INTERGOVERNMENTAL LINKING OF NUMERICAL MODELS FOR COASTAL WETLAND PLANNING

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ABSTRACT: The coastal area of northeastern Florida Bay, where it interfaces with the southeast portion of Everglades National Park, is of interest to water managers in ecological restoration, both inland and offshore. In order to represent the dynamic and interconnected surface-water and ground-water hydrology of this area, the US Geological Survey developed the Southern Inland and Coastal Systems (SICS) model by linking the two-dimensional dynamic surface-water model SWIFT2D with the variable-density ground-water flow model SEAWAT. Application of the coupled code to the SICS area has shown the capability of representing water-level fluctuations, leakage, discharge, salinity, and inundation patterns. In order to allow the SICS model to represent different water-supply scenarios, a further coupling with a regional model developed by the South Florida Water Management District and the U.S. Army Corps of Engineers is underway. Surface water flows into the SICS area, simulated by the regional model for various water-supply scenarios, provide boundary conditions for simulations that lend detailed insight into the effects of modifying the larger scale hydrologic system.

KEY TERMS: numerical model; coastal wetlands; ground-water/surface-water interactions

INTRODUCTION

The ability to model a complicated and highly interactive surface-water/ground-water system such as in southeastern Everglades National Park has been a step-by-step developmental process. The original effort was on a dynamic two-dimensional surface-water model using the SWIFT2D code (Leenderste, 1987). This code was modified for this application to account for rainfall and evapotranspiration, as well as the atypical vertical variations in frictional resistance found in wetlands (Swain, 1999). In this initial application, referred to as the Southern Inland and Coastal Systems (SICS) model, ground-water interactions were approximated by head-dependent boundaries or defined inflow. This model demonstrated a reasonable ability to reproduce coastal flows, wetland water velocity, and salinity concentrations in the surface water. This is a simplistic representation of surface-water/ground-water interactions, but the only way to represent the true interactivity of the water flowing through the wetlands and the water in the underlying aquifer is to couple the SWIFT2D model with a numerical model of ground-water flow and transport. The transport component must also account for density differences resulting from salinity variations at the coast and intruding through the aquifer inland. The SEAWAT variant of the three-dimensional finite difference ground-water model MODFLOW was found to fit these requirements (Langevin, 2001). The coupling of SWIFT2D and SEAWAT was accomplished by making these programs subroutines of a main code, which passes relevant information between the two models. This coupled code is called Flow and Transport in a Linked Overland-Aquifer Density Dependent System (FTLOADDS).

The application of the FTLOADDS code to the SICS area has produced improved results over the SWIFT2D only model, especially in salinity representation at the coastline. An important limitation in this model is the areal extent of the study area (figure 1). The flows entering the study area are heavily regulated by hydraulic structures on canals external to the study area. Many of the proposed modifications to the hydrologic system involve changes to existing structures or new structures. The effect of these changes on the SICS area cannot...
be represented by the SICS model alone, because the hydrology external to the area is perturbed. The regional hydrology’s response to modifications to the control system has been the focus of the South Florida Water Management Model (SFWMM), a large-scale model of surface water and ground water for South Florida developed by the South Florida Water Management District (SFWMD). The SFWMM represents the hydrology in 2-mile by 2-mile square cells. The key to using the SICS model to determine coastal wetland effects of varying scenarios is to use the conditions determined in the SFWMM as boundary conditions for the SICS model.

Background

The SFWMM prototype was developed in the late 1970’s, but the current version is quite different than the original. Overland flow is represented by a diffusion-analogy equation for flow between the 2-mile by 2-mile grid cells. Numerical analysis of this specific scheme indicates that water levels are produced with significantly more confidence than discharge values (Bales and others, 1997). The canals and control structures are represented using a “level-pool assumption”; the water level is assumed constant between control structures and a function of the volume of water in the canal reach. Volumes are calculated by the inflows and outflow of the regulating control structures. This indicates that flow volumes in the canals are computed in a manner inherently more accurate than those in the wetlands.

Surface-water boundary conditions for the SWIFT2D model can be specified in terms of defined water level or defined discharge. In terms of effect on model accuracy and realism, discharge may be considered a more desirable boundary condition for several reasons. Fixing water-level conditions at a boundary is basically stating that the boundary is capable of supplying or absorbing as much water as is necessary to maintain the specified water level. Under certain conditions, this can be quite unrealistic, creating huge flow rates. Logically this type of boundary is most appropriate for representing a large reservoir, such as an ocean boundary. Fixing discharge conditions at a boundary is basically stating that the boundary is capable of supplying a specific volume rate of water regardless of the water level. This is less subject to representing unrealistic situations, although it can certainly stray from the actual behavior of a real boundary. The ideal model setup of boundary conditions must be tempered by what data is actually available. Often water-level data, the most easily collected, is available at more locations and at shorter time intervals than discharge data. When using boundary conditions generated by the SFWMM regional model, both water level and discharge are produced at model cells, so the concerns are the applicability of values from cells to specific boundaries. This judgment would be based on the accuracy of values and the spatial locations of the cells and actual boundary location.

IMPORTANCE OF BOUNDARY CONDITION

The surface-water boundary conditions for the SICS model is shown in Figure 1. At the northernmost tip of the model are the discharges input from Taylor Slough Bridge and L-31W Canal. The L31W Canal is represented explicitly in the SFWMM but Taylor Slough Bridge is not. The flows between the 2-mile by 2-mile cells are all that’s defined for the Taylor Slough Bridge area. Using this flowrate to define flow at Taylor Slough Bridge would not be advised. This leads to the use of water levels in the appropriate SFWMM cell as a boundary condition at Taylor Slough Bridge. The implications of replacing a boundary defined by discharge by a water-level boundary are significant. As described in the previous section, a water-level boundary tends to be less flexible and more sensitive to errors than a discharge boundary. Figure 2 shows the alignment of cells in the SFWMM to the SICS model area.
The first step in testing the utility of SICS when linked to the SFWMM is the reaction of the SICS model when the discharge boundary at Taylor Slough Bridge is replaced by water-level values. Both discharge and water-level field data exists at Taylor Slough Bridge. The boundary condition was changed to field measured water levels for the simulated period August 1996 to June 1998. Figure 3 shows differences in water level at the field stations.
shown in figure 1 caused by changing this boundary condition. Figure 4 shows the differences in discharge at the coastal creek stations caused by this boundary condition change.

Figure 3. – Water level differences caused by changing Taylor Slough Bridge boundary conditions.
Figure 4. – Discharge Difference at Trout Creek caused by changing Taylor Slough Bridge boundary conditions.

Figures 3 and 4 demonstrate small differences in model results. It seems that changing the boundary at Taylor Slough Bridge to a water-level boundary raises water levels and discharges slightly through the system. Inspection of figure 3 indicates the smallest change at field station NP-EVER6, which can be seen in figure 1 to be the furthest from Taylor Slough Bridge.

The lack of sensitivity of the model simulation to the definition of the Taylor Slough Bridge boundary condition may be more due to the lower significance of the boundary on the entire system than the similarity of discharge and water level boundary conditions. A sensitivity analysis of the model was performed by comparing discharge variations at Trout Creek to variations in discharge at Taylor Slough Bridge. Raising the discharge at Taylor Slough Bridge by 50 percent only raised the discharge at Trout Creek by an average of 0.92 cubic meters per second (steres per second). Other water input and outputs to the system (such as rainfall and evapotranspiration) account for more of the water budget in the SICS area than the input at Taylor Slough Bridge.

DISCUSSION

It can be inferred from the results of this test that a water level boundary can be reasonable applied in the SICS model at Taylor Slough Bridge to facilitate linking to the SFWMM model. It has been shown that replacing the original boundary defined in terms of discharge with a boundary defined in terms of water level produces similar results. What remains to be seen is how various water-level time series, corresponding to different scenario runs in the SFWMM, affect the results of the SICS model simulation. Also, how variations in the other northern boundaries, which, although not transformed to water level values, must affect model results. When completed, the ability of the SICS model to utilize boundary conditions from the regional model will allow for a detailed and dynamic examination of the southeastern Everglades hydrology with insight into the hydrologic factors which affect restoration in this area.
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REFERENCES

