Work Plan

REVISION OF AFSIRS CROP WATER USE SIMULATION MODEL

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INTRODUCTION

There historically have been significant differences among the water management districts (WMDs) regarding evapotranspiration (ET) estimates for various crops. Differences exist, for example, between citrus ET estimates at coincident locations made by the South Florida Water Management District (SFWMD) versus those estimated by the St. Johns River Water Management District (SJRWMD) and the Southwest Florida Water Management District (SWFWMD). The agricultural community, consultants, the Tri-District MOU group, the Water Planning Coordination Group, and the District's Agricultural Advisory Committee noted these differences during the development of the 1998 Water Supply Assessment.

The SJRWMD has worked with agricultural agencies and the other WMDs to evaluate various crop and ET models based on the recommendations of these groups. In 2000, the SJRWMD Division of Water Supply Management determined that according to contract SD325AA ("Evaluation of Reference Evapotranspiration Methodologies and AFSIRS Crop Water Use Simulation Model"), there was a need to modify the methods used to collect ET data and modify the way crop water use is calculated using the Agricultural Field Scale Irrigation Requirements Simulation (AFSIRS) model.

The AFSIRS model was developed for the WMDs by the Institute of Food and Agricultural Sciences (IFAS) to provide a method for determining allocations for consumptive-use permitting programs. The model estimates irrigation requirements for Florida crops, soils, irrigation systems and climate conditions. Two significant advances have affected the viability of the existing AFSIRS model since the 1990 revision: 1) additional research on crop water requirements has been conducted, and 2) computer technology has changed significantly.

Opportunities to improve the estimates and projections of ET for permitting and planning purposes also have been discovered. This work plan provides the implementation guidelines necessary to make those improvements, based on recommendations in contract SD325AA. Recommendations from colleagues within Florida agencies and from members of the agricultural and climate communities also have been incorporated into the plan. These improvements are to be conducted over a 5-year period as summarized in the final schedule.

The work plan might be divided into four types of tasks: managerial, software modification, modeling and data enhancement, and experimentation and analysis. The managerial tasks will provide the support necessary to successfully coordinate and assure the completion of the tasks outlined below. Managerial tasks also will support the interactions between the University of Florida (UF), the SJRWMD, and other state agencies with a vested interest in consumptive water use permitting and planning. The software modification tasks are designed to eliminate limitations to the operational use of the AFSIRS software and to expand its applicability beyond permitting. The modeling and data enhancement tasks address the modification of outdated model components, as well as the development of enhancements that will increase the AFSIRS functionality significantly. It is anticipated that these two types of tasks may be addressed in parallel.

Continued cooperation, collaboration, and outreach among the WMDs, and ongoing university research facilitated by project investigators are implicit in this work plan. The experimental and

analysis tasks are designed primarily to develop crop coefficients over the duration of the project. Climate and water use data also will be used to validate and enhance the methods used for water use estimation.

TASK REVIEW

Task 1. Project Management

1. *Work Plan*
A comprehensive work plan will be developed, which will identify tasks, prioritize timing, and develop task descriptions and budgets. This work plan will be developed in cooperation with the SJRWMD and other agencies, and will include discussion and prioritization of the potential enhancements to the consumptive-use permitting process and its application to planning initiatives.

2. *AFSIRS Coordination*
This task will provide for the coordination of project tasks with other university staff and departments. It will involve scheduling, directing and approving project work products; formal recruitment of IFAS staff for support of this project; recruitment of graduate students and post-doctorial candidates; coordination, presentation development and documentation for meetings; project management; and administration. Communications with the SJRWMD project manager will occur on a regular basis.

Task 2. Software Modifications

Software modifications will be conducted in three phases, which will be staggered to introduce significant modifications to the AFSIRS software and to allow consumptive-use permitting staff to benefit quickly from new system developments. Transition to the new AFSIRS model should occur after the Phase I software development is complete and the climate database has been updated. The planned revised model will enhance user interface and reporting capabilities significantly, ease database maintenance, and facilitate the inclusion of model enhancements. The model also will be able to operate at regional, as well as farm scales. Model documentation, user-support features, and training requirements will address the current model and new enhancements.

The completed model will consist of three components: data storage, user interface, and reporting and data analysis. The majority of the data necessary on the crop-water use analysis will be stored in a relational database management system (RDBMS). Existing climate, crop, irrigation system, and soil databases will be ported to the RDBMS. Spatially distributed data will be maintained in an ArcView/ArcInfo geographic information system (GIS). The user interface and reporting features (existing features and new components) will be developed using a Visual Basic interface. The AFSIRS analysis will be conducted using C++ development tools and existing Fortran code will be ported to a C++ environment. The C++ environment will be object-oriented in order to simplify future modifications of the AFSIRS model components.

Phase 1

The first phase of redevelopment commenced with a project scope; and development interface, reporting, and storage modules created by SJRWMD personnel. UF developed and presented screen and report "mock-ups" for review. The software plan, which includes detailed scoping and timelines for the final product, was developed in conjunction with and approved by the SJRWMD.

The software developments aspects of Phase 1 included the Visual Basic interface and preliminary report development, RDBMS development and data porting, and development of GIS tools necessary to demonstrate the application of AFSIRS to regional water use. Reporting capabilities duplicated currently available tools. UF developed a testing-and-debugging plan that will be administered by SJRWMD permitting personnel. A temporary RDBMS-to-ASCII conversion utility was developed during Phase 1 to allow for the continued use of the Fortran analysis model with the new RDBMS. Phase 1 development was completed over a 12-month period.

1. *User Interface Enhancement*
   The AFSIRS software interface is an inflexible DOS-based tool. The user interface enhancements include online help, ability to modify system inputs, enhanced reporting requirements, and a range of return period predictions (e.g., 5-year, 10-year).

2. *Demonstration of GIS Integration*
   The AFSIRS software needs to be coupled with SJRWMD GIS/relational databases. The GIS databases should include soil types, long-term climate data, water table data, irrigation system data, and land-use data. The land-use and water table data should include present scenarios and future plans. Many of these databases already exist at SJRWMD in an acceptable format. The GIS integration should have the flexibility to use existing and planned layers. In Phase 1, a demonstration version of this system will be developed.

3. *Enhance Reporting Capabilities*
   Modifications to the AFSIRS model should allow for flexible reporting that is easily adaptable to future requirements, while capturing present needs. These needs include a clearly understandable and completely documented output that indicates user inputs; and a consistent presentation of results for any analysis period, averaged on a daily, weekly, monthly, or annual basis.

4. *Software Demonstration, Training, and User Manual*
   New users require training in and instructional support for the AFSIRS software. A user manual will be created that includes one or more examples of the application of the AFSIRS model. At the completion of Phase 1, a software training session will be provided.

Phase 2

The primary goals of Phase 2 are to finalize the GIS portion of the software and to port the Fortran code to an object-oriented development environment. Phase 2 also will integrate the model and data enhancements described in the next section. As the software is extended to address planning needs, additional training and user and technical documentation will be developed.

1. *Analysis Software Modification and Modular Design*
A Windows-based compiler that has or is compatible with a visual interface will be used. The program currently uses a DOS-based interface that was developed using the Fortran computer language and is incompatible with newer MS Windows-based compilers. The current software cannot be modified easily to include technical or user interface ranges, so a revised system should be developed in an object-oriented framework that will allow for easy update or replacement of model components.

2. *Full GIS Integration*
The AFSIRS software should be coupled with SJRWMD GIS/Oracle databases. The GIS databases should include soil types; long-term climate data; water table data; and irrigation system, crop acreages, and land-use data. The land-use and water table data should include present and future planning scenarios. Many of these databases already exist at SJRWMD in an acceptable format. The GIS integration should have the flexibility to use existing and planned layers. Accessing regional data at scales larger than available at individual farms is important for planning purposes. For example, Suwannee River WMD and North West Florida WMD have used AFSIRS to estimate current and future agricultural water requirements by county and region.

3. *Spatial Interpolation of Climate*
Water requirements for users located away from a National Oceanic & Atmospheric Administration (NOAA) weather station are estimated by parameters established through interpolating results from two or more stations. Florida's coastal regions have significantly different climate regimes from the inland regions. An appropriate and consistent tool for interpolating climate databases to small, specifically defined areas, such as local farms, is essential to implement AFSIRS at a local scale and will be developed as an integrated part of the system.

4. *Software Demonstration and Training*
A half-day software training session will be provided for the SJRWMD planning personnel. The user documentation will be enhanced to include any additional modifications or example scenarios relevant to planning.

Phase 3
Phase 3 provides for additional development to meet future needs, with regard to new software and information gathered under Tasks 3 and 4. Preliminary targets for this phase include:

1. *Integration of Crop Coefficients to Provide a Single Tool*
SJRWMD should determine agricultural and turf grass allocation consumptive-use permits, using both AFSIRS and the SJ87-SP4 document. A single tool would reduce confusion, increase confidence, and provide a more uniform and defensible approach for permitting. This integration is contingent upon successfully characterizing the AFSIRS parameters for crops permitted, using the SJ87-SP4 document.

2. *Linkage of Crop Models*
Numerous experiments and modeling tools are in development in the southeastern United States that will characterize water demands of specific crops and plants. Current initiatives in

Florida likely will develop additional information on landscapes and golf courses. This task provides the opportunity to integrate these new developments.

3. *Irrigation Management Tool*

AFSIRS must be extended so it can be used as a management tool or benchmark. This will allow rainfall and climate data to be input in a shorter period for comparison with actual irrigation use.

Task 3. Model and Data Enhancements

Climate Data Enhancement

1. *Facilitate Reference ET Network*

The spatial distribution of climate databases is quite sparse. The NOAA databases should be combined with other climate resources to create an expanded database. The successful development of these resources requires coordination among Florida's organizations. The university will facilitate the development of a coordinated system, which should include a description of current and potential data sources, as well as those that can be modified; agencies responsible for the meteorological data; necessary revisions; and recommendations for future expansions.

2. *Update and Expand Historical Climate Databases*

The AFSIRS climate databases include approximately 25 years (1951–76) of daily precipitation and potential ET data. The climate databases are at a series of locations that include Mobile, Alabama; and Tallahassee, Jacksonville, Gainesville, Daytona Beach, Orlando, Tampa, West Palm Beach, and Miami. The databases should be updated to include recent daily data (1976 to 2000) from the NOAA weather stations identified above. The precipitation values may be obtained directly from the NOAA weather stations. The daily potential ET values for the climate database are calculated quantities. The updated reference ET databases, based on the "Evaluation of Reference Evapotranspiration Methodologies and AFSIRS Crop Water Use Simulation Model" report results, should use the FAO Penman-Monteith method. This method requires daily measurements of incoming solar radiation, wind speed, dew point temperature, and maximum and minimum temperature data.

3. *Enhance Spatial Interpolation of AFSIRS Historical Climate Database*

The AFSIRS climate databases spatial distribution is quite sparse. Water requirements for users located away from a NOAA weather station are estimated by interpolating results from two or more stations. Florida's coastal regions have significantly different climate regimes from the inland regions. A consistent tool for interpolating climate databases to local farms is essential for implementing AFSIRS at a local scale.

The NOAA databases should complement other climate resources to create an expanded climate database. Approaches may include examination and integration of the Florida Automated Weather Network (FAWN) network, and remotely sensed precipitation and ET data. The integration methodology should establish a statistically robust and consistent framework to couple additional climate data with the existing database and develop spatially interpolated climate parameters.

Model Enhancement Priorities

1. *Conduct Sensitivity Analysis of Model Parameters*
Model and data-needs modifications should be based on an understanding of the relative importance of model parameters, with respect to irrigation requirements. Conducting a sensitivity analysis is a preliminary step prioritizing model and data needs. Parameters of interest include crop coefficients, ET methods, soil properties, and crop properties.

2. *Irrigation Component*
Irrigation systems play a significant role in the determination of the gross irrigation requirement. Significant variability in the systems, efficiencies, and application approaches, however, are not well addressed. The AFSIRS model should be enhanced to better characterize irrigation systems.

A literature review was conducted to document irrigation efficiencies for Florida irrigation systems. The compilation of digital photographs of irrigation systems provided a clear definition of the systems. Based on this review, irrigation evaluations may be conducted for those systems in which data is either suspect or does not exist.

The current irrigation options are: 1) irrigate to field capacity, 2) irrigate to fixed depth, and 3) use deficit irrigation. Landscape and golf courses automatically irrigate to a fixed depth, but the scheduling of automatic irrigation may not coincide with the timing of AFSIRS irrigation. Scheduled irrigation would more realistically simulate water needs, as well as provide information on water losses for scheduled systems and improved scheduling.

Model Enhancement Opportunities

Additional priorities likely will arise because of the sensitivity study, the experimental work, and the analyses of models and climate. The following is a preliminary list of additional model enhancements that might be conducted. Items may be added to this category, based on research in the early part of this study and input from the SJRWMD.

1. *Water Table Interaction*
The current AFSIRS model does not include water table effects on crop water requirements, which is a major limitation. Inclusion of the water table interactions should improve the ability to predict water requirements in regions with near-surface water tables. Possible approaches to addressing this issue include semi-empirical relationships or integration of existing models.

2. *Additional Water Requirements*
Additional water requirements for fertigation, chemigation, and freeze protection need to identified and quantified.

3. *Improved Soil Information*
Water use estimates are highly sensitive to the range of soil parameters based on the Natural

Resource Conservation Service (NRCS) soil survey. Improved data are necessary for the most widely observed soils and those with the greatest range of parameters.

Task 4. Experimentation and Analysis

Task 4 seeks to advance through experimentation the knowledge of specific crops' water use and the appropriate characterization of climate variables as necessary to force the long-term simulations of crop water use. Toward this goal, UF will purchase and deploy the instrumentation necessary to develop an experimental dataset. This dataset subsequently will be analyzed to characterize crop coefficients and to identify necessary climate corrections. The results will be implemented through Task 2 into the AFSIRS software. The main components necessary to successfully complete this task are outlined below.

1. *Instrumentation and Computer Equipment*
This task provides for the purchase of equipment necessary to perform current and future modification of the AFSIRS crop model. Instrumentation includes computer equipment and software, two combination eddy flux and meteorology systems, and a reference ET station. Funds also are allocated to support the installation and construction of three lysimeters at the IFAS Plant Science Research and Education Unit (PSREU). This component may be subdivided across multiple years.

2. *Crop Coefficient Instrumentation Establishment and Evaluation*
This task provides for the development and validation of parallel crop coefficient monitoring systems. The two systems are an eddy-correlation flux system and a weighing lysimeter system. A literature review was conducted, and an instrumentation and installation plan was developed for the weighing lysimeter. All instrumentation will be ordered, installed, and constructed as needed. Instrumentation will be set up initially at the IFAS PSREU.

A pilot study of the instrumentation will be conducted using a grass crop. A post-doctoral researcher is responsible for initial data collection and methodology evaluation. The researcher will manage the eddy correlation equipment, the reference ET weather station, and the weighing lysimeters. This person also will set up collection and storage methodology to assure data integrity and prevent accidental data loss. Data collection during this period will be checked for quality and instruments will be calibrated, if necessary. Any problems identified with the methodology will be addressed during this phase.

3. *Crop Coefficient Determination*
Timing and prioritization of crop coefficient determination were established by the SJRWMD and the UF. The coefficients were prioritized, based on a review of the acreage and the available crop coefficients data for priority row-crops and grasses. Each crop will be studied for a minimum of two years.

The project currently includes two sets of instruments necessary to measure ET: an eddy correlation system (EC1) and a series of three lysimeters. The purchase of a second eddy correlation system (EC2) is planned, using funds from the upcoming fiscal year. These three sets of instrumentation will be available to conduct crop coefficient studies over the next four years (years 2 to 5 of the AFSIRS contract).

The first crop study will measure grass ET using EC1 and the lysimeters. In addition to obtaining a grass crop coefficient, the relationship between the actual ET, as measured by the lysimeter and by the EC1, will be characterized. This will be done as necessary to make corrections to the EC measurements in the other crop coefficient studies. A subcomponent of this grass study may include quantification of irrigation demand under deficit irrigation.

Crop coefficients will be obtained for potatoes, sod, citrus, and cabbage. An additional crop with a single-year study may be possible. Table 1 summarizes the crops, the study years, the instrumentation, and the study location. The SJRWMD and the UF will identify the cooperators necessary for the upcoming citrus and sod studies. A final review of previous crop studies in Florida, Georgia, Alabama, South Carolina, and North Carolina will be conducted before commencing experimentation.

Crop	Study Years	Instrumentation	Location
Bahia Grass	2 and 3	EC1 and Lysimeter	PSREU
Potato	4 and 5 (Spring)	Lysimeter	PSREU
Cabbage	4 and 5 (Fall)	Lysimeter	PSREU
Citrus	3 and 4	EC2	TBA
Sod (St. Augustine)	4 and 5	EC1	TBA

Table 1. Crop coefficient study plan

4. *Climate Data Comparison to Reference ET Data*
The validity of the reference ET estimates is a function of the method and the climate data used in the estimates. The differences between the Penman and Penman-Monteith methods are quite small, as demonstrated in the report results ("Evaluation Of Reference Evapotranspiration Methodologies and AFSIRS Crop Water Use Simulation Model"). There is considerable confidence, therefore, in the ability to provide a reasonable reference ET estimate, given appropriate model inputs. The appropriateness of existing weather stations to provide climate data that meet reference ET standards, however, needs to be established. The reference crop is typically grass or alfalfa under well-watered conditions. The standard reference crop is grass in Florida. The height of the grass reference should be at least 8 cm and no more than 15 cm.

The available climate data are from NOAA weather stations that may or may not be properly maintained as reference ET sites. This task will compare climate data from a site that meets reference ET standards with a nearby weather station. The preliminary site selection is the PSREU. This site maintains a FAWN climate station in a location that does not meet reference ET standards and also has field sites that can be maintained to reference standards.

This research supports the analysis and comparison between the FAWN and reference ET data sets.

5. *Eddy Flux and Lysimeter Comparison*
The experiment's design is in keeping with the best experimental methods applied to crop coefficient research. Critical issues addressed for the successful determination of crop ET using lysimeters, according to the agricultural engineering standards, include fetch, lysimeter design and construction, and operations. An advantage of our experimental facility is the multiple lysimeters that may be used to characterize the variability of our results. The eddy flux instrumentation is emerging as a reasonably priced, portable, and robust method to estimate ET. It is particularly valuable to those crops that may not be measured readily in lysimeters, due to long establishment periods or size problems. It is critical that experiments conducted with the lysimeter measurements or the eddy correlation measurements result in the same crop coefficient values. Bahia grass crop coefficient study will be measured simultaneously using both instruments to ensure successful application of the eddy flux systems in citrus and sod. The results will be analyzed and procedures will be developed for the application of the eddy flux instrumentation to the citrus and sod crop coefficient studies.

6. *Water Use Estimation and Analysis*
Limited comparisons of the AFSIRS-modeled water budget exist. Model validation and correction are critical components to ensure that appropriate water is allocated. This task provides for the development of several datasets of crop water use that may be analyzed in comparison to the AFSIRS model, in order to identify and correct model discrepancies and to ensure that the model results are robust. Additional datasets that may be included in an expanded comparison are the Benchmark Farms water use data (citrus, fern, potato, and sod), and data from other ongoing field experiments in Florida and Georgia.

	Year 1		Year 2		Year 3		Year 4		Year 5	
Task	1-6	7-12	1-6	7-12	1-6	7-12	1-6	7-12	1-6	7-12
Managerial										
Work Plan	X	X								
Coordination	X	X	X							
Software Modifications										
Phase I	X	X								
Phase II				X	X					
Phase III						X	X	X		
Model/Data Enhancements										
Reference ET Network	X	X								
Update Climate DB		X	X							
Climate Spatial Interpolation		X	X	X	X					
Sensitivity Analysis			X							
Irrigation		X			X	X	X			
Additional Enhancements							X	X	X	X
Experimentation and Analysis										
Instrumentation and Computer I	X	X	X							
Instrumentation and Computer II				X						
Instrumentation Estab. And Eval.		X	X	X						
Develop Bahia Grass Coefficient			X	X	X	X	X			
Develop Potato Coefficient							X		X	X
Develop Cabbage Coefficient								X		X
Develop Citrus Coefficient					X	X	X	X	X	
Develop Sod Coefficient							X	X	X	X
Reference ET Comparison			X	X						
Eddy Flux vs. Lysimeter Comparison				X	X					
Water Use Estimation Comparison							X	X	X	X

Table 2. Proposed tasks and timeframes