What's New with HEC-RAS 5.1

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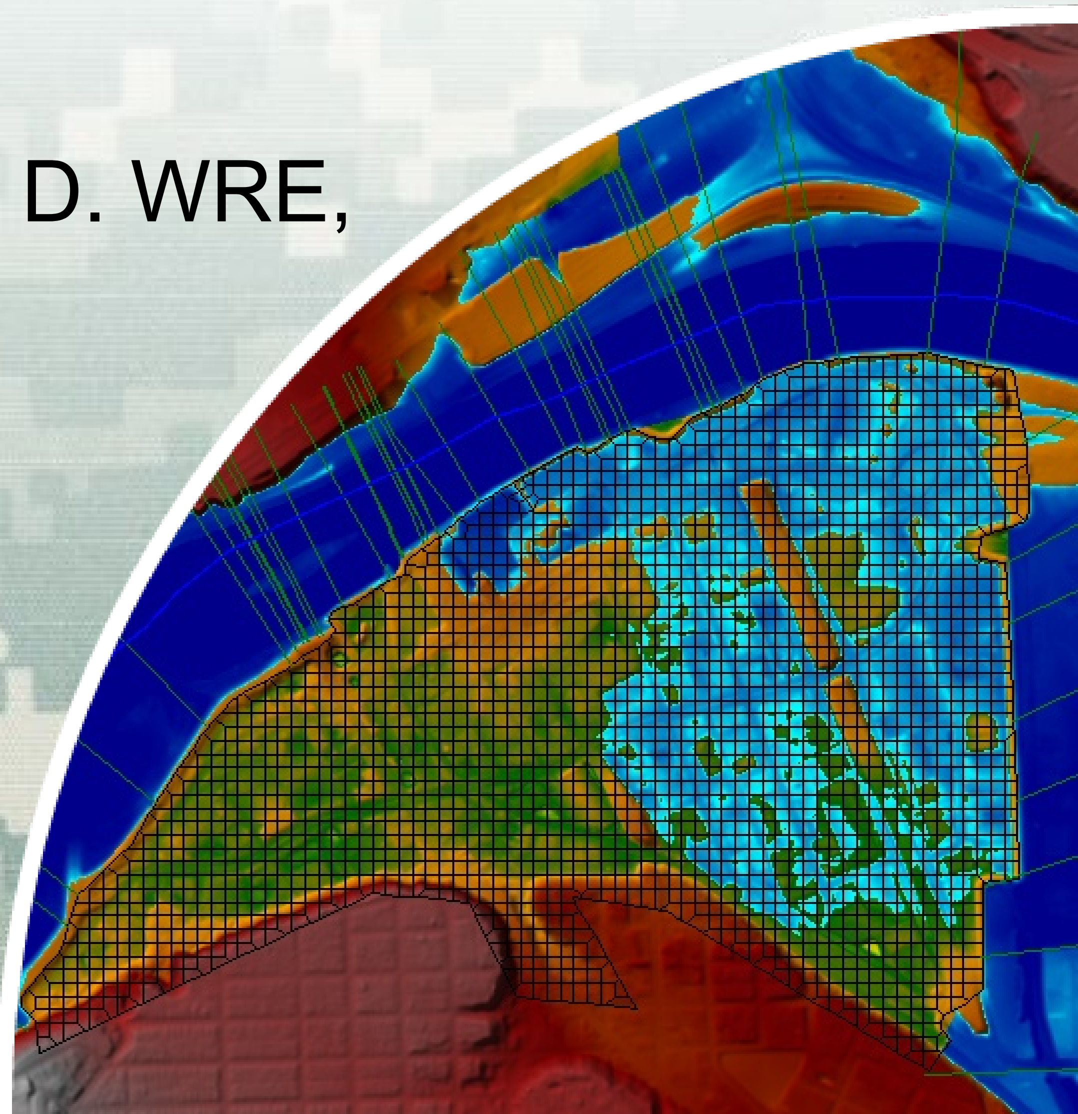


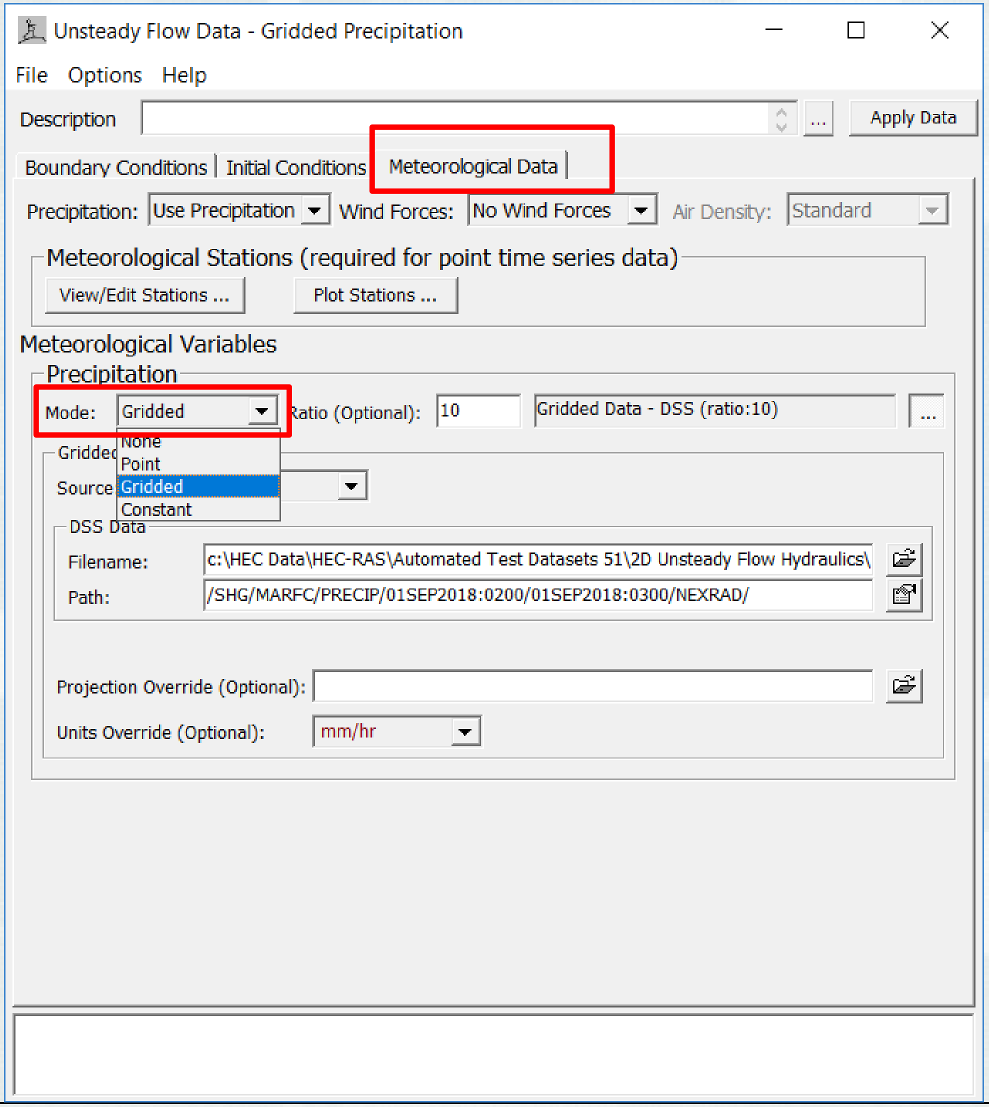
Major New Hydraulics Features for HEC-RAS 5.1

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

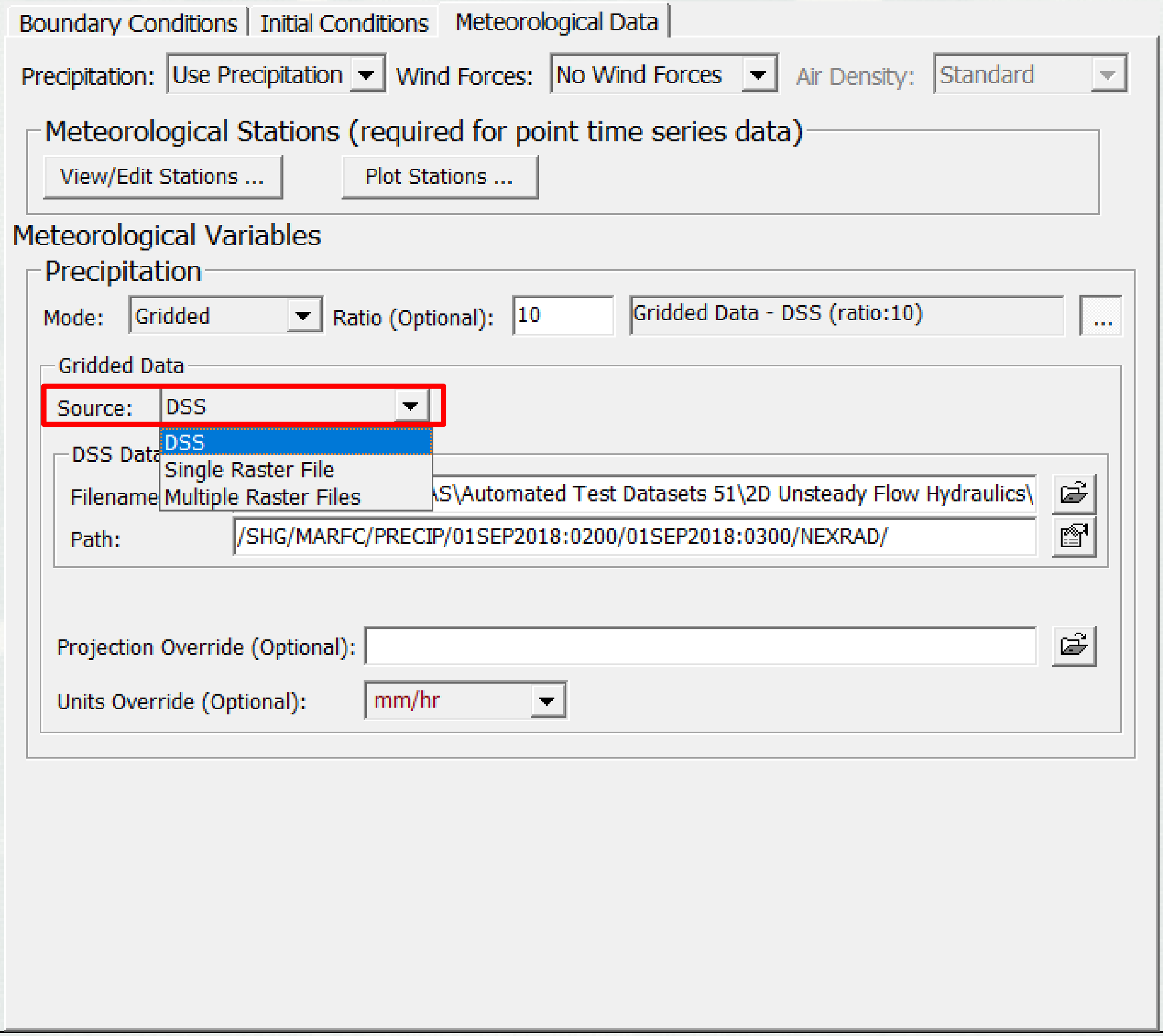
Spatial Precipitation

- 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

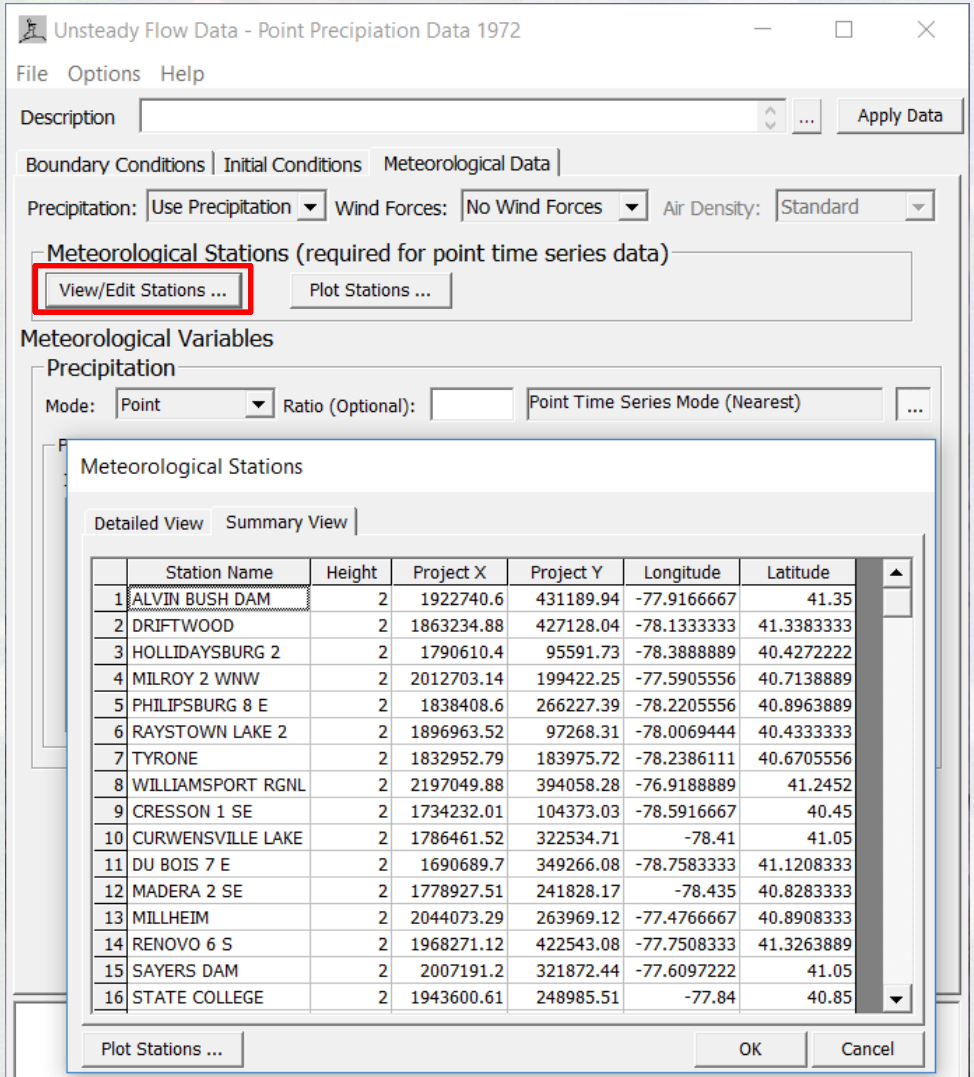


Gridded Data



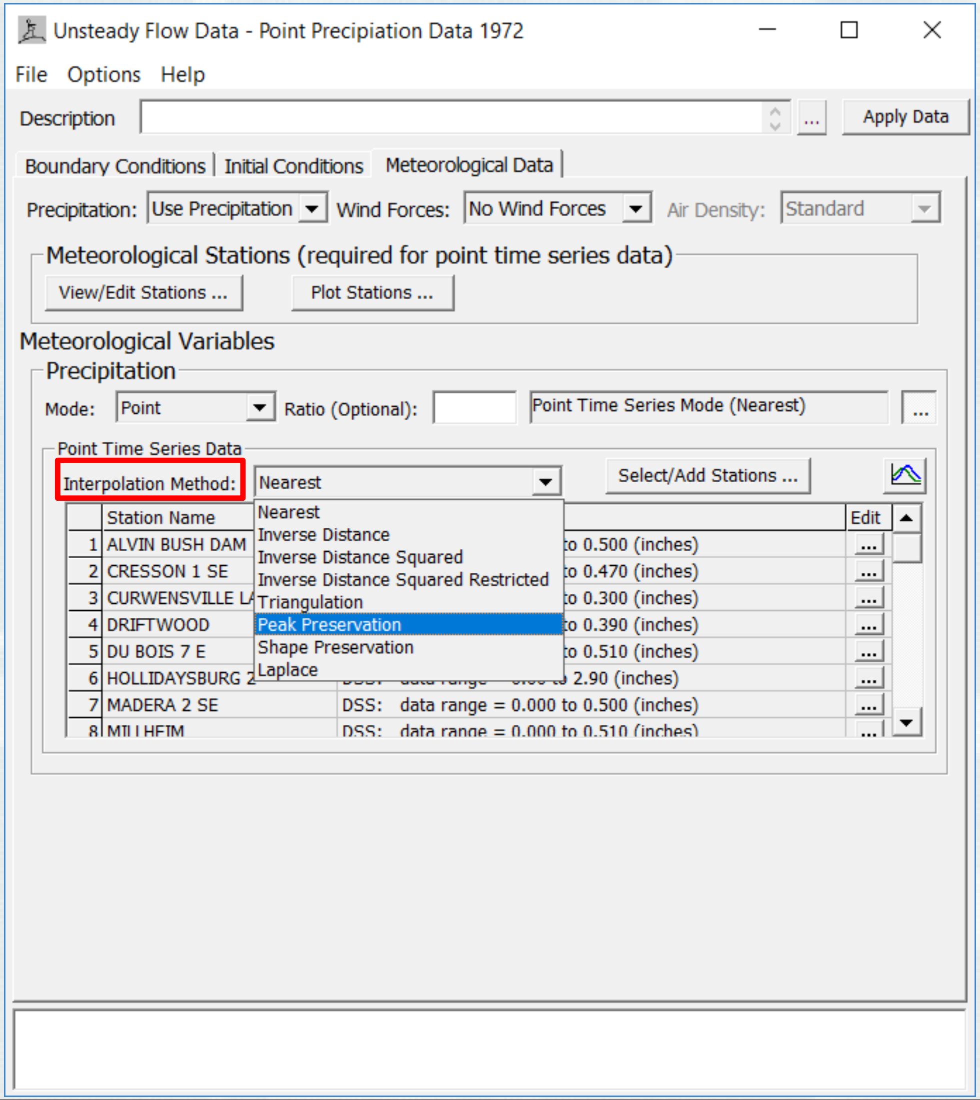
Gridded Precipitation example HEC-RAS

Point Gage Data

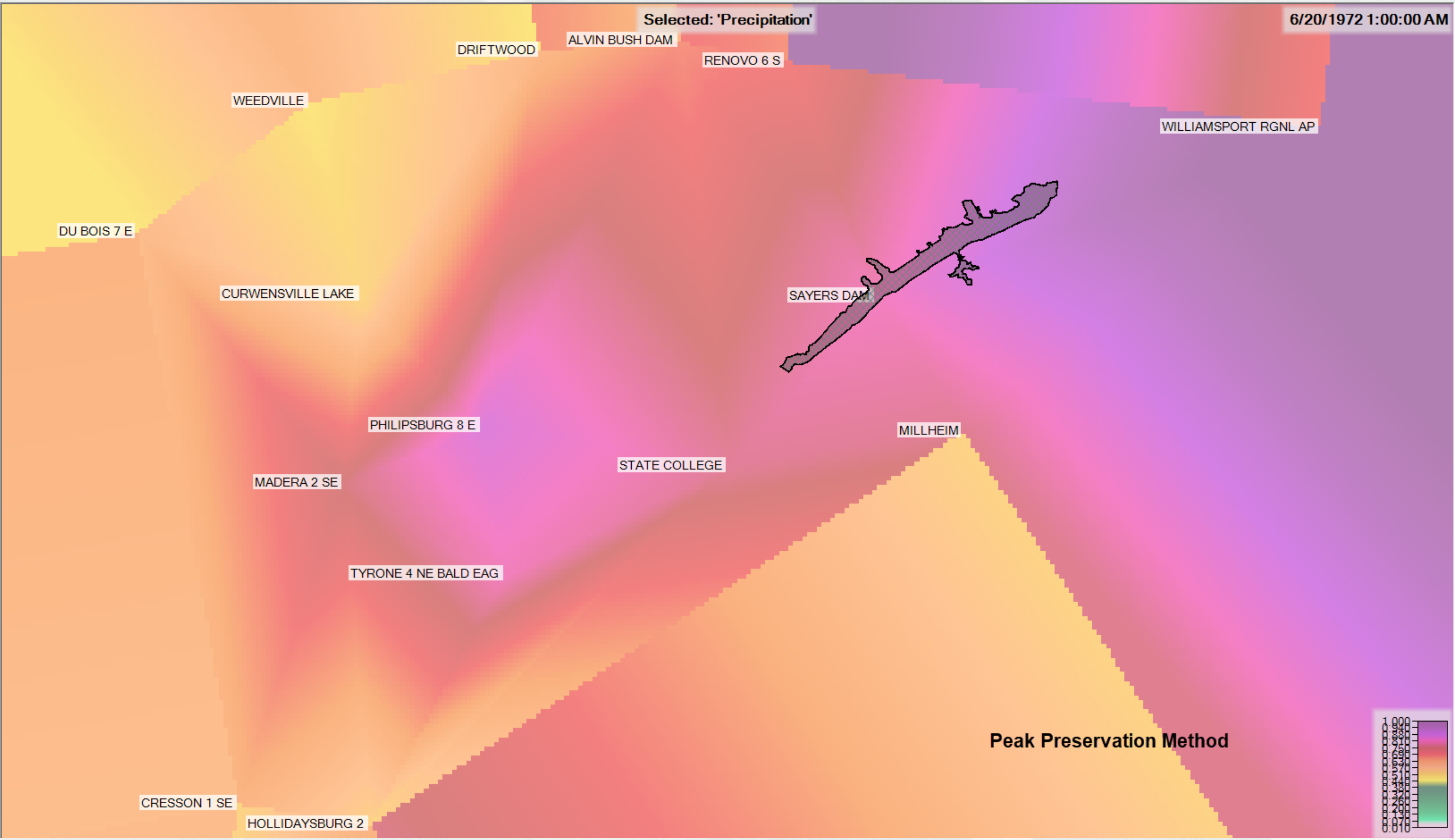


	Station Name	Height	Project X	Project Y	Longitude	Latitude
1	ALVIN BUSH DAM	2	1922740.6	431189.94	-77.9166667	41.35
2	DRIFTWOOD	2	1863234.88	427128.04	-78.1333333	41.3383333
3	HOLLIDAYSBURG 2	2	1790610.4	95591.73	-78.3888889	40.4272222
4	MILROY 2 WNW	2	2012703.14	199422.25	-77.5905556	40.7138889
5	PHILIPSBURG 8 E	2	1838408.6	266227.39	-78.2205556	40.8963889
6	RAYSTOWN LAKE 2	2	1896963.52	97268.31	-78.0069444	40.4333333
7	TYRONE	2	1832952.79	183975.72	-78.2386111	40.6705556
8	WILLIAMSPORT RGNL	2	2197049.88	394058.28	-76.9188889	41.2452
9	CRESSON 1 SE	2	1734232.01	104373.03	-78.5916667	40.45
10	CURWENSVILLE LAKE	2	1786461.52	322534.71	-78.41	41.05
11	DU BOIS 7 E	2	1690689.7	349266.08	-78.7583333	41.1208333
12	MADERA 2 SE	2	1778927.51	241828.17	-78.435	40.8283333
13	MILLHEIM	2	2044073.29	263969.12	-77.4766667	40.8908333
14	RENOVO 6 S	2	1968271.12	422543.08	-77.7508333	41.3263889
15	SAYERS DAM	2	2007191.2	321872.44	-77.6097222	41.05
16	STATE COLLEGE	2	1943600.61	248985.51	-77.84	40.85

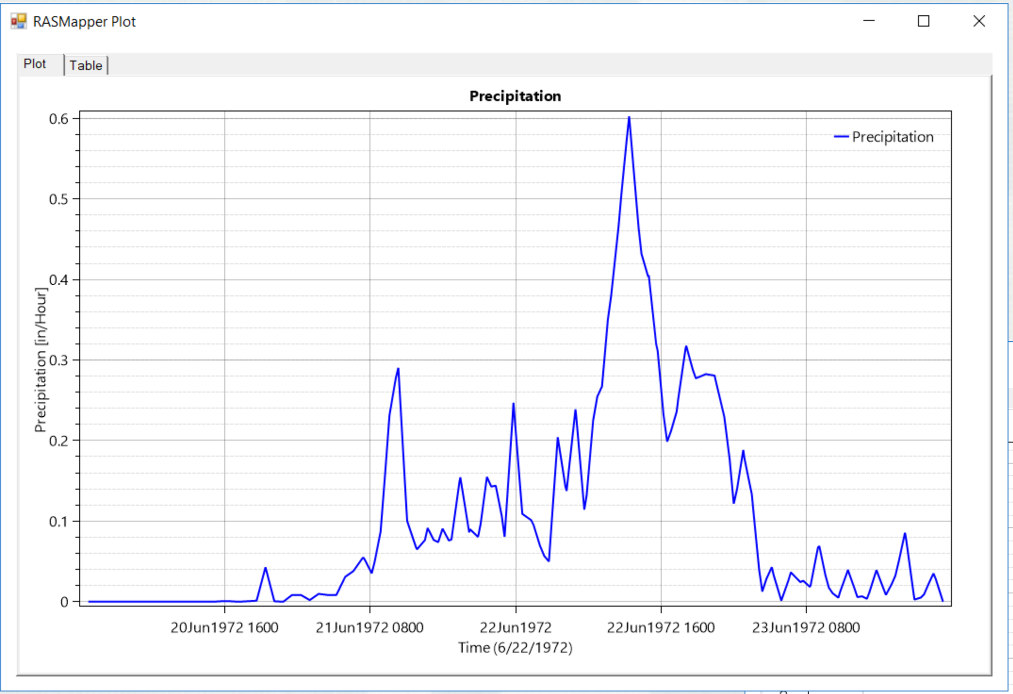
Point Gage Data

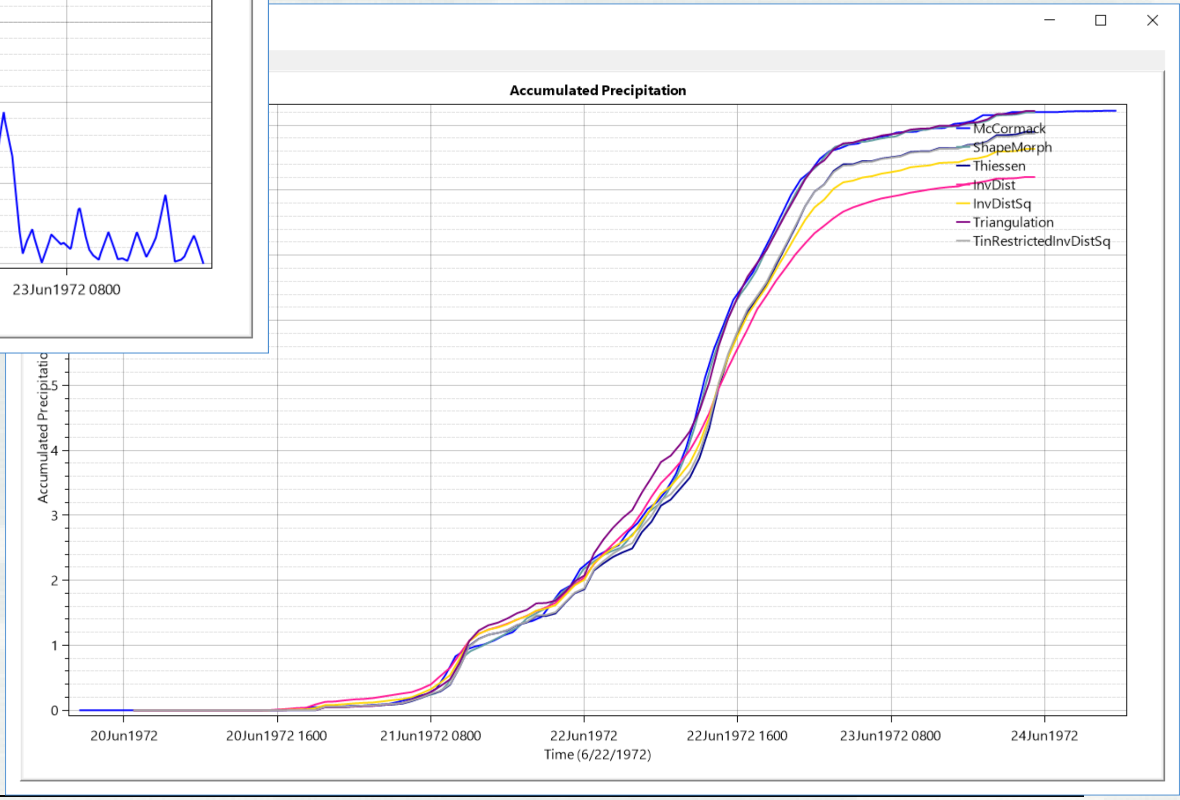


Cumulative Rainfall



Rainfall Time Series Plots





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

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

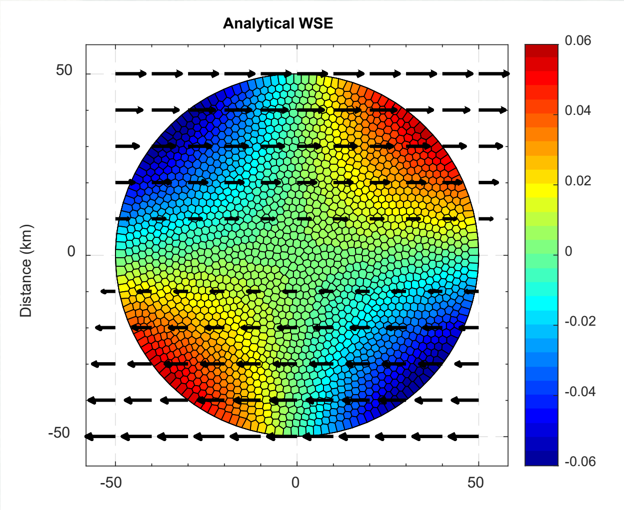
1D Momentum Equation

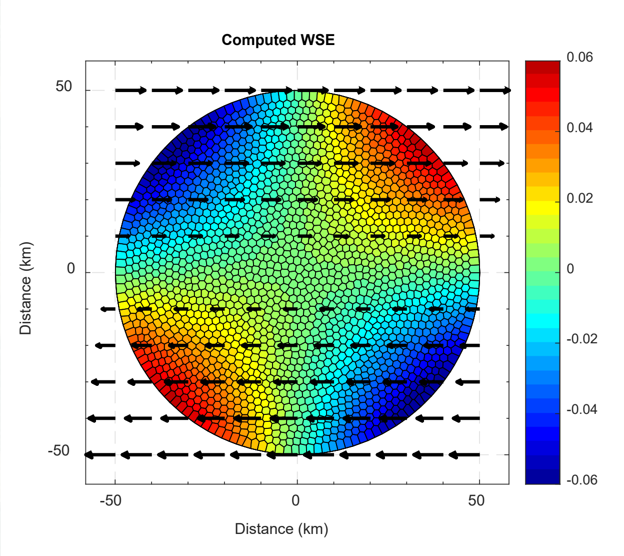
$$\frac{\partial Q}{\partial t} + \frac{\partial (VQ)}{\partial x} + gA\left(\frac{\partial \eta}{\partial x} + S_f + S_h\right) = T_w \frac{\tau_{sR}}{\rho_w}$$

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

Wind Verification

- Flat circular basin
- Spatially variable wind forcing in the x-direction only
- Linear bottom friction
- Polygonal mesh





Wind Application - Animation

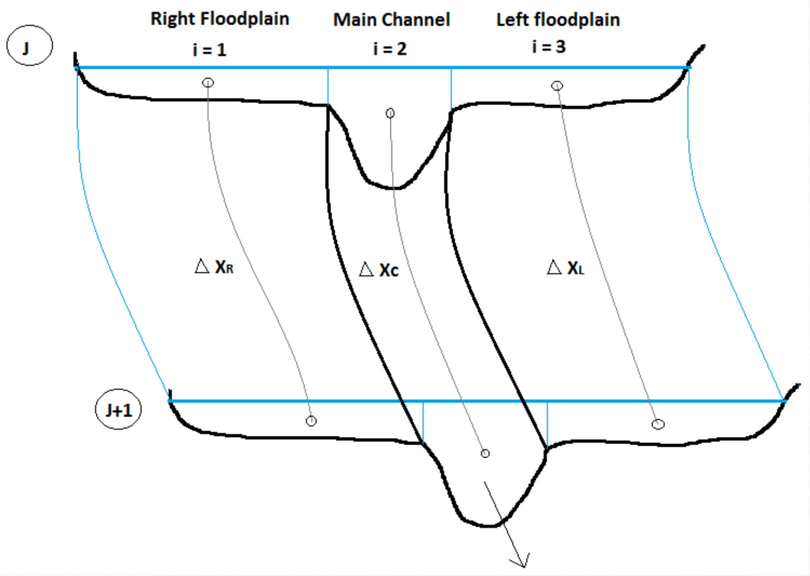
Wind 1D Profile Animation

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)

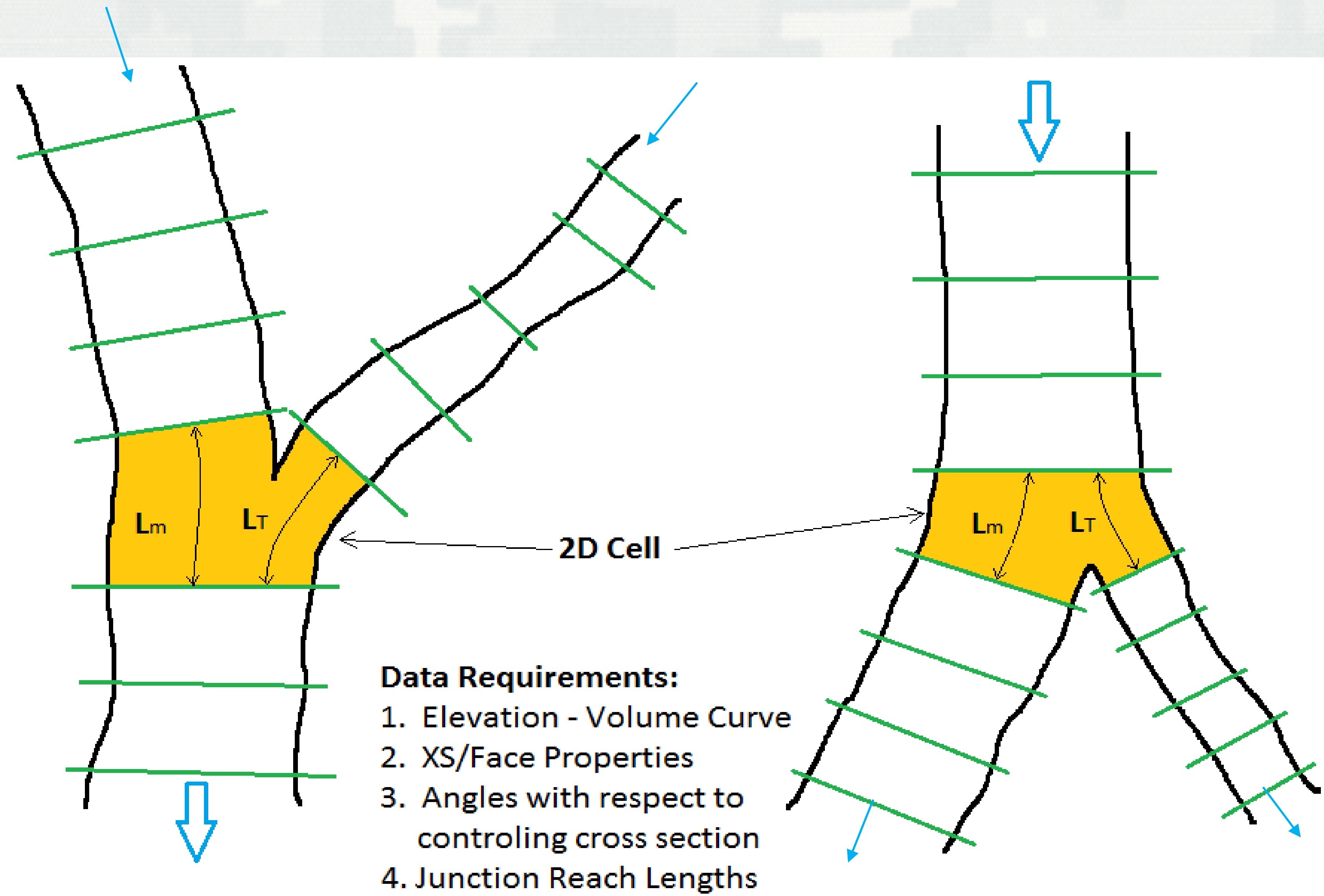
Partial Cells

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 $K_j = \sum_i K_{ji}$

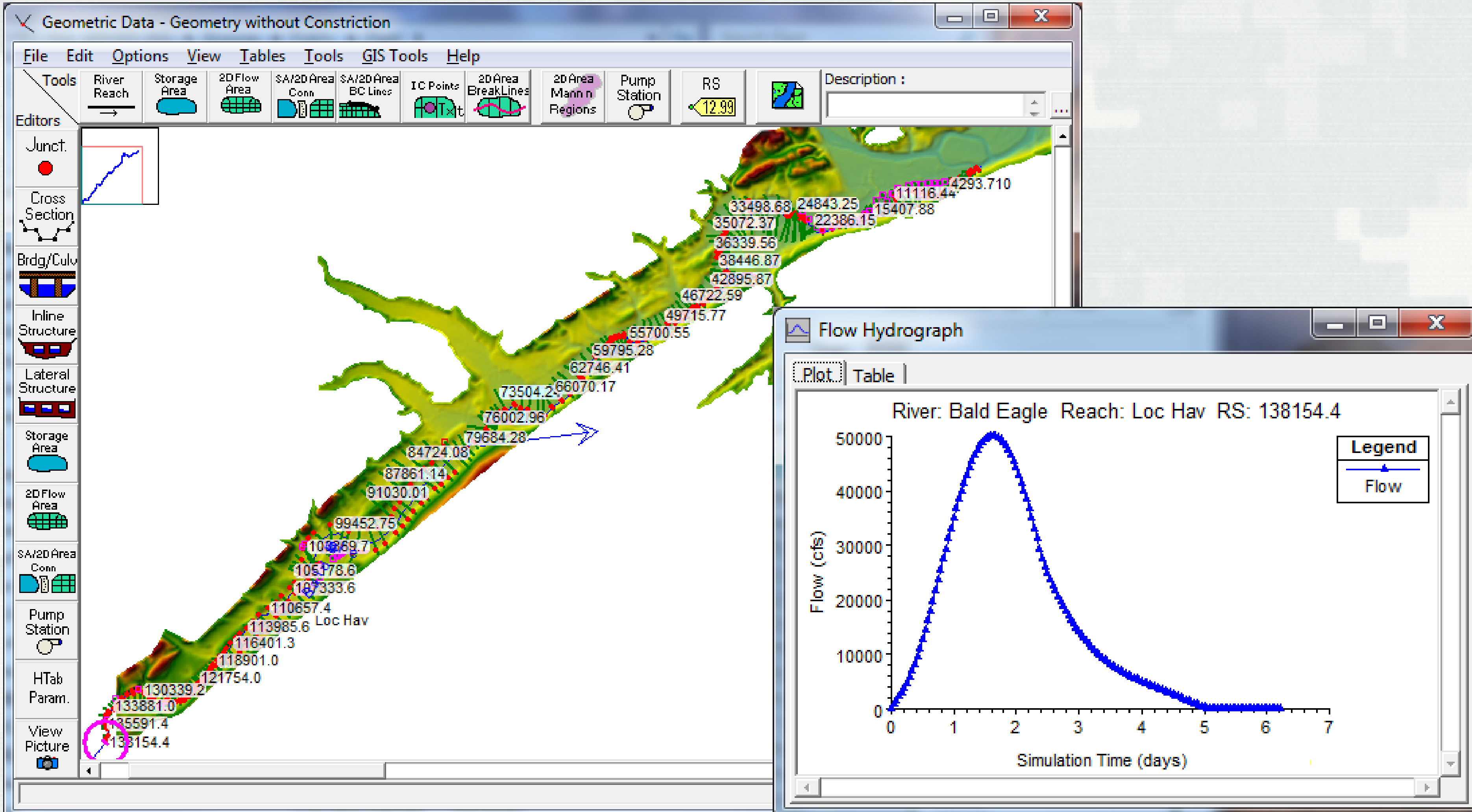
Junctions



Data Requirements:

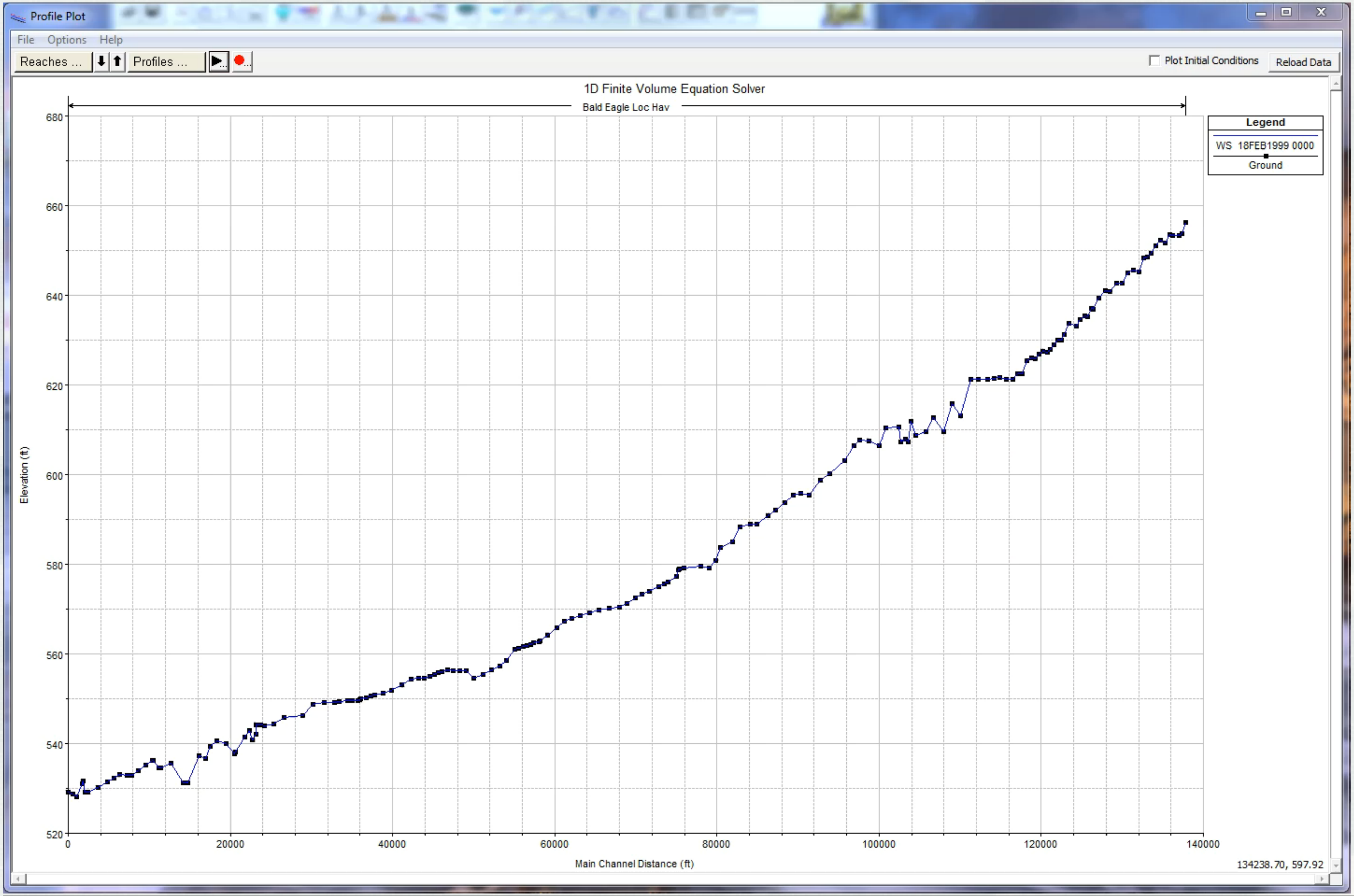
1. Elevation - Volume Curve
2. XS/Face Properties
3. Angles with respect to controling cross section
4. Junction Reach Lengths

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

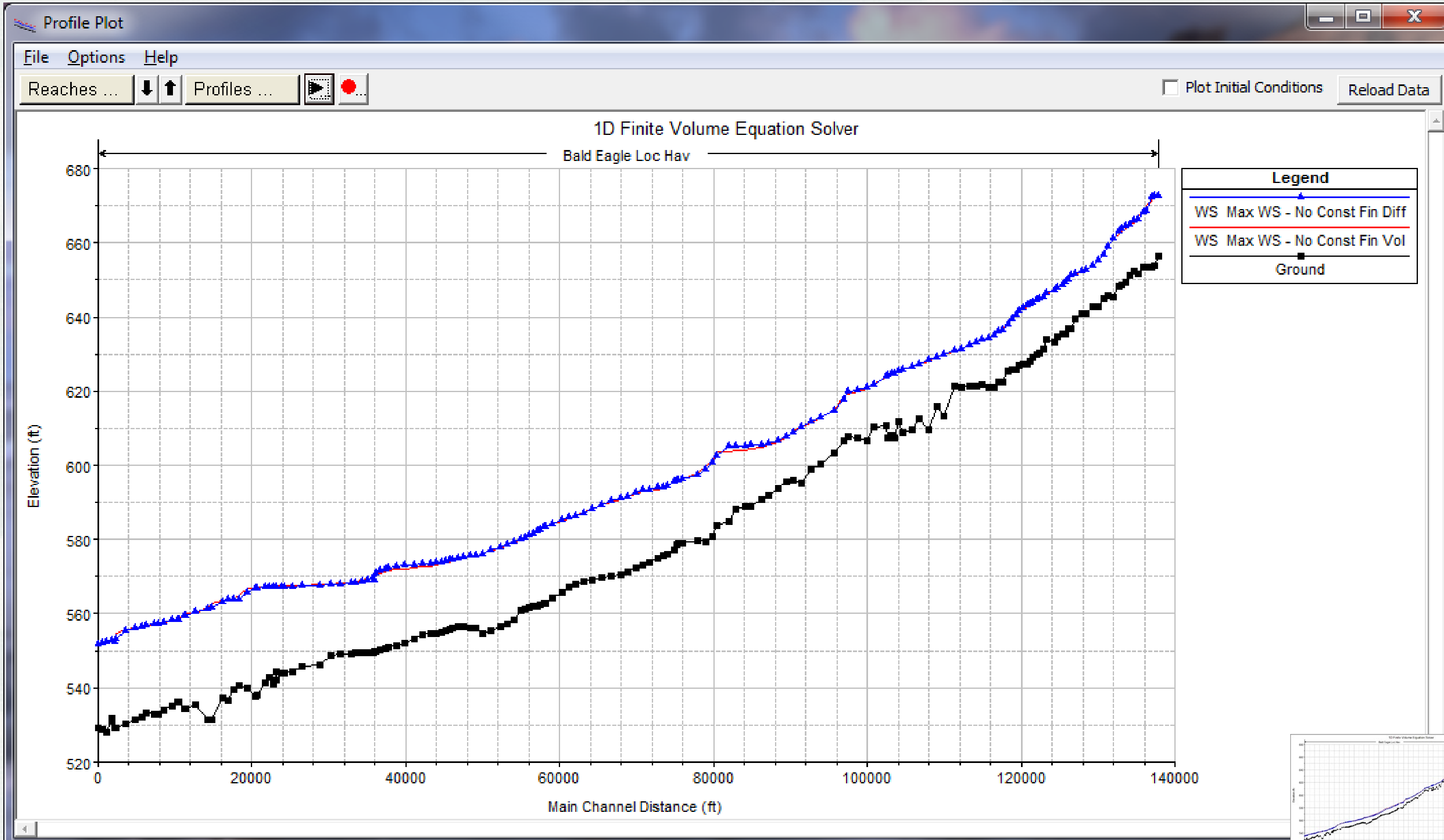


Natural River — Continued

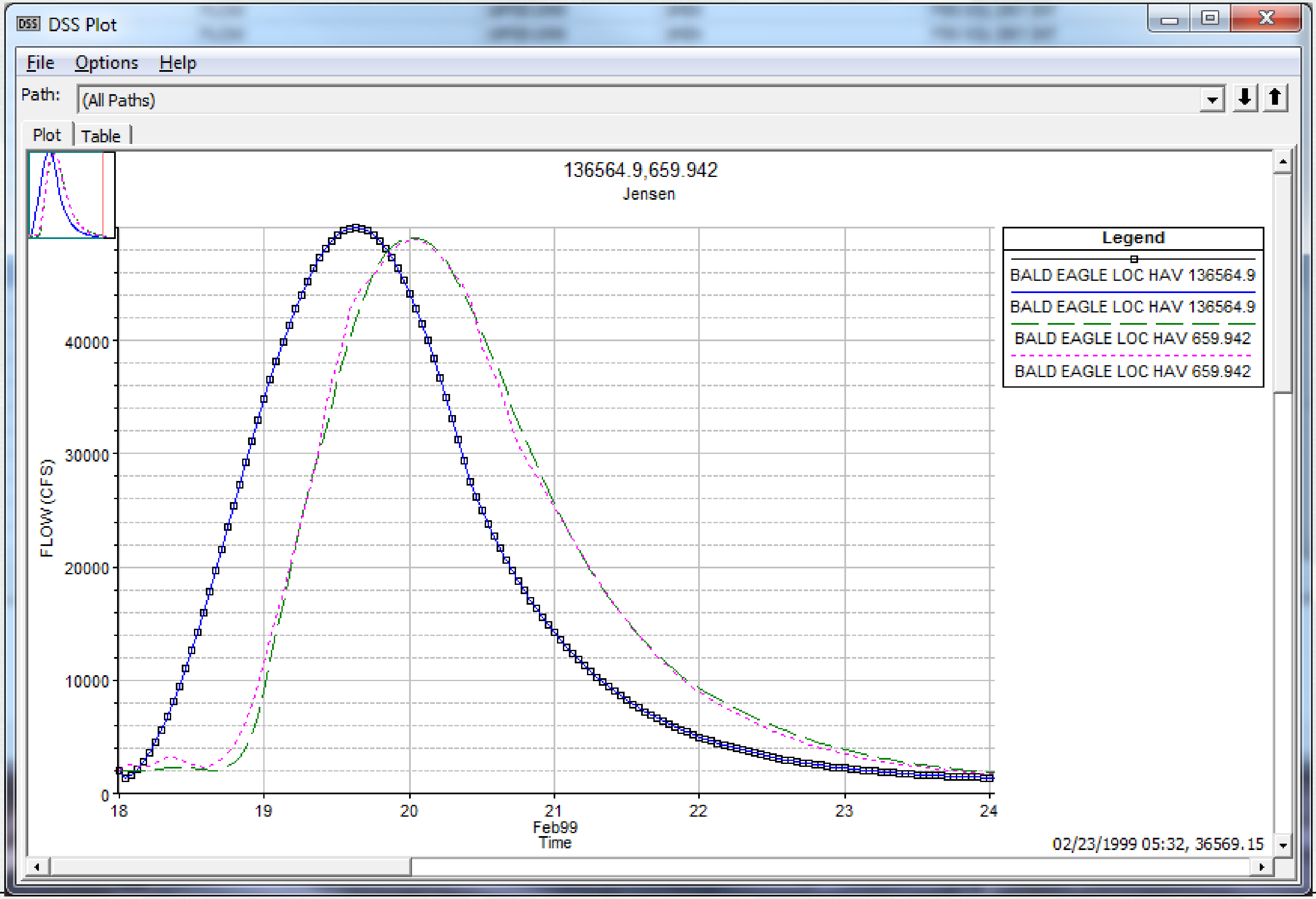
Animation - Finite Volume - Dry to Wet to Dry



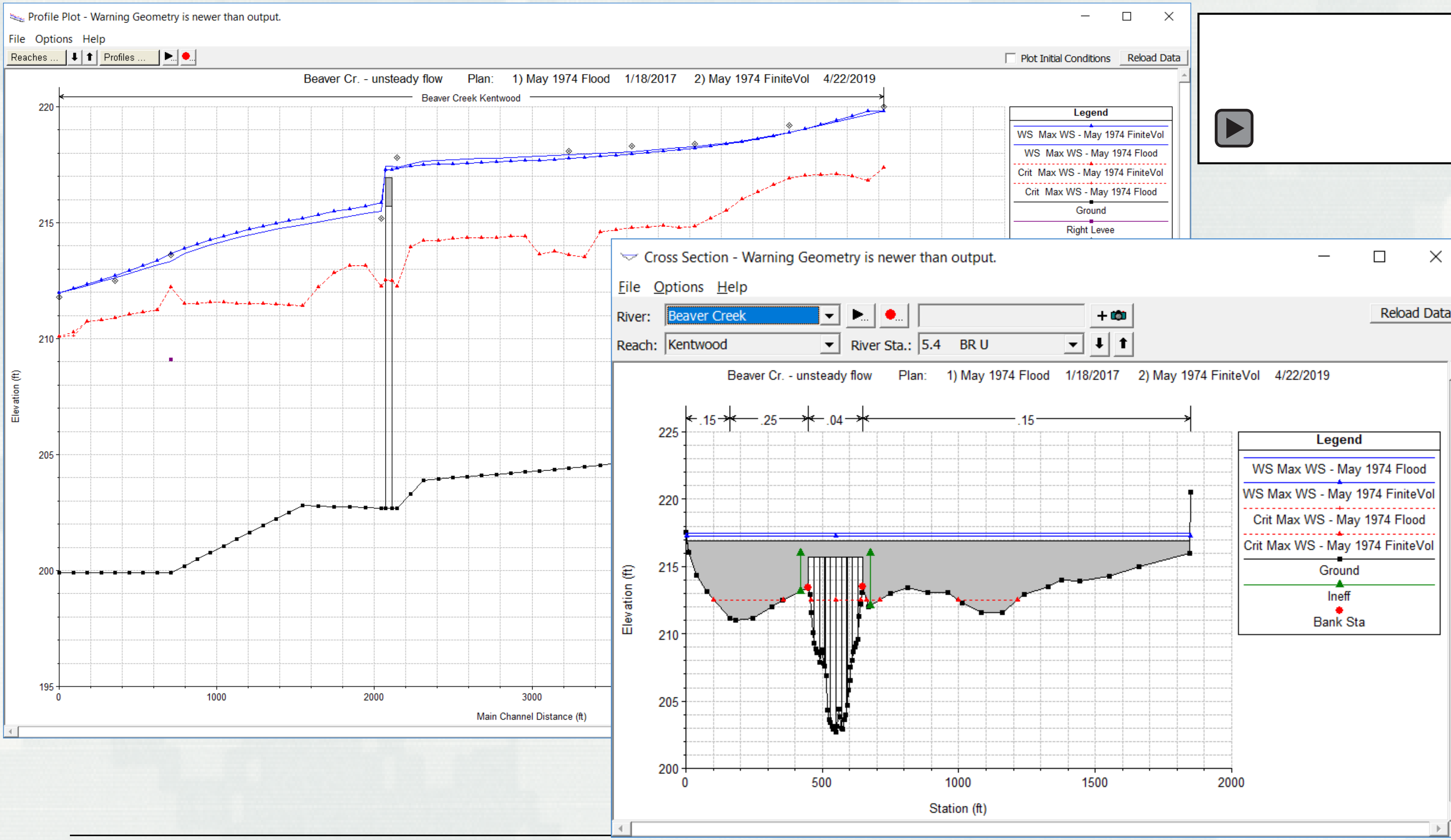
Natural River — Continued
Finite Volume vs Finite Difference – Starting Wet



Natural River — Continued
Upstream Inflow and Downstream Outflows



1D Bridge Hydraulics Beaver Creek

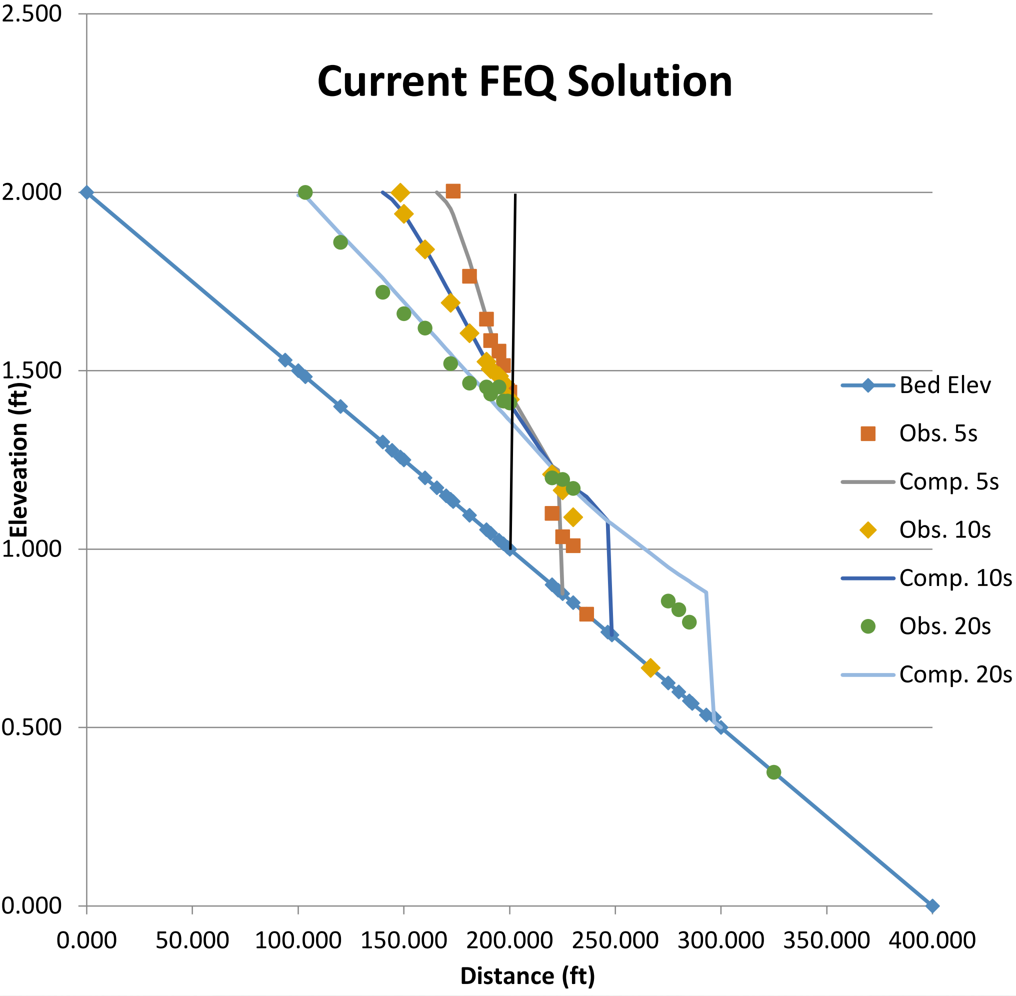


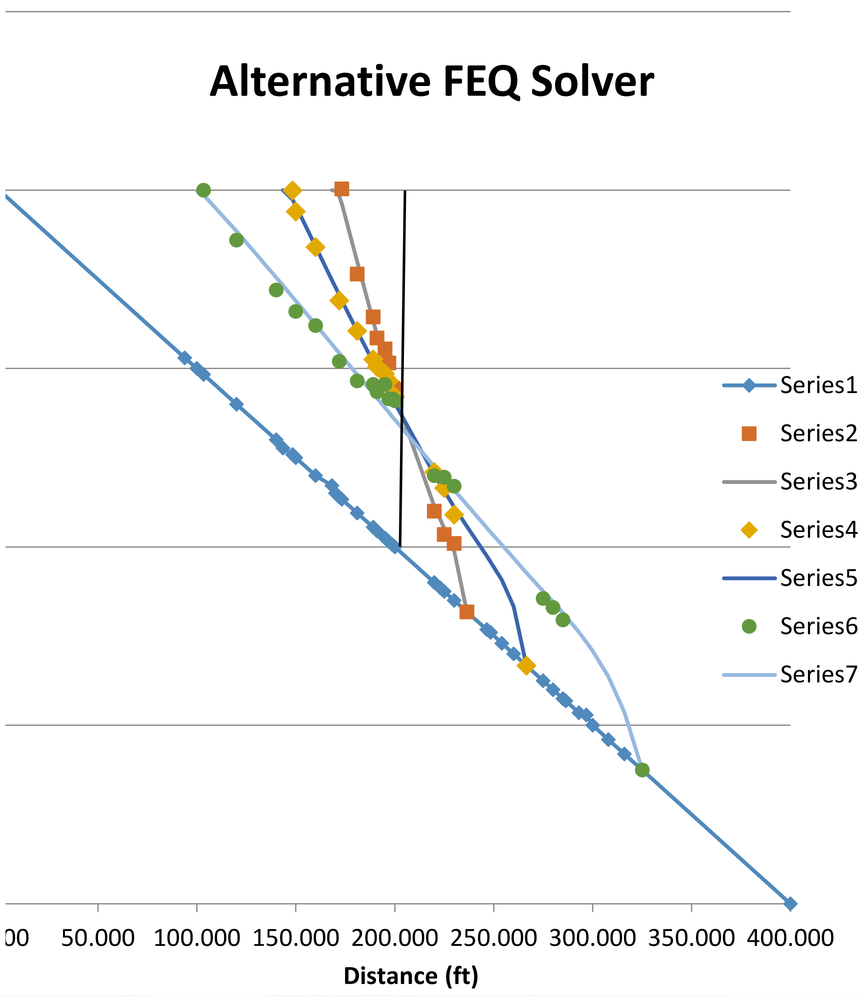
Bald Eagle Creek with Bridges

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

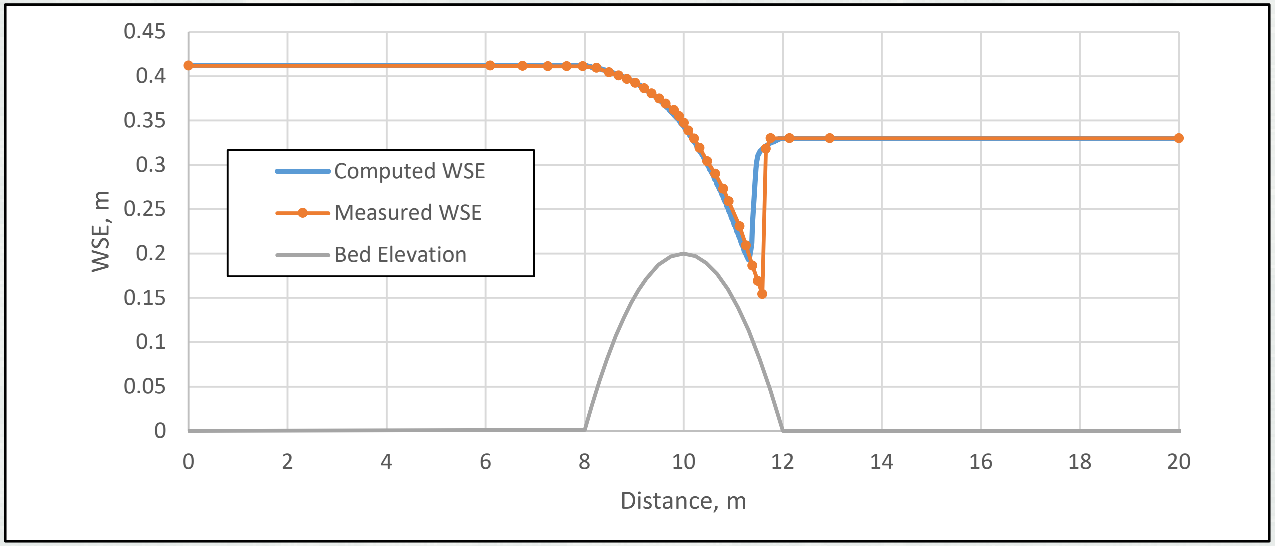
Sudden Dambreak in a Flume (WES Data Set and report from 1960)



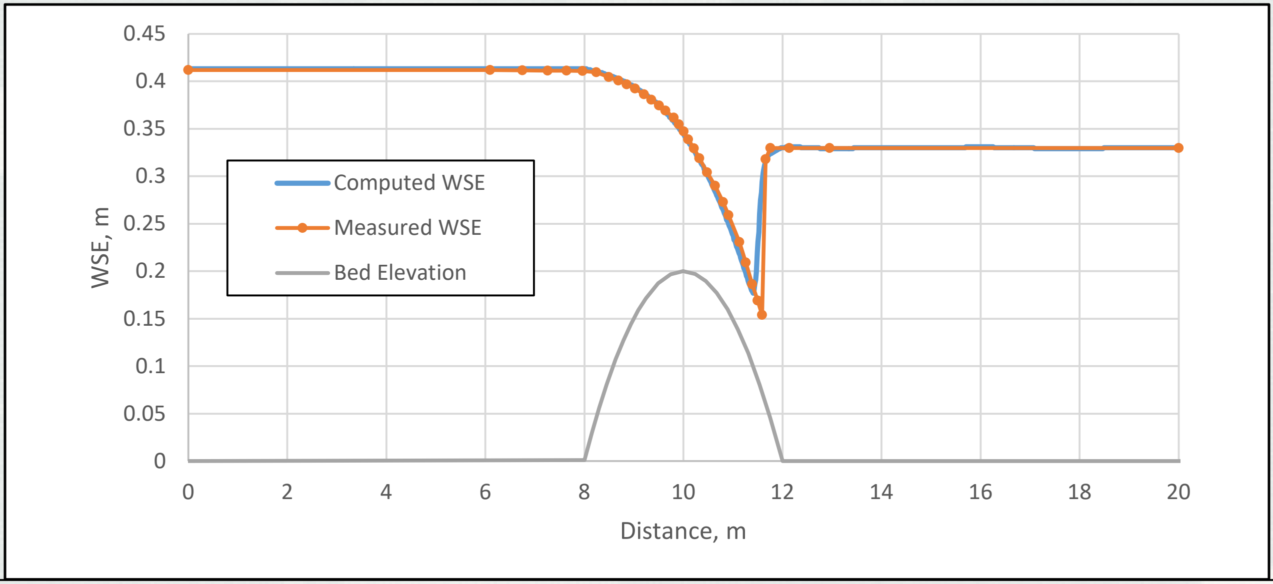


Flow over a Bump assuming no Friction

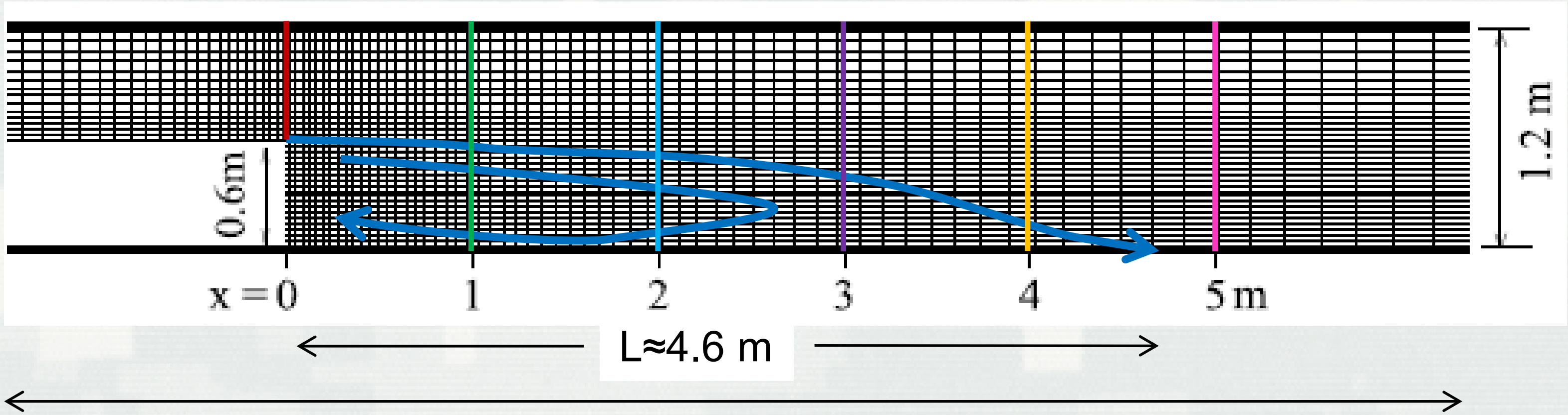
Current Solver:

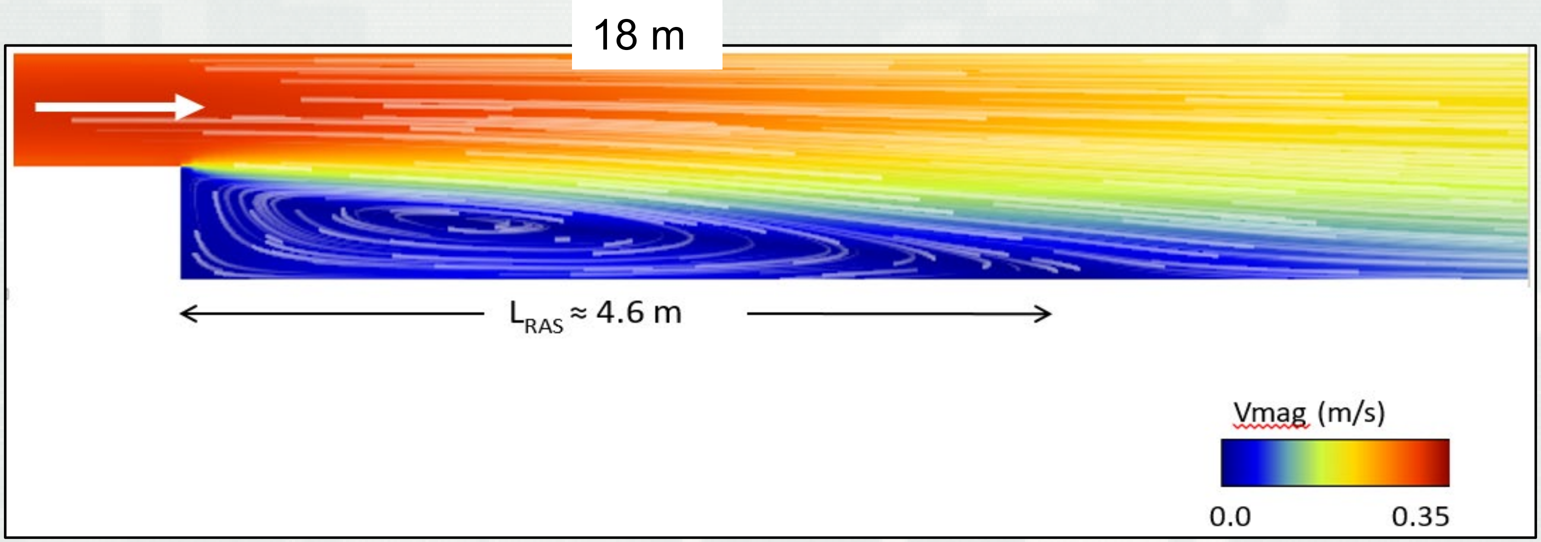


New Solver:



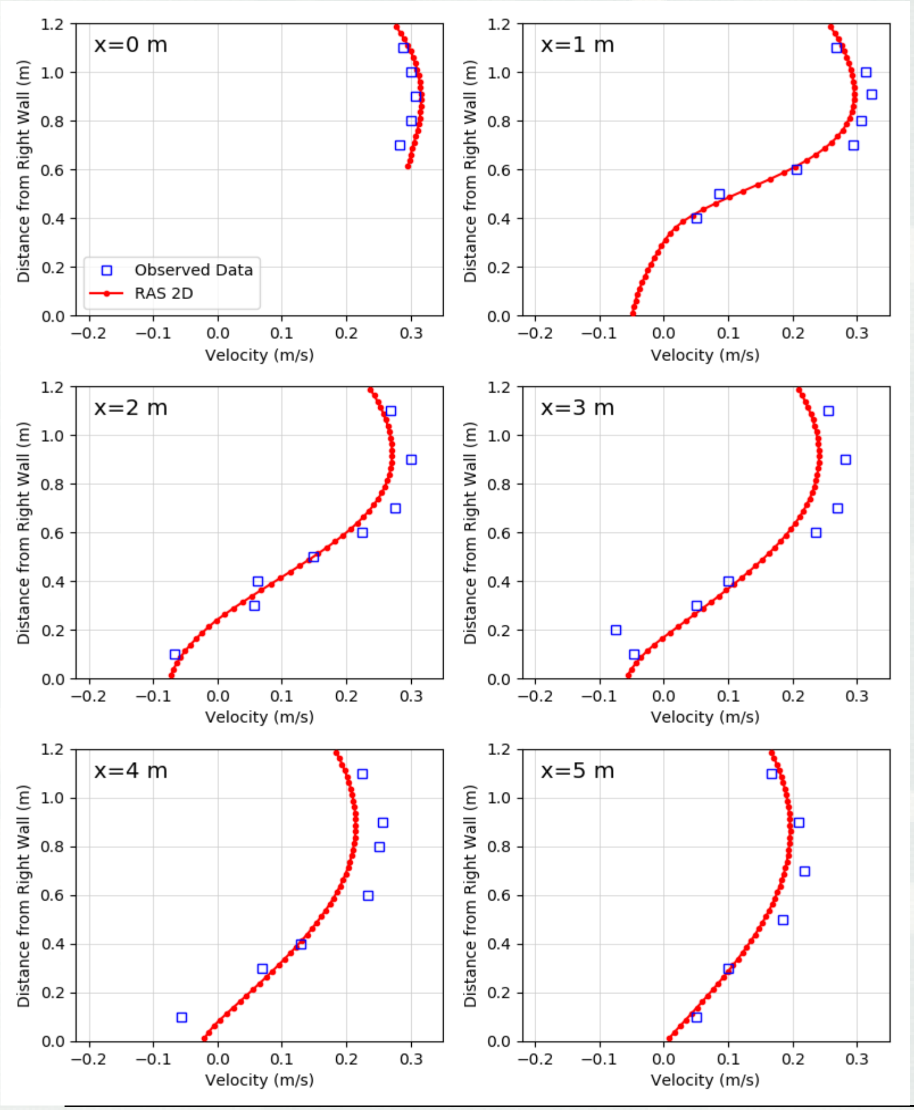
Sudden Expansion – Lab Data



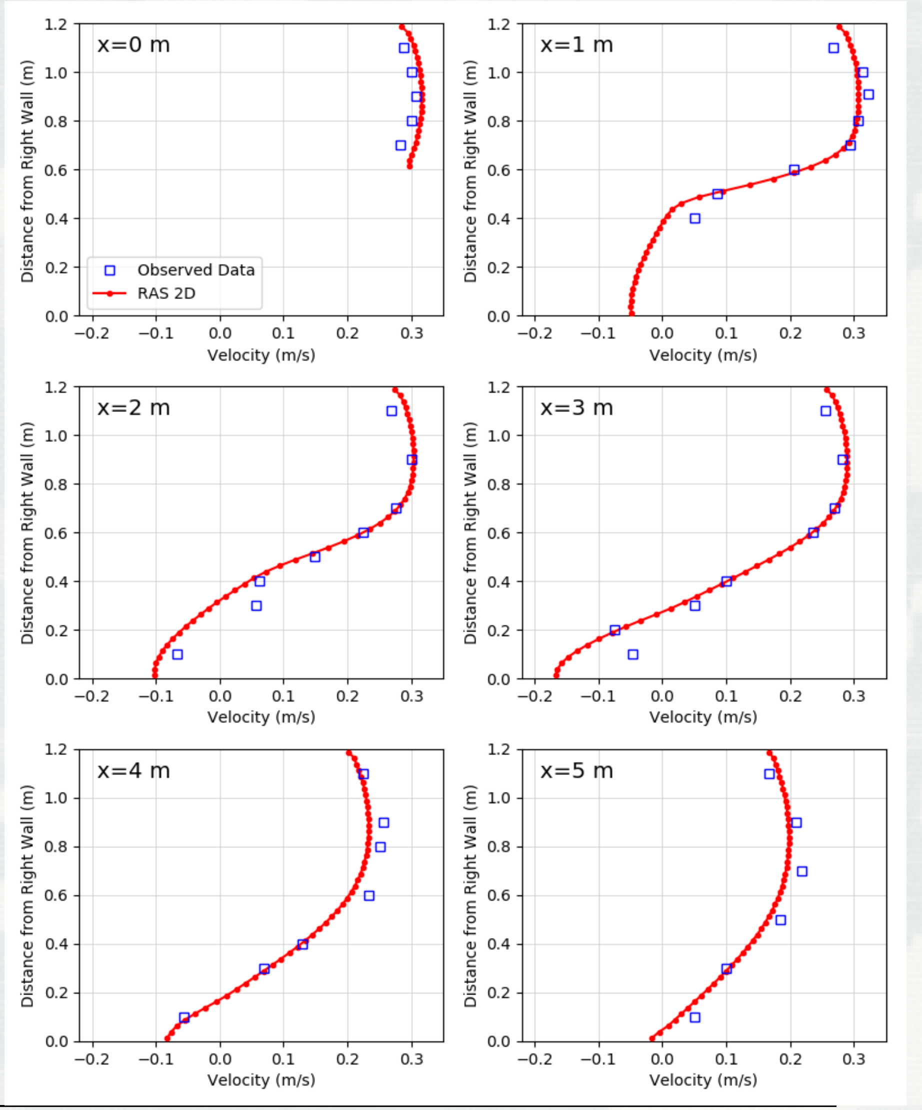


Sudden Expansion

Current Solver (D=1.4):



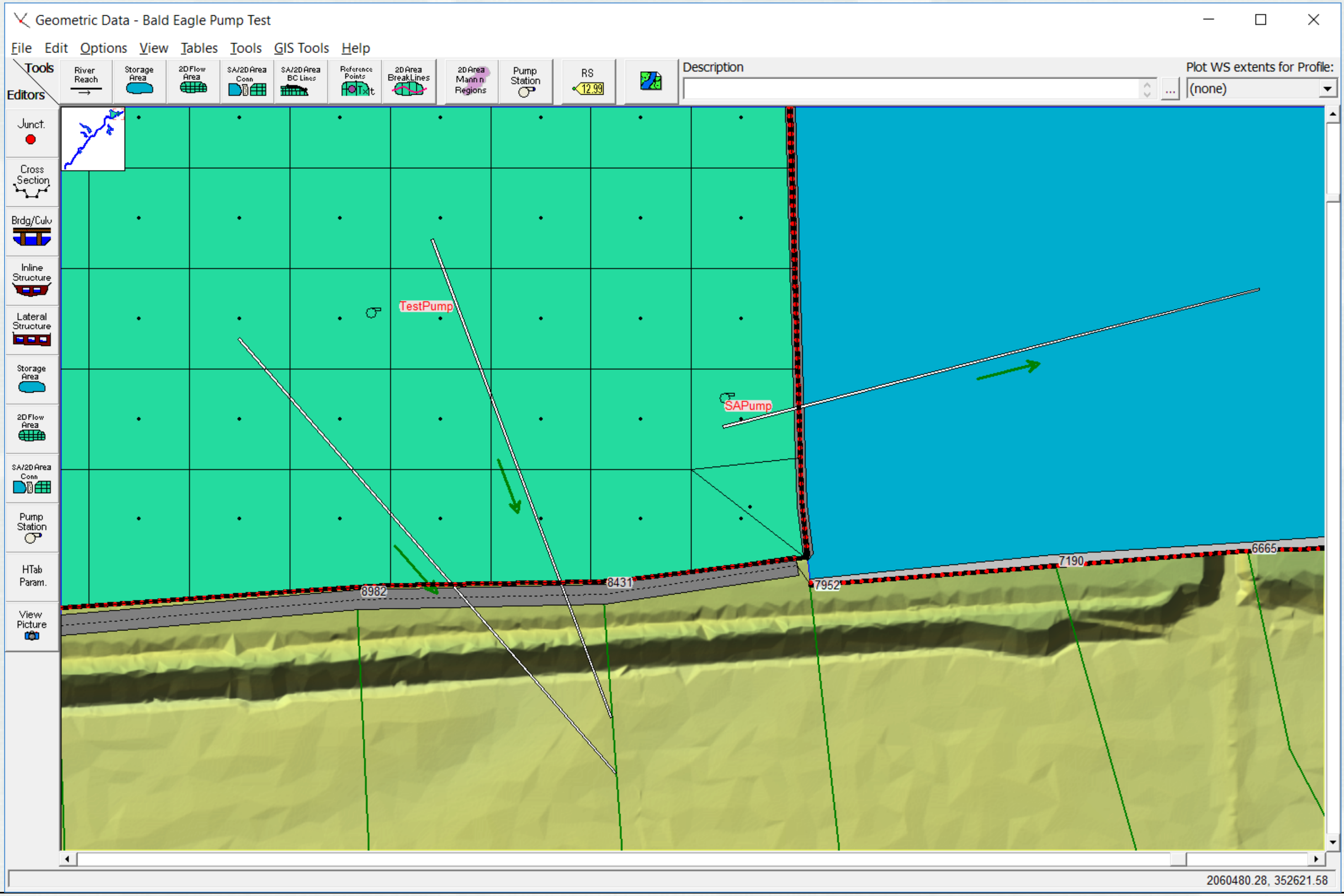
New Solver D=0.4:

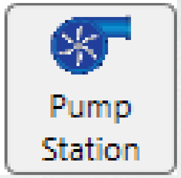


Pump Stations Connected to 2D Flow Areas

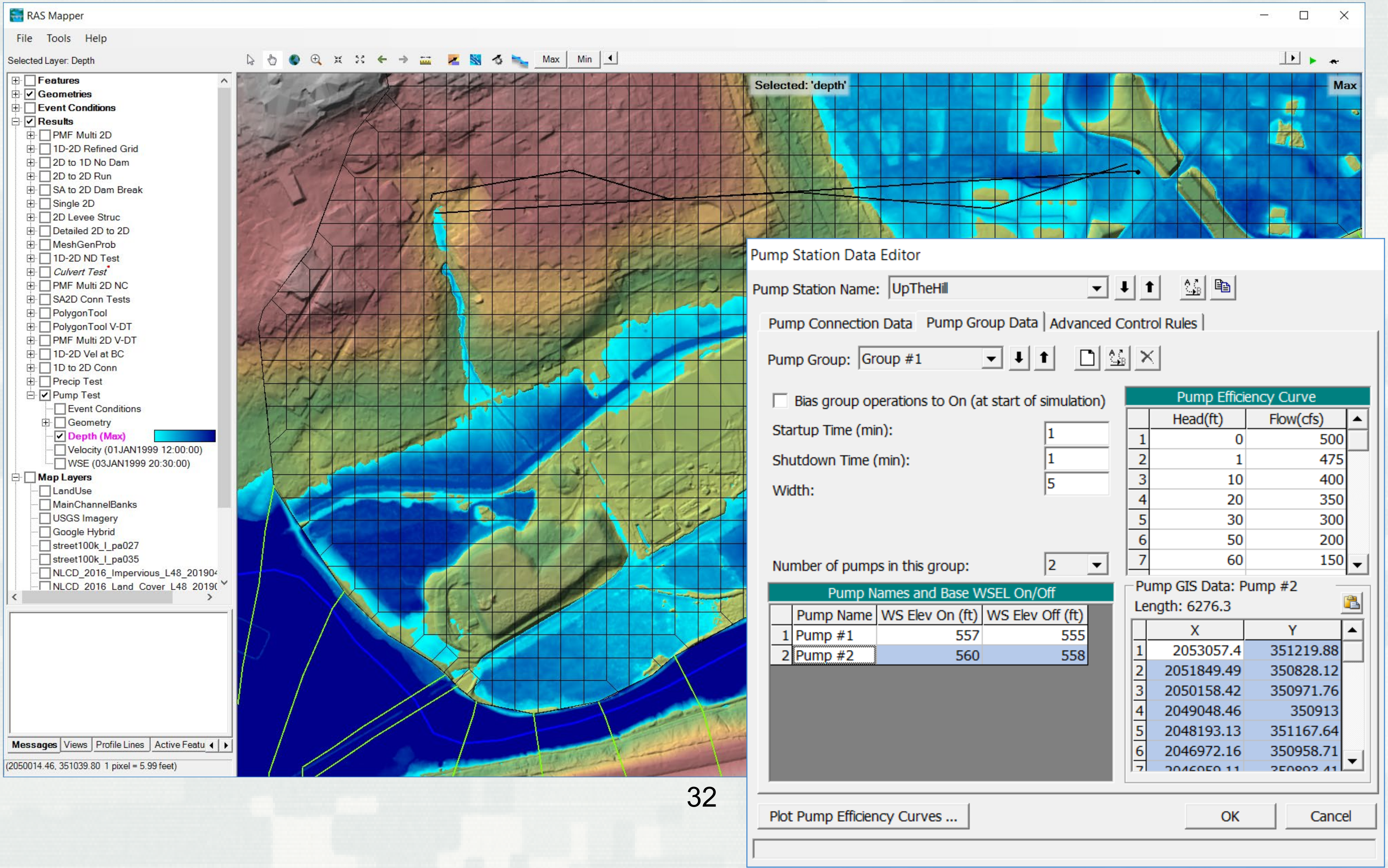
- Pump Stations now how spatial connections
  - X, Y coordinates for too and from locations
- Can now connect to 2D flow areas
  - 2D cell to another 2D cell
  - 2D cell to Storage Area
  - 2D cell to 1D river reach (XS location)

Pump Stations Example





Pump Stations Example



1D Bridge Hydraulics inside of a 2D Flow Area

- Develop a family of Headwater – Tailwater - Flow curves from 1D bridge hydraulic calculations
- Option to compute flow over the top of the bridge as weir flow or normal 2D flow equations
- Flows through the bridge opening will take into account momentum transfer
  - Flow and Velocity Boundary condition

Computational Speed Improvements

- New Matrix Format
  - Previous versions allowed the matrix to be Non-Symmetric
  - Version 5.1 uses a Symmetric matrix format
  - This allowed us to use a faster solver - Symmetric Positive Definite Solver
- Boundary Condition Cells
  - Previous version had B.C. cells along entire boundary of 2D area
    - Done for simplicity and consistency (.i.e. keep the code simple)
  - Version 5.1 only has extra cells a user defined boundary condition locations
    - Fewer cells means less computations – Faster solution

5.0.7 vs 5.1 2D Computational Speed

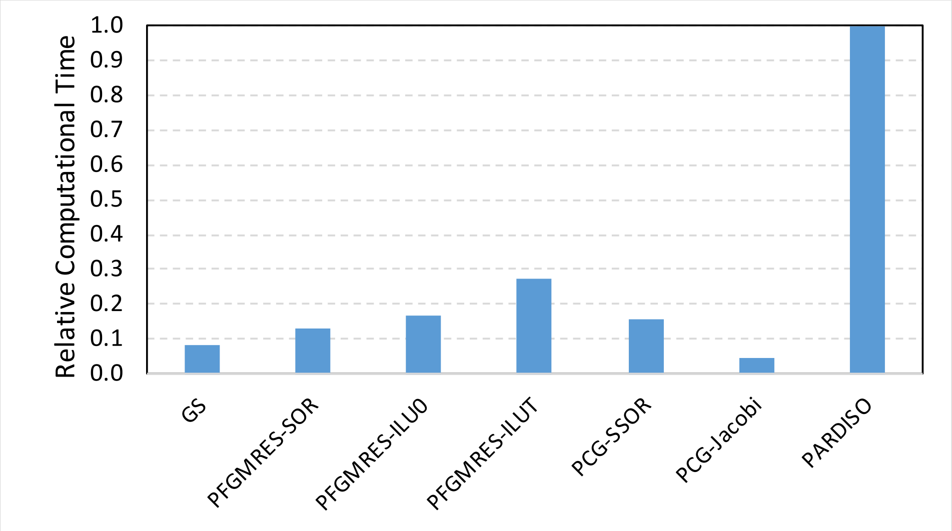
2D Test Name	Number Cells	Equation Type	5.0.7	5.1	Speed Factor
Bald Eagle Detailed	87,022	FEQ	1 hr 29 min 55s	59 min 37s	1.51
Muncie 2D 50ft Grid	5,376	FEQ	1 min 15s	55s	1.36
Saint Paul 2D	2,251	Diff	1 min 32s	1 min 01s	1.51
EU Test No 2	10,000	FEQ	40s	22s	1.82
EU Test No 4	80,000	FEQ	56s	40s	1.40
EU 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

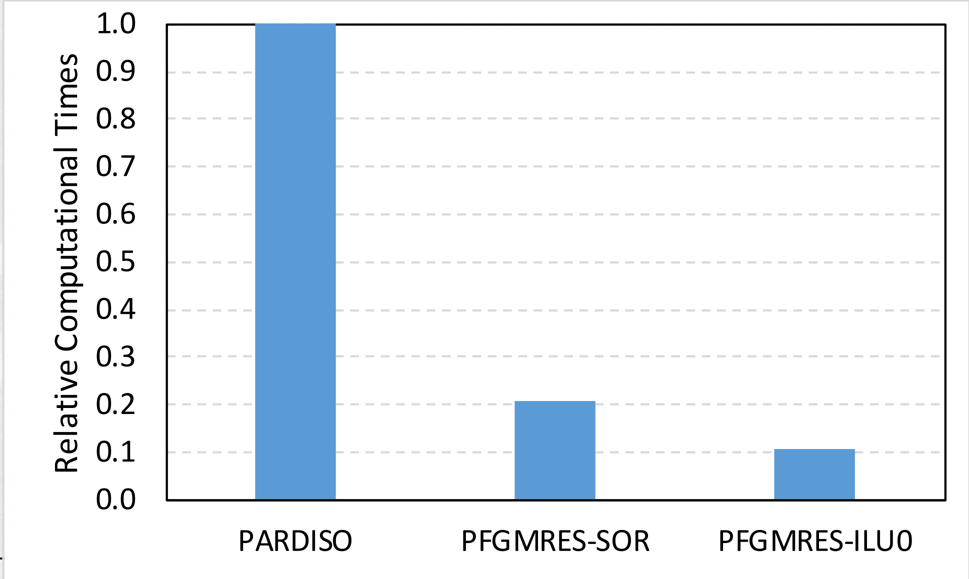
- HEC-RAS 5.0.7 uses a solver called PARDISO - direct solver
  - Better for model stability and volume accounting
  - Slower
- For HEC-RAS 5.1 we have added optional Iterative Solvers
  - Potentially faster
  - Requires user-based solution tolerance
  - Potentially less stable

Iterative Matrix Solvers
Note: Times are only for matrix solution

- Channel constriction and expansion



- Upper North Bosque River Watershed



5.0.7 vs 5.1 with Iterative Solvers

2D Test Name	Number Cells	Equation Type	5.0.7	5.1	5.1 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