TITLE: NUMERICAL REPRESENTATION OF DYNAMIC FLOW AND TRANSPORT AT THE EVERGLADES/FLORIDA BAY INTERFACE

Presenter: Dr. Eric D. Swain
US Geological Survey
9100 NW 36th St. # 107
Miami, Fl 33157

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1: ABSTRACT

The coastal area of Florida Bay interfaces with the wetlands of Everglades National Park. The region has been the location of multiple field studies to delineate important processes that affect the hydrology and ecology. Each of these process studies reveals specific details of the hydrologic regime, and an integrated hydrologic representation is needed to tie the results of the studies together. This is accomplished with the Southern Inland and Coastal Systems (SICS) numerical model. Two-dimensional unsteady flow is computed with constituent transport while allowing for drying and rewetting of model cells, flow over hydrologic barriers, wind effects, point inflows, and tidal boundaries. The primary interest in modeling this area is flow quantity and distribution at the coastal interface. The widely accepted USGS SWIFT2D code is used; modified to allow the representation of rainfall, evapotranspiration, and ground-water inflows and outflows. The field process studies yield information on land elevation, flow and conductivity at the major creeks, velocities and gradients in the wetlands, relation of evapotranspiration to vegetation and land type, distribution of wind effects on flow, flow resistance coefficients for vegetation type, location of salt-water interface, and ground-water seepage exchange. This volume of input data allows the development of a numerical model with a minimal calibration procedure. The ability of the model to identify important processes is demonstrated. Water-level and flow reversals at the coast are seen to be wind dominated. With these inland flows, the representation of salinity transport by the model is important. The model simulates flows through the wetlands and at the coast which compare well with the field measurements. Salinity transport is also simulated by the model, and values at the coast are reproduced.

2. INTRODUCTION

The Everglades National Park (ENP) is of great interest for numerous reasons. It is a pristine reserve for natural flora and fauna, but also is in close proximity to urban and agricultural areas. The amount and timing of water passing through the area into Florida

Bay is crucial for determining ecological effects and changes. Water levels in the wetlands have a great effect on wildlife and breeding patterns. The need for hydrologic information in this area has led to site-specific studies, many of which are in the US Geological Survey's South Florida Ecosystem Program (SFEP), but a numerical model is required to tie all the results together into an integrated view of the system.

In order to define flow conditions along the coastal areas of Florida Bay and to integrate the results of numerous process studies in the area, the two-dimensional dynamic surface-water model SWIFT2D (Leendertse, 1987) was applied to the region encompassing southern ENP and northern Florida Bay (fig. 1). The model includes capabilities necessary to simulate drying and flooding, wind forcing, topologic barriers, and the transport of constituents that affect density. With a 1000 by 1000 ft cell size, this model is a more detailed representation of the coastal system than any existing model of this area. The use of the prodigious results from the process studies also gives the model the most well-defined input parameters.

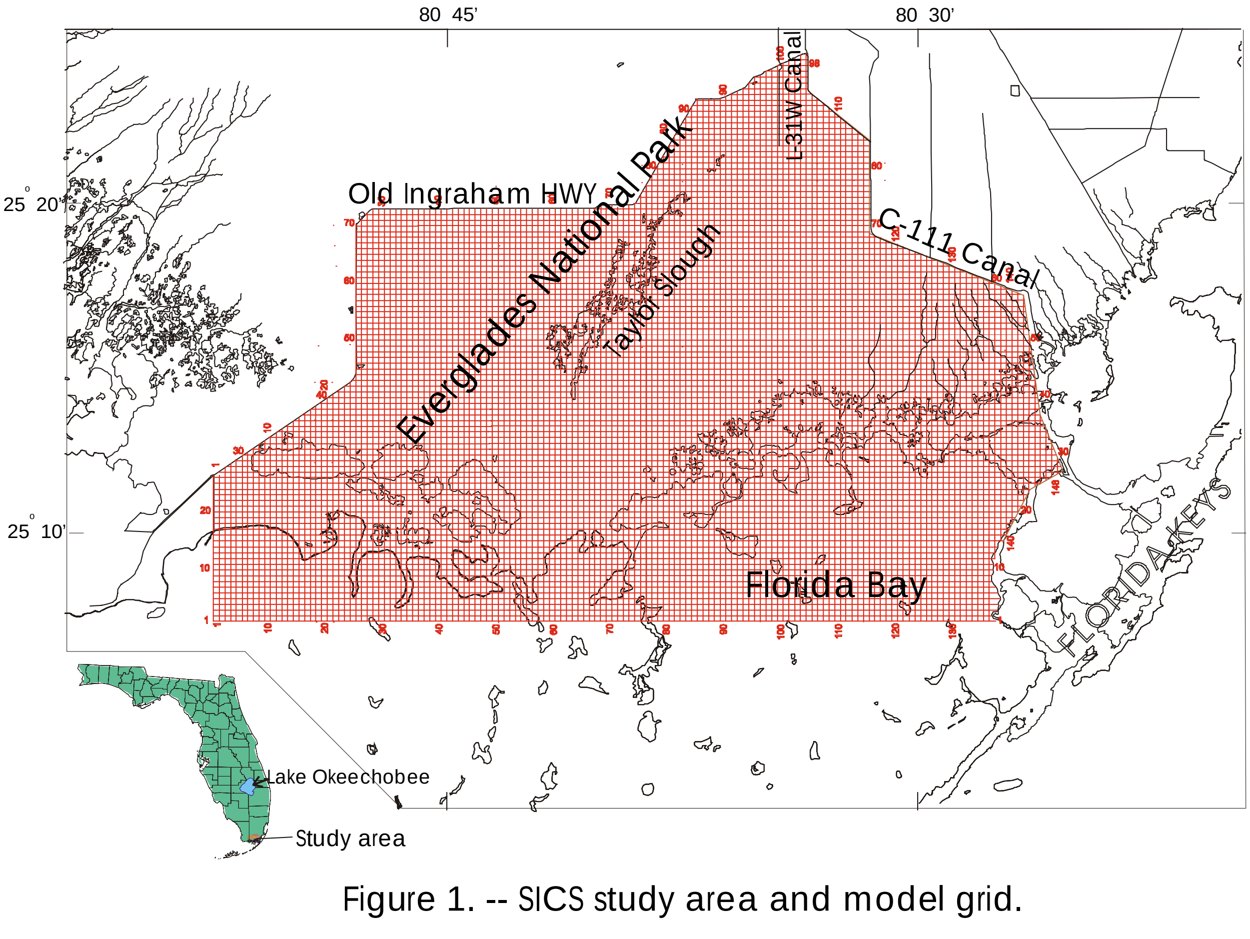

Figure 1. -- SICS study area and model grid.

3: MODEL DEVELOPMENT

The SWIFT2D model was originally designed for two-dimensional dynamic flow in estuaries and tidal areas. The application to this area required several modifications to the model code. Spatial variation of recharge is now represented in addition to the point recharge and discharge options already available. The ability to make cell by cell computation of evapotranspiration (ET) was also added, using the results of the local ET process study (German, 1995). A least-squares best-fit equation was used to relate ET to field-collected solar-radiation data and water depth. The process study on vegetation types and densities in the model area shows that solar radiation can be used as a surrogate for total available energy with reasonable accuracy. In order to represent the variation of wind forcing in vegetated and nonvegetated areas, a wind-sheltering coefficient for emergent vegetation was incorporated (Jenter, 1999). This reduces the wind friction coefficient in the vegetated wetland areas. The process studies yielded input values for land-surface elevation and bathymetry, frictional resistance terms, ET computation, location of ground-water inflows, and calibration and comparison of flow data at coastal creeks and in the wetlands. Results of field and laboratory studies relating wetland vegetation types to frictional resistance (Lee and Carter, 1996) were combined with areal mapping of vegetation to develop Manning's *n* terms for the model. The model relies on input values directly from the studies, so the calibration is kept to a minimum.

The model input data are divided into four categories:

1. Model area characterization data, including land topography, bathymetry, vegetative characteristics that affect frictional resistance, wind friction coefficient, and location of boundaries;

2. Hydrologic input data, including stage or discharge at all of the boundaries, applicable salinity timeseries, rainfall and ET parameters, and the wind field;

3. Observed data for comparison to model results, including unit discharges in the wetlands, measured discharge at coastal creeks, and coastal salinity; and

4. Calibration data not directly computed by the SFEP studies, but using insight from the SFEP, including the frictional resistance of the coastal creeks and the field-scale dispersion coefficient.

All data, except those in category 4, were directly determined from field studies, and the SFEP studies lend insight to develop category 4 data. The result is a model very heavily constrained by known input values. Because so many of the input parameters are determined by the process studies, the occurrence of nonunique solutions is unlikely.

4: MODEL RESULTS

Data from the process studies were used to construct two model run periods: a 2-week calibration simulation from July 22 to August 5, 1997, and a 7-month verification simulation from August 1, 1996 through February 28, 1997. Comparisons were made with coastal creek flows and unit discharges measured in the wetlands (fig. 2), both measured with acoustic technology (Patino, 1996). In many studies, water-level data, rather than discharge, are the only data available for model comparison. Matching water levels closely does not indicate that the model is accurately representing volumetric discharge, but the availability of discharge data at the coast and in the wetlands increases reliability in the model.

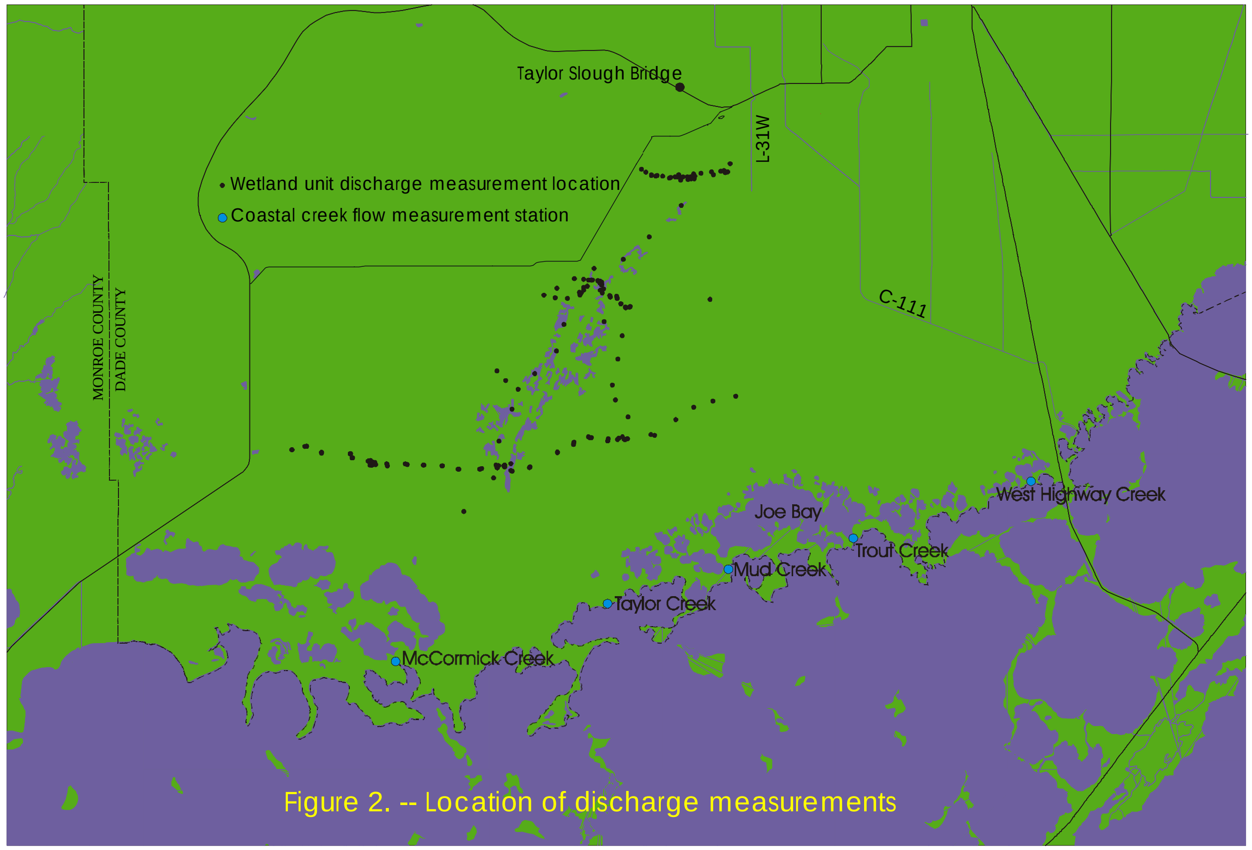

Figure 2. -- Location of discharge measurements

The calibration simulation demonstrated the ability of the model to reproduce the coastal flows, unit discharges in the wetlands, and coastal salinities. The model indicates that flow reversals at the coastal creeks are primarily due to wind forcing, and not variations in tidal level. Figure 3 shows measured and computed flows through Trout Creek, with and without wind forcing. The negative flow (to the north) is only reproduced in the simulation with wind forcing. However, in both simulations, the tidal boundary levels remain the same. Thus, it is only the local wind forcing that causes the reversals.

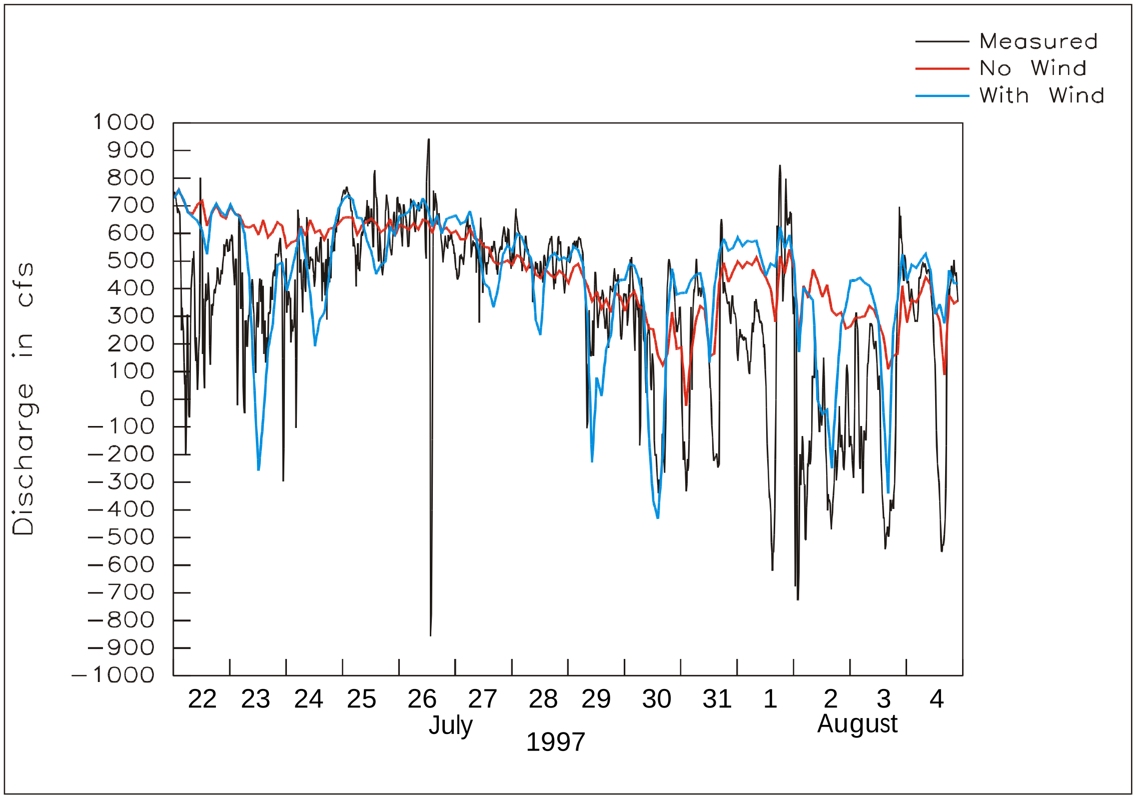

Figure 3. -- Differences in computed flow at Trout Creek with and without wind effects.

The fluctuations in salinity simulated at the coastal creek outlets were similar in magnitude to the field measurements. The model showed very large spatial variations in salinity at the coast, as would be expected at this interface. Both model and field measurements show the large salinity fluctuations as flows directionally vary in and out of the coastal creeks.

Comparisons of measured and computed wetland flows indicate similar flow directions and magnitudes (fig. 4). One of the difficulties in determining the unit discharge in the field is measuring the water depth. Overestimation of depth can occur because of the soft bottom muck, and may lead to field measured unit discharges significantly larger than the model-produced values.

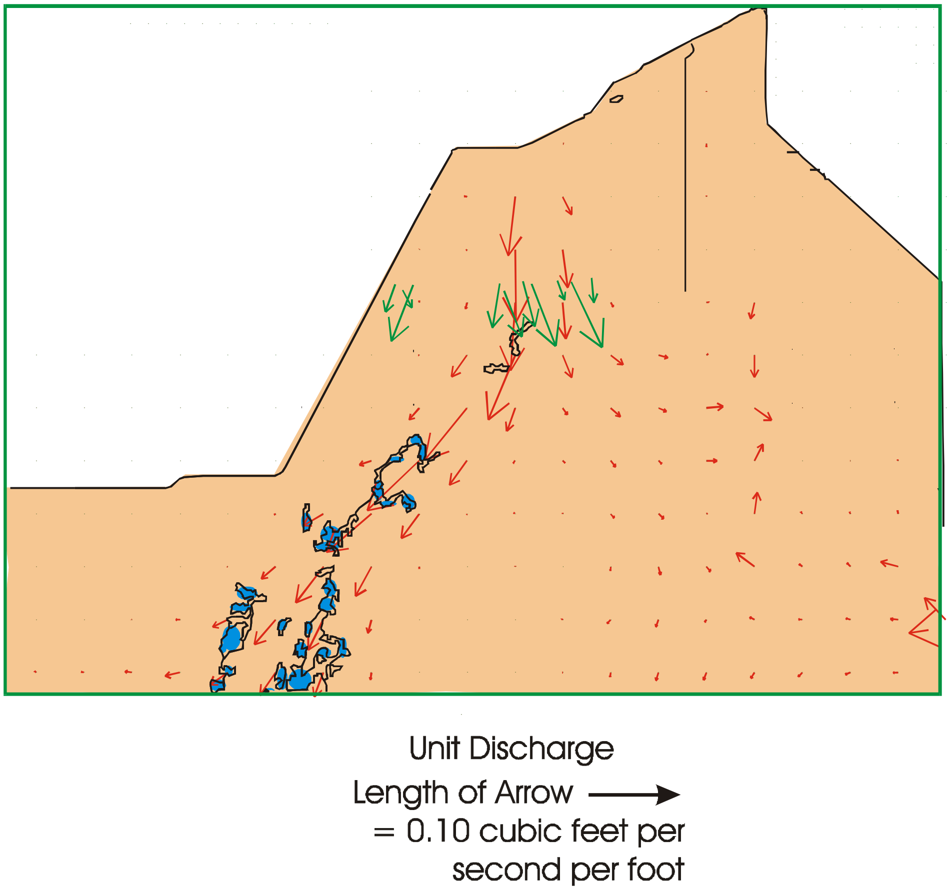

Figure 4. -- Wetland unit discharges.

The verification simulation demonstrated the utility of predicting long-term coastal flow volumes at creeks and elsewhere. The varying distribution of flows at high and low water-level conditions are also represented. Figure 5 shows a high and low water-level situation. The Joe Bay area is supplied from Taylor Slough, L-31W Canal, and C-111 Canal at high water-level conditions. Flows into Joe Bay are primarily from Taylor Slough at low water-level conditions. The flow distribution is controlled by the location of topographic high areas. This is a major factor at the Florida Bay interface where a coastal embankment confines overland flow to the creeks. The highest simulated water level gradients occur along this coastal embankment. Gradients between upstream of the embankment and the bay are on the order of 0.0003 ft/ft, whereas gradients in the open wetlands can be 0.00002 ft/ft. This magnitude of coastal gradients is supported by isolated field measurements.

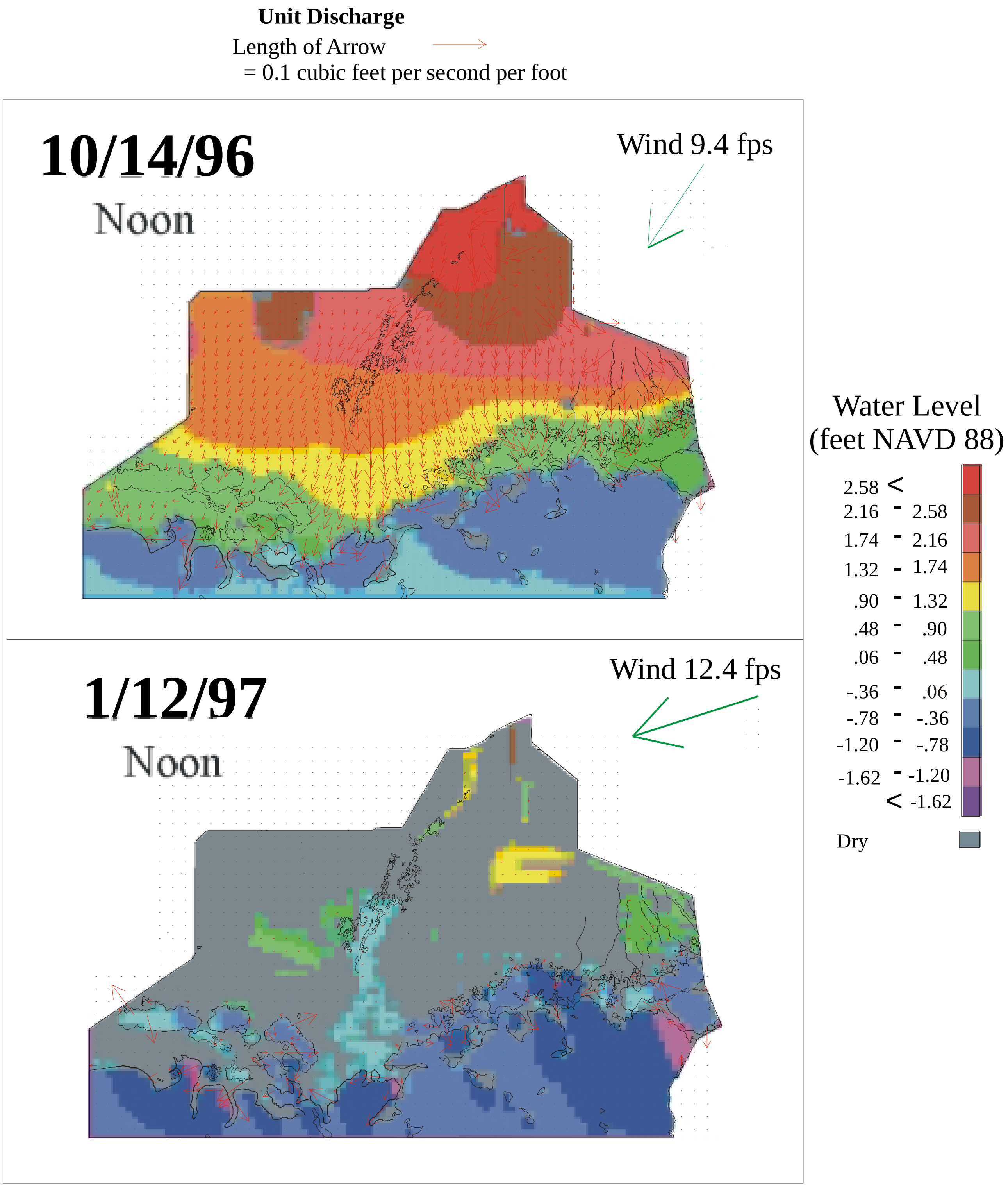

Figure 5. -- Model results showing variability in inundation.

A sensitivity analysis was performed on the major input parameters. The variation in the input parameters was based on the uncertainty, so the results indicate which parameters need to be better defined. The change in coastal flows when the parameter is perturbed is compared with the difference between measured and computed flows. When the perturbed change is larger than the measured/computed difference, the parameter is tagged as "sensitive" for the given creek. Rating the parameters on how many creeks show sensitivity yields information on where new information is most needed. The frictional resistance of the coastal creeks was identified as the parameter that required the most study. In descending order, this was followed by wind friction, additional sporadic ground-water inflow or boundary overtopping flow, the boundary water levels and flows, and finally the solar-radiation effect on ET. This low apparent sensitivity of the model to ET, as well as wetland friction factor and land-surface elevation, is not because the model is not significantly affected; it is due to the fact that these parameters are well defined by the intensive field studies.

5: FLOW ESTIMATION

In order to develop a simpler method to estimate coastal flows, a least-squares linear regression technique was applied to the measured and computed creek discharges. At ungaged sites, only the computed flows are available. The independent values were chosen to be those which could be obtained from field measurements and should have controlling effects on creek flows. These were: total head difference between Taylor Slough Bridge and each individual creek (figure 2), the wind components in the two orthogonal directions, 1-day antecedent rainfall total, and a variable to represent additional flow from ground-water or boundary overtopping. For West Highway Creek, nearest to C-111 canal (figure 2), it was considered necessary to include flows out of C-111 canal as an independent variable. Correlation parameters were higher for the computed flows, probably since unknown factors affect the measured flows. This method shows the ability to compute coastal flows simpler and faster than with the numerical model.

6: SUMMARY

This modeling effort helps to improve the state of hydrologic knowledge in the ENP/Florida Bay area and improves the estimation of coastal flows and the processes that control this system, inland and in the bay. The field-process studies that were used to develop the input data investigate all the major hydrologic effects, so the numerical model can be well defined and constrained. Results yield information on flow patterns, volumes, and timings, and the effects of wind and other hydrologic forcing functions on the system. The sensitivity analysis indicates which parameters need further field analysis based on their uncertainties. The regression analysis develops simplified relationships to be used to predict coastal flows based upon measurable field quantities. Water managers can use these model results to gain further insight into the hydrodynamics of this coastal region and the effects of system modifications.

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