Florida Water Resources Research Center
Annual Technical Report
FY 2013

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 2013) the Center supported multiple research projects including agreements with two of Florida's universities (Florida Atlantic University and the University of Florida), two state agencies (South Florida Water Management District, St. Johns River Water Management District) and one municipality (City of Sanford).

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 11 Ph.D. students all focusing on water resources issues during the reporting period (March 2013 to February 2014).

During FY 2013, 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 17 peer-reviewed journal articles, 2 book chapters, and 12 proceedings and presentations. 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 2013 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.

Watershed Management in the face of EPA's New Numeric Nutrient Criteria for Florida Waters. In January 2010 the US Environmental Protection Agency embarked on a new approach to regulate nutrient pollution in aquatic ecosystems. Previously, nutrients were managed according to narrative criteria that categorized water bodies as impaired using observed biological responses, specifically an imbalance in the native flora and fauna of the aquatic ecosystem. Now, rather than waiting for biological impairment to become apparent before implementing ecologically protective nutrient levels, EPA will regulate nutrients according to now finalized numeric criteria (http://water.epa.gov/lawsregs/rulesregs/upload/floridaprepub.pdf). Under this plan, concentration thresholds will be established for each water body type (i.e., lakes, wetlands, rivers/streams, springs, estuaries, and canals) and enforced uniformly statewide.

The overall goal of this project is to fund an interdisciplinary cohort of 6 Ph. D. Fellows to develop the new knowledge, and creative engineering, management and policy solutions needed to establish and achieve numeric nutrient criteria (NNC) for Florida's waters. The education and research of each Fellow will evolve from specific problems and research questions related to management of Florida's water and watersheds under NNC. The unique cross-disciplinary environment of our program will allow an integrated whole that will reflect disciplinary facets associated with this complex problem.

Sustainable Urban Infrastructure and Water Loss Management Including a Case Study of Sanford Florida. Continued growth in water demand in many parts of the country including Florida has placed significant stress on traditional groundwater and surface water sources for urban water supply. Regional water supply assessments by the water management districts have shown significant negative impacts of these developments including lowered groundwater tables accompanied by reduced flows in rivers and springs, declining lake levels, and increasing nutrient loads on receiving waters. In response to these problems, water utilities are required to evaluate alternative water supplies and water conservation to meet future water needs. Water losses on the utility side of the customer meters can be as high as 15-20%. A similar loss range exists on the customer side of the meter. Improved methods of water loss control can reduce these losses to 5% or less. The City of Sanford will be used as a case study to evaluate innovative methods of water loss control and the addition of water conservation practices. The EZ Guide 2.0 model will be refined to address these needs to find cost-effective solutions. EZ Guide 2.0 has been developed by the Conserve Florida Water Clearinghouse to find the optimal portfolio of traditional and alternative water supply options and demand management.

Development of a Passive Sensor for Measuring Water and Contaminant Fluxes in the Hyporheic Zone. The goal of this student lead seed project is to develop a new passive technology that will incorporate the field-tested concepts of the passive flux meter (PFM) to provide direct in situ measurements of water and contaminant fluxes within the hyporheic zone. The proposed effort will develop a new sensor, test it under controlled laboratory conditions and develop field deployment strategies. If a robust technology is developed from this seed project, follow on proposals will be generated to pursue additional funding to support further development of the novel technology. The new technology will improve the ability of site managers to formulate a site-wide contaminant mass balance, evaluate the efficacy of hyporheic zone for monitored natural attenuation, manage aquatic sediment site restoration, control private and public expectations of restoration efforts, and ensure protection of human health and the environment.

Development and Evaluation of Data Accuracy Assessment Algorithms for Identifying Anomalies in Hydro-meteorological Data (Phase I: Stage). The main objective of this multi-year study is to develop and

evaluate several statistical and data-mining based algorithms for identification and detection of outliers and data anomalies in hydro-meteorological data, especially stage data. This report discusses work that was completed in Phase I during year 2013. In this first phase of the work, algorithms for identification stage data anomalies were developed and evaluated and a prototype tool was developed. The first phase of work focused on stage data obtained from different hydraulic structures in SFWMD region from different sensors.

The premise of this work is that algorithms applicable in a standard test environment can help in the evaluation of data anomalies that will ultimately be used to improve existing stage data. The results of this study provide a complete evaluation of existing methods of data outlier detection. The methods were evaluated at different hydraulic structures and evaluated using a number of indices and skill scores including input from modelers and data management personnel at SFWMD. The study used data from a network of stage monitoring sensors automatically uploaded into the databases of SFWMD. This research is highly relevant and critical to a number of water resources management agencies (e.g. South Florida Water Management District (SFWMD)) 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).

Sustainable Urban Infrastructure and Water Loss Management Including a Case Study of Sanford Florida

Basic Information

Title:	Sustainable Urban Infrastructure and Water Loss Management Including a Case Study of Sanford Florida
Project Number:	2011FL269B
Start Date:	3/1/2012
End Date:	3/28/2015
Funding Source:	104B
Congressional District:	3
Research Category:	Engineering
Focus Category:	Water Supply, Management and Planning, Models
Descriptors:	
Principal Investigators:	James Heaney

Publications

1. Heaney, J. and J. Sansalone. 2012. A Vision for Urban Stormwater Management in 2050. Chapter 17 in Grayman, W. Loucks, D. and L. Saito, Eds. Toward a Sustainable Water Future: Vision for 2050, ASCE Press, Reston, VA.
2. Heaney, J., Friedman, K., and M. Morales. 2011. International Perspective on Urban Water Conservation. Proc. 8th Int. Conf. on Urban Watershed Man., Beijing, China, Sept.
3. Heaney, J., Switt, R., Friedman, K., Morales, M., and K. Riley. 2011. Overview of EZ Guide for Water Conservation Evaluations. Florida Water Resources Journal, September.
4. Friedman, K., Heaney, J., Morales, M. and J. Palenchar. 2011. Water Demand Management Optimization Methodology. Jour. American Water Works Assoc., Vol. 103, No. 9.
5. Morales, M., Heaney, J., Friedman, K., and Martin J. 2011. Estimating Commercial, Industrial, and Institutional Water Use on the Basis of Heated Building Area. Jour. American Water Works Assoc., Vol. 103, No. 6.
6. Morales, M., and J. Heaney. 2010. Predominant Commercial Sectors in Florida and their Water Use Patterns. Florida Water Resources Journal, August.
7. Friedman, K. and J. Heaney. 2009. Water Loss Management: Conservation Option in Florida s Urban Water Systems. Florida Water Resources Journal, August, p 24-32. http://www.fwrj.com/techarticles/0809%20FWRJ%20tech1.pdf.
8. Friedman, K. and J. Heaney. 2009.Validity of Water Audit and Water Loss Evaluations for Florida. Proc. Florida Section of AWWA Fall Conference, Orlando, December.
9. Morales, M., Heaney, J., Friedman, K. and J. Martin .2013. Parcel-level model of water and energy end use. Jour. American Water Works Assn., accepted for publication.
10. Friedman, K., Heaney, J. Morales, M. and J. Palenchar. 2013. Predicting and Managing Residential Potable Irrigation Using Parcel Level Databases. Jour. American Water Works Assn., accepted for publication.
11. Morales, M, Martin, J., Heaney, J. and K. Friedman. 2013. Parcel Level Modeling of Seven End Use Water Demands in 64 Public Supply Land Use Sectors. Jour. American Water Works Assn., accepted for publication.

12. Heaney, J., Switt, R., Friedman, K., Morales, M., and K. Riley. 2011. Overview of EZ Guide for Water Conservation Evaluations. Florida Water Res. Jour., Sept.
13. Heaney, J. and J. Sansalone. 2012. A Vision for Urban Stormwater Management in 2050. Chapter 17 in Grayman, W. Loucks, D. and L. Saito, Eds. Toward a Sustainable Water Future: Vision for 2050, ASCE Press, Reston, VA.
14. Friedman, K. 2013. Simulation/Optimization of Alternative Water Supply Planning Using Parcel Level Demand Estimation and Management Strategies.Ph.D. Dissertation, Dept. of Environmental Engineering Sciences, U. of Florida, Gainesville, FL.
15. Friedman, K., Heaney, J. Morales, M. and J. Palenchar. 2013. Predicting and Managing Residential Potable Irrigation Using Parcel Level Databases . Jour.American Water Works Assn., Vol. 105, No. 7.
16. Morales, M., Heaney, J., Friedman, K. and J. Martin .2013. Parcel-level model of water and energy end use. Jour . American Water Works Assn., Vol. 105, No. 8.
17. Morales, M, Martin, J ., Heaney, J. and K. Friedman. 2013. Parcel Level Modeling of Seven End Use Water Demands in 64 Public Supply Land Use Sectors. Jour. American Water Works Association, Vol. 105, No. 9.

Title. Sustainable Urban Infrastructure and Water Loss Management Including a Case Study of Sanford Florida

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Research Category. Engineering

Keywords. Urban water, demand management, water loss control, water use efficiency modeling

Abstract. Continued growth in water demand in many parts of the country including Florida has placed significant stress on traditional groundwater and surface water sources for urban water supply. Regional water supply assessments by the water management districts have shown significant negative impacts of these developments including lowered groundwater tables accompanied by reduced flows in rivers and springs, declining lake levels, and increasing nutrient loads on receiving waters. In response to these problems, water utilities are required to evaluate alternative water supplies and water conservation to meet future water needs. Water losses on the utility side of the customer meters can be as high as 15-20%. A similar loss range exists on the customer side of the meter. Improved methods of water loss control can reduce these losses to 5% or less. The City of Sanford will be used as a case study to evaluate innovative methods of water loss control and the addition of water conservation practices. The EZ Guide 2.0 model will be refined to address these needs to find cost-effective solutions. EZ Guide 2.0 has been developed by the Conserve Florida Water Clearinghouse to find the optimal portfolio of traditional and alternative water supply options and demand management.
The work elements for this effort include:

- Evaluate water consumption data using property appraisal attributes and typical water use benchmarks for indoor and outdoor use to determine water saving potential.
- Evaluate commercial, industrial, and institutional water use and water savings potential
- Perform water audit and estimate water losses and trends using automatic meter reading data.
- Inventory water infrastructure, ages, and historical leakage events.
- Develop relationships and refined methods for calculating real and apparent losses from sources to distribution system.
- Apply hydraulic modeling and other analysis to isolate areas of concern and further study.
- Evaluate benefits of master and customer meter change-out program.
- Evaluate effectiveness of other conservation BMPs and compare against new BMPs using the Conserve Florida Water Guide Version 2.0.
- Estimate the economically optimal level of water losses in the treatment and distribution systems.
- Develop trends, criteria and thresholds to establish water-saving goals.

The results will be published in refereed journals as part of doctoral research by three students.

One of the primary water uses in urban areas is irrigation. The increasing use of in-ground irrigation systems has drastically altered the use of water in the urban landscape. In-ground irrigation system installations have increased exponentially since they became widely available in the 1980s and are approaching saturation in new home construction. This availability of automated irrigation systems has increased the water demand for urban irrigation by allowing homeowners to easily water their entire yard on the days of their choosing. This use is typically highly seasonal and during the peak irrigation season often exceeds the indoor use, sometimes by several times. Because of the nearly ubiquitous nature of in-ground irrigation systems in new homes and frequent retro-fitting of older homes, larger average and much larger peak demands have been placed on municipal water systems. These demands follow both a seasonal and a diurnal cycle. The irrigation demand has caused an increased pressure on both the treatment systems and distribution systems, as well additional impacts on the environment. To mitigate the impact of additional aquifer withdrawals and to remove users from the potable water systems, many communities, including Sanford, are increasing the use of reclaimed water for irrigation. The use of reclaimed water requires an additional distribution system, but when installed allows irrigation demands to be met by non-potable water on a system that demands less reliability than the potable water system. This removal of irrigation uses can allow municipalities to alter their operation which can have the added benefit of reducing water system losses.

When reclaimed water is available at low or no cost the resource tends to be used at a higher rate than equivalent users on the potable water system. This is not surprising since residential potable water bills can easily be in the hundreds of dollars if large irrigation use is occurring on the potable water system. The City of Sanford is unusual in that a large number of its users (>2,400) have been served by a reclaimed water system for years. Additionally, Sanford meters these customers and charges a small cost for water use on the reclaimed system. This unique dataset provides information on use patterns and trends among reclaimed water users that can be compared against other water users. Sanford also has more than 100 users with irrigation meters. These are users on the potable water system that have a separate meter for their irrigation systems. As with the reclaimed users these users typically have higher water use because the additional cost of a separate meter usually limits this installation to more affluent property owners. This dataset provides for an accurate comparison between reclaimed and potable water irrigation users.

One potential downside of irrigation with reclaimed water is the potential increase in stormwater runoff that over-irrigation can cause. With no- or low-cost reclaimed water, users tend to irrigate more than they might otherwise. This additional application can contribute directly to runoff if irrigation systems apply more water than can infiltrate or have over-spray onto impervious surfaces. Also irrigation systems may not have a properly installed rain sensor to shut off the system when rainfall occurs. In this scenario irrigation can actually occur during or immediately after rainfall events greatly increasing the potential for runoff. Even when properly installed and set with a functional rain or soil moisture sensor, irrigation systems can still contribute to increased runoff by filling available soil storage and limiting the available capacity in the event of rainfall.

Statement of regional or State water problem. Improved water use efficiency is an integral component of sustainable urban water systems. Some traditional sources of water have been mined beyond their safe yield and have caused problems in terms of reduced surface flows and increased pollutant levels. Utilities in Florida, Georgia, and elsewhere are now required to develop quantifiable water conservation plans that can be part of their portfolio of options to meet future water needs.

Increased water use is placing a growing burden on already strained water resources in the southeast and nationwide. Innovative ideas are being used to combat this problem by increasing the reuse of water that was pumped for potable water use. Reclaimed water systems are increasing in prevalence in Florida to combat additional pumping of aquifers. While reclaimed water use does decrease the required pumping it is important to evaluate whether it can have adverse impacts on other portions of the hydrologic water budget. Stormwater control has been and remains an important component of water resources management in Florida. Reclaimed water users tend to irrigate at a higher rate than potable users due to the low-cost or free water. This water use can cause the unintended consequence of increased runoff.

Statement of results or benefits. Florida may be unique in having a statewide database of attributes of every one of its nine million parcels of land. We are linking this information with customer water use billing records to determine the optimal mix of demand management practices. This parcel data can be combined with billing data to provide a dataset that can be used to estimate water use and water application rates. Sanford is unique in that many users are on metered reuse accounts that allow for irrigation application to be evaluated at the parcel scale. The Seminole County Property Appraiser has developed a GIS dataset for the county that includes the area of each parcel that is covered by impervious surfaces. This data can be used to develop a parcel-level water budget to evaluate the impact of irrigation on runoff. These new techniques will be incorporated into EZ Guide software for use by water utilities and other water agencies

Nature, scope, and objectives of the project, including a timeline of activities. The schedule of activities is shown below.

1. Review the literature on reuse systems in general and in Florida in particular.
2. Develop a methodology for regional water supply planning to estimate outdoor water use for utilities as the residual water use from an aggregate monthly water budget analysis for the major sectors.

Table 1. Task schedule for the project.

ID	Task	Quarter															
		Year 1				Year 2				Year 3				Year 4			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Initial bottom up evaluation of water loss, water conservation, and water reuse saving potential using EZ Guide	X	X														
2	Perform water audit and estimate water losses and trends using AMR and other data			X	X	X	X	X	X	X							
3	Refined bottom up benefit-cost optimization of water loss,water conservation, and water reuse options using EZ Guide							X	X	X	X						
4	Estimate the economically optimal level of water losses in the treatment and distribution systems									X	X	X					
5	Develop trends, criteria and thresholds to establish water-saving goals for water loss program										X	X	X				
6	Review the literature on reuse systems in general and Florida in particular													X	X		
7	Develop a methodology for regional water supply planning to estimated outdoor water use for utilities as the residual water use from an aggregate monthly water budget for the major sectors														X	X	X
8	Progress Reports	X	X	X	X	X	X	X	X	X	X	X	X		X		
9	Final Reports				X				X				X				X

Methods, procedures, and facilities. The Conserve Florida Water Clearinghouse (www.conservefloridawater.org) has developed numerous tools for evaluating water loss and water conservation best management practices. Detailed information about these activities is available at their web site. The current staff of the Clearinghouse includes a lead faculty member, one project manager, three PhD students, an undergraduate student, a systems engineer, and a programmer.

Major Findings and accomplishments. The primary tasks for year 3 are shown above in table 1. The status of these two tasks is described below.

1. 1. Estimate the economically optimal level of water losses in the treatment and distribution systems

Based on a detailed review of water loss analysis methods, a modified version of the standardized water audit recommended by the American Water Works Association was utilized as a framework to analyze water losses in Sanford. Results from these detailed data driven analyses of water losses and customer demands in Sanford were compared to results obtained from existing estimates at the start of the project to demonstrate value added from project refinements. Next, a detailed water audit was compiled to better determine monthly and annual water loss and water usage trends in Sanford as compared to the initial evaluation. UF worked in collaboration with Sanford and Jones Edmunds, Inc. on compiling and analyzing relevant data needed to conduct the water audit. This included the generation of a water use and property attribute database for 15,102 parcels in Sanford. This data is then utilized to complete the standardized American Water Works Association M36 audit, quantifying each input in detail, and determining residual total and real (physical) losses.

After the detailed audit, a process level analysis of water loss, water usage, water reuse, and demand management options could be determined. This includes methodologies for analyzing infrastructure asset data as well as pressure variability and main break history to understand the process level mechanisms behind system leakage at the individual pipe level. A component analysis is presented which breaks down real losses, as determined from the detailed water audit, into background leakage, reported breaks, and unreported breaks. Additionally, a refined analysis of customer demand patterns was performed utilizing the generated parcel level customer database along with EZ Guide.

Once the detailed process level analysis was completed, the economically optimal level of water loss control and demand management for Sanford was evaluated which was then utilized to develop a proposed implementation plan which will feed into the performance tracking system to provide continuous feedback on the actual performance of the system. Priority pipe clusters were determined based on pipe attributes as well as spatial location allowing for evaluation of the economic feasibility of water loss savings potential from active leakage detection of distribution system mains. A marginal cost curve of water loss savings associated with active leakage detection is then presented. In addition to water loss reduction, cost effective strategies for demand management were analyzed in detail using EZ Guide. A calibrated EZ Guide for the representative 2010 year provides a realistic breakdown of customer demand by end uses, which forms the basis of demand management BMP analysis. EZ Guide sorts each BMP option by cost effectiveness to develop a marginal cost curve for water savings from demand management BMPs. These results are then combined with water loss management options to develop a final recommended combined leak detection and customer demand BMP program for Sanford. This is accomplished by comparing both demand management and water loss reduction strategies as a means to reduce existing water produced vs. the cost of providing an alternative water supply. Based on these results, a proposed water loss and demand reduction implementation plan was presented as well recommended action items for future studies.

2. Develop trends, criteria and thresholds to establish water-saving goals for water loss program

The final calibrated EZ Guide evaluation of customer demand patterns for the representative year (2010), shown in Table 2, indicates that single family residential is the largest demand sector with little potable irrigation due to the prevalence of reuse irrigation water in Sanford. Sanford also has significant commercial, institutional, and industrial usage, comprising 27.2% of total usage in 2010. Additionally, Sanford's annual percent water loss has declined from 22% in 2009, 18%, in 2010, and 11% losses in 2011. These observed declines are due, in part, to the ongoing meter replacement and infrastructure rehabilitation efforts by the City of Sanford to control water losses.

However, understanding and managing the detailed nature of water losses in Sanford remains an ongoing effort which can utilize the analysis methodologies presented in this report as a template for future evaluations with improved accuracy as Cityworks becomes

populated with system performance data such as pipe leakage and repair records. This framework to analyze Sanford's customer demands and water losses can be utilized by other utilities seeking to accomplish similar goals.

Table 2. Final calibrated EZ Guide based on 2010 conditions in Sanford

Sector	% Water Use	Residential gpcd	Gross gpcd	Population
Single Family	39.8%	79	55	34,652
Single Family- Indoor	33.8%	67	46	-
Single Family- Outdoor	6.1%	12	8	-
Multi-Family	15.0%	66	20	15,534
CII	27.2%	-	37	-
Commercial	11.7%	-	16	-
Industrial	3.6%	-	5	-
Institutional	11.9%	-	16	-
Unaccounted	18.0%	-	25	-
Total	100.0%	-	137	50,186

A detailed, bottom up, evaluation determined that 1.7 million gallons per day (mgd) from demand management and 0.68 mgd from active leakage detection could be cost effectively saved for a marginal cost of under $3/1,000 gallons. The total cost of implementing the full plan would be $8.5 million for demand management and $25,500/yr or $1,785,000 over a 70 year lifespan of a typical water main in Sanford. Additionally, an estimated 0.46 mgd is estimated to be saved from the ongoing meter replacement program. Therefore, a total savings potential of 2.84 mgd can be obtained from combined demand management and water loss control.

The City of Sanford has begun implementing the initial phases of its leakage detection efforts utilizing noise correlation technology in select priority areas with high expected leakage. Also, the City is exploring alternative monitoring and detection technologies. Additionally, several pipe rehabilitation projects have been completed utilizing pipe bursting with many more scheduled over the next several years to address Sanford's aging water infrastructure. Given estimated service lives of mains, a replacement analysis was performed comparing projected new pipe added with existing pipe retrofit due to service life attrition. Based on historical trends, a 1% annual growth of new pipes was assumed from 2012-2050. Figure 1 shows that the pipe replacement needs have increased in recent years and are projected to continue to increase as much of the original pipe infrastructure that was installed in the 1940s and 1950s is now due for replacement. As of 2012, 22% of pipes installed in Sanford are retrofits whereas 36% of pipes are projected to be retrofits in 2050. Additionally, Sanford is continuing its meter replacement and re-sizing program, with all residential meters projected to be done by the end of 2013 and all large multi-family and commercial meters to be completed within the next few years.

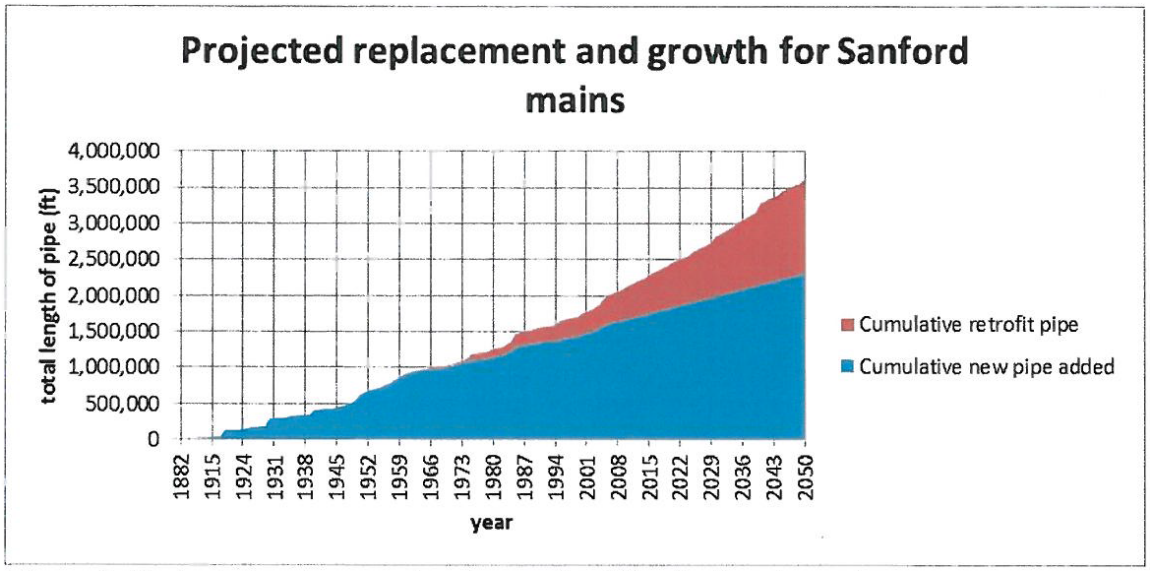

Figure 1. Projected replacement and growth of Sanford water mains.

Training potential. The number of graduate and undergraduate students, by degree level, who are expected to receive training in the project are listed below.

1. Kenneth Friedman, PhD student. Optimization of urban water systems-Graduated Dec. 2013
2. Miguel Morales, PhD student. Sustainable urban water-energy systems
3. Scott Knight, PhD student. Integrated water supply-storm water management systems

Watershed Management in the face of EPA's New Numeric Nutrient Criteria for Waters

Basic Information

Title:	Watershed Management in the face of EPA's New Numeric Nutrient Criteria for Waters
Project Number:	2011FL270B
Start Date:	3/1/2012
End Date:	3/28/2015
Funding Source:	104B
Congressional District:	3
Research Category:	Water Quality
Focus Category:	Sediments, Law, Institutions, and Policy, Management and Planning
Descriptors:	
Principal Investigators:	Wendy D Graham

Publications

1. Reijo, C.; Arnold, T.E.; Burkett, V.; Henson, W.R.; Laing, J.M.; Weinkam, G. 2012. Characterization of Nutrient Uptake Kinetics in a Spring-fed North Florida Stream. Poster presented at the 3rd Annual University of Florida Water Institute Symposium: Nutrient Dynamics, Policy, and Management in Watersheds. Gainesville, FL, Feb. 2012.
2. Henson, W.R. and Niswonger, R.G, Evaluating the Effects of Horizontal Spatial Discretization on Interflow in the Soil Zone Using the Richards and Groundwater Flow Equations, poster Presented at the Fall AGU Conference, San Francisco, CA, Dec. 2011.
3. Cohen, M.C., Henson W.R., Petitt, C. Burkett, V., Weinkam, G., Laing, J.M. Reijo, C. and Arnold, T. E. Nutrient Spiraling in a Bottomland Sub-Tropical Stream. 9th INTECOL International Wetlands Conference, Orlando FL, June 2012.
4. Henson W.R., DeRooij, R., Graham, W.D., Examining the Role of Aquifer Confinement and Model Discretization on Spring Water Discharge and Matrix-Conduit Exchange: Implications for Nutrient Fate and Transport. International Association of Hydrologists Groundwater Quality Conference. Gainesville, FL. April 2013.
5. Henson W.R., Graham, W.D., and Cohen, M.J, Examining the Spatial Distribution of Denitrification in the Upper Floridan Aquifer Using Aquifer Geochemistry and Isotopes of Nitrate. Poster Presentation at Geological Society of America Annual Meeting October 2013.
6. Henson, W.R., Medina, R.L., Mayers, C.J., Niswonger, R.G., and Regan, R.S., 2013, CRT Cascade Routing Tool to define and visualize flow paths for grid-based watershed models: U.S. Geological Survey Techniques and Methods 6-D2, 28 p.
7. Wangusi, N., Kiker, G., Muñoz-Carpena, R., and Henson, W.R., 2013, Improving watershed decisions using run-off and yield models at different simulation scales, Environmental Systems and Decisions, September 2013, Volume 33, Issue 3, pp 440-456.

TITLE. Watershed Management in the face of EPA's New Numeric Nutrient Criteria for Florida Waters

PRINCIPAL INVESTIGATOR.
Dr. Wendy Graham, Agricultural and Biological Engineering - Hydrologic Processes

COOPERATORS:
Dr. Mark Brenner, Geological Sciences - Paleolimnology
Dr. Mark Brown, Environmental Engineering Sciences – Systems Modeling
Dr. Mark Clark, Soil and Water Science - Nutrient Best Management Practices
Dr. Matt Cohen, Forest Resources and Conservation – Riverine Nutrient Dynamics
Dr. Tom Frazer, Forest Resources and Conservation – Ecological Consequences of Nutrient Enrichment
Richard Hamann, J.D., College of Law - Environmental Law

RESEARCH CATEGORY. Water Quality

KEYWORDS. Numeric Nutrient Criteria, Paleolimnology, Best Management Practices, Hydrologic Processes, Riverine Nutrient Dynamics, Aquatic Ecology, Systems Modeling

ABSTRACT.
The overall goal of this project is to fund an interdisciplinary cohort of 6 Ph. D. Fellows to develop the new knowledge, and creative engineering, management and policy solutions needed to establish and achieve numeric nutrient criteria (NNC) for Florida's waters. Funding for 4 Ph. D. Fellows has been provided by the University of Florida under the Water Institute Graduate Fellows program. **The USGS 104B support provided by this project provides partial funding for 2 additional Ph. D. students adding additional expertise in the areas of hydrologic processes and aquatic ecology**. The education and research of each Fellow evolves from specific problems and research questions related to management of Florida's water and watersheds under NNC. The unique cross-disciplinary environment of our program allows an integrated whole that will reflect disciplinary facets associated with this complex problem. Components currently funded by UF include Paleolimnology, Nutrient Best Management Practices, Riverine Nutrient Processing, Systems Modeling (Original Proposal PIs Brown, Brenner, Clark, Cohen, Hamann), Hydrologic Processes and Aquatic Ecology (Graham and Frazer, respectively).

STATEMENT OF REGIONAL OR STATE WATER PROBLEM.
In January 2010 the US Environmental Protection Agency embarked on a new approach to regulate nutrient pollution in aquatic ecosystems. Previously, nutrients were managed according to narrative criteria that categorized water bodies as impaired using observed biological responses, specifically an imbalance in the native flora and fauna of the aquatic ecosystem. Now, rather than waiting for biological impairment to become apparent before implementing ecologically protective nutrient levels, EPA will regulate nutrients according to now finalized numeric criteria (http://water.epa.gov/lawsregs/rulesregs/upload/floridaprepub.pdf). Under this plan, concentration thresholds will be established for each water body type (i.e., lakes, wetlands, rivers/streams, springs, estuaries, and canals) and enforced uniformly statewide.

This new approach constitutes a paradigm shift that has generated significant controversy. On one hand, it offers a simple metric for the regulatory process, and which may accelerate the timeline for listing and restoring degraded water bodies. It is also pre-emptive, reducing the risk of tipping water bodies into a degraded state that is often irreversible. On the other hand, it ignores the site-specificity that was an important component of narrative standards. Each river, lake and estuary is different, and adoption of a single standard is therefore "under-protective" of some systems and "over-protective" of others. The basis for setting such thresholds is fraught with uncertainty. Although development of alternative site-specific

criteria can be petitioned, the cost and time associated with gathering such additional data to modify numeric values for a particular water body will be considerable. Therefore, the proposed approach, while conferring simplicity and predictability will also create rigidity that precludes adaptation and optimization.

Adoption of numeric standards is intended to be a national endeavor, enacted on a state-by-state basis. In Florida, adoption of numeric criteria is contentious, in large part because of the number and wide diversity of water bodies in the state. The process unfolding now in Florida will undoubtedly influence how other states manage their surface water resources. This developing environmental management strategy provides an opportunity to provide guidance and rigorous oversight of the process. Graduate students trained in the crucible of this controversy, and engaged in the dialog it has engendered, will be well equipped to solve the trans-disciplinary problems associated with water resource conflict all over the world.

The currently funded Water Institute Graduate Fellows (WIGF) program links faculty and students from watershed science (Cohen), limnology (Brenner), wetlands and water quality extension (Clark), water law (Hamann), and systems modeling (Brown) to study the scientific basis for, and the design and implementation of numeric nutrient criteria for Florida waters. The USGS 104B funding extends these links to include hydrologic science (Graham), and aquatic ecology (Frazer), facets that obviously impact the design and implementation of numeric nutrient criteria.

STATEMENT OF RESULTS OR BENEFITS.

The WIGF program will provide a greater understanding and framework to address issues of water and watersheds and the interplay of policy and science required to manage them. The program will build a firm disciplinary base (each student's major), overlay coursework in complementary disciplines, and incorporate interdisciplinary training and research experiences. Specifically, this program will:

(1) Use a synthetic approach to understanding watershed-scale nutrient dynamics through the application of models, field measurements, and data mining.
(2) Explore effectiveness of best management practices for reducing nutrient loads.
(3) Explore the local-scale couplings and feedbacks among climate, land-use, water use, and nutrient cycling in watersheds, and how these relationships scale-up to affect nutrient fluxes to springs, lakes, wetlands and estuaries.
(4) Understand the effects of increased nutrient delivery on key biogeochemical and ecological processes that, in turn, influence the structure and function of aquatic ecosystems.
(5) Quantify nutrient uptake and recycling kinetics in streams and rivers to provide a needed quantitative foundation for establishment of downstream protective values (DPVs).
(6) Combine paleolimnological techniques with modeling approaches to develop reference (pre-disturbance) conditions for lakes.

Three primary outcomes of the program include:

(1) Education and training of 6 Ph .D. scientists and engineers to prepare them for the challenges of managing water and watersheds.
(2) Increased scientific understanding of the relationships between and uncertainty associated with watershed nutrient dynamics and ecological conditions in Florida waters.
(3) Provision of biophysical, social science and policy perspectives grounded in Florida water law toward a national effort to apply numeric nutrient criteria to surface waters.

Other features include institutionalization of cross-disciplinary research and education, internationalization of student perspectives, blending of disciplines in doctoral training, and dissemination of results within and outside traditional academic circles.

NATURE, SCOPE, AND OBJECTIVES OF THE PROJECT, INCLUDING A TIMELINE OF ACTIVITIES.

Our broadest goal is to develop a graduate program that stresses integration of engineering, biophysical, and social sciences and addresses issues related to management of water and watersheds through field-based teaching and research. The program consists of three elements:

Education - The educational experience fostered by this program will complement the disciplinary focus of each student's own research. The program will blend experiential learning and academic course work. A core set of interdisciplinary courses (some developed by the former UF NSF-funded IGERT in Adaptive Management) will be required of each student, regardless of discipline or major. A weekly seminar involving both faculty and students will focus on combining social, ethical and scientific domains as they relate to the program's focus using a Socratic format of inquiry and debate between participants to stimulate critical thinking and to illuminate ideas.

Research - We have identified a significant water management issue, numeric nutrient criteria (NNC), as the central topic around which our program will be constructed. The education and research experience of each student will evolve from and be shaped by specific problems and research questions related to adaptive management of Florida's water and watersheds under NNC. During the 1st fall semester we will devote our weekly Socratic seminar to identifying study watersheds and developing a scope of work addressing the research approach. The product of this will be a multi-authored "research report" that outlines the major watershed issues. Each student will draw from this experience in formulating his/her research topic.

Service - We will foster a component of ethical responsibility and civic involvement, which will be reinforced in core coursework and our continuing biweekly seminar that integrates ethics, communication, and leadership skills with research methods, scientific inquiry, and engineering practice. We anticipate involving undergraduates in studios, research, and special programs (including field trips) under mentorship of our graduate students. Finally, we will encourage students to get involved in community projects and education initiatives (e.g. watershed working groups) related to program objectives on a volunteer basis.

Project Outcome Timeline-

Student Recruitment (December, 2010 – February, 2011) – Each faculty member will be responsible for recruiting within his or her discipline. We will develop a brochure and web ad that showcases our WIGF Program for placement on various academic and professional web sites. In addition, we will advertise on the IGERT web site. We anticipate inviting students to UF campus in mid-February to mid-March. (All faculty members will participate)

Cohort Building Exercise I (August 2011) – Natural and Degraded Systems of Florida.
Similar to the "Everglades course" developed for the UF-IGERT, we will develop a 2-week course that will show case natural and degraded watersheds in north and central Florida. (All faculty members will participate)

Socratic Seminar (Fall 2011 and Spring 2012) - This weekly 3 hour seminar is required each semester. In the first year, we will focus on a synthetic dialog related to the cohort's research agenda that will

ultimately lead to development of a large integrative proposal. In later years the seminar will be used to focus student research questions. (All faculty members will participate)

Cohort Building Exercise II (Feb 2012) – Water Institute Symposium. Students will work with Water Institute staff in planning and developing a two-day Symposium at UF that will bring together scientists, managers, and policy experts to discuss watershed management and NNC.

Watershed Management & Restoration course (Summer 2012) – Modeled after the Watersheds course developed for the UF-IGERT, this required course will be team taught by WIGF Program faculty. (All faculty members will participate)

Cohort Building Exercise III (July-August 2012) –**Writeshop.** This writing workshop will be conducted following Summer 2012 as the culmination of the Socratic seminar; students and faculty will cloister at a location and write a major integrative proposal for submission in Fall 2012 to one of the following NSF programs: NSF-Biocomplexity, NSF-IGERT, NSF-WSC, NSF- CNH, NSF-Environmental Engineering, NSF- Hydrologic Sciences. (All faculty members will participate)

METHODS, PROCEDURES, AND FACILITIES.

The research theme addresses complex and emerging issues related to the management, protection, and regulation of nutrients in Florida watersheds. The US-EPA's proposed Numeric Nutrient Criteria (NNC) will have significant impacts on all sectors of Florida's economy including, industries discharging pollutants to lakes and flowing waters, publicly owned water treatment facilities, public and private storm water management agencies, and agriculture. It will require rethinking the way in which point source and non-point source discharges are dealt with as well as the institutional frameworks of governance and regulation that manage them. Real, cost-effective solutions, and public willingness to address the issue, will require not only the talent and efforts of Florida planners, designers, engineers and scientists, but an adaptive approach to implementation that adequately addresses scientific uncertainty and adapts to complex local conditions. Our research theme will address both the biophysical science and social policy dimensions of watershed research related to NNC.

We will use an experiential, multidisciplinary field-based program of research to study watersheds comparing nutrient dynamics, land use impacts, and management alternatives. Our goal is to provide quantitative science in support of flexible NNCs. There are already research programs underway at UF, with others proposed, and this WIGF Program will build on these existing initiatives. The watersheds will be identified in the first weeks of the program. The final decision will take into consideration the potential for synergistic activities with proposed and ongoing research initiatives at, for instance, the Santa Fe River basin, Newnans Lake, Lake Apopka, and Lake Alice. A key feature that ties our research theme to our educational/training program is integration of experiential, field-based research, whereby all students and faculty members on the team participate in field data collection, public management meetings (e.g., basin working groups, NNC public meetings) and weekly core seminars. Thus, we ensure integration across disciplines and a holistic perspective by each member of the team.

Field Campaigns **-** Our field research efforts will be organized into field campaigns in which all members of the program team participate. Campaigns will include such activities as water quality sampling, lake sediment coring, diurnal productivity measurements, administering stakeholder questionnaires, stormwater sampling, etc. Each campaign will be designed to collect data that will be used by one or more graduate students in their research projects. Each fellow/faculty team will be responsible for organizing filed campaigns as their research efforts take shape. This will help fellows develop skills in research design, management, and execution.

MAJOR FINDINGS AND ACCOMPLISHMENTS

Programmatic Accomplishments:

A national recruiting effort for the Water Institute Graduate Fellow (WIGF) cohort was conducted from December 2010 to February 2011. A total of 133 candidates applied for these fellowships, and the faculty team identified 17 excellent candidates from the pool. Eight of these candidates were invited to Gainesville during March 4-7th 2011 to participate in a recruitment weekend. Offers were made to 7 of these candidates and all accepted and enrolled in UF. The GPAs of the enrolled fellows ranged from 3.8 to 4.0 (mean 3.91) and the GREs ranged from 1100 to 1400 (mean 1270). One of the candidates has since withdrawn for personal reasons. The 2011 WIGF cohort now includes:

Tom Arnold (BS Penn State, MS UF, Advisor Mark Brenner, Geological Sciences)
Resources and Conservation)
Wesley Henson (BS/MS University of Nevada Reno, Advisor Wendy Graham, Agricultural and Biological Engineering)*
Joelle Liang (BS Berry College, MS North Carolina State University, Advisor Tom Frazer, Interdisciplinary Ecology)*
Charlie Nealis (BS/MS UF, Advisor Mark Clark, Soil and Water Sciences)
Courtney Riejo (BS Carroll University, MS Virginia Tech, Advisor Matt Cohen, Forest
Chris Pettit (BS New College, JD UF, Advisor Christine Overdevest, Environmental Sociology)
Grant Weinkam (BS Ohio University, MS University of Cincinnati, Advisor Mark Brown, Environmental Engineering Sciences)

*partially supported by USGS 104B grant.

During the Fall 2011 semester the WIGF faculty and student cohort participated in a 4 day group field trip around the state of Florida focused on visiting Natural and Degraded Systems of Florida and initiated a weekly Socratic Seminar (Fall 2011) to provide a synthetic dialog to refine the cohort's research agenda. The WIGF student cohort also assisted in the planning of the February 2012 Water Institute Symposium.

During Fall 2011 and Spring 2012 the students conducted a Tracer Additions for Spiraling Curve Characterization (TASCC) experiment (Covino et al. (2010)) to a low relief, spring-fed stream in Florida. Previously, the method has been tested only in mountain streams in the western United States. Using this robust methodology, the students successfully characterized the saturation kinetic curve of nitrogen through stream dosing experiments and presented research results at the 3rd Annual University of Florida Water Institute Symposium poster session as well as the 9th Annual INTECOL International Wetlands Conference.

During the Spring 2012 semester the weekly Socratic Seminar continued and the WIGF fellows helped host the Water Institute Symposium (Feb 15-16th, 2012). A two-day retreat was conducted in May 2012 during which the WIGF faculty and student cohort developed an integrative framework for their proposed individual Ph. D. work on nutrient dynamics, management and policy.

During the Summer 2012 semester the WIGF faculty and student cohort participated in the 5-week UF Law School Costa Rica Study abroad program. The WIGF students, in collaboration with UF Law Students and Costa Rican Law Students, worked on a variety of project, each of which focused on water

management issues pertinent to the Tempisque-Bebedero Basin, one of Costa Rica's largest and most water-limited watersheds. The Tempisque-Bebedero Basin and the Pacific Coast of Central America has been characterized as a "climate change hot-spot" due to predicted impacts on water resources, principally drought.

The 2012 projects included an investigation of the legal, socioeconomic, and environmental issues associated with rice production in the buffer zone of Palo Verde National Park; an assessment of the legal and scientific tools available for improving the health of the impaired wetland at Palo Verde National Park, an internationally recognized wetland; and an analysis of the institutional and legal framework for drought management in the Tempisque Basin. Participants also evaluated new recommendations for establishing minimum environmental flows in the Basin, investigated the environmental and social impacts of a proposed water storage dam in the Basin, and reviewed and critiqued current regulations for nutrient pollution in the Tempisque River. See http://www.law.ufl.edu/academics/academic-programs/study-abroad/summer-abroad/costa-rica/project-spotlight for detailed reports on the 2012 projects.

During the Fall 2012 semesters the WIGF students presented and defended their individual Ph. D. research proposals. The following proposals were approved by the students' supervisory committees

Student: T. Elliott Arnold, Ph. D. in Geological Sciencse, College of Liberal Arts and Sciences. Anticipated graduation date May 2015.
Proposed Dissertation Title: Estimating groundwater discharge into lakes via stable isotope and radium mass balance equations: Redefining nutrient budgets and nutrient sources.

Student: Wesley Henson, Ph. D. in Agricultural and Biological Engineering, College of Agricultural and Life Sciences and College of Engineering. Anticipated graduation date May 2015.
Proposed Dissertation Title: Examining the influence of water fluxes, flow paths and age on Nutrient Delivery: Implications for North Florida Springs.

Student: Joelle Liang, Ph. D. in Interdisciplinary Ecology, School of Natural Resources and the Environment. Anticipated graduation date May 2015.
Proposed Dissertation Title: Biogeochemistry and nutrient availability at the sediment-water interface in Florida springs and implications for management.

Student: Charles Nealis, Ph. D. in Soil and Water Sciences, College of Agricultural and Life Sciences. Anticipated graduation date May 2015.
Proposed Dissertation Title: Barriers and motivators to implementation of urban BMPs.

Student: Courtney Reijo, Ph. D. in Forest Resources and Conservation, College of Agricultural and Life Sciences. Anticipated graduation date May 2015.
Proposed Dissertation Title: Eutrophication in flowing waters: Metrics of nutrient limitation and processing in rivers.

Student: Grant Weinkam, Ph. D. in Environmental Engineering Sciences,. Anticipated graduation date May 2015.
Proposed Dissertation Title: Fate and future of phosphorus loading associated with land applied

reclaimed water in Florida.

During the Fall 2013 the WIGF student cohort co-instructed an honors-level undergraduate course entitled Environmental Issues in Water Resources. With a focus on water resource issues in the state of Florida, each fellow instructed a two-week section on material from his or her discipline and engaged the students in hands-on learning and discussion. At the end of each section, the instructors brought the students on a partial or full-day field trip to sites in north Florida which built upon the concepts presented in the section and introduced the students to local hydrology, current environmental issues, and ongoing restoration efforts. Throughout the course the instructors emphasized the importance of interdisciplinary collaboration when addressing issues in water resources. With this in mind, students completed a final paper surveying a water resources issue of their choice from an interdisciplinary perspective. Fellows concluded with a day of discussing "the future of freshwater in Florida" by synthesizing concepts and issues from each section of the course.

Research Progress by students partially supported by USGS 104B grant:

Joelle Laing: Joelle Laing is currently preparing field-based and tank experiments on the effects of organic matter and redox potential on the growth and success of species of submerged aquatic vegetation. As a result of nutrient inputs and other anthropogenic impacts, sediment organic matter contents have increased in many aquatic and estuarine waterbodies in Florida, potentially hindering the growth and reestablishment of native submerged aquatic vegetation (SAV). In Joelle's study she plans to assess the effects of organic matter on the growth and expansion of native SAV populations. Using this information, she plans to investigate approaches to restoration plantings which maximize success at sites high in sediment organic matter. Her field experiments will be based in Kings Bay as part of a large SAV restoration project soon being implemented by UF Faculty and other state personnel.

Joelle is conducting her dissertation research on the biogeochemical feedbacks contributing to the growth and success of species of submerged aquatic vegetation. Her research incorporates theory and data from multiple disciplines, including botany, ecology, geochemistry, and hydrology. Currently she is preparing a field study investigating the redox chemistry of sediments underlying different types of vegetation. Since sediment redox chemistry may influence the growth and reproductive success of species of vegetation, she plans to follow her field work with a laboratory experiment on the effects of redox potential on plant growth and reproduction. Her findings will expand theory related to eutrophication responses in lotic systems and will provide insight into the underlying mechanisms which cause nuisance vegetation to dominate in many disturbed lotic systems.

Wes Henson: Wes Henson has been evaluating process-based models to examine methods for representing dual permeability domains in karst aquifers. During summer 2013, he collected field data to investigate the spatial distribution of denitrification in the upper Floridan Aquifer across a gradient of aquifer confinement, using synopotic geochemical, isotopic, dissolved noble gas and aquifer tests. His current data analyses apply multivariate statistical methods and interpretation of isotopic data to determine where denitrification may be significant in the aquifer. In addition, during 2013 Wes served as Co-PI on an externally funded research project with the regional utility company (Gainesville Regional Utilities) assessing nitrate retention near their waste water injection facility. His future research will focus on how conduit flow processes affect travel time distributions (TTD) and residence times in karst aquifers. These are of great importance for understanding their influence on nutrient transformation and attenuation in the Floridan Aquifer.

In addition to his research, Wes participates in several science outreach activities: teaching elementary children about geology, wetlands, and water quality; leading high school 4-H workshops on wetlands and

springs; and mentoring an undergraduate student from the Agricultural and Biological Engineering department.

Joelle Laing, Wesley Henson and Water Institute Fellows indicating whether after seeing their impacts dams are good (thumbs up) or bad (thumbs down), Tempisque River Dam, Costa Rica 2012.

Joelle Laing surveying vegetation characteristics at a potential research site, May 2013.

Wesley Henson next to karst swallet in Santa Fe River basin, June 2012.

TRAINING POTENTIAL.

Two Ph. D. students are partially funded under this project in addition to UF funded cohort of 4 additional Ph. D. students. Each Ph. D. student has crafted dissertation around a topic and disciplinary facet of interest to them while contributing to the team's overall research theme of watershed management and policy in the face of Numeric Nutrient Criteria.

Development of Passive Sensor for Measuring Water and Contaminant Fluxes in the Hyporheic Zone

Basic Information

Title:	Development of Passive Sensor for Measuring Water and Contaminant Fluxes in the Hyporheic Zone
Project Number:	2013FL311B
Start Date:	2/1/2013
End Date:	3/28/2015
Funding Source:	104B
Congressional District:	3
Research Category:	Water Quality
Focus Category:	Solute Transport, Surface Water, Groundwater
Descriptors:	
Principal Investigators:	Mark Newman, Kirk Hatfield

Publications

1. Layton, L.E., H.R. Klammler, K. Hatfield, M.D. Annable, M.A. Newman, J. Cho, R. Gonzalez. Development of a Passive Sensor for Measuring Water and Contaminant Flux in the Hyporheic Zone. 8th IAHS International Groundwater Quality Conference. April 21-26, 2013. University of Florida. Gainesville, Florida.
2. Annable, M.D., L.E. Layton, K. Hatfield, M.A. Newman, J. Cho, R. Gonzalez, H.R. Klammler. Development of a Passive Sensor for Measuring Water and Contaminant Flux in the Hyporheic Zone. University of Guelph 2013 Consortium Meeting. May 29-31 2013. University of Guelph. Guelph, Ontario.
3. Layton, L.E., H.R. Klammler, K. Hatfield, M.D. Annable, M.A. Newman, J. Cho. Development of a Passive Sensor for Measuring Water and Contaminant Flux in the Hyporheic Zone. SETAC North America 34th Annual Meeting. November 17-21, 2013. Gaylord Opryland Hotel & Convention Center. Nashville, Tennessee.

Title: Development of a Passive Sensor for Measuring Water and Contaminant Fluxes in the Hyporheic Zone

Principal Investigator: Mark A. Newman, U. of Florida, markn@ufl.edu, 352-392-9537

Research Category: Engineering

Keywords: solute transport, surface water, groundwater

Abstract:
Aquatic sediments contaminated with semi-volatile organic compounds are often difficult to characterize and manage due to the tendency for the contaminants to be retained within the sediments for long periods of time due to the hydrophobic nature of some of the key compounds, such as polycyclic aromatic hydrocarbons and polychlorinated biphenyls. Technologies currently exist to identify groundwater discharge zones and infer estimates of contaminant mass flux based on total contaminant concentration in bulk sediment, though it is generally accepted that freely dissolved concentration in pore water is a better measure of potential exposure. The purpose of this research project is to demonstrate a new tool to provide more accurate characterization of sediment pore water and bioavailable contaminant fluxes through direct in-situ measurement. The hyporheic passive flux meter (PFM) is designed for passively and directly providing direct in-situ measurements of volumetric water flux and contaminant mass flux vertically through the upper surface sediment layer and into the overlying water column. The hyporheic PFM consists of an internal permeable sorbent which is impregnated with one or more water soluble tracers and is contained in a dedicated drive-point with an upper and lower screened opening. This configuration allows flow through the device if there is a pre-existing vertical gradient between the sediment bed and the water column. Once the hyporheic PFM has been deployed, the tracers are displaced from the sorbent at rates proportional to the average vertical specific discharge; thus, the mass loss of the tracers during deployment can be used to calculate specific discharge. Similarly, the cumulative mass of sorbed contaminants provide a direct measurement of the vertical contaminant flux during deployment. The hyporheic PFM prototype is currently being tested and validated through multiple bench-scale box aquifer experiments. The initial results show good agreement between the hyporheic PFM estimated and actual measured fluxes through the aquifer model. The laboratory testing will be followed by full-scale field deployments of the hyporheic PFM at sites with manageable conditions and previous contaminant characterization to demonstrate the ability to measure contaminant flux through the aquatic sediment bed.

RESEARCH PROBLEM:

The hyporheic zone comprises fluvial sediments within which there is exchange of water between a stream and the subsurface (Bencala, 2005). It is often characterized by chemical and temperature gradients that exert control on the behavior of solutes and organisms both at the interface and in the adjacent aquifer and stream environments (Brunke and Gonser, 1997; Hancock et al., 2005). It is an important zone for pollutant, energy and carbon cycling, and while there is a considerable body of knowledge about processes occurring within both rivers and aquifers, less is known about the processes that occur at the interface of these environmental compartments (EA Science Report SC050070, 2009). Contaminated sediment sites on the National Priorities List (USEPA, 1998) are often contaminated with semi-volatile organic compounds such as polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). Due to the hydrophobic nature of these key contaminants, sediment contamination is particularly difficult to manage due to the tendency for contaminants to be retained within sediments for long periods of time. Characterization and management of these sites requires new tools capable of quantifying the spatial distribution of contaminant mass flux and resulting contaminant loads.
In aquatic sediment systems contaminant mass flux occurs throughout the surface water column and sediment bed as a combination of dissolved contaminant mass flux (advective and diffusive) and sorbed contaminant mass flux (associated with sediment particle flux). Within the water column, sediment transport is typically defined in terms of the sediment load where there can be dissolved load, suspended load, and bed load. Dissolved contaminant mass flux can occur throughout the water column and

sediment bed whereas sorbed contaminant mass flux is coincident with suspended and mobile surface sediment transport.

Using this conceptual model for aquatic sediment systems, it is apparent that multiple devices will be required to quantify the contaminant mass loads depending upon the relevant mechanisms for sediment and contaminant mass flux. This research is aimed at developing a new low-cost technology that will complement emerging and existing technologies (surface water PFM, groundwater PFM, UltraSeep meter, traditional sediment traps, Trident Probe, Nortek Vectrino II velocimeter, Nortek Aquadopp Profiler, and Optical Backscatter Sensor) in order to provide requisite data to quantify the contaminant flux and evaluate the contaminant mass balance within the water column and sediment bed.

The new sensor incorporates the field tested concepts of the Passive Flux Meter (PFM) a device developed at the University of Florida (US Patent 6,402,547 B1, Hatfield et al 2002 and 2004; Campbell et al. 2006—*designated the Best Technology Paper published by ES&T, 2006*). The PFM is a self-contained permeable unit that is inserted into a well where it captures target contaminants from the pore water flowing through it. The sorbent matrix is also impregnated with known amounts of one or more fluid soluble resident tracers. These tracers are leached from the sorbent at rates proportional to the water flux (specific discharge).

After a specified period of exposure to flow, the PFM is removed for sampling and the sorbent is carefully extracted to quantify the mass of all contaminants intercepted by the meter and the residual masses of all resident tracers. The contaminant masses are used to calculate time-averaged contaminant mass fluxes, while residual resident tracer masses are used to calculate cumulative water flux.

RESEARCH OBJECTIVES

The goal of this student lead seed project is to develop a new passive technology that will incorporate the field-tested concepts of the passive flux meter (PFM) to provide direct *in situ* measurements of water and contaminant fluxes within the hyporheic zone. The proposed effort will develop a new sensor, test it under controlled laboratory conditions and develop field deployment strategies. If a robust technology is developed from this seed project, follow on proposals will be generated to pursue additional funding to support further development of the novel technology. The new technology will improve the ability of site managers to formulate a site-wide contaminant mass balance, evaluate the efficacy of hyporheic zone for monitored natural attenuation, manage aquatic sediment site restoration, control private and public expectations of restoration efforts, and ensure protection of human health and the environment. Specific objectives of the proposed work include:

1. Develop a prototype technology to quantify water and contaminant fluxes within the hyporheic zone.
2. Develop procedures for deploying the prototype technology in the field and evaluate its compatible use in conjunction with emerging and existing technologies to quantify contaminant flux and evaluate the contaminant mass balance over an aquatic sediment site.

METHODS:

As a seed proposal, this project provides supplemental support to the development of a new passive technology for quantifying water and contaminant fluxes within the hyporheic sediment zone; testing the device under controlled laboratory conditions; and developing field deployment methods. The proposed work includes 2 specific tasks.

Task 1: Develop a prototype hyporheic passive flux meter.

The original groundwater PFM design has been adapted in order to measure the vertical specific discharge of water and contaminant fluxes through the hyporheic sediment zone. Each hyporheic PFM is contained in a dedicated drive-point with two screened openings. If vertical flow is present in the sediment bed, there is a vertical head gradient which drives sediment pore water to flow through the

hyporheic PFM. The device contains an internal permeable sorbent which is impregnated with tracers and exposed to sediment pore water via flow between the two screens (Figure 1). During device deployment, hyporheic PFM tracers are eluted from the device at rates proportional to the average vertical specific discharge of water flowing through the sediment bed. Thus, by measuring tracer mass loss during deployment, the specific discharge may be calculated for water flowing through the sediment bed. If dissolved or complexed contaminants exist in the sediment pore water, then the cumulative mass of contaminant intercepted and retained on the hyporheic PFM sorbent can be used to determine the cumulative vertical contaminant mass flux (mass of contaminant per unit cross-sectional area). Sorption of background contaminants, to the solid sorbent (e.g. activated carbon) within the hyporheic PFM, pre-concentrates compounds prior to analysis and this substantially lowers device detection limits and improves the accuracy of flux calculations for trace contaminants. This is particularly important for higher molecular weight PAH and PCB congeners, many of which have very low aqueous solubilities.

As this is a new application, laboratory testing was conducted to characterize the performance of the hyporheic PFM. The required tasks included 1) development of transport theory following an approach developed by Klammler et al. (2011) to describe the flow of sediment water and the transport of tracers and contaminants through a vertical flux passive flux meter, 2) determine the location and size of inlet and outlet ports of the hyporheic PFM to optimize the determination of vertical specific discharge within the sediment, and 3) evaluate sorbent materials and tracers to select the optimal components for application with semi-volatile organics while taking into account flow velocities, requisite deployment durations, and high salinity issues that may affect tracer desorption or contaminant adsorption behavior.

Hyporheic PFM performance tests have been performed in laboratory flow cells for accuracy and precision in measuring cumulative vertical mass fluxes of water and dissolved contaminant. The flow cells contain prepared sediment packs and are equipped with reservoirs that can be used to apply known vertical hydraulic gradients (Figure 2). During these tests, the hyporheic PFM have been deployed for specific durations and permeated with known contaminant concentrations. Performance has been evaluated by comparing device measured specific discharges and contaminant fluxes with known specific discharges and contaminant fluxes created in the flow cell.

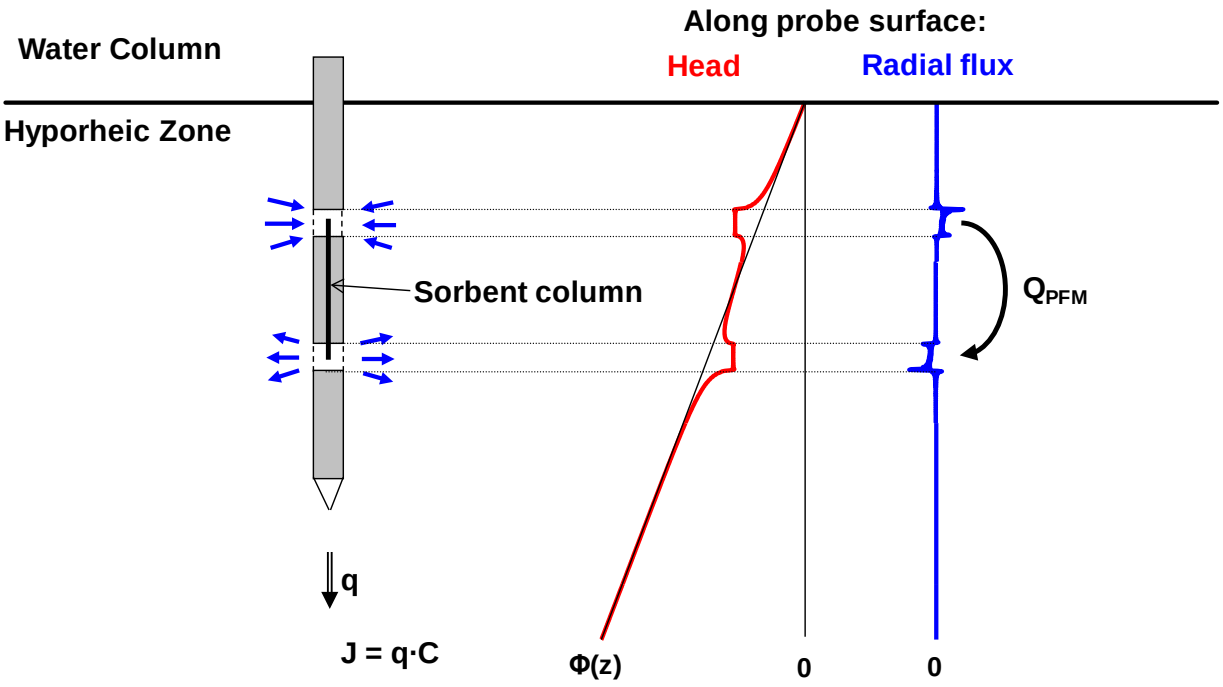

Figure 1: Hyporheic passive flux meter conceptual schematic.

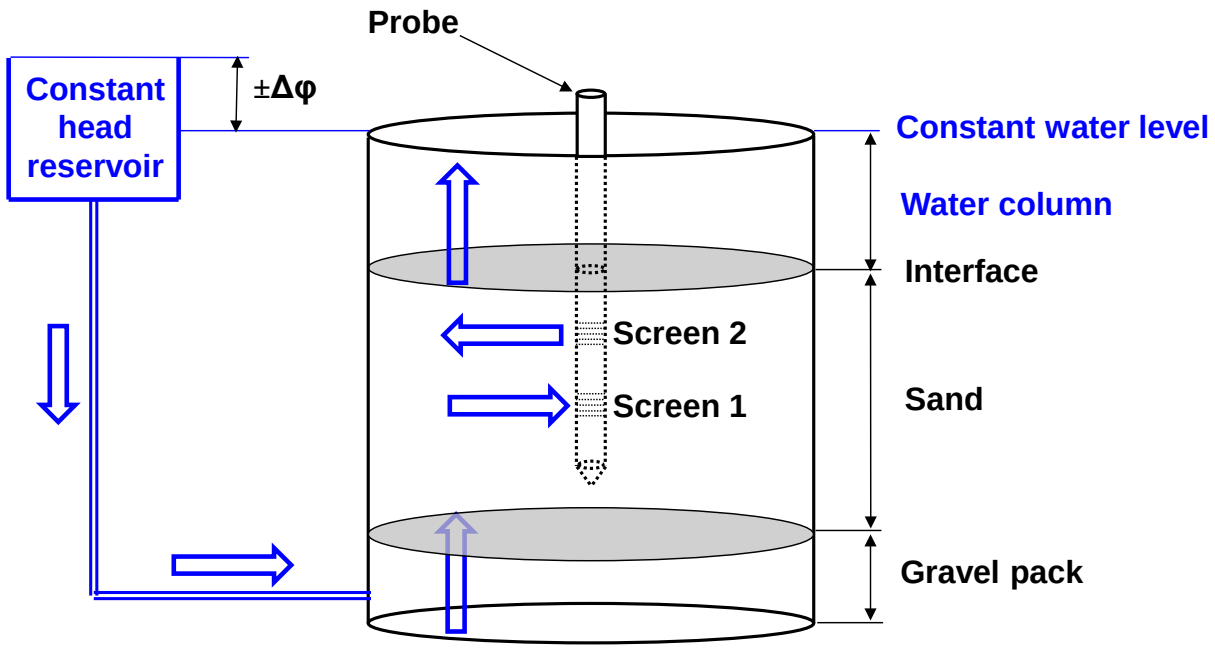

Figure 2: Flow cell for hyporheic PFM testing. Note: Current configuration is for upward flow through the sediment water interface. Relocation of the constant head reservoir can also allow for downward vertical flow through the sediment water interface.

Task 2: Sensor Integration and Deployment Testing. Develop procedures for deploying the prototype sensor in the field and evaluate its compatible use in conjunction with existing technologies to quantify contaminant flux and evaluate the contaminant mass balance within the water column and sediment bed.

PRINCIPAL FINDINGS

During the first year of support, nineteen laboratory experiments were performed in three series of tests. The initial series of six tests were performed using a constant head reservoir to establish a hydraulic gradient at a constant flow rate for varying elution volumes. This initial series of tests was used to evaluate optimal sorbent placement and packing within the flux meter prototype.

The second series of eight tests utilized a constant head reservoir and peristaltic pump to maintain a stable hydraulic gradient with constant elution volumes in order to evaluate performance of individual internal tracers for varying flow rates (i.e. flow rates were varied between tests, but total effluent volume was constant). Results were compared for cases in which the sorbent column within the prototype were either completely homogenized or divided into three equal vertical sections in order to evaluate device resolution for flux measurements.

The third series of five tests utilized a constant head reservoir and peristaltic pump maintaining constant flow rates with varied elution volumes to again evaluate the performance of individual internal tracers.

Results show that the rate of tracer loss from the flux meter is proportional to the volumetric water flux (specific discharge) through the sediment. Further tests will be performed to optimize prototype design and deployment strategies.

SIGNIFICANCE

Aquatic sediments are often the ultimate receptors of contaminants. Sediment contamination is particularly difficult to manage due to the tendency for contaminants to be retained within sediments for long periods of time. According to an estimate by the U.S. Environmental Protection Agency (U.S. EPA), approximately 10% or 1.2 billion cubic yards of the sediment underlying the country's surface water is sufficiently contaminated with toxic pollutants to pose potential risks to fish and to humans and wildlife that eat fish (U.S. EPA, 1998). As such, a critical research need that has been identified is development of tools for assessment of incoming off-site contaminant loads and methods to quantify how those loads might impact the surface sediment concentrations at a remediated sediment site. In most urban and industrial harbors and rivers, it is unlikely that all contaminant sources will be completely eliminated. Aquatic sediments will be exposed to continued input from such sources as permitted discharges, transport from upland or upstream contaminated sites, or from stormwater discharge. Recontamination from such sources can slow or even reverse recovery and methodologies are needed to manage for ongoing contaminant influx.

The likely applications of the new technology developed through this project can include any location where sediment quality may be compromised. These include contaminated industrial sites, Federal Superfund sites, urban waterways with legacy pollution due to historic manufactured gas production and/or power generation and numerous Navy sites. Liability no longer ends with the completion of a sediment remedial action such as dredging or capping. Instead, remedial actions often require long-term management and responsible parties are increasingly interested in designing remedial actions that will be effective despite ongoing low-level contaminant loading. The technology developed through this research can be used to quantify the potential loading from such ongoing sources, so that the load can be attenuated by the chosen remedial alternative.

REFERENCES

Annable, M.D., K. Hatfield, J. Cho, H. Klammler, B.L. Parker, J.A. Cherry, P.S.C. Rao, "Field-Scale Evaluation of the Passive Flux Meter for Simultaneous Measurement of Groundwater and Contaminant Fluxes". Environmental Science & Technology. Vol. 39, 2005, pp. 7194-7201.

Basu, N.B., P.S.C. Rao, I.C. Poyer, M.D. Annable, K. Hatfield. Flux-Based Assessment at a Manufacturing Site Contaminated with Trichloroethylene, Journal of Contaminant Hydrology, 86(1-2), 2006, pp. 105-127.

Bencala KE. 2005. Hyporheic exchange flows. In: Anderson MG and McDonnell JJ (Eds), Encyclopedia of Hydrological Sciences. John Wiley and Sons, London, Volume 3, Part 10, Chapter 113, pp 1733-1740.

Brunke M, Gonser T. 1997. The ecological significance of exchange processes between rivers and groundwater. Freshwater Biology 37: 1-33.

Campbell, T. J., K. Hatfield, H. Klammler, M. D. Annable, and P.S.C. Rao. Magnitude and directional measures of water and Cr(VI) fluxes by passive flux meter. Environmental Science and Technology. 2006. 40(20), 6392-6397.

Chadwick, D. B., 2008. Project Summary: Demonstration and Validation of Enhanced Monitored Natural Recovery at DoD Sites. ESTCP Project No. ER-200827. ESTCP, Alexandria, VA. http://serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Sediments/ER-200827/ER-200827.

Chadwick, D. B. and A. Hawkins. 2008. Final Report: Monitoring of Water and Contaminant Migration at the Groundwater-Surface Water Interface. ESTCP Project No. ER-200422. SPAWAR (San Diego, CA) and ESTCP (Alexandria, VA). http://serdpestcp.org/content/download/4642/67932/file/ER-0422-FR.pdf.

Chadwick, D.B., 2011. Project Summary: Demonstration of In Situ Treatment with Reactive Amendments for Contaminated Sediments in Active DoD Harbors. ESTCP Project No. ER-201131. ESTCP, Alexandria, VA. http://serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Sediments/ER-201131/ER-201131.

Environment Agency, 2009. The Hyporheic Handbook: A handbook on the groundwater–surface water interface and hyporheic zone for environment managers. Integrated Catchment Science Programme, Science Report: SC050070. Bristol, UK.

Gschwend, P.M. 2009. Project Summary: Passive Polyethylene Sampling in Support of In Situ Remediation of Contaminated Sediments. ESTCP Project No. ER-200915. ESTCP, Alexandria, VA. http://serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Sediments/ER-200915/ER-200915.

Hancock PJ, Boulton AJ, Humphreys WF. 2005. Aquifers and hyporheic zones: Towards an ecological understanding of groundwater. Hydrogeology Journal 13: 98-111.

Hatfield, K., M. Annable, J. Cho, P.S.C. Rao, and H. Klammler. A direct passive method for measuring water and contaminant fluxes in porous media. J. Contam. Hydrol. 2004, 75 (3-4): 155-181

Hatfield, K., M.D. Annable, S. Kuhn, P.S.C. Rao, and T. Campbell. 2002. A new method for quantifying contaminant flux at hazardous waste sites. Groundwater Quality 2001, IAHS Publication 275, Red Book, Sheffield United Kingdom, pp. 25-32.

Klammler, H., K. Hatfield, B. Nemer, and S.A. Mathias. 2011. A Trigonometric Interpolation Approach to Mixed Type Boundary Problems Associated with Permeameter Shape Factors, Water Resour. Res., 47, W03510.

United States Environmental Protection Agency (USEPA). 1998. EPA's contaminated sediment management strategy; EPA-823-R-98-001; U.S. Environmental Protection Agency, Office of Water, Washington, DC, 1998.

United States Environmental Protection Agency (USEPA). 2005. Contaminated Sediment Remediation Guidance for Hazardous Waste Sites. EPA-540-R-05-012. http://www.epa.gov/superfund/health/conmedia/sediment/pdfs/guidance.pdf.

Verreydt, G., J. Bronders, I. Van Keer, , L. Diels, P. Vanderauwera. Passive Samplers for Monitoring VOCs in Groundwater and the Prospects Related to Mass Flux Measurements. Ground Water Monitoring and Remediation. 2010. Vol. 30 (2). pp. 114-126. DOI: 10.1111/j1745-6592.2010.001281.x

Development and Evaluation of Data Accuracy Assessment Algorithms for Identifying Anomalies in Hydro-meteorological Data (Phase I: Stage)

Basic Information

Title:	Development and Evaluation of Data Accuracy Assessment Algorithms for Identifying Anomalies in Hydro-meteorological Data (Phase I: Stage)
Project Number:	2013FL313B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	19
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Methods, Models
Descriptors:	None
Principal Investigators:	Ramesh S Teegavarapu

Publications

1. Teegavarapu, Ramesh S.V., Aneesh Goly, and Jayantha Obeysekera. 2013. Influences of Atlantic Multidecadal Oscillation (AMO) Phases on Precipitation Extremes Journal of Hydrology, 2013. doi: 10.1016/j.jhydrol.2013.05.003.
2. Aneesh Goly and Ramesh S.V. Teegavarapu. 2014. Individual and Coupled Influences of AMO and ENSO on regional Precipitation Characteristics and Extremes. Water Resources Research. Accepted. doi: 10.1002/2013WR014540
3. Assessment of Influences of Climate Variability on Storm Event Characteristics. Paper presented at the Annual Meeting of EWRI ASCE, Cincinnati OH, 2013. doi: 10.1061/9780784412947.104
4. Selection and Evaluation of Different Spatial Resolutions for Statistical Downscaling of Precipitation. Paper presented at the Annual Meeting of EWRI ASCE, Cincinnati OH, 2013.
5. Assessment of various Statistical Downscaling Methods for Downscaling Precipitation in Florida. Paper presented at the Annual Meeting of EWRI ASCE, Cincinnati OH, 2013. doi: 10.1061/9780784412947.105
6. Statistical Characterization and Assessment of Precipitation Extremes during Different Phases of Multi-year and Multi-decadal Climatic Oscillations. Paper presented at the Annual Meeting of EWRI ASCE, Cincinnati OH, 2013.
7. Multi-Objective Optimization Methods for Bias Correction of Statistically Downscaled Precipitation. Paper presented at the Annual Meeting of EWRI ASCE, Cincinnati OH, 2013. doi: 10.1061/9780784412947.116
8. Ramesh, S. V. Teegavarapu, Tadasse Meskele, Chandra Pathak. 2012. Geo-Spatial Grid-based Transformation of Multi-Sensor Precipitation using Spatial Interpolation Methods. Computers and Geosciences. Volume 40, March 2012, pp. 28-39. http://dx.doi.org/10.1016/j.cageo.2011.07.004.
9. Ramesh S. V. Teegavarapu, Aneesh Goly, Jayantha Obeysekera. 2013. Influences of Atlantic Multidecadal Oscillation Phases on Regional Precipitation Extremes. Journal of Hydrology. Volume

495, July 2013, pp. 74-93. http://dx.doi.org/10.1016/j.jhydrol.2013.05.003

Title: Development and Evaluation of Data Accuracy Assessment Algorithms for Identifying Anomalies in Hydro-meteorological Data (Phase I: Stage)

Project Type: Research

Focus Categories: Hydrology, Methods, Models

Research Category: Hydrologic Processes

Keywords: Hydrometeorological Data, Stage, South Florida Water Management District, outliers, anomaly detection, statistical methods.

Start Date: 03/01/13

End Date: 02/28/2014

Principal Investigator: Ramesh S. V. Teegavarapu, Associate Professor, Department of Civil Engineering, Florida Atlantic University, Boca Raton, Florida, 33431. Email: ramesh@civil.fau.edu, Phone: (561) 297 3444

Abstract:

The main objective of this multi-year study is to develop and evaluate several statistical and data-mining based algorithms for identification and detection of outliers and data anomalies in hydro-meteorological data, especially stage data. This report discusses work that was completed in Phase I during year 2013. In this first phase of the work, algorithms for identification stage data anomalies were developed and evaluated and a prototype tool was developed. The first phase of work focused on stage data obtained from different hydraulic structures in SFWMD region from different sensors.

The premise of this work is that algorithms applicable in a standard test environment can help in the evaluation of data anomalies that will ultimately be used to improve existing stage data. The results of this study provide a complete evaluation of existing methods of data outlier detection. The methods were evaluated at different hydraulic structures and evaluated using a number of indices and skill scores including input from modelers and data management personnel at SFWMD. The study used data from a network of stage monitoring sensors automatically uploaded into the databases of SFWMD. This research is highly relevant and critical to a number of water resources management agencies (e.g. South Florida Water Management District (SFWMD)) 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).

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 2009, the Hydro Data Management (HDM) at SFWMD initiated an effort to develop and implement a Production Assessment and Tracking (PAT) system. The PAT system would enable HDM management, supervisors, and front line associates to monitor, track, and improve its deliverable's quality levels. The PAT development effort was led by a group of subject matter experts called the PAT Quality Task Force (QTF). The QTF defined long term and short term goals to help drive towards implementation of a full scale production PAT system. This research will build on the QTF's prior work related to defining data accuracy algorithms for surface water stage data, and provide additional recommendations for PAT system quality metric calculations with a focus on developing data accuracy algorithms.

There is a constant need to devise and implement data accuracy algorithms that will be part of a larger PAT system. The QTF has identified a need to explore algorithm development beyond the use of internal SFWMD resources. This study provides the HDM an exhaustive survey of literature of data accuracy algorithms, identify and evaluate candidate algorithms based on statistical principles, and prototype selected data accuracy algorithms for use at the SFWMD. The candidate algorithms were judged based on their performance determining data accuracy compared to the data accuracy levels obtained through human data processing. The focus of this project was exploratory with the goal to implement the potential data accuracy algorithms within a larger PAT system or other SFWMD systems at a later date.

Statement of Results and Benefits

This project provides a mix of applied and fundamental research that will be used to generate practical tools as well as to advance a fundamental understanding of data anomalies or outliers in hydrometeorological data. The outcomes provide new methods for assessment of outliers and data anomalies in hydrometeorological data. The methods have been developed considering methods used in data mining and knowledge discovery fields. In particular, the research helps 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?

and What kind of domain knowledge is essential for improve data anomaly detection algorithms ?

Results

Main Tasks

16.3 Data Collection, Review and Analyses – The research team collected and analyzed a number of data sets, as part of Task 1. The time series data sets included stage data at different structures. These data sets were for a period-of-record as determined appropriate by SFWMD. The research team also investigated similar previous works which were performed at the SFWMD and others, prior to performing this task.

The following sub-tasks were performed:

16.3.1 Literature Review: performed review of existing literature relating to the scientific determination of accuracy of data points with an emphasis on non-causal (considers historical and predictive future values) approaches.

16.4 Evaluation of different data anomaly detection algorithms

The following sub-tasks were performed.

16.4.1 Evaluation and consideration of simple standard statistical algorithms (median filter, variance analysis, etc.) developed by the QTF.

16.4.2 Identification and ranking of candidate algorithms that can be used to detect surface water level stage data anomalies and determine data accuracy.

16.5 Development of Standard Test Environment – A standard test environment was developed and provided to the District as a part of the deliverable for the project.

16.5.1 Build a prototype standard test environment for testing surface water level stage data accuracy algorithms.

16.5.2 Prototype and test candidate algorithms against a standard catalog of sample SFWMD data using probability of detection and probability of false alarm metrics to determine algorithm effectiveness.

16.6 Draft and Final Reports – A draft and final report have been submitted to the SFWMD.

Table 1. Project tasks and sub-tasks and completion dates

		Year 2013											Year 2014	
Tasks	Sub-Tasks	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	
16.3	16.3.1													
16.4	16.4.1													
	16.4.2													
16.5	16.5.1													
	16.5.2													
16.6	Draft Report													
	Final Report													

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 the project was 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 was developed as an initial screening tool to identify stage data anomalies. The rules considered 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 were also 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 ten different structures in the SFWMD region were used for the evaluation of data accuracy algorithms. The structures were selected considering the recommendations of the District project manager. Data collected from SFWMD were processed through prototype test environment developed by the research team. The environment utilizes 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 was developed using visual BASIC and MATLAB software platforms. The stage observations used by the test environment for identifying outliers was also evaluated by an expert team of modelers and hydrologists at SFWMD based on their judgment, past experience and scientific reasoning. A contingency table was 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 were ranked using detection rate as a performance measure.

This study provides 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 are ranked based on results from effectiveness tests using detection rate and false positive rate indices obtained from a 2 x 2 contingency table. The prototype test environment evaluates the potential outliers in stage data with the binary results (yes or no) from all the algorithms tested in this study. The test environment developed as a part of this study is generic in nature and can be expanded in its functionality in the future to detect anomalies in other hydrological variable datasets such as precipitation and others.

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.

Training Potential

This project has supported the research of three graduate students as outlined below.

Graduate Theses

1. Mr. Aneesh Goly (Ph.D. thesis title: Influences of Climate Variability and Change on Precipitation Characteristics and Extremes). July 2013.

2. Milla Pierce Influences Of Decadal And Multi-Decadal Oscillations On Regional Precipitation Extremes And Characteristics, November 2013.

3. Wilard Metullus will start working on his MS thesis Spring 2014.

References

Chandola, V. Banerjee, A., Kumar , V. 2009. Anomaly Detection —A Survey. ACM Computing Surveys 41, 3, 15.

Hodge, V. and Austin, J. 2009. A Survey of Outlier Detection Methodologies. Artificial Intelligence Review 22, 2 (85-126).

Kasunic, M.; McCurley, J. Goldenson, D. and Zubrow D. 2011. An Investigation of Techniques for Detecting Data Anomalies in Earned Value Management Data (CMU/SEI-2011-TR-027). Software Engineering Institute, Carnegie Mellon University.

Kriegel, H. P.; Kroger, P.; and Zimek, A. 2010. Outlier Detection Techniques. Tutorial at the 16th ACM International Conference on Knowledge Discovery and Data Mining (SIGKDD), Washington, DC.

Rogers, M., S. Rogers, 2012. A First Course in Machine Learning, CRC Press.

USACE, 2008. Department of the Army, U.S. Army Corps of Engineers. Environmental Quality—Environmental Statistics, Engineer Manual 1110-1-4014.

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:	2013FL312B
Start Date:	2/1/2013
End Date:	3/28/2014
Funding Source:	104B
Congressional District:	3
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	None
Principal Investigators:	Kirk Hatfield, Mark Newman

Publications

1. Perminova, I.V., S. N. Kalmykov, N. S. Shcherbina, S. A. Ponomarenko, V. A. Kholodov, A. P. Novikov, R. G. Haire, K. Hatfield. 2013. Humic functional derivatives and nanocoatings for remediation of actinide contaminated environments, Nanomaterials for Environmental Protection, Edited by B. I. Kharisov, O. V. Kharissova, and H. V. R. Dias. ISBN 0-471-9781118496978 Copyright © 2000 Wiley, Inc. (In review)
2. Klammler, H., K. Hatfield, J. Luz, M. Annable, M. Newman, J. Cho, A. Peacock, V. Stucker, J. Ranville & C. Clark. 2012. Water and contaminant flux estimation from multi-layer passive flux meter measurements, Advances in Fluid Mechanics, WIT Transactions on Engineering Sciences, Vol 74, pp 301-313.
3. Klammler, H., K. Hatfield, M.M. Mohamed, I.V. Perminova, M. Perlmutter. 2013. Capture and release zones of permeable reactive barriers under the influence of advective-dispersive transport in the aquifer, Advances in Water Resources. (In Review).
4. Shcherbina, N. S., S.S. Kalmykov, S. A. Ponomarenko, K. Hatfield, R. Haire, and Perminova, I. V. 2013. Partitioning of Waterborne Plutonium Partitioning to Immobile and Mobile Humic Materials in the Binary and Ternary Systems, Environmental Science & Technologies. (In Press).
5. Acar, Ö, H. Klammler, K. Hatfield, M. A. Newman, M. Annable, J. Cho, B. Parker, J. Cherry, P. Pehme, P. Quinn, and R. Kroeker. 2013. A stochastic model for estimating groundwater and contaminant discharges from fractured rock passive flux meter measurements. Water Resour. Res. VOL. 49, 1 15, doi:10.1002/wrcr.20109.
6. Karpiouk, L.A., S.A. Ponomarenko, A.I. Konstatinov, N. Hertkorn, A.M. Muzafarov, K. Hatfield, I.V. Perminova. 2012. Controlling Aqueous Sorption of Humic Substances on Silica Gel by Directed Alkoxysilyl-Derivatization of Their Functionalities, Colloids and Surfaces A: Physicochemical and Engineering Aspects, Vol 396, 224-232, DOI: 10.1016/j.colsurfa.2011.12.068.
7. Klammler H., K. Hatfield, J.A.G. Luz, M.D. Annable, M. Newman, J. Cho, A. Peacock, V. Stucker, J. Ranville, S. Cabaniss, and P. S. Rao. 2012. Contaminant Discharge and Uncertainty Estimates from Passive Flux Meter Measurements, Water Resour. Res. 48, W02512, DOI: 10.1029/2011WR010535.
8. Karpiouk, L.A., S.A. Ponomarenko, A. Mourran, D. Bochkariov, A. M. Muzafarov, K. Hatfield and I.V. Perminova. 2012. Self-assembly of alkoxysilanized humic substances into multidomain adlayers at the water-solid interface: linking surface morphology to molecular structures of adsorbate, Soft Matter, 8 (8), 2452 2459. DOI: 10.1039/C2SM06582G.

Information Transfer Program FY 2013

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 17 peer-reviewed journal articles, 2 book chapters, and 12 proceedings and presentations.

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 provided 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.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	0	0	0	0	0
Masters	0	0	0	0	0
Ph.D.	11	0	0	0	11
Post-Doc.	0	0	0	0	0
Total	11	0	0	0	11

Notable Awards and Achievements

The WRRC continues 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 2013:

STEM Education: 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 11 Ph.D. students all focusing on water resources issues during Fiscal Year 2013.

Support for Junior Faculty: WRRC supported faculty member Treavor Boyer (WRRC project 2011FL267B) was named College of Engineering nominee for the Excellence Award for Assistant Professor.

Support for established Faculty: James Heaney (WRRC 2011FL269B) was awarded the prestigious Warren A. Hall Medal for 2013 by the Universities Council on Water Resources (UCOWR). The Warren A. Hall Medal is a memorial established by friends and family to recognize the distinctive scholarly accomplishments of an individual in the water resources field. The Medal was awarded at UCOWR's Awards Banquet on June 12, 2013, at Lake Tahoe, California.

Publications from Prior Years