Fact Sheet

United States Geological Survey

South Florida Ecosystem Program

Review and Evaluation of a Model for Simulating the Natural Hydrology of South Florida

The South Florida Ecosystem Program is an intergovernmental effort to re-establish and maintain the ecosystem of south Florida. One element of the restoration effort is the development of a firm scientific basis for making management decisions. The U.S. Geological Survey (USGS) is one of the agencies that provides this needed scientific information through the USGS South Florida Ecosystem Program.

Background

The south Florida ecosystem has been greatly altered during the last 100 years. Drainage of the south Florida watershed began in the early 1880's, and by the early 1990's about 50 percent of the historic Everglades had been drained. In response to flooding and to provide water for a variety of human uses, a complex water-management system that includes levees, well fields, pumps, canals, and control structures was constructed throughout south Florida. Today, the south Florida ecosystem includes urban areas near the coast where nearly 4 million people live, intensively developed agricultural areas in the northern Everglades, and rangelands and wetlands throughout the region.

The South Florida Water Management Model (SFWMM) was developed by the South Florida Water Management District (SFWMD) in the late 1970's and early 1980's to simulate the hydrology and the highly managed water system in an approximately 7,600-mi² (square mile) area of south Florida. The effects of water-management activities, including ground-water pumping and canal control-structure operations, on time-varying ground- and surface-water conditions and on canal flows are simulated for selected land-use and water-management scenarios. The SFWMM is currently used by the SFWMD to evaluate feasible water-supply alternatives for projected land use and water demand in south Florida during the next 10 - 20 years

A multimillion dollar, interagency effort is underway to restore significant portions of the south Florida ecosystem and to enhance the quantity, quality, and timing of freshwater flows to the remaining Everglades. A key component of this restoration effort involves returning hydropatterns (primarily frequency, duration, depth, and spatial extent of water inundation) at selected key locations in the Everglades to those which might have occurred in the natural system before human-induced changes altered the landscape and hydrology, or pre-drainage conditions. The Natural System Model (NSM) was developed to simulate the pre-drainage condition hydrology of south Florida (see explanation above). The NSM has been proposed as the "best available tool" for estimating hydropattern targets for restoration efforts.

The Natural System Model (NSM) was developed by the South Florida Water Management District (SFWMD) in the late 1980's, and has been undergoing more or less continuous updates since that time. The NSM was developed directly from the South Florida Water Management Model (SFWMM), which is used to simulate the hydrology and highly managed water system in south Florida for evaluation of alternative water-resources management strategies. The NSM uses the same climatic input data (based on 1965-90 observations) and model parameters, and similar model algorithms and computational schemes as the SFWMM. However, to simulate the natural system, SFWMM physical features, such as topography, vegetation, land use, and hydromodifications, have been adjusted to represent pre-drainage condition in the NSM.

Overland flow is the dominant water-transport mechanism in the natural system, whereas ground-water and canal flows dominate in the managed, or existing system. In addition to overland flow, processes included in the NSM are rainfall, evapotranspiration, infiltration, ground-water flow, and flows in some small, east coast rivers. Inflows to Lake Okeechobee include estimated "natural" river inflows, overland flow, ground-water flow, and rainfall. Outflows from the lake to south Florida occur when the lake stage exceeds the estimated surface elevation at the southern rim of the lake. The NSM also includes estimated topographic, vegetative, and land-use conditions as they might have been prior to drainage activities.

The model domain covers an area of about 9,312 mi² (fig. 1), and consists of 2,328 2-mile by 2-mile square cells. Water level, velocity, land elevation, vegetation, and land use are assumed to be uniform within each cell, and flow may enter or exit the cell along any of the four sides. Rather than modeling all physical processes explicitly (such as the complete three-dimensional turbulent flow, and the heat and water transport associated with evapotranspiration), the NSM includes several parameters which are used to simplify descriptions of these complex processes. Model parameters for the NSM are obtained from the calibrated SFWMM.

Results from the NSM have been compared with output from the SFWMM for the same set of climatic inputs to estimate the effects of hydromodifications and water management on the pre-drainage hydrology. There remains some debate about the most appropriate use of the NSM for setting targets for hydrologic restoration of the south Florida ecosystem.

Problem

The accuracy and validity of the NSM cannot be tested using traditional modeling approaches because hydrologic data from the pre-drainage south Florida ecosystem do not exist for comparison with model results. Moreover, accurate, detailed information on historic vegetative and topographic conditions required for NSM operation is largely unavailable, leading to additional uncertainty in model output. Calibrated model parameters from the ground-water and canal flow dominated SFWMM are transferred directly to the NSM in which most of the water is transported by overland flow, but the full effects of these assumptions are unknown.

The performance of the NSM primarily has been evaluated by using three approaches. First, because the fundamental algorithms used in the NSM are the same as those used in the SFWMM, and because the SFWMM appears to perform adequately, it has been assumed that the NSM properly simulates the important hydrologic processes. Second, a series of tests were performed by the SFWMD to identify (1) the sensitivity of NSM output to changes in selected model parameters and (2) geographic areas in which the simulated hydrology is most sensitive to changes in model parameters. Third, results from the NSM have been compared with available but somewhat limited historic information on soils, vegetation, and estimated historic hydroperiods.

The NSM has been proposed as the "best available tool" for setting hydropattern targets for use in efforts to restore portions of the Everglades. Restoration costs may exceed one billion dollars, and decisions made using NSM results could have important and direct implications for the entire south Florida region.

Figure 1. Modern south Florida system with NSM grid and NSM rivers highlighted.

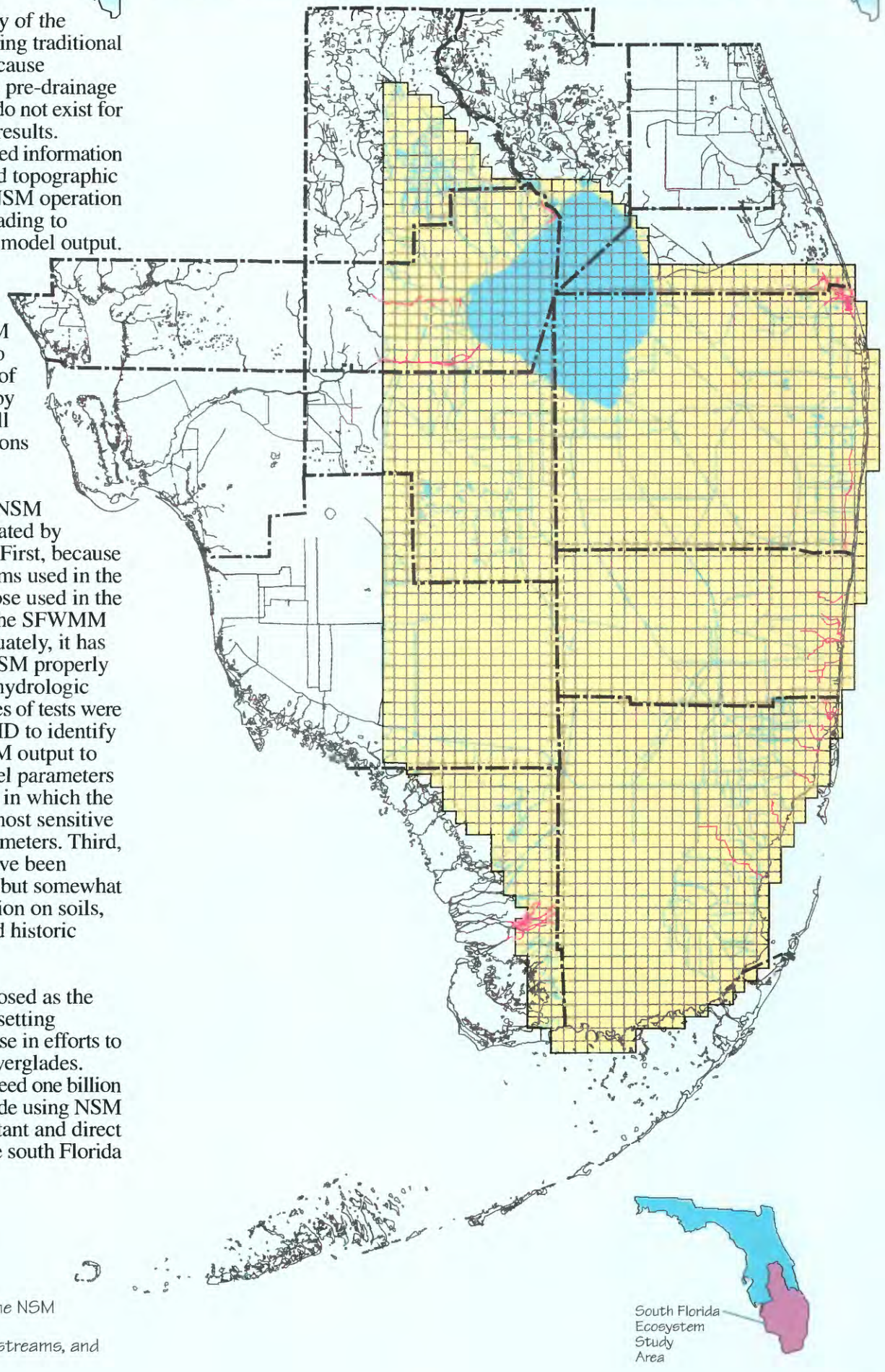
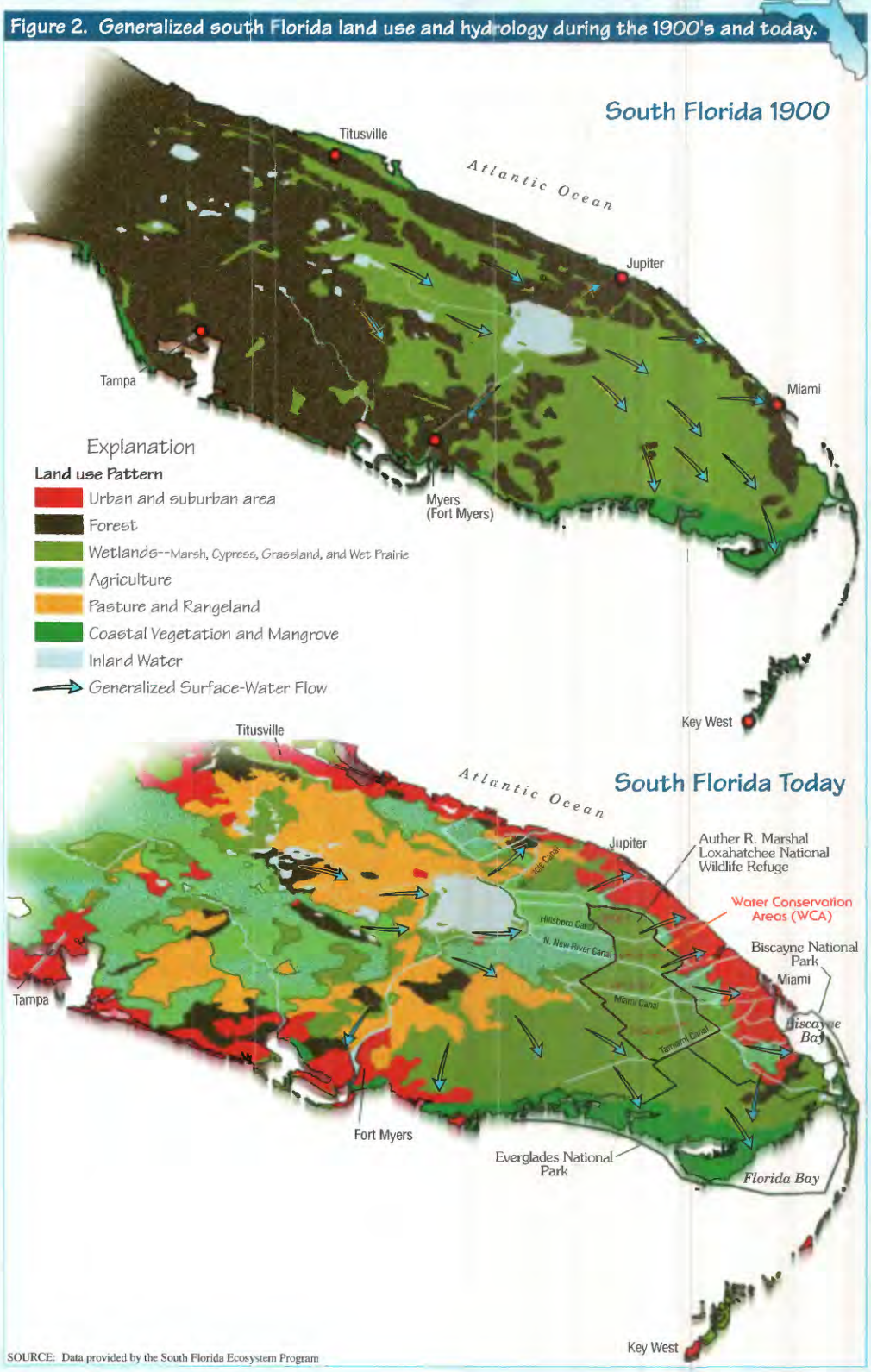


Figure 2. Generalized south Florida land use and hydrology during the 1900's and today.



SOURCE: Data provided by the South Florida Ecosystem Program

Study Objective

A study is being conducted to determine if the NSM can provide a reasonable simulation of south Florida hydrology for pre-drainage conditions, or *the natural system,* using recent climatic data. The absence of measured hydrologic, topographic, and vegetation data from the natural system for model construction and testing requires the application of novel procedures to determine if NSM results are "reasonable." Only selected components and features of the model are being reviewed because of the limited resources and time available for the review. The review is focusing on issues identified during discussions with the SFWMD, U.S. Army Corps of Engineers, National Park Service, and Florida Department of Environmental Protection. The study is being conducted by the USGS in cooperation with the U.S. Army Corps of Engineers, Jacksonville, Florida District.

Methods

The manner in which the physics of the natural system and the numerical approximation of these processes are represented in the NSM is being evaluated. Evaluations are being made by reviewing the scientific literature, reviewing the model results, conducting test simulations for selected special cases, and comparing NSM results with an independent flow model. Specific issues include (1) numerical solution of the differential equations describing overland, ground-water, and channel flows; (2) representation of the modeled region by the 2-mile by 2-mile grid; (3) appropriate temporal and spatial resolution of input and boundary data for vegetation, rainfall, and evapotranspiration; and (4) evapotranspiration calculations. Version 4.3 of the NSM was evaluated during this study.

Selected Results

The equations describing the ground-water component of the system appear to be complete and to be numerically solved in a rigorous manner. However, the ground-water boundary condition was not continuous at the Atlantic Ocean boundary. Revisions were made by the SFWMD staff to adjust this ground-water boundary condition.

Some discrepancies in the computation of overland flow were identified, including representation of the flow resistance, the use of flux limiters required to maintain numerical stability, and possible computer coding errors. The SFWMD staff made revisions to the NSM 4.3 to address these issues. The revised NSM 4.3 (called NSM 4.4) resulted in decreases in annual average ponding depth relative to those produced by NSM 4.3, changes in flow patterns near Lake Okeechobee, but little change in the annual average hydroperiod (number of days of inundated conditions at a site). However, annual average ponding depths simulated by NSM 4.4 were essentially the same as annual average

ponding depths simulated by an earlier version of the NSM (NSM 4.1).

Channel-flow algorithms were evaluated. Although some inconsistencies in the computation of river flows were identified, these inconsistencies had little effect on simulated results. This is because the pre-drainage flows are dominated by overland-flow processes.

NSM version 4.4 includes revisions to the ground-water boundary condition, adjustments in the overland flow computations, reduction in the computational time step from 24 to 6 hours, and other minor modifications.

Boundary Conditions

One potentially important issue not addressed in this study, because of limited time, concerns model boundary conditions. Boundary conditions generally are required for the operation of hydrologic models, and can be considered as the model input needed to allow the simulation of conditions within the modeled area to be performed.

Boundary conditions for the NSM are both time-varying and steady, and include conditions at the lateral boundaries of the model (river inflows and outflows, water level in Florida Bay and the Atlantic Ocean, and marine ground-water flow conditions), at the surface (water or soil) exposed to the atmosphere (precipitation, evapotranspiration, and wind), at the ground surface (flow resistance and soil infiltration parameters), and at the bottom of the aquifer (no flow). In some cases, the NSM boundary conditions represent a simplification of the physical system; for example ocean tides are represented by a monthly mean tide level. In other cases, the NSM boundary conditions very nearly represent the physical system—daily rainfall is used as model input.

By definition, boundary conditions affect simulated results throughout the modeled region. However, the effects of the boundary condition simplifications and the sensitivity of model results to changes in the boundary conditions are not well established for the NSM. Some specific issues which could be considered are:

- Are the model boundaries at the appropriate locations?
- Are the estimates of river inflows to Lake Okeechobee and outflows from the lake reasonable approximations of the natural system?
- What is the effect of a variable mean sea level on model results?
- What are the effects of a daily fluctuating tide on model results?
- What is the effect of more refined topographic resolution on simulated results and, in particular, on simulated depth of flow?
- How sensitive are model results to changes in any of the boundary conditions?

Schedule and Planned Products

This study was initiated in July 1995 and is planned for completion in September 1996. Technical memorandums which provide detailed information on findings have been prepared by the USGS throughout the project and submitted to the SFWMD, the U.S. Army Corps of Engineers, and the National Park Service. Issues identified in the memorandums generally are being addressed by SFWMD staff so that by the end of the project, most of the questions raised during the review will have been resolved. Products of the review include memorandums, this fact sheet, a revised NSM (prepared by SFWMD staff), and a final report which will briefly summarize technical issues identified in the review and their resolutions. Additionally, and perhaps more importantly, the final report will include recommendations for appropriate uses and applications of the NSM for planning restoration efforts of the south Florida ecosystem.

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Additional information can be found on the South Florida Ecosystem Home Page at: http://fl-h2o.usgs.gov/fs95134.html

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