

Tutorial on using HEC-GeoRAS with ArcGIS 10.x and HEC-RAS Modeling

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May 2016

Objective

The objective of this exercise is to explore and learn basic functions in HEC-GeoRAS for pre- and/or post-processing of GIS data and HEC-RAS results for flood inundation mapping using ArcGIS 10.x. It is expected that you are familiar with HEC-RAS and ArcGIS. If you want to get into details of HEC-GeoRAS that are not covered in this tutorial please refer to the HEC-GeoRAS users manual.

Computer Requirements

You must have a computer with windows operating system, and the following programs installed:

1. ArcGIS 10.x
2. HEC-GeoRAS
3. HEC-RAS

You can download HEC-RAS and HEC-GeoRAS (appropriate for your 10.x ArcGIS version) for free from the US Army Corps of Engineers Hydrologic Engineering Center website <http://www.hec.usace.army.mil/software/>

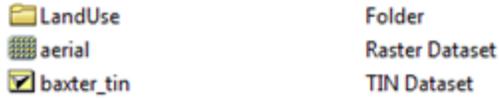
Data Requirement

The only essential dataset required for HEC-GeoRAS is the terrain data (TIN or DEM). Additional datasets that may be useful are aerial photograph (s) and land use information. The dataset supplied with this tutorial includes a small portion of the fictional Baxter River available with HEC-GeoRAS users manual.

The data (11.1 MB) required for this tutorial are available at the following link:

<ftp://ftp.ecn.purdue.edu/vmerwade/download/data/georasdata.zip>

Download the zip file on your local drive, and **unzip** its contents. The GeoRASData folder contains one sub-folder, one TIN dataset, and one aerial image (as raster grid) as shown below (ArcCatalog view):

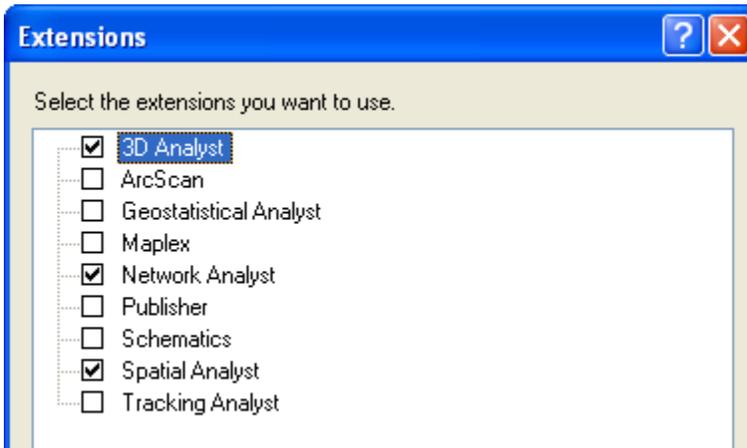


The *LandUse* folder contains a shapefile with land use data, *aerial* is the aerial image of the study area, and *baxter_tin* is the TIN dataset for the study area.

Getting Started

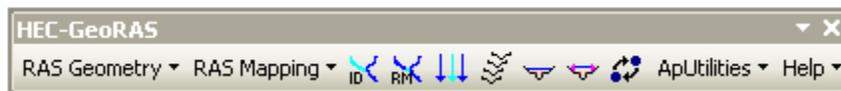
Start ArcMap by **clicking** *Start* → *Programs* → *ArcGIS* → *ArcMap*. Save the ArcMap document (by **clicking** *File* → *Save As..*) as *baxter_georas.mxd* in your working folder.

Since Hec-GeoRAS uses functions associated with ArcGIS *Spatial Analyst* and *3D Analyst* extensions, make sure these extensions are available, and are enabled. You can check this by **clicking** on *Customize* → *Extensions..*, and **checking** the boxes (if they are unchecked) next to *3D Analyst* and *Spatial Analyst* as shown below:



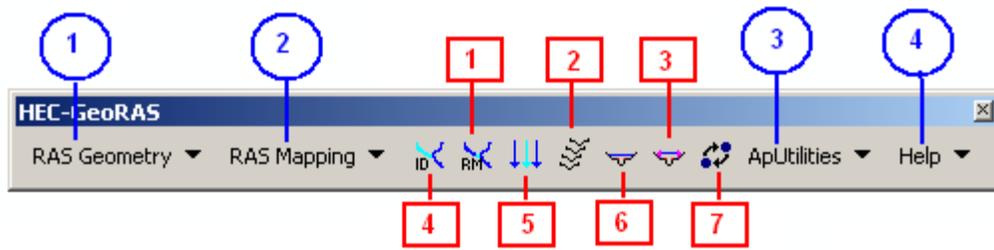
Close the Extensions window.

Now load the HEC-GeoRAS toolbar into ArcGIS by **clicking** on *Customize* → *Toolbars* → *HEC-GeoRAS* to see the toolbar as shown below:



You can either leave the HEC-GeoRAS toolbar on the map or dock it with other toolbars as desired.

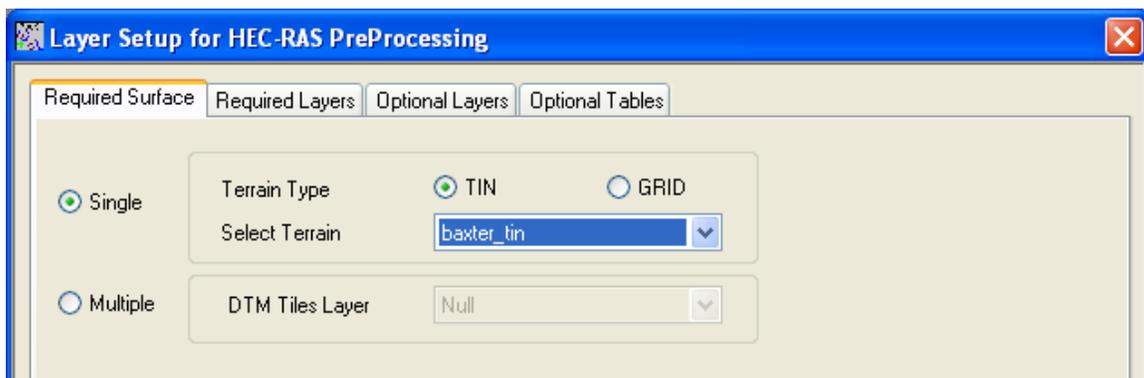
The HEC-GeoRAS toolbar has four menus (RAS Geometry, RAS Mapping, ApUtilities, Help) and seven tools/buttons (Assign RiverCode/ReachCode, Assign FromStation/ToStation, Assign LineType, Construct XS Cutlines, Plot Cross Section, and Assign Levee Elevation) as shown in circles and boxes, respectively in the figure below.



The *RAS Geometry* menu contains functions for pre-processing of GIS data for input to HEC-RAS. The *RAS Mapping* menu contains functions for post-processing of HEC-RAS results to produce flood inundation map. The *ApUtilities* menu contains functions mainly for data management. The *Help* menu is self-explanatory. You will learn more about the functions associated with these menus and buttons in the following sections.

Setting up Analysis Environment for HEC-GeoRAS

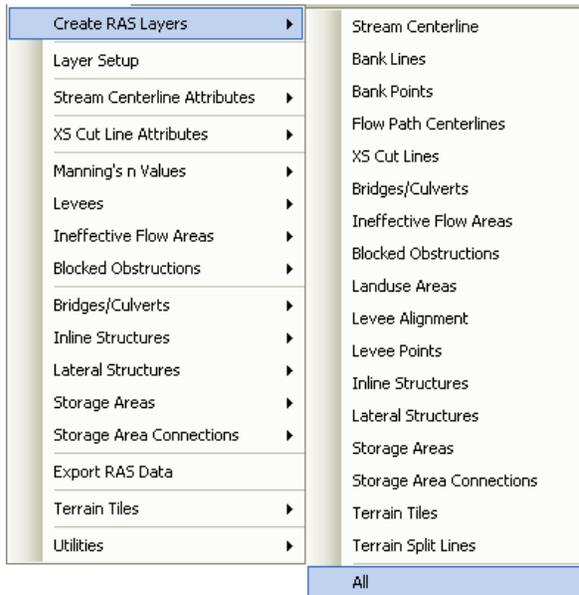
Using GIS for hydrologic/hydraulic modeling usually involves three steps: 1) pre-processing of data, 2) model execution, and 3) post-processing/visualization of results. To create a geometry file, you need terrain (elevation) data. **Click** on Add  button in ArcMap, and **browse** to *baxter_tin* to add the TIN to the map document. You must have the same coordinate system for all the data and data frames used for this tutorial (or any GeoRAS project). Because *baxter_tin* already has a projected coordinate system, it is applied to the data frame. You can check this by right-clicking on the data frame and looking at its properties. Next, click on RAS Geometry→Layer Setup. Select *baxter_tin* as the single TIN in the *Required Surface* tab, and **click OK**.



Creating RAS Layers

The geometry file for HEC-RAS contains information on cross-sections, hydraulic structures, river banks and other physical attributes of river channels. The pre-processing using HEC-GeoRAS involves creating these attributes in GIS, and then exporting them to the HEC-RAS geometry file. In HEC-GeoRAS, each attribute is stored in a separate feature class called as RAS Layer. So before creating river attributes in GIS, let us first create empty GIS layers using the RAS Geometry menu on the HEC-GeoRAS toolbar. **Click** on *RAS Geometry*→*Create RAS Layers*. You will see a list of all the possible attributes that you can have in the HEC-RAS geometry file. If you wish, you can click on

individual attribute to create a single layer at a time, or you can click on All to create all layers. For this tutorial, **click** on *ALL* to create all layers.



In the *Create All Layers* window, accept the default names, and **click** *OK*.

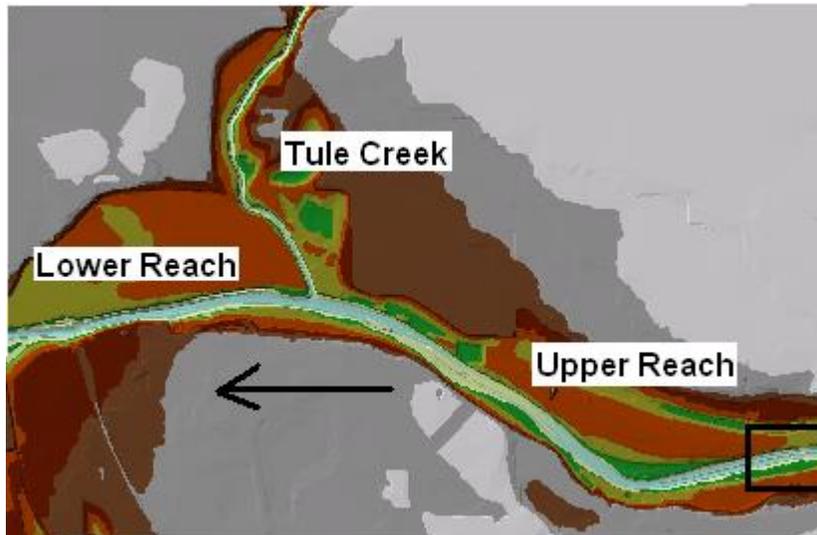


HEC-GeoRAS creates a geodatabase in the same folder where the map document is saved, gives the name of the map document to the geodatabase (Baxter_georas.mdb, in this case), and stores all the feature classes/RAS layers in this geodatabase.

After creating RAS layers, these are added to the map document with a pre-assigned symbology. Since these layers are empty, our task is to populate some or all of these layers depending on our project needs, and then create a HEC-RAS geometry file.

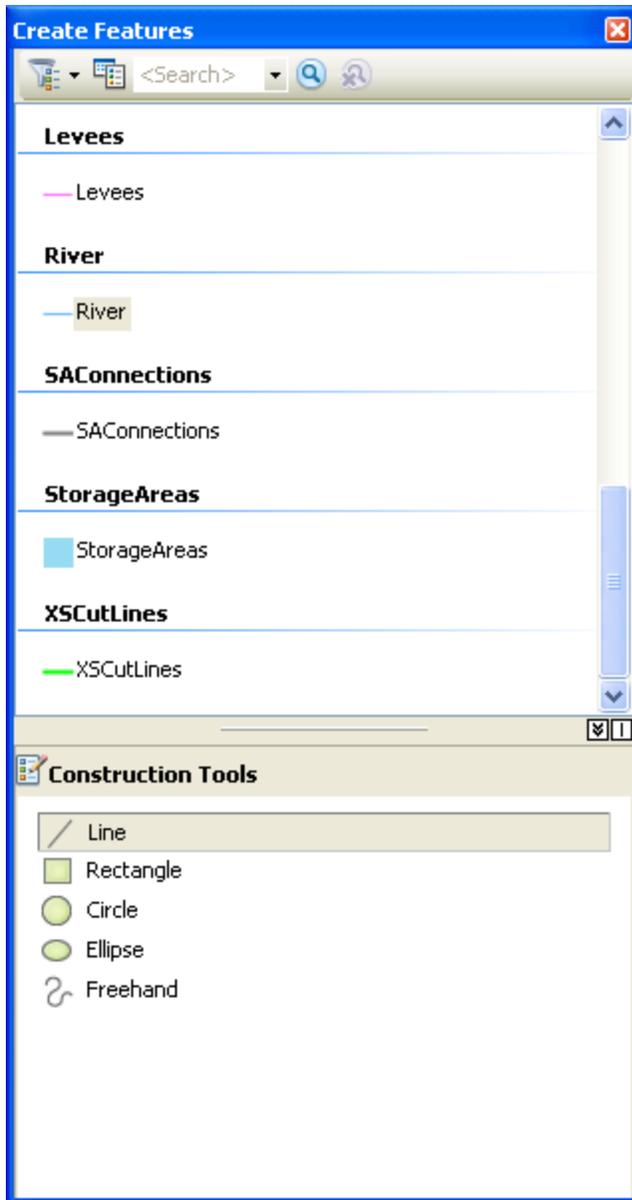
Creating River Centerline

Let us first start with river centerline. The river centerline is used to establish the river reach network for HEC-RAS. The *baxter_tin* dataset has the Baxter River flowing from east to west with Tule Creek as a tributary. So there are three reaches: upper Baxter River, lower Baxter River and Tule Creek Tributary as shown below:

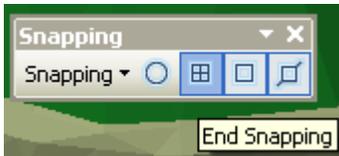


We will create/digitize one feature for each reach approximately following the center of the river, and aligned in the direction of flow. **Zoom-in** to the most upstream part of the upper Baxter reach to see the main channel (black outline shown in the above figure).

To create the river centerline (in River feature class), **start editing**. In the create features window, select River for features and Line for construction tools as shown in the figure below. (**Note:** While digitizing the centerline, make sure that you leave some space between the boundary of the dataset and the beginning/ending of your centerline.)



Using the straight segment tool on the Editor, **start digitizing** the river centerline from the upstream end of the upper Baxter River reach towards the downstream until you reach the intersection with the Tule Creek tributary. When you reach the intersection, double click to complete the centerline for the upper reach. If you need to pan, click the pan tool, pan through the map and then continue by clicking the sketch tool (do not double-click until you reach the junction). After finishing digitizing the upper Baxter Reach, **save the edits**. Before you start digitizing the Tule Creek tributary, modify some editing options. **Click** on *Editor* → *Snapping* → *Snapping Toolbar*, and select the check the *End Snapping* option as shown below. (**Note:** Setting the snapping options is not needed in ArcGIS versions 10.2 and higher because the editing digitizing tool will snap automatically to the end of an existing line)



We are selecting this snapping option because when we digitize the Tule tributary we want its downstream end coincide with the downstream end of the upper Baxter Reach. Now **start digitizing** the Tule Tributary from its upstream end (leave some space from the edge!) towards the junction with the Baxter River. When you come close to the junction, **zoom-in**, and you will notice that the tool will automatically try to snap (or hug!) to the downstream end of the upper Baxter Reach. **Double click** at this point to finish digitizing the Tule Tributary. **Save edits**. Finally, **digitize** the lower Baxter reach from junction with the Tule Tributary to the most downstream end of the Baxter River (again leave some space from the edge!). Again make sure you snap the starting point with the common end points of Upper Baxter Reach and Tule Tributary. **Save edits**, and **stop editing**. Snapping of all the reaches at the junction is necessary for connectivity and creating a junction that HEC-RAS will use to define the intersection of these lines.

After the reaches are digitized, the next task is to name them. Each river in HEC-RAS must have a unique river name, and each reach within a river must have a unique reach name. We can treat the main stem of the Baxter River as one river and the Tributary as the second river. To assign names to reaches, **click** on *Assign RiverCode/ReachCode* button to activate it as shown below:



With the button active, **click** on the upper Baxter River reach. You will see the reach will get selected, invoking the following window:



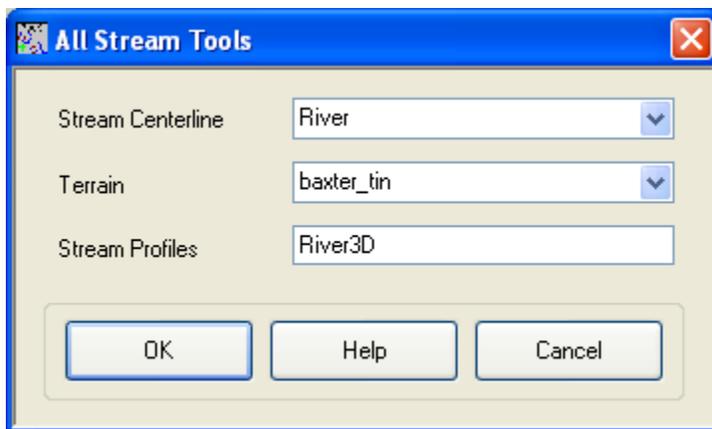
Assign the River and Reach name as *Baxter River* and *Upper Reach*, respectively, and **click OK**. **Click** on the tributary reach, and use *Tule Creek* and *Tributary* for River and Reach name, respectively. For lower Baxter River, use *Baxter River* and *Lower Reach* for River and Reach name, respectively.

Now open the attribute table of the River feature class, and you will see that the information you just provided on river and reach names is entered as feature attributes as shown below.

Shape	OID	Shape_Length	HydroID	River	Reach	FromNode	ToNode	ArcLength	FromSta	ToSta
Polyline	1	3751.333992	1	Baxter River	Upper Reach	<Null>	<Null>	<Null>	<Null>	<Null>
Polyline	2	664.793455	4	Tule Creek	Tributary	<Null>	<Null>	<Null>	<Null>	<Null>
Polyline	3	2747.78351	5	Baxter River	Lower Reach	<Null>	<Null>	<Null>	<Null>	<Null>

Also note that there are still some unpopulated attributes in the River feature class (FromNode, ToNode, etc.).

Before we move forward let us make sure that the reaches we just created are connected, and populate the remaining attributes of the River feature class. **Click** on *RAS Geometry* → *Stream Centerline Attributes* → *All*



Confirm *River* for *Stream Centerline* and *baxter_tin* for *Terrian TIN*, *River3D* for *Stream Profiles*, and **click** *OK*. This function will populate the FromNode and ToNode attribute of the River feature class. This will populate all attributes in River, and will also create 3D version (new feature class) of River centerline called River3D. Now open the attribute table for River, and understand the meaning of each attribute.

Shape	OID	Shape_Length	HydroID	River	Reach	FromNode	ToNode	ArcLength	FromSta	ToSta
Polyline	1	3751.333992	1	Baxter River	Upper Reach	1	2	3751.334	2747.7834	6499.11
Polyline	2	664.793455	4	Tule Creek	Tributary	3	2	664.793	0	664.793
Polyline	3	2747.78351	5	Baxter River	Lower Reach	2	4	2747.783	0	2747.78

HydroID is a unique number for a given feature in a geodatabase. The *River* and *Reach* attributes contain unique names for rivers and reaches, respectively. The *FromNode* and *ToNode* attributes define the connectivity between reaches. *ArcLength* is the actual length of the reach in map units, and is equal to *Shape_Length*. In HEC-RAS, distances are represented using station numbers measured from downstream to upstream. For example, each river has a station number of zero at the downstream end, and is equal to the length of the river at the upstream end. Since we have only one reach for Tule Creek tributary the *FromSta* attribute is zero and the *ToSta* attribute is equal to the *ArcLength*. Since the Baxter River has two reaches, the *FromSta* attribute for Upper Reach = *ToSta* attribute of lower reach, and the *ToSta* attribute for upper reach is the sum of *ArcLengths* for the upper and lower reach. **Close** the attribute table, and **save** the map document.

Creating River Banks

Bank lines are used to distinguish the main channel from the overbank floodplain areas. Information related to bank locations is used to assign different properties for cross-sections. For example, compared to the main channel, overbank areas are assigned higher values of Manning's n to account for more roughness caused by vegetation. Creating bank lines is similar to creating the channel centerline, but there are no specific guidelines with regard to line orientation and connectivity - they can be digitized either along the flow direction or against the flow direction, or may be continuous or broken.

To create a bank line (in Banks feature class), follow the same digitization procedure by selecting bank feature and straight segment tool. Although there are no specific guidelines for digitizing banks, to be consistent, follow these guidelines: 1) start from the upstream end; 2) looking downstream, digitize the left bank first and then the right bank. When digitizing the left bank, you do not have to stop at the intersection, you can have a single bank for the whole reach. On the right hand side, however, you cannot cross the creek so you will need two separate lines for the right bank of the Baxter River. **Digitize** banks for all three reaches and **save** the edits and the map document.

Creating Flowpaths

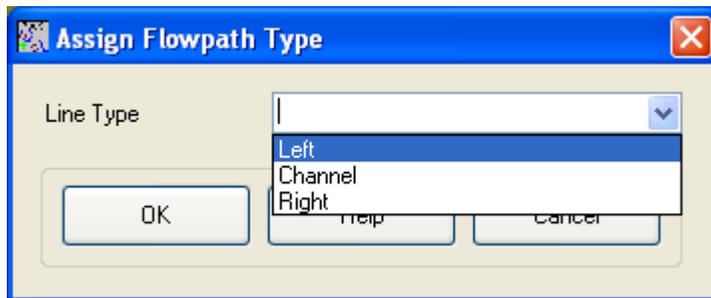
The flowpath layer contains three types of lines: centerline, left overbank, and right overbank. The flowpath lines are used to determine the downstream reach lengths between cross-sections in the main channel and over bank areas. If the river centerline that we created earlier lie approximately in the center of the main channel (which it does), it can be used as the flow path centerline. **Click** on *RAS Geometry* → *Create RAS Layers* → *Flow Path Centerlines*

Click *Yes* on the message box that asks if you want to use the stream centerline to create the flow path centerline. Confirm *River* for *Stream Centerline* and *Flowpaths* for *Flow Path Centerlines*, and **click** *OK*.



To create the left and right flow paths in Flowpaths feature class, **start editing**. Digitize flowpaths using the same digitization procedure as before. The left and right flowpaths must be digitized within the floodplain. These lines are used to compute distances between cross-sections in the over bank areas. Again, to be consistent, looking downstream, first digitize the left flowpath followed by the right flowpath for each reach. After digitizing, **save the edits** and **stop editing**. (**Note:** Make you digitize right and left flow path separately for each individual reach. Do not use a common flowpath line for multiple reaches.)

Now label the flowpaths by using the Assign LineType button . **Click** on the button (notice the change in cursor), and then **click** on one of the flow paths (left or right, looking downstream), and name the flow path accordingly as shown below:

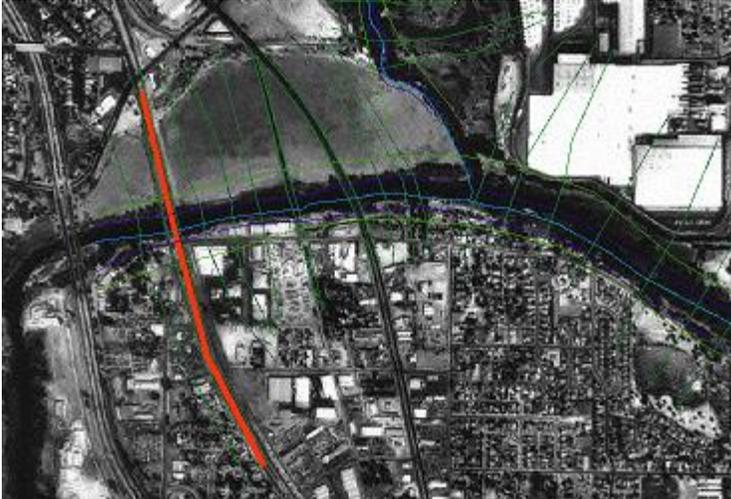


Label all flow paths, and confirm this by opening the attribute table of the Flowpaths feature class. The LineType field must have data for each row if all flowpaths are labeled as shown below.

Shape ^	OID ^	Shape_Length	LineType
Polyline	1	3751.333992	Channel
Polyline	2	664.793455	Channel
Polyline	3	2747.78351	Channel
Polyline	4	6154.070674	Left
Polyline	5	3645.480373	Right
Polyline	6	2282.559303	Right
Polyline	7	457.299417	Left
Polyline	8	368.453857	Right

Creating Cross-sections

Cross-sections are one of the key inputs to HEC-RAS. Cross-section cutlines are used to extract the elevation data from the terrain to create a ground profile across channel flow. The intersection of cutlines with other RAS layers such as centerline and flow path lines are used to compute HEC-RAS attributes such as bank stations (locations that separate main channel from the floodplain), downstream reach lengths (distance between cross-sections) and Manning's n. Therefore, creating adequate number of cross-sections to produce a good representation of channel bed and floodplain is critical. Certain guidelines must be followed in creating cross-section cutlines: (1) they are digitized perpendicular to the direction of flow; (2) must span over the entire flood extent to be modeled; and (3) always digitized from left to right (looking downstream). Even though it is not required, but it is a good practice to maintain a consistent spacing between cross-sections. In this exercise, let's use an approximate spacing of 150 meters (500 feet) for all cross-sections. In addition, if you come across a structure (eg. bridge/culvert) along the channel, make sure you define one cross-section each on the upstream and downstream of this structure. The upstream and downstream cross-sections must be no farther than 100 – 200 feet from the structure. Structures can be identified by using the aerial photograph provided with the tutorial dataset. For example, we will use one bridge location in this exercise just downstream of the junction with tributary as shown below (bridge location is shown in red):



To create cross-section cutlines in XSCutlines feature class, **start editing**. Digitize cross-section cutlines by using the same digitization procedure as before, but follow the guidelines outlined in the previous paragraph. While digitizing, make sure that each cross-section is wide enough to cover the floodplain. This can be done using the cross-sections profile tool . **Click** on the profile tool, and then **click** on the cross-section to view the profile. For example, if you get a cross-section profile shown in Figure A below, then there is no need to edit the cross-section, but if you get a cross-section as shown in Figure B below, then the cross-section needs editing. (**Note:** This tool stops the edit session so you will have to start the edit session every time after viewing the cross-section profile). If using the profile tool does not help you, make sure your cross-section is at least four to five times wider than the channel banks.

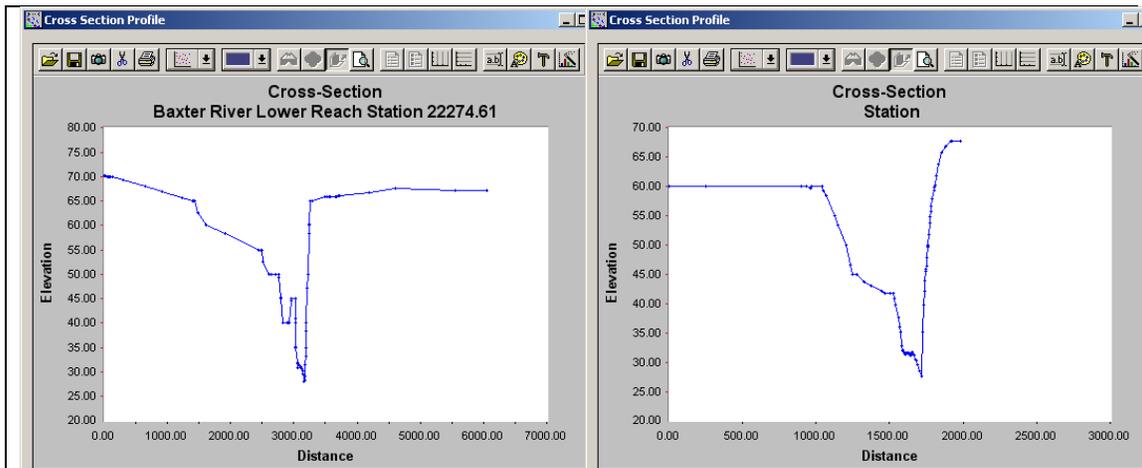
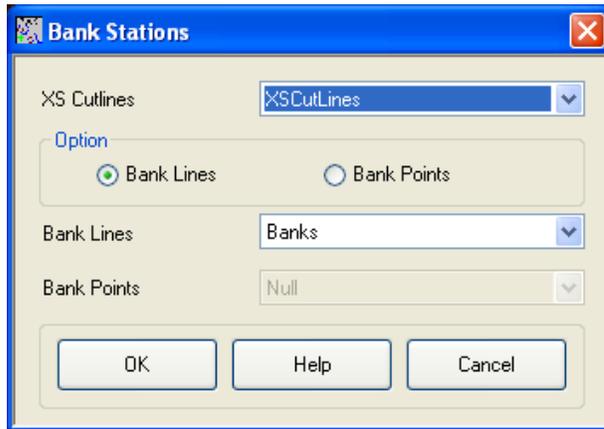


Figure A: adequate definition of cross-section

Figure b: inadequate definition of coss-section

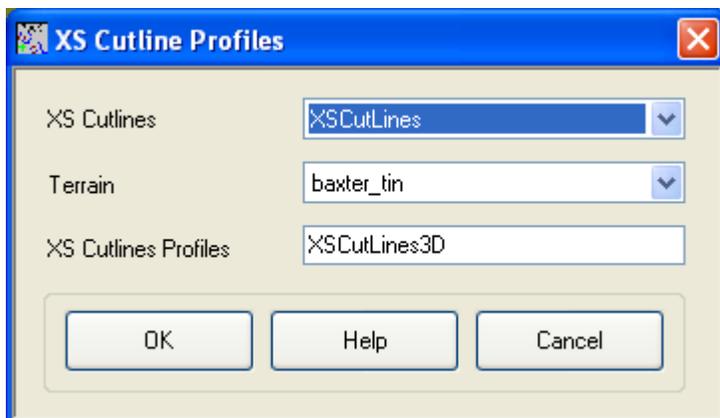
After digitizing the cross-sections, **save** the edits and **stop editing**. The next step is to add HEC-RAS attributes to these cutlines. We will add Reach/River name, station number along the centerline, bank stations and downstream reach lengths. Since all these attributes are based on the intersection of cross-sections with other layers, make sure each cross-section intersects with the centerline and overbank flow paths to avoid error messages.

Click on *RAS Geometry*→ *XS Cut Line Attributes*→ *River/Reach Names*. This tool uses the River and Reach attributes of the centerline, and copy them to the XS Cutlines. Next, **click** on *RAS Geometry*→*XS Cut Line Attributes*→*Stationing*. This tool will assign station number (distance from each cross-section to the downstream end of the river) to each cross-section cutline. Next, **click** on *RAS Geometry*→*XS Cut Line Attributes*→ *Bank Stations*. Confirm XSCutlines for XS Cut Lines, and Banks for Bank Lines, and **click** *OK*.



This tool assigns bank stations (distance from the starting point on the XS Cutline to the left and right bank, looking downstream) to each cross-section cutline. Finally, **click** on *RAS Geometry*→*XS Cut Line Attributes*→*Downstream Reach Lengths*. This tool assigns distances to the next downstream cross-section based on flow paths.

The cross-section cutlines are 2D lines with no elevation information associated with them (Polyline). When you used the profile tool earlier to view the cross-section profile, the program used the underlying terrain to extract the elevations along the cutline. You can convert 2D cutlines into 3D by **clicking** *RAS Geometry*→*XS Cut Line Attributes*→*Elevation*. Confirm *XSCutlines* for *XS Cut Lines*, and *baxter_tin* for *Terrian TIN*. The new 3D lines (XS Cut Lines Profiles) will be stored in the *XSCutLines3D* feature class. **Click** *OK*.

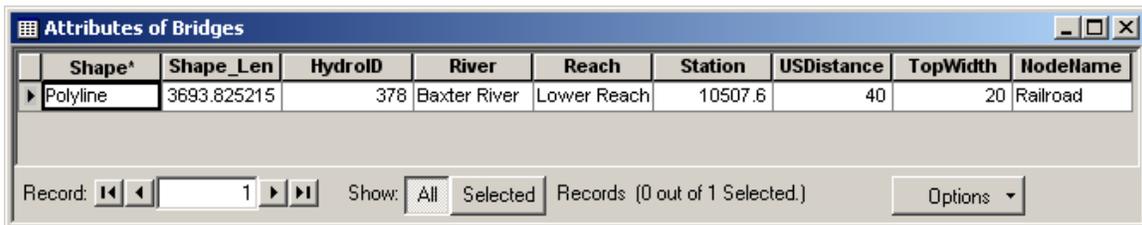


After this process is finished, open the attribute table of XSCutLines3D feature class and see that the shape of this feature class is now PolylineZ.

Creating Bridges and Culverts

After creating cross-sections, the next step is to define bridges, culverts and other structure along the river. Since we used aerial photograph while defining the cross-sections, our job of locating the bridge accomplished. To create bridges/culverts (in Bridges feature class), **start editing** to digitize bridges. A bridge or culvert is treated similar to a cross-section so the same criteria used for creating cross-sections must be used for bridge/culverts. Using Bridge as the edit feature and the straight segment tool on the editor toolbar, **digitize** bridge location just downstream of the tributary junction. While digitizing the bridge, make use of the terrain model to make sure the bridge/road centerline fall on the high ground. **Save** your edits and **stop** editing.

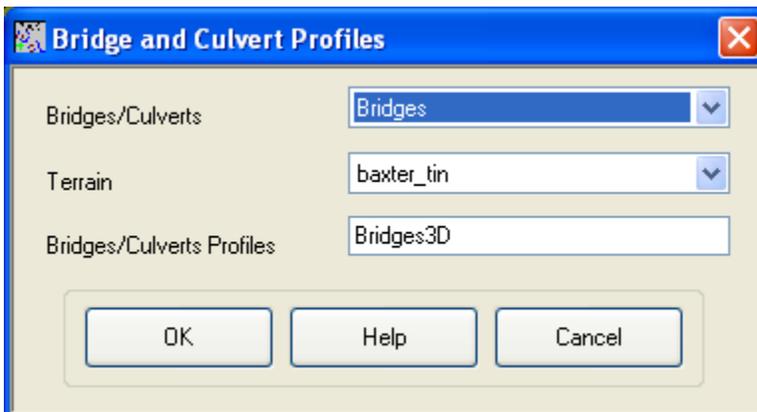
After digitizing bridges/culverts, you need to assign attributes such as River/Reach name and station number to these features. **Click** on *RAS Geometry* → *Bridge/Culverts* → *River/Reach Names* to assign river/reach names. Next **click** on *RAS Geometry* → *Bridge/Culverts* → *Stationing* to assign station numbers. Besides these attributes, you must enter additional information about the bridge(s) such as the name and width in its attribute table as shown below.



Shape*	Shape_Len	HydroID	River	Reach	Station	USDistance	TopWidth	NodeName
Polyline	3693.825215	378	Baxter River	Lower Reach	10507.6	40	20	Railroad

Close the attribute table, **save** edits and **stop** editing.

Similar to cross-sections, the Bridges feature class stores 2D polylines, you can make them 3D by **clicking** *RAS Geometry* → *Bridge/Culverts* → *Elevations* to create a new 3DBridges feature class. Confirm *Bridges* for *Bridges/Culverts*, *baxter_tin* for *Terrain*, *Bridges3D* for *Bridges/Culverts Profiles*, and **Click OK**.



Bridge and Culvert Profiles

Bridges/Culverts: Bridges

Terrain: baxter_tin

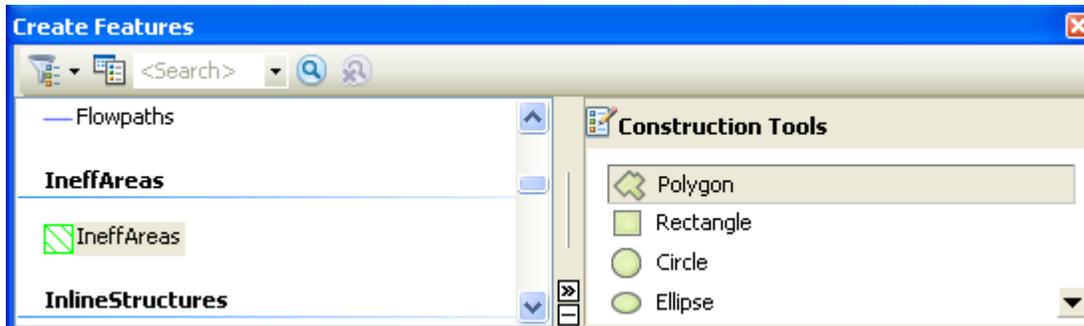
Bridges/Culverts Profiles: Bridges3D

OK Help Cancel

A new feature class (Bridges3D) will be created. You can check it is PolylineZ by opening its attribute table.

Creating ineffective flow areas

Ineffective flow areas are used to identify non-conveyance areas (areas with water but no flow/zero velocity) of the floodplain. For example, areas behind bridge abutments representing contraction and expansion zones can be considered as ineffective flow areas. To define ineffective areas (in IneffAreas feature class), **start editing**, and choose IneffAreas as the edit feature, and Polygon as the construction tool.

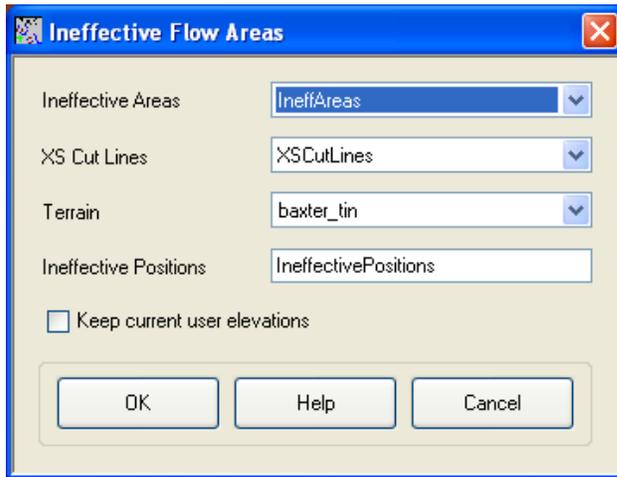


Use the sketch tool to define ineffective areas. The figure below shows an example of ineffective area for the bridge downstream of the tributary junction (**Note:** this is a polygon feature class).



HEC-RAS does not store all information about ineffective areas. Instead only the information where the ineffective area may interfere with cross-sections/flow is stored. Therefore, it is important that the ineffective flow area that you digitize must intersect with one or more cross-sections. To extract the position and elevation at points where these ineffective areas intersect with cross-sections, **click** on *RAS Geometry*→*Ineffective Flow Areas*→*Position*. Leave the default feature classes for *IneffectiveAreas*, *XS Cut Lines*, and *Terrain* unchanged. The position of ineffective areas will be stored in a new

table named *IneffectivePositions*. Leave current user elevations **unchecked**, and **Click OK**.



Open the attributes of the *IneffectivePositions* table (shown below) to understand how this information is stored. If you cannot find this table in the map document, add it manually from the geodatabase where all your other layers are stored.

OBJECTID *	XS2DID	IA2DID	BegFrac	EndFrac	BegElev	EndElev	UserElev
1	18	36	0.65724	0.83237	45.915	60.441	<Null>
2	18	37	0.37743	0.44781	57.227	53.251	<Null>
3	21	38	0.66403	0.82444	49.285	60.427	<Null>
4	21	39	0.34508	0.47791	59.62	38.507	<Null>

IA2DID is the HydroID of the ineffective flow area, *XS2DID* is the HydroID of the intersecting cross-section, *BeginFrac* and *EndFrac* are the relative positions of the first and last intersecting points (looking downstream) of the ineffective area with the cross-section. *BegElev* and *EndElev* are the elevations of the first and last intersecting points of the ineffective area with the cross-section. Since you left the *UserElev* box unchecked there are no values in this field.

Creating obstructions

Obstructions represent blocked flow areas (areas with no water and no flow). For example, buildings in the floodplain and levees are considered obstructions. We can add blocked obstructions to our study by using building locations in the aerial photograph. In the upper reach of the Baxter River just before Tule Creek, there are two building in the floodplain that can be considered as blocked obstructions.



To define blocked obstructions (in BlockedObs feature class), **start editing**, and choose BlockedObs as the edit feature and Polygon as the construction tool.

Using the straight segment tool, digitize the blocked obstruction polygon, **save edits** and **stop editing**. Similar to Ineffective flow areas, the positions and elevations of the intersection of this obstruction with cross-sections needs to be stored in a table. Click on *RAS Geometry* → *Blocked Obstructions* → *Positions*. Leave the default values in the *Blocked Obstructions* window, and **click OK**. You will notice that a new table (*BlockedPositions*) will be added to the map document, and its content are identical to *IneffectivePositions* table.

Assigning Manning's n values to cross-sections

The final task before exporting the GIS data to HEC-RAS geometry file is assigning Manning's n values to individual cross-sections. In HEC-GeoRAS, this is accomplished by using a land use feature class with Manning's n stored for different land use types. Ideally you will store this information in the LandUse feature class added to the map document. Since we created empty feature classes at the beginning of the tutorial, we do not have this information. We will remove this empty LandUse feature class, and add LandUse shapefile (stored in LandUse folder) provided with the tutorial dataset. (**Note:** you can also replace the LandUse feature class in Baxter_georas.mdb with the shapefile in ArcCatalog)

FID	Shape	LUCode	H_Value	Shape_Leng	Shape_Area
0	Polygon	Nearstream	0.035	74238.039962	47884074.2645
1	Polygon	Nearstream	0.035	94595.836838	77091525.3525
2	Polygon	Nearstream	0.035	19499.698779	3890744.91706
3	Polygon	Urban	0.05	25155.899476	37360769.6827
4	Polygon	Farming	0.06	57470.779847	132969468.043
5	Polygon	Urban	0.05	43729.482249	80210914.7352
6	Polygon	Urban	0.05	49495.579306	131147302.076
7	Polygon	Farming	0.06	98679.544048	569365177.1
8	Polygon	Farming	0.06	139480.817374	582945502.797
9	Polygon	Urban	0.05	77954.853646	194373174.064

The land use table must have a descriptive field identifying landuse type, which is *LUCode* in this case, and a field for corresponding Manning’s n values. In addition, HEC-GeoRAS requires the land use polygons to be non multi-part features (a multipart feature has multiple geometries in the same feature). The issue of non multi-part features is taken care of for the tutorial dataset.

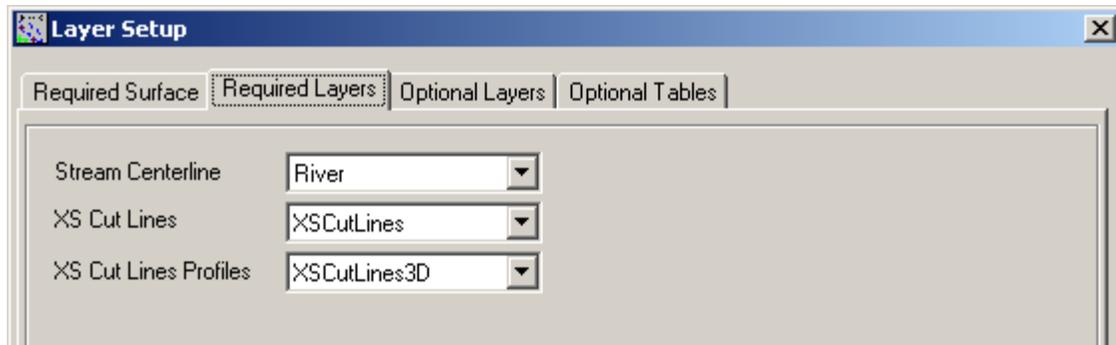
To assign Manning’s n values to cross-sections, **click** on *RAS Geometry* → *Manning’s n Values* → *Extract n Values*. Confirm *LandUse* for *Land Use*, choose *N_Value* for *Manning Field*, *XSCutLines* for *XS Cut Lines*, leave the default name *Manning* for *XS Manning Table*, and **click OK**. (**Note:** Summary Manning Table is not required if n values already exist in the LandUse table.)

Depending on the intersection of cross-sections with landuse polygons, Manning's n are extracted for each cross-section, and reported in the XS Manning Table (*Manning*). **Open** the Manning table, and see how the values are stored. Similar to previous tables, the data are organized as the feature identifier (*XS2DID*), its relative station number and the corresponding n value as shown below:

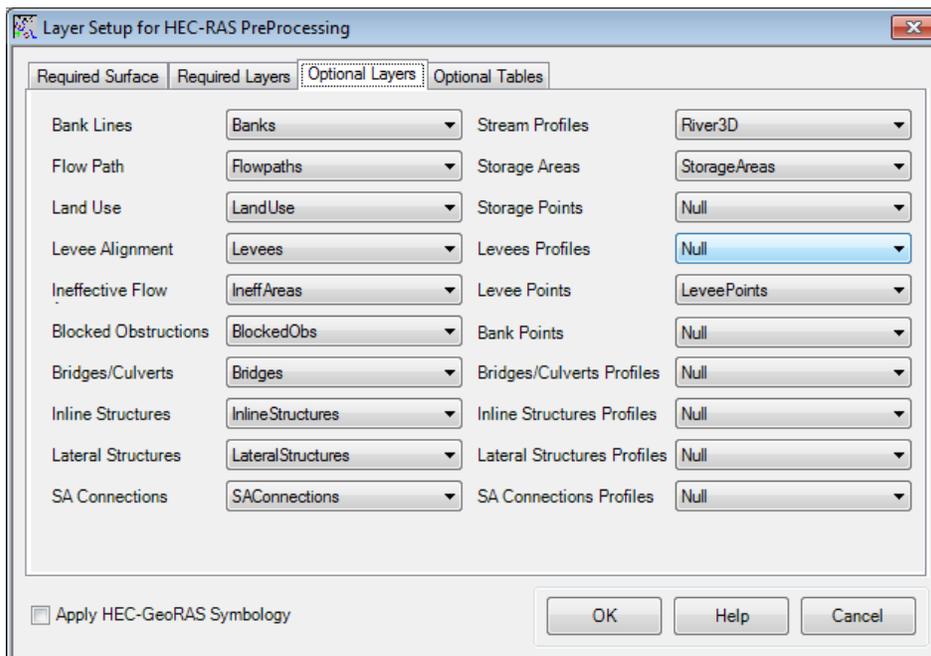
OBJECTID	XS2DID	Fraction	H_Value
1	14	0	0.06
2	14	0.20915	0.035
3	15	0	0.06
4	15	0.25046	0.035
5	15	0.75368	0.05
6	16	0	0.06
7	16	0.11408	0.035
8	16	0.80659	0.05
9	17	0	0.05
10	17	0.17139	0.035

Close the table. We are almost done with GeoRAS pre-processing. The last step is to create a GIS import file for HEC-RAS so that it can import the GIS data to create the geometry file. Before creating an import file, make sure we are exporting the right layers. **Click** on *RAS Geometry* → *Layer Setup*, and verify the layers in each tab. The required surface tab should have *baxter_tin* for *single Terrain* option.

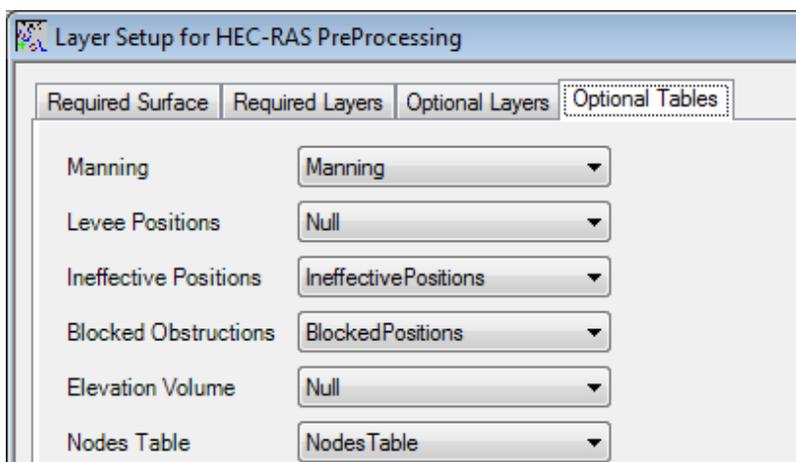
The *Required Layers* tab should have *River*, *XSCutLines* and *XSCutLines3D* for *Stream Centerline*, *XSCutmLines* and *XSCut Lines Profiles*, respectively.



In the *Optional Layers* tab, make sure appropriate layers are assigned.



Finally, verify optional tables and **Click OK**.



One final and most important step before proceeding further is the data check, which we will do manually. Do the checks on the following feature classes:

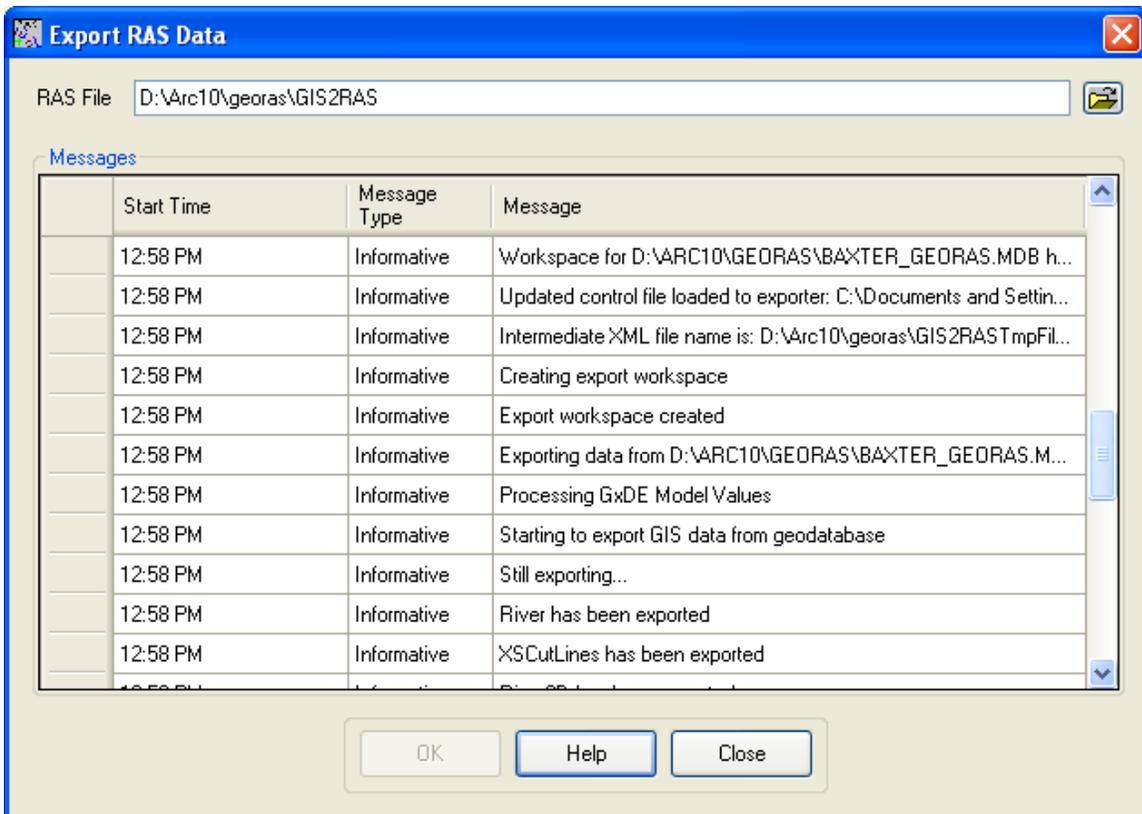
River: Open the attribute table of River, and make sure all the attributes are correctly populated. Check the connectivity of the centerlines and make sure there are no negative or invalid numbers for any fields.

Flowpaths: Open the attribute table for Flowpath, and make sure that that the LineType field is populated and that the line types are correct. For example, Left should represent the left flowpath and Right should represent the right flowpath for each reach.

XSCutlines: Open the attribute table for XSCutline, and make sure that all the attributes are populated. Make sure that all numbers are positive for StationNo, RLength, LLength and ChLength fields. If any number for RLength or LLength is negative for any cross-section, that cross-section was most likely digitized in the wrong direction. Go back and flip that cross-section, and re-assign the attributes. Do this for all cross-sections that have negative numbers for RLength or Length.

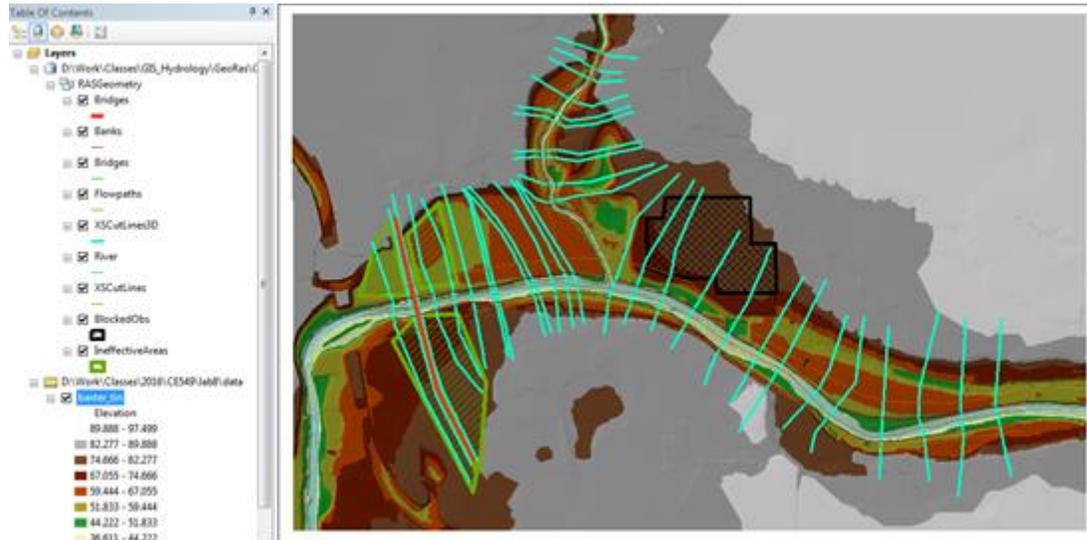
Tables: Open all the tables (BlockedObs, IneffectiveAreas and Manning to make sure they are populated)

After verifying all layers and tables, **click** on *RAS Geometry* → *Export RASData*. Confirm the location and the name of the export file (*GIS2RAS* in this case), and **click** *OK*. During the export, you will see a series of messages as shown below.



After the export is complete, close the window. This process will create two files: *GIS2RAS.xml* and *GIS2RAS.RASImport.sdf*. **Click OK** on the series of messages about computing times. You are done exporting the GIS data! The next step is to import these data into a HEC-RAS model.

The final layers in ArcMap should look something like the figure below.



(Note: Purdue students or others doing this exercise in one of my workshops, please let me see your data before closing the map document! It will save a lot of your time and my time in finishing this exercise successfully!)

Save the map document. You can either close the ArcMap session or leave it open (recommended!).

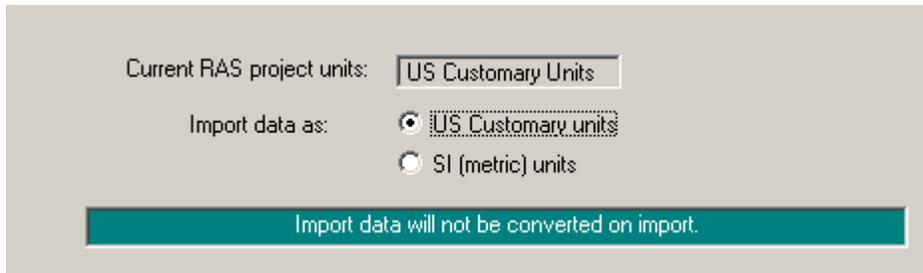
Importing Geometry data into HEC-RAS

Launch HEC-RAS by **clicking** on *Start*→*Programs*→*HEC*→*HEC-RAS*→*HEC-RAS 4.0*. **Save** the new project by going to *File*→*Save Project As..* and save as *baxter.prj* in your working folder as shown below:



Click OK.

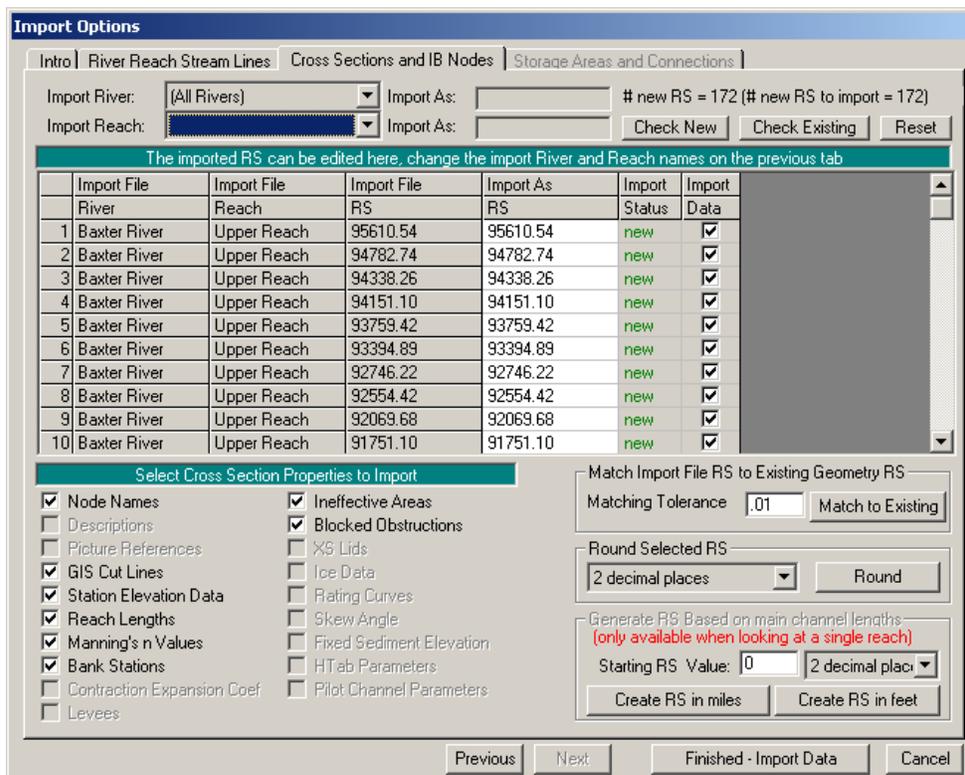
To import the GIS data into HEC-RAS, first go to geometric data editor by **clicking** on *Edit*→*Geometric Data...* In the geometric data editor, **click** on *File*→*Import Geometry Data*→*GIS Format*. **Browse** to *BaxterRAS.RASImport.sdf* file created in GIS, and **click OK**. The import process will ask for your inputs to complete. In the Intro tab, confirm US Customary Units for Import data as and **click Next**.



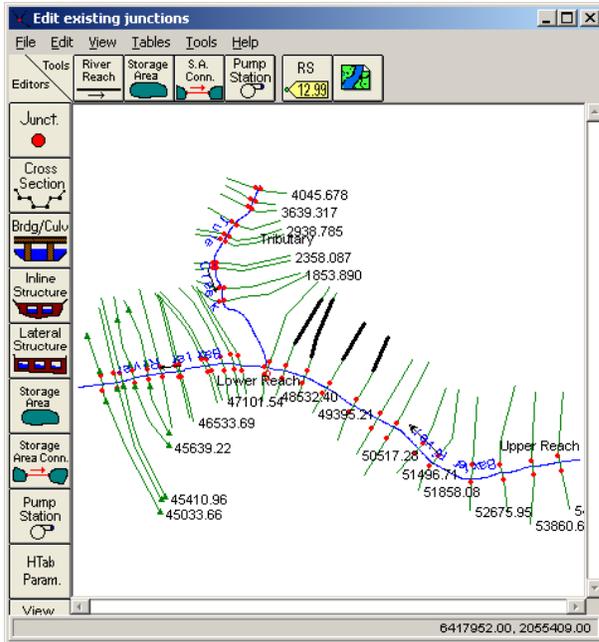
Confirm the River/Reach data, make sure all import stream lines boxes are checked, and **click Next**.

	Import File	Import File	Invert	Import As	Import As	Import	Import	Merge Mode
	River	Reach	#Points	River	Reach	Status	Stream Lines	
1	Baxter River	Upper Reach	178	Baxter River	Upper Reach	new	<input checked="" type="checkbox"/>	Replace
2	Baxter River	Lower Reach	330	Baxter River	Lower Reach	new	<input checked="" type="checkbox"/>	Replace
3	Tule Creek	Tributary	182	Tule Creek	Tributary	new	<input checked="" type="checkbox"/>	Replace

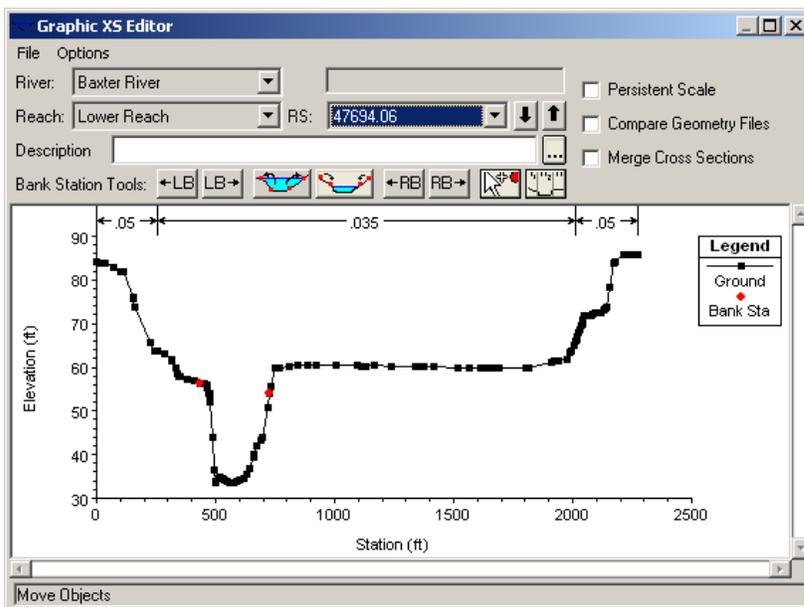
Confirm cross-sections data, make sure all Import Data boxes are **checked** for cross-sections, and **click OK** (accept default values for matching tolerance, round places, etc).



Since we do not have Storage areas, **click Finished-Import Data**. The data will then be imported to the HEC-RAS geometric editor as shown below:



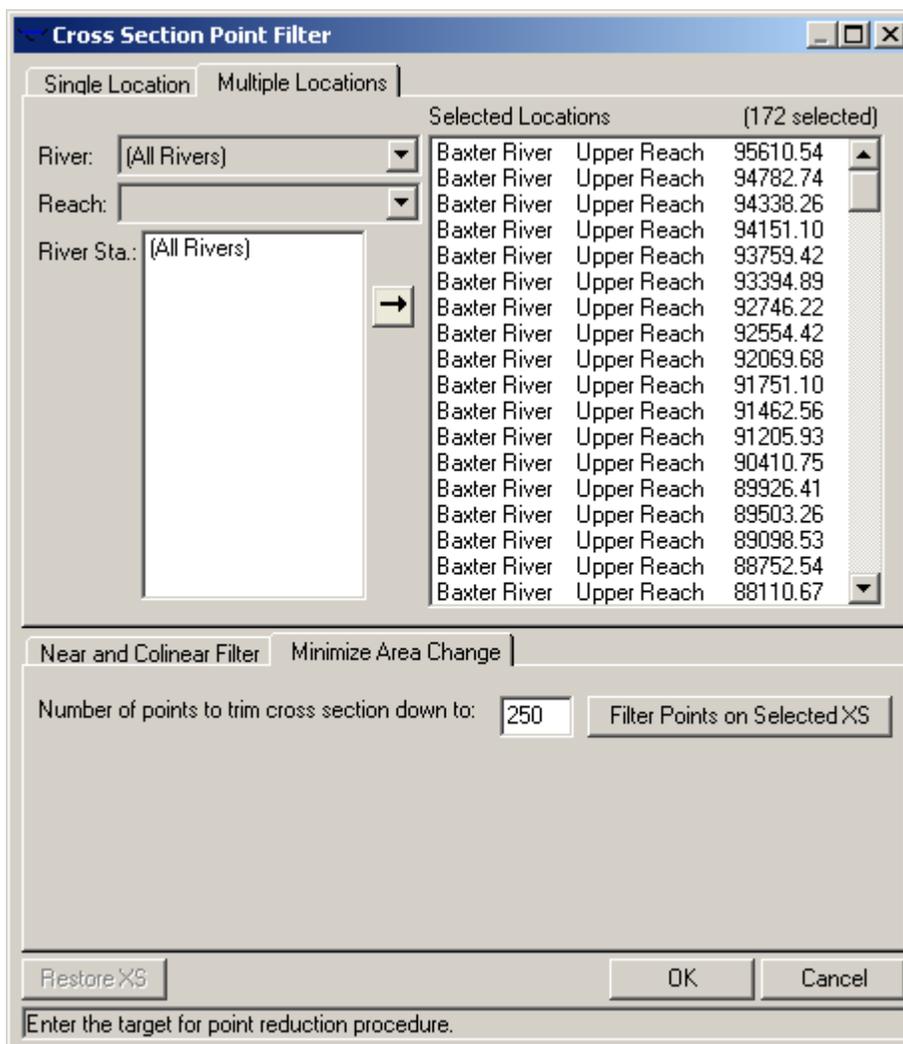
Save the geometry file by clicking *File*→*Save Geometry Data*. Before you proceed, it is a good practice to perform a quality check on the data to make sure no erroneous information is imported from GIS. You can use the tools in Geometric editor to perform the quality check. One of the best tools for editing cross-sections in HEC-RAS is the graphical cross-section editor. In the geometric editor, go to *Tools*→*Graphical Cross-section Edit*.



You can use the editor to move bank stations, change the distribution of Manning's n , add/move/delete ground points, edit structure, etc. You can play around with these tools and learn more about the functions.

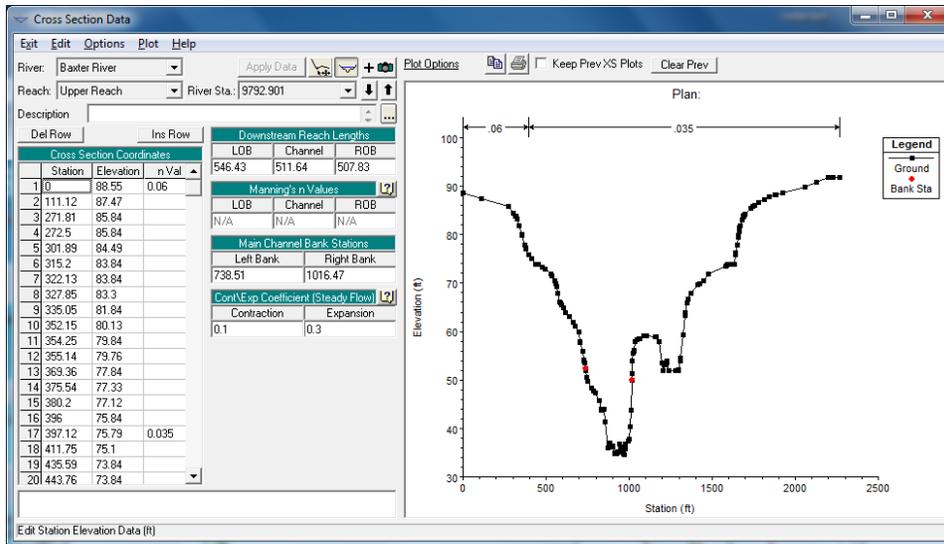
A cross-section in HEC-RAS can have up to 500 elevation points. Generally these many points are not required, and also when we extract cross-sections from a terrain using HEC-GeoRAS, we get a lot of redundant points. This issue can be handled by using the cross-section filter in HEC-RAS. In the Geometric data editor, click on *Tools*→*Cross Section Points Filter*.

In the Cross Section Point Filter, **select** the *Multiple Locations* tab. From the *River* drop down menu, **select** (*All Rivers*) option, and **click** on the select arrow button  to select all cross-sections for all reaches. Then **select** the *Minimize Area Change* tab at the bottom, and **enter** 250 for the number of points to trim cross-sections down to. The minimize area change will reduce the impact of change in cross-sectional area as a result of points removal. **Click** *Filter Points on Selected XS* button.



You will get a summary of number of points removed for the filtered cross-sections. You will notice that only a few cross-sections had points removal. **Close** the summary results box. You can select the Single Location tab to see the effect of points removal on the cross-sections.

Next, click on the geometry editor and select any cross-section. You should see the cross-section window as shown below (**Note:** Ignore the blue colored flow in the cross-section profile):



Each cross-section in HEC-RAS has the following information:

Location: This is described by using three pieces of information: River, Reach and River Station. The cross-section in Figure is located at a distance of 84816 ft (River Sta.) on the Upper Reach (Reach) of the Baxter River (River) from the most downstream end of the Baxter River.

Elevation Profile: This is the profile view that you see on the right hand side in the cross-section window. This profile is created by using the information from the station and elevation columns in the Cross Section Coordinates table on the left. The numbers in the station column shows the distance along the cross-section from left to right (looking downstream along the flow direction), and the elevation column shows the elevation at each station point. You can think of Station and Elevation as the (x,z) attributes for the cross-section line. Each station/elevation point is represented by a black dot on the cross-section profile.

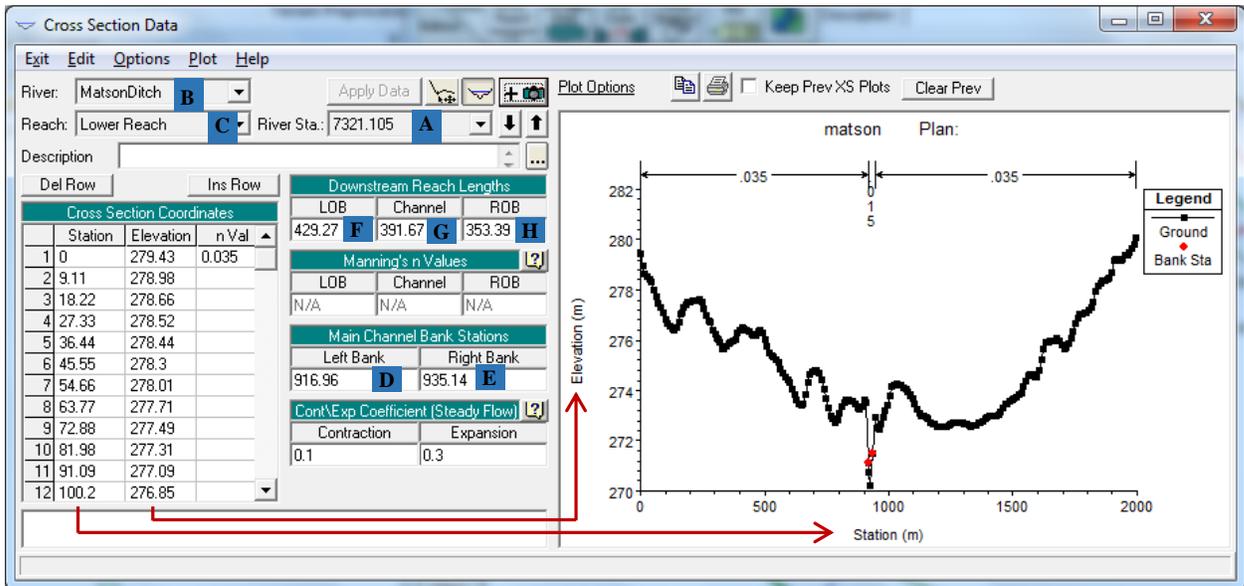
Bank locations: These are represented by two red dots on the cross-section profile. The location of these red dots is dictated by the station numbers for Left and Right Banks in the “Main Channel Bank Stations” table in the cross-section window.

Roughness (Manning’s n Values): The horizontal line at the top of the cross-section profile shows the distribution of Manning’s n value along the cross-section. This distribution is defined in the n Val column in the Cross Section Coordinates table. You will see that the n Val column is not populated for each row. The values are only reported at stations points where there is a change in the Manning’s n. For example, the Manning’s n is 0.06 at the beginning stays constant until the next change to 0.035.

Distance to the next downstream cross-section: This information is presented in the Downstream Reach Lengths table. The numbers for LOB, ROB and Channel represent the distances to the next downstream cross-section along the left over bank, right over bank and channel, respectively. These distances are computed by using the flow path features that are digitized in HEC-GeoRAS.

If you are wondering how this information gets into HEC-RAS, the figure below shows the attribute table of XSCutline and the corresponding information in HEC-RAS. (**Note:** this figure is for reference only to understand the connection between HEC-RAS and GeoRAS. It is not for Baxter River)

Shape *	Shape_Length	HydroID	Station	River	Reach	LeftBank	RightBank	LLength	ChLength	RLength
Polyline	1921.004607	5	7774.309	MatsonDitch	Lower Reach	0.496354	0.50169	517.2726	453.2037	368.7723
Polyline	1997.200591	6	7321.105	MatsonDitch	Lower Reach	0.459124	0.468225	429.2737	391.6729	353.3876
Polyline	1956.35069	7	6929.432	MatsonDitch	Lower Reach	0.47379	0.478926	467.6574	417.8507	369.7138
Polyline	2166.497029	8	6511.582	MatsonDitch	Lower Reach	0.539426	0.544042	336.7046	351.0277	337.0579
Polyline	2154.755818	9	6160.554	MatsonDitch	Lower Reach	0.55881	0.563458	277.2478	431.4077	395.6638

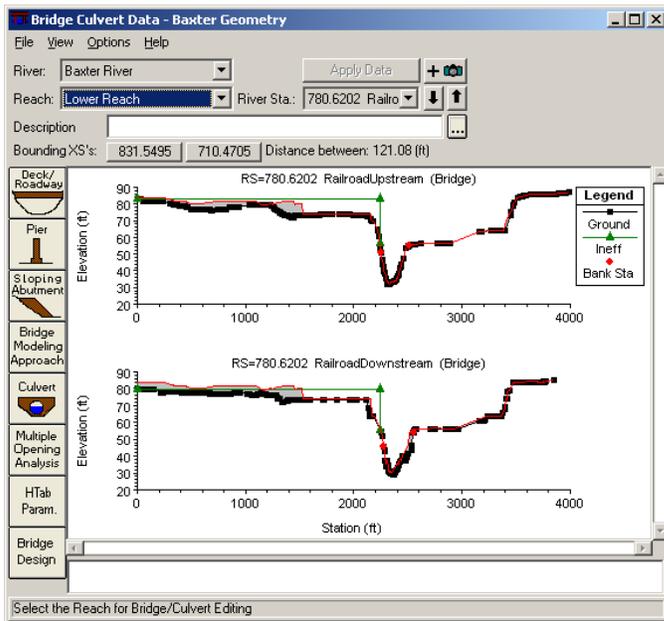


Editing Bridge Structure Data

Another main task that we want to do is to edit data related to structures. When you import river geometry from HEC-RAS to HEC-GeoRAS, the bridge profile needs to be edited to correct the geometry and structural details. **Click** on Bridge/Culvert editing

button , and select the *Railroad* bridge on the *Lower Reach* of the *Baxter River*.

Figure below shows a typical unedited bridge cross-section after import into HEC-RAS.



You will see the cross-section profile (black dots and black line) of the upstream or downstream cross-section, ineffective area (green lines) and red line is the ground profile of the bridge. The gray area which is basically blocking the flow is the bridge structure. As you can see currently the bridge is not properly represented in this figure. What we need to do here is define the elevation of the road and the opening through which the water will flow. This is done by using the Deck/Roadway editor.

The data for Deck/Roadway for an unedited bridge cross-section is shown below.

Deck/Roadway Data Editor

Distance	Width	Weir Coef
40	20	2.6

Clear Del Row Ins Row Copy US to DS

Upstream			Downstream		
Station	high chord	low chord	Station	high chord	low chord
1 0	83.84		0	83.84	
2 4.85	83.84		4.85	83.84	
3 14.53	83.84		14.53	83.84	
4 17.81	83.84		17.81	83.84	
5 27.63	83.84		27.63	83.84	
6 31.57	83.84		31.57	83.84	
7 42.17	83.84		42.17	83.84	
8 51.18	83.84		51.18	83.84	

U.S Embankment SS 0 D.S Embankment SS 0

Weir Data
 Max Submergence: 0.98 Min Weir Flow Et:

Weir Crest Shape
 Broad Crested
 Ogee

OK Cancel

Enter distance between upstream cross section and deck/roadway. (ft)

(Note: The figures and the numbers need to be interpreted appropriately based on your cross-section profile. Do not blindly use the same numbers that are presented here. They may not work for you). The high chord column in the above figure basically defines the top elevation of the bridge, and the low chord defines the elevation of the bottom of the bridge deck. In the absence of any values for low chord, the elevations on the cross-section profile are used as the low chord values. Therefore, in order to define an opening for the bridge, we need to first know the details of the bridge, its top elevation, opening height, etc. In this case (for the above figure only), let us assume that the bridge top elevation is 84 ft and the bridge deck is 6 ft deep. Also assume that the bridge opening starts at 2200 station and ends at 3400 station across the cross-section profile (this will give a bridge opening of 1200 ft). With these assumptions, we will enter the new high and low chord values as shown in the figure below. **Click** on the *Copy US to DS* button to copy the information from upstream to downstream, and **click OK**. Note that this information should generally be obtained from the field, but here we are assuming these values to just see how the opening is defined in HEC-RAS.

Del Row	Distance	Width	Weir Coef
Ins Row	50	20	2.6

Upstream			Downstream		
Station	high chord	low chord	Station	high chord	low chord
1	0.	84.	0.	84.	
2	2200.	84.	2200.	84.	
3	2200.	84.	2200.	84.	78.
4	3400.	84.	3400.	84.	78.
5	3400.	84.	3400.	84.	
6	4000.	84.	4000.	84.	
7					
8					

U.S Embankment SS: 0 D.S Embankment SS: 0

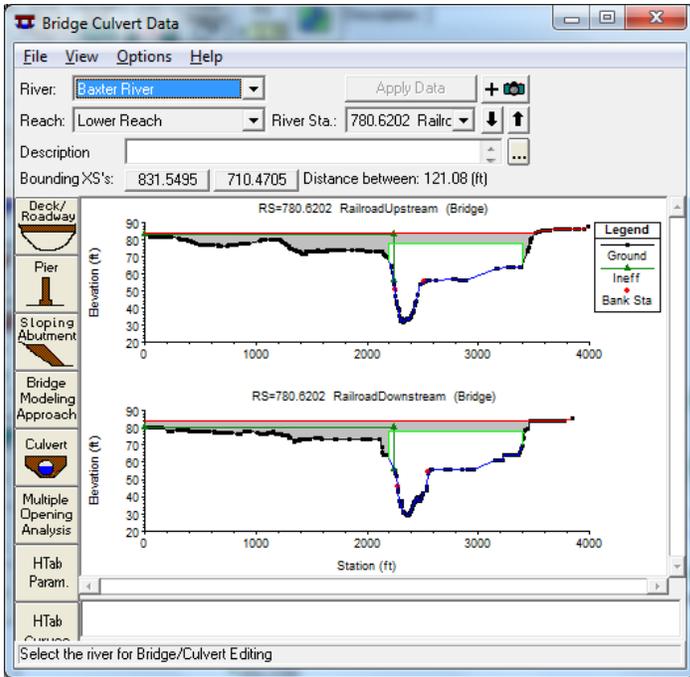
Weir Data
 Max Submergence: 0.95 Min Weir Flow Et:

Weir Crest Shape
 Broad Crested
 Ogee

Buttons: OK, Cancel, Clear, Copy US to DS

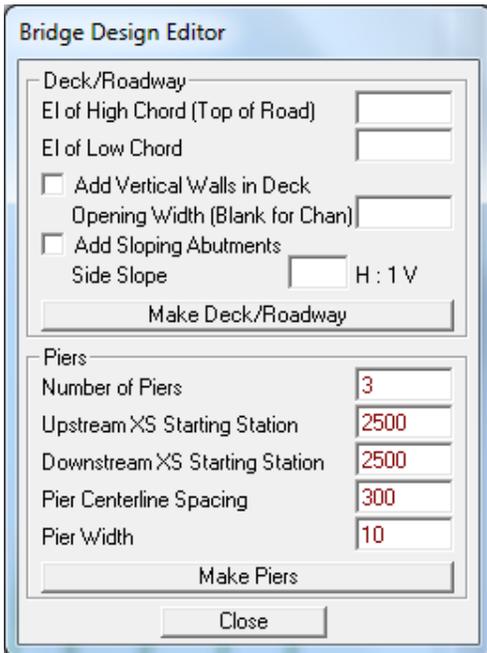
Enter distance between upstream cross section and deck/roadway. (ft)

After the high and low chord values are defined, the new cross-section with the bridge opening is shown below.

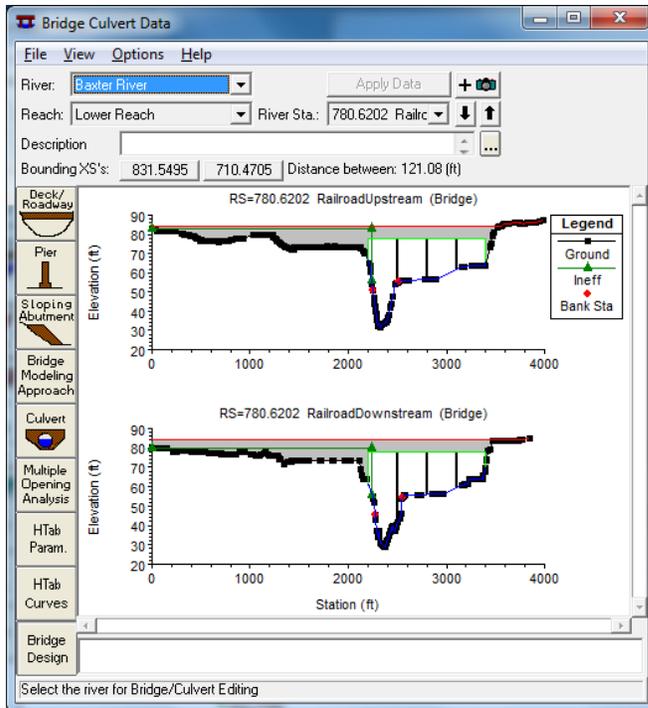


Try to understand how the information we entered for high chord/low chord in the Deck/Roadway editor got translated into the opening. Once the opening is defined, the next step is to use the Bridge Design tool to enter pier information. We will assume three

10 ft wide piers with a spacing of 300 ft. We can use the Bridge Design tool Bridge Design to enter this information as shown below.



Click on *Make Piers*, and then **click** *Close*. The bridge opening will look as shown in the figure below:



You need to know the actual bridge condition to be able to accurately enter this information, but for this tutorial we have used our intuition (and creativity!) in designing the bridge. After you are done editing the bridge data, **close** the bridge/culvert editor, **save** geometry data and **close** the geometric editor. We are done with geometric data! The next step is to enter flow data. For this tutorial we will run the model in steady state condition.

Entering Flow Data and Boundary Conditions

Flows are typically defined at the most upstream location of each river/tributary, and at junctions. There are situations where you need to define flows at additional locations, but for this tutorial we will use a simple case. Each flow that needs to be simulated is called a profile in HEC-RAS. For this exercise, we will create three hypothetical profiles.

In the main *HEC-RAS* window, **click** on *Edit* → *Steady Flow Data*. **Enter** 3 for number of profiles, and **click** *Apply Data*. Enter hypothetical flow conditions for these profiles as shown below:

Steady Flow Data - Baxter flow file

File Options Help

Enter/Edit Number of Profiles (2000 max):

Locations of Flow Data Changes

River:

Reach: River Sta.:

Flow Change Location			Profile Names and Flow Rates			
	River	Reach	RS	PF 1	PF 2	PF 3
1	Baxter River	Upper Reach	9792.901	24000	48000	96000
2	Baxter River	Lower Reach	3114.647	25000	50000	100000
3	Tule Creek	Tributary	4045.678	1000	2000	4000

The flow conditions defined in the above window are upstream conditions. To define downstream boundary, **click** on *Reach Boundary Conditions*. Then **select** *Downstream* for *Baxter River Lower Reach*, **click** on *Normal Depth*, and **enter** *0.001*.

Steady Flow Boundary Conditions

Set boundary for all profiles Set boundary for one profile at a time

Available External Boundary Condition Types

Selected Boundary Condition Locations and Types

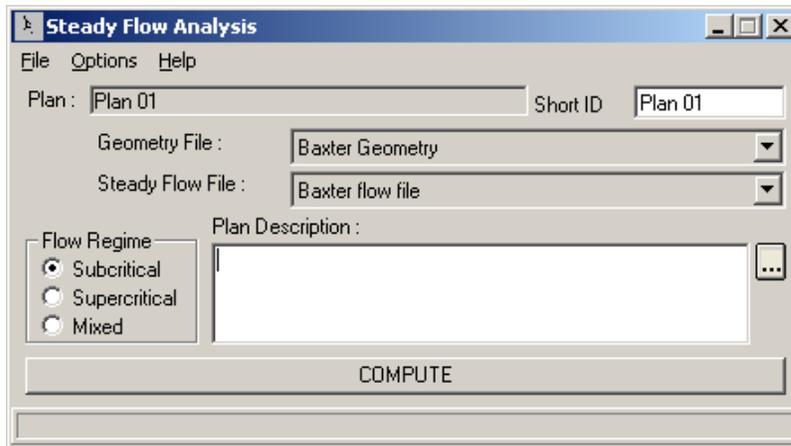
River	Reach	Profile	Upstream	Downstream
Baxter River	Upper Reach	all		Junction=2
Baxter River	Lower Reach	all	Junction=2	Normal Depth S = 0.001
Tule Creek	Tributary	all		Junction=2

Enter to make the boundary for selected location normal depth.

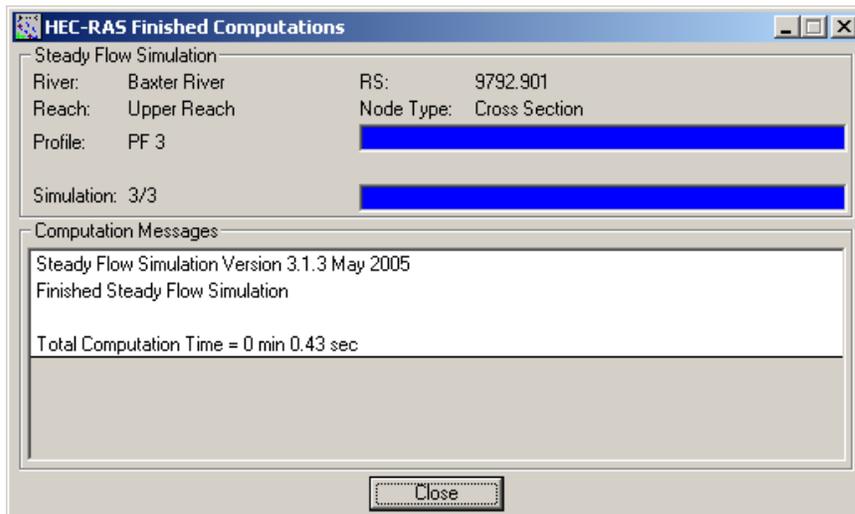
Click *OK*. **Save** the flow data (give whatever title you like), and **close** the *Steady Flow* editor. Now we are ready to run HEC-RAS!

Running HEC-RAS

In the main HEC-RAS window, **click** on *Run* → *Steady Flow Analysis*..



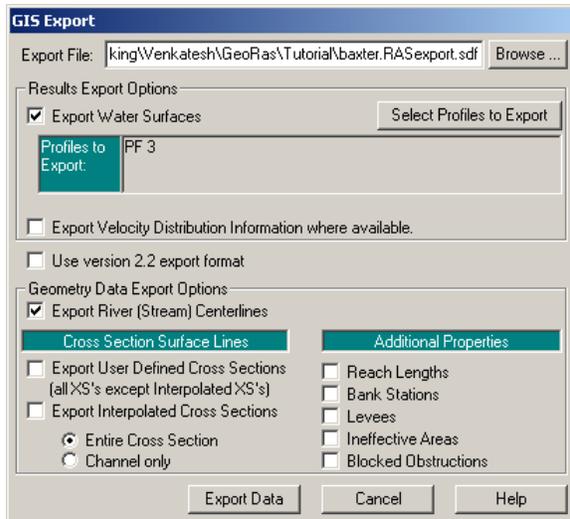
Select the *Subcritical Flow Regime*, and **click** on the *COMPUTE* button. (Note: If you get an error, you will need to modify geometry or flow data based on error messages to run the simulation successfully).



After successful simulation, **close** the computation window and the steady flow window. We will now export HEC-RAS results to ArcGIS to view the inundation extent, but before this step, you should look at the output results and verify them in HEC-RAS. This will help identify any errors in the input data and fix them, and run the simulation again, if necessary.

Exporting HEC-RAS Output to HEC GeoRAS

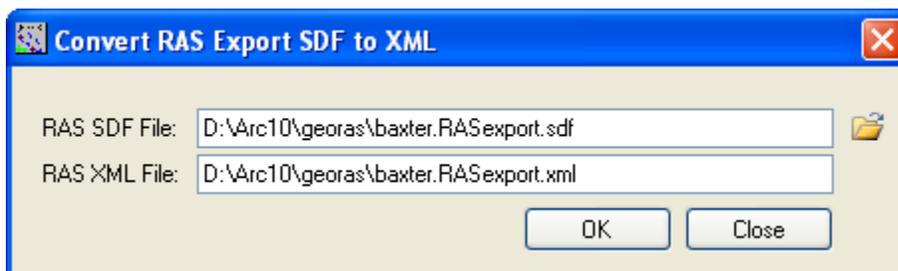
To export the data to ArcGIS **click** on *File*→*Export GIS Data...* in the main HEC-RAS window. Since we ran the model with three profiles, we can choose which profile we would like to export. **Click** on *Select Profiles to Export* button, and choose the profile you want to export. For this exercise we will choose the one with maximum flow (*PF3*), and accept the default export options.



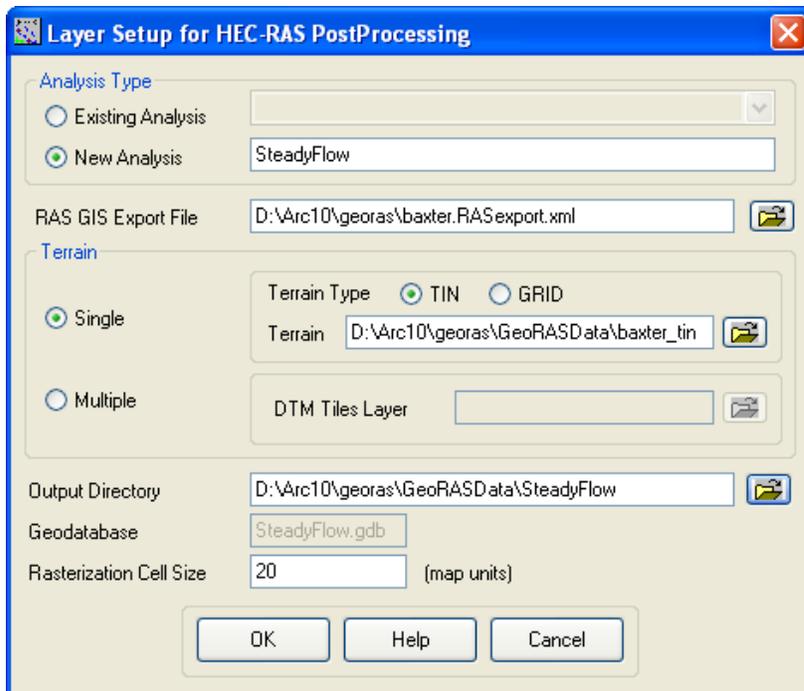
Click on *Export Data* button, which will create a SDF file in your working directory. **Save** the HEC-RAS project and **exit**. We will now return to ArcMap to create a flood inundation map.

Flood inundation mapping

In ArcMap (if you closed *baxter_georas.mxd* earlier, open it) **click** on *Import RAS SDF* file button  to convert the SDF file into an XML file. In the *Convert RAS Output ASCII File to XML* window, **browse** to *Baxter.RASexport.sdf*, and **click OK**. The XML file will be saved with the input file name in the same folder with an xml extension

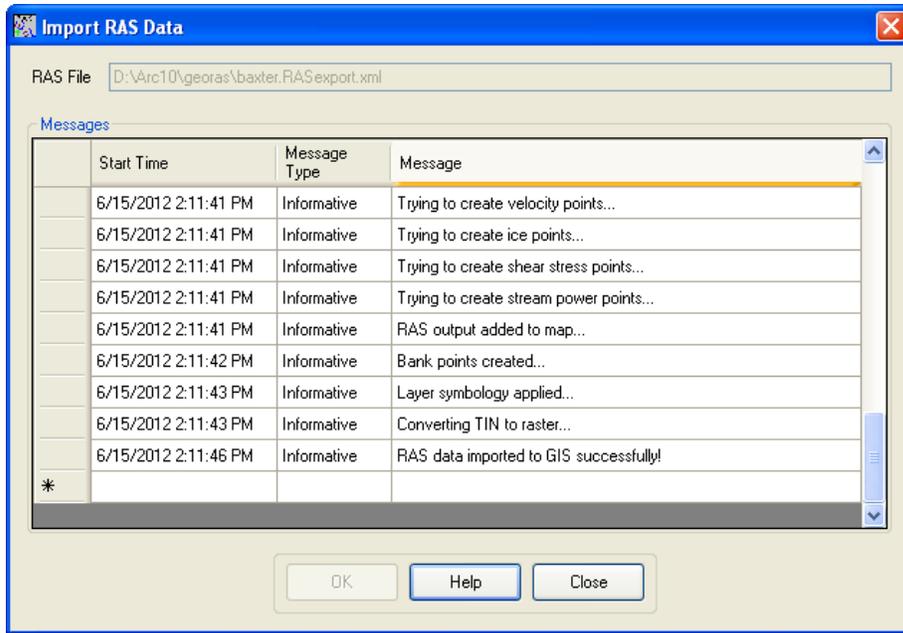


Now **click** on *RAS Mapping* → *Layer Setup* to open the post processing layer menu as shown below:

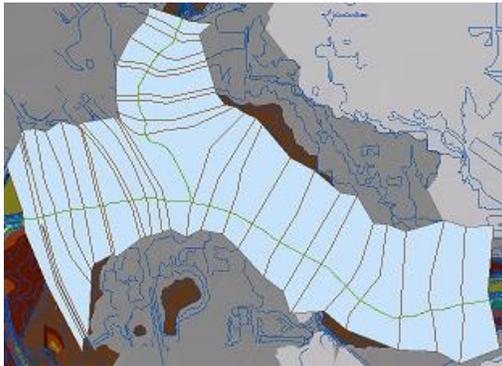


In the layer setup for post-processing, first **select** the *New Analysis* option, and **name** the new analysis as *Steady Flow*. **Browse** to *Baxter..RASexport.xml* for *RAS GIS Export File*. **Select** the *Single Terrain Type*, and **browse** to *baxter_tin*. **Browse** to your working folder for *Output Directory*. HEC-GeoRAS will create a geodatabase with the analysis name (*Steady Flow*) in your output directory. Accept the default *20* map units for *Rasterization Cell Size*. **Click** *OK*. A new map (data frame) with the analysis name (*Steady Flow*) will be added to ArcMap with the terrain data. At this stage the terrain TIN (*baxter_tin*) is also converted to a digital elevation model (DEM) and saved in the working folder (*Steady Flow*) as *dtmgrid*. The cell size of *dtmgrid* is equal to the *Rasterization Cell Size* you chose in the layer setup window.

Next **click** on *RAS Mapping* → *Import RAS Data*. Similar to during export, you will see a series of messages during the import as shown below.

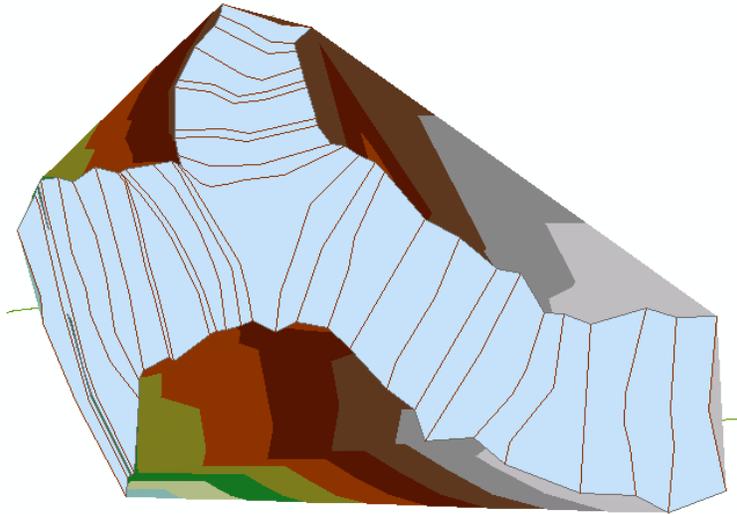


This will create a bounding polygon, which basically defines the analysis extent for inundation mapping, by connecting the endpoints of XS Cut Lines.



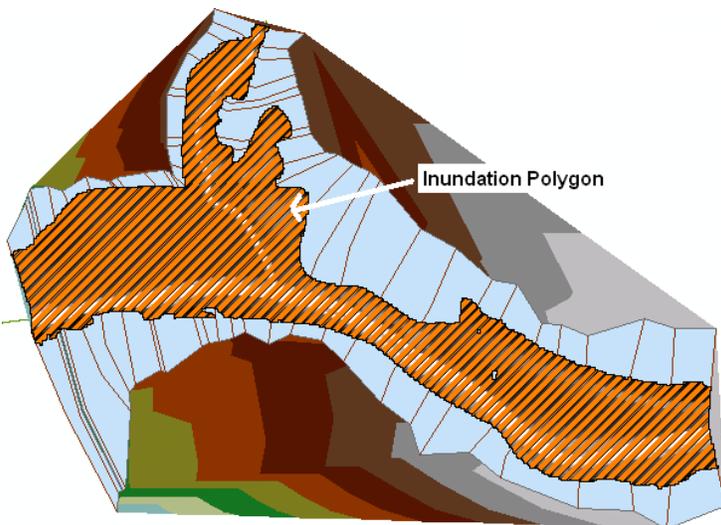
After the analysis extent is defined, we are ready to map the inundation extent. **Click on RAS Mapping→Inundation Mapping→ Water Surface Generation. Select PF3** (profile with highest flow), and **click OK**.

This will create a surface with water surface elevation for the selected profile. The TIN (*tP003*) that is created in this step will define a zone that will connect the outer points of the bounding polygon, which means the TIN will include area outside the possible inundation.



At this point we have a water surface (*tP003*) TIN, and we have an underlying terrain (*baxter_tin* and *dtmgrid*). Now we will subtract the terrain (*dtmgrid*) from the water surface TIN, by first converting the water surface TIN to a grid.

Click on *RAS Mapping* → *Inundation Mapping* → *Floodplain Delineation using Rasters*. Again, **select** *PF3* (profile with highest flow), and **click** *OK*. You will see a series of messages during the execution. During this step, the water surface TIN (*tP003*) is first converted to a GRID, and then *dtmgrid* is subtracted from the water surface grid. The area with positive results (meaning water surface is higher than the terrain) is flood area, and the area with negative results is dry. All the cells in water surface grid that result in positive values after subtraction are converted to a polygon, which is the final flood inundation polygon.



After the inundation map is created, you must check the inundation polygon for its quality. You will have to look at the inundation map and the underlying terrain to correct errors in the flood inundation polygon. Sometimes you will realize (at the end!) that your terrain has errors, which you need to fix in the HEC-RAS geometry file. The refinement

of flood inundation results to create a hydraulically correct output is not covered in this tutorial - this is an iterative process requiring several iterations between GIS and HEC-RAS. The ability to judge the quality of terrain and flood inundation polygon comes with the knowledge of the study area and experience.

Save the ArcMap document. Congratulations, you have successfully finished the HEC-GeoRAS tutorial!