Floodplain Inundation Mapping using Combined One-Dimensional/Two-Dimensional (1D/2D) Models

Kevin M. Miller, P.E., CFM, Gomez and Sullivan Engineers, D.P.C.
Outline

- Background
- Model Setup
- Calibration
- Results
- Lessons Learned
Background

- Objective: Update Inundation Mapping for Emergency Action Plan (EAP)

- Project Site: Pumped Storage Facility

- Modeling Software: HEC-RAS (5.0.3)
Background (Continued)

• Breach Flow Path
  • Not in well-defined channels
  • Enters receiving body perpendicular to its natural flow path

• Study Extent
  • 24 Miles
Background (Continued)

- Combined 1D/2D Model
  - Benefits over 1D only analysis
    - Increased hydraulic analysis detail where needed
  - Benefits over 2D only analysis
    - decrease effort during model setup
    - decrease computer run times
Model Setup

- Data Requirements
  - Ground Elevations (above/below water)

- Structures (Dams and Bridges)
  - Dams can be modeled in 1D and 2D portions of the model
  - Bridges are fully functional in 1D, but pressure flow cannot be modeled in 2D
Model Setup (Continued)

- Geometric Layout
  - Cross-Section Spacing and Orientation
  - Cell Size and Alignment

- Boundary Conditions
  - Flow Hydrographs
  - Water Levels/Rating Curves
Model Setup (Continued)

- Operational Data
  - Not enough response time to open more gates at the downstream dam to pass the breach flow (1.5 hours)
  - While the water is not expected to rise enough to fail the dam, the closed gates would be overtopped
  - Computational Fluid Dynamics (CFD) model used to evaluate discharge over the closed gates
Model Setup (Continued)

- **Operational Data (Continued)**
- Series of 2D slices analyzed, and results compared to full 3D models for some headwater elevations to confirm scaling
Model Setup (Continued)

- Operational Data (Continued)
  - Rating curve developed for flow over a closed gate
Model Setup (Continued)

- **Stability**
  - Steep slope required small cells (5 ft.) to model a smooth water surface and proper flow transfer
  - High velocity flow required small time step (0.1 secs) to meet Courant Condition
    - Courant Number $\left(\frac{V\Delta t}{\Delta x}\right)$ ideally $\leq 1$
Calibration

• A 2D model may require different Mannings Roughness values than a 1D model of the same area

• 2D models are better able to account for turbulence, form losses and bend losses

• The selection of cell size may also influence the estimation of these losses
Calibration (Continued)

- Observed water surface elevation (WSEL) available from significant historic event

- Calibrated WSEL 0.2 feet higher than Observed WSEL

- Calibrated Mannings Roughness of 0.01 in the channel
  - Increasing this by 0.01, increased the WSEL by approximately 1 foot

- Mannings Roughness converted to roughness height and was found to correlate well with other 2D model guidelines
Results

- Limited discharge capacity at downstream dam (due to closed gates) caused the flood wave to reflect back upstream.
Results (Continued)

- 2D models have more options to provide information in an EAP.

- However, the EAP developed from a Combined 1D/2D model should be consistent for emergency managers.

- Artificial “cross-sections” were developed in the 2D area for reporting results.
The values of all cells intersected by the artificial “cross-sections” are considered to determine the appropriate value to report in the EAP.

- The Federal Energy Regulatory Commission’s Engineering Guidelines indicate that the cell with the deepest inundation should be used for reporting, however this is not always the most critical cell.
- Maximum WSEL: Average of the cells within 2-standard deviations.
- All other parameters reported for the cell with the highest incremental rise.
Lessons Learned

- Combined 1D/2D Models allow for best of both worlds
  - Complex Analysis while maximizing value (less time and cost)

- Cell Size and Time Step Selection are interrelated
  - Determined by Model Accuracy and Stability

- Calibration is Crucial for 2D Models
  - 1D Model Mannings Roughness Guidelines: 0.025 – 0.04
  - Calibrated 2D Model Mannings Roughness: 0.01

- Engineering Judgement required to develop EAP
  - Selection of how to best report results
Questions?

Kevin Miller, PE, CFM
Water Resources Engineer
Gomez and Sullivan Engineers, D.P.C.
513-560-9715
kmiller@gomezandsullivan.com