NOAA SECTORAL APPLICATIONS RESEARCH PROGRAM (SARP)
PROJECT ANNUAL REPORT (DRAFT)

PROJECT TITLE

Managing Drought in the Apalachicola-Chattahoochee-Flint (ACF) River Basin through the Development of Improved Drought Indicators and Policy Alternatives

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PROJECT YEARS 2013-2016

TIME PERIOD ADDRESSED BY REPORT (e.g., August 2002-March 2003)

July 2014 – June 2015
I. PRELIMINARY MATERIALS

A Project Abstract (Limit to one page)

Recurring droughts led the National Integrated Drought Information System (NIDIS) to select the Apalachicola-Chattahoochee-Flint (ACF) River Basin as a pilot for developing a Drought Early Warning System (DEWS) for the Southeast. NIDIS efforts in the basin resulted in the development (and use) of a number of drought indicators derived mainly from precipitation, streamflows, and lake levels. However, because the ACF River Basin (and much of the Southeastern Coastal Plain) exhibits a highly interacting surface-groundwater system, a more comprehensive set of drought indicators that include groundwater levels is needed. Further, because groundwater levels respond to drought at a different time scale than other indicators and integrate the effect of drought over larger area, they can provide a more complete picture of the severity, spatial extent, and recovery from drought. Together with the analysis of existing drought policies, impediments to drought management, and other drought indicators, groundwater levels can then be used to develop more effective drought triggers and response policies.

The proposed project has two specific outcomes. First, the project will develop a spatially-explicit groundwater-level forecasting protocol that is tailored to the needs of stakeholders of the ACF River Basin, and that can be integrated as a drought indicator into NIDIS DEWS for the Southeast. Second, the project will develop new policy alternatives that can be used by state officials in Georgia for managing future droughts without adversely impacting the state’s agricultural economy and water resources. Thus, this project addresses the NOAA-CSI program goal of “research and development of innovative and broadly applicable tools, methodologies, and knowledge to support decision-making.” In addition, the project addresses both of the SARP focus areas: (1) climate extreme-event preparedness, planning, and adaptation and (2) Coping with Drought Initiative in support of the NIDIS. Successful completion of the proposed project will fill a crucial gap in understanding the effects of climate and irrigation pumpage on groundwater resources of the Southeast. The project is relevant to NOAA’s long-term goal of climate adaptation as described in the NOAA’s Next-Generation Strategic Plan by producing accurate groundwater-level predictions, identifying risks and vulnerabilities and policy options for alleviating risks, and informing decisions related to water use for irrigation.

B Objective of Research Project (Limit to one paragraph)

The overarching goals of the proposed project are to (a) define groundwater levels as a drought indicator in support of NIDIS DEWS and (b) develop effective drought management policies for the ACF River Basin to help resolve tri-state (AL-GA-FL) water conflicts. Specific objectives are to:

1. Quantify the effect of climate variability on groundwater levels under different overburden conditions;
2. Quantify how pumping for irrigation exacerbates the effect of drought on groundwater levels and streamflows;
3. Develop a procedure for forecasting groundwater levels; and
4. Analyze pros and cons of existing drought management policies and propose a set of policy alternatives that can be used to effectively manage drought in the basin.

C Approach (including methodological framework, models used, theory developed and tested, project monitoring and evaluation criteria) include a description of the key beneficiaries of the anticipated findings of this project (e.g., decision makers in a particular sector/level of government, researchers, private sector, science and resource management agencies) *(Limit to one page)*

- To address the first objective, 21 observation wells with 30 years of monthly groundwater level data were used to study the ENSO-groundwater level relationship. We also used Wavelet Analysis to identify teleconnection between ENSO-induced droughts and groundwater levels (GWL) in the Lower Apalachicola-Chattahoochee-Flint (ACF) River Basin. Mann-Whitney test was used to quantify how different ENSO phases affect GWL. Moderate and extreme drought events (e.g., 2000-2001 drought) and associated GWL recovery periods were studied.
- To address the second objective, we are using the groundwater model MODFE to simulate different irrigation scenarios for year 2001-02 to study how irrigation water withdrawals during drought affect GWL and exacerbate the effect of drought in the Lower ACF River Basin. We are building the model to simulate different irrigation scenarios for another drought event (i.e. year 2010-12) to get a complete picture of irrigation-droughts-GWL linkage in the study area.
- To address the third objective, we are quantifying how other climate variability phenomena (in addition to ENSO) [e.g., NAO (North Atlantic Oscillations), AMO (Atlantic Multidecadal Oscillations) and PDO (Pacific Decadal Oscillations)] affect surface and ground water interactions (i.e. baseflow) in the Flint River Basin.
- Linear Mixed Effects (LMEs) models are being used to study and quantify the individual and coupled impacts of climate variability on baseflow. Two statistical procedures are being used to fit the LMEs: the parametric maximum likelihood and the non-parametric Joint Rank Fit (JRFit). Both LME and JRFit are suitable for the analysis of clustered data as baseflow data appear to be clustered within a month.
- For the fourth objective, credible, spatially-explicit projections of irrigation water withdrawals in areas that may reduce Flint River flows under drought conditions are being developed. Georgia's challenge is to determine how to meet any mandated flow target at the state line during drought years without severely damaging the state's economy and the livelihoods of individuals who have become dependent on the vibrant irrigated agriculture in the Lower Flint River Basin. Addressing this challenge will require not only a detailed understanding of the close connections between the Basin's groundwater system and surface flows, but also an understanding of the agro-economic impacts of any change in irrigation water applications. This requires documenting the areas equipped for irrigation as well as actual rates of irrigation applications as a function of weather conditions, crop mix and timing of precipitation relative to varying crop water
requirements throughout the growing season. Mapping studies have documented considerable expansion of irrigation systems in recent years. This has occurred even in areas where no new permits are being issued because high crop prices have induced investment in new center pivots on lands previously permitted, but not yet developed. We will develop economic models of irrigation-system investment decisions, as well as within-season irrigation water use decisions. The models will use available data on acres equipped for irrigation, well-meter data, crop prices and daily weather.

- A related project objective is to examine the potential effectiveness of alternative regulatory approaches for reducing irrigation water withdrawals to protect surface streamflows during drought periods. This is an especially challenging problem because the supplemental nature of irrigation water use in the Flint River Basin causes water withdrawals to increase substantially during drought periods. Previous policy experiments involving payments to farmers to cease irrigating during drought years proved to be financially unsustainable and largely ineffective. Our work will examine the implications of more spatially-targeted approaches that make use of this project's findings on the temporal and spatial patterns of pumping impacts on base-flows as influenced by drought conditions. We will explore the potential policy value of improved drought forecasts based on large-scale atmospheric indices. In addition, we will model farmer responses to policy alternatives including long-term interruptible supply agreements, and caps on permitted withdrawals as a function of current or forecasted drought conditions.

- This work also will examine the possible impacts of anticipated policy changes on current investments in irrigation system expansion. For example, does the fear of future restrictions induce more rapid investment in new center pivots under existing permits than would occur in the absence of that threat? This will be explored by comparing rates of new irrigation system development in three areas, as defined by the Flint River Basin Regional Water Development and Conservation Plan: Capacity Use Areas (red), Restricted Use areas (yellow) and Conservation Use Areas (green).

D Description of any matching funds/activities used in this project (Limit to one paragraph)

We have expanded the scope of the project using the funds provided by the Center for Forest Sustainability at Auburn University and the funds provided by the NOAA RISA Program to the Southeast Climate Consortium. Although we planned to use only one Ph.D. student to work on this project, we now have two Ph.D. students who are working on this project.

II. ACCOMPLISHMENTS

A. Brief discussion of project timeline and tasks accomplished. Include a discussion of data collected, models developed or augmented, fieldwork undertaken, or analysis and/or evaluation undertaken, workshops held, training or other capacity building activities implemented. (This can be submitted in bullet form – limit to two pages)

- A lot of work has been done for the first two objectives. Please see §I.C. and §II.B.
For the fourth objective, Drs. Mark Masters and Kathleen Miller jointly supervised the work of an economics graduate student from Georgia State University, Rhita Simorankir, on estimation of the potential for expanded irrigation investment under existing grandfathered well permits. Rhita spent two months during summer 2014 working at the National Center for Atmospheric Research under Dr. Miller’s supervision. During that time, she worked on matching existing databases on wetted acres and permitted acres to produce a spatially detailed data set on acres permitted for irrigation but not yet wetted. This acreage represents a potential challenge for Georgia’s efforts to meet any mandated flow target at the state line because the well permits do not restrict the total quantity of water that can be withdrawn from the aquifer, and landowners could legally use their existing permits to supply water to new center pivots on such parcels. Ms. Simorankir produced detailed maps of this grandfathered acreage for comparison with the management areas defined by the Flint River Basin Regional Water Development and Conservation Plan.

In addition, the team collected and reviewed literature on market-based policy options for suspending irrigation during drought episodes or temporarily transferring irrigation permits to other uses; economic modelling of irrigation water demand; and irrigation system investment decisions.

We coordinated with the other members of the project team to ensure the policy relevance of their pumping impact assessments. Specifically, we requested a targeted assessment of the base-flow impacts of reduced pumping if implemented sequentially in the Capacity, Restricted and Conservation Use areas as defined by the Flint River Basin Regional Water Development and Conservation Plan. The results from this modeling are expected to be available in early summer.

Modeling focused on the economic impact of irrigation reduction is also underway using the following three scenarios agreed upon by the project team:

1. “All or nothing” temporary permit suspension. That is, a farmer would have their entire permit suspended for a period of time such that no irrigation could take place. This is designed to mimic possible implementation of the Flint River Drought Protection Act.
2. Permanent retirement of irrigated acreage through conservation easements or other means.
3. A voluntary irrigation suspension program designed to allow farmers to enter a pool of members that may be required to suspend irrigation for some portion of the growing season. Payments to the producers would be in the form of annual payments for participating in the pool, regardless if the suspension is triggered, plus additional per acre payments that would result from irrigation suspension.

A preliminary assessment was made of the utility of well meter data for estimating the influences of drought on irrigation water demands, but the short available records provide inadequate information. Analysis was hampered by the fact that shortly after this project was awarded, Florida asked the U.S. Supreme Court for permission to file a Complaint against Georgia, which the Court granted. This case and the ongoing evidence-gathering process by the Supreme Court’s Special Master prevented our project’s access to a portion of the data needed for a more complete analysis. We will return to that task once the data access restrictions are lifted.
B. **Summary of findings**, including their potential or actual implications for efforts to develop applications, methods, and science-based decision support capacity/systems and to foster sustainable resource management and vulnerability reduction. (*Limit to two pages*)

- Wavelet analysis results indicate that groundwater wells representing shallow and moderately deep overburden conditions have strong teleconnection (high power) with ENSO in the periodicities of 3-7 years throughout the period of record. Well under deep overburden did not show high power in any periodicities, possibly due to high overburden conditions.

- Mann-Whitney test results found significant differences (p-value < 0.01) in GW level anomalies between the El Niño and La Niña phase for all wells under shallow and moderately deep overburden condition.

- This relationship was found to be more significant during the recharge seasons (December-April) as compared to the non-recharge or agricultural-irrigation season (May-November).

- ENSO-phase induced anomalies were approximately 2.5 times greater during the recharge season than during the non-recharge season, which is in agreement with previous studies that indicate the predominant effect of ENSO phases on winter precipitation in the Southeast USA.

- Comparison of La Niña phases representing severe (2000-01) and average conditions indicated that during recharge and non-recharge seasons, average groundwater levels dropped approximately twice during the severe La Niña event of 2000-01, compared with the average La Niña phase.

- The results obtained can be used to develop procedures for forecasting groundwater levels, which can then be used to better manage groundwater resources of this region.

- Recovery times for the severe La Niña during 2000-01 were significantly longer than those during the short La Niña of 1988-89.

- Recovery time for groundwater levels from the severe La Niña event of 2000-01 averaged 22 months, while similar recovery for the short La Niña during 1988-89 averaged 2 months.

- Baseflow in this region exhibits ENSO teleconnection and increases during El Niño and decreases with La Niña.

- The results indicate that the phases of ENSO, AMO and NAO significantly affect baseflows in the Flint River.

- Interaction tests showed that the PDO and AMO phases modulate ENSO phase baseflows. La Niña associated with positive phases of PDO and AMO resulted in greater decrease in baseflow levels of approximately 28% and 33%, respectively.

- La Niña associated with negative phase of AMO showed above normal baseflows. The results illustrate the importance of coupled analyses of climate variability by providing a better understanding of the severity of droughts and their impact on baseflows.

- The results obtained from this study can be used by water managers in the region as a guide for the issuance of drought severity-based water restrictions.
C. **List of any reports, papers, publications or presentations** arising from this project; please send any reprints of journal articles as they appear in the literature. Indicate whether a paper is formally reviewed and published. *(No text limit)*

**Peer-reviewed Publication:**


**Published Abstracts with Presentations:**


**Presentations:**


D. **Discussion of any significant deviations** from proposed workplan (e.g., shift in priorities following consultation with program manager, delayed fieldwork due to late arrival of funds, obstacles encountered during the course of the project that have impacted outcome delivery).  
(*Limit to one paragraph*)

Work on the fourth objective was greatly affected by the lawsuit the State of Florida filed against the State of Georgia in October of 2013 over the use/allocation of Apalachicola-Chattahoochee-Flint (ACF) River Basin waters. Subsequent to this lawsuit, the Supreme Court appointed a Special Master to look into the water/use allocation issues in the ACF River Basin. The evidence-gathering process by the Supreme Court's Special Master has resulted in data inaccessibility, time constraints for project Co-PIs, and state restrictions on the release of information related to the project. Particularly, Mark Masters, a key member of the project team has been severely impacted by the evidence-gathering process. We also plan to draw upon the Special Master's report to the Court, which is scheduled for this fall, for completion of our policy analysis research. Therefore, we requested and obtained a one year no-cost extension of the period of performance to August 31, 2016.

E. **Where appropriate, describe the climate information products and forecasts** considered in your project (both NOAA and non-NOAA); identify any specific feedback on the NOAA products that might be helpful for improvement. (bulleted response)

- Daily and monthly precipitation and temperature records from National Climatic Data Center (NCDC)
- ENSO, NAO, AMO, and PDO indices from the NOAA Climate Prediction Center
- Groundwater and irrigation water withdrawal data from USGS

III. **Graphics: Please include the following graphics as attachments to your report**

A. One Power point slide depicting the overall project framework/approach/results to date
B. If appropriate, additional graphic(s) or presentation(s) depicting any key research results thus far
C. Photographs (if easy to obtain) from fieldwork to depict study information (if applicable).

IV. **WEBSITE ADDRESS FOR FURTHER INFORMATION (IF APPLICABLE)**

None

V. **ADDITIONAL RELEVANT INFORMATION NOT COVERED UNDER THE ABOVE CATEGORIES.**

The results of this study were shared with the USGS South Atlantic Water Science Center in Norcross, GA. In particular, this research identified groundwater wells that can serve as drought indicators in the Lower ACF River Basin. The results and recommendations (see attached) were shared with USGS and they are using our recommendation for the ACF River Basin Drought Assessment Webinars. These webinars are conducted on a monthly basis and Auburn is the lead in organizing and moderating these webinars. The webinars are a big part of NIDIS Drought Early Warning System (DEWS) for the Southeast.