Simplified Bridge Hydraulics in HEC-RAS

Workshop

1 Objective

This workshop will help students learn how to use HEC-RAS to use the 1D bridge option inside a 2D flow area.

The workshop will begin by developing a base geometry and plan that models a section of river with the shallow water equations (SWE) and then another geometry and plan will be developed with a Connection structure that will operate in bridge mode to simulate a road crossing. These simulations will then be compared.

The

2 Background

The figure below shows the terrain and bridge crossing (flow west to east). The floodplain is highly constricted at the bridge which includes four rows of piers, these piers are marked by purple lines in the view below. The square piers have 4ft sides.



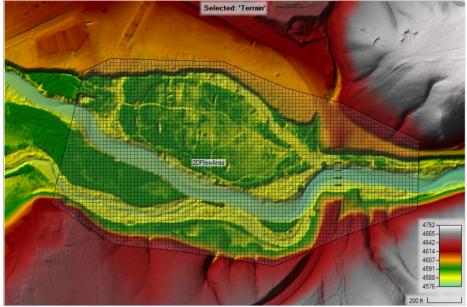
The flow event modeled does not overtop the bridge or hit the low chord.



3 Create Initial Model Geometry

- 1. **Open HEC-RAS** and start a new project
- 2. Open RAS Mapper
 - a. Set the **projection** ("GIS_Data" folder)
 - b. Create a **New Terrain** ("Terrain" folder)
 - c. Add a New Geometry.

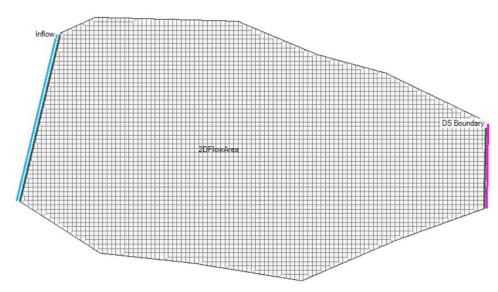
3. Set up a coarse 2D Flow Area mesh for the entire study area.



4. Try **20ft** cells with a n value of **0.04**.

📰 2D Flow Area Editor	\times
2D Flow Area: 2DFlow Area	
Computation Points Points Spacing (ft) DX: 20 DY: 20 Mesh State = Complete	
Generate Computation Points with All Breaklines Number of Cells = 4968 Average Cell Size = 406 Maximum Cell Size = 687 Minimum Cell Size = 314 Mesh Status = Success: Created in	
Generate Computation Points without Breaklines 00:00:00.078 Hydraulic Cell/Face Properties	_
Default Manning's n Value: 0.04	5
Force Mesh Recomputation Close	ie

- 5. Set up boundary condition lines
 - a. Inflow
 - b. **DS Boundary**



- 6. **Stop Editing** in RAS Mapper.
- 7. Close RAS Mapper
- 8. Open the **Geometric Data** editor.
 - a. Open the initial Geometry
 - b. Close the Geometric Data editor.

4 Enter Flow Data and Boundary Conditions

- 9. Open the **Unsteady Flow Data** editor.
- 10. <u>Set the downstream boundary to use **Normal Depth**</u>, s = **0.005**

Normal Depth Downstream Bounda	ry			
2D: 2DFlowArea BCLine: DS Boundary				
Friction Slope:	0.þ05			
 2D Flow Area Boundary Condition Para Compute separate water surface ele Compute single water surface for en 	evation per face along BC Line			
	OK Cancel			

11. Set the inflow to be a **Flow Hydrograph** Use a constant flow of **15,000 cfs**. Set the EG Slope to **0.00075**

_	t/Enter the Data's Starting	Time Ref <u>erence</u> Date: 01jan2000	Dat Time; 0000	ta time interva	il: 1 Hour	_
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7	01Jan2000 0600		6:00:00			
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12. Save the flow data

5 Create a Plan and Simulate

- 13. Open the Unsteady Flow Analysis window
- 14. Set up the time window, time step, and mapping output interval.

15. Set the Computation Options

a. Set the Equation Set to SWE-ELM (original/faster) and the Initial Conditions Time

	Parameter	(Default)	2DFlowArea
1	Theta (0.5-1.0)	1	1
2	Theta Warmup (0.5-1.0)	1	1
3	Water Surface Tolerance [max=0.2](ft)	0.01	0.01
4	Volume Tolerance (ft)	0.01	0.01
5	Maximum Iterations	20	20
6	Equation Set	Diffusion Wave	SWE-ELM (original/faster)
7	Initial Conditions Time (hrs)		1
8	Initial Conditions Ramp Up Fraction (0-1)	0.1	0.1
9	Number of Time Slices (Integer Value)	1	1
10	Turbulence Model	None	None
11	Longitudinal Mixing Coefficient	0.5	0.3
12	Transverse Mixing Coefficient	0.1	0.1
13	Smagorinsky Coefficient	0.05	0.05
14	Boundary Condition Volume Check		
15	Latitude for Coriolis (-90 to 90)		
16	Solver Cores	All Available	All Available
17	Matrix Solver	PARDISO (Direct)	PARDISO (Direct)
18	Convergence Tolerance		
19	Minimum Iterations	C C	0
20	Maximum Iterations	Ø	0
21	Restart Iteration	10	10
22	Relaxation Factor	1.5	1.3
23	SOR Preconditioner Iterations	10	10

16. **Save** the plan data as Base Plan

17. Compute

18. **Computation Time Step Check** ensure solution is smooth and stable, pick a new time step and re-run if necessary.

6 Create new Geometry and Plan with 1D Bridge

- 19. In RAS Mapper window use the "Save Geometry as ..." menu option to copy the base geometry to start.
- 20. Start editing and draw a centerline for the bridge deck and set the width to **40** ft. (draw from left to right looking downstream, which will be top to bottom in this case).
- 21. Enforce the 2D cell spacing around the centerline as appropriate.
 - SA/2D Connections Layer Properties (2D Flow Area + 1D Bridge) Visualization and Information | Features | Source Files | Vecto Addtional Option Line: ----- Fill Point: 100 Draw P Edit Label Features with Attribute Column(s) Label Points Label Segment Indexes Plot Width Plot Surface Update Legend with View Plot Breach Opacity: 100% Contours / Hillshade Plot Contours Interval: 5 -Color Edit Plot Hillshade Z Factor: • Copy Symbology Paste Symbology Reset Symbology
- 22. Add the Pier Centerline shapefile (in the GIS Data folder)

- 23. Turn on the stationing tick marks on the bridge centerline
- 24. Note the bridge centerline stations where the piers cross it, you will need these stations when entering the pier data.
- 25. Go the main **Geometry Schematic** and open the **2D Connection Data** Editor.
- 26. Ensure the structure type is modeled as Bridge (Internal to 2D Flow Area)
- 27. Add a deck roadway that spans the full range width of the XSs with a flat top roadway at an elevation of 4615 and a low chord at 4607 ft.

- 28. Set the upstream distance to **5**ft.
- 29. Select appropriate Weir Coefficient for this structure.
- 30. Add **4 Piers** that are **4ft** wide at the stations you noted earlier where the <u>centerline crossed the pier centerlines shapefile</u>.

Pier Data	Editor								
Add	Сору	Delete	Pier #	1 💌	L T				
Del Row	Cer	nterline Statio	n Upstream	241					
Ins Row	Cer	nterline Statio	n Downstrea	m 241					
Floating	LI Pier Deb	oris							
All On .	4		Apply floating	debris to this	pier				
Set Wo	Ht for		ris Width:						
			ris Height:	i i					
	Upstrea	m	Do	wnstream					
Pier	Width	Elevation	Pier Width	Elevation	•				
14		4570	4	4570					
24		4610	4	4610					
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- 31. Open the **Bridge Modeling Approach** and turn on the **Momentum** method and select an appropriate Cd coeficient for square nosed piers.
- 32. Open the HTab parameters and limit the curves for this simulation.

Connection Hydraulic Property Table Parameters						
Number of points on free flow curve:	50					
Number of submerged curves:	50					
Number of points on each submerged curves:	20					
Apply number of points to all Connect	ions					
Head water maximum elevation:	4618.					
Tail water maximum elevation (Optional):						
Maximum Flow (Recommended):	20000.					
ОК	Cancel					

- 33. Open the "External and Internal Bridge Cross Section" dialog.
 - ▼ Connection Data Editor 2D Flow Area + 1D Bridge

<u>F</u> ile <u>V</u> iew	Options	<u>H</u> elp				
Connection:	Exte	rnal and Internal Bridge Cross Sections				
Description	Con	Contr and Expan Coef for Bridge Cross Sections				
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From:	Mo	mentum Equation	ir Length:			
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Overflow Co	FIE	ssure flow criteria	Centerline			
Structure Type	e: Bridge	(Internal to 2D Flow Area)	Cut profile			
Plot:	US Insi	de Bridge 📃 📘 🕇	Clip Weir Pro			
Beck/ Roadway		N Deerfield Rd				

- 34. Set the Manning's values for the 4 XS's for this structure to use a value or 0.04.
- 35. Save geometry file.
- 36. **Save Plan As**, to create another plan with this geometry.
- 37. Compute

7 Compare Results

- 38. Create a **Profile Line** for the river centerline. (turn on Plot Tick Marks to help find where the bridge is in the profile)
- 39. Plot the WSE and compare the results.

Question: What is the difference in WS between the plans at the bridge?

<u>Question</u>: Look at the family of bridge curves and for the flow through the bridge track back the HW to find the prescribed TW and try to verify the loses were applied correctly.

<u>Question</u>: Is the cell size adequate for modeling the terrain, bridge, piers, etc?