

Inline and Lateral Structures

Eric Tichansky, PE, CFM



Goals

1. Use Cases for Hydraulic Structures in HEC-RAS
2. Computations for Hydraulic Structures
3. Controlling Hydraulic Structure in HEC-RAS

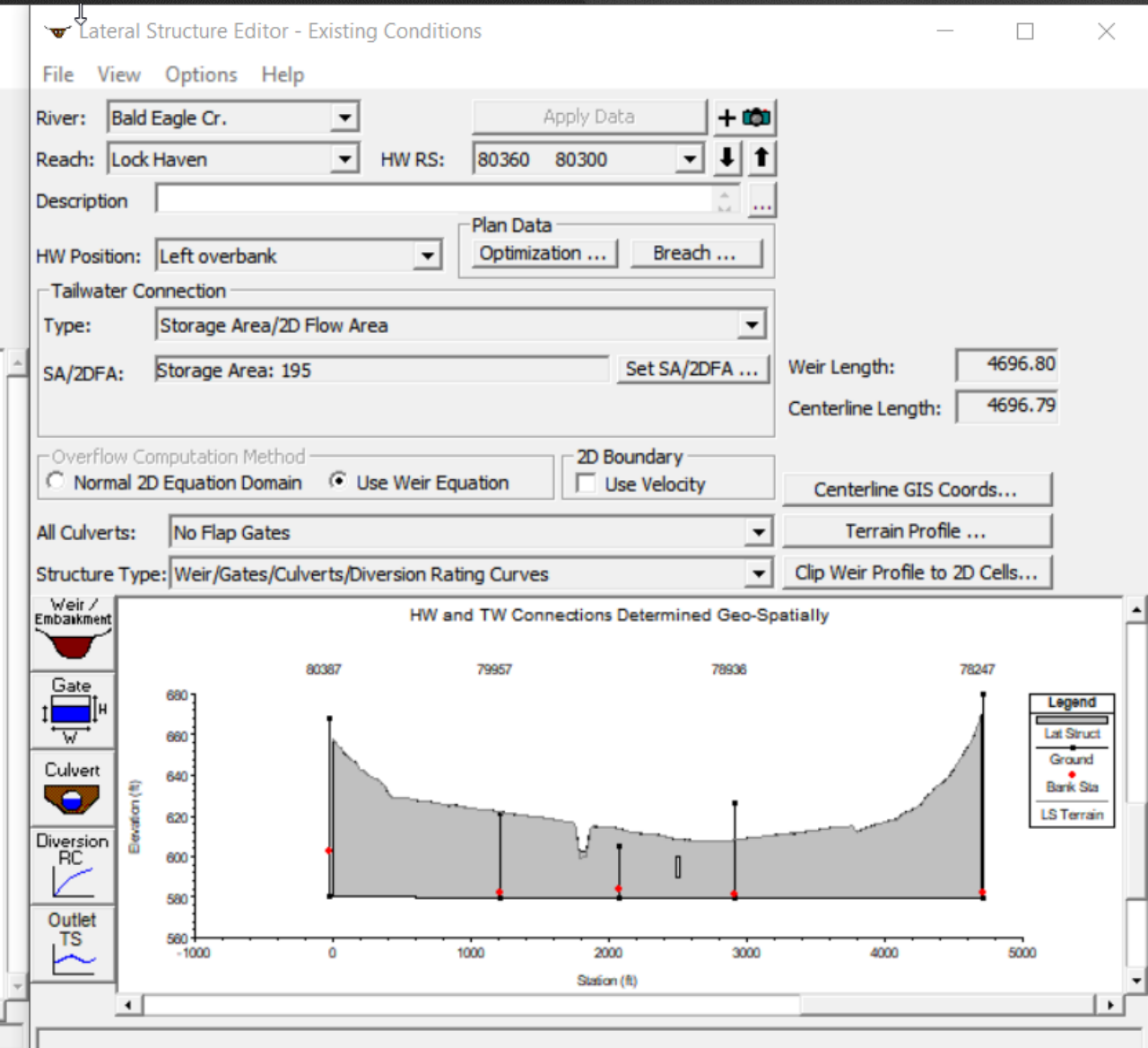
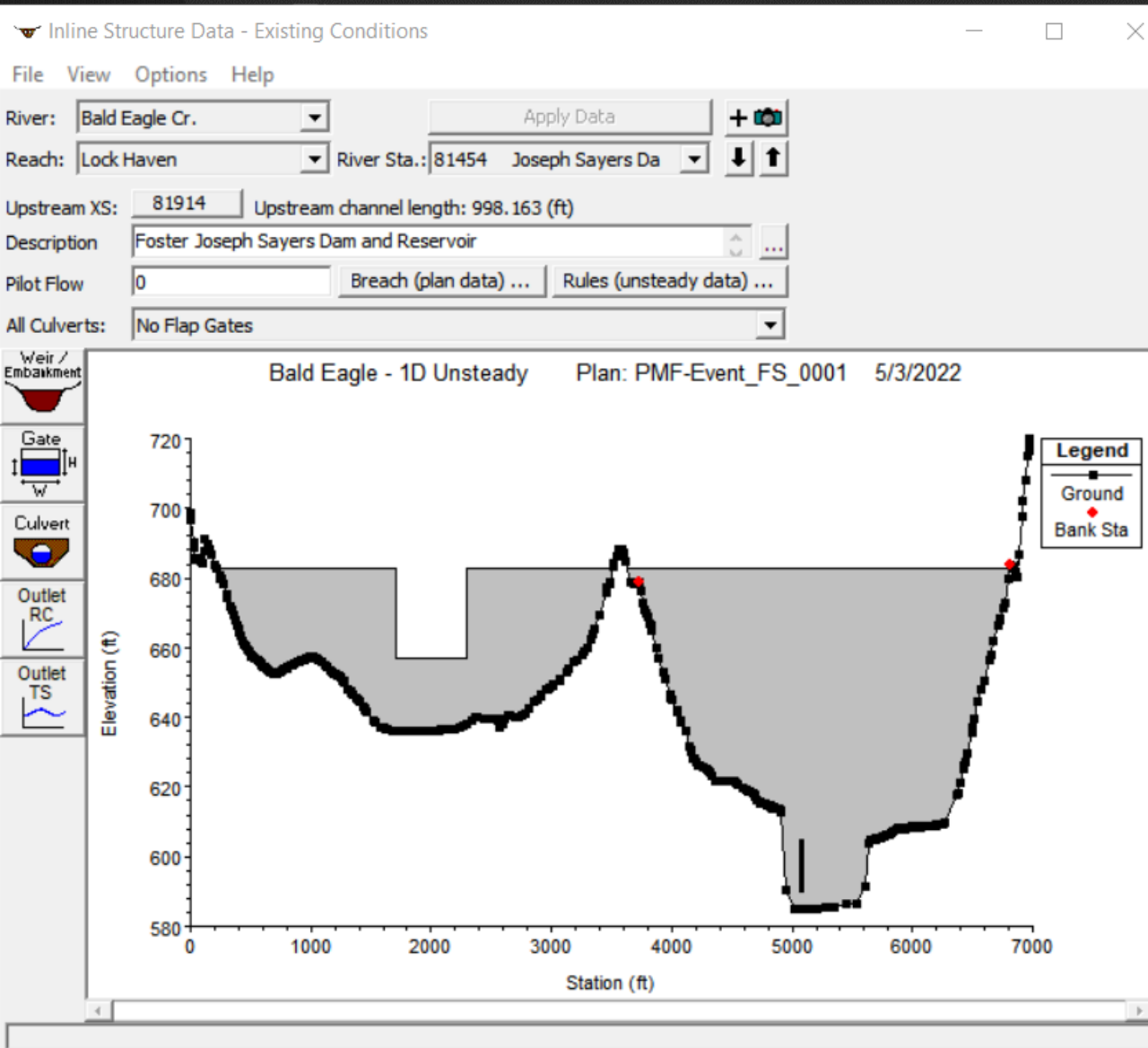
Overview

- Introduction to Hydraulic Structures
- Inline Structures
 - Uses
 - Weirs
 - Gates
 - Ratings
- Lateral Structures
 - Uses
 - Differences from Inline Structures

Inline & Lateral Structures

- Hydraulic structures are used to model:
 - Dams of all shapes and sizes
 - Drop structures and natural drops
 - Culverts
 - Levees
 - Diversions
 - Detention ponds
 - Natural overbank flow

Hydraulic Structure Features

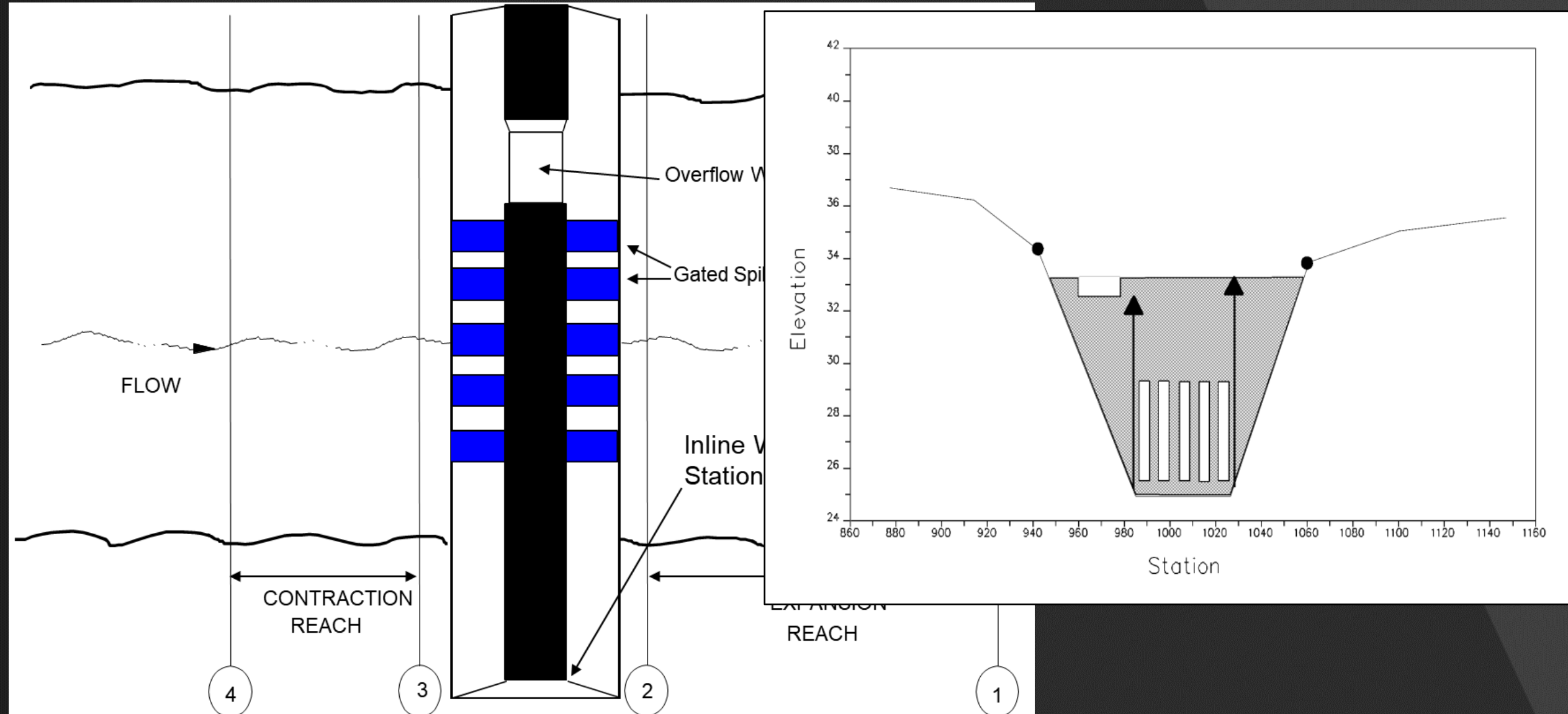


Inline Structures





Cross Section Layout

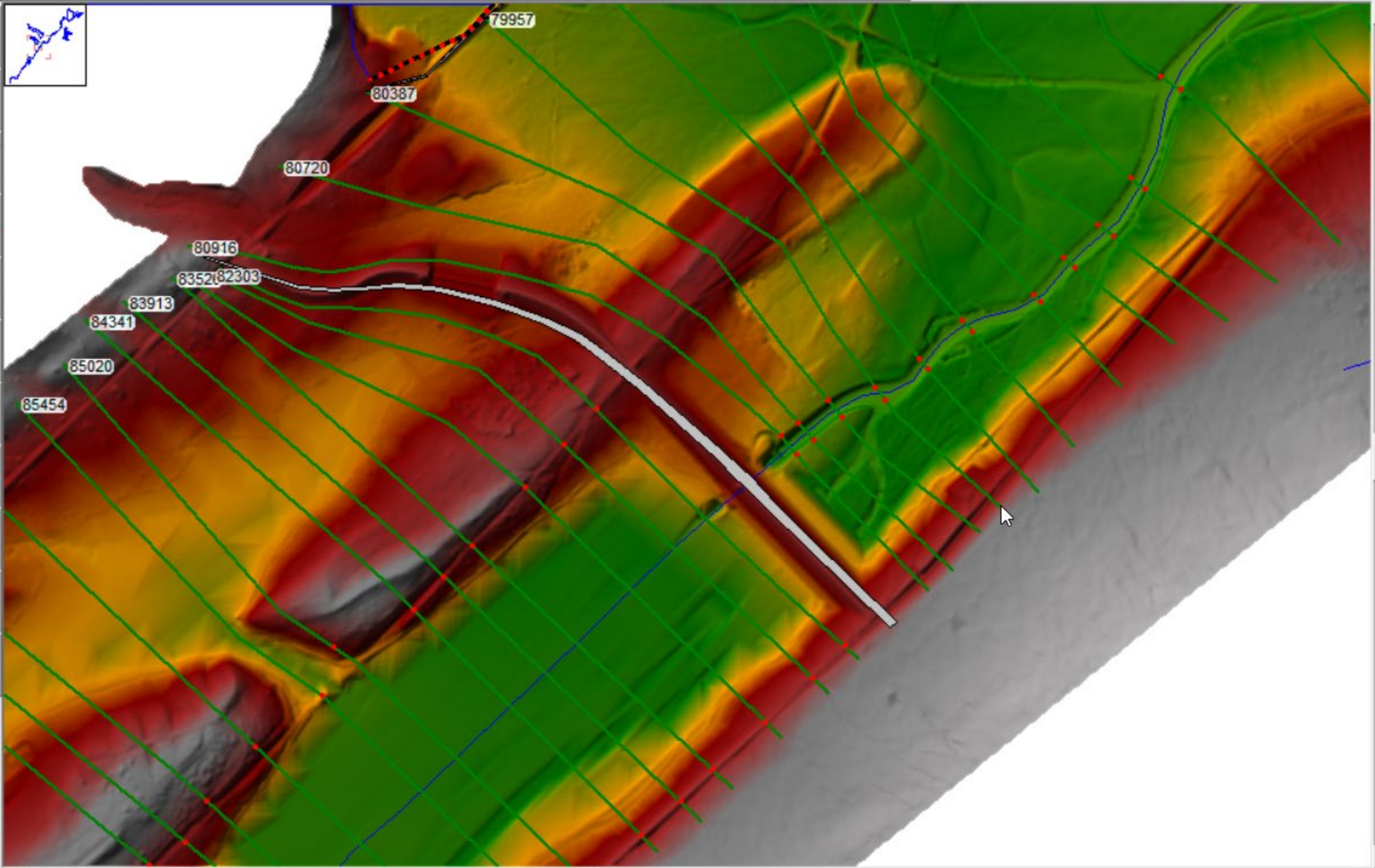


Tools River Reach Storage Area 2D Flow Area SA/2D Conn BC Lines Reference Lines IC Points Reference Points 2D Area BreakLines 2D Area Mann n Regions Pump Station RS 12.99

Description : Plot WS extents for Profile: (none)

Editors

- Junct.
- Cross Section
- Brdg/Culv
- Inline Structure
- Lateral Structure
- Storage Area
- 2D Flow Area
- SA/2D Conn
- Pump Station
- HTab Param.
- View Picture



Weir Options for Inline Structures

- Uses standard weir flow equation

$$Q = CLH^{3/2}$$

- HEC-RAS accounts for weir submergence to reduce flow
- Weir shape
 - Broad Crested
 - Ogee

Inline Structure Data - Existing Conditions

Inline Structure Weir Station Elevation Editor

Distance	Width	Weir Coef
450.	25.	3.95

Clear Del Row Ins Row Filter...

Edit Station and Elevation coordinates

	Station	Elevation
1	0	683
2	1700	683
3	1700	657
4	2300	657
5	2300	683
6	6980	683
7		
8		

U.S Embankment SS D.S Embankment SS

Weir Data

Weir Crest Shape

Broad Crested

Ogee

Spillway Approach Height:

Design Energy Head: Cd ...

OK Cancel

Select the Enter distance between upstream cross section and deck/roadway. (ft)

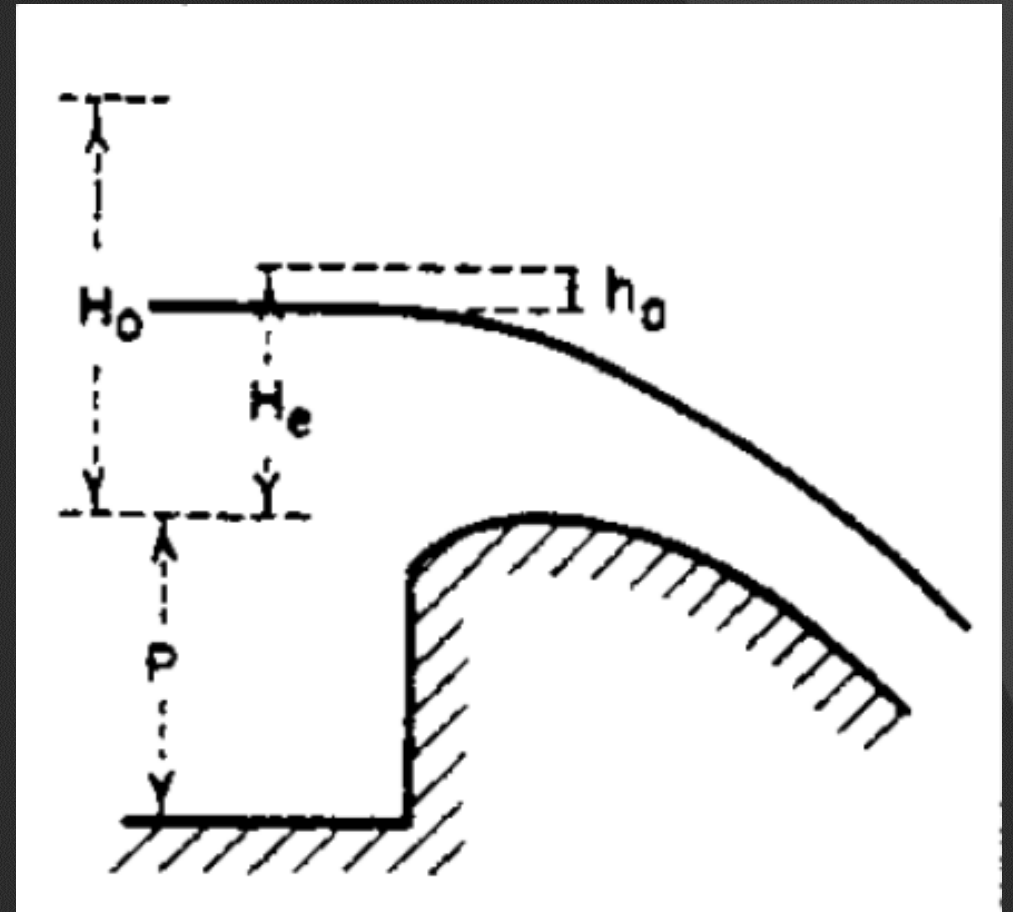
Legend

- Ground
- Bank Sta

Ogee Weir vs Broad Crested

- Broad Crested
 - Single weir coefficient
- Ogee
 - Spillway Approach Height (P)
 - Design Energy Head (H_e)
 - Weir coefficient (C)
- Ogee (C) Adjustment
 - Ratio of H_e / H_o

$$Q = CLH^{3/2}$$

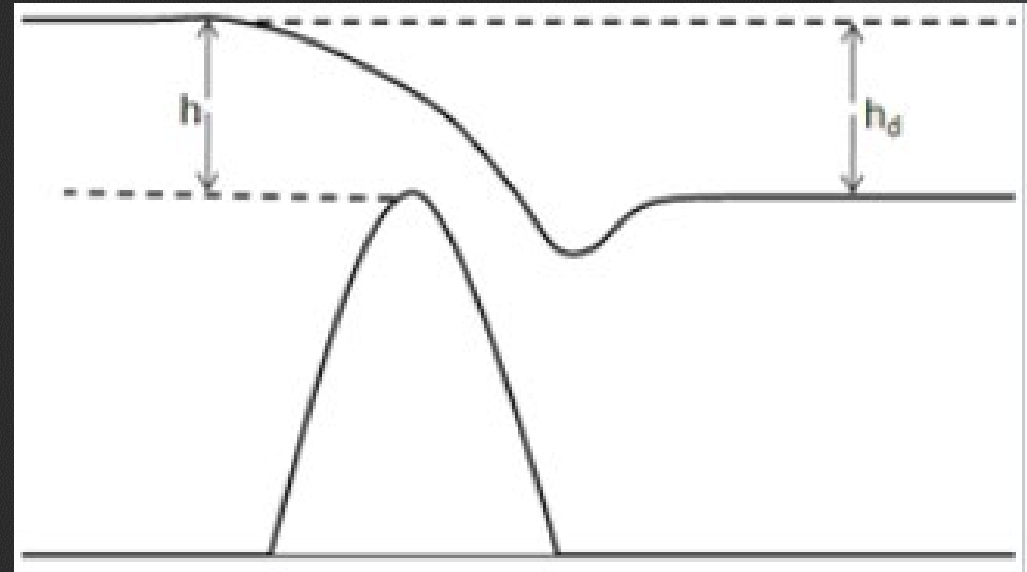
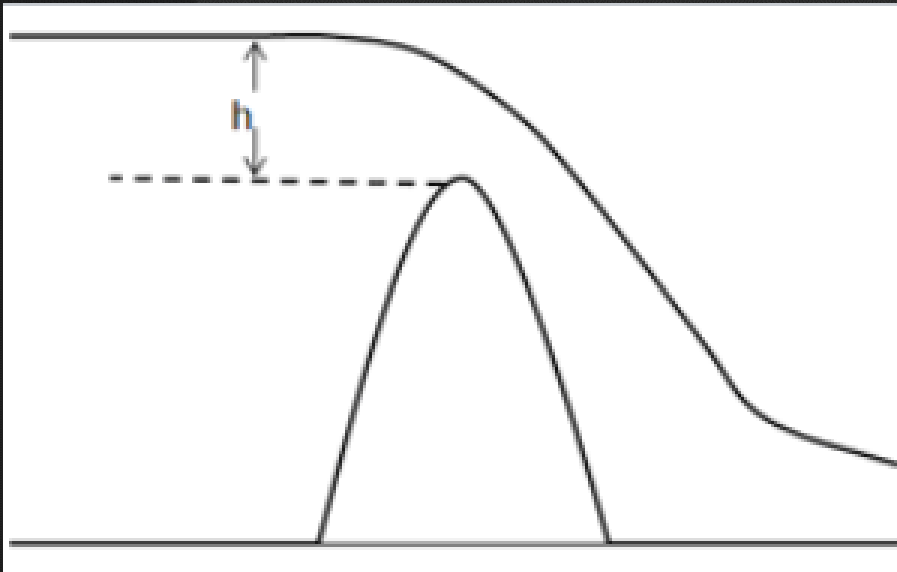


Typical Weir Coefficients

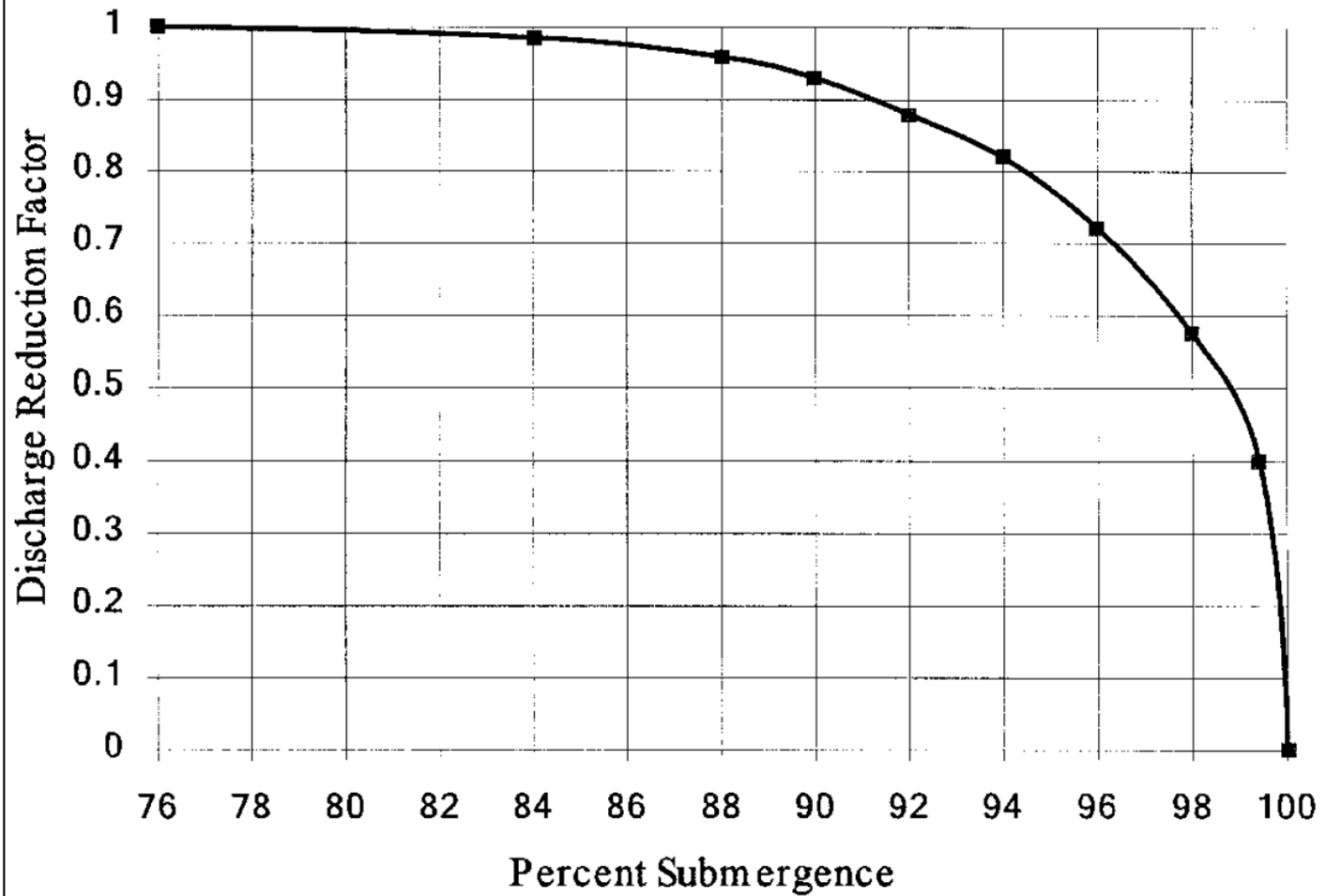
<i>Weir Crest Shape</i>	<i>Typical Coefficient Range</i>
Broad Crested	2.6 - 3.1
Ogee Crested	3.2 - 4.1
Sharp Crested	3.1 - 3.3

Weir Submergence

- Tailwater begins to impact flow
- RAS reduces weir flow coefficient automatically
- Different methods for Ogee and Broad Crested



Discharge Reduction for Submerged Flow



Gates

Gate methods

- Sluice
- Radial
- Overflow Gates
- Rating curve

Inline Gate Editor

Gate Group: Gate #1

Gate type (or methodology): Sluice

Gate Flow: Sluice Gate Flow

Sluice Discharge Coefficient: []

Submerged Orifice Flow: Orifice Coefficient (typically 0.8): 0.8

Head Reference: Center of opening

Flow Over Gate Sill (gate out of water): Broad Crested

Weir Coefficient: 3

Geometric Properties

Height: 15 Width: 60 Invert: 590

Opening Centerline Stations # Openings: 3

	Opening Name	Station	GIS Sta
1	Left Gate	5100	
2	Middle Gate	5250	
3	Right Gate	5400	
4			
5			
6			
7			

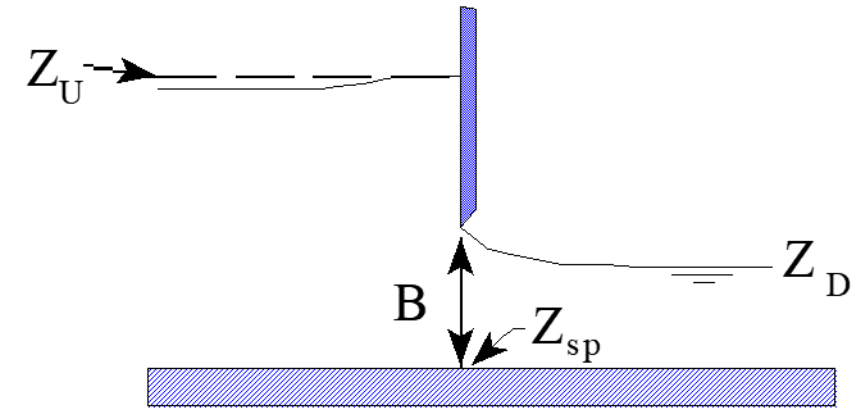
Opening GIS Data: Right Gate Length: 0

	X	Y
1		
2		
3		
4		
5		
6		
7		

Individual Gate Centerlines ...

OK Cancel Help

Sluice Gates



Gate Flow Types

- Gate Flow
- Submerged Orifice
- Weir Flow

Inline Gate Editor

Gate Group: Gate #1

Gate type (or methodology): Sluice

Gate Flow

Sluice Gate Flow

Sluice Discharge Coefficient (0.5-0.7): 0.65

Weir Flow Over Gate Sill (gate out of water)

Weir Shape: Broad Crested

Weir Coefficient: 3

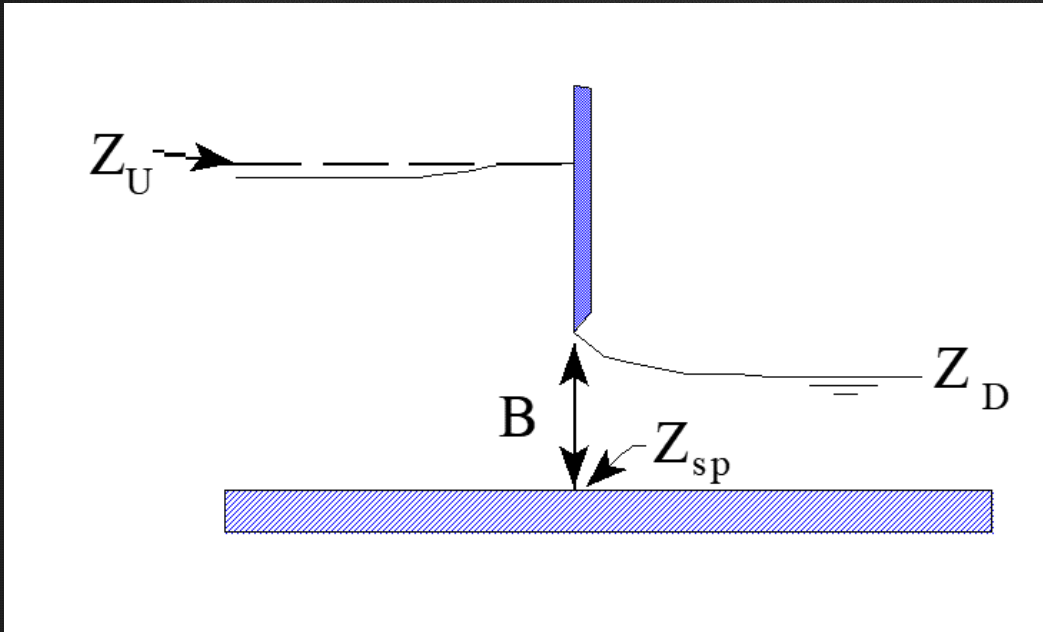
Submerged Orifice Flow

Orifice Coefficient (typically 0.8): 0.8

Head Reference: Center of opening

Geometric Properties

Sluice Gate Flow



$$Q = CWB\sqrt{2gH}$$

Where:

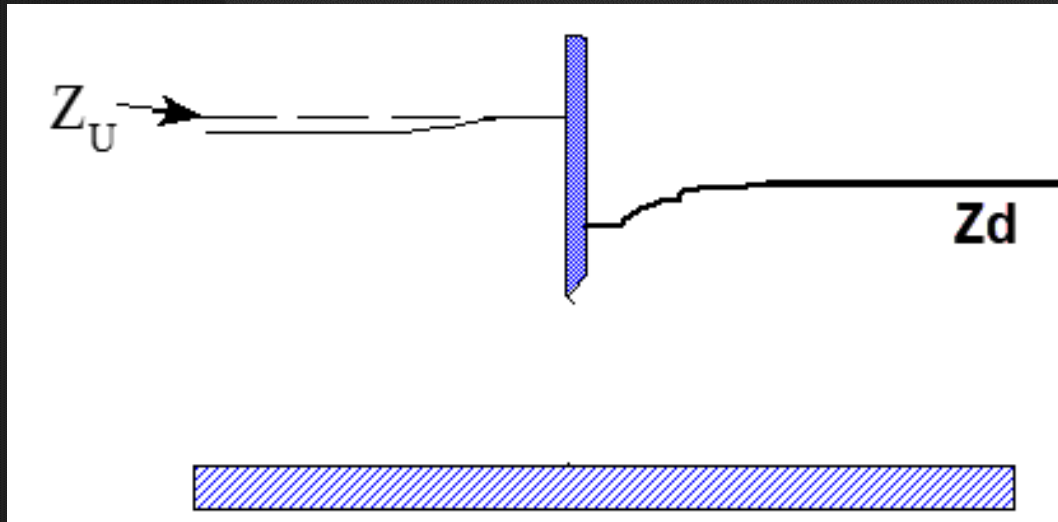
H = Upstream energy head ($Z_U - Z_{sp}$)

C = Discharge Coefficient, 0.5 to 0.7

W = Width

B = Opening

Orifice Flow / Submerged Flow

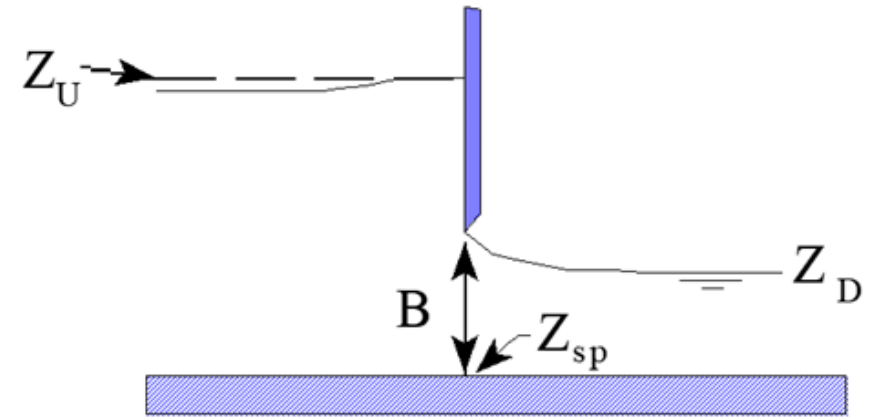
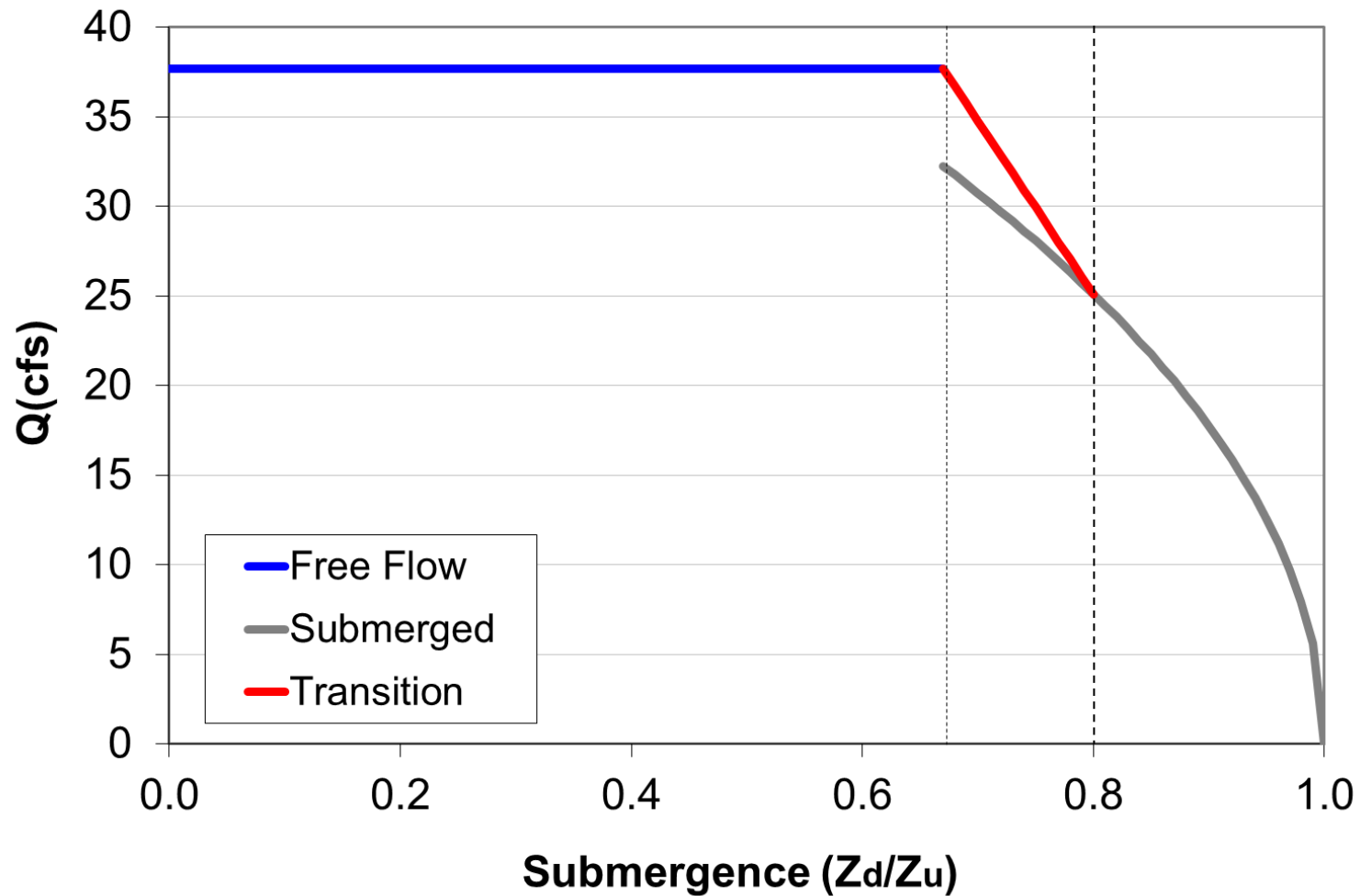


$$Q = CWB\sqrt{2gH}$$

Where: $H = Z_U - Z_D$

C = Discharge Coefficient, typically 0.8

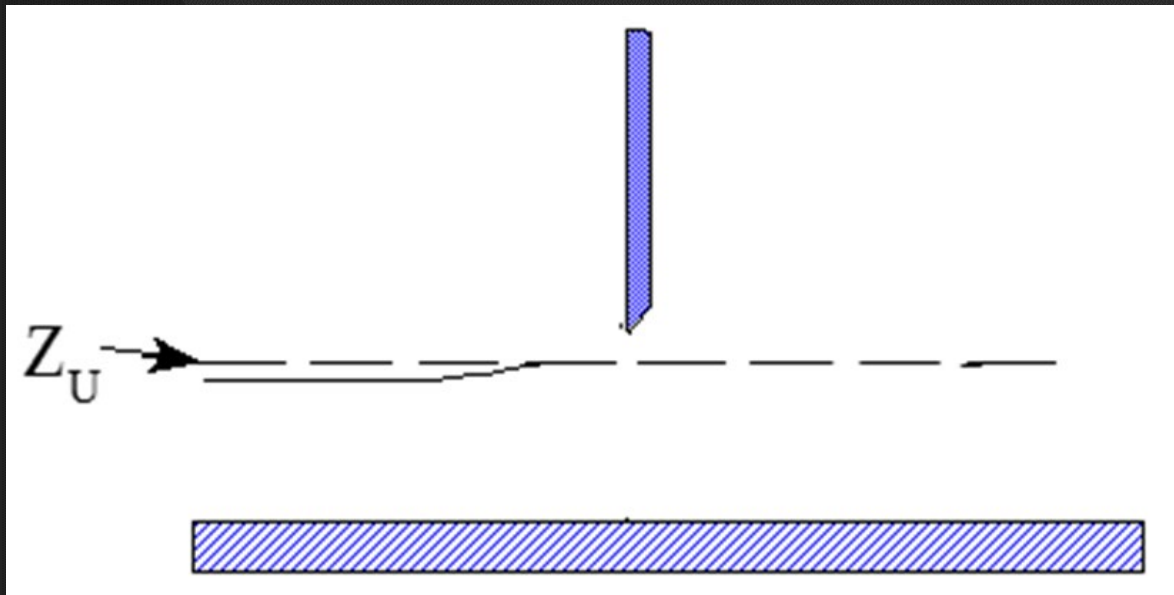
Submergence Transition



$$Q = CWB\sqrt{2g3H}$$

Where: $H = Z_U - Z_D$

Low Flow / Weir Flow

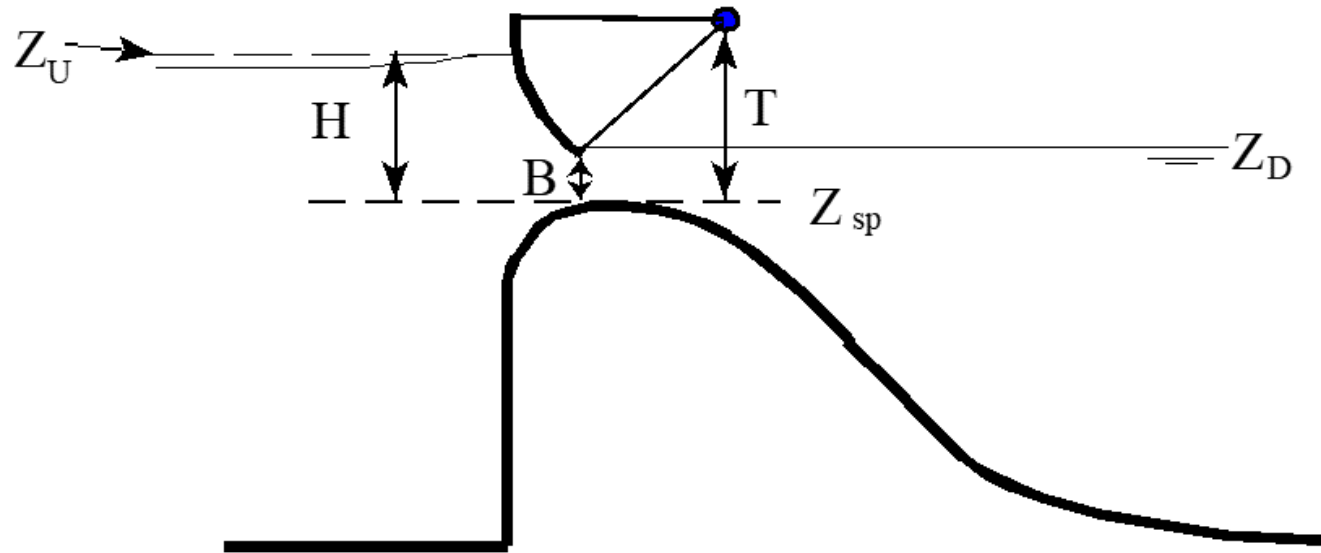


$$Q = CLH^{3/2}$$

Radial Gates



Radial Gate Flow



Inline Gate Editor

Gate Group: Gate #1

Gate type (or methodology): Radial

Gate Flow

Radial Gate Flow

Radial Discharge Coefficient (.06-0.8): 0.65

Trunnion Exponent: 0

Opening Exponent: 1

Head Exponent: 0.5

Trunnion Height: 10

Submerged Orifice Flow

Orifice Coefficient (typically 0.8): 0.8

Head Reference: Center of opening

$$Q = C \sqrt{2g} W T^{TE} B^{BE} H^{HE}$$

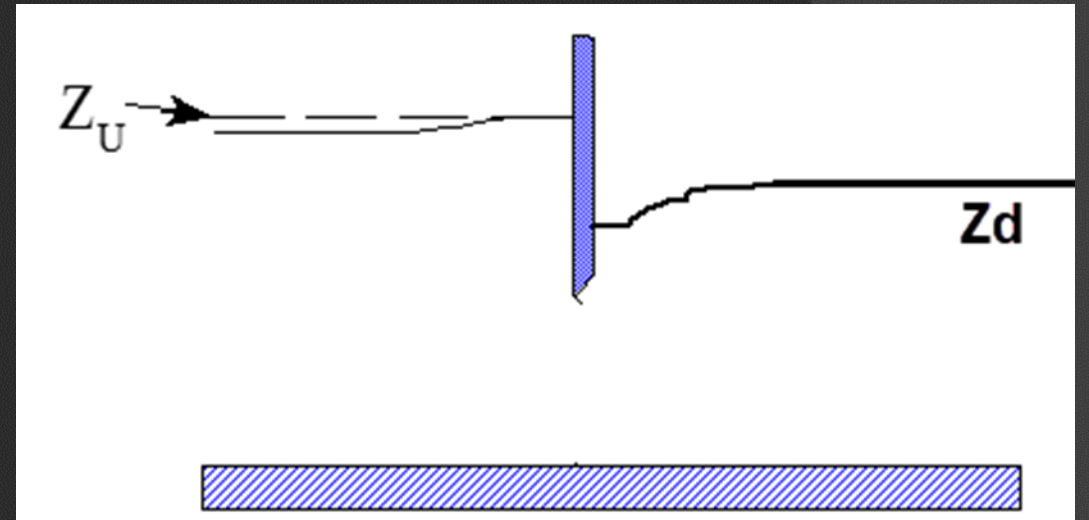
Radial Gate Submergence

- Tailwater increases and **begins** to impact flow

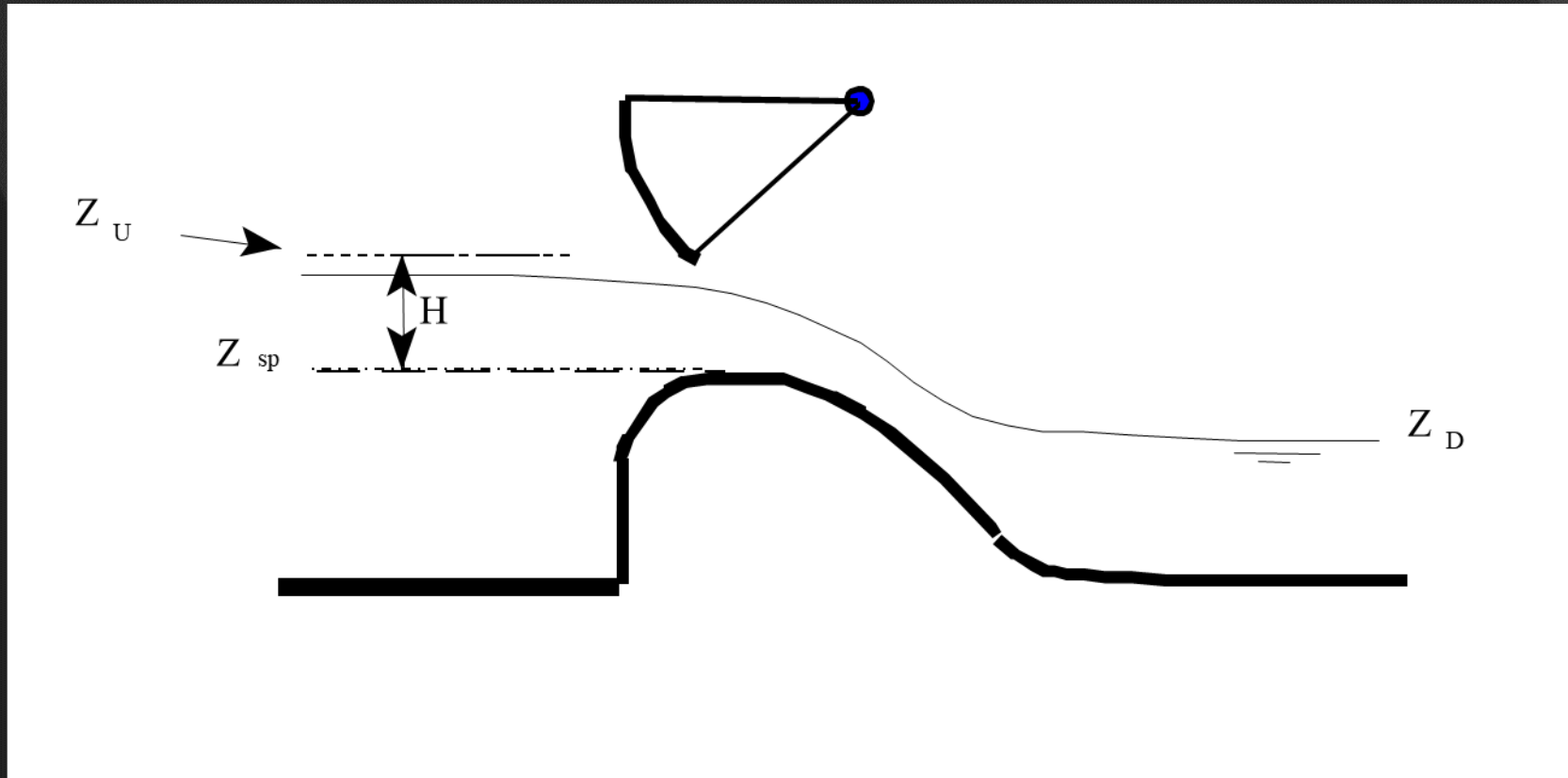
$$Q = C\sqrt{2g}WT^{TE}B^{BE}(3H)^{HE}$$

- Transitions to fully submerged orifice flow

$$Q = CWB\sqrt{2gH}$$



Low Flow / Weir Flow



$$Q = CLH^{3/2}$$

Overflow Gates

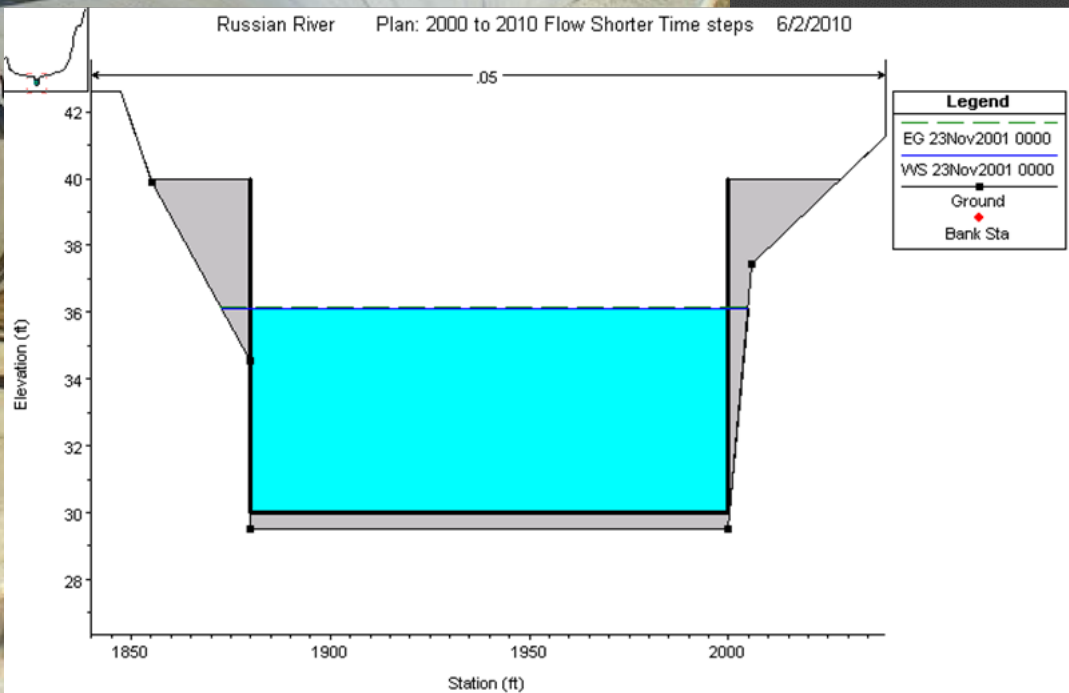
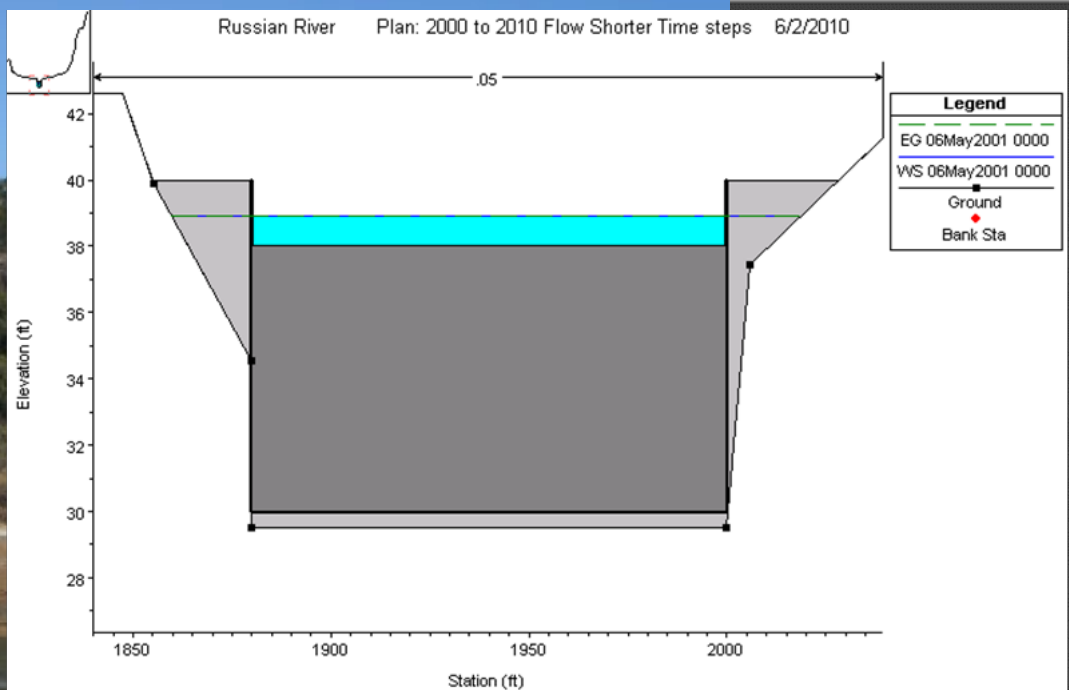


$$Q = CLH^{3/2}$$

Where:

H = Upstream energy head
($Z_U - Z_{sp}$)

C = Weir coefficient, 3.1 – 3.3





Outlet Rating Curve

Inline Structure Outlet Rating Curve

Outlet Rating Curve Name (32 chars max):

Stationing along structure for outlet flows:

Outlet Width:

Outlet Flow Computed as Function of Upstream:

Water Surface
 Flow

Outlet Rating Curve		
	Reference WS Elev	Outlet Flow
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

GIS Coordinates

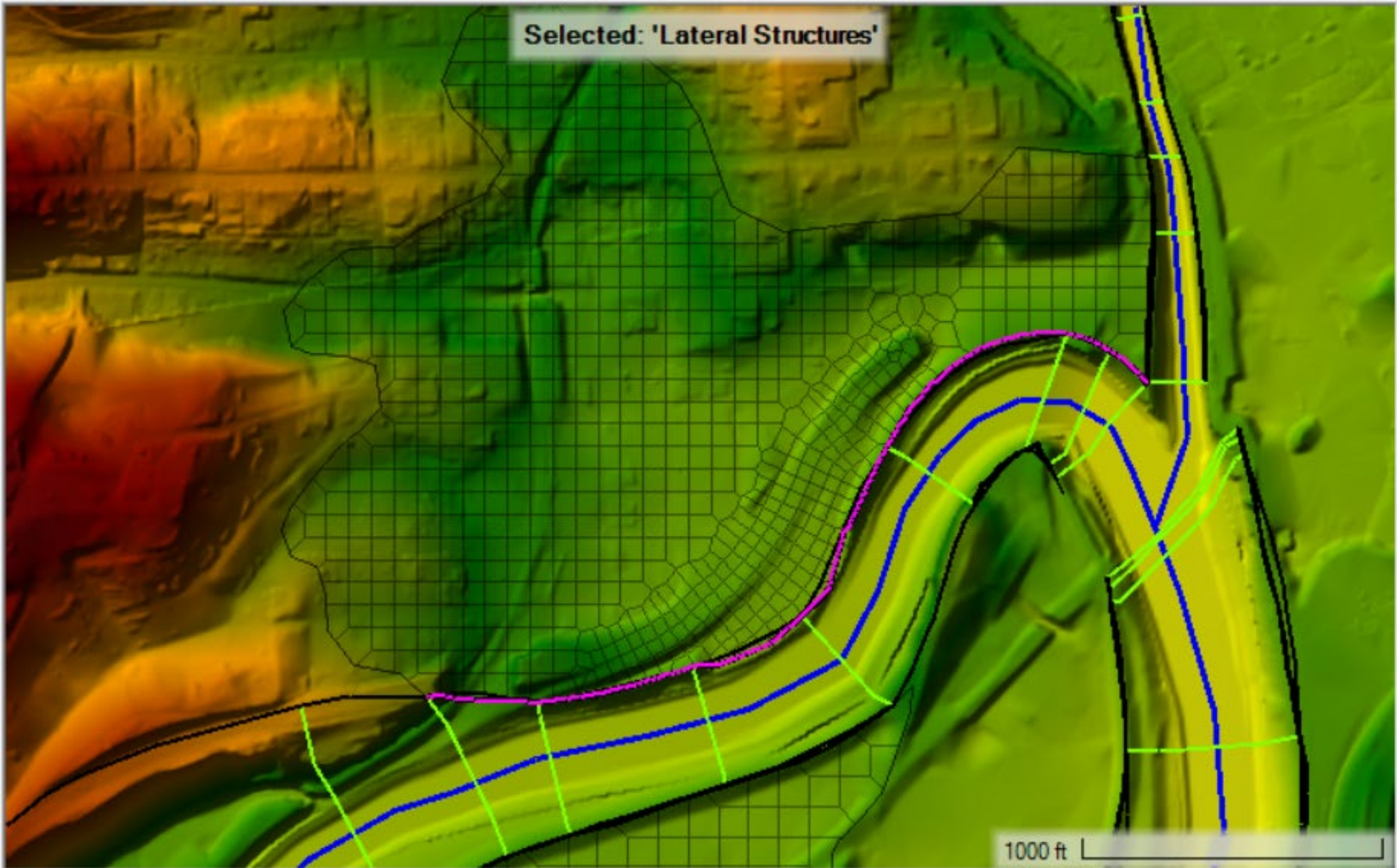
Lateral Structures

Lateral Weir – Sacramento River





Selected: 'Lateral Structures'



1000 ft

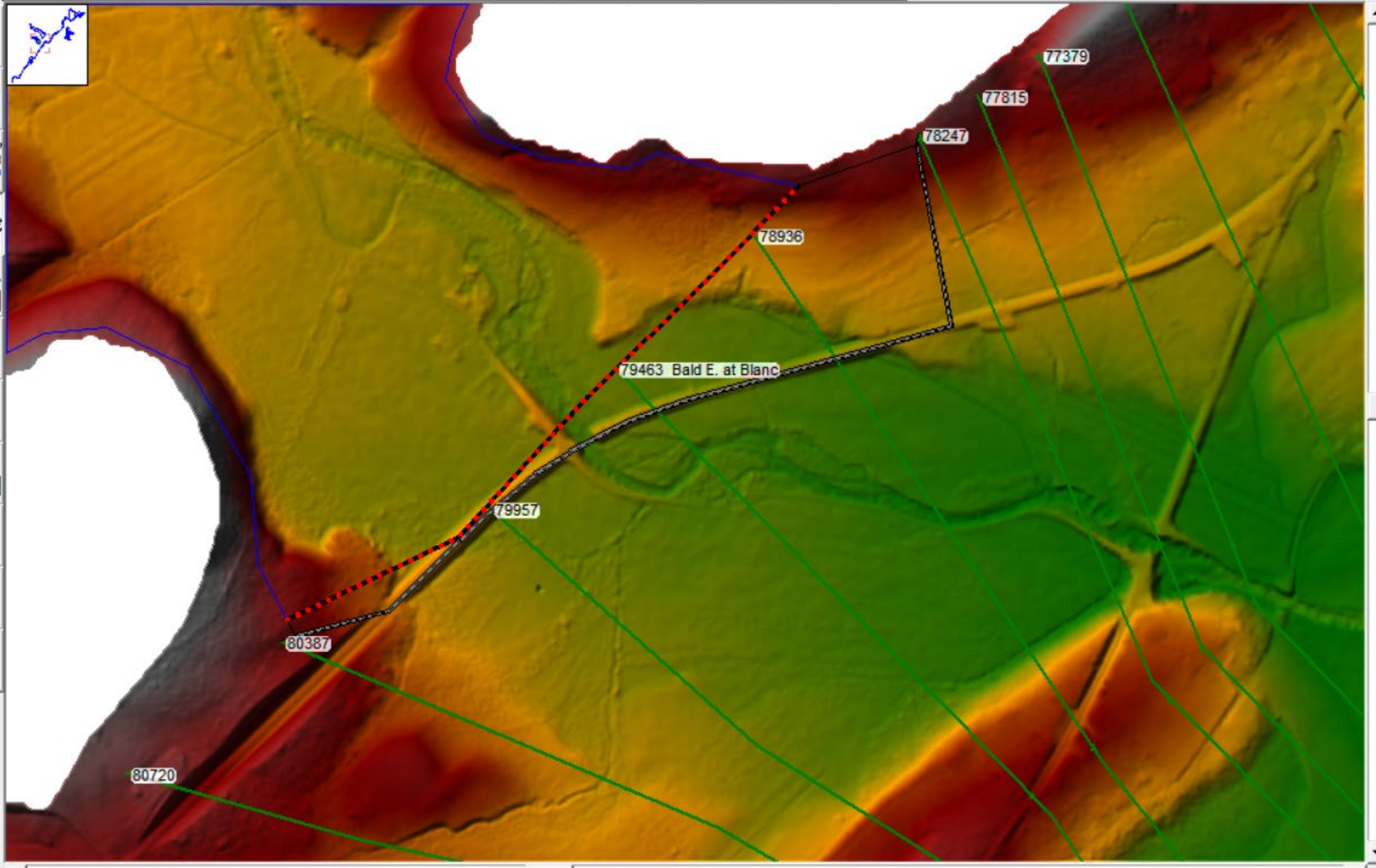


Tools: River Reach, Storage Area, 2D Flow Area, SA/2D Conn, BC Lines, Reference Lines, IC Points, Reference Points, 2D Area Break Lines, 2D Area Mann n Regions, Pump Station, RS (12.99)

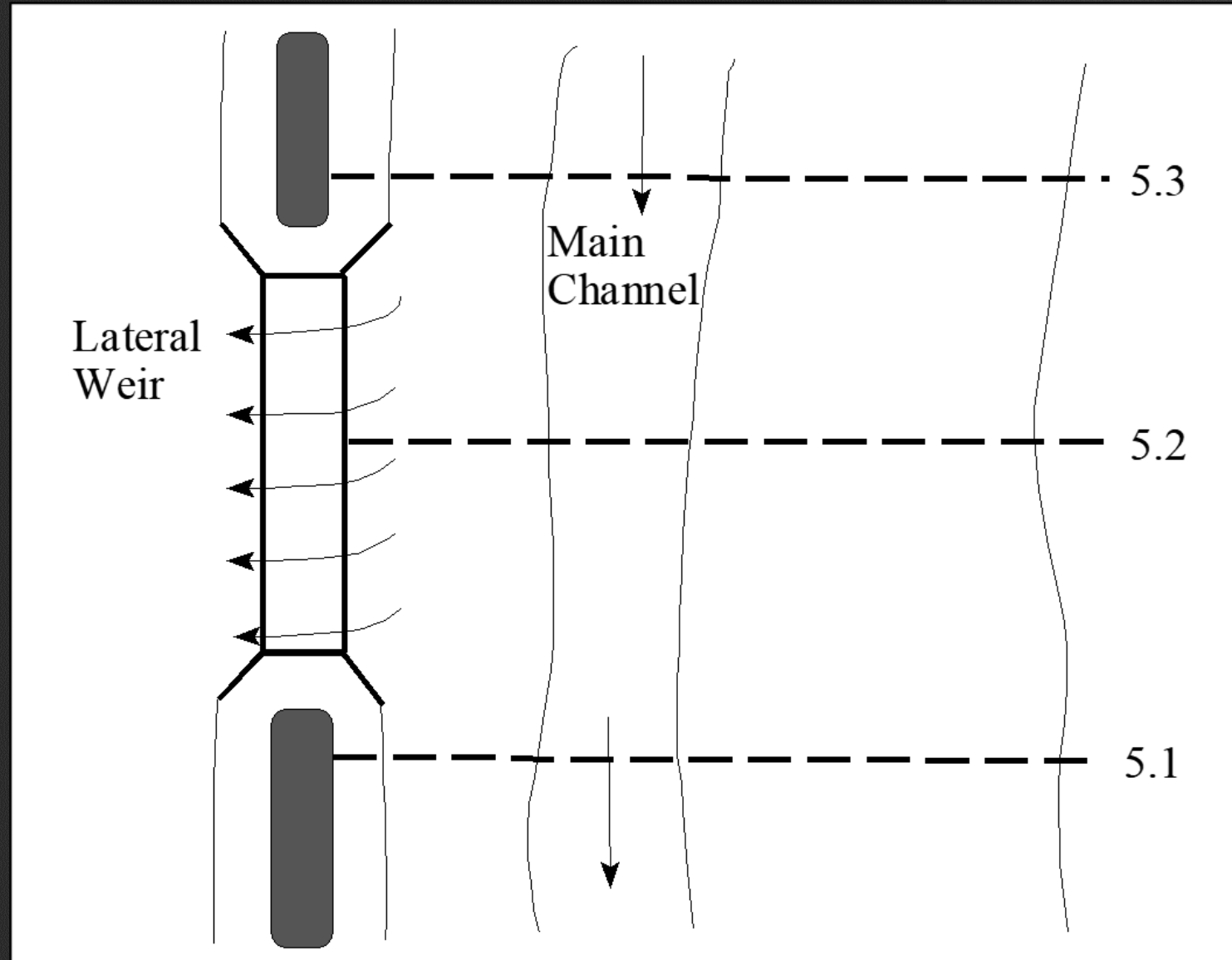
Description: Plot WS extents for Profile: (none)

Editors

- Junct.
- Cross Section
- Brdg/Culv
- Inline Structure
- Lateral Structure
- Storage Area
- 2D Flow Area
- SA/2D Conn
- Pump Station
- HTab Param.
- View Picture

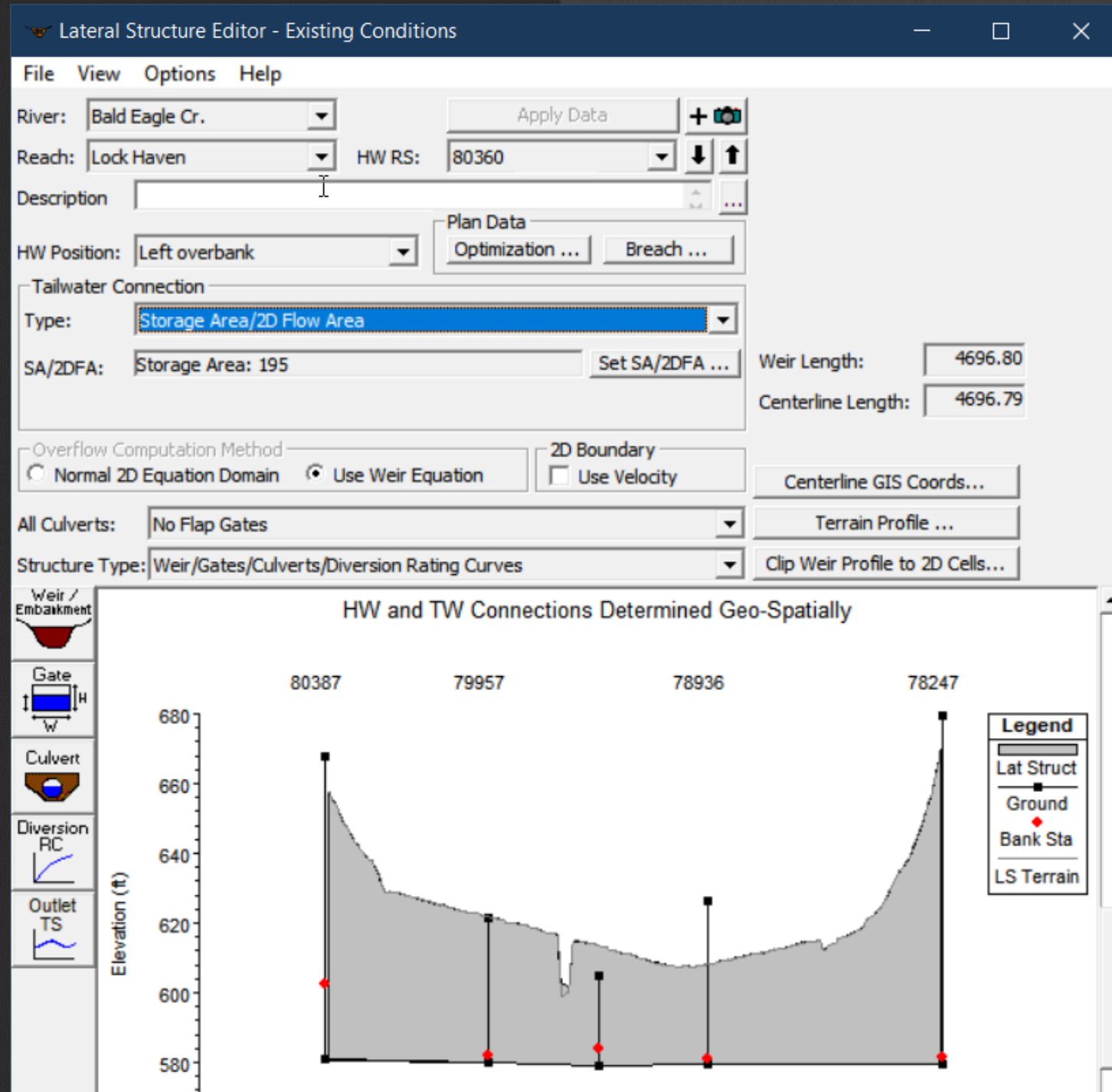


Cross Section Layout



Lateral Connections

- Headwater connected to cross sections:
 - Left or right
- Tailwater connected to
 - Other cross-sections
 - Storage Areas
 - 2D Areas
 - Out of system



File View Options Help

River:

Reach: HW RS:

HW Lateral Structure Connections

Computed Default Weir Stationing User Defined Weir Stationing

Default Computed Weir Stationing

	XS RSs	Weir Station
1	80387	-26.66
2	79957	1218.14
3	79463	2072.02
4	78936	2911.18
5	78247	4718.5
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		

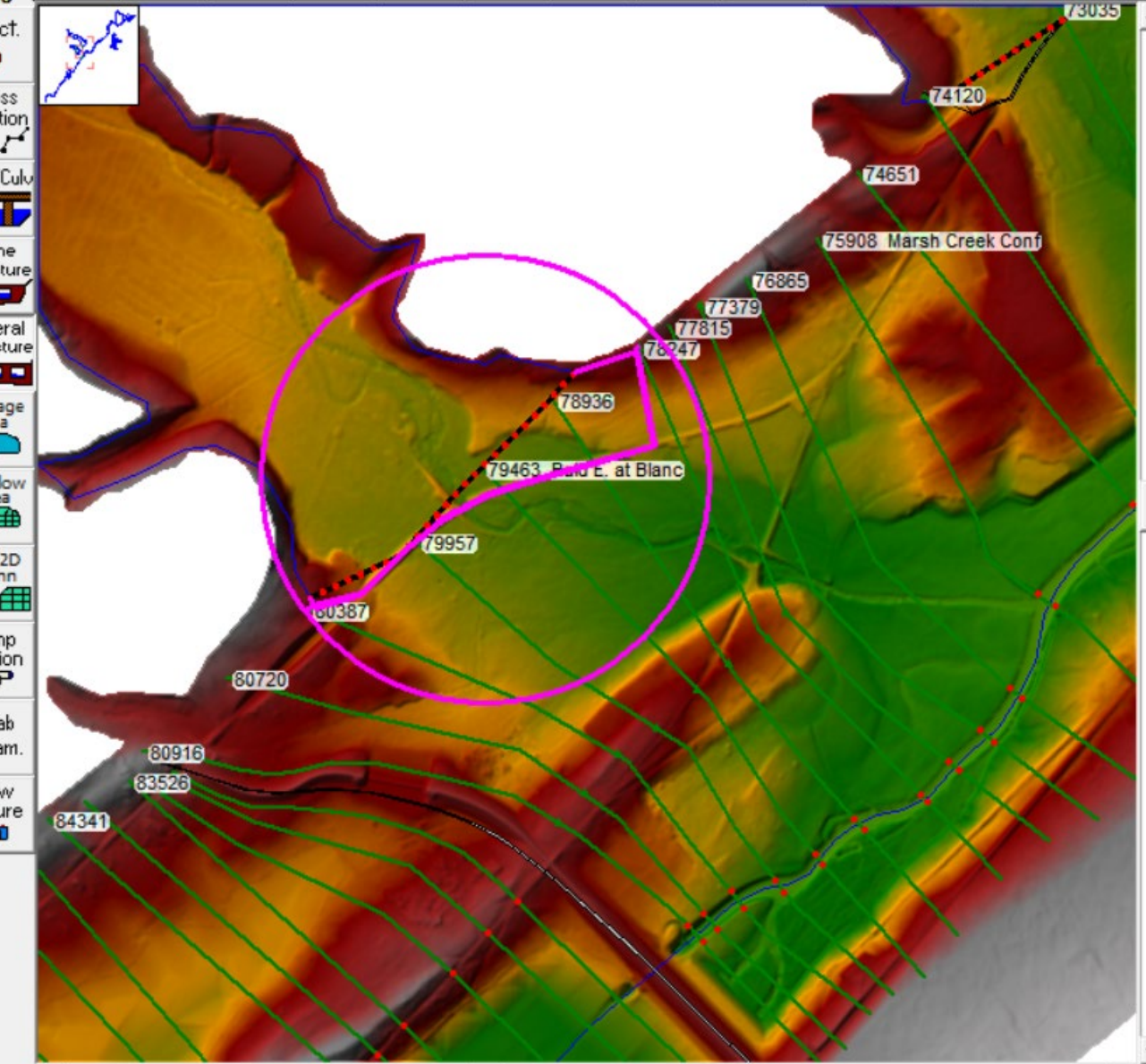
User Defined Weir Stationing

	XS RSs	Weir Station
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		

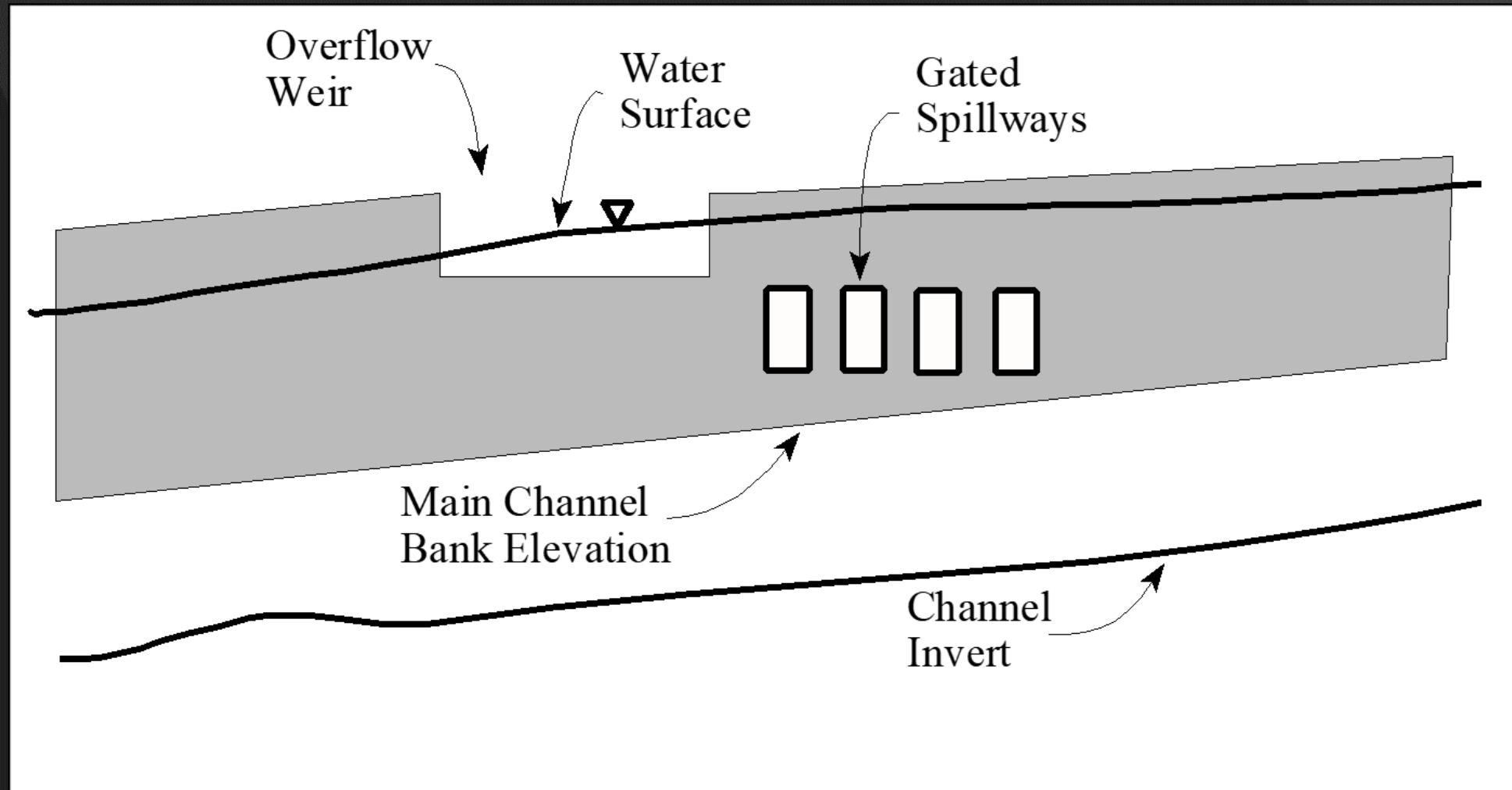
User Specified Connections
Option will not be used
because the lateral structure
has a geo-referenced
centerline.

Station (ft)

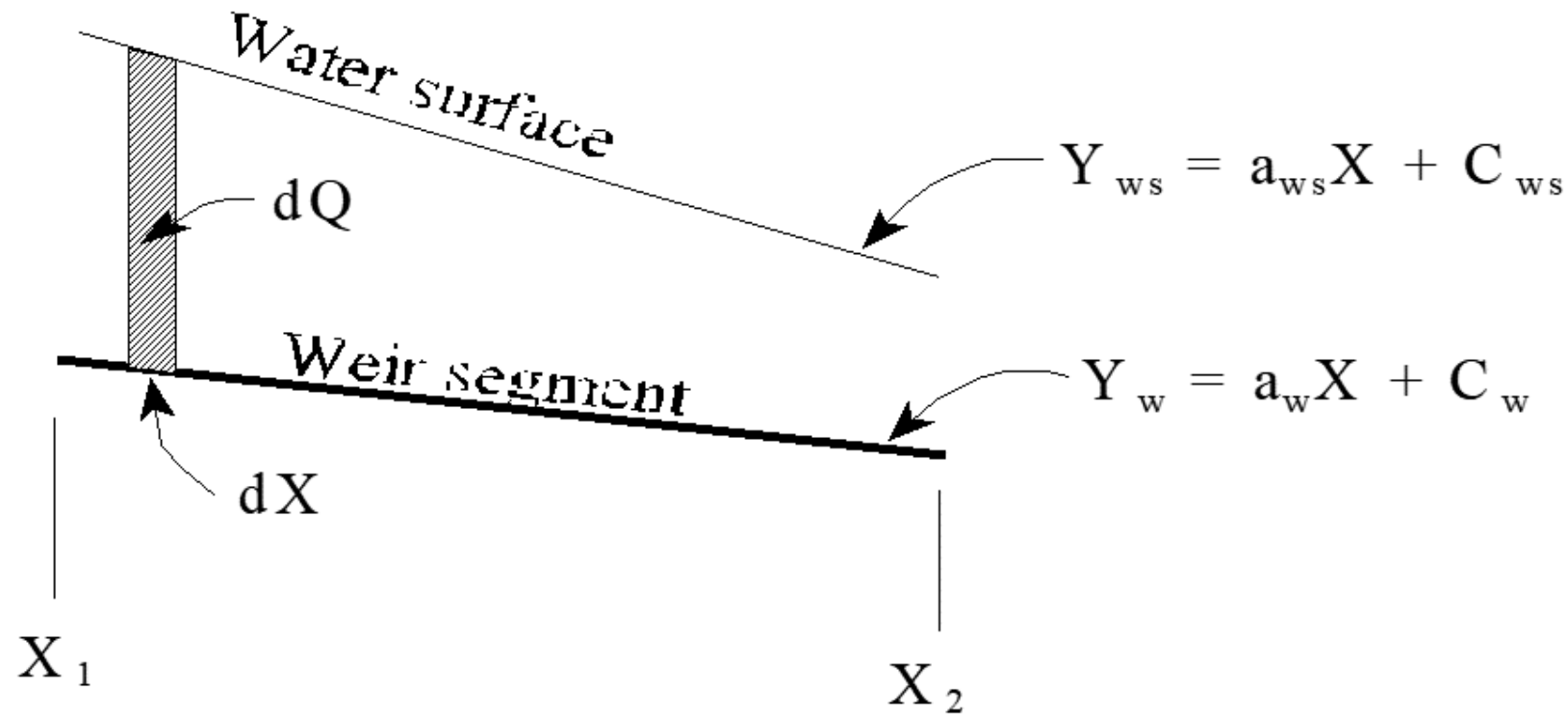
Edit Options View Tables Tools GIS Tools Help



Lateral Structure Computations



Lateral Structure Computations



Lateral Weir Coefficients (Guidelines)

Terrain Feature	Flow description	Range of Weir Coefficients
Non elevated overbank terrain. Lat Structure not elevated above ground	Overland flow escaping the main river.	0.2 to 0.5 SI Units: 0.11 to 0.28
Natural high ground barrier – 1 to 3 ft high	Not quite a weir. Water must flow over high ground. Flow does not pass through critical depth	0.5 to 1.0 SI Units: 0.28 to 0.55
Levee/Roadway – 1 to 3 ft elevated above ground	Flow over levee/road acts like weir flow, but becomes submerged easily.	1.0 to 2.0 SI Units: 0.55 to 1.1
Levee/Roadway – 3ft or higher above natural ground	Broad crested weir shape, flow over levee/road acts like weir flow	1.5 to 2.6 (2.0 default) SI Units: 0.83 to 1.43

Controlling Structures

Structure Boundary Conditions

Unsteady Flow Data - PMF-HMS_0001

File Options Help

Description: Apply Data

Boundary Conditions | Initial Conditions | Meteorological Data | Observed Data

Boundary Condition Types

Stage Hydrograph	Flow Hydrograph	Stage/Flow Hydr.	Rating Curve
Normal Depth	Lateral Inflow Hydr.	Uniform Lateral Inflow	Groundwater Interflow
T.S. Gate Openings	Elev Controlled Gates	Navigation Dams	IB Stage/Flow
Rules	Precipitation		

Add Boundary Condition Location

Add RS ... Add SA/2D Flow Area ... Add Conn ... Add Pump Sta ... Add Pipe Node ...

Select Location in table then select Boundary Condition Type

	River	Reach	RS	Boundary Condition
1	Bald Eagle Cr.	Lock Haven	137520	Flow Hydrograph
2	Bald Eagle Cr.	Lock Haven	81454 IS	T.S. Gate Openings
3	Bald Eagle Cr.	Lock Haven	80360 LS	Rules
4	Bald Eagle Cr.	Lock Haven	76865	Lateral Inflow Hydr.
5	Bald Eagle Cr.	Lock Haven	67130	Lateral Inflow Hydr.
6	Bald Eagle Cr.	Lock Haven	28519	Lateral Inflow Hydr.
7	Bald Eagle Cr.	Lock Haven	-1867	Normal Depth

Time Series Gate Openings

Gate Openings

River: Bald Eagle Cr. Reach: Lock Haven RS: 81454

Gate Group: Gate #1

Read from DSS before simulation

File:

Path:

Enter Table Data time interval: 1 Day

Select/Enter the Data's Starting Time Reference

Use Simulation Time: Date: 01Jan1999 Time: 1200

Fixed Start Time: Date: Time:

Hydrograph Data

	Date	Simulation Time (hours)	Gate Opening Height (ft)
1	01Jan1999 1200	0:00:00	1
2	02Jan1999 1200	24:00:00	1
3	03Jan1999 1200	48:00:00	1
4	04Jan1999 1200	72:00:00	1
5	05Jan1999 1200	96:00:00	1
6	06Jan1999 1200	120:00:00	1
7	07Jan1999 1200	144:00:00	1
8	08Jan1999 1200	168:00:00	1
9	09Jan1999 1200	192:00:00	1

Elevation Controlled Gates

Elevation Controlled Gates

River: Bald Eagle Cr. Reach: Lock Haven RS: 80360

Gate Group: Gate #1

Reference: Based on upstream WS

Upstream WS Elevation: Based on upstream WS

Upstream WS elevation: Based on specified reference

Upstream WS elevation at which gate begins to close: 583.

Gate Opening Rate:(ft/min): 0.1

Gate Closing Rate:(ft/min): 0.1

Maximum Gate Opening: 10.

Minimum Gate Opening: 0.2


Initial Gate Opening (Optional): 0.2

OK Cancel

Navigation Dam

Navigation Controlled Gates

River: Bald Eagle Cr. Reach: Lock Haven RS: 81454

Normal gate change time increment (hrs): Gate minimum opening: 

Rapidly varying flow gate change increment: Gate maximum opening:

Initial gate change time (ex 0800): Gate opening rate (ft/min):

Gate closing rate (ft/min):

Steady Profile Limits Table (Optional)

	Flow	WSMax	WSMin
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			

Hinge Point and Min and Max Pool Operations

Flow Monitor Min Pool Control | Max Pool Control

River: Reach: RS:

Water Surface Elevations **Flows and Flow Factors**

Open River: > Flow Open River:

Maximum High: > Flow Factor Max:

Maximum: > Flow Factor Target High:

Target High:

Target:

Target Low: > Flow Factor Target Low:

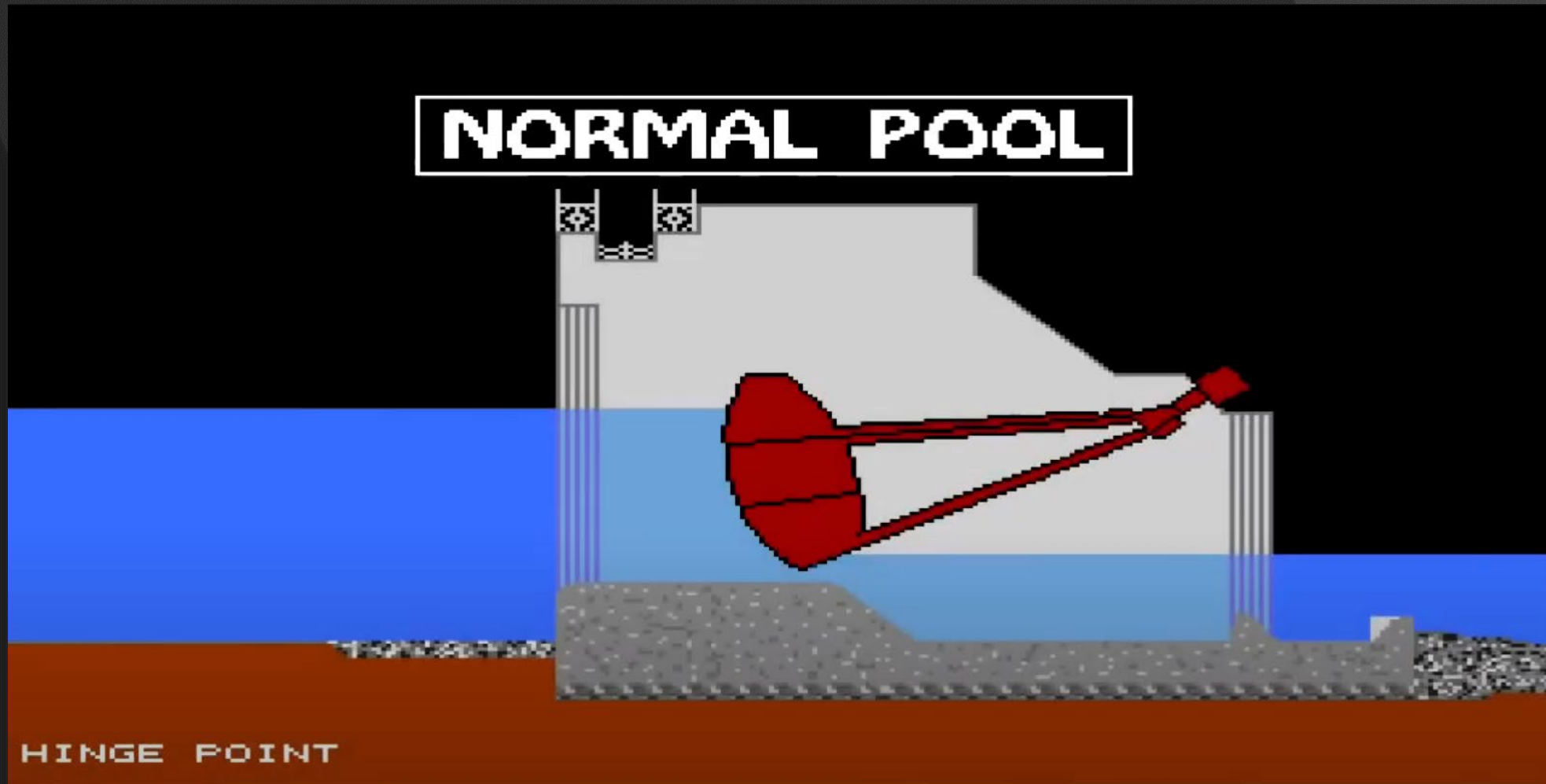
Minimum: > Flow Factor Min:

Minimum Low: > Flow Minimum:

Close Gates:

OK Cancel

Navigation Dam



Rules

- A script for how to operate structures
- Can apply to:
 - Inlines
 - Laterals
 - Storage Area Connections
 - Pumps
- Flexible and powerful

Operation Rules

Rule Based Operations Rule Font Size: 12 Bold Font

row	Operation
26	!
27	! The "new flow" is average of the flow at dam and at upstream end.
28	'Flow New' = 0.5 * 'Flow' + 0.5 * 'Flow Upstream'
29	!
30	! Adjust "Flow New" up or down depending on WSEL at dam.
31	!
32	If ('WSEL at dam' > 110.3) Then
33	'Flow New' = 1.5 * 'Flow New'
34	Elseif ('WSEL at dam' > 110.2) Then
35	'Flow New' = 1.2 * 'Flow New'
36	Elseif ('WSEL at dam' > 110.1) Then
37	'Flow New' = 1.1 * 'Flow New'
38	Elseif ('WSEL at dam' < 109.7) Then

Insert New Operation

Comment New Variable Get Sim Value Set Operational Param Branch (If/Else) Math Table

Branching Operation (If/Else/ElseIf/Else/Endif)

Branching Line Type:

- If () Then
- If () And/Or () Then
- ElseIf () Then
- ElseIf () And/Or () Then
- Else
- End If

Expression

Expression

'WSEL at' 110.3

Check Rule Set ... OK Cancel

Stability Considerations

Lateral and Inline Stability

HEC-RAS Unsteady Computation Options and Tolerances

General | 2D Flow Options | 1D/2D Options | Advanced Time Step Control | **1D Mixed Flow Options**

1D Unsteady Flow Options

Theta [implicit weighting factor] (0.6-1.0): 1.

Theta for warm up [implicit weighting factor] (0.6-1.0): 1.

Water surface calculation tolerance [max=0.2](ft): 0.02

Storage Area elevation tolerance [max=0.2](ft): 0.02

Flow calculation tolerance [optional] (cfs):

Max error in water surface solution (Abort Tolerance)(ft): 100.

Maximum number of iterations (0-40): 20

Maximum iterations without improvement (0-40):

1D/2D Unsteady Flow Options

Number of warm up time steps (0 - 100,000): 0

Time step during warm up period (hrs): 0

Minimum time step for time slicing (hrs): 0

Maximum number of time slices: 20

Lateral Structure flow stability factor (1.0-3.0): 2.

Inline Structure flow stability factor (1.0-3.0): 1.

Weir flow submergence decay exponent (1.0-3.0): 1.

Gate flow submergence decay exponent (1.0-3.0): 1.

Gravity (ft/s²): 32.174

Wind Forces

Reference Frame: Eulerian

Drag Formulation: Hsu (1988)

Geometry Preprocessor Options

Family of Rating Curves for Internal Boundaries

Use existing internal boundary tables when possible.

Recompute at all internal boundaries

1D Numerical Solution

Finite Difference (classic HEC-RAS methodology)

Finite Difference Matrix Solver

Skyline/Gaussian (Default: faster for dendritic systems)

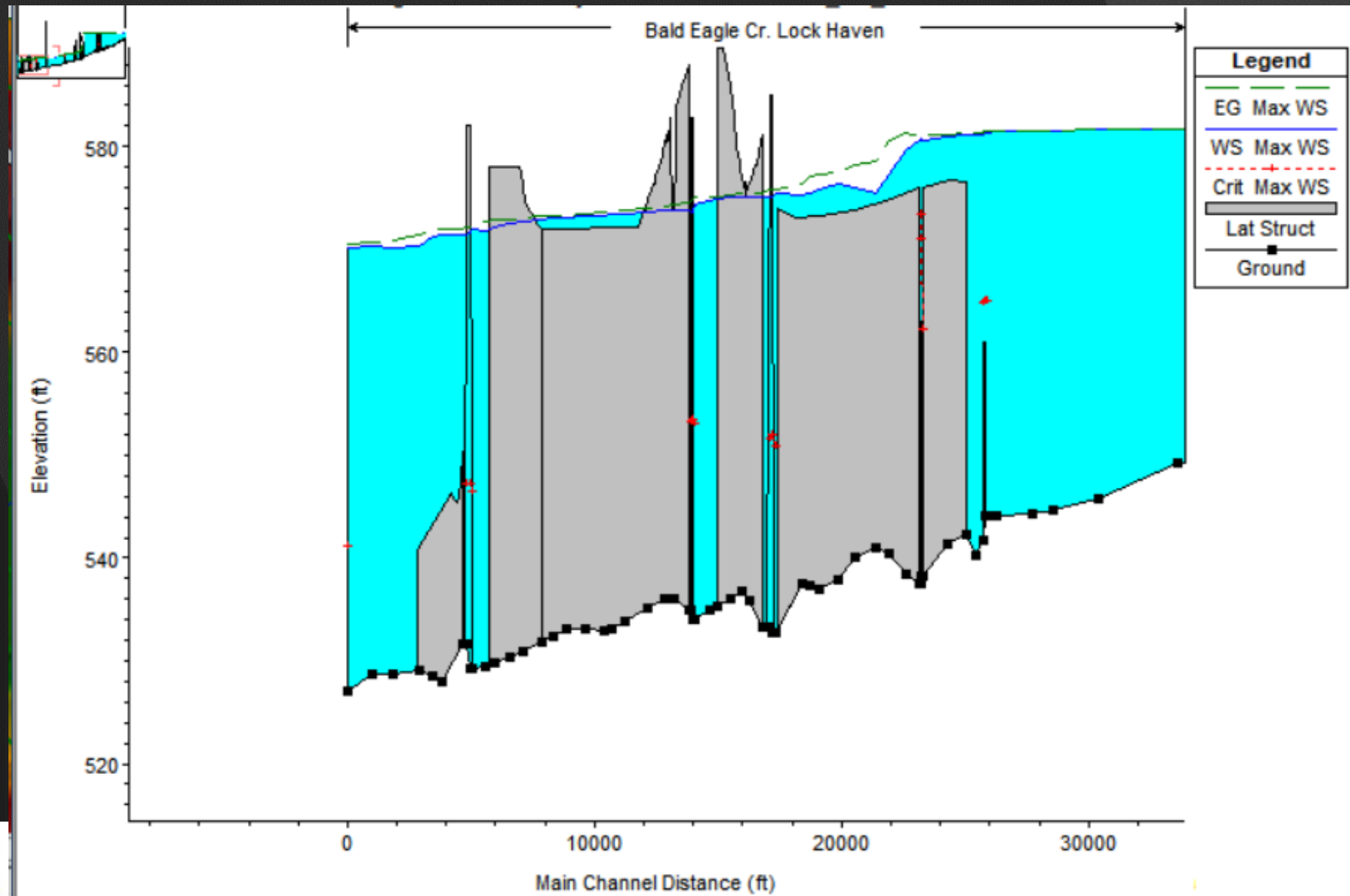
Pardiso (Optional: may be faster for large interconnected systems)

Finite Volume (new approach)

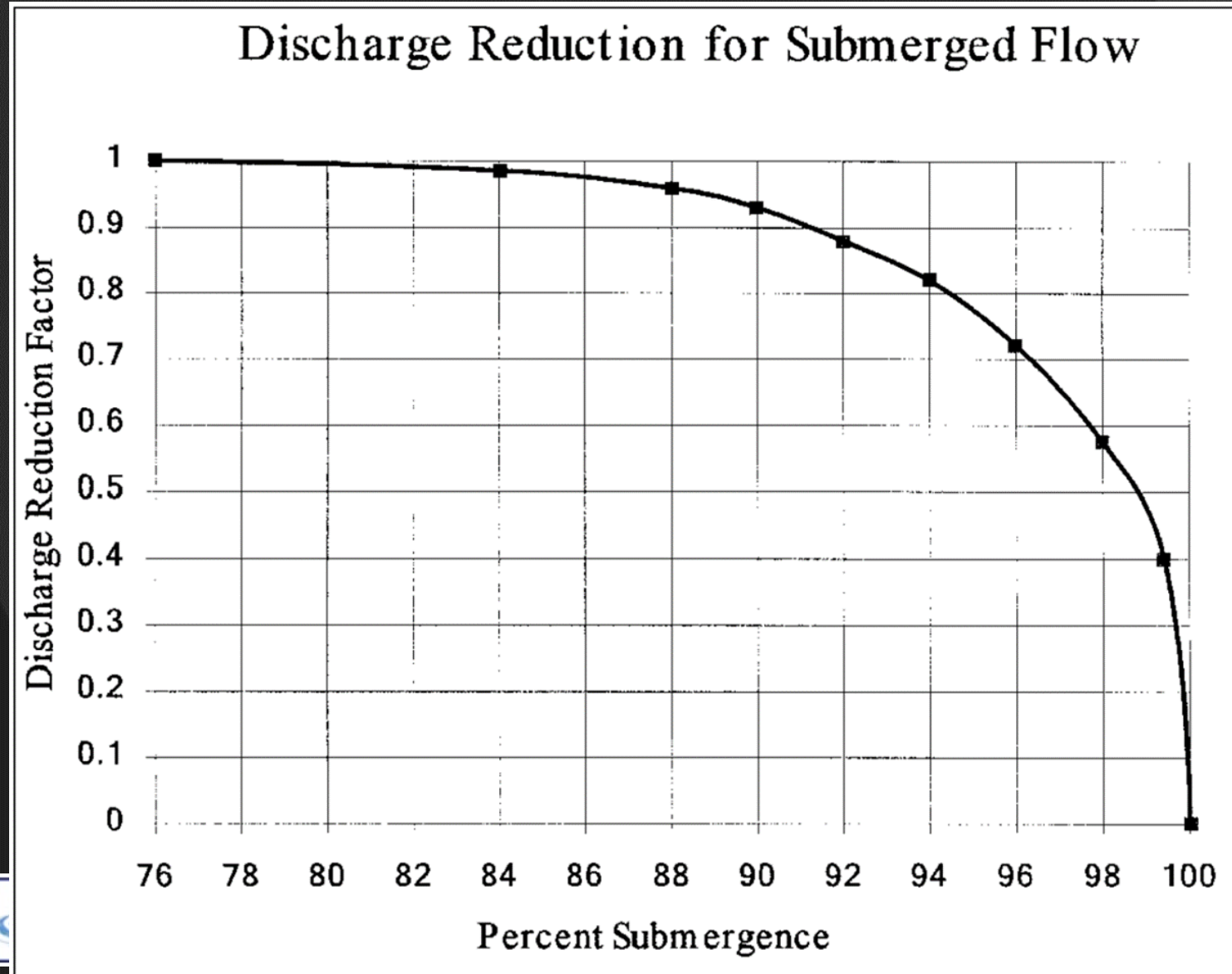
Number of cores to use with Pardiso solver: All Available

OK Cancel Defaults ...

Initial Overflow



Submergence Stability



Questions?