LAR BPWG
Technical Presentation
Understanding Numerical Models
February 21, 2017
Presentation Outline

• Model Concepts
• Model Assumptions
• Types of Models
• Examples of Model Applications
Key Points

- Numerical model results are **Approximate Solutions** based on Numerous Assumptions
- There are many types of models, and there is no one model to rule them all.
- Models are tools

"He uses statistics as a drunken man uses lamp posts—for support rather than for illumination."
- Andrew Lang
Key Points (courtesy of Deltares)

• All models are **wrong**, but some are **useful** (George Box, 1979)
  – Wrong ≠ Useless
  – Need to understand model errors and limitations:
    • Model formulations
    • Model applications
    • User error
    • Interpretation of model results

Quoted by Lesser (2009).
An Approach to Medium-term Coastal Morphological Modelling.
Model Concepts

- Conservation of Energy (1D steady state)
- Conservation of Mass
- Conservation of Momentum
Navier-Stokes Equations (sorry)

- Non-linear sets (more than 1 solution)
- Partial Differential Equations (no true solution)

Continuity:
\[ \frac{\partial \rho}{\partial t} + \frac{\partial (\rho u)}{\partial x} + \frac{\partial (\rho v)}{\partial y} + \frac{\partial (\rho w)}{\partial z} = 0 \]

X - Momentum:
\[ \frac{\partial (\rho u)}{\partial t} + \frac{\partial (\rho u^2)}{\partial x} + \frac{\partial (\rho uv)}{\partial y} + \frac{\partial (\rho uw)}{\partial z} = -\frac{\partial p}{\partial x} + \frac{1}{Re} \begin{bmatrix} \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial z} \\ \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{yz}}{\partial z} \\ \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z} \end{bmatrix} \]

Y - Momentum:
\[ \frac{\partial (\rho v)}{\partial t} + \frac{\partial (\rho uv)}{\partial x} + \frac{\partial (\rho v^2)}{\partial y} + \frac{\partial (\rho vw)}{\partial z} = -\frac{\partial p}{\partial y} + \frac{1}{Re} \begin{bmatrix} \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{yz}}{\partial z} \\ \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{yz}}{\partial z} \\ \frac{\partial \tau_{yz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z} \end{bmatrix} \]

Z - Momentum:
\[ \frac{\partial (\rho w)}{\partial t} + \frac{\partial (\rho uw)}{\partial x} + \frac{\partial (\rho vw)}{\partial y} + \frac{\partial (\rho w^2)}{\partial z} = -\frac{\partial p}{\partial z} + \frac{1}{Re} \begin{bmatrix} \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z} \\ \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{yz}}{\partial z} \\ \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z} \end{bmatrix} \]
Model Inputs/Assumptions

- Boundary Conditions
  - How much flow?
  - D.S. Water Level (typically)

- Bathymetry/Topography
  - Adequate resolution

- Momentum Loss
  - Bed Roughness
  - Turbulence

Figure from Bay-Delta SELFE Calibration Overview (DWR 2014)
Bed Roughness

- **Manning’s n**
  - Empirical (based on observation)
  - 1D assumption
  - Inherently accounts for skin, form, and turbulence
  - 1D -> 2D conversion is variable & dependent on 2D assumptions

<table>
<thead>
<tr>
<th>Description</th>
<th>Minimum</th>
<th>Normal</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture, no brush</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short grass</td>
<td>0.025</td>
<td>0.030</td>
<td>0.035</td>
</tr>
<tr>
<td>High grass</td>
<td>0.030</td>
<td>0.035</td>
<td>0.050</td>
</tr>
<tr>
<td>Cultivated areas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No crop</td>
<td>0.020</td>
<td>0.030</td>
<td>0.040</td>
</tr>
<tr>
<td>Mature row crops</td>
<td>0.025</td>
<td>0.035</td>
<td>0.045</td>
</tr>
<tr>
<td>Mature field crops</td>
<td>0.030</td>
<td>0.040</td>
<td>0.050</td>
</tr>
<tr>
<td>Shrubs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scattered shrubs, heavy weeds</td>
<td>0.035</td>
<td>0.050</td>
<td>0.070</td>
</tr>
<tr>
<td>Light shrubs and trees, in winter</td>
<td>0.035</td>
<td>0.050</td>
<td>0.060</td>
</tr>
<tr>
<td>Light shrubs and trees, in summer</td>
<td>0.040</td>
<td>0.060</td>
<td>0.080</td>
</tr>
<tr>
<td>Medium to dense shrubs, in winter</td>
<td>0.045</td>
<td>0.070</td>
<td>0.110</td>
</tr>
<tr>
<td>Medium to dense shrubs, in summer</td>
<td>0.070</td>
<td>0.100</td>
<td>0.160</td>
</tr>
</tbody>
</table>
Types of Models

- One Dimensional (HEC-RAS)
- Two-Dimensional (RMA-2)
- Three-Dimensional (SELFE)
- Computational Fluid Dynamics (FLUENT)
Variability between Models

- **Trivial Things**
  - User interfaces, labels, output format, etc.
- **Solver Approach**
  - Finite Element vs. Finite Volume
- **Turbulent Momentum Loss**
- **Channel Roughness**
  - Manning’s n, ks, emergent vegetation
- **Bells & Whistles**
  - Weir/culvert equations, etc.
Model Selection/Application

- What question is being asked?
- What is the scale of the issue?
- What are the dominant processes?
- What information is available?
Model Cascade

De Vriend, 1998
Deltares
Bullock Bend Example

• Design flows and Boundary Conditions
  – Existing CVFED HEC-RAS model

• Capacity Impacts/Design Hydrology
  – Simplified CVFED HEC-RAS

• Navigation/Geomorphistic Impacts
  – 2D AdH model
Using Model Data

- Model Sensitivity to Assumptions
  - Boundary Conditions
  - Grid resolution/Cross-section spacing
  - Bed roughness

- Understanding Model Limitations

- Multiple Solutions -> Range of Results

- Quantitative & Comparative Results
Questions?