CE 365K Hydraulic Engineering Design

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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.

HEC-RAS 4.1.0	X
<u>File Edit Run View Options G</u> IS Tools <u>H</u> elp	
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Project	
Plan:	
Geometry:	
Steady Flow:	
Unsteady Flow:	
Description :	nary Units

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.

HEC-RAS 4.1.0			
<u>File Edit R</u> un	<u>View</u> Options <u>G</u> IS Tools <u>H</u> elp		
	<u>- 7 10 🖤 😸 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 </u>	▝▓▎ᢦፇፇ፟ዾዾፘጞዾዀ፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟፟	
Project: 🕅 🛛	allerCreekXS	C:\\CE365K\Hmwk6\RAS\WallerCreekXS\WallerCreekXS.prj -	
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Description :		🚊 🛄 US Custo	mary Units

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.

River Reach

(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 <u>WallerCreekXS.xls</u>. 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, L. 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.

🗢 Cross Section Data	
Exit Edit Options Plot Help	
River: Waller Creek 💽 Apply Data 🙀 🔽	Plot Options 🖻 🎒 🗆 Keep Prev XS Plots Clear Prev
Reach: Main ▼ River Sta.: 0 ▼ Description Downstream	WallerCreekXS Plan:
Del Row Ins Row Downstream Reach Lengths Cross Section Coordinates LOB Channel RO	$\begin{array}{c} \leftarrow .05 \longrightarrow \leftarrow .05 \longrightarrow \leftarrow .05 \longrightarrow \\ \hline \\ B \end{array}$
Station Elevation	455 Ground
1 4863.5 457.18 Manning's n Values 2 4863.52 457.18 LOB Channel RO 3 4864.81 457.14 0.05 0.05 0.05 4 4869.11 457.01 Main Channel RO 0.05 0.05 5 4874.04 456.91 Left Bank Right Bank 4954.89 5056.93 6 4876.04 456.84 4954.89 5056.93 Cont <exp (steady="" coefficient="" flow<="" td=""> 9 4888.93 456.65 Contraction Expansion 10 4899.76 456.63 0.1 0.3</exp>	Image: Bank Sta B 450 € 445 5 12 430
	425 4850 4900 4950 5000 5050 5100 5150 5200 Station (ft)
Edit Station Elevation Data (ft)	

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.

Copy Cross Section						
Select a River and Reach and then enter a new river station.						
River:	Waller Creek	•				
Reach:	Main	•	River Sta:	1000		
			ОК	Cancel		

(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...

🤍 Geon	etric Data	Respect 1		-	
File Ed	it Options View Tables	Tools GIS Tools Help			
Tools	River Storage S.A. Pump Reach Area Conn. Station	XS Interpolation	►	Within a Reach	•
Editors		Channel Design/Modification		Between 2 XS's	
Junct.		Channel Modification (original)			A
	9000	Graphical Cross Section Edit			
Section		Channel Bank Stations			
<u> <u> </u></u>		Reverse Stationing Data			
Brdg/Culv		Cross Section Points Filter			
		Fixed Sediment Elevations			
Structure		Pilot Channels			
		Ineffective Areas	+		
Structure		Mannings N Set Channel to Single value			
		Datum Adjustment	•		
Area		Reach Connectivity			
Stormo		Reach Order for Computations			
Area Conn.		Reach Order> Find loops that prevent backwater solution			
Pump		Flave Daviaha and Falakara			
Station		Flow Roughness Factors			
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Param.					
View					\searrow^*
Picture	Some schematic data outside d	lefault extents (see View/Set Schematic Plot Extents)			1
	None of the XS's are Geo-Refer	enced (- Geo-ket user entered XS - Geo-ket interpolated XS - Non Ge	o-Refu	iser entered XS — Non Ger	U-Rei interpolated Xt *
					-0.0875, 1.0000

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

VS Interpolation - WallerCreekXS	×
River: Waller Creek Upper Riv Sta: 1000	l t
Distance Between XS's 10	-
Dec places in interp Sta/Elev: 0.00 - Maximum Distance (ft) - 10	
Cut Line GIS Coordinates Cut Linearly interpolate cut lines from bounding XS's (only available when bounding XS's are Georeferenced)	থ
 Generate for display as perpendicular segments to reach invert (will be repositioned as cross section data is changed) 	
Delete Existing Interpolated XS's	X5's
C	lose
Interp 99 xs's between "0" and "1000"	

- (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.

g→ Steady Flow Data - WallerCreekXS
<u>File Options</u> <u>H</u> elp
Enter/Edit Number of Profiles (25000 max): 1 Reach Boundary Conditions Apply Data
Locations of Flow Data Changes
River: Waller Creek 💌 Add Multiple
Reach: Main 💌 River Sta.: 1000 💌 Add A Flow Change Location
Flow Change Location Profile Names and Flow Rates
River Reach RS PF 1 1 Waller Creek Main 1000 2000
J Edit Steady flow data for the profiles (cfs)

- (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.

Steady Flow Bound	ary Conditions	hards	and and the second second]	1 L	the States
Set boundary for all profiles Set boundary for one profile at a time						
		Available Extern	ial Boundary Condti	on Types		
Known W.S.	Critical De	epth	Normal Depth	Ratin	ng Curve	Delete
	Sel	ected Boundary	Condition Location:	s and Types		
River	Reach	Profile	Upstrea	m	Downs	tream
Waller Creek	Main	all			Critical Depth	
Steady Flow Reach-Storage Area Optimization OK Cancel Help						
Select Boundary cor	ndition for the down:	stream side of se	lected reach.			

- (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.

HEC-RAS	Finished Computations	0.5. 5	-		
- Steady Flow	v Simulation				
River:	Waller Creek	RS:	1000		
Reach:	Main	Node Type:	Cross Section		
Profile:	PF 1				
Simulation:	1/1				
- Computatio	n Messages				
Steady Flor	w Simulation Version 4.1.0 Ja	an 2010			
Finished St	eady Flow Simulation				
Task		Time			
Complete F	rocess	0.14 sec			
Computatio	n messages written to: C:\U	sers\Nando\Do	cuments\Copy\Te	xas\Classes\2014_Spring\C	
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.

HEC-RAS	4.1.0	
<u>File Edit</u>	<u>R</u> un <u>V</u> iew <u>O</u> ptions <u>G</u> IS Tools <u>H</u> elp	
	(<u>576) 💱 🗟 A & & X</u> .	켰┍⊮삗⊂ਝ⊾⊵ ▣▤┏₨
Project:	WallerCreekXS	C:\\CE365K\Hmwk6\RAS\WallerCreekXS\WallerCreekXS.prj 📄
Plan:	WallerCreekXSRun	C:\\CE365K\Hmwk6\RAS\WallerCreekXS\WallerCreekXS.p02
Geometry:	WallerCreekXS	C:\\CE365K\Hmwk6\RAS\WallerCreekXS\WallerCreekXS.g01
Steady Flow:	WallerCreekXS	C:\\CE365K\Hmwk6\RAS\WallerCreekXS\WallerCreekXS.f01
Unsteady Flow	:	
Description :		🖕 🛄 US Customary Units

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.

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





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



			HE:
Open the	Cross-Section	Table	

ET.

		Cross Section Output		-	
<u>F</u> ile <u>Type</u> Options	<u>H</u> elp				
River: Waller Creek	▼ Profi	ile: PF 1	~		
Reach Main	▼ RS:	1000 💌	🖡 🗊 🛛 Plar	r: WCXSRun	-
	Plan: WCXS	SRun Waller Creek Main RS: 10	000 Profile: PF 1		
E.G. Elev (ft)	444.90	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.92	Wt. n-Val.		0.050	
W.S. Elev (ft)	443.98	Reach Len. (ft)	10.00	10.00	10.00
Crit W.S. (ft)		Flow Area (sq ft)		260.32	
E.G. Slope (ft/ft)	0.010000	Area (sq ft)		260.32	
Q Total (cfs)	2000.00	Flow (cfs)		2000.00	
Top Width (ft)	59.78	Top Width (ft)		59.78	
Vel Total (ft/s)	7.68	Avg. Vel. (ft/s)		7.68	
Max Chl Dpth (ft)	5.19	Hydr. Depth (ft)		4.35	
Conv. Total (cfs)	20000.3	Conv. (cfs)		20000.3	
Length Wtd. (ft)	10.00	Wetted Per. (ft)		62.63	
Min Ch El (ft)	438.79	Shear (lb/sq ft)		2.59	
Alpha	1.00	Stream Power (lb/ft s)	5153.57	0.00	0.00
Froth Loss (ft)	0.10	Cum Volume (acre-ft)		5.91	
C & E Loss (ft)	0.00	Cum SA (acres)		1.37	
		Errors, Warnings and Notes			
_					
Enter to move to next upstre	am river station loc	ation			

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 = 59.78 ft, 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.

Cross Section Output – 🗆 🗙					
<u>F</u> ile <u>Type</u> Options	<u>H</u> elp				
Biver: Waller Creek	▼ Profil	e [.] PE 1	•		
Reach Main	RS:		🛃 🚺 Pla	an: WCXSRun	_
Plan: WCXSRun Waller Creek Main RS: 0 Profile: PF1					
E.G. Elev (ft)	434.49	Element	Left OB	Channel	Right OB
Vel Head (ft)	1.70	Wt. n-Val.		0.050	
W.S. Elev (ft)	432.79	Reach Len. (ft)			
Crit W.S. (ft)	432.79	Flow Area (sq ft)		191.32	
E.G. Slope (ft/ft)	0.025421	Area (sq.ft)		191.32	
Q Total (cfs)	2000.00	Flow (cfs)		2000.00	
Top Width (ft)	56.39	Top Width (ft)		56.39	
Vel Total (ft/s)	10.45	Avg. Vel. (ft/s)		10.45	
Max Chl Dpth (ft)	4.00	Hydr. Depth (ft)		3.39	
Conv. Total (cfs)	12544.1	Conv. (cfs)		12544.1	
Length Wtd. (ft)		Wetted Per. (ft)		58.38	
Min Ch El (ft)	428.79	Shear (Ib/sq.ft)		5.20	
Alpha	1.00	Stream Power (Ib/ft s)	5153.57	0.00	0.00
Freth Loss (ft)		Cum Volume (acre-ft)			
C & E Loss (ft)		Cum SA (acres)			
Errors. Warnings and Notes					
Select River Station					

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.