

# Boundary and Initial Conditions for 2D Modeling

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# Overview

- Boundary Conditions (BC)
  - External
  - Internal
  - Global
- Initial Conditions (IC)
  - User-Specified
  - Ramp Up and Warm Up Periods
  - Restart File
  - Interpolate from Previous Results
- Observed Data



# External Boundary Conditions

- **Flow Hydrograph**

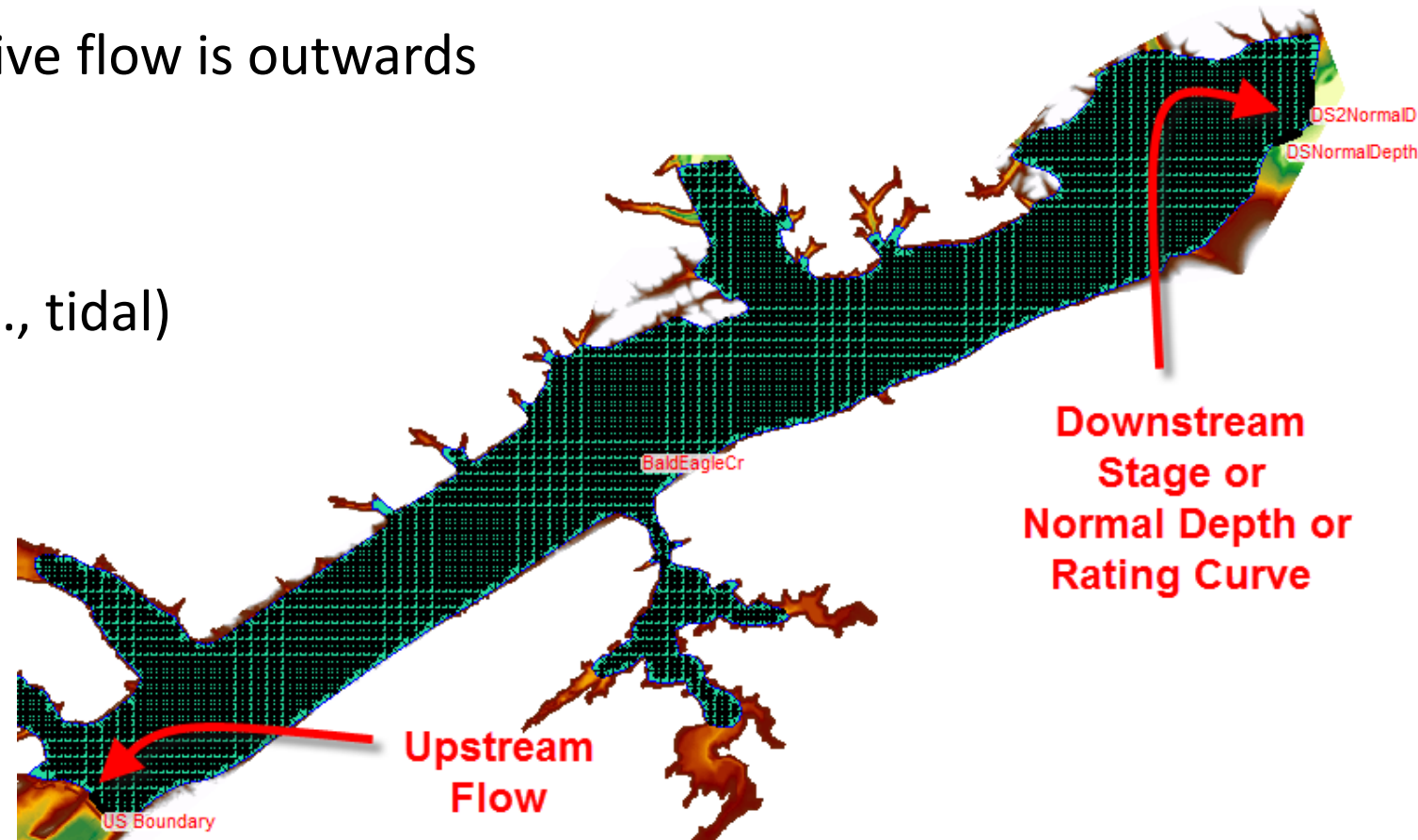
- Usually for inflow (upstream/lateral)
  - Can also be used for outflow
- Positive flow is inwards; Negative flow is outwards

- **Stage Hydrograph**

- Usually for outflow
- Can also be used for inflow (i.e., tidal)

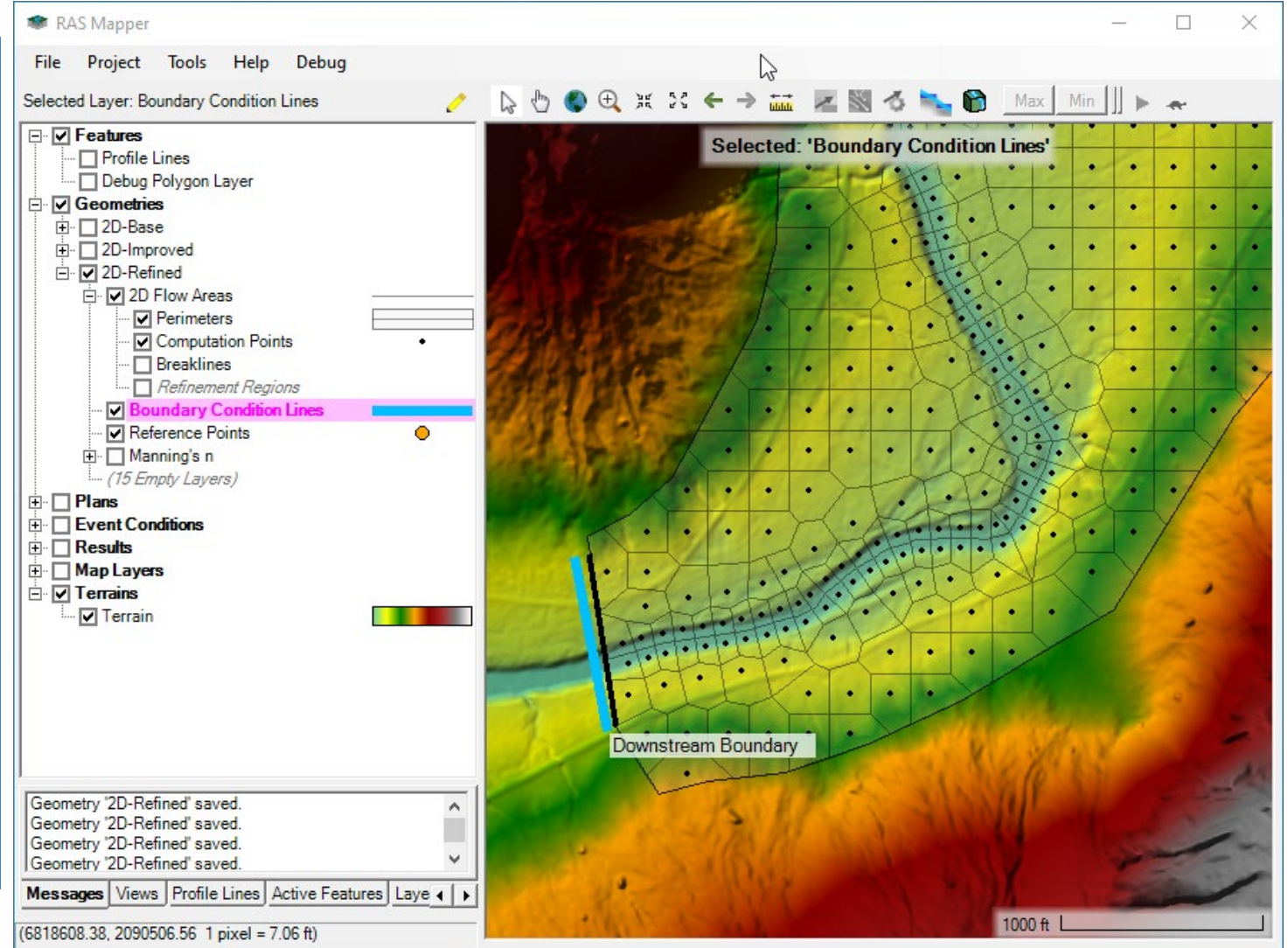
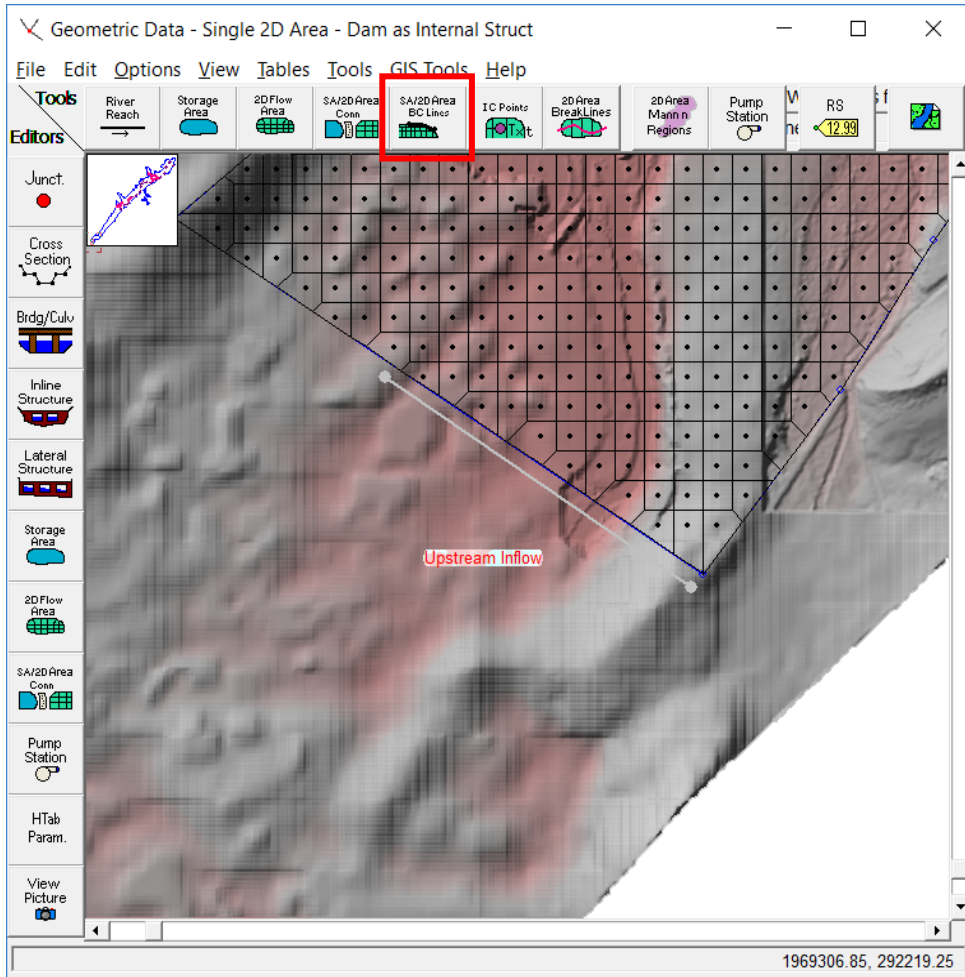
- **Normal Depth (outflow only)**

- **Rating Curve (outflow only)**





# Creating External Boundary Condition Lines





# External Boundary Condition Data

HEC-RAS 6.3.1

File Edit Run View Options GIS Tools Help

Project: BaldEagleCreekDemo  
 Plan: Single 2D Area -Precip Test  
 Geometry: Single 2D Area - Dam as Internal Struct  
 Steady Flow:  
 Unsteady Flow: Single 2D Area - Precip  
 Description: The United States Army Corps of Engineers has granted access to the information in

Unsteady Flow Data - Single 2D Area with Bridges

File Options Help

Description: [ ] [Apply Data]

Boundary Conditions | Initial Conditions | Meteorological Data | Observed Data

**Boundary Condition Types**

Stage Hydrograph	Flow Hydrograph	Stage/Flow Hydr.	Rating Curve
Normal Depth	Lateral Inflow Hydr.	Uniform Lateral Inflow	Groundwater Interflow
T.S. Gate Openings	Elev Controlled Gates	Navigation Dams	IB Stage/Flow
Rules	Precipitation		

**Add Boundary Condition Location**

Add RS ... Add SA/2D Flow Area ... Add Conn ... Add Pump Sta ... Add Pipe Node ...

Select Location in table then select Boundary Condition Type

River	Reach	RS	Boundary Condition
<b>Storage/2D Flow Areas</b>			
1	BaldEagleCr	BCLine: Upstream Inflow	Flow Hydrograph
2	BaldEagleCr	BCLine: DSNormalDepth	Normal Depth
3	BaldEagleCr	BCLine: DS2NormalDepth	Normal Depth
<b>SA/2D Area Conns</b>			
1	Sayers Dam		T.S. Gate Openings

- Open Unsteady Flow Data editor
- Required BC's appear automatically for geometry



# Flow Hydrograph & EG Slope

Flow Hydrograph

SA: 2D Area BCLine: BC Upstream (Upstream name)

Read from DSS before simulation Select DSS file and Path

File:

Path:

Enter Table Data time interval: 1 Minute

Select/Enter the Data's Starting Time Reference

Use Simulation Time: Date: 01JAN1999 Time: 1200

Fixed Start Time: Date:  Time:

No. Ordinates | Interpolate Missing Values | Del Row | Ins Row

Hydrograph Data			
	Date	Simulation Time (hours)	Flow (cfs)
1	01Jan1999 1200	00:00	400
2	01Jan1999 1201	00:01	416.67
3	01Jan1999 1202	00:02	833.33
4	01Jan1999 1203	00:03	1250

Time Step Adjustment Options ("Critical" boundary conditions)

Monitor this hydrograph for adjustments to computational time step

Max Change in Flow (without changing time step):

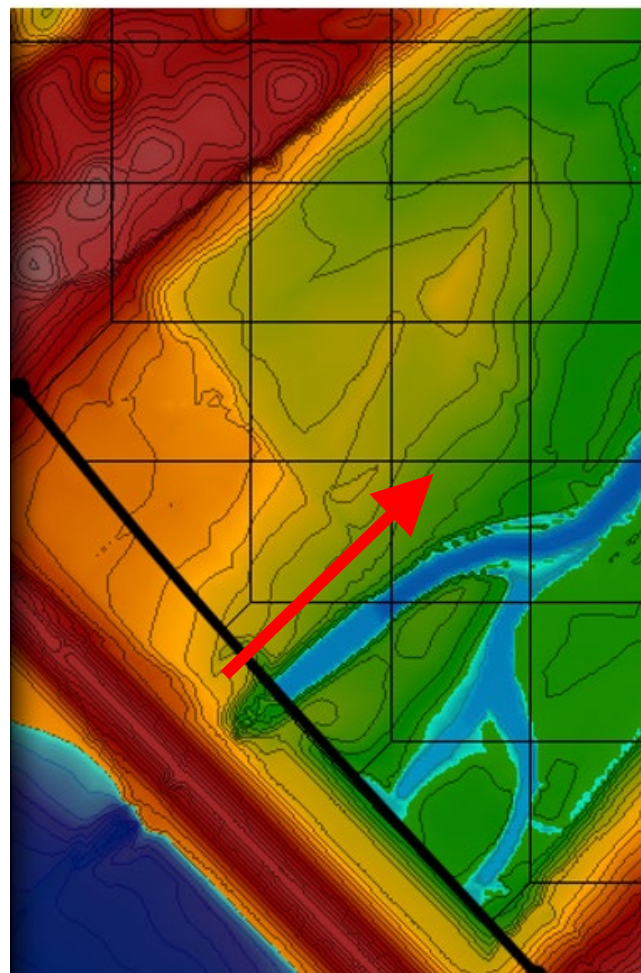
Min Flow:  Multiplier:  EG Slope for distributing flow along BC Line: 0.1  TW Check

Plot Data | OK | Cancel

- Time series from DSS or table
- **EG Slope** required to compute normal depth
- Flow distributed to boundary cells based on conveyance
- **TW Check** option uses higher of TW and normal depth
- Face velocities computed for shallow water equations

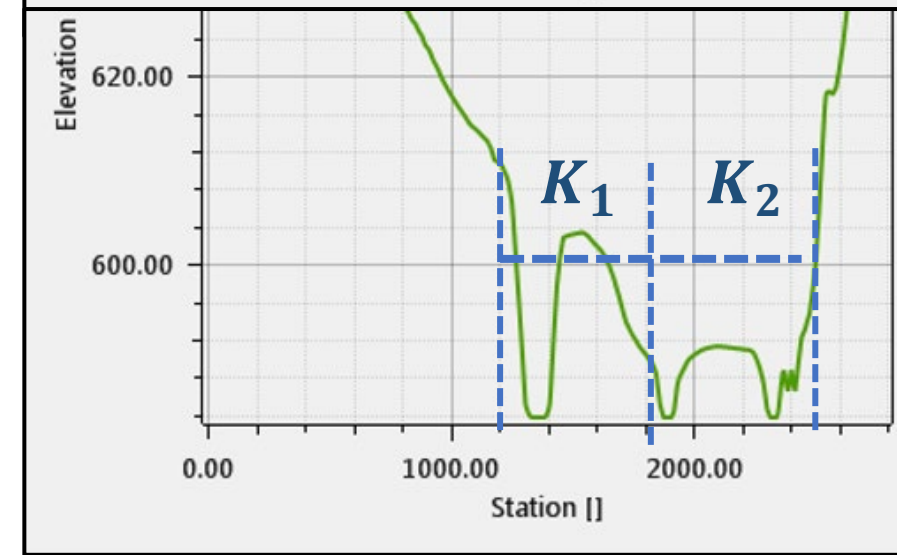
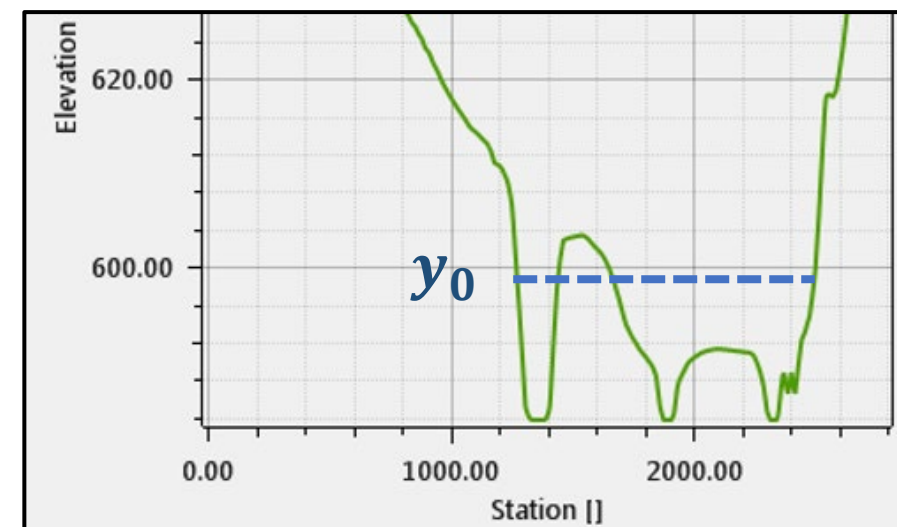


# Flow Distribution along Boundary



$$Q = \frac{1.49}{n} * AR^{2/3} S_f^{1/2}$$

$$K = \frac{1.49}{n} * AR^{2/3}$$



- Flow is distributed to cells based on EG Slope Conveyance or actual water surface



# Stage Hydrograph

- Inflow or outflow
- All wet faces at the boundary assigned the same stage
- Flow computed per wet face
- **Use Initial Stage** option applies a horizontal water level from the boundary inwards

Stage Hydrograph

SA: BaldEagleCr BCLine: DS Stage

Read from DSS before simulation

File:  Path:

Enter Table

Select/Enter the Data's Starting Time Reference

Use Simulation Time: Date: 01JAN1999 Time: 1200

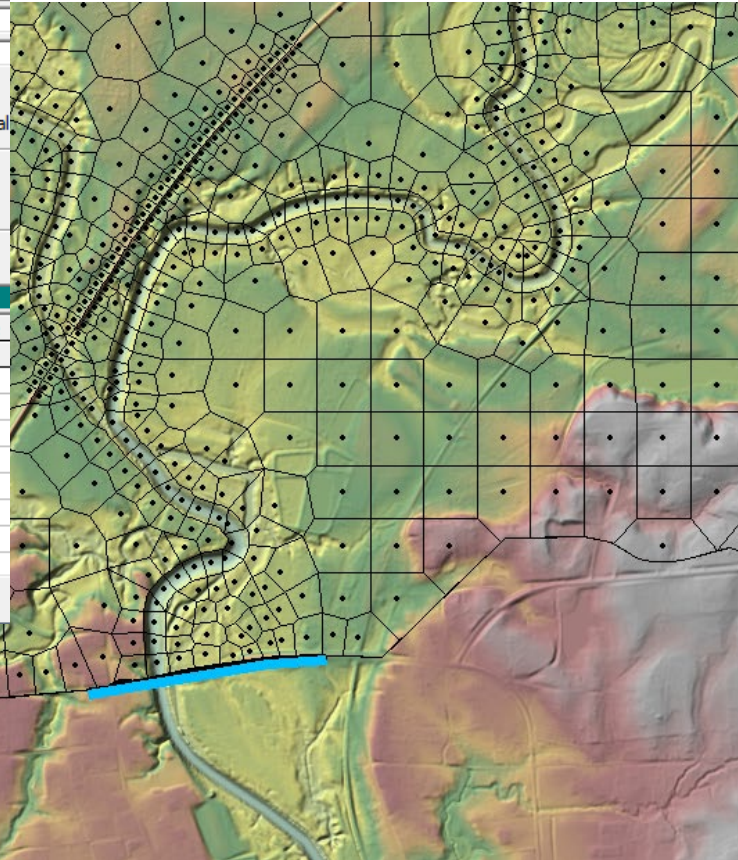
Fixed Start Time: Date:  Time:

No. Ordinates Interpolate Missing Values Del Row Ins Row

	Date	Simulation Time (hours)	Stage (ft)
1	01Jan1999 1200	00:00	536.13
2	01Jan1999 1300	01:00	537.07
3	01Jan1999 1400	02:00	536.86
4	01Jan1999 1500	03:00	537.53
5	01Jan1999 1600	04:00	538.18
6	01Jan1999 1700	05:00	539.73
7	01Jan1999 1800	06:00	540.38
8	01Jan1999 1900	07:00	540.77

Use Initial Stage (recommended)

Plot Data OK



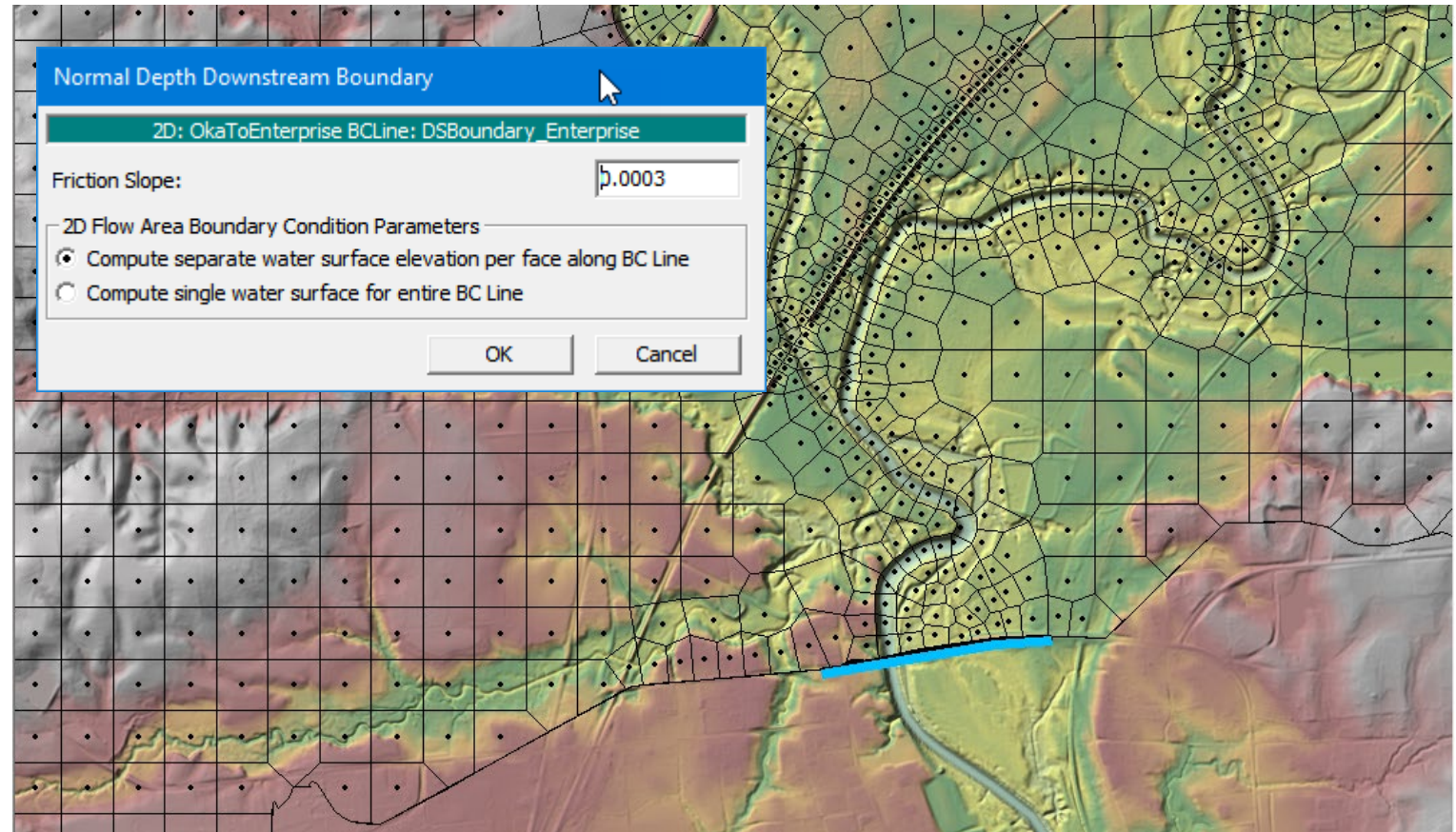




# Normal Depth



- Only for **outflow**
- $Q = \frac{1.49}{n} * AR^{2/3} S_f^{1/2}$
- Manning's Eq. used to compute **flow per face**
- Boundary stage can vary
- Should be reserved for situations where no other data is available





# Rating Curve

Unsteady Flow Data - 2D Lower

File Options Help

Boundary Conditions | Initial Conditions |

Boundary Condition Types

Stage Hydrograph	Flow Hydrograph	Stage/Flow Hydr.	Rating
Normal Depth	Lateral Inflow Hydr.	Uniform Lateral Inflow	Groundwa
T.S. Gate Openings	Elev Controlled Gates	Navigation Dams	IB Sta

Rules

Add Boundary Condition Location

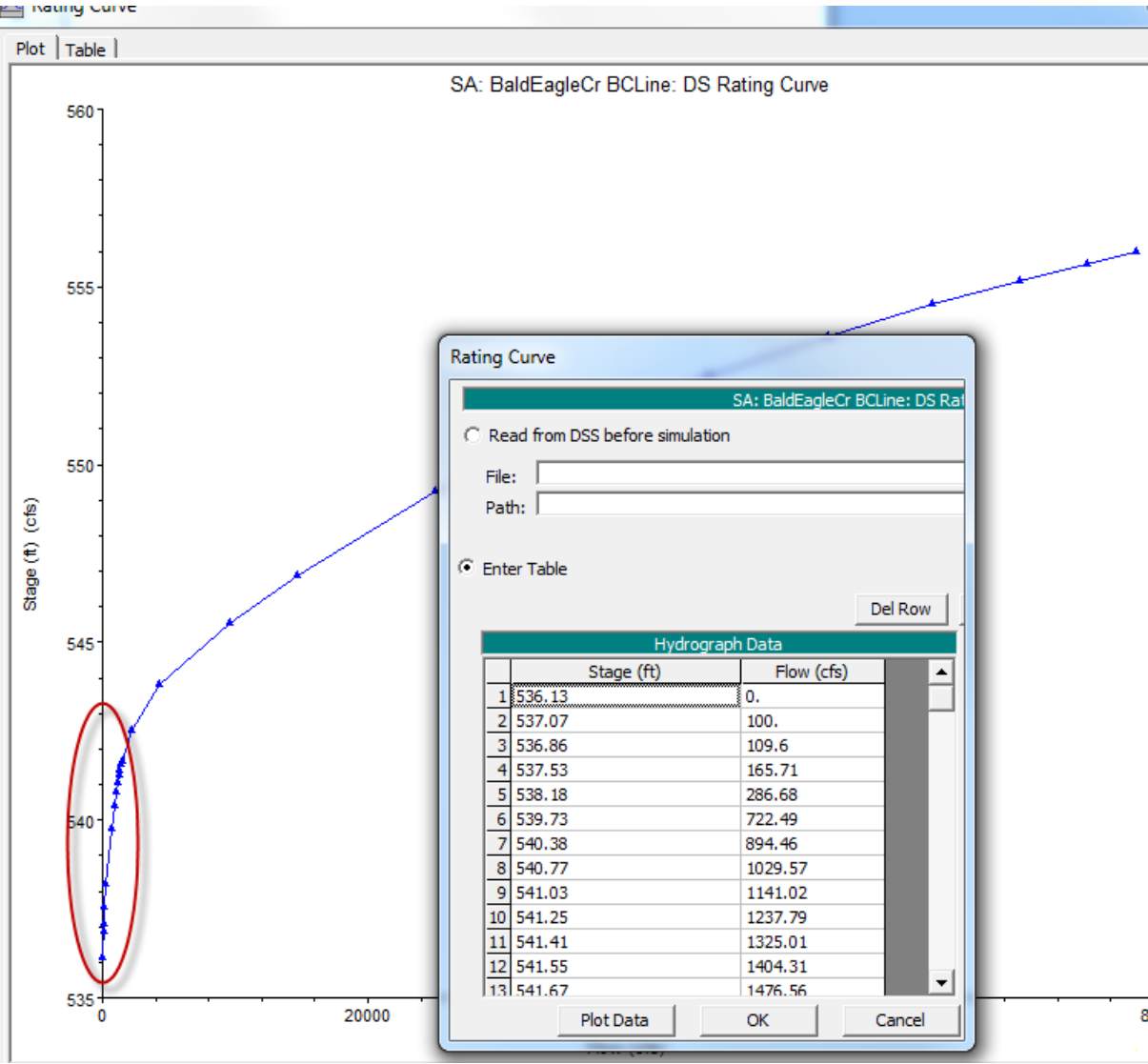
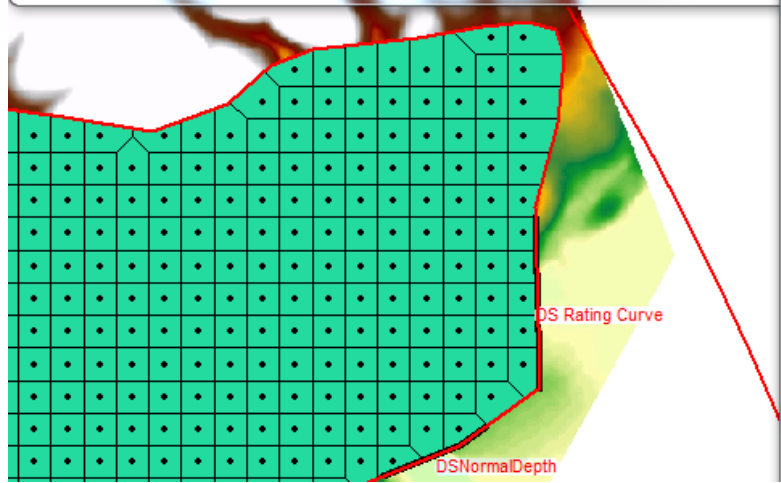
Add RS ... Add Storage Area ... Add SA Connection ... Add Pum

Select Location in table then select Boundary Condition Type

River	Reach	RS	Boundary Condition

Storage/2D Flow Areas

	Boundary Condition
1 BaldEagleCr BCLine: US Boundary	Flow Hydrograph
2 BaldEagleCr BCLine: DS Rating Curve	Rating Curve
3 BaldEagleCr BCLine: DSNormalDepth	Normal Depth





# Rating Curve Considerations

- Flow based on conveyance-averaged WSE
- Flow distribution based on conveyance
- Watch out for a steeply sloped curve and/or sharp transitions in the curve
- Watch out for “bad” low flow curve
- Zero flow point on Rating Curve does **NOT** have to be at invert (could be higher)
- Can have initialization problems (when RC is not consistent with cold-start conditions)

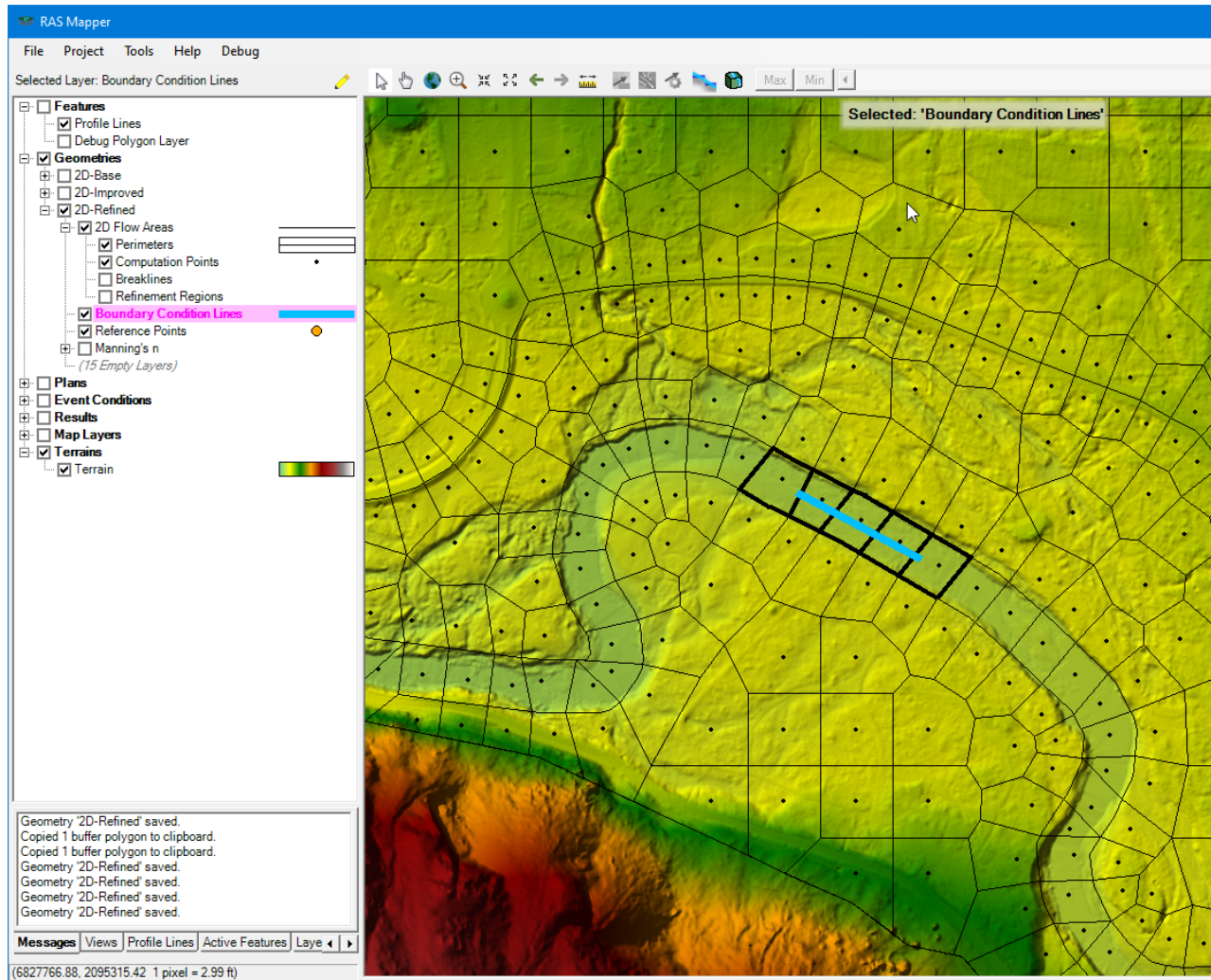


# External Boundaries Summary

- Extend boundary condition locations **away from study area of interest**
- Normal Depth is an approximate boundary
- Stage creates a horizontal WSE along the boundary cells (place normal to flow)
- Rating curve does not account for changes in flow for rising and falling-limbs of hydrograph



# Internal Flow Hydrographs



- Must be **inside** of the 2D Flow Area
- Can have positive or negative flows
- No flow direction; volume added only
- Flow is distributed to cells based on **length** of line in each cell



# Internal (2D Area) Precipitation BC

- Time-series applied to individual 2D areas
- Precipitation rates spatially uniform
- Specified as period cumulative depths

Precipitation Hydrograph

2D: LeveeB\_Interior

Read from DSS before simulation Select DSS file and Path

File:

Path:

Enter Table Data time interval: 15 Minute

Select/Enter the Data's Starting Time Reference

Use Simulation Time: Date: 26May1984 Time: 0000

Fixed Start Time: Date:  Time:

No. Ordinates Interpolate Missing Values Del Row Ins Row

Hydrograph Data		
	Date	Precipitation (in)
	Simulation Time (hours)	
1	25May1984 2400	0.05
2	26May1984 0015	0.05
3	26May1984 0030	0.05
4	26May1984 0045	0.05
5	26May1984 0100	0.05
6	26May1984 0115	0.05
7	26May1984 0130	0.05
8	26May1984 0145	0.05
9	26May1984 0200	0.05
10	26May1984 0215	0.05
11	26May1984 0230	0.05

Plot Data OK Cancel

Unsteady Flow Data - Single 2D Area - Precip

File Options Help

Description:  Apply Data

Boundary Conditions | Initial Conditions | Meteorological Data | Observed Data

Boundary Condition Types

Stage Hydrograph	Flow Hydrograph	Stage/Flow Hydr.	Rating Curve
Normal Depth	Lateral Inflow Hydr.	Uniform Lateral Inflow	Groundwater Interflow
T.S. Gate Openings	Elev Controlled Gates	Navigation Dams	IB Stage/Flow
Rules	Precipitation		

Add Boundary Condition Location

Add RS ... Add SA/2D Flow Area ... Add SA/2D Area Conn ... Add Pump Station ...

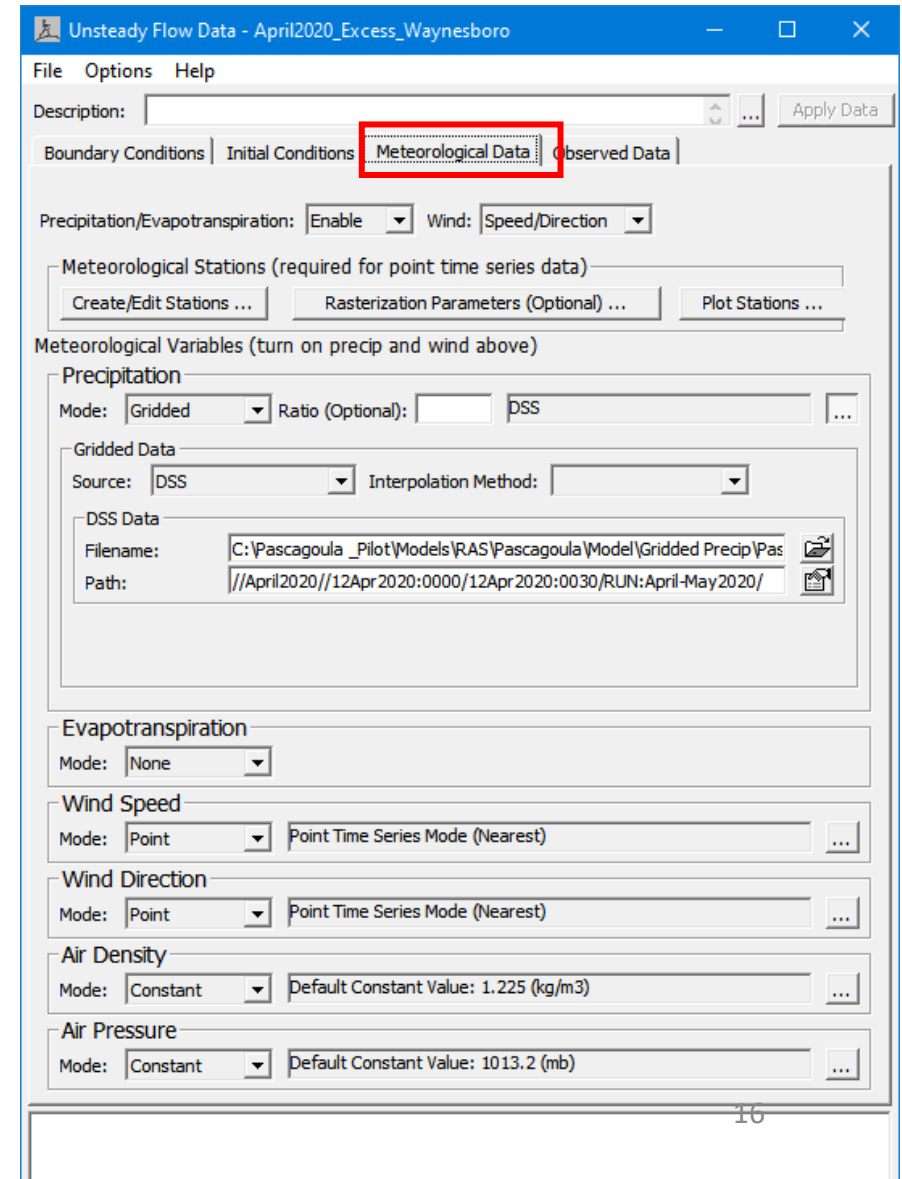
Select Location in table then select Boundary Condition Type

River	Reach	RS	Boundary Condition
<b>Storage/2D Flow Areas</b>			<b>Boundary Condition</b>
1	BaldEagleCr		Precipitation
2	BaldEagleCr	BCLine: Upstream Inflow	Flow Hydrograph
3	BaldEagleCr	BCLine: DSNormalDepth	Normal Depth
4	BaldEagleCr	BCLine: DS2NormalD	Normal Depth
<b>SA/2D Area Conns</b>			<b>Boundary Condition</b>
1	Dam		T.S. Gate Openings



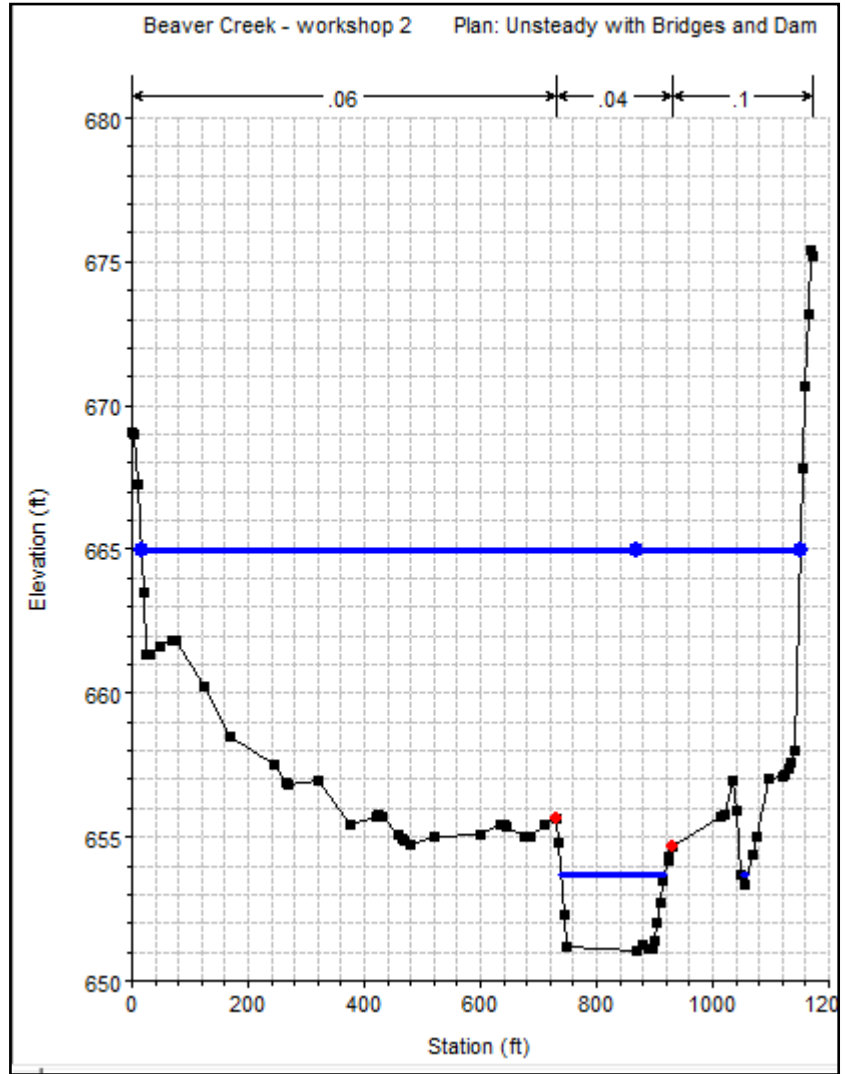
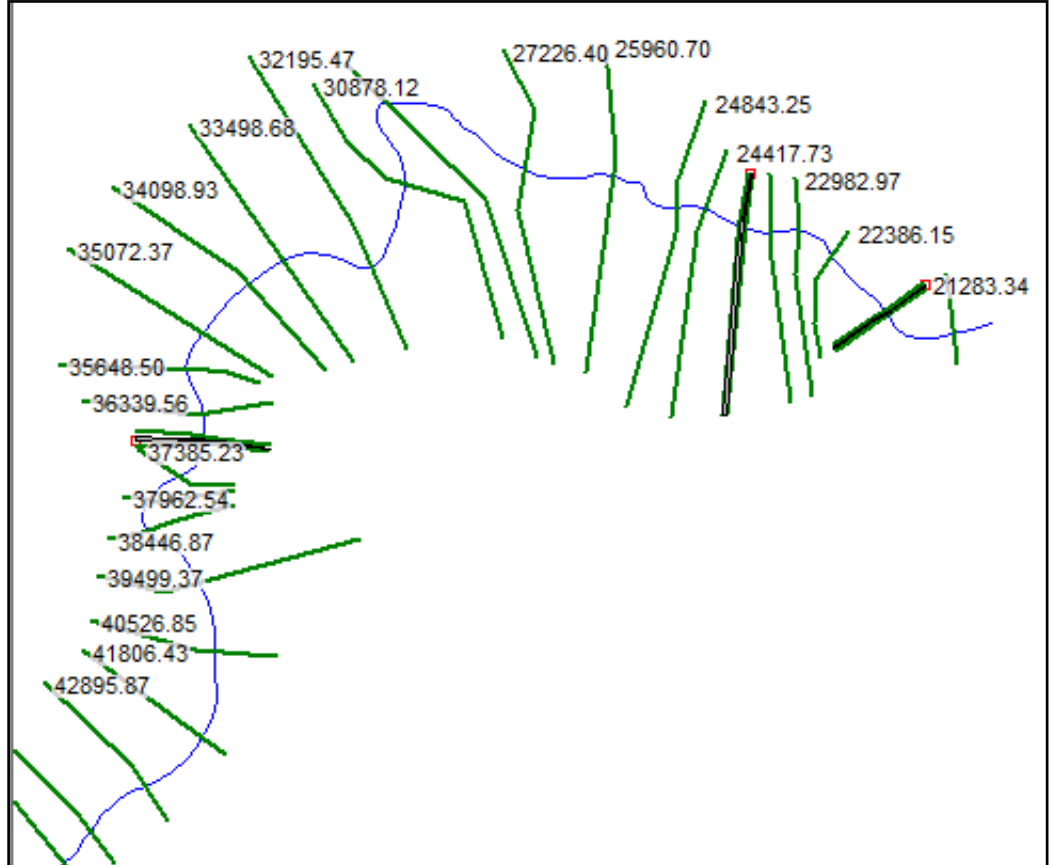
# Global Boundary Conditions

- Applied to the **entire domain**
- Specified in **Meteorologic Data** tab
- Types of Boundaries:
  1. Precipitation
  2. Evapotranspiration Potential
  3. Wind
  4. Air Density
  5. Air Pressure
- Types of Data
  1. Point
  2. Constant
  3. Gridded





# Initial Conditions in 1D







# 2D Initial Conditions Overview



- **User Specified Initial Conditions**
  - Single horizontal WSE
  - Project initial stage boundary values
  - Initial Conditions Points
- **Initial Conditions/ Warm Up**
  - 2D Initial Conditions
  - 1D/2D Warm Up Period
- **Use Restart File**
  - Restart File created by previous run
- **Interpolate from Previous Results**
  - Interpolates wse, velocity, and flows for 1D and 2D
  - Geometries do not have to be the same



# 2D Horizontal Initial Elev

- Single WSEL per 2D area
- Not so useful...by itself

Unsteady Flow Data - Single 2D Area with Bridges

File Options Help

Description:  Apply Data

Boundary Conditions Initial Conditions Meteorological Data Observed Data

Initial Flow Distribution Method

Restart Filename:  
  
 Prior WS Filename:  
  
 Profile:

Enter Initial flow distribution (Optional - leave blank to use boundary conditions)

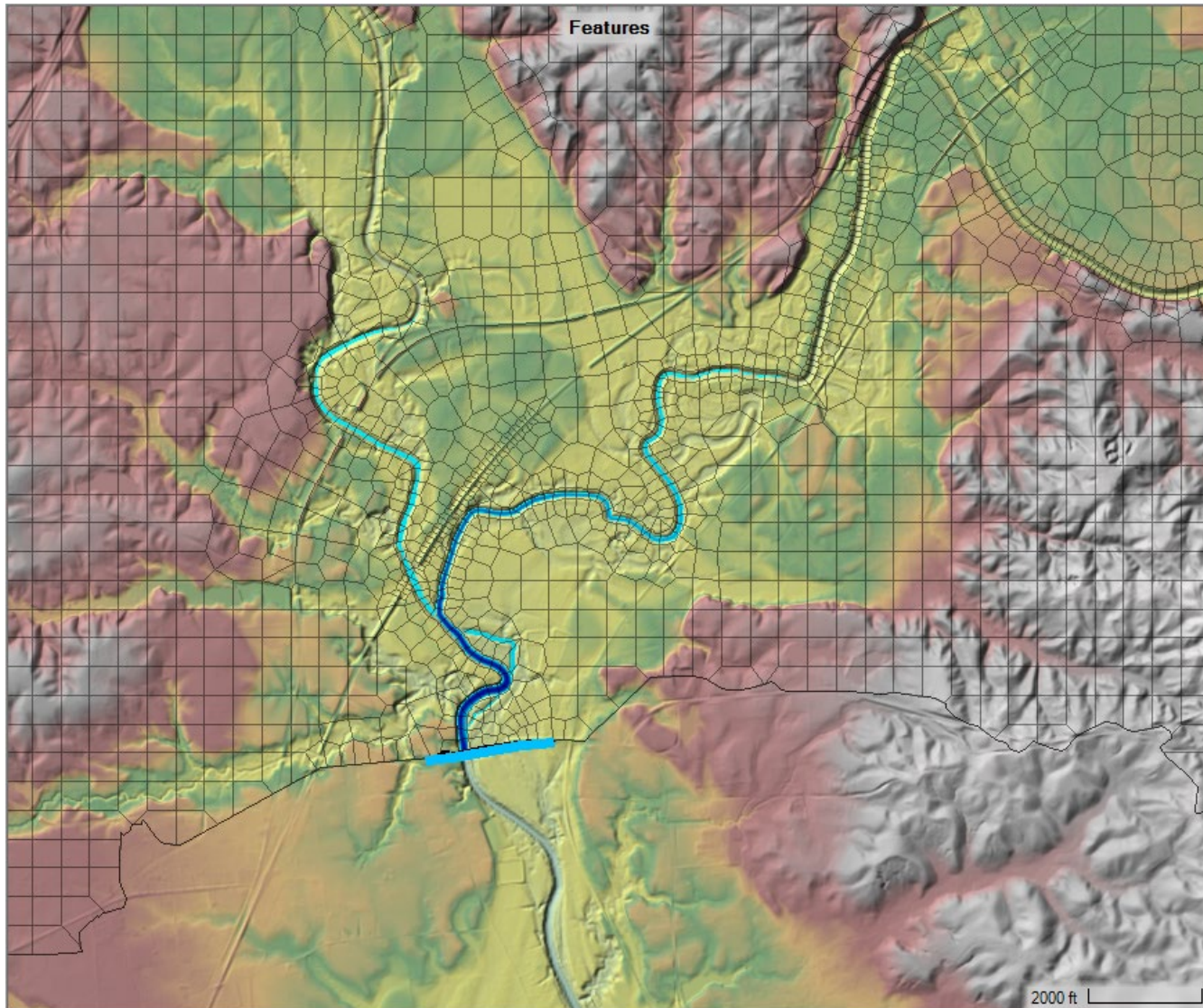
User specified fixed flows (Optional)			
River	Reach	RS	Initial Flow
1			

Keep initial elevations constant during warmup

Storage Area/2D Flow Area	Initial Elevation
1 2D: BaldEagleCr	



# 2D Initial Stage Hydrograph



Stage Hydrograph

2D: OkaToEnterprise BCLine: DSBoundary\_Enterprise

Read from DSS before simulation Select DSS file and Path

File:

Path:

Enter Table Data time interval: 1 Hour

Select/Enter the Data's Starting Time Reference

Use Simulation Time: Date: 13APR2020 Time: 2400

Fixed Start Time: Date:  Time:

No. Ordinates

Hydrograph Data		
	Date	Simulation Time (hours)
1	13Apr2020 2400	0:00:00
2	14Apr2020 0100	1:00:00
3	14Apr2020 0200	2:00:00
4	14Apr2020 0300	3:00:00
5	14Apr2020 0400	4:00:00
6	14Apr2020 0500	5:00:00
7	14Apr2020 0600	6:00:00

Use Initial Stage (recommended)



# Initial Conditions Points

Selected Layer: Initial Condition Points

Selected: 'Initial Condition Points' (5 selected)

Initial Flow Distribution Method

Restart Filename:

Prior WS Filename:

Profile:

Enter Initial flow distribution (Optional - leave blank to use boundary conditions)

Add RS...

User specified fixed flows (Optional)			
River	Reach	RS	Initial Flow
1			

Initial Elevation of Storage Areas/2D Flow Areas (Optional)

Keep initial elevations constant during warmup

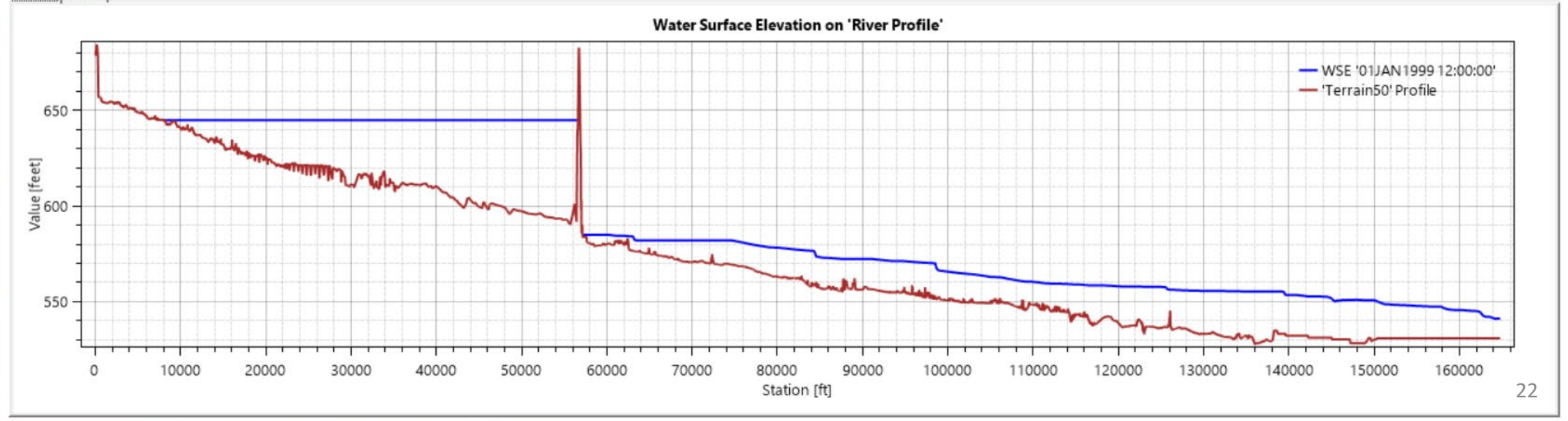
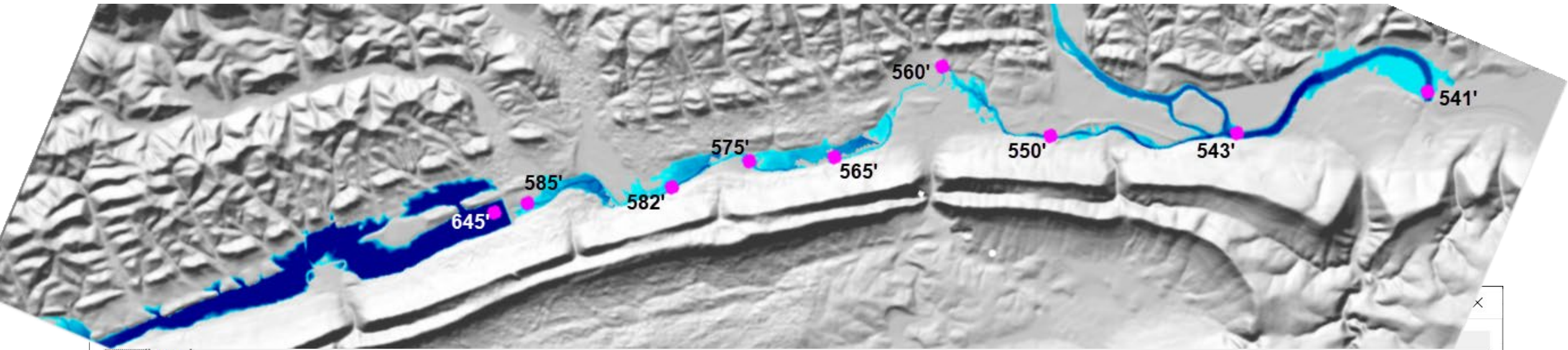
Storage Area/2D Flow Area	Initial Elevation
1 2D: OkaToEnterprise	
2 IC Point: WestUpper	229
3 IC Point: ConfluenceLower	225
4 IC Point: EastUpper	229
5 IC Point: WestUpperUpper	239
6 IC Point: EastUpperUpper	240

Messages Views Profile Lines Active Features Layer

(2212515.89, 3415711.32 1 pixel = 28.88 ft)



# Initial Conditions Backwater Profile



# 2D Initial Conditions Time

- Each 2D Area warms up individually
- **Initial Condition Time:**
  - Time allowed to run
- **Ramp Up Fraction:**
  - Period over which flow & stage are ramped up to the initial condition
  - Flows & stages then held constant

HEC-RAS Unsteady Computation Options and Tolerances

General | 2D Flow Options | 1D/2D Options | Advanced Time Step Control | 1D Mixed Flow Options

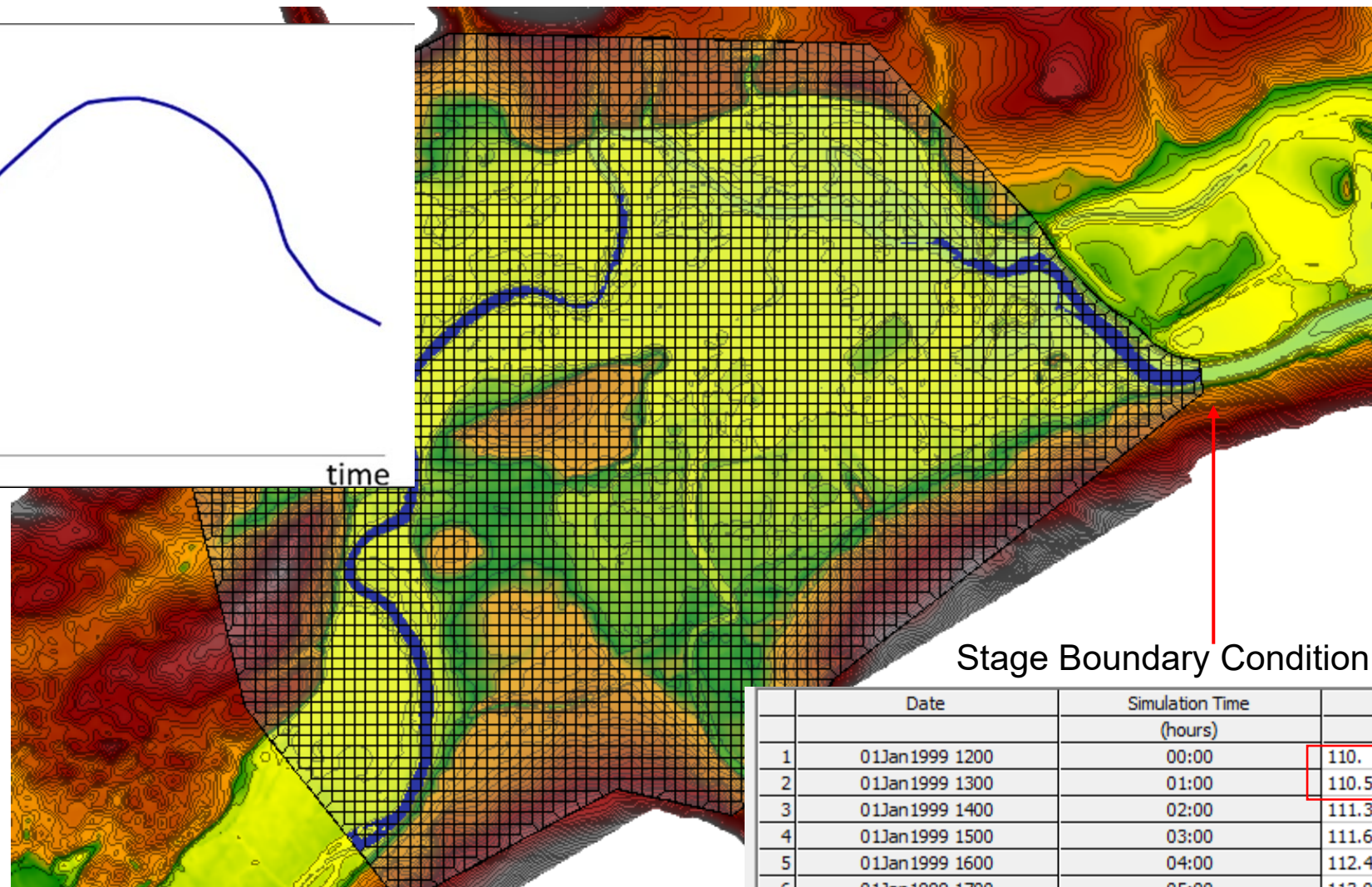
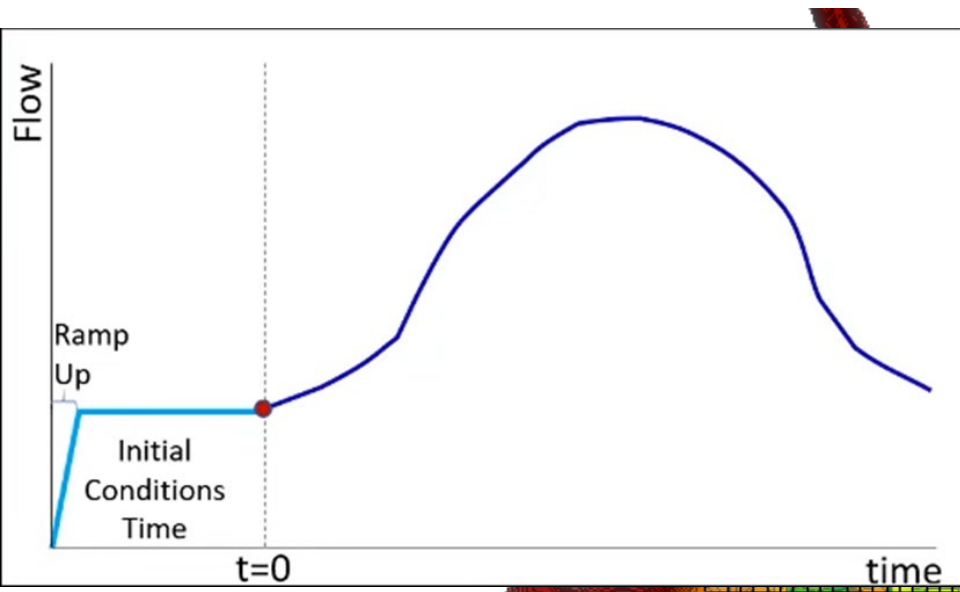
Use Coriolis Effects (not used with Diffusion Wave equation)

Parameter	(Default)	BaldEagleCr
1 Theta (0.6-1.0)	1	1
2 Theta Warmup (0.6-1.0)	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	Diffusion Wave
7 Initial Conditions Time (hrs)		
8 Initial Conditions Ramp Up Fraction (0-1)	0.5	0.5
9 Number of Time Slices (Integer Value)	1	1
10 Turbulence Model	None	None
11 Longitudinal Mixing Coefficient	0.3	0.3
12 Transverse Mixing Coefficient	0.1	0.1
13 Smagorinsky Coefficient	0.05	0.05
14 Boundary Condition Volume Check	<input type="checkbox"/>	<input type="checkbox"/>
15 Latitude for Coriolis (-90 to 90)		
16 Solver Cores	All Available	12 Cores
17 Matrix Solver	Pardiso (Direct)	Pardiso (Direct)
18 Convergence Tolerance		
19 Minimum Iterations	0	0
20 Maximum Iterations	0	0
21 Restart Iteration	10	10
22 Relaxation Factor	1.3	1.3
23 SOR Preconditioner Iterations	10	10

OK Cancel Defaults ...



# 2D Initial Conditions in Progress



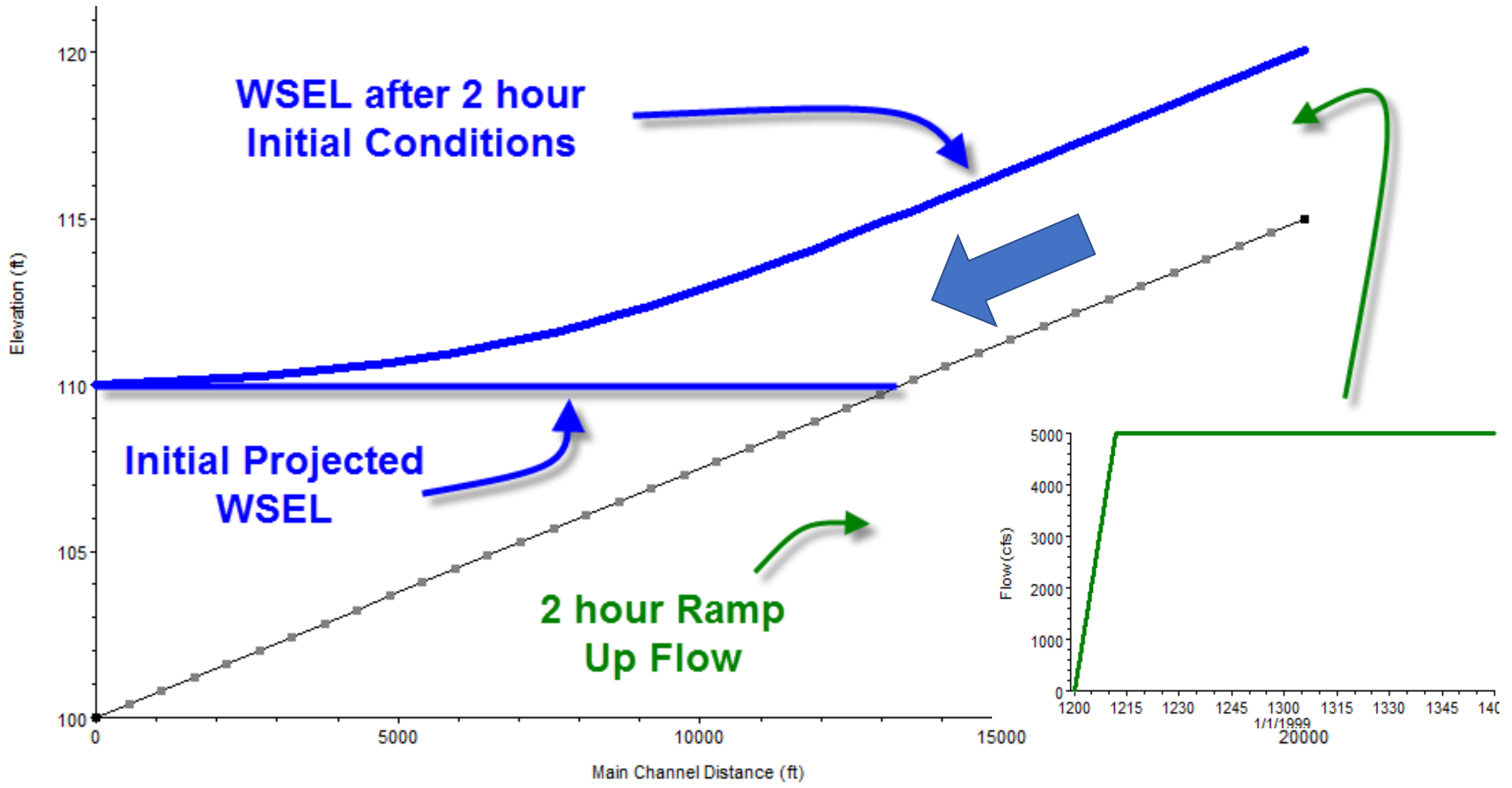
Stage Boundary Condition

	Date	Simulation Time (hours)	
1	01Jan1999 1200	00:00	110.
2	01Jan1999 1300	01:00	110.53
3	01Jan1999 1400	02:00	111.35
4	01Jan1999 1500	03:00	111.68
5	01Jan1999 1600	04:00	112.42
6	01Jan1999 1700	05:00	113.05

Use Initial Stage (recommended)    ? Data    OK



# 2D Initial Conditions Profile







# 1D/2D Warm Up Period

- Runs **whole model domain**
- Holds all the BC's constant and allows the model to stabilize
- Runs after 2D Initial Conditions
- Timestep optional

HEC-RAS Unsteady Computation Options and Tolerances

General | 2D Flow Options | 1D/2D Options | Advanced Time Step Control | 1D Mixed Flow Options

**1D/2D Unsteady Flow Options**

Number of warm up time steps (0 - 100,000):	20
Time step during warm up period (hrs):	0
Minimum time step for time slicing (hrs):	0
Maximum number of time slices:	20
Lateral Structure flow stability factor (1.0-3.0):	2.
Inline Structure flow stability factor (1.0-3.0):	1.
Weir flow submergence decay exponent (1.0-3.0):	1.
Gate flow submergence decay exponent (1.0-3.0):	1.
Gravity (ft/s <sup>2</sup> ):	32.174

1D Unsteady Flow Options

Theta [implicit weighting factor] (0.6-1.0):	1.
Theta for warm up [implicit weighting factor] (0.6-1.0):	1.
Water surface calculation tolerance [max=0.2](ft):	0.02
Storage Area elevation tolerance [max=0.2](ft):	0.02
Flow calculation tolerance [optional] (cfs):	
Max error in water surface solution (Abort Tolerance)(ft):	100.
Maximum number of iterations (0-40):	20
Maximum iterations without improvement (0-40):	

Wind Forces

Reference Frame:	Eulerian
Drag Formulation:	Hsu (1988)

Geometry Preprocessor Options

Family of Rating Curves for Internal Boundaries

Use existing internal boundary tables when possible.

Recompute at all internal boundaries

1D Numerical Solution

Finite Difference (classic HEC-RAS methodology)

Finite Difference Matrix Solver

Skyline/Gaussian (Default: faster for dendritic systems)

Pardiso (Optional: may be faster for large interconnected systems)

Finite Volume (new approach)

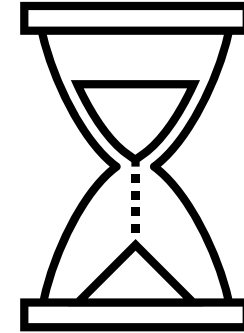
Number of cores to use with Pardiso solver: All Available

OK Cancel Defaults ...



# Using a Restart File

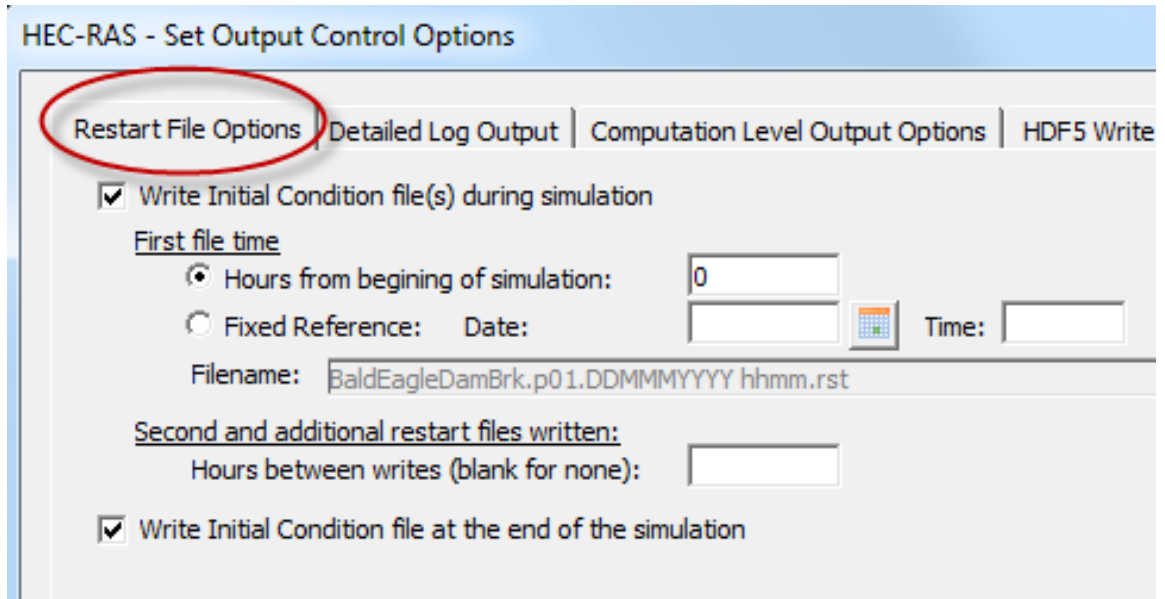
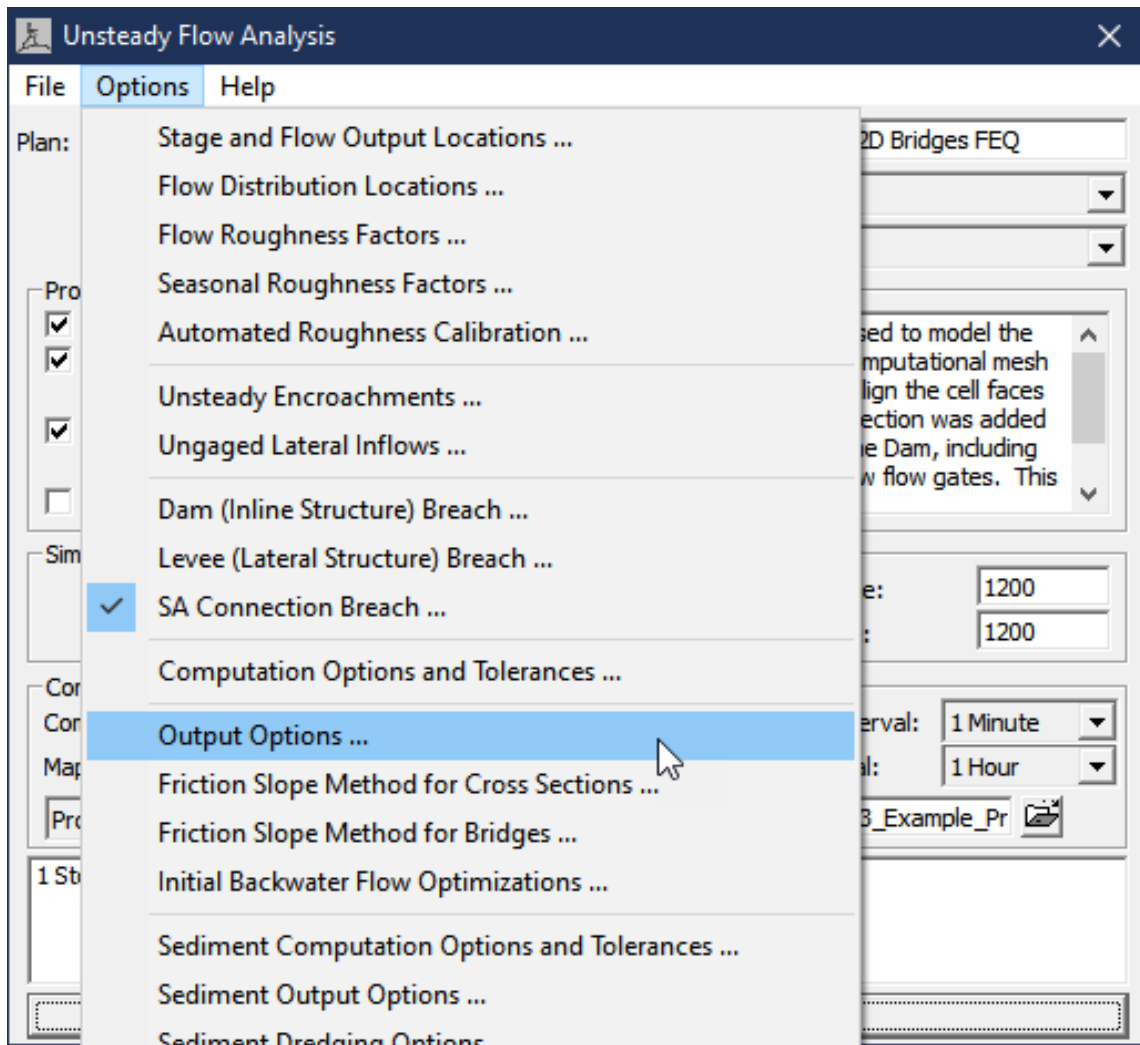
**Avoid Ramp Up / Warm Up Compute Time!**



1. Run initial conditions once
2. Write **Initial Condition File** out
3. Create a new **Unsteady Flow Plan**
4. Select **Use a Restart File**
5. Adjust starting date, and any hydrographs, if needed (if you start model later than previous run).

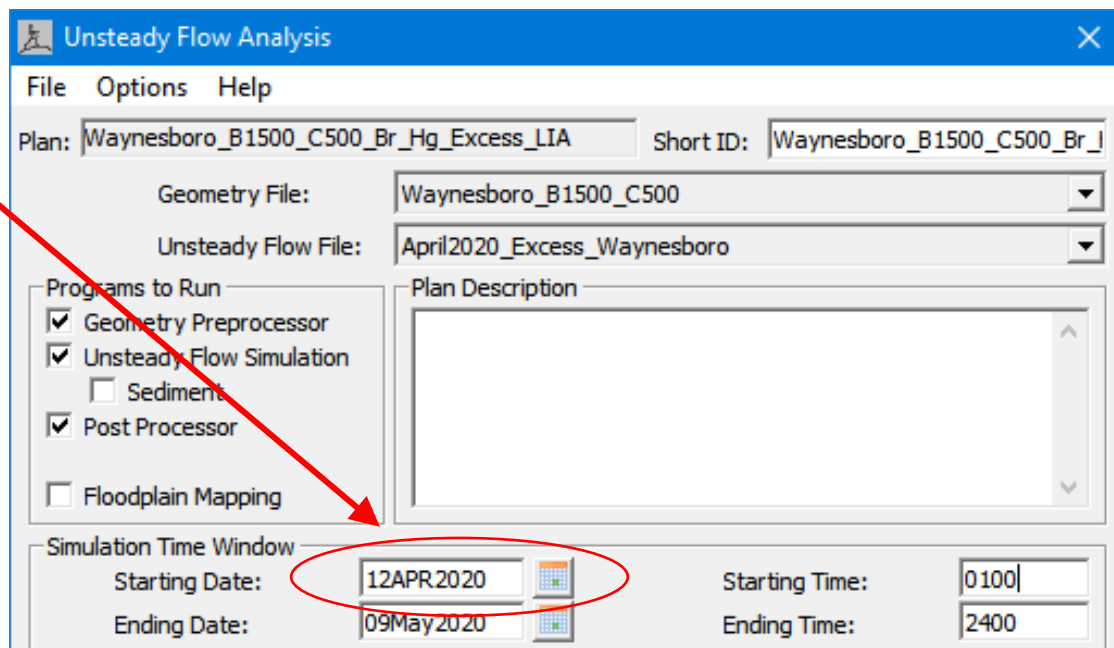
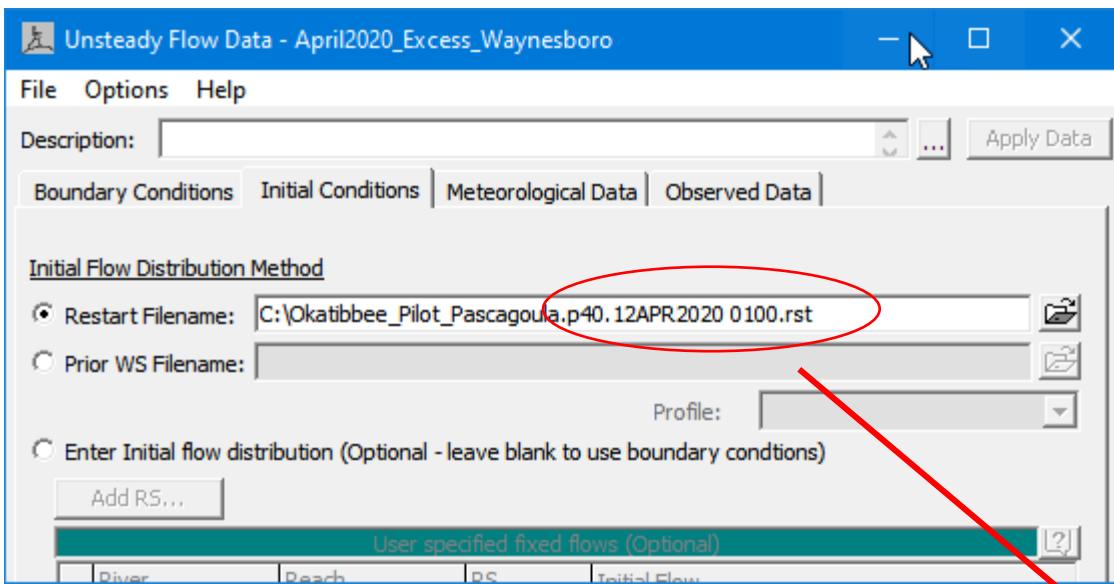


# Write Initial Condition File





# Select Restart File





# Restart File Notes

- Geometry must be the same
- Version must be the same
- Can switch 2D equation if desired
  - Use to run DWE to create Restart for SWE
- Can change the time step
- Can change the output interval
- Can change flow and plan data



# Initializing From Previous Results

- User selects a previous plan results file (*ProjectName.p##.hdf*) and profile time
- **Geometry does not have to be the same**
- Interpolates water levels, velocities, and flows
- Works for 1D and 2D

Unsteady Flow Data - Interpolated Initial Conditions

File Options Help

Description:

Boundary Conditions Initial Conditions Meteorological Data

Initial Flow Distribution Method

Restart Filename:

Results Filename:

Enter initial flow distribution (Optional - leave blank to use boundary conditions)

User specified fixed flows (Optional)

	River	Reach	RS	Initial Flow
1				

Initial Elevation of Storage Areas/2D Flow Areas (Optional)

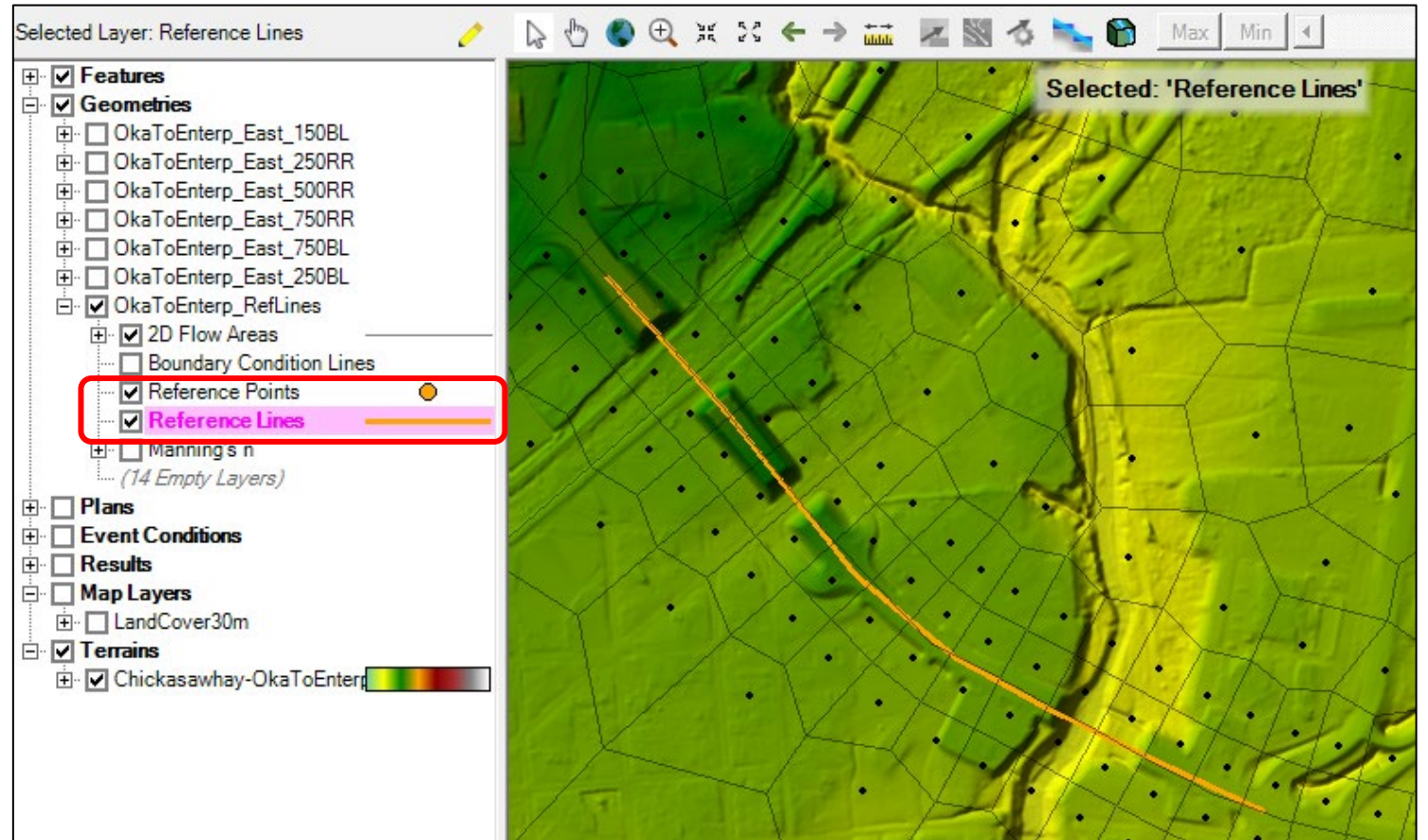
Keep initial elevations constant during warmup

	Storage Area/2D Flow Area	Initial Elevation
1	2D: BaldEagleCr	



# Observed Data Locations

- Reference Lines
  - Stage
  - Flow
  - Rating
  - HWM
  
- Reference Points
  - Stage
  - HWM





# Observed Data Entry

- Observed data locations defined in geometry
- Observed data set in the Unsteady Flow File

Unsteady Flow Data - Jan1996

File Options Help

Description: June 2016 Calibration Storm Gridded Rainfall

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

Set/Edit Observed Data RS Locations

No RS specified

Observed Stages

	Location	Summary	Edit
1	BC Line: Downstream Boundary	DSS: no data (feet)	...
2	Ref Line: Thurmond Gage	DSS: data range = 1034.80 to 1041.61 (feet)	...
3	Ref Line: Hinton Gage	DSS: data range = 1357.08 to 1359.48 (feet)	...

Observed Flows

	Location	Summary	Edit
1	Ref Line: Thurmond Gage	DSS: Error reading dss pathname: /LOWER NEW/NE	...
2	Ref Line: Hinton Gage	DSS: data range = 3620.00 to 17100.00 (cfs)	...
3	Ref Line: Piney Creek Gage	DSS: Error reading dss pathname: /LOWER NEW/PI	...

Observed Rating Curves

	Location	Summary	Edit
--	----------	---------	------

High Water Marks Data

	Location	Summary	Edit
--	----------	---------	------





# Accessing Observed Data Locations

RAS Mapper

File Project Tools Help

Selected Layer: Reference Lines

Features

- Profile Lines
- New Perimeter

Geometries

- Event Conditions

Results

- Jan1996Calib1000
  - Event Conditions
  - Geometry
    - Cross Sections
    - 2D Flow Areas
    - SA/2D Connections
    - Boundary Condition Lines
    - Reference Points
    - Reference Lines
    - Manning's n
  - Depth (31JAN1996 00:00:00)
  - Velocity (02JAN1996 00:00:00)

Geometry 'Lower New Base 1000' saved.

Messages Views Profile Lines Active Features Layer Values

(4243002.01, 5772212.25 1 pixel = 6.47 ft)

Selected: 'Reference Lines'

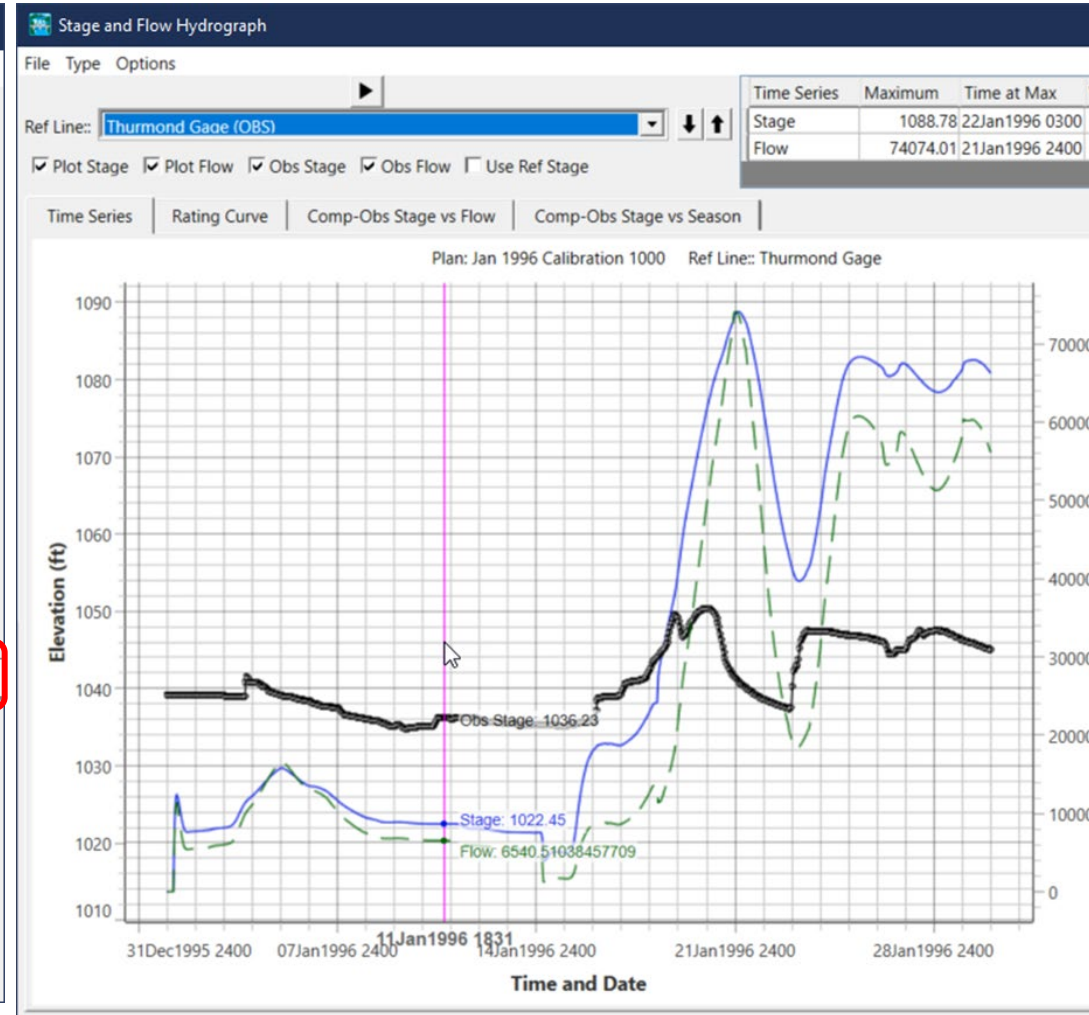
All Enabled Results

- Plot Time Series
- Plot Property Table

Reference Line: Thurmond Gage (Jan1996Calib 1000)

- Results Time Series
- Results Profile Plot
- Copy Selected Feature Ctrl+C
- Zoom to Selected Feature
- Plot Terrain Profile
- Save as Profile Line
- View Points
- Geospatial Operations

Hydrographs



# Questions?