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Model for Simulation of Surface-Water Flow and Transport through Freshwater-Wetland and Coastal-Marine Ecosystems in Everglades National Park, Florida

Raymond W. Schaffranek and Ami L. Riscassi, U.S. Geological Survey, Reston, VA

TIME Model Input

Time-series data input to the TIME model within the computational domain and along the open boundaries include:

- flow discharges, water levels, and salinities
- time sequences of grids of rainfall data
- meteorological parameters and wind conditions

Wetland, canal, culvert, and hydraulic structure water levels and discharges define inflow conditions at the freshwater model boundaries identified in Figure 7. Tide levels and salt concentrations at coastal stations are used to define flow and transport conditions along the southwest Gulf coast and Florida Bay boundaries.

Figure 7. Locations of road culverts, flow stations, and hydraulic control structures in the TIME model domain.

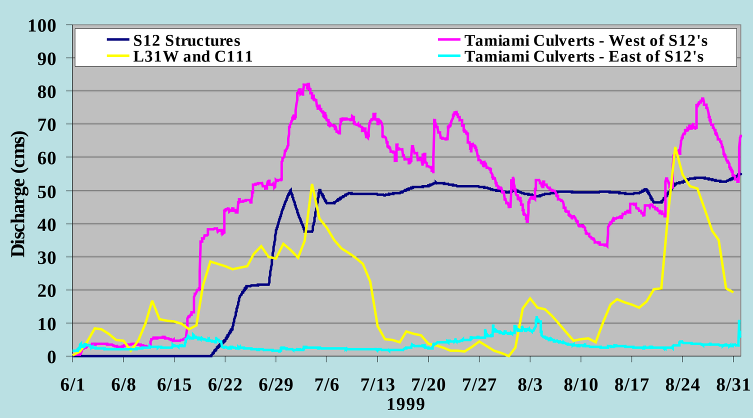

Figure 8. Inflows specified as open boundary conditions.

Internal and boundary inflows from hydraulic structures and road culverts used to conduct TIME model simulations are shown in Figure 8. Inflows from the L-31W and C-111 canals, the sum of the S-12A-D releases and inflows through 19 culverts to the east and 49 culverts to the west are plotted in Figure 8.

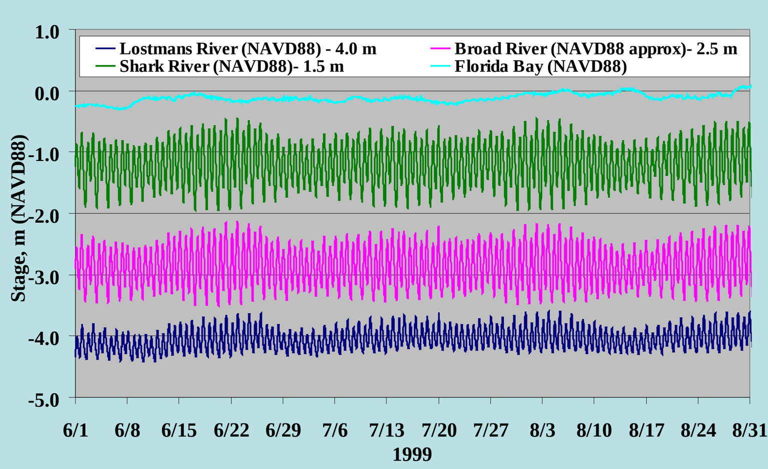

Figure 9. Water-surface elevations specified as open boundary conditions.

Tide levels at Lostmans, Broad, and Shark Rivers and the mean of water levels at McCormick Creek, Taylor River, and Trout Creek are illustrated in Figure 9. The significantly greater range of the semi-diurnal tides along the Gulf coast versus the wind-driven tides of Florida Bay is evident in Figure 9.

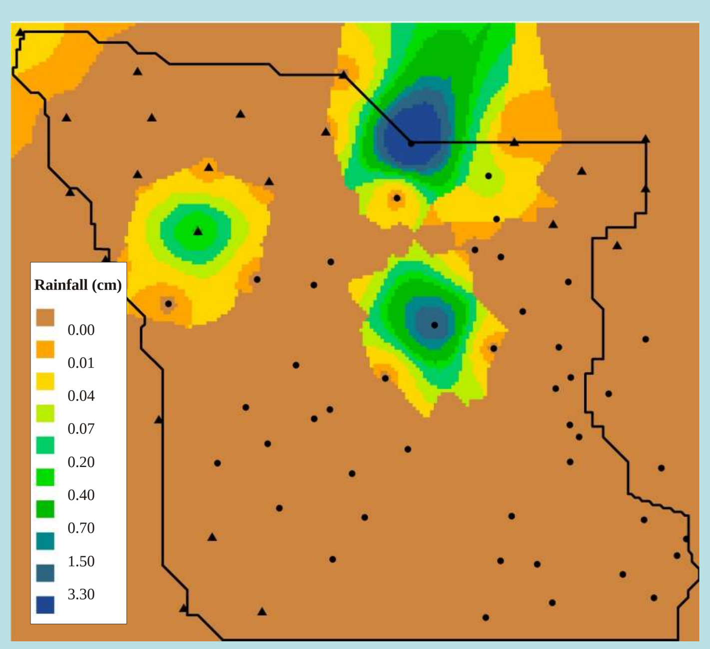

Figure 10. Rainfall on June 16, 1999, between 1500 and 1600 hours in 500-m-square TIME grid resolution.

An example input rainfall grid for the TIME model is shown in figure 10. Hourly precipitation grids are interpolated from 47 rain gages, circles in Figure 10, and 23 sets of NEXRAD rainfall estimates at un-gaged sites, triangles in Figure 10. (NEXRAD rainfall estimates were obtained from the University of Miami.)

The TIME Project

A hydrodynamic/transport model has been developed to simulate flow exchanges and salt fluxes between surface- and ground-water systems comprising the land-margin interface of the Everglades with Florida Bay and the Gulf of Mexico. The U.S. Geological Survey (USGS) two-dimensional Surface Water Integrated Flow and Transport model SWIFT2D (Schaffranek, 2004) has been coupled to the USGS three-dimensional, variable-density, ground-water model SEAWAT, a coupled version of MODFLOW and the transport model MT3D (Langevin and others, 2003). The TIME (Tides and Inflows in the Mangroves of the Everglades) model encompasses the freshwater wetlands and the saltwater-freshwater mixing zone of the mangrove ecotone in Everglades National Park (Figure 1).

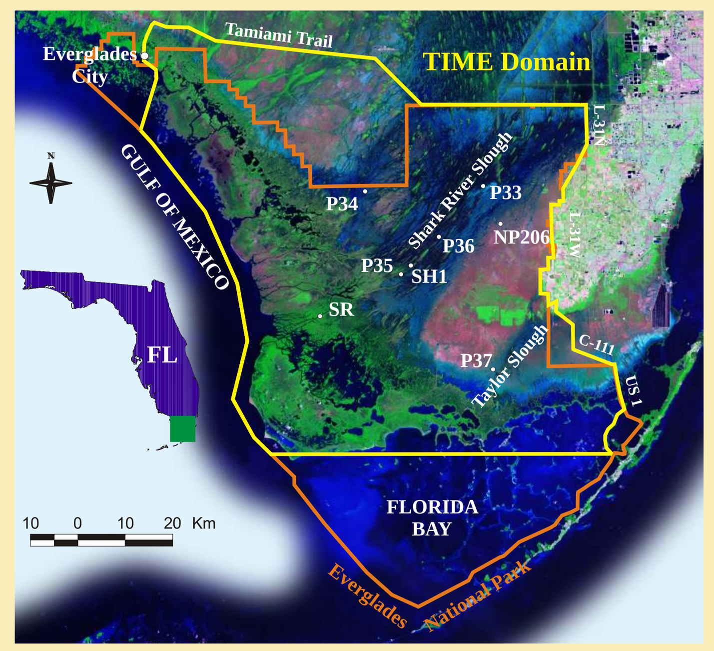

Figure 1. The TIME model domain.

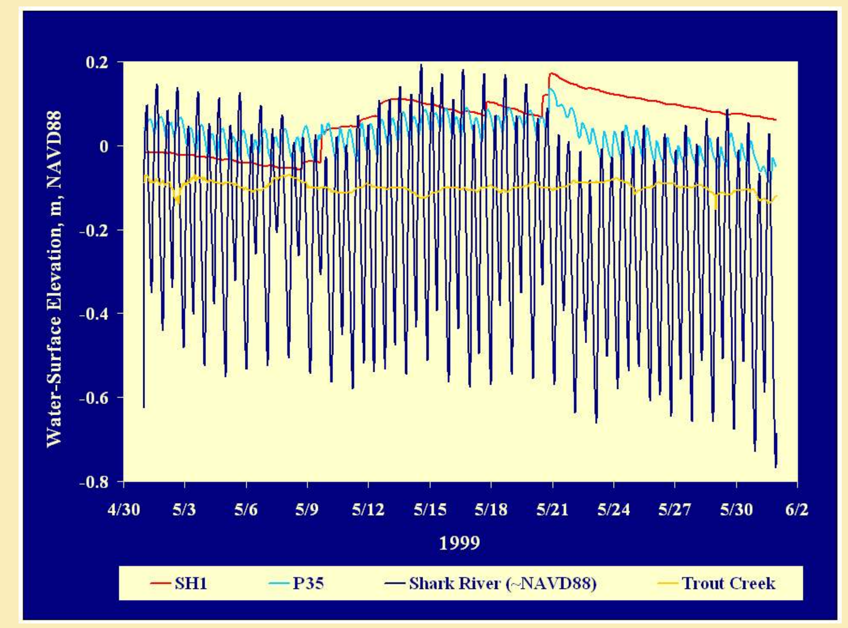

Figure 2. Water levels in Shark River, Shark River Slough, and Trout Creek.

Surface-water levels, ground-water heads, flow velocities, salt concentrations, rainfall, and meteorological data have been collected to support the model development. A plot of water-level data from sites SR, P35, and SH1 in Figure 2 shows the diminishing effect of tidal propagation through the mangrove marsh ecotone. A plot of water levels in Trout Creek shows the diminished tidal effect in Florida Bay. Water depths in the wetlands typically range up to 1 m, the semi-diurnal tide range along the Gulf coast is on the order of 1.5 m, and water levels along the northern coastline of Florida Bay fluctuate about 0.05 m daily.

Langevin, C.D., Shoemaker, W.B., and Guo, Weixing, 2003, MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model Documentation of the SEAWAT-2000 Version with the Variable-Density Flow Process (VDF) and the Integrated MT3DMS Transport Process (IMT): U.S. Geological Survey Open-File Report 03-426, 43 p.

Schaffranek, R.W., 2004, Simulation of surface-water integrated flow and transport in two dimensions: SWIFT2D user's manual: U.S. Geological Survey Techniques and Methods, book 6, chap.1, section B, 115 p.

TIME Model Grids

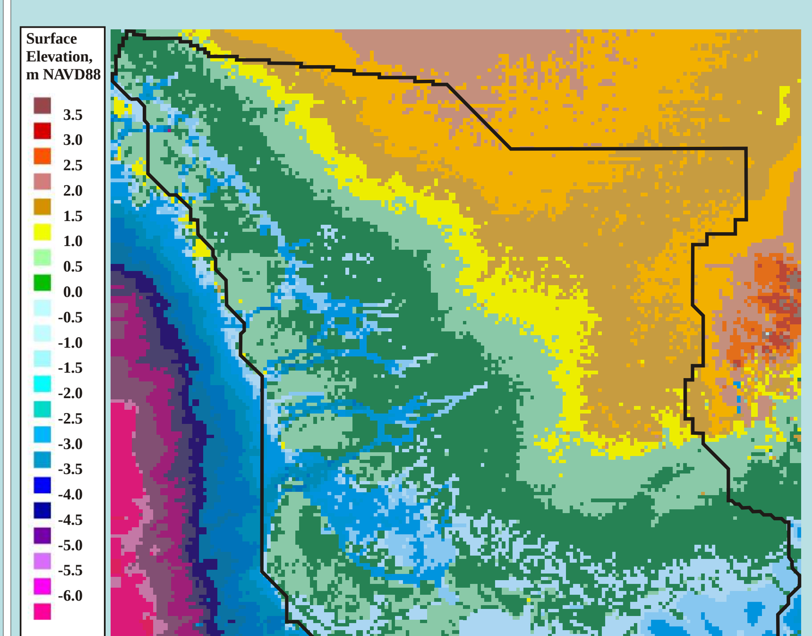

Figure 3. Land-surface elevations.

The TIME model grid is comprised of 194 (E/W) by 174 (N/S) 500-m-square cells. The TIME model grid of mean land-surface elevations is shown in Figure 3. The grid was generated from topographic data collected by helicopter GPS in the wetlands and bathymetric surveys in tidal creeks and coastal embayments. Grid size was chosen to coincide with the resolution and simulation requirements of ecological models.

A companion grid of vegetation types is shown in Figure 4. Twenty land-cover classifications derived from 1997 Landsat Thematic Mapper imagery were aggregated into seven vegetation types and one open water class. Vegetation classes are used to evaluate evapotranspiration processes, frictional-resistance effects, and wind-stress conditions. Frictional-resistance and wind-sheltering coefficients based on the vegetation map are shown in Figures 5 and 6, respectively. Resistance coefficients determined from field data are pro-rated to the 500-m grid from the 30.5-m Landsat imagery. Wind sheltering coefficients are based on the extent of emergent vegetation associated with each plant type. Evapotranspiration rates are evaluated from modified Priestly-Taylor equations correlating ET to solar radiation and simulated water depth.

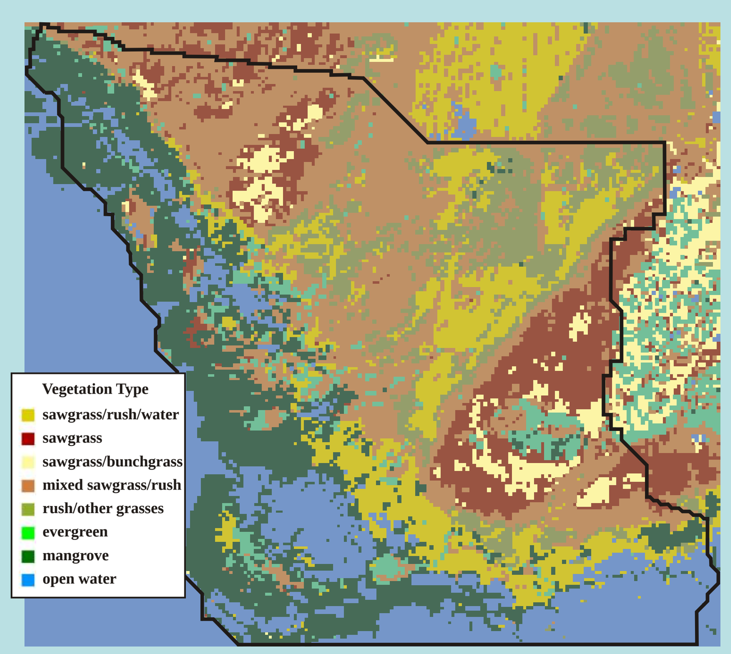

Figure 4. Vegetation types.

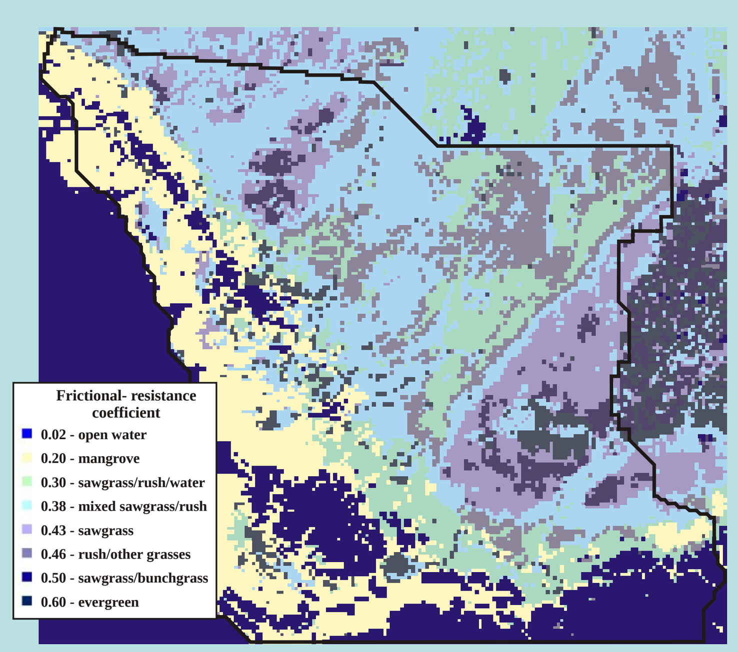

Figure 5. Frictional- resistance coefficients.

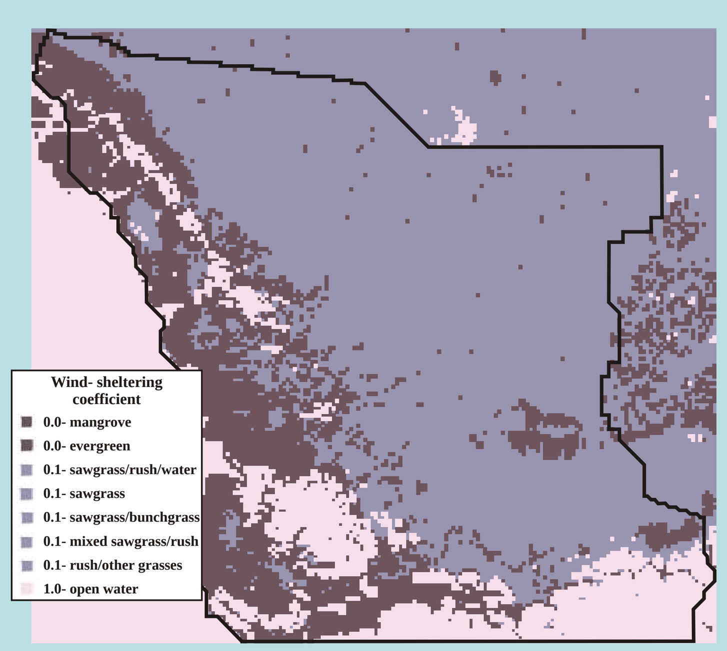

Figure 6. Wind-sheltering coefficients.

TIME Model Output

Types of simulation output derived from the TIME model include:

- time series of flow quantities at cell locations
- time series of mass and constituent fluxes through transects
- grids of flow quantities at specified times

Simulated and measured water levels are shown in Figure 11 as light and dark colors, respectively. Mean differences (measured minus simulated) for the two-month simulation are 0.026, -0.044, -0.047, 0.027, and 0.103 m at monitoring sites P33, NP206, P36, P34, and P37 respectively (gage locations shown in Figure 1). (This model simulation setup does not include ground-water exchanges.)

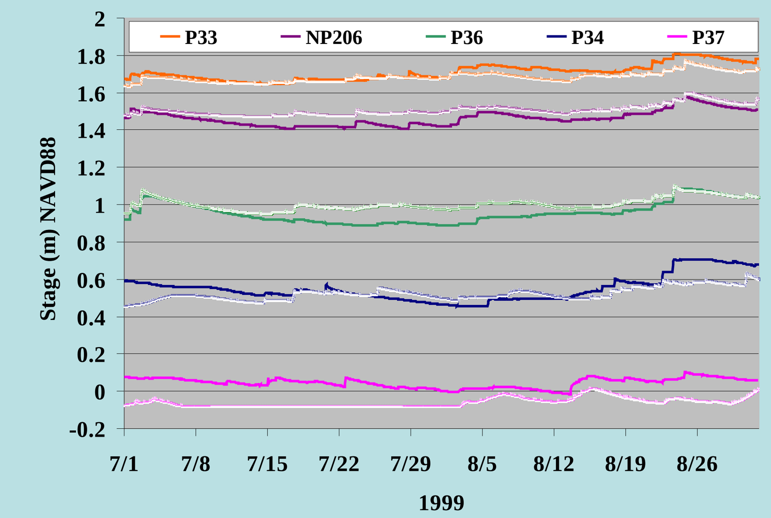

Figure 11. Water levels simulated (light colors) and measured (dark colors) at P33, NP206, P36, P34, and P37.

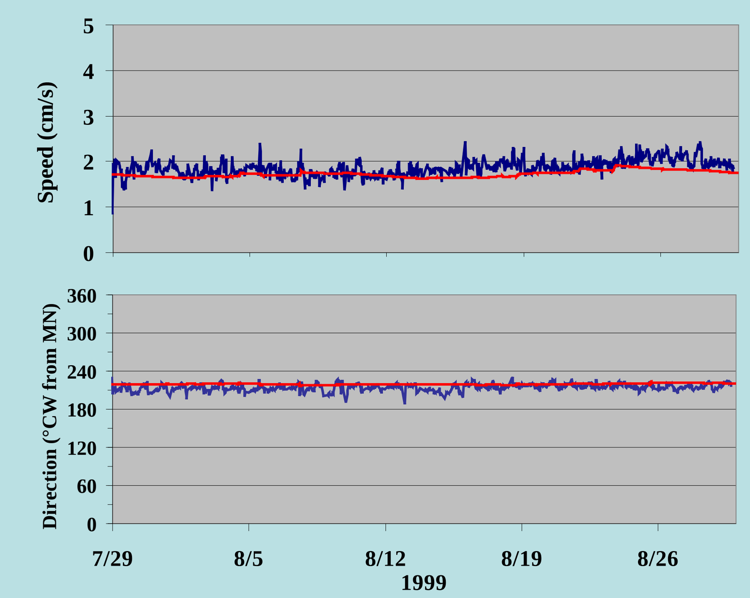

Figure 12. Flow speeds and directions simulated (red) and measured (blue) at SH1.

Measured point velocities and simulated flow speeds and directions in the 500-m-square cell corresponding to monitoring site SH1 are shown in Figure 12. Simulated flow velocities are slightly smaller in magnitude and more westerly in direction than measured point velocities. Mean differences (measured minus simulated) for the month of concurrent data are 0.14 cm/s and -5 degrees for speed and direction, respectively.

A map of simulated flow velocities, shown as vectors, superimposed on flow depths is presented in Figure 13. For optimal visualization of model results, only every third flow vector is plotted, and larger tidal-affected flow velocities are not shown. This preliminary model setup does not include ground-water interaction and lacks treatment of some physical features. Salient features of the flow regimes in the wetlands of Taylor, Shark River, and other western sloughs are reasonably captured in the simulation.

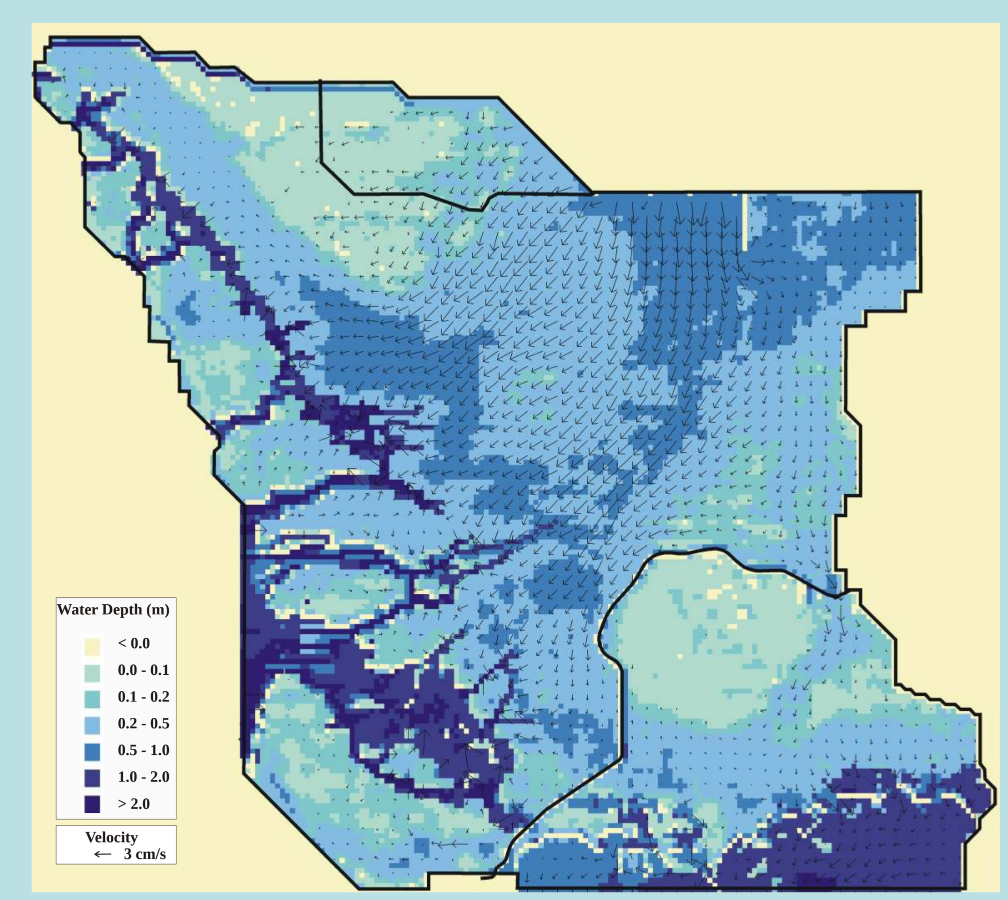

Figure 13. Preliminary simulated flow depths and velocities at midnight on August 31, 1999.