Florida Water Resources Research Center
Annual Technical Report
FY 2016

Introduction

The mission of the Florida Water Resources Research Center at the University of Florida is to facilitate communication and collaboration between Florida s Universities and the state agencies that are responsible for managing Florida s water resources. A primary component of this collaborative effort is the development of graduate training opportunities in critical areas of water resources that are targeted to meet Florida s short- and long-term needs.

The Florida Water Resources Research Center coordinates graduate student funding that is available to the state of Florida under the provisions of section 104 of the Water Resources Research Act of 1984. Over the past year (Fiscal Year 2016) the Center supported multiple research projects including agreements with two Florida universities (Florida Atlantic University and the University of Florida), two state agencies (South Florida Water Management District and St. Johns River Water Management District), and partial support from industry partner CH2M Hill as part of a University Consortium for Field Focused Research.

Recognizing the importance of STEM (Science, Technology, Engineering, and Mathematics) Education initiatives, the Florida Water Resources Research Center is very proud to have supported the research efforts of 6 Ph.D. students and one Post-Doctoral researcher all focusing on water resources issues relevant to Florida and the Nation.

During FY 2016, along with providing support to graduate students within the state of Florida, the Center also facilitated development of research at both the state and national level producing 18 peer-reviewed journal articles and 1 US Patent. The Center is a state repository for water resources related publications and maintains a library of technical reports that have been published as a result of past research efforts (Dating back to 1966). Several of these publications are widely used resources for water policy and applied water resources research in the state of Florida and are frequently requested by others within the United States. As part of the WRRC information and technology transfer mission, the library was converted to digital form and is provided free to the public through the WRRC Digital Library available on the center website (http://wrrc.essie.ufl.edu/).

Research Program Introduction

During FY 2016 the Water Resources Research Center supported four 104B research projects and four center-affiliated research projects. The supported research projects considered a wide range of water resource related issues while maintaining focus on topics relevant to Florida and the nation.

104B Research Projects

Transport and loss of nitrogen within the Upper Floridan Aquifer in the Silver Springs Springshed. This project is investigating groundwater flow characteristics and natural attenuation rates of nitrogen loads in the upper Floridan Aquifer System. Groundwater velocities, ages, nitrate fluxes, and denitrification rates were measured within a network of wells using a suite of monitoring techniques. The data from this project will be used directly in springshed models that will be applied by the St. Johns River Water Management District.

Agricultural Water Security Through Sustainable Use of the Floridan Aquifer. This project is working to develop, evaluate and disseminate research-based knowledge that helps landowners and policy makers to adopt practices and policies that ensure economic and environmental sustainability of the coupled hydrological, ecological, and agricultural systems that rely on the Upper Floridan Aquifer (UFA) which is among the largest and most productive aquifers in the world and represents a vital regional resource shared between Florida, Georgia and Alabama. The region is dependent on the UFA to support agricultural activities worth over $7.5 billion but faces significant threats to agricultural water security, environmental quality, and social fabric.

Development of Methods for Quantifying Water and Contaminant Fluxes in Karst Systems. The goal of this student lead seed project is to evaluate and develop new tools and technologies for improved water resources management within karst systems. The investigation will evaluate existing and nascent methodologies for water resources management that look beyond standard best management practices in order to develop management tools that can help governmental agencies to analyze the quantity of water available and the amount used in their regions as well as consider the water resource as an economic good in the broadest sense or concept, rather than exclusively in monetary terms. The outcome of this project will be a thorough evaluation of economic and systems based methods for evaluating water resources management within karst systems and recommendations for which methods are most promising.

Development and Evaluation of Data Accuracy Assessment Algorithms for Identifying Anomalies in Hydro-meteorological Data (Phase II). This project incorporates a mix of applied and fundamental research in order to generate useful practical tools that will advance the fundamental understanding of data anomalies or outliers in hydrometeorological data. Acquisition of hydrologic and hydraulic data is the key component of water resources management in central and south Florida. The results of this research are highly relevant and critical to all water resources management agencies that currently use stage data for modeling and management of day-to-day operations of water resources systems and development of protocols for flood control warnings. The products derived from this study are expected to be tested for real-time evaluation of stage data by South Florida Water Management District (SFWMD).

Transport and loss of nitrogen within the Upper Floridan Aquifer in the Silver Springs Springshed

Basic Information

Title:	Transport and loss of nitrogen within the Upper Floridan Aquifer in the Silver Springs Springshed
Project Number:	2016FL326B
Start Date:	3/1/2016
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	3
Research Category:	Ground-water Flow and Transport
Focus Categories:	Nitrate Contamination, Nutrients, None
Descriptors:	None
Principal Investigators:	James Jawitz

Publication

1. Klammler H, Jawitz JW, Annable MD, Yaquian JA, Hatfield K, and Burger P, 2017. Large aquifer storage changes due to saltwater interaction affect groundwater balances over decades, Geophysical Research Letters. In review

Statement of regional or State water problem: Spring systems are among the most significant of ecologic resources in the State of Florida. Declines in the ecological character of some of the key spring systems in the state have increased the interest and support for restoration efforts.

Statement of results or benefits: The goal of this project is to determine groundwater flow characteristics and natural attenuation rates of N loads in the upper Floridan Aquifer System. Groundwater velocities, ages, nitrate fluxes, and denitrification rates will be measured at a network of wells using a suite of monitoring techniques. The data from this project will be used directly in springshed models.

Nature, scope, and objectives of the project

Project objectives are:

- Modify borehole dilution and passive flux meter methods for application in a) matrix flow in the upper Floridan, b) flow through zones with fractures, and c) flow through karst cavities.
- Develop push-pull tracer test methods for applications in complex karst aquifers.
- Use flux meters to quantify groundwater flow and N fluxes at multiple depths in approximately 30 wells.
- Quantify denitrification rates through push pull tracer tests in selected wells.
- Age dating of groundwater samples from selected locations using environmental tracers.

Tasks and deliverable time frames are listed in the table below.

TASK/DELIVERABLE	SUBTASK/DELIVERABLE	Anticipated Start	Anticipated End
Task 1. Modify borehole dilution and passive flux meter methods for application in a) matrix flow in the upper Floridan, b) flow through zones with fractures, and c) flow through karst cavities.	Report	6/1/2014	6/1/2017
Task 2. Use flux meters to quantify groundwater flow and N fluxes at multiple depths in approximately 30 wells.	Data	6/1/2014	6/1/2017
Task 3. Develop push-pull tracer test methods for	Report	6/1/2014	6/1/2017

applications in complex karst aquifers.			
Task 4. Quantify denitrification rates through push pull tracer tests in selected wells.	Data	6/1/2015	6/1/2017
Task 5. Age dating of groundwater samples from selected locations using environmental tracers.	Age Data	6/1/2015	6/1/2017
Task 6. Final Report	Report	6/1/2015	6/1/2017

Methods, procedures, and facilities. In the case of the karstified Silver Springs aquifer the interplay of slow matrix flow and fast fracture / conduit flow creates highly complex flow and transport conditions. Hydraulic and reactive properties of the aquifer will be measured using four approaches:

1. Borehole dilution tests
2. Passive Flux Meters
3. Push-pull tracer tests
4. Groundwater age dating tracers

I. Borehole dilution tests

Borehole dilution tests will be modified and used to characterize the groundwater velocity distribution vertically in selected wells and in critical regions of the springshed (Tasks 1). This data provides an initial assessment of the hydraulically active regions of the aquifer and a measure of the relative importance of fracture and karst features in the springshed. The borehole dilution campaign will guide the next phase of higher resolution special data collection including design aspects of the sampling plan.

II. Passive Flux Meters

Passive flux meters (PFMs) provide local flux measurements of groundwater, nitrate and its degradation products. Using PFM, karst flux data becomes available as depth profiles along monitoring wells, which allows a characterization several important features: (1) Vertical heterogeneity of flow and transport as produced by spatial heterogeneity in input sources and aquifer characteristics. This type of information is fundamental for assessing the internal dispersion and mixing behavior of the aquifer as well as for the interpretation of any kind of point measurements. (2) Vertical trends in flow and transport as produced by the large scale boundary conditions of the aquifer. This may help delimiting the hydraulically active upper portion of the aquifer from a possibly stagnant lower part. The size of the active aquifer is directly related to the mean nitrate travel time towards the spring and stagnant parts of the aquifer may act as

additional nitrate reservoirs, with nitrate uptake and release by diffusion from / into the active aquifer. (3) The spatial distribution of well averaged groundwater and nitrate fluxes may contribute to identifying larger scale flow, transport and reaction patterns between recharge locations and the spring. Comparing depth averaged fluxes of nitrate and its degradation products, for example, at different distances from the spring allows conclusions about nitrate reaction behavior at the transport scale. (4) Temporal variations in measured fluxes (e.g., between rainy and dry seasons) indicates the temporal variability of aquifer behavior and may be used to validate assumptions involved in the simplified aquifer response models (Task 3).

III. Push-pull tracer tests

Push-pull tests provide in-situ measurements of groundwater velocity, effective porosity, dispersivity, retardation factors and nitrate degradation rates (Task 2) (Kim et al., 2005). These measurements may again be obtained as depth profiles over monitoring wells and may serve for: (1) Mutual validation of PFM and push-pull results for groundwater flux. (2) Assessment of reservoir size (i.e., aquifer storage and mean travel time) by combining PFM observed active aquifer depth with measurements of spatially variable effective porosity. (3) Local scale dispersivity is again fundamental for small scale nitrate mixing before reaching the spring, while (4) retardation and degradation are first order parameters influencing mean travel time and the aquifer's natural nitrate attenuation capacity (Task 4). The latter is of great interest for achieving long term aquifer restoration goals, as it is a tool to distinguish nitrate degradation from nitrate storage in hydraulically stagnant parts of the aquifer, which may be released again over longer time scales. Consequently, direct observations of nitrate degradation rates are essential complements to overall nitrate input-output balances.

IV. Groundwater age dating tracers

The age of groundwater at the Silver Springs vents and in wells throughout the springshed can provide critical information on spatial contributions of N loads (Task 5). The data acquired through deployments of borehole dilution and passive flux meters with identify regions of the aquifer where groundwater age date would provide high value information. The results will provide a measure of local groundwater age distribution with area and groundwater depth to refine our understanding of the travel time from areas of the springshed to the Silver Springs discharge.

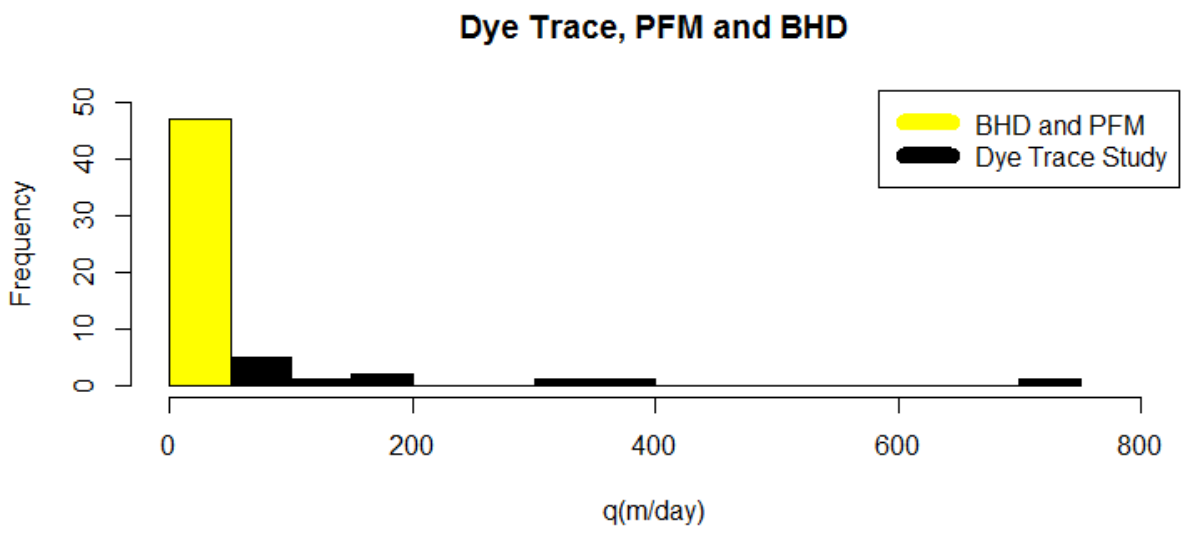
<u>Major findings and accomplishments to date</u>

Borehole Dilution. Borehole dilution tests were performed in four wells within a 5km radius from Silver Springs between May and October 2016. Every test was performed at several depths in each well, consequently the large variety of q values derived from the test. BHD tests were performed in both matrix and conduit zones, identified from fractures visible in borehole videos, within each well with the exception of M820 which did not have any fractures or indications of high flux zones. For this analysis we considered $q > 1$ m/day conduit flux while q below this rate was considered matrix flux. Based on this bimodal analysis we have found four locations characterized as conduit flux.

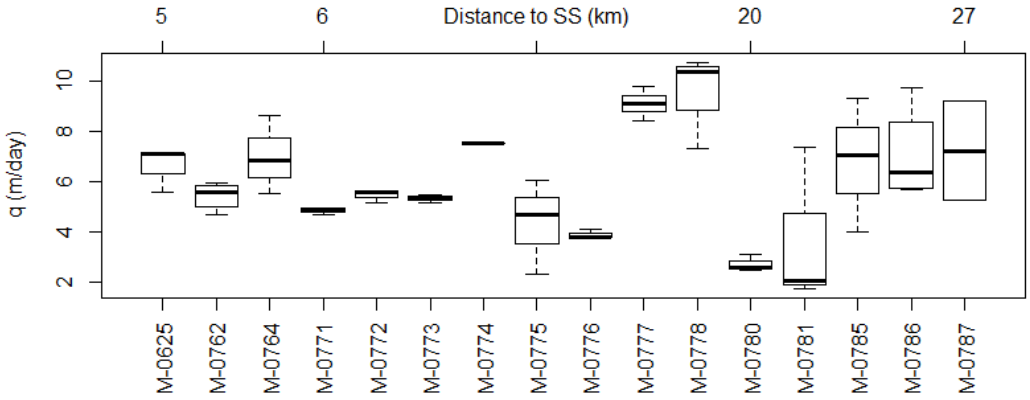
Well ID	Depth (ft bls)	Predominant porosity	Slope ln(C/C0)	q (cm/day)	Tracer
M0789	99-109	Matrix	-0.00017	1.0	KCl
M0789	107-117	Matrix	-0.000209	1.2	KCl
M0789	89-99	Matrix	-0.00044	2.6	KCl
M0820	88-83	Matrix	-0.001647	10.8	KCl
M0789	69-79	Matrix	-0.002714	16.0	KCl
M0820	93-88	Matrix	-0.003419	22.5	KCl
M0820	88-83	Matrix	-0.0035	23.0	Rhodamine
M0789	79-89	Matrix	-0.004838	28.4	KCl
M0820	93-88	Matrix	-0.0053	34.9	Rhodamine
M0820	98-93	Matrix	-0.005838	38.4	KCl
M0820	103-98	Matrix	-0.0061	40.1	KCl
Sprayfield	90-85	Matrix	-0.006108	40.2	KCl
M0820	103-98	Matrix	-0.0081	53.3	Rhodamine
M0820	98-93	Matrix	-0.0088	57.9	Rhodamine
Sprayfield	85-80	Matrix	-0.010236	67.3	KCl
Sprayfield	77-72	Conduit	-0.029437	193.6	KCl
Sprayfield	67-62	Conduit	-0.049109	323.0	KCl
M0789	120-130	Conduit	-0.1318	775.0	Rhodamine
M0789	120-130	Conduit	-0.14787	869.5	KCl
M0789	120-130	Conduit	-0.150638	885.8	KCl
M0789	120-130	Conduit	-0.1725	1014.3	Rhodamine
M0789	120-130	Conduit	-0.175199	1030.2	KCl
M0789	120-130	Conduit	-0.1769	1040.2	Rhodamine
M0625	111-117	Conduit	-0.3952	3588.7	KCl
M0625	111-117	Conduit	-0.4005	3636.8	KCl

The BHD technique enables measuring q over the spectrum between PFM's and dye trace studies as PFM's can reliable measure very slow flux and dye trace studies have been used to measure high water velocities (>100 m/day), BHD can effectively measure q below 30 m/day. For instance, the lowest q measured with the BHD 1 cm/day, well within the detectable range for PFM. The highest q measured through BHD was 35 m/day, which is also well within the low end results find through dye trace studies in the area.

A histogram of all the performed tests seem to have a travel time distribution of the gamma type.



Flux Meters. Passive flux meters have been deployed in 16 wells in the UFA throughout the Silver Springshed. PFMs deployed in this project had three layers of GAC, thus the variability in q on the chart below, some wells had more than one PFM installed in them which contributed to larger ranges of q. Regardless of the distance between Silver Springs (top x axis) and each well, q did not exceed 10 cm/day in any of the tested wells.



- Next steps. In situ measurements of groundwater flux are being compared to dye tracer tests, and together these data can be used in a mass balance framework to estimate the aquifer porosity and the fraction of the aquifer that is conduit vs matrix. These results will be compared to similar water quality data from groundwater samples. This will enable assessment of the degree of heterogeneity of Darcy fluxes and solute fluxes. The final piece of this analysis will consider heterogeneity in solute transformations such that an entire springshed mass balance

can be estimated from land surface, through the vadose zone, in the aquifer and then discharging at the spring.

- Students supported. This project has supported two graduate students and one postdoc.

Related research.

Florida Department of Environmental Protection, 2007. Florida Springs Initiative: Program Summary and Recommendations. Florida Department of Environmental Protection, Tallahassee, Florida

Heffernan, J., Liebowitz, D., Frazer, T., Evans, J., and Cohen, M., 2010. Algal blooms and the nitrogen-enrichment hypothesis in Florida springs: evidence, alternatives, and adaptive management. Ecological Applications 20(3): 816-829.

Heffernan, J., Albertin, A. Fork, M., Katz, B., and Cohen, M. 2012. Denitrification and inference of nitrogen sources in the karstic Floridan aquifer. Biogeosciences 9: 1671–1690.

Knowles, L. 1996. Estimation of Evapotranspiration in the Rainbow Springs and Silver Springs Basins in North-Central Florida, U.S. Geological Survey, Water-Resources Investigations Report 96-4024.

Munch, D., Toth, D. Huang, C., Davis, J., Fortich, C., Osburn, W., Phlips, E., Allen, M., Knight, R., Clarke, R., and Knight, S., 2006. Fifty-year retrospective study of the ecology of Silver Springs, Florida. Special Publication SJ2007-SP4, St. Johns River Water Management District, Palatka, Fl.

Phelps, G.G., 2004, Chemistry of Ground Water in the Silver Springs Basin, Florida, with an Emphasis on Nitrate: U.S. Geological Survey Scientific Investigations Report 2004-5144, 54 p.

Agricultural Water Security Through Sustainable Use of the Floridan Aquifer

Basic Information

Title:	Agricultural Water Security Through Sustainable Use of the Floridan Aquifer
Project Number:	2016FL327B
Start Date:	3/1/2016
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	3
Research Category:	Water Quality
Focus Categories:	Water Quality, Water Quantity, Agriculture
Descriptors:	None
Principal Investigators:	David Kaplan, Damian Adams

Publications

There are no publications.

Statement of regional or State water problem.

The Upper Floridan Aquifer (UFA) is a rich, common-pool resource that provides drinking water for 10 million people, supplements lakes, springs and streams across a 53,300 km^2 region, and is tapped for irrigation to support a robust, multi-state agricultural enterprise. In a significant portion of the study area the UFA is unconfined (i.e., not protected by an overlying clay layer) and thus is rapidly recharged by typically abundant rainfall and easily polluted by a variety of land uses. Well-drained soils in the region are well-suited for agricultural production; however, they typically require supplemental irrigation and significant fertilization to achieve competitive yields. Direct connections among the soils, aquifer, springs, rivers and streams make aquatic ecosystems extremely sensitive to changes in groundwater quantity and quality. Like many other common-pool resources, quality and quantity of water in the UFA have deteriorated while remaining largely accessible to its users, however declining aquifer water levels and aquatic ecosystem health are driving the implementation of more stringent environmental standards that are in conflict with agricultural water use and land management trajectories.

In Florida, groundwater quality standards have transitioned from regulation based on the human health standard of 10 mg/l nitrate-nitrogen (NO_3-N) to an ecosystem-protective numeric nutrient criteria (NNC) standard of 0.35mg/l NO_3-N in groundwater emerging from spring vents (FDEP 2013). None of the monitored springs in the basin proposed for this study currently meet the NNC (FDEP 2010). The highest NO_3-N concentrations occur in agricultural areas and isotopic measurements indicate that the major source is fertilizer (Katz 2004, 2009). Total maximum daily loads (TMDLs) for the UFA-fed Suwannee and Santa Fe Rivers are based on achieving average monthly NO_3-N of 0.35mg/l throughout the river reaches (Hallas and Magley 2008). Achieving the NNC and TMDLs for the Santa Fe River will require NO_3-N load reductions ranging from 35% to 58% (Hallas and Magley 2008).

Florida also mandates development of minimum flows and levels (MFLs) for aquifers, springs and rivers to prevent harm to natural water bodies (s. 373.042, Florida Statutes). MFLs have been adopted for the upper and lower Santa Fe River (WRA 2007; SRWMD 2013), but are not being met and will require an estimated 13.8 million gallons per day reduction in agricultural and/or public water supply withdrawals from the UFA (SRWMD 2013). Taken together, the gaps between mandated and measured water quality and quantity described above illustrate the critical conflict between environmental, economic, and legal components of this tightly coupled system and represent an important scientific and social challenge. Importantly, stakeholders and experts throughout the region hold a variety of beliefs and attitudes about groundwater quality and quantity and often disagree on how threats to the system should be managed.

Statement of results or benefits.

With this work we aim to provide scientifically supported guidance on future land use and management scenarios that can adequately protect this important resource while maintaining agriculture viability in order to move forward from this conflict towards a potential solution (or range of solutions) that are acceptable to a variety of stakeholders.

Project outcomes will include a coupled biophysical and economic modeling platform that will allow us (and stakeholders) to assess a variety of alternative land use and management scenarios in which economically viable agricultural and silvicultural production are compatible with environmental regulations. These scenarios will be the central product of the project, allowing us to translate environmental goals into economic outcomes and enabling discussion of how stakeholders might transform social priorities sufficiently to achieve a sustainable water future.

This information will be of use to state, and federal land and water management agencies responsible for setting, implementing, and enforcing environmental regulations (e.g., the Suwannee River Water Management District, Florida Department of Environmental Protection, Florida Department of Agricultural and Consumer Services, and US Environmental Protection Agency), many of which are supporting the larger research effort. The information provided will also be useful for growers and other land-owners looking for ways to meet regulatory requirements without giving up their agricultural production or way-of life.

Nature, scope, and objectives of the project, including a timeline of activities.
The overall goal of this project is to create, evaluate and disseminate research-based knowledge that can lead landowners and policy makers to adopt practices and policies that ensure economic and environmental sustainability of the coupled hydrological, ecological, and agricultural systems that rely on the UFA. The research elements proposed here focus on the development of biophysical and economic models in support of this overarching goal, and proposal PIs and the student associated with this 104B proposal will work towards the following objectives:

1. Compile hydrological datasets and develop a spatially distributed, coupled surface water-groundwater model for SFRB
2. Model farm- and forest-level financial impacts of BMP adoption for alternative production systems
3. Quantify regional impacts of potential land uses and BMP adoption on economic activity
4. Develop baseline and alternative future land use and management scenarios for the Santa Fe River Basin (SFRB), and assess water quantity and quality impacts of alternate land use scenarios relative to the base case and existing environmental regulation

Project Tasks and Timeline *(Note: tasks associated with the PhD student partially funded by this 104B proposal are noted in italics).*

Student recruitment (pre-Year 1) *– The PIs will develop recruitment materials and will work with the UF Water Institute and their tenure-home departments to advertise the position. We anticipate inviting students to visit the UF campus and interview for the position in mid-Spring.*

BMP research synthesis and review (Year 1) *– The student(s) will draw from an existing review and associated database to identify a suite of BMPs that will be included in the coupled modeling platform and the scenario analyses.*

Biophysical modeling (Years 1 to 4) *– Team members will build and refine a coupled groundwater and surface water modeling framework for the study area, and will assess environmental impacts associated with various assumptions about BMP adoption, etc. The student(s) will work with team members to couple the biophysical modeling framework with the farm/forest-scale modeling and regional economic analysis.*

Training in farm-scale, forest-scale, and regional economic modeling (Years 1 and 2) – The second student or postdoc will be trained to employ existing enterprise-level economic and financial models, including *FLIPSim* for agricultural operations and a forest stand-level spreadsheet model developed by PI Adams, and to employ the regional economic modeling framework *Implan*.

Enterprise budgets review and updates (Years 1 to 3) – The second student or postdoc will review, develop and update crop budgets needed to inform farm- and forest-scale economic analysis and complete modeling at this scale. Extension agents and producers will be engaged through interviews and focus groups to generate results that help determine the enterprise-level financial impacts of BMP adoption.

Farm and forest-scale scenario analysis (Years 2 and 3) *– Alternative production and BMP adoption assumptions will be used to create competing output scenarios.*

Regional scale economic modeling (Years 3 to 5) – The second student or postdoc will work with PIs to compile information on agricultural production in the study area to determine baseline economic contributions from agriculture, and identify market trends and other factors likely to affect the composition of agriculture in the UFA. The student will then construct regional economic models of the study area using *Implan* software and county datasets.

Scenario and tradeoff analysis (Year 5) *– Results will be packaged as distinct scenario outputs, including expected environmental and economic impacts (farm/forest-scale and regional scale) for alternative assumptions about BMP adoption.*

Methods, procedures, and facilities.

A. Biophysical Model Development and Implementation

The SFRB is an ecologically sensitive, predominantly agricultural/ silvicultural HUC-8 watershed with major land uses representative of the area served by the UFA; it is also subject to stringent environmental regulations that are not currently being met. An important hydrogeologic feature of this karst region is the strong surface water-groundwater (SW-GW) interaction where the aquifer is unconfined. River and spring base-flows are dependent on groundwater, either via spring vents or diffuse seepage (Cohen 2008, Srivastava and Graham, 2014) as well as surface drainage systems in areas where the aquifer is confined. As such, a spatially distributed modeling approach that

characterizes the coupled SW-GW system, and can simulate impacts of thousands of GW wells and SW withdrawals for irrigation, is required to accurately model regional hydrology and water quality.

SWAT (Soil and Water Assessment Tool; Neitsch et al. 2011, Graham et al. 2009) simulates watershed hydrology, erosion, and water quality, and is capable of modeling crop growth and yield, nutrient uptake, irrigation and nutrient management, and BMP application for diverse land uses. While SWAT's surface water modeling and river routing components are robust (e.g., Setegn et al. 2010), its groundwater modeling capabilities are limited (Guzman et al. 2012). MODFLOW (Harbaugh 2005) is a powerful tool for simulating groundwater flow and quality (when linked with a transport model such as MT3D (Zheng, 2010)), but has limited land use or surface water modeling capabilities. Use of the coupled SWAT-MODFLOW model (SWAT-MF; Guzman et al. 2012) will allow us to employ each model's strengths to best represent linkages between land use and management and system hydrology and water quality.

SWAT-MF development will build from previous modeling activities in the SFRB. Srivastava and Graham (2014) developed a coupled SW-GW model (PARFLOW-CLM; Kollet and Maxwell 2008) for the SFRB that has been used to understand geologic, climatic and vegetative controls on hydrology and solute transport. We will use the large volume of data compiled to develop this model, and our previous modeling experience in the SFRB, to expedite model development. Modeled land uses will include general land use categories (e.g., urban, agriculture, pasture, forest, water, wetlands, etc.), which will be further resolved to characterize specific crops and cropping systems. We will develop a baseline (current) scenario that includes dominant agricultural/ silvicultural land uses: agronomic crops (corn, cotton, peanuts, hay); improved and unimproved pastures; pine plantations; emerging crops such as sesame, canola and carrot; and minor land uses (e.g. additional vegetable crops, dairies). Alternative future land uses, cropping systems, and irrigation and nutrient management practices will then be incorporated to evaluate their ability to reduce water use and nutrient loadings. Potential crop management options include cover crops, conservation tillage, irrigation BMPs, nutrient management BMPs, high planting density, reduced-intensity rotations, and conversion of cropland to silviculture.

The model will be calibrated and validated for the baseline scenario according to standard procedures (e.g., Moriasi et al. 2007). Targeted model outputs will include: 1) below root zone water and nutrient leaching (assessed against previous, on-going and proposed BMP studies; 2) groundwater levels, spring/river flows, and ground and surface water NO_3-N concentrations (assessed against existing monitoring data); and 3) agricultural/ silvicultural yields (assessed using previous, on-going and proposed BMP studies). Model parameter uncertainties will be assessed using the informal Generalized Likelihood Uncertainty Estimation (Beven and Binley 1992, Beven and Freer 2001) and/or the formal Differential Evolution Adaptive Metropolis (Vrugt et al. 2008) methods. Input data uncertainty will also be assessed following a strategy similar to Harmel et al. (2006).

Historical NLDAS climate data (1-hour resolution over a 12 km grid covering the continental US from 1979-present; Cosgrove et al. 2003) will be used to force local- and regional-scale models for baseline conditions. To characterize the range of likely future climate conditions, we will model future scenarios using both the historic climate data and publicly available, statistically downscaled daily climate projections (e.g. http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/ or MACA downscaled data developed for the SE by the PINEMAP CAP Project) that span the range of warm-wet to warm-dry scenarios projected for the SE US (Wuebbles et al. 2014).

B. Economic Research and Modeling

The coupled biophysical models will inform understanding of whether environmental regulatory standards (e.g., minimum flows and levels) are achievable in the study area under alternative scenarios. Economic modeling is needed, however, to assess whether these scenarios would be feasible and socially acceptable with respect to impacts on agricultural producers and regional economies. Economic models will be developed at both the farm/forest enterprise (i.e., individual producer) and regional scales.

At the enterprise scale, farm/forest-level production budgets and models will predict impacts of BMP adoption on financial viability of agricultural enterprises under alternative scenarios. The student will develop and update crop budgets and use the Farm-level Income and Policy Simulation Model System (FLIPSim, Richardson and Nixon 1986) to develop a farm-scale financial analysis model for alternative production scenarios (Kay et al. 2011). FLIPSim is a well-established framework for enterprise financial analysis that has been used to understand the impact of changes in land use, cropping systems and BMPs on farm and forest enterprises (e.g., Osei et al. 2012). We will update several existing crop budgets (e.g., accounting for new technologies) and create new budgets as needed for new crops (e.g., sesame, canola, carrots) using data collected from producers, suppliers, Extension agents, and others through interviews and focus groups as needed. Results that predict enterprise-level financial impacts of BMPs for different land uses and cropping systems will be presented to a panel of producers for validation.

Policy and regulatory changes in the UFA that affect farm- and forest-level management decisions are expected to have broad financial implications for agricultural and regional economies (Taylor et al. 1992). BMP adoption may lead to implementation costs, increased annual operating and maintenance costs, and changes to crop yields that have significant financial implications for landowners (Schmit and Knoblauch 1995). Thus, a better understanding of how regulations may affect viability of agricultural enterprises is needed to inform policy decisions.

Regional-scale economic models will assess the economic contributions of agriculture, forestry and other major industries in the study area that are dependent upon and impact the UFA and quantify regional impacts of potential land uses and BMP adoption on economic activity (e.g., Smajgl et al. 2008). To do so, we will first compile information on current and historic agricultural production in the study area using county-level data sources (e.g., USDA Census of Agriculture) and the Implan database (Implan Group

2014). These data will be used to determine baseline economic contributions of agriculture, silviculture and other major water-relevant industries in the study area. Next, we will forecast impacts of market trends, regulations, and other major market considerations on the future composition of agriculture in the study areas by extrapolation using linear, exponential and power functions fit to historic data. We will construct regional economic models of the study area using the Implan Input-Output/Social Accounting Matrix (IO/SAM) software and county datasets. I-O/ SAM models estimate economic multipliers that capture changes in economic activity from indirect effects (e.g., changes in direct employment through input supply chain purchases) and induced effects (e.g., household spending; Miller and Blair 2009). Outputs include industry revenues, employment, income, value added (GDP), taxes, capital investment, transfer payments, and domestic and international trade for 536 industry sectors including 18 sectors in crop, livestock, and forestry production. Sector information in the models for key agricultural commodities in the study area will be customized to reflect new project data.

Finally, the project team will work with stakeholders to create several policy scenarios, and generate results that characterize the expected impacts on environmental and economic conditions at both farm/forest and regional scales. A baseline scenario of current land uses, crop rotations, cultivation practices and water and nutrient management practices will be developed based on a review of the literature and semi-structured interviews with stakeholders. This baseline scenario will be used to understand the current economic impact of agriculture and silviculture in the region, understand impacts of current land uses on receiving waters, and provide a baseline for comparison with hypothetical future scenarios. A tractable suite of future scenarios used to explore the economic-environmental tradeoffs of scenarios that incorporate changes in financial incentives, land use, BMP adoption, BMP effectiveness, environmental regulation, and climate. Scenarios will be specifically designed to answer research questions about the spatial scale and geographic configuration of land use changes, rates of BMP adoption, and BMP efficiency improvements required to meet environmental regulations. While scenarios developed specifically to achieve environmental goals may not be economically feasible and/or socially acceptable, the results will be essential for illustrating inherent conflicts in the study area and communicating system limitations to stakeholders. Regional economic-environmental tradeoffs determined from baseline and scenario analyses will inform future work (outside the scope of this proposal) on the economic feasibility and social acceptability of future scenarios.

Major findings and accomplishments from last year. Accomplishments during the previous reporting year are summarized below following the tasks listed in the **Project Tasks and Timeline** section. The research team has advanced these activities via biweekly meetings between PI/co-PIs and students and monthly meetings with the whole project team. *(Note: tasks associated with the PhD student partially funded by this 104B proposal are noted in italics)*:

Student recruitment (pre-Year 1 - COMPLETE) *– The PIs developed recruitment materials and worked with the UF Water Institute and their tenure-home departments to*

advertise the position. A PhD student (Sagarika Rath) was recruited and began work on the project in fall 2016.

***BMP research synthesis and review (Year 1 – ONGOING)** – The student reviewed watershed-scale models to identify a modeling platform capable of meeting project goals (couples surface water and groundwater, includes crop growth and yield, capable of simulating existing and novel BMPs). We found that the coupled SWAT-MODFLOW modeling system will likely adequately meet these requirements and have moved forward with model domain development and additional benchmarking activities (see below). BMP review and associated database development is ongoing and will be informed by upcoming stakeholder engagement activities supported by a recently funded parallel research project.*

***Biophysical modeling (Years 1 to 4 – ONGOING)** – The PhD student and PI/co-PIs began work to build and refine a coupled groundwater and surface water modeling framework for the study area to assess environmental impacts associated with various assumptions about BMP adoption, etc. To date, the team has developed a preliminary model domain for the Lower Santa Fe River Basin using the SWAT-MF, and we are exploring the potential and utility of expanding the domain to include the larger Suwannee River watershed. Additionally, we have identified two important farm/forest-scale benchmarking activities to build confidence in the crop growth and yield modules in SWAT. The first task is a comparison of growth and yield for standard agronomic rotations (i.e., corn-peanut) as simulated by SWAT vs. the Decision Support System for Agrotechnology Transfer (**DSSAT**) model. The second task is a comparison of timber growth as simulated by SWAT vs. the Physiological Processes Predicting Growth (3-PG) model. For both benchmarking activities, the more rigorous crop growth models have been calibrated using regional experimental field data.*

Training in farm-scale, forest-scale, and regional economic modeling (Years 1 and 2 – ONGOING) – The second student (Unmesh Koirala) also began working on the project in Fall 2016 and has begun training to employ existing enterprise-level economic and financial models, including *FLIPSim* for agricultural operations and a forest stand-level spreadsheet model developed by PI Adams, and to employ the regional economic modeling framework *Implan*.

Enterprise budgets review and updates (Years 1 to 3 – ONGOING) – The second student began to review, develop and update crop budgets needed to inform farm- and forest-scale economic analysis and complete modeling at this scale and has selected four crops to focus on: corn, blueberries, loblolly pine, and slash pine.

Related research. Literature cited herein summarize the existing state of knowledge and serve to point out the research gaps this proposal aims to fill. This work aims to leverage the diverse portfolio of ongoing agricultural and silvicultural BMP field research and modeling being pursued at UF by proposal PIs and our many partners in the larger research initiative. The proposed work leverages data and outputs from two ongoing projects: (1) a large, 5-year field study, funded by Florida's water management districts,

the Florida Department of Environmental Protection, and the Florida Department of Agricultural and Consumer Services, which is quantifying the impacts of various silviculture treatments and environmental conditions (e.g., soil type) on water quality and water recharge from forests; and (2) a study funded internally by the University of Florida, which is supporting the development of a forest stand-level coupled water yield-carbon-timber production model, and the implementation of a forest landowner survey to determine preferences toward BMP adoption and payment program features. Finally, a large 5-year project recently funded by the USDA

Training potential. One Ph.D. student has been funded by this project (Sagarika Rath). Sagarika has made strong progress on literature review, model identification, and training since her appointment in August 2016. Our research group has also funded a second PhD student (Unmesh Koirala) focused on economic research and modeling and advised by Adams (SFRC). As summarized above, Unmesh has begun to review, develop and update crop budgets needed to inform farm- and forest-scale economic analysis and recently held his first committee meeting to present preliminary findings.

Evaluation of Methods for Improved Management of Water Resources within Karst Systems

Basic Information

Title:	Evaluation of Methods for Improved Management of Water Resources within Karst Systems
Project Number:	2016FL328B
Start Date:	3/1/2016
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	3
Research Category:	Ground-water Flow and Transport
Focus Categories:	Groundwater, Management and Planning, Models
Descriptors:	None
Principal Investigators:	Mark Newman, Kirk Hatfield

Publications

There are no publications.

1. STATEMENT OF REGIONAL OR STATE WATER PROBLEM:

It is estimated that the United States derives 40% of its potable water needs from karst aquifers (Quinlan and Ewers, 1989) and for the total population of the earth, it is 25% (Ford and Williams, 1989). Clearly, the importance of karst aquifers cannot be overstated; and, understanding their evolution, hydraulic behavior, critical functions in a watershed, and vulnerability to contamination are topics of high importance.

Karst is a terrain with distinctive landforms and hydrology created from the dissolution of soluble carbonate rocks such as limestone and dolomite. Over millions of years, dissolution transforms the underlying carbonate rock aquifers from a laminar or diffusive dominated flow regime to a system where diffusive flow feeds a well-developed network of solution conduits with primarily turbulent flow. This conduit network flow is typically manifested at ground surface as spring discharge. When the water table falls beneath the level of surface streams, theses streams lose water to underlying developed cave systems. If this condition persists, more and more surface drainage will be diverted underground, stream valleys will virtually disappear only to be replaced by closed basins or sinkholes.

Thus, karst terrain is characterized by springs, sinkholes, and subsurface caves and conduits that produce highly productive aquifers which are extremely vulnerable to contamination from surface sources (i.e., agriculture, urban storm water, etc.). The issue of vulnerability is extremely pertinent to the karst environment. Groundwater flow through unconsolidated aquifer media tends to move slowly and the inter- and intra-granular surface area of the porous media acts to a limited extent attenuate contaminants (i.e. through sorption) [see Figure 1]. For Karst aquifers, flow can be quite rapid once it reaches a conduit; consequently, the short hydraulic residence times and limited opportunity for surface-dependent attenuation leave karst aquifers highly vulnerable to contamination.

Karst hydrogeology is defined by a network of interconnected fissures, fractures and conduits emplaced in a relatively low-permeability rock matrix. Most of the ground-water flow and transport occurs through the network of openings, while most of the ground-water storage occurs in the matrix. As a result, most karst aquifers are highly heterogeneous and anisotropic.

For many karst aquifers, a large percentage of the water stored underground is perched, or suspended, above the main part of the aquifer in the "epikarst" (Figure 2) (Alexander et al., 2003). The epikarst is situated beneath the topsoil and above the unaltered bedrock. Water in the epikarst is stored in enlarged joints and bedding planes, spaces around pieces of float (rocks that have been detached from the bedrock), porosity within residual chert rubble, and the smaller conduits in the bedrock. During floods, the epikarst may recharge the saturated zone by direct and fast infiltration through a transient conduit connection that is established between infiltration and phreatic zones. During other periods, the epikarst contributes delayed recharge by slow infiltration.

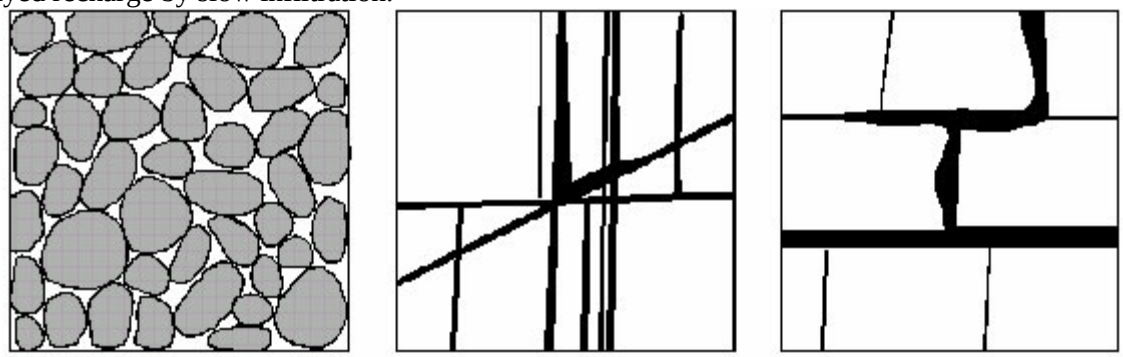


Figure 1. Schematic drawing of the common types of aquifer media. Note the reduction in inter granular surface area from intergranular media to fractured or solution enhanced.

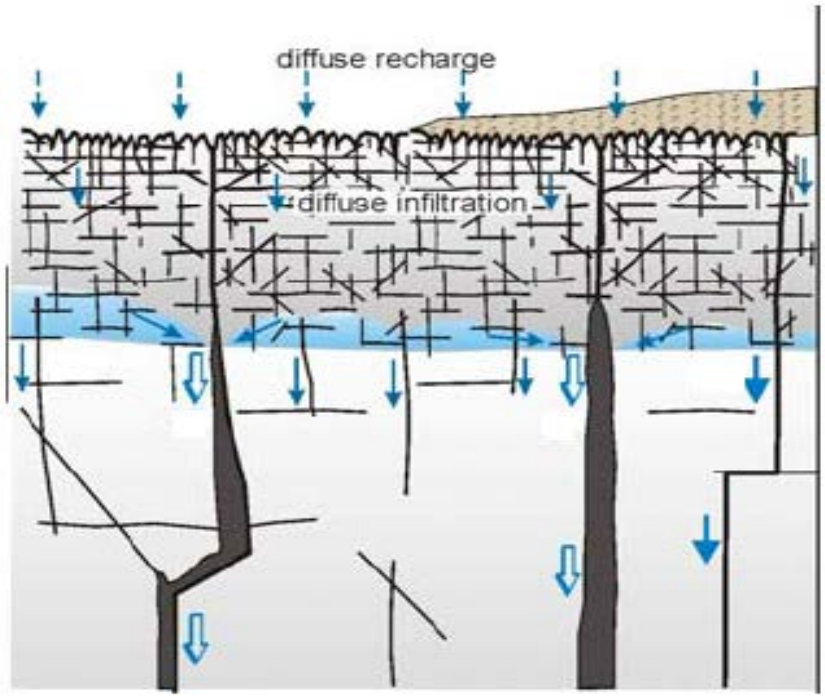


Figure 2. Epikarst Zone

Karst aquifers are commonly modeled as a system of branching tributary conduits, which connect together to drain a groundwater basin and discharge to a perennial spring (Worthington, 2002). The system is roughly analogous to a roofed-over creek. In comparison, granular or fractured bedrock aquifers have no equivalent "underground river" or channel. For the most part the conduit locations are indeterminate, and as such various types of surface features, such dolines fracture, depressed water tables, and sinkholes are used to guide the construction of a conduit network for numerical flow transport modeling.

Due to the complexity and heterogeneity of karst aquifers, the information gathered from classical borehole techniques of hydrologic testing and analysis (e.g., pump tests) are difficult to interpret. In addition karst aquifers typically exhibit dual groundwater flow regimes, that is, a slow (diffuse) flow in porous medium that feeds fast flow in the conduit network. In particular, groundwater modeling tools based on Darcy's law alone and developed for unconsolidated porous media type aquifers cannot adequately accommodate both the rapid flow of groundwater through conduits and the slow flow and storage of groundwater in the matrix of karst aquifers.

One objective of this project is to evaluate existing methods for modeling water resources within karst systems and how these models are typically used to inform water resources management decisions. A second objective is to evaluate economic and systems based methods, such as using the concept of embodied energy or "emergy" (Odum 1995 and 1996), to develop management tools that can help governmental agencies to analyze the quantity of water available and the amount used in their regions as well as consider the water resource as an economic good in the broadest sense, rather than exclusively monetary terms.

2. TECHNICAL APPROACH AND PROJECT UPDATE:

As a seed proposal, this project has provided supplemental support to aid the evaluation of existing and nascent methodologies for water resources management that look beyond standard best management practices in order to develop management tools that can help governmental agencies to analyze the quantity of water available and the amount used in their regions as well as consider the water resource as an economic good in the broadest sense, rather than exclusively monetary terms. The work has included three tasks.

Task 1: Evaluate existing methods managing water resources within karst regions. A detailed review existing methods for modeling water resources within karst systems and how these models are typically used to inform water resources management decisions is in progress.

Task 2: Use historical data available from Florida's Water Management Districts to analyze trends in water withdrawals from the karst Floridan Aquifer, and evaluate them in terms of their costs, benefits, and impacts. The five water management districts within the state of Florida all maintain historical databases of water withdrawals, spring flows, river and water body levels that can all be used to assess historical trends in the performance of the karst Floridan aquifer system as a supply of water for municipal, agricultural, and industrial uses. The objective of this task is to collect and review all available data and assess how the system may be more efficiently modeled by considering economic and systems based approaches. Data collection and review is in progress.

Task 3: Recommend the most promising approaches for optimal management of water resources within karst regions. Following a detailed review of existing methods and management practices of water resources within karst regions, recommendations will be made for the most promising method(s) for future consideration and potential application to karst systems.

3. TRAINING POTENTIAL:

This student lead seed project provides support for 1 Ph.D. student (Mario Cortazar Cepeda), and is the basis for his doctoral dissertation. This project also provides partial support for 1 Masters Student.

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Data Quality Improvement for NEXRAD and Stage Data Phase II

Basic Information

Title:	Data Quality Improvement for NEXRAD and Stage Data Phase II
Project Number:	2016FL329B
Start Date:	3/1/2016
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	19
Research Category:	Climate and Hydrologic Processes
Focus Categories:	Hydrology, Methods, Models
Descriptors:	None
Principal Investigators:	Ramesh S Teegavarapu

Publications

1. Teegavarapu, R. S., and Nayak, A. 2017. Evaluation of Long-term Trends in Extreme Precipitation: Implications of In-filled Historical Data Use for Analysis. Journal of Hydrology. Vol. 550. pp.616-634.
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4. Goly, A., Teegavarapu, R. S., & Mondal, A. (2014). Development and evaluation of statistical downscaling models for monthly precipitation. Earth Interactions, 18(18), 1-28.

Statement of State or Regional Problem

Acquisition of hydrologic and hydraulic data is the key component of water resources management in central and south Florida. The South Florida Water Management District (SFWMD) is responsible for the collection, validation, and archiving of the District's hydrologic data. The types of data include rainfall, evaporation, water levels (stage), water control structure (gate and pump) operations, and flow. The South Florida Water Management District requires accurate data collection, processing and archiving of these data for the purposes mentioned above. In early 2013, the Hydro Data Management (HDM) at SFWMD initiated an effort to review and evaluate different data accuracy assessment algorithms for development of a prototype tool for identifying the anomalies in stage data. In the completed first phase of this study a prototype tool, Hydrologic Data Evaluation Tool (HDET) was developed. This project represents the third phase of this continuing effort and will build on the prior work from phase II and work towards several improvements and testing of the HDET.

Statement of Results and Benefits

This phase of work constitutes a mix of applied and fundamental research expected to generate useful practical tools as well as to advance a fundamental understanding of data anomalies or outliers in hydrometeorological data. The research effort will provide new methods for assessment of outliers and data anomalies in hydrometeorological data. The current work incorporates methods used in data mining and knowledge discovery fields. This research is meant to help answer the following fundamental yet practical questions: 1) What are the available statistical data outlier detection algorithms? 2) Are conceptually simple median-based methods are adequate for identification of anomalies? 3) What methods are available for data that are not normally distributed? 4) What is utility of methods based on emerging soft computing approaches? 5) Once the outliers are identified, what methods can be used for evaluation of the data outlier identification algorithms? 6) What is the skill of the method used for outlier identification? What kind of domain knowledge is essential for improve data anomaly detection algorithms? The third phase of the study will focus on neighborhood based approaches for outlier/anomaly identification and also on the performance metrics for evaluation of different methods.

Research Methodology

Data cleaning is one of the first steps in data storage and analysis process requiring identification of outliers, non-homogeneous observations and datasets suspected to be influenced by instrumental and sensor-based, human and transcription errors. Hydrologic and climate data measured under varying field conditions and multiple sensors are known to be plagued by the problem of data anomalies. Techniques for identifying outliers and

methods for performance evaluation of anomaly detection methods are critical for task of maintaining unbiased, clean and error-free homogeneous data. The main focus of this study is identification of anomalies from stage data collected by SFWMD using a number of statistical and data mining anomaly detection techniques. A rule-based approach using rules with "If-Then-Else" construct will also be developed as an initial screening tool to identify stage data anomalies. The rules consider site-specific stage value lower and upper bounds defined by sensor measurement and structure-related physical limits. Rules that help identify temporary or long-term sensor failure will also be included in the system. The failure of a sensor may be identified based on lack of recorded variations in stage values for a long period of time, unexplained spikes at regular intervals, missing observations of stage and abnormal trends in stage levels over a period of time that could not be explained by any influencing physical process preceding this trend.

Stage data collected from at least ten different structures in the SFWMD region will be used for the evaluation of data accuracy algorithms. The structures will be selected considering the recommendations of the District project manager. Data collected from SFWMD are to be processed through a prototype test environment to be developed by a consultant. The environment will be utilizing a graphical user interface (GUI) to help users directly interact with system and visually evaluate the outliers and carry out a series of steps to detect anomalies in stage. The environment will be developed using visual BASIC and MATLAB software platforms. The stage observations used by the test environment for identifying any outliers will also be evaluated by an expert team of modelers and hydrologists at SFWMD based on their judgment, past experience and scientific reasoning. A contingency table is prepared to evaluate the performances of different data anomaly assessment algorithms by using results of analyses from the team and the algorithms from the test environment. Algorithms will be ranked using detection rate as a performance measure. It is anticipated that the study will provide a select suite of data accuracy assessment algorithms in a prototype test environment that can be used by the SFWMD for detection of anomalies in stage data. The algorithms will be ranked based on results from effectiveness tests using detection rate and false positive rate indices obtained from a 2 x 2 contingency table. The test environment is expected to be functional in future for near real-time application.

Related Recent Research

Several techniques have been used in the past few decades for data anomaly and outlier detection. These techniques include: 1) classification-based, 2) near-neighbor-based; 3) clustering-based; 4) statistical; 5) information-theoretic and 6) spectral. Some of these methods are discussed and reviewed by Chandola (2009) and others (Kasunic et al., 2011; Kriegel et al., 2010; Hodge and Austin, 2004). A number of anomaly detection techniques under these six categories will be investigated in this study. These techniques use median

filters, statistical control charts, moving range control charts, exponentially weighted moving average charts, moving average charts, Grubb's, Rosner and Dixon tests, Tukey's boxplots and auto-regressive integrated moving average (ARIMA)-based method, 3-signa (3-σ) outlier, discordance, fourth-spread outlier and Walsh tests. Some of these techniques use visual assessments and some others require the assumption of normality and minimum number of samples. Normality of data can be achieved by using different transformations including Box-Cox and traditional variants.

Major Findings and Accomplishments from Last Year

Tool Prototype Testing and Evaluations (Phase III)

The prototype tool: Hydrologic Data Evaluation Tool (HDET) is being evaluated and improved using methods from data mining and knowledge discovery fields. The tool and code have been provided to SFWMD for continued testing.

Information Transfer Program Introduction

Through the Information Transfer Program the Florida WRRC actively supports the transfer of results of water resources research in Florida to the scientific and technical community who are actively addressing Florida's water resources issues.

Florida Water Resources Information Transfer

Basic Information

Title:	Florida Water Resources Information Transfer
Project Number:	2016FL330B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	3
Research Category:	Not Applicable
Focus Categories:	None, None, None
Descriptors:	None
Principal Investigators:	Kirk Hatfield, Mark Newman

Publications

1. Alexander B.V., I.V. Perminova, S.A. Ponomarenko, A.I. Konstantinov, A. Vyacheslavov, and K. Hatfield. 2016. Nature-like solution for removal of Direct Brown 1 azo dye from aqueous phase using humics-modified silica gel, Chemosphere, 145, 83-88.
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4. Klammler, H., K. Hatfield, M. A. Newman, J. Cho, M. D. Annable, B. L. Parker, J. A. Cherry, and I. Perminova. 2016. A new device for characterizing fracture networks and measuring groundwater and contaminant fluxes in fractured rock aquifers, Water Resour. Res., 52, 5400-5420, doi:10.1002/2015WR018389.
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10. Volikov, A.B., S.A. Ponomarenko, A. Gutsche, H. Nirschl, K. Hatfield, and I.V. Perminova. 2016.

Targeted design of water-based humic substances-silsesquioxane soft materials for nature-inspired remedial applications, Royal Society of Chemistry Advances, 6(53), 48222-48230. DOI: 10.1039/C6RA08636E.

11. Yadav, Bidhyananda, K. Hatfield. 2017. A Machine Learning Approach for Mean Velocity Prediction in Ungauged Basins, Environmental Modelling & Software, (In Review).
12. Yadav, Bidhyananda, K. Hatfield. 2017. Stream Network Conflation with Topographic DEMs, Environmental Modelling & Software, (In Review).

Information Transfer Program FY 2016

During the review period, the Florida WRRC actively supported the transfer of water resources research findings and results to the scientific and technical community that addresses Florida's water resource problems. The Center provided support for preparation and presentation of **18 peer-reviewed journal articles and 1 US Patent.**

WRRC Website: The Center maintains a website (http://wrrc.essie.ufl.edu/) which is used to provide timely information regarding applied water resources research within the state of Florida. The Center website provides information regarding ongoing research supported by the WRRC, lists research reports and publications that are available, and provides links to other water-resources organizations and agencies, including the five water management districts in Florida and the USGS.

WRRC Digital Library: The Center maintains a library of technical reports that have been published as a result of past research efforts (Dating back to 1966). Several of these publications are widely used resources for water policy and applied water resources research in the state of Florida and are frequently requested by others within the United States. As part of the WRRC information and technology transfer mission, the library was converted to digital form and is maintained free to the public through the WRRC Digital Library which is housed on the center website http://wrrc.essie.ufl.edu/reports/.

USGS Summer Intern Program

None.

Notable Awards and Achievements

The WRRC continued efforts to maximize the level graduate student funding available to the state of Florida under the provisions of section 104 of the Water Resources Research Act. Listed below are some of the Center's notable achievements for FY 2016:

STEM Education: Recognizing the importance of STEM (Science, Technology, Engineering, and Mathematics) Education initiatives, the Florida Water Resources Research Center is proud to have supported the research efforts of 6 Ph.D. students and one Post-Doctoral researcher all focusing on water resources issues during Fiscal Year 2016.

UCOWR Best Dissertation Award: Dr. Miguel Morales dissertation, Innovative Water and Energy Demand Management Practices in the Public Water Supply Sectors was selected as the first place recipient of the 2016 UCOWR Ph.D. Dissertation Award in the category of Water Policy and Socio-Economics. (This was the third time in four years that a University of Florida student supported by the Florida WRRC has won this award). Dr. Morales work was supported in part by WRRC project 2011FL269B. Dr. Morales presented his research at the UCOWR/NIWR Water Resources Conference, June 21-23, 2016 in Pensacola, FL.

US Patent Awarded: Sediment Bed Passive Flux Meter, 2016 (US Patent 9,404,783). This student-lead seed project (2013FL311B) generated a patent for a new passive technology capable of measuring water and contaminant fluxes across sediment beds in streams, rivers, lakes, and estuaries. The resulting technology has a wide range of potential applications.