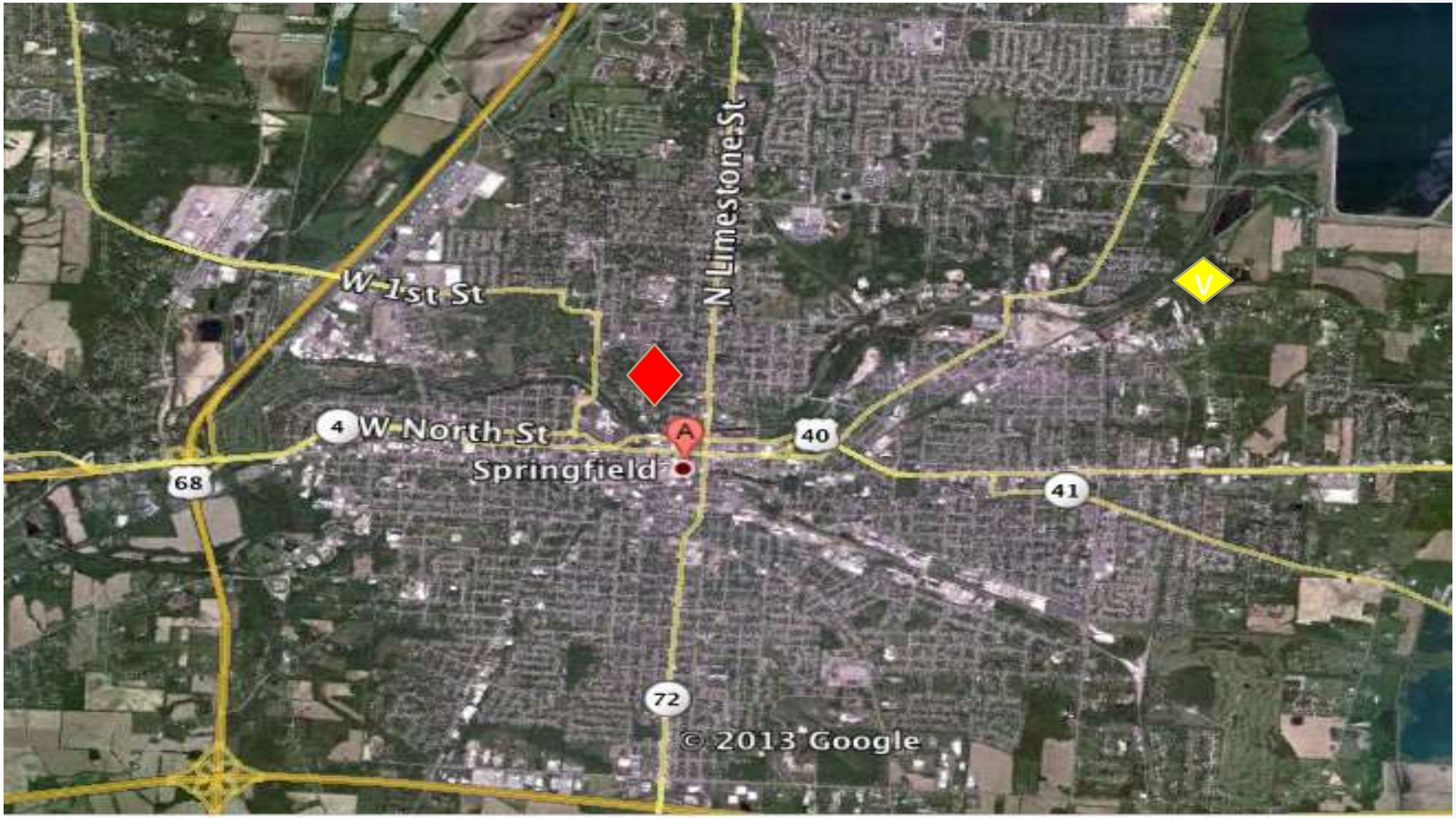
Beaver Creek Corridor Design and Analysis

By: Alex Previte

Overview

- Introduction
- Key concepts
- Model Development
- Design
- Accuracy
- Conclusion

Refresh



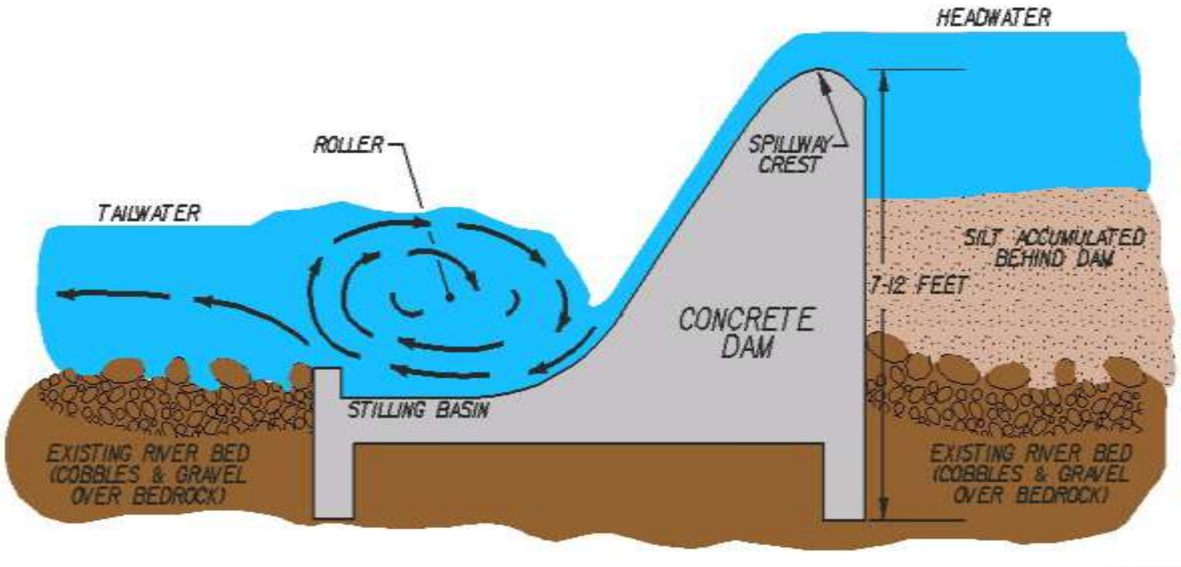
= Beaver Creek Site

= Wittenberg

Introduction

- Low head dam : small overflow dam used to alter the flow characteristics of a river or stream

- Dangers:
  - Drowning
  - Alter Ecosystem
  - User Friendly: Kayaking

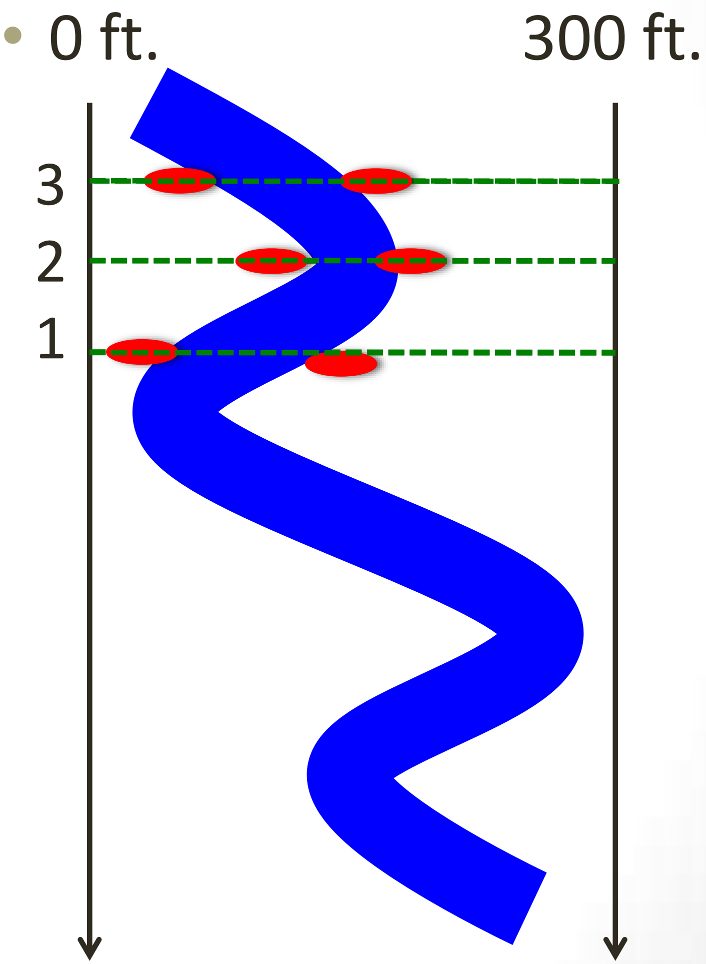


Introduction

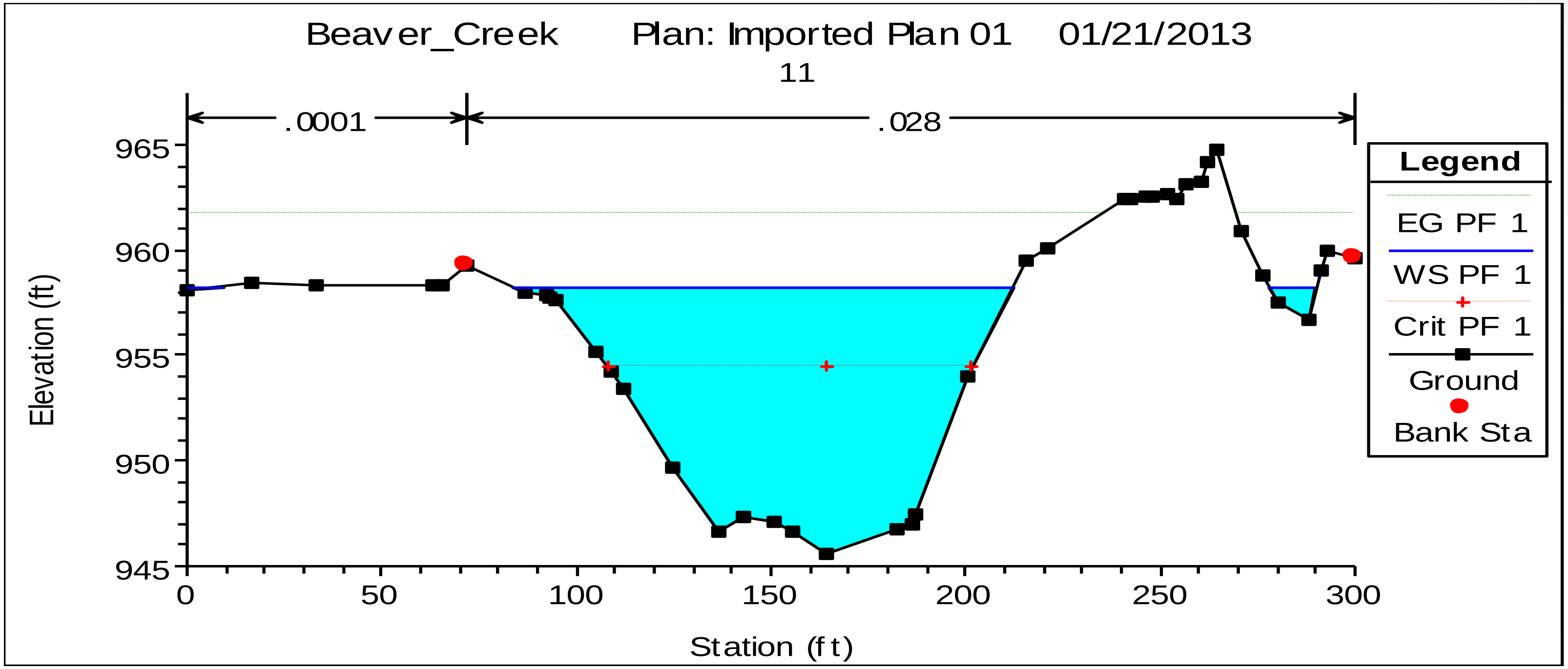
- HEC-RAS
  - Hydrologic Engineering Centers River Analysis System
- Computer program
- Used for analyzing rivers and streams
- Able to compute flow characteristics given certain parameters

Profile Plot

- Geometry profile
  - Data taken over 300 Ft (horizontally)
  - Contain contour of stream at vertical location
- Cross-sections
  - "River stations"
  - Contain Profile information (Geometry)
  - Tracks distance (Upstream to downstream)

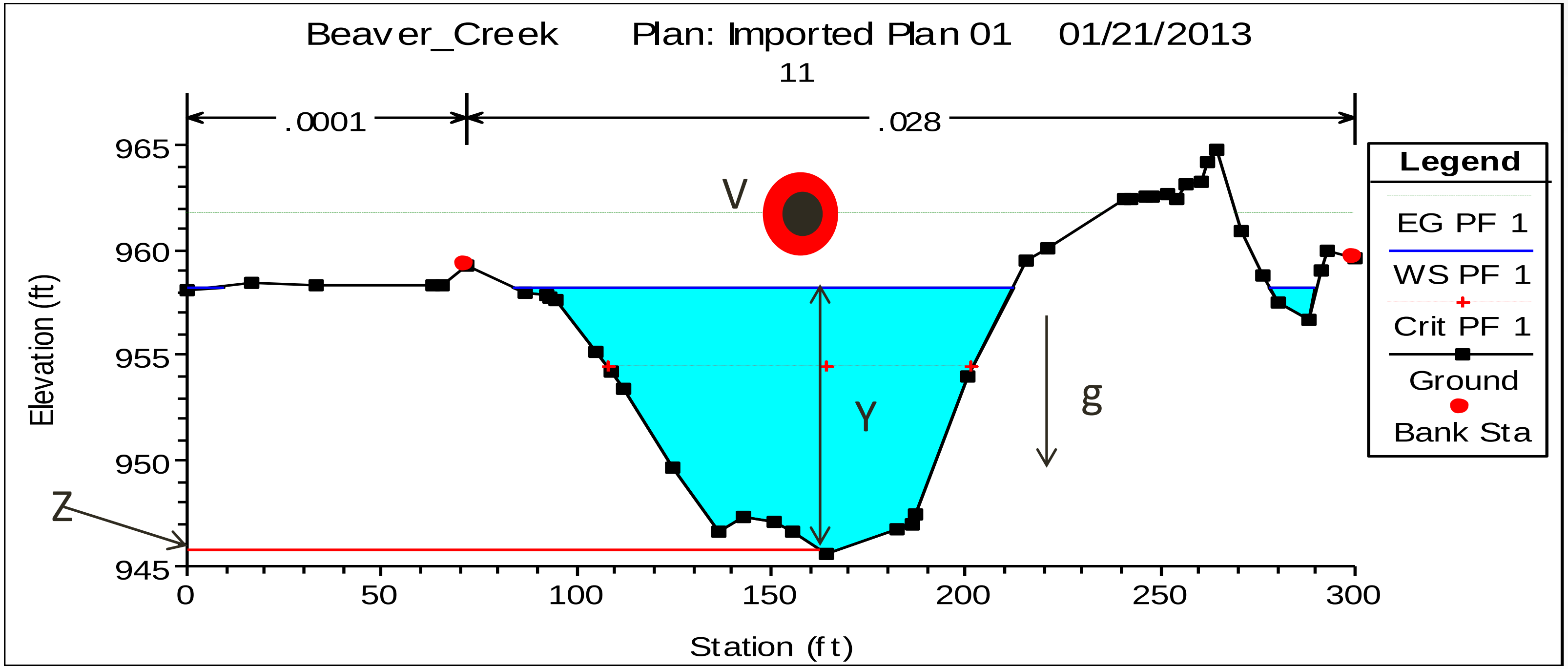


Cross-Section



- X-axis = Horizontal width of River Station
- Y-axis = Elevation above sea level
- ● = Bank Station marker
- Contour = shape of creek bed at that station
- Stage Height (Y) = Distance from channel bottom to surface

Energy Equation



a_1, a_2 = Velocity weighting coefficients (error in average velocity)

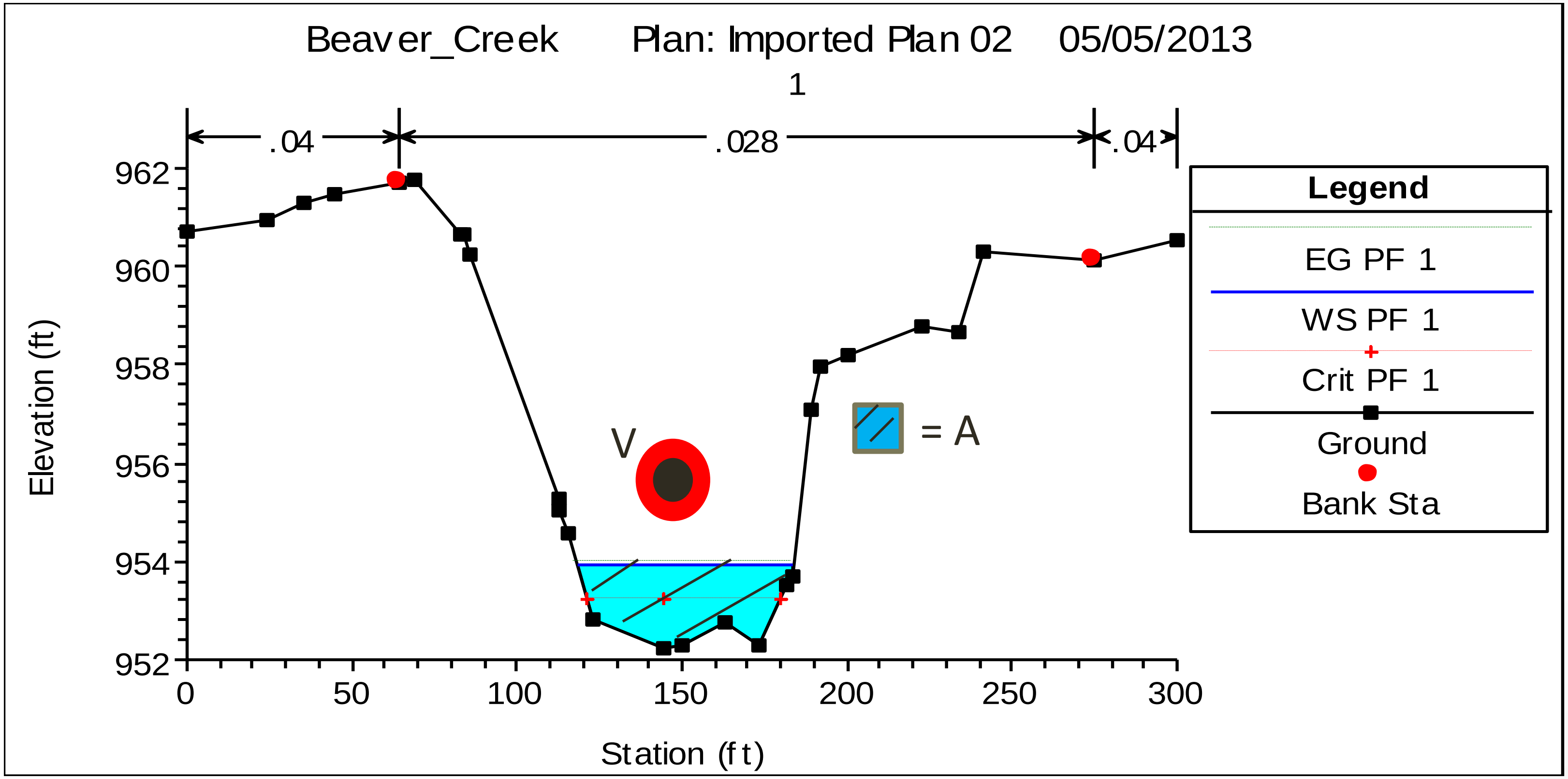
h_e = Energy head loss

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

Development

- Determine and adjust Manning n value
- River bank adjustment
- One low-head dam replaced by a single v-notch drop structure
- Hydraulic Jump
  - Subcritical to supercritical

Manning Equation



- Equation: $Q = VA = \left(\frac{1.00}{n}\right) AR^{\frac{2}{3}}\sqrt{S}$

n = Manning's Roughness Coefficient
R = Hydraulic Radius, (m)
S = Channel Slope, (m/m)

Manning N

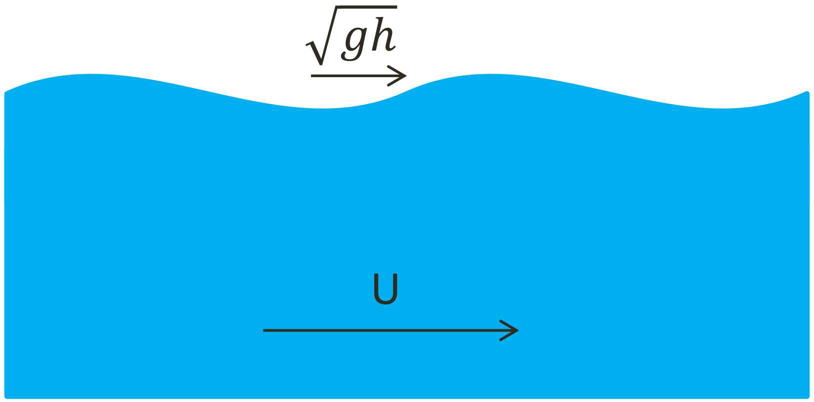
- Similar to coefficient of friction
- Shows the resistance to fluid flow
- Higher n means more resistant to flow

Manning's n for Channels (Chow, 1959).

Type of Channel and Description	Minimum	Normal	Maximum
Natural streams - minor streams (top width at floodstage < 100 ft)			
1. Main Channels			
a. clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. same as above, but more stones and weeds	0.030	0.035	0.040
c. clean, winding, some pools and shoals	0.033	0.040	0.045
d. same as above, but some weeds and stones	0.035	0.045	0.050
e. same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. same as "d" with more stones	0.045	0.050	0.060
g. sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Froude Number

- Froude Number→ $Fr = \frac{U}{\sqrt{gh}}$
- U = Velocity of flow
- g = Acceleration of gravity
- h = Depth of flow relative to the channel bottom
- $\sqrt{gh}$ = Wave velocity
- Unitless

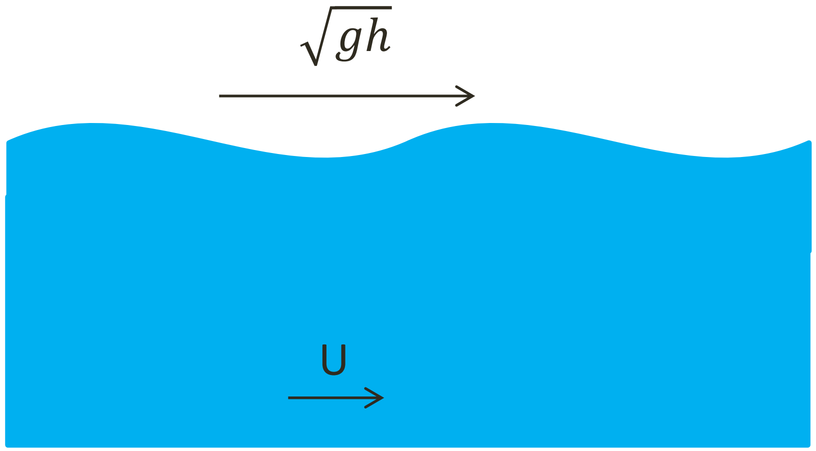


Supercritical and Subcritical Flow

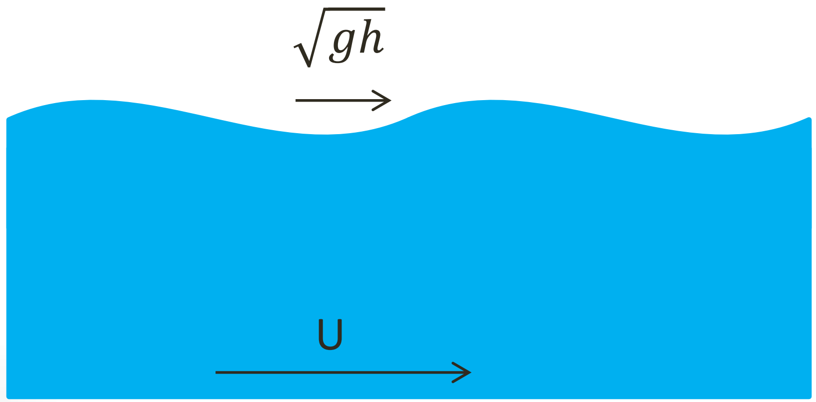
- Is the Froude number > or < than 1?
  - Fr>1 = Supercritical
  - Fr<1 = Subcritical

- Supercritical → When flow velocity is greater than wave velocity
- Subcritical → When flow velocity is less than wave velocity
- Hydraulic Jump→ Occurs when a flow at high velocity discharges into a zone that can't sustain that high wave velocity.

Sub or Supercritical Flow



- Subcritical Flow

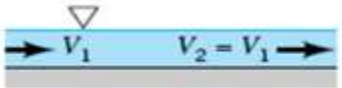
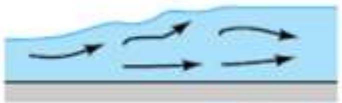


- Supercritical Flow

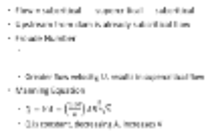
Hydraulic Jumps

With V-notch want to create a hydraulic jump

TABLE 10.3
Classification of Hydraulic Jumps (Ref. 12)

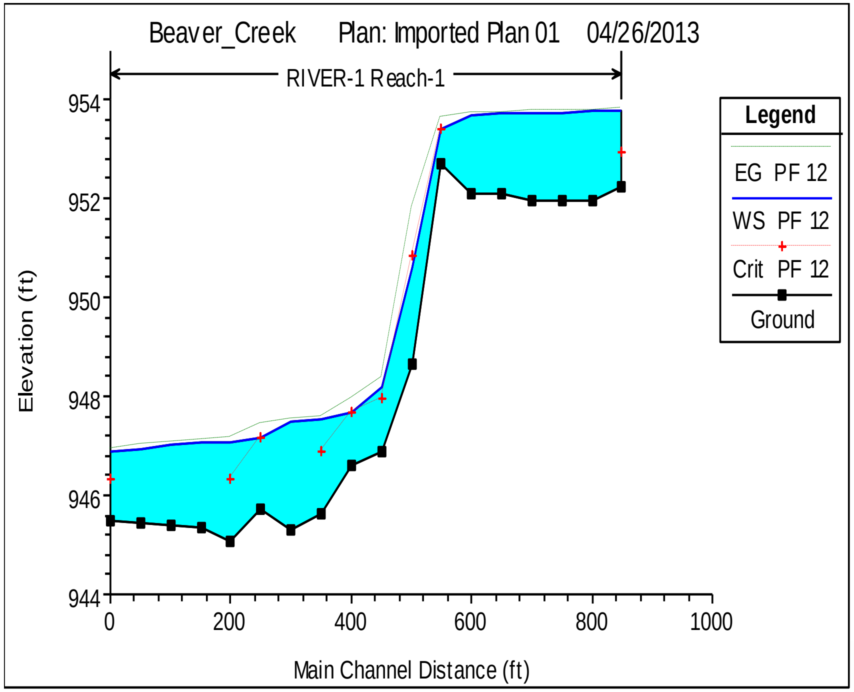
Fr_1	y_2/y_1	Classification	Sketch
<1	1	Jump impossible	
1 to 1.7	1 to 2.0	Standing wave or undulant jump	
1.7 to 2.5	2.0 to 3.1	Weak jump	
2.5 to 4.5	3.1 to 5.9	Oscillating jump	
4.5 to 9.0	5.9 to 12	Stable, well-balanced steady jump; insensitive to downstream conditions	
>9.0	>12	Rough, somewhat intermittent strong jump	

Designing V-notch

- Flow = subcritical → supercritical → subcritical
- Upstream from dam is already subcritical flow
- Froude Number
  - 
  - Greater flow velocity, U, results in supercritical flow
- Manning Equation
  - $Q = VA = \left(\frac{1.00}{n}\right) AR^{\frac{2}{3}}\sqrt{s}$
  - Q is constant, decreasing A, increases V

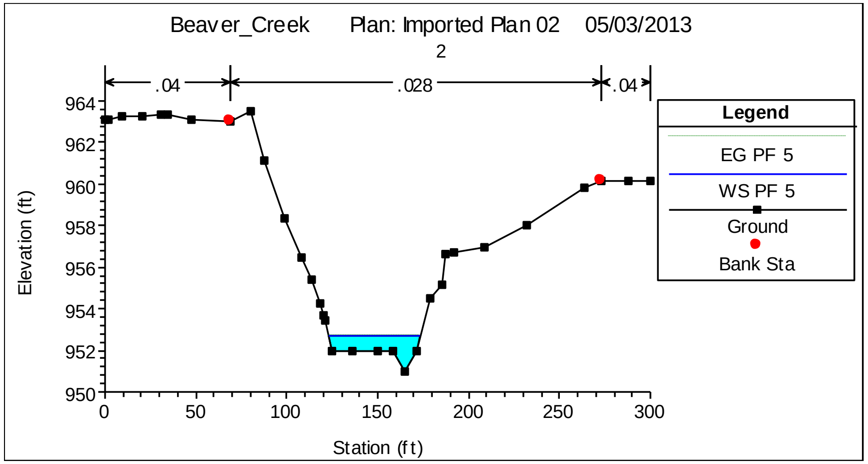
Designing V-notch

- Flow Prior to dam is subcritical
- Fr<1
- Supercritical flow over the dam
- Fr>1
- Not safely passable by kayak or canoe

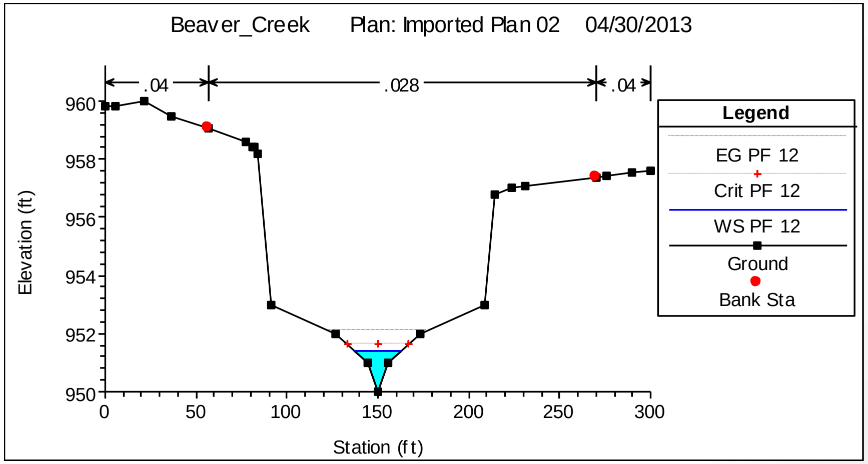


Designing V-notch

- Original channel shape at the dam site

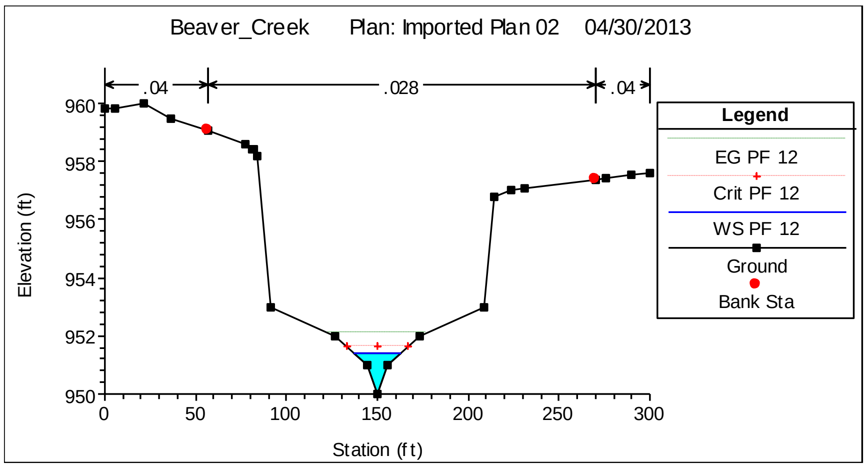


- Redesigned V-notch
- Decrease area, increase velocity of flow



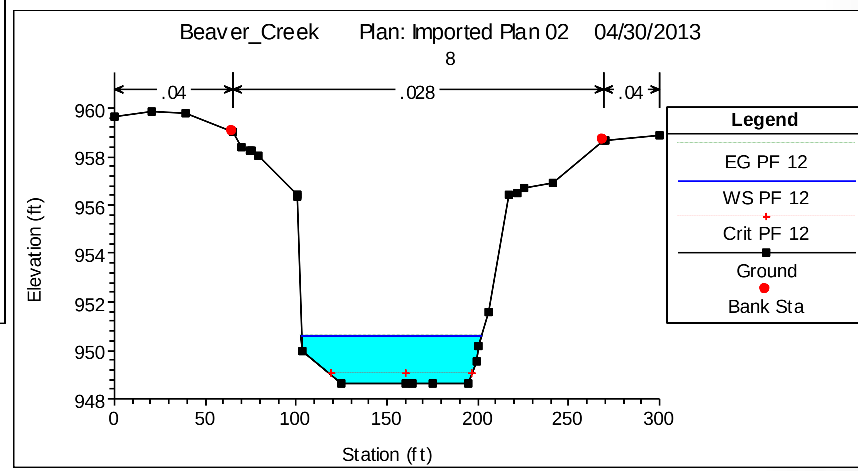
Hydraulic Jump

- Constant Q (93 cfs)



- Stage height at V-notch is 1.43 ft.

- Stage height of cross-section following V-notch is 1.94 ft.



- Hydraulic Jump?

Hydraulic Jump

- Ratio of height $\frac{y_2}{y_1}$ = 1.36
  - y_1 is the stage height of the v-notch
  - y_2 is the stage height of the following cross-section
  - Success!
  - Created an undulant jump or rapid which is passable by both canoe and kayak

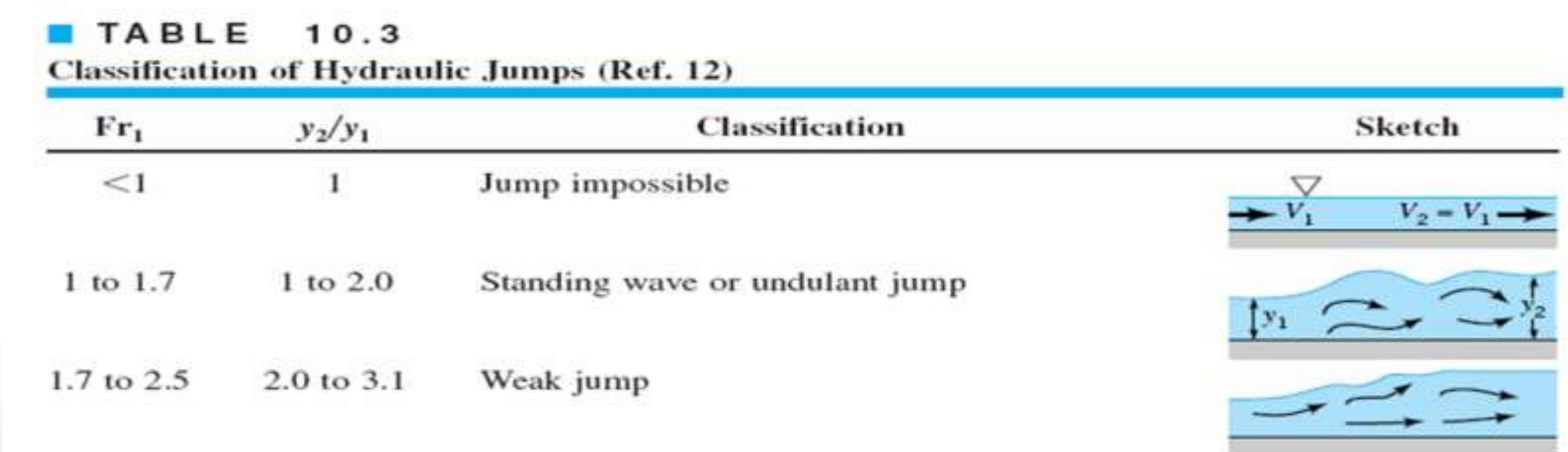
- Ratio of height $\frac{y_2}{y_1}$ = 1.36
  - y_1 is the stage height of the v-notch
  - y_2 is the stage height of the following cross-section
  - Success!

Hydraulic Jump

- Is the model consistent?

	Q (cfs)	A (ft^2)	V (f/s)	$\sqrt{gh}$	Fr
V-notch	93	18.83	4.94	3.75	1.32
post V	93	163.18	0.57	4.36	0.13

  - $Fr_1 = 1.32 > 1$, $Fr_2 = 0.13 < 1$
  - Supercritical to subcritical flow
  - Indeed our structure has a Hydraulic jump



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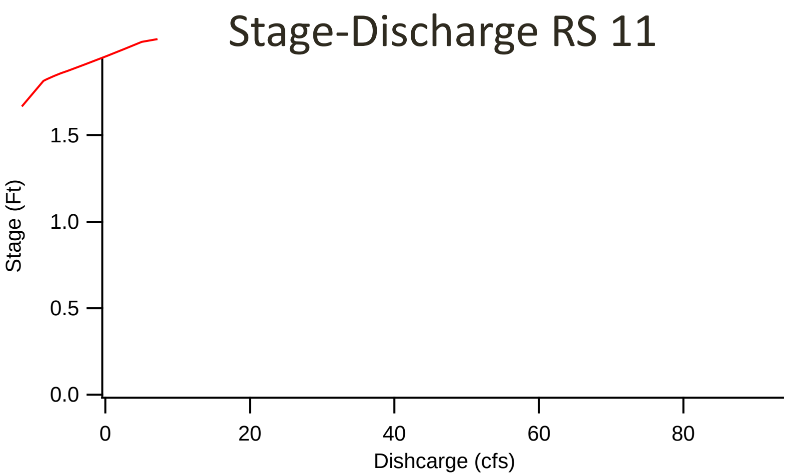
1 to 1.7	1 to 2.0	Standing wave or undulant jump	y_1 y_2
1.7 to 2.5	2.0 to 3.1	Weak jump	

Model Accuracy

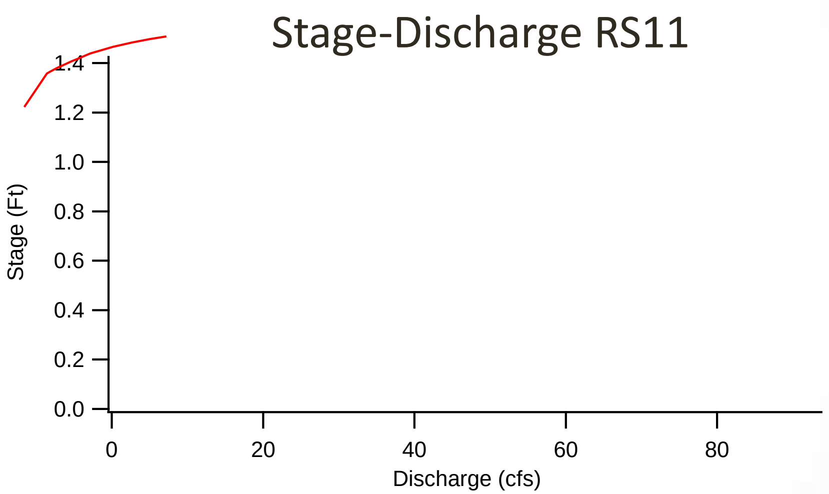
- Is stage height unreasonably high?
  - Uncharacteristic flow can damage downstream structure of bed
  - Must be consistent with the stage discharge of previous structure
  - Offset rating curves for comparison

Stage-Discharge Curve

- Pre Modification



- Post Modification



- Dam is located at RS 11
- Similar shape indicates similar behavior
- Reasonable stage height in modification
- Indicates that if these structural changes are implemented, the creek will resume its normal flow downstream of modification
- Roughly a 2.5 inch decrease in stage height

Conclusion

- HEC-RAS modeling to create modification to creek
- Model was consistent
- Dam modifications are possible

Acknowledgements

- Dr. George
- Dr. Williams

Questions?