Dam Breach Analysis – 1D vs. 2D

PREPARED FOR:

2018 KAMM CONFERENCE

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Overview

Importance of Being Prepared

1D vs. 2D Modeling

Representative Project Overview

1D vs. 2D Results Comparison
Introduction

Statistics from the National Inventory of Dams
Introduction

Statistics from the National Inventory of Dams
Introduction

“By failing to prepare, you are preparing to fail.”
- Benjamin Franklin
2D vs. 1D Modeling

What’s the difference?

Definitions

▪ 1D Modeling
  Solves the fully dynamic St. Venant equations of conservation of mass and momentum along a singular dimension.

▪ 2D Modeling
  Solves the fully dynamic St. Venant equations of conservation of mass and momentum along two dimensions.
2D vs. 1D Modeling

Hydraulic Modeling Utilizing HEC-RAS 2D

▪ 1D Advantages
  o Fewer geometric data are required
  o Shorter computational time
  o In-bank flows computed more efficiently
  o Relatively smaller output files
  o Hydraulic structures (2D uses culvert eqns)

▪ 2D Advantages
  o Flowpaths do not need to be predefined
  o Provides realistic depiction of flow throughout a system
    o Perform 1D and 2D modeling within the same unsteady flow model allows users to model larger river systems, 1D where appropriate (main river) and 2D modeling in areas that require a higher level of hydrodynamics
  o Flowpaths can change with flow depth
    o Cross-momentum of flow splits is accounted for (significant for road systems)
    o Losses due to 2D effects (i.e. bends, flow separations, etc.) automatically included within computations
    o Floodplain storage is implicitly defined
    o Inputs and outputs can be defined spatially in GIS-type environments (better data continuity)
    o Does not require extraction of cross sections from survey data
  o Detailed Flood Mapping and Flood Animations – based on underlying terrain, each cell can be partially wet/dry reflected in the mapping and animations
    o Can provide results directly for mapping flood extents and inundation depths, velocities, and safety hazards
2D vs. 1D Modeling

Hydraulic Modeling Utilizing HEC-RAS 2D

▪ When is 1D Okay
  o Locations where flow isn’t required to spread (uni-directional flow)
  o Well-defined channel/overbank systems (defined valleys)
  o Simply-connected floodplains where flow in main channel is well connected to flow in the overbank and both are primarily uni-directional
  o When elevation data of only limited quality/quantity are available

▪ When is 2D Preferable
  o Anywhere flow is expected to spread
  o Urbanized Areas
  o Wide Floodplains
  o Downstream of Levee Breaks
  o Downstream of Upground Reservoir Breaks
  o Wetland Studies
  o Lake or Estuary Studies
  o Water Quality and Sediment Transport
2D vs. 1D Modeling

Hydraulic Modeling Utilizing HEC-RAS 2D

- 1D or 2D?
  - What is the length-to-width ratio of the project area? (> or < 3:1?)
  - Does the project have features that force flow to rapidly contract or expand?
  - What kind of output animations are needed to convey the results to the stakeholders?
Representative Project Overview

Four Eagles Lake – Camden, Ohio

- 25.5-acre reservoir at normal pool
- 45-foot high, 620-foot long embankment
- 3.1 sq mi drainage area
- High Hazard Dam
Representative Project Overview
Representative Project Overview

Project Overview Aerial Map
Representative Project Overview

Project Overview Hillshade Map
Project Overview
# Dam Breach Assumptions/Parameters

## Four Eagles Lake Dam Characteristics

<table>
<thead>
<tr>
<th>Feature/Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Embankment Height</td>
<td>45 feet</td>
</tr>
<tr>
<td>Length of Dam</td>
<td>620 feet</td>
</tr>
<tr>
<td>Crest Width</td>
<td>18 feet</td>
</tr>
<tr>
<td>Crest Elevation</td>
<td>957.96 feet</td>
</tr>
<tr>
<td>Reservoir Area at Top of Dam</td>
<td>42 acres</td>
</tr>
<tr>
<td>Storage Capacity at Top of Dam</td>
<td>616 acre-feet</td>
</tr>
<tr>
<td>Principal Spillway Type</td>
<td>Concrete weir with baffled chute</td>
</tr>
<tr>
<td>Principal Spillway Crest Elevation</td>
<td>947.46 feet</td>
</tr>
<tr>
<td>Storage Capacity at Principal Spillway Elevation</td>
<td>255 acre-feet</td>
</tr>
<tr>
<td>Reservoir Area at Principal Spillway</td>
<td>25.5 acres</td>
</tr>
<tr>
<td>Emergency Spillway Type</td>
<td>Grass-lined open channel with 3H:1V side slopes</td>
</tr>
<tr>
<td>Emergency Spillway Crest Elevation</td>
<td>952.46 feet</td>
</tr>
</tbody>
</table>
## Dam Breach Assumptions/Parameters

### Summary of Breach Results

Probable Maximum Flood

<table>
<thead>
<tr>
<th>Scenario</th>
<th>PMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pool Elevation at Breach, Initial (ft)</td>
<td>957.77</td>
</tr>
<tr>
<td>Time Breach Occurs</td>
<td>13:04</td>
</tr>
<tr>
<td>Breach Type</td>
<td>Piping</td>
</tr>
<tr>
<td>Storage Volume at Breach (ac-ft)</td>
<td>608.61</td>
</tr>
<tr>
<td>Discharge at Dam, Peak (cfs)</td>
<td>63,063</td>
</tr>
</tbody>
</table>
HEC-RAS Geometry Map

1D

2D: 10-foot by 10-foot grid
2D Results – Inundation Boundary
2D Results – Inundation Boundary
2D Results – Inundation Boundary
2D Results – Inundation Boundary
2D Results – Particle Tracing
2D Results - Particle Tracing
2D Results - Particle Tracing
2D Results - Particle Tracing
2D Results - Particle Tracing
2D Results – Time Series
2D Results – Time Series
2D Results – Inundation Boundary
2D Results – Inundation Boundary
2D Results – Inundation Boundary
1D vs 2D Results – Inundation Boundary
1D vs 2D Results – Inundation Boundary
1D vs 2D Results – Inundation Boundary
1D vs 2D Results – Inundation Boundary
1D vs 2D Results – WSEL Profiles

PMF Breach - Water Surface Elevation Profiles (Entire Downstream Reach)
1D vs 2D Results – WSEL Profiles

PMF Breach - Water Surface Elevation Profiles (Downstream End of Study)
1D vs 2D Results – Velocity Profiles
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1D vs 2D Results – Velocity Profiles
1D vs. 2D Modeling

1D or 2D? Which one should we use?
1D vs. 2D Modeling

Hydraulic Modeling Utilizing HEC-RAS 2D

“All models are wrong, but some are useful.”
-George E. P. Box

“For every complex problem there is an answer that is clear, simple, and wrong.”
-H.L. Mencken
Questions

Thank You
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