

HYDROLOGY REPORT

Farmington Gower Farm Bridge #2324 – Farmington, Maine

General Information and Scope

This study is prepared to provide hydrologic information from water resources agencies on the Gower Farm Bridge crossing over Beales Brook. It will be used in the hydraulic evaluation of the existing and proposed culvert replacement. The existing bridge is a corrugated steel elliptical pipe culvert placed in 1958 with a span of 13' and a rise of 13'-10". The scope is to determine flood flow elevations, velocities, and overtopping potential for the existing and proposed culverts. With a measured bank full width of 16', and with the requirement of having a minimum proposed culvert width of 1.2 x Bank full width or nearly 20', ensures that the proposed culvert width or span is much larger than the existing culvert.

Hydrologic information and flow data are sought from different sources:

- 1- Federal Emergency management Agency (FEMA)
- 2- United States Geological Survey (USGS)
- 3- Maine DOT Hydrology Department

Federal Emergency Management Agency (FEMA)

FEMA flood insurance studies performed for Farmington in 1984 covered most of the flood plain for the Sandy River, which is located downstream of the bridge. Based on the FEMA flood maps, the Sandy River overflows its banks to an elevation of 349.00 ft at the 100-year event. However, the flood stage at the Sandy River does not reflect the flood stage at the bridge location as they are separate streams, and Beales brook is a tributary channel upstream of the Sandy River. FEMA did not provide any other hydrologic information such as flood flows for the river.

United States Geological Survey (USGS)

The USGS does not maintain any gaging stations at or near the bridge. However, there is a gaging station downstream on the Sandy River, but the gage flow data for the river cannot be used to obtain flows for the tributary upstream Beales Brook.

Maine DOT Hydrology Department

The Maine DOT hydrology department determined that the watershed area is 4.60 mi² with 5.9% wetlands. The flows were then calculated using Hodgkins 1999 regression analysis of the rainfall data with the following tabulated amounts:

Flow Return Period	Q (cfs)
Q _{1.1}	84.9
Q ₂	178.6
Q ₅	284.5
Q ₁₀	361.0
Q ₂₅	473.7
Q ₅₀	557.1
Q ₁₀₀	652.6
Q ₅₀₀	886.7

The above flood flow data will be used in the hydraulic analysis of both the existing and the proposed culvert, such that conclusions can be drawn about their hydraulic adequacy.

SUMMARY

Drainage Area	4.6	mi ²
Q _{1.1}	84.9	ft ³ /s
Q ₁₀	361.0	ft ³ /s
Q ₂₅	473.7	ft ³ /s
Q ₅₀	557.1	ft ³ /s
Q ₁₀₀	652.6	ft ³ /s
Q ₅₀₀	886.7	ft ³ /s

Reported by: Naous, Roger

Date: November 27, 2017

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

HYDRAULIC REPORT

Existing Culvert:

The 108 ft long existing culvert was analyzed with the Maine DOT data using HY-8 culvert analysis software. The model is considered representative of the current hydraulic conditions since the slopes used in the culvert and at the tail-water are same as the existing slopes. The downstream channel slope was calculated as the average slope for a quite a long distance downstream, and the culvert used in the model was the same as the existing.

Discharge Names	Total Discharge	Culvert Discharge	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	84.90	84.90	332.01	2.59	-0.80	1-S2n	1.99	2.02	1.99	1.42	6.63	2.61
Q2	178.60	178.60	333.21	3.79	1.85	1-S2n	2.87	2.95	2.95	2.19	7.91	3.35
Q5	284.50	284.50	334.25	4.83	2.75	1-S2n	3.63	3.75	3.73	2.85	9.04	3.89
Q10	361.00	361.00	334.90	5.48	3.34	1-S2n	4.10	4.25	4.10	3.25	10.03	4.19
Q25	473.70	473.70	335.75	6.33	4.14	1-S2n	4.73	4.87	4.86	3.78	10.43	4.54
Q50	557.10	557.10	336.33	6.91	4.73	1-S2n	5.17	5.30	5.29	4.13	10.95	4.77
Q100	622.41	622.41	336.90	7.48	5.19	1-S2n	5.50	5.61	5.61	4.39	11.33	4.93
Q500	886.70	886.70	339.23	9.81	3.09	1-S2n	6.74	6.79	6.74	5.31	12.72	5.46

The results indicate that the Q₅₀ design flow with a head water elevation of 336.33' has a HW/D value of 0.50, and the Q₅₀₀ flow with a headwater elevation of 339.23' has a HW/D value of 0.71. Therefore, there is freeboard available at all flows that are inlet controlled with both the Headwater HW and the Tail water Tw < D, and with the outlet at normal flow conditions. Based on the analysis, roadway overtopping does not occur, and this correlates well with bridge maintenance and local resident information that no overtopping has ever taken place on this bridge. However, due to the supercritical flow conditions in the culvert, the high velocities ranging from nearly 10 ft/s at Q₁₀ to nearly 13 ft/s at Q₅₀₀ suggests a larger culvert could be used to better accommodate flows and reduce outlet velocities. The observed erosion of embankments and the formed scour pool downstream strongly support this recommendation.

Proposed Culvert:

A 20' wide x 12' rise proposed concrete box culvert of the same length as the existing one is suggested to replace the existing corrugated metal pipe culvert. The culvert was sized to meet 1.2 x bankfull width requirements and to accommodate the design flows with no possibility of overtopping at largest flood flows. The culvert is embedded two feet into the stream bed to form a natural stream bed channel, and includes wildlife banks and a low flow channel. The culvert

slope was flattened to reduce flow velocities in the culvert; especially in the low flow channel for fish passage. This was achieved by raising the downstream invert while keeping the upstream invert unchanged. An HY-8 analysis was conducted and computations were cross checked by hand calculations. The model was adjusted such that the top width of flow at Q1.1 equaled the bank-full width of 16'-0", and the top of the wildlife banks were above or at the Q1.1 level. The wild life banks were set at 2' above the stream bed, and made to transition back to stream bed level at each end. The analysis results are tabulated below:

Discharge Names	Total Discharge	Culvert Discharge	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	84.90	84.90	331.37	2.30	2.95	2-M2c	2.62	1.96	1.96	1.67	5.82	2.19
Q2	178.60	178.60	332.47	3.07	4.05	2-M2c	3.59	2.65	2.65	2.55	7.22	2.79
Q5	284.50	284.50	333.35	3.81	4.93	2-M2c	4.29	3.34	3.34	3.32	7.71	3.22
Q10	361.00	361.00	333.91	4.21	5.49	2-M2c	4.73	3.65	3.65	3.78	8.35	3.46
Q25	473.70	473.70	334.67	4.75	6.25	2-M2c	5.32	4.08	4.08	4.39	9.14	3.75
Q50	557.10	557.10	335.19	5.13	6.77	2-M2c	5.73	4.38	4.38	4.79	9.65	3.93
Q100	622.41	622.41	335.58	5.41	7.16	2-M2c	6.03	4.60	4.60	5.08	10.02	4.06
Q500	886.70	886.70	337.04	6.68	8.62	3-M2t	7.15	5.43	5.44	6.12	11.22	4.49

The results indicate that overtopping will not occur at any of the flows, and the type of flow for all flows is outlet controlled with both the headwater HW and the tail water $T_w < D$, and with the outlet at critical depth conditions, except for Q500 whose outlet depth is at tail water. Some reduction in outlet velocities is achieved due to increased culvert size, flow area, slope reduction, and increased roughness using a natural stream bed bottom.

Stream bed channel and Habitat connectivity analysis

The proposed culvert includes 2 ft wide wildlife banks and a low flow channel. The maximum velocity in the low flow channel when flowing full at 3.75 cfs is 1.7 ft/s, which is within the allowable velocities for adult Atlantic Salmon 2-3 ft/s, and when flowing half full at 0.9 cfs at a velocity of 1.0 ft/s, provided for the passage of juvenile Atlantic Salmon. The tops of the wildlife banks are set at the Q1.1 flow elevation. The slope throughout the culvert was reduced to 0.5% from original 0.9% such that the velocity in the low flow channel is reduced to tolerable levels for the Salmon to swim upstream. The profile of the culvert and stream bed does not contain any head cuts or downstream incisions. The culvert downstream invert is slightly embedded below the stream bed, and a 4' deep downstream scour hole exists outside the culvert outlet. It is recommended that both the stream bed and downstream banks be armored due to strong evidence of bank erosion, falling vegetation, and trees in the channel. Filling of downstream

scour holes is also recommended to achieve a stable stream profile. The full Habitat Connectivity Design report is included in the Hydraulics Data Appendix E.

SUMMARY

		Existing Structure	Recommended Structure
		13.8' rise steel plate pipe	20'x12' Concrete Box Culvert
Total Area of Waterway Opening	ft ²	132.7	195.8
Headwater elevation @ Q _{1.1}	ft	332.01	331.37
Headwater elevation @ Q ₁₀	ft	334.90	333.91
Headwater elevation @ Q ₂₅	ft	335.75	334.67
Headwater elevation @ Q ₅₀	ft	336.33	335.19
Headwater elevation @ Q ₁₀₀	ft	336.90	335.58
Headwater elevation @ Q ₅₀₀	ft	339.23	337.04
Freeboard @ Q ₅₀	ft	6.89	4.23
Freeboard @ Q ₁₀₀	ft	6.32	3.84
Outlet Velocity @ Q _{1.1}	ft/s	6.63	5.82
Outlet Velocity @ Q ₁₀	ft/s	10.03	8.35
Outlet Velocity @ Q ₂₅	ft/s	10.43	9.14
Outlet Velocity @ Q ₅₀	ft/s	10.95	9.65
Outlet Velocity @ Q ₁₀₀	ft/s	11.33	10.02
Outlet Velocity @ Q ₅₀₀	ft/s	12.72	11.22

Reported by: Naous, Roger

Date: March 14, 2018

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

APPENDIX E

Hydraulics Data

WIN: 21880.00
 Town: Farmington
 Route No. US 2 / ME 27
 Asset ID: 2324
 Lat: 44.6368 Long: -70.09738

Project Name: Farmington Gower Farm Br
 Stream Name: Beales Brook
 Bridge Name: Gower Farm
 Analysis by: CSH
 Date: 3/10/2017

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

Enter data in blue cells only!

	km ²	mi ²	ac
A	11.91	4.60	2944.0
W	0.70	0.3	171.9

P _c	413274	4947012
County	Franklin	
pptA	45.6	
SG	0.004	

A (km ²)	11.91
W (%)	5.84

Conf Lvl 0.67

Enter data in [mi²]

Watershed Area *DRNAREA*

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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 Maine Dept. Transportation
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 ver. 2016 Feb 05

References:

Hodgkins, G.A., 1999.
 Estimating the magnitude of peak flows for streams
 in Maine for selected recurrence intervals
WRIR 99-4008, USGS Augusta, ME

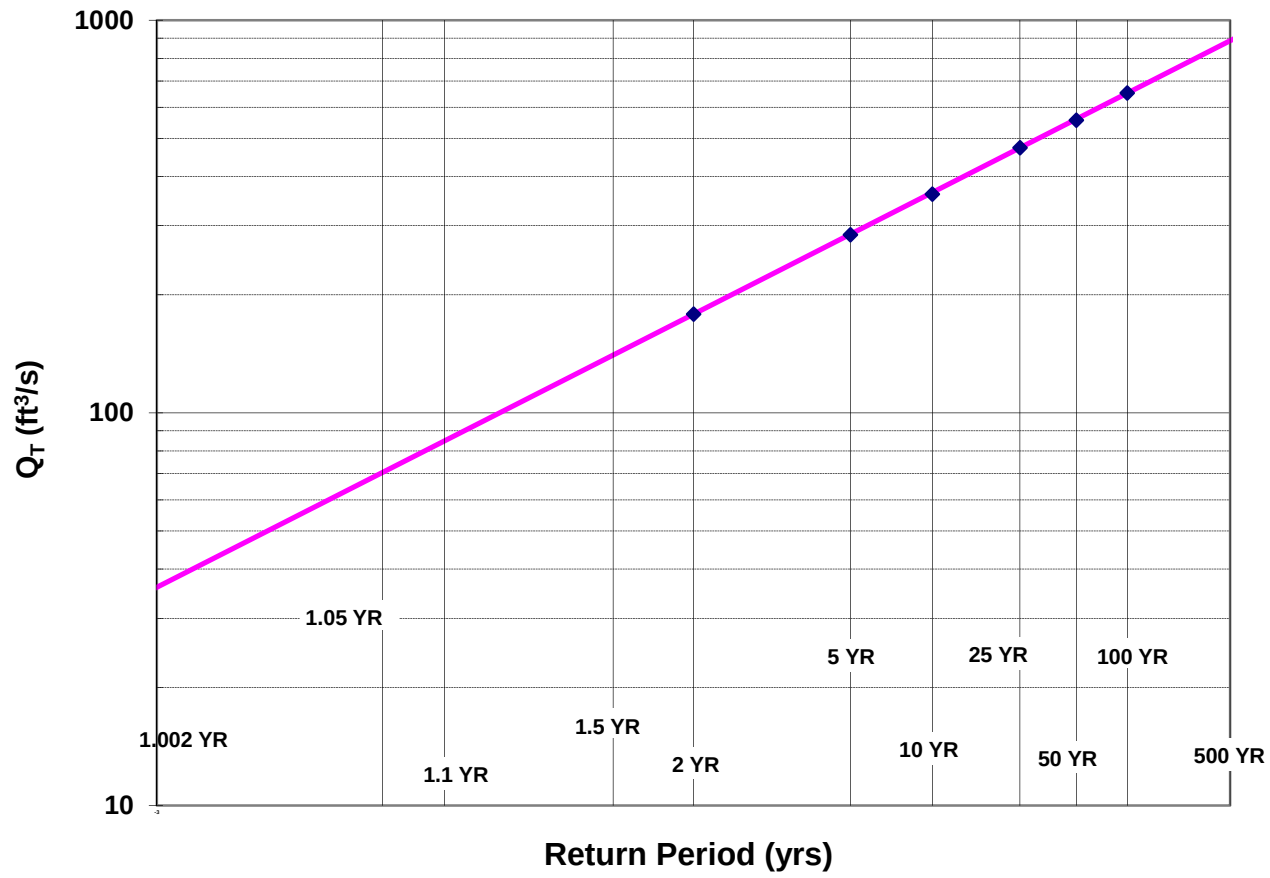
Lombard, P.J. & G.A. Hodgkins, 2015.
 Peak flow regression equations for small, ungaged streams in
 Maine - Comparing map-based to field-based variables
SIR 2015-4059, USGS, Augusta, ME

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

Ret Pd	Peak Flow Estimate		
T (yr)	Lower	Q _T (m ³ /s)	Upper
1.1		2.41	
2		5.06	
5		8.06	
10		10.22	
25		13.41	
50		15.78	
100		18.48	
500		25.11	

Q _T (ft ³ /s)
84.9
178.6
284.5
361.0
473.7
557.1
652.6
886.7

Log-Normal Probability Plot



WIN: 21880.00
 Town: Farmington
 Route No. US 2 / ME 27
 Asset ID: 2324
 Lat: 44.63678 Long: -70.09738

Project Name: Farmington Gower Farm Br
 Stream Name: Beales Brook
 Bridge Name: Gower Farm
 Analysis by: CSH
 Date: 3/10/2017

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

MAINE MONTHLY MEDIAN FLOWS and HYDRAULIC GEOMETRY BY USGS REGRESSION EQUATIONS (2004)

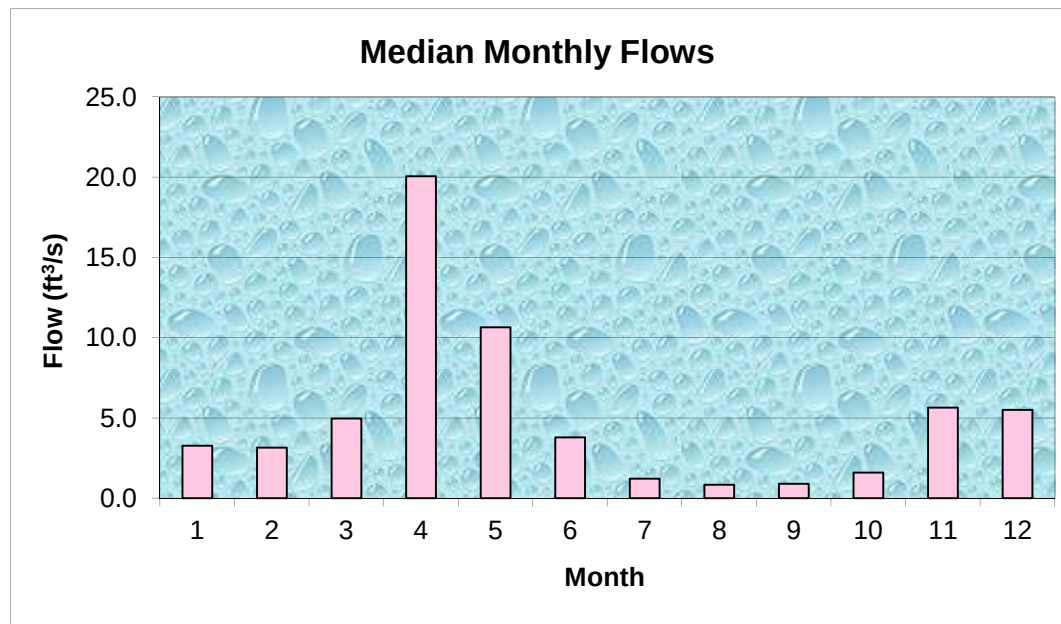
	Value	Variable	Explanation
	4.60	A	Area (mi ²)
413274.5	4947012	P_c	Watershed centroid (E,N; UTM; Zone 19; meters)
	89.56	DIST	Distance from Coastal reference line (mi)
	45.6	pptA	Mean Annual Precipitation (inches)
	0.00	SG	Sand & Gravel Aquifer (decimal fraction of watershed area)

Month	Q_{median} (ft ³ /s)	(m ³ /s)
Jan	3.28	0.0928
Feb	3.16	0.0895
Mar	4.98	0.1410
Apr	20.05	0.5683
May	10.65	0.3018
Jun	3.79	0.1074
Jul	1.22	0.0347
Aug	0.85	0.0241
Sep	0.91	0.0257
Oct	1.60	0.0453
Nov	5.66	0.1603
Dec	5.50	0.1559

Q_{bf}	25.8
ann avg	9.6
ann med	5.0
$Q_{1.002}$	35.9
$Q_{1.01}$	48.8
$Q_{1.05}$	70.5
Q_{bf}	67.7

assume v = 4ft/s

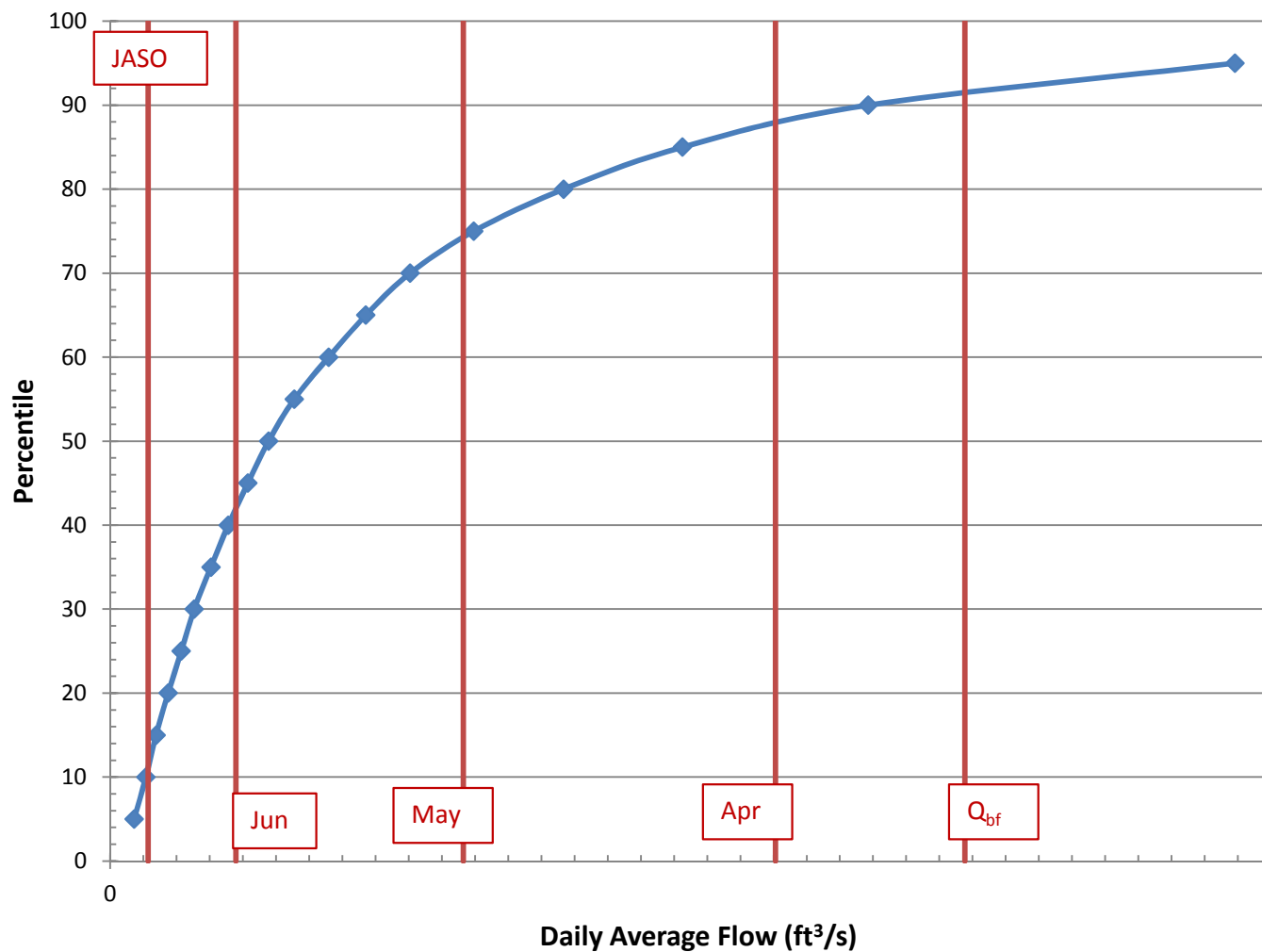
W_{bf}	17.0	estimated bankfull width (ft)
d_{bf}	1.0	estimated bankfull depth (ft)
A_{bf}	16.9	estimated bankfull flow area (ft ²)



References

Dudley, R.W., 2004. Hydraulic Geometry Relations ..., SIR 2004-5042
 Dudley, R.W., 2004. Estimating Monthly Streamflows ... , SIR 2004-5026

Daily Average Flow Distribution



Daily Avg Flow Dist

$A_{ws} = (mi^2)$ 4.6

$Q (ft^3/s)$

Pctl	Median	84 th pctl
5	0.72	1.17
10	1.08	1.62
15	1.38	2.02
20	1.75	2.45
25	2.14	2.87
30	2.53	3.27
35	3.04	3.74
40	3.56	4.30
45	4.15	4.86
50	4.78	5.74
55	5.55	6.68
60	6.59	7.84
65	7.71	9.13
70	9.04	10.65
75	10.96	12.81
80	13.67	15.29
85	17.25	19.60
90	22.85	26.32
95	33.91	40.92

Q_{bf} 25.8

$Q_{1.002}$ 35.9

$Q_{1.1}$ 84.9

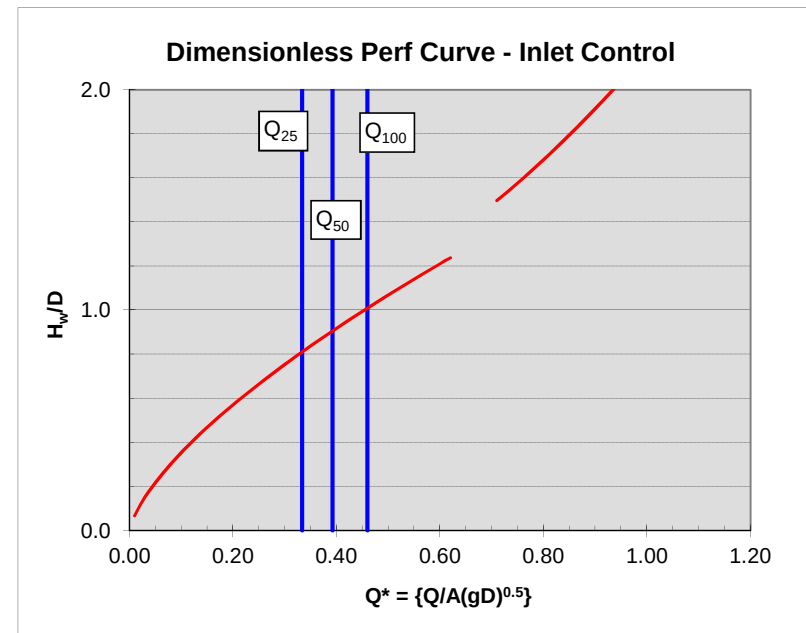
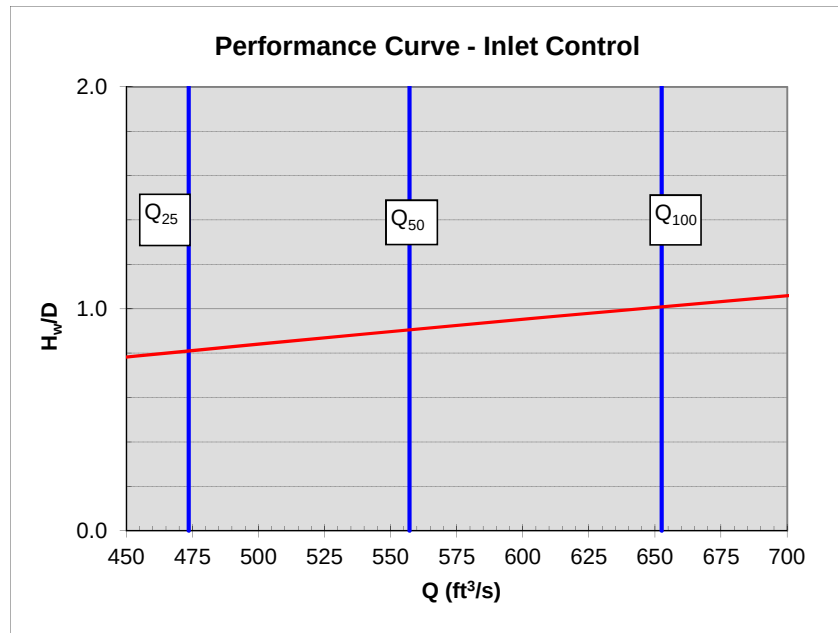
Q_2 178.6

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

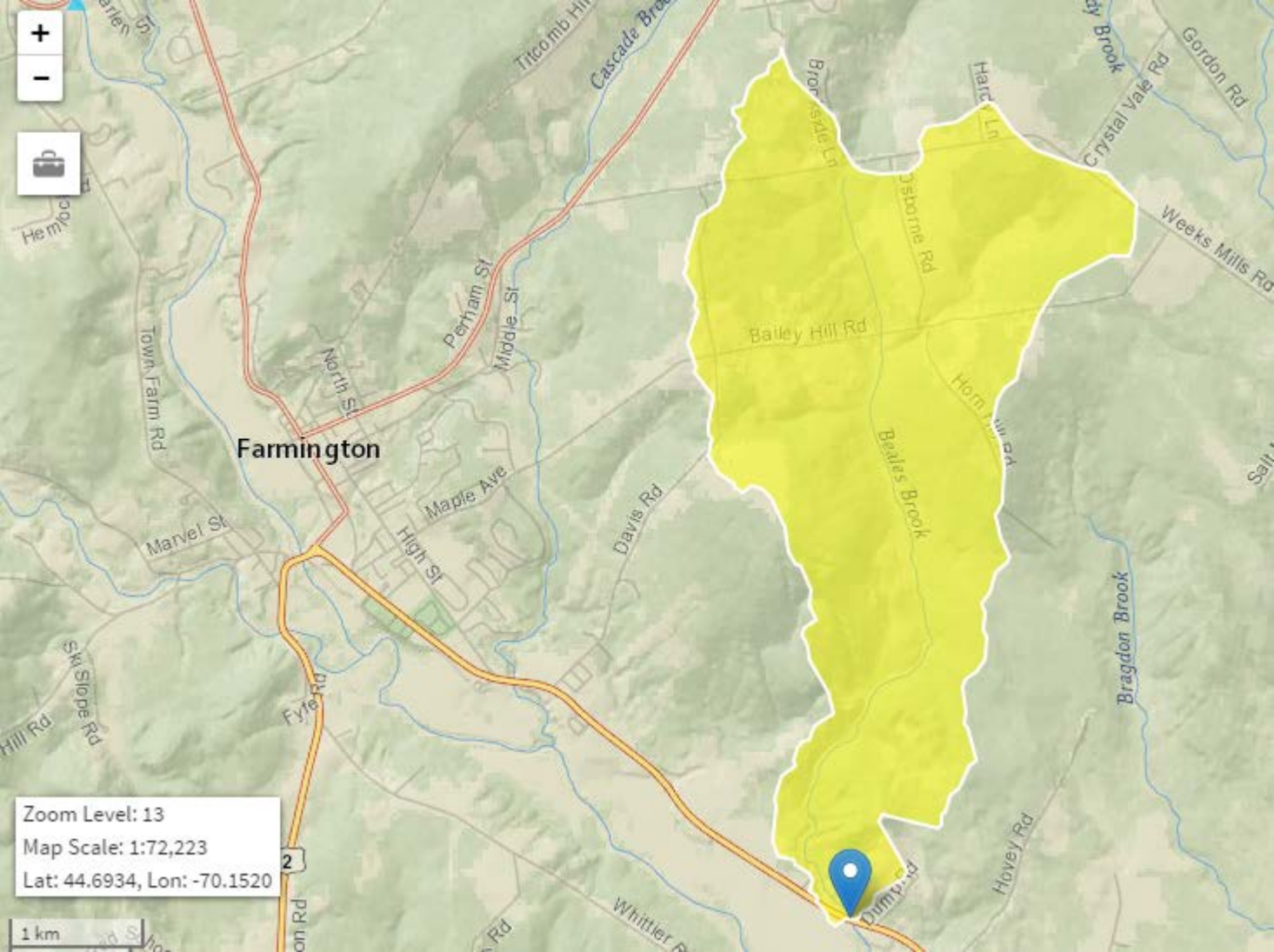
Preliminary Culvert Sizing - Round & Box Culverts

Shape:	Box				
Type:	Box 0 ww				
D or R (ft)	6	Q_{25}	473.7	trial D / R =	10.4
w (ft)	17 box width	Q_{50}	557.1	trial w: BFW =	17.0
Slope (ft/ft)	0.02	Q_{100}	652.6		
A (ft ²)	102.00				
g (ft/s ²)	32.2				

Note:
culvert dimensions are for open flow area; adjust for lost capacity
due to embedding / backfilling (min {2' / 25% rise} embedment)







Farmington

Zoom Level: 13
Map Scale: 1:72,223
Lat: 44.6934, Lon: -70.1520

1 km

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	4.6	square miles
STORNWI	Percentage of storage (combined water bodies and wetlands) from the National Wetlands Inventory	5.84	percent
ELEV	Mean Basin Elevation	577.2	feet
PRECIP	Mean Annual Precipitation	45.5	inches
SANDGRAVAP	Percentage of land surface underlain by sand and gravel aquifers	0.42	percent
COASTDIST	Shortest distance from the coastline to the basin centroid	90.8	miles
CENTROIDX	Basin centroid horizontal (x) location in state plane coordinates	413274.49	State plane coordinates
CENTROIDY	Basin centroid vertical (y) location in state plane units	4947011.64	State plane coordinates
SANDGRAVAF	Fraction of land surface underlain by sand and gravel aquifers	0.004	dimensionless
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	0.4	percent
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	2.9	percent
LC06WATER	Percent of open water, class 11, from NLCD 2006	0.15	percent
ELEVMAX	Maximum basin elevation	803.6	feet
BSLDEM10M	Mean basin slope computed from 10 m DEM	8.25	percent
STATSGOA	Percentage of area of Hydrologic Soil Type A from STATSGO	1.85	percent

Bankfull Statistics Parameters [100 Percent (NaN square miles) Central and Coastal Bankfull 2004 5042]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
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DRNAREA	Drainage Area	4.6	square miles	2.92	298
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Bankfull Statistics Flow Report [100 Percent (NaN square miles) Central and Coastal Bankfull 2004 5042]

Statistic	Value	Unit	Average standard error of estimate
Bankfull Streamflow	25.8	ft^3/s	54.1
Bankfull Width	17	ft	33
Bankfull Depth	0.998	ft	26.2
Bankfull Area	16.9	ft^2	57.4

Bankfull Statistics Citations

Dudley, R.W.,2004, Hydraulic-Geometry Relations for Rivers in Coastal and Central Maine: U.S. Geological Survey Scientific Investigations Report 2004-5042, 30 p (<http://pubs.usgs.gov/sir/2004/5042/pdf/sir2004-5042.pdf>)

Peak-Flow Statistics Parameters [100 Percent (NaN square miles) Statewide Peak Flow DA LT 12sqmi 2015 5049]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	4.6	square miles	0.31	12
STORNWI	Percentage of Storage from NWI	5.84	percent	0	22.2

Peak-Flow Statistics Flow Report [100 Percent (NaN square miles) Statewide Peak Flow DA LT 12sqmi 2015 5049]

Statistic	Value	Unit	Average standard error of prediction
1.01 Year Peak Flood	51.4	ft^3/s	38
2 Year Peak Flood	178	ft^3/s	34
5 Year Peak Flood	284	ft^3/s	35
10 Year Peak Flood	361	ft^3/s	37
25 Year Peak Flood	473	ft^3/s	39

Statistic	Value	Unit	Average standard error of prediction
50 Year Peak Flood	557	ft ³ /s	41
100 Year Peak Flood	652	ft ³ /s	42
250 Year Peak Flood	743	ft ³ /s	44
500 Year Peak Flood	886	ft ³ /s	47

Peak-Flow Statistics Citations

Lombard, P.J., and Hodgkins, G.A.,2015, Peak flow regression equations for small, ungaged streams in Maine— Comparing map-based to field-based variables: U.S. Geological Survey Scientific Investigations Report 2015–5049, 12 p.
(<http://dx.doi.org/10.3133/sir20155049>)

HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Existing Gower Farm Culvert

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
332.01	Q1.1	84.90	84.90	0.00	1
333.21	Q2	178.60	178.60	0.00	1
334.25	Q5	284.50	284.50	0.00	1
334.90	Q10	361.00	361.00	0.00	1
335.75	Q25	473.70	473.70	0.00	1
336.33	Q50	557.10	557.10	0.00	1
336.90	Q100	622.41	622.41	0.00	1
339.23	Q500	886.70	886.70	0.00	1
347.00	Overtopping	1770.46	1770.46	0.00	Overtopping

Rating Curve Plot for Crossing: Existing Gower Farm Culvert

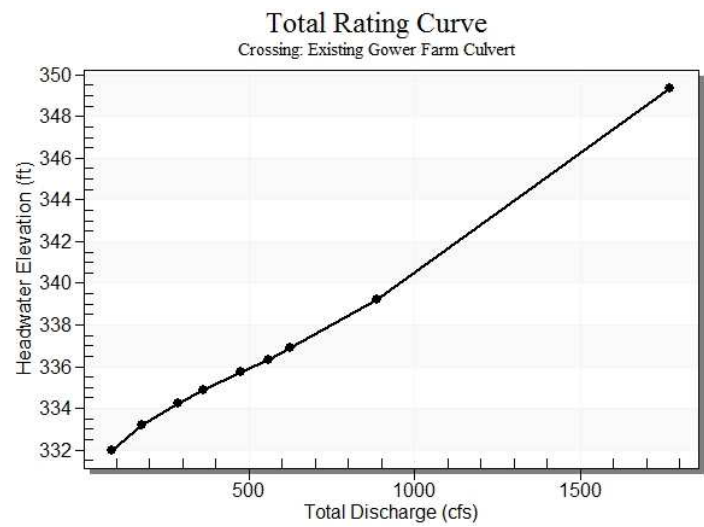


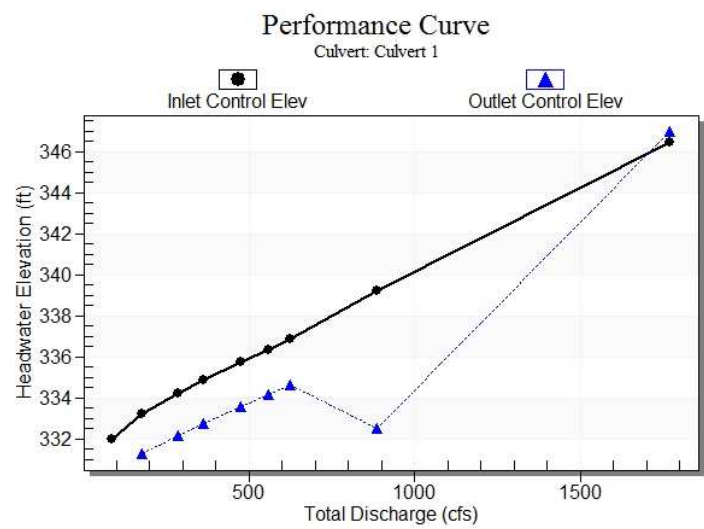
Table 2 - Culvert Summary Table: Culvert 1

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	84.90	84.90	332.01	2.585	0.0*	1-S2n	1.987	2.025	1.987	1.422	6.635	2.614
Q2	178.60	178.60	333.21	3.787	1.854	1-S2n	2.866	2.954	2.946	2.186	7.910	3.353
Q5	284.50	284.50	334.25	4.831	2.745	1-S2n	3.628	3.752	3.728	2.847	9.041	3.889
Q10	361.00	361.00	334.90	5.477	3.339	1-S2n	4.103	4.252	4.103	3.253	10.032	4.186
Q25	473.70	473.70	335.75	6.325	4.139	1-S2n	4.733	4.873	4.861	3.781	10.432	4.545
Q50	557.10	557.10	336.33	6.905	4.726	1-S2n	5.168	5.298	5.293	4.133	10.949	4.769
Q100	622.41	622.41	336.90	7.481	5.189	1-S2n	5.496	5.615	5.610	4.389	11.326	4.927
Q500	886.70	886.70	339.23	9.810	3.087	1-S2n	6.737	6.794	6.737	5.307	12.716	5.457

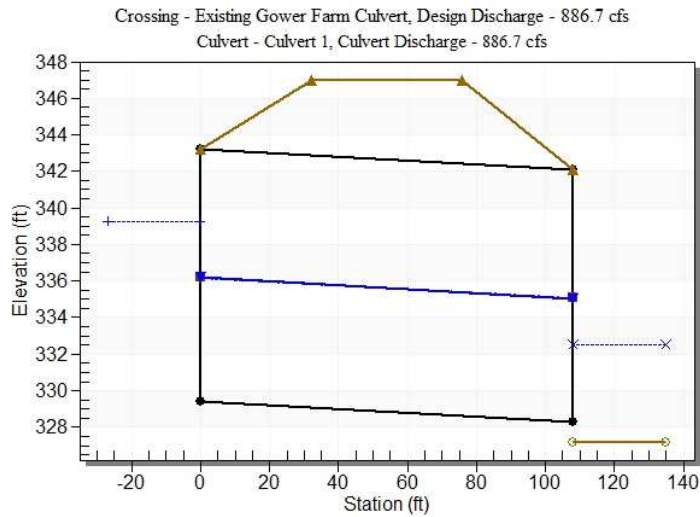
* Full Flow Headwater elevation is below inlet invert.

Straight Culvert
Inlet Elevation (invert): 329.42 ft, Outlet Elevation (invert): 328.26 ft
Culvert Length: 108.01 ft, Culvert Slope: 0.0107
Inlet Throat Elevation: 329.42 ft, Inlet Crest Elevation: 329.49 ft

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



S

Inlet Station: 0.00 ft

Inlet Elevation: 329.42 ft

Outlet Station: 108.00 ft

Outlet Elevation: 328.26 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: User Defined

Barrel Span: 13.00 ft

Barrel Rise: 13.80 ft

Barrel Material: Corrugated Metal Riveted or Welded

Embedment: 0.00 in

Barrel Manning's n: 0.0270 (top and sides)

Manning's n: 0.0270 (bottom)

Culvert Type: Straight

Inlet Configuration: Thin Edge Projecting

Inlet Depression: Yes

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

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
84.90	328.62	1.42	2.61	0.21	0.41
178.60	329.39	2.19	3.35	0.33	0.43
284.50	330.05	2.85	3.89	0.43	0.45
361.00	330.45	3.25	4.19	0.49	0.46
473.70	330.98	3.78	4.54	0.57	0.46
557.10	331.33	4.13	4.77	0.62	0.47
622.41	331.59	4.39	4.93	0.66	0.47
886.70	332.51	5.31	5.46	0.79	0.48

Tailwater Channel Data - Existing Gower Farm Culvert

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 20.00 ft

Side Slope (H:V): 2.00 (1:1)

Channel Slope: 0.0024

Channel Manning's n: 0.0320

Channel Invert Elevation: 327.20 ft

Roadway Data for Crossing: Existing Gower Farm Culvert

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

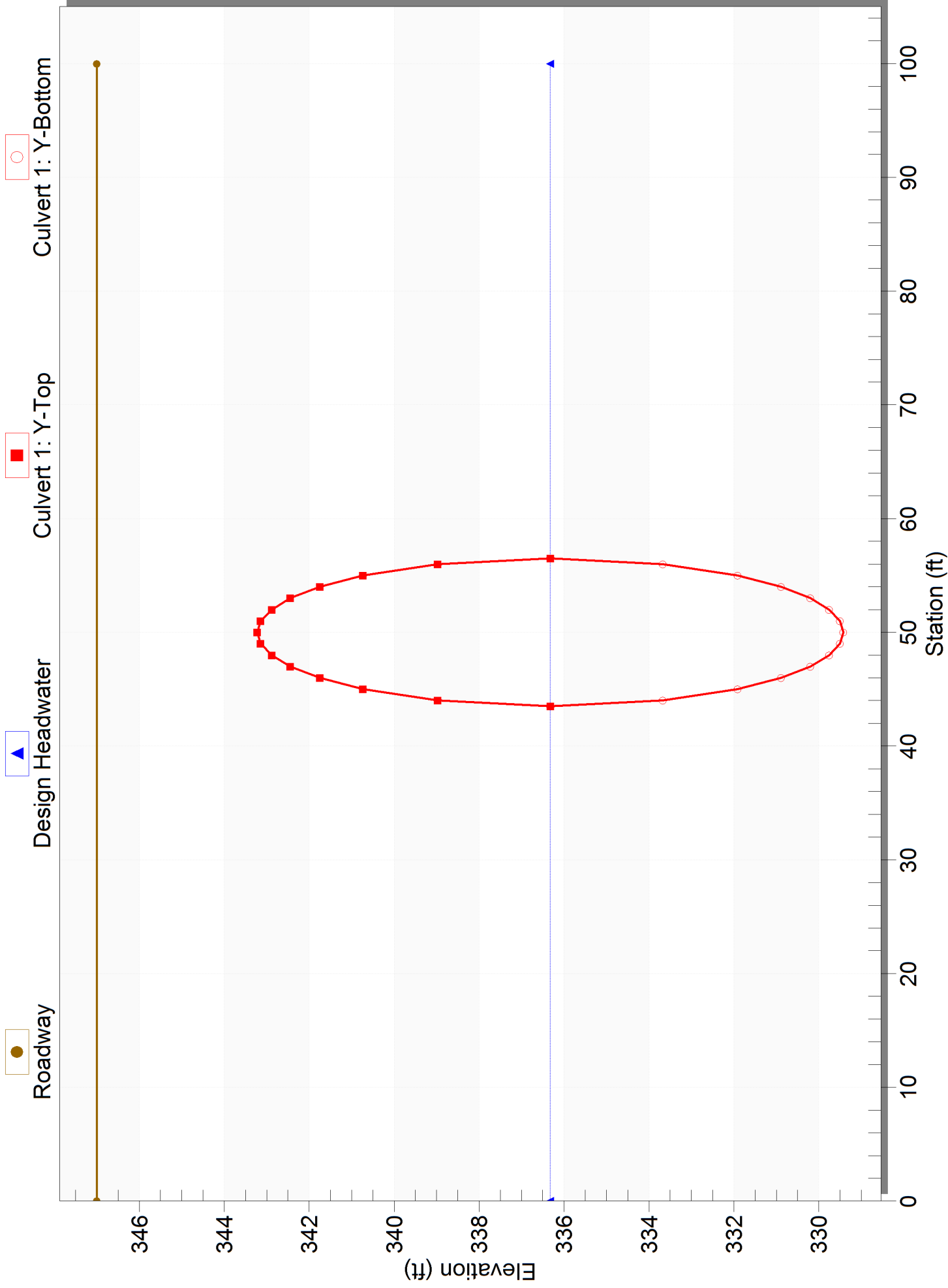
Crest Elevation: 347.00 ft

Roadway Surface: Paved

Roadway Top Width: 44.00 ft

Crossing: Existing Gower Farm Culvert, Culvert: Culvert 1

Front View (Not to scale)



HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Gower Farm Bridge Proposed

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
331.45	Q1.1	84.90	84.90	0.00	1
332.56	Q2	178.60	178.60	0.00	1
333.45	Q5	284.50	284.50	0.00	1
334.01	Q10	361.00	361.00	0.00	1
334.77	Q25	473.70	473.70	0.00	1
335.29	Q50	557.10	557.10	0.00	1
335.68	Q100	622.41	622.41	0.00	1
337.14	Q500	886.70	886.70	0.00	1
347.00	Overtopping	2839.54	2839.54	0.00	Overtopping

Rating Curve Plot for Crossing: Gower Farm Bridge Proposed

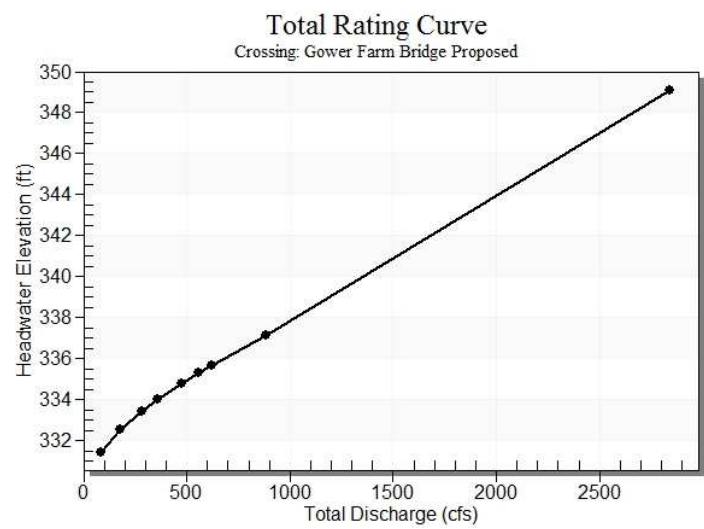
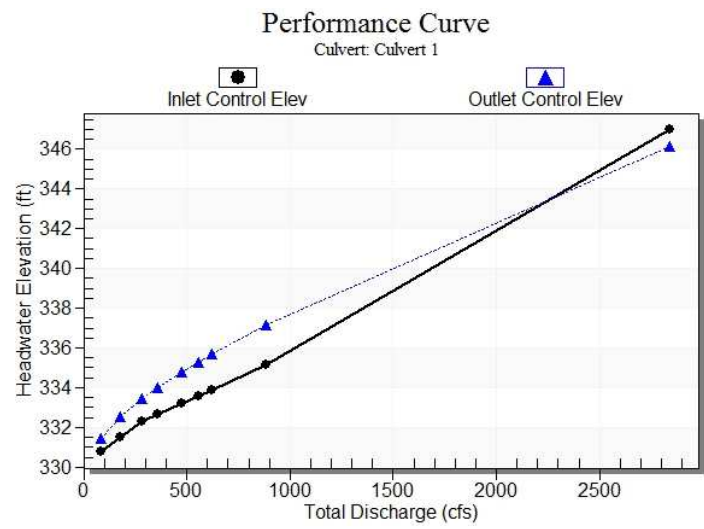


Table 2 - Culvert Summary Table: Culvert 1

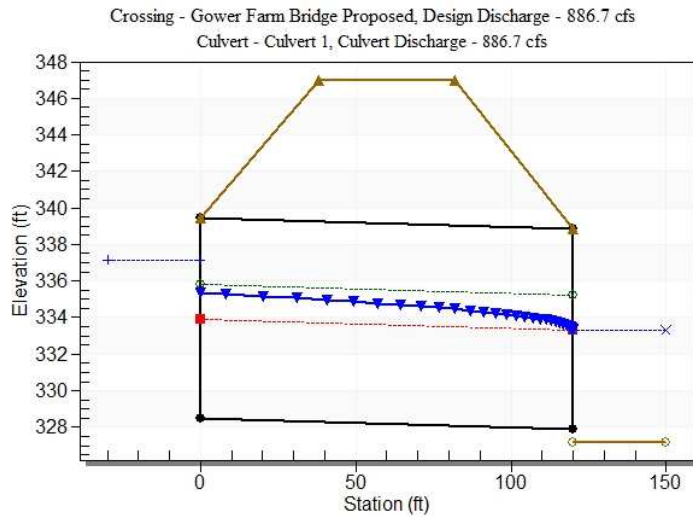
Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)	*****
Q1.1	84.90	84.90	331.45	2.300	2.983	2-M2c	2.682	1.960	1.960	1.665	5.816	2.185	*****
Q2	178.60	178.60	332.56	3.067	4.094	2-M2c	3.660	2.653	2.653	2.552	7.224	2.788	*****
Q5	284.50	284.50	333.45	3.806	4.977	2-M2c	4.381	3.337	3.337	3.315	7.711	3.223	*****
Q10	361.00	361.00	334.01	4.207	5.540	2-M2c	4.841	3.654	3.654	3.782	8.347	3.463	*****
Q25	473.70	473.70	334.77	4.750	6.299	2-M2c	5.453	4.084	4.084	4.387	9.139	3.753	*****
Q50	557.10	557.10	335.29	5.125	6.821	2-M2c	5.872	4.380	4.380	4.788	9.647	3.934	*****
Q100	622.41	622.41	335.68	5.404	7.212	2-M2c	6.185	4.599	4.599	5.081	10.015	4.062	*****
Q500	886.70	886.70	337.14	6.679	8.671	3-M2t	7.340	5.429	5.455	6.125	11.188	4.489	*****

 Straight Culvert
 Inlet Elevation (invert):
 328.47 ft, Outlet
 Elevation (invert):
 327.87 ft
 Culvert Length: 120.00
 ft, Culvert Slope:
 0.0050

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



S

Inlet Station: 0.00 ft

Inlet Elevation: 328.47 ft

Outlet Station: 120.00 ft

Outlet Elevation: 327.87 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: User Defined

Barrel Span: 20.00 ft

Barrel Rise: 11.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120 (top and sides)

Manning's n: 0.0420 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Gower Farm Bridge Proposed)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
84.90	328.87	1.67	2.19	0.25	0.32
178.60	329.75	2.55	2.79	0.38	0.34
284.50	330.52	3.32	3.22	0.50	0.35
361.00	330.98	3.78	3.46	0.57	0.35
473.70	331.59	4.39	3.75	0.66	0.36
557.10	331.99	4.79	3.93	0.72	0.36
622.41	332.28	5.08	4.06	0.76	0.37
886.70	333.32	6.12	4.49	0.92	0.38

Tailwater Channel Data - Gower Farm Bridge Proposed

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 20.00 ft

Side Slope (H:V): 2.00 (1:1)

Channel Slope: 0.0024

Channel Manning's n: 0.0420

Channel Invert Elevation: 327.20 ft

Roadway Data for Crossing: Gower Farm Bridge Proposed

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

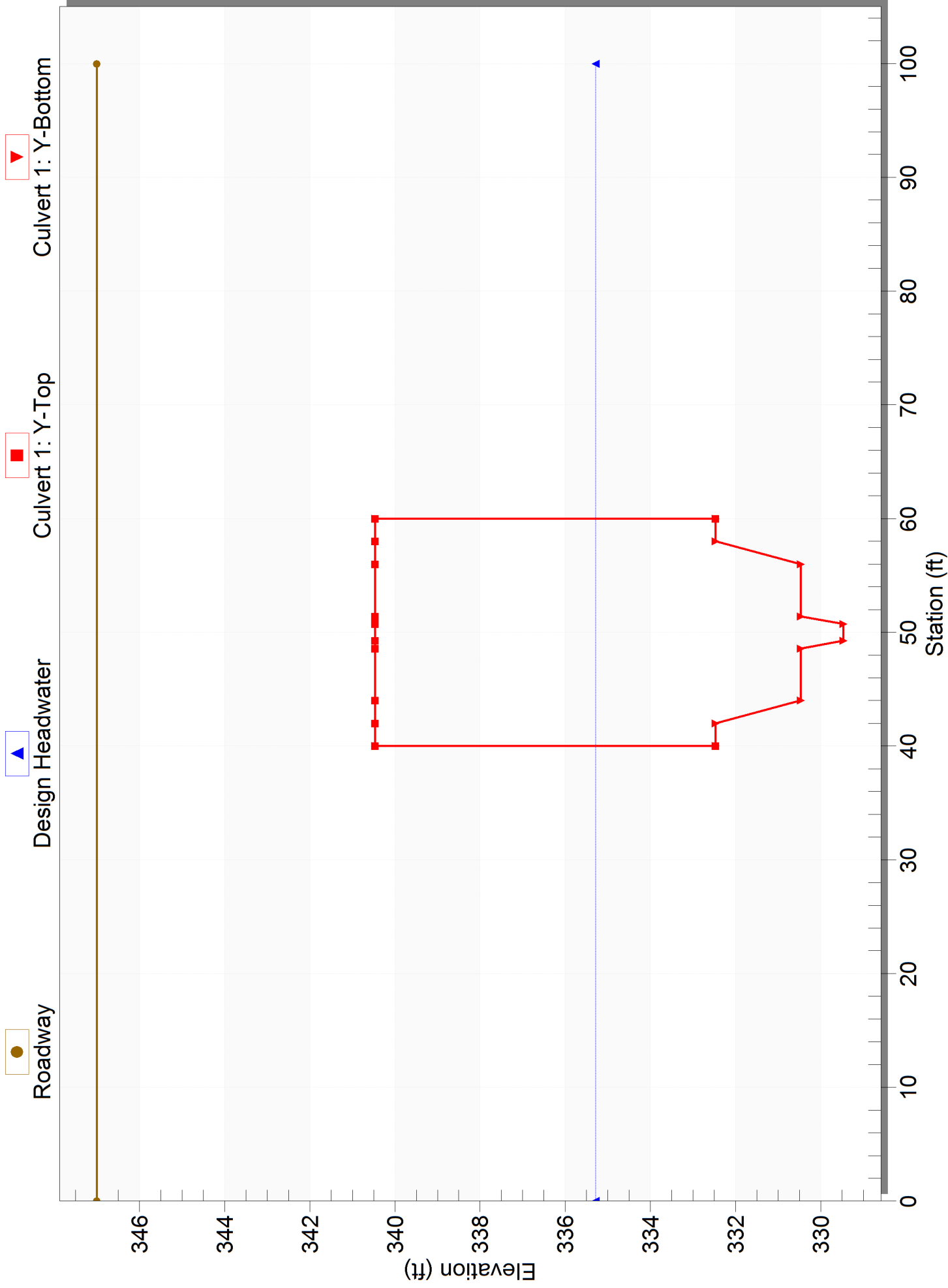
Crest Elevation: 347.00 ft

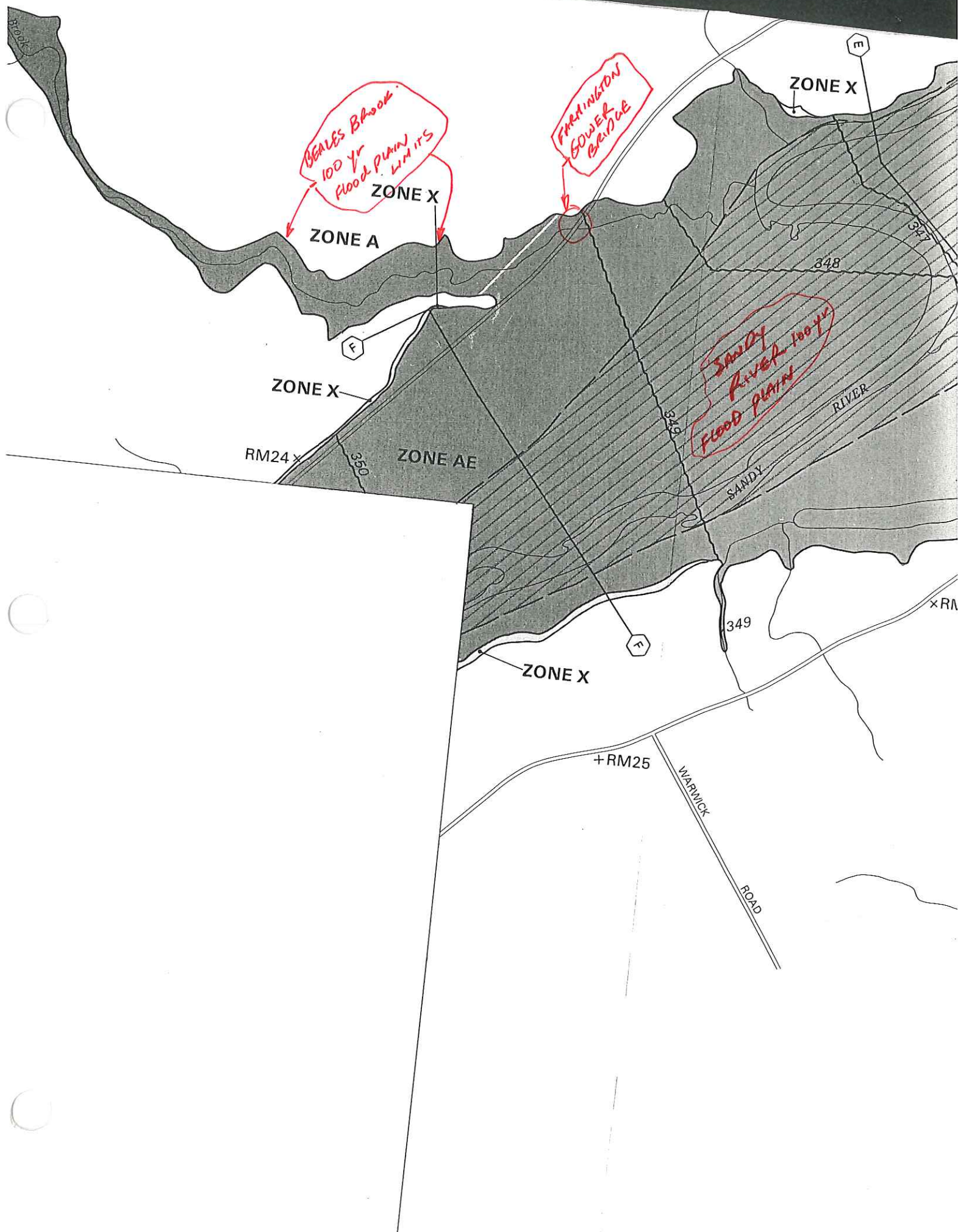
Roadway Surface: Paved

Roadway Top Width: 44.00 ft

Crossing: Gower Farm Bridge Proposed, Culvert: Culvert 1

Front View (Not to scale)





5' Deep Gcounhole

* RIVER EATEN PART OF
EMBANKMENT

- BEAVER DAM
- INLET CURB

20'

x 20

12x24

* FORD
W/STRA
W/STRA
W/STRA

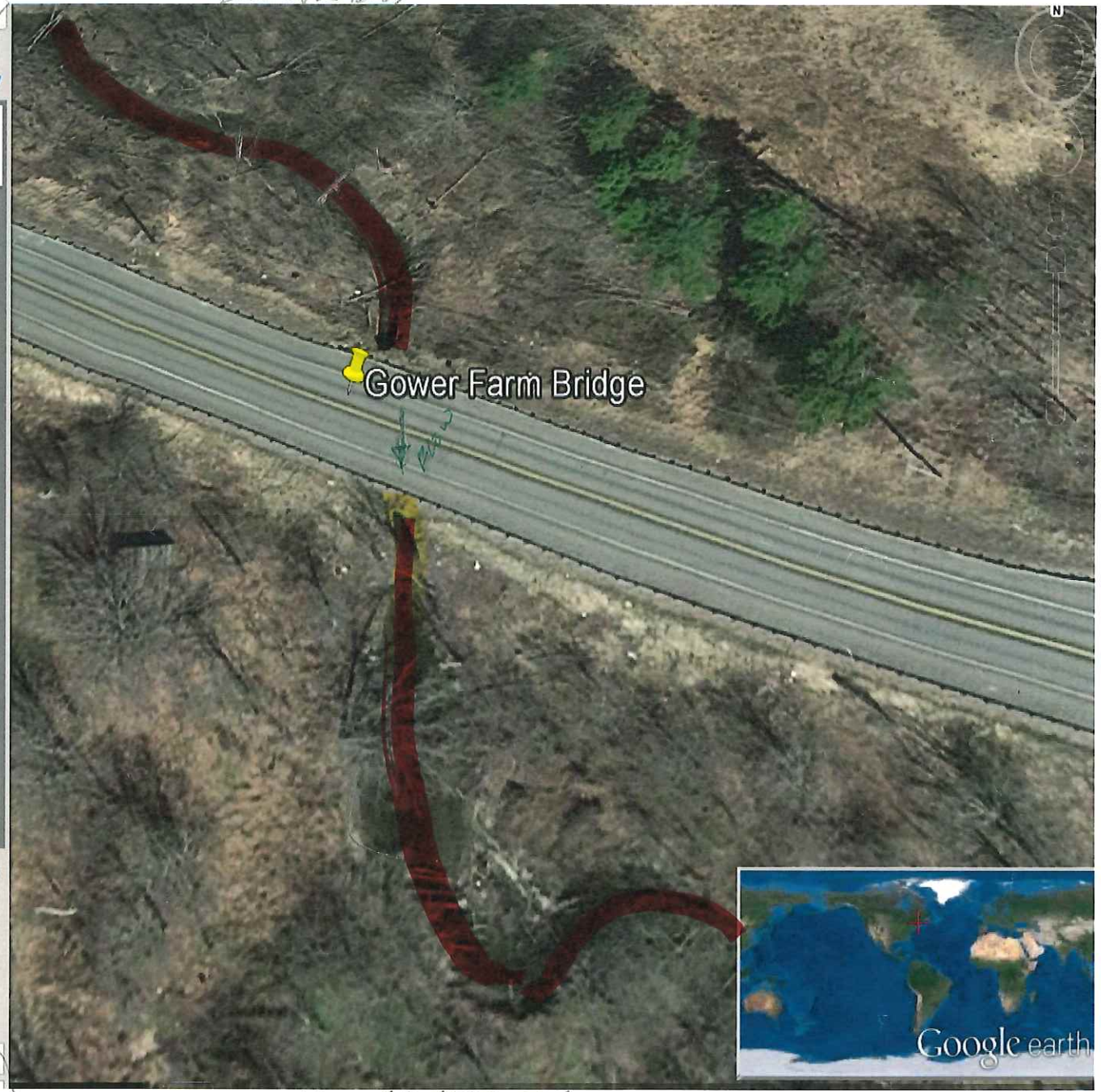
2yr 8

Flg 200

16'



BR# 2324



Gower Farm Bridge

* INLET ACCRETION
* BEAVER DAM unstable structure.
**200' ft upstream &
DOWNSTREAM**

Survey
200' beyond
push bar.

put station Rod.
@ 6" public count.
Slour pool
down stream.

BEAVER
DAM
Low stability
Disgr as if not there.

2' below
STREAM BED

upstream
BFW - 14' 100'
BFW - 16' 150'
BFW - 16' 250'
BFW - 16' 350'
BFW - 16' 400'

BFW 16'

* GRADIENT IS
FINE FOR FISH

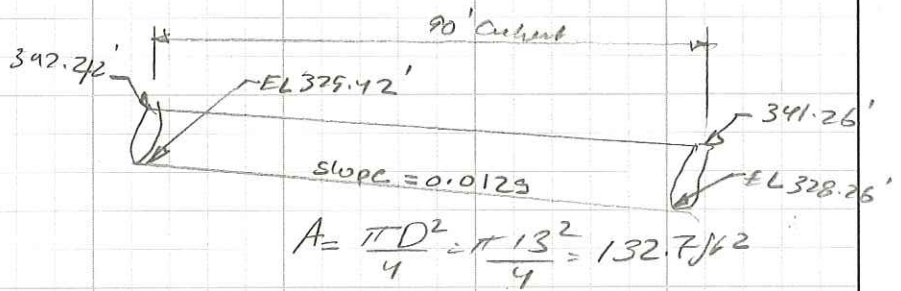
NOTES FROM SITE VISIT GOWER FARM BRIDGE #2324
ON 10/17/12

- 1 - Measured BFW in 5 LOCATIONS upstream & DOWNSTREAM
14', 16', 16', 16', 16'. CALL IT 16'
- 2 - GRADIENT O.K FOR FISH PASSAGE
- 3 - pebble count NOT performed due to SOIL CONDITIONS
- 4 - Big slow pool downstream nearly 5' deep
- 5 - INLET ACCUMULATION, SAND BARS, BEAVER DAMS present
unstable structures. DESIGN AS IF these obstructions are
not there.
- 6 - Survey 200' beyond push bar
- 7 - Embankment, erosion downstream at bend.
- 8 - Alignment of Culvert to remain as is no adjustments possible
- 9 - 12x20 or 12x24 Box culvert to be considered built up with
Min of 2' Dry shelves at low flow for aquatic passage
- 10 - 2' Min embedment with natural stream bottom.
- 11 - FORCED INSTREAM WORK WINDOWS.
- 12 - no perched outlet noted, fish passage available at low flow
- 13 - low streambed Gradient.

Assume INLET control

Curve

$$\text{slope} = \frac{329.42' - 328.26'}{90'} = 0.0129$$



CRITERIA = $0.9 = \frac{HW}{D} \Rightarrow HW = 0.9D = 11.7'$ Equiv ELEV = $329.42' - 11.7' = 341.12'$

$HW_{ELEV} = 341.12'$ $HW = 11.7'$

$TW = 0.5 D = 0.5 \times 13 = 6.5'$ $TW_{ELEV} = 334.76'$

CRITERIA

upst INVERT = 329.42'

Downst INV = 328.26'

$HW_{ELEV} = 341.12' = 11.7'$

$TW_{ELEV} = 334.76' = 6.5'$

OUTLET DISCHARGE VELOCITY = ?

$V_{outlet} = 12 \text{ ft/sec}$ (RIP RAP)

Slope = 0.0129 (should be resulting in less than 3 ft/sec with pipe flowing full)

INLET COEFF $\Rightarrow K_E = 0.9$ (abundant rip rap)

$Q_{50\%} = 5571 \text{ cfs}$, $V_1 = Q/A = 5571 \text{ cfs} / 132.7 \text{ ft}^2 = 4.19 \text{ ft/sec}$

LOSSES

$H_L = H_e + H_f + H_v + H_b + H_j + H_g$

H_L = total energy loss, ft

H_e = entrance loss $\Rightarrow K_E \frac{V^2}{2g} = 0.9 \left(\frac{4.19^2}{2 \times 32.2} \right) = 0.24'$

H_f = Friction loss $\Rightarrow H_f = \frac{2.9 n^2 L}{K^{1.33}} \left[\frac{V^2}{2g} \right]$

n = Manning roughness = 0.024 corrugate pipe

R = Hydraulic Radius = approx. $TW = 0.5D \Rightarrow A = \frac{132.7}{2} = 66.35 \text{ ft}^2$

$PP = 2\pi r/2 = \pi r = \pi(6.5) = 20.4'$

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$$\Rightarrow R = 66.35 / 20.4' = 3.25 \text{ ft}$$

$$H_f = \frac{29 \times 0.024^2 \times 90'}{(3.25)^{1.33}} \left[\frac{4.15^2}{2 \times 32.2} \right] = 0.09'$$

$$H_v = \frac{V^2}{2g} = \frac{(4.15)^2}{2 \times 32.2} = 0.27' \text{ (Velocity head)}$$

$$H_b = \text{barrel losses} = 0 \text{ NO BENDS}$$

$$H_j = \text{Junction losses} = 0 \text{ NO junctions}$$

$$H_g = \text{losses at gates} = 0 \text{ NO GATES}$$

$$\text{Exit loss} = 1.0 \left[\frac{V^2}{2g} - \frac{V^2}{2g} \right]$$

V_d = channel velocity downstream of the culvert fps (neglected)

$$H_o = H_v = \frac{V^2}{2g} = 0.27'$$

BARREL LOSSES

$$H = H_e + H_o + H_f$$

$$= (1 + K_e + 19.63 \frac{L}{R^{1.33}}) \left[\frac{V^2}{2g} \right]$$

$$= \left[1 + 0.9 + \frac{19.63 \times 0.024 \times 90}{(3.25)^{1.33}} \right] \left[\frac{V^2}{2g} \right] = 1.917 \left[\frac{V^2}{2g} \right]$$

ENERGY GRAADLINE

$$H_{w0} + \frac{V_1^2}{2g} = T_w + \frac{V_d^2}{2g} + h_L$$

$$H_L = 0.24' + 0.09' + 0.27' = 0.6'$$

$$H_{w0} + \frac{(7.4)^2}{2g} = 6.5' + \frac{V_d^2}{2g} + 0.6'$$

$$H_{w0} + 0.85' = 7.1'$$

$$H_{w0} = 7.1' - 0.85' = 6.25'$$

$$\Rightarrow \frac{H_{w0}}{D} = \frac{6.25}{13} = 0.48 < 0.9 \text{ O.K.}$$

findy downstream velocity

$$\frac{V_1^2}{2g} + \frac{P_1}{\gamma} + Z_1 = \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + Z_2 + h_L$$

$$\frac{V_1^2}{2g} + Z_1 - Z_2 = \frac{V_2^2}{2g} + h_L$$

$$Z_1 - Z_2 = 1.16'$$

$$\frac{(4.15)^2}{32.2} + 1.16' = \frac{V_2^2}{2g} + 0.6'$$

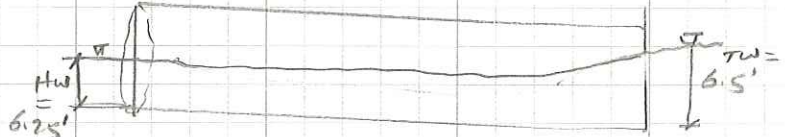
$$1.433' = \frac{V_2^2}{2g} + 0.6'$$

$$\frac{V_2^2}{2g} = 1.433 - 0.6 = 0.832'$$

$$V_2^2 = 53.58 \text{ ft}^2/\text{s}^2 \quad V_2 = 7.4 \text{ ft/s}$$

∴ Culvert flows partially full, no graphs are only available for full flow conditions
 (2) Q₅₀

OUTLET CONTROL



Comparison with Hy-8 Results

$$H_w = 337.1'$$

Q₅₀

$$H_w = 337.1 - 329.42 = 7.68'$$

$$H_w = 6.75'$$

Manual

$$T_w = 5.21'$$

$$T_{w \text{ Manual}} = 6.5'$$

DO NOT MISTAKE This must be same assumptions wrong.

check $T_w < d_c$

FROM CHART 4B FOR $Q = 557.1 \text{ cfs}$ & $D = 13'$

$$d_c = 5.2' < T_w = 6.5'$$

$$\frac{d_c + P}{2} = \frac{5.2' + 13'}{2} = 9.1'$$

$$T_w = 6.5' < \frac{d_c + P}{2} = 9.1'$$

Flow type III $T_w > d_c$

$$T_w < \frac{d_c + D}{2} = \frac{5.2' + 13'}{2} = 9.1' \quad \text{yes}$$

$$\text{then } H_w = h_o + H - \text{sol}$$

$$h_o = \text{larger } T_w \text{ or } \left(\frac{d_c + D}{2} \right) = 7.35'$$

$$H_w = 7.35 + 1.63 - 1.16 = 7.82' \quad \checkmark$$

$$H = 1.517 \left[\frac{V}{7.5} \right]^2 = 1.517 \left[\frac{7.4}{7.5} \right]^2 = 1.63'$$

$$\text{sol} = 0.0125 \times 50' = 1.16'$$

$$H_{w \text{ calculated}} = 7.68' \quad (\text{Hy-8})$$

$$H_{w \text{ calc}} = 7.82' \quad (\text{Manual}) \quad \checkmark$$

$$\% \text{ error} = \frac{7.82 - 7.68}{7.68} \times 100 = 1.7\% \quad \text{O.K.}$$

$$\frac{H_w}{D} = \frac{7.68}{13} = 0.59 \quad \text{@ } Q_{50} = 59\%$$

$$T_w (\text{Hy-8}) = 5.21'$$

$$T_{w \text{ calc}} = 7.82' - 0.6' - 1.16' = 5.59' \quad \text{O.K.}$$

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Report procedure for $Q_{500} = 886.70 \text{ cfs}$

$$Q_{500} = 886.7 \text{ cfs} \quad V_1 = Q/A = 886.7 / 132.7 \text{ ft}^2 = 6.68 \text{ ft/s}$$

Losses

$$H_L = H_e + H_f + H_v + H_b + H_j + H_s$$

$$H_L = H_e + H_f + H_v$$

$$H_e = 0.9 \left(\frac{6.68^2}{2 \times 32.2} \right) = 0.62'$$

$$H_f = \frac{29 \times 0.024^2 \times 90 \left[\frac{V^2}{25} \right]}{R^{1.33}}$$

$$R = \frac{A}{P} = \frac{98}{25.5} = 3.84'$$

$$H_f = \frac{29 \times 0.024^2 \times 90 \left[\frac{6.68^2}{25} \right]}{(3.84)^{1.33}}$$

$$H_f = 0.17'$$

$$H_v = \frac{V^2}{25} = \frac{6.68^2}{2 \times 32.2} = 0.65'$$

$$\text{Exit Losses } H_o = H_v = \frac{V^2}{25} = 0.65'$$

BARREL LOSSES

$$H = H_e + H_o + H_f$$

$$= \left[1 + K_e + \left[\frac{19.63 n^2 L}{R^{1.33}} \right] \right] \left[\frac{V^2}{25} \right]$$

$$= 1 + 0.9 + \frac{19.63 \times 0.024^2 \times 90 \left[\frac{V^2}{25} \right]}{(3.84)^{1.33}}$$

$$= 2.07 \left[\frac{V^2}{25} \right]$$

$$R = \frac{A}{P}$$

$$\text{Assume } TW = 0.7D = 0.7 \times 13 = 9.1'$$

$$A =$$

$$r = 6.5', a = 6.5' - 4' = 2.5'$$

Area of TRIANGLE

$$= \frac{2.5' \times 6.0'}{2} = 7.5 \text{ ft}^2$$

$$\text{Area OBA} = 7.5 \times 2 = 15 \text{ ft}^2 \quad \sin \theta = \frac{2.5}{6.5} = 0.384$$

$$\theta = 22.6^\circ$$

$$\alpha = 90^\circ - 22.6^\circ = 67.4^\circ$$

$$\angle \alpha = 134.8^\circ$$

$$\cos \theta = \frac{x}{6.5}$$

$$x = 6.5 \cos 22.6 = 6.00'$$

$$\Leftrightarrow \frac{A_s}{A_c} = \frac{m}{360^\circ}$$

$$A_s = \frac{m}{360^\circ} \times A_c = \frac{134.8}{360} \times (132.7 \text{ ft}^2) = 49.7 \text{ ft}^2$$

$$\text{Area SCA} = 49.7 \text{ ft}^2 - 15 \text{ ft}^2 = 34.7 \text{ ft}^2$$

$$\text{Area of flow} = 132.7 - 34.7 = 98 \text{ ft}^2$$

$$\frac{P_s}{P_c} = \frac{m}{360} \Rightarrow P_s = \frac{134.8}{360} \times 2\pi \times 6.5' = 15.3 \text{ ft}$$

$$P_{\text{flow}} = 2\pi r - 15.3 \text{ ft} = 2 \times \pi \times 6.5 - 15.3 = 25.5 \text{ ft}$$

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ENERGY GRADELINE

$$H_{w0} + \frac{V_1^2}{2g} = T_w + \frac{V_2^2}{2g} + h_L$$

$$H_L = 0.62' + 0.17' + 0.65' = 1.48'$$

$$H_w + \frac{(4.5)^2}{2g} = 9.1' + \frac{V_2^2}{2g} + 1.48'$$

$$H_w = 10.2'$$

$$\frac{H_w}{D} = \frac{10.2}{13} = 0.78 < 0.90 \text{ o.k.}$$

findy Downstream Velocity

$$\frac{V_1^2}{2g} + \frac{P_1}{\gamma} + z_1 = \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + z_2 + h_L$$

$$\frac{V_1^2}{2g} + z_1 - z_2 = \frac{V_2^2}{2g} + h_L$$

$$z_1 - z_2 = 1.16'$$

$$\frac{(6.68)^2}{2 \times 32.2} + 1.16 = \frac{V_2^2}{2g} + 1.48'$$

$$1.853 = \frac{V_2^2}{2g} + 1.48'$$

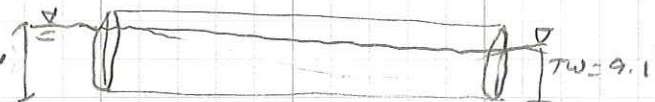
$$\frac{V_2^2}{2g} = 1.853 - 1.48 = 0.373$$

$$V_2^2 = 24.02 \Rightarrow V_2 = 4.9 \frac{ft}{sec}$$

∴ Culvert flows partially full (w) Q500
 NOMOGRAPHS ARE ONLY VALID FOR
 FULL FLOW conditions

INLET CONTROL

$$H_w = 10.2'$$



Compare with Hx8

$$H_w = 335.35'$$

Q500

$$H_w = 335.35 - 329.42' = 9.97' \quad (H_1 - 8)$$

$$T_w = 6.05'$$

$$H_w = 10.2' \quad \text{o.k.}$$

$$H_w = 9.1'$$

check $T_w < d_c$

$$T_w = 9.1' > d_c = 7.2'$$

$T_w > d_c$ Flow type III

$$\text{if } T_w = 9.1 > \frac{d_c + D}{2} = \frac{0.74' + 13}{2} = 6.87' \text{ o.k.}$$

$$H_w = h_o + h - SOL$$

$$H_w = 9.1' + 0.71 - 1.16 = 8.65'$$

$$h_o = \text{legacy } T_w \text{ at } \left(\frac{d_c + D}{2}\right) = 9.1'$$

$$h = 1.917 \left[\frac{V^2}{2g} \right] = 1.917 \left[\frac{4.9^2}{2 \times 32.2} \right] = 0.71'$$

$$SOL = 1.16'$$

$$H_{w_{H_8}} = 9.97'$$

$$H_{w_{Mand}} = 10.2'$$

Culvert does not flow full

$$\frac{H_w}{D} = \frac{10.2}{13} = 0.78 \text{ or } 78\% \text{ (w) } Q_{500}$$

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FROM CHART 51B INLET CONTROL Curves - Circular structural plates.

$\frac{Q}{AD^{0.5}}$ vs $\frac{HW}{D}$ curves for mitered inlet.

$$Q_{500\text{flow}} = 557.1 \text{ cfs} \quad A = 132.7 \text{ ft}^2 \quad D = 13'$$

$$\therefore \frac{Q}{AD^{0.5}} = \frac{557.1 \frac{\text{ft}^3}{\text{sec}}}{132.7 \text{ ft}^2 \cdot (13')^{0.5}} = 1.164$$

for Mitered edge $\frac{HW}{D} = 0.60 \Leftrightarrow HW = 0.60 \times 13 = 7.8'$

$HW = 7.68'$ (Hy-8)	$HW = 7.82'$ (Manual)	$HW = 7.8'$ CH 51B
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FROM CHART 51B INLET CONTROL Curves - Circular structural plate.

$\frac{Q}{AD^{0.5}}$ vs $\frac{HW}{D}$ curves for mitered inlet.

$$Q_{500\text{flow}} = 886.7 \text{ cfs} \quad A = 132.7 \text{ ft}^2 \quad D = 13'$$

$$\frac{Q}{AD^{0.5}} = \frac{886.7 \frac{\text{ft}^3}{\text{sec}}}{132.7 \text{ ft}^2 \cdot 13'^{0.5}} = 1.85$$

for Mitered edge $\frac{HW}{D} = 0.8 \Leftrightarrow HW = 0.8 \times 13 = 10.4'$

$HW = 9.97'$ (Hy-8)	$HW = 10.2'$ (Manual)	$HW = 10.4'$ (chart)
------------------------	--------------------------	-------------------------

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DESIGN FLOW

$$Q_{50} = 557.1 \text{ cfs}$$

CHECK FLOW

$$Q_{100} = 622.41 \text{ cfs}$$

USING METHOD IN HDS-5

$$\text{Culvert span} = 90'$$

$$ELSF = 329.42'$$

$$\text{slope} = 0.0847$$

TW depth:

Q_{50} :

$$Q = \frac{1.49}{n} \times A \times R^{\frac{2}{3}} \times S^{\frac{1}{2}}$$

$$A = \left[\frac{16 + (16 + 2yn)}{2} \right] yn = [16 + yn] yn$$

$$R = \frac{A}{P} = \frac{[16 + yn] yn}{[16 + 2.828yn]}$$

$$557.1 = \frac{1.49}{0.032} \times \frac{[16 + yn] yn^{\frac{5}{3}}}{[16 + 2.828yn]^{\frac{2}{3}}} (0.0847)^{\frac{1}{2}}$$

$$41.1 = \frac{[16 + yn] yn^{\frac{5}{3}}}{[16 + 2.828yn]^{\frac{2}{3}}}$$

$$\text{Try } yn = 2' \rightarrow 50.5'$$

$$\text{Try } yn = 1.8' \rightarrow 42.3'$$

$$\text{Say } yn = 1.7'$$

$$\therefore \text{TW depth} = 1.22'$$

above
culvert

INLET CONTROL

$$A = 1327.7 \text{ ft}^2 \quad D = 13'$$

$$AD^{0.5} = 1327.7 \text{ ft}^2 \times 13' = 478.4$$

$$Q/AD^{0.5} = 557.1 / 478.4 = 1.16$$

BASED ON CHART 51B FOR MITERED CULVERT $\frac{HW}{D} = 0.6$

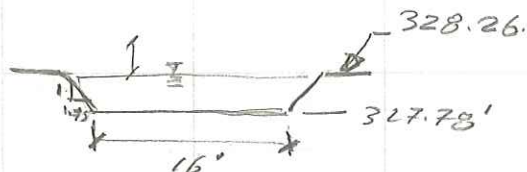
$$HW = 0.6 \times 13' = 7.8' \quad , \quad EL_{Hi} = 329.42' + 7.8' = 337.22'$$

Q_{50}

FOR THE CHECK FLOW

$$Q/AD^{0.5} = 622.41 / 478.4 = 1.3$$

BASED ON CHART 51B FOR MITERED INLET CONTROL circular culvert.



Channel slope = 0.0847

Manning's n = 0.032

Channel invert elev = 327.78'

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$$\Rightarrow \frac{H_w}{D} = 0.7, H_w = 0.7 \times 13 = 9.1'$$

$$EL_{Hi} = 329.42 + 9.1' = 338.52'$$

$$Q_{100}$$

OUTLET CONTROL

FROM Hydraulic conditions for circular conduits. CHART 4B

for $Q_{50} = 557.1 \text{ cfs} \rightarrow dc = 5.2' < D = 13'$

$Q_{100} = 627.41 \text{ cfs} \rightarrow dc = 5.6' < D = 13'$

$TW = 1.22 < dc$ $\therefore$ Supercritical flow

FOR Q_{50} $\frac{dc + D}{2} = \frac{5.2' + 13'}{2} = 9.1'$
 $TW = 5.2'$

$h_o =$ creating TW at $\frac{dc + D}{2} = 9.1'$

$EL_{h_o} = EL_o + H + h_o$ $EL_o = 328.26'$ (INV ELEV @ outlet)

$H_{\text{head losses}} = 0.6'$ previous calc.

$EL_{h_o} = 328.26' + 9.1' + 0.6' = 337.96'$

FOR Q_{50} FOR BOTH CASES

INLET CONTROL

$\frac{H_w}{D} = \frac{7.8}{13} = 0.6$



OUTLET CONTROL

$\frac{H_w}{D} = \frac{9.7}{13} = 0.75$



FOR BOTH CASES control is O.K.

@ Q_{50}

MaineDOT

MaineDOT

② $Q_{100} = 622.41 \text{ cfs}$

$$622.41 \text{ cfs} = \frac{1.49}{2.032} \frac{[(16 + y_n) y_n]^{5/3}}{[16 + 2.828 y_n]^{2/3}} (0.0847)^{1/2}$$

$$45.9 = \frac{[(16 + y_n) y_n]^{5/3}}{[16 + 2.828 y_n]^{2/3}}$$

try $y_n = 1.9' \rightarrow 46.3'$

try $y_n = 1.88' \rightarrow 45.5'$

Tw depth = $327.78 + 1.88 - 328.26 = 1.4'$

INLET CONTROL (previously computed)

$\frac{H_w}{D} = 0.7$ $H_w = 0.7 \times 13 = 9.1'$ $EL_{hi} = 329.42 + 9.1 = 338.52'$
 Q_{100}

OUTLET CONTROL

$Q_{100} = 622.41 \text{ cfs} \rightarrow d_c = 5.6' < D = 13'$

$Tw = 1.4' < d_c \therefore$ supercritical flow

for Q_{100} $\frac{d_c + D}{2} = \frac{5.6 + 13}{2} = 9.3'$
 $Tw = 5.6'$

$h_o =$ greater of Tw or $\frac{d_c + D}{2} = 9.3'$

$EL_{h_o} = EL_o + H + h_o$ $EL_o = 328.26'$

$EL_{h_o} = 328.26 + 0.76 + 9.3'$
 $= 338.32'$

$HL = H_e + H_f + H_v = 0.31 + 0.11 + 0.34 = 0.76'$

$H_e = 0.9 \left(\frac{V^2}{2g} \right) = 0.9 \left(\frac{4.65^2}{2 \times 32.2} \right) = 0.31'$

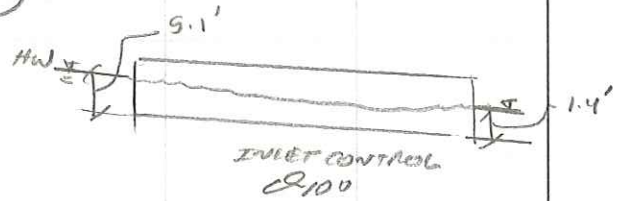
$H_f = \frac{29 n^2 L}{K^{1.33}} \left[\frac{V^2}{g} \right] = \frac{29 \times 0.024^2 \times 90'}{R^{1.33}}$

$M_{fw} = 66.35 \text{ ft}^2$ $P = \frac{2\pi r}{2} = 20.4'$

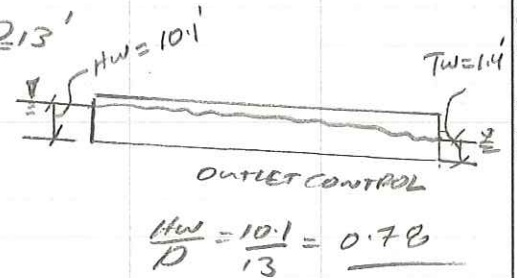
$R = 3.25$, $R = \frac{A}{P} = \frac{66.35}{20.4} = 3.25$

$H_f = \frac{29 \times 0.024^2 \times 90'}{(3.25)^{1.33}} \left[\frac{4.65^2}{2 \times 32.2} \right] = 0.11'$

$H_v = \frac{V^2}{2g} = \frac{(4.65)^2}{2 \times 32.2} = 0.34'$



$\frac{H_w}{D} = \frac{9.1}{13} = 0.7$



$\frac{H_w}{D} = \frac{10.1}{13} = 0.78$

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MaineDOT

$$Q_{500} = 886.70 \text{ cfs}$$

$$886.70 \text{ cfs} = \frac{1.49}{0.032} \frac{[16 + y_n] y_n^{5/3}}{[16 + 2.828 y_n]^{2/3}} (0.0847)^{1/2}$$

$$65.4 = \frac{[16 + y_n] y_n^{5/3}}{[16 + 2.828 y_n]^{2/3}}$$

$$\text{Try } y_n = 2.5' \rightarrow 53.4$$

$$y_n = 2.2' \rightarrow 59.2$$

$$y_n = 2.25' \rightarrow 61.5$$

$$y_n = 2.26' \rightarrow 62.0$$

$$y_n = 2.28' \rightarrow 62.9$$

$$y_n = 2.32' \rightarrow 64.8$$

$$y_n = 2.33' \leftarrow 65.3$$

$$TW \text{ depth} = 327.78' + 2.33' - 328.26' = 1.85'$$

INLET CONTROL

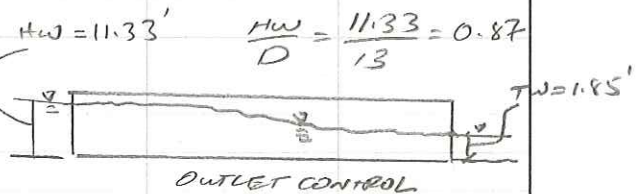
$$\frac{H_w}{D} = 0.8 \quad H_w = 0.8 \times 13 = 10.4' \quad EL_{hi} = 329.42' + 10.4' = \underline{339.82'}$$

OUTLET CONTROL

$$Q_{500} = 886.70 \text{ cfs} \rightarrow d_c = 6.7' < D = 13'$$

$$TW = 1.85' < d_c \text{ Supercritical flow}$$

$$\text{For } Q_{500} \quad \frac{d_c + D}{2} = \frac{6.7 + 13}{2} = 9.85' \\ TW = 5.6'$$



$$h_o = \text{water of } TW \text{ at } \frac{d_c + D}{2} = 9.85'$$

$$EL_{ho} = EL_o + H_L + h_o \quad H_L = 1.48' \text{ previously computed}$$

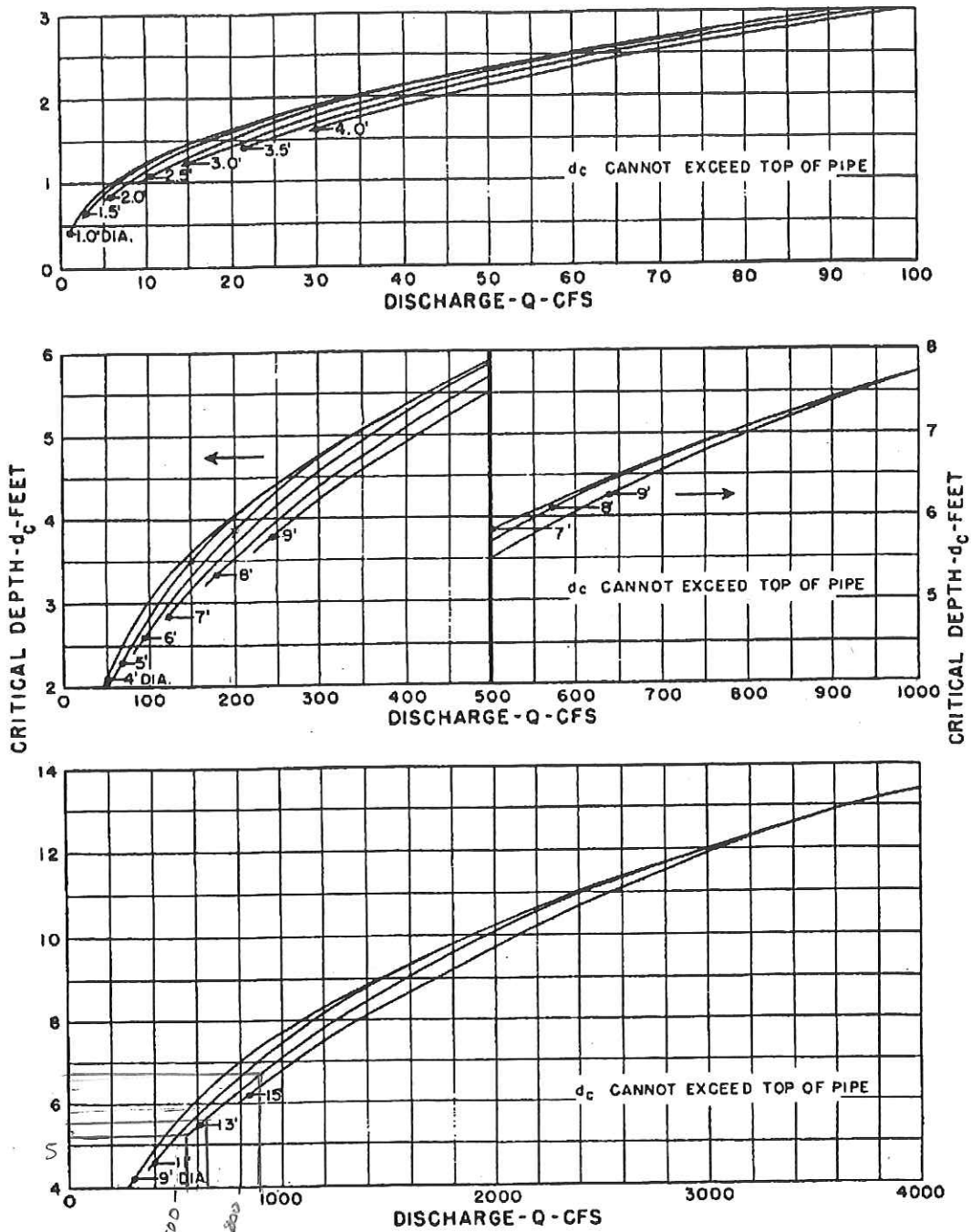
$$EL_{ho} = 329.42' + 1.48' + 9.85' = 340.75'$$

Both Below top of Culvert
OK

MaineDOT

MaineDOT

CHART 4B



BUREAU OF PUBLIC ROADS
JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

$$\begin{aligned}
 Q_{50} &= 557.1 \text{ cfs} \rightarrow d_c = 5.2' \\
 Q_{100} &= 622.41 \text{ cfs} \rightarrow d_c = 5.6' \\
 Q_{500} &= 886.70 \text{ cfs} \rightarrow d_c = 6.7'
 \end{aligned}$$

231

21880.00
 FARMINGTON GOWD SH NO-7-
 FARM BR
 EXISTING CURVE

325

Q/100

$$Q/100 \text{ Flow} = 622.41 \text{ cfs}$$

$$\frac{Q}{A D^{0.5}} = \frac{622.41}{132.7 \times 13^{0.5}} = 1.3 \rightarrow \frac{H_w}{D} = 0.7 \Rightarrow H_w = 0.7 \times 13 = 9.1'$$

CHART 51

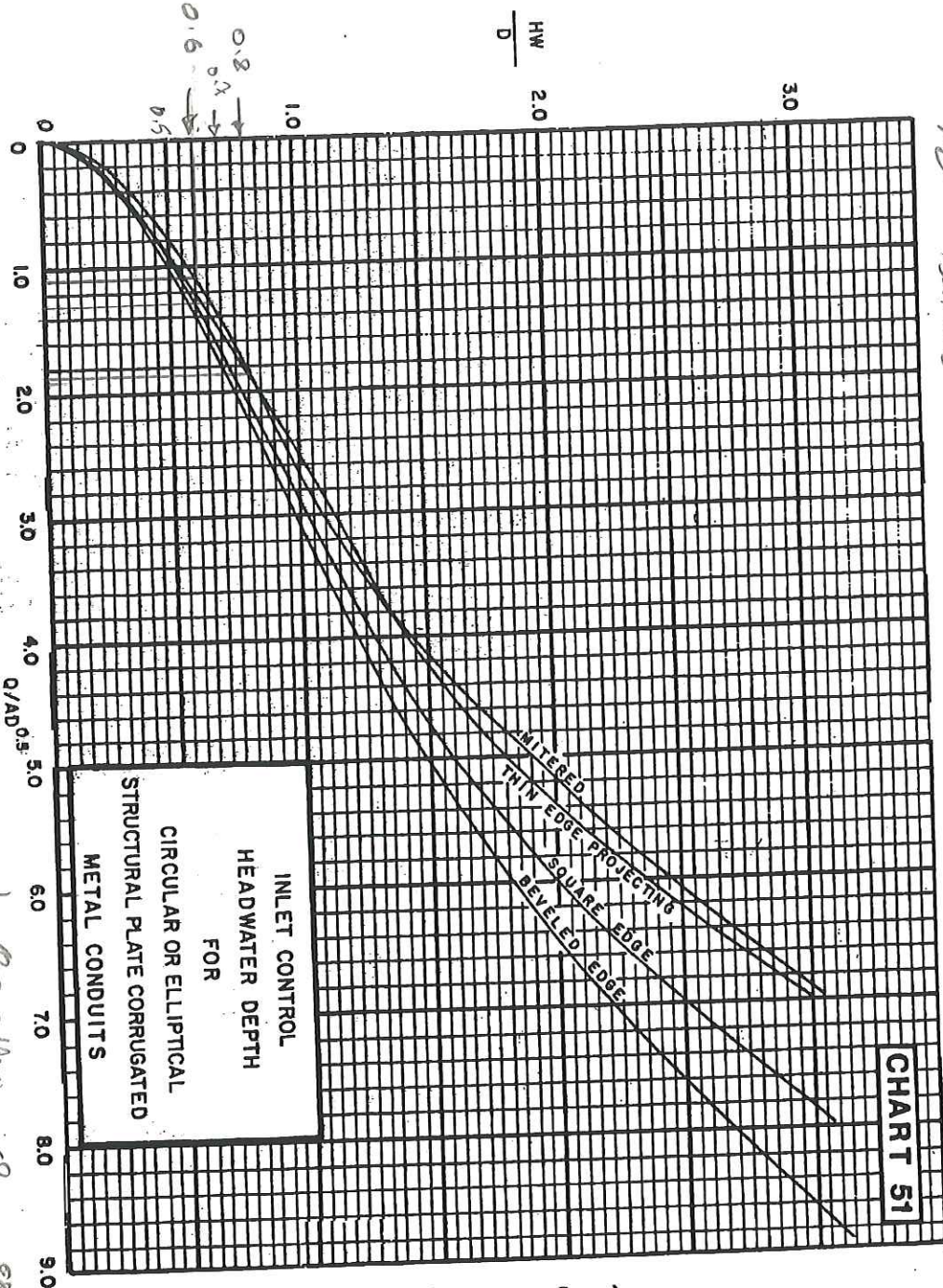


CHART 51B
 (English Units)

Q/500

$$\frac{Q}{A D^{0.5}} = \frac{557.1 \text{ cfs}}{132.7 \times 13^{0.5}} = 1.16$$

$$\frac{H_w}{D} = 0.6, H_w = 0.6 \times 13 = 7.8'$$

Q/500

$$\frac{Q}{A D^{0.5}} = \frac{886.7 \text{ cfs}}{132.7 \times 13^{0.5}} = 1.85$$

$$\frac{H_w}{D} = 0.8, H_w = 0.8 \times 13 = 10.4'$$



APR 12 2018

DATE _____

PROJ. NO.

21880.00

FILE NO.

— OF

DATE _____

LOCATION

FARMINGTON GOWER

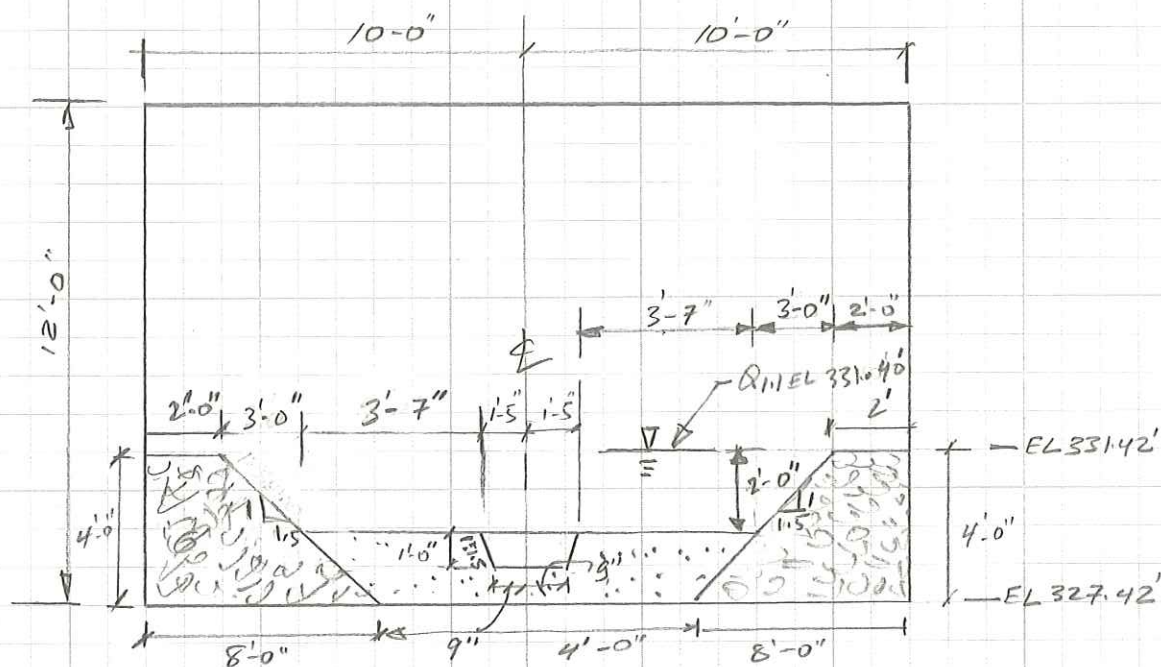
SHEET NO.

— OF

SUBJECT

Дир. Выходит

FARMER

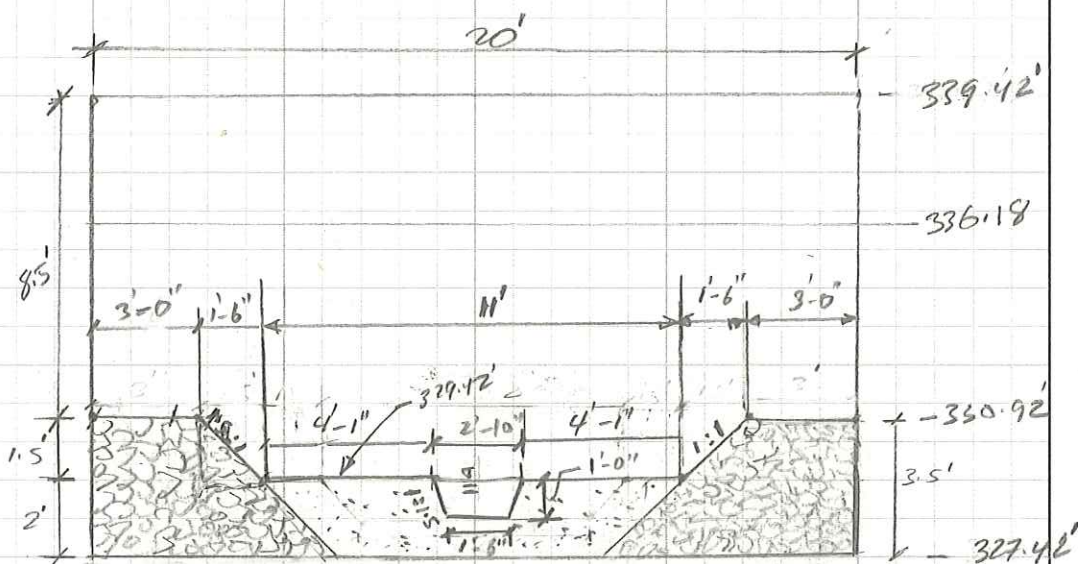


GOWER FARM BRIDGE BOX Culvert
REVISED

- 1) So that $Q_{1.1}$ is at or below top of wildlife bank.
- 2) Top width of flow at $Q_{1.1} = 16' =$ bank full width of channel.

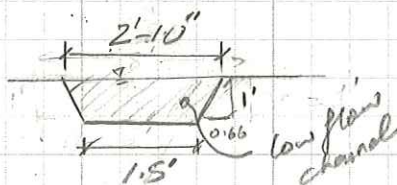
MaineDOT

MaineDOT



* $Q_{1.1} = 84.9 \text{ cf}$

Try low flow channel



$$\begin{array}{r} 18.75 \\ 2.17 \\ \hline 105.2 \end{array}$$

$$n = 0.042 \text{ (natural channel)}$$

$$b_0 = 1.5' + 2(1.2) = 3.9' \text{ flowing full}$$

$$A_{flow} = \frac{(15' + 2.83')}{2} \times 12 = 2.17 \text{ } \sigma^{12}$$

$$R = \frac{A}{b_0} = \frac{2.17 \text{ pr}_2}{3.5} = 0.57 \text{ pr}$$

$$Q = \frac{1.45}{1} A \cdot R^{2/3} S^{1/2} \text{ using a } 0.5\% \text{ slope } n = 0.042$$

$$Q = \frac{1.45}{0.042} \times 2.17 \text{ ft}^2 (0.57)^{2/3} (0.005)^{1/2}$$

$Q = 3.74 \text{ cfs} < Q_{1.1} = 84.9 \text{ cfs}$

OK FOR
Adult Salmon Bm

But $Q_{111} = 84.5 \text{ cfs} > \text{capacity}$

Q1.1 flow is ABOVE STREAMBED

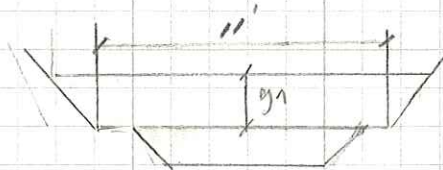
$$Q_{aff} = 84.5 \text{ cfs} - 27.4 \text{ cfs} = 57.5 \text{ cfs}$$

EVALUATE γ_n for $\alpha = 57.5^\circ$

$$b_0 = 11' + 2(1.414) \text{ yn} = 11' + 2.828 \text{ yn}$$

$$A_{flow} = \left[\frac{11' + (11' + 2q_n)}{2} \right] q_n = [11' + q_n] q_n$$

$$R = \frac{A}{b_0} = \frac{[11' + y_n] y_n}{[11' + 2.823 y_n]}$$



8-12

MaineDOT

$$2) 57.5 cfs = \frac{1.49}{0.032} \frac{[(1+y_n)y_n]^{5/3}}{[1+2.875y_n]^{2/3}} \times (0.00966)^{1/2}$$

$$12.56 = \frac{[(1+y_n)y_n]^{5/3}}{[1+2.875y_n]^{2/3}}$$

Try $y_n = 1' \rightarrow 10.92$

Try $y_n = 1.1' \rightarrow 12.80$

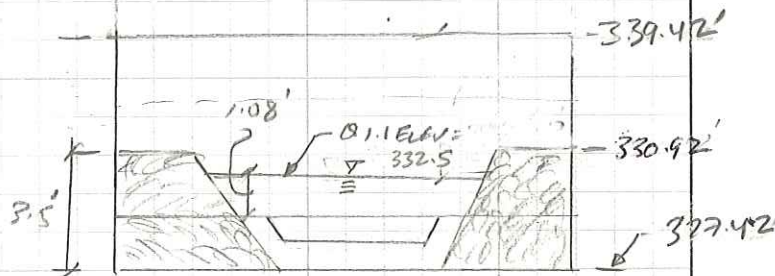
Try $y_n = 1.08' \rightarrow 12.41$

$y_n = 1.09' \checkmark$

$$A/cow = 7ft^2 + (11' + y_n)y_n$$

$$= 7ft^2 + (11' + 1.09')1.09' = 20.7 ft^2$$

$$V = Q/A = 84.9/20.2 = 4.20 ft/sec$$



$Q_{1.1} \text{ depth} = 3.08' \text{ above current invert}$

$Q_{1.1} \text{ ELEV} = 327.42 + 3.08 = 332.50$

$H_w/d = \frac{3.08}{12} = 0.26, 26\% \text{ full}$

$Q_{1.1} \text{ ELEV} (14-8) = 333.28'$

* $Q_2 = 178.6$

$Q_{diff} = 178.6 - 27.4 = 151.2 cfs$

$$151.2 cfs = \frac{1.49}{0.032} \frac{[(1+y_n)y_n]^{5/3}}{[1+2.875y_n]^{2/3}} \times (0.00966)^{1/2}$$

$$33.04 = \frac{[(1+y_n)y_n]^{5/3}}{[1+2.875y_n]^{2/3}}$$

Try $y_n = 1.5 \rightarrow 21.5$

$Q_{corrected 1.5' \text{ depth}} = \frac{1.49}{0.032} \times \frac{[(1+y_n)y_n]^{5/3}}{[1+2.875y_n]^{2/3}} \times (0.00966)^{1/2}$

$Q = 98.2 cfs$

TOTAL $Q = 27.4 + 98.2 = 125.6$

top of top of shelf

$Q_{remaining} = 178.6 - 125.6 = 53 cfs$

for a box section

$p = b_0 = 20' + 2y_n$

$A = 20'y_n$

$$53 cfs = \frac{1.49}{0.032} \frac{20y_n \left[\frac{20y_n}{20+2y_n} \right]^{2/3}}{(0.00966)^{1/2}}$$

$$53 cfs = \frac{1.49}{0.032} \times \frac{(20y_n)^{5/3}}{(20+2y_n)^{2/3}} \times (0.00966)^{1/2}$$

$R = \frac{A}{P}$

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$$11.58 = \frac{[20 y_n]^{5/3}}{[20 + 2 y_n]^{2/3}}$$

$$y_n = 0.5' \rightarrow 6.09$$

$$y_n = 0.7' \rightarrow 10.55 \checkmark$$

$$\text{TOTAL DEPTH} = 3.5' + 0.7' = 4.2'$$

$$*Q_5 = 284.5 \text{ cfs}$$

$$Q_{\text{diff}} = Q_5 - Q_2 = 284.5 \text{ cfs} - 178.6 \text{ cfs}$$

$$= 105.9 \text{ cfs}$$

$$105.9 \text{ cfs} = \frac{1.49}{0.032} \times \frac{(20 y_n)^{5/3}}{(20 + 2 y_n)^{2/3}} \times (0.00566)^{1/2}$$

$$23.14 = \frac{(20 y_n)^{5/3}}{(20 + 2 y_n)^{2/3}}$$

$$\text{let } y_n = 1.5' \rightarrow 35.8'$$

$$y_n = 1.2' \rightarrow 25.13$$

$$y_n = 1.18' \rightarrow 24.46$$

$$y_n = 1.17' \rightarrow 24.13$$

$$y_n = 1.15' \rightarrow 23.47$$

$$y_n = 1.14' \rightarrow 23.15 \checkmark$$

$$*Q_{10} = 361.0 \text{ cfs}$$

$$Q_{\text{diff}} = Q_{10} - Q_5 = 361.0 - 284.5 = 76.5 \text{ cfs}$$

$$76.5 \text{ cfs} = \frac{1.49}{0.032} \times \frac{(20 y_n)^{5/3}}{(20 + 2 y_n)^{2/3}} \times (0.00566)^{1/2}$$

$$16.7 = \frac{(20 y_n)^{5/3}}{[20 + 2 y_n]^{2/3}}$$

$$\text{let } y_n = 0.8' \rightarrow 13.0$$

$$y_n = 0.9' \rightarrow 15.8$$

$$y_n = 0.95 \rightarrow 17.2$$

$$y_n = 0.93 \rightarrow 16.7 \checkmark$$

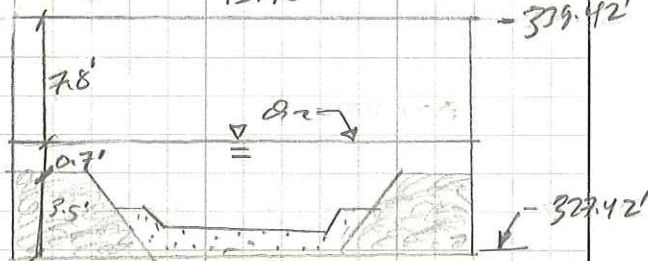
$$\frac{H_w}{D} = \frac{6.27}{12} = 52$$

52% full

$$A_{\text{flow}} = 17 \text{ ft}^2 + \frac{(11 + 14)}{2} \times 1.5' + 0.7 \times 20'$$

$$= 39.75 \text{ ft}^2$$

$$V = Q/A = 178.6 / 39.75 = 4.49 \text{ ft/sec}$$



$$Q_2 \text{ depth} = 4.2'$$

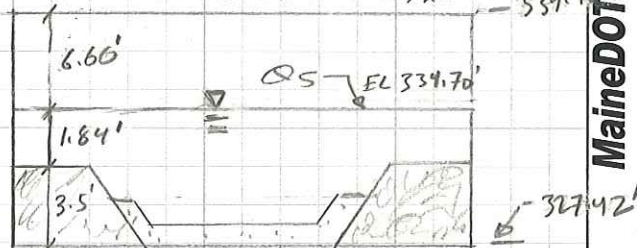
$$Q_2 \text{ ELEV} = 329.42' + 4.2' = 333.62'$$

$$\frac{H_w}{D} = \frac{4.2}{12} = 0.35, 35\% \text{ full}$$

$$Q_2 (H_y - 8) = 334.25'$$

$$A_{\text{flow}} = 25.75 + 1.84(20) = 62.55 \text{ ft}^2$$

$$V = Q/A = 284.5 / 62.55 = 4.55 \text{ ft/sec}$$



$$Q_5 \text{ depth} = 4.2' + 1.14' = 5.34'$$

$$Q_5 \text{ ELEV} = 329.42' + 5.34' = 334.76'$$

$$\frac{H_w}{D} = \frac{5.34}{12} = 0.45 \approx 45\% \text{ full}$$

$$Q_5 (H_y - 8) = 335.14'$$

$$A_{\text{flow}} = 25.75 + 2.77 \times 20 = 81.15 \text{ ft}^2$$

$$V = Q/A = 361.0 / 81.15 = 4.45 \text{ ft/sec}$$



$$Q_{10} \text{ depth} = 5.34' + 0.93' = 6.27'$$

$$Q_{10} \text{ ELEV} = 329.42' + 6.27' = 335.69'$$

$$Q_{10} (H_y - 8) = 335.72' \checkmark$$

* $Q_{25} = 473.7 \text{ cfs}$

$Q_{diff} = Q_{25} - Q_{10} = 473.7 - 361.0 = 112.7 \text{ cfs}$

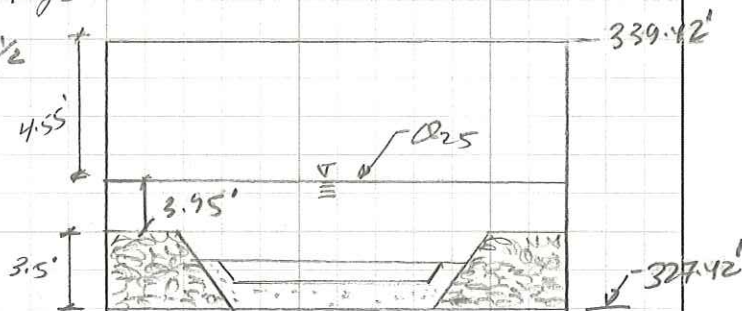
$112.7 \text{ cfs} = \frac{1.49 \times (20y_n)^{5/3}}{0.032 (20+2y_n)^{2/3}} (0.00966)^{1/2}$

$24.6 = \frac{(20y_n)^{5/3}}{(20+2y_n)^{2/3}}$

$\text{at } y_n = 1.2' \rightarrow 25.13$
 $y_n = 1.18' \rightarrow 24.5$

$A_{flow} = 25.75 + 3.95 \times 20 = 104.75$

$V = 473.7 / 104.75 = 4.52 \text{ ft/sec}$



$Q_{25} \text{ depth} = 6.27 + 1.18 = 7.45'$

$Q_{25} \text{ ELEV} = 329.42 + 7.45' = 336.87'$

$\frac{HW}{D} = \frac{7.45}{12} = 0.62 \quad 62\% \text{ full}$

$Q_{25} (Hy-E) = 336.50'$

$Q_{50} = 557.1 \text{ cfs}$

$Q_{diff} = Q_{50} - Q_{25} = 557.1 - 473.7 = 83.4 \text{ cfs}$

$83.4 \text{ cfs} = \frac{1.49 \times (20y_n)^{5/3}}{0.032 (20+2y_n)^{2/3}} (0.00966)^{1/2}$

$18.22 = \frac{(20y_n)^{5/3}}{(20+2y_n)^{2/3}}$

$\text{at } y_n = 1.0 \rightarrow 18.77$
 $\text{at } y_n = 0.98 \rightarrow 18.16$

$A_{flow} = 25.75 + 4.53 \times 20 = 124.35$

$V = 557.1 / 124.35 = 4.48 \text{ ft/sec}$



$Q_{50} \text{ depth} = 7.45' + 0.98' = 8.43'$

$Q_{50} \text{ ELEV} = 329.42 + 8.43' = 337.85'$

$\frac{HW}{D} = \frac{8.43}{12} = 0.70 \approx 70\% \text{ full}$

$Q_{50} (Hy-E) = 337.04'$

$Q_{100} = 652.7$

$Q_{diff} = Q_{100} - Q_{50} = 652.7 - 557.1 = 95.6 \text{ cfs}$

$95.6 \text{ cfs} = \frac{1.49 \times (20y_n)^{5/3}}{0.032 (20+2y_n)^{2/3}} (0.00966)^{1/2}$

$20.95 = \frac{(20y_n)^{5/3}}{(20+2y_n)^{2/3}}$

$\text{at } y_n = 1.02' \rightarrow 19.37$

$\text{at } y_n = 1.05' \rightarrow 20.29$

$\text{at } y_n = 1.06' \rightarrow 20.60$

$\text{at } y_n = 1.07' \rightarrow 20.92$

$A_{flow} = 25.75 + 6 \times 20$
 $= 145.75 \text{ ft}^2$

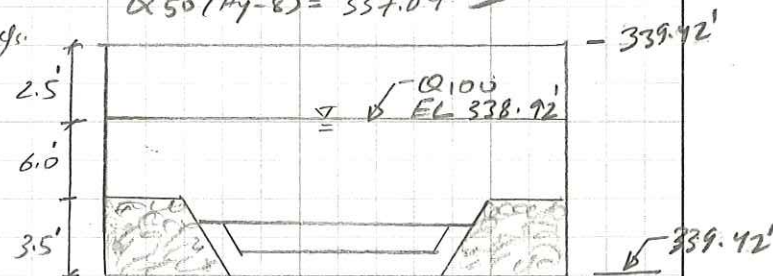
$V = \frac{652.7}{145.75} = 4.48 \text{ ft/sec}$

$\frac{HW}{D} = \frac{9.50}{12} = 79\% \approx 79\% \text{ full}$

$Q_{100} (Hy-E) = 337.44'$

$Q_{100} \text{ depth} = 8.43' + 1.07' = 9.50'$

$Q_{100} \text{ ELEV} = 329.42 + 9.50' = 338.92'$



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$$Q_{500} = 886.7$$

$$Q_{diff} = Q_{500} - Q_{100} = 886.7 - 652.7 = 234 cfs$$

$$234 cfs = \frac{1.49}{0.032} \frac{(20 y_n)^{5/3}}{(20 + 2 y_n)^{2/3}} (0.000266)^{1/2}$$

$$51.13 = \frac{(20 y_n)^{5/3}}{(20 + 2 y_n)^{2/3}}$$

$$\text{for } y_n = 2.0' \rightarrow 56.2$$

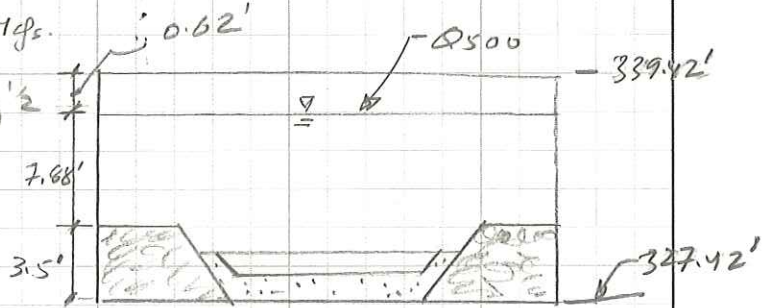
$$\text{for } y_n = 1.95' \rightarrow 54.0$$

$$\text{for } y_n = 1.9' \rightarrow 51.9$$

$$\text{for } y_n = 1.85' \rightarrow 51.4$$

$$\text{for } y_n = 1.88' \rightarrow 51.06 \checkmark$$

∴ LOOKS LIKE



$$Q_{500} \text{ depth} = 9.50' + 1.88' = 11.38'$$

$$Q_{100} \text{ ELEV} = 329.42' + 11.38' = 340.8'$$

$$\frac{H_w}{D} = \frac{11.38}{12} = 0.95 \approx 95\% \text{ full}$$

$$Q_{100} (11.38) = 338.96'$$

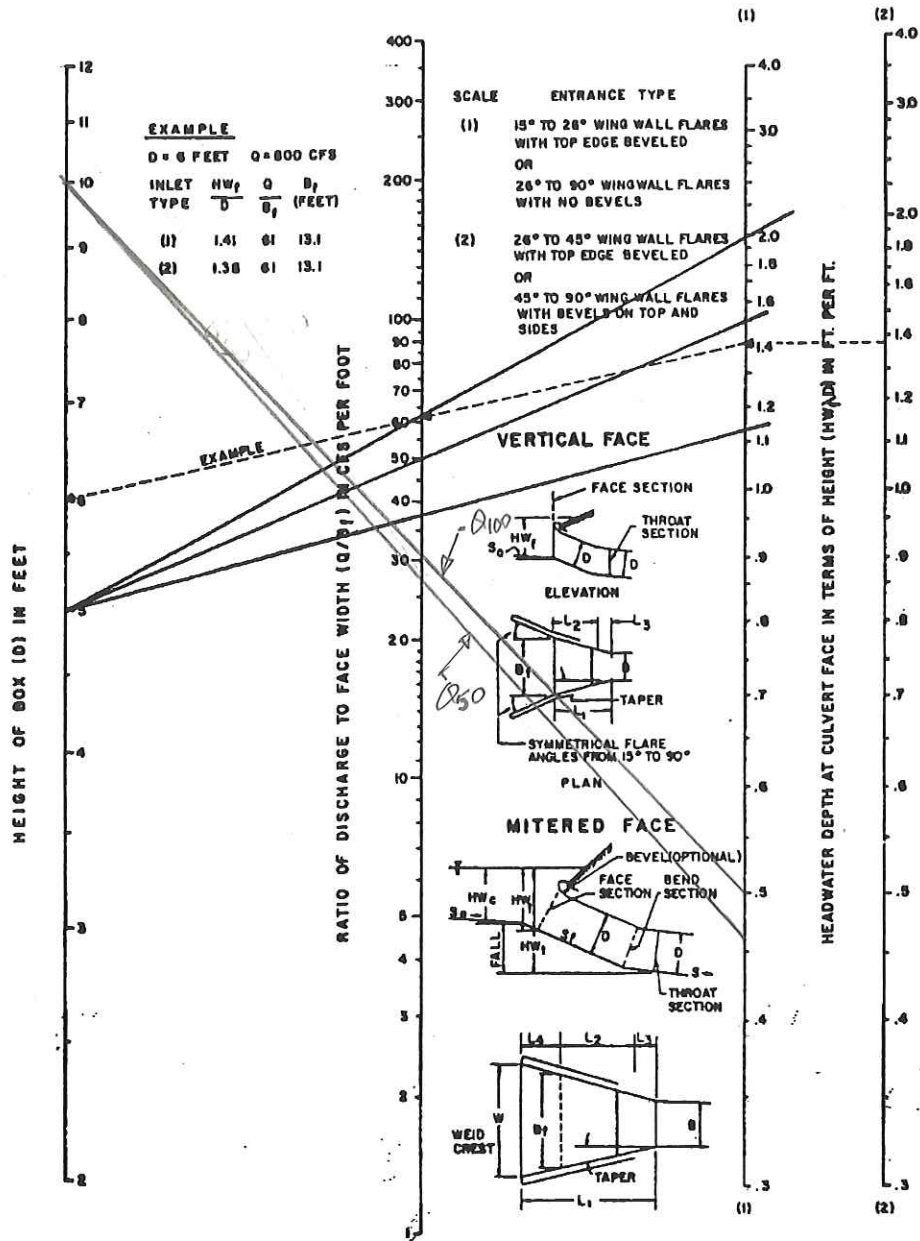
$$M_{flow} = 25.75 + 7.68 \times 20 = 163.35$$

$$V = 886.7 / 163.35 = 4.83 \text{ ft/sec}$$

MaineDOT

MaineDOT

CHART 59B



Q₅₀

$$\frac{Q}{NB} = 28 \frac{\text{cfs}}{\text{ft}}$$

$$D = 12 \text{ ft}$$

$$\frac{HW}{D} = 0.46$$

$$HW = 0.46 \times 10' = 4.60'$$

FACE CONTROL FOR BOX
CULVERTS WITH SLOPE
TAPERED INLETS

PRELIM. BY
FINAL CHK. BY
ITEM NO.

FEB 02 2018

DATE
DATE
SUBJECT

PROJ. NO. 21880-00
LOCATION FARMINGTON LOWER
SUBJECT proposed Box Culvert

FILE NO. 1 OF
SHEET NO. 6 OF

check flows using nomograph charts 59.B FOR BOX CULVERTS.

INLET CONTROL

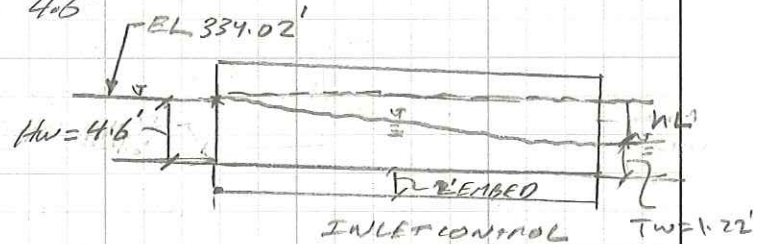
$Q_{50} = 557.1 \text{ cfs}$ $NB = 20'$

$\frac{Q}{NB} = 28 \frac{\text{cfs}}{\text{ft}}$ FROM CHART FOR 2' EMBEDEDMENT $\Rightarrow$
Culvert depth for headwater = 10'

$\frac{H_w}{D} = 0.46$

$H_w = 0.46 \times 10 = 4.6'$

$EL_{ho} = 329.42' + 4.6' = 334.02'$



OUTLET CONTROL

$Tw = 1.22'$ (previously computed)

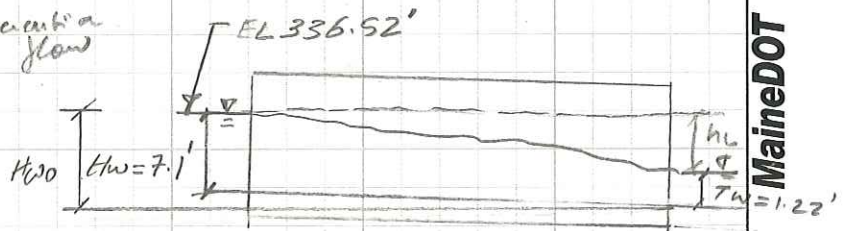
$Q_{50} = 557.1 \text{ cfs}$ $B = 20'$ $Q/B = 557.1/20 = 28.18 \text{ cfs/ft}$

FROM CHART 14B $\frac{Q}{B} = 28 \rightarrow dc = 3' < D = 10'$

$Tw = 1.22' < dc = 3'$ Supercritical flow

$\frac{dc + D}{2} = \frac{3' + 10'}{2} = 6.5'$

$Tw = 1.22'$



$h_o = \text{greater of } Tw \text{ or } \frac{dc + D}{2} = 6.5'$

$EL_{ho} = EL_o + h_o + HL = 329.42' + 6.50' + 0.6' = 336.52'$

$H_w = 336.65$ (HY-8) USE HY-8 (NO shelf just at segment of 24")

$H_w = 336.08'$ (Culvert with Aquatic shelf & low flow channel)

$H_w = 336.52'$ (HEC 5, NOMOGRAPHS)

CHECK FLOWS USING NOMOGRAPHS CHARTS 59B FOR BOX CULVERTS

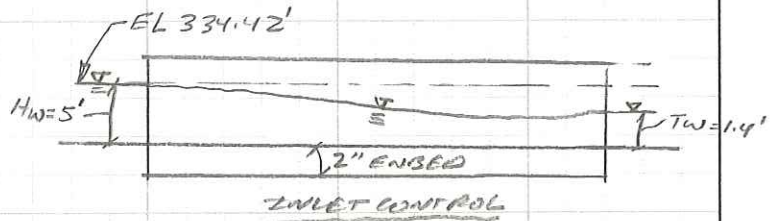
INLET CONTROL

$Q_{100} = 622.41 \text{ cfs}$ $NB = 20'$

$\frac{Q}{NB} = 31$ FROM CHART FOR 2' EMBEDMENT $\rightarrow$
 Culvert depth of 10'

$\frac{HW}{D} = 0.5$ $HW = 0.5 \times 10 = 5'$

$EL_{H0} = 329.42' + 5.0' = 334.42'$



OUTLET CONTROL

$TW = 1.4'$ (previously computed)

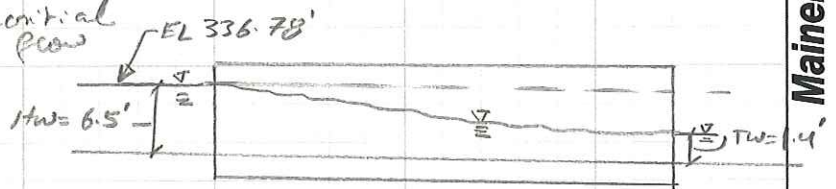
$Q_{100} = 622.41 \text{ cfs}$ $B = 20'$ $\frac{Q}{B} = \frac{622.41}{20} = 31 \frac{\text{cfs}}{\text{ft}}$

FROM CHART 14B $\frac{Q}{B} = 31 \rightarrow dc = 3.2' < D = 10'$

$TW = 1.4' < dc = 3.2'$ Supercritical flow

$\frac{dc + D}{2} = \frac{3.2 + 10}{2} = 6.6'$

$TW = 1.22'$



$h_0 = \text{greater of } TW \text{ or } \frac{dc + D}{2} = 6.6'$

$EL_{H0} = EL_0 + H + h_0 = 329.42' + 6.6' + 0.76' = 336.78'$

$HW = 337.05$ (Hy-8) USE Hy-8 (NO shelf just a bedrock of 24")

$HW = 336.48'$ (culvert with aquatic shelf below flow channel)

$HW = 336.78'$ (HEC5, NOMOGRAPHS) ✓

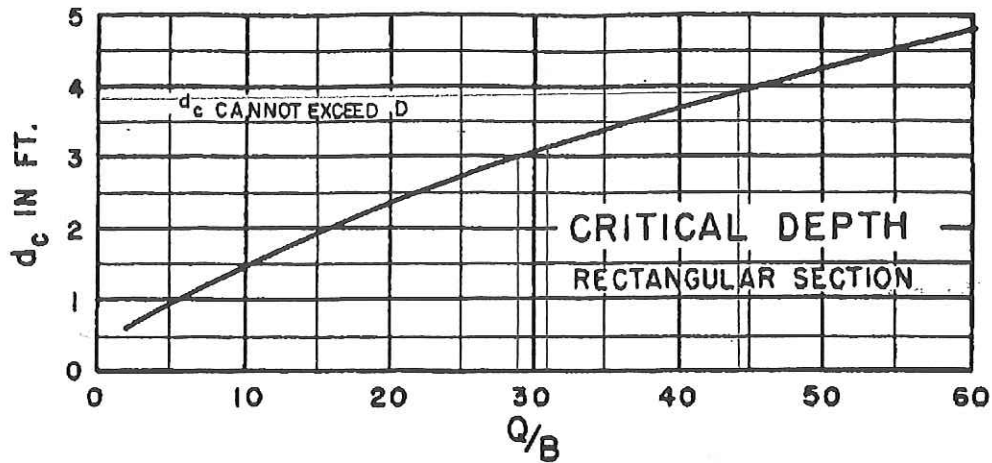
MaineDOT

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21880100
FARMINGTON
GOWER FARM
BRIDGE

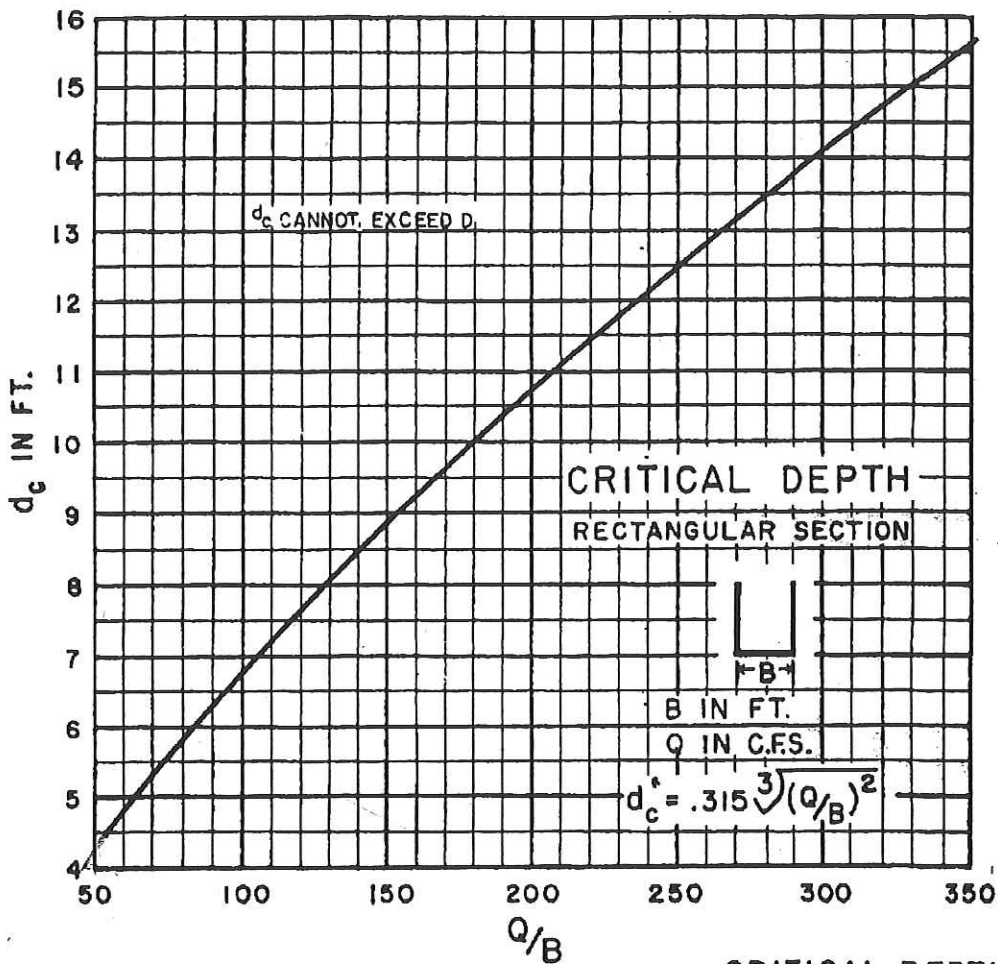
-9-

CHART 14B



$d_c = 3.0'$
 Q_{50}

$d_c = 3.2'$
 Q_{100}



BUREAU OF PUBLIC ROADS JAN 1963

CRITICAL DEPTH
RECTANGULAR SECTION

Habitat Connectivity Design Report

Farmington Gower Farm Bridge # 2324

Over Beales Brook, Win # 21880.00

Existing Structure information

- 1- A 108' long skewed at 30 degrees, corrugated elliptical steel pipe with 13' span and 13'-9 1/2" rise; with culvert ends mitered to slope embankments.
- 2- Based on site observation, connectivity conditions seem favorable. There are no head cuts upstream, no channel incisions downstream. However, the culvert outlet is slightly embedded below stream bed, and a 4' deep scour hole exists downstream. The general gradient upstream, downstream, and thru culvert is consistent.

Information Collection

Eric Ham measured BFW at 5 locations 3 upstream and 2 downstream using stadia rod. The upstream measurements were approximately 100 ft apart at 14', 16', and 16'. The two downstream measurements of 16' each were taken beyond the scour pool which has formed outside of the culvert outlet.

Due to the muddy soil in the stream, a pebble count was not performed, because no pebbles are present in the stream bed. The type of soil that exists makes a pebble count extremely difficult to collect.

Table references

Table 1

Watershed Area (mi ²)	Average Calculated BFW (ft)	Measured BFW (ft)	1.2 BFW (ft)
4.6	16	16	19.2

Table 2- Proposed Structure

Width (ft)	Length (ft)	Channel Bottom width between proposed banks (ft)	Proposed bank height above CSM (ft)
20	97	20	4.0

Longitudinal Profile

- US and DS extent: Average upstream extent 125 feet stations 3+15 to 4+50
Average downstream extent 200 feet stations 0+00 to 2+00
- Proposed Average US and Average DS slope: Average US and DS slope is 0.5 %
- Existing Average slope of each stream Segment: US 1.0%, DS 0.8%
- Sediment Wedge / Aggradation: None observed.
- Existing Structure inverts: US; 329.42', DS; 328.26'
- Proposed structure inverts: US; 327.42', DS; 326.88'
- Push Bar /scour pool extent: Scour pool directly downstream between stations 2+00 and 1+25. Almost 5' deep scour pool with max depth at station 1+60. No push bars visible from survey.
- Steps/ stable stream features: There are no steps made of rocks and large stones that indicate stream stability. This sand and clay bed stream is highly unstable and subject to erosion of stream bed and embankments.
- Vertical adjustment profile line for each distinct stream segment: Low and High VAP marked on profile. The design profile lies in between the low and high VAP's. The slope was adjusted to be flatter to reduce velocities in the low flow channel and at high flows, set to match the natural slope.
- Stream Restoration: The stream is highly erodible due to stream composition. Placing rip rap upstream, downstream, and at banks is highly recommended to prevent scour and erosion. Filling up the scour pool at the outlet to achieve stable channel profile and armoring the stream bed is recommended. Bank lines material diversity is recommended to reduce erosion potential.
- Water surface elevations: Shown for existing bank full height, and proposed

culvert. Top of bank elevations and right and left bank full indicators are also shown on profile.

Stream Channel Characteristics

Baseline Geomorphic Conditions:

Highly erodible and meandering stream. No armoring factors such stones and pebbles are present in the stream. Evidence of banks erosion due to presence of falling trees and logs. Beaver dams and sand bars are also present upstream. A cover vegetation at banks and around stream help keep banks from much worse erosion conditions. Lateral channel shift is also possible if vegetation at banks disappears in the future, due to aggradation and degradation action and varying velocities at stream bends.

Stream habitat types: Atlantic salmon rearing habitat.

Key features: N/A

Other general notes: N/A

Scour pool or other anthropogenic scour:

yes approximately 5' scour pool at the outlet.

Substrate Analysis: No pebble count performed.

Alignment

At the inlet, the stream runs almost along the roadway. Adjusting the culvert to line up with the upstream section will result in more skew, a much longer culvert, and misalignment with the downstream stream section. Realigning the upstream end of the channel is much more realistic in this case.

Preliminary Habitat Connectivity Design

New culvert Inverts: Upstream 327.42', Downstream: 326.88'

Top of stream bed elevations at invert locations Upstream 329.42', Downstream 328.88'

Design Slope: 0.5%

Hydraulic check- new structure needs to be 100% full or less at Q 100: 67.9% full at Q500

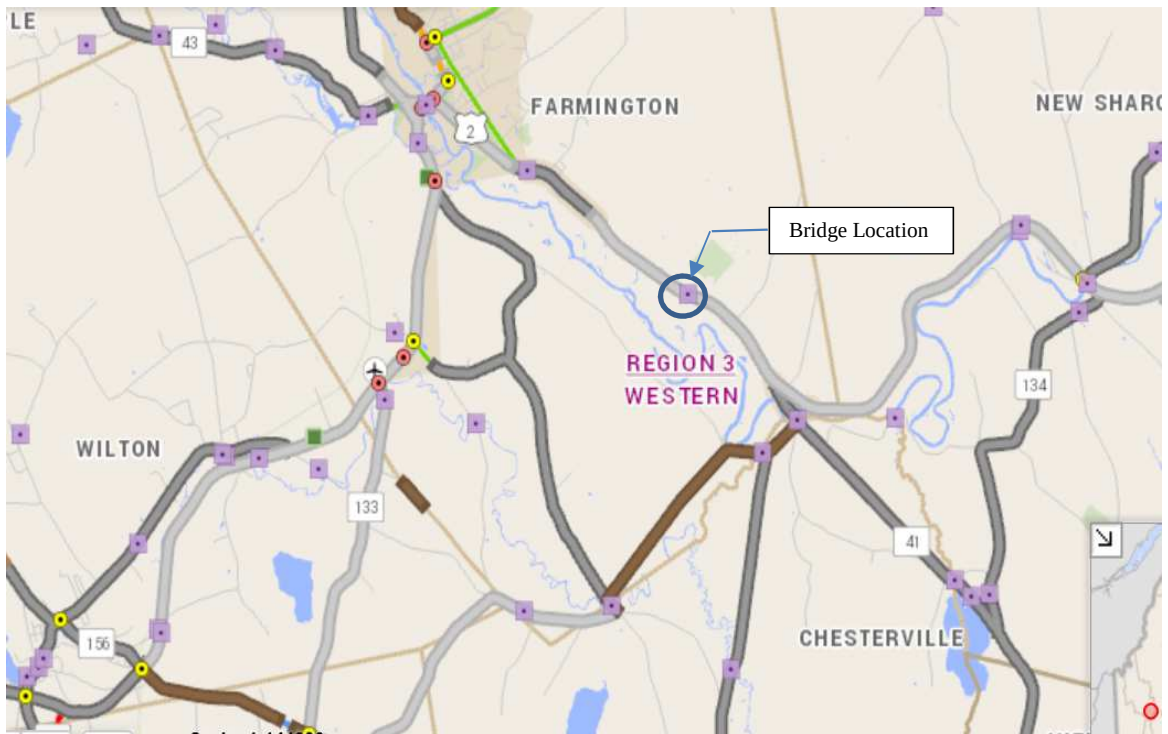
Thickness of culvert streambed material CSM: 2' to top of streambed inside culvert, 4.0' to top of wild life banks.

Low flow channel: 1' minimum depth to provide room for both Adult and Juvenile Salmonids, moderately sloped to 0.8% to generate flow velocities within Salmonids fish swim capabilities.

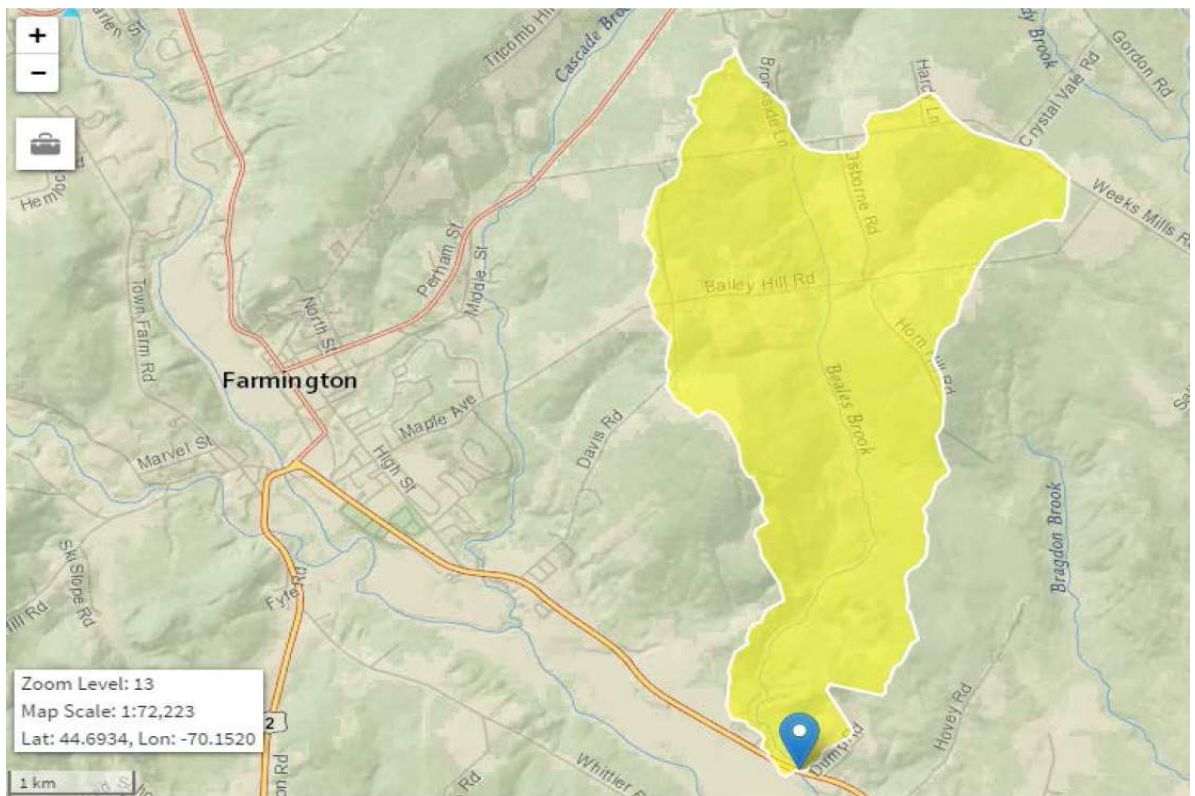
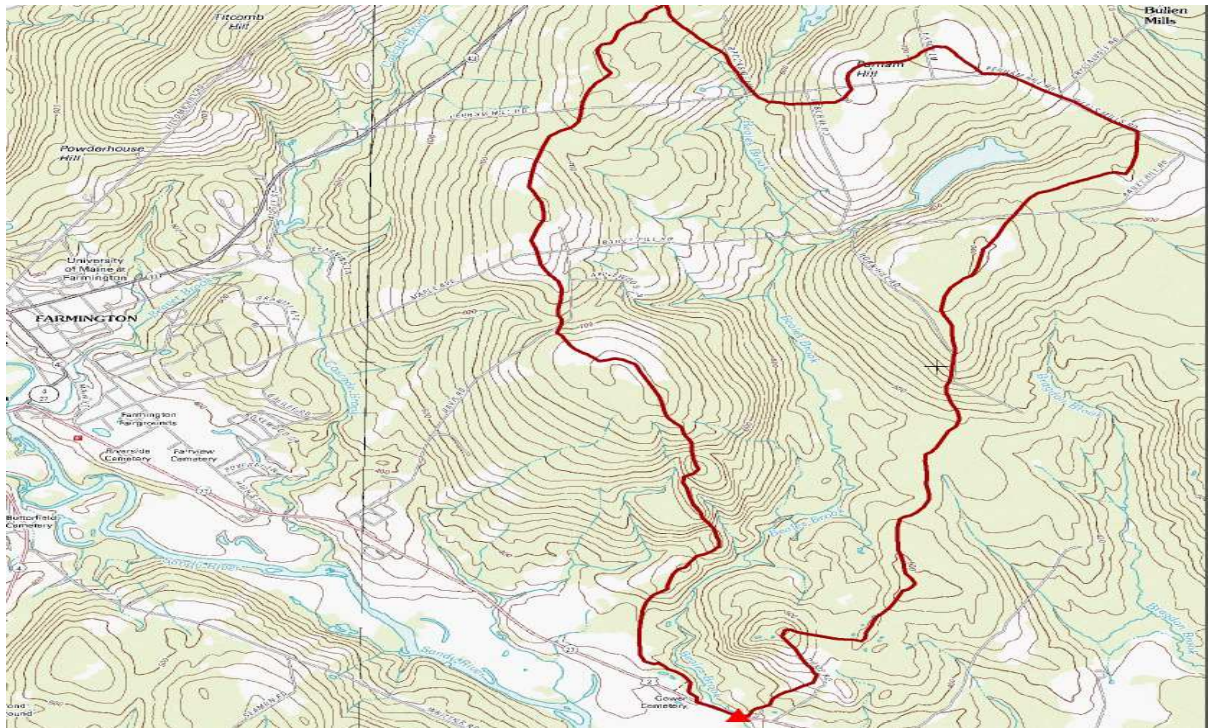
Figure List

Table 1 and Table 2: Included in report.

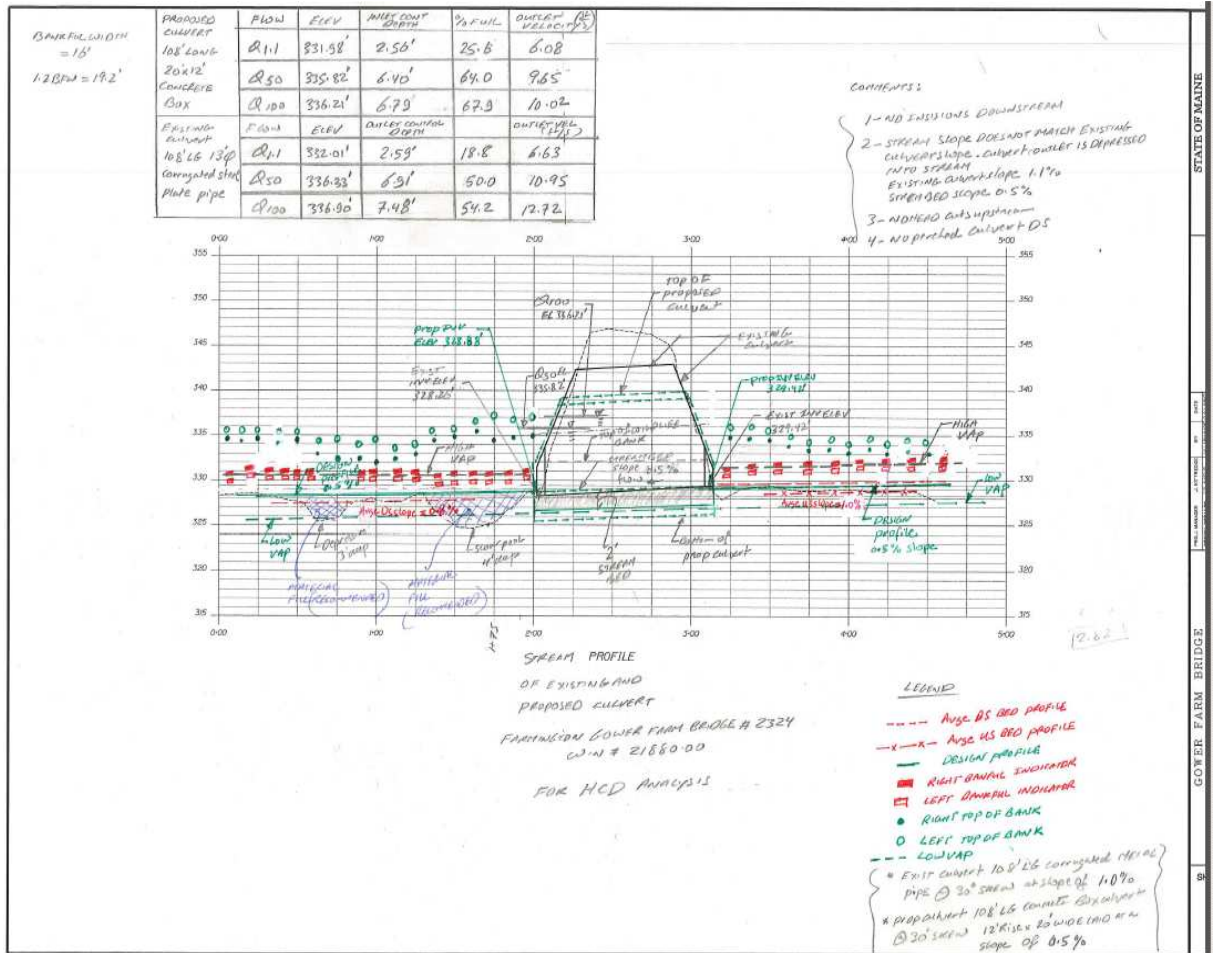
Map (showing project location):



Map (showing entire watershed polygon):

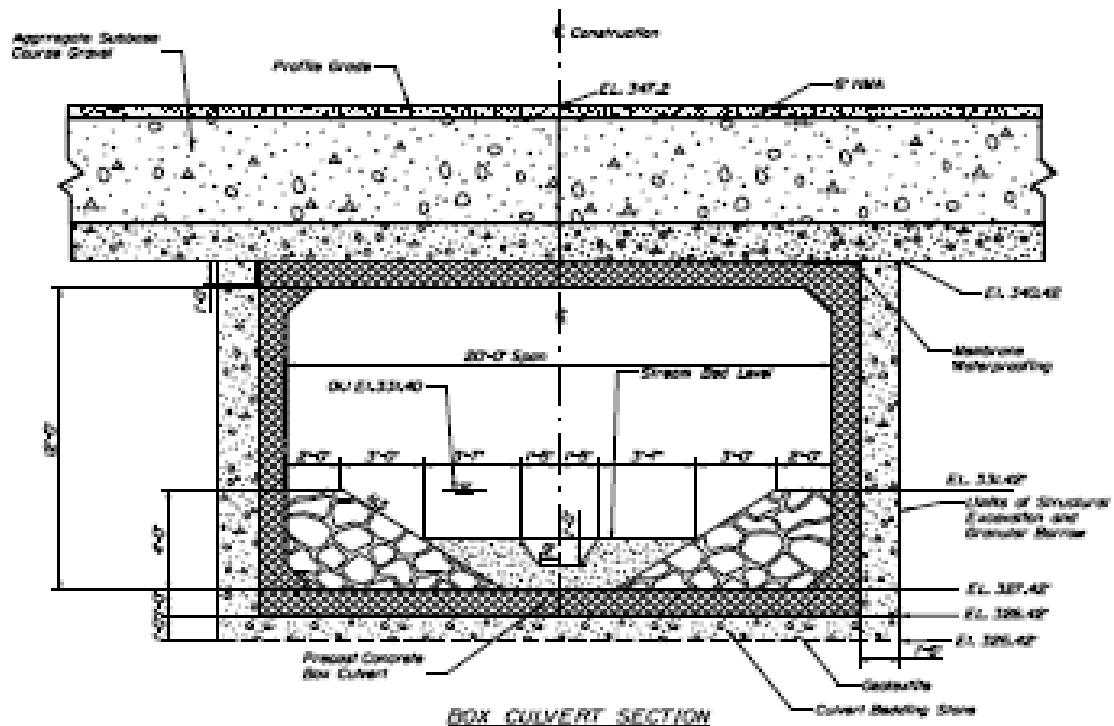
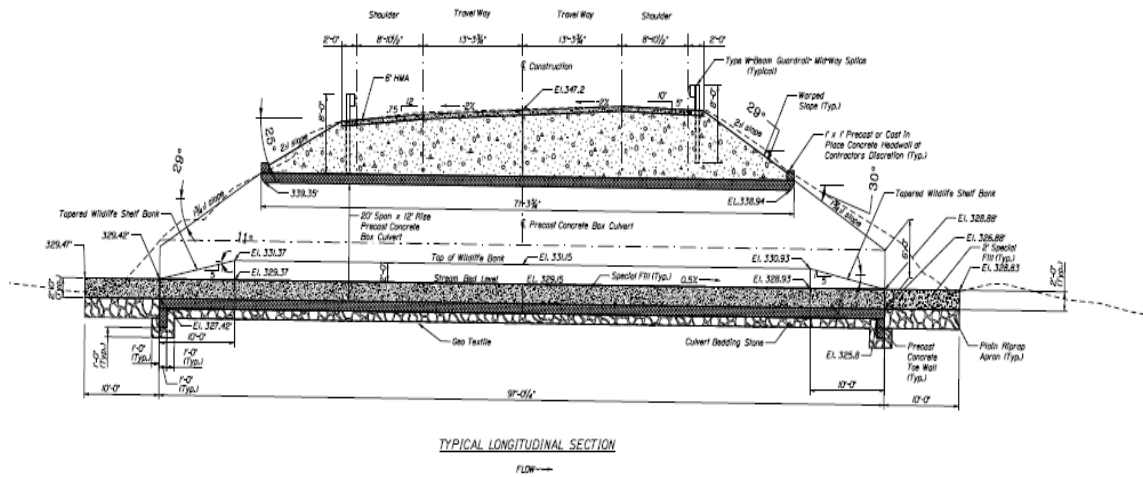


Longitudinal Profile:



A PDF electronic file is also provided for the above profile

Proposed culvert sections:



HCD

Substrate analysis results with curve:

Not provided. Pebble count was not performed, and soil samples from the stream were not collected.

Photos:



Photo 1: Culvert inlet.



Photo 2: Upstream view and embankment.



Photo 3: At culvert outlet.



Photo 4: Downstream view.



Photo 5: Measuring bank full width with Stadia Rod.



Photo 6: Culvert inlet



Photo 7: Upstream obstructions fallen trees shrubs etc.



Photo 8: upstream banks conditions.



Photo 9: Downstream scour pool



Photo 10: At culvert inlet



Photo 11: Culvert condition below flow line.

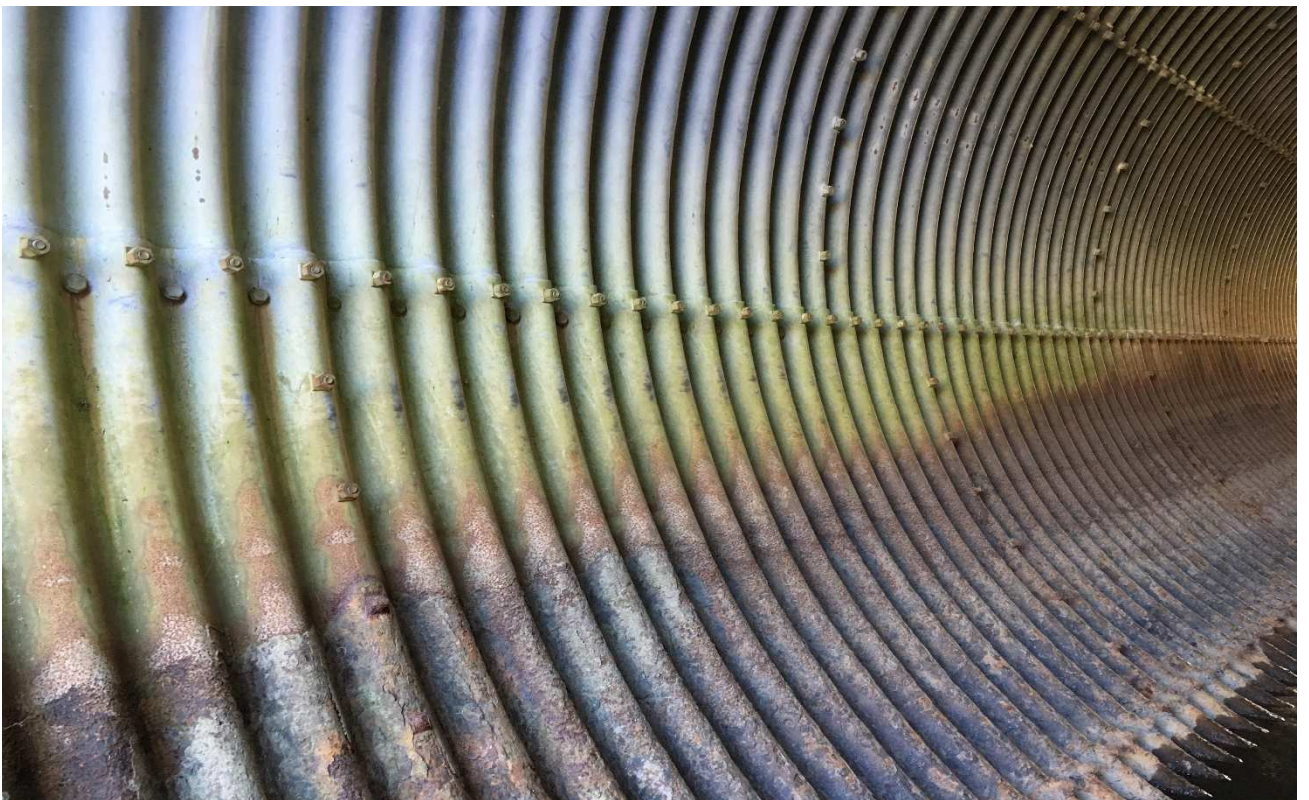


Photo 12: Corrosion of culvert walls