Introducion to Hydrologic Engineering Centers River Analysis System (HEC- RAS)

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One – dimensional river models (1-D models)

Assumptions

- Flow is one dimensional
- Streamline curvature is small
- Boundary friction – resistance laws
- Channel bed slope is small

Conservation of

- Mass – flow & sediment continuity equation
- Energy
- Momentum – dynamic equation

HEC-RAS is designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels.

Major capabilities of HEC-RAS.

- User interface
- Hydraulic Analysis Components
- Data Storage and Management
- Graphics and Reporting
- RAS Mapper

HEC-RAS

U.S. Army Corps of Engineers River Analysis System (HEC-RAS) developed by the Hydrologic Engineering Center.

- Graphical user interface (GUI)
- Hydraulic analysis components
- Data storage and management capabilities
- Graphics and reporting facilities

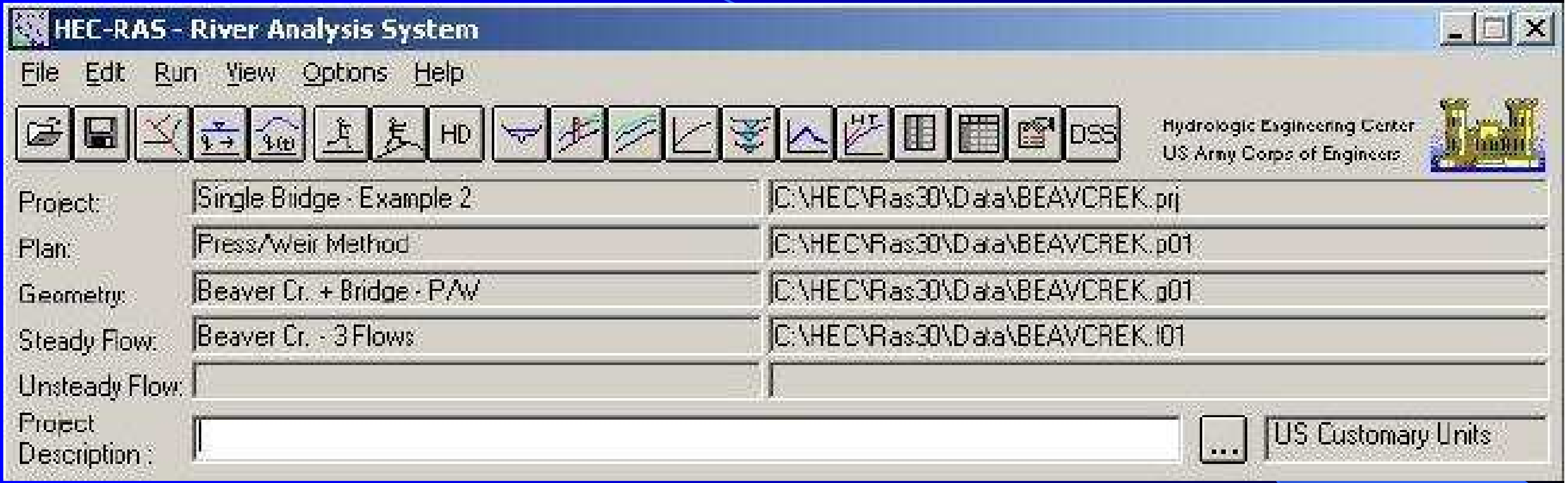
One-dimensional hydraulic analysis components for:

(1) steady flow water surface profile computations;
(2) unsteady flow simulation; and
(3) movable boundary sediment transport computations.

User interface

The user interacts with HEC-RAS through a graphical user interface (GUI). The interface provides for

- File management
- Data entry and editing
- Hydraulic analyses
- Tabulation and graphical displays of input and output data
- Reporting facilities
- On-line help



HEC-RAS main window

Hydraulic Analysis Components

(1) Steady Flow Water Surface Profiles

(2) Unsteady Flow Simulation;

(3) Movable Boundary Sediment Transport computations

(4) Water Quality Analysis.

All four components use a common geometric data representation and common geometric and hydraulic computation routines.

Hydraulic design features

Steady Flow Water Surface Profiles

a) Calculating water surface profiles for steady gradually varied flow.
b) The system can handle a full network of channels, a dendritic system, or a single river reach.
c) The steady flow component is capable of modeling
   - subcritical,
   - supercritical, and
   - mixed flow regimes water surface profiles.

The basic computational procedure

- based on the solution of the one-dimensional energy equation.
- Energy losses are evaluated by
  - friction (Manning's equation) and
  - contraction/expansion (coefficient multiplied by the change in velocity head).
- The momentum equation used in situations where the water surface profile is rapidly varied.
  - mixed flow regime calculations (i.e. hydraulic jumps), hydraulics of bridges, and evaluating profiles at river confluences (stream junctions).
- The effects of various obstructions such as bridges, culverts, weirs, and structures in the flood plain may be considered in the computations.

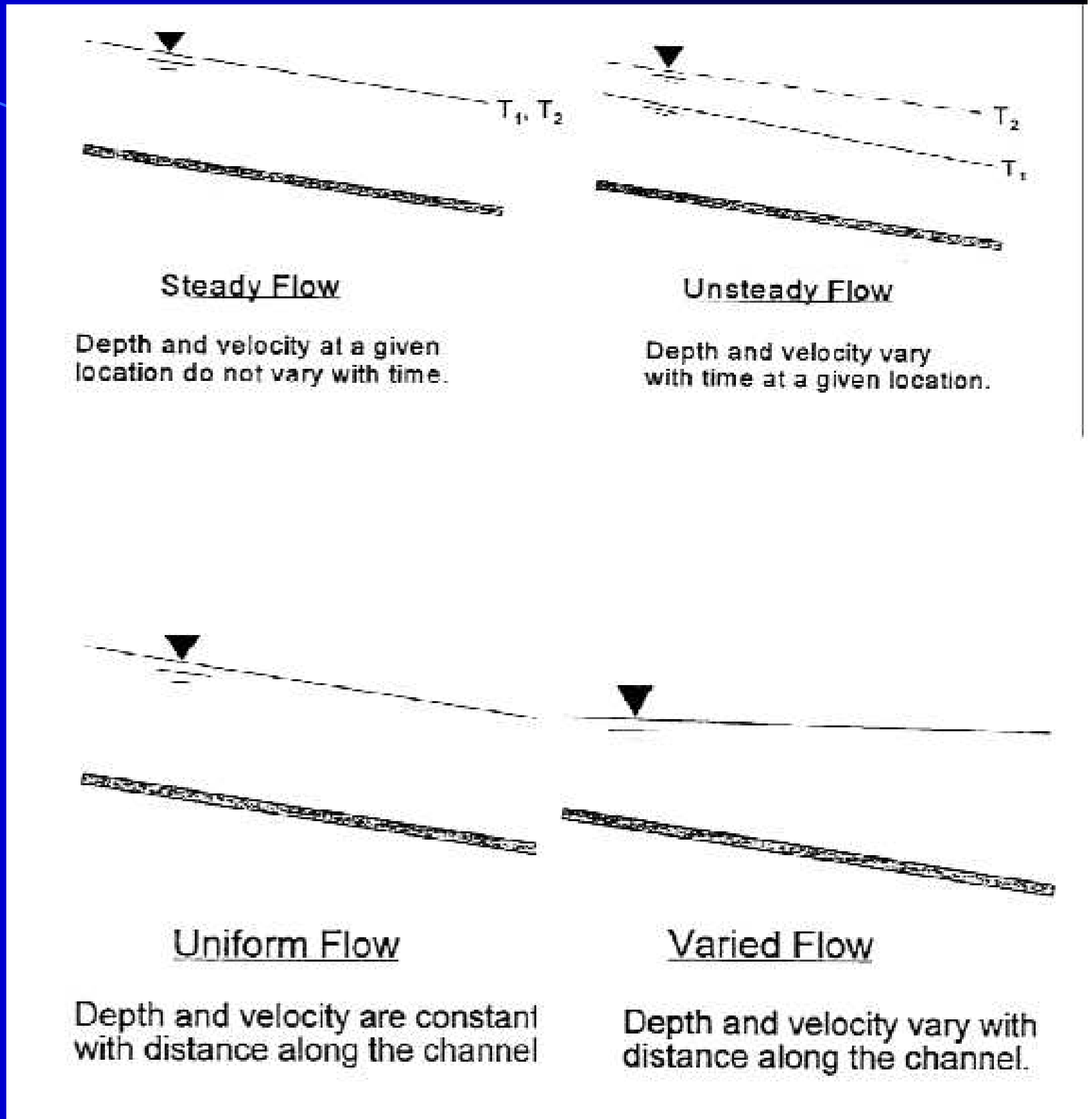
Flow Classification

Classification by Time

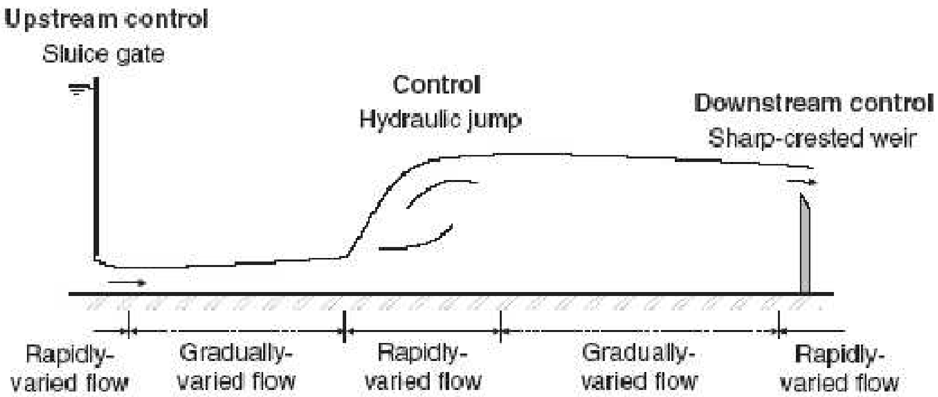
Steady Flow – Constant Flow Rate Unsteady Flow – Changing Flow Rate

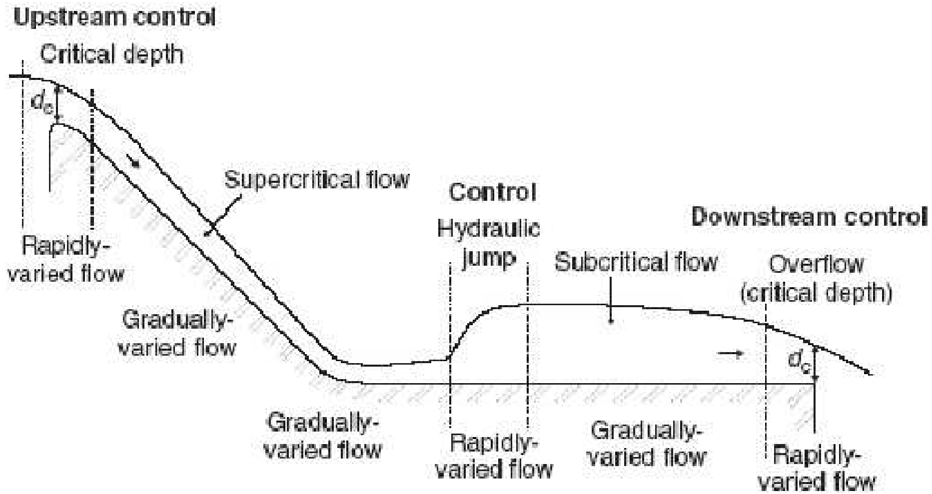
Classification by Distance

Uniform Flow – Characterized by constant depth and constant mean flow velocity Non-uniform Flow – Characterized by varying depth and constant mean flow velocity (In most Practical Cases)

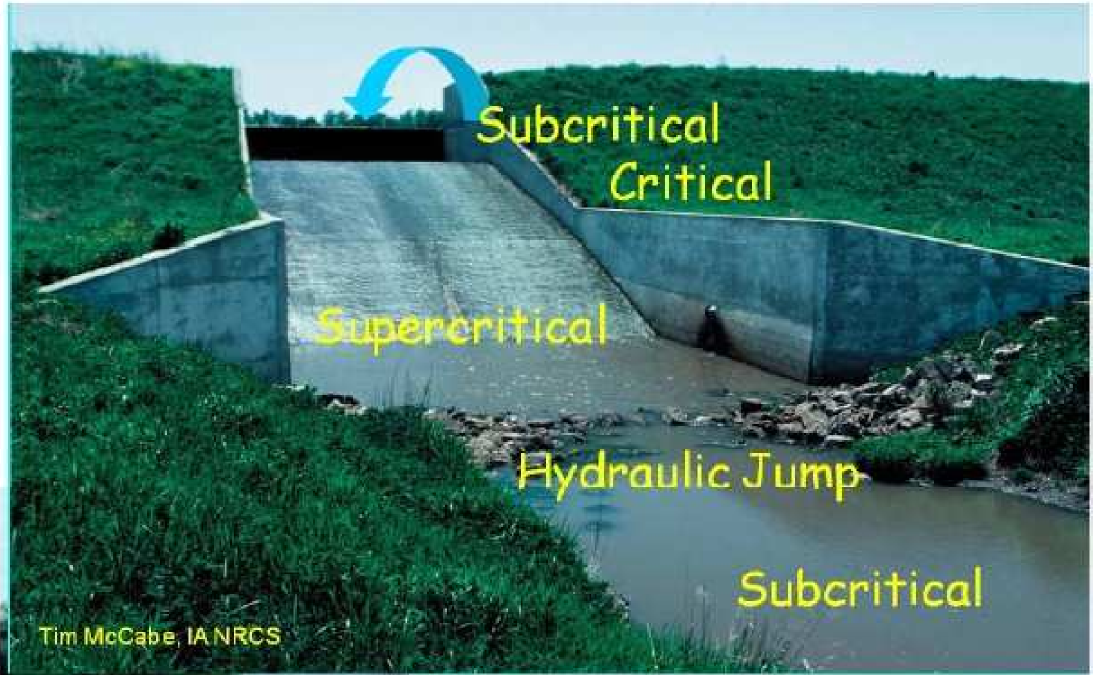


Types





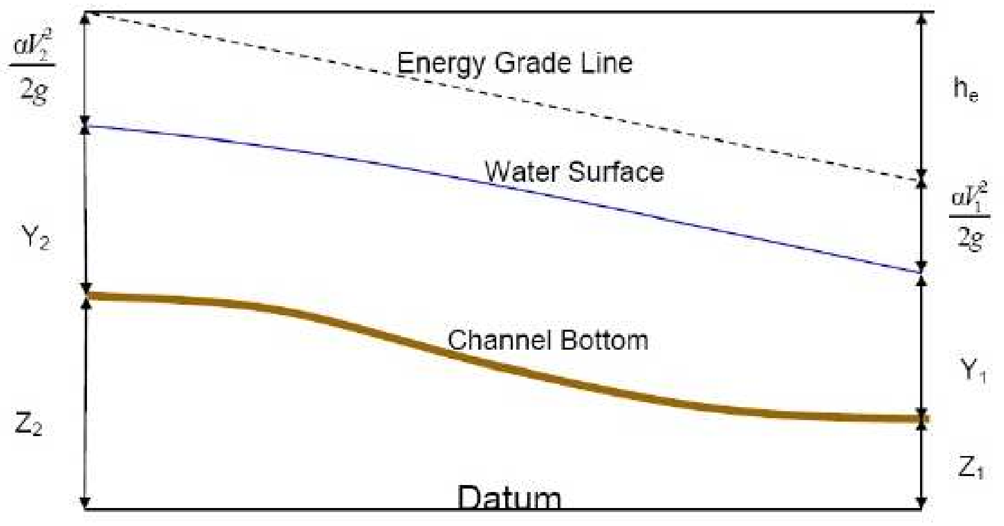
$d_o > d_c$	Mild slope	Uniform flow: $Fr_o < 1$ (subcritical flow)
$d_o = d_c$	Critical slope	Uniform flow: $Fr_o = 1$ (critical flow)
$d_o < d_c$	Steep slope	Uniform flow: $Fr_o > 1$ (supercritical flow)


Subcritical
Critical
Supercritical
Hydraulic Jump
Subcritical
Tim McCabe, IA NRCS


Subcritical
Critical
Supercritical
Hydraulic Jump
Subcritical

Governing Equations
Energy Equation

Gradually Varied Flow Computations involve solution of one dimensional energy equation
Water surface profiles are computed from one cross section to the other using Iteration method/ standard step method Computational procedure…..
The energy equation is only applicable to gradually varied flow situation



$$Z_2 + Y_2 + \frac{a_2 V_2^2}{2g} = Z_1 + Y_1 + \frac{a_1 V_1^2}{2g} + h_e$$

Where: Z_1, Z_2 = elevation of the main channel inverts

Y_1, Y_2 = depth of water at cross sections

V_1, V_2 = average velocities (total discharge/ total flow area)

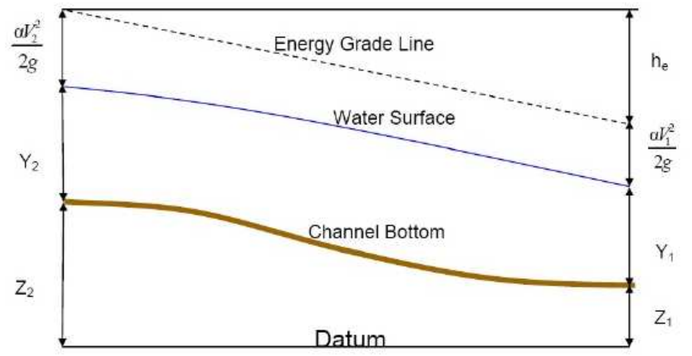
a_1, a_2 = velocity weighting coefficients

g = gravitational acceleration

h_e = energy head loss

Computation Procedure

1. Assume water surface elevation at upstream/ downstream cross-section
2. Based on the assumed water surface elevation, determine the corresponding total conveyance and velocity head using Manning’s Equation
3. With values from step 2,compute and solve equation for he
4. With values from steps 2 and 3,solve energy equation for WS2.
5. Compare the computed value of WS2 with value assumed instep 1; repeat steps 1 through 5 until the values agree to within 0.01 feet, or the user-defined tolerance.

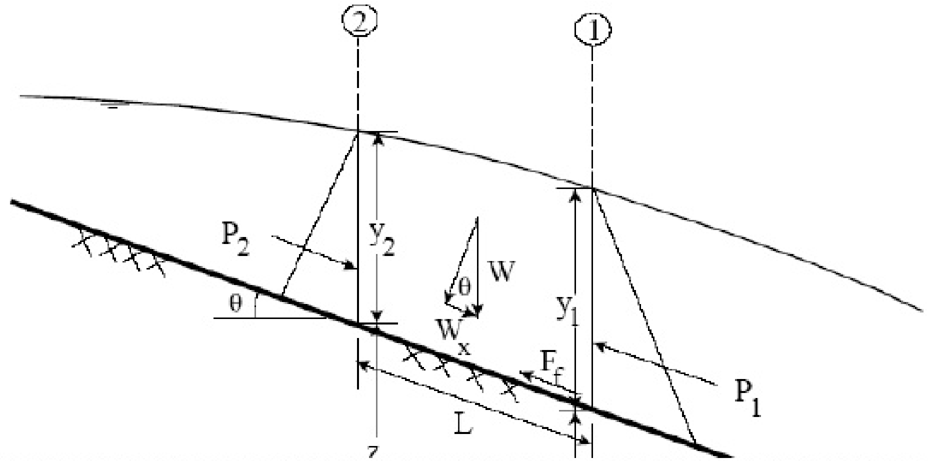


$$Q = K S_f^{1/2}$$

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

Governing Equations
Momentum Equation

Rapidly Varied Flow
(Sharp crested weir, Hydraulic jump, Sluice gate etc)
Whenever flow encounters transition from supercritical flow to subcritical flow or vice-versa, the flow varies rapidly and energy equation is not valid
Momentum equations are applied to account for various hydraulic parameters in rapidly varied flow



$$\frac{Q_2^2 \beta_2}{g A_2} + A_2 \bar{Y}_2 + \left(\frac{A_1 + A_2}{2}\right) L S_0 - \left(\frac{A_1 + A_2}{2}\right) L \bar{S}_f = \frac{Q_1^2 \beta_1}{g A_1} + A_1 \bar{Y}_1$$

Governing Equations
General Notes

The momentum and energy equations may be written similarly. Note that the loss term in the energy equation represents internal energy losses while the loss in the momentum equation (hm) represents losses due to external forces

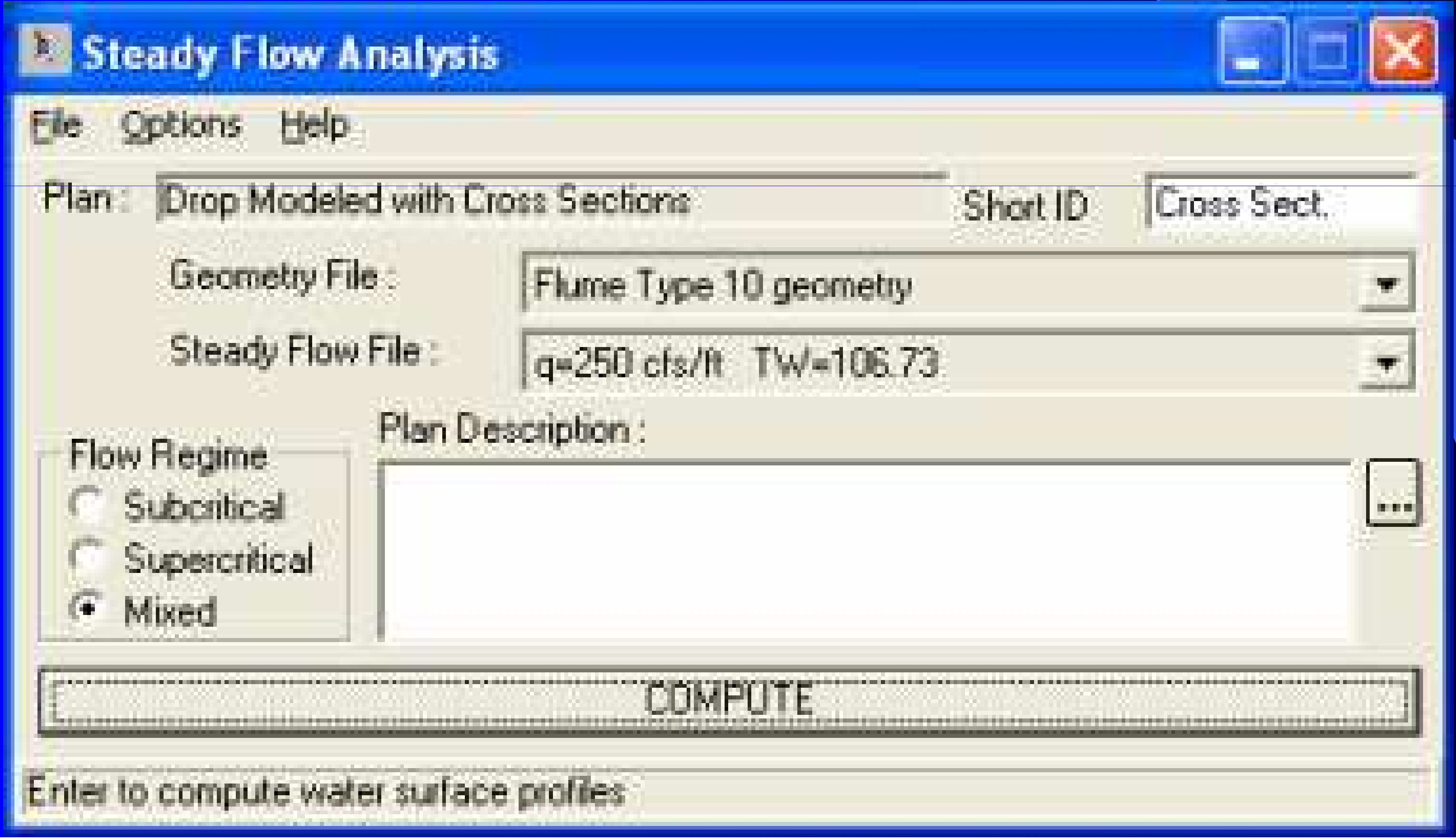
In uniform flow, the internal and external losses are identical. In gradually varied flow, they are close

Basic Data Requirement
Any Simulation in HEC-RAS requires following 5 Steps

1)Define geometry
2)Define flows (steady/unsteady analysis)
3)Define Boundary conditions
4)Perform Simulations
5)Review Output and Results

All above steps are simple and user friendly in HEC-RAS provided you have sound understanding of hydraulic phenomena involve in particular analysis Before going to model practice, above mentioned five steps would be explained in next slides

The steady flow system is designed for application in flood plain management and flood insurance studies to evaluate floodway encroachments. Also, capabilities are available for assessing the change in water surface profiles due to channel improvements, and levees.

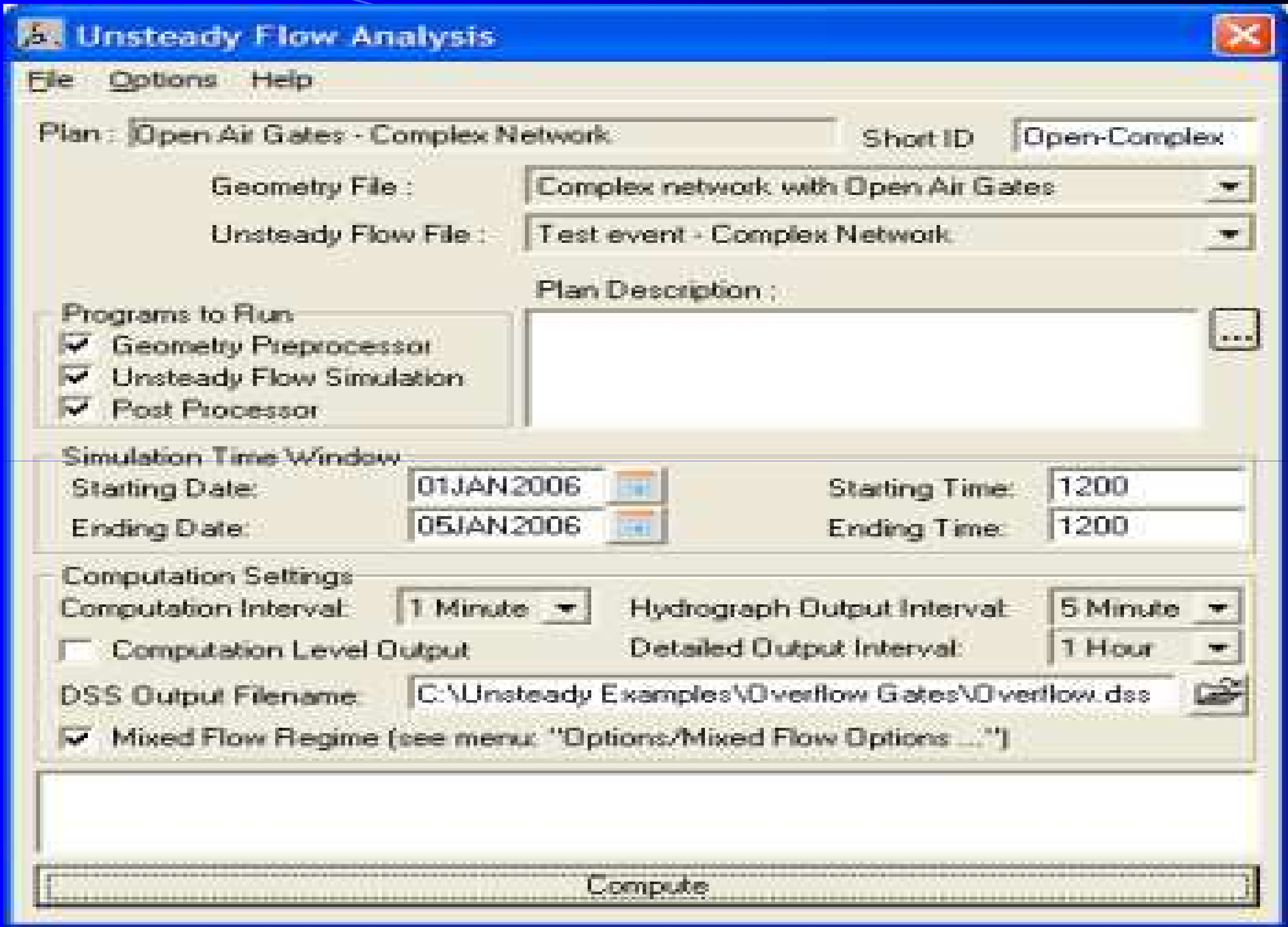


Unsteady Flow Simulation

- ❖Simulating one-dimensional unsteady flow through a full network of open channels.
- ❖The unsteady flow equation solver was adapted from Dr. Robert L. Barkau's UNET model
- ❖The unsteady flow component was developed primarily for subcritical flow regime calculations.
- ❖The model can now perform mixed flow regime (subcritical, supercritical, hydraulic jumps, and draw downs) calculations

- The hydraulic calculations for cross-sections, bridges, culverts, and other hydraulic structures that were developed for the steady flow component were incorporated into the unsteady flow module.

- Special features of the unsteady flow component include:
  - Dam break analysis;
  - levee breaching and overtopping;
  - Pumping stations;
  - navigation dam operations; and
  - pressurized pipe systems.



Unsteady Flow Analysis
File Options Help
Plan : Open Air Gates - Complex Network
Short ID Open-Complex
Geometry File : Complex network with Open Air Gates
Unsteady Flow File : Test event - Complex Network
Plan Description :
Programs to Run
Geometry Preprocessor
Unsteady Flow Simulation
Post Processor
Simulation Time Window
Starting Date: 01JAN2006
Ending Date: 05JAN2006
Starting Time: 1200
Ending Time: 1200
Computation Settings
Computation Interval: 1 Minute
Hydrograph Output Interval: 5 Minute
Computation Level Output
Detailed Output Interval: 1 Hour
DSS Output Filename: C:\Unsteady Examples\Overflow Gates\Overflow.dss
Mixed Flow Regime (see menu: "Options/Mixed Flow Options ...")
Compute

Sediment Transport/Movable Boundary Computations

This component of the modeling system is intended for the simulation of one-dimensional sediment transport/movable boundary calculations resulting from scour and deposition over moderate time periods (typically years, although applications to single flood events are possible).

The sediment transport potential is computed by grain size fraction, thereby allowing the simulation of hydraulic sorting and armoring.

Major features include the ability to model a full network of streams, channel dredging, various levee and encroachment alternatives, and the use of several different equations for the computation of sediment transport.

The model is designed to simulate long-term trends of scour and deposition in a stream channel that might result from modifying the frequency and duration of the water discharge and stage, or modifying the channel geometry.

This system can be used to evaluate deposition in reservoirs, design channel contractions required to maintain navigation depths, predict the influence of dredging on the rate of deposition, estimate maximum possible scour during large flood events, and evaluate sedimentation in fixed channels.

Data Storage and Management

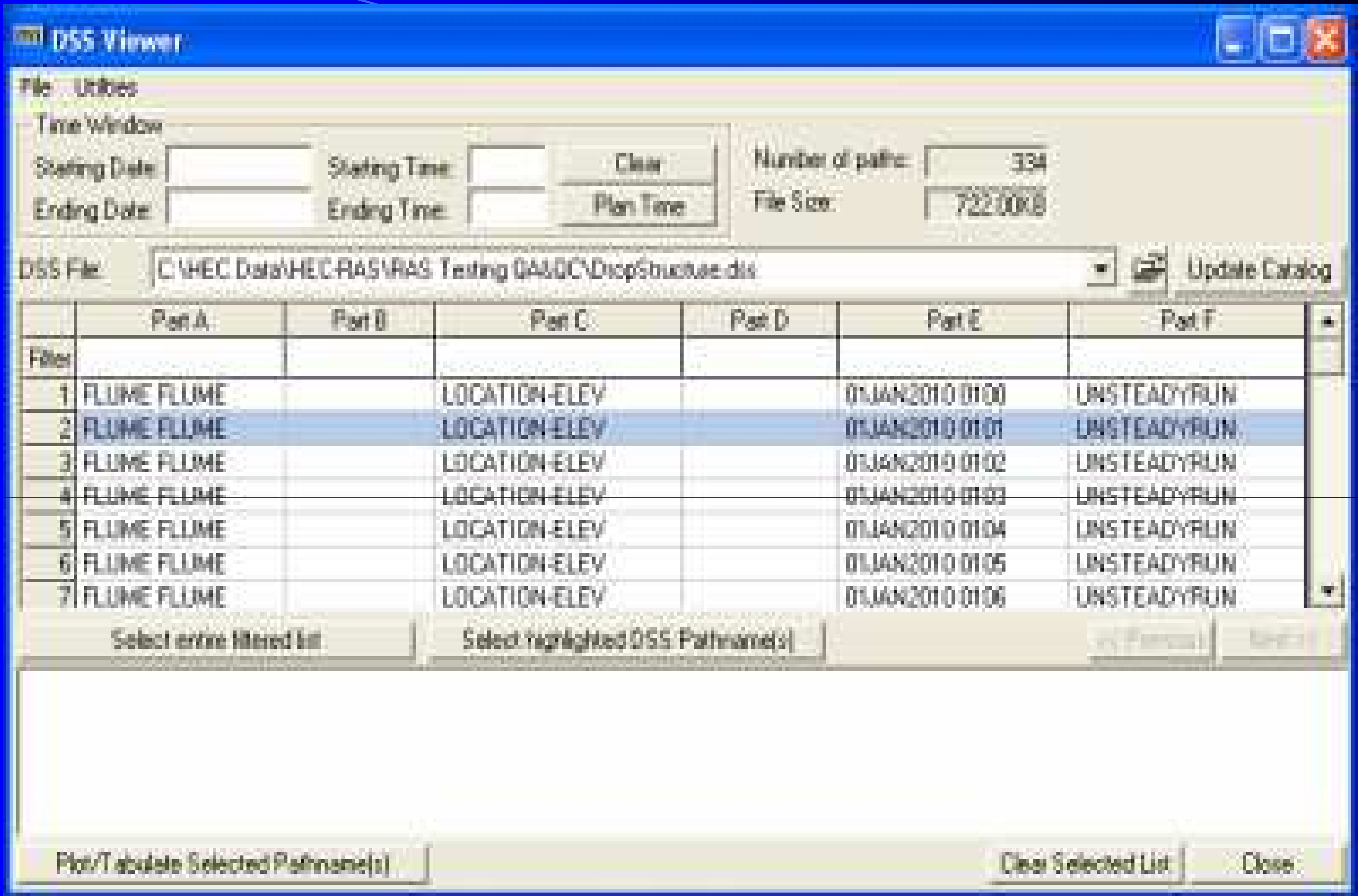
Data Storage is accomplished through the use of

- “Flat" files (ASCII and binary)
- The HEC-DSS

User input data are stored in flow files under separate categories of project, plan, geometry, steady flow, unsteady flow, and sediment data

Data management is accomplished through the user interface.

- The interface provides for renaming, moving, and deletion of files on a project-by-project basis.



DSS Viewer
File Utilities
Time Window
Starting Date
Starting Time
Clear
Ending Date
Ending Time
Plan Time
Number of paths: 334
File Size: 722.00KB
DSS File: C:\HEC Data\HEC-RAS\RAS Testing QA&QC\DropStructure.dss
Update Catalog
Part A
Part B
Part C
Part D
Part E
Part F
Filter
1 FLUME FLUME LOCATION-ELEV 01JAN2010 0100 UNSTEADYRUN
2 FLUME FLUME LOCATION-ELEV 01JAN2010 0101 UNSTEADYRUN
3 FLUME FLUME LOCATION-ELEV 01JAN2010 0102 UNSTEADYRUN
4 FLUME FLUME LOCATION-ELEV 01JAN2010 0103 UNSTEADYRUN
5 FLUME FLUME LOCATION-ELEV 01JAN2010 0104 UNSTEADYRUN
6 FLUME FLUME LOCATION-ELEV 01JAN2010 0105 UNSTEADYRUN
7 FLUME FLUME LOCATION-ELEV 01JAN2010 0106 UNSTEADYRUN
Select entire filtered list
Select highlighted DSS Pathname(s)
Plot/Tabulate Selected Pathname(s)
Clear Selected List
Close

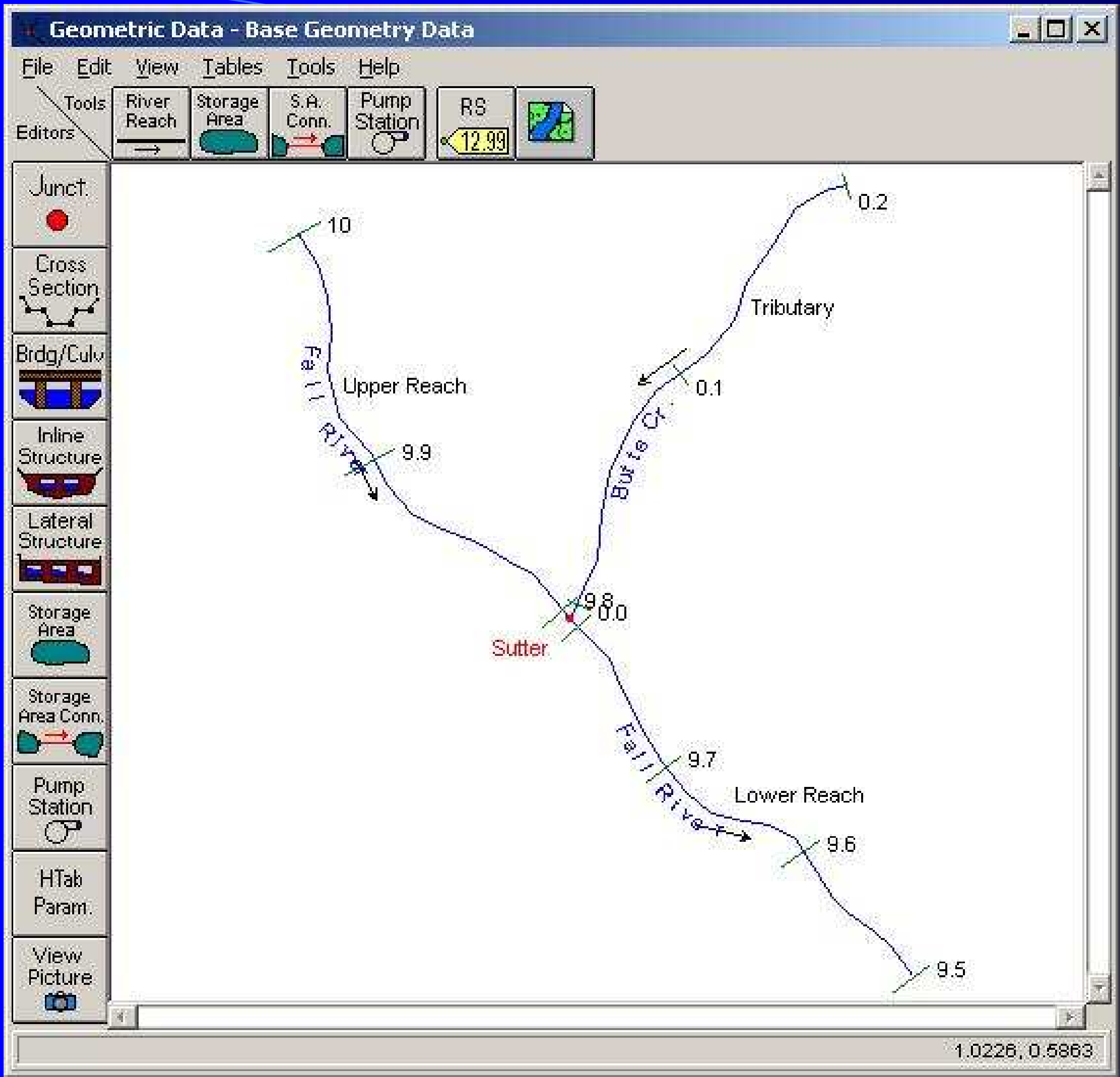
Graphics and Reporting

Graphics include

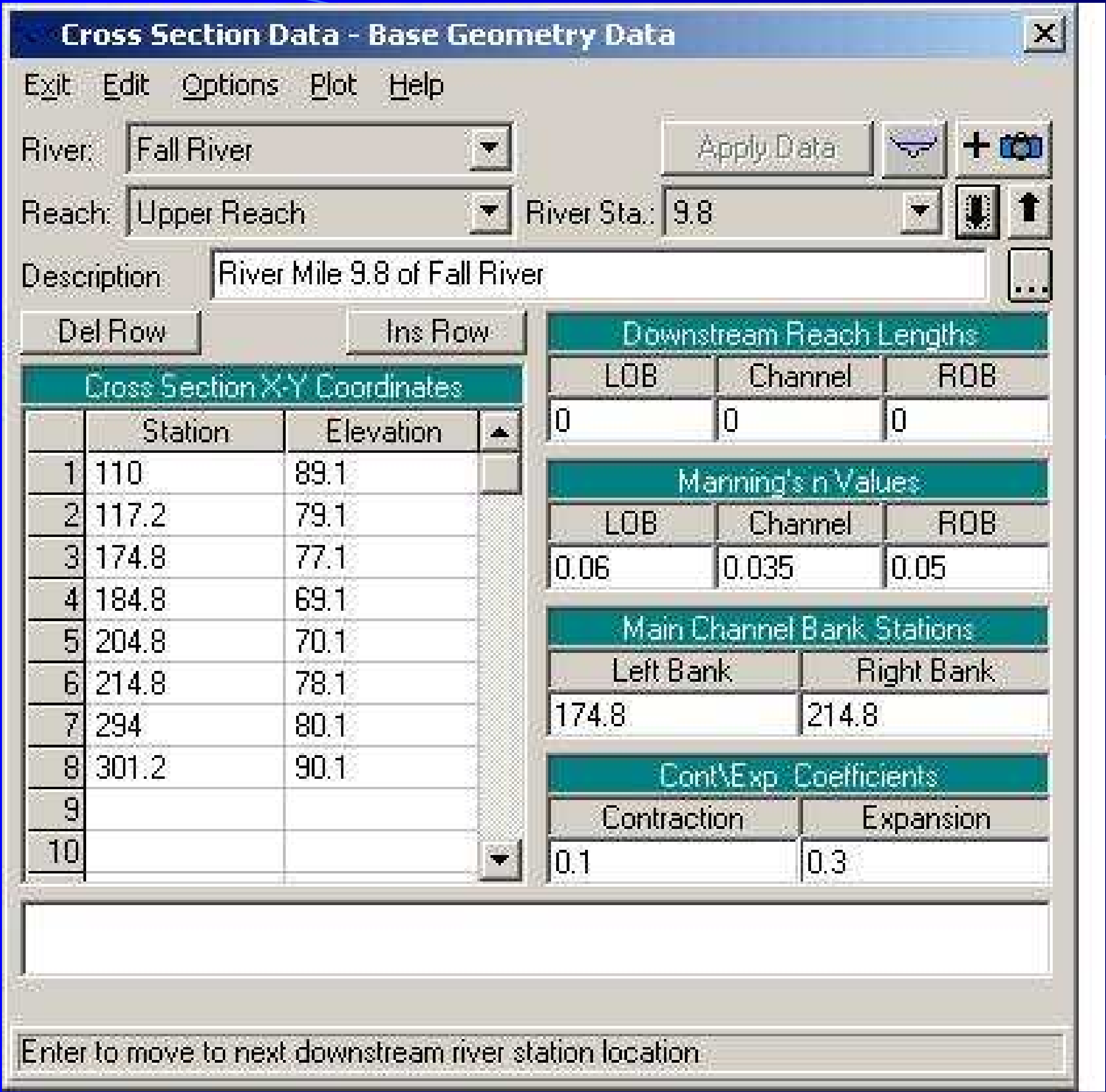
- X-Y plots of the river system schematic,
- cross-sections,
- profiles,
- rating curves,
- hydrographs,
- A three-dimensional plot

Tabular output

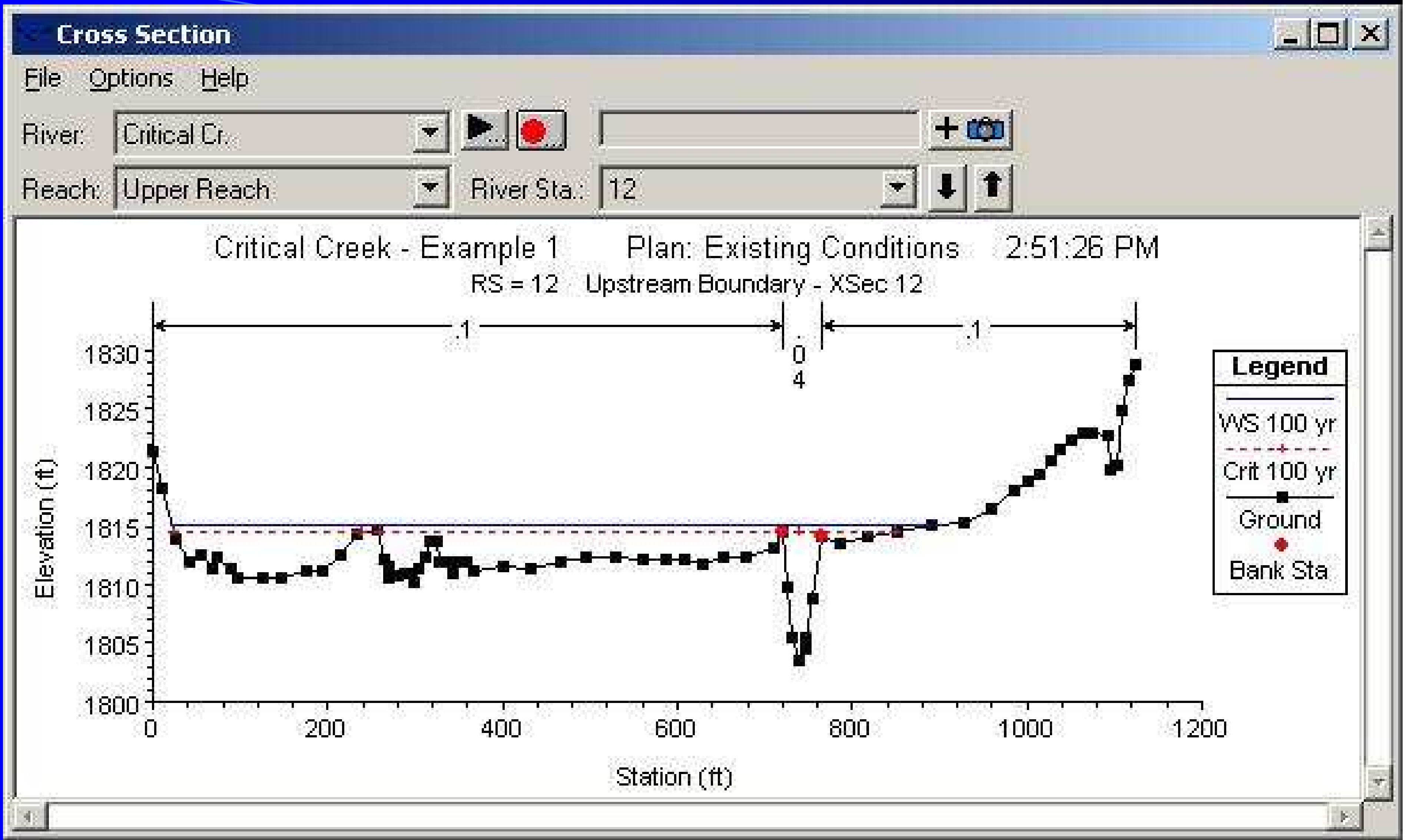
- pre-defined tables
- customized tables



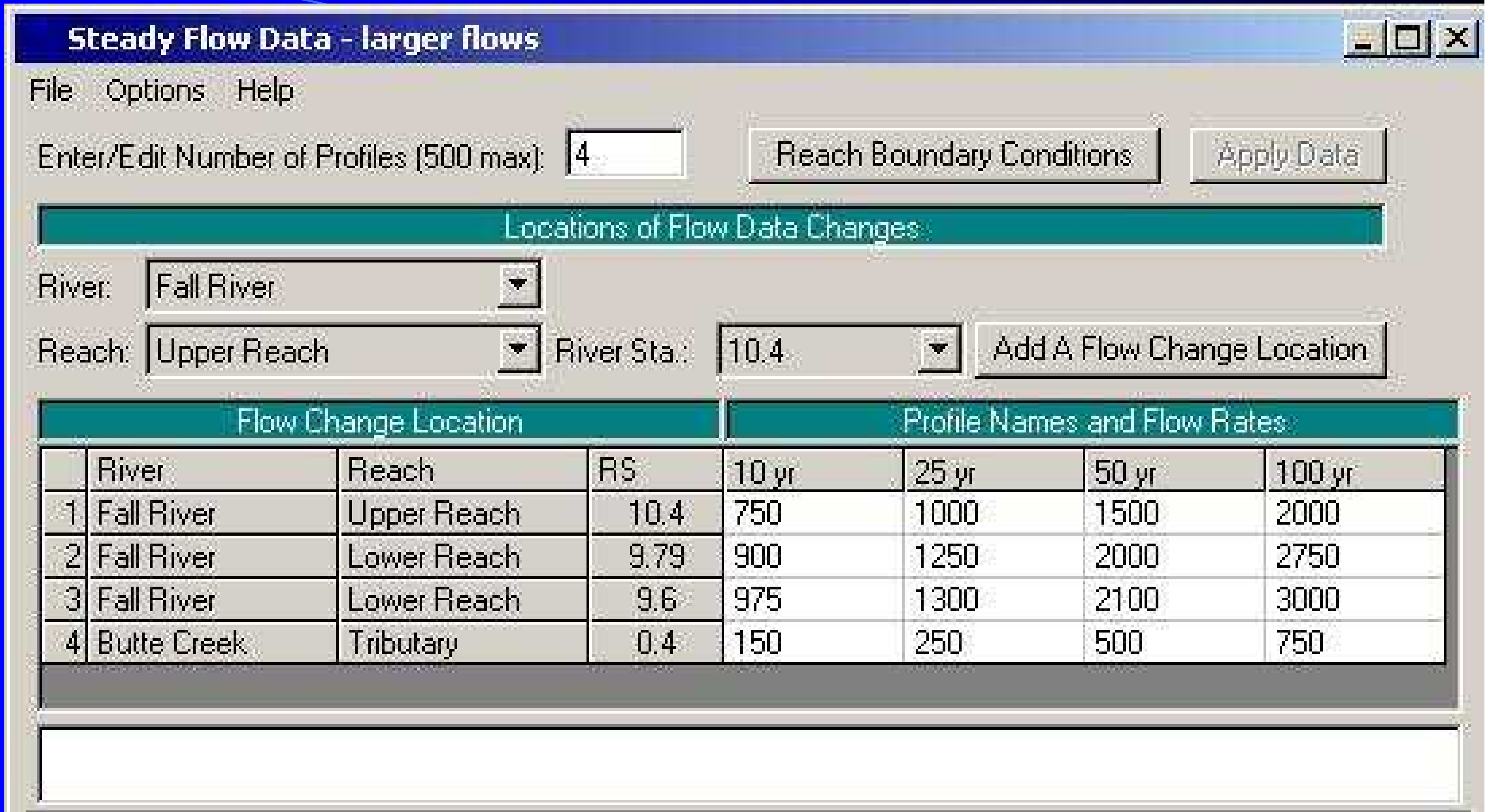
River Schematic editor



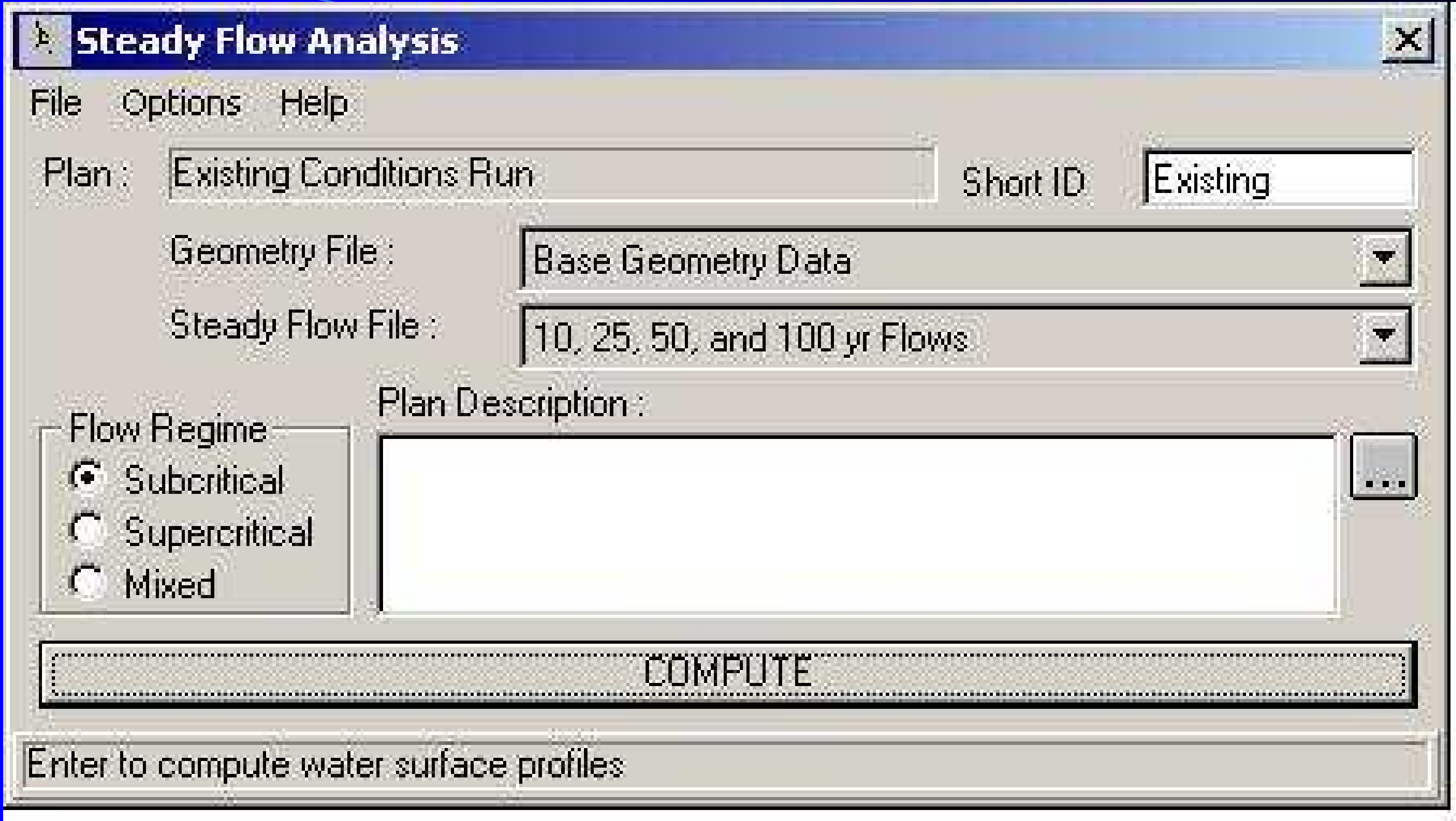
HEC-RAS cross-section editor



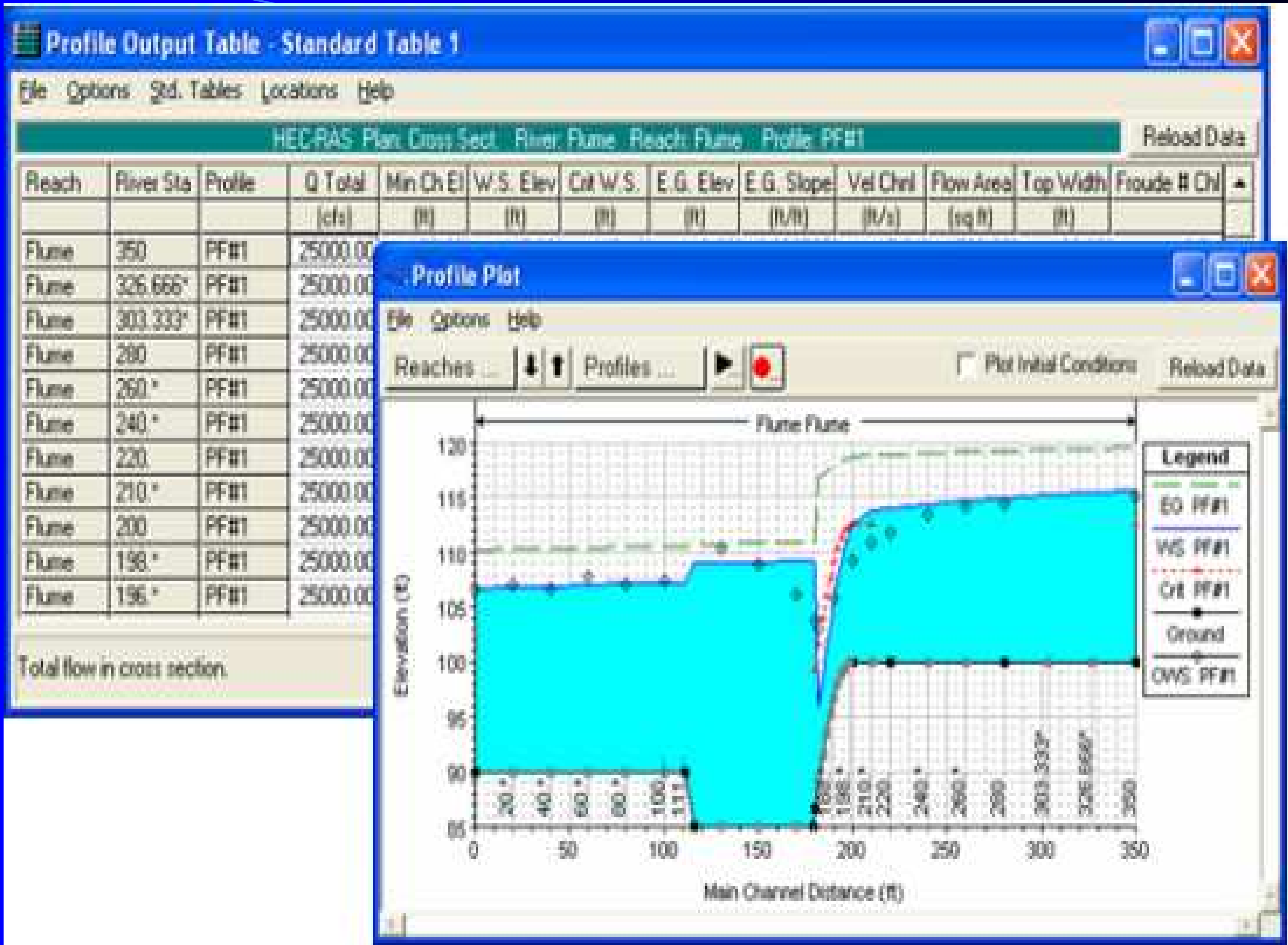
HEC-RAS
cross – section plot

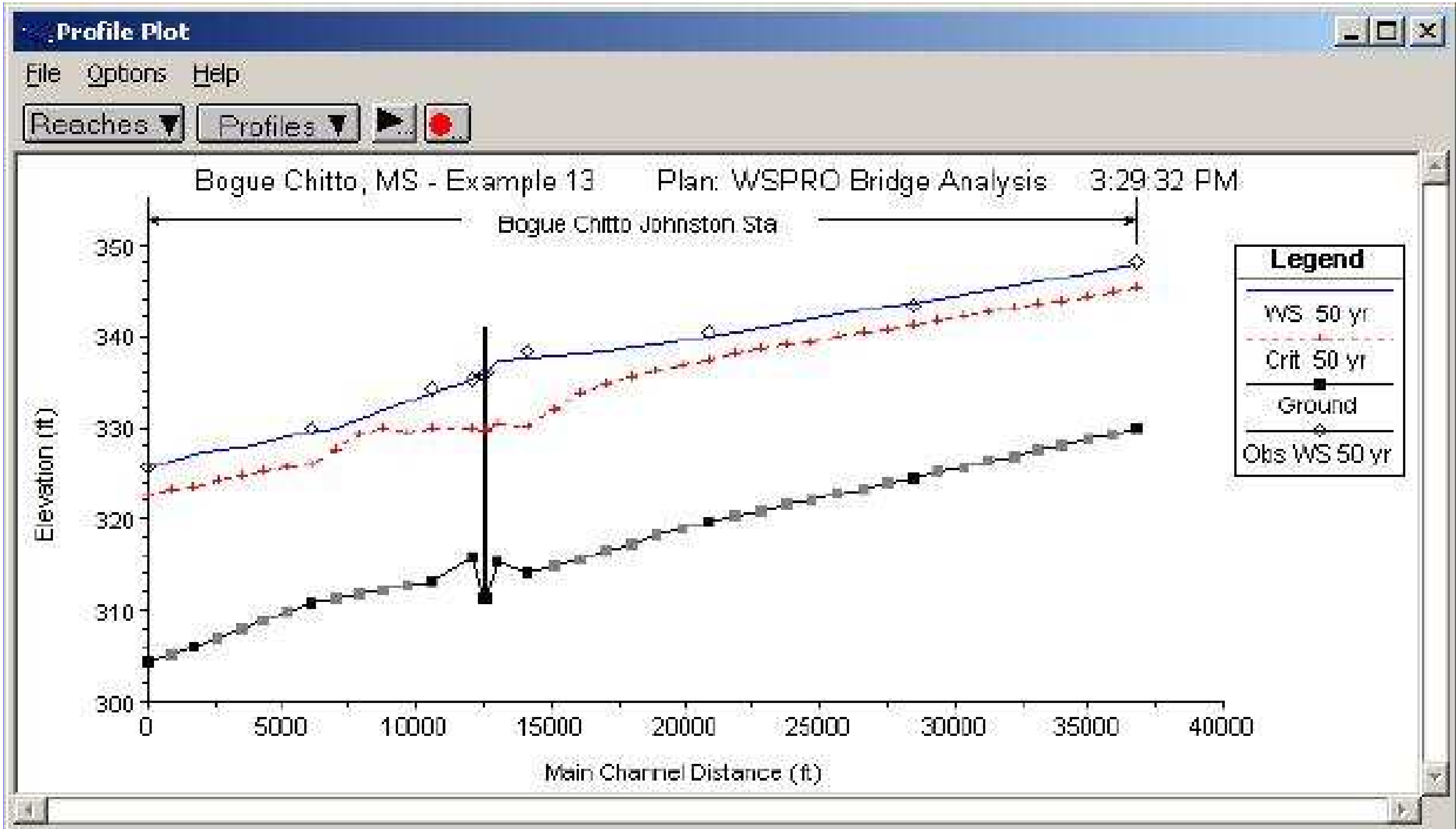


HEC-RAS Steady Flow data editor

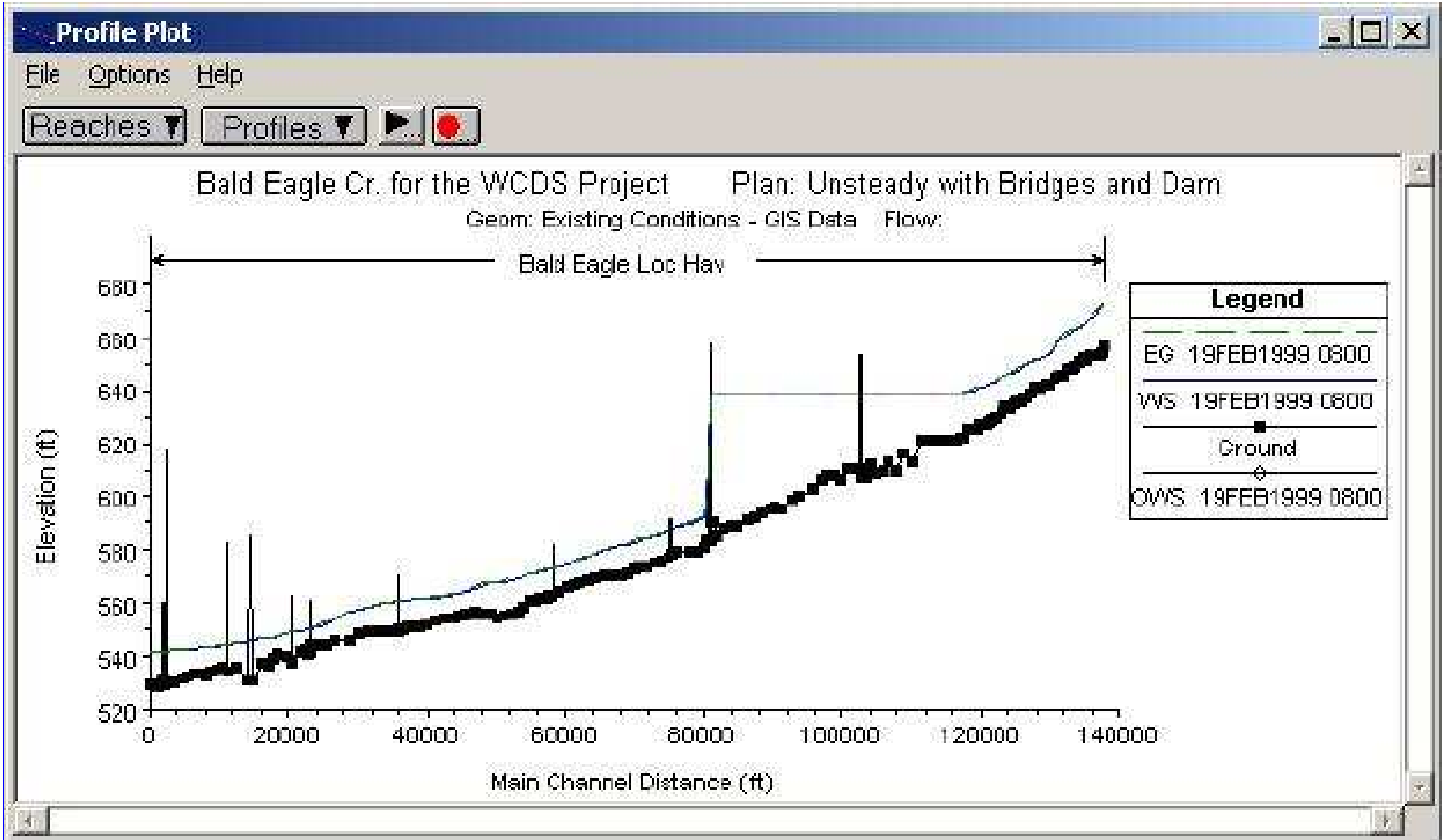


HEC-RAS Steady Flow computation Editor

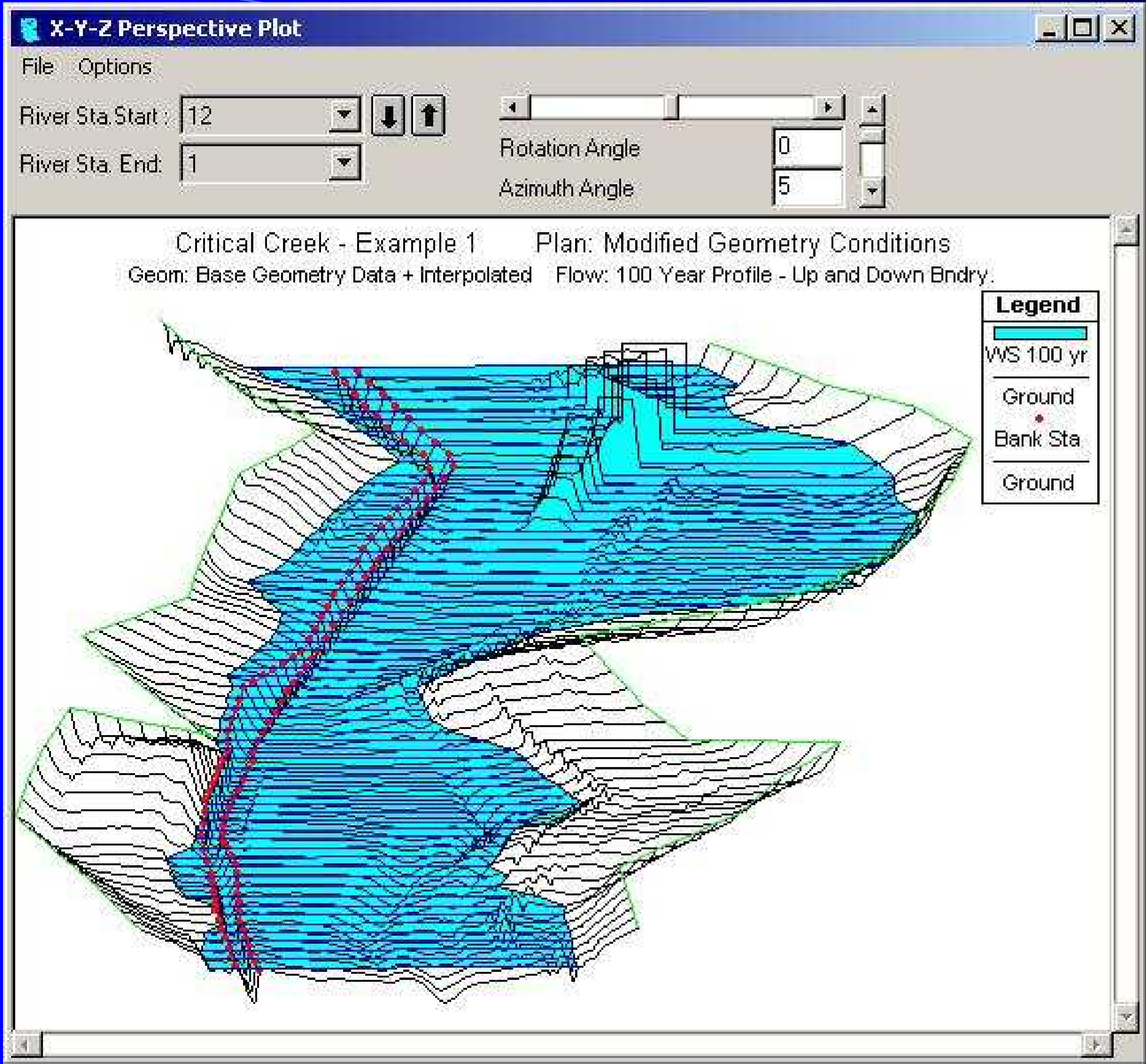

Profile Output Table - Standard Table 1
File Options Std. Tables Locations Help
HEC-RAS Plan: Cross Sect River: Flume Reach: Flume Profile: PF#1
Reload Data
Reach River Sta Profile Q Total Min Ch El W.S. Elev Crit W.S. E.G. Elev E.G. Slope Vel Chnl Flow Area Top Width Froude # Chl
(cfs) (ft) (ft) (ft) (ft) (ft/ft) (ft/s) (sq ft) (ft)
Flume 350 PF#1 25000.00
Flume 326.666* PF#1 25000.00
Flume 303.333* PF#1 25000.00
Flume 280 PF#1 25000.00
Flume 260.* PF#1 25000.00
Flume 240.* PF#1 25000.00
Flume 220 PF#1 25000.00
Flume 210.* PF#1 25000.00
Flume 200 PF#1 25000.00
Flume 198.* PF#1 25000.00
Flume 196.* PF#1 25000.00
Total flow in cross section.
Profile Plot
File Options Help
Reaches ... Profiles ...
Plot Initial Conditions
Reload Data
Flume Flume
Legend
EG PF#1
WS PF#1
Crit PF#1
Ground
OWS PF#1
Elevation (ft)
Main Channel Distance (ft)



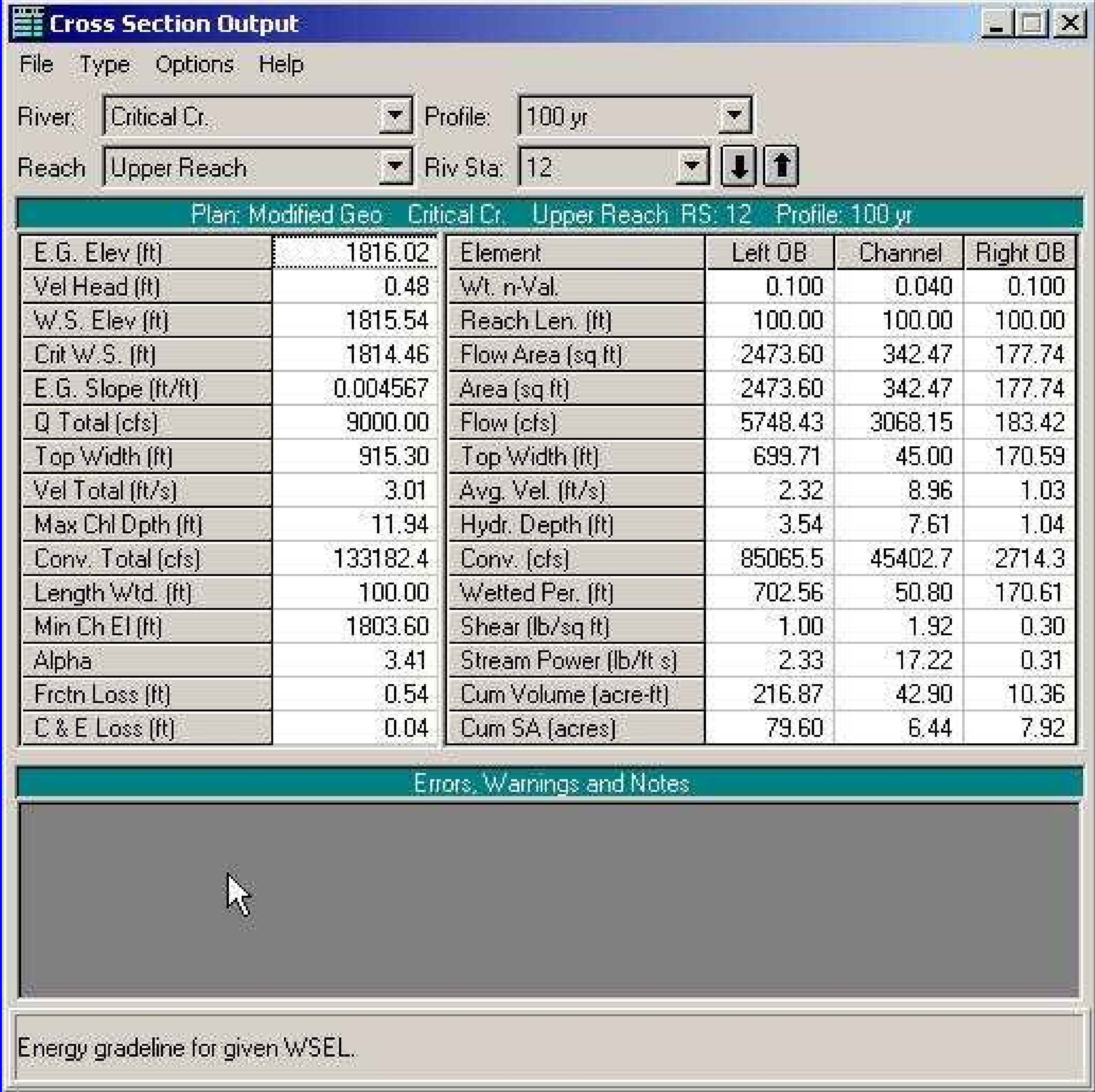
HEC-RAS Profile plot output



HEC-RAS Profile plot output



HEC-RAS Perspective plot output



E.G. Elev (ft)	1816.02
Vel Head (ft)	0.48
W.S. Elev (ft)	1815.54
Crit W.S. (ft)	1814.46
E.G. Slope (ft/ft)	0.004567
Q Total (cfs)	9000.00
Top Width (ft)	915.30
Vel Total (ft/s)	3.01
Max Chl Dpth (ft)	11.94
Conv. Total (cfs)	133182.4
Length Wtd. (ft)	100.00
Min Ch El (ft)	1803.60
Alpha	3.41
Frctn Loss (ft)	0.54
C & E Loss (ft)	0.04

Element	Left OB	Channel	Right OB
Wt. n-Val.	0.100	0.040	0.100
Reach Len. (ft)	100.00	100.00	100.00
Flow Area (sq ft)	2473.60	342.47	177.74
Area (sq ft)	2473.60	342.47	177.74
Flow (cfs)	5748.43	3068.15	183.42
Top Width (ft)	699.71	45.00	170.59
Avg. Vel. (ft/s)	2.32	8.96	1.03
Hydr. Depth (ft)	3.54	7.61	1.04
Conv. (cfs)	85065.5	45402.7	2714.3
Wetted Per. (ft)	702.56	50.80	170.61
Shear (lb/sq ft)	1.00	1.92	0.30
Stream Power (lb/ft s)	2.33	17.22	0.31
Cum Volume (acre-ft)	216.87	42.90	10.36
Cum SA (acres)	79.60	6.44	7.92

HEC-RAS cross section data tabular output

Profile Output Table - Standard Table 1

File Options Std. Tables User Tables Locations Help

HEC-RAS Plan: Exist Cond River: Critical Cr. Reach: Upper Reach Profile: 100 yr

Reload Data

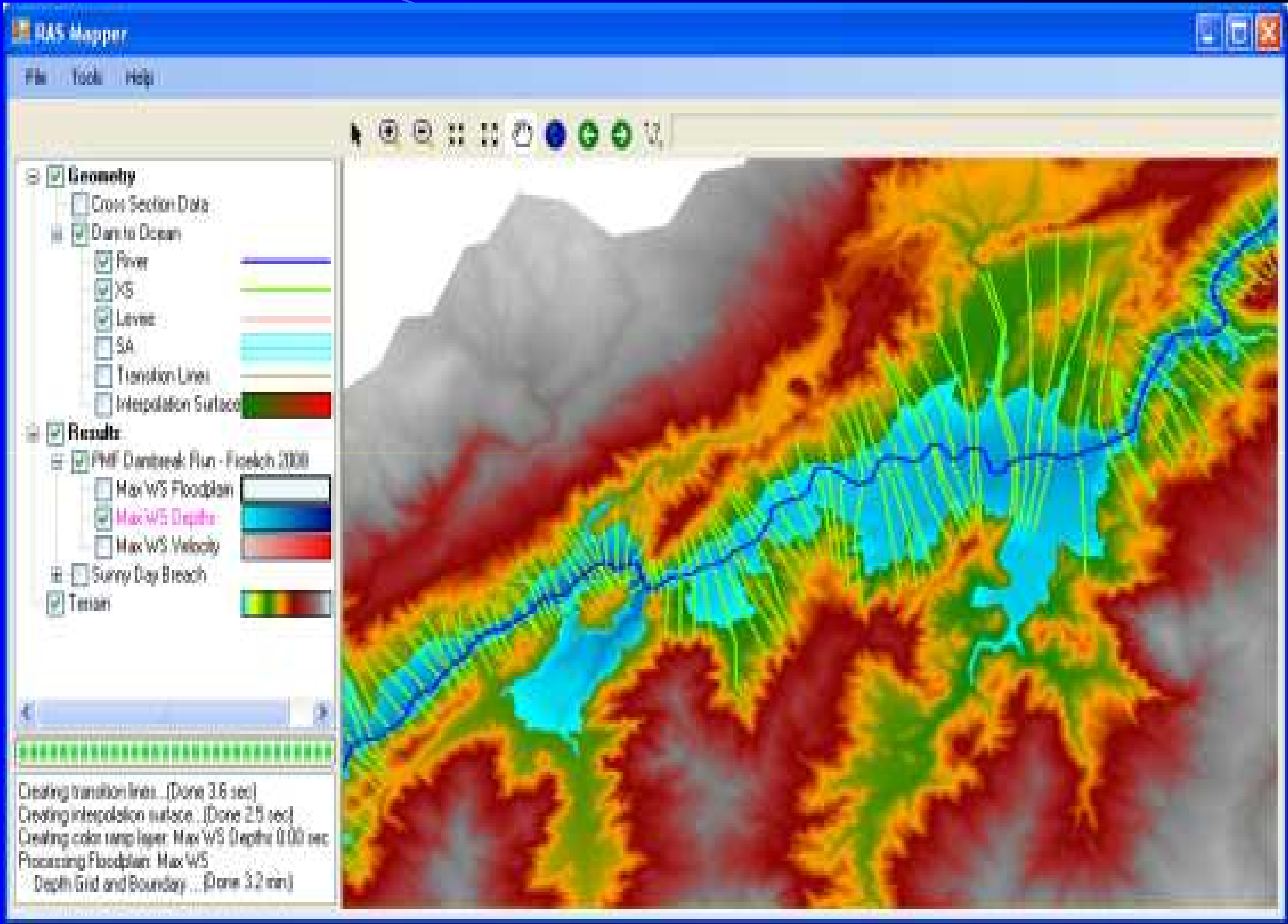
Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Upper Reach	12	9000.00	1803.60	1815.06	1814.46	1815.76	0.006851	10.51	2558.45	878.61	0.69
Upper Reach	11	9000.00	1800.70	1810.42	1810.42	1811.87	0.008552	12.03	1734.74	562.38	0.82
Upper Reach	10	9000.00	1794.40	1804.46	1803.69	1804.98	0.010276	10.48	2478.11	914.50	0.79
Upper Reach	9	9000.00	1789.70	1799.31	1799.31	1800.16	0.008851	11.48	2719.81	1216.82	0.80
Upper Reach	8	9500.00	1784.30	1793.89	1793.89	1795.08	0.008613	12.38	2524.66	1110.69	0.81
Upper Reach	7	9500.00	1777.20	1789.88	1788.87	1791.00	0.007410	13.16	2155.56	526.61	0.76
Upper Reach	6	9500.00	1774.50	1784.29	1784.29	1786.35	0.011143	13.38	1266.30	332.38	0.93
Upper Reach	5	9500.00	1768.50	1776.81	1776.81	1778.18	0.013216	13.55	1830.26	583.34	0.97
Upper Reach	4	9500.00	1763.00	1773.44	1772.23	1773.88	0.004991	9.32	2988.72	760.42	0.59
Upper Reach	3	9500.00	1759.40	1767.29	1765.75	1769.34	0.019810	16.09	1610.99	621.76	1.20
Upper Reach	2	9500.00	1753.60	1761.54	1760.03	1762.10	0.009413	10.36	2323.62	682.71	0.79
Upper Reach	1	9500.00	1747.40	1756.71	1755.71	1757.21	0.010002	9.91	2403.99	728.01	0.79

HEC-RAS profile data tabular output

RAS Mapper

HEC-RAS has the capability to perform inundation mapping of water surface profile results directly from HEC-RAS.

1. Using the HEC-RAS geometry and computed water surface profiles, inundation depth and floodplain boundary datasets are created.
2. Additional geospatial data can be generated for analysis of velocity, shear stress, stream power, ice thickness, and floodway encroachment data.
3. In order to use the RAS Mapper for for analysis, you must have a terrain model in the binary raster floating-point format (.flt).



RAS Mapper
File
Tools
Help
Geometry
Cross Section Data
Dam to Ocean
River
XS
Levees
SA
Transition Lines
Interpolation Surface
Results
PMF Dambreak Run - Froelich 2008
Max WS Floodplain
Max WS Depths
Max WS Velocity
Sunny Day Breach
Terrain
Creating transition lines...(Done 3.6 sec)
Creating interpolation surface...(Done 2.5 sec)
Creating color ramp layer: Max WS Depths 0.00 sec
Processing Floodplain: Max WS
Depth Grid and Boundary....(Done 3.2 min)