



2-D Mobile Bed Hydraulic Modeling

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

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IAFSM 2020 Annual Conference

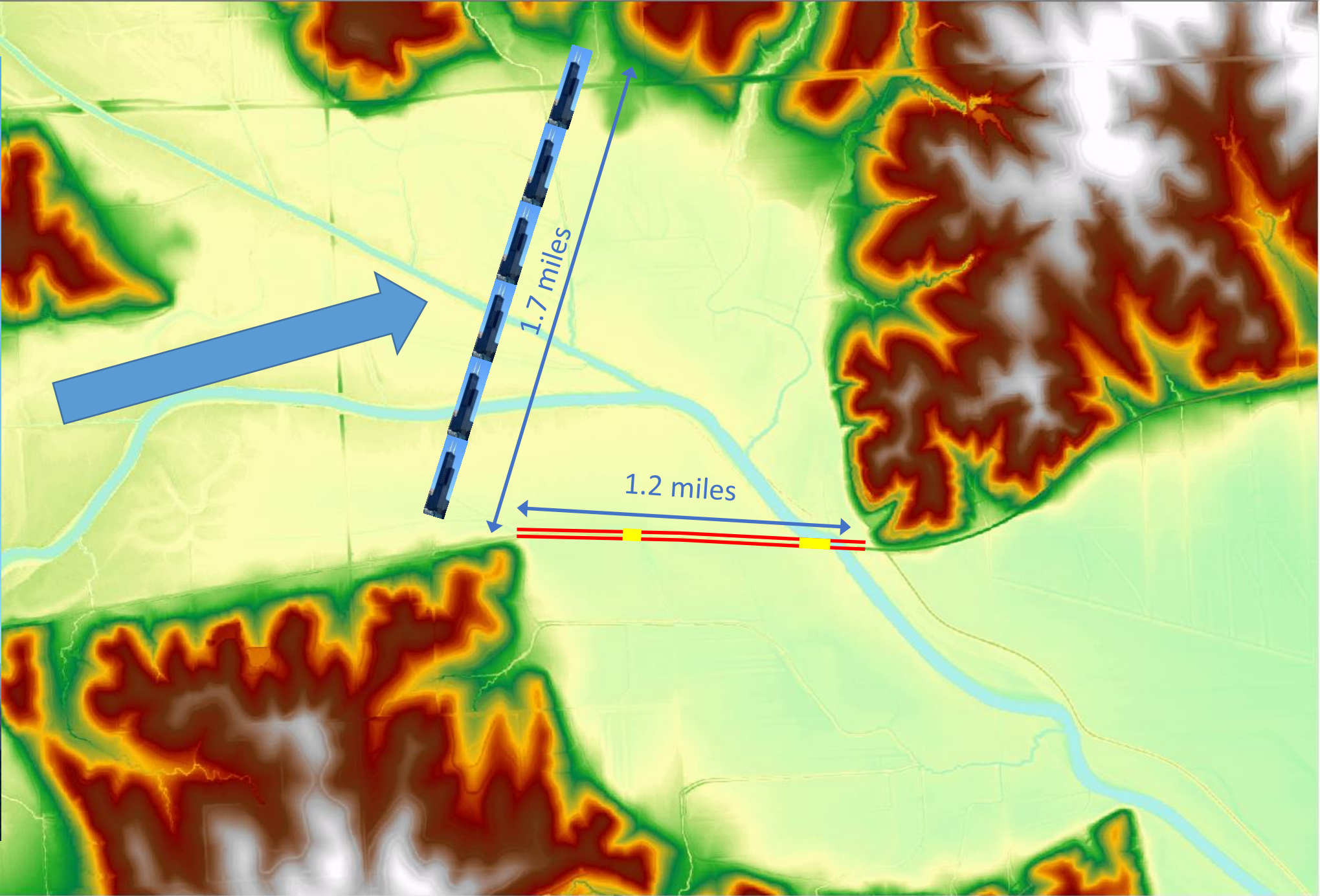
Introduction

~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



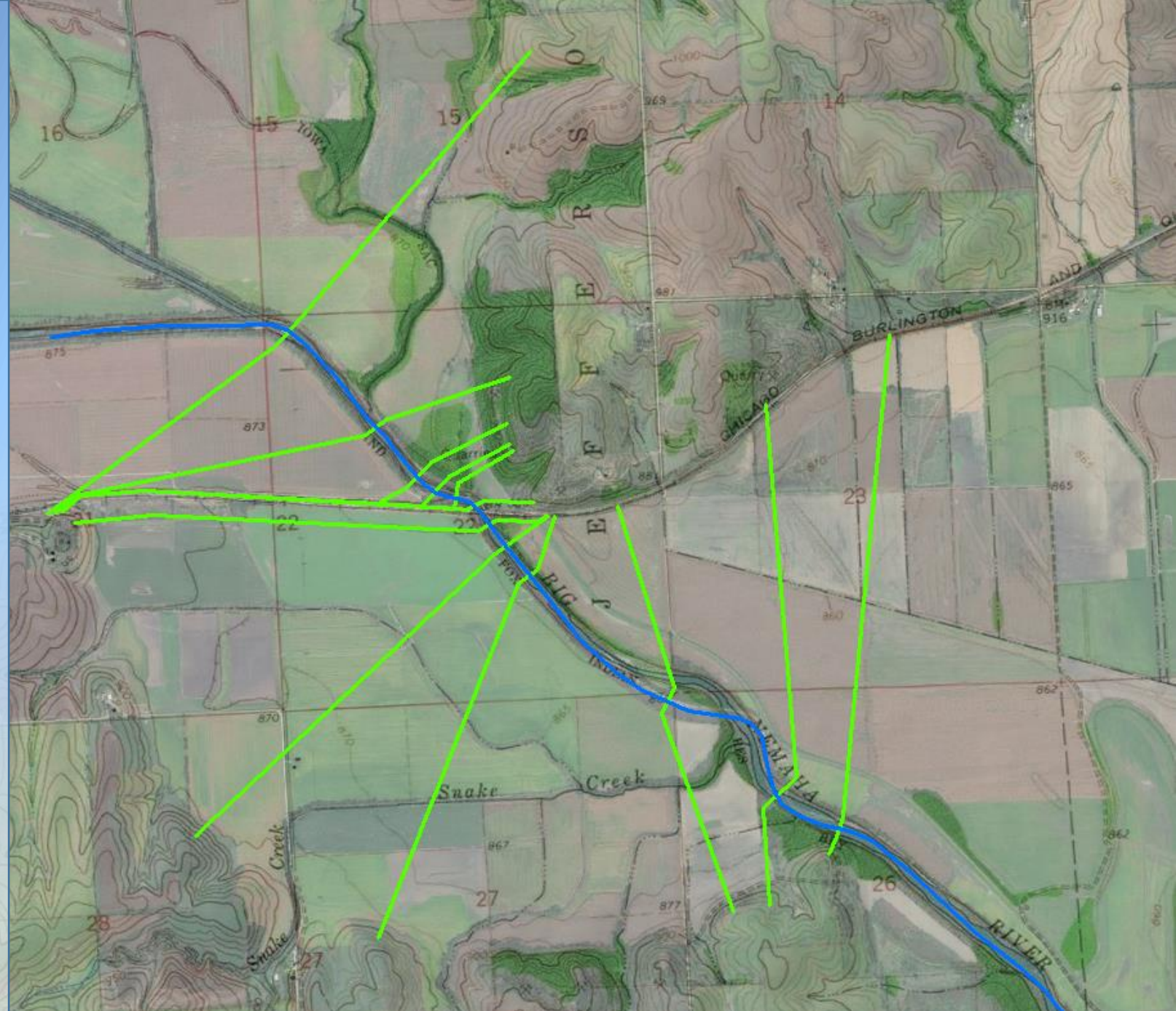


1-D HEC-RAS

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

Goals

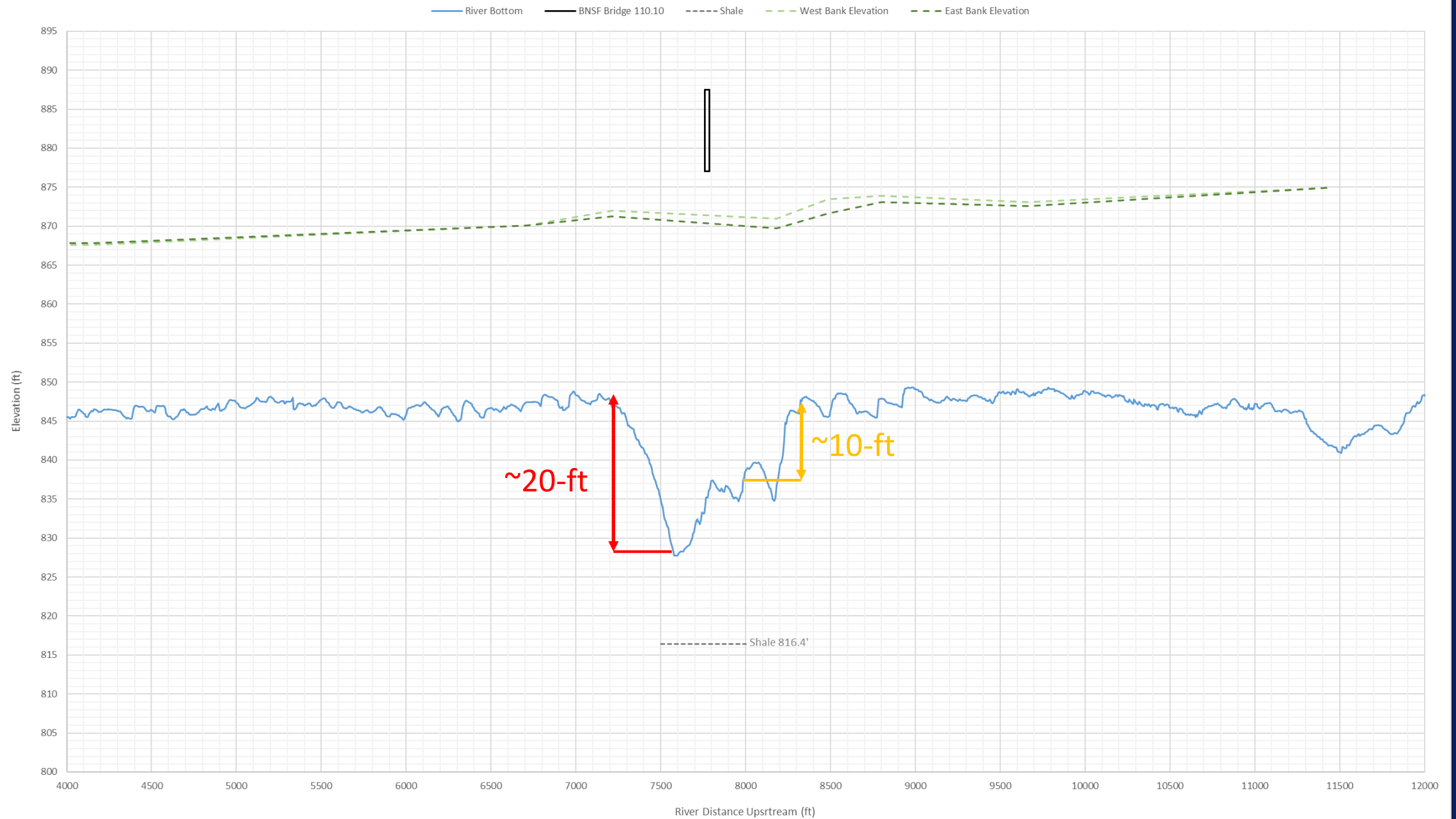
- Quantify Floodplain Impacts (Permit)
- Estimate Scour Potential (Design)



Bathymetric Survey

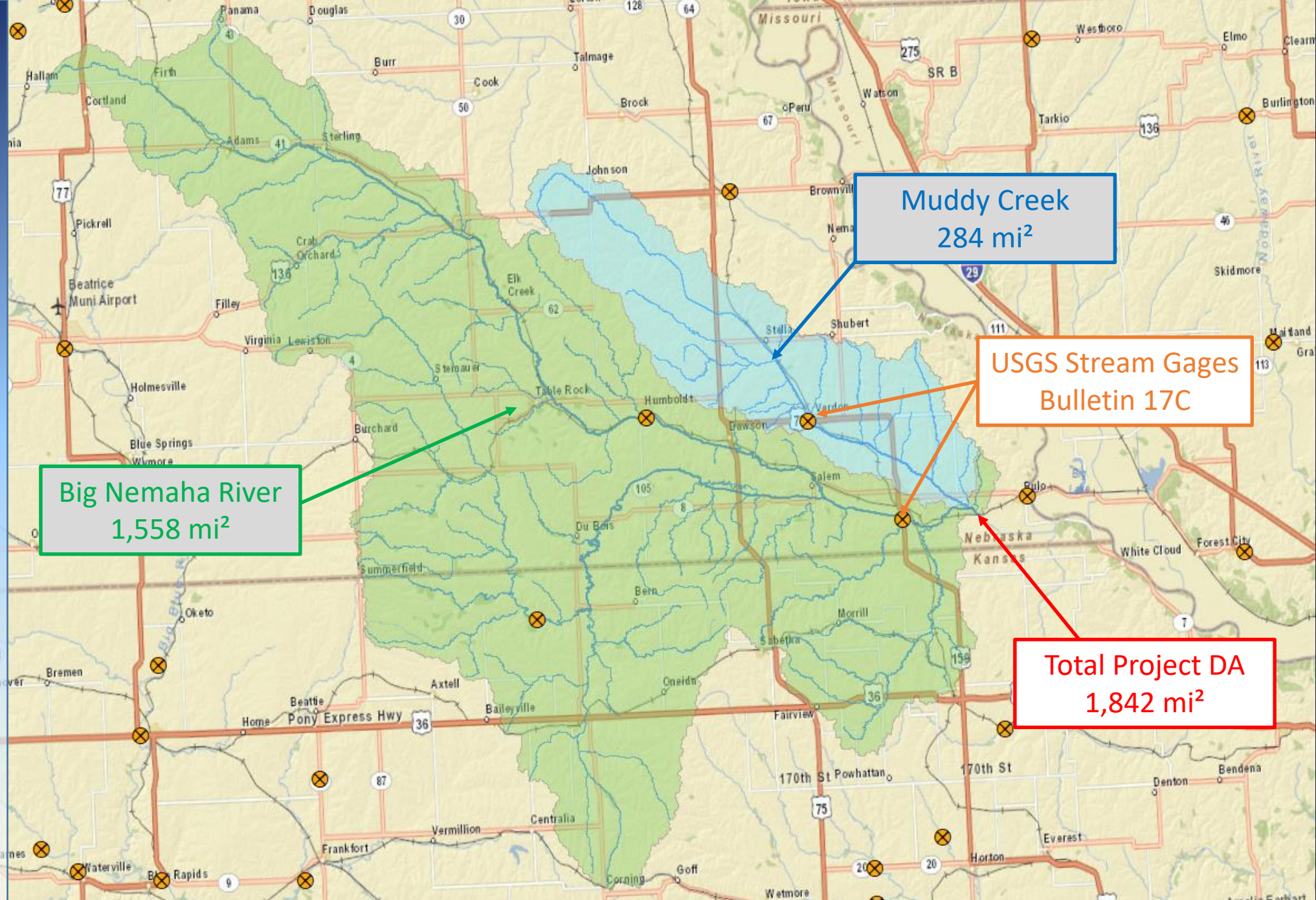


Big Nehama River Profile at BNSF Bridge 110.10 Preston, NE



This topographic map illustrates a river section with two bridges: an existing bridge labeled '(E) BRIDGE' and a proposed bridge labeled '(P) BRIDGE'. The map includes contour lines indicating elevation, with labels such as 840, 845, 850, 855, 860, 865, 870, 875, 880, 885, 890, 895, 900, 905, 910, 915, 920, 925, 930, 935, 940, 945, 950, 955, 960, 965, 970, 975, 980, 985, 990, 995, 1000, 1005, 1010, 1015, 1020, 1025, 1030, 1035, 1040, 1045, 1050, 1055, 1060, 1065, 1070, 1075, 1080, 1085, 1090, 1095, 1100, 1105, 1110, 1115, 1120, 1125, 1130, 1135, 1140, 1145, 1150, 1155, 1160, 1165, 1170, 1175, 1180, 1185, 1190, 1195, 1200, 1205, 1210, 1215, 1220, 1225, 1230, 1235, 1240, 1245, 1250, 1255, 1260, 1265, 1270, 1275, 1280, 1285, 1290, 1295, 1300, 1305, 1310, 1315, 1320, 1325, 1330, 1335, 1340, 1345, 1350, 1355, 1360, 1365, 1370, 1375, 1380, 1385, 1390, 1395, 1400, 1405, 1410, 1415, 1420, 1425, 1430, 1435, 1440, 1445, 1450, 1455, 1460, 1465, 1470, 1475, 1480, 1485, 1490, 1495, 1500, 1505, 1510, 1515, 1520, 1525, 1530, 1535, 1540, 1545, 1550, 1555, 1560, 1565, 1570, 1575, 1580, 1585, 1590, 1595, 1600, 1605, 1610, 1615, 1620, 1625, 1630, 1635, 1640, 1645, 1650, 1655, 1660, 1665, 1670, 1675, 1680, 1685, 1690, 1695, 1700, 1705, 1710, 1715, 1720, 1725, 1730, 1735, 1740, 1745, 1750, 1755, 1760, 1765, 1770, 1775, 1780, 1785, 1790, 1795, 1800, 1805, 1810, 1815, 1820, 1825, 1830, 1835, 1840, 1845, 1850, 1855, 1860, 1865, 1870, 1875, 1880, 1885, 1890, 1895, 1900, 1905, 1910, 1915, 1920, 1925, 1930, 1935, 1940, 1945, 1950, 1955, 1960, 1965, 1970, 1975, 1980, 1985, 1990, 1995, 2000, 2005, 2010, 2015, 2020, 2025, 2030, 2035, 2040, 2045, 2050, 2055, 2060, 2065, 2070, 2075, 2080, 2085, 2090, 2095, 2100, 2105, 2110, 2115, 2120, 2125, 2130, 2135, 2140, 2145, 2150, 2155, 2160, 2165, 2170, 2175, 2180, 2185, 2190, 2195, 2200, 2205, 2210, 2215, 2220, 2225, 2230, 2235, 2240, 2245, 2250, 2255, 2260, 2265, 2270, 2275, 2280, 2285, 2290, 2295, 2300, 2305, 2310, 2315, 2320, 2325, 2330, 2335, 2340, 2345, 2350, 2355, 2360, 2365, 2370, 2375, 2380, 2385, 2390, 2395, 2400, 2405, 2410, 2415, 2420, 2425, 2430, 2435, 2440, 2445, 2450, 2455, 2460, 2465, 2470, 2475, 2480, 2485, 2490, 2495, 2500, 2505, 2510, 2515, 2520, 2525, 2530, 2535, 2540, 2545, 2550, 2555, 2560, 2565, 2570, 2575, 2580, 2585, 2590, 2595, 2600, 2605, 2610, 2615, 2620, 2625, 2630, 2635, 2640, 2645, 2650, 2655, 2660, 2665, 2670, 2675, 2680, 2685, 2690, 2695, 2700, 2705, 2710, 2715, 2720, 2725, 2730, 2735, 2740, 2745, 2750, 2755, 2760, 2765, 2770, 2775, 2780, 2785, 2790, 2795, 2800, 2805, 2810, 2815, 2820, 2825, 2830, 2835, 2840, 2845, 2850, 2855, 2860, 2865, 2870, 2875, 2880, 2885, 2890, 2895, 2900, 2905, 2910, 2915, 2920, 2925, 2930, 2935, 2940, 2945, 2950, 2955, 2960, 2965, 2970, 2975, 2980, 2985, 2990, 2995, 3000, 3005, 3010, 3015, 3020, 3025, 3030, 3035, 3040, 3045, 3050, 3055, 3060, 3065, 3070, 3075, 3080, 3085, 3090, 3095, 3100, 3105, 3110, 3115, 3120, 3125, 3130, 3135, 3140, 3145, 3150, 3155, 3160, 3165, 3170, 3175, 3180, 3185, 3190, 3195, 3200, 3205, 3210, 3215, 3220, 3225, 3230, 3235, 3240, 3245, 3250, 3255, 3260, 3265, 3270, 3275, 3280, 3285, 3290, 3295, 3300, 3305, 3310, 3315, 3320, 3325, 3330, 3335, 3340, 3345, 3350, 3355, 3360, 3365, 3370, 3375, 3380, 3385, 3390, 3395, 3400, 3405, 3410, 3415, 3420, 3425, 3430, 3435, 3440, 3445, 3450, 3455, 3460, 3465, 3470, 3475, 3480, 3485, 3490, 3495, 3500, 3505, 3510, 3515, 3520, 3525, 3530, 3535, 3540, 3545, 3550, 3555, 3560, 3565, 3570, 3575, 3580, 3585, 3590, 3595, 3600, 3605, 3610, 3615, 3620, 3625, 3630, 3635, 3640, 3645, 3650, 3655, 3660, 3665, 3670, 3675, 3680, 3685, 3690, 3695, 3700, 3705, 3710, 3715, 3720, 3725, 3730, 3735, 3740, 3745, 3750, 3755, 3760, 3765, 3770, 3775, 3780, 3785, 3790, 3795, 3800, 3805, 3810, 3815, 3820, 3825, 3830, 3835, 3840, 3845, 3850, 3855, 3860, 3865, 3870, 3875, 3880, 3885, 3890, 3895, 3900, 3905, 3910, 3915, 3920, 3925, 3930, 3935, 3940, 3945, 3950, 3955, 3960, 3965, 3970, 3975, 3980, 3985, 3990, 3995, 4000, 4005, 4010, 4015, 4020, 4025, 4030, 4035, 4040, 4045, 4050, 4055, 4060, 4065, 4070, 4075, 4080, 4085, 4090, 4095, 4100, 4105, 4110, 4115, 4120, 4125, 4130, 4135, 4140, 4145, 4150, 4155, 4160, 4165, 4170, 4175, 4180, 4185, 4190, 4195, 4200, 4205, 4210, 4215, 4220,

Hydrology



Hydrology

Big Nemaha River

Water Year	Date	Gage Height (feet)	Stream-flow (cfs)
1974	Oct. 11, 1973	31.40	71,600
1993	Jul. 06, 1993	29.77	59,000
1965	Jun. 29, 1965	28.90	47,700
1960	Mar. 28, 1960	27.75	46,900
1982	Aug. 13, 1982	27.60	46,000
2007	May 07, 2007	30.46	44,900
1979	Mar. 03, 1979	26.10	44,800
2013	May 30, 2013	28.91	44,800
1978	May 07, 1978	25.85	44,000

Bulletin 17C and
Adjusted for Total Area

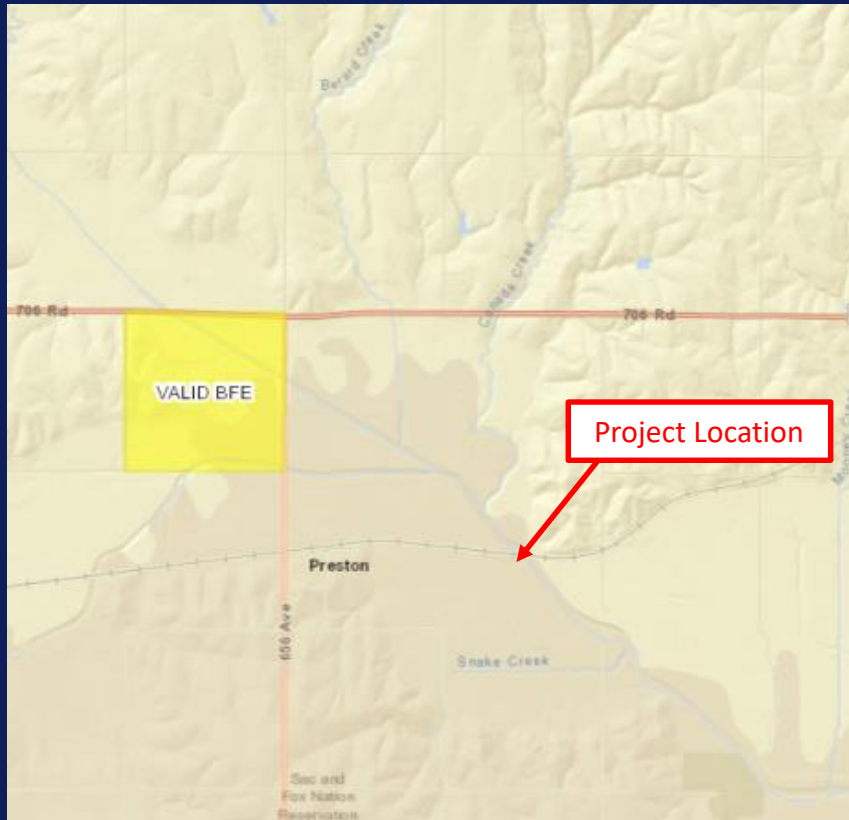


Muddy Creek

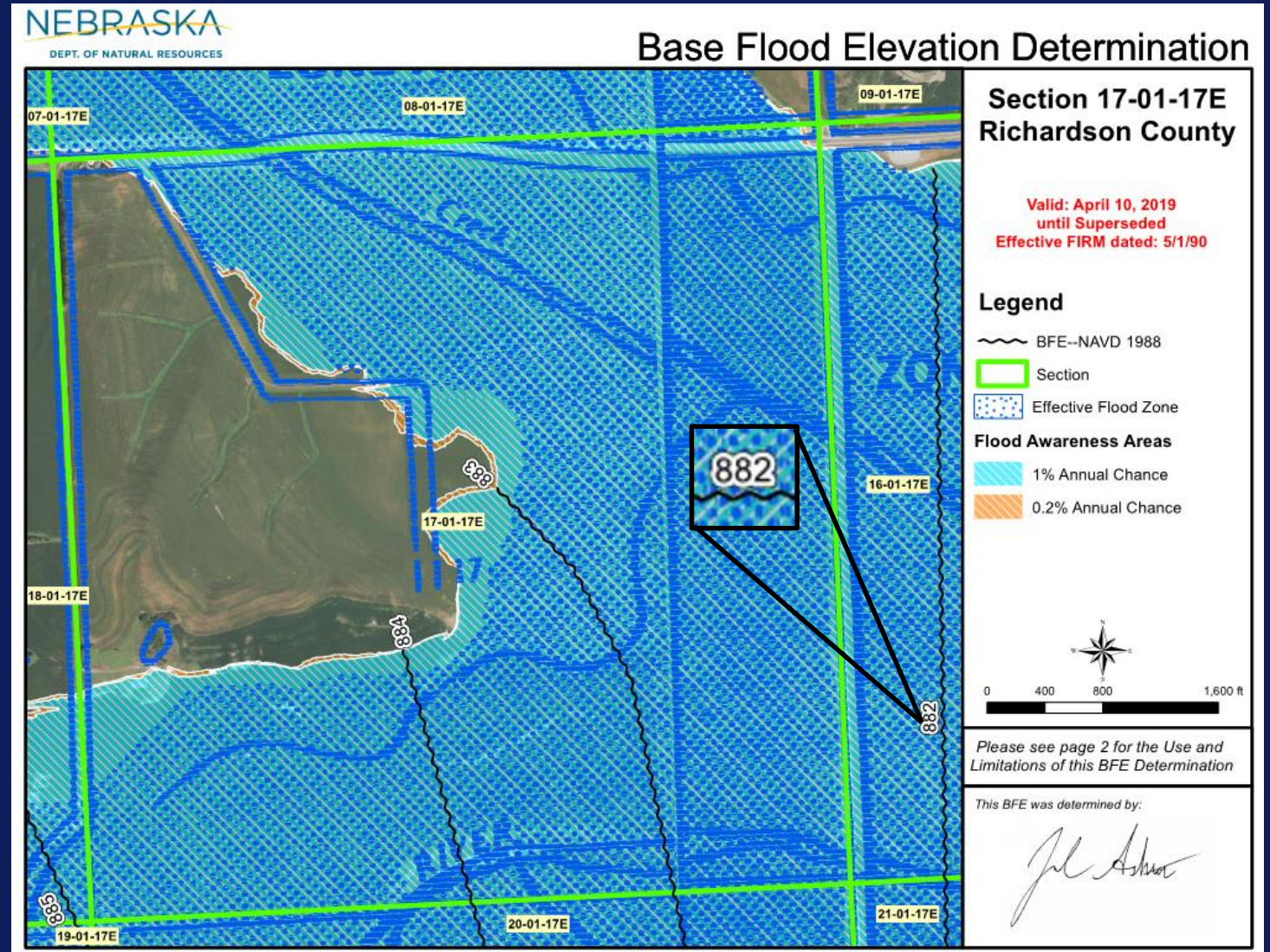
Water Year	Date	Gage Height (feet)	Stream-flow (cfs)
1973	Aug. 12, 1973	32.71	35,000
1958	Jul. 10, 1958	31.50	31,900
1960	Mar. 27, 1960	23.90	20,000
1961	Sep. 30, 1961	24.58	17,800
1954	Jun. 17, 1954	22.97	17,100
1964	Jun. 17, 1964	22.20	13,800
1969	May 07, 1969	21.75	13,000
1957	Jun. 17, 1957	18.35	10,200
1962	May 28, 1962	19.60	10,100

Adjusted Project Location	
% Chance Exceedance	Flow (cfs)
0.2	170,275
0.5	147,191
1	130,287
2	113,823
5	92,622
10	76,858
20	61,057
50	38,815
80	24,270
90	18,863
95	15,265
99	10,174

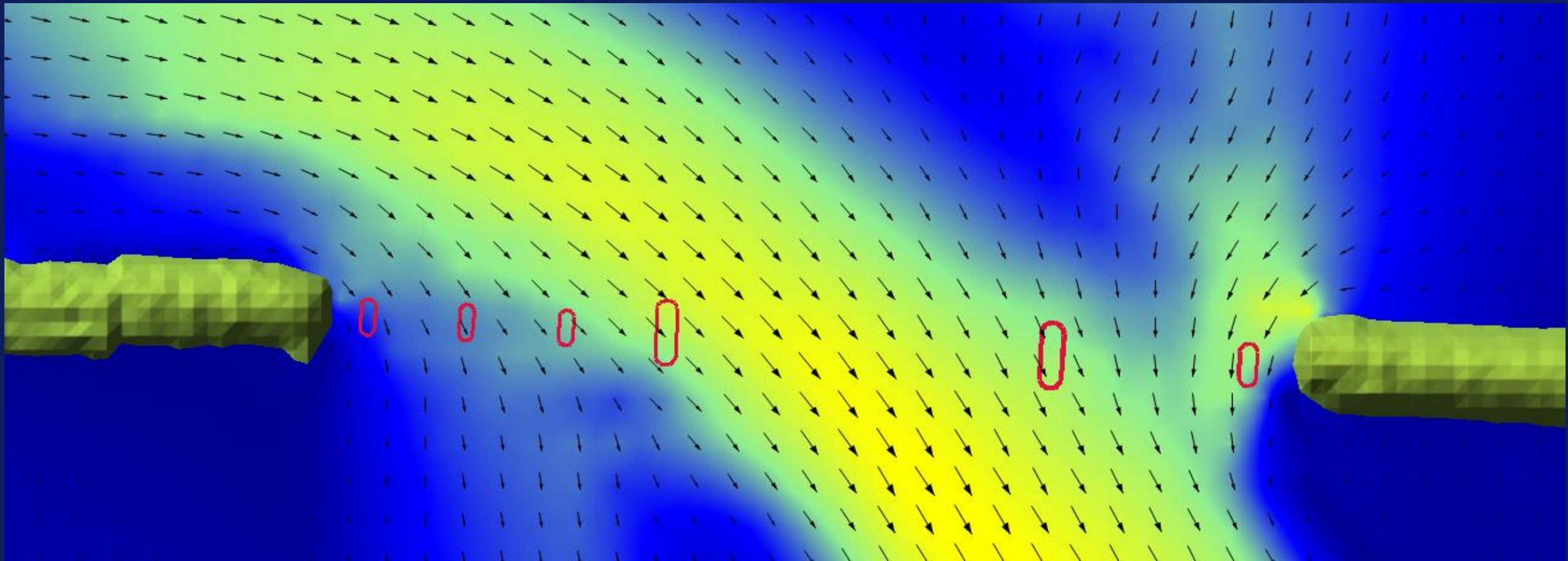
Calibration



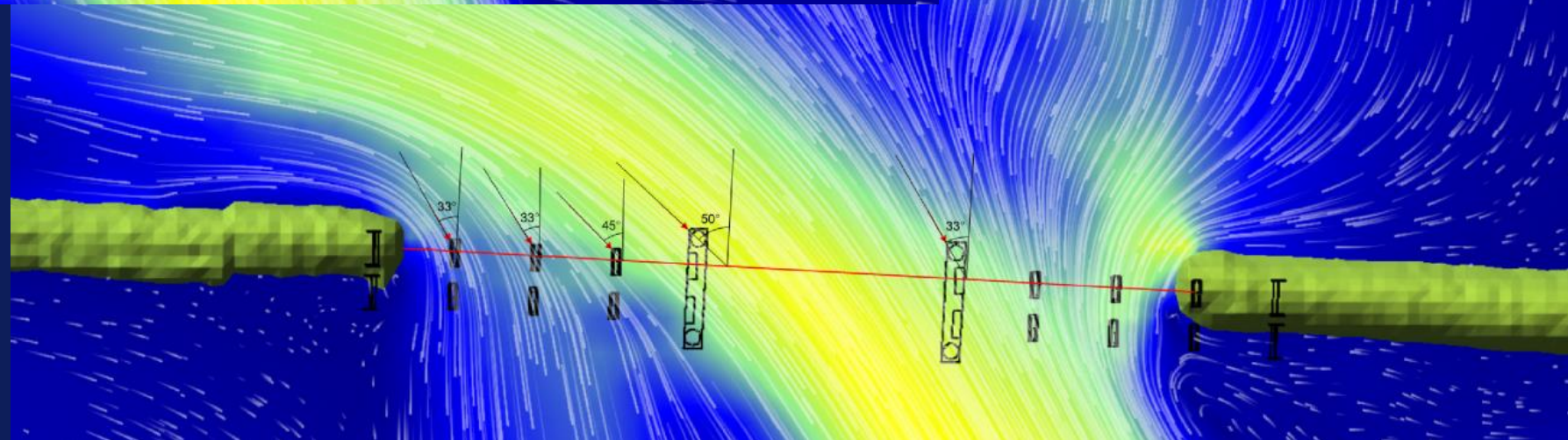
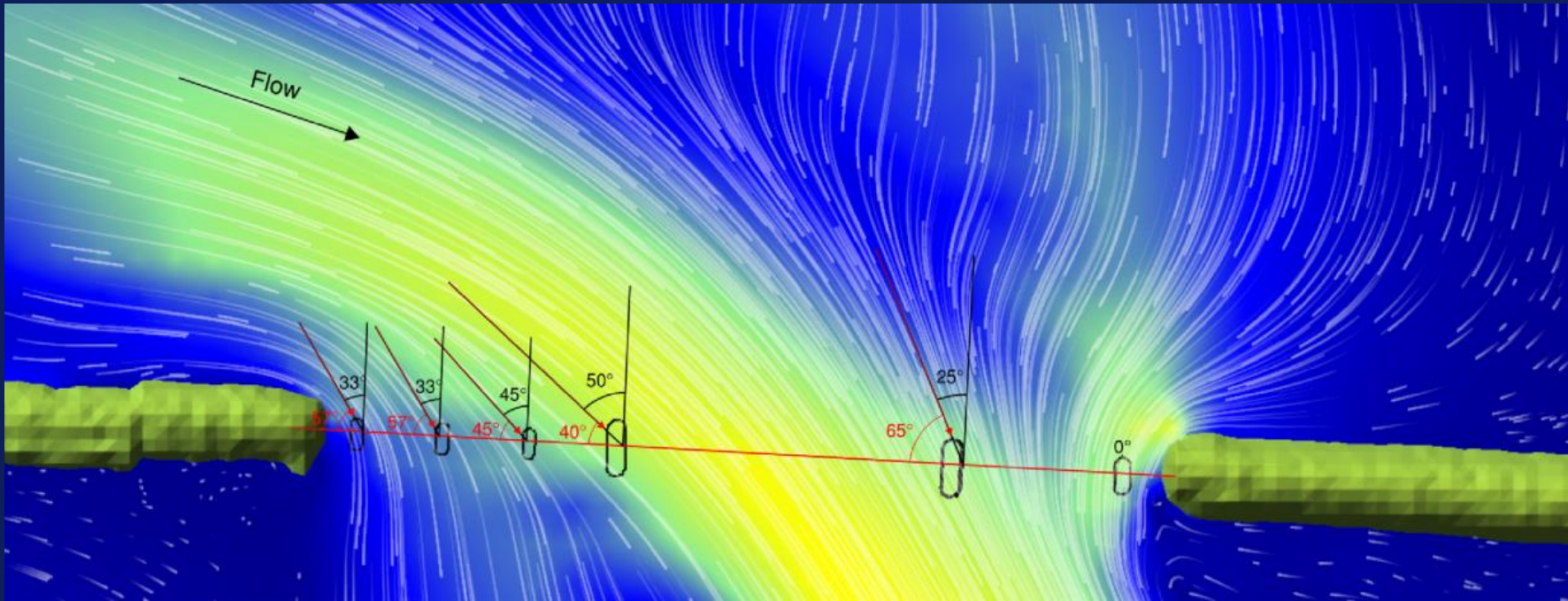
- Regression Equations
- Recent Storm Event
- BFE Determination



Flow Angle of Attack

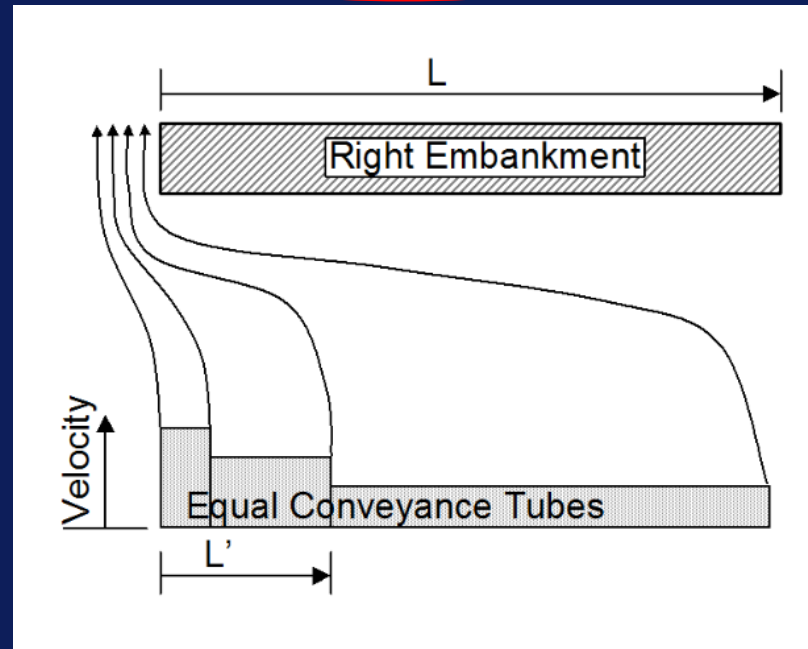


Flow Angle of Attack

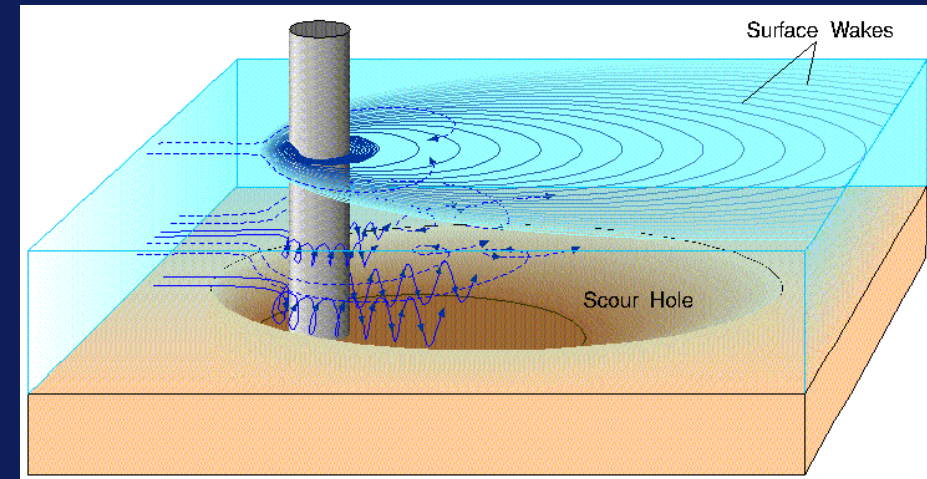


HEC-18 Bridge Scour

Contraction Scour



Pier (Local) Scour

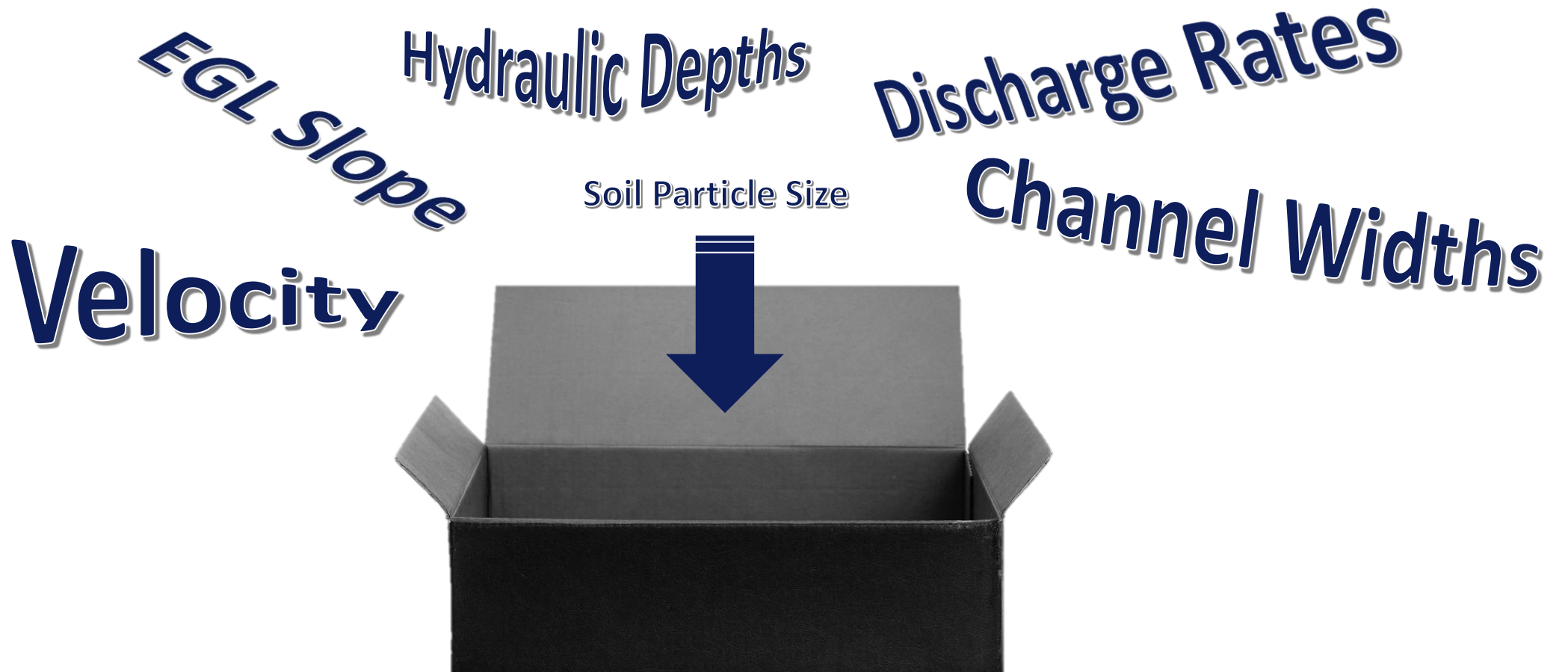


Evaluating Scour at Bridges
Fifth Edition

U.S. Department of Transportation
Federal Highway Administration



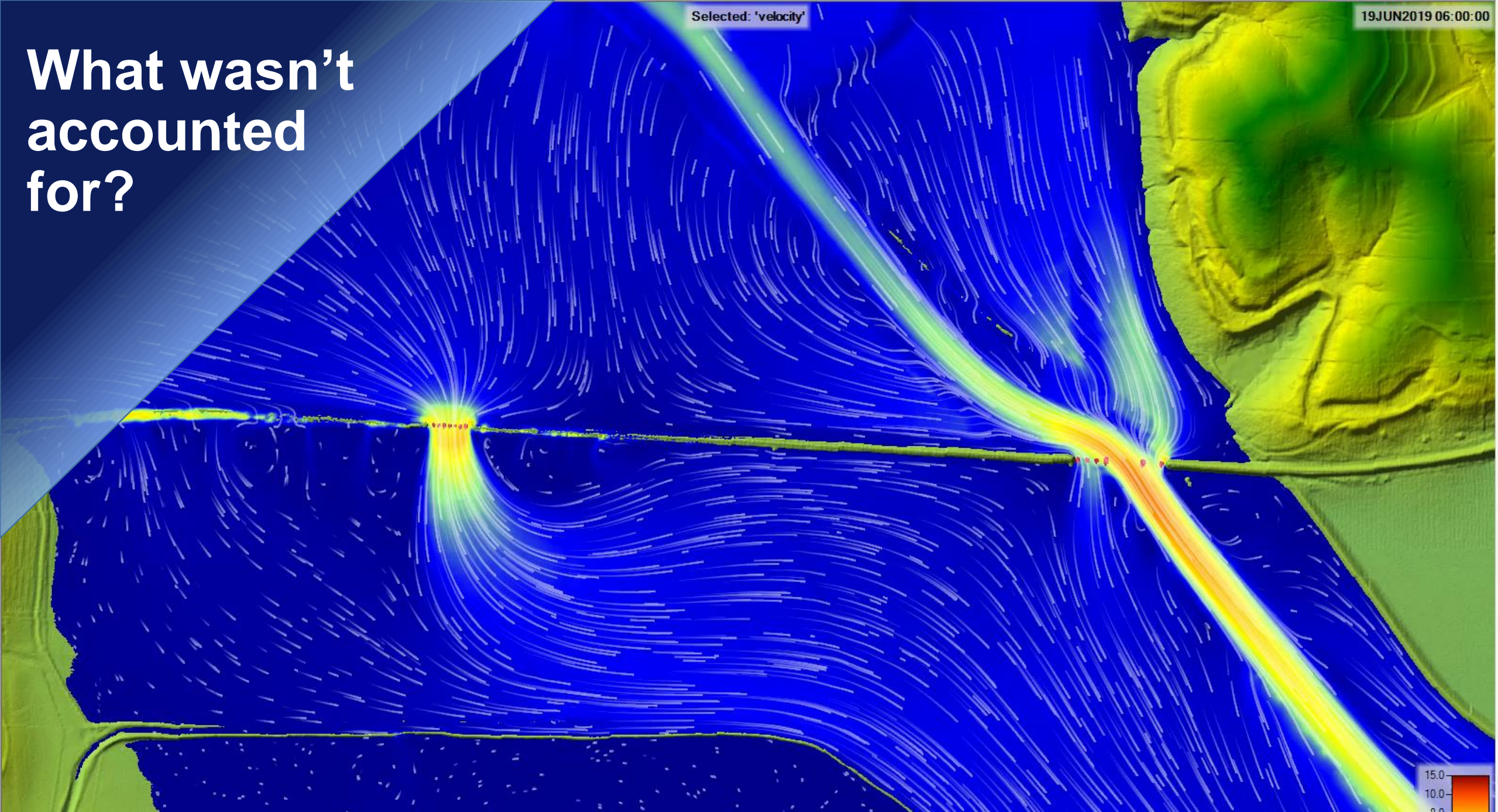
Scour Analysis



Scour Results

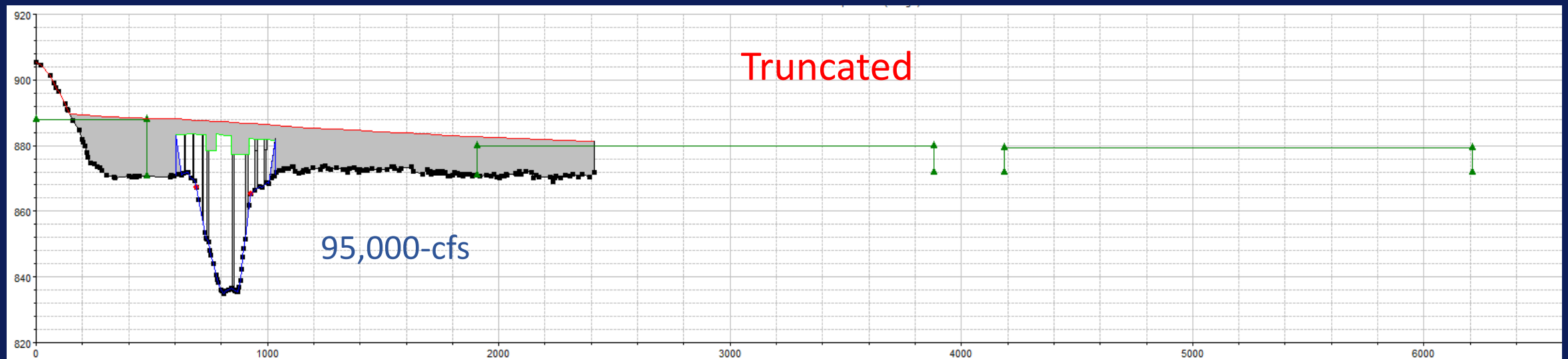
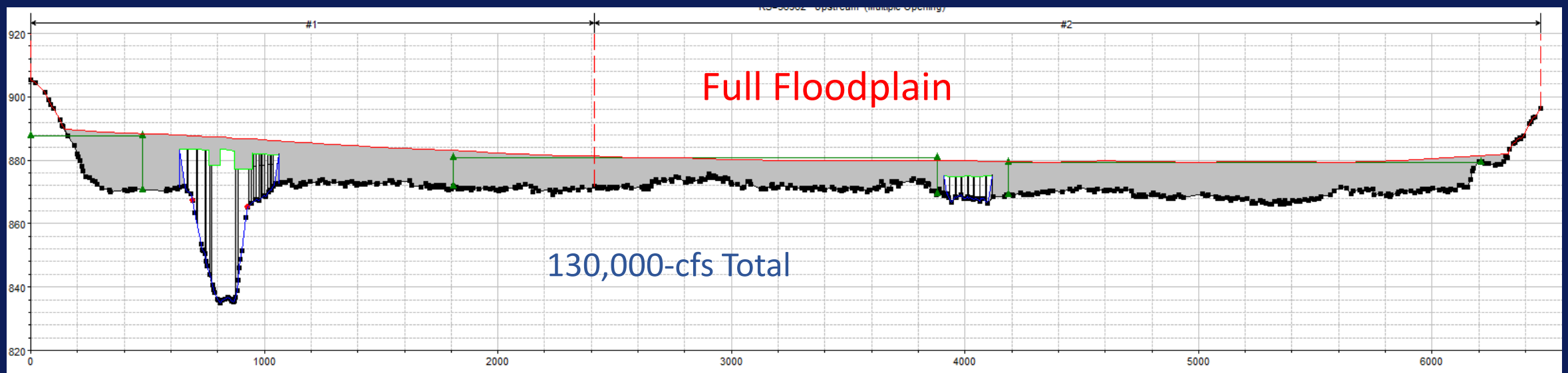


What wasn't
accounted
for?

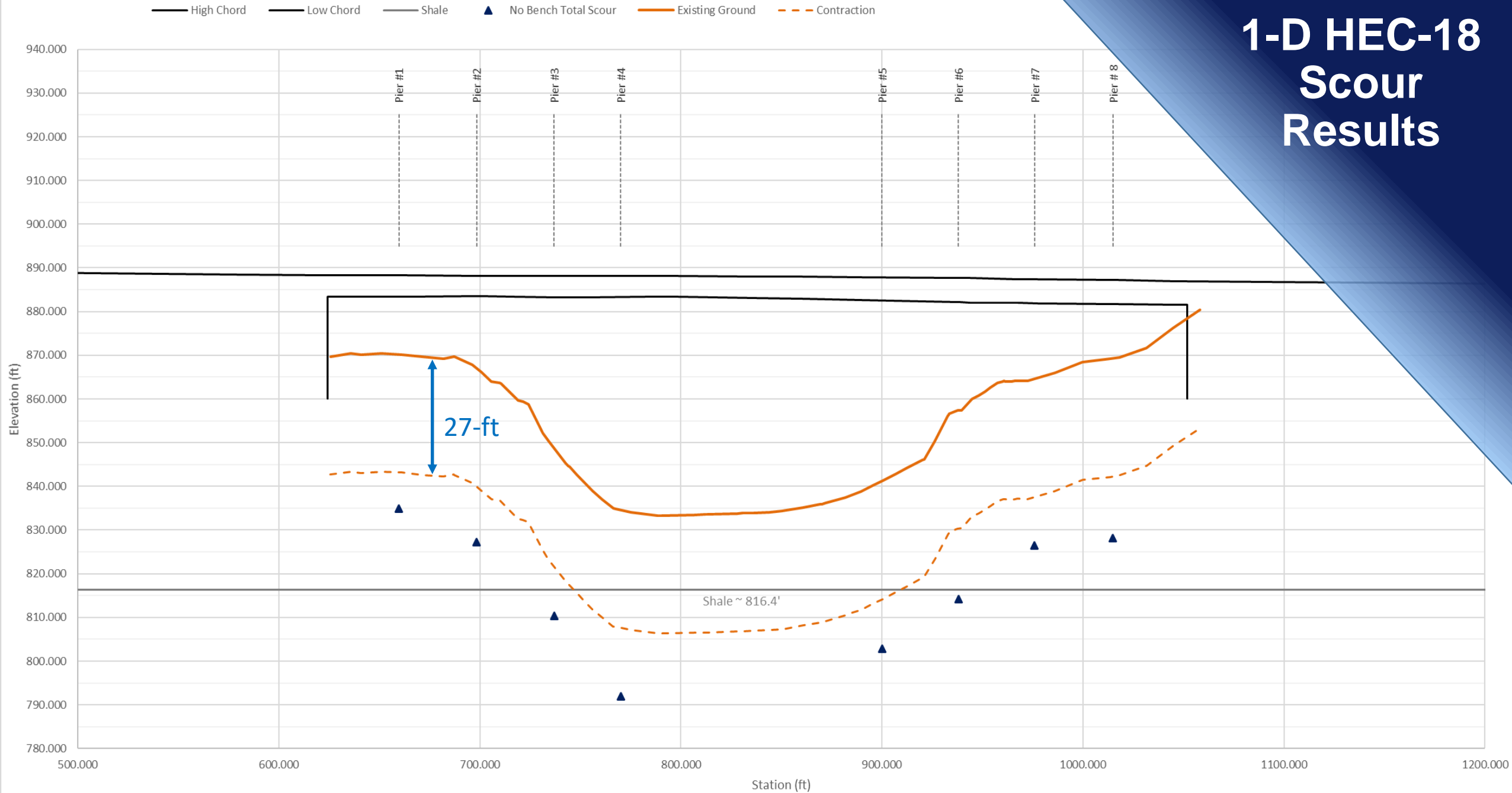


Truncated 1-D Model

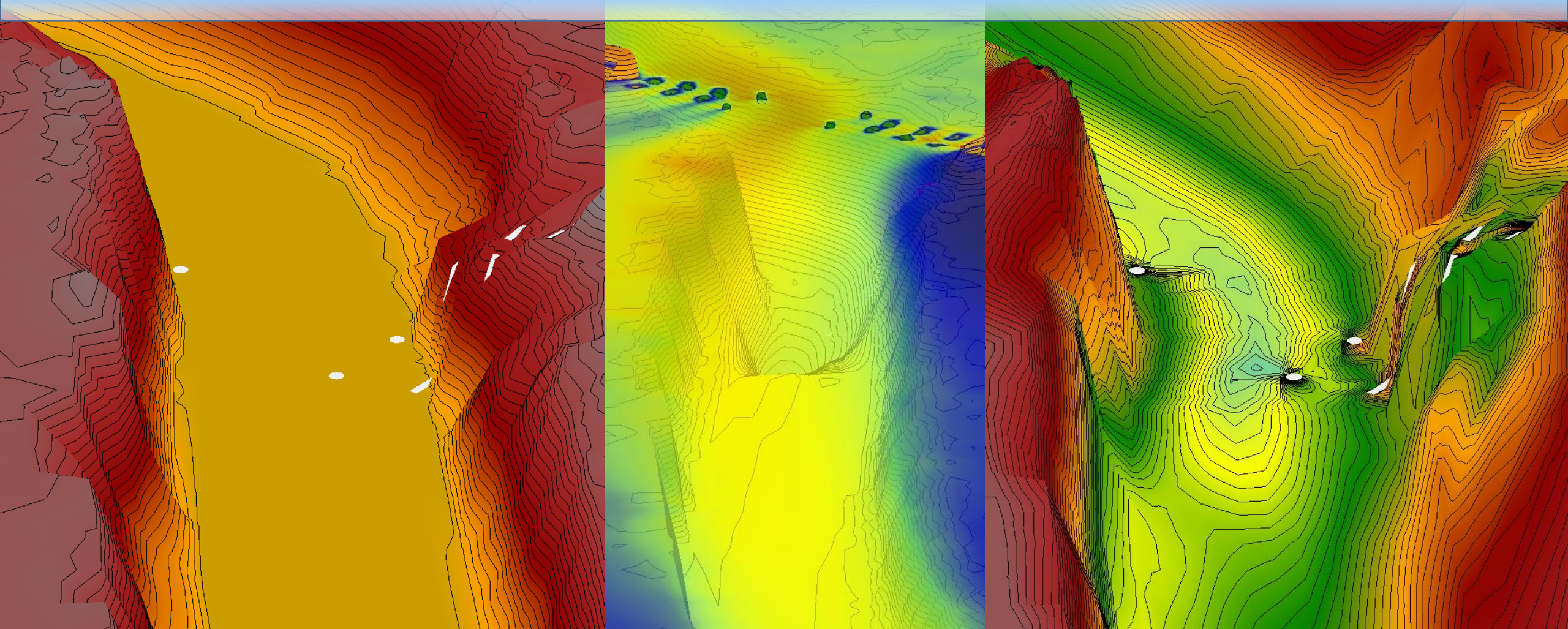




1-D HEC-18 Scour Results



SRH-2D (Sedimentation and River Hydraulics)



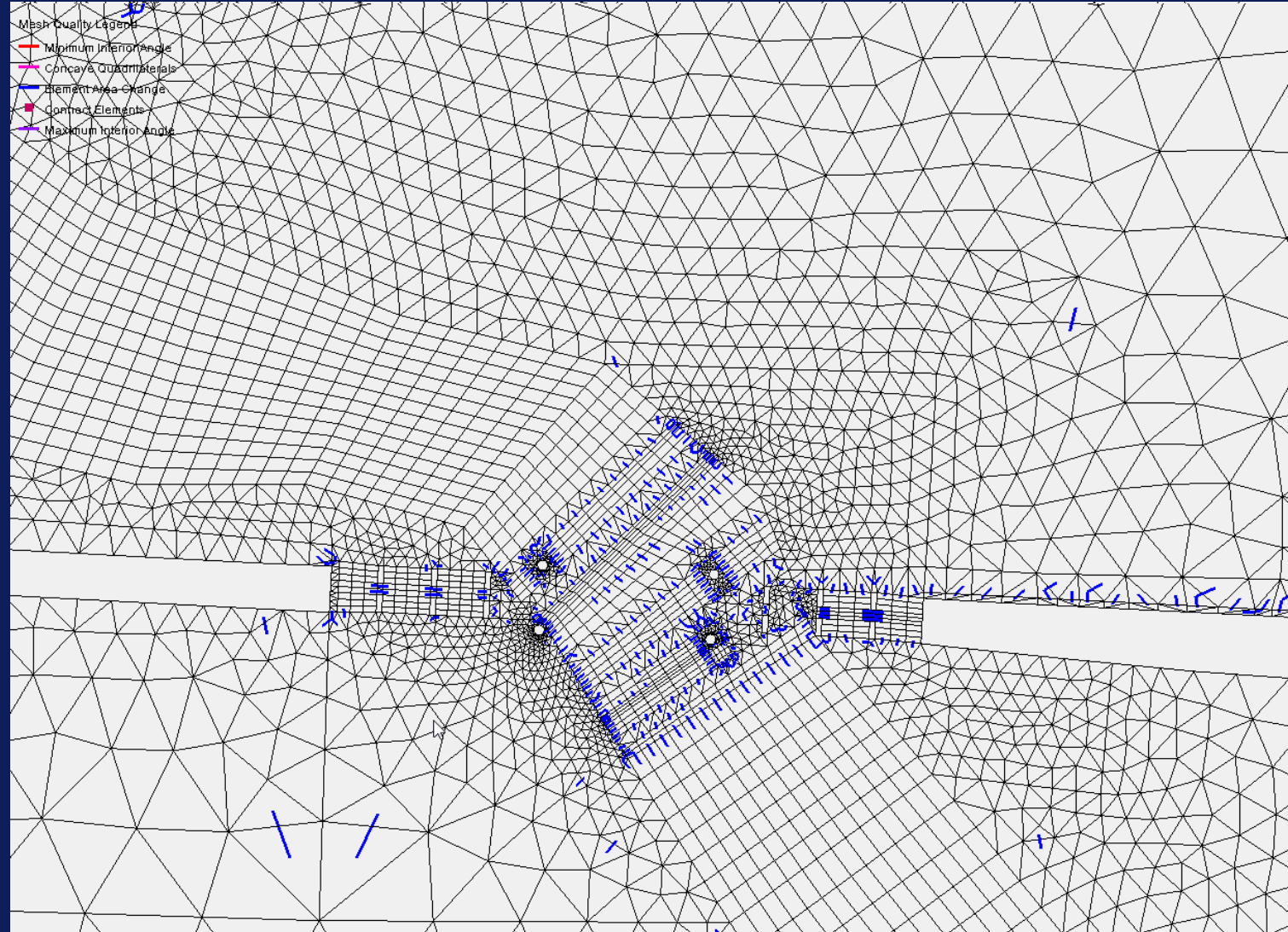
2D Steady State

- 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

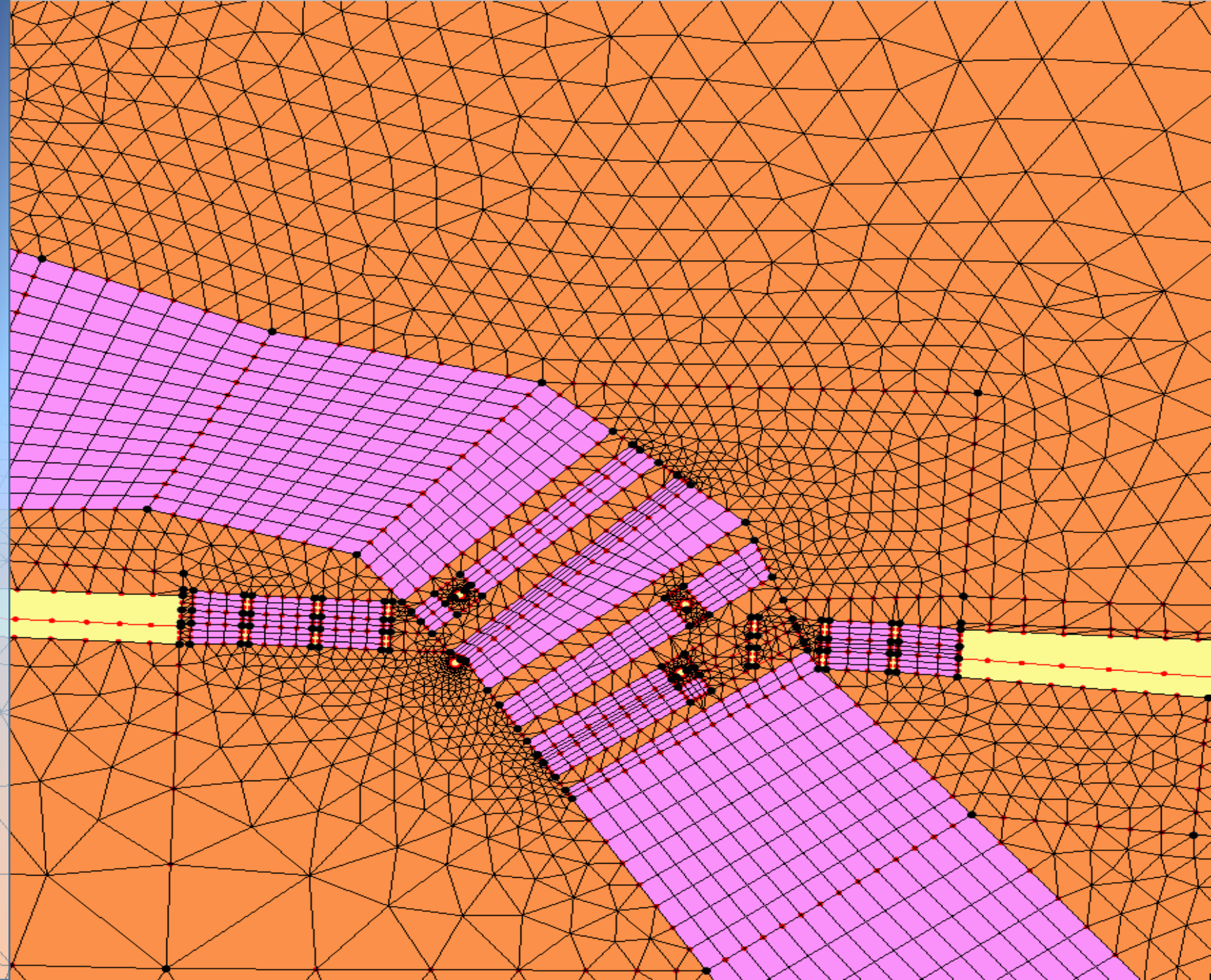


Mesh Density and Quality

- 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

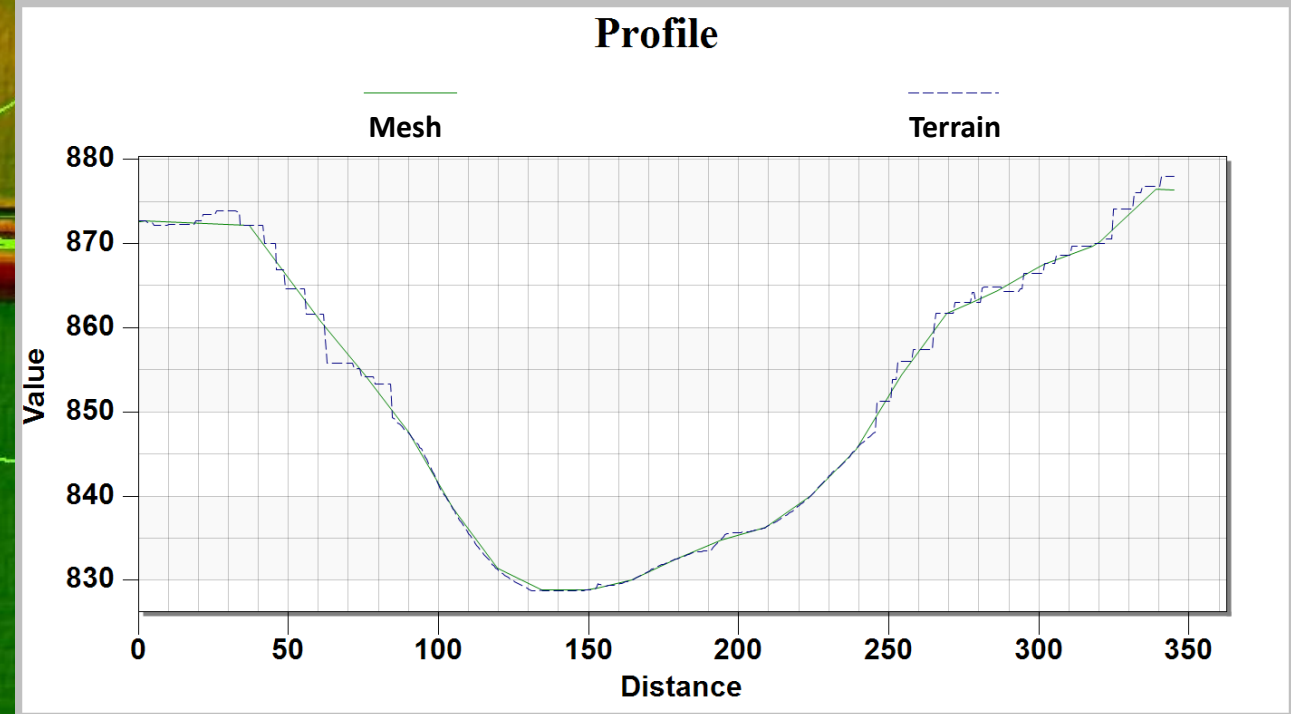


Quadrilateral Elements



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

View Values

Coverage Type: **Bridge Scour**

Coverage Name: **Bridge Scour**

Main channel (approach):

Approach section left bank station (ft)	151.015
Approach section right bank station (ft)	405.108
Approach section main channel width (ft)	254.092
Approach section main channel flow (cfs)	946554
Approach section main channel flow area (ft ²)	7580.94
Approach section main channel wetted perimeter (ft)	242.323
Approach section main channel hydraulic radius (ft)	31.2844
Approach section main channel hydraulic depth (ft)	29.8354
(used for average depth upstream of contraction)	
Approach section main channel maximum depth (ft)	34.9159
Approach section main channel unit discharge (cfs/ft)	3725.23
Approach section main channel average velocity (ft/s)	124.86
Approach section critical velocity (ft/s)	0

Left overbank (approach; Used for overbank contraction scour calculations):

Left overbank average flow depth (ft):	9.70123
Left overbank average velocity (ft/s):	2.30397
Left overbank flow width (ft):	151.015
Left overbank flow (cfs):	3375.4
Left overbank unit discharge (cfs/ft):	22.3514

Right overbank (approach; Used for overbank contraction scour calculations):

Right overbank average flow depth (ft):	8.32967
Right overbank average velocity (ft/s):	3.07467
Right overbank flow width (ft):	156.305
Right overbank flow (cfs):	4003.14
Right overbank unit discharge (cfs/ft):	25.611

CONTRACTED SECTION HYDRAULIC PARAMETERS:

Entire cross section:

Energy grade line slope at the contracted section (ft/ft)	0.00131943
Total flow in the contracted section (cfs)	155719
Contracted section total flow area (ft ²)	11325.1
Contracted section total wetted perimeter (ft)	517.001

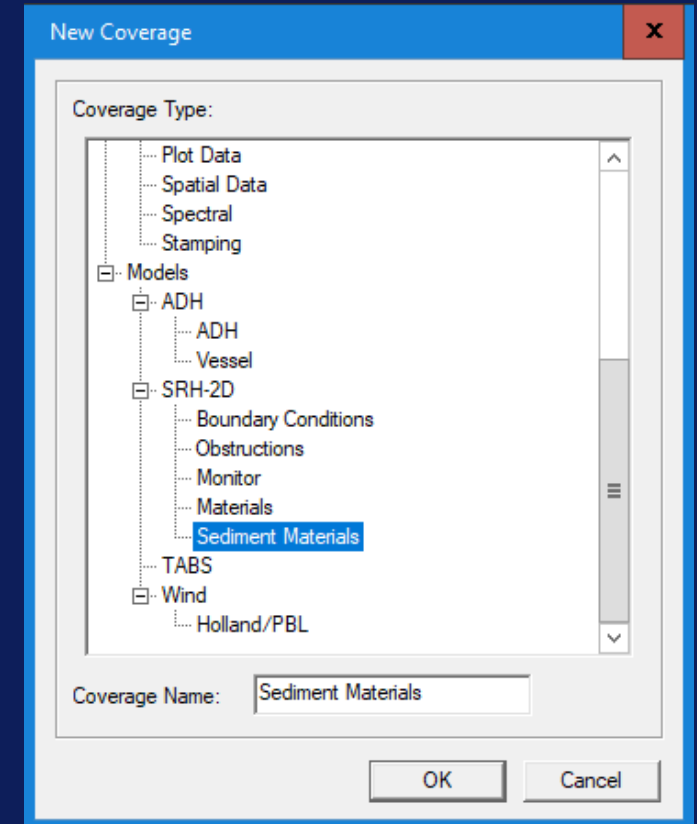
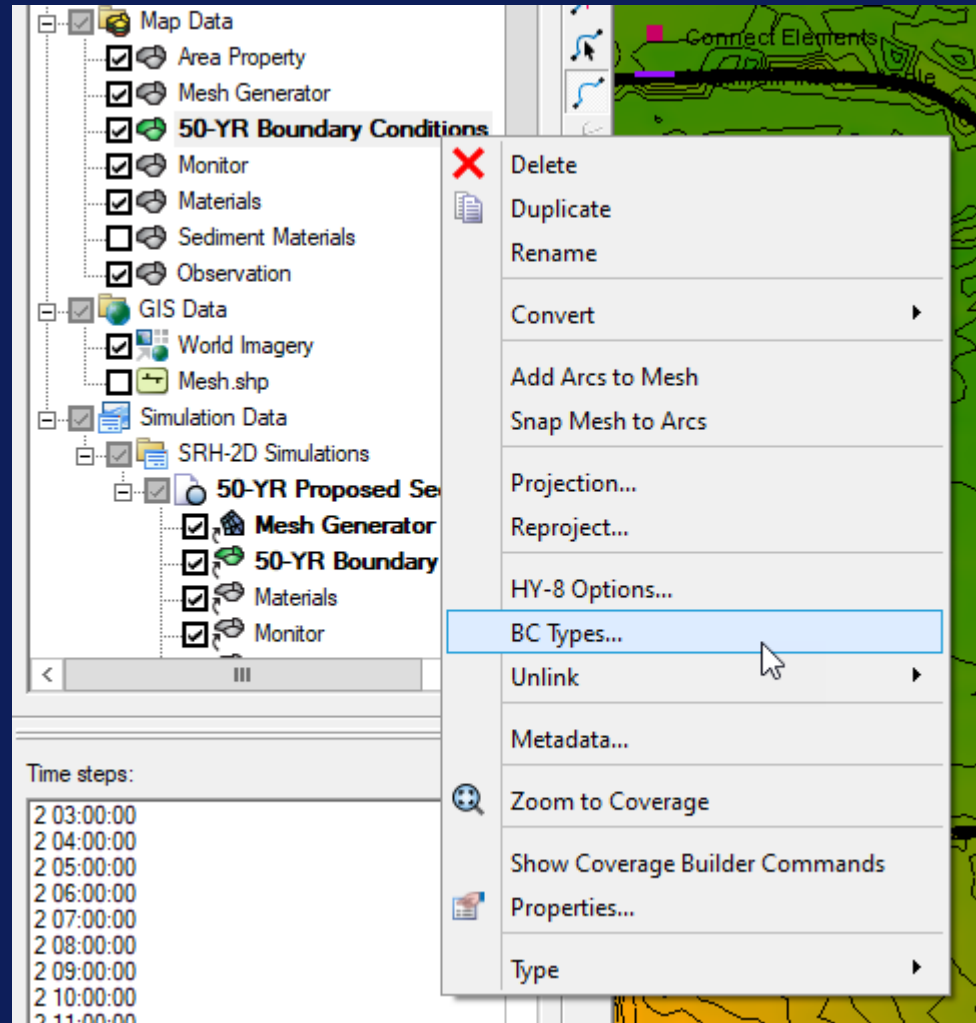
Main channel:

Contracted section left bank station (ft)	196.477
Contracted section right bank station (ft)	419.501
Contracted section main channel width (ft)	223.024
Contracted section main channel adjusted width (ft)	197.678
(adjusted for piers and skew)	
Contracted section main channel flow (cfs)	55357.8
Contracted section main channel flow area (ft ²)	8741.66
Contracted section main channel adjusted flow area (ft ²)	7748.2
(adjusted for piers and skew)	
Contracted section main channel skew angle (degrees)	27.5815
Contracted section main channel wetted perimeter (ft)	228.861

OK **Close**

2D Sediment Workflow

- 2 Changes
 - Boundary Condition
 - Materials



Boundary Condition – Sediment Transport

BC Type Parameters

Run Type

Hydro/Transport:

Flow

Flow

Mobile

On

Output:

Sediment Transport Parameters

Sediment Specific Gravity:

2.65

	Particle Diameter Threshold (mm)
1	0.0625
2	0.125
3	0.25
4	0.5
5	1
6	2
7	4

Bin Size
Phi Scale

Sediment Transport Equation:

Engelund-Hansen

Transport Equation Coefficients

Non-Transport Equation Dependent

Water Temperature:

20.0

Adaptation Coefficients for Suspended Load

Deposition Coefficient:

0.25

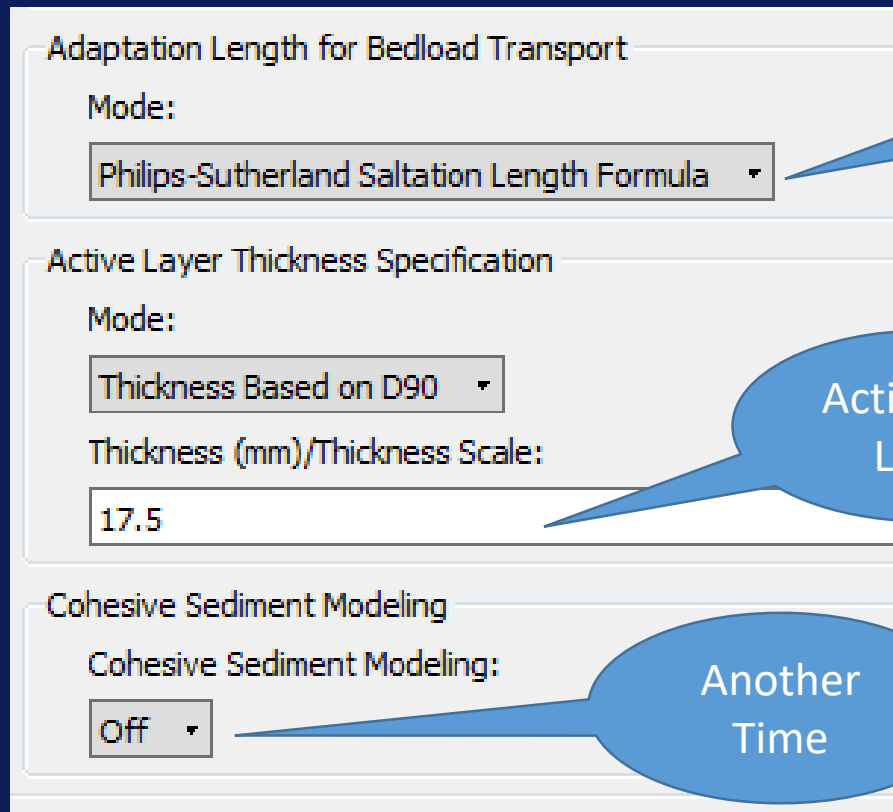
Erosion Coefficient:

1.0

8 Equations
Source?

Defaults

Boundary Conditions - Part 2



The screenshot shows a software interface with three main sections. The first section, 'Adaptation Length for Bedload Transport', has a 'Mode:' dropdown menu set to 'Philips-Sutherland Saltation Length Formula'. A blue callout bubble points to this menu with the text '5 Methods Source?'. The second section, 'Active Layer Thickness Specification', has a 'Mode:' dropdown menu set to 'Thickness Based on D90' and a 'Thickness (mm)/Thickness Scale:' input field with the value '17.5'. A blue callout bubble points to the input field with the text 'Active Bed Layer'. The third section, 'Cohesive Sediment Modeling', has a 'Cohesive Sediment Modeling:' dropdown menu set to 'Off'. A blue callout bubble points to this menu with the text 'Another Time'.

Adaptation Length for Bedload Transport

Mode:

Philips-Sutherland Saltation Length Formula

Active Layer Thickness Specification

Mode:

Thickness Based on D90

Thickness (mm)/Thickness Scale:

17.5

Cohesive Sediment Modeling

Cohesive Sediment Modeling:

Off

5 Methods
Source?

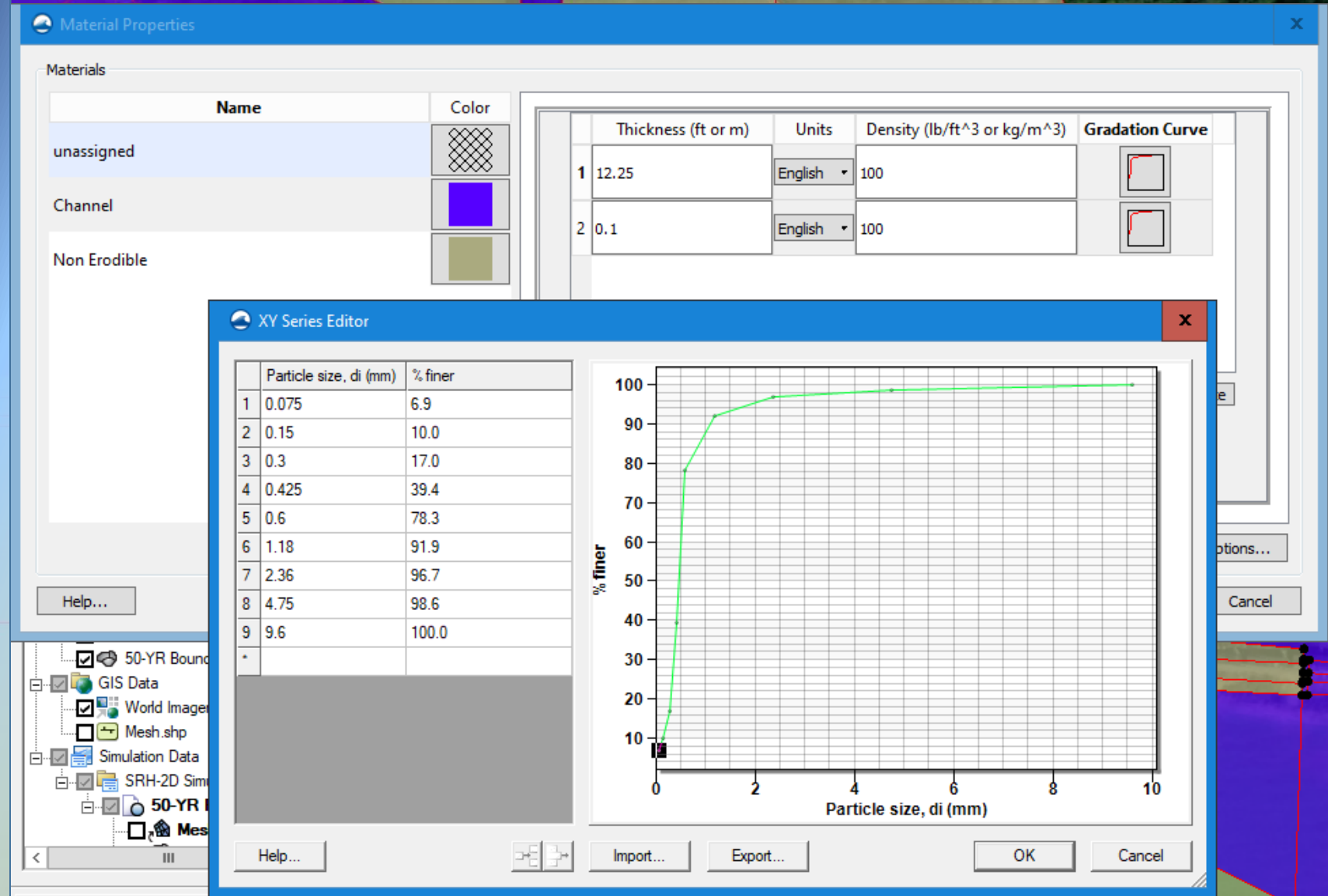
Active Bed
Layer

Another
Time

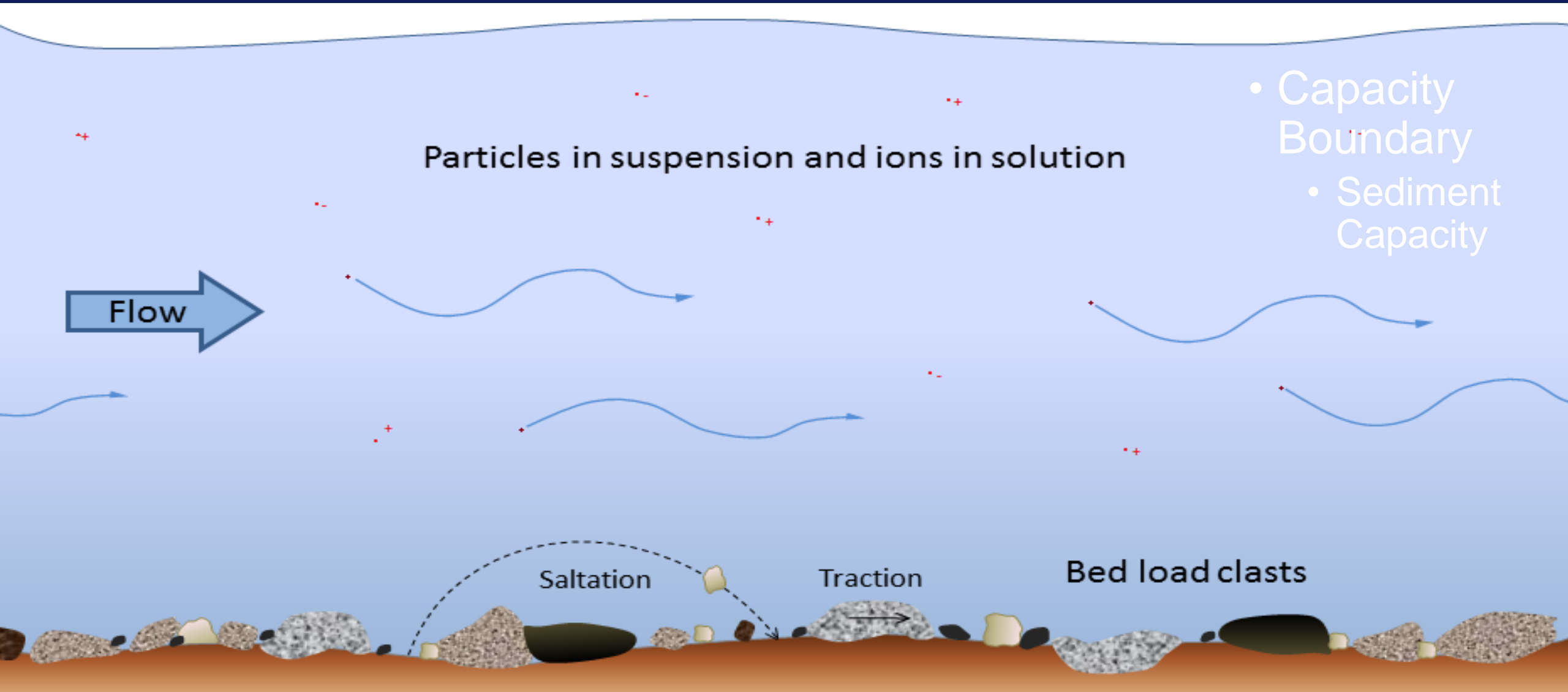
- Total Sediment Load
 - Bed Load
 - Suspended Load
 - Wash Load
- Sediment Type
 - FHWA!

Sediment Materials

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



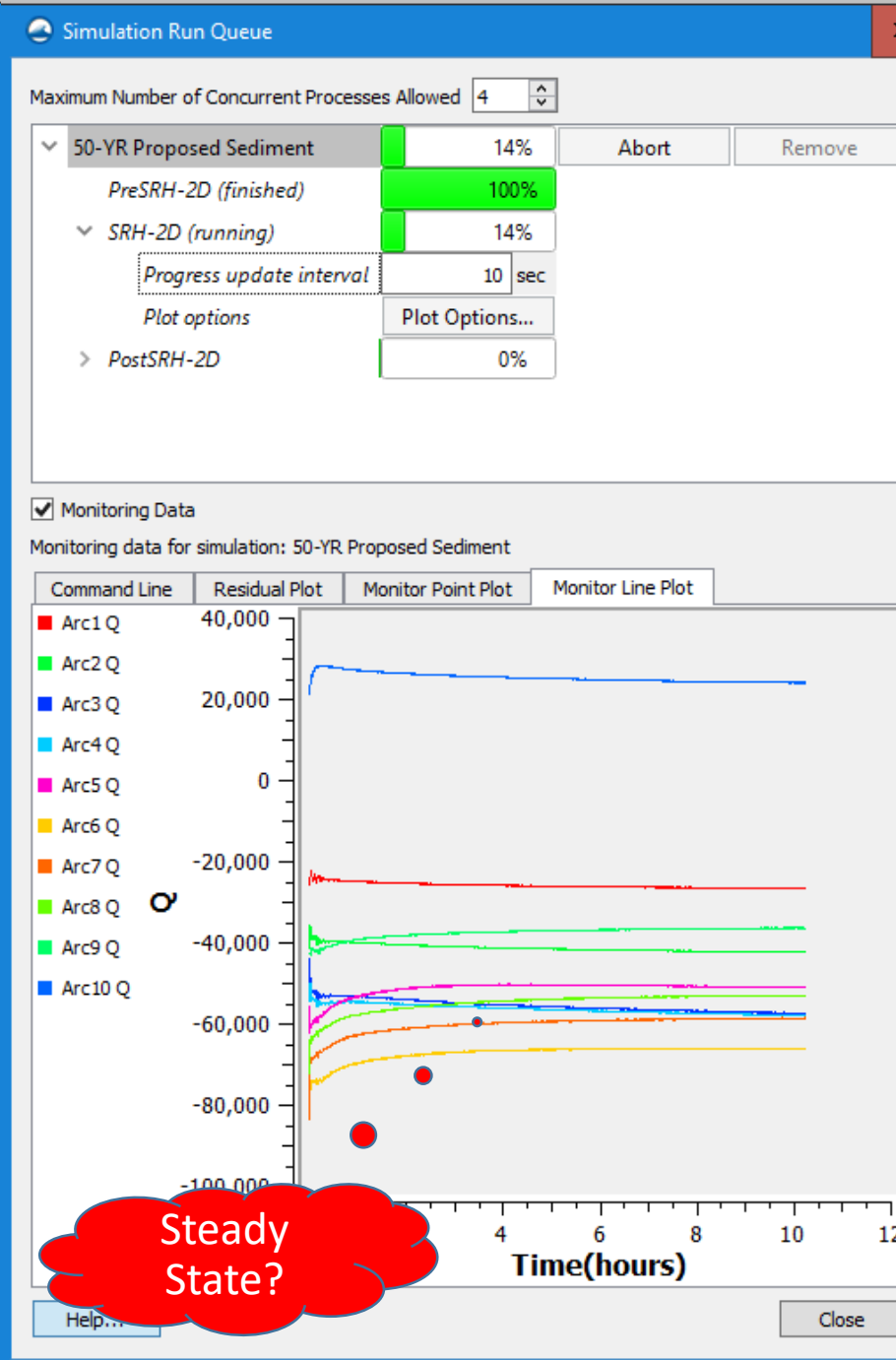
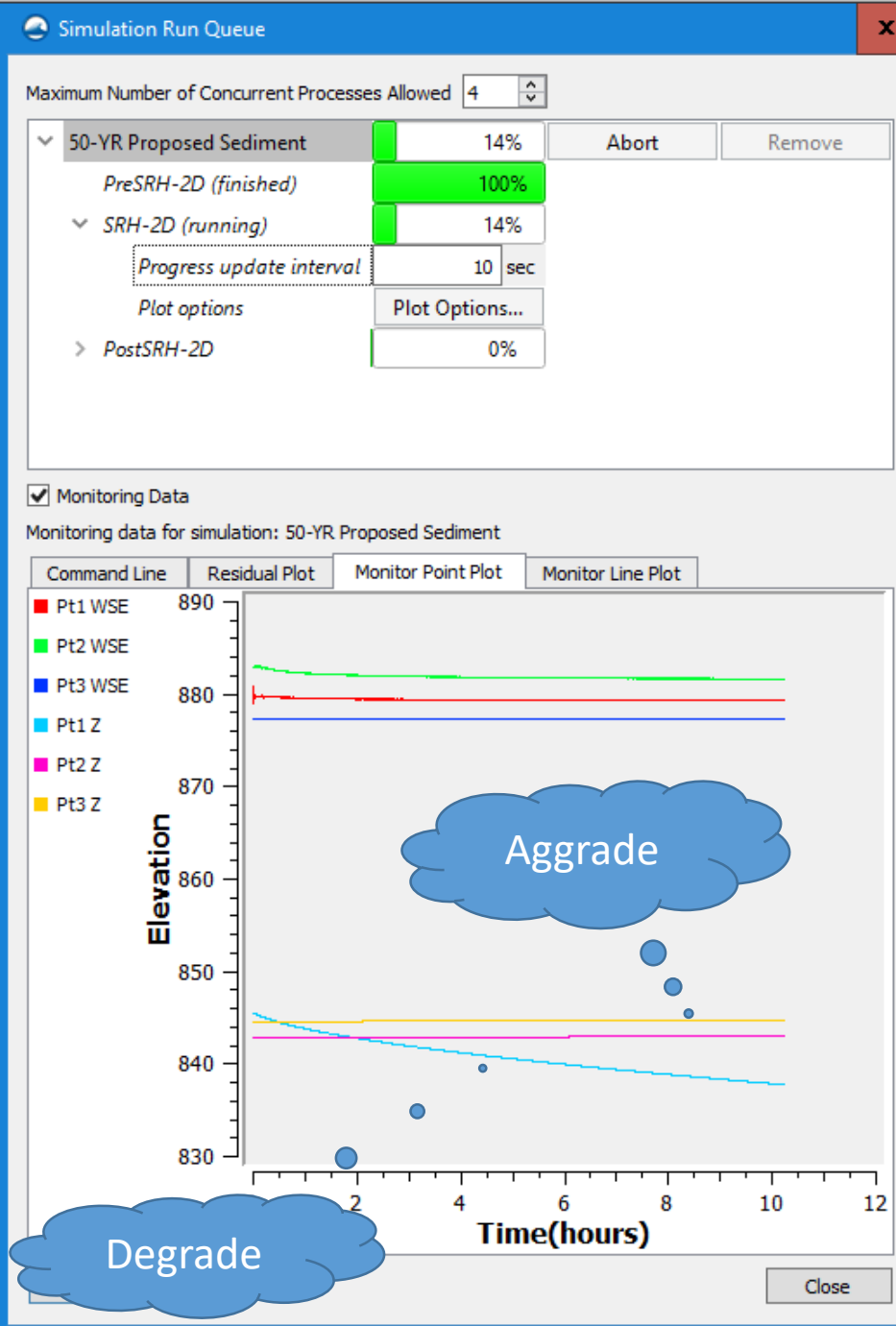
Upstream Sediment Inflow



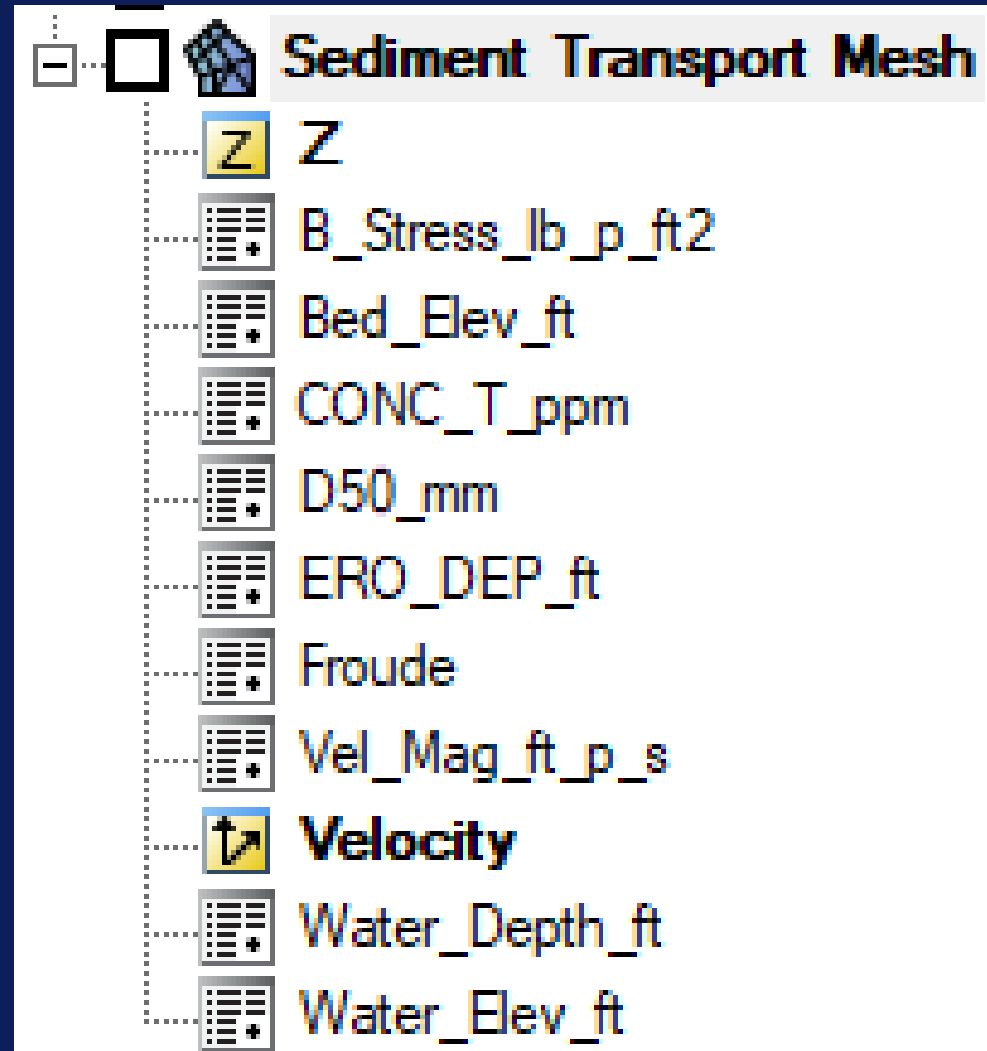
Model Results

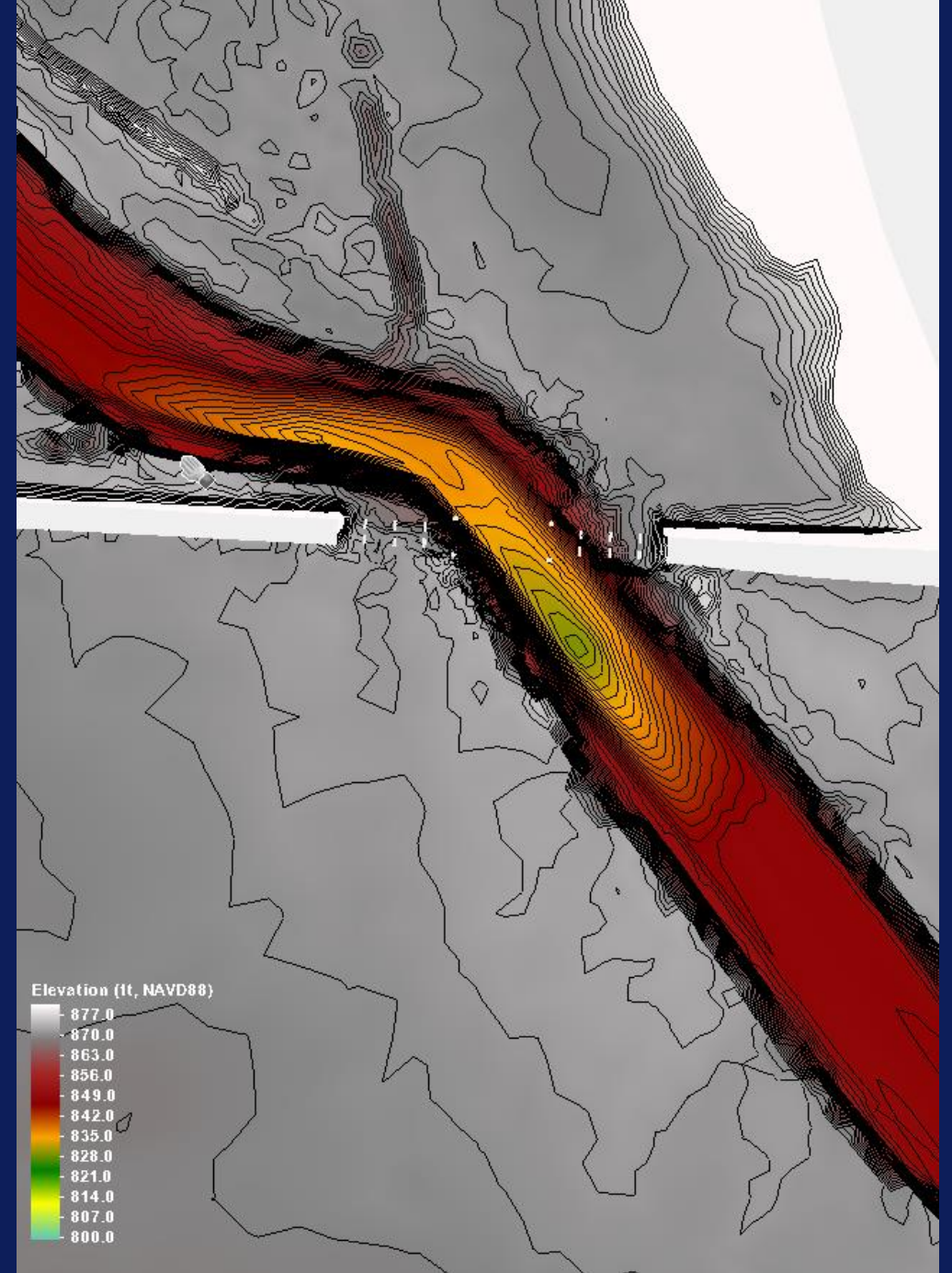
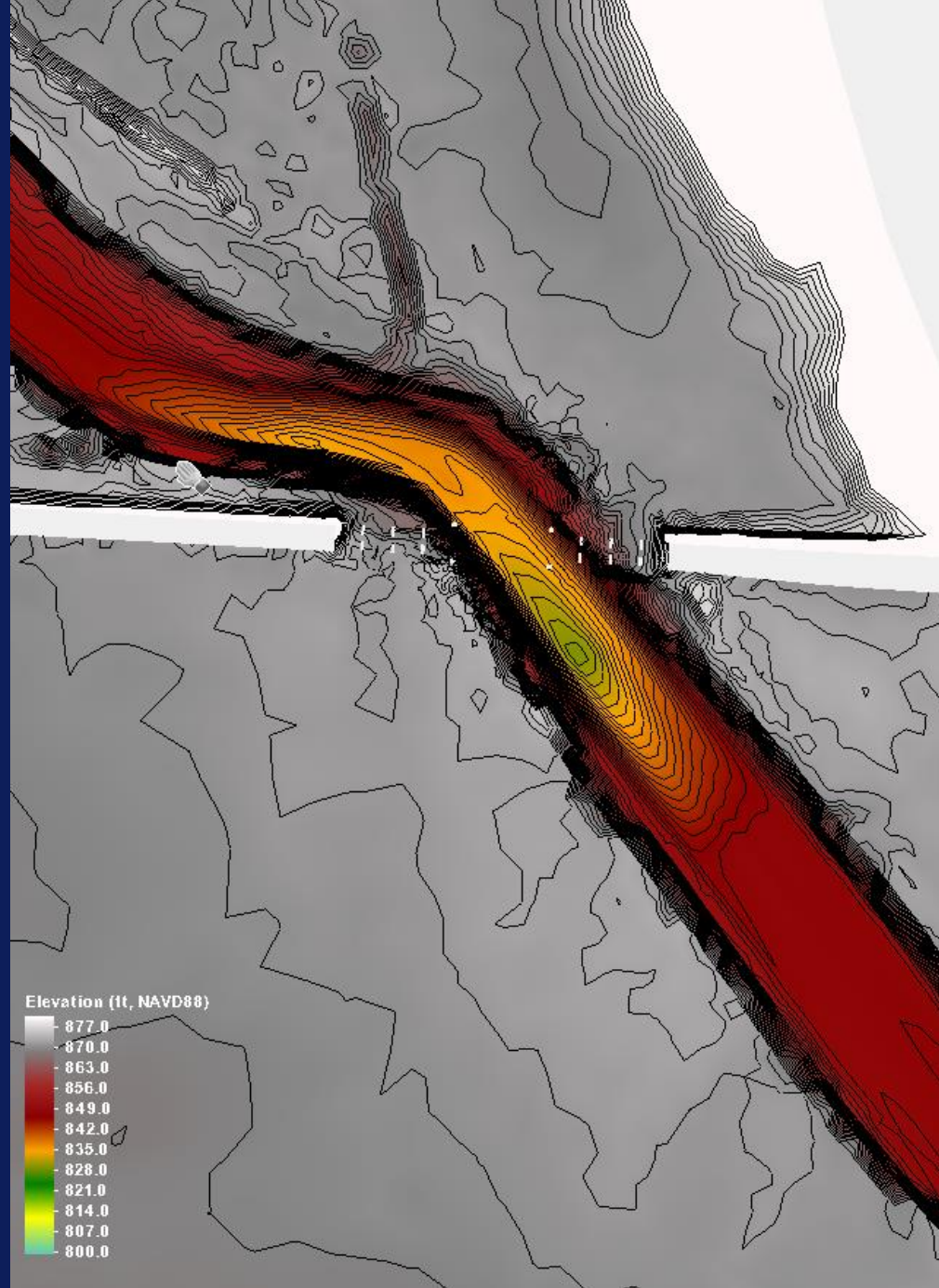


Simulation Queue



Available Results

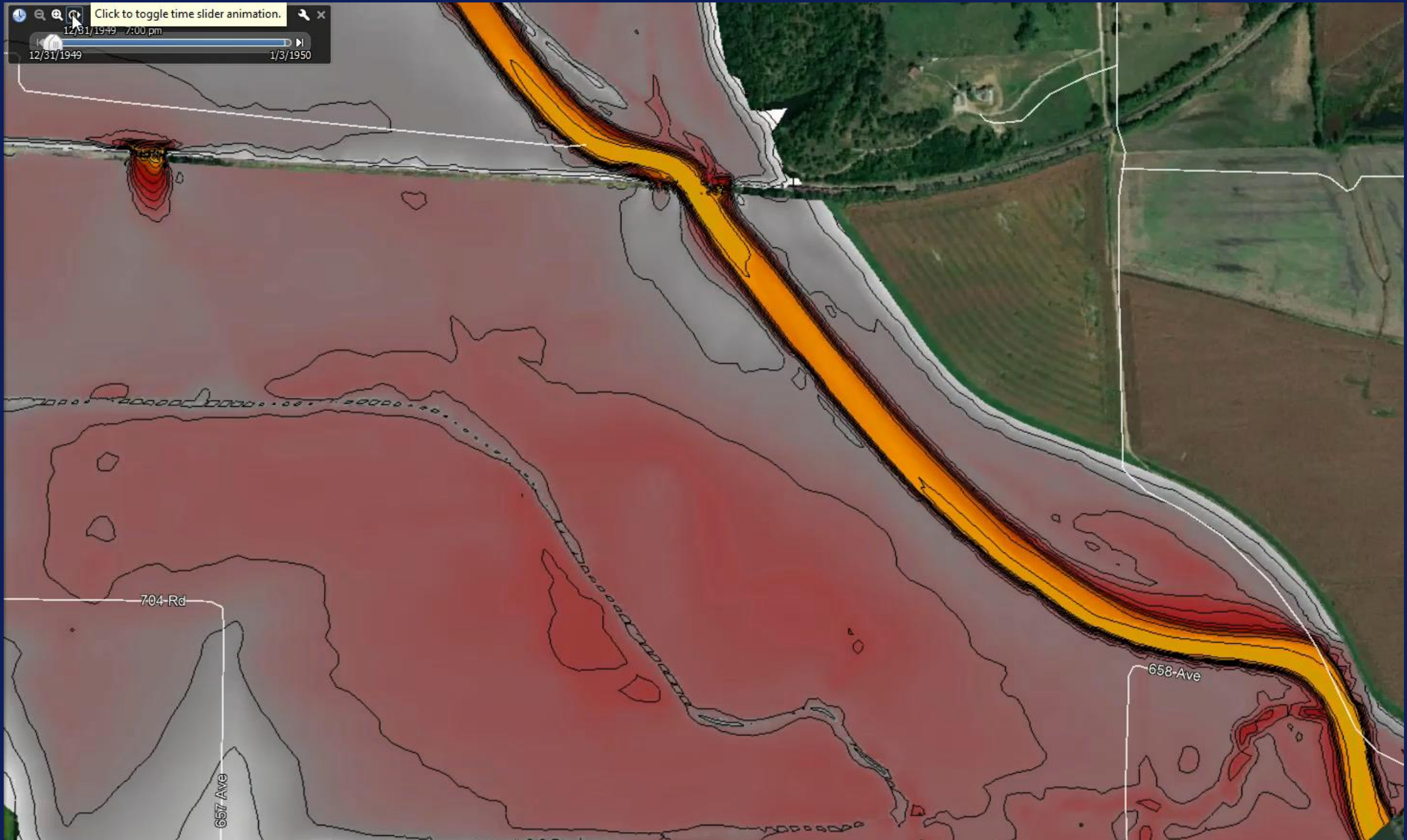


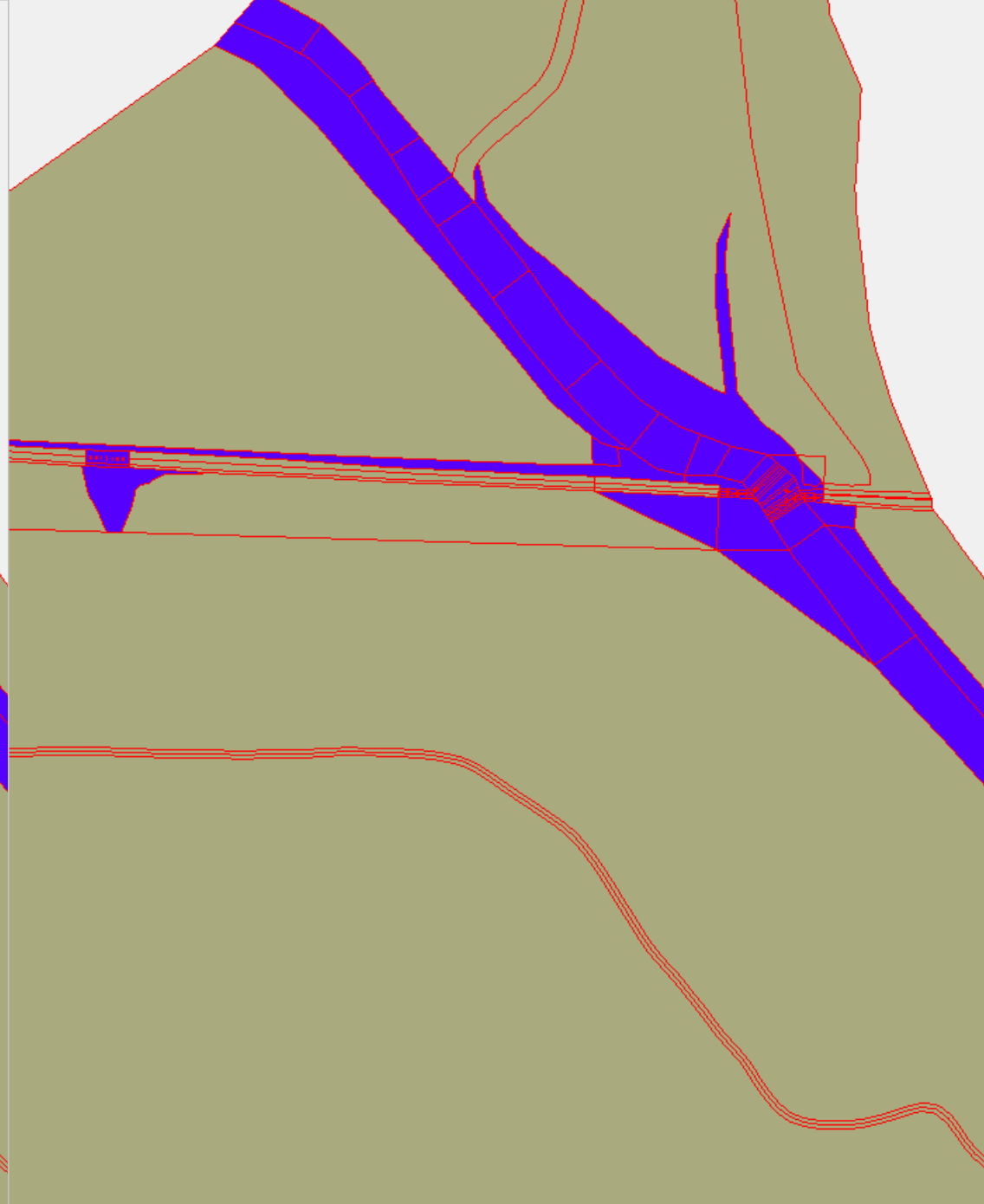
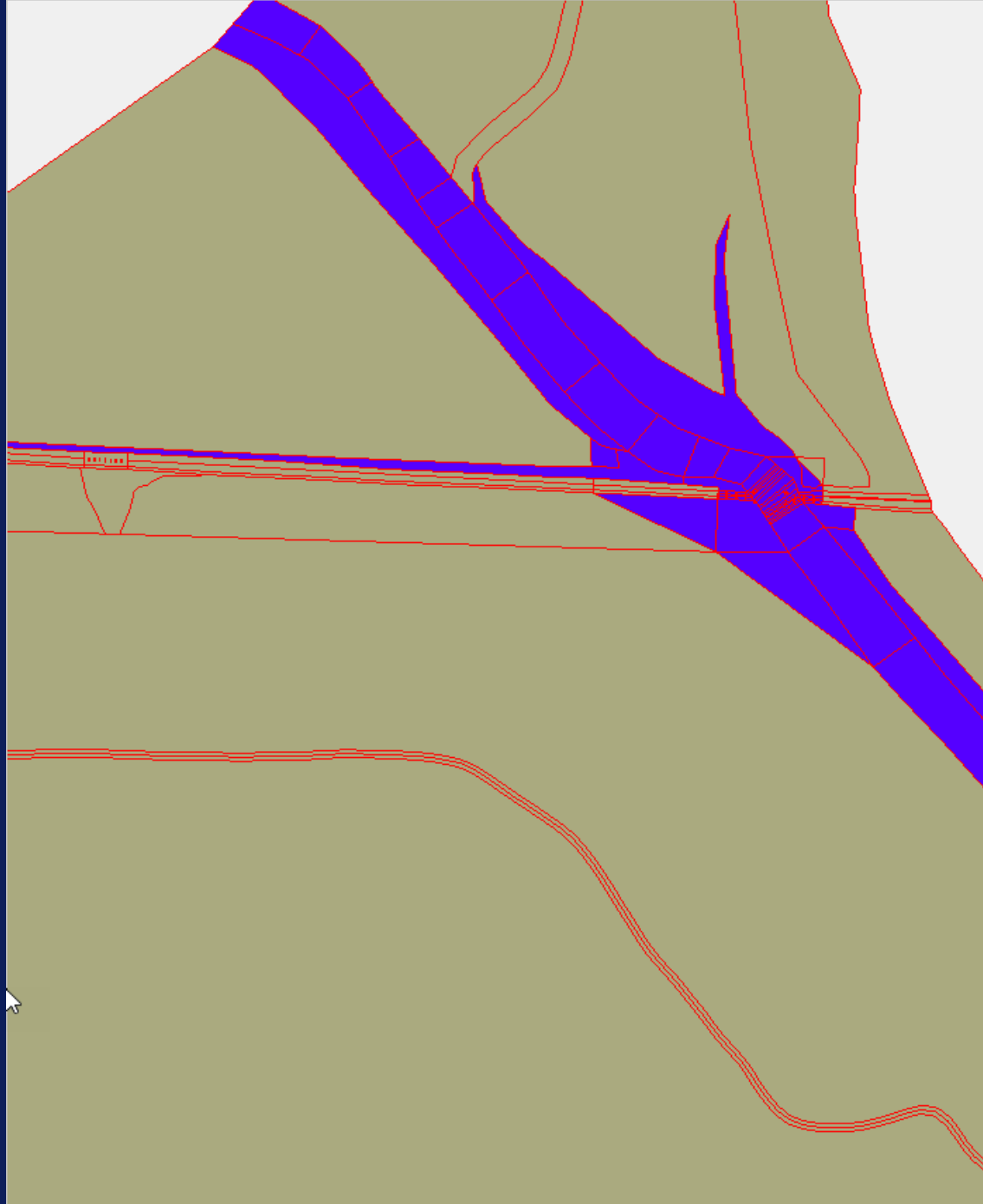


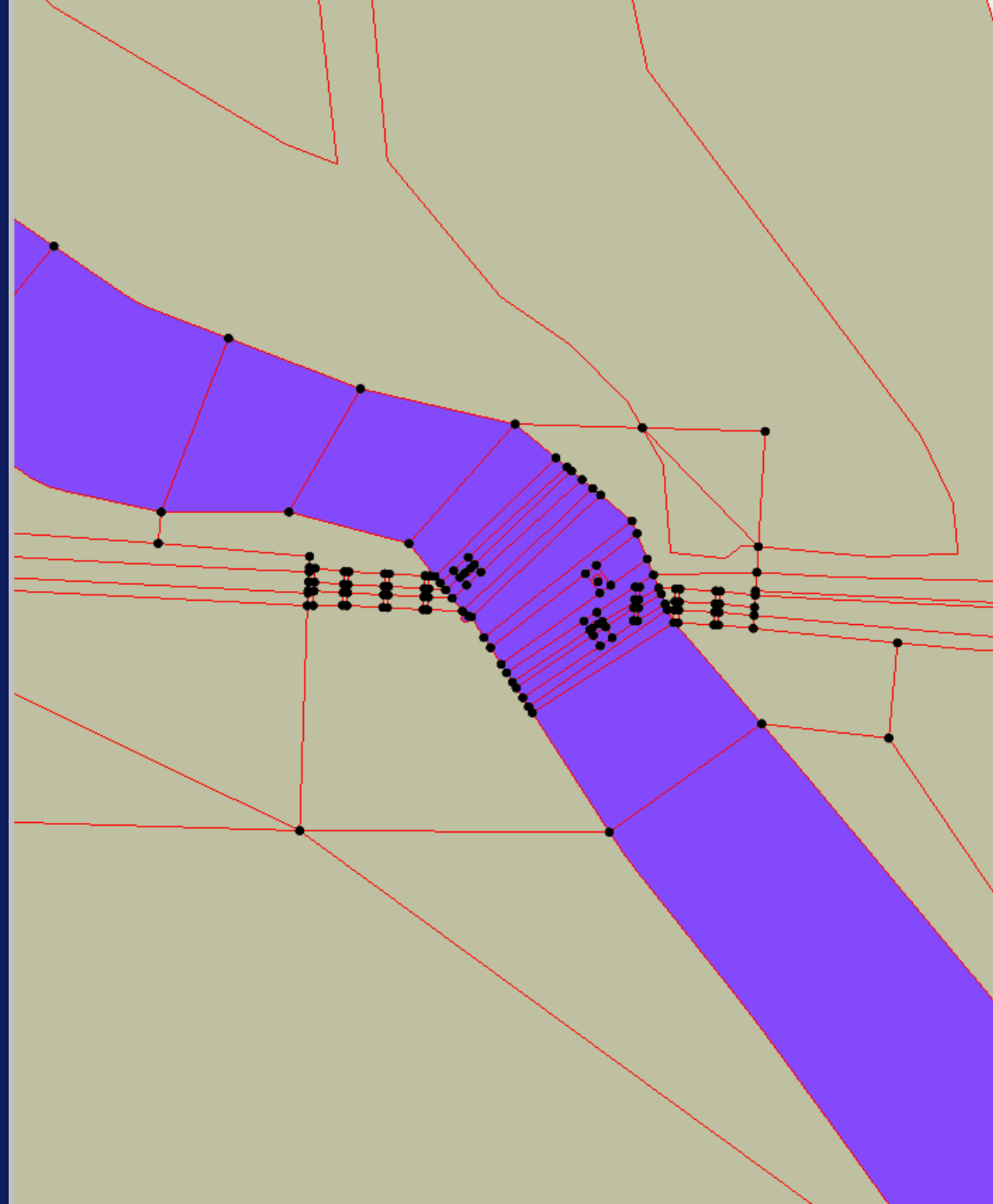
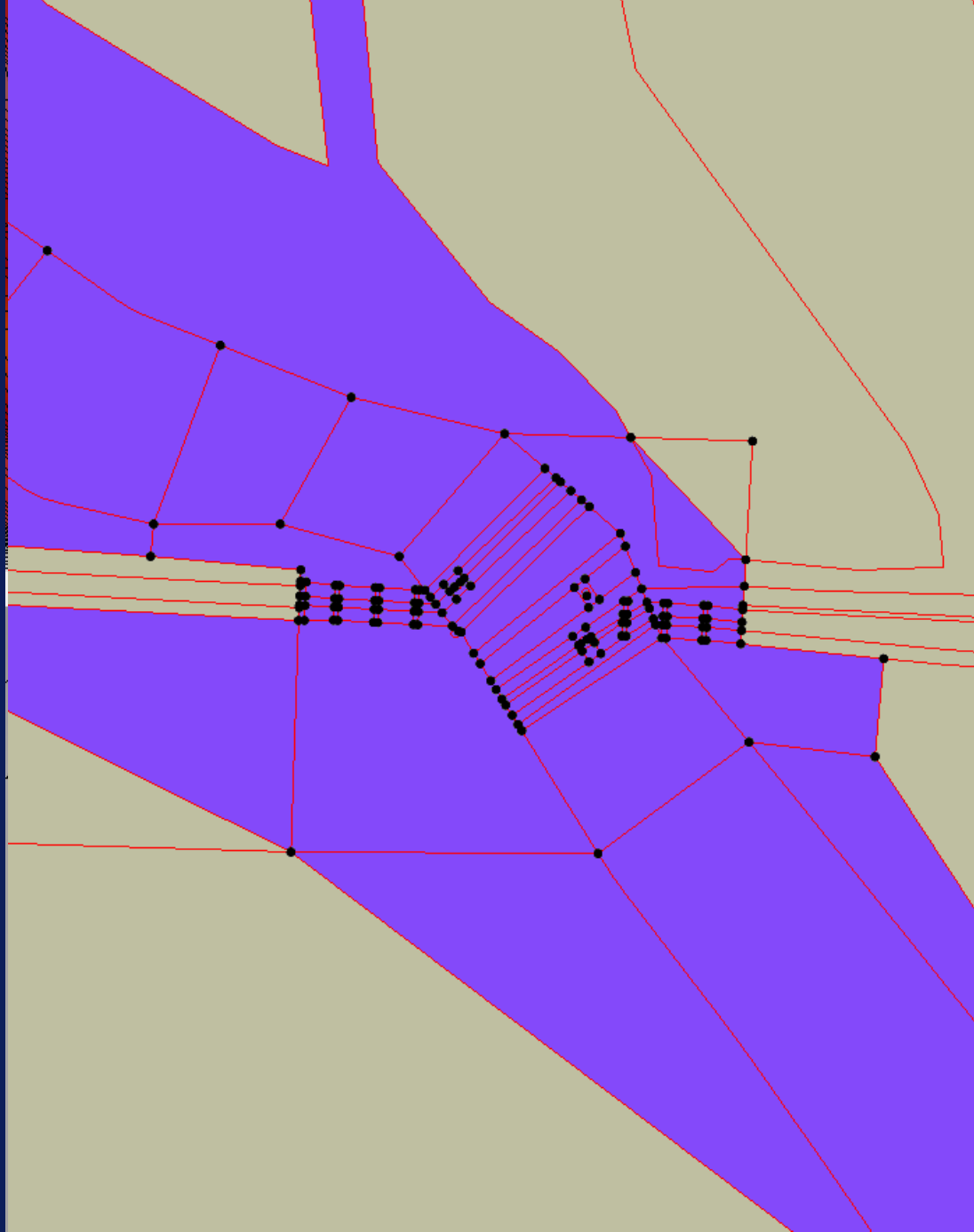
Click to toggle time slider animation.

12/31/1949 7:00 pm

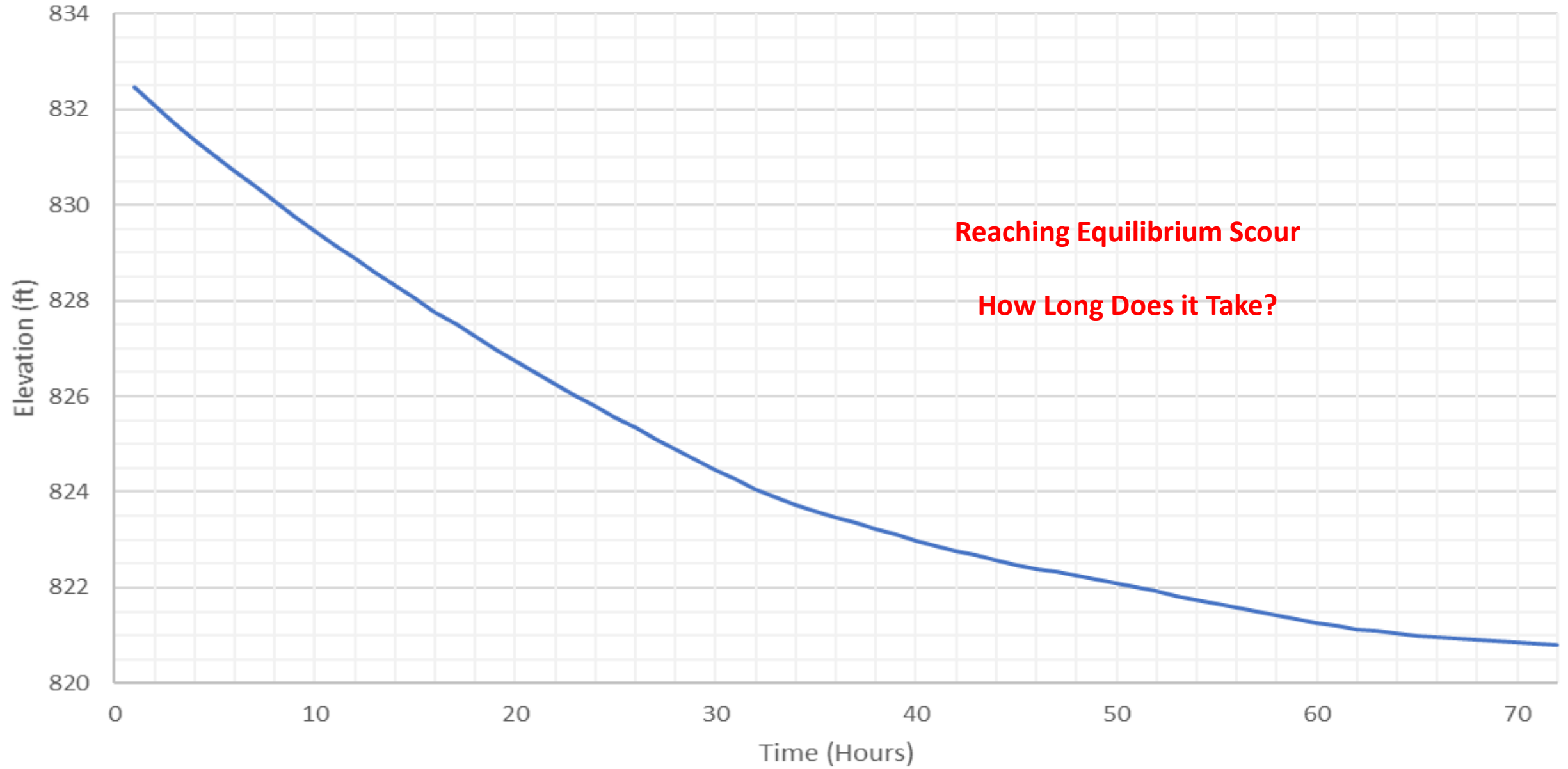
12/31/1949 1/3/1950







Bed Elevation vs Time



How'd We Do



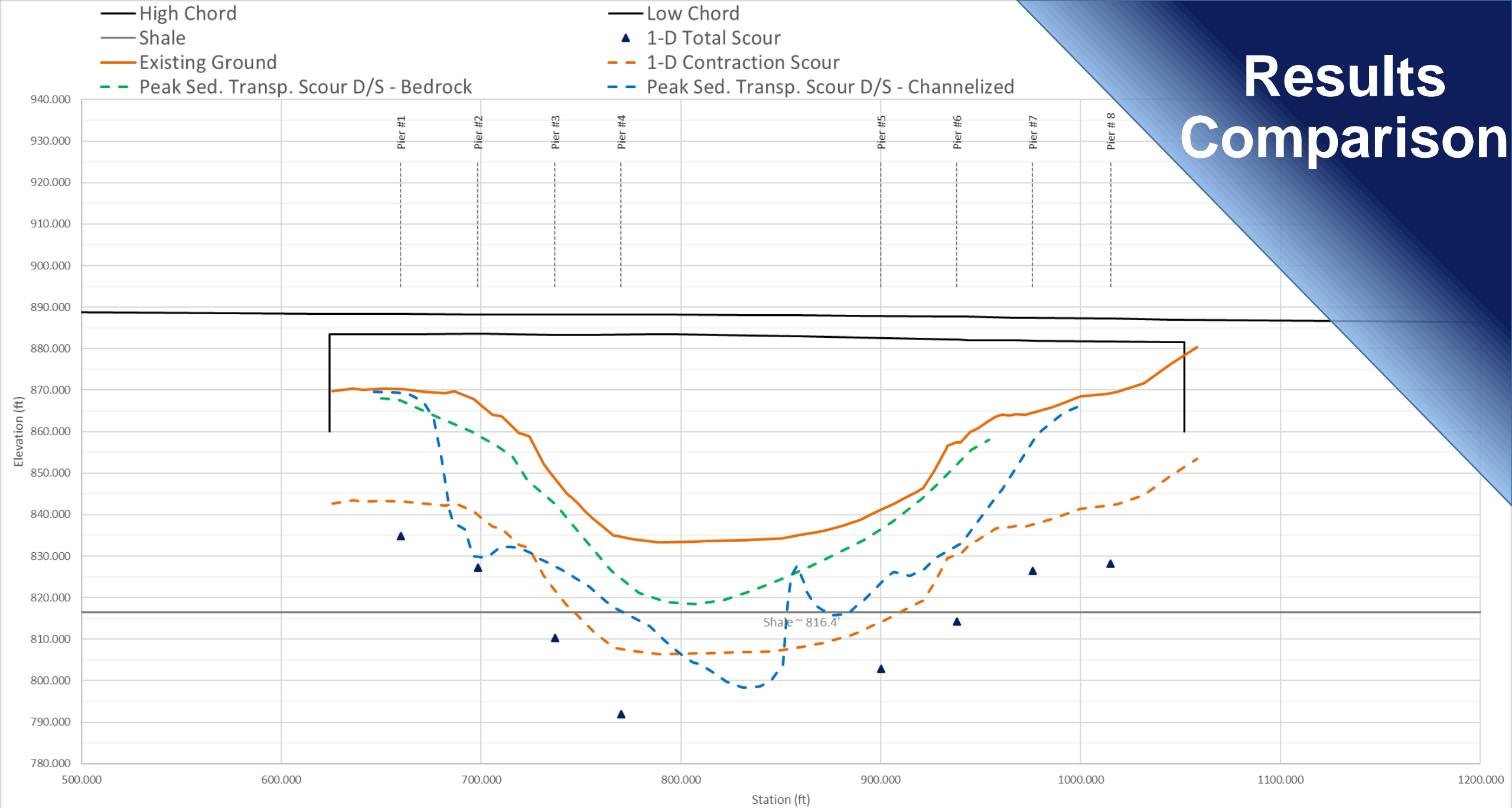
NAILED IT!



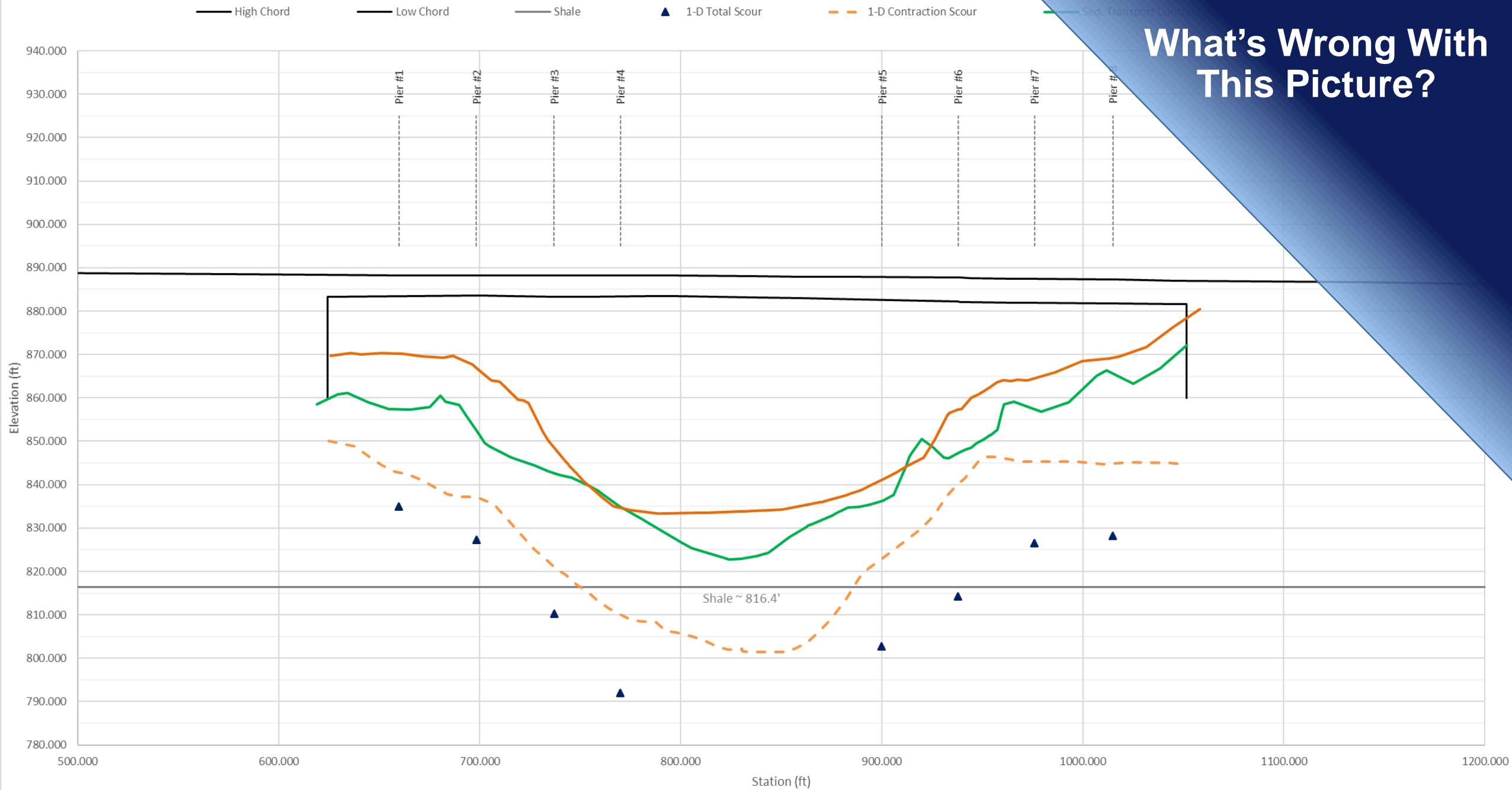
Comparison Table

Model	1-D HEC-18	2-D HEC-18	2-D Sediment Transport (Pre-Scour)	2-D Sediment Transport (Post-Scour to Bedrock)	2-D Sediment Transport (Post-Scour)
Flow Through Bridge (cfs)	95,317	92,339	92,339	84,700	101,000
Contraction Scour Depth (ft)	27.0	28.7	N/A	12.3	34.8
Contraction Scour Bed Elevation (ft)	806.3	804.6	833.0	820.7	798.22

Results Comparison

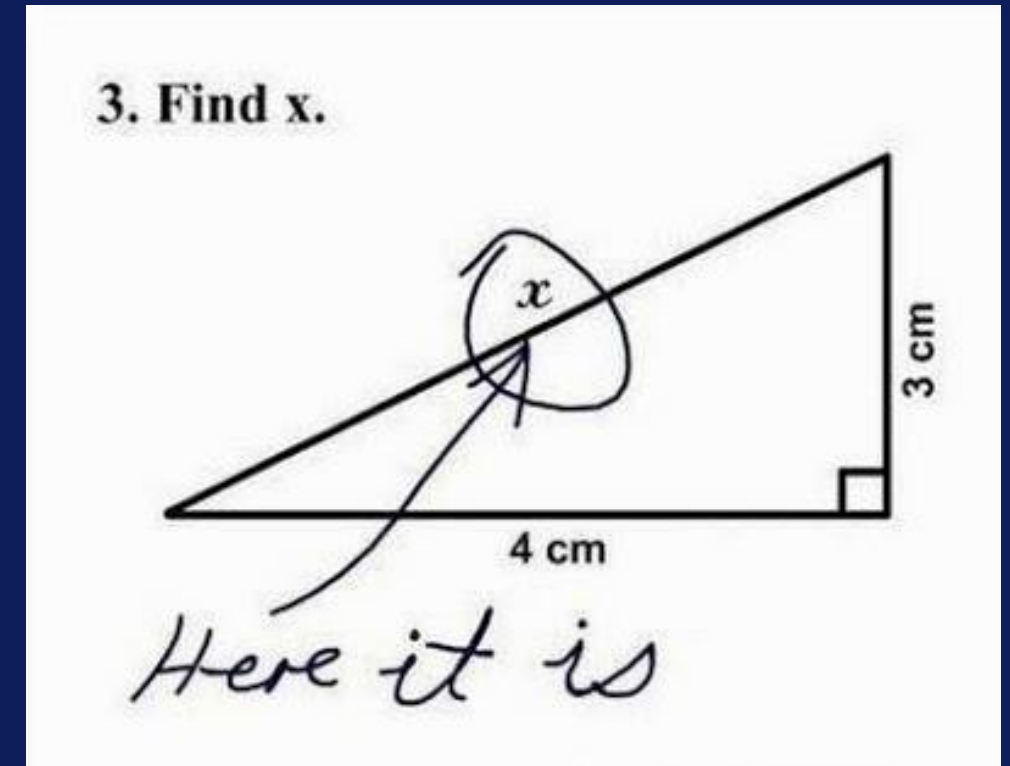


What's Wrong With This Picture?



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

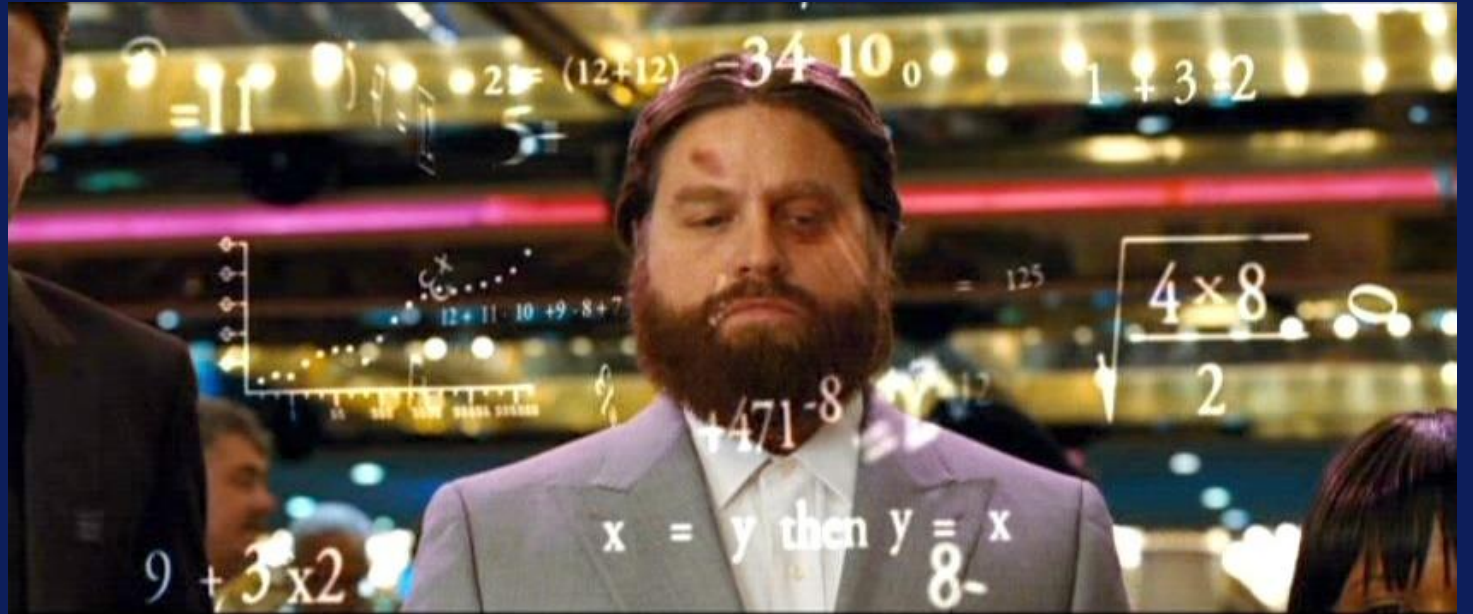
- Steady vs Unsteady
 - $\frac{1}{4}$ Speed
 - 1 simulation hour = 1.5 real hours
- Troubleshooting and Iterating



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.



Dilbert.com DilbertCartoonist@gmail.com

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



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YOU DON'T
KNOW
ANYTHING
ABOUT MY
PROJECT.



THAT
MAKES
TWO OF
US.

