Introduction to HEC-RAS

CORINNE HORNER, E.I.T.

DECEMBER 7, 2016

Overview

Introduction to Software and Capabilities

Computational Procedures

1-D Steady Flow Example

Applications

Graduate Experience



Introduction

Hydraulic Engineering Center's-River Analysis System (HEC-RAS)

US Army Corps of Engineers (USACE)

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





Introduction

Allows user to perform 1-D, steady flow, 1 and 2-D unsteady flow, and sediment/mobile bed transport computations as well as water temperature and quality modeling

Software package includes:

- Graphical user interface (GUI)
- Hydraulic analysis components
- Data storage and management
- Graphics generation
- Report generation

Hydraulic Analysis Capabilities

Steady flow water surface profiles

1-D and 2-D unsteady flow simulation

Sediment transport/movable boundary conditions

Water quality analysis



Steady Flow

One-dimensional energy equation:

$$z_2 + y_2 + \alpha_2 \frac{{v_2}^2}{2g} = z_1 + y_1 + \alpha_1 \frac{{v_1}^2}{2g} + h$$

- Z= elevation of channel inverts
- Y= depth of water
- v= average velocity
- g= gravitational acceleration
- α= velocity weighting coefficients
- h_e= energy head loss



Energy losses, $\rm h_e$

- Friction: Manning's Equation
- Contraction/expansion: contraction coefficient

$$h_e = L\overline{S_f} + C \left| \frac{\alpha_1 v_1^2}{2g} - \frac{\alpha_2 v_2^2}{2g} \right|$$

L=discharge weighted reach length

S_f=representative friction slope between two sections

C=contraction/expansion coefficient

Continuity equation:

$$v_1 A_1 = v_2 A_2$$

Manning's Equation:

$$Q = K S_f^{1/2}$$
$$K = \frac{1}{n} R_h^{2/3} A$$

v=average flow velocity

A=cross-sectional area

Q= flow

n=Manning's coefficient

R_h=hydraulic radius

S_f=friction slope

K=conveyance

Uses standard step method to compute water surface along reach:

- Iterative technique that calculates water surface elevation using two adjacent cross-sections
- Assumes 1-D steady, gradually varied flow
- Constant velocity and horizontal water surface across channel sections
- Requires known cross-sections along reach
- Solves the energy equation section by section

$$\Delta x = \frac{\left(y_2 + \alpha_2 \frac{v_2^2}{2g}\right) - \left(y_1 + \alpha_1 \frac{v_1^2}{2g}\right)}{S_f - S_o}$$

Standard step general procedure:

- Assume initial water surface elevation
 - If supercritical flow regime: assume WS at an upstream cross section
 - If subcritical flow regime: assume WS at a downstream cross section
- Use resulting cross section geometry to calculate conveyance and velocity head
- Compute representative friction slope and energy losses
- Solve 1-D energy equation for water surface at cross-section 2
- Compare assumed value with calculated value and iterate until values agree within a user-specified tolerance (usually 0.01 ft)

Program is constrained by a maximum number of iterations for balancing WS

Common sources of error:

- Too few cross-sections
- Inadequate cross-sectional data
- Incorrect boundary condition specified
 - supercritical, subcritical, critical

Rapidly Varied Flow: Momentum Equation

Unsteady Flow: full dynamic Saint-Venant Equation



Steady Flow Data Requirements

Geometric:

- River system schematic
- Hydraulic geometry
- Reach length
- Hydraulic structures and obstructions

Coefficients:

- Manning's n
- Contraction coefficient, C

Steady Flow:

- Discharge
- Flow regime
- Boundary conditions



1-D Steady Flow Example

1) Start a new project

- 2) Enter geometric and flow data
- 3) Perform hydraulic calculations
- 4) View Results



Example: Start a New Project

Back

Open HEC-RAS 5.0.0 (available on computers in Engineering computer labs)



Unsteady Flow Data: Unsteady Flow Analysis:

simulation

Perform an unsteady flow

Edit and/or enter

unsteady flow data

XYZ Perspective Plot:

View 3D multiple cross

section plot

Example: Start a New Project

Start a New Project

Select drive and directory to work in and enter the project title and file name

8		HEC-RAS 5.0.0 – 🗆 🗙						New Project			
File	Edit Run View Options GIS Tools Help			- F [Til.			Ele Nese	Colored Colder	Default Drainst Felder	Degements
	New Project	💐 🗢 🤟 🗏 🛛 🗸 🖉 🖬 🛅 🗗 oss 🛛 🛛 🚺	Li	$\overline{\mathbf{x}}$				File Name	Selected Folder	Default Project Polder	Documents
	Open Project		H	7	HECRAS Present	ation		[Example.pr]	U:\chorner		
	Save Project								🔄 U: \		
	Save Project As	· · · · · · · · · · · · · · · · · · ·							Chorner		
	Rename Project Title										
	Delete Project			:							
	Project Summary	👌 🛄 US Customary Units		w:							
	Import HEC-2 Data										
	Import HEC-RAS Data			-							
	Generate Report										
	Export GIS Data										
	Export to HEC-DSS										
	Restore Backup Data										
	Debug Report (compress current plan files)										
	Exit				ОК	Cancel	Help	Create Folder	🖃 u: D\nasstr	pre.engr.colostate.edu\stud	ents\GRAD1 💌
					Set drive and pat	h, then enter a r	new project title and file	e name.) _a_ ar [((ilasa	s ereng, resissibilitereda plad	

Click Edit > Geometric Data... or press



Draw the river schematic, naming each river, reach, and junction



Click Cross Section button

Enter cross-sectional data, downstream reach lengths, and coefficients



Use this cross section to create remaining cross sections in example.

Options > Copy Current Cross Section...

Options > Adjust Elevations: can adjust all cross-section elevations by +/-



Options > Adjust Stations: can reduce/extend overbanks by certain percentage by adjusting the stationing



Create remaining cross-sections using these tools and the specifications below:

Cross Section		Adjusted	Adj	usted Static	oning	Downstream Reach Lengths				
Reach	River Sta.	Elevation	Left O.B.	Channel	Right O.B.	Left O.B.	Channel	Right O.B.		
Upper	9.8	-0.4	0.8	-	0.8	0	0	0		
Lower	9.79	-0.1	1.2	1.2	1.2	500	500	500		
Lower	9.7	-0.5	1.2	1.2	1.2	500	500	500		
Lower	9.6	-0.3	-	-	-	500	500	500		
Lower	9.5	-0.2	-	-	-	0	0	0		
Butte Cr.	0.1	-0.6	-	-		500	500	500		
Butte Cr.	0.0	-0.3	-	=	-	0.0	0.0	0.0		

*Be sure to Apply Data after editing each new cross section

Save cross-sectional geometry: go to the Geometric Data window > click **File** > **Save Geometry Data As** > enter a title > press **OK**



Enter Junction data by clicking the **Junct.** button

- the energy equation will be used to compute the water surface through the junction
- If the momentum equation is selected, you will be able to enter an angle of flow for one or more reaches flowing into or out of the junction



Example: Enter Steady Flow Data

8		HEC-RAS 5.0.0	- - ×
File Ed	t Run View Options GIS Tools Help	_	
œ₽	Geometric Data	: * < # < < < < > < < < < < < < < < < < < < <	I will
Projec	Steady Flow Data	U:\Example.prj	
Plan:	Quasi Unsteady Flow (Sediment Analysis)		
Geom	Unsteady Flow Data	by chorner (Example.g01 $\frac{\pi}{q \rightarrow}$	
Stead	Sediment Data	File Ontions Help	
Unste	Water Quality Data	The options help	
Descri	Hater equality bate in	Enter/Edit Number of Profi	iles (32000 max): 3 Re

Enter steady flow data by clicking **Edit** in your HEC-RAS main window > click **Steady Flow Data...** > Change Number of Profiles to 3 > Select River Station 9.6 of the Lower Reach of Fall River using the drop down windows and click **Add A Flow Change Location** > click **Reach Boundary Conditions...** to enter required boundary conditions

<u>v</u> ¶→				Ste	eady Flow	Data		- 🗆 🗙			
File	e Options Helj	p									
Ent	Enter/Edit Number of Profiles (32000 max): 3 [Reach Boundary Conditions] Apply Data										
		Loc	ations of F	low Data Char	iges						
Riv	er Fall River	-				A	dd Multiple				
			and the Co			dd A Elow Cha	ngo Location				
Rea	acre ILower Reach		ver sta. U	3.0	V A	uu a riow cha	nge Locauon				
	Flow C	hange Location				Profile N	lames and Flow Rates				
	River	Reach	RS	PF 1	PF 2	PF 3					
1	Fall River	Upper Reach	10	500	2000	5000					
2	Fall River	Lower Reach	9.79	600	2500	6500					
3	Fall River	Lower Reach	9.6	650	2700	7000					
4	Butte Cr.	Tributary	0.2	100	500	1500					
Ent	er to edit the bound	lary conditions									
		,									

Example: Enter Steady Flow Data

This example assumes a subcritical flow regime throughout the river system, therefore, you must only enter a downstream boundary at the Lower Reach of Fall River

Select the cell you wish to enter a BC for > click the type of BC you wish to apply (in this case, select **Normal Depth** and enter an average energy slope of 0.0004 ft/ft) > click **OK** > **File** > **Save Flow Data**

	Steady Flow Data										
	Steady Flow Boundary Conditions										
	Set boundary for	or all profiles		C Set boundary f	or one profile at a time						
			Available Exter	nal Boundary Condtion	Types						
Known W.S. Critical Dept			epth	Normal Depth	Rating Curve	ng Curve Delete					
		Se	lected Boundar	y Condition Locations a	nd Types						
	River	Reach	Profile	Upstream	Down	Downstream					
	Fall River	Upper Reach	all		Junction=Sutt	Junction=Sutter					
	Fall River	Lower Reach	all	Junction=Sutter	Normal Depth	Normal Depth S = 0.0004					
	Butte Cr.	Tributary	all		Junction=Sutt	ter					
			1	_		1					
	Steady Flow Reach	-Storage Area Op a changes.	timization		OK Cancel	Help					

Example: Perform Hydraulic Calculations

Before computations can be performed, you must create a plan that defines which geometry and flow data are to be used: HEC-RAS 5.0.0

Click Run > Steady Flow Analysis...

Create a new plan by clicking **File** > **New Plan** > name the plan and the short identifier Select the Flow Regime (in this case, we are assuming Subcritical flow) and save the plan: **File** > **Save Plan** Click **Compute**

8		HEC-RAS 5.0.0
File Edit	Run View Options GIS Tools Help Steady Flow Analysis	
Project: Plan: Geometry: Steady Flow:	Unsteady Flow Analysis Sediment Analysis Water Quality Analysis Hydraulic Design Functions	JJ:\Example.prj JJ:\chorner\Example.g01 JJ:\chorner\Example.f01
Unsteady Flo Description :	Run Multiple Plans Run RAS-MODFLOW Coupled Model	US Customary Units
	Uncertainty Analysis	

v	<u>F</u>	Steady Flow Analysis		-		×			
	File Options Help								
Pr	Plan : Existing Conditions Ru	n Short ID	Existing						
Co	Geometry File :	Base Geometric Data				•			
om	Steady Flow File :	10, 2, and 1% chance events				•			
nd	Flow Regime Subcritical Supercritical Mixed Optional Programs Floodplain Mapping	Plan Description :							
	Compute								
	Enter to compute water surfac	e profiles							

Example: Perform Hydraulic Calculations

or 🗃	HEC-RAS Finished Computations – 🗖 💌
Write Geometry Information	
Layer: Complete	
Steady Flow Simulation	
River: Fall River	RS: 10
Reach: Upper Reach	Node Type: Cross Section
Profile: 100-yr	
Simulation: 3/3	
Computation Messages	
Plan: Existing Conditions Kun (Example Simulation started at: 060e2016 12:13:05 PM Using 64 Bit Computation Engines Writing Geometry Computing Bank Lines Bank lines generated in 75 ms Computing Niver Edge Lines River Edge Lines generated in 6 ms Computing XS Interpolation Surfaces XS Interpolation Surfaces generated in 58 ms Completed Writing Geometry Writing Event Conditions Event Conditions Complete Steady Flow Simulation HEC-RAS 5.0.0 M Finished Steady Flow Simulation Computations Summary Computation Task Completing Geometry Steady Flow Computations(64) Complete Process	:bruary 2016
Pause Take Snapshot of Resul	Close

With the computation complete you can view:

- Cross section plots
- Profile plots
- General Profile plot
- Rating Curves
- X-Y-Z Perspective plots
- Detailed tabular output at individual cross section
- Limited tabular output at multiple cross sections

8	HEC-RAS 5.0.0	- • ×
File Edit Run	View Options GIS Tools Help Cross-Sections Water Surface Profiles General Profile Plot General Profile Plot Rating Curves X-Y-Z Perspective Plots X-Y-Z Perspective Plots Stage and Flow Hydrographs Hydraulic Property Tables Detailed Output Tables Profile Summary Table Summary Err,Warn, Notes	2 V L L B B DSS
	DSS Data Unsteady Flow Spatial Plot (computation interval) Unsteady Flow Time Series Plot (computation interval) WQ Spatial Plot WQ Time Series Plot Sediment Output Sediment Output (old)	



Font Sizes ...





			Cross Section Output	t		- 🗆 🗙						Dro
	File Type Options	Help						. 1				PIO
I	River: Butte Cr.	▼ Profi	le: 10-yr	•					File Opt	tions Std. T	ables Lo	ocatior
	Peach Tributary	- PS-	0.2	J 1 Plan: Evic	ting			- 1				
l	Reach [mbdtary	K3.			sung			- 1	River	Reach	River Sta	Profil
		Plan: Exist	ing Butte Cr. Tributary RS: 0.	2 Profile: 10-yr				- 1				1
	E.G. Elev (ft)	76.64	Element	Left OB	Channel	Right OB		- 1	Fall River	Upper Reach	10	10-vr
	Vel Head (ft)	0.06	Wt. n-Val.		0.040			- 1	Fall River	Upper Reach	10	50-vr
	W.S. Elev (ft)	76.58	Reach Len. (ft)	500.00	500.00	500.00		- 1	Eall River	Upper Reach	10	100-1
	Crit W.S. (ft)		Flow Area (sq ft)	-	48.97			- 1		opperneeden		100
	E.G. Slope (ft/ft)	0.000836	Area (sq ft)	-	48.97			- 1	Fall Diver	Lipper Peach	0.0	10-10
	Q lotal (cfs)	100.00	Flow (cts)	-	100.00			- 1	Eall Divor	Upper Reach	0.0	50-yr
		11.08		-	11.08		11	- 18		Upper Reach	5.5	30-yi
	Vel Total (Tt/S)	2.04	Avg. vel. (tt/s)	-	2.04		11	. 8		opper Reach	9.9	100-
	Max Chi Upth (ft)	0.00	Hydr. Depth (ft)	-	9.92			- 11	-			
	Conv. Total (CIS)	5450.2	Wotted Der (ft)		19.60		1		Fall River	Upper Reach	9.8	10-yr
	Min Ch El (#)	300.00	Shoar (h (ca ft)		10.09		11	-	Fall River	Upper Reach	9.8	50-yr
	Aloba	70.00	Stream Dower (b/ft c)		0.14		ΗË	1	Fall River	Upper Reach	9.8	100-
	Erctp Loss (ft)	1.00	Cum Volume (acre-ft)		1.31		IH-	Pre				
	C & ELoss (ft)	0.09	Cum SA (acres)		0.26				Fall River	Lower Reach	9.79	10-yr
	C & C 2033 (it)	0.00	Call SX (acres)		0.20			-	Fall River	Lower Reach	9.79	50-yr
			Errors, Warnings and Notes	•				m	Fall River	Lower Reach	9.79	100-)
								ł	-			
							ry		Fall River	Lower Reach	9.7	10-yr
							E	-1	Fall River	Lower Reach	9.7	50-yr
								1				
l									Total flow i	n cross section	ı.	
	Select Profile											

file Output Table - Standard Table 1 _ 🗆 🗙 ns Help HEC-RAS Plan: Existing Reload Data Min Ch El W.S. Elev Crit W.S. E.G. Elev E.G. Slope Vel Chnl Q Total (cfs) (ft) (ft) (ft) (ft) (ft/ft) (ft/s) 500.00 70.00 76.45 76.59 0.000770 3.06 2000.00 70.00 81.61 81.84 0.000644 4.31 5000.00 70.00 86.16 86.35 0.000434 4.63 76.08 76.22 0.000710 500.00 69.50 2.97 2000.00 69.50 81.31 81.53 0.000597 4.20 85.92 86.13 0.000437 4.70 5000.00 69.50 75.87 0.000688 500.00 69.10 75.74 2.94 81.22 0.000628 4.33 2000.00 69.10 80.98 5000.00 69.10 85.62 85.89 0.000521 5.16 2.90 600.00 69.00 75.70 75.83 0.000636 2500.00 69.00 80.92 81.18 0.000640 4.49 6500.00 69.00 85.53 85.85 0.000589 5.62 600.00 68.50 75.50 75.58 0.000360 2.28 3.51 👻 2500.00 68.50 80.76 80.92 0.000360 ▶

Applications

Bridge and culvert modeling

Inline structures (i.e. dams)

Lateral structures (i.e. spillways)

Flood management



Graduate School







Omaha, NE

University of Portland, OR BS Environmental Engineering CSU, CO MS Hydraulic Engineering

References

Ndolo Goy and Julien, 2014. CIVE 401 HEC-RAS Presentation. Available at: http://www.engr.colostate.edu/~pierre/ce_old/classes/CIVE%20401/HEC-RAS%20Lecture/HEC-RAS%20Patrick%20Ndolo%20Goy/CIVE401-HEC-RAS.pdf

Lai, Goy, and Julien. 2015. CIVE 401 HEC-RAS Presentation. Available at: http://www.engr.colostate.edu/~pierre/ce_old/classes/CIVE%20401/HEC-RAS%20Lecture/F15CIVE401%20HECRAS%20Presentation%20%28final%29-1.pdf

US Army Corps of Engineers. HEC-RAS User's Manual. Available at: http://www.hec.usace.army.mil/software/hec-ras/documentation/HEC-RAS%205.0%20Users%20Manual.pdf