

HYDROLOGY REPORT

Farmington Williams #1 Bridge #2980 – Farmington, Maine

General Information and Scope

This study is conducted to provide hydrologic information from water resources agencies on the Williams #1 Bridge crossing over Williams Brook. It will be used in the hydraulic evaluation of the existing and proposed culvert replacement. The existing bridge is a 20 ft span corrugated steel plate arch culvert built in 1954. The scope is to determine flood flow elevations, velocities, and overtopping potential for the existing and proposed culverts. With a measured bankfull width of 20', and with the requirement of having a minimum proposed culvert width of 1.2 x Bank full width or nearly 24', 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 conducted for Farmington in 1995 did not cover Williams brook and its vicinity. However, a flood map showing the 100 yr. flood limits for the brook had no information on flood stage elevations for the flood zone. Flood flows were also not produced for the Williams Brook by FEMA.

United States Geological Survey (USGS)

The USGS does not maintain any gaging stations at or near the bridge. No other hydrological information is available for the brook from USGS.

Maine DOT Hydrology Department

The Maine DOT hydrology department performed a hydrological study of the drainage basin that contributes flow to the stream. They determined that the watershed area for the stream is 4.70 mi² with 2.44% wetlands. Using Hodgkins 1999 regression analysis of rainfall data, flood flows were calculated and tabulated as follows:

Flow Return Period	Q (cfs)
Q _{1.1}	95.8
Q ₂	204.3
Q ₅	328.1
Q ₁₀	419.6
Q ₂₅	550.7
Q ₅₀	652.8
Q ₁₀₀	764.6
Q ₅₀₀	1047.2

The above flood flows will be used to conduct a hydraulic analysis of both the existing and the proposed culverts, such that conclusions can be drawn about their hydraulic adequacy.

SUMMARY

Drainage Area	4.7	mi ²
Q _{1.1}	95.8	ft ³ /s
Q ₁₀	419.6	ft ³ /s
Q ₂₅	550.7	ft ³ /s
Q ₅₀	652.8	ft ³ /s
Q ₁₀₀	764.8	ft ³ /s
Q ₅₀₀	1047.2	ft ³ /s

Reported by: Naous, Roger

Date: February 15, 2018

HYDRAULIC REPORT

Existing Culvert:

The 63 ft long existing culvert was analyzed with the Maine DOT data using HY-8 culvert analysis software. The model is representative of the current hydraulic behavior because the invert elevations and therefore the slope in the culvert are the same as existing. The culvert itself was modelled to be identical to the existing one in terms of type, area, and roughness of a wood cribbing bottom. The results of the analysis 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	95.80	95.80	343.48	1.65~	1.60	2-M2c	1.09	0.89	0.89	1.07	5.43	4.22
Q2	204.30	204.30	344.56	2.73~	2.66	2-M2c	1.77	1.48	1.48	1.67	6.96	5.48
Q5	328.10	328.10	345.58	3.75~	3.66	2-M2c	2.42	2.04	2.04	2.19	8.13	6.40
Q10	419.60	419.60	346.26	4.43~	4.33	2-M2c	2.87	2.40	2.40	2.52	8.86	6.92
Q25	550.70	550.70	347.11	5.28~	5.21	2-M2c	3.47	2.88	2.88	2.94	9.73	7.53
Q50	652.80	652.80	347.69	5.86~	5.86	2-M2c	3.94	3.22	3.22	3.23	10.34	7.94
Q100	764.60	764.60	348.37	6.49	6.54	2-M2c	4.44	3.58	3.58	3.53	10.96	8.32
Q500	1047.20	1047.20	350.00	8.08	8.17	2-M2c	5.77	4.40	4.40	4.19	12.33	9.14

The results indicate that the Q₅₀ design flow with a head water elevation of 347.69' has an HW/D value of 0.59, and the Q₁₀₀ flow with a headwater elevation of 348.47' has an HW/D value of 0.66. All flows are outlet controlled with both the headwater HW and the tail water TW < D, and with the outlet at critical depth. Overtopping does not seem to occur, but due to supercritical flow conditions in the culvert, the high velocities ranging from nearly 9 ft/s at Q₁₀ to over 12 ft/s at Q₅₀₀ suggests a larger culvert could be more ideal to better accommodate flows and reduce outlet velocities.

Proposed Culvert:

A 24' wide x 11' rise proposed concrete box culvert 72' ft long is suggested to replace the existing steel arch culvert. The culvert was sized to meet 1.2 x bank full width requirement and to accommodate the design flows with a low probability of overtopping. 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 invert elevations at the culvert were adjusted to reduce flow velocities especially in the low flow channel for fish passage. The inlet invert and outlet elevations are slightly adjusted to meet this purpose. An HY-8 analysis was conducted and checked by hand calculations. The model was iterated changing slopes and elevations of wildlife

banks until the top width of flow at Q1.1 was equal to the bank-full width of 20'-0", and the top of the wild life bank was at Q1.1 elevation or higher. The wild life banks were set at 1.5' above the stream bed, and made to transition back to the stream bed level at each end. The analysis results are as follows:

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	95.80	95.80	343.54	2.17	2.67	2-M2c	2.23	1.90	1.90	0.94	5.52	3.94
Q2	204.30	204.30	344.58	2.94	3.71	2-M2c	3.05	2.54	2.54	1.47	6.96	5.17
Q5	328.10	328.10	345.45	3.62	4.58	2-M2c	3.62	3.15	3.15	1.93	7.61	6.09
Q10	419.60	419.60	346.02	4.03	5.15	2-M2c	3.99	3.47	3.47	2.23	8.26	6.61
Q25	550.70	550.70	346.77	4.57	5.90	2-M2c	4.48	3.89	3.89	2.61	9.04	7.23
Q50	652.80	652.80	347.31	4.96	6.44	2-M2c	4.82	4.19	4.19	2.87	9.58	7.63
Q100	764.60	764.60	347.88	5.43	7.01	2-M2c	5.18	4.51	4.51	3.14	10.09	8.03
Q500	1047.20	1047.20	349.20	6.63	8.33	2-M2c	6.00	5.25	5.25	3.75	11.20	8.86

The results indicate that overtopping will not occur at any of the flows, and the type of flow is outlet controlled. The model is also quite sensitive to slope. Some reduction in outlet velocities is achieved due to increased culvert size, flow area, slope adjustment, and increased roughness of natural stream bed.

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 3.66 cfs is 2.2 ft/s, which is within the allowable velocities for adult Atlantic Salmon, and when flowing half full at 1.0 cfs at a velocity of 1.3 ft/s, set for the passage of juvenile Atlantic Salmon. The top of the wildlife banks is set at the Q1.1 bank full width and elevation. The slope throughout the culvert was set at 1.0%, such that the velocity in the low flow channel is reduced to tolerable levels for the Salmon's upstream swimming ability. The profile of the culvert and stream bed does not contain any head cuts or downstream incisions. The culvert downstream invert is slightly perched, where a 2' deep downstream scour hole exists just outside the culvert outlet. It is recommended that the stream bed and downstream banks be armored due to strong evidence of bank erosion and falling vegetation and trees into 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
		20' Dia steel Arch culvert	24'x11' concrete Box Culvert
Total Area of Waterway Opening	ft ²	157.10	215.21
Headwater elevation @ Q _{1.1}	ft	343.48	343.54
Headwater elevation @ Q ₁₀	ft	346.26	346.02
Headwater elevation @ Q ₂₅	ft	347.11	346.77
Headwater elevation @ Q ₅₀	ft	347.69	347.31
Headwater elevation @ Q ₁₀₀	ft	348.37	347.88
Headwater elevation @ Q ₅₀₀	ft	350.00	349.20
Freeboard @ Q ₅₀	ft	4.14	3.56
Freeboard @ Q ₁₀₀	ft	3.46	2.99
Outlet Velocity @ Q _{1.1}	ft/s	5.43	5.52
Outlet Velocity @ Q ₁₀	ft/s	8.86	8.26
Outlet Velocity @ Q ₂₅	ft/s	9.73	9.04
Outlet Velocity @ Q ₅₀	ft/s	10.34	9.58
Outlet Velocity @ Q ₁₀₀	ft/s	10.96	10.09
Outlet Velocity @ Q ₅₀₀	ft/s	12.33	11.20

Reported by: Naous, Roger

Date: March 19, 2019

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

APPENDIX E

Hydraulics Data

WIN:	21690.00
Town:	Farmington
Route No.	156
Asset ID:	3181
Lat:	44.5944
Long:	-70.13112

Project Name:	Farmington 21690 Williams #2
Stream Name:	Wilson Stream
Bridge Name:	Williams #2
Analysis by:	DFB
Date:	10/17/2017

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

Enter data in blue cells only!

	km ²	mi ²	ac
A	12.17	4.70	3008.0
W	0.30	0.1	73.4

P _c	408458	4937681
County	Franklin	
pptA	45.6	
SG	0.02	

A (km ²)	12.17
W (%)	2.44

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

NWI Wetlands % *STORNWI*

Worksheet prepared by:

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Environmental Office

Maine Dept. Transportation

Augusta, ME 04333-0016

207-557-1052

Charles.Hebson@maine.gov

ver. 2017 Jun. 09

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

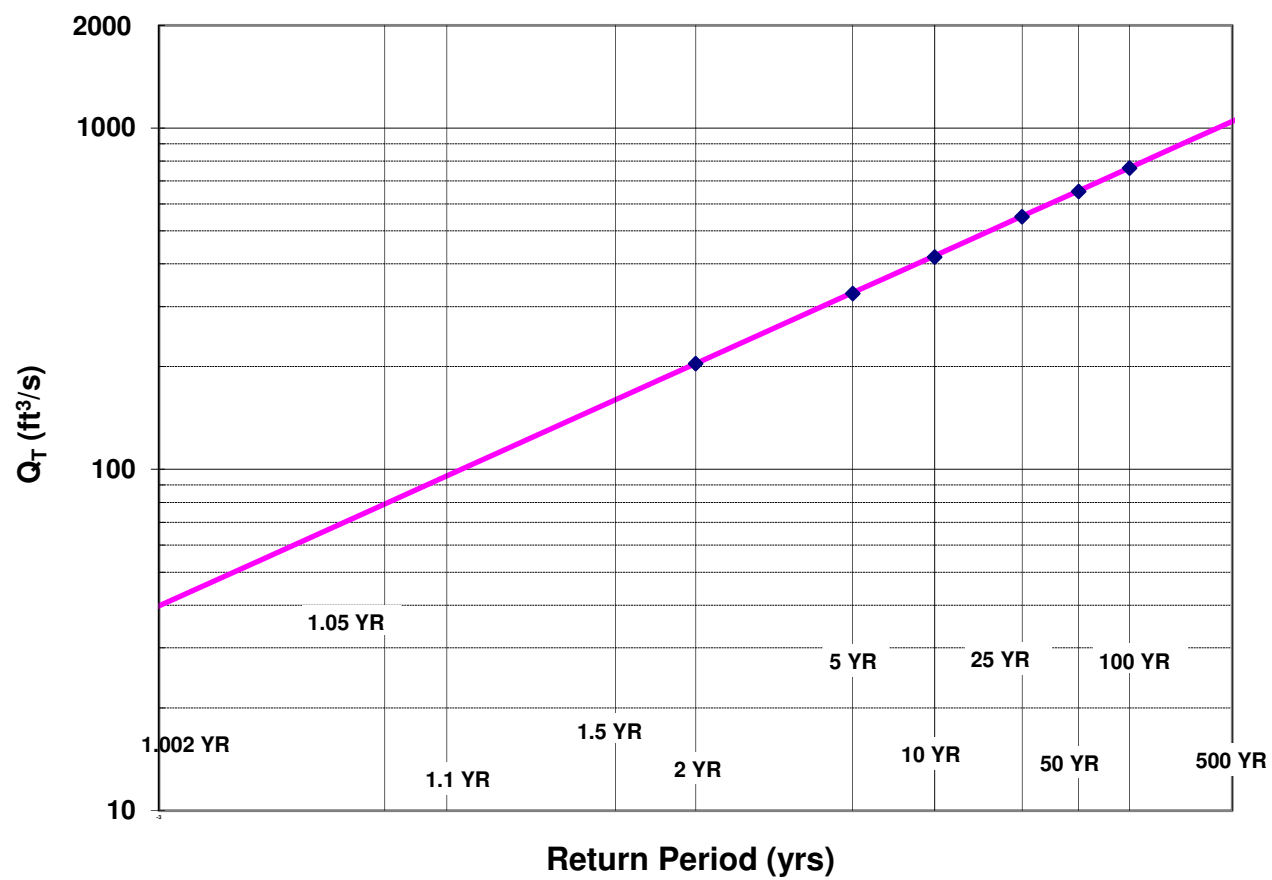
SIR 2015-4059, USGS, Augusta, ME

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

Ret Pd	Peak Flow Estimate		
T (yr)	Lower	Q _T (m ³ /s)	Upper
1.1		2.71	
2		5.79	
5		9.29	
10		11.88	
25		15.60	
50		18.49	
100		21.66	
500		29.66	

Q _T (ft ³ /s)
95.8
204.3
328.1
419.6
550.7
652.8
764.6
1047.2

Log-Normal Probability Plot



WIN: 21690.00
 Town: Farmington
 Route No. 156
 Asset ID: 3181
 Lat: 44.59444 Long: -70.13112

Project Name: Farmington 21690 Williams #2
 Stream Name: Wilson Stream
 Bridge Name: Williams #2
 Analysis by: DFB
 Date: 10/17/2017

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

MAINE MONTHLY MEDIAN FLOWS and HYDRAULIC GEOMETRY BY USGS REGRESSION EQUATIONS (2004, 2013)

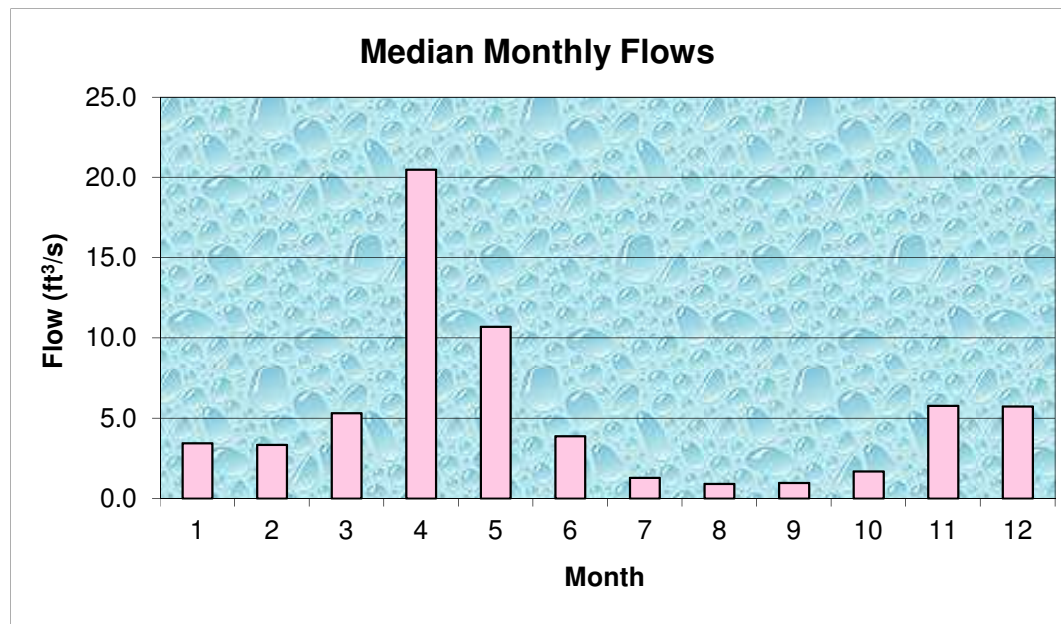
	Value	Variable	Explanation
	4.70	A	Area (mi ²)
408457.9	4937681	P_c	Watershed centroid (E,N; UTM; Zone 19; meters)
	86.06	$DIST$	Distance from Coastal reference line (mi)
	45.6	$pptA$	Mean Annual Precipitation (inches)
	0.02	SG	Sand & Gravel Aquifer (decimal fraction of watershed area)

Month	Q_{median} (ft ³ /s)	(m ³ /s)
Jan	3.45	0.0978
Feb	3.34	0.0948
Mar	5.32	0.1508
Apr	20.49	0.5808
May	10.70	0.3032
Jun	3.88	0.1100
Jul	1.30	0.0368
Aug	0.91	0.0258
Sep	0.97	0.0275
Oct	1.70	0.0481
Nov	5.78	0.1638
Dec	5.74	0.1626

Q_{bf}	26.4
ann avg	9.8
ann med	5.1
$Q_{1.002}$	39.8
$Q_{1.01}$	54.4
$Q_{1.05}$	79.2
Q_{bf}	82.8

assume $v = 4\text{ft/s}$

W_{bf}	20.6	estimated bankfull width (ft)
d_{bf}	1.0	estimated bankfull depth (ft)
A_{bf}	17.2	estimated bankfull flow area (ft ²)



References

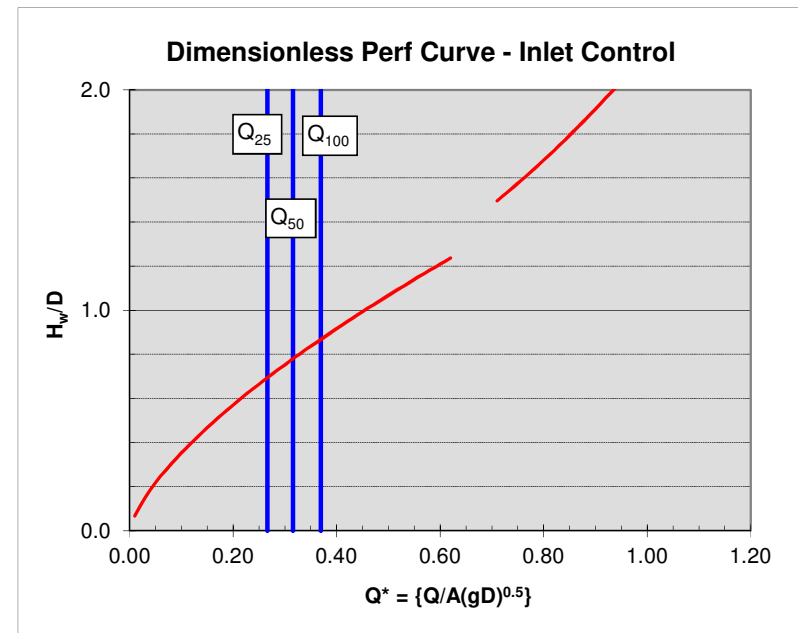
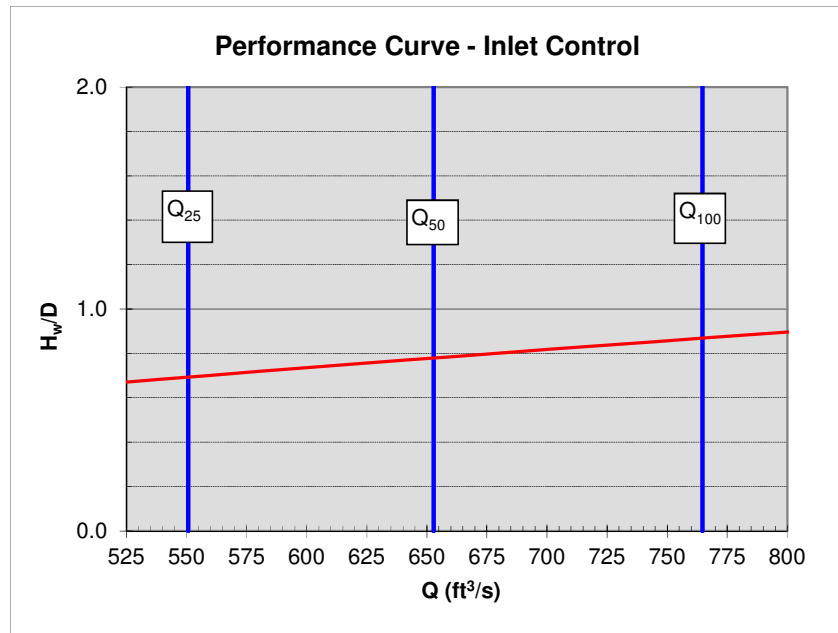
Dudley, R.W., 2013. FY2013 Progress Report - Phase 1 ..., USFWS QRP Project
 Dudley, R.W., 2004. Estimating Monthly Streamflows ..., SIR 2004-5026

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

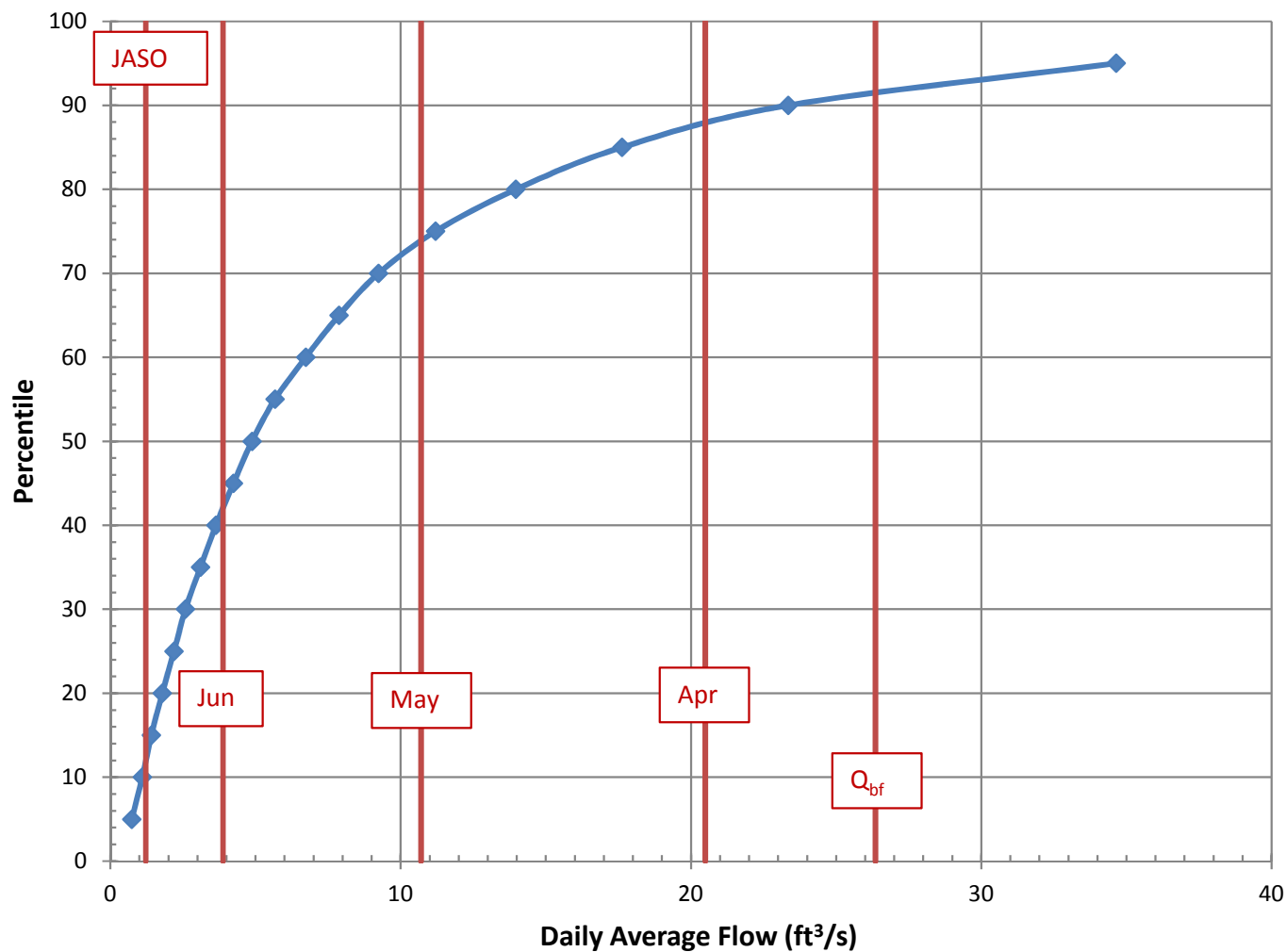
Preliminary Culvert Sizing - Round & Box Culverts

Shape:	Box			
Type:	Box 0 ww			
D or R (ft)	11	Q_{25}	550.7	trial D / R = 11.1 trial w: BFW = 20.6
w (ft)	10 box width	Q_{50}	652.8	
Slope (ft/ft)	0.02	Q_{100}	764.6	
A (ft ²)	110.00			
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)



Daily Average Flow Distribution

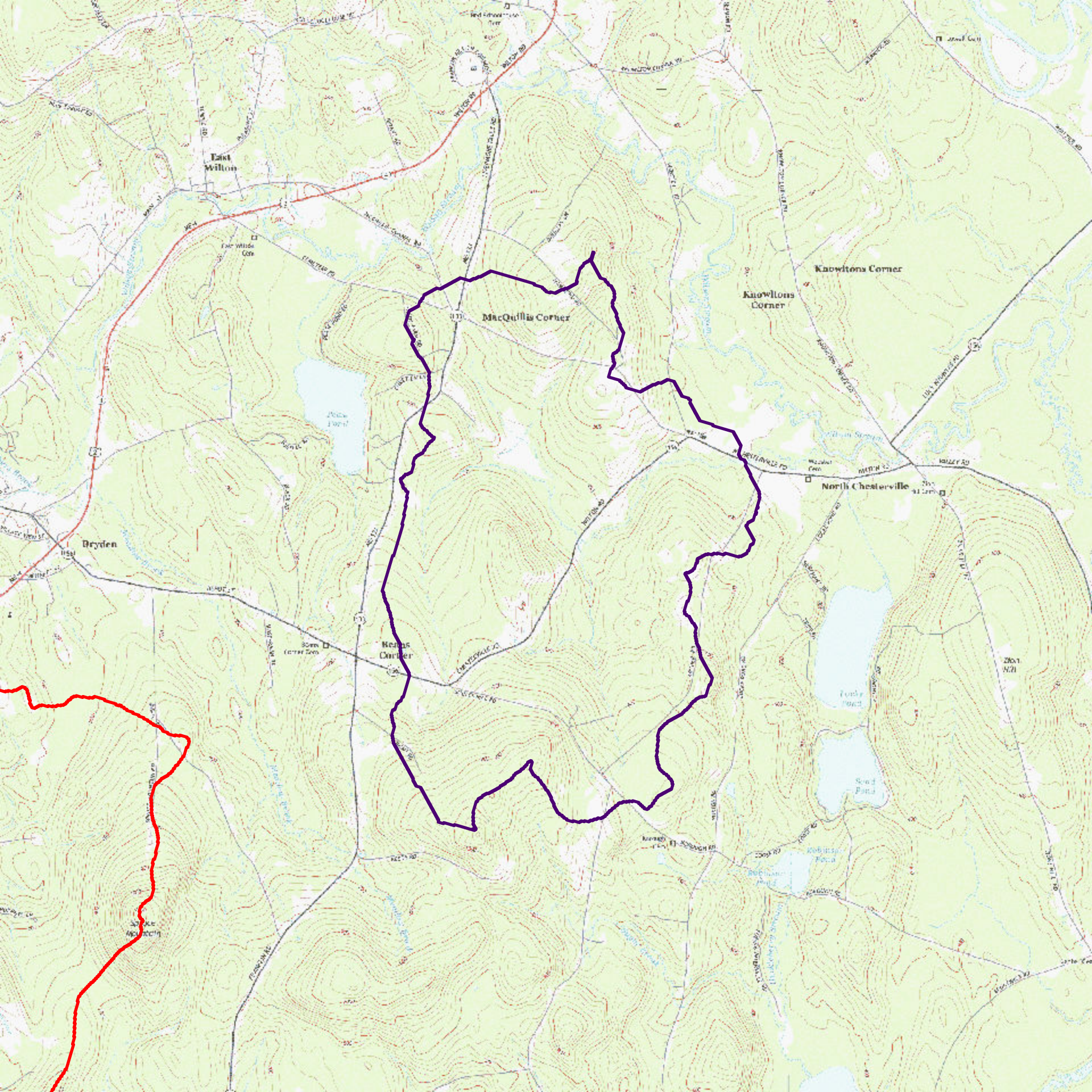


Daily Avg Flow Dist

$A_{ws} = (mi^2)$ 4.7
 $Q (ft^3/s)$

Pctl	Median	84 th pctl
5	0.74	1.19
10	1.10	1.65
15	1.41	2.06
20	1.79	2.50
25	2.19	2.93
30	2.59	3.34
35	3.10	3.82
40	3.64	4.39
45	4.24	4.96
50	4.88	5.86
55	5.67	6.82
60	6.73	8.01
65	7.88	9.33
70	9.24	10.88
75	11.20	13.09
80	13.97	15.63
85	17.63	20.02
90	23.35	26.89
95	34.65	41.81

Q_{bf}	26.4
$Q_{1.002}$	39.8
$Q_{1.1}$	95.8
Q_2	204.3



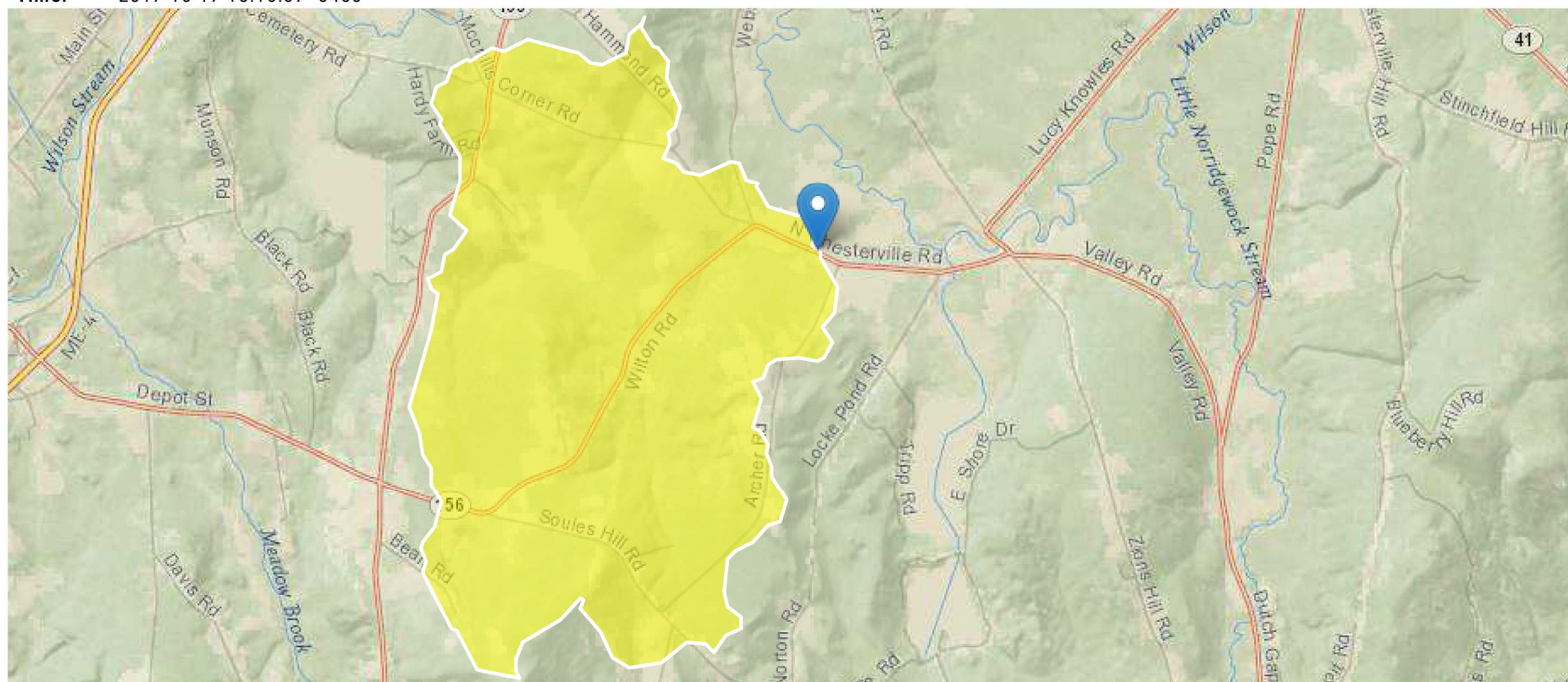
Farmington 21690 Williams Bridge

Region ID: ME

Workspace ID: ME20171017191547801000

Clicked Point (Latitude, Longitude): 44.59444, -70.13112

Time: 2017-10-17 15:16:07 -0400



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	4.7	square miles
STORNWI	Percentage of storage (combined water bodies and wetlands) from the Nationa Wetlands Inventory	2.44	percent

Parameter Code	Parameter Description	Value	Unit
SANDGRAVAF	Fraction of land surface underlain by sand and gravel aquifers	0.019	dimensionless
ELEV	Mean Basin Elevation	545.7	feet
BSLDEM10M	Mean basin slope computed from 10 m DEM	9.3	percent
CENTROIDX	Basin centroid horizontal (x) location in state plane coordinates	408457.86	
CENTROIDY	Basin centroid vertical (y) location in state plane units	4937681.02	
COASTDIST	Shortest distance from the coastline to the basin centroid	87	miles
ELEVMAX	Maximum basin elevation	1067.1	feet
LC06WATER	Percent of open water, class 11, from NLCD 2006	0	percent
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	5.14	percent
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	0.67	percent
PRECIP	Mean Annual Precipitation	44.6	inches
SANDGRAVAP	Percentage of land surface underlain by sand and gravel aquifers	1.85	percent
STATSGOA	Percentage of area of Hydrologic Soil Type A from STATSGO	5.58	percent

Bankfull Statistics Parameters [Central and Coastal Bankfull 2004 5042]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	4.7	square miles	2.92	298

Bankfull Statistics Flow Report [Central and Coastal Bankfull 2004 5042]

Statistic	Value	Unit
Bankfull Streamflow	26.4	ft ³ /s
Bankfull Width	17.2	ft
Bankfull Depth	1.01	ft
Bankfull Area	17.2	ft ²

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 [Statewide Peak Flow DA LT 12sqmi 2015 5049]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	4.7	square miles	0.31	12
STORNWI	Percentage of Storage from NWI	2.44	percent	0	22.2

Peak-Flow Statistics Flow Report [Statewide Peak Flow DA LT 12sqmi 2015 5049]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	SEp
1.01 Year Peak Flood	57.8	ft^3/s	38
2 Year Peak Flood	204	ft^3/s	34
5 Year Peak Flood	328	ft^3/s	35
10 Year Peak Flood	419	ft^3/s	37
25 Year Peak Flood	550	ft^3/s	39
50 Year Peak Flood	652	ft^3/s	41
100 Year Peak Flood	764	ft^3/s	42
250 Year Peak Flood	878	ft^3/s	44
500 Year Peak Flood	1050	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>)

Low-Flow Statistics Parameters [Statewide LowFlow SIR 2004 5026]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	4.7	square miles	9.79	1418

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
SANDGRAVAF	Fraction of Sand and Gravel Aquifers	0.019	dimensionless	0	0.455

Low-Flow Statistics Disclaimers [Statewide LowFlow SIR 2004 5026]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Low-Flow Statistics Flow Report [Statewide LowFlow SIR 2004 5026]

Statistic	Value	Unit
7 Day 10 Year Low Flow	0.158	ft ³ /s

Low-Flow Statistics Citations

Dudley, R.W., 2004, Estimating Monthly, Annual, and Low 7-Day, 10-Year Streamflows for Ungaged Rivers in Maine: U.S. Geological Survey Scientific Investigations Report 2004-5026, 22 p. (<http://water.usgs.gov/pubs/sir/2004/5026/pdf/sir2004-5026.pdf>)

Flow-Duration Statistics Parameters [Statewide Annual SIR 2015 5151]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	4.7	square miles	14.9	1419
SANDGRAVAF	Fraction of Sand and Gravel Aquifers	0.019	dimensionless	0	0.212
ELEV	Mean Basin Elevation	545.7	feet	239	2120

Flow-Duration Statistics Disclaimers [Statewide Annual SIR 2015 5151]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Flow-Duration Statistics Flow Report [Statewide Annual SIR 2015 5151]

Statistic	Value	Unit
1 Percent Duration	0.0214	ft ³ /s
5 Percent Duration	0.116	ft ³ /s

Statistic	Value	Unit
10 Percent Duration	0.3	ft ³ /s
25 Percent Duration	1.38	ft ³ /s
50 Percent Duration	4.49	ft ³ /s
75 Percent Duration	11.4	ft ³ /s
90 Percent Duration	25.5	ft ³ /s
95 Percent Duration	40.5	ft ³ /s
99 Percent Duration	104	ft ³ /s

Flow-Duration Statistics Citations

Dudley, R.W., 2015, Regression equations for monthly and annual mean and selected percentile streamflows for ungaged rivers in Maine: U.S. Geological Survey Scientific Investigations Report 2015–5151, 35 p. (<http://dx.doi.org/10.3133/sir20155151>)

Annual Flow Statistics Parameters [Statewide Annual SIR 2015 5151]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	4.7	square miles	14.9	1419
SANDGRAVAF	Fraction of Sand and Gravel Aquifers	0.019	dimensionless	0	0.212
ELEV	Mean Basin Elevation	545.7	feet	239	2120

Annual Flow Statistics Disclaimers [Statewide Annual SIR 2015 5151]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Annual Flow Statistics Flow Report [Statewide Annual SIR 2015 5151]

Statistic	Value	Unit
Mean Annual Flow	10.7	ft ³ /s

Annual Flow Statistics Citations

Dudley, R.W.,2015, Regression equations for monthly and annual mean and selected percentile streamflows for ungaged rivers in Maine: U.S. Geological Survey Scientific Investigations Report 2015-5151, 35 p. (<http://dx.doi.org/10.3133/sir20155151>)

HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Farmington Williams #1 Existing

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
343.48	Q1.1	95.80	95.80	0.00	1
344.56	Q2	204.30	204.30	0.00	1
345.58	Q5	328.10	328.10	0.00	1
346.26	Q10	419.60	419.60	0.00	1
347.11	Q25	550.70	550.70	0.00	1
347.69	Q50	652.80	652.80	0.00	1
348.37	Q100	764.60	764.60	0.00	1
350.00	Q500	1047.20	1047.20	0.00	1
354.50	Overtopping	1748.21	1748.21	0.00	Overtopping

Culvert

Rating Curve Plot for Crossing: Farmington Williams #1 Existing Culvert

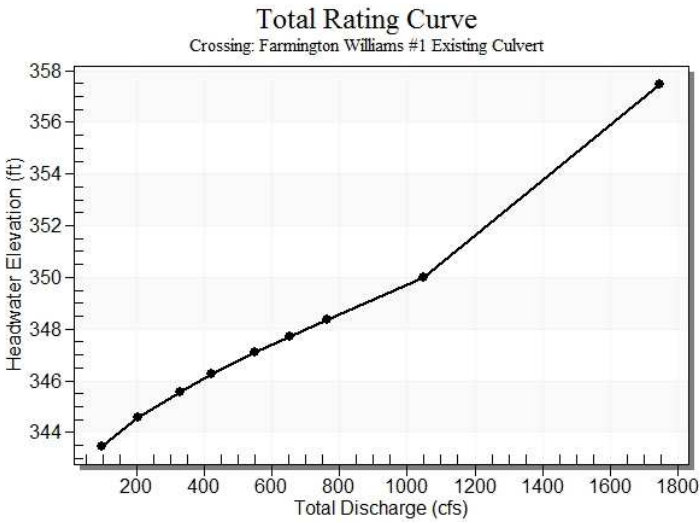
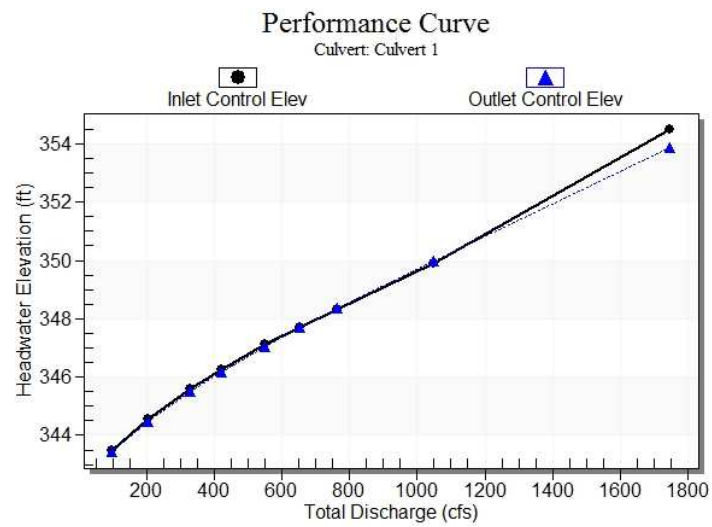


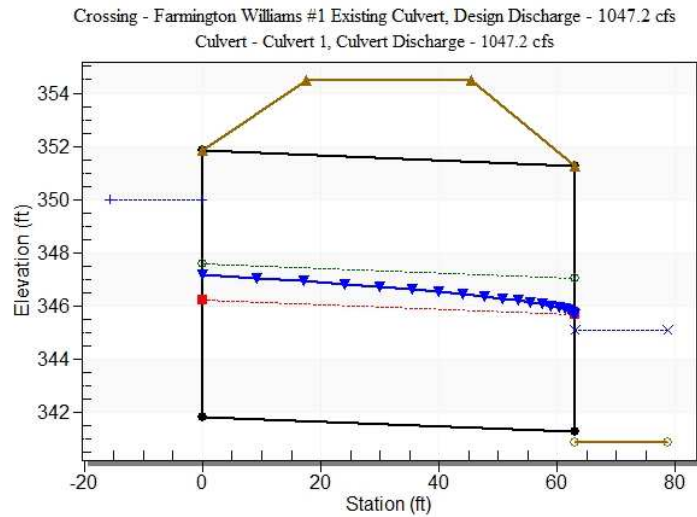
Table 2 - Culvert Summary Table: Culvert 1

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	95.80	95.80	343.48	1.649	1.605	2-M2c	1.086	0.886	0.886	1.073	5.428	4.221	*****
Q2	204.30	204.30	344.56	2.732	2.663	2-M2c	1.768	1.476	1.476	1.670	6.963	5.476	Straight Culvert
Q5	328.10	328.10	345.58	3.750	3.665	2-M2c	2.422	2.036	2.036	2.193	8.131	6.398	Inlet Elevation (invert): 341.83 ft, Outlet Elevation (invert): 341.28 ft
Q10	419.60	419.60	346.26	4.432	4.330	2-M2c	2.868	2.399	2.399	2.522	8.855	6.921	Culvert Length: 63.00 ft, Culvert Slope: 0.0087
Q25	550.70	550.70	347.11	5.282	5.212	2-M2c	3.475	2.879	2.879	2.938	9.727	7.533	*****
Q50	652.80	652.80	347.69	5.861	5.860	2-M2c	3.938	3.222	3.222	3.231	10.342	7.936	*****
Q100	764.60	764.60	348.37	6.494	6.541	2-M2c	4.442	3.576	3.576	3.526	10.959	8.325	*****
Q500	1047.20	1047.20	350.00	8.084	8.170	2-M2c	5.771	4.405	4.405	4.187	12.334	9.138	*****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



S

Inlet Station: 0.00 ft

Inlet Elevation: 341.83 ft

Outlet Station: 63.00 ft

Outlet Elevation: 341.28 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Arch, Open Bottom

Barrel Span: 20.00 ft

Barrel Rise: 10.00 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0350 (top and sides)

Manning's n: 0.0320 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Farmington Williams #1 Existing

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
95.80	341.97	1.07	4.22	0.59	0.75
204.30	342.57	1.67	5.48	0.92	0.80
328.10	343.09	2.19	6.40	1.20	0.83
419.60	343.42	2.52	6.92	1.38	0.84
550.70	343.84	2.94	7.53	1.61	0.86
652.80	344.13	3.23	7.94	1.77	0.87
764.60	344.43	3.53	8.32	1.94	0.88
1047.20	345.09	4.19	9.14	2.30	0.90

Culvert)**Tailwater Channel Data - Farmington Williams #1 Existing Culvert**

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 19.00 ft

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

Channel Slope: 0.0088

Channel Manning's n: 0.0320

Channel Invert Elevation: 340.90 ft

Roadway Data for Crossing: Farmington Williams #1 Existing Culvert

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 354.50 ft

Roadway Surface: Paved

Roadway Top Width: 28.00 ft

HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Farmington Williams #1 Proposed

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
343.54	Q1.1	95.80	95.80	0.00	1
344.58	Q2	204.30	204.30	0.00	1
345.45	Q5	328.10	328.10	0.00	1
346.02	Q10	419.60	419.60	0.00	1
346.77	Q25	550.70	550.70	0.00	1
347.31	Q50	652.80	652.80	0.00	1
347.88	Q100	764.60	764.60	0.00	1
349.20	Q500	1047.20	1047.20	0.00	1
354.50	Overtopping	2438.48	2438.48	0.00	Overtopping

Culvert

Rating Curve Plot for Crossing: Farmington Williams #1 Proposed Culvert

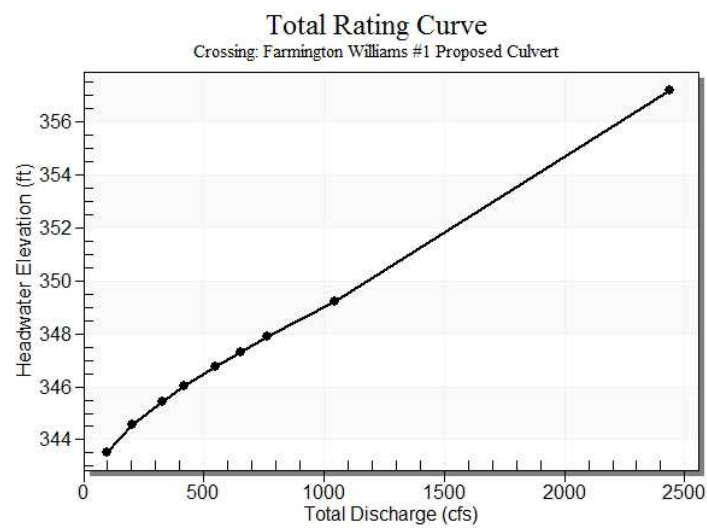
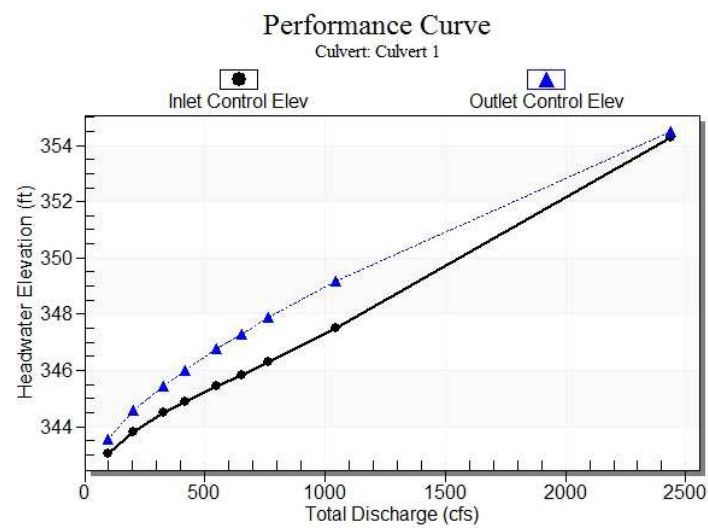


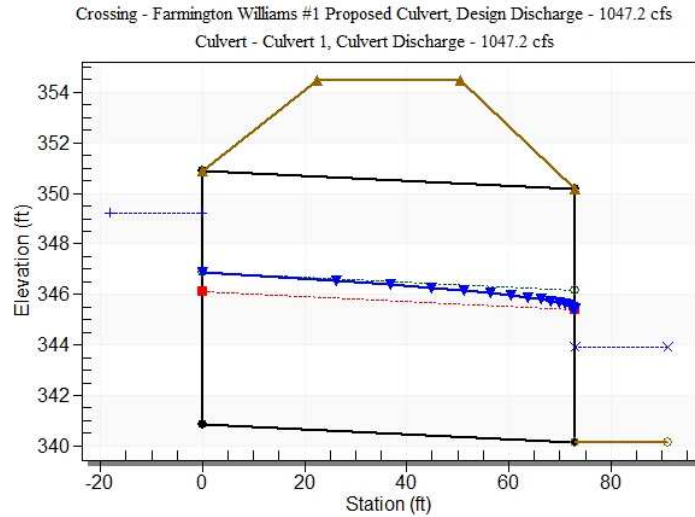
Table 2 - Culvert Summary Table: Culvert 1

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	95.80	95.80	343.54	2.172	2.671	2-M2c	2.235	1.901	1.901	0.939	5.524	3.944	*****
Q2	204.30	204.30	344.58	2.937	3.712	2-M2c	3.047	2.536	2.536	1.467	6.956	5.170	Straight Culvert
Q5	328.10	328.10	345.45	3.625	4.579	2-M2c	3.623	3.146	3.146	1.935	7.610	6.086	Inlet Elevation (invert): 340.87 ft, Outlet Elevation (invert): 340.16 ft
Q10	419.60	419.60	346.02	4.033	5.149	2-M2c	3.994	3.467	3.467	2.231	8.260	6.609	Culvert Length: 73.00 ft, Culvert Slope: 0.0097
Q25	550.70	550.70	346.77	4.570	5.899	2-M2c	4.476	3.887	3.887	2.608	9.043	7.227	*****
Q50	652.80	652.80	347.31	4.959	6.443	2-M2c	4.822	4.190	4.190	2.874	9.575	7.635	*****
Q100	764.60	764.60	347.88	5.429	7.008	2-M2c	5.177	4.508	4.508	3.144	10.089	8.029	*****
Q500	1047.20	1047.20	349.20	6.634	8.326	2-M2c	5.997	5.245	5.245	3.753	11.202	8.857	*****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



S

Inlet Station: 0.00 ft

Inlet Elevation: 348.87 ft

Outlet Station: 73.00 ft

Outlet Elevation: 344.16 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: User Defined

Barrel Span: 24.00 ft

Barrel Rise: 10.00 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: Farmington Williams #1

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
95.80	341.10	0.94	3.94	0.52	0.74
204.30	341.63	1.47	5.17	0.81	0.79
328.10	342.09	1.93	6.09	1.06	0.82
419.60	342.39	2.23	6.61	1.22	0.84
550.70	342.77	2.61	7.23	1.43	0.86
652.80	343.03	2.87	7.63	1.58	0.87
764.60	343.30	3.14	8.03	1.73	0.88
1047.20	343.91	3.75	8.86	2.06	0.90

Proposed Culvert)**Tailwater Channel Data - Farmington Williams #1 Proposed Culvert**

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 24.00 ft

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

Channel Slope: 0.0088

Channel Manning's n: 0.0320

Channel Invert Elevation: 340.16 ft

Roadway Data for Crossing: Farmington Williams #1 Proposed Culvert

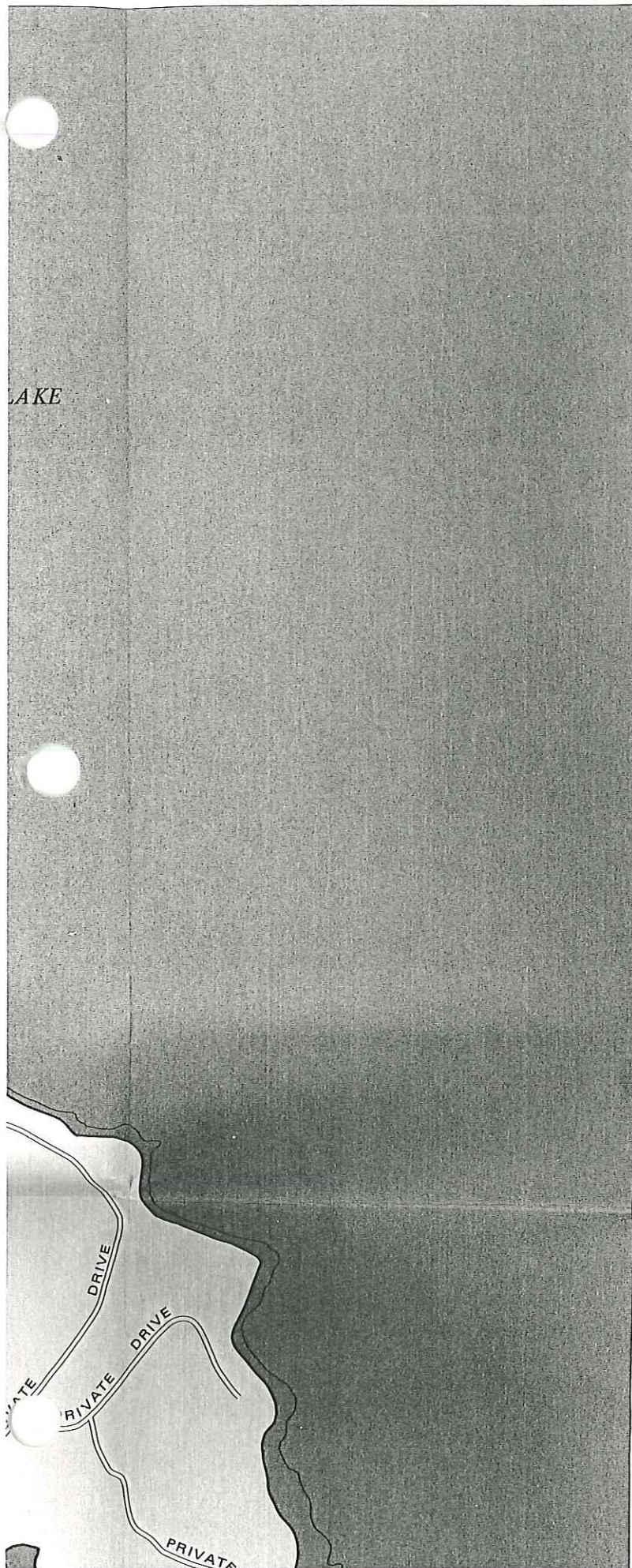
Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 354.50 ft

Roadway Surface: Paved

Roadway Top Width: 28.00 ft



KEY TO MAP

500-Year Flood Boundary	→	ZONE B
100-Year Flood Boundary	→	ZONE A1 DATE
Zone Designations* With Date of Identification e.g., 12/2/74		ZONE A5 DATE
100-Year Flood Boundary	→	ZONE B
500-Year Flood Boundary	→	ZONE B
Base Flood Elevation Line With Elevation In Feet**	~~~~~	513
Base Flood Elevation in Feet Where Uniform Within Zone**		(EL 987)
Elevation Reference Mark		RM7X
River Mile		• M1.5

**Referenced to the National Geodetic Vertical Datum of 1929

*EXPLANATION OF ZONE DESIGNATIONS

ZONE	EXPLANATION
A	Areas of 100-year flood; base flood elevations and flood hazard factors not determined.
A0	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; average depths of inundation are shown, but no flood hazard factors are determined.
AH	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; base flood elevations are shown, but no flood hazard factors are determined.
A1-A30	Areas of 100-year flood; base flood elevations and flood hazard factors determined.
A99	Areas of 100-year flood to be protected by flood protection system under construction; base flood elevations and flood hazard factors not determined.
B	Areas between limits of the 100-year flood and 500-year flood; or certain areas subject to 100-year flooding with average depths less than one (1) foot or where the contributing drainage area is less than one square mile; or areas protected by levees from the base flood. (Medium shading)
C	Areas of minimal flooding. (No shading)
D	Areas of undetermined, but possible, flood hazards.
V	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors not determined.
V1-V30	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors determined.

NOTES TO USER

Certain areas not in the special flood hazard areas (zones A and V) may be protected by flood control structures.

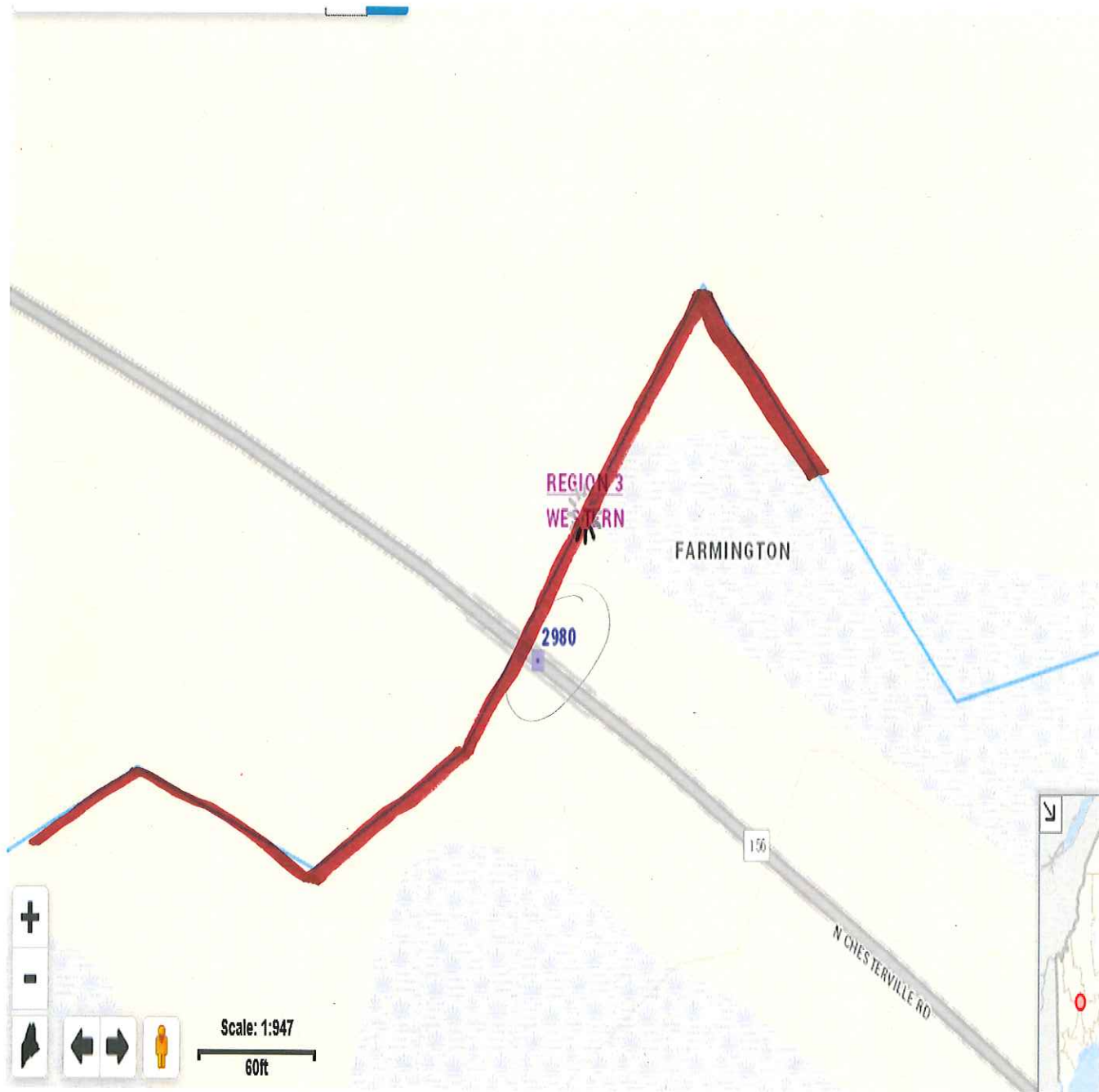
This map is for flood insurance purposes only; it does not necessarily show all areas subject to flooding in the community or all planimetric features outside special flood hazard areas.

For adjoining map panels, see separately printed Index To Map Panels.

INITIAL IDENTIFICATION:

APRIL 18, 1975

FLOOD HAZARD BOUNDARY MAP REVISIONS:



BR # 2980

NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

TOWN OF
FARMINGTON,
MAINE
FRANKLIN COUNTY

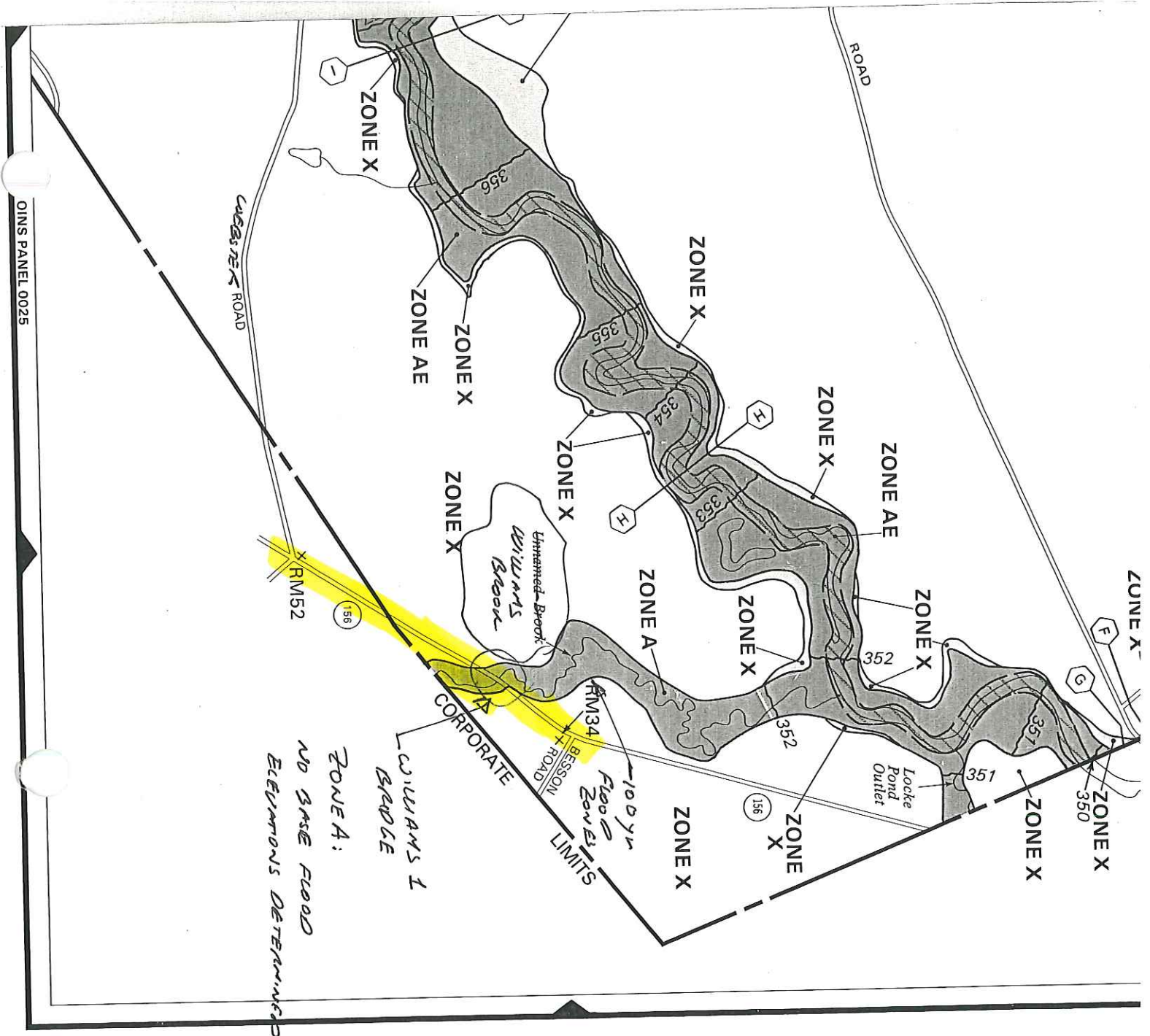
PANEL 15 OF 25
(SEE MAP INDEX FOR PANELS NOT PRINTED)

COMMUNITY-PANEL NUMBER
230057 0015 C
MAP REVISED:
JULY 3, 1995



Federal Emergency Management Agency

AINS PANEL 0025



NOTES FROM SITE VISIT WILLIAMS #1 BRIDGE #2980
ON 10/17/12

- 1- upstream BFW (MEASURED) = 20'
- 2- CLAY TYPE RIVER BOTTOM.
- 3- PEBBLE COUNT NOT PERFORMED DUE TO SOIL CONDITIONS
- 3- Deposition of 8' wide at the outlet of the pipe arch.
- 4- Wood logs are intentionally placed along culvert @ about 5' on center.
- 5- UNSTABLE FLOWS AND UNSTABLE STREAM BED (Alluvial)
- 6- Bank full elevation is at scour mark
- 7- Scour pool downstream is not too big but it is deep
- 8- LOW GRADE stream
- 9- FLOW IS FROM SOUTH TO NORTH
- 10- Culvert inlet can be adjusted to better match stream. this may affect current skew.
- 11- LOW GRADE STREAM BED. less than $\frac{1}{2}\%$
- 12- GRADIENT IS OK FOR FISH PASSAGE
- 13- NO INSIONS DOWNSTREAM OR UNDER CUT upstream.
- 14- Generally acceptable for fish passage

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Existing Culvert

DESIGN FLOW

$$Q_{50} = 652.8 \text{ cfs}$$

check flow

$$Q_{100} = 764.6 \text{ cfs}$$

USING METHOD IN HDS-5-

Culvert length = 63'

$$EL_{SF} = 341.83'$$

$$\text{stream slope} = 0.0088$$

TW DEPTH

$$Q_{50} =$$

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

$$A = \frac{19 + (19 + 2y_1)}{2} y_1 = [19 + y_1] y_1$$

$$R = \frac{A}{P} = \frac{[19 + y_1] y_1}{[19 + 2.828 y_1]}$$

$$652.8 \text{ cfs} = \frac{1.49}{0.032} \times \frac{[19 + y_1] y_1^{5/3}}{[19 + 2.828 y_1]^{2/3}} (0.0088)^{1/2}$$

$$149245 = \frac{[19 + y_1] y_1^{5/3}}{[19 + 2.828 y_1]^{2/3}} = \frac{[19 y_1 + y_1^2]^{5/3}}{[19 + 2.828 y_1]^{2/3}}$$

$$\text{Try } y_1 = 2' \rightarrow 59.9$$

$$\text{Try } y_1 = 3' \rightarrow 118.4$$

$$\text{Try } y_1 = 3.5' \rightarrow 153.16 \quad y_1 = 3.4' \quad TW = 3.4'$$

$$\text{Try } y_1 = 3.4' \rightarrow 146.26$$

INLET CONTROL $A = \frac{\pi r^2}{2} = \frac{\pi \times 10'^2}{2} = 157.1 \text{ ft}^2 \quad D = 10'$

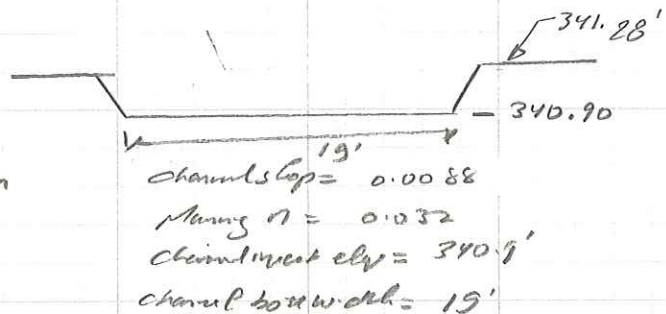
$$AD^{0.5} = 157.1 \text{ ft}^2 \times (10')^{0.5} = 496.8$$

$$Q/AD^{0.5} = 652.8 / 496.8 = 1.31$$

BASE ON CHART 43B for $Q = 652.8 \text{ cfs}$ & $A = 157.1 \text{ ft}^2$ for

$$R_{is}/spu = 10/20 = 0.5 \quad \frac{HW}{P} = 0.5 \quad HW = 5'$$

$$EL_{hi} = 341.83' + 5' = 346.83'$$



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OUTLET CONTROL

FROM CHART 44A for $Q/A D^{0.5} = 1.31$ $\frac{d_c}{D} = 0.47$

$$d_c = 0.47 \times 10 = 4.7' < D = 10'$$

$$d_c = 4.7' > TW = 3.4'$$

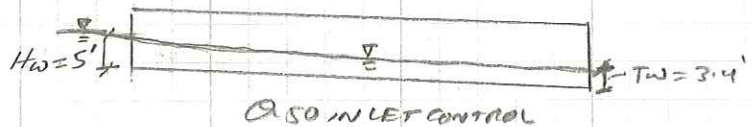
FOR Q50 $\frac{d_c + D}{2} = \frac{4.7' + 10}{2} = 7.35'$
 $TW = 3.4'$

$h_o =$ cresting TW at $\frac{d_c + D}{2} = 7.35'$ $H = 0.5'$

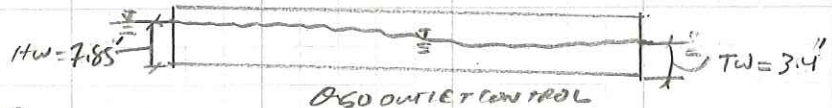
$E_{h_o} = E_{l_o} + H + h_o$ $E_{l_o} = 341.83' + 7.35' + 0.5' = \underline{\underline{349.68'}}$

for Q50 for both cases

INLET CONTROL



OUTLET CONTROL



FLOW IS OUTLET CONTROLLED

$HW = 7.85'$, $TW = 3.4'$ (control from)

$HW_{ELEV} = 349.43'$ (calculated)

$HW_{HY-8} = 347.94'$ USE HY-8 Results.

∴ outlet controlled from with TW @ critical depth

TW Depth $Q_{100} = 764.6$ cfs

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

$A = \left[\frac{19 + (19 + 2y_n)}{2} \right] y_n = [19 + y_n] y_n = [19y_n + y_n^2]$

$R = \frac{A}{P} = \frac{[19y_n + y_n^2]}{[19 + 2.828y_n]}$

$764.8 = \frac{[19y_n + y_n^2]^{5/3} \times 1.49}{[19 + 2.828y_n]^{2/3} \times 0.0088}^{1/2}$

$175.0 = \frac{[19y_n + y_n^2]^{5/3}}{[19 + 2.828y_n]^{2/3}}$

$y_n \rightarrow 3.7' \rightarrow 168.8$
 $y_n \rightarrow 3.8' \rightarrow 176.6$
 $TW = 3.8'$

PRELIM. BY _____
FINAL CHK. BY _____
ITEM NO. _____

FEB 12 2018

DATE _____ PROJ. NO. 21690-00
DATE _____ LOCATION FARMINGTON W. LUMS
SUBJECT EXISTING GUT #13R

FILE NO. 1 OF
3 OF

INLET CONTROL $A = 157.1 \text{ ft}^2$ $D = 10'$

$$AD^{0.5} = 157.1 \times 10^{0.5} = 456.8$$

$$Q/AD^{0.5} = 764.6 / 456.8 = 1.67 \approx 1.7$$

BASED ON CHART 43B for $Q = 764.6 \text{ cfs}$ $A = 157.1 \text{ ft}^2$

$$\frac{H_w}{D} = 0.56 \Rightarrow H_w = 0.56 \times 10 = 5.6'$$

$$EL_{hi} = 341.83' + 5.6' = 347.43'$$

OUTLET CONTROL

FROM CHART 44A for $Q/AD^{0.5} = 1.7$ $\frac{d_c}{D} = 0.57$

$$d_c = 0.57 \times 10 = 5.7' > T_w = 3.8'$$

$$\text{FOR } R_{100} \quad \frac{d_c + D}{2} = \frac{5.7' + 10}{2} = 7.85' \quad H = 0.7'$$

$$EL_{ho} = EL_o + h + h_o, \quad h_o = \text{grating} \quad T_w \text{ OR } \frac{d_c + D}{2} = 7.85'$$

$$EL_{ho} = 341.83 + 7.85 + 0.7 = \boxed{350.38' \text{ (calculated)}}$$

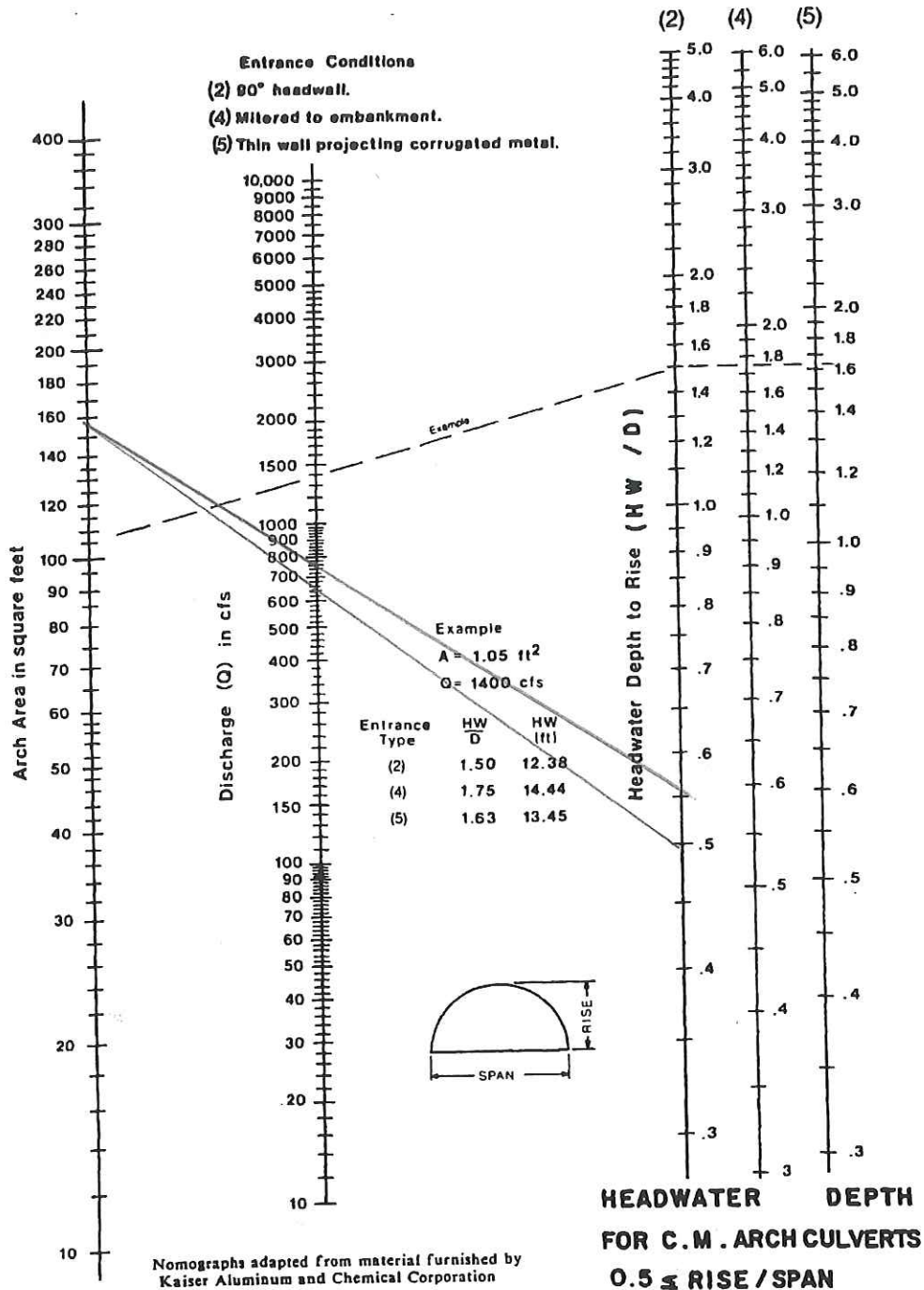
$$\boxed{EL_{ho} H_{y-8} = 348.64'}$$

USE H_{y-8} Results.

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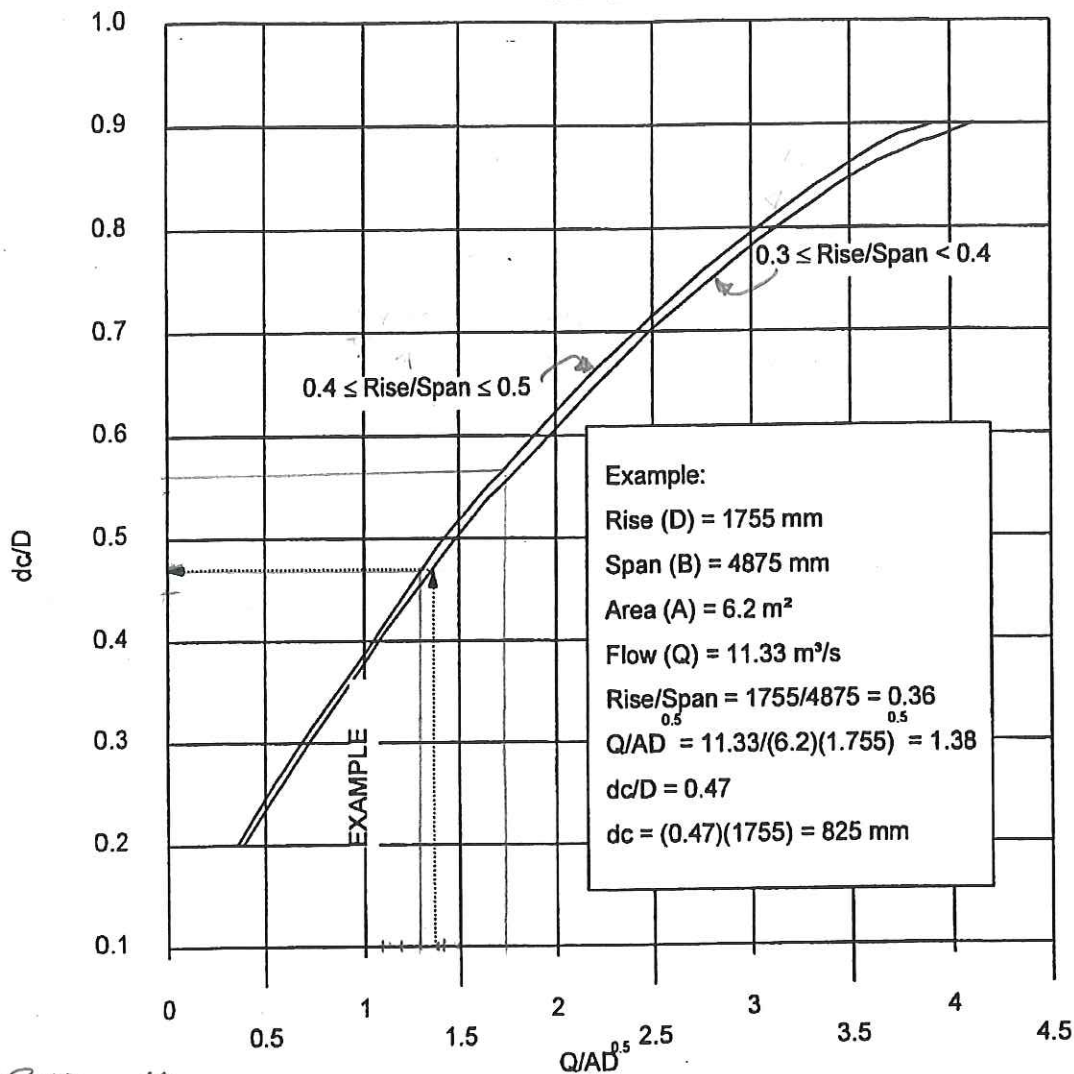
MaineDOT

CHART 43B



$Q_{50} = 852.8 \text{ cfs}$
 $Q_{100} = 764.6 \text{ cfs}$
 $\frac{H_W}{D} = 0.5$
 $\frac{H_W}{D} = 0.56$
 $H_W = 0.5 \times 10' = 5'$
 $H_W = 0.56 \times 10' = 5.6'$

CHART 44A



$$\frac{RISE}{SPAN} = \frac{10}{24} = 0.42$$

$$Q_{50} = 652.8 \text{ cfs}$$

$$\frac{Q}{AD^{0.5}} = 1.31 \rightarrow \frac{dc}{D} = 0.47$$

$$dc = 0.47 \times 10 = 4.7'$$

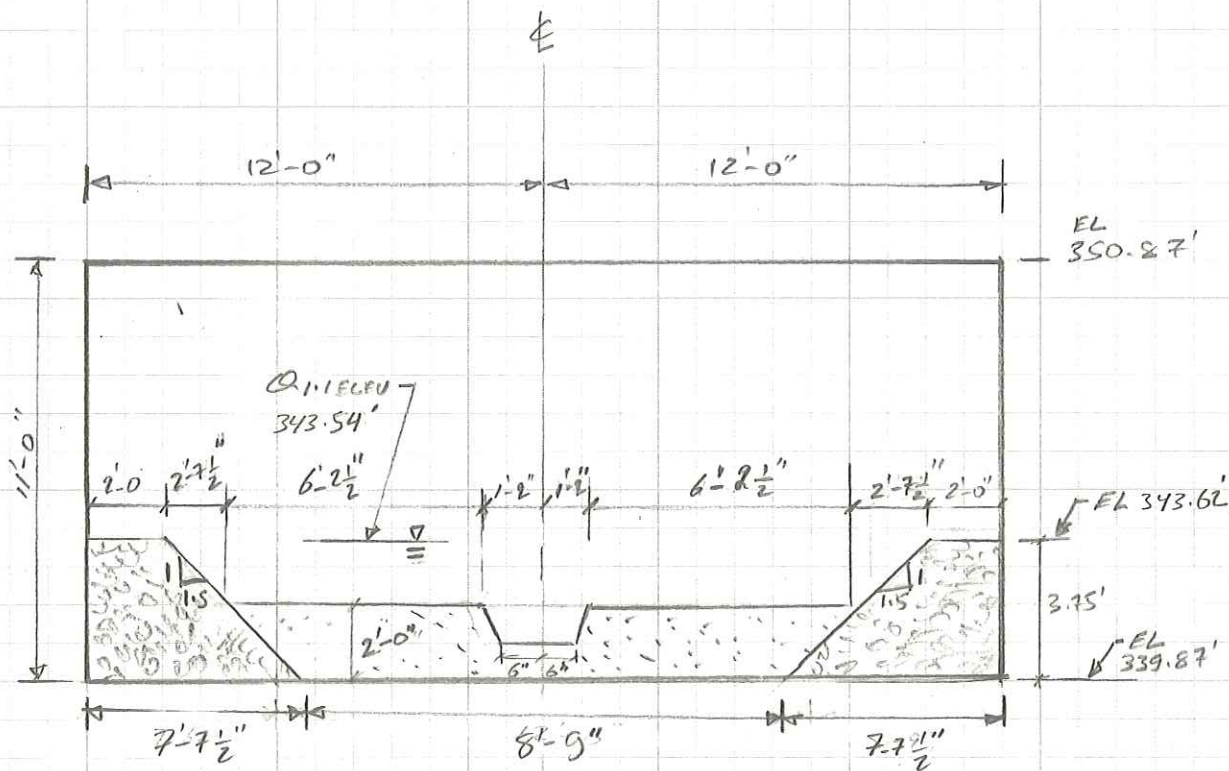
$$Q_{100} = 764.6 \text{ cfs}$$

$$\frac{Q}{AD^{0.5}} = 1.7 \rightarrow \frac{dc}{D} = 0.57$$

$$dc = 0.57 \times 10 = 5.7'$$

**Dimensionless Critical Depth Chart
for Corrugated Metal Arch Culverts**

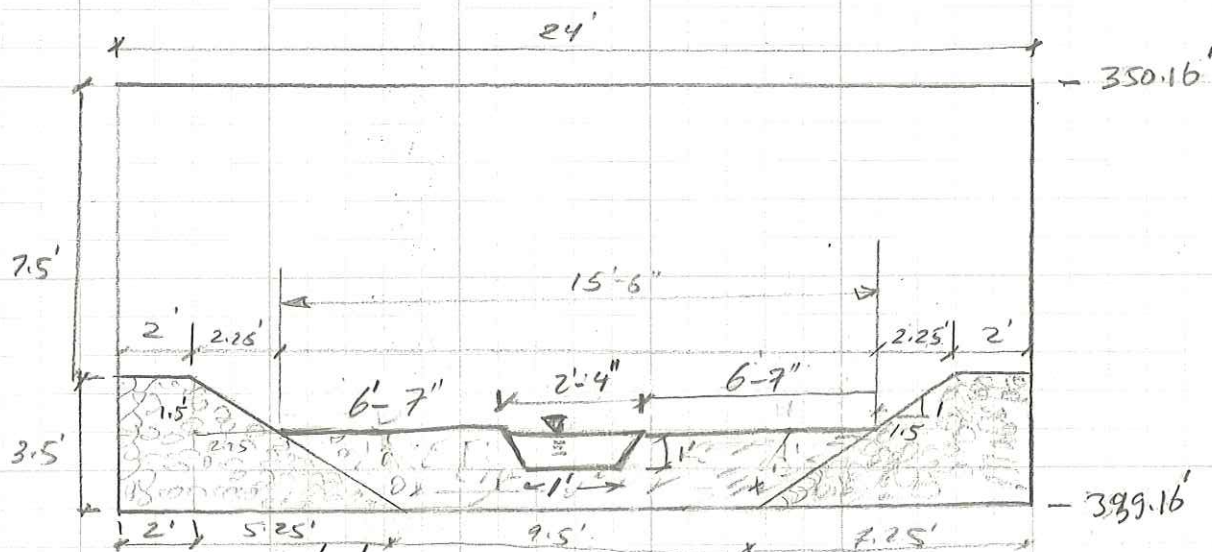
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14' + 15"
 15' - 3" -
 29' - 0"

FEB 12 2019



CULVERT AREA = $24 \times 11 = 264 \text{ ft}^2$

WILDLIFE BANKS = $\left[\left(\frac{7.25 + 2}{2} \right) \times 3.5 \right] \times 2 = 32.3 \text{ ft}^2$

SIDEWALKS = $\left(\frac{9.5 + 15.5}{2} \right) \times 2 = 25 \text{ ft}^2$

LOW FLOW CHANNEL = $\left(\frac{9.5 + 7.5}{2} \right) \times 1 = 8.5 \text{ ft}^2 = \left(\frac{1 + 2.33}{2} \right) \times 1 = 1.66 \text{ ft}^2$

TOTAL AVAILABLE AREA = $264 \text{ ft}^2 - 32.3 - 25 + 8.5 = 215.2 \text{ ft}^2$

Eg channel depth = $(264 \text{ ft}^2 - 215.2 \text{ ft}^2) / 24 = 2.03 \text{ ft. Say } 24" \text{ O.D.}$

DETERMINE CAPACITY of low flow channel

$n = 0.032$ (natural channel)

$b_0 = 1 + 2(1.2) = 3.4'$

Aflow = 1.5 ft^2 } $R = \frac{A}{b_0} = \frac{1.66 \text{ ft}^2}{3.4 \text{ ft}} = 0.49'$

$Q = \frac{1.49}{0.042} \times 1.66 \text{ ft}^2 \times (0.49)^{2/3} (0.01)^{1/2} = 3.66 \text{ cfs}$

$Q = 3.66 \text{ cfs} < Q_{1.1} = 95.8 \text{ cfs}$

∴ low flow channel will fill up at much lower flow than $Q_{1.1}$

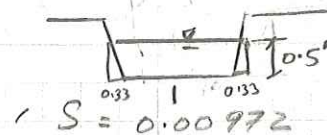
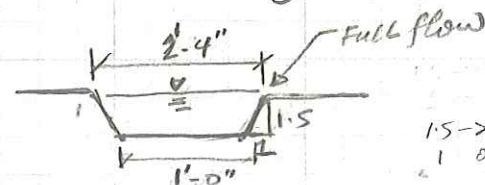
② velocity = $\frac{Q}{A} = \frac{3.66}{1.66} = 2.2 \text{ ft/sec}$ O.K. FOR ADULT SALMONID

at 6" deep flow Aflow = $\left(\frac{1 + 1 + 2(0.33)}{2} \right) \times 0.5 = 0.67 \text{ ft}^2$

$b_0 = 1 + 2(0.6) = 2.2'$

$R = \frac{0.67}{2.2} = 0.30$

$Q = \frac{1.49}{0.042} \times 0.67 \text{ ft}^2 \times (0.30)^{2/3} (0.01)^{1/2} = 1.0 \text{ cfs}$
 $Q = 1.0 \text{ cfs}$ $V = \frac{Q}{A} = \frac{1.0 \text{ cfs}}{0.67} = 1.5 \text{ ft/sec}$



$6" \rightarrow 1.5'$
 $4" \rightarrow 1'$
 $\sqrt{0.66^2 + 1} = 1.2'$

∴ 0.2 ft/sec from 2 ft/sec

LEVEL of flow @ Q_{1.1}

$$Q_{\text{remain}} = Q_{1.1} - 30.8 \text{ cfs} = 95.8 - 30.8 = 65 \text{ cfs}$$

with low flow channel full @ $Q \ll Q_{1.1}$

determine stage @ $Q = 65 \text{ cfs}$ above streambed.

Estimate y_n for $Q = 65 \text{ cfs}$

$$b_0 = 15.5' + 2(1.8y_n) = 15.5 + 3.6y_n$$

$$\begin{aligned} A_{\text{flow}} &= \left[\frac{15.5' + 15.5' + 2(1.5y_n)}{2} \right] \times y_n \\ &= \left[\frac{15.5' + 15.5' + 3y_n}{2} \right] \times y_n \\ &= \left[\frac{31 + 3y_n}{2} \right] \times y_n = [15.5 + 1.5y_n] y_n \\ &= [15.5y_n + 1.5y_n^2] \end{aligned}$$

$$R = \frac{A_{\text{flow}}}{b_0} = \frac{15.5y_n + 1.5y_n^2}{[15.5 + 3.6y_n]}$$

$$65 \text{ cfs} = \frac{1.49}{0.032} \times [15.5y_n + 1.5y_n^2] \times \left[\frac{15.5y_n + 1.5y_n^2}{[15.5 + 3.6y_n]} \right]^{2/3} \times (0.00972)^{1/2}$$

$$65 \text{ cfs} = \frac{1.49}{0.032} \frac{[15.5y_n + 1.5y_n^2]^{5/3}}{[15.5 + 3.6y_n]^{2/3}} \times (0.00972)^{1/2}$$

$$14.16 = \frac{[15.5y_n + 1.5y_n^2]^{5/3}}{[15.5 + 3.6y_n]^{2/3}}$$

$$y_n \rightarrow 0.5' \rightarrow 4.9$$

$$y_n \rightarrow 1.0' \rightarrow 15.72$$

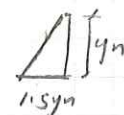
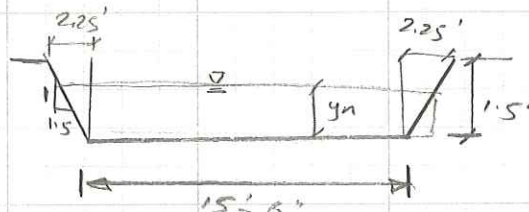
$$y_n \rightarrow 0.9' \rightarrow 13.16$$

$$y_n \rightarrow 0.95' \rightarrow 14.42$$

$$y_n \rightarrow 0.94' \rightarrow 14.17 \checkmark$$

$$\begin{aligned} A_{\text{flow}} &= [15.5 \times 0.94 + 1.5 \times 0.94^2] + A_{\text{low flow channel}} \\ &= 15.89 + 8.5 \text{ ft}^2 = 24.39 \text{ ft}^2 \end{aligned}$$

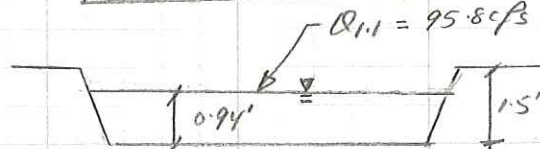
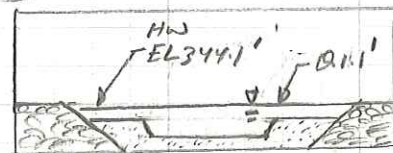
$$Vel = 95.8 \text{ cfs} / 24.39 \text{ ft}^2 = 3.92 \text{ ft/sec}$$



$$= \sqrt{1.5y_n^2 + 1.0^2}$$

$$y_n \sqrt{3.25}$$

$$= 1.8y_n$$



$Q_{1.1}$ depth = 2.94' above invert

$$Q_{1.1} \text{ ELEV} = 341.16 + 2.94' = 344.1'$$

$$Q_{1.1} \text{ ELEV } H_{y-8} = 345.29'$$

$$\text{Velocity} = 5.1 \text{ ft/sec } H_{y-8}$$

$$Q_2 = 204.30 \text{ cfs}$$

DETERMINE capacity of channel up to the willow bend

$$\text{CAP LOW FLOW channel} = 30.8 \text{ cfs}$$

cap of channel above stream bed.

$$Q = \frac{1.49}{0.032} \times A \times R^{2/3} \times S^{1/2}$$

$$A = \frac{(7.5' + 9.5')}{2} \times 1.5' = 12.75 \text{ ft}^2, \quad b_0 = 7.5' + 2(2.7') = 12.9'$$

$$R = \frac{A}{b_0} = \frac{12.75 \text{ ft}^2}{12.9 \text{ ft}} = 0.99$$

$$Q = \frac{1.49}{0.032} \times 12.75 \times (0.99)^{2/3} \times (0.00972)^{1/2}$$

$$Q = 58.1 \text{ cfs}$$

$$\text{TOTAL CAPACITY low flow + top channel} = 30.8 + 58.1 = 88.9 \text{ cfs}$$

$$Q_{\text{man}} = 204.30 - 88.9 = 115.4 \text{ cfs}$$

$$115.4 \text{ cfs} = \frac{1.49}{0.032} \times A \times R^{2/3} \times S^{1/2}, \quad A = 24 \times y_n$$

$$R = \frac{24 y_n}{24 + 2 y_n}$$

$$25.14 = \frac{[24 y_n]^{5/3}}{[24 + 2 y_n]^{2/3}}$$

$$b_0 = 24 + 2 y_n$$

$$\begin{aligned} A \times R^{2/3} &= 24 y_n \left[\frac{24 y_n}{24 + 2 y_n} \right]^{2/3} \\ &= 24 y_n \left[\frac{24 y_n}{24 + 2 y_n} \right]^{2/3} \\ &= \frac{[24 y_n]^{5/3}}{[24 + 2 y_n]^{2/3}} \end{aligned}$$

$$y_n = 1.0' \rightarrow 22.75$$

$$y_n = 1.1' \rightarrow 26.53$$

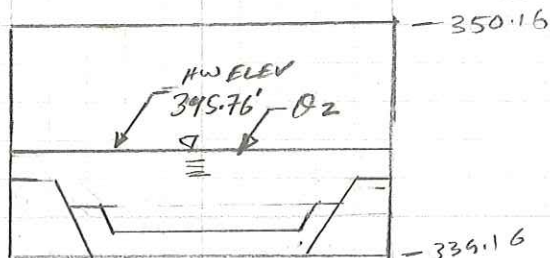
$$y_n = 1.08' \rightarrow 25.76$$

$$y_n = 1.07' \rightarrow 25.37$$

$$y_n = 1.06' \rightarrow 24.95$$

$$\begin{aligned} A_{\text{flow}} &= 12.75 \text{ ft}^2 + 8.5 \text{ ft}^2 \\ &\quad + 1.06 \times 24 \text{ ft}^2 \\ &= 46.67 \text{ ft}^2 \end{aligned}$$

$$\begin{aligned} \text{VEL} &= \frac{204.30}{46.7} \\ &= 4.37 \text{ fps} \end{aligned}$$



$$Q_2 \text{ depth} = 2' + 1.5' + 1.06' = 4.56' \text{ above invert}$$

$$Q_2 \text{ ELEV} = 341.16' + 4.56' = 345.76'$$

$$Q_2 \text{ 1.1 ELEV (1+y-8)} = 346.22' \quad \text{VEL (1+y-8)} = 6.53 \text{ fps}$$

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$$Q_5 = 328.1 \text{ cfs}$$

$$Q_{\text{rem}} = 328.1 \text{ cfs} - Q_2 = 328.1 - 204.30 = 123.8 \text{ cfs}$$

$$123.8 \text{ cfs} = \frac{1.49}{0.032} \times A \times R^{2/3} \times S^{1/2}$$

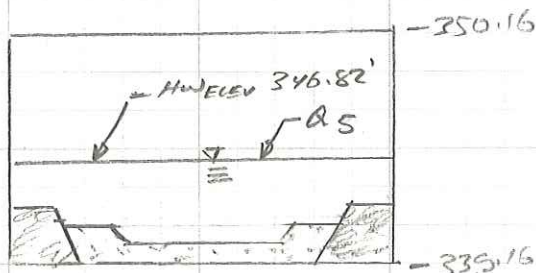
$$26.9 = \frac{[24 y_n]^{5/3}}{[24 + 24 y_n]^{2/3}}$$

$$y_n = 1.1 \rightarrow 26.53 \checkmark \text{ O.K.}$$

$$y_n = 1.12 \rightarrow 27.33 \checkmark$$

$$A_{\text{flow}} = 46.7 \text{ ft}^2 + 1.1 \times 24 = 73.1 \text{ ft}^2$$

$$V_{EL} = 328.1 / 73.1 = 4.48 \text{ fps}$$



$$Q_5 \text{ depth} = 2' + 1.5' + 1.06' + 1.1' = 5.66' \text{ above m.s.l.}$$

$$Q_5 \text{ ELEV} = 341.16 + 5.66 = 346.82'$$

$$Q_5 (H_y - 8) = 347.11'$$

$$Q_5 \text{ vel } (H_y - 8) = 7.57 \text{ fps}$$

$$Q_{10} = 419.6 \text{ cfs}$$

$$Q_{\text{rem}} = 419.6 - 328.1 = 91.5 \text{ cfs}$$

$$91.5 \text{ cfs} = \frac{1.49}{0.032} \times A \times R^{2/3} \times S^{1/2}$$

$$19.93 = \frac{[24 y_n]^{5/3}}{[24 + 24 y_n]^{2/3}}$$

$$y_n = 0.8' \rightarrow 19.85$$

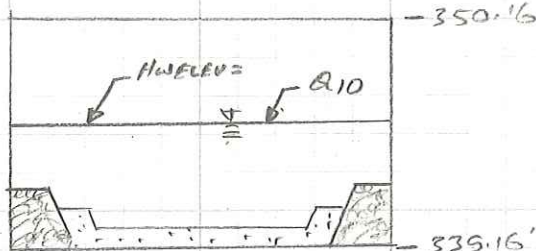
$$y_n = 0.9' \rightarrow 19.18'$$

$$y_n = 0.92' \rightarrow 19.88$$

$$y_n = 0.93'$$

$$A_{\text{flow}} = 73.1 \text{ ft}^2 + 0.93 \times 24 \text{ ft}^2 = 95.4 \text{ ft}^2$$

$$V_{EL} = 419.6 / 95.4 = 4.39 \text{ fps}$$



$$Q_{10} \text{ depth} = 5.66' + 0.93' = 6.59'$$

$$Q_{10} \text{ ELEV} = 341.16 + 6.59 = 347.75'$$

$$Q_{10} (H_y - 8) = 347.65'$$

$$Q_{10} \text{ (vel } H_y - 8) = 8.22 \text{ fps}$$

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$$Q_{25} = 550.70'$$

$$Q_{rem} = 550.70 - 415.6 = 131.1 \text{ cfs}$$

$$131.1 \text{ cfs} = \frac{1.49}{0.032} \times A \times R^{2/3} \times (0.00972)^{1/2}$$

$$28.55 = \frac{[24y_1]^{5/3}}{[24+7y_1]^{2/3}}$$

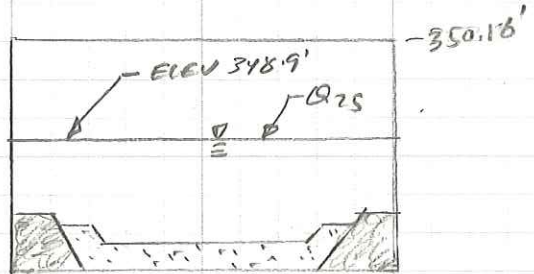
$$y_1 = 1.12 \rightarrow 27.3$$

$$y_1 = 1.2 \rightarrow 30.5$$

$$y_1 = 1.15 \rightarrow 28.5 \checkmark$$

$$A_{flow} = 95.4 + 24 \times 1.15 = 123 \text{ ft}^2$$

$$Vel = 550.7 / 123 = 4.47 \text{ fps}$$



$$Q_{25 depth} = 6.59 + 1.15 = 7.74'$$

$$Q_{25 ELEV} = 341.16 + 7.74 = 348.9'$$

$$Q_{25 (HY-8)} = 348.45' \checkmark$$

$$V_{25 (HY-8)} = 9.01 \text{ fps}$$

$$Q_{50} = 652.80'$$

$$Q_{rem} = 652.80 - 550.7 = 102.1 \text{ cfs}$$

$$102.1 = \frac{1.49}{0.032} \times A \times R^{2/3} \times (0.00972)^{1/2}$$

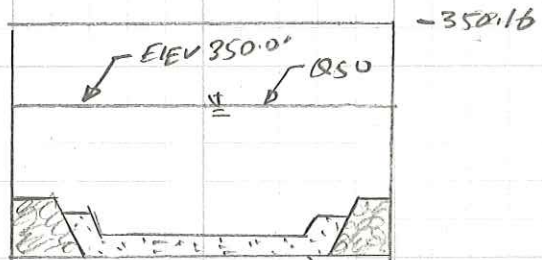
$$22.24 = \frac{(24y_1)^{5/3}}{(24+7y_1)^{2/3}}$$

$$y_1 = 1.0 \rightarrow 27.75 \checkmark$$

$$y_1 = 0.99 \rightarrow 19.07$$

$$A_{flow} = 123 \text{ ft}^2 + 1 \times 24 \text{ ft}^2 = 147 \text{ ft}^2$$

$$Vel = 652.8 / 147 = 4.44 \text{ fps}$$



$$Q_{50 depth} = 7.74' + 1' = 8.84'$$

$$Q_{50 ELEV} = 341.16 + 8.84 = 350.0'$$

$$Q_{50 (HY-8)} = 349.00'$$

$$V_{50 (HY-8)} = 9.54 \text{ fps}$$

$$Q_{100} = 764.60'$$

$$Q_{rem} = 764.60 - 652.80 = 111.8 \text{ cfs}$$

$$111.8 \text{ cfs} = \frac{1.49}{0.032} \times A \times R^{2/3} \times (0.00972)^{1/2}$$

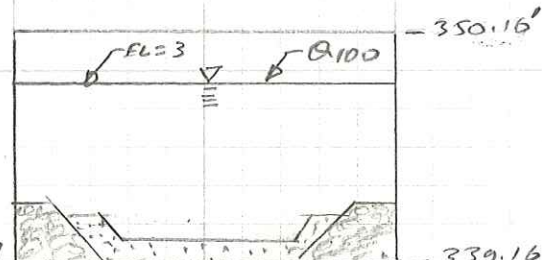
$$24.35 = \frac{(24y_1)^{5/3}}{(24+7y_1)^{2/3}} \left\{ \begin{array}{l} A_{flow} = 147 \text{ ft}^2 + 1.04 \times 24 \\ = 171.96 \text{ ft}^2 \end{array} \right.$$

$$y_1 = 1.1 \rightarrow 26.5$$

$$y_1 = 1.05 \rightarrow 24.6 \checkmark$$

$$y_1 = 1.04 \rightarrow 24.24$$

$$Vel = \frac{764.6}{171.96} = 4.46 \text{ fps}$$



$$Q_{100 depth} = 8.84' + 1.04 = 9.88'$$

$$Q_{100 ELEV} = 341.16 + 9.88 = 351.48'$$

$$Q_{100 (HY-8)} = 349.57'$$

$$V_{100 (HY-8)} = 10.07 \text{ fps}$$

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PRELIM. BY
FINAL CHK. BY
ITEM NO.

DATE **FEB 12 2018**

PROJ. NO. 21690.00
LOCATION FARMINGTON WILLIAM
SUBJECT PROP BOX CULVERT

FILE NO. 12 OF
SHEET NO. 6 OF

$$Q_{500} = 1047.20$$

$$Q_{rem} = 1047.2 - 764.6 = 282.6 \text{ cfs}$$

$$282.6 \text{ cfs} = \frac{1.49}{0.032} \times A \times R^{\frac{2}{3}} \times (0.00972)^{\frac{1}{2}}$$

$$61.5 = \frac{[24 y_n]^{\frac{5}{3}}}{[24 + 2 y_n]^{\frac{4}{3}}}$$

$$y_n = 2.0' \rightarrow 68.7'$$

$$y_n = 1.9' \rightarrow 63.4'$$

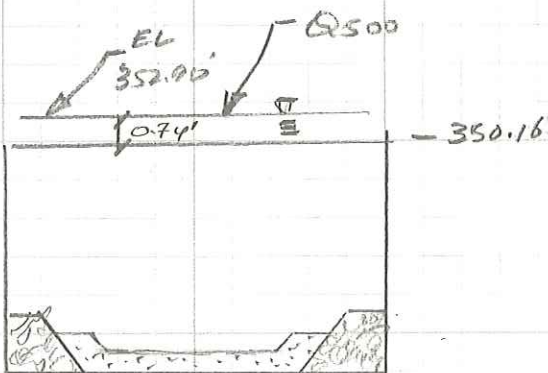
$$y_n = 1.8' \rightarrow 58.2$$

$$y_n = 1.85' \rightarrow 60.8$$

$$y_n = 1.86' \rightarrow 61.3$$

$$A_{flow} = 171.56 + 1.86' \times 24' = 216.6 \text{ ft}^2$$

$$VEL = 1047.2 / 216.6 = 4.83 \text{ fps}$$



$$Q_{500} \text{ depth} = 9.88' + 1.86' = 11.74'$$

$$Q_{500} \text{ elev} = 341.16 + 11.74' = 352.90'$$

$$Q_{500} (Hy-E) = 350.93'$$

$$V_{100} (Hy-E) = 11.18 \text{ fps}$$

The Q_{500} flow is above the top of culvert for 0.74'

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check flows using nomograph charts 14B for Box culverts.

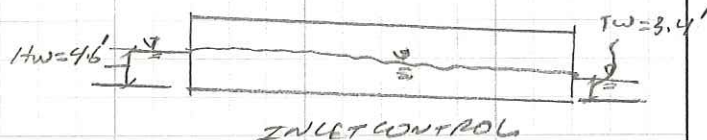
INLET CONTROL

$Q_{50} = 652.8 \text{ cfs}$ $NB = 24'$

$\frac{Q}{NB} = \frac{652.8 \text{ cfs}}{24'} = 27.2 \text{ cfs/ft}$ FROM CHART FOR 2' EMBEDMENT & culvert depth
 $\text{ft of } 9' \text{ above stream bed} = 9'$

$\frac{HW}{D} = 0.51$ $HW = 0.51 \times 9' = 4.6'$

$EL_{h0} = 341.87' + 4.6' = 346.47'$



OUTLET CONTROL

$TW = 3.4'$ (previously computed)

$Q_{50} = 652.8 \text{ cfs}$ $B = 24'$ $Q/B = 27.2 \text{ cfs/ft}$

FROM CHART 14B $dc = 2.8' < D = 9'$

$TW = 3.4' > dc = 2.8'$ Subcritical flow

$h_0 = \text{larger of } \frac{dc + D}{2} = \frac{2.8 + 9}{2} = 5.9' \text{ or } TW = 3.4'$

$EL_{h0} = EL_0 + h_0 + h_L = 341.87' + 5.9' + 0.4' = 348.17'$

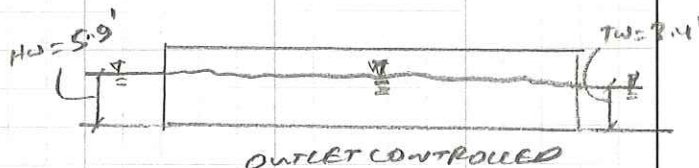
COMPARISON

$HW = 348.17'$ (HAND CALL)

$HW(\text{Hy-8}) = 349.00'$ (culvert with streambed)

$HW(\text{culvert with wined life body}) = 350.00'$ (HAND CALL)

$HW(\text{culvert with wined life body}) = 348.12'$ (Hy-8)



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check flows using NOMOGRAPHIC CHARTS 14B box culvert.

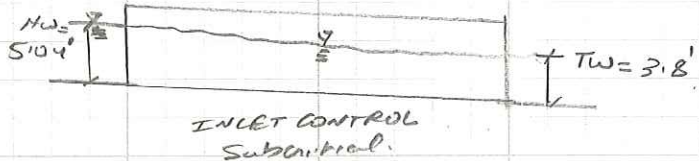
INLET CONTROL

$Q_{100} = 764.6 \text{ cfs}$ $NB = 24'$

$\frac{Q}{NB} = \frac{764.6}{24} = 31.8 \frac{\text{cfs}}{\text{ft}}$ FROM CHART for 2' EMBEDMENT P
 Culvert depth = 9'

$H_w = 0.56$ $H_w = 0.56 \times 9 = 5.04'$

$EL_{H0} = 341.87' + 5.04' = 346.91'$



OUTLET CONTROL

$TW = 3.8'$ (previously computed)

$Q_{100} = 764.6 \text{ cfs}$ $B = 24'$ $Q/B = 31.8 \frac{\text{cfs}}{\text{ft}}$

FROM CHART 14B $dc = 3.2' < D = 9'$

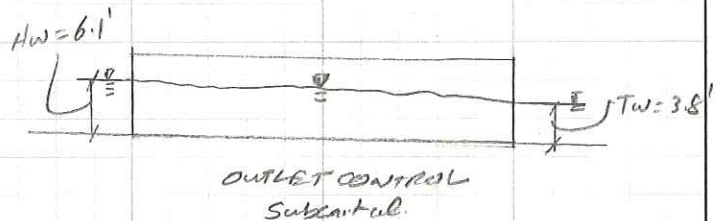
$TW = 3.8' > dc = 3.2'$ subcritical flow

$h_0 = \text{avg of } \frac{dc + D}{2} = \frac{3.2 + 9}{2} = 6.1' \text{ or } TW = 3.8'$

$EL_{H0} = EL_0 + h_0 + h_L = 341.87' + 6.1' + 0.6' = 348.57'$

COMPARISON

$H_w = 348.47'$ (HAND CALC)



$H_w(Hy-6) = 349.57'$ (Culvert with structure)

$H_w(\text{Culvert with Aqueduct stop}) = 351.48'$ (HAND CALC)

$H_w(\text{Culvert with wild life barrier}) = 348.71'$ (Hy-6)

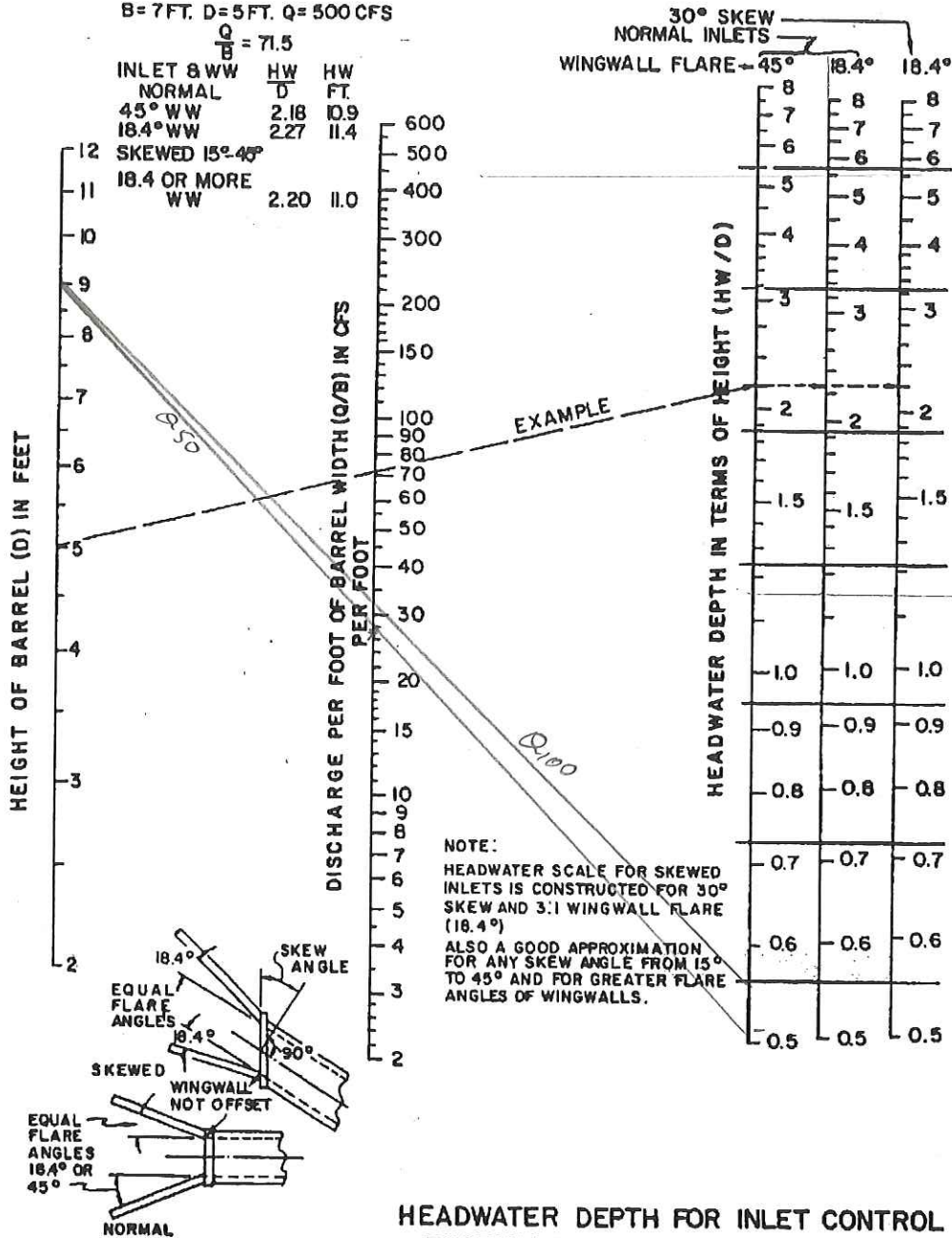
CHART 12B

EXAMPLE

B = 7 FT. D = 5 FT. Q = 500 CFS

$$\frac{Q}{B} = 71.5$$

INLET & WW	HW D	HW FT.
NORMAL		
45° WW	2.18	10.9
18.4° WW	2.27	11.4
SKEWED 15°-45°		
18.4 OR MORE WW	2.20	11.0



HEADWATER DEPTH FOR INLET CONTROL
RECTANGULAR BOX CULVERTS
FLARED WINGWALLS
NORMAL AND SKEWED INLETS
3/4" CHAMFER AT TOP OF OPENING

for $Q_{50} = 652.8 \text{ cfs}$, $B = 24'$

$\frac{Q}{B} = 27.2 \text{ cfs/ft}$ for 9' culvert.

$\frac{H_w}{D} = 0.51'$

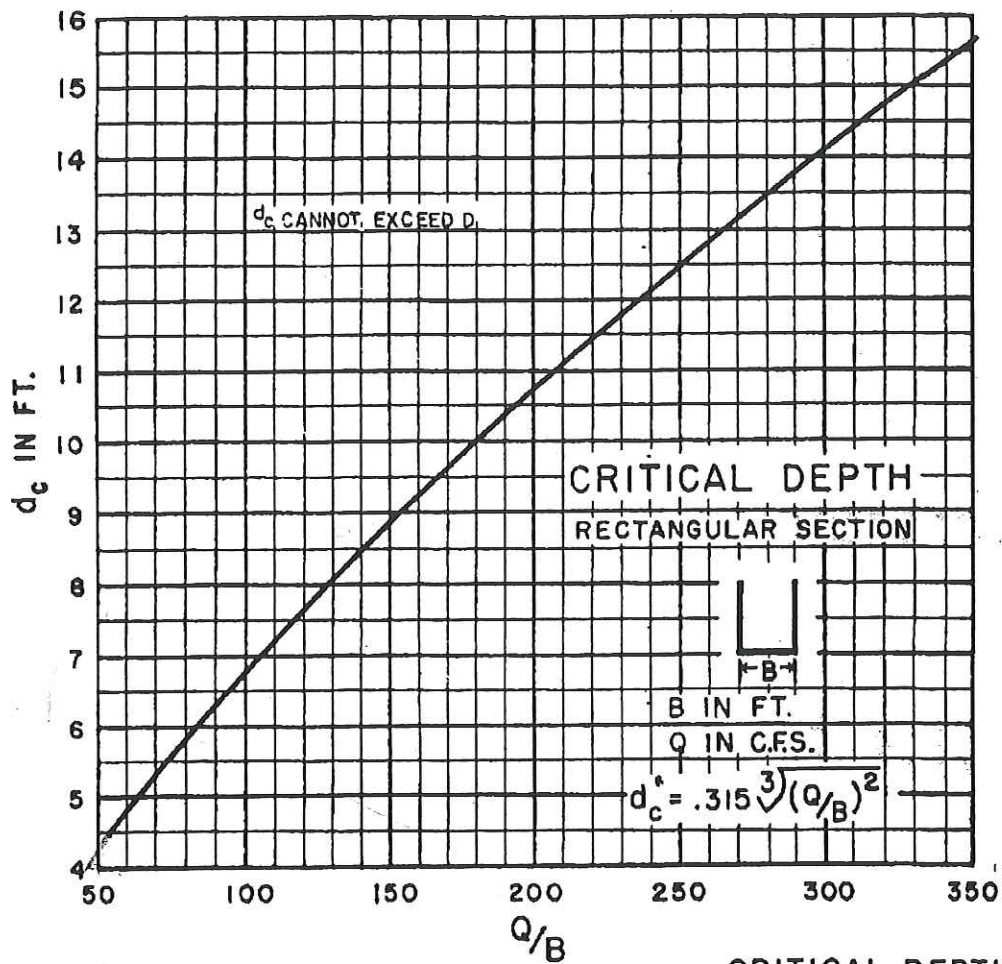
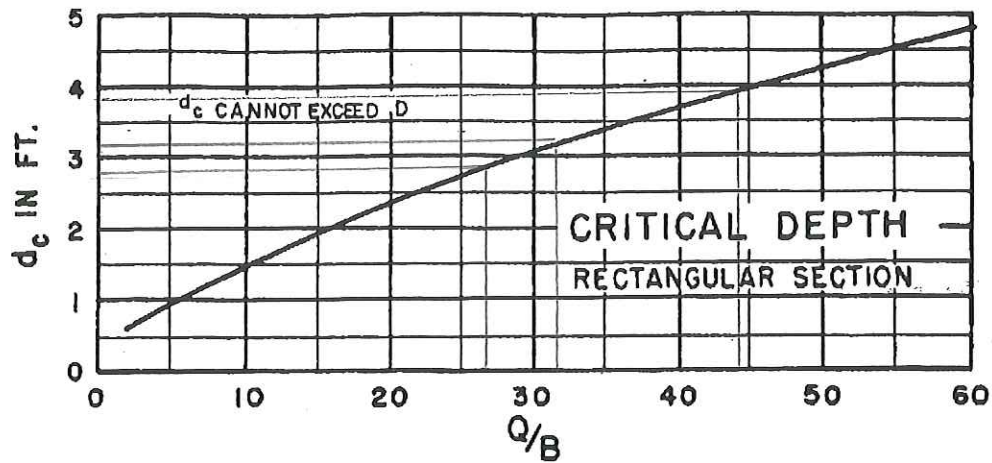
247

for $Q_{100} = 764.6 \text{ cfs}$, $B = 24'$

$\frac{Q}{B} = 31.8$ for 9' culvert.

$\frac{H_w}{D} = 0.56$

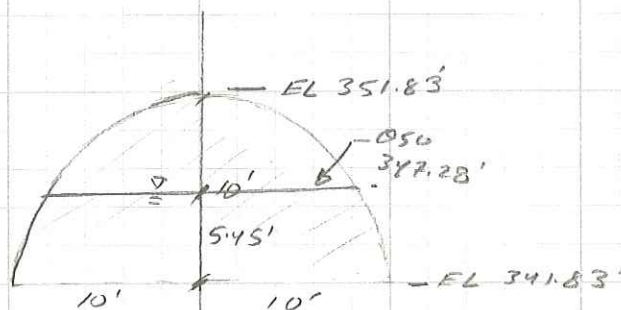
CHART 14B



BUREAU OF PUBLIC ROADS JAN 1963

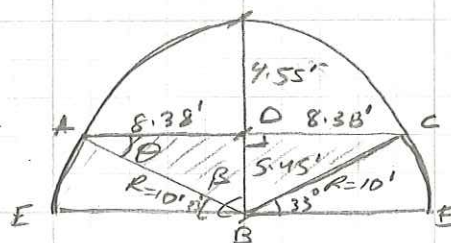
CRITICAL DEPTH
RECTANGULAR SECTION

OPENING AT ELEV 347.28' FOREXISTING CULVERT



$$\Rightarrow \frac{HW}{D} (OSD) = \frac{5.45'}{10'} = 0.54 \text{ or } 54\% \text{ full}$$

$$\begin{aligned} \text{Area of Culvert} &= \frac{\pi D^2}{4} \times \frac{1}{2} \text{ or } \pi r^2 \times \frac{1}{2} \\ &= \pi (10')^2 \times \frac{1}{2} = 157.1 \text{ ft}^2 \end{aligned}$$



FROM TRIANGLE ABD

$$AB^2 = BD^2 + AD^2$$

$$10^2 = 5.45^2 + AD^2$$

$$AD^2 = 10^2 - 5.45^2 = 70.3$$

$$AD = 8.38'$$

$$\text{AREA OF AOCB} = \frac{1}{2} (8.38') \times 5.45' = 45.7 \text{ ft}^2$$

$$\text{ANGLE BAD} \Rightarrow \tan \theta = \frac{5.45}{8.38} = 0.650, \theta = 33^\circ$$

$$B = 90 - 33 = 57^\circ$$

$$\text{Area of SECTOR} = 157.1 \text{ ft}^2 \times \frac{33^\circ}{360^\circ} = 14.4 \text{ ft}^2, \text{ BEC} = \text{BEA} = 14.4 \text{ ft}^2$$

$$\therefore \text{TOTAL AREA} = \text{ABCD} + 2(\text{BEC}) = 45.7 + 2(14.4) = 74.5 \text{ ft}^2$$

$$Q_{\text{full}} = \frac{1.49}{0.032} \times A \times R^{2/3} \times S^{1/2} = \frac{1.49}{0.032} \times 157.1 \text{ ft}^2 \times (3.056)^{2/3} \times (0.00873)^{1/2}$$

$$= 1439 \text{ ft}^3/\text{sec}$$

$$Wp = \frac{2\pi r^3}{3} + 20' = \frac{2 \times \pi \times 10^3}{3} + 20'$$

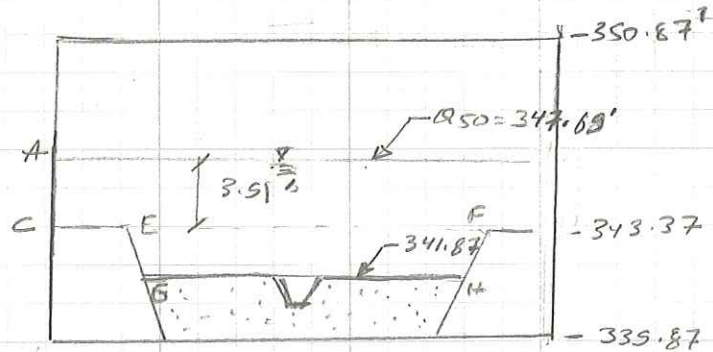
$$= 51.4'$$

$$R_{\text{full}} = \frac{157.1}{51.4} = 3.056$$

$$\frac{Q_{SD}}{Q_{\text{full}}} = \frac{652.8}{1439} = 0.453 \approx 45.3\%$$

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$$A = (3.91' \times 24') + \left(\frac{15.5' + 20'}{2} \right) \times (1.5') + \left(\frac{1' + 2.33}{2} \right) \times 1$$

$$A = 93.84 \text{ ft}^2 + 26.63 \text{ ft}^2 + 1.66 \text{ ft}^2 = \boxed{122.1 \text{ ft}^2}$$

$$A_{\text{full}} = (350.87' - 343.37') \times 24' + \left(\frac{15.5' + 20'}{2} \right) \times 1.5' + 1.66 \text{ ft}^2$$

$$= 180 \text{ ft}^2 + 26.63 \text{ ft}^2 + 1.66 \text{ ft}^2 = 208.3 \text{ ft}^2$$

$$W_p = 24' + 7.5' + 7.5' + 2' + 2' + 2.7' + 2.7' + 6.58' + 6.58' + 1' + 1.2' + 1.2' = 65.2 \text{ ft}$$

$$R_{\text{full}} = A_{\text{full}} / W_p = 208.3 \text{ ft}^2 / 65.2 \text{ ft} = 3.195$$

$$Q_{\text{full}} = \frac{1.49}{0.032} \times (208.3 \text{ ft}^2) \times (3.195)^{2/3} \times (0.01)^{1/2}$$

$$Q_{\text{full}} = 2104 \text{ ft}^3/\text{s}$$

$$\frac{Q_{50}}{Q_{\text{full}}} = \frac{652.8}{2104} = 0.31 \approx 31.0\% \text{ full} \Rightarrow Q_{50}$$

$$\text{or } \frac{Q_{500}}{Q_{\text{full}}} = \frac{1047.2}{2104} = 49.8\% \checkmark$$

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Habitat Connectivity Design Report

Farmington Williams #1 Bridge # 2980
Over Williams Brook, Win # 21690.00

Existing Structure information

- 1- 63' long, 20' diameter Corrugated steel plate arch mitered to match embankment slopes.
- 2- Generally alluvial stream. Based on site observations, survey and stream profile there are no head cuts upstream, no channel incisions downstream. A low stream gradient upstream, downstream, and thru culvert. A perched outlet seems to exist at a formed scour pool directly downstream. There are fallen vegetation and tree logs into stream; an evidence of bank line erosion. Upstream beaver dams were also noted.

Information Collection

Eric Ham measured BFW at 20' using stadia rod.

Due to the muddy conditions in the stream, a sample pebble collection was not performed. Therefore, a pebble count and particle distribution curves cannot be produced. The type of soil that exists makes pebbles extremely difficult to collect.

Table references

Table 1

Watershed Area (mi ²)	Average Calculated BFW (ft)	Measured BFW (ft)	1.2 BFW (ft)
4.7	20	20	24

Table 2- Proposed Structure

Width (ft)	Length (ft)	Channel Bottom width between proposed banks (ft)	Proposed bank height above CSM (ft)
24	73	20	3.75

Longitudinal Profile

- US and DS extent: Average upstream extent 85 feet stations 1+90 to 2+75
Average downstream extent 120 feet stations 0+00 to 1+20
- Proposed Average US and Average DS slope: Average US and DS slope is 1.0 %
- Existing Average slope of each stream Segment: US 0.8%, DS 0.7%
- Sediment Wedge / aggradation: One at station 0+70 DS, 6" deep or less
- Existing Structure inverts: US; 341.83', DS; 341.28'
- Proposed structure inverts: US; 339.87', DS; 339.16'
- Push Bar /scour pool extent: Scour pool directly downstream between stations 0+80 and 1+20. Two feet plus deep scour pool with max depth at station 1+00. No push bars visible from survey. Sandy deposition of 8' wide inside the culvert at the outlet.
- Steps/ stable stream features: There are no steps made of rocks and large stones that indicate stream stability. This sandy silty stream is highly unstable horizontally and vertically and subject to erosion of stream bed and embankments.
- Vertical adjustment profile line for each distinct stream segment: The current stream profile does not warrant raising or lowering the stream bed. The design profile can be the same like the current one with slight slope adjustments
- Stream Restoration: Placing rip rap upstream, downstream, and at banks is highly recommended to prevent further scour and erosion. Aggradation and deposition of sand inside culvert should be removed to place the new culvert. Filling up of scour hole at the outlet to achieve stable stream bed profile is recommended.
- Water surface elevations: Shown for existing bank full height and existing culvert. Top of bank elevations and right and left bank full indicators are also shown on the profile.

Stream Channel Characteristics

Baseline Geomorphic Conditions:

Alluvial stream. A sandy stream that is highly erodible due to absence of stabilizing rocks and rip rap. Clay type stream bottom. Unstable banks and stream bed. Sand deposition inside culvert due to aggradation at low flows. Signs of possible stream migration and lateral shift is a cause of concern for the future stream stability.

Stream habitat types:

Atlantic salmon rearing habitat.

Key features

Other general notes

Sand bar aggradations is evidence of moving sediment through the system. Another sign that Habitat Connectivity design is appropriate in this location.

Scour pool or other anthropogenic scour

Scour pool at outlet and erosion due to high stream velocity evident at downstream banks and at stream bed.

Substrate Analysis:

No pebble count performed because a pebble sample was not collected.

Alignment

How does the proposed structure align with the stream?

The proposed culvert aligns well with the stream. The culvert is placed normal to the center line of the roadway at 0 skew.

Preliminary Habitat Connectivity Design

New Inverts:

The proposed culvert inverts are 2' below stream bed elevations at the design profile. They are US; 339.87', DS; 339.16'

Design Stream bed elevation at the invert locations US; 341.87', DS; 341.16'

Design Slope: Design slope for the entire stream including culvert is 1.0%

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

The Q100 flow for the new structure is 65% full.

Thickness of culvert streambed material CSM:

Two feet for stream bed inside culvert. 3.75 feet deep wild life banks inside culvert.

Low flow channel: 1' minimum depth to provide room for both Adult and Juvenile Salmonids, sloped to 1.0 % to generate flow velocities within Salmonids fish swim capabilities.

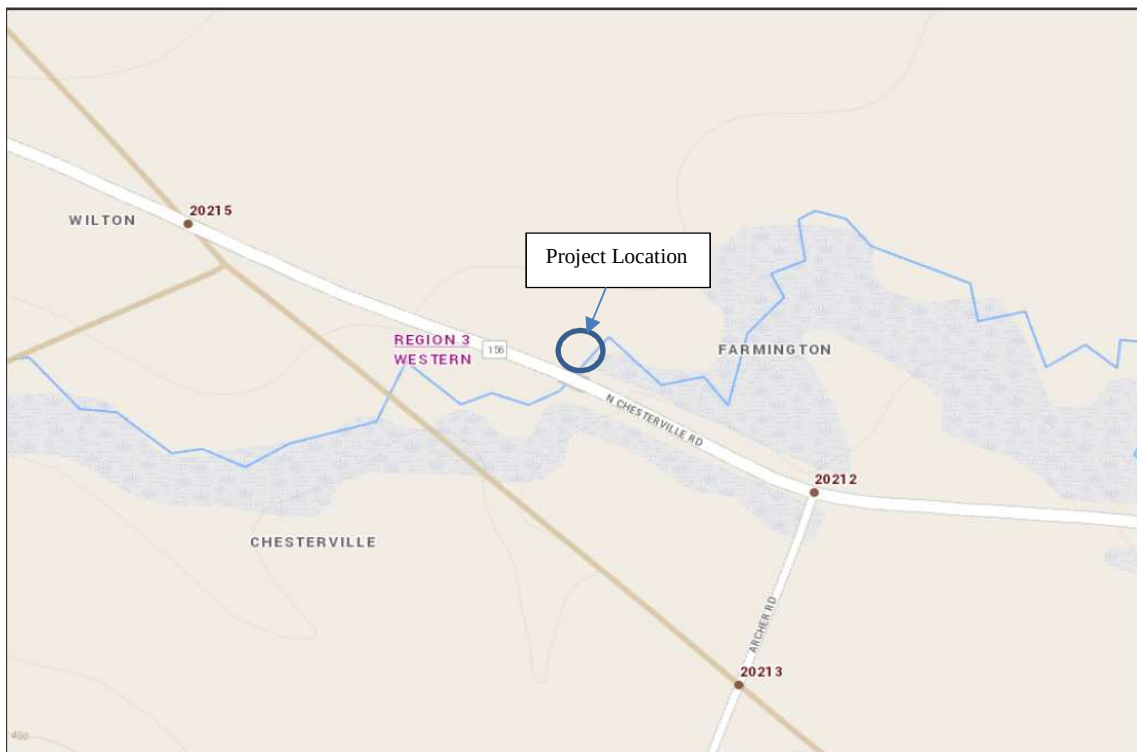
Figure List

Table 1

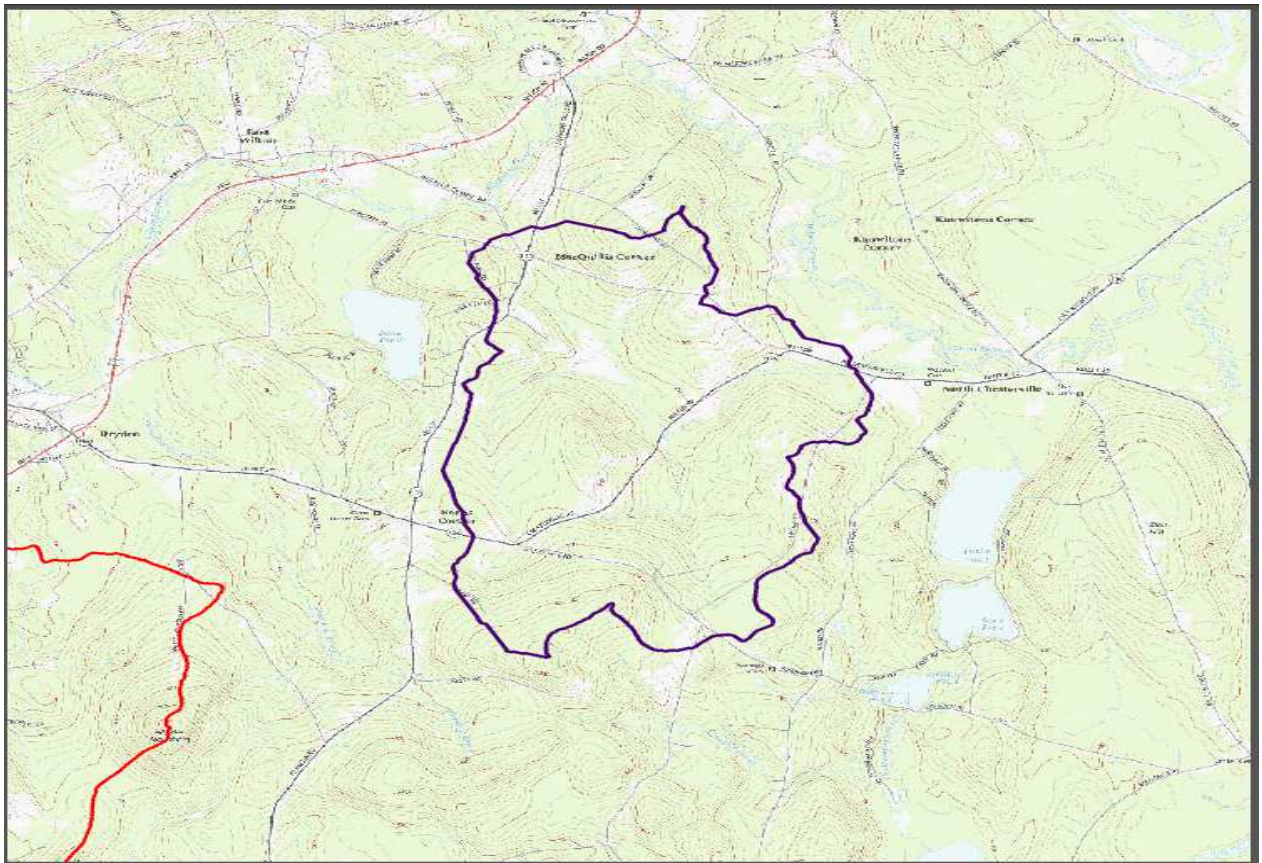
Table 1 and Table 2

Included in report

Map (showing project location)

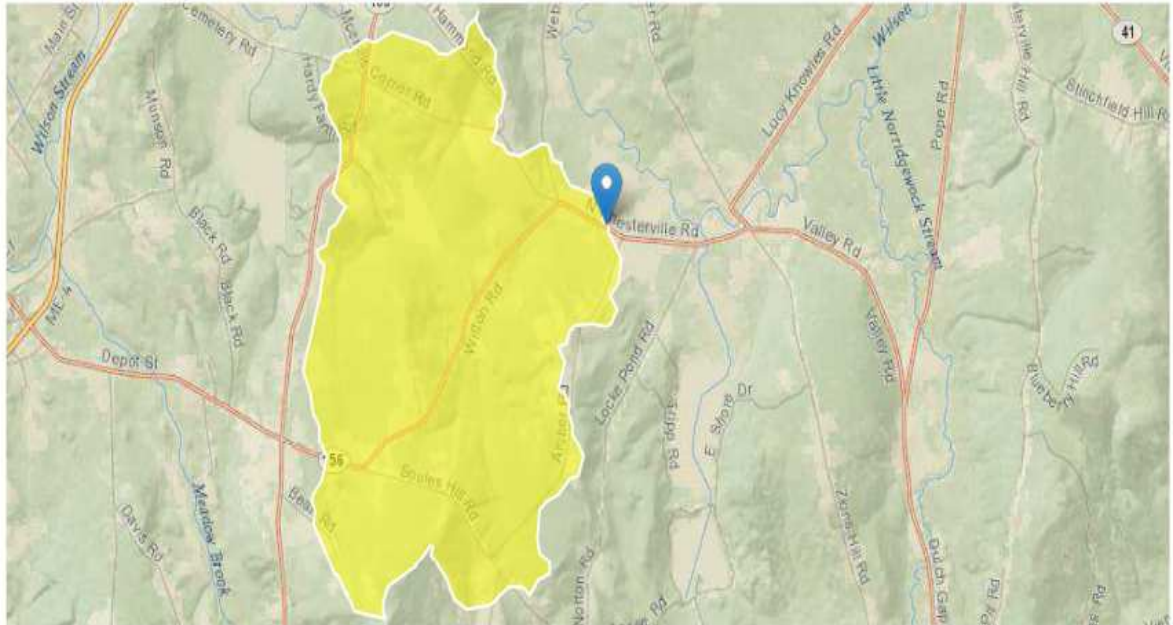


Map (showing entire watershed polygon)



Farmington 21690 Williams Bridge

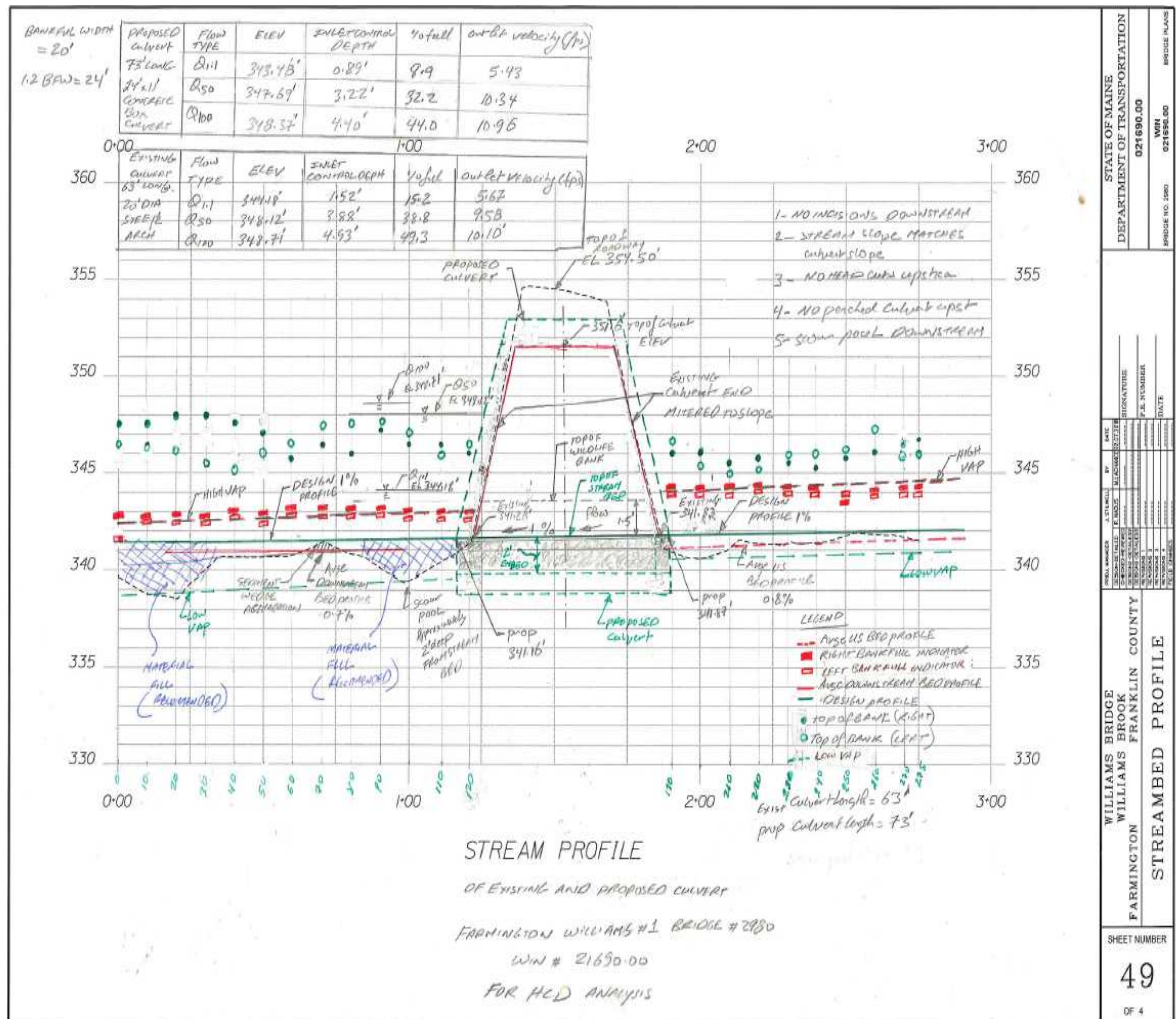
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Time: 2017-10-17 15:16:07 -0400



Basin Characteristics

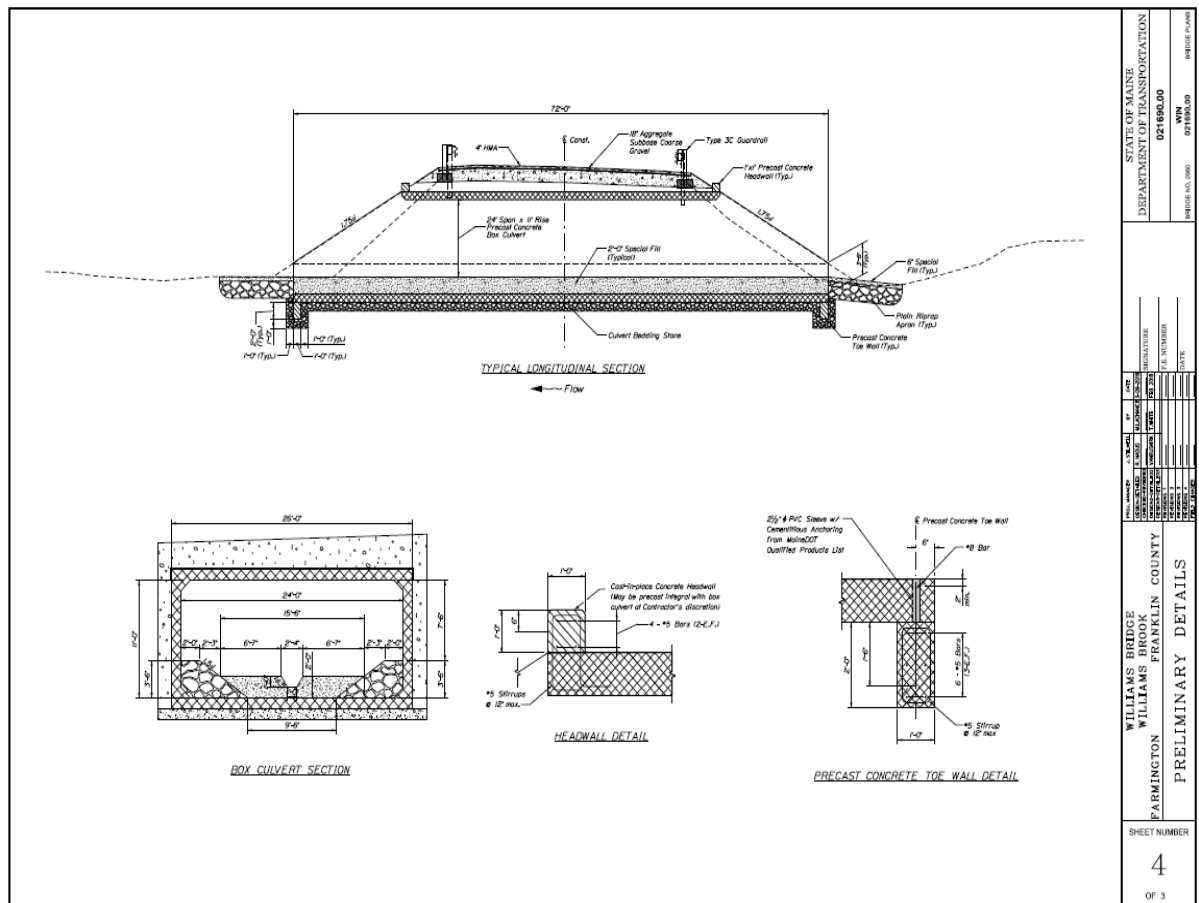
Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	4.7	square miles
STORNI	Percentage of storage (combined water bodies and wetlands) from the National Wetlands Inventory	2.44	percent

Longitudinal Profile:



A PDF electronic copy of the above profile will be also provided.

Proposed Culvert sections:



Substrate analysis results with curve:

Samples were not collected due to muddy conditions and the type of material in the stream bed. There are virtually no pebbles in this sandy alluvial stream.

Photos:



Photo 1: Upstream view.



Photo 2: Downstream view.



Photo 3: Upstream embankment.



Photo 4: Downstream embankment.



Photo 5: Looking Downstream. Sand aggradation at the left side.



Photo 6: Measuring water depth inside culvert.



Photo 7: Measuring upstream bankfull width.



Photo 8: Culvert end view.



Photo 9: Close-up view of sand aggradation.



Photo 10: Mud line at stream banks.



Photo 11: Fallen tree across stream.



Photo 12: Trees and shrubs upstream.