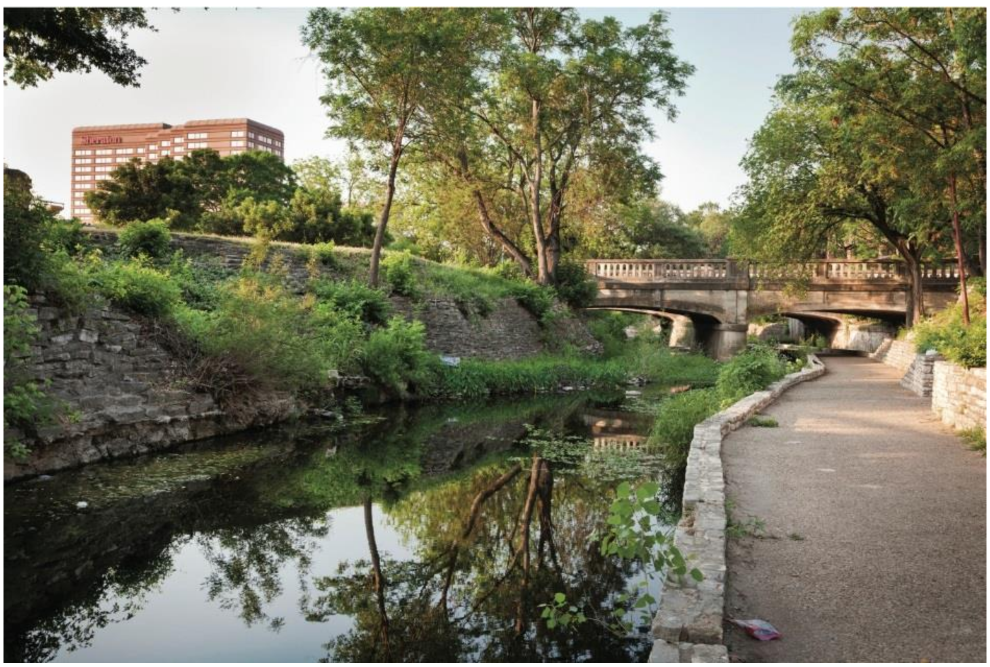
CE 365K **Exercise 2: HEC-RAS Modeling** **Spring 2014**
Hydraulic Engineering Design

This exercise was prepared by Fernando R. Salas and David R. Maidment

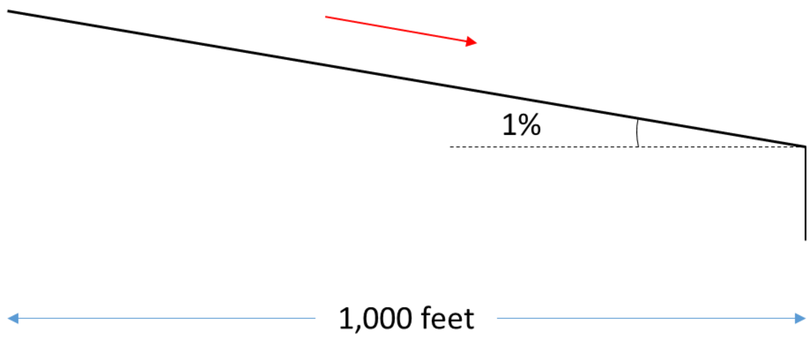
Introduction

In this exercise, we will learn how to setup a simple model in HEC-RAS. HEC-RAS is a river routing software developed by the U.S. Army Corps of Engineers and is widely used for flood analysis in the U.S. In fact, many FEMA flood plain maps are generated from HEC-RAS analysis.

To help you learn how to use HEC-RAS, we will create our own HEC-RAS model using a real cross section from nearby Waller Creek. We will use this cross section to create a fictional river reach spanning 1,000 feet and perform a steady-state flow analysis to study how the water surface changes along the length of the reach. The reach will have a gradual slope, 1%, and a free overfall at the downstream end.



Source: Landscape Architecture Magazine



Download Instructions

You can use HEC-RAS on the LRC computers, or you can download the software by **navigating to the website below and clicking on "*Downloads"*** on the left hand side of the screen.

http://www.hec.usace.army.mil/software/hec-ras/

Note: You will need to use a PC with Windows XP, Vista or 7 (both 32-bit and 64-bit).

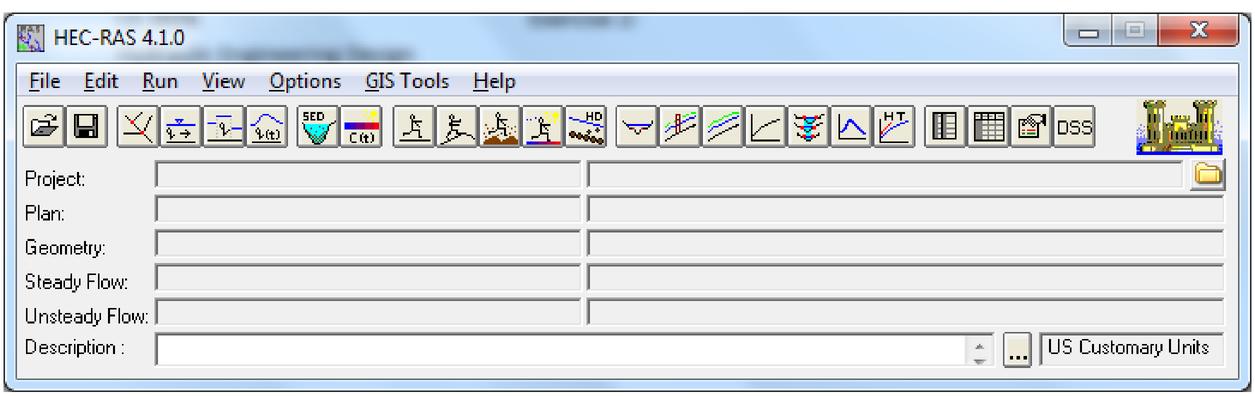
Download the HEC-RAS 4.1 Setup Package and install it on your personal computer. Follow the setup instructions and click through the default configurations.

If you would like to see the complete HEC-RAS user manual and reference guide, go to the following website.

http://www.hec.usace.army.mil/software/hec-ras/documentation.aspx

Running HEC-RAS

Double click on the HEC-RAS icon to open the program. You will see a window like the one below with many buttons laid out across the top. These buttons help you navigate to the corresponding windows that display and describe your model.

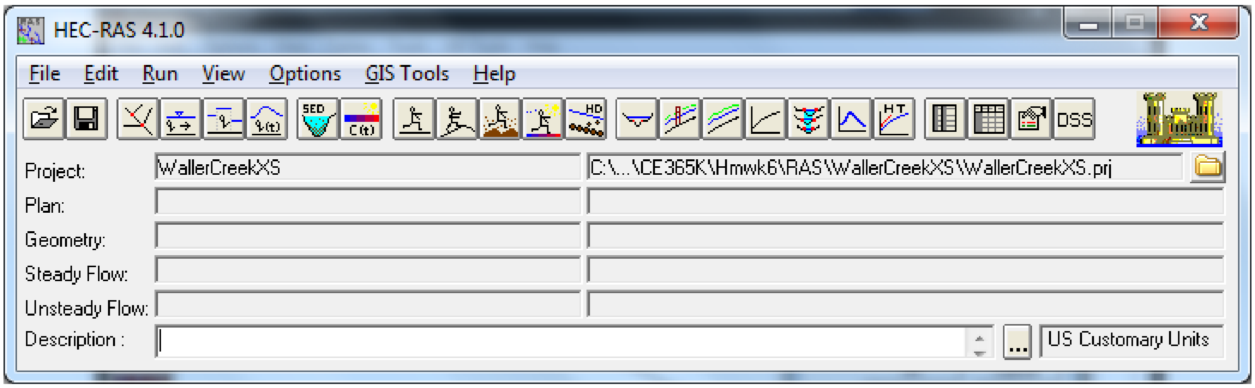


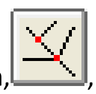
The first step in building a HEC-RAS model is to create a new project that stores and organizes all of the related HEC-RAS files for your particular model and model run. To create a new project, **go to *File* ->**

New Project. Navigate to the folder that you want to store your new project in, give the project a name such as WallerCreekXS and then save it by clicking on OK.

Note: you will want to store all of your HEC-RAS files in the same folder.

Once you create a new project, you will see the Project name and path on the main HEC-RAS window. The project by default will be set to US Customary Units but you can change this by going to Options -> Unit System. The other files listed on the main HEC-RAS window will be populated as you go through this exercise. A typical HEC-RAS model needs a project, plan, geometry, and steady or unsteady flow file to run.



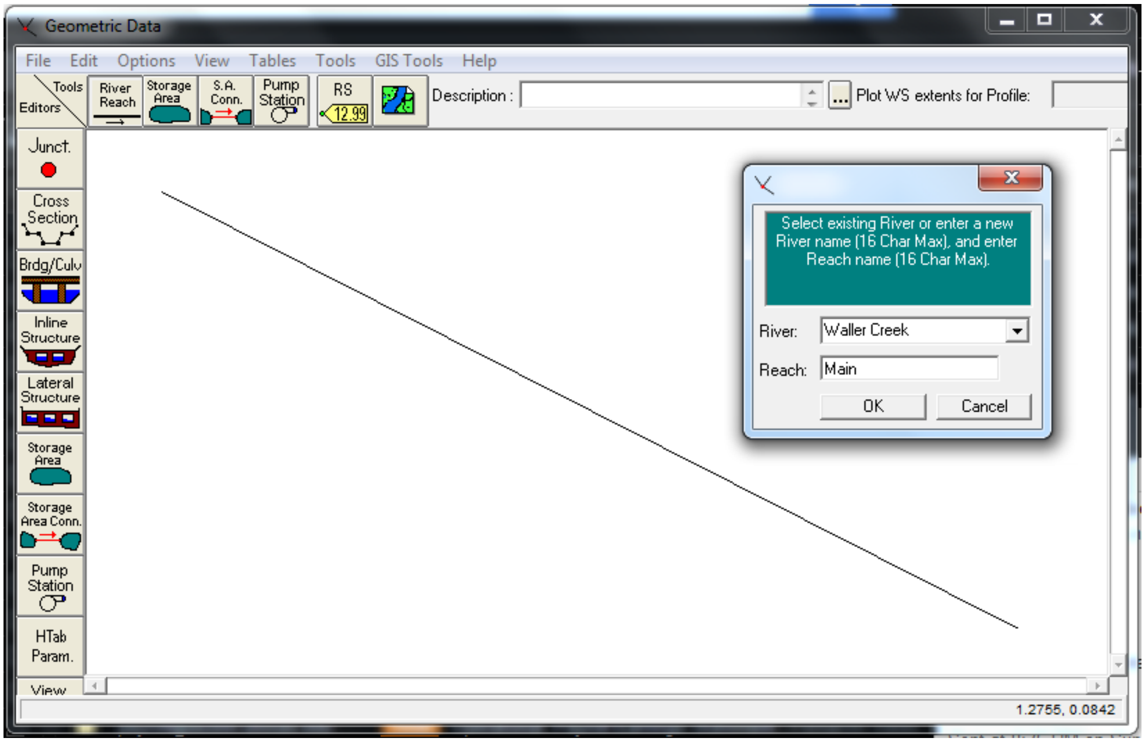
Next, go click on the Edit/Enter geometric data button, , to open the geometric data editor window. We will now create a fictional river reach which will provide the basis of our analysis.

To create a river reach:

(1) Click on the River Reach button, 

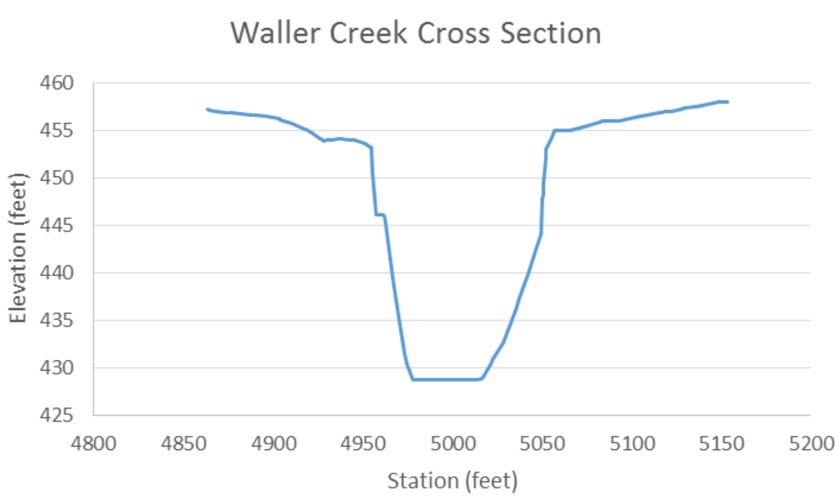
.
(2) Click once at the top left of the white space; you will see a line drawn as you move your cursor.
(3) Double click once at the bottom right of the white space.
(4) In the window that pops up, name the River, Waller Creek, and the Reach, Main.
(5) Click OK.

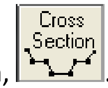
Your window should look like figure below.



Now we will create a cross section using data from an existing Waller Creek cross section. The cross section data can be found in the attached Excel worksheet; it is named WallerCreekXS.xls. Open the Excel sheet to see the cross section data. The Station field contains the x-coordinate data and the Elevation field contains the y-coordinate data; the elevation data represents the elevation above mean sea level in feet. If you would like a quick preview of the cross section, feel free to graph it using the Excel graphing tools.

Note: The Station data describes the relative position of the cross section, in feet, to the other cross sections contained in the HEC-RAS model. In this example, you don't need to worry about the station values for this particular cross-section.



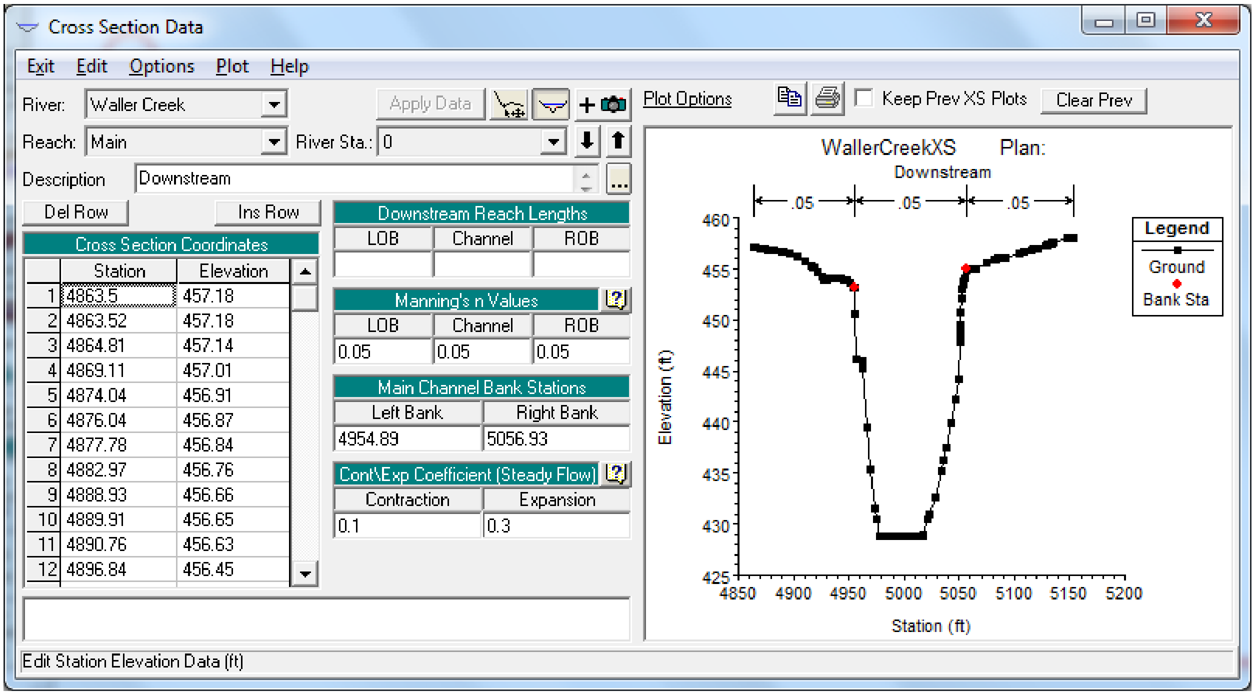
In the **Geometric Data** editor window, click on the Cross Section button, 

. This button will bring up the Cross Section Data editor window. This window allows you to input the x and y coordinates of a cross section along with its physical properties such as its' downstream length to the next downstream cross section, Manning's N value, and bank station position. The bank station position tells HEC-RAS where the flood plain of the cross section begins on both sides of the cross section.

To create a new cross section:

(1) Go to Options -> Add a new Cross Section…
(2) Enter the station of the new cross section. In this case we will input 0 to indicate the most downstream cross section; the 0 indicates the number of feet upstream of the most downstream cross section.
(3) Next, go to the Excel sheet and highlight the cross section data without highlighting the first row (e.g. A2:A212 and B2:B12).
(4) Copy the selected Excel data and return to the Cross Section Data editor window. In this window, highlight row 1 through row 211 for both the Station and Elevation columns. Once highlighted, go to Edit -> Paste.
(5) Enter 0.05 for the Manning's N values (i.e. LOB, Channel, ROB); HEC-RAS lets you specify the Manning's N value for the main channel, left of bank and right of bank portion of the cross section. The 0.05 Manning's N value is typical for a section of river with cobbles and large boulders.
(6) Input 4954.89 for the Left Bank station and 5056.93 for the Right Bank station.
(7) Input 0.1 for the Contraction and 0.3 for the Expansion. These coefficients are used to capture the effects of bridges on flow modeling. In this example, we can ignore these coefficients.
(8) Give the cross section a Description (e.g. Downstream).
(9) Click on **Apply Data** to finalize the cross section.

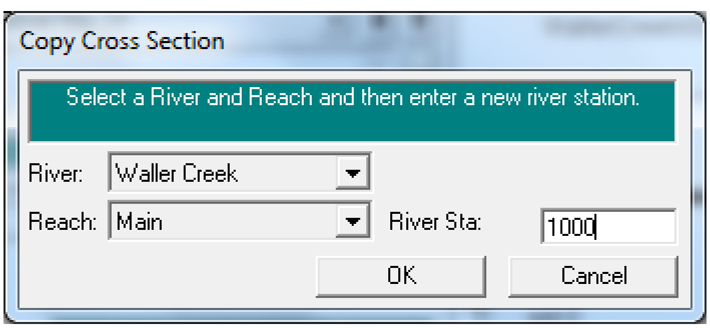
Note: For this example we are using existing data to define our cross section however if you wanted to setup your own HEC-RAS model, you could use your own data.



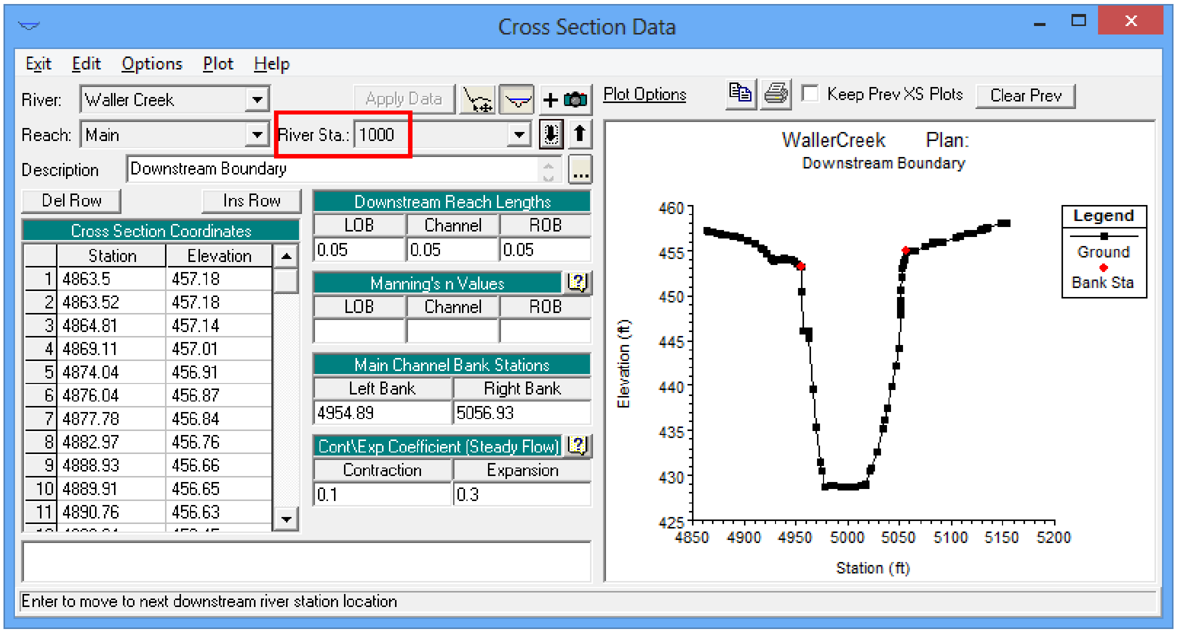
Now that we have created the downstream cross section for our reach, we will now create the most upstream cross section by copying the cross section we just created.

To copy a cross section:

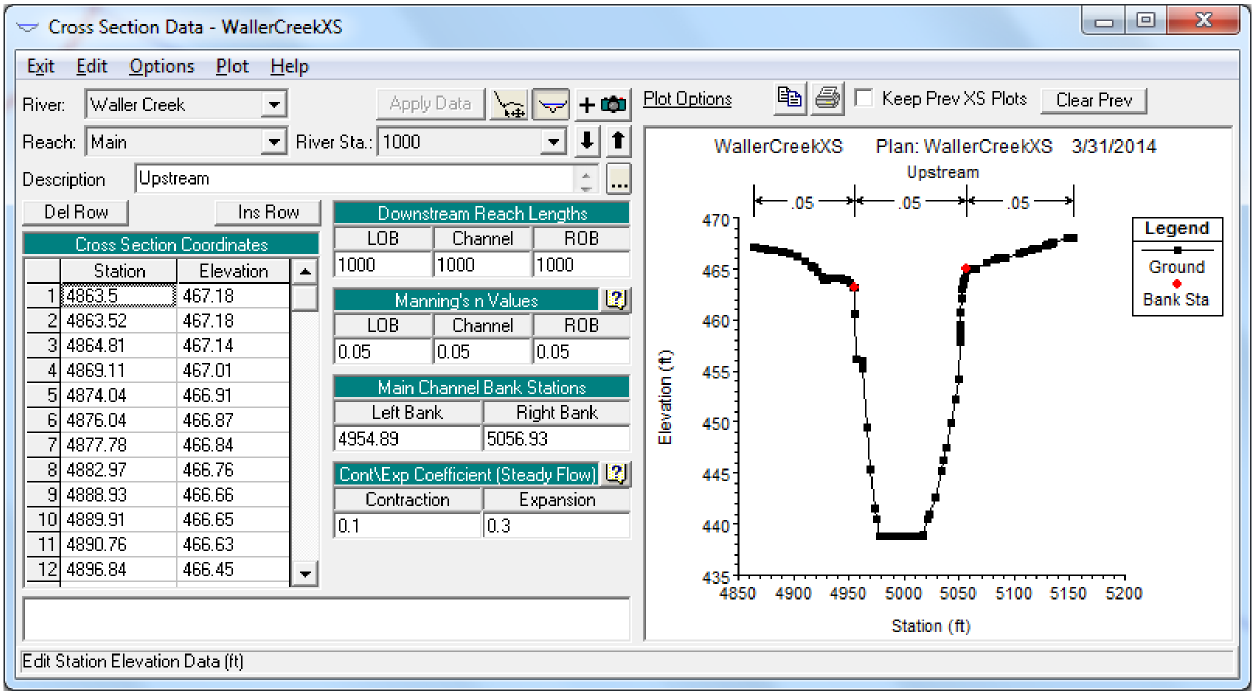
(1) Go to Options -> Copy Current Cross Section…
(2) Give the cross section a River Station of 1000 indicating that the new cross section will be 1,000 feet upstream of the first cross section we created.



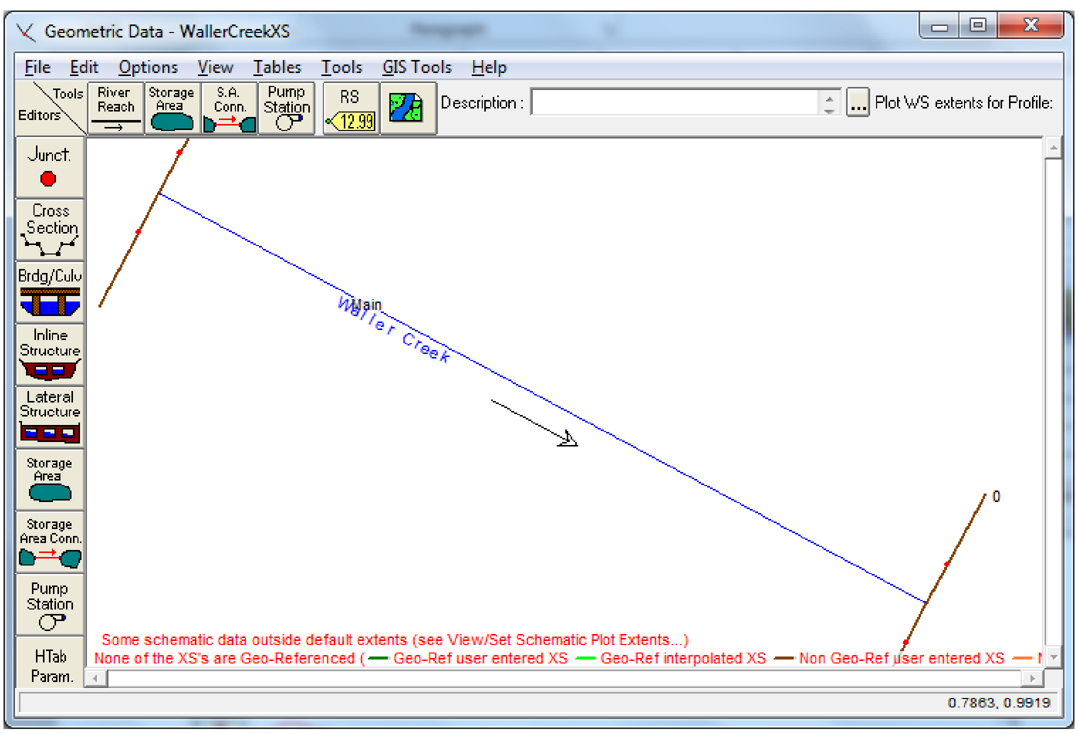
(3) Click OK.
Now when you look at the cross-section Editor, you'll see that the River Sta is set at 1000



(4) Change the Description to **Upstream**.
(5) Enter 1000 for the LOB, Channel and ROB Downstream Reach Lengths. If this cross section was located along a curve, you could change the corresponding reach lengths on each side of the channel.
(6) In the Cross Section Data editor window, go to Options -> Adjust Elevations…
(7) Enter 10 in the window that pops up to adjust all the elevation points for the new cross section by 10 feet; this represents a 1% slope between the two cross sections.
(8) Click OK.
(9) Click on Apply Data to finalize the upstream cross section.



You can now Exit the Cross Section Data editor window. By doing so, you will be taken back to the Geometric Data editor window where you will see the plan view of the river reach we created with the upstream and downstream cross sections.

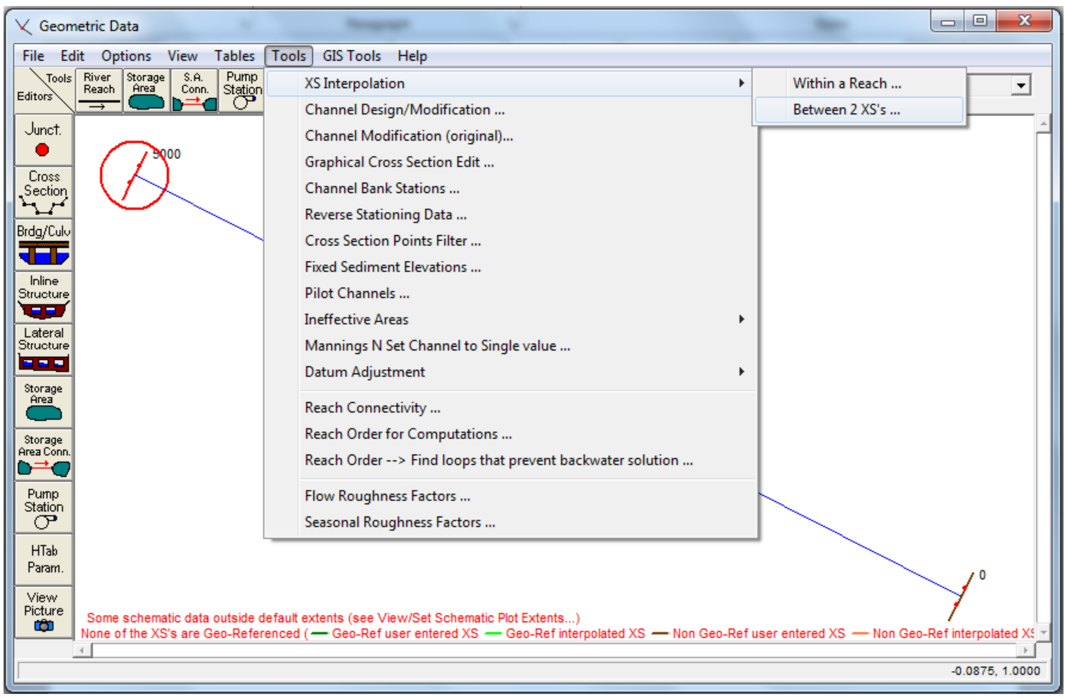


Now would be a good time to save the geometry we just created. Go to File -> Save Geometry Data. Give the file a title such as WallerCreekXS and make sure the file is being saved in the same folder as your project file. Click OK. If you go to the main HEC-RAS window, you will now see the name of the geometry file along with the path to the file.

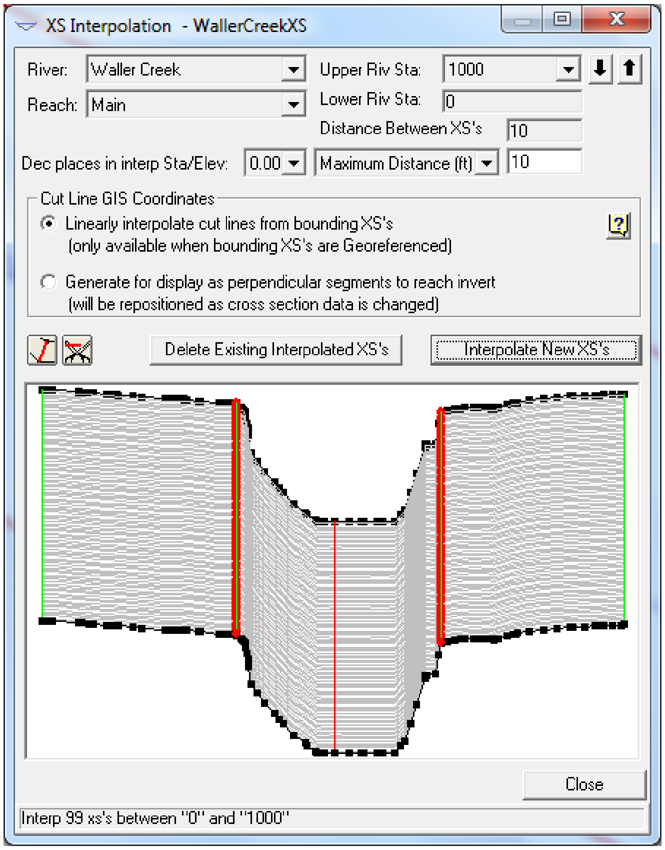
In order to study the flow along this river reach, we will create several cross sections in between the upstream and downstream cross sections by interpolating between these points.

To create cross sections by interpolating:

(1) Open the Geometric Data editor window.
(2) Go to Tools -> XS Interpolation -> Between 2 XS's…

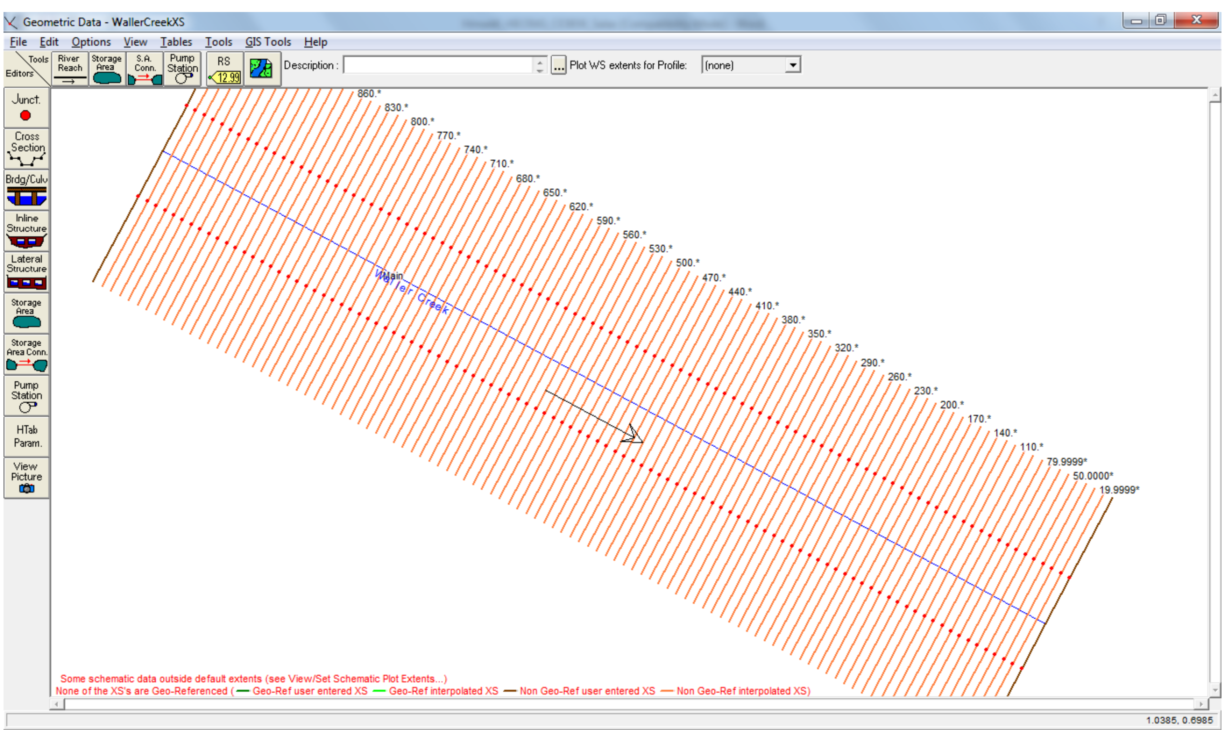


(3) Enter 10 beside the Maximum Distance (ft) box.
(4) Click on Interpolate New XS's.



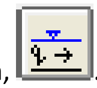
(5) Click Close.

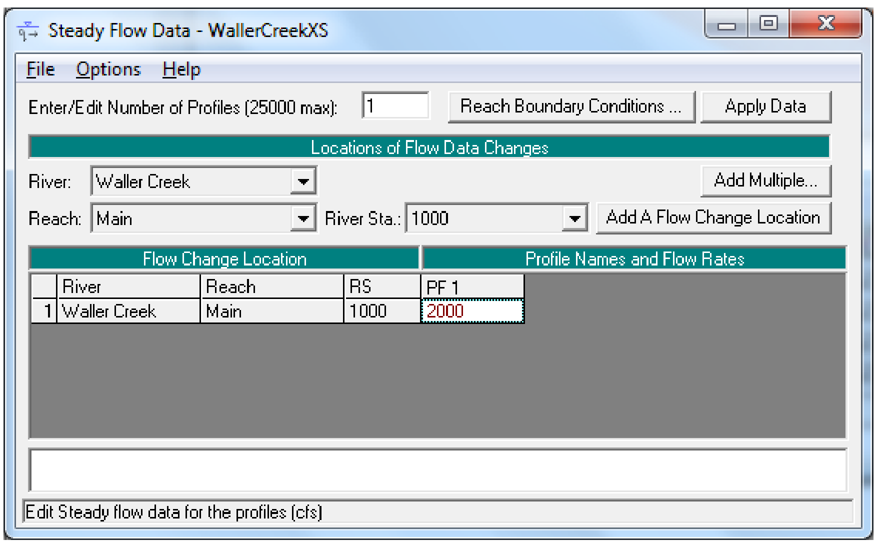
(6) Go to File -> Save Geometry Data.



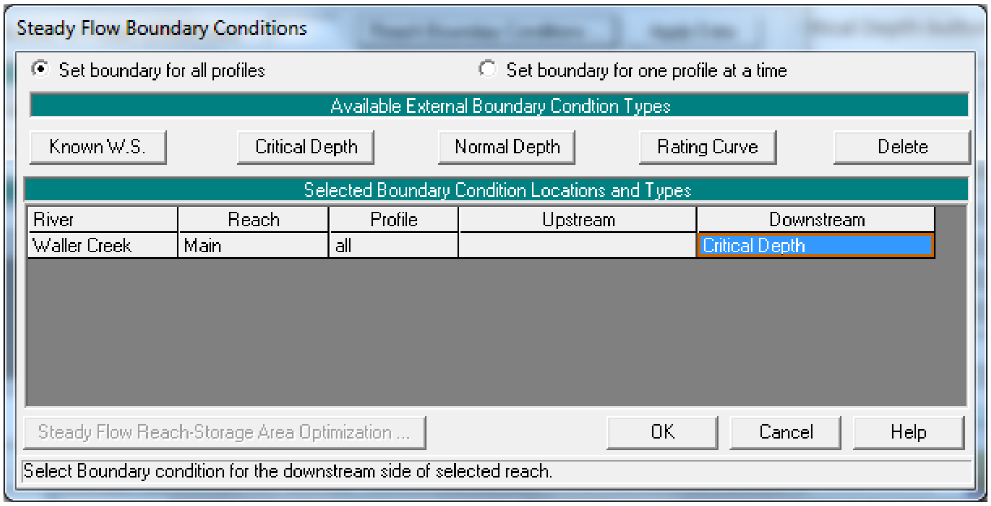
When you are finished saving your geometry, you can close the Geometric Data editor window to return to the main HEC-RAS window. We will now define the flow conditions for the HEC-RAS model. Although HEC-RAS allows us to perform both steady and unsteady analyses, for this example we will perform a steady state analysis. At minimum, to run HEC-RAS, you need to define a boundary condition at the upstream cross section and downstream cross section.

To Define Steady Flow Conditions:

(1) On the main HEC-RAS window, click on the Edit/Enter steady flow data button, .
(2) Enter 2000 in the PF1 column to indicate a flow of 2,000 cfs at the upstream cross section.



(3) Click on the Reach Boundary Conditions… button.
(4) Highlight the empty box in the Downstream column and click on the Critical Depth button. This will essentially create a free overfall at the downstream cross section.



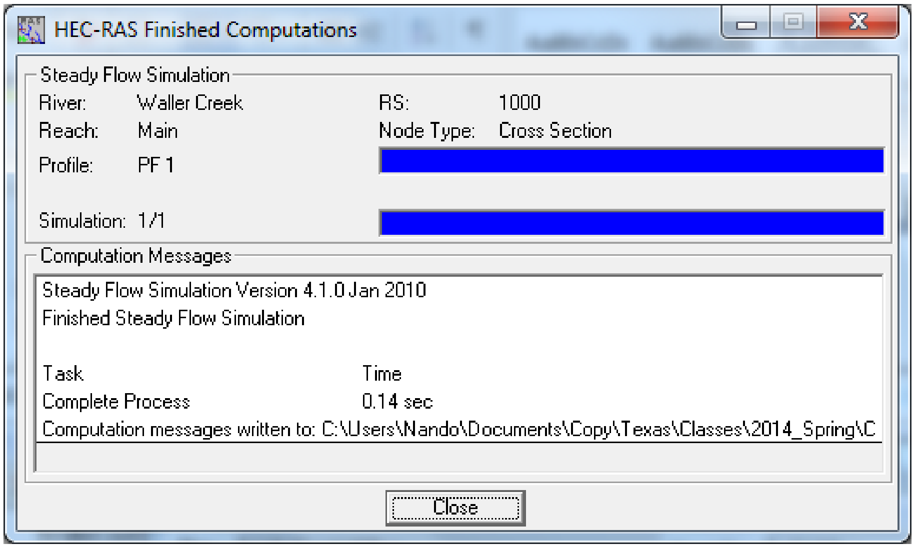
(5) Click OK.
(6) In the Steady Flow Data editor window, click on Apply Data.
(7) Save the flow data by going to File -> Save Flow Data.
(8) Give the flow data a title such as WallerCreekXS and click OK. Make sure the flow data file is saved in the same folder as your other HEC-RAS files.

After saving the flow data, you will see the name of the flow data file and its path in the main HEC-RAS window.

The last thing you will need to define is the plan file. The plan file in HEC-RAS is used to define a model run and tells HEC-RAS which geometry file and flow data file to use for that particular model run.

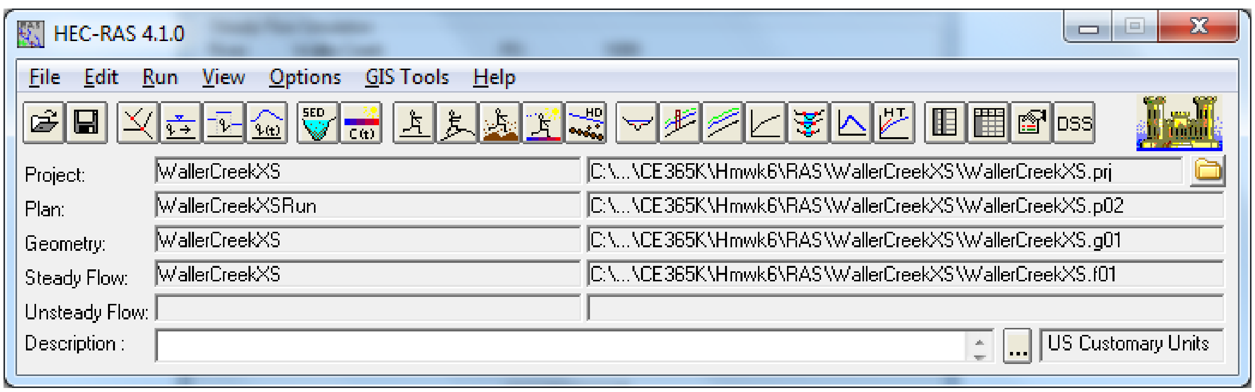
To perform a model run in HEC-RAS:

(1) In the main HEC-RAS window go to Run -> Steady Flow Analysis.
(2) Make sure the correct geometry and steady flow file are populated in the window and then go to File -> Save Plan.
(3) Give the plan a title such as WallerCreekXSRun and click OK. Again, make sure the plan file is saved in the same folder as your other HEC-RAS files. You will need to enter a Short ID for the model run such as WCXSRun.
(4) After saving the plan data, make sure subcritical is selected for the Flow Regime and then click Compute.
(5) If you the model ran successfully you will see a window similar to the one below. Click Close.



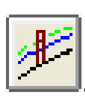
(6) Go to File -> Exit to close the Steady Flow Analysis editor window. Congrats!!

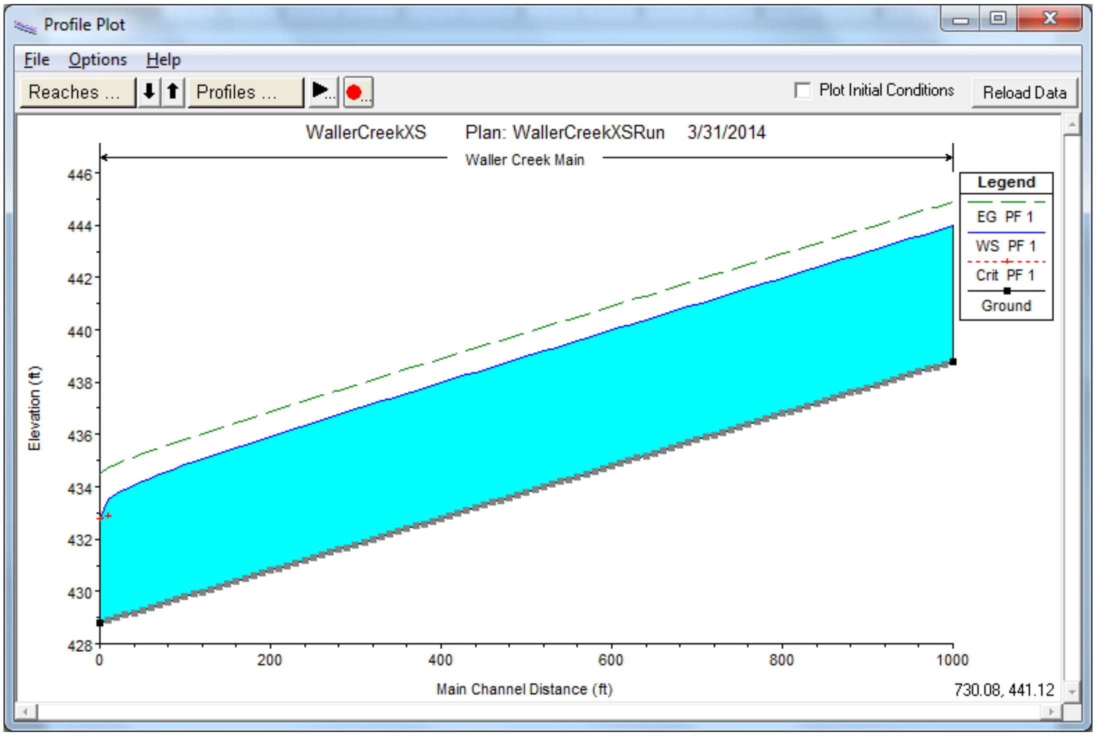
In the main HEC-RAS window you will see all of the files that correspond to your successful model run.



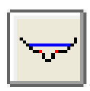
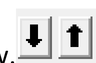
We will now visualize the results of your steady state analysis.

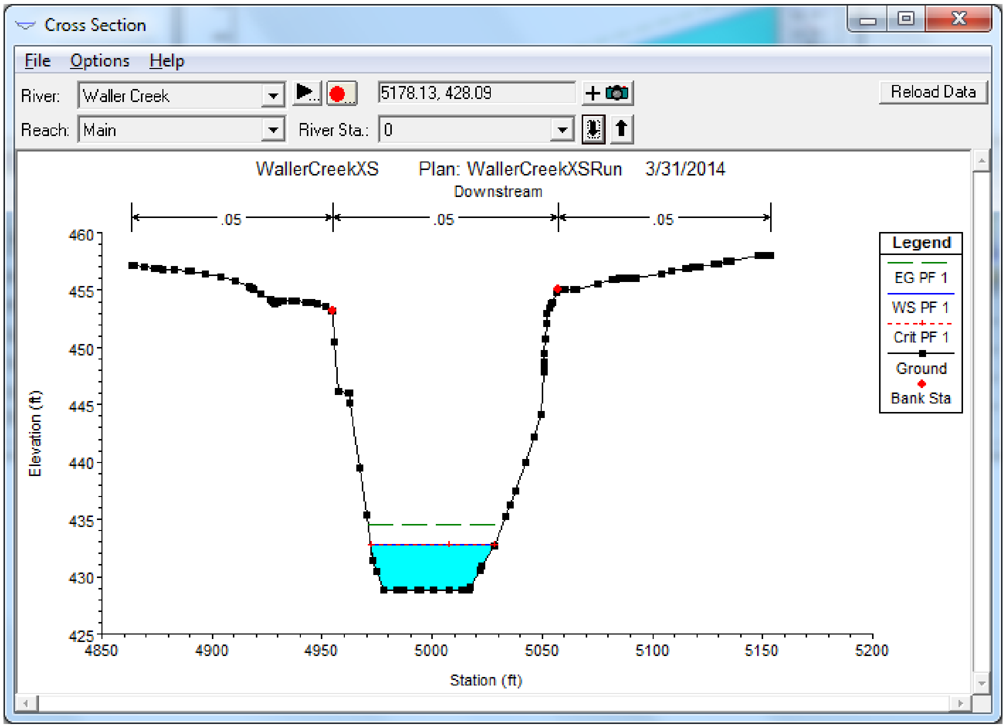
To view the profile of the reach:

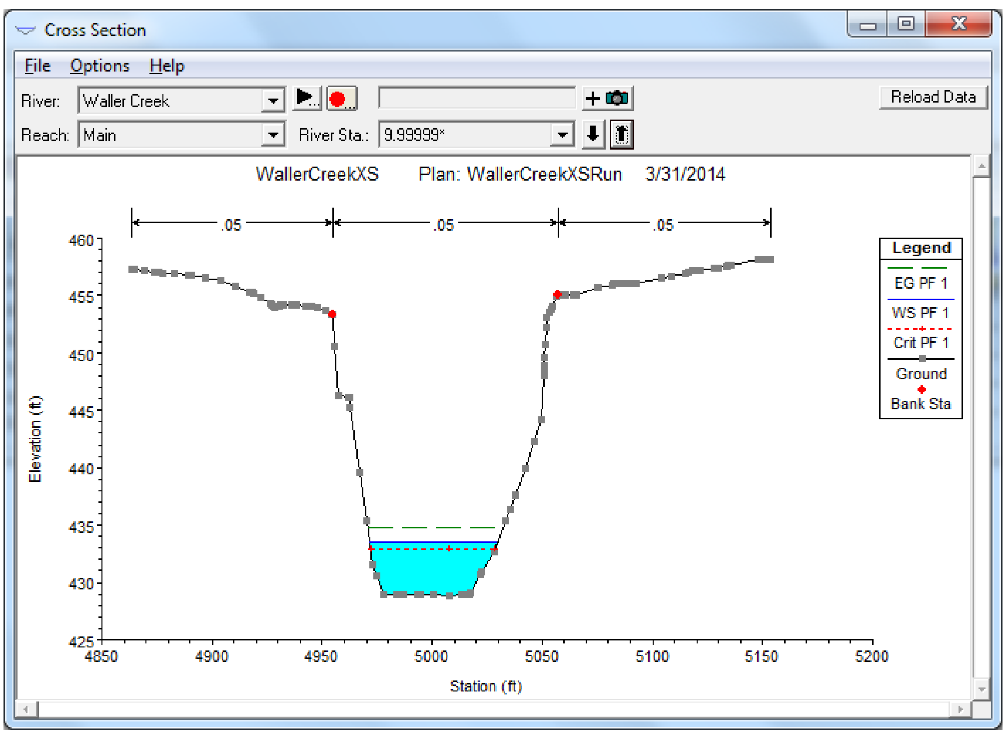
(1) Click on the View profiles button, .
(2) Study the Profile Plot. What do you notice? The x-axis shows the distance upstream from the most downstream cross section while the y-axis shows the elevation. The legend shows the Energy Grade line, EG, the Water Surface line, WS, and Critical Depth line, Crit.
(3) Close the Profile Plot window.



To view the cross sections along the reach:

(1) Click on the View cross sections button, .
(2) In the Cross Section window you can cycle through all the cross sections in the model by clicking on the arrows next to River Sta. at the top of the window. 
(3) If you start at station 0 and move upstream, do you notice the water surface changing? Like the Profile Plot, you will see the EG, WS and Crit lines plotted.

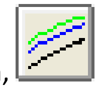




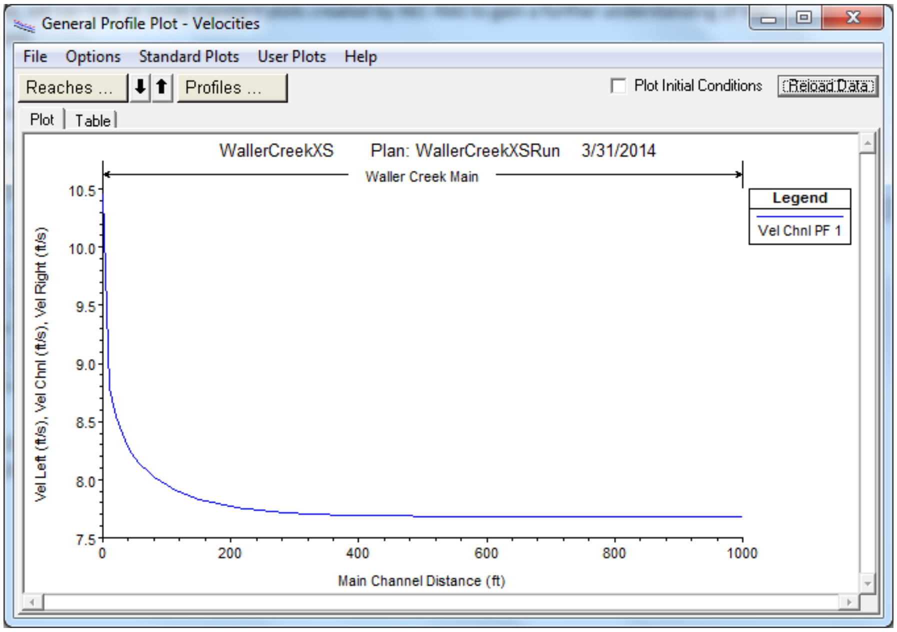
(4) Close the Cross Section window.

Finally, we can look at some standard plots created by HEC-RAS to gain a further understanding of the analysis.

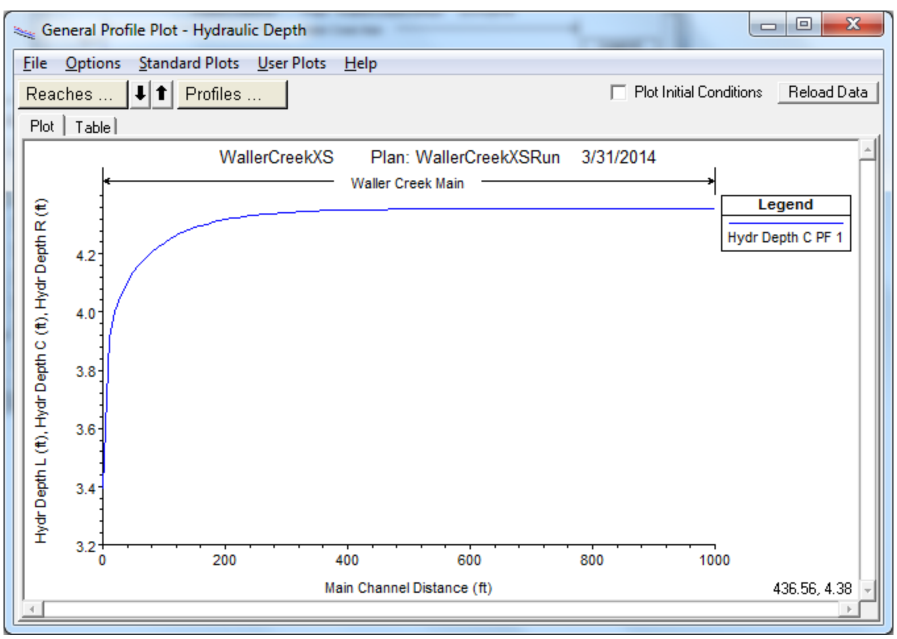
To view General Profile Plots:

(1) In the main HEC-RAS window, click on the View General Profile Plot button, .

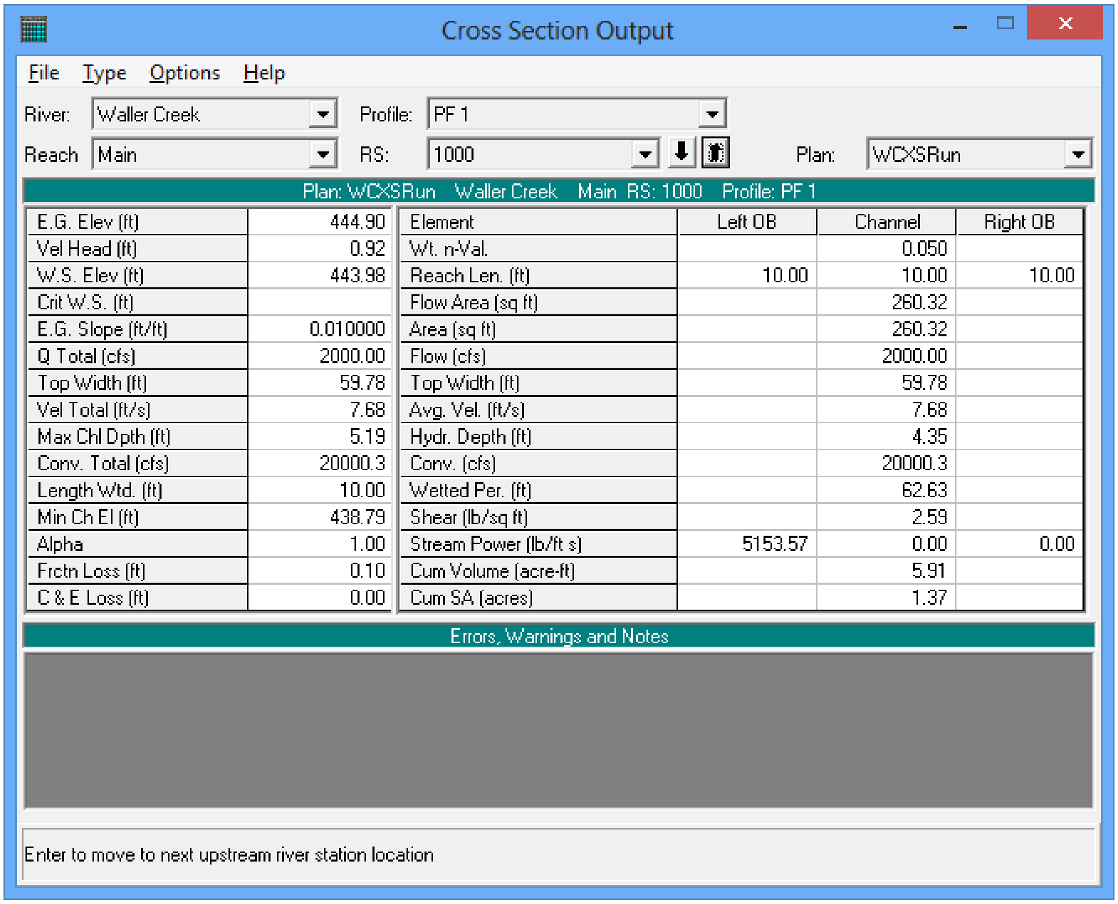
(2) The General Profile Plot window will open and you will see a graph of the channel velocity as a function of upstream distance. Does this help you understand the results of the simulation?



(3) You can look at some other standard plots by going to Standard Plots -> …



Open the Cross-Section Table 



Cross Section Output

File Type Options Help

River: Waller Creek   Profile: PF 1

Reach Main   RS: 1000   Plan: WCXSRun

Plan: WCXSRun Waller Creek Main RS: 1000 Profile: PF 1

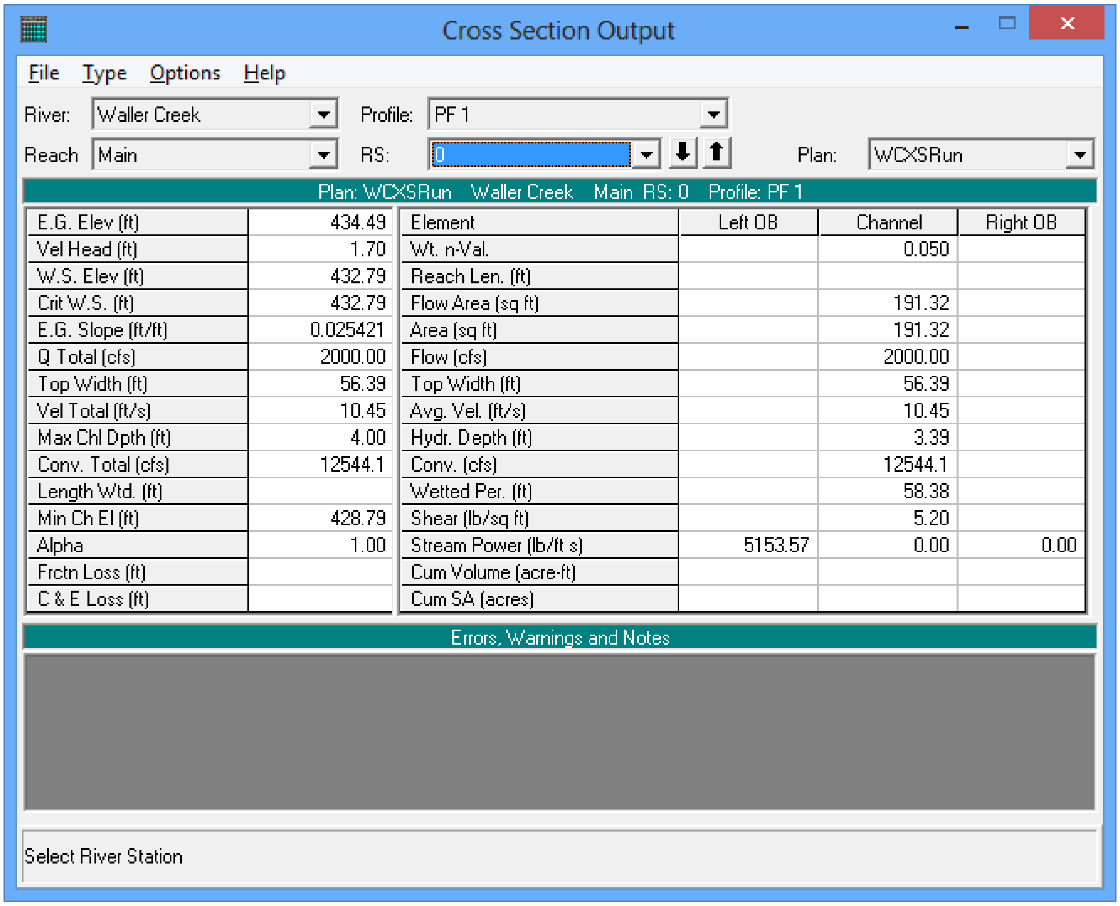
		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	444.90	Wt. n-Val.		0.050	
Vel Head (ft)	0.92	Reach Len. (ft)	10.00	10.00	10.00
W.S. Elev (ft)	443.98	Flow Area (sq ft)		260.32	
Crit W.S. (ft)		Area (sq ft)		260.32	
E.G. Slope (ft/ft)	0.010000	Flow (cfs)		2000.00	
Q Total (cfs)	2000.00	Top Width (ft)		59.78	
Top Width (ft)	59.78	Avg. Vel. (ft/s)		7.68	
Vel Total (ft/s)	7.68	Hydr. Depth (ft)		4.35	
Max Chl Dpth (ft)	5.19	Conv. (cfs)		20000.3	
Conv. Total (cfs)	20000.3	Wetted Per. (ft)		62.63	
Length Wtd. (ft)	10.00	Shear (lb/sq ft)		2.59	
Min Ch El (ft)	438.79	Stream Power (lb/ft s)	5153.57	0.00	0.00
Alpha	1.00	Cum Volume (acre-ft)		5.91	
Frctn Loss (ft)	0.10	Cum SA (acres)		1.37	
C & E Loss (ft)	0.00				

Errors, Warnings and Notes

Enter to move to next upstream river station location

At the Upstream end, Cross-Section 1000 shown above are the results for various hydraulic parameters of the flow. At the upper end of the channel, the flow is uniform **(E.G. Slope = 0.01 which is equal to the bed slope of 0.01)** and Manning's equation applies. The water depth (Max Chl Depth) = 5.19 ft = W.S. Elev (443.98) – Min Ch El (438.79). The velocity of the flow is 7.78 ft/s. The top width, T = 59.78ft, the area of the flow is A = 260.32 sq ft, and the wetted perimeter P = 62.63 ft. Note that the "Hydraulic Depth" is equal to the A/T and is not the same as the hydraulic radius.

At the downstream end, Cross-Section 0, shown below, the flow is critical **(W.S. Elev = Crit W.S.),** the water depth is 4.00 ft and the velocity is 10.45 ft/s. The depth is lower than normal depth and velocity is greater because the flow is going over a free overall at the end of the channel.



		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	434.49	Wt. n-Val.		0.050	
Vel Head (ft)	1.70	Reach Len. (ft)			
W.S. Elev (ft)	432.79	Flow Area (sq ft)		191.32	
Crit W.S. (ft)	432.79	Area (sq ft)		191.32	
E.G. Slope (ft/ft)	0.025421	Flow (cfs)		2000.00	
Q Total (cfs)	2000.00	Top Width (ft)		56.39	
Top Width (ft)	56.39	Avg. Vel. (ft/s)		10.45	
Vel Total (ft/s)	10.45	Hydr. Depth (ft)		3.39	
Max Chl Dpth (ft)	4.00	Conv. (cfs)		12544.1	
Conv. Total (cfs)	12544.1	Wetted Per. (ft)		58.38	
Length Wtd. (ft)		Shear (lb/sq ft)		5.20	
Min Ch El (ft)	428.79	Stream Power (lb/ft s)	5153.57	0.00	0.00
Alpha	1.00	Cum Volume (acre-ft)			
Frctn Loss (ft)		Cum SA (acres)			
C & E Loss (ft)					

Save your HEC-RAS file before closing the program.

To be turned in:

(1) A screen capture of the longitudinal profile of the water depth in the channel.

(2) Screen captures of the Cross-sections at the upstream and downstream ends of the channel. Document the velocity, depth and top width of the flow at these two cross-sections.

(3) Use the data provided by the HEC-RAS program to verify uniform flow conditions at the upstream end of the channel and critical flow conditions at the downstream end of the channel.