CULVERT REPLACEMENT STUDY (PID 79901)
LUC-25-5.04 OVER DELAWARE CREEK

Submitted to

Ohio Department of Transportation – District 2
317 E. Poe Road
Bowling Green, OH 43402

December 2020

DGL Consulting Engineers, LLC
3455 Briarfield Boulevard, Suite E
Maumee, Ohio 43537

www.dgl-ltd.com

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Culvert Replacement Study

Introduction

The intent of this study is to determine and study two proposed work alternatives for the rehabilitation or replacement of the SR 25 (Anthony Wayne Trail) structure over Delaware Creek in the City of Toledo. The structure also carries Fanning Drive on the west and Rohr Blvd. on the east over Delaware Creek.

Rehabilitation and replacement options will be investigated. Replacement options requiring open cut excavation will not be investigated due to the approximate 40 feet of fill over the structure.

Background and Design Methodology

The project site is located within FEMA Flood Zone AE (sheet 2). USGS Ohio Streamstats was used to determine hydrology. Basin characteristics were derived from selecting a point at the location of the existing culvert along Delaware Creek on the StreamStats web-based program. Overall boundary limits were reviewed, to ensure calculated drainage area appeared to be correct. No changes were made to the boundaries. Flow statistics were then calculated via the web-based application. See sheets 3 through 8 for the StreamStats report.

The project site is located 2000 feet west (upstream) of the Maumee River. The FEMA Flood Insurance Study for Lucas County, dated August 16, 2011, shows water surfaces downstream of this culvert being controlled by backwater from the Maumee River (sheet 9).

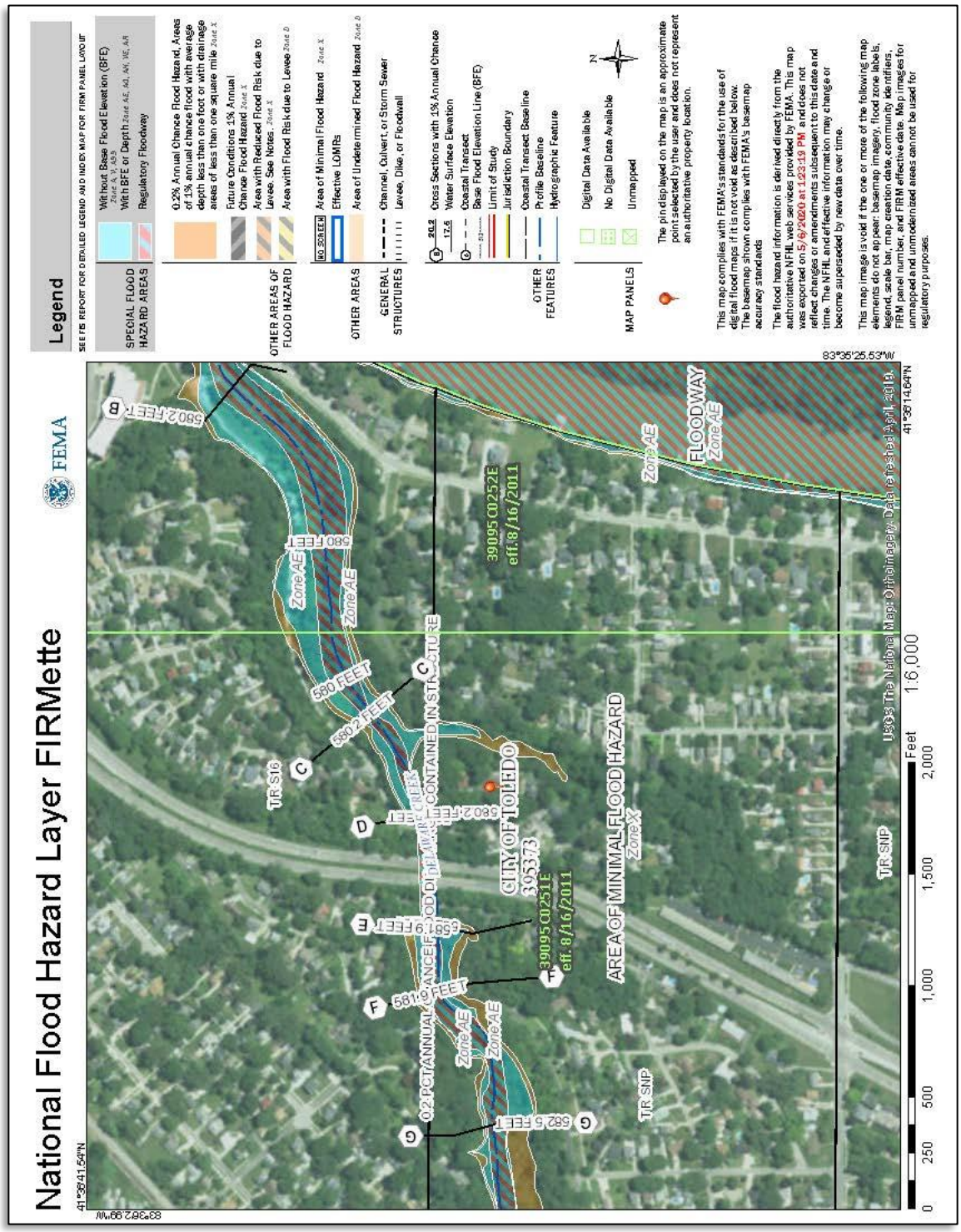
Tailwater elevations used are taken from the Lucas County FEMA Flood Insurance Study with the 100 year tailwater elevation shown in the Floodway Data table (NAVD) (sheet 10) and the 10 and 50 year elevations taken from the Flood Profiles drawing (NGVD) (sheet 11). The 25 year frequency was interpolated from the 10 and 50 year frequencies.

Due to the vast difference in times of concentration between the Maumee River (6370 sq. mi.) and Delaware Creek (4.7 sq. mi.) tailwater produced by Delaware Creek will also be investigated.

HY-8 was used to model the existing and proposed hydraulics, based on the survey data collected and calculated flows.

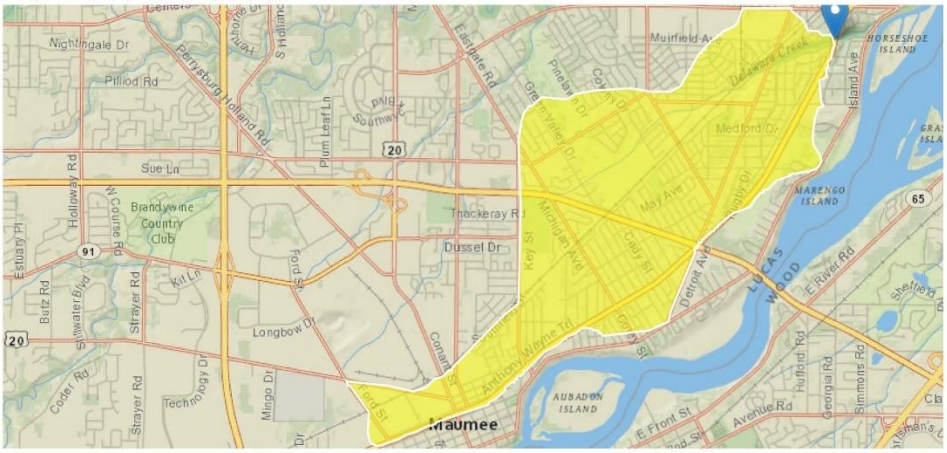
Use the local road (Rohr Blvd.) as the control for the design frequency because it is 25'± below the elevation of SR 25. Use a 10-year design frequency (L&D Vol. 2 1004.2) since ADT < 2000 vehicles per day.

Culvert Replacement Study



LUC-25-5.04 over Delaware Creek

Region ID: OH
Workspace ID: OH20200428172650332000
Clicked Point (Latitude, Longitude): 41.60835, -83.59679
Time: 2020-04-28 13:27:07 -0400



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	4.68	square miles
LC92STOR	Percentage of water bodies and wetlands determined from the NLCD	1.09	percent
PRECIP	Mean Annual Precipitation	39.3	inches
FOREST	Percentage of area covered by forest	13.3	percent
LAT_CENT	Latitude of Basin Centroid	41.5896	decimal degrees
STREAM_VARG	Streamflow variability index as defined in WRIR 02-4068, computed from regional grid	0.56	dimensionless
LONG_CENT	Longitude Basin Centroid	83.6281	decimal degrees
OHREGC	Ohio Region C Indicator	0	dimensionless
OHREGA	Ohio Region A Indicator	0	dimensionless
CSL1085LFP	Change in elevation divided by length between points 10 and 85 percent of distance along the longest flow path to the basin divide, LFP from 2D grid	10.4	feet per mi

Culvert Replacement Study

Monthly Flow Statistics Parameters[Low Flow LatGT 41.2 wr02 4068]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	4.68	square miles	0.12	7422
LC92STOR	Percent Storage from NLCD1992	1.09	percent	0	19
PRECIP	Mean Annual Precipitation	39.3	inches	34	43.2
FOREST	Percent Forest	13.3	percent	0	99.1
LAT_CENT	Latitude of Basin Centroid	41.5896	decimal degrees	41.2	41.59
STREAM_VARG	Streamflow Variability Index from Grid	0.56	dimensionless	0.25	1.13

Monthly Flow Statistics Flow Report[Low Flow LatGT 41.2 wr02 4068]

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

Statistic	Value	Unit	SE	SEp
January Mean Flow	7.32	ft^3/s	16.6	16.6
February Mean Flow	10.8	ft^3/s	11.9	11.9
March Mean Flow	11.7	ft^3/s	14	14
April Mean Flow	9.84	ft^3/s	11.2	11.2
May Mean Flow	5.63	ft^3/s	19.5	19.5
June Mean Flow	3.18	ft^3/s	27	27
July Mean Flow	2.08	ft^3/s	28.2	28.2
August Mean Flow	1.67	ft^3/s	36.8	36.8
September Mean Flow	1.02	ft^3/s	43.6	43.6
October Mean Flow	2.58	ft^3/s	50.8	50.8
November Mean Flow	4.79	ft^3/s	37.5	37.5
December Mean Flow	7.71	ft^3/s	21.8	21.8

Monthly Flow Statistics Citations

Koltun, G. F., and Whitehead, M. T.,2002, Techniques for Estimating Selected Streamflow Characteristics of Rural, Unregulated Streams in Ohio: U. S. Geological Survey Water-Resources Investigations Report 02-4068, 50 p (https://pubs.er.usgs.gov/publication/wri024068)

Annual Flow Statistics Parameters[Low Flow LatGT 41.2 wr02 4068]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	4.68	square miles	0.12	7422
PRECIP	Mean Annual Precipitation	39.3	inches	34	43.2
LAT_CENT	Latitude of Basin Centroid	41.5896	decimal degrees	41.2	41.59

Annual Flow Statistics Flow Report[Low Flow LatGT 41.2 wr02 4068]

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

Statistic	Value	Unit	SE	SEp

Culvert Replacement Study

Statistic	Value	Unit	SE	SEp
Mean Annual Flow	5.69	ft^3/s	11.4	11.4

Annual Flow Statistics Citations

Koltun, G. F., and Whitehead, M. T.,2002, Techniques for Estimating Selected Streamflow Characteristics of Rural, Unregulated Streams in Ohio: U. S. Geological Survey Water-Resources Investigations Report 02-4068, 50 p (https://pubs.er.usgs.gov/publication/wri024068)

General Flow Statistics Parameters[Low Flow LatGT 41.2 wri02 4068]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	4.68	square miles	0.12	7422
LC92STOR	Percent Storage from NLCD1992	1.09	percent	0	19
STREAM_VARG	Streamflow Variability Index from Grid	0.56	dimensionless	0.25	1.13
LAT_CENT	Latitude of Basin Centroid	41.5896	decimal degrees	41.2	41.59

General Flow Statistics Flow Report[Low Flow LatGT 41.2 wri02 4068]

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

Statistic	Value	Unit	SE	SEp
Harmonic Mean Streamflow	0.433	ft^3/s	65.9	65.9

General Flow Statistics Citations

Koltun, G. F., and Whitehead, M. T.,2002, Techniques for Estimating Selected Streamflow Characteristics of Rural, Unregulated Streams in Ohio: U. S. Geological Survey Water-Resources Investigations Report 02-4068, 50 p (https://pubs.er.usgs.gov/publication/wri024068)

Flow Percentile Statistics Parameters[Low Flow LatGT 41.2 wri02 4068]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	4.68	square miles	0.12	7422
LC92STOR	Percent Storage from NLCD1992	1.09	percent	0	19
STREAM_VARG	Streamflow Variability Index from Grid	0.56	dimensionless	0.25	1.13
LAT_CENT	Latitude of Basin Centroid	41.5896	decimal degrees	41.2	41.59
LONG_CENT	Longitude of Basin Centroid	83.6281	decimal degrees	80.53	84.6

Flow Percentile Statistics Flow Report[Low Flow LatGT 41.2 wri02 4068]

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

Statistic	Value	Unit	SE	SEp
25th Percentile Flow	0.59	ft^3/s	29.2	29.2
50th Percentile Flow Median	1.3	ft^3/s	40.3	40.3
75th Percentile Flow	3.28	ft^3/s	47.9	47.9

Culvert Replacement Study

Flow Percentile Statistics Citations

Koltun, G. F., and Whitehead, M. T.,2002, Techniques for Estimating Selected Streamflow Characteristics of Rural, Unregulated Streams in Ohio: U. S. Geological Survey Water-Resources Investigations Report 02-4068, 50 p (https://pubs.er.usgs.gov/publication/wri024068)

Low-Flow Statistics Parameters[Low Flow Region A 2012 5136]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	4.68	square miles	1	1250
STREAM_VARG	Streamflow Variability Index from Grid	0.56	dimensionless	0.24	1.12

Low-Flow Statistics Flow Report[Low Flow Region A 2012 5136]

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

Statistic	Value	Unit	SE
1 Day 10 Year Low Flow	0.0622	ft^3/s	53.1
7 Day 10 Year Low Flow	0.0797	ft^3/s	40
30 Day 10 Year Low Flow	0.125	ft^3/s	35.7
90 Day 10 Year Low Flow	0.197	ft^3/s	29.8

Low-Flow Statistics Citations

Koltun, G.F., and Kula, S.P.,2013, Methods for estimating selected low-flow statistics and development of annual flow-duration statistics for Ohio: U.S. Geological Survey Scientific Investigations Report 2012–5138, 195 p. (http://pubs.usgs.gov/sir/2012/5138/)

Flow-Duration Statistics Parameters[Low Flow Region A 2012 5136]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	4.68	square miles	1	1250
STREAM_VARG	Streamflow Variability Index from Grid	0.56	dimensionless	0.24	1.12

Flow-Duration Statistics Flow Report[Low Flow Region A 2012 5136]

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

Statistic	Value	Unit	SE
80 Percent Duration	0.416	ft^3/s	29.1

Flow-Duration Statistics Citations

Koltun, G.F., and Kula, S.P.,2013, Methods for estimating selected low-flow statistics and development of annual flow-duration statistics for Ohio: U.S. Geological Survey Scientific Investigations Report 2012–5138, 195 p. (http://pubs.usgs.gov/sir/2012/5138/)

Probability Statistics Parameters[P zero Flow 2012 5136]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit

Culvert Replacement Study

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	4.68	square miles	1	1250
STREAM_VARG	Streamflow Variability Index from Grid	0.56	dimensionless	0.24	1.12

Probability Statistics Flow Report[P zero Flow 2012 5138]

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

Statistic	Value	Unit	PC
Probability zero flow 1Day	0.0341	dim	91
Probability zero flow 7Day	0.0148	dim	94
Probability zero flow 30Day	0.000646	dim	97

Probability Statistics Citations

Koltun, G.F., and Kula, S.P.,2013, Methods for estimating selected low-flow statistics and development of annual flow-duration statistics for Ohio: U.S. Geological Survey Scientific Investigations Report 2012–5138, 195 p. (http://pubs.usgs.gov/sir/2012/5138/)

Peak-Flow Statistics Parameters[Peak Flow Full Model Reg B SIR2019 5018]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	4.68	square miles	0.04	6309
OHREGC	Ohio Region C Indicator 1 if in C else 0	0	dimensionless	0	1
OHREGA	Ohio Region A Indicator 1 if in A else 0	0	dimensionless	0	1
CSL1085LFP	Stream Slope 10 and 85 Longest Flow Path	10.4	feet per mi	1.21	457
LC92STOR	Percent Storage from NLCD1992	1.09	percent	0	7.1

Peak-Flow Statistics Flow Report[Peak Flow Full Model Reg B SIR2019 5018]

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

Statistic	Value	Unit	PII	PIu	SEp
2 Year Peak Flood	207	ft^3/s	108	394	40.1
5 Year Peak Flood	323	ft^3/s	177	589	37.2
10 Year Peak Flood	408	ft^3/s	222	748	37.6
25 Year Peak Flood	521	ft^3/s	282	963	38.1
50 Year Peak Flood	610	ft^3/s	327	1140	37.8
100 Year Peak Flood	701	ft^3/s	371	1320	39.6
500 Year Peak Flood	923	ft^3/s	484	1760	40.3

Peak-Flow Statistics Citations

Koltun, G.F.,2019, Flood-frequency estimates for Ohio streamgages based on data through water year 2015 and techniques for estimating flood-frequency characteristics of rural, unregulated Ohio streams: U.S. Geological Survey Scientific Investigations Report 2019–5018, xx p. (https://dx.doi.org/10.3133/sir20195018)

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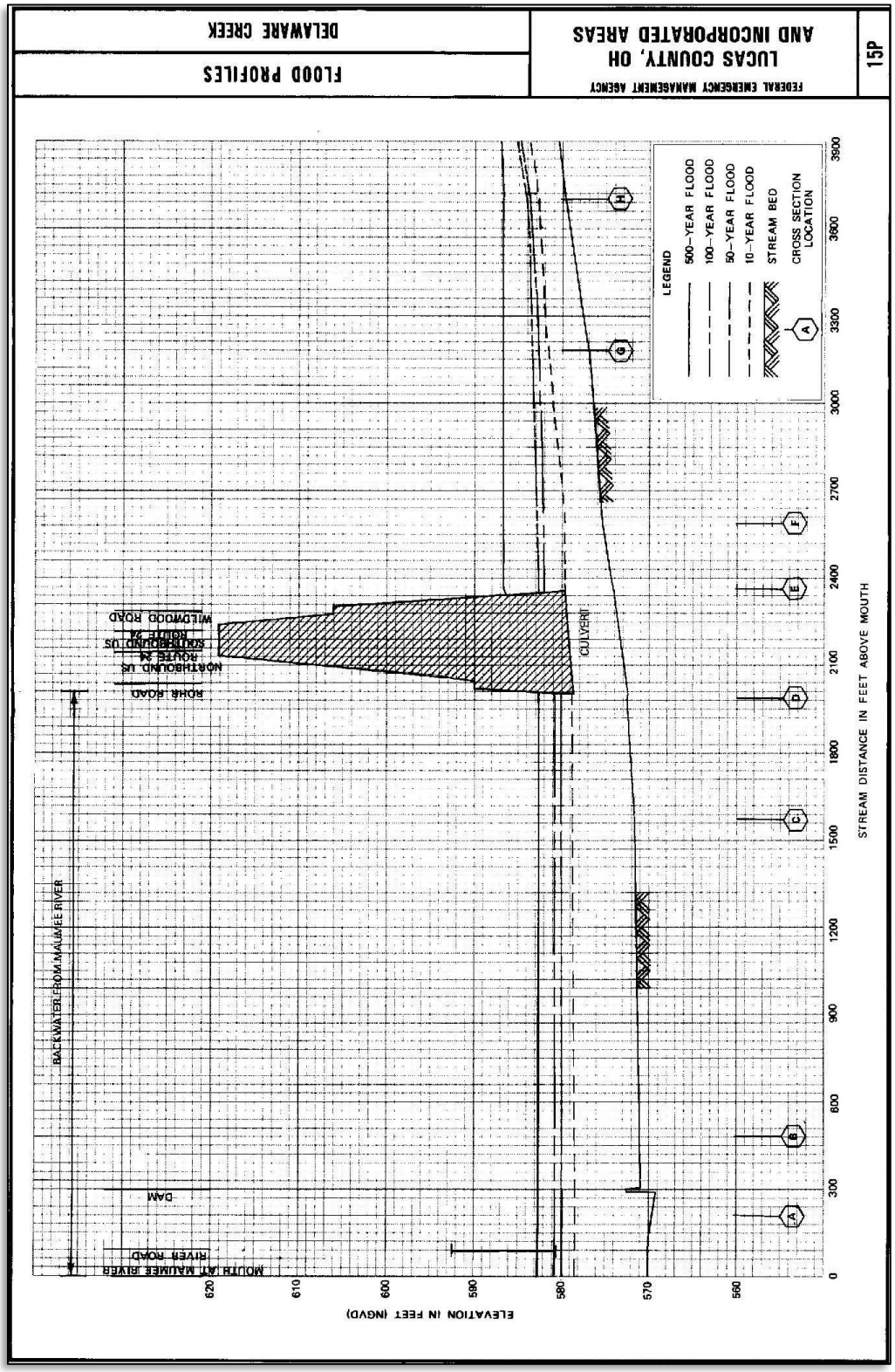
Application Version: 4.3.11

Culvert Replacement Study



Culvert Replacement Study

FLOODING SOURCE		FLOODWAY				1-PERCENT-ANNUAL-CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	WIDTH REDUCED FROM PRIOR STUDY (FEET)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
DELAWARE CREEK									
A	202	52	397	1.7		580.2	578.1[2]	578.6	0.5
B	482	115	842	0.8		580.2	578.2[2]	578.6	0.4
C	1,572	30	197	3.3		580.2	578.2[2]	578.6	0.4
D	1,982	22	132	5.0		580.2	578.5[2]	579.0	0.5
E	2,360	50	349	1.7		581.9	581.9	582.3	0.4
F	2,570	45	193	3.1		581.9	581.9	582.4	0.5
G	3,165	72	291	2.1		582.5	582.5	583.0	0.5
H	3,680	34	87	6.9		583.6	583.6	583.8	0.2
I	4,180	33	317	1.9	94	585.9	585.9	586.0	0.1
J	4,560	31	72	8.4		586.7	586.7	586.7	0.0
K	4,730	39	124	4.8		588.8	588.8	588.9	0.1
L	4,890	26	119	5.0		589.2	589.2	589.6	0.4
M	5,200	19	74	8.1		590.4	590.4	591.1	0.7
N	5,400	25	74	7.2		593.0	593.0	593.0	0.0
O	5,660	72	313	1.7		597.7	597.7	598.0	0.3
P	5,780	73	319	1.7		597.8	597.8	598.1	0.3
Q	7,345	64	508	0.7		605.4	605.4	605.9	0.5

[1] Feet above confluence with Maumee River
[2] Elevation computed without consideration of backwater effects from Maumee River

TABLE 14

FEDERAL EMERGENCY MANAGEMENT AGENCY

LUCAS COUNTY, OHIO
AND INCORPORATED AREAS

FLOODWAY DATA

DELAWARE CREEK

Stream Flows and Culvert Tailwater Elevations
From FEMA FIS Study
LUC-25-5.04 over Delaware Creek

NAVD = NGVD - 0.6'

Recurrance Interval	Estimated Discharge	Tailwater Elevation based on Maumee River	
(Years)	(CFS)	NGVD	NAVD
Q_{10}	408	578.4 *	577.8
Q_{25}	521	579.0 ©	578.4
Q_{50}	610	579.9 *	579.3
Q_{100}	701	580.8	580.2 §

* - Tailwater elevation from FEMA Flood Profiles
§ - Tailwater elevation from FEMA Floodway Data Table
© - Tailwater elevation interpolated from Q_{10} and Q_{50} frequencies

Culvert Replacement Study

Existing Structure

The existing structure is a single radius concrete arch (6' rise x 12' span) that has a length of 340 feet and a maximum fill of 40 feet over the culvert. Cast-in-place reinforced concrete headwalls are at both the inlet and outlet. The culvert has an inlet elevation of 572.71 and an outlet elevation of 571.91. The culvert is constructed of stone on the middle portion and reinforced concrete on the end portions. The culvert was constructed in 1900 with a major rehabilitation in 1951. The opening area is approximately 56.7 square feet.

See pages 13 through 15 for pictures of the existing culvert. Page 16 is a field sketch showing existing culvert details provided by DGL's survey team. Sheet 17 shows the existing culvert opening used in the HY-8 calculations.

Existing Hydraulics

Calculate slope for downstream tailwater calculations for Delaware Creek Tailwaters:
StreamStats = (10.4 ft./mi.) / (5280 mi./ft.) = 0.0019 ft./ft.
Survey (Water Surface) = (574.5 – 573.3) / 615 = 0.0020 ft. / ft. **(USE)**
Survey (Channel Bottom) = (574.1 – 572.7) / 615 = 0.0023 ft. / ft.

The "Existing Structure Hydraulic Summary" table (sheet 21) shows three different headwater values for this structure. First, headwater elevations calculated using tailwaters shown in the FEMA study (from Maumee River) are shown. Next, headwaters calculated using normal depth flow in Delaware Creek are shown. The downstream section used for these normal depth flows is shown on sheets 18 and 19. The third set of headwater elevations shown were taken from the FEMA study and occur just upstream of the existing structure.

We will be proceeding using calculations based on Delaware Creek tailwaters because; the huge difference in times of concentration between the Maumee River and Delaware Creek are such that maximum flows in each stream do not happen at the same time. In addition to this, the lower Delaware Creek values are closer to the elevations shown in the FEMA study.

Culvert Replacement Study

Culvert Outlet

Channel Downstream of Culvert Looking Upstream (West)

Culvert Inlet

Inside Culvert Near Outlet Looking Upstream (West)

Culvert Replacement Study

Inside Culvert Looking Downstream (East)

Inlet Showing Concrete Struts

Culvert Replacement Study

Sheet No. 1 of 1

Design By: GSW/RMC Date: 10-27-2020 Checked By: _____ Date: _____

Subject: SR 25 CULVERT Comm No.: 19168-2

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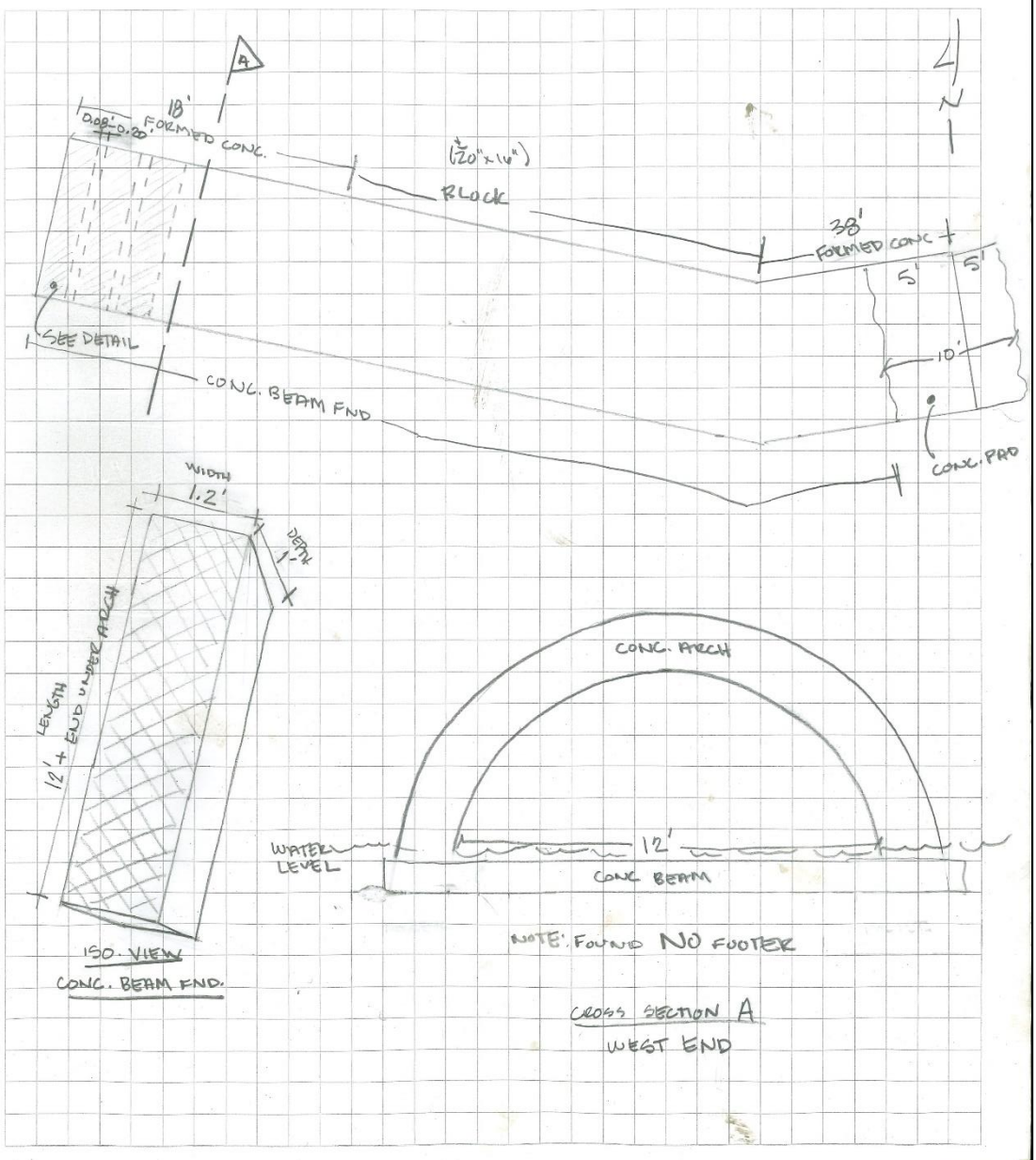
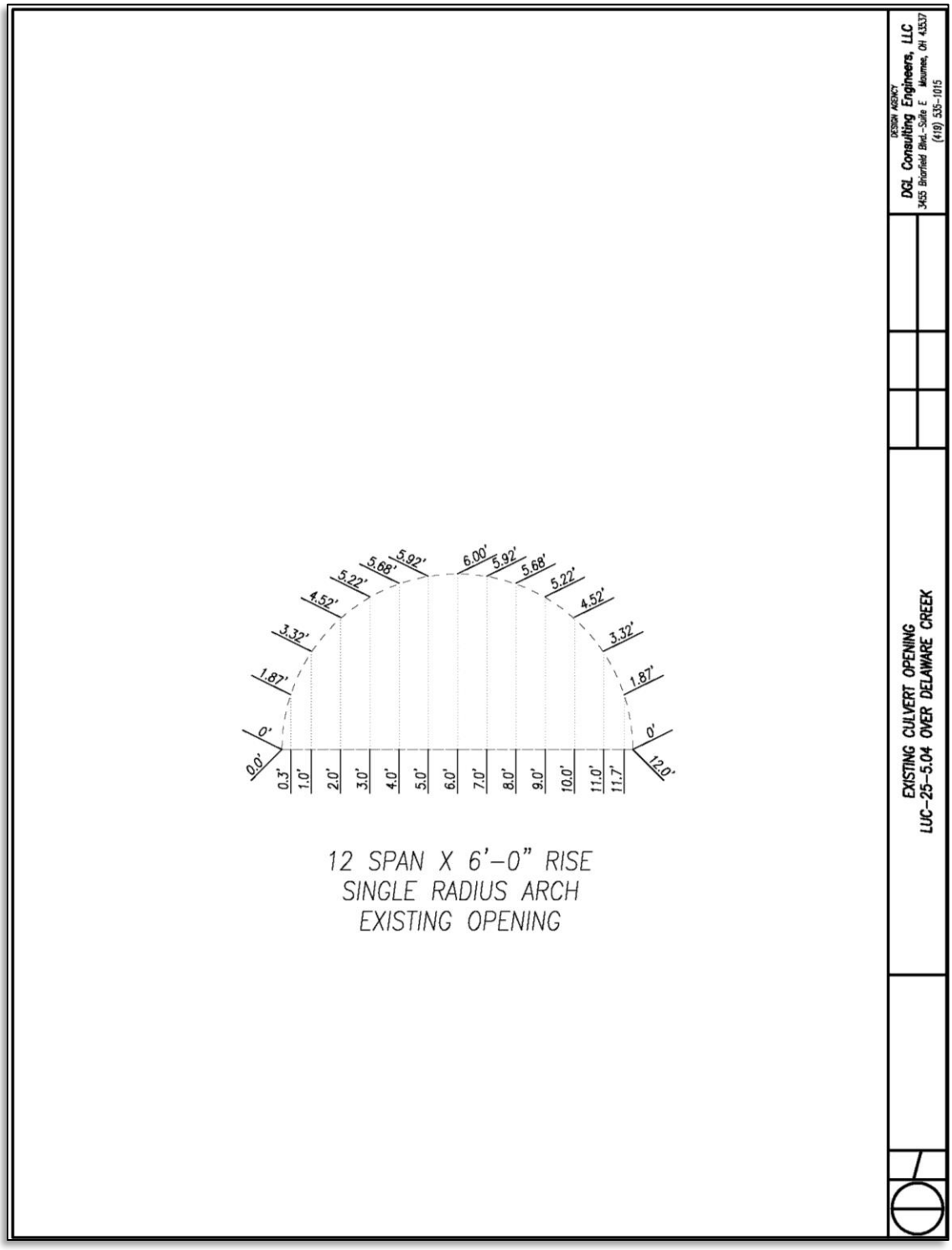
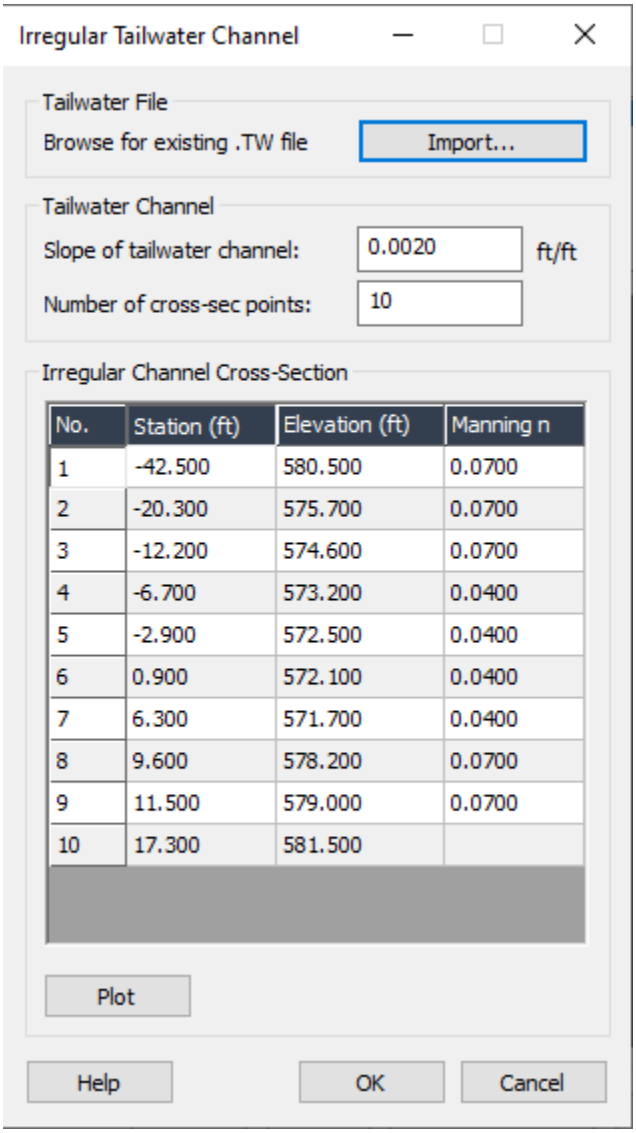


Culvert Replacement Study

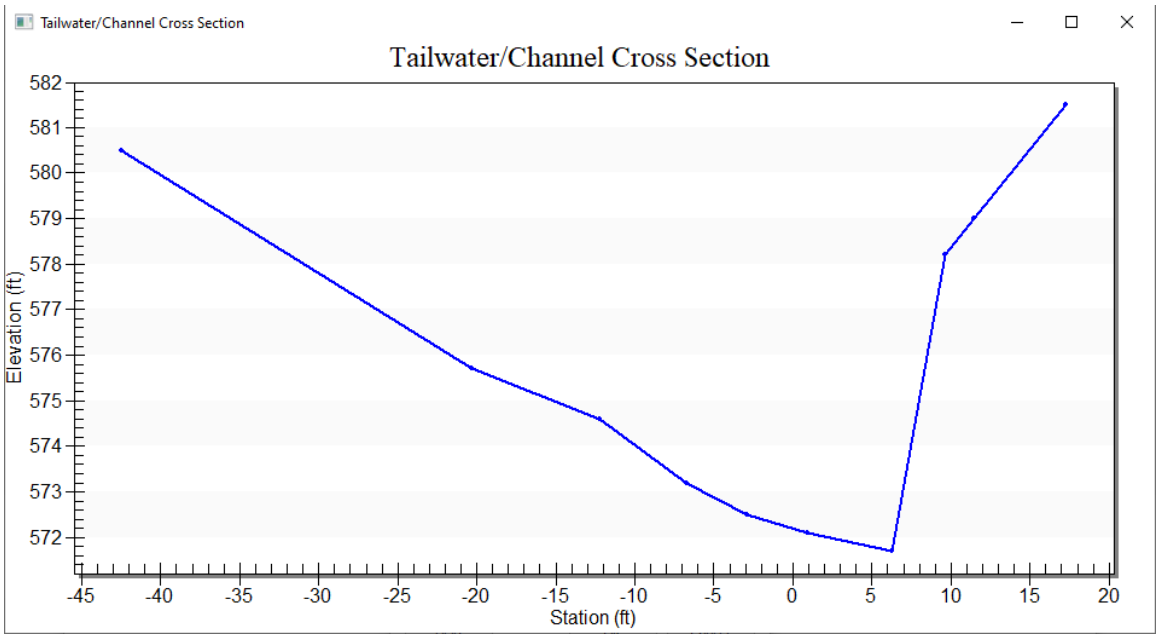


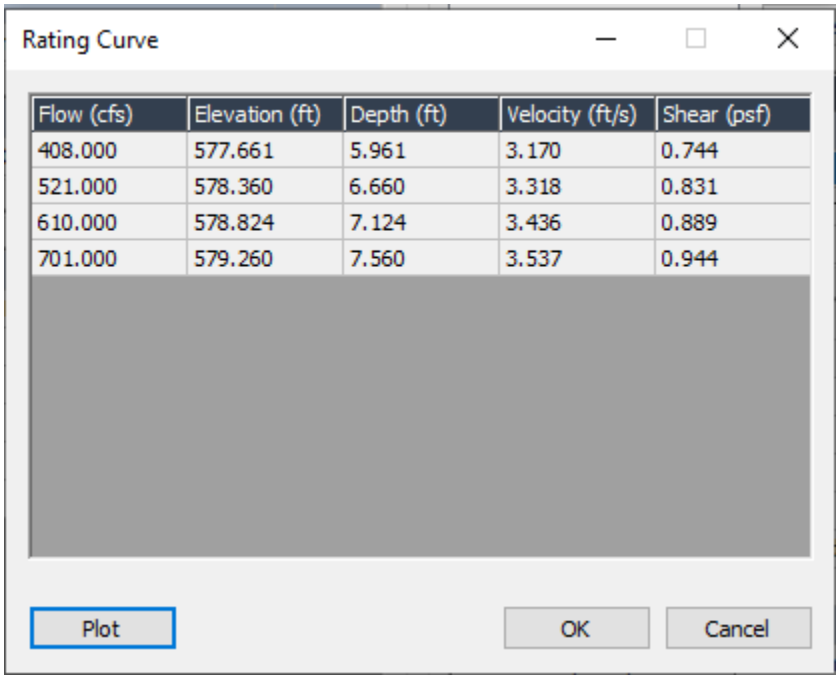
Delaware Creek Tailwater Information



No.	Station (ft)	Elevation (ft)	Manning n
1	-42.500	580.500	0.0700
2	-20.300	575.700	0.0700
3	-12.200	574.600	0.0700
4	-6.700	573.200	0.0400
5	-2.900	572.500	0.0400
6	0.900	572.100	0.0400
7	6.300	571.700	0.0400
8	9.600	578.200	0.0700
9	11.500	579.000	0.0700
10	17.300	581.500	

Culvert Replacement Study





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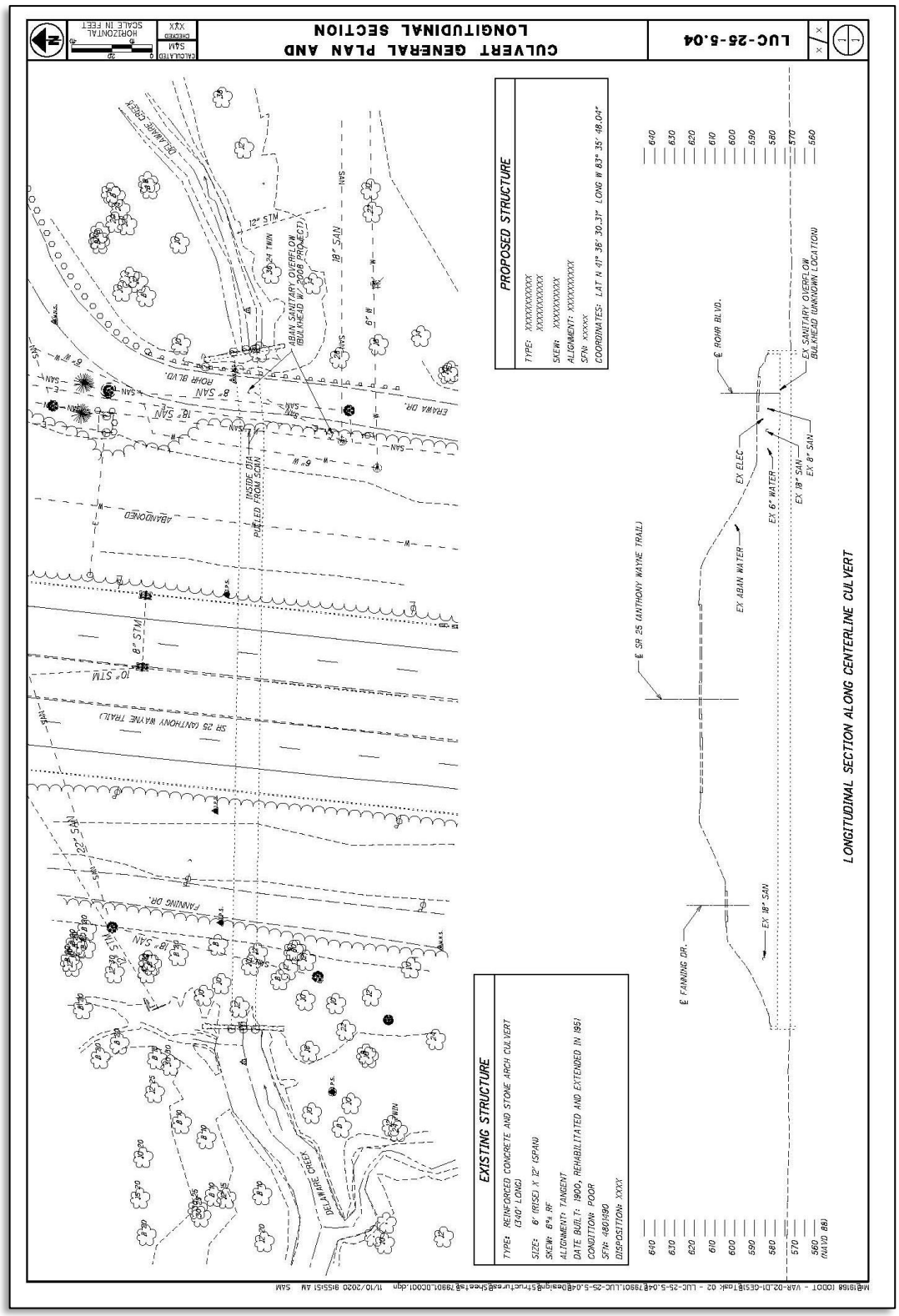


Existing Structure Hydraulic Summary

LUC-25-5.04 over Delaware Creek

Recurrance Interval	Estimated Discharge (cfs)	Using Tailwaters Produced by Maumee River			Using Tailwaters Produced by Delaware Creek			Headwaters From FEMA Flood Profiles
		Tailwater	Headwater	Velocity (ft/s)	Tailwater	Headwater	Velocity (ft/s)	
Q_{10}	408	577.8	581.1	7.3	577.7	580.8	7.3	579.1
Q_{25}	521	578.4	583.7	9.3	578.4	583.6	9.3	-
Q_{50}	610	579.3	586.4	10.8	578.8	585.9	10.8	581.4
Q_{100}	701	580.2	589.3	12.5	579.3	588.3	12.5	582.2

All elevations NAVD datum

Proposed Structures

Per the scope we will be looking at alternatives for rehabilitation/reconstruction that do not include open cut construction.

Design Year Frequency (L&D Vol. 2 – 1004.2)

Use the local road (Rohr Blvd.) as the control for the design frequency because it is 25'± below the elevation of SR 25. Use a 10-year design frequency (L&D Vol. 2 1004.2) since ADT < 2000 vehicles per day.

Allowable Headwater (L&D Vol.2 - 1006)

Section 1006.2.2 E will control, no increase in the 100-year elevation shall occur in a FEMA designated floodway. The allowable design year headwater controls would allow an increase in the design headwater elevations that would also result in an increase in the 100-year headwater elevation. Therefore the 100-year FEMA control will apply.

Alternative 1 - Culvert Linings

The existing structure is a single radius arch so using a single radius arch as a liner would make sense to have the minimum reduction in size for the proposed opening. Contech aluminum and steel corrugated single radius arch were investigated. The 11' x 5'-9" was investigated but was too close in size to the existing opening and left no room for grout between the existing and proposed arches. The 11' x 4'-6" arch fits neatly within the existing arch and is placed on 9" high concrete pedestals placed along the bottom edge of the existing culvert, the area between the existing culvert and proposed lining will be filled with grout. See sheet 24 for a sketch of the proposed culvert opening. Both the steel Multi-Plate (n = 0.030) and the Aluminum Structural Plate (n = 0.033) have the same shape, the Aluminum Structural Plate option and will included as Alternative 1(a) using the more conservative n = 0.033 value.

Alternative 1(b) is a smooth steel arch structure with the same geometry as the corrugated structures but a material that possesses a much smoother n = 0.012.

Both Alternatives 1(a) and 1(b) produce backwaters higher than those produced by the 100-year backwater of the existing structure. Alternative 1(a) produces a backwater that is 16.3' feet above the existing and Alternative 1(b) produces a backwater 5.8' above the existing.

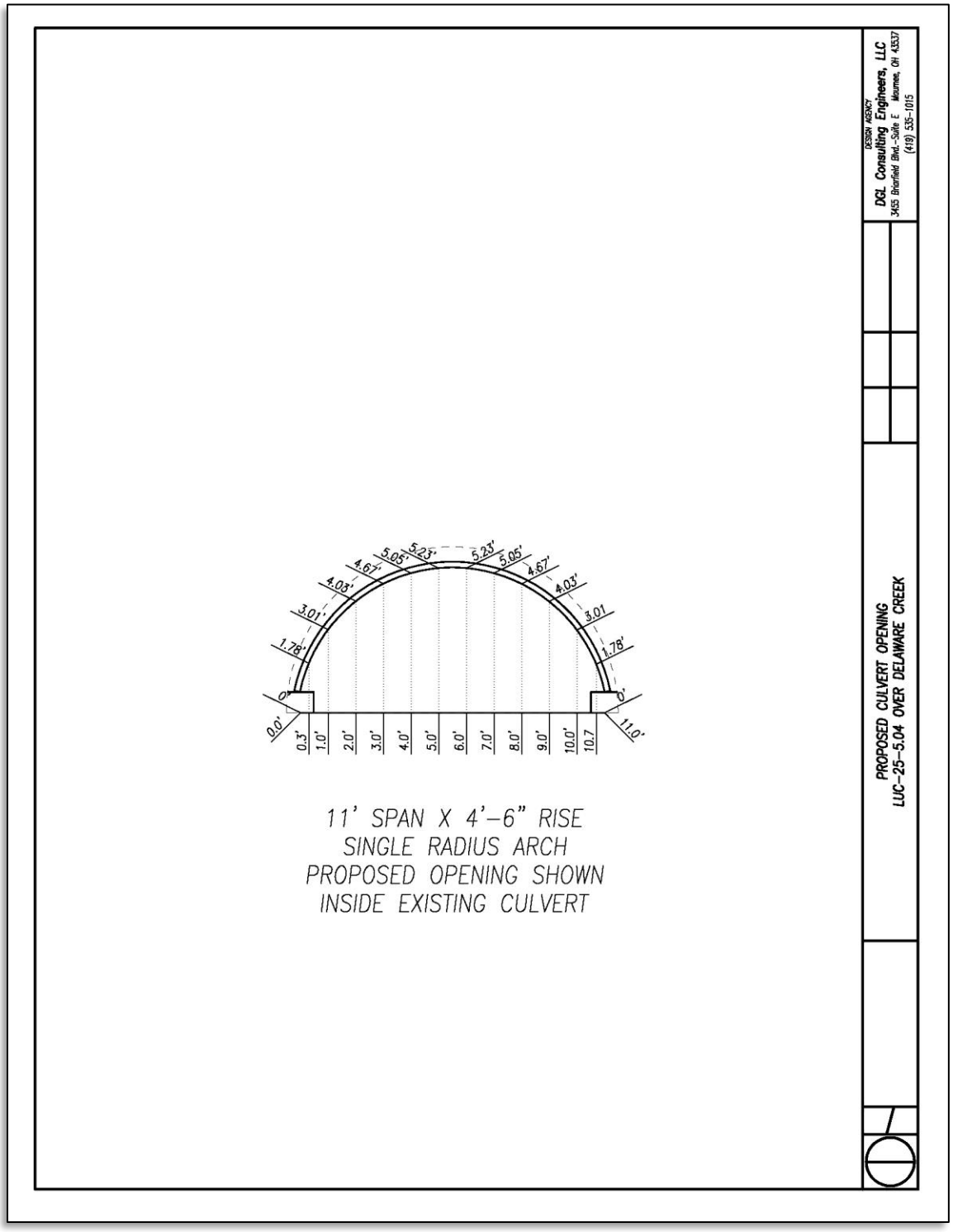
Culvert Replacement Study

To lower the 100-year backwater elevations we propose adding an additional pipe that will be jack and bored adjacent to the existing culvert\liner combination. The proposed pipe will have an invert 2’ above the existing invert to retain low channel flow in the existing pipe. Sizes of the jack and bored pipe were increased until the 100-year water surface produced by the combination of pipes was lower than that of the existing structure. Alternative 1(a) required the addition of a 60” pipe to lower the proposed headwater, whereas Alternative 1(b) required the addition of a 48” pipe.

Alternative 2 - Tunneling a new culvert

This alternative consists of tunneling a new culvert adjacent to the existing culvert. The minimum culvert size required to not exceed the existing structures 100-year headwater elevation is 90” circular tunnel.

Culvert Replacement Study



Proposed Structures Hydraulic Summary

LUC-25-5.04 over Delaware Creek

Existing structure Headwater elevation = 588.3 (100 Year)

Alternative 1(a)							
Recurrance Interval	Estimated Discharge (cfs)	Tailwater	11' x 4.6" Corrugated Aluminum Plate Liner (44.8 sf)		11' x 4'-6" Corrugated Aluminum Plate Liner[1] + 60" Pipe[2] (63.8 sf)		
			Headwater	Velocity (fps)	Headwater	Velocity[1](fps)	Velocity[2](fps)
Q_{10}	408	577.7	586.1	9.1	580.9	5.6	10.0
Q_{25}	521	578.4	592.3	11.6	583.3	7.0	11.5
Q_{50}	610	578.8	598.0	13.6	585.5	8.1	13.0
Q_{100}	701	579.3	604.6	15.6	588.2	9.3	14.9

Alternative 1(b)							
Recurrance Interval	Estimated Discharge (cfs)	Tailwater	11' x 4.6" Smooth Plate Liner (44.8 sf)		11' x 4'-6" Smooth Plate Liner[1] + 48" Pipe[2] (56.8 sf)		
			Headwater	Velocity (fps)	Headwater	Velocity[1](fps)	Velocity[2](fps)
Q_{10}	408	577.7	583.0	9.1	580.7	6.8	9.0
Q_{25}	521	578.4	586.9	11.6	583.3	8.7	10.7
Q_{50}	610	578.8	590.2	13.6	585.6	10.3	12.4
Q_{100}	701	579.3	594.1	15.6	588.0	10.8	14.1

Alternative 2				
Recurrance Interval	Estimated Discharge (cfs)	Tailwater	90" Pipe (44.2 sf)	
			Headwater	Velocity (fps)
Q_{10}	408	577.7	581.4	11.2
Q_{25}	521	578.4	583.2	12.9
Q_{50}	610	578.8	585.2	14.3
Q_{100}	701	579.3	587.7	15.9

All elevations NAVD datum.

Conclusion and Recommendations

Cost estimates for the three alternatives are as follows and are detailed in Appendix E.

Alternative 1(a) – 11'-0" x 4'-6" Single Radius Corrugated Liner Pipe with Additional 60" Diameter Culvert	$1,046,000
Alternative 1(b) – 11'-0" x 4'-6" Single Radius Smooth Liner Pipe with Additional 48" Diameter Culvert	$1,066,000
Alternative 2 – 90" Diameter Pipe (Adjacent to Existing Culvert)	$1,528,000

Alternative 2 is the recommended alternative based on ODOT's preference for single culvert pipe structures.

It should also be noted that jack and bore process for culverts of this length is a very specialized process with a select few contractors having the capacity and/or experience to perform the work. As a result, unit prices can be volatile depending on the workload of qualified contractors.

Appendix A – Existing HY8 Output

HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Crossing 1

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
579.39	Q 10	408.00	408.00	0.00	1
581.20	Q 25	521.00	521.00	0.00	1
582.72	Q 50	610.00	610.00	0.00	1
584.41	Q 100	701.00	701.00	0.00	1
620.00	Overtopping	1863.41	1863.41	0.00	Overtopping

Rating Curve Plot for Crossing: Crossing 1

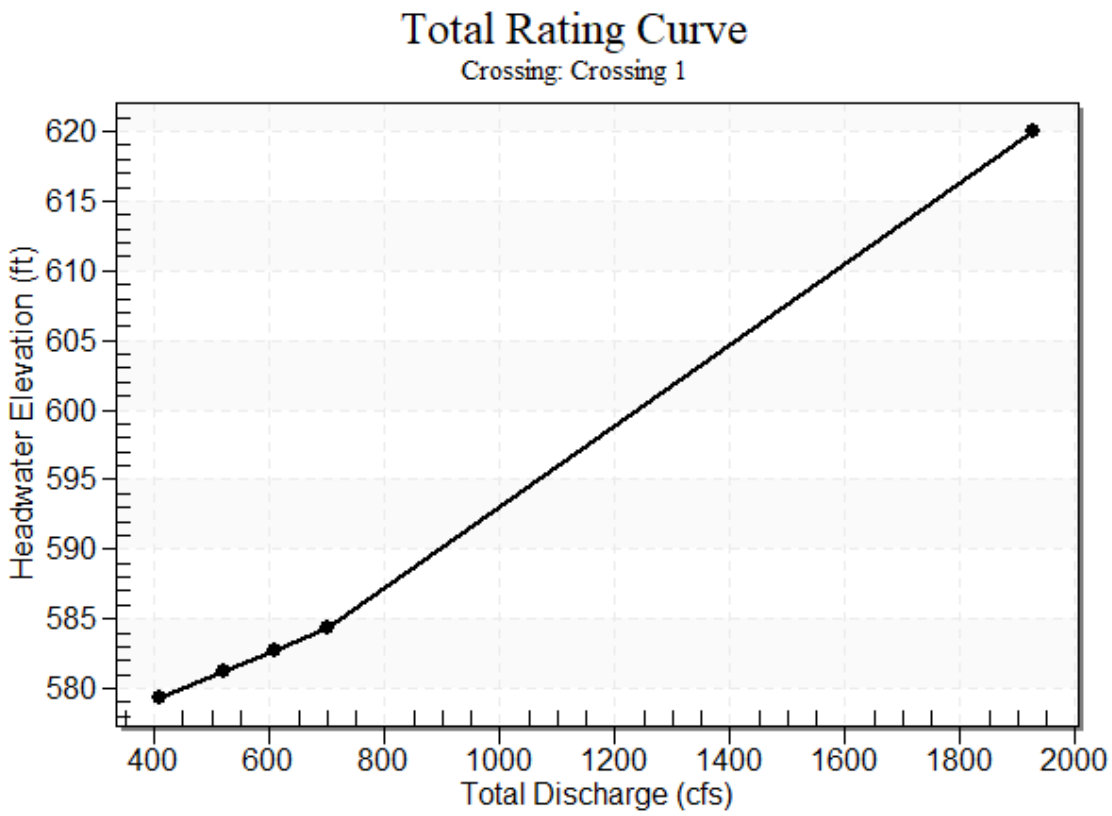


Table 2 - Culvert Summary Table: Culvert 1

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)
Q 10	408.00	408.00	579.39	5.697	6.683	7-M1t	3.753	3.308	5.751	5.961	7.316
Q 25	521.00	521.00	581.20	7.156	8.494	4-FFf	4.970	3.852	6.000	6.660	9.257
Q 50	610.00	610.00	582.72	8.394	10.012	4-FFf	6.000	4.244	6.000	7.124	10.839
Q 100	701.00	701.00	584.41	9.747	11.699	4-FFf	6.000	4.603	6.000	7.560	12.456

****

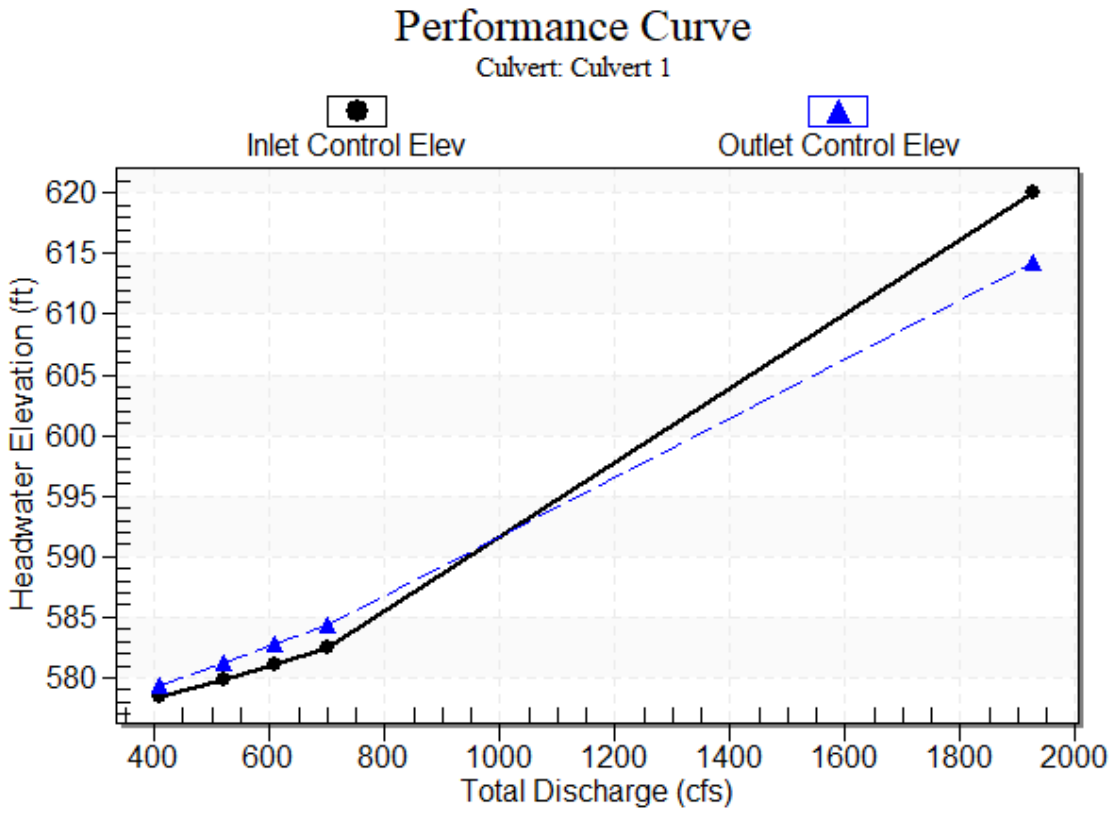
Straight Culvert

Inlet Elevation (invert): 572.71 ft, Outlet Elevation (invert): 571.91 ft

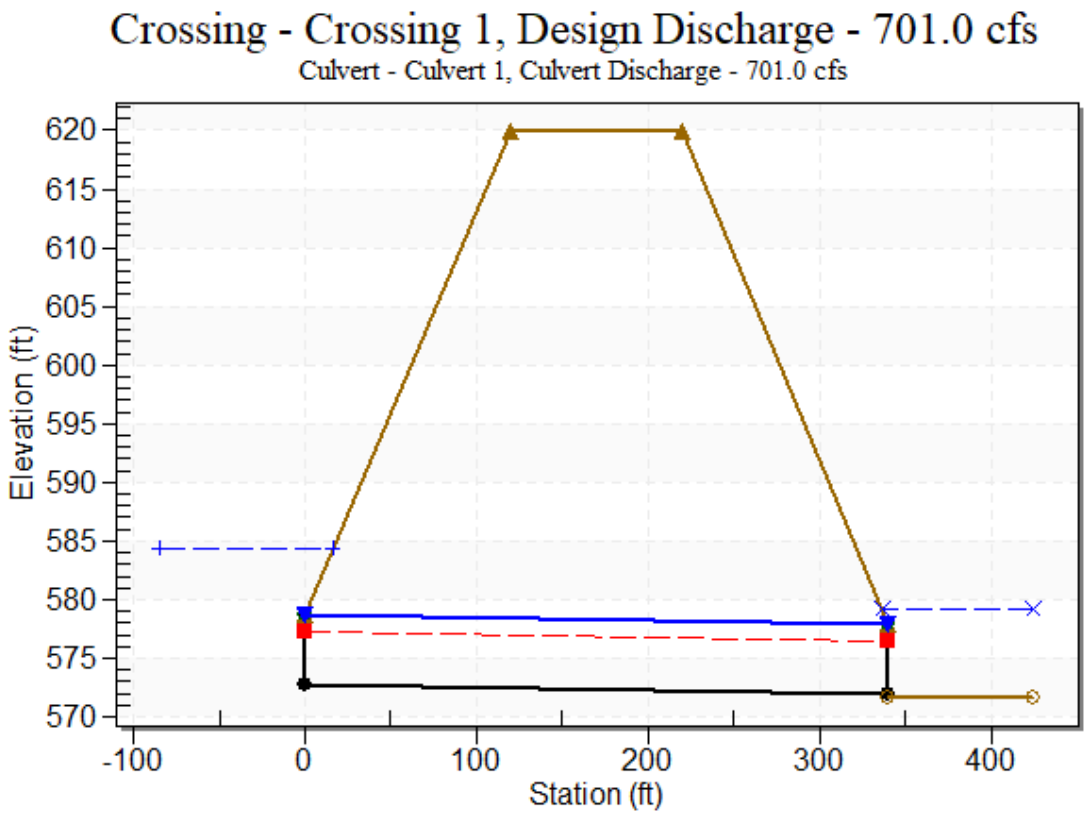
Culvert Length: 340.00 ft, Culvert Slope: 0.0024

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 572.71 ft

Outlet Station: 340.00 ft

Outlet Elevation: 571.91 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: User Defined

Barrel Span: 12.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

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

Manning's n: 0.0120 (bottom)

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Crossing 1)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
408.00	577.66	5.96	3.17	0.74	0.31
521.00	578.36	6.66	3.32	0.83	0.30
610.00	578.82	7.12	3.44	0.89	0.31
701.00	579.26	7.56	3.54	0.94	0.31

Tailwater Channel Data - Crossing 1

Tailwater Channel Option: Irregular Channel

Roadway Data for Crossing: Crossing 1

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 620.00 ft

Roadway Surface: Paved

Roadway Top Width: 100.00 ft

HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Crossing 1

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
579.51	Q 10	408.00	408.00	0.00	1
581.24	Q 25	521.00	521.00	0.00	1
583.20	Q 50	610.00	610.00	0.00	1
585.35	Q 100	701.00	701.00	0.00	1
620.00	Overtopping	1863.41	1863.41	0.00	Overtopping

Rating Curve Plot for Crossing: Crossing 1

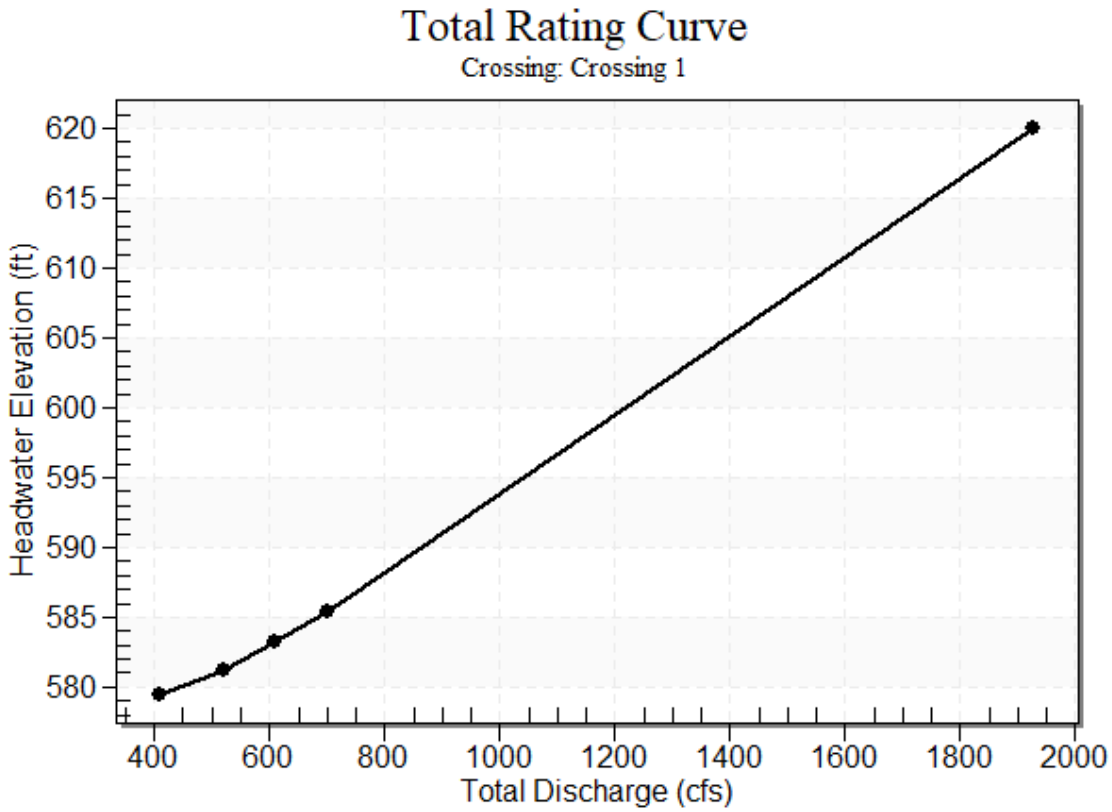


Table 2 - Culvert Summary Table: Culvert 1

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)
Q 10	408.00	408.00	579.51	5.697	6.802	7-M1t	3.753	3.308	5.890	5.200	7.265
Q 25	521.00	521.00	581.24	7.156	8.534	4-FFf	4.970	3.852	6.000	5.800	9.257
Q 50	610.00	610.00	583.20	8.394	10.489	4-FFf	6.000	4.244	6.000	6.700	10.839
Q 100	701.00	701.00	585.35	9.747	12.639	4-FFf	6.000	4.603	6.000	7.600	12.456

****

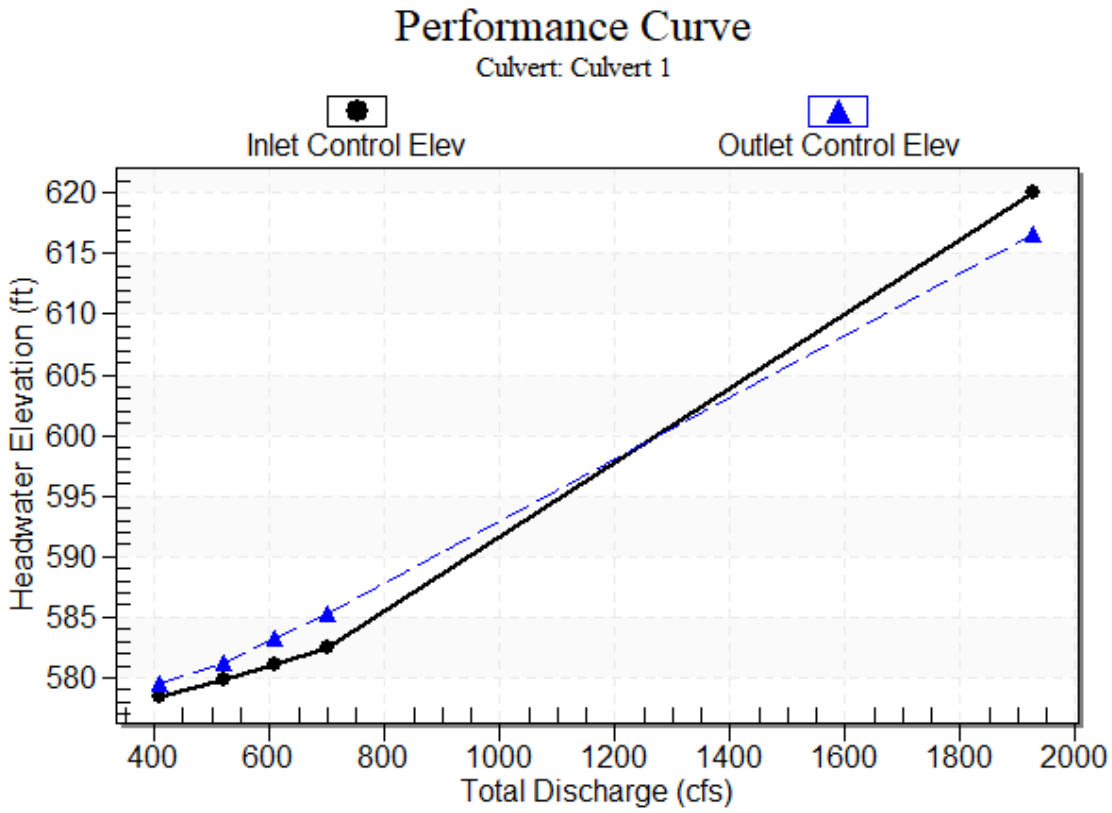
Straight Culvert

Inlet Elevation (invert): 572.71 ft, Outlet Elevation (invert): 571.91 ft

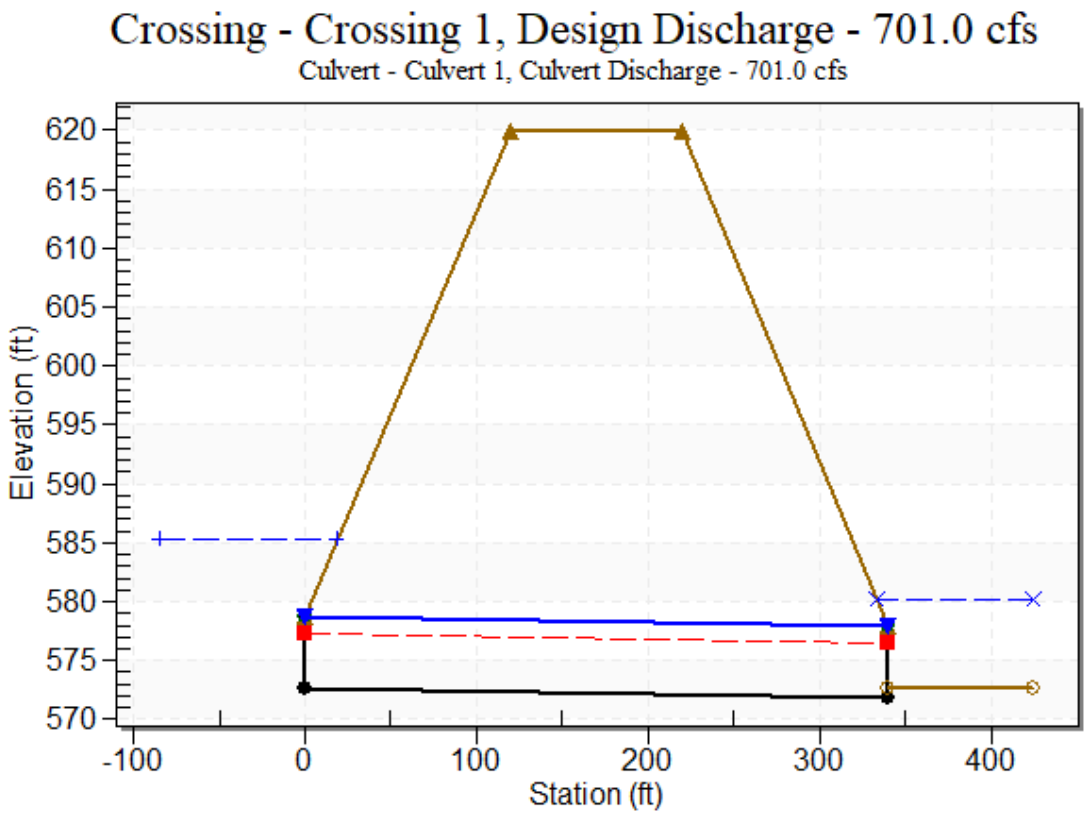
Culvert Length: 340.00 ft, Culvert Slope: 0.0024

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 572.71 ft

Outlet Station: 340.00 ft

Outlet Elevation: 571.91 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: User Defined

Barrel Span: 12.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

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

Manning's n: 0.0120 (bottom)

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Crossing 1)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)
408.00	577.80	577.80	3.00
521.00	578.40	578.40	3.30
610.00	579.30	579.30	3.10
701.00	580.20	580.20	2.80

Tailwater Channel Data - Crossing 1

Tailwater Channel Option: Enter Rating Curve

Channel Invert Elevation: 572.60 ft

Roadway Data for Crossing: Crossing 1

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 620.00 ft

Roadway Surface: Paved

Roadway Top Width: 100.00 ft

Appendix B – Proposed HY8 Output

HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Crossing 1

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
586.30	Q 10	408.00	408.00	0.00	1
592.58	Q 25	521.00	521.00	0.00	1
598.45	Q 50	610.00	610.00	0.00	1
605.29	Q 100	701.00	701.00	0.00	1
620.00	Overtopping	866.88	866.88	0.00	Overtopping

Rating Curve Plot for Crossing: Crossing 1

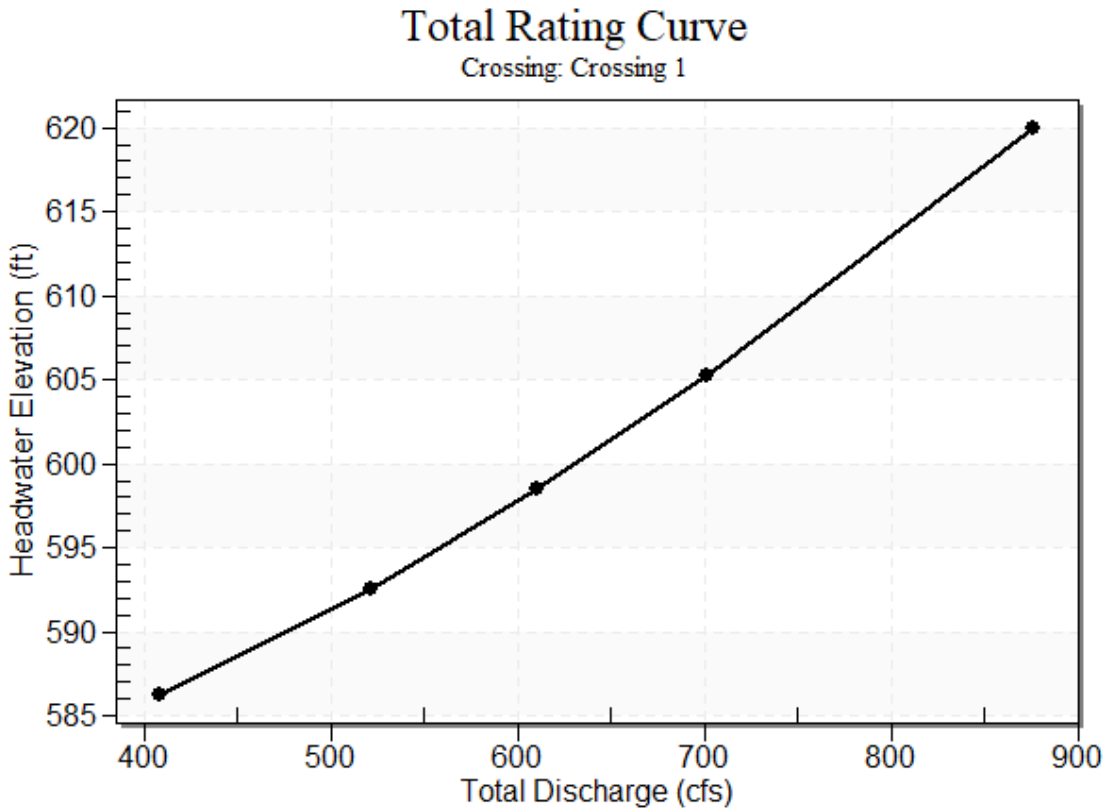


Table 2 - Culvert Summary Table: Culvert 1

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)
Q 10	408.00	408.00	586.30	6.548	13.592	4-FFf	5.230	3.453	5.230	5.961	9.096
Q 25	521.00	521.00	592.58	8.483	19.865	4-FFf	5.230	4.011	5.230	6.660	11.615
Q 50	610.00	610.00	598.45	10.388	25.736	4-FFf	5.230	4.340	5.230	7.124	13.599
Q 100	701.00	701.00	605.29	12.685	32.582	4-FFf	5.230	4.629	5.230	7.560	15.627

****

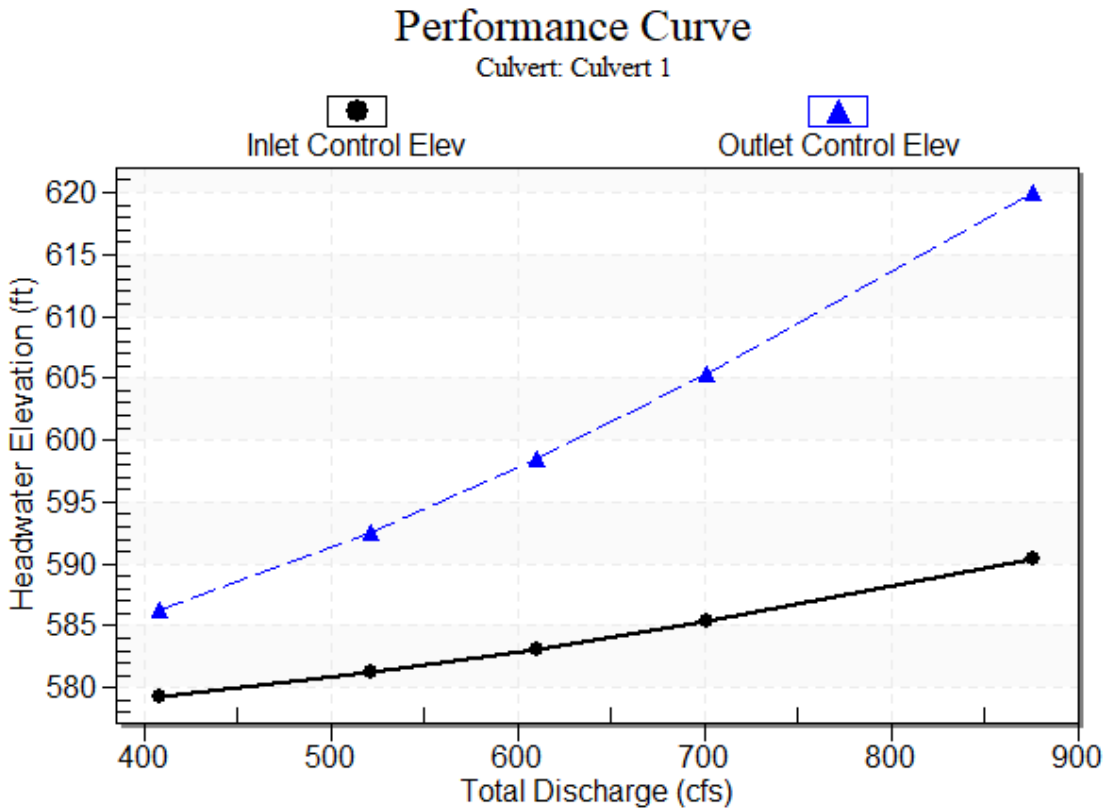
Straight Culvert

Inlet Elevation (invert): 572.71 ft, Outlet Elevation (invert): 571.91 ft

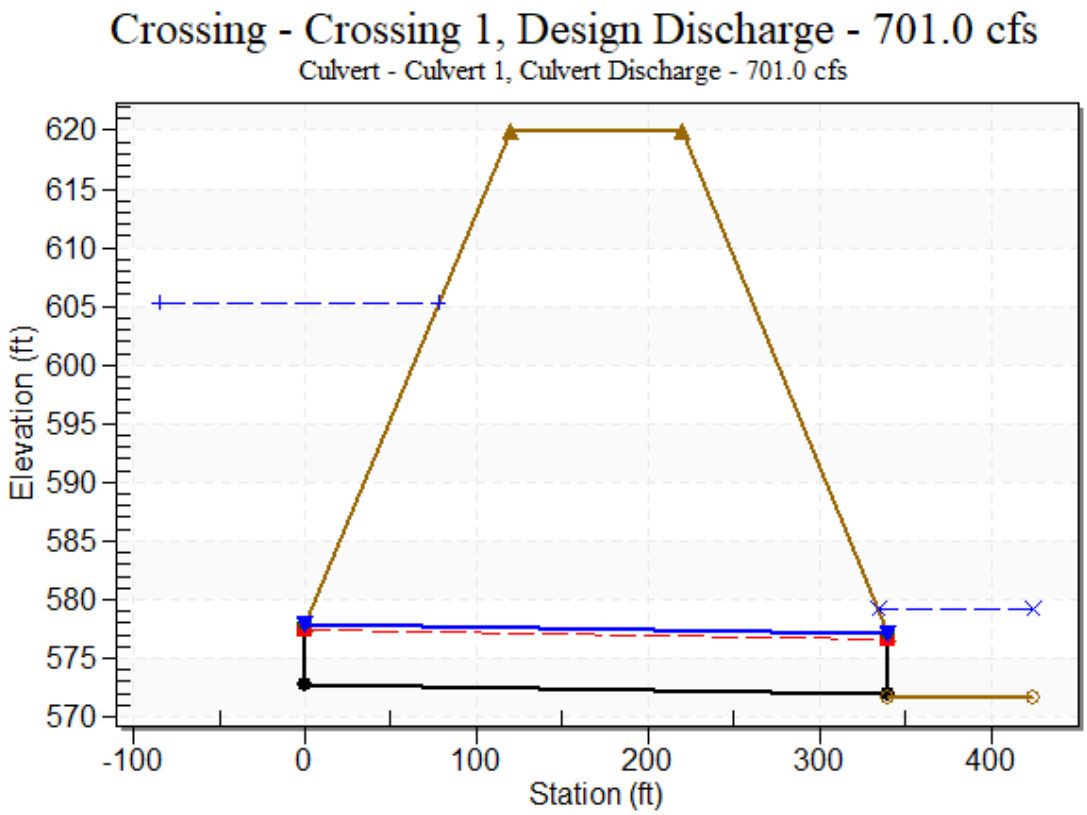
Culvert Length: 340.00 ft, Culvert Slope: 0.0024

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 572.71 ft

Outlet Station: 340.00 ft

Outlet Elevation: 571.91 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: User Defined

Barrel Span: 11.00 ft

Barrel Rise: 5.23 ft

Barrel Material: Corrugated Metal Riveted or Welded

Embedment: 0.00 in

Barrel Manning's n: 0.0340 (top and sides)

Manning's n: 0.0300 (bottom)

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Crossing 1)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
408.00	577.66	5.96	3.17	0.74	0.31
521.00	578.36	6.66	3.32	0.83	0.30
610.00	578.82	7.12	3.44	0.89	0.31
701.00	579.26	7.56	3.54	0.94	0.31

Tailwater Channel Data - Crossing 1

Tailwater Channel Option: Irregular Channel

Roadway Data for Crossing: Crossing 1

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 620.00 ft

Roadway Surface: Paved

Roadway Top Width: 100.00 ft

HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Crossing 1

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Culvert 2 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
580.87	Q 10	408.00	252.60	155.43	0.00	6
583.31	Q 25	521.00	313.01	208.01	0.00	5
585.53	Q 50	610.00	363.86	246.17	0.00	7
588.15	Q 100	701.00	417.69	283.31	0.00	5
620.00	Overtopping	1511.92	909.09	602.83	0.00	Overtopping

Rating Curve Plot for Crossing: Crossing 1

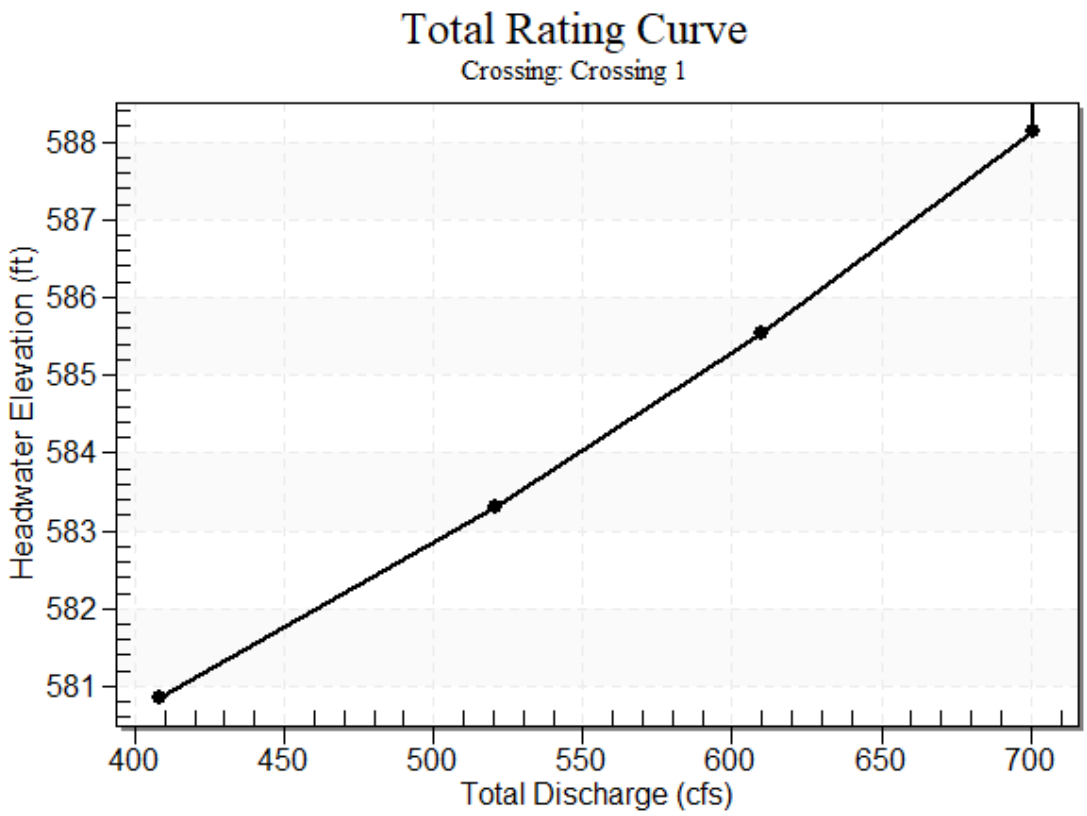


Table 2 - Culvert Summary Table: Culvert 1

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)
Q 10	408.00	252.60	580.87	4.368	8.154	4-FFf	5.230	2.541	5.230	5.961	5.631
Q 25	521.00	313.01	583.31	5.095	10.596	4-FFf	5.230	2.929	5.230	6.660	6.978
Q 50	610.00	363.86	585.53	5.873	12.821	4-FFf	5.230	3.218	5.230	7.124	8.112
Q 100	701.00	417.69	588.15	6.707	15.438	4-FFf	5.230	3.503	5.230	7.560	9.312

****

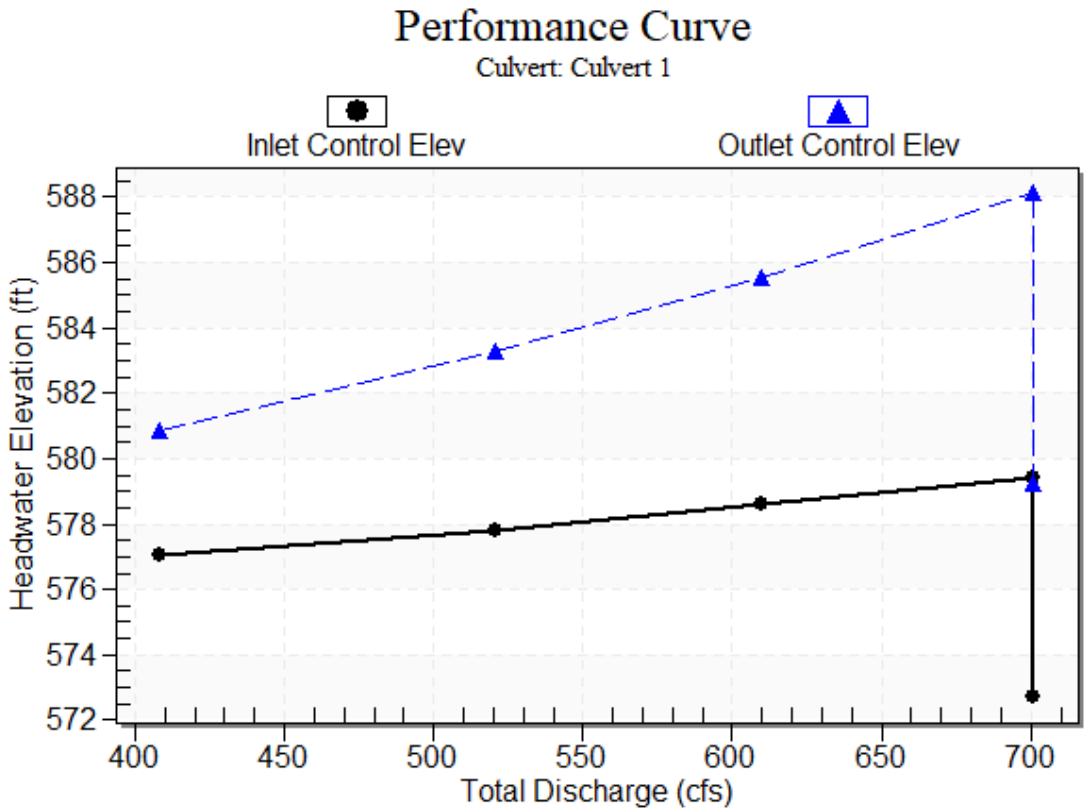
Straight Culvert

Inlet Elevation (invert): 572.71 ft, Outlet Elevation (invert): 571.91 ft

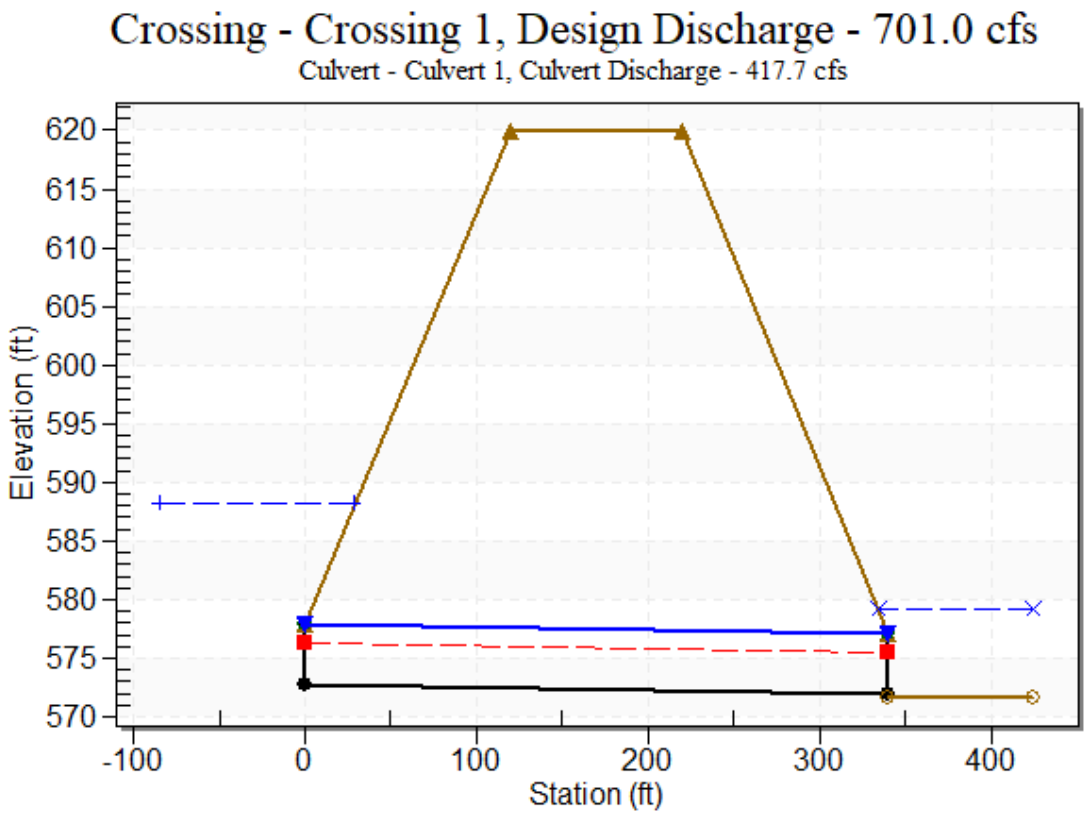
Culvert Length: 340.00 ft, Culvert Slope: 0.0024

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 572.71 ft

Outlet Station: 340.00 ft

Outlet Elevation: 571.91 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: User Defined

Barrel Span: 11.00 ft

Barrel Rise: 5.23 ft

Barrel Material: Corrugated Metal Riveted or Welded

Embedment: 0.00 in

Barrel Manning's n: 0.0330 (top and sides)

Manning's n: 0.0300 (bottom)

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Culvert Summary Table: Culvert 2

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)
Q 10	408.00	155.43	580.87	5.970	6.154	3-M2t	4.920	3.589	3.751	5.961	9.994
Q 25	521.00	208.01	583.31	8.013	8.596	7-M2t	4.920	4.114	4.450	6.660	11.501
Q 50	610.00	246.17	585.53	9.908	10.824	7-M2t	4.920	4.390	4.914	7.124	12.949
Q 100	701.00	283.31	588.15	12.090	13.437	4-FFf	4.920	4.576	4.920	7.560	14.902

****

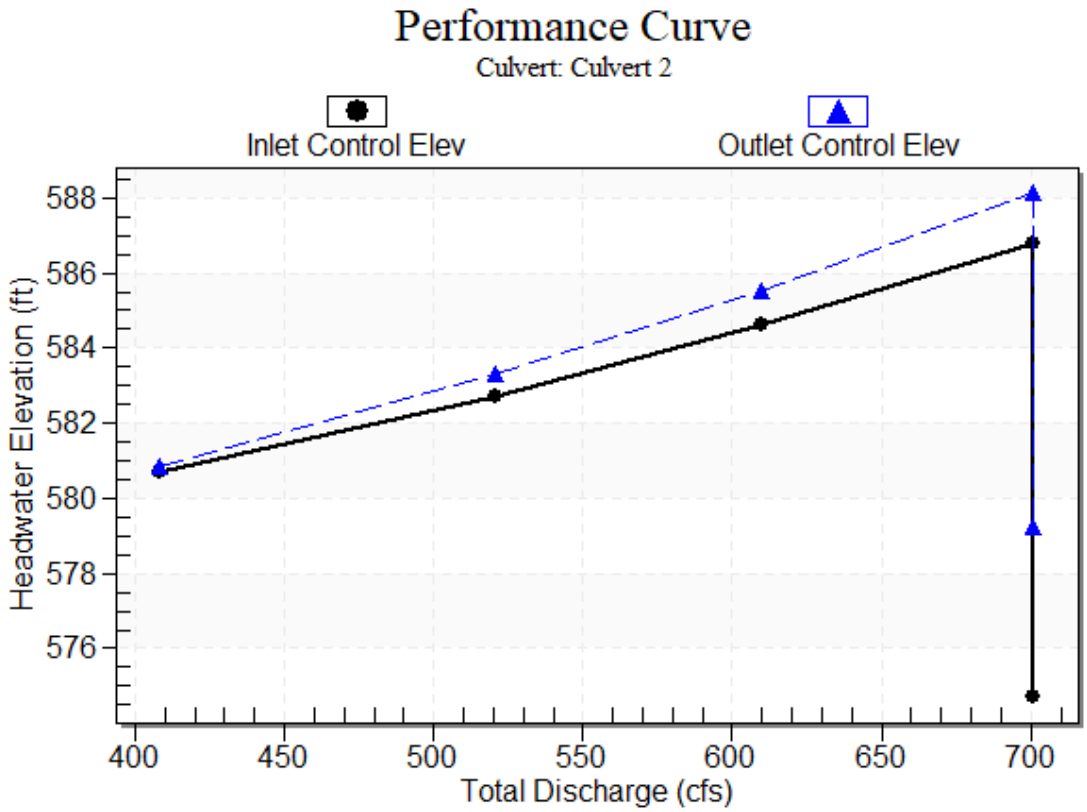
Straight Culvert

Inlet Elevation (invert): 574.71 ft, Outlet Elevation (invert): 573.91 ft

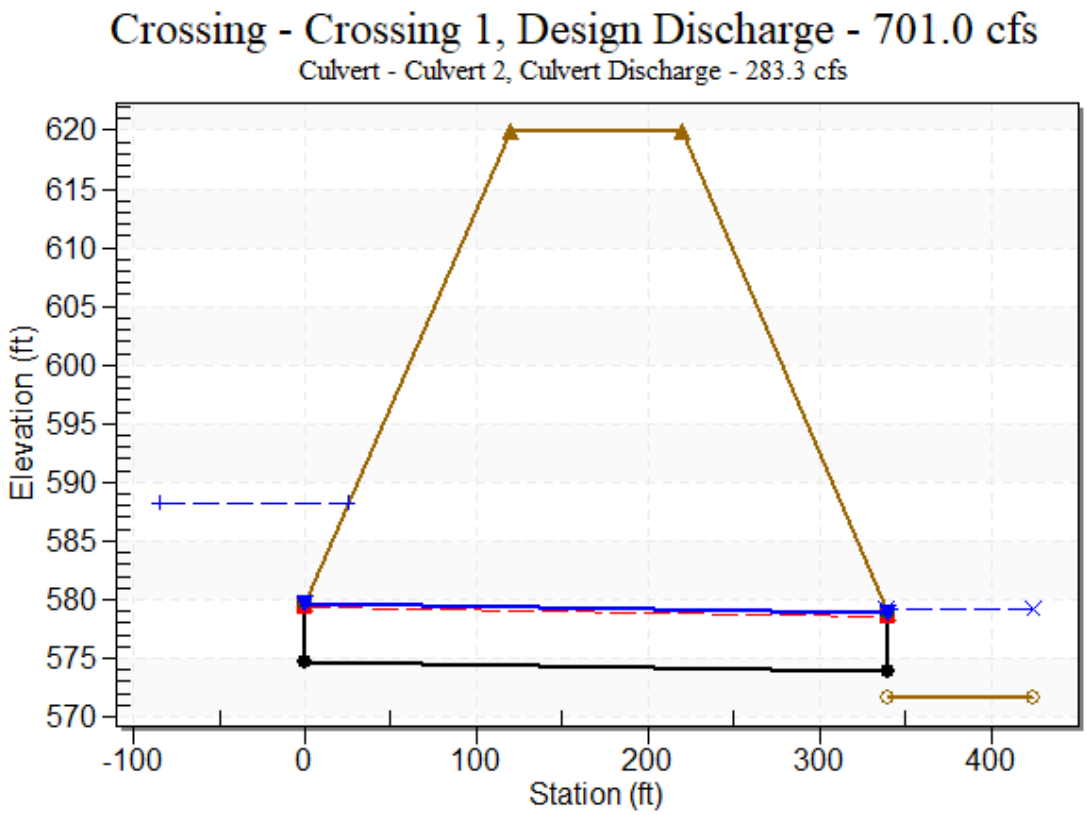
Culvert Length: 340.00 ft, Culvert Slope: 0.0024

****

Culvert Performance Curve Plot: Culvert 2



Water Surface Profile Plot for Culvert: Culvert 2



Site Data - Culvert 2

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 574.71 ft

Outlet Station: 340.00 ft

Outlet Elevation: 573.91 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 2

Barrel Shape: Circular

Barrel Diameter: 4.92 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 4 - Downstream Channel Rating Curve (Crossing: Crossing 1)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
408.00	577.66	5.96	3.17	0.74	0.31
521.00	578.36	6.66	3.32	0.83	0.30
610.00	578.82	7.12	3.44	0.89	0.31
701.00	579.26	7.56	3.54	0.94	0.31

Tailwater Channel Data - Crossing 1

Tailwater Channel Option: Irregular Channel

Roadway Data for Crossing: Crossing 1

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 620.00 ft

Roadway Surface: Paved

Roadway Top Width: 100.00 ft

HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Crossing 1

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
583.04	Q 10	408.00	408.00	0.00	1
586.90	Q 25	521.00	521.00	0.00	1
590.23	Q 50	610.00	610.00	0.00	1
594.06	Q 100	701.00	701.00	0.00	1
620.00	Overtopping	1204.21	1204.21	0.00	Overtopping

Rating Curve Plot for Crossing: Crossing 1

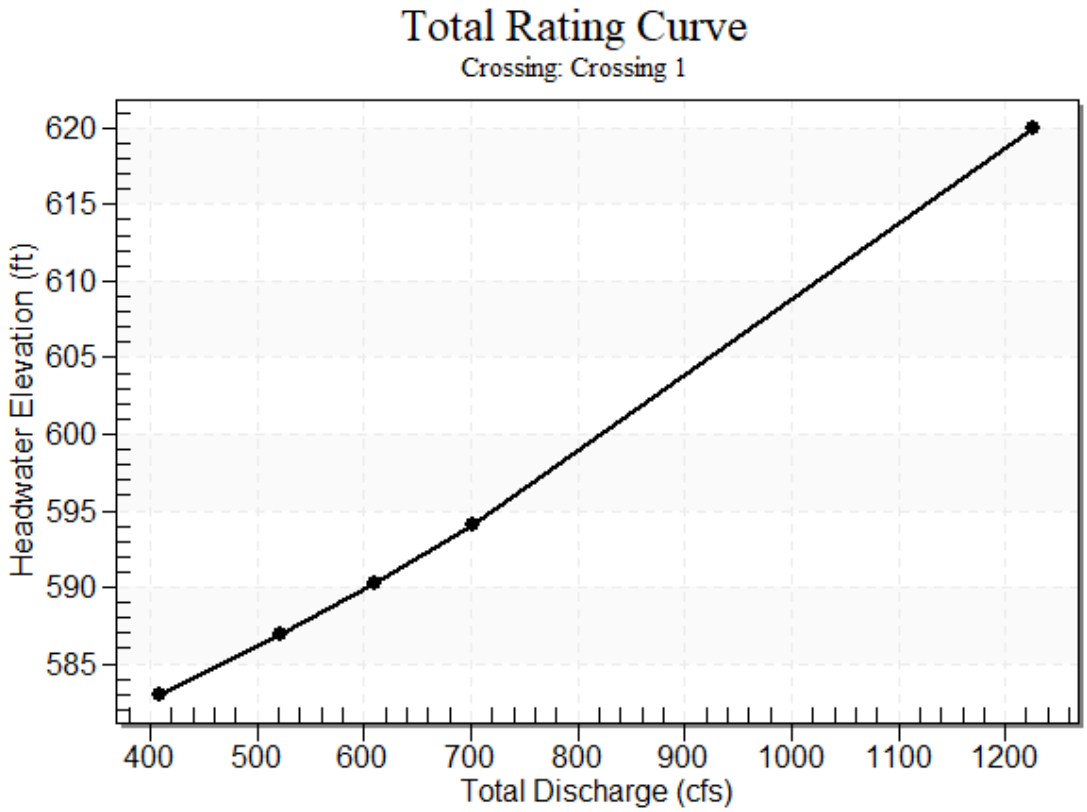


Table 2 - Culvert Summary Table: Culvert 1

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)
Q 10	408.00	408.00	583.04	6.548	10.327	4-FFf	5.230	3.453	5.230	5.662	9.096
Q 25	521.00	521.00	586.90	8.483	14.194	4-FFf	5.230	4.011	5.230	6.339	11.615
Q 50	610.00	610.00	590.23	10.388	17.521	4-FFf	5.230	4.340	5.230	6.792	13.599
Q 100	701.00	701.00	594.06	12.685	21.349	4-FFf	5.230	4.629	5.230	7.208	15.627

****

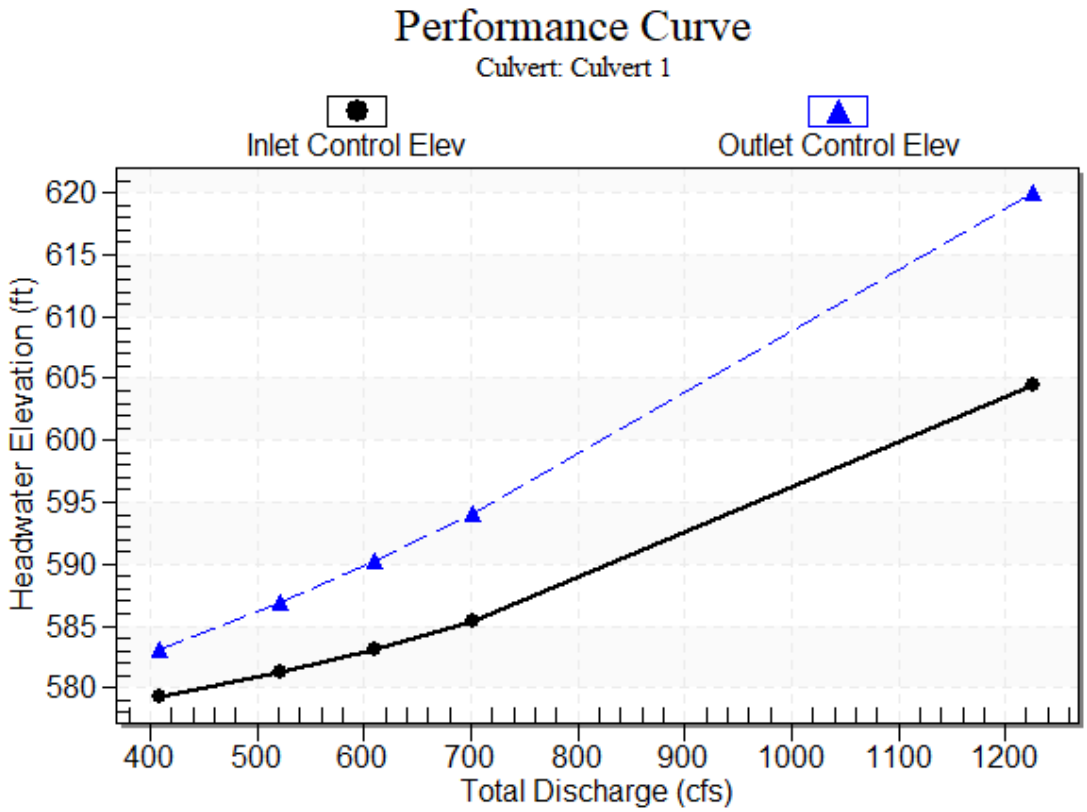
Straight Culvert

Inlet Elevation (invert): 572.71 ft, Outlet Elevation (invert): 571.91 ft

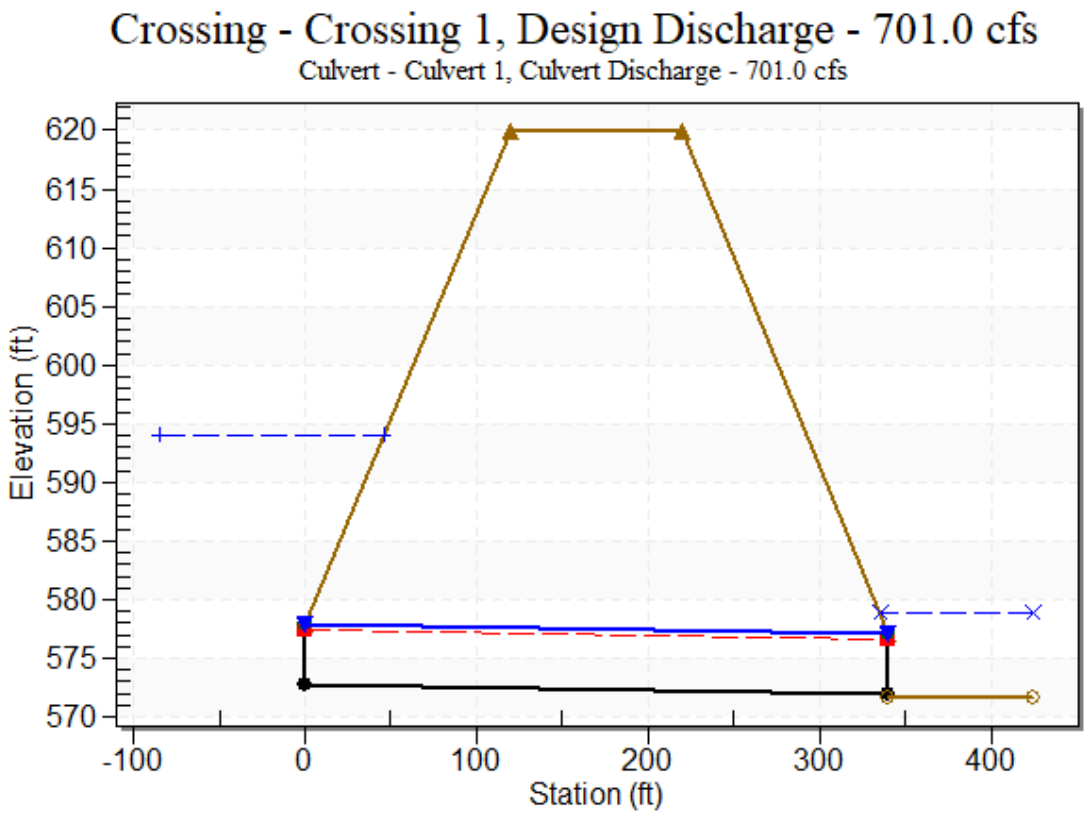
Culvert Length: 340.00 ft, Culvert Slope: 0.0024

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 572.71 ft

Outlet Station: 340.00 ft

Outlet Elevation: 571.91 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: User Defined

Barrel Span: 11.00 ft

Barrel Rise: 5.23 ft

Barrel Material: Concrete

Embedment: 0.00 in

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

Manning's n: 0.0300 (bottom)

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Crossing 1)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
408.00	577.36	5.66	3.48	0.88	0.34
521.00	578.04	6.34	3.63	0.99	0.34
610.00	578.49	6.79	3.75	1.06	0.34
701.00	578.91	7.21	3.86	1.12	0.34

Tailwater Channel Data - Crossing 1

Tailwater Channel Option: Irregular Channel

Roadway Data for Crossing: Crossing 1

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 620.00 ft

Roadway Surface: Paved

Roadway Top Width: 100.00 ft

HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Crossing 1

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Culvert 2 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
580.71	Q 10	408.00	306.45	101.55	0.00	7
583.28	Q 25	521.00	392.11	128.91	0.00	6
585.56	Q 50	610.00	460.32	149.66	0.00	5
588.03	Q 100	701.00	531.01	170.01	0.00	6
620.00	Overtopping	1569.85	1204.21	365.65	0.00	Overtopping

Rating Curve Plot for Crossing: Crossing 1

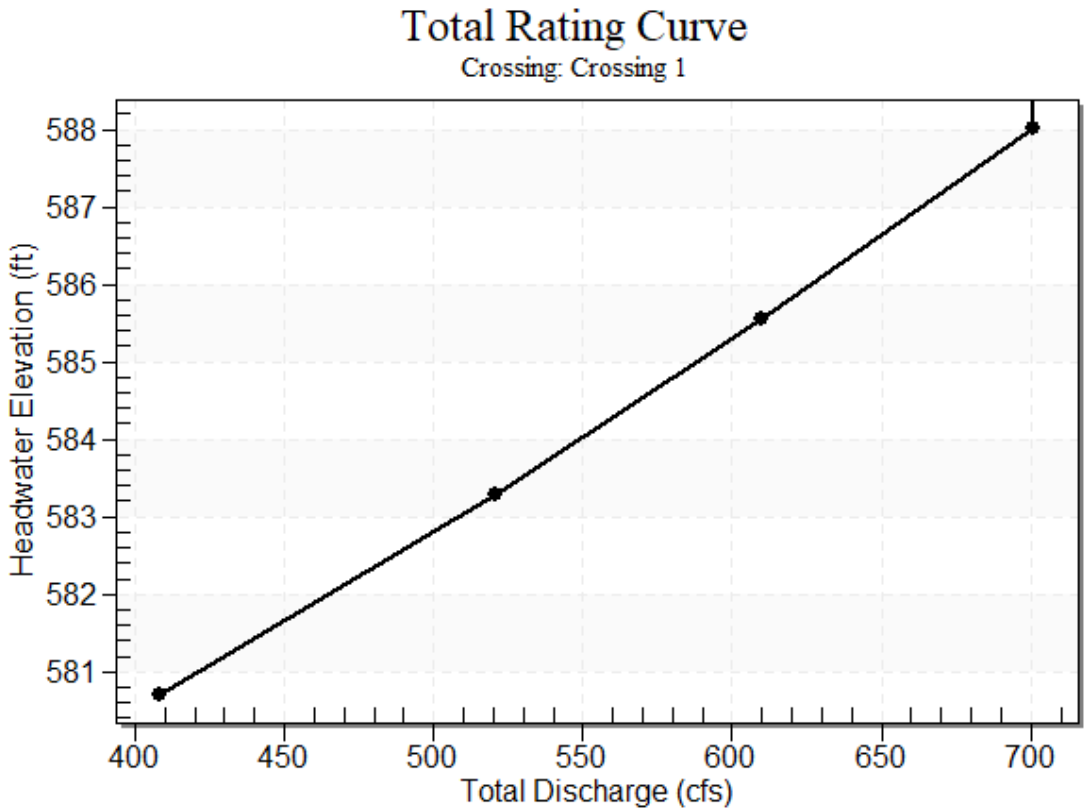


Table 2 - Culvert Summary Table: Culvert 1

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)
Q 10	408.00	306.45	580.71	4.999	8.004	4-FFf	5.230	2.888	5.230	5.662	6.832
Q 25	521.00	392.11	583.28	6.305	10.570	4-FFf	5.230	3.370	5.230	6.339	8.741
Q 50	610.00	460.32	585.56	7.425	12.848	4-FFf	5.230	3.718	5.230	6.792	10.262
Q 100	701.00	531.01	588.03	8.697	15.316	4-FFf	5.230	4.053	5.230	7.208	11.838

****

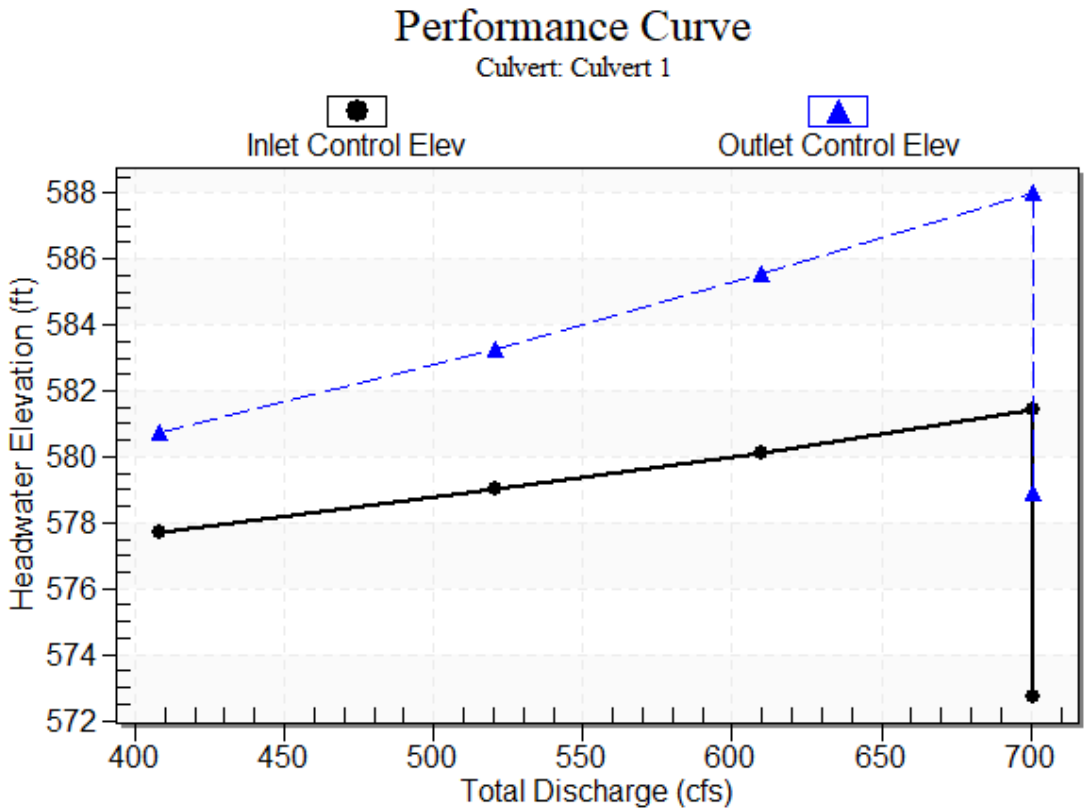
Straight Culvert

Inlet Elevation (invert): 572.71 ft, Outlet Elevation (invert): 571.91 ft

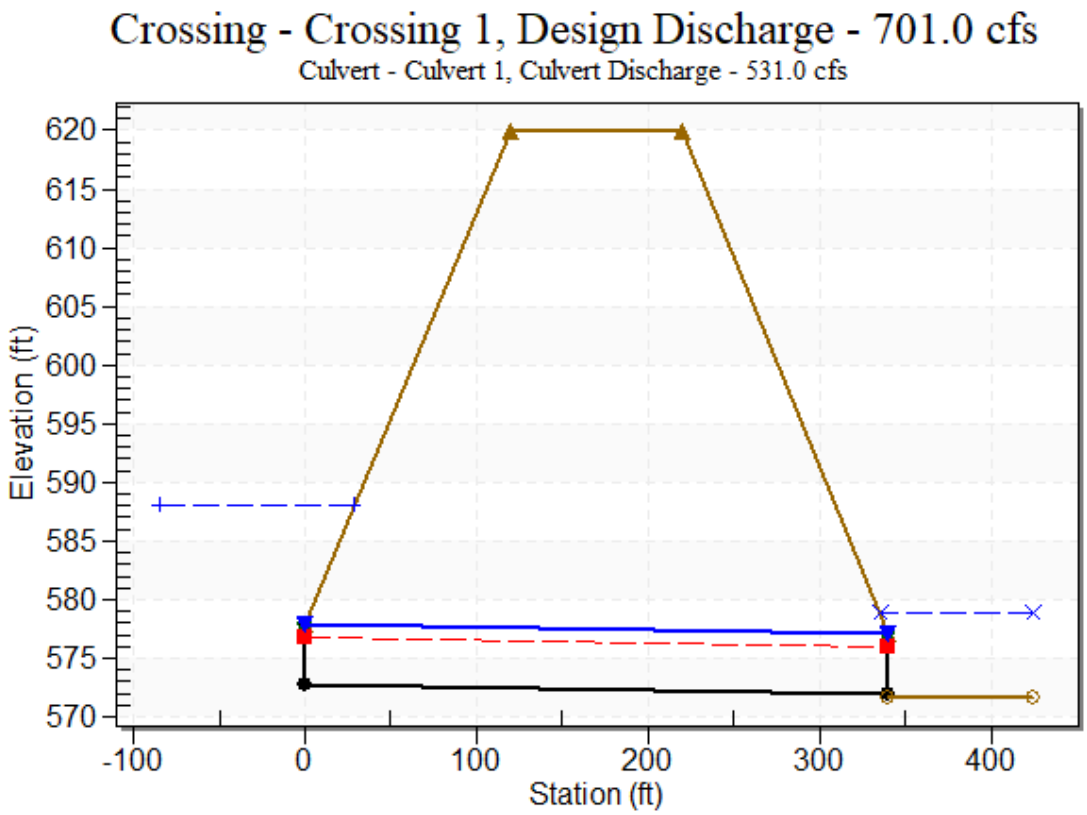
Culvert Length: 340.00 ft, Culvert Slope: 0.0024

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 572.71 ft

Outlet Station: 340.00 ft

Outlet Elevation: 571.91 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: User Defined

Barrel Span: 11.00 ft

Barrel Rise: 5.23 ft

Barrel Material: Concrete

Embedment: 0.00 in

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

Manning's n: 0.0300 (bottom)

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Culvert Summary Table: Culvert 2

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)
Q 10	408.00	101.55	580.71	5.432	6.004	7-M2t	3.920	3.064	3.452	5.662	9.024
Q 25	521.00	128.91	583.28	7.119	8.570	4-FFf	3.920	3.399	3.920	6.339	10.681
Q 50	610.00	149.66	585.56	8.702	10.846	4-FFf	3.920	3.577	3.920	6.792	12.400
Q 100	701.00	170.01	588.03	10.498	13.315	4-FFf	3.920	3.694	3.920	7.208	14.087

****

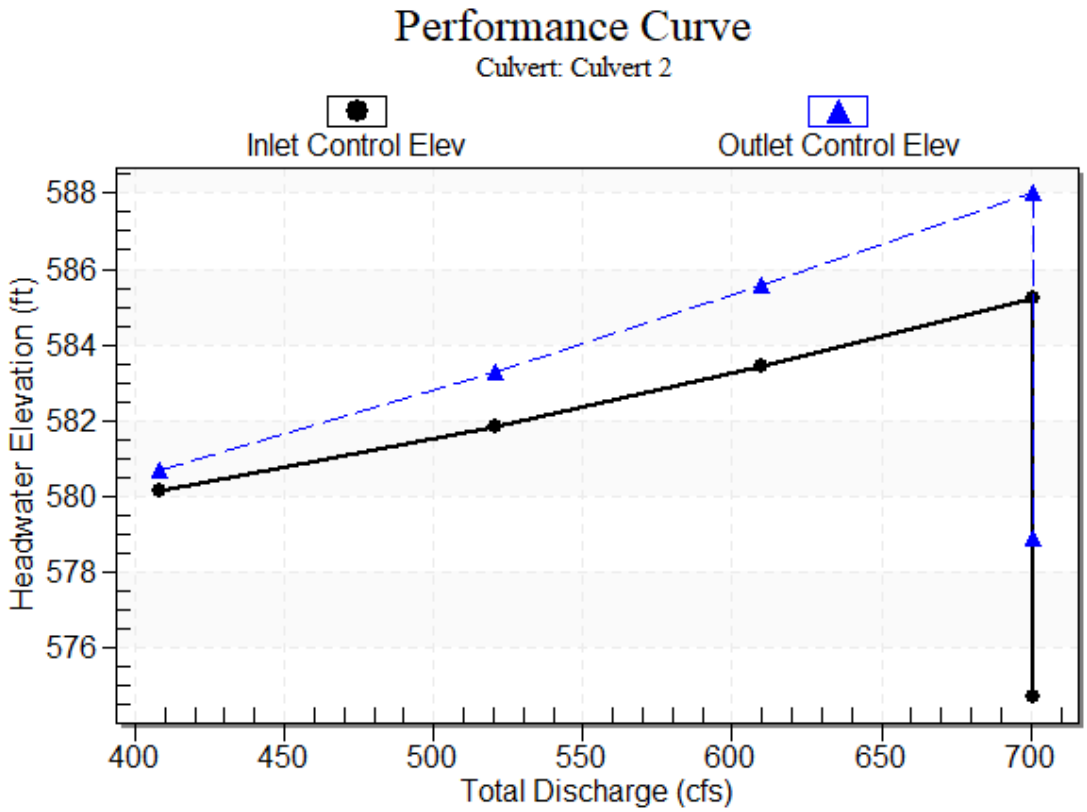
Straight Culvert

Inlet Elevation (invert): 574.71 ft, Outlet Elevation (invert): 573.91 ft

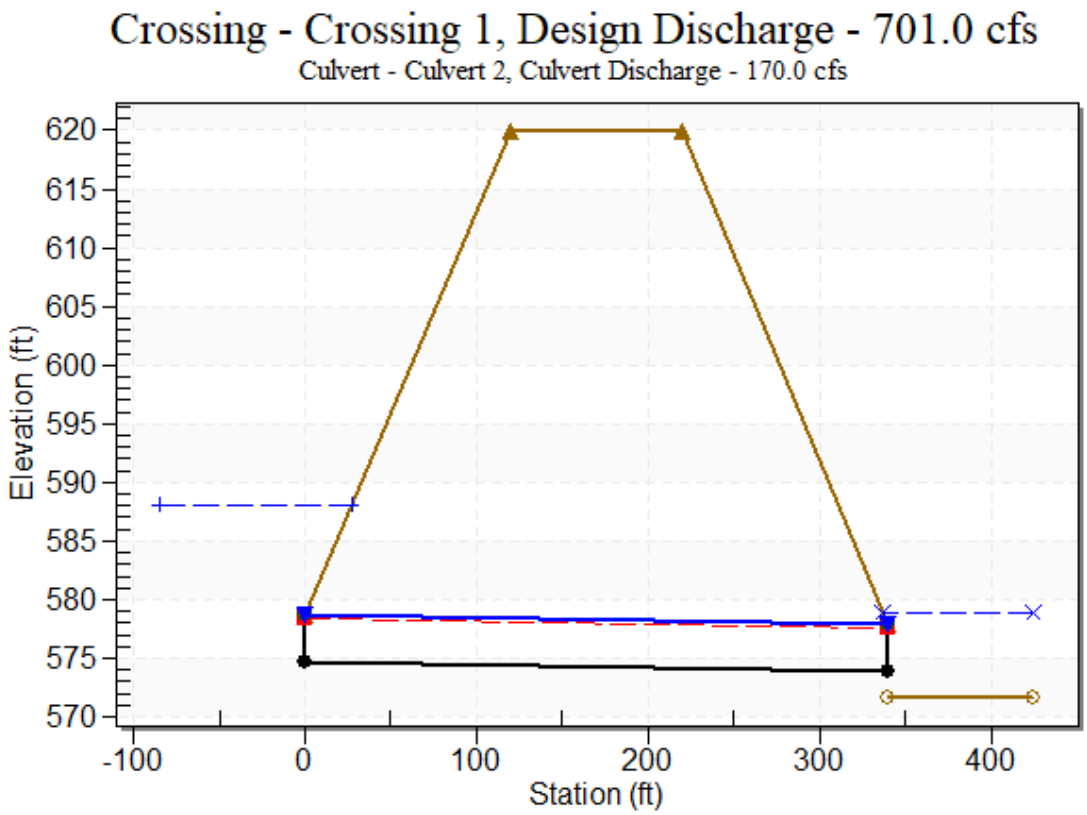
Culvert Length: 340.00 ft, Culvert Slope: 0.0024

****

Culvert Performance Curve Plot: Culvert 2



Water Surface Profile Plot for Culvert: Culvert 2



Site Data - Culvert 2

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 574.71 ft

Outlet Station: 340.00 ft

Outlet Elevation: 573.91 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 2

Barrel Shape: Circular

Barrel Diameter: 3.92 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 4 - Downstream Channel Rating Curve (Crossing: Crossing 1)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
408.00	577.36	5.66	3.48	0.88	0.34
521.00	578.04	6.34	3.63	0.99	0.34
610.00	578.49	6.79	3.75	1.06	0.34
701.00	578.91	7.21	3.86	1.12	0.34

Tailwater Channel Data - Crossing 1

Tailwater Channel Option: Irregular Channel

Roadway Data for Crossing: Crossing 1

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 620.00 ft

Roadway Surface: Paved

Roadway Top Width: 100.00 ft

HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Crossing 1

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
581.41	Q 10	408.00	408.00	0.00	1
583.24	Q 25	521.00	521.00	0.00	1
585.24	Q 50	610.00	610.00	0.00	1
587.66	Q 100	701.00	701.00	0.00	1
620.00	Overtopping	1412.40	1412.40	0.00	Overtopping

Rating Curve Plot for Crossing: Crossing 1

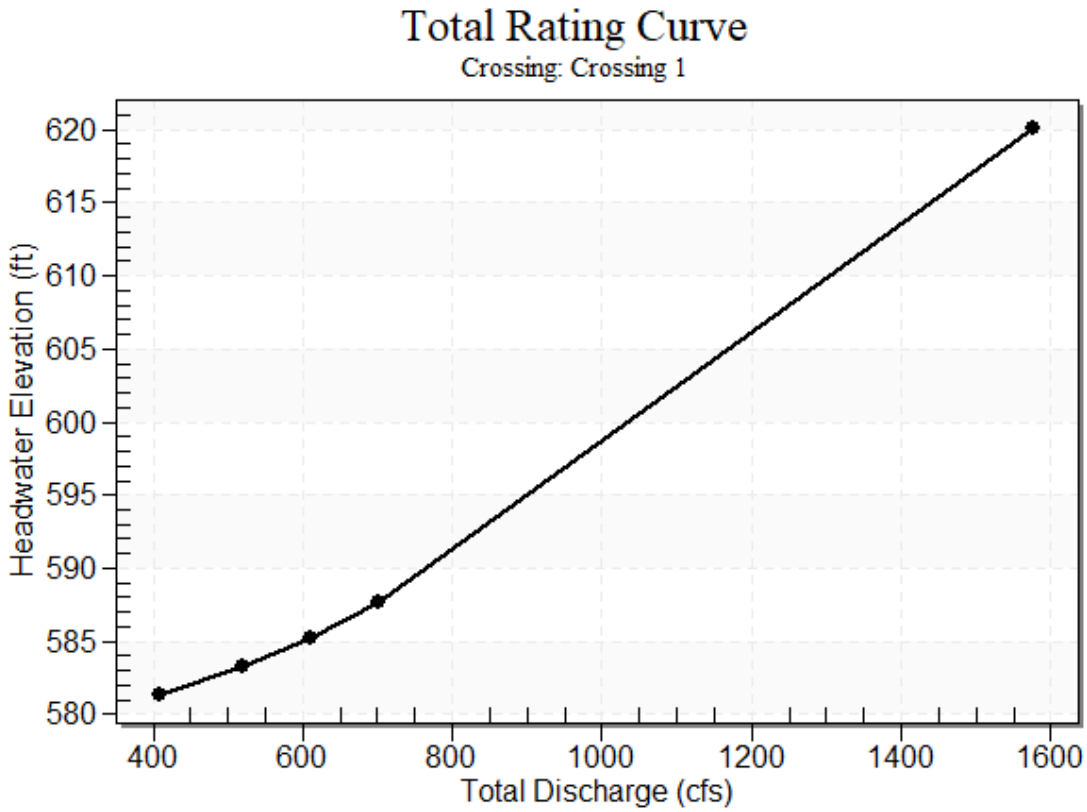


Table 2 - Culvert Summary Table: Culvert 1

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)
Q 10	408.00	408.00	581.41	8.454	8.702	3-M2t	6.214	5.231	5.751	5.961	11.224
Q 25	521.00	521.00	583.24	10.532	10.517	3-M2t	7.500	5.900	6.450	6.660	12.890
Q 50	610.00	610.00	585.24	12.534	12.517	7-M2t	7.500	6.329	6.914	7.124	14.327
Q 100	701.00	701.00	587.66	14.952	14.841	7-M2t	7.500	6.675	7.350	7.560	15.943

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Straight Culvert

Inlet Elevation (invert): 572.71 ft, Outlet Elevation (invert): 571.91 ft

Culvert Length: 340.00 ft, Culvert Slope: 0.0024

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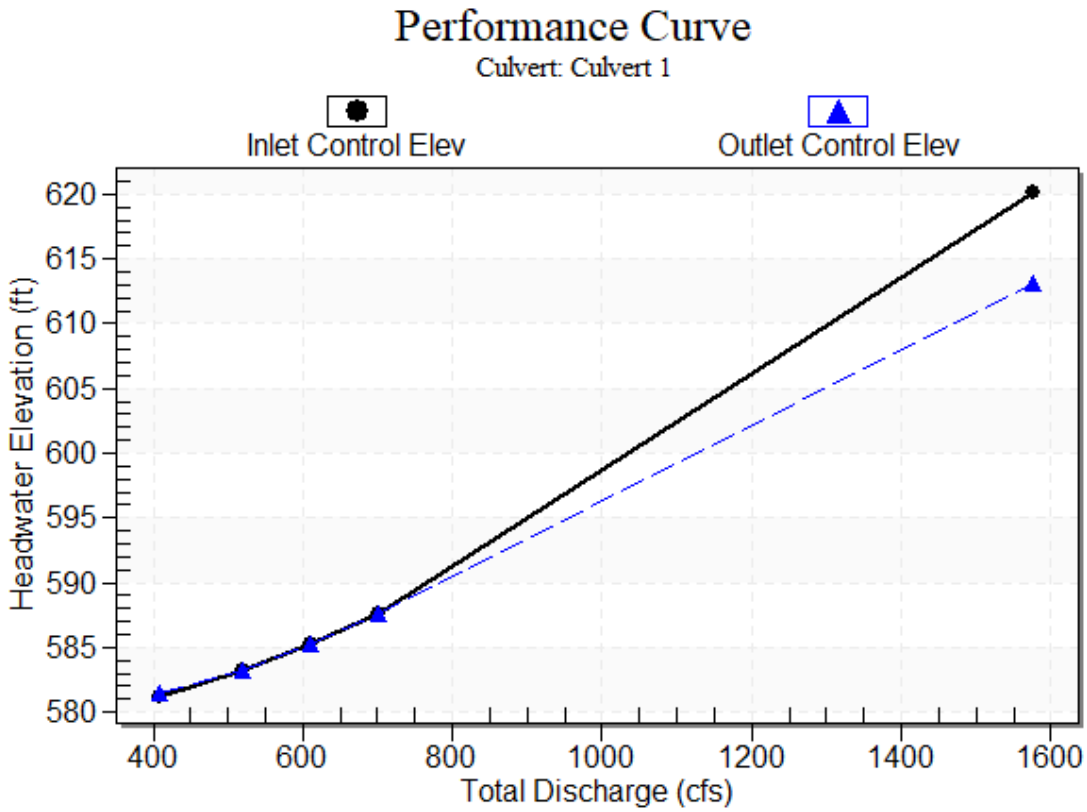
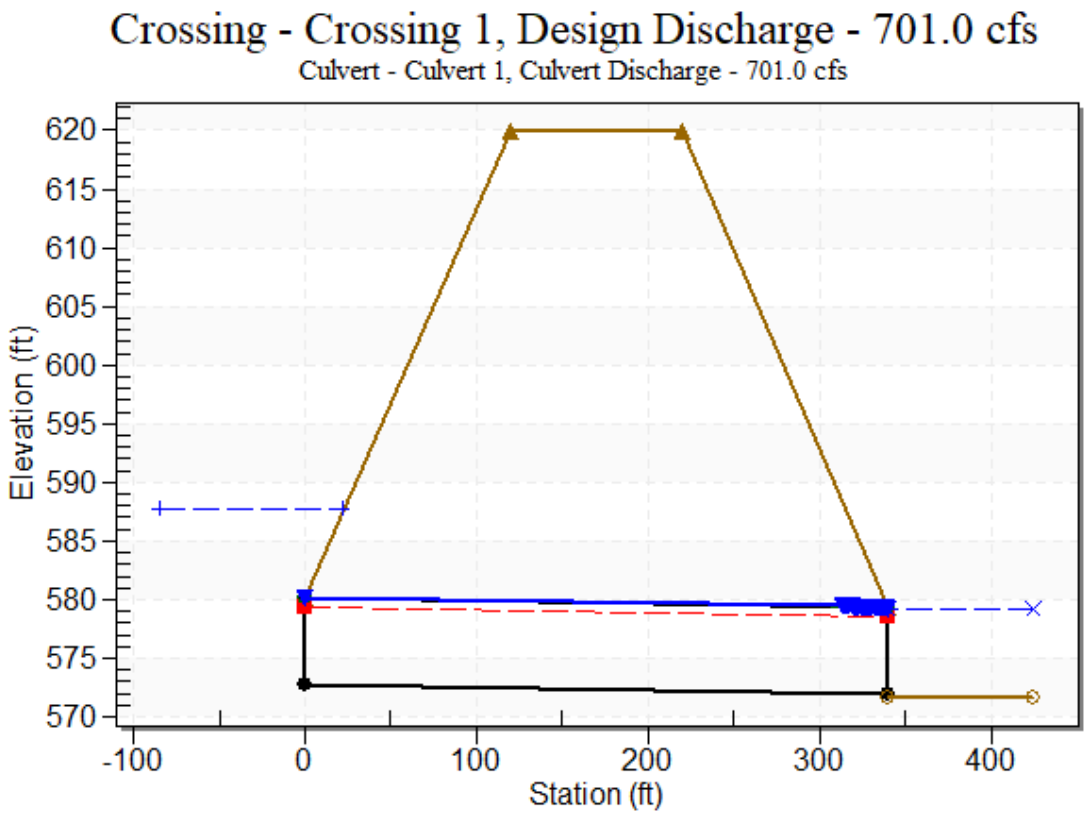
Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 572.71 ft

Outlet Station: 340.00 ft

Outlet Elevation: 571.91 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Circular

Barrel Diameter: 7.50 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Crossing 1)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
408.00	577.66	5.96	3.17	0.74	0.31
521.00	578.36	6.66	3.32	0.83	0.30
610.00	578.82	7.12	3.44	0.89	0.31
701.00	579.26	7.56	3.54	0.94	0.31

Tailwater Channel Data - Crossing 1

Tailwater Channel Option: Irregular Channel

Roadway Data for Crossing: Crossing 1

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 1000.00 ft

Crest Elevation: 620.00 ft

Roadway Surface: Paved

Roadway Top Width: 100.00 ft

Appendix C – Contech Info

CONTECH®
ENGINEERED SOLUTIONS

Structural Plate Design Guide

7th Edition

MULTI-PLATE®

Aluminum Structural Plate

Aluminum Box Culvert

SUPER-SPAN™

SUPER-PLATE®

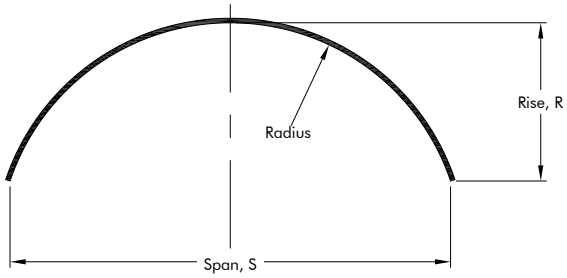
BridgeCor®

TABLE 22. MULTI-PLATE® SINGLE RADIUS ARCH 6″ X 2″											
Dimensions		Rise/Span Ratio	Radius (Inches)	Waterway (Area Ft.²)	Nominal Arc Length	Plate Make-Up (see Note 2)					
Span (Ft.-In.)	Rise (Ft.-In.)				Pi	9 Pi	15 Pi	18 Pi	21 Pi	24 Pi	Total Plates
6-0	1-10	0.30	41	7.9	27	1		1			2
	2-4	0.38	37	10.0	30		2				2
	3-2	0.53	36	15.0	36		1		1		2
7-0	2-5	0.34	45	12.1	33		1	1			2
	2-10	0.41	43	14.9	36		1		1		2
	3-8	0.52	42	20.4	42			1		1	2
8-0	2-11	0.36	51	17.0	39			1	1		2
	3-4	0.42	49	20.3	42			1		1	2
	4-2	0.52	48	26.6	48					2	2
9-0	2-11	0.33	59	19.2	42			1		1	2
	3-11	0.43	55	26.5	48					2	2
	4-8	0.52	54	33.6	54			3			3
10-0	3-6	0.35	64	25.4	48					2	2
	4-5	0.44	61	33.5	54			3			3
	5-3	0.52	60	41.4	60			1	2		3
11-0	3-6	0.32	73	27.8	51		1	2			3
	4-6	0.41	68	36.9	57			2	1		3
	5-9	0.52	66	50.0	66				2	1	3
12-0	4-1	0.34	78	35.3	57			2	1		3
	5-0	0.42	73	45.2	63				3		3
	6-3	0.52	72	59.4	72					3	3
13-0	4-1	0.33	87	38.1	60			1	2		3
	5-1	0.40	81	48.9	66				2	1	3
	6-9	0.52	78	69.7	78			2	2		4
14-0	4-8	0.31	91	47.0	66				2	1	3
	5-7	0.38	86	58.5	72					3	3
	7-3	0.44	84	80.7	84			2		2	4
15-0	4-8	0.52	101	48.9	69				2	2	4
	5-8	0.33	93	62.8	75			3	1		4
	6-7	0.44	91	74.8	81			1	3		4
	7-9	0.52	90	92.6	90				2	2	4
16-0	5-3	0.31	105	60.1	75			3	1		4
	7-1	0.42	97	86.2	87				3	1	4
	8-4	0.52	96	105.3	96			3	2		5
17-0	5-3	0.31	115	63.4	78			2	2		4
	7-2	0.42	103	91.9	90				2	2	4
	8-10	0.52	102	118.8	102			1	4		5
18-0	5-9	0.32	119	74.8	84			2		2	4
	7-8	0.43	109	104.6	96			3	2		5
	8-11	0.50	108	126.0	105				5		5
19-0	6-4	0.33	123	87.1	90			2		2	4
	8-3	0.43	115	118.1	102			1	4		5
	9-5	0.50	114	140.7	111				3	2	5
20-0	6-4	0.32	133	91.0	93				1	3	4
	8-3	0.42	122	124.4	105				5		5
	10-0	0.50	120	156.3	117				1	4	5
21-0	6-11	0.33	137	104.6	99			2	3		5
	8-10	0.42	128	139.2	111				3	2	5
	10-6	0.50	126	172.6	123			1	5		6
22-0	6-11	0.32	146	109.3	102			1	4		5
	8-11	0.40	135	145.9	114				2	3	5
	11-0	0.50	132	189.8	129				5	1	6
23-0	8-0	0.35	147	133.6	111				3	2	5
	9-10	0.43	140	171.1	123			1	5		6
	11-6	0.50	138	207.8	135				3	3	6
24-0	8-6	0.36	152	149.4	117				1	4	5
	10-4	0.43	146	188.3	129				5	1	6
	12-0	0.50	144	226.6	141				1	5	6
25-0	8-7	0.34	160	155.6	120					5	5
	10-10	0.43	152	206.3	135				3	3	6
	12-6	0.50	150	246.2	147				7		7
26-0	8-7	0.33	169	161.4	123			1	5		6
	11-0	0.42	158	214.9	138				2	4	6
	13-1	0.50	156	266.7	153				5	2	7

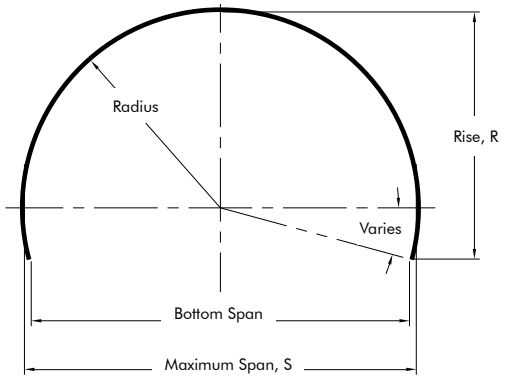
Notes:
1. Dimensions are to inside crests of corrugations are are subject to manufacturing tolerances.
2. These plate arrangements will be furnished unless otherwise noted on assembly drawings.
3. Additional arch sizes with a Rise-to-Span ratio in the range of 0.30 to 0.65 are available. Contact your Contech representative.

TABLE 23. MULTI-PLATE® SINGLE RADIUS ARCH 6″ X 2″							
WEIGHT TABLES							
Arc Length	Gage Thickness (Inches) Weight Shown as Pounds per Foot of Structure						
	12	10	8	7	5	3	1
Pi	(0.111)	(0.140)	(0.170)	(0.188)	(0.218)	(0.249)	(0.280)
24	42	53	64	69	80	91	102
27	50	63	76	82	95	108	120
30	55	69	83	90	104	118	132
33	60	75	90	98	113	128	144
36	64	81	97	106	122	139	155
39	69	87	105	114	131	149	167
42	74	93	112	121	140	159	178
45	79	99	119	130	150	171	191
48	84	105	127	138	160	182	204
51	92	115	139	151	174	198	221
54	96	121	146	159	184	208	233
57	101	127	153	167	193	218	244
60	106	133	160	174	201	229	256
63	110	139	168	182	210	239	267
66	116	145	175	190	220	250	280
69	121	152	183	199	230	262	293
72	126	158	191	207	240	273	305
75	133	168	202	219	254	288	322
78	138	174	209	227	263	298	333
81	143	179	216	235	272	308	345
84	147	185	223	243	281	318	356
87	152	192	231	251	290	330	369
90	157	198	239	260	300	341	382
93	163	205	246	268	310	352	395
96	168	211	254	276	320	364	407
99	175	220	265	288	333	377	422
102	179	226	272	296	342	388	434
105	184	232	279	303	351	398	446
108		238	287	312	361	409	458
111		245	295	320	370	421	471
114		251	302	329	380	432	484
117		257	310	337	390	443	496
120		264	318	345	400	455	509
123			328	356	412	467	523
126			335	364	421	478	535
129			343	372	431	489	547
132				381	440	500	560
135				389	450	512	573
138				398	460	523	585
141				406	470	534	598
144					479	546	611
147					491	557	624
150					503	567	636
153					515	575	650

Notes:
1. Approximate weights include galvanized steel material, bolts, and nuts.
2. Gages 5/16 and 3/8 are available. Contact your Contech representative.



Single Radius Arch – R/S < 0.50



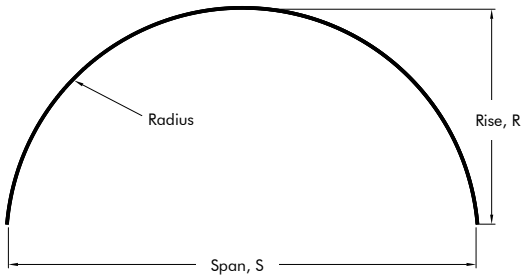
Single Radius Arch – R/S > 0.50

MULTI-PLATE Pedestrian Underpass

Single Radius Arch

TABLE 44. ARCH 9" X 2-1/2" DETAILS

Span (Ft.-In.	Rise (Ft.-In.)	Approx Area (Sq. Ft.)	Radius (Inches)	Rise/ Span Ratio	Total N		Span (Ft.-In.	Rise (Ft.-In.)	Approx Area (Sq. Ft.)	Radius (Inches)	Rise/ Span Ratio	Total N	
					Structure	Rib						Structure	Rib
7-0	2-4	12.0	45.25	.34	11		17-0	5-3	63.5	114.25	.31	26	16
	2-10	14.8	43.00	.40	12			6-3	77.9	107.00	.37	28	16
	3-3	17.5	42.00	.46	13			7-2	91.7	103.50	.42	30	16
	3-8	20.3	42.00	.52	14			8-0	105.2	102.25	.47	32	16
8-0	2-11	17.0	50.50	.36	13			8-10	118.7	102.00	.52	34	16
	3-4	20.2	48.75	.42	14		18-0	5-9	74.8	118.75	.32	28	18
	4-2	26.4	48.00	.52	16			6-9	89.9	112.50	.38	30	18
9-0	2-11	19.1	59.00	.33	14	8		7-8	104.5	109.25	.43	32	18
	3-10	26.3	54.50	.43	16			8-6	118.8	108.25	.47	34	18
	4-8	33.4	54.00	.50	18			8-11	125.9	108.00	.50	35	17
10-0	3-6	25.3	64.00	.35	16	10	19-0	6-4	86.9	123.50	.33	30	18
	4-5	33.3	60.50	.44	18	10		7-4	102.7	118.00	.38	32	18
	5-2	41.2	60.00	.52	20	9		8-2	118.0	115.25	.43	34	18
11-0	3-6	27.8	72.75	.32	17	11		9-0	133.2	114.25	.48	36	18
	4-6	36.8	67.50	.41	19	11		9-5	140.7	114.00	.50	37	17
	5-9	49.9	66.00	.52	22	10	20-0	6-4	91.2	132.50	.32	31	19
12-0	4-1	35.3	77.50	.34	19	11		7-4	108.4	125.75	.37	33	19
	5-0	45.0	73.25	.42	21	11		8-3	124.4	122.25	.41	35	19
	6-3	59.3	72.00	.52	24	12		9-2	140.4	120.50	.46	37	19
13-0	4-1	38.1	86.50	.31	20	12		10-0	156.3	120.00	.50	39	19
	5-1	48.9	80.50	.39	22	12		10-4	164.2	120.00	.52	40	20
	5-11	59.3	78.25	.46	24	12	21-0	6-4	95.4	142.00	.30	32	20
	6-9	69.5	78.00	.52	26	12		7-5	113.5	133.75	.35	34	20
14-0	4-8	46.9	91.25	.33	22	14		8-4	130.7	129.25	.40	36	20
	5-7	58.4	86.00	.40	24	14		9-3	147.6	127.50	.44	38	20
	6-5	69.5	84.25	.46	26	14		10-1	164.3	126.00	.48	40	20
	7-3	80.6	84.00	.52	28	14		10-10	181.0	126.00	.52	42	20
15-0	4-8	50.0	100.50	.31	23	15	22-0	6-11	109.2	142.25	.31	34	20
	5-8	62.6	93.50	.38	25	15		7-11	127.9	139.00	.36	36	20
	6-7	74.7	91.00	.44	27	15		8-11	146.0	135.00	.40	38	20
	7-5	86.5	90.00	.49	29	15		9-9	163.6	133.00	.44	40	20
	7-9	92.5	90.00	.52	30	14		10-7	181.1	132.00	.48	42	20
16-0	5-3	60.0	105.00	.32	25	15		11-5	198.6	132.00	.52	44	20
	6-2	73.3	99.25	.39	27	15	23-0	7-6	123.8	151.00	.33	36	20
	7-1	86.2	96.75	.44	29	15		8-0	133.6	147.25	.35	37	21
	7-11	98.9	96.00	.49	31	15		8-6	143.2	144.50	.37	38	20
	8-3	105.2	96.00	.52	32	14		8-11	152.7	142.25	.39	39	21
								9-5	162.0	140.75	.41	40	20
								9-10	171.3	139.50	.43	41	21
								10-3	180.5	139.00	.45	42	20
								10-8	189.6	138.25	.47	43	21
								11-1	198.8	138.0	.48	44	20
								11-6	207.9	138.00	.50	45	21
								11-11	217.1	138.00	.52	46	20



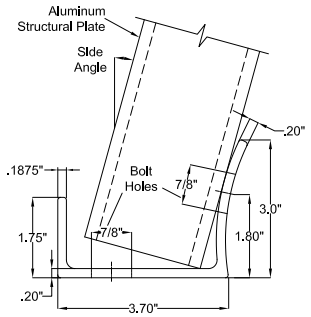
Single Radius Arch

Notes:
1. N = 9.625"
2. Dimensions to inside corrugation crests are subject to manufacturing tolerances.
3. For minimum covers that require reinforcing ribs, columns in the table show minimum lengths of rib.
4. Arch shapes shown are single radius with a rise/span ratio of 0.30 or greater.

TABLE 45. ARCH 9" X 2-1/2" STRUCTURES (HL-93 LOADING)

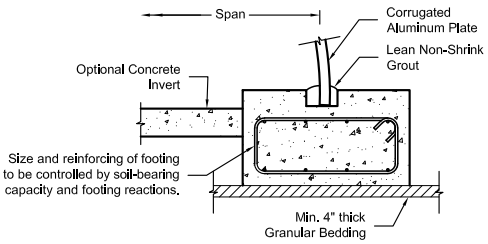
Span (Ft.-In.)	Rise (Ft.-In.)	Approx Area (Sq. Ft.)	Metal Thickness (Inches) — Reinforcing Rib Type Rib Spacing (Inches) (Maximum Cover — Ft.) Minimum Height of Cover (Feet)					
			1.25	1.50	2.00	2.50	3.00	3.50
7-0	2-4	12.0	.175 (45)	.125 (31)	.125 (31)	.125 (31)	.125 (31)	.125 (31)
	2-10	14.8						
	3-3	17.5						
	3-8	20.3						
8-0	2-11	17.0	.250 (63)	.150 (36)	.125 (27)	.125 (27)	.125 (27)	.125 (27)
	3-4	20.2						
	4-2	26.4						
9-0	2-11	19.1		.200 (43)	.125 (24)	.125 (24)	.125 (24)	.125 (24)
	3-10	26.3						
	4-8	33.4						
10-0	3-6	25.3	.125-II-9 (21)	.125-II-18 (21)	.125 (21)	.125 (21)	.125 (21)	.125 (21)
	4-5	33.3						
	5-2	41.2						
11-0	3-6	27.8	.150-II-9 (26)	.125-II-18 (19)	.125-II-27 (19)	.125 (19)	.125 (19)	.125 (19)
	4-6	36.8						
	5-9	49.9						
12-0	4-1	35.3	.225-II-9 (37)	.125-II-9 (18)	.125-II-27 (18)	.125 (18)	.125 (18)	.125 (18)
	5-0	45.0						
	6-3	59.3						
13-0	4-1	38.1		.150-II-9 (22)	.125-II-27 (16)	.150 (22)	.125 (16)	.125 (16)
	5-1	48.9						
	5-11	59.3						
	6-9	69.5						
14-0	4-8	46.9		.200-II-9 (28)	.125-II-18 (15)	.175 (24)	.125 (15)	.125 (15)
	5-7	58.4						
	6-5	69.5						
	7-3	80.6						
15-0	4-8	50.0		.250-II-9 (33)	.125-II-9 (13)	.125-II-27 (13)	.125 (13)	.125 (13)
	5-8	62.6						
	6-7	74.7						
	7-5	86.5						
	7-9	92.5						
16-0	5-3	60.0		.150-IV-9 (17)	.125-II-9 (12)	.125-II-27 (12)	.150 (17)	.125 (12)
	6-2	73.3						
	7-1	86.2						
	7-11	98.9						
	8-3	105.2						
17-0	5-3	63.5		.150-VI-18 (16)	.225-II-18 (26)	.150-II-27 (16)	.175 (19)	.150 (16)
	6-3	77.9						
	7-2	91.7						
	8-0	105.2						
	8-10	118.7						
18-0	5-9	74.8		.150-VI-9 (15)	.175-IV-18 (18)	.125-IV-27 (11)	.200 (21)	.175 (18)
	6-9	89.9						
	7-8	104.5						
	8-6	118.8						
	8-11	125.9						
19-0	6-4	86.9		.150-VI-9 (14)	.125-VI-18 (10)	.125-IV-27 (10)	.125-II-27 (10)	.175 (17)
	7-4	102.7						
	8-2	118.0						
	9-0	133.2						
	9-5	140.7						
20-0	6-4	91.2		.150-VI-9 (13)	.150-VI-9 (13)	.150-IV-27 (13)	.150-II-27 (13)	.200 (19)
	7-4	108.4						
	8-3	124.4						
	9-2	140.4						
	10-0	156.3						
	10-4	164.2						
21-0	6-4	95.4		.175-VI-9 (15)	.175-VI-18 (15)	.175-IV-18 (15)	.175-II-27 (15)	.225 (20)
	7-5	113.5						
	8-4	130.7						
	9-3	147.6						
	10-1	164.3						
	10-10	181.0						
22-0	6-11	109.2		.200-VI-9 (17)	.175-VI-18 (14)	.175-IV-18 (14)	.175-IV-27 (14)	.250 (22)
	8-0	127.9						
	8-11	146.0						
	9-9	163.6						
	10-7	181.1						
	11-5	198.6						
23-0	7-6	123.8		.225-VI-9 (18)	.225-VI-18 (18)	.225-IV-18 (18)	.225-IV-54 (18)	.250-II-27 (21)
	8-0	133.6						
	8-6	143.2						
	8-11	152.7						
	9-5	162.0						
	9-10	171.3						
	10-3	180.5						
	10-8	189.6						
	11-1	198.8						
	11-6	207.9						
	11-11	217.1						

Notes:
1. Table based upon AASHTO LRFD Bridge Design Specification for Highway Bridges.
2. Per AASHTO 12.6.6.3, minimum cover is the vertical distance from the top of the corrugated structure to the bottom of flexible or top of rigid pavement.
3. Minimum cover for off highway construction loads must be checked.
4. Minimum cover heights < span/8 determined by moment capacity analysis.
5. Greater cover heights possible with other plate thickness/rib combinations.
6. Footing reactions are available upon request.



Aluminum Receiving Channel

Weight is equal to 2 lbs per foot per side.



Slotted Concrete Footing

For a single radius arch, the dimensions of the keyway shall be a minimum of 4" height x 8" wide.

Manning's *n* Values for Corrugated Metal Products

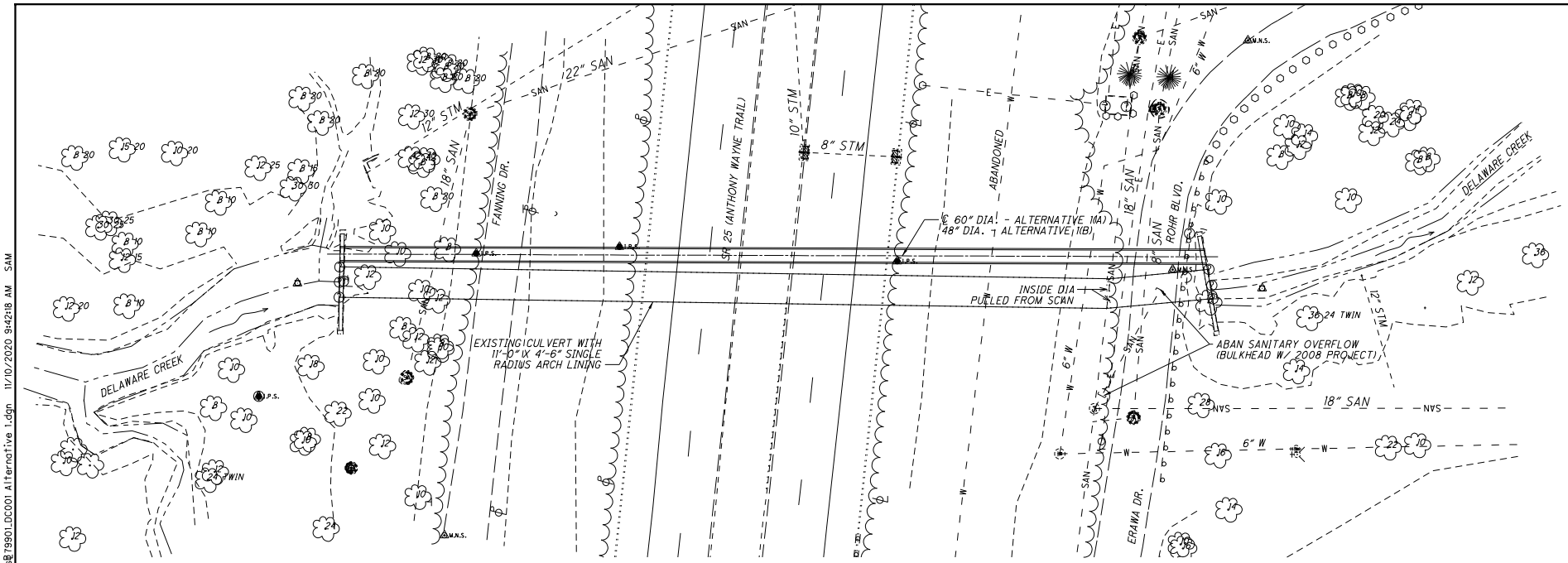
[Per NCSPA]

Pipe Diameter (ft)	Pipe Diameter (in)	1-1/2" x 1/4" Helical ●	2-2/3" x 1/2" Helical ●	2-2/3" x 1/2" Annular ●	3" x 1" Helical ●	3" x 1" Annular ●	5" x 1" Helical ●	6" x 2" Annular (Multi-Plate) ●	9" x 2-1/2" Annular (ALSP & ALBC)	15" x 5-1/2" Annular (BridgeCor)	2-Flange Liner Plate
0.50	6										
0.67	8	0.012									
0.83	10	0.014									
1.0	12		0.011	0.024							
1.3	15		0.012	0.024							
1.5	18		0.013	0.024							
1.8	21		0.013	0.024							
2.0	24		0.015	0.024							
2.5	30		0.017	0.024							
3.0	36		0.018	0.024	0.022	0.027					
3.5	42		0.019	0.024	0.022	0.027					
4.0	48		0.020	0.024	0.023	0.027	0.022				
4.5	54		0.021	0.024	0.023	0.027	0.022				
5.0	60		0.021	0.024	0.024	0.027	0.023	0.033	0.035		0.038
5.5	66		0.021	0.024	0.025	0.027	0.024	0.033	0.035		0.038
6.0	72		0.021	0.024	0.026	0.027	0.024	0.033	0.034		0.038
6.5	78		0.021	0.024	0.027	0.027	0.025	0.033	0.034		0.038
7.0	84		0.021	0.024	0.027	0.027	0.025	0.032	0.034		0.037
7.5	90			0.024	0.027	0.027	0.025	0.032	0.034		0.037
8.0	96			0.024	0.027	0.027	0.025	0.032	0.034		0.037
8.5	102				0.027	0.027	0.025	0.032	0.034		0.037
9.0	108				0.027	0.027	0.025	0.032	0.033		0.037
9.5	114				0.027	0.027	0.025	0.032	0.033		0.037
10.0	120				0.027	0.027	0.025	0.030	0.033		0.035
10.5 to 13.5	126 to 162						0.025	0.030	0.033		0.035
14 to 20	168 to 240							0.028	0.032	0.035	0.033
> 21	> 252							0.028	0.031	0.035	0.033

● from National Corrugated Steel Pipe Association (NCSPA)

ULTRA FLO spiral-ribbed pipe (3/4" x 3/4" x 7-1/2") and Smooth Cor double wall pipe each have a Manning's n of 0.012 for all diameters.

Appendix D – Culvert Plan Sheets



EXISTING STRUCTURE

TYPE: REINFORCED CONCRETE AND STONE ARCH CULVERT (340' LONG)

SIZE: 6' (RISE) X 12' (SPAN)

SKEW: 6°± RF

ALIGNMENT: TANGENT

DATE BUILT: 1900, REHABILITATED AND EXTENDED IN 1951

CONDITION: POOR

SFN: 4801490

DISPOSITION: TO BE REPLACED

PROPOSED STRUCTURE

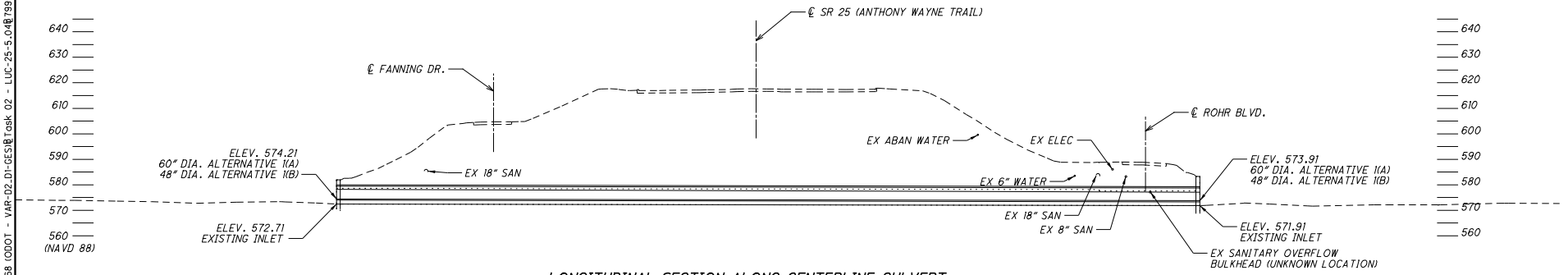
TYPE: 11'-0" X 4'-6" SINGLE RADIUS ARCH CULVERT LINER (340' LONG) WITH 60" DIA. CONCRETE PIPE - ALTERNATIVE 1(A) OR 48" DIA. CONCRETE PIPE - ALTERNATIVE 1(B)

SKEW: 6° RF

ALIGNMENT: TANGENT

SFN:

COORDINATES: LAT N 41° 36' 30.31" LONG W 83° 35' 48.04"



LONGITUDINAL SECTION ALONG CENTERLINE CULVERT

HORIZONTAL SCALE IN FEET 0 10 20 40

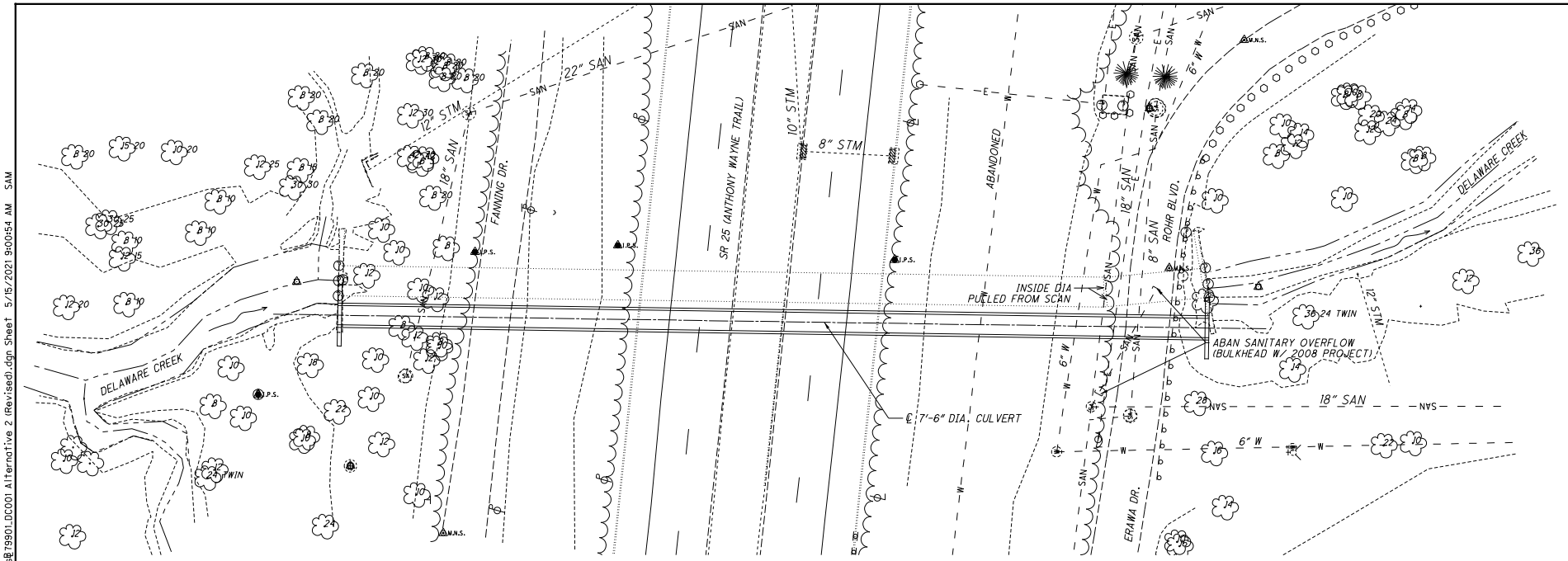
CALCULATED SAM CHECKED XXX

CULVERT GENERAL PLAN AND LONGITUDINAL SECTION - ALTERNATIVE #1

LUC-25-5.04

X / X

1 / 1

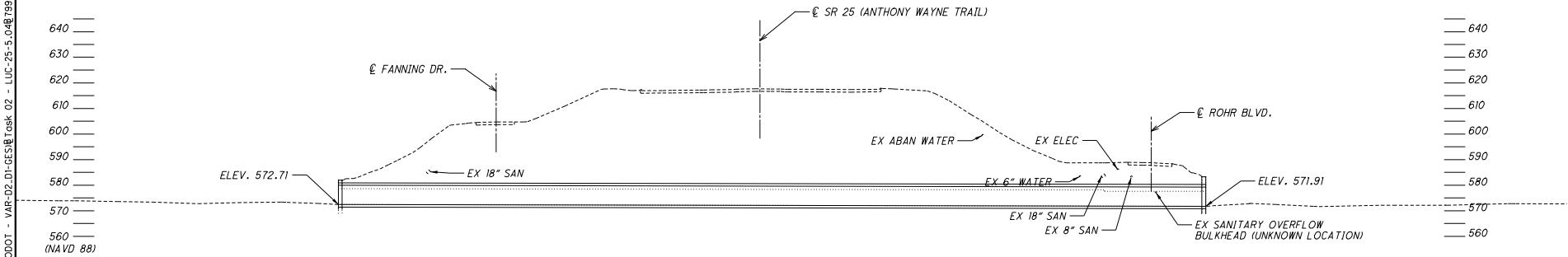


EXISTING STRUCTURE

TYPE: REINFORCED CONCRETE AND STONE ARCH CULVERT (340' LONG)
SIZE: 6' (RISE) X 12' (SPAN)
SKEW: 6°± RF
ALIGNMENT: TANGENT
DATE BUILT: 1900, REHABILITATED AND EXTENDED IN 1951
CONDITION: POOR
SFN: 4801490
DISPOSITION: TO BE REPLACED

PROPOSED STRUCTURE

TYPE: REINFORCED CONCRETE CULVERT (340' LONG)
SIZE: 7'-6" DIAMETER
SKEW: 6° RF
ALIGNMENT: TANGENT
SFN:
COORDINATES: LAT N 41° 36' 30.31" LONG W 83° 35' 48.04"



LONGITUDINAL SECTION ALONG CENTERLINE CULVERT

CULVERT GENERAL PLAN AND
LONGITUDINAL SECTION - ALTERNATIVE #2

HORIZONTAL SCALE IN FEET
0 10 20 40

CALCULATED SAM
CHECKED XXX

LUC-25-5.04

X / X

1 / 1

Appendix E - Cost Estimates

PRELIMINARY COST ESTIMATE
LUC-25-5.04 FEASIBILITY STUDY

Alternative 1(a) - 11'-0" x 4'-6" Single Radius Corrugated Aluminum Arch Culvert Liner Pipe with Additional 60" Diameter Culvert

Portions of Structure Removed					= $	25,000.00
Cofferdams, Cribs and Sheeting					= $	25,000.00
Concrete QC1 Concrete, Footing						
44	C.Y.	@	$	500.00	= $	22,000.00
Concrete QC1 Concrete, Headwall						
62	C.Y.	@	$	1,000.00	= $	62,000.00
Concrete QC1 Concrete, Misc (Liner Pedestal)						
19	C.Y.	@	$	1,200.00	= $	22,800.00
Epoxy Coated Reinforcing Steel						
22000	LB	@	$	1.15	= $	25,300.00
Conduit, 60" Diameter, Bored or Jacked						
340	Foot	@	$	1,450.00	= $	493,000.00
Liner Pipe, 11'-0" x 4'-6" Single Radius Corrugated Pipe						
340	Foot	@	$	890.00	= $	302,600.00
Backfill for Liner Pipe						
340	Foot	@	$	200.00	= $	68,000.00
Total					= $	1,046,000.00

PRELIMINARY COST ESTIMATE
LUC-25-5.04 FEASIBILITY STUDY

Alternative 1(b) - 11'-0" x 4'-6" Single Radius Smooth Arch Culvert Liner Pipe with Additional 48" Diameter Culvert

Portions of Structure Removed					= $	25,000.00
Cofferdams, Cribs and Sheeting					= $	25,000.00
Concrete QC1 Concrete, Footing						
44	C.Y.	@	$	500.00	= $	22,000.00
Concrete QC1 Concrete, Headwall						
62	C.Y.	@	$	1,000.00	= $	62,000.00
Concrete QC1 Concrete, Misc. (Liner Pedestal)						
19	C.Y.	@	$	1,200.00	= $	22,800.00
Epoxy Coated Reinforcing Steel						
22000	LB	@	$	1.15	= $	25,300.00
Conduit, 48" Diameter, Bored or Jacked						
340	Foot	@	$	1,200.00	= $	408,000.00
Liner Pipe, 11'-0" x 4'-6" Single Radius Pipe Smooth Pipe						
340	Foot	@	$	1,200.00	= $	408,000.00
Backfill for Liner Pipe						
340	Foot	@	$	200.00	= $	68,000.00
Total					= $	1,066,000.00

PRELIMINARY COST ESTIMATE
LUC-25-5.04 FEASIBILITY STUDY

Alternative 2 - 90" Diameter Pipe

Portions of Structure Removed					= $	25,000.00
Special - Fill and Plug Existing Conduit					= $	204,000.00
340	Foot	@	$	600.00		
Cofferdams, Cribs and Sheeting					= $	25,000.00
Concrete QC1 Concrete, Footing						
33	C.Y.	@	$	500.00	= $	16,500.00
Concrete QC1 Concrete, Headwall						
47	C.Y.	@	$	1,000.00	= $	47,000.00
Epoxy Coated Reinforcing Steel						
18000	LB	@	$	1.15	= $	20,700.00
Conduit, 90" Diameter, Bored or Jacked						
340	Foot	@	$	3,500.00	= $	1,190,000.00
Total					= $	1,528,000.00