Comparison and Utilization of 1D, 2D, and 3D Hydraulic Models on a Complex Diversion Structure

Brinton Swift, P.E.
Project Partners

- Coastal Resource and Protection Agency
- U.S. Army Corps of Engineers
- HDR
- The Water Institute of the Gulf
- BCG Engineering
- Moffatt & Nichol
- Dynamic Solutions
- GeoEngineers
- Fugro
Presentation Overview

- Hydraulic Model Overview
- Application of Hydraulic Models
- Example of Hydraulic Modeling on Project
  - Project Needs
  - Model Selection
  - Model Results
  - Model Coordination
  - Lessons Learned
- Recommendations
Hydraulic Models

- 1 Dimensional Models
  - Cross Section Based Depth Averaged
    - Steady or Unsteady Modeling Approaches

- 2 Dimensional Models
  - Grid or Mesh Based Depth Averaged

- 3 Dimensional Models
  - Structured or Unstructured Grid or Mesh
General Application Of Hydraulic Models

- 1 Dimensional Model
  - Steady or Unsteady Riverine Systems
  - Flow Primarily One Direction
  - Minimal Split Flow

- 2 Dimensional Model
  - Shallow Floodplain Flow
  - Braided or Split Flow Conditions
  - Minimal Depth Varied Velocity (Sand Bars, River Bends, etc)

- 3 Dimensional Model
  - Complex Riverine Systems
  - Flow Around Structures
  - Depth Varied Velocities
Modeling For Mid Barataria Sediment Diversion

- **Large Scale Sediment Diversion on Mississippi River Goals**
  - Divert 15,000-75,000 cfs of Water and Sand
  - Maximize Land Building and Habitat Creation in Barataria Basin
  - Reduce Impacts to Environment and Residents
  - Limit Impacts to Navigation

- **Modeling Needs**
  - Identify Optimum Channel Size
  - Determine Impacts to Barataria Basin Hydraulics
  - Understand Inlet Hydraulics
  - Optimize Inlet Sediment Capture
Modeling for Mid Barataria Sediment Diversion

- **Modeling Approach**
  - **1 Dimensional Analysis**
    - Optimize 10% Channel Hydraulics
    - Investigate Channel Sediment Conveyance
    - Review Gate Operation and Bridge Impacts
  - **2 Dimensional Analysis**
    - Look at Impacts to Barataria Basin
    - Review Channel Geometry Hydraulic Impacts
    - Couple River and Basin Models
  - **3 Dimensional Analysis**
    - Identify Complex Hydraulics around Intake, Control Structures, and Transitions
    - Provide Better Understanding of Hydraulic Losses
    - Determine Sediment Capture Impacts
  - **Additional Models**
    - Water Quality
    - Storm Surge
    - Wave
    - Delta Land Building
Mid Barataria 1 Dimensional Model

- HEC-RAS Unsteady Model
  - Upstream Stage Boundary
  - Downstream Normal Depth Boundary
  - Approximate Expansion of Flow into Barataria Basin

- Benefits
  - Many Iterations of Geometric and Boundary Conditions
  - Runs very quickly

- Limitations
  - Doesn’t capture dynamics of structures and outfall
Mid Barataria 2 Dimensional Model

- HEC-RAS 2D Model
  - Barataria Basin
  - Linked River, Channel, Outfall Model
    - 1-Mile Outfall Area

- Benefits
  - Easy to set up
  - Relatively fast model run times
  - Large model domain
  - Stable platform

- Limitations
  - More difficult to run iterations of geometry
  - Doesn’t capture depth varied velocities around structures
Mid Barataria 3 Dimensional Model

- **FLOW3D CFD Model**
  - Investigated Inlet Combinations
  - Linked River, Channel, Outfall Model
  - Investigated Hydraulic Losses

- **Benefits**
  - Capable of modeling complex hydraulics of inlet, tracers, and particle tracking
  - Fairly easy to set up with the right solid files

- **Limitations**
  - Long model run times
  - Slightly more unstable
Mid Barataria Model Results

- 1 Dimensional HEC-RAS Model
  - Ran over 150 hydraulic models and 30 sediment transport models.
  - Identified long initial long term deposition rates in the diversion channel.
  - Created relationship curves for diversion channel geometry and velocities.
  - Investigated sensitivity to Barataria Basin water surface elevations.
Mid Barataria Model Results

- 2 Dimensional HEC-RAS Model Compared with 3 Dimensional FLOW3D Model
Mid Barataria Model Results

- 2 Dimensional HEC-RAS Model Compared with 3 Dimensional FLOW3D Model
Mid Barataria Model Results Comparison

- 2 Dimensional and 3 Dimensional in Good Agreement
- 1 Dimensional model clearly not in good agreement
  - Upstream energy losses appear to not be captured
  - Flow is definitely varied between the 3 inlet channels
Mid Barataria Model Coordination

- Inlet Losses
  - Much greater than expected ~ 2 ft
  - Adjusted HEC-RAS model for inlet losses
Mid Barataria Model Coordination

- HEC-RAS Ineffective Flow Areas
  - Adjusted based on 3D model results

1 Dimensional HEC-RAS

Ineffective Flow Boundaries

Upstream End Transition

3 Dimensional FLOW3D

velocity magnitude and vectors

(y multiplied by 1.e-05)
Mid Barataria Model Comparison

- Water Surface Elevations
  - Excellent agreement
  - Allowed Iterations of Channel Geometry, Operation, Assumptions
    - Promising results required confirmation with 2 Dimensional and 3 Dimensional Models
Mid Barataria Modeling

- **Lessons Learned**
  - Terrain is important
  - Time step is important
  - Grids are important, you can go overboard!
  - Model planning is essential
  - Significant hydraulic losses need to be considered around structures

- **Next Steps**
  - Linked hydraulic model with full Barataria Basin
  - Project specific geomorphic modeling
  - Physical Models (LSU & CPRA Small Scale Mississippi River Model)
  - Water quality models for Barataria Basin
Hydraulic Modeling Recommendations

- Each type of model is very useful
- Understand strengths and weakness of each model
- Plan modeling approach well in advance with entire project team
- Understand the system features!
- Sanity check everything!
Questions?