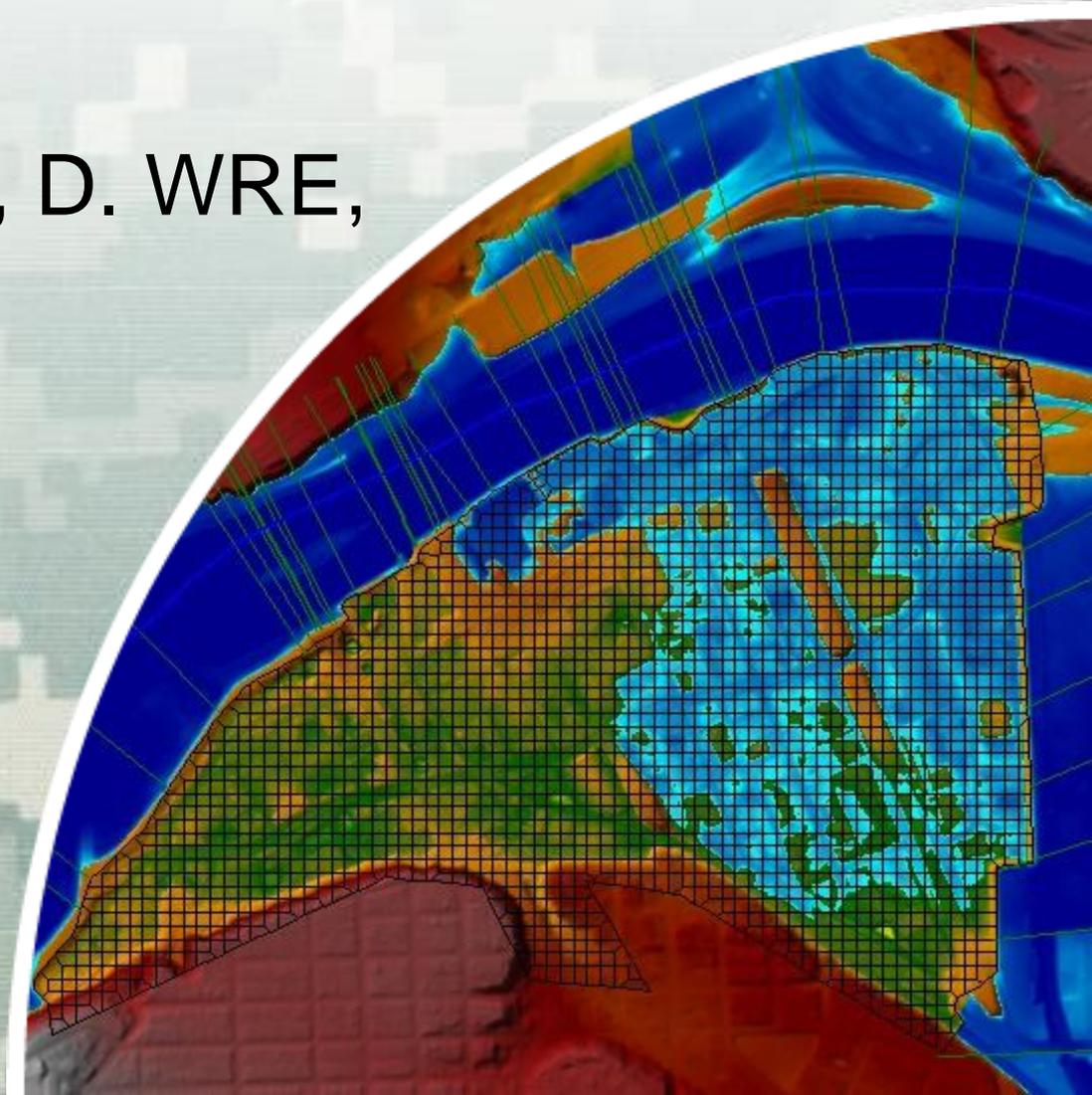


What's New with HEC-RAS 6.0

Gary Brunner, P.E., D. WRE,
M.ASCE



Major New Hydraulics Features for HEC-RAS 6.0

- Spatial Precipitation
- Spatial Infiltration
- Bridge Hydraulics inside 2D Flow Areas
- Wind Forces
- 1D Finite Volume solver
- New 2D full momentum solver with greater Momentum conservation properties
- Pump stations inside 2D Flow Areas
- Computational speed improvements
- 3D Visualization tool

Spatial Precipitation

- Gridded Data
 - HEC-DSS file format (from HEC-MetView)
 - GRIB - NWS
 - NetCDF - NWS
- Point Gage Data
 - HEC-DSS time series
 - Regular Interval
 - Irregular Interval
 - User Entered into a Table

Unsteady Flow Boundary Conditions

Unsteady Flow Data - Gridded Precipitation

File Options Help

Description:

Boundary Conditions | Initial Conditions | **Meteorological Data** | Observed Data

Precipitation/Evapotranspiration: Wind:

Meteorological Stations (required for point time series data)

Meteorological Variables

Precipitation

Mode: Ratio (Optional):

DSS Data

Filename:

Path:

Projection Override (Optional):

Evapotranspiration

Mode:

Gridded Data

Boundary Conditions | Initial Conditions | **Meteorological Data** | Observed Data

Precipitation/Evapotranspiration: Wind:

Meteorological Stations (required for point time series data)

Meteorological Variables

Precipitation

Mode: Ratio (Optional):

Gridded Data

Source:

DSS Data:

Filename:

Path:

Projection Override (Optional):

Evapotranspiration

Mode:

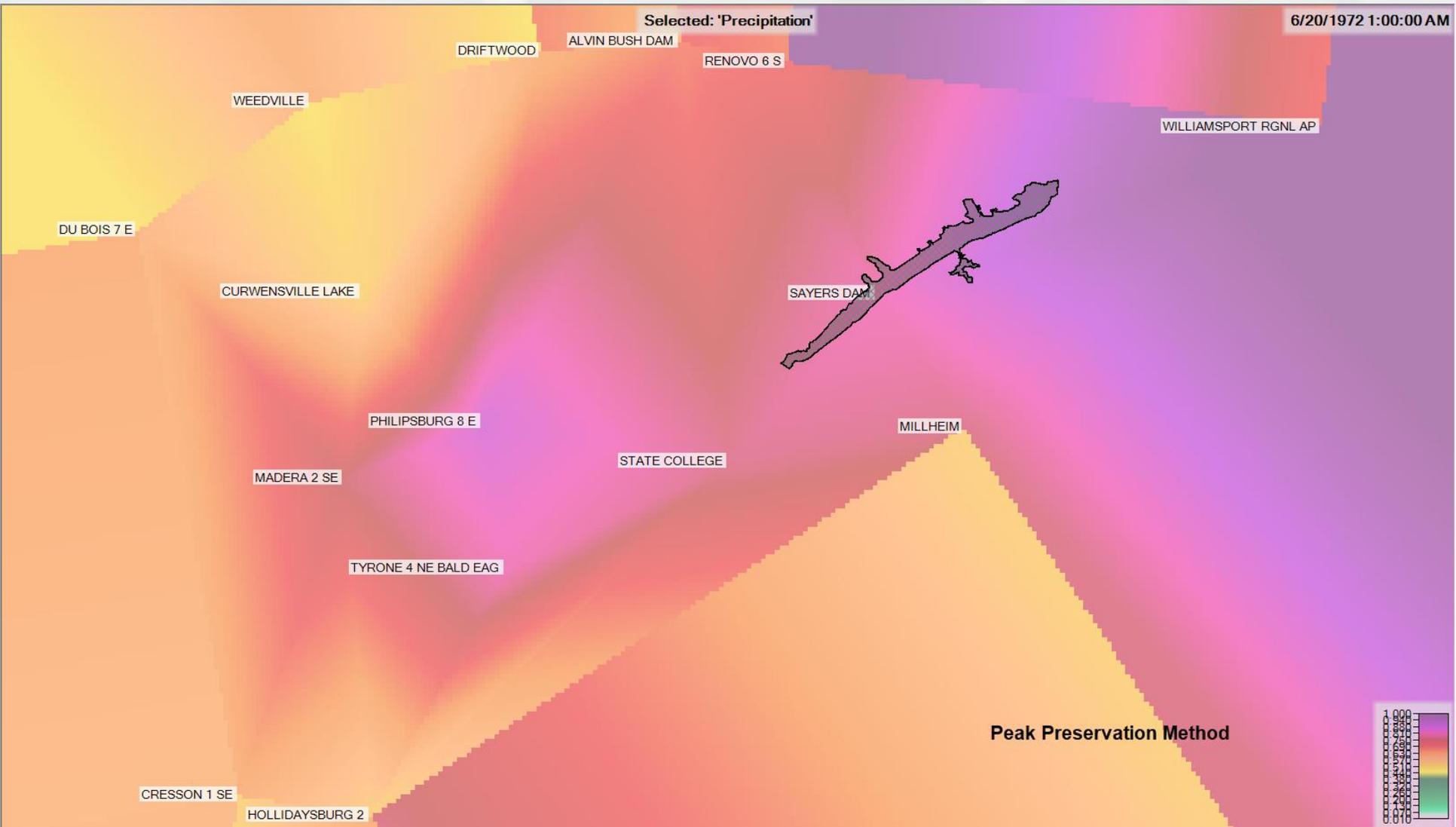
Point Gage Data

The screenshot shows the 'Unsteady Flow Data - Point Precipitation Data 1972' window. The 'Point Time Series Data' section is highlighted with a red box. The 'Interpolation Method' dropdown menu is open, showing the following options:

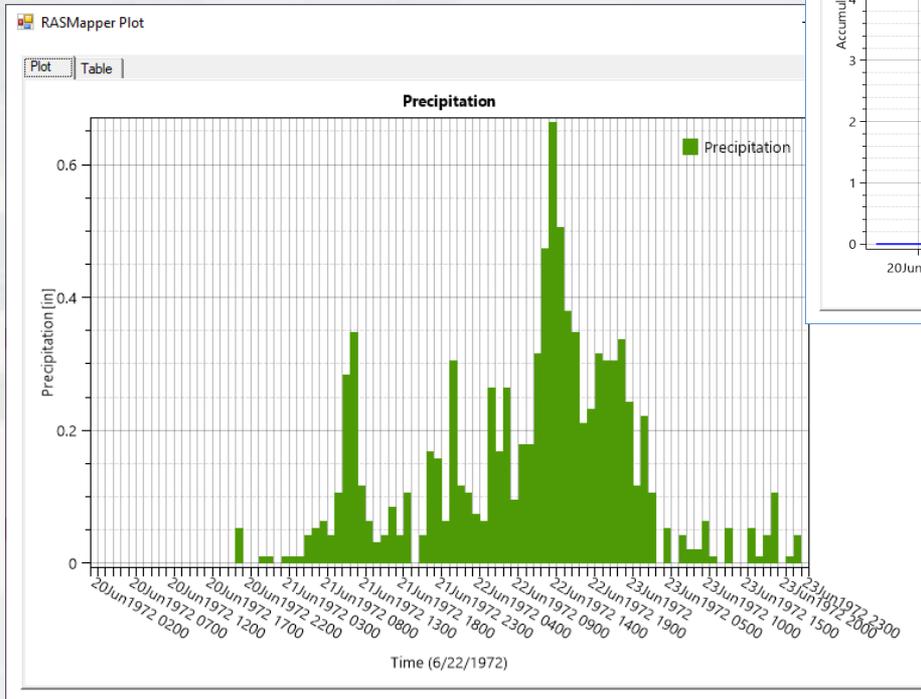
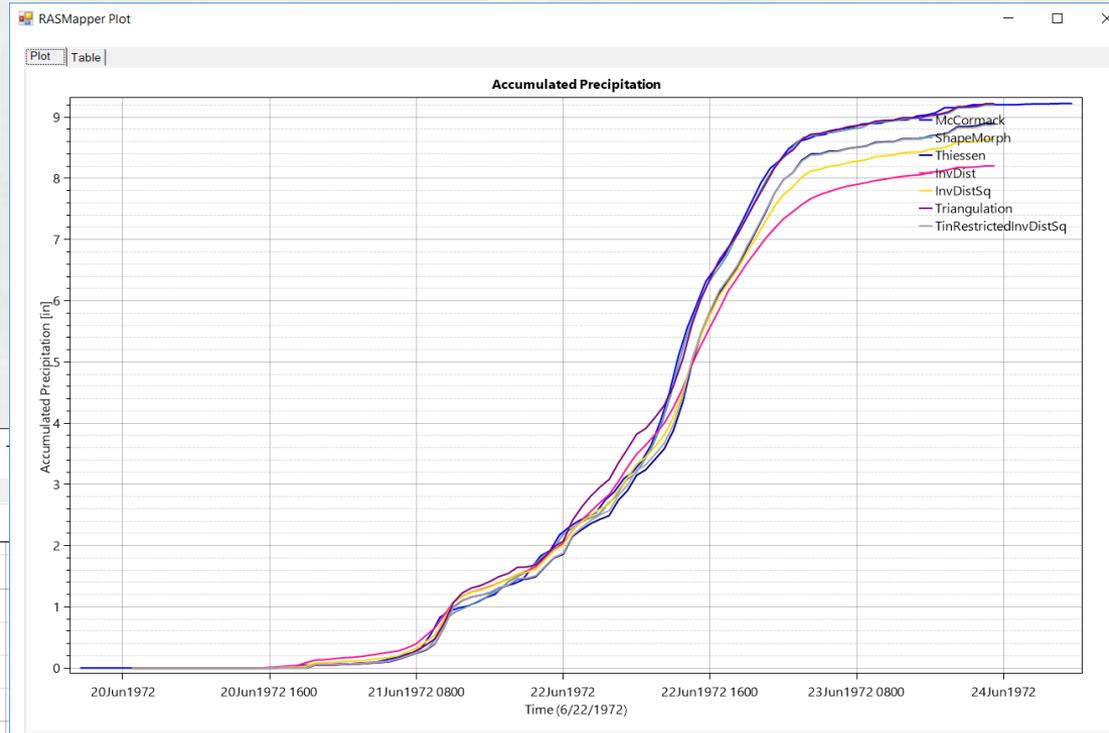
- Thiessen Polygon
- Inv Distance
- Inv Distance Sq
- Inv Distance Sq (Restricted)
- Triangulation
- Peak Preservation (selected)
- Shape Preservation
- Laplace

Station Name	Interpolation Method	Distance	Units	Edit
1 ALVIN BUSH DAM	Thiessen Polygon	0.500	(inches)	...
2 DRIFTWOOD	Inv Distance Sq	0.390	(inches)	...
3 HOLLIDAYSBURG	Triangulation	2.90	(inches)	...
4 PHILIPSBURG 8 E	Peak Preservation	0.550	(inches)	...
5 WILLIAMSPORT P	Shape Preservation	0.850	(inches)	...
6 GREGSON 1 SE	Laplace	0.470	(inches)	...
7 CURWENSVILLE LAKE	DSS: data range = 0.000 to 0.300		(inches)	...

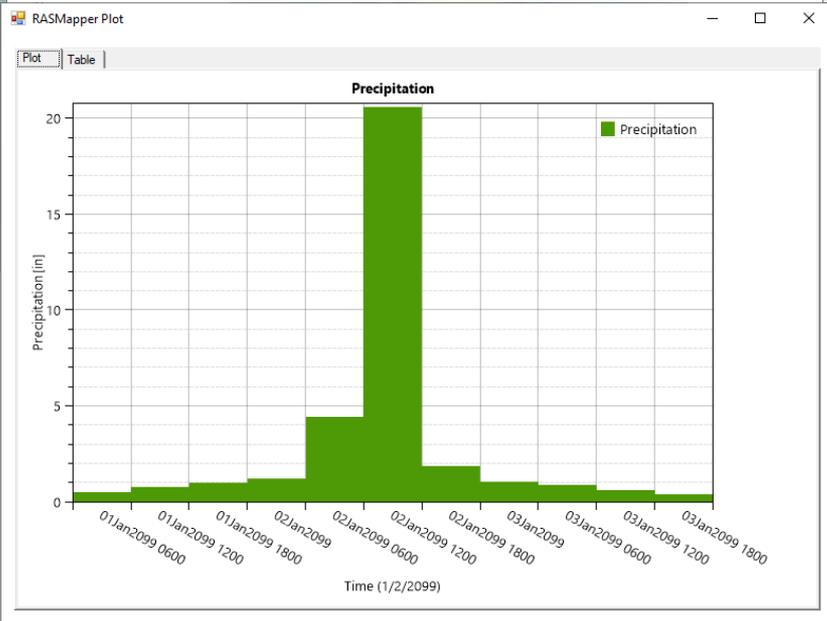
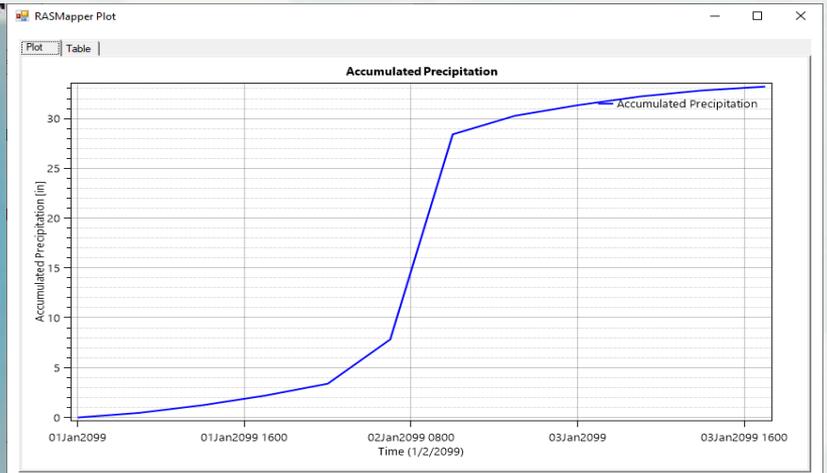
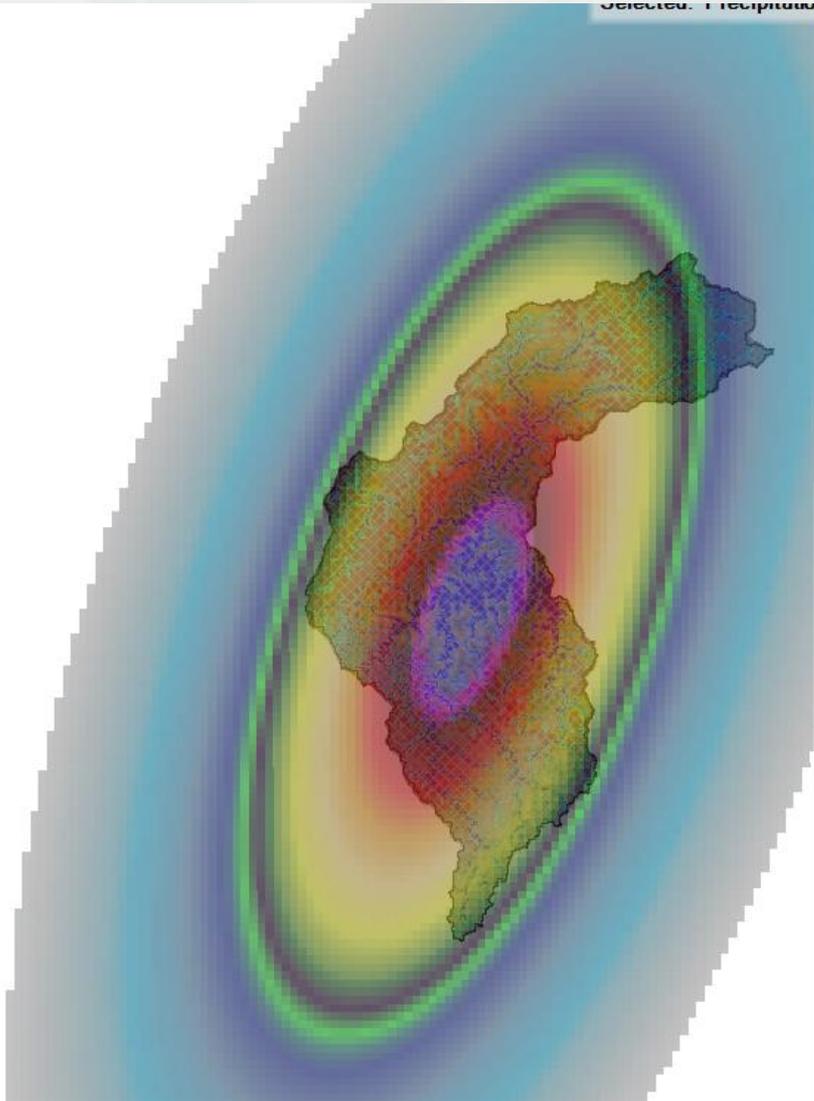
Cumulative Rainfall



Rainfall Time Series Plots



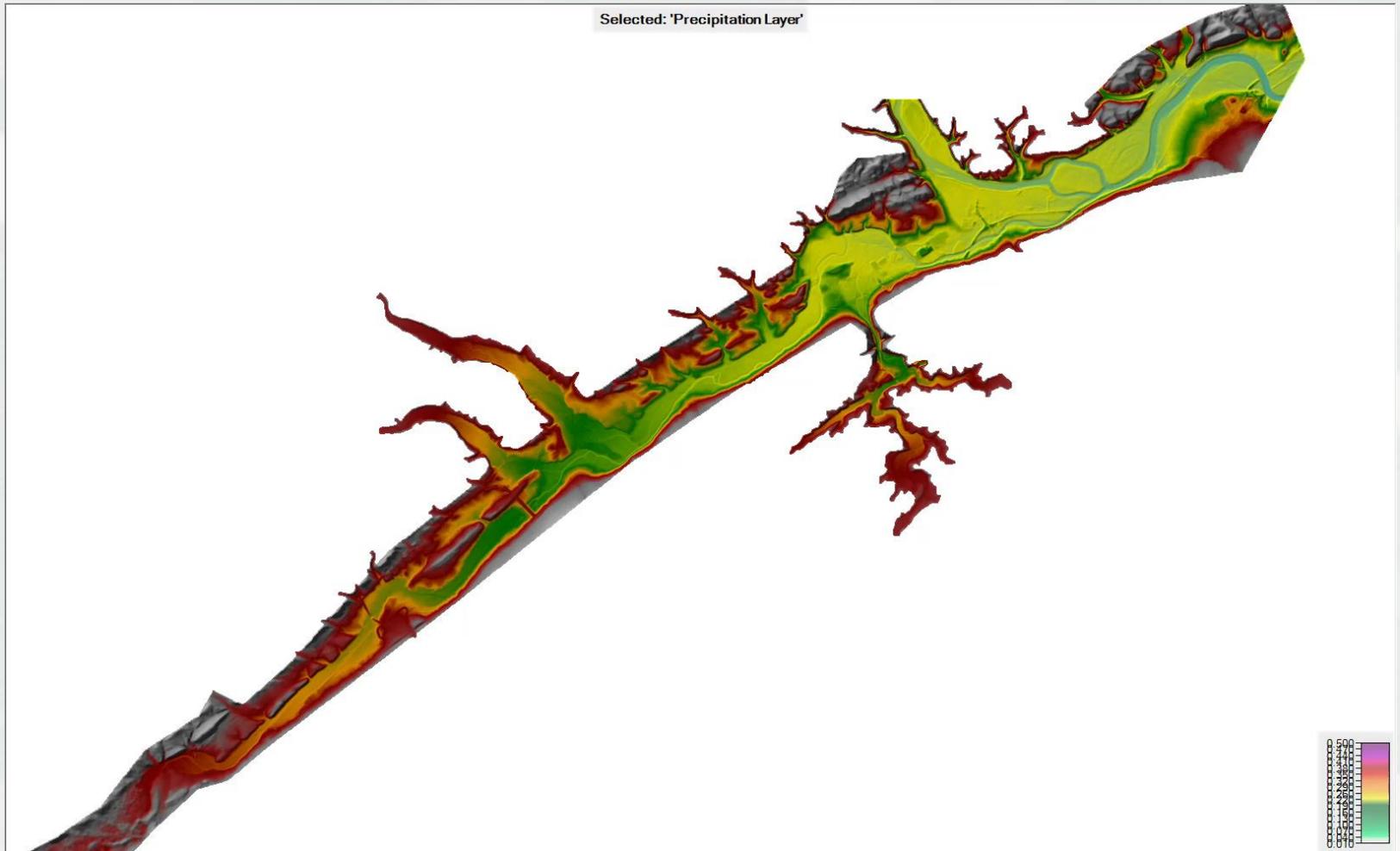
PMP Example

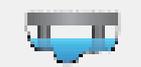


Spatial Infiltration

- Three Methods
 - Deficit – Constant method
 - SCS Curve Number
 - Green and Ampt
- Spatial Data
 - Soils
 - Land cover
- Other Optional Data
 - Evapotranspiration
 - Mean Monthly Pan evaporation data

Gridded Precipitation example HEC-RAS





Bridge/
Culv

Bridge Hydraulics inside of a 2D Flow Area

- Utilizing existing HEC-RAS **1D Bridge Hydraulics methods** inside of a 2D Flow Area.
- Model complete range of Bridge Hydraulic flow regimes:
 - **Low flow**
 - **Pressure flow**
 - **Pressure flow and weir flow (road over topping)**
 - **Low flow and weir flow**

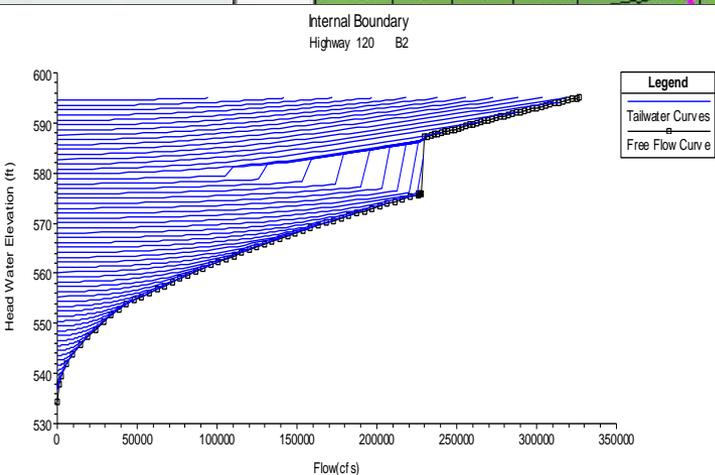
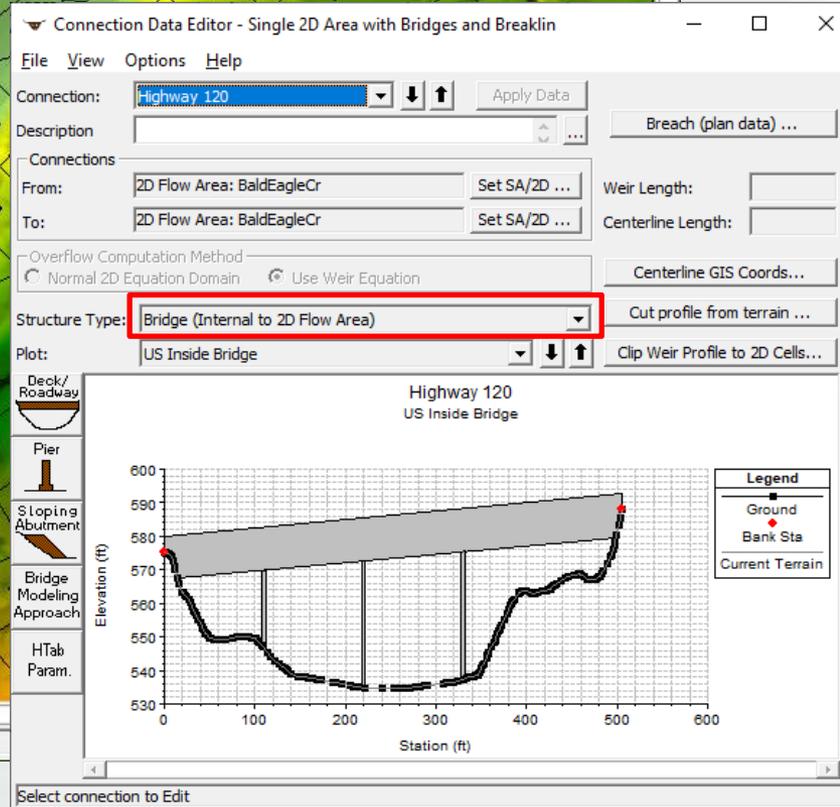
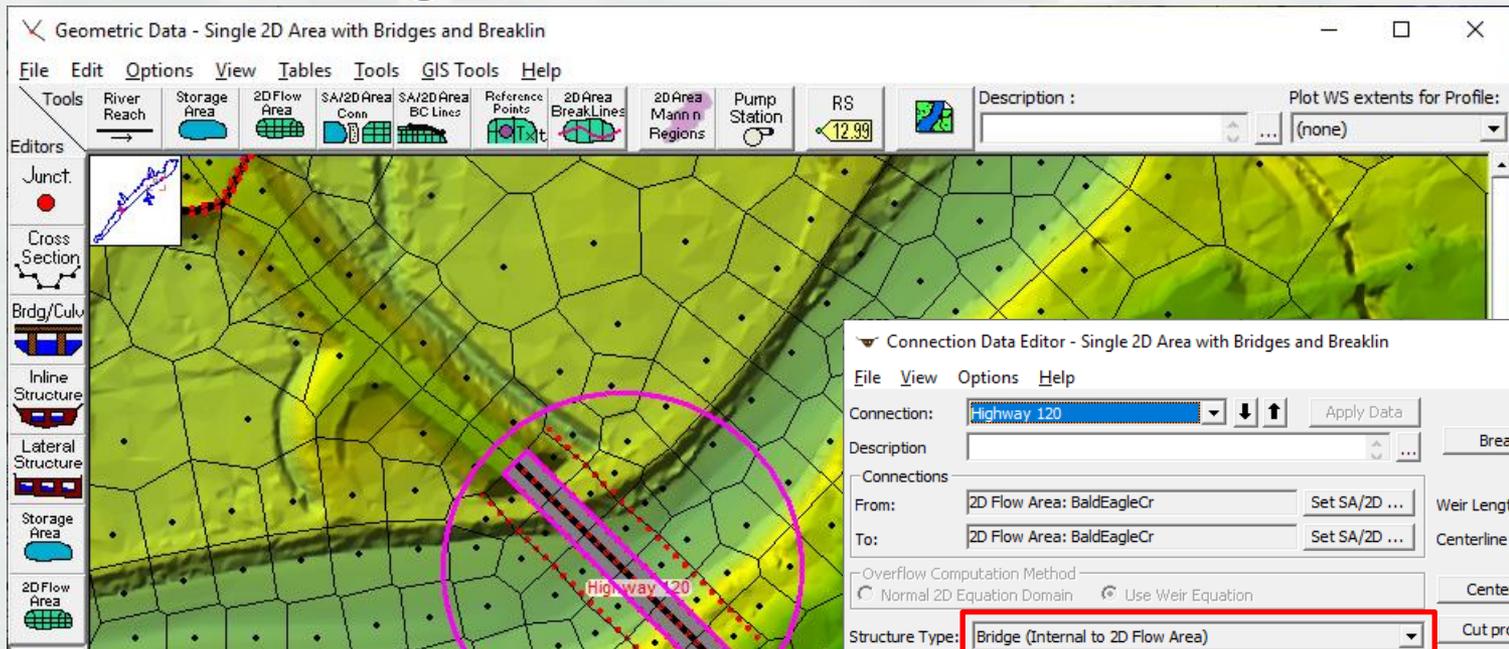
Why is it Important?

- Previous versions of HEC-RAS had **no method for handling bridges** inside of a 2D Flow Areas
- Modelers were forced to do 1D channels with 2D Floodplains where bridges are important.
 - **1D to 2D connections can be complicated**
 - **Time consuming**
 - **May cause instabilities**
 - **Less accurate for channel to floodplain flow transfers**
 - **More computation time to develop models and possible run times.**
- The new 2D Bridge Capability has the following benefits:
 - **Less need for combined 1D/2D modeling**
 - **Able to develop more detailed 2D models**
 - **Greater Modeling flexibility**
 - **More Stable numerical solutions**
 - **More accurate flow transfers from channel to floodplain**
 - **Possibly faster computationally (model specific)**

Approach

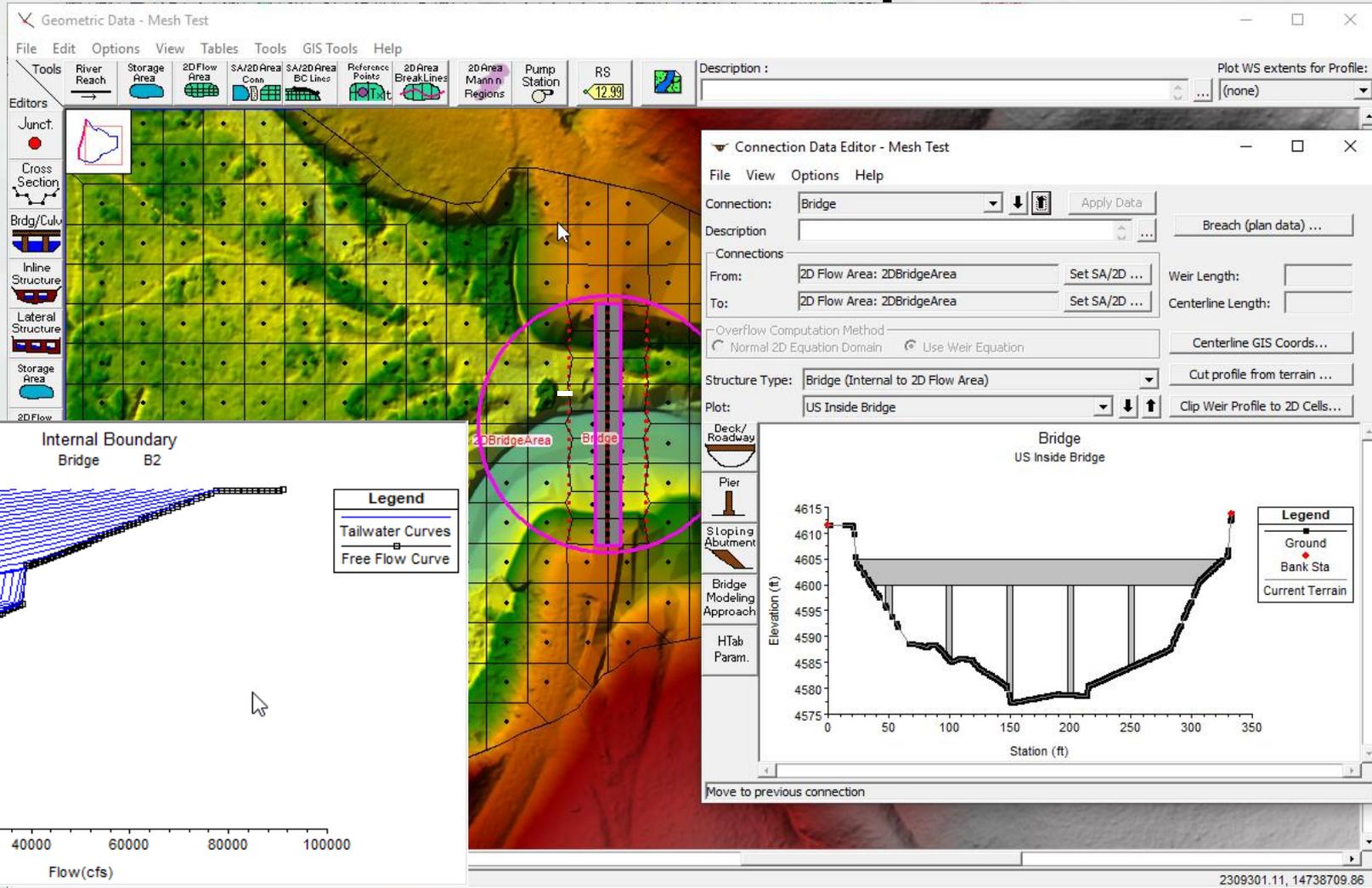
- Use HEC-RAS 1D Bridge Geometry and Cross Section Layout (automated layout) inside of 2D Flow Area
- Develop a family of Headwater-Tailwater-Flow curves from RAS 1D bridge hydraulic calculations
- Using a special momentum equation that gets applied only at the bridge 2D cell faces:
 - Friction loss, pressure differential, and convective acceleration forces are equated from the water surface difference in the bridge curves.
 - The forces are distributed across multiple faces though the bridge based on conveyance.
 - Local acceleration is calculated on the fly, as it is not a force in curves
- Bridge faces are then solved in 2D just like all other faces.
- Extremely efficient – almost no increase in computations.

1D Bridge Data and Curves

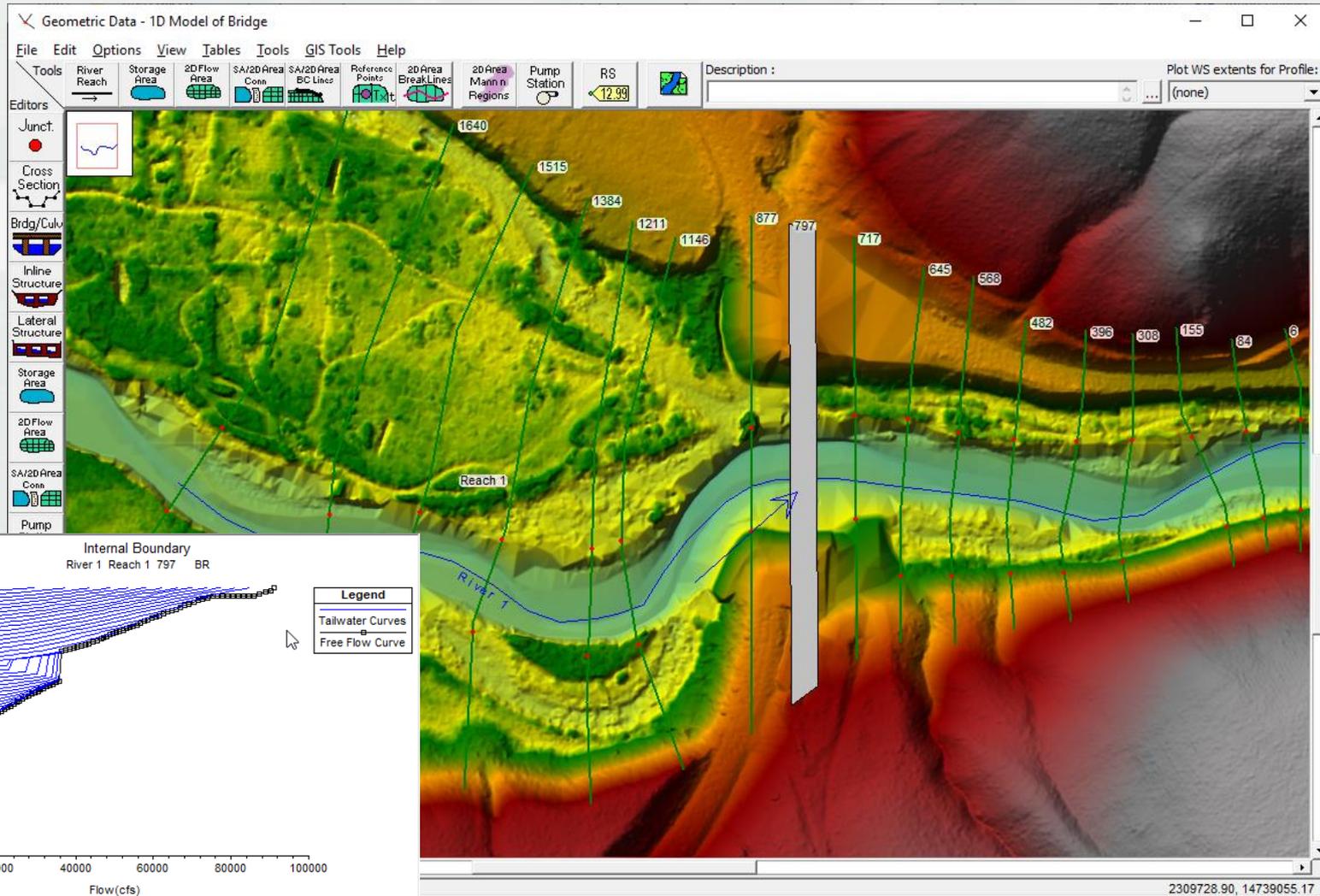


Results

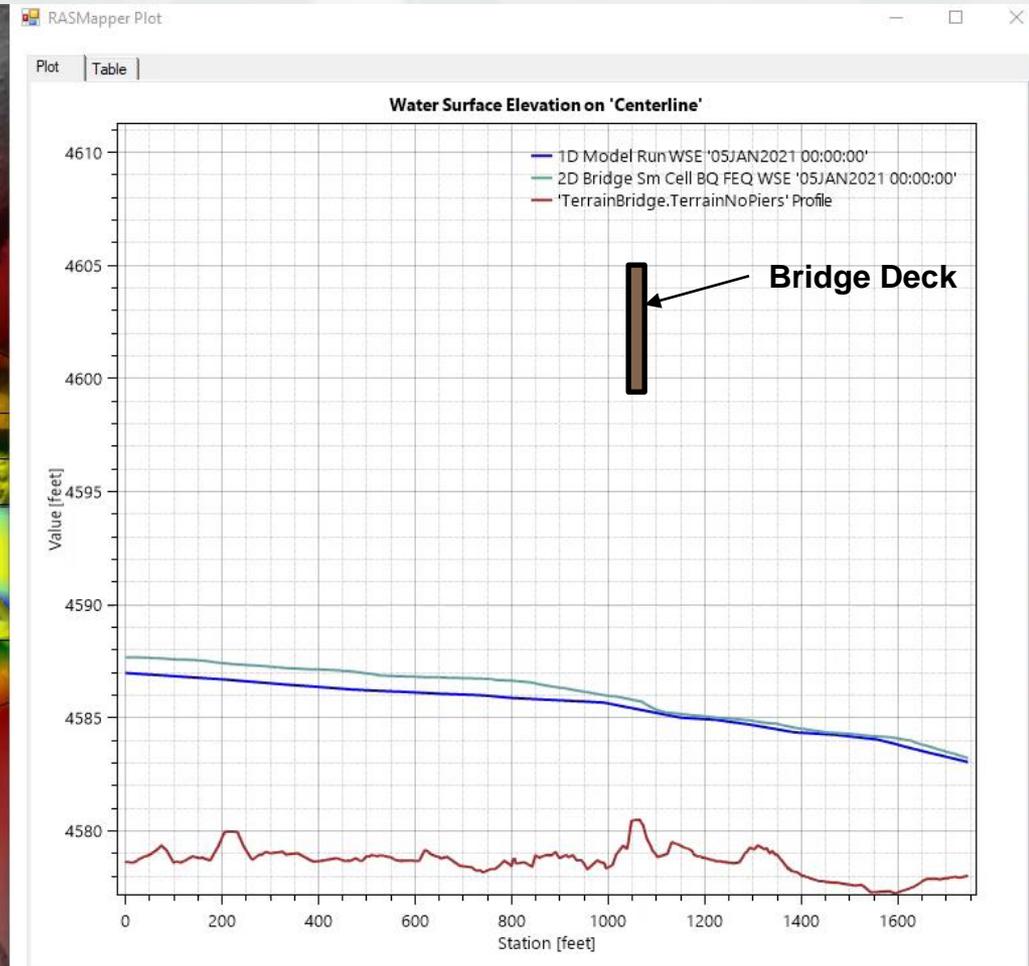
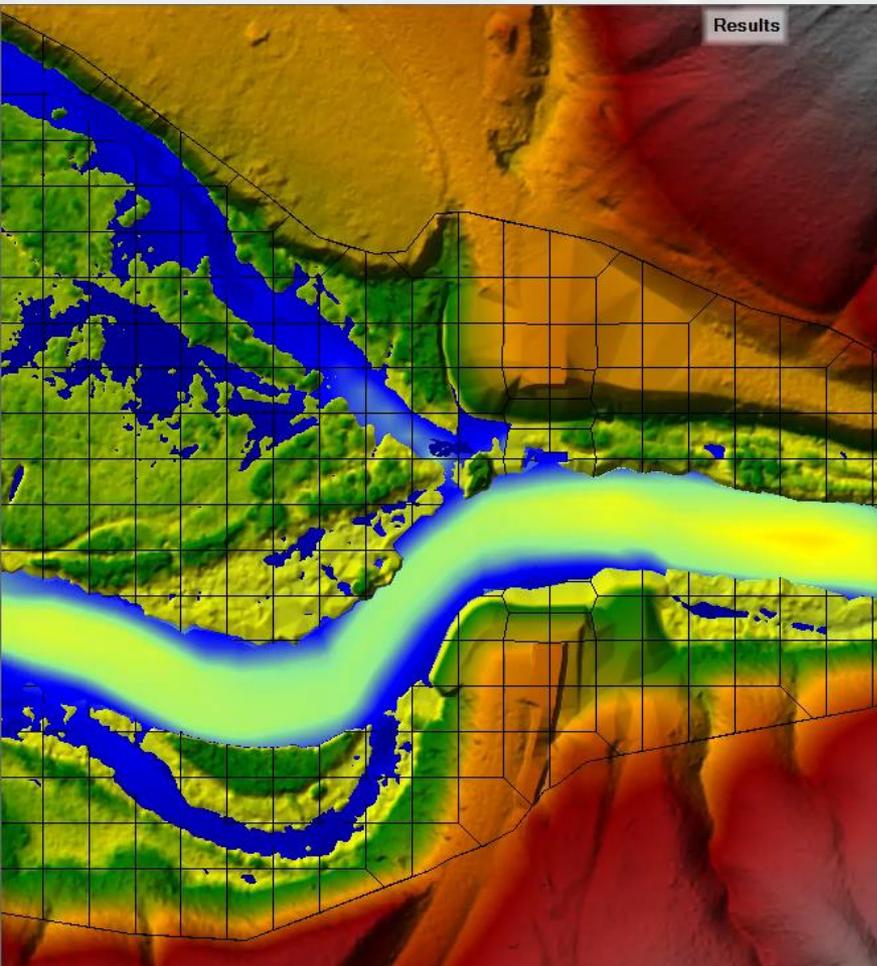
1D vs 2D Model Comparison



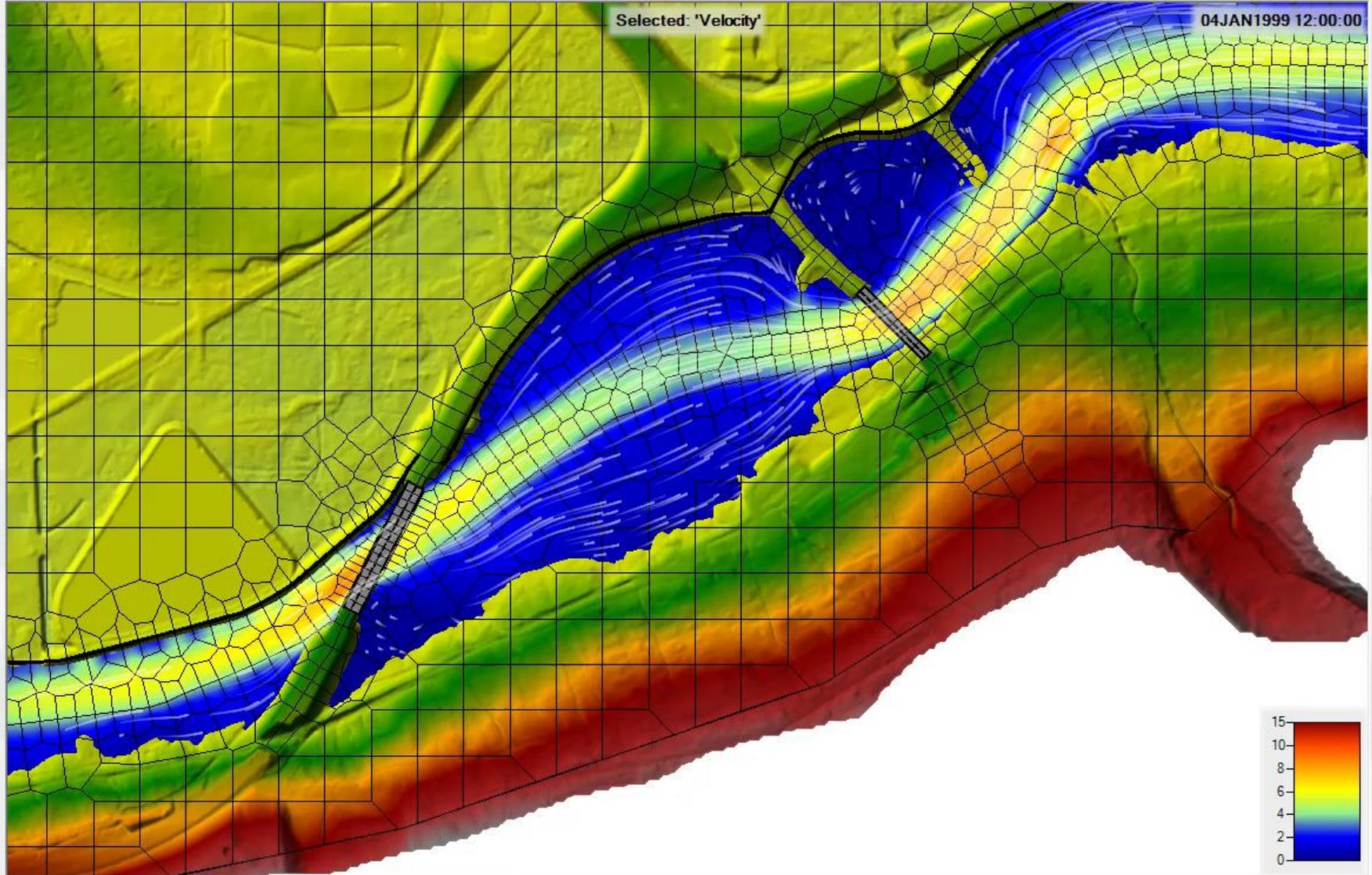
1D Model of Same Area



1D and 2D Comparison Animation



Multiple Bridges



Wind Forces

- Added to 1D and 2D solution algorithms
 - 1D Finite Difference and 1D Finite Volume SWE
 - 2D SWE - current and new equation solver.
 - **Not** in 2D Diffusion Wave solver

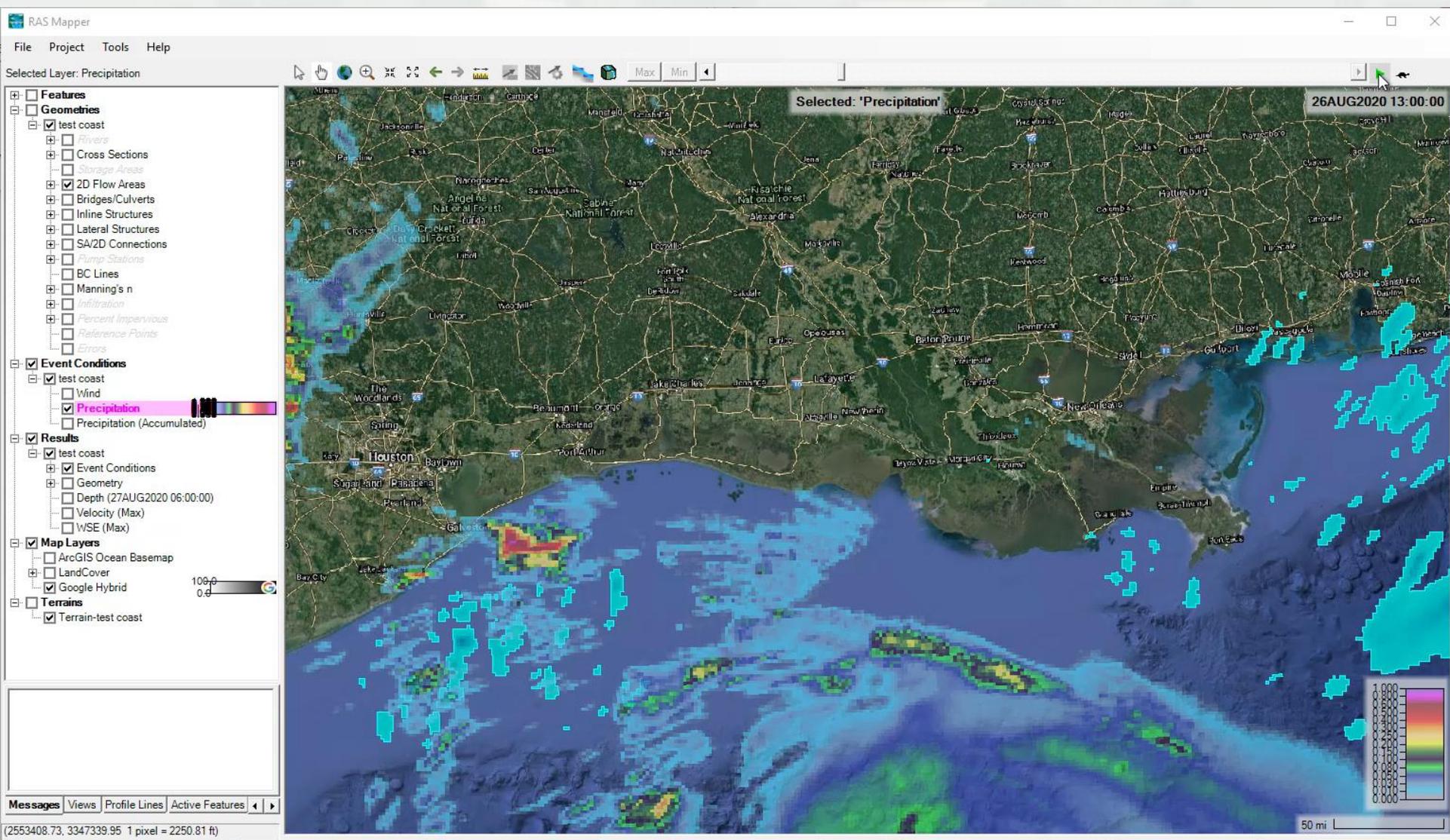
1D Momentum Equation
$$\frac{\partial Q}{\partial t} + \frac{\partial(VQ)}{\partial x} + gA \left(\frac{\partial \eta}{\partial x} + S_f + S_h \right) = T_w \frac{\tau_{sR}}{\rho_w}$$

- Data Sources
 - Gridded Data
 - Gaged Point data
 - User Entered Table

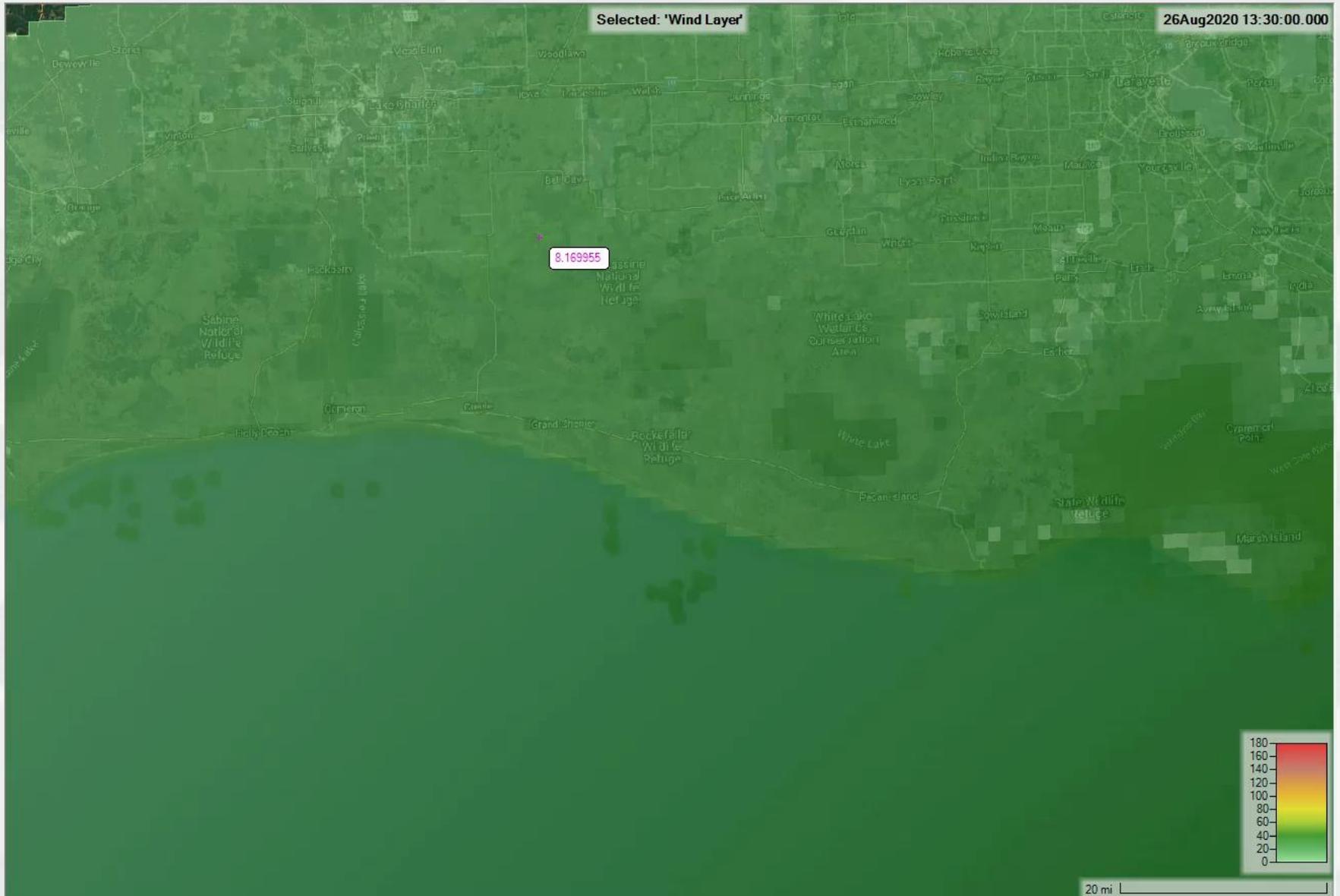
Animations

Spatial Wind Forces in 2D Modeling Hurricane Laura 2020

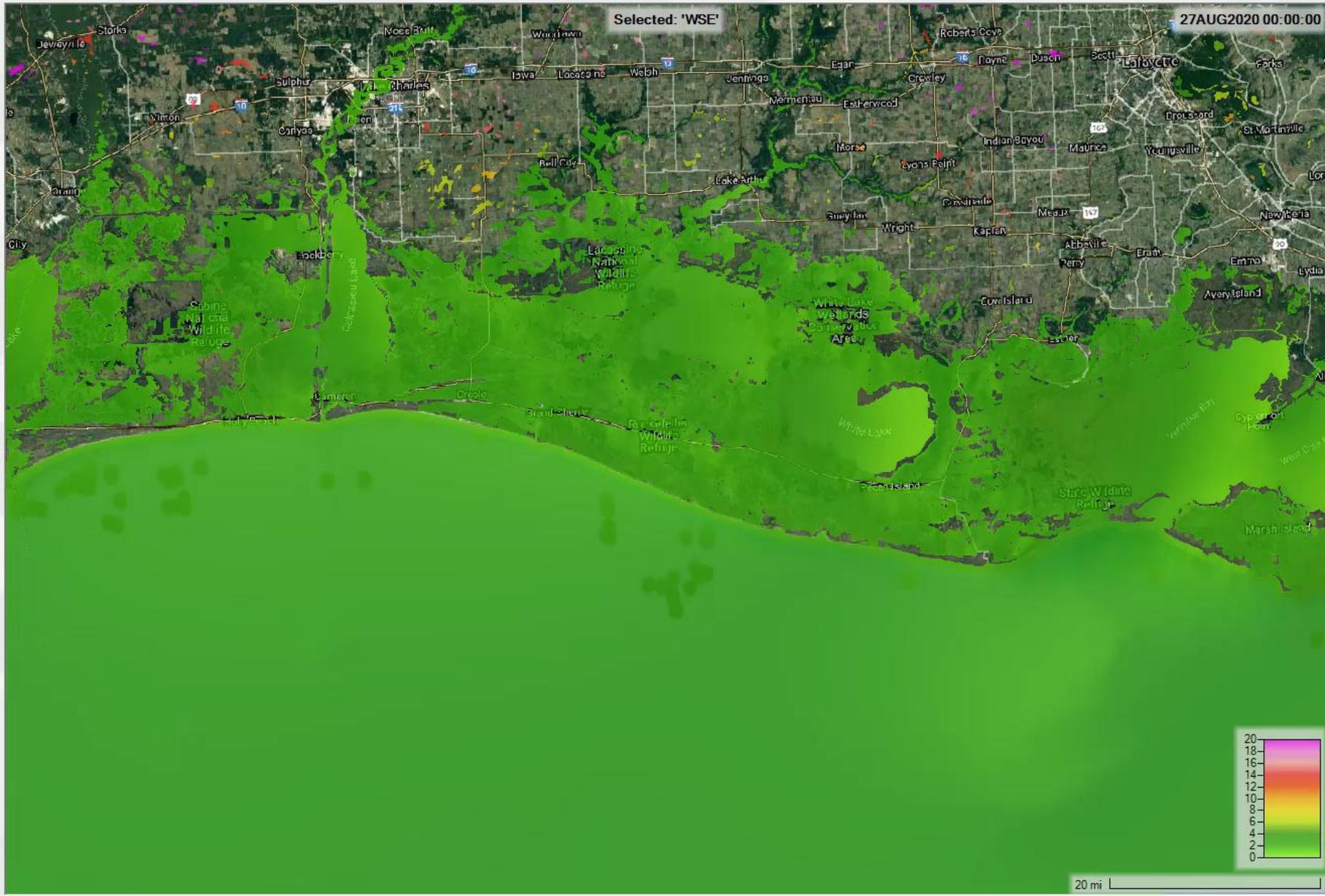
Hurricane Laura Precipitation



Hurricane Laura Wind Field



Hurricane Laura Water Surface

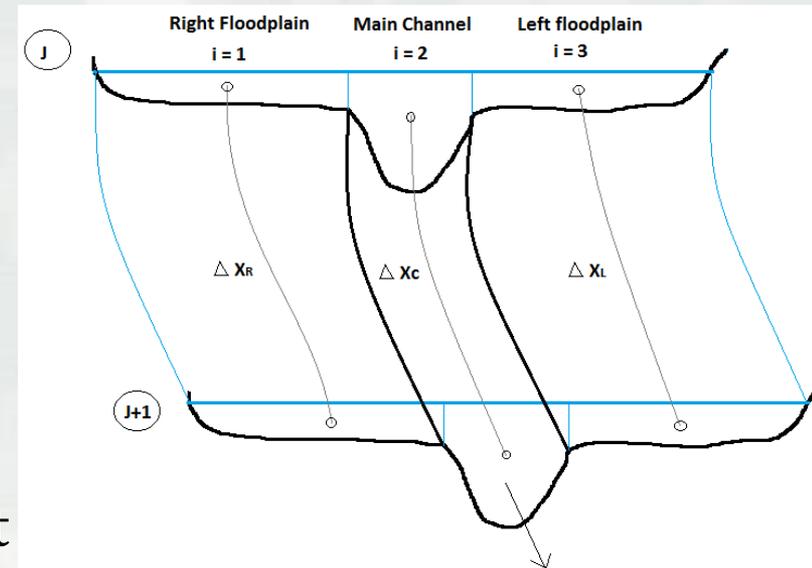


1D Finite Volume Solution Algorithm

- **The new 1D Finite Volume algorithm has the following positive attributes:**
 - Can start with channels completely dry, or they can go dry during a simulation (wetting/drying)
 - Very stable for low flow modeling
 - Can handle extremely rapidly rising hydrographs without going unstable
 - Handles subcritical to supercritical flow, and hydraulic jumps better – No special option to turn on.
 - Junction analysis is performed as a single 2D cell when connecting 1D reaches (continuity and momentum is conserved through the junction)

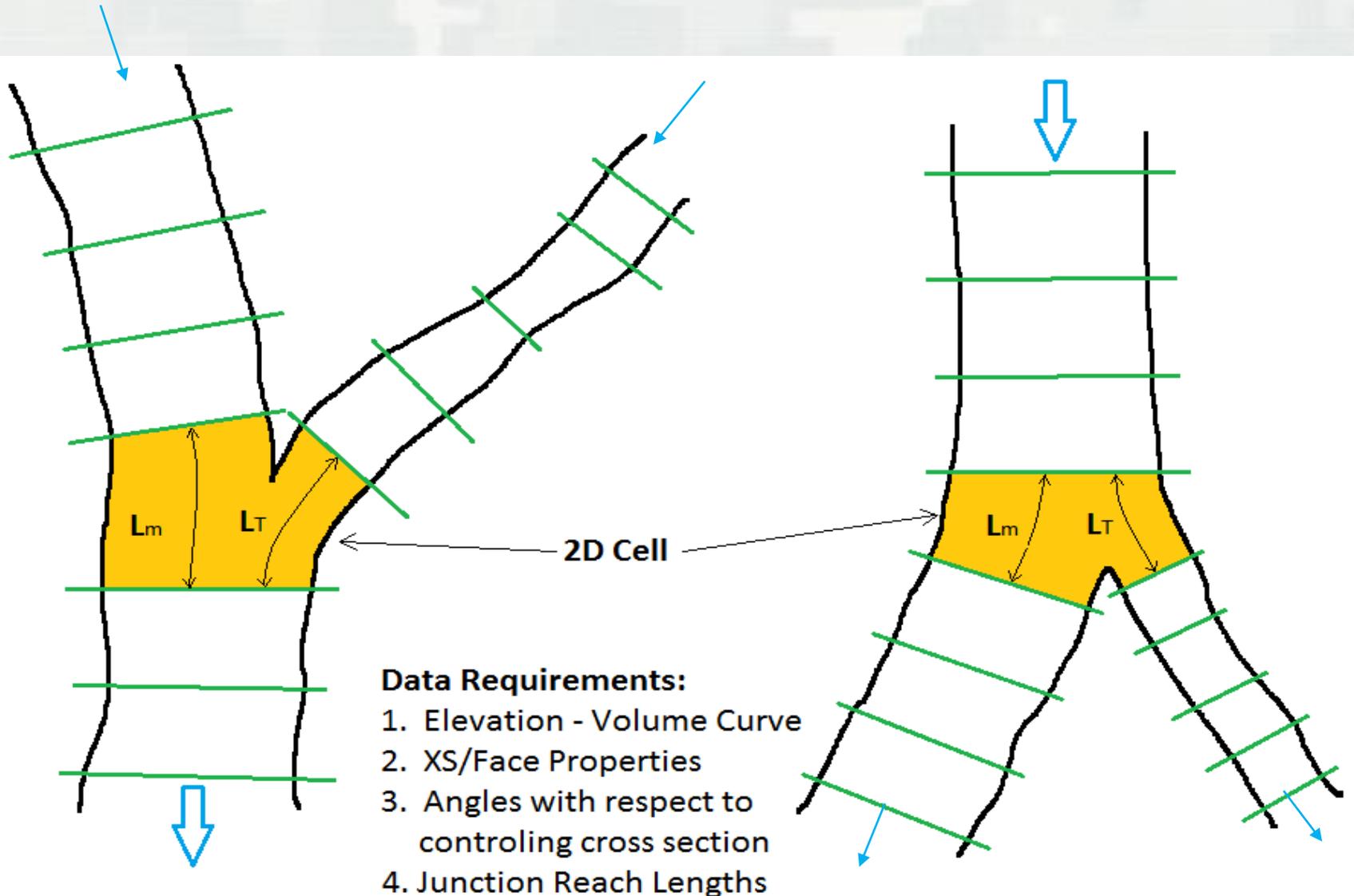
Partial Cells

Left floodplain, Main channel, Right floodplain

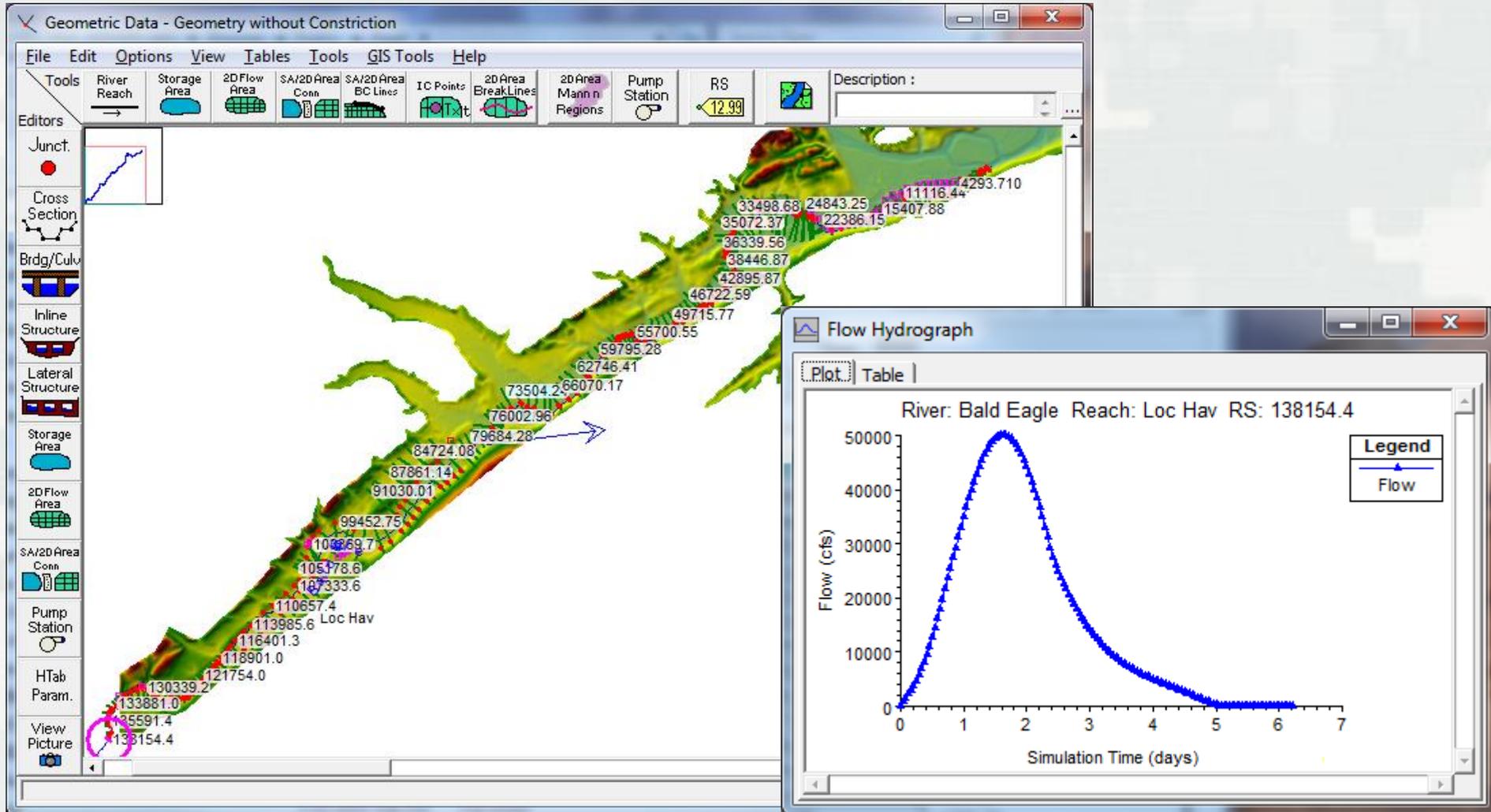


- Separate cells for main channel, left floodplain and right floodplain.
- Current Finite Difference uses only two flow areas: channel & floodplain
- Notation: Partial cells indexed by i
- u_{ji} = channel or overbanks velocities at
- A_{ji} = channel or overbanks partial areas for cross-section j
- $A_j = \sum_i A_{ji}$ cross-section total area
- Cross-section partial conveyance $K_{ji} = \left(A_{ji} R_{ji}^{2/3} \right) / (n_{ji} / k)$
- Cross-section total conveyance $K_j = \sum_i K_{ji}$

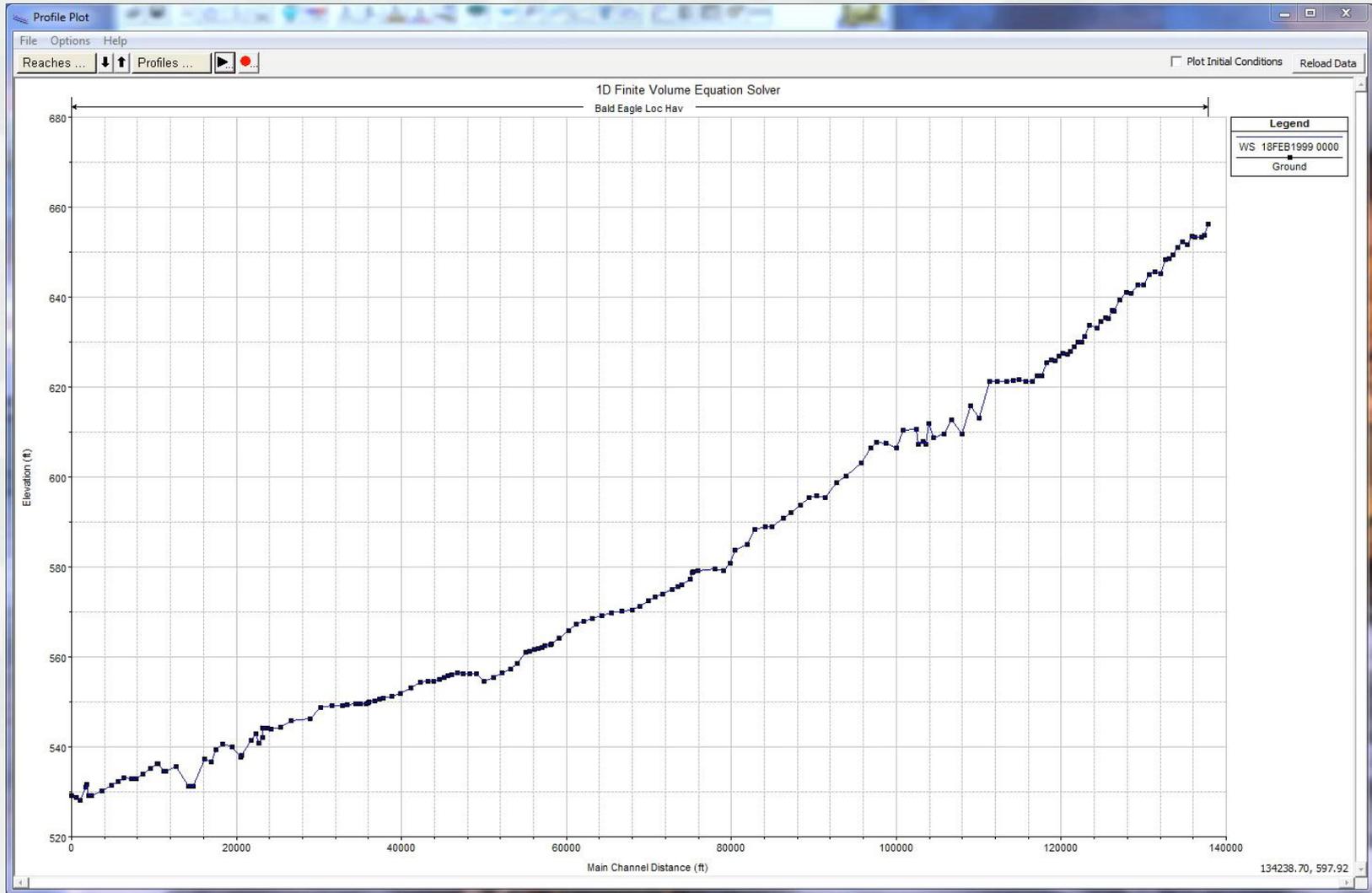
Junctions



Natural River – No Connections Starting Dry, then wet, then dry

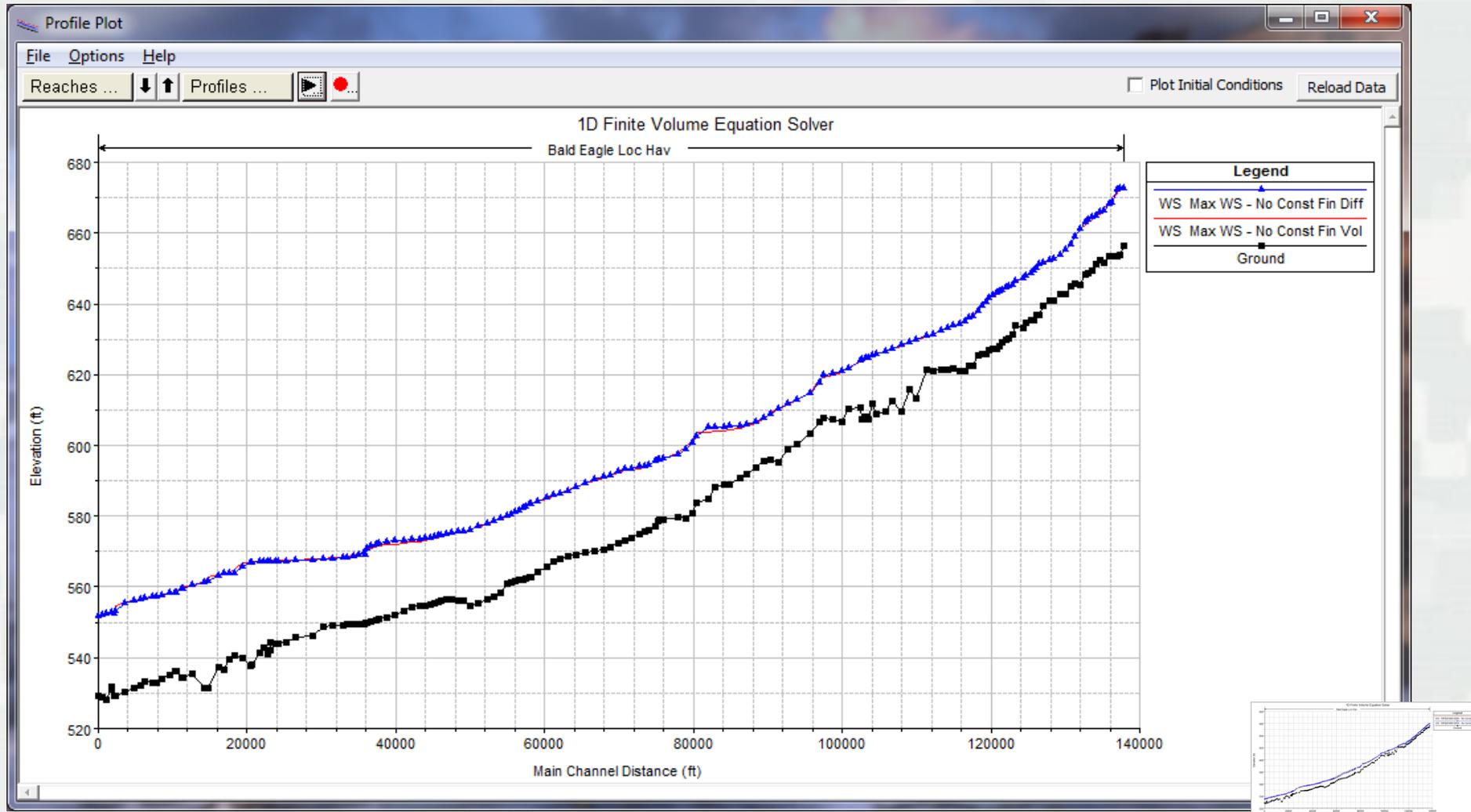


Natural River — Continued Animation - Finite Volume - Dry to Wet to Dry



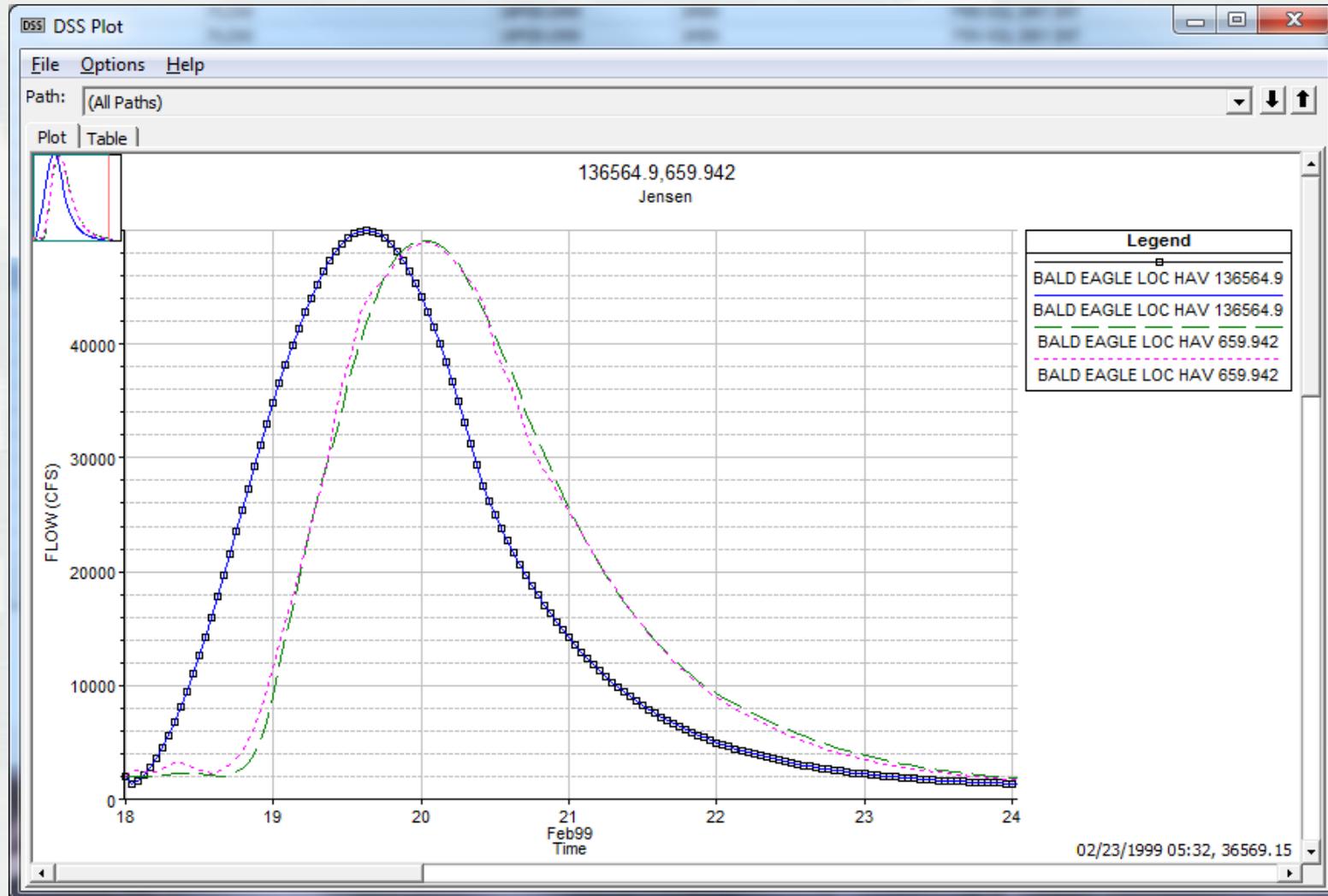
Natural River — Continued

Finite Volume vs Finite Difference – Starting Wet

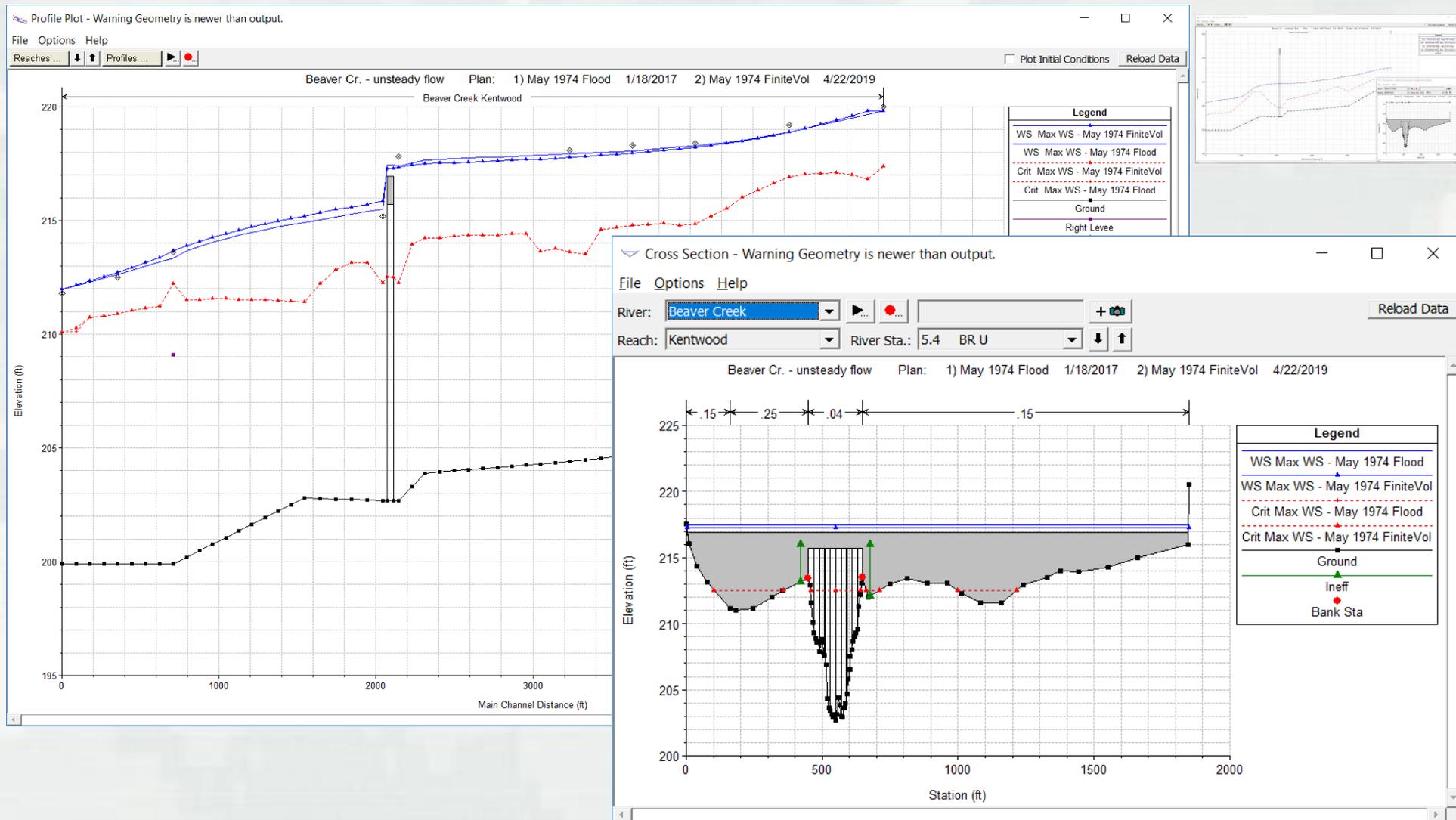


Natural River — Continued

Upstream Inflow and Downstream Outflows



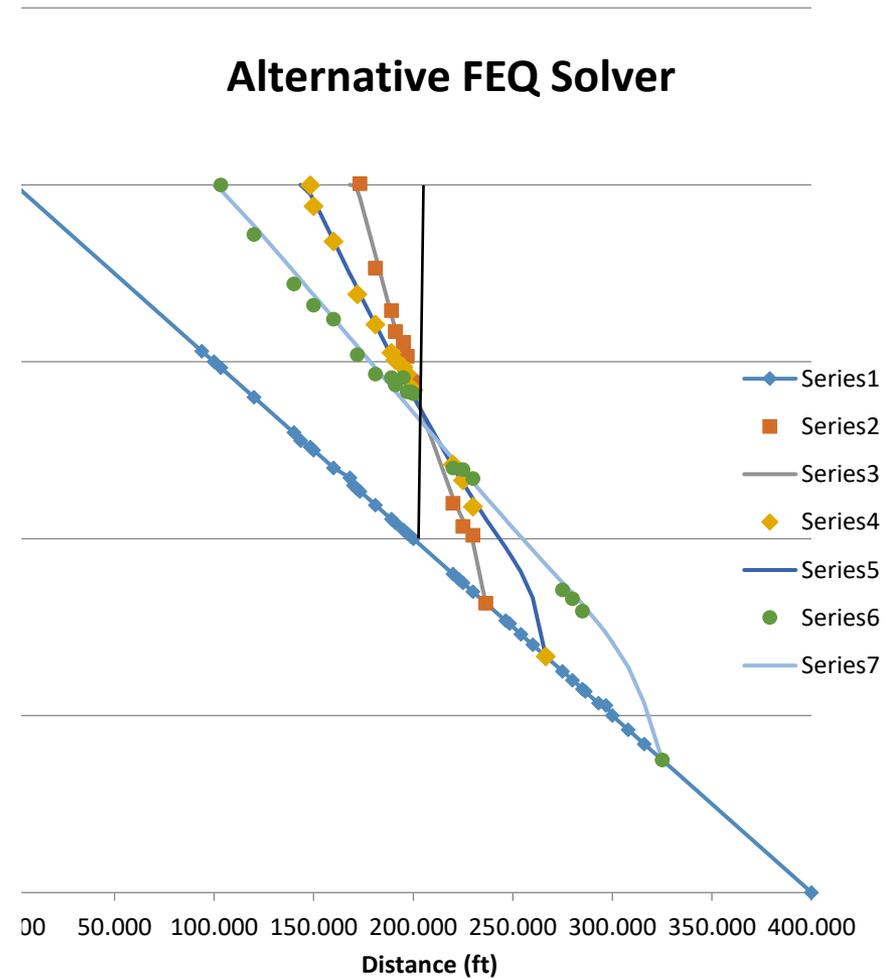
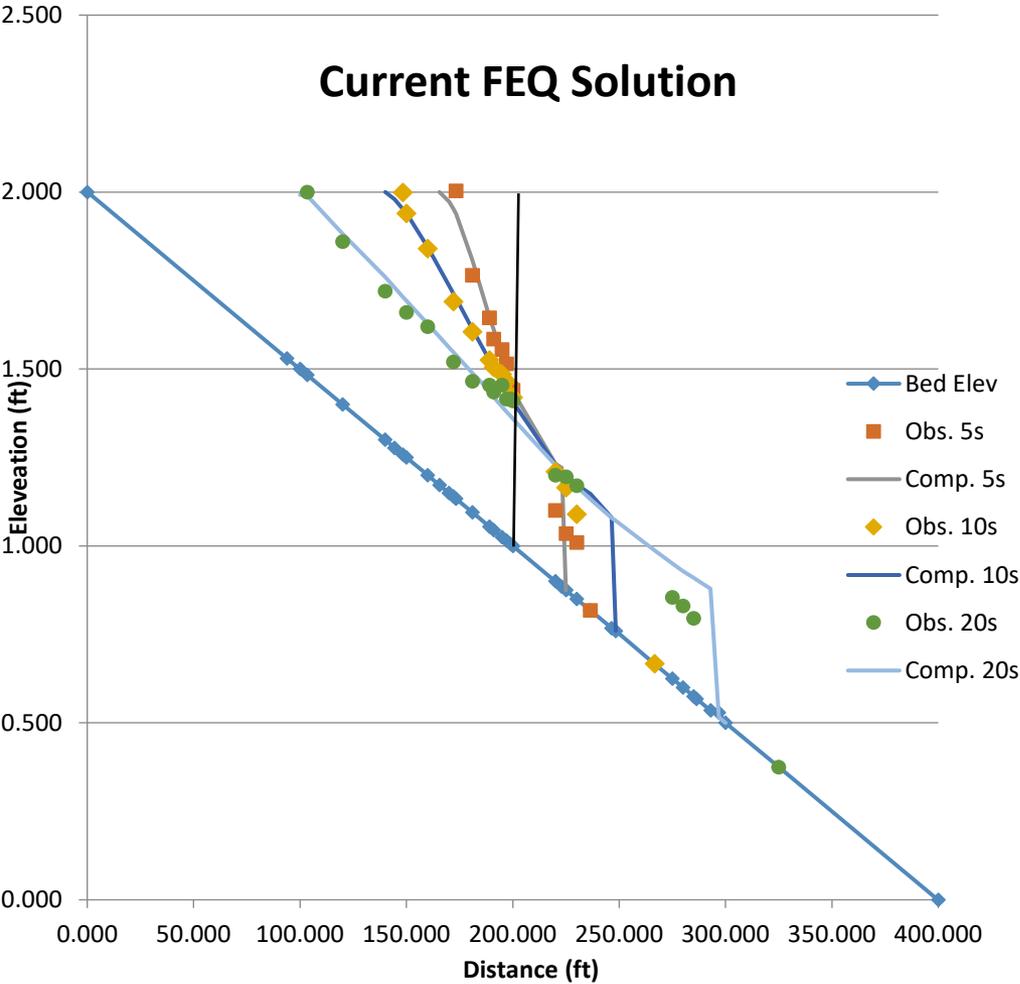
1D Bridge Hydraulics Beaver Creek



Alternative Solution Scheme for Shallow Water Equations

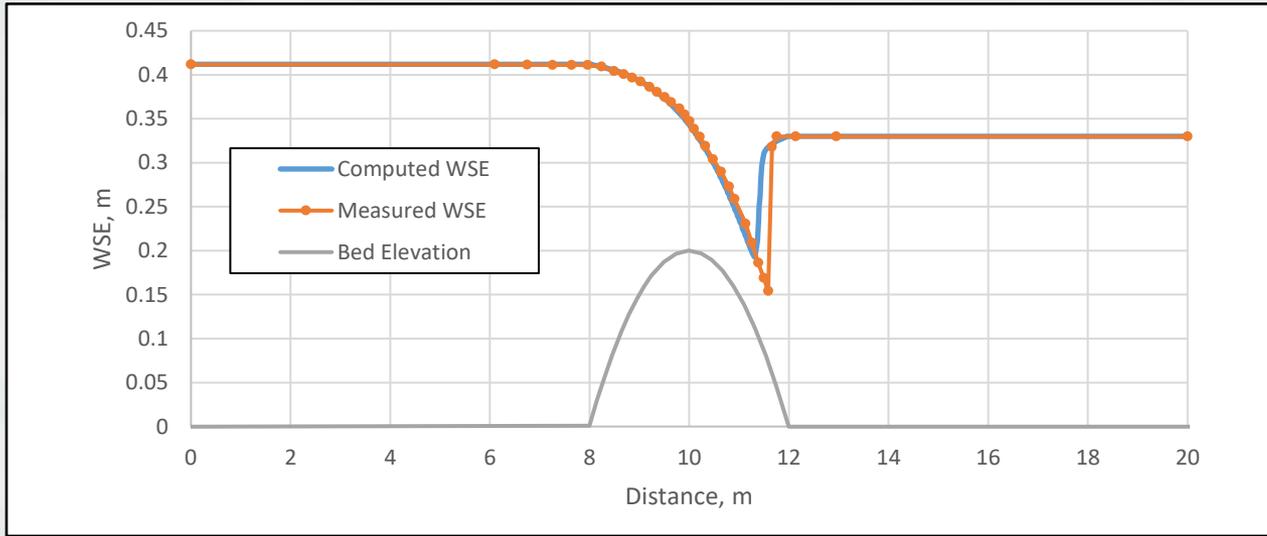
- Momentum - conservative discretization of the acceleration terms
 - Greater momentum conservation than current solver in current version
- Semi Explicit – Time step is somewhat limited by the Courant condition
 - Generally requires smaller time steps and more computational time to run

Sudden Dambreak in a Flume (WES Data Set and report from 1960)

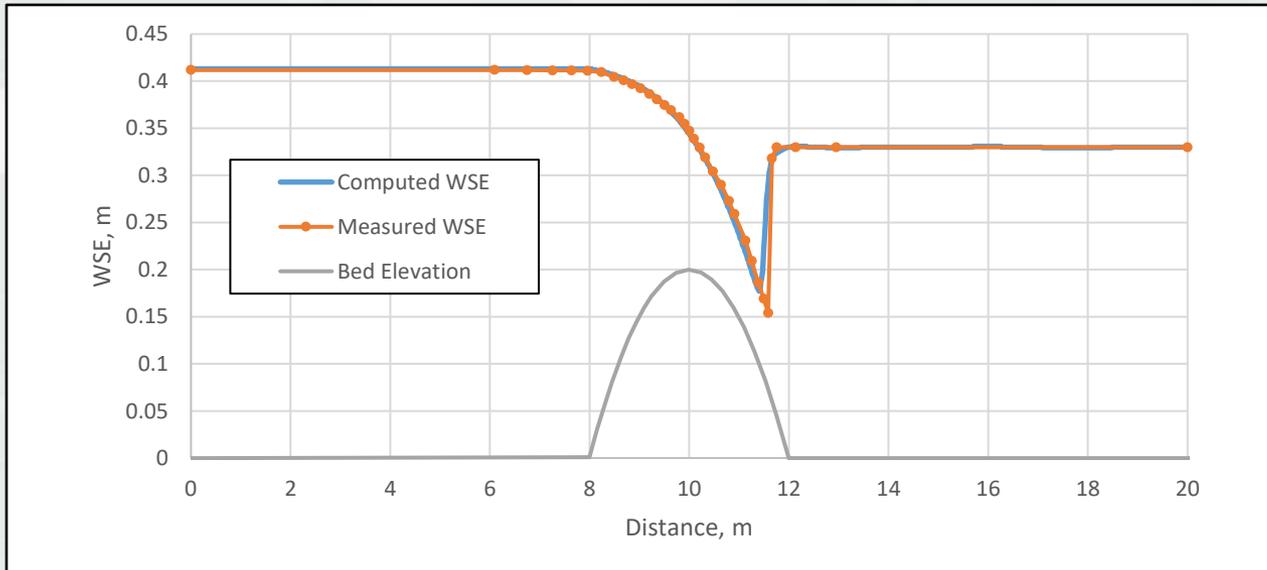


Flow over a Bump assuming no Friction

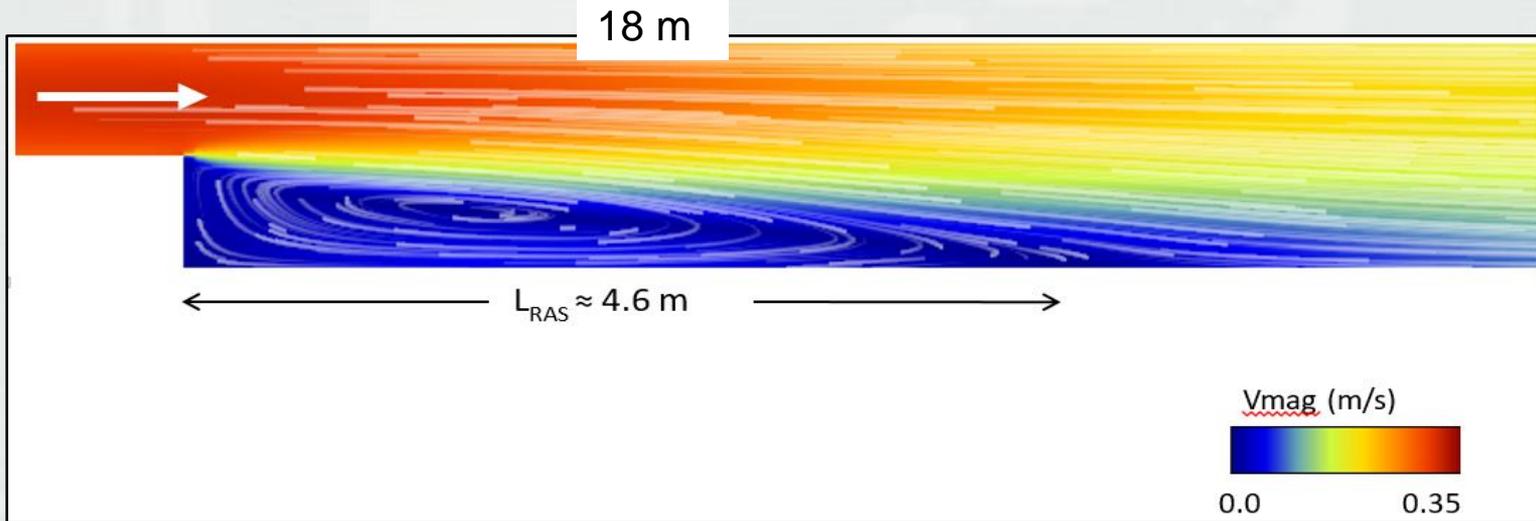
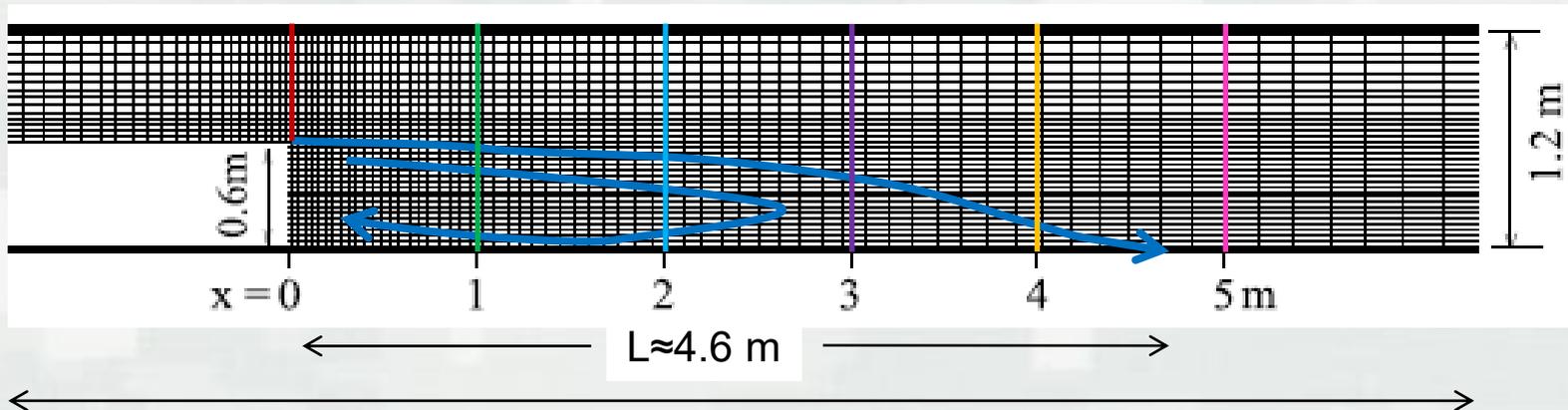
Current Solver:



New Solver:

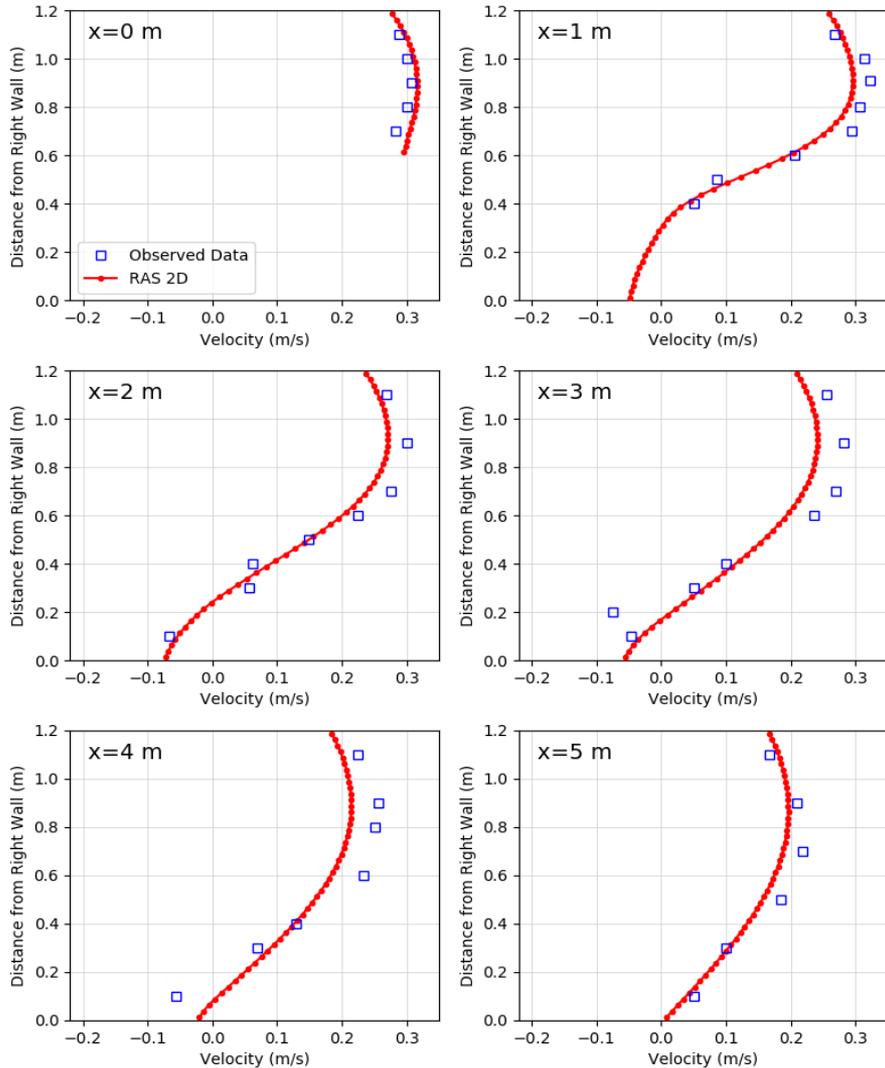


Sudden Expansion – Lab Data

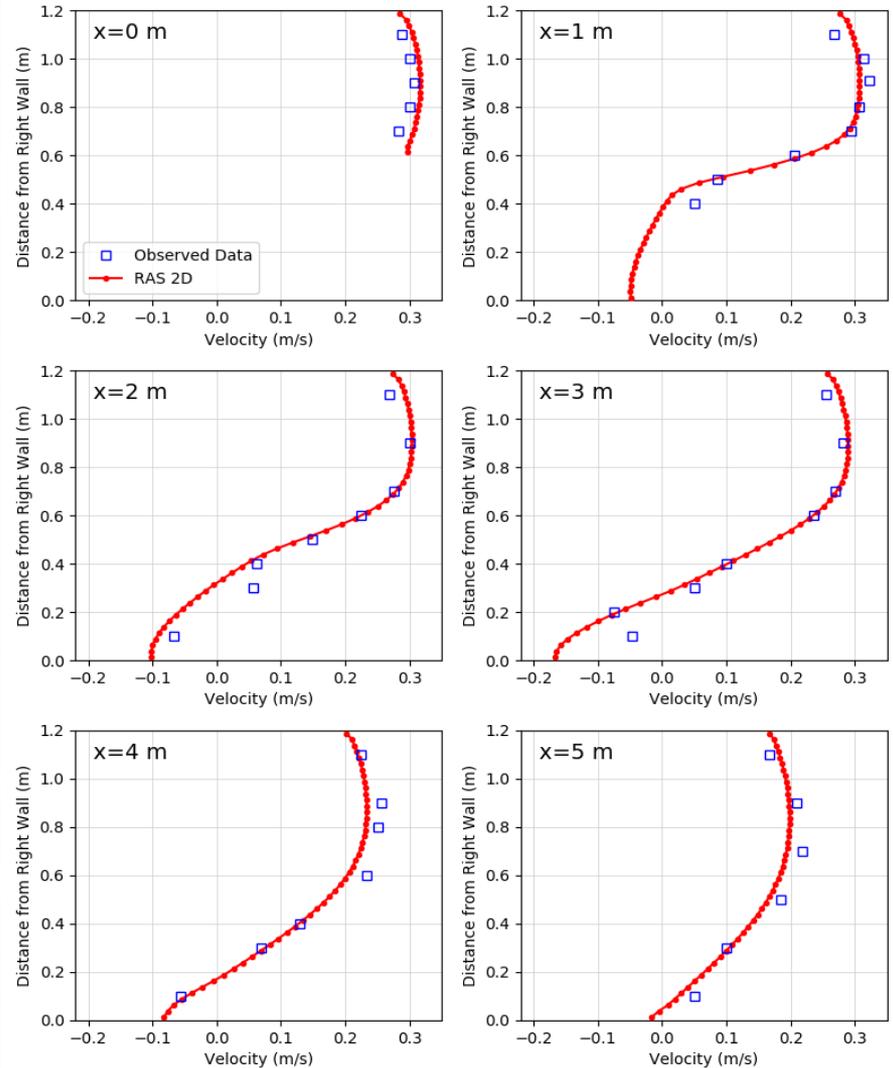


Sudden Expansion

Current Solver ($D_{LT} = 0.7$):



New Solver D_L & $D_T = 0.4$:



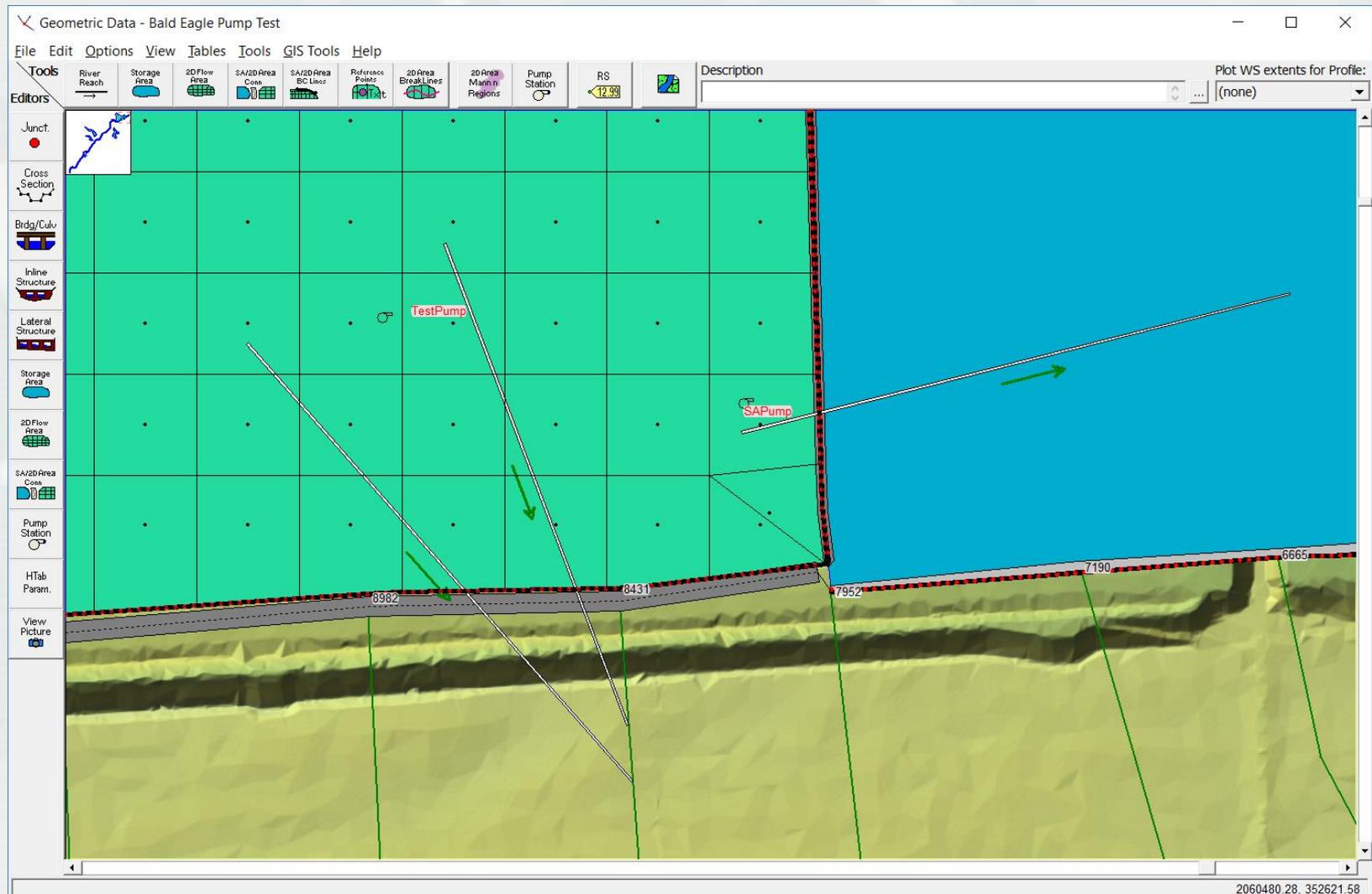


Pump Stations Connected to 2D Flow Areas

- Pump Stations now how spatial connections
 - X, Y coordinates for too and from locations
- Can now connect to 2D flow areas
 - 2D cell to another 2D cell
 - 2D cell to Storage Area
 - 2D cell to 1D river reach (XS location)



Pump Stations Example





Pump Stations Example

RAS Mapper

File Tools Help

Selected Layer: Depth

Features

- Geometries
- Event Conditions
- Results
 - PMF Multi 2D
 - 1D-2D Refined Grid
 - 2D to 1D No Dam
 - 2D to 2D Run
 - SA to 2D Dam Break
 - Single 2D
 - 2D Levee Struc
 - Detailed 2D to 2D
 - MeshGenProb
 - 1D-2D ND Test
 - Culvert Test
 - PMF Multi 2D NC
 - SA2D Conn Tests
 - PolygonTool
 - PolygonTool V-DT
 - PMF Multi 2D V-DT
 - 1D-2D Vel at BC
 - 1D to 2D Conn
 - Precip Test
 - Pump Test
 - Event Conditions
 - Geometry
 - Depth (Max)**
 - Velocity (01JAN1999 12:00:00)
 - WSE (03JAN1999 20:30:00)
- Map Layers
 - LandUse
 - MainChannelBanks
 - USGS Imagery
 - Google Hybrid
 - street100k_1_pa027
 - street100k_1_pa035
 - NLCD_2016_Impervious_L48_20190
 - NLCD 2016 Land Cover L48 20190

Messages Views Profile Lines Active Featu

2050014.46, 351039.80 1 pixel = 5.99 feet

Selected: 'depth'

Pump Station Data Editor

Pump Station Name: UpTheHill

Pump Connection Data Pump Group Data Advanced Control Rules

Pump Group: Group #1

Bias group operations to On (at start of simulation)

Startup Time (min): 1

Shutdown Time (min): 1

Width: 5

Number of pumps in this group: 2

Pump Efficiency Curve		
	Head(ft)	Flow(cfs)
1	0	500
2	1	475
3	10	400
4	20	350
5	30	300
6	50	200
7	60	150

Pump Names and Base WSEL On/Off			
	Pump Name	WS Elev On (ft)	WS Elev Off (ft)
1	Pump #1	557	555
2	Pump #2	560	558

Pump GIS Data: Pump #2		
	X	Y
1	2053057.4	351219.88
2	2051849.49	350828.12
3	2050158.42	350971.76
4	2049048.46	350913
5	2048193.13	351167.64
6	2046972.16	350958.71
7	2046050.11	350802.41

Plot Pump Efficiency Curves ...

OK Cancel

Computational Speed Improvements

- New Matrix Format
 - Previous versions allowed the matrix to be **Non-Symmetric**
 - Version 6.0 uses a **Symmetric matrix format**
 - This allowed us to use a faster solver - **Symmetric Positive Definite Solver**
- Additional Parallelization
 - Additional parallelization was done on the 2D code for both matrix setup and solution.

2D Computational Speed

2D Test Name	Number Cells	Equation Type	5.0.7	6.0	Speed Factor
Bald Eagle Detailed	87,022	FEQ	1 hr 29 min 55s	59 min 37s	1.51
Muncie 2D 50ft Grid	5,376	FEQ	1 min 15s	55s	1.36
Saint Paul 2D	2,251	Diff	1 min 32s	1 min 01s	1.51
EU Test No 2	10,000	FEQ	40s	22s	1.82
EU Test No 4	80,000	FEQ	56s	40s	1.40
EU Test No 5	7,460	FEQ	50s	36s	1.39
EU Test No 6	36,492	FEQ	1 min 18s	50s	1.56
EU Test No 7 20m grid	16,590	FEQ	12 min 25s	10 min 26s	1.19
EU Test 8A 2m grid	97,000	FEQ	1 hr 10 min 36s	48 min 26s	1.45
Yolo Bypass2	17,129	FEQ	9 min 34s	8 min 11s	1.17
Boise River	10,423	FEQ	10 min 46s	6 min 57s	1.55
Truckee River 1D/2D	162,805	Diff	1 hr 18 min 27s	47 min 6s	1.67
400 sq mi Watershed	2,033,190	Diff	16 hrs 45 min 14s	9 hrs 53 min 55s	1.69
Average Speed Increase					1.50

2D Iterative Matrix Solvers

- HEC-RAS 5.0.7 uses a solver called **PARDISO - direct solver**
 - Better for model stability and volume accounting
 - Slower
- For HEC-RAS 6.0 we have added optional **Iterative Solvers**
 - Potentially faster
 - Requires user-based solution tolerance
 - Potentially less stable

With Iterative Solvers

2D Test Name	Number Cells	Equation Type	5.0.7	6.0	6.0 Iter Solv	Speed Factor
Bald Eagle Detailed	87,022	FEQ	1 hr 29 min 55s	59 min 37s	51 min 47s	1.73
Muncie 2D 50ft Grid	5,376	FEQ	1 min 15s	55s	51s	1.47
Saint Paul 2D	2,251	Diff	1 min 32s	1 min 01s	1 min 52s	0.82
EU Test No 2	10,000	FEQ	40s	22s	13s	3.08
EU Test No 4	80,000	FEQ	56s	40s	25s	2.24
EU Test No 5	7,460	FEQ	50s	36s	24s	2.08
EU Test No 6	36,492	FEQ	1 min 18s	50s	37s	2.11
EU Test No 7 20m grid	16,590	Diff	12 min 25s	10 min 26s	6 min 57s	1.79
EU Test 8A 2m grid	97,000	FEQ	1 hr 10 min 36s	48 min 26s	15 min 2s	4.69
Yolo Bypass2	17,129	FEQ	9 min 34s	8 min 11s	5 min 41s	1.68
Boise River	10,423	FEQ	10 min 46s	6 min 57s	4 min 50s	2.23
Truckee River 1D/2D	162,805	Diff	1 hr 18 min 27s	47 min 6s	1 hr 10 min 30s	1.1
400 sq mi Watershed	2,033,190	Diff	16 hrs 45 min 14s	9 hrs 53 min 55s	11 hr 3 mins 43s	1.52
Average Speed Increase						2.04

3D Visualization tool

