Data Requirements for Unsteady Flow Models

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The objective of this lecture is to discuss geomtric data options in HEC-RAS and how the geometric pre-processsor uses the geometric to preprocess hydraulic tables for use in unsteady flow simulations.

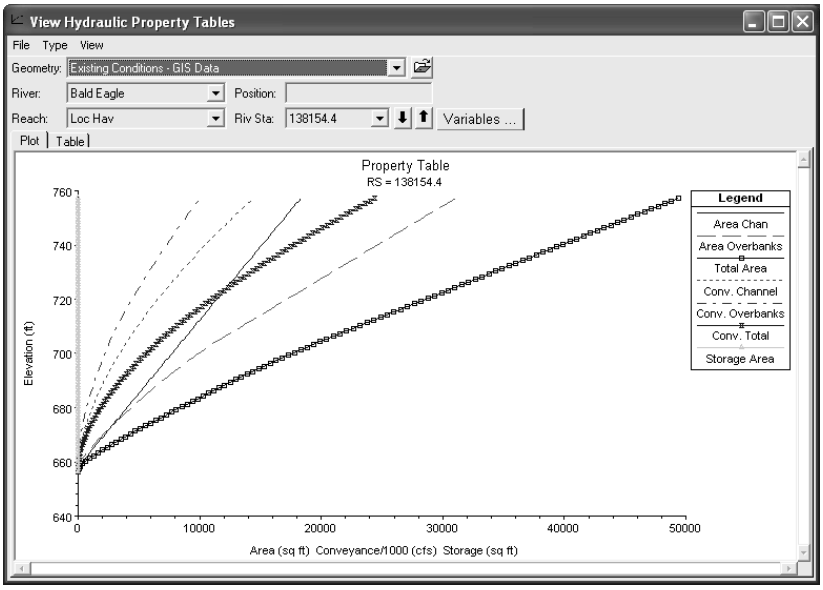
Geometry Preprocessor

- What does it do?
  - Processes geometric data into a series of hydraulic tables and rating curves.
- Why do we use it for unsteady flow?
  - Instead of calculating hydraulic variables for each cross-section during each iteration, the program interpolates the hydraulic variables from the tables.

2

The preprocessor is used to process the geometric data into a series of hydraulic property tables and rating curves. This is done in order to speed up the unsteady flow calculations. Instead of calculating hydraulic variables for each cross-section during each iteration, the program interpolates the hydraulic variables from the tables. The preprocessor must be executed at at least once, but then only needs to be re-executed if something in the geometric data has changed.

Hydraulic Property Plot



3

Cross sections are processed into tables of elevation versus hydraulic properties of areas, conveyances, and storage. Each table contains a minimum of 21 points (a zero point at the invert and 20 computed values). The user is required to set an interval to be used for spacing the points in the cross section tables. The interval can be the same for all cross sections or it can vary from cross section to cross section. This interval is very important, in that it will define the limits of the table that is built for each cross section. On one hand, the interval must be large enough to encompass the full range of stages that may be incurred during the unsteady flow simulations. On the other hand, if the interval is too large, the tables will not have enough detail to accurately depict changes in area, conveyance, and storage with respect to elevation.

Conveyance Calculations

- Manning's Equation

$$Q = K S_f^{1/2}$$

$$K = \frac{1.486}{n} A R^{2/3}$$

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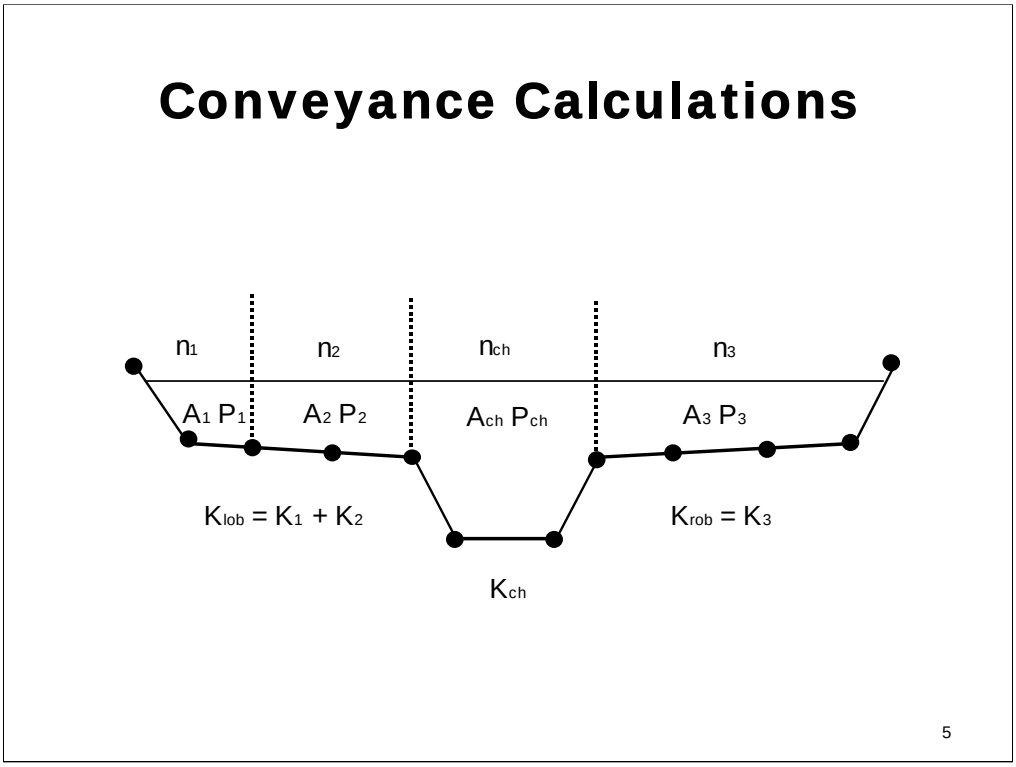
Conveyance is calculated from the above form of Manning's equation (based on English units):

where:

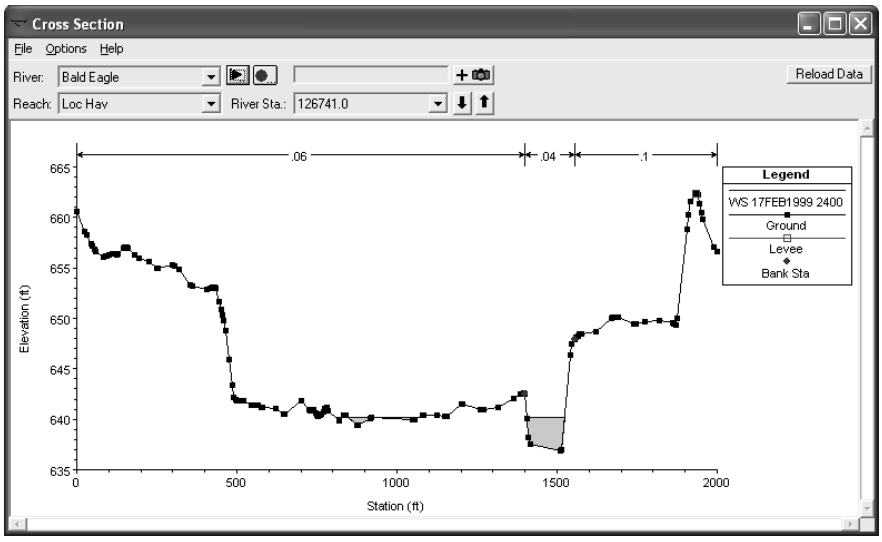
K	=	conveyance for subdivision
n	=	Manning's roughness coefficient for subdivision
A	=	flow area for subdivision
R	=	hydraulic radius for subdivision (area / wetted perimeter)
S_f	=	friction slope



The determination of total conveyance and the velocity coefficient for a cross section requires that flow be subdivided into units for which the velocity is uniformly distributed. The approach used in HEC-RAS is to subdivide flow in the overbank areas using the input cross section n-value break points (locations where n-values change) as the basis for subdivision.

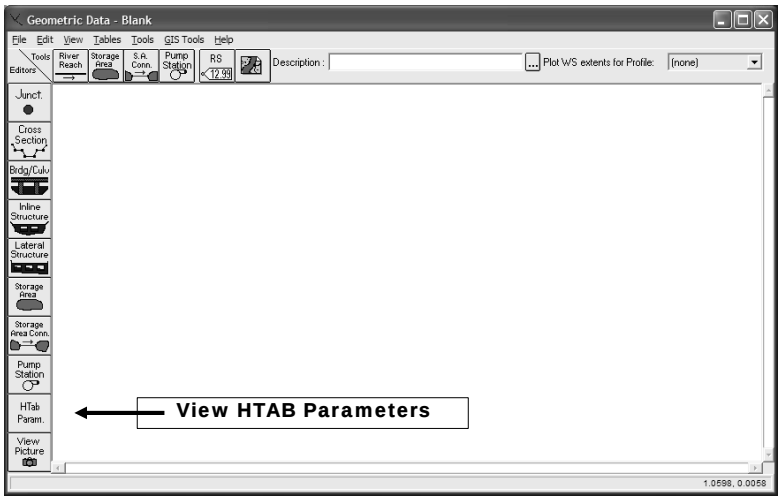
The program sums up all the incremental conveyances in the overbanks to obtain a conveyance for the left overbank and the right overbank. The main channel conveyance is normally computed as a single conveyance element. The total conveyance for the cross section is obtained by summing the three subdivision conveyances (left, channel, and right).

Cross Section Example



6

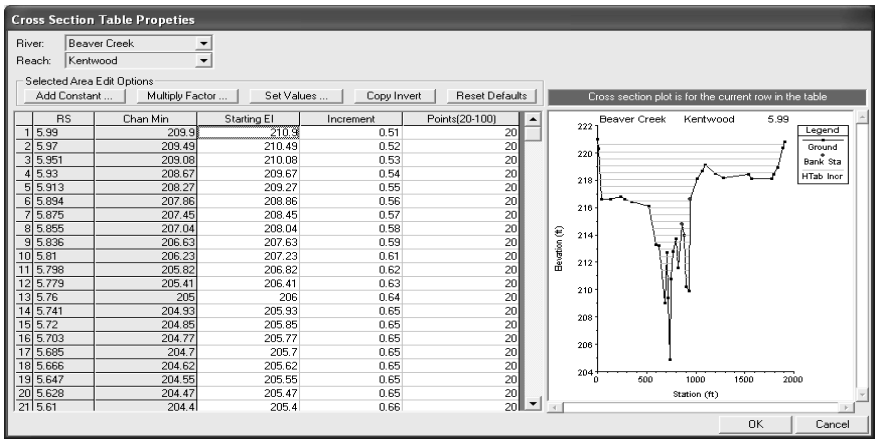
Cross Section Table Parameters



7

The **Geometric Data Editor** is shown in the above figure. From this editor, select the button labeled **Htab Param.** to view and edit the cross section table parameters.

Cross Section Table Parameters



- Starting Elevation
- Increment
- Number of Points

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As shown in the figure, the table contains three columns in which the user can enter information: starting elevation; increment; and Number of Points. The first time the user opens this editor all of the columns are automatically filled. The starting elevation columns are automatically filled to an elevation one foot higher than the invert, however, the user can change these values to whatever they want. The second and third columns are used for the table increment and the number of points. These two variables will describe the extent to which the table encompasses the cross section data. A default value will be set for the increment and the number of points. Normally the increment will be set to one foot, and the number of points will be set to a value that will allow the table to extend to the top of the cross section. If this combination would end up with less than 20 points, then the number of points is set to 20 and the increment is reduced to get the table to the top of the cross section. The user can set these values individually for each cross section, or they can highlight a series of cross sections and use the **Set Values** button to enter the value for all of the highlighted sections. Other options are available to multiply highlighted fields by a factor or add a constant to all of them. Additionally, cut, copy, and paste buttons are available for manipulating the data.

Entering Geometric Parameters

- Manning's n Values
- Ineffective Flow Areas
  - Non-Permanent vs. Permanent
  - Normal vs. Multiple Blocks
- Blocked Obstruction
- Levees

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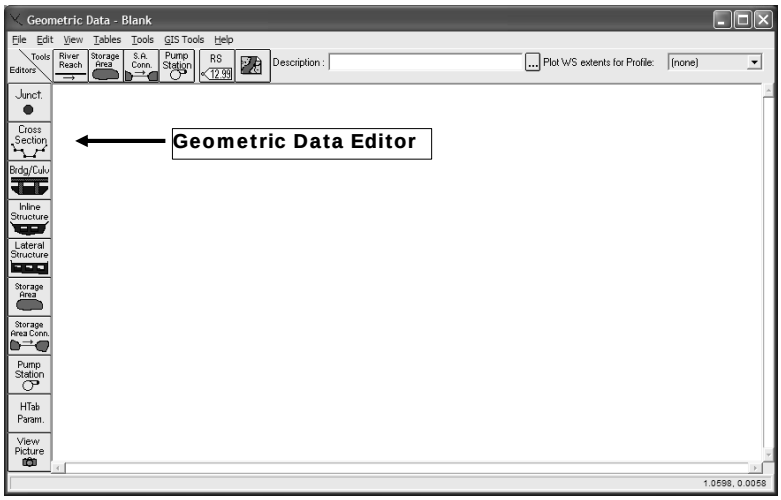
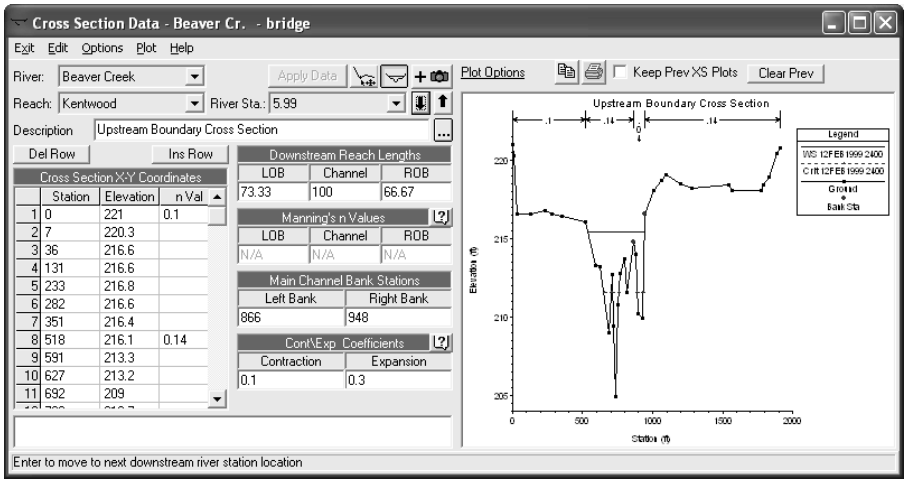
Entering Geometric Parameters



10

The **Geometric Data Editor** is shown in the above figure. From this editor, select the button labeled **Cross Section** to view and edit the cross section geometry.

Manning's n Values



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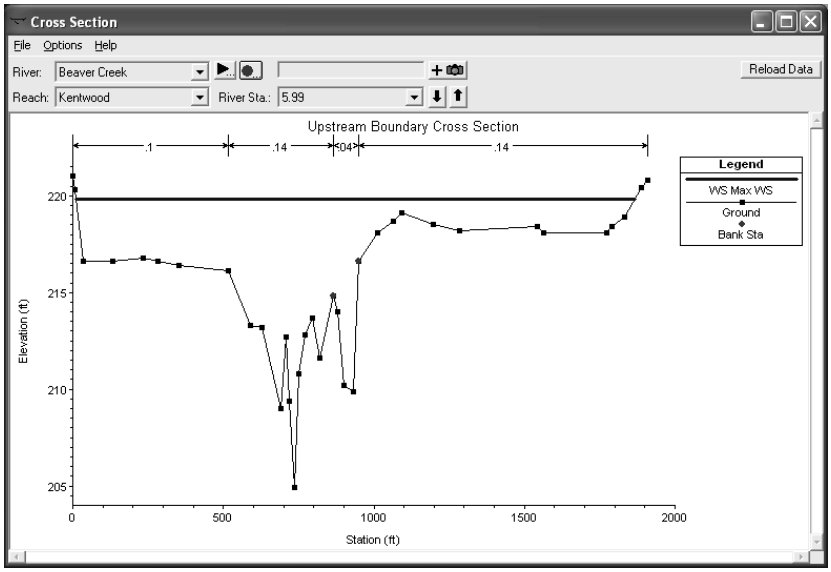
Selection of an appropriate value for Manning's n is very significant to the accuracy of the computed water surface profiles. The value of Manning's n is highly variable and depends on a number of factors including: surface roughness; vegetation; channel irregularities; channel alignment; scour and deposition; obstructions; size and shape of the channel; stage and discharge; seasonal change; temperature; and suspended material and bedload.

Manning's n Values



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The above figure illustrates the horizontal variation in Manning's n values along the cross section.

There are several references a user can access that show Manning's n values for typical channels. An extensive compilation of n values for streams and floodplains can be found in Chow's book "Open-Channel Hydraulics" [Chow, 1959]. Excerpts from Chow's book, for the most common types of channels, are shown in Table 3.1 of the Hydraulic Reference Manual for HEC-RAS version 3.0 on pages 3-14 and 3-15.

Entering Geometric Parameters

- Manning's n Values
- Ineffective Flow Areas
  - Non-Permanent vs. Permanent
  - Normal vs. Multiple Blocks
- Blocked Obstruction
- Levees

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Ineffective Flow Areas

- Areas where water is not actively being conveyed. The velocity of water in the downstream direction is close to zero.
- This water is included in the storage calculations and other wetted cross section parameters, but it is not included as part of the active flow area.

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This option allows the user to define areas of the cross section that will contain water that is not actively being conveyed (ineffective flow). Ineffective flow areas are often used to describe portions of a cross section in which water will pond, but the velocity of that water, in the downstream direction, is close to zero. This water is included in the storage calculations and other wetted cross section parameters, but it is not included as part of the active flow area.

In unsteady flow modeling it is important to account for channel storage as well as conveyance. In steady flow modeling it is sometimes possible to completely ignore portions of the cross section that are dead storage, this is not the case in unsteady flow modeling because the hydrograph volume must be recognized. It may be useful to think of storage-only portions of a cross section as having extremely high n-values, which effectively nulls the conveyance.

Ineffective Flow Areas Requirements

- Ineffective Flow Stations
  - Left and/or right ineffective flow stations denote the location of the ineffective flow areas along the cross section.
- Trigger Elevations
  - Water elevation at which the ineffective flow area begins to convey flow (non-permanent), or remains ineffective (permanent).

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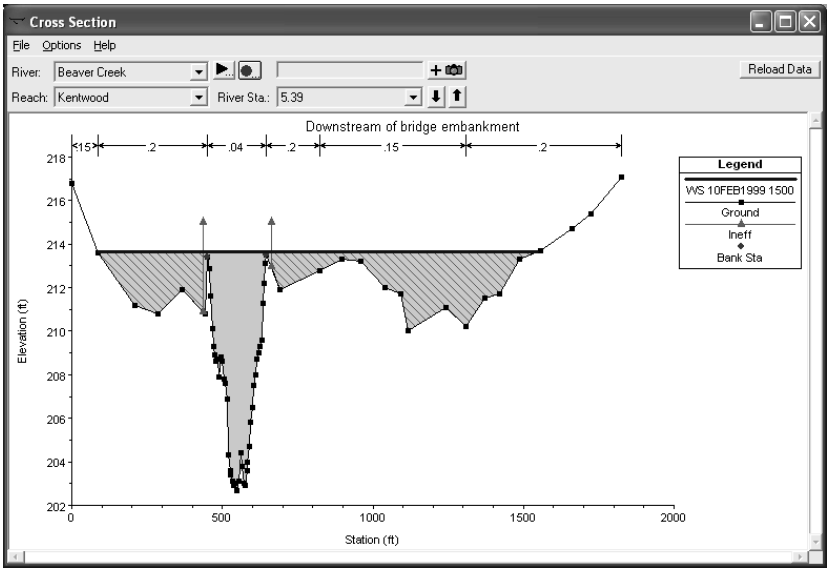
Setting an ineffective flow area requires at least one bank station and elevation. The bank station denotes the location of the ineffective flow area along the cross section. There are two different methods for setting bank stations (normal and multiple blocks).

When the water surface surpasses the trigger elevation, the ineffective flow area will either begin to convey flow or remain ineffective depending upon its type (permanent on non-permanent). The concepts of permanent and non-permanent ineffective flow areas are addressed in the next set of slides.

Non-Permanent Ineffective Flow Area



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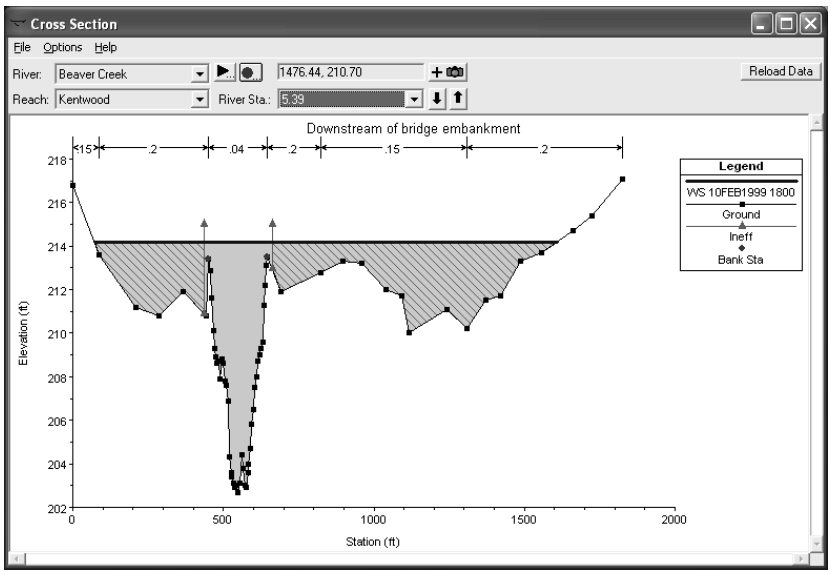
As shown in the slide, there are two ineffective flow areas (left bank and right bank). The ineffective flow areas are set to non-permanent. This means that the left bank and right bank areas will not convey flow until the trigger elevation has been reached. The trigger elevation is denoted by the end point of the two arrows. In this example the trigger elevation is 216 feet.

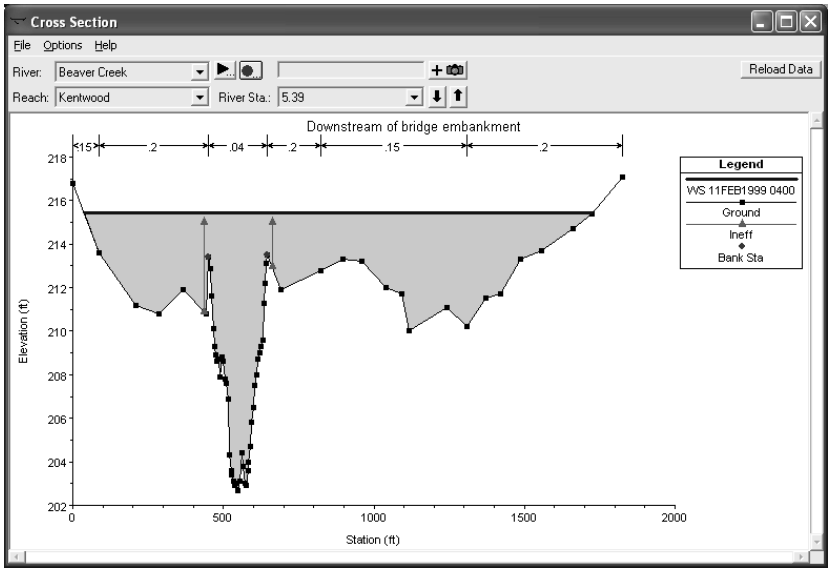
Non-Permanent Ineffective Flow Area



17

The water surface is rising but has not exceeded the trigger elevation. The rising water surface has increased the storage in the left and right overbanks but has not increased the conveyance in these areas because ineffective flow areas account for storage and not conveyance.

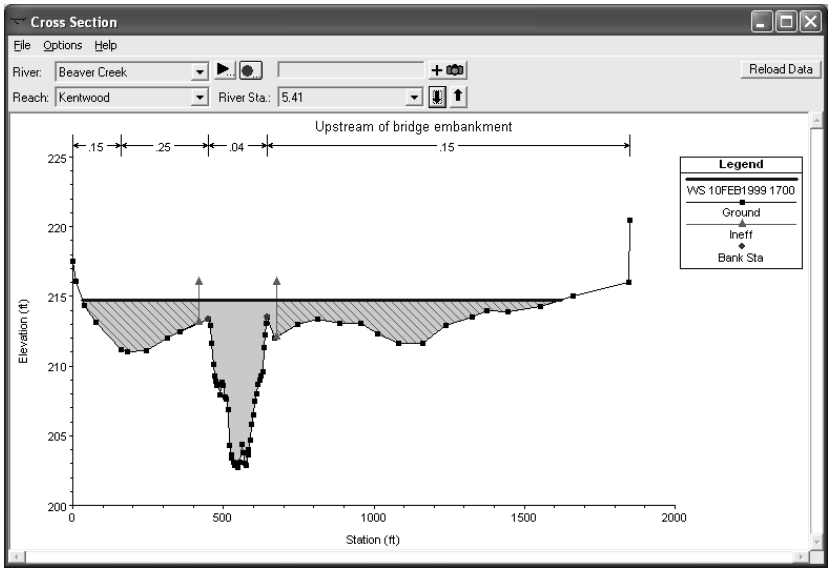
Non-Permanent Ineffective Flow Area



18

For non-permanent ineffective flow areas, once the water surface is higher than the trigger elevation, the entire ineffective flow area becomes effective (as shown in the slide). Water is assumed to be able to move freely in that area based on the roughness, wetted perimeter, and area of each subdivision. The left and right overbanks are no longer considered storage but are now active flow areas.

Permanent Ineffective Flow Area

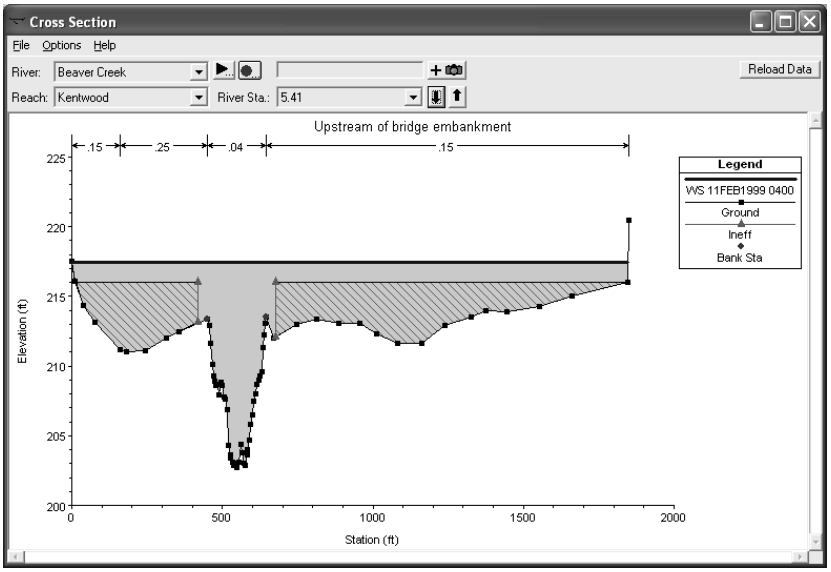


19

Occasionally you may need to have ineffective flow areas remain ineffective permanently. The ineffective flow areas can be set to the permanent mode individually from the cross section editor, or through a table from the geometric data editor.

In this example, the same ineffective flow areas were used except they were set to permanent. As seen in the slide when the water surface is below the trigger elevation the permanent ineffective flow area behaves like the non-permanent area.

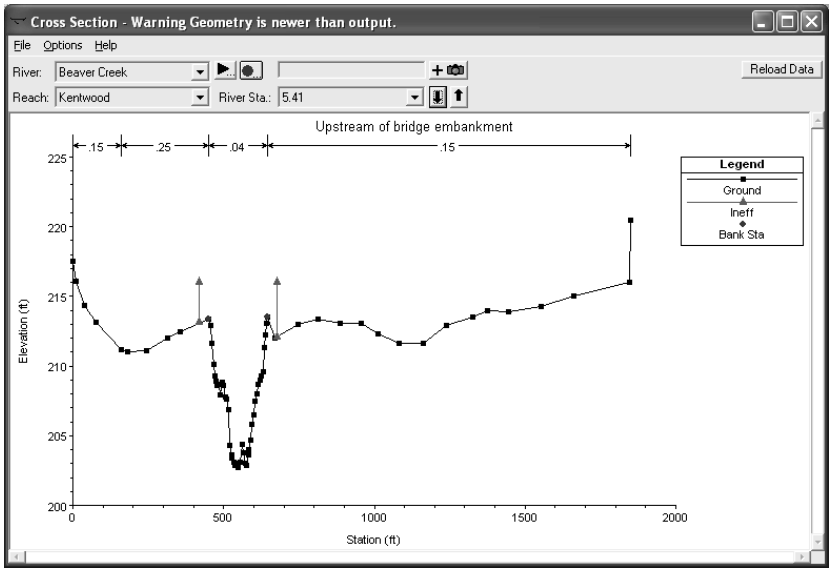
Permanent Ineffective Flow Area



20

For permanent ineffective flow areas, when the water surface elevation surpasses the trigger elevation, the area below the trigger elevation remains ineffective. Water above the trigger elevation is assumed to convey flow.

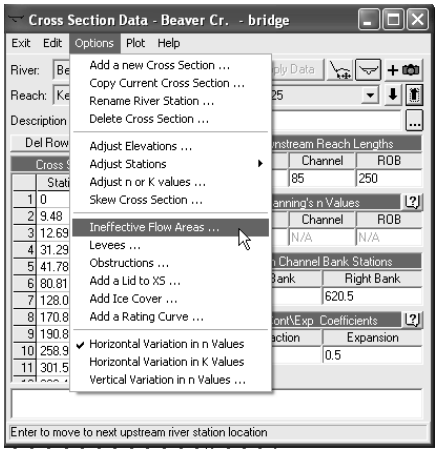
Normal Ineffective Flow Areas

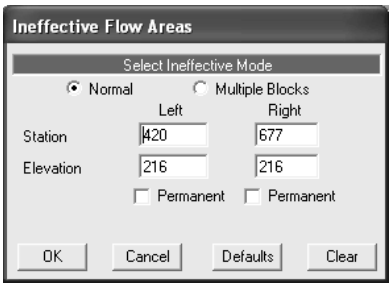


21

The normal ineffective flow area option allows the user to define a left station and elevation and a right station and elevation (normal ineffective areas). When this option is used, and if the water surface is below the established ineffective elevations, the areas to the left of the left station and to the right of the right station are considered ineffective.

Normal Ineffective Flow Areas

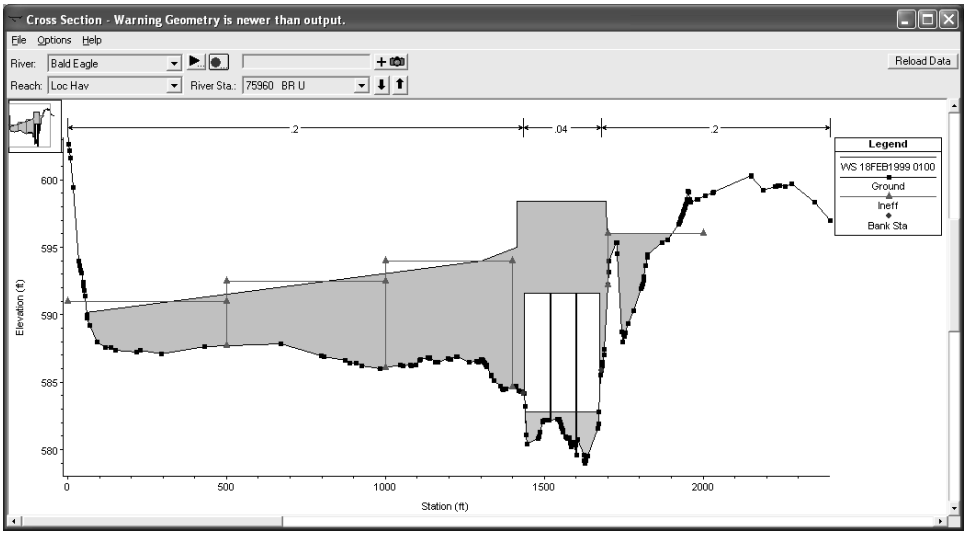




22

Set the normal ineffective flow area locations by selecting **Ineffective Flow Areas** under the **Options** menu of the **Cross Section Data Editor**. In the ineffective flow area window, select the radio button labeled **Normal**. Notice the box labeled **Permanent**, check this box if the ineffective flow area never conveys flow.

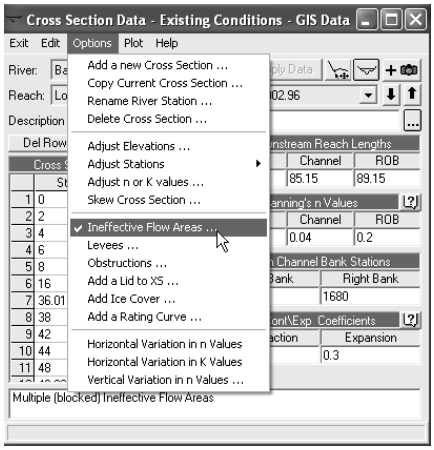
Blocked Ineffective Flow Areas

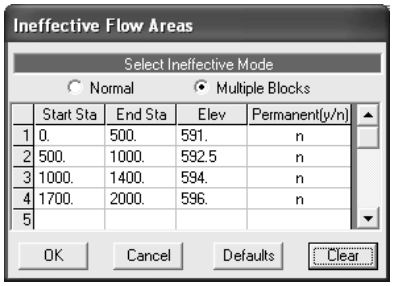


23

The multiple block ineffective area option allows for the establishment of blocked ineffective flow area . Multiple blocked ineffective flow areas are useful for bridge geometry with slopes or multiple openings.

Blocked Ineffective Flow Areas





24

Blocked ineffective flow areas require the user to enter an elevation, a left station, and a right station for each ineffective block. Up to ten blocked ineffective flow areas can be entered at each cross section. Notice the column labeled **Permanent (y/n)**, change this column to “y” for permanent ineffective flow areas.

Entering Geometric Parameters

- Manning's n Values
- Ineffective Flow Areas
  - Non-Permanent vs. Permanent
  - Normal vs. Multiple Blocks
- Blocked Obstruction
- Levees

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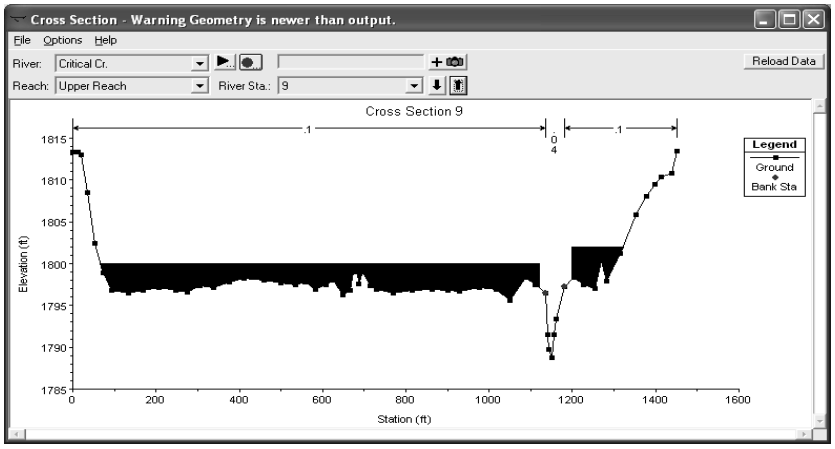
Blocked Obstructions



- Decrease Flow Area
- Add Wetted Perimeter

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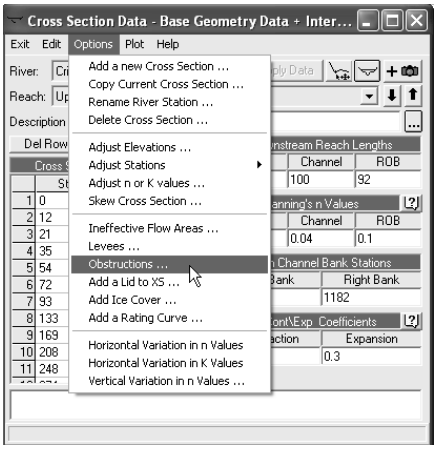
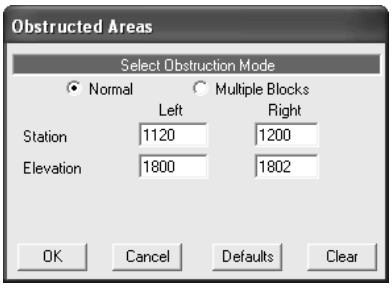
Blocked obstructions allow the user to define areas of the cross section that will be permanently blocked out. Blocked obstructions decrease flow area and add wetted perimeter when the water comes in contact with the obstruction. A blocked obstruction does not prevent water from going outside of the obstruction.

Blocked Obstructions





27

The user may define a left station and elevation and a right station and elevation (normal blocked areas). When this option is used, the area to the left of the left station and to the right of the right station will be completely blocked out.

Entering Geometric Parameters

- Manning's n Values
- Ineffective Flow Areas
  - Non-Permanent vs. Permanent
  - Normal vs. Multiple Blocks
- Blocked Obstruction
- Levees

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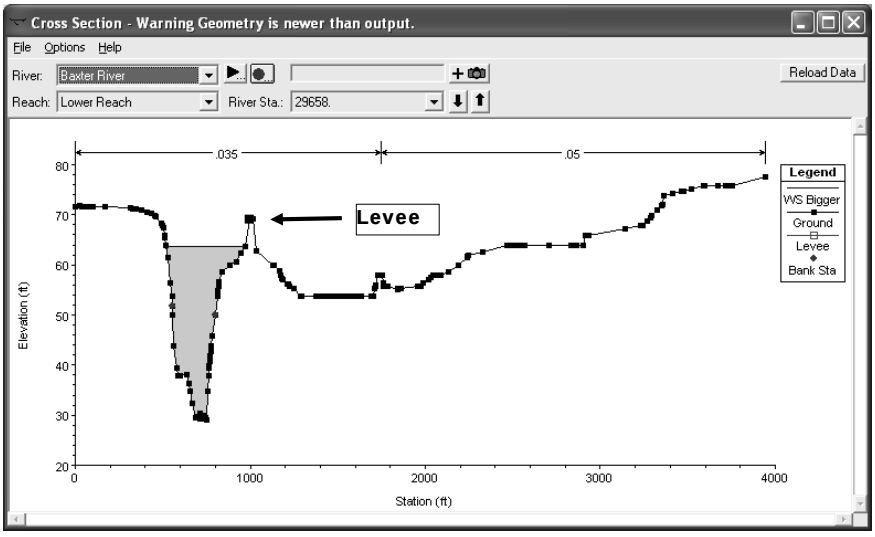
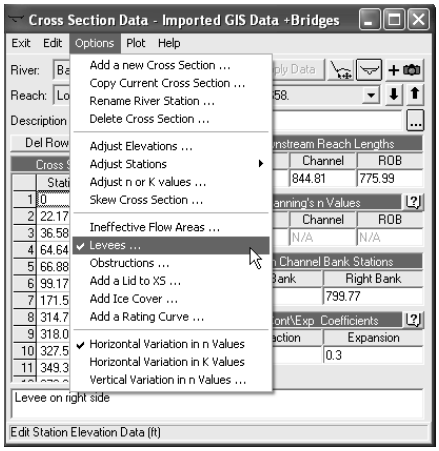
Levees

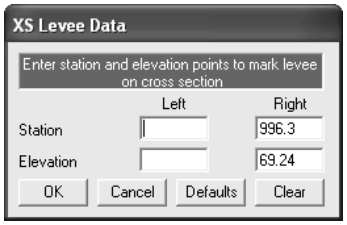


29

This option allows the user to establish a left and/or right levee station and elevation on any cross section. When levees are established, no water can go to the left of the left levee station or to the right of the right levee station until either of the levee elevations are exceeded. Levee stations must be defined explicitly, or the program assumes that water can go anywhere within the cross section. An example of a cross section with a levee on the left side is shown in the figures. In this example the levee station and elevation is associated with an existing point on the cross section.

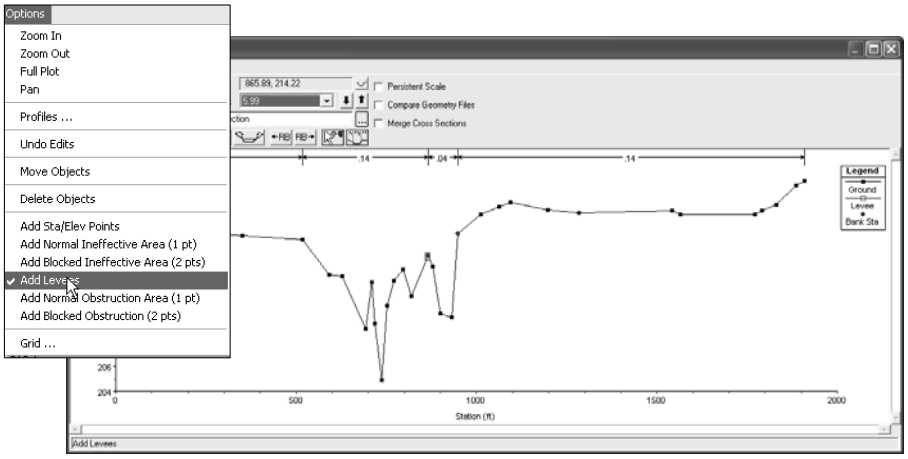
Levees


Cross Section Data - Imported GIS Data +Bridges
Exit
Edit
Options
Plot
Help
River:
Reach:
Description
Add a new Cross Section ...
Copy Current Cross Section ...
Rename River Station ...
Delete Cross Section ...
Adjust Elevations ...
Adjust Stations
Adjust n or K values ...
Skew Cross Section ...
Ineffective Flow Areas ...
Levees ...
Obstructions ...
Add a Lid to XS ...
Add Ice Cover ...
Add a Rating Curve ...
Horizontal Variation in n Values
Horizontal Variation in K Values
Vertical Variation in n Values ...
Channel
ROB
844.81
775.99
N/A
N/A
Right Bank
799.77
Expansion
0.3
Levee on right side
Edit Station Elevation Data (ft)


XS Levee Data
Enter station and elevation points to mark levee on cross section
Left
Right
Station
996.3
Elevation
69.24
OK
Cancel
Defaults
Clear

30

Graphical Cross Section Editor



Located in the **Geometric Data Editor** under the **Tools** menu.

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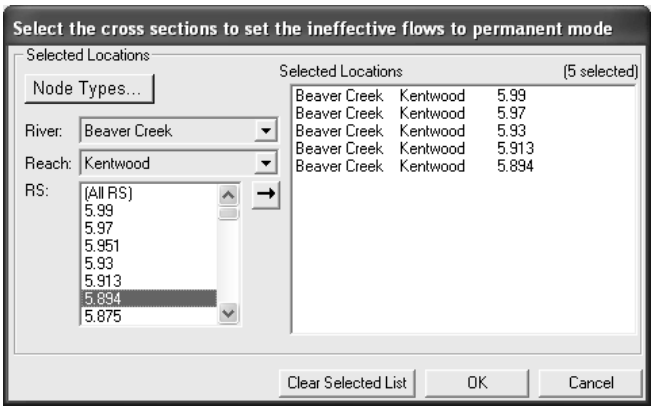
A graphical cross section editor is available from the **Tools** menu of the **Geometric Data Editor**. The user has the option to move objects (objects are ground points, main channel bank stations, ineffective flow areas, levees, and blocked obstructions), delete objects, or add new objects.

To move an object, the user first selects **Move Objects** from the **Options** menu. Then move the mouse pointer over the object that you want to move, press down the left mouse button, and then move the object. When you are finished moving the object, simply release the left mouse button and the object will be moved. To delete an object, first select **Delete Objects** from the **Options** menu. Next, move the mouse pointer over the object that you would like to delete and click the left mouse button. Whatever object is closest to the mouse pointer will be deleted. To add an object to the cross section, first select the type of object you want to add from the available list under the **Options** menu. Once you have selected an object type to add, move the mouse pointer to the location where you would like to add it and click the left mouse button. If the object that you are adding requires more than one point, such as blocked ineffective flow areas and blocked obstructions, then continue to move the mouse pointer and click the left mouse button to add the additional points.

Setting Ineffective Areas to Permanent



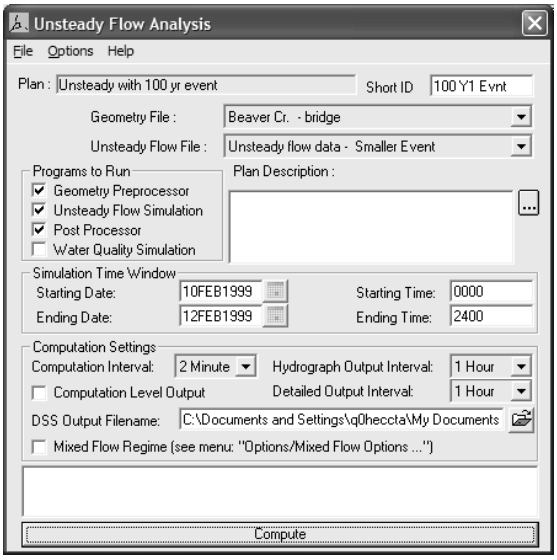
Located in the **Geometric Data Editor** under the **Tools** menu.

32

The default in HEC-RAS is to set ineffective flow areas to non-permanent. To change a set of river stations from non-permanent to permanent, select **Setting Ineffective Areas to Permanent Mode…** under the **Tools** menu located in the **Geometric Data Editor**. Then select the proper river, reach, and river stations.

This is especially useful after using the **Graphical Cross Section Editor** because there is no option in the editor to change between non-permanent and permanent.

Geometry Preprocessor



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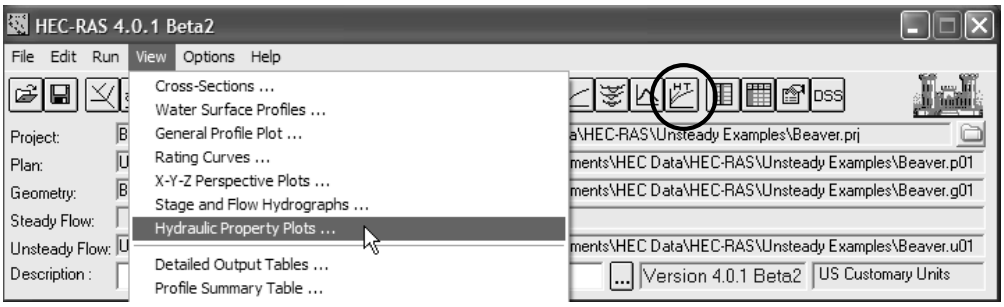
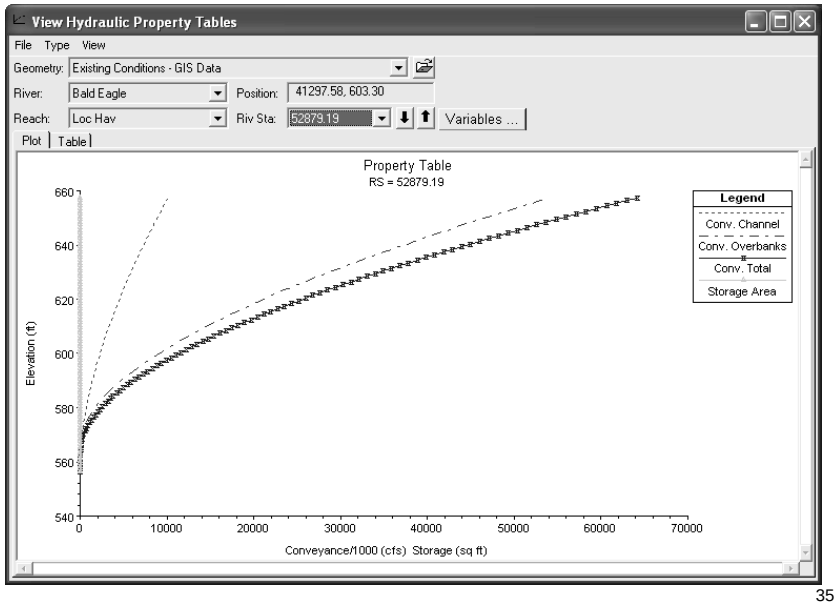
The geometric preprocessor is located in the **Unsteady Flow Analysis Window**, found from the main program window under the **Run** menu.

Hydraulic Property Tables



View output from the geometric preprocessor by examining the hydraulic property tables and plots. The output is located under the **View** menu, or the shaded button in the figure.

Hydraulic Property Plot



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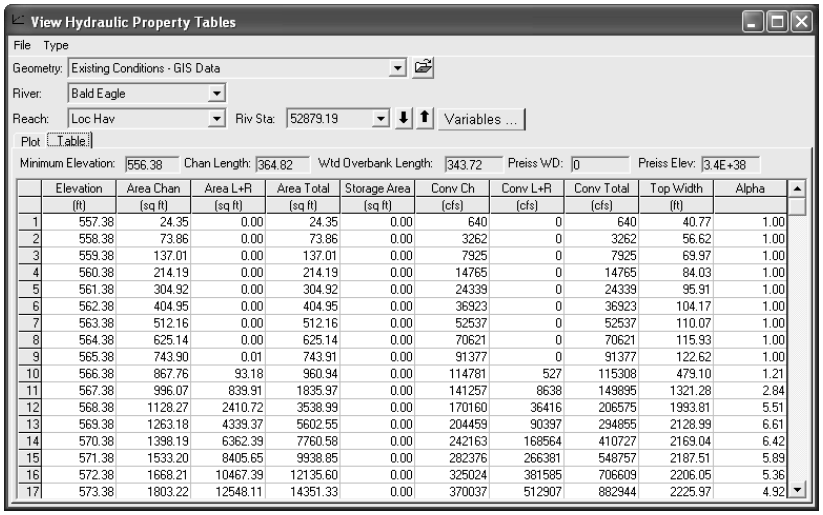
Output can be viewed in graphical form. Viewing the graphical output is a good diagnostic tool for examining cross section geometry. The relationship of area, storage, and conveyance should be examined for abrupt changes with elevation. Any abrupt changes should be reviewed to determine the overall significance within that particular model.

Hydraulic Property Table



	Elevation	Area Chan	Area L+R	Area Total	Storage Area	Conv Ch	Conv L+R	Conv Total	Top Width	Alpha
	(ft)	(sq ft)	(sq ft)	(sq ft)	(sq ft)	(cfs)	(cfs)	(cfs)	(ft)	
1	557.38	24.35	0.00	24.35	0.00	640	0	640	40.77	1.00
2	558.38	73.86	0.00	73.86	0.00	3262	0	3262	56.62	1.00
3	559.38	137.01	0.00	137.01	0.00	7925	0	7925	69.97	1.00
4	560.38	214.19	0.00	214.19	0.00	14765	0	14765	84.03	1.00
5	561.38	304.92	0.00	304.92	0.00	24339	0	24339	95.91	1.00
6	562.38	404.95	0.00	404.95	0.00	36923	0	36923	104.17	1.00
7	563.38	512.16	0.00	512.16	0.00	52537	0	52537	110.07	1.00
8	564.38	625.14	0.00	625.14	0.00	70621	0	70621	115.93	1.00
9	565.38	743.90	0.01	743.91	0.00	91377	0	91377	122.62	1.00
10	566.38	867.76	93.18	960.94	0.00	114781	527	115308	479.10	1.21
11	567.38	996.07	839.91	1835.97	0.00	141257	8638	149895	1321.28	2.84
12	568.38	1128.27	2410.72	3538.99	0.00	170160	36416	206575	1993.81	5.51
13	569.38	1263.18	4339.37	5602.55	0.00	204459	90397	294855	2128.99	6.61
14	570.38	1398.19	6362.39	7760.58	0.00	242163	168564	410727	2169.04	6.42
15	571.38	1533.20	8405.65	9938.85	0.00	282376	266381	548757	2187.51	5.89
16	572.38	1668.21	10467.39	12135.60	0.00	325024	381585	706609	2206.05	5.36
17	573.38	1803.22	12548.11	14351.33	0.00	370037	512907	882944	2225.97	4.92

36

Detailed output is also available for each computed increment. Detailed output can be examined to determine a specific elevation or station where a problem is occurring.

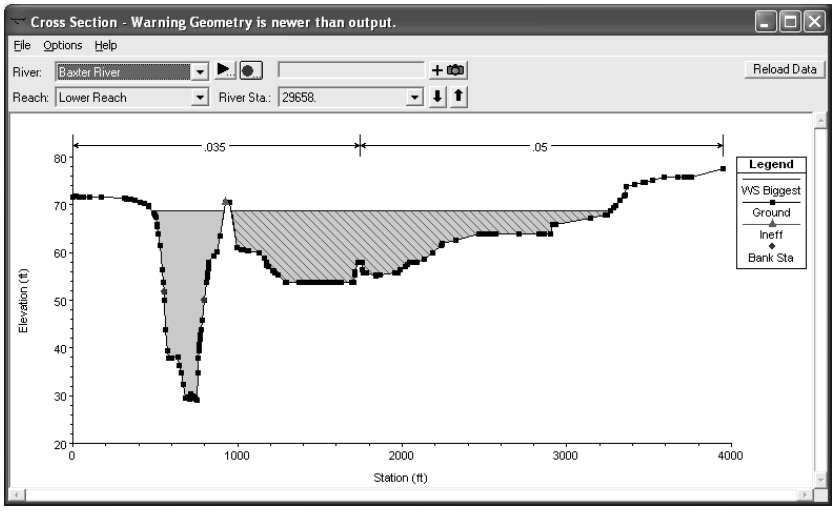
Geometry and Unsteady Flow

- What is going to happen to the water when it gets out of the channel?
  - Ineffective Flow Areas
  - Levees
  - Conveyance Calculations Using Subdivisions

37

When examining geometry, the user must consider where water may leave the main channel and how it will behave once out of the main channel. Knowing these factors gives the user a general idea of how to correctly model the situation within the framework of HEC-RAS.

Ineffective Flow Areas

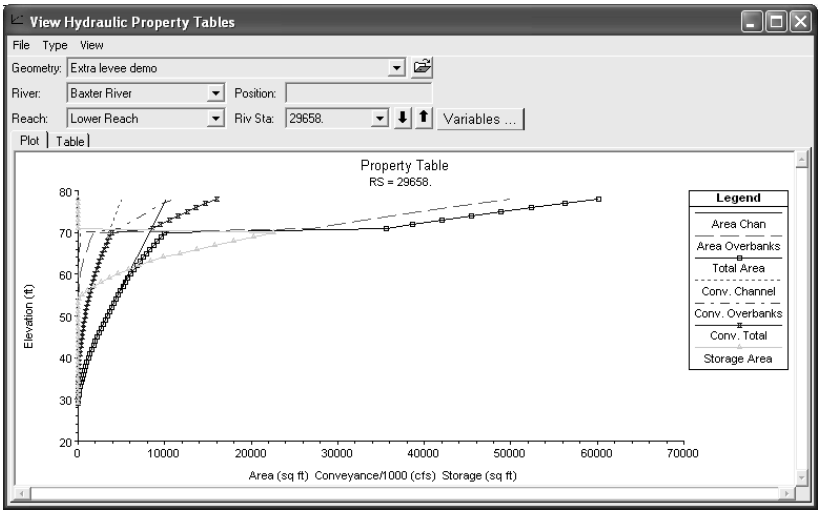


38

As seen in the figure, there is water in the right overbank. Because RAS is a one-dimensional model, the water surface elevation will be the same for the entire cross section. The user must determine if water can physically enter the right overbank at this cross section by examining upstream and downstream cross sections.

If water will enter the right overbank then the user must determine how to model this area.

Non-Permanent Ineffective Flow

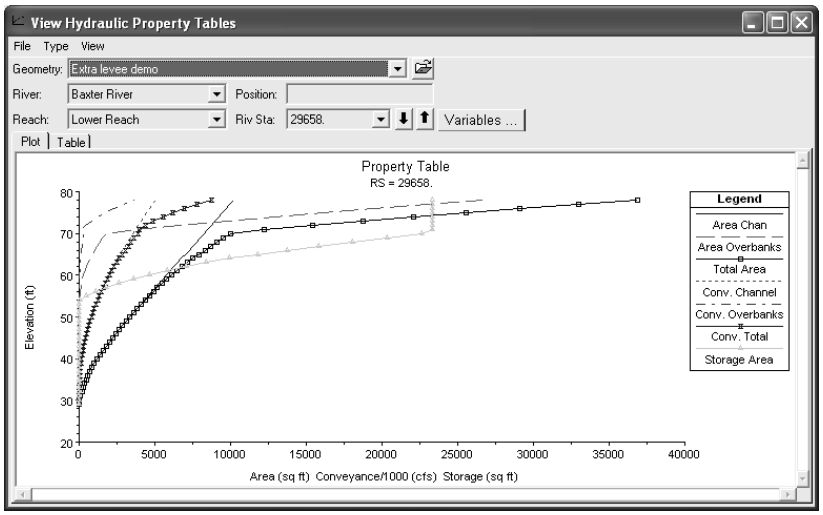


39

The figure above represents the previous cross section with the right overbank modeled as non-permanent ineffective flow. As seen on the figure, the storage in the cross section increases until reaching the trigger elevation where the ineffective flow area is turned off. By turning off the ineffective flow area the storage in the cross section returns to zero and the area of the cross section increases.

If the water level could possibly reach the trigger elevation then this is probably not the proper way to model this cross section. The change in volume of storage, and the change in area of the cross section, is too significant to model with a non-permanent ineffective flow area.

Permanent Ineffective Flow Area

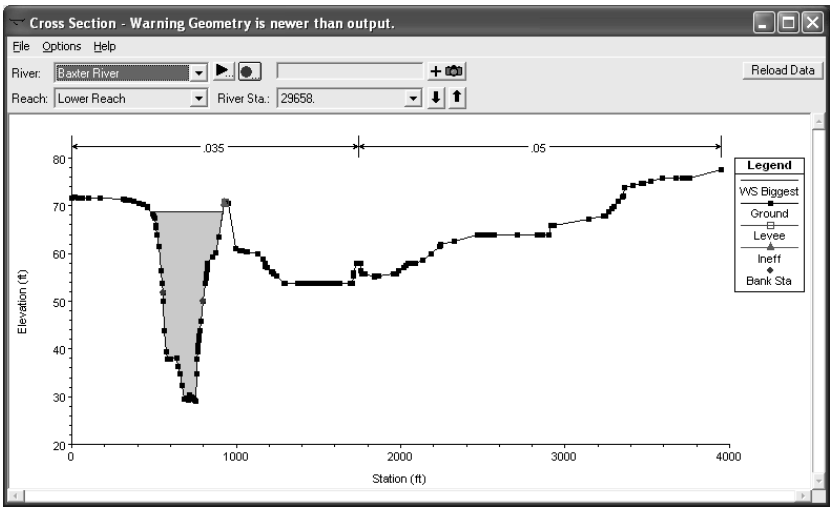


40

The figure above represents the previous cross section with the right overbank modeled as permanent ineffective flow. As seen on the figure, the storage in the cross section increases until reaching the top of the ineffective flow area where it remains constant.

If the water level could possibly reach the trigger elevation, while remaining relatively stationary, then this is probably a better representation compared to a non-permanent ineffective flow area.

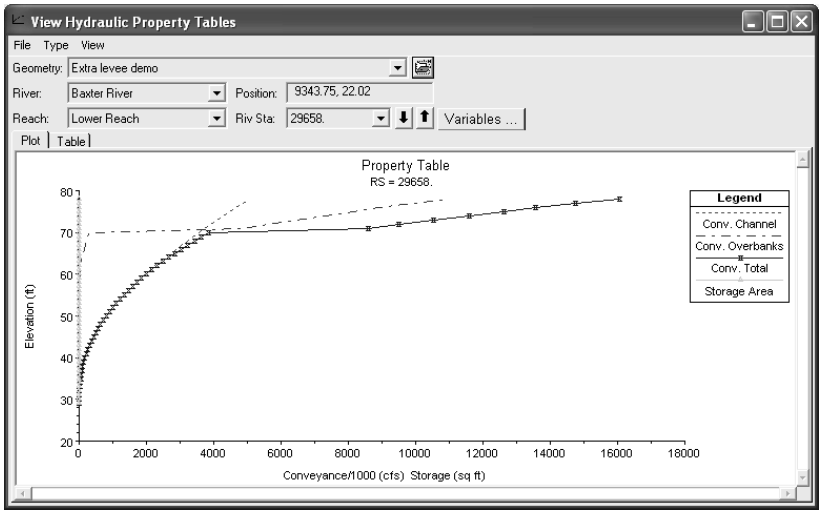
Levees



41

If it is determined that water will not enter the right overbank, then the area should be modeled with a levee. When the levee is established, no water can go to the right of the right levee station until the levee elevation is exceeded.

Levees



42

As seen on the figure, if the levee elevation is exceeded there will be an extremely large increase in conveyance with elevation for this geometry. This would not be the proper way to model the cross section if the levee is overtopped. Keep in mind that the magnitude of conveyance on the x-axis is divided by 1000.

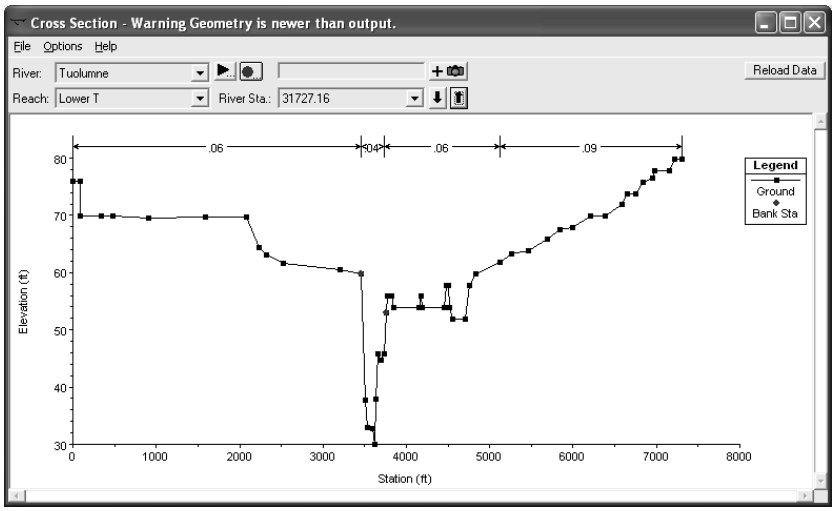
Storage Area Option

- What if adding a levee or ineffective flow area has a significant affect on the conveyance and storage relationships?
  - Alter the cross section by terminating it at the beginning of the problem area.
  - Model the area that was deleted with a lateral weir and off-stream storage area.
  - Storage areas will be discussed in impending lectures.

43

If the cross sectional geometry denotes a significant change in storage or conveyance when a levee is overtopped then this cross section should be altered. The cross section should be terminated at the levee and the area that was deleted should be modeled as a storage area. Abrupt and significant changes in storage and conveyance should be avoided because they can cause instabilities in the unsteady flow model.

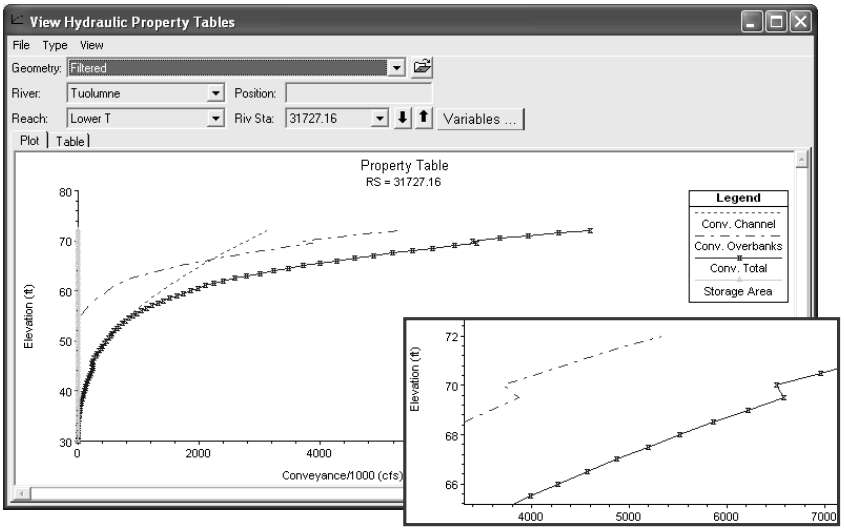
Conveyance Subdivisions



44

As shown in the figure above, there is a distinct increase in elevation located at station 2000. The entire left bank is being modeled with one Manning's n value. Remember that RAS computes the left and right overbank conveyances using subdivision of Manning's n.

Conveyance Subdivisions

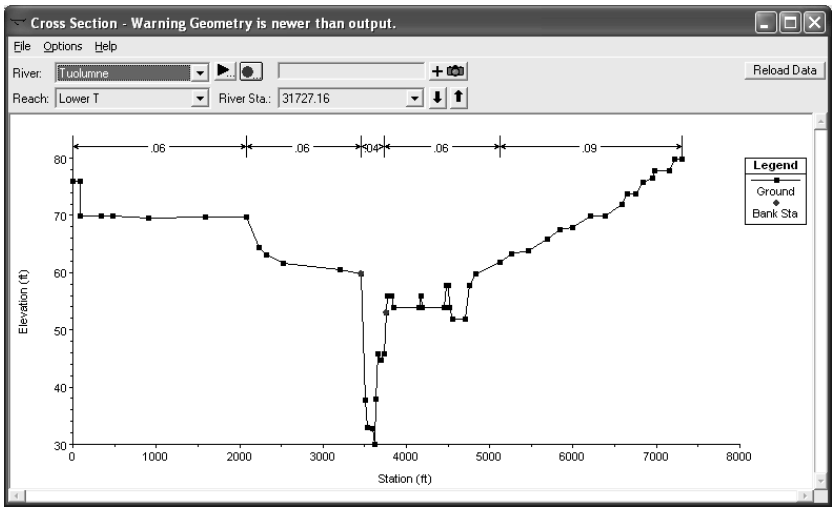


45

As seen in the figure, there is a hitch in the increase of conveyance with elevation at just above 75 feet. This corresponds to the steep increase in elevation located at station 2000 on the previous figure.

HEC-RAS uses Manning's equation to calculate conveyance. Imbedded in this equation are relationships for channel depth, channel area, and wetted perimeter. In this example, when the calculations go just above the elevation of 75 feet, Manning's equation sees an enormous increase in wetted perimeter for a minute increase in water depth. The conveyance answer found from this calculation is dramatically different from the conveyance answer found at the previous calculation below 75 feet.

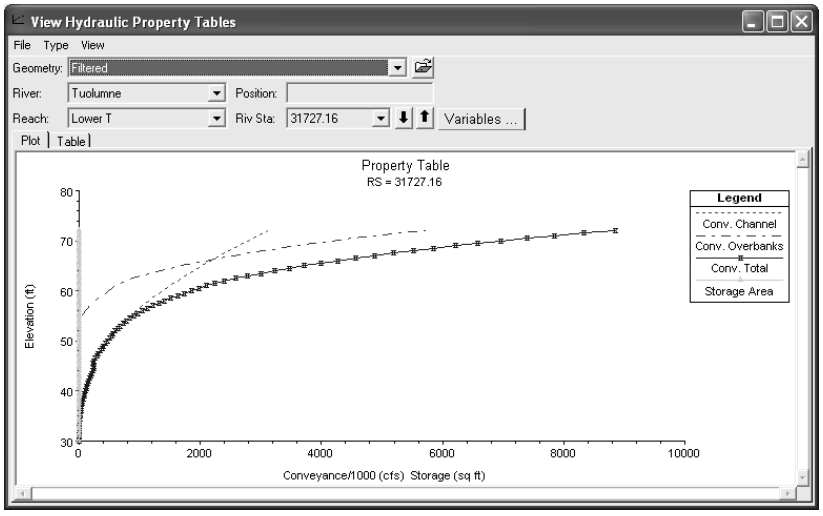
Conveyance Subdivisions



46

To account for this situation, a subdivision made by inserting another Manning's n value must be added at the point of discontinuity. The value does not need to be different, as long as the subdivision is present, RAS will calculate separate conveyances for the geometry.

Conveyance Subdivisions



47

As seen on the figure, this subdivision for the left overbank smoothed the relationship between conveyance and elevation.

Questions?

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