2D Hydraulic and Scour Analysis for Bridge Replacement

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Project Overview
Bridge over Missouri River along Route 47

- Original Bridge
  - Built in 1934-36
  - 2 Lanes of traffic

- New Structure
  - Nine span bridge
  - 2555 feet long
  - 4 Lanes of traffic
Potential reasons to consider 2D Model

- HEC-18 states consider a 2D model “for bridges with complex flow characteristics…”
  - Embankments skewed to the flood flows
  - Multiple floodplain openings
  - Wide flood plains
  - Highly contracted flows
  - etc
- Not necessary for all bridges
Hydraulic Model Setup

- TUFLOW Classic Model
- Includes entire floodplain
- Inflow Upstream/WSE downstream
- Elevations: Lidar, single/multi beam bathy
- 40ft square grid cells
- Piers represented as partially blocked cells
- Bridge deck not included (won’t submerge)
Contraction Scour

- Can 1D model accurately represent how much water contracts under the bridge and how much goes over the roadway?
Local Scour Approach

- CSU Equation for channel piers
- FDOT Methodology for overbank piers
  - “…FDOT Methodology should be considered as an alternative, particularly for wide piers in shallow flows with fine bed material.” – HEC18 5th Edition
Impact of Angle of Attack
CSU Equation

\[
\frac{y_s}{y_1} = 2.0 K_1 K_2 K_3 \left( \frac{a}{y_1} \right)^{0.65} Fr_1^{0.43}
\]

- Scour depth proportional to \( K_2 \)
- At least double the scour if angle of attack > 30 degrees

<table>
<thead>
<tr>
<th>Angle</th>
<th>L/a=4</th>
<th>L/a=8</th>
<th>L/a=12</th>
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<tr>
<td>0</td>
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<td>1.0</td>
<td>1.0</td>
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<tr>
<td>15</td>
<td>1.5</td>
<td>2.0</td>
<td>2.5</td>
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<td>2.0</td>
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<td>3.5</td>
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<tr>
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<td>2.3</td>
<td>3.3</td>
<td>4.3</td>
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<tr>
<td>90</td>
<td>2.5</td>
<td>3.9</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Angle = skew angle of flow
L = length of pier
Impact of Angle of Attack
Florida DOT Methodology

\[ a_{\text{proj}} = a \cos \theta + L \sin \theta \]

\[ a^* = K_{sf} a_{\text{proj}} \]

where:
- \( a \) = Effective pier width, ft (m)
- \( \theta \) = Angle of attack in degrees
- \( L \) = Pier length, ft (m)
- \( K_{sf} \) = Shape factor (1.0 unless square nosed)

Scour depth is proportional to \( a^* \)

If length > 4 width and 30 degree angle of attack, scour increases by a factor of 2.86
Hydraulic Model Results

- Flow split between channel and floodplain
- Channel piers – Flows aligned with piers
- Overbank piers – Flows skewed to piers
Summary

- 2D hydraulic models for scour analysis
  - Provide more accurate flows for contraction scour
  - Provide angle of attack
- 2D models not always necessary
- HEC-18 gives descriptions of when a 2D model may be more appropriate