2-D Mobile Bed Hydraulic Modeling

Man-made Impacts on the Floodplain of a Highly Erodible Stream

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Introduction

~450-ft Rail Bridge in need of Replacement

- Location: Preston, NE
- Owned by BNSF
- Built in early 1940's
- ~200-ft Overflow Relief Bridge Structure

Today’s Presentation

- Project Overview
- Estimating Scour Potential in Complex Hydraulic Environments Utilizing 1-D Models
- Can 2-D Models Make this Process Easier?
- Sediment Transport Modeling a useful tool?
- Results Comparison and Discussion of Findings
1-D HEC-RAS

- Cross-Sections
- River
- Flow Paths
- Banks
- Bridge (Multiple Opening)
- Ineffective Areas

Goals

- Quantify Floodplain Impacts (Permit)
- Estimate Scour Potential (Design)
Bathymetric Survey
Hydrology

- Big Nemaha River: 1,558 mi²
- Muddy Creek: 284 mi²
- Total Project DA: 1,842 mi²

USGS Stream Gages Bulletin 17C
### Hydrology

#### Big Nemaha River

<table>
<thead>
<tr>
<th>Water Year</th>
<th>Date</th>
<th>Gage Height (feet)</th>
<th>Streamflow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>Jul. 06, 1993</td>
<td>29.77</td>
<td>59,000</td>
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</table>

<table>
<thead>
<tr>
<th>Water Year</th>
<th>Date</th>
<th>Gage Height (feet)</th>
<th>Streamflow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>Jun. 29, 1965</td>
<td>28.00</td>
<td>47,700</td>
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<td>1960</td>
<td>Mar. 28, 1960</td>
<td>27.73</td>
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<td>1982</td>
<td>Aug. 13, 1982</td>
<td>27.00</td>
<td>46,000</td>
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<td>2007</td>
<td>May 07, 2007</td>
<td>30.46</td>
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<td>1979</td>
<td>Mar. 03, 1979</td>
<td>26.10</td>
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<tr>
<td>2013</td>
<td>May 30, 2013</td>
<td>28.91</td>
<td>44,800</td>
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<tr>
<td>1978</td>
<td>May 07, 1978</td>
<td>25.83</td>
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</table>

#### Muddy Creek

<table>
<thead>
<tr>
<th>Water Year</th>
<th>Date</th>
<th>Gage Height (feet)</th>
<th>Streamflow (cfs)</th>
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<tbody>
<tr>
<td>1973</td>
<td>Aug. 12, 1973</td>
<td>32.71</td>
<td>35,000</td>
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<tr>
<td>1958</td>
<td>Jul. 10, 1958</td>
<td>31.50</td>
<td>31,900</td>
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<table>
<thead>
<tr>
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<th>Date</th>
<th>Gage Height (feet)</th>
<th>Streamflow (cfs)</th>
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</thead>
<tbody>
<tr>
<td>1960</td>
<td>Mar. 27, 1960</td>
<td>23.90</td>
<td>20,000</td>
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<tr>
<td>1961</td>
<td>Sep. 30, 1961</td>
<td>24.50</td>
<td>17,800</td>
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<tr>
<td>1954</td>
<td>Jun. 17, 1954</td>
<td>22.97</td>
<td>17,100</td>
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<tr>
<td>1964</td>
<td>Jun. 17, 1964</td>
<td>22.20</td>
<td>12,800</td>
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<td>1969</td>
<td>May 07, 1969</td>
<td>21.75</td>
<td>13,000</td>
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<tr>
<td>1957</td>
<td>Jun. 17, 1957</td>
<td>18.35</td>
<td>10,200</td>
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<tr>
<td>1962</td>
<td>May 28, 1962</td>
<td>19.60</td>
<td>10,100</td>
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#### Adjusted Project Location

<table>
<thead>
<tr>
<th>% Chance Exceedance</th>
<th>Flow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>170,275</td>
</tr>
<tr>
<td>0.5</td>
<td>147,191</td>
</tr>
<tr>
<td>1</td>
<td>130,287</td>
</tr>
<tr>
<td>2</td>
<td>113,823</td>
</tr>
<tr>
<td>5</td>
<td>92,622</td>
</tr>
<tr>
<td>10</td>
<td>76,858</td>
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<tr>
<td>20</td>
<td>61,057</td>
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<tr>
<td>50</td>
<td>38,815</td>
</tr>
<tr>
<td>80</td>
<td>24,270</td>
</tr>
<tr>
<td>90</td>
<td>18,863</td>
</tr>
<tr>
<td>95</td>
<td>15,265</td>
</tr>
<tr>
<td>99</td>
<td>10,174</td>
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</tbody>
</table>
Calibration

- Regression Equations
- Recent Storm Event
- BFE Determination
Flow Angle of Attack
Flow Angle of Attack
HEC-18 Bridge Scour

Contraction Scour

Pier (Local) Scour
Scour Analysis

- EGL slope
- Hydraulic Depths
- Velosity
- Discharge Rates
- Channel Widths
- Soil Particle Size
Scour Results
What wasn’t accounted for?
Truncated 1-D Model
Full Floodplain

130,000-cfs Total

Truncated

95,000-cfs
1-D HEC-18 Scour Results

27-ft
SRH-2D (Sedimentation and River Hydraulics)
2D Steady State

- Steady Flow – No Transport
- Restart Required
- Ensure model accuracy
  - Keep Sediment Transport in Mind
  - Low Resolution Mesh
- 2D Parts
  - Mesh Density and Quality
  - Polygons/Mesh Orientation
  - Topo Surface
  - Materials
  - Boundary Conditions
Mesh Density and Quality

- Computationally Complex
  - Steady
    - 150,000 elements (computer power)
  - Sediment
    - 40,000 but 30 is better
  - 5-ft to 100-ft
  - Maintain Quality
    - Hole in mesh
      - No Slip
Quadrilateral Elements
Surface Terrain

- Stamped Channel
  - HEC-RAS
  - SMS
- Resolution vs Detail
Materials & Boundary Conditions

- Informed by 1D
  - 1-mile to eliminate boundary influence
- Calibration
  - Pressure Flow
  - Levee Overtopping
2D/1D Scour Tool
2D Sediment Workflow

- 2 Changes
  - Boundary Condition
  - Materials
Boundary Condition – Sediment Transport

- Bin Size
- Phi Scale

8 Equations Source?

Defaults
Boundary Conditions - Part 2

- Total Sediment Load
  - Bed Load
  - Suspended Load
  - Wash Load
- Sediment Type
  - FHWA!

5 Methods Source?

- Philips-Sutherland Saltation Length Formula
- Thickness Based on D90
- Thickness (mm)/Thickness Scale: 17.5
- Cohesive Sediment Modeling: Off
Sediment Materials

- Soil Type
- Boring Investigation
  - Detail?
- Level of Influence

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Model Results
Simulation Queue

Aggrade

Steady State?
Available Results

- Sediment Transport Mesh
  - Z
  - B_Stress_lb_p_ft2
  - Bed_Elev_ft
  - CONC_T_ppm
  - D50_mm
  - ERO_DEP_ft
  - Froude
  - Vel_Mag_ft_p_s
  - Velocity
    - Water_Depth_ft
    - Water_Elev_ft
Reaching Equilibrium Scour

How Long Does it Take?
How’d We Do

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<table>
<thead>
<tr>
<th>Model</th>
<th>1-D HEC-18</th>
<th>2-D HEC-18</th>
<th>2-D Sediment Transport (Pre-Scour)</th>
<th>2-D Sediment Transport (Post-Scour to Bedrock)</th>
<th>2-D Sediment Transport (Post-Scour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Through Bridge (cfs)</td>
<td>95,317</td>
<td>92,339</td>
<td>92,339</td>
<td>84,700</td>
<td>101,000</td>
</tr>
<tr>
<td>Contraction Scour Depth (ft)</td>
<td>27.0</td>
<td>28.7</td>
<td>N/A</td>
<td>12.3</td>
<td>34.8</td>
</tr>
<tr>
<td>Contraction Scour Bed Elevation (ft)</td>
<td>806.3</td>
<td>804.6</td>
<td>833.0</td>
<td>820.7</td>
<td>798.22</td>
</tr>
</tbody>
</table>
What's Wrong With This Picture?
Questions to ask yourself

• What’s the right level of complexity
  • 1D, 2D + 1D HEC18, 2D Sediment Transport

• How much historic data is available?
  • Calibration

• Where do I need borings?
  • How many
  • Is a surface investigation enough
    • Assumptions
    • Risk

• What about the channel
  • Equilibrium
  • Bed forms
Simulation Time

• Steady vs Unsteady
  • ¼ Speed

• 1 simulation hour = 1.5 real hours

• Troubleshooting and Iterating
Key Variables

***Start With a Well Calibrated Hydraulic Model!!

• Upstream Boundary – Capacity
• Boring Locations
• Soil Distribution
• Equations
• Sediment Depth
• Concentration
• Flow Distribution
• Time
Moral of the Story

• HEC18 vs. Sediment Transport

  • HEC-18
    • Continued refinement
    • 2D doesn’t fit every problem
    • HEC18 – 2D Informed

  • Sediment Transport
    • Black Box
    • Viable Tool
    • Continued improvement and verification
    • Contraction Only
To Be Continued

- Continued Research
  - Unverified approach
  - Incorporating pier scour
  - Long term degradation

- Coming down the pipeline
  - Bank Migration
  - 3D modeling
    - Pier scour
    - Supercomputer?
I NEED A BUDGET ESTIMATE FOR MY PROJECT, BUT I DON'T HAVE A SCOPE OR A DESIGN FOR IT YET.

OKAY, MY ESTIMATE IS $3,583,729.

YOU DON'T KNOW ANYTHING ABOUT MY PROJECT. THAT MAKES TWO OF US.