Hydraulics Report
Sanders Circle Culvert Replacement
Sanders Circle, East Montpelier, Vermont

Civil & Structural Engineers
DeWolfe ENGINEERING ASSOCIATES
PROFESSIONAL CORPORATION

DATE: March 12, 2024

TO: Gina Jenkins, East Montpelier Town Administrator

FROM: John Svagzdys, PE

PROJECT: Sanders Circle Culvert Replacement, DEA Project #24014

LOCATION: East Montpelier, Vermont, Sanders Circle (TH-19), over Long Meadow Brook
2,000 feet north of intersection with Horn of the Moon Road (TH-18)
Coordinates: 44.32881 N, 72.55315 W

Introduction

The Town of East Montpelier has retained DeWolfe Engineering Associates, PC (DeWolfe) to design a replacement for the culvert that formerly crossed under Sanders Circle at the location described above. The former culvert was an approximately 8' wide and 5'–3" high metal plate pipe arch culvert, destroyed in the July 2023 rain event that caused significant flooding damage across the state. The structure was destroyed due to overtopping of the gravel surface roadway and subsequent erosion of the roadway and embankments. At the time of the topographic survey of the project site in February 2024, only one section of the former culvert remained, at the inlet.

The following report presents DeWolfe's analysis of the hydrology and hydraulics of potential replacement culvert structures.

Hydrology

DeWolfe evaluated the 50, 20, 10, 5, 1, and 0.2 percent Annual Exceedance Probability (AEP) stream flows at the existing culvert location using the regional regression equations for Vermont (USGS, Olson, 2014, as published in the StreamStats web application), and New England (NETC, Jacobs, 2010).

The drainage basin of the culvert has the following physical characteristics:

Drainage Area	1.08 square miles
Land Cover	Forest
Max Elevation	1642 ft
Min Elevation	936 ft
Flow Length	16,325 ft
Average Drainage Basin Slope	4.3%
Water Bodies and Wetlands (NLCD 2006)	2.96 %

Table 1: Basin characteristics

Stream flow estimates vary depending on the calculation method used. In this analysis we have made conservative assumptions overall in the selection of flows to inform adequate sizing of structures. The NETC calculated flows were higher in all cases and were selected as the design flows for this project (shown in bold in Table 2 below).

AEP	USGS Streamflow (cfs)	NETC Streamflow (cfs)	Notes
50%	41.8	**51.3**	
20%	67.8	**82.1**	
10%	88.4	**109.5**	
4%	119	**147**	Local road design flow per VTrans and culvert design flow per VT DEC River Management Engineer
2%	145	**176**	
1%	174	**207**	Check flow per VTrans
0.2%	255	**306**	

Table 2: Calculated streamflow by AEP

Channel Morphology

The channel for this perennial stream is straight to sinuous with an estimated local channel slope of 1.9 ±0.2% upstream of the structure and 2.5 ±0.2% downstream of the structure. These slopes are based on interpolation of LiDAR contours approximately 500-600 feet upstream and downstream of the culvert location.

Downstream field measurements of bankfull width and depth are complicated by significant erosion and debris from the July 2023 flood event and upstream measurement was not possible at the time of this report writing because of ponded and frozen water from the beaver dam at the culvert inlet and winter conditions. Based on field observations, survey data, and consultation with the regional River Management Engineer, Jaron Borg, downstream bankfull width is determined to be 14 feet at a bankfull depth of 1.5 feet. This measurement is taken at a point approximately 30 feet downstream of the outlet concrete cradle remains. Upstream bankfull width measurements were not obtained due to site constraints.

Existing Conditions

The destroyed structure was a corrugated metal plate pipe arch with an approximately 2.8% longitudinal slope, based on field measurements of the remnants of the destroyed culvert. The pipe arch span measured on-site was 8’ and the height was 5’–3”. The closest commonly available size is 95” x 67”, which has a cross sectional area of 37 square feet. The culvert was constructed of three 20-foot long sections. The two downstream sections were washed downstream along with the roadway embankment. The upstream length is still in place and has been blocked by recent beaver activity. The culvert invert is rusted and deteriorated to the point

that much of the invert of the remaining section has completely corroded through. Based upon analysis of the closest common size pipe-arch, the existing structure was adequate to pass the 4% AEP storm. This structure resulted in a headwater depth of approximately 3.88 feet at 4% AEP and 4.87 feet at 1% AEP.

There is significant beaver activity directly upstream of the structure. We understand that directly after the July 7, 2023 flood event that destroyed the structure, there was no debris in the culvert remains. At the February 5, 2024 site visit, the remaining culvert barrel was almost completely blocked with woody debris and there was a beaver dam at the remaining culvert inlet.

The location directly downstream of significant beaver activity makes the structure prone to blockage and the culvert appears to be undersized for stream stability due to the significant scour pool at the former culvert outlet.

Replacement Recommendations

The following structure recommendations have been selected to meet the current VTrans hydraulics standards, the Vermont Stream Alteration General Permit standards, and provide aquatic organism passage.

- Concrete Box Culvert: span of 14 feet x height of 5.5 feet. The box invert should be buried 18 inches, resulting in a clear opening height of 4 feet. Bed retention sills should be 12” at the edges of the box and 6” at the center, creating a V-shape across the full width of the box. Sills should be spaced no more than 8 feet apart throughout the structure with one sill placed at the inlet and one at the outlet. Based upon velocity at the culvert outlet in the 2% AEP streamflow, the structure should be filled level to the streambed with E-Stone Type I allowing flow to be kept above the surface, providing the conditions necessary for aquatic organism passage. This structure resulted in a headwater depth of approximately 2.27 feet at 4% AEP and 2.87 feet at 1% AEP.
- Metal Plate Arch Culvert: either a metal plate pipe arch culvert or open bottom metal plate arch with a span of 14 feet and clear opening height of 7 feet, minimum. If a pipe arch culvert is selected, the invert should be buried and bed retention sills provided as described above. If an open bottom arch is selected, the natural bed material should be maintained to maximum extent possible and disturbed areas should be restored with E-Stone Type I. This structure resulted in a headwater depth of approximately 2.79 feet at 4% AEP and 3.11 feet at 1% AEP.

To match the approximate local stream slope, the structures recommended above have been modeled with a culvert slope of 3%. With this slope, the channel at the outlet will need to be built up to the filled invert of the proposed culvert to fill the existing scour pool and prevent there being a drop in the stream bed at the culvert outlet.

The outlet channel should be protected with E-stone based on the maximum outlet velocity in the 2% AEP streamflow. The outlet velocity for the proposed structures in this storm is 8.3 to 8.7 ft/s therefore the outlet channel should be protected with E-Stone Type I embedded 18”.

Stone Fill, Type II should be used to protect any disturbed channel banks or roadway slopes at the structure's inlet and outlet, up to a height of at least one-foot above the top of the opening. The stone fill should not constrict the channel or structure opening.

The replacement structure will be provided with flared wingwalls to increase the hydraulic efficiency of the culvert inlet and outlet and to protect against erosion. Headwalls will be provided at the inlet and outlet to retain the roadway side slopes.

Conclusion

A box culvert with a 14' span and 4' clear opening or an arch with a 14' span and 7' clear opening will provide sufficient hydraulic capacity and meet Vermont Stream Alteration General Permit requirements for the proposed culvert replacement on Long Meadow Brook under Sanders Circle. The replacement culvert will be aligned with the stream channel, be provided with head and wing walls, and will have an E-stone invert for aquatic organism passage.

Please feel free to contact us with any questions on this report or if you need further information.

References

Chow, Ven Te, 2013, Applied Hydrology, McGraw-Hill Companies

Jacobs, 2010, Estimating the Magnitude of Peak Flows for Steep Gradient Streams in New England, The New England Transportation Consortium, NETCR81, Project No. NETC 04-3

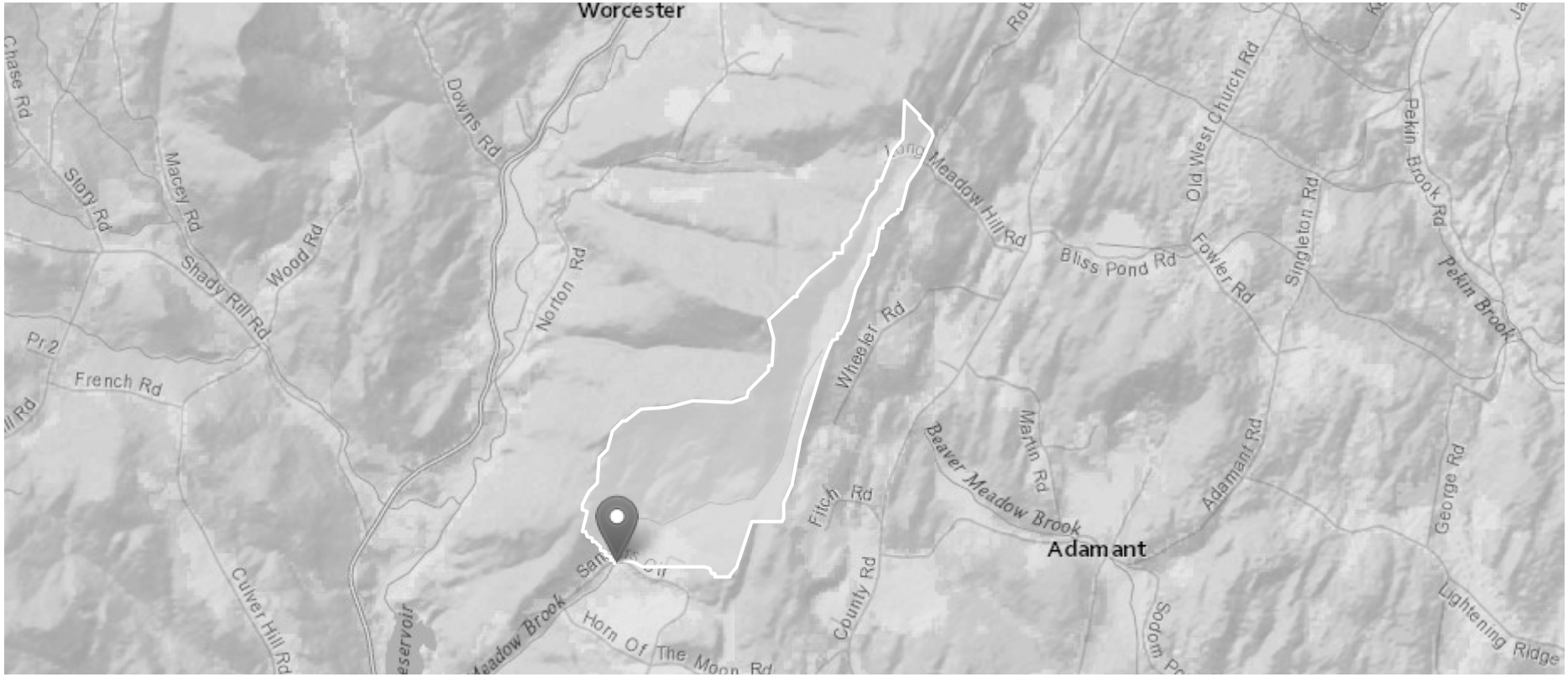
Olson, S. A., 2014, Estimation of Flood Discharges at Selected Annual Exceedance Probabilities for Unregulated, Rural Streams in Vermont, United States Geologic Survey, USGS Scientific Investigations Report 2014-5078.

VCGI (Vermont Center for Geographic Information), et. al., 2013. 0.7-Meter Bare Earth Digital Elevation Model (DEM). Available at: http://maps.vcgi.vermont.gov/arcgis/services/EGC_services/IMG_VCGI_LIDARDEM_SP_NOCACHE_v1/ImageServer

VTDEC (Vermont Department of Environmental Conservation), 2017. Stream Alteration General Permit. April 06, 2017.

Sanders Circle Culvert

Region ID: VT
Workspace ID: VT20240205161839547000
Clicked Point (Latitude, Longitude): 44.32867, -72.55320
Time: 2024-02-05 11:19:10 -0500



Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
CENTROIDX	Basin centroid horizontal (x) location in state plane coordinates	496744.4	meters
CENTROIDY	Basin centroid vertical (y) location in state plane units	204307.8	meters
DRNAREA	Area that drains to a point on a stream	1.08	square miles
EL1200	Percentage of basin at or above 1200 ft elevation	71.8	percent
LC06STOR	Percentage of water bodies and wetlands determined from the NLCD 2006	2.96	percent
OUTLETX	Basin outlet horizontal (x) location in state plane coordinates	495755	feet
OUTLETY	Basin outlet vertical (y) location in state plane coordinates	203155	feet
PRECPRIS10	Basin average mean annual precipitation for 1981 to 2010 from PRISM	45	inches

Peak-Flow Statistics

Peak-Flow Statistics Parameters [Statewide Peak Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	1.08	square miles	0.18	689
LC06STOR	Percent Storage from NLCD2006	2.96	percent	0	18.5
PRECPRIS10	Mean Annual Precip PRISM 1981 2010	45	inches	33.5	70.4

Peak-Flow Statistics Flow Report [Statewide Peak Flow]

PIL: Lower 90% Prediction Interval, PIU: Upper 90% Prediction Interval, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIL	PIU	ASEp
50-percent AEP flood	41.8	ft^3/s	23.7	73.6	34.8
20-percent AEP flood	67.8	ft^3/s	37.8	122	36.1
10-percent AEP flood	88.4	ft^3/s	47.3	165	38.6
4-percent AEP flood	119	ft^3/s	60.2	235	42.5
2-percent AEP flood	145	ft^3/s	70.7	297	44.9
1-percent AEP flood	174	ft^3/s	81.9	369	47.3
0.5-percent AEP flood	207	ft^3/s	92.8	462	50.8
0.2-percent AEP flood	255	ft^3/s	107	605	55.2

Peak-Flow Statistics Citations

Olson, S.A.,2014, Estimation of flood discharges at selected annual exceedance probabilities for unregulated, rural streams in Vermont, with a section on Vermont regional skew regression, by Veilleux, A.G.: U.S. Geological Survey Scientific Investigations Report 2014–5078, 27 p. plus appendixes. (http://pubs.usgs.gov/sir/2014/5078/)

Bankfull Statistics

Bankfull Statistics Parameters [Appalachian Highlands D Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	1.08	square miles	0.07722	940.1535

Bankfull Statistics Parameters [New England P Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	1.08	square miles	3.799224	138.999861

Bankfull Statistics Parameters [USA Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	1.08	square miles	0.07722	59927.7393

Bankfull Statistics Flow Report [Appalachian Highlands D Bieger 2015]

Statistic	Value	Unit
Bieger_D_channel_width	15.7	ft
Bieger_D_channel_depth	1.15	ft
Bieger_D_channel_cross_sectional_area	18.2	ft^2

Bankfull Statistics Disclaimers [New England P Bieger 2015]

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

Bankfull Statistics Flow Report [New England P Bieger 2015]

Statistic	Value	Unit
Bieger_P_channel_width	25.8	ft
Bieger_P_channel_depth	1.4	ft
Bieger_P_channel_cross_sectional_area	36	ft^2

Bankfull Statistics Flow Report [USA Bieger 2015]

Statistic	Value	Unit
Bieger_USA_channel_width	12.7	ft
Bieger_USA_channel_depth	1.23	ft

Statistic	Value	Unit
Bieger_USA_channel_cross_sectional_area	17.8	ft^2

Bankfull Statistics Flow Report [Area-Averaged]

Statistic	Value	Unit
Bieger_D_channel_width	15.7	ft
Bieger_D_channel_depth	1.15	ft
Bieger_D_channel_cross_sectional_area	18.2	ft^2
Bieger_P_channel_width	25.8	ft
Bieger_P_channel_depth	1.4	ft
Bieger_P_channel_cross_sectional_area	36	ft^2
Bieger_USA_channel_width	12.7	ft
Bieger_USA_channel_depth	1.23	ft
Bieger_USA_channel_cross_sectional_area	17.8	ft^2

Bankfull Statistics Citations

Bieger, Katrin; Rathjens, Hendrik; Allen, Peter M.; and Arnold, Jeffrey G.,2015, Development and Evaluation of Bankfull Hydraulic Geometry Relationships for the Physiographic Regions of the United States, Publications from USDA-ARS / UNL Faculty, 17p. (https://digitalcommons.unl.edu/usdaarsfacpub/1515?utm_source=digitalcommons.unl.edu%2Fusdaarsfacpub%2F1515&utm_medium=PDF&utm_campaign=PDFCoverPages)

Maximum Probable Flood Statistics

Maximum Probable Flood Statistics Parameters [Crippen Bue Region 1]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	1.08	square miles	0.1	10000

Maximum Probable Flood Statistics Flow Report [Crippen Bue Region 1]

Statistic	Value	Unit
Maximum Flood Crippen Bue Regional	3550	ft^3/s

Maximum Probable Flood Statistics Citations

Crippen, J.R. and Bue, Conrad D.1977, Maximum Floodflows in the Conterminous United States, Geological Survey Water-Supply Paper 1887, 52p. (https://pubs.usgs.gov/wsp/1887/report.pdf)

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Application Version: 4.19.3
StreamStats Services Version: 1.2.22
NSS Services Version: 2.2.1

Sanders Circle
East Montpelier
Mar 2024

New England
Transportation Consortium
Peak Flows
Jacobs, 2010

Civil & Structural Engineers
DeWolfe
ENGINEERING ASSOCIATES, PC

Drainage Area (A) =	1.08	SqMi		Notes
Mean Annual Precip (P) =	43.63	in		
	NETC Peak Flow	Stream Stats Flow		
Q2 =	51.3	41.8	cfs	
Q5 =	82.1	67.8	cfs	
Q10 =	109.5	88.4	cfs	
Q25 =	147	119	cfs	Design Flow
Q50 =	176	145	cfs	
Q100 =	207	174	cfs	Check Flow
Q500 =	306	255	cfs	

HY-8 Culvert Analysis Report

Culvert Data: Existing Pipe Arch

Table 1 - Culvert Summary Table: Existing Pipe Arch

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)
50% AEP	51.30 cfs	51.30 cfs	938.05	2.05	0.0*	1-S2n	1.07	1.41	1.07	1.02	8.53	4.19
4% AEP	147.00 cfs	147.00 cfs	939.88	3.88	1.425	1-S2n	1.87	2.52	1.92	1.84	11.65	5.83
1% AEP	207.00 cfs	207.00 cfs	940.87	4.87	2.514	1-S2n	2.29	3.06	2.38	2.22	12.77	6.45

* Full Flow Headwater elevation is below inlet invert.

Culvert Barrel Data

Culvert Barrel Type Straight Culvert

Inlet Elevation (invert): 936.00 ft,

Outlet Elevation (invert): 934.35 ft

Culvert Length: 60.02 ft,

Culvert Slope: 0.0275

Culvert Data Summary - Existing Pipe Arch

Barrel Shape: Pipe Arch

Barrel Span: 95.00 in

Barrel Rise: 67.00 in

Barrel Material: Steel or Aluminum

Embedment: 0.00 in

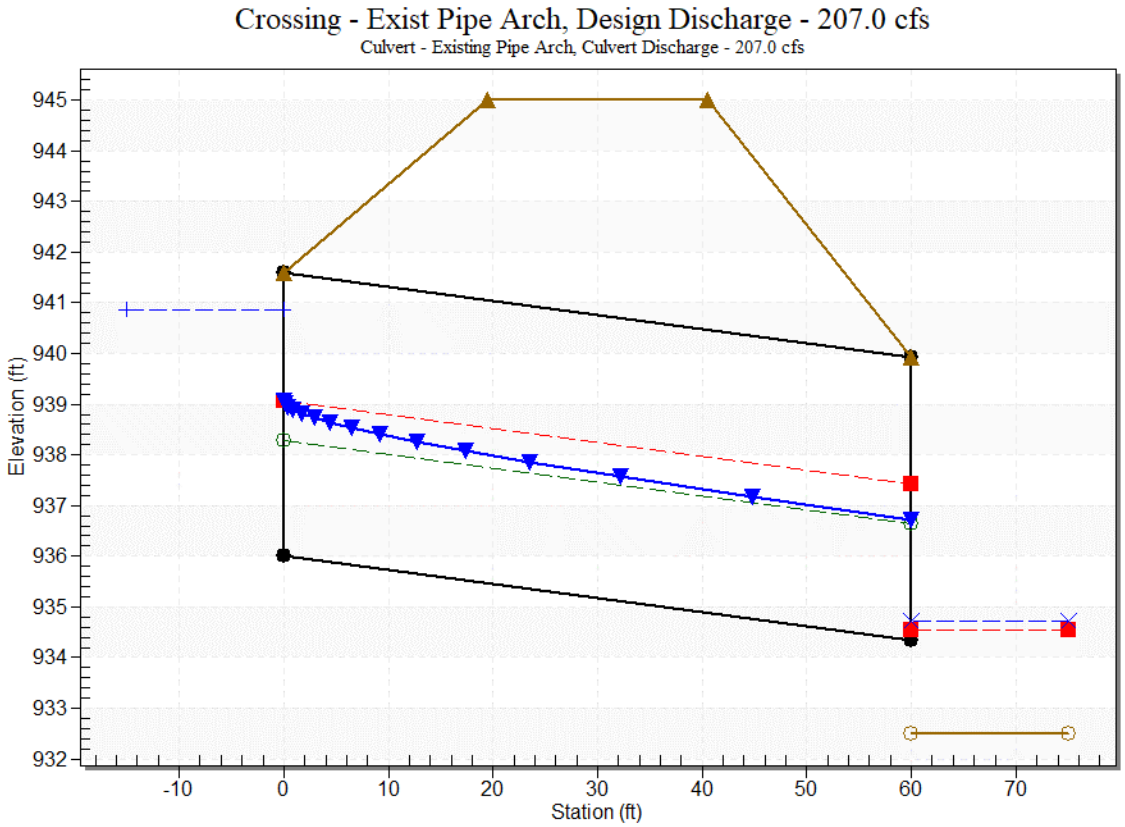
Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Headwall

Inlet Depression: None

Water Surface Profile Plot for Culvert: Existing Pipe Arch



HY-8 Culvert Analysis Report

Culvert Data: Concrete Box

Table 1 - Culvert Summary Table: Concrete Box

Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
50% AEP	51.30 cfs	51.30 cfs	937.12	1.12	0.0*	1-S2n	0.66	0.75	0.66	0.97	5.52	4.45
4 % AEP	147.00 cfs	147.00 cfs	938.27	2.27	0.492	1-S2n	1.26	1.51	1.26	1.75	8.33	6.21
1% AEP	207.00 cfs	207.00 cfs	938.87	2.87	1.085	1-S2n	1.56	1.89	1.56	2.11	9.50	6.88

* Full Flow Headwater elevation is below inlet invert.

Culvert Barrel Data

Culvert Barrel Type Straight Culvert

Inlet Elevation (invert): 936.00 ft,

Outlet Elevation (invert): 934.50 ft

Culvert Length: 50.02 ft,

Culvert Slope: 0.0300

Culvert Data Summary - Concrete Box

Barrel Shape: Concrete Box

Barrel Span: 14.00 ft

Barrel Rise: 5.50 ft

Barrel Material: Concrete

Embedment: 18.00 in

Barrel Manning's n: 0.0150 (top and sides)

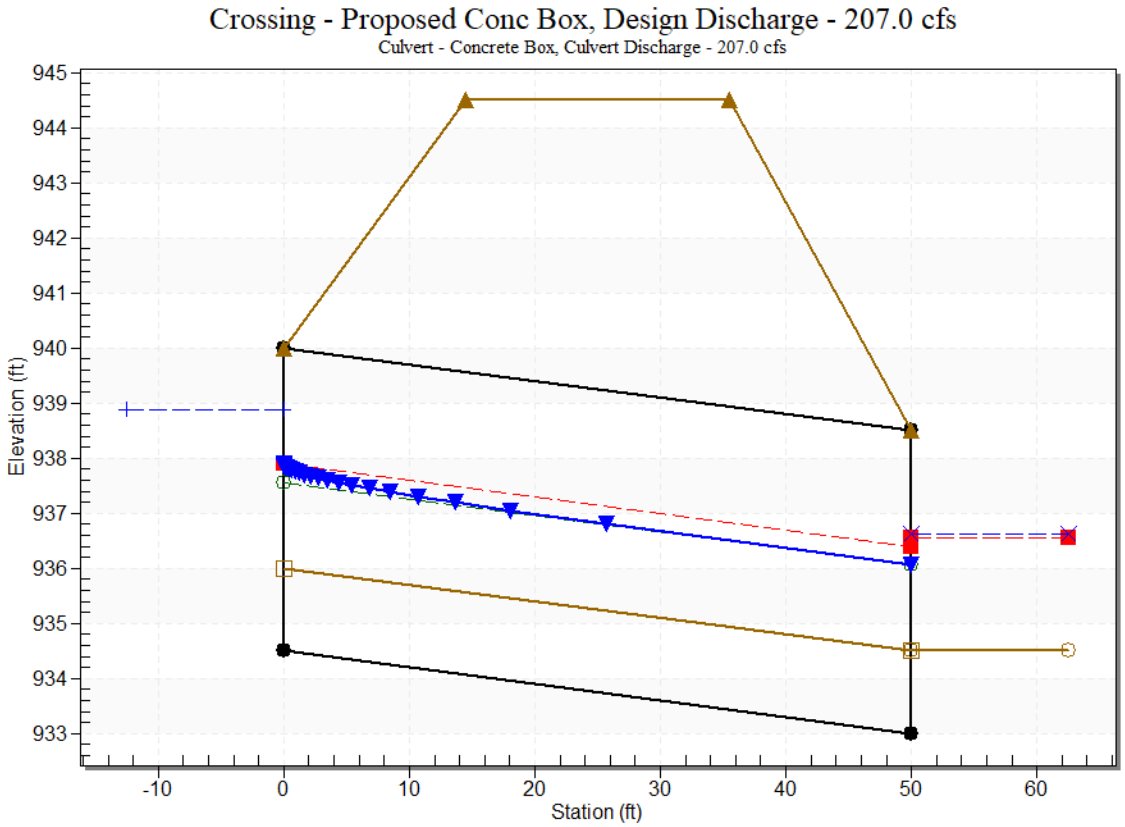
Manning's n: 0.0350 (bottom)

Culvert Type: Straight

Inlet Configuration: Square Edge (30-75º flare) Wingwall (Ke=0.4)

Inlet Depression: None

Water Surface Profile Plot for Culvert: Concrete Box



HY-8 Culvert Analysis Report

Culvert Data: Proposed Open Bottom Arch

Table 1 - Culvert Summary Table: Proposed Open Bottom Arch

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)
50% AEP	51.30 cfs	51.30 cfs	937.24	1.22	0.0*	1-S2n	0.67	0.75	0.67	1.02	5.49	4.19
4% AEP	176.00 cfs	176.00 cfs	938.81	2.79	0.669	1-S2n	1.45	1.70	1.45	2.03	8.73	6.15
1% AEP	207.00 cfs	207.00 cfs	939.13	3.11	0.916	1-S2n	1.61	1.89	1.61	2.22	9.27	6.45

* Full Flow Headwater elevation is below inlet invert.

Culvert Barrel Data

Culvert Barrel Type Straight Culvert

Inlet Elevation (invert): 936.02 ft,

Outlet Elevation (invert): 934.52 ft

Culvert Length: 50.02 ft,

Culvert Slope: 0.0300

Culvert Data Summary - Proposed Open Bottom Arch

Barrel Shape: Arch, Open Bottom

Barrel Span: 14.00 ft

Barrel Rise: 7.25 ft

Barrel Material: Corrugated Steel

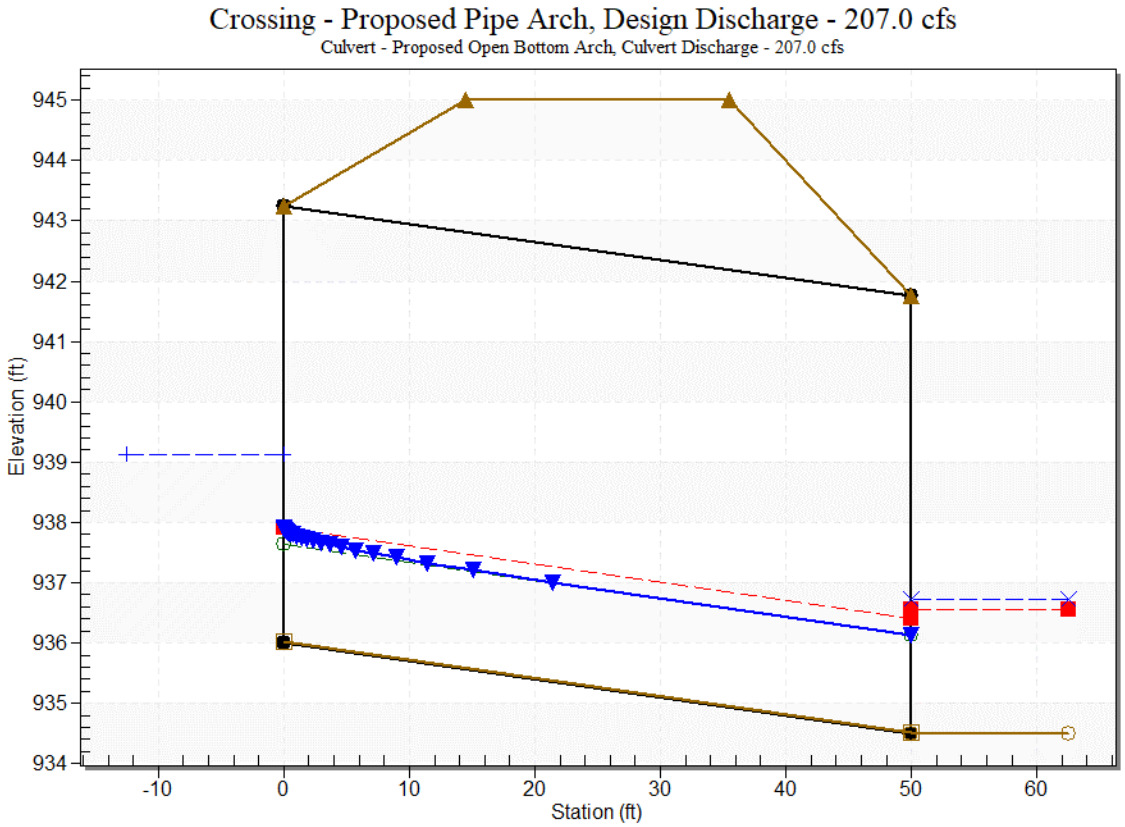
Embedment: 0.25 in

Barrel Manning's n: 0.0240 (top and sides)

Manning's n: 0.0350 (bottom)

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Water Surface Profile Plot for Culvert: Proposed Open Bottom Arch