Water Resources Research Center
Annual Technical Report
FY 2001

Introduction

The Florida Water Resources Research Center (WRRC) was re-established as a separate entity from the combined Center for Wetlands and Water Resources Research in 1995. Historically, since 1964, the WRRC as a separate or combined center has been a university-wide focus for water-resources research and has served as the Water Resources Center for the state of Florida. The mission of the WRRC is to serve as a center of expertise in water resources field, assist public and private interests in the conservation, development, and use of water resources, provide opportunities for professional training, assist local, state, regional, and federal agencies in planning and regulation, and communicate research findings to interested users. The WRRC administers funding received from the federal Water Resources Research Act 1964 and coordinates water-resources research and technology transfer as authorized by the funding, acts as a liaison for Florida agencies and water management districts, promotes water-resources research by seeking external support, and seeks to enhance the state and national image of the University of Florida (UF) as a focal point for water resources research. The WRRC is funded in part by Section 104 of Public Law 98-242 and Public Law 104-99, which are administered by the U.S. Geological Survey, Department of the Interior. Additional funding and support are provided by UF and research sponsors that include state agencies such as the water management districts.

Research Program

Flow Duration Curves to Advance Ecologically Sustainable Water Management

Basic Information

Title:	Flow Duration Curves to Advance Ecologically Sustainable Water Management
Project Number:	2001FL4341B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	6th
Research Category:	Climate and Hydrologic Processes
Focus Category:	Surface Water, Water Quantity, Management and Planning
Descriptors:	Water Levels, Decision Models, Stochastic Hydrology, Rivers, Eco-Hydrology, Minimum Flows and Levels, Water Quality,Watershed Management
Principal Investigators:	Jennifer Jacobs, Gerard Ripo

Publication

1. Good, J. C., and J. M. Jacobs, 2001, Ecologically Sustainable Watershed Management using Annualized Flow Duration Curves, ASCE World Water and Environmental Resources Congress, Orlando, FL, May. (paper reviewed by conference committee).
2. Jacobs, J. M., and G. Ripo, 2001, Minimum Flows and Levels for the Lower Suwannee River-Implementation and Methodology. University of Florida, Gainesville, Florida, June, 129 pages.
3. Good, J. C., and J. M. Jacobs, 2001, Use of Annualized Flow Duration Curves for Minimum Flows Levels. Florida Section ASAE Annual Conference, Orlando, Florida, Cocoa Beach, Florida, May 10-11.
4. Jacobs, J. M., and J. C. Good, 2000, Application of Annualized Flow Duration Curves to Minimum Water Flows and Levels, Proceedings of the American Geophysical Union 2000 Spring Meeting, Washington, DC.

Project Number: FL-4341

Start Date: 3/01

End Date: 2/02

Title: Flow Duration Curves to Advance Ecologically Sustainable Water Management

Investigators: Dr. Jennifer Jacobs

Congressional District: 6

Focus Categories: SW, WQN, M&P

Descriptors: Watershed Management, Water Quantity, Minimum Flows and Levels, Eco-Hydrology, Rivers, Stochastic Hydrology, Decision Models, Water Levels, and Water Resources Development.

Problem and Research Objectives:

Per Florida Statutes (F.S.), the Florida Water Management Districts and the Florida Department of Environmental Protection are charged with setting minimum surface water flows for water courses. As defined by Section 373.042, F.S., "the minimum flow for a given water course shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." Towards this end, Florida's Water Management Districts have initiated the development of minimum flows and levels (MFLs) for selected rivers and streams in their respective jurisdictions. Recent advances in systems ecology have shown that natural streamflow variability over the full range of flows, drought to flood flows, is critical to the ecosystem dynamics. Thus, the prevention of significant harm to ecosystems needs to address a full regime of flow conditions.

Florida's Statutes are well aligned with current national objectives. The widespread modification and management of river systems has had major ecological impacts in North America. The negative impacts have caused a major change in watershed management. The result of this change is the undoing of many large river engineering projects. Dams are being removed across the country from the Columbia River to northern Maine. More locally, the Kissimmee River in Florida is being restored to its natural channel. Florida is considering removing the Rodham Dam and restoring the Oklawaha River. Efforts to restore the Everglades will take place over the next few decades. Watershed management and planning has changed from focused analysis of water supply diversions, flood protection and hydropower generation to a more holistic view. While much progress has been made in the development of instream flow analysis, a significant gap exists in the hydrological sciences between the research progress and the approaches implemented by practitioners. A demand exists for tools that can support resource managers' and policy makers' new mission. These tools must provide the ability to synthesize ecology with hydrology and to enhance policy design (Walters and Josh, 1999).

The goal of this research was to develop a methodology that uses flow duration curves to accurately, quickly, and easily integrate streamflow data and ecologically significant hydrologic data for the development of minimum flows and levels. Linked ecological and hydrological indicators were used deterministically to adjust the entire range of flows. The outcome of this research is an optimized management system that maximizes available water while sustaining ecosystems. The methodology is the engine for a graphically based analysis and planning tool. This tool is applicable throughout the planning and implementation phase of a MFL program to help policymakers, technical staff, and other interested parties understand the impact of proposed ecological constraints on available streamflow and to validate that the cumulative withdrawals meet the MFLs. An integrated software program that includes a statistical analysis tool for the annual FDCs and FDC modification and inversion routines was created in order to facilitate the application of the methodology and analysis of hydrological responses to proposed changes. The methodology can provide insight for managers of rivers where ecosystem functions are important criteria for river management and restoration.

Methodology:

Three gaging stations along the Suwannee River were analyzed to develop a database necessary for the development of regional minimum flows and levels. The data used was assumed to be stationary and was examined through a time trend analysis. The resulting database was analyzed to develop summaries of hydrologic data and analyses that specifically address the MFL purposes. These analyses included: a determination of seasonality and an appropriate climatic year for segmentation of the data; a frequency analysis to characterize extreme high and low flows; a calculation of a period of record flow duration curve (POR FDC) and annual flow duration curves (AFDCs); an event-duration-frequency analysis to examine flow timing; a determination of indicators of Hydrologic Alteration as prescribed by the Range of Variability Approach; and a fitting of distribution frequencies of inter-annual curves, for a more robust characterization of the complete annual flow regime. Concurrent analysis of precipitation measurements from three long-term precipitation stations was done to characterize the lower basin meteorological data over the complete gaging stations' history.

Having characterized the Suwannee River gages, a methodology was developed that uses flow duration curves to accurately and easily integrate streamflow data and hydrologically significant ecological data for the development of MFLs. This approach integrated ecological and hydrological indicators, which are then used deterministically to adjust the entire range of flows. The outcome of this effort is a set of criteria that maximizes available water while sustaining ecosystems. The developed MFL methodology was compared with two other possible withdrawal scenarios.

Principal Findings and Significance:

Many studies that examine large historic periods of recorded hydrologic data require a method for separating continuous data into independent sets. The common water year is generally accepted as an appropriate separation of data focuses on high flow events. This study focused on the hydrologic effects on the ecology, thereby making a sole examination of maximum events insufficient. The identification of extreme high and low flow events as integral parts of the health of a river ecosystem made it necessary to determine a water year that would not separate annual extreme events. Based upon the analysis of ten extreme annual conditions and their corresponding Julian day of occurrence, the ideal water year for the investigation was found to begin on February 1st and end on January 31st.

The MFL methodology was developed through a unique approach that collectively integrates ecological control points within a flow duration curve framework. In this context a "control point" identifies a specific measure that must be considered for the establishment of instream flows. This framework focuses on the assessment of withdrawals that are sustainable without unacceptable change to the water resources or ecology of the area as opposed to the remediation of unacceptable change. In these cases, two specific measures for the quantification of a control point are required: 1) hydrologic flow measures and 2) allowable flow modifications. These points may result from legislative measures or from ecological investigations that identify flow conditions critical for the ecology and will ultimately provide the basis necessary to determine maximum withdrawal rates.

Flow modifications are performed within the POR FDC allowing for control of timing and magnitudes of withdrawals. The methodology results in graphical tools. Graphs depicting the historic variation in available streamflow, the reliability of available streamflow, and streamflow available for withdrawal versus total streamflow could be used to assess if the proposed withdrawals adequately protect the ecology of the river.

A case study was conducted to demonstrate the application of the methodology to the establishment of MFLs in the lower Suwannee River basin. The study used three control points and allowable shifts that were derived from ecological studies conducted by SRWMD. Each control point addressed a different portion of the flow regime, capturing a range of ecological criteria. The first control point was based upon floodplain inundation and captured a high portion of the flow regime. The second control point addressed the moderate-low in the flow regime and was derived from the location of the freshwater/salinity transition between the Suwannee River and the Gulf of Mexico. The third control point was based upon water supply under drought conditions and represented the lowest portion of the flow regime.

In order to improve the understanding of the FDC allocation methodology, it is contrasted to other allocation approaches. Two other possible withdrawal scenarios were considered in order to identify the effect of the shifting method on the available water: (1) a constant percent flow withdrawal; and (2) a constant flow withdrawal. The withdrawal scenarios were based on the most conservative shift that would result based upon the allowable shifts identified for three control points used. The FDC methodology resulted in a much larger quantity of available water (427.7 mgd) than either a constant percent (2.03.7 mgd) or a constant shift (113.0 mgd). The percent method has a larger firm yield than the constant available flow method because the water available for allocation increases with increasing streamflow. This large difference among the results from the FDC shift being determined with respect to all the control points, allowing for a much larger amount of available water in the median flow regime. The minimum percent and constant withdrawal scenarios are both ecologically conservative. However, neither single criteria methodology was able to allow for the availability of relatively large quantities during median flow conditions.

Development of a Multi-Scale, Multi-Process Hydrologic Model

Basic Information

Title:	Development of a Multi-Scale, Multi-Process Hydrologic Model
Project Number:	2001FL4361B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	6th
Research Category:	Ground-water Flow and Transport
Focus Category:	Hydrology, Models, Surface Water
Descriptors:	Hydrologic Models, Ground Water Hydrology, Watershed Management
Principal Investigators:	Andrew L James, Wendy D Graham

Publication

1. S. Liu, W. D. Graham, and A. I. James, Presented at the 2002 AGU Spring Meeting, A Hydrologic Model Coupling Overland Flow with Flow in the Unsaturated and Saturated Zones, Washington, D.C.

Project Number: FL-4361

Start Date: 3/01

End Date: 2/02

Title: Development of a Multi-Scale, Multi-Process Hydrologic Model

Investigators: Andrew L. James, Wendy D. Graham, John J. Warwick

Congressional District: 6

Focus Categories: HYDROL, MOD, WS

Descriptors: Hydrologic Models, Ground Water Hydrology, Watershed Management

Problem and Research Objectives: The natural hydrology of south Florida has been extensively altered though channelization to provide adequate water for urban growth and agriculture and to provide flood protection to the area. Currently, water resource management in south Florida is governed by a number of federal, state, and county agencies. These agencies have developed or adopted hydrologic models to address a diverse set of needs. These range from large-scale models used to estimate impacts of alternative water management practices across all of south Florida to field-scale models used to predict local impacts such as flooding or agricultural production. A primary difficulty in applying these models to such a diverse setting is the need to address the problem of aggregating a variety of coupled hydrologic processes occurring over a wide range of temporal and spatial scales into a coherent and accurate model of a hydrologic system.

The primary goal of this project is to investigate how hydrologic processes such as ground water flow, river/canal flow, overland flow, infiltration, evapotranspiration, etc., are manifested across a broad range of spatial and temporal scales. Our main focus is on the interaction of these processes. An earlier phase of this project focused on developing the various components of an integrated hydrologic model and establishing the linkages between these components. The current objectives of this research are:

- Use stochastic and/or deterministic averaging techniques to upscale predictions using effective parameters based on the detailed variability of input parameters (current grant year).
- Check the sensitivities of modeled hydrologic processes to spatial and temporal variability in physical parameters (current grant year).
- Test and demonstrate the validity of the model by applying it to the C-111 basin and predicting impacts of alternative water management scenarios on hydroperiod, water supply, and flood prediction (next grant year).

Methodology: To address these tasks, we have been developing a hydrologic model that simulates a number of hydrologic processes. The specific processes modeled for this project are:

1) Unconfined saturated ground water flow.
2) Infiltration through the vadose zone.
3) Evapotranspiration.
4) Overland flow.

These processes are modeled in separate physical domains, and linkage between the domains is accomplished through matching of fluxes through the domain boundaries. The primary objective of our model is to arrive at a solution for the dependent variables (e.g. head and flux) within each subdomain that balances the flux of water between all the domains. This is accomplished using an iterative process that solves the governing equations simultaneously in each subdomain.

Principal Findings and Significance: One of the most challenging aspects of water resource management is the accurate modeling of a wide range of interrelated processes such as ground water flow, infiltration, evapotranspiration, overland flow, river/canal flow, rainfall, etc. Interactions between these processes include the exchange of water between rivers, lakes, and ground water, the relation between the soil moisture content and soil type and the amount of runoff generated from a rainfall event, the partitioning of water in the unsaturated zone between flow into the water table and plant uptake, etc. One of the issues that must be addressed in understanding these interactions is the question of how to take into account the variability of hydrologic parameters such as soil type, surface roughness, topography, evapotranspiration, and hydraulic conductivity, all of which can exhibit significant spatial variability.

To understand these effects, a series of model simulations of coupling overland flow and groundwater flow has been run to determine how the combination of variability in surface topography, surface roughness characteristics (Manning coefficients), and saturated hydraulic conductivity affects recharge to groundwater and runoff. Infiltration through the unsaturated zone is modeled using a one-dimensional form of Richard's Equation. Overland flow is modeled using a two-dimensional Galerkin finite element model of the diffusion wave equation on a triangular mesh. These simulations were loosely based on similar numerical experiments conducted by Zhang and Cundy (1989). The random fields were generated by turning bands algorithms. Simulations with uniform hydrologic parameters were also conducted for comparison. One hundred replicates were simulated for the random Manning coefficient case. One hundred and fifty replicates were simulated for random surface elevation and saturated hydraulic conductivity fields.

The results show that the mean hydrograph for the random Manning coefficient and random surface elevation fields are very close to that generated by the uniform case. However, the mean discharge begins earlier for the simulations with random saturated hydraulic conductivities, and the peak discharge rate is lower than that for the uniform case. The simulations using random Manning's coefficients and surface elevations generated a mean head profile (along the centerline of the mesh, parallel to the down-slope gradient) very similar to that obtained from the uniform case while the random hydraulic conductivity field produced a mean head profile that was slightly lower than the uniform case. Unlike the discharge hydrograph prediction, the uncertainty associated with the prediction of the mean head profile is slightly lower for the random hydraulic conductivity case than the simulations using either random Manning's coefficients or random surface elevations. In all cases, maximum uncertainty about the mean water depth occurs at the upstream boundary.

Flux into the soil was also estimated for all cases. For the simulations using random Manning's coefficients and surface elevations, the predictions for the vertical mean Darcy flux at the soil surface and near soil surface (approximately 19 cm deep) are very close to that obtained from the uniform case. Random variations in the saturated hydraulic conductivity have a much greater influence on Darcy flux within the soil column.

Flow in the saturated zone is modeled with a three-dimensional mixed finite element method applied to the standard groundwater flow equations. To date, coupling between the saturated zone and unsaturated zone has not worked effectively. This is due to the use of a moving-mesh approach for the saturated zone. The convergence properties of this approach are highly dependent on recharge rates, making a number of model problems highly inefficient. As an alternative, we have developed a three-dimension model combining saturated and unsaturated groundwater flow using the head-based form of Richard's equation, which reduces to the standard groundwater flow equation in the saturated zone. This approach does not rely on a moving mesh technique. The current year's modeling of hydrology in south Florida will use this approach.

Information Transfer Program

Information Transfer

Basic Information

Title:	Information Transfer
Project Number:	2001FL4401B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	6th
Research Category:	Not Applicable
Focus Category:	Education, None, None
Descriptors:	Information Transfer
Principal Investigators:	Louis H. Motz

Publication

1. Motz, L. H.; G. D., Sousa, and M. D., Annable, Water Budget and Vertical Conductance for Lowry (Sand Hill) Lake in North-Central Florida, U.S.A. Journal of Hydrology, Elsevier Science, Amsterdam, The Netherlands, 250 (2001): pp. 134-148.
2. Watson, B. J.; L. H., Motz, and M. D., Annable, 2001, Water Budget and Vertical Conductance for Magnolia Lake. Journal of Hydrologic Engineering, American Society of Civil Engineers (ASCE), 6(3): pp. 208-216, May-June.
3. Motz, L. H.; F., Gordu, and R., Yurtal, 2001, Simulation and Optimization of Groundwater Use in Coastal Areas. EOS, Transactions of the American Geophysical Union, 82(47); p. F373, Movember 20 (abstract).
4. Motz, L. H., 2001, Predicting Long-Term impacts of Well Field Pumping. In: Guifen Li, Gemeral Editor. Development, Planning and Management of Surface and Ground Water Resources. Proceedings of Theme A, XXIX IAHR Congress, International Associations of Hydraulic Engineering and Research, Beijing, China, pp. 234-238, September 16-21.
5. Dogan, A., and L. H., Motz, 2001, Transient Simulation of a Regional Groundwater Flow Model and Application to North-Central Florida. In: Z. Sen, F. Karaosmanoglu, and S. Sirdas, Editors. Proceedings of the International Sumposium on Water Resources and Environmental Impact Assessment, Istanbul, Turkey, pp. 313-322, July 11-13.
6. Tiruneh, N. D., and L. H., Motz, 2001, Climate Change, Sea Level Rise, and Saltwater Intrusion. World Water & Environmental Congress, American Society of Civil Engineers (ASCE), Orlando, Florida, May 20-24.
7. Gordu, F., L. H., Motz, and R., Yural, 2001, Simulation of Seawater Intrusion in the Goksu Delta at Silifke, Turkey. First International Conference on Saltwater Intrusion and Coastal Aquifers,

International Association for Hydraulic Research, Essaouira, Morocco, April, 23-25.
8. Gordu, F., R., Yurtal, and L. H., Motz, 2001, Optimization of Groundwater Use in the Goksu Delta at Silifke, Turkey. First International Conference on Saltwater Intrusion and Coastal Aquifers, International Association for Hydraulic Research, Essaouira, Morocco, April, 23-25.

Information Transfer

FL-4401

During FY 2001, the Florida WRRC actively promoted the transfer of the results of water resources research in Florida. The target audience was the scientific and technical community who address Florida's water problems on a professional basis. Specific activities that were part of this task included maintaining an updated mailing list with email address and a web-based home page. The email list and home page were used to provide timely information about research proposal deadlines and other water-related activities. The home page describes ongoing research at the WRRC and lists research reports and publications that are available. Also, the home page is used to list research opportunities available through the WRRC and elsewhere, and it provides links to other water resource organizations and agencies, including the five water management districts in Florida and the USGS. The WRRC continues to maintain a library of technical reports that have been published in past years by the WRRC. Copies of these reports can be checked out by researchers, and also they are distributed upon request at the cost of reproduction and mailing. As newer reports become available, electronic versions of these reports will be make available for distribution by downloading from the WRRC home page. Financial support was provided for publishing research results in refereed scientific and technical journals and conference proceedings. Also, support was provided for printing theses and dissertations that are of interest to the target audience. Dr. Louis H. Motz, who is the Director of the WRRC, was the Principal Investigator for this task.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	0	0	0	0	0
Masters	2	0	0	0	2
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	3	0	0	0	3

Notable Awards and Achievements

Publications from Prior Projects

1. Wise, William R., and Raleigh D. Myers, 2002, Modified Falling Head Permeameter Analyses of Soils from Two South Florida Wetlands, Journal of the American Water Resources Association, 38(1), pp. 111-117.
2. Wise, William R., Michael D. Annable, Jo Anne E. Walser, Randal S. Switt, and Douglas T. Shaw, 2000, A Wetland-Aquifer Interaction Test, Journal of Hydrology, 227, pp. 257-272.
3. Sarkar, D. and G.A. O'Connor, 2001, Using the PI Soil Test to Estimate Available Phosphorus in Biosolids Amended Soil, Commun, Soil Sci, Plant Anal, 32:2049-2063.
4. Lu, P. and G.A. O'Connor, 2001, Biosolids Effects on Phosphorus Retention and Release in Some Sandy Florida Soils, J. Environ. Qual., 30:1059-1063.
5. Elliott, H.A., G.A. O'Connor, and S. Brinton, 2002, Phosphorus Leaching from Biosolids-Amended Sandy Soils, J. Environ. Qual, 31:681-689.
6. O'Connor, G.A., D. Sarkar, D.A. Graetz, and H.A. Elliott, 2002, Characterizing forms, Solubilities, Bioavailabilities, and Mineralization Rates of Phosphorus in Biosolids, Commercial Fertilizers, and Manures, (Phase I Final Report), IWA Publishing, London, UK, 86 pg.