 Et seq. The District is the entity responsible for watershed and stormwater management, wastewater management, and water supply and conservation management planning within the 15-county metropolitan area which includes Bartow, Cherokee, Clayton, Cobb, Coweta, DeKalb, Douglas, Fayette, Forsyth, Fulton, Gwinnett, Hall, Henry, Paulding, and Rockdale Counties. The District is governed by a 26 member Governing Board made of 16 elected officials and 10 citizen members appointed by the Governor, Lieutenant Governor, and Speaker of the House. The District also includes six Basin Advisory Councils (BACs) to provide a forum for stakeholder input and a Technical Coordination Committee (TCC) made up of local government staff. The District last updated and adopted the plan in 2009. The primary objectives of the 2016 plan update are to: 1)use the 2009 plan as a foundation, build on or modify sections that need improvement while addressing new requirements and challenges as described in this scope of work, 2) update the plan consistent with Georgia Environmental Division (EPD) guidance, District Governing Board, TCC and BACs guidance, 3) advance the District's on-going approach to integrated water planning, and 4) update the plan with the most current data and information covering a wide range of areas including management issues, plant capacities, demand forecasts, etc. The plan update will be prepared with involvement of local governments, State agencies, the District's TCC and BACs, other regional water planning councils and other interested stakeholders. The plan update will also build upon and be coordinated with existing planning and regulatory activities being undertaken by local governments within the District, regional and state governmental agencies, as well as with plans being developed by the State, including the Regional Water Plans.

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NONPOINT SOURCE AND GREEN INFRASTRUCTURE PLANNING IN THE ATLANTA REGION

While much work has been completed to address many of our Region's water quality challenges, much more work remains to be done. Nonpoint source pollution (NPS) continues to impact the Region's water resources. Many sources and solutions for NPS are beyond the scope of regulations, but are still in need of better management. In light of this need the Metropolitan North Georgia Water Planning District (MWPD) will during its 2016 plan update work will develop strategies that begin to outline how we address NPS as a region. This strategy, at a minimum, will identify potential NPS sources, recommend strategies, management practices, goals, and metrics for addressing NPS, and highlight available resources for addressing NPS pollution. To further support this effort, the MWPD will also develop a strategy to address Green Infrastructure (GI) at a regional scale. This strategy will, at a minimum, identify barriers and opportunities to GI, discuss high-level costs and benefits, include discussions of regional GI beyond stormwater, and make recommendations for overcoming barriers to regional GI. While these strategies will not provide for new requirements to regional jurisdictions, they will provide a first step in how the region approaches both the challenges and opportunities associated with nonpoint source management and green infrastructure implementation. An overview of expected outcomes from the development of these strategies and potential future considerations will be discussed.

Hoghooghi[1], Nahal and David E. Radcliffe[2]
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EFFECT OF ONSITE WASTEWATER TREATMENT SYSTEMS ON TOTAL NITROGEN AND BASE FLOW IN URBAN STREAMS OF METROPOLITAN ATLANTA, GEORGIA

Onsite Wastewater Treatment Systems (OWTS) are widely used in the southeastern United States and it is estimated that 37% of the homes in Georgia are on OWTSs (EPA, 2002). OWTS can be a source of nitrogen pollution of surface and ground waters as a result of poor maintenance or high density. As droughts persist, the extent to which water use by OWTS represents consumptive use (defined here as water that does not return to streams) has been debated. The overall goal of this study was to determine the impact of OWTSs on stream water quality and quantity in urban watersheds in metropolitan Atlanta. Out of the 24 selected watersheds ranging in area from 0.18 to 8.8 Km2, twelve were characterized as having high density and twelve are characterized as having low density of OWTSs. Three times a year under base flow conditions, stream flow was measured. Among those streams, 4 streams were equipped with ISCO automated samplers and programmed to sample during storms as a function of gage height. Of these four sites

TRACK 4 ABSTRACTS: Wednesday 8:30 – 10:00 AM

Session 4.3 – Room Q: Understanding the state of our water resources

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U. S. GEOLOGICAL SURVEY HYDROLOGIC MONITORING IN GEORGIA

The hydrologic monitoring program of the United States Geological Survey (USGS) has been the foundation of water policy and decisions since the early 1890's. Water monitoring can vary from discrete measurements, or samples manually collected, to sophisticated instrumentation that continuously records and transmits data in real-time. The USGS hydrologic monitoring program is more than just a consistent practice in data collection, it includes intensive quality-assurance, real-time processing for viewing on the web, and eventual publication and archival of all collected data. The State of Georgia has USGS state-wide hydrologic networks that measure surface-water levels and flows, quality of the surface waters, and availability of groundwater resources. The first USGS streamgage to measure river levels and flows in Georgia was installed at the Etowah River near Canton in 1892. Since 2000, the streamgaging network has more than tripled in size to over 330 locations, all with real-time satellite telemetry and over eighty percent collecting precipitation data. Since the early 1970's, the USGS has collected discrete water-quality data at nearly 50 locations to monitor the long-term water-quality trends of Georgia's rivers. Recent development of water-quality monitors over the past several decades now allows for continuous monitoring at more than 120 locations of select water-quality constituents. Groundwater levels at 164 locations have been continuously monitored by the USGS for more than 70 years, with discrete measurement dating back to the 1890's. These hydrologic networks are operated in cooperation with other Federal, State, and local agencies, and the data collected are available to the public. While individual users may be interested in a single gage or well, the data from that location, aggregated to a regional or national level, can provide a broader evaluation of the water resource conditions. The USGS hydrologic monitoring program has an extremely diverse base of stakeholders, including water resources planners and managers, researchers, river forecasters, modelers, emergency managers, dam operators, and recreational users. New tools, such as WaterAlert, WaterWatch, river webcams, storm-tide monitoring, and site-specific flood inundation libraries, continue to highlight the USGS hydrologic monitoring program as the foundation of water resources research and policy decisions in Georgia and beyond.

Shelton, John M.
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BEYOND THE STREAMGAGE

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

Kistenmacher, M. and Aris P. Georgakakos
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INFORMING THE DEVELOPMENT OF A SUSTAINABLE WATER MANAGEMENT PLAN FOR THE ACF RIVER BASIN

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

ments, and inform the planning process toward developing a consensus management plan. This article describes the technical process and tools developed to support the stakeholder information needs. These activities included comprehensive surveys of individual stakeholders' interests and performance evaluation metrics, development of different modeling tools (e.g., ACFDSS, ResSim, hydrologic models, hydro-dynamic models) to evaluate a host of water management alternatives (WMAs), development of post-processing tools to interpret complex technical information into stakeholder-meaningful findings and conclusions, and multiple workshops with each stakeholder caucus and the ACFS as a whole. The technical assessments considered many potentially promising water management alternatives including making adjustments to in-stream and off-stream water uses; power generation management policies, reservoir coordination strategies, and modifications to the existing water infrastructure. Throughout this process, model results were analyzed and presented to highlight the effects of different WMAs on a wide range of performance metrics representing individual stakeholder preferences. Several rounds of modeling were conducted to help stakeholders appreciate the implications of the current operations, evaluate trade-offs among several key water uses, and identify the most promising WMAs included in the ACFS recommendations to the United States Army Corps of Engineers and the riparian states.

Bodwell, J.
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STATEWIDE WATER LOSS MANAGEMENT GETS CREATIVE TO LEVERAGE LONG-TERM IMPROVEMENTS

In 2012, the Georgia Environmental Finance Authority (GEFA) and Environmental Protection Division (EPD) implemented an overwhelmingly successful 10-month statewide training and technical assistance program for the AWWA Water Auditing and Loss Control Methodology. Over 100 small water systems throughout Georgia were trained in the area of water loss auditing and loss control. In 2013 and 2014, GEFA took the management of water loss from the classroom directly to water infrastructure. GEFA and EPD, in partnership with private consultants, designed and implemented Phase 2 of the Water Auditing and Loss Control training and technical assistance program. Phase 2 leveraged the outcomes of the 2012 training program into "on the ground" technical assistance activities. These activities – including source meter flow verification, customer meter accuracy testing, and pilot leak detection surveys – provided validation to the audits, while providing each water system with critical insight into the most effective next steps for water loss control in their system. With over 75 participating water systems in Phase 2, GEFA conducted a formal qualification process to select the industry's top water loss control companies, then matched those companies with water systems – based on the Phase 1 audit results. These water systems are improving their understanding and efficiency of system operations while the state of Georgia sees improved conservation of water resources. GEFA hopes the investment in Phase 1 training and Phase 2 technical assistance will increase applications for capital project for water loss control.

Cameron, Christopher, Peter Hawman, Andrew Herring, Gail Miller, Caren Remillard, Dr. Marguerite Madden
NASA DEVELOP, UGA Center, Dept. of Geography, University of Georgia

UTILIZING SATELLITE AND UAS IMAGERY TO DOCUMENT LAND COVER TRENDS IMPACTING WATER QUALITY, WILDLIFE HABITATS AND ARCHEOLOGY OF THE OCMULGEE RIVER CORRIDOR

The NASA DEVELOP Ocmulgee River Water Resources and Ecological Forecasting team partnered with the Georgia Department of Natural Resources (GA DNR) to conduct a project focused on conserving the Ocmulgee River corridor. The corridor is home to unique species such as Atlantic sturgeon, short nosed sturgeon, black bear, and millions of migratory birds. It also holds a rich archeological record of Native American settlement. Over the years, this area has experienced increasing urbanization pressure. The goal of this project was to analyze land cover trends over the past 15 years using National Land Cover Dataset (NLCD) classifications and Landsat 8 images to predict future changes within the Ocmulgee River watersheds. With this goal in mind, a current land cover map was created and the team performed a time-series analysis. Threatened and endangered species habitats and hydrologic characteristics were overlaid with the classification maps to identify areas of concern. Using the results of this project, GA DNR decision makers will be able to predict the impacts of environmental change on water quality and prioritize water resource management along the Ocmulgee River.

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ANTIMICROBIAL PESTICIDE REGISTRATION FOR THE REMOVAL OF BACTERIA FROM STORMWATER RUNOFF

Essential features of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) are explored for the implementation of antimicrobial pesticides to control pathogenic bacteria in stormwater runoff. FIFRA defines a pesticide in terms of the inherent intent of a substance, not its characteristics. Stormwater quality programs, including Coastal Zone Management Plans, have largely focused on monitoring and meeting TMDLs or advisory limits with little regard to effective and sustainable antibacterial BMPs. The stormwater community has experienced a recent proliferation of antimicrobial BMPs carrying implied or explicit public health claims targeting pathogens such as fecal coliform, E. coli and enterococci. FIFRA requires that antimicrobial pesticides first be registered with the U.S. EPA and subsequently in states and any U.S. lands where they are to be sold. Only registered pesticidal products can carry public health claims and certain terms are cited which are considered by EPA as making such claims. Critical registration distinctions between chemical based "pesticide product" and mechanical based "pesticide device" are explained. Registration rules differ for these two types of antimicrobial mechanisms. Current approaches to antimicrobial BMPs are cited, some of which may not comply with FIFRA. A registration approach is proposed for pesticide products and devices. A "gray area" for public domain, land based stormwater BMPS is identified where their widespread implementation could be interpreted to conflict with FIFRA. The Georgia Beach Water Monitoring Program is cited as an example of bacteria monitoring.

Grundtner, Ashley and Satish C. Gupta
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P SPECIATION IN SEDIMENTS OF THE MINNESOTA RIVER BASIN

Sediments are a dominant P reservoir in a variety of aquatic ecosystems and play a critical role in governing dissolved P concentrations. We assess how P properties of the sediments change as they move downstream from the Greater Blue Earth River Basin to the Minnesota/Mississippi confluence. In this study, we analyzed bed load and suspended sediments for equilibrium phosphorus concentration (EPC0), their potential to desorb soluble P, and P sequential extraction fractions. Results showed that sediment samples have higher total P concentration than the P concentration in soils from the surrounding area, thus indicating some P adsorption from river waters. After correcting for particle enrichment, some sediment samples showed higher concentrations of inorganic P downstream than upstream of the WWTPs. Sequential fractionation showed a predominance of calcium-bound P in bed load sediments. Finally, a comparison of the EPC0 values showed that the majority of sediments are acting as a source of P, particularly during low flow periods. We synthesize these results in the context of historical sediment P in Lake Pepin and how sediments from various sources in the Minnesota River Basin may have contributed to this P.

TRACK 1 ABSTRACTS: Wednesday 10:30 – 12:00 PM

Session 1.4 – Masters Hall: Adapting to a changing coast I

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DEVELOPMENT OF A COASTAL DROUGHT INDEX USING SALINITY DATA

The freshwater-saltwater interface in surface-water bodies along the coast is an important factor in the ecological and socio-economic dynamics of coastal communities. It influences community composition in freshwater and saltwater ecosystems, determines fisheries spawning habitat, and controls freshwater availability for municipal and industrial water intakes. There are many definitions of drought, with most describing a decline in precipitation having negative impacts on water supply and agriculture. Indices have been developed for hydrological, agricultural, meteorological, and socio-economic drought types that incorporate data such as rainfall, streamflow, soil moisture, groundwater levels, and snow pack. These indices were developed for upland areas and may not be appropriate for characterizing drought in coastal areas. Because of the uniqueness of drought impacts on coastal ecosystems, a need exists to develop a coastal drought index. The availability of real-time and historical salinity datasets provides an opportunity to develop a salinity-based coastal drought index. The challenge of characterizing salinity dynamics in response to drought is excluding responses attributable to occasional saltwater intrusion events. Our approach to develop a coastal drought index modified the Standardized Precipitation Index and applied it to sites in South Carolina and Georgia. Coastal drought indices characterizing 1-, 3-, 6-, 9-, and 12-month drought conditions were developed. Evaluation of the coastal drought index indicates that it can be used for different estuary types, for comparison between estuaries, and as an index for wet in addition to drought conditions.

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INVESTIGATIONS IN COASTAL WATER QUALITY FOR OWTS PLANNING EFFORTS

The population in coastal Georgia is growing at a significant rate. Coastal cities have limited funding and time to upgrade their municipal treatment plant infrastructure to counter the rise in population. Therefore, onsite septic wastewater systems (OWTS) have and will continue to be heavily permitted. These systems have the potential to greatly impair water quality if not maintained, leaching dangerous levels of bacteria and nitrogen, thus causing serious health issues to both humans and wildlife. With growing concerns, it is extremely important to establish water quality and land use assessment tools to enable better public health planning. The University of Georgia Marine Extension Service and project partners conducted a survey of geo-locating and inspecting OWTS in proximity of state waterways of 11 coastal counties. A GIS database, maps and a septic pollution susceptibility index for each county were derived from project data. Two pilot study have begun for further research. A project to analyze surface water quality in relation to OWTS densities in Glynn County, GA has begun. A nonpoint source indicator transport model is being developed with ArcGIS ModelBuilder from utilization of project data. Another study has begun to determine nitrogen fate and transport in coastal Georgia soils on a mounded onsite septic system, a relatively new technology implemented in the region. The soils project will produce a 2-D Hydrus model. This powerful toolset will assist planners in environ-mental health protection strategies for Coastal Georgia.

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SALTWATER INTRUSION IN THE FLORIDAN AQUIFER SYSTEM NEAR DOWNTOWN BRUNSWICK, GA

Since 1959, the U.S. Geological Survey (USGS) has lead a cooperative water program (CWP) with local government to assess the effect of groundwater development on saltwater intrusion within the Floridan aquifer system (FAS) near Brunswick. 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, a 2,720-foot-deep test well drilled south of Brunswick suggests the source of saltwater was located below the UFA in the Fernandina permeable zone of the Lower Floridan aquifer. During calendar year 2014, the CWP included continuous water-level recording at 13 wells completed in either the Floridan, Brunswick, or surficial aquifer systems; synoptic water- level measurements in 56 wells to map the potentiometric surface of the UFA in the Brunswick/Glynn County area during October 2014; and sampling a total of 52 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 in recent years. Results from nine additional samples collected at industrial wells located near the northern part of the chloride plume indicate vertical migration of chlorides between the upper and lower water-bearing zones of the UFA.

TRACK 8 ABSTRACTS: Wednesday 8:30 – 10:00 AM

Session 8.1 – Press Box

Panel Discussion: Coordinating with agriculture on water stewardship

Agriculture represents a significant part of Georgia's economy, land-use, and character while also providing lessons on how to manage water resources. This panel will discuss the role agriculture has played in the stewardship of our water resources as well as what opportunities may exist in the future for even more collaboration between water stewardship and agriculture.

Moderator: Chris Faulkner, *Watershed Planner, Atlanta Regional Commission, 40 Courtland St. NE, Atlanta, GA 30303*

Panel Guests:

Chris Faulkner, *Watershed Planner, Atlanta Regional Commission*

Angela Bray, *Environmental Planner, South Georgia Regional Commission*

Gary Hawkins, Biological and Agricultural Engineering, The University of Georgia, Tifton, GA 31793-5766 *UGA*

TRACK 6 ABSTRACTS: Wednesday 8:30 – 10:00 AM

Session 6.3 – Room D: Habitat and water quality assessment I

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A COMPARISON OF MACROINVERTEBRATE COMMUNITIES WITHIN TWO SOUTHEASTERN RIVERS

Macroinvertebrates are ubiquitous to nearly all freshwater ecosystems, are diverse taxonomically and functionally, and because they can have relatively short- (i.e., days to weeks) to long- (i.e., years) life cycles can reflect changes in a system over space and time. These characteristics make aquatic macroinvertebrate communities ideal indicators of aquatic ecosystem health and quality. As part of ongoing continuous monitoring projects on the Savannah and Ogeechee Rivers quarterly macroinvertebrate assessments were initiated in the summer of 2014. Hester-Dendy samplers were placed along ~140 miles of each river. After 30 days, samplers were collected. Macroinvertebrates were measured and identified to the lowest practical taxonomic level and classified into functional feeding groups to allow for an assessment of trophic relationships within communities. Macroinvertebrate abundance (ind./m2) and biomass (mg/m2) were calculated. In addition, differences between samples were also assessed by comparing common metrics used in the biological assessment of streams in the region (i.e. richness, diversity, composition, and biotic integrity). Total macroinvertebrate abundance was higher within Ogeechee River sites averaging 1,458 ±192 ind./m2 compared to 674 ±188 ind./m2 for Savannah River sites (P=0.020), with collector-gatherers abundance accounting for much of this increase (P=0.03).Longitudinal trends of abundance remained relatively stable within the Ogeechee River. In contrast, abundances within the Savannah consistently trended upward from 344 ind/m2 at the uppermost sampling site to their peak of 1363 ind/m2 at the furthest downstream site. Preliminary results suggest that there are no other significant differences between any other functional feeding groups or metrics.

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PHYSICAL ATTRIBUTES AND CLUTCH SIZE OF THE DAGGERBLADE GRASS SHRIMP, *PALAEMONETES PUGIO*, IN THREE COASTAL WATERWAYS OF SAVANNAH, GEORGIA

The daggerblade grass shrimp, *Palaemonetes pugio*, inhabits estuaries along the East and Gulf coasts of the United States, is a link between trophic levels, and is exposed to varying environmental conditions within these coastal habitats. The purpose of this study was to determine the relationship between shrimp length, weight, and clutch size at 3 estuarine locations in Savannah, Georgia. The study was conducted from August to October 2014 at Moon River, Country Club Creek, and Wilmington River. Male and female shrimp were collected by dip net twice a month during low tide. Length and weight were measured and clutch size was recorded for ovigerous females. There was a consistent ordinal rank in attributes among sites. Mean length was 29.22 ± 4.08, 27.06 ± 2.39, and 24.43 ± 2.90 mm at Country Club Creek, Wilmington River, and Moon River, respectively. Mean weight was 235.21 ± 105.03 mg at Country Club Creek, 177.76 ± 48.93 mg at Wilmington River, and 136.14 ±51.93 mg at Moon River. Largest mean clutch size was 172.49 ± 46.41 eggs/female at Country Club Creek, followed by 140.74 ± 39.99 eggs/female at Wilmington River, and 106.95 ± 33.83 eggs/female at Moon River. Trematode abundance ranged from 0-113 cysts/shrimp. Shrimp at Country Club Creek had the greatest average weight, length, and clutch size, while shrimp at Moon River had the lowest. Further re-search will include analyzing sediment and shrimp tissue to determine if there is any correlation between polycyclic aromatic hydrocarbon concentration and *P. pugio* clutch size.

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VISUAL STREAM MONITORING: EXPLORING GEORGIA'S VISUAL MONITORING METHODS

Visual stream monitoring is one of the easiest and most important ways for citizens to assess stream health, and it is often the most overlooked. Recently, Georgia Adopt-A-Stream produced an updated version of their visual stream monitoring program including a revised manual, forms and procedures. The highlight of the procedures is a newly developed rapid habitat assessment of instream conditions. This assessment is Georgia specific and includes an evaluation of 10 parameters for both rocky and muddy bottom streams. Created for volunteers, the visual assessment includes drawings of stream conditions, in-depth directions and a poster guide with descriptions and photographs. Additionally, the visual monitoring procedures encourage taking photo points, cross-section measurements and pebble counts. All data can be entered and viewed by the public through our online database. The website displays data in matrixes and graphs, producing time-lapse reproductions of the cross-section measurements. The visual assessment compliments other monitoring activity, indicating the chemical and biological health of a stream. This presentation will

describe the process Georgia Adopt-A-Stream went through to update the visual monitoring program, sharing lessons learned while demonstrating the value of these surveys in assessing stream health with our volunteers and partners across the State.

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WATERSHED AND LONGITUDINAL MONITORING EVENTS

Georgia Adopt-Adopt-A-Stream partners annually with many organizations, universities and watershed groups to conduct sampling events with volunteers on a watershed level. These monitoring events range from one-day snapshots to week-long paddle trips. One-day sampling events, also called 'Blitzs' River Adventures and River Rendezvous, generally target 20-50 sites within a watershed. The multi-day events involve sampling anywhere from 10 to 20 sites per day, 70-120 sites per event, and are usually part of a larger activity such as "Paddle Georgia." The multi-day events are located on a different Georgia river each year and bring along hundreds of citizens on the adventure. Partners for these events include local governments, watershed organizations, Adopt-A-Stream groups and many other entities which provide sampling equipment, technical support and sponsorship. Depending on the objectives of the event, data can be collected on many parameters including water quality chemistry, bacteria, macroinvertebrates and physical characteristics. Data is posted on our website/database and is available for citizens and partners to view in graphs and basic GIS or download for analysis. In addition to collecting and sharing the data, small reports are written and shared with the public, and the information has been used at the local, state and federal level. During this presentation we will discuss Georgia's volunteer water quality monitoring program and how we've used watershed- wide sampling events to connect with a larger

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UPSTREAM, DOWNSTREAM: THE UNRELIABLE AQUATIC BORDER BETWEEN THE UNITED STATES AND CANADA

The length of the U.S.-Canadian border is approximately 5525 miles if the Alaska-Canada border alone is included in the total. The joint marine environment of the United States and Canada includes the Atlantic Ocean between Nova Scotia and Maine, the Pacific Ocean in the British Columbia and Washington State region and the Great Lakes St. Lawrence Seaway system. The marine environment is viewed as particularly vulnerable and porous to smuggling activity; however, not all potential threats relate to smuggling. The water supply Walkerton, Ontario became contaminated with the highly dangerous O157:H7 strain of E. coli bacteria, from farm runoff into an adjacent well that had been known for years to be vulnerable to contamination. Starting May 11, 2000, many people of the community of about 5,000 people began to simultaneously experience symptoms of E. coli infection. For days the Walkerton Public Utilities Commission insisted the water supply was "OK" despite being in possession of laboratory tests that had found evidence of contamination. Seven people died directly from drinking the E. coli-contaminated water, and might have been saved if the Walkerton Public Utilities Commission had admitted to contaminated water sooner. About 2,500 became ill. Walkerton is located on the Saugeen River, which flows into Lake Huron. Hypothetically, any outbreak could have easily passed into Lake Huron and onto U.S. shores, creating a disruption of water supplies in the United States. This research-in-progress examines the Walkerton Tragedy a bit closer, as well as the potential for disruptions in other locations.

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	8	0	0	0	8
Ph.D.	3	0	0	0	3
Post-Doc.	0	0	0	0	0
Total	11	0	0	0	11

Notable Awards and Achievements

SUSTAINABLE WATER MANAGEMENT IN THE APALCHICOLA-CHATTAHOOCHEE FLINT (ACF) RIVER BASIN

The development of an equitable ACF water sharing compact has challenged Alabama, Florida, and Georgia for more than two decades. Among the outstanding critical needs are (i) inclusive and effective stakeholder participation in planning and management processes; and (ii) development of comprehensive and reliable information and knowledge pertaining to the interdependencies of the basin water uses and their local and basinwide impacts.

The ACF Stakeholders (ACFS; http://acfstakeholders.org/) was established in 2010 to address the need for effective stakeholder participation and the development of a sustainable water management plan. ACFS is an inclusive 503(c) nonprofit organization with membership from 56 river basin stakeholders and is open to any group with interest in the ACF water management--cities, lake associations, farmers, industries, environmental citizen groups, power companies, fishermen, NGO's, and many others

Under this project, GWRI is developing the technical information and knowledge base necessary to inform the stakeholder discussions toward a consensus and sustainable ACF water management plan. The main project tasks include:

-Comprehensive assessment of the historical ACF basin unimpaired inflows; -Development of modeling tools for (1) river and reservoir simulation, (2) reservoir optimization, and (3) estuary hydrodynamic flow and salinity assessments; -Systematic and integrated use of the modeling tools to quantify the benefits, impacts, and tradeoffs of various water management alternatives formulated by the ACF stakeholder caucuses; -Communication of assessment findings to ACF stakeholder through several interactive workshops; -Development of reservoir regulation policies and other management strategies reflecting and realizing the stakeholder shared vision for sustainable water management.

In May 2015, ACF Stakeholders, Inc. (ACFS) completed and unanimously approved a Sustainable Water Management Plan (SWMP) for equitably managing water in the Apalachicola, Chattahoochee and Flint River Basin, including its impact on the Apalachicola Bay.

The official copy of the SWMP is available at http://acfstakeholders.org/swmp/ .