Florida International University Department of Civil and Environmental Engineering

Tutorial on using HEC-GeoRAS 10.6 with ArcGIS 10.6 and HEC-RAS 5.0.7 for flood inundation mapping in Steady and Unsteady Flow Conditions (1D and 2D)

Updated on January 28, 2021

Instructor: Prof. Arturo S. Leon, Ph.D., P.E., D. WRE Questions and comments to <u>arleon@fiu.edu</u> Research Web page of Instructor: <u>http://web.eng.fiu.edu/arleon/</u>

Objectives of this Tutorial: The objective of this tutorial is to give a brief introduction on the use of HEC-GeoRAS with ArcGIS and HEC-RAS for flood inundation mapping in **one-** and **two- dimensional steady** and **unsteady** flow conditions

Computer Requirements

- 1. HEC-GeoRAS version 10.6 or newer
- 2. ArcGIS 10.6 or newer (***if you use a newer version of ArcGIS 10.6**, install the same version of HEC-GeoRAS at <u>http://downloads.esri.com/archydro/</u>).
- 3. HEC-RAS version 5.0.7 or newer

You can download the latest versions of HEC-RAS and HEC-GeoRAS from the US Army Corps of Engineers Hydrologic Engineering Center website at http://www.hec.usace.army.mil/software/

Data Requirements

The data required for this tutorial is available at

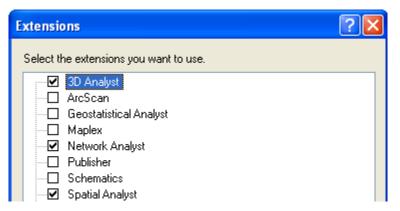
http://web.eng.fiu.edu/arleon/Teaching_unsteady_rivers.html. Download the zip file <u>on your</u> local drive (e.g. C:\) (If you do not work in your local drive, you may have problems exporting <u>HEC-RAS to Arc GIS</u>), and unzip its contents. The GeoRASData folder contains three subfolders, one TIN dataset, a RASModel and one aerial image (as raster grid) as shown below (ArcCatalog view):

| Name | Date modified | Туре | Size |
|------------|-------------------|-------------|------|
| 👢 Aerials | 9/26/2013 8:59 PM | File folder | |
| 👢 RASModel | 9/26/2013 8:59 PM | File folder | |
| 👢 Terrain | 9/26/2013 8:59 PM | File folder | |

Getting Started

Start ArcGIS by clicking *Start* \rightarrow *Programs* \rightarrow *ArcGIS* \rightarrow *ArcGIS*. Save the ArcGIS document (by clicking *File* \rightarrow *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 checked. You can check this by **clicking** on *Customize* \rightarrow *Extensions*, and **checking** the boxes (if they are unchecked) next to *3D Analyst* and *Spatial Analyst* as shown below:



Close the Extensions window.

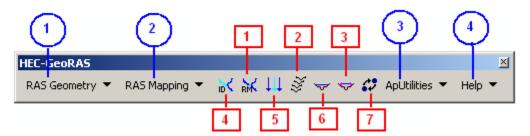
Now load the HEC-GeoRAS toolbar into ArcGIS by **clicking** on *Customize* \rightarrow *Toolbars* \rightarrow *HEC-GeoRAS* to see the toolbar as shown below:

| HEC-GeoRAS | - X |
|--|--------|
| RAS Geometry 🔹 RAS Mapping 📲 😽 🙀 👭 💭 💝 🖙 🛟 ApUtilities 🔹 | Help 🕶 |

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 *ApUtilites* menu contains functions mainly for data management. The *Help* menu is self-explanatory.

Running HEC-RAS

This hydraulics tutorial doesn't cover pre-processing of data. You can find multiple tutorials on pre-processing. In our class, will use the HEC-RAS model provided in the folder RASModel (see above).

Now launch HEC-RAS, open the RASModel and Run it for Subcritical flow conditions.

Exporting HEC-RAS Output (Before exporting HEC-RAS to ArcGIS, you need to run the HEC-RAS Model)

To export the HEC-RAS output data to ArcGIS **click** on *File* \rightarrow *Export GIS Data*... in the main HEC-RAS window. **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 (*Biggest* profile), and accept

the default export options.

| GIS Export | Contraction of the local division of the loc |
|---|--|
| · | BaxterExample10 - smaller\RASModel\Baxter.RASexport.sdf |
| Reaches and Storage Areas to Export Select Reaches to Export | eaches (3/3) |
| Select Storage Areas to Export Sto | orage Areas (2/2) |
| Results Export Options Water Surfaces Water Surf Profiles to Biggest Export: | face Extents Select Profiles to Export |
| Flow Distribution (550/550 have detailed va Velocity Shear Stress Stream Power | Additional Information Ice Thickness (where available) |
| Geometry Data Export Options | |
| Cross Section Surface Lines User Defined Cross Sections (all XS's except Interpolated XS's) Interpolated Cross Sections Entire Cross Section Channel only | Additional Properties Reach Lengths Bank Stations (improves velocity, ice, shear and power mapping) Levees Ineffective Areas Blocked Obstructions Manning's n |
| | Export Data Close Help |

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 ArcGIS to create a flood inundation map.

Flood inundation mapping

In ArcGIS (open *Baxter10.mxd*, which is provided in the data) **click** on *Import RAS SDF* file button to convert the SDF file into an XML file. In the *Convert RAS Export RAS SDF to XML* window, **browse** to *Baxter.RASexport.sdf* (RASModel Folder), and **click** *OK*. The XML file will be saved with the input file name in the same folder with an xml extension

| Convert RAS E | xport SDF to XML |
|--------------------------------|---|
| RAS SDF File: RAS XML File: | ARC_GIS\BaxterExample10 - smaller\RASModel\Baxter.RASexport.sdf |
| | OK Close |

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

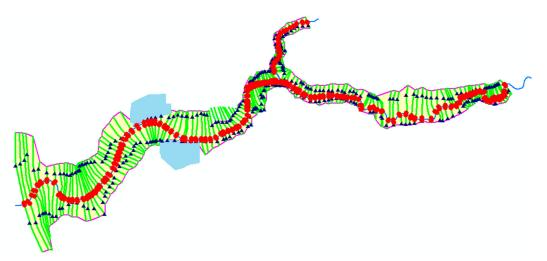
| Analysis Type Existing Analysis New Analysis | Steady TestCE540 |
|--|--|
| RAS GIS Export File Terrain | 3axterExample10 - smaller\RASModel\Baxter.RASexport.xml |
| Single | Terrain Type TIN GRID Terrain \BaxterExample10 - smaller\Terrain\baxter_tin |
| Multiple | DTM Tiles Layer |
| Output Directory | ARC_GIS\BaxterExample10 - smaller\RASModel\TestCE540 |
| Geodatabase | TestCE540.gdb |
| Rasterization Cell Size | 20 (map units) |

In the layer setup for post-processing, first **select** the *New Analysis* option, and **name** the new analysis as *Test_CE540*, or any name you like. **Browse** to *Baxter.RASexport.xml* for *RAS GIS Export File* (RASModel folder). **Select** the *Single Terrain* Type, and **browse** to *baxter_tin* in the Terrain folder. **Browse** to your working folder for *Output Directory* (e.g., RASModel/*Test_CE540*). HEC-GeoRAS will create a geodatabase with the analysis name (e.g., *Test_CE540*) 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 (e.g., *Test_CE540*) will be added to ArcGIS 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 (e.g., *Test_CE540*) 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* \rightarrow *Import RAS Data* and then **click** *Ok*. Similar to during export, you will see a series of messages during the import as shown below.

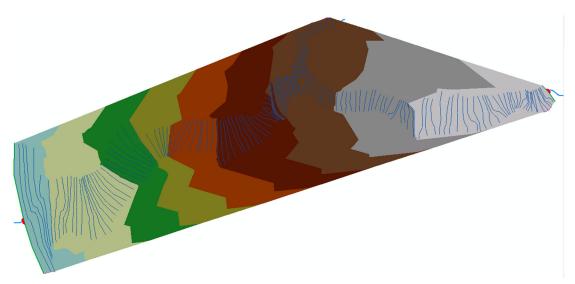
| Mes | sages | | | |
|-----|------------------|-----------------|--|---|
| | Start Time | Message Type | Message | 1 |
| | 9/26/2013 11:11: | Informative | 173 feature(s) has been imported to XSCutlines | |
| | 9/26/2013 11:11: | Informative | Completed importing RAS data to GIS | |
| | 9/26/2013 11:11: | Informative | Trying to create velocity points | |
| | 9/26/2013 11:11: | Informative | Trying to create ice points | |
| | 9/26/2013 11:11: | Informative | Trying to create shear stress points | |
| | 9/26/2013 11:11: | Informative | Trying to create stream power points | |
| | 9/26/2013 11:11: | Informative | RAS output added to map | |
| | 9/26/2013 11:11: | Informative | Bank points created | |
| | 9/26/2013 11:11: | Informative | Layer symbology applied | |
| | 9/26/2013 11:11: | Informative | Converting TIN to raster | |
| | 9/26/2013 11:11: | Informative | RAS data imported to GIS successfully! | |
| * | | | | |

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



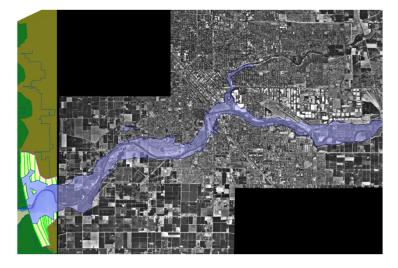
After the analysis extent is defined, we are ready to map the inundation extent. Click on RAS Mapping/Inundation Mapping/Water Surface Generation. Select Biggest (profile with highest flow), and click OK.

This will create a surface with water surface elevation for the selected profile. The TIN that is created in this step (*t Biggest*) 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 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 \rightarrow Inundation Mapping \rightarrow Floodplain Delineation using Rasters. Again, select Biggest (profile with highest flow), and click OK. You will see a series of messages during the execution. During this step, the water surface TIN 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 accuracy. You may want to superimpose your results with the aerial map, which is available in the *Aerials* folder in the working directory (Right click on your directory, then **Add data** and choose **Aerials** in your working folder). It is very common to find errors in the terrain. If you detect these errors, you need to fix it in the HEC-RAS geometry file. After the errors are fixed, you need to repeat the conversion process of HEC-RAS to HEC-GEO RAS again. Don't forget to **Save** the ArcGIS document.

Hydraulic modeling

Now, let's play with the hydraulics of flooding.

Flooding in Steady Flow Conditions (One-dimensional)

Open HEC-RAS and open the *Baxter.prj* project that is located in the RASModel folder. In the main HEC-RAS window, click on Edit/Steady Flow Data/Reach Boundary Conditions. Then **select** *Downstream* for *Baxter River Lower Reach*, **click** on *Normal Depth*, and **enter** 0.0001 as follows:

Steady Flow Boundary Conditions Set boundary for one profile at a time Set boundary for all profiles Available External Boundary Condtion Types Known W.S. Critical Depth Normal Depth Rating Curve Delete 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 Tule Creek Tributary all Junction=2 Steady Flow Reach-Storage Area Optimization OK Cancel Help Select Boundary condition for the downstream side of selected reach.

Save the data and Run the HEC-RAS model (Subcritical flow).

| 📩 Steady Flow Analysis 📃 🗉 🔀 | | | | |
|--|----------------------------|-------------|--|--|
| File Options Help | | | | |
| Plan : Steady Flows | Short ID | Steady Flow | | |
| Geometry File : | Imported GIS Data +Bridges | - | | |
| Steady Flow File : | Steady Flows | • | | |
| Flow Regime Plan Des Subcritical Mixed | scription : | | | |
| Compute | | | | |
| Enter to compute water surface profiles | | | | |

Then export the HEC-RAS output data to ArcGIS. Click on *File* \rightarrow *Export GIS Data*... in the main HEC-RAS window. Click on *Select Profiles to Export* button, and choose the *Biggest* profile. Also, select the options shown below.

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| GIS Export | |
|--|--|
| Export File: m:\Arturo\Teaching\Unsteady_ | flow_Rivers_Pipe_Networks_CE_540\Lectures\HEC-GEORAS |
| Reaches and Storage Areas to Export— | |
| Select Reaches to Export | eaches (3/3) |
| Select Storage Areas to Export S | torage Areas (2/2) |
| Results Export Options | |
| Water Surfaces Vater Su | Inface Extents Select Profiles to Export |
| Profiles to Export: Flow Distribution (173/173 have detailed v | alues) Additional Information |
| ✓ Velocity ✓ Shear Stress ✓ Stream Power | ☐ Ice Thickness (where available) |
| Geometry Data Export Options | |
| Cross Section Surface Lines | Additional Properties |
| User Defined Cross Sections (all XS's except Interpolated XS's) Interpolated Cross Sections | ✓ Reach Lengths ✓ Bank Stations (improves velocity, ice, shear and power mapping) ✓ Levees |
| Entire Cross Section C Channel only | ✓ Ineffective Areas ✓ Blocked Obstructions ✓ Manning's n |
| | Export Data Close Help |

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 open ArcGIS.

In ArcGIS (open *Baxter10.mxd*, which is located in the sub folder *BaxterExample10 - smaller*) **click** on *Import RAS SDF* file button to convert the SDF file into an XML file. In the *Convert RAS Export RAS SDF to XML* window, **browse** to *Baxter.RASexport.sdf* (located in the sub folder RASModel), and **click** *OK*. The XML file will be saved with the input file name in the same folder with an xml extension

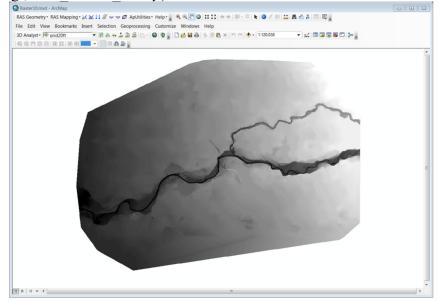
| rganize • New folder | | | | • | |
|---|---|-------------------------------|-------------------|-------------------|------------------|
| 3 Recent Places | * | Name | Date modified | Туре | |
| Dutter | | 😤 Baxter.RASexport.sdf | 9/28/2013 8:46 PM | SQL Server Compa. | |
| Desktop | | 诸 Baxter_Ice.RASexport.sdf | 4/30/2012 2:28 PM | SQL Server Compa | |
| Libraries | = | 💰 Baxter_Steady.RASexport.sdf | 4/27/2012 3:01 PM | SQL Server Compa | |
| 📙 Leon, Arturo 💺 Computer | | 🖻 GIS2RAS.RASImport.sdf | 4/27/2012 2:44 PM | SQL Server Compa | |
| Local Disk (C:) | | | | | |
| DVD RW Drive (D:) | | | | | No pre availa |
| Removable Disk (E:) | | | | | a. unu |
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| Removable Disk (G:) | | | | | |
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| | - | • | | | |

| Convert RAS | Export SDF to XML | × |
|---------------|---|---------|
| RAS SDF File: | 0_CE540\BaxterExample10 - smaller\RASModel\Baxter.RASexport.sdf | |
| RAS XML File: | $0_CE540 \ Baxter Example 10 - smaller \ RASModel \ Baxter. RAS export xml \\$ | |
| | OK Close | |

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

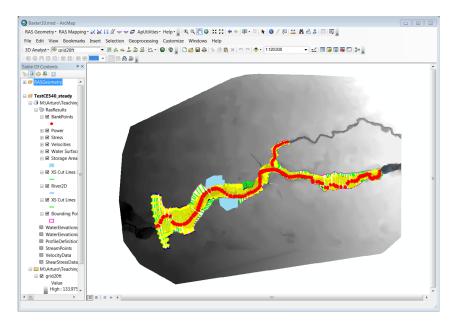
| Kayer Setup for HEC- | RAS PostProcessing |
|--|---|
| Analysis Type Existing Analysis New Analysis | Steady TestCE540_steady |
| RAS GIS Export File Terrain | 3axterExample10 - smaller\RASModel\Baxter.RASexport.xml |
| Single | Terrain Type TIN O GRID Terrain terExample10 - smaller\Terrain\grid20\grid20tf |
| Multiple | DTM Tiles Layer |
| Output Directory | 0\BaxterExample10 - smaller\RASModel\TestCE540_steady |
| Geodatabase | TestCE540_steady |
| Rasterization Cell Size | 20 (map units) |
| | OK Help Cancel |

In the layer setup for post-processing, first **select** the *New Analysis* option, and **name** the new analysis as *Test_CE540_steady* or any other name you like. **Browse** to *Baxter.RASexport.xml* for *RAS GIS Export File*. **Select** the *Single Terrain* Grid Type, and **browse** to *grid20ft*. **Browse** to your working folder for *Output Directory (RASModel* in this case). HEC-GeoRAS will create a geodatabase with the analysis name (e.g., *Test_CE540_steady*) 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 (e.g., *Test_CE540_steady*) will be added to ArcGIS with the terrain data.

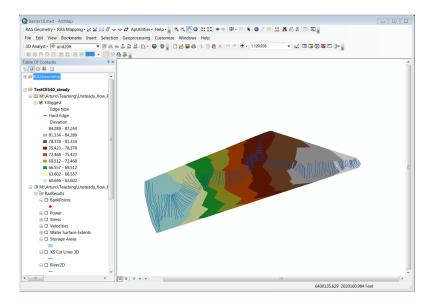


Next click on RAS Mapping \rightarrow Import RAS Data. Similar to during export, you will see a series of

messages during the import. This will create a bounding polygon as follows.



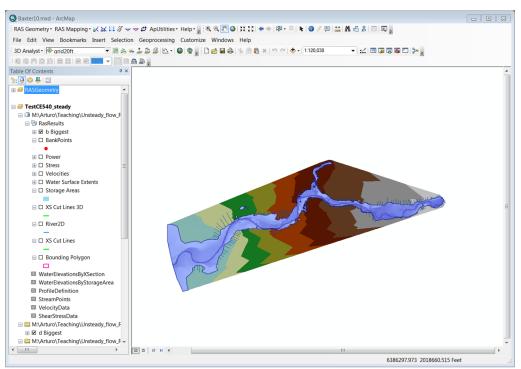
After the analysis extent is defined, we are ready to map the inundation extent. Click on *RAS Mapping/ Inundation Mapping/ Water Surface Generation*. Select *Biggest* (profile with highest flow), and click *OK*. This will create a surface with water surface elevation for the selected profile as follows.



At this point we have a water surface and we have an underlying terrain. Now we will subtract the terrain from the water surface. Before this, for visualization purposes, I would suggest to add *Land Use* to the *Test_CE540_steady* data frame. To do this, right click on the *Test_CE540_steady* data frame. Then, Add data/Baxter10.mdb/ RASGeometry/LandUse.

Next, Click on RAS Mapping \rightarrow Inundation Mapping \rightarrow Floodplain Delineation using Rasters. Again, select *Biggest* (profile with highest flow), and click OK. You will see a series of messages during the execution. Then, a polygon will be created that represents the flooded area.

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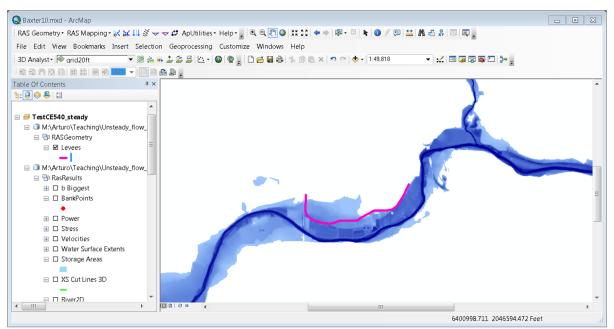


After the inundation map is created, you must check the inundation polygon for its accuracy. For this you may need to superimpose your results with the geometry of the river, aerial map, levee lines, etc. To do this for instance you can turn off all TINs except "d biggest" and insert various types of data to the *Test_CE540_steady* data frame. To do this, right click on the *Test_CE540_steady* data frame. Then, Add data/Baxter10.mdb/RASGeometry/

| distant of the local line has been used to |
|--|
| 🌮 ApUtilities - Help - 💂 🔍 🔍 🏹 🥥 🗱 🐼 🛭 🗢 🕅 🖗 - 🖾 🗼 🚳 🗯 : |
| eoprocessing Customize Windows Help |
| 🚊 🗟 🗠 = 🚳 🌚 💂 🗄 🖸 🚔 🖶 🎒 🛍 🗙 🔊 🕾 🔶 1:120.038 🔹 💌 |
| |
| |
| |
| Add Data |
| Look in: RASGeometry Cook in: RASGeometry Cook in: RASGeometry Cook in: LeveePoints Cook in: LeveePoints CootoursSft CootoursSft Flowpaths StorageAreas ContoursSft Con |
| Name: Show of type: Datasets, Layers and Results Add Cancel |
| |

Then click for instance on *levees* and Add. This will result in a figure as shown below. You can edit the thickness of the levee line.

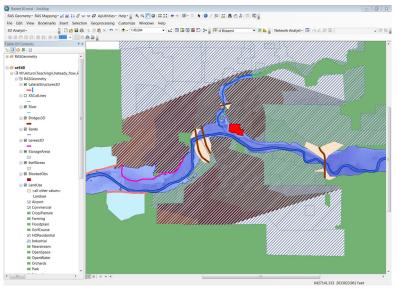
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For LandUse you may want to edit the categories. To do this, double click on *LandUse*. Next click in *Categories* and enter *LandUse* in the Value Field. Then click on *Add All Values*. This will show all land uses in different colors.

| eneral Source Selection | | | | | L Popup |
|--|---|----------------------|--------------------------------|-------------------------|---------|
| - eatures | Draw catego | ries using unique va | alues of one field. | Import. | |
| Categories | Value Field | | Color Ramp | | |
| - Unique values - Unique values, many fiel - Match to symbols in a sty | | | | | • |
| Juantities | Sym Value | | Label | Co 🔺 | |
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| Aultiple Attributes | <head< td=""><td>ling></td><td>Landuse</td><td>90</td><td></td></head<> | ling> | Landuse | 90 | |
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| | Comme | ercial | Commercial | 11 | 1 |
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| 4 III 9 | Floodp | | Floodplain | 3 | × |
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For Flooding in urban areas you may want to group the land uses in two or three regions [example: large losses (e.g., residential, commercial), and small losses (floodplain, farming, etc.)] To achieve this you will need to manually edit the colors for the various land uses. This will result in a plot like shown below:



In the figure above, the water exceeded the levee line and flooded part of the urban area. In the lab session, we will play with *levee* structures to protect urban areas. Also, we will discuss common external and internal boundary conditions and the input data for these boundaries. Finally, we will discuss **mixed flow** conditions, interpolation procedures and appropriate parameters for simulation.

It is very common to find errors in the results. If you detect these errors, you need to fix them in HEC-RAS. Then you need to repeat the conversion process. Don't forget to **Save** the ArcGIS document. The common errors will be discussed in the computer lab session.

Furthermore, you may want to remove extremely low water depths (e.g., below 1 cm or 1/2 inch). To do this, double click in the water depth ("d") layer and select the *Symbology* tab. In this tab, select the *Minimum-Maximum* histogram in the lower region of the window. Then, check the *Edit High/Low Values* option. This will allow you to modify the minimum and maximum values of water depth that you want to show (see snapshot below).

| Layer Properties | | 8 |
|---|---|---|
| General Source Extent Show: Unique Values | | |
| Classified Stretched Discrete Color | | Â |
| | Color Value Label Labeling 52.4544 High : 52.4544 | |
| | Edit High/Low Values 1.52588e-005 Low : 1.52588e-005 | E |
| | Color Ramp: | |
| ** | Display Background Value: 0 as | |
| | Stretch Type: Minimum-Maximum Histograms | |
| About symbology | Apply Gamma Stretch: 1 | Ŧ |
| | OK Cancel Appl | у |

Flooding in Unsteady Flow Conditions (One-dimensional)

Open HEC-RAS and open the *Baxter.prj* project that is located in the RASModel folder. In the main HEC-RAS window, click on Edit/Unsteady Flow Data.

| 👌 Unsteady Flow Data | | | | |
|------------------------------|---------------------|----------------|----------------------------|-----------------------|
| File Options Help | | | | |
| Boundary Conditions Initia | al Conditions | | | Apply Data |
| | В | oundary Con | dition Types | |
| Stage Hydrograph | Flow Hydro | ograph | Stage/Flow Hydr. | Rating Curve |
| Normal Depth | Lateral Inflo | w Hydr. | Uniform Lateral Inflow | Groundwater Interflow |
| T.S. Gate Openings | Elev Controll | ed Gates | Navigation Dams | IB Stage/Flow |
| Rules | | | | |
| | Add | Boundary Co | ndition Location | |
| Add RS | Add Storage | Area | Add SA Connection | Add Pump Station |
| Se | elect Location in t | able then sele | ect Boundary Condition Typ | De |
| River Re | each | RS | Boundary Condition | |
| 1 Baxter River Up | per Reach | 84816. | | |
| 2 Baxter River Lov | wer Reach | 1192. | | |
| 3 Tule Creek Tril | butary | 10982. | | |

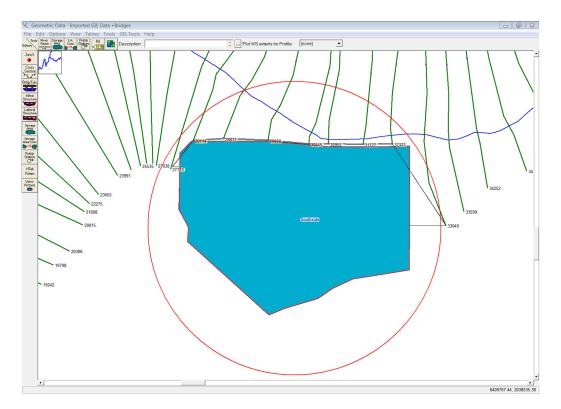
In the Unsteady Flow Data editor, open the *Flood Event* file. Double click on flood Hydrograph (Baxter River Upper Reach) to see the hydrograph data. You could also plot this data as follows.

| Flow Hydrograph | Flow Hydrograph |
|---|--|
| River: Baxter River Reach: Upper Reach RS: 84816. | Plot Table |
| River. Baxter River. Reach: Upper Reach. RS: 84816. C Read from DSS before simulation Select DSS file and Path File: Path: Path: Path: Image: Select/Enter the Data's Starting Time Reference Image: Use Simulation Time: Date: Image: Time: Date: Image: Time: Time: | River: Baxter River Reach: Upper Reach RS: 84816. |
| No. Ordinates Interpolate Missing Values Del Row Ins Row | 60000 |
| Hydrograph Data. | 40000 |
| Date Simulation Time Flow | 20000 - |
| (hours) (cfs) (1 01Jan2005 0100 00:00 2000. | |
| 2 01 Jan2005 0200 01:00 2583.51 | $0 + \frac{1}{2} + \frac{1}{2} + \frac{1}{3} + \frac{1}{5} + $ |
| 3 01 Jan 2005 0300 02:00 4324.85 | |
| 4 01 Jan 2005 0400 03:00 7196.54 | Simulation Time (days) |
| 5 01 Jan 2005 0500 04:00 11153.31 | |
| 6 01 Jan 2005 0600 05:00 161 32.74 | |
| 7 01 Jan 2005 0700 06:00 22056.32 | |
| Time Step Adjustment Options ("Critical" boundary conditions) Monitor this hydrograph for adjustments to computational time step Max Change in Flow (without changing time step): Min Flow: Multiplier: Plot Data OK | |

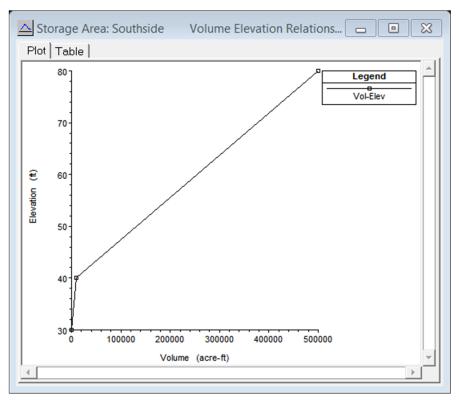
HEC-RAS provides the option to quickly scale the hydrograph. For instance, multiply the hydrograph ordinates by 2 as follows.

| Flo | Flow Hydrograph | | | | | |
|-----|--|--|---|---|---|----------|
| | River: Baxter River Reach: Upper Reach RS: 84816. | | | | | |
| 0 | C Read from DSS before simulation Select DSS file and Path | | | | | |
| | File: | | | | | |
| | Path | . [| | | | |
| | 1 0.01 | . , | | | | |
| 6 | Enter | Table | De | ta time inte | rval: 1 Hour | r 🔻 |
| | | ect/Enter the Data's St | | | 1 | |
| | | Jse Simulation Time: | Date | | 05 Tim | ie: 0100 |
| | O F | ixed Start Time: | Date: | | Tim | ie: |
| | | 1 | | , , | | , |
| | No. | Ordinates Interpo | late Missing | Values | Del Row | Ins Row |
| | | | Hydrogra | aph Data | | |
| | | Date Simulation Time Flow | | | | |
| | | Date | | | | |
| | | | (ho | urs) | (cfs) | |
| | 1 | 01Jan2005 0100 | (ho 00 | urs) :00 | (cfs) 2000. | |
| | 2 | 01 Jan2005 0100 01 Jan2005 0200 | (ho 00 01 | urs) :00 :00 | (cfs) 2000. 2583.51 | |
| | 2 | 01 Jan2005 0100 01 Jan2005 0200 01 Jan2005 0300 | (ho 00 01 02 | urs) :00 :00 :00 | (cfs) 2000. 2583.51 4324.85 | |
| | 2 | 01 Jan2005 0100 01 Jan2005 0200 01 Jan2005 0300 01 Jan2005 0400 | (ho 00 01 | urs) :00 :00 :00 :00 | (cfs) 2000. 2583.51 4324.85 7196.54 | |
| | 2 | 01 Jan2005 0100 01 Jan2005 0200 01 Jan2005 0300 | (ho 00 01 02 03 | urs) :00 :00 :00 :00 :00 | (cfs) 2000. 2583.51 4324.85 | |
| | 2 3 4 5 | 01 Jan2005 0100 01 Jan2005 0200 01 Jan2005 0300 01 Jan2005 0400 01 Jan2005 0500 | (ho 00 01 02 03 03 | urs) 00 00 00 00 00 00 | (cfs) 2000. 2583.51 4324.85 7196.54 11153.31 | |
| | 2 3 4 5 6 7 | 01 Jan2005 0100 01 Jan2005 0200 01 Jan2005 0300 01 Jan2005 0400 01 Jan2005 0500 01 Jan2005 0600 01 Jan2005 0700 | (ho 00 01 02 03 04 05 06 | urs) 00 00 00 00 00 00 00 | (cfs) 2000. 2583.51 4324.85 7196.54 11153.31 16132.74 22056.32 | |
| | 2 3 4 5 6 7 | 01 Jan2005 0100 01 Jan2005 0200 01 Jan2005 0300 01 Jan2005 0400 01 Jan2005 0500 01 Jan2005 0600 | (ho 00 01 02 03 04 06 06 | urs) 00 00 00 00 00 00 " boundary | (cfs) 2000. 2583.51 4324.85 7196.54 11153.31 16132.74 22056.32 conditions) — | |
| | 2 3 4 5 6 7 | 01 Jan2005 0100 01 Jan2005 0200 01 Jan2005 0300 01 Jan2005 0400 01 Jan2005 0500 01 Jan2005 0600 01 Jan2005 0700 e Step Adjustment Opti | (ho 00 01 02 03 04 05 06 06 06 06 06 06 07 | urs) 00 00 00 00 00 00 | (cfs) 2000. 2583.51 4324.85 7196.54 11153.31 16132.74 22056.32 conditions) — putational time | |
| | 2 3 4 5 6 7 Time | 01 Jan2005 0100 01 Jan2005 0200 01 Jan2005 0300 01 Jan2005 0400 01 Jan2005 0500 01 Jan2005 0600 01 Jan2005 0700 e Step Adjustment Opti fonitor this hydrograph Max Change in Flow (v | (ho 00 01 02 03 04 04 05 06 06 06 06 06 06 06 06 06 06 06 07 07 07 07 07 07 07 07 07 07 07 07 07 | urs) 00 00 00 00 00 00 " boundary ents to com ging time st | (cfs) 2000. 2583.51 4324.85 7196.54 11153.31 16132.74 22056.32 conditions) — putational time | |
| | 2 3 4 5 6 7 | 01 Jan2005 0100 01 Jan2005 0200 01 Jan2005 0300 01 Jan2005 0400 01 Jan2005 0500 01 Jan2005 0600 01 Jan2005 0700 e Step Adjustment Opti fonitor this hydrograph Max Change in Flow (000000000000000000000000000000000000 | (ho 00 01 02 03 04 05 06 06 06 06 06 06 07 | urs) 00 00 00 00 00 00 " boundary ents to com ging time st | (cfs) 2000. 2583.51 4324.85 7196.54 11153.31 16132.74 22056.32 conditions) — putational time | |

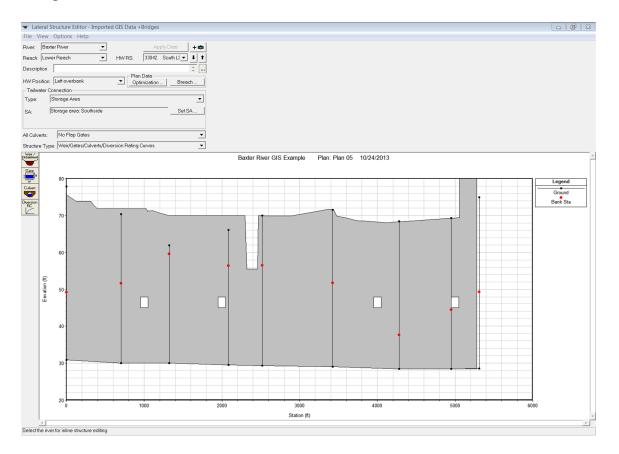
Now, let's work with Storage areas for temporal storage of water. First, you would need to add a *storage area* such as depicted below



Then, a Volume Elevation curve for the reservoir is specified as shown below



Also, it is necessary to add data of Station and Elevation for the lateral structure that connects the *Storage area* with the river as follows.



Do not forget to specify the initial water depth for the storage area. To do this, in the Unsteady Flow Data editor, select the *initial conditions* tab and then enter the initial water stage for the storage areas as depicted below.

| ູ່ ສູ່ Un | steady Flow Data | - Flood Event | | | |
|-----------|---|-----------------------|---------------|-------------------|----------------------------|
| File | Options Help | | | | |
| Bour | ndary Conditions In | itial Conditions | | | Apply Data |
| | ial Flow Distribution N | | | | |
| 0 | Use a Restart File Enter Initial flow dist | Filename | : | | ¥ |
| | Enter Initial now dist | nouuon | | | |
| | Add RS | | | | |
| | | Locat | tions of Flow | Data Changes | |
| | River | Reach | RS | Initial Flow | |
| | 1 Baxter River | Upper Reach | 84816. | 2000 | |
| 1 | 2 Baxter River | Lower Reach | 47694. | 4000 | |
| | 3 Tule Creek | Tributary | 10982. | 2000 | |
| | Initia | l Elevation of Storag | o Aroac | | Import Min SA Elevation(s) |
| | 1 | r Elevalion of Storag | | | |
| _ | Storage Area | | | Initial Elevation | |
| | 1 Northside | | | 63.34 | |
| 1 | 2 Southside | | | 30 | |

Now, let's add gates to the *lateral structure* as depicted below

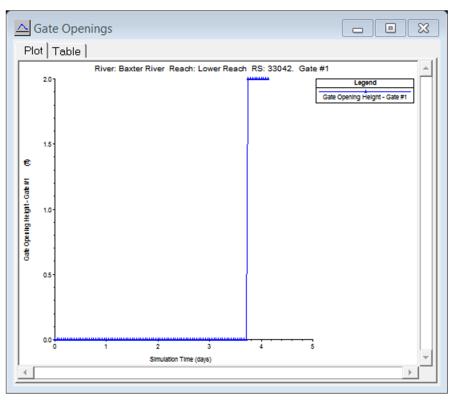
| Lateral Gate Editor | | |
|----------------------|----------------------------------|------------------|
| Gate Group: Gate #1 | • • • D 🐁 | |
| | Gate type (or methodology): Slu | uice 💌 |
| Geometric Properties | Gate Flow | |
| Height: 3 | Sluice Gate Flow | |
| Width: 100 | Sluice Discharge Coefficien | t (0.5-0.7): 0.5 |
| Invert: 45 | | |
| # Openings: 4 | | |
| Centerline Stations | | |
| Station | Submerged Orifice Flow | |
| 1 1000. | Orifice Coefficient (typically 0 | .8): 0.8 |
| 3 4000. 4 5000. | Head Reference: | Sill (Invert) |
| 5 | [Weir Flow Over Gate Sill (gate | out of water) |
| 6 | Weir Shape: | Broad Crested 💌 |
| 8 | | |
| 9 | Weir Coefficient: | 3 |
| 11 | | |
| 12 | | |
| | | |
| | OK | Cancel Help |

When using gates, it is necessary to specify how the gates will be operated. To do this, in the Unsteady Flow Data editor/*Boundary conditions* tab you would need to select the method of gate operation. For this application, choose *T.S Gate Openings*. Double click on the *T.S Gate Openings*

field and enter data of gate opening heights for all times of simulation. Do not forget to save the data.

| 5. Unsteady Flow Data | a - Flood Event | | | |
|-----------------------|--------------------|----------------|---------------------------|-----------------------|
| File Options Help | | | | |
| Boundary Conditions | nitial Conditions | | | Apply Data |
| | E | Boundary Cor | dition Types | |
| Stage Hydrograph | Flow Hydr | rograph | Stage/Flow Hydr. | Rating Curve |
| Normal Depth | Lateral Inflo | ow Hydr. | Uniform Lateral Inflow | Groundwater Interflow |
| T.S. Gate Openings | Elev Control | led Gates | Navigation Dams | IB Stage/Flow |
| Rules | | | | |
| | Add | Boundary Co | ondition Location | |
| Add RS | Add Storage | e Area | Add SA Connection | Add Pump Station |
| | Select Location in | table then sel | ect Boundary Condition Ty | pe |
| River | Reach | RS | Boundary Condition | |
| 1 Baxter River | Upper Reach | 84816. | Flow Hydrograph | |
| 2 Baxter River | Lower Reach | 33042. LS | T.S. Gate Openings | |
| 3 Baxter River | Lower Reach | 1192. | Normal Depth | |
| 4 Tule Creek | Tributary | 10982. | Flow Hydrograph | |

| Gate Openings | | | | | |
|--|---|--------------------------|--|--|--|
| River: Baxter Riv | River: Baxter River Reach: Lower Reach RS: 33042. | | | | |
| Gate | Gate Group: Gate #1 ▼ ↓ 1 | | | | |
| Read from DSS before sim | ulation | Select DSS file and Path | | | |
| File: | | | | | |
| | | | | | |
| Path: | | | | | |
| Enter Table | Data time | interval: 1 Hour 💌 | | | |
| -Select/Enter the Data's Sta | rtina Time Refere | ence | | | |
| Use Simulation Time: | - | an2005 Time: 0100 | | | |
| C Fixed Start Time: | D G. (0.) / / | | | | |
| C Fixed Start Time: | Date: | Time: | | | |
| No. Ordinates Interpol | ate Missing Value | es Del Row Ins Row | | | |
| | Hydrograph Da | ata | | | |
| Date | Simulation Tin | | | | |
| | (hours) | (ft) | | | |
| 1 01 Jan 2005 0100 | 00:00 | 0. | | | |
| 2 01 Jan2005 0200 3 01 Jan2005 0300 | 01:00 | 0. | | | |
| 4 01 Jan 2005 0400 | 03:00 | 0. | | | |
| 5 01 Jan 2005 0500 | 04:00 | 0. | | | |
| 6 01 Jan 2005 0600 | 05:00 | 0. | | | |
| 7 01 Jan 2005 0700 | 06:00 | 0. | | | |
| 8 01 Jan 2005 0800 | | | | | |
| 9 01 Jan 2005 0900 | 08:00 | 0. | | | |
| 10 01 Jan 2005 1000 | 09:00 | 0. | | | |
| F | Plot Data | OK Cancel | | | |



Now, Click on Unsteady Flow Analysis (main HEC-RAS window).

| 5 Unsteady Flow Analysis | 8 |
|---|--|
| File Options Help | |
| Plan : Plan 05 | Short ID Steady Flow |
| Geometry File : | Imported GIS Data +Bridges |
| Unsteady Flow File : | Flood Event |
| Programs to Run ✓ Geometry Preprocessor ✓ Unsteady Flow Simulation ✓ Post Processor | Plan Description : |
| Simulation Time Window Starting Date: 01jan21 Ending Date: 04jan21 | |
| Computation Settings Computation Interval: 10 Minu Computation Level Output DSS Output Filename: m:\Artu | te Hydrograph Output Interval: 1 Hour Detailed Output Interval: 1 Hour ro\Teaching\Unsteady_flow_Rivers_Pipe_Netw |
| | nu: "Options/Mixed Flow Options") |
| | Compute |

Click on *Compute* and *Save* the HEC-RAS model.

| HEC-RAS Computations | | | |
|---|-------------------|-------------------------|----------|
| Geometry Processor | | | |
| River: Baxter River Reach: Lower Reach | RS: | 1192. Orașe Reștian | |
| IB Curve: | Node Type: | Cross Section | |
| ib ouve. | | | |
| Unsteady Flow Simulation | | | |
| Simulation: | | | |
| Time: 95.0000 05JAN2005 | 00:00:00 | Iteration: 2 | |
| Writing Profiles 600 | | | |
| PostProcess | | | |
| River: Baxter River Reach: Upper Reach | RS: Node Type: | 53861. Cross Section | |
| | Node Type. | Cross Section | |
| Profile: 02JAN20051600 | | | |
| Simulation: 41/97 | | | |
| Computation Messages | | | |
| At River Tule Creek Reach Tribut | tary R.S. 45 | 14. | _ |
| Finished Unstack Flow Simulation | | | |
| Finished Unsteady Flow Simulation | | | |
| Writing Results to DSS | | | |
| Finished Writing Results to DSS | | | |
| Reading Data for Data Process | | | |
| Reading Data for Post Process | | | |
| Running Post Processor Version 4.1.0 J | Jan 2010 | | |
| | | | _ |
| Ľ | Chain | | |
| | Stop | | |

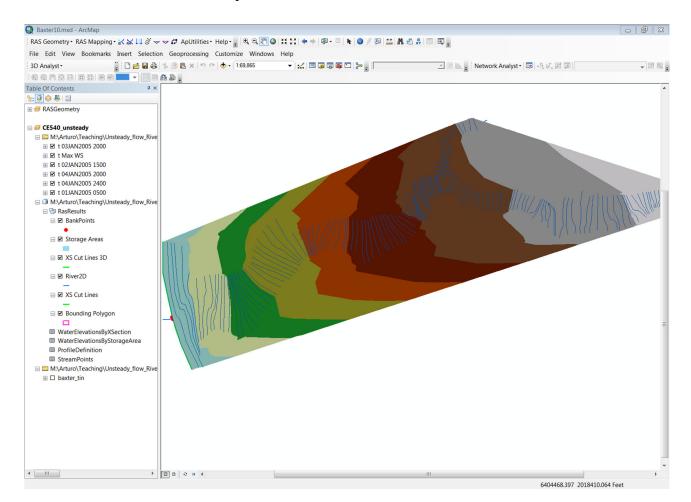
Then export the HEC-RAS output data to ArcGIS. Click on *File* \rightarrow *Export GIS Data...* in the main HEC-RAS window. Click on *Select Profiles to Export* button, and select few profiles, including the maximum. Click on *Export Data* button, which will create a SDF file in your working directory. Save the HEC-RAS project and exit.

We will now open ArcGIS. In ArcGIS (open *Baxter10.mxd*, which is located in the sub folder *BaxterExample10 - smaller*) click on *Import RAS SDF* file button to convert the SDF file into an XML file. In the *Convert RAS Export RAS SDF to XML* window, browse to *Baxter.RASexport.sdf* (located in the sub folder RASModel), 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:

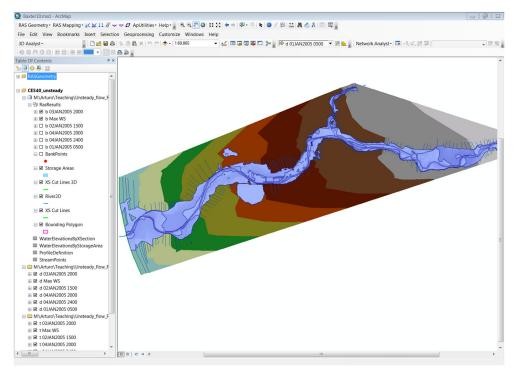
| Layer Setup for HEC- | RAS PostProcessing |
|--|--|
| Analysis Type Existing Analysis New Analysis | Steady CE540_unsteady |
| RAS GIS Export File Terrain | 3axterExample10 - smaller\RASModel\Baxter.RASexport.xml |
| Single | Terrain Type TIN GRID Terrain \BaxterExample10 - smaller\Terrain\baxter_tin |
| Multiple | DTM Tiles Layer |
| Output Directory | ady\BaxterExample10 - smaller\RASModel\CE540_unsteady |
| Geodatabase | CE540_unsteady.g |
| Rasterization Cell Size | 20 (map units) |
| | OK Help Cancel |

In the layer setup for post-processing, first **select** the *New Analysis* option, and **name** the new analysis as *CE540_unsteady* or any name you like. **Browse** to *Baxter.RASexport.xml* for *RAS GIS Export File*. **Select** the *Single Terrain TIN* Type, and **browse** to *Baxter_tin*. **Browse** to your working folder for *Output Directory (RASModel* in this case). Accept the default 20 map units for *Rasterization Cell Size*. **Click** *OK*. A new map (data frame) with the analysis name (e.g., *CE540 unsteady*) will be added to ArcGIS with the terrain data.

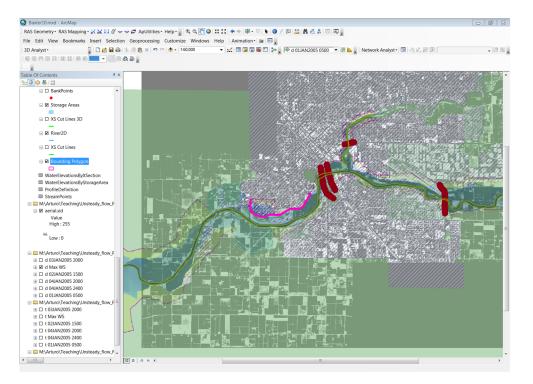
Next **click** on *RAS Mapping* \rightarrow *Import RAS Data*. Similar to during export, you will see a series of messages during the import. This will create a bounding polygon. After the analysis extent is defined, we are ready to map the inundation extent. **Click** on *RAS Mapping/ Inundation Mapping/ Water Surface Generation*. **Select** All profiles, and **click** *OK*. This will create a surface with water surface elevation for the selected profiles as follows.

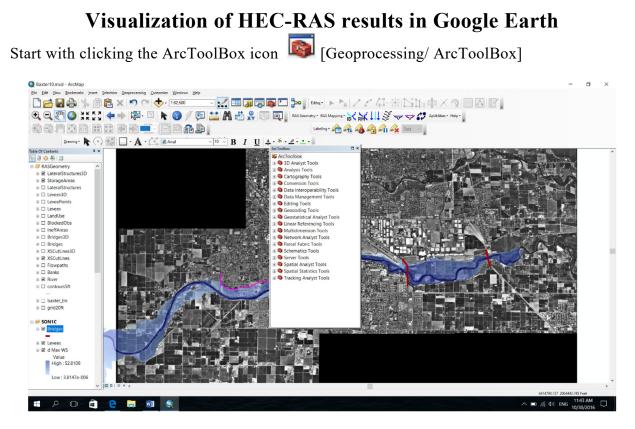


At this point we have a water surface and we have an underlying terrain. Now we will subtract the terrain from the water surface. Next, **Click** on *RAS Mapping* \rightarrow *Inundation Mapping* \rightarrow *Floodplain Delineation using Rasters*. Again, **select** All profiles, and **click** *OK*. You will see a series of messages during the execution. Then, a polygon will be created that represents the flooded area.

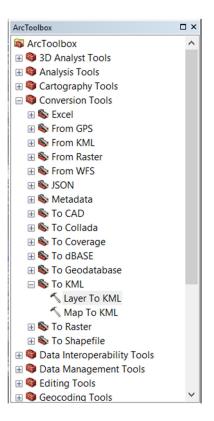


After the inundation map is created, you must check the inundation polygon for accuracy. For this you may need to superimpose your results with the geometry of the river, aerial map, levee lines, etc. (similar to the Steady Flow case). Notice in the plot above that there are unfeasible polders of water outside of the flooding area, meaning that the hydraulic simulation is not correct. Here you may need to add ineffective areas or blocked obstructions to avoid these unfeasible polders. Also, if the flooding extension is extending until the bounding polygon, this may mean that the bounding polygon needs to be extended to capture the full extension of flooding. In the computer lab session we will play with *levees* and other structures to protect urban areas. We will also learn how to check that your unsteady flow calculations make sense.





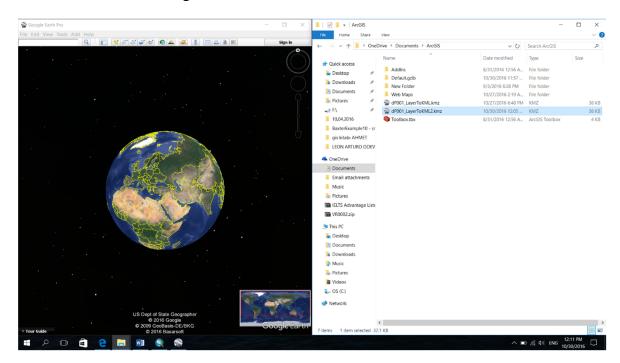
In the ArcToolBox list, select Conversion Tools \rightarrow To KML \rightarrow Layer to KML as follows



In the *Layer to KML* window, choose the layer that you would like to use (e.g., max water depth, maximum water surface elevation). In the figure below, the maximum water depth was used. The directory for the output file also needs to be specified.

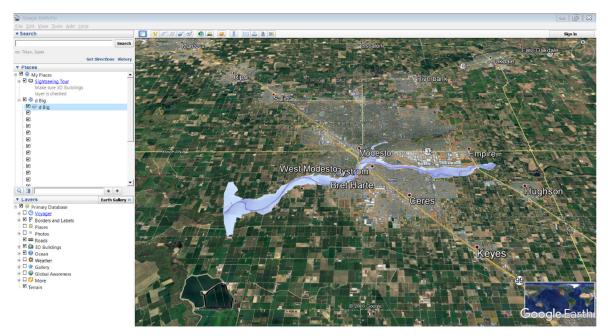
| S Layer To KML | |
|---|--------------|
| Layer | ^ |
| d Max WS | - 🖻 |
| Output File | |
| C:\Users\AYSEY\OneDrive\Belgeler\ArcGIS\dP001_LayerToKML2.kmz | 2 |
| Layer Output Scale (optional) | |
| | 0 |
| Clamped features to ground (optional) | |
| * Data Content Properties | |
| * Extent Properties | |
| * Output Image Properties | |
| | \sim |
| OK Cancel Environments. | Show Help >> |

Click OK in the window above to create the KML file. Next, open Google Earth. Then, drag the created KML file to the Google Earth window.

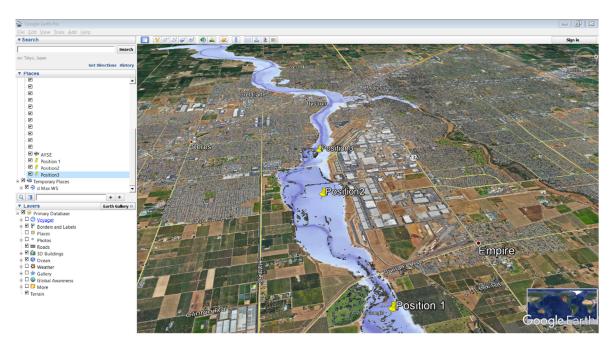


This will overlay the maximum water depth layer on Google Earth as shown below.

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Before animating the inundation, you may want to adjust the perspective in Google Earth. In Google Earth select *Tools/Options/3D View* and then use the *maximum elevation exaggeration* (e.g., 3.0). Then Press *Shift* in the Keyboard and change the vertical angle with the mouse wheel. Play with this option until an appropriate view of the structures (e.g., bridges) is obtained.



Next, click on the *Record a Tour* icon ^{ed}. This will bring the following window

To start recording, click the red button. Then, using the mouse move and zoom-in along the river and structures as needed. To stop recording, click the red button again. To see the animation, click the play button.



2D Flooding using HEC-RAS (with and without levees)

First, create a **new** HEC-RAS Project (File/New Project) and save it in a new Folder (Example: C:\temp\Baxter2D\test2D_1). Then click on the *RAS Mapper* icon . In the *RAS Mapper* window, highlight the *Terrains* option and right click on it. Then select the option *Create a new RAS terrain*. This will bring a window for creating a *Spatial Reference System* as follows

| HEC-RAS | Spatial Reference System | 83 |
|---------|---|----|
| 0 | It is recommended that the Project Spatial Reference System (SRS) be set before creating GIS data. Would you like to set the SRS now? Click 'Yes' to jump to the dialog where the ESRI Projection file (*.prj) file is set, or 'no' to go directly to the terrain creation dialog. | |
| | Yes No | |

Select the **No** option because the Raster data of the Baxter River that we used in our previous tutorial has already a projection. This will result in the following window for a *New Terrain Layer*.

| New Terrain Layer | | | | | | |
|---|---|-----------------------------------|------------------|------------------|-------------|---------|
| Set SRS | Spatial Reference Syster | m Projection is not specified for | or this project! | | | |
| + Filename × ↓ | | | Projection | Cell Size | Rounding | Info |
| Output Terrain File - Rounding (Precision) | 1/32 | ✓ Create Stitches | | ge Inputs to Sir | ngle Raster | |
| Vertical Conversion: Filename: | Use Input File (Default) C:\temp\Baxter2D\test2D_1\T | errain \Terrain.hdf | | | | <u></u> |
| | | | | | Create | Cancel |

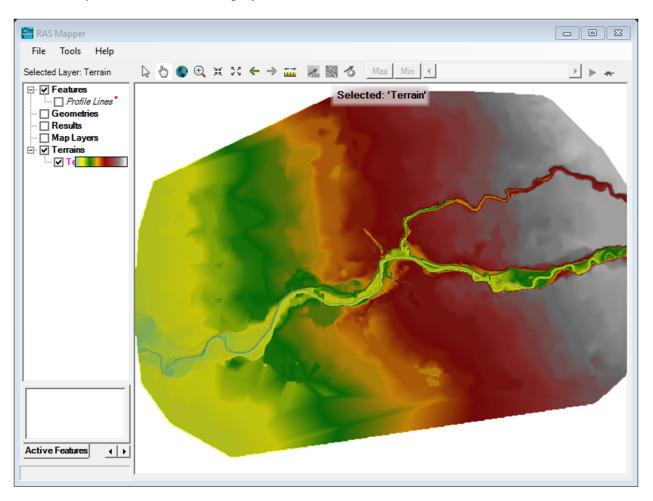
In the above window click on the plus icon (+) and open the raster data in the Directory you downloaded from the class website Terrain/grid20/grid20ft. The name of the file is w001001.adf. This again will bring a window for creating a *Spatial Reference System*. Now select **Yes**. Note in the window that this raster file has a projection associated with it. Now click on the button *Create* as follows

| New Terrain Layer | | | | | | |
|-----------------------|--------------------------|-----------------------------------|------------|-----------------|-------------|--------|
| Set SRS | | | | | | |
| Input Terrain Files | | | | | | |
| + Filename | | Projection | | Cell Size | Rounding | Info |
| 001001 // | | PROJCS["NAD83 / California zone 3 | 3",GEOGCS[| 20 | (na) | i |
| × wootoot.adf | | | | | | |
| | | | | | | |
| + | | | | | | |
| + | | | | | | |
| | | | | | | |
| Output Terrain File | | | | | | |
| Rounding (Precision): | 1/32 | Create Stitches | - Marra | e Inputs to Sir | ala Pastar | |
| ricanang (riccionin). | 17.52 | I♥ Create Stitches | i werge | e inputs to Sir | igie naster | |
| Vertical Conversion: | Use Input File (Default) | ▼ | | | | |
| Filename: | C:\temp\Baxter2D\test2D | _1\Terrain\Terrain.hdf | | | | 2 |
| | , . | | | | | |
| | | | | | Create | Cancel |
| | | | | | | |

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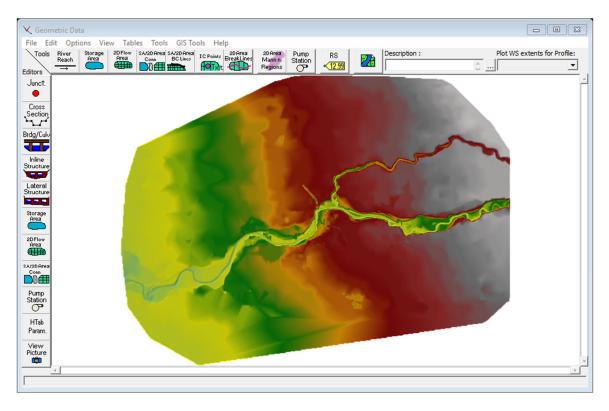
This will create the Terrain. Close the resulting window and save your HEC-RAS project.

Now open the *RAS Mapper* again and check the Terrain box to visualize the terrain. If the terrain is not displayed, highlight and check the terrain option and right click on it. Then, select the option *Zoom to Layer* and this should display the terrain as follows



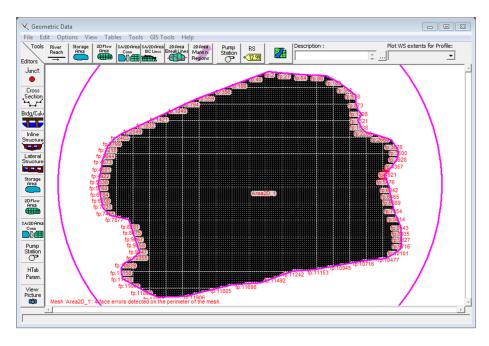
Save your HEC-RAS project and open the Geometry Tab 🖄 and you should be able to see the

Terrain as follows:

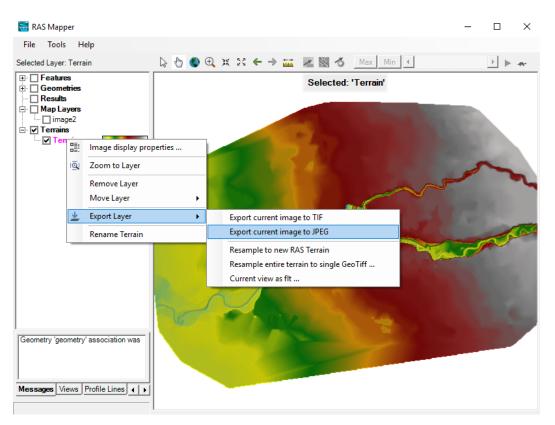


Because this section is focused on 2D modeling, we will use the 2DFlow Area icon, which is

located at the top of the Geometry window (). Now select the Area of your domain and give a name to it. Click OK and now you have the 2DFlow Area which will be the domain for the 2D simulation. Then select the 2D area you created and right click on it and select Edit 2DFlow Area. Then click on "Generate Computation Points on regular Interval ..." Then use a Dx and Dy equal to 10-200. Click on Generate Points in 2D Flow Area and the mesh will be created. If your Dx and/or Dy are too small, HEC-RAS will not generate the mesh due to memory allocation issues.



Once the mesh is generated, sometimes the DEM image is lost. To bring the DEM back, we need to export this from the *RAS Mapper* as follows

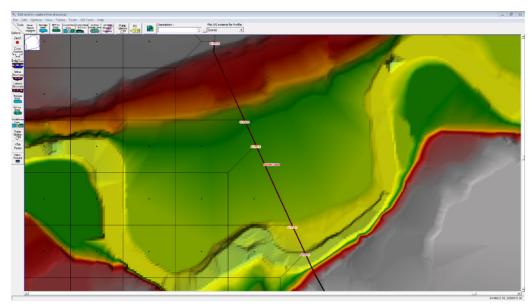


Assign a name to the *.jpg* image and save it. After you have exported the image you need to add it as a *Map Layer*. To do this, in *RAS Mapper* highlight and check the *Map Layers* option and right click on it. Then, select *Map data layers/Add existing layers* and search for the image you have exported. You can also add various existing *Map Layers* in *RAS Mapper*. For instance, the *Google Satellite Map* can be exported in *RAS Mapper* by selecting *Tools/Add Web Imagery/Google Satellite*. To select which background picture to show in the HEC-RAS *Geometry Data* window

use the icon

To hide the mesh, in the *Geometric Data* tab, select *View/View Options* and here uncheck the buttons *Fill in Storage Areas/2D Flow Areas*.

Before you create the boundary lines (Upstream Baxter River, Upstream Tule Creek, and Downstream Baxter River), it may be a good idea to edit you 2D Flow Area, especially along the boundaries. To do this, in the Geometry Tab is use the *Edit* option to *Add Points, Move points* and *Remove Points*. Now you can create the boundary lines using the icon for Upstream Baxter River, Upstream Tule Creek, and Downstream Baxter River. The figure below is for Upstream Baxter River. Please make sure that the upstream end boundary lines are not outside of the main channel of the river as this will give an unrealistic inundation area. Also, make sure that the boundary lines are perpendicular to the flow direction. At the downstream boundaries, try to make the boundary line as large as possible to allow to pass the maximum flow rate without producing backwater due to the boundary.



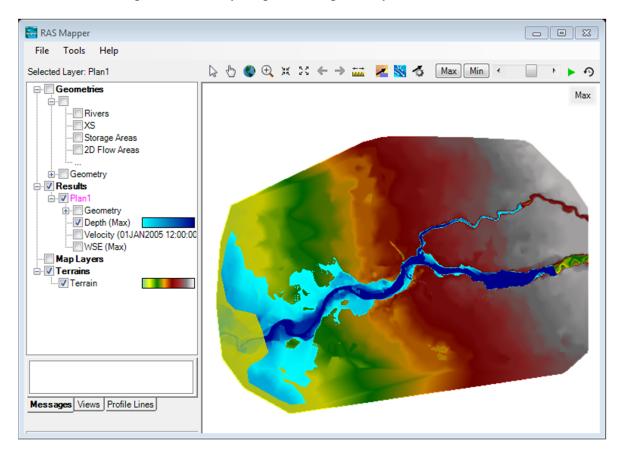
Once you edited the boundary lines, you may want to rebuild your mesh (Use *Force Mesh Recomputation* and *Generate Computation Points on Regular Interval with all Breaklines*). Once this is complete save your geometry data and start to add the boundary conditions as usual (Edit/Unsteady Flow Data). You can use the same boundary conditions as the *1D Unsteady* flow data. To copy this data, you can open another instance of HEC-RAS and copy the data directly (use Ctrl "C" and Ctrl "V"). For each inflow hydrograph, at the bottom of the table, enter 0 for *EG Slope for distributing flow along BC Line*. Next, *save* the unsteady flow data. Next, create the Plan with the dates and parameters of the simulation in a similar way to the *1D Unsteady* case. Before running your model, as shown below, make sure that in the *Plan* you select *Options/Calculation Options and Tolerances/2D Flow Options* and in *Initial conditions Time*, you select the number of hours for the initial flow calculations. I would suggest to use a *steady flow* for the first "x" hours where x is at least two times the time period that it takes for the flow to travel from the most upstream end to the most downstream end.

| Parameter (Default) Area2D_1 Theta (0.6-1.0): 1 1 Theta Warmup (0.6-1.0): 1 1 Water Surface Tolerance [max=0.2](ft) 0.01 0.01 Volume Tolerance (ft) 0.01 0.01 Maximum Iterations 20 20 Equation Set Diffusion Wave Diffusion Wave Initial Conditions Time (hrs) 0.1 0.1 Number of Time Slices (Integer Value) 1 1 Eddy Viscosity Transverse Mixing Coefficient Boundary Condition Volume Check Latitude for Coriolis (-90 to 90) | mber of cores to use in 2D computatio | ns: All Available 🔽 | |
|--|---|---------------------|----------------|
| Theta Warmup (0.6-1.0): 1 1 Water Surface Tolerance [max=0.2](ft) 0.01 0.01 Volume Tolerance (ft) 0.01 0.01 Maximum Iterations 20 20 Equation Set Diffusion Wave Diffusion Wave Initial Conditions Time (hrs) 200 200 Initial Conditions Ramp Up Fraction (0-1) 0.1 0.1 Number of Time Slices (Integer Value) 1 1 Eddy Viscosity Transverse Mixing Coefficient 0 0 Boundary Condition Volume Check | Parameter | (Default) | Area2D_1 |
| Water Surface Tolerance [max=0.2](ft) 0.01 0.01 Volume Tolerance (ft) 0.01 0.01 Maximum Iterations 20 20 Equation Set Diffusion Wave Diffusion Wave Initial Conditions Time (hrs) 200 200 Initial Conditions Ramp Up Fraction (0-1) 0.1 0.1 Number of Time Slices (Integer Value) 1 1 Eddy Viscosity Transverse Mixing Coefficient 0 0 Boundary Condition Volume Check | Theta (0.6-1.0): | 1 | 1 |
| Volume Tolerance (ft) 0.01 0.01 Maximum Iterations 20 20 Equation Set Diffusion Wave Diffusion Wave Initial Conditions Time (hrs) 200 200 Initial Conditions Ramp Up Fraction (0-1) 0.1 0.1 Number of Time Slices (Integer Value) 1 1 Eddy Viscosity Transverse Mixing Coefficient 0 0 | | 1 | . 1 |
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| Equation Set Diffusion Wave Diffusion Wave Initial Conditions Time (hrs) 200 Initial Conditions Ramp Up Fraction (0-1) 0.1 0.1 Number of Time Slices (Integer Value) 1 1 Eddy Viscosity Transverse Mixing Coefficient Boundary Condition Volume Check | Volume Tolerance (ft) | 0.01 | 0.01 |
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| Initial Conditions Ramp Up Fraction (0-1) 0.1 0.1 Number of Time Slices (Integer Value) 1 1 Eddy Viscosity Transverse Mixing Coefficient 0 1 Boundary Condition Volume Check 0 0 | Equation Set | Diffusion Wave | Diffusion Wave |
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| Eddy Viscosity Transverse Mixing Coefficient Boundary Condition Volume Check | Initial Conditions Ramp Up Fraction (0- | -1) 0.1 | 0.1 |
| Boundary Condition Volume Check | Number of Time Slices (Integer Value) | 1 | . 1 |
| | Eddy Viscosity Transverse Mixing Coef | fficient | |
| Latitude for Coriolis (-90 to 90) | Boundary Condition Volume Check | | |
| | Latitude for Coriolis (-90 to 90) | | |

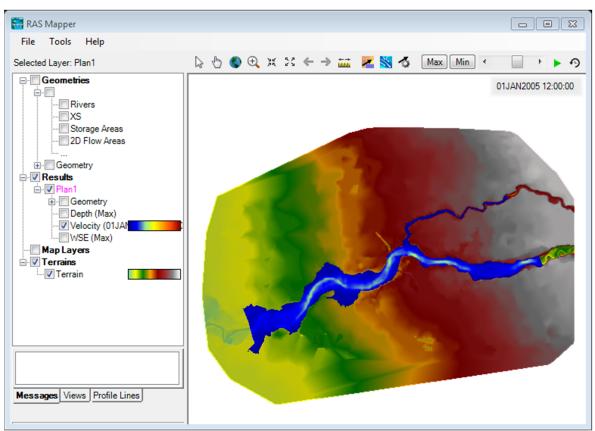
Now you should be able to run the model. After the model is run, the visualization is done in *RAS Mapper* by checking the box *Results*. Here you may want to animate the water depth, velocity or the water surface elevation. The results at different times can be visualized by scrolling the following tab to the left or right.



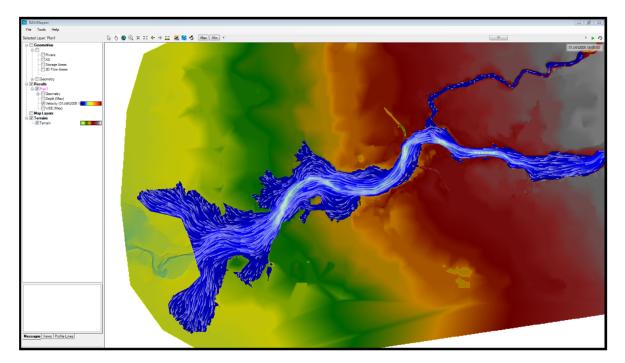
The above tab is located in the upper right corner of the *RAS Mapper* window. The two figures below show water depth and velocity snapshots, respectively.



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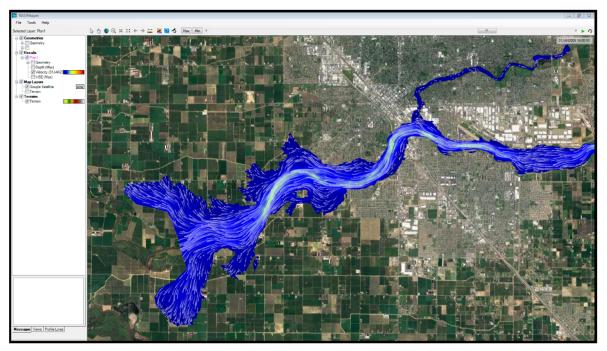


If you would like to visualize the particle tracing you can use the icon \bigotimes and then click on the icon \bigotimes to select the parameters of the tracing. Below is a snapshot of the particle tracing.

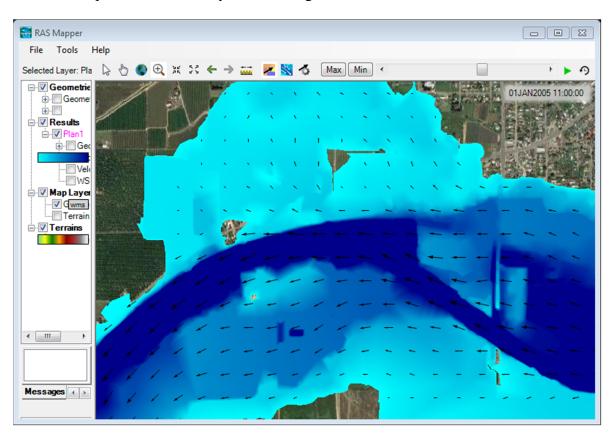


You can also add layers using *Tools/Add Map Layers* to show Aerial Maps available for the area (e.g., Google Satellite). One of this is shown below. Make sure that the appropriate Map layer is checked.

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We can also visualize the velocity arrows at a given time. To do this use the icon \checkmark in *RAS Mapper*. To control the separation of the arrows, modify the *spacing* of *Static Arrows* using the icon \checkmark . A snapshot of the velocity arrows at a given time is shown below:

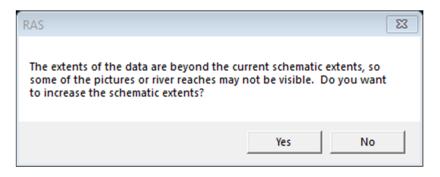


As for the 1D case, you need to check if the results make sense. If they don't, we need to redo the simulations with the necessary corrections. This will be explained in the computer lab in more detail.

Adding Levees in 2D Modeling

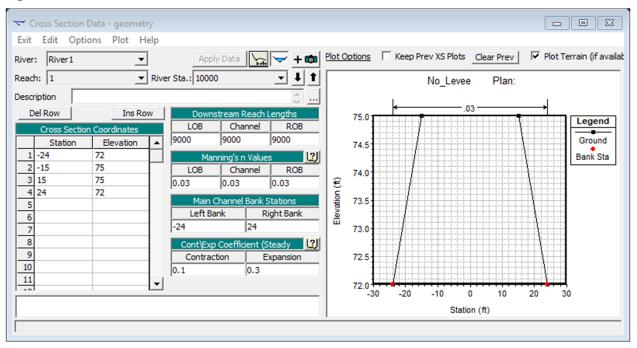
To add levees, we can use the *lifting terrain* approach as described in

http://hecrasmodel.blogspot.com/2015/06/lifting-terrain-in-hec-ras-50.html. Following this approach, we open the *Geometry* tab in HEC-RAS containing the terrain created previously. In the *Geometry* tab, we first define *breaklines* along existing or future levees (2D Area Breaklines), then we create a river reach along the breakline (from upstream to downstream). When creating the river reach we are asked the following question:

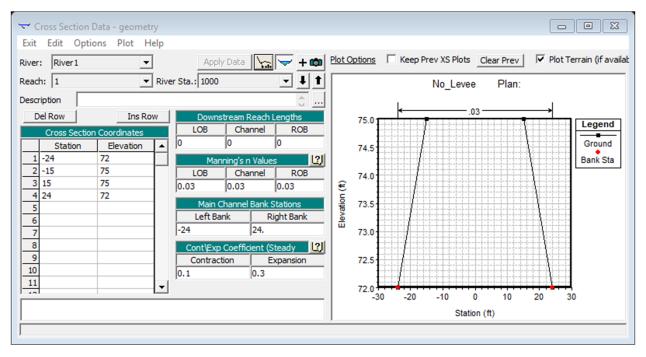


Select No. Then add two cross-sections representing the levees in the river reach. To make sure that the levee is wide enough to be well captured in the terrain model, I used a levee width of 30 ft. I also used a side slope of 3:1 (z = 3). There is no need to project the levee side slope to the ground as HEC-RAS will do it for you. The two created cross-sections are shown below.

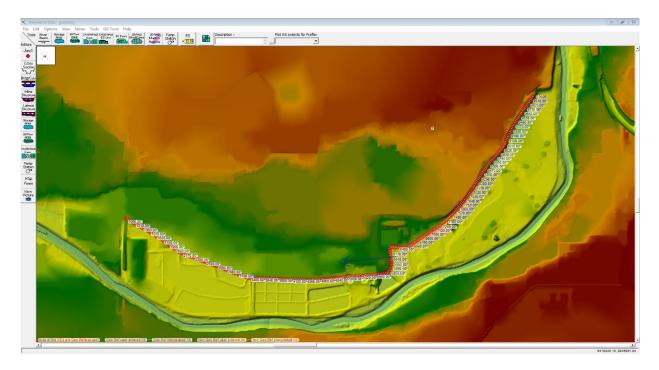
Upstream cross-section



Downstream cross-section



Then, I interpolated between the two cross-sections with a spacing of 30 ft, which resulted in the following plot.

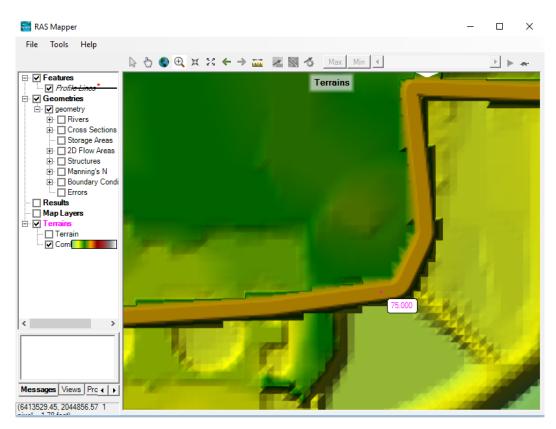


Then, export the levee as a terrain. To do this, *in RAS Mapper*, select the geometry you are using, right click on *Geometry* and select *Export Layer* and then *Create terrain GeoTiff from XS's* (channel only). Save the terrain as for instance Baxter_withLevee1 and use an appropriate raster size. I used 5 ft. If you want to create a channelization (e.g., meandering for river restoration) instead of a levee, you may use a similar approach. The only difference is that you would need to use the *Create terrain GeoTiff from XS's* (overbanks and channel) to account for the outer side slopes of the channel berms. This will be shown in the lab.

Now we need to combine both terrains (levee and original terrain). To do this, in *RAS Mapper/Tools* select the option "*New terrain*" and add the two terrain models. Also, give a name to the new terrain (e.g., Combined). Furthermore, make sure that the levee terrain is in the top of the list as this should have priority in the combination of terrains. Your new terrain layer, should look as follows:

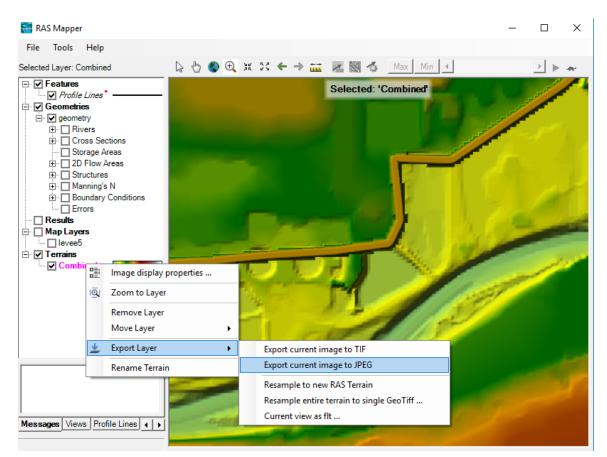
| | iin Layer | 1 | | | | | |
|------------------|------------------------------------|----------------------------------|--|---------|--------------|-------------|------|
| | et SRS | | | | | | |
| + | Filename | | Projection | | Cell Size | Rounding | Info |
| | Baxter_withLe | vee1.tif | PROJCS["NAD83_California_zone_3",GE | EOGCS[| 5 | None | i |
| × | Terrain.grid20f | t.tif | PROJCS["NAD83_California_zone_3",GE | OGCS[| 20 | (na) | i |
| ¥ | | | | | | | |
| Output | Terrain File | 1/32 | ▼ Create Stitches | □ Merge | Inputs to Si | ngle Raster | |
| Output Roundi | Terrain File | 1/32 Use Input File (Default) | ✓ Create Stitches | ☐ Merge | Inputs to Si | ngle Raster | |
| Output Roundi | ing (Precision): Il Conversion: | Use Input File (Default) | ✓ Create Stitches ✓ | Merge | Inputs to Si | ngle Raster | - 2 |

The combined terrain of my assumed levee and the original terrain is shown below.



Please make sure that there is only one combined terrain in the RAS folder. If there are multiple terrains, the geometry file may not display the terrain you desire to show. If you have issues

showing the correct terrain in the *Geometry* Tab, you may want to remove all terrain other than the combined terrain in the *RAS Mapper*. Also, you may want to export the image of the combined terrain in *RAS Mapper* as follows



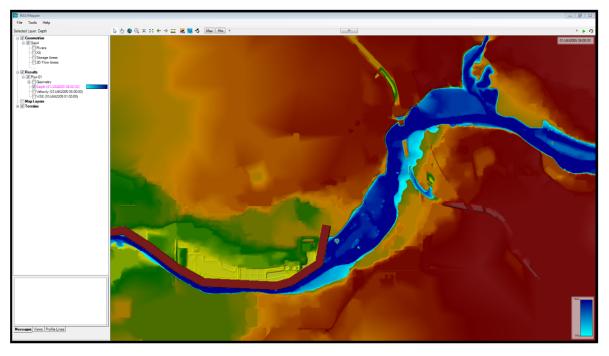
Assign a name to the *.jpg* image and save it. After you have exported the image you need to add it as a *Map Layer*. To do this, in *RAS Mapper* highlight and check the *Map Layers* option and right click on it. Then, select *Map data layers/Add existing layers* and search for the image you have exported. To select which background picture to show in the HEC-RAS *Geometry Data* window

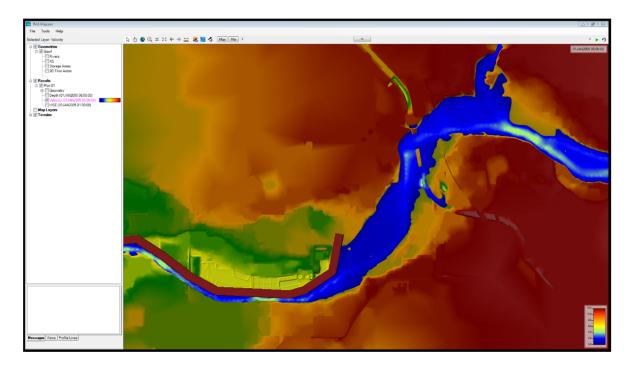
use the icon



Once the combined terrain is displayed in the *Geometry* Tab, we follow the same approach described in the previous section to obtain flood inundation. Please make sure that the levee is wide enough to be well captured in the terrain model you create. At the same time, make sure that the number of cells don't exceed about 10'000,000 as the computer in the lab may ran out of memory. I used a mesh size of Dx and Dy equal to 10 ft. The two figures below show snapshots of water depth and velocity, respectively, when considering the assumed levee.

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Finally, the figure below shows a snapshot of the particle tracing around the levee area.

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