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Coal Combustion Residuals Unit
Inflow Design Flood Control System Plan

Virginia Electric and Power Company
Chesterfield Power Station
Upper (East) Pond
Chesterfield County, Virginia

GAI Project Number: C1500035.00

October 2016

Prepared by: GAI Consultants, Inc.
Richmond Office
4198 Cox Road, Suite 114
Glen Allen, Virginia 23060

Prepared for: Virginia Electric and Power Company
5000 Dominion Boulevard
Glen Allen, Virginia 23060

Table of Contents

Certification/Statement of Professional Opinion

The Coal Combustion Residuals CCR Unit Inflow Design Flood Control System Plan (Plan) for the Chesterfield Power Station Upper (East) Pond was prepared by GAI Consultants, Inc. (GAI). The Plan was based on certain information that, other than for information GAI originally prepared, GAI has relied on but not independently verified. This Certification/Statement of Professional Opinion is therefore limited to the information available to GAI at the time the Plan was written. On the basis of and subject to the foregoing, it is my professional opinion as a Professional Engineer licensed in the Commonwealth of Virginia that the Plan has been prepared in accordance with good and accepted engineering practices as exercised by other engineers practicing in the same discipline(s), under similar circumstances, at the same time, and in the same locale. It is my professional opinion that the Plan was prepared consistent with the requirements of § 257.82(c) of the United States Environmental Protection Agency's "Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments," published in the Federal Register on April 17, 2015 with an effective date of October 19, 2015 (40 CFR 257 Subpart D).

The use of the words "certification" and/or "certify" in this document shall be interpreted and construed as a Statement of Professional Opinion and is not and shall not be interpreted or construed as a guarantee, warranty or legal opinion.

GAI Consultants, Inc.

Kevin M. Bortz, P.E.
Assistant Engineering Manager

Date 10/13/2016

Acronyms

CCR	Coal Combustion Residuals
CCR Rule	"Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments," 40 CFR 257 Subpart D (2015)
CFR	Code of Federal Regulations
DEQ	Virginia Department of Environmental Quality
Dominion	Virginia Electric and Power Company d/b/a Dominion
EPA	United States Environmental Protection Agency
GAI	GAI Consultants, Inc.
H&H	Hydrologic and Hydraulic
IDFCS	Inflow Design Flood Control System
Plan	CCR Unit Inflow Design Flood Control System Plan
Station	Dominion Chesterfield Power Station
UEP	Upper (East) Pond
VPDES	Virginia Pollutant Discharge Elimination System
VPDES Permit	Virginia Pollutant Discharge Elimination System Permit No. VA0004146

1.0 Introduction

The Chesterfield Power Station (Station) is owned by Virginia Electric and Power Company d/b/a Dominion Virginia Power (Dominion) and is located in Chesterfield, VA. The Station includes the Upper (East) Pond (UEP) impoundment, which is used for the long term storage of coal combustion residuals (CCR).

The UEP is located on Dominion property at the Chesterfield Power Station in Chesterfield County, Virginia (coordinates 37° 22' 15.2" North and 77° 22' 8.3" West) and is bounded by the Old Channel of the James River on the south, Henricus Historical Park on the east, and Aiken Swamp on the north.

The UEP is regulated as an existing CCR surface impoundment under the Environmental Protection Agency's "Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments" [40 CFR 257 Subpart D] published in the Federal Register on April 17, 2015 with an effective date of October 19, 2015 (CCR Rule). The UEP is currently regulated by Virginia Department of Environmental Quality (DEQ) Virginia Pollutant Discharge Elimination System Permit No. VA0004146 (VPDES Permit).

2.0 Purpose

This CCR Unit Inflow Design Flood Control System Plan (Plan) is prepared pursuant to § 257.82(c) of the CCR Rule [40 CFR § 257.82(c)].

3.0 Initial Inflow Design Flood Control System Plan

In accordance with § 257.73(a)(2), an initial Hazard Potential Classification was prepared for the UEP under current conditions. The UEP was determined to be a "significant hazard potential" CCR impoundment (GAI Consultants, 2016). As required by § 257.82(a)(3), the inflow design flood for a significant hazard potential CCR surface impoundment is a 1,000-year flood.

As required by § 257.82(c)(1), this Plan includes:

- Documentation of how the inflow design flood control system (IDFCS) has been designed, constructed, operated, and maintained to adequately manage flow into the UEP during and following the peak discharge of the inflow design flood [§ 257.82(a)(1)];
- Documentation of how the IDFCS has been designed, constructed, operated, and maintained to adequately manage flow from the UEP so as to collect and control the peak discharge resulting from the inflow design flood [§ 257.82(a)(2)]; and
- Documentation of how the IDFCS has been designed, constructed, operated, and maintained to adequately address the requirements of § 257.3-3 [§ 257.82(b)].

3.1 Site Configuration

The UEP consists of earthen embankments and stored CCR contained within the embankments. Perimeter channels convey stormwater runoff to a stormwater sediment pond situated at the east end of the UEP. The stormwater sediment pond discharges through VPDES Permit Outfall 005. Drawing E1-114 depicts existing conditions at the UEP.

3.2 Flow Into the Upper (East) Pond

The UEP embankment crest is at approximate elevation 41 at its lowest point, and the crest ranges from three feet to 35 feet above the approximate surrounding ground elevation. As such, there is no stormwater flow into the UEP and no need for a corresponding control system. The criteria established in § 257.82(a)(1) are therefore met.

3.3 Flow From the Upper (East) Pond

Interior perimeter channels and culverts, in conjunction with the stormwater sediment pond, comprise the IDFCS for the UEP. Drawing E1-114 depicts existing conditions at the UEP and identifies the interior perimeter channels and culverts and the stormwater sediment pond.

The bottom elevation of the stormwater sediment pond is at approximately 26 feet and the top of stormwater sediment pond containment (coincident with the UEP embankment crest) is at approximate minimum elevation 41 feet. Discharge from the stormwater sediment pond is controlled by a principal spillway riser tower structure, which is a 6 foot by 6 foot square concrete box. The tower structure is fitted with six 16-inch diameter flanged pipe openings (with five being available for discharge) with the lowest available opening at invert elevation 28.33 feet (Virginia Power, 1992). The principal spillway outfall pipe is a 24-inch diameter concrete pipe, which discharges to VPDES Permit Outfall 005.

In this Plan, management of the inflow design flood is defined as having the capacity to convey the peak discharge resulting from the flood. The capacity of each stormwater runoff control feature was evaluated and compared to the peak discharge resulting from the inflow design flood (1,000-year flood). Hydrologic and hydraulic (H&H) analyses are contained in Appendix A. Information for the components of the IDFCS was obtained from the 2003 Closure Plan, "New Ash Pond Stop Log Conversion, DCR-91-20" (Virginia Power, 1992), site topographic mapping, and site observations. Constructed geometry for the interior perimeter channels and culverts is summarized in Table 1 and Table 2 respectively, along with the 1,000-year peak discharges and capacities.

Table 1 -
Summary of Channel Geometry and Capacities -

Interior Perimeter Channel	Segment Number	Lining	Channel Slope (ft/ft)	Bottom Width (ft)	Depth* (ft)	Side Slopes (Left, Right H:1V)	1,000 year peak discharge (cubic feet per second)**	Capacity (cubic feet per second)**
North Perimeter Channel	1	Grass	0.005	10	2.7	3,3	170	212
	2	Concrete	0.005	4	1	2,3	223	2,224
	3	Concrete	0.005	6	5	2,2	295	5,562
West Perimeter Channel	1	Grass	0.005	12	1.6	3,2	25	139
South Perimeter Channel	1	Grass	0.005	0	3	3,5	73	119
	2	Concrete	0.005	4	1	3,2	160	806
	3	Concrete	0.005	4	1	3,2	310	1,984
	4	Concrete	0.005	4	2	3,2	424	7,415

*For concrete channels, depth listed is the depth of concrete. Capacity listed includes grassed conveyance above the top of the concrete lining. -
** Discharge and capacity are listed for the downstream end of a channel reach. -

Table 2 -
Summary of Culvert Properties and Capacities -

Culvert	Material	Diameter (ft)	Length (ft)	Culvert Slope (ft/ft)	1,000 year peak discharge (cubic feet per second)	Capacity (cubic feet per second)
East Culvert	CMP	5.5	400	0.005	295	325*
West Culvert	Concrete Ductile Iron	2.5 1.0	140 140	0.005 0.005	25	35
South Culvert	CMP	5.0	360	0.005	424	470*

* Capacity includes overflow channel to stormwater sediment pond.

The analyses indicate that all interior perimeter channels and culverts that are part of the IDFCS are capable of passing the peak discharge from the 1,000-year flood.

The UEP stormwater sediment pond was modeled for its performance during a 1,000-year flood. Appendix A contains calculations and results of the modeling. The model shows that the pool in the stormwater sediment pond from a 1,000-year flood would attain an estimated peak water surface elevation of 39.58 feet. The UEP embankment crest provides containment from the stormwater sediment pond pool and has a minimum containment at approximate elevation 41 feet.

Channels, culverts, and the stormwater sediment pond are routinely inspected (Dominion, 2014). These inspections meet the IDFCS requirements for maintenance in the CCR Rule.

3.4 Surface Water Requirements

40 CFR 257.3-3 states that "a facility shall not cause a discharge of pollutants into waters of the United States that is in violation of the National Pollutant Discharge Elimination System (NPDES) under section 402 of the Clean Water Act, as amended." DEQ administers the NPDES program in Virginia under the VPDES program. The UEP is regulated under an existing VPDES Permit. Discharges from the UEP are limited and monitored in accordance with the requirements in the VPDES permit, which functions to satisfy the requirements of § 257.82(b) of the CCR Rule.

4.0 Conclusion

It is GAI's opinion, based on a review of available material and additional analyses performed for this Plan, that the existing UEP Inflow Design Flood Control System is in compliance with the requirements in § 257.82 of the CCR Rule for a significant hazard impoundment.

5.0 References

Dominion. 2014. *Report of 2014 Safety Inspection, Chesterfield Power Station Upper Ash Pond Dam.*

GAI Consultants Inc. 2015. *Dominion Chesterfield Power Station, Upper (East) Pond-Max Drawdown-Stability.*

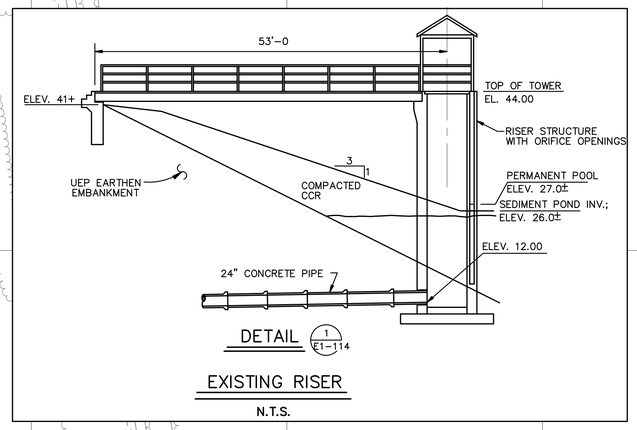
GAI Consultants Inc. 2016. *Initial Hazard Potential Classification Assessment Report, Upper (East) Pond, Chesterfield Power Station, Chesterfield County, Virginia*.

United States Environmental Protection Agency. 2015. *40 CFR Parts 257 and 261 Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities; Final Rule.* April 17, 2015.

Virginia Department of Environmental Quality. *Virginia Pollutant Discharge Elimination System (VPDES) - Permit No. VA0004146.* -

Virginia Power. 1992. *New Ash Pond Stop Log Conversion, DCR-91-20.*, January 1992. -

DRAWING -



EXISTING RISER

N.T.S.

NORTH

EXISTING LOWER (WEST) POND

OVERHEAD ELECTRIC LINE

ELECTRICAL POLES (TYP.)

HENRICUS HISTORICAL PARK

EXISTING 66" BCCMP EAST CULVERT

NORMAL POOL

EXISTING OUTLET PIPE

EXISTING RISER SEE DETAIL 1 E1-114

EXISTING VPDES OUTFALL 005 ELEV. 7.6'

POOL LEVEL AT INFLOW DESIGN FLOOD

EXISTING 60" BCCMP CULVERT

EXISTING 60" BCCMP SOUTH CULVERT

NORTH PERIMETER CHANNEL 3

NORTH PERIMETER CHANNEL 2

NORTH PERIMETER CHANNEL 1

APPROXIMATE 100- YEAR FLOODPLAIN

EXISTING 30" WEST CULVERT

EXISTING SLOPE DRAIN (TYP)

APPROXIMATE LOCATION UNDERGROUND ELECTRIC

UPPER (EAST) POND

WEST PERIMETER CHANNEL

APPROXIMATE LOCATION UNDERGROUND ELECTRIC

ACTIVE CCR PLACEMENT AREA (SEE NOTE 1)

SOUTH PERIMETER CHANNEL 4

PROPERTY LINE

SOUTH PERIMETER CHANNEL 1

SOUTH PERIMETER CHANNEL 2

SOUTH PERIMETER CHANNEL 3

REFERENCES:

1. BASE MAPPING PROVIDED BY TUCK MAPPING SOLUTIONS, INC. NORTH AMERICAN DATUM 1983 (U.S. FEET). AIRBORNE SURVEY PHOTOGRAPHY FLIGHT FLOWN OCTOBER 8, 2014. COMPLETED APRIL 30, 2015.
2. PROPERTY BOUNDARY IS FROM D&M SURVEYORS, P.C., TAX ID NO. 811-660-3332-0000, 05/08/15.
3. APPROXIMATE RPA BOUNDARY IS FROM GOLDER ASSOCIATES, "WETLAND DELINEATION MAP", DRAWING 1520610F01, 04/03/15.
4. APPROXIMATE 100-YEAR FLOODPLAIN LIMITS OBTAINED FROM FEMA PANELS 51041C0335D AND 51041C0351D.

LEGEND:

- EXISTING CONTOUR — 1850
- EXISTING VEGETATED CHANNEL
- EXISTING CONCRETE CHANNEL
- TREES
- FENCING — X
- PROPERTY LINE
- OVERHEAD ELECTRIC LINE — OHE
- UNDERGROUND ELECTRIC LINE — UE
- BURIED PIPE — BP
- APPROXIMATE RESOURCE PROTECTION AREA (RPA) BOUNDARY
- APPROXIMATE 100-YEAR FLOODPLAIN

NOTES:

1. THIS DRAWING DEPICTS ESTIMATED CONDITIONS IN JANUARY 2016. THE GRADING IS SHOWN FOR INFORMATION ONLY. ESTIMATED GRADES ARE DEPENDENT UPON STATION OPERATIONS.
2. EXISTING GRADES ARE BASED ON SURVEY FROM OCTOBER 2014 AND PLANNED CCR PLACEMENT ACTIVITIES THROUGH 2015.

SCALE: 1" = 120'

120 0 120 240

NO.:	DATE:	DWN:	CHK:	APV:	DESCRIPTION:

REVISION RECORD

This drawing was produced with computer aided drafting technology and is supported by electronic drawing files. Do not revise this drawing via manual drafting methods.

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DRAWING TITLE

PLAN VIEW - EXISTING CONDITIONS

PROJECT	CLIENT
UPPER (EAST) POND INFLOW DESIGN REPORT **CHESTERFIELD POWER STATION** **CHESTERFIELD COUNTY, VIRGINIA**	**DOMINION** **GLEN ALLEN, VIRGINIA**

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ISSUING OFFICE: Murrysville | 4200 Triangle Lane, Export, PA 15632-1358

DRAWN BY:	CHECKED BY:	APPROVED BY:	GAI FILE NUMBER:
NEIMAJC	**BORTZKM**	**JOYCEJM**	**C150035-00-000-00-C-E1-114**
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	AS SHOWN	**10/7/2016**	
REVISION 0	SHEET NO.: **1 OF 1**		GAI DRAWING NUMBER: **E1-114**

APPENDIX A
Hydrologic and Hydraulic Assessment

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SUBJECT CHESTERFIELD POWER STATION-UPPER (EAST) POND
HYDROLOGIC AND HYDRAULIC CAPACITY ASSESSMENT
BY BERKEME DATE 10/05/2016 PROJ. NO. C150035.00
CHKD. BY URBANCE DATE 10/07/2016

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APPENDIX A

TABLE OF CONTENTS:

*Appendix sheet numbers correspond to *italic* numbers in the upper right hand corner of each page.

SUBJECT CHESTERFIELD POWER STATION-UPPER (EAST) POND
HYDROLOGIC AND HYDRAULIC CAPACITY ASSESSMENT

BY BERKEME DATE 10/05/2016 PROJ. NO. C150035.00

CHKD. BY URBANCE DATE 10/07/2016

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OBJECTIVE:

The purpose of this assessment is to estimate the hydrologic and hydraulic (H&H) capacity for the current site configuration at the Chesterfield Power Station's Upper (East) Pond (UEP) for the inflow design flood event to show compliance with the updated CCR Rule.

Section 257.82 of the Environmental Protection Agency (EPA) Coal Combustion Residual (CCR) Rule established in April 2015 states that "the inflow design flood control system (for CCR surface impoundments) must adequately manage flow into the Impoundment during and following the peak discharge of the inflow design flood." The UEP (CCR) Impoundment is regulated as a significant hazard CCR surface impoundment, and per the CCR Rule, the inflow design flood is the 1,000-year event.

This calculation will estimate peak discharges for the 1,000-year event for surface runoff control structures (channels, culverts, and stormwater sediment pond) that control and contain stormwater discharge from the impoundment. The peak discharges will be compared to calculated hydraulic capacity for each structure to demonstrate compliance with the CCR Rule.

METHODOLOGY:

Drainage areas to site features requiring evaluation were delineated using project mapping. A Drainage Area Map is included in these calculations (sheet 7). Under the inflow design flood, benches were assumed to be ineffective as diversions when delineating watersheds. The Natural Resources Conservation Service (NRCS) TR-55 method and the computer program Hydraflow Hydrographs were utilized to estimate peak flow rates to each runoff control structure. Hydraflow calculations are included as Attachment 2 to this calculation. Rainfall data for the site location were obtained from NOAA Atlas 14.

REFERENCES

1. TR-55, Urban Hydrology For Small Watersheds, Natural Resources Conservation Services, June 1986.
2. NOAA Atlas 14. Rainfall data for Dutch Gap Conservation Area, Accessed 12/10/2015 (for Closure Plan Calculations).
3. Hydraflow Hydrographs Extension for AutoCAD Civil 3D. Version 10 by Autodesk, Inc. 2013
4. Tuck Mapping As-Built Contour Data. March 3, 2016.
5. Upper (East) Pond Max Drawdown Stability Calculation, GAI Consultants Inc., December 17, 2015.

SUBJECT CHESTERFIELD POWER STATION-UPPER (EAST) POND
HYDROLOGIC AND HYDRAULIC CAPACITY ASSESSMENT
BY BERKEME DATE 10/05/2016 PROJ. NO. C150035.00
CHKD. BY URBANCE DATE 10/07/2016

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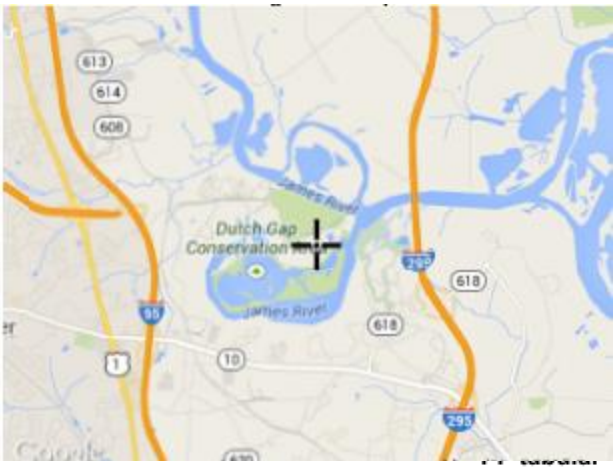
6. Revised Closure Plan, Upper (East) Pond, Chesterfield Power Station, Chesterfield County, Virginia. GAI Consultants, Inc. 2003.
7. Closure Plan Drawings, Upper East Pond, Chesterfield Power Station, Chesterfield County, Virginia. GAI Consultants, Inc. 1997.
8. Survey from D & M Surveyors P.C., September 29, 2016.

RAINFALL DATA:

Rainfall data for the site were obtained from Reference 2. These values are summarized below:

2-year, 24-hour event = 3.36 in (for use in Time of Concentration Calculation)
1,000-year, 24-hour event = 13.1 in



PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]										
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
24-hr	2.78 (2.54–3.06)	3.36 (3.08–3.71)	4.31 (3.93–4.76)	5.11 (4.65–5.64)	6.31 (5.69–6.94)	7.33 (6.57–8.05)	8.45 (7.52–9.27)	9.70 (8.55–10.6)	11.6 (10.0–12.6)	13.1 (11.3–14.4)

CURVE NUMBERS:

The following curve numbers used in the H&H Calculations of Reference 6 were also used for this assessment:

The following curve numbers were used to represent the site conditions currently present:

Coal Combustion Residuals (CCR)	=	85
Vegetated Final Soil Cover (good condition)	=	74
Gravel Haul Roads	=	89

Water (Stormwater Sediment Pond)	=	98

The Hydraflow model was used to calculate a composite curve number for each watershed.

TIME OF CONCENTRATION DATA:

Time of concentration (TOC) flow paths were estimated within the Hydraflow model using the methods provided in TR-55, incorporating sheet flow, shallow concentrated flow, and channel flow segments. Slopes and channel dimensions were estimated from the project mapping which was developed from survey information (Reference 4). A minimum TOC of 6 minutes was used. The following roughness coefficients were used in the sheet flow calculations (Reference 6):

CCR (No Vegetation)	=	0.03
Final Cover with Good Vegetation	=	0.24

Channel geometry and Manning's values for use in the TOC calculations were taken from Reference 6.

SUMMARY OF HYDRAULIC CALCULATIONS:

Capacity of the channels was estimated using the computer program Bentley FlowMaster (v8i), and capacity of the culverts was estimated using the Federal Highway Administration (FHWA) software HY-8. Channel dimensions and culvert properties were taken from References 4, 6, 7, and 8. Cross sections for each channel segment were taken at the downstream end of the channel segment where the entire watershed has contributed runoff. The stormwater sediment pond was modeled in Hydraflow, using the average end area method to estimate storage. Contour areas were estimated from Reference 4. The following Information on the pond's outlet structures was taken from References 5, 6, and 7 and entered into the Hydraflow model:

- Pond outfall culvert is 24-inches in diameter, with an inlet invert elevation of 12.0' and an outlet invert elevation of 7.6'. The length of the culvert is approximately 192' (Reference 7).
- The riser tower has a crest elevation of 44.0 feet, and the inside of the riser is a 6 foot by 6 foot square (Reference 6).
- The riser has five open 16-inch diameter orifices with inverts at the following elevations 28.33 feet, 32.66 feet, 35.33 feet, 38.58 feet, and 41.41 feet (Reference 5).
- The embankment is at elevation 41.00 ft (Reference 7).

SUBJECT CHESTERFIELD POWER STATION-UPPER (EAST) POND
HYDROLOGIC AND HYDRAULIC CAPACITY ASSESSMENT
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CHKD. BY URBANCE DATE 10/07/2016

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A summary of results is provided in Table 1 and Table 2.

Table 1: Summary of Channel/Culvert Hydraulic Capacity

Culvert/Channel	1,000 year peak flow rate (cfs)	Capacity (cfs)
North Perimeter Channel Segment 1	170	212
North Perimeter Channel Segment 2	223	2,224
North Perimeter Channel Segment 3	295	5,562
South Perimeter Channel Segment 1	73	119
South Perimeter Channel Segment 2	160	806
South Perimeter Channel Segment 3	310	1,984
South Perimeter Channel Segment 4	424	7,415
West Perimeter Channel	25	139
East Culvert (North Perimeter Channel)	295	325
West Culvert (West Perimeter Channel)	25	35
South Culvert (South Perimeter Channel)	424	470

Table 2: Stormwater Sediment Basin Hydraulic Capacity

Pond	1,000 year Water Surface Elevation (ft)	Embankment Crest/Allowable WSE (ft)
Stormwater Sediment Pond	39.58	41.00

SUBJECT CHESTERFIELD POWER STATION-UPPER (EAST) POND
HYDROLOGIC AND HYDRAULIC CAPACITY ASSESSMENT

BY BERKEME DATE 10/05/2016 PROJ. NO. C150035.00

CHKD. BY URBANCE DATE 10/07/2016

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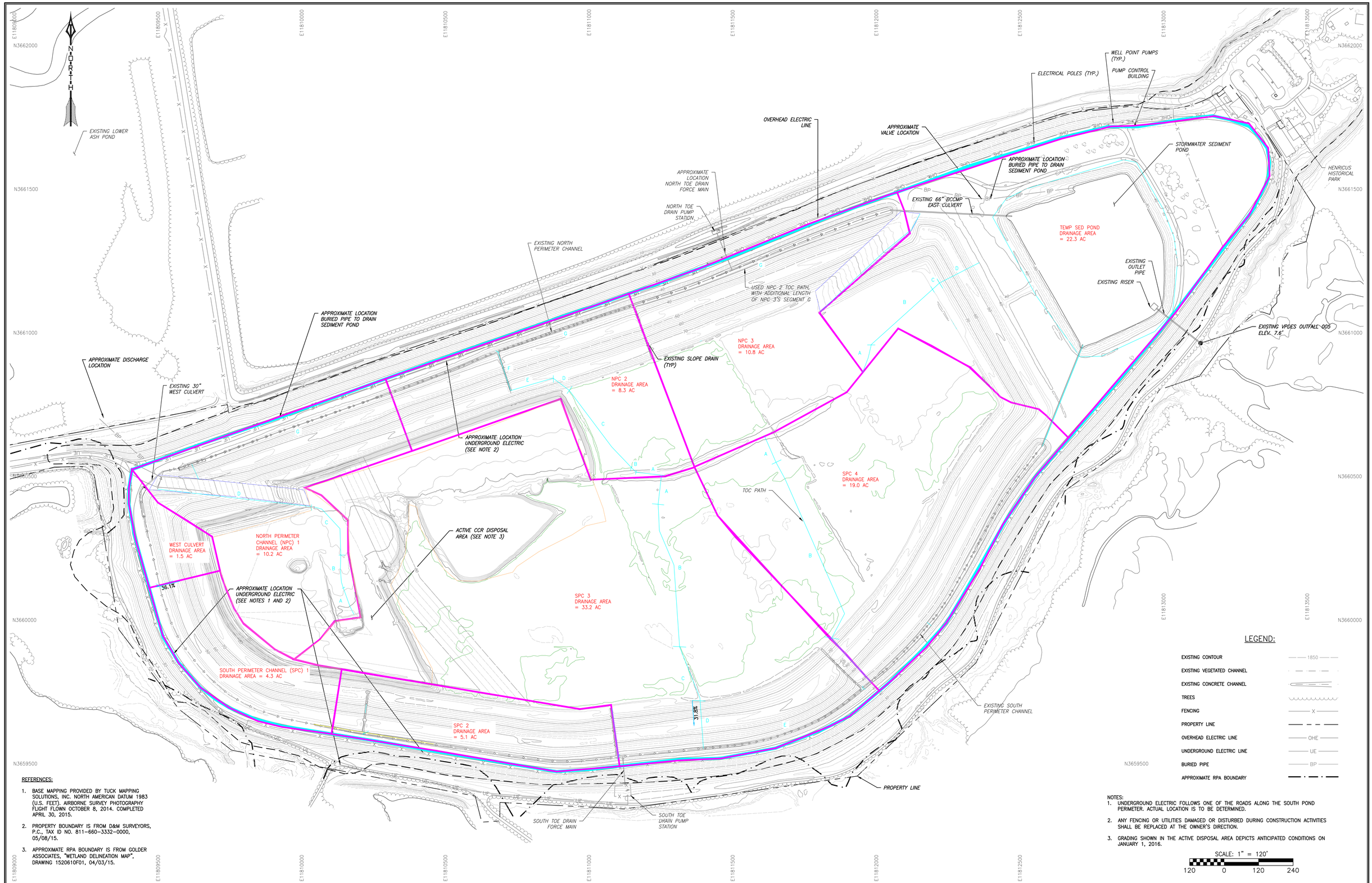
ATTACHMENT 1

DRAINAGE AREA MAP



LEGEND:

- EXISTING CONTOUR — 1850
- EXISTING VEGETATED CHANNEL
- EXISTING CONCRETE CHANNEL
- TREES
- FENCING — X
- PROPERTY LINE
- OVERHEAD ELECTRIC LINE — OHE
- UNDERGROUND ELECTRIC LINE — UE
- BURIED PIPE — BP
- APPROXIMATE RPA BOUNDARY

REFERENCES:

1. BASE MAPPING PROVIDED BY TUCK MAPPING SOLUTIONS, INC. NORTH AMERICAN DATUM 1983 (U.S. FEET). AIRBORNE SURVEY PHOTOGRAPHY FLIGHT FLOWN OCTOBER 8, 2014. COMPLETED APRIL 30, 2015.
2. PROPERTY BOUNDARY IS FROM D&M SURVEYORS, P.C., TAX ID NO. 811-660-3332-0000, 05/08/15.
3. APPROXIMATE RPA BOUNDARY IS FROM GOLDER ASSOCIATES, "WETLAND DELINEATION MAP", DRAWING 1520610F01, 04/03/15.

NOTES:
1. UNDERGROUND ELECTRIC FOLLOWS ONE OF THE ROADS ALONG THE SOUTH POND PERIMETER. ACTUAL LOCATION IS TO BE DETERMINED.
2. ANY FENCING OR UTILITIES DAMAGED OR DISTURBED DURING CONSTRUCTION ACTIVITIES SHALL BE REPLACED AT THE OWNER'S DIRECTION.
3. GRADING SHOWN IN THE ACTIVE DISPOSAL AREA DEPICTS ANTICIPATED CONDITIONS ON JANUARY 1, 2016.

SCALE: 1" = 120'

120 0 120 240

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					REVISION RECORD

This drawing was produced with computer aided drafting technology and is supported by electronic drawing files. Do not revise this drawing via manual drafting methods.

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DRAWING TITLE
EXISTING CONDITIONS - DRAINAGE AREA MAP

PROJECT	CLIENT
UPPER ASH POND IDFCSP **CHESTERFIELD POWER STATION** **CHESTER** **CHESTERFIELD COUNTY, VIRGINIA**	**DOMINION** **GLEN ALLEN, VIRGINIA**

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ISSUING OFFICE: Murrysville | 4200 Triangle Lane, Export, PA 15632-1358

DRAWN BY:	CHECKED BY:	APPROVED BY:	GAI FILE NUMBER:
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	AS SHOWN	**--/--/----**	
REVISION **0**	SHEET NO.: **1 OF 1**		GAI DRAWING NUMBER: **E1-002**

SUBJECT CHESTERFIELD POWER STATION-UPPER (EAST) POND
HYDROLOGIC AND HYDRAULIC CAPACITY ASSESSMENT
BY BERKEME DATE 10/05/2016 PROJ. NO. C150035.00
CHKD. BY URBANCE DATE 10/07/2016

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ATTACHMENT 2

STAGE-DISCHARGE FOR POND

SUBJECT CHESTERFIELD POWER STATION-UPPER (EAST) POND
HYDROLOGIC AND HYDRAULIC CAPACITY ASSESSMENT
BY URBANCE DATE 06/15/2016 PROJ. NO. C150035.00
CHKD. BY BERKEME DATE 06/15/2016

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Chesterfield
SEDIMENTATION POND
STAGE-DISCHARGE ANALYSIS

Elev (ft)	Head on first orifice row	Flow in first row (cfs)	Head on second orifice row	Flow in second row (cfs)	Head on third orifice row	Flow in third row (cfs)	Head on fourth orifice row	Flow in fourth row (cfs)	Head on fifth orifice row	Flow in fifth row (cfs)	Head on riser	Orifice Flow in Riser	Weir Flow in Riser	Net Flow in Riser	Head on Outlet Pipe	V^2 / 2g	Allowable Flow in Outlet Pipe	**Total Orifice Flow (cfs)**
26.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00	2.19	149.30	**0.00**
30	1.00	6.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.00	3.44	187.15	**6.73**
31	2.00	9.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.00	3.76	195.48	**9.52**
32	3.00	11.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.00	4.07	203.46	**11.65**
33	4.00	13.45	0.00	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	4.38	211.14	**14.16**
34	5.00	15.04	0.67	5.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00	4.70	218.55	**20.55**
35	6.00	16.47	1.67	8.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	5.01	225.72	**25.17**
36	7.00	17.79	2.67	10.99	0.00	1.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.00	5.32	232.66	**30.74**
37	8.00	19.02	3.67	12.89	1.00	6.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.00	5.64	239.41	**38.64**
38	9.00	20.17	4.67	14.53	2.00	9.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.00	5.95	245.97	**44.22**
39	10.00	21.26	5.67	16.01	3.00	11.65	0.00	0.97	0.00	0.00	0.00	0.00	0.00	0.00	20.00	6.26	252.36	**49.90**
40	11.00	22.30	6.67	17.37	4.00	13.45	0.75	5.84	0.00	0.00	0.00	0.00	0.00	0.00	21.00	6.58	258.59	**58.96**
41	12.00	23.29	7.67	18.62	5.00	15.04	1.75	8.90	0.00	0.00	0.00	0.00	0.00	0.00	22.00	6.89	264.67	**65.86**

Orifice		Orifice		Orifice		Orifice		Orifice	
Circular - 16"		Circular - 16"		Circular - 16"		Circular - 16"		Circular - 16"	
Invert	28.33	Invert	32.66	Invert	35.33	Invert	38.58	Invert	41.41
Diam (in)	16.000	Diam (in)	16.000	Diam (in)	16.000	Diam (in)	16.000	Diam (in)	16.000
Area (sf)	1.396	Area (sf)	1.396	Area (sf)	1.396	Area (sf)	1.396	Area (sf)	1.396
centroid el.	29.00	centroid el.	33.33	centroid el.	36.00	centroid el.	39.25	centroid el	42.08
C	0.6	C	0.6	C	0.6	C	0.6	C	0.6
No. holes	1	No. holes	1	No. holes	1	No. holes	1	No. holes	1

RISER DATA	
Crest	44
Area (sf)	36.00
Perimeter (ft)	24.00
Weir C	3.33
Orifice C	0.6

BARREL	
HDPE - n =	0.011
Diameter (ft)	2
Inlet Invert	12
Outlet Invert	7.6
Outlet TW	19.00
Area (sf)	12.57
Length (ft)	192
Ke	0.5
R (ft)	0.5

The outlet pipe calculation is based on outlet control
The equation used is the outlet control equation in HDS - 5:
$H = (1 + Ke + (29 * n^2 * L)/R^{1.33}) * V^2 / 2g$

SUBJECT CHESTERFIELD POWER STATION-UPPER (EAST) POND
HYDROLOGIC AND HYDRAULIC CAPACITY ASSESSMENT
BY BERKEME DATE 10/05/2016 PROJ. NO. C150035.00
CHKD. BY URBANCE DATE 10/07/2016

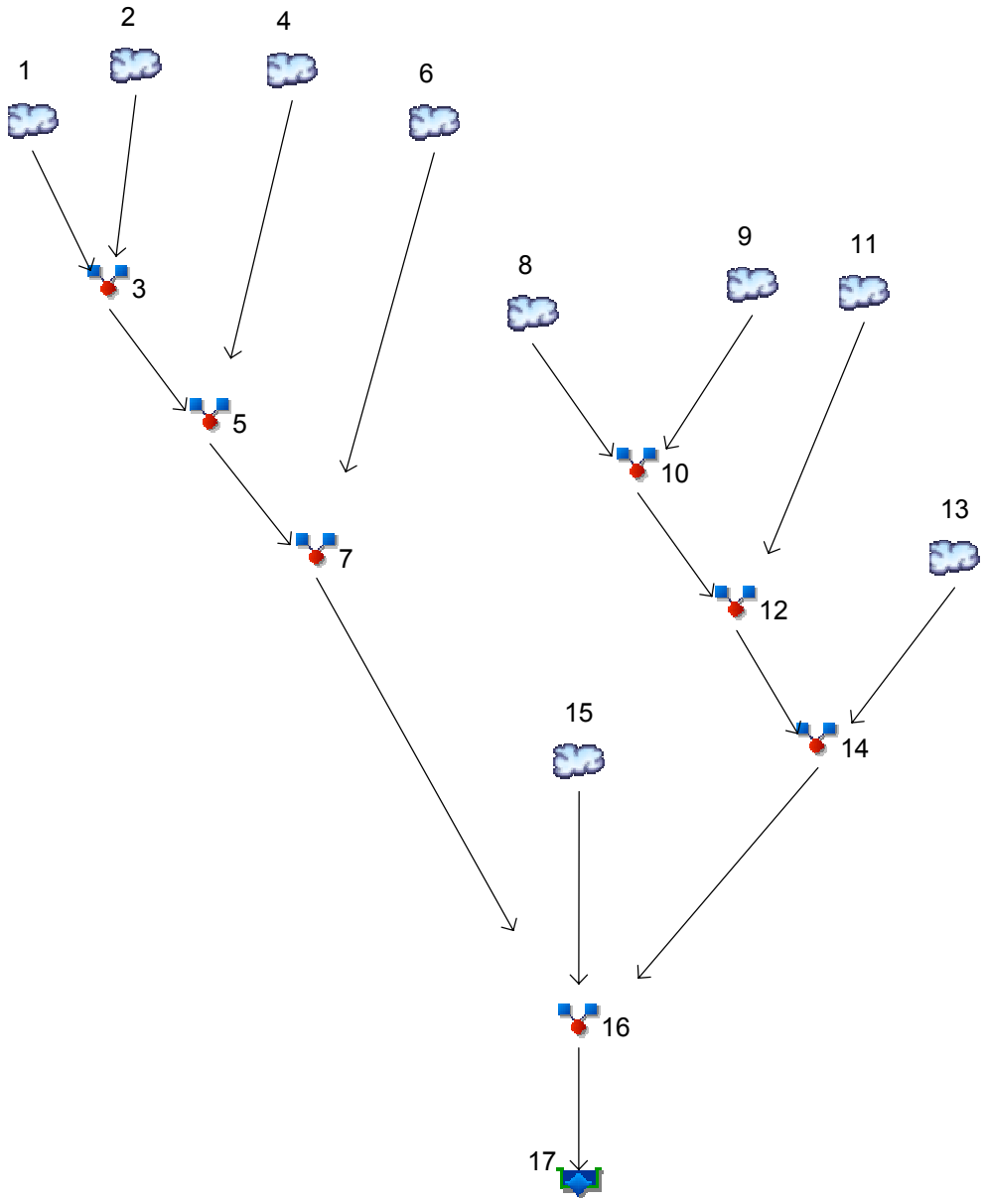
gai consultants

ATTACHMENT 3

HYDRAFLOW ROUTING

Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. v10



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. v10

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	72.81	1	717	155,489	------	------	------	South Perimeter Channel 1
2	SCS Runoff	86.36	1	717	184,418	------	------	------	South Perimeter Channel 2
3	Combine	159.17	1	717	339,907	1, 2	------	------	SPC 2 Total
4	SCS Runoff	272.18	1	734	1,233,292	------	------	------	South Perimeter Channel 3
5	Combine	309.81	1	719	1,573,200	3, 4	------	------	Total flow to South Perimeter Channe
6	SCS Runoff	135.94	1	737	666,227	------	------	------	South Perimeter Channel 4
7	Combine	424.60	1	734	2,239,426	5, 6	------	------	South Perimeter Total
8	SCS Runoff	25.40	1	717	54,240	------	------	------	West Perimeter Channel (West Culve
9	SCS Runoff	147.25	1	721	403,196	------	------	------	North Perimeter Channel 1
10	Combine	168.27	1	720	457,436	8, 9	------	------	NPC 1 Total
11	SCS Runoff	74.16	1	730	288,896	------	------	------	North Perimeter Channel 2
12	Combine	223.01	1	721	746,334	10, 11	------	------	NPC 2 Total
13	SCS Runoff	94.52	1	731	384,385	------	------	------	North Perimeter Channel 3
14	Combine	294.52	1	722	1,130,716	12, 13	------	------	North Perimeter Channel Total
15	SCS Runoff	247.03	1	726	887,493	------	------	------	Temporary Sed Pond
16	Combine	898.08	1	723	4,257,634	7, 14, 15	------	------	Total To Sed Pond
17	Reservoir	55.19	1	859	3,653,877	16	39.58	3,247,439	<no description>

Note: Hydraflow does not have an input option for a 1,000yr return interval, so the 1,000yr rainfall was entered as input for the 10yr return period.

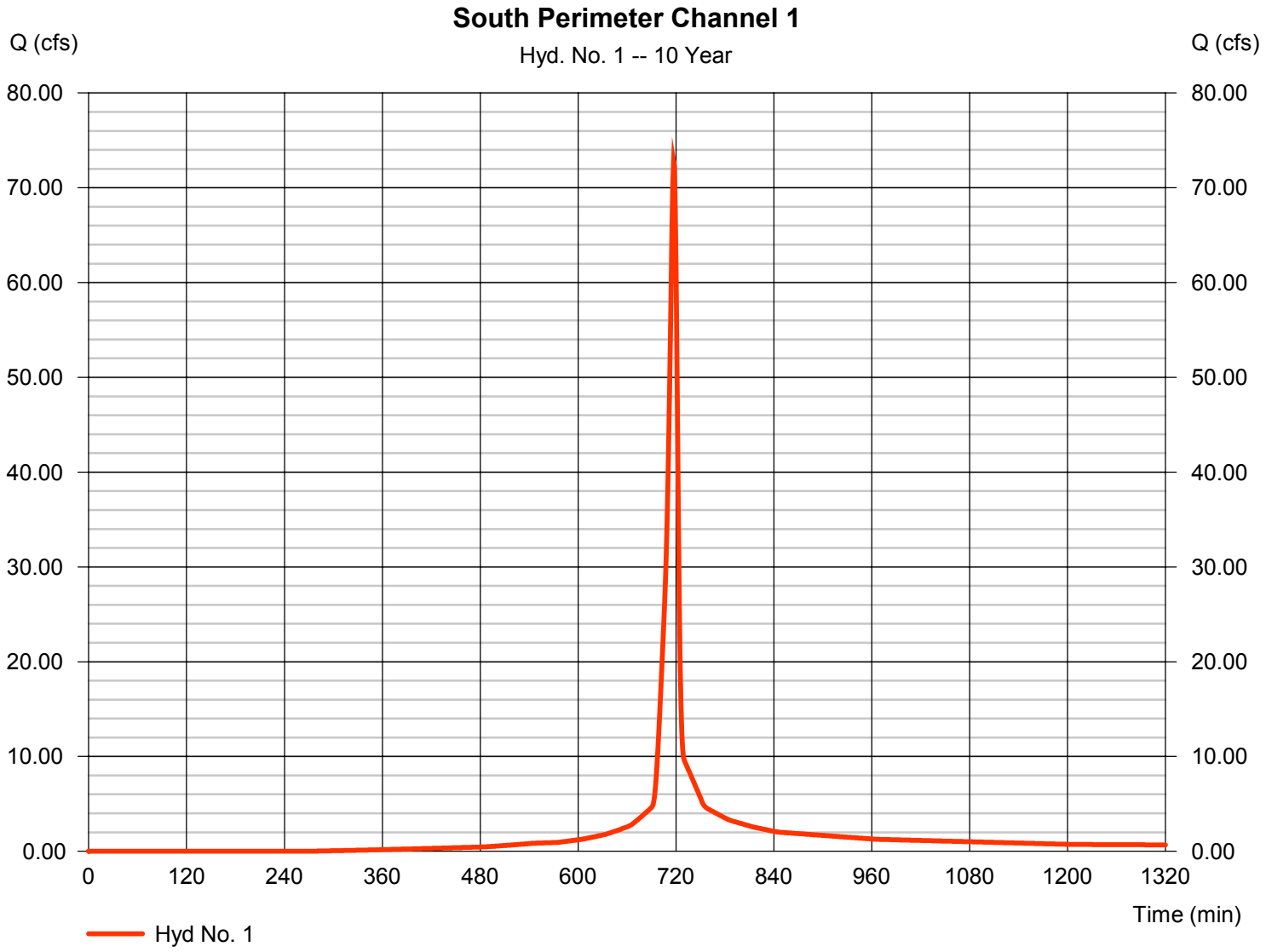
Hydrograph Report

Hyd. No. 1

South Perimeter Channel 1

Hydrograph type	= SCS Runoff	Peak discharge	= 72.81 cfs
Storm frequency	= 10 yrs	Time to peak	= 717 min
Time interval	= 1 min	Hyd. volume	= 155,489 cuft
Drainage area	= 4.300 ac	Curve number	= 74*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 6.00 min
Total precip.	= 13.10 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(3.600 x 85) + (7.300 x 74)] / 4.300

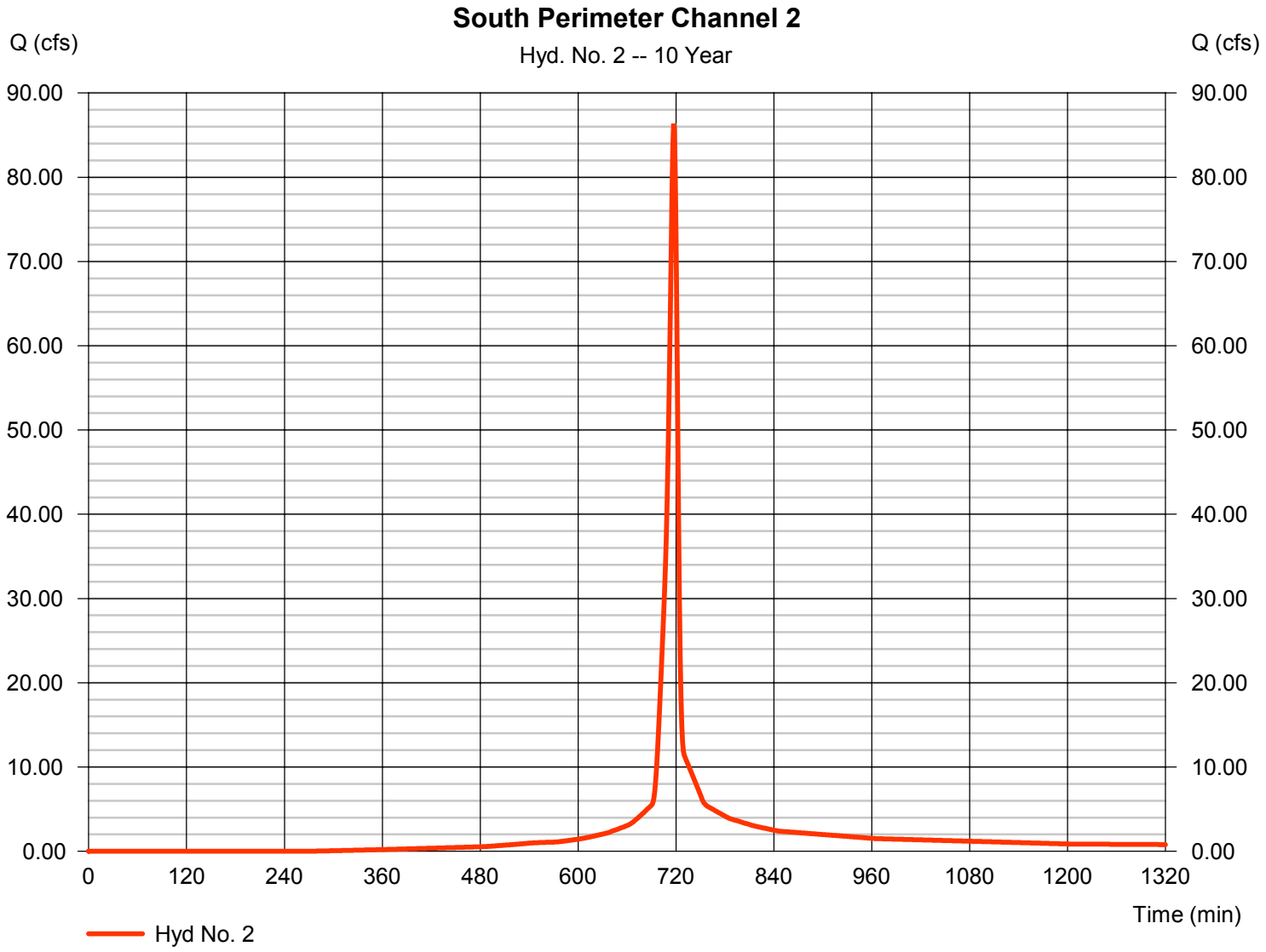


Hydrograph Report

Hyd. No. 2

South Perimeter Channel 2

Hydrograph type	= SCS Runoff	Peak discharge	= 86.36 cfs
Storm frequency	= 10 yrs	Time to peak	= 717 min
Time interval	= 1 min	Hyd. volume	= 184,418 cuft
Drainage area	= 5.100 ac	Curve number	= 74
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 6.00 min
Total precip.	= 13.10 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

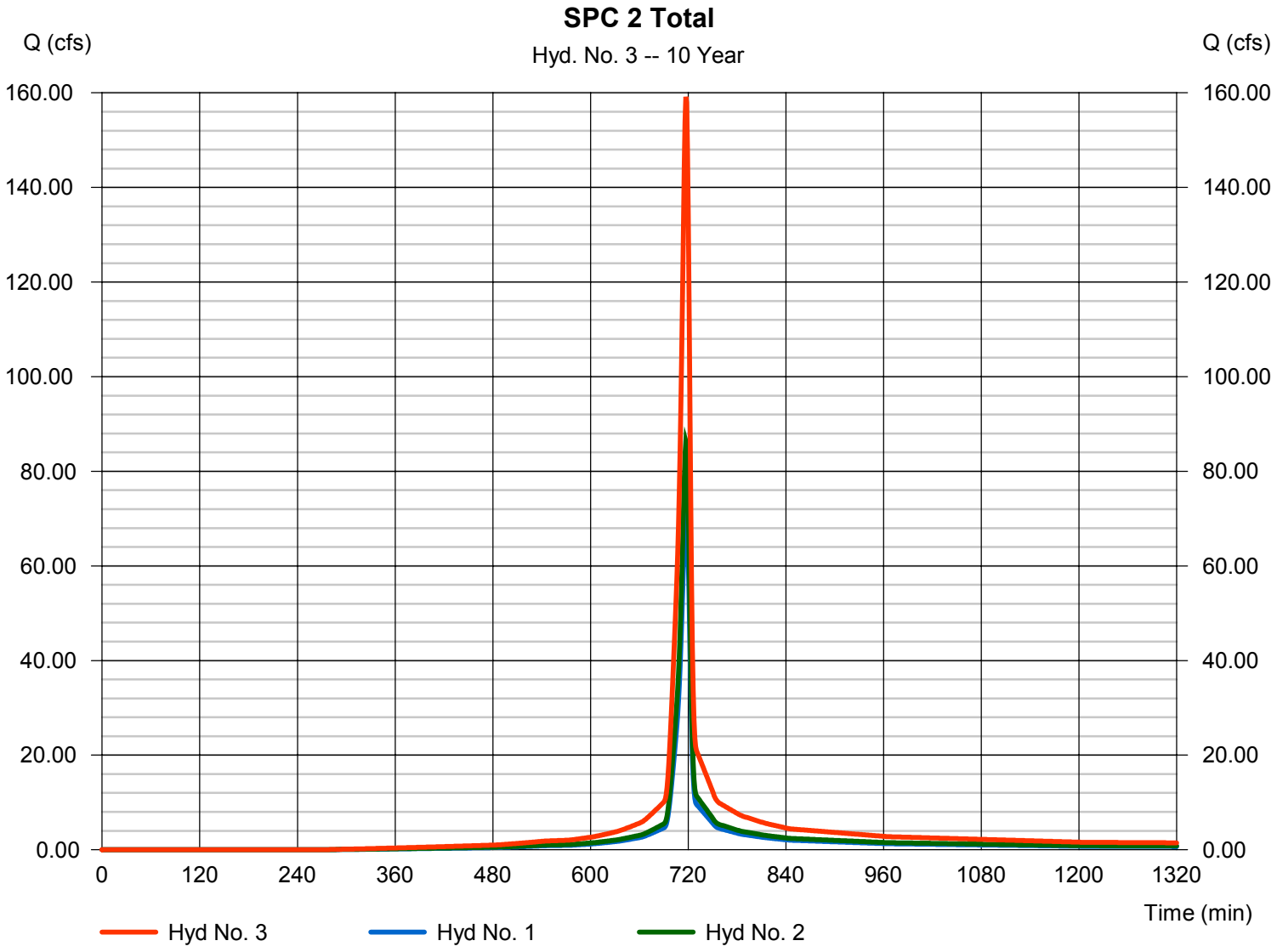


Hydrograph Report

Hyd. No. 3

SPC 2 Total

Hydrograph type	= Combine	Peak discharge	= 159.17 cfs
Storm frequency	= 10 yrs	Time to peak	= 717 min
Time interval	= 1 min	Hyd. volume	= 339,907 cuft
Inflow hyds.	= 1, 2	Contrib. drain. area	= 9.400 ac



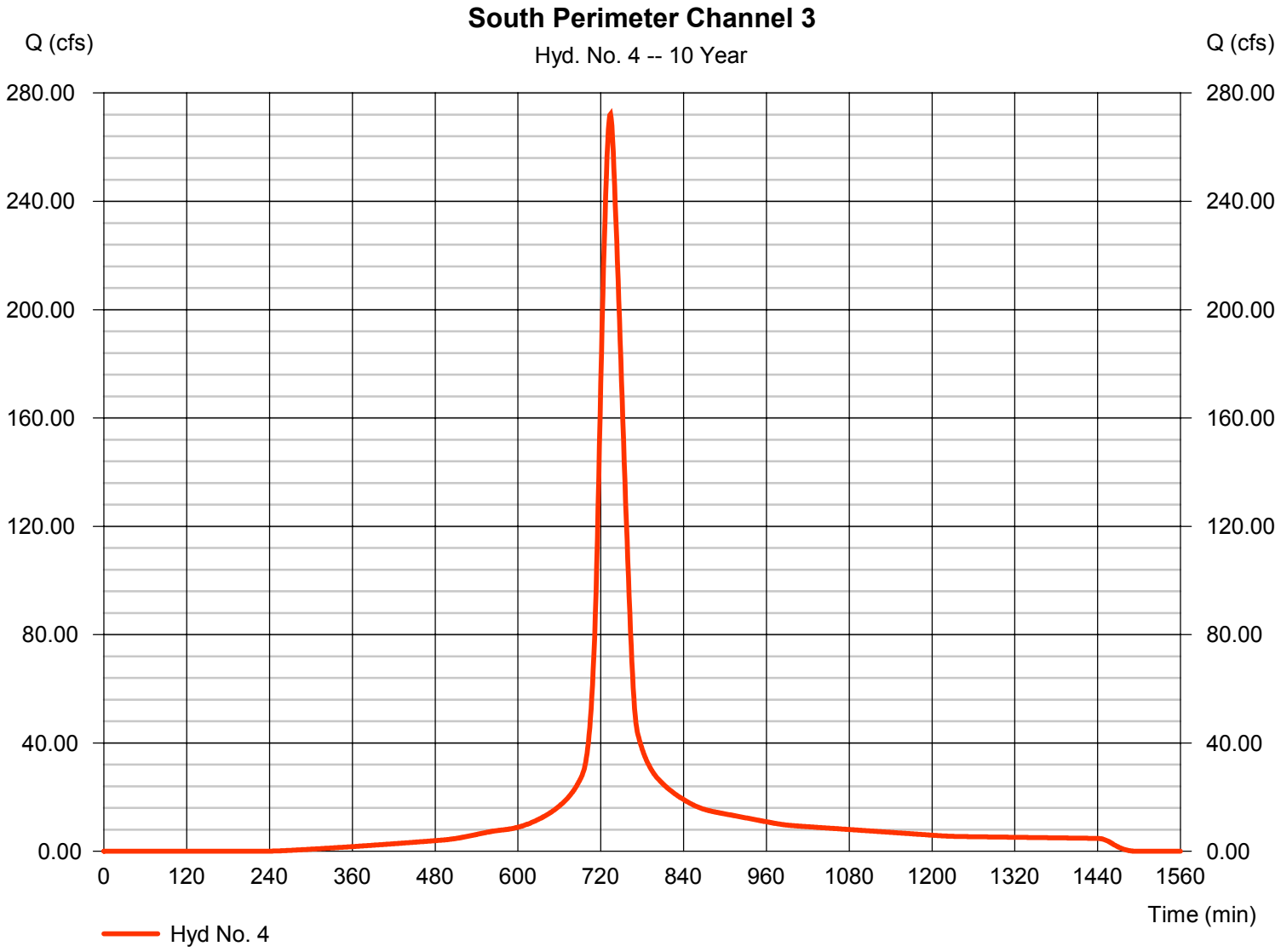
Hydrograph Report

Hyd. No. 4

South Perimeter Channel 3

Hydrograph type	= SCS Runoff	Peak discharge	= 272.18 cfs
Storm frequency	= 10 yrs	Time to peak	= 734 min
Time interval	= 1 min	Hyd. volume	= 1,233,292 cuft
Drainage area	= 33.200 ac	Curve number	= 78*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 34.10 min
Total precip.	= 13.10 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(10.600 x 85) + (22.600 x 74)] / 33.200



TR55 Tc Worksheet

Hyd. No. 4

South Perimeter Channel 3

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.240		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.36		0.00		0.00		
Land slope (%)	= 2.50		0.00		0.00		
Travel Time (min)	**= 12.74**	**+**	**0.00**	**+**	**0.00**	**=**	**12.74**
Shallow Concentrated Flow							
Flow length (ft)	= 507.00		202.00		163.00		
Watercourse slope (%)	= 0.10		0.50		33.00		
Surface description	= Unpaved		Unpaved		Unpaved		
Average velocity (ft/s)	=0.51		1.14		9.27		
Travel Time (min)	**= 16.56**	**+**	**2.95**	**+**	**0.29**	**=**	**19.81**
Channel Flow							
X sectional flow area (sqft)	= 114.00		0.00		0.00		
Wetted perimeter (ft)	= 37.00		0.00		0.00		
Channel slope (%)	= 0.50		0.00		0.00		
Manning's n-value	= 0.035		0.015		0.035		
Velocity (ft/s)	=6.40						
			0.00				
					0.00		
Flow length (ft)	({0})600.0		0.0		0.0		
Travel Time (min)	**= 1.56**	**+**	**0.00**	**+**	**0.00**	**=**	**1.56**

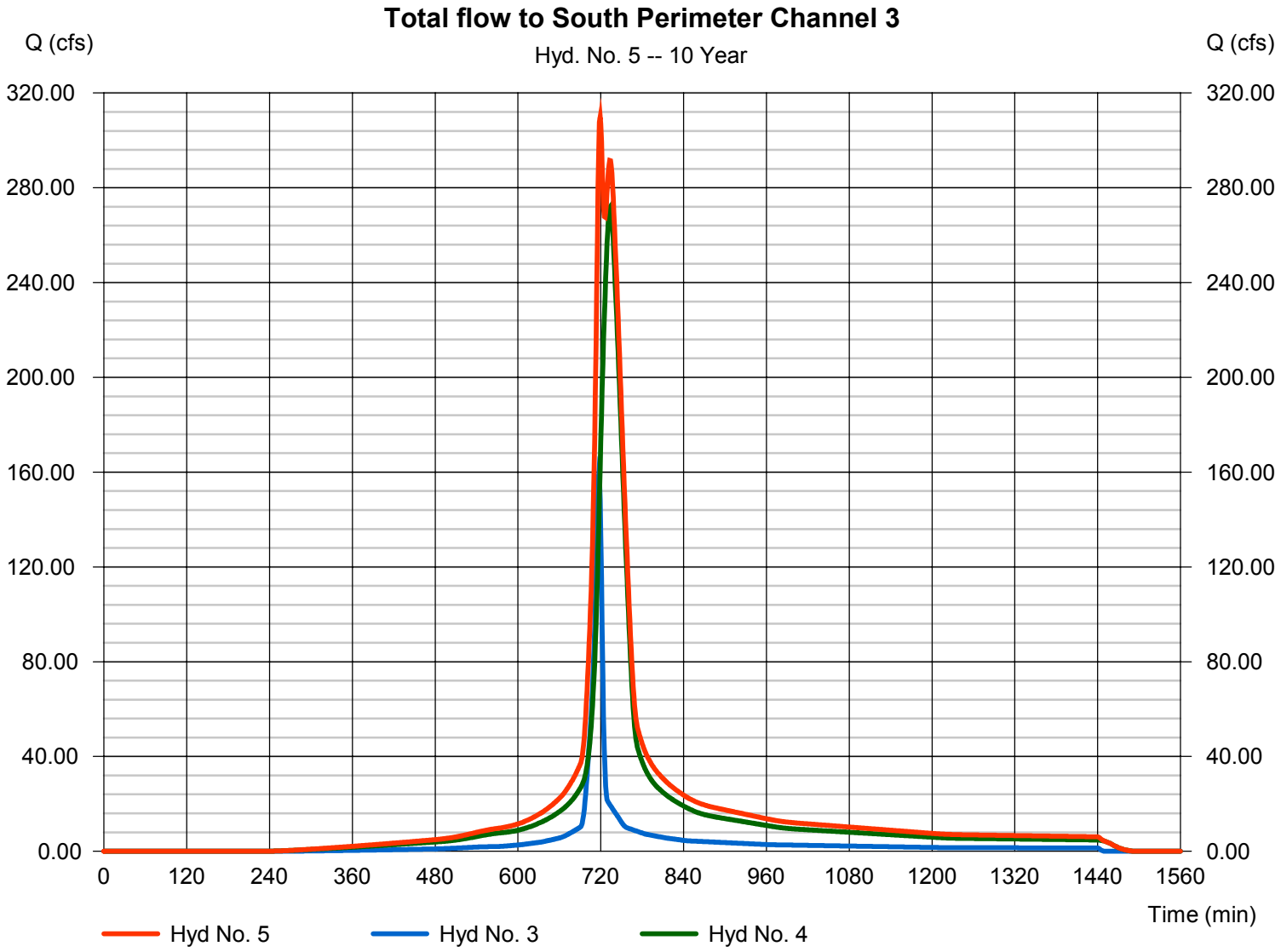
Total Travel Time, Tc ..... 34.10 min

Hydrograph Report

Hyd. No. 5

Total flow to South Perimeter Channel 3

Hydrograph type	= Combine	Peak discharge	= 309.81 cfs
Storm frequency	= 10 yrs	Time to peak	= 719 min
Time interval	= 1 min	Hyd. volume	= 1,573,200 cuft
Inflow hyds.	= 3, 4	Contrib. drain. area	= 33.200 ac

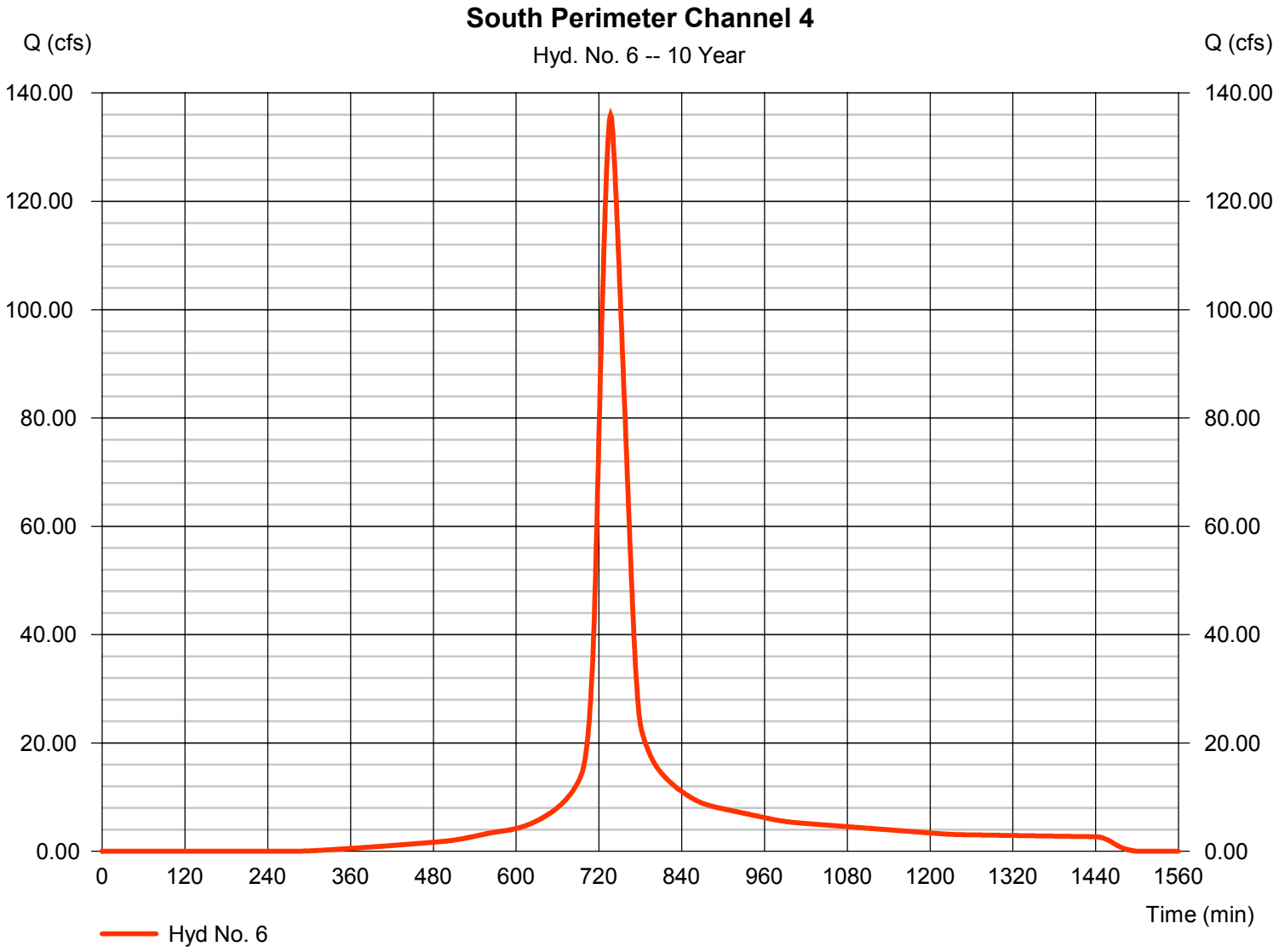


Hydrograph Report

Hyd. No. 6

South Perimeter Channel 4

Hydrograph type	= SCS Runoff	Peak discharge	= 135.94 cfs
Storm frequency	= 10 yrs	Time to peak	= 737 min
Time interval	= 1 min	Hyd. volume	= 666,227 cuft
Drainage area	= 19.000 ac	Curve number	= 74
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 40.50 min
Total precip.	= 13.10 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hyd. No. 6

South Perimeter Channel 4

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.240		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.36		3.36		0.00		
Land slope (%)	= 1.00		0.00		0.00		
Travel Time (min)	**= 18.38**	**+**	**0.00**	**+**	**0.00**	**=**	**18.38**
Shallow Concentrated Flow							
Flow length (ft)	= 603.00		208.00		0.00		
Watercourse slope (%)	= 0.10		33.00		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=0.51		9.27		0.00		
Travel Time (min)	**= 19.70**	**+**	**0.37**	**+**	**0.00**	**=**	**20.07**
Channel Flow							
X sectional flow area (sqft)	= 239.00		0.00		0.00		
Wetted perimeter (ft)	= 53.00		0.00		0.00		
Channel slope (%)	= 0.50		0.00		0.00		
Manning's n-value	= 0.034		0.034		0.035		
Velocity (ft/s)	=8.50						
			0.00				
					0.00		
Flow length (ft)	({0})1023.0		0.0		0.0		
Travel Time (min)	**= 2.01**	**+**	**0.00**	**+**	**0.00**	**=**	**2.01**

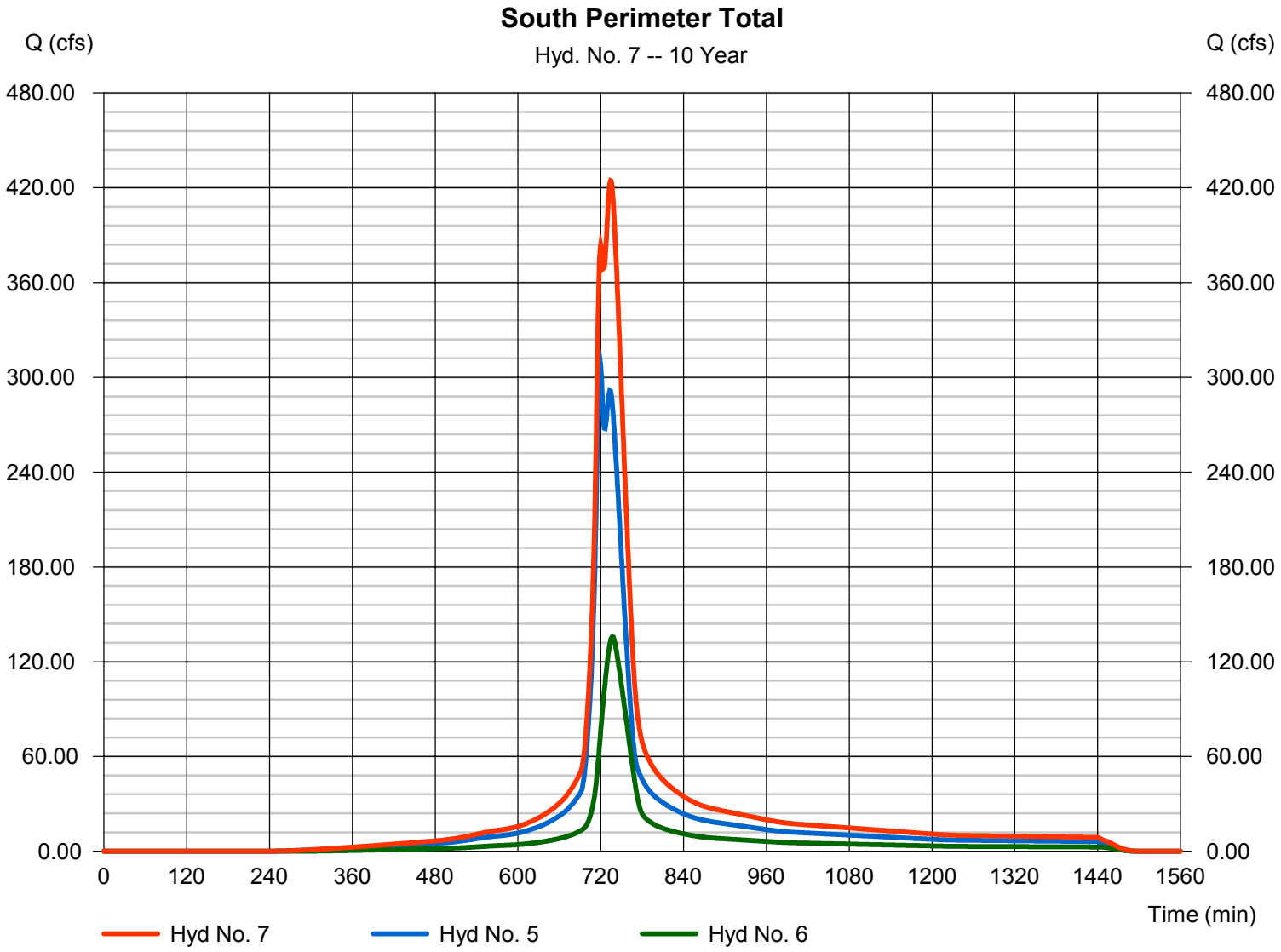
Total Travel Time, Tc ..... 40.50 min

Hydrograph Report

Hyd. No. 7

South Perimeter Total

Hydrograph type	= Combine	Peak discharge	= 424.60 cfs
Storm frequency	= 10 yrs	Time to peak	= 734 min
Time interval	= 1 min	Hyd. volume	= 2,239,426 cuft
Inflow hyds.	= 5, 6	Contrib. drain. area	= 19.000 ac

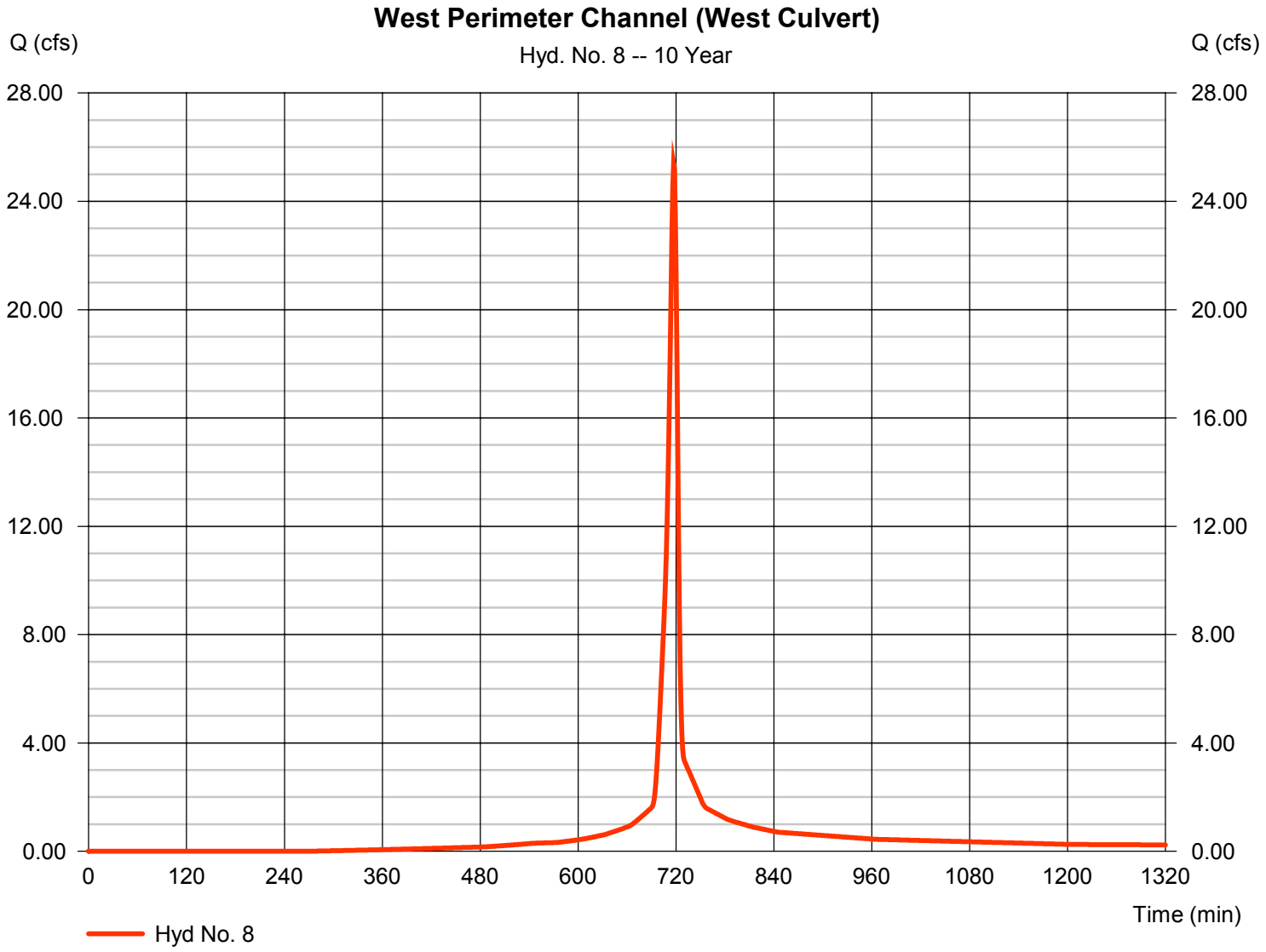


Hydrograph Report

Hyd. No. 8

West Perimeter Channel (West Culvert)

Hydrograph type	= SCS Runoff	Peak discharge	= 25.40 cfs
Storm frequency	= 10 yrs	Time to peak	= 717 min
Time interval	= 1 min	Hyd. volume	= 54,240 cuft
Drainage area	= 1.500 ac	Curve number	= 74
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= User	Time of conc. (Tc)	= 6.00 min
Total precip.	= 13.10 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



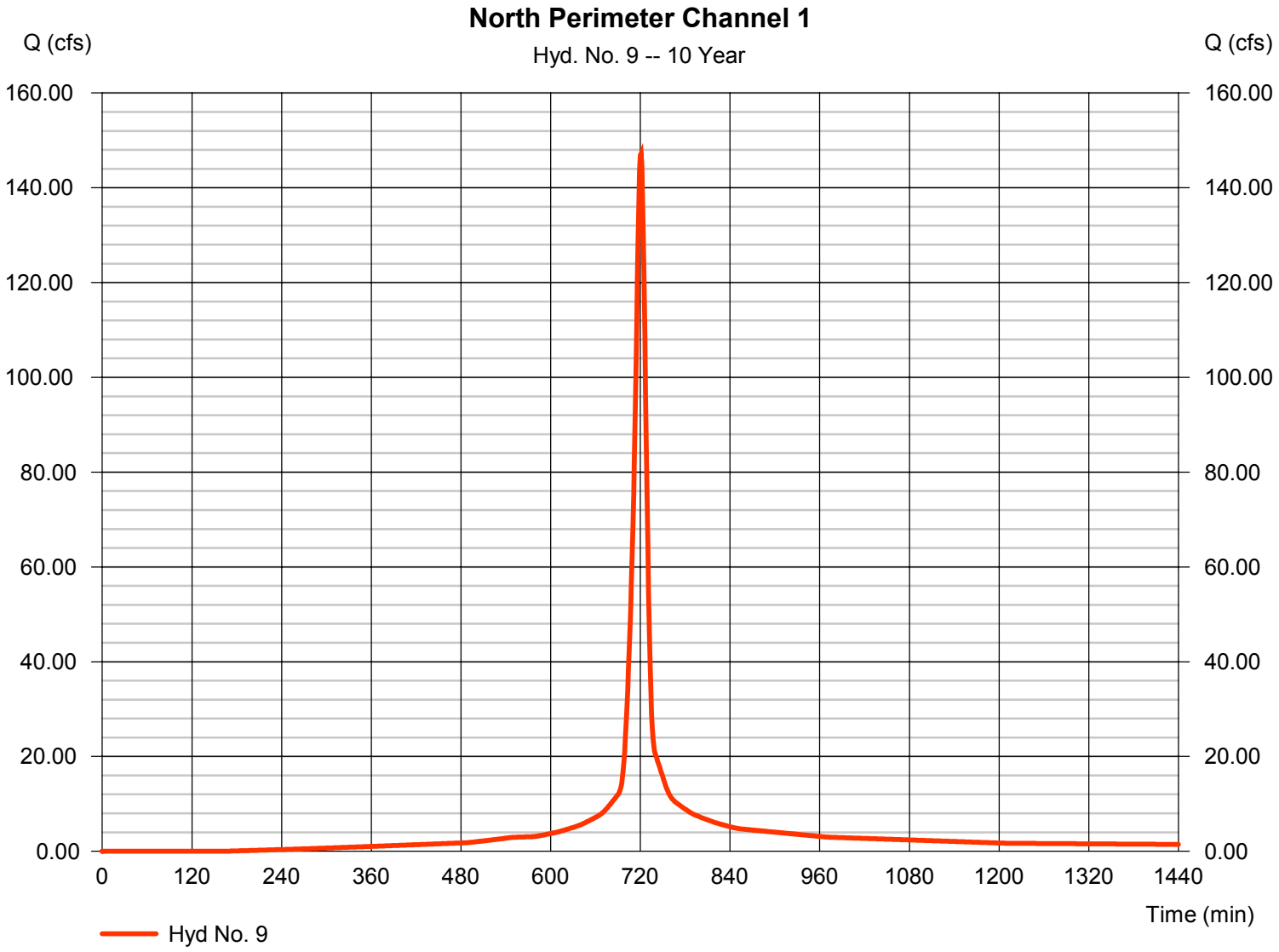
Hydrograph Report

Hyd. No. 9

North Perimeter Channel 1

Hydrograph type	= SCS Runoff	Peak discharge	= 147.25 cfs
Storm frequency	= 10 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 403,196 cuft
Drainage area	= 10.200 ac	Curve number	= 84*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.40 min
Total precip.	= 13.10 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(4.300 x 85) + (0.630 x 89) + (5.270 x 74)] / 10.200



TR55 Tc Worksheet

Hyd. No. 9

North Perimeter Channel 1

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.030		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.36		0.00		0.00		
Land slope (%)	= 2.00		0.00		0.00		
Travel Time (min)	**= 2.64**	**+**	**0.00**	**+**	**0.00**	**=**	**2.64**
Shallow Concentrated Flow							
Flow length (ft)	= 116.00		211.00		0.00		
Watercourse slope (%)	= 2.00		0.50		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=2.28		1.14		0.00		
Travel Time (min)	**= 0.85**	**+**	**3.08**	**+**	**0.00**	**=**	**3.93**
Channel Flow							
X sectional flow area (sqft)	= 4.50		18.00		0.00		
Wetted perimeter (ft)	= 4.80		15.00		0.00		
Channel slope (%)	= 10.00		0.50		0.00		
Manning's n-value	= 0.040		0.040		0.015		
Velocity (ft/s)	=11.28						
			2.98				
					0.00		
Flow length (ft)	({0})540.0		903.0		0.0		
Travel Time (min)	**= 0.80**	**+**	**5.06**	**+**	**0.00**	**=**	**5.85**

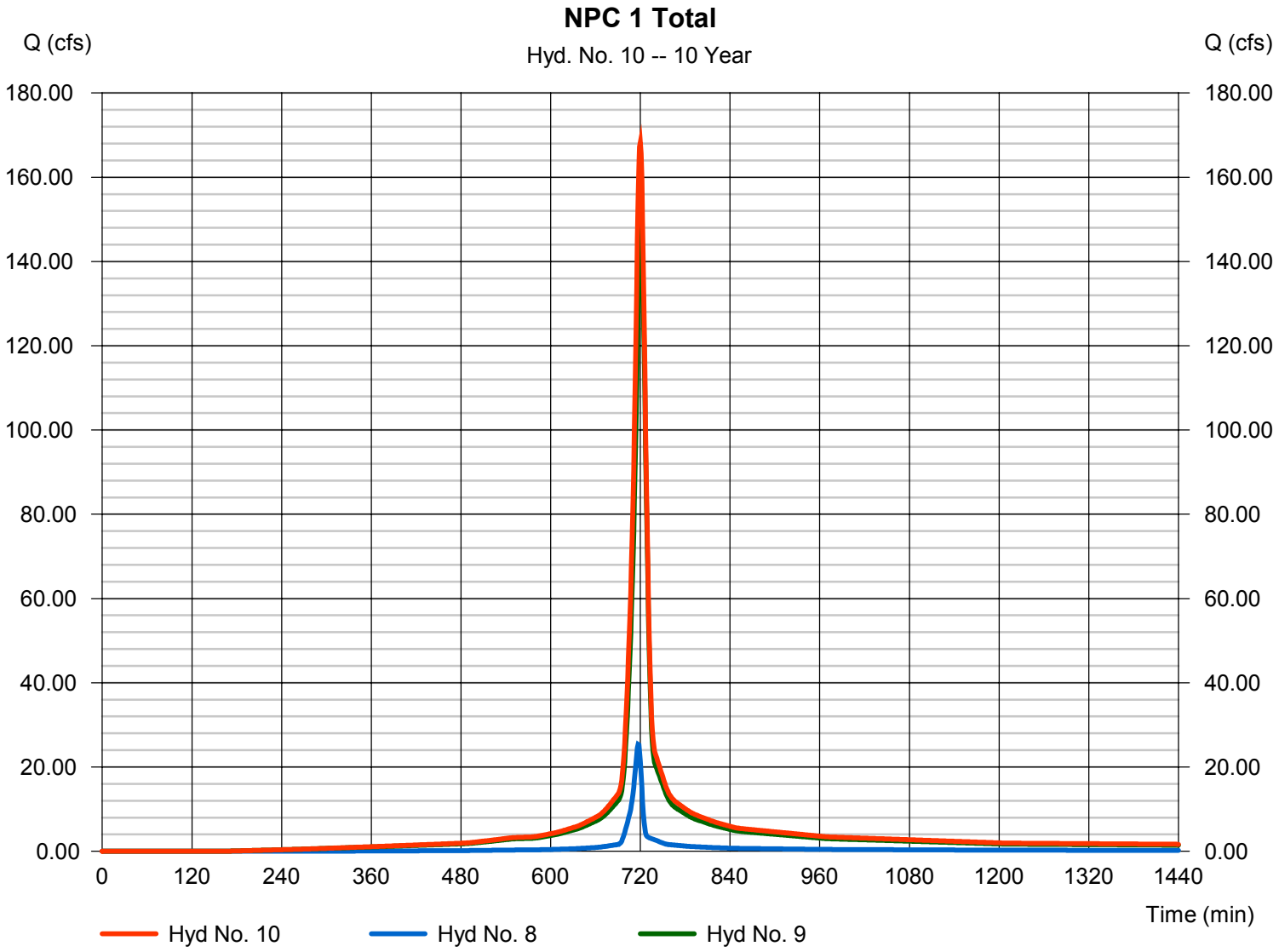
Total Travel Time, Tc ..... 12.40 min

Hydrograph Report

Hyd. No. 10

NPC 1 Total

Hydrograph type	= Combine	Peak discharge	= 168.27 cfs
Storm frequency	= 10 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 457,436 cuft
Inflow hyds.	= 8, 9	Contrib. drain. area	= 11.700 ac

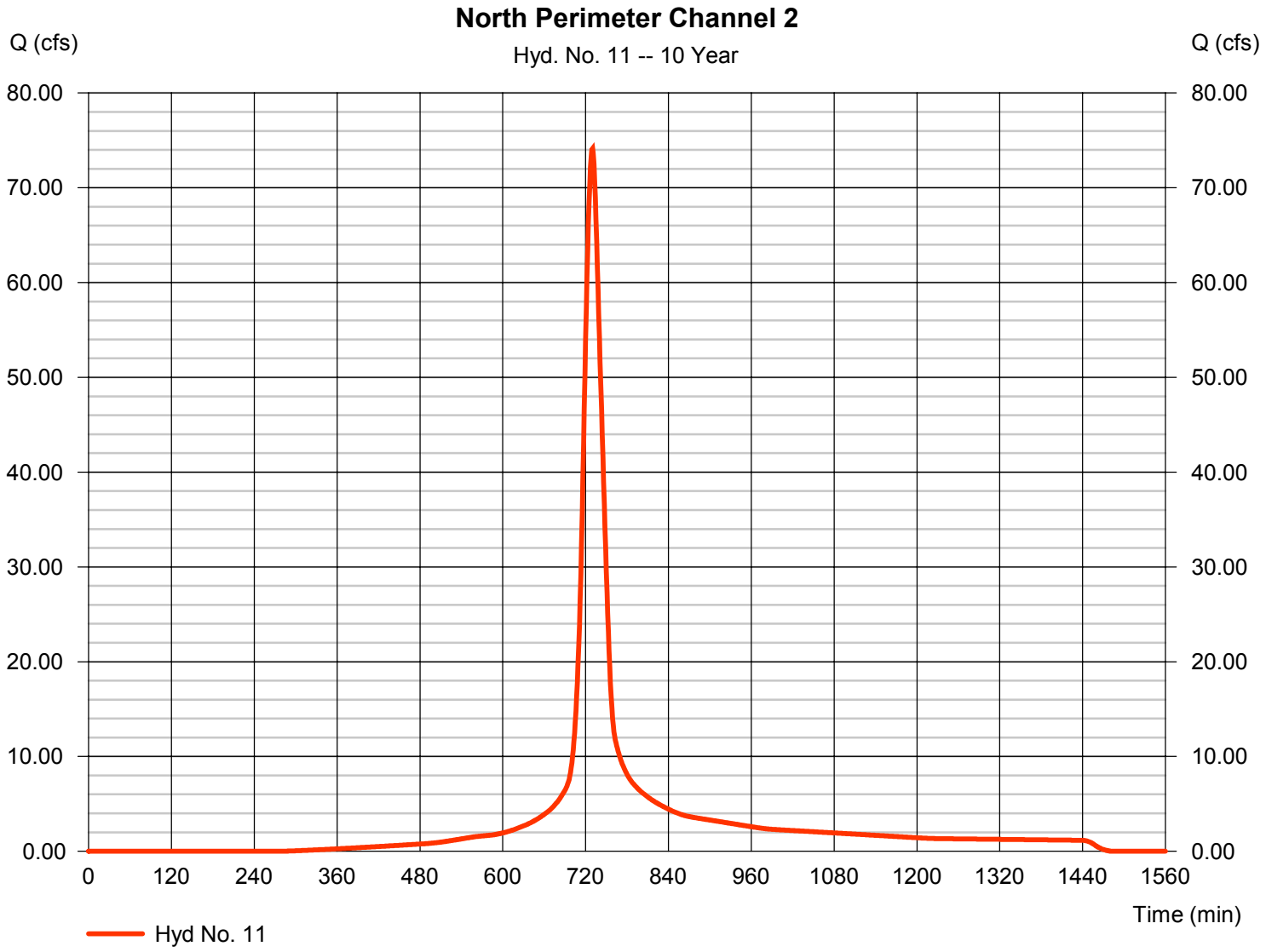


Hydrograph Report

Hyd. No. 11

North Perimeter Channel 2

Hydrograph type	= SCS Runoff	Peak discharge	= 74.16 cfs
Storm frequency	= 10 yrs	Time to peak	= 730 min
Time interval	= 1 min	Hyd. volume	= 288,896 cuft
Drainage area	= 8.300 ac	Curve number	= 74
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 27.70 min
Total precip.	= 13.10 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hyd. No. 11

North Perimeter Channel 2

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.240		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.36		0.00		3.90		
Land slope (%)	= 2.00		0.00		0.00		
Travel Time (min)	**= 13.93**	**+**	**0.00**	**+**	**0.00**	**=**	**13.93**
Shallow Concentrated Flow							
Flow length (ft)	= 23.00		345.00		71.00		
Watercourse slope (%)	= 17.00		0.10		33.00		
Surface description	= Unpaved		Unpaved		Unpaved		
Average velocity (ft/s)	=6.65		0.51		9.27		
Travel Time (min)	**= 0.06**	**+**	**11.27**	**+**	**0.13**	**=**	**11.45**
Channel Flow							
X sectional flow area (sqft)	= 11.50		12.00		114.00		
Wetted perimeter (ft)	= 23.20		11.00		36.00		
Channel slope (%)	= 1.00		33.00		0.50		
Manning's n-value	= 0.040		0.015		0.032		
Velocity (ft/s)	=2.33						
			60.49				
					7.13		
Flow length (ft)	({0})155.0		143.0		495.0		
Travel Time (min)	**= 1.11**	**+**	**0.04**	**+**	**1.16**	**=**	**2.31**

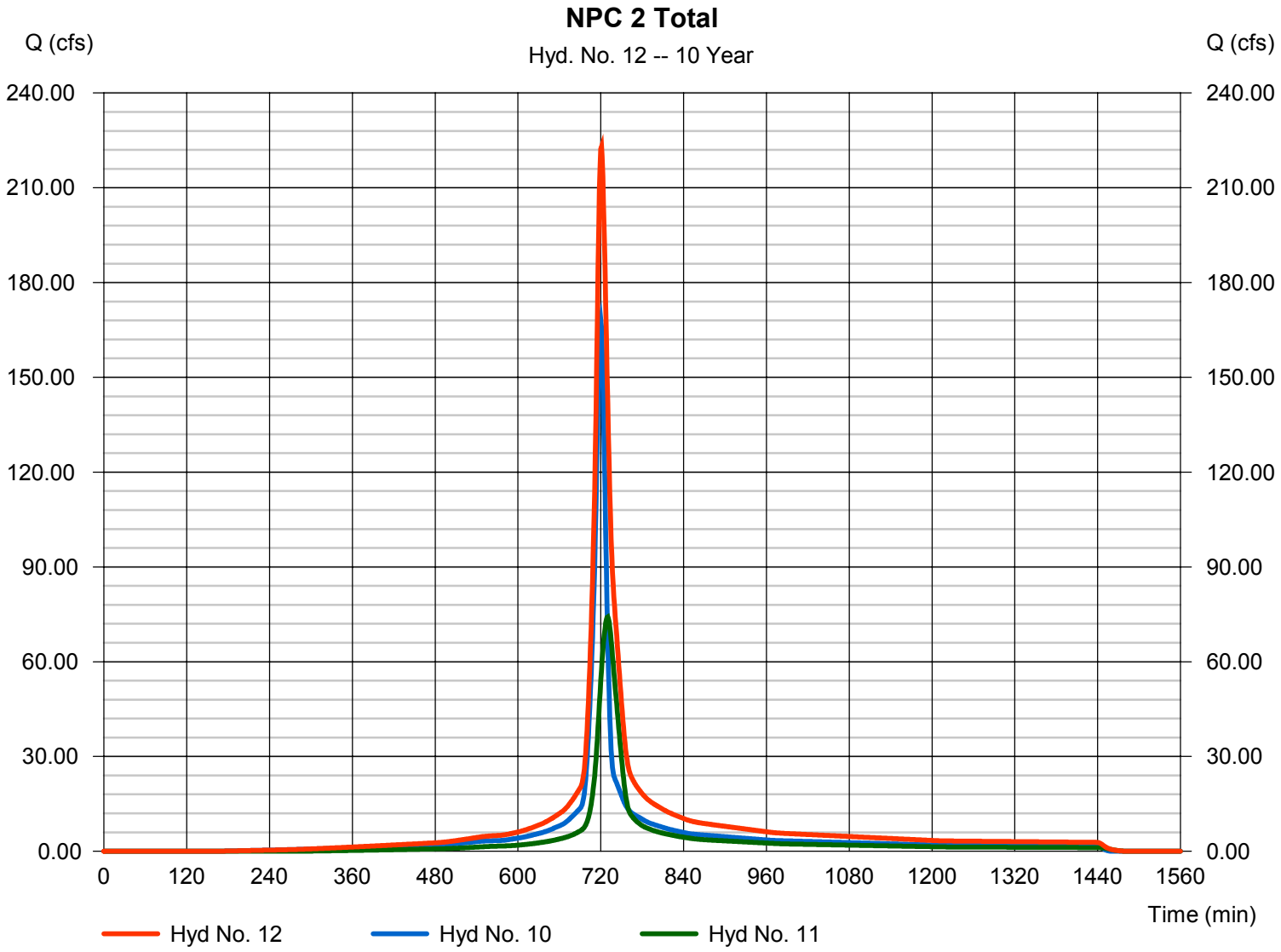
Total Travel Time, Tc ..... 27.70 min

Hydrograph Report

Hyd. No. 12

NPC 2 Total

Hydrograph type	= Combine	Peak discharge	= 223.01 cfs
Storm frequency	= 10 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 746,334 cuft
Inflow hyds.	= 10, 11	Contrib. drain. area	= 8.300 ac



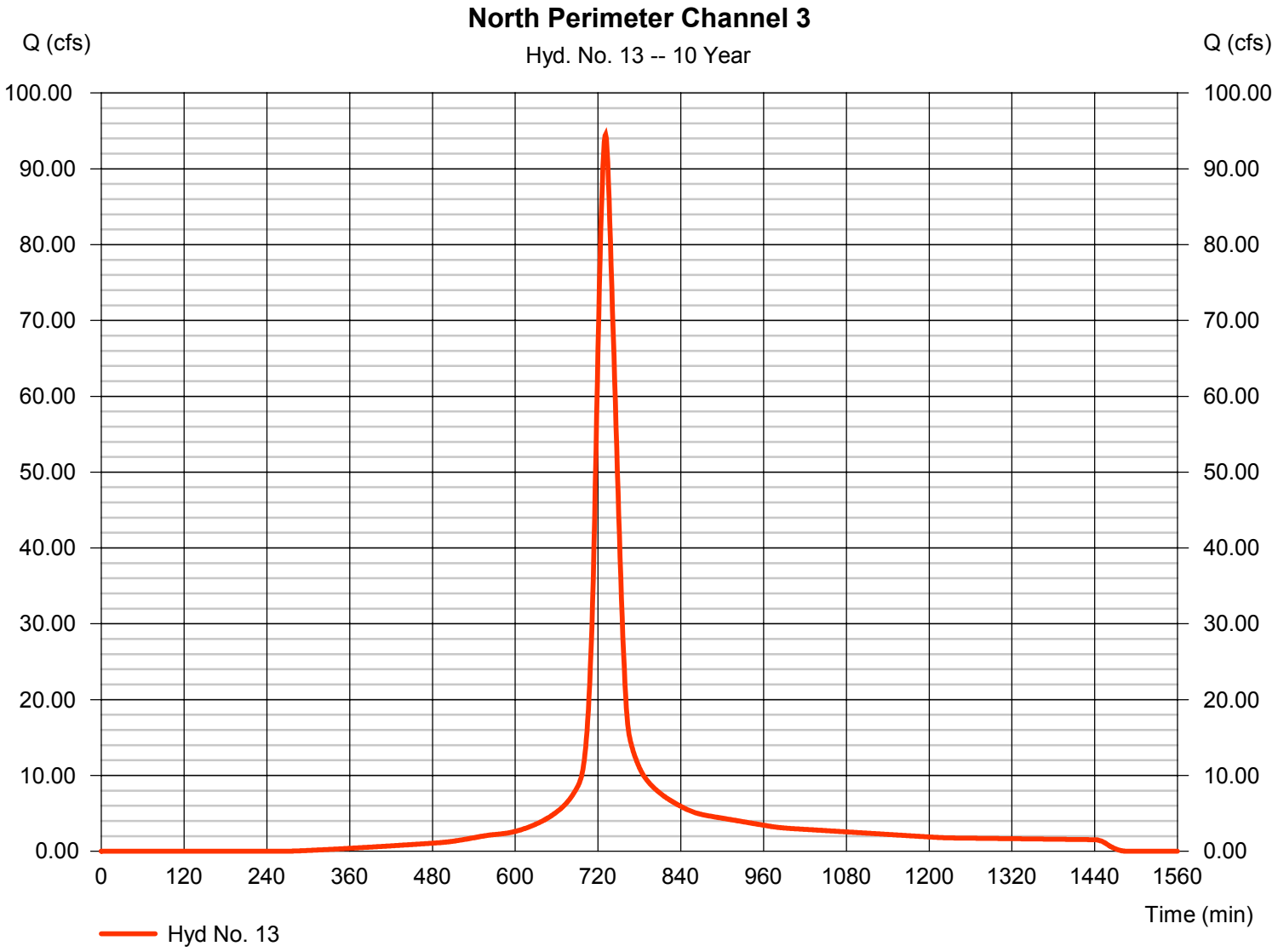
Hydrograph Report

Hyd. No. 13

North Perimeter Channel 3

Hydrograph type	= SCS Runoff	Peak discharge	= 94.52 cfs
Storm frequency	= 10 yrs	Time to peak	= 731 min
Time interval	= 1 min	Hyd. volume	= 384,385 cuft
Drainage area	= 10.800 ac	Curve number	= 75*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 29.20 min
Total precip.	= 13.10 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.700 x 89) + (10.100 x 74)] / 10.800



TR55 Tc Worksheet

Hyd. No. 13

North Perimeter Channel 3

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.240		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.36		0.00		0.00		
Land slope (%)	= 2.00		0.00		0.00		
Travel Time (min)	**= 13.93**	**+**	**0.00**	**+**	**0.00**	**=**	**13.93**
Shallow Concentrated Flow							
Flow length (ft)	= 23.00		345.00		71.00		
Watercourse slope (%)	= 17.00		0.10		33.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=6.65		0.51		11.68		
Travel Time (min)	**= 0.06**	**+**	**11.27**	**+**	**0.10**	**=**	**11.43**
Channel Flow							
X sectional flow area (sqft)	= 11.50		12.00		264.00		
Wetted perimeter (ft)	= 23.20		11.00		55.00		
Channel slope (%)	= 1.00		33.00		0.50		
Manning's n-value	= 0.040		0.015		0.033		
Velocity (ft/s)	=2.33						
			60.49				
					9.13		
Flow length (ft)	({0})155.0		143.0		1450.0		
Travel Time (min)	**= 1.11**	**+**	**0.04**	**+**	**2.65**	**=**	**3.80**

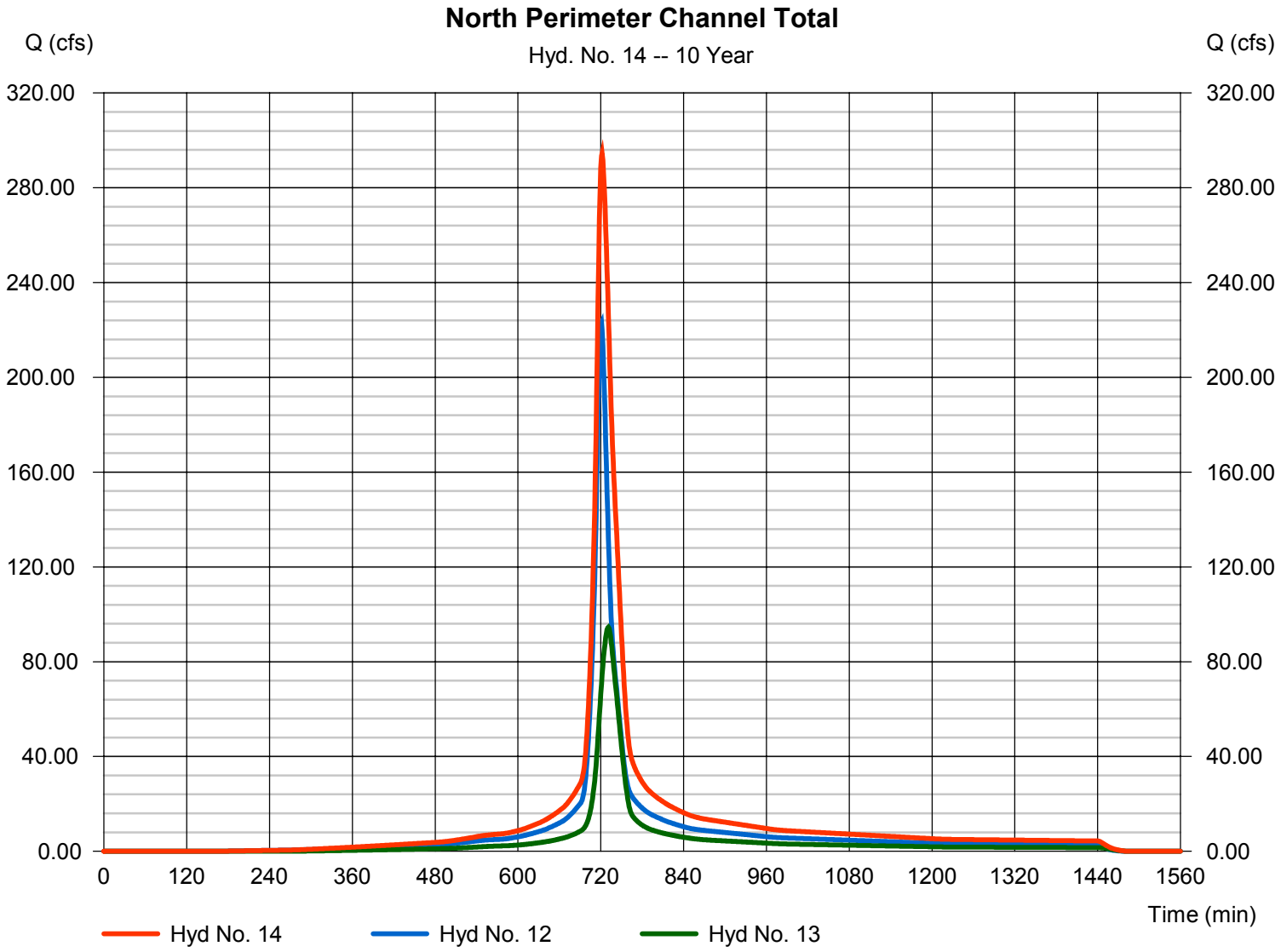
Total Travel Time, Tc ..... 29.20 min

Hydrograph Report

Hyd. No. 14

North Perimeter Channel Total

Hydrograph type	= Combine	Peak discharge	= 294.52 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 1,130,716 cuft
Inflow hyds.	= 12, 13	Contrib. drain. area	= 10.800 ac



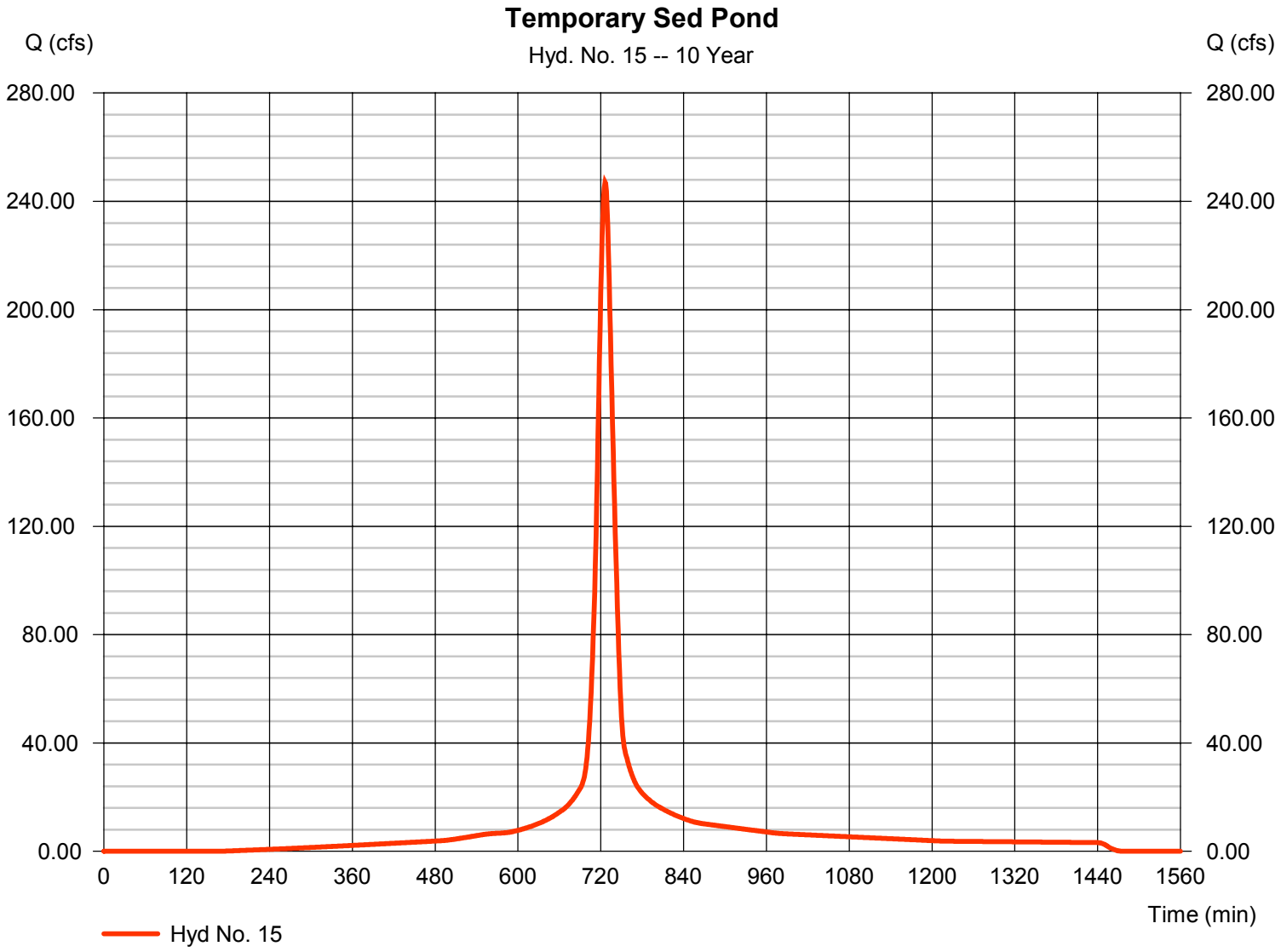
Hydrograph Report

Hyd. No. 15

Temporary Sed Pond

Hydrograph type	= SCS Runoff	Peak discharge	= 247.03 cfs
Storm frequency	= 10 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 887,493 cuft
Drainage area	= 22.300 ac	Curve number	= 84*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 22.10 min
Total precip.	= 13.10 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(6.800 x 100) + (15.500 x 74)] / 22.300



TR55 Tc Worksheet

Hyd. No. 15

Temporary Sed Pond

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.240		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.36		0.00		0.00		
Land slope (%)	= 1.00		0.00		0.00		
Travel Time (min)	**= 18.38**	**+**	**0.00**	**+**	**0.00**	**=**	**18.38**
Shallow Concentrated Flow							
Flow length (ft)	= 322.00		33.00		156.00		
Watercourse slope (%)	= 1.00		6.00		33.00		
Surface description	= Unpaved		Unpaved		Unpaved		
Average velocity (ft/s)	=1.61		3.95		9.27		
Travel Time (min)	**= 3.33**	**+**	**0.14**	**+**	**0.28**	**=**	**3.75**
Channel Flow							
X sectional flow area (sqft)	= 0.00		0.00		0.00		
Wetted perimeter (ft)	= 0.00		0.00		0.00		
Channel slope (%)	= 0.00		0.00		0.00		
Manning's n-value	= 0.015		0.015		0.015		
Velocity (ft/s)	=0.00						
			0.00				
					0.00		
Flow length (ft)	({0})0.0		0.0		0.0		
Travel Time (min)	**= 0.00**	**+**	**0.00**	**+**	**0.00**	**=**	**0.00**

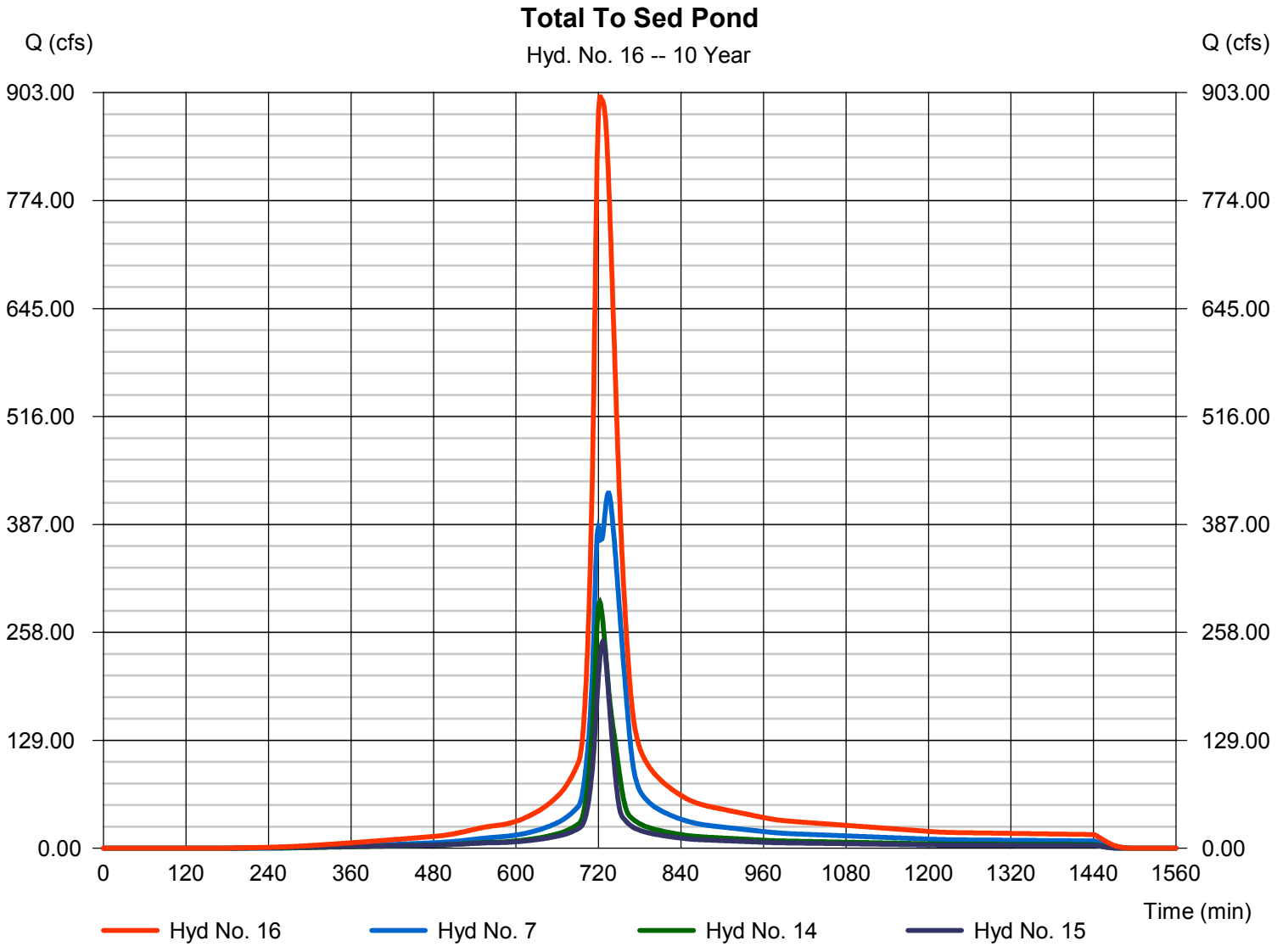
Total Travel Time, Tc ..... 22.10 min

Hydrograph Report

Hyd. No. 16

Total To Sed Pond

Hydrograph type	= Combine	Peak discharge	= 898.08 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 4,257,634 cuft
Inflow hyds.	= 7, 14, 15	Contrib. drain. area	= 22.300 ac



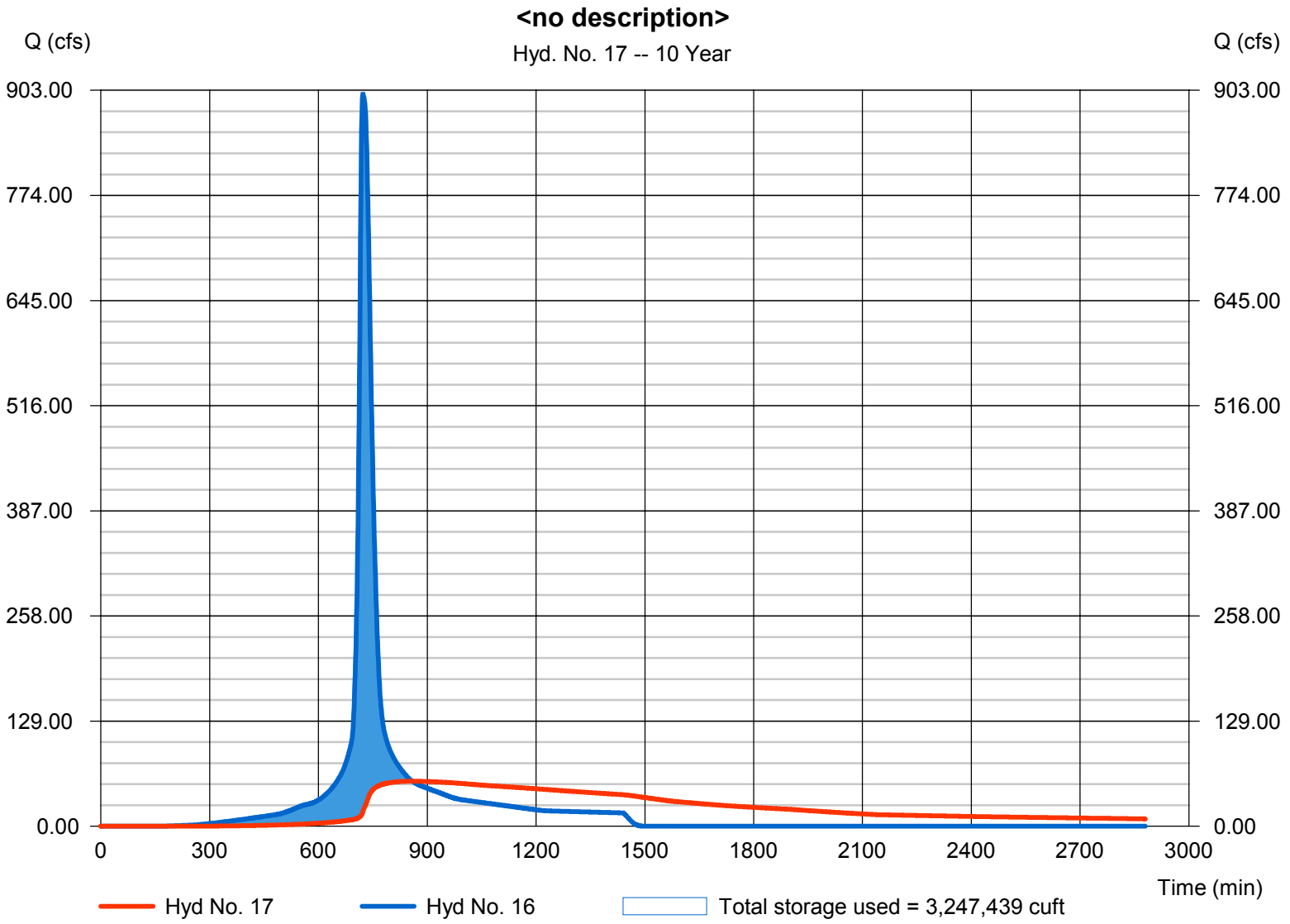
Hydrograph Report

Hyd. No. 17

<no description>

Hydrograph type	= Reservoir	Peak discharge	= 55.19 cfs
Storm frequency	= 10 yrs	Time to peak	= 859 min
Time interval	= 1 min	Hyd. volume	= 3,653,877 cuft
Inflow hyd. No.	= 16 - Total To Sed Pond	Max. Elevation	= 39.58 ft
Reservoir name	= SW Sed Pond (with Rating Curve)	Max. Storage	= 3,247,439 cuft

Storage Indication method used. Wet pond routing start elevation = 28.00 ft.



Pond No. 6 - SW Sed Pond (with Rating Curve)

Pond Data

Contours -User-defined contour areas. Average end area method used for volume calculation. Begining Elevation = 26.00 ft

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	26.00	200,376	0	0
2.00	28.00	209,204	409,580	409,580
4.00	30.00	218,032	427,236	836,816
5.00	31.00	223,192	220,612	1,057,428
6.00	32.00	230,301	226,747	1,284,175
7.00	33.00	236,244	233,272	1,517,447
8.00	34.00	243,972	240,108	1,757,555
9.00	35.00	251,103	247,538	2,005,093
10.00	36.00	257,115	254,109	2,259,202
11.00	37.00	263,413	260,264	2,519,466
12.00	38.00	270,347	266,880	2,786,346
13.00	39.00	284,785	277,566	3,063,912
14.00	40.00	343,743	314,264	3,378,176
15.00	41.00	634,318	489,030	3,867,206
16.00	42.00	634,318	634,318	4,501,524
17.00	43.00	634,318	634,318	5,135,842
18.00	44.00	634,318	634,318	5,770,160

Culvert / Orifice Structures

	[A]	[B]	[C]	[PrfRsr]
Rise (in)	= 0.00	0.00	0.00	0.00
Span (in)	= 0.00	0.00	0.00	0.00
No. Barrels	= 0	0	0	0
Invert El. (ft)	= 0.00	0.00	0.00	0.00
Length (ft)	= 0.00	0.00	0.00	0.00
Slope (%)	= 0.00	0.00	0.00	n/a
N-Value	= .013	.013	.013	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	No

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 0.00	0.00	0.00	0.00
Crest El. (ft)	= 0.00	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= ---	---	---	---
Multi-Stage	= No	No	No	No

Exfil.(in/hr) = 0.000 (by Wet area)

TW Elev. (ft) = 0.00

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).

Stage / Storage / Discharge Table

Stage ft	Storage cuft	Elevation ft	Clv A cfs	Clv B cfs	Clv C cfs	PrfRsr cfs	Wr A cfs	Wr B cfs	Wr C cfs	Wr D cfs	Exfil cfs	User cfs	Total cfs
0.00	0	26.00	---	---	---	---	---	---	---	---	---	---	0.000
2.00	409,580	28.00	---	---	---	---	---	---	---	---	---	---	0.000
4.00	836,816	30.00	---	---	---	---	---	---	---	---	---	6.730	6.730
5.00	1,057,428	31.00	---	---	---	---	---	---	---	---	---	9.520	9.520
6.00	1,284,175	32.00	---	---	---	---	---	---	---	---	---	11.65	11.65
7.00	1,517,447	33.00	---	---	---	---	---	---	---	---	---	14.16	14.16
8.00	1,757,555	34.00	---	---	---	---	---	---	---	---	---	20.55	20.55
9.00	2,005,093	35.00	---	---	---	---	---	---	---	---	---	25.17	25.17
10.00	2,259,202	36.00	---	---	---	---	---	---	---	---	---	30.74	30.74
11.00	2,519,466	37.00	---	---	---	---	---	---	---	---	---	38.64	38.64
12.00	2,786,346	38.00	---	---	---	---	---	---	---	---	---	44.22	44.22
13.00	3,063,912	39.00	---	---	---	---	---	---	---	---	---	49.90	49.90
14.00	3,378,176	40.00	---	---	---	---	---	---	---	---	---	58.96	58.96
15.00	3,867,206	41.00	---	---	---	---	---	---	---	---	---	65.86	65.86
16.00	4,501,524	42.00	---	---	---	---	---	---	---	---	---	73.27	73.27
17.00	5,135,842	43.00	---	---	---	---	---	---	---	---	---	83.33	83.33
18.00	5,770,160	44.00	---	---	---	---	---	---	---	---	---	90.99	90.99

SUBJECT CHESTERFIELD POWER STATION-UPPER (EAST) POND
HYDROLOGIC AND HYDRAULIC CAPACITY ASSESSMENT
BY BERKEME DATE 10/05/2016 PROJ. NO. C150035.00
CHKD. BY URBANCE DATE 10/07/2016

gai consultants

ATTACHMENT 4

HYDRAULIC CAPACITY FOR CHANNELS

North Perimeter Channel Seg #1

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.00500	ft/ft
Normal Depth	2.74	ft

Section Definitions

Station (ft)	Elevation (ft)
-0+59	42.03
-0+31	41.40
-0+15	40.91
-0+05	38.17
0+00	38.17
0+05	38.17
0+13	40.91
0+24	44.46

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(-0+59, 42.03)	(-0+15, 40.91)	0.015
(-0+15, 40.91)	(0+13, 40.91)	0.040
(0+13, 40.91)	(0+24, 44.46)	0.040

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Discharge	211.91	ft³/s
Elevation Range	38.17 to 44.46 ft	
Flow Area	54.03	ft²

North Perimeter Channel Seg #1

Results

Wetted Perimeter		29.62	ft
Hydraulic Radius		1.82	ft
Top Width		28.80	ft
Normal Depth		2.74	ft
Critical Depth		1.89	ft
Critical Slope		0.02164	ft/ft
Velocity		3.92	ft/s
Velocity Head		0.24	ft
Specific Energy		2.98	ft
Froude Number		0.50	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	2.74	ft
Critical Depth	1.89	ft
Channel Slope	0.00500	ft/ft
Critical Slope	0.02164	ft/ft

Cross Section for North Perimeter Channel Seg #1

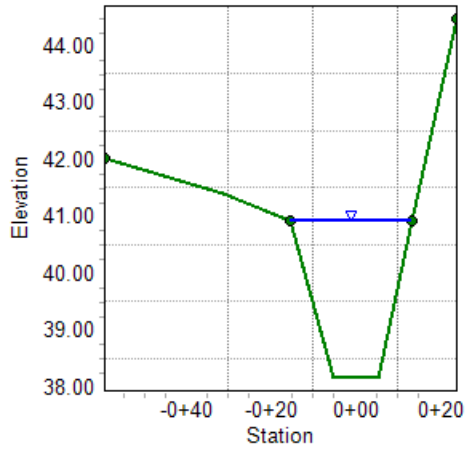
Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.00500	ft/ft
Normal Depth	2.74	ft
Discharge	211.91	ft³/s

Cross Section Image



North Perimeter Channel Seg #2

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.00500	ft/ft
Normal Depth	9.23	ft

Section Definitions

Station (ft)	Elevation (ft)
-0+26	40.65
-0+06	32.50
-0+04	31.42
0+00	31.50
0+03	32.46
0+46	44.36

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(-0+26, 40.65)	(-0+06, 32.50)	0.040
(-0+06, 32.50)	(0+03, 32.46)	0.015
(0+03, 32.46)	(0+46, 44.36)	0.040

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Discharge		2224.00	ft³/s
Elevation Range	31.42 to 44.36 ft		
Flow Area		285.41	ft²
Wetted Perimeter		62.14	ft
Hydraulic Radius		4.59	ft

North Perimeter Channel Seg #2

Results

Top Width		59.04	ft
Normal Depth		9.23	ft
Critical Depth		7.57	ft
Critical Slope		0.01363	ft/ft
Velocity		7.79	ft/s
Velocity Head		0.94	ft
Specific Energy		10.17	ft
Froude Number		0.62	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	9.23	ft
Critical Depth	7.57	ft
Channel Slope	0.00500	ft/ft
Critical Slope	0.01363	ft/ft

Cross Section for North Perimeter Channel Seg #2

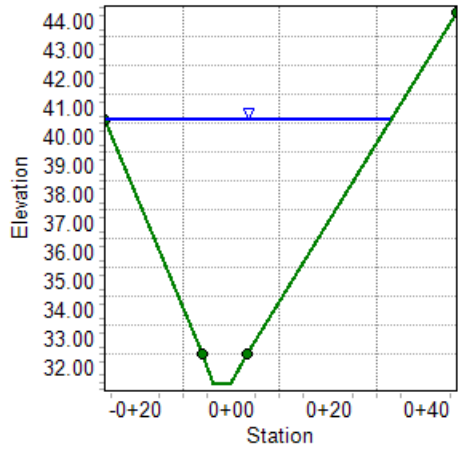
Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.00500	ft/ft
Normal Depth	9.23	ft
Discharge	2224.00	ft³/s

Cross Section Image



North Perimeter Channel Seg #3

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.00500	ft/ft
Normal Depth	13.83	ft

Section Definitions

Station (ft)	Elevation (ft)
-0+38	41.43
-0+18	33.50
-0+06	27.90
0+00	27.60
0+11	33.52
0+46	45.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(-0+38, 41.43)	(-0+18, 33.50)	0.040
(-0+18, 33.50)	(0+11, 33.52)	0.015
(0+11, 33.52)	(0+46, 45.00)	0.040

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Discharge		5561.57	ft³/s
Elevation Range	27.60 to 45.00 ft		
Flow Area		499.46	ft²
Wetted Perimeter		78.31	ft
Hydraulic Radius		6.38	ft

North Perimeter Channel Seg #3

Results

Top Width		72.71	ft
Normal Depth		13.83	ft
Critical Depth		12.31	ft
Critical Slope		0.00927	ft/ft
Velocity		11.14	ft/s
Velocity Head		1.93	ft
Specific Energy		15.76	ft
Froude Number		0.75	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	13.83	ft
Critical Depth	12.31	ft
Channel Slope	0.00500	ft/ft
Critical Slope	0.00927	ft/ft

Cross Section for North Perimeter Channel Seg #3

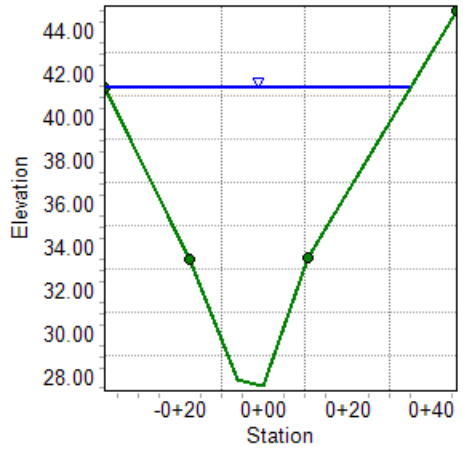
Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.00500	ft/ft
Normal Depth	13.83	ft
Discharge	5561.57	ft³/s

Cross Section Image



South Perimeter Channel Seg #1

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.00500	ft/ft
Normal Depth	2.86	ft

Section Definitions

Station (ft)	Elevation (ft)
-0+14	45.00
0+00	40.44
0+09	42.00
0+16	43.30

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(-0+14, 45.00)	(0+16, 43.30)	0.040

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Discharge	118.65	ft³/s
Elevation Range	40.44 to 45.00 ft	
Flow Area	36.02	ft²
Wetted Perimeter	25.64	ft
Hydraulic Radius	1.40	ft
Top Width	24.94	ft
Normal Depth	2.86	ft
Critical Depth	2.14	ft
Critical Slope	0.02360	ft/ft

South Perimeter Channel Seg #1

Results

Velocity		3.29	ft/s
Velocity Head		0.17	ft
Specific Energy		3.03	ft
Froude Number		0.48	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	2.86	ft
Critical Depth	2.14	ft
Channel Slope	0.00500	ft/ft
Critical Slope	0.02360	ft/ft

Cross Section for South Perimeter Channel Seg #1

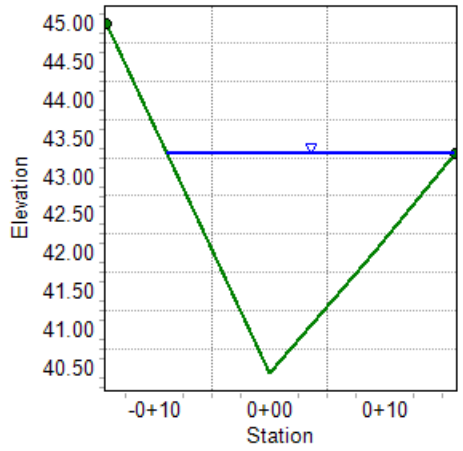
Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.00500	ft/ft
Normal Depth	2.86	ft
Discharge	118.65	ft³/s

Cross Section Image



South Perimeter Channel Seg #2

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.00500	ft/ft
Normal Depth	6.06	ft

Section Definitions

Station (ft)	Elevation (ft)
-0+59	52.50
-0+30	43.19
-0+07	36.64
-0+04	35.63
0+00	35.63
0+02	36.57
0+16	41.69

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(-0+59, 52.50)	(-0+07, 36.64)	0.040
(-0+07, 36.64)	(0+02, 36.57)	0.015
(0+02, 36.57)	(0+16, 41.69)	0.040

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Discharge	806.29	ft³/s
Elevation Range	35.63 to 52.50 ft	
Flow Area	131.58	ft²
Wetted Perimeter	42.84	ft

South Perimeter Channel Seg #2

Results

Hydraulic Radius		3.07	ft
Top Width		40.86	ft
Normal Depth		6.06	ft
Critical Depth		4.88	ft
Critical Slope		0.01476	ft/ft
Velocity		6.13	ft/s
Velocity Head		0.58	ft
Specific Energy		6.64	ft
Froude Number		0.60	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	6.06	ft
Critical Depth	4.88	ft
Channel Slope	0.00500	ft/ft
Critical Slope	0.01476	ft/ft

Cross Section for South Perimeter Channel Seg #2

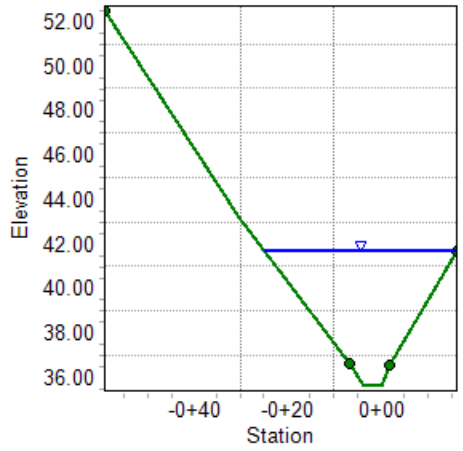
Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.00500	ft/ft
Normal Depth	6.06	ft
Discharge	806.29	ft³/s

Cross Section Image



South Perimeter Channel Seg #3

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.00500	ft/ft
Normal Depth	8.85	ft

Section Definitions

Station (ft)	Elevation (ft)
-0+34	42.16
-0+07	32.84
-0+04	31.91
0+00	31.90
0+02	32.87
0+25	40.75

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(-0+34, 42.16)	(-0+07, 32.84)	0.040
(-0+07, 32.84)	(0+02, 32.87)	0.015
(0+02, 32.87)	(0+25, 40.75)	0.040

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Discharge	1983.84	ft³/s
Elevation Range	31.90 to 42.16 ft	
Flow Area	258.77	ft²
Wetted Perimeter	58.02	ft
Hydraulic Radius	4.46	ft

South Perimeter Channel Seg #3

Results

Top Width		55.03	ft
Normal Depth		8.85	ft
Critical Depth		7.23	ft
Critical Slope		0.01370	ft/ft
Velocity		7.67	ft/s
Velocity Head		0.91	ft
Specific Energy		9.76	ft
Froude Number		0.62	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	8.85	ft
Critical Depth	7.23	ft
Channel Slope	0.00500	ft/ft
Critical Slope	0.01370	ft/ft

Cross Section for South Perimeter Channel Seg #3

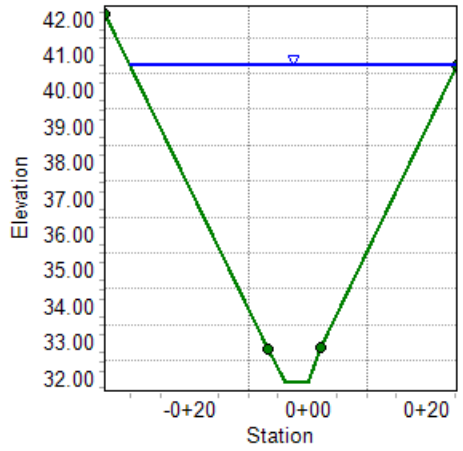
Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.00500	ft/ft
Normal Depth	8.85	ft
Discharge	1983.84	ft³/s

Cross Section Image



Worksheet for South Perimeter Channel Seg #4

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.00500	ft/ft
Normal Depth	13.67	ft

Section Definitions

Station (ft)	Elevation (ft)
-0+48	42.00
-0+27	34.26
-0+17	30.00
-0+12	27.83
0+00	27.71
0+10	33.01
0+30	41.38

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(-0+48, 42.00)	(-0+27, 34.26)	0.040
(-0+27, 34.26)	(0+10, 33.01)	0.015
(0+10, 33.01)	(0+30, 41.38)	0.040

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Discharge	7415.08	ft³/s
Elevation Range	27.71 to 42.00 ft	
Flow Area	581.59	ft²
Wetted Perimeter	81.72	ft

Worksheet for South Perimeter Channel Seg #4

Results

Hydraulic Radius		7.12	ft
Top Width		76.13	ft
Normal Depth		13.67	ft
Critical Depth		12.45	ft
Critical Slope		0.00777	ft/ft
Velocity		12.75	ft/s
Velocity Head		2.53	ft
Specific Energy		16.20	ft
Froude Number		0.81	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	13.67	ft
Critical Depth	12.45	ft
Channel Slope	0.00500	ft/ft
Critical Slope	0.00777	ft/ft

Cross Section for South Perimeter Channel Seg #4

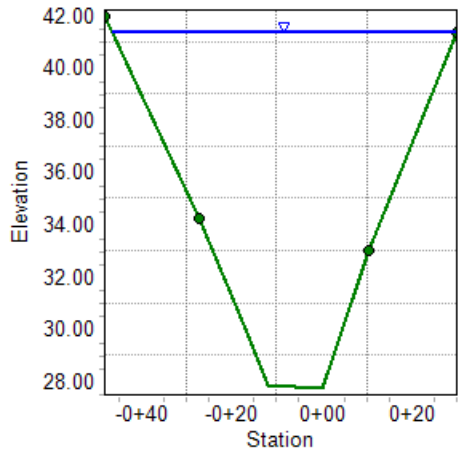
Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.00500	ft/ft
Normal Depth	13.67	ft
Discharge	7415.08	ft³/s

Cross Section Image



West Perimeter Channel Seg #1

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.00500	ft/ft
Normal Depth	1.45	ft

Section Definitions

Station (ft)	Elevation (ft)
-0+13	41.28
0+00	41.30
0+02	39.89
0+06	39.55
0+14	39.68
0+16	40.99
0+21	41.65
0+37	44.02

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(-0+13, 41.28)	(0+16, 40.99)	0.015
(0+16, 40.99)	(0+37, 44.02)	0.040

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Discharge	138.63	ft³/s
Elevation Range	39.55 to 44.02 ft	
Flow Area	18.63	ft²
Wetted Perimeter	16.73	ft

West Perimeter Channel Seg #1

Results

Hydraulic Radius		1.11	ft
Top Width		16.05	ft
Normal Depth		1.45	ft
Critical Depth		1.84	ft
Critical Slope		0.00369	ft/ft
Velocity		7.44	ft/s
Velocity Head		0.86	ft
Specific Energy		2.31	ft
Froude Number		1.22	
Flow Type	Supercritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.45	ft
Critical Depth	1.84	ft
Channel Slope	0.00500	ft/ft
Critical Slope	0.00369	ft/ft

Cross Section for West Perimeter Channel Seg #1

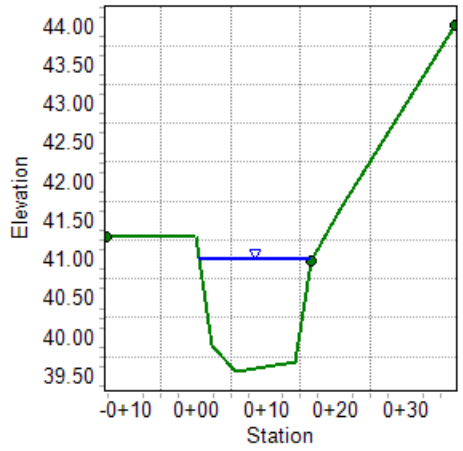
Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Channel Slope	0.00500	ft/ft
Normal Depth	1.45	ft
Discharge	138.63	ft³/s

Cross Section Image



SUBJECT CHESTERFIELD POWER STATION-UPPER (EAST) POND
HYDROLOGIC AND HYDRAULIC CAPACITY ASSESSMENT
BY BERKEME DATE 10/05/2016 PROJ. NO. C150035.00
CHKD. BY URBANCE DATE 10/07/2016

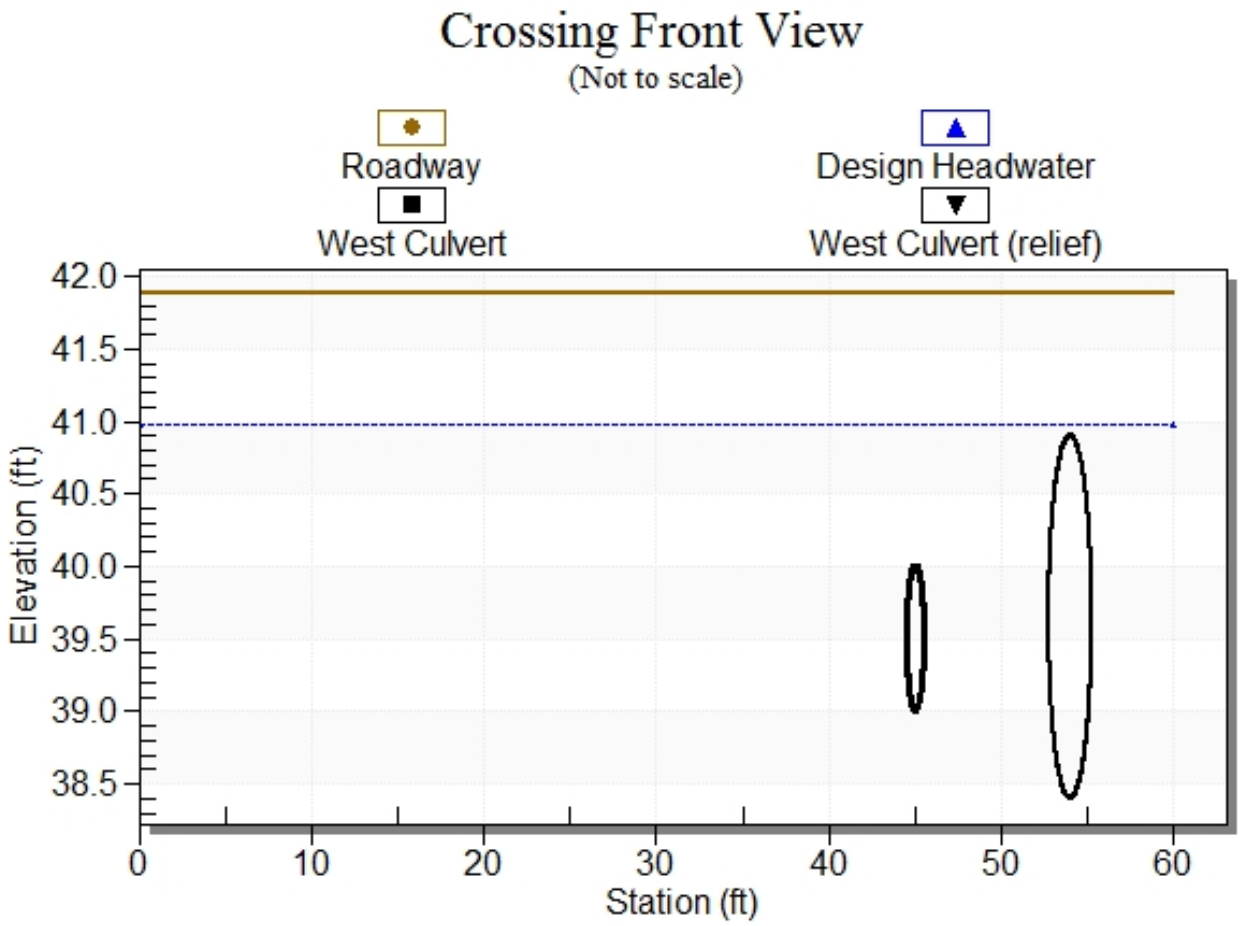
gai consultants

ATTACHMENT 5

HYDRAULIC CAPACITY FOR CULVERTS

HY-8 Culvert Analysis Report
West Culvert

Crossing Front View (Roadway Profile): West Culvert



HY-8 Culvert Analysis Report
East Culvert

Crossing Front View (Roadway Profile): East Culvert

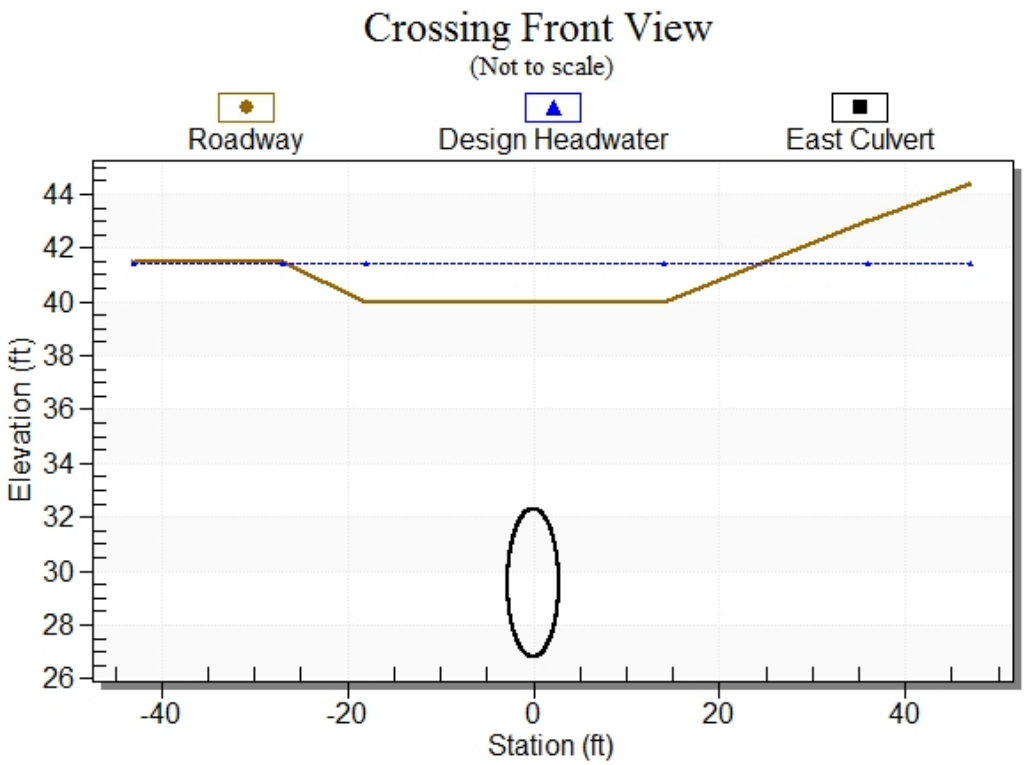


Table 1 - Culvert Summary Table: East Culvert

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	39.58	0.000	12.780	0-NF	0.000	0.000	5.500	14.950	0.000	0.000
32.50	32.50	39.75	2.117	12.951	4-FFf	1.831	1.538	5.500	14.950	1.368	0.000
65.00	59.72	40.16	2.937	13.356	4-FFf	2.568	2.110	5.500	14.950	2.514	0.000
97.50	72.28	40.42	3.279	13.624	4-FFf	2.872	2.328	5.500	14.950	3.042	0.000
130.00	81.01	40.64	3.507	13.840	4-FFf	3.082	2.475	5.500	14.950	3.410	0.000
162.50	87.82	40.83	3.680	14.025	4-FFf	3.245	2.583	5.500	14.950	3.696	0.000
195.00	93.46	40.99	3.821	14.190	4-FFf	3.380	2.668	5.500	14.950	3.934	0.000
227.50	98.31	41.14	3.940	14.341	4-FFf	3.496	2.739	5.500	14.950	4.138	0.000
260.00	102.61	41.28	4.045	14.480	4-FFf	3.606	2.800	5.500	14.950	4.319	0.000
292.50	106.45	41.41	4.138	14.610	4-FFf	3.704	2.853	5.500	14.950	4.481	0.000
294.50	106.68	41.42	4.143	14.618	4-FFf	3.710	2.856	5.500	14.950	4.490	0.000

********** -

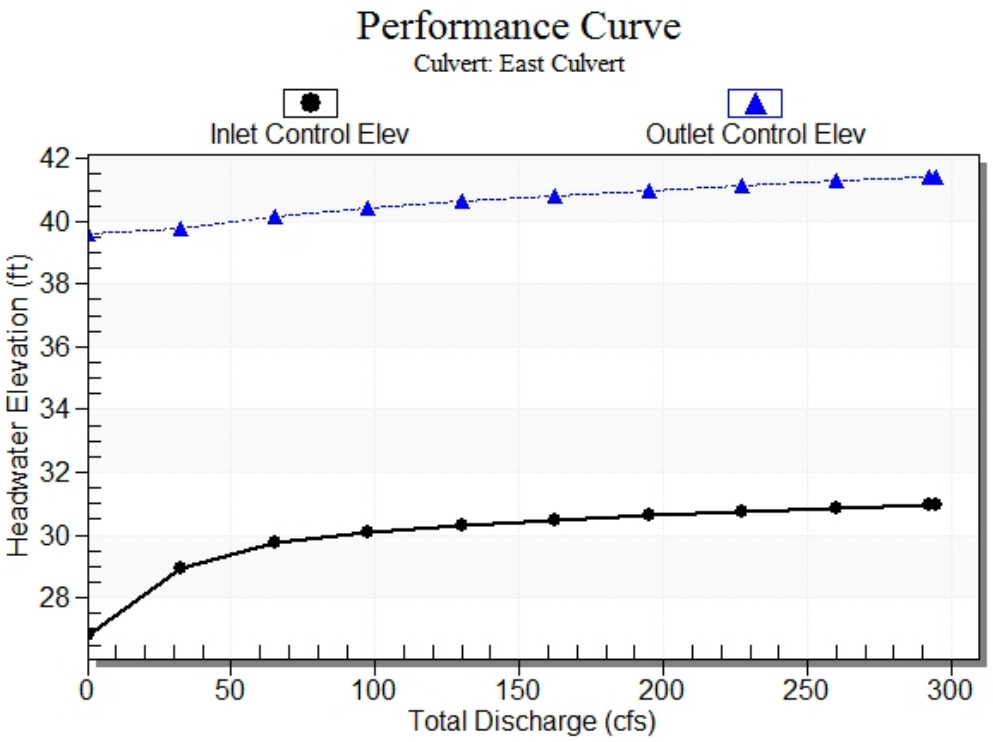
Straight Culvert -

Inlet Elevation (invert): 26.80 ft, Outlet Elevation (invert): 24.63 ft -

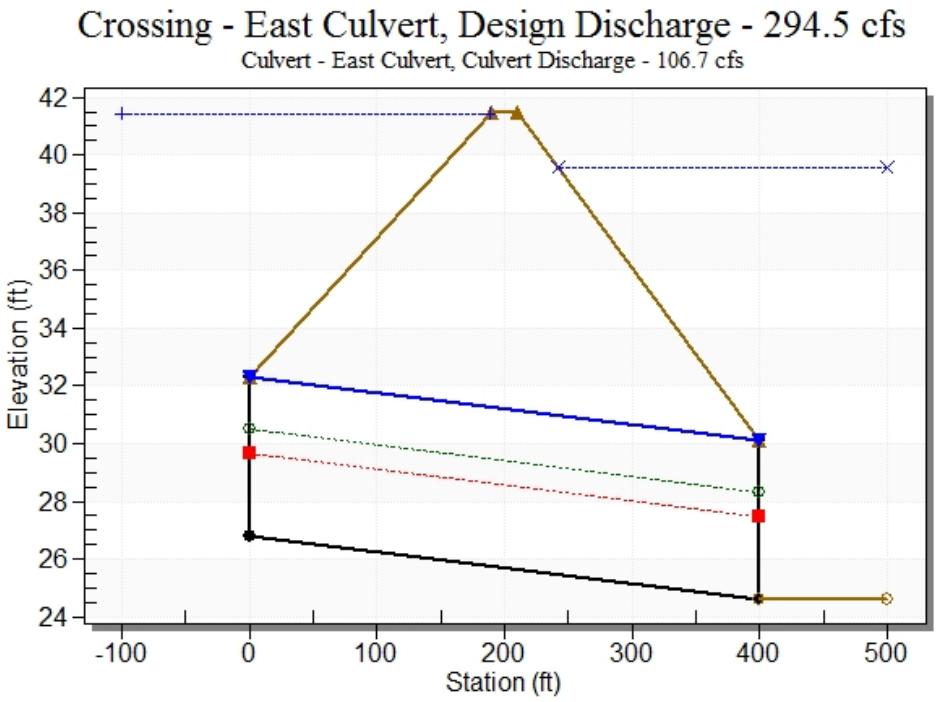
Culvert Length: 400.01 ft, Culvert Slope: 0.0054 -

********** -

Culvert Performance Curve Plot: East Culvert



Water Surface Profile Plot for Culvert: East Culvert



Site Data - East Culvert

Site Data Option: Culvert Invert Data
Inlet Station: 0.00 ft
Inlet Elevation: 26.80 ft
Outlet Station: 400.00 ft
Outlet Elevation: 24.63 ft
Number of Barrels: 1

Culvert Data Summary - East Culvert

Barrel Shape: Circular
Barrel Diameter: 5.50 ft
Barrel Material: Corrugated Steel
Embedment: 0.00 in
Barrel Manning's n: 0.0240
Culvert Type: Straight
Inlet Configuration: Square Edge with Headwall
Inlet Depression: NONE

Table 2 - Downstream Channel Rating Curve (Crossing: East Culvert)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
0.00	39.58	14.95
32.50	39.58	14.95
65.00	39.58	14.95
97.50	39.58	14.95
130.00	39.58	14.95
162.50	39.58	14.95
195.00	39.58	14.95
227.50	39.58	14.95
260.00	39.58	14.95
292.50	39.58	14.95
294.50	39.58	14.95

Tailwater Channel Data - East Culvert

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 39.58 ft

Roadway Data for Crossing: East Culvert

Roadway Profile Shape: Irregular Roadway Shape (coordinates)

Irregular Roadway Cross-Section:

Coord No.	Station (ft)	Elevation (ft)
0	-43.00	41.50
1	-27.00	41.50
2	-18.00	40.00
3	14.00	40.00
4	36.00	43.00
5	47.00	44.40

Roadway Surface: Gravel

Roadway Top Width: 20.00 ft

Table 1 - Culvert Summary Table: West Culvert

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	38.40	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
3.50	3.35	39.21	0.815	0.016	1-S2n	0.559	0.597	0.559	0.295	4.046	1.106
7.00	6.16	39.53	1.128	0.281	1-S2n	0.770	0.819	0.770	0.444	4.778	1.421
10.50	8.80	39.79	1.392	0.511	1-S2n	0.935	0.983	0.935	0.562	5.260	1.638
14.00	11.39	40.04	1.636	0.746	1-S2n	1.076	1.131	1.076	0.664	5.630	1.807
17.50	14.15	40.27	1.868	0.998	1-S2n	1.220	1.266	1.220	0.756	5.951	1.948
21.00	17.37	40.52	2.120	1.307	1-S2n	1.380	1.408	1.380	0.839	6.247	2.069
24.50	20.47	40.92	2.357	1.629	1-S2n	1.534	1.534	1.534	0.916	6.485	2.176
25.40	21.36	40.98	2.426	2.576	7-M2c	1.578	1.568	1.568	0.935	6.591	2.202
31.50	27.10	41.37	2.896	2.970	7-M2c	1.896	1.773	1.773	1.056	7.281	2.359
35.00	30.36	41.61	3.197	3.209	7-M2c	2.147	1.876	1.876	1.121	7.685	2.439

********** -

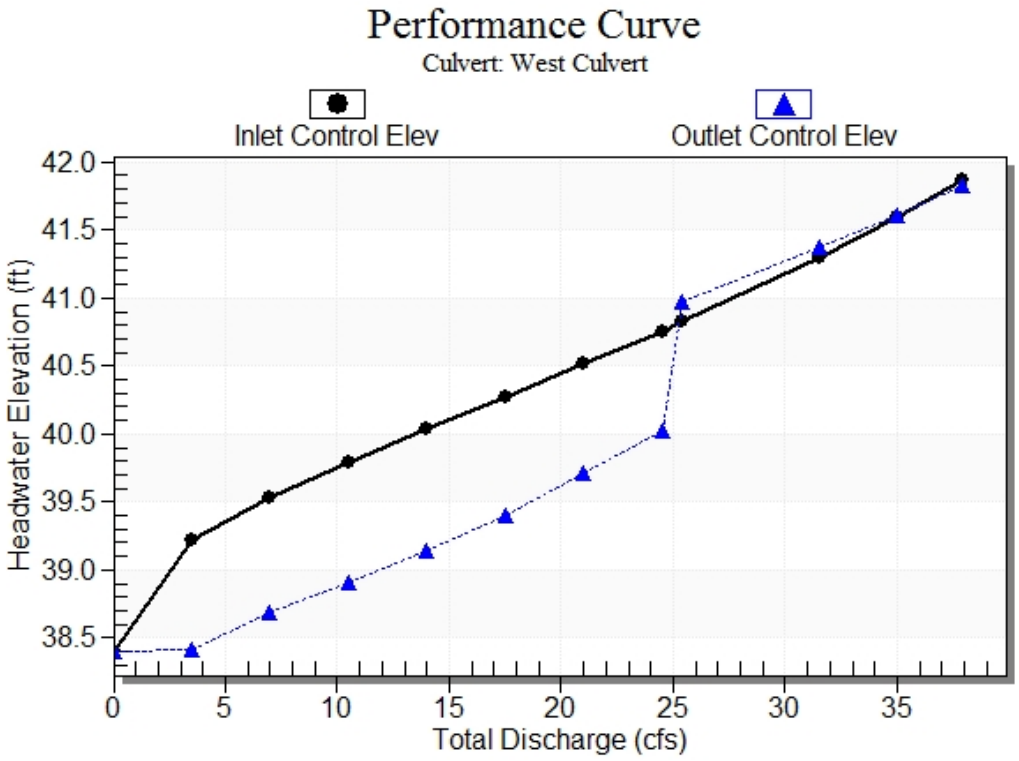
Straight Culvert -

Inlet Elevation (invert): 38.40 ft, Outlet Elevation (invert): 37.80 ft -

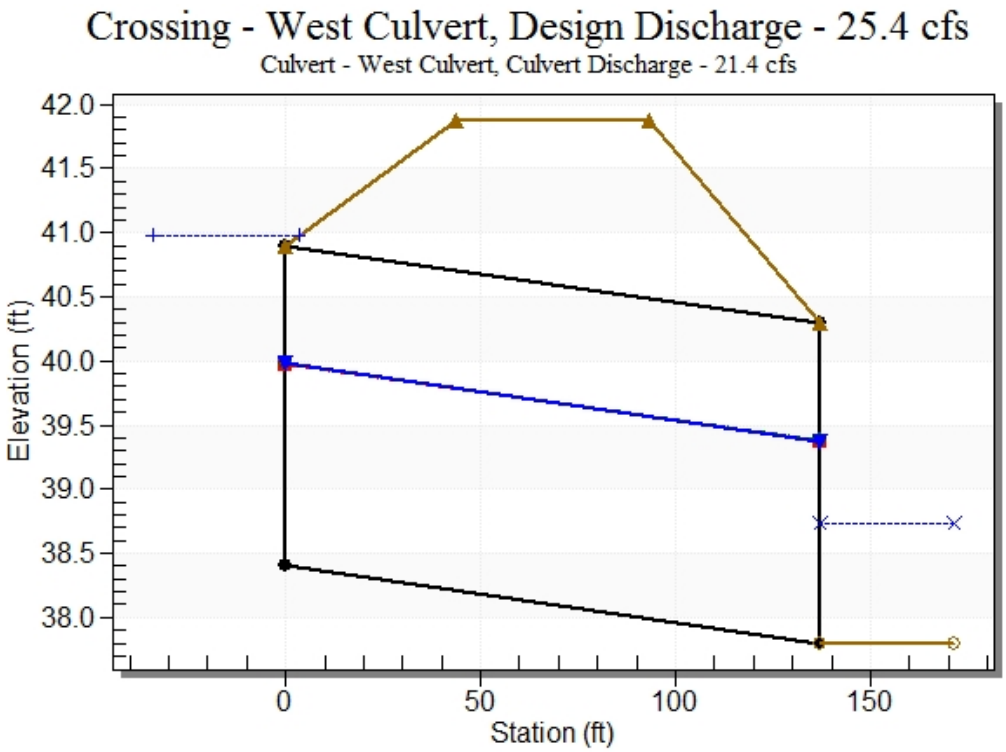
Culvert Length: 137.00 ft, Culvert Slope: 0.0044 -

********** -

Culvert Performance Curve Plot: West Culvert



Water Surface Profile Plot for Culvert: West Culvert



Site Data - West Culvert

Site Data Option: Culvert Invert Data
Inlet Station: 0.00 ft
Inlet Elevation: 38.40 ft
Outlet Station: 137.00 ft
Outlet Elevation: 37.80 ft
Number of Barrels: 1

Culvert Data Summary - West Culvert

Barrel Shape: Circular
Barrel Diameter: 2.50 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 2 - Culvert Summary Table: West Culvert (relief)

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	38.40	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
3.50	0.16	39.21	0.215	0.0*	1-S2n	0.142	0.159	0.142	0.295	2.202	1.106
7.00	0.84	39.53	0.527	0.0*	1-S2n	0.346	0.380	0.346	0.444	3.459	1.421
10.50	1.68	39.79	0.792	0.0*	1-S2n	0.513	0.550	0.513	0.562	4.154	1.638
14.00	2.60	40.04	1.035	0.538	5-S2n	0.682	0.685	0.682	0.664	4.543	1.807
17.50	3.34	40.27	1.261	1.268	7-M2c	0.868	0.779	0.779	0.756	5.091	1.948
21.00	3.64	40.52	1.367	1.519	7-M2c	1.000	0.811	0.811	0.839	5.340	2.069
24.50	3.98	40.92	1.499	1.918	7-M2c	1.000	0.844	0.844	0.916	5.635	2.176
25.40	4.04	40.98	1.520	1.975	7-M2c	1.000	0.848	0.848	0.935	5.681	2.202
31.50	4.39	41.37	1.671	2.372	7-M2c	1.000	0.877	0.877	1.056	6.005	2.359
35.00	4.58	41.61	1.763	2.609	7-M2t	1.000	0.892	0.921	1.121	6.060	2.439

* Full Flow Headwater elevation is below inlet invert.

********** -

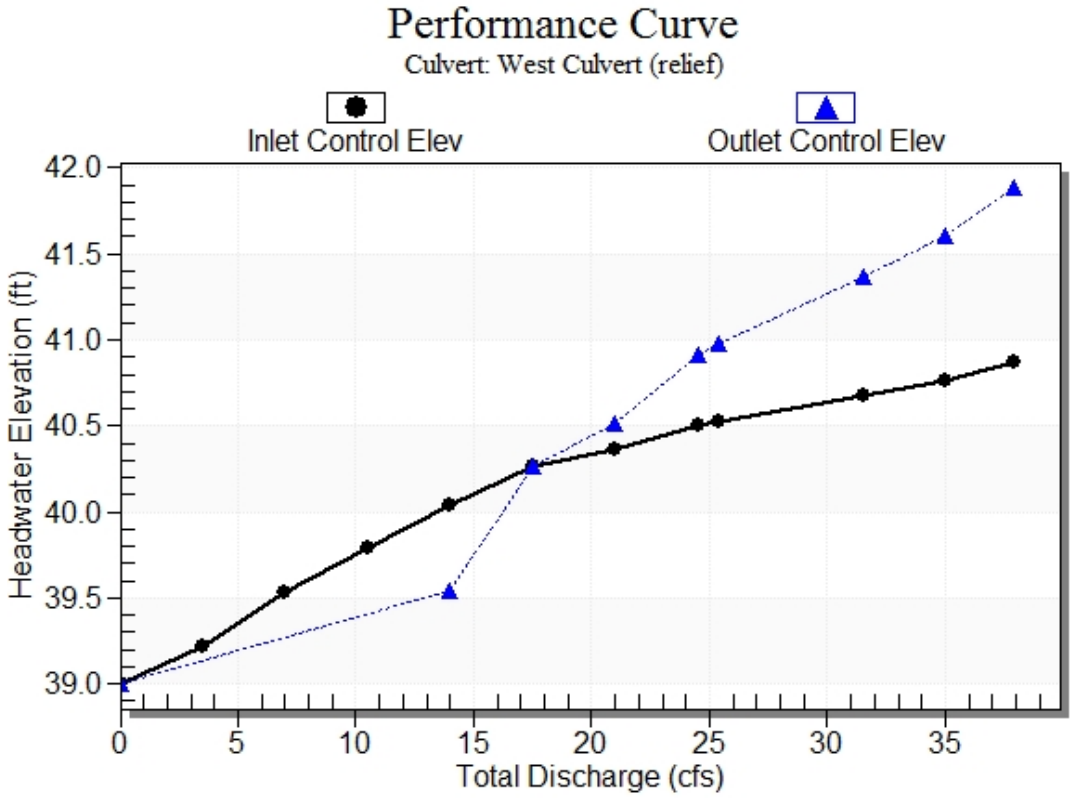
Straight Culvert -

Inlet Elevation (invert): 39.00 ft, Outlet Elevation (invert): 38.00 ft -

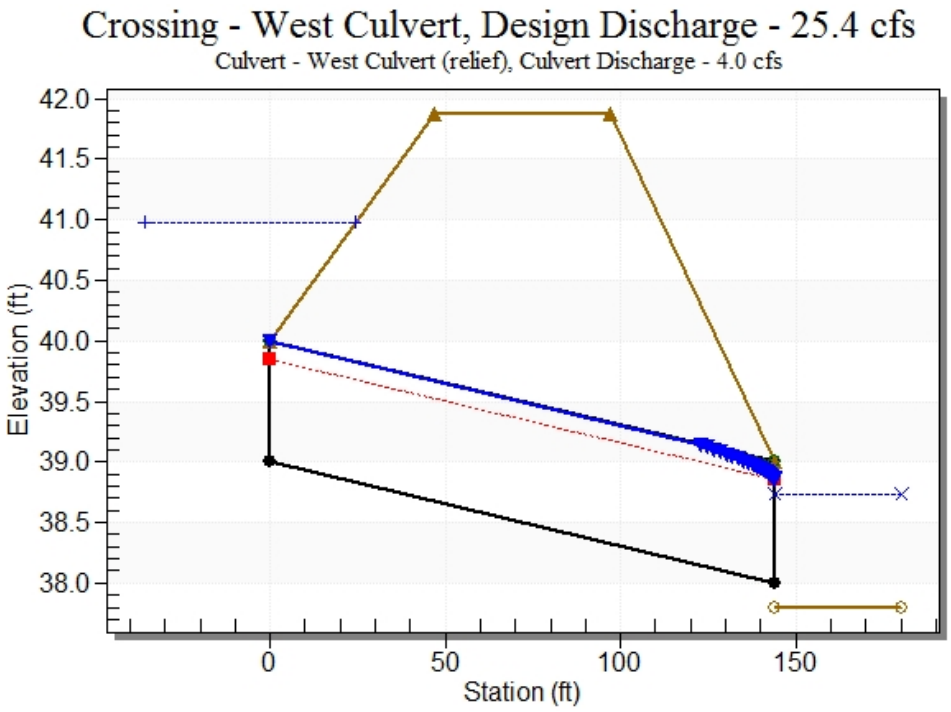
Culvert Length: 144.00 ft, Culvert Slope: 0.0069 -

********** -

Culvert Performance Curve Plot: West Culvert (relief)



Water Surface Profile Plot for Culvert: West Culvert (relief)



Site Data - West Culvert (relief)

Site Data Option: Culvert Invert Data
Inlet Station: 0.00 ft
Inlet Elevation: 39.00 ft
Outlet Station: 144.00 ft
Outlet Elevation: 38.00 ft
Number of Barrels: 1

Culvert Data Summary - West Culvert (relief)

Barrel Shape: Circular
Barrel Diameter: 1.00 ft
Barrel Material: Concrete
Embedment: 0.00 in
Barrel Manning's n: 0.0120
Culvert Type: Straight
Inlet Configuration: Grooved End Projecting
Inlet Depression: NONE

Table 3 - Downstream Channel Rating Curve (Crossing: West Culvert)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	37.80	0.00	0.00	0.00	0.00
3.50	38.09	0.29	1.11	0.09	0.37
7.00	38.24	0.44	1.42	0.14	0.39
10.50	38.36	0.56	1.64	0.18	0.41
14.00	38.46	0.66	1.81	0.21	0.42
17.50	38.56	0.76	1.95	0.24	0.43
21.00	38.64	0.84	2.07	0.26	0.43
24.50	38.72	0.92	2.18	0.29	0.44
25.40	38.74	0.94	2.20	0.29	0.44
31.50	38.86	1.06	2.36	0.33	0.44
35.00	38.92	1.12	2.44	0.35	0.45

Tailwater Channel Data - West Culvert

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 10.00 ft

Side Slope (H:V): 2.50 (_:1)

Channel Slope: 0.0050

Channel Manning's n: 0.0400

Channel Invert Elevation: 37.80 ft

Roadway Data for Crossing: West Culvert

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 60.00 ft

Crest Elevation: 41.88 ft

Roadway Surface: Gravel

Roadway Top Width: 50.00 ft

HY-8 Culvert Analysis Report
South Culvert

Crossing Front View (Roadway Profile): South Culvert

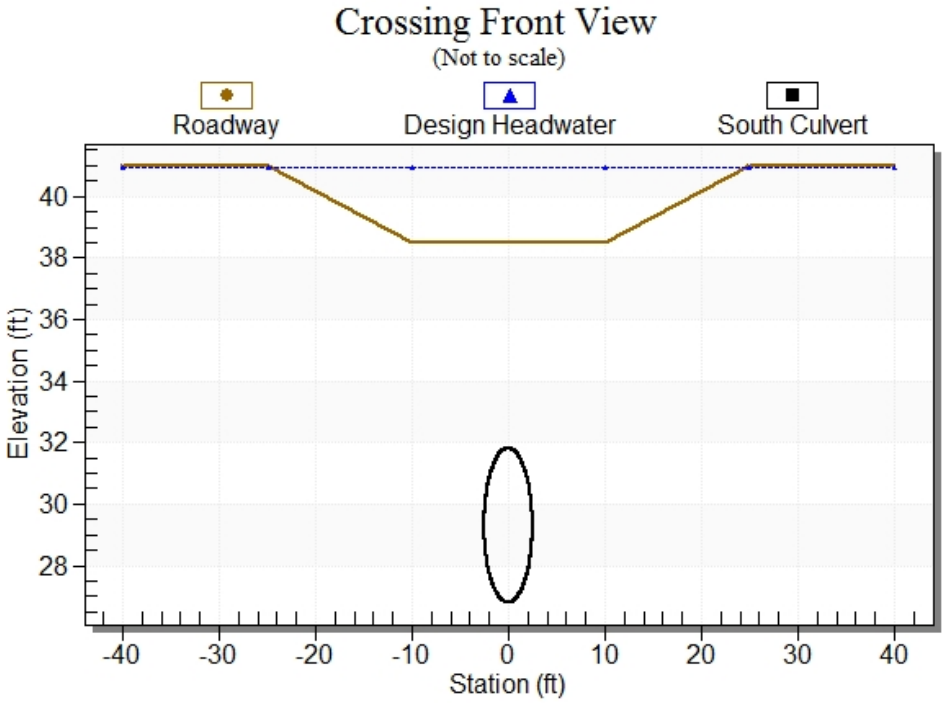


Table 1 - Culvert Summary Table: South Culvert

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	39.58	0.000	12.780	0-NF	0.000	0.000	5.000	14.230	0.000	0.000
47.00	9.72	39.60	1.156	12.803	4-FFf	1.090	0.850	5.000	14.230	0.495	0.000
94.00	19.36	39.67	1.655	12.870	4-FFf	1.563	1.208	5.000	14.230	0.986	0.000
141.00	31.85	39.82	2.156	13.023	4-FFf	2.048	1.566	5.000	14.230	1.622	0.000
188.00	43.36	40.03	2.552	13.230	4-FFf	2.444	1.837	5.000	14.230	2.208	0.000
235.00	52.40	40.24	2.843	13.437	4-FFf	2.741	2.027	5.000	14.230	2.669	0.000
282.00	59.68	40.43	3.067	13.632	4-FFf	2.977	2.170	5.000	14.230	3.039	0.000
329.00	65.79	40.62	3.249	13.816	4-FFf	3.175	2.286	5.000	14.230	3.351	0.000
376.00	71.08	40.79	3.403	13.989	4-FFf	3.359	2.381	5.000	14.230	3.620	0.000
423.00	75.76	40.95	3.537	14.153	4-FFf	3.521	2.462	5.000	14.230	3.858	0.000
424.60	75.92	40.96	3.541	14.159	4-FFf	3.527	2.464	5.000	14.230	3.866	0.000

********** -

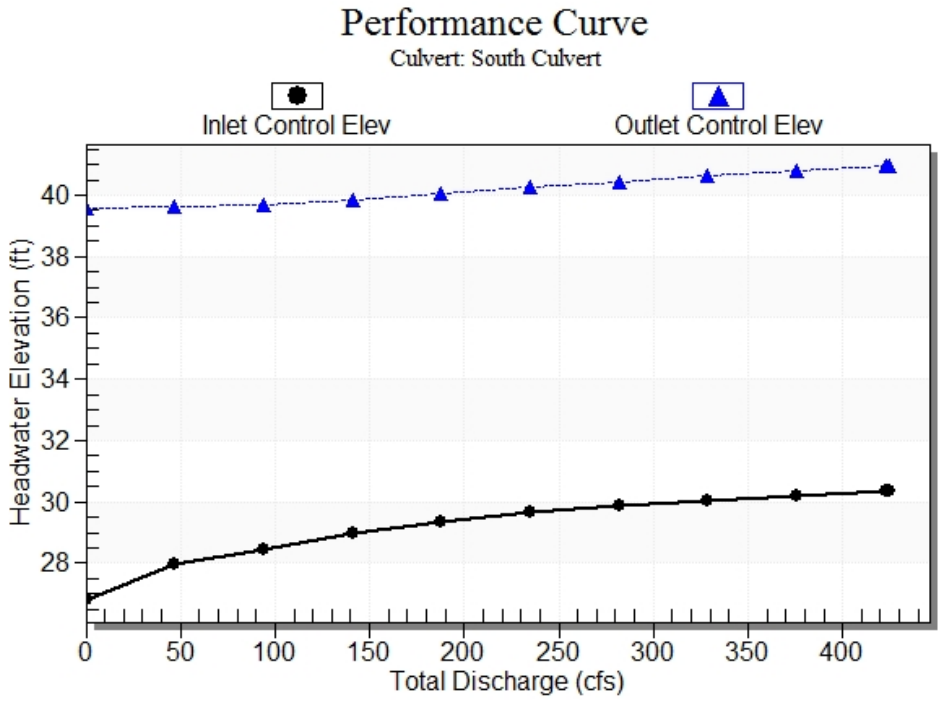
Straight Culvert -

Inlet Elevation (invert): 26.80 ft, Outlet Elevation (invert): 25.35 ft -

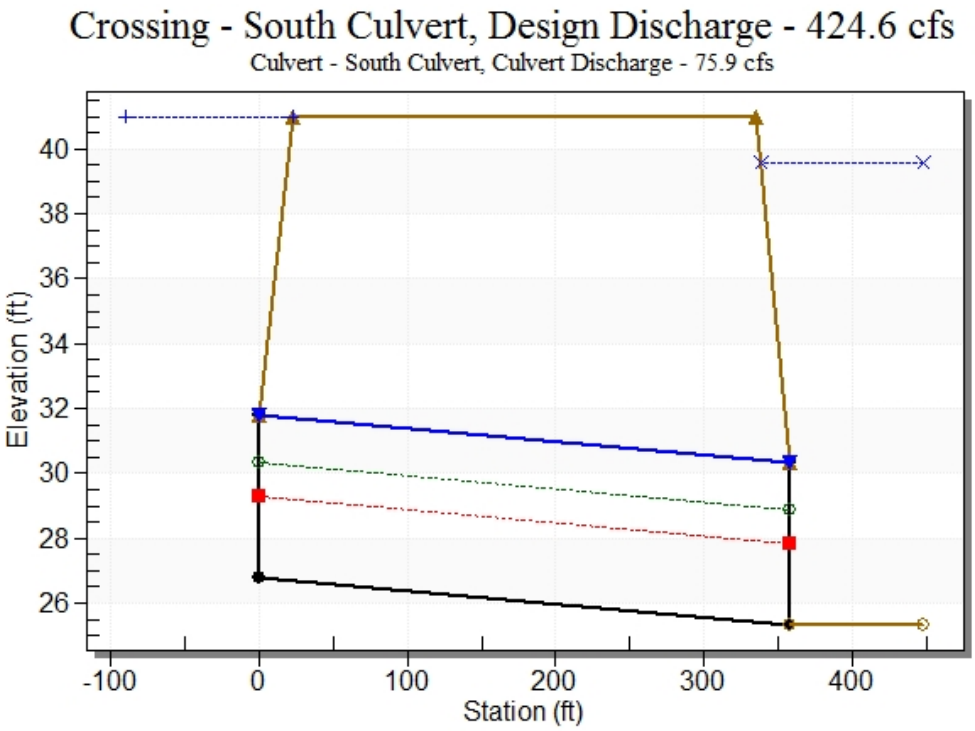
Culvert Length: 358.00 ft, Culvert Slope: 0.0041 -

********** -

Culvert Performance Curve Plot: South Culvert



Water Surface Profile Plot for Culvert: South Culvert



Site Data - South Culvert

Site Data Option: Culvert Invert Data
Inlet Station: 0.00 ft
Inlet Elevation: 26.80 ft
Outlet Station: 358.00 ft
Outlet Elevation: 25.35 ft
Number of Barrels: 1

Culvert Data Summary - South Culvert

Barrel Shape: Circular
Barrel Diameter: 5.00 ft
Barrel Material: Corrugated Steel
Embedment: 0.00 in
Barrel Manning's n: 0.0240
Culvert Type: Straight
Inlet Configuration: Square Edge with Headwall
Inlet Depression: NONE

Table 2 - Downstream Channel Rating Curve (Crossing: South Culvert)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
0.00	39.58	14.23
47.00	39.58	14.23
94.00	39.58	14.23
141.00	39.58	14.23
188.00	39.58	14.23
235.00	39.58	14.23
282.00	39.58	14.23
329.00	39.58	14.23
376.00	39.58	14.23
423.00	39.58	14.23
424.60	39.58	14.23

Tailwater Channel Data - South Culvert

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 39.58 ft

Roadway Data for Crossing: South Culvert

Roadway Profile Shape: Irregular Roadway Shape (coordinates)

Irregular Roadway Cross-Section:

Coord No.	Station (ft)	Elevation (ft)
0	-40.00	41.00
1	-25.00	41.00
2	-10.00	38.50
3	10.00	38.50
4	25.00	41.00
5	40.00	41.00

Roadway Surface: Gravel

Roadway Top Width: 312.00 ft