
Chufang Chen¹, Ehab Meselhe², Michael Waldon³, Hongqing Wang², and Matthew Harwell³

¹ University of Florida, School of Natural Resources and Environment
² Center for Louisiana Water Studies, University of Louisiana at Lafayette, Lafayette, LA
³ DOI Everglades Program Team – USFWS, Boynton Beach, FL
Background
Background

• Changes in water quantity, timing and quality are impacting the Refuge’s ecosystem.

• It is a priority for the Refuge to ensure appropriate water management decision rules (regulation schedule)
  – Fish and Wildlife
  – Nutrients’ Loading
  – Flood Control
  – Water Supply
Marsh Bathymetry
L-7 & L-39 Canal Bathymetry

Obtained from University of Florida - IFAS
L-40 Canal Bathymetry

Obtained from University of Florida - IFAS
Legend

⭐ USGS Stages

🔺 Hydraulic Structures
Evapotranspiration

- Reduction factor $f_{ET}$

$$ET = f_{ET} \times ET_{obs}$$

$$f_{ET} = \text{Maximum} \left[ f_{ET\text{min}}, \text{Minimum} \left( 1, \frac{H}{H_{ET}} \right) \right]$$

- $f_{ET\text{min}}$ is the minimum percentage that ET can be reduced
- $H$ is the water depth
- $H_{ET}$ is the depth below which ET is reduced
- ET is reduced to 20% when the depth = 0 and is 100% when the depth is $\geq 0.20$ m.
MIKE FLOOD

- Dynamic model coupling MIKE21 with MIKE11
- Finite difference solver
- Flooding and drying capabilities
- Groundwater losses in canal and marsh can be included
- Spatially variable marsh resistance, precipitation, ET and dispersion coefficient can be included
- Control structure can be used to access alternative of Regulation Schedule
- Developed by DHI Water & Environment (DHI, 2008)
Grid for Marsh Simulation
Canal in MIKE 11

L40 chainage 28272

L7 chainage 33620
Model Setup

• Period of study 1995-2006
  - calibration 2000-2004

• Lateral cell link of MIKE21 to MIKE11

• Initial water level – uniform in the marsh and canal

• Initial concentration – spatially varied in marsh based on measurements using inverse distance, uniform in canal

• Time integration method – Euler

• Time step – 5 min for hydrodynamics, variable for water quality ranging from 1 min to 3 min
Model Calibration - Hydrodynamics

Parameters:

- Marsh and canal roughness: bed resistance is calculated based on Manning's equation
- Wetting and drying depths
- Coefficients for ET reduction - $f_{ETmin}$ and $H_{ET}$
- Seepage rate in the marsh and the canal
Gage 1-7 (Soil Level - 4.8 m)

Stage (m)

1/1/2000
12/31/2000
12/31/2001
12/31/2002
12/31/2003
12/30/2004
12/30/2005
12/30/2006

Observed
Model Prediction

- North
- 1-7
- South
- 1-8
- 1.8C
- 1.8
- 1.9

- 1-7

- North

- South

- 1-8

- 1.8C

- 1.8

- 1.9

- 1-7
Gage 1-8T (Soil Level - 4.6 m)

Stage (m)


1.8C
1.8
1.7

Observed
Model Prediction
Gage South (Soil Level - 4.47 m)

Stage (m)


Observed  Model Prediction

North
South

1-7
1-8
1-8C
1-9

<table>
<thead>
<tr>
<th>Parameter</th>
<th>North</th>
<th>1-7</th>
<th>1-8T</th>
<th>1-9</th>
<th>South</th>
<th>1-8C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bias (m)</strong></td>
<td>0</td>
<td>0.041</td>
<td>0.093</td>
<td>0.07</td>
<td>0.117</td>
<td>0.067</td>
</tr>
<tr>
<td><strong>RMSE (m)</strong></td>
<td>0.085</td>
<td>0.088</td>
<td>0.125</td>
<td>0.102</td>
<td>0.15</td>
<td>0.155</td>
</tr>
<tr>
<td><strong>Variance Reduction</strong></td>
<td>46%</td>
<td>66%</td>
<td>82%</td>
<td>77%</td>
<td>80%</td>
<td>74%</td>
</tr>
<tr>
<td><strong>R (Correl Coef)</strong></td>
<td>0.82</td>
<td>0.87</td>
<td>0.45</td>
<td>0.91</td>
<td>0.9</td>
<td>0.86</td>
</tr>
<tr>
<td><strong>Nash-Sutcliffe Eff</strong></td>
<td>0.669</td>
<td>0.708</td>
<td>0.631</td>
<td>0.72</td>
<td>0.614</td>
<td>0.566</td>
</tr>
</tbody>
</table>
## Validation Statistics (2005-2006)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>North</th>
<th>1-7</th>
<th>1-8T</th>
<th>1-9</th>
<th>South</th>
<th>1-8C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bias (m)</strong></td>
<td>0.083</td>
<td>0.101</td>
<td>0.129</td>
<td>0.117</td>
<td>0.133</td>
<td>0.111</td>
</tr>
<tr>
<td><strong>RMSE (m)</strong></td>
<td>0.087</td>
<td>0.106</td>
<td>0.136</td>
<td>0.121</td>
<td>0.14</td>
<td>0.131</td>
</tr>
<tr>
<td><strong>Variance Reduction</strong></td>
<td>88%</td>
<td>89%</td>
<td>91%</td>
<td>93%</td>
<td>91%</td>
<td>83%</td>
</tr>
<tr>
<td><strong>R (Correl Coef)</strong></td>
<td>0.96</td>
<td>0.95</td>
<td>0.96</td>
<td>0.97</td>
<td>0.96</td>
<td>0.91</td>
</tr>
<tr>
<td><strong>Nash-Sutcliffe Eff</strong></td>
<td>0.534</td>
<td>0.487</td>
<td>0.405</td>
<td>0.479</td>
<td>0.434</td>
<td>0.463</td>
</tr>
</tbody>
</table>
Hydrodynamic Animation I
06/2005-01/2006
Hydrodynamic Animation II
06/2006-12/2006

MzResultView1

H Water Depth m [m]
- Above 1.68
- 1.56 - 1.68
- 1.44 - 1.56
- 1.32 - 1.44
- 1.20 - 1.32
- 1.08 - 1.20
- 0.96 - 1.08
- 0.84 - 0.96
- 0.72 - 0.84
- 0.60 - 0.72
- 0.48 - 0.60
- 0.36 - 0.48
- 0.24 - 0.36
- 0.12 - 0.24
- 0.00 - 0.12
- Below 0.00
- Undefined Value

06/29/06 12:00:00, Time step 2371 of 2555
Water Quality Modeling

Modules: AD and ECO Lab

- AD: Standard advection-dispersion module

- ECO Lab
  - Open process module for ecological modeling
  - Template independent of grid system
  - Components - state variables, constants, forcings, auxiliary variables, processes, and derived outputs
ECO Lab

MIKE FLOOD ECO Lab Equations:

Rate of mass accumulation = Mass inflow - Mass outflow + Dispersion in – Dispersion out + Production - Disappearance

\[ A_{\text{cell}} \frac{dhc}{dt} = Q_i C_i b - Q_o C_o + \text{Disp} + \text{Source} - K_s C \]

• Mass inflow – aerial deposition
  wet deposition = rain rate * rain concentration
dry deposition = loading rate

• Mass outflow
  evaporation = does not transport mass
  transpiration = ET * % trans * C
ECO Lab (cont.)

• Chloride (CL) is modeled as conservative tracer

• Sulphate is modeled using Monod relationship with half saturation constant

\[
\text{disappearance rate} = -k_0 \frac{c}{k_{1/2} + c}
\]

• Total Phosphorus (TP) is modeled following DMSTA dynamics (Walker and Kadlec, 2005) (http://www.wwwalker.net/dmsta/index.htm)
  - water column storage
  - biomass storage
DMSTA

TP cycling processes
Auxiliary variables

• Concentration multiplier $F_c$
  \[
  \frac{0.3}{0.3 + C}
  \]

• Depth function $F_z$
  \[
  \begin{cases} 
    1 & \text{if } Z_x \leq 0 \\
    \min(1, \text{depth} / Z_x) & \text{otherwise}
  \end{cases}
  \]
# DMSTA Calibration Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Uptake Rate</td>
<td>K1</td>
<td>0.24</td>
<td>m³/mg-year</td>
</tr>
<tr>
<td>Recycle Rate</td>
<td>K2</td>
<td>0.005</td>
<td>m²/mg-year</td>
</tr>
<tr>
<td>Burial Rate</td>
<td>K3</td>
<td>0.75</td>
<td>1/year</td>
</tr>
<tr>
<td>Depth Scaling Factor</td>
<td>Z_x</td>
<td>0.6</td>
<td></td>
</tr>
</tbody>
</table>
- Initial P storage in the sediment layer

http://www.wwwalker.net/dmsta/doc/doc_storage.htm
Conclusions

- Model results in good agreement with observations.
- Statistics are encouraging that model would meet project objectives.
- Model is computationally efficient (Intel (R) T7600 2.33GHz, 3.25GB RAM)
  - to run 1 year of hydrodynamic requires 0.75 CPU hours
  - to run 1 year for CL requires 2.0 CPU hours
- New model of 400m resolution available for Refuge restoration planning applications and the Everglades simulation.
Future/Ongoing Developments

• Validate models for the Period of Record between 1995 and 1999

• Ground water seepage will be enhanced by MIKE SHE.

• Regulation Schedule and management scenarios are being assessed.
Questions?