Development of a Spatially Distributed Flow Dynamics Model in the Everglades Ridge and Slough Landscape

Joong-Hyuk Min[1], James W. Jawitz[1], Rajendra Paudel[1], and Andrew I. James[2]

[1]Soil and Water Science Department, University of Florida, Gainesville, FL, USA
[2]Soil and Water Engineering Technology, Inc., Gainesville, FL, USA

UF UNIVERSITY of FLORIDA
The Foundation for The Gator Nation
Environmental Hydrology Laboratory

Acknowledgment: *This work was funded by the US Department of Interior and National Park Service (Cooperative Agreement #: H5000060106).*

Introduction

Human intervention to the Everglades during the last century caused the loss of historic surface flow. The disturbed hydrology has been suspected as a trigger of the partial loss of unique ridge and slough landscape pattern in the central Everglades. For the recent restoration efforts, the role of surface water flow and sediment transport has been highlighted due to the importance of physical and ecological impacts on the landscape formation, maintenance, and degradation.

In this study, a spatially distributed flow dynamics model was developed for the ridge and slough landscape. The Regional Simulation Model (RSM), originally developed by South Florida Water Management District (SFWMD), was used as the modeling framework. This model will serve as the hydrodynamic foundation of a hydro-ecosystem model, which involves both sediment transport and net peat accretion that may be different between ridge and slough habitats.

Objectives

- To develop a two-dimensional (2-D), spatially distributed flow dynamics model for the Everglades ridge and slough landscape.
- To test the model against hydrologic data, such as water level (WL), depth (WD), and flow velocity, collected from the well-conserved area.

Site Description

The selected model domain is a 1.5 by 4 km rectangle located approximately 4 km south of Alligator Alley (I-75) in Water Conservation Area (WCA) 3A (Fig. 1). This area is considered as one of well-conserved ridge and slough areas including the historic landscape pattern. The ratio of ridge and slough landscape is about 1:1. Jorczak (2006) reported that site 3A1, which is located 2.4 km west of the model domain, had an average topographic difference of 16 cm between ridge and slough.

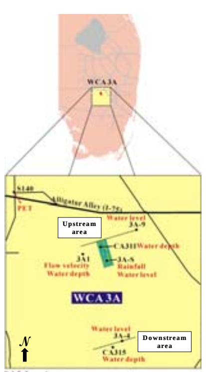

Fig. 1. Location map of study area and hydrologic data monitoring points.

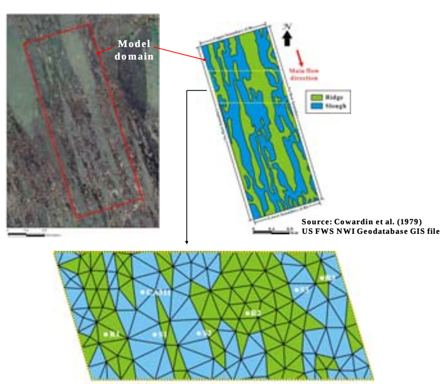

Fig. 2. Model domain and simulation output points.

Model Setup

- Modeling framework: RSM Hydrologic Simulation Engine (HSE).
- Simulation period: Jan. 1, 2002 to Dec. 31, 2004 (3 yrs).
- Simulation time step: 6 hrs.

Mesh generation

- Model grid: Irregular triangle mesh (2dm file) generated by GMS (Fig. 3).
- Number of cells: 962.
  - Ridge: 486 / Slough: 476

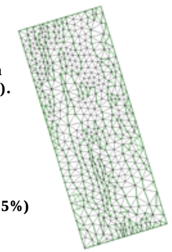

Fig. 3. 2-D mesh generated by GMS.

Model bathymetry

- Regional slough topography (0.0025%)
  - Upstream: avg. WL at 3A-9 – avg. WD at CA311 for the 3 yrs.
  - Downstream: avg. WL at 3A-4 – avg. WD at CA315 for the 3 yrs.
  - Interpolation scheme: Spline.
- Regional ridge topography (0.0019%)
  - Upstream: Slough + 0.16 m (Jorczak, 2006).
  - Downstream: Slough + 0.25 m (Jorczak, 2006).
  - Interpolation scheme: Spline.
- Model bathymetry (Fig. 4)
  - The gently sloping landscape was set to be slightly steeper in the slough than the ridges, generating topographic differences between the ridge and slough that increased from 0.16 to 0.18 m along the main flow direction.
- Soil depth: 0.8 m

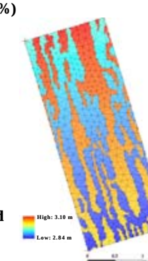

Fig. 4. The model bathymetry.

Model boundary

- Upper: Transient WL boundary (3A-9 in DBHYDRO).
- Lower: Transient WL boundary (linearly interpolated between 3A-9 and 3A-4 in DBHYDRO).
- Right and Left: No flow boundary.

Model input data

- Spatially uniform rates of rainfall and ET were applied.
  - Rainfall: 3A-S in DBHYDRO.
  - PET: S140 in DBHYDRO.
  - Crop coef: Monthly averaged values, calibrated in SFWMM v5.5 (sawgrass plains: 0.88 ± 0.05).
- Hydraulic resistance (Manning coef.)

$$\text{Manning's } n = a(\text{water depth})^b$$

  - Empirical constants: a (determined by model calibration to the velocity profiles measured at 3A1) and b (-0.77).
  - Detention depth: 0.03 m.

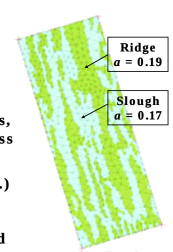

Fig. 5. Hydraulic resistance const. (a) estimated by model calibration.

Results

Hydrologic simulation: Hydraulic head

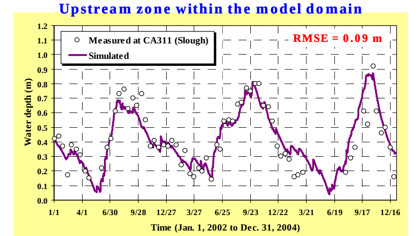

Fig. 6. Model fit of water depth (R^2 = 0.74).

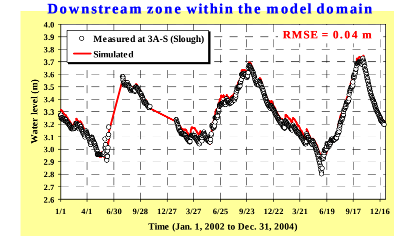

Fig. 7. Model fit of water level (R^2 = 0.99).

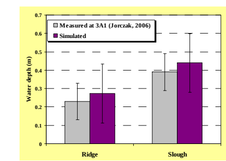

Fig. 8. Average water depth (± 1 SD) from Nov. 2002 to Feb. 2004. For comparison, water depth simulated at R1, R2, R3 and S1, S2, S3 was averaged in the ridge and slough areas, respectively.

Hydrologic simulation: Flow velocity

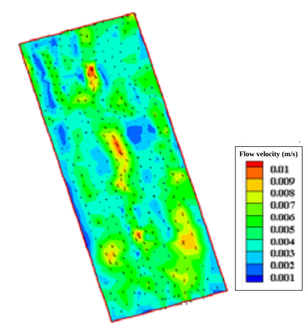

Fig. 9. A snapshot of computed flow velocity map (June 18, 2002).

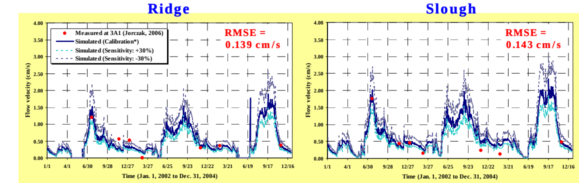

Fig. 10. Model fit of flow velocity at the ridge (R^2 = 0.86) and slough areas (R^2 = 0.90). Sensitivity of model-calculated flow velocities to change in hydraulic resistance constant, a (± 30%) was denoted. *For model calibration, average of flow velocity profiles simulated at R1, R2, R3 and S1, S2, S3 was used.

Discussion and Further Study

- Despite several simplifying assumptions made in this study due to the lack of high resolution spatial data available for the model development, the simulated time series profiles on WL, WD, and flow velocity matched closely to the field observations for 3 years.
- Our simulation results suggest that the RSM HSE can be used to accurately predict the relatively small-scaled hydrology of the Everglades ridge and slough landscape.
- The best-fit values of hydraulic resistance constant (a) for the ridge and slough portions, determined through model calibration to the flow velocity profiles measured at each zone, are 0.19 and 0.17, respectively. These values are much less, compared to the ones for similar areas such as sawgrass plains (1.25) and Ridge and Slough II (0.765) in SFWMM. More systematic field monitoring on the flow velocity in ridge and slough zone is required to validate the values.
- To determine key mechanisms of the landscape degradation and evaluate various restoration strategies, this flow dynamics model will be linked with an optimized ecosystem model.