Introduction to HEC-RAS

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Overview

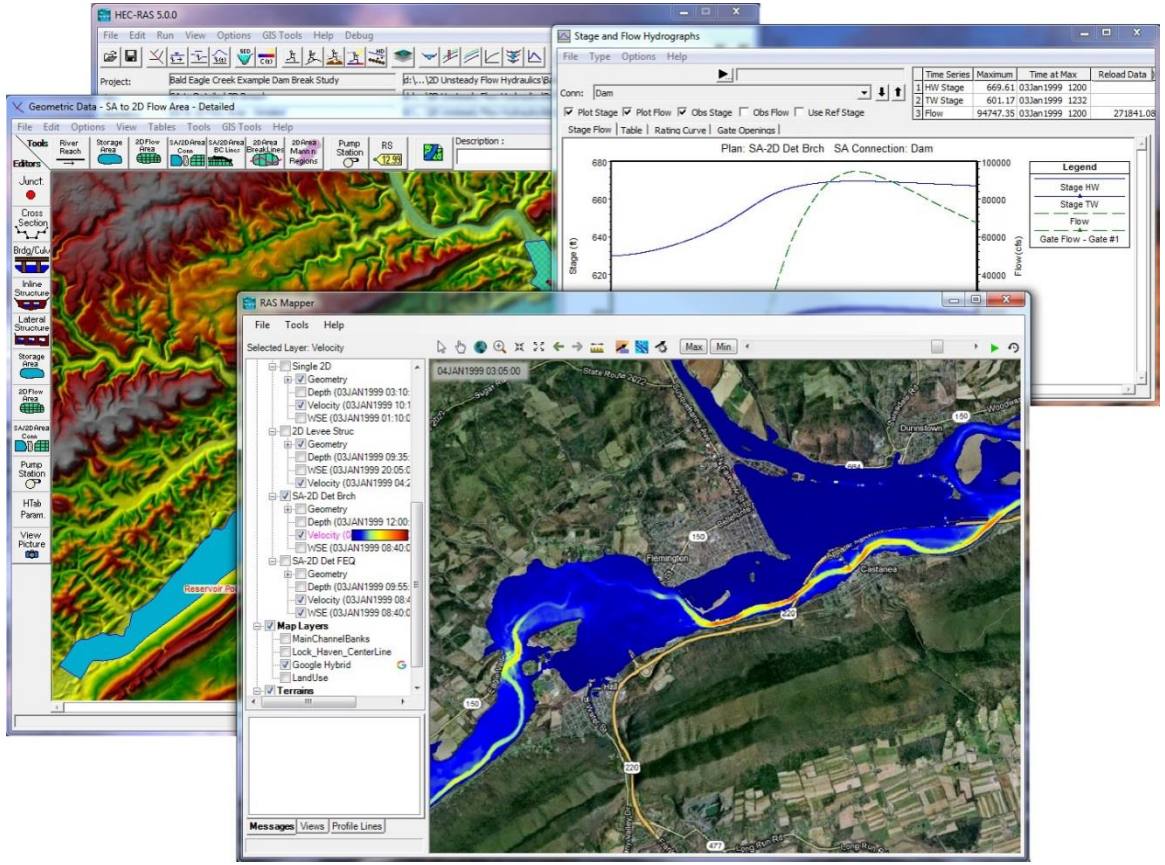
Introduction to Software and Capabilities

Computational Procedures

1-D Steady Flow Example

Applications

Graduate Experience

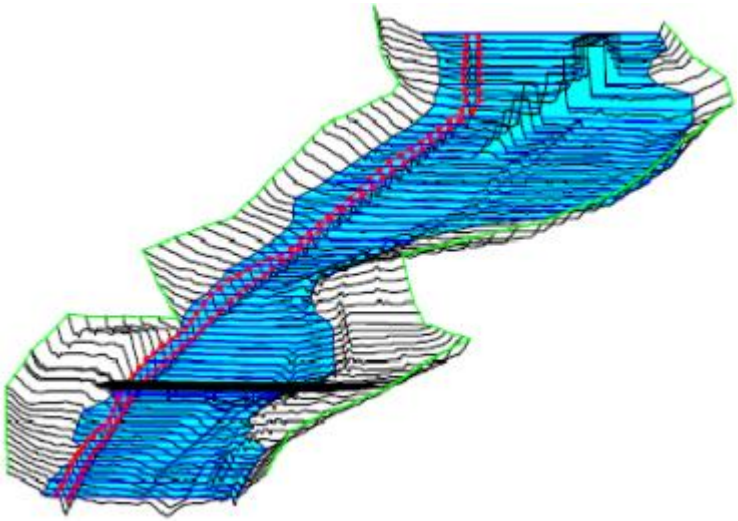


Introduction

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

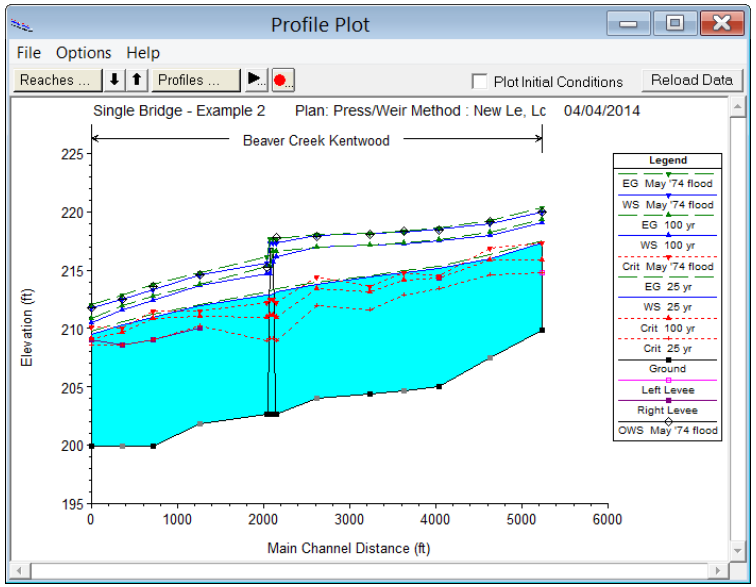
Hydraulic Analysis Capabilities

Steady flow water surface profiles

1-D and 2-D unsteady flow simulation

Sediment transport/movable boundary conditions

Water quality analysis



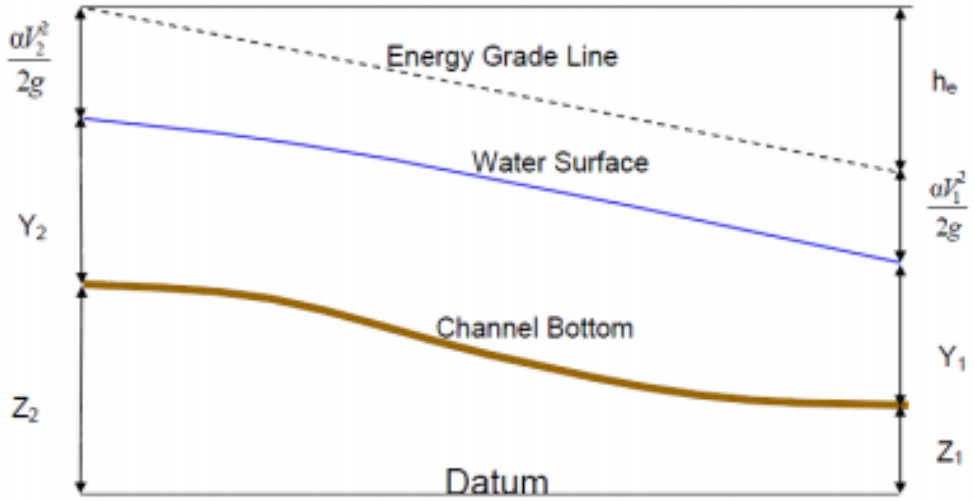
Computational Procedures

Steady Flow

One-dimensional energy equation:

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

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



Computational Procedures

Energy losses, 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

Computational Procedures

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

Computational Procedures

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

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

Computational Procedure

Standard step general procedure:

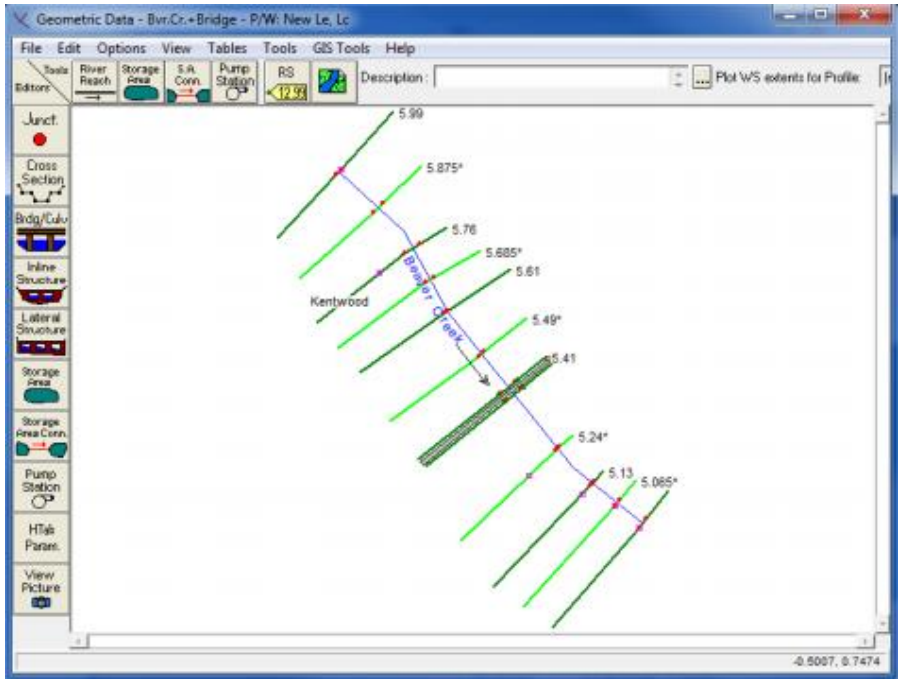
- Assume initial water surface elevation
  - If **supercritical** flow regime: assume WS at an **upstream** cross section
  - If **subcritical** flow regime: assume WS at a **downstream** cross section
- Use resulting cross section geometry to calculate conveyance and velocity head
- Compute representative 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)

Computational Procedure

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



<u>Rapidly Varied Flow:</u> Momentum Equation

<u>Unsteady Flow:</u> full dynamic Saint-Venant Equation

Steady Flow Data Requirements

Geometric:

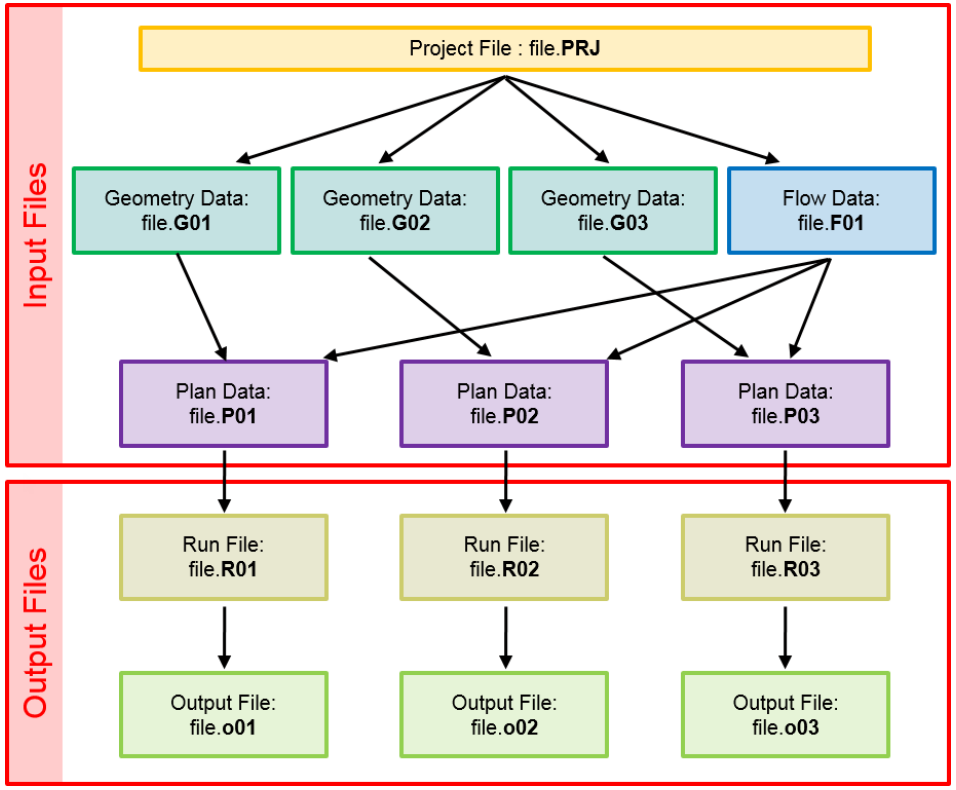
- River system schematic
- Hydraulic geometry
- Reach length
- Hydraulic structures and obstructions

Coefficients:

- Manning's n
- Contraction coefficient, C

Steady Flow:

- Discharge
- Flow regime
- Boundary conditions



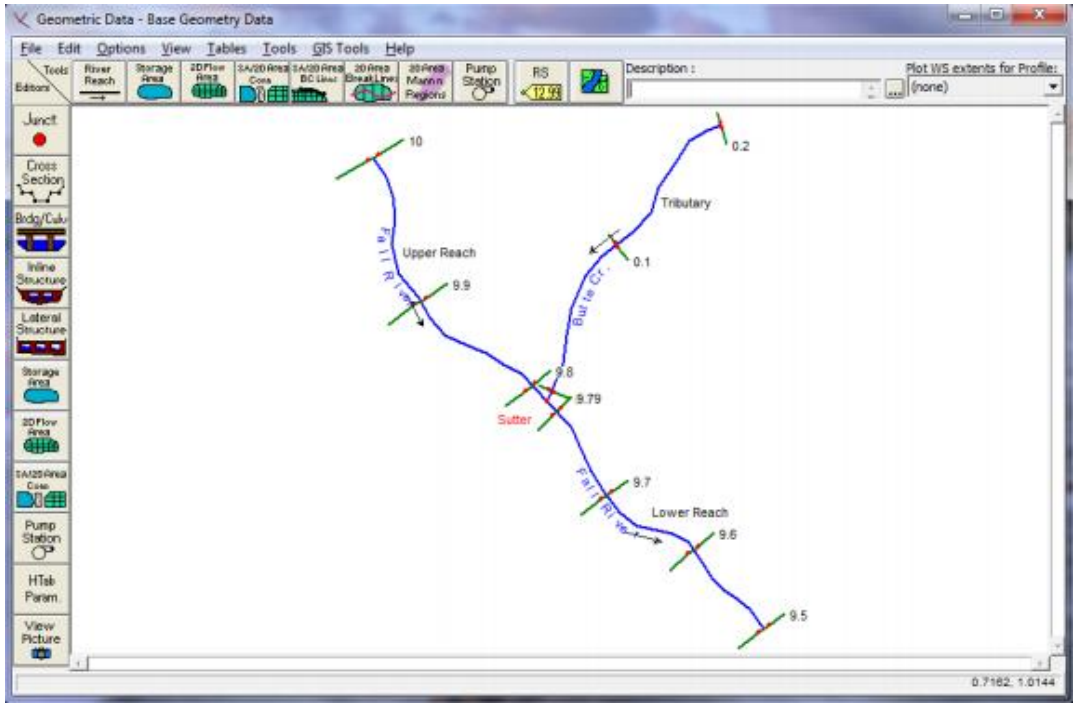
1-D Steady Flow Example

1) Start a new project

2) Enter geometric and flow data

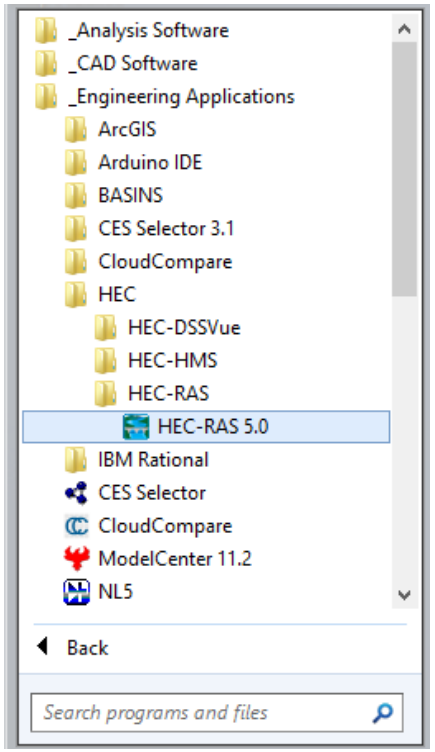
3) Perform hydraulic calculations

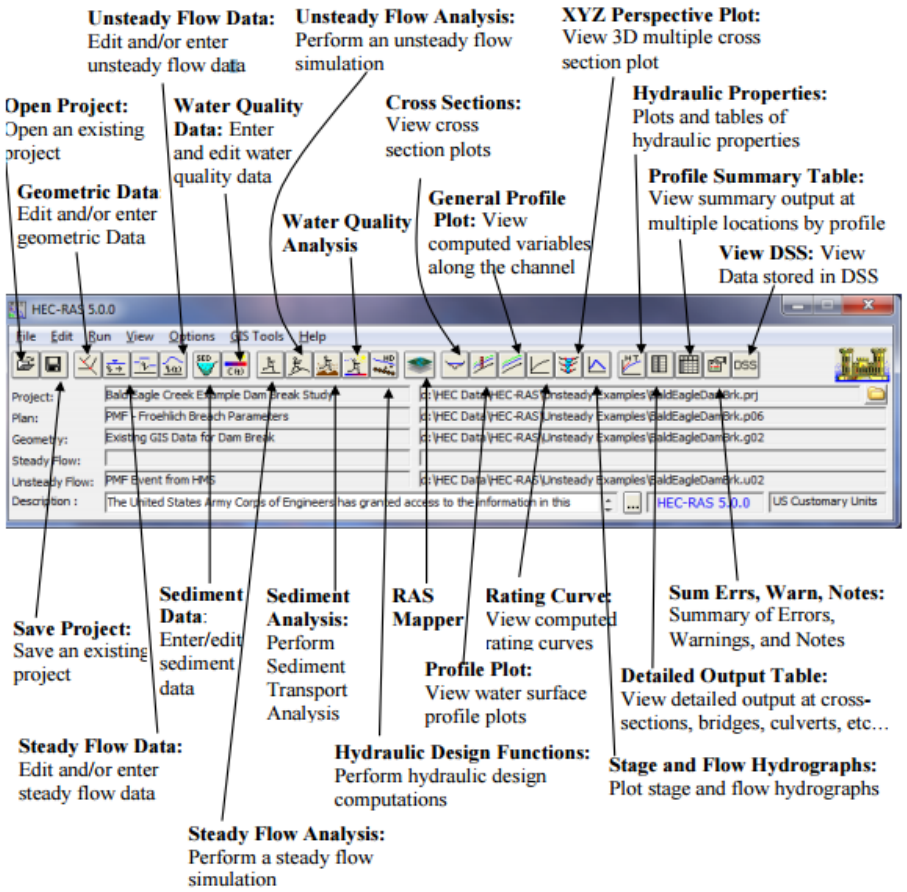
4) View Results



Example: Start a New Project

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

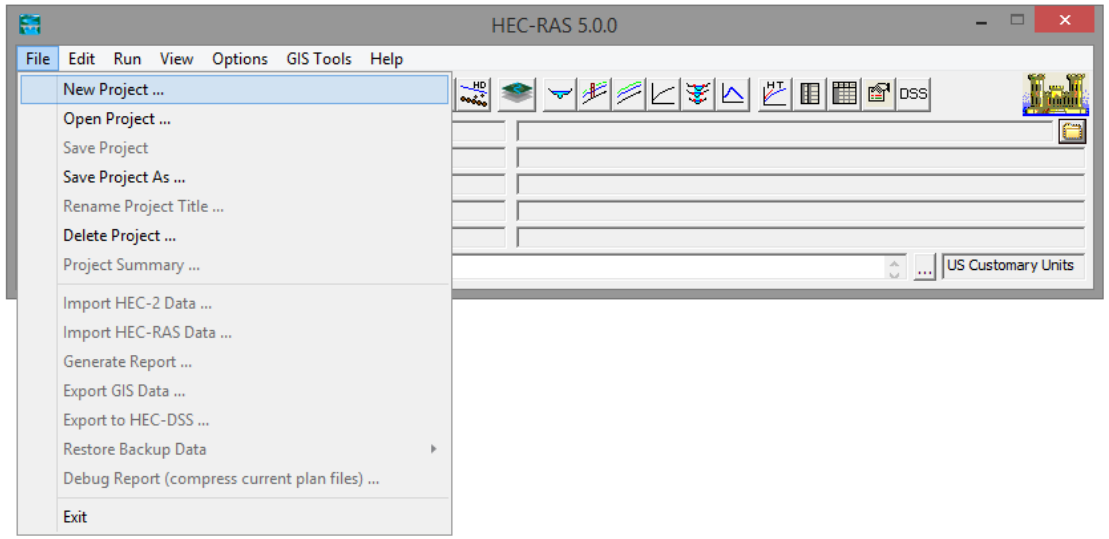


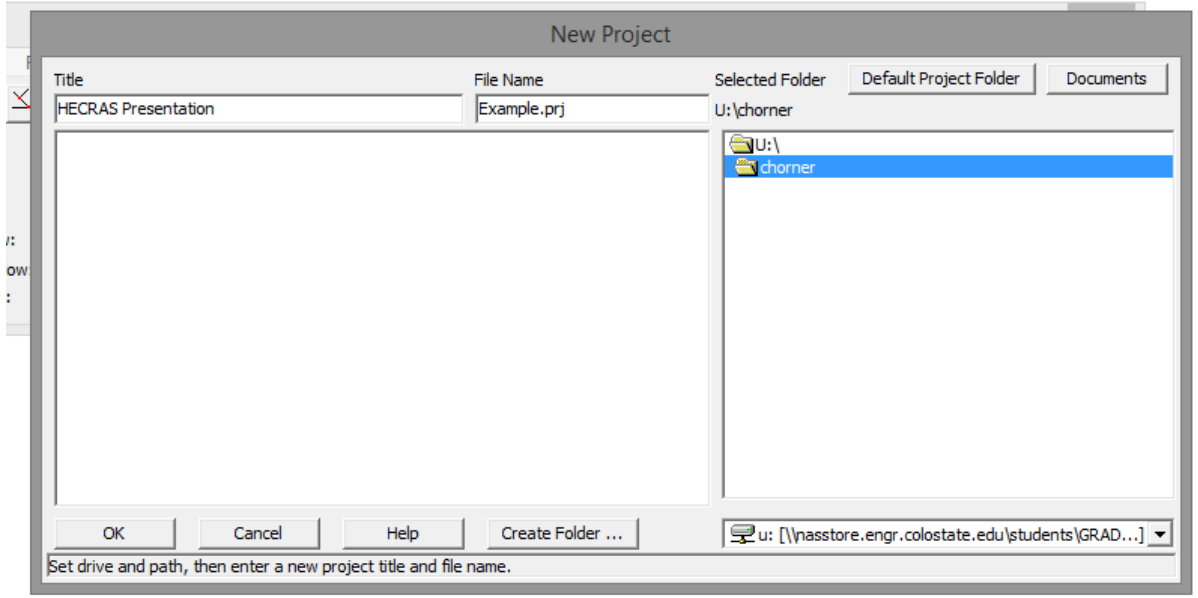


Example: Start a New Project

Start a **New Project**

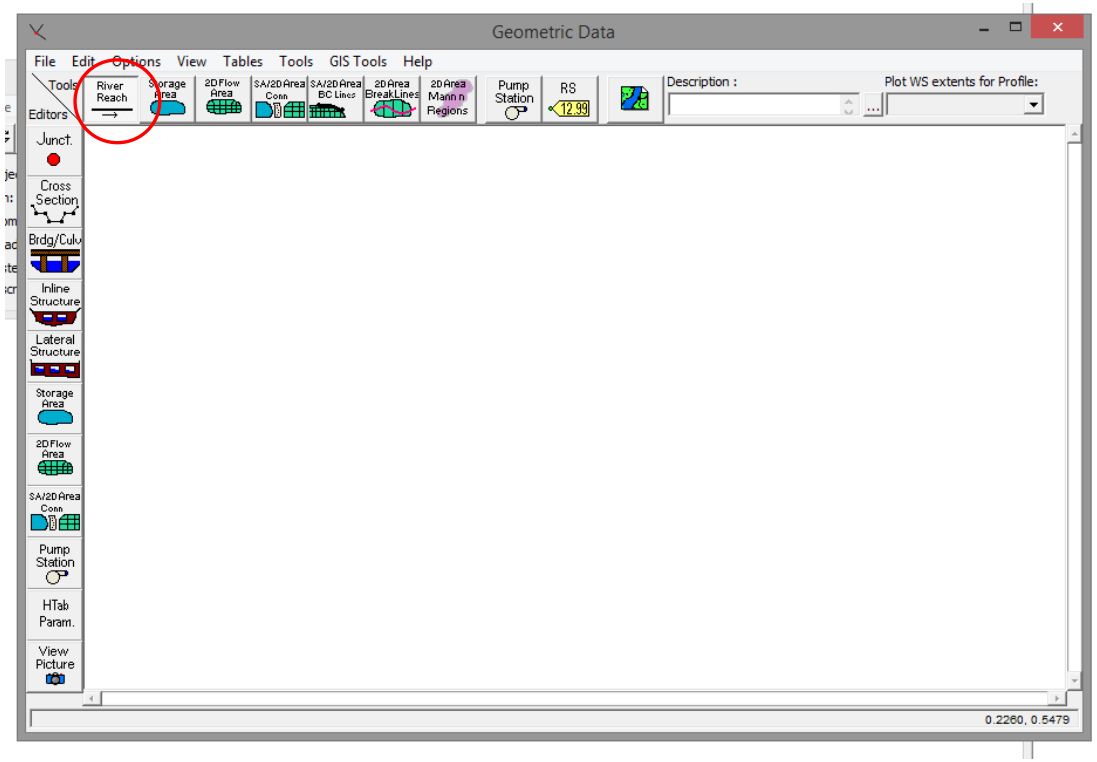
Select drive and directory to work in and enter the project title and file name



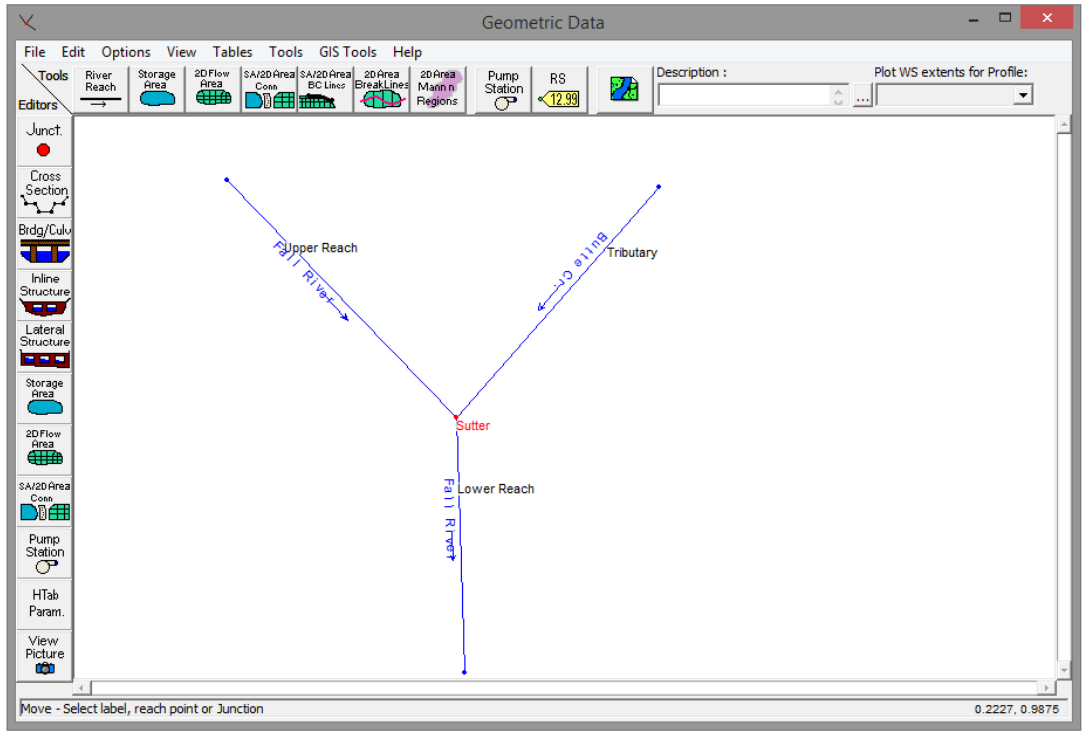


Example: Enter Geometric Data

Click **Edit** > **Geometric Data…** or press 
Select **River Reach**



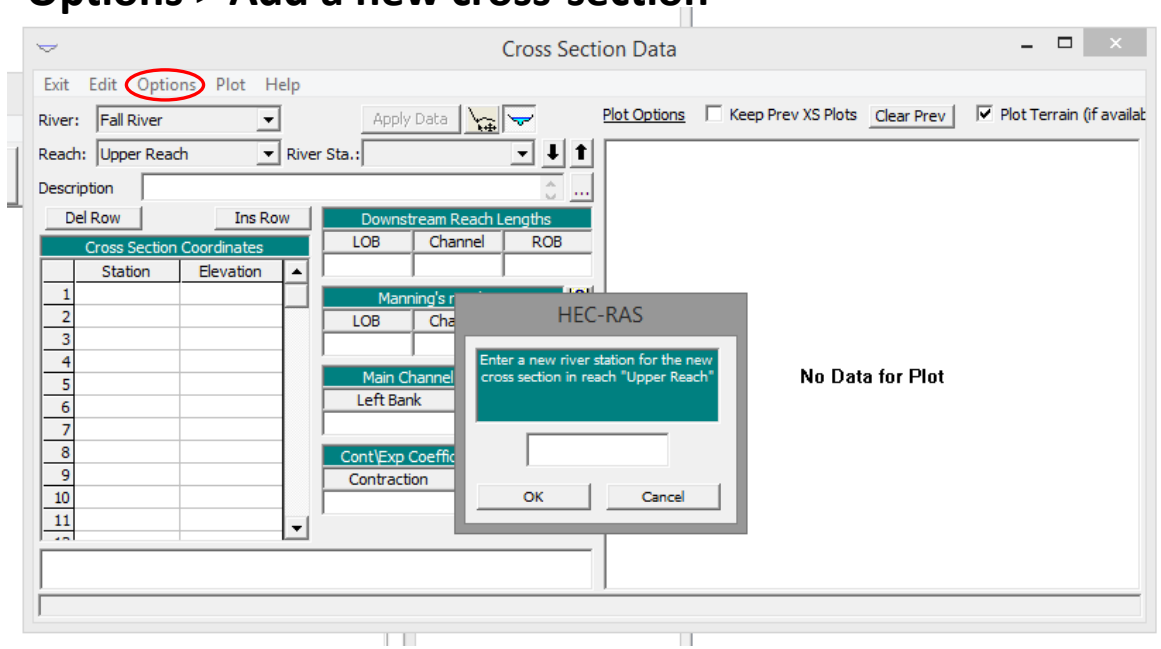
Draw the river schematic, naming each river, reach, and junction



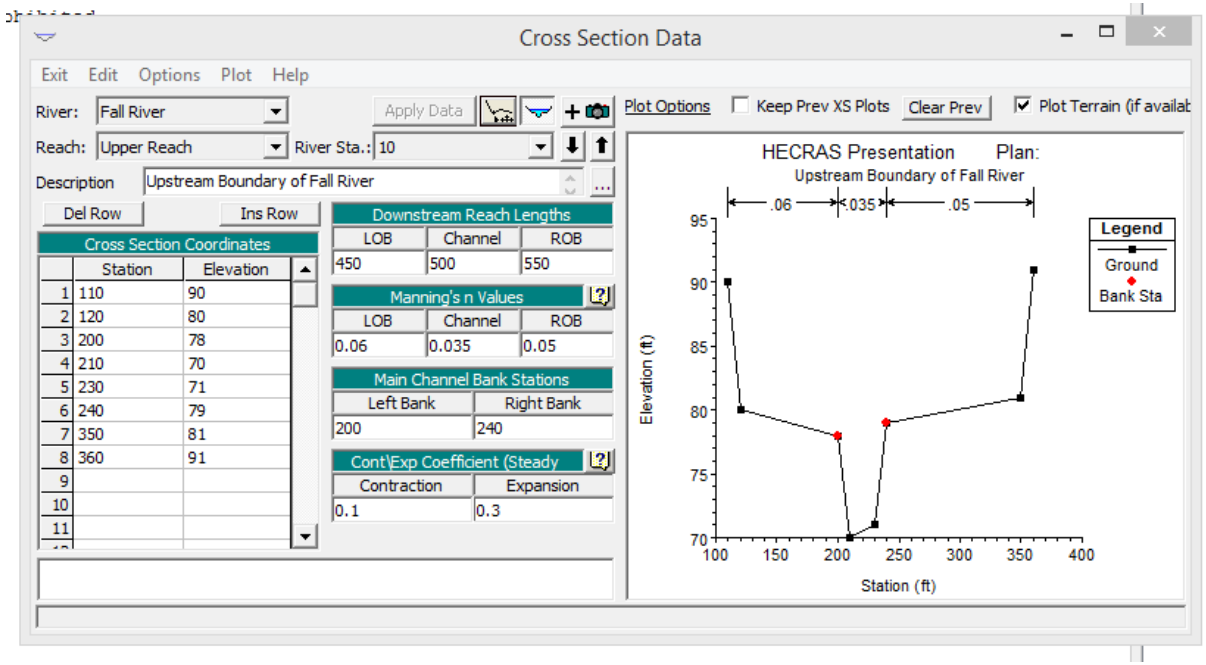
Example: Enter Geometric Data

Click **Cross Section** button 

Options > **Add a new cross-section**



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

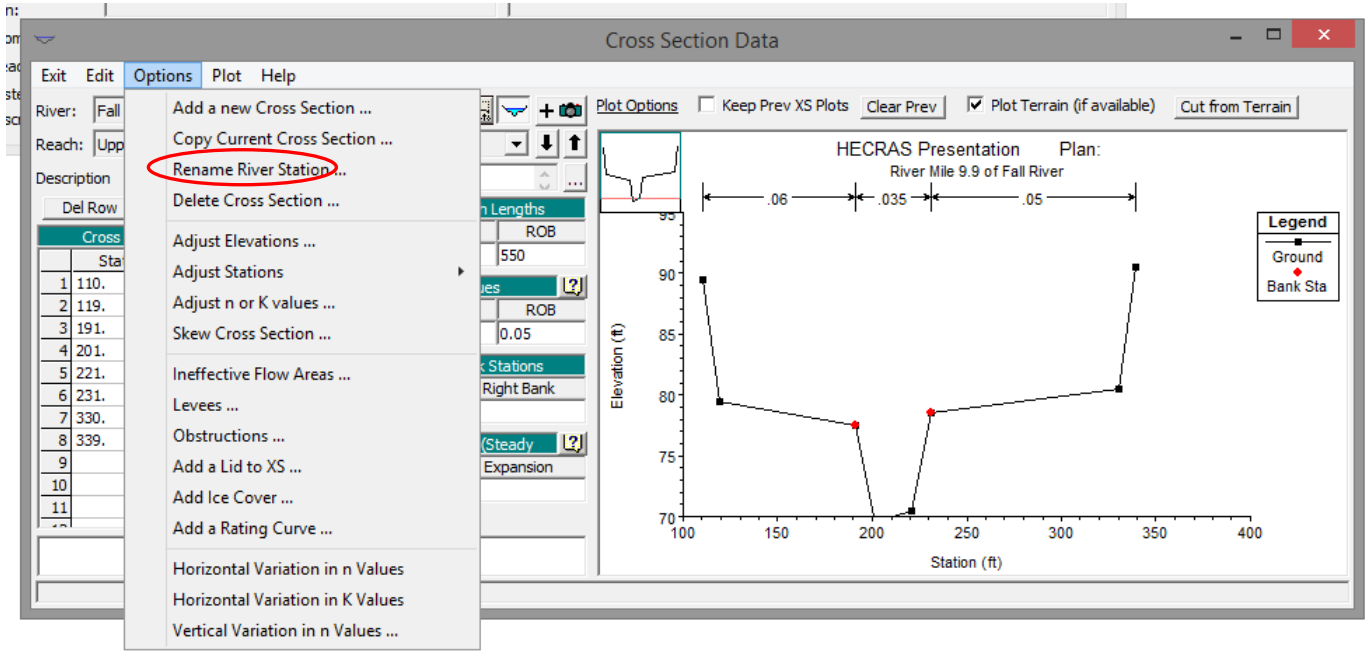


Example: Enter Geometric Data

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

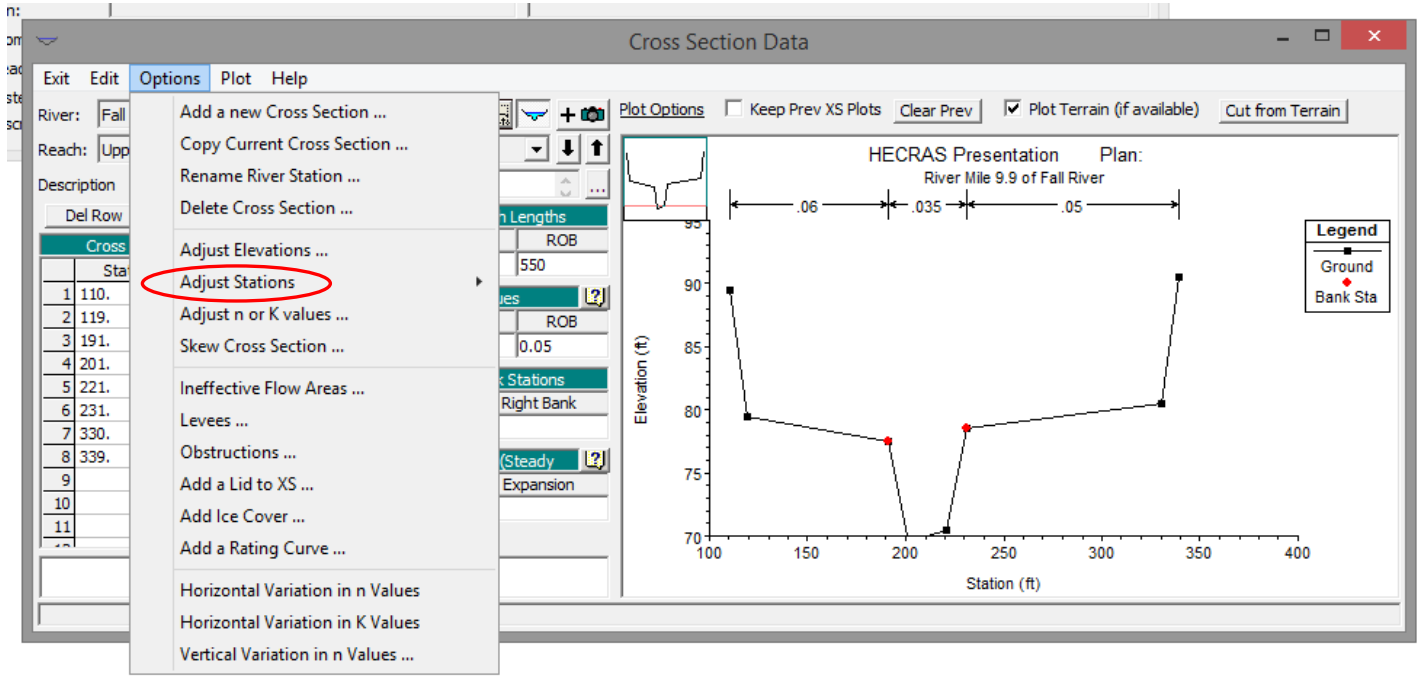
Options > **Copy Current Cross Section…**

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



Example: Enter Geometric Data

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



Example: Enter Geometric Data

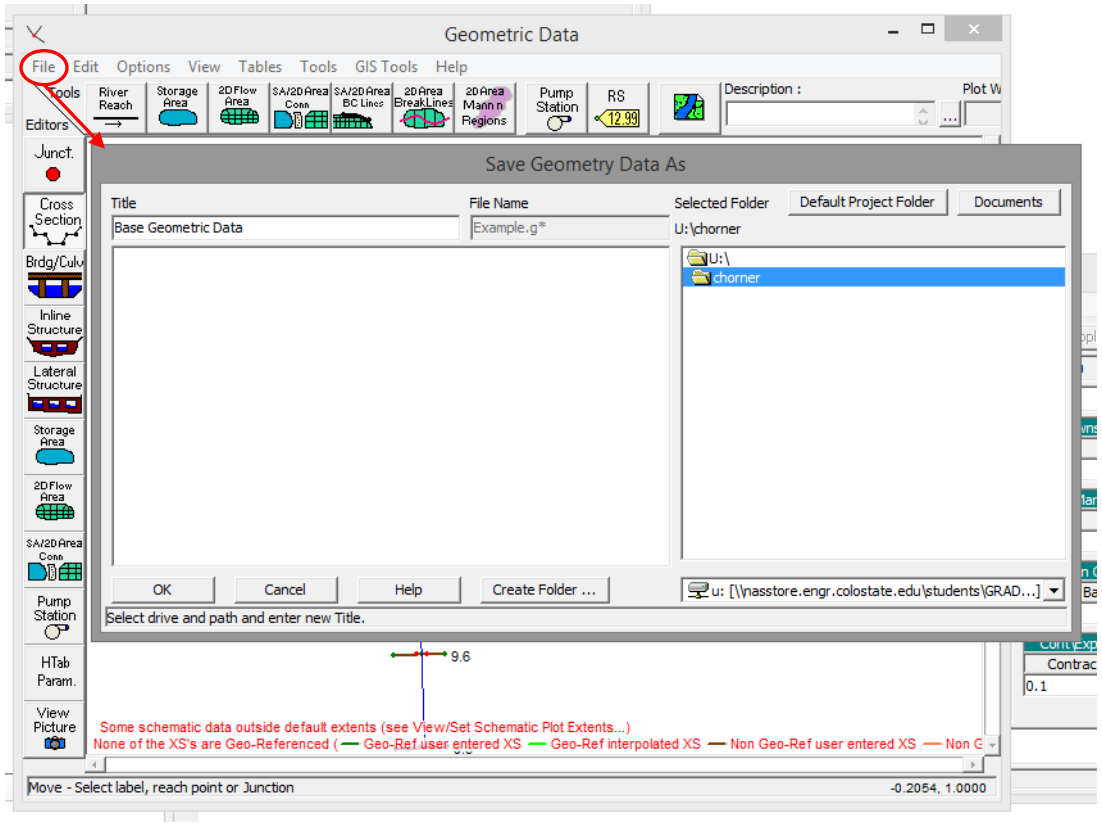
Create remaining cross-sections using these tools and the specifications below:

Cross Section		Adjusted Elevation	Adjusted Stationing			Downstream Reach Lengths		
Reach	River Sta.		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

Example: Enter Geometric Data

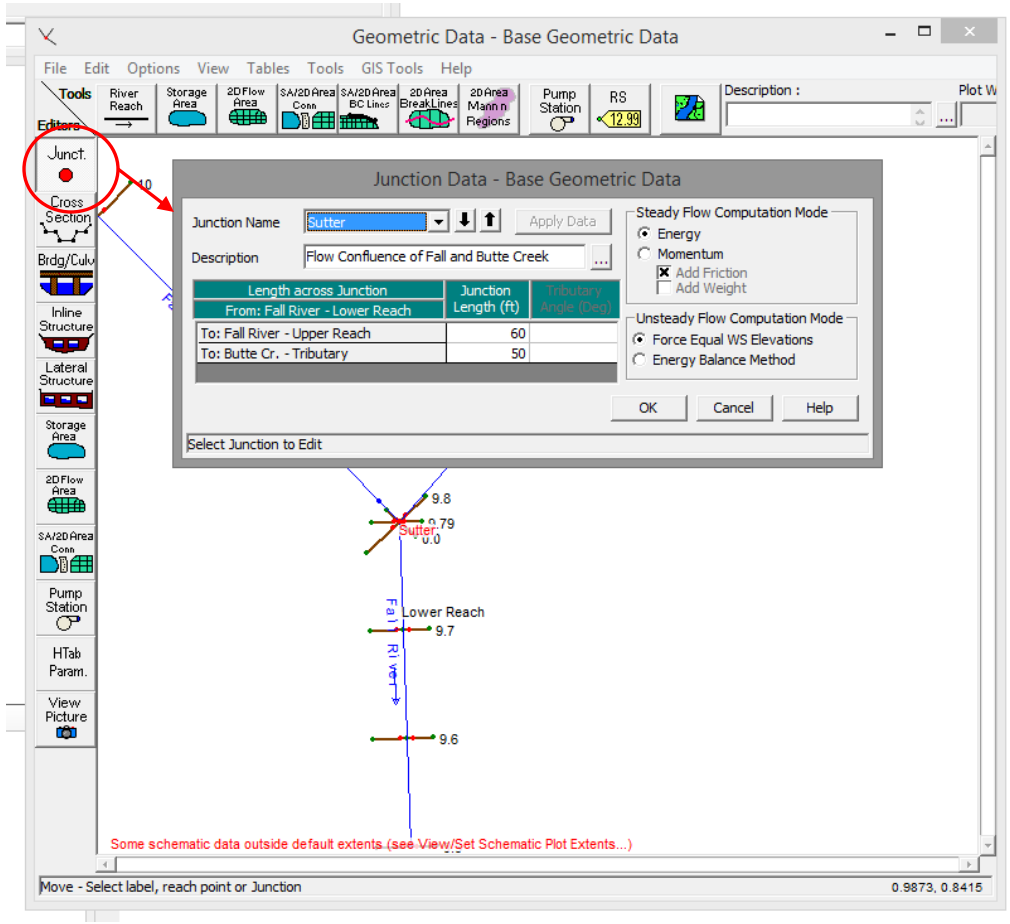
Save cross-sectional geometry: go to the Geometric Data window > click **File** > **Save Geometry Data As** > enter a title > press **OK**



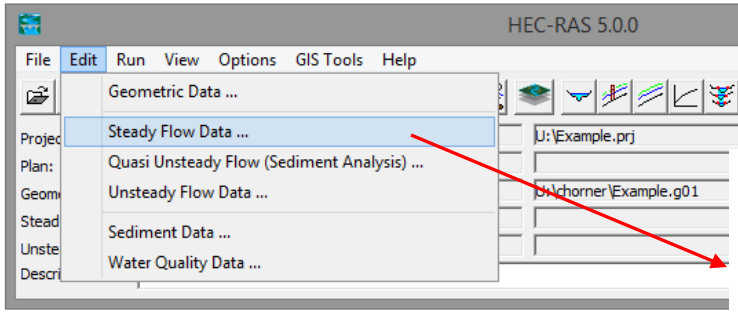
Example: Enter Geometric Data

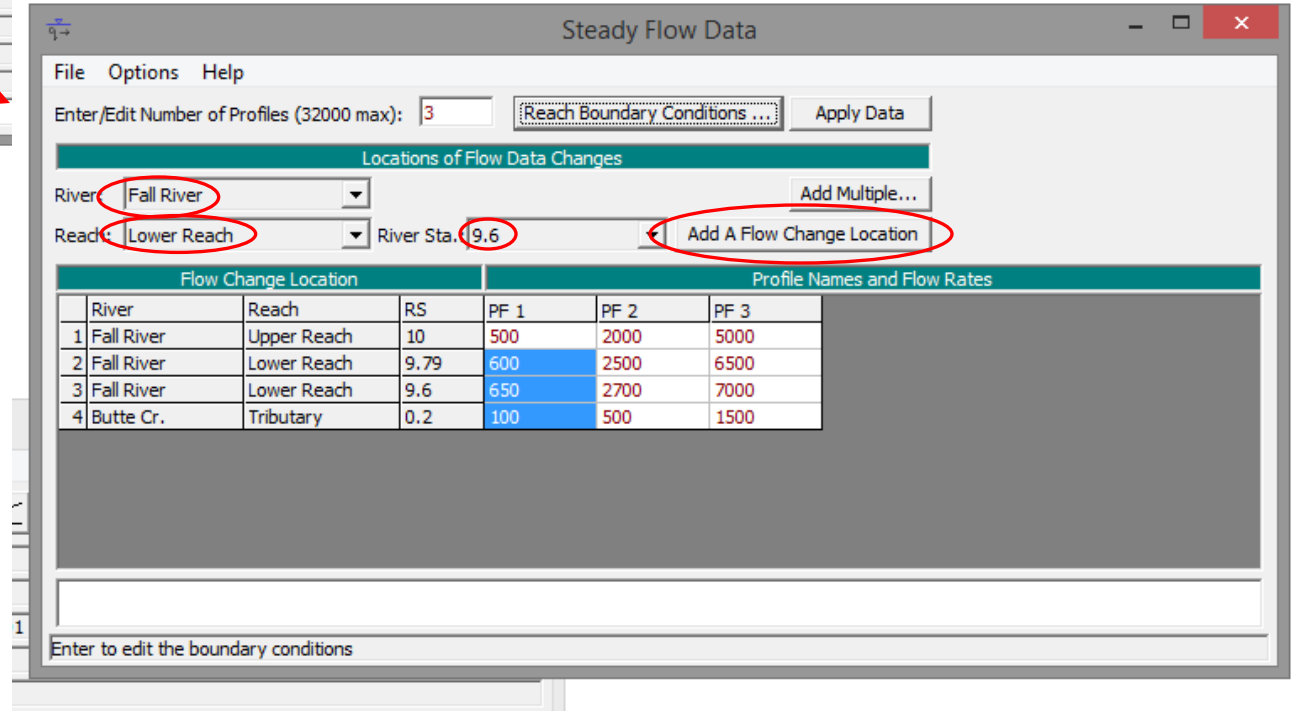
Enter Junction data by clicking the **Junct.** button

- 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





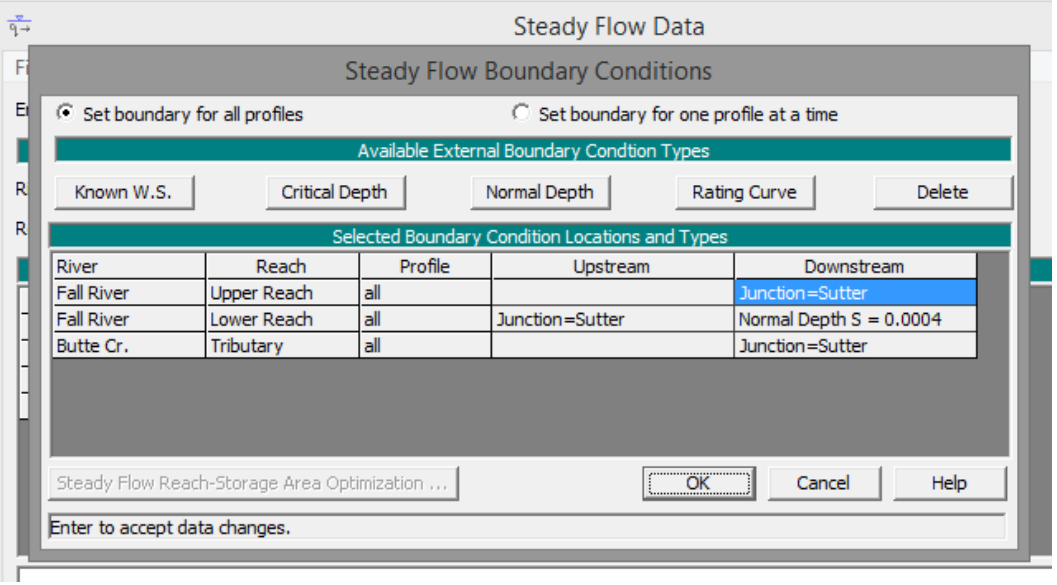
	River	Reach	RS	PF 1	PF 2	PF 3
1	Fall River	Upper Reach	10	500	2000	5000
2	Fall River	Lower Reach	9.79	600	2500	6500
3	Fall River	Lower Reach	9.6	650	2700	7000
4	Butte Cr.	Tributary	0.2	100	500	1500

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

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

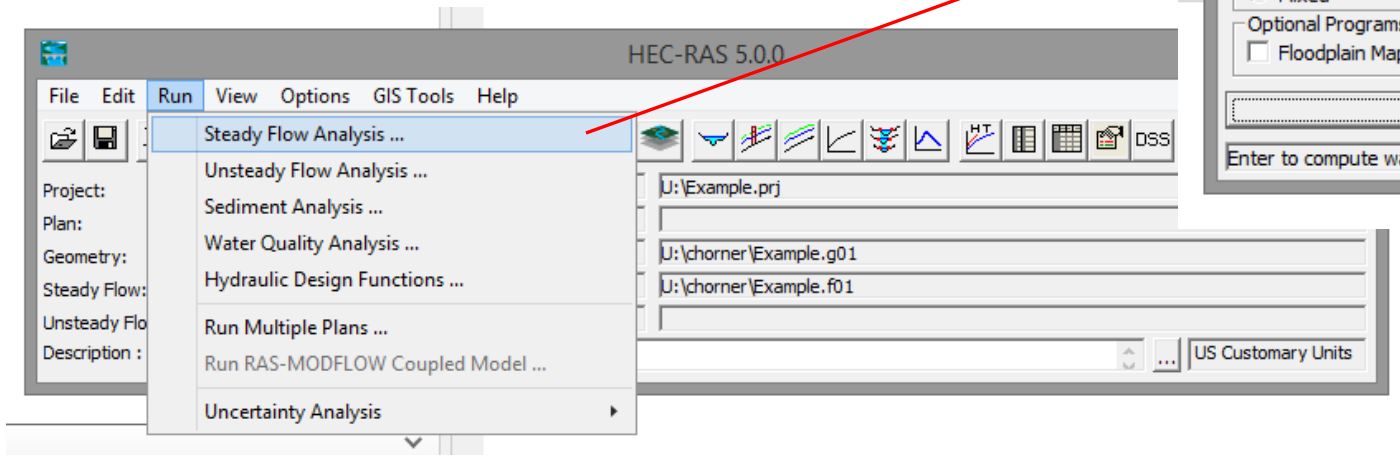
Select the cell you wish to enter a BC for > click the type of BC you wish to apply (in this case, select **Normal Depth** and enter an average energy slope of 0.0004 ft/ft) > click **OK** > **File** > **Save Flow Data**

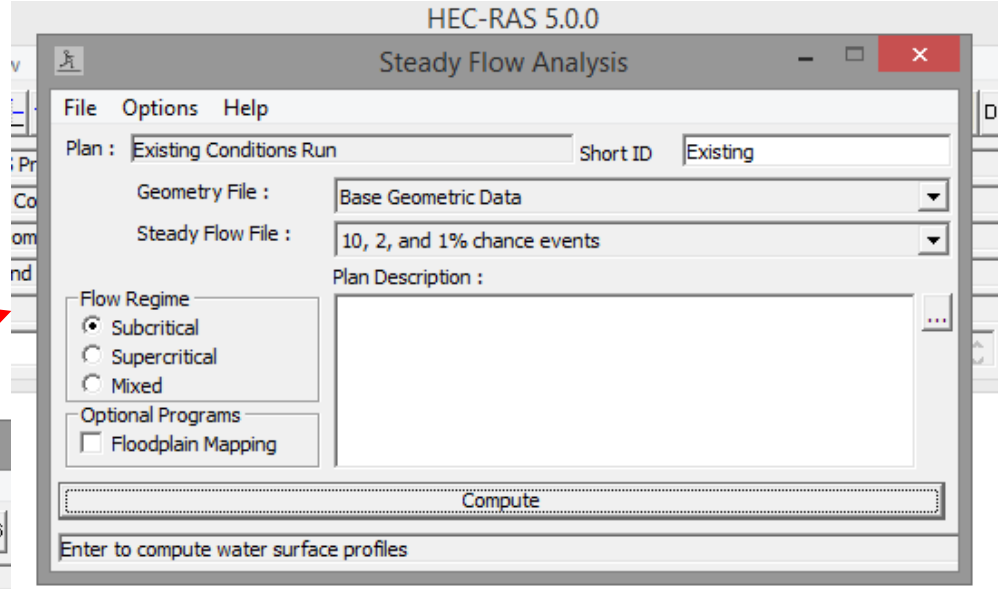


Example: Perform Hydraulic Calculations

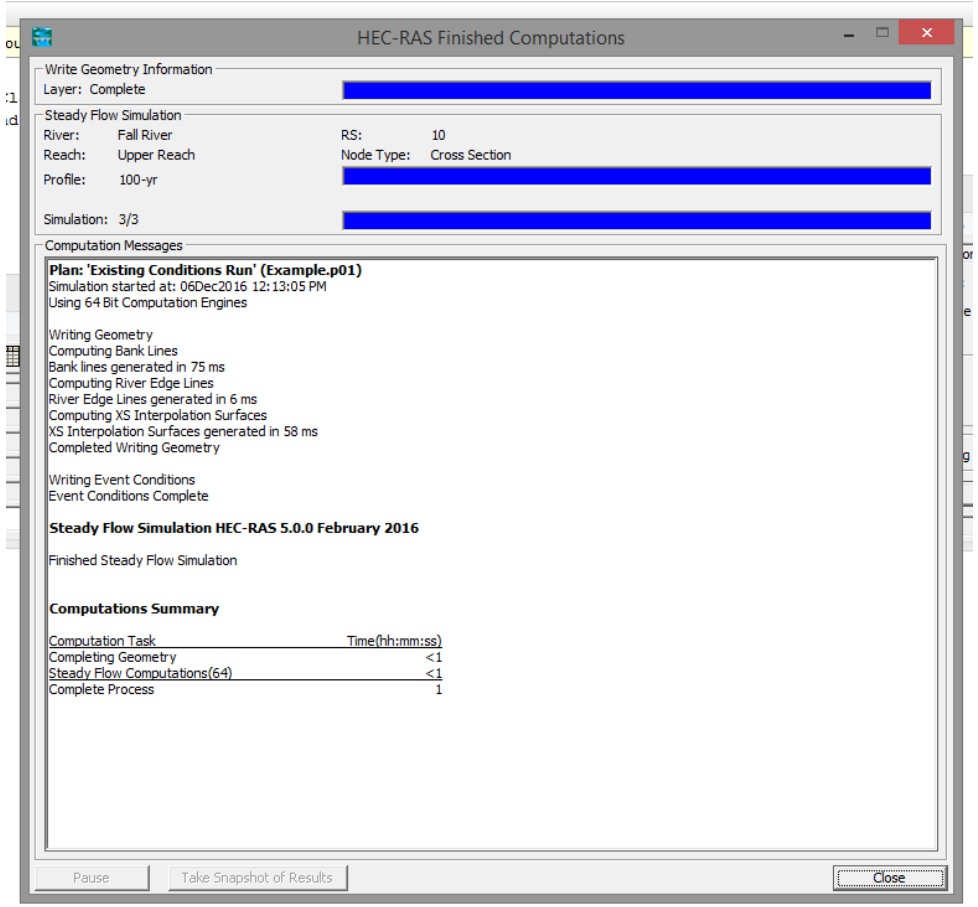
Before computations can be performed, you must create a plan that defines which geometry and flow data are to be used:

- 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**





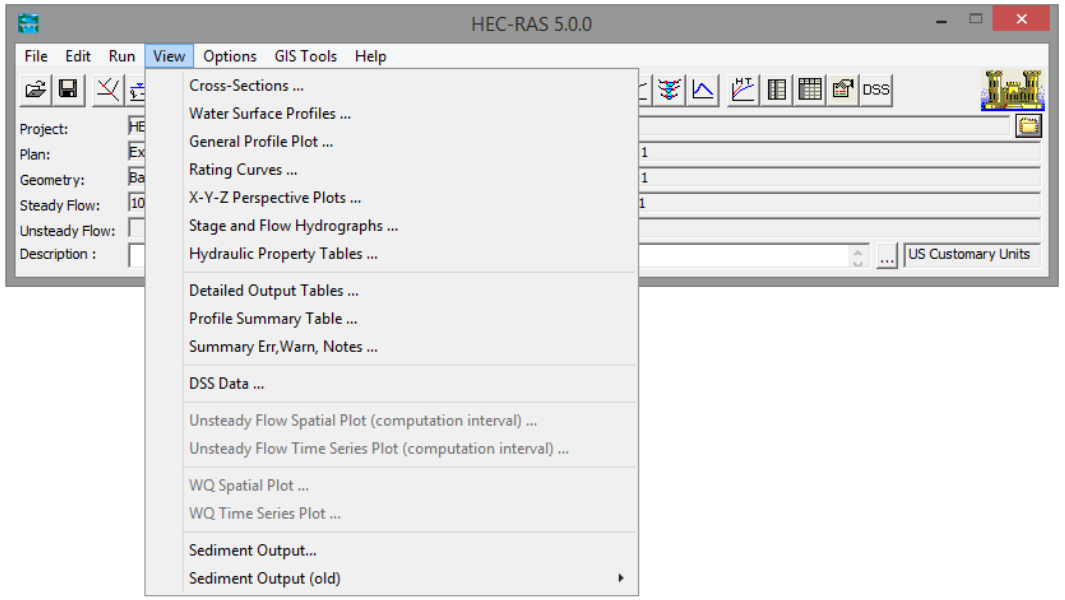
Example: Perform Hydraulic Calculations



Example: View Results

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



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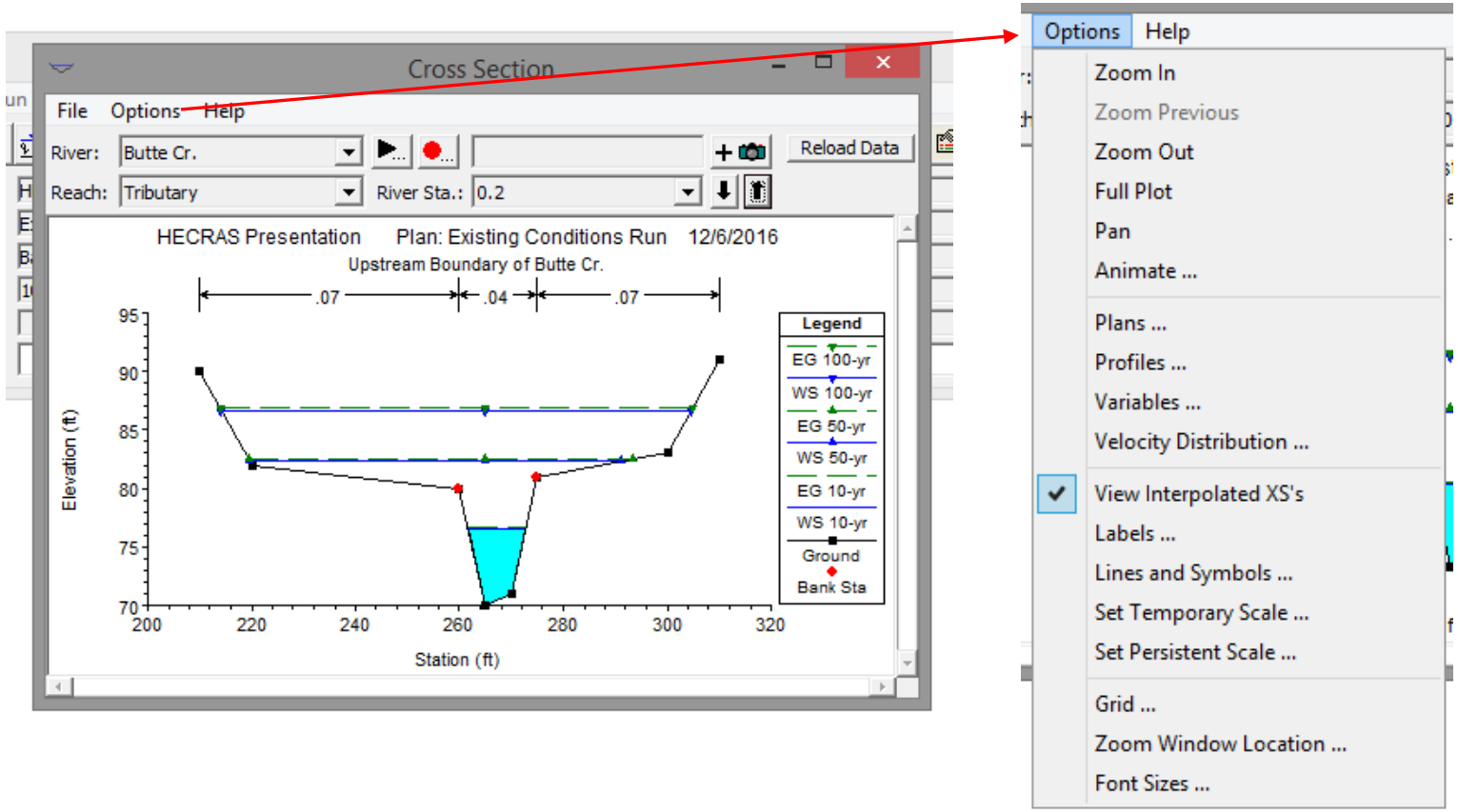

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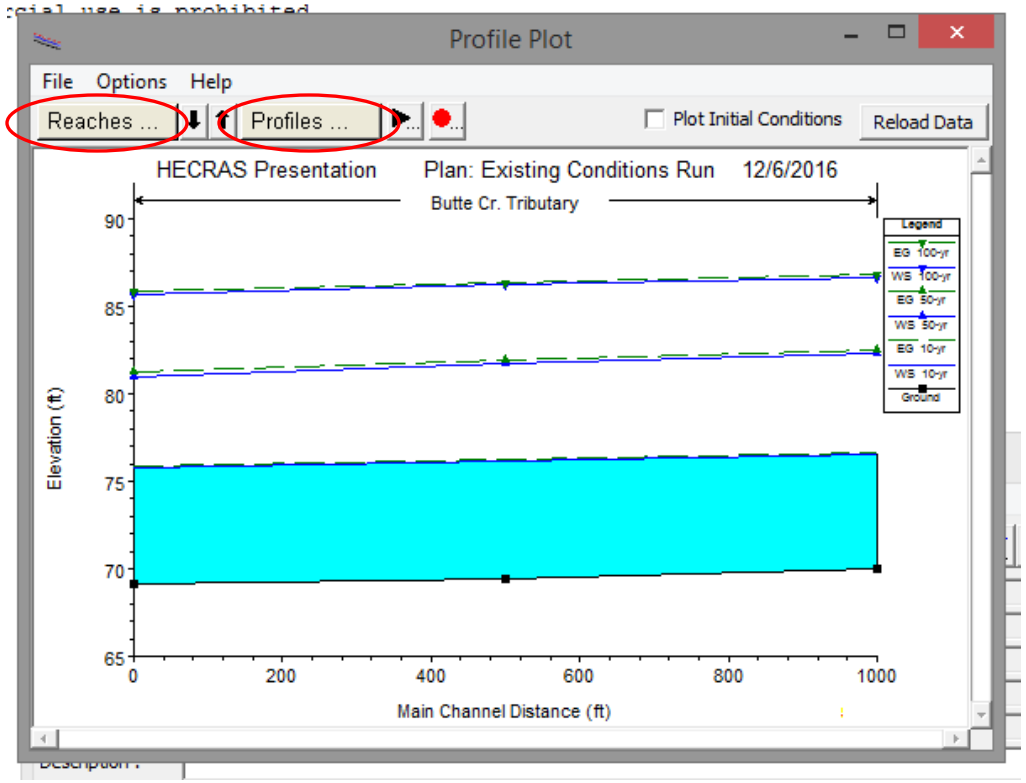

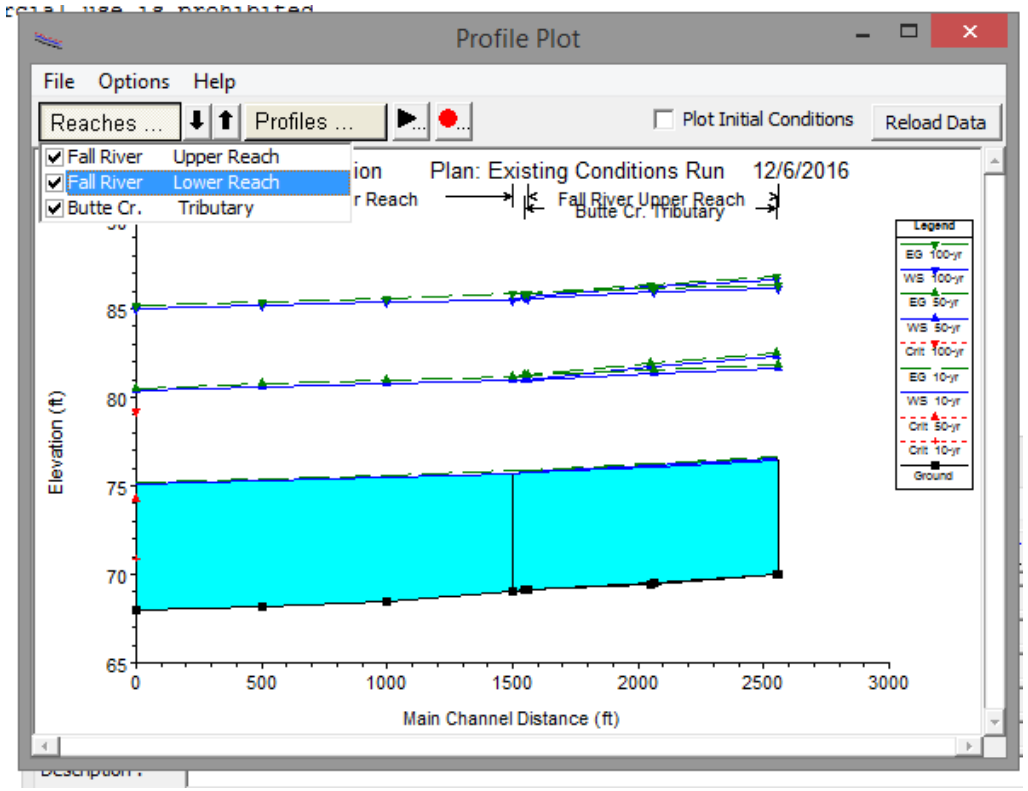

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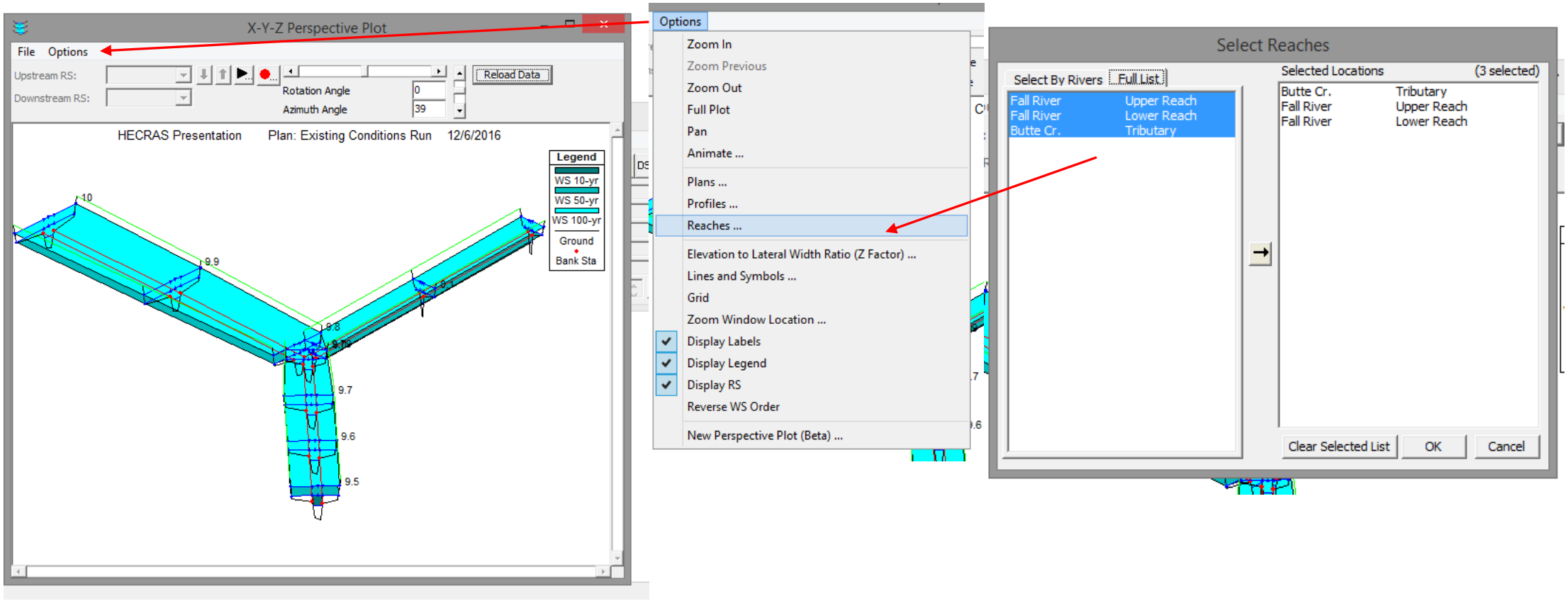

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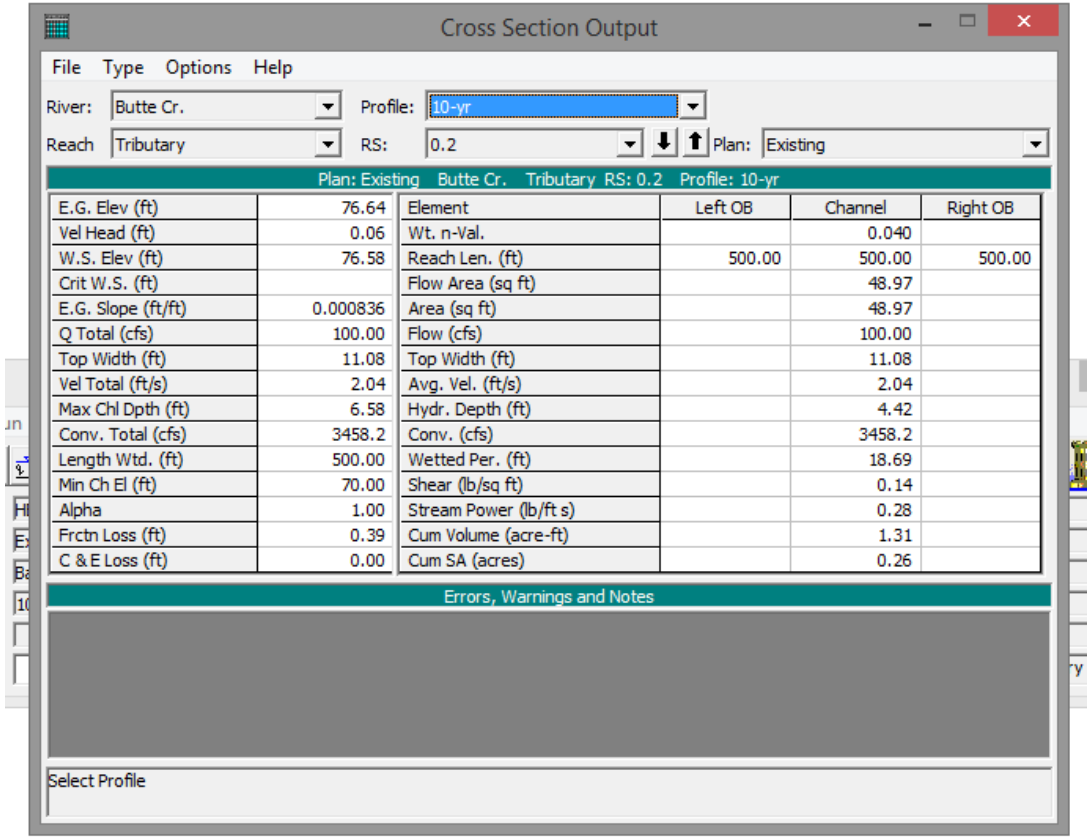


Cross Section Output

File Type Options Help

River: Butte Cr. Profile: 10-yr

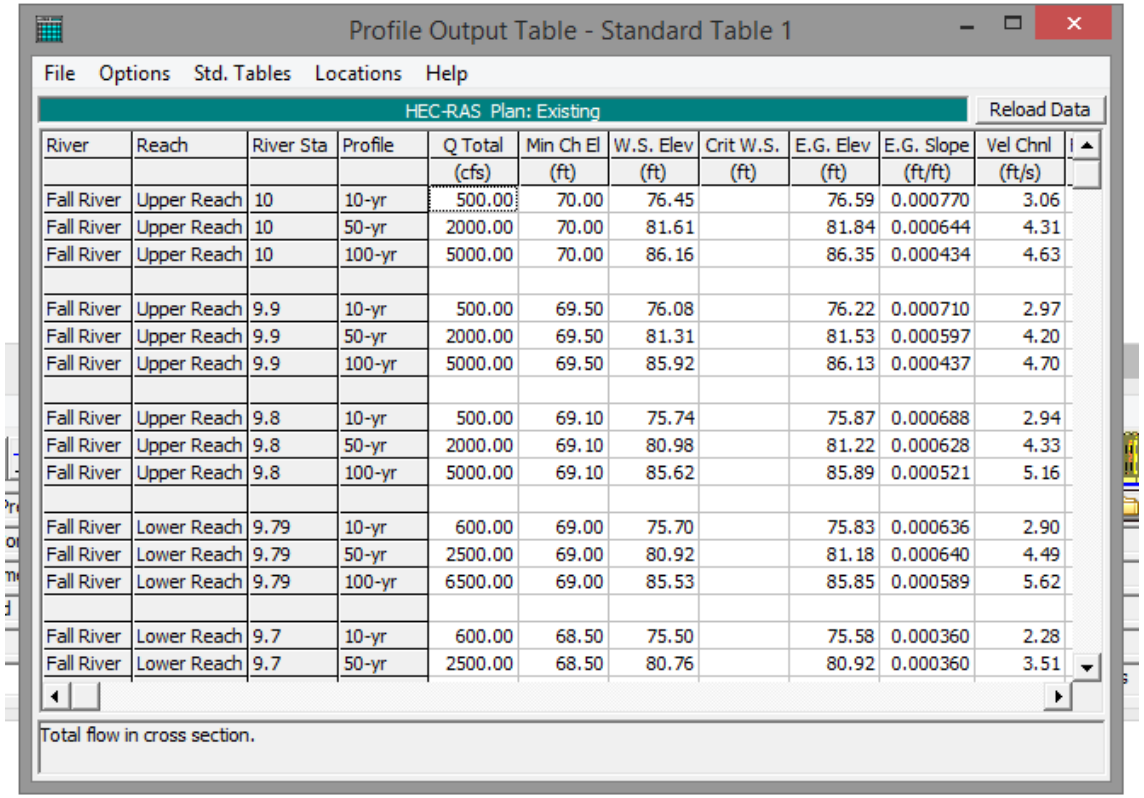
Reach Tributary RS: 0.2 Plan: Existing

Plan: Existing Butte Cr. Tributary RS: 0.2 Profile: 10-yr

		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	76.64	Wt. n-Val.		0.040	
Vel Head (ft)	0.06	Reach Len. (ft)	500.00	500.00	500.00
W.S. Elev (ft)	76.58	Flow Area (sq ft)		48.97	
Crit W.S. (ft)		Area (sq ft)		48.97	
E.G. Slope (ft/ft)	0.000836	Flow (cfs)		100.00	
Q Total (cfs)	100.00	Top Width (ft)		11.08	
Top Width (ft)	11.08	Avg. Vel. (ft/s)		2.04	
Vel Total (ft/s)	2.04	Hydr. Depth (ft)		4.42	
Max Chl Dpth (ft)	6.58	Conv. (cfs)		3458.2	
Conv. Total (cfs)	3458.2	Wetted Per. (ft)		18.69	
Length Wtd. (ft)	500.00	Shear (lb/sq ft)		0.14	
Min Ch El (ft)	70.00	Stream Power (lb/ft s)		0.28	
Alpha	1.00	Cum Volume (acre-ft)		1.31	
Frctn Loss (ft)	0.39	Cum SA (acres)		0.26	
C & E Loss (ft)	0.00				

Errors, Warnings and Notes

Select Profile



Profile Output Table - Standard Table 1

File Options Std. Tables Locations Help

HEC-RAS Plan: Existing Reload Data

River	Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)
Fall River	Upper Reach	10	10-yr	500.00	70.00	76.45		76.59	0.000770	3.06
Fall River	Upper Reach	10	50-yr	2000.00	70.00	81.61		81.84	0.000644	4.31
Fall River	Upper Reach	10	100-yr	5000.00	70.00	86.16		86.35	0.000434	4.63
Fall River	Upper Reach	9.9	10-yr	500.00	69.50	76.08		76.22	0.000710	2.97
Fall River	Upper Reach	9.9	50-yr	2000.00	69.50	81.31		81.53	0.000597	4.20
Fall River	Upper Reach	9.9	100-yr	5000.00	69.50	85.92		86.13	0.000437	4.70
Fall River	Upper Reach	9.8	10-yr	500.00	69.10	75.74		75.87	0.000688	2.94
Fall River	Upper Reach	9.8	50-yr	2000.00	69.10	80.98		81.22	0.000628	4.33
Fall River	Upper Reach	9.8	100-yr	5000.00	69.10	85.62		85.89	0.000521	5.16
Fall River	Lower Reach	9.79	10-yr	600.00	69.00	75.70		75.83	0.000636	2.90
Fall River	Lower Reach	9.79	50-yr	2500.00	69.00	80.92		81.18	0.000640	4.49
Fall River	Lower Reach	9.79	100-yr	6500.00	69.00	85.53		85.85	0.000589	5.62
Fall River	Lower Reach	9.7	10-yr	600.00	68.50	75.50		75.58	0.000360	2.28
Fall River	Lower Reach	9.7	50-yr	2500.00	68.50	80.76		80.92	0.000360	3.51

Total flow in cross section.

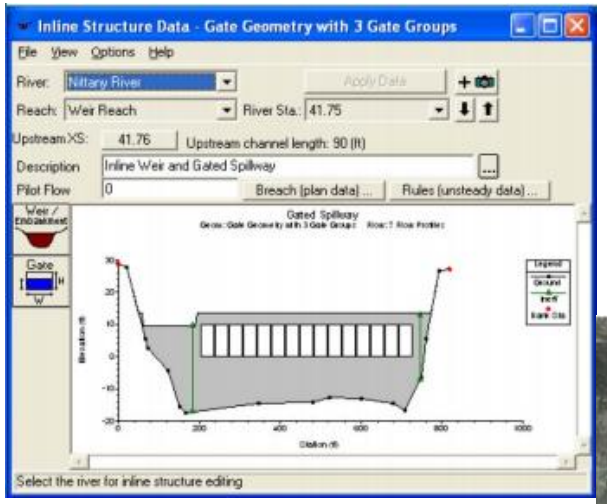
Applications

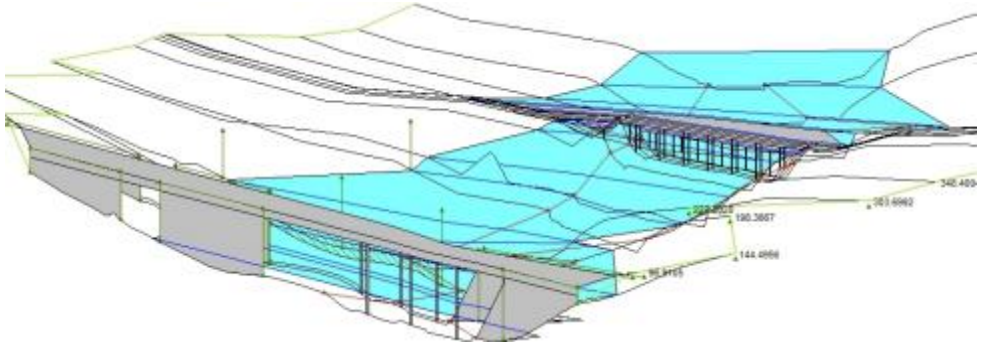
Bridge and culvert modeling

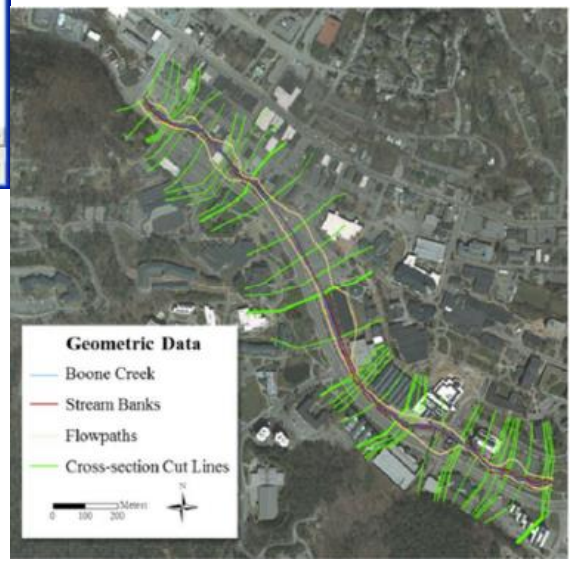
Inline structures (i.e. dams)

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

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