

HEC-RAS 2D Workshop

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US Army Corps
of Engineers®



Introduction

The hydraulic modeling is the application of fluid dynamic to simulate the movement of water. Hydraulic models are applied to determine the extent of a floodplain and probability of a flood occurrence.

By 2D hydraulic model, we can determine what would happen if, for instance, the dam failed and given that information how far the extent of the flood inundation goes, how fast the floodwave propagates, thus we can prepare evacuation maps, emergency action plans, etc. On the other hand, the 1D models, cannot determine the direction of flow, where the floodwave goes, and this is based upon the engineers judgment to address these unknowns. The 1D models can be useful in domains having confined corridors, steep valleys, etc., while 2D models are considered to be more practical in flat terrain, highly urbanized area where floodwave flowing around the buildings and through roads in various directions.

2D hydraulic models have been around for over 15-20 years, however, the real problems that consulting firms and municipalities have not been using the 2D modeling software were due to difficulties of setting up the 2D models and lack of required information, e.g. terrain models, landcover variation, etc., while setting up the model.

Introduction

HEC-RAS 2D software developed by Hydrologic Engineering Center of U.S. Army Corps of Engineer is an free advanced two-dimensional flow simulator and hydraulic analyst where allows user to perform 2D and combined 1D/2D unsteady flow routing.

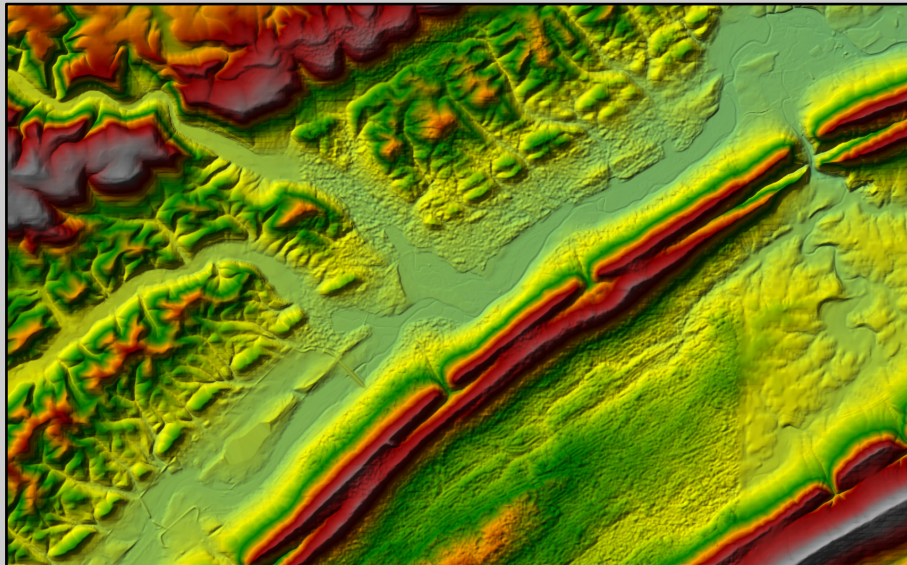
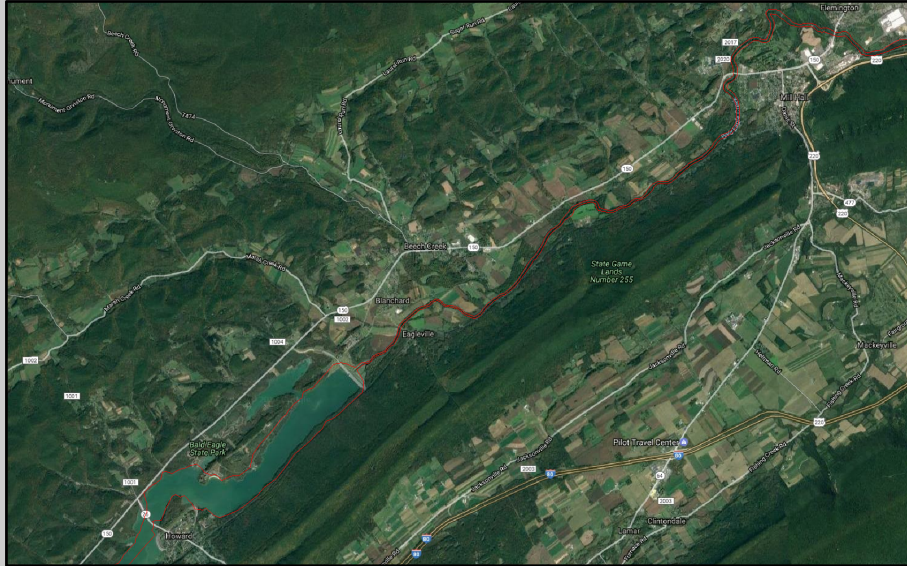
The 2D flow simulation by HEC-RAS 2D can be performed in number of ways. The following are examples:

- Detailed 2D channel modeling
- Detailed 2D channel and floodplain modeling
- Combined 1D channels with 2D floodplain areas
- Combined 1D channels/floodplains with 2D flow areas behind levees
- Directly connect 1D reaches into and out of 2D flow areas
- Directly connect a 2D flow area to 1D Storage Area with a hydraulic structure
- Multiple 2D flow areas in the same geometry
- Directly connect multiple 2D flow areas with hydraulic structures
- Simplified to very detailed Dam Breach analyses
- Simplified to very detailed Levee Breach analyses
- Mixed flow regime. The 2D capability (as well as the 1D) can handle supercritical and subcritical flow, as well as the flow transitions from subcritical to super critical and super critical to subcritical (hydraulic jumps).

Objectives of This Workshop

1. Introduction to HEC-RAS 2D and two dimensional modeling advantages relative to 1D models
2. Required geophysical and flow information for setting up HEC-RAS 2D models
3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS
4. Overview of how to execute a combined 1D/2D unsteady flow model in HEC-RAS
5. Overview of how to demonstrate the result of a combined 1D/2D unsteady flow model in HEC-RAS and RAS Mapper output capabilities

Study Domain



Location:

Bald Eagle Creek, Pennsylvania

Existing Structures:

Dam, Levee, man-made and/or geophysical Obstructions

Required Operating Systems:

Windows XP, Vista, 7, 8, 8.1, and 10 both 32-bit and 64-bit

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1. Introduction to HEC-RAS 2D and two dimensional modeling advantages relative to 1D models

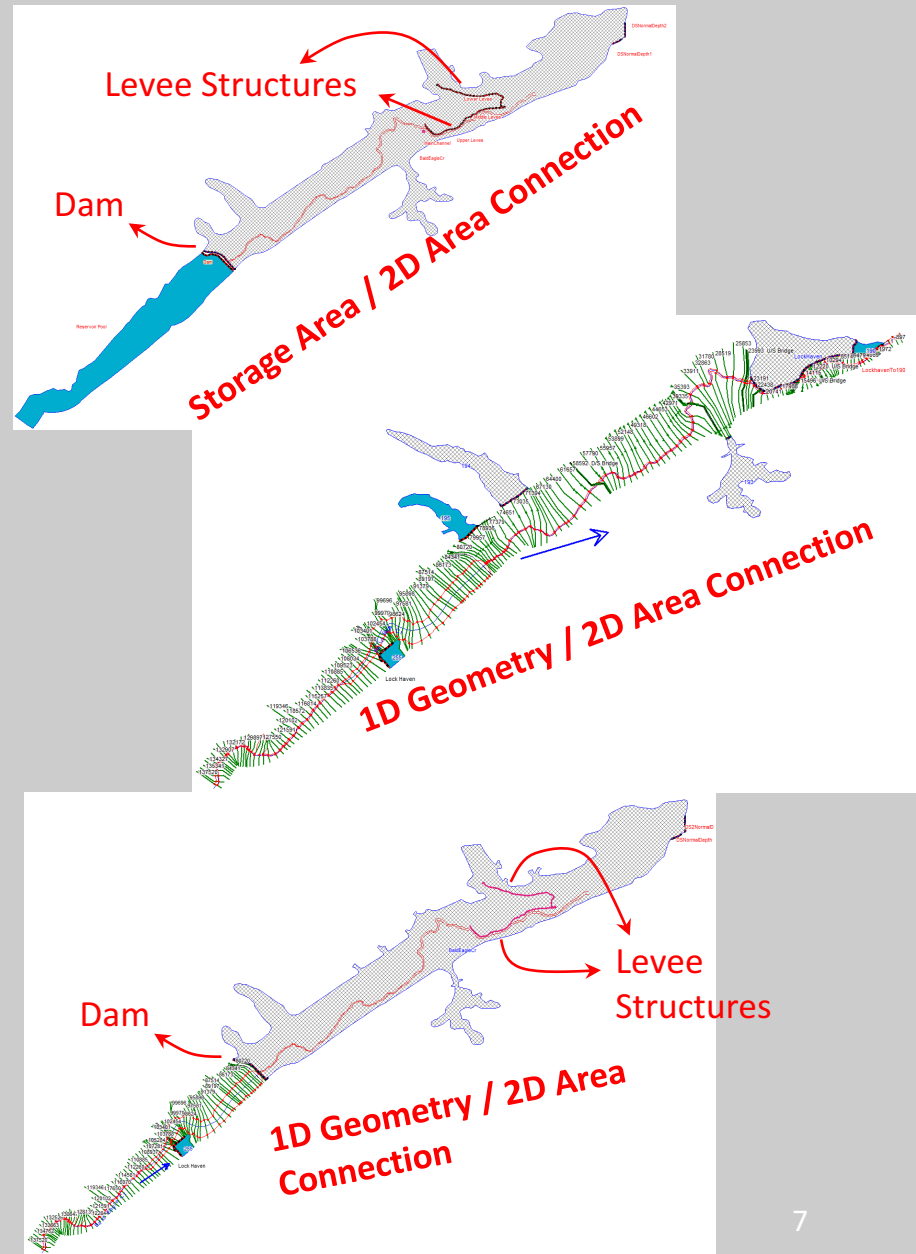
- HEC has added the ability to perform two-dimensional (2D) hydrodynamic routing within [the unsteady flow analysis portion of HEC-RAS](#).
- Users can now perform one-dimensional (1D) unsteady-flow modeling, two-dimensional (2D) unsteady-flow modeling (Saint Venant equations or Diffusion Wave equations), as well as combined 1D and 2D unsteady-flow routing.
- 2D flow modeling is accomplished by adding 2D flow area elements into the model in the same manner as adding a storage area.
- A 2D flow area is added by drawing a 2D flow area polygon; developing the 2D computational mesh; then linking the 2D flow areas to 1D model elements and/or directly connecting boundary conditions to the 2D areas.

1. Introduction to HEC-RAS 2D and two dimensional modeling advantages relative to 1D models

Different Association of 1D - 2D Geometries

- The 2D flow modeling algorithm in HEC-RAS has the following capabilities:

- Can perform 1D, 2D, and combined 1D and 2D modeling.
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- Multi-Processor Based Solution Algorithm (Parallel Computing).
- 64-Bit and 32-Bit Computational Engines.

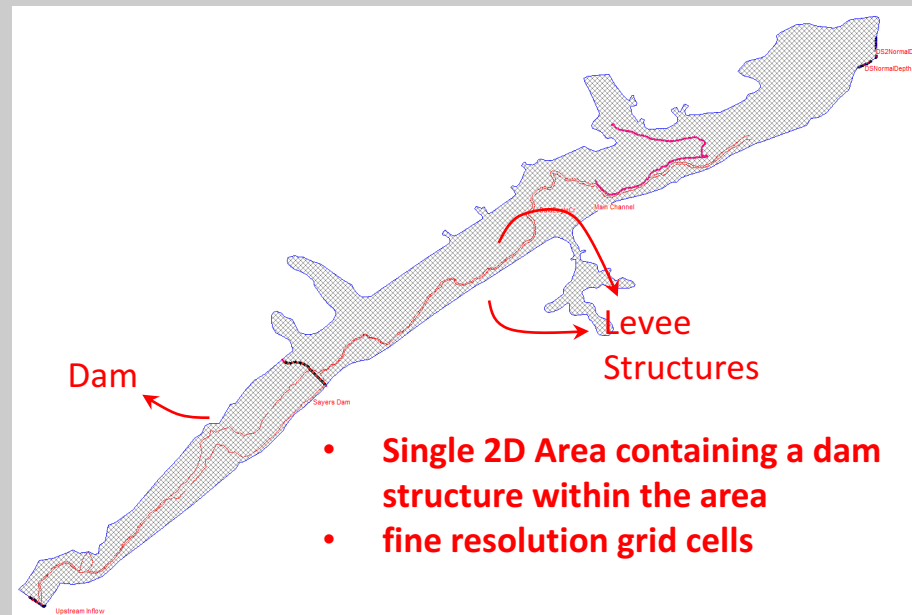
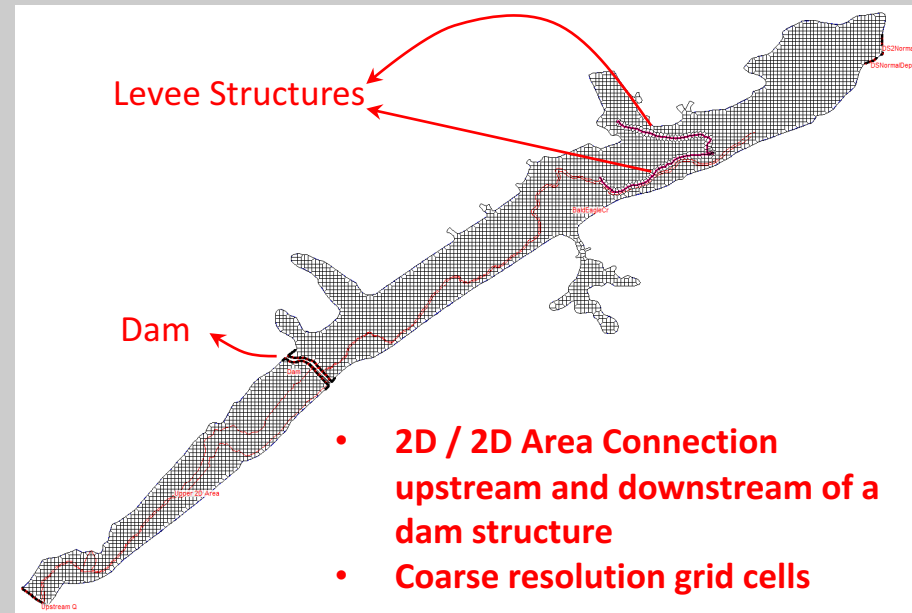


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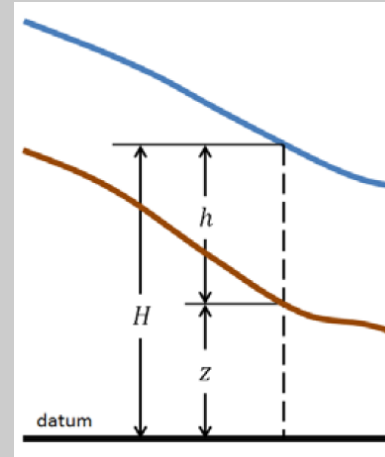
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$$H(x, y, t) = z(x, y) + h(x, y, t)$$

z : bed elevation

h : water depth

H : water surface elevation

u, v : x, y velocities

g : gravi. accel. ; v_t : horz. Eddy. Coeff.

c_f : bed friction coeff. ; f : Coriolis par.

Full Saint-Venant (Dynamic Wave) equation:

$$\frac{\partial H}{\partial t} + \frac{\partial hu}{\partial x} + \frac{\partial hv}{\partial y} + q = 0 \quad \text{continuity equ.}$$

Momentum equs.

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = -g \frac{\partial H}{\partial x} + v_t \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) - c_f u + f v$$

$$\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} = -g \frac{\partial H}{\partial y} + v_t \left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right) - c_f v + f u$$

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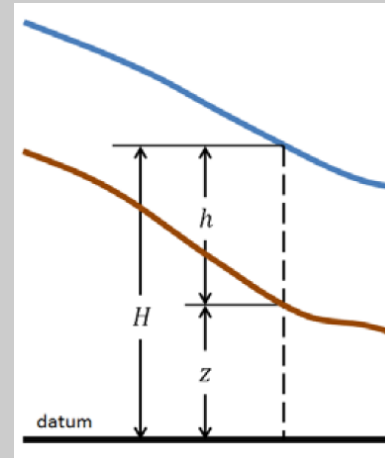
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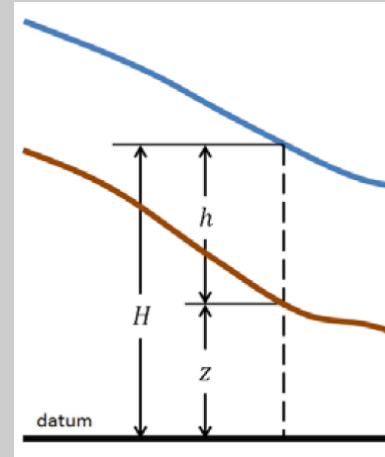
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Unsteady, advection, turbulence, and Coriolis Terms can be disregarded to arrived at simplified form

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Diffusion Wave equation:

$$\frac{\partial H}{\partial t} + \frac{\partial hu}{\partial x} + \frac{\partial hv}{\partial y} + q = 0 \quad \text{continuity equ.}$$

Momentum equs.

$$g \frac{\partial H}{\partial x} + g(S_x - S_f) = 0$$

$$g \frac{\partial H}{\partial y} + g(S_y - S_f) = 0$$

$$S_x = \frac{dz}{dx} ; S_y = \frac{dz}{dy} ; S_f = \frac{\tau}{\rho g R}$$

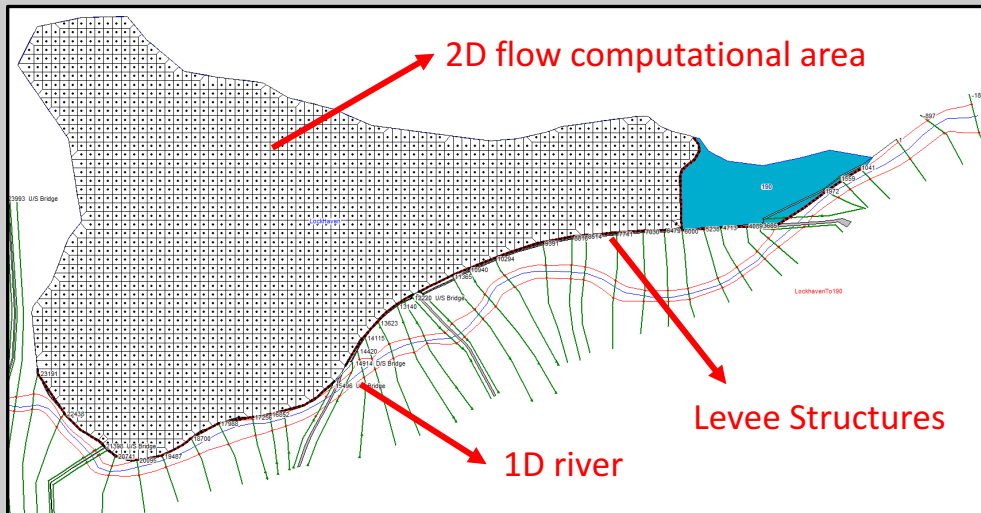
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- The implicit solution algorithm allows for larger computational time steps than explicit methods.
- The Finite Volume Method provides an increment of improved stability and robustness over traditional finite difference and finite element techniques.
- 2D flow areas can start completely dry, and handle a sudden rush of water into the area.
- Additionally, the algorithm can handle subcritical, supercritical, and mixed flow regimes.

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- The 1D and 2D solution algorithms are tightly coupled on a time step by time step basis with an option to iterate between 1D and 2D flow transfers within a time step.
- For Instance, consider a river that is modeled in 1D with the area behind a **levee** is modeled in 2D (connected hydraulically with a Lateral Structure). Flow over the **levee** (Lateral Structure) and/or through any **levee** breach is computed with a headwater from the 1D river and a tailwater from the 2D flow area to which it is connected. The weir equation is used to compute flow over the levee and through the breach.

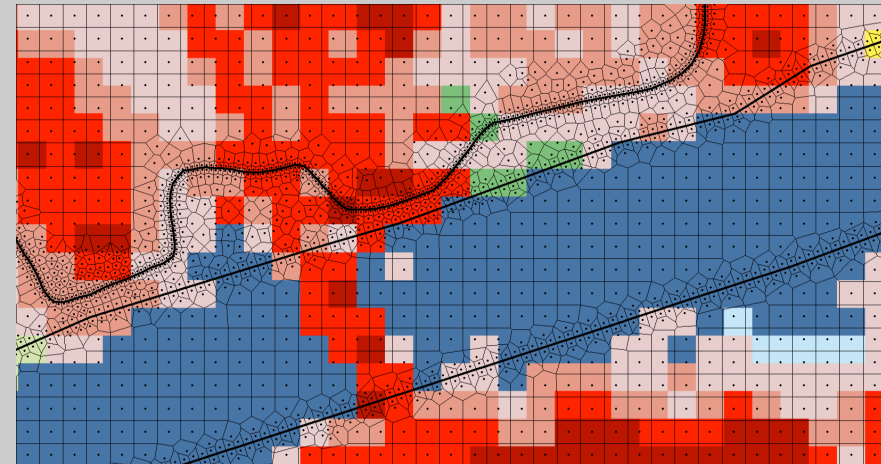


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- The software was designed to use unstructured computational meshes, but can also handle structured meshes.
- This means that computational cells can be triangles, squares, rectangles, or even five and six-sided elements (the model is limited to elements with up to eight sides). The computational mesh does not need to be orthogonal but if the mesh is orthogonal the numerical discretization is simplified and more efficient.



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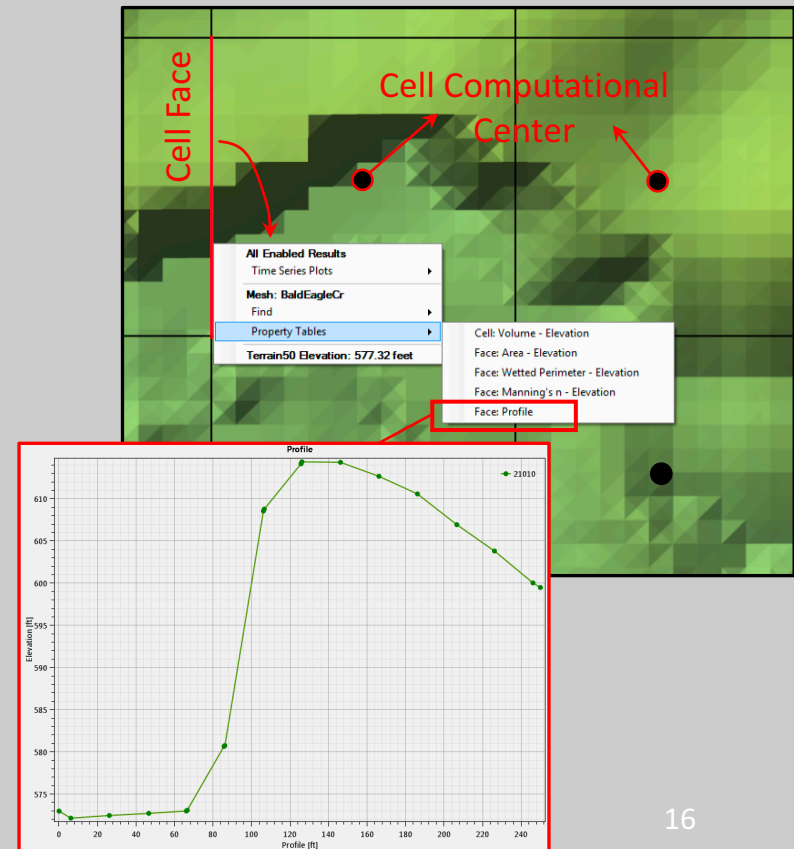
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- Within HEC-RAS, computational cells do not have to have a flat bottom, and cell faces/edges do not have to be a straight line, with a single elevation.
- Instead, each Computational cell and cell face is based on the details of the underlying terrain.
- HEC-RAS has a 2D flow area pre-processor that processes the cells and cell faces into detailed hydraulic property tables based on the underlying terrain used in the modeling process.
- This type of model is often referred to in the literature as a “high resolution subgrid model” (Casulli, 2008).

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- For an example, consider a model built from a detailed terrain model (2ft grid-cell resolution) with a computation cell size of 200x200 ft. The 2D flow area pre-processor computes an elevation-volume relationship, based on the detailed terrain data (2ft grid), within each cell.

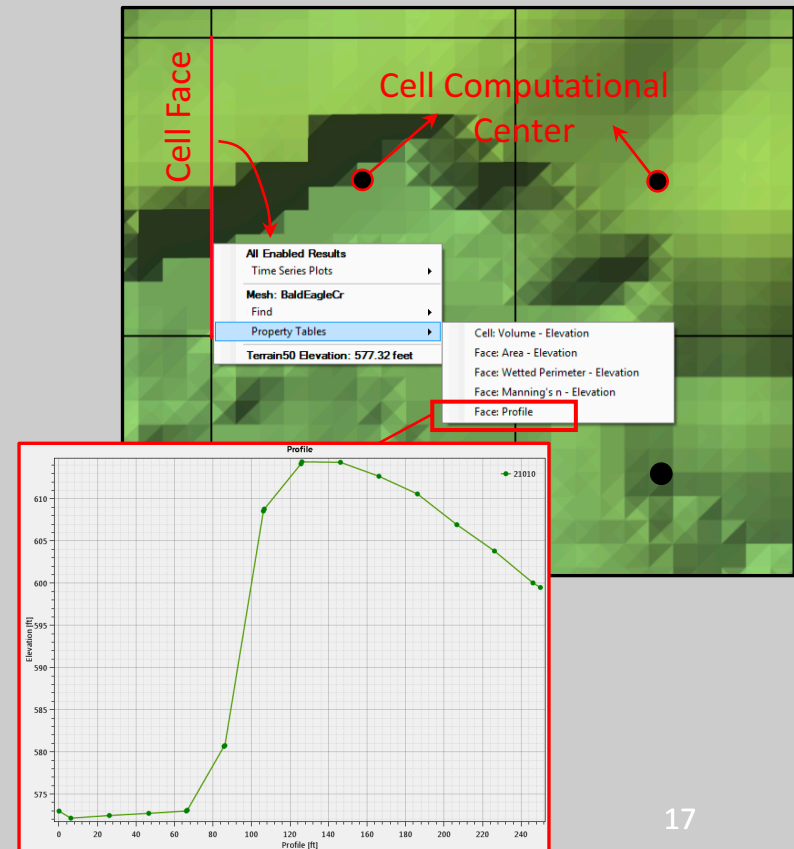


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- The cell computational centers are the locations where the water surface elevation is computed for each cell.
- Each cell face is a detailed cross section based on the underlying terrain below the line that represents the cell face.



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- A cell can be partially wet with the correct water volume for the given water surface elevation (WSEL).
- Each computational cell face is evaluated similar to a cross section and is pre-processed into detailed hydraulic property tables (elevation versus wetted perimeter, area, roughness, etc...).
- The flow moving across the face (between cells) is based on this detailed data.
- A small channel that cuts through a cell, and is much smaller than the cell size, is still represented by the cell's elevation volume relationship, and the hydraulic properties of the cell faces.
- Additionally, the placement of cell faces along the top of controlling terrain features (roads, high ground, walls, etc...) can further improve the hydraulic calculations using fewer cells overall.

(application of *breakline*)

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- The 2D flow area computational solution has been programmed to take advantage of multiple processors on a computer (referred to as parallelization), allowing it to run much faster than on a single processor.

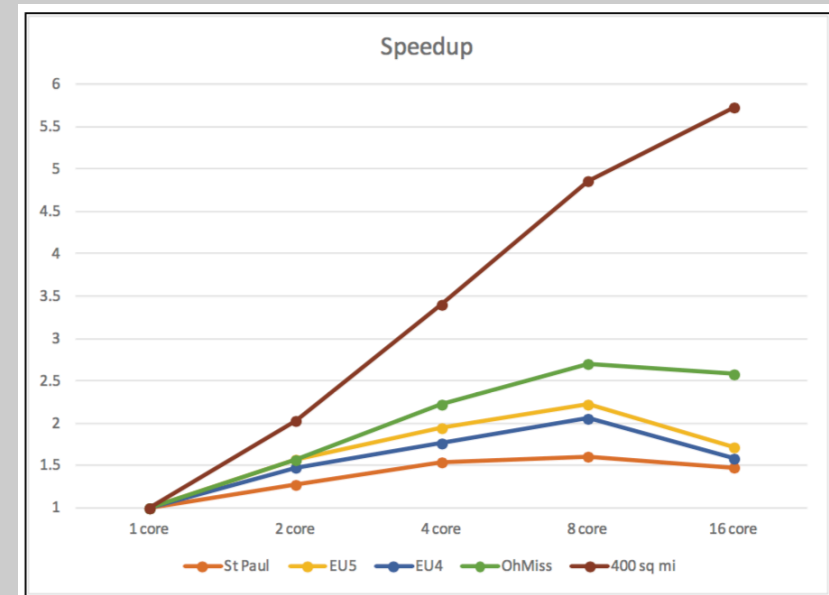


Figure 4-5. Number of processor cores vs. computational speed.

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- 2D model made over larger area
- 2D model having the most geometrical details and specifications

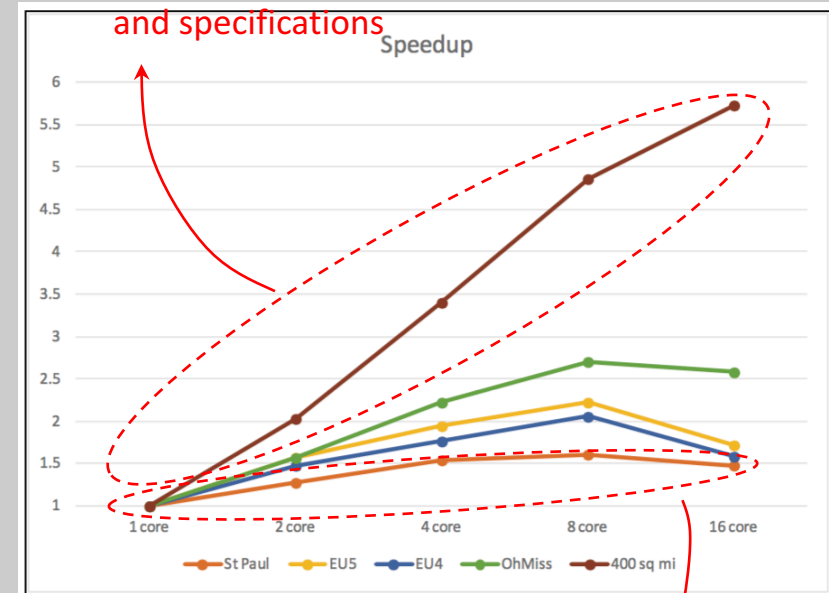


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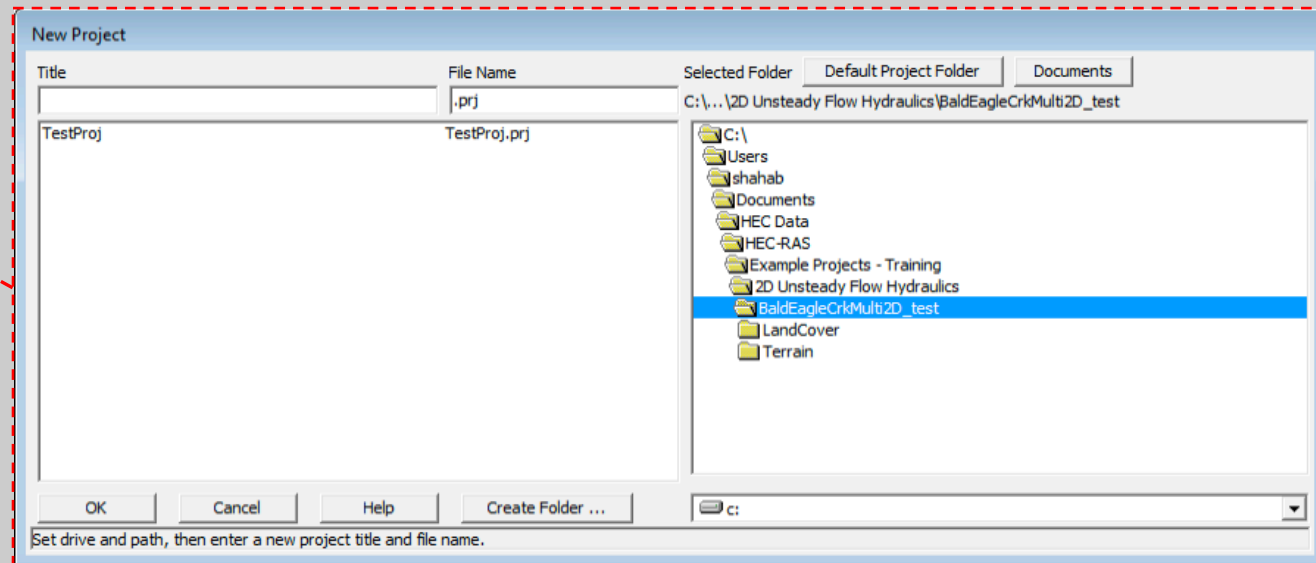
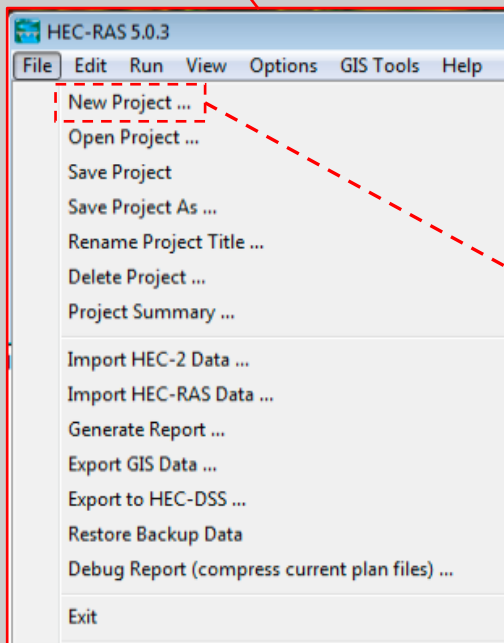
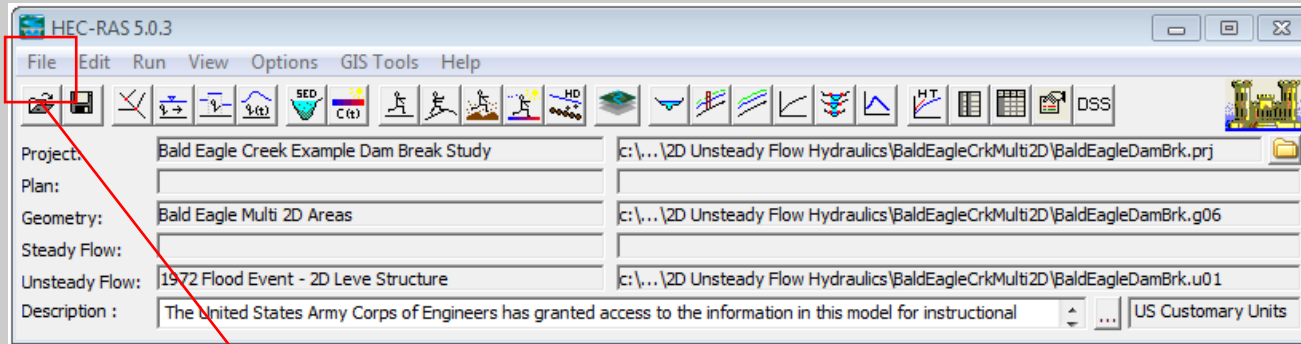
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- HEC-RAS now comes with both 64 bit and 32-bit computational engines. The software will use the 64-bit computational engines automatically if installed on a 64-bit operating system.
- The 64-bit computational engines run faster than the 32-bit and can handle much larger data sets.

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2. Required geophysical and flow information for setting up HEC-RAS 2D models

- Define a project:

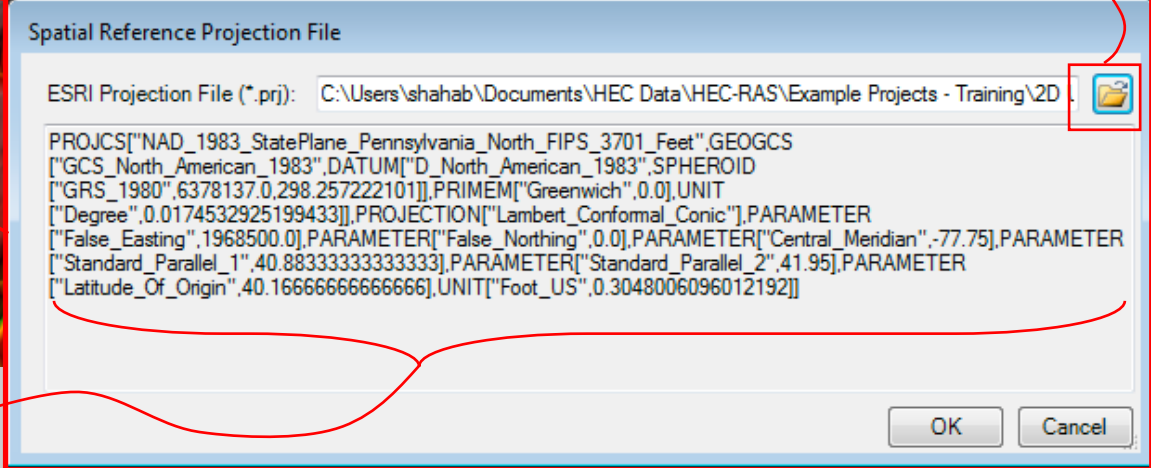
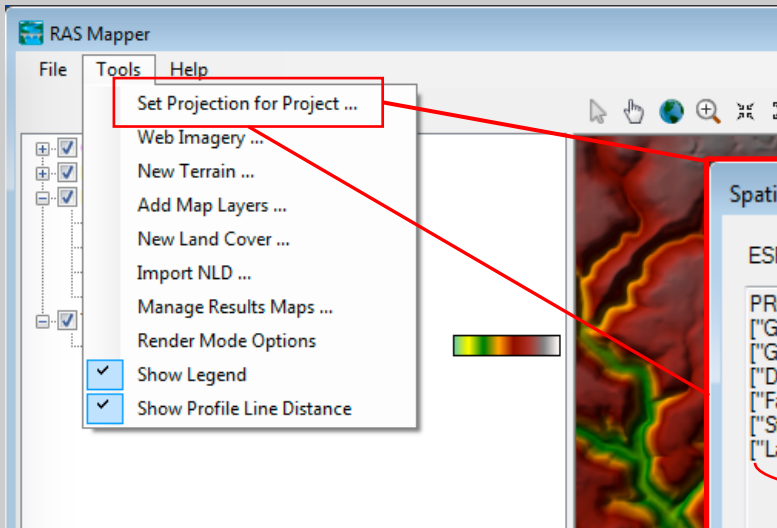


2. Required geophysical and flow information for setting up HEC-RAS 2D models

- Establish a Horizontal Coordinate Projection to use for your model, from within **HEC-RAS Mapper**:

If the data is in a specific spatial coordinate projection, that projection should be set in RAS Mapper.

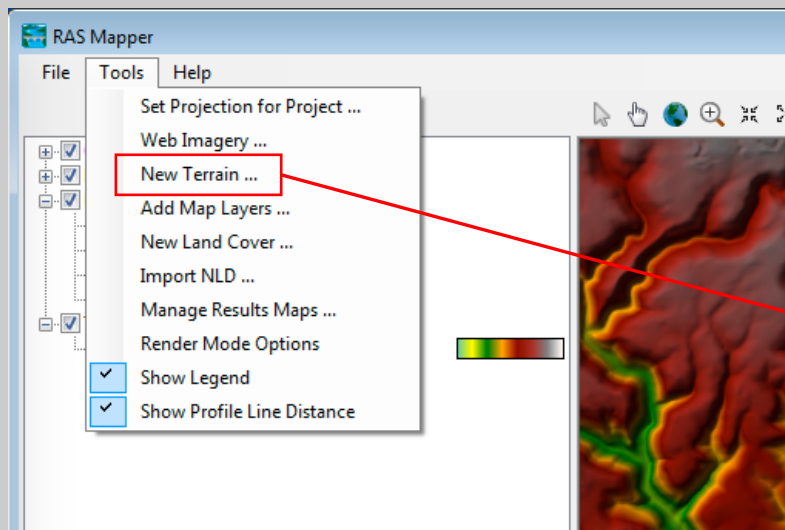
You can set the mapping projection based upon the projection (existing *.prj ESRI projection file) of a shapefile, raster, etc.



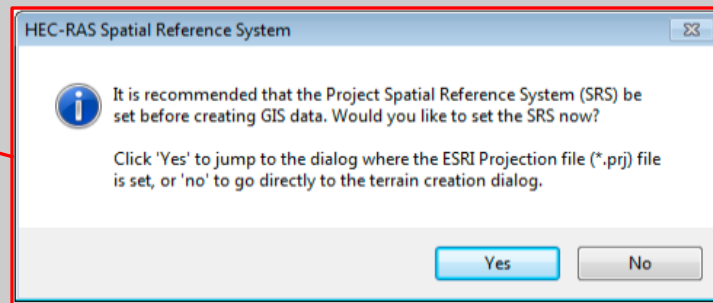
Once spatial references are set and assigned, a summary of their geospatial information will be highlighted.

2. Required geophysical and flow information for setting up HEC-RAS 2D models

- Developing a Terrain Model for use in 2D Modeling and Results Mapping:
 - It is absolutely essential to have a detailed and accurate terrain model in order to create a detailed and accurate hydraulics model. The quality of the terrain data can be a limiting factor in the quality of the hydraulics model the user can create.
 - **HEC-RAS uses gridded data for terrain modeling.**
 - It is necessary to create a terrain model in HEC-RAS Mapper before the user can perform any model computations that contain 2D flow areas, or before the user can visualize any 1D, 2D, or combine 1D/2D mapping results.

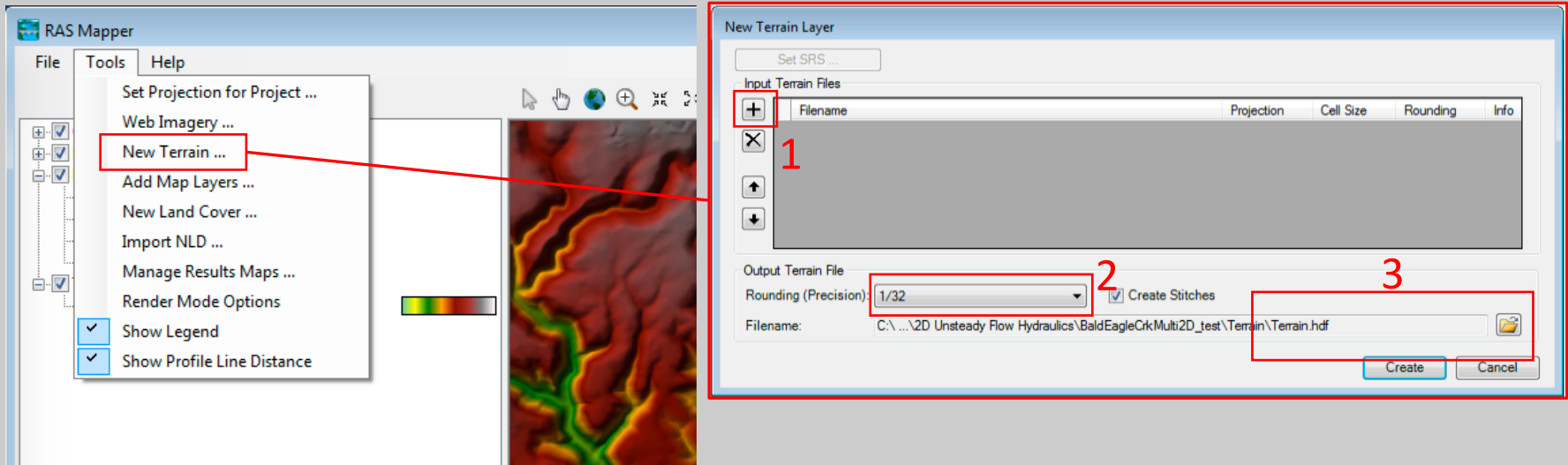


If you have not established a Horizontal Coordinate Projection yet, then this will pop-up



2. Required geophysical and flow information for setting up HEC-RAS 2D models

- Developing a Terrain Model for use in 2D Modeling and Results Mapping:
 1. RAS Mapper can import terrain data that is in the **floating point grid format (*.flt)**; **GeoTIFF (*.tif)** format; **ESRI grid (*.adf)** files;
 2. Define the elevation precision of the new terrain data layer (**Rounding [Precision]** field, 1/32 is the default for English units)
 3. This allows the user to provide a name for the new Terrain Layer (**Filename** field, the default name is “Terrain”)

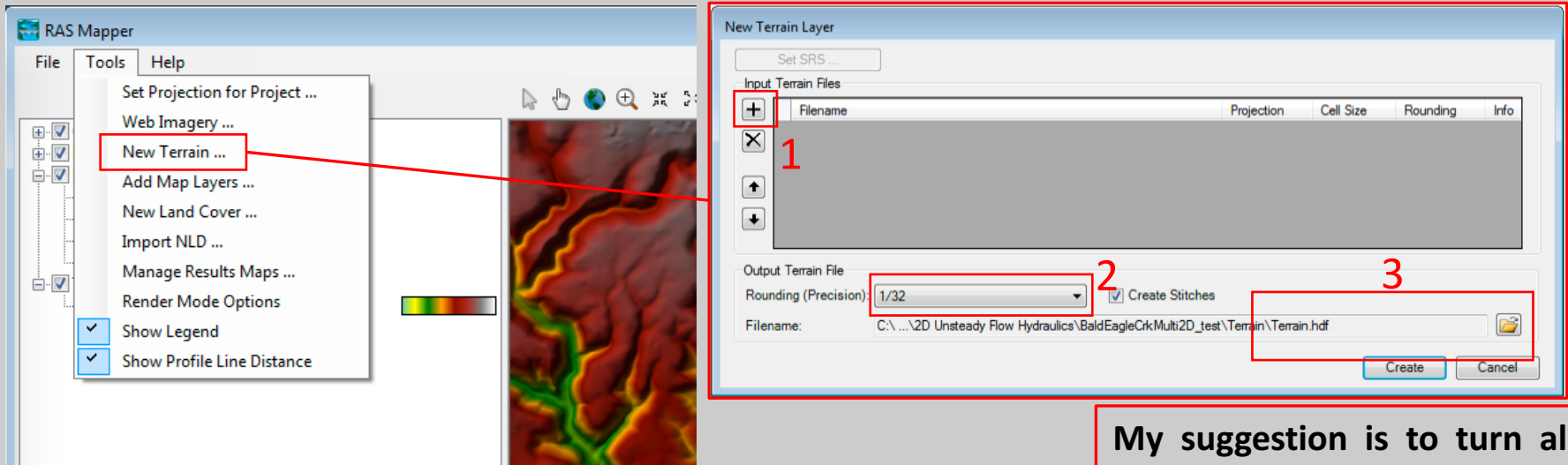


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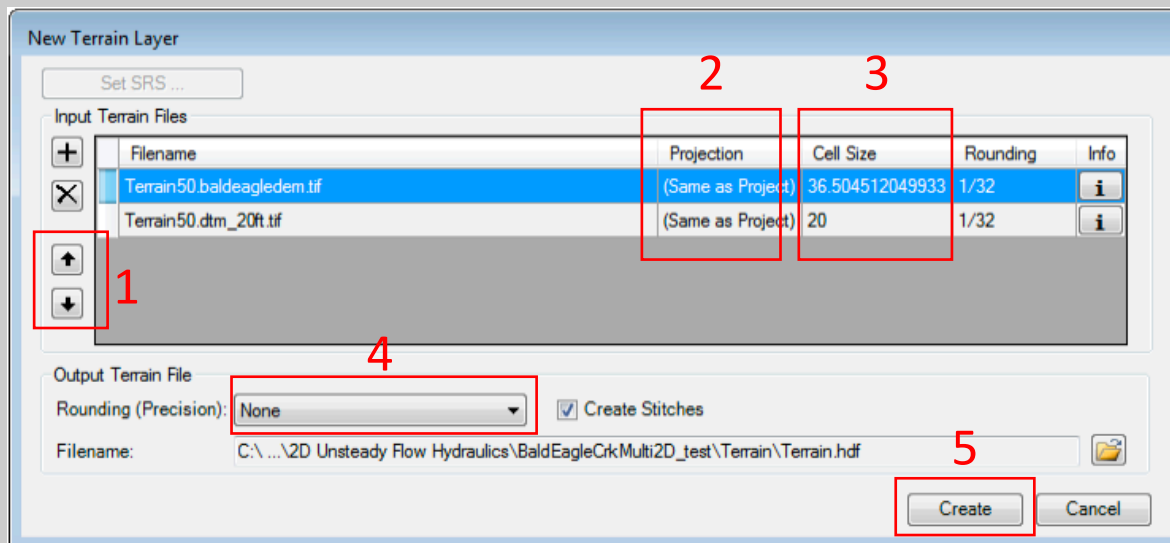


Floating point grids consist of a main file with the *.flt file extension, and they also have a *.hdr file, and possibly a *.prj file that goes along with it. Note: if the *.flt file is not in the same projection as what has been set in RAS Mapper, then the user must have a *.prj file that describes the projection of the *.flt file).

My suggestion is to turn all Raster terrain files into *.tif format first and then import them as new terrain in RAS Mapper.

2. Required geophysical and flow information for setting up HEC-RAS 2D models

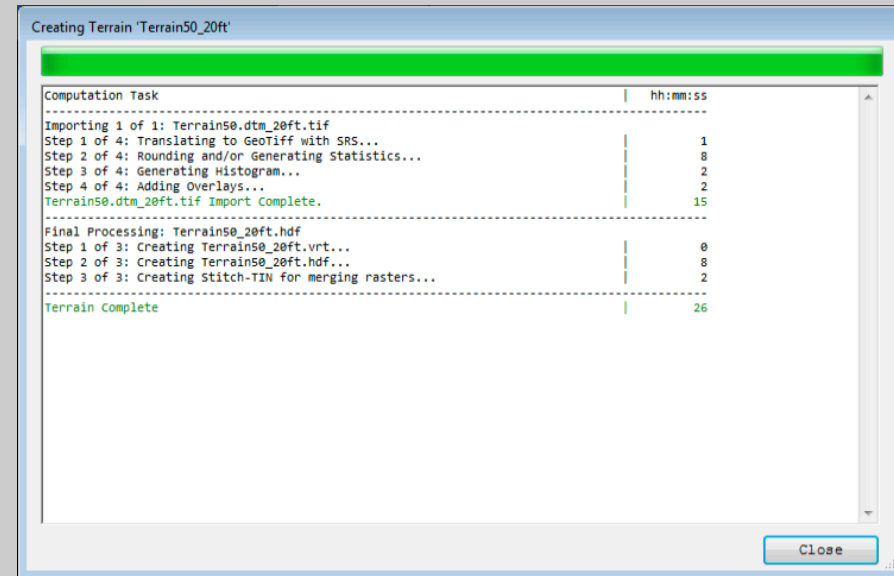
- Developing a Terrain Model for use in 2D Modeling and Results Mapping:
 - The final “Terrain.hdf” can be made up of multiple “*.tif” images having different spatial resolutions. Use the up and down arrow buttons to set the priority of the grid layers. If one grid has more detail (finer resolution) than others, the user will want to give it a higher priority for creating the combined Terrain Layer.
 - Highlights the projection of the uploaded the terrain data. If they have the projection similar to the one assigned as general reference system then it would reported as (Same as Project) which is the case for current example.
 - This allows the user learn about the cell size (spatial resolution) of the raster image. The unit is based upon what that is set at the beginning of model set-up. Here it is in English unit.



- Set “Rounding (Precision)” as “None” in order to keep the terrain vertical resolution as it is.
- Once the Create button is pressed, RAS Mapper will convert the grids into the GeoTIFF (*.tif) file format.

2. Required geophysical and flow information for setting up HEC-RAS 2D models

- Developing a Terrain Model for use in 2D Modeling and Results Mapping:
 - Once the **GeoTIFF** files are created, RAS Mapper also creates a ***.hdf** file and a ***.vrt** file.
 - The ***.hdf (Hierarchical Data Format)** file contains information on how the **multiple GeoTIFF** files are stitched together. The ***.vrt (Virtual Raster Translator)** file is an XML file that contains information about all of the raster files (***.tif**).
 - The user can drag and drop the ***.vrt** file onto an **ArcGIS** project and it will then know about all of the raster files that make up the terrain layer. Additionally, they will have the same scale and color ramp when they are plotted.

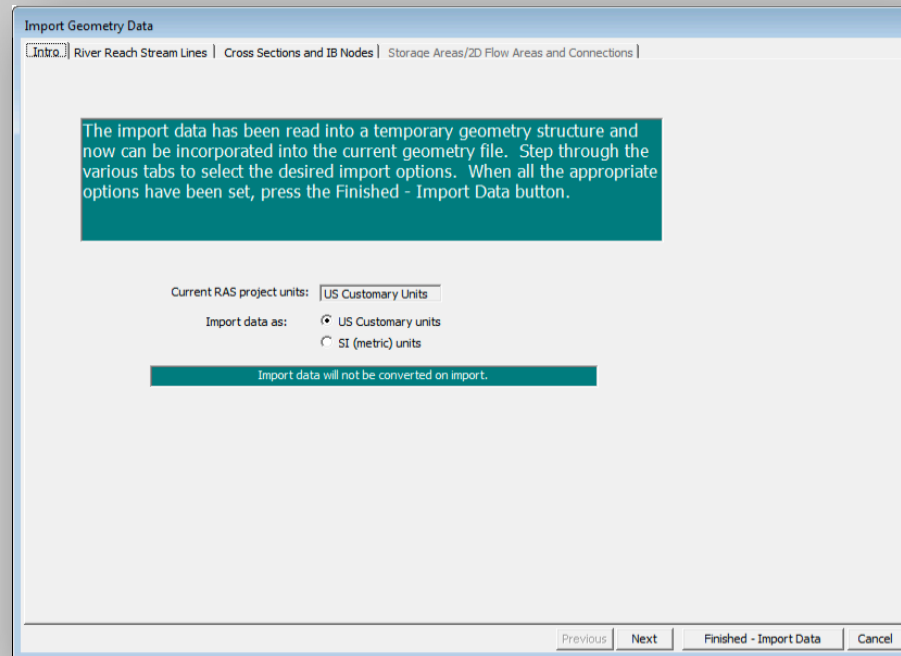
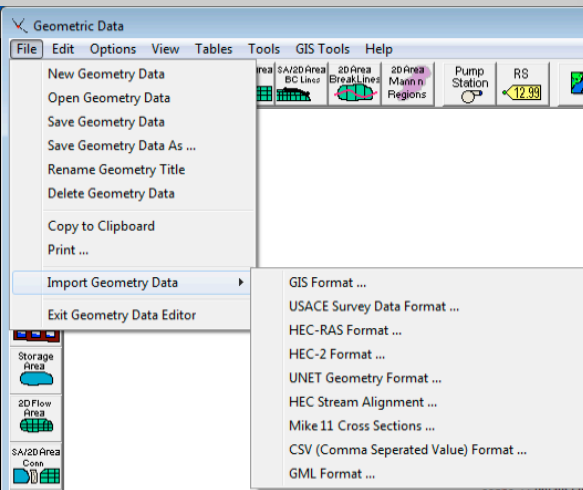


Note: After a Terrain data set is created, the user will be able to display this terrain layer as a background image in the HEC-RAS geometry editor. Terrain layers, and any other Map Layers developed in RAS Mapper are available for display in the HEC-RAS Geometry editor.

2. Required geophysical and flow information for setting up HEC-RAS 2D models

- Using Cross Section Data to Modify/Improve the Terrain Model:
 - One of the major problems in hydraulic modeling is that terrain data does not often include the actual terrain underneath the water surface in the channel region.
 - Mapper can now be used to create a terrain model of the channel region from the HEC-RAS cross sections and the Cross Section Interpolation Surface.

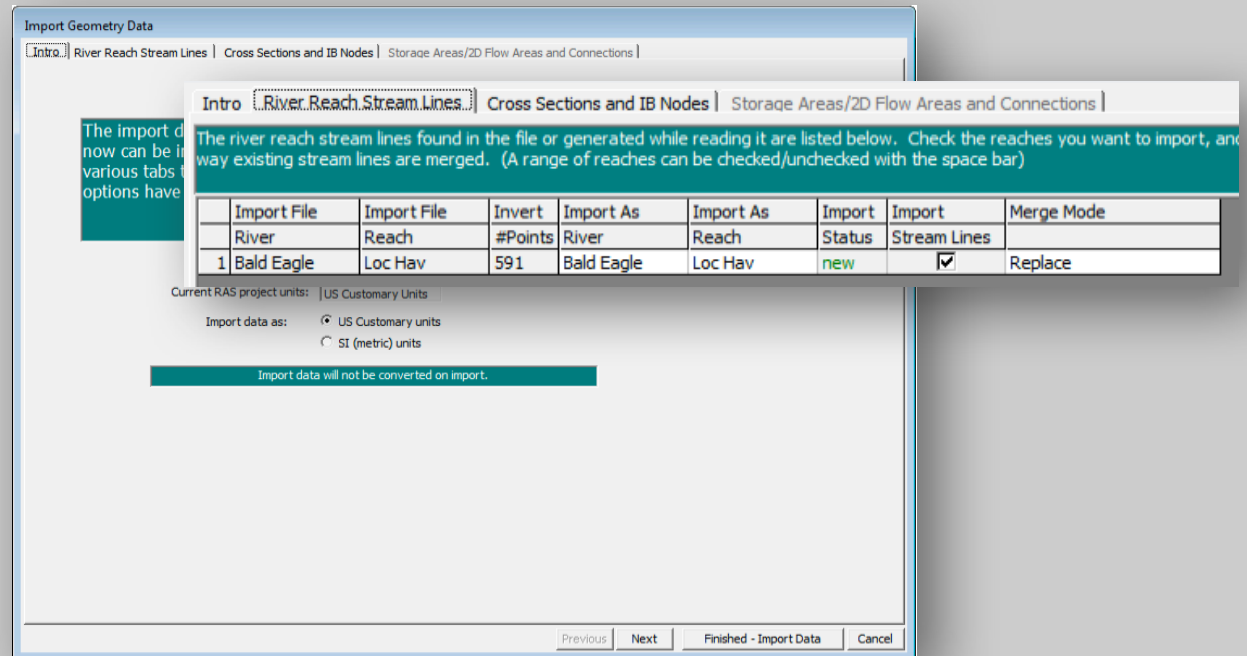
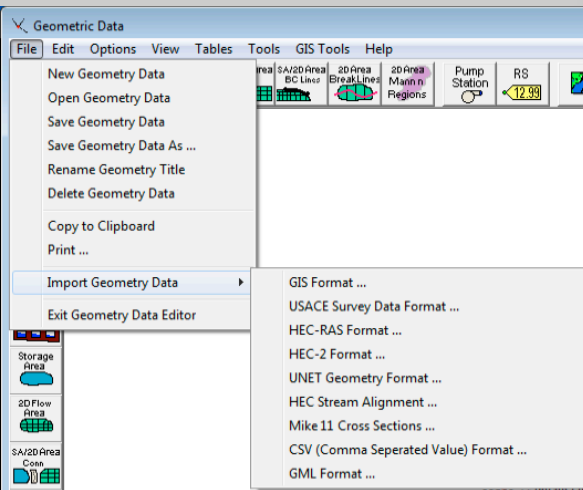
Importing Existing 1D Geometry Data



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Importing Existing 1D Geometry Data

Geometric Data

File Edit Options View Tables Tools GIS Tools Help

New Geometry Data
Open Geometry Data
Save Geometry Data
Save Geometry Data As ...
Rename Geometry Title
Delete Geometry Data
Copy to Clipboard
Print ...
Import Geometry Data
Exit Geometry Data Editor

GIS Format ...
USACE Survey Data Form
HEC-RAS Format ...
HEC-2 Format ...
UNET Geometry Format
HEC Stream Alignment
Mike 11 Cross Sections
CSV (Comma Separated)
GML Format ...

Import Geometry Data

Intro | River Reach Stream Lines | Cross Sections and IB Nodes | Storage Areas/2D Flow Areas and Connections

Node Types in Table
☒ Cross Sections (XS) ☒ Bridges and Culverts (BR/Culv) ☒ Inline Structures (IS) ☒ Lateral Structures (LS)

Import River: (All Rivers) Import As: # RS = 189 # New = 189 # Import = 189
Import Reach: Import As: Check New Check Existing Reset

The imported RS can be edited here, change the import River and Reach names on the previous tab

Import File	Import File	Import File	Import As	Import Status	Import Data
River	Reach	RS	RS		
1 Bald Eagle	Loc Hav	138154.4	138154.4	new	<input checked="" type="checkbox"/>
2 Bald Eagle	Loc Hav	137690.8	137690.8	new	<input checked="" type="checkbox"/>
3 Bald Eagle	Loc Hav	137327.0	137327.0	new	<input checked="" type="checkbox"/>
4 Bald Eagle	Loc Hav	136564.9	136564.9	new	<input checked="" type="checkbox"/>
5 Bald Eagle	Loc Hav	136202.3	136202.3	new	<input checked="" type="checkbox"/>
6 Bald Eagle	Loc Hav	135591.4	135591.4	new	<input checked="" type="checkbox"/>
7 Bald Eagle	Loc Hav	135068.7	135068.7	new	<input checked="" type="checkbox"/>
8 Bald Eagle	Loc Hav	134487.2	134487.2	new	<input checked="" type="checkbox"/>
9 Bald Eagle	Loc Hav	133881.0	133881.0	new	<input checked="" type="checkbox"/>
10 Bald Eagle	Loc Hav	133446.1	133446.1	new	<input checked="" type="checkbox"/>
11 Bald Eagle	Loc Hav	132973.6	132973.6	new	<input checked="" type="checkbox"/>
12 Bald Fanle	Loc Hav	132363.8	132363.8	new	<input checked="" type="checkbox"/>

Select Cross Section Properties to Import

☒ Node Names ☒ Ineffective Areas
☐ Descriptions ☐ Blocked Obstructions
☐ Picture References ☐ XS Lids
☒ GIS Cut Lines ☐ Ice Data
☒ Station Elevation Data ☐ Rating Curves
☒ Reach Lengths ☐ Skew Angle
☒ Manning's n Values ☐ Fixed Sediment Elevation
☒ Bank Stations ☒ HTab Parameters
☐ Contraction Expansion Coef ☐ Pilot Channel Parameters
☒ Levees

Match Import File RS to Existing Geometry RS
Matching Tolerance: .01 Match to Existing

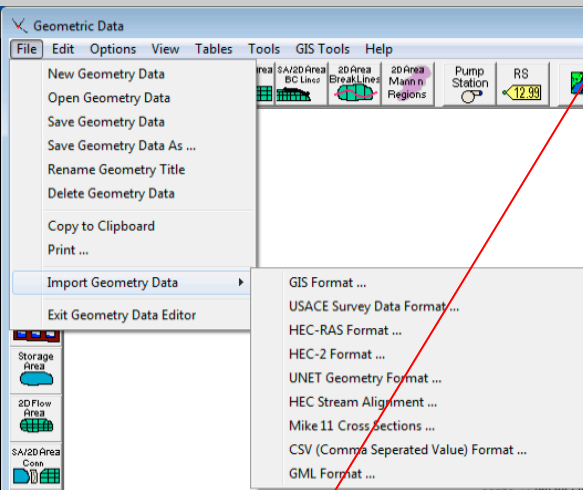
Round Selected RS
2 decimal places Round

Generate RS Based on main channel lengths
(only available when looking at a single reach)
Starting RS Value: 0 2 decimal place
Create RS in miles Create RS in feet

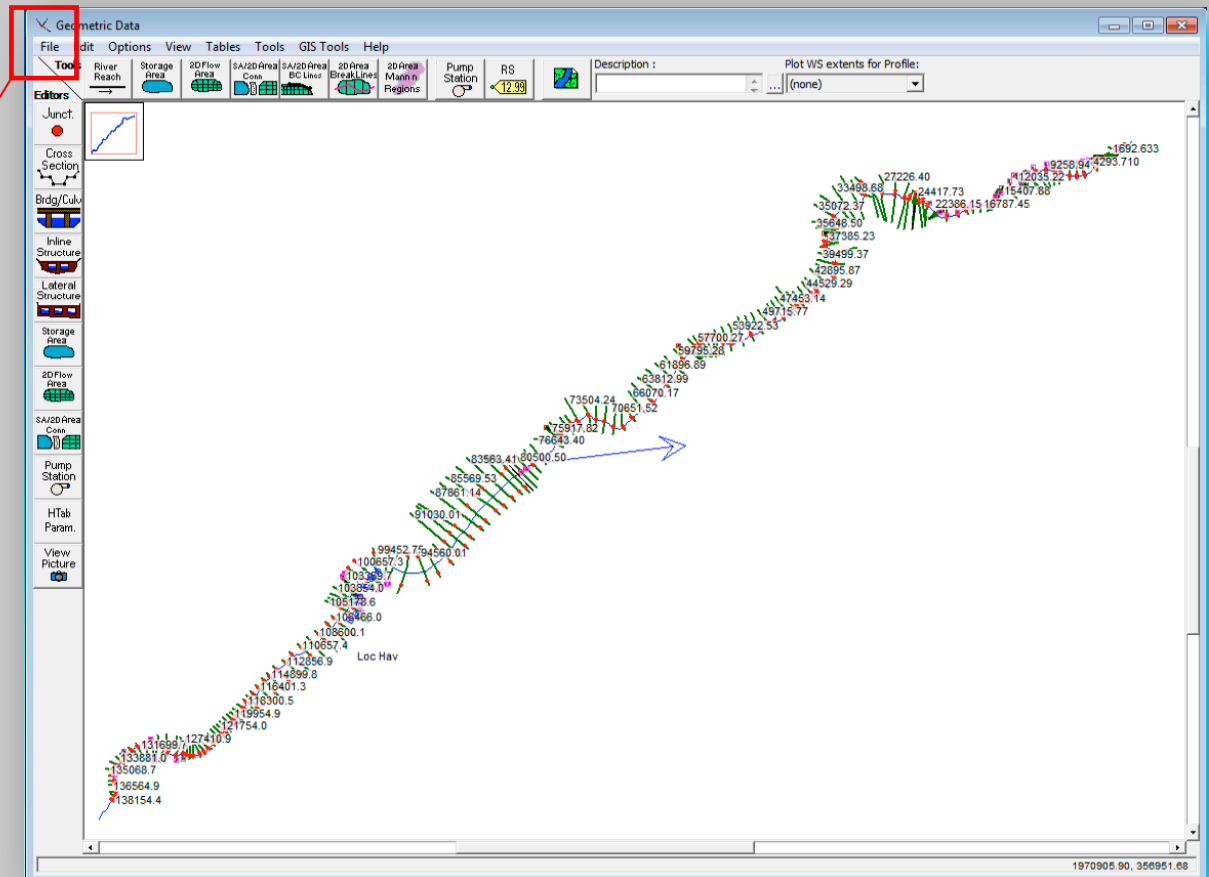
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Importing Existing 1D Geometry Data



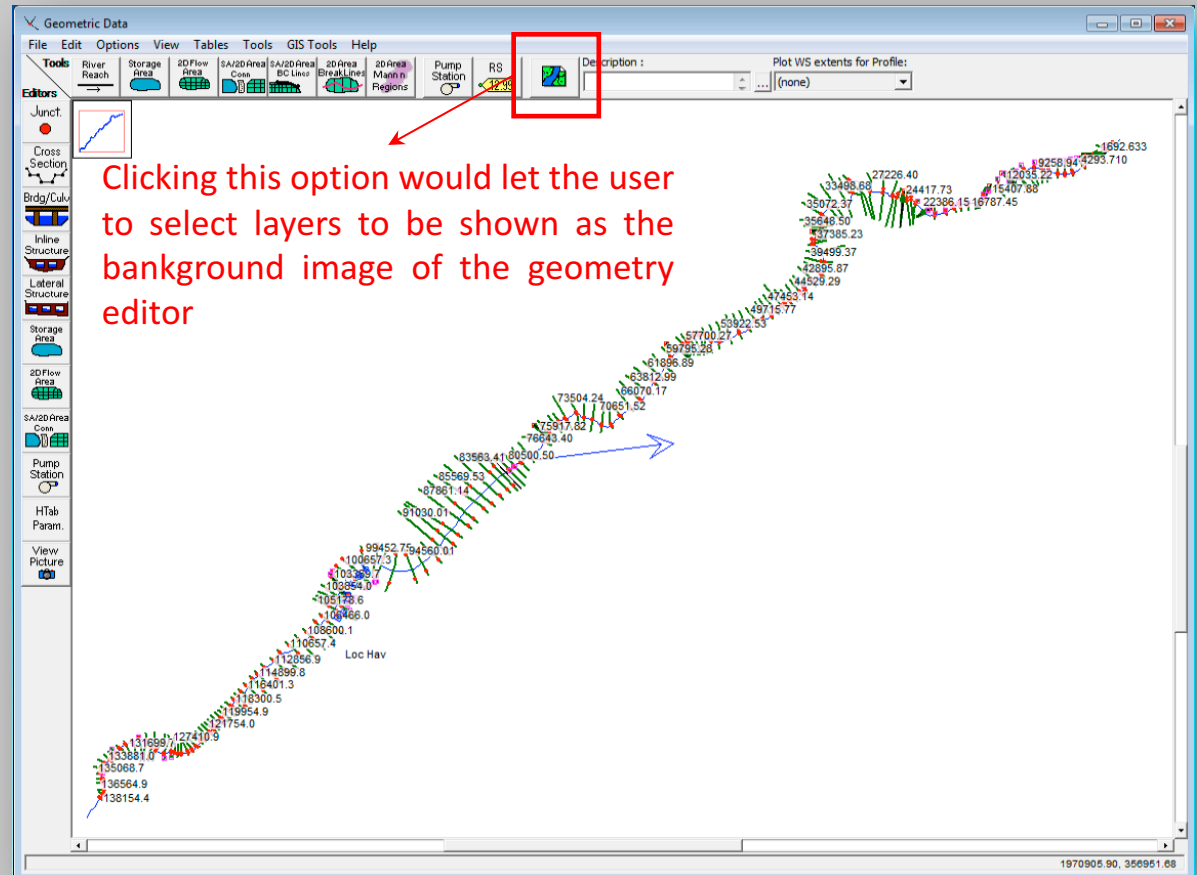
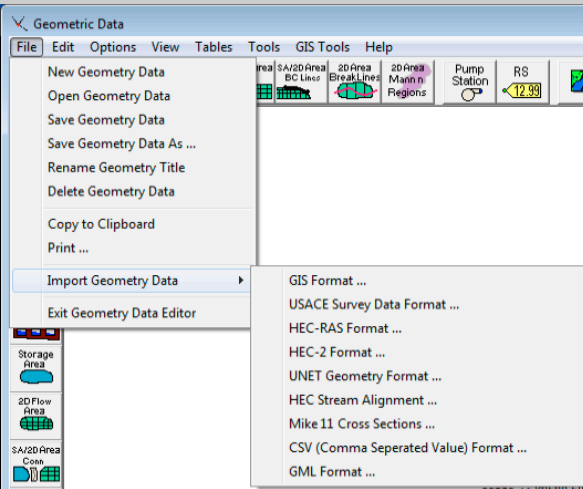
Save the geometry data immediately after being imported



2. Required geophysical and flow information for setting up HEC-RAS 2D models

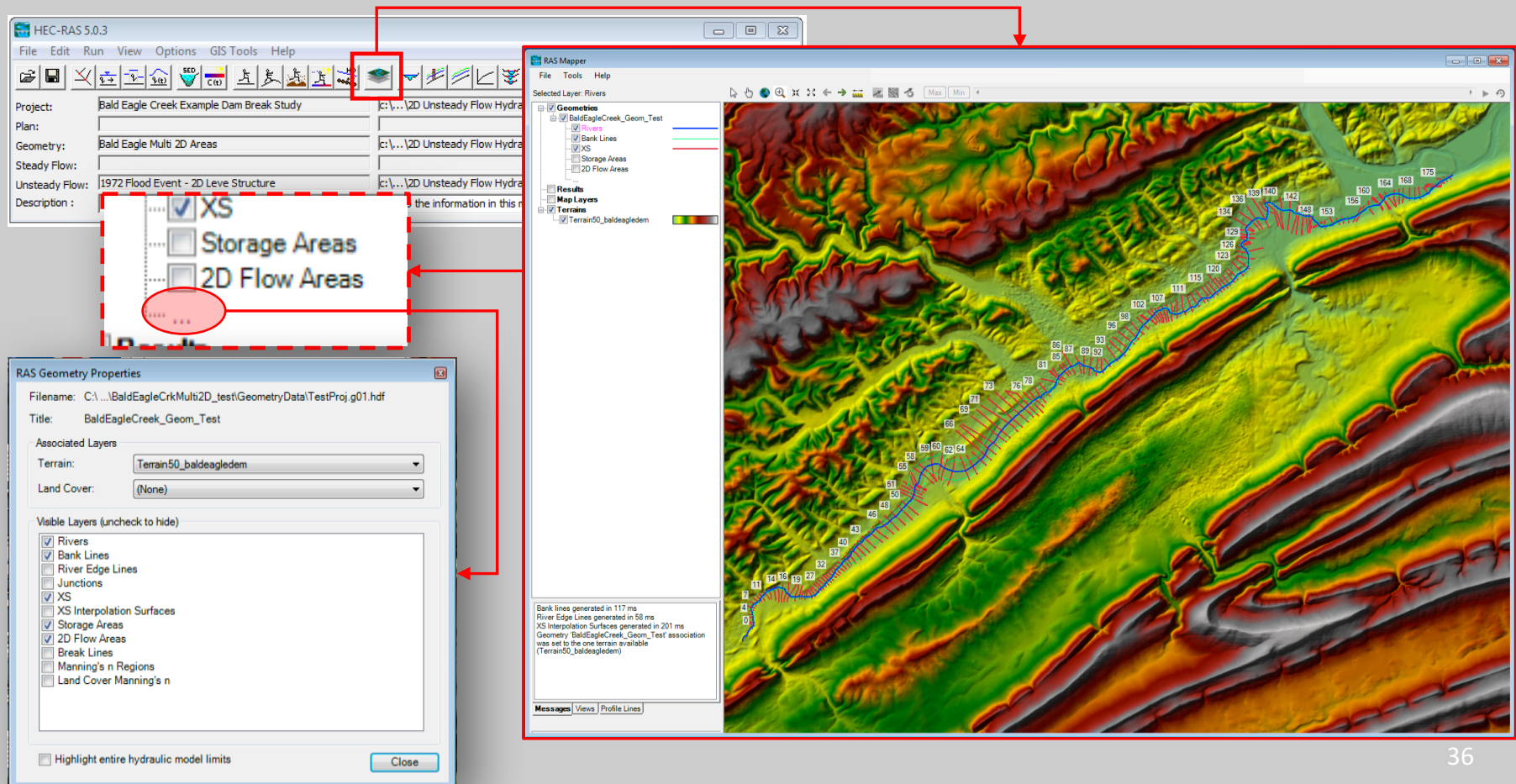
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Importing Existing 1D Geometry Data



2. Required geophysical and flow information for setting up HEC-RAS 2D models

- Using Cross Section Data to Modify/Improve the Terrain Model:
 - From HEC-RAS Mapper, turn on the Geometry layer for the geometry data to be used in creating the channel terrain model.
 - Once the geometry layers are completed, the channel terrain model is created by right clicking on the **Geometry layer** and selecting **Export Layer**, then **Create Terrain GeoTIFF from XS's (channel only)**.



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The image displays the HEC-RAS 5.0.3 software interface, specifically the RAS Mapper window, which is used for creating and managing 2D hydraulic models. The main window shows a 3D terrain model of a river channel, with various layers and data points visible. A red box highlights the 'RAS Mapper' window, and a red arrow points to the 'RAS Geometry Properties' dialog box.

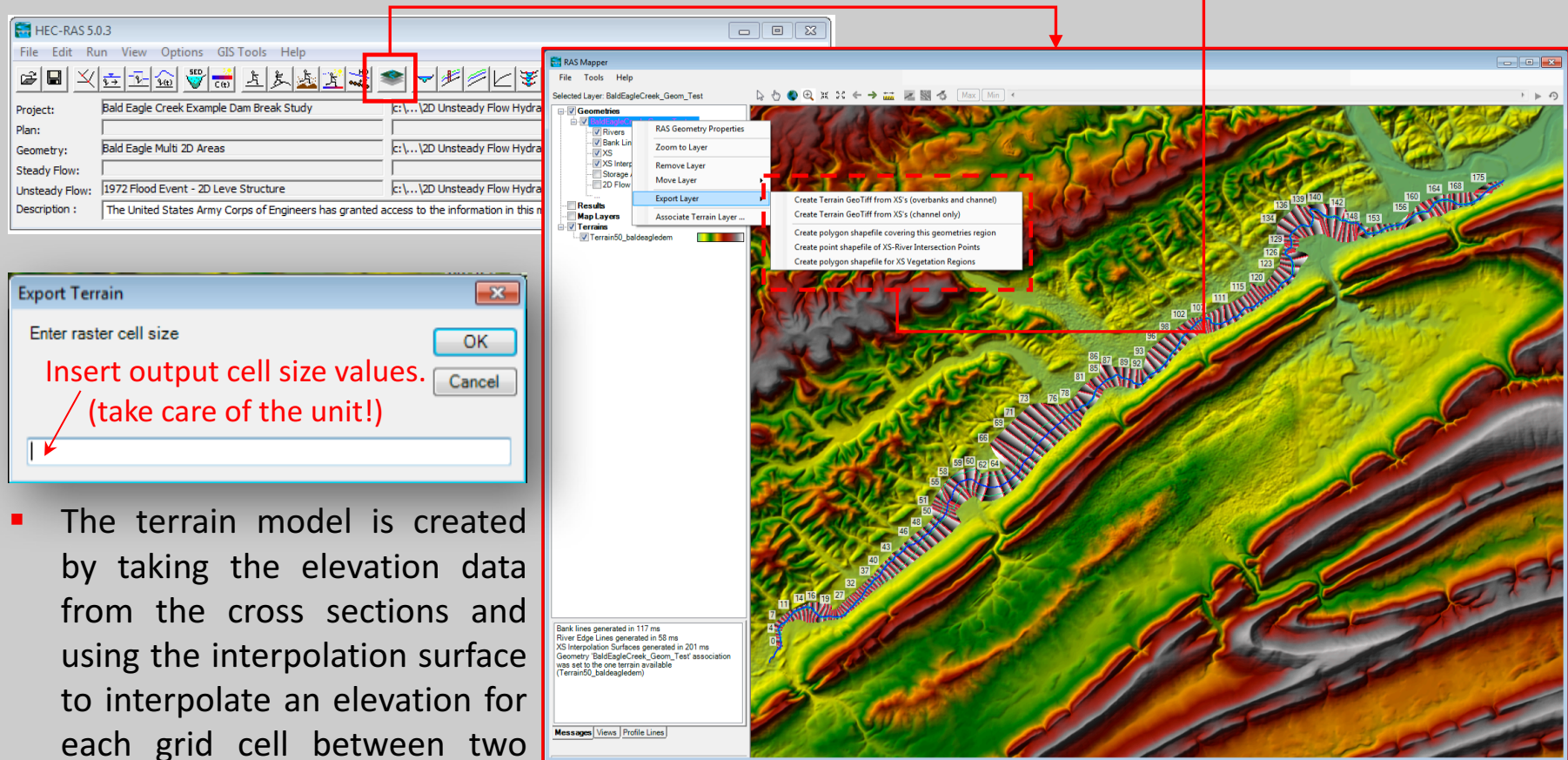
The 'RAS Geometry Properties' dialog box is open, showing the 'Associated Layers' section. The 'Terrain' dropdown is set to 'Terrain50_baldeadgledem'. The 'Land Cover' dropdown is set to '(None)'. The 'Visible Layers (unchecked to hide)' section lists several layers, including 'Rivers', 'Bank Lines', 'River Edge Lines', 'Junctions', 'XS', 'XS Interpolation Surfaces', 'Storage Areas', '2D Flow Areas', 'Break Lines', 'Manning's n Regions', and 'Land Cover Manning's n'. The 'XS Interpolation Surfaces' layer is highlighted with a red circle.

Red text annotations are present: 'Check this' and 'This is the information (along with the terrain) that is used to create the new channel geometry.' with arrows pointing to the 'XS Interpolation Surfaces' layer in the 'RAS Geometry Properties' dialog.

The 'RAS Mapper' window shows a list of layers on the left, including 'BaldEagleCreek_Geom_Test', 'Rivers', 'Bank Lines', 'XS', 'XS Interpolation Surfaces', 'Storage Areas', '2D Flow Areas', 'Terrain', and 'Terrain50_baldeadgledem'. The main view displays a 3D terrain model with a river channel and various data points (e.g., 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200).

2. Required geophysical and flow information for setting up HEC-RAS 2D models

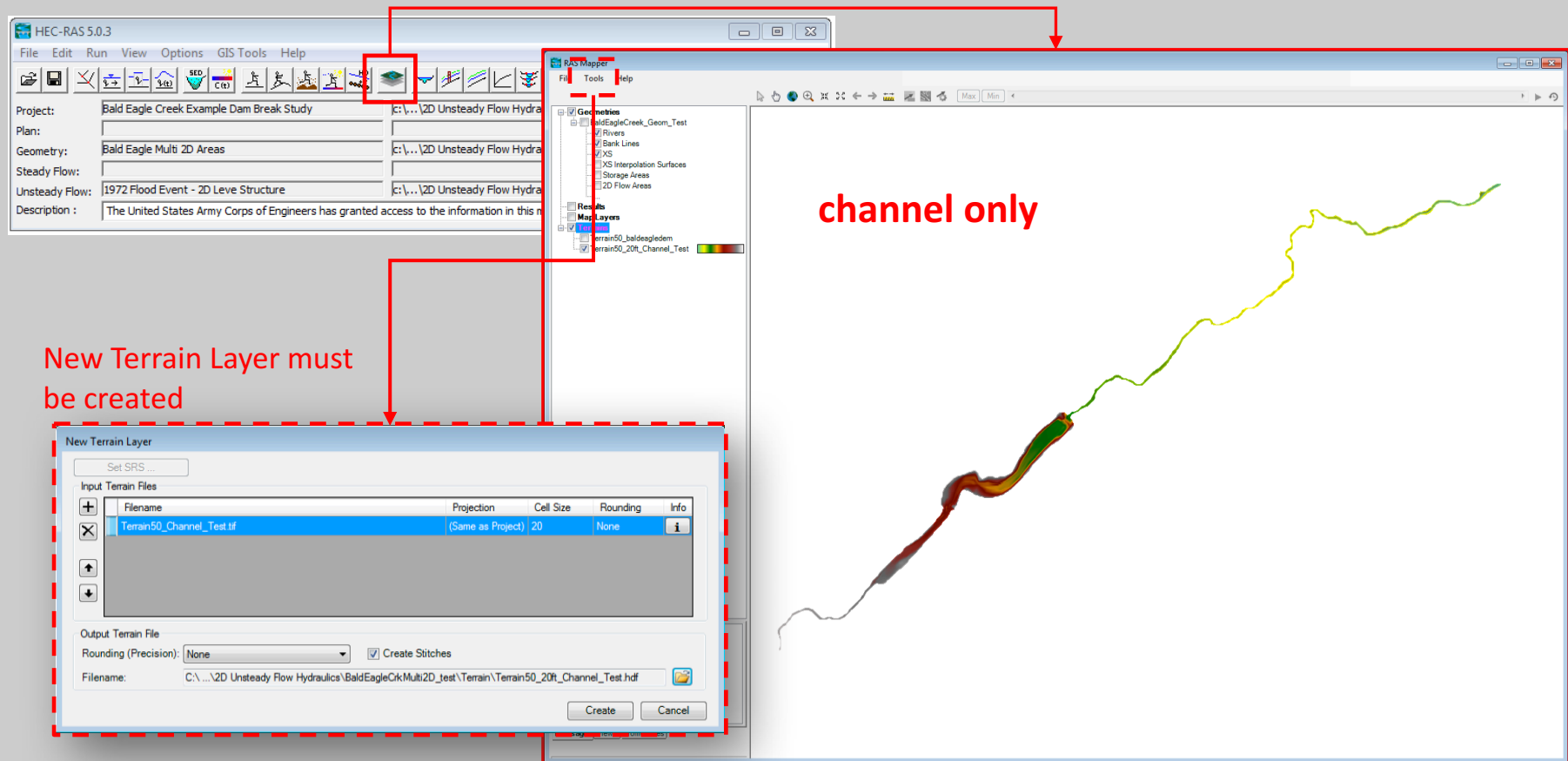
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- The terrain model is created by taking the elevation data from the cross sections and using the interpolation surface to interpolate an elevation for each grid cell between two cross sections.

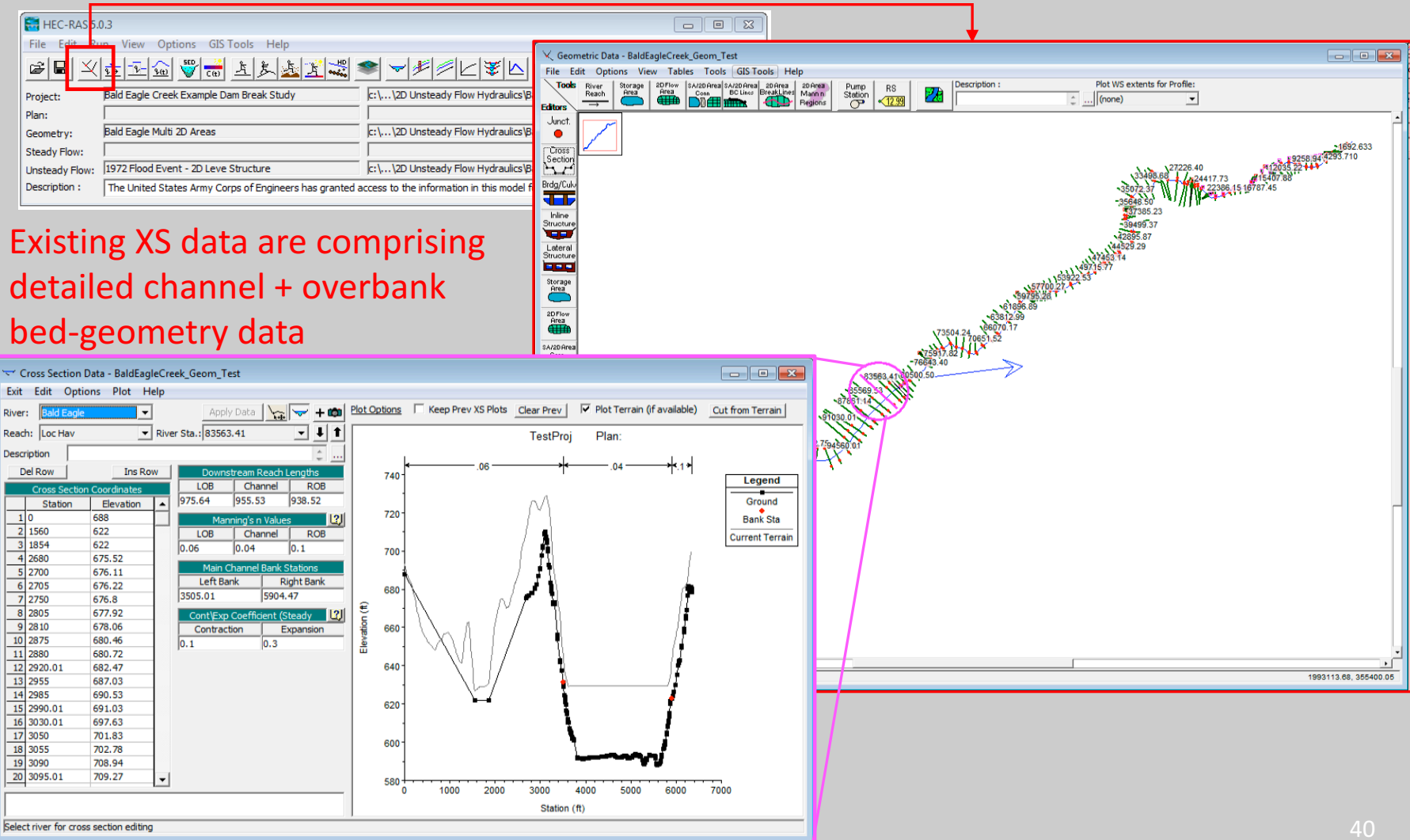
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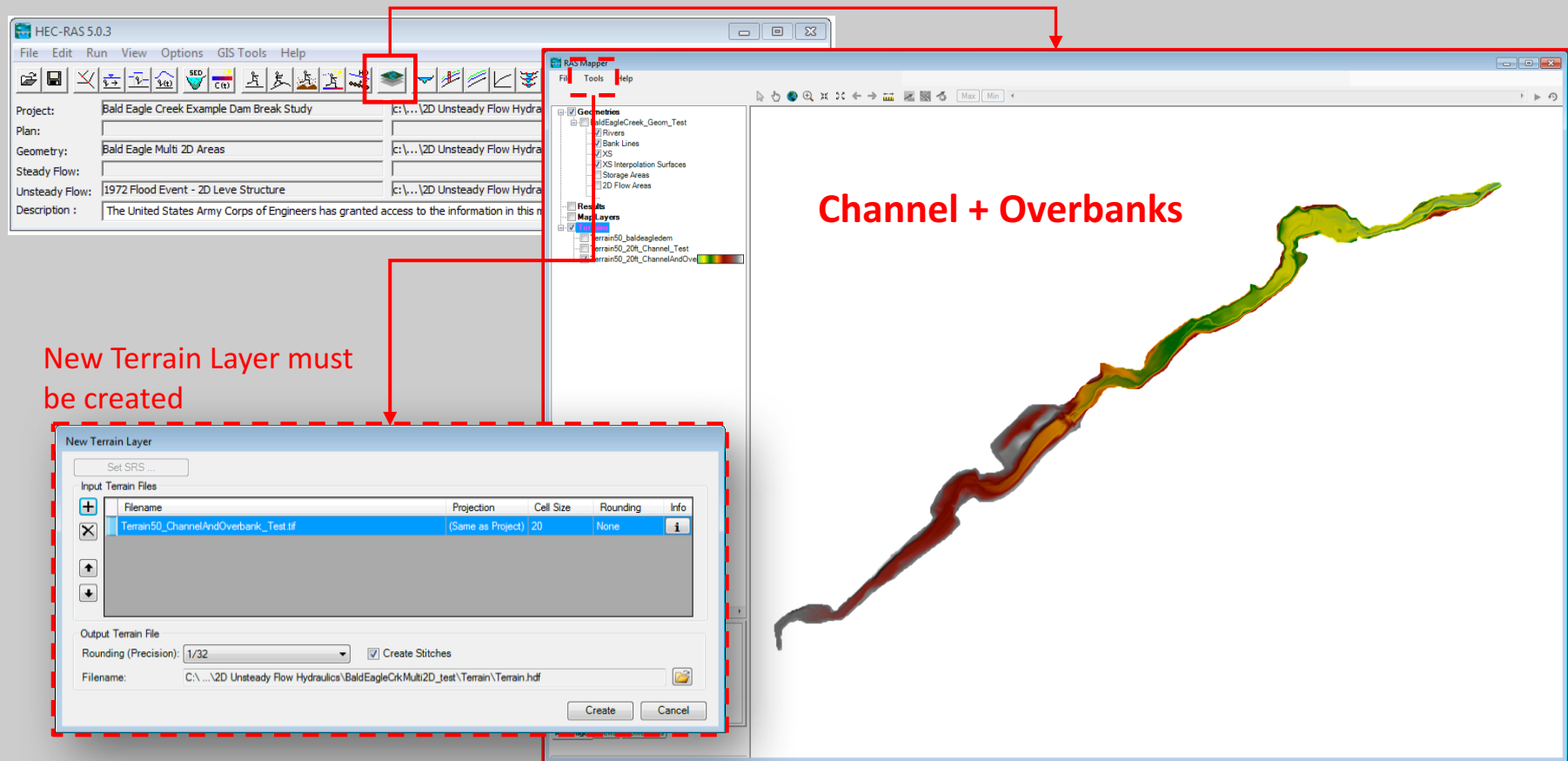
2. Required geophysical and flow information for setting up HEC-RAS 2D models

- Using Cross Section Data to Modify/Improve the Terrain Model:
 - Let's create combined Channel and Overbank terrains



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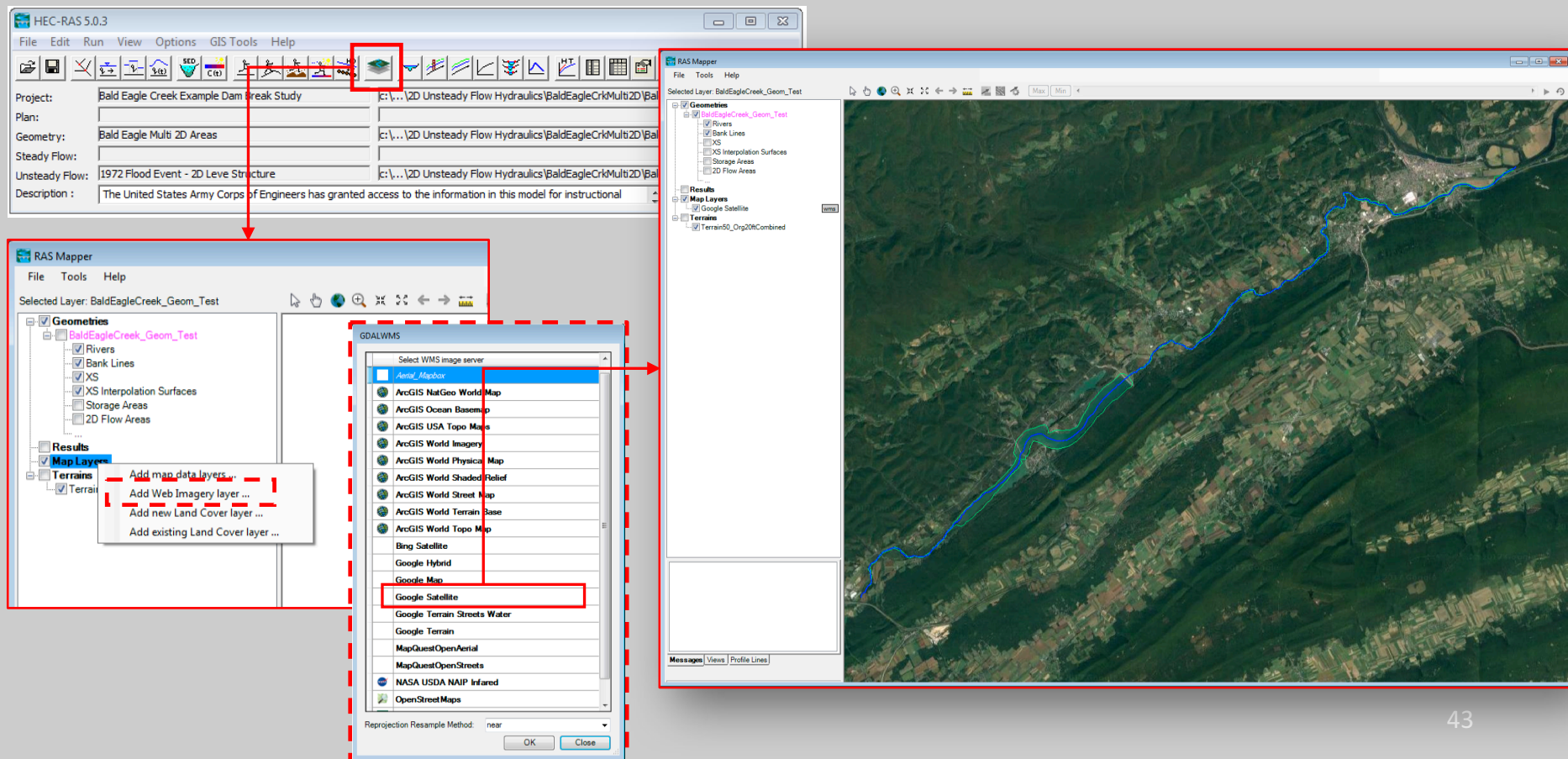


Objectives of This Workshop

1. Introduction to HEC-RAS 2D and two dimensional modeling advantages relative to 1D models
2. Required geophysical and flow information for setting up HEC-RAS 2D models
- 3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS**
4. Overview of how to execute a combined 1D/2D unsteady flow model in HEC-RAS
5. Overview of how to demonstrate the result of a combined 1D/2D unsteady flow model in HEC-RAS and RAS Mapper output capabilities

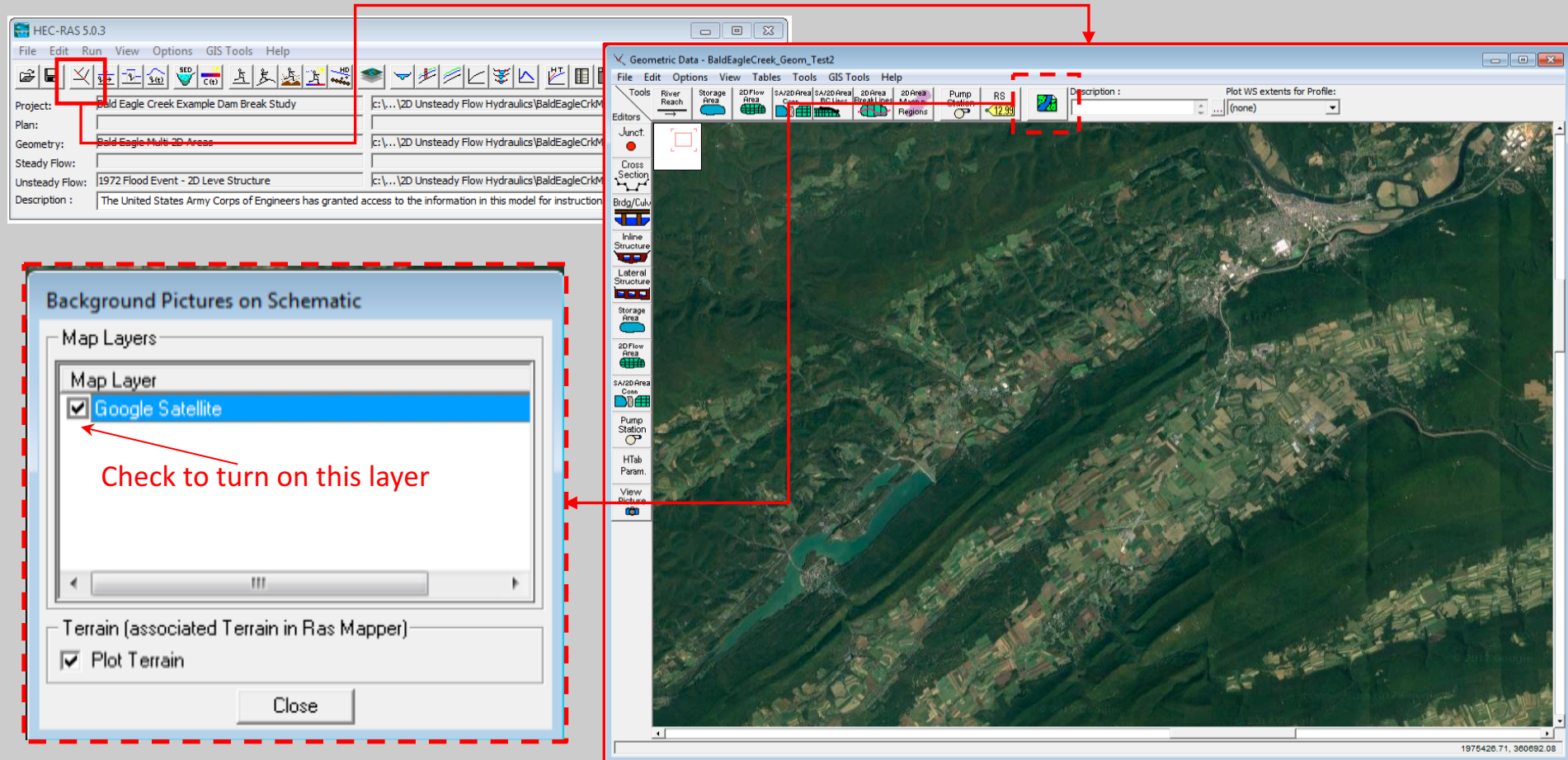
3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Development of 2D computational mesh:
 - The user will most likely select a nominal grid resolution to use (e.g. 200 x 200 ft cells), and the automated tools within HEC-RAS will build the computational mesh.
 - After the initial mesh is built, the user can refine the grid with break lines and the mesh editing tools.
 - A background true color image of the natural topography (e.g. Google map) is really helpful in better delineating 2D Computational mesh boundaries.



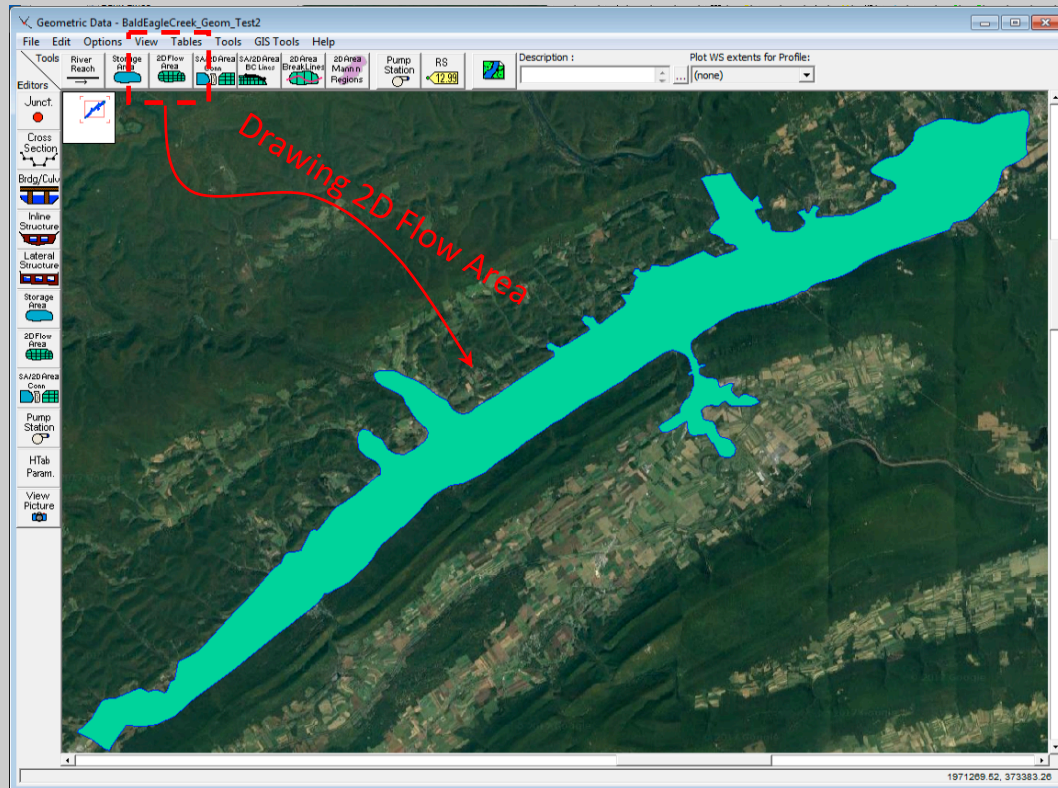
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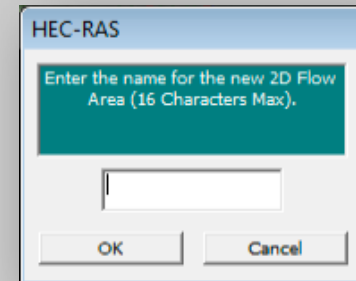


3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Development of 2D computational mesh:
 - The user must add a 2D flow area polygon to represent the boundary of the 2D area using the 2D flow area drawing tool in the Geometric Data editor (just as the user would create a Storage Area).
 - Additionally, the user may want to bring in a shapefile that represents the protected area, if they are working with a leveed system.
 - The boundary between a 1D river reach and a 2D flow area should be high ground that separates the two. For levees and roadways this is obviously the centerline of the levee and the roadway.



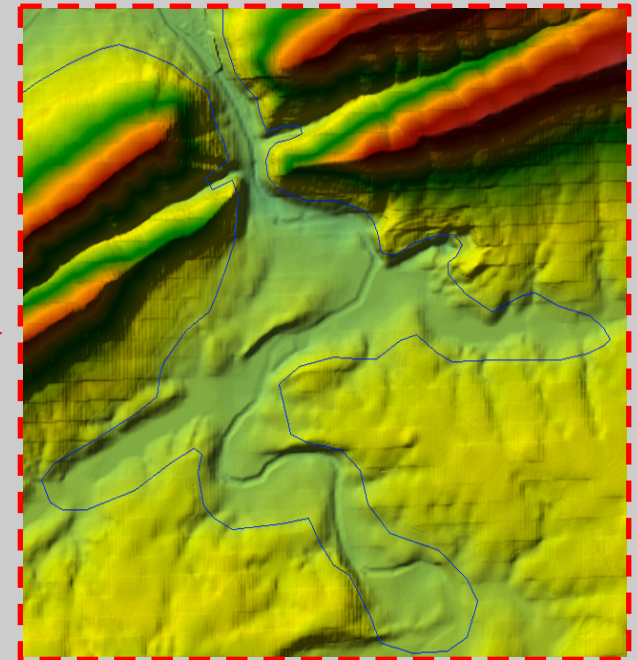
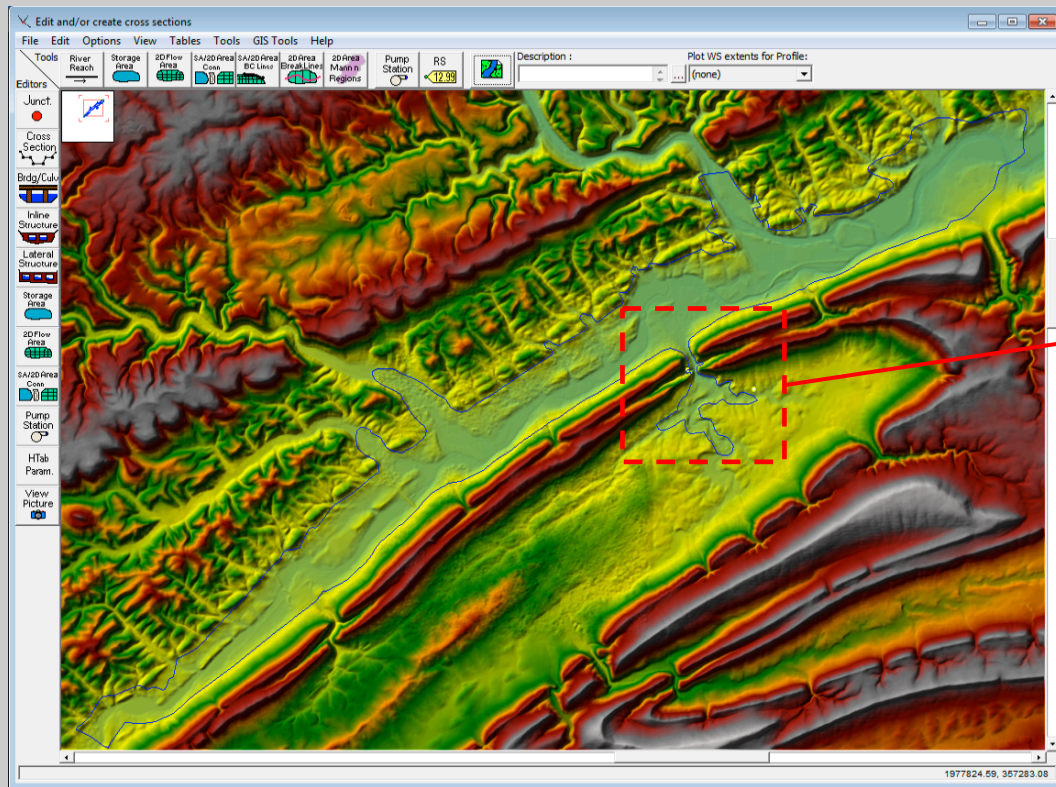
You will be prompted to specify
a name for the 2D flow area



NOTE: A 2D flow area must be drawn within the limits of the terrain model area being used for the study.

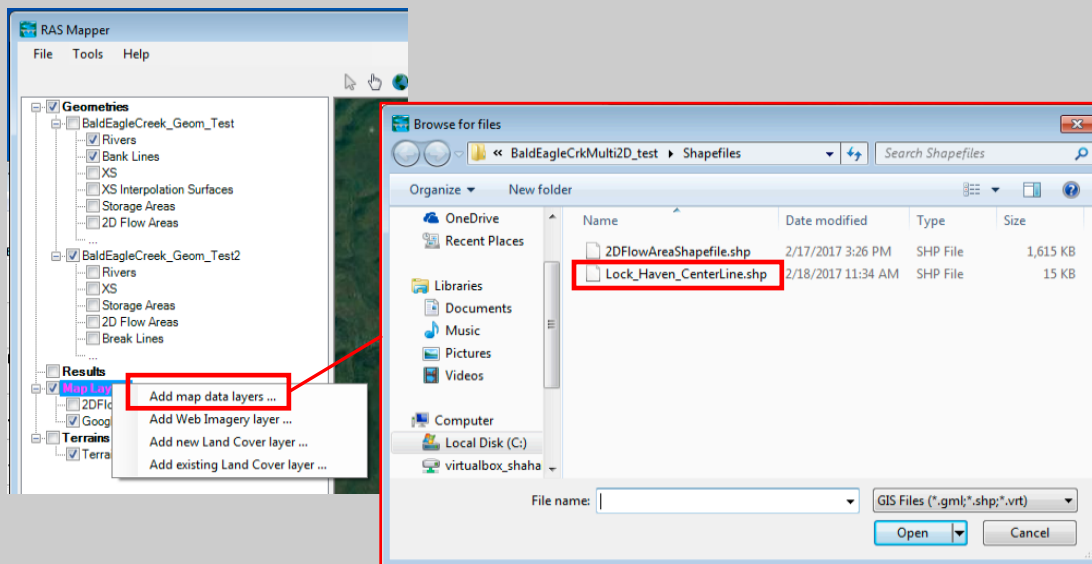
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3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Adding **breaklines** inside 2D flow areas:
 - Before the computational mesh is created the user may want to add break lines to enforce the mesh generation tools to align the computational cell faces along the break lines.
 - Break lines should be added to any location that is a barrier to flow, or controls flow/direction.
 - Break lines can also be added after the main computational mesh is formed, and the mesh can be regenerate just around that break line.

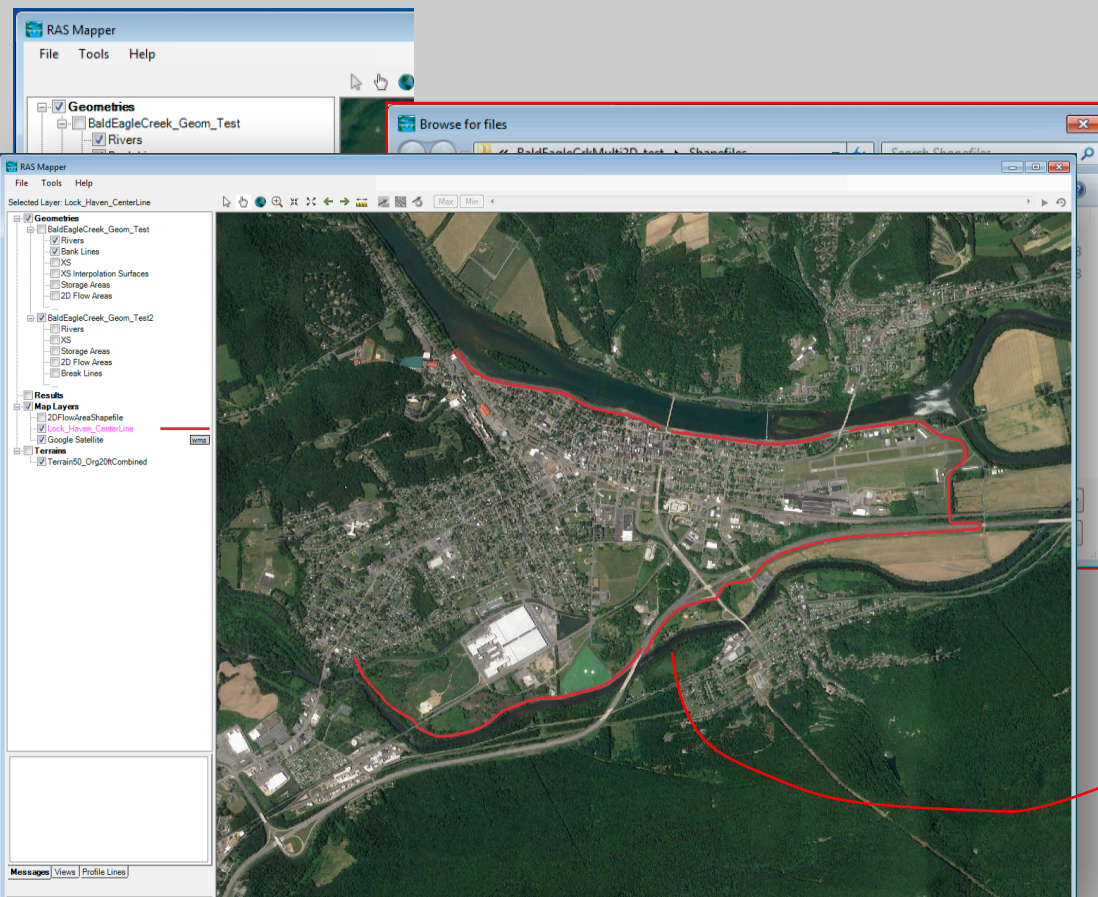


Breaklines can be imported from:

- **Shapefiles**
- Drawing by hand
- Pasting detailed coordinates for an existing breakline into the breakline coordinates table

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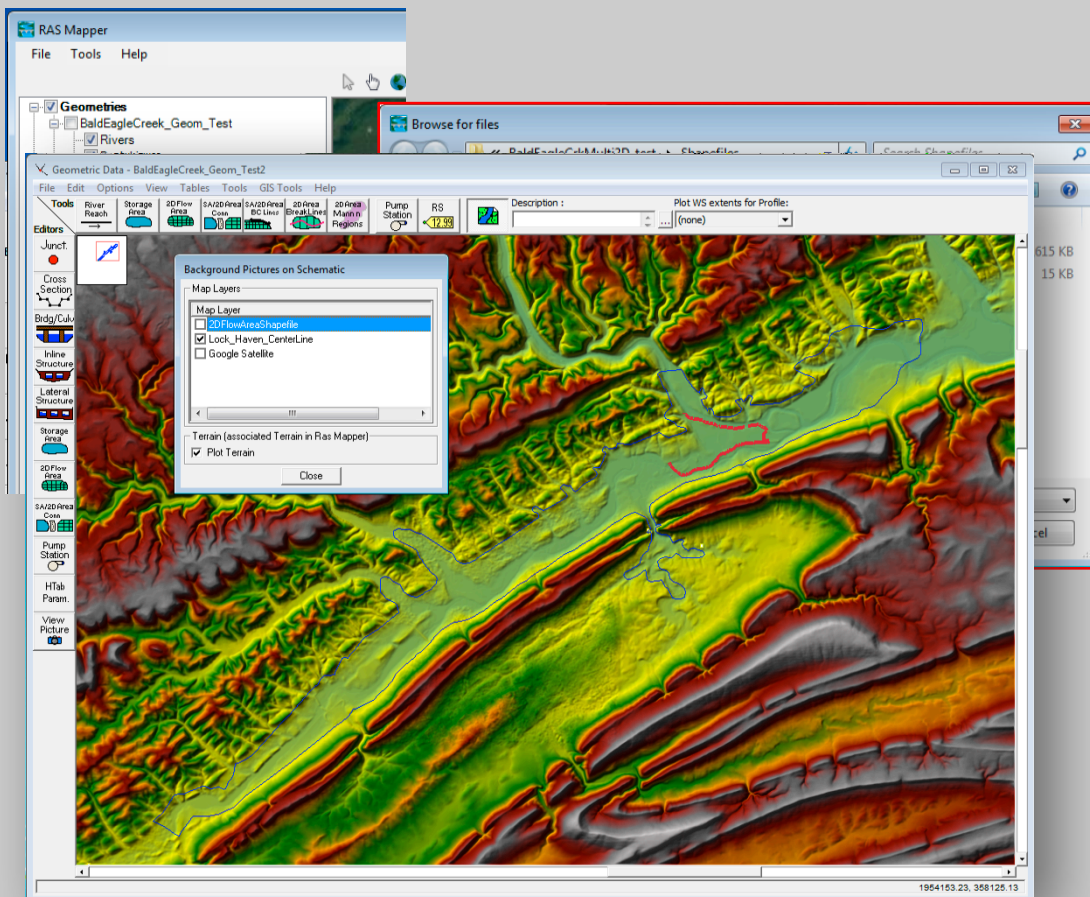


Breaklines can be imported from:

- **Shapefiles**
 - Drawing by hand
 - Pasting detailed coordinates for an existing breakline into the breakline coordinates table
- ✓ Now this also will be observable as a layer at Geometry Editor window.
- ✓ The outline color and line thickness can be modified. Double clicking the "Lock_Haven_CenterLine" will open up a new window where user can adjust the outline view of the line.

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The image displays three overlapping screenshots from the HEC-RAS Mapper software interface, illustrating the steps to import breaklines from a shapefile.

Top Screenshot: Shows the 'RAS Mapper' window with the 'Geometries' tree on the left. The '2D Flow Areas' folder is expanded, showing 'BaldEagleCreek_Geom_Test'. A 'Browse for files' dialog box is open, showing the 'Shapefiles' folder containing 'BaldEagleCrkMulti2D_test'.

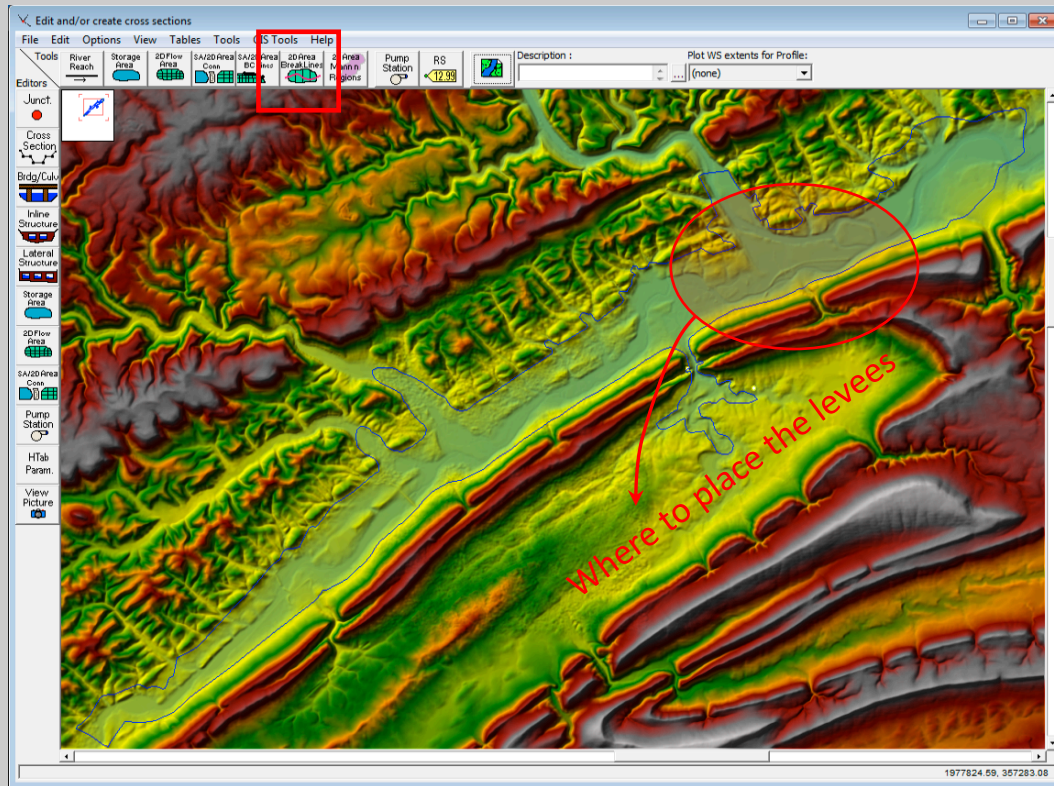
Middle Screenshot: Shows the 'Geometric Data - BaldEagleCreek_Geom_Test2' window. The 'Tools' menu is open, and the 'Breaklines Coordinates Table...' option is highlighted with a red arrow. The 'Breaklines GIS Coordinates' table is visible, showing a list of coordinates (X, Y) for the 'Lower' breakline.

Bottom Screenshot: Shows the 'Enter/Select Vector File (shapefile or gml)' dialog box. The 'Shapefiles' folder is selected, and the file 'Lock_Haven_CenterLine.shp' is highlighted with a red circle. The 'File name' field is empty, and the 'File type' is set to 'Vector Files (*.shp, *.gml)'. The 'Import Lines' button in the 'Breaklines GIS Coordinates' table is also highlighted with a red circle.

Names (Select one or Many)	X (ft)	Y (ft)
Upper	2060298.13241794	354322.35770418
Middle	2060289.308824	354269.416140548
Lower	2060280.48523006	
	2060306.95601188	
	2060324.60319975	
	2060518.7222664	
	2060633.42898761	
	2060704.01773011	
	2060695.10414518	
	2060624.60539367	
	2060509.89867247	
	2060262.83804218	
	2060112.83694523	
	2059971.65944221	
	2059777.54037556	
	2059645.18646648	
	2059459.89099377	
	2059168.7123938	
	2058718.70910293	

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 - Before the computational mesh is created the user may want to add break lines to enforce the mesh generation tools to align the computational cell faces along the break lines.
 - Break lines should be added to any location that is a barrier to flow, or controls flow/direction.
 - Break lines can also be added after the main computational mesh is formed, and the mesh can be regenerate just around that break line.

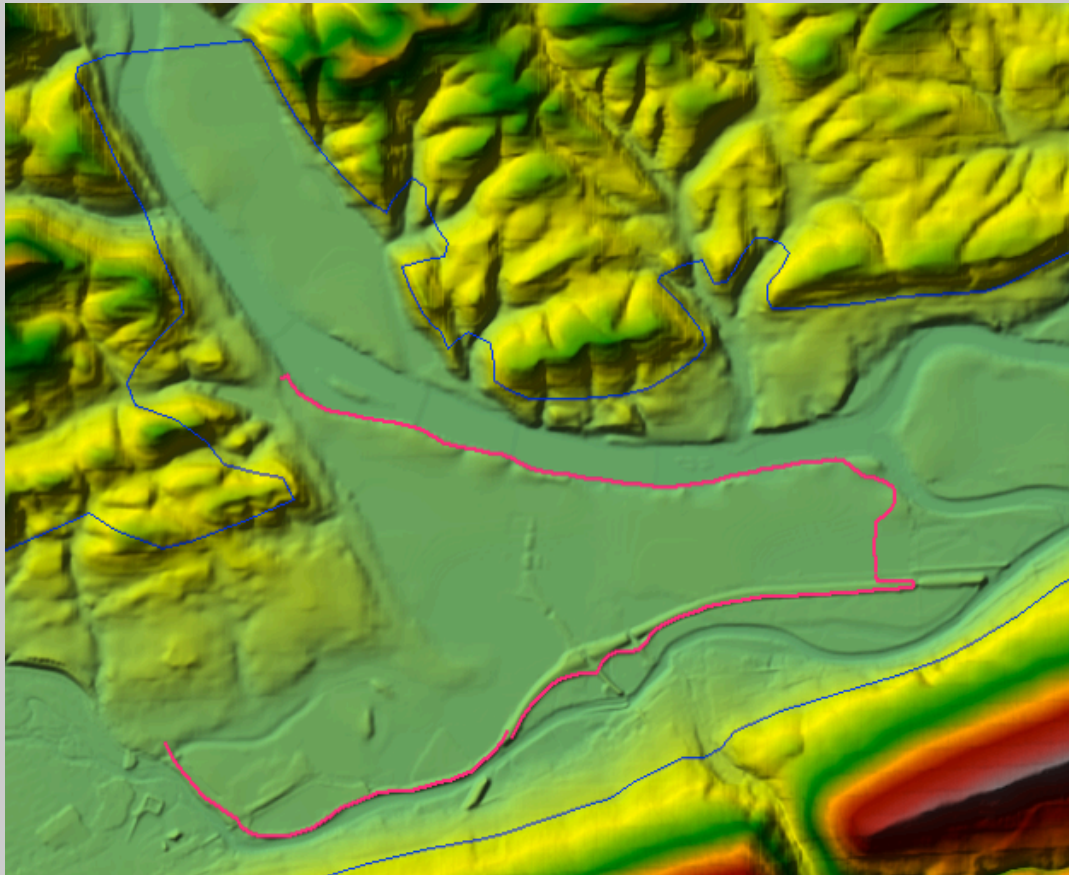


Breaklines can be imported from:

- Shapefiles
- **Drawing by hand**
- Pasting detailed coordinates for an existing breakline into the breakline coordinates table

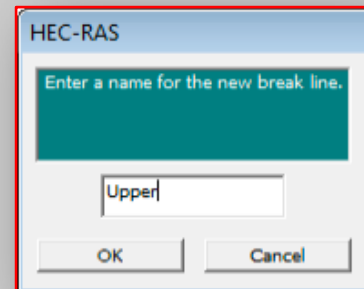
3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Adding **breaklines** inside 2D flow areas:
 - Before the computational mesh is created the user may want to add break lines to enforce the mesh generation tools to align the computational cell faces along the break lines.
 - Break lines should be added to any location that is a barrier to flow, or controls flow/direction.
 - Break lines can also be added after the main computational mesh is formed, and the mesh can be regenerate just around that break line.



Breaklines can be imported from:

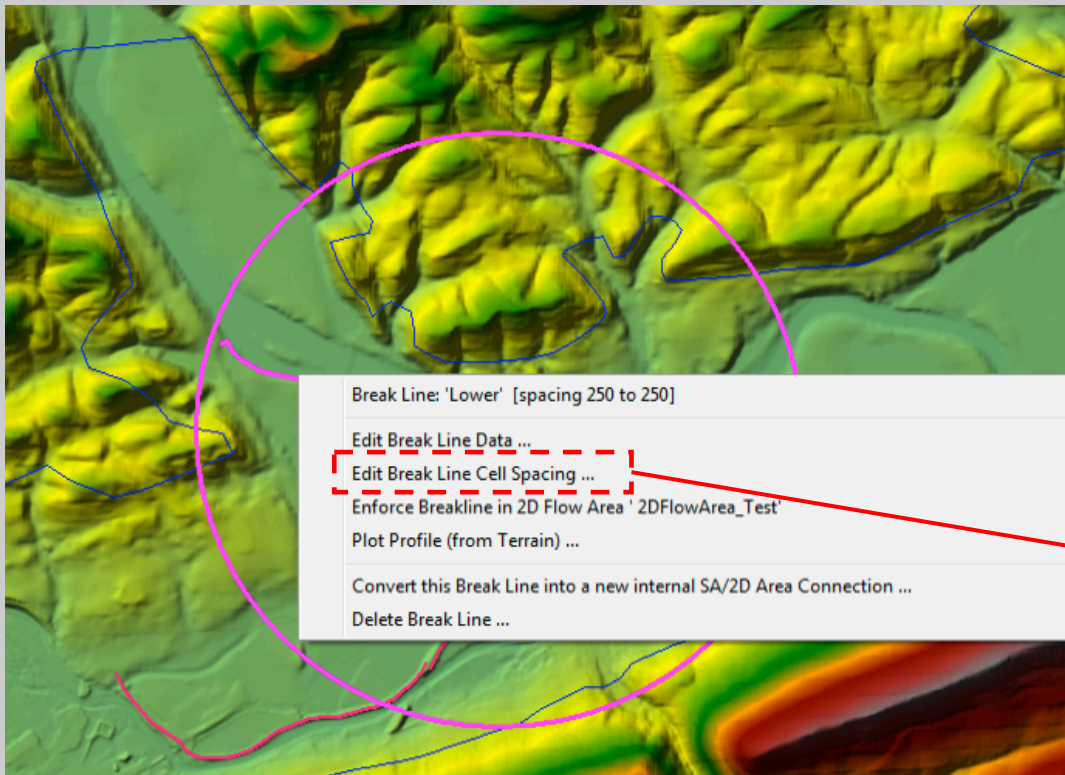
- Shapefiles
- **Drawing by hand**
- Pasting detailed coordinates for an existing breakline into the breakline coordinates table



Once a break line is drawn the software will ask you to enter a name for the break line.

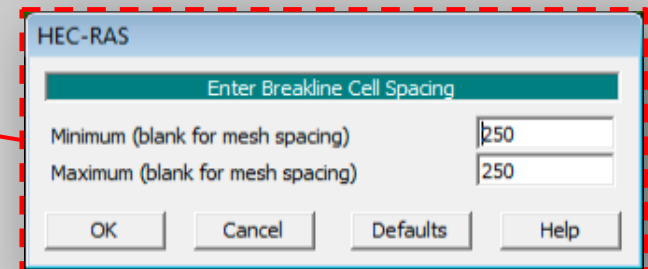
3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Adding **breaklines** inside 2D flow areas:
 - Before the computational mesh is created the user may want to add break lines to enforce the mesh generation tools to align the computational cell faces along the break lines.
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Breaklines can be imported from:

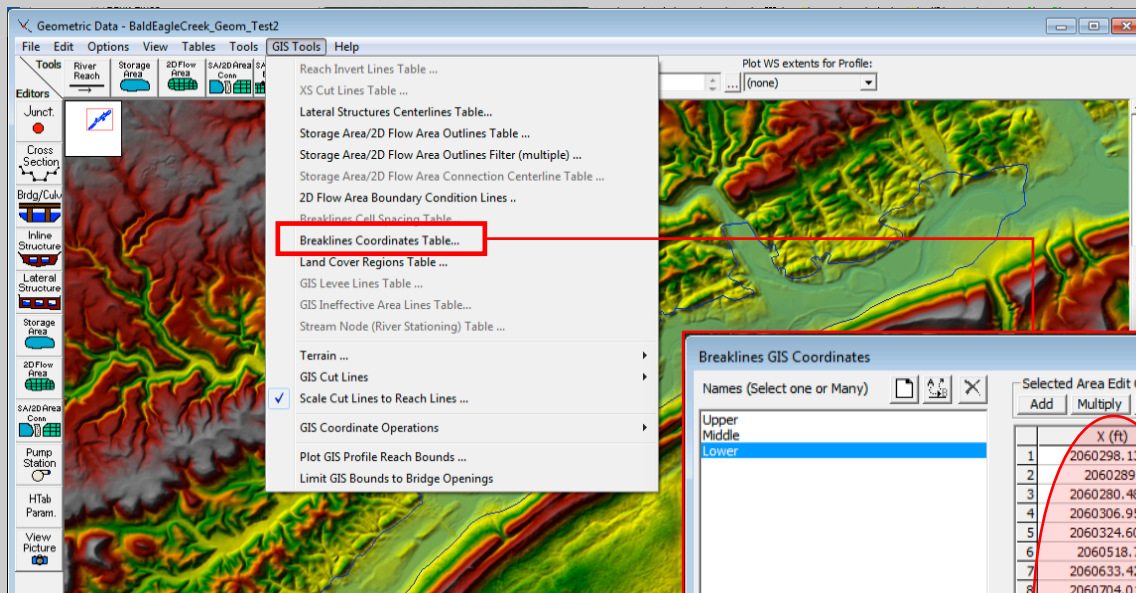
- Shapefiles
- **Drawing by hand**
- Pasting detailed coordinates for an existing breakline into the breakline coordinates table



3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

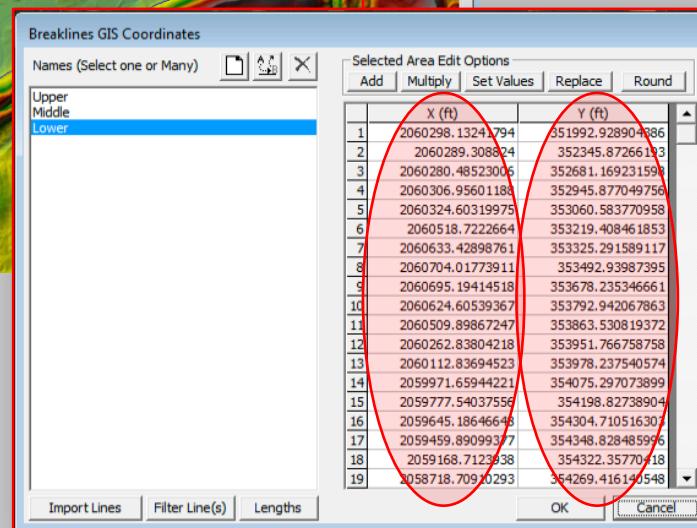
- Adding **breaklines** inside 2D flow areas:

- Before the computational mesh is created the user may want to add break lines to enforce the mesh generation tools to align the computational cell faces along the break lines.
- Break lines should be added to any location that is a barrier to flow, or controls flow/direction.
- Break lines can also be added after the main computational mesh is formed, and the mesh can be regenerate just around that break line.



Breaklines can be imported from:

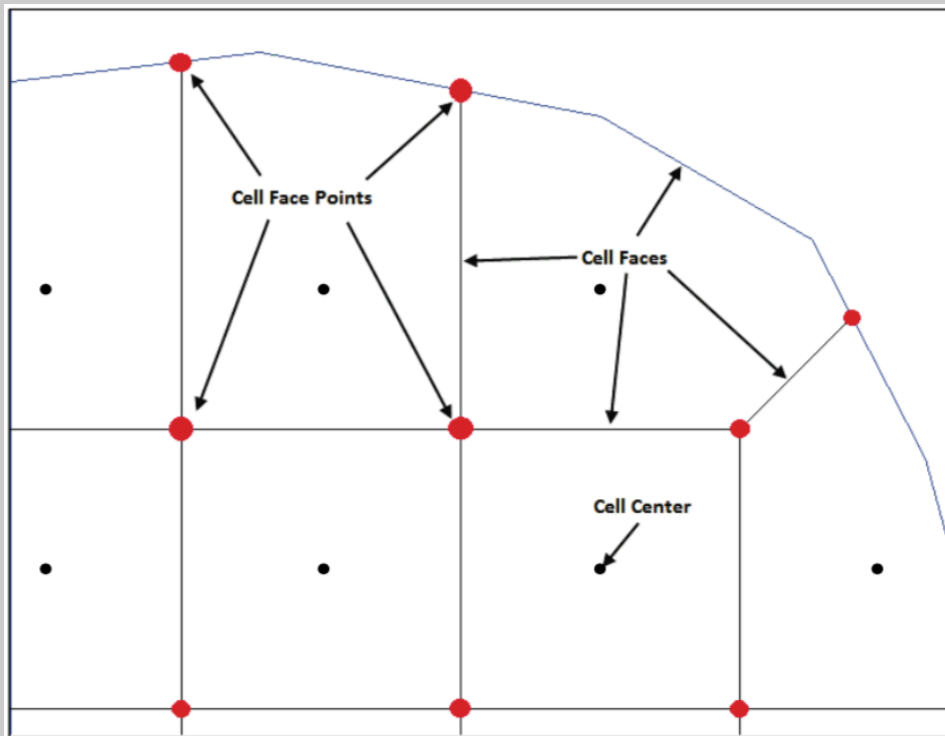
- Shapefiles
- Drawing by hand
- Pasting detailed coordinates for an existing breakline into the breakline coordinates table



3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Creating the 2D Computational Mesh:

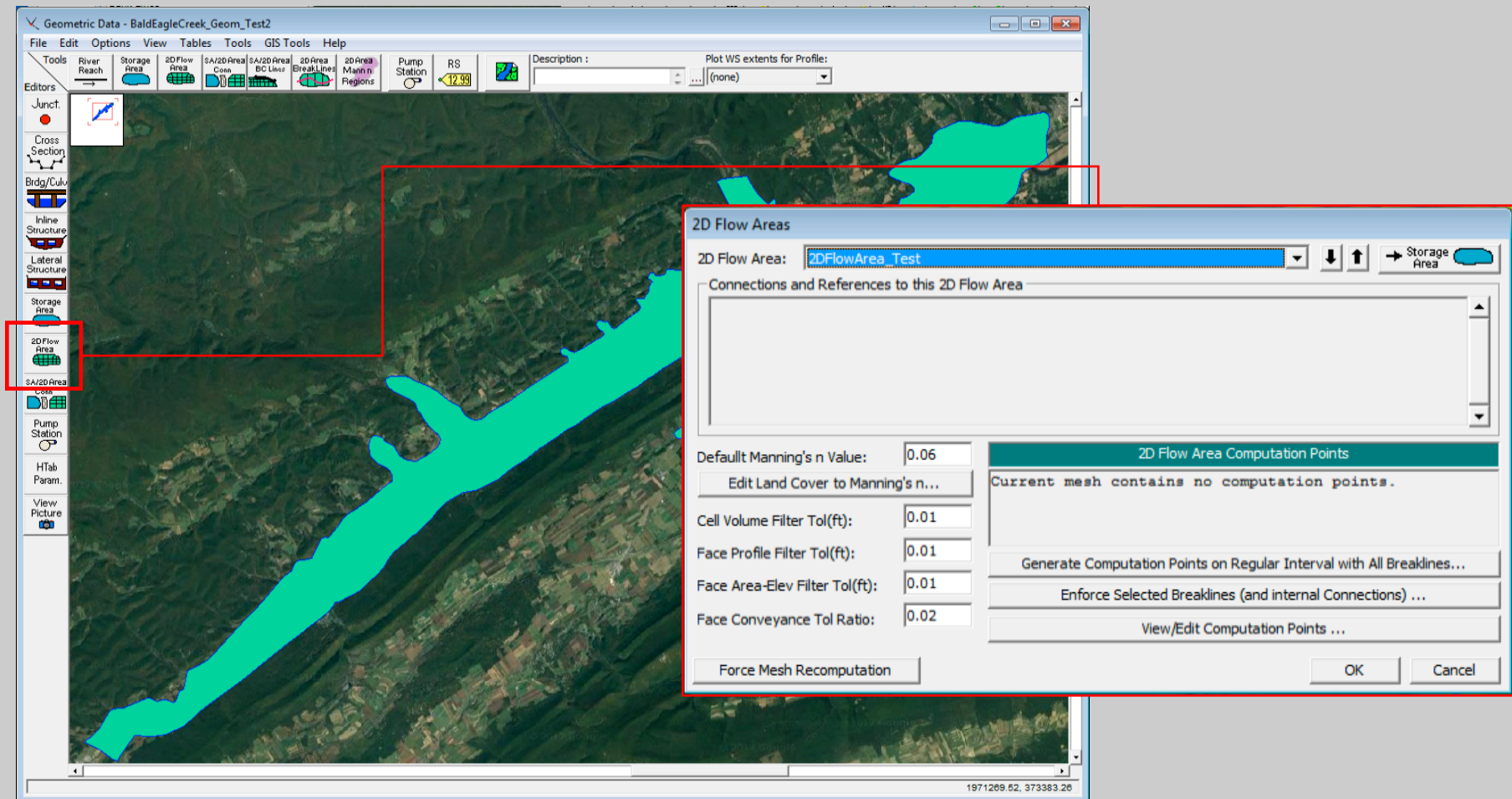
- After all the break lines have been added, the computational mesh can be generated. Keep in mind the user can also add additional break lines after the mesh has been generated, and the computational mesh can be refined around an individual break line at any time.
- The 2D flow area defines the boundary for which 2D computations will occur.



- ✓ **Cell Center:** this is where the water surface elevation is computed for the cell. The cell center does not necessarily correspond to the exact cell centroid.
- ✓ **Cell Face:** Faces are generally straight lines, but they can also be multi-point lines, such as the outer boundary of the 2D flow area.
- ✓ **Cell Face Points:** are the ends of the cell faces. The Face Point (FP) numbers for the outer boundary of the 2D flow area are used to hook the 2D flow area to a 1D elements and boundary conditions.

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Creating the 2D Computational Mesh:
 - The 2D Flow Area editor allows the user to select a nominal grid size for the initial generation of the 2D flow area computational mesh.
 - The 2D flow area defines the boundary for which 2D computations will occur.



3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Creating the 2D Computational Mesh:
 - For example, if the user enters **Spacing DX = 250**, and **Spacing DY = 250**, they will get a computational mesh that has grids that are 250 x 250 everywhere, except around break lines and the outer boundary.

✓ This will open a popup window that will allow the user to enter a nominal cell size.

✓ This defines the spacing between the computational grid-cell centers.

2D Flow Area Generate Points

Computation Point Spacing

Spacing DX = 250

Spacing DY = 250

Shift Generated Points (Optional)

Shift Right = 0

Shift Up = 0

Generate Points in 2D Flow Area Cancel

2D Flow Areas

2D Flow Area: 2DFlowArea_Test

Connections and References to this 2D Flow Area

Default Manning's n Value: 0.06

Edit Land Cover to Manning's n...

Cell Volume Filter Tol(ft): 0.01

Face Profile Filter Tol(ft): 0.01

Face Area-Elev Filter Tol(ft): 0.01

Face Conveyance Tol Ratio: 0.02

Force Mesh Recomputation

2D Flow Area Computation Points

Current mesh contains no computation points.

Generate Computation Points on Regular Interval with All Breaklines...

Enforce Selected Breaklines (and internal Connections) ...

View/Edit Computation Points ...

OK Cancel

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Creating the 2D Computational Mesh:

- Since the user can enter break lines, the mesh generation tools will automatically try to “snap” the cell faces to the breaklines. The cells formed around break lines may not always have cell faces that are aligned perfectly with the break lines.

✓ Will create cells that are aligned with the breaklines, which helps ensures that flow cannot go across that cells face until the water surface is higher than the terrain along that breakline.

✓ The user can enter a different cell spacing to be used for each breakline.

2D Flow Areas

2D Flow Area: 2DFlowArea_Test

Connections and References to this 2D Flow Area

Default Manning's n Value: 0.06

Edit Land Cover to Manning's n...

Cell Volume Filter Tol(ft): 0.01

Face Profile Filter Tol(ft): 0.01

Face Area-Elev Filter Tol(ft): 0.01

Face Conveyance Tol Ratio: 0.02

Force Mesh Recomputation

2D Flow Area Computation Points

Mesh contains: 18632 cells

Generate Computation Points on Regular Interval with All Breaklines...

Enforce Selected Breaklines (and internal Connections) ...

View/Edit Computation Points ...

Enforce Breaklines (and Internal Connections)

Avail Breaklines/Connections

Upper
Middle
Lower

Enforce

Upper
Middle
Lower

Select All Clear All

OK Cancel

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Creating the 2D Computational Mesh:
 - Since the user can enter break lines, the mesh generation tools will automatically try to “snap” the cell faces to the breaklines. The cells formed around break lines may not always have cell faces that are aligned perfectly with the break lines.

✓ The user can view these points by pressing the **View/Edit Computational Point's button**, which brings the points up in a table. The user can cut and paste these into a spreadsheet, or edit them directly if desired (It is not envisioned that anyone will edit the points in this table or Excel, but the option is available).

	X	Y
18619	2048999.369421...	355263.8750365...
18620	2049072.203188...	355503.0303049...
18621	2048747.822127...	355374.2382449...
18622	2048874.484646...	355589.7761908...
18623	2048533.492123...	355504.0039183...
18624	2048665.759728...	355716.1483992...
18625	2048321.305230...	355660.5971519...
18626	2048485.355964...	355849.2432670...
18627	2048139.514795...	355868.8569173...
18628	2048348.191127...	356006.5311284...
18629	2048065.592481...	355926.4824789...
18630	2048090.418116...	356175.2468007...
18631	2047878.372442...	356945.9646193...
18632	2047895.198078...	356194.7289412...

2D Flow Area Computation Points

Mesh contains: 18632 cells

Generate Computation Points on Regular Interval with All Breaklines...

Enforce Selected Breaklines (and internal Connections) ...

View/Edit Computation Points ...

OK Cancel

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Creating the 2D Computational Mesh:
 - Since the user can enter break lines, the mesh generation tools will automatically try to “snap” the cell faces to the breaklines. The cells formed around break lines may not always have cell faces that are aligned perfectly with the break lines.

The screenshot shows the HEC-RAS software interface. The main window displays a map of a river area with a 2D flow area highlighted in cyan. The 'Tools' menu is open, and the '2D Flow Area' tool is selected. A red box highlights the '2D Flow Area' tool in the 'Editors' panel. A red dashed box highlights a text box containing two checkmarks and instructions. Two dialog boxes are open: 'Land Cover to Manning's n (2D Flow Areas Only)' and '2D Flow Area Computation Points'.

✓ This field is used to enter a default Manning's n values that will be used for the cell faces in the 2D flow area.

✓ This must be re-checked once a land cover layer is created and associated with the 2D geometry.

Land Cover to Manning's n (2D Flow Areas Only)

Set Manning's n to Override Default Land Cover Values

Selected Area Edit Options: Add Constant ... Multiply Factor ... Set Values ... Replace ...

Land Cover Layer		Geometry Overrides (Blank for Default Values)	
Name	Default Mann n	Base Mann n (blank for default)	
1		0.06	

Associated Layer: Not yet associated with this Geometry

OK Cancel

2D Flow Area Computation Points

Default Manning's n Value: 0.06

Mesh contains: 18632 cells

Cell Volume Filter Tol(ft): 0.01

Face Profile Filter Tol(ft): 0.01

Face Area-Elev Filter Tol(ft): 0.01

Face Conveyance Tol Ratio: 0.02

Generate Computation Points on Regular Interval with All Breaklines...

Enforce Selected Breaklines (and internal Connections) ...

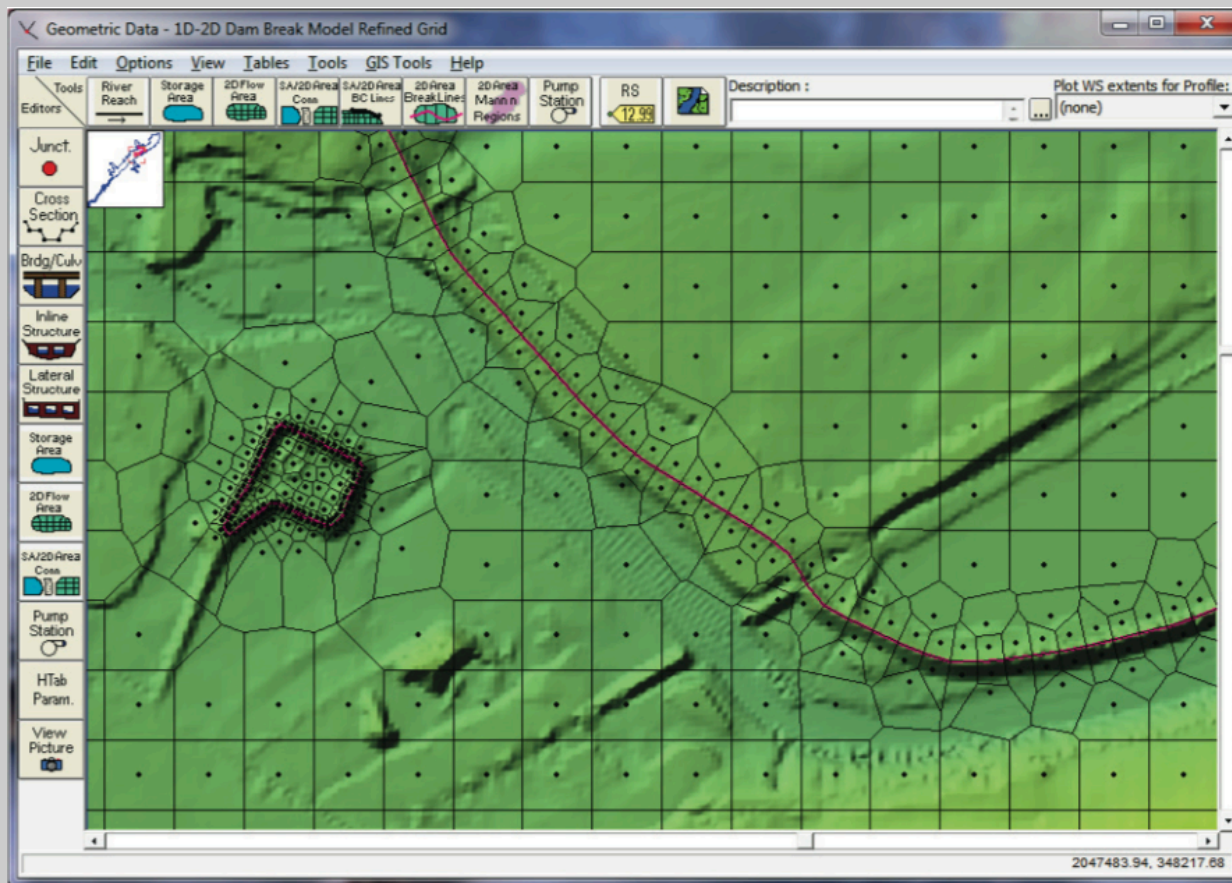
View/Edit Computation Points ...

Force Mesh Recomputation

OK Cancel

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

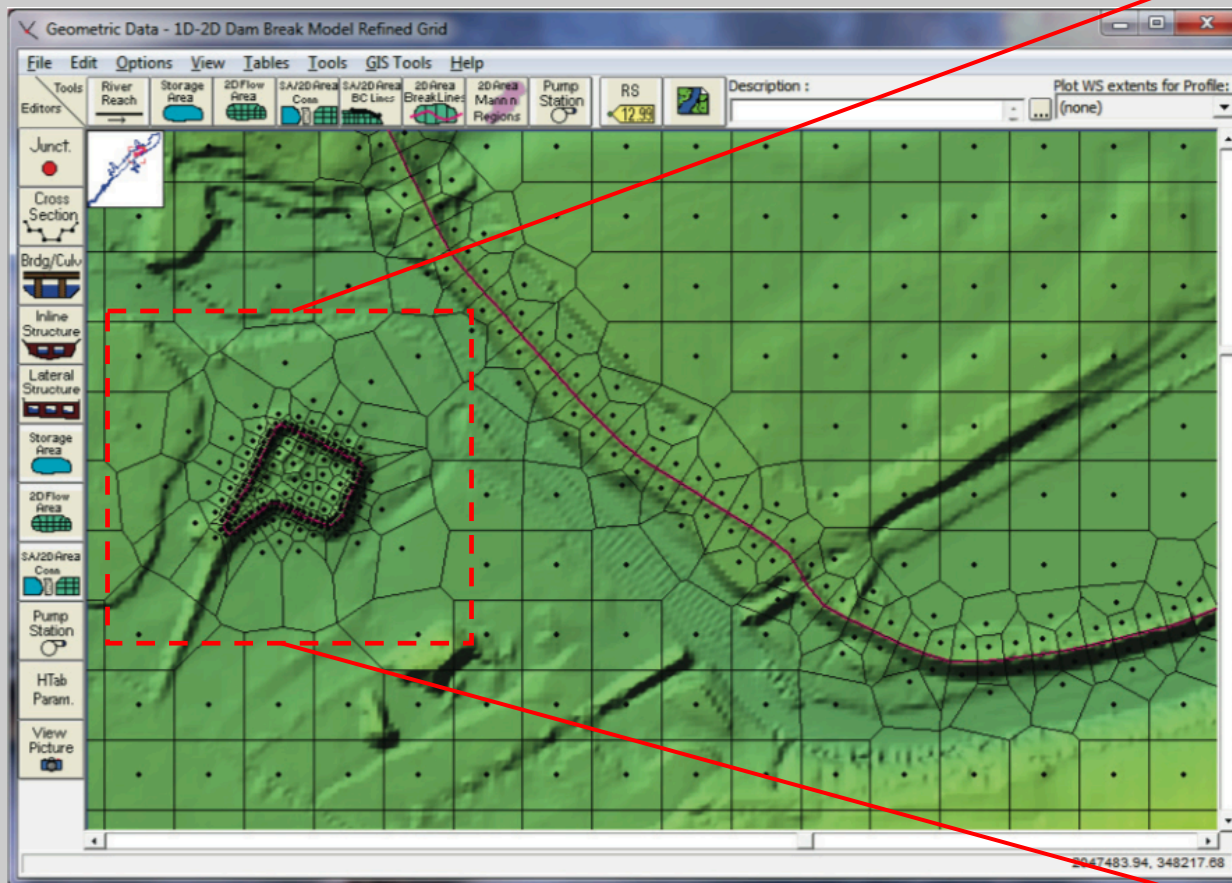
- Assessing the 2D Computational Mesh:
 - The computational mesh will control the movement of water through the 2D flow area.
 - The computational cell faces control the flow movement from cell to cell.
 - One water surface elevation is calculated for each grid cell center at each time step.



- Within HEC-RAS, the underlying terrain and the computational mesh are preprocessed in order to develop detailed elevation-volume relationships for each cell, and also detailed hydraulic property curves for each cell face (elevation vs. wetted perimeter, area, and roughness).
- Where the water surface slope is flat and not changing rapidly, larger grid cell sizes are appropriate.
- Steeper slopes, and localized areas will require smaller grid cells to capture those changes.

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Assessing the 2D Computational Mesh:
 - The computational mesh will control the movement of water through the 2D flow area.
 - The computational cell faces control the flow movement from cell to cell.
 - One water surface elevation is calculated for each grid cell center at each time step.



- HEC-RAS allows the user to enter a new break line on top of an existing mesh and then regenerate the mesh around that break line, without changing the computational points of the mesh in other areas.
- The user can draw a new break line, then left click on the break line and select the option **“Enforce Break line in 2D Flow Area”**. Once this option is selected, new cells will be generated around the break line with cell faces that are aligned along the break line.

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Assessing the 2D Computational Mesh:
 - The user can control the size/spacing of cells along the break line.
 - The option **“Edit Break Line Cell Spacing”** allows the user to enter a minimum and maximum cell spacing to be used when forming cells along that break line. The minimum cell spacing is used directly along the break line.

The screenshot displays the HEC-RAS interface with a 2D computational mesh overlaid on a topographic map. A red dashed line indicates a break line. A callout box points to the mesh along the break line, stating: "The min cell size gets used right along the break line, then it transitions out the max cell size by doubling the cell size as it goes outward from the break line." Another callout box points to the 'Edit Break Line Cell Spacing' dialog box, which is titled 'HEC-RAS' and 'Enter Breakline Cell Spacing'. The dialog box contains the following options and values:

- Break Line: 'Middle' [spacing 250 to 250]
- Edit Break Line Data ...
- Edit Break Line Cell Spacing ...
- Enforce Breakline in 2D Flow Area '2DFlowArea_Test'
- Plot Profile (from Terrain) ...
- Convert this Break Line into a new internal SA/2D Area Connection ...
- Delete Break Line ...

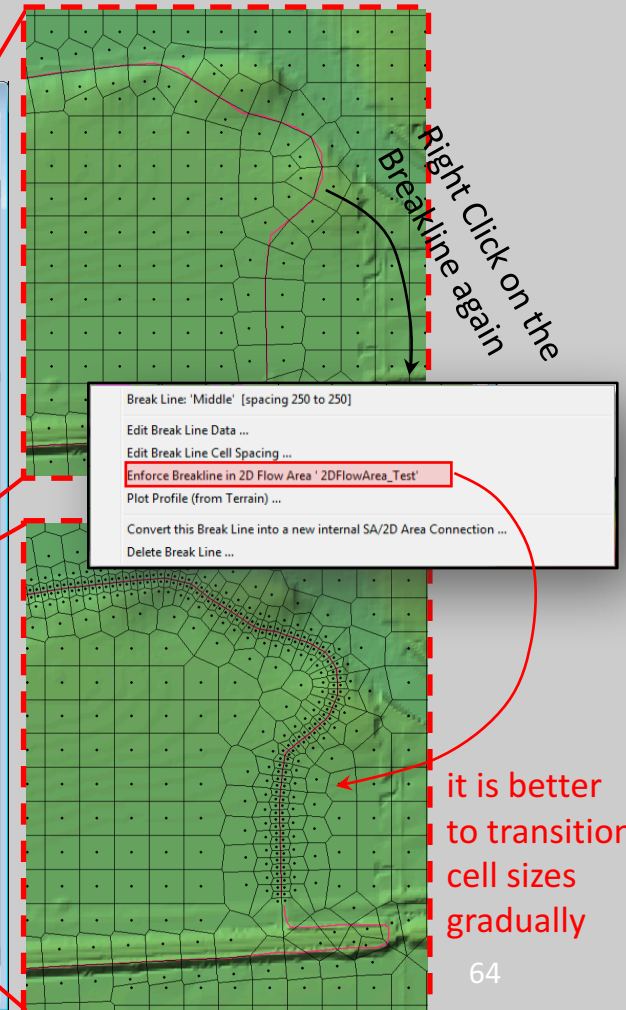
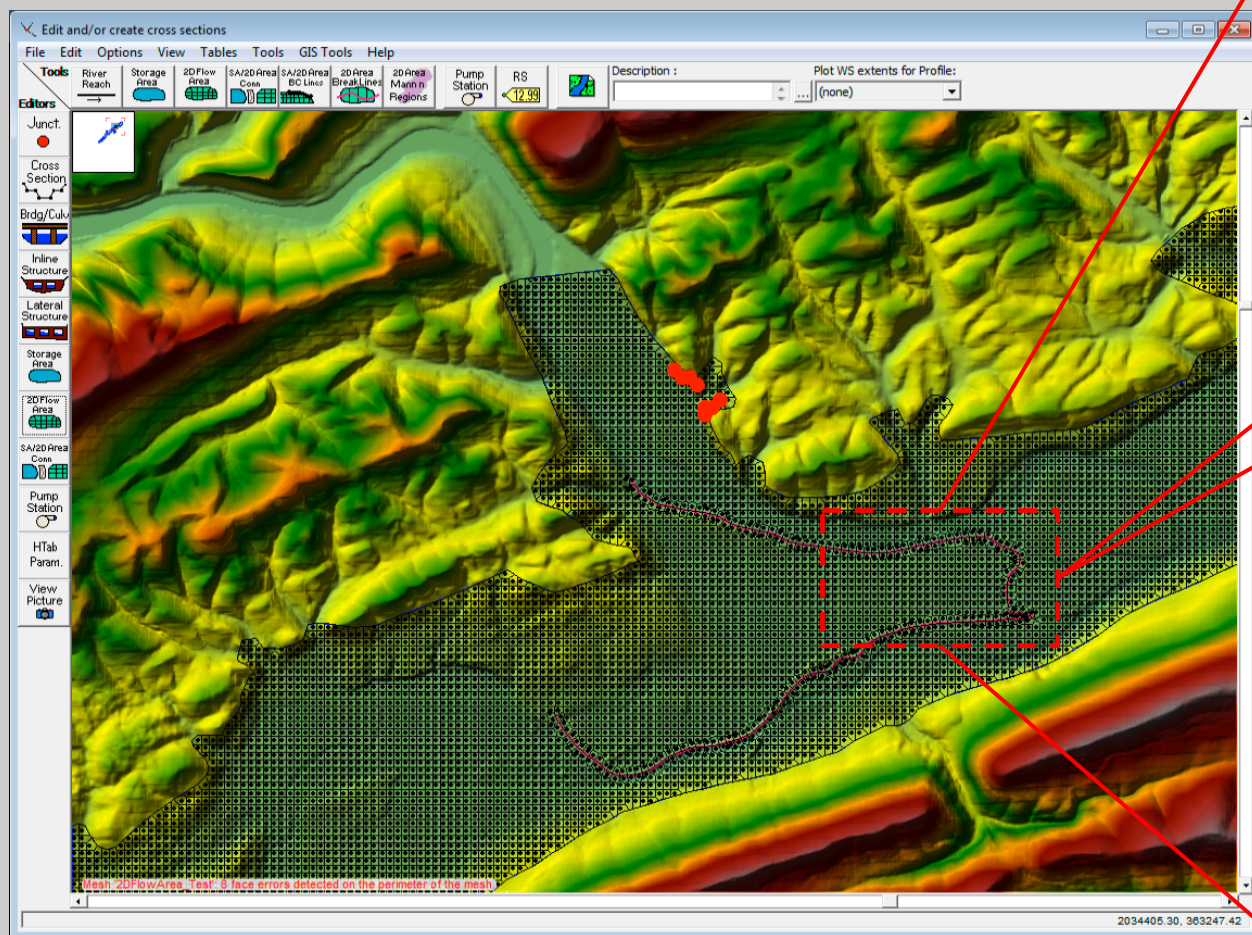
The 'Enter Breakline Cell Spacing' dialog box shows the following values:

Parameter	Value
Minimum (blank for mesh spacing)	50
Maximum (blank for mesh spacing)	250

Buttons: OK, Cancel, Defaults, Help

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

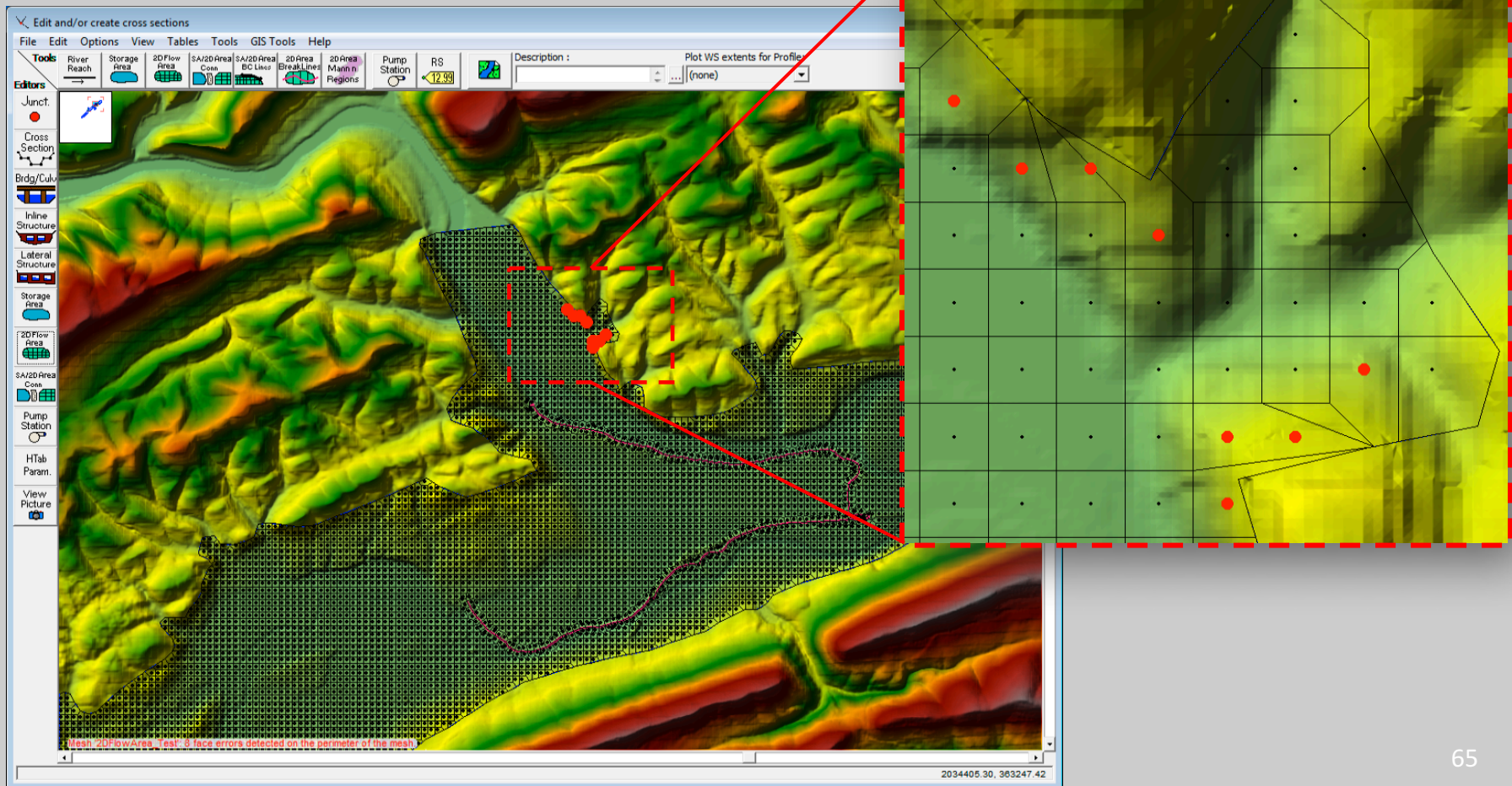
- Assessing the 2D Computational Mesh:
 - After entering the break line cell spacing the user must select the **“Enforce Break line in 2D Flow Area”** option to enforce the new association of cell spacing.
 - When creating a mesh around a break line, it may be desirable or even necessary to use smaller cells than the nominal cell size used in other areas of the mesh.



3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Assessing the 2D Computational Mesh:

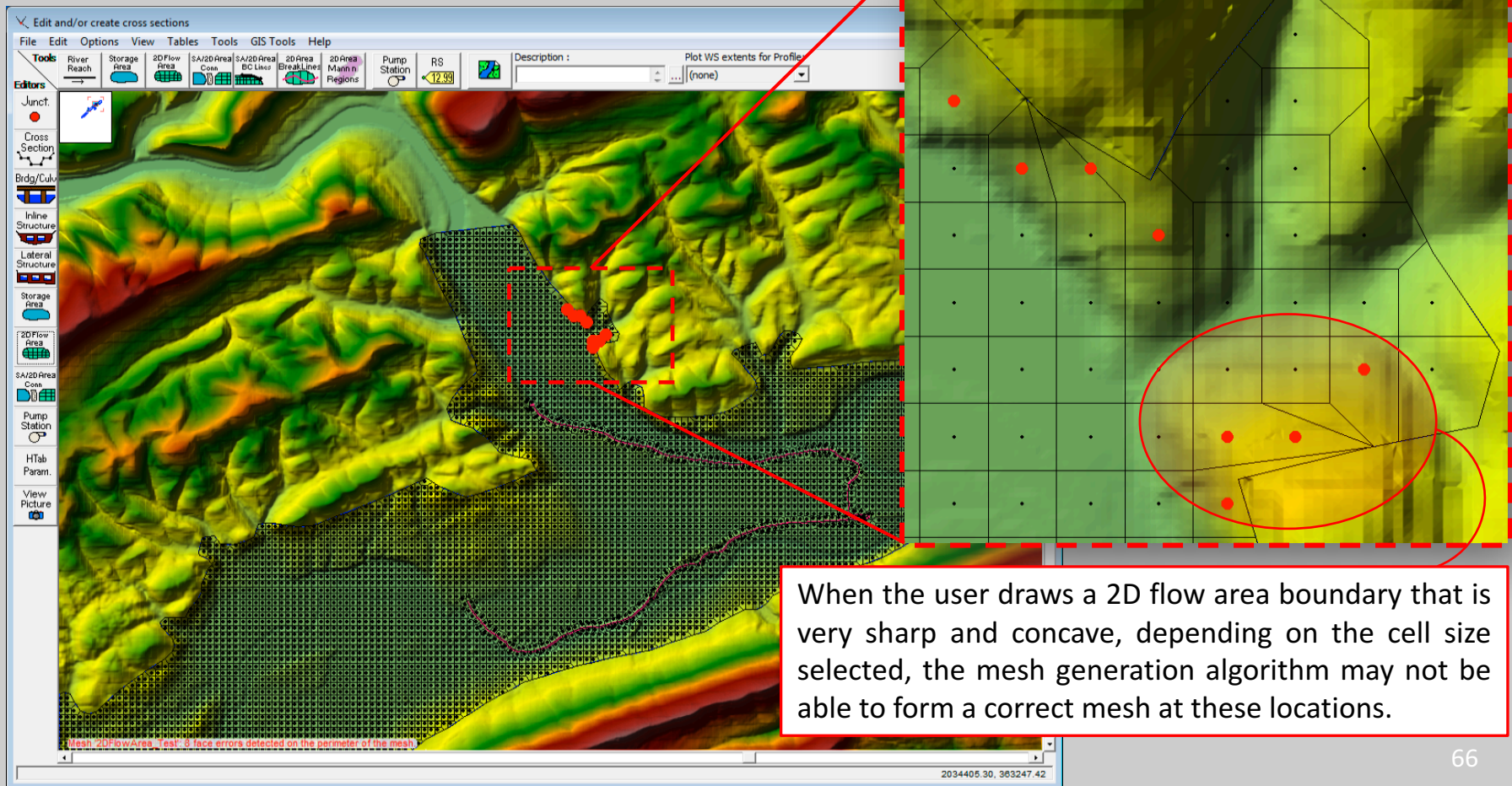
- Cells around the break lines and the 2D flow area boundary will typically be irregular in shape, in order to conform to the user specified break lines and boundary polygon.
- The mesh generation tools utilize the irregular boundary, as well as try to ensure that no cell is smaller in area than the nominal cell size.



3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Assessing the 2D Computational Mesh:

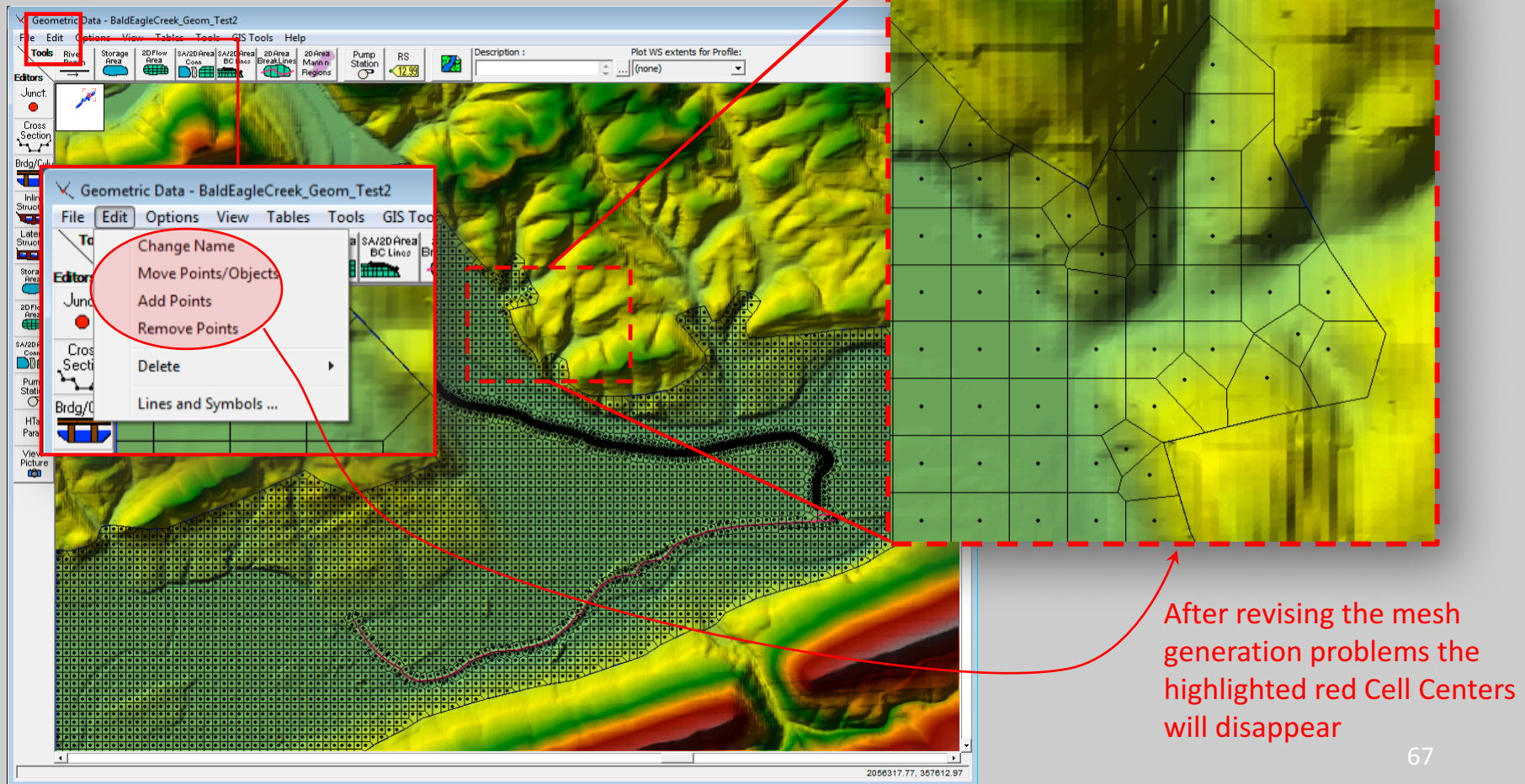
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3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

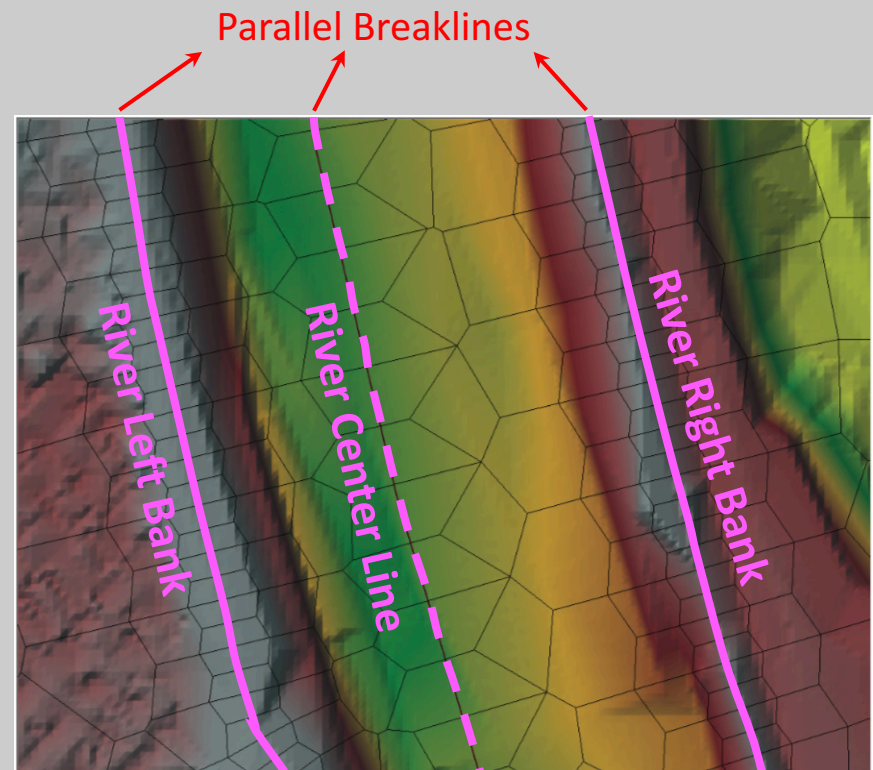
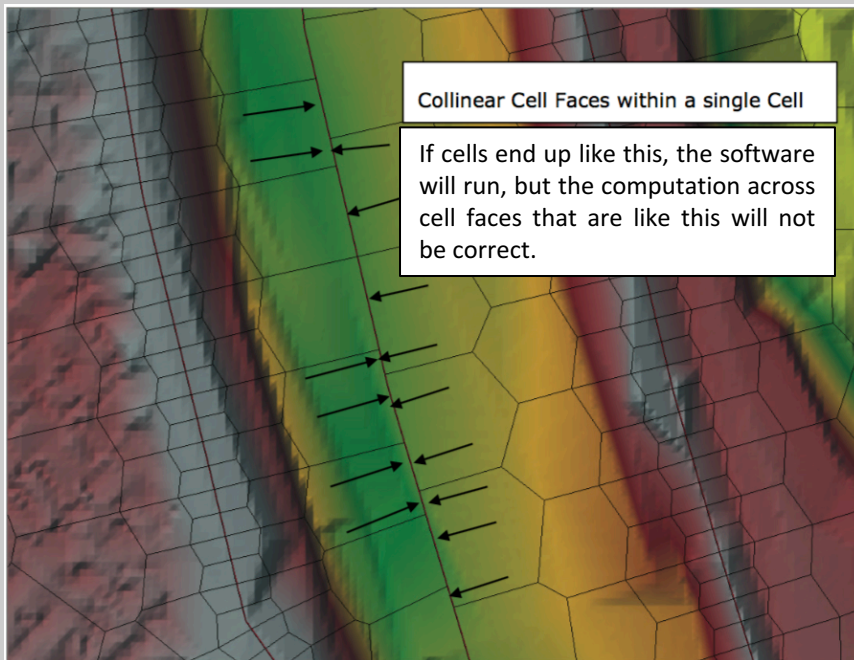
- Assessing the 2D Computational Mesh:

- Cells around the break lines and the 2D flow area boundary will typically be irregular in shape, in order to conform to the user specified break lines and boundary polygon.
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3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

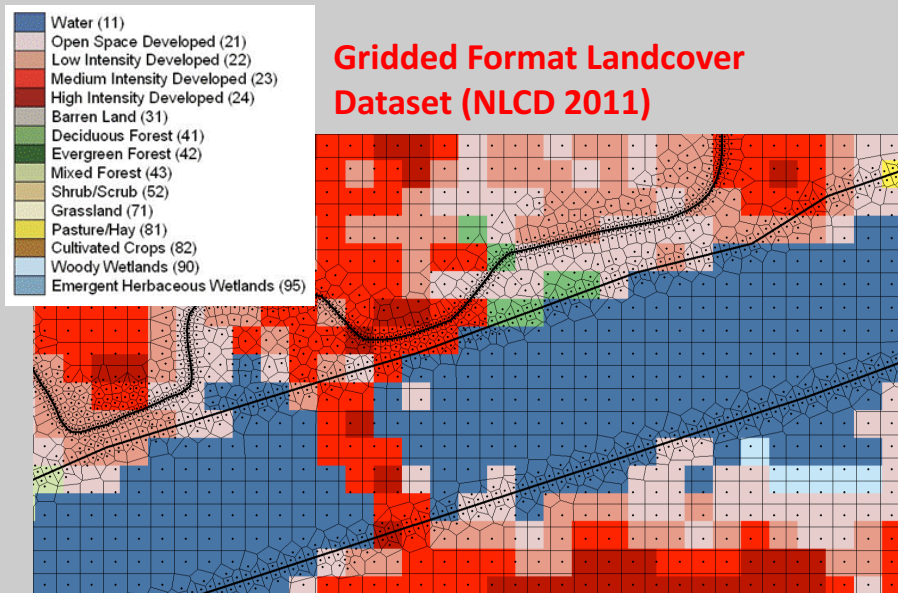
- Assessing the 2D Computational Mesh:
 - Computational cells used within the HEC-RAS 2D code cannot have two faces that are collinear (i.e. they cannot form a straight line).
 - The problem of “**Cell with Collinear Faces**” generally caused by placing two or more break lines parallel to each other, and close together, such that the creation of cells along one break line can create problems with cells along the other break line. (like the left figure below)
 - Where two cells meet (at a face point), the outside angle formed by the two faces must be greater than 180 degrees.



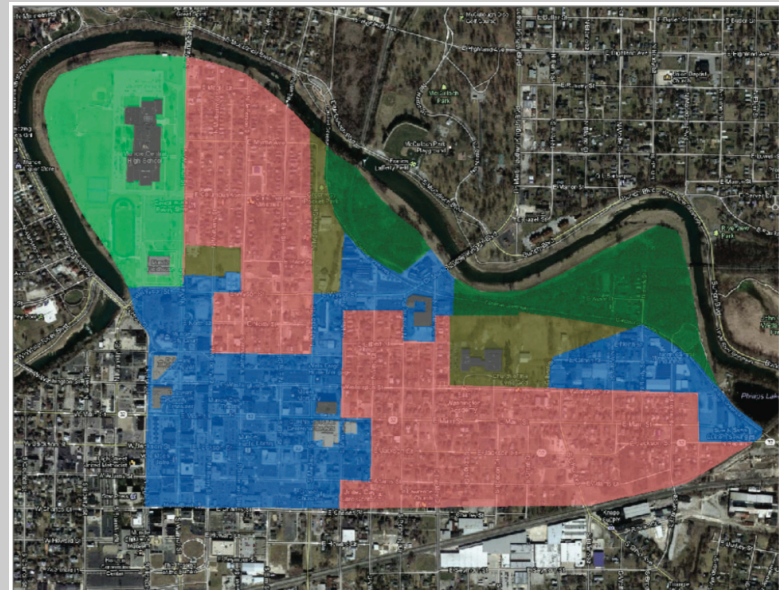
3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Creating a Spatially Varied Manning's Roughness Layer:
 - A spatially varying land cover data set can be created in RAS Mapper, and then associated with a specific geometry data set.
 - There are two types of land cover layers which can be applied in HEC-RAS 2D: 1. user defined polygons (shapefile) where user can override specific roughness values to a particular area, 2. Classified gridded layer (e.g. National Landcover Dataset layers).
 - **NOTE:** User's must have a land cover data set in order utilize spatially varying Manning's n values within 2D Flow Areas, and to also utilize the capability of specifying User define Manning's n Regions.
 - **RAS Mapper** allows the user to use multiple land use data files and types, to create a single land use coverage layer in HEC-RAS.
 - **RAS Mapper** ingests the various land use data types and creates a combined land-use coverage (Layer) and stores it as a **GeoTIFF file**.

Gridded Format Landcover Dataset (NLCD 2011)

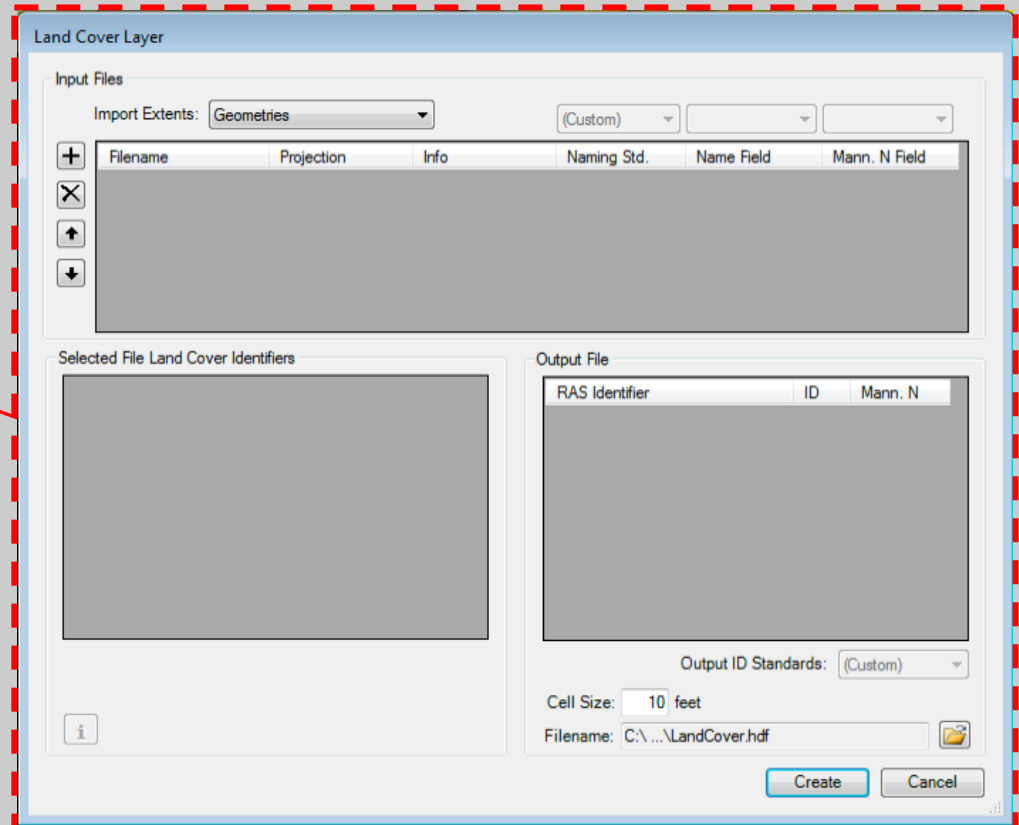
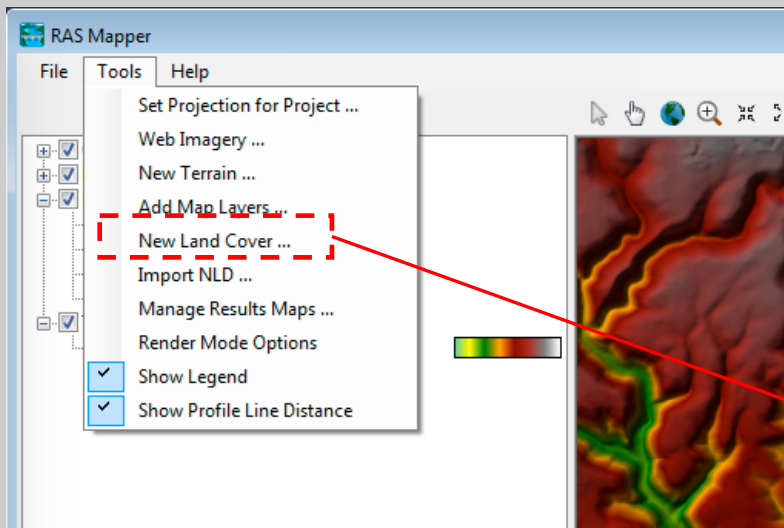


User-defined polygon (shapefile) as landcover layers



3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

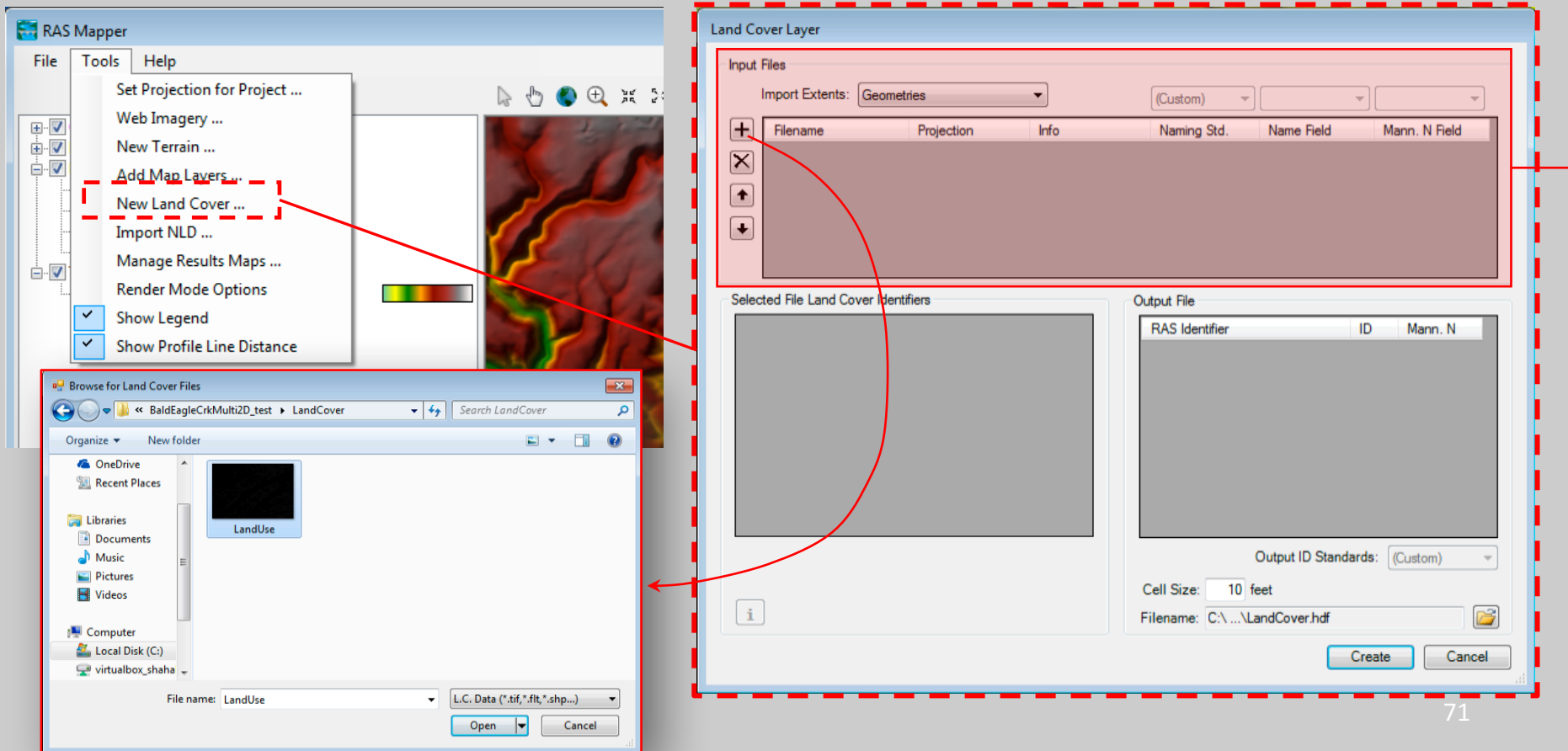
- Creating a Spatially Varied Manning's Roughness Layer:
 - A spatially varying land cover data set can be created in RAS Mapper, and then associated with a specific geometry data set.



3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Creating a Spatially Varied Manning's Roughness Layer:
 - A spatially varying land cover data set can be created in RAS Mapper, and then associated with a specific geometry data set.

The **"Input Files"** section is for selecting the grid and shapefiles to be used as input, as well as setting their priority.



3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Creating a Spatially Varied Manning's Roughness Layer:

- A spatially varying land cover data set can be created in RAS Mapper, and then associated with a specific geometry data set.

The Selected File Land Cover Identifiers section is used to display the numeric value (Integer) and the text label of the land cover data for the file currently selected (highlighted) in the Input Files section.

RAS Mapper

File Tools Help

- Set Projection for Project ...
- Web Imagery ...
- New Terrain ...
- Add Map Layers ...
- New Land Cover ...**
- Import NLD ...
- Manage Results Maps ...
- Render Mode Options
- Show Legend
- Show Profile Line Distance

Land Cover Layer

Input Files

Import Extents: Geometries (Custom)

Filename	Projection	Info	Naming Std.	Name Field	Mann. N Field
LandUse.tif	(Same as Project)	Cell Size: 5 US su...	(Custom)	N/A	N/A

Selected File Land Cover Identifiers

Name Field	RAS Identifier
0	NoData
3	3
9	9
11	11
1	1
7	7
2	2
5	5

Output File

RAS Identifier	ID	Mann. N
NoData	0	
1	1	
10	2	
11	3	
12	4	
13	5	
14	6	

Output ID Standards: (Custom)

Cell Size: 10 feet Output Size: ~1 MB

Filename: C:\...\LandCover.hdf

Create Cancel

Legend

- Water (11)
- Open Space Developed (21)
- Low Intensity Developed (22)
- Medium Intensity Developed (23)
- High Intensity Developed (24)
- Barren Land (31)
- Deciduous Forest (41)
- Evergreen Forest (42)
- Mixed Forest (43)
- Shrub/Scrub (52)
- Grassland (71)
- Pasture/Hay (81)
- Cultivated Crops (82)
- Woody Wetlands (90)
- Emergent Herbaceous Wetlands (95)

You can edit/rename the "RAS identifier" according to the **NLCD 2011 landcover IDs**.

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Creating a Spatially Varied Manning's Roughness Layer:
 - A spatially varying land cover data set can be created in RAS Mapper, and then associated with a specific geometry data set.

The Output File section is used to show what HEC-RAS will use for the Land Cover Identifiers, their numeric ID, and optionally a user entered Manning's n value for each Land Cover type

The image displays two screenshots from the HEC-RAS software interface. The left screenshot shows the RAS Mapper application with the 'Tools' menu open, highlighting 'New Land Cover ...'. The right screenshot shows the 'Land Cover Layer' dialog box, which is used to define the land cover data set and its output file.

RAS Mapper - Tools Menu

- File
- Tools
- Help
- Set Projection for Project ...
- Web Imagery ...
- New Terrain ...
- Add Map Layers ...
- New Land Cover ...**
- Import NLD ...
- Manage Results Maps ...
- Render Mode Options
- Show Legend

Land Cover Layer Dialog Box

Input Files

Filename	Projection	Info	Naming Std.	Name Field	Mann. N Field
LandUse.tif	(Same as Project)	Cell Size: 5 US su...	(Custom)	N/A	N/A

Selected File Land Cover Identifiers

Name Field	RAS Identifier
15	woody wetlands
14	shrub/scrub
12	open water
8	emergent herbaceous wet...
10	grassland/herbaceous
13	pasture/hay
4	developed, high intensity

Output File

RAS Identifier	ID	Mann. N
NoData	0	
barren land rock/sand/clay	1	0.04
cultivated crops	8	0.06
deciduous forest	9	0.1
developed, high intensity	10	0.15
developed, low intensity	11	0.1
developed, medium intensity	13	0.08

Set Manning's n to Override Default Land Cover Values

Selected Area Edit Options: Add Constant ... Multiply Factor ... Set Values ... Replace ...

Land Cover Layer		Geometry Overrides (Blank for Default Values)	
Name	Default Mann n	Base Mann n (blank for default)	MainChannel
1 nodata		0.06	0.04
2 barren land rock/sand/clay	0.04	0.04	0.04
3 cultivated crops	0.06	0.06	0.04
4 deciduous forest	0.1	0.1	0.04
5 developed, high intensity	0.15	0.15	0.04
6 developed, low intensity	0.1	0.1	0.04
7 developed, medium intensity	0.08	0.08	0.04
8 developed, open space	0.04	0.04	0.04
9 emergent herbaceous wetlands	0.08	0.08	0.04
10 evergreen forest	0.12	0.12	0.04
11 grassland/herbaceous	0.045	0.045	0.04
12 mixed forest	0.08	0.08	0.04
13 open water	0.035	0.035	0.04
14 pasture/hay	0.06	0.06	0.04
15 shrub/scrub	0.08	0.08	0.04
16 woody wetlands	0.12	0.12	0.04

Associated Layer: d:\...\Example Data\2D Unsteady Flow Hydraulics\BaldEagleCreekMulti2D\LandCover\LandUse.tif

Output ID Standards: (Custom)

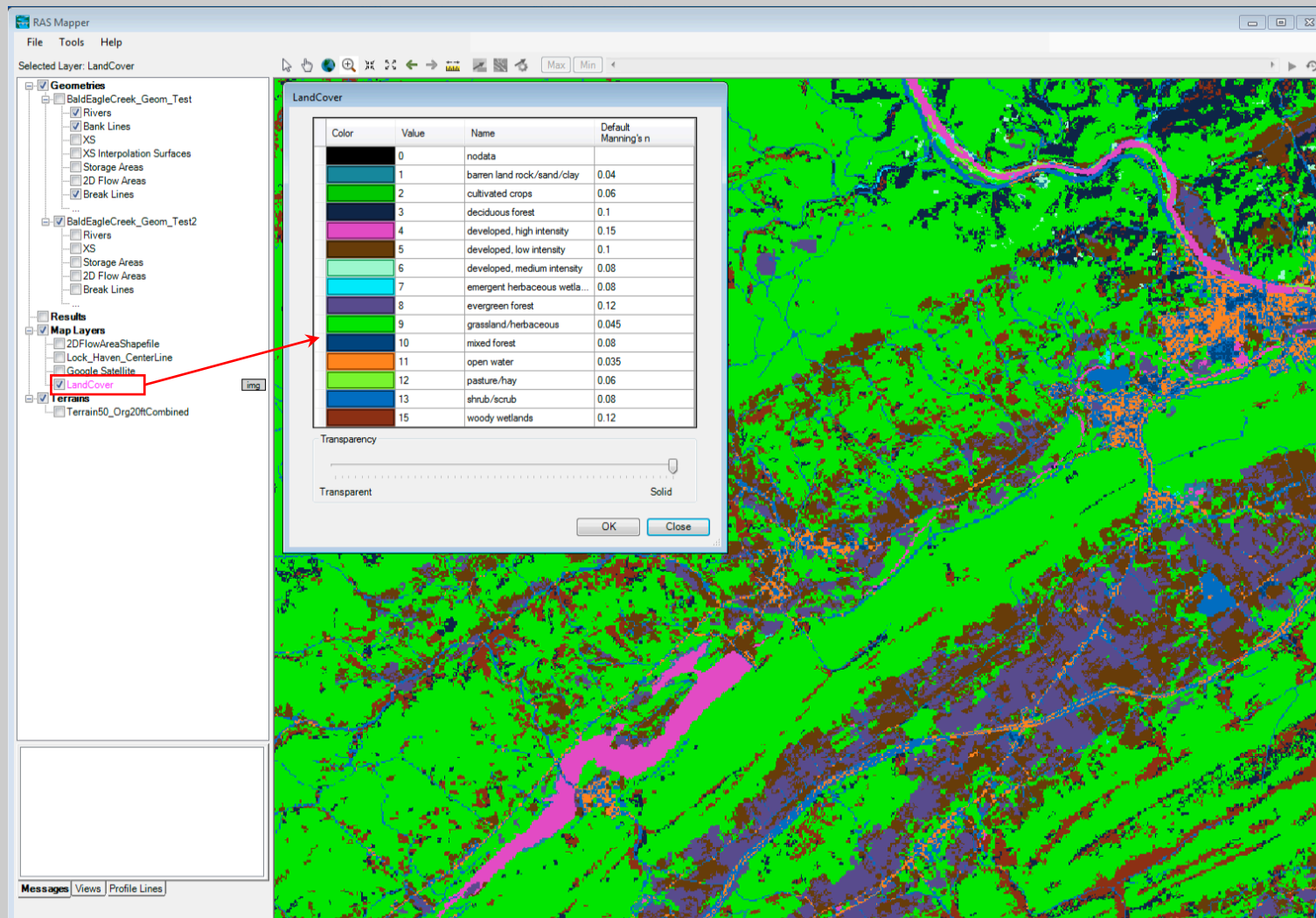
Cell Size: 10 feet Output Size: ~1 MB

Filename: C:\...\LandCover.tdf

Create Cancel

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Creating a Spatially Varied Manning's Roughness Layer:
 - A spatially varying land cover data set can be created in RAS Mapper, and then associated with a specific geometry data set.

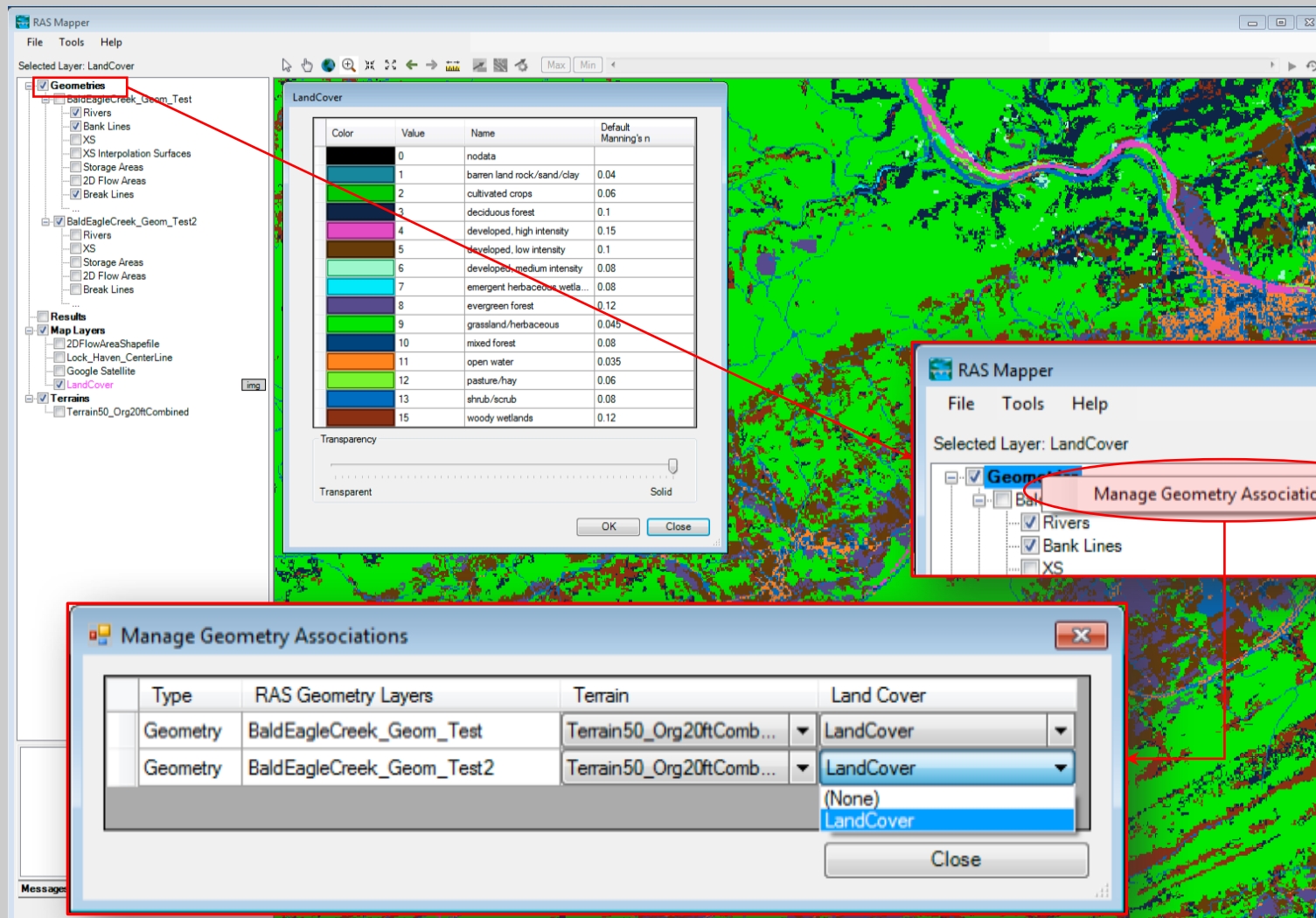


Once the user has created a Land Cover layer in the *.tif file format, then they need to associate that data layer with the geometry file(s) they want to use it with.

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

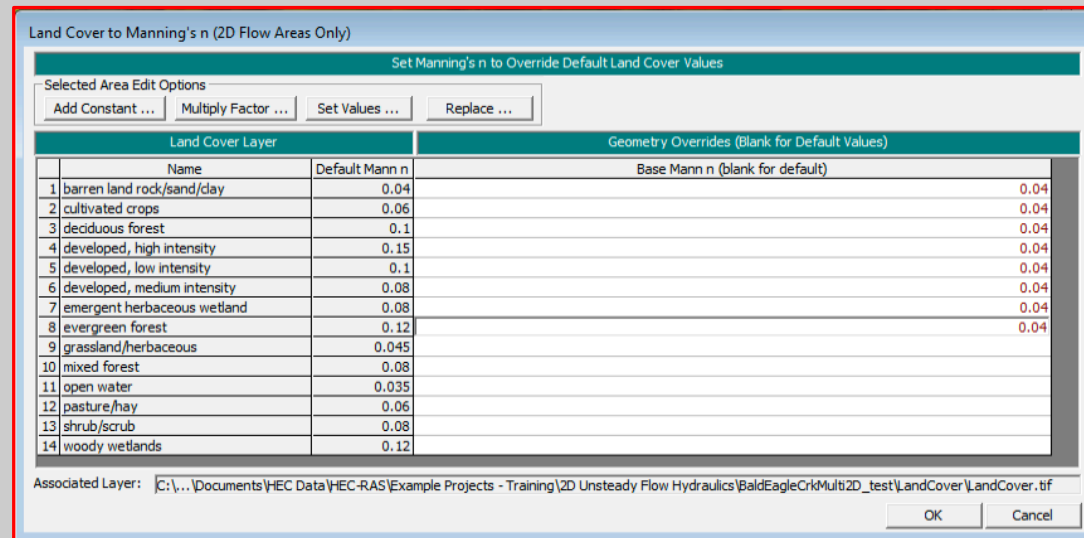
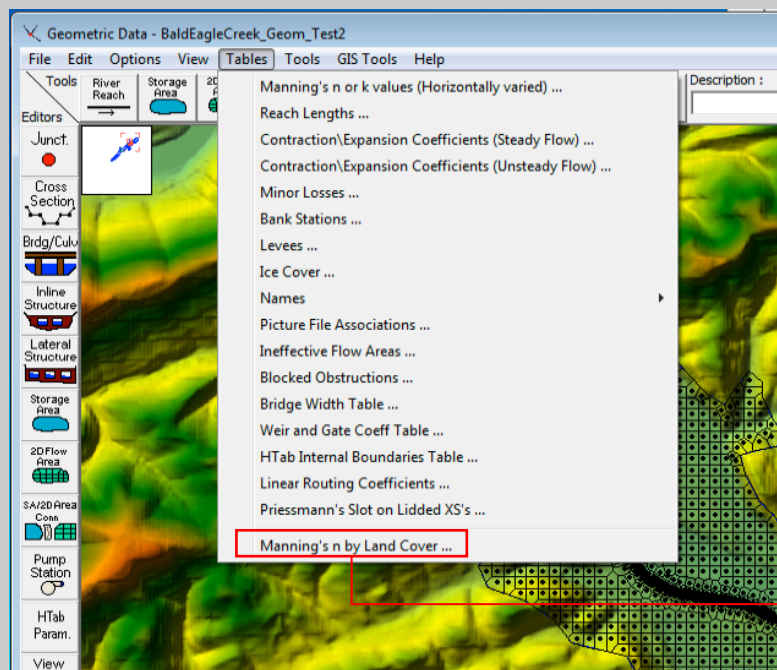
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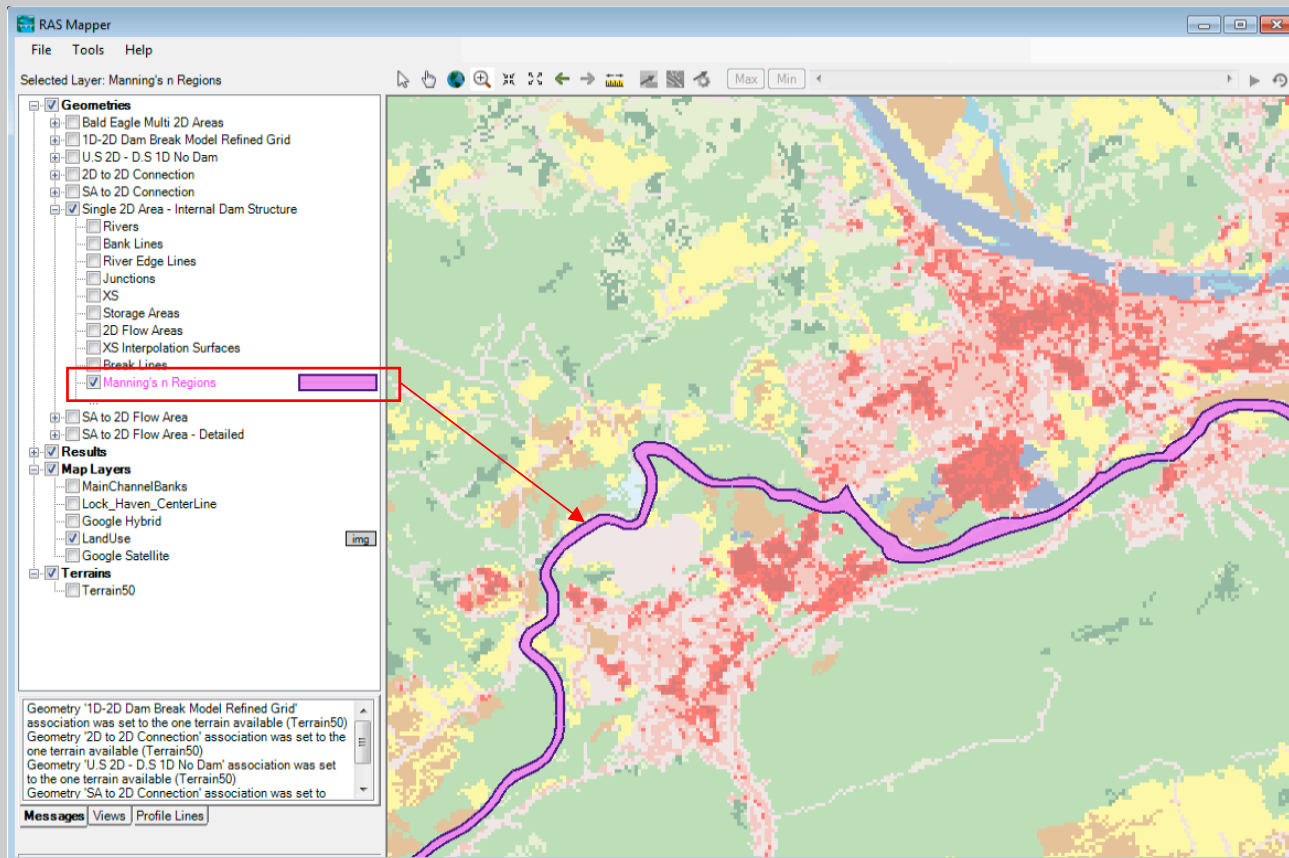
3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Creating a Spatially Varied Manning's Roughness Layer:
 - Once a Land Cover layer is associated with a geometry file, the user can then build a table of Land Cover versus Manning's n values, which can then be used in defining roughness values for 2D flow areas.
 - This Land Cover versus roughness table is developed from within the HEC-RAS geometric data editor for a specific geometry file.



3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

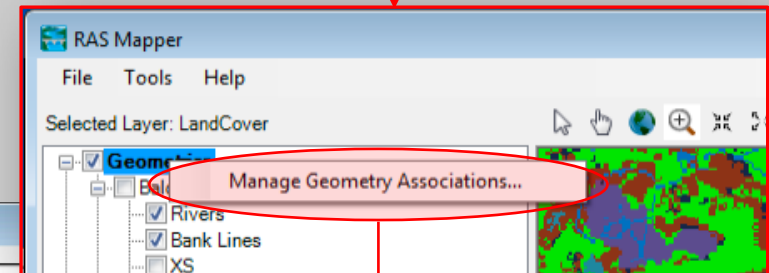
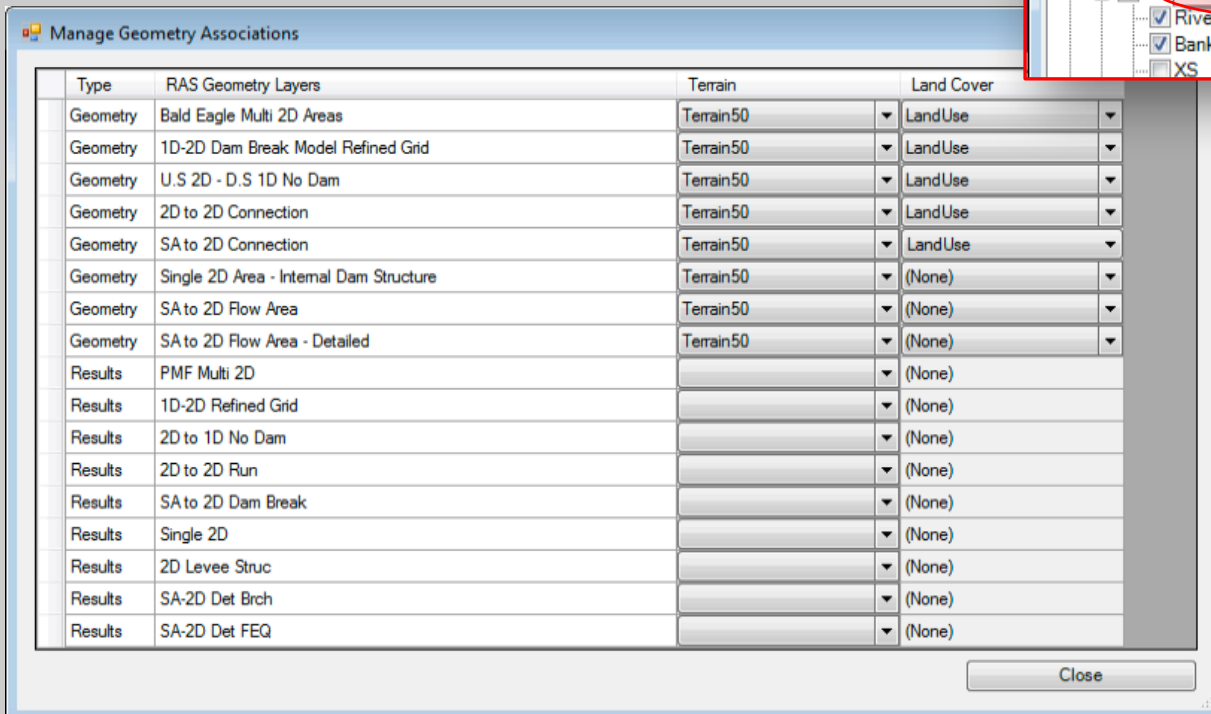
- Creating a Spatially Varied Manning's Roughness Layer:
 - In addition to defining Manning's n values by Land Cover, the user has the option to create their own 2D flow area Manning's n value regions.
 - These regions are user defined polygons that can be used to override the base Manning's n values within that polygon. They can also be used to calibrate a model.
 - The user defined 2D flow area "**Manning's n Regions**" are defined in the Geometric data editor, and apply only to that geometry file.



- This Manning's n by Land Cover table will be used during the 2D flow area pre-processing stage (i.e. the process where the software creates the cell and cell face table properties).
- In order to get these Manning's n values into the 2D flow area property tables, the 2D flow area Hydraulic Property tables **must be recomputed**.

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

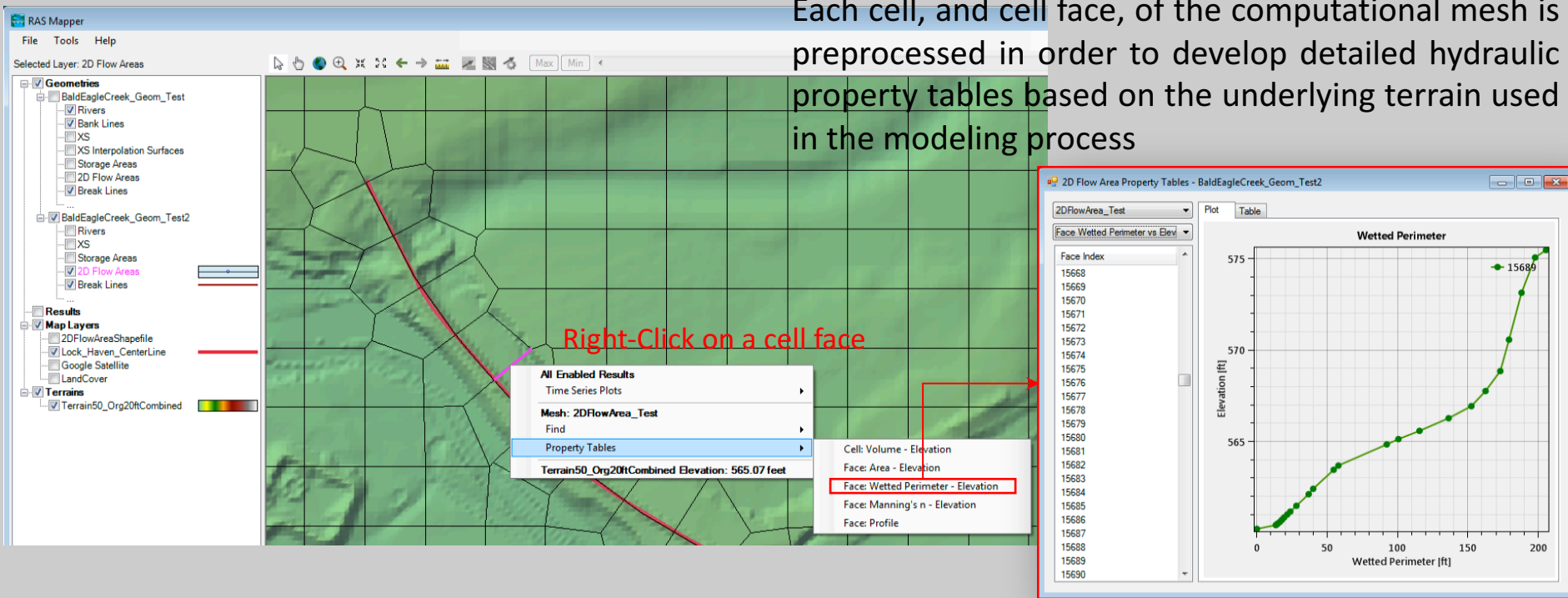
- Creating Hydraulic Property Tables for the 2D Cells and Cell Faces:
 - Once a terrain model is created, and optionally a Manning's n by Land Cover table, then the following steps are required to create the hydraulic property tables for the 2D cells and cell faces, which are used in the 2D hydraulic computations:
 - ✓ **Associating a Terrain Layer with a Geometry File**
 - ✓ 2D Cell and Cell Face Geometric Preprocessor
 - ✓ Running the 2D Geometric Preprocessor



3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

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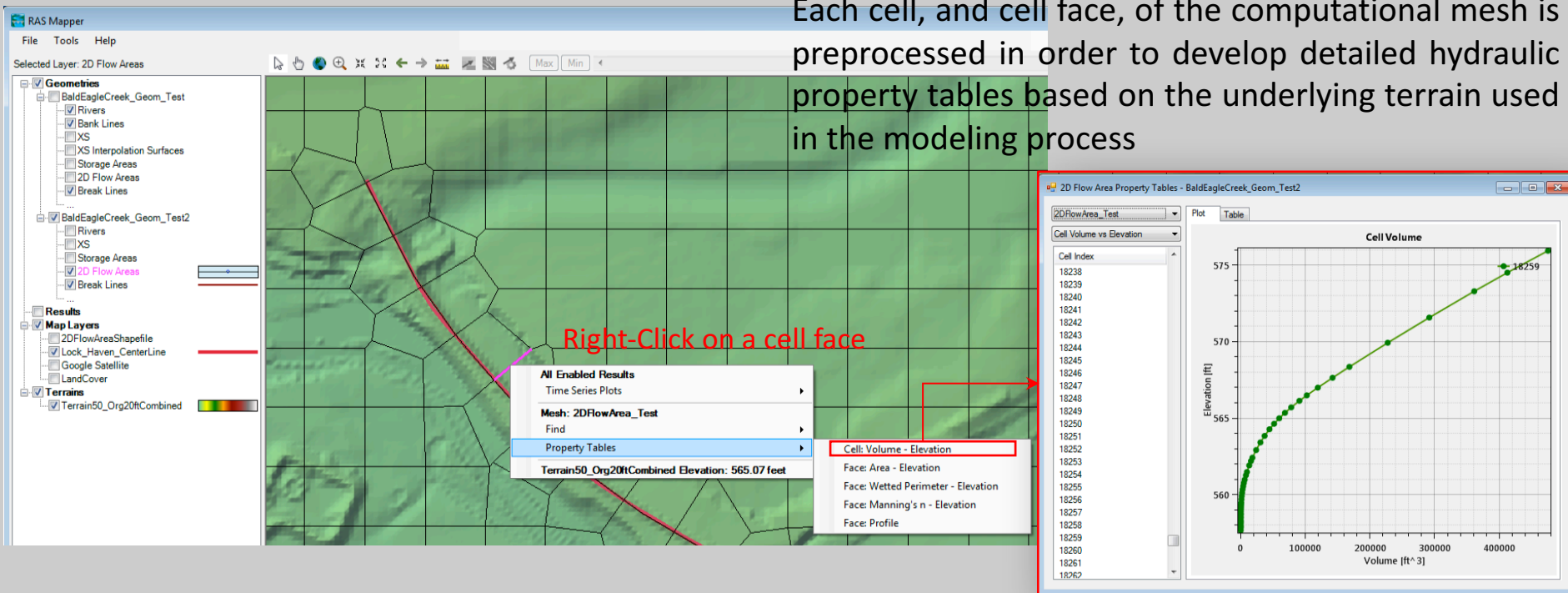
Each cell, and cell face, of the computational mesh is preprocessed in order to develop detailed hydraulic property tables based on the underlying terrain used in the modeling process



3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

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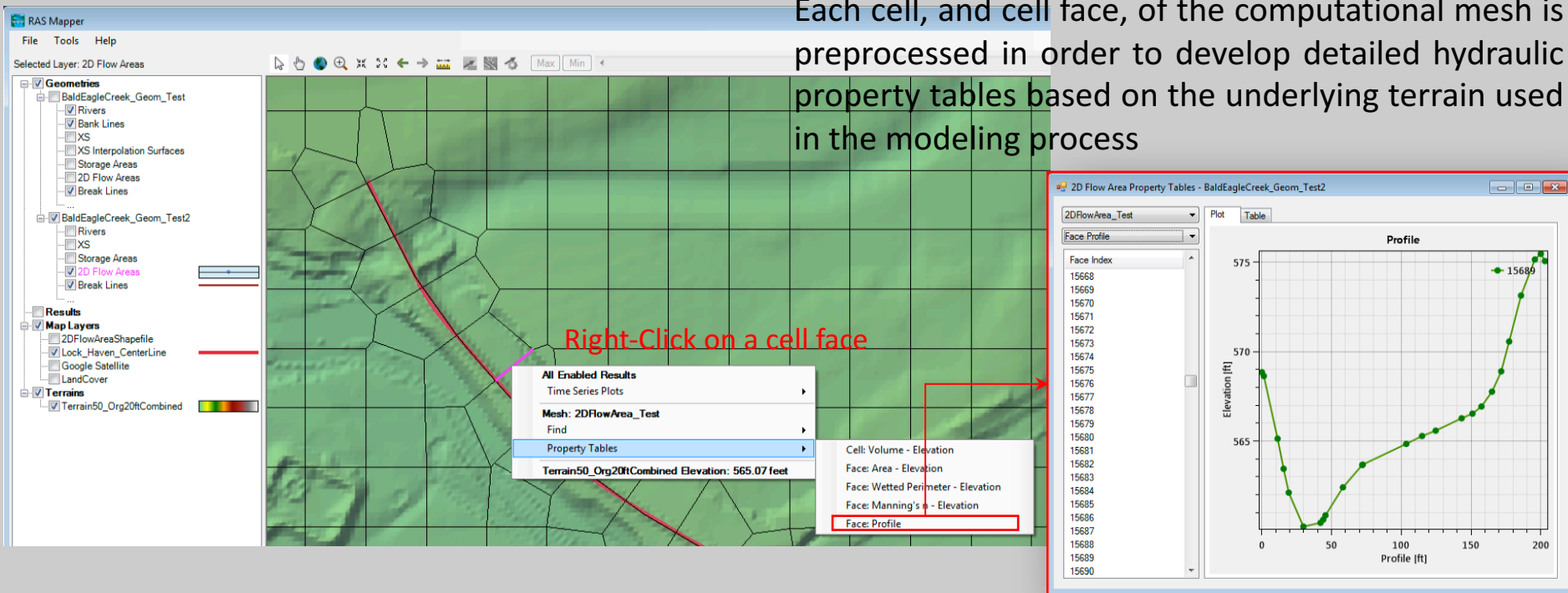
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Each cell, and cell face, of the computational mesh is preprocessed in order to develop detailed hydraulic property tables based on the underlying terrain used in the modeling process

The screenshot shows the RAS Mapper interface with the 2D Flow Areas layer selected. A right-click context menu is open over a cell face, showing options for creating property tables. The 'Face: Profile' option is highlighted. The '2D Flow Area Property Tables - BaldEagleCreek_Geom_Test2' window is also open, displaying a table of hydraulic properties for the selected cell face.

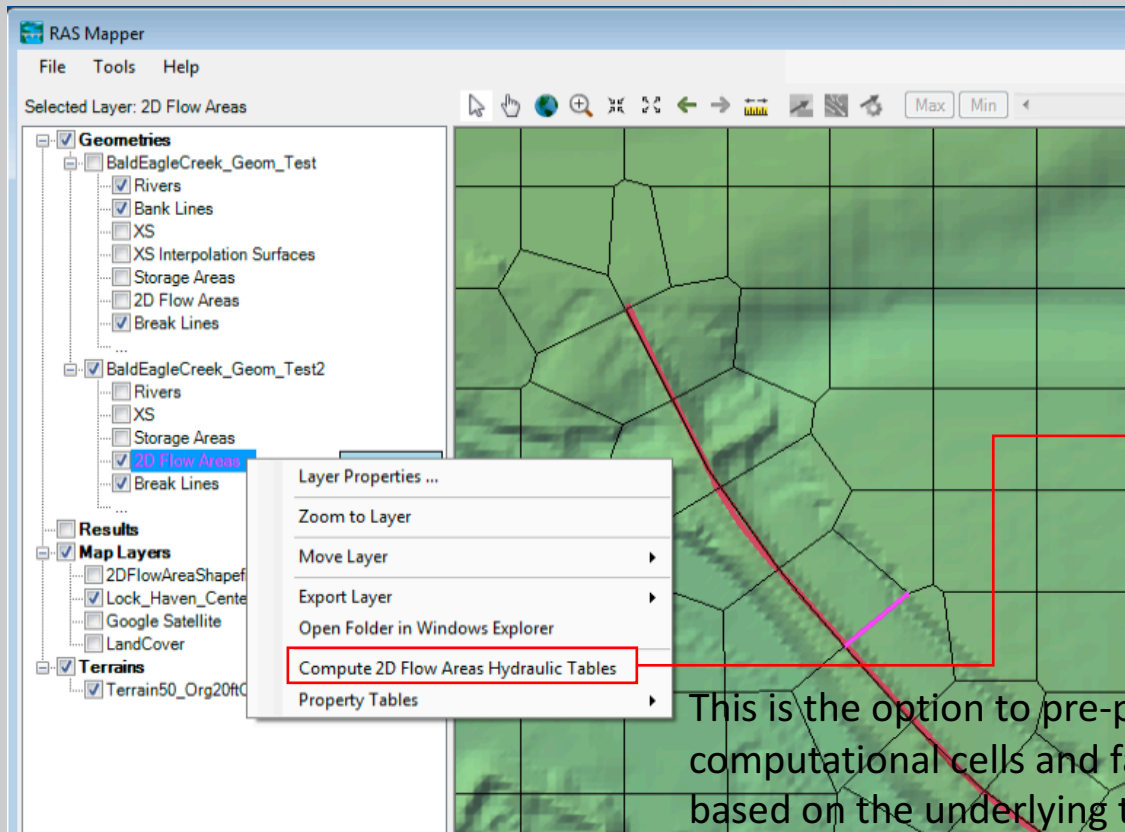
Right-Click on a cell face

Cell: Volume - Elevation
Face: Area - Elevation
Face: Wetted Perimeter - Elevation
Face: Manning's n - Elevation
Face: Profile

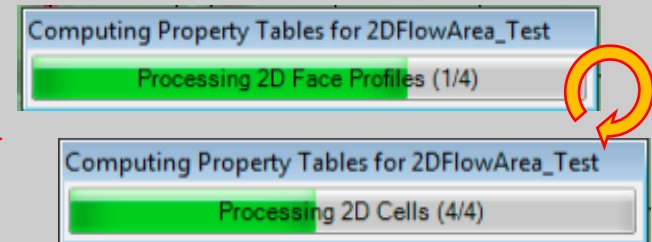
Face Index	Profile (ft)	Elevation (ft)
1	0	568.8569
2	1.4161	568.6416
3	11.3073	565.1329
4	15.6002	563.4509
5	19.2788	562.1188
6	29.7842	560.2157
7	42.0434	560.4257
8	43.9682	560.6025
9	45.6177	560.8467
10	58.1523	562.4123
11	71.9566	563.6633
12	72.3363	563.685
13	103.5155	564.8429
14	114.8885	565.2823
15	124.6344	565.5838
16	143.2565	566.2767
17	150.9733	566.5363
18	157.4406	566.938
19	164.9875	567.7643

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- Creating Hydraulic Property Tables for the 2D Cells and Cell Faces:
 - Once a terrain model is created, and optionally a Manning's n by Land Cover table, then the following steps are required to create the hydraulic property tables for the 2D cells and cell faces, which are used in the 2D hydraulic computations:
 - ✓ Associating a Terrain Layer with a Geometry File
 - ✓ 2D Cell and Cell Face Geometric Preprocessor
 - ✓ **Running the 2D Geometric Preprocessor**



After associating the geometry files with the terrain layer, the user can run the 2D flow area geometric pre-processor from within RAS Mapper.



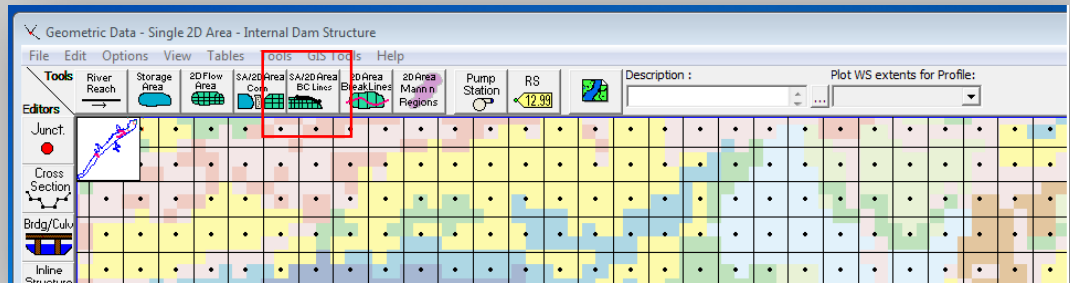
This is the option to pre-process the 2D flow area computational cells and faces into detailed tables based on the underlying terrain data.

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- External 2D flow area Boundary Conditions:

- In addition to connecting a 2D flow area to 1D River Reaches and Storage Areas, there are five types of external boundary conditions that can be linked directly to the 2D flow areas:

- ✓ Flow Hydrograph
- ✓ Stage Hydrograph
- ✓ Normal Depth
- ✓ Rating Curve
- ✓ Precipitation



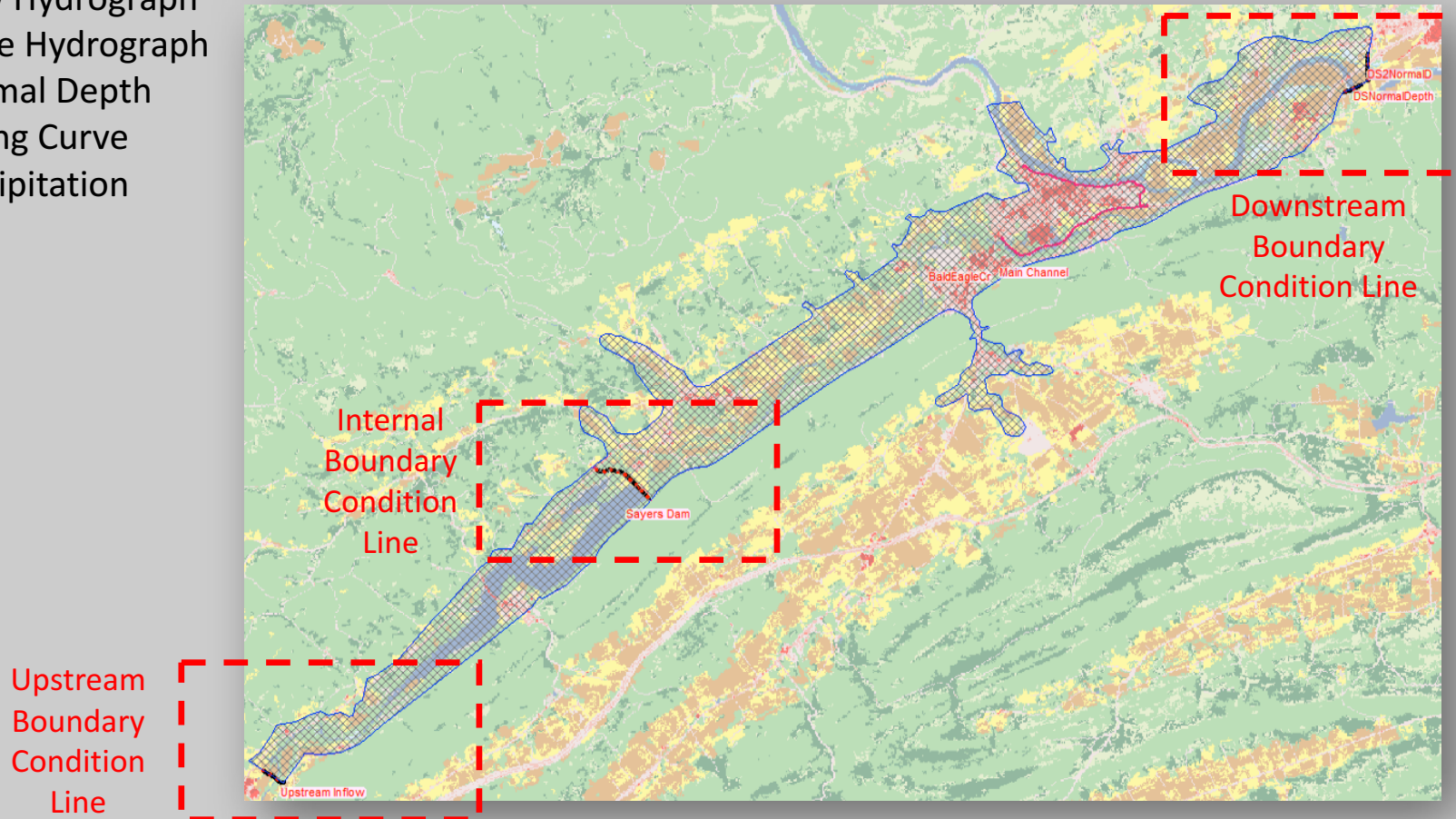
- The **Normal Depth** and **Rating Curve** boundary conditions can only be used at locations where flow will leave a 2D flow area.
- The **Flow** and **Stage Hydrograph** boundary conditions can be used for putting flow into or taking flow out of a 2D flow area.
- For a **Flow Hydrograph**, positive flow values will send flow into a 2D flow area, and negative flow values will take flow out of a 2D area.
- For the **Stage Hydrograph**, stages higher than the ground/water surface in a 2D flow area will send flow in, and stages lower than the water surface in the 2D flow area will send flow out.
- If a cell is dry and the **Stage** boundary condition is lower than the 2D flow area cell minimum elevation, then no flow will transfer.
- The **Precipitation** boundary condition can be applied directly to any 2D flow area as a time series of rainfall excesses

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

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- ✓ Precipitation

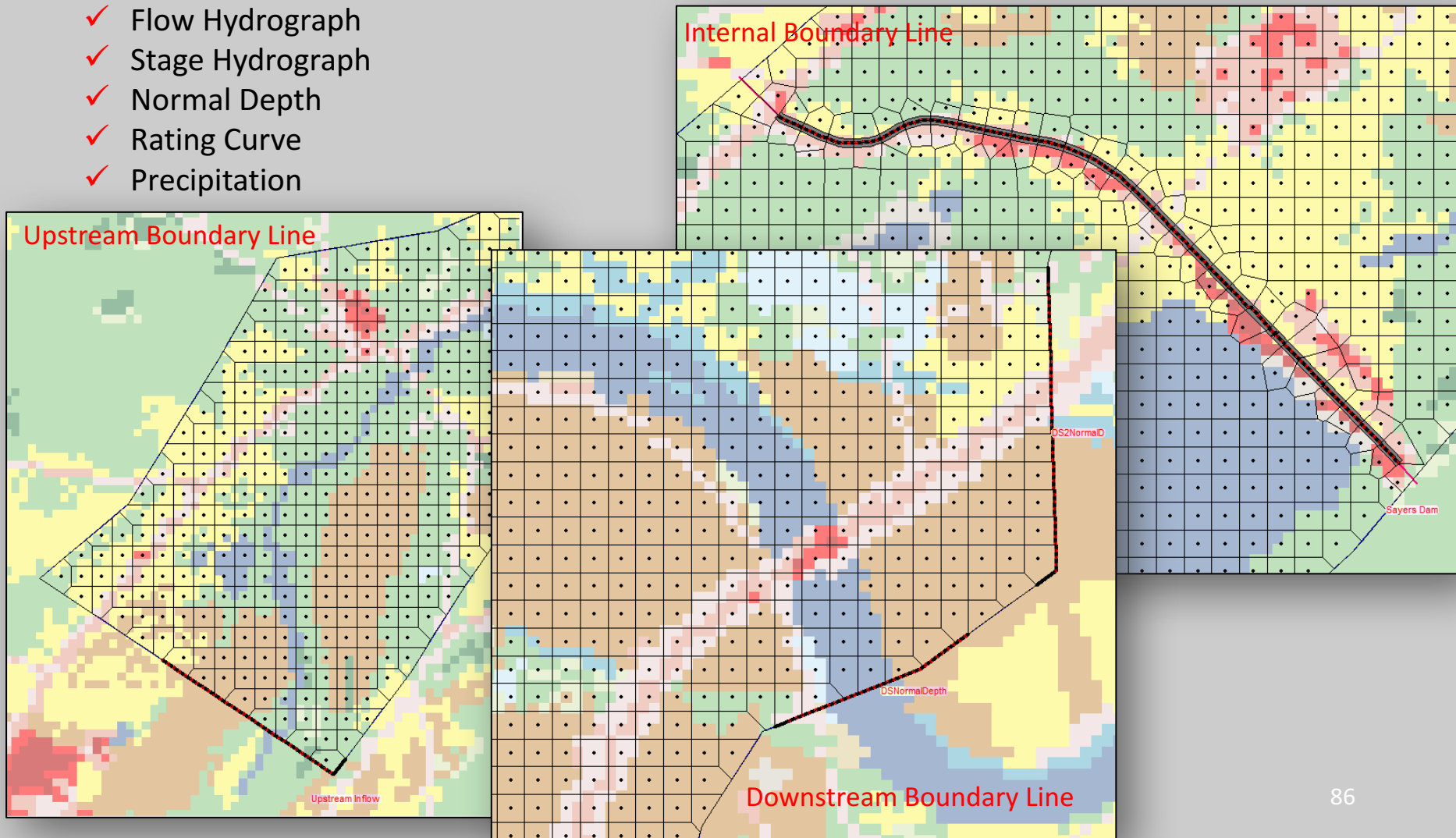


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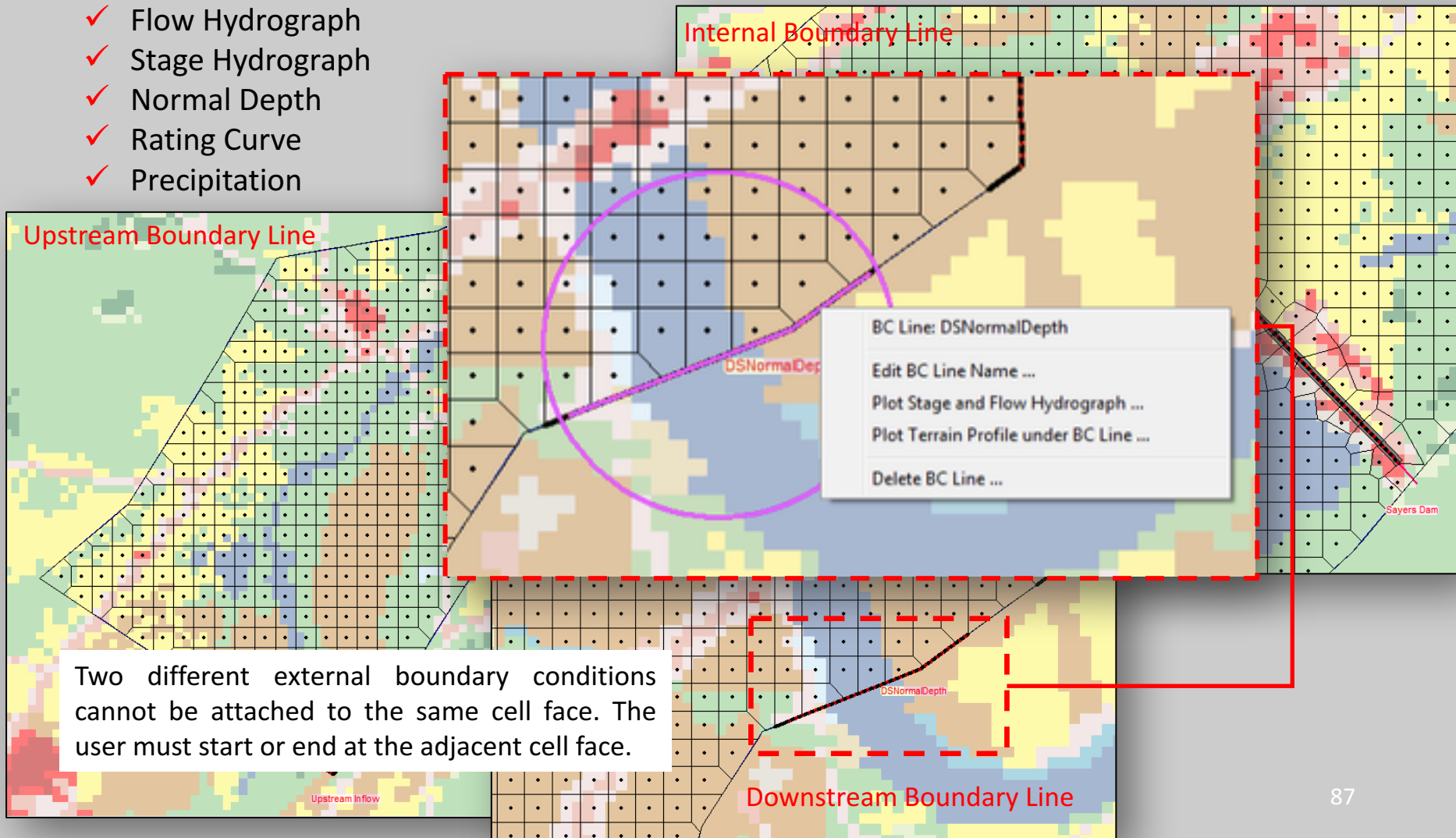


3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- External 2D flow area Boundary Conditions:

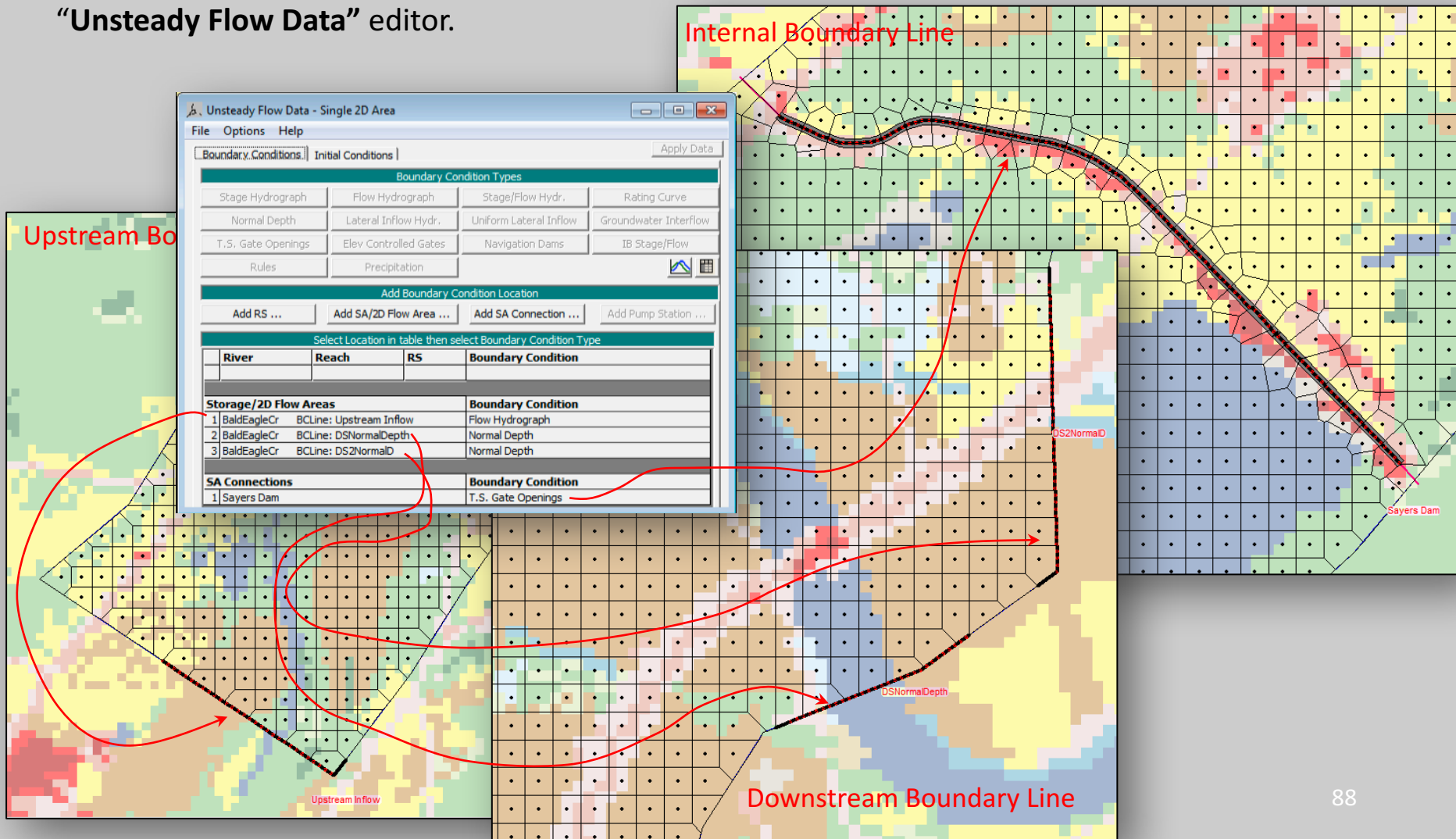
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- ✓ Stage Hydrograph
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- ✓ Rating Curve
- ✓ Precipitation



3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- External 2D flow area Boundary Conditions:
 - Once all of the 2D flow area boundary conditions have been identified (drawn with the “SA/2D Area BC Lines” tool), the boundary condition type and the boundary condition data are entered within the “Unsteady Flow Data” editor.



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The screenshot displays the HEC-RAS Unsteady Flow Data editor window, titled "Unsteady Flow Data - Single 2D Area". The window is divided into several sections:

- Boundary Conditions:** A list of boundary condition types is shown, including Stage Hydrograph, Flow Hydrograph (highlighted with a red box), 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, and Precipitation.
- Add Boundary Condition Location:** Buttons for "Add RS ...", "Add SA/2D Flow Area ...", "Add SA Connection ...", and "Add Pump Station ...".
- Select Location in table then select Boundary Condition Type:** A table with columns: River, Reach, RS, and Boundary Condition.
- Storage/2D Flow Areas:** A table listing areas and their boundary conditions.
- SA Connections:** A table listing connections and their boundary conditions.

The "Flow Hydrograph" dialog box is open, showing the "Enter Table" option selected. The "Data time interval" is set to "1 Hour". The "Hydrograph Data" table is populated with the following data:

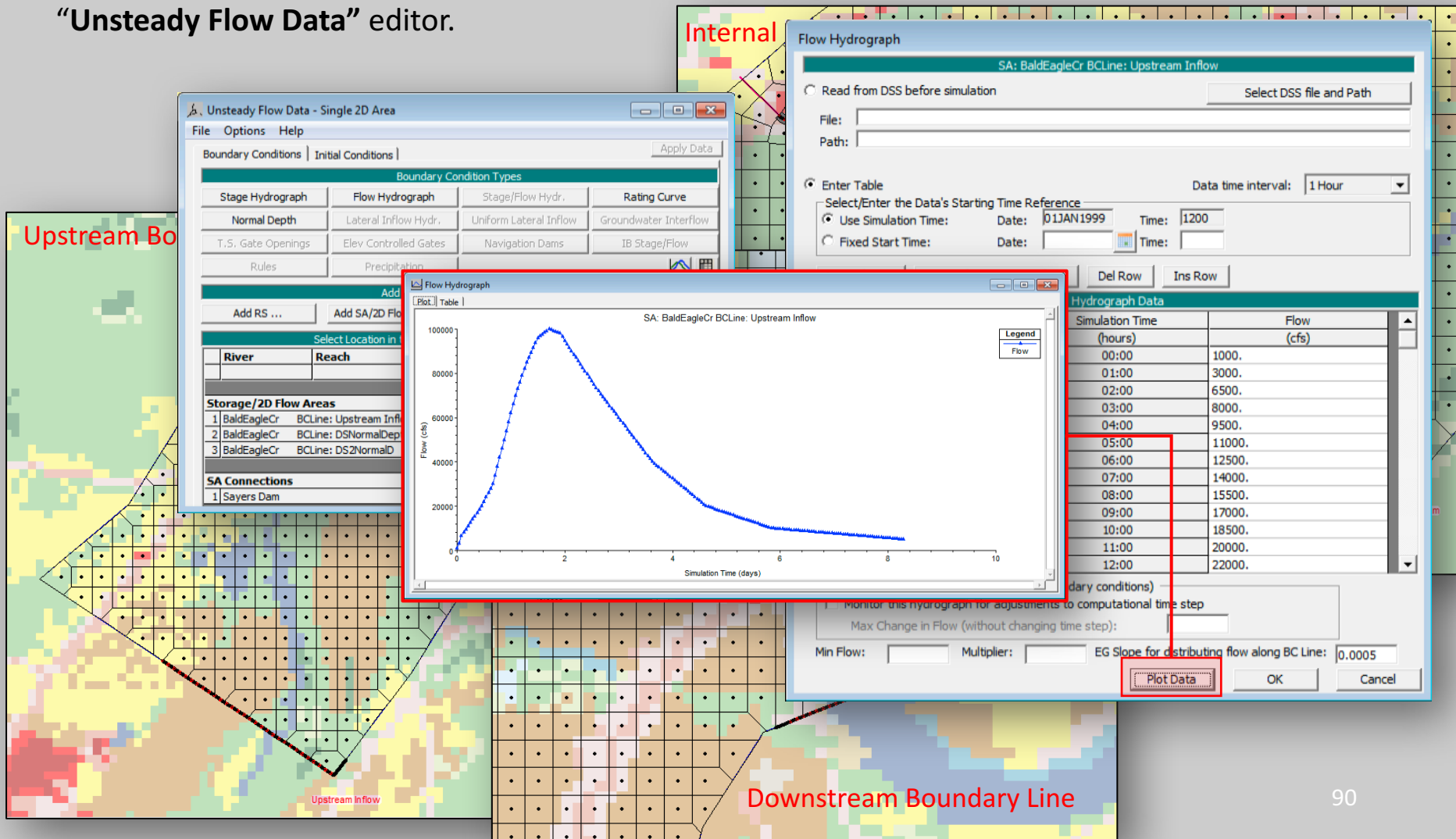
	Date	Simulation Time (hours)	Flow (cfs)
1	01Jan1999 1200	00:00	1000.
2	01Jan1999 1300	01:00	3000.
3	01Jan1999 1400	02:00	6500.
4	01Jan1999 1500	03:00	8000.
5	01Jan1999 1600	04:00	9500.
6	01Jan1999 1700	05:00	11000.
7	01Jan1999 1800	06:00	12500.
8	01Jan1999 1900	07:00	14000.
9	01Jan1999 2000	08:00	15500.
10	01Jan1999 2100	09:00	17000.
11	01Jan1999 2200	10:00	18500.
12	01Jan1999 2300	11:00	20000.
13	01Jan1999 2400	12:00	22000.

The "Time Step Adjustment Options" section is also visible, with the "Monitor this hydrograph for adjustments to computational time step" checkbox checked. The "Max Change in Flow (without changing time step)" is set to 0.0005. The "Min Flow" is 0, the "Multiplier" is 1, and the "EG Slope for distributing flow along BC Line" is 0.0005.

The background map shows a 2D flow area with a grid. A red box highlights the "Upstream Boundary Line" and another red box highlights the "Downstream Boundary Line".

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

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- External 2D flow area Boundary Conditions:
 - Once all of the 2D flow area boundary conditions have been identified (drawn with the “SA/2D Area BC Lines” tool), the boundary condition type and the boundary condition data are entered within the “Unsteady Flow Data” editor.

The screenshot displays the HEC-RAS Unsteady Flow Data editor for a single 2D area. The background shows a 2D flow area map with a grid and various boundary lines. A red line outlines the 'Internal Boundary Line' and 'Sayers Dam'. A red box highlights the 'Upstream Inflow' area. The 'Unsteady Flow Data - Single 2D Area' window is open, showing the 'Boundary Conditions' tab. The 'Boundary Condition Types' section lists various options, with 'T.S. Gate Openings' selected. The 'Add Boundary Condition Location' section shows the 'Add SA/2D Flow Area ...' button. The 'Select Location in table then select Boundary Condition Type' table lists the 'Sayers Dam' location. The 'SA Connections' table shows the 'Sayers Dam' connection. The 'Gate Openings' window is also open, showing the 'SA Conn: Sayers Dam' and the 'Gate Group: Gate #1'. The 'Enter Table' option is selected, and the 'Data time interval' is set to 1 Hour. The 'Hydrograph Data' table is shown with columns for Date, Simulation Time, and Gate Opening Height.

Upstream Inflow

Internal Boundary Line

Sayers Dam

Unsteady Flow Data - Single 2D Area

File Options Help

Boundary Conditions | Initial Conditions | Apply 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 Connection ... Add Pump St...

Select Location in table then select Boundary Condition Type

River	Reach	RS	Boundary Condition
Storage/2D Flow Areas			
1	BaldEagleCr	BCLine: Upstream Inflow	Flow Hydrograph
2	BaldEagleCr	BCLine: DSNormalDepth	Normal Depth
3	BaldEagleCr	BCLine: DS2NormalD	Normal Depth
SA Connections			
1	Sayers Dam		T.S. Gate Openings

Gate Openings

SA Conn: Sayers Dam

Gate Group: Gate #1

☐ 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: 01JAN1999 Time: 1200

☐ Fixed Start Time: Date: Time:

No. Ordinates Interpolate Missing Values Del Row Ins Row

Hydrograph Data

	Date	Simulation Time (hours)	Gate Opening Height (ft)
1	01Jan1999 1200	00:00	2.
2	01Jan1999 1300	01:00	2.
3	01Jan1999 1400	02:00	2.
4	01Jan1999 1500	03:00	2.
5	01Jan1999 1600	04:00	2.
6	01Jan1999 1700	05:00	2.
7	01Jan1999 1800	06:00	2.
8	01Jan1999 1900	07:00	2.
9	01Jan1999 2000	08:00	2.

Plot Data OK Cancel

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- 2D Flow Area Initial Conditions:

- 2D flow areas can:

- ✓ start completely dry
- ✓ be set to a single water surface elevation
- ✓ set by using a Restart File from a previous run
- ✓ they can be established using the 2D Initial Conditions Ramp up Time option at the beginning of the run.

- Nothing needs to be done to start a 2D flow area in a dry condition, this is the default option.
- The model starts with the initial conditions, it then holds all of the boundary conditions constant, based on their value at the beginning of the simulation, and then it runs a series of time steps with the constant inflow.
- This allows the model to settle down to water surface elevations and flows that are consistent with the unsteady flow equations being applied.

Unsteady Flow Data - Single 2D Area

File Options Help

Boundary Conditions [Initial Conditions] Apply Data

Initial Flow Distribution Method

☐ Use a Restart File Filename:

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

Add RS...

User specified fixed flows (Optional)

	River	Reach	RS	Initial Flow
1				1000

Initial Elevation of Storage Areas/2D Flow Areas (Optional) Import Min SA Elevation(s)

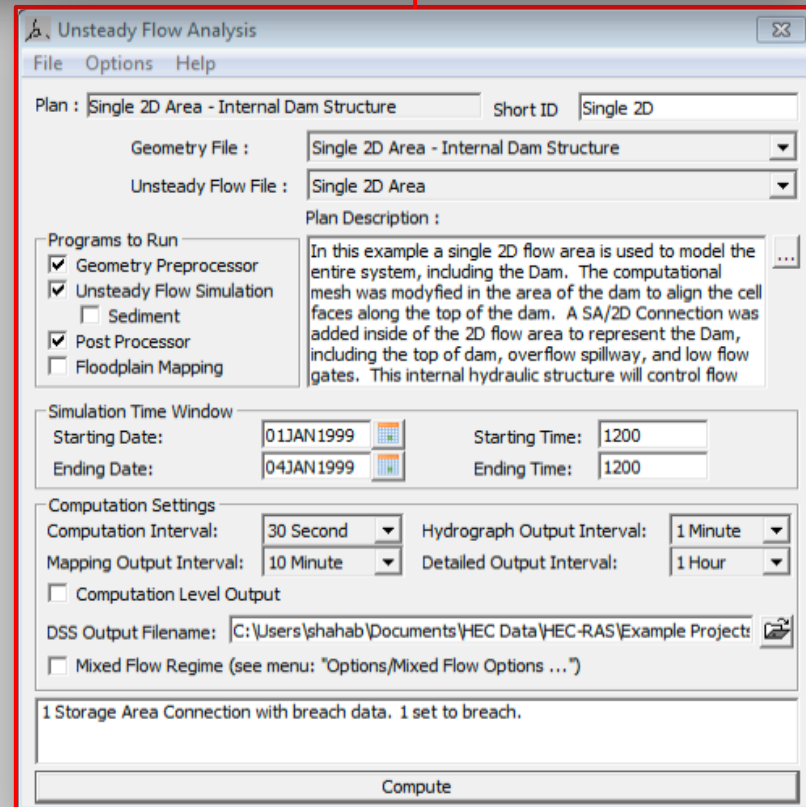
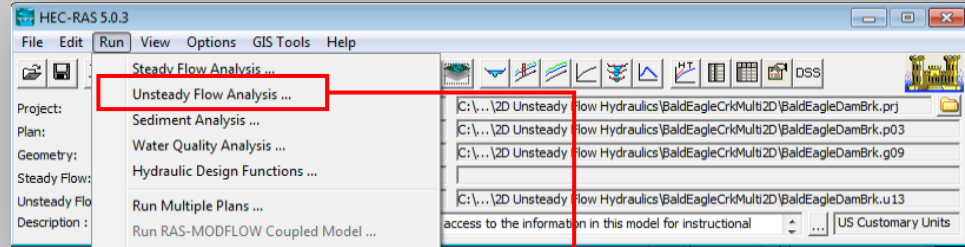
☐ Keep initial elevations constant during warmup

	Storage Area/2D Flow Area	Initial Elevation
1	BaldEagleCr	

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

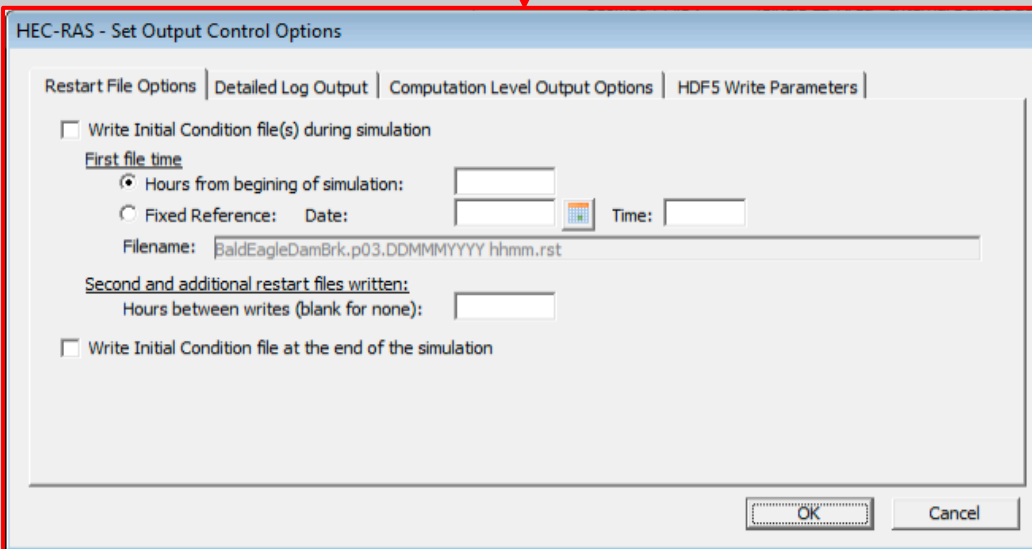
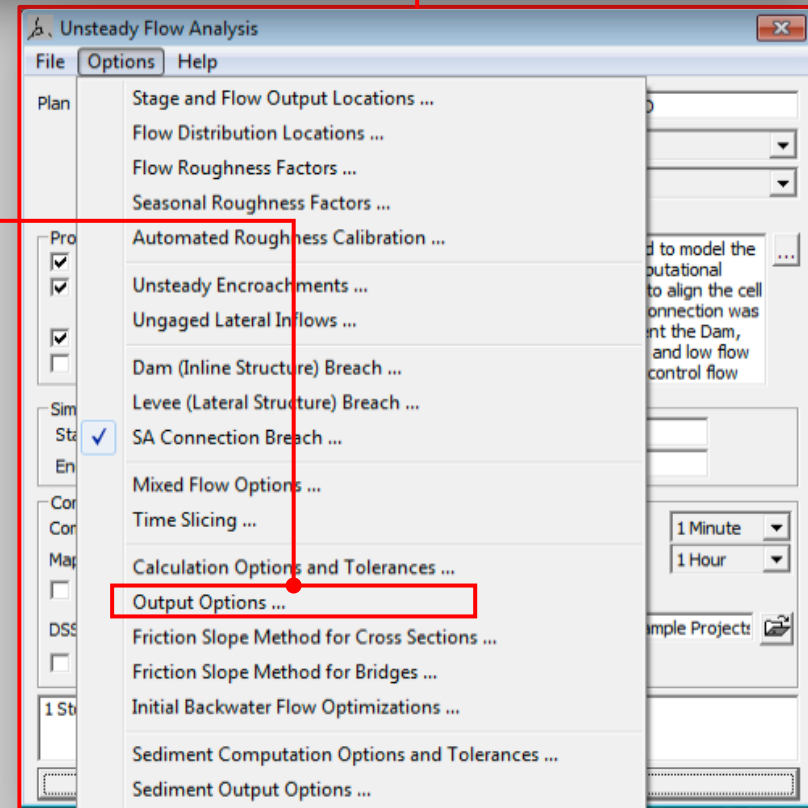
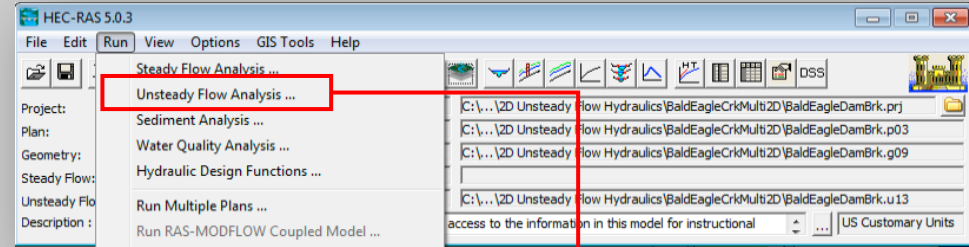
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 - ✓ set by using a Restart File from a previous run
 - ✓ they can be established using the 2D Initial Conditions Ramp up Time option at the beginning of the run.

- A **Restart File** can be used to establish initial conditions for an entire HEC-RAS model.
- If a previous run has been made, and the option to write out a **Restart File** was used, then a Restart File can be used as the initial conditions for a subsequent run.
- For 2D modeling, the **Restart File** will contain a water surface elevation for every cell in the model.
- **Restart files** can be generated using either of the 2D equation sets (full Saint Venant or Diffusion Wave), and can be used to start a model with a different equation set



3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

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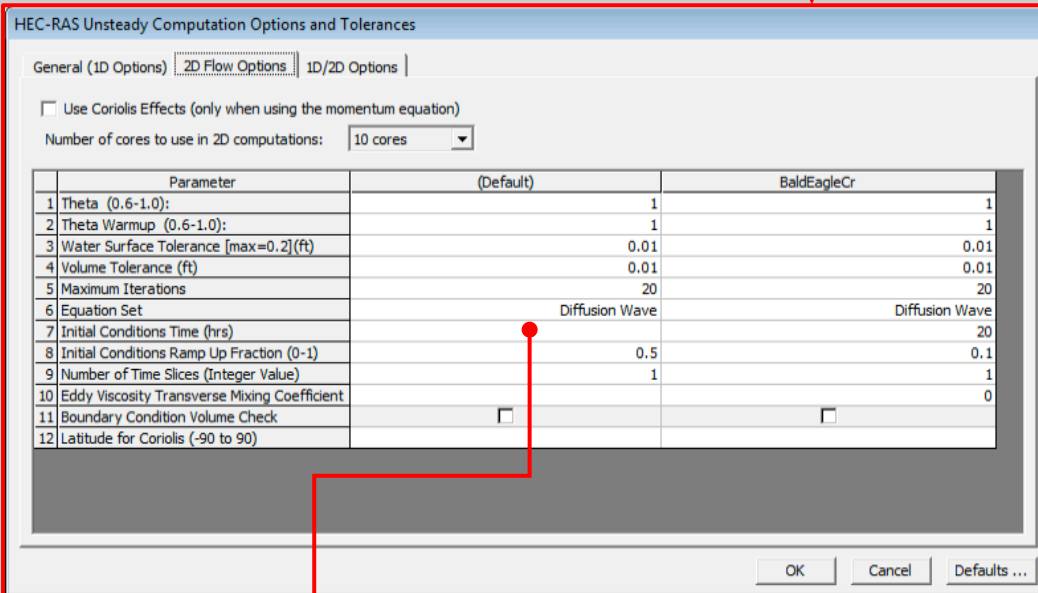
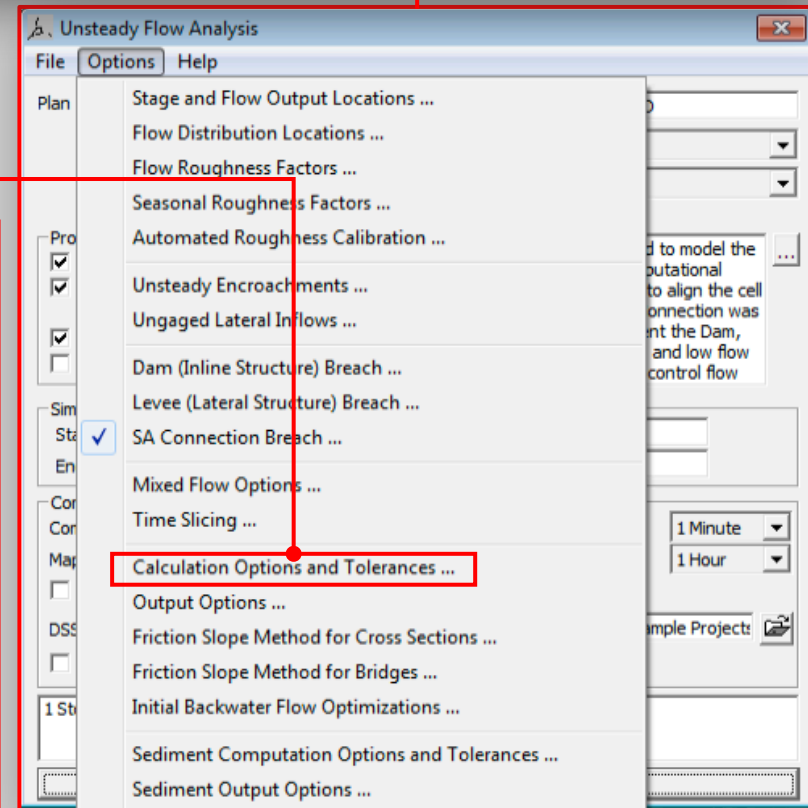
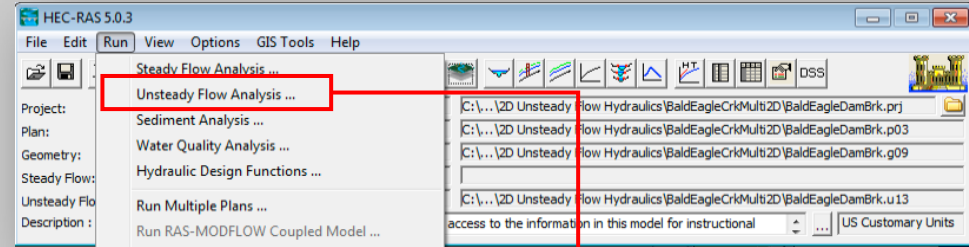


3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

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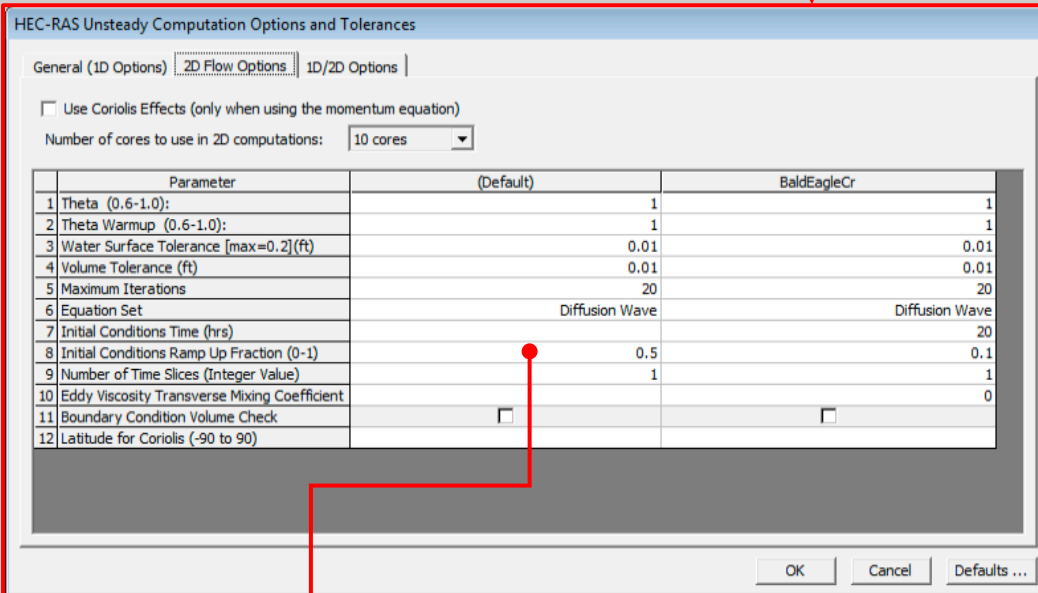
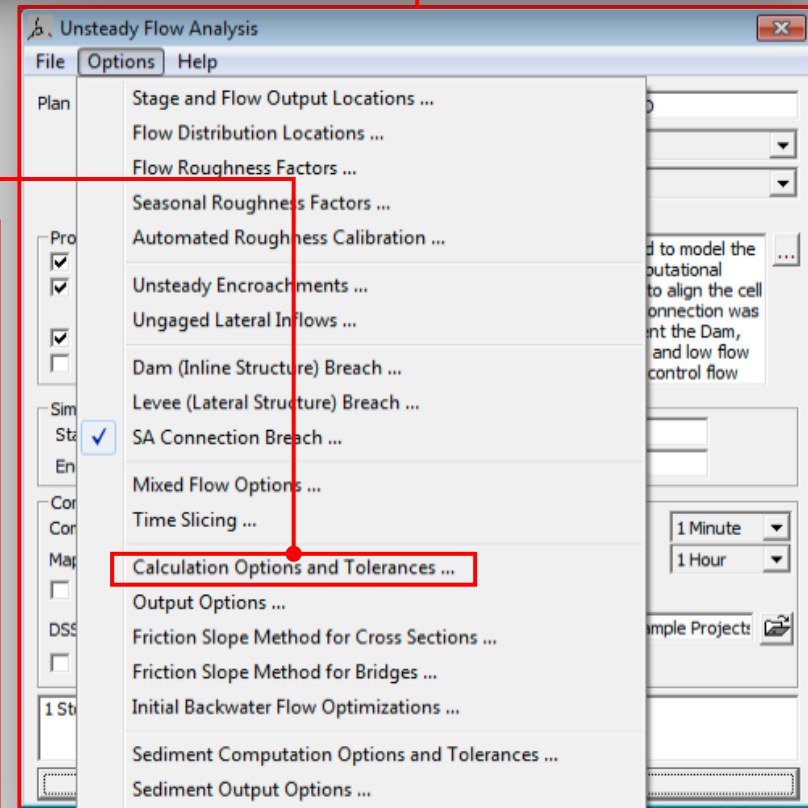
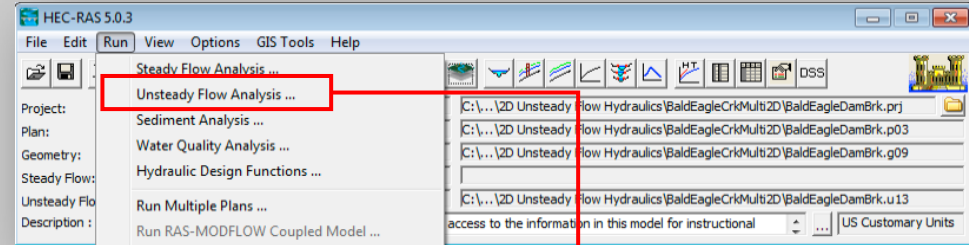
If a 2D area has external boundary conditions (flow hydrographs or stage hydrographs) then the 2D flow area “**Initial Condition Ramp Up Time**” must be turned on to get flow through the 2D area in order to establish its initial conditions before the start of the simulation (or even before the start of the overall model warm-up time).

3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS

- 2D Flow Area Initial Conditions:

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- Additionally, the user must enter what fraction of that time is used for ramping the 2D boundary conditions up from zero to their first value (i.e. a stage or a flow coming in).

Objectives of This Workshop

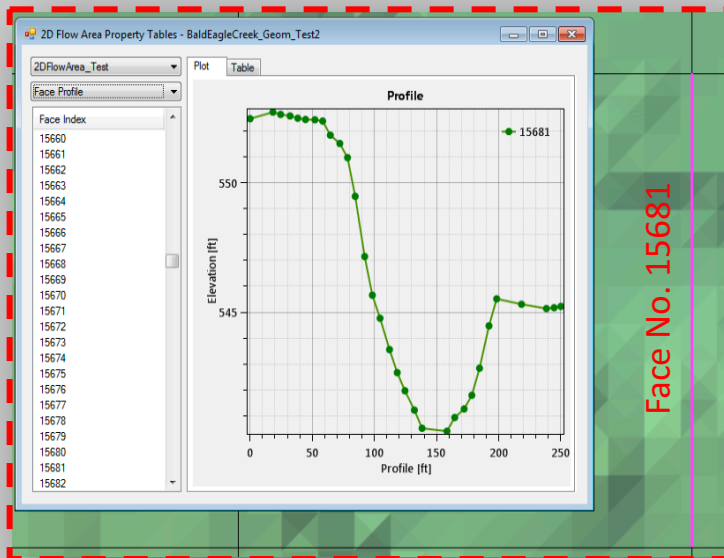
1. Introduction to HEC-RAS 2D and two dimensional modeling advantages relative to 1D models
2. Required geophysical and flow information for setting up HEC-RAS 2D models
3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS
4. Overview of how to execute a combined 1D/2D unsteady flow model in HEC-RAS
5. Overview of how to demonstrate the result of a combined 1D/2D unsteady flow model in HEC-RAS and RAS Mapper output capabilities

4. Overview of how to execute a combined 1D/2D unsteady flow model in HEC-RAS

- Running a combined 1D/2D unsteady flow model in HEC-RAS is no different than running a standalone 1D unsteady flow model.
- HEC-RAS has the ability to perform two-dimensional unsteady flow routing with either the Full Saint Venant equations (with added terms for turbulence modeling and Coriolis effects) or the Diffusion wave equations.
- Within HEC-RAS the Diffusion Wave equations are set as the default, however, the user should always test if the full Saint Venant Equations are needed for their specific application.
- **A general approach is to use the Diffusion wave equations while developing the model and getting all the problems worked out**
- Once the model is in good working order, then make a second HEC-RAS Plan and switch the computational method to the Full Momentum equation option
- **Full Momentum will generally require a smaller computation interval than the Diffusion wave method to run in a stable manner. If there are significant differences between the two runs, the user should assume the Full Momentum (Saint Venant equations) answer is more accurate**
- There are some obvious situations that the Full Momentum equation set should always be used:
 - ✓ **Highly Dynamic Flood Waves** (e.g. dam breaching or flash flood analysis)
 - ✓ **Abrupt Contractions and Expansions** (e.g. In areas of very abrupt contractions and expansions)
 - ✓ **Tidally Influenced Conditions** (e.g. modeling a bay, estuary, or a river that is tidally influenced)
 - ✓ **General Wave Propagation Modeling** (e.g. wave run-up on a wall or around an object)
 - ✓ **Super Elevation around Bends** (a tight bend in either a natural or designed channel, and you want to see if there is any super elevation of the water surface on the outside of the bend)
 - ✓ **To compute a detailed velocity distribution at or near a hydraulic structure** (e.g. through a bridges and around the abutments and piers; through a gate or culvert; etc.)

4. Overview of how to execute a combined 1D/2D unsteady flow model in HEC-RAS

- Selecting an Appropriate Grid Size and Computational Time Step
 - Assigning an appropriate mesh cell size (or sizes) and computational time step (ΔT) is very important to getting accurate answers with 2D flow areas.
 - It is very important to understand the way the computational mesh is representing the underlying terrain in order to make a good decision on how many cells, and of what size, will be necessary to model the terrain and the event accurately.
 - The HEC-RAS cell faces are detailed cross sections, which get processed into detailed elevation versus area, wetted perimeter, and roughness.
 - The key to making a good computational mesh in HEC-RAS is ensuring that the faces of the cells capture the high point of barriers to the flow.
 - A single water surface elevation is computed in the center of each cell. So the larger the cell size, the further apart are the computed values of the water surface, and thus the slope of the water surface is averaged over longer distances (in two dimensions)



- If the water surface slope will vary rapidly, smaller cell sizes must be used in that area to capture the changing water surface and its slope.
- HEC-RAS allows the user to vary the cell size and shape at all locations in the model.
- It is also recommended to align grid cells along the main channel by means of adding **Breaklines**.

250 ft. X 250 ft. mesh grid laid over the 20 ft. X 20 ft. terrain model

4. Overview of how to execute a combined 1D/2D unsteady flow model in HEC-RAS

- Selecting an Appropriate Grid Size and Computational Time Step
 - The cell size must be adequate to describe the water surface slope and changes in the water surface slope.
 - If the water surface slope does not change rapidly, larger cell sizes can be used to accurately compute the water surface elevation and slope. If the water surface slope changes rapidly, then smaller cell sizes need to be used to have enough computation points to describe the changing water surface
 - While cell sizes (and shapes) can vary, transitioning from larger to smaller cell sizes should be done gradually to improve computational accuracy.
 - Picking an adequate time step is a function of the cell size and the velocity of the flow moving through those cells.
 - **Users should always test the consistency of their computational mesh and selected time step. The consistency principle requires a reduction of both the space (grid) and time steps in order to guarantee convergence of a solution.**

Diffusion Wave Equations:

$$C = \frac{V\Delta T}{\Delta X} \leq 2.0 \quad (\text{with a max } C = 5.0)$$

Or

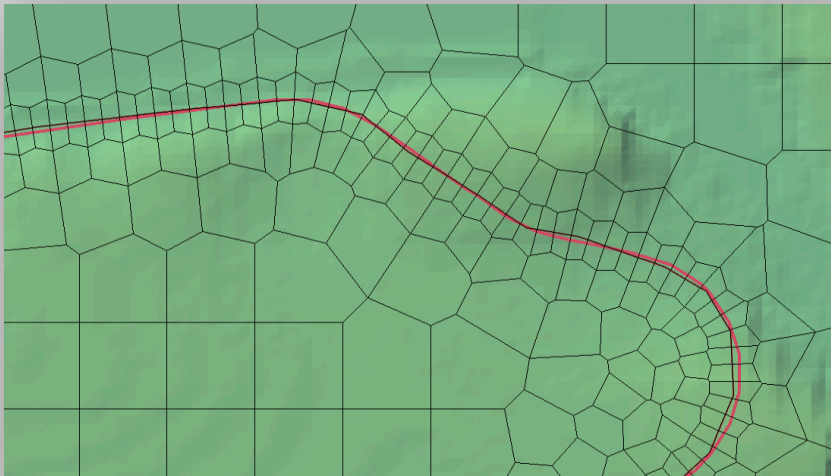
$$\Delta T \leq \frac{2\Delta X}{V} \quad (\text{With } C = 1.0)$$

Saint Venant Equations (full momentum):

$$C = \frac{V\Delta T}{\Delta X} \leq 1.0 \quad (\text{with a max } C = 3.0)$$

Or

$$\Delta T \leq \frac{\Delta X}{V} \quad (\text{With } C = 1.0)$$



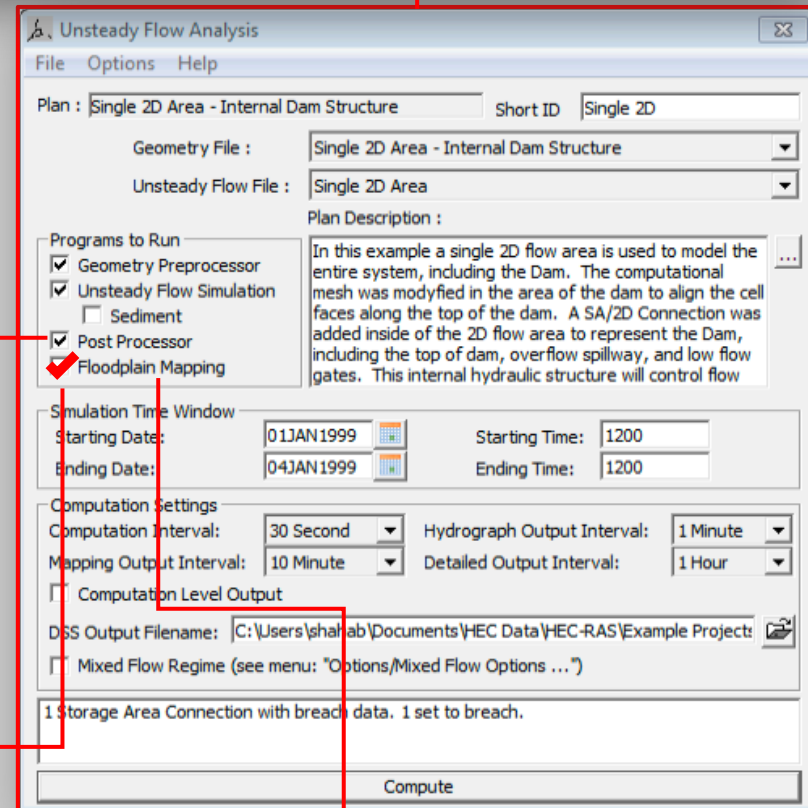
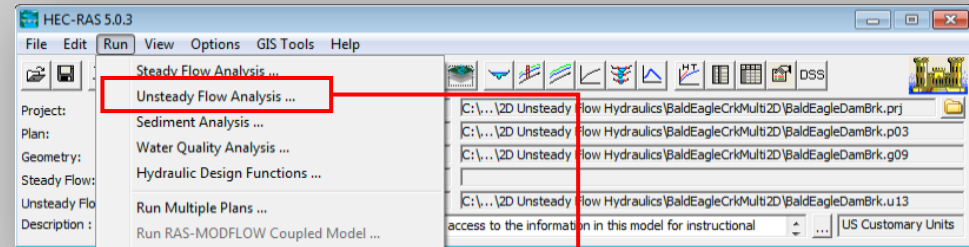
Where:	C	=	Courant Number
	V	=	Flood wave velocity (wave celerity) (ft/s)
	ΔT	=	Computational time step (s)
	ΔX	=	Average cell size (ft)

4. Overview of how to execute a combined 1D/2D unsteady flow model in HEC-RAS

- Performing the computation

1. make a Plan by selecting the geometry that contains the combined 1D and 2D data
2. select an unsteady-flow file for the event to run, and give the Plan a Title and a Short ID
3. recheck the association of the terrain model and landcover layer
4. The post processor option provides additional (and detailed) output for 1D areas and it is only applicable for 1D data sets and mixed 1D/2D data sets.

5. If this option is turned on, after the program has completed the unsteady flow computations and the post processing, the last thing it will do is run a separate process called "ComputeFloodMaps.exe" in order to generate a depth grid (stored to disk) of the maximum inundation that occurred at all locations in the model. **This option is not required for flood mapping.**

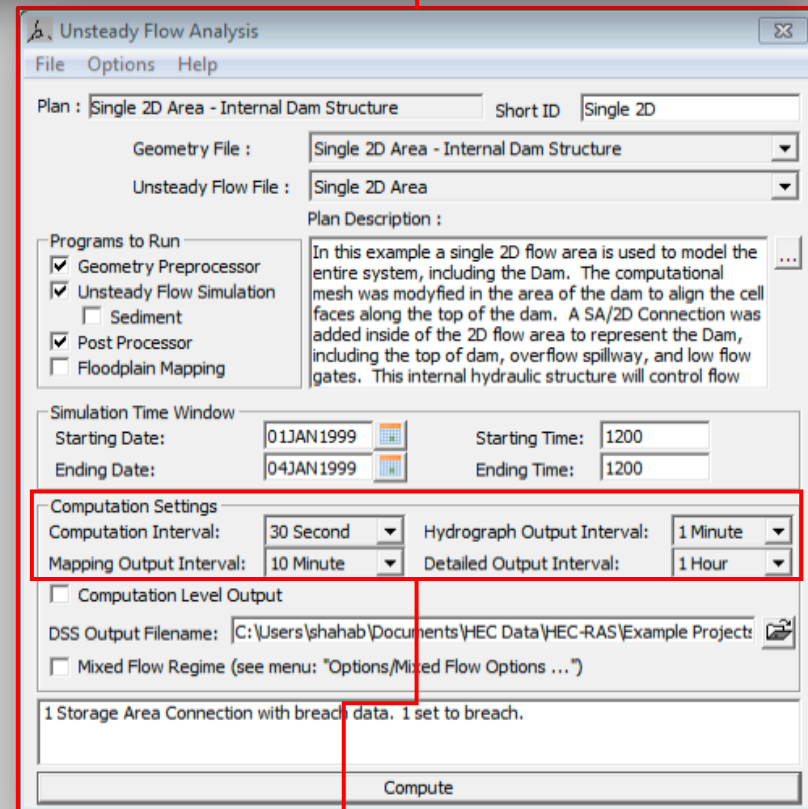
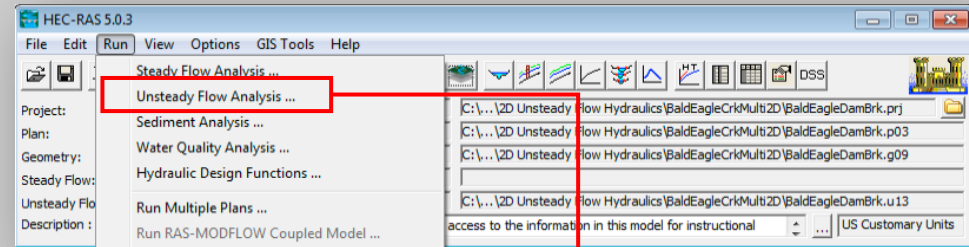


In general, this option will most likely not be used when running HEC-RAS in standalone mode.

4. Overview of how to execute a combined 1D/2D unsteady flow model in HEC-RAS

- Performing the computation

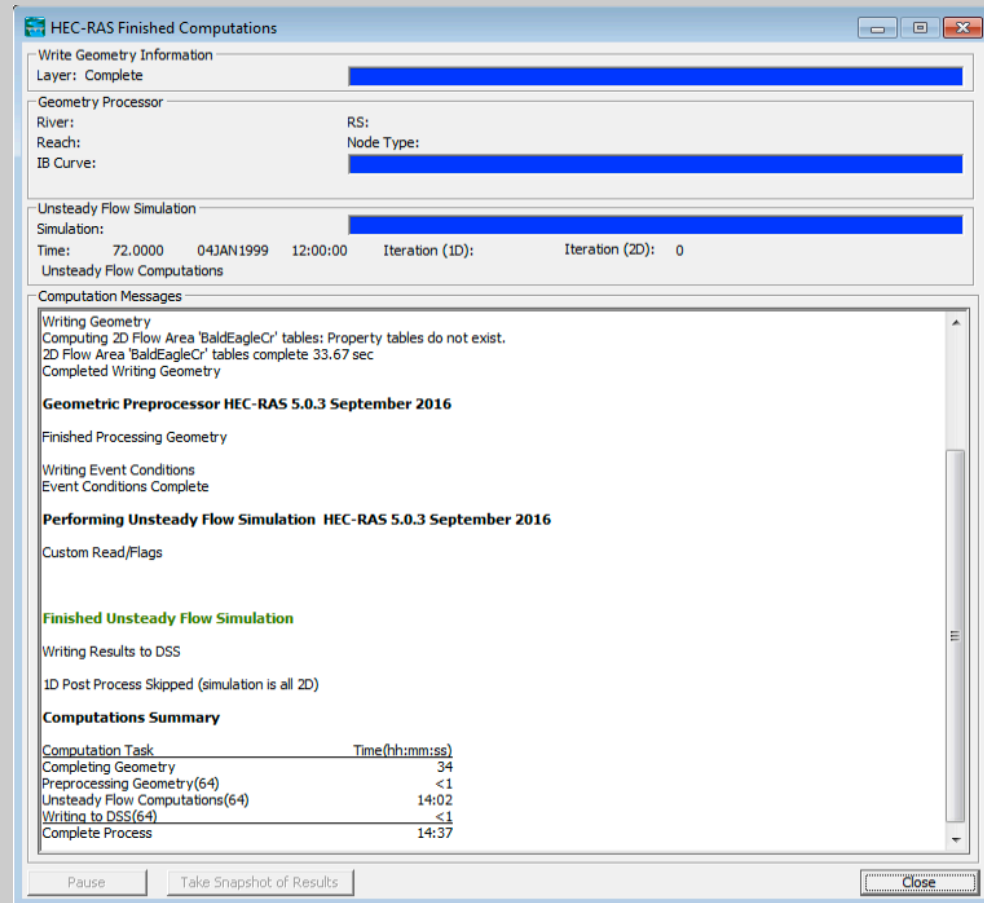
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- Setting **Computation, Hydrograph, and Mapping Output Intervals** (to be applied in RAS Mapper).
- **Computation Interval < Hydrograph and Mapping Output Intervals**

4. Overview of how to execute a combined 1D/2D unsteady flow model in HEC-RAS

- Computation Progress, Numerical Stability, and Volume Accounting
 - As the Unsteady flow simulation runs, information is provided as to the progress of the run, how many iterations the 1D and 2D components are using to solve a particular time step, and numerical stability messages are written to the Computational Messages window.
 - If any 1D or 2D element (cross section, storage area, or 2D cell) is not solved to within the pre-defined numerical tolerance during a time step, a message will be written to the message window. This message will provide information as to which cross section, storage area, or 2D cell had the greatest amount of numerical error for that time step.

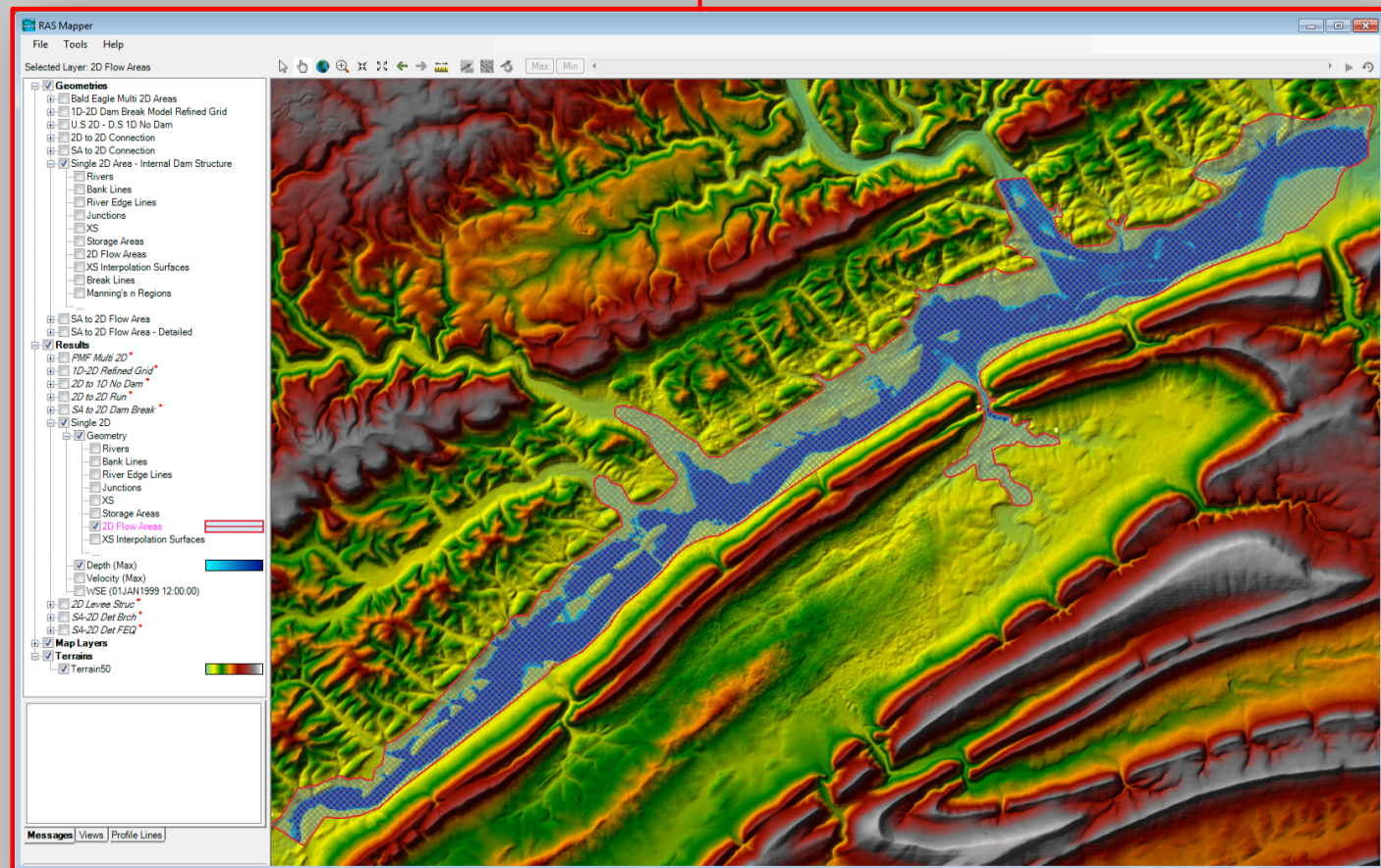
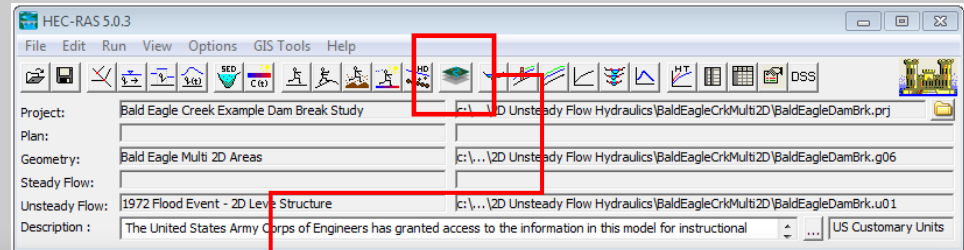


Objectives of This Workshop

1. Introduction to HEC-RAS 2D and two dimensional modeling advantages relative to 1D models
2. Required geophysical and flow information for setting up HEC-RAS 2D models
3. Overview of how to set-up a combined 1D/2D unsteady flow model in HEC-RAS
4. Overview of how to execute a combined 1D/2D unsteady flow model in HEC-RAS
5. Overview of how to demonstrate the result of a combined 1D/2D unsteady flow model in HEC-RAS and RAS Mapper output capabilities

5. Overview of how to demonstrate the result of a combined 1D/2D unsteady flow model in HEC-RAS and RAS Mapper output capabilities

- Once the user has completed an unsteady-flow run of the 1D/2D model, results can be viewed within **RAS Mapper**



RAS Mapper has the following capabilities:

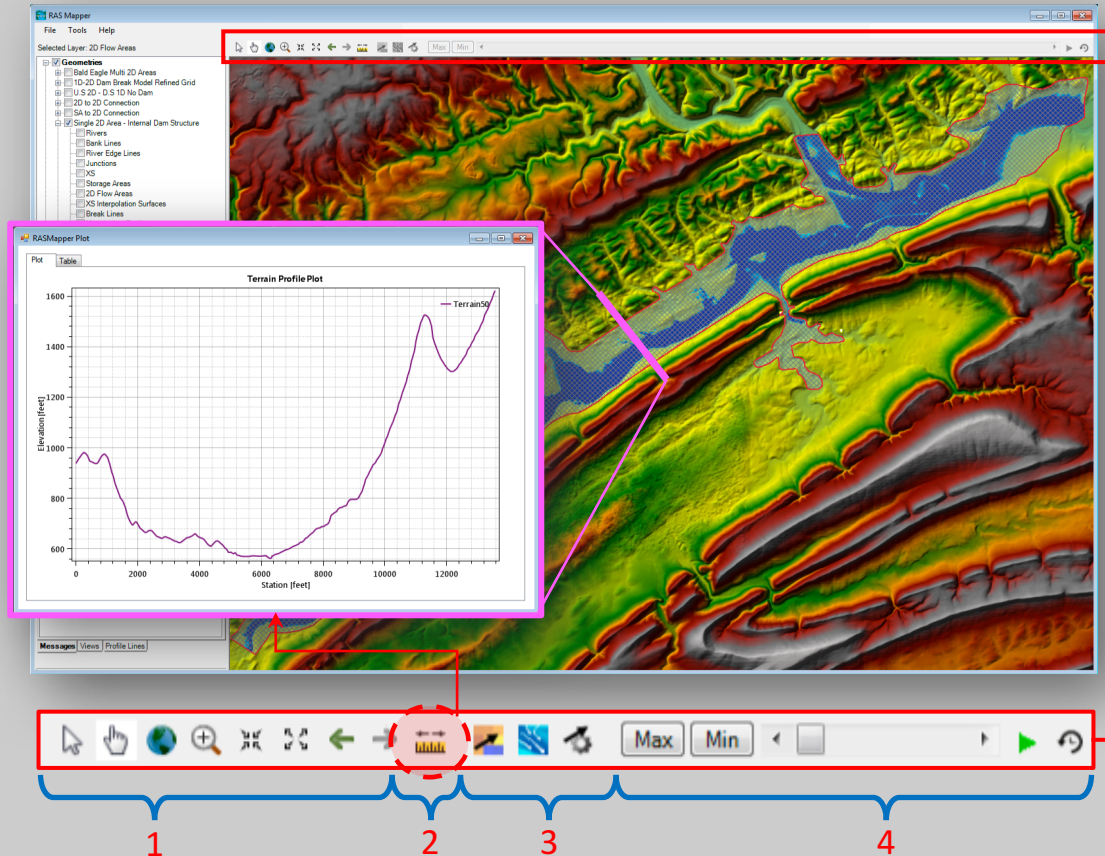
-
- The screenshot shows the RAS Mapper application window. The title bar reads "RAS Mapper". The menu bar includes "File", "Tools", and "Help". The toolbar contains various icons for file operations and viewing. The left-hand tree view is expanded to "Results", showing a list of model outputs. The main window displays a topographic map with a blue-shaded flow area and a red line indicating a break. A legend at the bottom left shows color-coded scales for Depth (Max), Velocity (Max), and Terrain.

-

5. Overview of how to demonstrate the result of a combined 1D/2D unsteady flow model in HEC-RAS and RAS Mapper output capabilities

RAS Mapper has the following capabilities:

- Develop terrain models for use in 2D modeling and visualizing 1D/2D model results. Terrain models can be developed from one or more terrain tiles, and these tiles can have different grid resolutions.
- Develop Land Cover Layers for use in defining Manning's n values for 2D flow areas.
- Various types of map layer results can be generated (shapfiles and rasters)
- Computed model results can be displayed dynamically on the fly, or they can be written to a static (stored to disk) map layer/depth grid.
- Computed model results can be animated (dynamic mapping) or shown for a specific instance in time.
- Time series plots and tables can be displayed for 1D and 2D output directly from RAS Mapper, at any location where there is a map layer result.

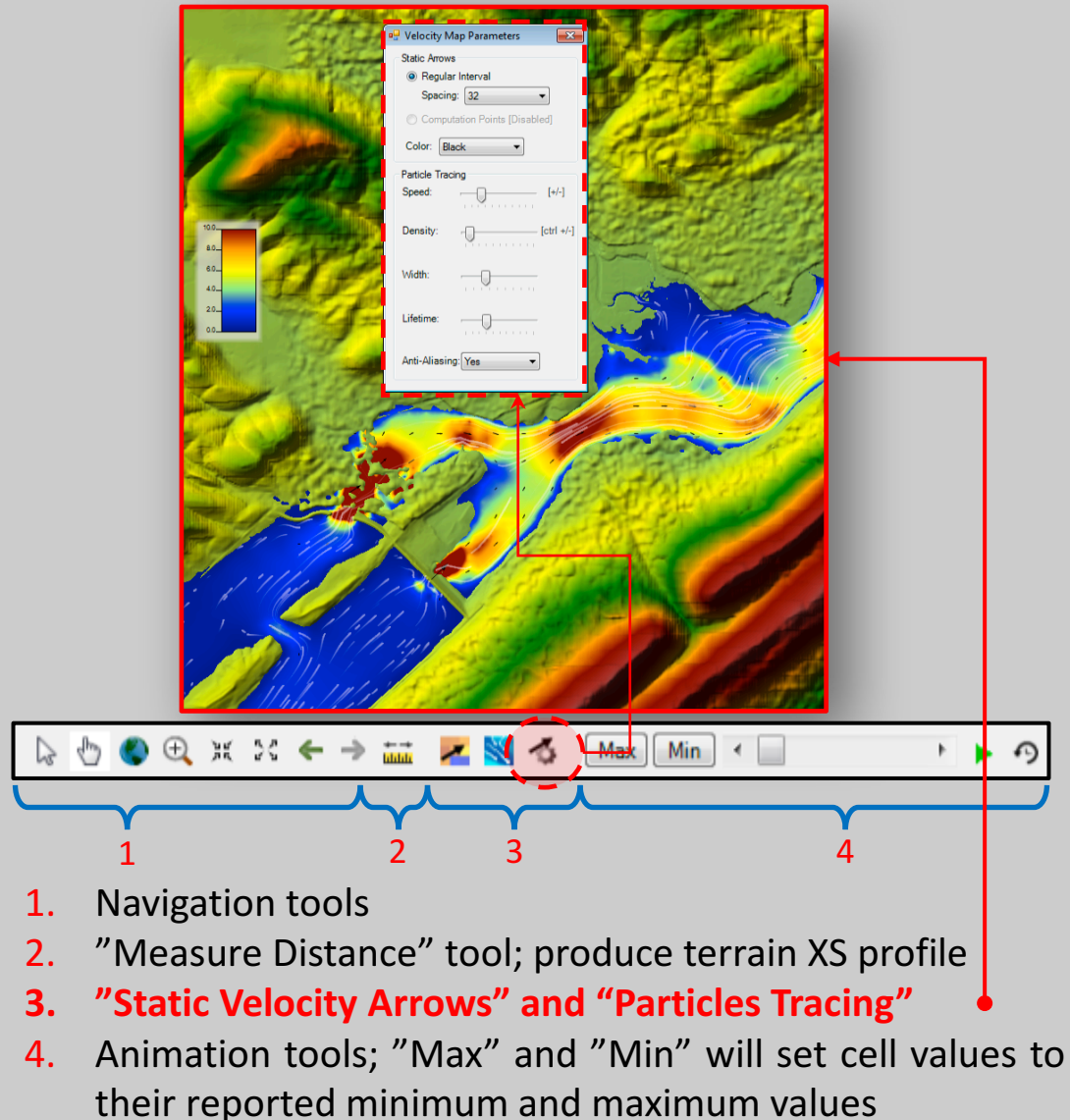


1. Navigation tools
2. **"Measure Distance" tool; produce terrain XS profile**
3. "Static Velocity Arrows" and "Particles Tracing"
4. Animation tools; "Max" and "Min" will set cell values to their reported minimum and maximum values

5. Overview of how to demonstrate the result of a combined 1D/2D unsteady flow model in HEC-RAS and RAS Mapper output capabilities

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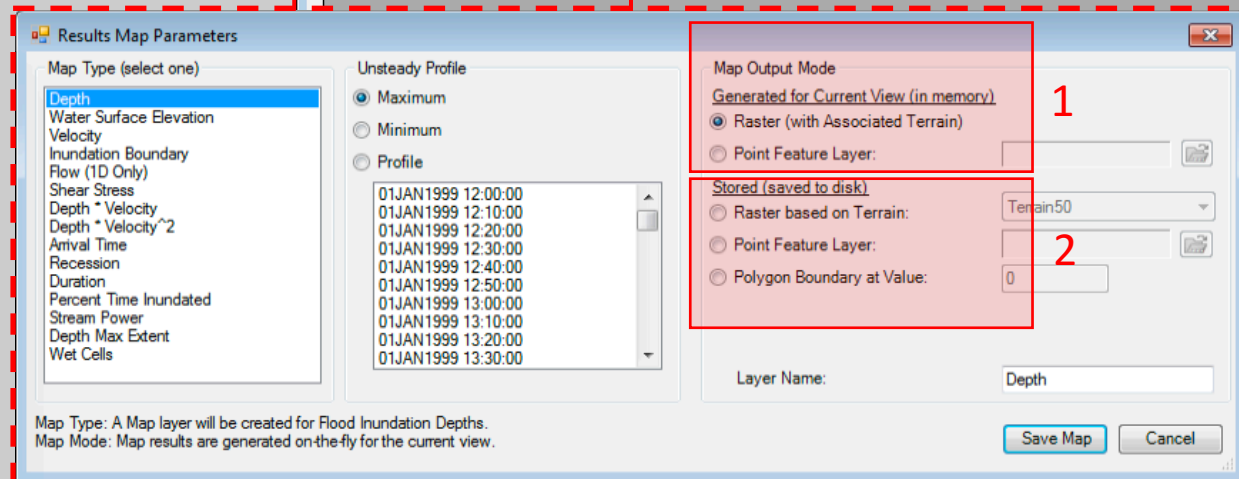
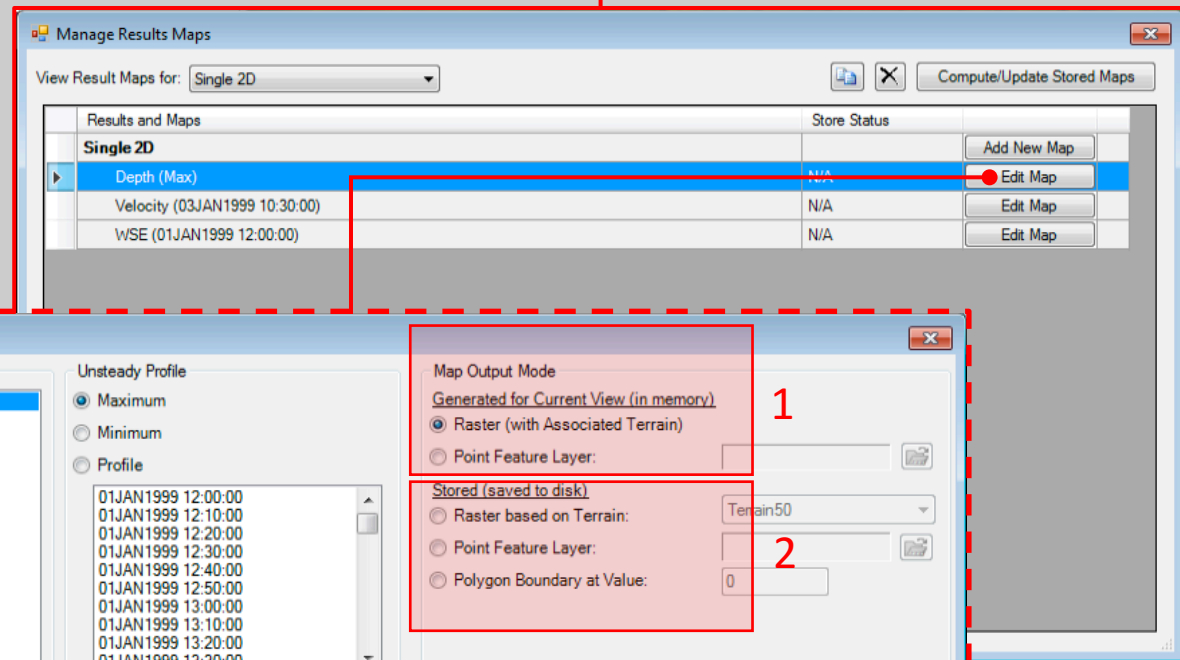
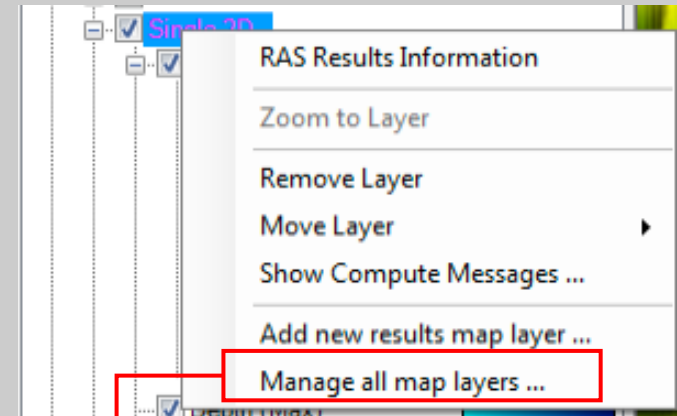
5. Overview of how to demonstrate the result of a combined 1D/2D unsteady flow model in HEC-RAS and RAS Mapper output capabilities

Creating Static (Stored) Maps

- this editor will allow the user to create new map layers (Add New Map), as well as generate stored maps to a file
- Only the map layers that are turned on will be available to plot.

Results Map Parameters: Map Output Mode

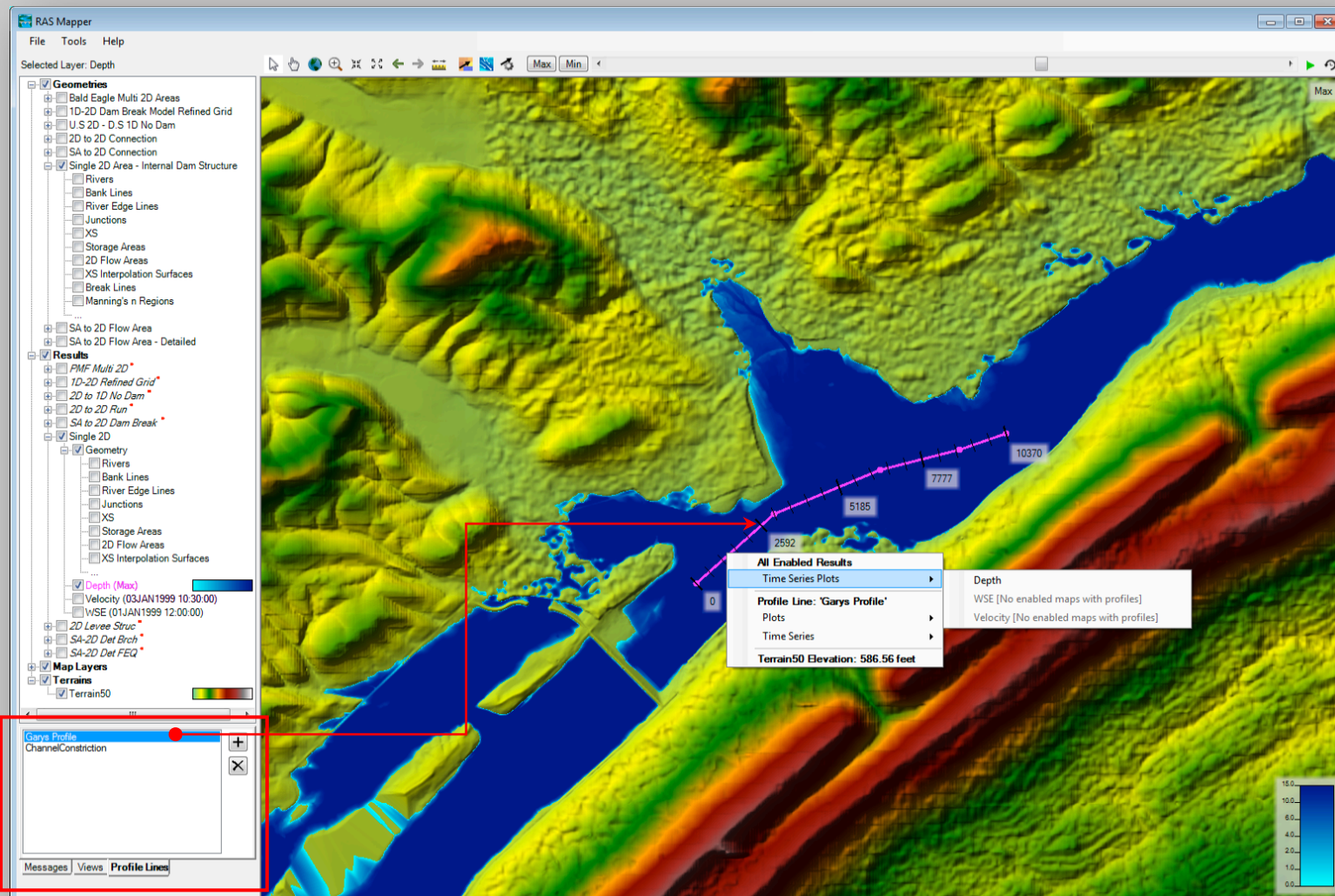
1. Layers generated to be used and visualized only within RAS Mapper platform
2. Saving Layers (Raster or Shapefiles) generated from computed maps and layers to a local disk.



5. Overview of how to demonstrate the result of a combined 1D/2D unsteady flow model in HEC-RAS and RAS Mapper output capabilities

Profile Lines

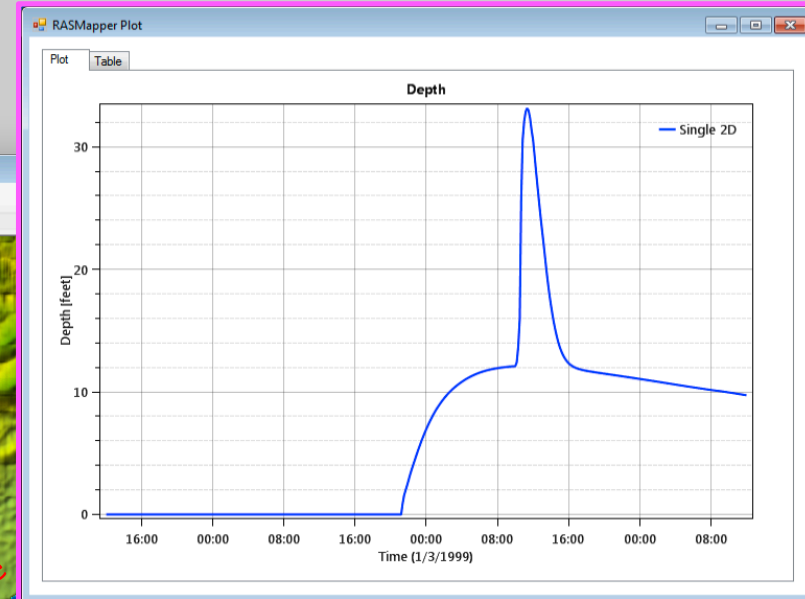
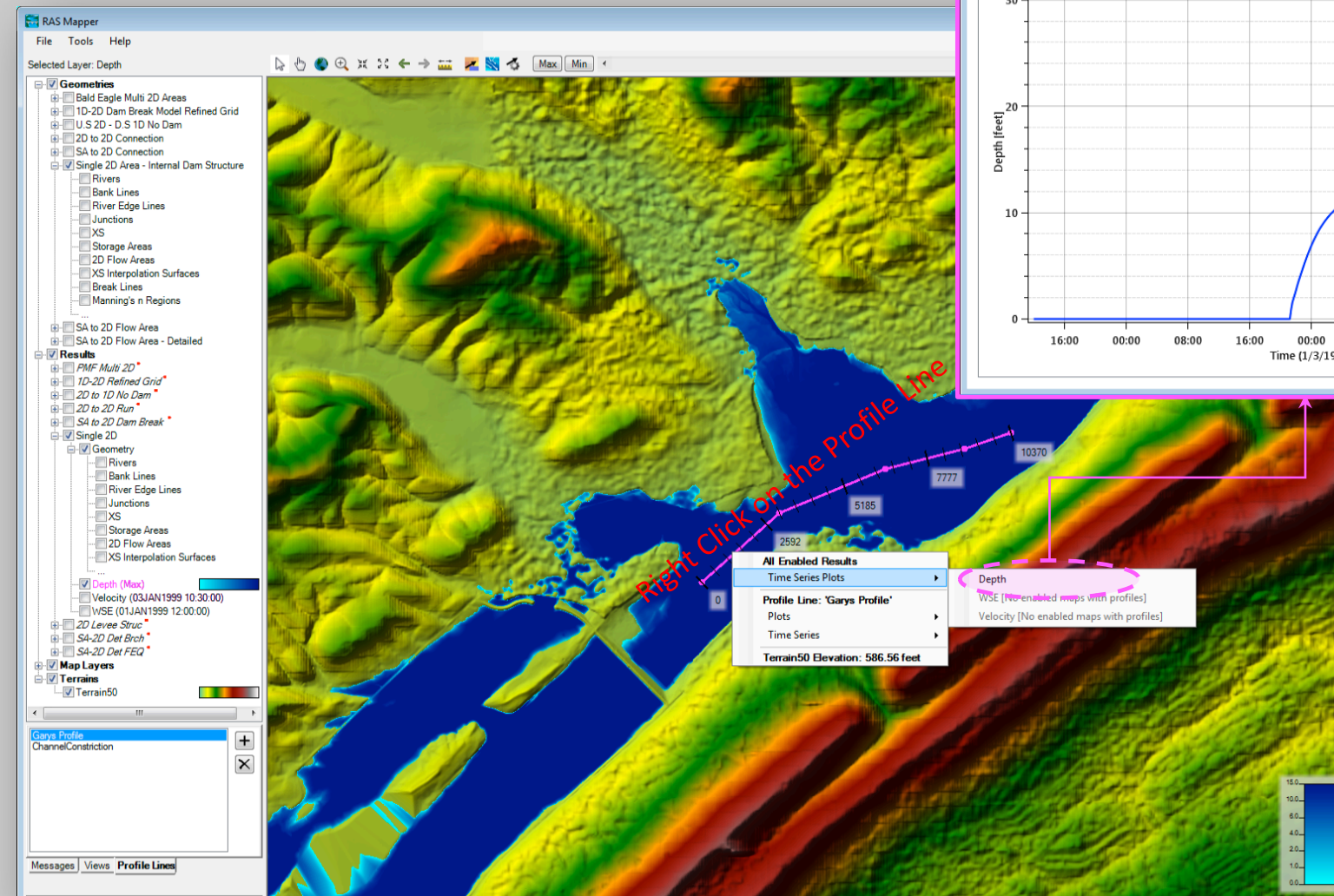
- HEC-RAS Mapper has the option for user to draw a line on the map, give that line a name, then use that line to plot whatever results is turned on over top of the line.



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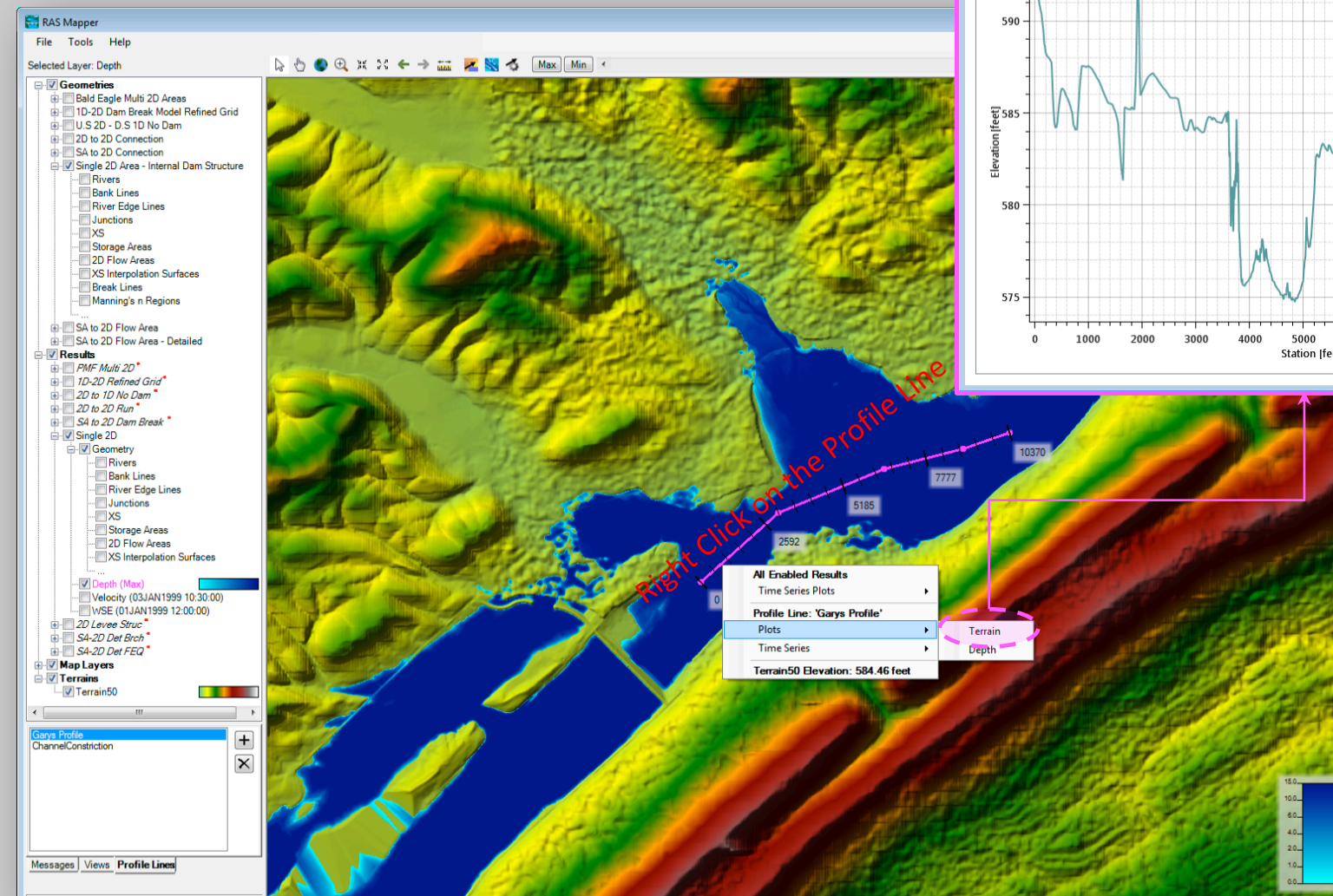
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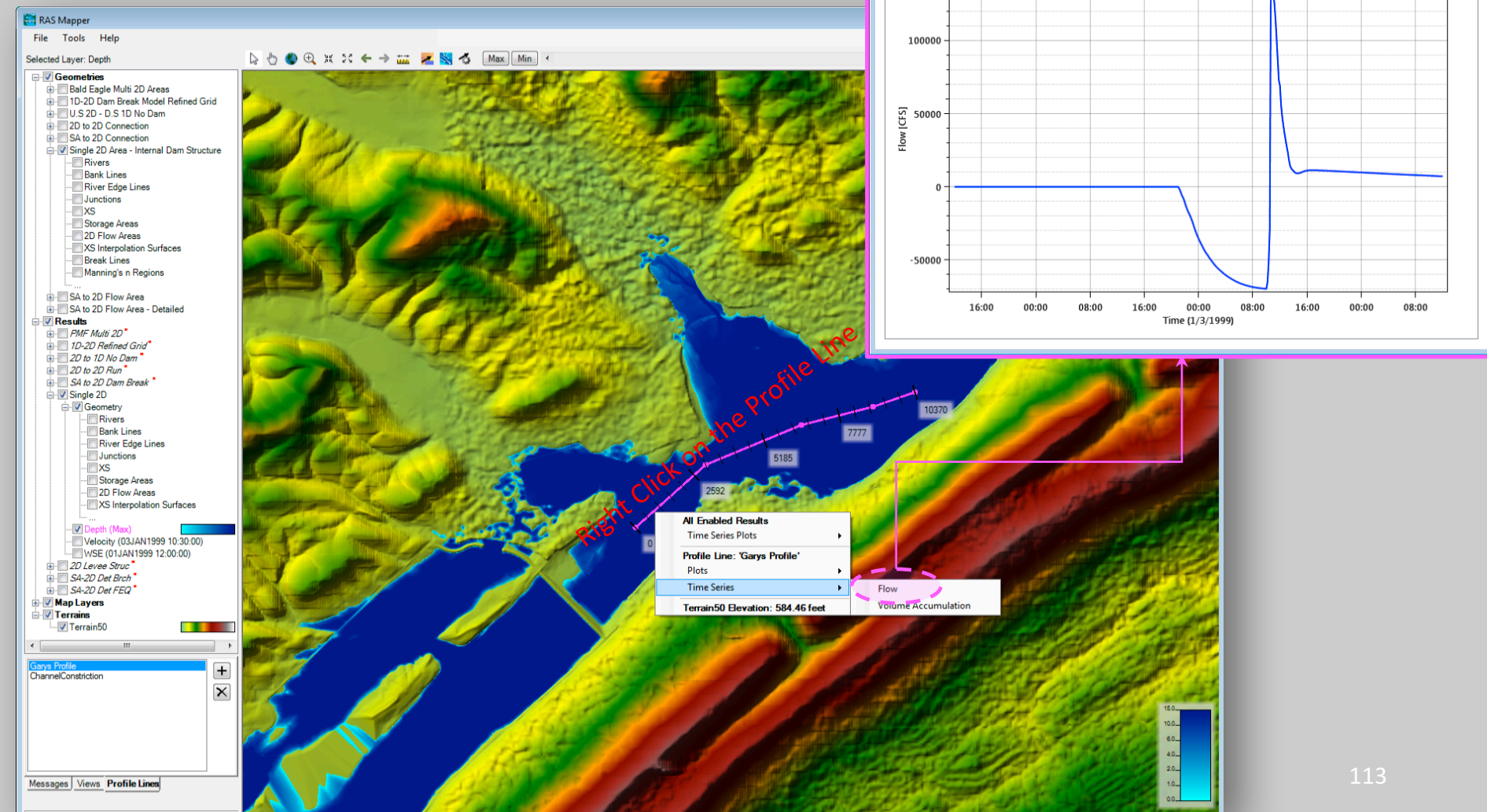
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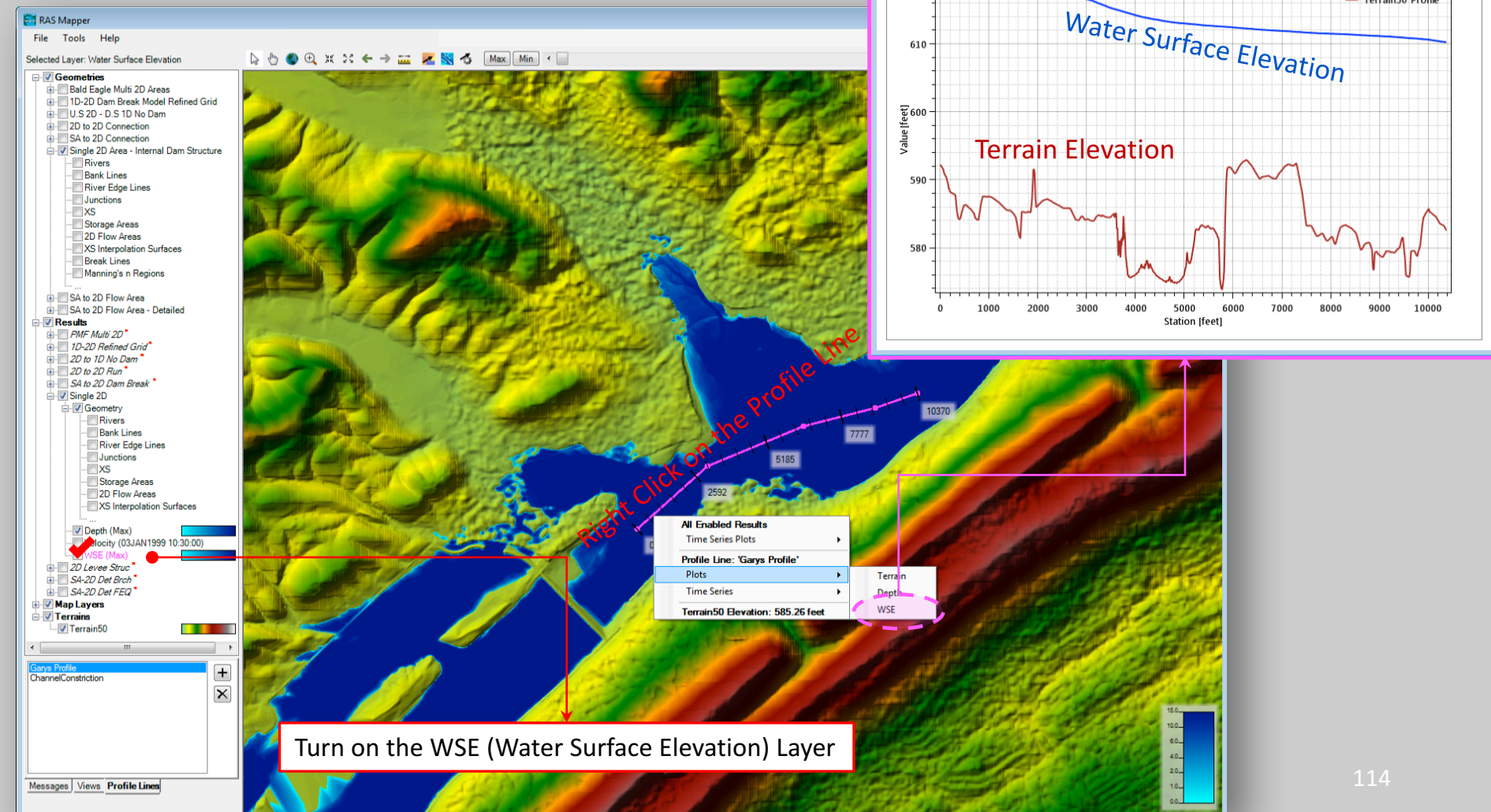
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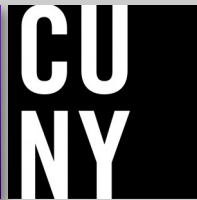
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Thank You 😊

References:

- HEC-RAS 5.0 User's Manual
- HEC-RAS 5.0 2D Modeling User's Manual
- The RAS Solution, <http://hecrasmodel.blogspot.com/>



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