SYCAMORE ACRES DRAINAGE ANALYSIS

ROCKVILLE, MARYLAND

December 21, 2012

Prepared For:
Montgomery County Department of Transportation
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Introduction

The purpose of this report is to present the findings of a drainage study that was performed within the Sycamore Acres community near Rockville, Maryland. The study concentrated on the existing drainage patterns and conditions within the community and poses possible resolutions to any problems that were discovered. The study was focused along Willow Lane where there have been reports of property inundation near the existing culvert under the roadway. The study also included the areas upstream and downstream from Willow Lane.

The project is located between Olney and Aspen Hills in Montgomery County and is just south of MD 200 and just east of Upper Rock Creek Park (a Maryland National Capital property). The project site is within the Washington Metropolitan Area, Rock Creek watershed (02-14-02-06). The existing storm runoff patterns were modeled based on Geographic Information System (GIS) topography and contours, soil properties, and data collected by field visits. The study will calculate the runoff produced by the project area and analyze how effectively the flow is conveyed through the community.

Methodology

Existing drainage patterns and conditions are evaluated based on the amount of runoff generated and how that runoff is routed to a specific Point Of Investigation (POI). The area contributing runoff to a POI is also known as the Drainage Area (DA) for that POI. Storm events that produce rainfall are categorized by the statistical probability that a storm producing that much rainfall in a 24 hour period will occur in a one year time frame. For example, a rainfall that has a 100% probability of occurring (1 in 1 chance) in any given year is termed a “one-year event.” In Montgomery County about 2.70 inches of rain in a 24-hour period produces a one-year storm event. This rainfall depth is termed the one-year design storm. Similarly, a storm that has a 50% (1 in 2) chance of occurring in any given year is termed a “two-year event." A two-year flood occurs when a storm event produces about 2.95 inches of rain in a 24 hour period. The storm that has a 10% (1 in 10) chance of occurring in any given year is termed a “ten-year event." A ten-year flood occurs when a storm event produces 4.87 inches of rainfall in a 24 hour period.

TABLE 1: Rainfall Summary

Storm Event (years)	NOAA Depth (inches)
1	2.70
2	2.95
10	4.87
25	6.13

Urban development has a profound influence on the hydrology in a drainage area. The hydrology of a site changes during the initial clearing and grading that occur during construction. Trees, meadow grasses, and agricultural crops that had intercepted and absorbed rainfall are removed and natural depressions that had temporarily ponded water are graded to a uniform slope. The situation worsens after construction. Roof tops, roads, parking lots, driveways and other impervious surfaces no longer allow rainfall to soak into the ground. Consequently, most rainfall is converted directly to stormwater runoff.

The volume of stormwater runoff produced by a drainage area increases sharply as the impervious cover increases. For example, a one acre parking lot can produce 16 times more stormwater runoff than a one acre meadow each year. The increase in stormwater runoff can be too much for the existing natural drainage system to handle. Stormwater runoff is a powerful force that influences the geometry of streams. After development, both the frequency and magnitude of storm flows increase dramatically. Consequently, urban stream channels experience more bankfull and sub-bankfull flow events each year than they had prior to development. Flow events that exceed the capacity of the stream channel spill out into adjacent floodplains. These are termed “overbank” floods and can damage property and downstream drainage structures.

Under traditional engineering practice, most storm drain systems and culverts in Maryland are designed with enough capacity to safely pass the peak discharge from the ten-year design storm. Open swales are designed with enough flow area to successfully convey the runoff from the two-year event without overtopping the banks of the channel.

Existing Drainage Conditions

The project drainage area is bordered by Emory Lane to the west, Thistlebridge Drive to the east, Pinetree Road to the north, and Holly Ridge Road to the south. There are three existing culverts that route the majority of the runoff through the community. These culverts are located on Sycamore Lane just north of Prince Road, Willow Lane between Pinetree Road and Holly Ridge Road, and on Emory Lane between Monty Court and Walkingfern Drive. See Appendix B for the Location Map and Appendix C for the Drainage Area Map.

The entire project area consists of single family homes with heavily wooded lots approximately 1.25 acres in area. According to the USDA Natural Resources Conservation Service Web Soil Survey the project area consists of both hydrologic group ‘B’ and ‘C’ soils. See Appendix D for the Web Soil Survey results. According to the Web Soil Survey the soils have the following characteristics:

> *Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.*

> *Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.*

The total project area was broken down into three smaller sub-drainage areas corresponding to the area reaching each individual culvert. The Sycamore DA consists of the area east of Sycamore Road, approximately 41.78 acres. The runoff in this area is conveyed along roadside swales and through driveway culverts until it reaches the POI at the existing 49” wide by 33” high metal pipe arch culvert under Sycamore Lane. The runoff then continues westward in a stream channel that connects the Sycamore culvert to the culvert under Willow Lane. There is also an additional 24.28 acre DA that contributes to the Willow Lane culvert, this runoff is conveyed along roadside swales and through driveway culverts until it reaches the twin 30” wide by 19” high elliptical metal pipes running under Willow Lane. The Willow Lane DA is comprised of the area between Willow Lane and Sycamore Lane. Once through the Willow Lane culvert the runoff from the 41.78 acre Sycamore DA and the runoff from the 24.28 acre Willow DA combine and travel in a stream channel following residential property lines towards the Emory Lane culvert. There is also an additional Emory DA of 19.75 acres that consists of the area between Emory Lane and Willow Lane. This DA produces runoff that combines with the flow in the stream channel before it reaches the twin 23” wide by 14” high elliptical concrete pipes running under Emory Lane.

Once the boundaries of the three sub-areas were formed a Runoff Curve Number (RCN) was calculated for each. The RCN is based on the area's hydrologic soil group, land use, treatment and hydrologic condition. The RCN is used to predict the amount of infiltration and runoff an area will produce and is an efficient method for determining the approximate amount of direct runoff from a rainfall event in a particular area. The typical RCN ranges from 30 to 98 with the higher number producing a greater amount of runoff and the lower value corresponding to greater amount of infiltration.

Once the drainage area boundaries and soil types had been identified the next step was to calculate the Time of Concentration (Tc) for each drainage area. The Time of Concentration is defined as the time after the beginning of a rainfall event when all portions of the drainage area are contributing simultaneous runoff to the point of investigation (POI), in this case the POI is each culvert being analyzed. The Tc is calculated as the time it takes for runoff to flow from the most hydraulically remote point of the drainage area to the point of investigation. The Time of Concentration is affected by the type of ground cover, density of the grass and trees, slope of the ground, and the dimensions of swales and channels. Densely vegetated areas such as woods or meadows will produce a longer Tc while impervious areas like pavement or buildings will produce a shorter Tc.

TABLE 2: Drainage Area Summary

AREA (acres)	AREA (square miles)	RCN	Tc (hours)
DRAINAGE AREA TO SYCAMORE LANE			
41.78	0.0653	69.24	0.699
ADDITIONAL DRAINAGE AREA TO WILLOW LANE			
24.28	0.0379	68.48	0.570
ADDITIONAL DRAINAGE AREA TO EMORY LANE			
19.75	0.0309	68.68	0.543

The dimensions and conditions of the existing swales, stream channels, and culverts were visually inspected by an engineer during a site visit. The dimensions of channels, the type of ground cover and any obstructions within the channel or culvert can impact the runoff of each drainage area. See Appendix A for site photos.

Stormwater Runoff Analysis

The WinTR-20 program was used to compute the runoff produced by each drainage area. The runoff is measured in cubic feet per second or cfs. WinTR-20 is a computer program created by the USDA-Natural Resources Conservation Service. The program is used to model the storm event runoff from a watershed. Runoff from multiple drainage areas can be combined into one single POI. TR-20 may be used to evaluate flooding problems, alternatives for flood control (reservoirs, channel modification, and diversion), and impacts of changing land use on the hydrologic response of watersheds. See Appendix F for the WinTR-20 results. The following Table is a summary of the runoff discharge reaching each of the three culverts.

TABLE 3: Runoff Summary

	RUNOFF (cfs)			
DRAINAGE AREA	1-YEAR STORM	2-YEAR STORM	10-YEAR STORM	25-YEAR STORM
SYCAMORE CULVERT	12.0	15.9	53.8	83.1
WILLOW CULVERT	18.7	24.8	85.6	133.0
EMORY CULVERT	24.1	31.9	111.1	173.1

Culvert Capacity Analysis

The HY-8 program was used to evaluate the performance and capacity of the three existing culverts. The HY-8 program was developed by the Federal Highways Administration and is used to evaluate the hydraulics of a culvert system. Results (peak flows) computed by WinTR-20 can be imported into HY-8 and used to design/evaluate different sizes and combinations of culverts. HY-8 uses the runoff into the culvert, the downstream channel dimensions, the culvert dimensions and the roadway elevations to evaluate the culvert performance.

Table 4 on the following page summarizes the performance of the three culverts that were analyzed as part of this study. The DA column represents the discharge from the contributing Drainage Area to each POI, this value was taken from the WinTR-20 results. The CULVERT column represents the total flow through the culvert; this value was calculated by the HY-8 program. The values highlighted in green indicate the runoff amount that the culvert is successfully conveying without overtopping the roadway. The values highlighted in red indicate that the runoff produced by the DA is greater than what the existing culvert can successfully route without overtopping the roadway.

TABLE 4: Culvert Capacity

CULVERT	DISCHARGE (cfs)							
	1-YR STORM		2-YEAR STORM		10-YEAR STORM		25-YEAR STORM	
	DA	CULVERT	DA	CULVERT	DA	CULVERT	DA	CULVERT
SYCAMORE	12.0	12.0	15.9	15.9	53.8	53.8	83.1	**73.55**
WILLOW	18.7	18.7	24.8	24.8	85.6	**33.68**	133.0	**31.92**
EMORY	24.1	**21.21**	31.9	**21.68**	111.1	**20.15**	173.1	**N/A**

The results from the HY-8 program show that the only culvert within the Sycamore Acres study area that can successfully convey the runoff from the 10-year storm event is the culvert under Sycamore Lane. The bolded red numbers in Table 4 represent conditions where the runoff into the culvert is greater than its capacity; resulting in the runoff overtopping the roadway.

When the runoff exceeds the culvert capacity the water begins to pool at the inlet to the pipe causing a buildup of headwater. As the headwater rises it must be displaced, as the depth of the headwater pooling at the inlet begins to increase the area upstream of the culvert will flood until the water surface elevation overtops the roadway. Headwater being discharged over the roadway causes dangerous conditions for drivers; as the depth of the water increases, the chance for hydroplaning and accidents also increases.

At the Willow Lane culvert the runoff from storm events greater than the two-year storm is not successfully passed through the culvert. As the runoff exceeds the culvert capacity the water pooling at the headwall backs up into the upstream channel. Due to the shallow depth of the upstream channel (this will be discussed shortly) the pooling water overtops the banks of the channel and inundates the adjacent properties. The topography of the area upstream from the Willow Culvert is fairly level and a portion of the residential properties are set at a lower elevation than the roadway. The pooling water continues to back-up onto the residential properties until the roadway elevation is reached, at that point the water will overtop the roadway and continue into the channel on the opposite side of Willow Lane (downstream side).

At Emory Lane the twin concrete pipes are set at a shallow depth and there is no headwall. The existing culvert is insufficiently sized to pass the one-year storm. As the headwater begins to pool at the culvert inlet the roadway is quickly overtopped. Due to minimal vertical clearance between the culvert and the roadway, the residential properties upstream from the culvert are not inundated as severely as they are at Willow Lane. The headwater does overtop the channel, but due to the width of the upstream channel and the grading of the residential lots, the runoff will overtop the roadway before it impacts any residential structures.

Based on the GIS topography there is approximately a 10' elevation difference between the crown of the roadway at Emory Lane and the crown of the roadway at Willow Lane. Due to this vertical drop between Willow Lane and Emory Lane there is no correlation between the headwater pooling at the Emory Culvert and the poor performance of the Willow Culvert. The headwater at the Emory Culvert will overtop the roadway before it impacts the performance of the Willow Lane culvert

Culvert Capacity Improvements

Willow Lane

The current culvert under Willow Lane consists of two 30" wide by 19" high elliptical corrugated metal pipes. The culvert has a stone and mortar headwall and no endwall. The top of the existing pipes are approximately 8" below the crown of the roadway. The maximum capacity of the current culvert before runoff overtops the roadway is 34.1 cfs, well below the estimated 94.7 cfs of runoff from the 10-year storm. The southern pipe of the Willow culvert is in poor condition. Figure 6 in Appendix A shows the existing corrosion damage to the metal pipe. The majority of the pipe invert is missing and the soil below the pipe has been exposed.

The capacity of the culvert under Willow Lane needs to be improved to convey the 10-year storm successfully (without overtopping). The cross sectional area of the two existing metal pipes is too small to pass the runoff from the Willow DA and the upstream Sycamore DA. There are various culvert options to achieve this; the first option would be to replace the existing culvert with a precast concrete box culvert. The minimum interior dimensions of a box culvert would need to be 6.0' wide by 2.0' high, this is not a typical size produced by precast manufacturers and may need to be substituted with a more common 6'x3' culvert. In order to reduce the impacts of lowering the upstream and downstream channel depth to accept a culvert 3.0' in height compared to the existing culvert that is only 19" high, the culvert should be embedded 1.0' into the channel and designed so that the top of the culvert could be the wearing surface of the roadway. Another option would be to replace the two existing elliptical pipes with three 34" wide by 22" high elliptical concrete pipes. The three-pipe design represents the minimum recommended design to pass the runoff from the 10-year storm. The design of a two-culvert system would require significant lowering of the channel upstream and downstream of the culvert which would be unpractical.

The lowering of the channel invert is required to accommodate a pipe with a taller cross section and also to lower the upstream channel in order to provide a greater headwater depth for increased runoff storage before the flow is routed through the culvert. Redesign of the upstream and downstream channel would require work within the property lines of the existing residences adjacent to the Willow Lane culvert. The downstream channel will need to be widened to a minimum 2.0' wide flat bottom channel with 3:1 side slopes. The lowering and widening of the channel upstream and downstream of the Willow Lane culvert will also help contain the runoff from the 10-year storm and prevent overtopping of the channel banks. If the invert of the upstream channel is lowered 1.20' it will require reconstruction of the upstream channel for approximately 60 linear feet. Lowering of the downstream channel will require reconstruction for approximately 80 linear feet.

Emory Lane

The current culvert under Emory Lane consists of twin 23" wide by 14" high elliptical concrete pipes. The culvert has no headwall or endwall. The top of the existing pipes are approximately 10" below the crown of the roadway. The maximum capacity of the current culvert before runoff overtops the roadway is 21.68 cfs, well below the estimated 111.1 cfs of runoff from the 10-year storm.

The capacity of the culvert under Emory Lane needs to be improved to convey the 10-year storm successfully (without overtopping). The cross sectional area of the two existing concrete pipes is too small to pass the runoff from the Emory DA and the upstream Willow and Sycamore drainage areas. There are various culvert options to achieve this; the first option would be to replace the existing culvert with a precast concrete box culvert. The minimum interior dimensions of a box culvert would need to be 7.0' wide by 2.0' high, this is not a typical size produced by precast manufacturers and may need to be substituted with a more common 7'x3' culvert. In order to reduce the impacts of lowering the upstream and downstream channel depth to accept a culvert 3.0' in height compared to the existing culvert that is only 14" high, the culvert should be embedded 1.0' into the channel and designed so that the top of the culvert could be the wearing surface of the roadway. Another option would be to replace the two existing elliptical pipes with three 38" wide by 24" high elliptical concrete pipes. The three-pipe design represents the minimum recommended design to pass the runoff from the 10-year storm. The design of a two-culvert system would require significant lowering of the channel upstream and downstream of the culvert.

The lowering of the channel invert is required to accommodate a pipe with a taller cross section and also to lower the upstream channel in order to provide a greater headwater depth for increased runoff storage before the flow is routed through the culvert. Redesign of the upstream channel would require work within the property lines of the existing residences adjacent to the Emory Lane culvert. The downstream channel improvements would be within Upper Rock Creek Park and any construction within this property will require the approval of Maryland National Capital Park and Planning Commission. The lowering of the channel upstream and downstream of the Emory Lane culvert will also help contain the runoff from the 10-year storm and prevent overtopping of the channel banks. If the invert of the upstream channel is lowered the construction would extend approximately 140 linear feet upstream. If the downstream channel is lowered it would extend for approximately 160 linear feet into the Park property. Appendix G includes calculations to support the proposed improvements.

Stream Channel Capacity Improvements

Sycamore Lane to Willow Lane

The runoff exiting the culvert under Sycamore Lane enters a poorly defined channel running along a residential property line between 16006 and 16012 Sycamore Lane. The channel is shallow and the invert is covered with leaves, rocks, and branches. As the runoff reaches the end of these two properties it makes a bend and runs along the rear of the 16013 Willow Lane property. The channel continues to be poorly defined and there are various collections of dirt, leaves, branches, and fallen trees that hinder the flow of the channel. The channel then makes another bend and runs along the property line between 16013 and 16017 Willow Lane. A berm has been constructed on the 16017 side of the property line; the top of the berm is at a high enough elevation to prevent any runoff from the channel to enter the 16017 property. The flow is forced along the base of the berm in a shallow grass swale on the 16013 property. When the flow reaches Willow Lane it is forced to make an abrupt bend toward the headwall of the culvert due to the construction of the berm.

The two-year storm discharge from the Sycamore culvert was calculated as 15.9 cfs; as the flow nears the Willow Culvert the runoff increases to 24.8 cfs. If a trapezoidal shaped grass channel was constructed to convey this flow it would need to have a minimum 2.0’ wide flat bottom and 3:1 sides with a total depth of 1.1'. Figure 1 depicts the minimum required swale dimensions.

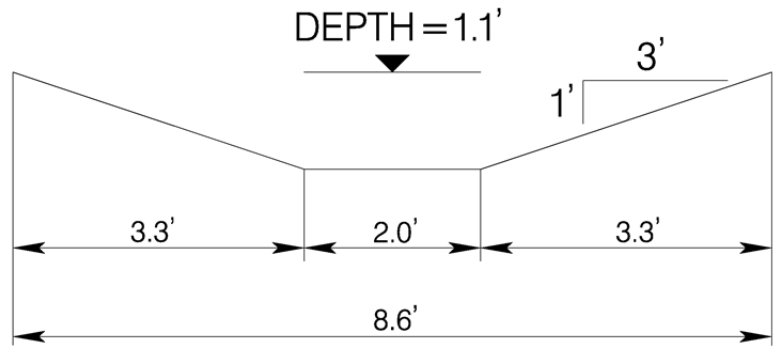


FIGURE 1: Sycamore to Willow Swale

The entire swale from Sycamore Lane to Willow Lane would benefit if the invert was excavated to the proper depth and width. The poor shape and heavy debris build-up in the channel impair the ability of the flow to travel within the swale. The berm that was constructed on the 16017 Willow Lane property prevents the flow from following its natural pattern along the property line. The flow is now forced onto the adjacent property and no longer has a direct path into the Willow Lane culvert. The flow into the culvert would benefit if the berm was removed and a channel having proper dimensions was excavated along the property line allowing the runoff to flow directly into the culvert.

<u>Willow Lane to Emory Lane</u>

The runoff exiting the culvert under Willow Lane is forced to make a 90 degree bend and run southward along Willow Lane and then make another 90 degree bend and run along the property line between 16006 and 16012 Willow Lane. As the flow nears Emory Lane it runs along the property line between 16105 and 16109 Emory Lane. The channel along Willow Lane and between the 16006 and 16012 properties is in fair condition. It could be improved by grading a flat bottom and removing the grass and sediment build-up especially at the 90 degree bends. As the flow enters the swale between the properties on Emory Lane the channel becomes less defined, and there is heavy grass cover on all sides of the channel (which impede the flow). This section of the channel would benefit from excavation to lower the invert of the channel and widen the channel to a minimum 2.0' flat bottom swale.

The two-year storm discharge from the Willow culvert was calculated as 24.8 cfs; as the flow nears the Emory Culvert the runoff increases to 31.9 cfs. If a trapezoidal shaped grass channel was constructed to convey this flow it would need to have a minimum 2.0' wide flat bottom and 3:1 sides with a total depth of 1.4'. Figure 2 depicts the minimum required swale dimensions.

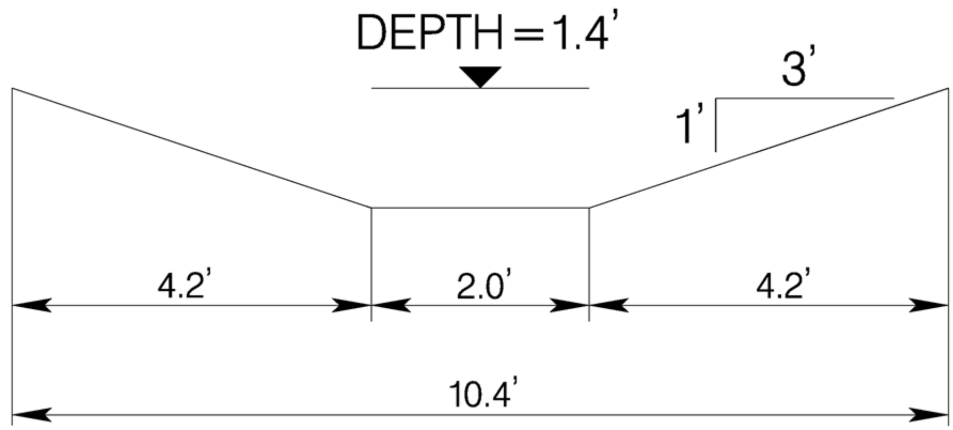


FIGURE 2: Willow to Emory Swale

Any construction to the existing drainage swales will need to be performed on private residential property. The alignment of the existing stream channel may need to be altered in order to avoid tree and root impacts. The 90 degree bends should try to be avoided and replaced with a more gradual flow path. If channel reconstruction is performed, the neighboring property owners will need to realize that periodic mowing and maintenance is vital to the health of the stream channel. Removal of leaves, sediment, and fallen branches will help ensure that the channel can convey the runoff from the 2-year storm event.

Conclusion

The Sycamore Acres community is an example of a neighborhood that was originally constructed by the community developer over sixty years ago with little consideration given to Montgomery County drainage design standards. The existing runoff is routed through roadside ditches and also along residential property lines often in shallow narrow channels. The existing culverts under Willow Lane and Emory lane have a shallow embedment depth and are undersized. The two culverts cannot pass the 10-year storm without the roadway being overtopped.

In order to convey the 10-year storm the culverts under Willow and Emory Lanes will need to be increased from two barrel to three barrel culverts or to precast concrete box culverts. The size (cross sectional area) of the existing pipes will need to be increased to improve performance. The inverts of the existing culverts as well as the upstream and downstream channels will need to be lowered in order to pass the 10-year storm and to provide proper clearance between the crown of the pipes and the roadway paving section.

A drainage system that can convey the 10-year storm will mark a significant improvement to the Sycamore Acres community. An improved system can reduce the frequency that runoff overtops the roadway and inundates adjacent properties. Improved drainage conditions will help increase driver safety and reduce damage to residential properties.

APPENDIX A

SITE PHOTOS

FIGURE 1: Chanel Upstream of Sycamore Culvert

FIGURE 2: Sycamore Culvert Headwall

FIGURE 3: Sycamore CMP Arch

FIGURE 4: Channel Upstream of Willow Culvert

FIGURE 5: Willow Culvert Headwall

FIGURE 6: Willow Culvert Southern Pipe

FIGURE 7: Willow Culvert Outlet

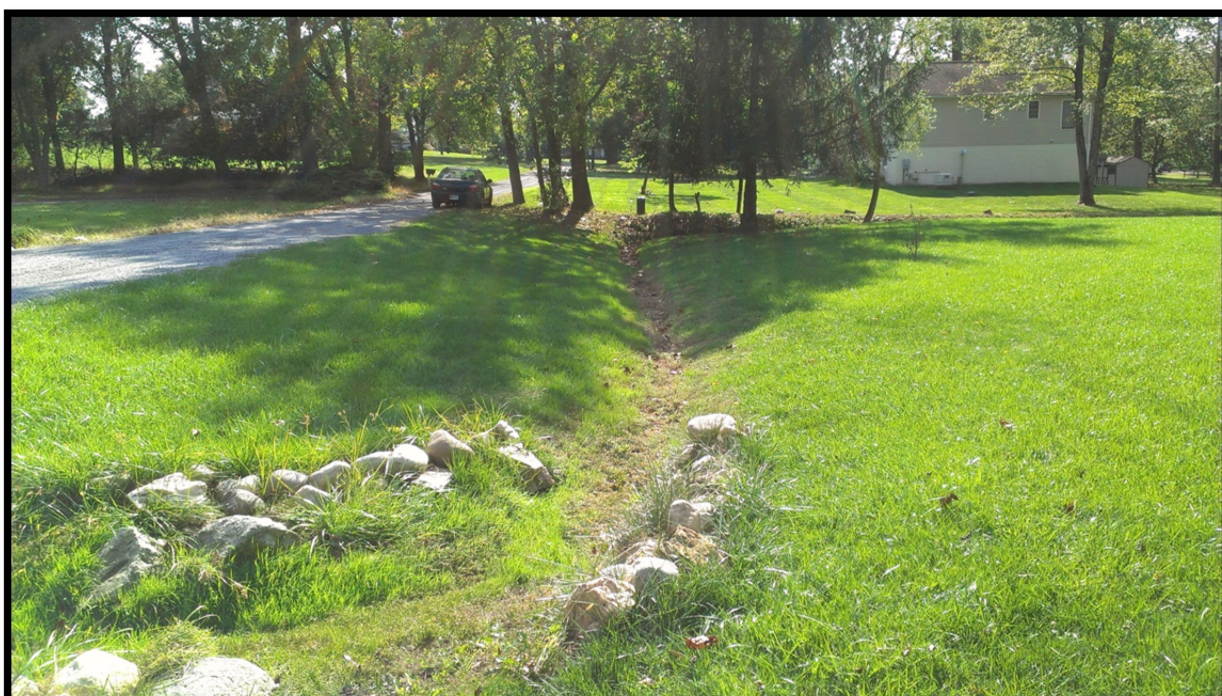


FIGURE 8: Downstream of Willow Culvert

FIGURE 9: Upstream of Emory Culvert

FIGURE 10: Inlet to Emory Culvert

FIGURE 11: Emory RCP Culvert

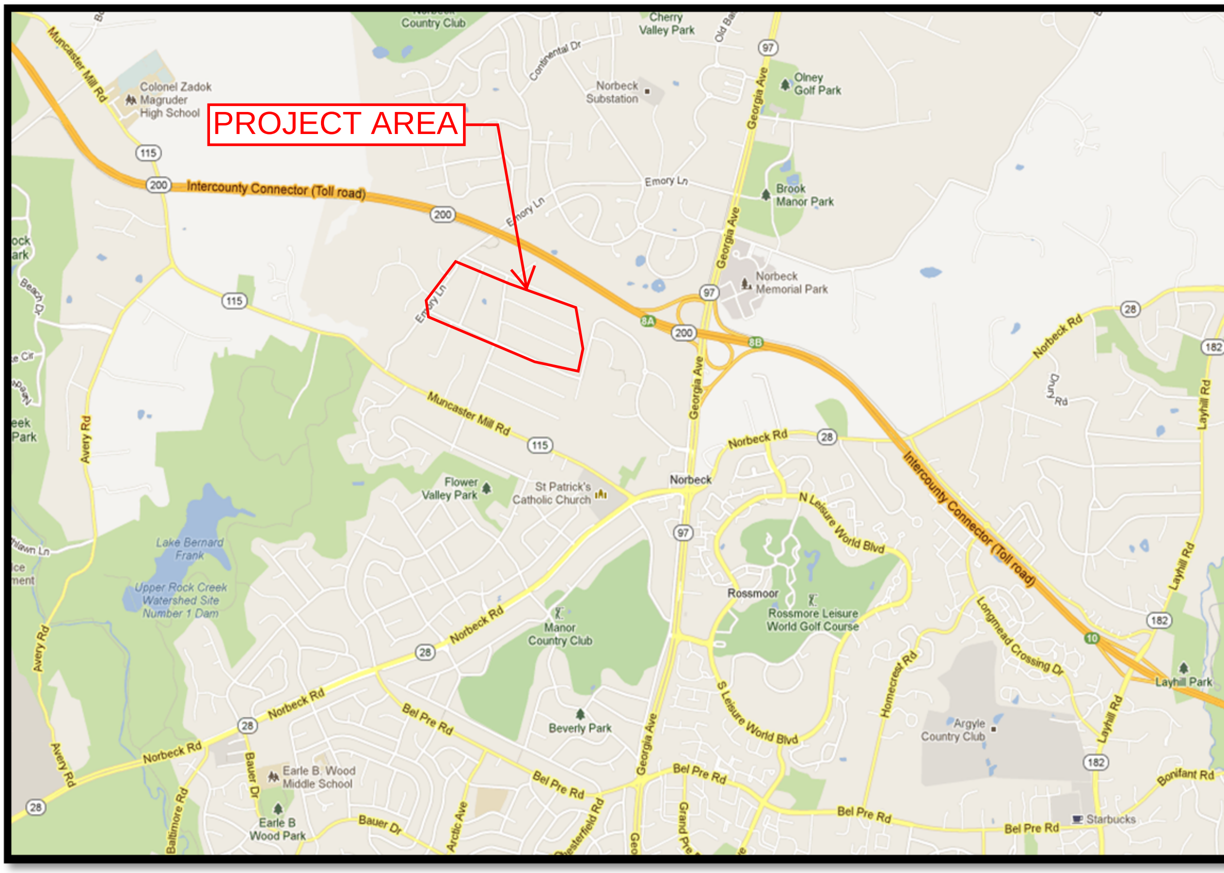
FIGURE 12: Emory Culvert Outlet and Downstream

FIGURE 13: Willow Culvert Upstream Berm

FIGURE 14: Channel Downstream of Willow Culvert Through Vacant Property

APPENDIX B

LOCATION MAP



LOCATION MAP

APPENDIX C

DRAINAGE AREA MAP

LEGEND

- DA BOUNDARY
- Tc PATH
- SOIL BOUNDARY
- B — SOIL TYPE

THE WILSON T. BALLARD CO.
CONSULTING ENGINEERS
OWINGS MILLS, MARYLAND

NO.	REVISION	DATE	BY

MONTGOMERY COUNTY
DEPARTMENT OF TRANSPORTATION
ROCKVILLE, MARYLAND

RECOMMENDED FOR APPROVAL

Chief, Transportation Planning and Design Section — Date

APPROVED

Chief, Division of Transportation Engineering — Date

Designed by : TMR Drawn by : BEL Checked by : PDU

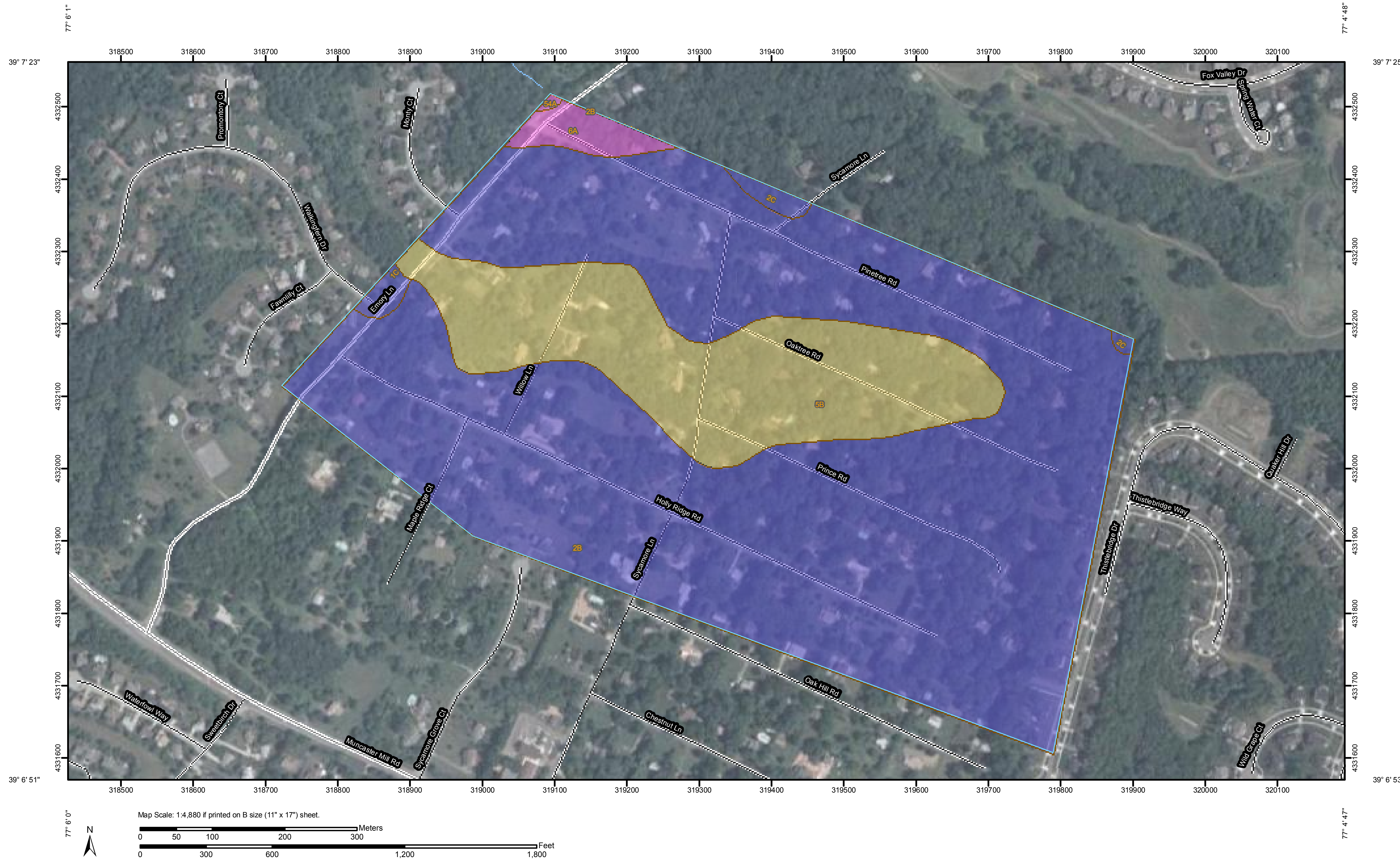
WILLOW LANE
CENTERWAY ROAD TO WOODFIELD ROAD (MD 124)

SCALE: 1" = 200' DATE: DEC., 2012

Project No. : 501109 SHEET ____ OF X

APPENDIX D

SOIL MAPPING


77° 6' 1"
77° 4' 48"
39° 7' 23"
39° 7' 25"
318500
318600
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4332100
4332000
4331900
4331800
4331700
4331600
54A
2B
6A
2C
1C
5B
2C
2B
Promontory Ct
Monty Ct
Wallingford Dr
Fawnlilly Ct
Emory Ln
Sycamore Ln
Pinetree Rd
Oaktree Rd
Willow Ln
Prince Rd
Holly Ridge Rd
Maple Ridge Ct
Sycamore Ln
Thistlebridge Dr
Thistlebridge Way
Quaker Hill Dr
Fox Valley Dr
Spring Water Ct
Oak Hill Rd
Chestnut Ln
Muncaster Mill Rd
Sycamore Grove Ct
Sweetbirch Dr
Waterfowl Way
Wild Grape Ct
39° 6' 51"
39° 6' 53"
77° 6' 0"
77° 4' 47"
Map Scale: 1:4,880 if printed on B size (11" x 17") sheet.
N
Meters
0 50 100 200 300
Feet
0 300 600 1,200 1,800

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Map Units

Soil Ratings

A

A/D

B

B/D

C

C/D

D

Not rated or not available

Political Features

Cities

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

MAP INFORMATION

Map Scale: 1:4,880 if printed on B size (11" × 17") sheet.

The soil surveys that comprise your AOI were mapped at 1:15,840.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 18N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Montgomery County, Maryland
Survey Area Data: Version 7, Feb 2, 2007

Date(s) aerial images were photographed: 6/21/2005

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Hydrologic Soil Group— Summary by Map Unit — Montgomery County, Maryland (MD031)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
1C	Gaila silt loam, 8 to 15 percent slopes	B	0.7	0.5%
2B	Glenelg silt loam, 3 to 8 percent slopes	B	115.6	77.6%
2C	Glenelg silt loam, 8 to 15 percent slopes	B	0.9	0.6%
5B	Glenville silt loam, 3 to 8 percent slopes	C	29.3	19.7%
6A	Baile silt loam, 0 to 3 percent slopes	D	2.4	1.6%
54A	Hatboro silt loam, 0 to 3 percent slopes, frequently flooded	D	0.1	0.1%
Totals for Area of Interest			**149.0**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: *None Specified*

Tie-break Rule: Higher

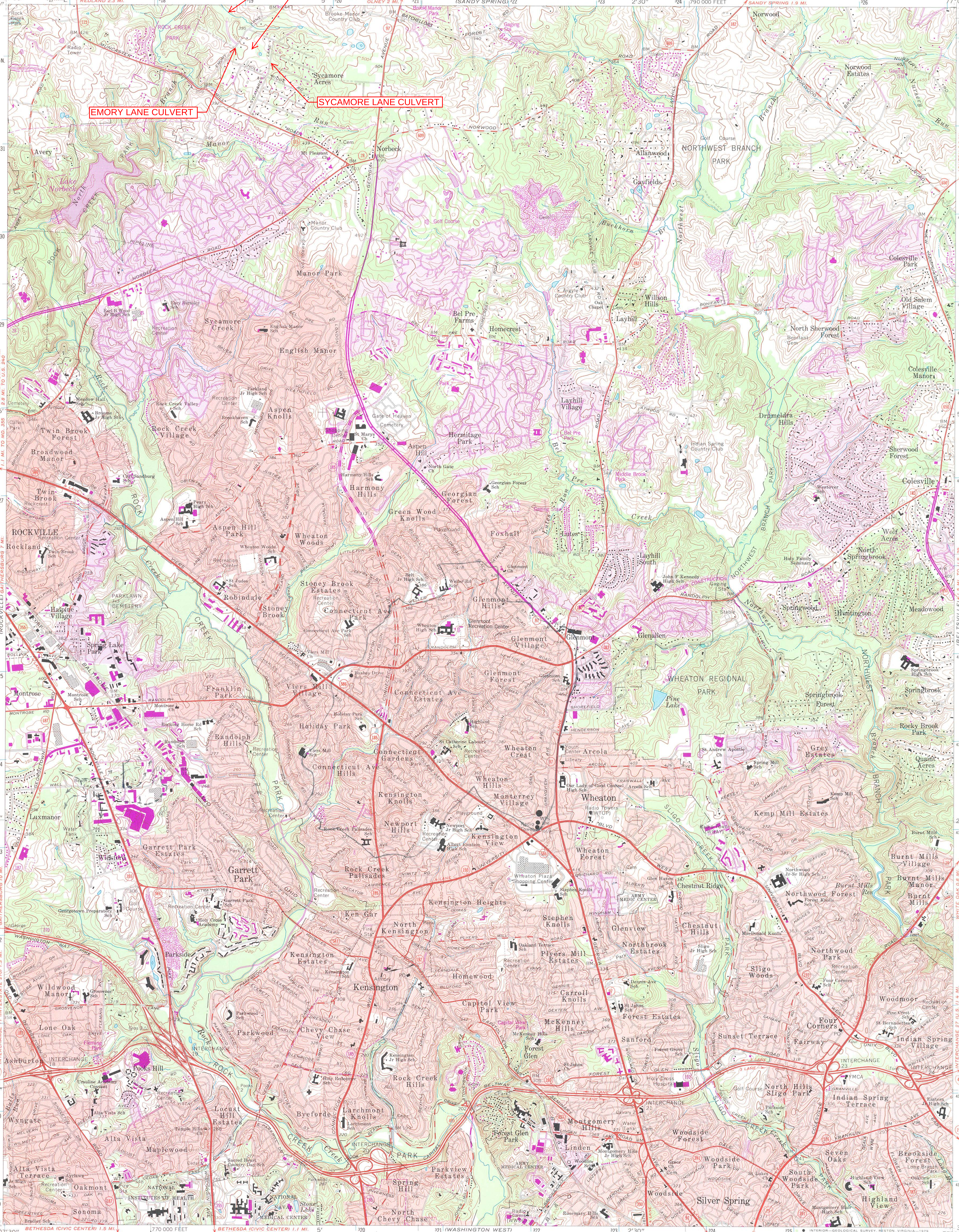
APPENDIX E

USGS MAP

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

KENSINGTON QUADRANGLE
MARYLAND–MONTGOMERY CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

F-20



Mapped, edited, and published by the Geological Survey
Control by USGS, USC&GS, and WSSC
Topography by photogrammetric methods from aerial photographs taken 1955. Field checked 1956. Revised 1965
Polyconic projection. 1927 North American datum
10,000-foot grid based on Maryland coordinate system
1000-meter Universal Transverse Mercator grid ticks, zone 18, shown in blue
To place on the predicted North American Datum 1983 move the projection lines 8 meters south and 26 meters west as shown by dashed corner ticks
There may be private inholdings within the boundaries of the National or State reservations shown on this map
Fine red dashed lines indicate selected fence and field lines where generally visible on aerial photographs. This information is unchecked
Red tint indicates areas in which only landmark buildings are shown

UTM GRID AND 1979 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

Areas covered by dashed light-blue pattern are subject to controlled inundation to 351 feet

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

QUADRANGLE LOCATION

ROAD CLASSIFICATION
Heavy-duty — Light-duty
Medium-duty — Unimproved dirt
Interstate Route — U. S. Route — State Route

KENSINGTON, MD.
N3900—W7700/7.5
1965
PHOTOREVISED 1979
DMA 5562 II SE—SERIES V833

Boundary lines shown in purple compiled from latest information available from the controlling authority
Purple tint indicates extension of urban areas
Revisions shown in purple and woodland compiled from aerial photographs taken 1977 and other source data. This information not field checked. Map edited 1979

F-20

APPENDIX F

TR-20 RESULTS

```
WinTR-20 Printed Page File      Beginning of Input Data List
U:\Montgomery County Drainage\Willow Lane\Willow Lane.inp

WinTR-20: Version 1.11                    0         0         0.1       0
Willow Lane Culvert Investigation
Existing Conditions - 12/05/12 - TMR

SUB-AREA:
          Sycamore  R01                   0.0653    69.24     0.699
          Willow    R02                   0.0379    68.48     0.570
          Emory     OUTLET                0.0309    68.68     0.543

STREAM REACH:
          R01       R02       Willow                830.      830.
          R02       OUTLET    Emory                 694.      694.


STORM ANALYSIS:
          Storm 01            0.0       2.70      Type II   2
          Storm 02            0.0       2.95      Type II   2
          Storm 10            0.0       4.87      Type II   2
          Storm 25            0.0       6.13      Type II   2
          Storm 50            0.0       7.23      Type II   2
          Storm 100           0.0       8.46      Type II   2

STREAM CROSS SECTION:
          Sycamore  454.0               454.0
                    450.0     0.        0.        0.        .022
                    450.3     1.52      0.96      4.4       .021
                    451.0     18.51     6.0       10.0      .022
                    452.0     92.89     20.0      18.0      .022
                    454.0     513.52    72.0      34.0      .022
          Willow    410.5               412.0
                    410.0     0.        0.        0.        .021
                    410.5     1.875     0.75      2.0       .021
                    411.0     29.063    7.75      12.0      .021
                    412.0     145.775   29.75     32.0      .021
                    412.5     272.72    48.25     42.0      .021
          Emory     401.5               403.5
                    400.0     0.        0.        0.        .012
                    401.5     24.745    7.125     8.5       .012
                    402.5     94.068    24.625    26.5      .012
                    403.5     296.058   65.125    54.5      .012




GLOBAL OUTPUT:
                    0.1       0.050     NNNNN     NNNNNN




WinTR-20 Printed Page File      End of Input Data List
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Willow Lane Culvert Investigation
Existing Conditions - 12/05/12 - TMR

Name of printed page file:
U:\Montgomery County Drainage\Willow Lane\Willow Lane.out

Area or Reach Identifier	Drainage Area (sq mi)	Alternate	Storm 01 (cfs)	Storm 02 (cfs)	Storm 10 (cfs)	Storm 25 (cfs)	Storm 50 (cfs)
			----------- Peak Flow by Storm -----------				
Sycamore	0.065		12.0	15.9	53.8	83.1	110.4
Willow	0.038		7.4	9.9	34.6	53.9	71.7
Emory	0.031		6.4	8.5	29.4	45.7	60.8
R01	0.065	Sycamore	12.0	15.9	53.8	83.1	110.4
DOWNSTREAM			12.0	15.8	53.8	83.0	110.2
R02	0.103	Willow	18.7	24.8	85.6	133.0	176.8
DOWNSTREAM			18.7	24.8	85.3	132.7	176.7
OUTLET	0.134	Emory	24.1	31.9	111.1	173.1	231.1

```
 Area or    Drainage               ----------- Peak Flow by Storm -----------
  Reach       Area    Alternate  Storm 100
```

Identifier	(sq mi)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
Sycamore	0.065	142.0				
Willow	0.038	92.5				
Emory	0.031	78.1				
R01	0.065	142.0				
DOWNSTREAM		142.0				
R02	0.103	227.7				
DOWNSTREAM		227.5				
OUTLET	0.134	297.9				

APPENDIX G

HY-8 RESULTS

HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Willow Option 2

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Willow Option 2 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
400.38	1-YR	18.70	18.70	0.00	1
400.60	2-YR	24.80	24.80	0.00	1
402.72	10-YR	85.60	85.60	0.00	1
403.58	25-yr	133.00	101.87	30.94	5
403.34	Overtopping	97.58	97.58	0.00	Overtopping

Rating Curve Plot for Crossing: Willow Option 2

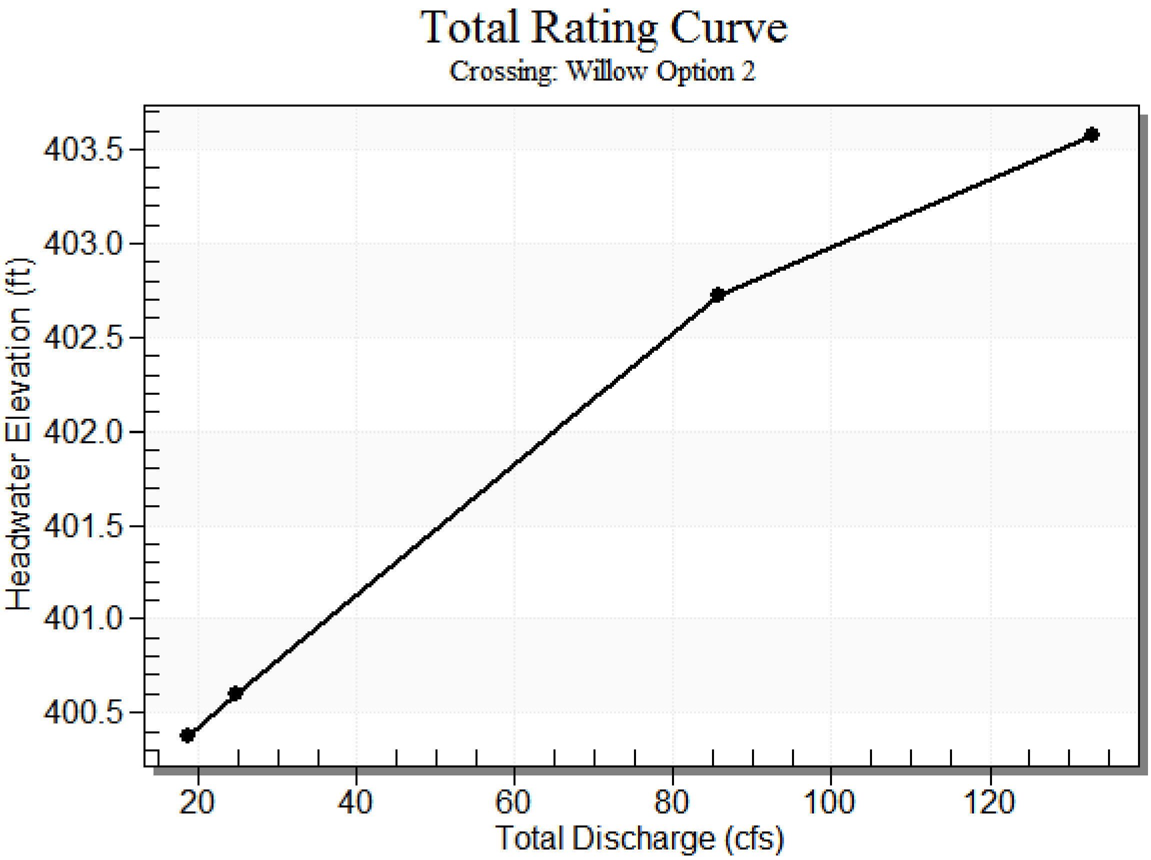


Table 2 - Culvert Summary Table: Willow Option 2

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)
1-YR	18.70	18.70	400.38	1.141	1.260	1-S1t	0.567	0.671	1.190	1.190	2.619
2-YR	24.80	24.80	400.60	1.370	1.482	1-S1t	0.686	0.810	1.346	1.346	3.072
10-YR	85.60	85.60	402.72	3.603	3.445	5-FFf	1.574	1.849	2.000	2.266	7.133
25-yr	133.00	101.87	403.58	4.461	4.434	5-FFf	2.000	2.000	2.000	2.714	8.489

****

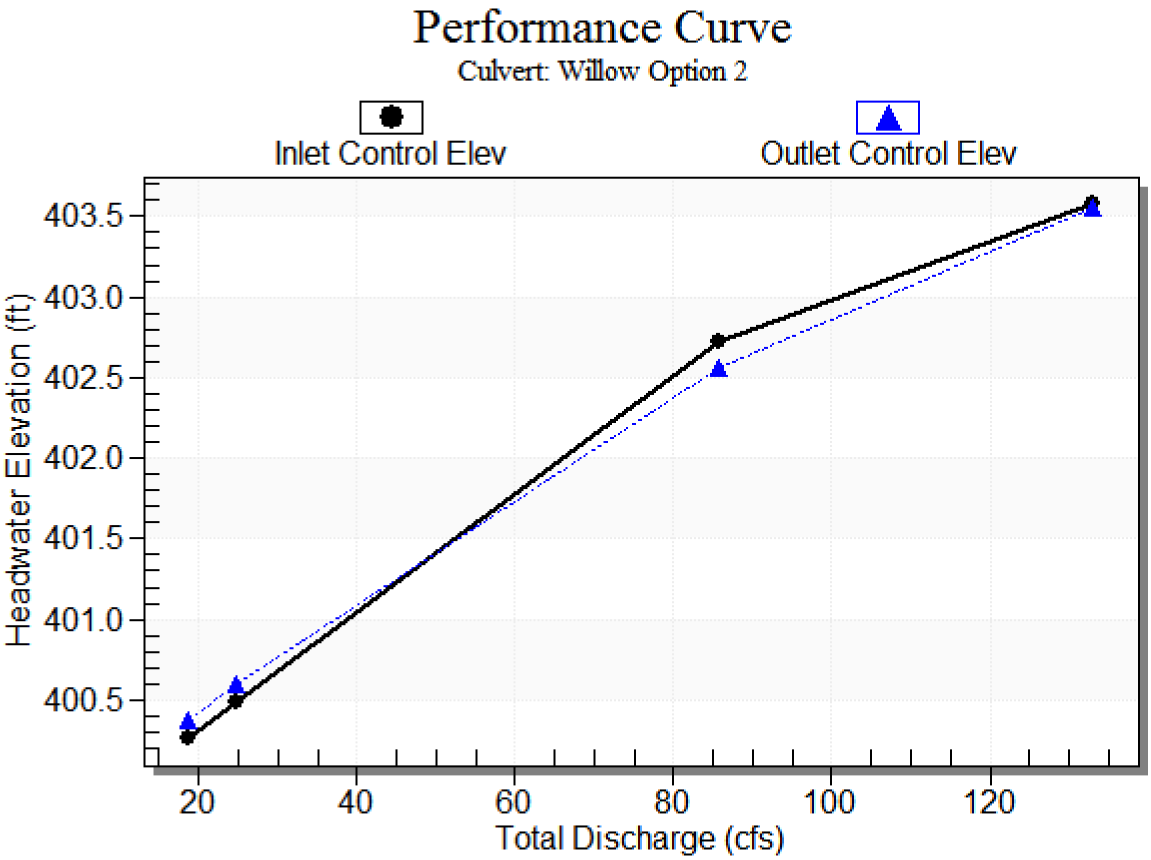
Straight Culvert

Inlet Elevation (invert): 399.12 ft, Outlet Elevation (invert): 399.00 ft

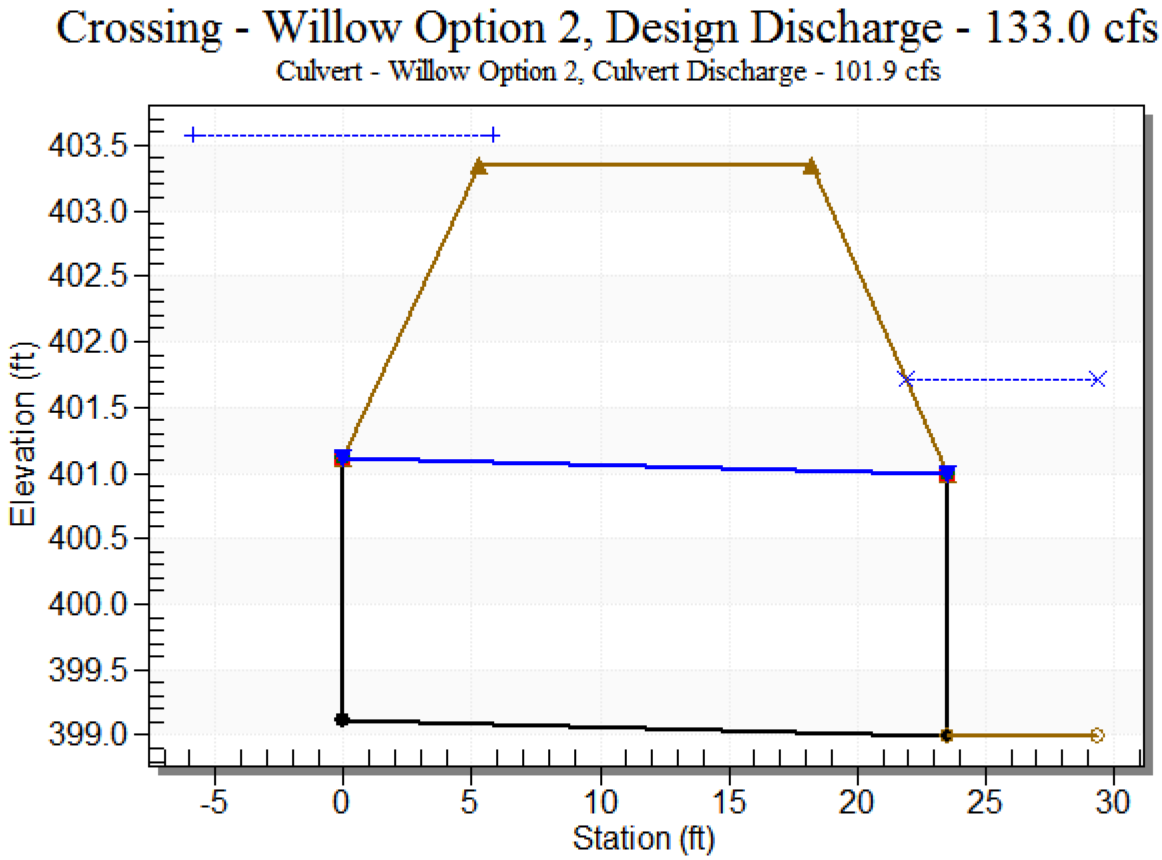
Culvert Length: 23.50 ft, Culvert Slope: 0.0051

****

Culvert Performance Curve Plot: Willow Option 2



Water Surface Profile Plot for Culvert: Willow Option 2



Site Data - Willow Option 2

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 399.12 ft

Outlet Station: 23.50 ft

Outlet Elevation: 399.00 ft

Number of Barrels: 1

Culvert Data Summary - Willow Option 2

Barrel Shape: Concrete Box

Barrel Span: 6.00 ft

Barrel Rise: 2.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge (90º) Headwall

Inlet Depression: NONE

Table 3 - Downstream Channel Rating Curve (Crossing: Willow Option 2)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
18.70	400.19	1.19	2.32	0.37	0.49
24.80	400.35	1.35	2.50	0.42	0.50
85.60	401.27	2.27	3.41	0.71	0.54
133.00	401.71	2.71	3.81	0.85	0.55

Tailwater Channel Data - Willow Option 2

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 2.00 ft

Side Slope (H:V): 4.00 (_:1)

Channel Slope: 0.0050

Channel Manning's n: 0.0350

Channel Invert Elevation: 399.00 ft

Roadway Data for Crossing: Willow Option 2

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 403.34 ft

Roadway Surface: Gravel

Roadway Top Width: 13.00 ft

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 4 - Summary of Culvert Flows at Crossing: Emory Option 2

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Emory Option 2 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
399.72	1-YR	24.10	24.10	0.00	1
399.96	2-YR	31.90	31.90	0.00	1
402.59	10-YR	111.10	111.10	0.00	1
403.34	25-yr	173.10	126.26	46.74	6
403.05	Overtopping	120.63	120.63	0.00	Overtopping

Rating Curve Plot for Crossing: Emory Option 2

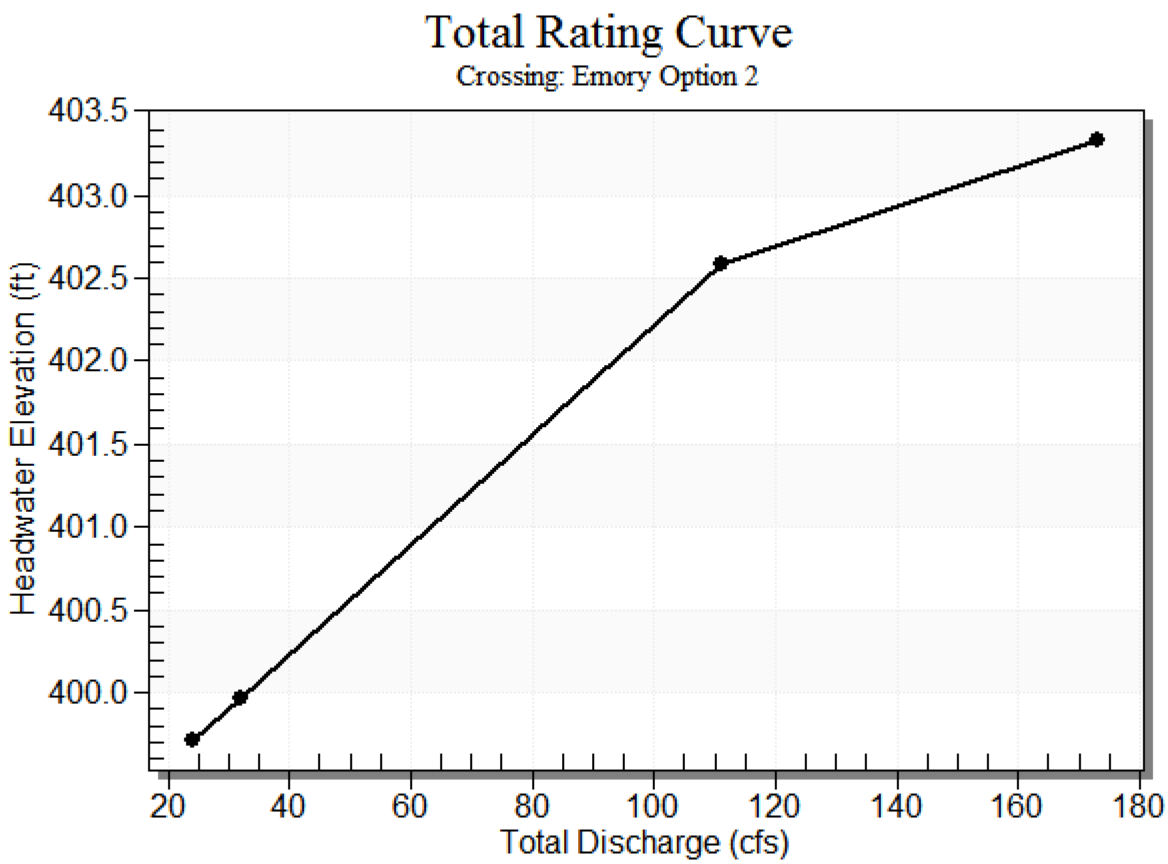


Table 5 - Culvert Summary Table: Emory Option 2

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)
1-YR	24.10	24.10	399.72	1.217	0.840	1-JS1t	0.598	0.717	1.008	1.008	3.414
2-YR	31.90	31.90	399.96	1.460	1.057	1-JS1t	0.718	0.864	1.163	1.163	3.919
10-YR	111.10	111.10	402.59	4.091	3.622	5-JS1f	1.649	1.985	2.000	2.128	7.936
25-yr	173.10	126.26	403.34	4.840	4.611	5-FFf	2.000	2.000	2.000	2.609	9.019

****

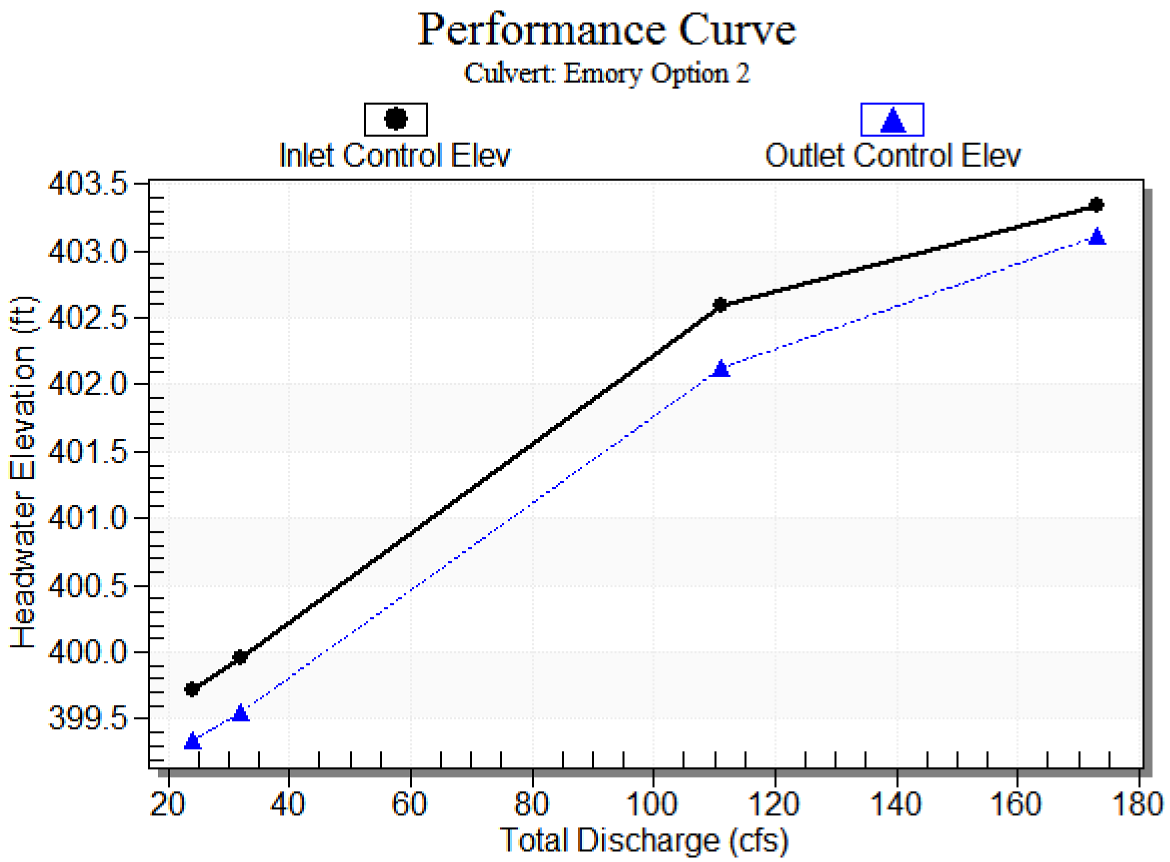
Straight Culvert

Inlet Elevation (invert): 398.50 ft,   Outlet Elevation (invert): 398.25 ft

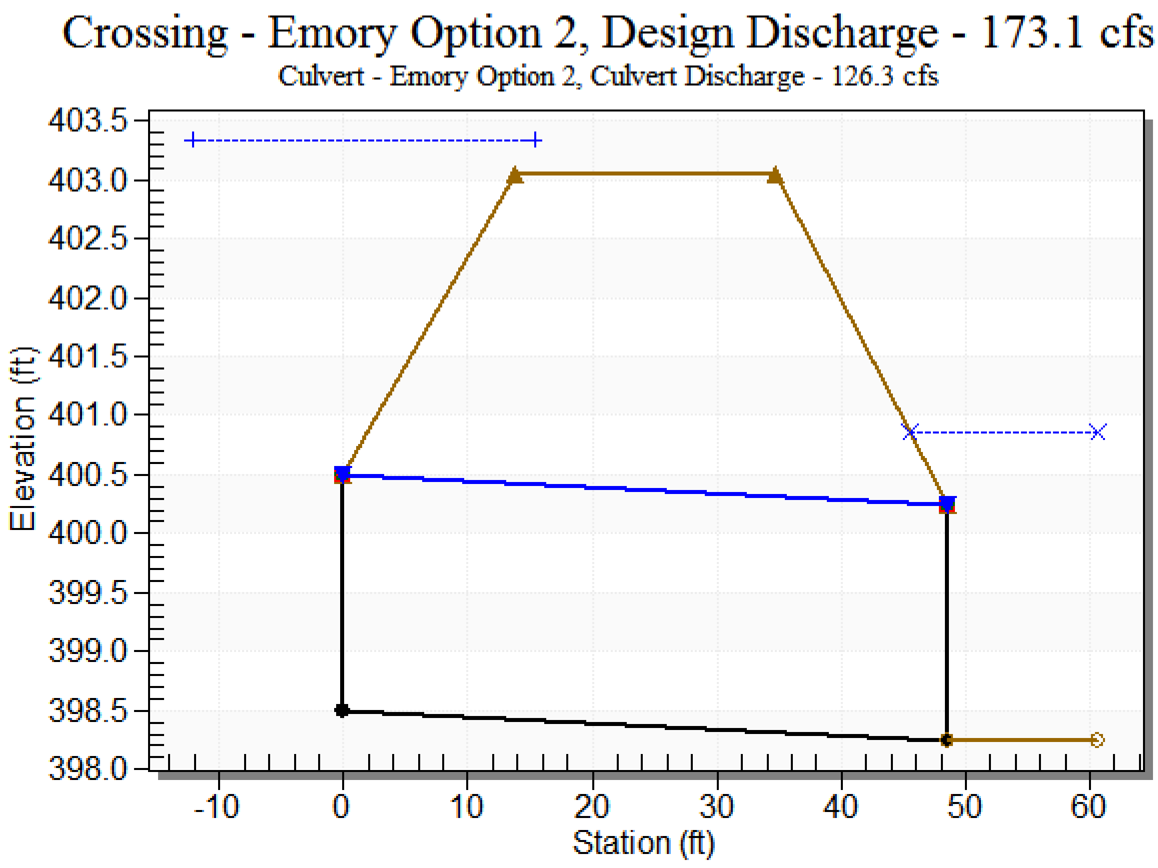
Culvert Length: 48.50 ft,   Culvert Slope: 0.0052

****

Culvert Performance Curve Plot: Emory Option 2



Water Surface Profile Plot for Culvert: Emory Option 2



Site Data - Emory Option 2

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 398.50 ft

Outlet Station: 48.50 ft

Outlet Elevation: 398.25 ft

Number of Barrels: 1

Culvert Data Summary - Emory Option 2

Barrel Shape: Concrete Box

Barrel Span: 7.00 ft

Barrel Rise: 2.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge (90º) Headwall

Inlet Depression: NONE

Table 6 - Downstream Channel Rating Curve (Crossing: Emory Option 2)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
24.10	399.26	1.01	2.38	0.31	0.49
31.90	399.41	1.16	2.58	0.36	0.50
111.10	400.38	2.13	3.60	0.66	0.55
173.10	400.86	2.61	4.04	0.81	0.56

Tailwater Channel Data - Emory Option 2

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 6.00 ft

Side Slope (H:V): 4.00 (_:1)

Channel Slope: 0.0050

Channel Manning's n: 0.0350

Channel Invert Elevation: 398.25 ft

Roadway Data for Crossing: Emory Option 2

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 403.05 ft

Roadway Surface: Paved

Roadway Top Width: 21.00 ft

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 7 - Summary of Culvert Flows at Crossing: Willow Option 1

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Willow Option 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
400.96	1-YR	18.70	18.70	0.00	1
401.16	2-YR	24.80	24.80	0.00	1
403.18	10-YR	85.60	85.60	0.00	1
403.65	25-YR	133.00	86.68	46.25	6
403.34	Overtopping	89.87	89.87	0.00	Overtopping

Rating Curve Plot for Crossing: Willow Option 1

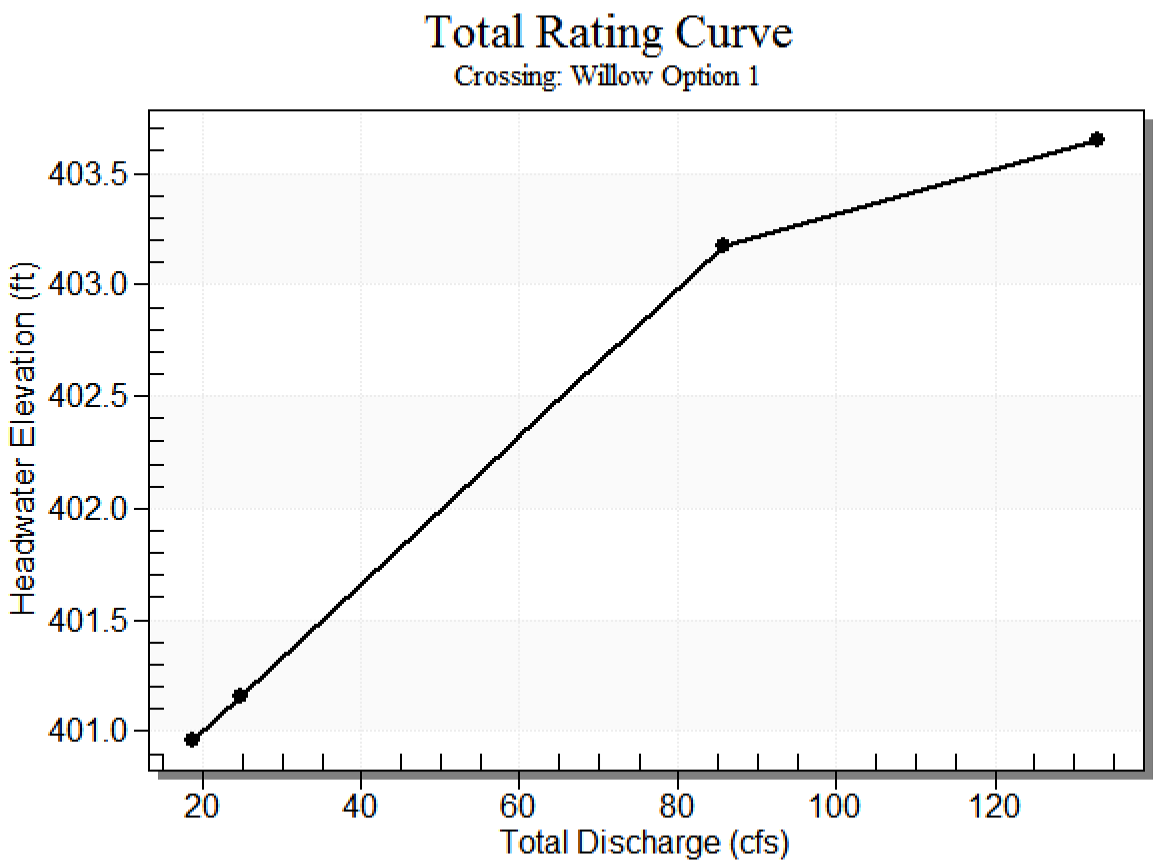


Table 8 - Culvert Summary Table: Willow Option 1

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)
1-YR	18.70	18.70	400.96	0.970	1.143	1-S1t	0.625	0.701	1.097	1.097	2.368
2-YR	24.80	24.80	401.16	1.154	1.338	1-S1t	0.723	0.819	1.250	1.250	2.699
10-YR	85.60	85.60	403.18	3.031	3.357	4-FFf	1.833	1.552	1.833	2.160	7.163
25-YR	133.00	86.68	403.65	3.076	3.834	4-FFf	1.833	1.560	1.833	2.604	7.254

****

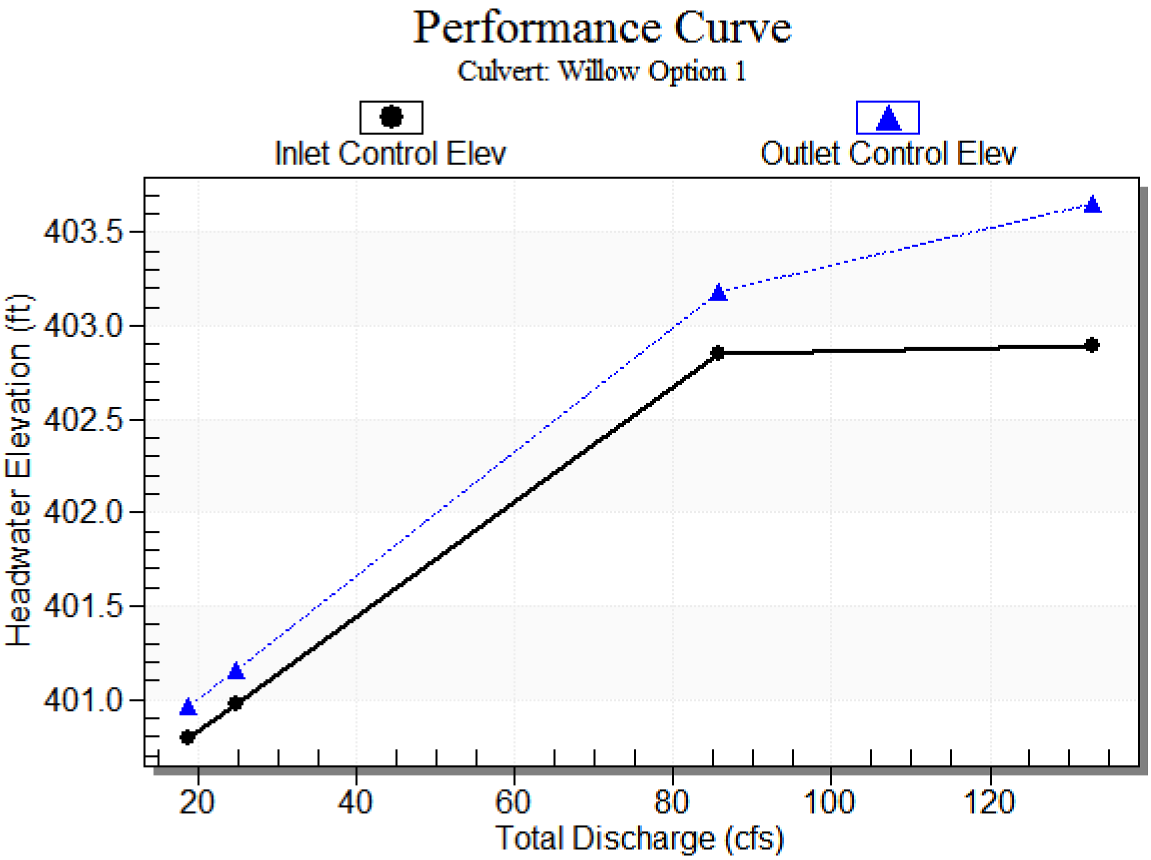
Straight Culvert

Inlet Elevation (invert): 399.82 ft,   Outlet Elevation (invert): 399.70 ft

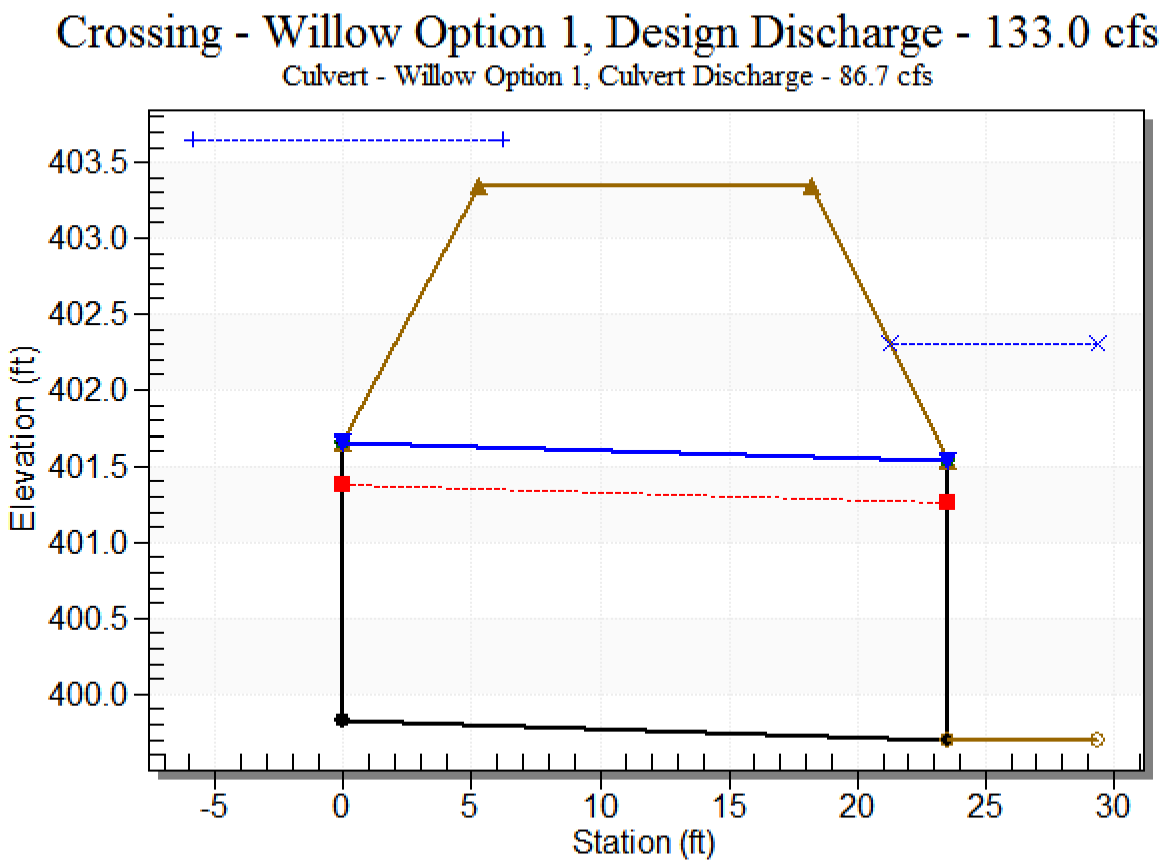
Culvert Length: 23.50 ft,   Culvert Slope: 0.0051

****

Culvert Performance Curve Plot: Willow Option 1



Water Surface Profile Plot for Culvert: Willow Option 1



Site Data - Willow Option 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 399.82 ft

Outlet Station: 23.50 ft

Outlet Elevation: 399.70 ft

Number of Barrels: 3

Culvert Data Summary - Willow Option 1

Barrel Shape: Elliptical

Barrel Span: 34.00 in

Barrel Rise: 22.00 in

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 9 - Downstream Channel Rating Curve (Crossing: Willow Option 1)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
18.70	400.80	1.10	2.31	0.34	0.49
24.80	400.95	1.25	2.48	0.39	0.50
85.60	401.86	2.16	3.41	0.67	0.54
133.00	402.30	2.60	3.81	0.81	0.55

Tailwater Channel Data - Willow Option 1

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 3.00 ft

Side Slope (H:V): 4.00 (_:1)

Channel Slope: 0.0050

Channel Manning's n: 0.0350

Channel Invert Elevation: 399.70 ft

Roadway Data for Crossing: Willow Option 1

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 403.34 ft

Roadway Surface: Gravel

Roadway Top Width: 13.00 ft

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 10 - Summary of Culvert Flows at Crossing: Emory Option 1

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Emory Option 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
400.32	1-YR	24.10	24.10	0.00	1
400.52	2-YR	31.90	31.90	0.00	1
402.77	10-YR	111.10	111.10	0.00	1
403.38	25-YR	173.10	115.44	57.55	6
403.05	Overtopping	118.72	118.72	0.00	Overtopping

Rating Curve Plot for Crossing: Emory Option 1

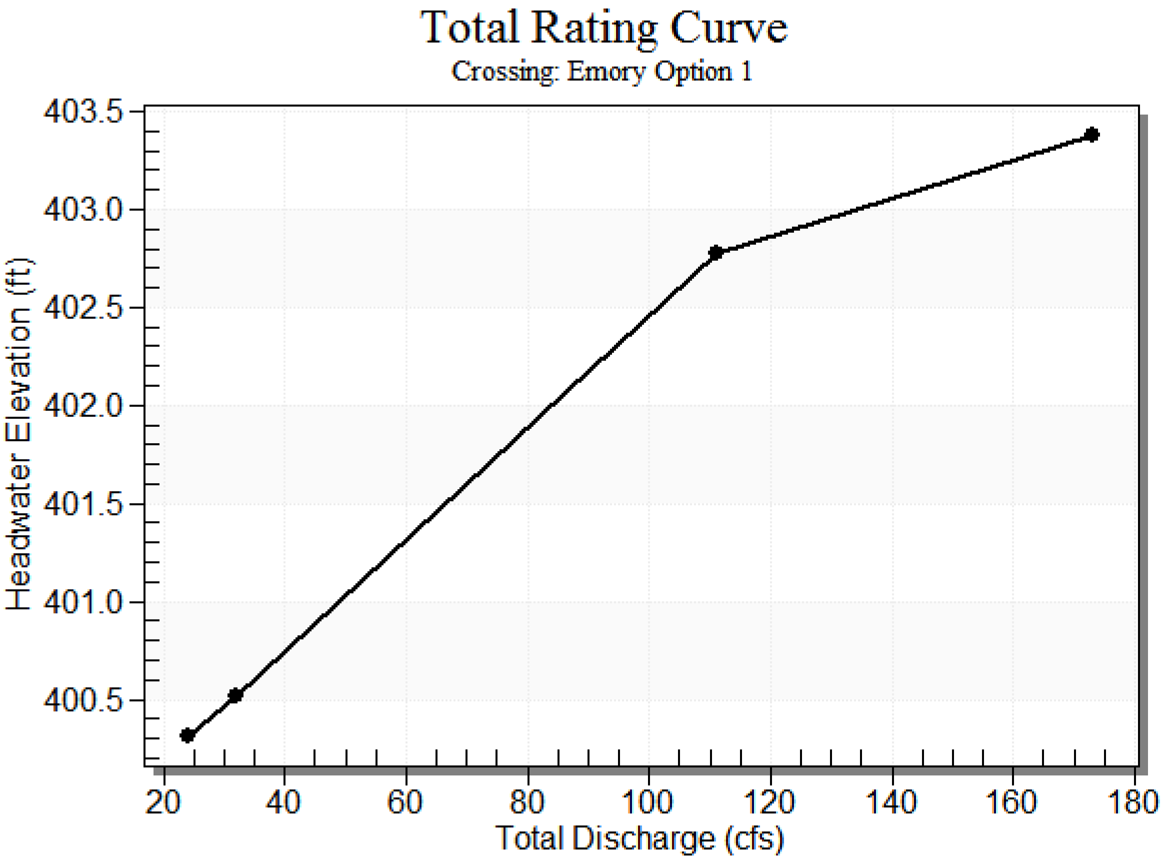


Table 11 - Culvert Summary Table: Emory Option 1

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)
1-YR	24.10	24.10	400.32	1.066	0.836	1-JS1t	0.675	0.765	1.008	1.008	3.099
2-YR	31.90	31.90	400.52	1.267	1.048	1-JS1t	0.778	0.894	1.163	1.163	3.458
10-YR	111.10	111.10	402.77	3.382	3.522	4-FFf	2.000	1.715	2.000	2.128	7.710
25-YR	173.10	115.44	403.38	3.543	4.134	4-FFf	2.000	1.743	2.000	2.609	8.011

****

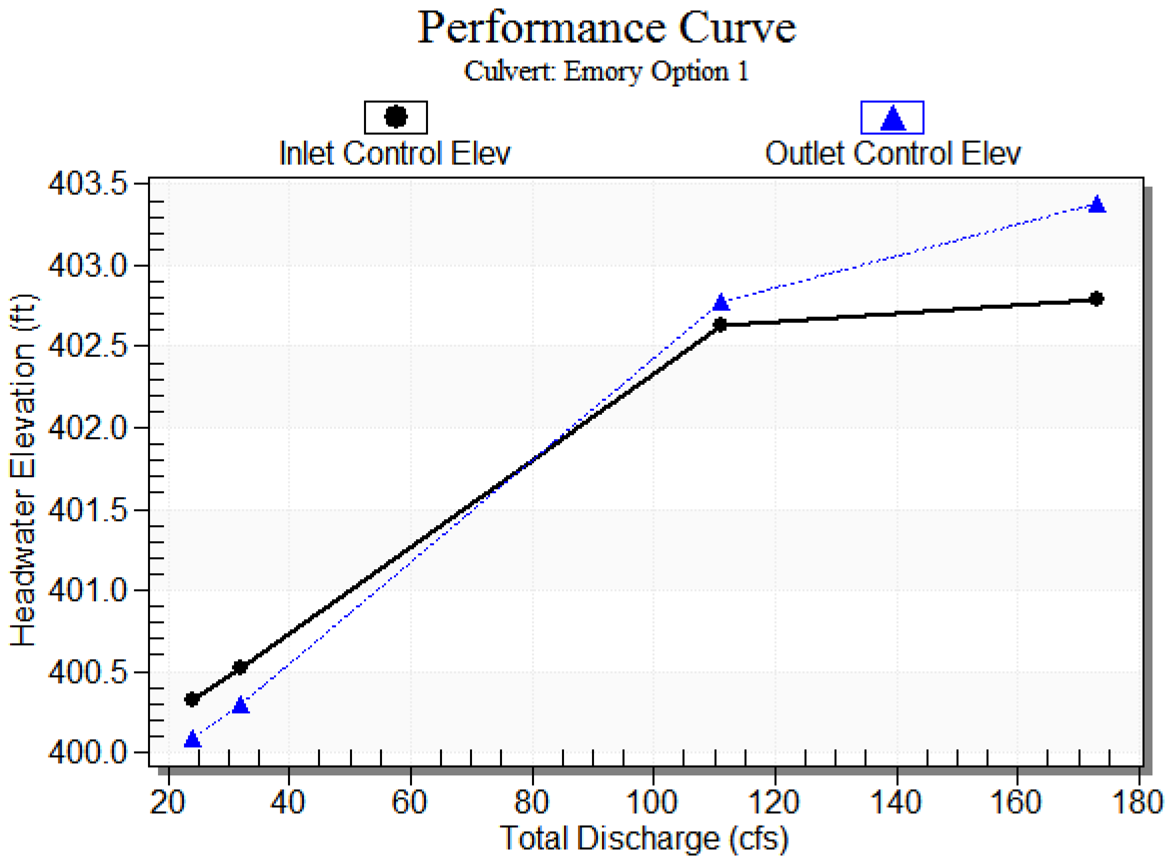
Straight Culvert

Inlet Elevation (invert): 399.25 ft,   Outlet Elevation (invert): 399.00 ft

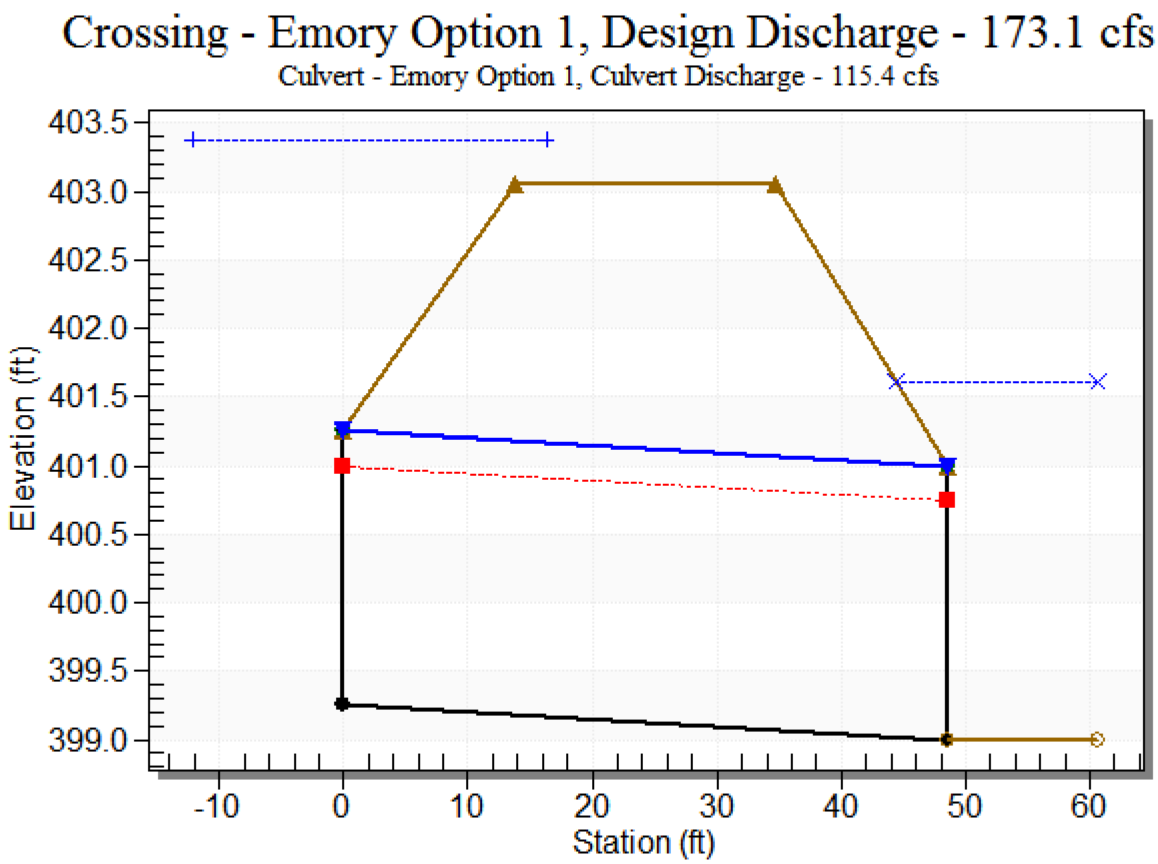
Culvert Length: 48.50 ft,   Culvert Slope: 0.0052

****

Culvert Performance Curve Plot: Emory Option 1



Water Surface Profile Plot for Culvert: Emory Option 1



Site Data - Emory Option 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 399.25 ft

Outlet Station: 48.50 ft

Outlet Elevation: 399.00 ft

Number of Barrels: 3

Culvert Data Summary - Emory Option 1

Barrel Shape: Elliptical

Barrel Span: 38.00 in

Barrel Rise: 24.00 in

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 12 - Downstream Channel Rating Curve (Crossing: Emory Option 1)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
24.10	400.01	1.01	2.38	0.31	0.49
31.90	400.16	1.16	2.58	0.36	0.50
111.10	401.13	2.13	3.60	0.66	0.55
173.10	401.61	2.61	4.04	0.81	0.56

Tailwater Channel Data - Emory Option 1

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 6.00 ft

Side Slope (H:V): 4.00 (_:1)

Channel Slope: 0.0050

Channel Manning's n: 0.0350

Channel Invert Elevation: 399.00 ft

Roadway Data for Crossing: Emory Option 1

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 403.05 ft

Roadway Surface: Paved

Roadway Top Width: 21.00 ft

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 13 - Summary of Culvert Flows at Crossing: Sycamore Existing

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Sycamore Existing CMP Arch Discharge (cfs)	Roadway Discharge (cfs)	Iterations
451.60	1-YR	12.00	12.00	0.00	1
451.83	2-YR	15.90	15.90	0.00	1
453.71	10-YR	53.80	53.80	0.00	1
455.19	25-YR	83.10	73.55	9.38	11
455.09	Overtopping	72.49	72.49	0.00	Overtopping

Rating Curve Plot for Crossing: Sycamore Existing

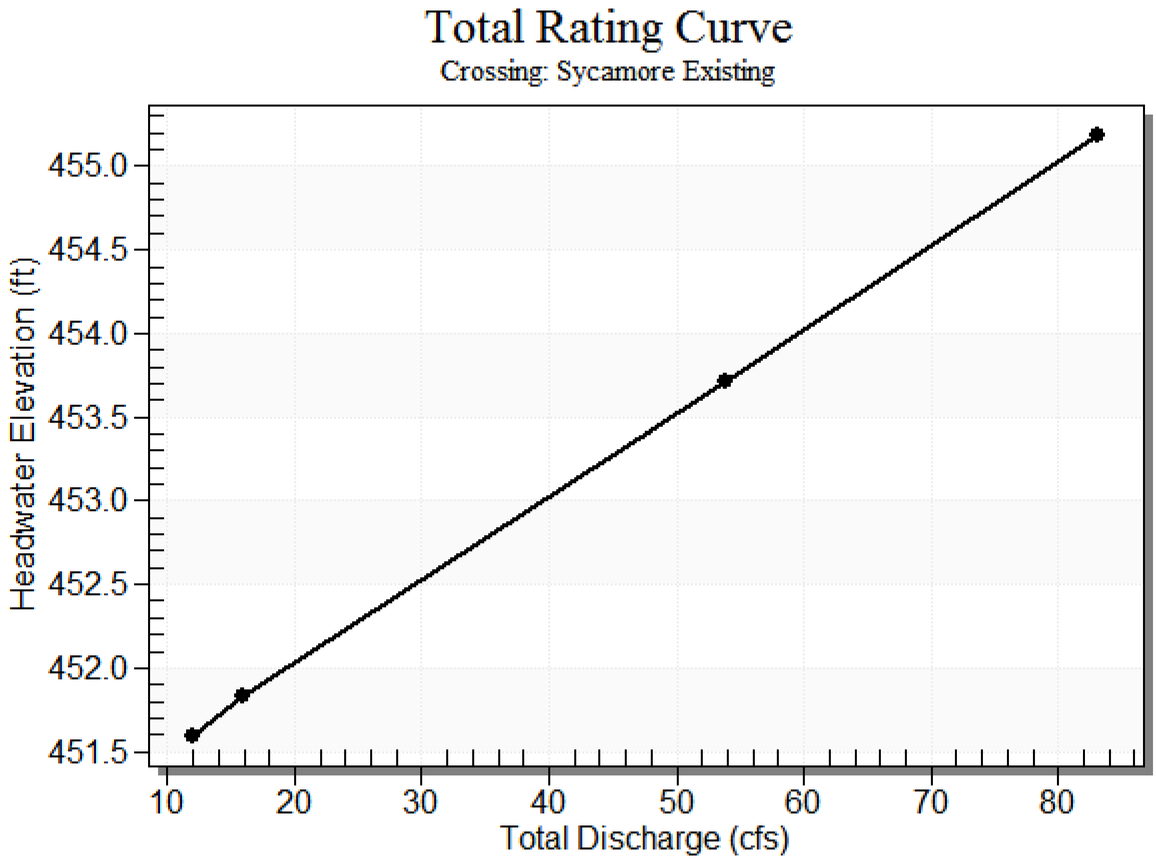


Table 14 - Culvert Summary Table: Sycamore Existing CMP Arch

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)
1-YR	12.00	12.00	451.60	1.135	1.233	2-M2c	0.875	0.762	0.762	0.562	4.612
2-YR	15.90	15.90	451.83	1.345	1.462	2-M2c	1.036	0.901	0.901	0.722	5.017
10-YR	53.80	53.80	453.71	3.296	3.344	7-M2c	2.736	1.826	1.826	1.304	7.980
25-YR	83.10	73.55	455.19	4.609	4.827	7-M2c	2.736	2.165	2.165	1.570	9.409

****

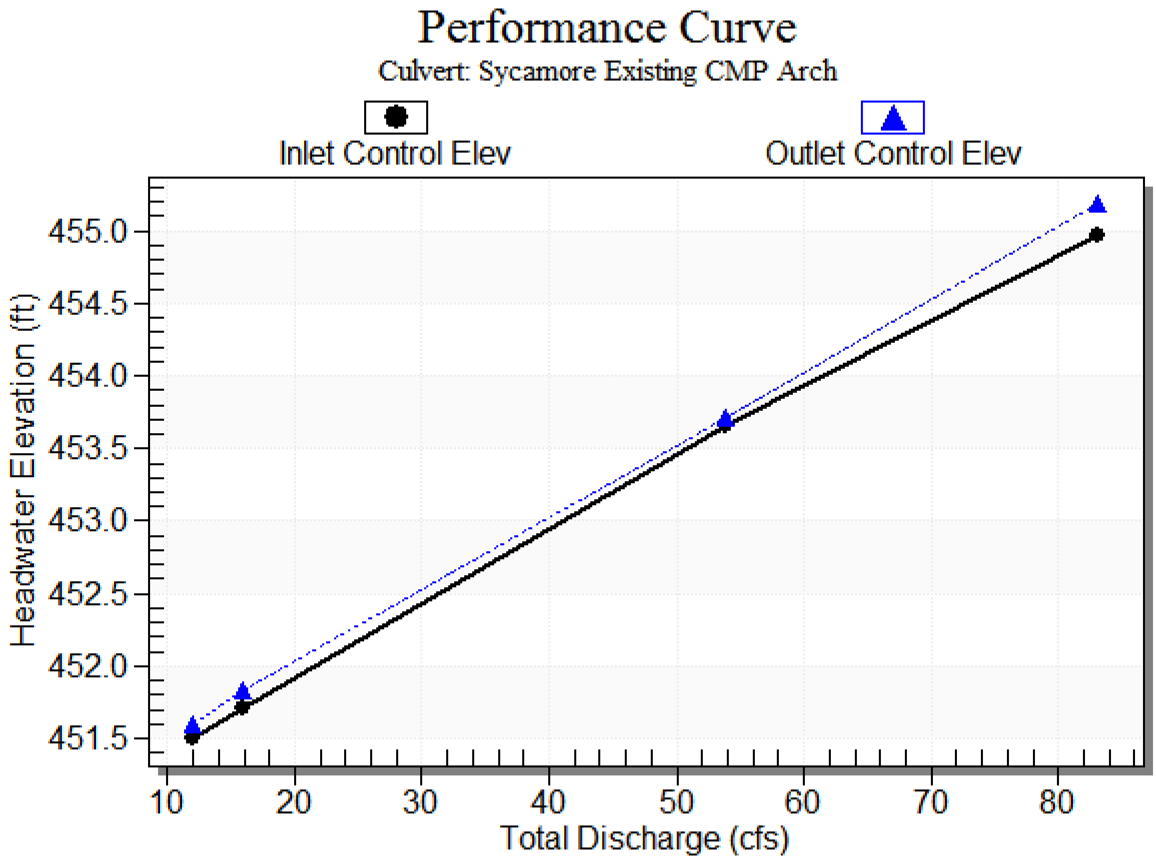
Straight Culvert

Inlet Elevation (invert): 450.36 ft,   Outlet Elevation (invert): 450.01 ft

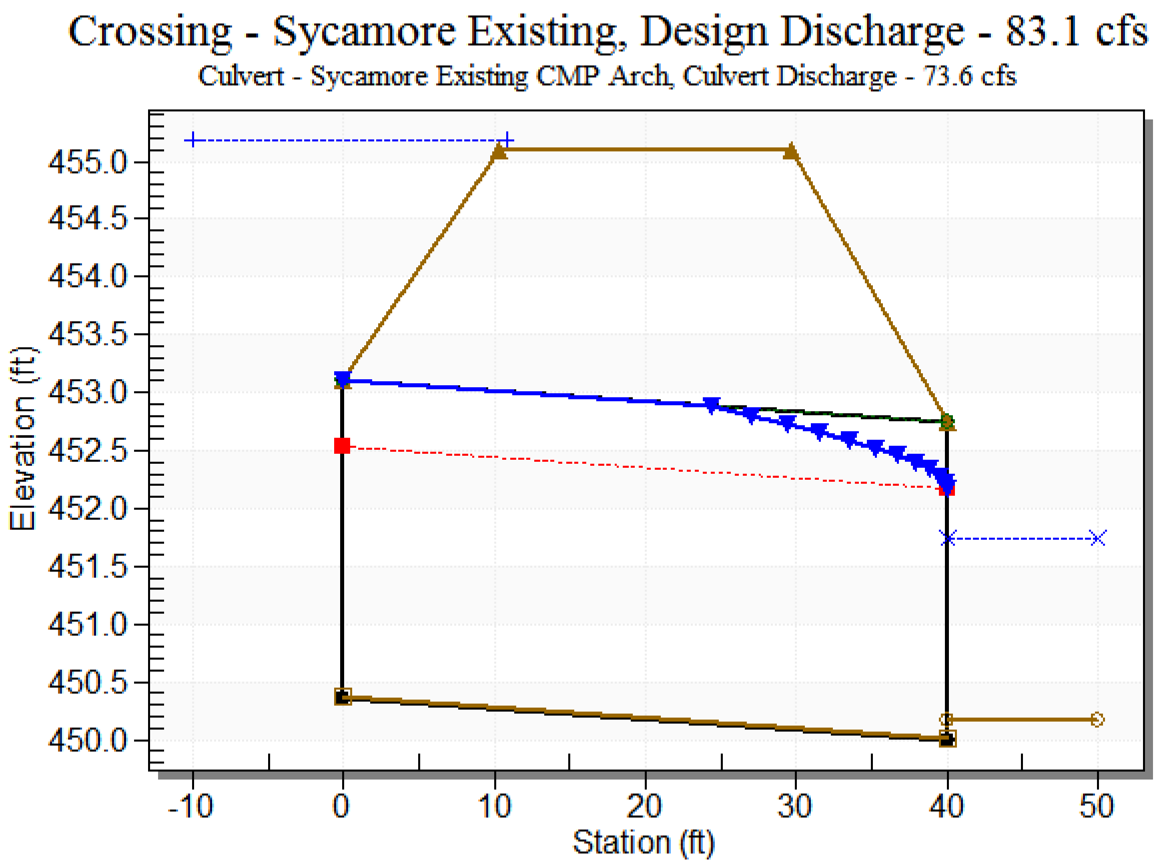
Culvert Length: 40.00 ft,   Culvert Slope: 0.0088

****

Culvert Performance Curve Plot: Sycamore Existing CMP Arch



Water Surface Profile Plot for Culvert: Sycamore Existing CMP Arch



Site Data - Sycamore Existing CMP Arch

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 450.35 ft

Outlet Station: 40.00 ft

Outlet Elevation: 450.00 ft

Number of Barrels: 1

Culvert Data Summary - Sycamore Existing CMP Arch

Barrel Shape: Pipe Arch

Barrel Span: 49.00 in

Barrel Rise: 33.00 in

Barrel Material: Steel or Aluminum

Embedment: 0.17 in

Barrel Manning's n: 0.0250 (top and sides)

Manning's n: 0.0300 (bottom)

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: NONE

Table 15 - Downstream Channel Rating Curve (Crossing: Sycamore Existing)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)
0.00	450.17	0.00	0.00
1.52	450.30	0.13	1.58
18.51	451.00	0.83	3.09
92.89	452.00	1.83	4.64
513.52	454.00	3.83	7.13

Tailwater Channel Data - Sycamore Existing

Tailwater Channel Option: Enter Rating Curve

Channel Invert Elevation: 450.17 ft

Roadway Data for Crossing: Sycamore Existing

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 455.09 ft

Roadway Surface: Paved

Roadway Top Width: 19.50 ft

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 16 - Summary of Culvert Flows at Crossing: Willow Existing

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Willow Existing CMP Discharge (cfs)	Roadway Discharge (cfs)	Iterations
402.43	1-YR	18.70	18.70	0.00	1
402.73	2-YR	24.80	24.80	0.00	1
403.68	10-YR	85.60	33.68	51.86	4
403.86	25-YR	133.00	31.92	100.85	3
403.34	Overtopping	35.29	35.29	0.00	Overtopping

Rating Curve Plot for Crossing: Willow Existing

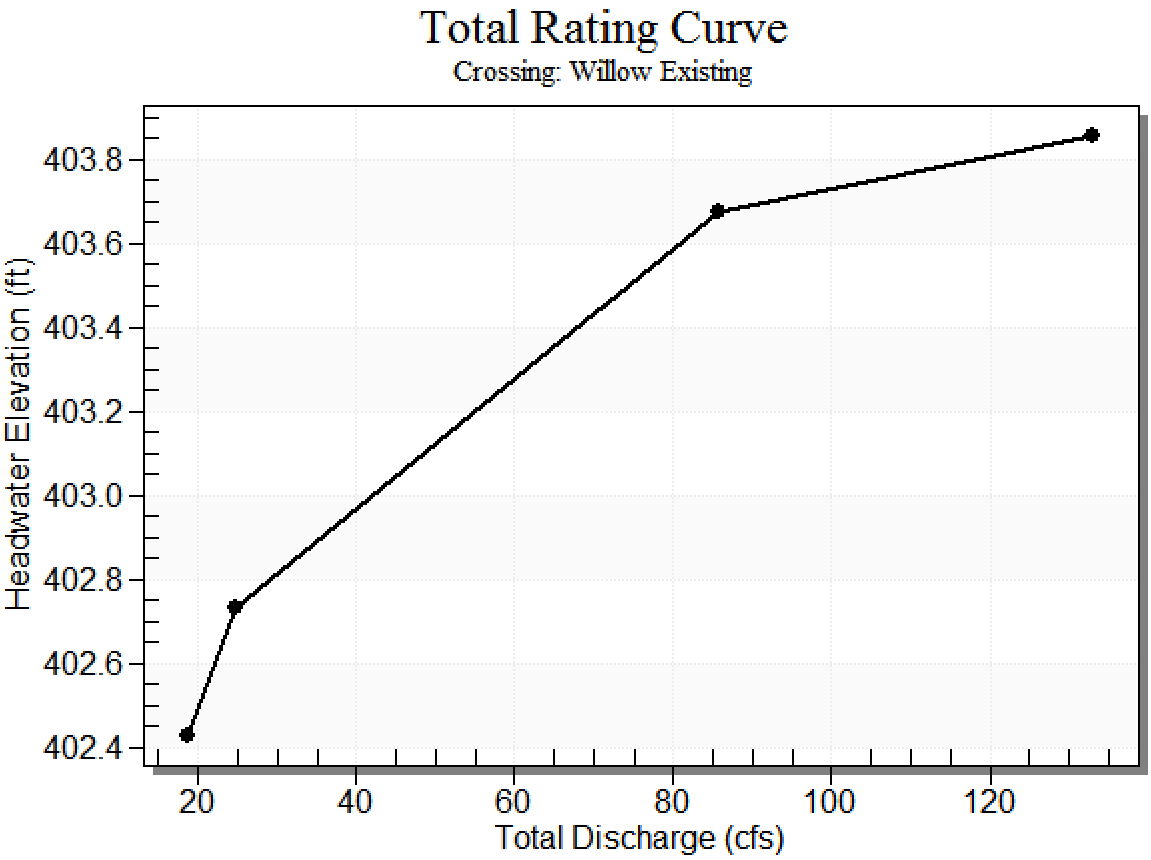


Table 17 - Culvert Summary Table: Willow Existing CMP

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)
1-YR	18.70	18.70	402.43	1.310	0.495	1-S2n	0.729	0.902	0.729	0.884	6.436
2-YR	24.80	24.80	402.73	1.611	1.086	5-S2n	0.862	1.051	0.868	1.171	6.913
10-YR	85.60	33.68	403.68	2.115	2.557	4-FFf	1.046	1.236	1.583	2.048	5.609
25-YR	133.00	31.92	403.86	2.006	2.739	4-FFf	1.010	1.202	1.583	1.273	5.316

****

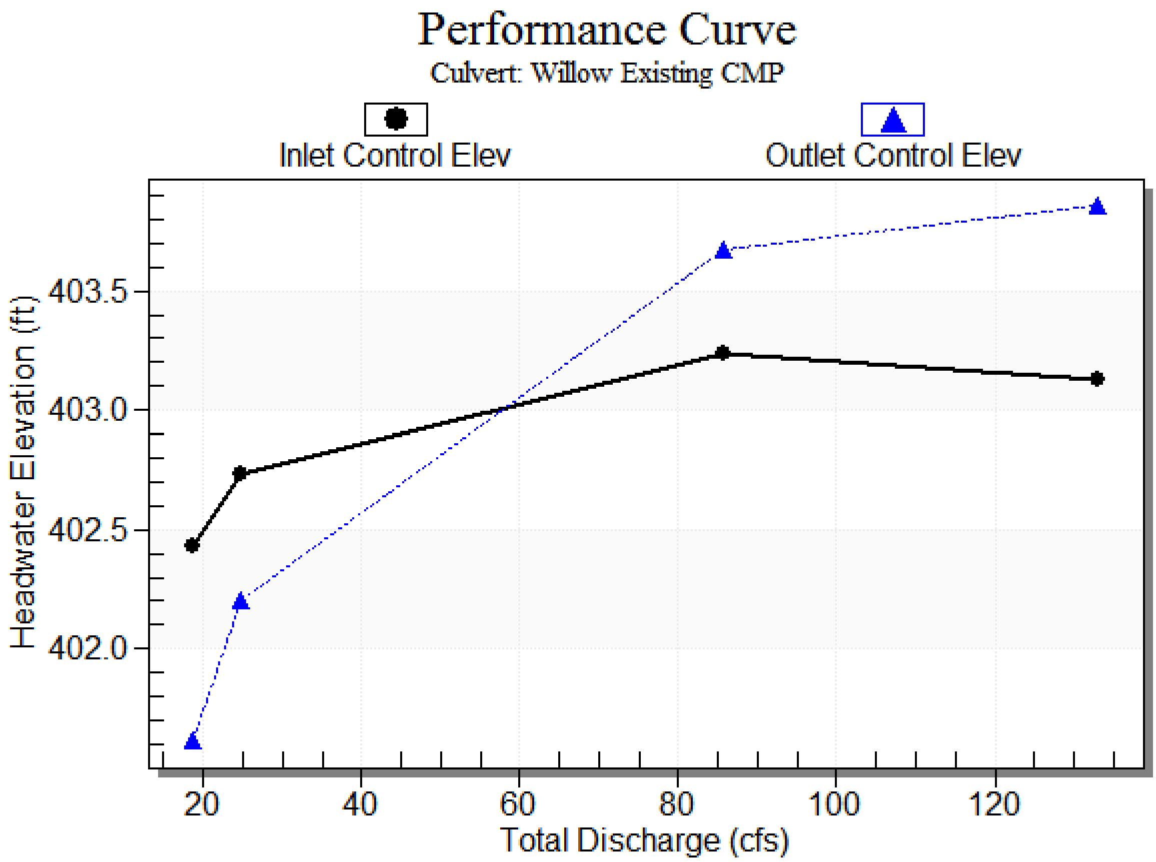
Straight Culvert

Inlet Elevation (invert): 401.12 ft,   Outlet Elevation (invert): 400.00 ft

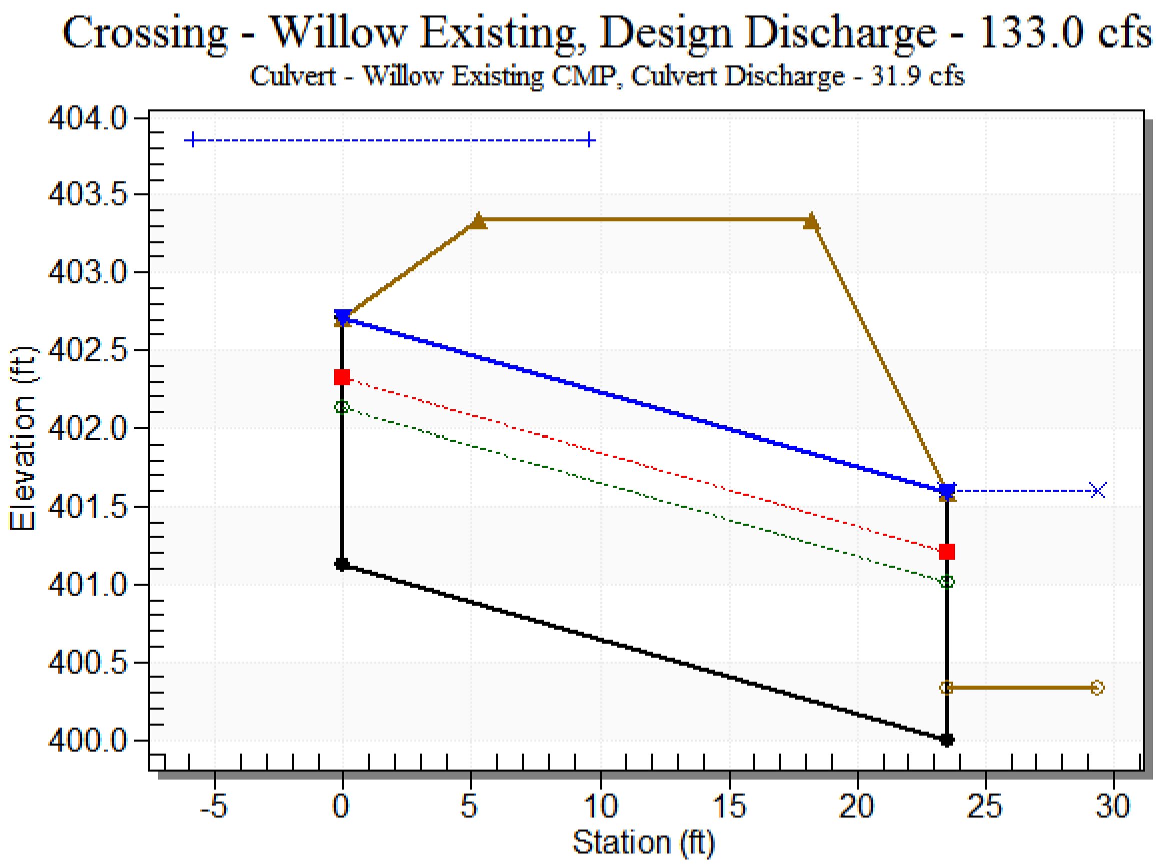
Culvert Length: 23.53 ft,   Culvert Slope: 0.0477

****

Culvert Performance Curve Plot: Willow Existing CMP



Water Surface Profile Plot for Culvert: Willow Existing CMP



Site Data - Willow Existing CMP

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 401.12 ft

Outlet Station: 23.50 ft

Outlet Elevation: 400.00 ft

Number of Barrels: 2

Culvert Data Summary - Willow Existing CMP

Barrel Shape: Elliptical

Barrel Span: 30.00 in

Barrel Rise: 19.00 in

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0300

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: NONE

Table 18 - Downstream Channel Rating Curve (Crossing: Willow Existing)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)
0.00	400.33	0.00	0.00
24.75	401.50	1.17	3.47
94.07	402.50	2.17	3.82
296.06	403.50	3.17	4.55

Tailwater Channel Data - Willow Existing

Tailwater Channel Option: Enter Rating Curve

Channel Invert Elevation: 400.33 ft

Roadway Data for Crossing: Willow Existing

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 403.34 ft

Roadway Surface: Gravel

Roadway Top Width: 13.00 ft

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 19 - Summary of Culvert Flows at Crossing: Emory Existing

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Emory Existing RCP Discharge (cfs)	Roadway Discharge (cfs)	Iterations
403.10	1-YR	24.10	21.21	2.83	7
403.15	2-YR	31.90	21.68	9.96	6
403.50	10-YR	111.10	20.15	90.75	4
403.74	25-YR	173.10	-1.#J	173.09	1000
403.05	Overtopping	20.84	20.84	0.00	Overtopping

Rating Curve Plot for Crossing: Emory Existing

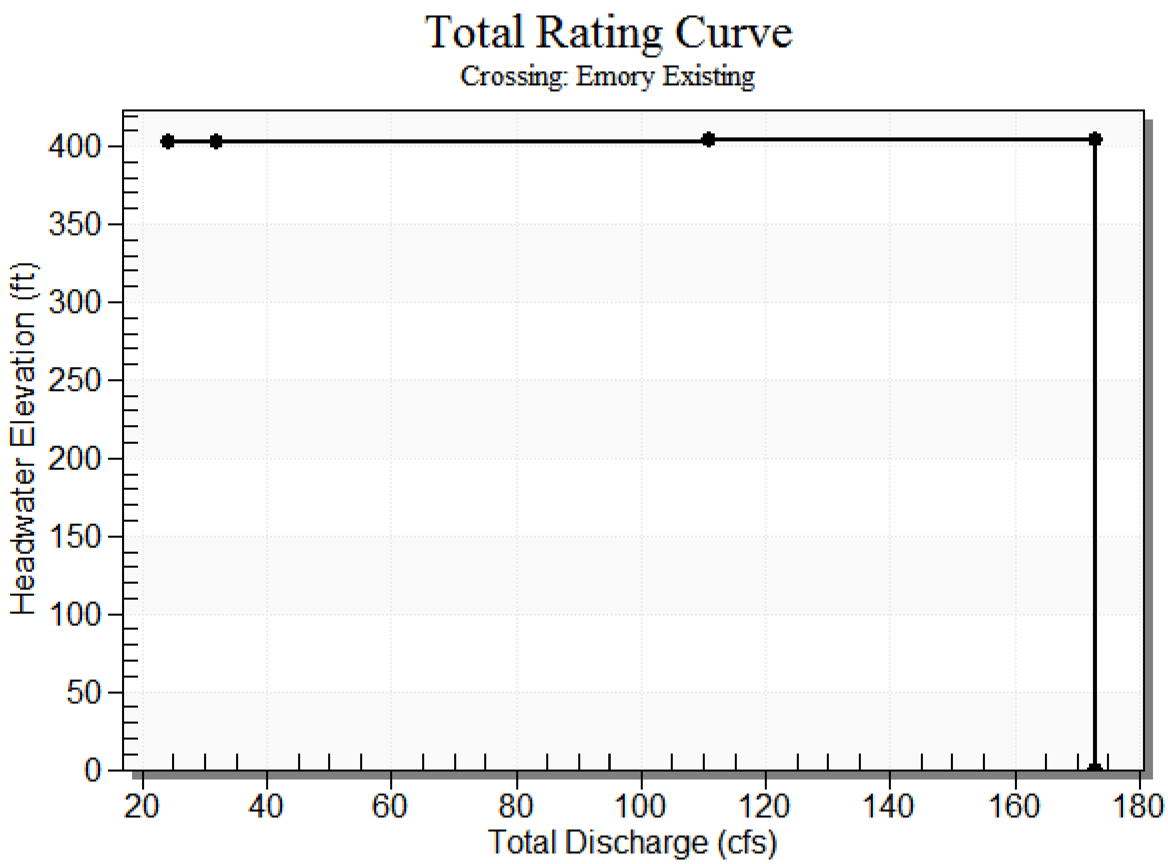


Table 20 - Culvert Summary Table: Emory Existing RCP

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)
1-YR	24.10	21.21	403.10	2.115	1.455	5-S2n	0.697	1.034	0.741	1.130	8.963
2-YR	31.90	21.68	403.15	2.175	1.679	5-S2n	0.707	1.042	0.751	1.296	9.013
10-YR	111.10	20.15	403.50	1.985	2.518	4-FFf	0.675	1.013	1.167	2.321	6.046
25-YR	173.10	-1.#J	403.74	0.000	1.847	0-NF	0.000	0.000	1.167	2.827	0.000

****

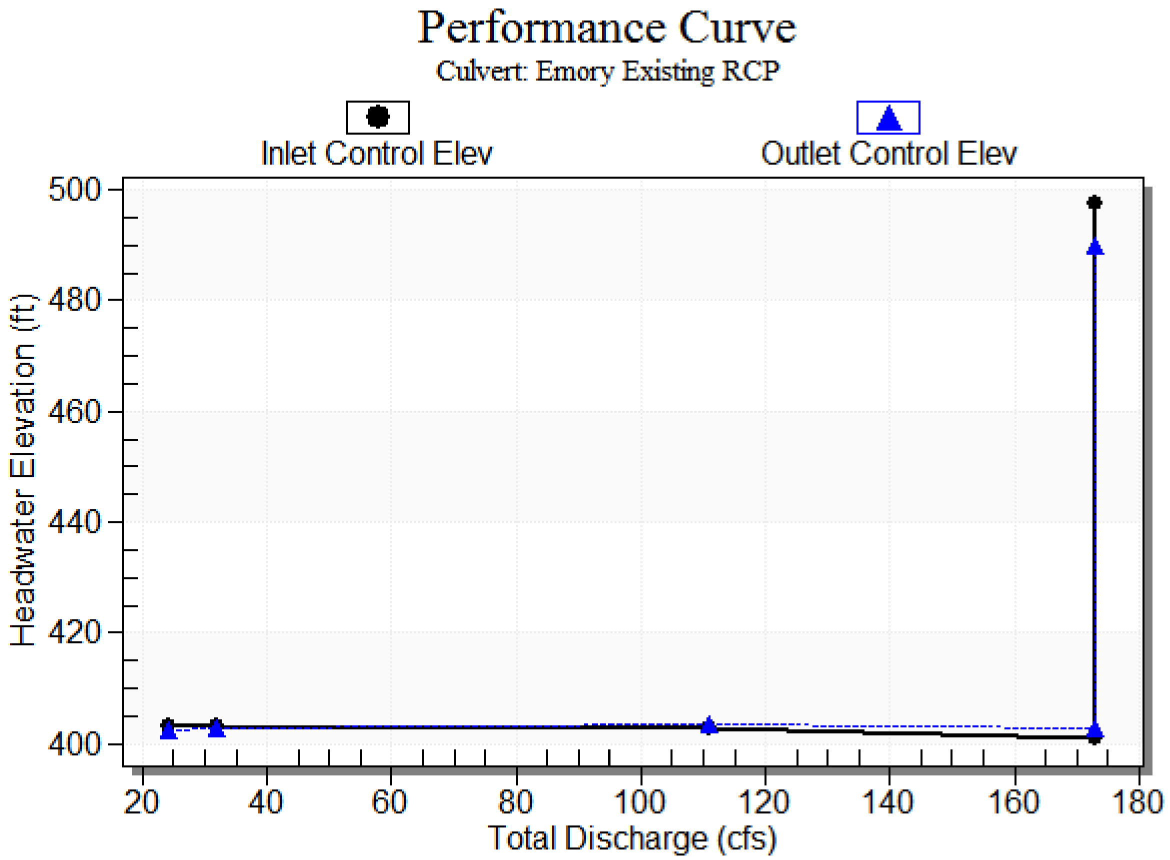
Straight Culvert

Inlet Elevation (invert): 400.98 ft,   Outlet Elevation (invert): 400.00 ft

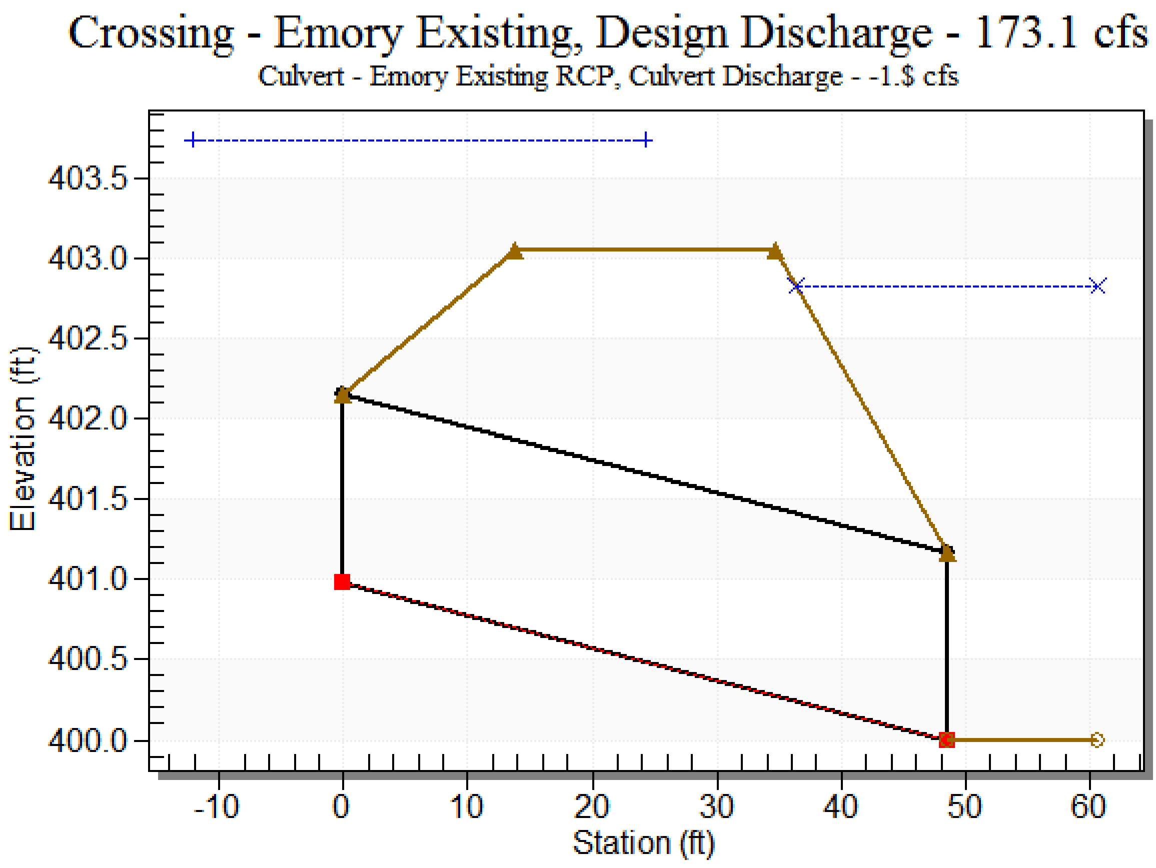
Culvert Length: 48.51 ft,   Culvert Slope: 0.0202

****

Culvert Performance Curve Plot: Emory Existing RCP



Water Surface Profile Plot for Culvert: Emory Existing RCP



Site Data - Emory Existing RCP

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 400.98 ft

Outlet Station: 48.50 ft

Outlet Elevation: 400.00 ft

Number of Barrels: 2

Culvert Data Summary - Emory Existing RCP

Barrel Shape: Elliptical

Barrel Span: 23.00 in

Barrel Rise: 14.00 in

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 21 - Downstream Channel Rating Curve (Crossing: Emory Existing)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
24.10	401.13	1.13	2.24	0.85	0.45
31.90	401.30	1.30	2.42	0.97	0.46
111.10	402.32	2.32	3.35	1.74	0.50
173.10	402.83	2.83	3.76	2.12	0.51

Tailwater Channel Data - Emory Existing

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 5.00 ft

Side Slope (H:V): 4.00 (_:1)

Channel Slope: 0.0120

Channel Manning's n: 0.0600

Channel Invert Elevation: 400.00 ft

Roadway Data for Crossing: Emory Existing

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 403.05 ft

Roadway Surface: Paved

Roadway Top Width: 21.00 ft

USGS Flow Types

Flow Control	Length Full	Flow Type		Flow Profiles	Outlet		Outlet Depth
		HW>D	HW<D		TW>D	TW<D	
Inlet	none	5	1	S2		n	Normal
Inlet	none	5	1	S1		t	Tailwater (TW)
Inlet	none	5	1	JS1		t	Jump, S1, TW
Inlet	none	5	1	M3, S3, H3, A3		t	Tailwater
Inlet	none	5	1	H3J, A3J		t	H3, Jump, TW
Inlet	part	5	1	S1	f		Full
Inlet	part	5	1	S1	f		Full
Inlet	part	5	1	JS1	f		Jump, S1, Full
Inlet	part	5	1	H3J, A3J	f		H3, Jump, Full
Outlet	none		2	M2, H2, A2		c	Critical
Outlet	none		3	M2, H2, A2		t	Tailwater
Outlet	none		3	M1		t	Tailwater
Outlet	part		3	M1	f		Full
Outlet	all	4		FF	f		Full
Outlet	most	6		FF		t	Tailwater
Outlet	most	6		FF		c	Critical
Outlet	part	7		M1		t	Tailwater
Outlet	part	7		M2, H2, A2		t	Tailwater
Outlet	part	7		M2, H2, A2		c	Critical

Close

APPENDIX H

CHANNEL CALCULATIONS

```
**************************************************
*         THE WILSON T. BALLARD COMPANY          *
* Trapez./Triangle Channel Uniform Flow Analysis *
**************************************************
```

Description: Sycamore to Willow 2-year storm

Input Data:

Discharge (cfs): 24.8
Channel bottom width (ft): 2.0
Channel side slope (V=1 H=?): Left: 3.0 Right: 3.0
Channel profile slope: 0.018
Manning roughness n (leave blank for grass ditches): 0.035

Results:

Flow depth (ft): 1.097
Flow velocity (fps): 4.272
Critical depth (ft): 1.051
Critical slope: 0.02174
Grass ditch n:

```
*************************************************
*         THE WILSON T. BALLARD COMPANY         *
* Trapez./Triangle Channel Uniform Flow Analysis *
*************************************************
```

Description: Willow to Emory 2-year storm

Input Data:

Discharge (cfs): 31.9
Channel bottom width (ft): 2.0
Channel side slope (V=1 H=?): Left: 3.0 Right: 3.0
Channel profile slope: 0.01
Manning roughness n (leave blank for grass ditches): 0.035

Results:

Flow depth (ft): 1.403
Flow velocity (fps): 3.662
Critical depth (ft): 1.188
Critical slope: 0.02103
Grass ditch n: