HYDRAULIC ENGINEERING USING HEC-RAS

1 - Theory and Background

In this section the student is instructed to solve a series of site specific natural stream flooding examples. The illustrative examples range from the determination of backwater curves for a simple stream network to the solution of stream elevations with culvert and bridge crossings. In all of these examples, the computer program HEC-RAS is used to determine stream widths, elevations and flows.

This section has an introduction where the basic elements of HEC-RAS are given, with a description of the mathematical and physical principles used and the special features of the program. This is followed by a presentation of the main elements of the program, data requirements, geometric data, boundary conditions, etc. Then each illustrative example is given with the procedure outlines and figures of the windows shown on the computer, as well as tables with data input. A complete set of the windows input data is given and, in some cases, blank windows are given to show how the data should be input to the program.

The examples have figures of cross sections, longitudinal and perspective views of the stream flows. The output is tabulated in a report at the end of each example; stream velocities, discharge, critical water surface, elevations, etc. are given.

The Hydrologic Engineering Center River Analysis System (HEC-RAS) is intended for calculating water surface profiles for steady gradually varied flow in nature or man-made channels. This water surface engineering software package (Army Corps. Eng. (1995)) will replace the HEC-2 backwater and ultimately the HEC-6 erosion and sedimentation programs. HEC-RAS program will import HEC-2 input data files and perform a hydraulics analysis yielding the same results as the HEC-2 model.

The HEC-RAS computer model has a large number of options, such as mixed flow regime analysis, allowing analysis of both sub- and supercritical flow regimes in a single computer run, culvert and bridge routines allowing for multiple openings of different types and sizes, quasi 2-D velocity distributions, and x-y-z graphics of the river channel system.

HEC-RAS operates under the MS-Windows environment (version 3.1 or Windows 95) and provides state-of-the-art Graphical User Interface (GUI) graphics for both input and output.

MODEL USERS BACKGROUND

A description of the HEC-RAS model and its use is given in a site example. There will be little instruction on the hydraulics to determine the computer input parameters. The user should have taken a first course where open-channel hydraulics are discussed. A number of references (Chow (1959), French (1985), Linsley, et. al. (1992)) are given for review purposes.

HYDRAULIC ANALSYSIS

The HEC-RAS model can handle a full network of channels, a branching system, or a single river reach. The steady flow component is capable of modeling subcritical, supercritical and mixed flow regime water surface profiles.

The solution of the one-dimensional energy equation is used as the basic computational procedure. The flow in natural and man-made channels is estimated by the use of the one-dimensional Manning Equation (see Chow (1959)). Energy losses are evaluated by friction and contraction/expansion (coefficient multiplied by the change in velocity head). Where the water surface profile is rapidly varied, the momentum equation is utilized. By the use of these equations, the program can handle hydraulic jumps, hydraulics of bridges, and evaluate stream profiles.

The program can also be used to determine the effects of various obstructions such as bridges, culverts, and structures in the flood plain. Flood plain management and flood insurance studies to evaluate floodway encroachments may be evaluated by the steady flow system component of the program. Also, capabilities are available for assessing the change in water surface profiles due to the channel improvements, levees, and ice cover.

Special features of the steady-flow component include: multiple plan analysis; multiple profile components; and multiple bridge and/or culvert opening analysis.

DATA REQUIREMENTS

The function of the HEC-RAS program is to determine water surface elevations at all locations of interest. The data needed to perform these computations are separated into geometric data and steady flow data (boundary conditions).

GEOMETRIC DATA

The basic geometric data consists of establishing how the various river reaches are connected (River System Schematic); cross section data; reach lengths; energy loss coefficients (function losses, contraction and expansion losses); and stream junction information. Hydraulic structure data (bridges, culverts, etc.) will be covered in this module (see the illustrative examples for details).

THE RIVER SYSTEM SCHEMATIC

The schematic defines how the various river reaches are connected. The program can handle simple single reach modules or complex networks. The river system schematic is developed by drawing and connecting the various reaches of the system within the geometric data editor (see the following sections on input data and the illustrative examples). This schematic data must be the first input into the HEC-RAS model.

Each river reach on the schematic is given a unique identifier. Each cross section in a reach must use the unique “reach” identifier as well as a “river station” identifier. The user is required to draw each reach from upstream to downstream, in what is considered to be the positive flow direction. The connection of reaches are considered junctions and must be numbered. Junctions should be established at locations where two or more streams come together or split apart. Junctions should not be established with a single reach flowing into another single reach.

CROSS SECTION GEOMETRY

Boundary geometry for the analysis of flow in natural streams is specified in terms of ground surface profiles (cross sections) and the measured distances between them (reach lengths). Cross sections should be perpendicular to the anticipated flow lines and extend across the entire flood plain (these cross sections may be curved or bent).

Cross sections are requires at locations where changes occur in discharge, slope, shape or roughness; at locations where levees begin or end and at bridges or control structures such as weirs.

Each cross section is identified by a Reach and River Station label. The cross section is described by entering the station and elevations (x-y data) from left to right, with respect to looking in the downstream direction. When numbering River Station Identifiers, assume the higher numbers are upstream and the lower numbers are downstream within a reach.

Each data point in the cross section in a given station number corresponding to the horizontal distance from a starting point on the left. Stationing must be entered from left to right in increasing order (see the illustrative example for the details).

REACH LENGTH

The reach length (distance between cross sections) should be measured along the anticipated path of the center of mass of the left and right overbank and the center of the channel (these distances may be curved).

MANNING'S *n*

The value of *n* depends on: 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. Three values of *n* will be selected for each cross section in the following illustrative example; *n* for the left and right overbank and *n* for the center of the channel, see Chow (1959) and French (1985) for selection of numerical values of *n*.

CONTRACTION AND EXPANSION COEFFICIENTS

Contraction or expansion of flow due to changes in the cross section is a cause of energy loss between cross sections. The loss may be computed from the contraction and expansion coefficients specified on the cross section data editor. Refer to references Army Corps. of Eng. (1995), Chow (1959) and French (1985) for these coefficients.

STREAM JUNCTION DATA

Junction data consists of reach lengths across the junction and tributary angles (only if the momentum equation is selected). In the following illustrative examples, the energy equation was used to model the junction. The energy equation does not take into account the angle of any tributary. In most cases, the amount of energy loss due to the angle of the tributary flow is not significant.

FLOW REGIME

The flow regime must be specified on the Steady Flow Analysis window of the user interface. Computations are used upstream for subcritical flow and downstream for supercritical flow. In cases where the flow regime will pass from subcritical to supercritical or supercritical to subcritical, the program should be run in a mixed flow regime mode.

BOUNDARY CONDITIONS

Boundary conditions are necessary to establish the starting water surface elevations (WS) at the ends of the river system. The WS is only necessary at the downstream end for subcritical regime, the WS is only necessary at the upstream end for the supercritical regime, and the WS is necessary for both downstream and upstream for the mixed flow regime. Boundary conditions are not necessary at junctions.

DISCHARGE DATA

Discharge information is required at each cross section starting from upstream to downstream for each reach. The flow rate can be changed at any cross section within a reach.

SOFTWARE ACQUISITION AND INSTALLATION

The HEC-RAS program can be obtained from the Internet at:

http://www.wrc-hec.usace.army.mil/software/software.html

The HEC-RAS manual published by the Army Corps of Engineers is also available at this site. The installation instructions are given on the Internet.

ILLUSTRATIVE EXAMPLES

In this section there are four illustrative examples:

1) Stream Network Analysis: The flooding analysis of a stream network located in New Braintree, Massachusetts is given in the first example.
2) Bridge Analysis: In the second example, a bridge is placed across one of the tributaries in example one and the backwater curves are determined.
3) Culvert Analysis: The flooding of the stream network given in example one is determined with the addition of a culvert in one of the tributaries.
4) Encroachment Analysis: In this last example, the backwater curves are determined for obstructions placed in one of the tributaries in the stream network in example one.

2 - References

1. Chow, V.T.: *"Open Channel Hydraulics"*, McGraw Hill, New York: 1959.
2. French, R.H.: *"Open Channel Hydraulics"*, McGraw Hill, New York ,1985.
3. *"HEC-RAS River Analysis System"*, U.S. Army Corps or Engineers, Davis, California, 1995
4. Linsley, R., Franzini, J., Freyberg, D., and Tchobanoglous, G.: "*Water Resource Engineering"*, McGraw-Hill, New York, 1992.

3 - Example 1: HECRAS Water Surface Profile

In this example, determination of the flooding of a stream will be illustrated.

1. If you are using Windows 3.x, at the DOS prompt type win to enter Windows then find the HEC-RAS folder and double click on the HEC-RAS icon to run the program. If you are using Windows 95, find the HEC-RAS folder in the Start Menu and click on HEC-RAS to start the program.
2. Using the mouse select New Project from the File pull down menu in the main HEC-RAS window (Figure 1).

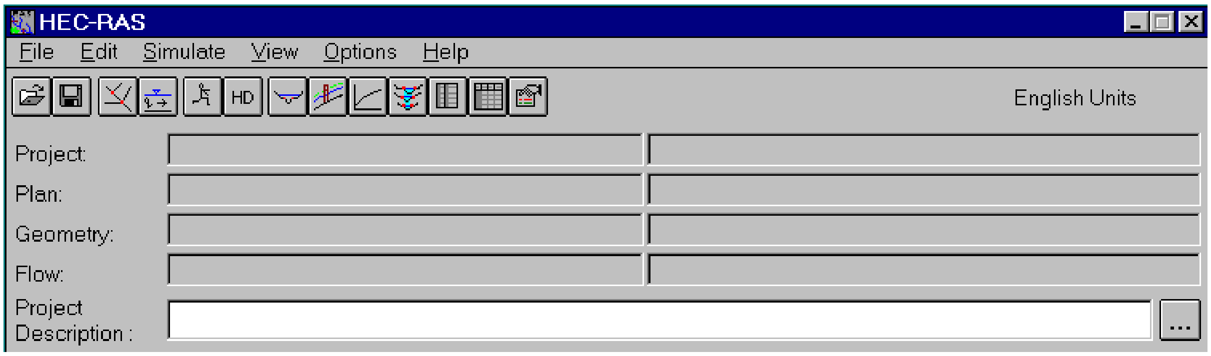

Figure 1 HEC-RAS Main Window

3. Select a drive, and select a path by double clicking in the directory box of the New Project window. For this example, double click on the data subdirectory for c:\hecras\data. Enter a title and an eight (8) character filename (with a .prj extender) in the respective boxes for the project. For this example, the title is Winimusset Brook, and the filename is winmst.prj Click OK when complete. A dialog box will appear to confirm your selection. Press OK to continue, or Cancel to start over.
4. The English System of units is the default. To use the Metric System, select Unit System from the Options pull down menu in the main HEC-RAS window to change from the English System to the Metric System.
5. Select Geometric data from the Edit pull down menu in the main HEC-RAS window.
6. In the Geometric Data window, click on the River Reach tool with the mouse and draw the following river schematic by clicking the left mouse button and dragging the reach in the direction of the flow (Figure 2). Double-click the mouse to end the reach. Give each reach a name. When two reaches meet, you will be prompted to enter the name of the junction.
7. Click on the Cross Section tool on the left side of the Geometric Data window.
8. In the Cross Section Data window (Figure 3), click on the Reach pull-down menu to choose the reach in which to enter cross section data.

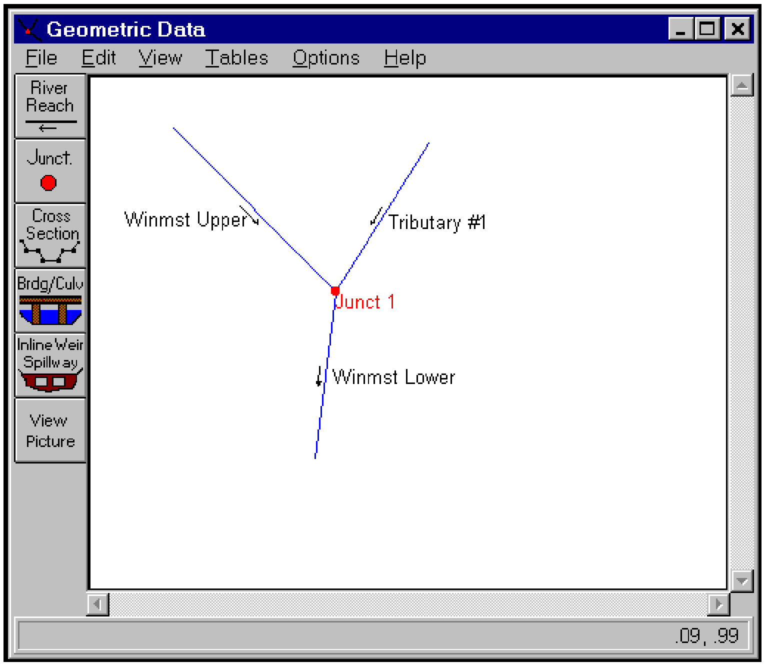

Figure 2 Completed Geometric Data Screen

9. Select Add a new Cross Section from the Options pull down menu in the Cross Section Data window and enter the river station label. HEC-RAS requires that river cross-sections be entered starting upstream using the highest number as a "river station" label and proceeding downstream in the direction of flow (Figure 3).

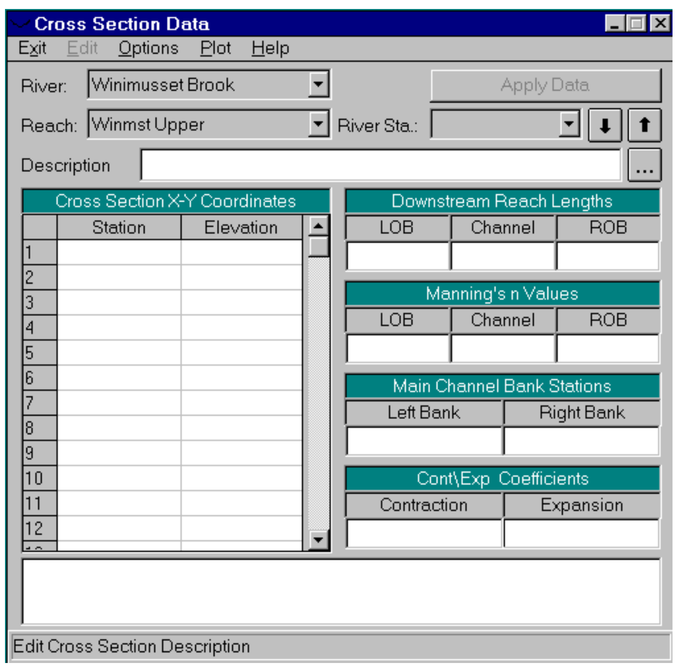

Figure 3: Cross Section Data Screen

10. Enter cross section station and elevation data, downstream reach lengths, Manning's n Values, Main Channel Bank Stations, Contraction/Expansion Coefficients and an optional description (Figure 4). Cross-sections should be taken perpendicular to the flow. The cross section X-Y Coordinates are selected as follows:

    A. For the first station, start from the left of the stream looking downstream, enter a length of zero in the station column station and its corresponding elevation. This station should be above the main channel and flow area.

    B. Subsequent station lengths are all measured from the first station. Enter the corresponding elevations for each station.

    C. The last station is on the right of the river valley, above the main channel and flow area.

    Click on Apply Data to accept entry for this cross-section (Figure 4). Select Plot Cross Section from the Plot pull down menu to visually check cross-section for errors.

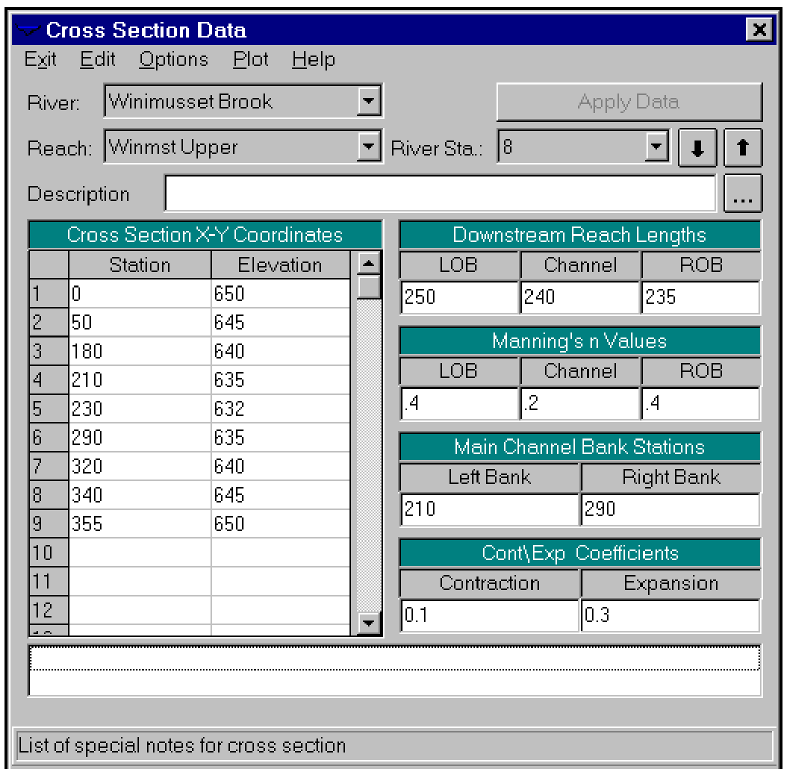

Figure 4: Example of Cross Section Data Entry

11. Repeat Steps 9 and 10 until all stations for the present reach are entered. Then, change the Reach using the Reach pull-down menu and enter data for the rest of the reaches. Press the apply data button after each cross section is entered. Table 1 lists the data for the remaining cross sections and reaches.

12. After all the cross section data is entered, select Exit Cross Section Editor from the Exit pull down menu in the Cross Section Data window.

13. From the geometric data window, choose the junction tool to edit junction data. Enter the length across the junction for each reach (see Figure 5). Select Energy as the computation mode and click on OK to return to the Geometric Data window.

Reaches	Length (ft)
Tributary #1 to Winmst Lower	250
Winmst Upper to Winmst Lower	175

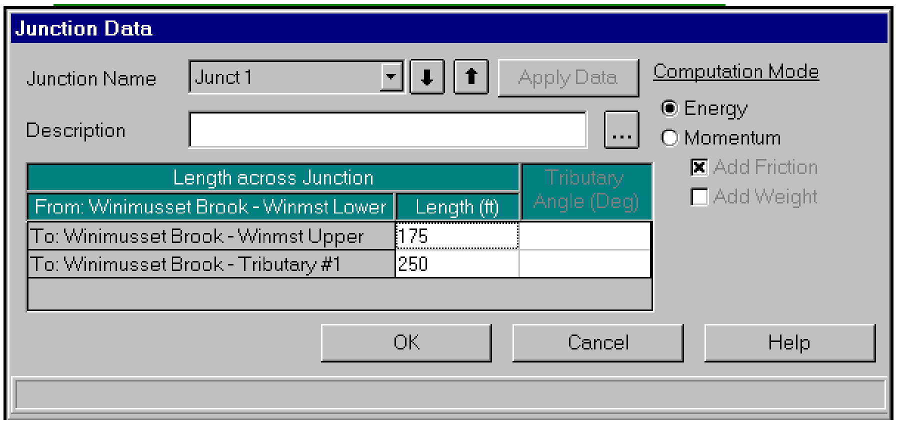

Figure 5 Junction Data Editor

14. In the geometric data window, select Exit Geometry Data Editor from the File pull down menu to return to the main HEC-RAS window.

15. In the main HEC-RAS window, select Steady Flow Data from the Edit pull down menu to enter flow and boundary conditions. Enter a 2 in the "Number of profiles to be calculated" input for the two profiles modeled in this example (Figure 6). Enter the flow at the farthest upstream station of each reach for each profile to be modeled. Once a flow value is entered at the upstream end of a reach, it is assumed that the flow remains constant until another flow value is encountered. For example, if the flow is 100cfs at station 7, and an additional 20cfs enters the stream at station 5, then the flow at station 5 must be entered as 120cfs. In this example, 10 cfs will be added to Tributary #1 at station number 2, to bring the flow in Tributary #1 from 19 cfs to 29 cfs. Select the correct reach and new flow change station by using the Reach and Station pull down menus in the Steady Flow Data window, press Add A Flow Change Location, and enter the new flow at that station.

16. Click on the Reach Boundary Conditions button in Figure 6 to enter the steady flow boundary conditions window (Figure 7). Since we are computing multiple water surface profiles, click on Set Boundary for one profile at a time. Figure 8 will appear on the screen.

Sta.	Length of Reach			Mannings n			Main Sta.		Cont/Exp Coeff.		Cross Section Data
	LOB	Chan	ROB	LOB	Chan	ROB	LOB	ROB	Cont.	Exp.	Station/Elevation

Winmst Upper

8											
7											
6											
5											
4											
3											
2											
1											

Tributary #1

4											
3											
2											
1											

Winmst Lower

3											
2											
1											

TABLE 1 Cross Section Data – To Be Completed By Student

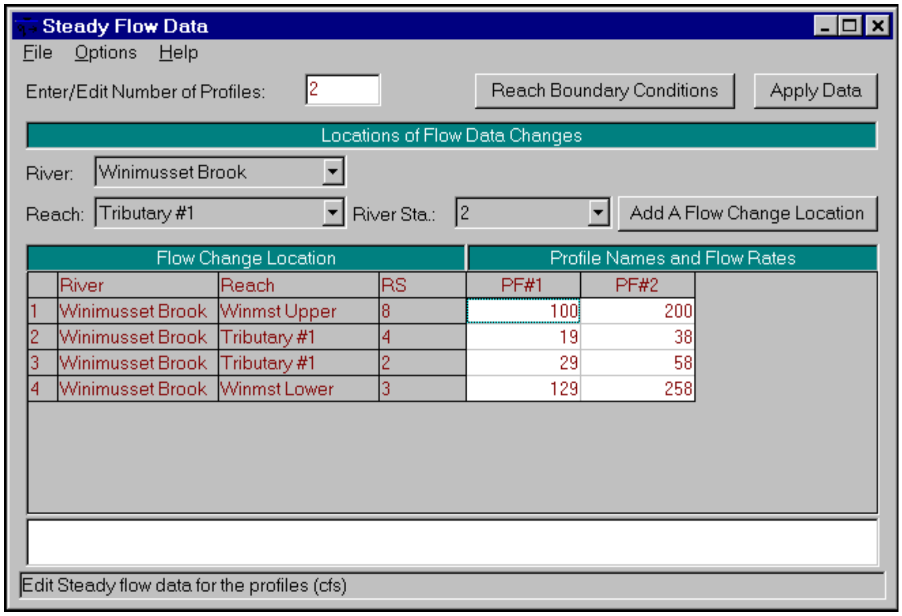

Figure 6: Steady Flow Data Window

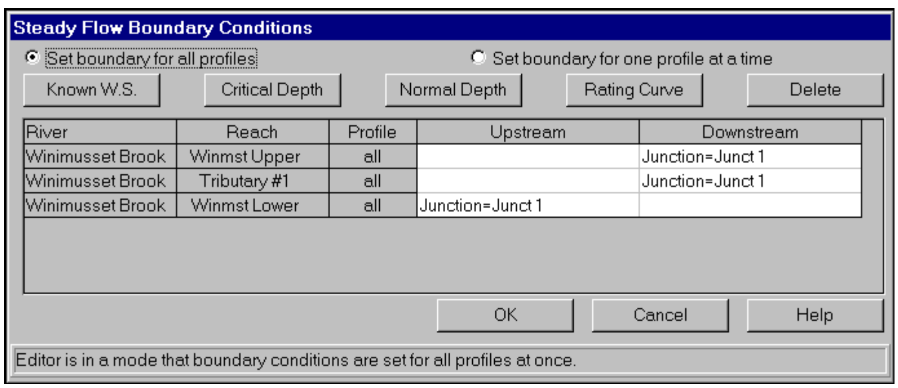

Figure 7: Steady Flow Boundary Conditions

For supercritical flow, select an upstream boundary condition. For subcritical flow, enter a downstream boundary condition. For mixed flow, flow which has both super and subcritical sections, select both an upstream and downstream boundary condition. A mixed flow regime is anticipated in this example and, therefore, all upstream and downstream boundary conditions are required. For profiles 1 and 2, choose critical depth for Winmst Upper-Up Stream and Tributary 1-Up Stream, and choose Known W.S. for Winmst Lower-Down Stream (Figure 8). The known W.S. elevations are determined from a downstream weir.

Flow	Known Water Surface Elevation
Profile 1: 129 cfs	602.8 feet
Profile 2: 258 cfs	605 feet

Click on OK to accept data.

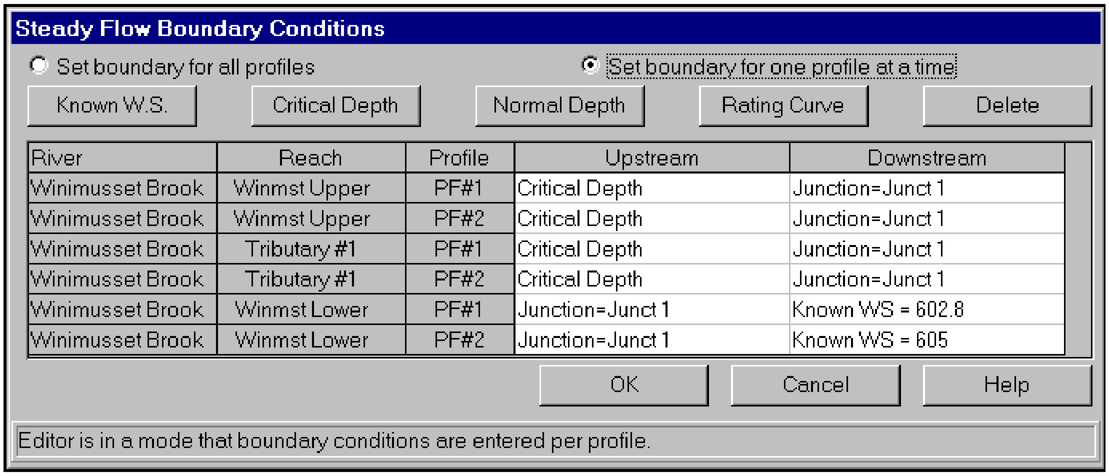

Figure 8: Multiple Steady Flow Boundary Conditions

17. Select Exit Flow Data editor from the File pull down menu of the Steady Data Flow window to return to main HEC-RAS window.
18. Select Save Project from the File pull down menu in the main HEC-RAS window to save all geometric and flow data.
19. Select Steady Flow Analysis from the Simulate pull down menu of the main HEC-RAS window. For this example, choose Mixed Flow Regime (Figure 9).
20. Select Critical Depth Output Option from the Options pull down menu of the Steady Flow Analysis window. Choose Critical Always Calculated, and press OK

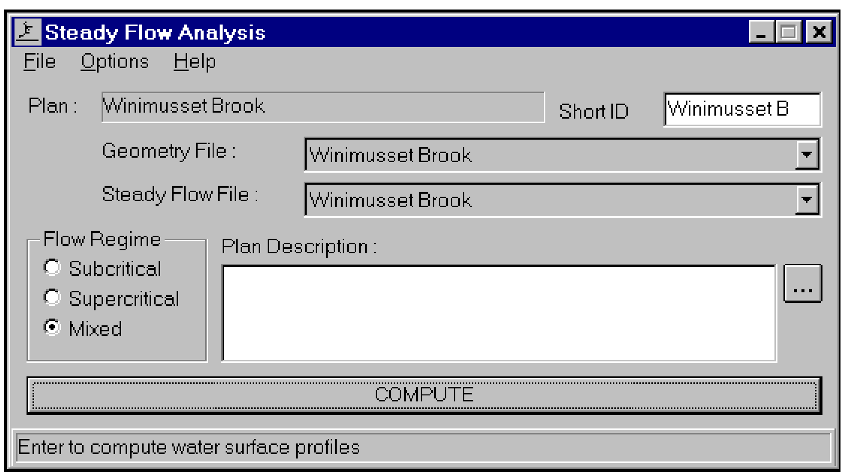

Figure 9: Steady Flow Analysis Window

21. Press Compute in the Steady Flow Analysis window to begin the HEC-RAS analysis. A DOS window will show the progress of the analysis (Figure 10). PROGRAM TERMINATED NORMALLY indicates that the analysis is complete. Double click the windows function button in the upper left corner to close this window.

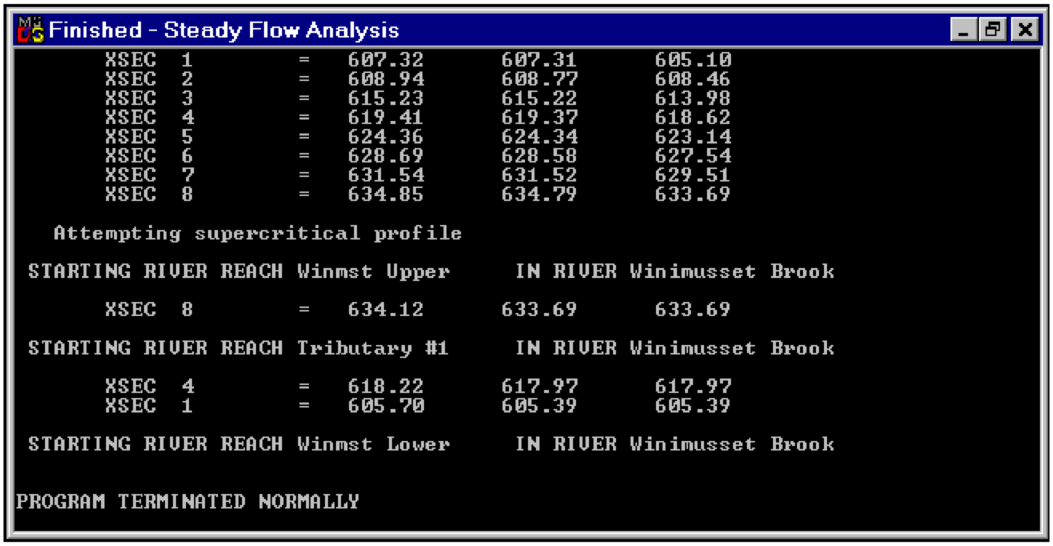

Figure 10: Steady Flow Analysis Window

22. From the Steady Flow Analysis window, select Exit from the File pull down menu to return to the main HEC-RAS window.
23. From the main HEC-RAS window, select Cross Sections from the View pull down menu. At the top of the Cross Section window, click on the Reach and River Station pull-down menus to view the water surface elevation at a desired reach and cross section (Figure 11). Choose Profiles and Variables from the Options pull down menu to plot different water surface profile runs, and different variables (i.e. critical depth), respectively. Print this cross section by selecting Print from the File pull down menu and clicking on the Print button in the print options window. Exit by selecting Exit from the File pull down menu of the View Cross Section window.
24. From the main HEC-RAS window, select Water Surface Profiles from the View pull down menu to view the water surface profile for an entire reach or several reaches (Figure 12). To include the critical depth elevation in the profile, select Variables from the Options pull down menu of the Profile Plot window, click on critical depth, and press OK. To change the viewed reach, select Reaches... from the Options pull down menu of the Profile Plot window, double click on the available reach(es) to be viewed (they will appear in the Selected Reaches column) and press OK (Figure 13). Print this water surface profile by selecting Print from the File pull down menu of the Profile Plot window, and clicking on the Print button in the print options window. Exit by selecting Exit from the File pull down menu of the Profile Plot window.

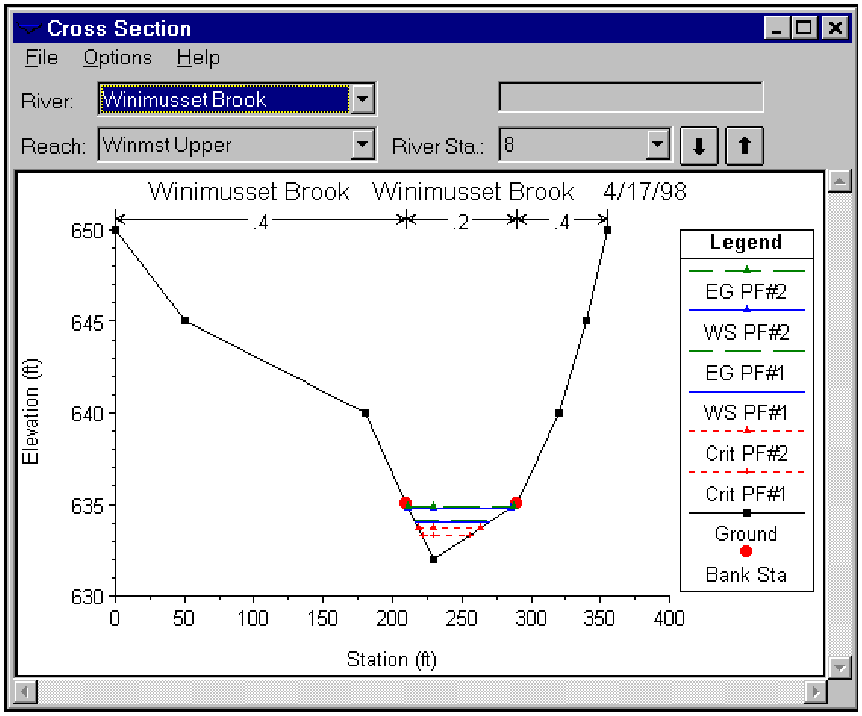

Figure 11: Cross Section Output Window

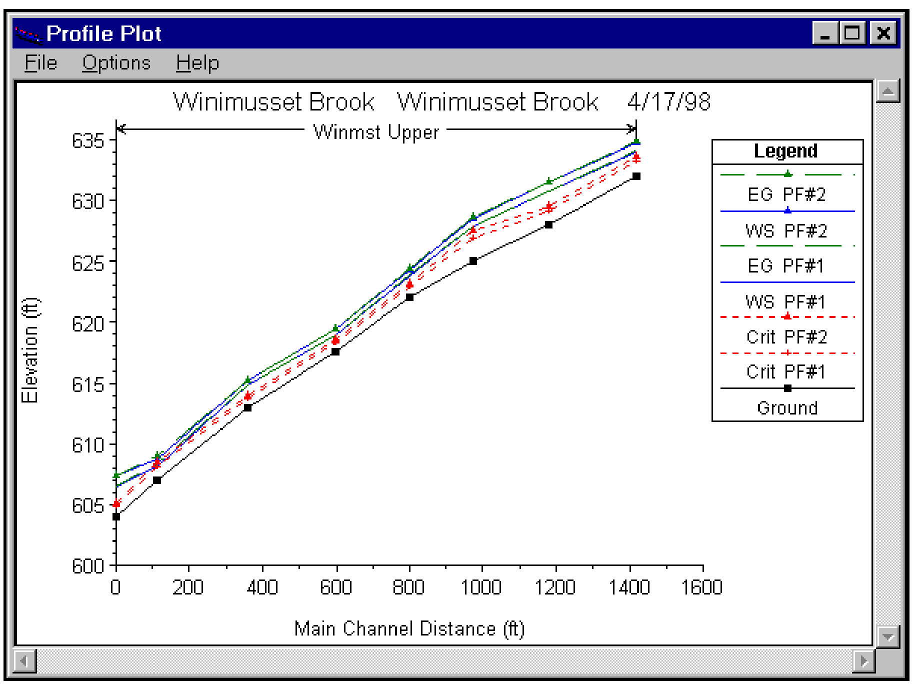

Figure 12: Water Surface Profiles Window

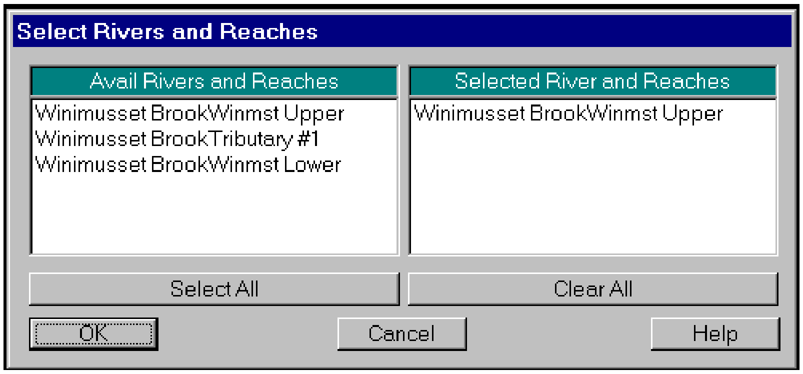

Figure 13: Reaches Viewed Window

25. From the main HEC-RAS window, select X-Y-Z Perspective Plots from the View pull down menu to view a three dimensional representation of the floodplain (Figure 14). Select the reach to be viewed by using the Reach pull-down menu in the upper left corner. Print this water surface profile by clicking the printer icon in the lower left and selecting Print in the print options window. Exit by selecting Exit from the File pull down menu of the View: X-Y-Z Perspective Plots window.

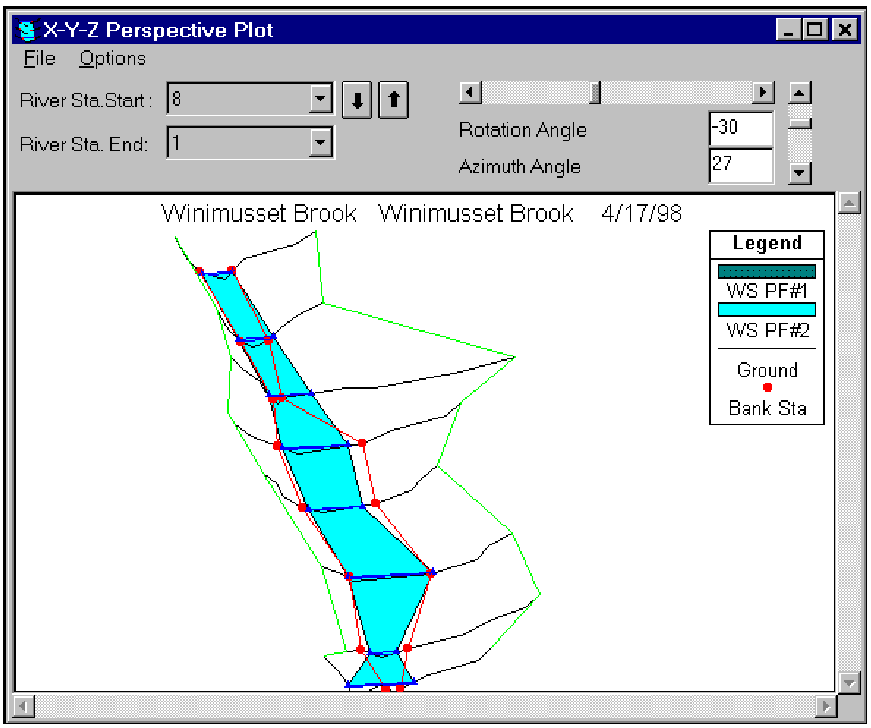

Figure 14: XYZ Perspective Plot Window

26. In the main HEC-RAS window, select Profile Table from the View pull down menu to view a table of results for a reach or several reaches (Table 2). From the Profile Table window, select Reaches from the Options pull down menu to choose the reach or reaches to be summarized. Note, this table is also available in the Report Generator (see step #29). Exit by selecting Exit from the File pull down menu of the Profile Table window.

Reach	River Sta	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)	Flow Area (sq ft)	Top Width (ft)	Froude #
Winmst Upper	8	100	632	634.05	633.28	634.1	0.056442	1.79	55.91	54.61	0.31
Winmst Upper	7	100	628	630.71	629.15	630.72	0.006181	0.83	122.48	78.48	0.11
Winmst Upper	6	100	625	627.85	626.89	627.93	0.049826	2.46	56.09	65.19	0.32
Winmst Upper	5	100	622	623.85	622.86	623.86	0.013344	0.81	122.74	132.64	0.15
Winmst Upper	4	100	617.5	618.88	618.35	618.91	0.060333	1.42	70.26	101.98	0.3
Winmst Upper	3	100	613	614.78	613.74	614.79	0.007968	0.61	162.98	182.78	0.11
Winmst Upper	2	100	607	608.1	608.1	608.39	0.734252	4.28	23.36	42.32	1.02
Winmst Upper	1	100	604	606.46	604.85	606.47	0.004476	0.78	209.52	139.38	0.1
Tributary #1	4	19	617	617.74	617.74	617.93	0.836851	3.49	5.45	14.77	1.01
Tributary #1	3	19	613	614.82	613.67	614.82	0.004416	0.46	41.19	45.38	0.09
Tributary #1	2	29	607	607.78	607.78	607.98	0.827317	3.59	8.07	20.75	1.02
Tributary #1	1	29	604	606.54	605.03	606.55	0.002561	0.6	109.25	120.22	0.07
Winmst Lower	3	129	603	605.9	604.03	605.9	0.002564	0.58	229.39	132.84	0.07
Winmst Lower	2	129	602	603.07	603.07	603.35	0.740206	4.21	30.61	57.14	1.01
Winmst Lower	1	129	595	602.8	596.59	602.8	0.000115	0.22	597.78	139.66	0.02

Table 2: Profile Table Output

27. From the main HEC-RAS window, select Summary Error Warn Notes from the View pull down menu (Figure 15). Press Close when done.

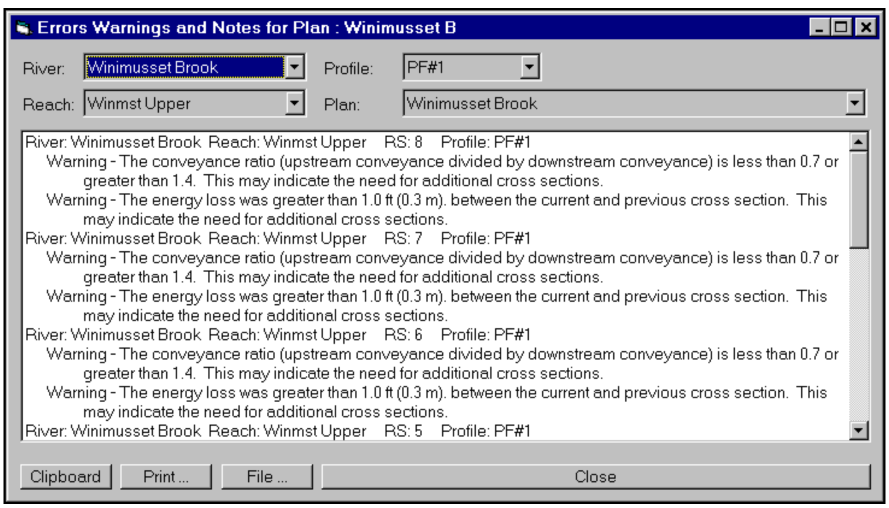

Figure 15 Summary of Errors, Warnings and Notes

28. From the main HEC-RAS window, select Generate Report from the File pull down menu to create a report containing all input and output values for this project (Figure 16). Select any specific tables, or available summary tables to include in this report with the mouse. Table 2: Profile Table Output, shown above in step 27, can be included in the report by selecting Standard Table 1. Click on Generate Report to execute report. The default report filename will be winimuss.rep and can be imported into any word processor as ASCII text. The HEC-RAS report is located in Appendix 1. Press Close when done.

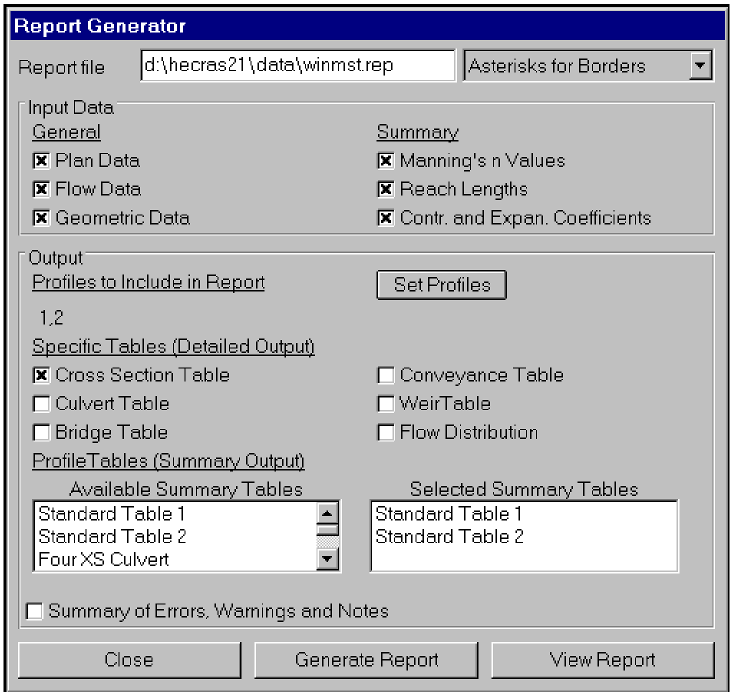

Figure 16 Report Generator

Appendix 1 has the report generator output. The first two pages have information on the input data. Then each cross section data is given, starting with the furthest upstream cross section. First a list of the input data for each cross section is listed, followed by a table of the calculated water surface elevations, velocity heads, etc. These output parameters are divided into left and right overbanks and center of channel. The value of the output parameter is zero when the left and/or right overbank data is blank.

And finally, the warnings for the cross sections are listed before the data for the next cross section is given. For the cross section Winmst Upper, river station 8, the warning about the conveyance ratio and energy loss may be reduced by adding one or more cross sections between 7 and 8.

Because the remaining cross section data is similar to the given cross section data they are not included in Appendix 1. The output ends with Standard Tables 1 and 2 which summarize the data given in the preceding cross section data tables. The flow is subcritical for all the cross sections (Froude number less than 1) with the exception of cross sections 2 and 4 for the Tributary and Winmst Upper and Lower cross section 2. The velocities at these cross sections are also the largest, with values exceeding 4 feet per second. These high velocities may cause stream erosion. By subtracting the Min. Ch. El. From the W.S. Elev, the depth of the water at each cross section may be obtained (Standard Table 1).

4 - Example 2: Incorporating Bridges into a HEC-RAS Analysis

In this example, determination of flooding of the stream given in Example 1 with a bridge crossing in the upper reach of Winnimusset Brook between cross sections 4 and 5 will be illustrated.

1. Open the project reviewed in Section 3 of this tutorial. Create a copy of this project with a new name by choosing Save Project As under the File pull-down menu of the main HEC-RAS window and double clicking the "data" folder in the Directories window of the Save Project As dialog box (Figure 17). Enter the Project title "Winimusset Brook with Bridge" and the filename winbrdg.prj and press OK.

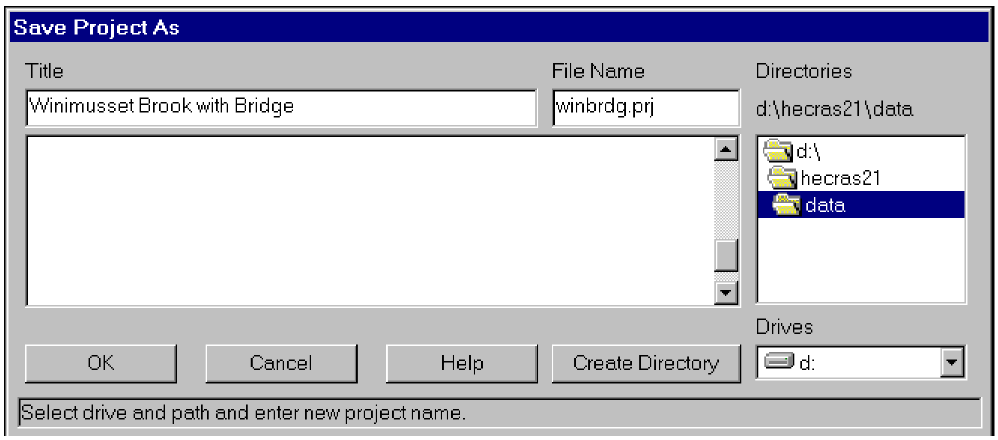

Figure 17: Save Project As Window

2. The bridge will be inserted between cross sections 4 and 5 in the Winimusset Upper Reach as shown in Figure 18.

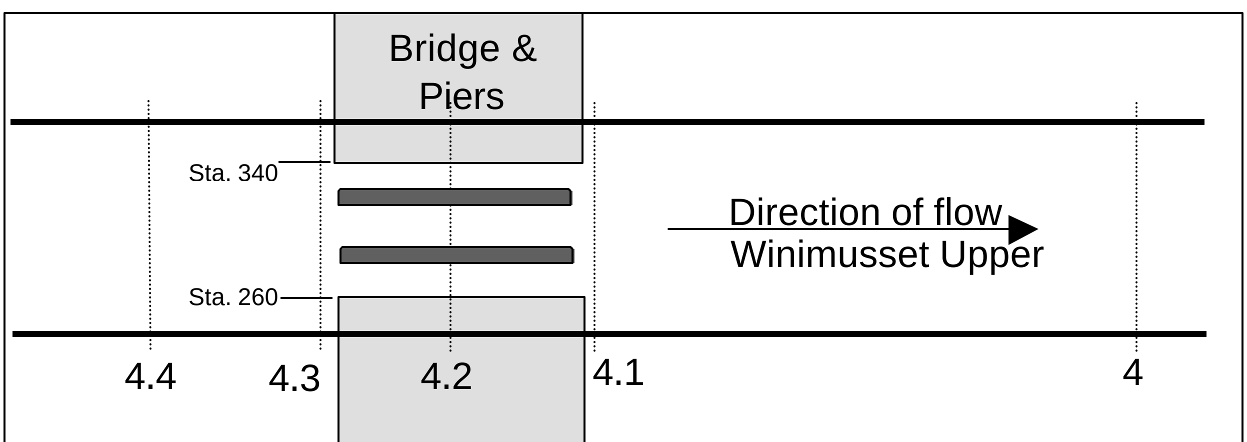

Figure 18: Winimusset Upper Reach Schematic with Bridge

Cross sections 4.1, 4.3, and 4.4 in Winimusset Upper Reach must be added and the reach lengths of cross section 5 must be modified as shown in Table 3. To better model one dimensional flow, section 4 should be at least four times the average length of the side constrictions (average of the wetted left and right banks) caused by the structure abutments (defined SA) downstream from section 4.1, and section 4.4 should be at least one SA upstream from section 4.3. See steps 5 through 12 from Section 3 for procedure to enter cross sections (we are defining SA as 30 feet).

Sta.	Length of Reach			Mannings n			Main Sta.		Cont/Exp Coeff.		Cross Section Data Station/Elevation									
	LOB	Chan	ROB	LOB	Chan	ROB	LOB	ROB	Cont	Exp										
5	30	30	30	0.4	0.2	0.4	250	465	0.1	0.3	0	40	175	250	410	465	530	570	590	
											640	635	630	625	622	625	630	635	640	
4.4	30	30	30	0.4	0.2	0.4	140	375	0.1	0.3	0	30	140	300	375	410	460			
											635	630	625	621	625	630	635			
4.3	20	20	20	0.4	0.2	0.4	260	325	0.1	0.3	0	25	125	190	260	300	325	380	400	450
											635	630	625	621	620	619	620	625	630	635
4.1	120	120	120	0.4	0.2	0.4	260	325	0.1	0.3	0	25	125	190	260	300	325	380	400	450
											635	630	625	621	620	619	620	625	630	635

Table 3: Supplemental Cross Sections for Bridge Example

3. Select cross-section 4.3 while in the Cross Section Data window. Choose Ineffective Flow Areas from the Options pull down menu.
4. Enter the stations and elevations from Table 4 in the Ineffective Flow Areas window (Figure 19) that represent the blockage in the river channel due to the bridge abutments. Elevation 623 is the bottom chord of the bridge deck. Press OK when done.
5. Repeat step 3 for cross-section 4.1.

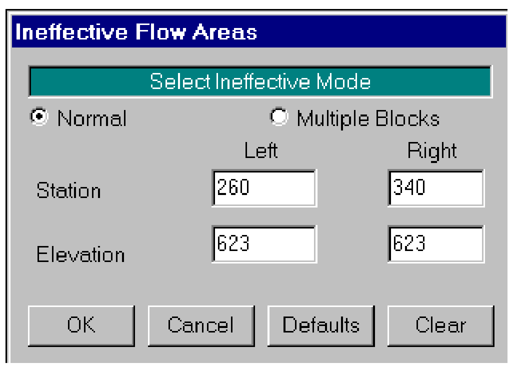

Figure 19: Ineffective Flow Areas Window

Cross Section	4.3		4.1	
	Left	Right	Left	Right
Station	260	340	260	340
Elevation	623	623	623	623

Table 4: Ineffective Flow Values for Bridge Example

6. From the geometric data window, choose the bridge/culvert tool to edit bridge data.
7. Choose Add a Bridge and/or Culvert from the Options pull down menu of the bridge culvert data window (Figure 20) and enter the station in Winimusset Brook where the bridge is to be located (Station 4.2 in this example). The bridge culvert data window will change to show the up and downstream stations directly adjacent to the bridge station shown (Figure 21).

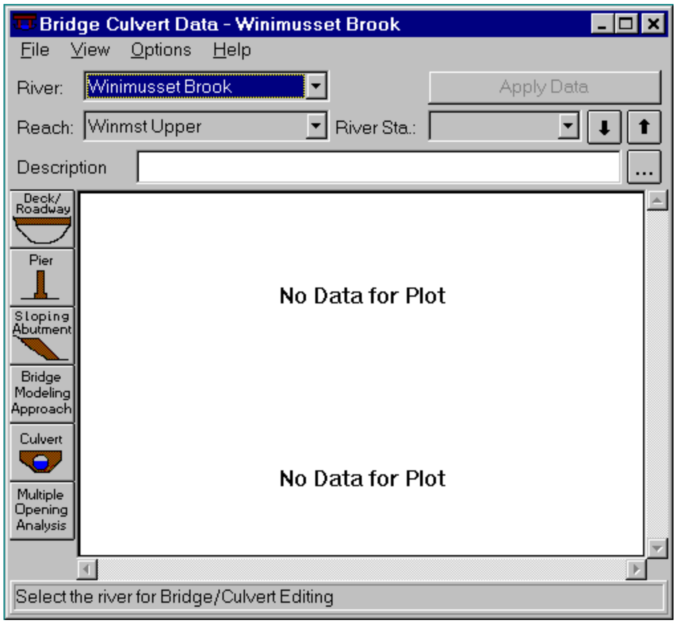

Figure 20: Bridge/Culvert Data Window

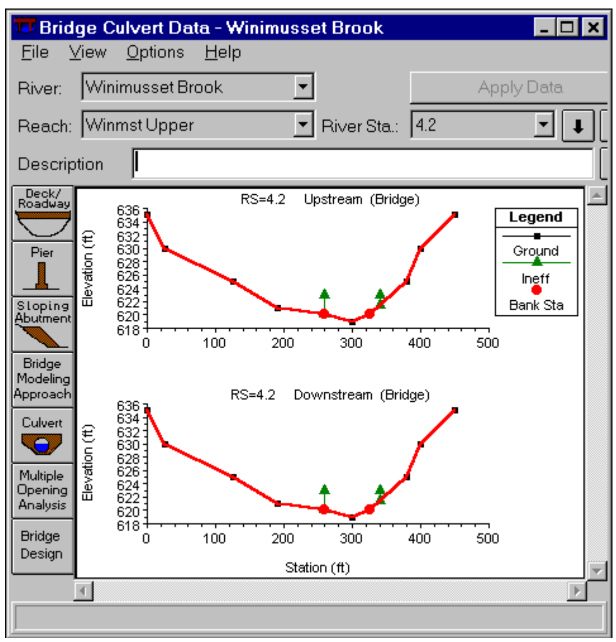

Figure 21: Bridge at River Station 4.2

8. Choose the Deck/Roadway tool from the Bridge/culvert Data Window to edit the bridge deck (Figure 22). The distance from the upstream cross section to the bridge is 1 foot. The width of the bridge deck is 19 feet. High Chord and Low Chord define the top and bottom elevation of the bridge deck, respectively. The top of the roadway is at 625 feet. For simplicity, the first station is 0 with an elevation of 625. The deck is assumed to be 2 feet thick and therefore, the bottom chord elevation at the span is 623 feet. The bottom chord must be lower than the cross section data at all positions, except the bridge span, and is set to 0 feet elevation for simplicity. Use Del Row or Ins Row to delete or insert a row of data. Upstream and downstream bridge data is assumed to

be equal. Press Copy Up to Down to copy upstream data to the downstream columns. Press OK to accept data and continue. The Bridge/Culvert data window will be updated as in Figure 23 below:

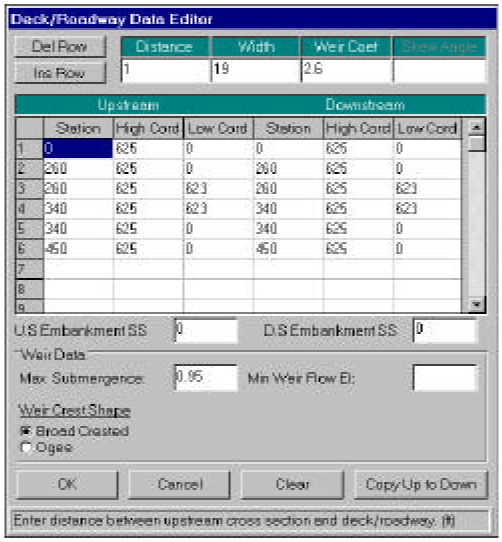

Figure 22: Deck/Roadway Data Editor

9. Choose the Pier tool from the Bridge/Culvert Data window to edit pier data (Figure 24). For this example, there are two identical 1 foot wide piers located at a centerline station of 296.6 and 303.2. The piers have a two foot wide footing and have identical upstream and downstream characteristics. The transition from pier to pier footing occurs from elevation 620.1 to 620. When data for Pier #1 is complete, press Copy to copy Pier #1 data to the new Pier #2. Adjust the Centerline Stations accordingly. Press OK when complete. The Bridge/Culvert data window will be updated as in Figure 25. A close-up view using Zoom in from the View pull down menu of the Bridge/Culvert data window is shown in Figure 26.

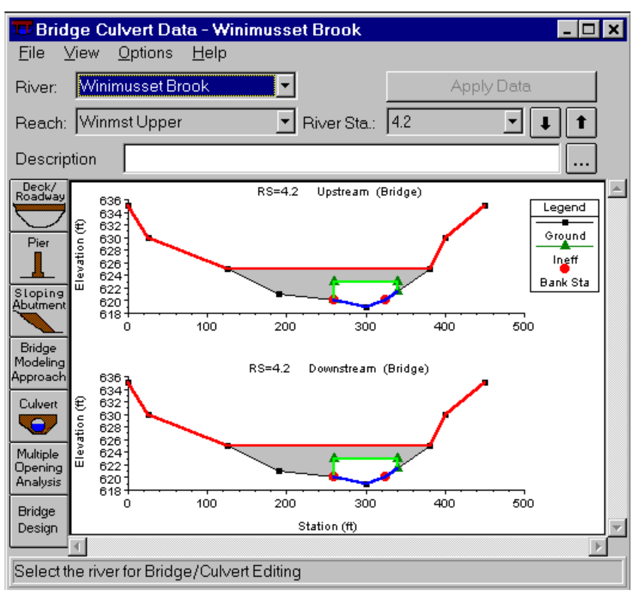

Figure 23: Bridge/Culvert Data Window with Bridge Deck

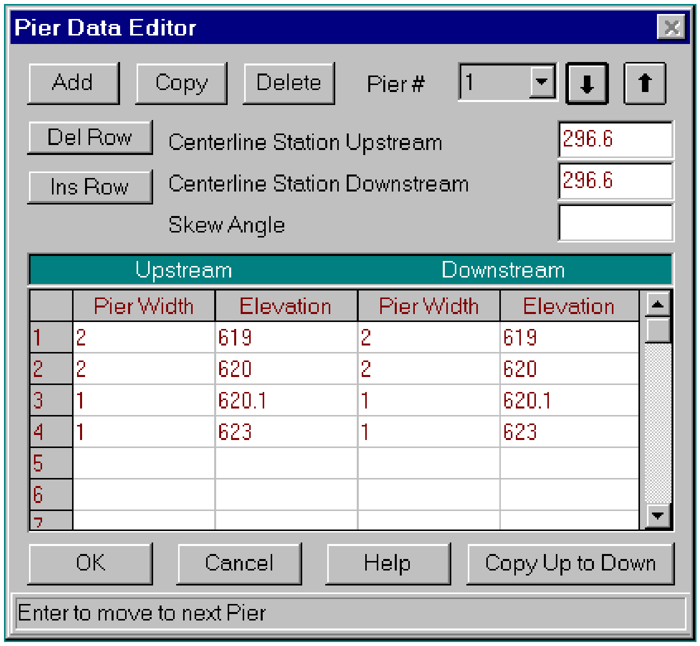

Figure 24: Pier Data Editor

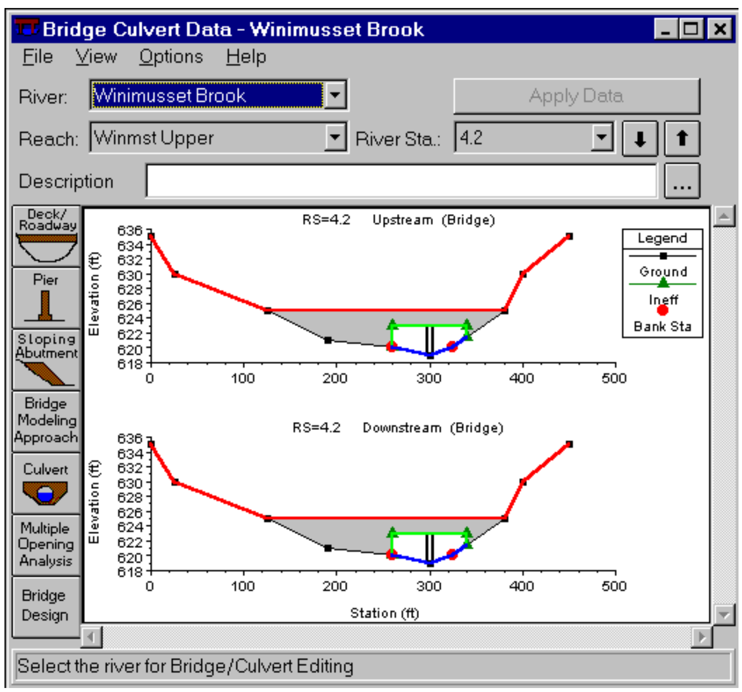

Figure 25: Bridge/Culvert Data Window with Piers

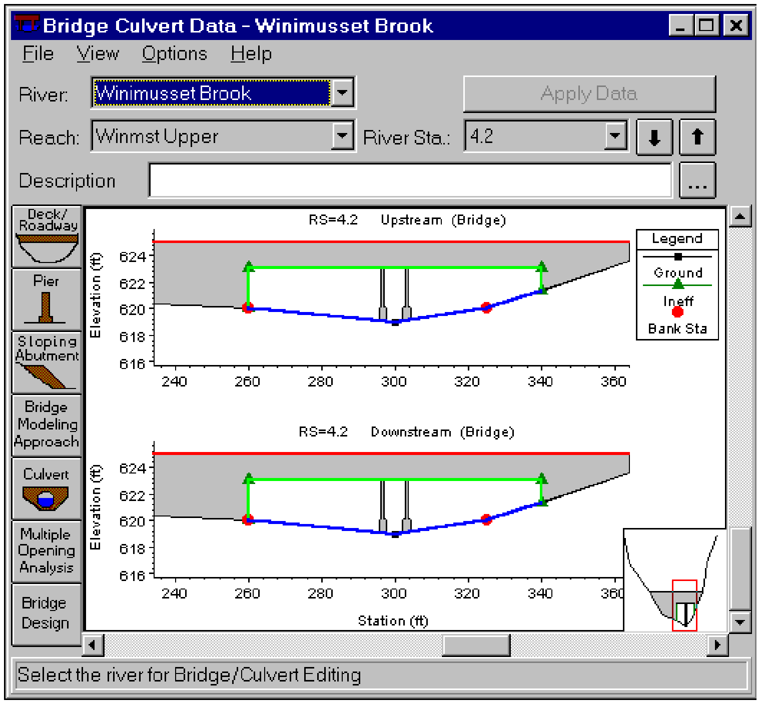

Figure 26: Bridge/Culvert Data Window with Piers (Close-up)

10. Choose the Bridge Modeling Approach tool from the Bridge Culvert Data editor window. The bridge routines have the ability to model:
    - Low flow: Open channel flow through the bridge
    - Low flow and weir flow: HEC-RAS will adjust for submerged weir flow.
    - Pressure flow: Orifice or sluice gate type-bottom chord of the bridge completely submerged
    - Pressure & weir flow: Bottom chord submerged and overflow top chord to produce weir flow

    <u>Low flow</u>

    There are three classes - subcritical, mixed and supercritical. In this example, mixed flow will be used. There are four methods available for computing losses through the bridge: Energy (standard step), Momentum balance, Yarnell eq. (empirical) and USGS contracted opening method (empirical). The user can select any or all these methods in the computation.

    <u>High Flow</u>

    Flow that comes in contact with the low chord is defined as high flow. HEC-RAS has the ability to use the Energy (standard step method) or use separate hydraulic equations for pressure and/or weir flow. The user must select either energy or pressure approach. In Figure 27, the drag coefficient must be used for the momentum equation, the pier shape K for the Yarnell equation. For the high flow methods, if the pressure and/or weir is selected, the following coefficients are available: inlet submerged Cd range from 0.35 to 0.5 (blank defaults to a program selection), submerged inlet and outlet including lower chord, typical Cd range from 0.7 to 0.9 (0.8 common), when the maximum lower chord is left blank, HEC-RAS will select a value. All of these coefficients may be found in the HEC-RAS manual. For both the low and high flow methods, the energy method has the widest range of bridge flow situations and is selected here, Figure 27.

11. Choose Exit from the File pull down menu of the Bridge Culvert Data editor Window.
12. Choose Exit Geometry Data Editor from the File pull down menu of the Geometric Data Window.
13. Save the project and run a steady flow analysis starting from Step 18 in Section 3.
14. Figure 28 shows the result of the steady flow analysis with a close-up view of the bridge in a profile plot of the Winimusset Upper reach. A full report for this analysis, including a bridge summary table (selected from the Report Generator window) is in Appendix 2.

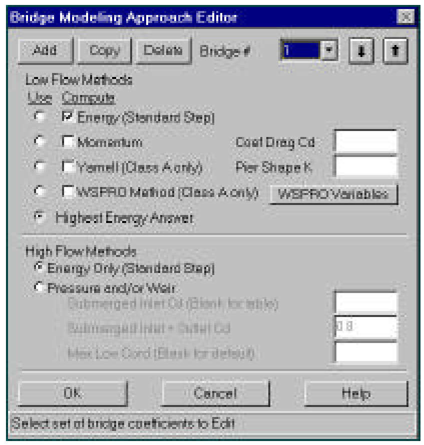

Figure 27: Bridge Modeling Approach Editor Window

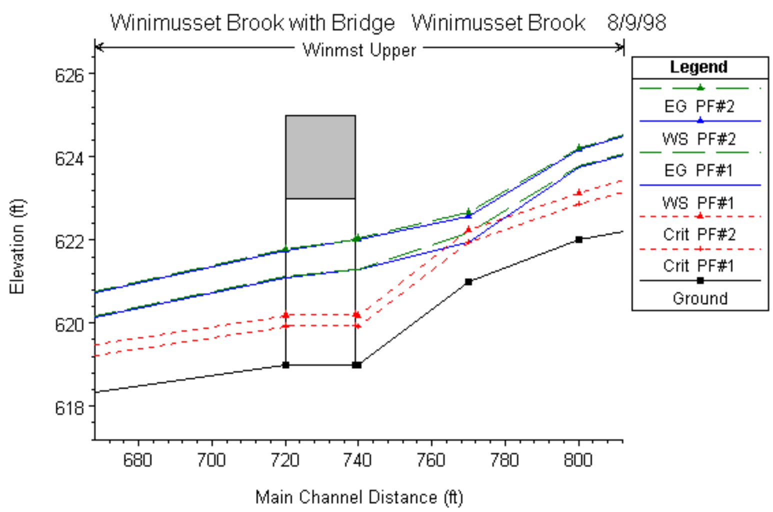

Figure 28: Profile Plot of Winimusset Upper Steady Flow Analysis Results (Close-up)

The report generator output has the same format as that given in Appendix 1, for Example 1. The only difference in the bridge output data is given in Appendix 2. The input data for the bridge is given and tables of output for river station 4.2, similar to the cross section output data with inside bridge upstream (BR US) and inside bridge downstream (BR DS) are given. The Standard Tables 1 and 2 are similar to Example 1 and are given in Appendix 2.

5 - Example 3: Incorporating Culverts into a HEC-RAS Analysis

In this example, determination of the flooding of a stream given in Example 1 with a culvert in the upper reach of Winnimusset Brook between cross sections 4 and 5 will be illustrated.

1. Open the project reviewed in Part 1 of this tutorial. Create a copy of this project with a new name by choosing Save Project As under the File pull-down menu of the main HEC-RAS window and double clicking the "data" folder in the Directories window (Figure 29). Enter "Winimusset Brook with Culvert" as a project title and the filename winclvrt.prj and press OK.

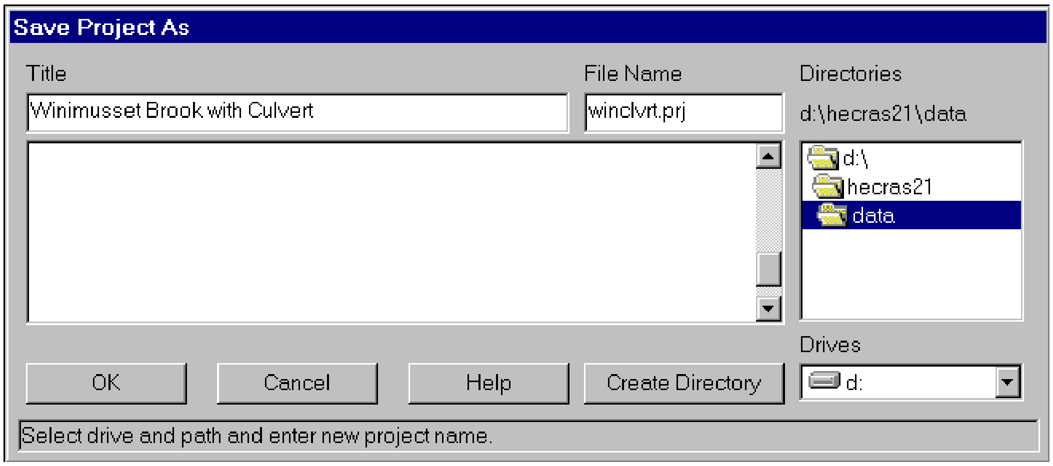

Figure 29: Save Project As Window

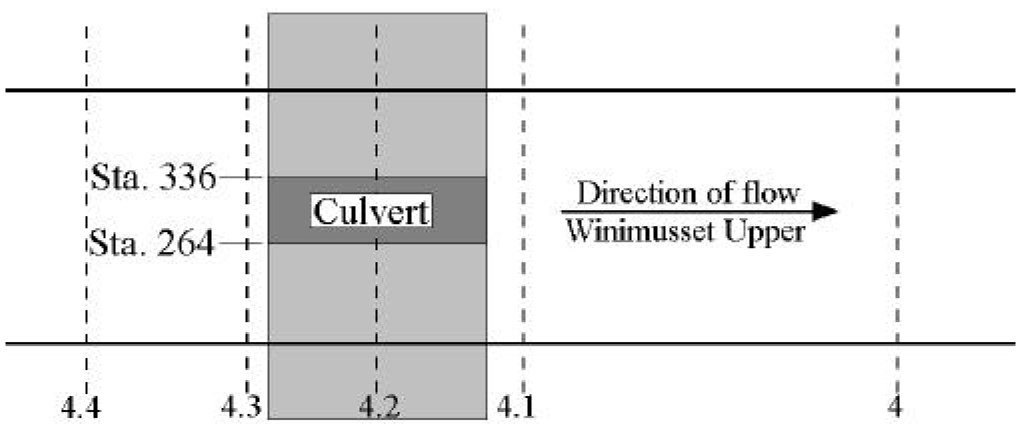

Figure 30: Schematic of Culvert

2. The culvert will be inserted between cross sections 4 and 5 in the Winimusset Upper reach (Figure 30). Cross sections 4.1, 4.3, and 4.4 in Winimusset Upper Reach must be added, and the reach lengths of cross section 5 must be modified as shown in Table 5. To better model one dimensional flow, section 4 should be at least four time the average length of the side constrictions caused by the

structure abutments (defined SA) downstream from section 4.1, and section 4.4 should be at least one SA upstream from section 4.3. See steps 5 through 12 from Section 3 for procedure to enter cross sections. We have selected SA equal to 30 feet.

Sta.	Length of Reach			Mannings n			Main Sta.		Cont/Exp Coeff.		Cross Section Data Station/Elevation
	LOB	Chan	ROB	LOB	Chan	ROB	LOB	ROB	Cont	Exp.	
5	30	30	30	0.4	0.2	0.4	250	465	0.1	0.3	0 40 175 250 410 465 530 570 590 640 635 630 625 622 625 630 635 640
4.4	30	30	30	0.4	0.2	0.4	140	375	0.1	0.3	0 30 140 300 375 410 460 635 630 625 621 625 630 635
4.3	20	20	20	0.4	0.2	0.4	260	325	0.1	0.3	0 25 125 190 260 300 325 380 400 450 635 630 625 621 620 619 620 625 630 635
4.1	120	120	120	0.4	0.2	0.4	260	325	0.1	0.3	0 25 125 190 260 300 325 380 400 450 635 630 625 621 620 619 620 625 630 635

Table 5: Supplemental Cross Sections for Culvert

3. Select cross-section 4.3 while in the cross section data window. Choose Ineffective Flow Areas from the Options pull down window.
4. Enter the stations and elevations from Table 6 in the Ineffective Flow Areas window (Figure 31) that represent the blockage in the river channel due to the culvert abutements. Elevation 632 is the top chord of the roadway deck. Click OK when all of the data has been entered.

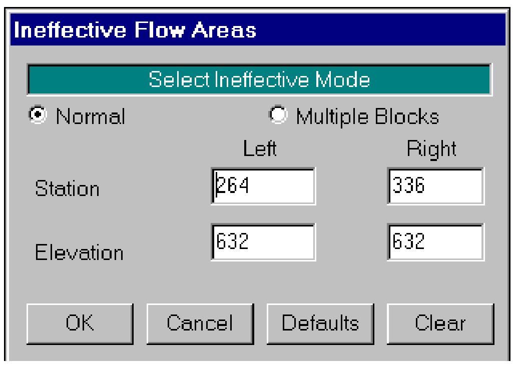

Figure 31: Ineffective Flow Area Window

Cross Section	4.3		4.1	
	Left	Right	Left	Right
Station	264	336	264	336
Elevation	632	632	632	632

Table 6: Ineffective Flow Values for Culvert Example

5. Repeat step 3 for cross-section 4.1.
6. From the geometric data window, choose the bridge/culvert tool to edit culvert data.
7. Choose Add a Bridge and/or Culvert from the Options pull down menu of the bridge culvert data window (Figure 32) and enter the station in Winimusset Brook where the culvert is to be located (Station 4.2 in this example). The Bridge Culvert Data window will change to show the up and downstream stations directly adjacent to the culvert station (Figure 33).

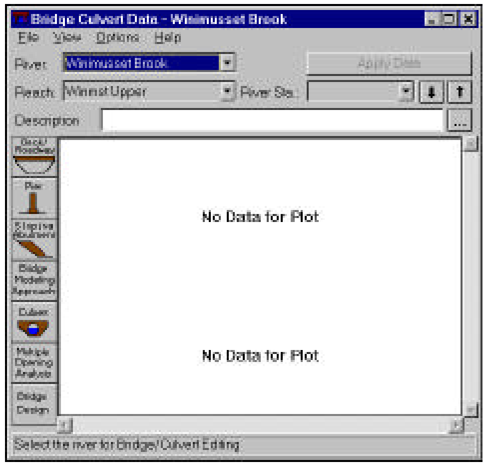

Figure 32: Bridge/Culvert Data Window

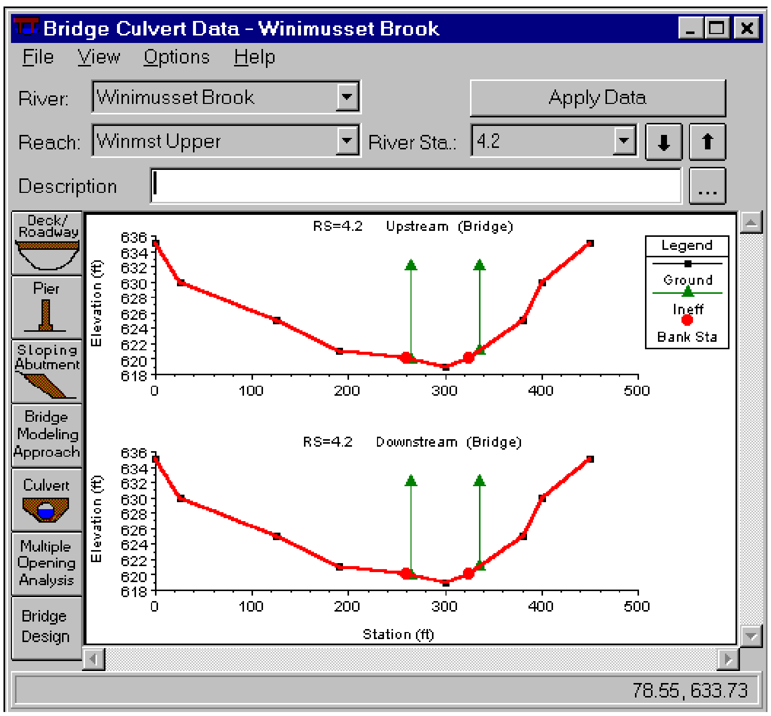

Figure 33: Culvert Position at River Station 4.2

8. Choose the Deck/Roadway tool from the Bridge/culvert Data Window to edit the culvert roadway deck (Figure 34). Upstream and downstream deck data is assumed to be equal. The distance from the upstream cross section to the culvert is 1 foot. The width of the culvert deck is 19 feet. High Chord and Low Chord define the top and bottom elevation of the roadway deck, respectively. The top of the roadway is at 632 feet. For simplicity, the first station is 0 with an elevation of 632. The bottom chord must be lower than the cross section data at all positions, and is set to 0 feet elevation for simplicity. Press OK to accept data and continue.

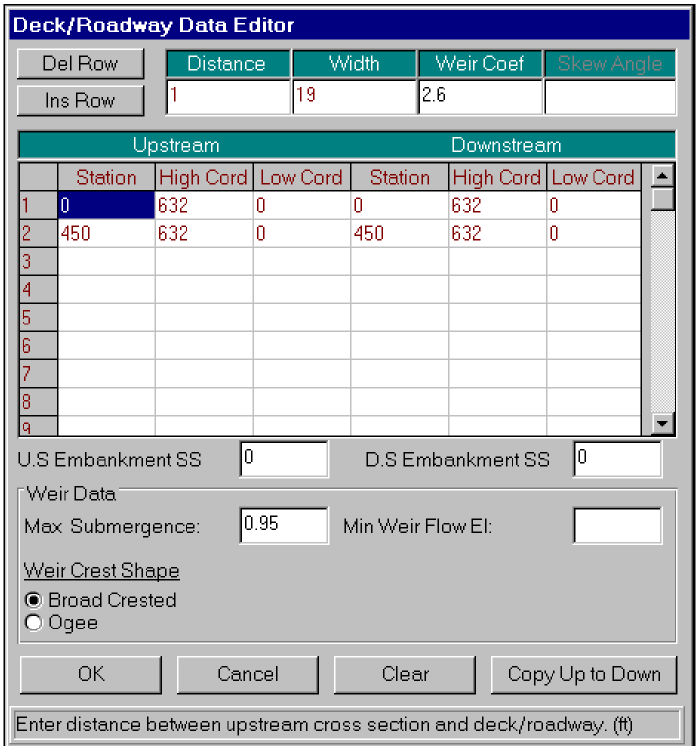

Figure 34: Deck/Roadway Data Editor Window

9. Choose the Culvert tool from the Bridge/culvert Data Window to enter the Culvert Data Editor window (Figure 35). Enter the shape, diameter (if applicable), length, n value, upstream and downstream invert elevations and centerline stations, and all other necessary information. Press OK to accept data and continue. The Bridge/Culvert data window will be updated as in Figure 36 below. A close-up view using Zoom in from the View pull down menu of the Bridge/Culvert data window is shown in Figure 37.

   The following culvert information is required:

   - Shape: there are 8 available shapes (box is used in this example)
   - Rise: maximum height of the culvert is 12 feet
   - Span: maximum width of the culvert is 72 feet
   - Chart #: the Federal Highway Administration chart number. Once the culvert shape is selected, the FHWA number is selected (a rectangular concrete culvert is used in this example)
   - Scale: FHWA type of culvert entrance. Once the chart number is selected the scale number will show up in the scale box.

   The remaining parameters for the Culvert Data Editor are self explanatory.

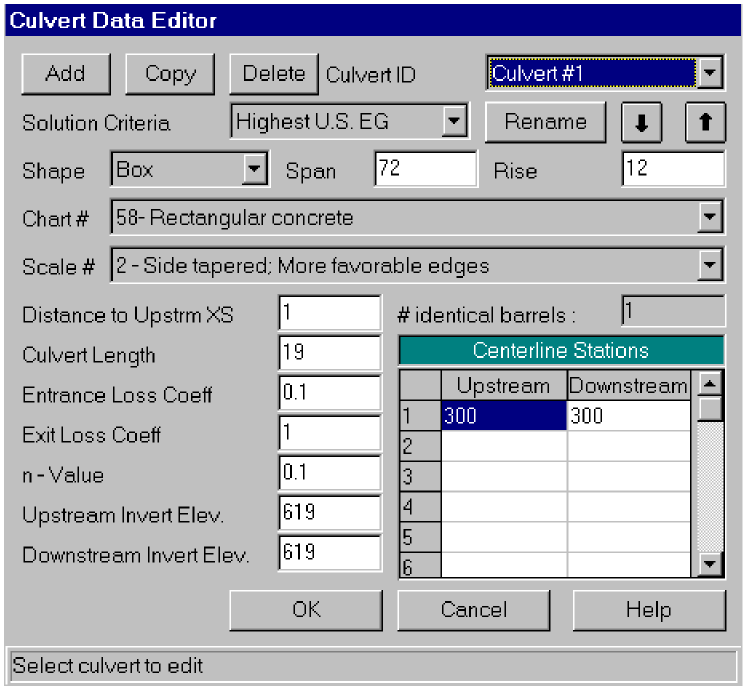

Figure 35: Culvert Data Editor

1. Choose Exit from the File pull down menu of the Bridge Culvert Data Editor window.
2. Choose Exit Geometry Data Editor from the File pull down menu of the Geometric Data Window.
3. Save the project and run a steady flow analysis, starting from step 18 in Section 3.
4. In this example, only one profile was computed. The Steady Flow Data values are given below in table 7

Reach	Station	Flow (cfs)
Winmst Upper	8	100
Tributary #1	4	29
Winmst Lower	3	129

Table 7: Steady Flow Data for Culvert Example

5. Figure 38 shows the result of the steady flow analysis with a close-up view of the culvert in a profile plot of the Winimusset Upper reach. A full report for this analysis, including a culvert summary table (selected from the Report Generator window) is in Appendix 3.

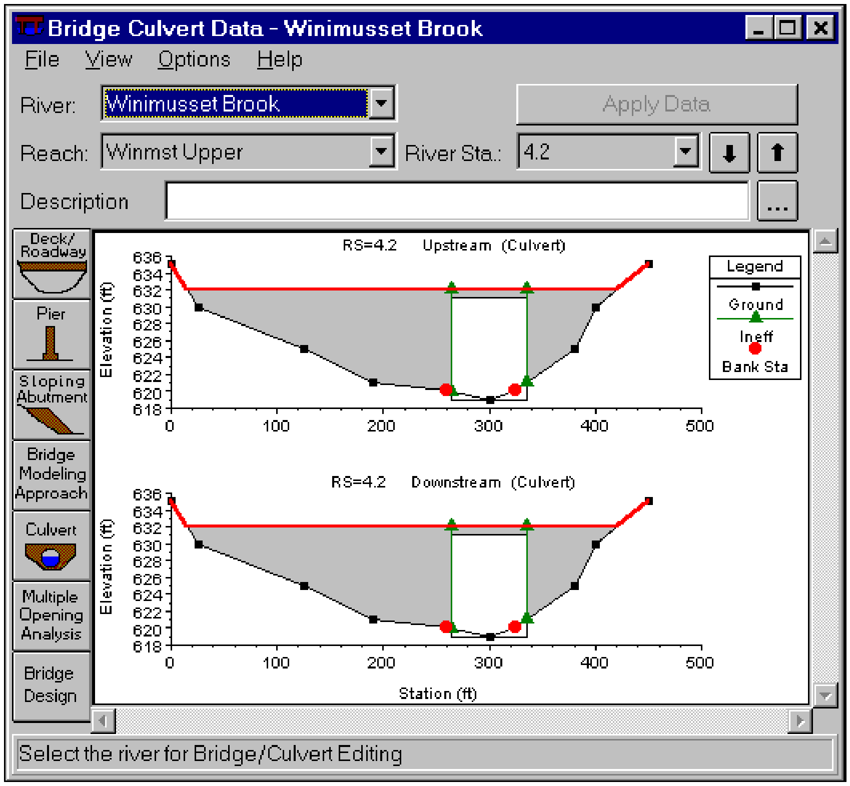

Figure 36: Bridge/Culvert Data Window with Culvert

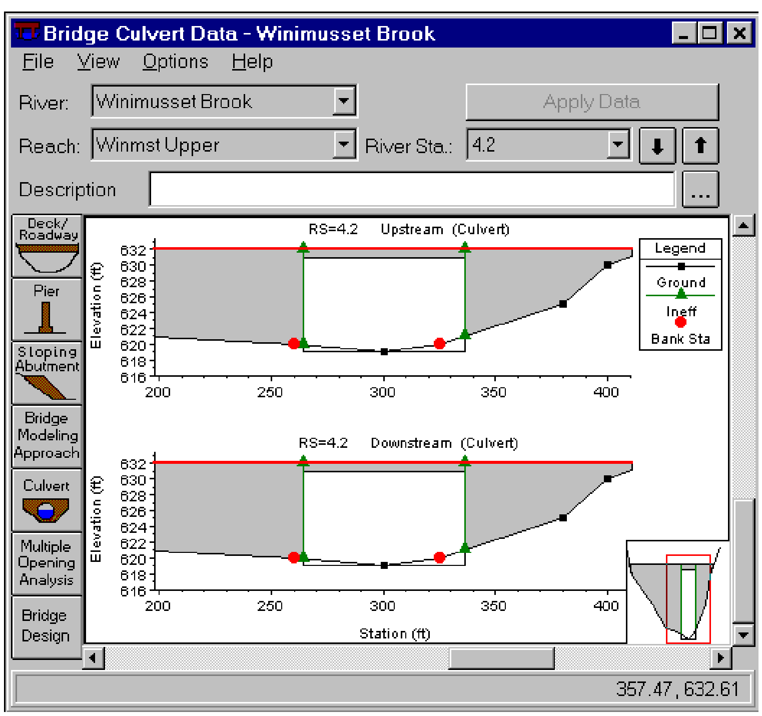

Figure 37: Bridge/Culvert Data Window with Culvert (Close-up)

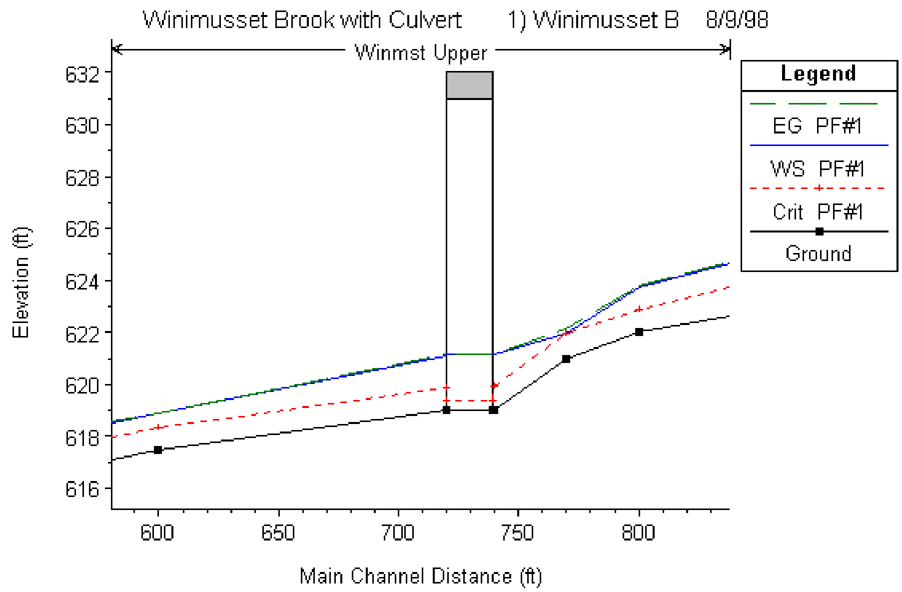

Figure 38: Profile Plot of Winimusset Upper Steady Flow Analysis Results (Close-up)

The report generator output has the same format as that given in Appendix 1, for Example 1. The only difference is the culvert output data, given in Appendix 3. The input data for the culvert is given and a table of output for river station 4.2 inside the culvert. The Standard Tables 1 & 2 are similar to Example 1 and are given in Appendix 3.

6 - Example 4: Encroachment in a HEC-RAS Analysis

In this example, determination of the flood of a stream given in Example 1 will be illustrated with an encroachment in the upper reach of Winimusset Brook between cross sections 6 and 7.

1. Open the project reviewed in Section 3 of this tutorial. Create a copy of this project with a new name by choosing Save Project As under the File pull-down menu of the main HEC-RAS window and double clicking the "data" folder in the Directories window. Enter "Winimusset Brook with Encroachment" as a project title and the filename winencr.prj and press OK.
2. Flow profile two (2) will be the encroachment profile and should be identical to profile 1, in both flow and boundary conditions. Profile one (1), is used as a baseline profile to compare the encroachment to. See steps 14 and 15 in Section 3 of this tutorial for profile and boundary condition data instructions. For this example, the following flow conditions will be used:

Reach	**Profile 1**	**Profile 2**
Winmst Upper	200	200
Tributary #1	58	58
Winmst Lower	258	258
Boundary Conditions: Winmst Lower Downstream	Known WS=605	Known WS=605

3. Choose Steady Flow Analysis from the Simulate pull down menu in the main HEC-RAS window.
4. Choose Encroachments from the Options pull down menu in the Steady Flow Analysis window. The Encroachments window will appear (Figure 39).
5. This example will encroach upon two (2) river stations in the Winimusset Upper Reach using the following values:

Winimusset Upper River Station	Value 1	Value2
7	129	209
6	585	615
All others	0	900

where Value 1 is the distance to the left bank encroachment, and Value 2 is the distance to the right bank encroachment. All other stations in this and all other reaches use Value 1 and 2 of 0 feet and 900 feet, respectively, which set encroachment limits well beyond the channel, thus preventing encroachment (Figure 39). First, set all of the river stations to a Value 1 of 0, a Value 2 of 900 and calculation method to Method 1 by entering the data in the appropriate fields in the Set Range of Values section of the Encroachments dialog box and then clicking on the Set Selected Range button. Then set Values 1 and 2 of stations 6 and 7 to their appropriate values.

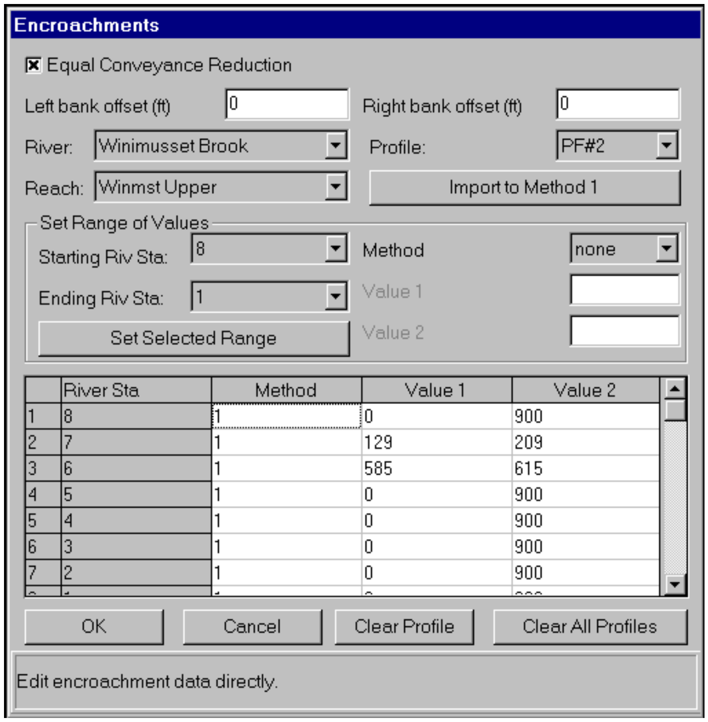

Figure 39: Encroachments Window

6. Save the project and run a steady flow analysis, starting from step 18 in Section 3. Figure 40 shows the zoomed in results of the encroachment analysis at section 7 in Winimusset Upper Reach. A full report for this analysis, including encroachment summary tables (selected from the Report Generator window) is in Appendix 4.

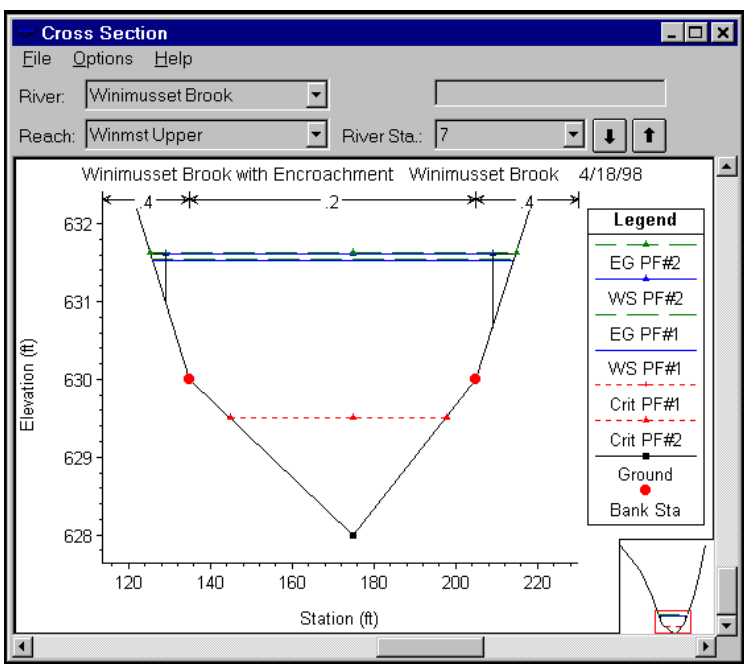

Figure 40: Encroachment Results at Winmst Upper Sta. 7 (Zoomed)

The report generator output has the same format as that given in Appendix 1 for Example 1. The only difference in the encroachment output data is given in Appendix 4. The change in the output for the example is a list of the method used for encroachment and the left and right stations input data. Note, only stations 6 and 7 have changed since this is where the encroachment takes place. Profile output tables encroachment 1, 2 and 3 are also given in Appendix 4. Note, the water surface elevation changes due to the encroachment changes (Winmst Upper 6, 7 and 8). These tables show changes in the water surface elevations due to encroachment (Delta WS).

Appendix 1: HEC-RAS Report Generator Output – Water Surface Profile Example

```
                        HEC-RAS Version 2.1 October 1997
                          U.S. Army Corp of Engineers
                         Hydrologic Engineering Center
                           609 Second Street, Suite D
                          Davis, California 95616-4687
                                 (530) 756-1104

            X     X  XXXXXX    XXXX        XXXX       XX      XXXX
            X     X  X       X    X       X   X     X  X    X
            X     X  X       X            X   X    X    X   X
            XXXXXXX  XXXX    X       XXX  XXXX     XXXXXX    XXXX
            X     X  X       X            X  X     X    X        X
            X     X  X       X    X       X   X    X    X        X
            X     X  XXXXXX    XXXX       X    X   X    X   XXXXX

********************************************************************************

PROJECT DATA
Project Title: Winimusset Brook
Project File : winmst.prj
Run Date and Time: 4/17/98 5:20:42 PM

Project in English units

********************************************************************************

PLAN DATA

Plan Title: Winimusset Brook
Plan File : d:\hecras21\data\winmst.p01

           Geometry Title: Winimusset Brook
           Geometry File : d:\hecras21\data\winmst.g01

           Flow Title    : Winimusset Brook
           Flow File     : d:\hecras21\data\winmst.f01

Plan Summary Information:
Number of:  Cross Sections =   15    Mulitple Openings =    0
            Culverts       =    0    Inline Weirs      =    0
            Bridges        =    0

Computational Information
    Water surface calculation tolerance =  0.01
    Critical depth calculaton tolerance =  0.01
    Maximum number of interations       =  20
    Maximum difference tolerance        =  0.3
    Flow tolerance factor               =  0.001

Computational Flow Regime: Mixed Flow

********************************************************************************

FLOW DATA

Flow Title: Winimusset Brook
Flow File : d:\hecras21\data\winmst.f01

Flow Data (cfs)
*****************************************************************************
* River           Reach           RS      *           PF#1           PF#2 *
* Winimusset BrookWinmst Upper    8       *            100            200 *
* Winimusset BrookTributary #1    4       *             19             38 *
* Winimusset BrookTributary #1    2       *             29             58 *
* Winimusset BrookWinmst Lower    3       *            129            258 *
*****************************************************************************

Boundary Conditions
********************************************************************************************************
* River           Reach           Profile          *           Upstream                Downstream    *
********************************************************************************************************
* Winimusset BrookWinmst Upper    PF#1             *             Critical                            *
* Winimusset BrookWinmst Upper    PF#2             *             Critical                            *
* Winimusset BrookTributary #1    PF#1             *             Critical                            *
* Winimusset BrookTributary #1    PF#2             *             Critical                            *
* Winimusset BrookWinmst Lower    PF#1             *                                Known WS = 602.8 *
* Winimusset BrookWinmst Lower    PF#2             *                                  Known WS = 605 *
********************************************************************************************************

********************************************************************************

GEOMETRY DATA

Geometry Title: Winimusset Brook
Geometry File : d:\hecras21\data\winmst.g01

Reach Connection Table
*********************************************************************************
* River           Reach            *  Upstream Boundary  * Downstream Boundary *
*********************************************************************************
* Winimusset Brook Winmst Upper     *                     *   Junct 1           *
* Winimusset Brook Tributary #1     *                     *   Junct 1           *
* Winimusset Brook Winmst Lower     *   Junct 1           *                     *
*********************************************************************************

CROSS SECTION          RIVER: Winimusset Brook
REACH: Winmst Upper       RS: 8

INPUT
Description:
Station Elevation Data    num=       9
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
       0     650      50     645     180     640     210     635     230     632
     290     635     320     640     340     645     355     650
```

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.4	210	.2	290	.4

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
210	290	250	240	235	.1	.3

CROSS SECTION OUTPUT Profile #PF#1

			Left OB	Channel	Right OB
W.S. Elev (ft)	634.05	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.05	Wt. n-Val.		0.200	
E.G. Elev (ft)	634.10	Reach Len. (ft)	250.00	240.00	235.00
Crit W.S. (ft)	633.28	Flow Area (sq ft)		55.91	
E.G. Slope (ft/ft)	0.056442	Area (sq ft)		55.91	
Q Total (cfs)	100.00	Flow (cfs)		100.00	
Top Width (ft)	54.61	Top Width (ft)		54.61	
Vel Total (ft/s)	1.79	Avg. Vel. (ft/s)		1.79	
Max Chl Dpth (ft)	2.05	Hydr. Depth (ft)		1.02	
Conv. Total (cfs)	420.9	Conv. (cfs)		420.9	
Length Wtd. (ft)	240.01	Wetted Per. (ft)		54.81	
Min Ch El (ft)	632.00	Shear (lb/sq ft)		3.59	
Alpha	1.00	Stream Power (lb/ft s)		6.43	
Frctn Loss (ft)	3.37	Cum Volume (acre-ft)	0.12	3.47	0.27
C & E Loss (ft)	0.01	Cum SA (acres)	0.21	3.03	0.06

Warning - The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross sections.
Warning - The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross section. This may indicate the need for additional cross sections.

CROSS SECTION OUTPUT Profile #PF#2

			Left OB	Channel	Right OB
W.S. Elev (ft)	634.79	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.06	Wt. n-Val.		0.200	
E.G. Elev (ft)	634.85	Reach Len. (ft)	250.00	240.00	235.00
Crit W.S. (ft)	633.69	Flow Area (sq ft)		103.59	
E.G. Slope (ft/ft)	0.043599	Area (sq ft)		103.59	
Q Total (cfs)	200.00	Flow (cfs)		200.00	
Top Width (ft)	74.33	Top Width (ft)		74.33	
Vel Total (ft/s)	1.93	Avg. Vel. (ft/s)		1.93	
Max Chl Dpth (ft)	2.79	Hydr. Depth (ft)		1.39	
Conv. Total (cfs)	957.8	Conv. (cfs)		957.8	
Length Wtd. (ft)	240.02	Wetted Per. (ft)		74.61	
Min Ch El (ft)	632.00	Shear (lb/sq ft)		3.78	
Alpha	1.00	Stream Power (lb/ft s)		7.30	
Frctn Loss (ft)	3.30	Cum Volume (acre-ft)	0.40	5.47	0.50
C & E Loss (ft)	0.01	Cum SA (acres)	0.42	3.65	0.13

Warning - The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross sections.
Warning - The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross section. This may indicate the need for additional cross sections.

Profile Output Table - Standard Table 1

Reach	River Sta	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)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
Winmst Upper	8	100.00	632.00	634.05	633.28	634.10	0.056442	1.79	55.91	54.61	0.31
Winmst Upper	8	200.00	632.00	634.79	633.69	634.85	0.043599	1.93	103.59	74.33	0.29
Winmst Upper	7	100.00	628.00	630.71	629.15	630.72	0.006181	0.83	122.48	78.48	0.11
Winmst Upper	7	200.00	628.00	631.52	629.51	631.54	0.006595	1.12	190.05	88.21	0.12
Winmst Upper	6	100.00	625.00	627.85	626.89	627.93	0.049826	2.46	56.09	65.19	0.32
Winmst Upper	6	200.00	625.00	628.58	627.54	628.69	0.046613	2.98	118.61	104.49	0.33
Winmst Upper	5	100.00	622.00	623.85	622.86	623.86	0.013344	0.81	122.74	132.64	0.15
Winmst Upper	5	200.00	622.00	624.34	623.14	624.36	0.015125	1.02	196.95	168.02	0.17
Winmst Upper	4	100.00	617.50	618.88	618.35	618.91	0.060333	1.42	70.26	101.98	0.30
Winmst Upper	4	200.00	617.50	619.37	618.62	619.41	0.047507	1.55	129.25	138.31	0.28
Winmst Upper	3	100.00	613.00	614.78	613.74	614.79	0.007968	0.61	162.98	182.78	0.11
Winmst Upper	3	200.00	613.00	615.22	613.98	615.23	0.008934	0.80	250.73	213.09	0.13
Winmst Upper	2	100.00	607.00	608.10	608.10	608.39	0.734252	4.28	23.36	42.32	1.02
Winmst Upper	2	200.00	607.00	608.77	608.46	608.94	0.238220	3.34	59.93	67.78	0.63
Winmst Upper	1	100.00	604.00	606.46	604.85	606.47	0.004476	0.78	209.52	139.38	0.10
Winmst Upper	1	200.00	604.00	607.31	605.10	607.32	0.004740	1.02	339.85	163.71	0.11
Tributary #1	4	19.00	617.00	617.74	617.74	617.93	0.836851	3.49	5.45	14.77	1.01
Tributary #1	4	38.00	617.00	618.00	617.97	618.22	0.647107	3.77	10.08	20.08	0.94
Tributary #1	3	19.00	613.00	614.82	613.67	614.82	0.004416	0.46	41.19	45.38	0.09
Tributary #1	3	38.00	613.00	615.28	613.89	615.28	0.004566	0.59	67.92	69.16	0.09
Tributary #1	2	29.00	607.00	607.78	607.78	607.98	0.827317	3.59	8.07	20.75	1.02
Tributary #1	2	58.00	607.00	608.03	608.03	608.29	0.754151	4.13	14.05	27.37	1.02
Tributary #1	1	29.00	604.00	606.54	605.03	606.55	0.002561	0.60	109.25	120.22	0.07
Tributary #1	1	58.00	604.00	607.37	605.39	607.37	0.001708	0.62	229.68	161.65	0.06
Winmst Lower	3	129.00	603.00	605.90	604.03	605.90	0.002564	0.58	229.39	132.84	0.07
Winmst Lower	3	258.00	603.00	606.63	604.36	606.64	0.003414	0.83	330.37	145.60	0.09
Winmst Lower	2	129.00	602.00	603.07	603.07	603.35	0.740206	4.21	30.61	57.14	1.01
Winmst Lower	2	258.00	602.00	605.07	603.41	605.09	0.010421	1.03	253.49	187.82	0.14
Winmst Lower	1	129.00	595.00	602.80	596.59	602.80	0.000115	0.22	597.78	139.66	0.02
Winmst Lower	1	258.00	595.00	605.00	597.09	605.00	0.000121	0.29	923.00	156.00	0.02

Profile Output Table - Standard Table 2

Reach	River Sta	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width

			(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
Winmst Upper	8		634.10	634.05	0.05	3.37	0.01		100.00		54.61
Winmst Upper	8		634.85	634.79	0.06	3.30	0.01		200.00		74.33
Winmst Upper	7		630.72	630.71	0.01	2.78	0.01	0.22	99.57	0.22	78.48
Winmst Upper	7		631.54	631.52	0.02	2.84	0.01	1.72	196.56	1.72	88.21
Winmst Upper	6		627.93	627.85	0.09	4.05	0.02	7.84	91.05	1.11	65.19
Winmst Upper	6		628.69	628.58	0.11	4.30	0.03	40.20	154.10	5.70	104.49
Winmst Upper	5		623.86	623.85	0.01	4.95	0.00		100.00		132.64
Winmst Upper	5		624.36	624.34	0.02	4.95	0.00		200.00		168.02
Winmst Upper	4		618.91	618.88	0.03	4.11	0.01		100.00		101.98
Winmst Upper	4		619.41	619.37	0.04	4.17	0.01		200.00		138.31
Winmst Upper	3		614.79	614.78	0.01	6.37	0.03		100.00		182.78
Winmst Upper	3		615.23	615.22	0.01	6.27	0.02	0.04	199.93	0.03	213.09
Winmst Upper	2		608.39	608.10	0.28	1.59	0.05		100.00		42.32
Winmst Upper	2		608.94	608.77	0.17	1.57	0.05		200.00		67.78
Winmst Upper	1		606.47	606.46	0.01	0.56	0.00	2.95	57.23	39.82	139.38
Winmst Upper	1		607.32	607.31	0.01	0.69	0.00	10.32	107.29	82.39	163.71
Tributary #1	4		617.93	617.74	0.19	2.58	0.02		19.00		14.77
Tributary #1	4		618.22	618.00	0.22	2.88	0.07		38.00		20.08
Tributary #1	3		614.82	614.82	0.00	6.82	0.02		19.00		45.38
Tributary #1	3		615.28	615.28	0.01	6.97	0.03	0.05	37.63	0.32	69.16
Tributary #1	2		607.98	607.78	0.20	0.79	0.01		29.00		20.75
Tributary #1	2		608.29	608.03	0.26	0.69	0.08		58.00		27.37
Tributary #1	1		606.55	606.54	0.00	0.64	0.00	11.94	15.94	1.12	120.22
Tributary #1	1		607.37	607.37	0.00	0.74	0.00	32.16	22.96	2.87	161.65
Winmst Lower	3		605.90	605.90	0.01	2.53	0.03	0.31	128.22	0.47	132.84
Winmst Lower	3		606.64	606.63	0.01	1.55	0.00	1.74	253.63	2.64	145.60
Winmst Lower	2		603.35	603.07	0.28	0.09	0.08		129.00		57.14
Winmst Lower	2		605.09	605.07	0.02	0.08	0.00	0.12	257.88	0.00	187.82
Winmst Lower	1		602.80	602.80	0.00			0.05	128.82	0.13	139.66
Winmst Lower	1		605.00	605.00	0.00			0.78	255.37	1.85	156.00

Appendix 2: HEC-RAS Report Generator Output – Bridge Example

```
                        HEC-RAS Version 2.1 October 1997
                          U.S. Army Corp of Engineers
                         Hydrologic Engineering Center
                          609 Second Street, Suite D
                         Davis, California 95616-4687
                                (916) 756-1104


            X     X  XXXXXX    XXXX        XXXX       XX      XXXX
            X     X  X        X    X       X   X     X  X    X
            X     X  X        X            X   X    X    X   X
            XXXXXXX  XXXX     X       XXX  XXXX     XXXXXX    XXXX
            X     X  X        X            X  X     X    X        X
            X     X  X        X    X       X   X    X    X        X
            X     X  XXXXXX    XXXX        X    X   X    X   XXXXX

********************************************************************************

PROJECT DATA
Project Title: Winimusset Brook with Bridge
Project File : winbrdg.prj
Run Date and Time: 8/9/98 6:38:28 PM

Project in English units

********************************************************************************

PLAN DATA

Plan Title: Winimusset Brook
Plan File : d:\hecras21\data\winbrdg.p01

           Geometry Title: Winimusset Brook
           Geometry File : d:\hecras21\data\winbrdg.g01

           Flow Title    : Winimusset Brook
           Flow File     : d:\hecras21\data\winbrdg.f01

Plan Summary Information:
Number of:  Cross Sections =   18    Mulitple Openings =    0
            Culverts       =    0    Inline Weirs      =    0
            Bridges        =    1

Computational Information
    Water surface calculation tolerance =  0.01
    Critical depth calculaton tolerance =  0.01
    Maximum number of interations       =  20
    Maximum difference tolerance        =  0.3
    Flow tolerance factor               =  0.001

Computational Flow Regime: Mixed Flow

********************************************************************************

FLOW DATA

Flow Title: Winimusset Brook
Flow File : d:\hecras21\data\winbrdg.f01

Flow Data (cfs)
*****************************************************************************
* River           Reach           RS      *           PF#1           PF#2 *
* Winimusset BrookWinmst Upper    8       *            100            200 *
* Winimusset BrookTributary #1    4       *             19             38 *
* Winimusset BrookTributary #1    2       *             29             58 *
* Winimusset BrookWinmst Lower    3       *            129            258 *
*****************************************************************************

Boundary Conditions
*********************************************************************************************************
* River           Reach           Profile          *           Upstream                  Downstream    *
*********************************************************************************************************
* Winimusset BrookWinmst Upper    PF#1             *             Critical                               *
* Winimusset BrookWinmst Upper    PF#2             *             Critical                               *
* Winimusset BrookTributary #1    PF#1             *             Critical                               *
* Winimusset BrookTributary #1    PF#2             *             Critical                               *
* Winimusset BrookWinmst Lower    PF#1             *                                  Known WS = 602.8 *
* Winimusset BrookWinmst Lower    PF#2             *                                    Known WS = 605 *
*********************************************************************************************************

********************************************************************************

GEOMETRY DATA

Geometry Title: Winimusset Brook
Geometry File : d:\hecras21\data\winbrdg.g01

Reach Connection Table
********************************************************************************
* River            Reach            *  Upstream Boundary  * Downstream Boundary *
********************************************************************************
* Winimusset Brook Winmst Upper     *                     *   Junct 1           *
* Winimusset Brook Tributary #1     *                     *   Junct 1           *
* Winimusset Brook Winmst Lower     *   Junct 1           *                     *
********************************************************************************

BRIDGE                 RIVER: Winimusset Brook
REACH: Winmst Upper       RS: 4.2

INPUT
Description:
Distance from Upstream XS =       1
Deck/Roadway Width        =      19
```

```
Weir Coefficient          =     2.6
Bridge Deck/Roadway Skew  =
Upstream  Deck/Roadway Coordinates
    num=      6
     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord
************************************************************************
       0     625       0     260     625       0     260     625     623
     340     625     623     340     625       0     450     625       0

Upstream Bridge Cross Section Data
Station Elevation Data    num=      10
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
       0     635      25     630     125     625     190     621     260     620
     300     619     325     620     380     625     400     630     450     635

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
       0      .4     260      .2     325      .4

Bank Sta: Left   Right    Coeff Contr.   Expan.
            260     325           .1       .3
Ineffective Flow     num=       2
   Sta L   Sta R    Elev   Sta L   Sta R    Elev
************************************************
       0     260     623     340     450     623

Downstream  Deck/Roadway Coordinates
    num=      6
     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord
************************************************************************
       0     625       0     260     625       0     260     625     623
     340     625     623     340     625       0     450     625       0

Downstream Bridge Cross Section Data
Station Elevation Data    num=      10
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
       0     635      25     630     125     625     190     621     260     620
     300     619     325     620     380     625     400     630     450     635

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
       0      .4     260      .2     325      .4

Bank Sta: Left   Right    Coeff Contr.   Expan.
            260     325           .1       .3
Ineffective Flow     num=       2
   Sta L   Sta R    Elev   Sta L   Sta R    Elev
************************************************
       0     260     623     340     450     623

Upstream Embankment side slope              =       0 horiz. to 1.0 vertical
Downstream Embankment side slope            =       0 horiz. to 1.0 vertical
Maximum allowable submergence for weir flow =     .95
Elevation at which weir flow begins         =
Energy head used in spillway design         =
Spillway height used in design              =
Weir crest shape                            = Broad Crested

Number of Piers =  2

Pier Data
Pier Station     Upstream=   296.6    Downstream=   296.6
Upstream     num=       4
    Width   Elev    Width   Elev    Width   Elev    Width   Elev
****************************************************************
       2     619       2     620       1   620.1       1     623
Downstream     num=       4
    Width   Elev    Width   Elev    Width   Elev    Width   Elev
****************************************************************
       2     619       2     620       1   620.1       1     623

Pier Data
Pier Station     Upstream=   303.2    Downstream=   303.2
Upstream     num=       4
    Width   Elev    Width   Elev    Width   Elev    Width   Elev
****************************************************************
       2     619       2     620       1   620.1       1     623
Downstream     num=       4
    Width   Elev    Width   Elev    Width   Elev    Width   Elev
****************************************************************
       2     619       2     620       1   620.1       1     623

Number of Bridge Coefficient Sets =  1

Low Flow Methods and Data
       Energy
Selected Low Flow Methods = Highest Energy Answer

High Flow Method
       Energy Only

Additional Bridge Parameters
       Add Friction component to Momentum
       Do not add Weight component to Momentum
       Class B flow critical depth computations use critical depth
           inside the bridge at the downstream end
       Criteria to check for pressure flow = Upstream water surface

BRIDGE OUTPUT    Profile #PF#1
Opening : Bridge #1
*********************************************************************************************
* E.G. US. (ft)          *      621.30 * Element               *Inside BR US *Inside BR DS *
* W.S. US. (ft)          *      621.29 * E.G. Elev (ft)        *      621.30 *      621.11 *
* Q Total (cfs)          *      100.00 * W.S. Elev (ft)        *      621.28 *      621.10 *
* Q Bridge (cfs)         *      100.00 * Crit W.S. (ft)        *      619.95 *      619.95 *
* Q Weir (cfs)           *             * Max Chl Dpth (ft)     *        2.28 *        2.10 *
* Weir Sta Lft (ft)      *             * Vel Total (ft/s)      *        0.84 *        0.96 *
* Weir Sta Rgt (ft)      *             * Flow Area (sq ft)     *      118.78 *      104.47 *
* Weir Submerg           *             * Froude # Chl          *        0.12 *        0.14 *
* Weir Max Depth (ft)    *             * Specif Force (cu ft)  *      104.77 *       84.14 *
```

Min Top Rd (ft)	625.00	Hydr Depth (ft)	1.54	1.39
Min El Prs (ft)	623.00	W.P. Total (ft)	85.56	82.73
Delta EG (ft)	0.19	Conv. Total (cfs)	1110.6	920.1
Delta WS (ft)	0.20	Top Width (ft)	77.12	75.05
BR Open Area (sq ft)	252.60	Frctn Loss (ft)	0.18	0.00
BR Open Vel (ft/s)	0.96	C & E Loss (ft)	0.00	0.00
Coef of Q		Shear Total (lb/sq ft)	0.70	0.93
Br Sel Mthd	Energy only	Power Total (lb/ft s)	0.59	0.89

BRIDGE OUTPUT   Profile #PF#2

Opening : Bridge #1

		Element	Inside BR US	Inside BR DS
E.G. US. (ft)	622.03	E.G. Elev (ft)	622.02	621.78
W.S. US. (ft)	622.01	W.S. Elev (ft)	622.00	621.75
Q Total (cfs)	200.00	Crit W.S. (ft)	620.21	620.21
Q Bridge (cfs)	200.00	Max Chl Dpth (ft)	3.00	2.75
Q Weir (cfs)		Vel Total (ft/s)	1.15	1.29
Weir Sta Lft (ft)		Flow Area (sq ft)	174.27	154.84
Weir Sta Rgt (ft)		Froude # Chl	0.14	0.16
Weir Submerg		Specif Force (cu ft)	213.82	173.76
Weir Max Depth (ft)		Hydr Depth (ft)	2.23	1.99
Min Top Rd (ft)	625.00	W.P. Total (ft)	91.92	90.42
Min El Prs (ft)	623.00	Conv. Total (cfs)	1924.9	1616.7
Delta EG (ft)	0.25	Top Width (ft)	78.00	78.00
Delta WS (ft)	0.26	Frctn Loss (ft)	0.24	0.00
BR Open Area (sq ft)	252.60	C & E Loss (ft)	0.00	0.00
BR Open Vel (ft/s)	1.29	Shear Total (lb/sq ft)	1.28	1.64
Coef of Q		Power Total (lb/ft s)	1.47	2.11
Br Sel Mthd	Energy only			

Profile Output Table - Standard Table 1

Reach	River Sta	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)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
Winmst Upper	8	100.00	632.00	634.07	633.28	634.12	0.053026	1.75	57.23	55.25	0.30
Winmst Upper	8	200.00	632.00	634.80	633.69	634.86	0.042171	1.91	104.89	74.79	0.28
Winmst Upper	7	100.00	628.00	630.68	629.15	630.69	0.006471	0.84	120.67	78.21	0.11
Winmst Upper	7	200.00	628.00	631.49	629.51	631.51	0.006813	1.13	187.96	87.93	0.13
Winmst Upper	6	100.00	625.00	627.99	626.89	628.06	0.036554	2.22	66.02	72.86	0.28
Winmst Upper	6	200.00	625.00	628.80	627.54	628.88	0.032214	2.61	142.36	115.98	0.28
Winmst Upper	5	100.00	622.00	623.76	622.86	623.77	0.017397	0.90	111.12	126.20	0.17
Winmst Upper	5	200.00	622.00	624.18	623.13	624.20	0.022475	1.18	169.77	155.99	0.20
Winmst Upper	4.4	100.00	621.00	621.93	621.93	622.17	0.774362	3.93	25.47	54.71	1.01
Winmst Upper	4.4	200.00	621.00	622.56	622.23	622.68	0.197793	2.80	71.47	91.64	0.56
Winmst Upper	4.3	100.00	619.00	621.29	619.90	621.30	0.005901	0.84	125.67	153.96	0.11
Winmst Upper	4.3	200.00	619.00	622.01	620.16	622.03	0.007419	1.18	182.81	173.43	0.13
Winmst Upper	4.2	Bridge									
Winmst Upper	4.1	100.00	619.00	621.10	619.90	621.11	0.008739	0.95	110.42	148.64	0.13
Winmst Upper	4.1	200.00	619.00	621.75	620.16	621.77	0.010798	1.32	162.14	166.39	0.16
Winmst Upper	4	100.00	617.50	618.88	618.35	618.91	0.060333	1.42	70.26	101.98	0.30
Winmst Upper	4	200.00	617.50	619.37	618.62	619.41	0.047507	1.55	129.25	138.31	0.28
Winmst Upper	3	100.00	613.00	614.78	613.74	614.79	0.007968	0.61	162.98	182.78	0.11
Winmst Upper	3	200.00	613.00	615.22	613.98	615.23	0.008934	0.80	250.73	213.09	0.13
Winmst Upper	2	100.00	607.00	608.10	608.10	608.39	0.734252	4.28	23.36	42.32	1.02
Winmst Upper	2	200.00	607.00	608.77	608.46	608.94	0.238220	3.34	59.93	67.78	0.63
Winmst Upper	1	100.00	604.00	606.46	604.85	606.47	0.004476	0.78	209.52	139.38	0.10
Winmst Upper	1	200.00	604.00	607.31	605.10	607.32	0.004740	1.02	339.85	163.71	0.11
Tributary #1	4	19.00	617.00	617.74	617.74	617.93	0.836851	3.49	5.45	14.77	1.01
Tributary #1	4	38.00	617.00	618.00	617.97	618.22	0.647107	3.77	10.08	20.08	0.94
Tributary #1	3	19.00	613.00	614.82	613.67	614.82	0.004416	0.46	41.19	45.38	0.09
Tributary #1	3	38.00	613.00	615.28	613.89	615.28	0.004566	0.59	67.92	69.16	0.09
Tributary #1	2	29.00	607.00	607.78	607.78	607.98	0.827317	3.59	8.07	20.75	1.02
Tributary #1	2	58.00	607.00	608.03	608.03	608.29	0.754151	4.13	14.05	27.37	1.02
Tributary #1	1	29.00	604.00	606.54	605.03	606.55	0.002561	0.60	109.25	120.22	0.07
Tributary #1	1	58.00	604.00	607.37	605.39	607.37	0.001708	0.62	229.68	161.65	0.06
Winmst Lower	3	129.00	603.00	605.90	604.03	605.90	0.002564	0.58	229.39	132.84	0.07
Winmst Lower	3	258.00	603.00	606.63	604.36	606.64	0.003414	0.83	330.37	145.60	0.09
Winmst Lower	2	129.00	602.00	603.07	603.07	603.35	0.740206	4.21	30.61	57.14	1.01
Winmst Lower	2	258.00	602.00	605.07	603.41	605.09	0.010421	1.03	253.49	187.82	0.14
Winmst Lower	1	129.00	595.00	602.80	596.59	602.80	0.000115	0.22	597.78	139.66	0.02
Winmst Lower	1	258.00	595.00	605.00	597.09	605.00	0.000121	0.29	923.00	156.00	0.02

Profile Output Table - Standard Table 2

Reach	River Sta	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
Winmst Upper	8	634.12	634.07	0.05	3.41	0.01		100.00		55.25
Winmst Upper	8	634.86	634.80	0.06	3.34	0.01		200.00		74.79
Winmst Upper	7	630.69	630.68	0.01	2.63	0.01	0.20	99.59	0.20	78.21
Winmst Upper	7	631.51	631.49	0.02	2.63	0.01	1.67	196.65	1.67	87.93
Winmst Upper	6	628.06	627.99	0.07	4.27	0.02	10.19	88.36	1.45	72.86
Winmst Upper	6	628.88	628.80	0.08	4.66	0.02	46.95	146.39	6.66	115.98
Winmst Upper	5	623.77	623.76	0.01	1.58	0.02		100.00		126.20
Winmst Upper	5	624.20	624.18	0.02	1.51	0.01		200.00		155.99
Winmst Upper	4.4	622.17	621.93	0.24	0.60	0.07		100.00		54.71
Winmst Upper	4.4	622.68	622.56	0.12	0.62	0.03		200.00		91.64

Winmst Upper	4.3	621.30	621.29	0.01	0.01	0.00		98.05	1.95	153.96
Winmst Upper	4.3	622.03	622.01	0.02	0.01	0.00		192.35	7.65	173.43
Winmst Upper	4.2	Bridge								
Winmst Upper	4.1	621.11	621.10	0.01	2.20	0.00		98.46	1.54	148.64
Winmst Upper	4.1	621.77	621.75	0.03	2.37	0.00		193.57	6.43	166.39
Winmst Upper	4	618.91	618.88	0.03	4.11	0.01		100.00		101.98
Winmst Upper	4	619.41	619.37	0.04	4.17	0.01		200.00		138.31
Winmst Upper	3	614.79	614.78	0.01	6.37	0.03		100.00		182.78
Winmst Upper	3	615.23	615.22	0.01	6.27	0.02	0.04	199.93	0.03	213.09
Winmst Upper	2	608.39	608.10	0.28	1.59	0.05		100.00		42.32
Winmst Upper	2	608.94	608.77	0.17	1.57	0.05		200.00		67.78
Winmst Upper	1	606.47	606.46	0.01	0.56	0.00	2.95	57.23	39.82	139.38
Winmst Upper	1	607.32	607.31	0.01	0.69	0.00	10.32	107.29	82.39	163.71
Tributary #1	4	617.93	617.74	0.19	2.58	0.02		19.00		14.77
Tributary #1	4	618.22	618.00	0.22	2.88	0.07		38.00		20.08
Tributary #1	3	614.82	614.82	0.00	6.82	0.02		19.00		45.38
Tributary #1	3	615.28	615.28	0.01	6.97	0.03	0.05	37.63	0.32	69.16
Tributary #1	2	607.98	607.78	0.20	0.79	0.01		29.00		20.75
Tributary #1	2	608.29	608.03	0.26	0.69	0.08		58.00		27.37
Tributary #1	1	606.55	606.54	0.00	0.64	0.00	11.94	15.94	1.12	120.22
Tributary #1	1	607.37	607.37	0.00	0.74	0.00	32.16	22.96	2.87	161.65
Winmst Lower	3	605.90	605.90	0.01	2.53	0.03	0.31	128.22	0.47	132.84
Winmst Lower	3	606.64	606.63	0.01	1.55	0.00	1.74	253.63	2.64	145.60
Winmst Lower	2	603.35	603.07	0.28	0.09	0.08		129.00		57.14
Winmst Lower	2	605.09	605.07	0.02	0.08	0.00	0.12	257.88	0.00	187.82
Winmst Lower	1	602.80	602.80	0.00			0.05	128.82	0.13	139.66
Winmst Lower	1	605.00	605.00	0.00			0.78	255.37	1.85	156.00

Profile Output Table - Six XS Bridge

Reach	River Sta	E.G. Elev (ft)	W.S. Elev (ft)	Crit W.S. (ft)	Frctn Loss (ft)	C & E Loss (ft)	Top Width (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Vel Chnl (ft/s)
Winmst Upper	4.4	622.17	621.93	621.93	0.60	0.07	54.71		100.00		3.93
Winmst Upper	4.4	622.68	622.56	622.23	0.62	0.03	91.64		200.00		2.80
Winmst Upper	4.3	621.30	621.29	619.90	0.01	0.00	153.96		98.05	1.95	0.84
Winmst Upper	4.3	622.03	622.01	620.16	0.01	0.00	173.43		192.35	7.65	1.18
Winmst Upper	4.2 BR U	621.30	621.28	619.95	0.18	0.00	77.12		97.75	2.25	0.89
Winmst Upper	4.2 BR U	622.02	622.00	620.21	0.24	0.00	78.00		191.14	8.86	1.24
Winmst Upper	4.2 BR D	621.11	621.10	619.95	0.00	0.00	75.05		98.22	1.78	1.00
Winmst Upper	4.2 BR D	621.78	621.75	620.21	0.00	0.00	78.00		192.49	7.51	1.39
Winmst Upper	4.1	621.11	621.10	619.90	2.20	0.00	148.64		98.46	1.54	0.95
Winmst Upper	4.1	621.77	621.75	620.16	2.37	0.00	166.39		193.57	6.43	1.32
Winmst Upper	4	618.91	618.88	618.35	4.11	0.01	101.98		100.00		1.42
Winmst Upper	4	619.41	619.37	618.62	4.17	0.01	138.31		200.00		1.55

Profile Output Table - Bridge Only

Reach	River Sta	E.G. US. (ft)	Min El Prs (ft)	BR Open Area (sq ft)	Prs O WS (ft)	Q Total (cfs)	Min Top Rd (ft)	Q Weir (cfs)	Delta EG (ft)
Winmst Upper	4.2	621.30	623.00	252.60		100.00	625.00		0.19
Winmst Upper	4.2	622.03	623.00	252.60		200.00	625.00		0.25

Profile Output Table - Bridge Comparison

Reach	River Sta	E.G. US. (ft)	W.S. US. (ft)	Br Sel Mthd	Energy EG (ft)	Momen. EG (ft)	Yarnell EG (ft)	WSPRO EG (ft)	Prs O EG (ft)	Prs/Wr EG (ft)	Energy/Wr EG (ft)
Winmst Upper	4.2	621.30	621.29	Energy only	621.30						
Winmst Upper	4.2	622.03	622.01	Energy only	622.03						

Appendix 3: HEC-RAS Report Generator Output – Culvert Example

```
                        HEC-RAS Version 2.1 October 1997
                          U.S. Army Corp of Engineers
                         Hydrologic Engineering Center
                          609 Second Street, Suite D
                          Davis, California 95616-4687
                                 (916) 756-1104

            X     X  XXXXXX    XXXX        XXXX       XX      XXXX
            X     X  X        X    X       X   X     X  X    X
            X     X  X        X            X   X    X    X   X
            XXXXXXX  XXXX     X       XXX  XXXX     XXXXXX    XXXX
            X     X  X        X            X  X     X    X        X
            X     X  X        X    X       X   X    X    X        X
            X     X  XXXXXX    XXXX        X    X   X    X   XXXXX

********************************************************************************

PROJECT DATA
Project Title: Winimusset Brook with Culvert
Project File : winclvrt.prj
Run Date and Time: 8/9/98 7:08:00 PM

Project in English units

********************************************************************************

PLAN DATA

Plan Title: Winimusset Brook
Plan File : d:\hecras21\data\winclvrt.p01

           Geometry Title: Winimusset Brook
           Geometry File : d:\hecras21\data\winclvrt.g01

           Flow Title    : Winimusset Brook
           Flow File     : d:\hecras21\data\winclvrt.f01

Plan Summary Information:
Number of:  Cross Sections =   18    Mulitple Openings =    0
            Culverts       =    1    Inline Weirs      =    0
            Bridges        =    0

Computational Information
    Water surface calculation tolerance =  0.01
    Critical depth calculaton tolerance =  0.01
    Maximum number of interations       =  20
    Maximum difference tolerance        =  0.3
    Flow tolerance factor               =  0.001

Computational Flow Regime: Mixed Flow

********************************************************************************

FLOW DATA

Flow Title: Winimusset Brook
Flow File : d:\hecras21\data\winclvrt.f01

Flow Data (cfs)
*************************************************************
* River          Reach           RS      *           PF#1 *
* Winimusset BrookWinmst Upper    8       *            100 *
* Winimusset BrookTributary #1    4       *             29 *
* Winimusset BrookWinmst Lower    3       *            129 *
*************************************************************

Boundary Conditions
*********************************************************************************************************
* River          Reach           Profile         *           Upstream                Downstream    *
*********************************************************************************************************
* Winimusset BrookWinmst Upper    PF#1            *             Critical                             *
* Winimusset BrookTributary #1    PF#1            *             Critical                             *
* Winimusset BrookWinmst Lower    PF#1            *                                Known WS = 602.8 *
*********************************************************************************************************

********************************************************************************

GEOMETRY DATA

Geometry Title: Winimusset Brook
Geometry File : d:\hecras21\data\winclvrt.g01

Reach Connection Table
*********************************************************************************
* River            Reach            *  Upstream Boundary  * Downstream Boundary *
*********************************************************************************
* Winimusset Brook Winmst Upper     *                     *   Junct 1           *
* Winimusset Brook Tributary #1     *                     *   Junct 1           *
* Winimusset Brook Winmst Lower     *   Junct 1           *                     *
*********************************************************************************

CULVERT                RIVER: Winimusset Brook
REACH: Winmst Upper       RS: 4.2

INPUT
Description:
Distance from Upstream XS =       1
Deck/Roadway Width        =      19
Weir Coefficient          =     2.6
Bridge Deck/Roadway Skew  =
Upstream  Deck/Roadway Coordinates
    num=       2
```

Sta	Hi Cord	Lo Cord	Sta	Hi Cord	Lo Cord
0	632	0	450	632	0

Upstream Bridge Cross Section Data

Station Elevation Data num= 10

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	635	25	630	125	625	190	621	260	620
300	619	325	620	380	625	400	630	450	635

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.4	260	.2	325	.4

Bank Sta: Left	Right	Coeff Contr.	Expan.
260	325	.1	.3

Ineffective Flow num= 2

Sta L	Sta R	Elev	Sta L	Sta R	Elev
0	264	632	336	450	632

Downstream Deck/Roadway Coordinates

num= 2

Sta	Hi Cord	Lo Cord	Sta	Hi Cord	Lo Cord
0	632	0	450	632	0

Downstream Bridge Cross Section Data

Station Elevation Data num= 10

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	635	25	630	125	625	190	621	260	620
300	619	325	620	380	625	400	630	450	635

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.4	260	.2	325	.4

Bank Sta: Left	Right	Coeff Contr.	Expan.
260	325	.1	.3

Ineffective Flow num= 2

Sta L	Sta R	Elev	Sta L	Sta R	Elev
0	264	632	336	450	632

```
Upstream Embankment side slope              =       0 horiz. to 1.0 vertical
Downstream Embankment side slope            =       0 horiz. to 1.0 vertical
Maximum allowable submergence for weir flow =     .95
Elevation at which weir flow begins         =
Energy head used in spillway design         =
Spillway height used in design              =
Weir crest shape                            = Broad Crested
```

Number of Culverts = 1

Culvert Name	Shape	Rise	Span
Culvert #1	Box	12	72

FHWA Chart # 58- Rectangular concrete

FHWA Scale # 2 - Side tapered; More favorable edges

Solution Criteria = Highest U.S. EG

Culvert Upstrm Dist	Length	n Value	Entrance Loss Coef	Exit Loss Coef
1	19	.1	.1	1

Upstream Elevation = 619

Centerline Station = 300

Downstream Elevation = 619

Centerline Station = 300

CULVERT OUTPUT Profile #PF#1

Culvert ID : Culvert #1

Culv Q (cfs)	100.00	Culv Vel In (ft/s)	0.65
# Barrels	1	Culv Vel Out (ft/s)	0.65
Q Barrel (cfs)	100.00	Culv Inv El Up (ft)	619.00
W.S. US. (ft)	621.13	Culv Inv El Dn (ft)	619.00
E.G. US. (ft)	621.15	Culv Frctn Ls (ft)	0.01
Delta WS (ft)	0.02	Culv Ext Lss (ft)	
Delta EG (ft)	0.01	Culv Ent Lss (ft)	0.00
E.G. IC (ft)	619.70	Q Weir (cfs)	
E.G. OC (ft)	621.15	Weir Sta Lft (ft)	
Culv WS In (ft)	621.14	Weir Sta Rgt (ft)	
Culv WS Out (ft)	621.13	Weir Submerg	
Culv Nml Depth (ft)		Weir Max Depth (ft)	
Culv Crt Depth (ft)	0.39	Weir Avg Depth (ft)	
Culv Ful Lngh (ft)		Min Top Rd (ft)	632.00

Profile Output Table - Standard Table 1

Reach	River Sta	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)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
Winmst Upper	8	100.00	632.00	634.07	633.28	634.12	0.053026	1.75	57.23	55.25	0.30
Winmst Upper	7	100.00	628.00	630.68	629.15	630.69	0.006471	0.84	120.67	78.21	0.11
Winmst Upper	6	100.00	625.00	627.99	626.89	628.06	0.036554	2.22	66.02	72.86	0.28
Winmst Upper	5	100.00	622.00	623.76	622.86	623.77	0.017397	0.90	111.12	126.20	0.17
Winmst Upper	4.4	100.00	621.00	621.93	621.93	622.17	0.774362	3.93	25.47	54.71	1.01
Winmst Upper	4.3	100.00	619.00	621.13	619.90	621.15	0.008606	0.97	108.50	149.67	0.13
Winmst Upper	4.2	Culvert									
Winmst Upper	4.1	100.00	619.00	621.12	619.89	621.13	0.008879	0.98	107.41	149.26	0.13
Winmst Upper	4	100.00	617.50	618.88	618.35	618.91	0.060333	1.42	70.26	101.98	0.30
Winmst Upper	3	100.00	613.00	614.78	613.74	614.79	0.007968	0.61	162.98	182.78	0.11
Winmst Upper	2	100.00	607.00	608.10	608.10	608.39	0.734252	4.28	23.36	42.32	1.02
Winmst Upper	1	100.00	604.00	606.46	604.85	606.47	0.004476	0.78	209.52	139.38	0.10
Tributary #1	4	29.00	617.00	618.21	617.87	618.27	0.120862	2.04	14.56	24.14	0.43
Tributary #1	3	29.00	613.00	614.96	613.80	614.97	0.006775	0.60	48.17	49.08	0.11
Tributary #1	2	29.00	607.00	607.78	607.78	607.98	0.827317	3.59	8.07	20.75	1.02
Tributary #1	1	29.00	604.00	606.54	605.03	606.55	0.002561	0.60	109.25	120.22	0.07
Winmst Lower	3	129.00	603.00	605.90	604.03	605.90	0.002564	0.58	229.39	132.84	0.07
Winmst Lower	2	129.00	602.00	603.07	603.07	603.35	0.740206	4.21	30.61	57.14	1.01
Winmst Lower	1	129.00	595.00	602.80	596.59	602.80	0.000115	0.22	597.78	139.66	0.02

Profile Output Table - Standard Table 2

Reach	River Sta	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
Winmst Upper	8	634.12	634.07	0.05	3.41	0.01		100.00		55.25
Winmst Upper	7	630.69	630.68	0.01	2.63	0.01	0.20	99.59	0.20	78.21
Winmst Upper	6	628.06	627.99	0.07	4.27	0.02	10.19	88.36	1.45	72.86
Winmst Upper	5	623.77	623.76	0.01	1.58	0.02		100.00		126.20
Winmst Upper	4.4	622.17	621.93	0.24	0.78	0.04		100.00		54.71
Winmst Upper	4.3	621.15	621.13	0.01				98.23	1.77	149.67
Winmst Upper	4.2	Culvert								
Winmst Upper	4.1	621.13	621.12	0.01	2.22	0.00		98.27	1.73	149.26
Winmst Upper	4	618.91	618.88	0.03	4.11	0.01		100.00		101.98
Winmst Upper	3	614.79	614.78	0.01	6.37	0.03		100.00		182.78
Winmst Upper	2	608.39	608.10	0.28	1.59	0.05		100.00		42.32
Winmst Upper	1	606.47	606.46	0.01	0.56	0.00	2.95	57.23	39.82	139.38
Tributary #1	4	618.27	618.21	0.06	3.29	0.02	0.06	28.88	0.06	24.14
Tributary #1	3	614.97	614.96	0.01	6.97	0.02		29.00		49.08
Tributary #1	2	607.98	607.78	0.20	0.79	0.01		29.00		20.75
Tributary #1	1	606.55	606.54	0.00	0.64	0.00	11.94	15.94	1.12	120.22
Winmst Lower	3	605.90	605.90	0.01	2.53	0.03	0.31	128.22	0.47	132.84
Winmst Lower	2	603.35	603.07	0.28	0.09	0.08		129.00		57.14
Winmst Lower	1	602.80	602.80	0.00			0.05	128.82	0.13	139.66

Profile Output Table - Four XS Culvert

Reach	River Sta	E.G. Elev (ft)	W.S. Elev (ft)	Vel Head (ft)	Frctn Loss (ft)	C & E Loss (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Top Width (ft)
Winmst Upper	4.4	622.17	621.93	0.24	0.78	0.04		100.00		54.71
Winmst Upper	4.3	621.15	621.13	0.01				98.23	1.77	149.67
Winmst Upper	4.2	Culvert								
Winmst Upper	4.1	621.13	621.12	0.01	2.22	0.00		98.27	1.73	149.26
Winmst Upper	4	618.91	618.88	0.03	4.11	0.01		100.00		101.98

Profile Output Table - Culvert Only

Reach	River Sta	E.G. US. (ft)	W.S. US. (ft)	E.G. IC (ft)	E.G. OC (ft)	Min Top Rd (ft)	Culv Q (cfs)	Q Weir (cfs)	Delta WS (ft)	Culv Vel In (ft/s)	Culv Vel Out (ft/s)
Winmst Upper	4.2 Culvert #1	621.15	621.13	619.70	621.15	632.00	100.00		0.02	0.65	0.65

Appendix 4: HEC-RAS Report Generator Output – Encroachment Example

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                        HEC-RAS Version 2.1 October 1997
                          U.S. Army Corp of Engineers
                         Hydrologic Engineering Center
                           609 Second Street, Suite D
                          Davis, California 95616-4687
                                 (916) 756-1104

            X     X  XXXXXX    XXXX        XXXX       XX      XXXX
            X     X  X        X    X       X   X     X  X    X
            X     X  X        X            X   X    X    X   X
            XXXXXXX  XXXX     X       XXX  XXXX     XXXXXX    XXXX
            X     X  X        X            X  X     X    X        X
            X     X  X        X    X       X   X    X    X        X
            X     X  XXXXXX    XXXX        X    X   X    X   XXXXX

********************************************************************************

PROJECT DATA
Project Title: Winimusset Brook with Encroachment
Project File : winencr.prj
Run Date and Time: 4/18/98 9:53:08 PM

Project in English units

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PLAN DATA

Plan Title: Winimusset Brook
Plan File : d:\hecras21\data\winencr.p01

           Geometry Title: Winimusset Brook
           Geometry File : d:\hecras21\data\winencr.g01

           Flow Title    : Winimusset Brook
           Flow File     : d:\hecras21\data\winencr.f01

Plan Summary Information:
Number of:  Cross Sections =   15    Mulitple Openings =    0
            Culverts       =    0    Inline Weirs      =    0
            Bridges        =    0

Computational Information
    Water surface calculation tolerance =  0.01
    Critical depth calculaton tolerance =  0.01
    Maximum number of interations       =  20
    Maximum difference tolerance        =  0.3
    Flow tolerance factor               =  0.001

Computational Flow Regime: Mixed Flow

Encroachment Data
   Equal Conveyance = True
   Left Offset      =       0
   Right Offset     =       0

River = Winimusset Brook Reach = Winmst Upper
RS      Profile           Method  Value1  Value2
8       PF#2                   1       0     900
7       PF#2                   1     129     209
6       PF#2                   1     585     615
5       PF#2                   1       0     900
4       PF#2                   1       0     900
3       PF#2                   1       0     900
2       PF#2                   1       0     900
1       PF#2                   1       0     900

********************************************************************************

FLOW DATA

Flow Title: Winimusset Brook
Flow File : d:\hecras21\data\winencr.f01

Flow Data (cfs)
*****************************************************************************
* River           Reach          RS      *           PF#1           PF#2 *
* Winimusset BrookWinmst Upper    8      *            200            200 *
* Winimusset BrookTributary #1    4      *             58             58 *
* Winimusset BrookWinmst Lower    3      *            258            258 *
*****************************************************************************

Boundary Conditions
********************************************************************************************************
* River           Reach           Profile          *           Upstream                Downstream    *
********************************************************************************************************
* Winimusset BrookWinmst Upper    PF#1             *             Critical                            *
* Winimusset BrookWinmst Upper    PF#2             *             Critical                            *
* Winimusset BrookTributary #1    PF#1             *             Critical                            *
* Winimusset BrookTributary #1    PF#2             *             Critical                            *
* Winimusset BrookWinmst Lower    PF#1             *                                 Known WS = 605 *
* Winimusset BrookWinmst Lower    PF#2             *                                 Known WS = 605 *
********************************************************************************************************

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GEOMETRY DATA

Geometry Title: Winimusset Brook
Geometry File : d:\hecras21\data\winencr.g01

Reach Connection Table
*********************************************************************************
* River            Reach           *  Upstream Boundary  * Downstream Boundary *
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Winimusset Brook Winmst Upper		Junct 1
Winimusset Brook Tributary #1		Junct 1
Winimusset Brook Winmst Lower	Junct 1	

Profile Output Table - Encroachment 1

Reach	River Sta	W.S. Elev (ft)	Prof Delta WS (ft)	E.G. Elev (ft)	Top Wdth Act (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Enc Sta L (ft)	Ch Sta L (ft)	Ch Sta R (ft)	Enc Sta R (ft)
Winmst Upper	8	634.79		634.85	74.33		200.00			210.00	290.00	
Winmst Upper	8	634.71	-0.08	634.77	72.15		200.00		0.00	210.00	290.00	900.00
Winmst Upper	7	631.52		631.54	88.21	1.72	196.56	1.72		135.00	205.00	
Winmst Upper	7	631.61	0.10	631.63	80.00	1.89	196.63	1.47	129.00	135.00	205.00	209.00
Winmst Upper	6	628.58		628.69	104.49	40.20	154.10	5.70		590.00	610.00	
Winmst Upper	6	628.76	0.18	628.92	30.00	8.68	184.79	6.52	585.00	590.00	610.00	615.00
Winmst Upper	5	624.34		624.36	168.02		200.00			250.00	465.00	
Winmst Upper	5	624.34	0.00	624.36	168.02		200.00		0.00	250.00	465.00	900.00
Winmst Upper	4	619.37		619.41	138.31		200.00			155.00	340.00	
Winmst Upper	4	619.37	0.00	619.41	138.31		200.00		0.00	155.00	340.00	900.00
Winmst Upper	3	615.22		615.23	213.09	0.04	199.93	0.03		205.00	410.00	
Winmst Upper	3	615.22	0.00	615.23	213.09	0.04	199.93	0.03	0.00	205.00	410.00	900.00
Winmst Upper	2	608.77		608.94	67.78		200.00			335.00	450.00	
Winmst Upper	2	608.77	0.00	608.94	67.78		200.00		0.00	335.00	450.00	900.00
Winmst Upper	1	607.31		607.32	163.71	10.32	107.29	82.39		225.00	262.50	
Winmst Upper	1	607.31	0.00	607.32	163.71	10.32	107.29	82.39	0.00	225.00	262.50	900.00
Tributary #1	4	618.48		618.60	29.50	0.64	56.72	0.64		80.00	100.00	
Tributary #1	4	618.48	0.00	618.60	29.50	0.64	56.72	0.64		80.00	100.00	
Tributary #1	3	615.52		615.52	77.01	0.27	56.62	1.11		90.00	140.00	
Tributary #1	3	615.52	0.00	615.52	77.01	0.27	56.62	1.11		90.00	140.00	
Tributary #1	2	608.03		608.29	27.37		58.00			0.00	80.00	
Tributary #1	2	608.03	0.00	608.29	27.37		58.00			0.00	80.00	
Tributary #1	1	607.37		607.37	161.65	32.16	22.96	2.87		187.00	200.00	
Tributary #1	1	607.37	0.00	607.37	161.65	32.16	22.96	2.87		187.00	200.00	
Winmst Lower	3	606.63		606.64	145.60	1.74	253.63	2.64		325.00	442.00	
Winmst Lower	3	606.63	0.00	606.64	145.60	1.74	253.63	2.64		325.00	442.00	
Winmst Lower	2	605.07		605.09	187.82	0.12	257.88	0.00		320.00	480.00	
Winmst Lower	2	605.07	0.00	605.09	187.82	0.12	257.88	0.00		320.00	480.00	
Winmst Lower	1	605.00		605.00	156.00	0.78	255.37	1.85		105.00	235.00	
Winmst Lower	1	605.00	0.00	605.00	156.00	0.78	255.37	1.85		105.00	235.00	

Profile Output Table - Encroachment 2

Reach	River Sta	Prof Delta WS (ft)	Top Wdth Act (ft)	K Perc L (ft)	Enc Sta L (ft)	Dist Center L (ft)	Center Station (ft)	Dist Center R (ft)	Enc Sta R (ft)	K Perc R (ft)	Encr WD (ft)
Winmst Upper	8		74.33				250.00				
Winmst Upper	8	-0.08	72.15		0.00	250.00	250.00	650.00	900.00		900.00
Winmst Upper	7		88.21				170.00				
Winmst Upper	7	0.10	80.00	0.01	129.00	41.00	170.00	39.00	209.00	0.21	80.00
Winmst Upper	6		104.49				600.00				
Winmst Upper	6	0.18	30.00	19.42	585.00	15.00	600.00	15.00	615.00	0.64	30.00
Winmst Upper	5		168.02				357.50				
Winmst Upper	5	0.00	168.02		0.00	357.50	357.50	542.50	900.00		900.00
Winmst Upper	4		138.31				247.50				
Winmst Upper	4	0.00	138.31		0.00	247.50	247.50	652.50	900.00		900.00
Winmst Upper	3		213.09				307.50				
Winmst Upper	3	0.00	213.09	0.00	0.00	307.50	307.50	592.50	900.00	0.00	900.00
Winmst Upper	2		67.78				392.50				
Winmst Upper	2	0.00	67.78		0.00	392.50	392.50	507.50	900.00		900.00
Winmst Upper	1		163.71				243.75				
Winmst Upper	1	0.00	163.71	0.00	0.00	243.75	243.75	656.25	900.00	0.00	900.00
Tributary #1	4		29.50				90.00				
Tributary #1	4	0.00	29.50				90.00				
Tributary #1	3		77.01				115.00				
Tributary #1	3	0.00	77.01				115.00				
Tributary #1	2		27.37				40.00				
Tributary #1	2	0.00	27.37				40.00				
Tributary #1	1		161.65				193.50				
Tributary #1	1	0.00	161.65				193.50				
Winmst Lower	3		145.60				383.50				
Winmst Lower	3	0.00	145.60				383.50				
Winmst Lower	2		187.82				400.00				
Winmst Lower	2	0.00	187.82				400.00				
Winmst Lower	1		156.00				170.00				
Winmst Lower	1	0.00	156.00				170.00				

Profile Output Table - Encroachment 3

Reach	River Sta	Top Wdth Act (ft)	Area (sq ft)	Vel Total (ft/s)	W.S. Elev (ft)	Base WS (ft)	Prof Delta WS (ft)
Winmst Upper	8	74.33	103.59	1.93	634.79	634.79	

Winmst Upper	8		72.15	97.59	2.05	634.71	634.79	-0.08
Winmst Upper	7		88.21	190.05	1.05	631.52	631.52	
Winmst Upper	7		80.00	194.75	1.03	631.61	631.52	0.10
Winmst Upper	6		104.49	118.61	1.69	628.58	628.58	
Winmst Upper	6		30.00	70.69	2.83	628.76	628.58	0.18
Winmst Upper	5		168.02	196.95	1.02	624.34	624.34	
Winmst Upper	5		168.02	196.95	1.02	624.34	624.34	0.00
Winmst Upper	4		138.31	129.25	1.55	619.37	619.37	
Winmst Upper	4		138.31	129.25	1.55	619.37	619.37	0.00
Winmst Upper	3		213.09	250.73	0.80	615.22	615.22	
Winmst Upper	3		213.09	250.73	0.80	615.22	615.22	0.00
Winmst Upper	2		67.78	59.93	3.34	608.77	608.77	
Winmst Upper	2		67.78	59.93	3.34	608.77	608.77	0.00
Winmst Upper	1		163.71	339.85	0.59	607.31	607.31	
Winmst Upper	1		163.71	339.85	0.59	607.31	607.31	0.00
Tributary #1	4		29.50	21.76	2.67	618.48	618.48	
Tributary #1	4		29.50	21.76	2.67	618.48	618.48	0.00
Tributary #1	3		77.01	85.30	0.68	615.52	615.52	
Tributary #1	3		77.01	85.30	0.68	615.52	615.52	0.00
Tributary #1	2		27.37	14.05	4.13	608.03	608.03	
Tributary #1	2		27.37	14.05	4.13	608.03	608.03	0.00
Tributary #1	1		161.65	229.68	0.25	607.37	607.37	
Tributary #1	1		161.65	229.68	0.25	607.37	607.37	0.00
Winmst Lower	3		145.60	330.37	0.78	606.63	606.63	
Winmst Lower	3		145.60	330.37	0.78	606.63	606.63	0.00
Winmst Lower	2		187.82	253.49	1.02	605.07	605.07	
Winmst Lower	2		187.82	253.49	1.02	605.07	605.07	0.00
Winmst Lower	1		156.00	923.00	0.28	605.00	605.00	
Winmst Lower	1		156.00	923.00	0.28	605.00	605.00	0.00