

HYDROLOGY REPORT

Rocky Stream Bridge carries Route 9 over Rocky Stream, in the town of Crawford, Maine. Rocky Stream starts in T19 ED BPP, and flows north until it meets with the East Machias River approximately half a mile downstream of the bridge location.

The drainage basin characteristics for the Rocky Stream Bridge are based on peak flow estimates provided by the MainedOT Environmental Office. Peak flows are calculated using the 1999 USGS full regression equations. No other flow data is available.

SUMMARY

Drainage Area	7.40	mi ²
April Avg. Flow	29.62	ft ³ /s
August Avg. Flow	1.43	ft ³ /s
Ordinary High (Q _{1.1})	83.8	ft ³ /s
10-year flood (Q ₁₀)	319.8	ft ³ /s
25-year flood (Q ₂₅)	420.2	ft ³ /s
Design Discharge (Q ₅₀)	480.2	ft ³ /s
Check Discharge (Q ₁₀₀)	562.8	ft ³ /s
Scour Discharge (Q ₅₀₀)	743.3	ft ³ /s

Reported by: Benjamin Bartlett

Date: January 23, 2018

Note: All elevations based on North American Vertical Datum (NAVD) of 1988.

HYDRAULIC REPORT

EXISTING CULVERT

The existing culvert was analyzed using the HY-8 program version 7.30. No nearby structures exist to affect the tailwater. The Rocky Stream joins the East Machias River downstream approximately half a mile, but is assumed to not affect the tailwater. The tailwater conditions are modeled as an irregular channel located downstream from the outlet. Based on the USGS topographic map and existing plans, the stream slope is approximately 23 feet of rise over one mile (5280 feet) of length, or 0.44%.

Using the flows calculated with the regression equations by the MaineDOT Environmental Office and the dimensions of the culvert, the headwater to culvert depth ratio (H_w/D) was calculated at Q50 and Q100. These values are 0.77 for Q50 and 0.86 for Q100. Both are below the 0.9 used for design according to the Bridge Design Guide. At Q100 the freeboard to edge of the shoulder is approximately 4.75', almost 5 times the 1' minimum required in the BDG. The HY-8 model shows overtopping around 992 cfs, about 250 cfs greater than Q500. According to Region 4 engineers, there is no known flooding of the road at this location. Based on inspection photos, typical water depths inside the culvert range from several inches to 2 feet. Survey data from February 2016 show approximately 3 feet of water in the culvert.

Bankfull width was determined by MaineDOT Environmental staff to be 20'. This would make 1.2 bankfull width 24'.

REPLACEMENT AT 1.2 BANKFULL WIDTH

Concrete Box

Multiple precast concrete box culvert rises were analyzed for hydraulic capacity, including an 8' rise and a 9' rise. To maintain a natural streambed surface for fish passage, the boxes will be embedded 2' below streambed to allow for special fill and rocks to be placed at the bottom of the box. For environmental purposes, streambanks will be added inside the box. The tailwater was modeled using roughly the same irregular channel used to evaluate the existing culvert. The only difference was the low point in the channel was raised to an elevation of 117' to reflect the riprap apron at the outlet.

The first size analyzed was a 24' span by 8' rise by 88' long box culvert. The box was embedded 2', with the invert elevations at 115.75' for the inlet and 115.5' for the outlet. This puts the culvert at a slope of approximately 0.3%. The H_w/D for Q50 is 0.82. This is below the maximum 0.9 required in the Bridge Design Guide. At Q100 the H_w/D is 0.9. Outlet velocities at Q50 and Q100 were greatly reduced over the existing. The velocity at Q50 dropped 4.42 ft/s from 13.05 to 8.63, and the velocity at Q100 dropped 4.4 ft/s from 13.52 to 9.12.

The next size that was analyzed was a 24' span by 9' rise box. This option was analyzed with the same embedment and invert elevations as the 8' rise box. The Hw/D at Q50 for the 9' rise is 0.7. This value is below the recommended value in the BDG. At Q100 the Hw/D is 0.77. The outlet velocity at Q50 dropped 4.41 ft/s from 13.05 to 8.64, and the velocity at Q100 dropped 4.43 ft/s from 13.52 to 9.09.

Aluminum Box

The final option that was analyzed for hydraulic capacity was a 24'-7" span by 9'-9" rise aluminum box culvert. This option was analyzed with the same embedment and invert elevations as the concrete box culverts. This option also was analyzed with the streambanks inside the box. The Hw/D at Q50 for this option is 0.66. This value is below the recommended value in the BDG. At Q100 the Hw/D is 0.72. The outlet velocities also dropped with this option, dropping from 13.05 ft/s to 8.91 ft/s at Q50 and 13.52 ft/s to 9.39 ft/s at Q100.

SUMMARY

All the alternatives analyzed are hydraulically feasible. The headwater elevations for the two different size concrete box culverts are approximately the same, which shows that the rise isn't much of a factor with such a large span. The headwater elevations for the aluminum culvert were slightly higher than that of the concrete box culverts. The proposed alternative will be chosen based on other factors, such as constructability, cover, and clearance. Refer to the Summary of Preliminary Design for additional information about the proposed alternatives.

SUMMARY

		Existing Structure	Recommended Structure	Concrete Box 24' by 9'	Aluminum Box 24'-7" by 9'-9"
		Pipe Arch 12'-10" by 8'-4"	Concrete Box 24' by 8'		
Total Area of Waterway Opening	ft ²	85	128	152	133
Headwater elevation @ Q _{1.1}	ft	120.3	119.7	119.7	119.7
Headwater elevation @ Q ₁₀	ft	123.1	121.7	121.7	121.9
Headwater elevation @ Q ₂₅	ft	123.9	122.3	122.3	122.5
Headwater elevation @ Q ₅₀	ft	124.4	122.7	122.7	122.9
Headwater elevation @ Q ₁₀₀	ft	125.1	123.1	123.1	123.4
Headwater elevation @ Q ₅₀₀	ft	126.8	124.1	124.1	124.4
Hw/D Ratio @ Q ₅₀	ft	0.77	0.82	0.70	0.66
Hw/D Ratio @ Q ₁₀₀	ft	0.86	0.9	0.77	0.72
Outlet Velocity @ Q _{1.1}	ft/s	7.6	5.4	5.4	5.6
Outlet Velocity @ Q ₁₀	ft/s	11.5	8.0	8.0	7.8
Outlet Velocity @ Q ₂₅	ft/s	12.4	8.3	8.3	8.5
Outlet Velocity @ Q ₅₀	ft/s	13.1	8.6	8.6	8.9
Outlet Velocity @ Q ₁₀₀	ft/s	13.5	9.1	9.1	9.4
Outlet Velocity @ Q ₅₀₀	ft/s	14.6	10.0	10.0	10.4

Reported by: Benjamin Bartlett
Date: March 7, 2018

Note: All elevations based on North American Vertical Datum (NAVD) of 1988.

Appendix E

Hydraulics Data

Project Name:	CRAWFORD, ROCKY STR BR #3620	PIN:	18949
Stream Name:	Rocky Brook	Town:	Crawford
Bridge Name:	Rocky Str Br	Bridge No.:	3620
Route No.:	ME9	USGS Quad:	
Analysis by:	CSH	Date:	1/21/2016

Peak Flow Calculations by USGS Regression Equations (Hodgkins, 1999 & Lombard/Hodgkins, 2015)

Enter data in blue cells only!

	km ²	mi ²	ac
A	19.17	7.40	4736.0
W	3.60	1.39	889.6
P _c	613069	4981585	
County	Washington		
pptA	44.2		
SG	0.00		
A (km ²)	19.17		
W (%)	18.78		

Enter data in [mi²]

Watershed Area
Wetlands area (by NWI)

watershed centroid (E, N; UTM 19N; meters)

choose county from drop-down menu

mean annual precipitation (inches; by look-up)

sand & gravel aquifer as decimal fraction of watershed A

Worksheet prepared by:

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Environmental Office
Maine Dept. Transportation
Augusta, ME 04333-0016
207-557-1052
Charles.Hebson@maine.gov

Conf Lvl

Ret Pd T (yr)	Peak Flow Estimate		
	Lower	Q _T (m ³ /s)	Upper
1.1		2.37	
2		4.74	
5		7.35	
10		9.06	
25		11.90	
50		13.60	
100		15.94	
500		21.05	

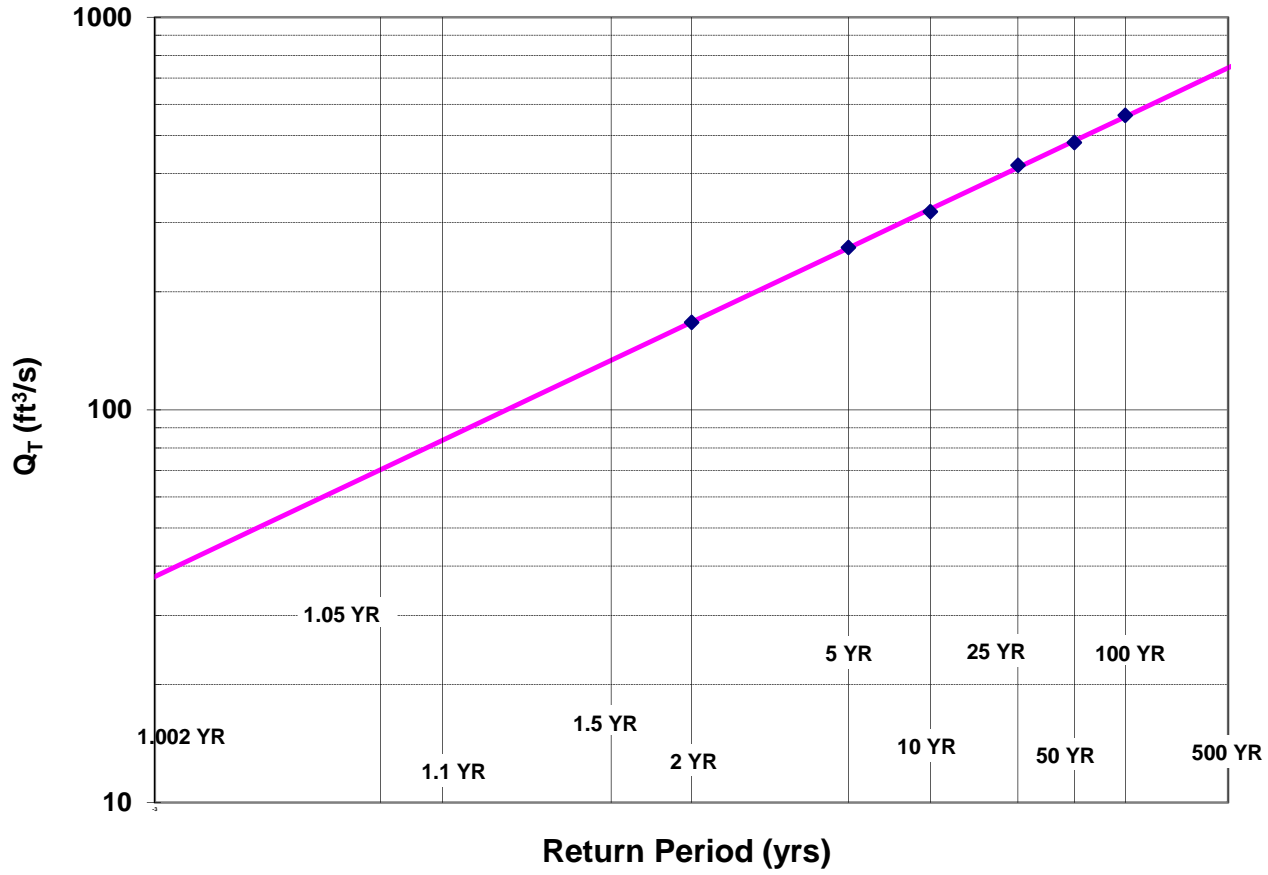
Q _T (ft ³ /s)
83.8
167.3
259.4
319.8
420.2
480.2
562.8
743.3

Reference:

Hodgkins, G., 1999.
Estimating the magnitude of peak flows for streams
in Maine for selected recurrence intervals
Water-Resources Investigations Report 99-4008
US Geological Survey, Augusta, Maine

$$Q_T = b \times A^a \times 10^{-wW}$$

Log-Normal Probability Plot



Project Name: CRAWFORD, ROCKY STR BR #3620
Stream Name: Rocky Brook
Bridge Name: Rocky Str Br
Route No.: ME9
Analysis by: CSH

PIN: 18949
Town: Crawford
Bridge No.: 3620
USGS Quad: 0
Date: 1/21/2016

DO NOT ENTER ANY DATA ON THIS PAGE; EVERYTHING IS CALCULATED

MAINE MONTHLY MEDIAN FLOWS BY USGS REGRESSION EQUATIONS (2004)

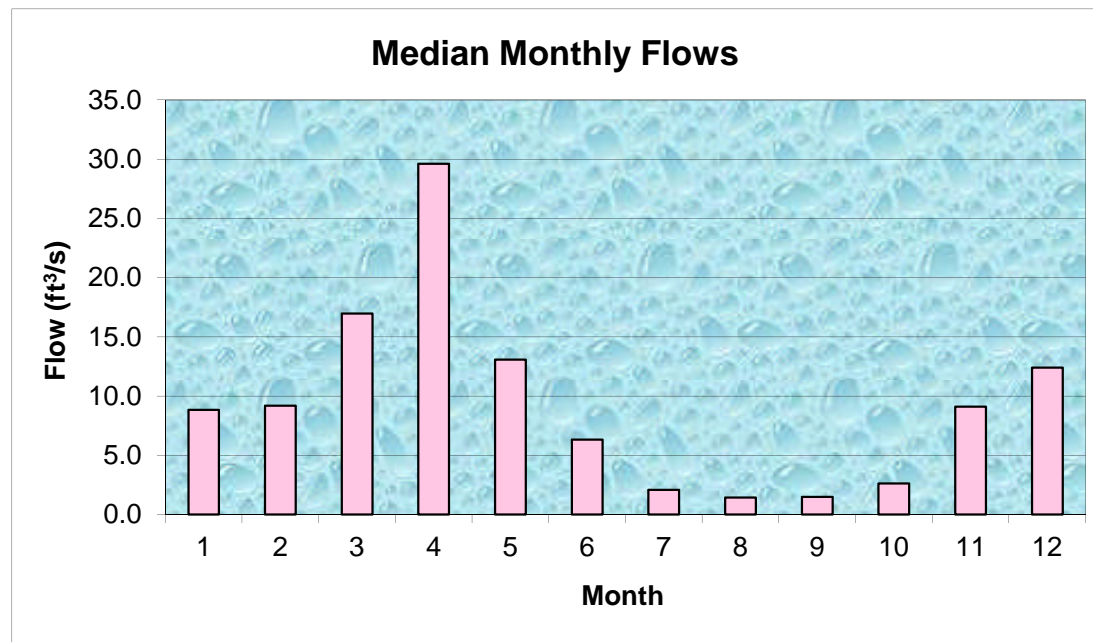
Worksheet prepared by:
 Charles S. Hebson, PE
 Chief Hydrologist
 Maine Dept. Transportation
 Augusta, ME 04333-0016
 207-624-3073
Charles.Hebson@maine.gov

Value	Variable	Explanation
7.400	A	Area (mi ²)
613069	P _c	Watershed centroid (E,N; UTM; Zone 19; meters)
46.35	DIST	Distance from Coastal reference line (mi)
44.2	pptA	Mean Annual Precipitation (inches)
0.00	SG	Sand & Gravel Aquifer (decimal fraction of watershed area)

Month	Q _{median} (ft ³ /s)	(m ³ /s)
Jan	8.85	0.2509
Feb	9.20	0.2608
Mar	16.98	0.4811
Apr	29.62	0.8393
May	13.07	0.3705
Jun	6.32	0.1792
Jul	2.09	0.0593
Aug	1.43	0.0405
Sep	1.51	0.0427
Oct	2.63	0.0747
Nov	9.12	0.2583
Dec	12.41	0.3517

Q _{bf}	42.4
ann avg	15.0
ann med	7.6
Q _{1.002}	37.6
Q _{1.01}	50.0
Q _{1.05}	70.4

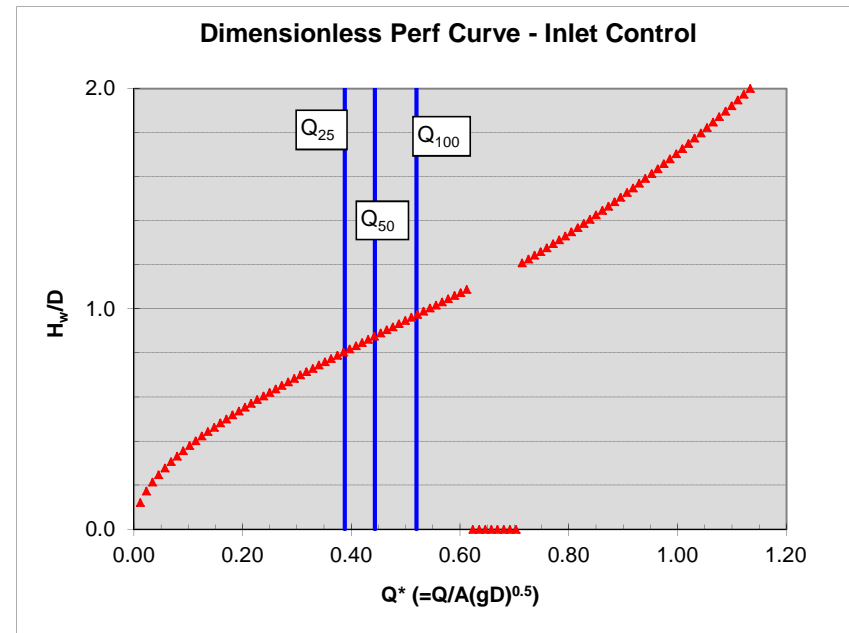
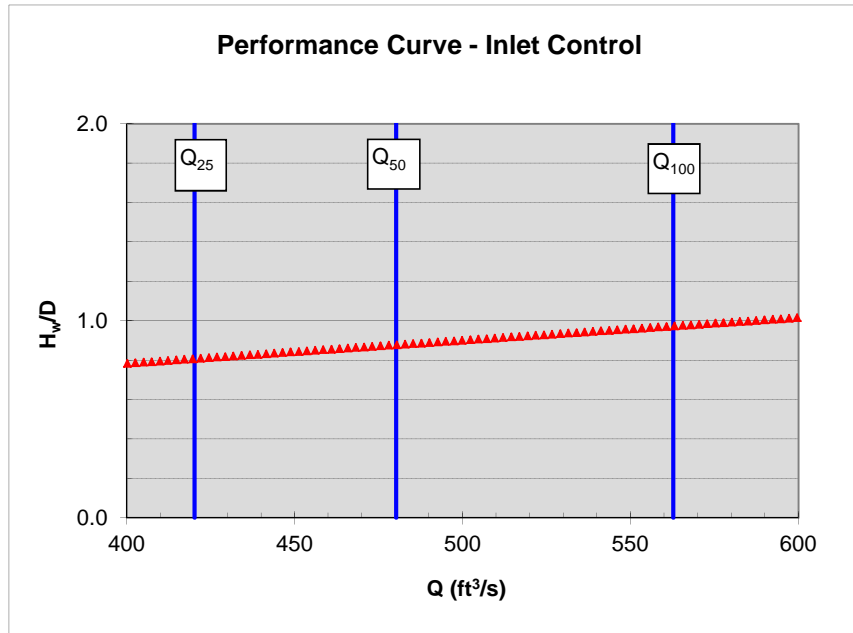
W _{bf}	21.7	estimated bankfull width
d _{bf}	1.7	
Q _{bf}	146.1	assume v = 4ft/s

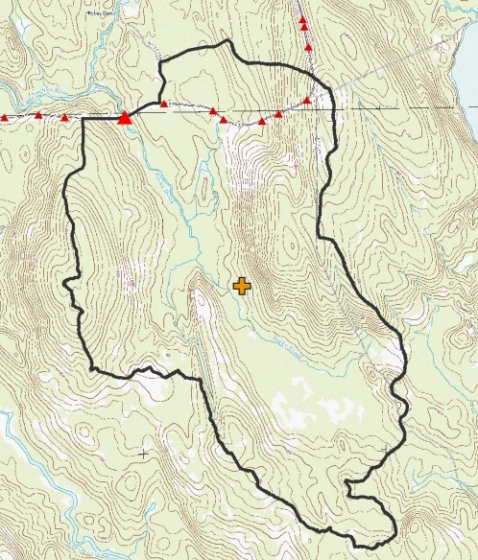


NOTE: This page is for preliminary sizing only.
Final design should be done with HY8 or HDS-5

Preliminary Culvert Sizing - Round Pipes

Type:	Circ RCP Proj	Q ₂₅	420.2	
D (ft)	9	Q ₅₀	480.2	trial D = 8.92
w (ft)	9 box width	Q ₁₀₀	562.8	
Slope (ft/ft)	0.02			
A (ft ²)	63.62			
g	32.2			





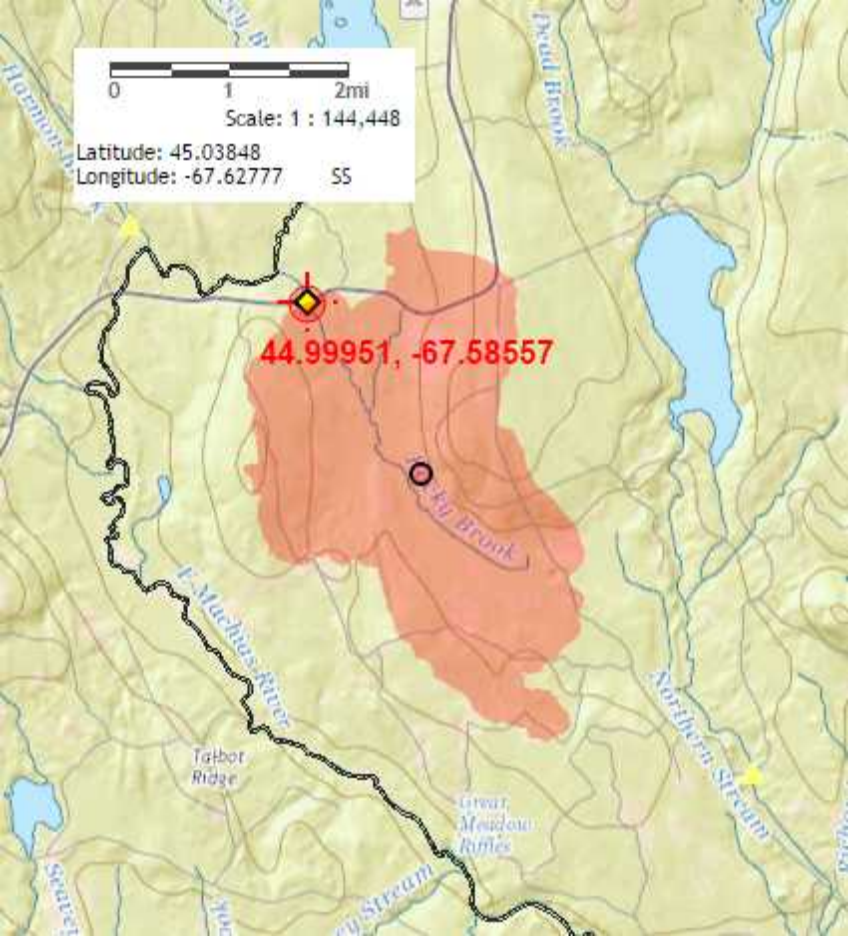


Scale: 1 : 144,448

Latitude: 45.03848

Longitude: -67.62777 SS

44.99951, -67.58557



HY-8 Culvert Analysis Report

Tailwater Channel Data - Existing

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0044

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	-48.60	123.00	0.1000
2	0.00	120.57	0.0600
3	34.67	119.56	0.0500
4	53.13	118.92	0.0500
5	75.00	118.07	0.0500
6	80.64	118.21	0.0500
7	94.57	115.38	0.0500
8	100.00	115.26	0.0500
9	104.41	115.15	0.0500
10	119.32	117.57	0.0500
11	125.00	117.78	0.0500
12	136.47	119.77	0.0500
13	150.00	122.62	0.0600
14	175.00	123.41	0.1000
15	200.00	123.61	0.0000

Roadway Data for Crossing: Existing

Roadway Profile Shape: Irregular Roadway Shape (coordinates)

Irregular Roadway Cross-Section:

Coord No.	Station (ft)	Elevation (ft)
0	0.00	130.10
1	25.00	130.08
2	50.00	130.09
3	75.00	130.13
4	100.00	130.20
5	125.00	130.32
6	150.00	130.48
7	175.00	130.64

Roadway Surface: Paved

Roadway Top Width: 44.00 ft

Site Data - Existing

Site Data Option: Culvert Invert Data
Inlet Station: 0.00 ft
Inlet Elevation: 117.93 ft
Outlet Station: 84.00 ft
Outlet Elevation: 115.44 ft
Number of Barrels: 1

Culvert Data Summary - Existing

Barrel Shape: Pipe Arch
Barrel Span: 154.40 in
Barrel Rise: 99.70 in
Barrel Material: Steel Structural Plate
Embedment: 0.00 in
Barrel Manning's n: 0.0330
Culvert Type: Straight
Inlet Configuration: Mitered
Inlet Depression: NONE

Straight Culvert
Inlet Elevation (invert): 117.93 ft, Outlet Elevation (invert): 115.44 ft
Culvert Length: 84.04 ft, Culvert Slope: 0.0296

Table 1 - Summary of Culvert Flows at Crossing: Existing

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Existing Discharge (cfs)	Roadway Discharge (cfs)	Iterations
120.27	Q1.1	83.80	83.80	0.00	1
121.47	Q2	167.30	167.30	0.00	1
122.51	Q5	259.40	259.40	0.00	1
123.06	Q10	319.80	319.80	0.00	1
123.89	Q25	420.20	420.20	0.00	1
124.37	Q50	480.20	480.20	0.00	1
125.06	Q100	562.80	562.80	0.00	1
126.79	Q500	743.30	743.30	0.00	1
130.08	Overtopping	1004.34	1004.34	0.00	Overtopping

Table 2 - Culvert Summary Table: Existing

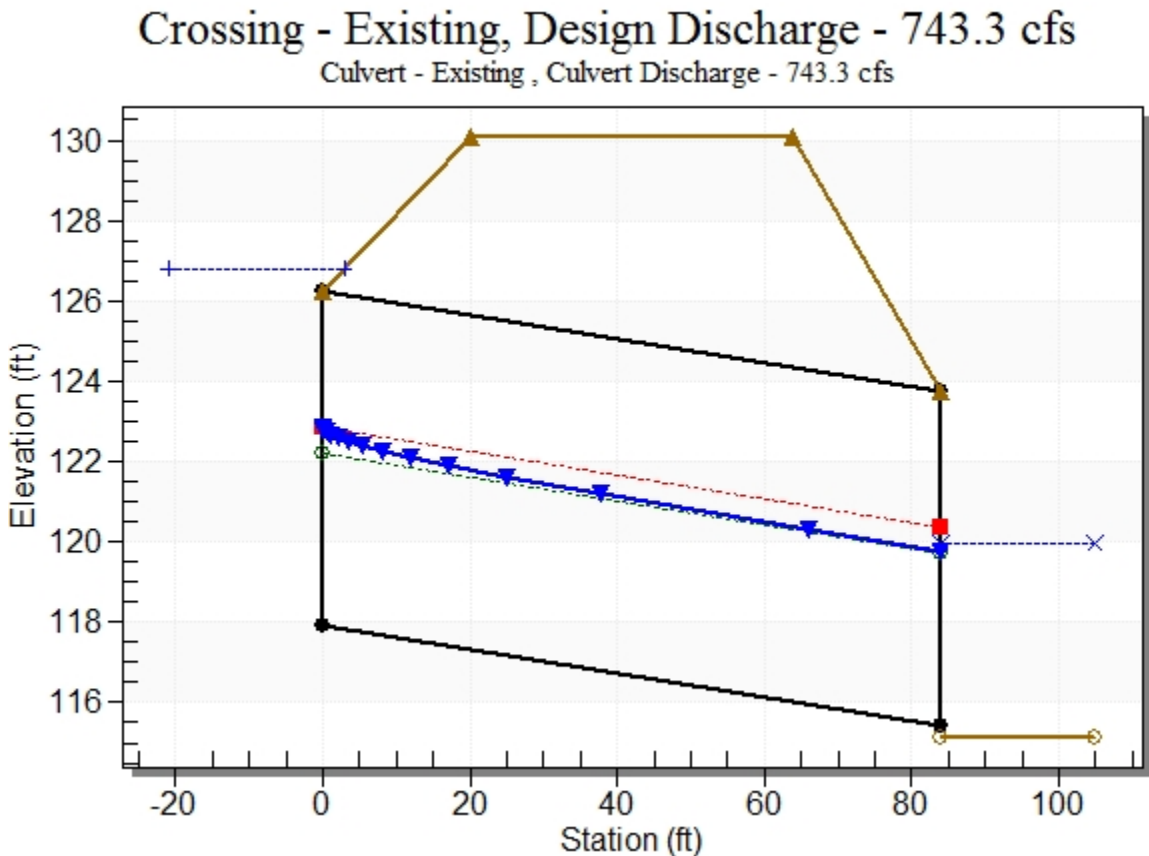
Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
Q1.1	83.80	83.80	120.27	2.337	0.0*	1-S2n	1.152	1.391	1.152	1.961	7.574	2.243
Q2	167.30	167.30	121.47	3.541	0.109	1-S2n	1.697	2.045	1.697	2.735	9.350	2.568
Q5	259.40	259.40	122.51	4.583	0.977	1-S2n	2.177	2.636	2.205	3.386	10.649	2.584
Q10	319.80	319.80	123.06	5.131	1.439	1-S2n	2.466	2.984	2.466	3.655	11.543	2.678
Q25	420.20	420.20	123.89	5.957	2.222	1-S2n	2.926	3.510	2.960	4.028	12.360	2.808
Q50	480.20	480.20	124.37	6.438	2.710	1-S2n	3.182	3.800	3.182	4.218	13.053	2.878
Q100	562.80	562.80	125.06	7.125	3.430	1-S2n	3.534	4.173	3.568	4.442	13.516	2.982
Q500	743.30	743.30	126.79	8.863	5.480	5-S2n	4.294	4.923	4.323	4.793	14.634	3.276

* Full Flow Headwater elevation is below inlet invert.

Table 3 - Downstream Channel Rating Curve (Crossing: Existing)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
83.80	117.11	1.96	2.24	0.54	0.36
167.30	117.89	2.74	2.57	0.75	0.37
259.40	118.54	3.39	2.58	0.93	0.37
319.80	118.81	3.66	2.68	1.00	0.37
420.20	119.18	4.03	2.81	1.11	0.38
480.20	119.37	4.22	2.88	1.16	0.38
562.80	119.59	4.44	2.98	1.22	0.39
743.30	119.94	4.79	3.28	1.32	0.41

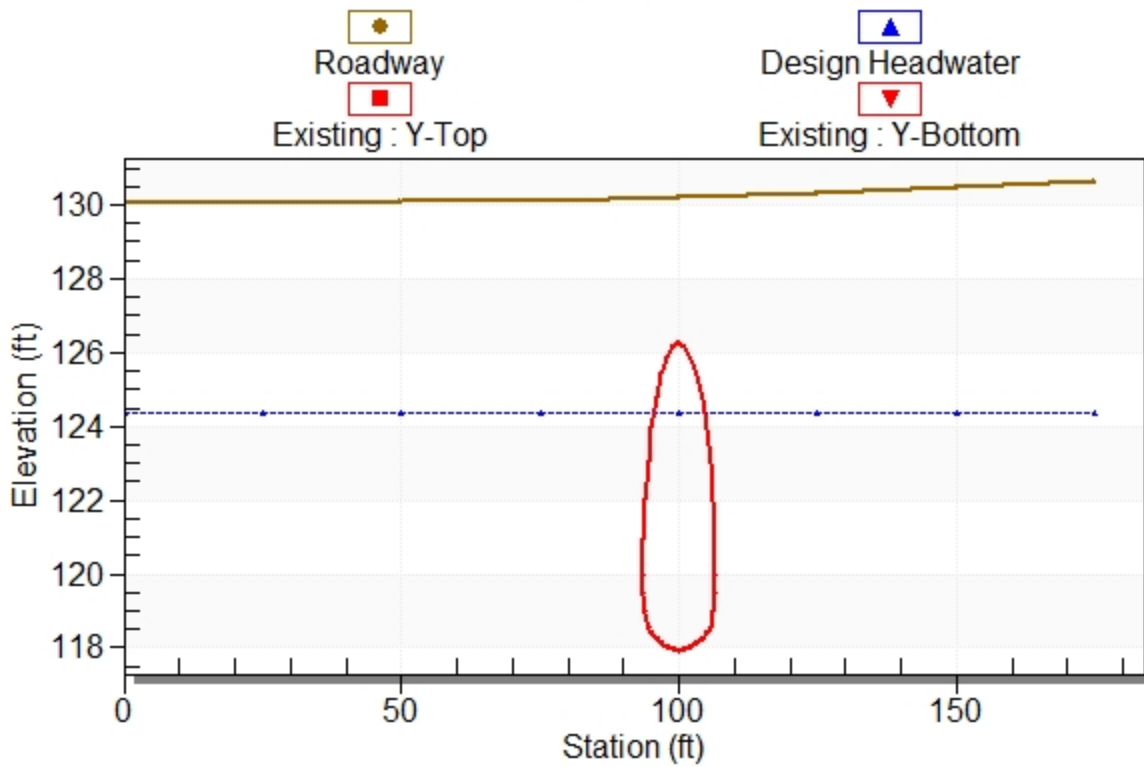
Water Surface Profile Plot for Culvert: Existing



Crossing Front View (Roadway Profile): Existing

Crossing Front View

(Not to scale)



Tailwater Channel Data - Box option 8'

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0044

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	-48.60	123.00	0.1000
2	0.00	120.57	0.0600
3	34.67	119.56	0.0500
4	53.13	118.92	0.0500
5	75.00	118.07	0.0500
6	80.64	118.21	0.0500
7	94.57	117.00	0.0500
8	100.00	117.00	0.0500
9	104.41	117.00	0.0500
10	119.32	117.57	0.0500
11	125.00	117.78	0.0500
12	136.47	119.77	0.0500
13	150.00	122.62	0.0600
14	175.00	123.41	0.1000
15	200.00	123.61	0.1000

Roadway Data for Crossing: Box option 8'

Roadway Profile Shape: Irregular Roadway Shape (coordinates)

Irregular Roadway Cross-Section:

Coord No.	Station (ft)	Elevation (ft)
0	0.00	130.10
1	39.96	130.10
2	89.26	130.20
3	100.00	130.20
4	125.72	130.40
5	160.85	130.60
6	200.00	130.90

Roadway Surface: Paved

Roadway Top Width: 44.00 ft

Site Data - Box 8'

Site Data Option: Culvert Invert Data
Inlet Station: 0.00 ft
Inlet Elevation: 115.75 ft
Outlet Station: 94.00 ft
Outlet Elevation: 115.50 ft
Number of Barrels: 1

Culvert Data Summary - Box 8'

Barrel Shape: User Defined
Barrel Span: 24.00 ft
Barrel Rise: 8.00 ft
Barrel Material: Concrete
Embedment: 24.00 in
Barrel Manning's n: 0.0120 (top and sides)
Manning's n: 0.0500 (bottom)
Culvert Type: Straight
Inlet Configuration: Mitered to Conform to Slope
Inlet Depression: NONE

Straight Culvert
Inlet Elevation (invert): 117.75 ft, Outlet Elevation (invert): 117.50 ft
Culvert Length: 94.00 ft, Culvert Slope: 0.0027

Table 4 - Summary of Culvert Flows at Crossing: Box option 8'

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Box 8' Discharge (cfs)	Roadway Discharge (cfs)	Iterations
119.67	Q 1.1	83.80	83.80	0.00	1
120.57	Q 2	167.30	167.30	0.00	1
121.29	Q 5	259.40	259.40	0.00	1
121.70	Q 10	319.80	319.80	0.00	1
122.32	Q 25	420.20	420.20	0.00	1
122.67	Q 50	480.20	480.20	0.00	1
123.12	Q 100	562.80	562.80	0.00	1
124.05	Q500	743.30	743.30	0.00	1
130.10	Overtopping	1454.66	1454.66	0.00	Overtopping

Table 5 - Culvert Summary Table: Box Option 8'

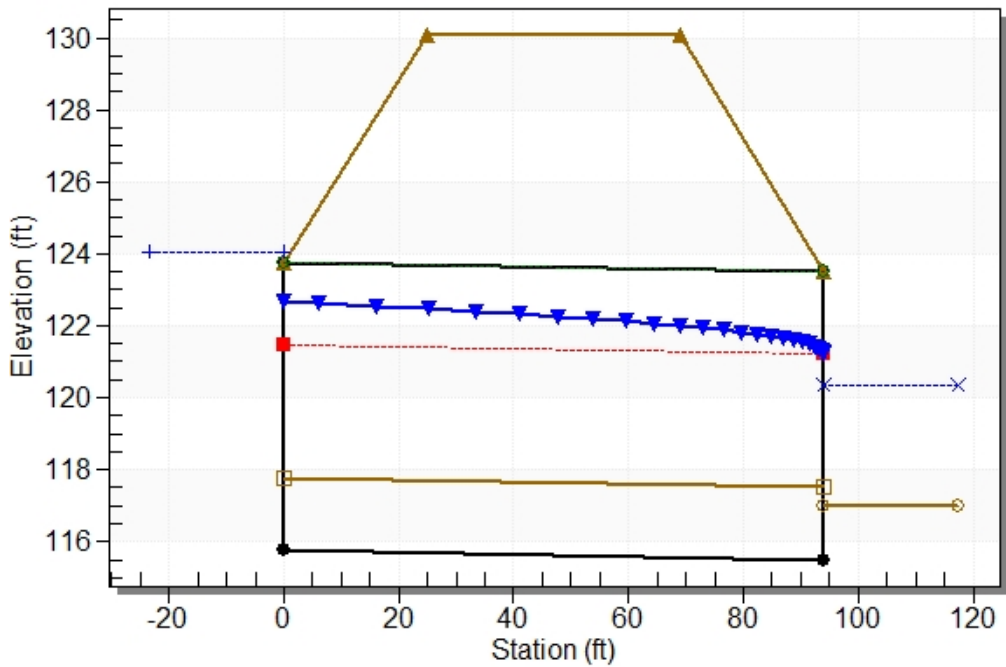
Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
Q 1.1	83.80	83.80	119.67	1.388	1.923	2-M2c	1.930	0.953	0.953	1.399	5.435	1.694
Q 2	167.30	167.30	120.57	2.160	2.817	2-M2c	2.764	1.508	1.508	1.861	6.630	2.052
Q 5	259.40	259.40	121.29	2.846	3.542	2-M2c	3.421	1.996	1.996	2.239	7.544	2.298
Q 10	319.80	319.80	121.70	3.216	3.954	2-M2c	3.797	2.280	2.280	2.444	8.013	2.423
Q 25	420.20	420.20	122.32	3.827	4.574	2-M2c	4.374	2.754	2.754	2.710	8.262	2.644
Q 50	480.20	480.20	122.67	4.192	4.920	2-M2c	4.701	2.952	2.952	2.843	8.634	2.768
Q 100	562.80	562.80	123.12	4.692	5.374	2-M2c	5.113	3.207	3.207	3.014	9.116	2.914
Q500	743.30	743.30	124.05	5.751	6.296	7-M2c	6.000	3.731	3.731	3.348	10.002	3.164

Table 6 - Downstream Channel Rating Curve (Crossing: Box option 8')

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
83.80	118.40	1.40	1.69	0.38	0.33
167.30	118.86	1.86	2.05	0.51	0.35
259.40	119.24	2.24	2.30	0.61	0.36
319.80	119.44	2.44	2.42	0.67	0.37
420.20	119.71	2.71	2.64	0.74	0.38
480.20	119.84	2.84	2.77	0.78	0.39
562.80	120.01	3.01	2.91	0.83	0.40
743.30	120.35	3.35	3.16	0.92	0.42

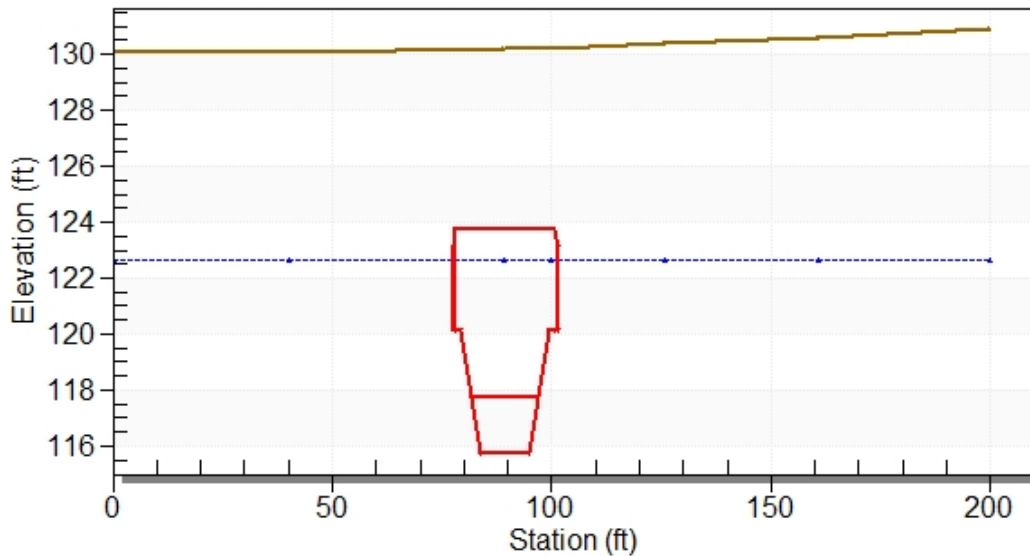
Water Surface Profile Plot for Culvert: Box 8'

Crossing - Box option 8', Design Discharge - 743.3 cfs
 Culvert - Box 8', Culvert Discharge - 743.3 cfs



Crossing Front View (Roadway Profile): Box option 8'

Crossing Front View
 (Not to scale)



Tailwater Channel Data - Box Option 9'

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0044

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	-48.60	123.00	0.1000
2	0.00	120.57	0.0600
3	34.67	119.56	0.0500
4	53.13	118.92	0.0500
5	75.00	118.07	0.0500
6	80.64	118.21	0.0500
7	94.57	117.00	0.0500
8	100.00	117.00	0.0500
9	104.41	117.00	0.0500
10	119.32	117.57	0.0500
11	125.00	117.78	0.0500
12	136.47	119.77	0.0500
13	150.00	122.62	0.0600
14	175.00	123.41	0.1000
15	200.00	123.61	0.0000

Roadway Data for Crossing: Box Option 9'

Roadway Profile Shape: Irregular Roadway Shape (coordinates)

Irregular Roadway Cross-Section:

Coord No.	Station (ft)	Elevation (ft)
0	0.00	130.10
1	25.00	130.08
2	50.00	130.09
3	75.00	130.13
4	100.00	130.20
5	125.00	130.32
6	150.00	130.48
7	175.00	130.64

Roadway Surface: Paved

Roadway Top Width: 44.00 ft

Site Data - Box 9'

Site Data Option: Culvert Invert Data
Inlet Station: 0.00 ft
Inlet Elevation: 115.75 ft
Outlet Station: 94.00 ft
Outlet Elevation: 115.50 ft
Number of Barrels: 1

Culvert Data Summary - Box 9'

Barrel Shape: User Defined
Barrel Span: 24.00 ft
Barrel Rise: 9.00 ft
Barrel Material: Concrete
Embedment: 24.00 in
Barrel Manning's n: 0.0120 (top and sides)
Manning's n: 0.0500 (bottom)
Culvert Type: Straight
Inlet Configuration: Mitered to Conform to Slope
Inlet Depression: NONE

Straight Culvert
Inlet Elevation (invert): 117.75 ft, Outlet Elevation (invert): 117.50 ft
Culvert Length: 94.00 ft, Culvert Slope: 0.0027

Table 7 - Summary of Culvert Flows at Crossing: Box Option 9'

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Box 9' Discharge (cfs)	Roadway Discharge (cfs)	Iterations
119.67	Q1.1	83.80	83.80	0.00	1
120.57	Q2	167.30	167.30	0.00	1
121.29	Q5	259.40	259.40	0.00	1
121.70	Q10	319.80	319.80	0.00	1
122.32	Q25	420.20	420.20	0.00	1
122.67	Q50	480.20	480.20	0.00	1
123.12	Q100	562.80	562.80	0.00	1
124.05	Q500	743.30	743.30	0.00	1
130.08	Overtopping	1657.92	1657.92	0.00	Overtopping

Table 8 - Culvert Summary Table: Box Option 9'

Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
Q1.1	83.80	83.80	119.67	1.394	1.923	2-M2c	1.904	0.952	0.952	1.399	5.438	1.694
Q2	167.30	167.30	120.57	2.171	2.817	2-M2c	2.737	1.496	1.496	1.861	6.686	2.052
Q5	259.40	259.40	121.29	2.851	3.543	2-M2c	3.410	1.982	1.982	2.239	7.607	2.298
Q10	319.80	319.80	121.70	3.250	3.954	2-M2c	3.800	2.277	2.277	2.444	8.023	2.423
Q25	420.20	420.20	122.32	3.804	4.574	2-M2c	4.371	2.750	2.750	2.710	8.277	2.644
Q50	480.20	480.20	122.67	4.136	4.920	2-M2c	4.701	2.950	2.950	2.843	8.643	2.768
Q100	562.80	562.80	123.12	4.592	5.374	2-M2c	5.110	3.214	3.214	3.014	9.092	2.914
Q500	743.30	743.30	124.05	5.583	6.296	2-M2c	5.951	3.730	3.730	3.348	10.005	3.164

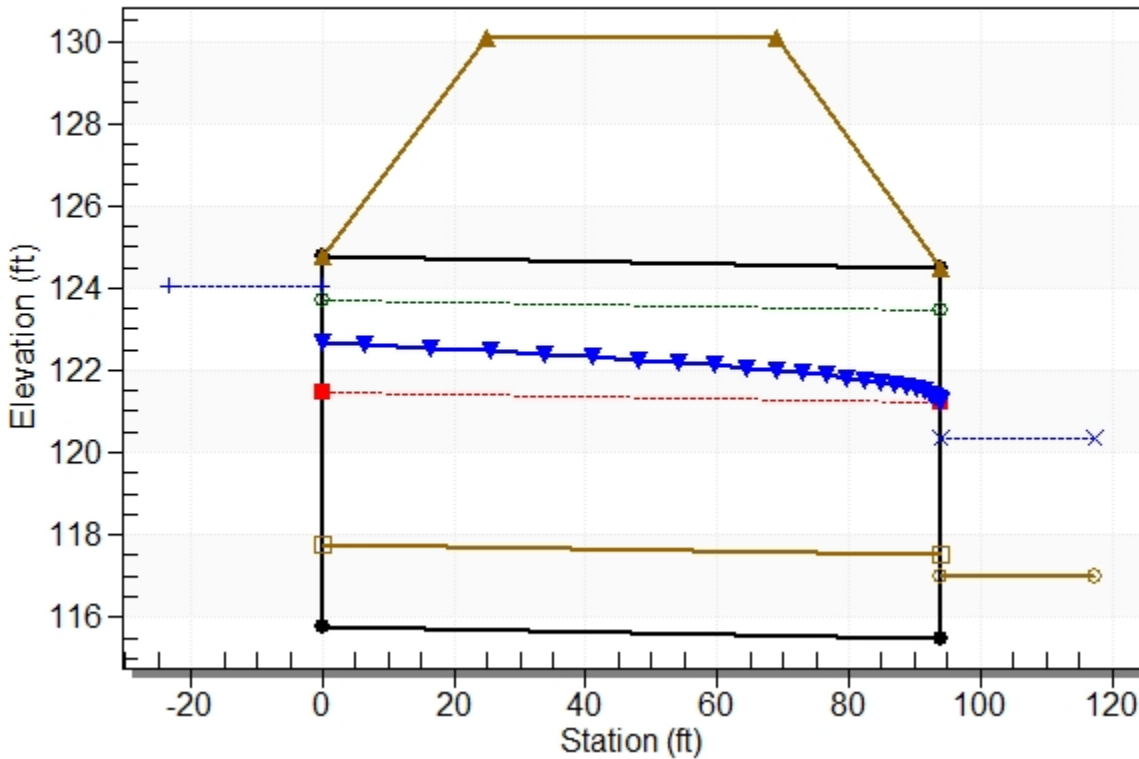
Table 9 - Downstream Channel Rating Curve (Crossing: Box Option 9')

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
83.80	118.40	1.40	1.69	0.38	0.33
167.30	118.86	1.86	2.05	0.51	0.35
259.40	119.24	2.24	2.30	0.61	0.36
319.80	119.44	2.44	2.42	0.67	0.37
420.20	119.71	2.71	2.64	0.74	0.38
480.20	119.84	2.84	2.77	0.78	0.39
562.80	120.01	3.01	2.91	0.83	0.40
743.30	120.35	3.35	3.16	0.92	0.42

Water Surface Profile Plot for Culvert: Box Option 9'

Crossing - Box Option 9', Design Discharge - 743.3 cfs

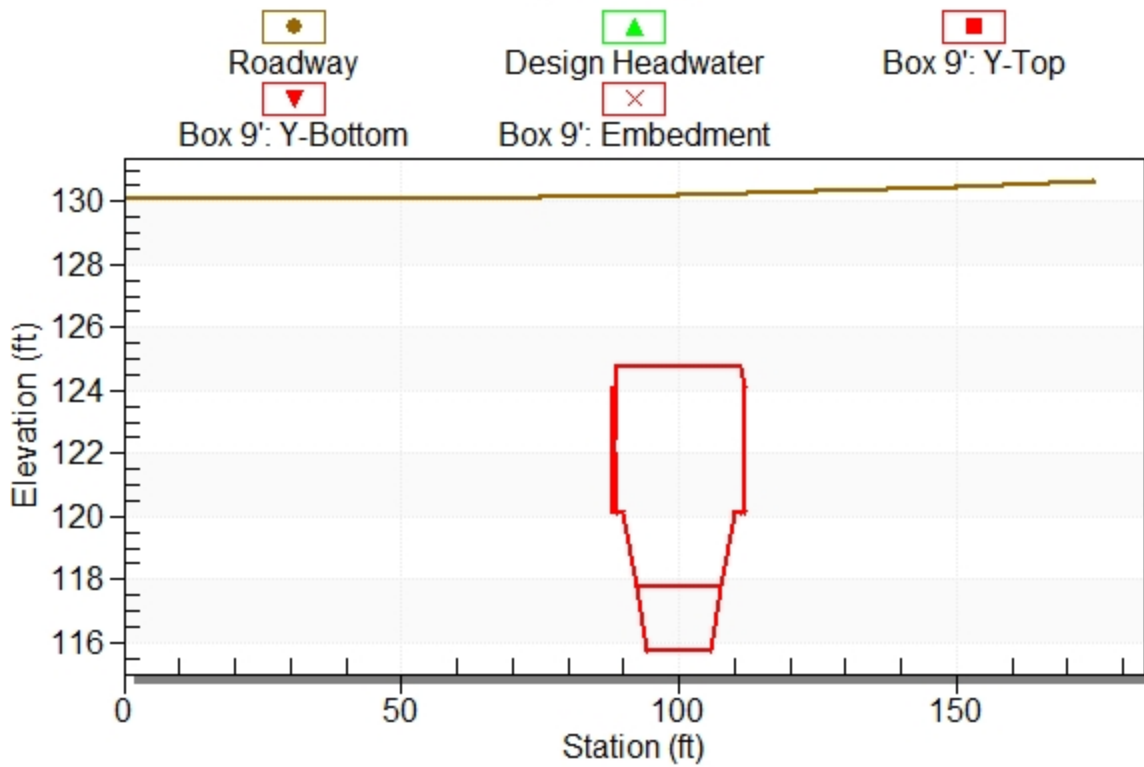
Culvert - Box 9', Culvert Discharge - 743.3 cfs



Crossing Front View (Roadway Profile): Box Option 9'

Crossing Front View

(Not to scale)



Tailwater Channel Data – Aluminum Box

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0040

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	-48.60	123.00	0.1000
2	0.00	120.57	0.0600
3	34.67	119.56	0.0500
4	53.13	118.92	0.0500
5	75.00	118.07	0.0500
6	80.64	118.21	0.0500
7	94.57	117.00	0.0500
8	100.00	117.00	0.0500
9	104.41	117.00	0.0500
10	119.32	117.57	0.0500
11	125.00	117.78	0.0500
12	136.47	119.77	0.0500
13	150.00	122.62	0.0600
14	175.00	123.41	0.1000
15	200.00	123.61	0.0000

Roadway Data for Crossing: Aluminum Box

Roadway Profile Shape: Irregular Roadway Shape (coordinates)

Irregular Roadway Cross-Section:

Coord No.	Station (ft)	Elevation (ft)
0	0.00	130.10
1	39.96	130.10
2	89.26	130.20
3	100.00	130.20
4	125.72	130.40
5	160.85	130.60
6	200.00	130.90

Roadway Surface: Paved

Roadway Top Width: 44.00 ft

Site Data - Aluminum Box

Site Data Option: Culvert Invert Data
Inlet Station: 0.00 ft
Inlet Elevation: 115.75 ft
Outlet Station: 72.00 ft
Outlet Elevation: 115.50 ft
Number of Barrels: 1

Culvert Data Summary - Aluminum Box

Barrel Shape: User Defined
Barrel Span: 21.86 ft
Barrel Rise: 9.75 ft
Barrel Material: Corrugated Metal Riveted or Welded
Embedment: 24.00 in
Barrel Manning's n: 0.0350 (top and sides)
Manning's n: 0.0500 (bottom)
Culvert Type: Straight
Inlet Configuration: Thin Edge Projecting
Inlet Depression: NONE

Straight Culvert
Inlet Elevation (invert): 117.75 ft, Outlet Elevation (invert): 117.50 ft
Culvert Length: 72.00 ft, Culvert Slope: 0.0035

Table 10 - Summary of Culvert Flows at Crossing: Aluminum Box

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Aluminum Box Discharge (cfs)	Roadway Discharge (cfs)	Iterations
119.73	Q 1.1	83.80	83.80	0.00	1
120.68	Q 2	167.30	167.30	0.00	1
121.44	Q 5	259.40	259.40	0.00	1
121.87	Q 10	319.80	319.80	0.00	1
122.51	Q 25	420.20	420.20	0.00	1
122.88	Q 50	480.20	480.20	0.00	1
123.36	Q 100	562.80	562.80	0.00	1
124.35	Q 500	743.30	743.30	0.00	1
130.10	Overtopping	1628.37	1628.37	0.00	Overtopping

Table 11 - Culvert Summary Table: Aluminum Box

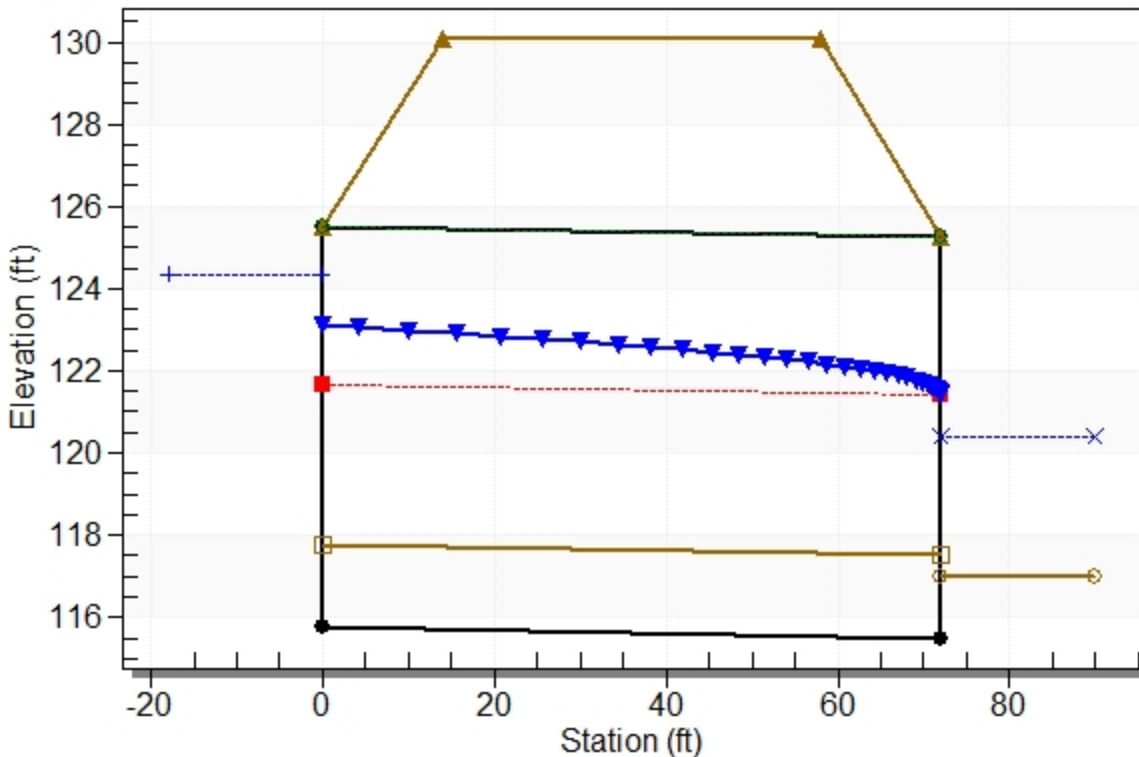
Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
Q 1.1	83.80	83.80	119.73	1.474	1.982	2-M2c	2.018	1.021	1.021	1.426	5.620	1.637
Q 2	167.30	167.30	120.68	2.286	2.929	2-M2c	2.979	1.604	1.604	1.898	6.866	1.982
Q 5	259.40	259.40	121.44	2.977	3.689	2-M2c	3.757	2.121	2.121	2.284	7.785	2.218
Q 10	319.80	319.80	121.87	3.394	4.116	2-M2c	4.229	2.527	2.527	2.493	7.750	2.339
Q 25	420.20	420.20	122.51	3.960	4.765	2-M2c	4.992	2.894	2.894	2.757	8.505	2.563
Q 50	480.20	480.20	122.88	4.318	5.128	2-M2c	5.498	3.098	3.098	2.893	8.908	2.681
Q 100	562.80	562.80	123.36	4.809	5.609	2-M2c	6.389	3.373	3.373	3.068	9.394	2.819
Q 500	743.30	743.30	124.35	5.848	6.603	2-M2c	7.750	3.916	3.916	3.410	10.372	3.057

Table 12 - Downstream Channel Rating Curve (Crossing: Aluminum Box)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
83.80	118.43	1.43	1.64	0.36	0.32
167.30	118.90	1.90	1.98	0.47	0.34
259.40	119.28	2.28	2.22	0.57	0.34
319.80	119.49	2.49	2.34	0.62	0.35
420.20	119.76	2.76	2.56	0.69	0.37
480.20	119.89	2.89	2.68	0.72	0.38
562.80	120.07	3.07	2.82	0.77	0.39
743.30	120.41	3.41	3.06	0.85	0.40

Water Surface Profile Plot for Culvert: Aluminum Box

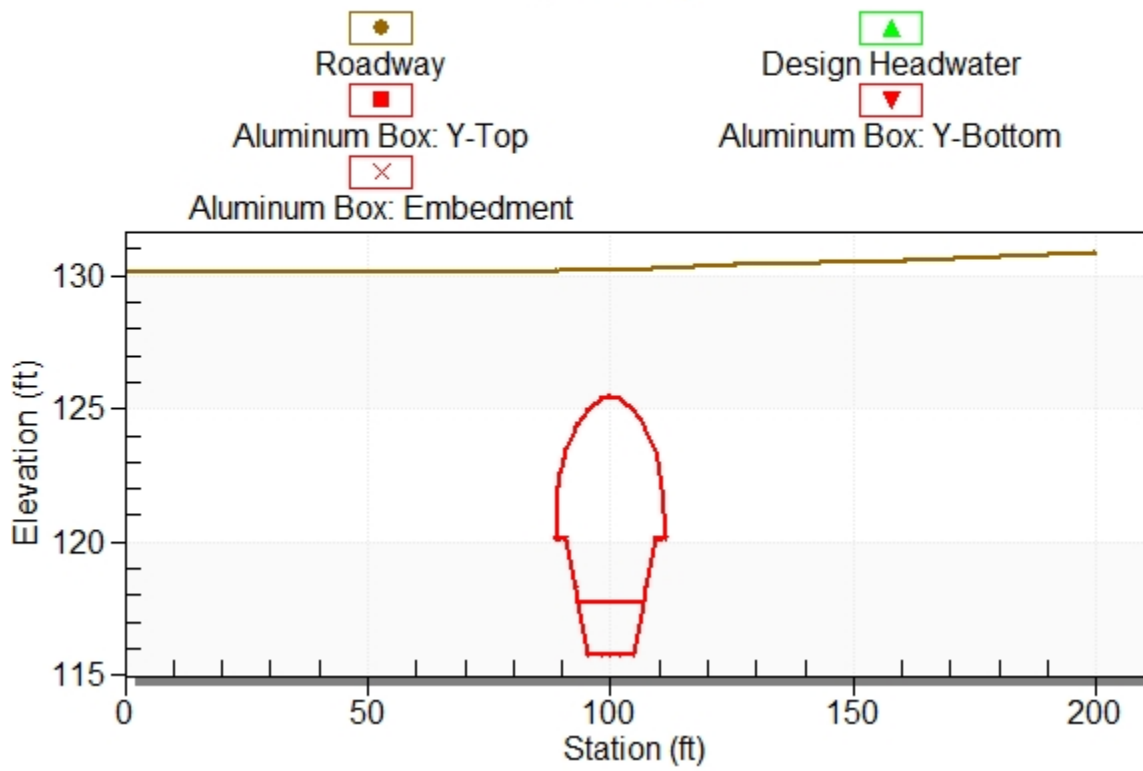
Crossing - Crawford, Design Discharge - 743.3 cfs
 Culvert - Aluminum Box, Culvert Discharge - 743.3 cfs



Crossing Front View (Roadway Profile): Aluminum Box

Crossing Front View

(Not to scale)



Culvert	Invert Elevation (ft)	Q50 Elevation (ft)	Water Depth (ft)	Culvert Depth (ft)	Hw/D	Q100 Elevation (ft)	Hw/D	Increase over Existing (ft)
Existing	117.93	124.37	6.44	8.33	0.77	125.06	0.86	0.00
Concrete Box 24' x 8'	117.75	122.67	4.92	6.00	0.82	123.12	0.9	-1.94
Concrete Box 24' x 9'	117.75	122.67	4.92	7.00	0.70	123.12	0.77	-1.94
Aluminum Box 24'-7" x 9'-9"	117.75	122.88	5.13	7.75	0.66	123.36	0.72	-1.70