Significance of Microtopography as a Control on Surface-Water Flow in Wetlands

Jungyill Choi[1], Judson Harvey, and Jessica T. Newlin

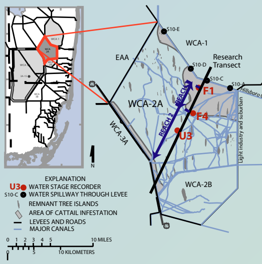
U.S. Geological Survey, Reston, VA

[1] - now at S.S. Papadopulos and Associates, Inc., Bethesda, MD

INTRODUCTION

Microtopography rarely has been considered in wetland surface-water flow models, even though the ground surface often undulates significantly. To our knowledge, no previous model of surface-water flow in the Everglades has considered how microtopography (1) decreases the cross-sectional area available for flow at low water levels, (2) increases flow resistance due to flow over and around microtopographic features, and (3) increases surface-water exchange with sediment porewater.

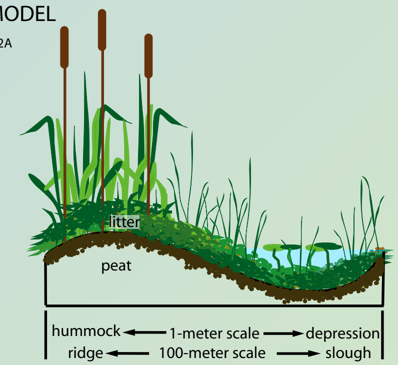
SITE DESCRIPTION



- The study area is Water Conservation Area 2A in the central Everglades. The general direction of flow is parallel with the research transect from spillway S10-C toward site U3. Microtopographic data was collected at sites F1 and U3. The surface-water flow model uses two reaches (F1 to F4 and F4 to U3), and simulates surface-water elevations at sites F4 and U3.

SURFACE-WATER FLOW MODEL

- The ground-surface elevation in WCA-2A varies by as much as 0.4 m vertically (over a horizontal distance of 100 meters), which is half of the typical annual fluctuation in surface-water depth (0.8 m) in that part of the Everglades.



- Rate Law (Hammer and Kadlec, 1986; Kadlec, 1990)

$$v = K_f \cdot d^b \cdot S_f^{\,l}$$

where v is velocity,
K_f is the flow conductance,
d is the depth,
b is the depth exponent,
S_f is the friction slope, and
l is the slope exponent.

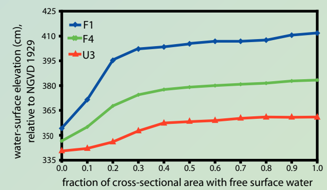
- Governing Flow Equation (assume diffusion wave approximation of the momentum equation and the slope exponent is equal to 1 for laminar flow conditions (modified from Hammer and Kadlec, 1986))

$$f_w \cdot S_s \cdot \frac{dh}{dt} + (1 - f_w) \cdot S_y \cdot \frac{dh}{dt} = \frac{d}{dx}\left(f_w \cdot K_f \cdot d^{\,b+1} \cdot \frac{dh}{dx}\right) + (P - ET + GW_i)$$

where f_w is the fraction of free surface water normal to flow (function of water level and microtopography),
S_s is the surface-water storage coefficient,
h is the surface-water elevation,
S_y is the specific yield of the wetland sediments (i.e. subsurface-water storage coefficient),
P is the precipitation,
ET is the evapotranspiration,
GW_i is the ground-water inflow,
t is time, and x is downstream distance.

PARAMETERIZATION

- **Fraction of free surface water** is estimated from the inverse cumulative distribution of the 100-m scale microtopographic measurements at sites F1 and U3, and is interpolated using a distance-weighted average for site F4.



- **Surface-water storage coefficient** is estimated from field measurements of vegetation.

$$S_s = 1 - \frac{\text{(average dry biomass of vegetation)}}{\text{(dry particle density of the vegetation)}}$$

Storage Coefficient (average)	Value based on field measurements		
	F1	F4	U3
S_s	0.99	0.97	0.97
S_y	0.7	---	0.8

- **Specific yield** (i.e., subsurface-water storage coefficient in wetland sediment) is estimated using a mass balance equation where total rainfall is equal to the change in volume of free surface water plus the change in volume of water in the porewater of the wetland sediments.

MASS BALANCE

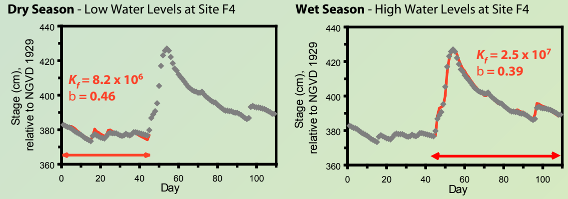
$$[\text{Rainfall depth}] \cdot \text{Area} = [f_w \cdot DH \cdot \text{Area} \cdot S_s] + [(1 - f_w) \cdot DH \cdot \text{Area} \cdot S_y]$$

where DH is the change in surface-water elevation as a result of the rainfall on the given area.

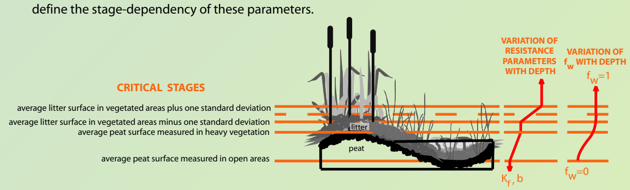
STAGE-DEPENDENCY OF FLOW PARAMETERS

- Inverse modeling (using the USGS parameter optimization program, UCODE) shows that the optimal flow parameters (K_f and b) for the dry season are different than the optimal parameters for the wet season.

Dry Season - Low Water Levels at Site F4 **Wet Season** - High Water Levels at Site F4



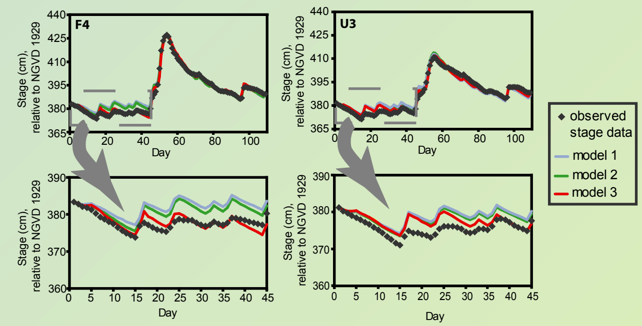
- The inversely estimated flow parameters (K_f and b) and variation of the fraction of free-surface water in a cross section (f_w) from wet and dry seasons are correlated with microtopographic measurements to define the stage-dependency of these parameters.



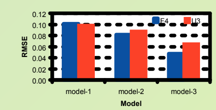
MODELING RESULTS

- Comparison of three different models

	Are K_f and b stage-dependent?	Is the **cross-sectional area** of flow **controlled by microtopographic data**?	Is **storage-exchange** with sediment porewater **controlled by microtopographic data**?
Model 1	No	No	No
Model 2	No	Yes	Yes
Model 3	Yes	Yes	Yes



- The Root Mean Squared Error (RMSE) of the model 3 simulation was improved over model 1 by 55% at site F4 and 34% at site U3. The incorporation of microtopographic variability, therefore, improves the model's accuracy in simulating the observed data in WCA-2A.



CONCLUSION

- A wetland surface-flow modeling approach that incorporates microtopography improves simulations of flow and water level in the Everglades, particularly when water levels are relatively low.
- Results of this study indicate that microtopography is a significant control on surface-water flow in the Everglades, especially when the surface-water elevation declines to depths that begin to expose microtopographic highs.
- Current modeling efforts focus on objectively determining the critical stages that affect stage-dependence in the flow parameters using an inverse modeling approach.

REFERENCES

Hammer, D.E., and Kadlec, R.H. 1986. A model for wetland surface water dynamics: Water Resources Research, vol. 22, no. 13, pp. 1951-1958.

Kadlec, Robert H. 1990. Overland flow in wetlands - vegetation resistance: Journal of Hydraulic Engineering, vol. 116, no. 5, pp. 691-706.

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