

Culvert Design Process

Hydrology



Site Assessment



Alignment and Profile



Bed and Banks



Structure



Sediment Mobility & Stability



Hydraulic modeling to verify capacity

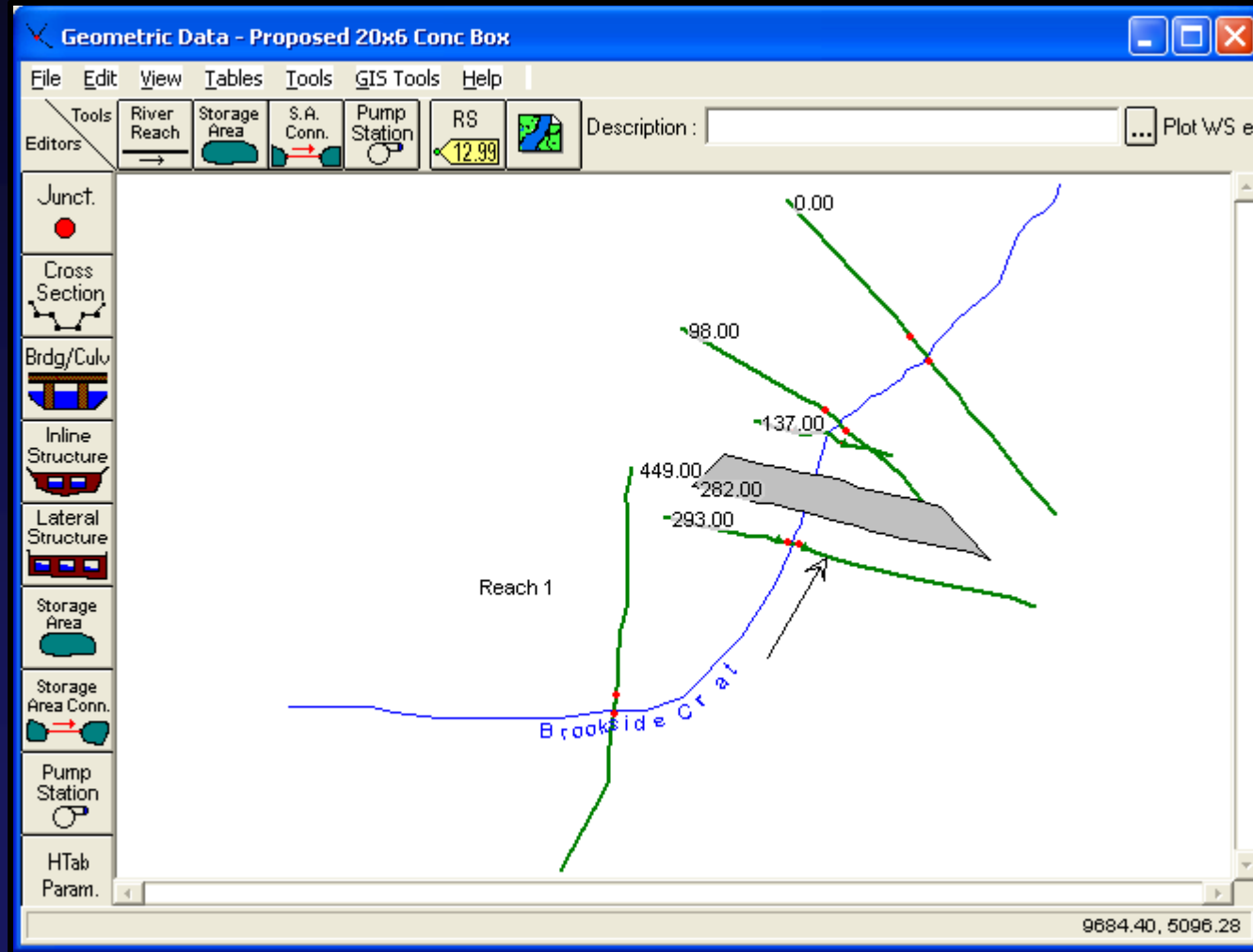
- Select initial culvert size and shape
 - Design flood
 - Bankfull width and channel shape
- Model Culvert
 - Check Q_{100} for $HW/D < 1$
 - Check $Q_{1.5}$ or Q_2
- Repeat process if needed

Culvert size and bankfull width

- Bankfull Width at Reference Reach
 - Straight segment
 - Narrow
 - Unaffected by road crossing
- Bankfull Width – Brookside Cr Ex
 - Min = 8.3 feet
 - Mean = 9.1 feet
 - Range = 8.3-10.5 feet, n=5
- Select Culvert Width \geq BF Width
- Compare H&H Width to BF Width



HEC-RAS geometric data



HEC-RAS geometric data



HEC-RAS x-sec editor

Cross Section Data - Proposed 20x6 Conc Box

Exit Edit Options Plot Help

River: Brookside Cr at Apply Data Plot Options Keep Prev XS Plots Clear Prev

Reach: Reach 1 River Sta.: 0.00

Description: XS1 (farthest downstream)

Del Row	Ins Row	Downstream Reach Lengths		
Cross Section Coordinates		LOB	Channel	ROB
1	-100	0	0	0
2	-10			
3	0			
4	15.08			
5	33.67			
6	46.12			
7	49.27			
8	52.53			
9	56.46			
10	64.4			
11	86.65			
12	102.49			
13	125.15			
14	163.93			
15	198.26			
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				

Manning's n Values		
LOB	Channel	ROB
N/A	N/A	N/A

Main Channel Bank Stations	
Left Bank	Right Bank
33.67	56.46

Cont' Exp Coefficient (Steady Flow)	
Contraction	Expansion
0.1	0.3

Brookside Cr at Brookside Road Plan: Proposed 20x6 Conc Box 3/18/2010
 Geom: Proposed 20x6 Conc Box Flow: 500-yr, 100-yr, 1.5-yr, Htprf, Ltprf
 XS1 (farthest downstream) Note: n values for first profile.

Legend

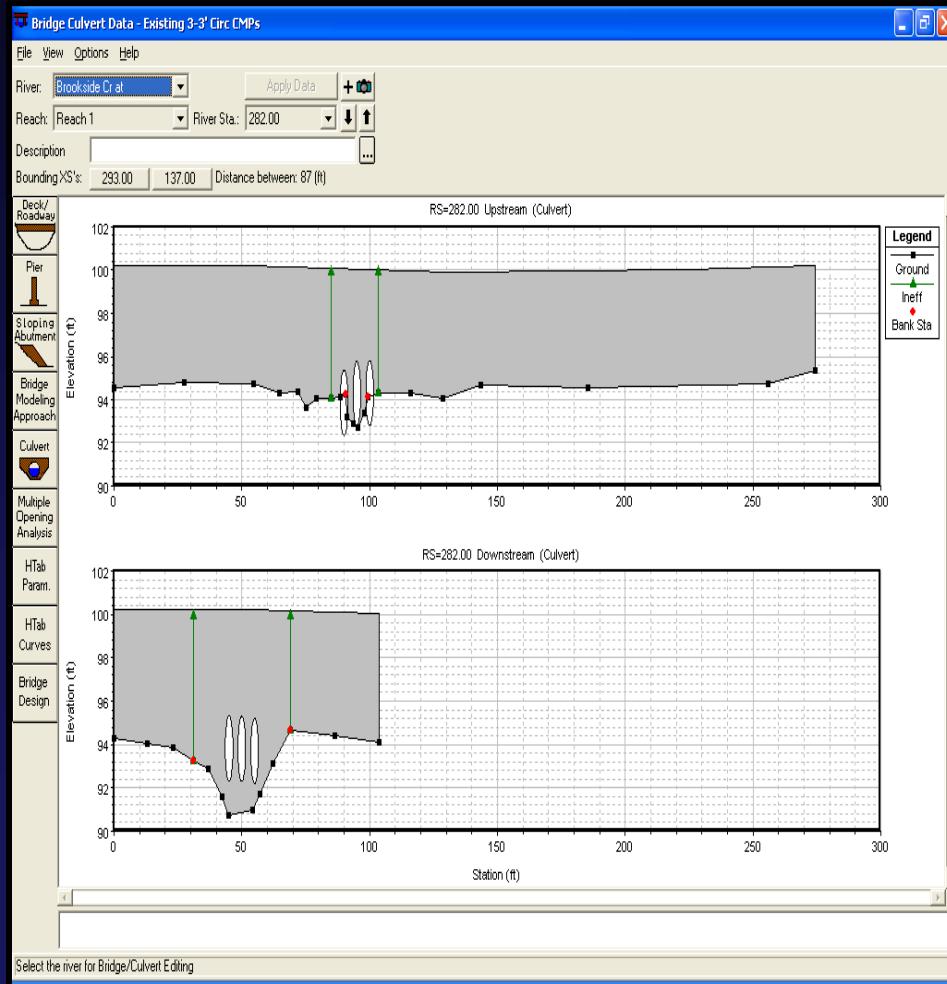
- WS 500-yr (449 cfs)
- WS 100-yr (381 cfs)
- WS 1.5-yr (78 cfs)
- WS Htprf (13.7 cfs)
- WS Ltprf (0.2 cfs)
- Ground
- Bank Sta

Vertical Variation in n values

Enter to move to next upstream river station location



HEC-RAS bridge/culvert editor



HEC-RAS culvert editor

Culvert Data Editor

Add ... Copy Delete ... Culvert ID: **Culvert Left**

Solution Criteria: Highest U.S. EG Rename ...

Shape: Circular Span: Diameter: 3

Chart #: 2 - Corrugated Metal Pipe Culvert

Scale #: 3 - Pipe projecting from fill

Distance to Upstrm XS: 15 Upstream Invert Elev: 92.36

Culvert Length: 54 Downstream Invert Elev: 92.31

Entrance Loss Coeff: 0.9 # identical barrels: 1

Exit Loss Coeff: 1

Manning's n for Top: 0.019

Manning's n for Bottom: 0.019

Depth to use Bottom n: 0

Depth Blocked: 0

Centerline Stations		
	Upstream	Downstream
1	90.	45.
2		
3		
4		

OK Cancel Help

Select culvert to edit



HEC-RAS flows and models

Steady Flow Data - 500-yr, 100-yr, 1.5-yr, Hfpf, Lfpf

File Options Help

Enter/Edit Number of Profiles (25000 max): Reach Boundary Conditions ... Apply Data

Locations of Flow Data Changes

River: Add Multiple...

Reach: River Sta.: Add A Flow Change Location

Flow Change Location			Profile Names and Flow Rates				
River	Reach	RS	500-yr (449 cfs)	100-yr (381 cfs)	1.5-yr (78 cfs)	Hfpf (13.7 cfs)	Lfpf (0.2 cfs)
1 Brookside Cr at	Reach 1	449.00	474	381	78	19.6	0.2

Edit Steady flow data for the profiles (cfs)

Steady Flow Boundary Conditions

Set boundary for all profiles Set boundary for one profile at a time

Available External Boundary Condition Types

Selected Boundary Condition Locations and Types

River	Reach	Profile	Upstream	Downstream
Brookside Cr at	Reach 1	all	Normal Depth S = 0.0022	Normal Depth S = 0.0022

Steady Flow Reach-Storage Area Optimization ...

Enter to accept data changes.

Steady Flow Analysis

File Options Help

Plan : Short ID

Geometry File :

Steady Flow File :

Flow Regime

Subcritical

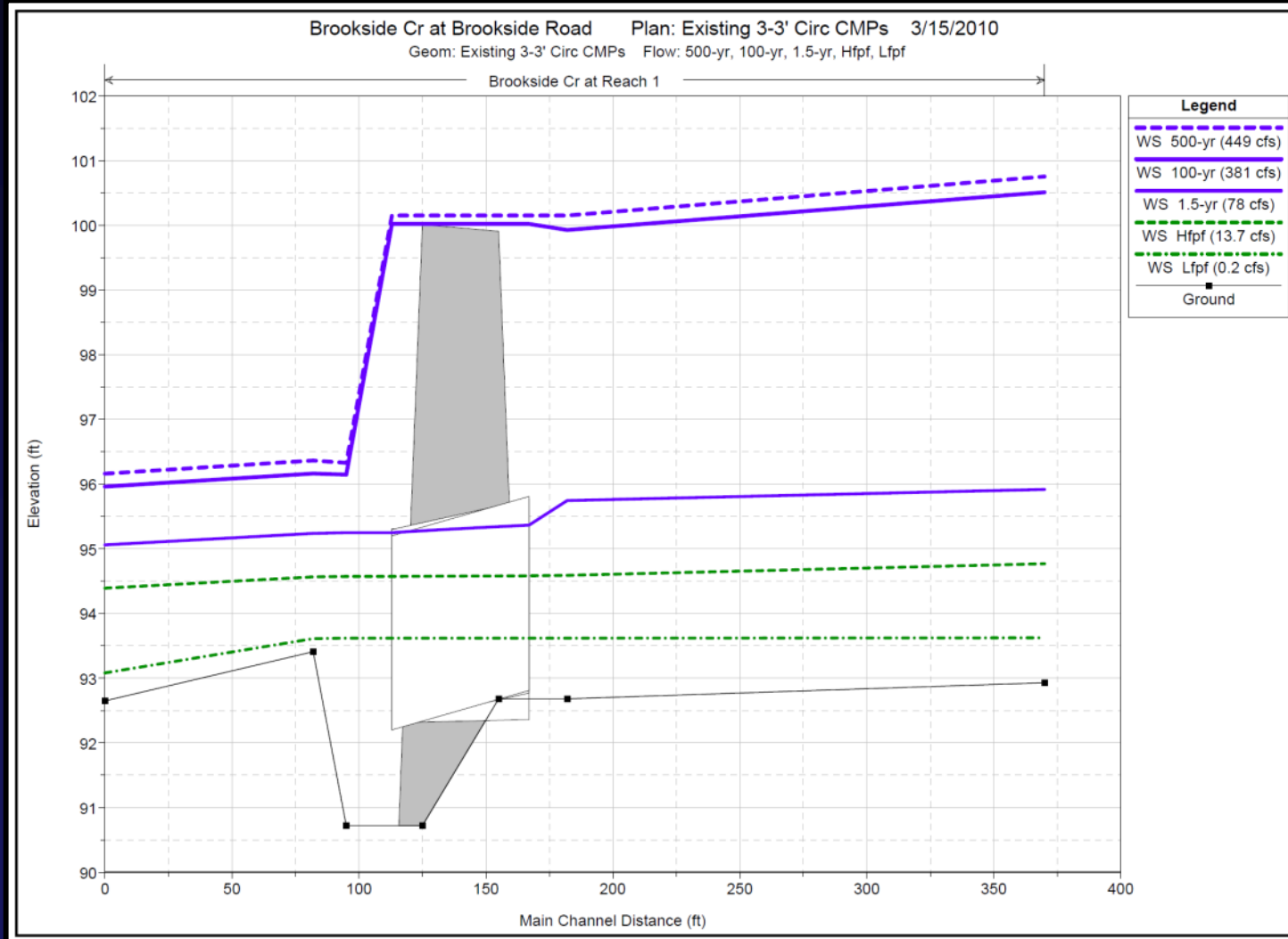
Supercritical

Mixed

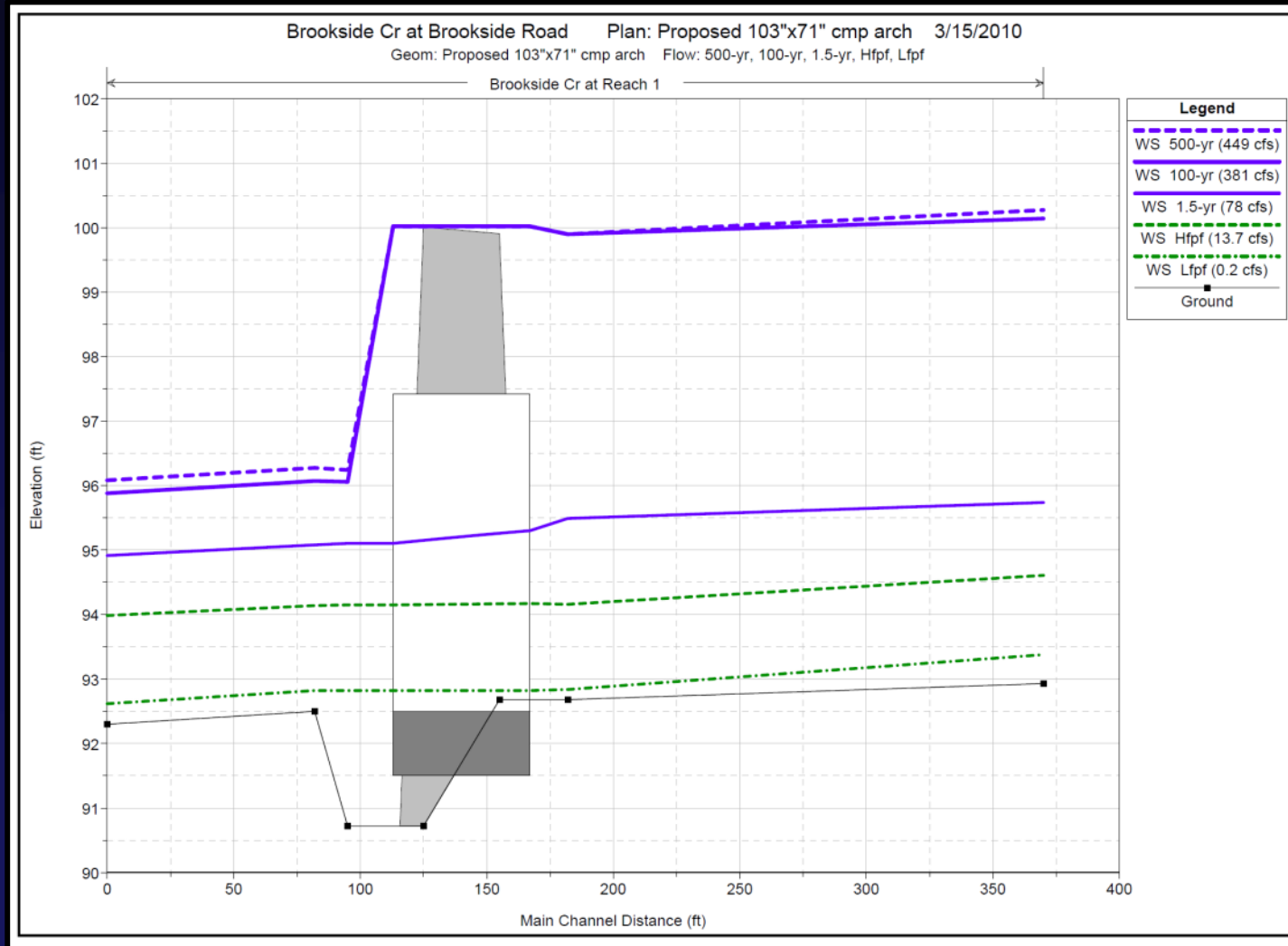
Plan Description :

Enter to compute water surface profiles

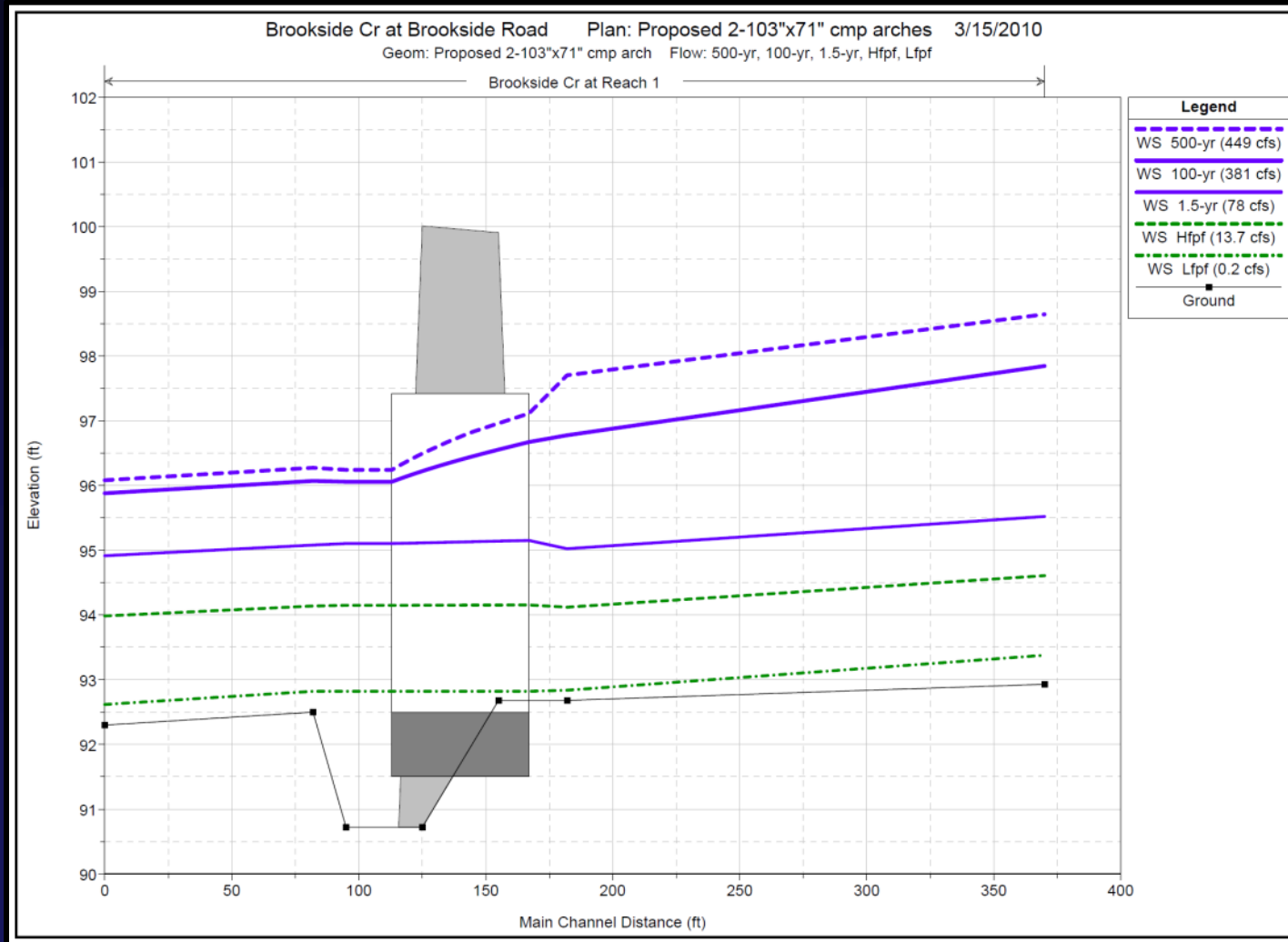
Existing 3-36" circular CMP profile



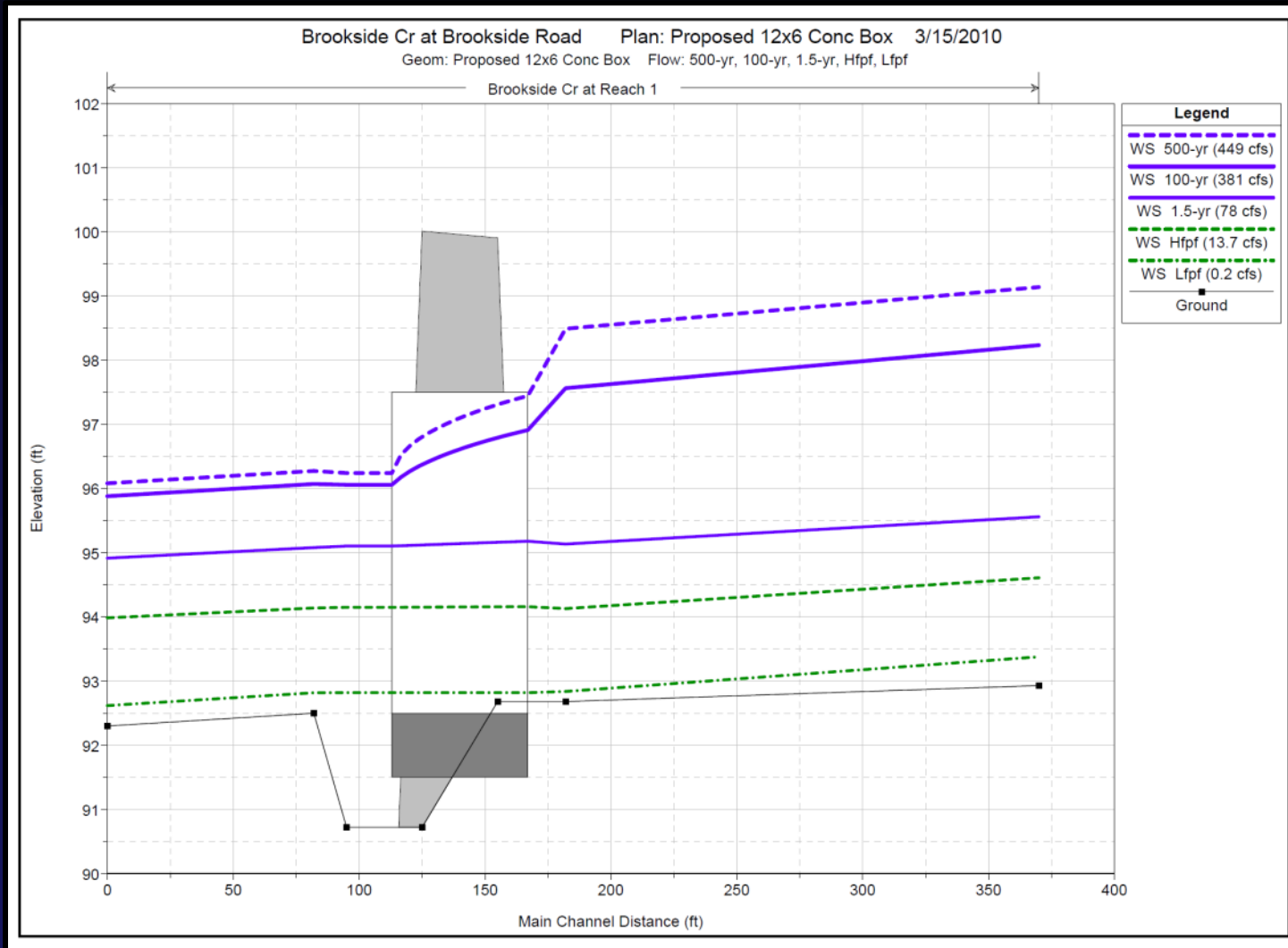
103"x71" CMP profile



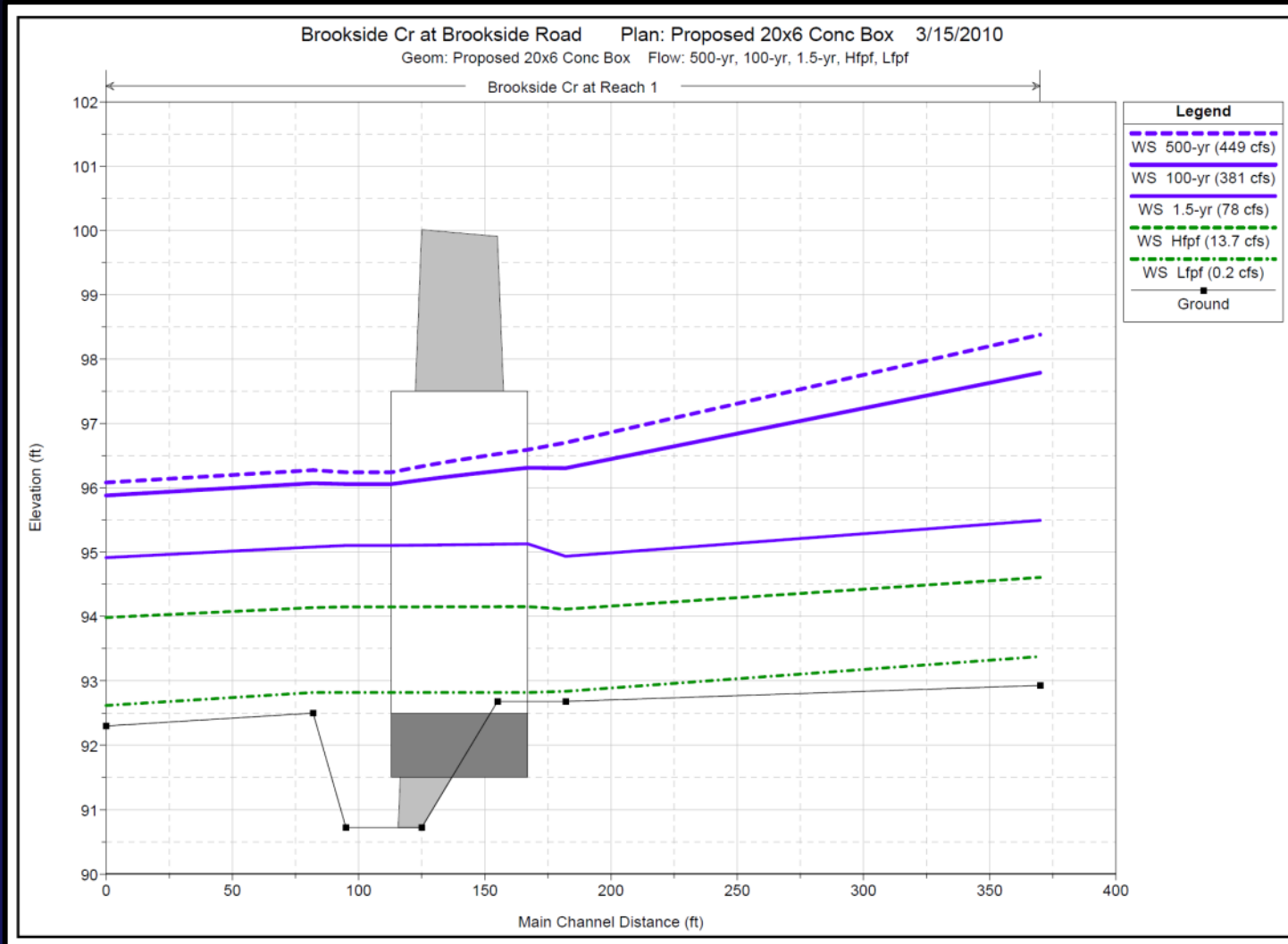
2-103"x71" CMP profile



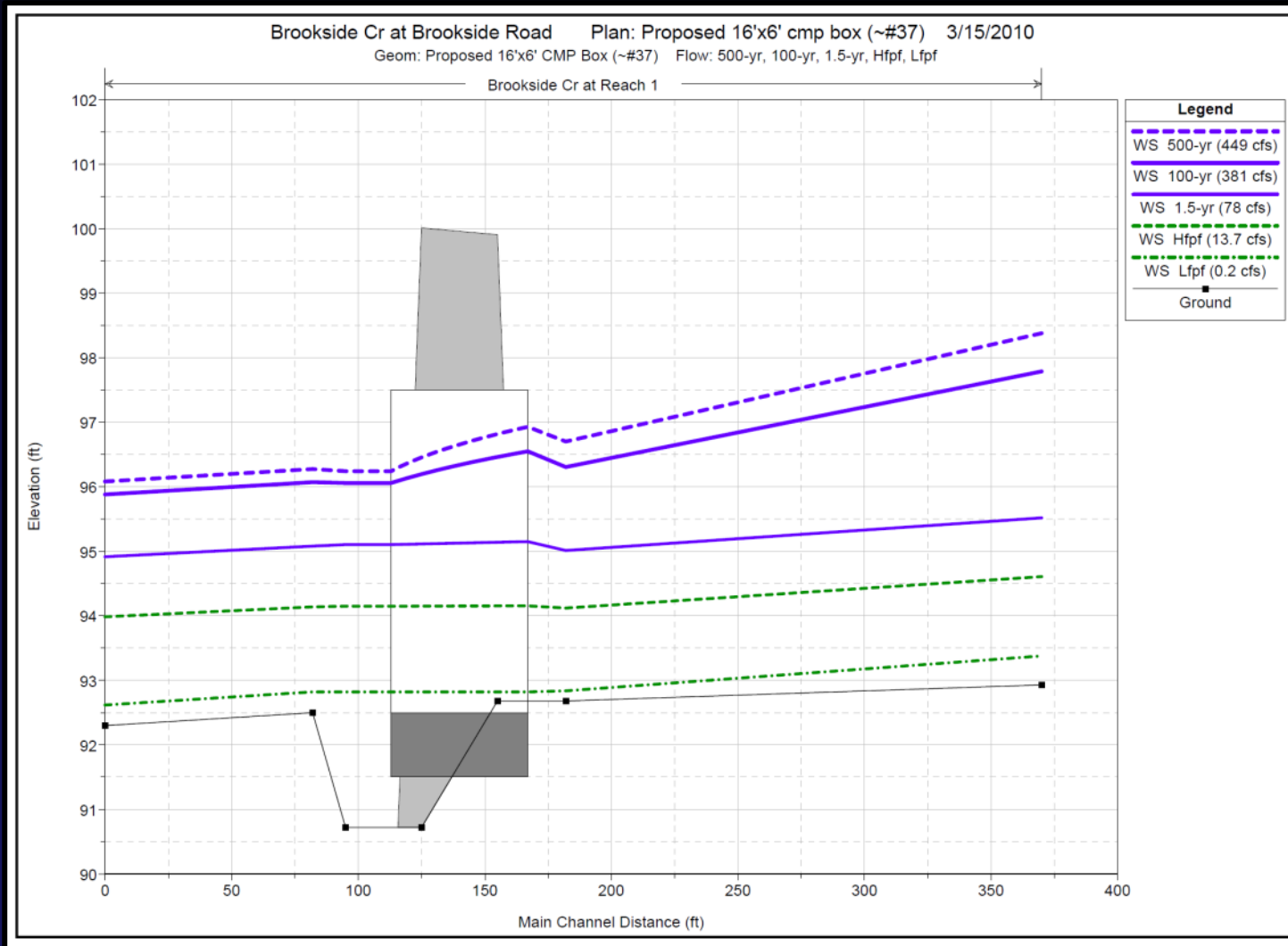
12'x6' concrete box



20'x6' concrete box



16'x6' aluminum box



20'x6' concrete box, culvert table

HEC-RAS Plan: 20'x6' conc box River: Brookside Cr at Reach: Reach 1

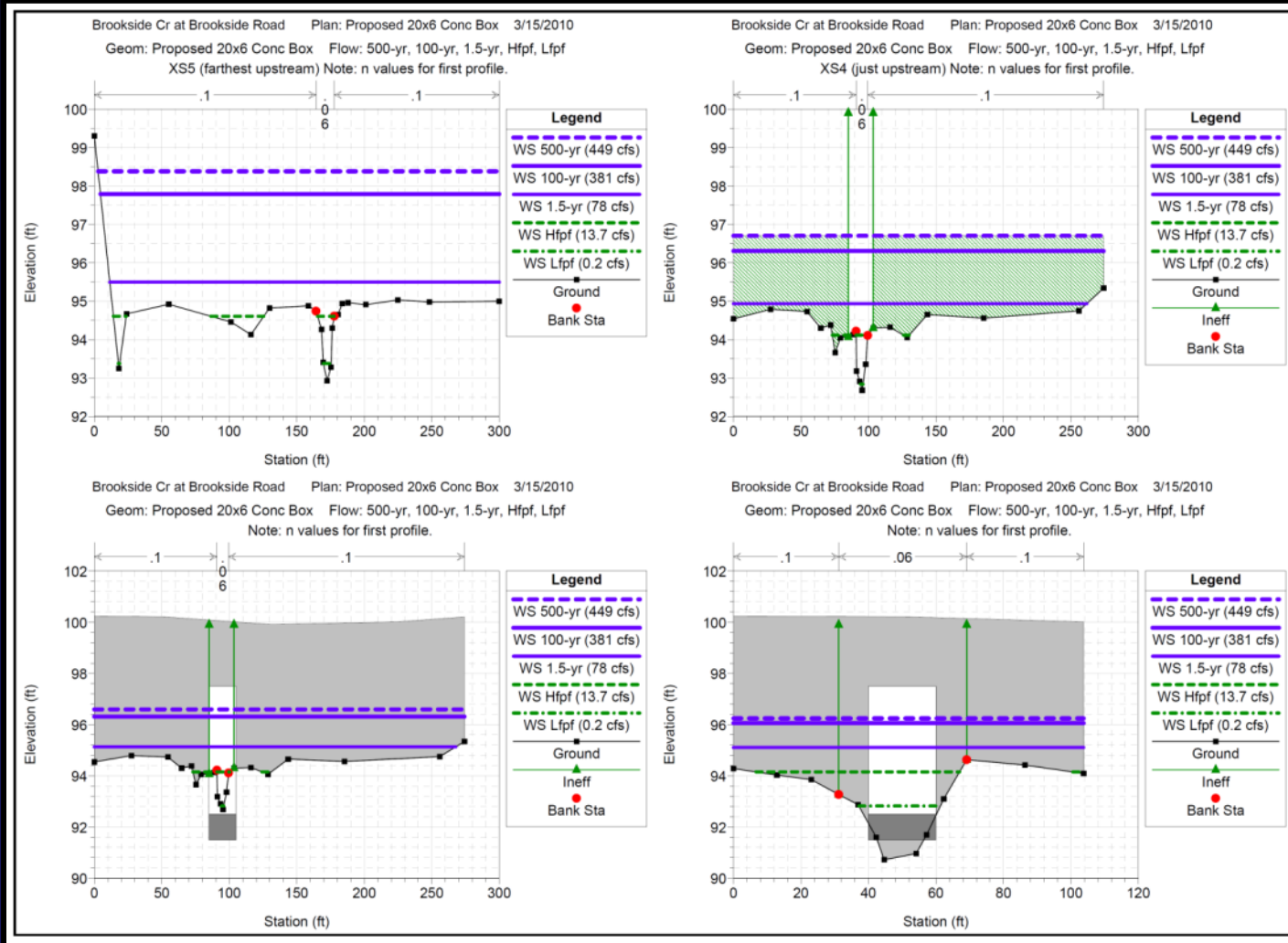
Reach	River Sta	Profile	E.G. US. (ft)	W.S. US. (ft)	E.G. IC (ft)	E.G. OC (ft)	Min El Weir Flow (ft)	Q Culv Group (cfs)	Q Weir (cfs)	Delta WS (ft)	Culv Vel US (ft/s)	Culv Vel DS (ft/s)
Reach 1	282.00 Culvert #1	500-yr (449 cfs)	97.37	96.70	97.12	97.37	100.02	474.00		0.46	5.79	6.33
Reach 1	282.00 Culvert #1	100-yr (381 cfs)	96.89	96.31	96.50	96.89	100.02	381.00		0.25	5.00	5.35
Reach 1	282.00 Culvert #1	1.5-yr (78 cfs)	95.18	94.94	93.89	95.18	100.02	78.00		0.17	1.48	1.50
Reach 1	282.00 Culvert #1	Hfpf (13.7 cfs)	94.16	94.12	92.93	94.16	100.02	13.70		0.03	0.41	0.42
Reach 1	282.00 Culvert #1	Lfpf (0.2 cfs)	92.82	92.84	92.53	92.82	100.02	0.20		0.02	0.03	0.03

20'x6' concrete box, x-sec table

HEC-RAS Plan: 20'x6' conc box River: Brookside Cr at Reach: Reach 1

Reach	River Sta	Profile	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
Reach 1	449.00	500-yr (449 cfs)	474.00	92.93	98.38	95.35	98.38	0.000154	0.81	1061.86	297.23	0.07
Reach 1	449.00	100-yr (381 cfs)	381.00	92.93	97.79	95.27	97.79	0.000179	0.80	886.48	295.45	0.07
Reach 1	449.00	1.5-yr (78 cfs)	78.00	92.93	95.50	94.60	95.50	0.000627	0.84	216.90	288.54	0.11
Reach 1	449.00	Hfpf (13.7 cfs)	13.70	92.93	94.61	93.67	94.62	0.001514	0.85	25.37	60.95	0.16
Reach 1	449.00	Lfpf (0.2 cfs)	0.20	92.93	93.38	93.06	93.38	0.000781	0.14	1.48	6.62	0.05
Reach 1	293.00	500-yr (449 cfs)	474.00	92.68	96.70	96.70	98.14	0.040986	10.88	55.62	274.23	1.01
Reach 1	293.00	100-yr (381 cfs)	381.00	92.68	96.31	96.31	97.56	0.041141	10.08	48.34	274.23	1.00
Reach 1	293.00	1.5-yr (78 cfs)	78.00	92.68	94.94	94.56	95.18	0.015576	4.25	23.13	261.77	0.56
Reach 1	293.00	Hfpf (13.7 cfs)	13.70	92.68	94.12	93.47	94.16	0.004972	1.62	8.54	27.52	0.29
Reach 1	293.00	Lfpf (0.2 cfs)	0.20	92.68	92.84	92.84	92.87	0.810542	1.38	0.14	1.84	0.87
Reach 1	282.00	Culvert										
Reach 1	137.00	500-yr (449 cfs)	474.00	90.72	96.24		96.39	0.002457	3.08	153.90	103.76	0.27
Reach 1	137.00	100-yr (381 cfs)	381.00	90.72	96.06		96.16	0.001852	2.59	146.93	103.76	0.23
Reach 1	137.00	1.5-yr (78 cfs)	78.00	90.72	95.10		95.11	0.000200	0.70	110.69	103.76	0.07
Reach 1	137.00	Hfpf (13.7 cfs)	13.70	90.72	94.15		94.15	0.000021	0.18	75.00	63.49	0.02
Reach 1	137.00	Lfpf (0.2 cfs)	0.20	90.72	92.82		92.82	0.000000	0.01	32.69	24.15	0.00
Reach 1	98.00	500-yr (449 cfs)	474.00	92.50	96.28		96.33	0.002930	2.66	351.35	209.36	0.28
Reach 1	98.00	100-yr (381 cfs)	381.00	92.50	96.07		96.12	0.002779	2.46	308.70	208.64	0.27
Reach 1	98.00	1.5-yr (78 cfs)	78.00	92.50	95.08		95.10	0.001840	1.47	103.62	205.16	0.20
Reach 1	98.00	Hfpf (13.7 cfs)	13.70	92.50	94.14		94.15	0.001644	0.81	17.36	28.61	0.14
Reach 1	98.00	Lfpf (0.2 cfs)	0.20	92.50	92.82		92.82	0.002753	0.16	1.24	6.38	0.06
Reach 1	0.00	500-yr (449 cfs)	474.00	92.30	96.08	95.22	96.11	0.002201	2.19	450.44	298.26	0.23
Reach 1	0.00	100-yr (381 cfs)	381.00	92.30	95.88	95.12	95.91	0.002201	2.08	390.15	298.26	0.23
Reach 1	0.00	1.5-yr (78 cfs)	78.00	92.30	94.92	93.76	94.94	0.002201	1.51	106.12	268.92	0.21
Reach 1	0.00	Hfpf (13.7 cfs)	13.70	92.30	93.99	92.90	94.00	0.002201	0.79	17.48	20.27	0.13
Reach 1	0.00	Lfpf (0.2 cfs)	0.20	92.30	92.62	92.40	92.62	0.002204	0.14	1.45	7.19	0.05

20'x6' concrete box, x-sec graphs



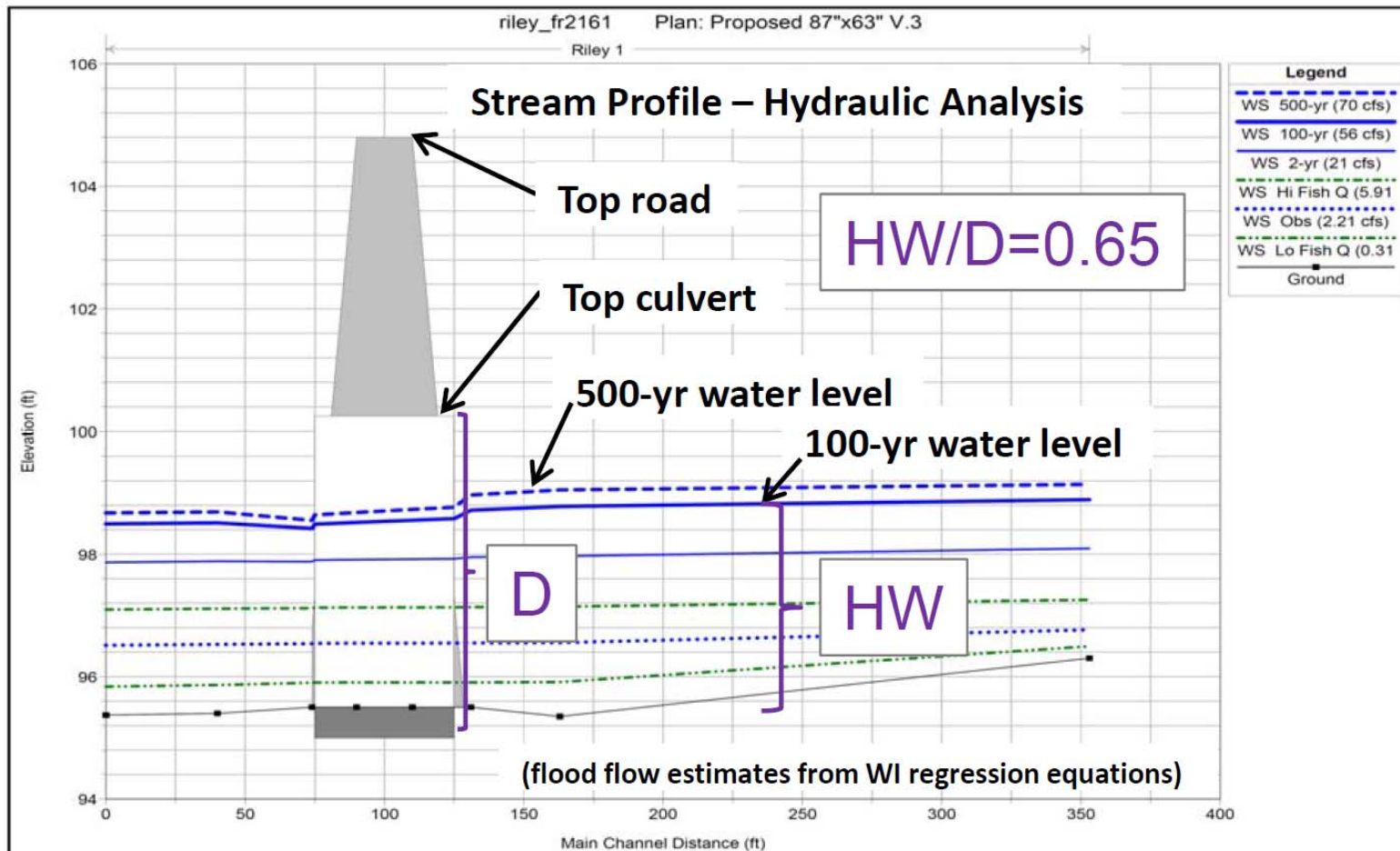
Brookside Cr. HEC-RAS summary

100-yr flood, 381 cfs

Culvert	W.S. US (ft)	W.S. DS (ft)	Delta WS (ft)	Culv Vel US (ft/sec)	Culv Vel DS (ft/sec)
Exist 3-3' Circ	99.93	96.15	3.78	10.06	10.06
103"x71"	99.90	96.06	3.84	9.49	11.50
2-103"x71"	96.78	96.06	0.72	6.13	6.89
12'x6' Conc Box	97.57	96.06	1.51	7.19	8.92
20'x6' Conc Box	96.31	96.06	0.25	5.00	5.35
16'6"x6'8" Al Box	96.31	96.06	0.25	5.88	6.69

Note: W.S.=water surface, US=upstream, DS=downstream, Vel=velocity

7.25'x5.25' CMP – 104% of min BFW

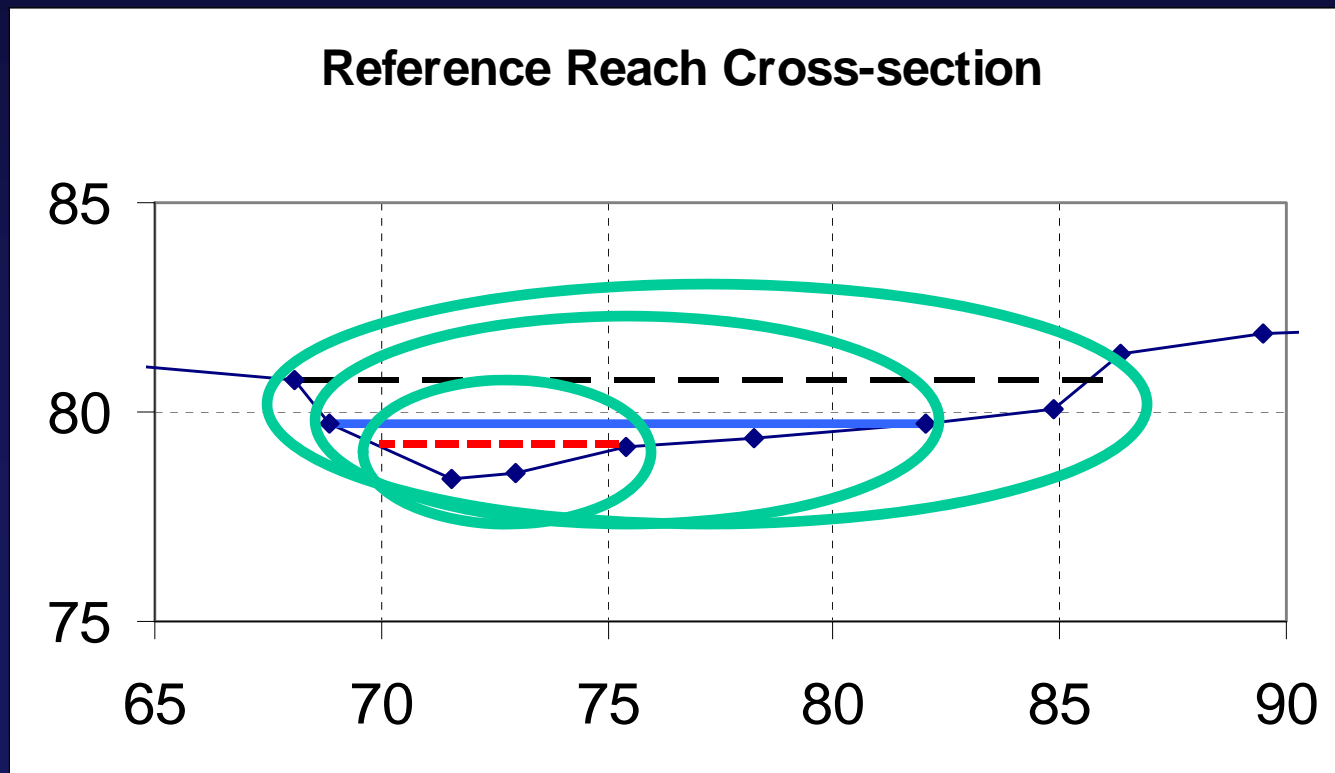


In N WI, many BFW culverts pass the Q_{100} with a minor head increase and headwater below the top of culvert.

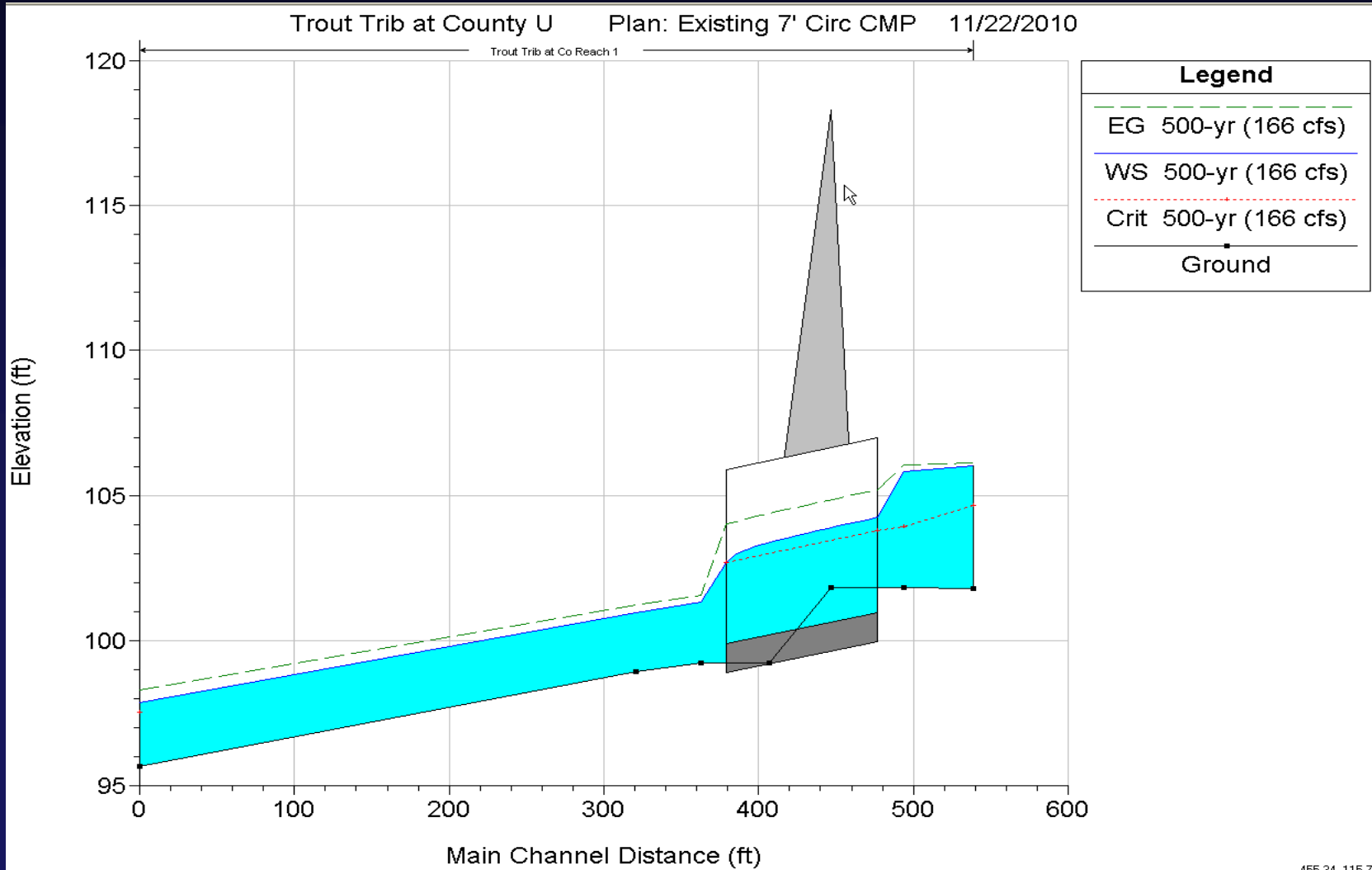
Stream simulation structure design

Stream simulation culvert width

- First estimate: Span channel and banks
- Hydraulic capacity



HEC-RAS profile plot

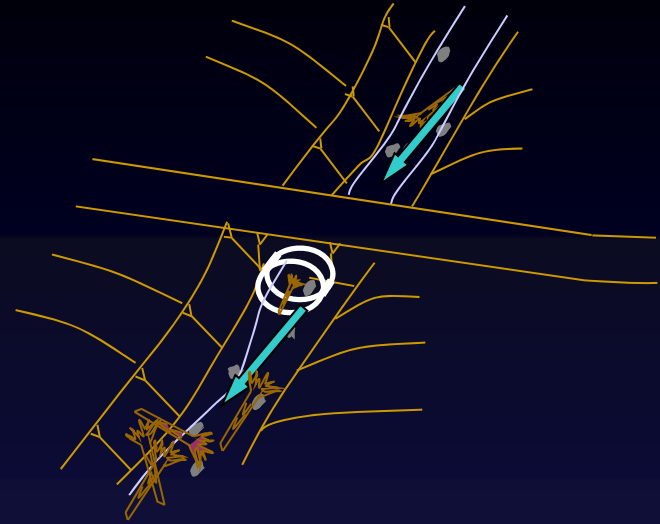


Stream simulation culvert width

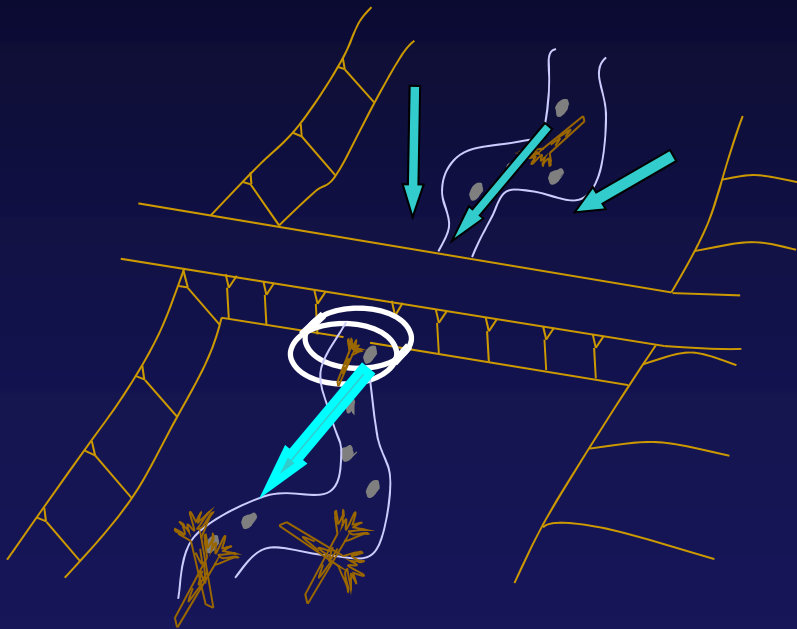
Some benefits of structures wider than bankfull width:

- Banks match reference channel.
- Minimize inlet contraction during high flow events.
- Provides increased variability of hydraulic conditions during high flows.
- Can create dry habitat conditions for passage of additional organisms—increases “openness”.
- More important on high volume traffic roads.

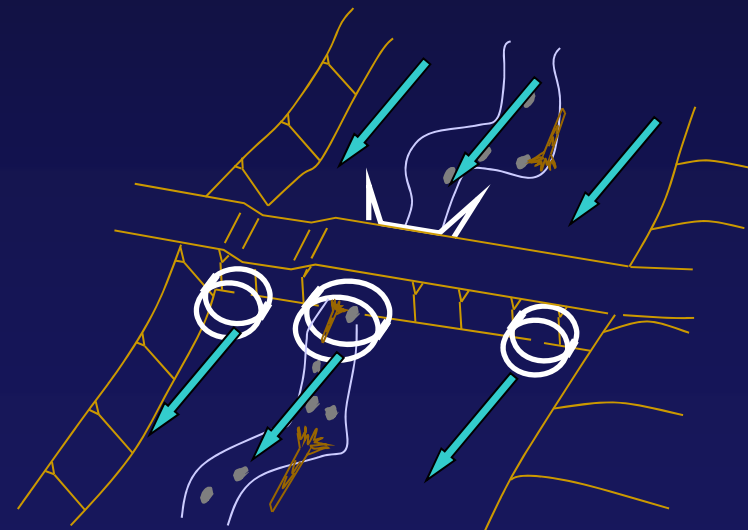
Stream simulation culvert width



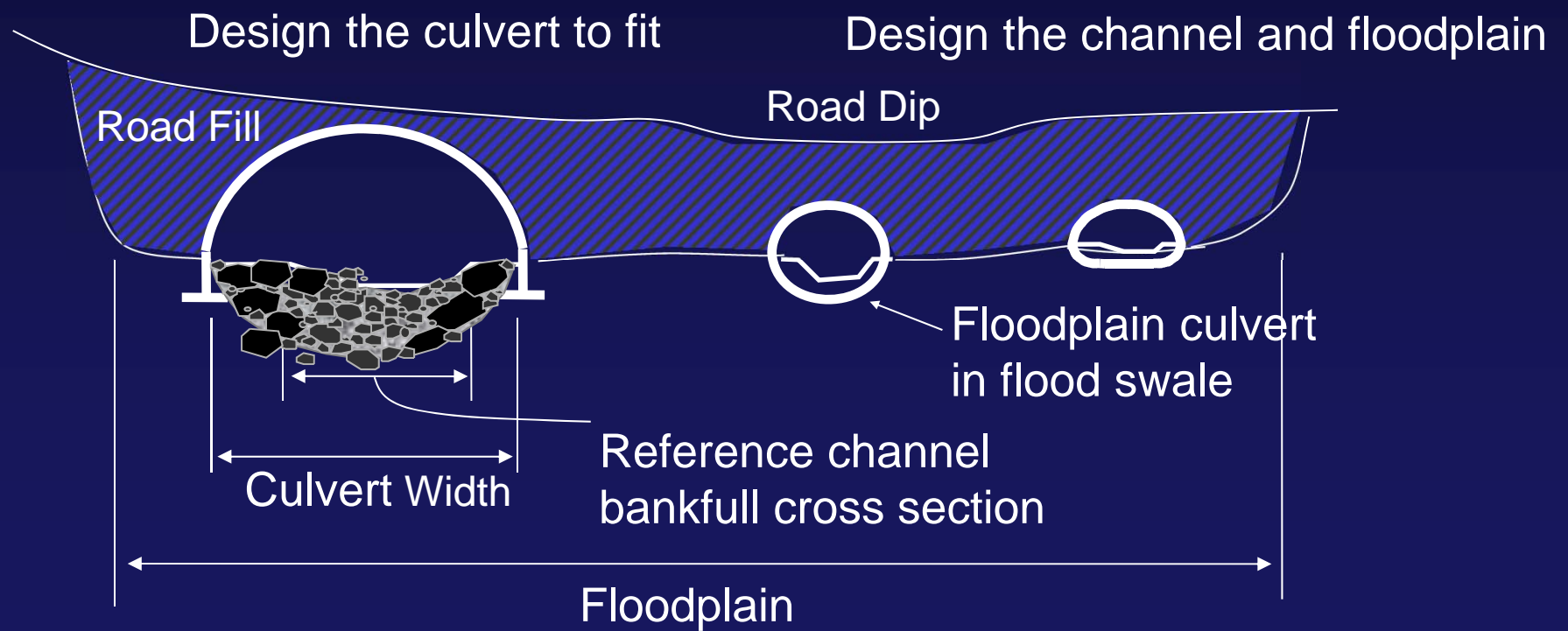
a. Confined



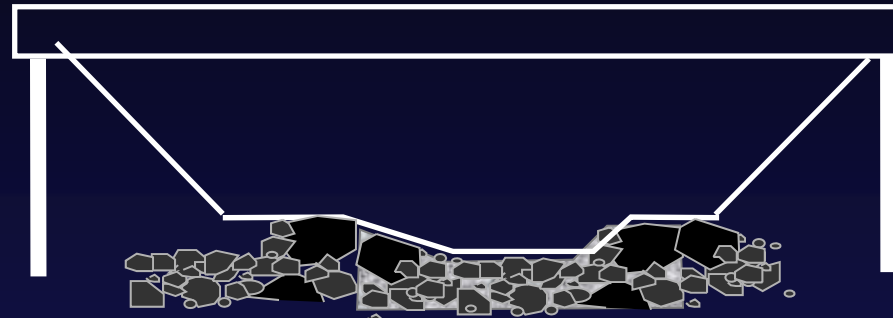
b. Unconfined
with wider culvert



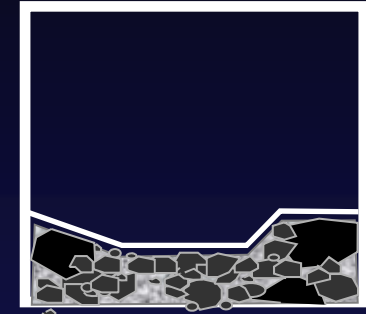
c. Unconfined
with floodplain culverts



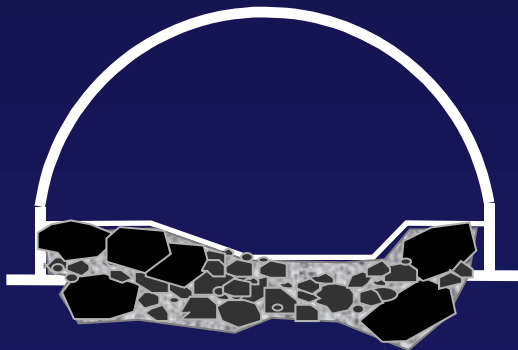
Structure types



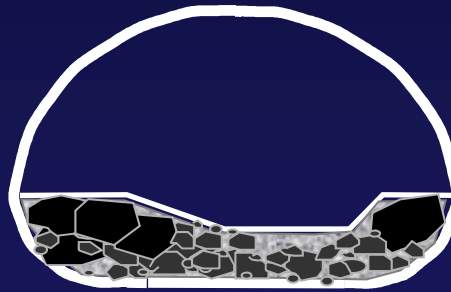
Bridge



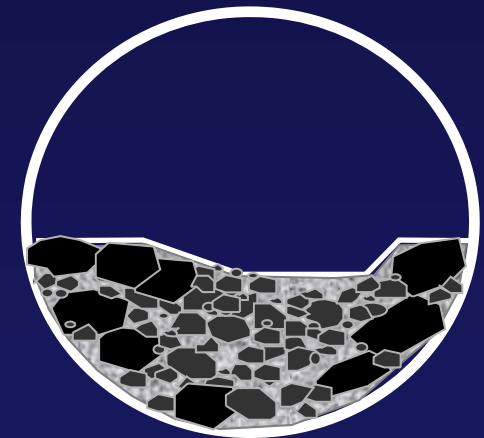
Box



Bottomless Arch



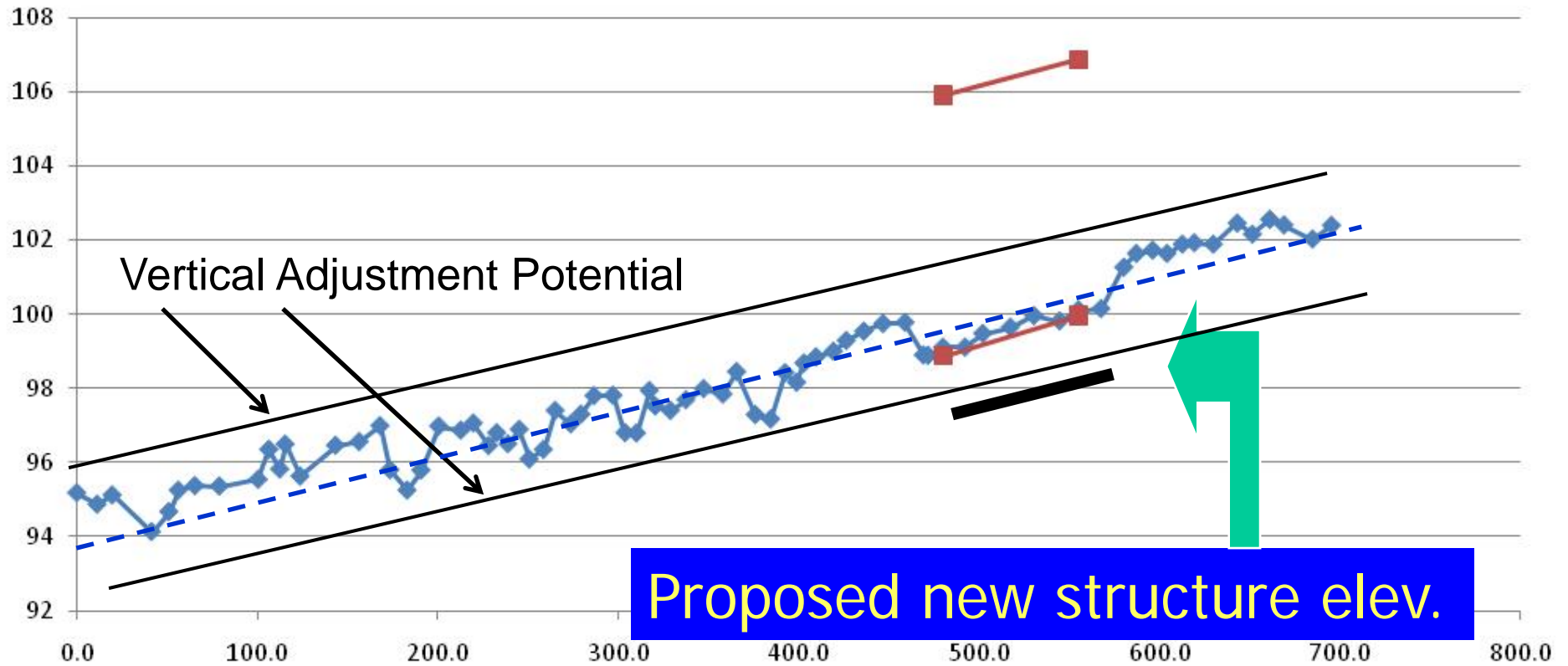
Pipe Arch



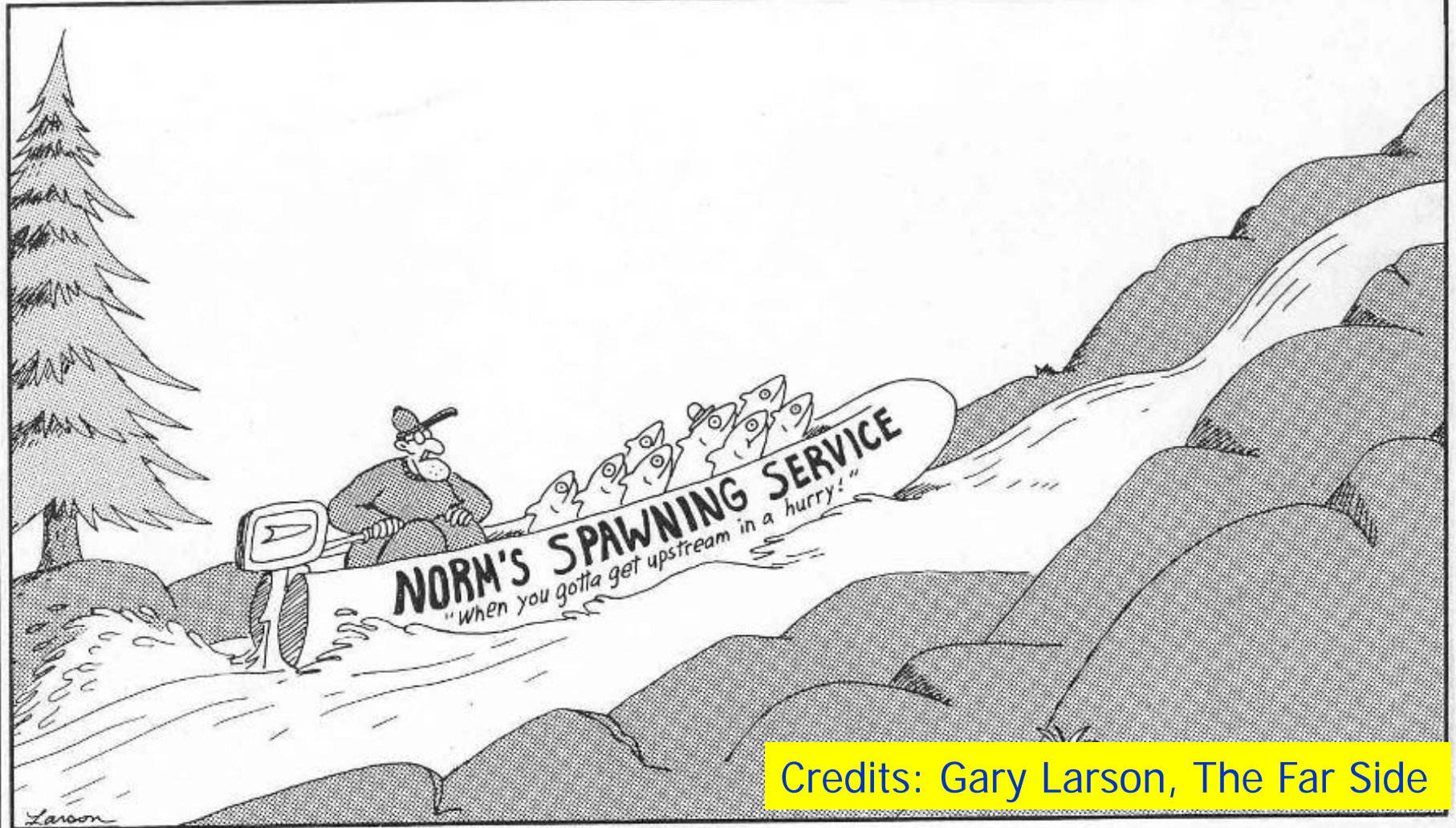
Embedded Round

Elevation

Trout Cr. Longitudinal Profile



Questions?



Credits: Gary Larson, The Far Side