Culvert Design Process

Hydrology

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Site Assessment

↓

Alignment and Profile

↓

Bed and Banks

↓

Structure

↓

Sediment Mobility & Stability

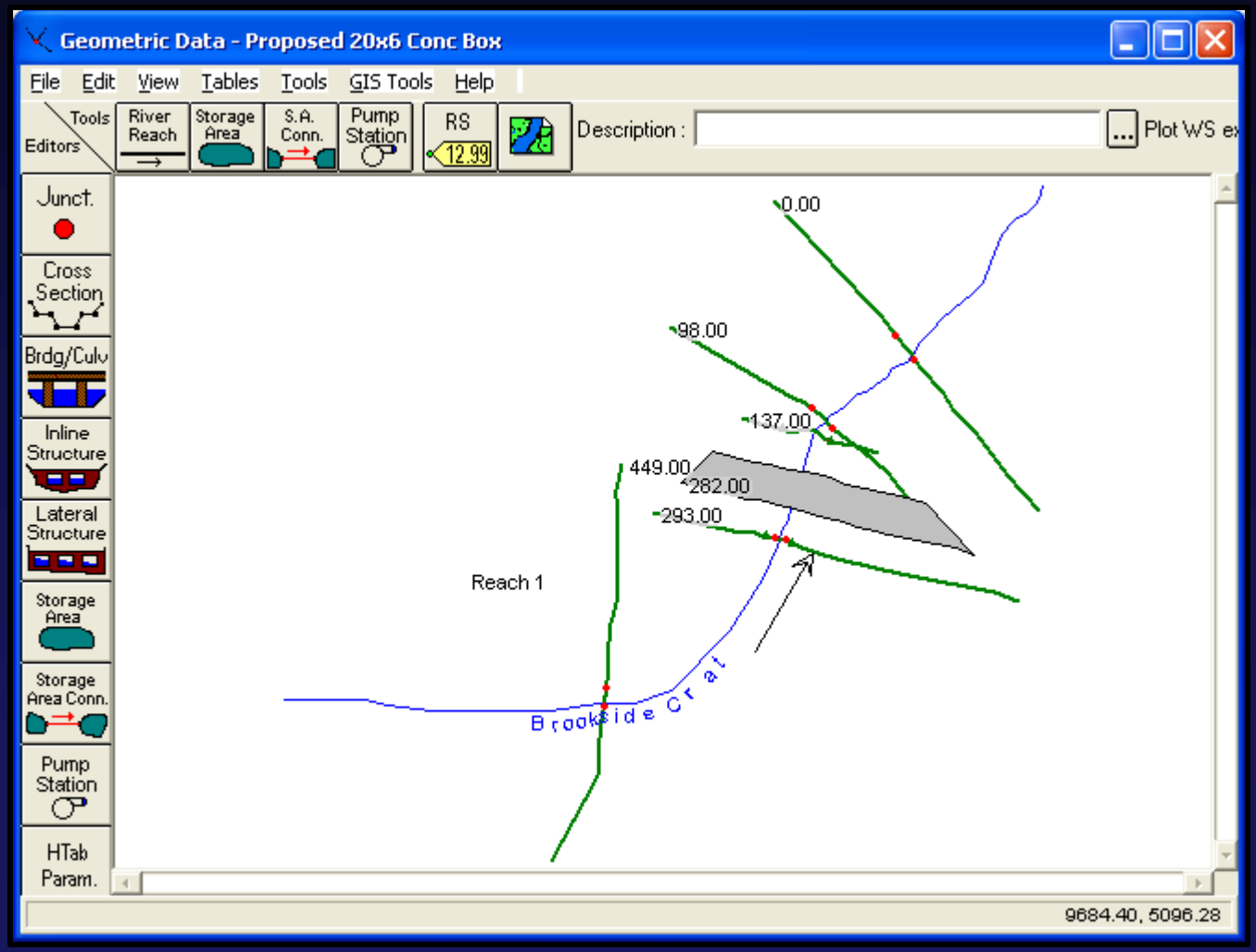
Hydraulic modeling to verify capacity

- 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

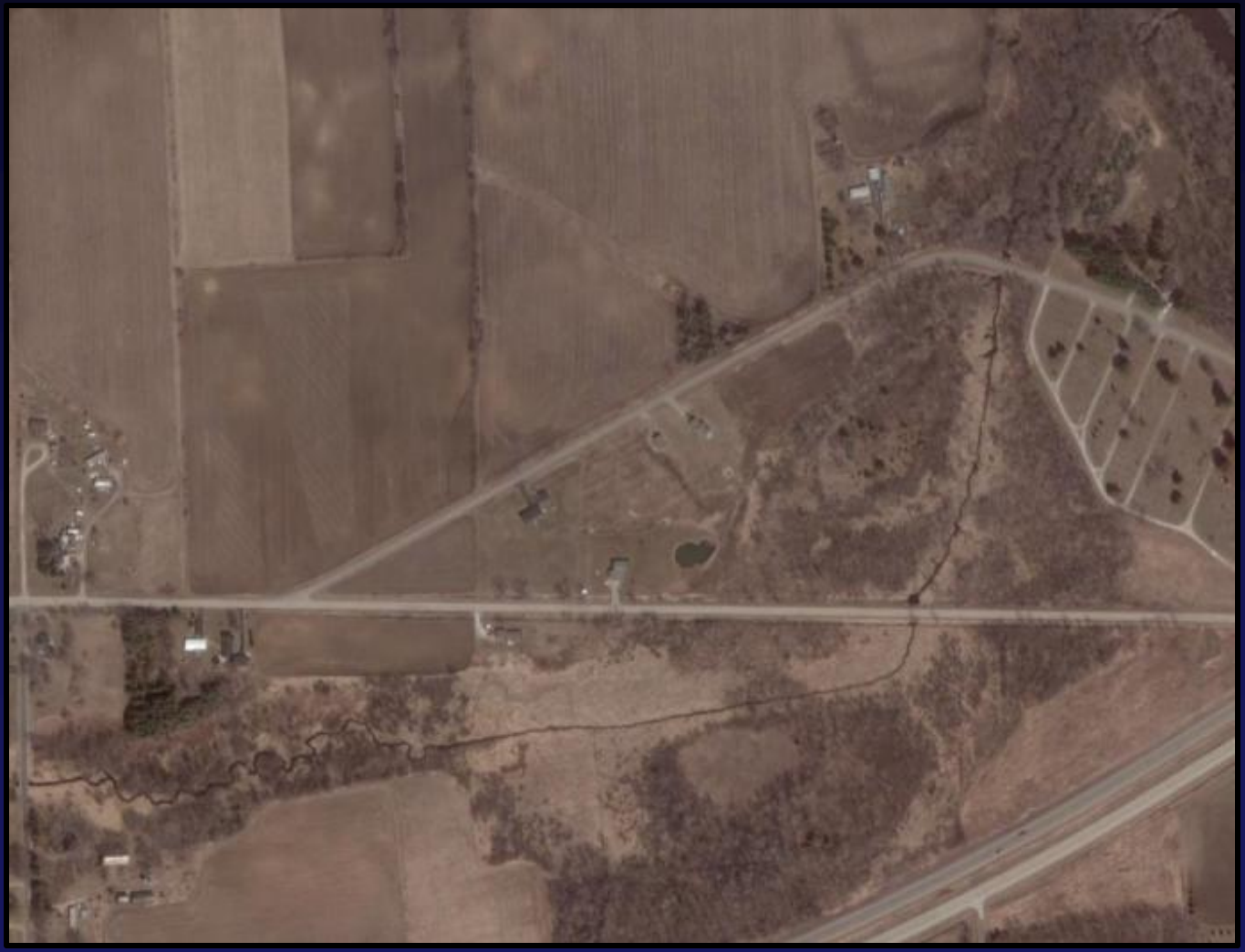
Culvert size and bankfull width

- 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

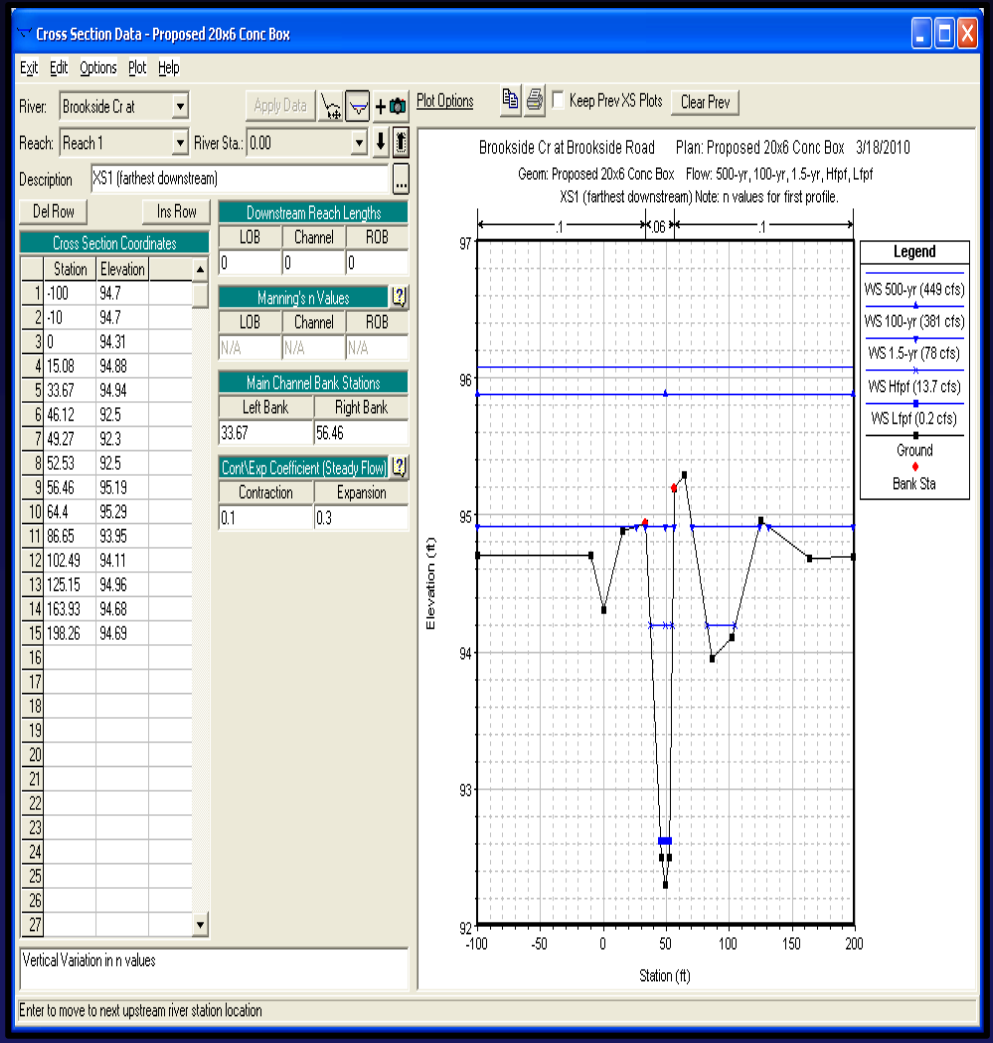
HEC-RAS geometric data



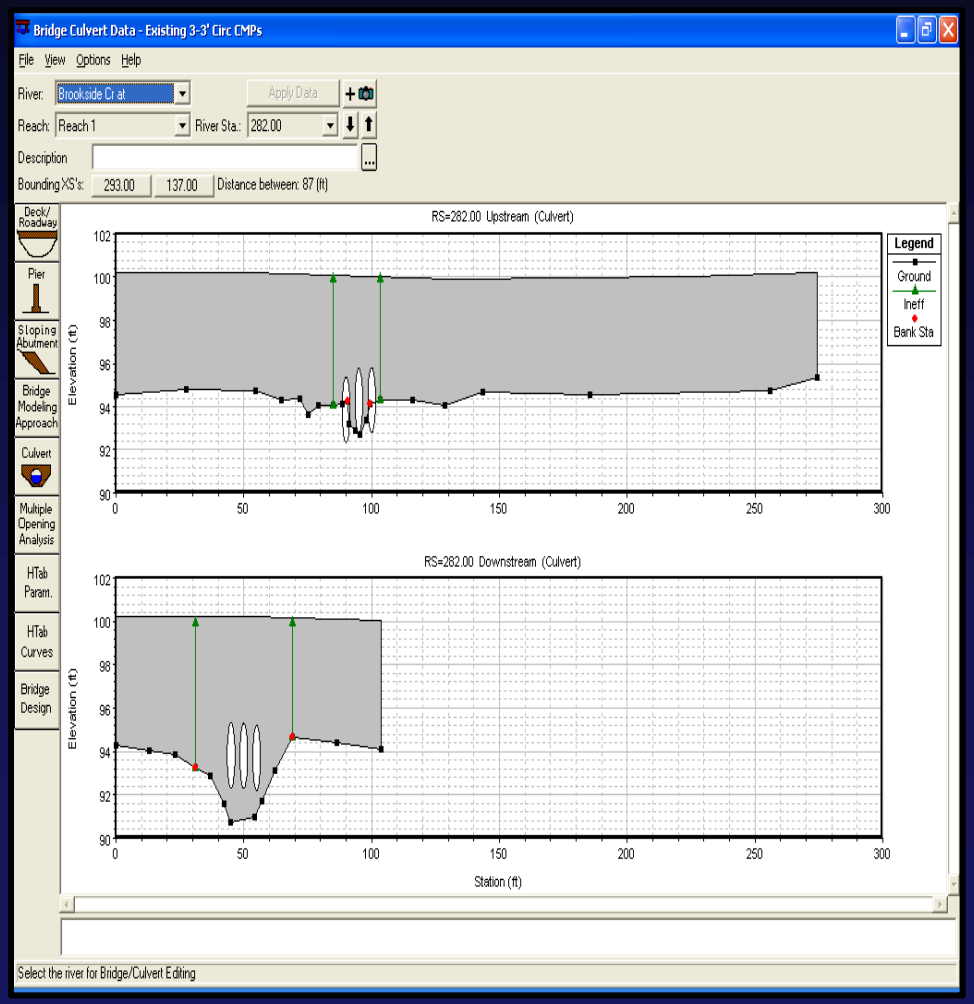
HEC-RAS geometric data



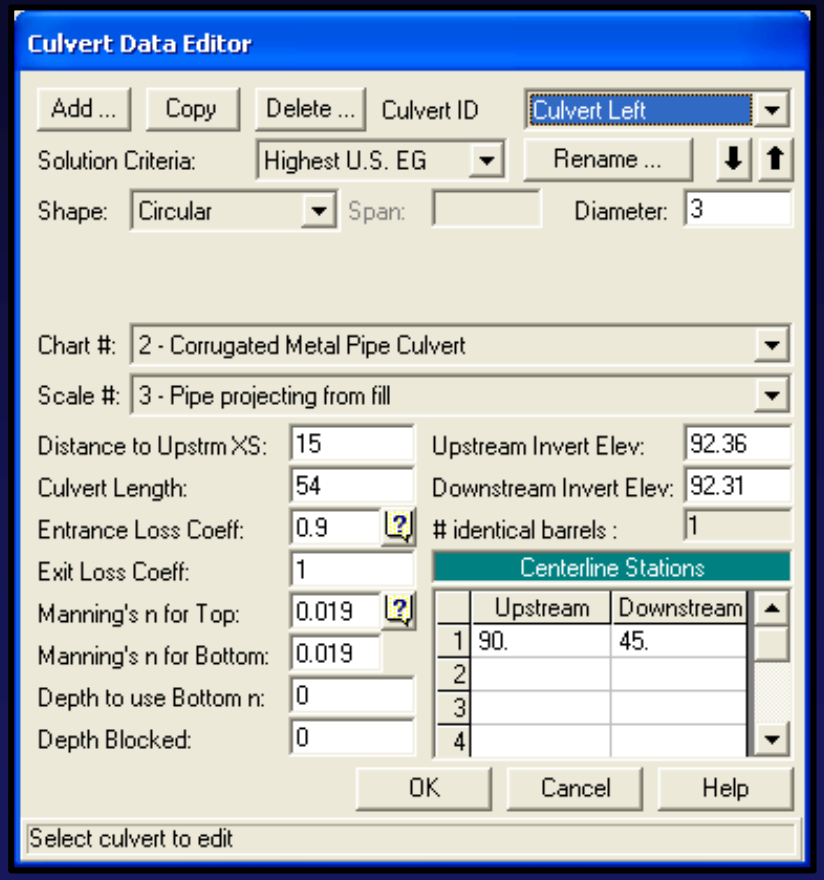
HEC-RAS x-sec editor



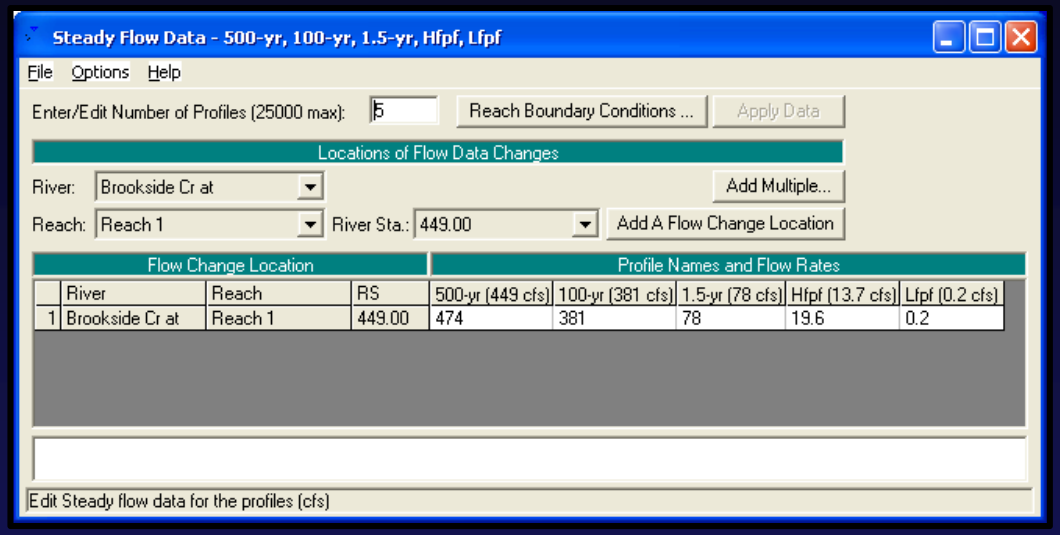
HEC-RAS bridge/culvert editor

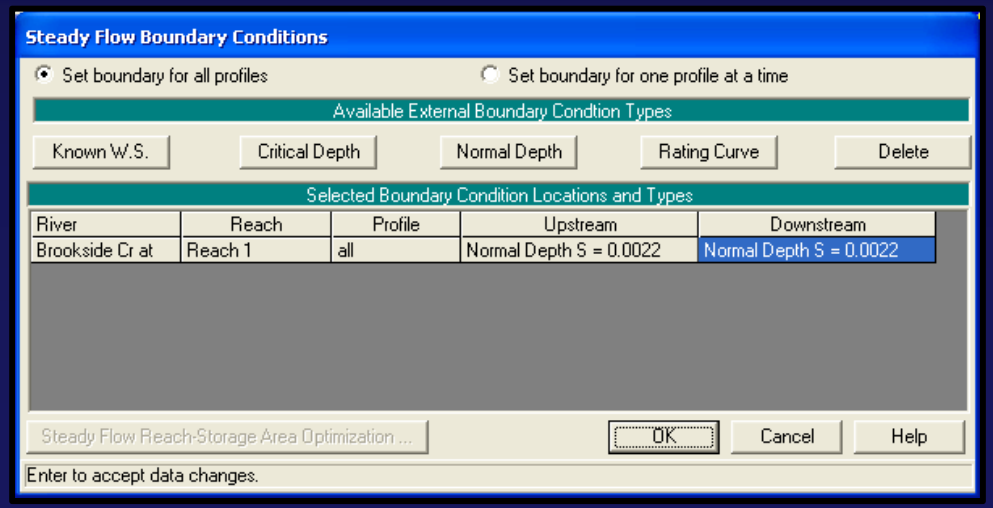


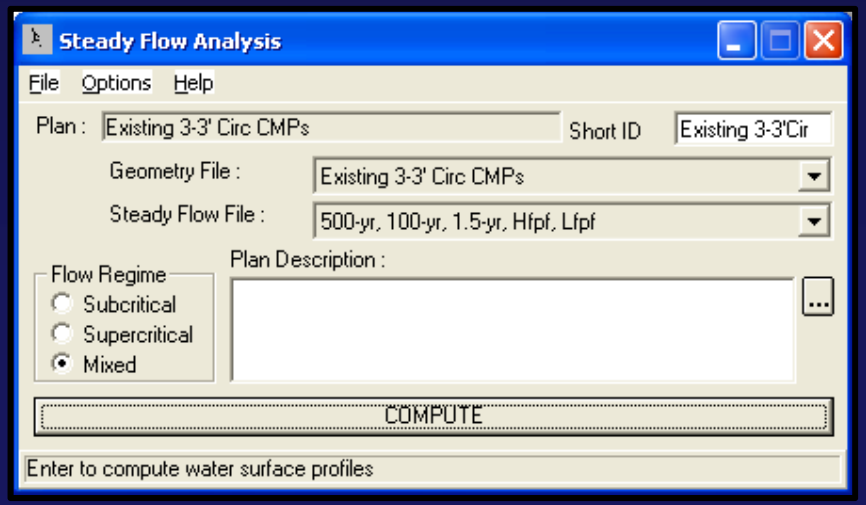
HEC-RAS culvert editor



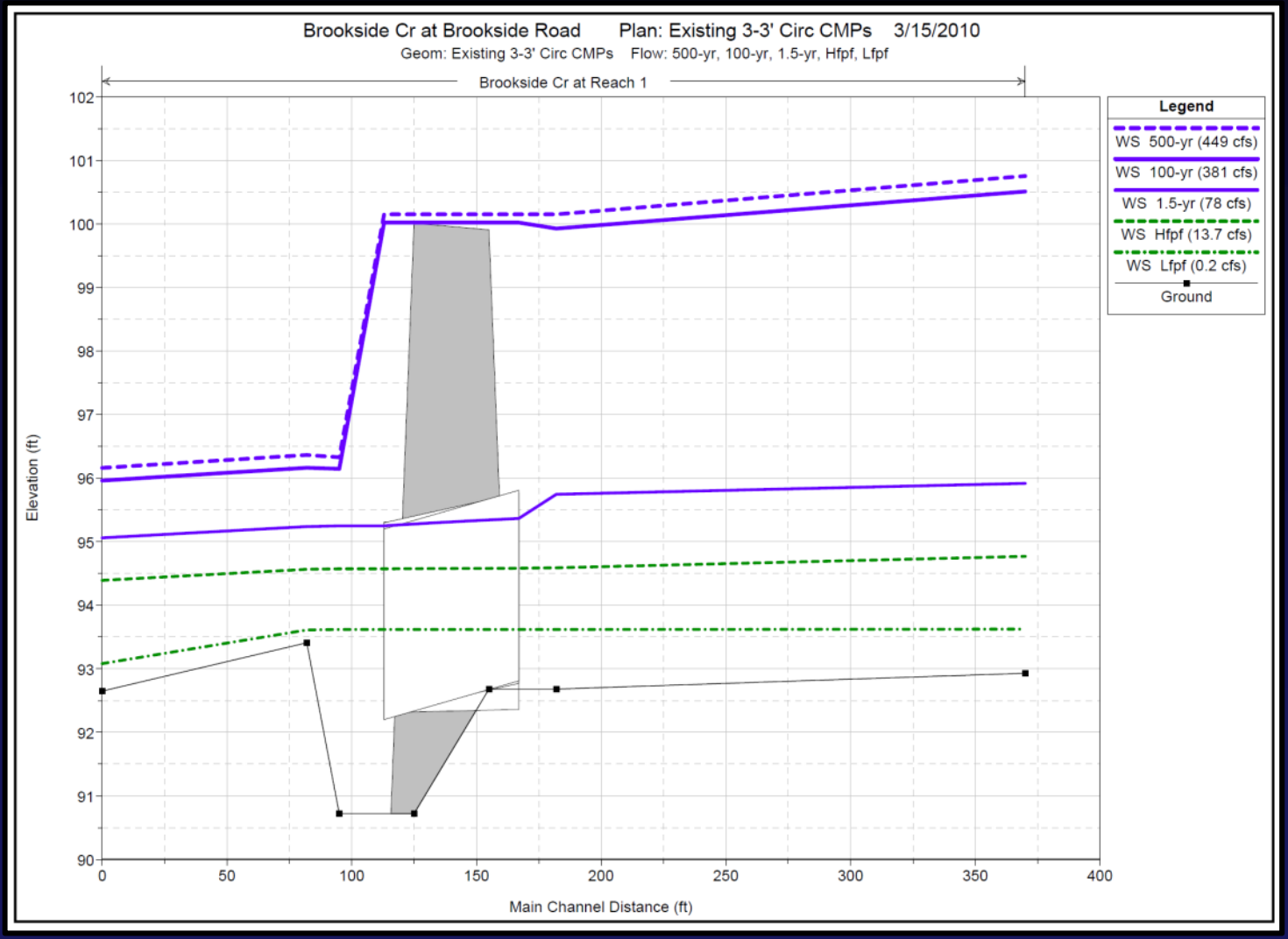
HEC-RAS flows and models



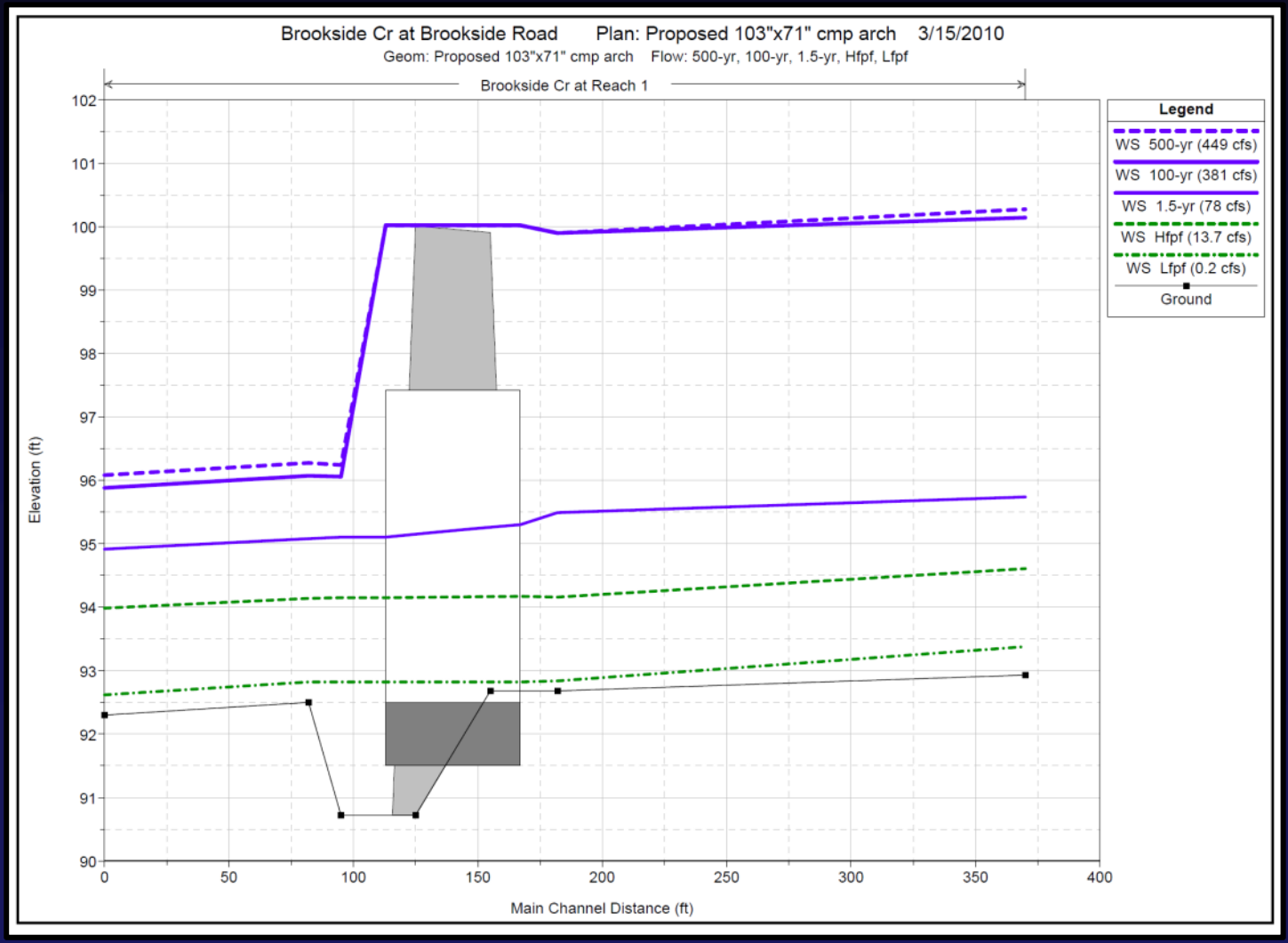




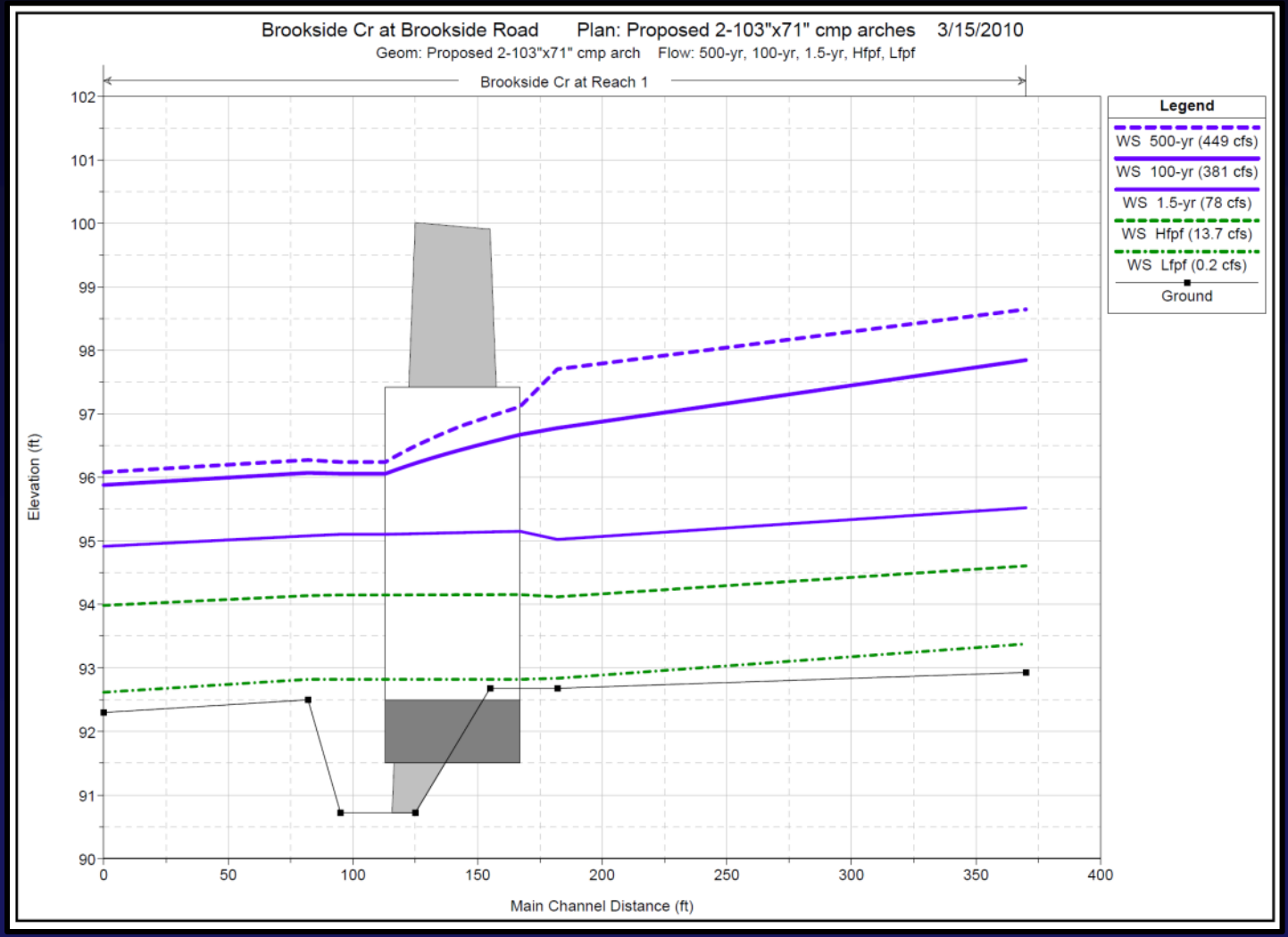
Existing 3-36” circular CMP profile



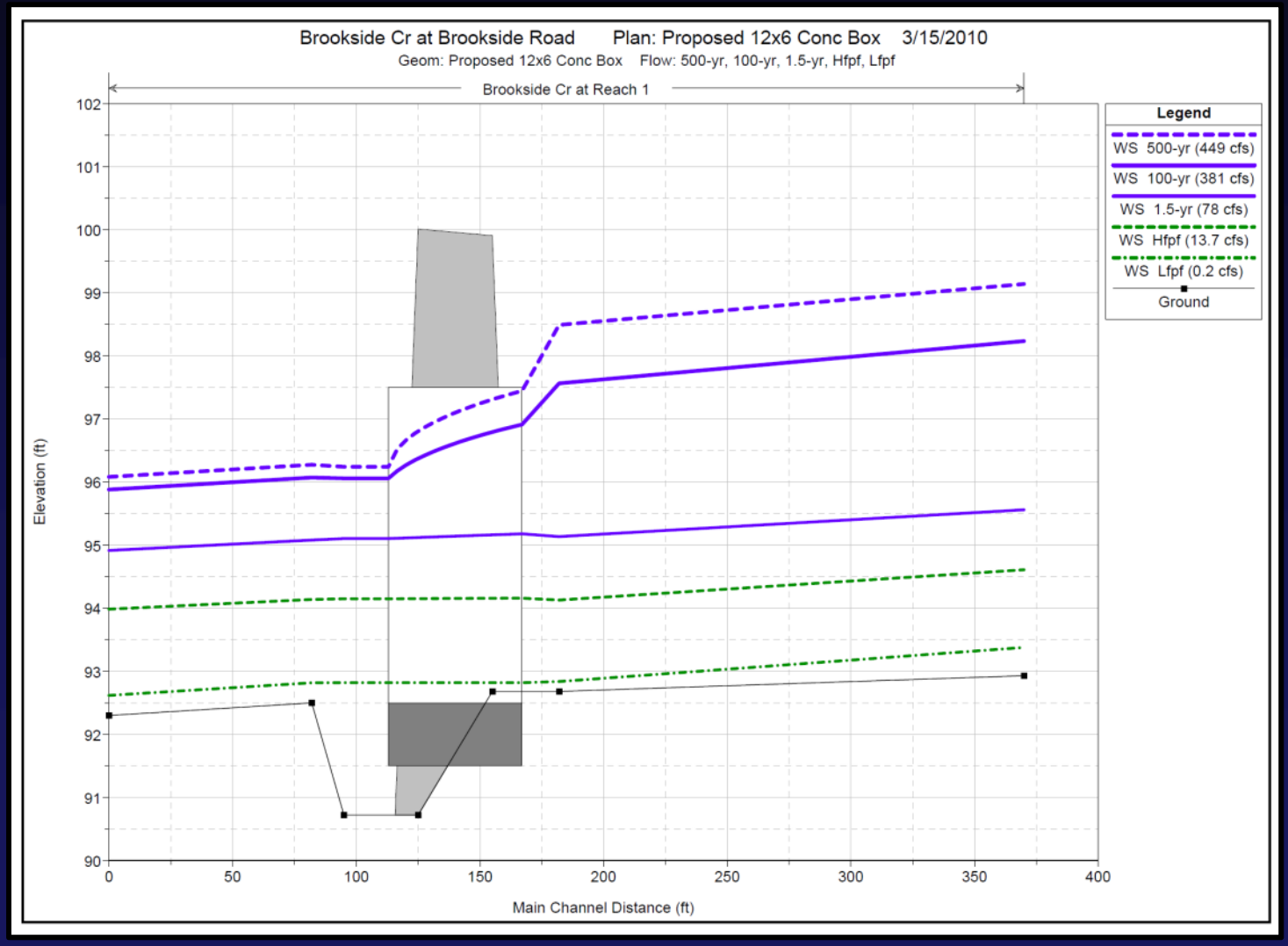
103”x71” CMP profile



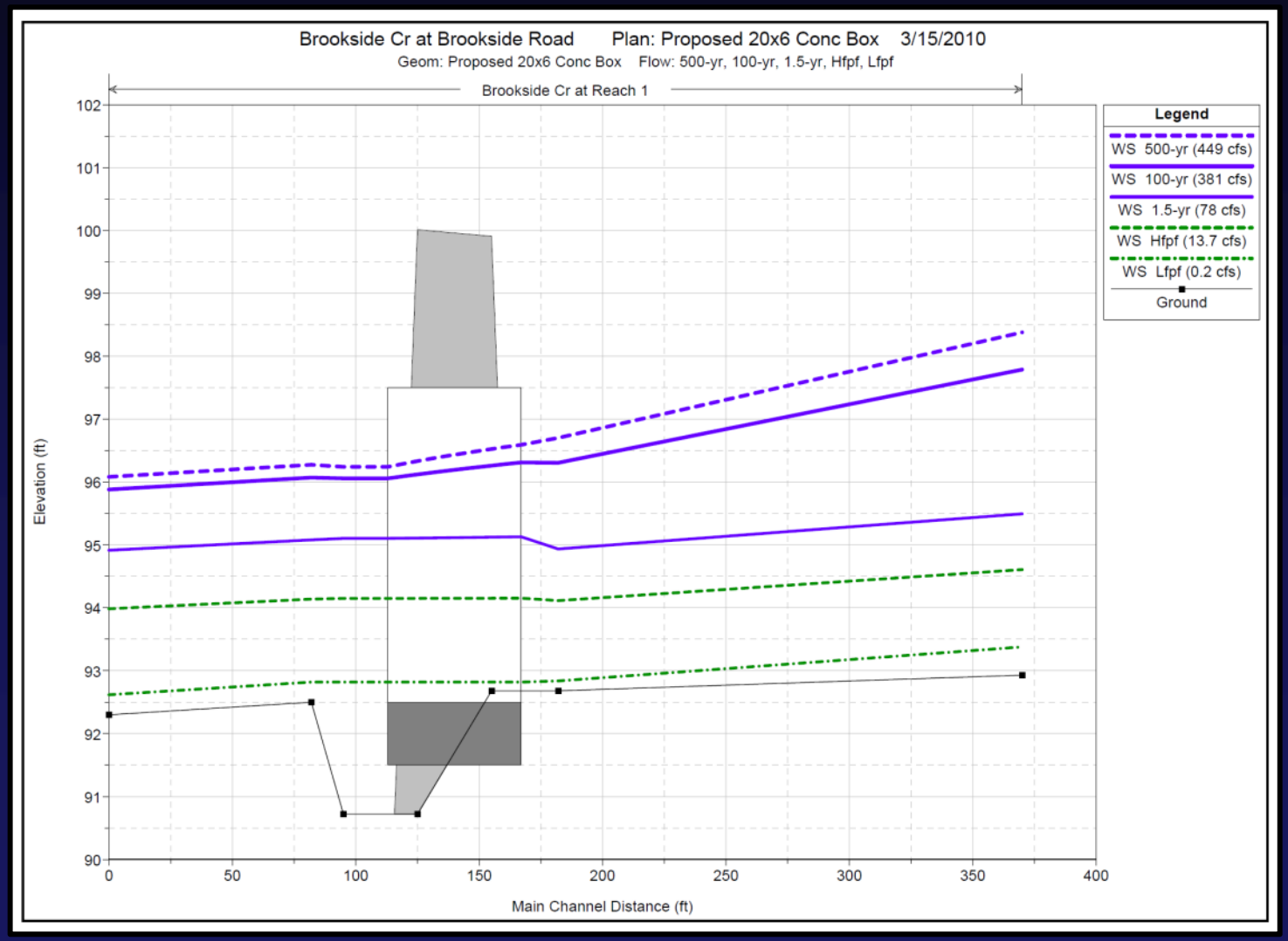
2-103”x71” CMP profile



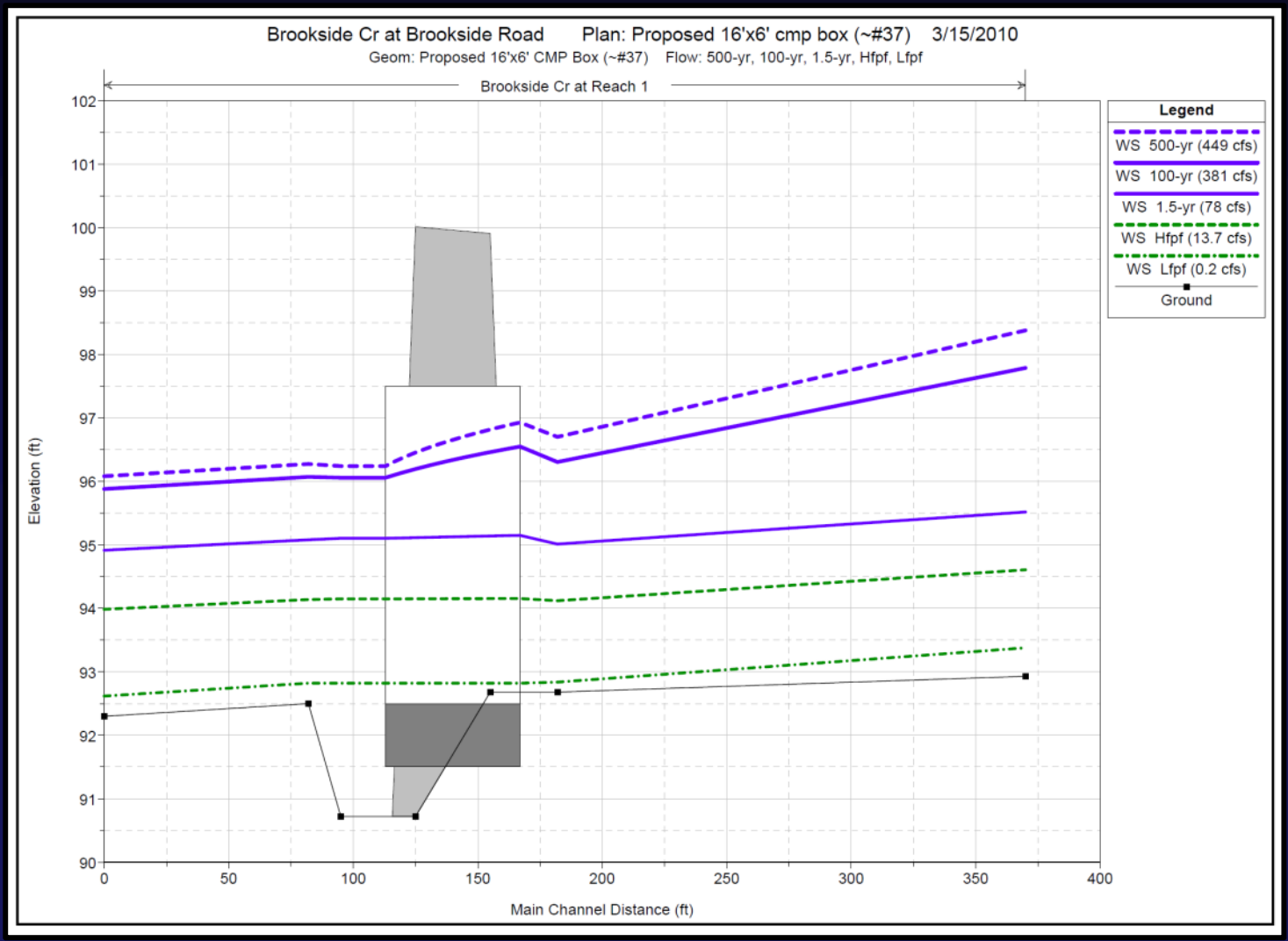
12’x6’ concrete box



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

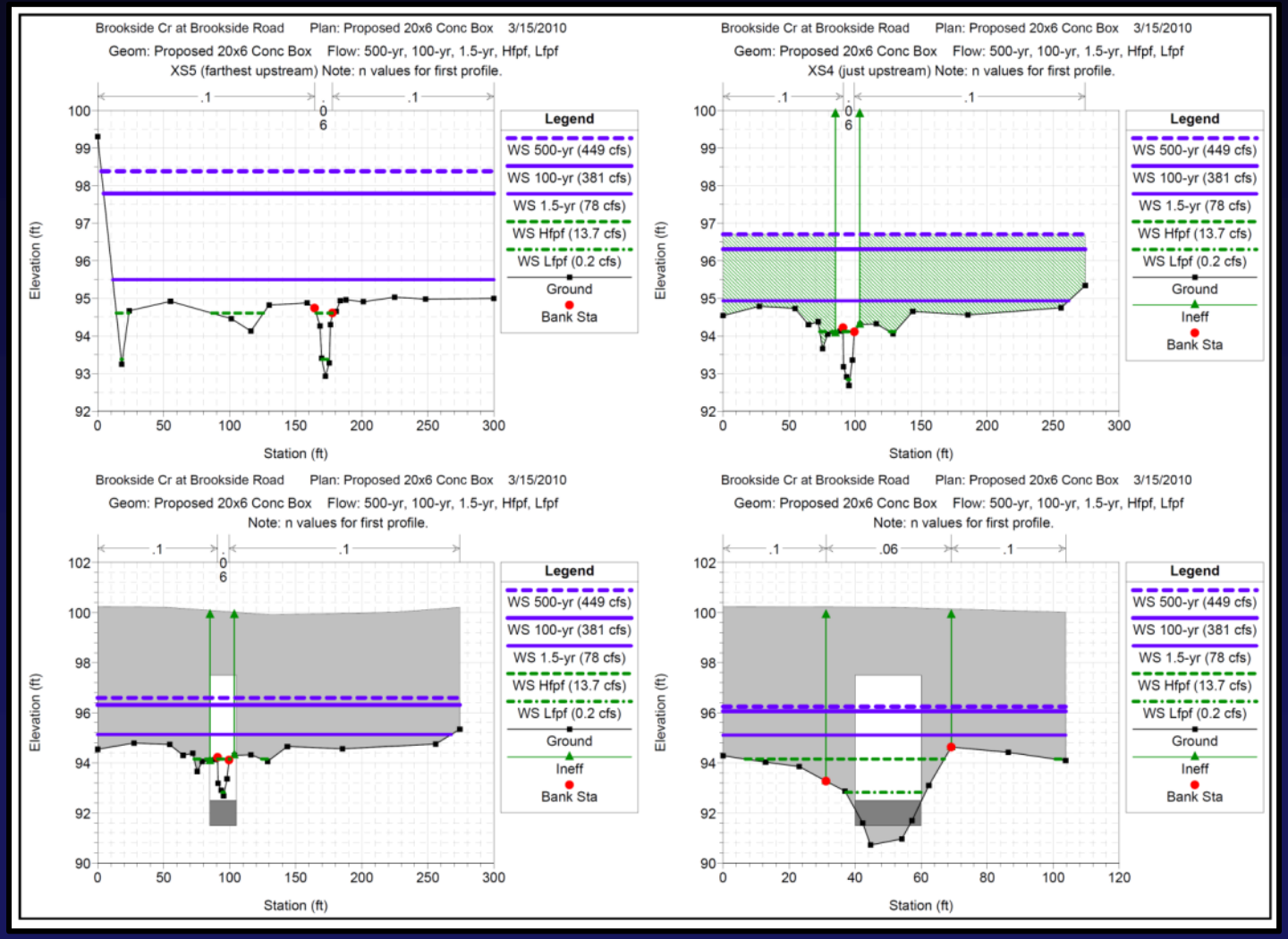
Reach	River Sta	Profile	E.G. US.	W.S. US.	E.G. IC	E.G. OC	Min El Weir Flow	Q Culv Group	Q Weir	Delta WS	Culv Vel US	Culv Vel DS
			(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(ft)	(ft/s)	(ft/s)
Reach 1	282.00 Culvert #1	500-yr (449 cfs)	97.37	96.70	97.12	97.37	100.02	474.00		0.46	5.79	6.33
Reach 1	282.00 Culvert #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	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)	
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



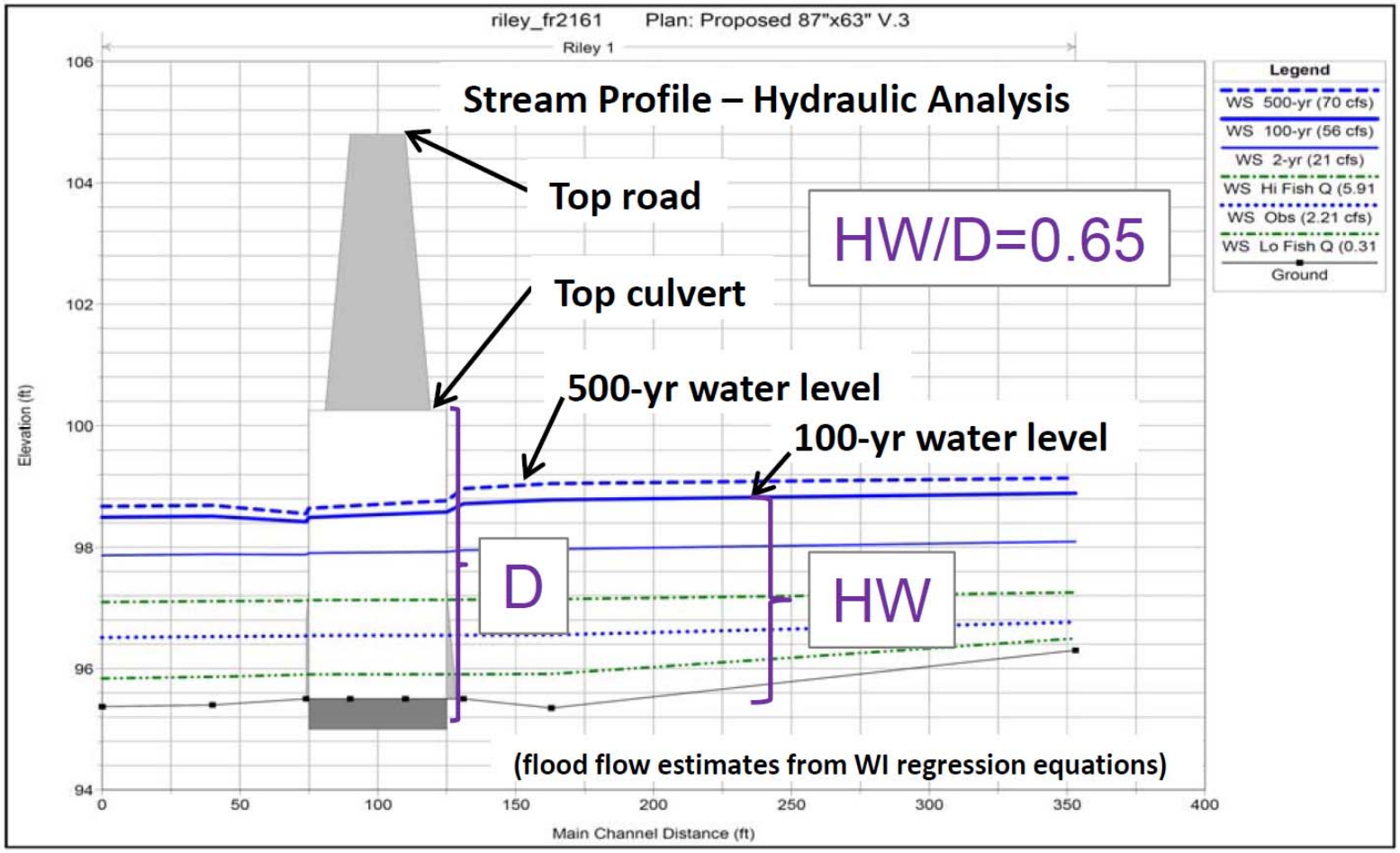
Brookside Cr. HEC-RAS summary

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

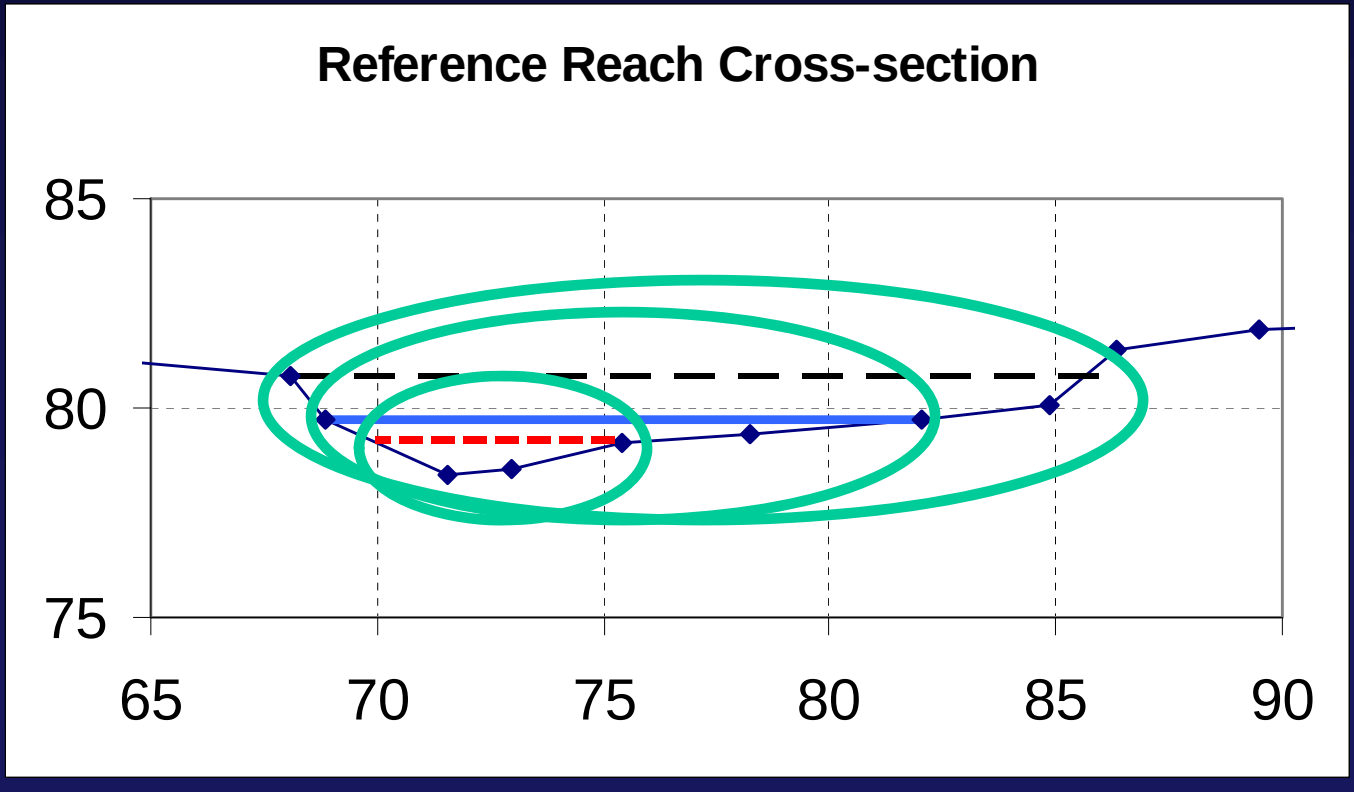


In N WI, many BFW culverts pass the Q_{100} with a minor head increase and headwater below the top of culvert.

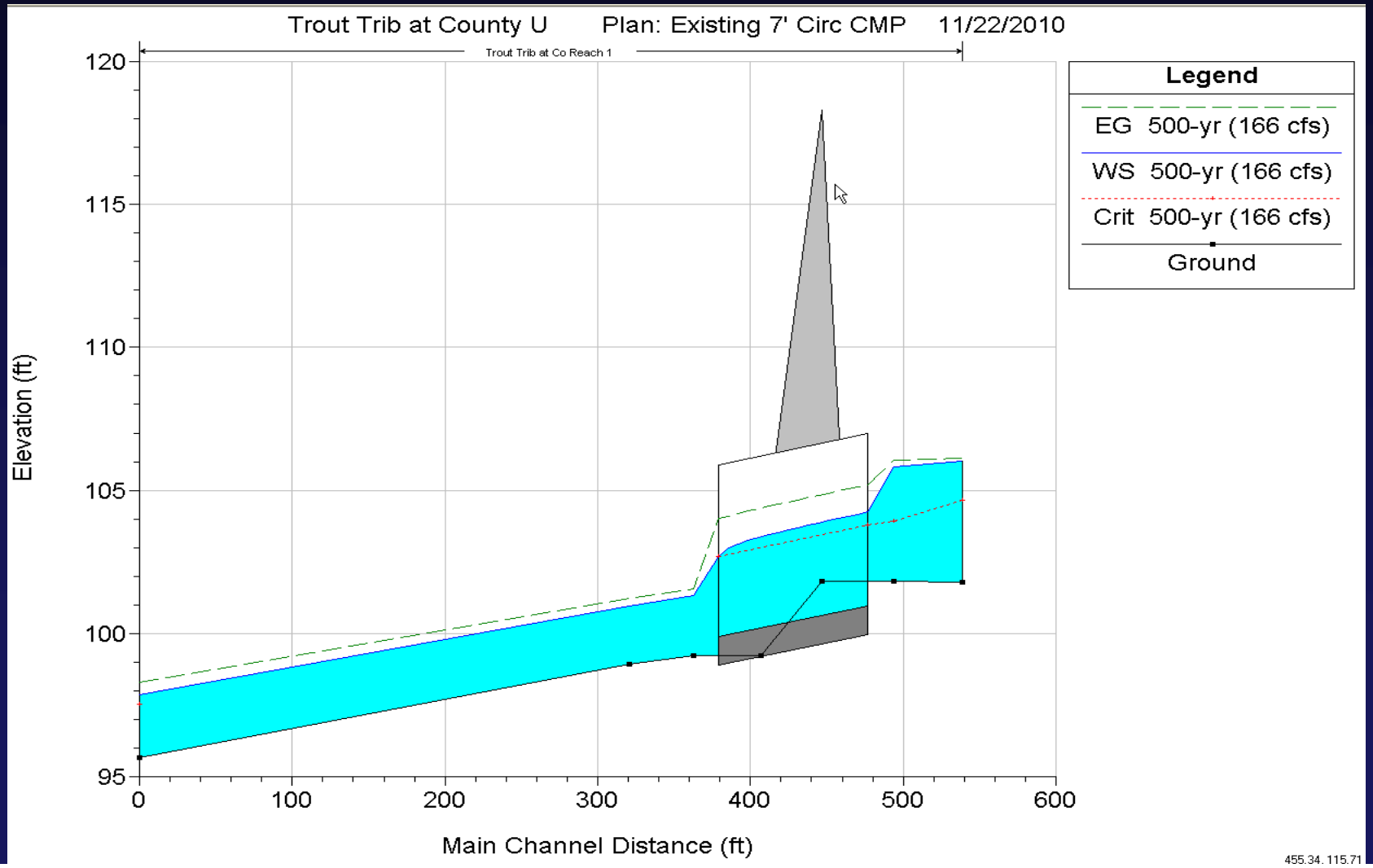
Stream simulation structure design

Stream simulation culvert width

- First estimate: Span channel and banks
- Hydraulic capacity



HEC-RAS profile plot

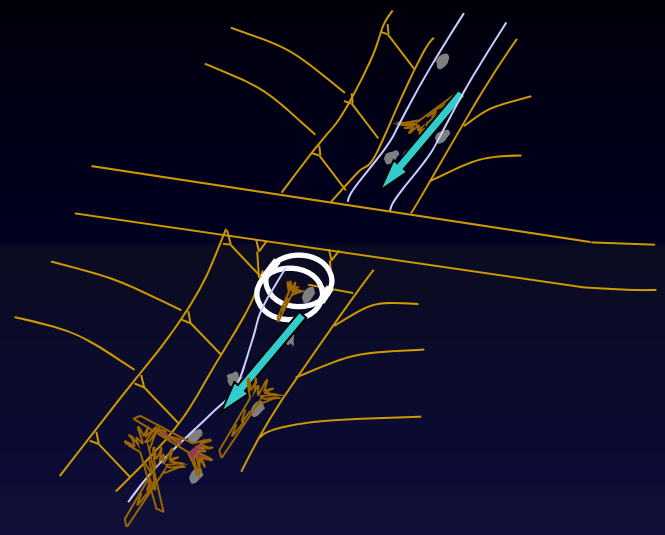


Stream simulation culvert width

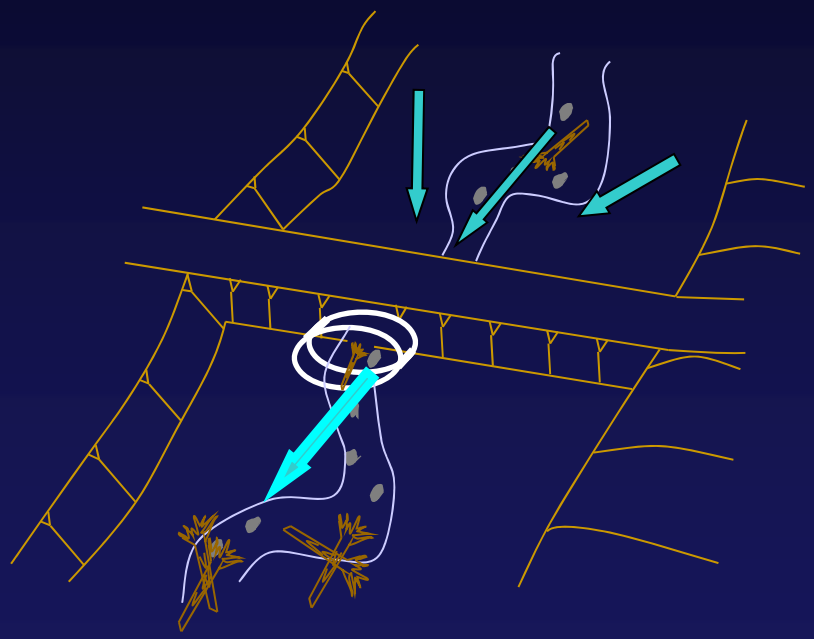
Some benefits of structures wider than bankfull width:

- 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.

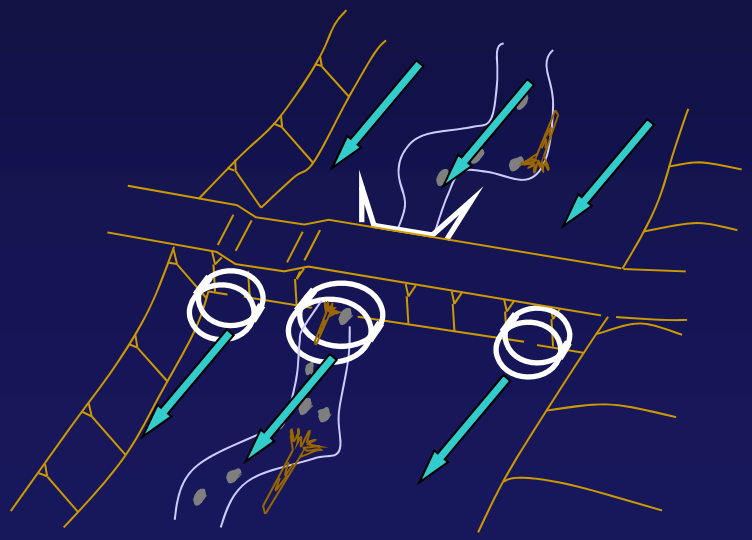
Stream simulation culvert width



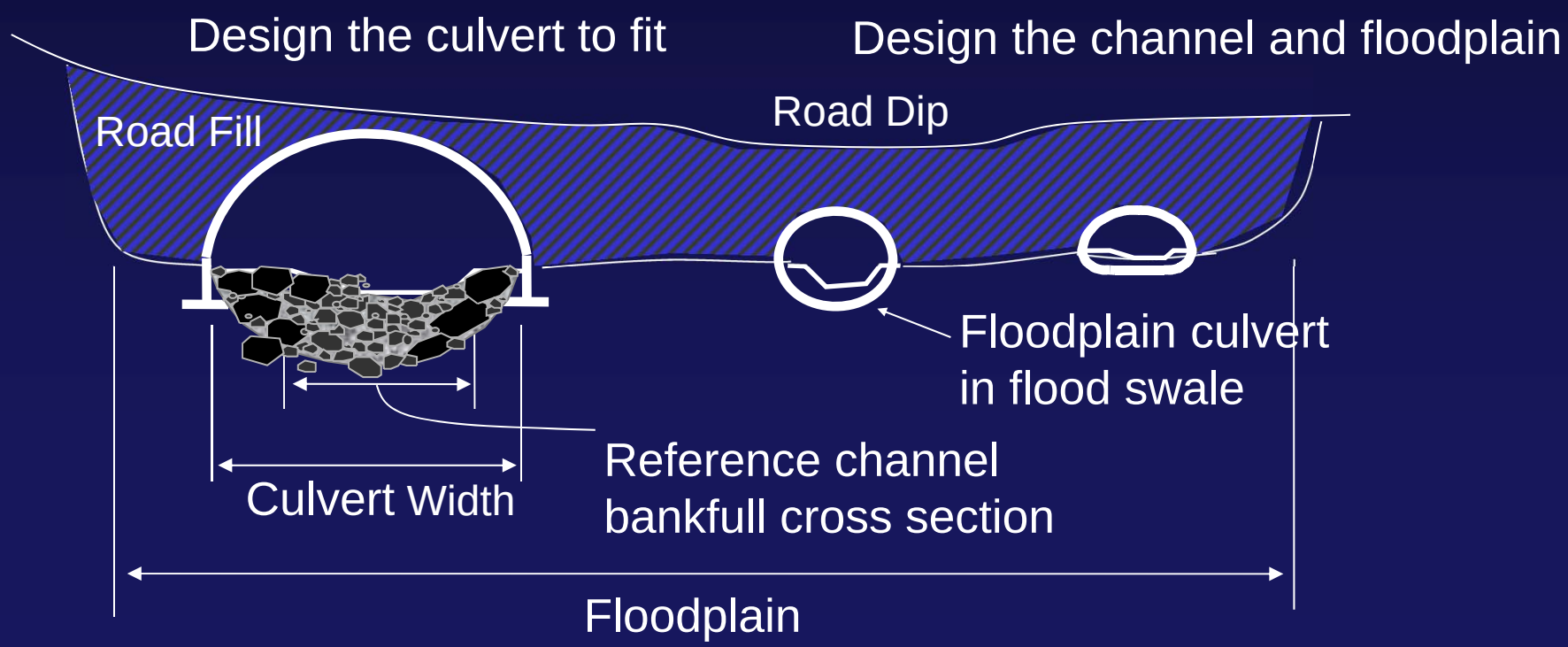
a. Confined



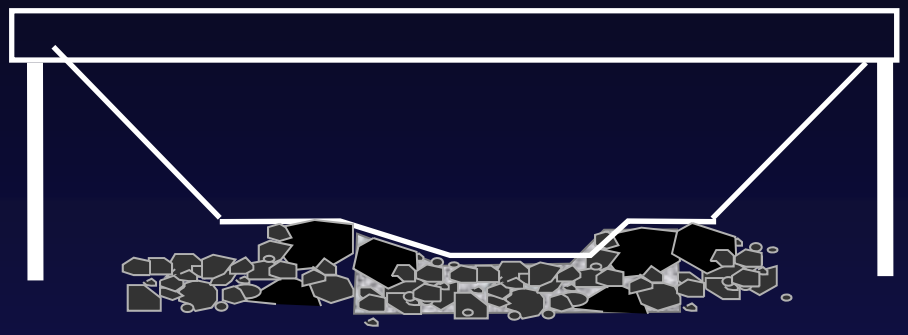
b. Unconfined
with wider culvert



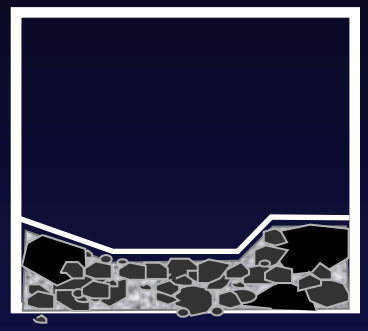
c. Unconfined
with floodplain culverts


Design the culvert to fit
Design the channel and floodplain
Road Fill
Road Dip
Floodplain culvert
in flood swale
Reference channel
bankfull cross section
Culvert Width
Floodplain

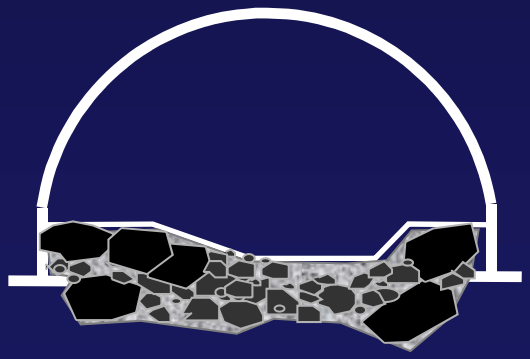
Structure types



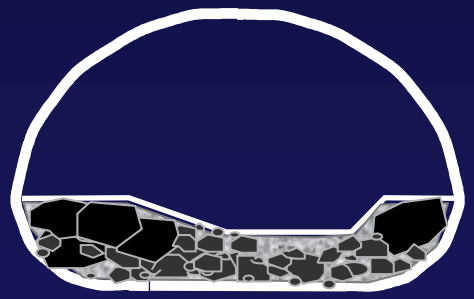
Bridge



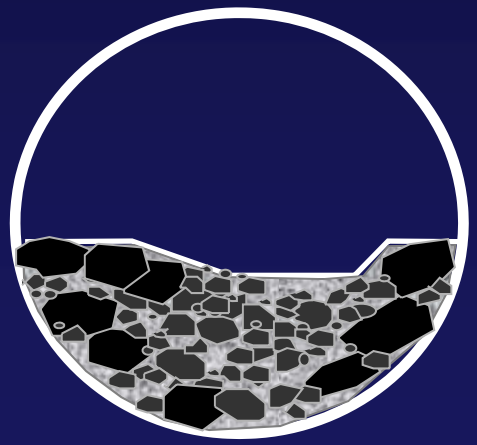
Box



Bottomless Arch

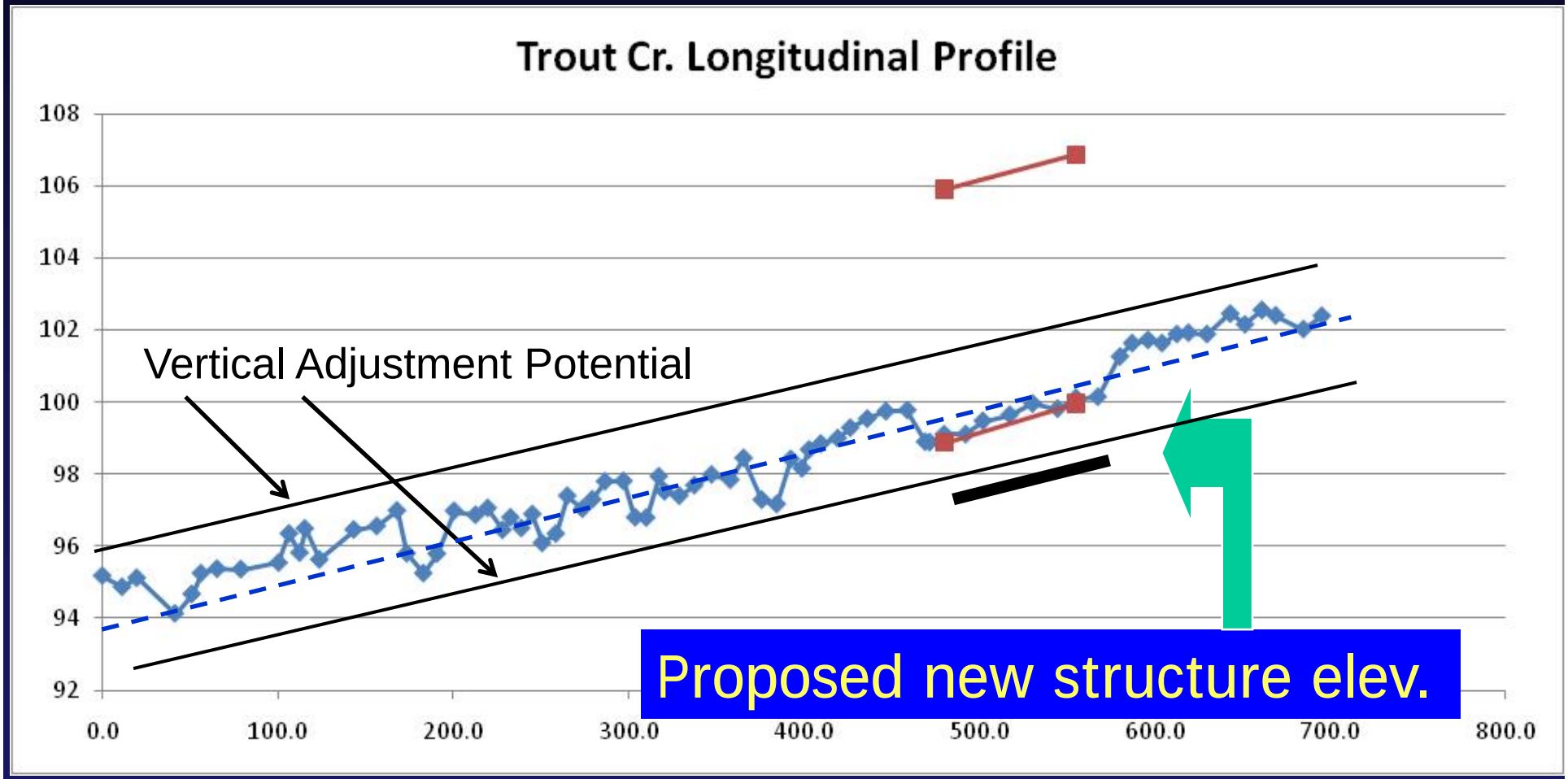


Pipe Arch



Embedded Round

Elevation


Trout Cr. Longitudinal Profile
108
106
104
102
100
98
96
94
92
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
Vertical Adjustment Potential
Proposed new structure elev.

Questions?

Credits: Gary Larson, The Far Side