Overview of Optional Capabilities

Alex Sanchez

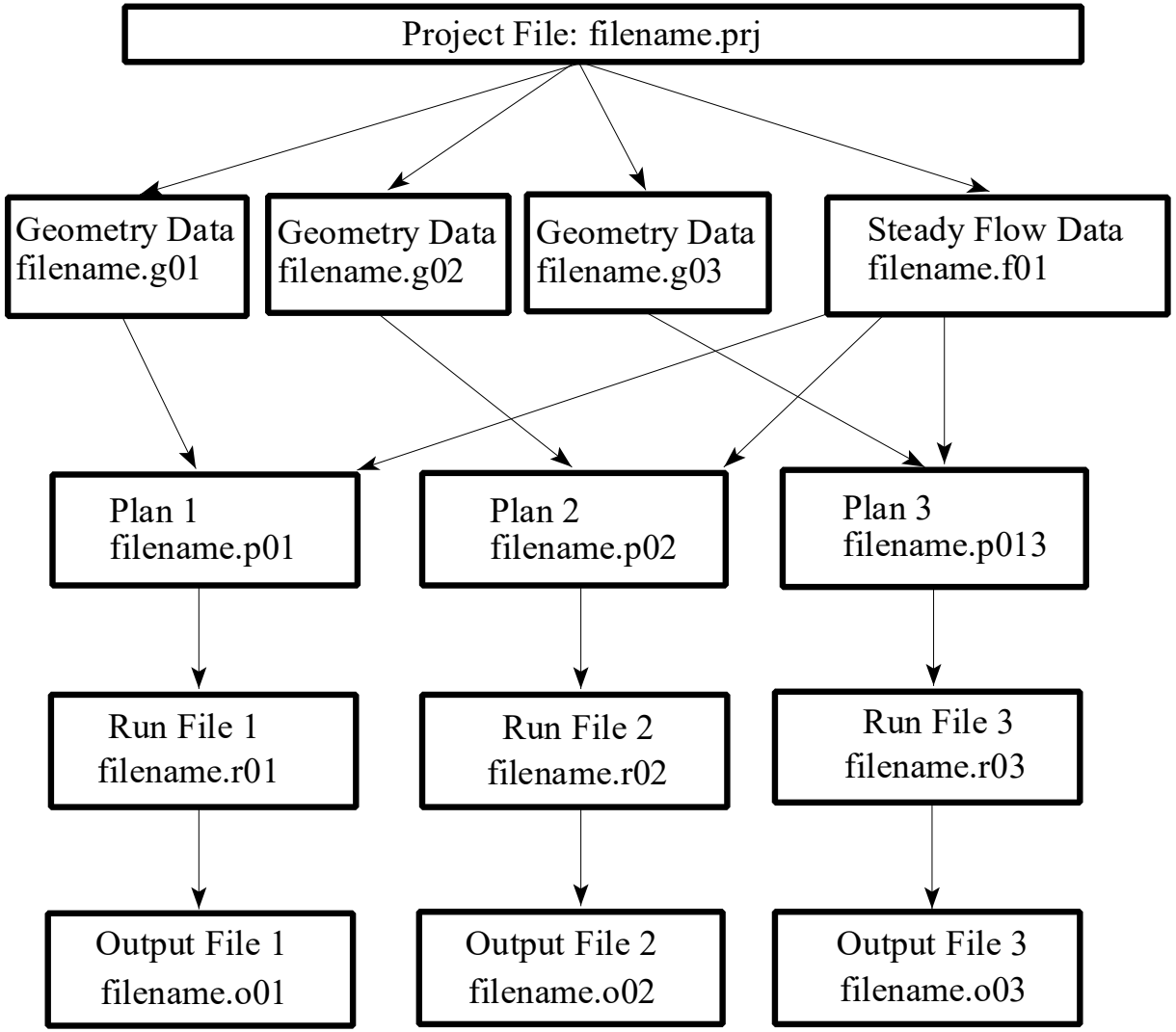
USACE, Institute for Water Resources, Hydrologic Engineering Center

US Army Corps of Engineers

Optional Capabilities

- Multiple Plan Analysis
- Cross-Section Interpolation
- Mixed Flow Regime Calculations
- Flow Distribution Calculations
- Inline Weirs and Gated Spillways
- Flow Optimizations
- Others

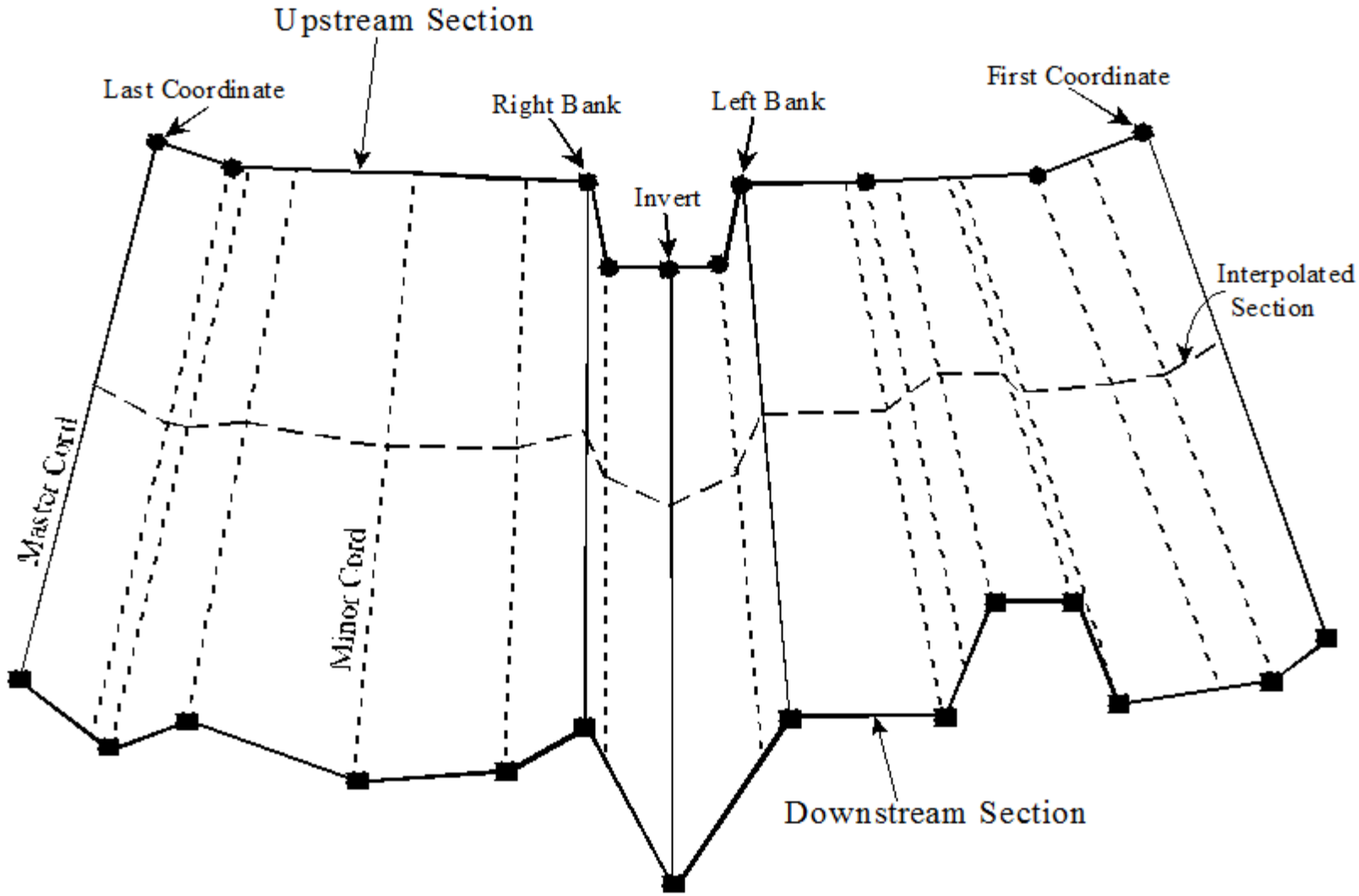
Multiple Plan Analysis



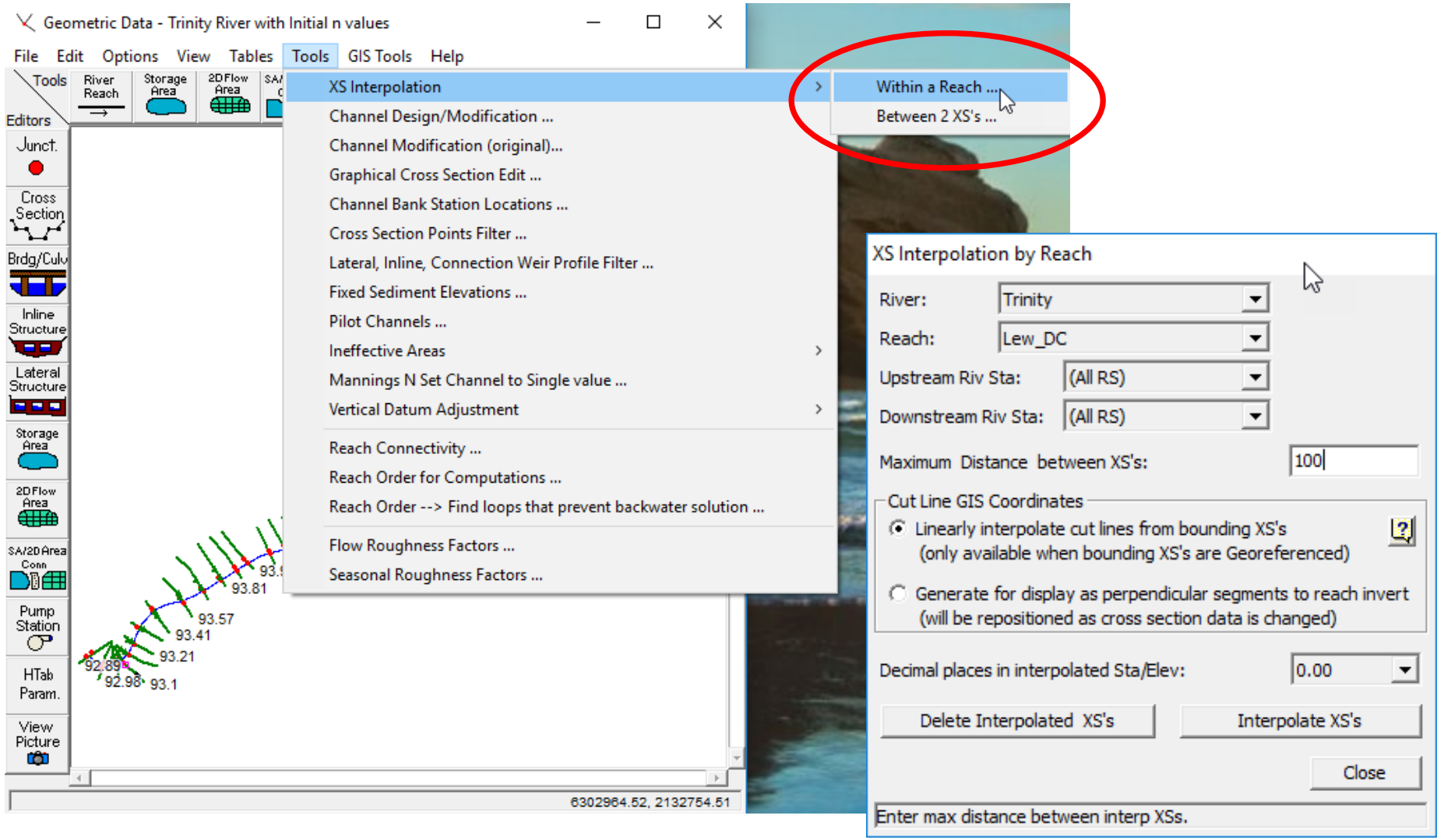
Cross-Section Interpolation May Be Needed When:

- Change in velocity head is too large
- Better model friction losses
- Prevent the program from defaulting to critical depth
- Generate a smoother plot of the water surface profile

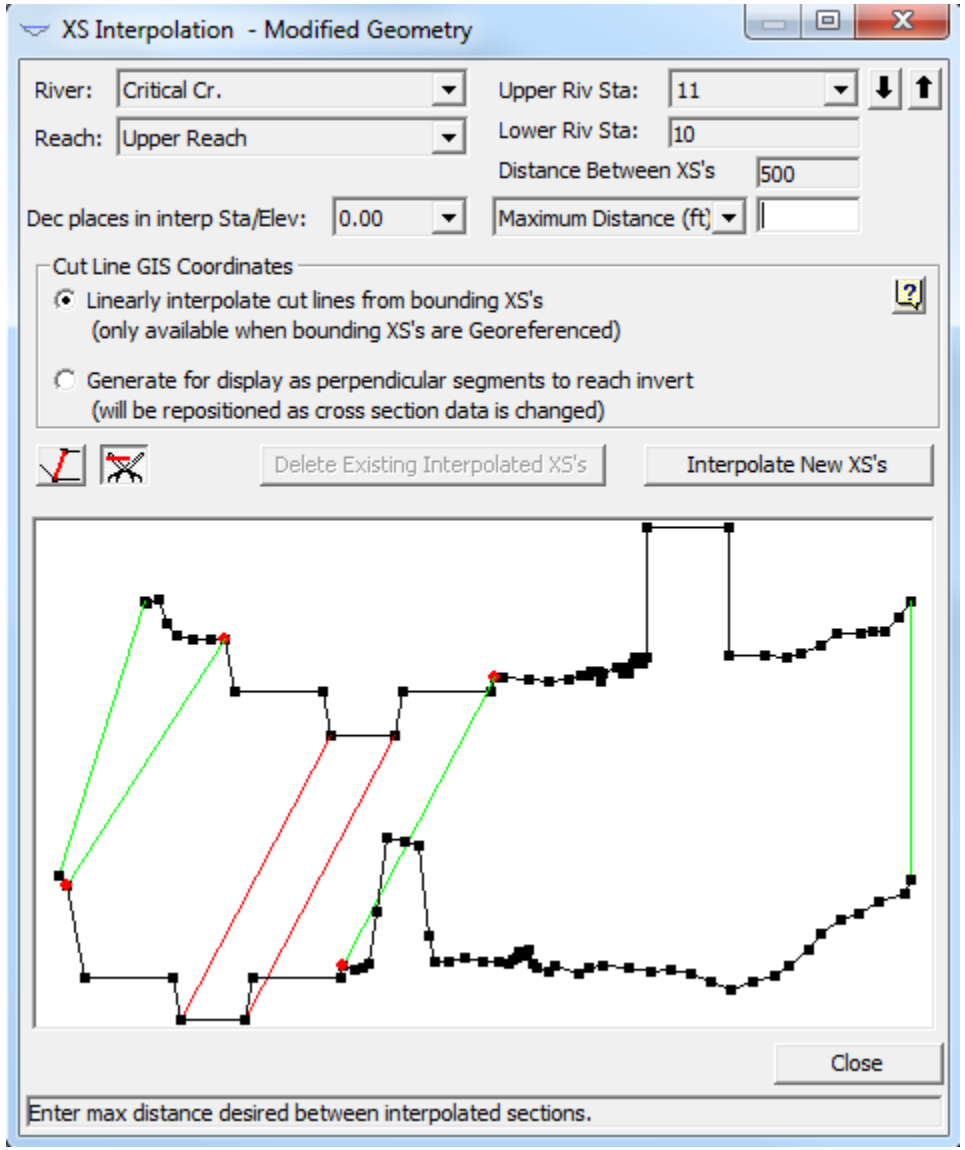
Cross-Section Interpolation

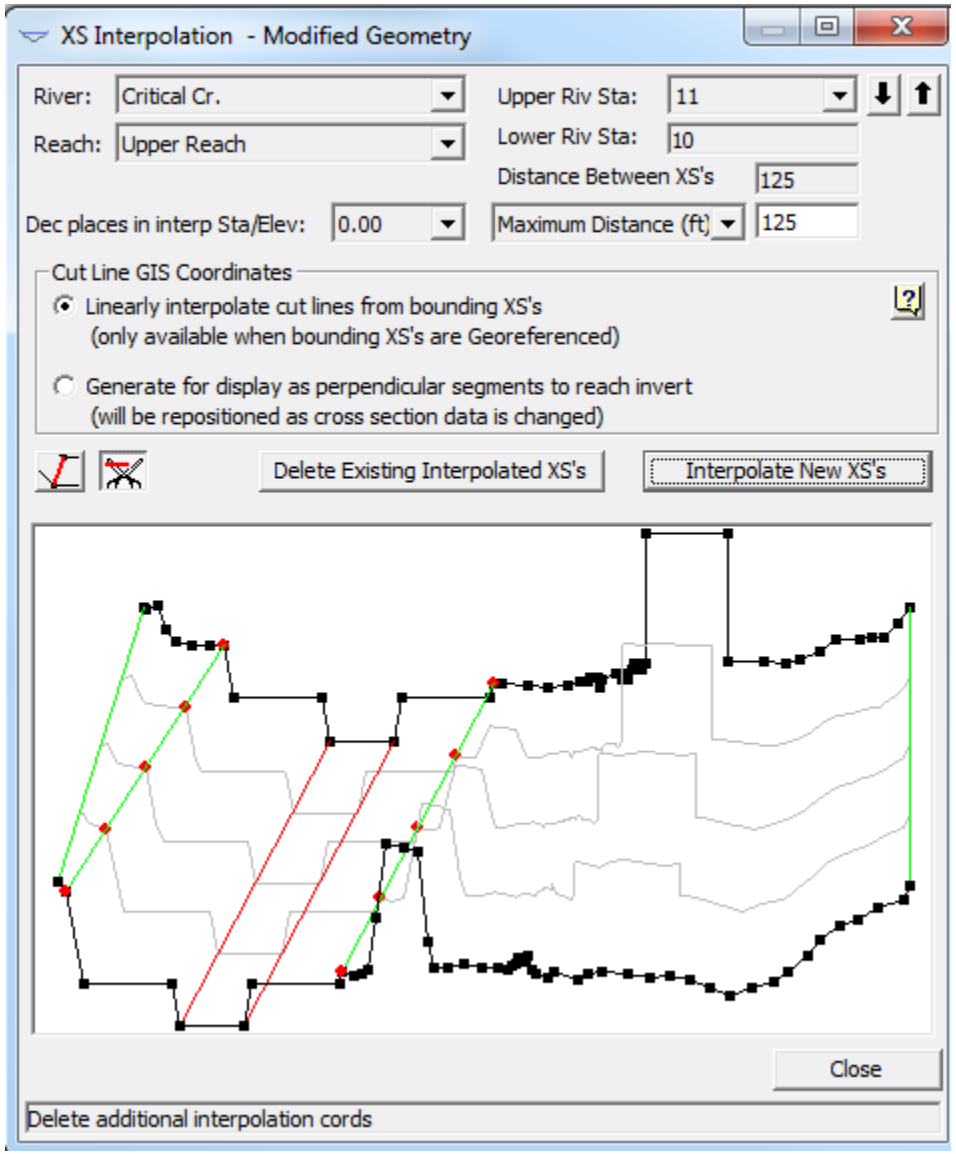


Interpolation within a Reach

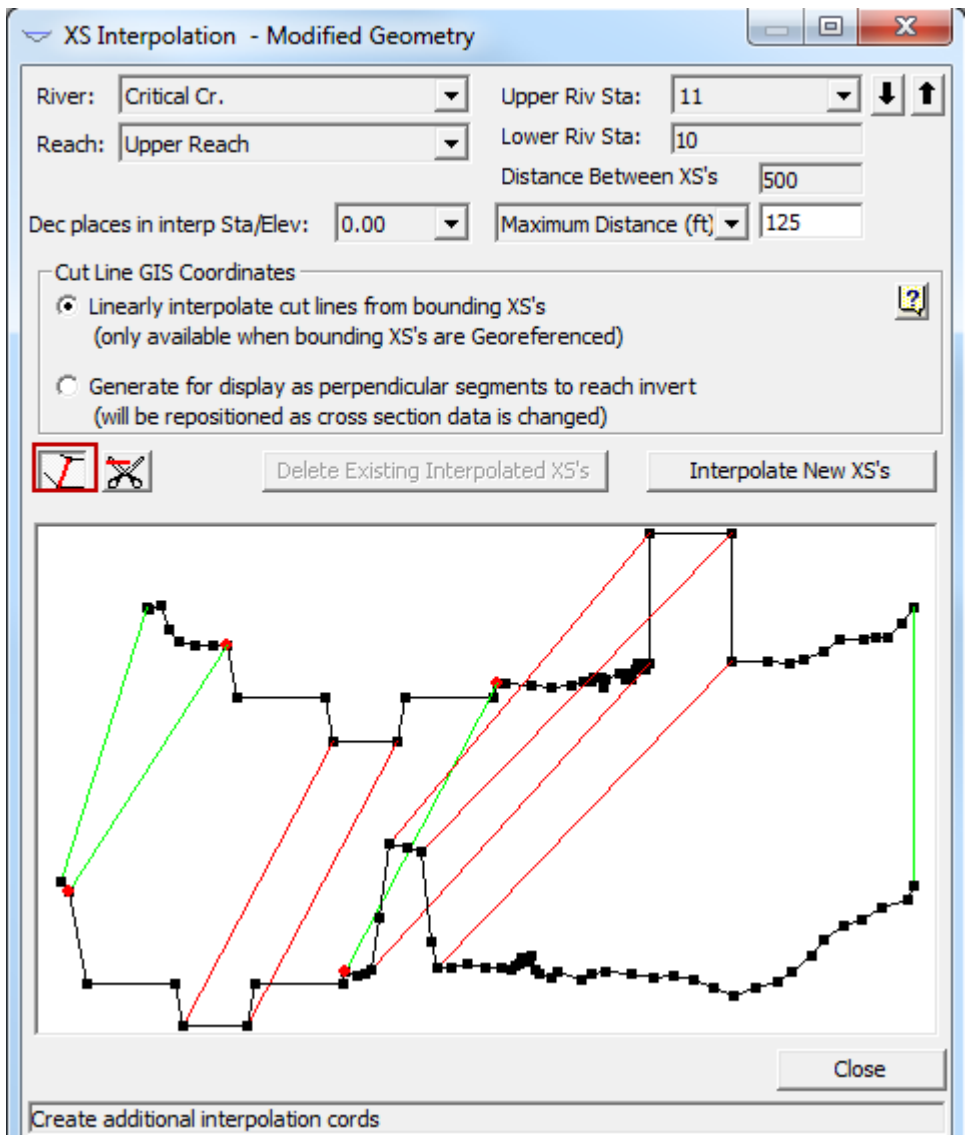


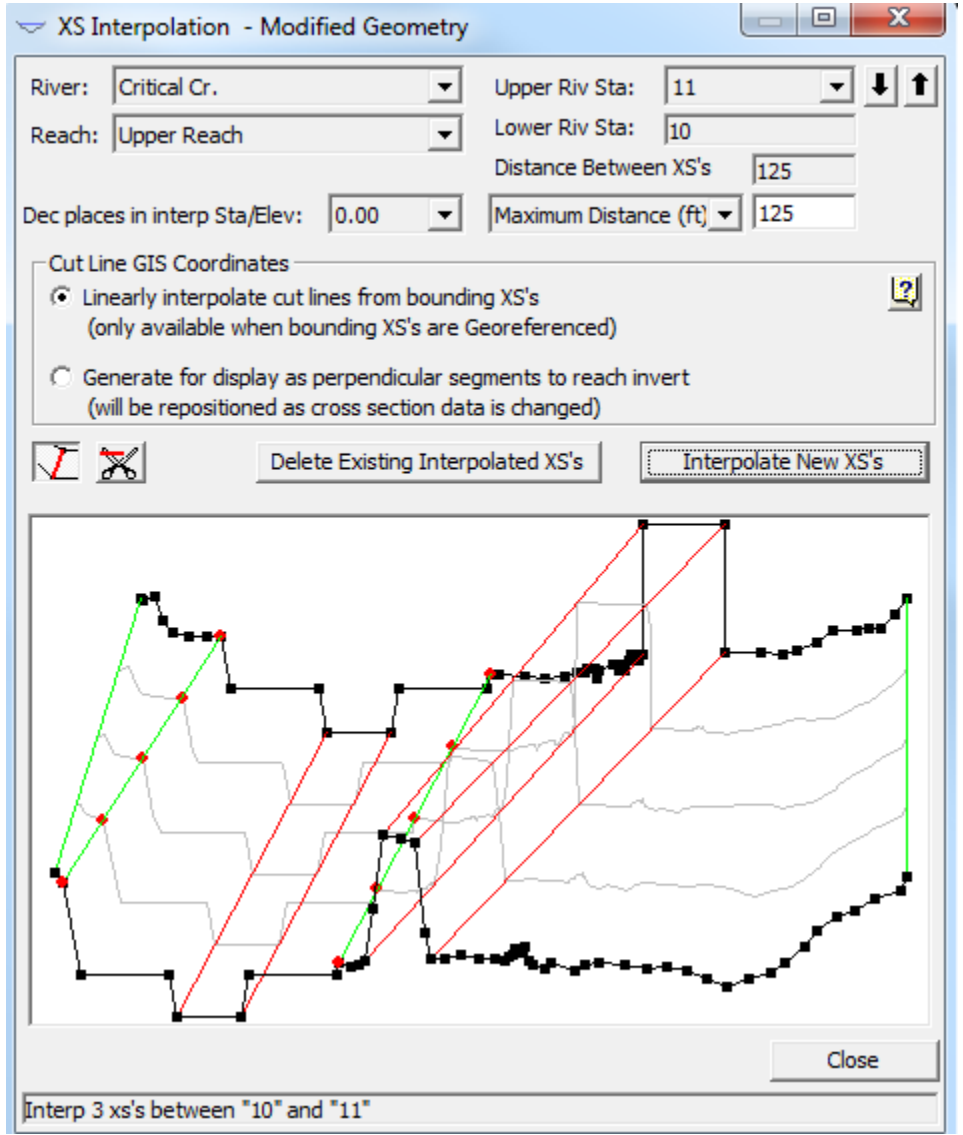
Interpolation between 2 XS's



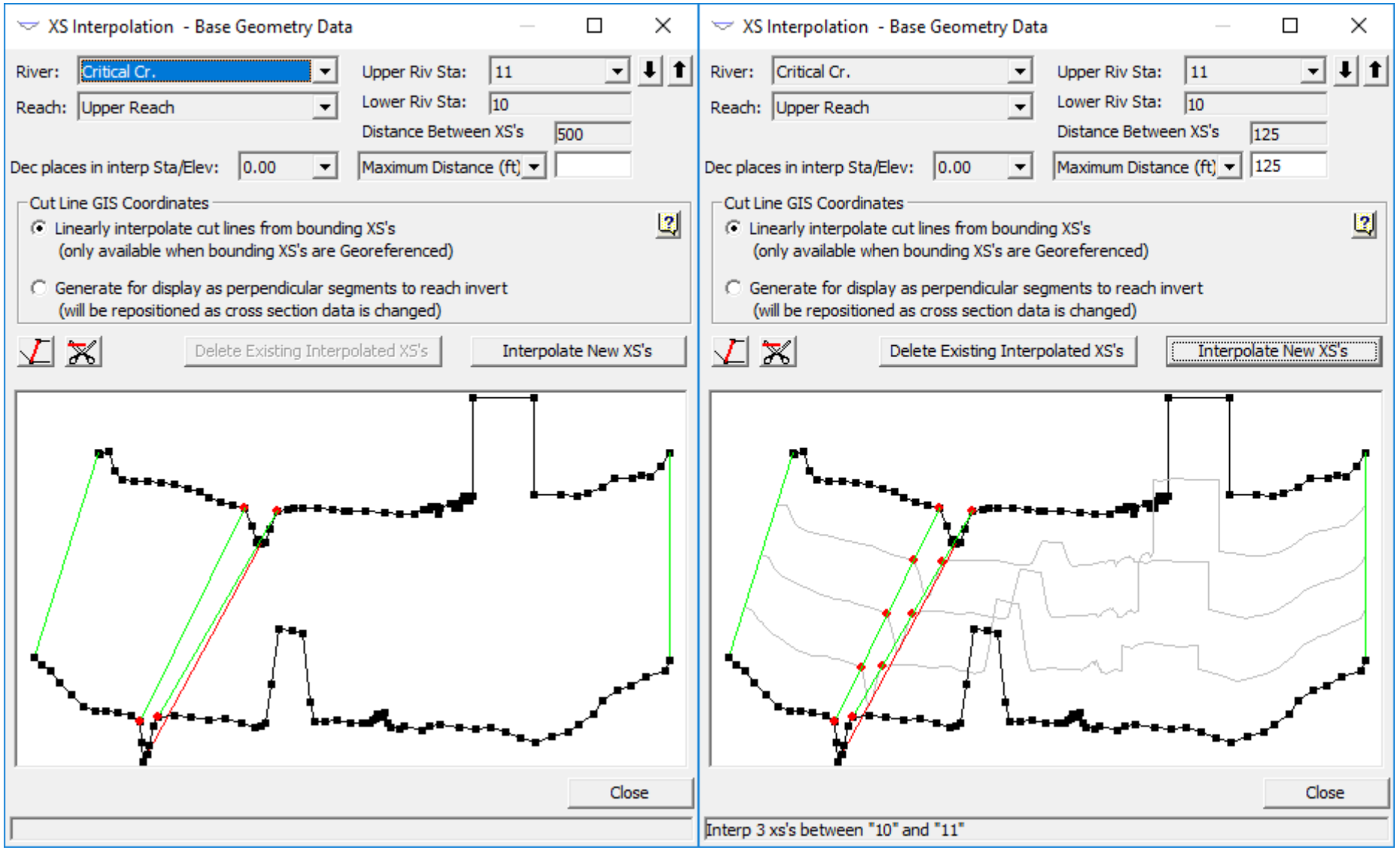


Adding Additional Master Cords

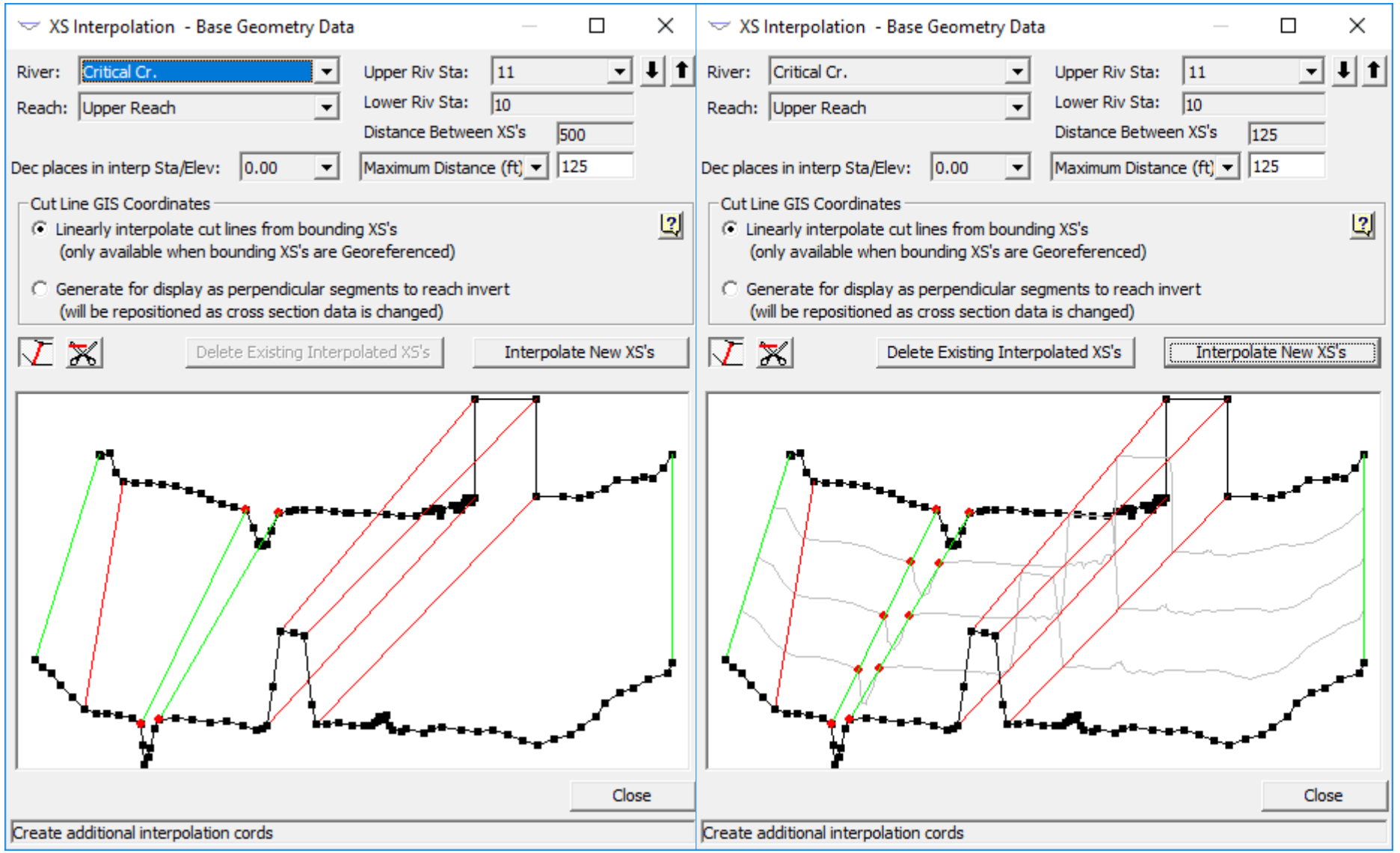




Interpolation between 2 XS's



Adding Additional Master Cords



Cross-Section Interpolation

CAUTION: Automatic interpolation should not be used as a replacement for required cross-section data!

US Army Corps of Engineers

Mixed Flow Regime

- Subcritical Flow
- Supercritical Flow
- Mixed Flow

Specific Force Equation

$$M = \frac{\beta_1 Q_1^2}{gA_1} + A_1\bar{Y}_1 = \frac{\beta_2 Q_2^2}{gA_2} + A_2\bar{Y}_2$$

where

β : momentum coefficient (i.e. Boussinesq coeff.)

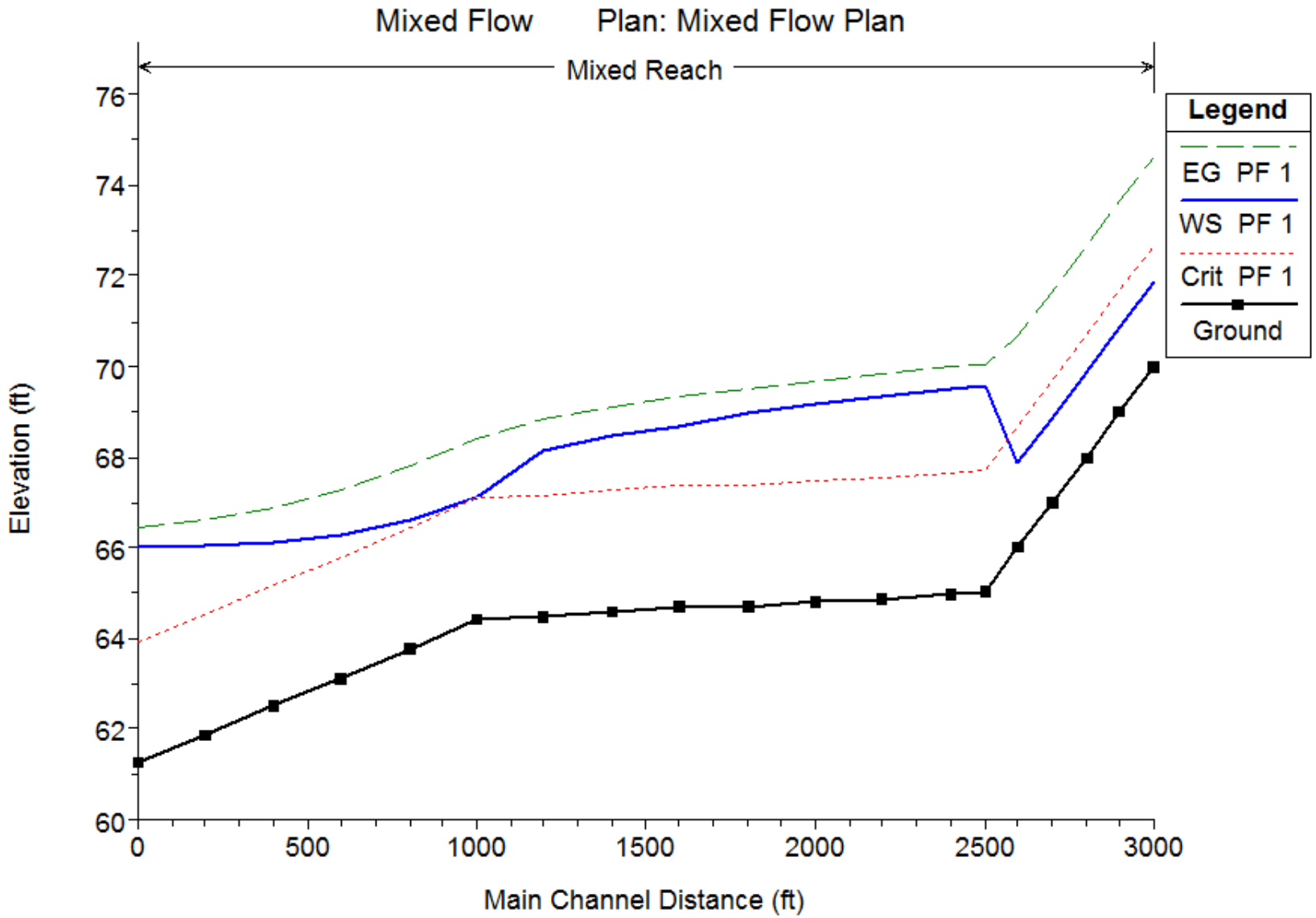
Q : discharge

A : area

g : gravity

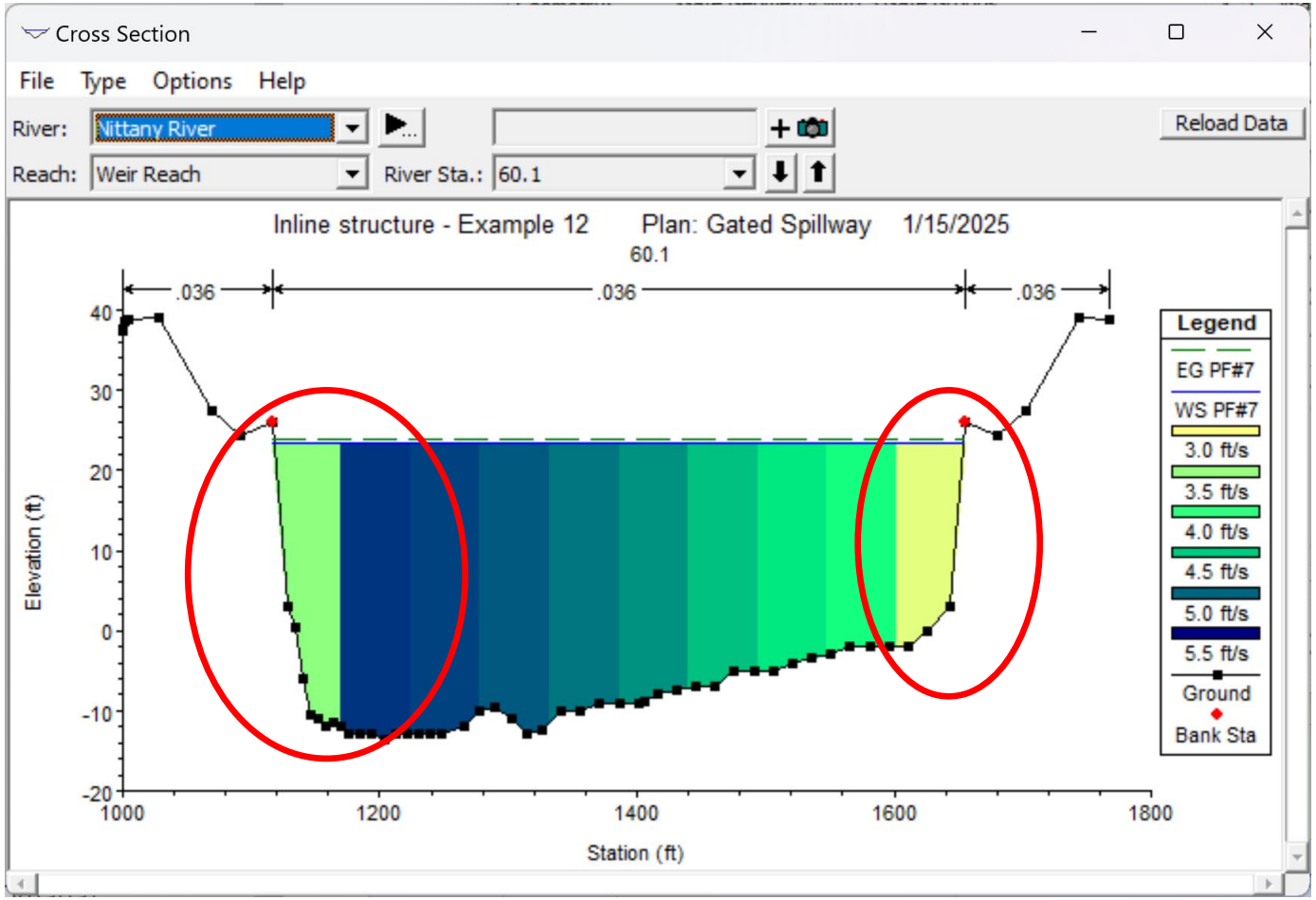
$\bar{Y}$: water depth from surface to area centroid

Mixed Flow

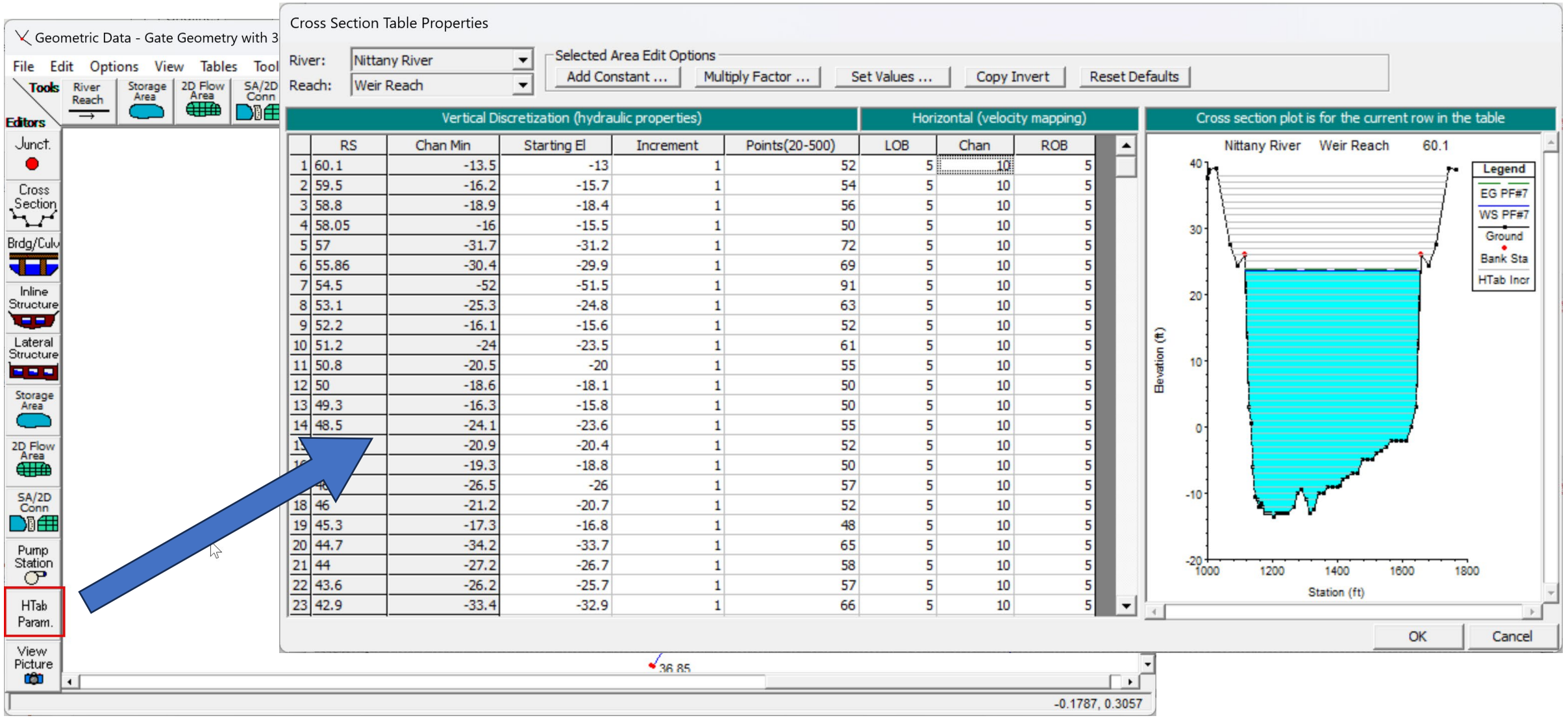

Mixed Flow Plan: Mixed Flow Plan
Mixed Reach
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Elevation (ft)
76
74
72
70
68
66
64
62
60
0
500
1000
1500
2000
2500
3000
Main Channel Distance (ft)

Flow Distribution Option

- Allows the user to see the amount of flow, and the flow velocity, in different parts of the cross-section
- Only for plotting; not used for calculations
- Distribution computed on conveyance only; no lateral mixing
- Increases the size of the output

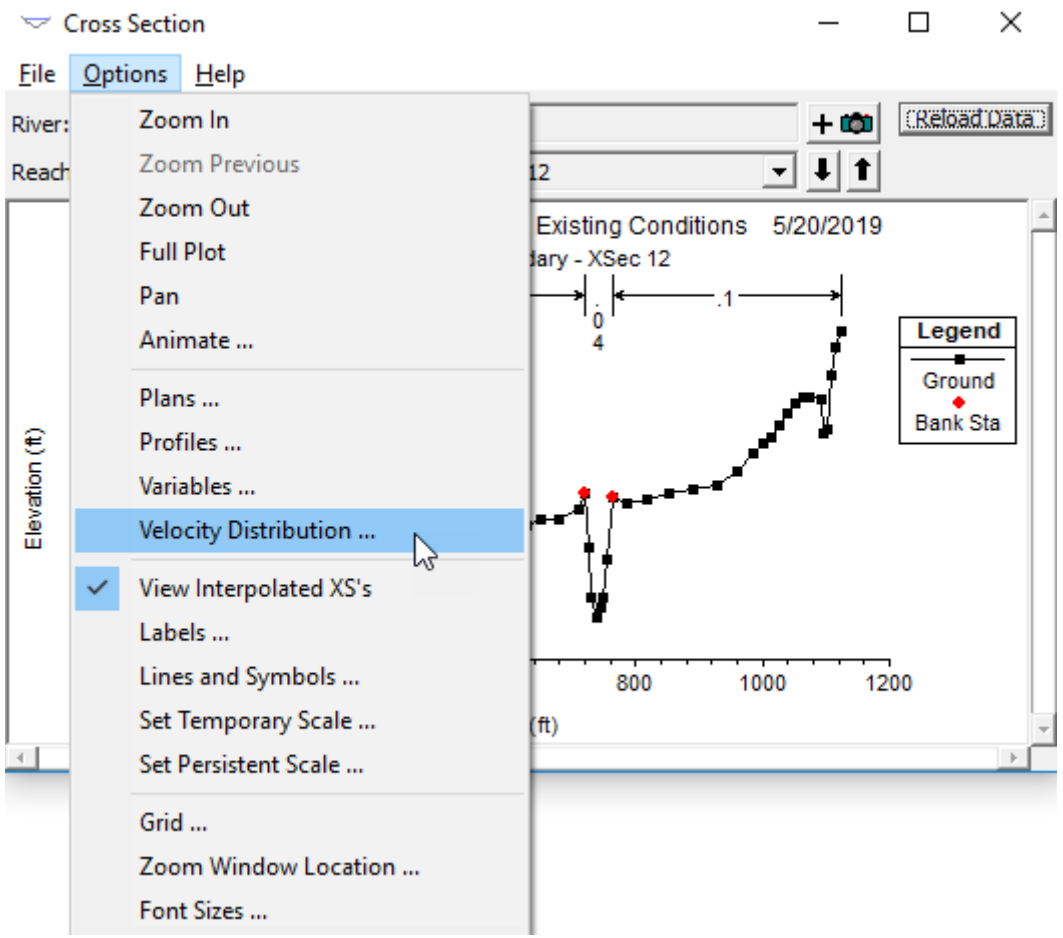


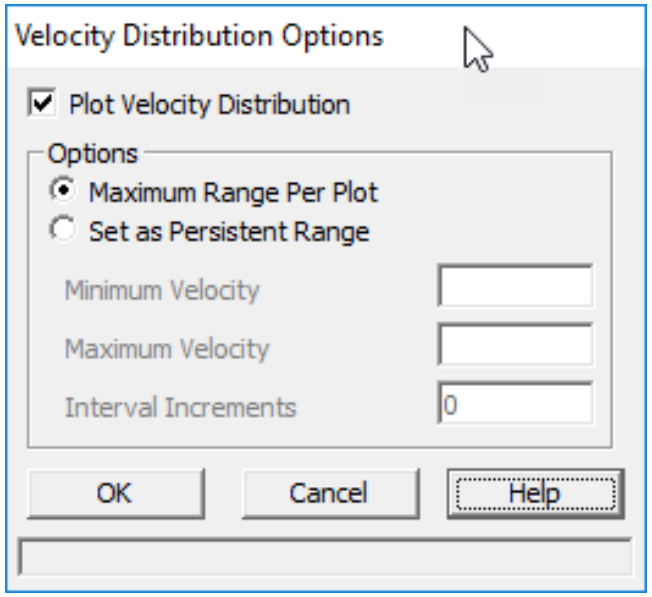
Setting the Flow Distribution Locations



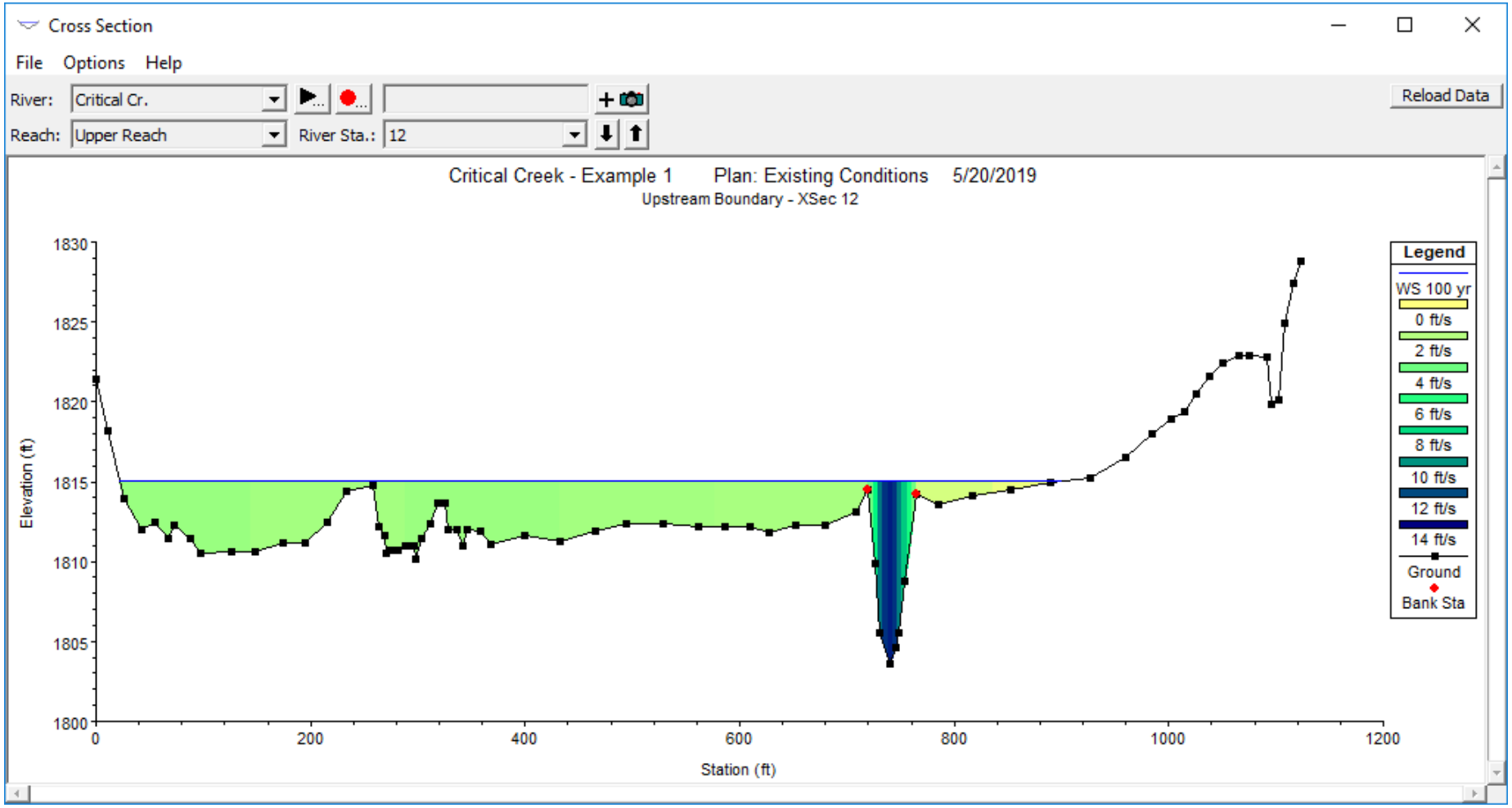
	RS	Chan Min	Starting El	Increment	Points(20-500)	LOB	Chan	ROB
1	60.1	-13.5	-13	1	52	5	10	5
2	59.5	-16.2	-15.7	1	54	5	10	5
3	58.8	-18.9	-18.4	1	56	5	10	5
4	58.05	-16	-15.5	1	50	5	10	5
5	57	-31.7	-31.2	1	72	5	10	5
6	55.86	-30.4	-29.9	1	69	5	10	5
7	54.5	-52	-51.5	1	91	5	10	5
8	53.1	-25.3	-24.8	1	63	5	10	5
9	52.2	-16.1	-15.6	1	52	5	10	5
10	51.2	-24	-23.5	1	61	5	10	5
11	50.8	-20.5	-20	1	55	5	10	5
12	50	-18.6	-18.1	1	50	5	10	5
13	49.3	-16.3	-15.8	1	50	5	10	5
14	48.5	-24.1	-23.6	1	55	5	10	5
15		-20.9	-20.4	1	52	5	10	5
16		-19.3	-18.8	1	50	5	10	5
17		-26.5	-26	1	57	5	10	5
18	46	-21.2	-20.7	1	52	5	10	5
19	45.3	-17.3	-16.8	1	48	5	10	5
20	44.7	-34.2	-33.7	1	65	5	10	5
21	44	-27.2	-26.7	1	58	5	10	5
22	43.6	-26.2	-25.7	1	57	5	10	5
23	42.9	-33.4	-32.9	1	66	5	10	5

Plotting Velocity Distribution

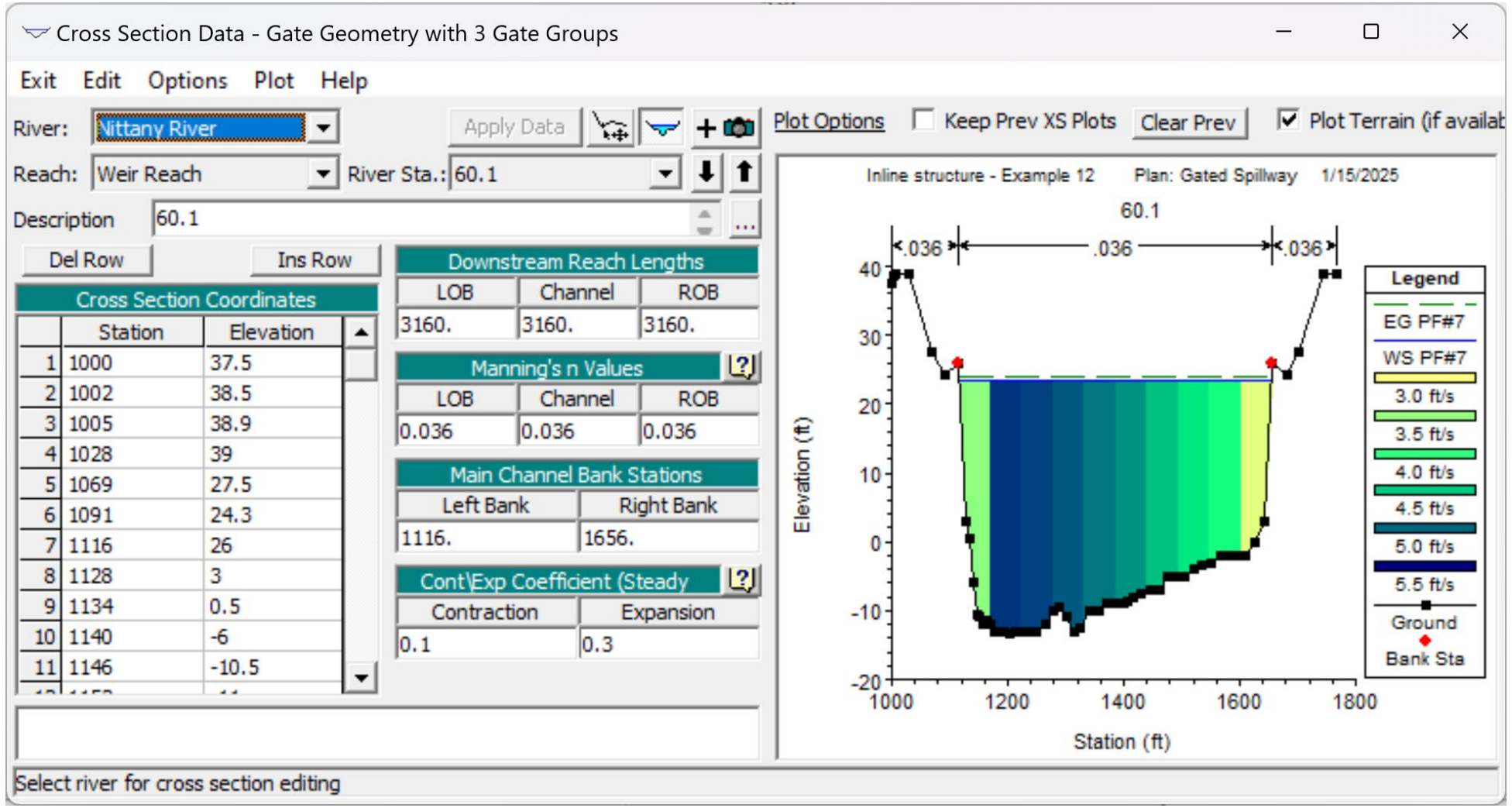




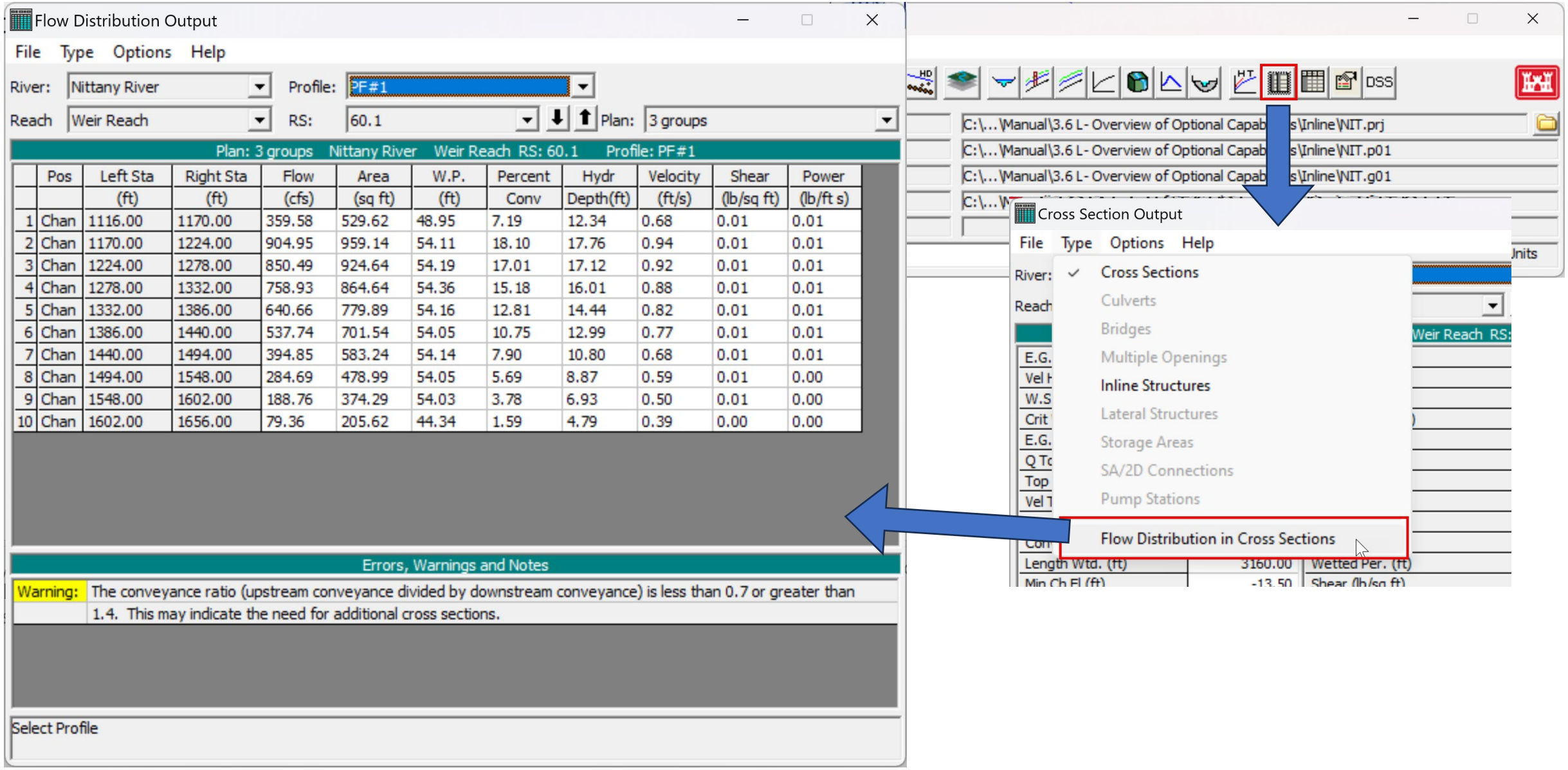
Velocity Distribution Plot



Cross-section Editor with Flow Distribution



Flow Distribution Output

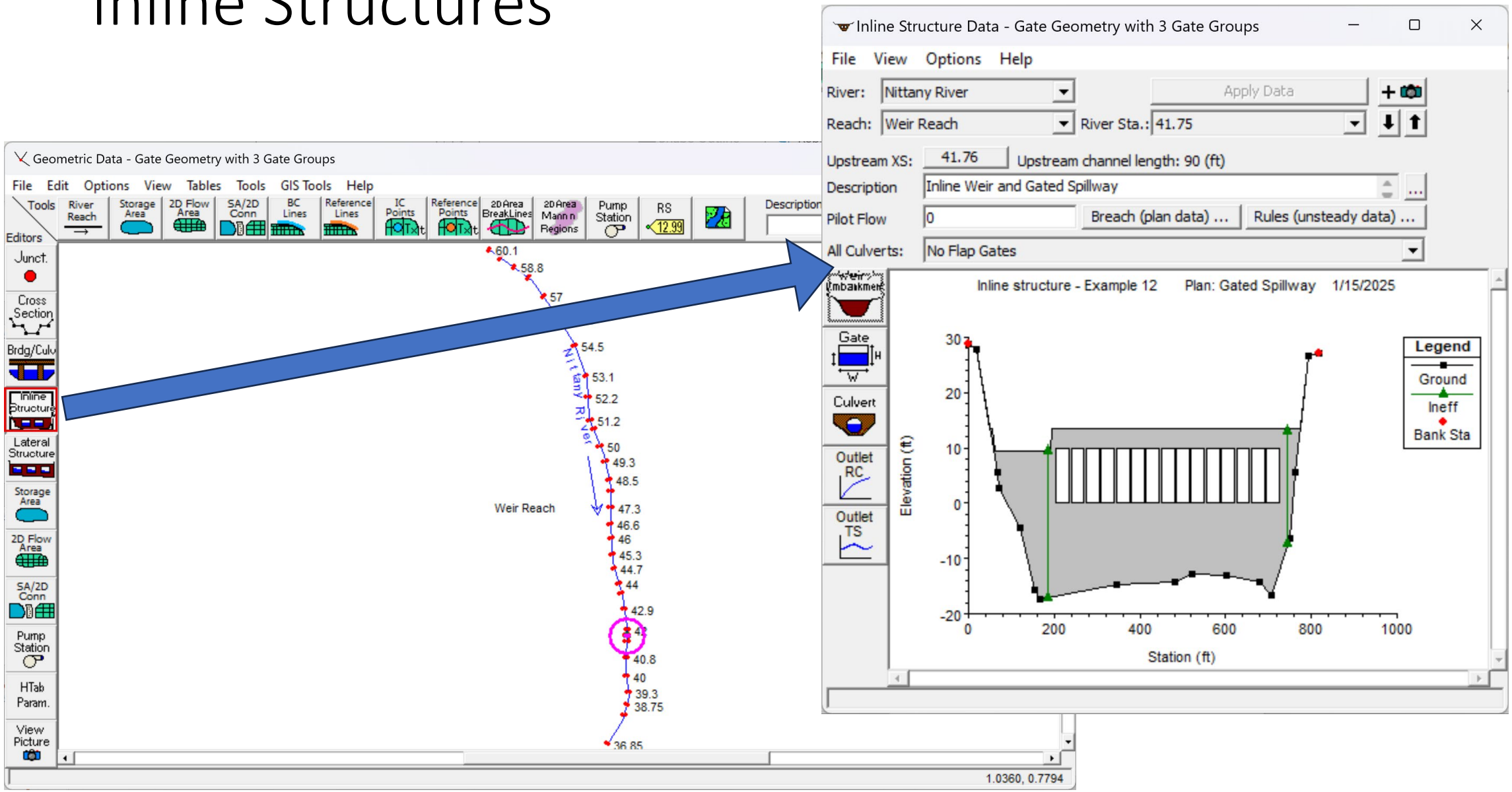


	Pos	Left Sta (ft)	Right Sta (ft)	Flow (cfs)	Area (sq ft)	W.P. (ft)	Percent Conv	Hydr Depth(ft)	Velocity (ft/s)	Shear (lb/sq ft)	Power (lb/ft s)
1	Chan	1116.00	1170.00	359.58	529.62	48.95	7.19	12.34	0.68	0.01	0.01
2	Chan	1170.00	1224.00	904.95	959.14	54.11	18.10	17.76	0.94	0.01	0.01
3	Chan	1224.00	1278.00	850.49	924.64	54.19	17.01	17.12	0.92	0.01	0.01
4	Chan	1278.00	1332.00	758.93	864.64	54.36	15.18	16.01	0.88	0.01	0.01
5	Chan	1332.00	1386.00	640.66	779.89	54.16	12.81	14.44	0.82	0.01	0.01
6	Chan	1386.00	1440.00	537.74	701.54	54.05	10.75	12.99	0.77	0.01	0.01
7	Chan	1440.00	1494.00	394.85	583.24	54.14	7.90	10.80	0.68	0.01	0.01
8	Chan	1494.00	1548.00	284.69	478.99	54.05	5.69	8.87	0.59	0.01	0.00
9	Chan	1548.00	1602.00	188.76	374.29	54.03	3.78	6.93	0.50	0.01	0.00
10	Chan	1602.00	1656.00	79.36	205.62	44.34	1.59	4.79	0.39	0.00	0.00

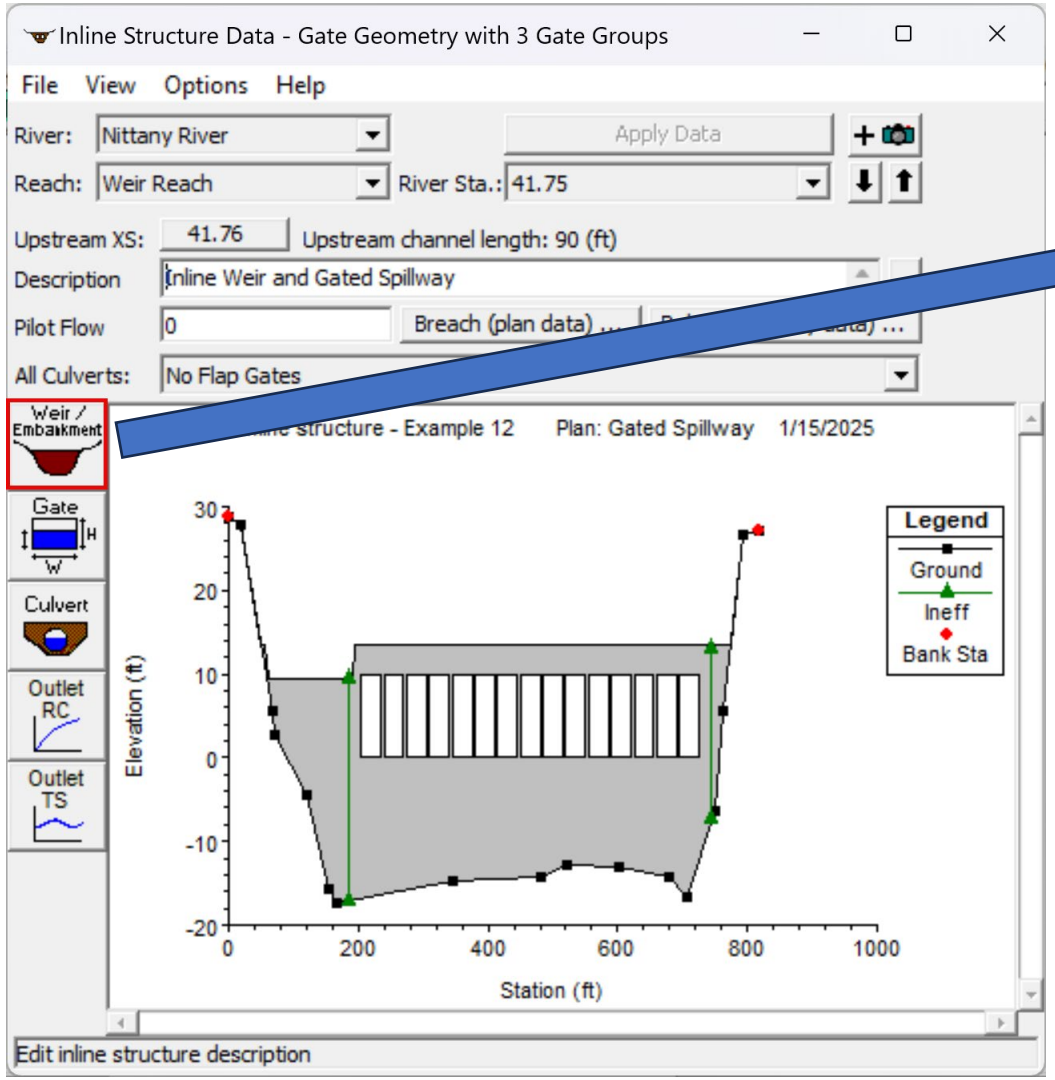
CAUTION

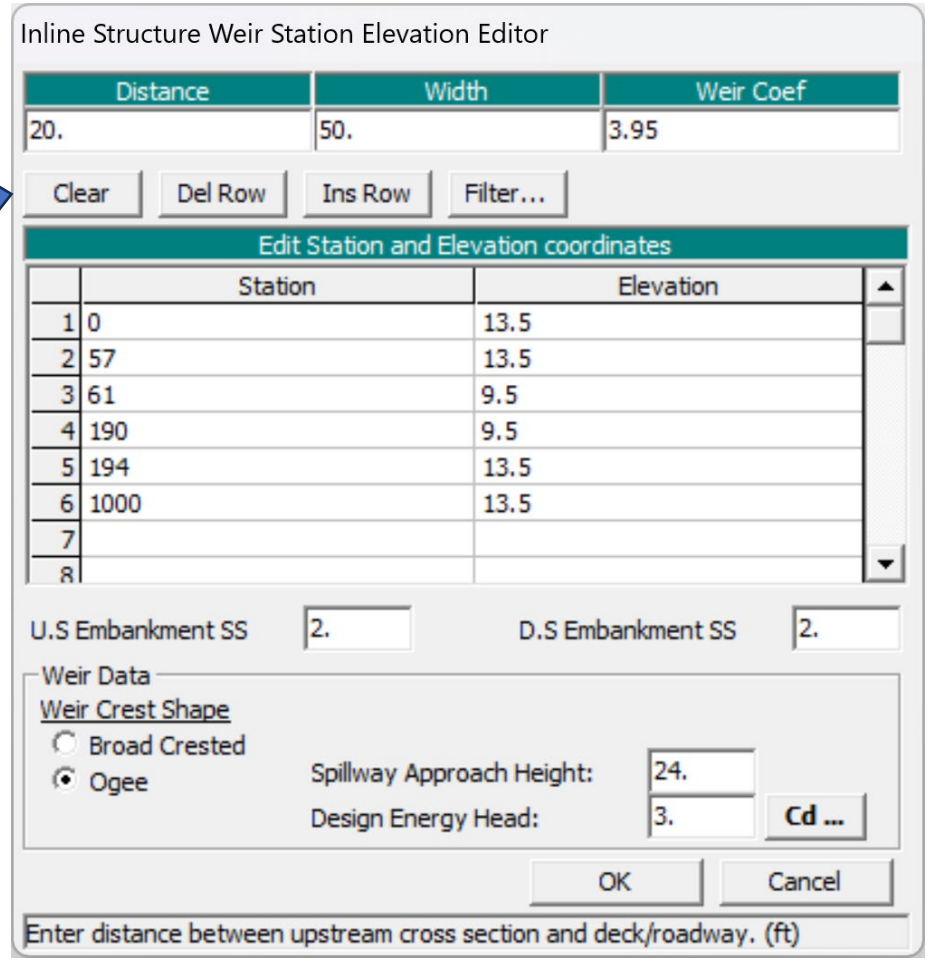
- Flow distribution varies vertically and horizontally (3-D problem)
- HEC-RAS Steady Flow is a 1-D model
- No lateral mixing - Flow distribution is based on area and wetted perimeter of each flow slice (using fewer slices is generally better)
- Not actually representative of hydraulic calculations UNLESS the XS discretization's match

Inline Structures

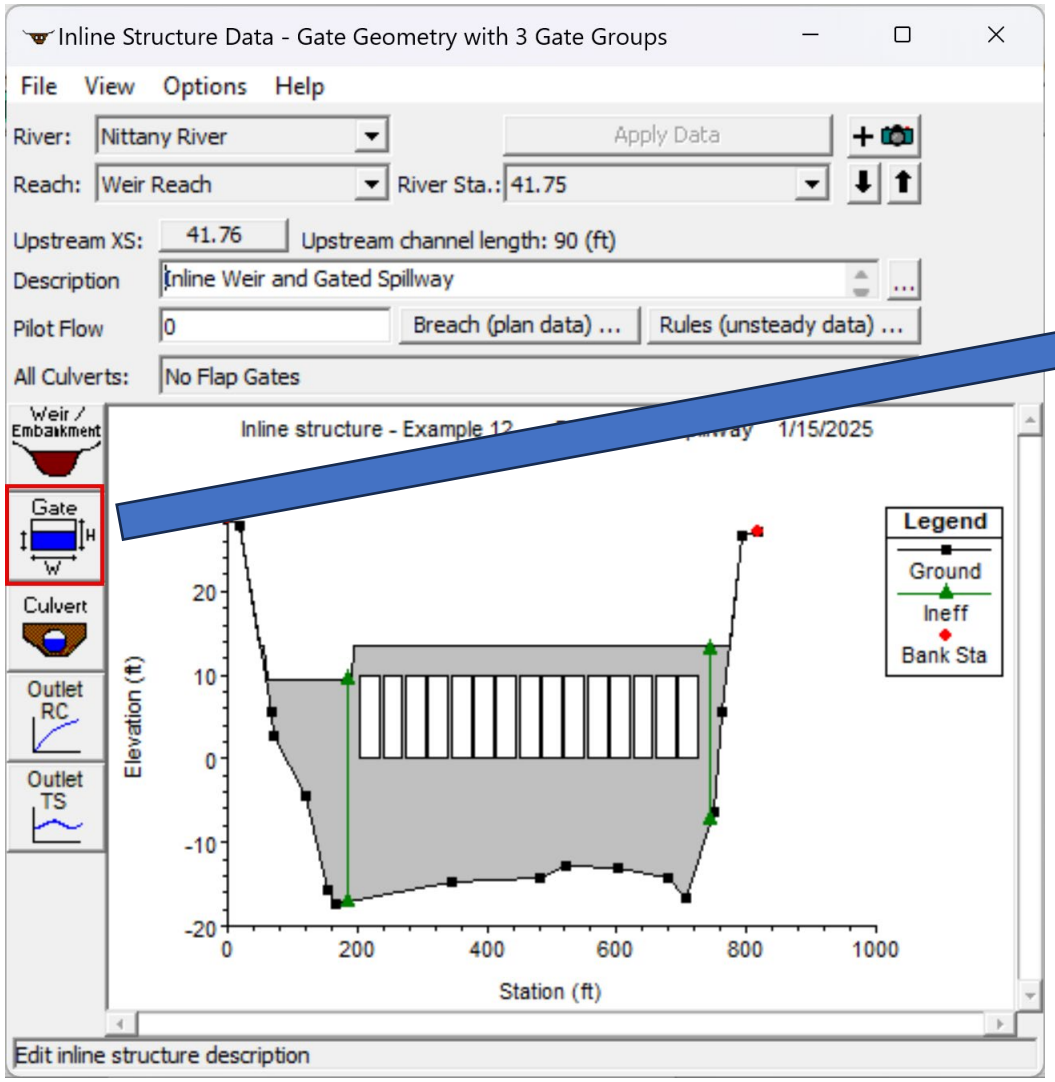


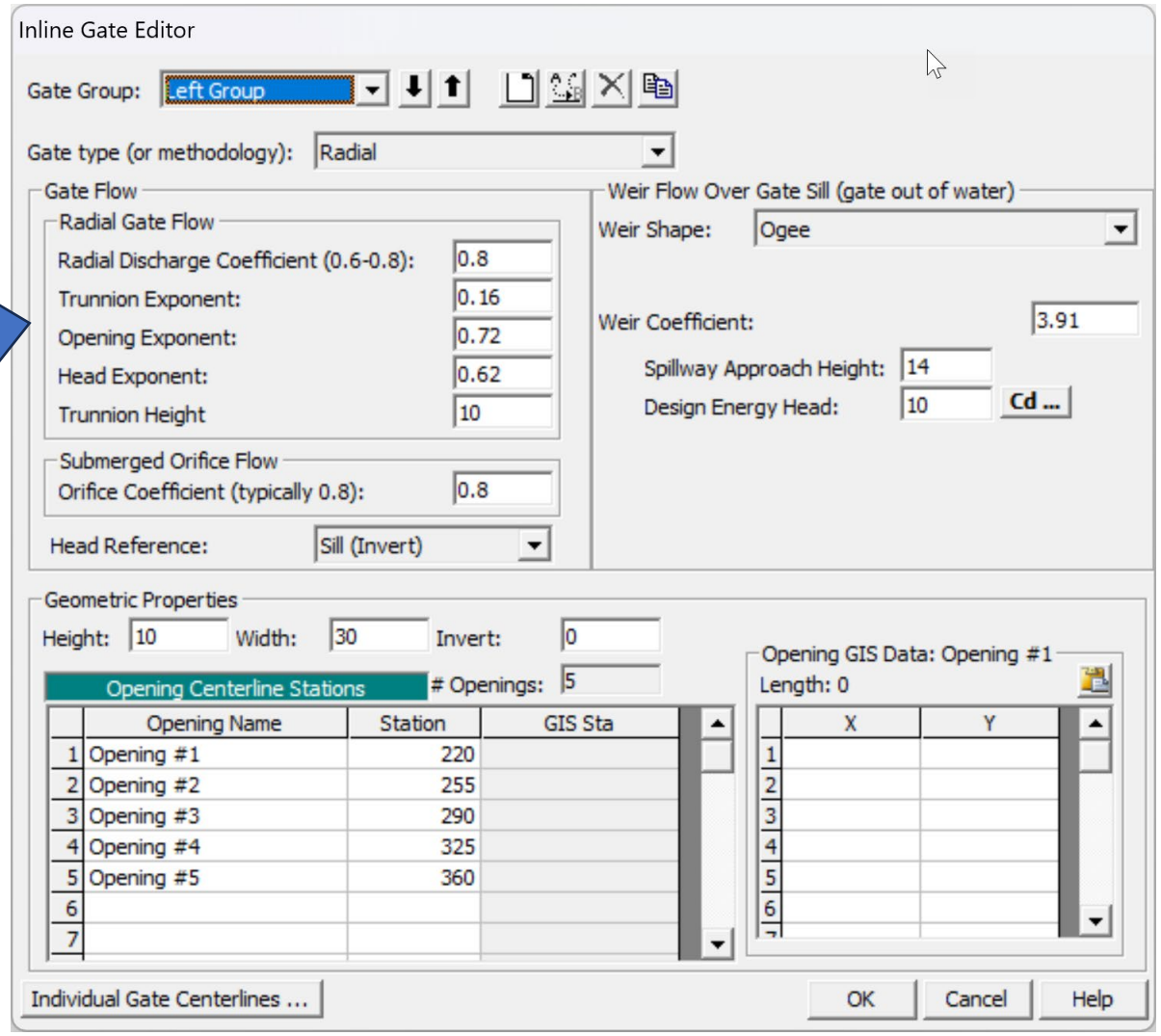
Weir/Embankment





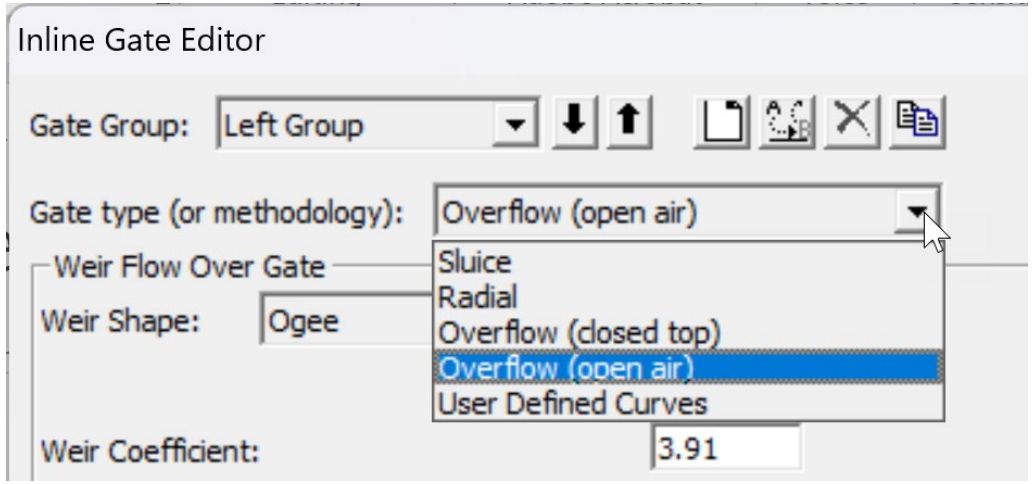
Gate Editor

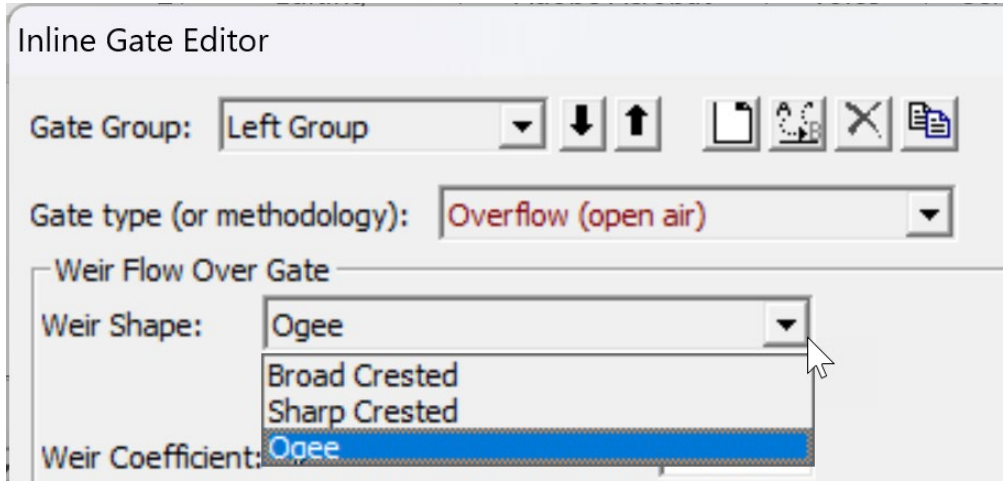

Inline Structure Data - Gate Geometry with 3 Gate Groups
File View Options Help
River: Nittany River
Apply Data
Reach: Weir Reach
River Sta.: 41.75
Upstream XS: 41.76
Upstream channel length: 90 (ft)
Description
Inline Weir and Gated Spillway
Pilot Flow
0
Breach (plan data) ...
Rules (unsteady data) ...
All Culverts:
No Flap Gates
Weir / Embankment
Gate
Culvert
Outlet RC
Outlet TS
Inline structure - Example 12
1/15/2025
Legend
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
Edit inline structure description


Inline Gate Editor
Gate Group: Left Group
Gate type (or methodology): Radial
Gate Flow
Radial Gate Flow
Radial Discharge Coefficient (0.6-0.8): 0.8
Trunnion Exponent: 0.16
Opening Exponent: 0.72
Head Exponent: 0.62
Trunnion Height 10
Submerged Orifice Flow
Orifice Coefficient (typically 0.8): 0.8
Head Reference: Sill (Invert)
Weir Flow Over Gate Sill (gate out of water)
Weir Shape: Ogee
Weir Coefficient: 3.91
Spillway Approach Height: 14
Design Energy Head: 10
Cd ...
Geometric Properties
Height: 10
Width: 30
Invert: 0
Opening Centerline Stations
Openings: 5
Opening Name | Station | GIS Sta
1 Opening #1 220
2 Opening #2 255
3 Opening #3 290
4 Opening #4 325
5 Opening #5 360
Opening GIS Data: Opening #1
Length: 0
X | Y
Individual Gate Centerlines ...
OK
Cancel
Help

Gate Editor

- Up to 10 gate groups each with up to 25 gate openings
- All gates in each group must be identical
- Gate type
  - Sluice (i.e. vertical lift)
  - Radial (i.e. tainter)
  - Overflow (closed top)
  - Overflow (open air)
- Weir type
  - Ogee
  - Broad crested





Gate Types

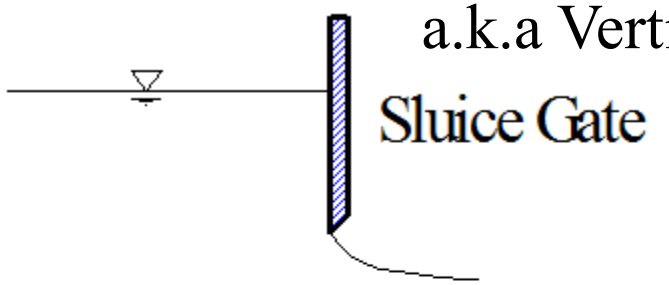
Radial Gate

Sluice Gate

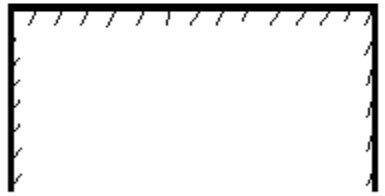
Overflow Gate

Sluice and Radial Gates

a.k.a Vertical Left Gate

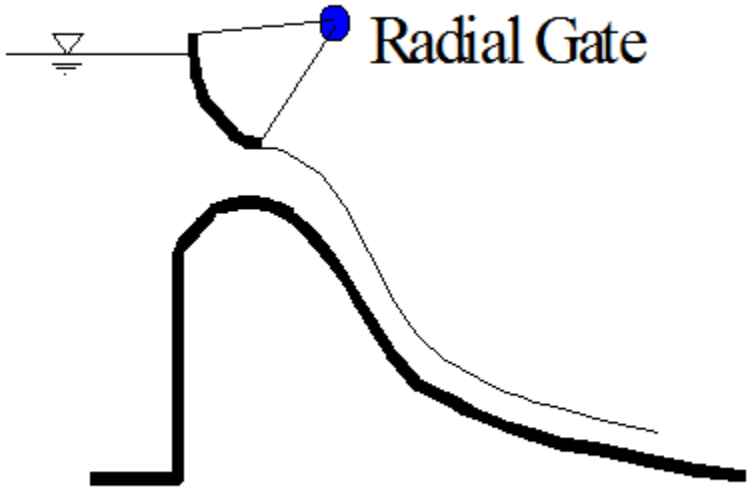


Sluice Gate



Broad Crested Spillway

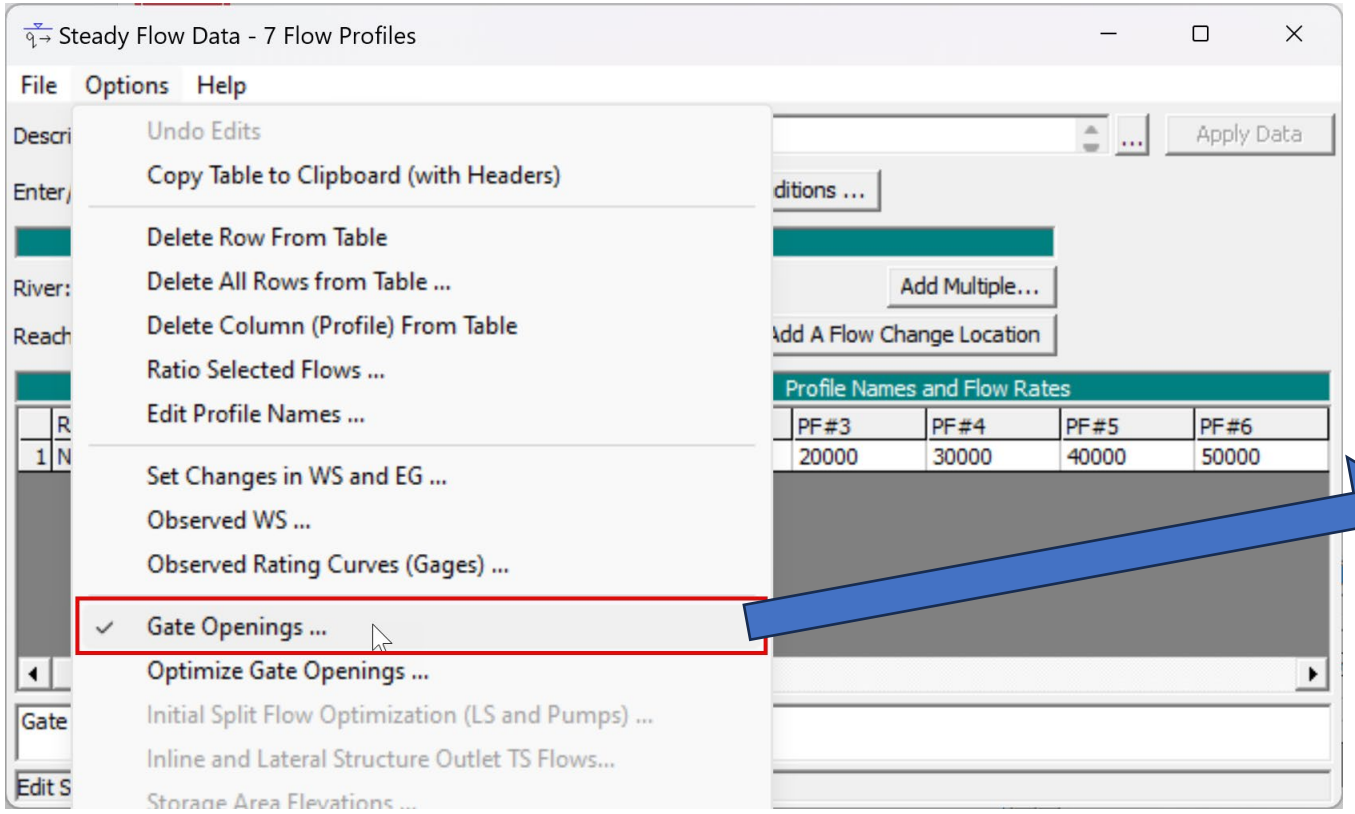
a.k.a Tainter Gate

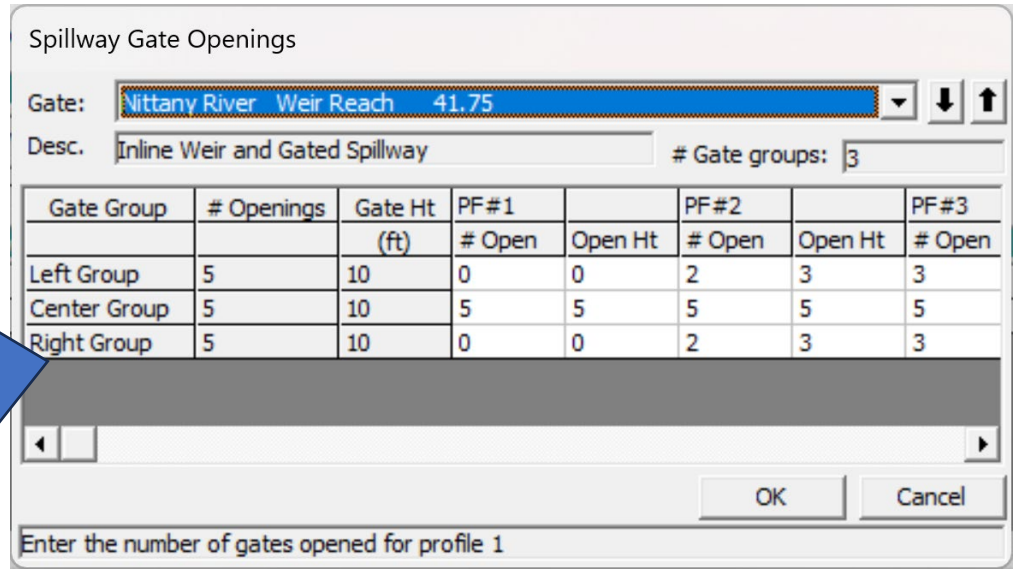


Radial Gate

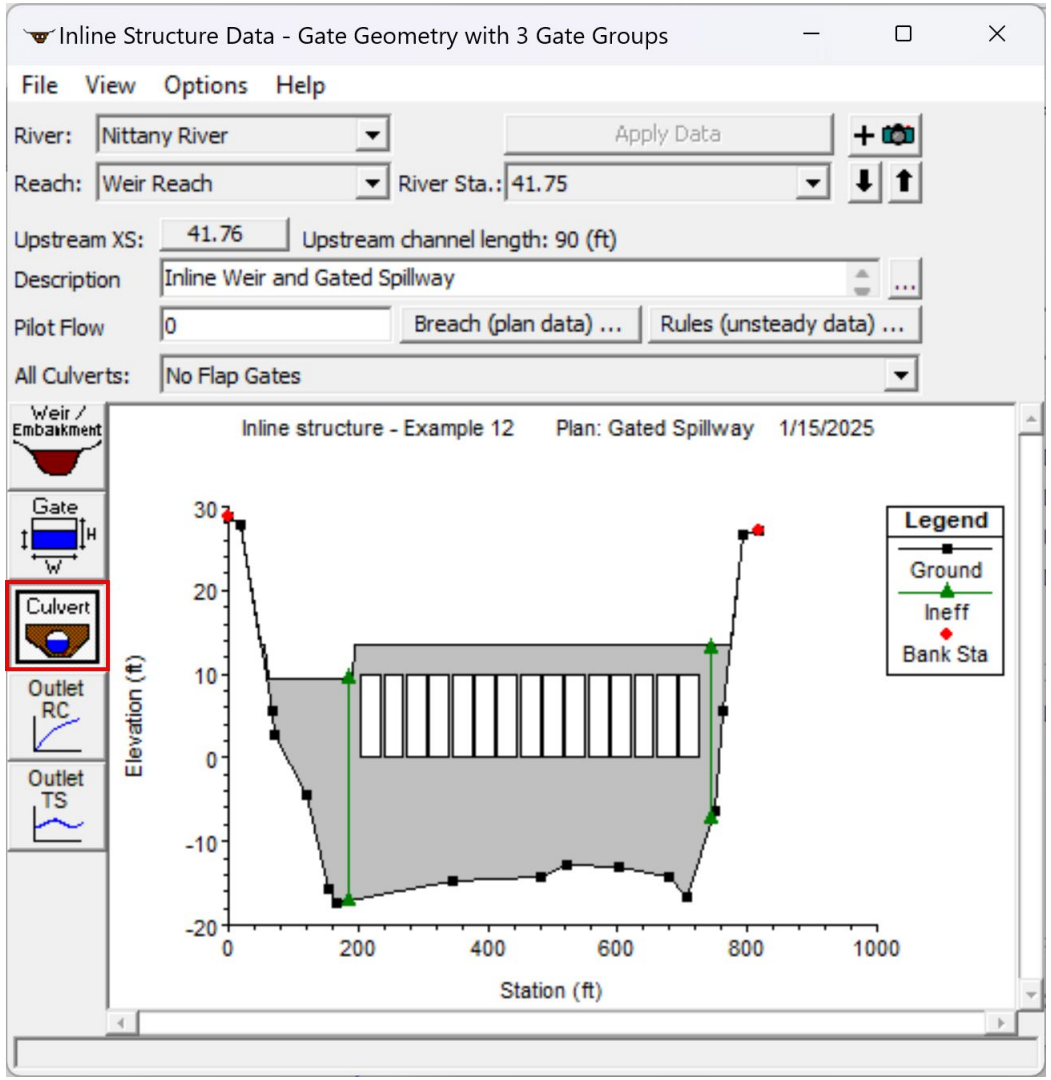
Ogee Spillway Crest

Setting the Gate Opening



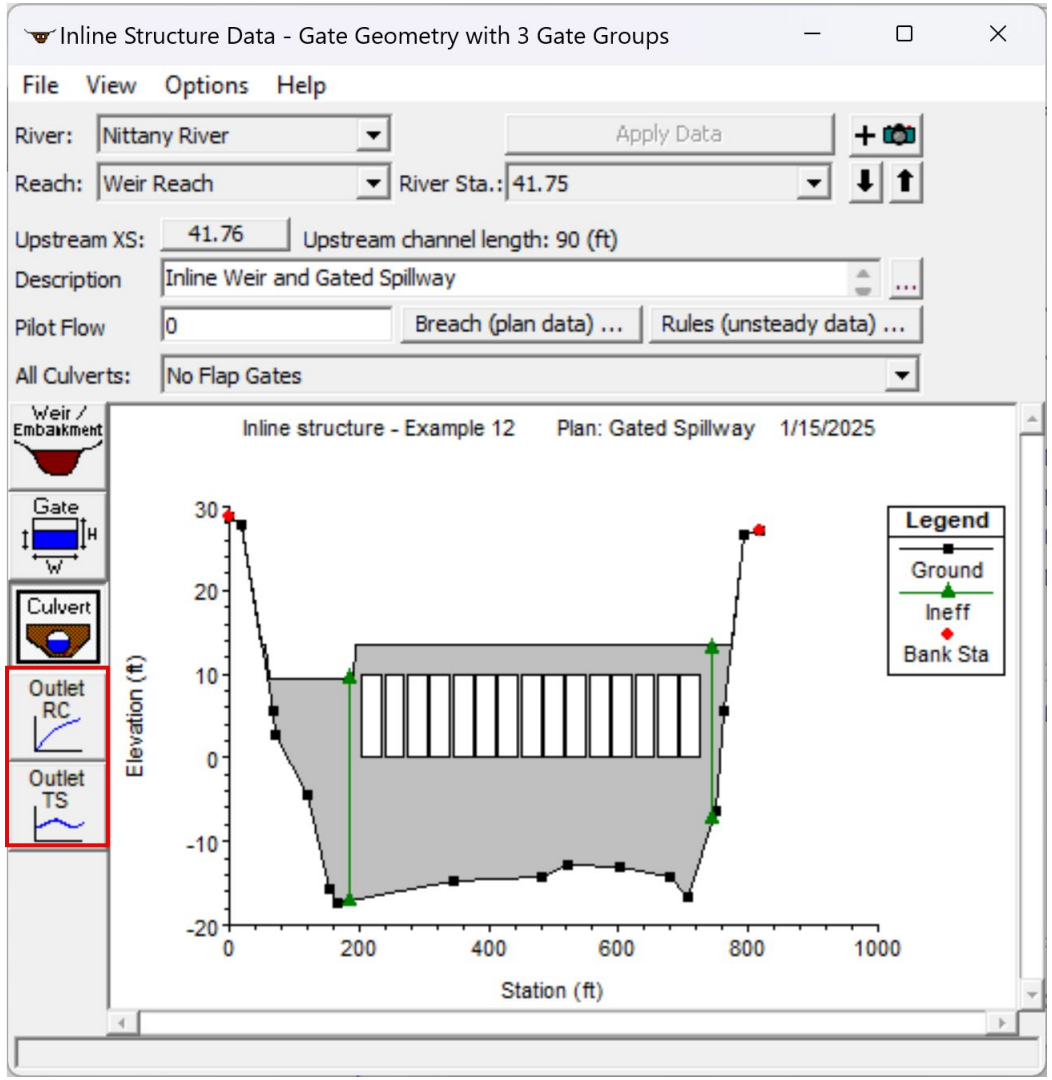


Culverts at Inlet Structures

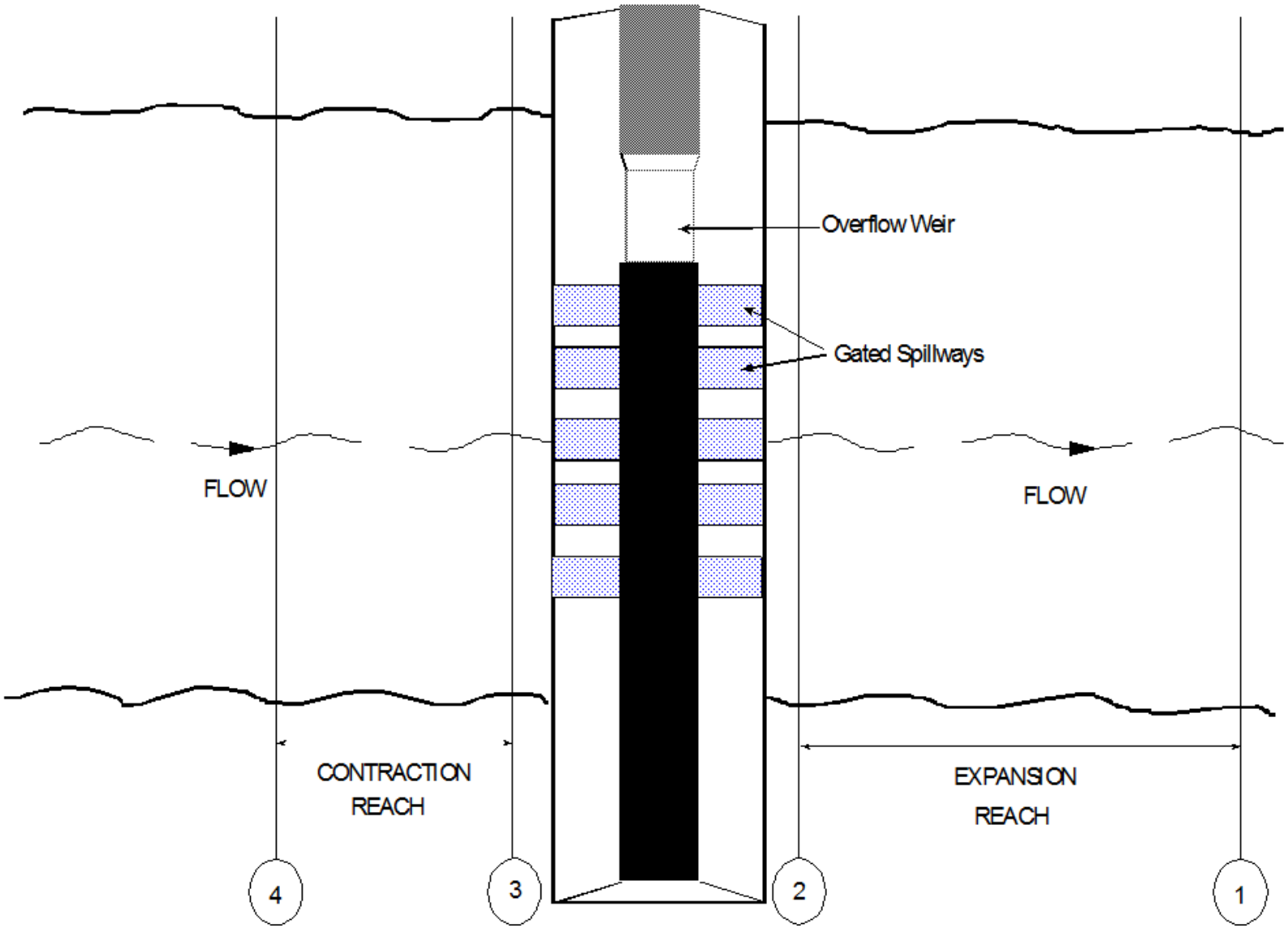


Notes

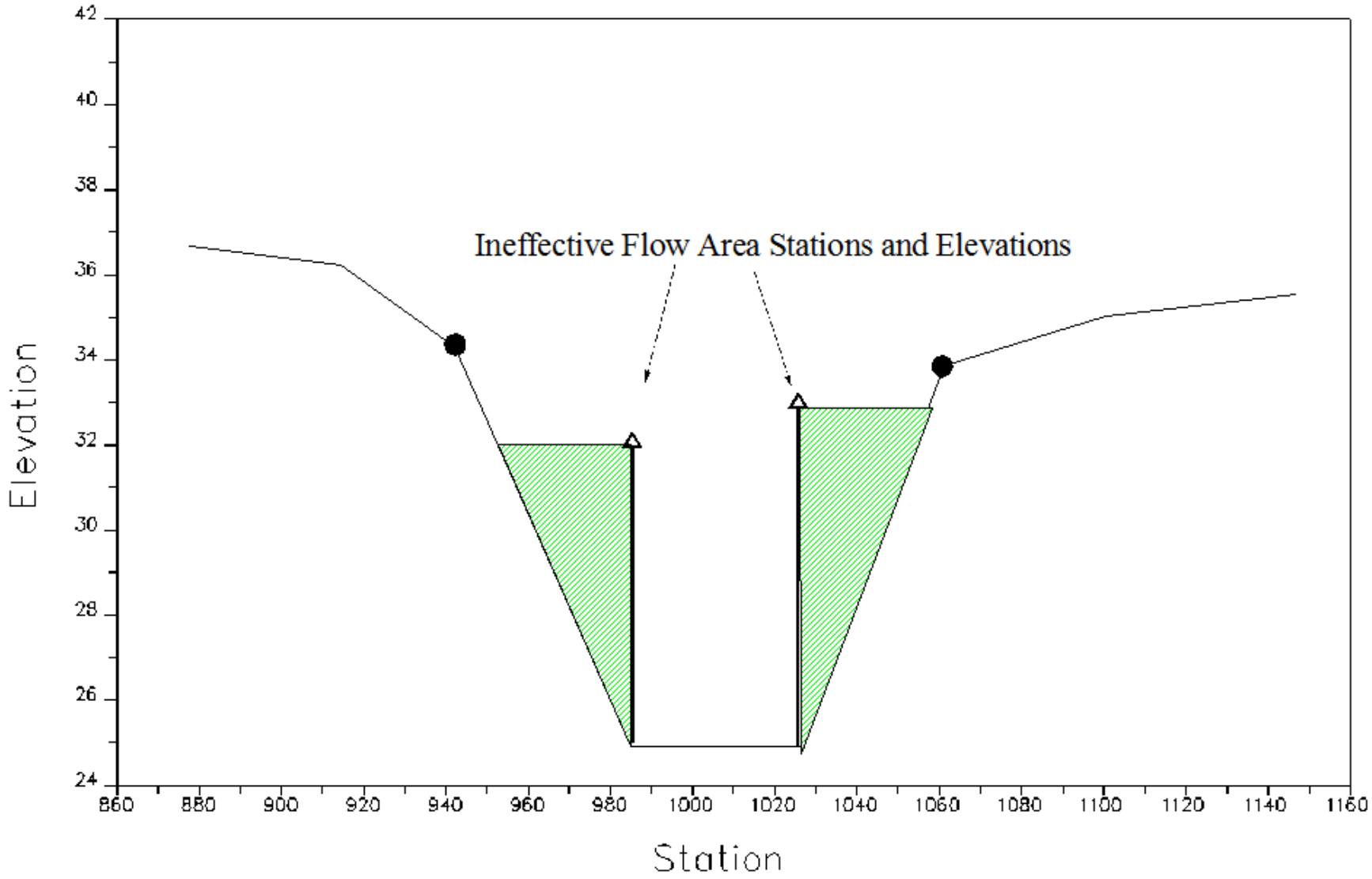
- Not applicable to steady flow
  - Outlet Rating Curve
  - Outlet Time Series
  - Rules
  - Breaching



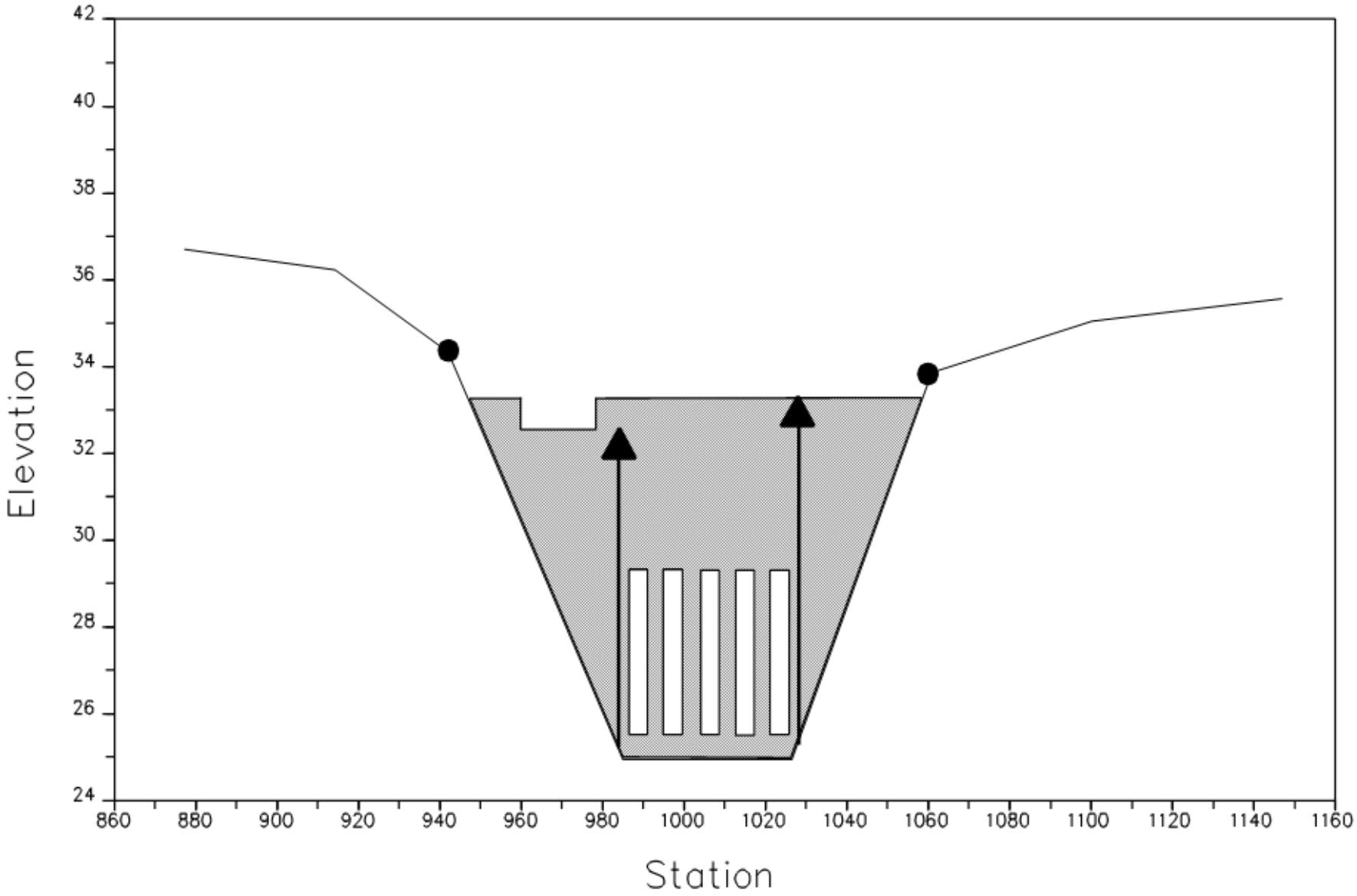
Cross-Section Layout



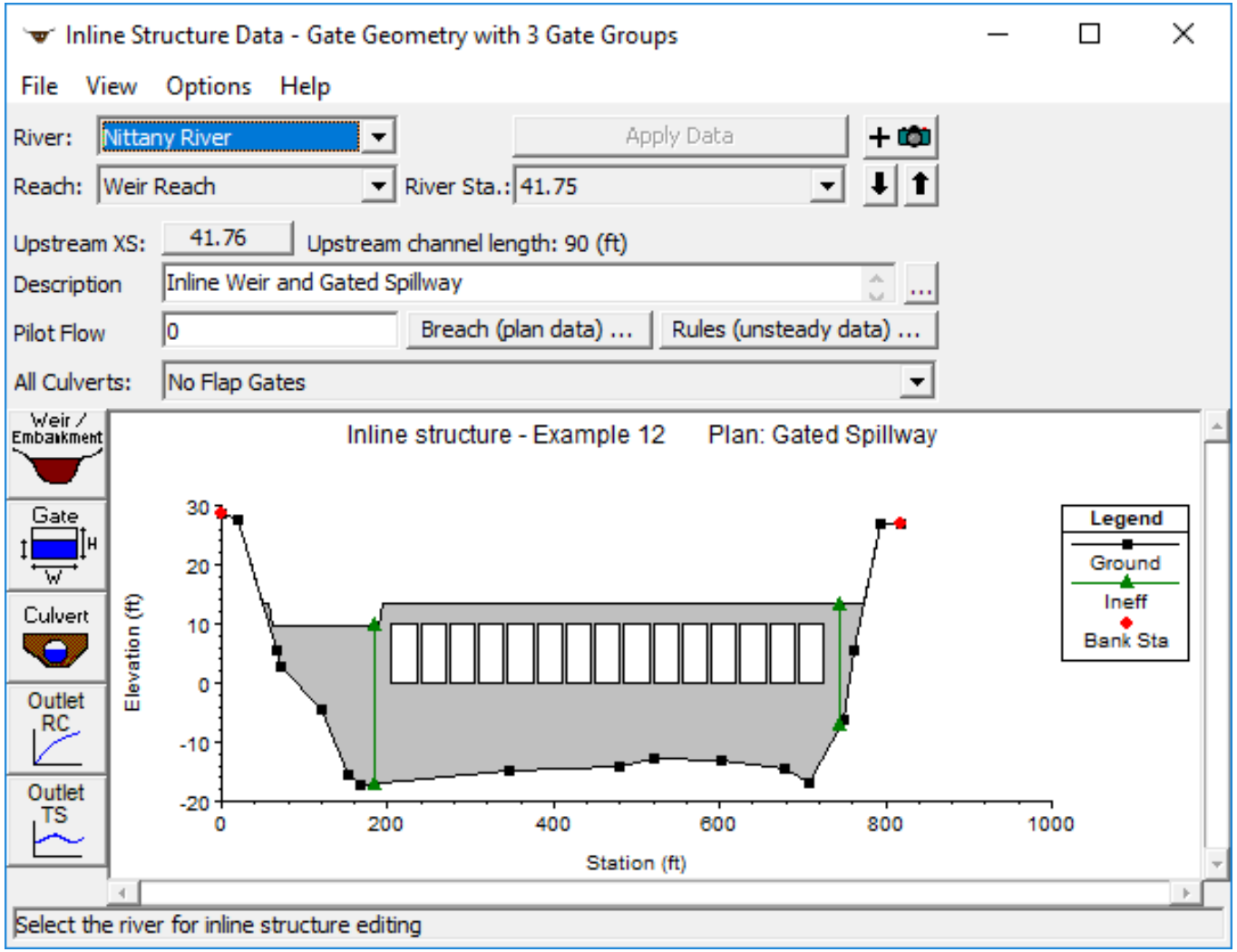
Cross-Section 2



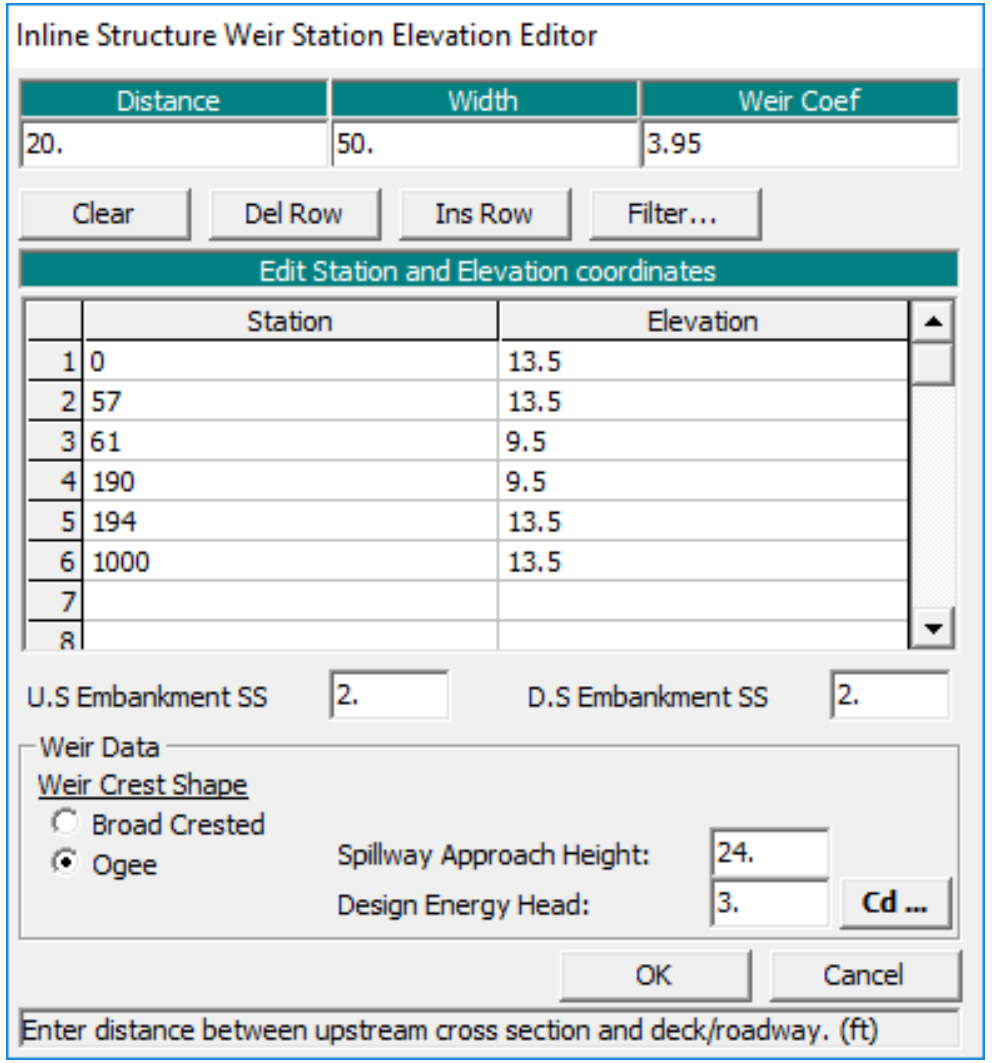
Cross-Section 3



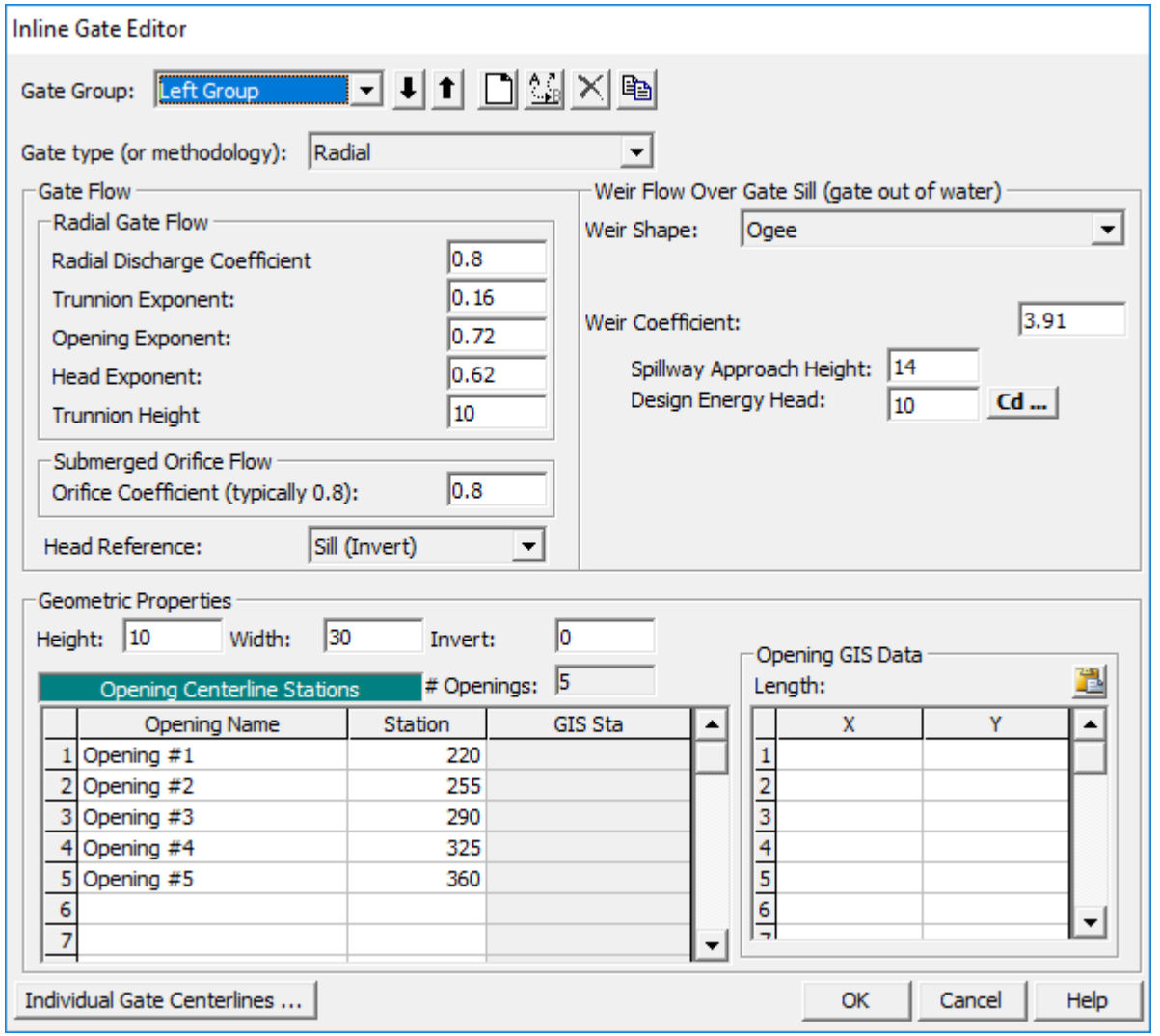
Inline Weir Editor



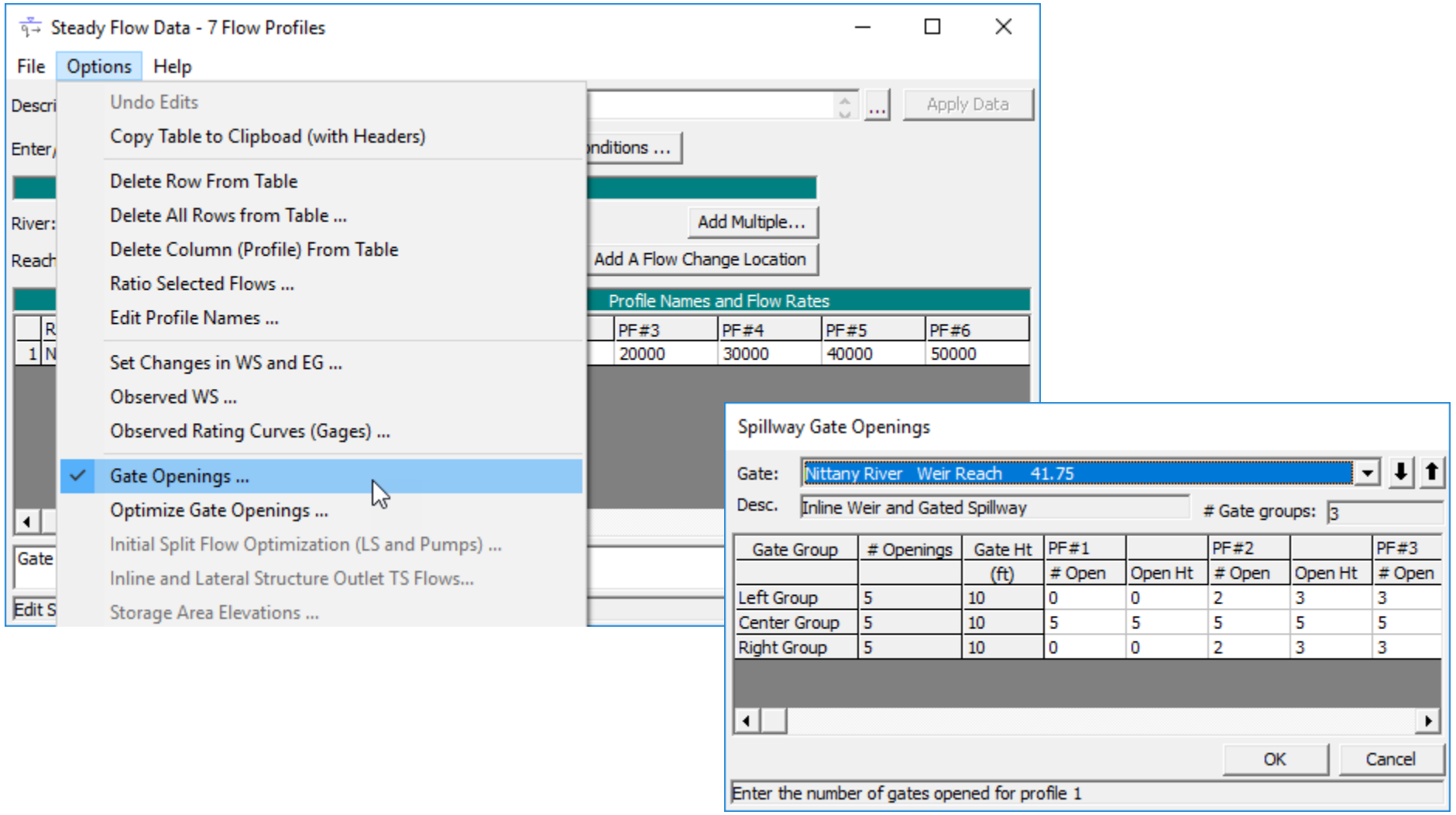
Weir/Embankment



Gate Editor

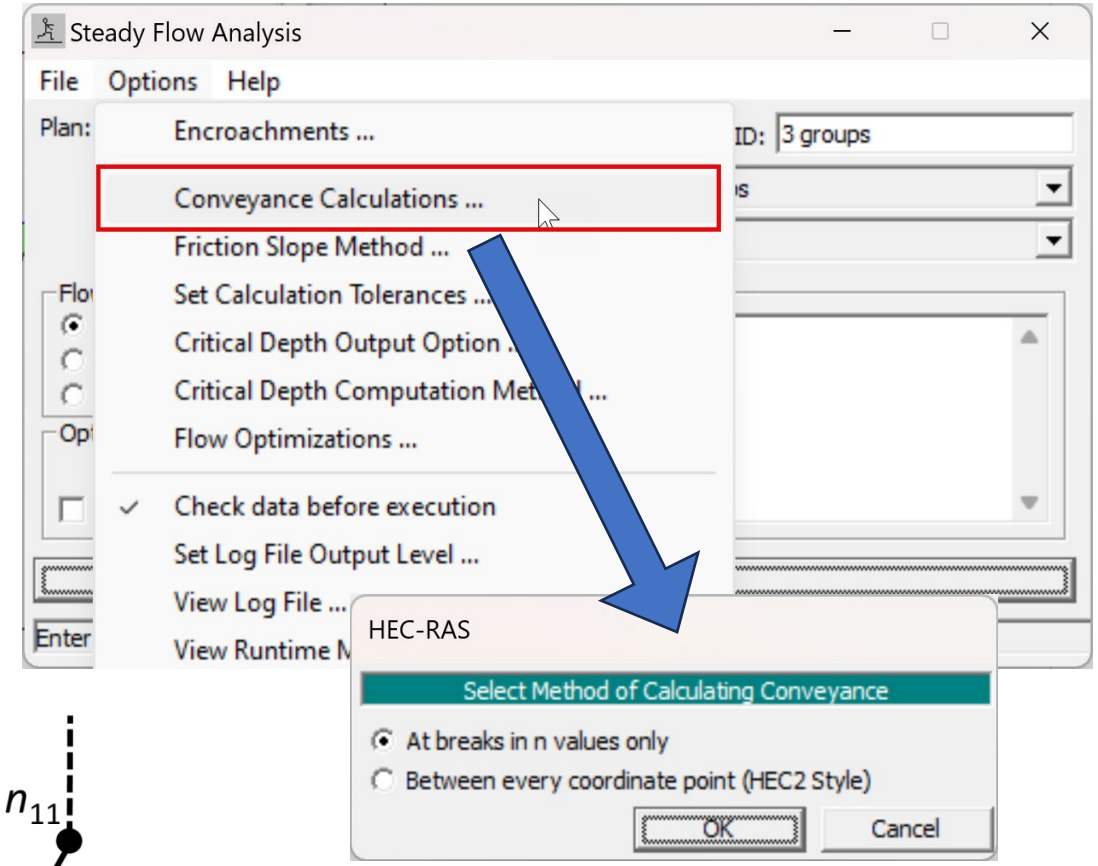

Inline Gate Editor
Gate Group:
Left Group
Gate type (or methodology):
Radial
Gate Flow
Radial Gate Flow
Radial Discharge Coefficient
0.8
Trunnion Exponent:
0.16
Opening Exponent:
0.72
Head Exponent:
0.62
Trunnion Height
10
Submerged Orifice Flow
Orifice Coefficient (typically 0.8):
0.8
Head Reference:
Sill (Invert)
Weir Flow Over Gate Sill (gate out of water)
Weir Shape:
Ogee
Weir Coefficient:
3.91
Spillway Approach Height:
14
Design Energy Head:
10
Cd ...
Geometric Properties
Height:
10
Width:
30
Invert:
0
Opening Centerline Stations
Openings:
5
Opening Name
Station
GIS Sta
1 Opening #1 220
2 Opening #2 255
3 Opening #3 290
4 Opening #4 325
5 Opening #5 360
Opening GIS Data
Length:
X
Y
Individual Gate Centerlines ...
OK
Cancel
Help

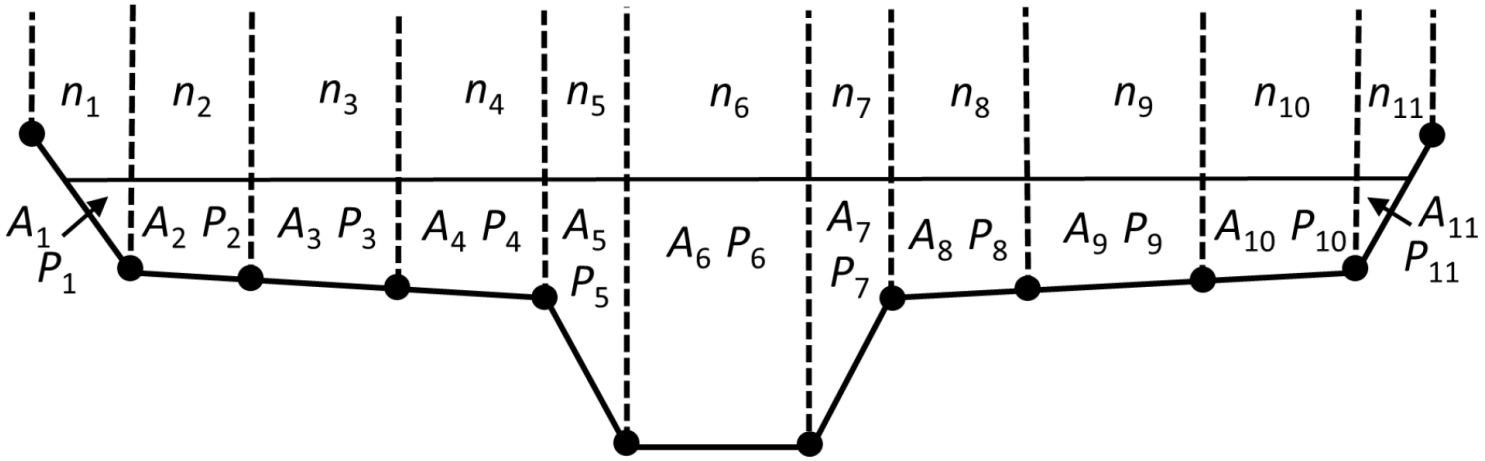
Setting the Gate Opening



Conveyance Calculations

- HEC2 approach is the Divided Channel Method with subdivisions to set to stations
- Usually not good except for simplified cross-sections





Friction Slope Method

- Average Conveyance (default):

$$\bar{S}_f = \left(\frac{Q_1+Q_2}{K_1+K_2}\right)^2$$

- Average Mean:

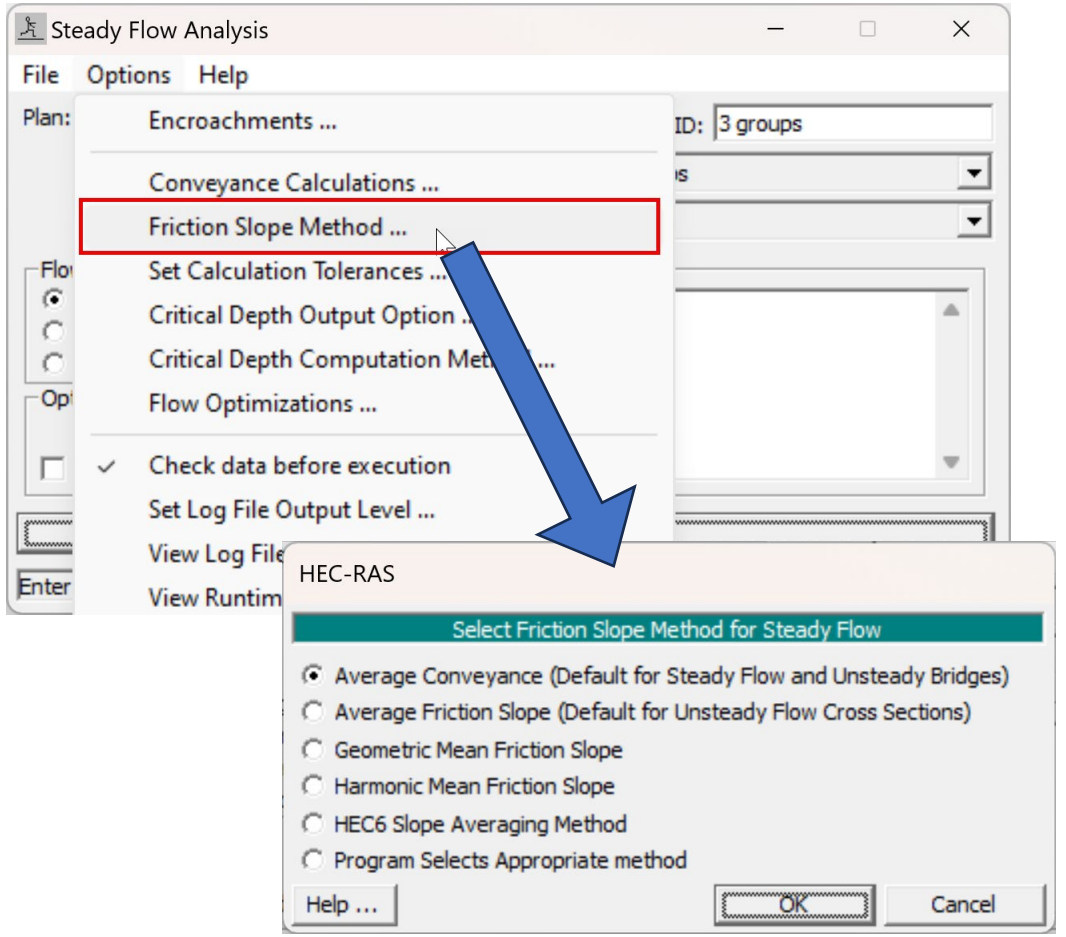
$$\bar{S}_f = \frac{S_{f1}+S_{f2}}{2}$$

- Geometric Mean:

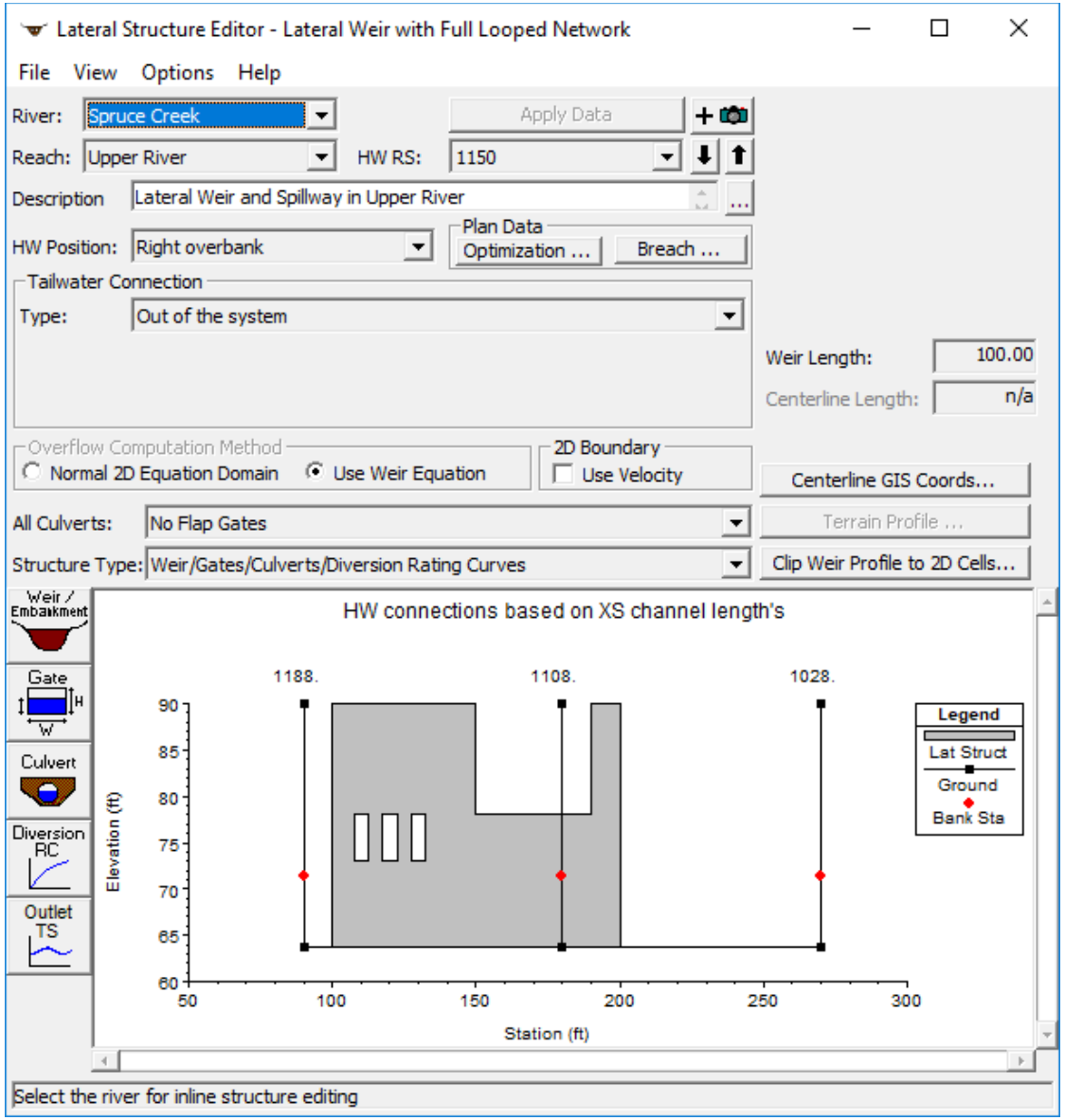
$$\bar{S}_f = \sqrt{S_{f1}S_{f2}}$$

- Harmonic Mean:

$$\bar{S}_f = \frac{2S_{f1}S_{f2}}{S_{f1}+S_{f2}}$$

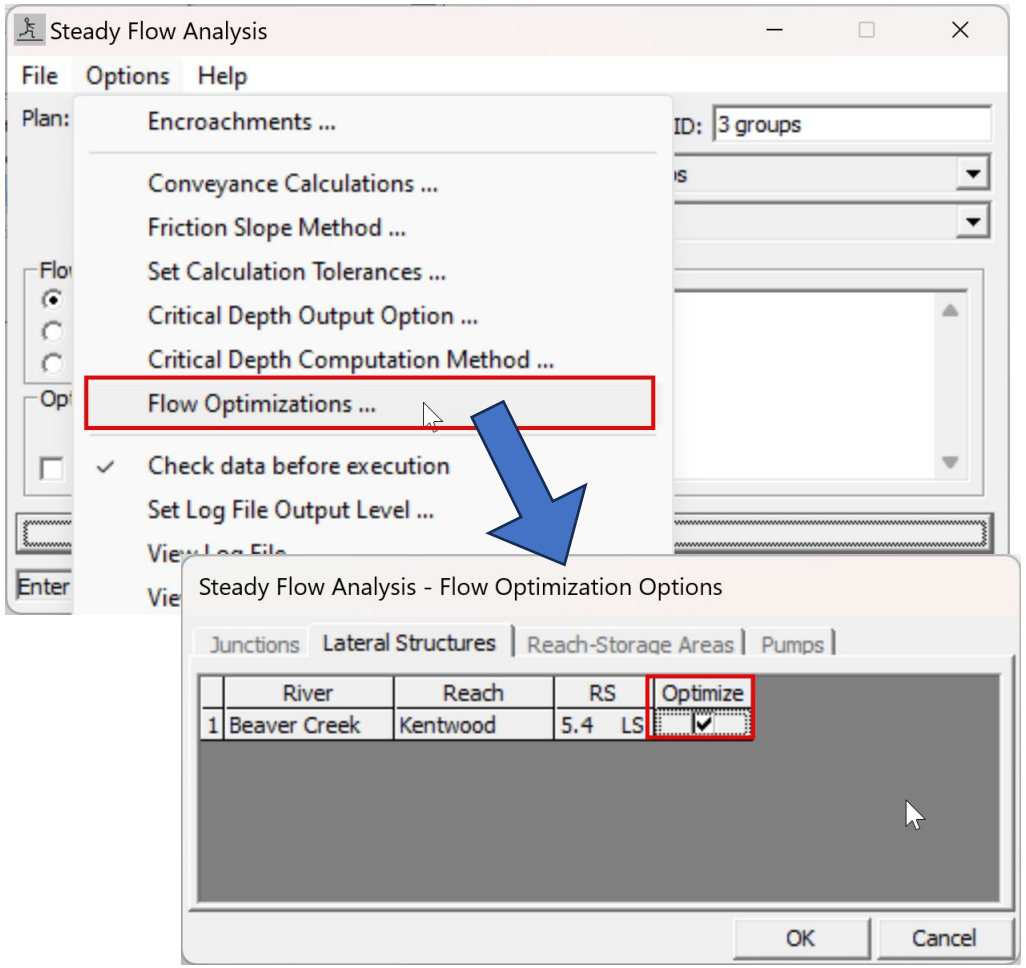


Lateral Structure



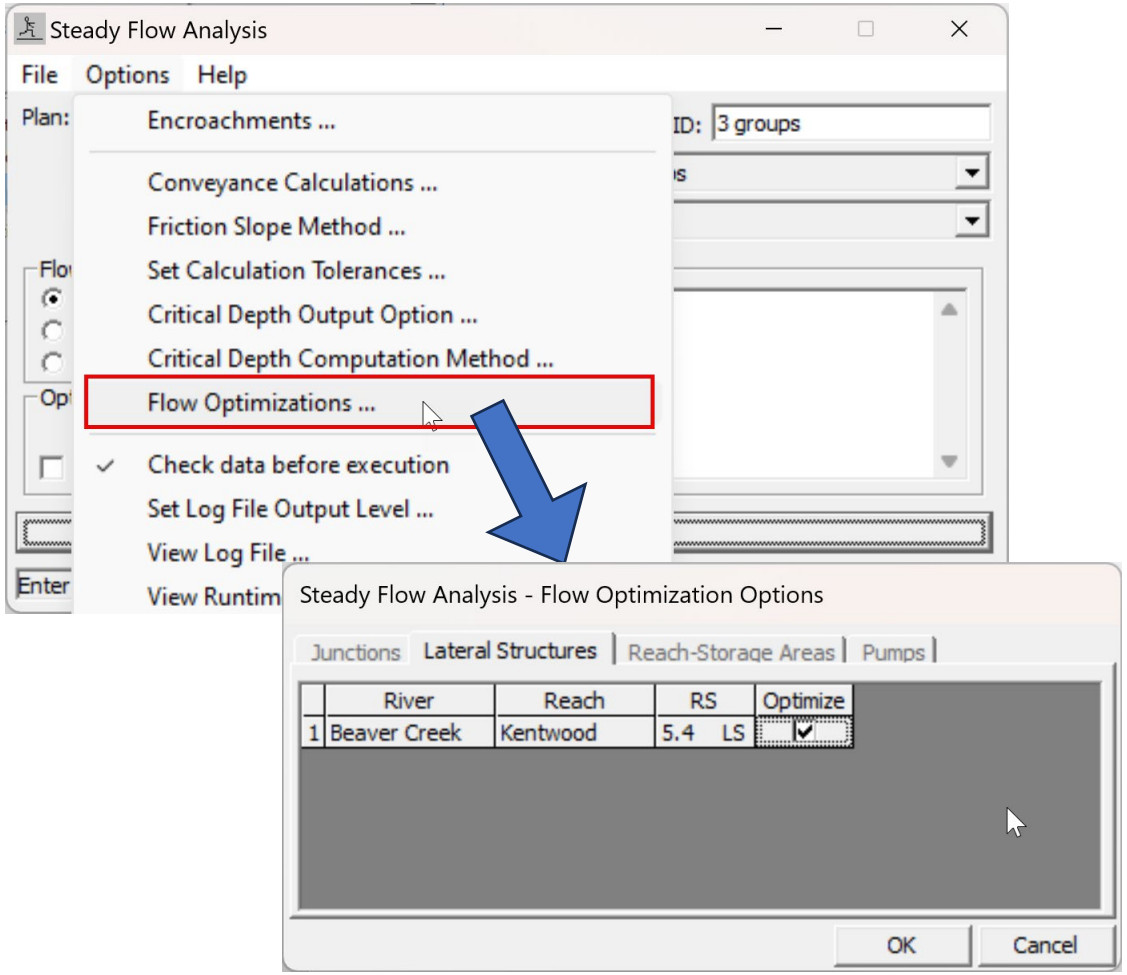
Lateral Structure Optimization

- Flows at lateral structures is a function of the water surface which is a function of the flow
- Optimization iterates until flow and stage converge
- If optimization is off, the lateral flows are calculated based on the backwater and will be overestimated



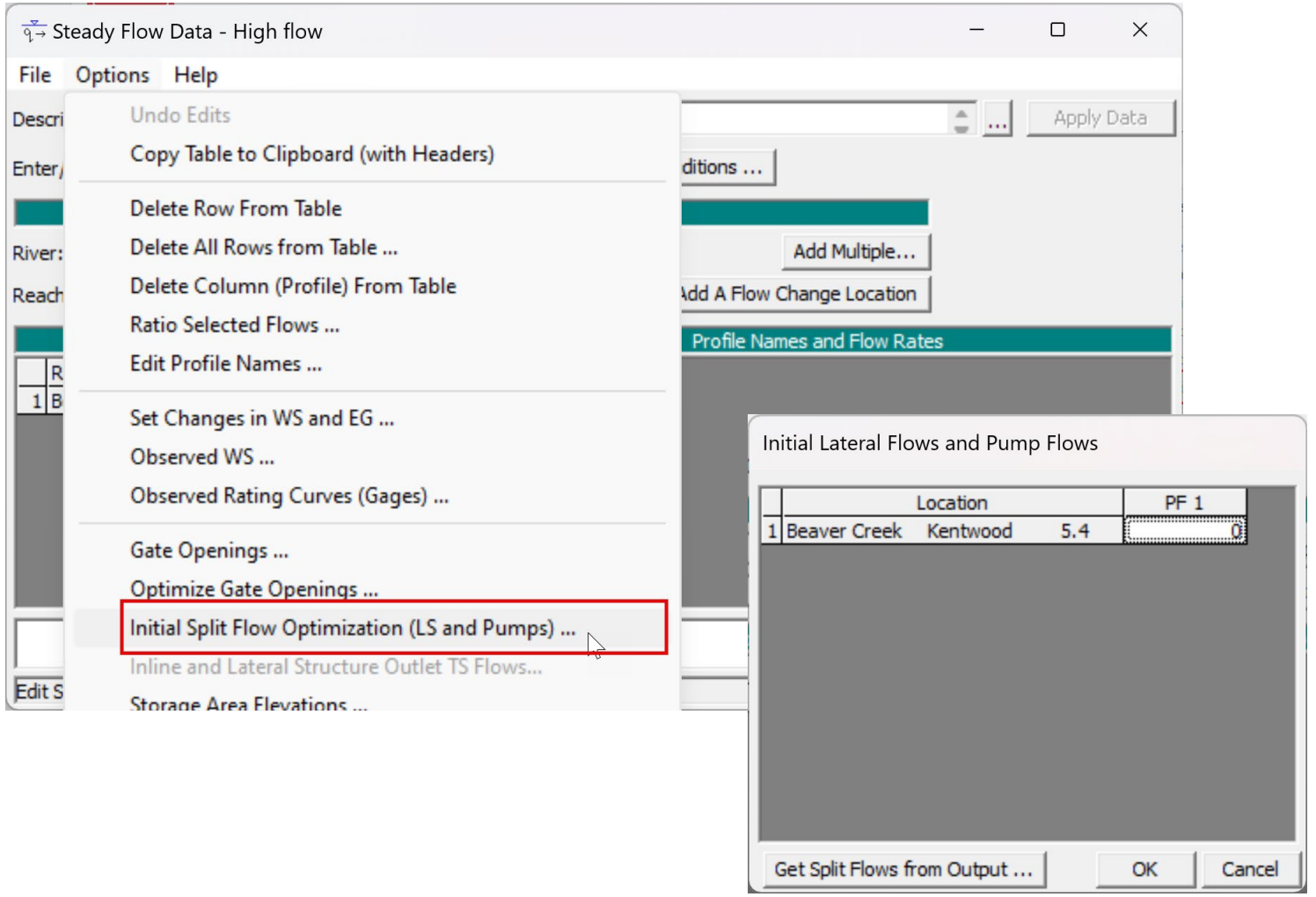
Flow Optimizations

- Occur at split flows:
  - Stream junctions
    - Iterates to match the EG at downstream XS's of junction
  - Lateral structures
    - Starts with zero flow and iteratively reduces flow until convergence
  - Reach-storage areas
    - To match user specified elevations
  - Pump stations



Initial Split Flows

- Steady Flow Data editor



Calculation Tolerances

Standard Step Method

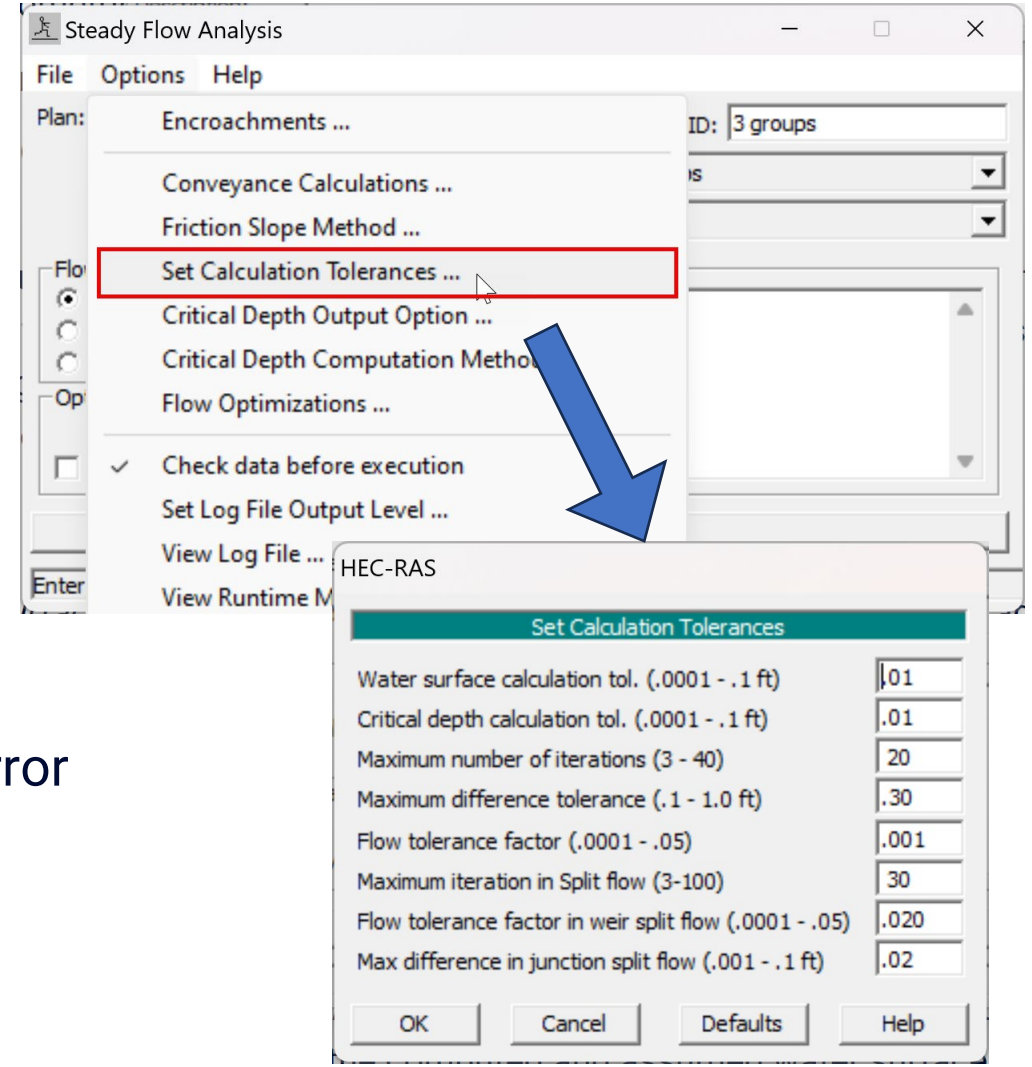
- *Water surface tolerance*
  - Compared with difference between computed and assumed water surface elevations
- Critical depth tolerance
- Minimum difference tolerance
  - If max iterations, compared with best (i.e. minimum) error solution

Bridges and Culverts

- Flow Tolerance Factor
  - Multiplied by total flow and compared to flow error

Optimizations

- Maximum Iteration in Split Flow
- Flow Tolerance Factor in Wier Split Flow
- Maximum Difference in Junction Split Flow



Questions?

US Army Corps of Engineers