

DA-FR-118

DA-FR-118 is located in a meadow and forested areas with undulating to rolling slopes and contains agricultural land, existing dirt road and gravel road. No new impervious area is proposed within DA-FR-118. Multiple points of analysis were evaluated within DA-FR-118 to evaluate the effects on each receiving stream/channel following construction. Specifically, DA-FR-118 was divided into five sub-drainage areas (sub-areas A to E).

Pre-construction agricultural areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction. In non-agricultural areas, land use will be restored following construction as noted in the Stormwater Management (SWM) Narrative and the Annual Standards and Specifications. Agricultural areas within the limits of disturbance (LOD) are included in the SWM quality analysis and the total permanent right-of-way is analyzed via VRRM; in these calculations agricultural areas are considered "Forest/Open Space". The total phosphorus load reduction required for DA-FR-113 is -0.71 lbs.

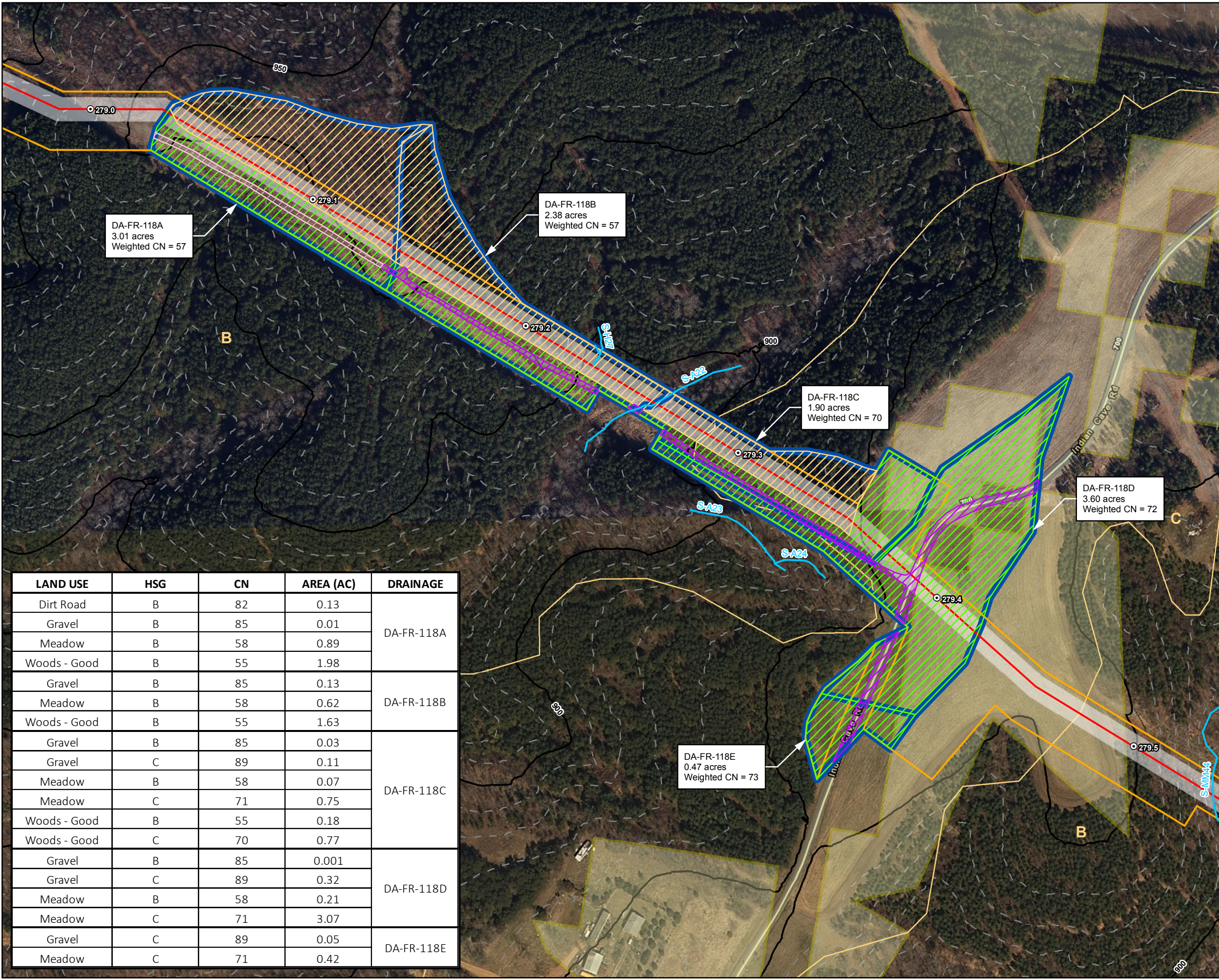
Stormwater quantity is met via the energy balance method sub-areas DA-FR-118D and DA-FR-118E. In addition to the energy balance method, storm water quantity in sub-areas DA-FR-118A, DA-FR-118B and DA-FR-118C is met by seven 2 ft by 30 ft, nine 2 ft by 30 ft and nine 2 ft by 50 ft compost amended water bar areas respectively (See General Detail MVP-ES38 for a full schedule). Sub-areas DA-FR-118A, DA-FR-118B and DA-FR-118C contain entirely non-agricultural areas within the LOD, therefore an Improvement Factor of 0.8 is used when applying the Energy Balance Method per 9VAC25-870-66.B.3.a. Sub-area DA-FR-118D contains both agricultural and non-agricultural areas within the LOD. For SWM quantity, agricultural areas within the study area are considered/included but an Improvement Factor of 1.0 is used when applying the Energy Balance Method to account for the exemption of agricultural areas (§ 62.1-44.15:34 and 9VAC25-870-300) since such areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction. In addition, sub-area DA-FR-118E within the LOD will be restored to a land use condition that is equivalent to the existing land use condition following construction. For these reasons, an Improvement Factor of 1.0 was assumed when completing the energy balance calculations.

The Hydraflow 10-year 24-hour peak discharge results indicate a reduction in flows ranging from 0 to 0.07 cfs for sub-drainage areas DA-FR-118 A, DA-FR-118C, DA-FR-118D and DA-FR-118E. The Hydraflow 10-year 24-hour peak discharge increased by 0.23 cfs flow for DA-FR-118B (as seen in the following table). The increase in 10-yr peak flow in sub-area DA-FR-118B will have little/no impact on flood stage in the

downstream channel. Furthermore, there are no nearby property owners. For these reasons, no further analysis is required.

Sub-Area	Pre Peak Flow, 10-yr Q (cfs)	Post Peak Flow, 10-yr Q (cfs)	Flow Differential
DA-FR-118A	5.33	5.30	-0.03
DA-FR-118B	3.75	3.98	0.23
DA-FR-118C	7.44	7.37	-0.07
DA-FR-118D	11.46	11.46	0.00
DA-FR-118E	1.41	1.41	0.00

Figures and calculations for each of the sub-areas for DA-FR-118 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.



Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Dirt Road
- Gravel
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)
1:2,400

200 100 0 200 Feet

W N E S

Mountain Valley Pipeline Project

Mountain Valley PIPELINE

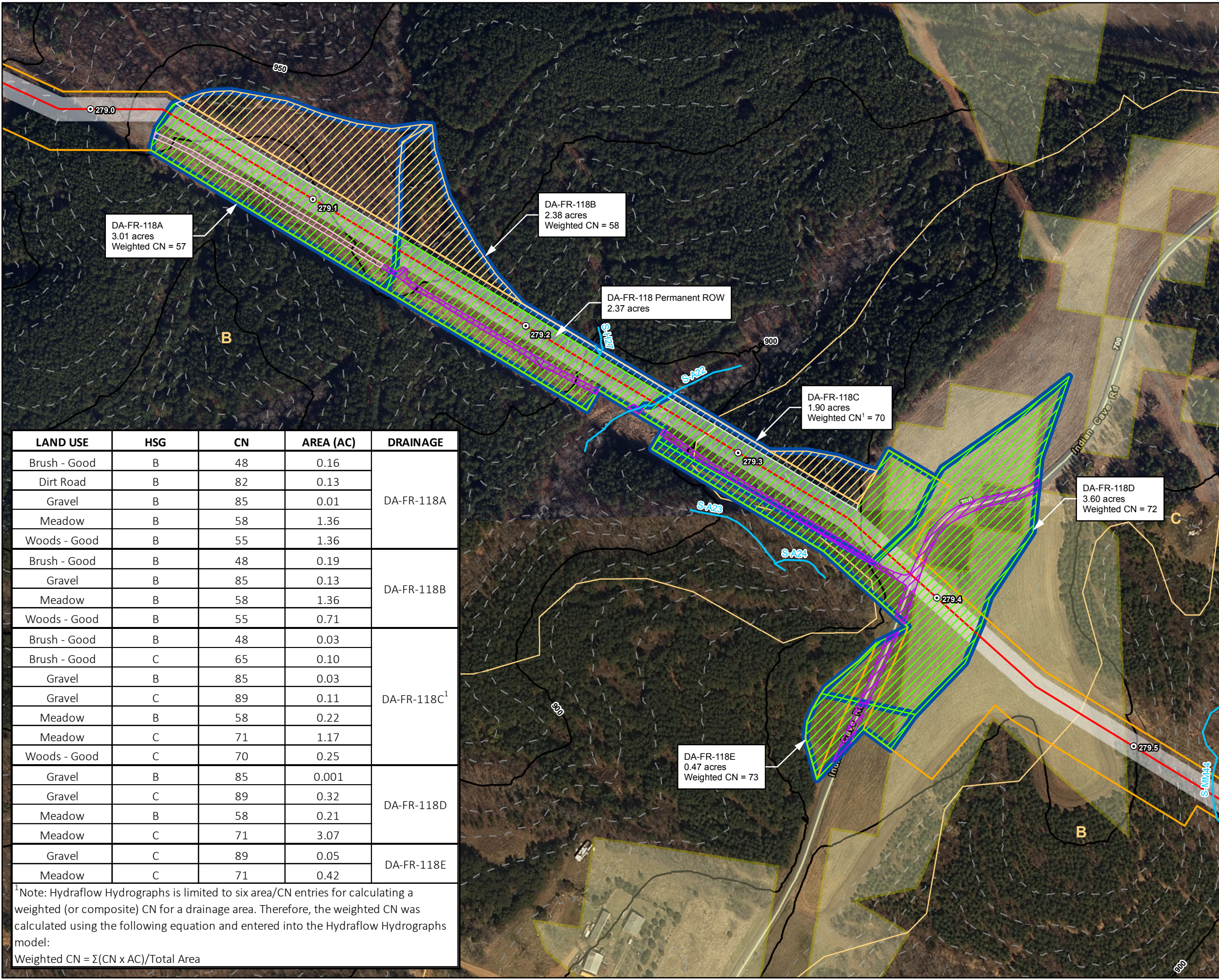
Pre-Construction Drainage Area Map
DA-FR-118
Spread 11

Figure 1
Franklin County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Dirt Road	B	82	0.13	DA-FR-118A
Gravel	B	85	0.01	
Meadow	B	58	0.89	
Woods - Good	B	55	1.98	
Gravel	B	85	0.13	DA-FR-118B
Meadow	B	58	0.62	
Woods - Good	B	55	1.63	
Gravel	B	85	0.03	DA-FR-118C
Gravel	C	89	0.11	
Meadow	B	58	0.07	
Meadow	C	71	0.75	
Woods - Good	B	55	0.18	
Woods - Good	C	70	0.77	
Gravel	B	85	0.001	DA-FR-118D
Gravel	C	89	0.32	
Meadow	B	58	0.21	
Meadow	C	71	3.07	
Gravel	C	89	0.05	DA-FR-118E
Meadow	C	71	0.42	



LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Brush - Good	B	48	0.16	DA-FR-118A
Dirt Road	B	82	0.13	
Gravel	B	85	0.01	
Meadow	B	58	1.36	
Woods - Good	B	55	1.36	
Brush - Good	B	48	0.19	DA-FR-118B
Gravel	B	85	0.13	
Meadow	B	58	1.36	
Woods - Good	B	55	0.71	DA-FR-118C ¹
Brush - Good	B	48	0.03	
Brush - Good	C	65	0.10	
Gravel	B	85	0.03	
Gravel	C	89	0.11	
Meadow	B	58	0.22	
Meadow	C	71	1.17	DA-FR-118D
Woods - Good	C	70	0.25	
Gravel	B	85	0.001	
Gravel	C	89	0.32	
Meadow	B	58	0.21	DA-FR-118E
Meadow	C	71	3.07	
Gravel	C	89	0.05	
Meadow	C	71	0.42	

¹Note: Hydraflow Hydrographs is limited to six area/CN entries for calculating a weighted (or composite) CN for a drainage area. Therefore, the weighted CN was calculated using the following equation and entered into the Hydraflow Hydrographs model:
Weighted CN = $\sum(CN \times AC) / \text{Total Area}$

Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Dirt Road
- Gravel
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

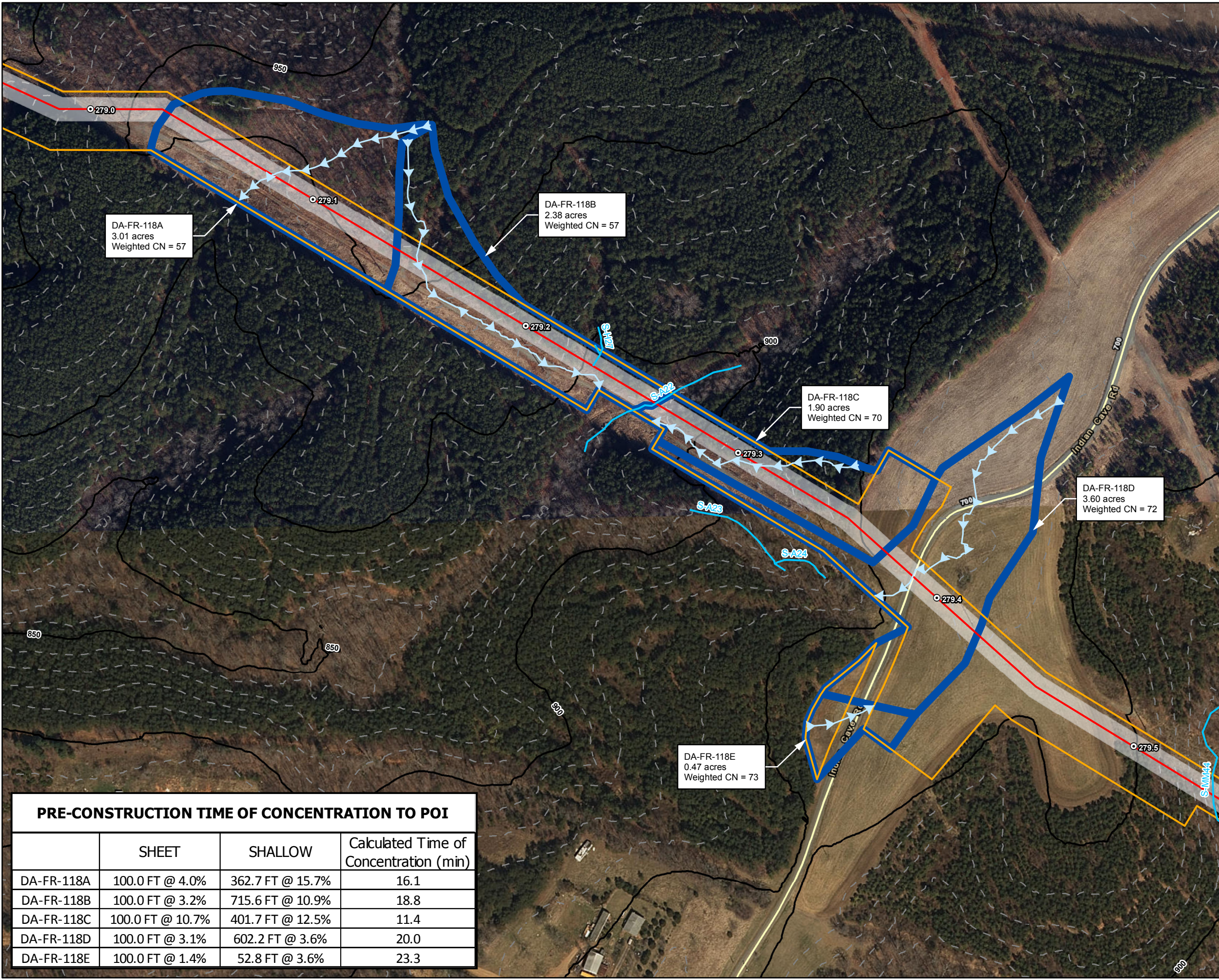
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200 100 0 200 Feet

Mountain Valley Pipeline Project

Post-Construction Drainage Area Map
DA-FR-118
Spread 11
Figure 2
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.



Legend

Milepost

Delineated Stream

Existing 50' Contour

Existing 10' Contour

Road Centerline

Alignment Centerline

Limit of Disturbance

Permanent Right-of-Way

Time of Concentration

Drainage Area

NAD 1983 UTM 17N (feet)

1:2,400

2001000200

Feet

N

W

E

S



PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET	SHALLOW	Calculated Time of Concentration (min)
DA-FR-118A	100.0 FT @ 4.0%	362.7 FT @ 15.7%	16.1
DA-FR-118B	100.0 FT @ 3.2%	715.6 FT @ 10.9%	18.8
DA-FR-118C	100.0 FT @ 10.7%	401.7 FT @ 12.5%	11.4
DA-FR-118D	100.0 FT @ 3.1%	602.2 FT @ 3.6%	20.0
DA-FR-118E	100.0 FT @ 1.4%	52.8 FT @ 3.6%	23.3

Mountain Valley

PIPELINE

Pre-Construction Drainage Area and Time of Concentration

DA-FR-118

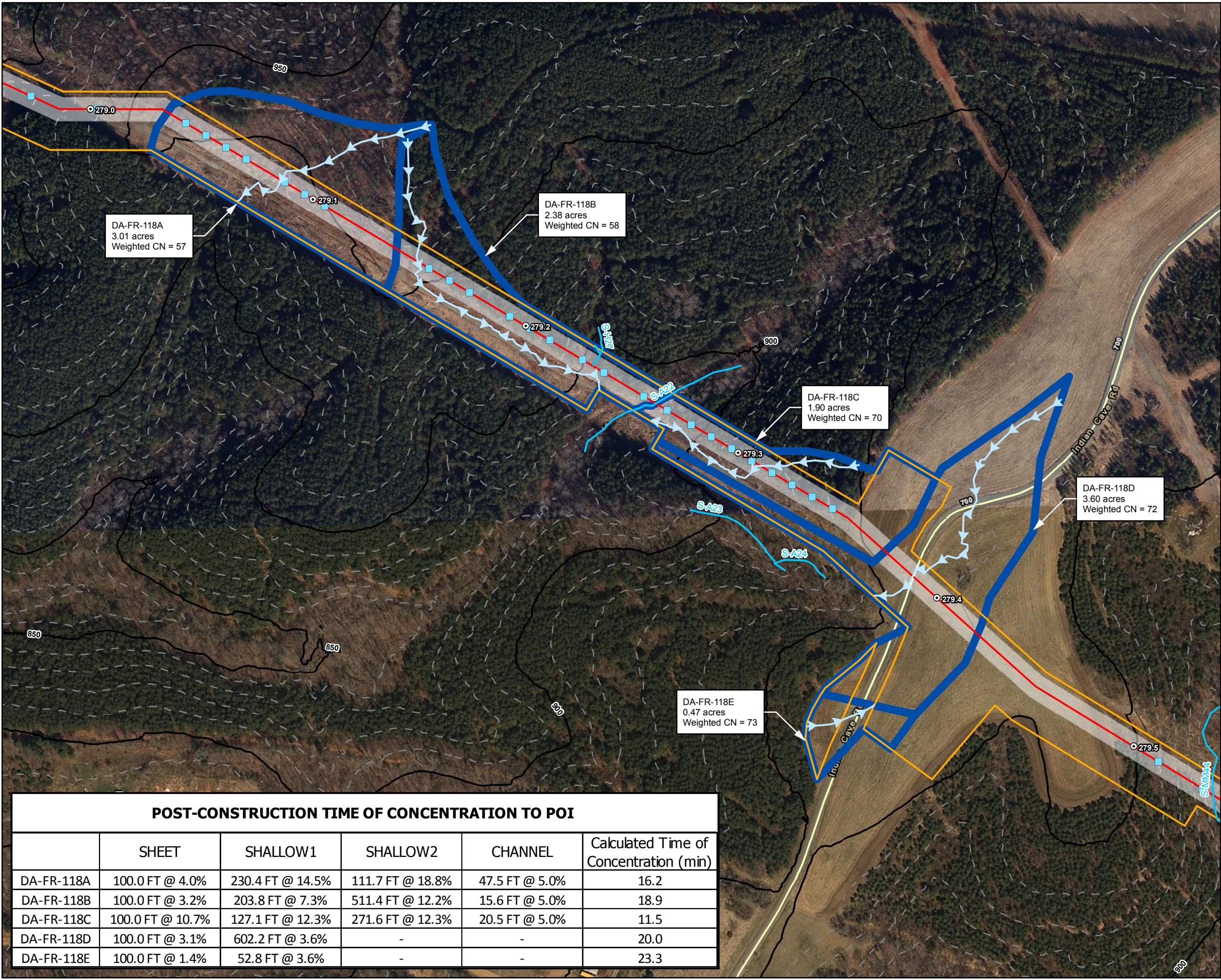
Spread 11

Figure 3

Franklin County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.



Legend

- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- - Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- ▭ Drainage Area

NAD 1983 UTM 17N (feet)

1:2,400

200 100 0 200 Feet

W N E S



Mountain Valley Pipeline Project

Mountain Valley
PIPELINE

**Post-Construction Drainage Area
and Time of Concentration
DA-FR-118
Spread 11**

Figure 4
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from NHDPlus 2016, Elevation data derived from LiDAR provided by EQT 2016.

DEQ Virginia Runoff Reduction Method Re-Development Compliance Spreadsheet - Version 3.0

BMP Design Specifications List: 2013 Draft Stds & Specs

Site Summary - Linear Development Project***

Total Rainfall (in):	43
Total Disturbed Acreage:	2.37

Site Land Cover Summary

Pre-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	1.54	0.79	0.00	2.33	98
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.00	0.04	0.00	0.04	2
					2.37	100

Post-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	1.54	0.79	0.00	2.33	98
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.00	0.04	0.00	0.04	2
					2.37	100

* Forest/Open Space areas must be protected in accordance with the Virginia Runoff Reduction Method

Site Tv and Land Cover Nutrient Loads

	Final Post-Development (Post-ReDevelopment & New Impervious)	Post- ReDevelopment	Post- Development (New Impervious)	Adjusted Pre- ReDevelopment
Site Rv	0.05	0.05	--	0.05
Treatment Volume (ft ³)	420	420	--	420
TP Load (lb/yr)	0.26	0.26	--	0.26

Baseline TP Load (lb/yr): 0.9717* *Reduction below new development load limitation not required

Pre- ReDevelopment TP Load per acre (lb/acre/yr)	Final Post-Development TP Load per acre (lb/acre/yr)	Post-ReDevelopment TP Load per acre (lb/acre/yr)
0.11	0.11	0.11

Total TP Load Reduction Required (lb/yr)	-0.71	N/A***	N/A***
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***This is a linear development project

	Final Post-Development Load (Post-ReDevelopment & New Impervious)	Pre- ReDevelopment
TN Load (lb/yr)	1.89	1.89

Site Compliance Summary - ***Linear Development Project

Maximum % Reduction Required Below Pre-ReDevelopment Load	20%
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** Note: % Reduction will reduce post-development TP load to less than or equal to baseline load of 0.97 lb/yr (0.41 lb/ac/yr)
[Post-Dev Reduction Requirement = Post-Dev TP load - baseline load of 0.97 lb/yr], baseline load = site area x 0.41 lb/ac/yr*

Total Runoff Volume Reduction (ft ³)	0
Total TP Load Reduction Achieved (lb/yr)	0.00
Total TN Load Reduction Achieved (lb/yr)	0.00
Remaining Post Development TP Load (lb/yr)	0.26
Remaining TP Load Reduction (lb/yr) Required	0.00

**** TARGET TP REDUCTION EXCEEDED BY 0.71 LB/YEAR ****

**Reduction below new development load limitation not required*

DA-FR-118A

STORAGE VOLUME OF WATERBAR WITH SOIL COMPOST AMENDMENT AREA

Equations Used:

¹V_{gravel} storage = L*W*D_{gravel}*(40/100)

²V_{soil} storage = L*W*D_{soil}*(20/100)

³V_{surface} storage = [W*S*D^2]/2+[L*S*D^2]/2+[W*L*D]+[(2*S*D)^2*D]/3]

¹Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that gravel is made up of 40% voids.

²Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that soil compost amendment is made up of 20% voids.

³Equation #1 under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, but calculation also takes into account surface side slopes.

Inputs:	Depth of Gravel Layer, D _{gravel} (ft) =	0	
	Depth of Soil Amendment Area, D _{soil} (ft) =	1	Refer to Table 4.3 in VA DEQ Stormwater Design Specification No. 4; Note that compost amendment may not be necessary for HSG A/B soils Assume max. length of 50' for waterbar soil amendment areas (i.e., limited to permanent ROW)
	Length of Waterbar Soil Amendment Area, L (ft) =	30	
	Width of Waterbar Soil Amendment Area, W (ft) =	2	
	Inside Embankment Side Slopes, S (H:V) =	2	Assume 2H:1V surface side slopes for waterbars
	Number of Perm. Waterbars in Drainage Area, n =	7	
	Design Infiltration Rate, IR (in/hr) =	0.2	Min. rate of 0.30 in/hr for HSG A soils and 0.15-0.30 in/hr for HSG B soils (see Chap. 4, p. 4-30 in VA Stormwater Management Handbook Volume II (First Edition, 1999)
	Surface Ponding Depth, D (ft) =	0.5	Assume 0.5' CFS height at the end of waterbars

Calculations:	Total Storage Depth per BMP (ft) =	1.5
	Surface Storage Volume per BMP (cf) =	46.66666667
	Subsurface Storage Volume per BMP (cf) =	12
	Total Storage Volume per BMP (cf) =	58.66666667
	Total BMP Storage Volume in Drainage Area (cf) =	410.6666667
	Calculated Infiltration Period per BMP (hr) =	58.66666667

Depth-Storage Data				
Depth (ft)	Width (ft)	Length (ft)	Storage Volume per BMP (cf)	Storage Volume in Drainage Area (cf)
0	2	30	0	0
0.5	2	30	6	42
1	2	30	12	84
1.5	4	32	58.66666667	410.6666667
2	6	34	141.3333333	989.3333333

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.708	3801
Developed Condition	0.568	3391
Pre-Developed (Forest) Condition	0.463	3110

*Peak Flow and Runoff Volume inputs taken from Hydraulflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1: $Q_{developed} \leq IF \times [(Q_{pre-developed} \times RV_{pre-developed}) / RV_{developed}]$ ----->

Q (cfs)		Q (cfs)
0.568	≤	0.635
	OK	

Check #2: $Q_{developed} \leq Q_{pre-developed}$ ----->

0.568	≤	0.708
	OK	

Check #3: $Q_{developed} \text{ shall not be required to be } \leq (Q_{forest} \times RV_{forest}) / RV_{developed}$ ---->

0.568	<u>shall not</u> be required to be ≤	0.425
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STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p><i>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</i></p> <p><i>For Paved Road land surface types a Manning’s n value of 0.011 was used.</i></p> <p><i>Sources:</i></p> <p><i>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</i></p> <p><i>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</i></p>	

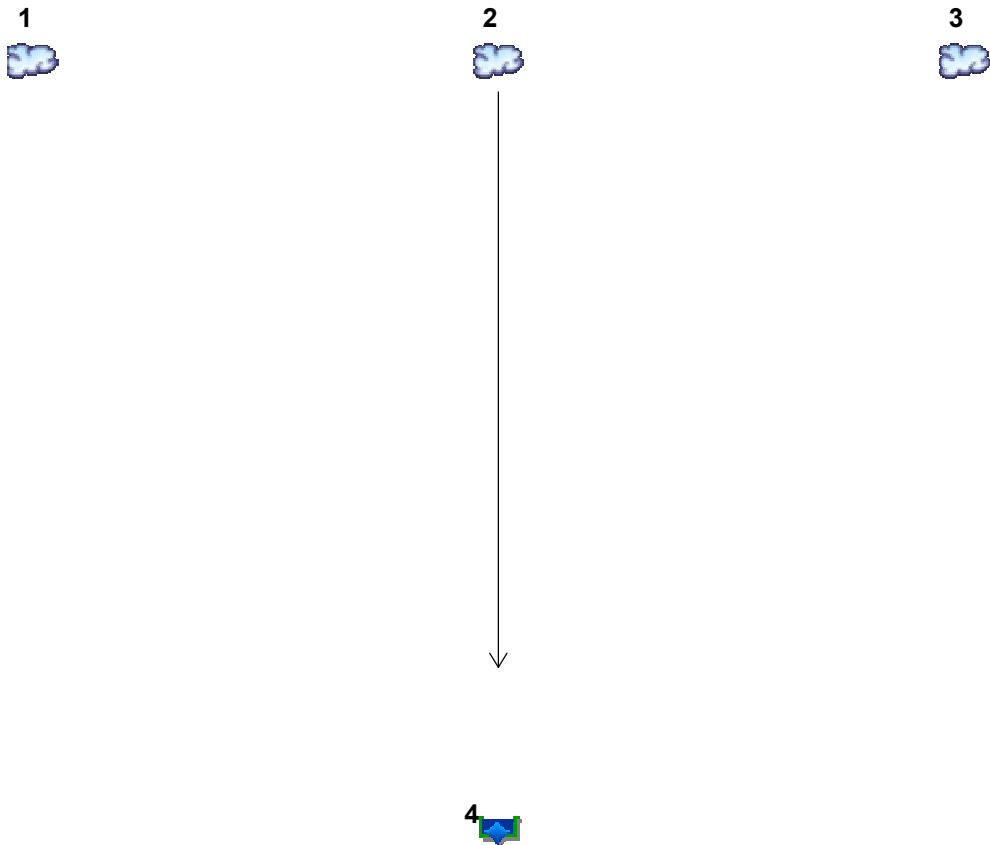
Table 2 – Manning's n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's n value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's n value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-118A PRE
2	SCS Runoff	DA-FR-118A POST
3	SCS Runoff	DA-FR-118A Pre-Forested
4	Reservoir	WB Soil Amendment

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.708	1	727	3,801	-----	-----	-----	DA-FR-118A PRE
2	SCS Runoff	0.708	1	727	3,801	-----	-----	-----	DA-FR-118A POST
3	SCS Runoff	0.463	1	727	3,110	-----	-----	-----	DA-FR-118A Pre-Forested
4	Reservoir	0.568	1	733	3,391	2	935.55	471	WB Soil Amendment
DA-FR-118a.gpw					Return Period: 1 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

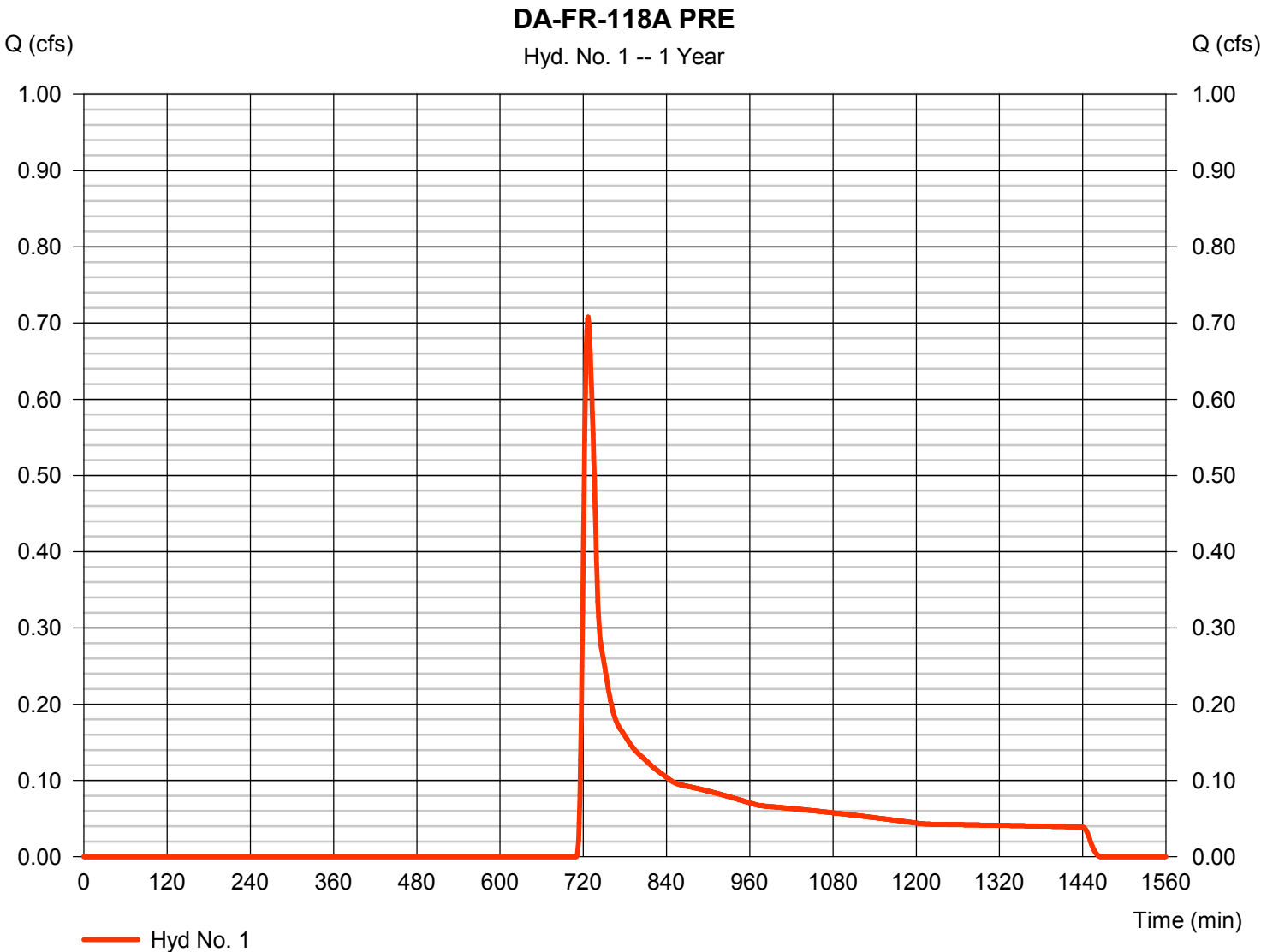
Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-FR-118A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.708 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 3,801 cuft
Drainage area	= 3.010 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.10 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.135 x 82) + (0.006 x 85) + (0.888 x 58) + (1.984 x 55)] / 3.010



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-118A PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 4.00	0.00	0.00				
Travel Time (min)	= 15.13	+	0.00	+	0.00	=	15.13
Shallow Concentrated Flow							
Flow length (ft)	= 362.70	0.00	0.00				
Watercourse slope (%)	= 15.70	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=6.39	0.00	0.00				
Travel Time (min)	= 0.95	+	0.00	+	0.00	=	0.95
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	= 0.040	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				16.10 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

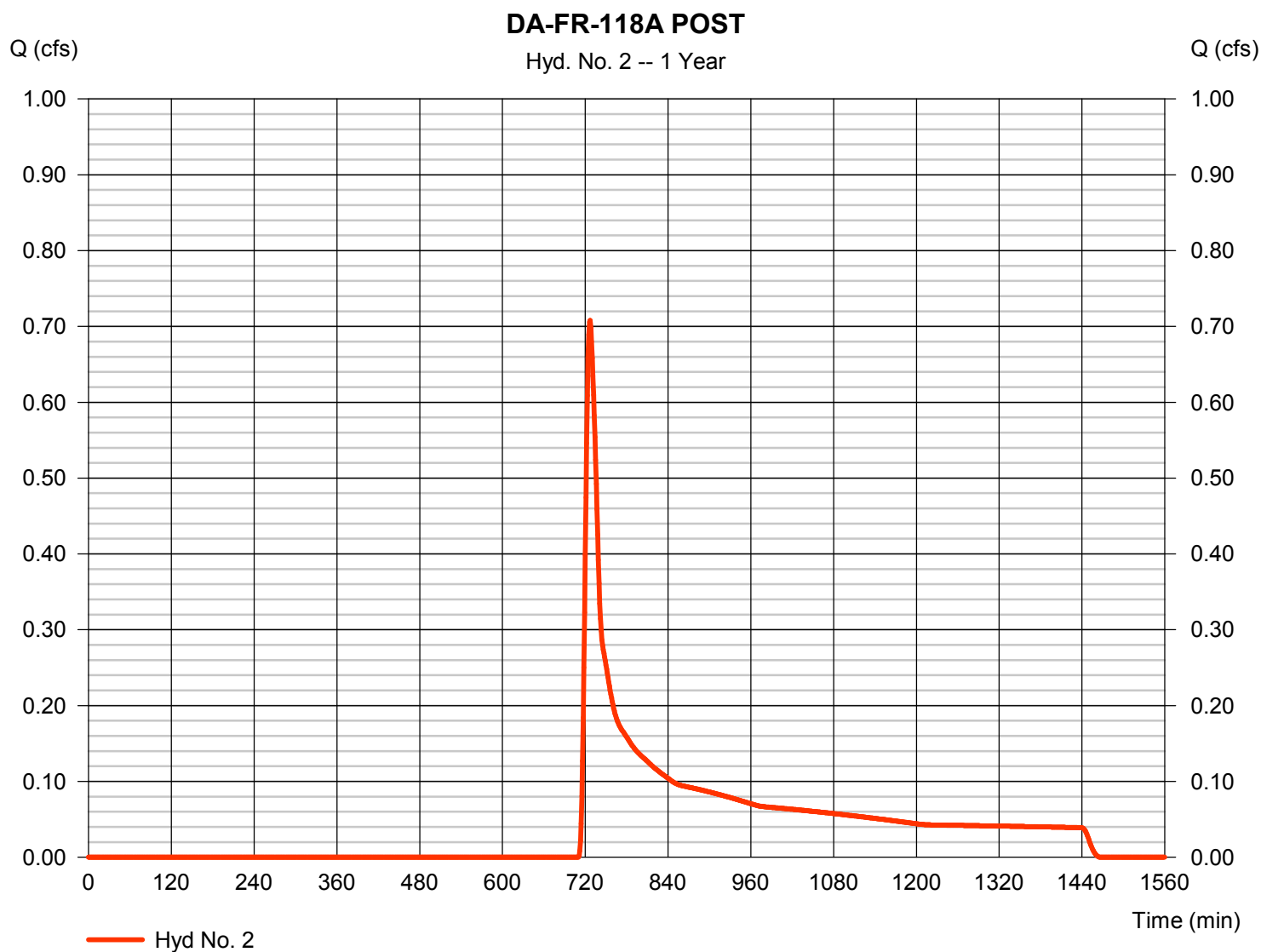
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-FR-118A POST

Hydrograph type	= SCS Runoff	Peak discharge	= 0.708 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 3,801 cuft
Drainage area	= 3.010 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.20 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.156 \times 48) + (0.135 \times 82) + (0.006 \times 85) + (1.357 \times 58) + (1.359 \times 55)] / 3.010$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-118A POST

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.800	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 4.00	0.00	0.00				
Travel Time (min)	= 15.13	+	0.00	+	0.00	=	15.13
Shallow Concentrated Flow							
Flow length (ft)	= 230.40	111.70	0.00				
Watercourse slope (%)	= 14.50	18.80	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=6.14	7.00	0.00				
Travel Time (min)	= 0.63	+	0.27	+	0.00	=	0.89
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	(0)47.5	0.0	0.0				
Travel Time (min)	= 0.16	+	0.00	+	0.00	=	0.16
Total Travel Time, Tc					16.20 min		

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

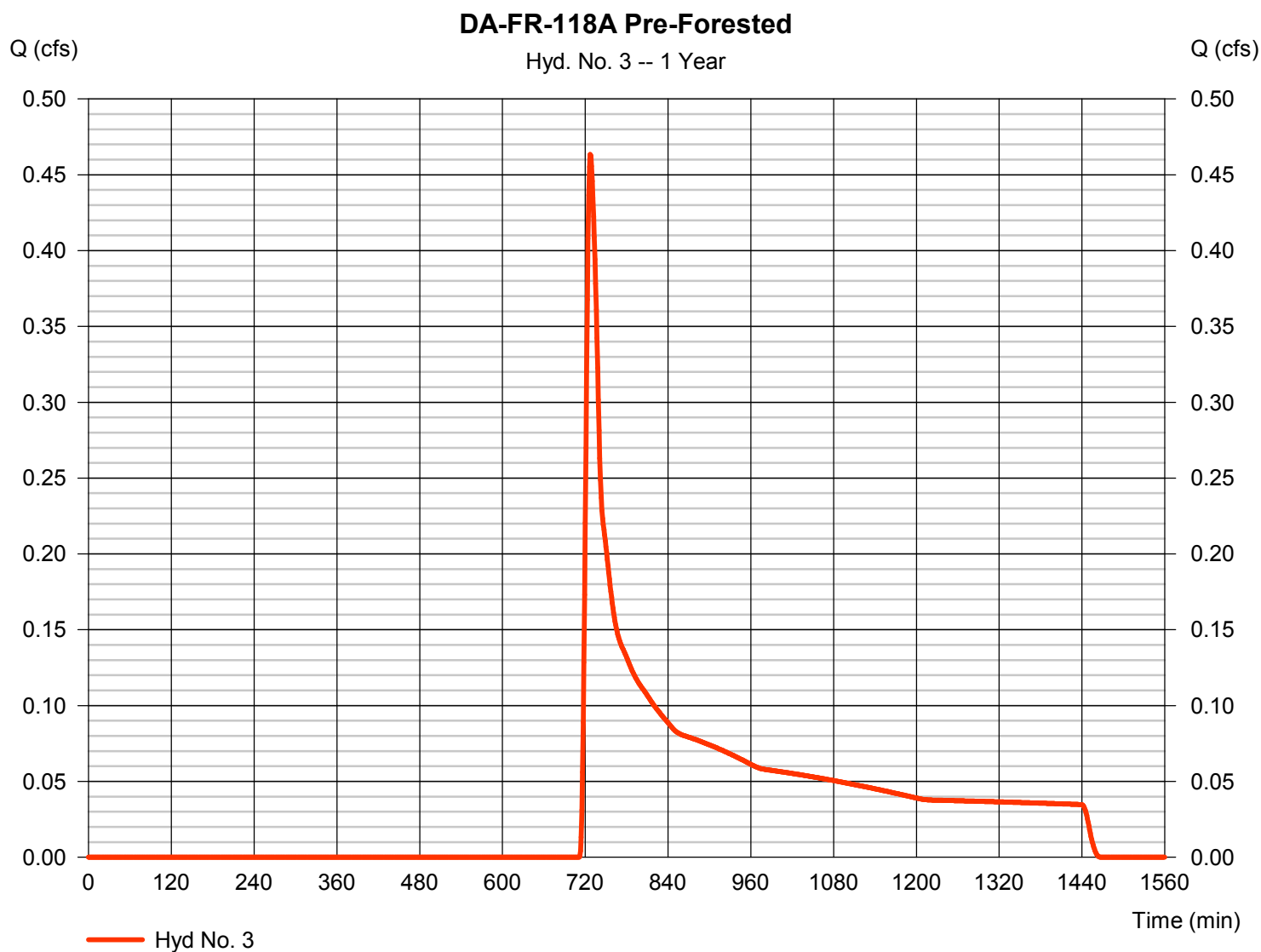
Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-FR-118A Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.463 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 3,110 cuft
Drainage area	= 3.010 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.10 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(3.010 x 55)] / 3.010



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-118A Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 4.00	0.00	0.00				
Travel Time (min)	= 15.13	+	0.00	+	0.00	=	15.13
Shallow Concentrated Flow							
Flow length (ft)	= 362.70	0.00	0.00				
Watercourse slope (%)	= 15.70	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=6.39	0.00	0.00				
Travel Time (min)	= 0.95	+	0.00	+	0.00	=	0.95
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	= 0.030	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				16.10 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

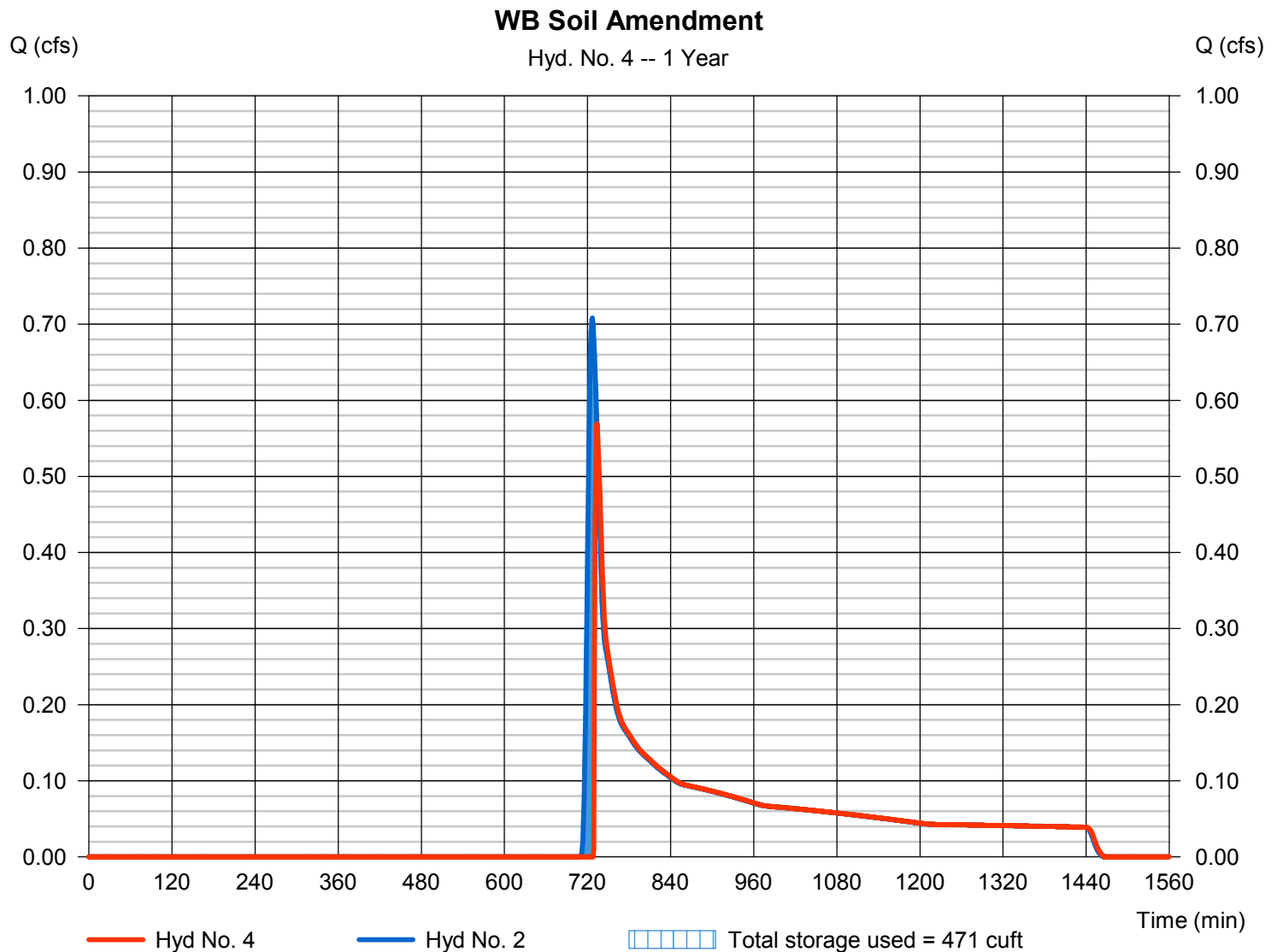
Wednesday, 08 / 16 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 0.568 cfs
Storm frequency	= 1 yrs	Time to peak	= 733 min
Time interval	= 1 min	Hyd. volume	= 3,391 cuft
Inflow hyd. No.	= 2 - DA-FR-118A POST	Max. Elevation	= 935.55 ft
Reservoir name	= Waterbar Soil Amendment	Max. Storage	= 471 cuft

Storage Indication method used.



Pond No. 1 - Waterbar Soil Amendment

Pond Data

Pond storage is based on user-defined values.

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	934.00	n/a	0	0
0.50	934.50	n/a	42	42
1.00	935.00	n/a	42	84
1.50	935.50	n/a	327	411
2.00	936.00	n/a	579	989

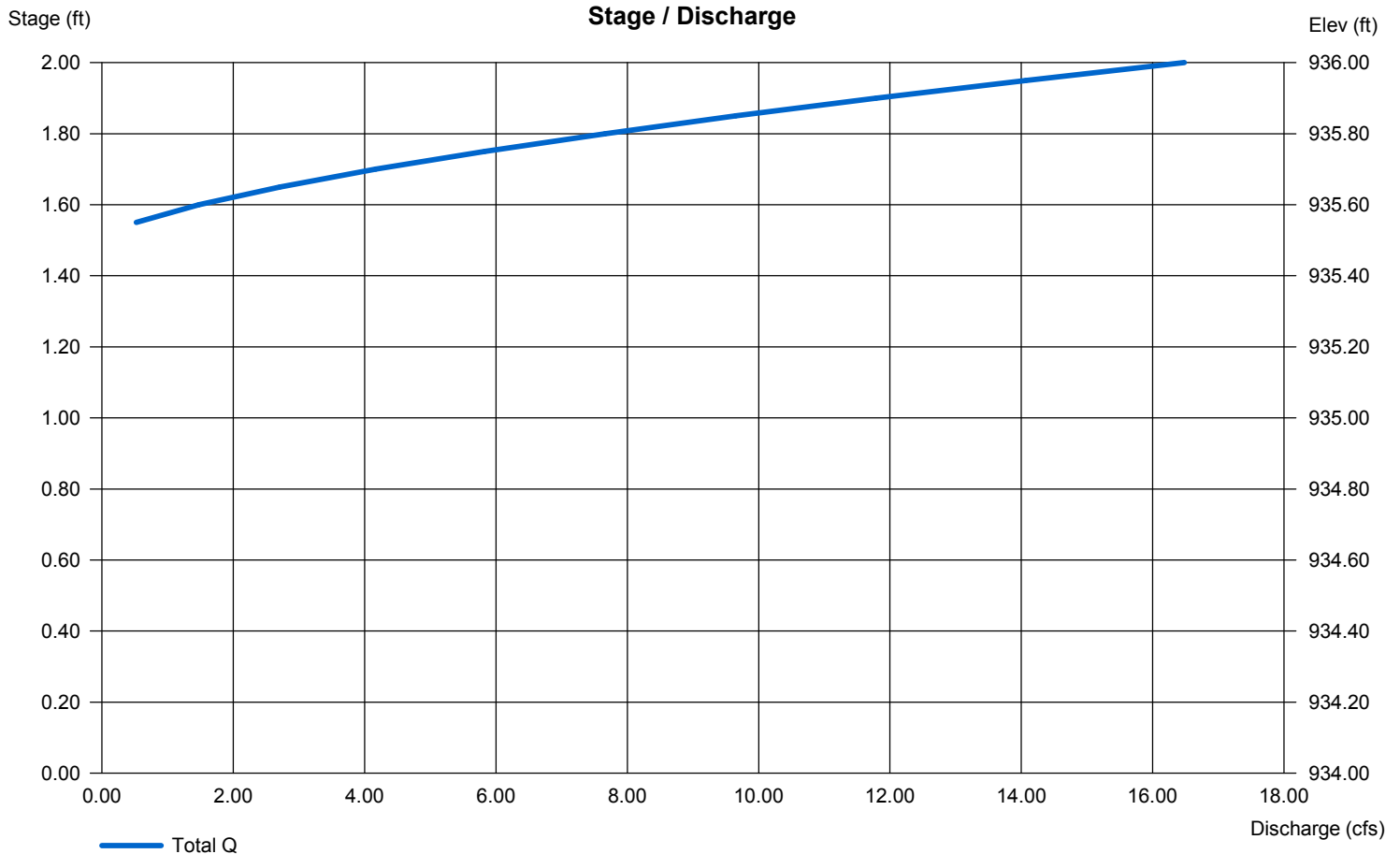
Culvert / Orifice Structures

	[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)	= 14.00	0.00	0.00	0.00
Crest El. (ft)	= 935.50	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= Rect	---	---	---
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).



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	1.259	1	726	5,456	-----	-----	-----	DA-FR-118A PRE
2	SCS Runoff	1.259	1	726	5,456	-----	-----	-----	DA-FR-118A POST
3	SCS Runoff	0.920	1	726	4,598	-----	-----	-----	DA-FR-118A Pre-Forested
4	Reservoir	1.215	1	728	5,045	2	935.59	511	WB Soil Amendment
DA-FR-118a.gpw					Return Period: 2 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

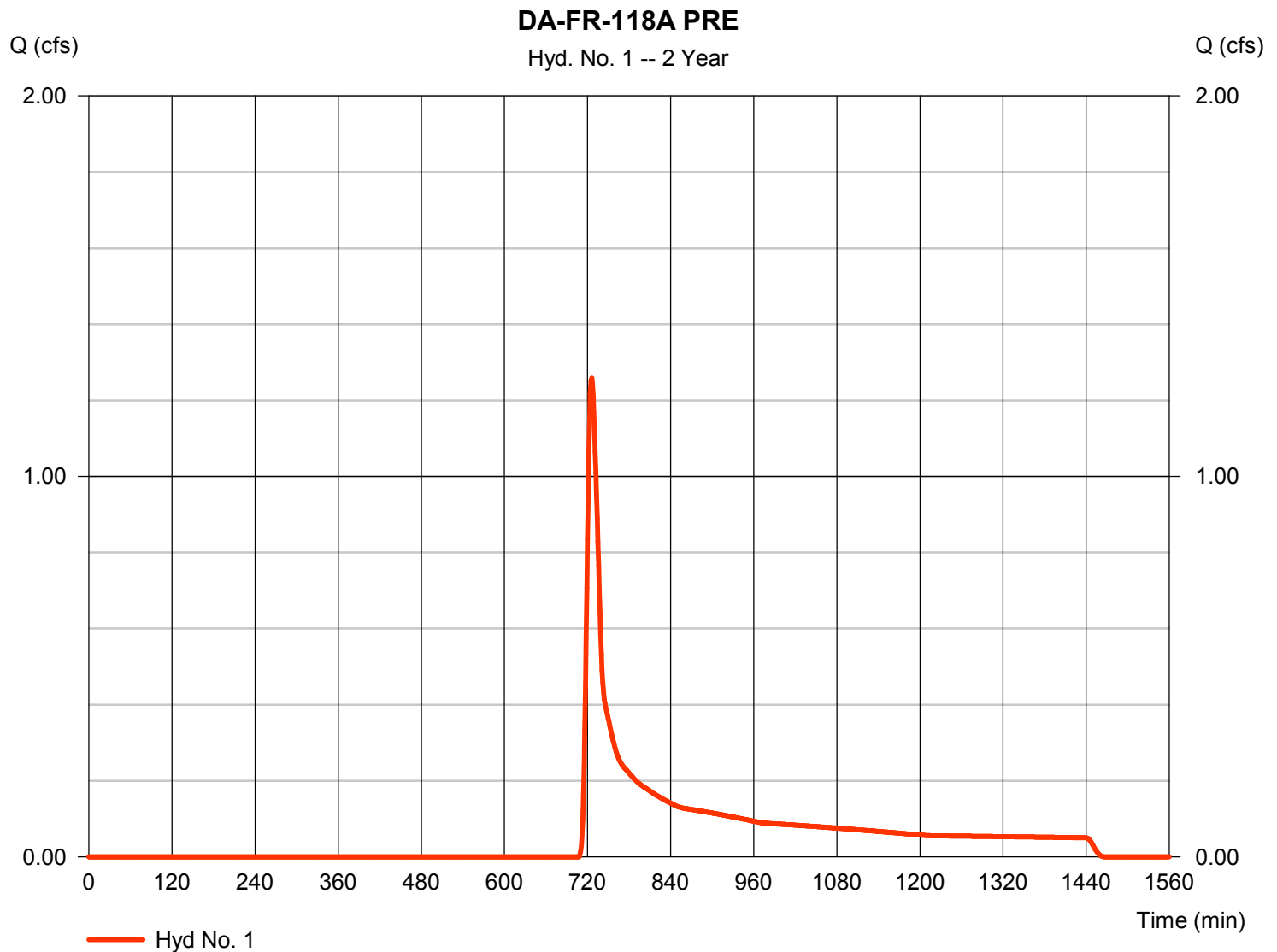
Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-FR-118A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 1.259 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 5,456 cuft
Drainage area	= 3.010 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.10 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.135 \times 82) + (0.006 \times 85) + (0.888 \times 58) + (1.984 \times 55)] / 3.010$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

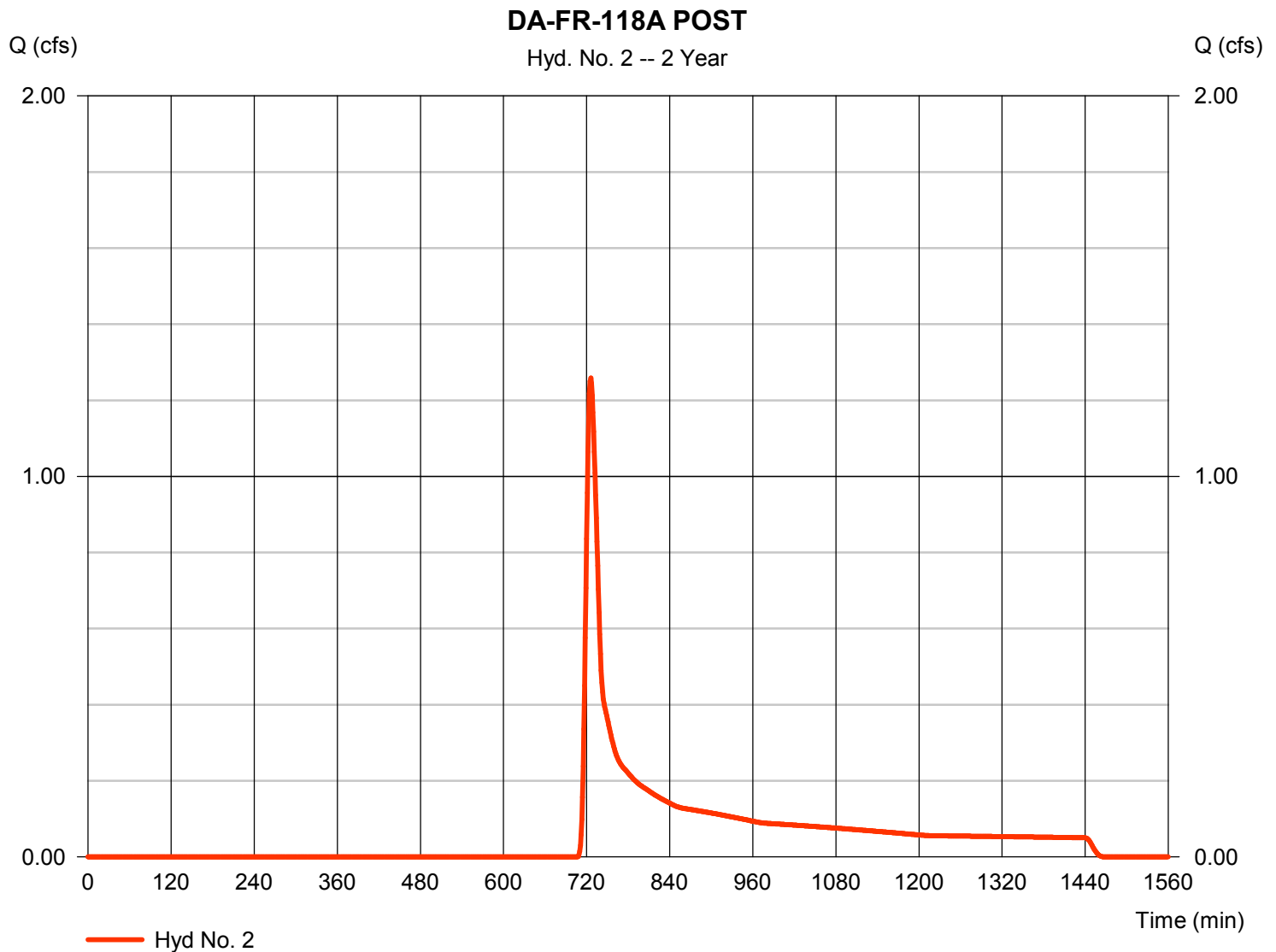
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-FR-118A POST

Hydrograph type	= SCS Runoff	Peak discharge	= 1.259 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 5,456 cuft
Drainage area	= 3.010 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.20 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.156 \times 48) + (0.135 \times 82) + (0.006 \times 85) + (1.357 \times 58) + (1.359 \times 55)] / 3.010$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

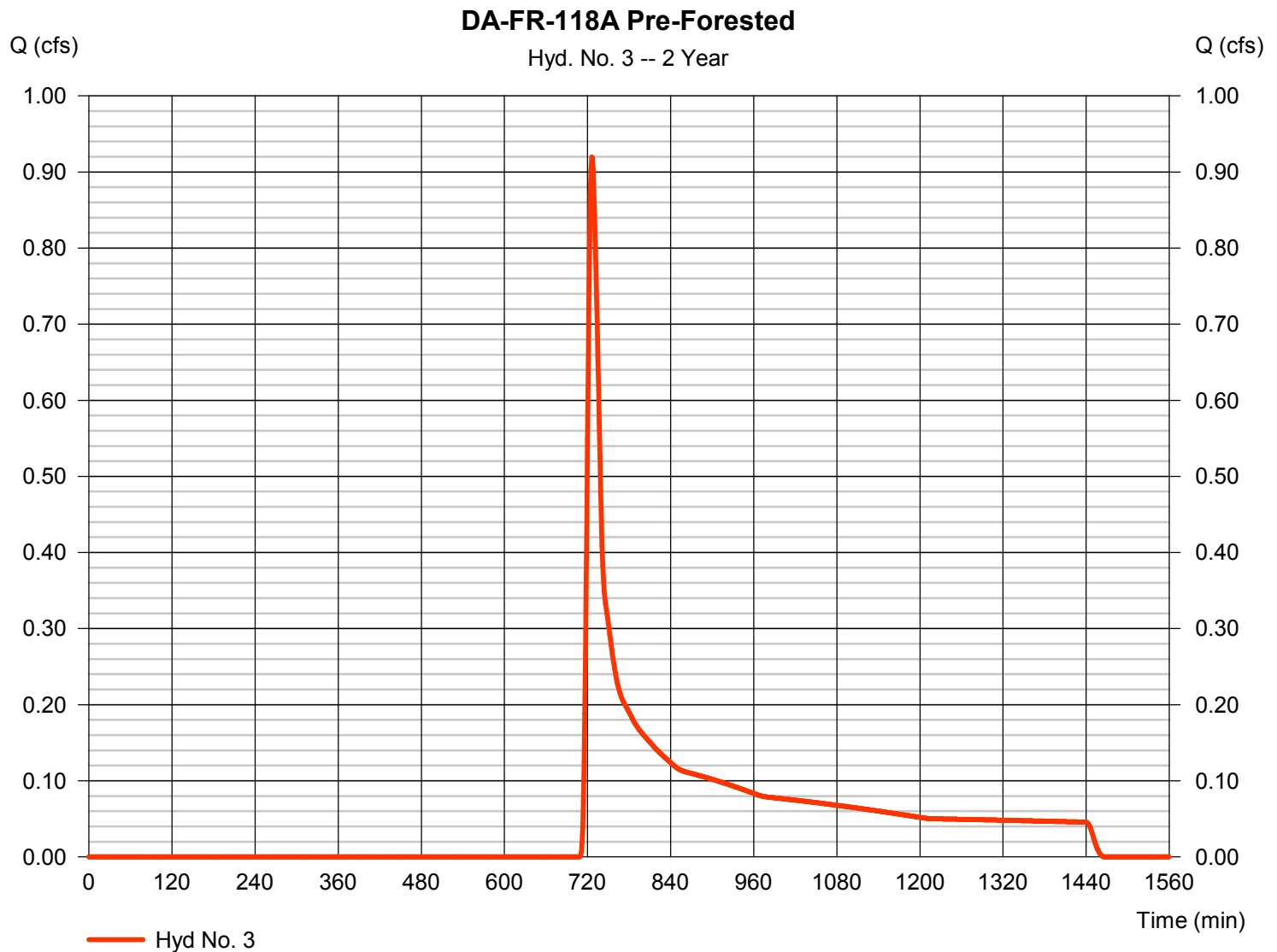
Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-FR-118A Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.920 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 4,598 cuft
Drainage area	= 3.010 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.10 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(3.010 x 55)] / 3.010



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

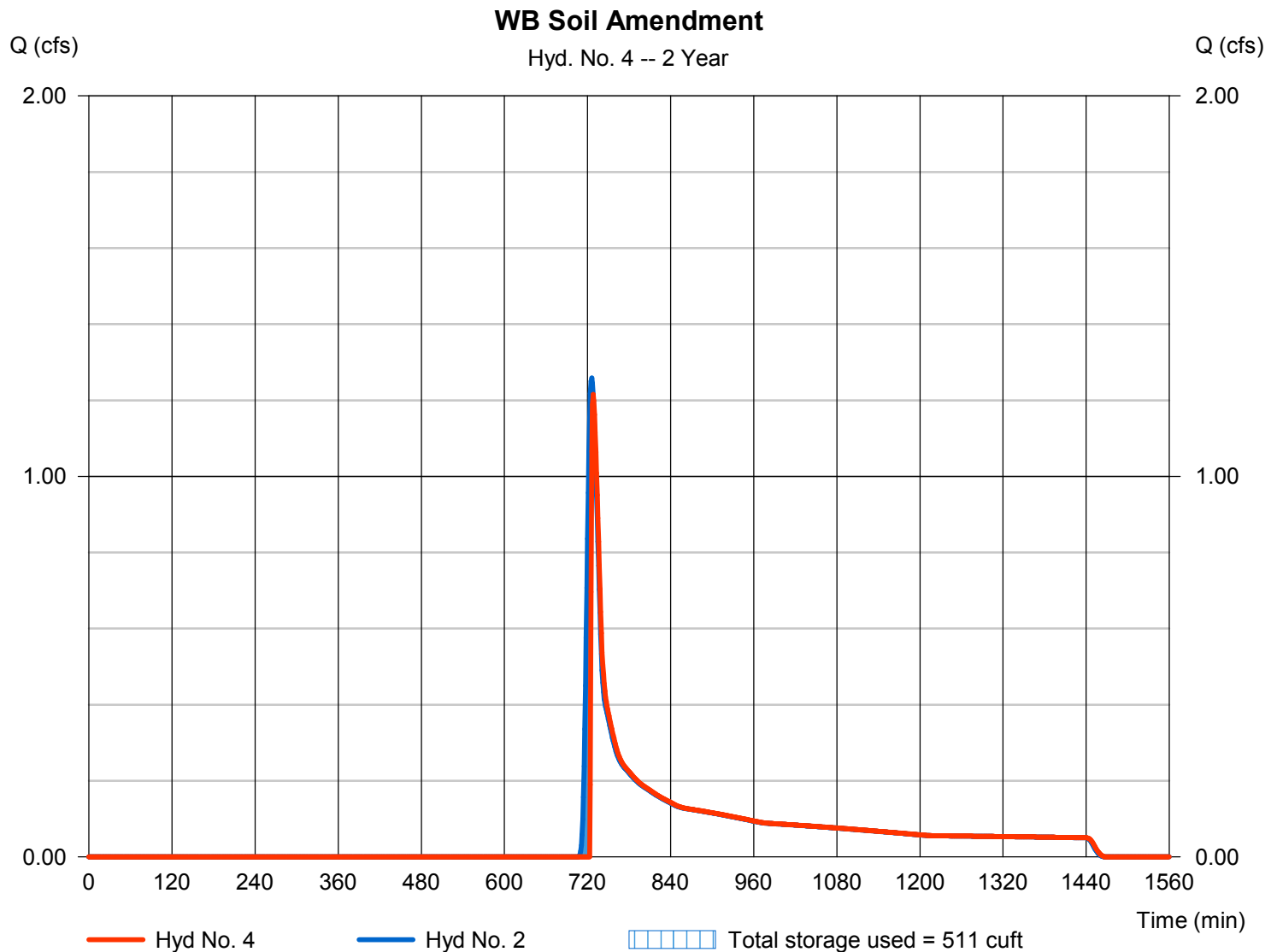
Wednesday, 08 / 16 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 1.215 cfs
Storm frequency	= 2 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 5,045 cuft
Inflow hyd. No.	= 2 - DA-FR-118A POST	Max. Elevation	= 935.59 ft
Reservoir name	= Waterbar Soil Amendment	Max. Storage	= 511 cuft

Storage Indication method used.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	5.326	1	724	16,560	-----	-----	-----	DA-FR-118A PRE
2	SCS Runoff	5.326	1	724	16,560	-----	-----	-----	DA-FR-118A POST
3	SCS Runoff	4.652	1	724	14,918	-----	-----	-----	DA-FR-118A Pre-Forested
4	Reservoir	5.302	1	725	16,149	2	935.73	682	WB Soil Amendment
DA-FR-118a.gpw					Return Period: 10 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

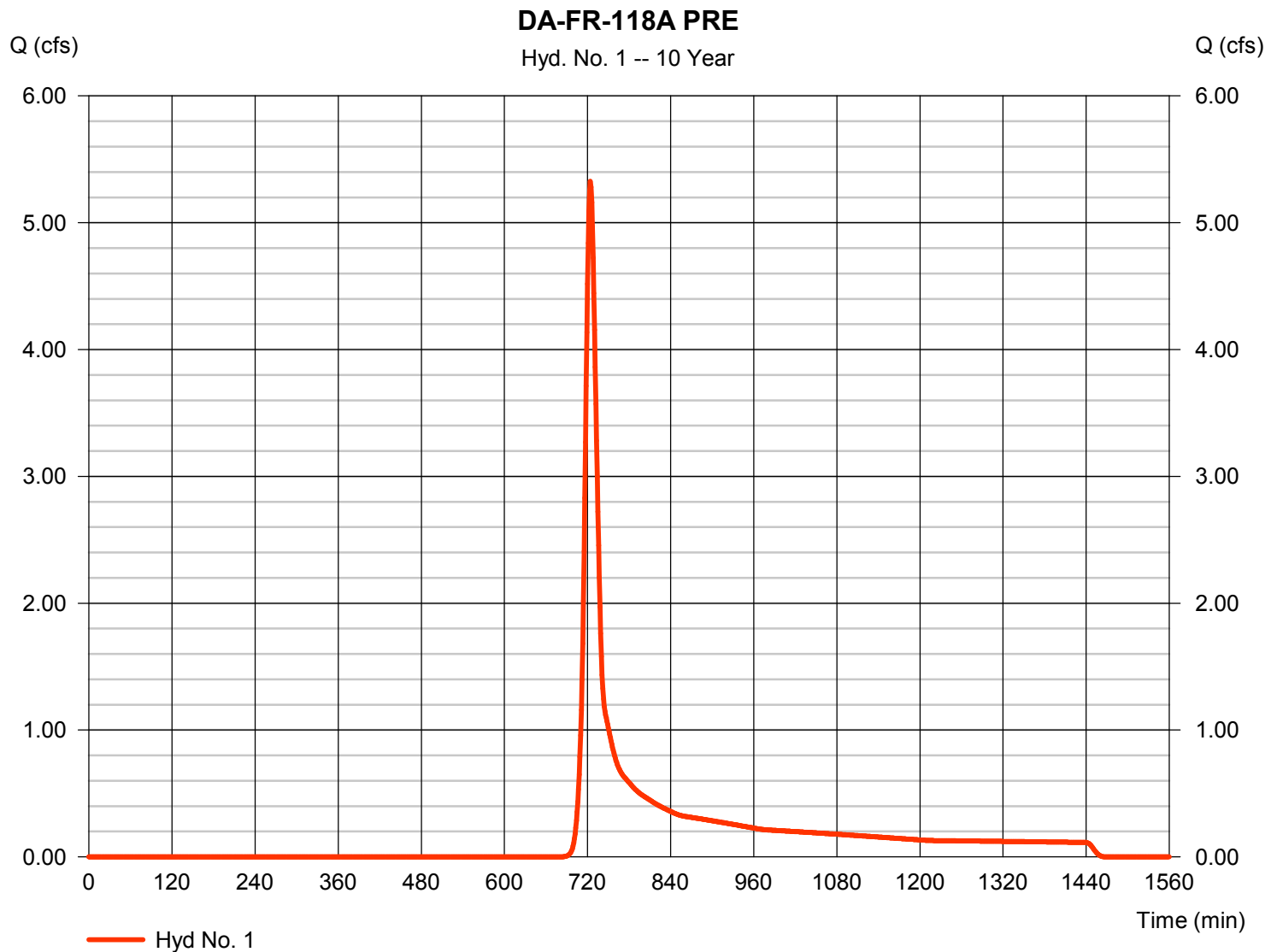
Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-FR-118A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 5.326 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 16,560 cuft
Drainage area	= 3.010 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.10 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.135 \times 82) + (0.006 \times 85) + (0.888 \times 58) + (1.984 \times 55)] / 3.010$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

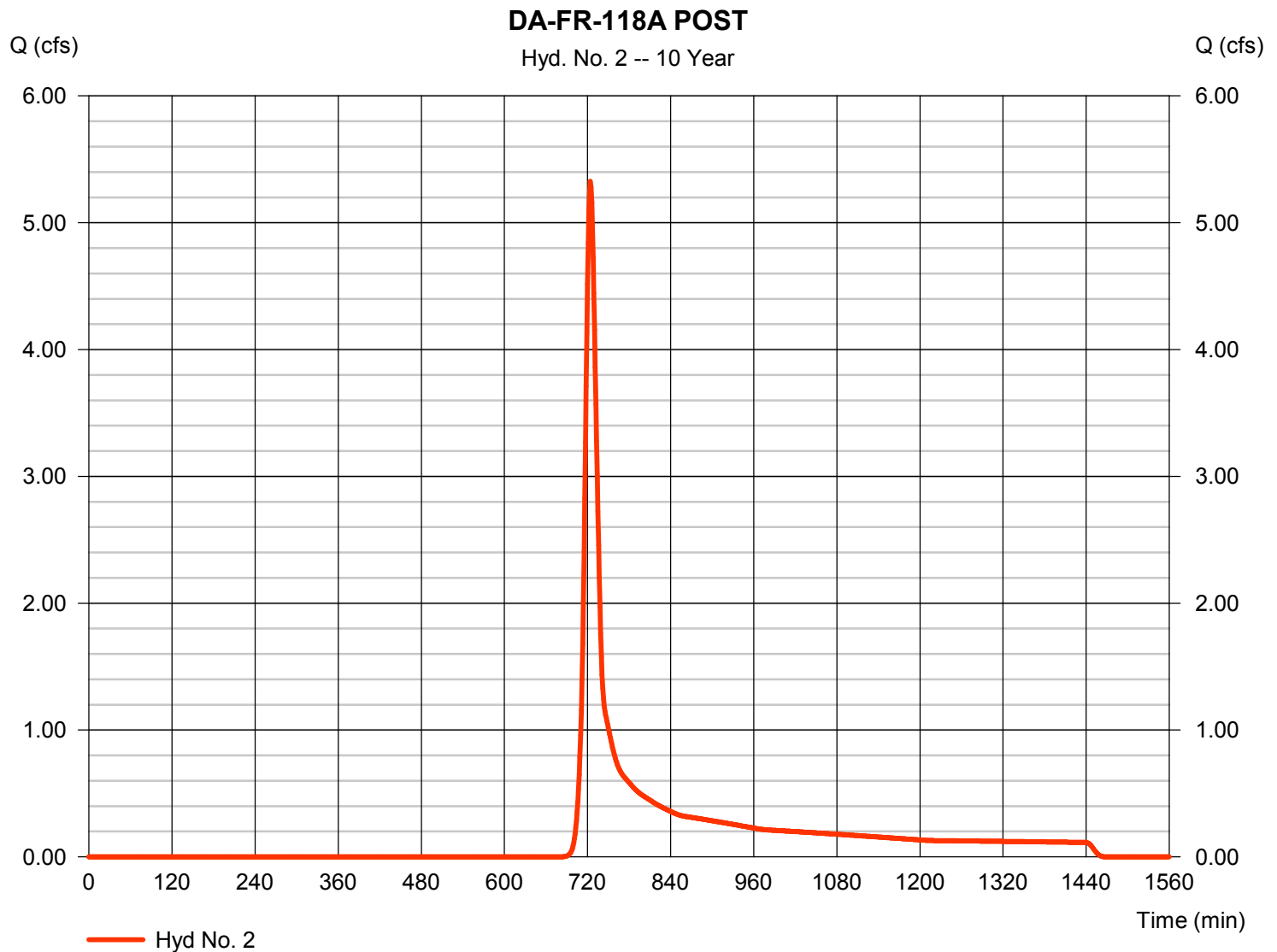
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-FR-118A POST

Hydrograph type	= SCS Runoff	Peak discharge	= 5.326 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 16,560 cuft
Drainage area	= 3.010 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.20 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.156 \times 48) + (0.135 \times 82) + (0.006 \times 85) + (1.357 \times 58) + (1.359 \times 55)] / 3.010$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

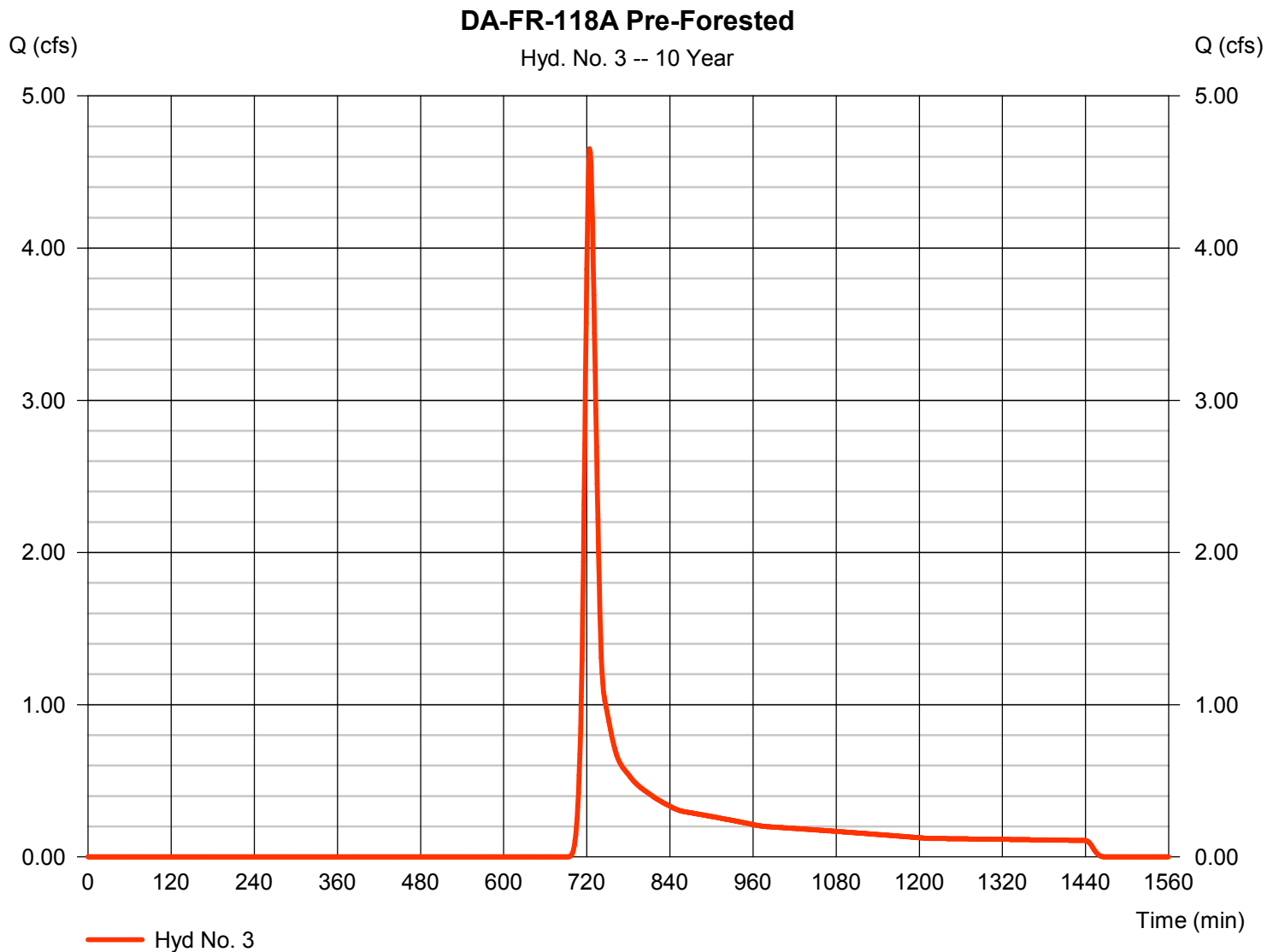
Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-FR-118A Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 4.652 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 14,918 cuft
Drainage area	= 3.010 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.10 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(3.010 x 55)] / 3.010



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

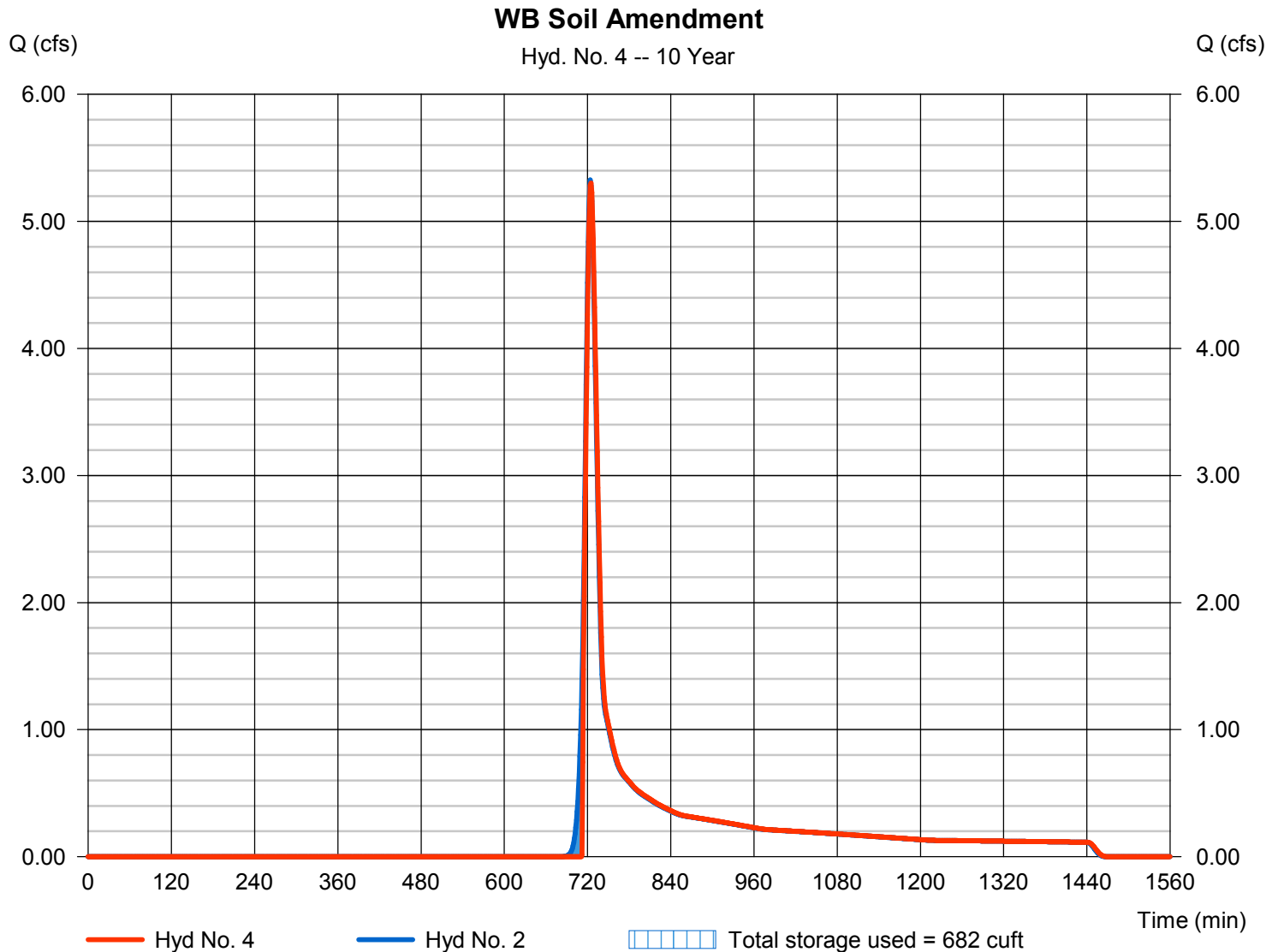
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Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 5.302 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 16,149 cuft
Inflow hyd. No.	= 2 - DA-FR-118A POST	Max. Elevation	= 935.73 ft
Reservoir name	= Waterbar Soil Amendment	Max. Storage	= 682 cuft

Storage Indication method used.



$$\text{Intensity} = B / (T_c + D)^E$$

Tc = time in minutes. Values may exceed 60.

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DA-FR-118B

STORAGE VOLUME OF WATERBAR WITH SOIL COMPOST AMENDMENT AREA

Equations Used:

$$^1V_{\text{gravel storage}} = L * W * D_{\text{gravel}} * (40/100)$$

$$^2V_{\text{soil storage}} = L * W * D_{\text{soil}} * (20/100)$$

$$^3V_{\text{surface storage}} = [W * S * D^2 * 2] + [L * S * D^2 * 2] + [W * L * D] + [(2 * S * D)^2 * D] / 3$$

¹Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that gravel is made up of 40% voids.

²Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that soil compost amendment is made up of 20% voids.

³Equation #1 under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, but calculation also takes into account surface side slopes.

Inputs:	Depth of Gravel Layer, D_{gravel} (ft) =	0	
	Depth of Soil Amendment Area, D_{soil} (ft) =	1	Refer to Table 4.3 in VA DEQ Stormwater Design Specification No. 4; Note that compost amendment may not be necessary for HSG A/B soils Assume max. length of 50' for waterbar soil amendment areas (i.e., limited to permanent ROW)
	Length of Waterbar Soil Amendment Area, L (ft) =	30	
	Width of Waterbar Soil Amendment Area, W (ft) =	2	
	Inside Embankment Side Slopes, S (H:V) =	2	Assume 2H:1V surface side slopes for waterbars
	Number of Perm. Waterbars in Drainage Area, n =	9	
	Design Infiltration Rate, IR (in/hr) =	0.2	Min. rate of 0.30 in/hr for HSG A soils and 0.15-0.30 in/hr for HSG B soils (see Chap. 4, p. 4-30 in VA Stormwater Management Handbook Volume II (First Edition, 1999)
	Surface Ponding Depth, D (ft) =	0.5	Assume 0.5' CFS height at the end of waterbars

Calculations:	Total Storage Depth per BMP (ft) =	1.5
	Surface Storage Volume per BMP (cf) =	46.66666667
	Subsurface Storage Volume per BMP (cf) =	12
	Total Storage Volume per BMP (cf) =	58.66666667
	Total BMP Storage Volume in Drainage Area (cf) =	528
	Calculated Infiltration Period per BMP (hr) =	58.66666667

Depth-Storage Data				
Depth (ft)	Width (ft)	Length (ft)	Storage Volume per BMP (cf)	Storage Volume in Drainage Area (cf)
0	2	30	0	0
0.5	2	30	6	54
1	2	30	12	108
1.5	4	32	58.66666667	528
2	6	34	141.3333333	1272

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.493	2969
Developed Condition	0.401	2729
Pre-Developed (Forest) Condition	0.324	2428

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1: $Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->

Q (cfs)		Q (cfs)
0.401	≤	0.429
	OK	

Check #2: $Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->

0.401	≤	0.493
	OK	

Check #3: $Q_{\text{developed}}$ shall not be required to be ≤ $(Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ ---->

0.401	<u>shall not</u> be required to be ≤	0.288
-------	--------------------------------------	-------

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p><i>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</i></p> <p><i>For Paved Road land surface types a Manning’s n value of 0.011 was used.</i></p> <p><i>Sources:</i></p> <p><i>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</i></p> <p><i>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</i></p>	

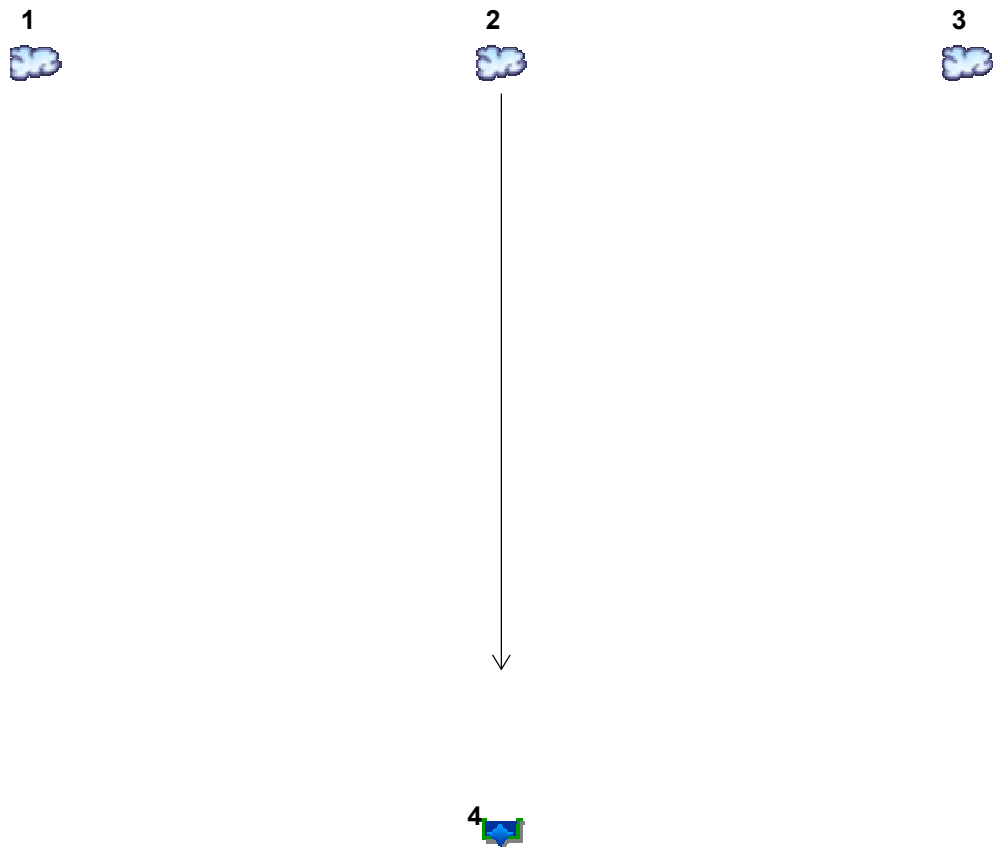
Table 2 – Manning's n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's n value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's n value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-118B PRE
2	SCS Runoff	DA-FR-118B POST
3	SCS Runoff	DA-FR-118B Pre-Forested
4	Reservoir	WB Soil Amendment

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.493	1	729	2,969	-----	-----	-----	DA-FR-118B PRE
2	SCS Runoff	0.589	1	729	3,257	-----	-----	-----	DA-FR-118B POST
3	SCS Runoff	0.324	1	730	2,428	-----	-----	-----	DA-FR-118B Pre-Forested
4	Reservoir	0.401	1	740	2,729	2	955.53	573	WB Soil Amendment
DA-FR-118b.gpw					Return Period: 1 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

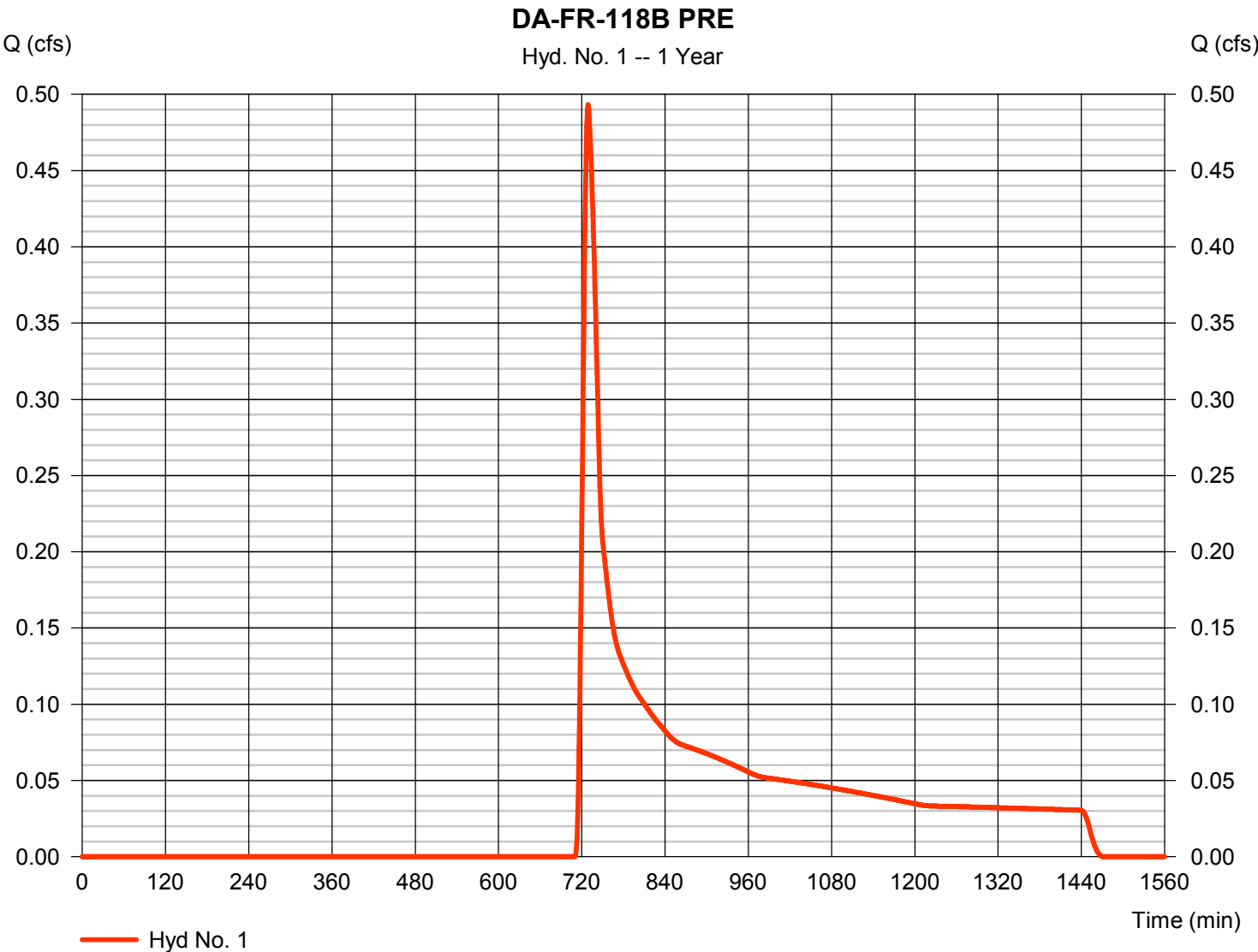
Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-FR-118B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.493 cfs
Storm frequency	= 1 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 2,969 cuft
Drainage area	= 2.380 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.80 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.128 x 85) + (0.620 x 58) + (1.635 x 55)] / 2.380



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-118B PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 3.20	0.00	0.00	
Travel Time (min)	= 16.55	+ 0.00	+ 0.00	= 16.55
Shallow Concentrated Flow				
Flow length (ft)	= 715.60	0.00	0.00	
Watercourse slope (%)	= 10.90	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=5.33	0.00	0.00	
Travel Time (min)	= 2.24	+ 0.00	+ 0.00	= 2.24
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	= 0.040	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				18.80 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

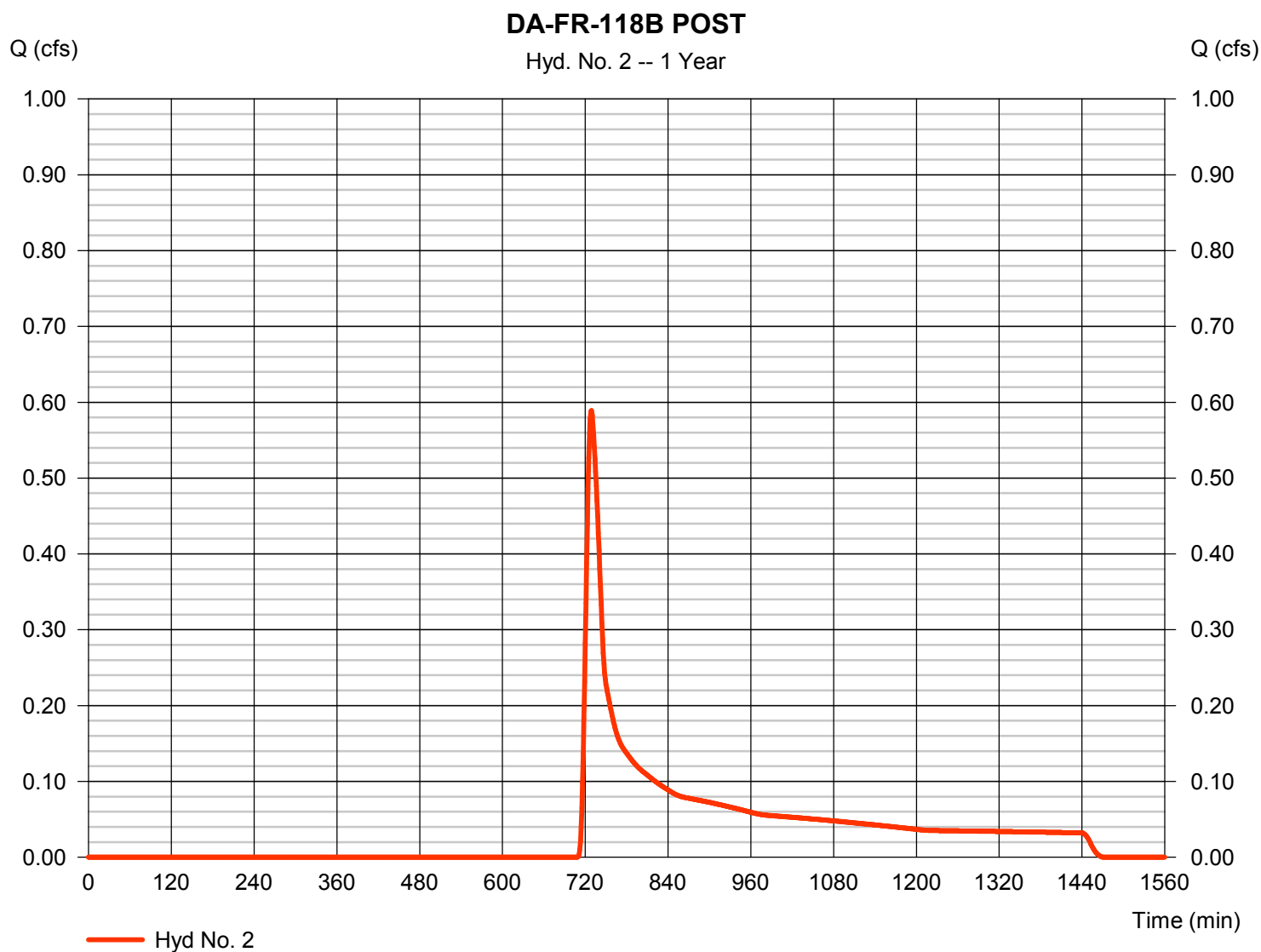
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-FR-118B POST

Hydrograph type	= SCS Runoff	Peak discharge	= 0.589 cfs
Storm frequency	= 1 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 3,257 cuft
Drainage area	= 2.380 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.192 \times 48) + (0.128 \times 85) + (1.355 \times 58) + (0.707 \times 55)] / 2.380$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-118B POST

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.800	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 3.20	0.00	0.00				
Travel Time (min)	= 16.55	+	0.00	+	0.00	=	16.55
Shallow Concentrated Flow							
Flow length (ft)	= 203.80	511.40	0.00				
Watercourse slope (%)	= 7.30	12.20	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=4.36	5.64	0.00				
Travel Time (min)	= 0.78	+	1.51	+	0.00	=	2.29
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	(0)15.6	0.0	0.0				
Travel Time (min)	= 0.05	+	0.00	+	0.00	=	0.05
Total Travel Time, Tc					18.90 min		

Hydrograph Report

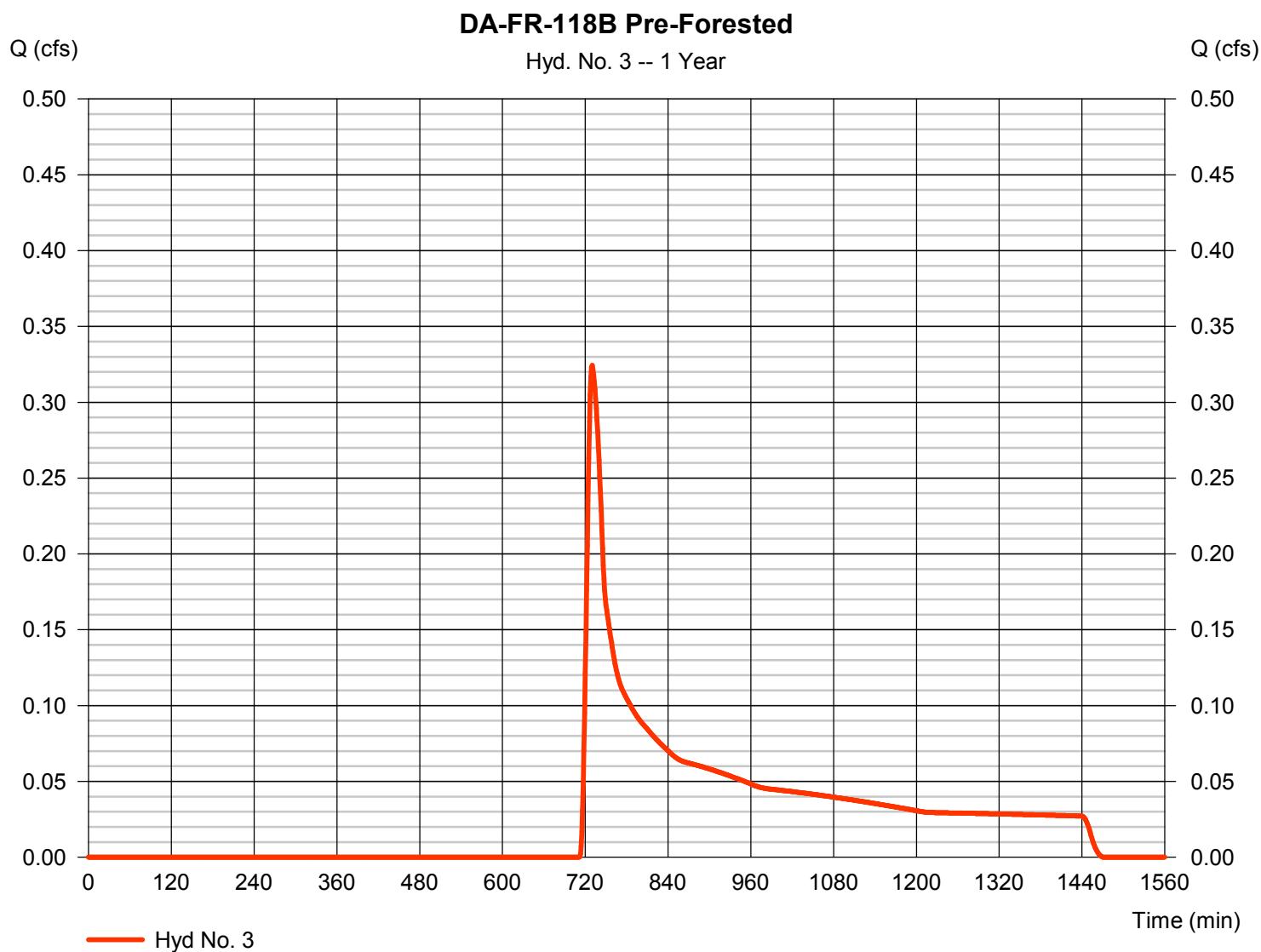
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-FR-118B Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.324 cfs
Storm frequency	= 1 yrs	Time to peak	= 730 min
Time interval	= 1 min	Hyd. volume	= 2,428 cuft
Drainage area	= 2.380 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.80 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.380 \times 55)] / 2.380$ 

TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-118B Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 3.20	0.00	0.00				
Travel Time (min)	= 16.55	+	0.00	+	0.00	=	16.55
Shallow Concentrated Flow							
Flow length (ft)	= 715.60	0.00	0.00				
Watercourse slope (%)	= 10.90	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.33	0.00	0.00				
Travel Time (min)	= 2.24	+	0.00	+	0.00	=	2.24
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	= 0.030	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				18.80 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

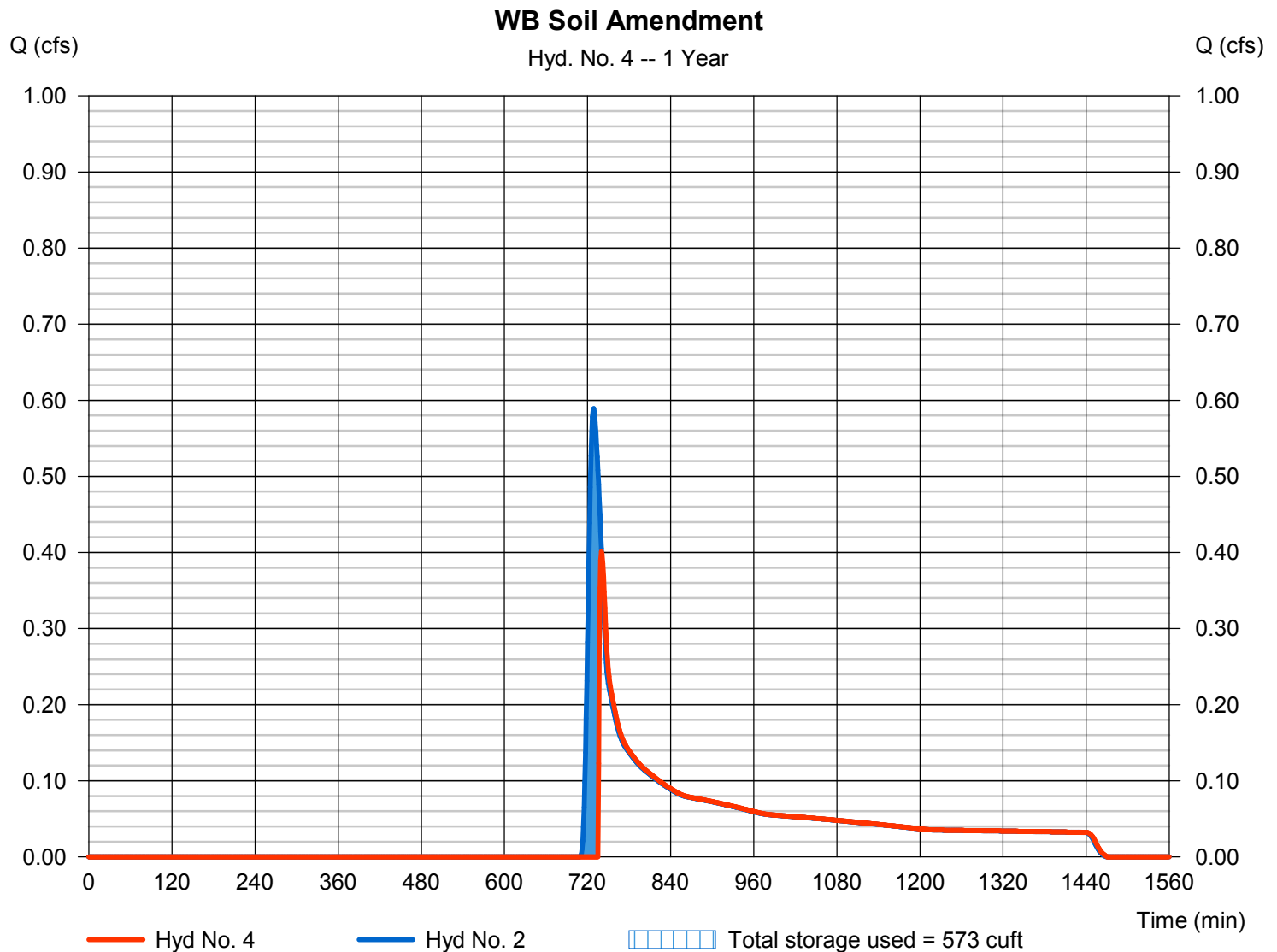
Wednesday, 08 / 16 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 0.401 cfs
Storm frequency	= 1 yrs	Time to peak	= 740 min
Time interval	= 1 min	Hyd. volume	= 2,729 cuft
Inflow hyd. No.	= 2 - DA-FR-118B POST	Max. Elevation	= 955.53 ft
Reservoir name	= Waterbar Soil Amendment	Max. Storage	= 573 cuft

Storage Indication method used.



Pond No. 1 - Waterbar Soil Amendment

Pond Data

Pond storage is based on user-defined values.

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	954.00	n/a	0	0
0.50	954.50	n/a	54	54
1.00	955.00	n/a	54	108
1.50	955.50	n/a	420	528
2.00	956.00	n/a	744	1,272

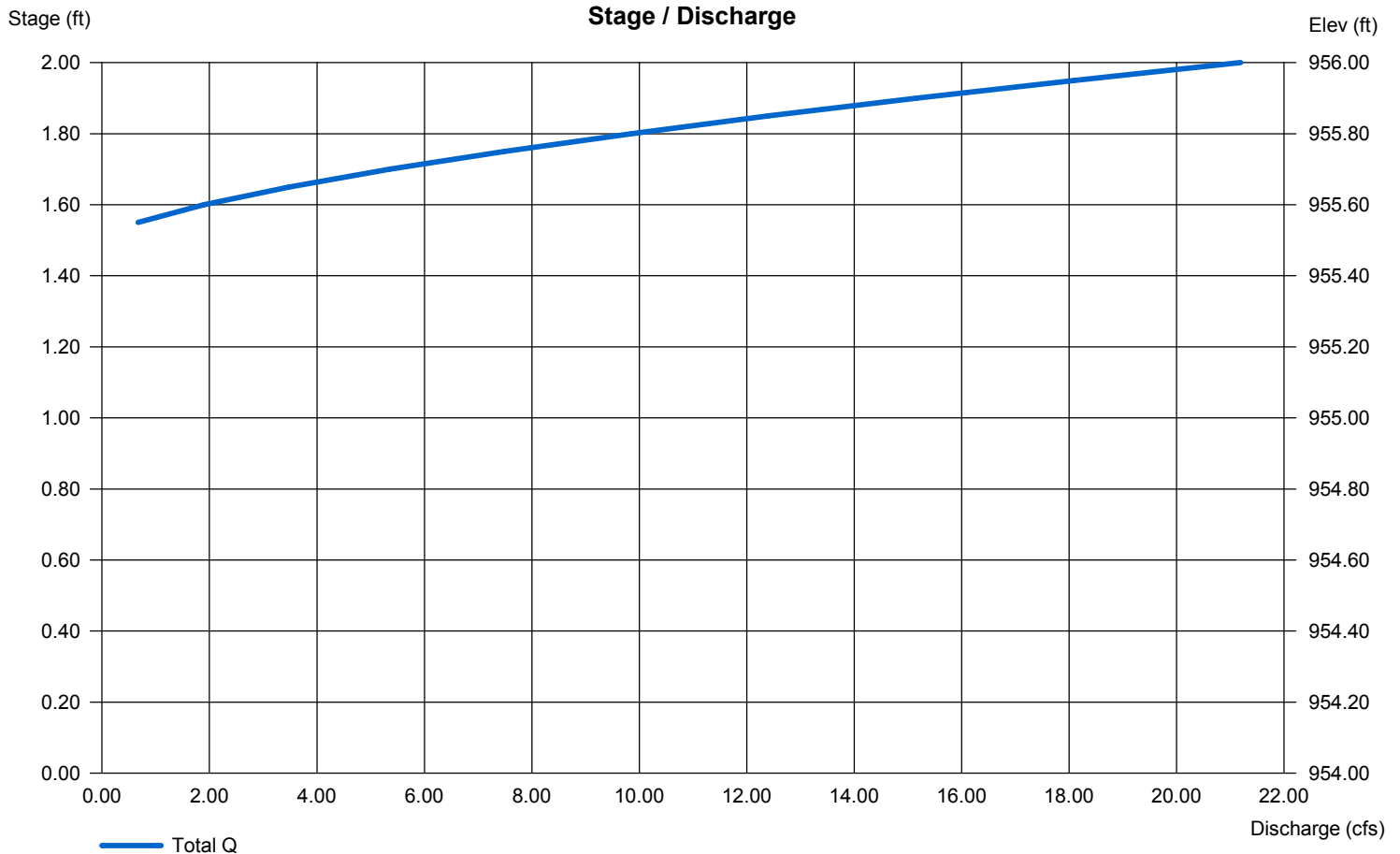
Culvert / Orifice Structures

	[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)	= 18.00	0.00	0.00	0.00
Crest El. (ft)	= 955.50	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= Rect	---	---	---
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).



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.875	1	728	4,260	-----	-----	-----	DA-FR-118B PRE
2	SCS Runoff	1.003	1	728	4,614	-----	-----	-----	DA-FR-118B POST
3	SCS Runoff	0.640	1	729	3,590	-----	-----	-----	DA-FR-118B Pre-Forested
4	Reservoir	0.911	1	732	4,086	2	955.56	617	WB Soil Amendment
DA-FR-118b.gpw					Return Period: 2 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

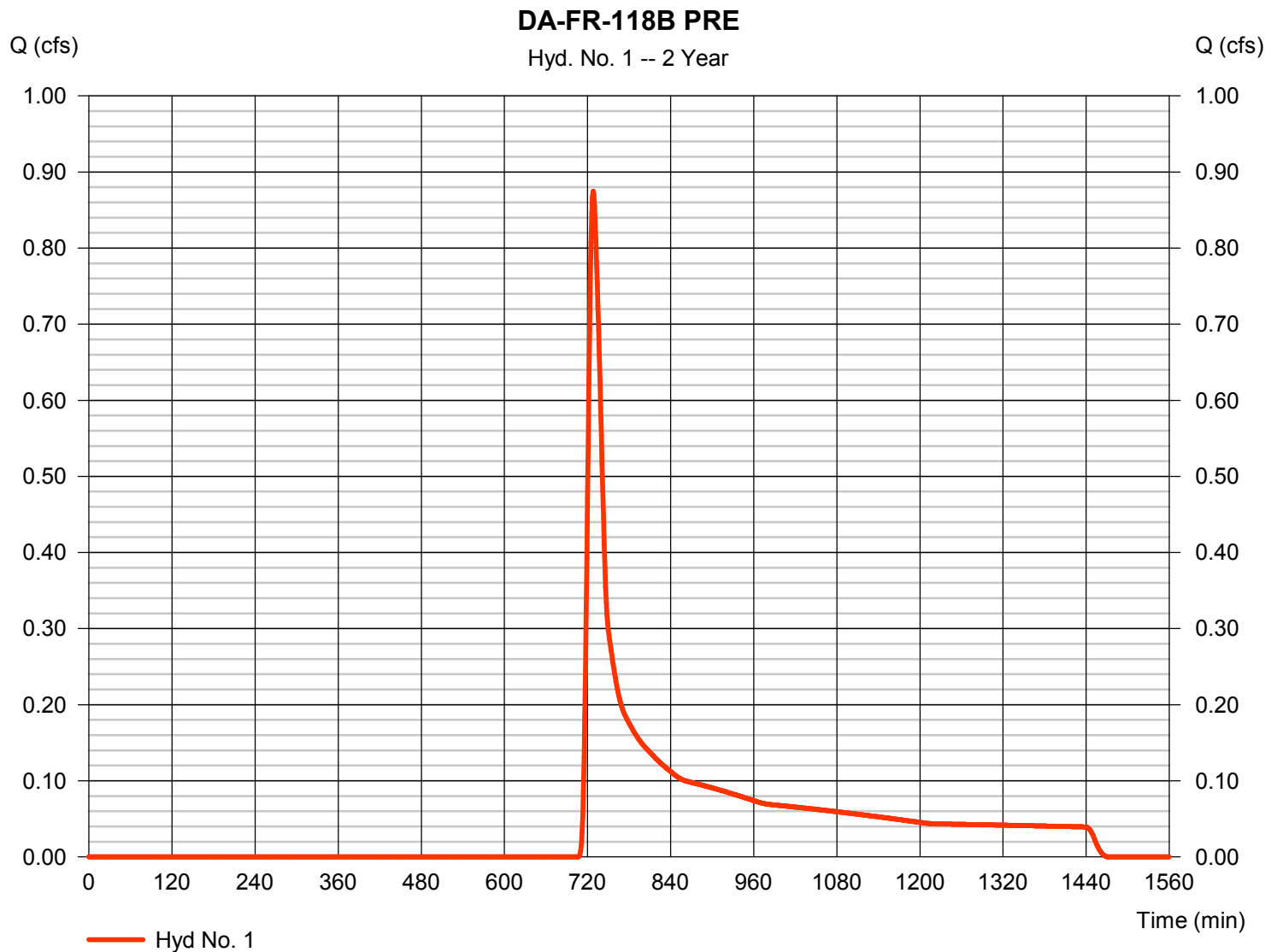
Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-FR-118B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.875 cfs
Storm frequency	= 2 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 4,260 cuft
Drainage area	= 2.380 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.80 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.128 \times 85) + (0.620 \times 58) + (1.635 \times 55)] / 2.380$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

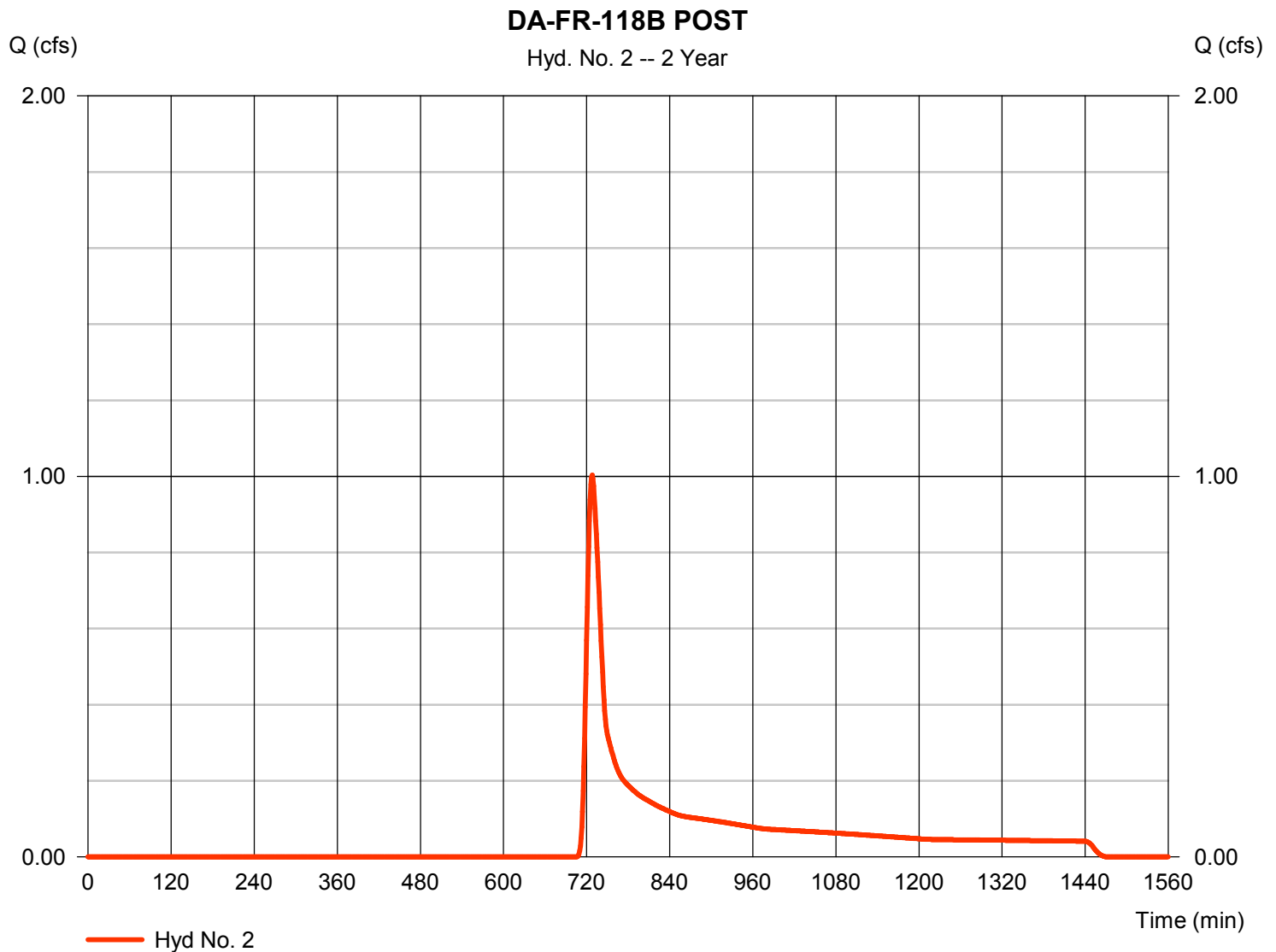
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-FR-118B POST

Hydrograph type	= SCS Runoff	Peak discharge	= 1.003 cfs
Storm frequency	= 2 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 4,614 cuft
Drainage area	= 2.380 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.90 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.192 \times 48) + (0.128 \times 85) + (1.355 \times 58) + (0.707 \times 55)] / 2.380$



Hydrograph Report

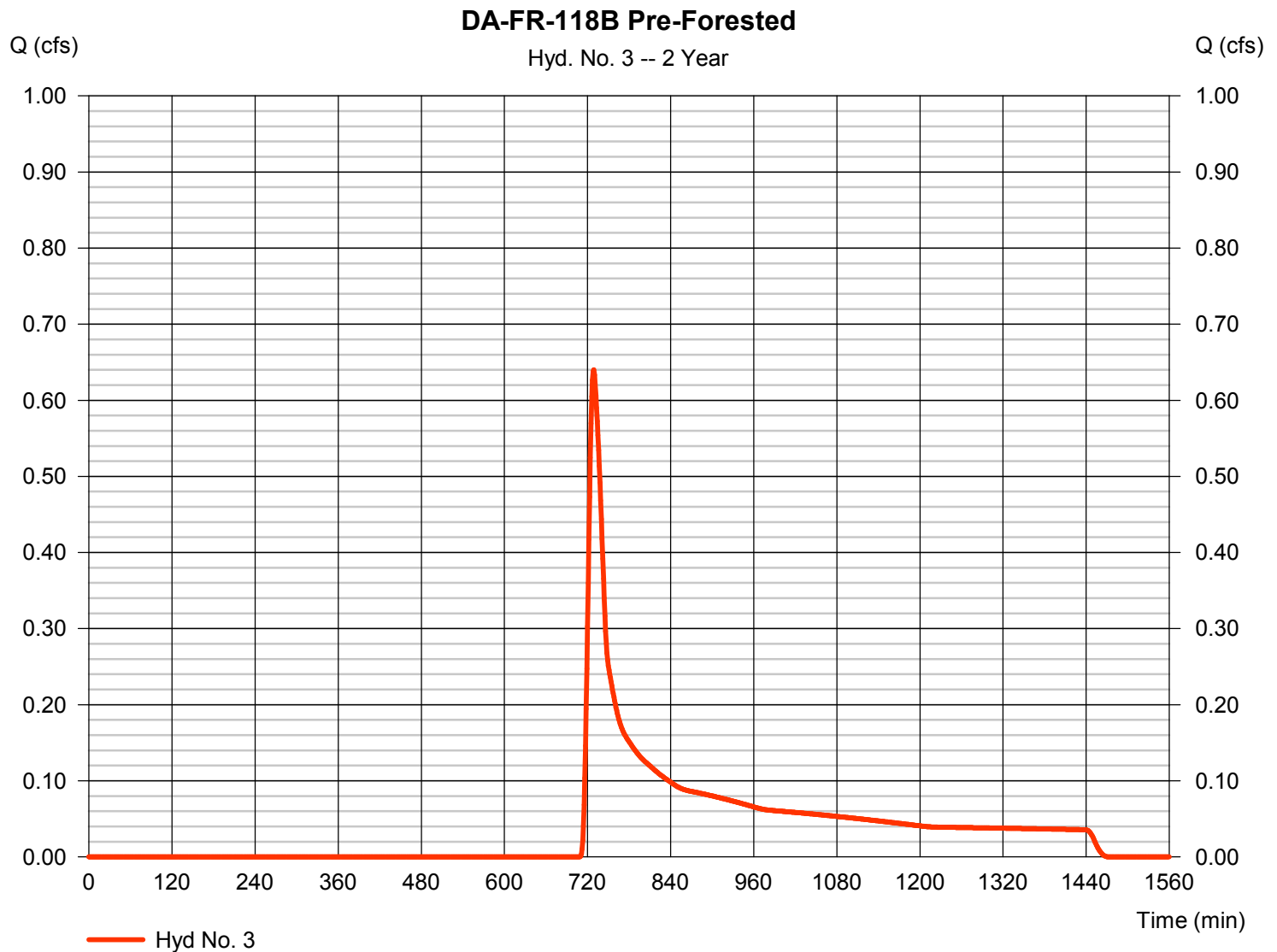
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-FR-118B Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.640 cfs
Storm frequency	= 2 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 3,590 cuft
Drainage area	= 2.380 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.80 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.380 \times 55)] / 2.380$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

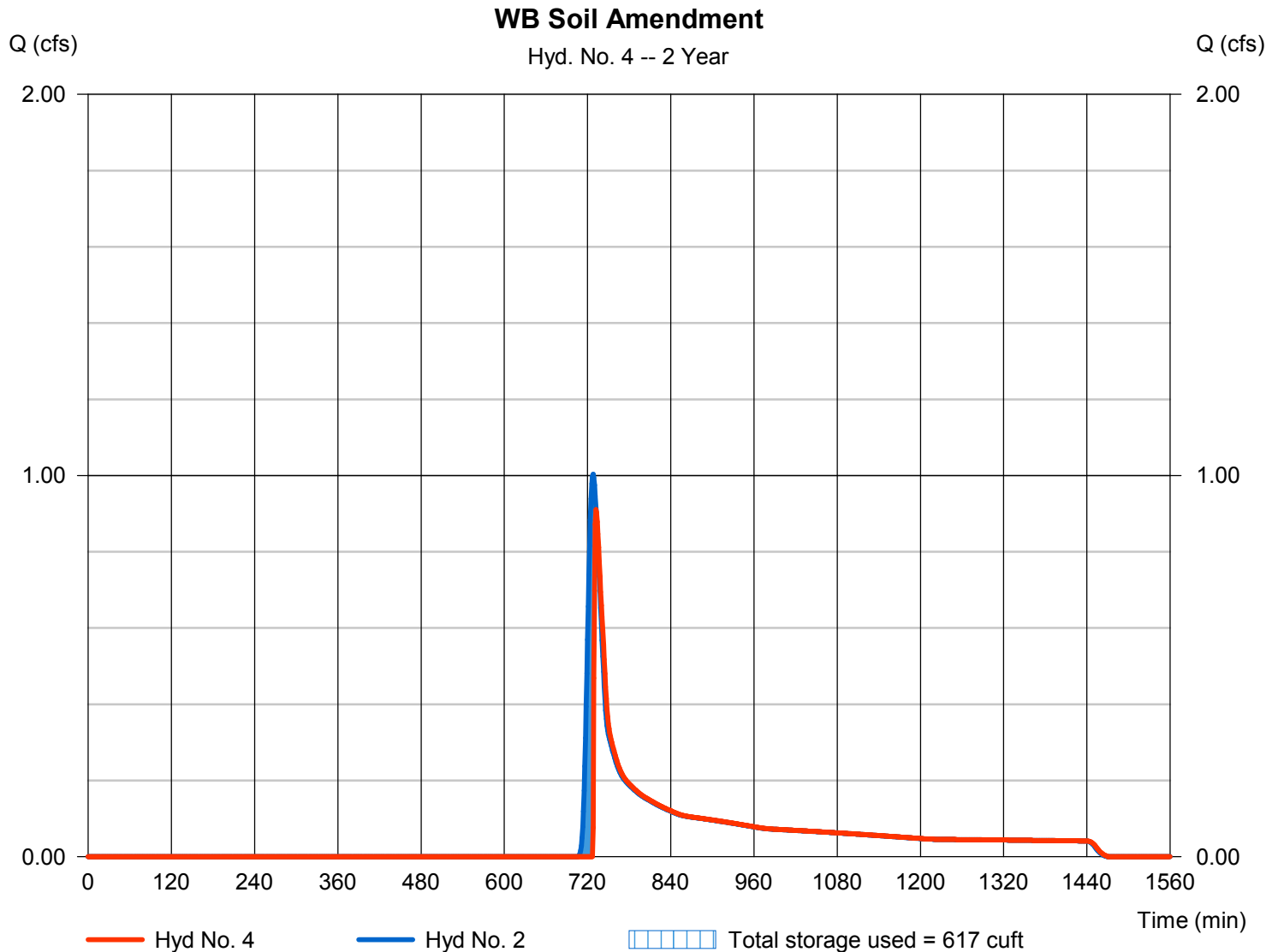
Wednesday, 08 / 16 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 0.911 cfs
Storm frequency	= 2 yrs	Time to peak	= 732 min
Time interval	= 1 min	Hyd. volume	= 4,086 cuft
Inflow hyd. No.	= 2 - DA-FR-118B POST	Max. Elevation	= 955.56 ft
Reservoir name	= Waterbar Soil Amendment	Max. Storage	= 617 cuft

Storage Indication method used.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	3.748	1	726	12,932	-----	-----	-----	DA-FR-118B PRE
2	SCS Runoff	3.993	1	726	13,589	-----	-----	-----	DA-FR-118B POST
3	SCS Runoff	3.264	1	726	11,650	-----	-----	-----	DA-FR-118B Pre-Forested
4	Reservoir	3.976	1	727	13,061	2	955.66	771	WB Soil Amendment
DA-FR-118b.gpw					Return Period: 10 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

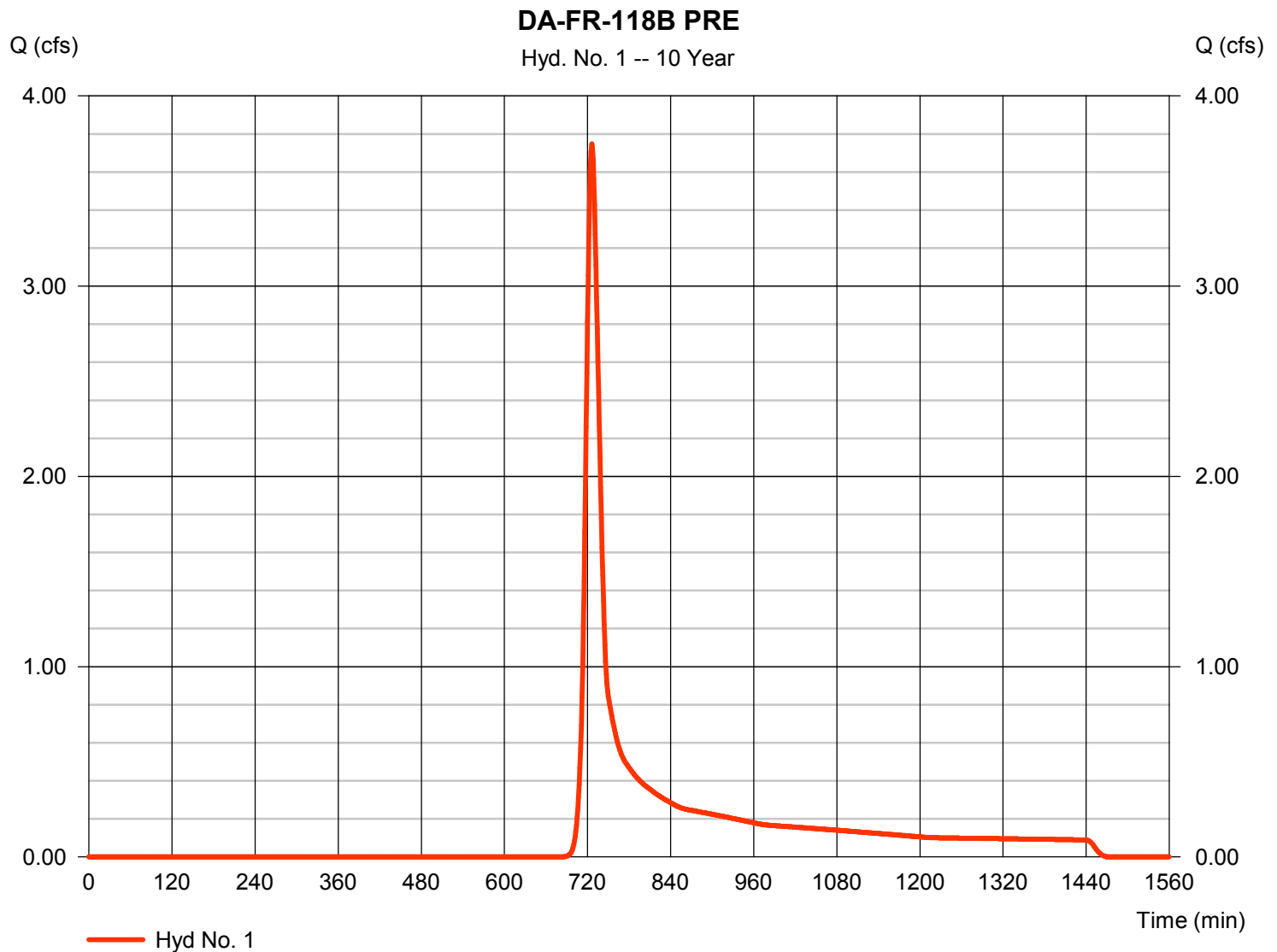
Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-FR-118B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 3.748 cfs
Storm frequency	= 10 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 12,932 cuft
Drainage area	= 2.380 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.80 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.128 \times 85) + (0.620 \times 58) + (1.635 \times 55)] / 2.380$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

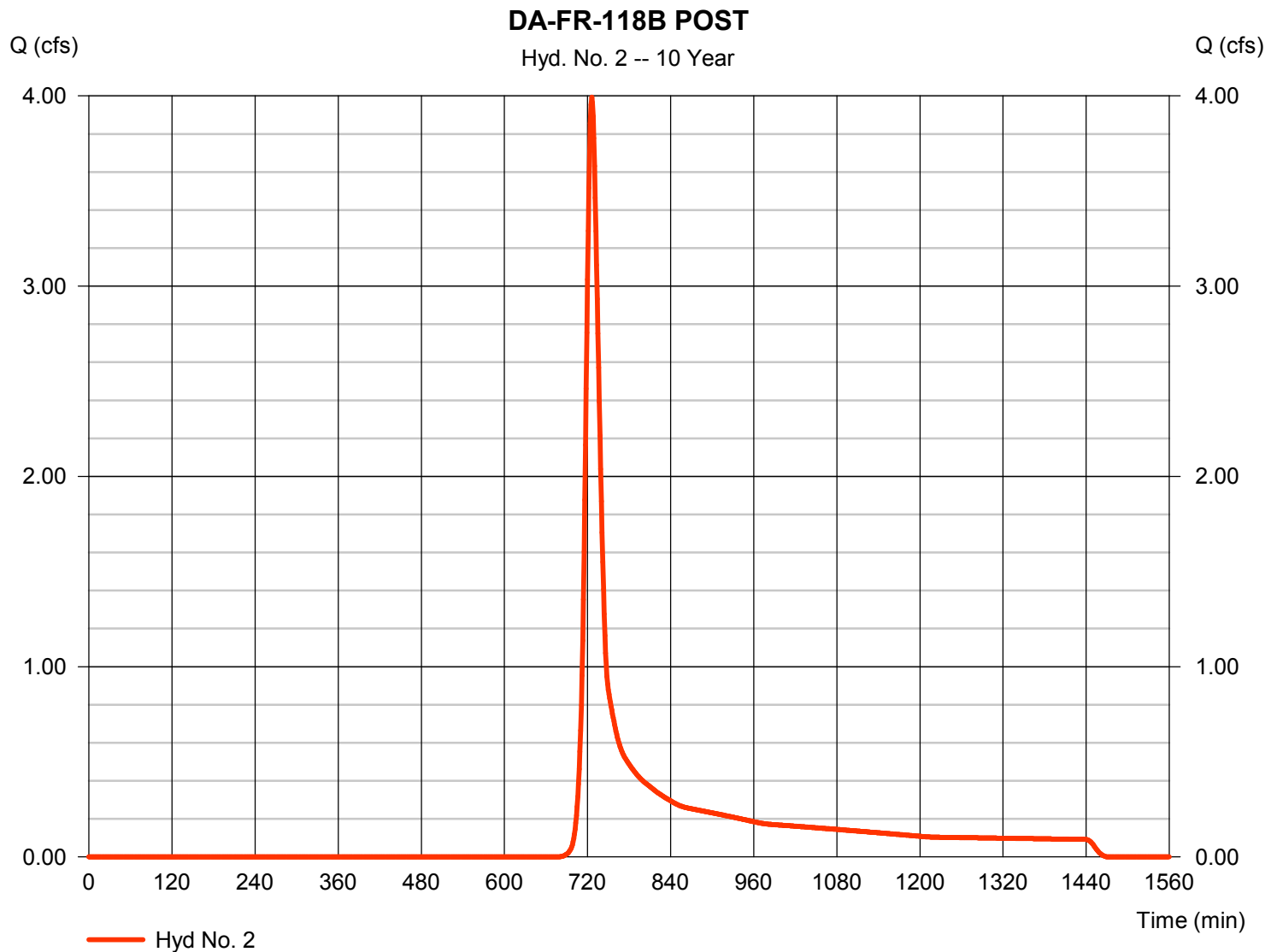
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-FR-118B POST

Hydrograph type	= SCS Runoff	Peak discharge	= 3.993 cfs
Storm frequency	= 10 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 13,589 cuft
Drainage area	= 2.380 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.90 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.192 \times 48) + (0.128 \times 85) + (1.355 \times 58) + (0.707 \times 55)] / 2.380$



Hydrograph Report

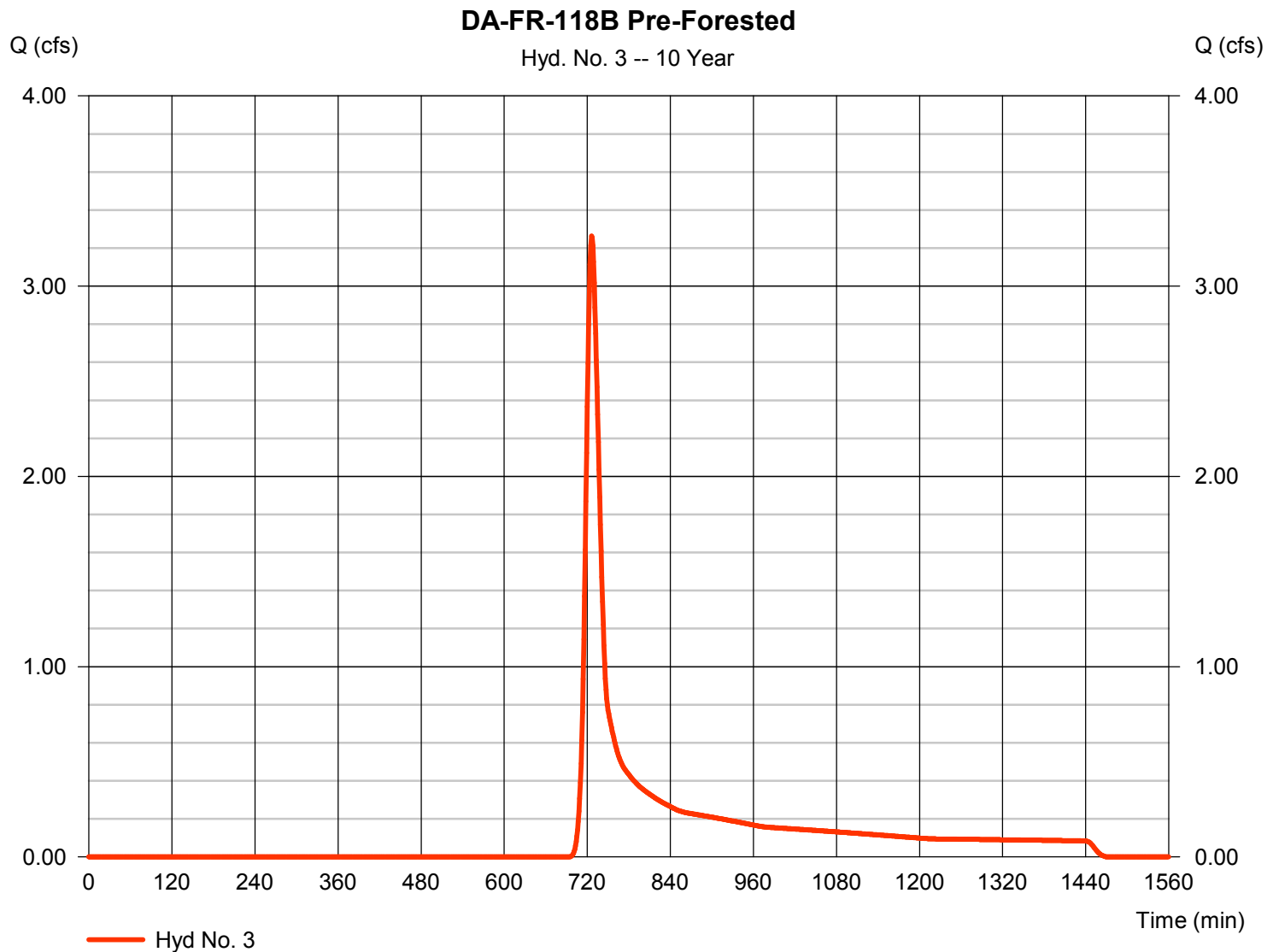
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-FR-118B Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 3.264 cfs
Storm frequency	= 10 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 11,650 cuft
Drainage area	= 2.380 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.80 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.380 \times 55)] / 2.380$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

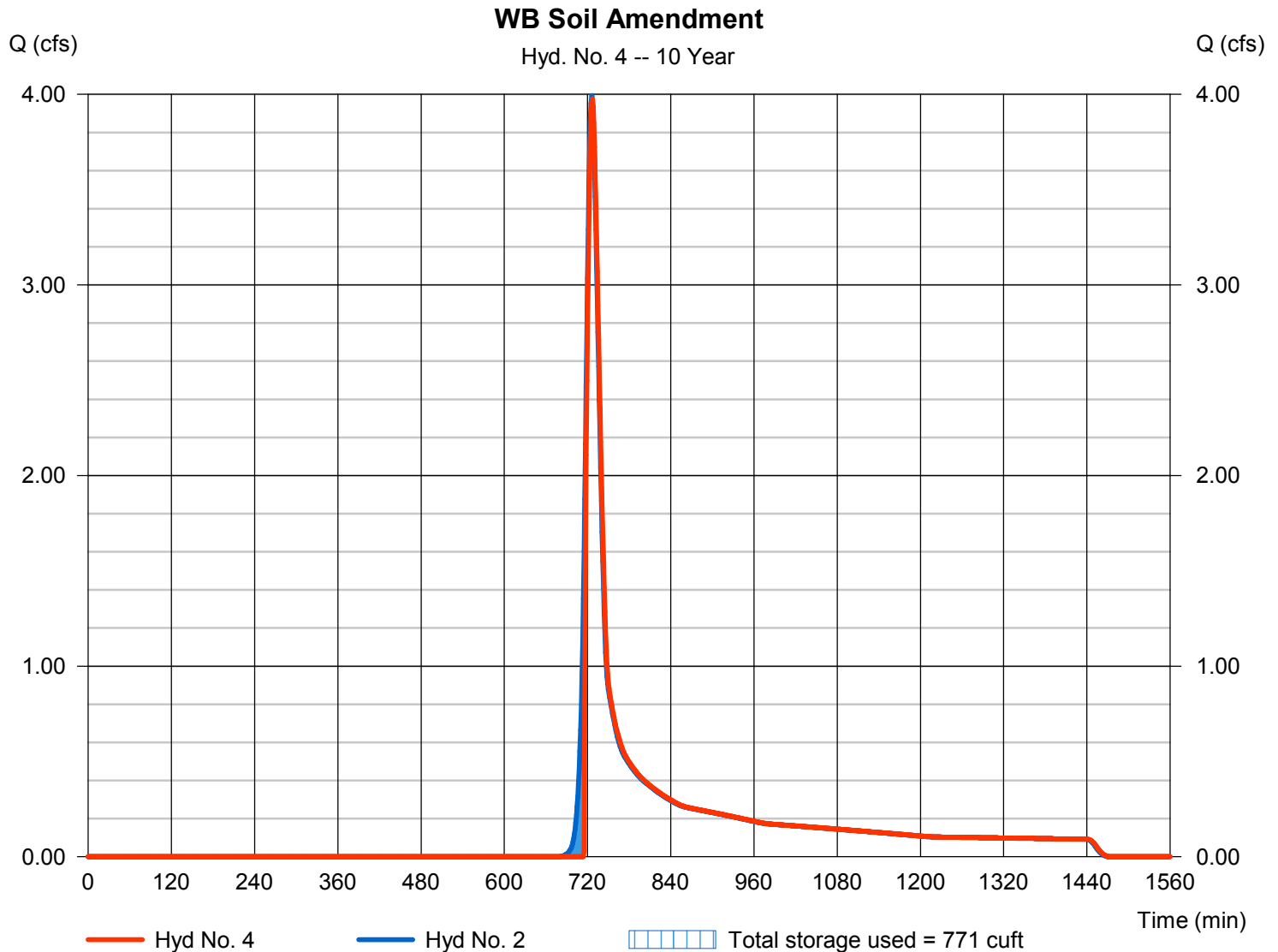
Wednesday, 08 / 16 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 3.976 cfs
Storm frequency	= 10 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 13,061 cuft
Inflow hyd. No.	= 2 - DA-FR-118B POST	Max. Elevation	= 955.66 ft
Reservoir name	= Waterbar Soil Amendment	Max. Storage	= 771 cuft

Storage Indication method used.



$$\text{Intensity} = B / (T_c + D)^E$$

Tc = time in minutes. Values may exceed 60.

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DA-FR-118C

STORAGE VOLUME OF WATERBAR WITH SOIL COMPOST AMENDMENT AREA

Equations Used:

$$^1V_{\text{gravel storage}} = L * W * D_{\text{gravel}} * (40/100)$$

$$^2V_{\text{soil storage}} = L * W * D_{\text{soil}} * (20/100)$$

$$^3V_{\text{surface storage}} = [W * S * D^2 * 2] + [L * S * D^2 * 2] + [W * L * D] + [(2 * S * D)^2 * D] / 3]$$

¹Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that gravel is made up of 40% voids.

²Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that soil compost amendment is made up of 20% voids.

³Equation #1 under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, but calculation also takes into account surface side slopes.

Inputs:	Depth of Gravel Layer, D_{gravel} (ft) =	0	
	Depth of Soil Amendment Area, D_{soil} (ft) =	1	Refer to Table 4.3 in VA DEQ Stormwater Design Specification No. 4; Note that compost amendment may not be necessary for HSG A/B soils Assume max. length of 50' for waterbar soil amendment areas (i.e., limited to permanent ROW)
	Length of Waterbar Soil Amendment Area, L (ft) =	50	
	Width of Waterbar Soil Amendment Area, W (ft) =	2	
	Inside Embankment Side Slopes, S (H:V) =	2	Assume 2H:1V surface side slopes for waterbars
	Number of Perm. Waterbars in Drainage Area, n =	9	
	Design Infiltration Rate, IR (in/hr) =	0.2	Min. rate of 0.30 in/hr for HSG A soils and 0.15-0.30 in/hr for HSG B soils (see Chap. 4, p. 4-30 in VA Stormwater Management Handbook Volume II (First Edition, 1999)
	Surface Ponding Depth, D (ft) =	0.5	Assume 0.5' CFS height at the end of waterbars

Calculations:	Total Storage Depth per BMP (ft) =	1.5
	Surface Storage Volume per BMP (cf) =	76.66666667
	Subsurface Storage Volume per BMP (cf) =	20
	Total Storage Volume per BMP (cf) =	96.66666667
	Total BMP Storage Volume in Drainage Area (cf) =	870
	Calculated Infiltration Period per BMP (hr) =	58

Depth-Storage Data				
Depth (ft)	Width (ft)	Length (ft)	Storage Volume per BMP (cf)	Storage Volume in Drainage Area (cf)
0	2	50	0	0
0.5	2	50	10	90
1	2	50	20	180
1.5	4	52	96.66666667	870
2	6	54	229.3333333	2064

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	2.438	6226
Developed Condition	2.223	5356
Pre-Developed (Forest) Condition	2.106	5529

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1: $Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->

Q (cfs)		Q (cfs)
2.223	≤	2.267
	OK	

Check #2: $Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->

2.223	≤	2.438
	OK	

Check #3: $Q_{\text{developed}}$ shall not be required to be ≤ $(Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ ---->

2.223	<u>shall not</u> be required to be ≤	2.174
-------	--------------------------------------	-------

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p><i>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</i></p> <p><i>For Paved Road land surface types a Manning’s n value of 0.011 was used.</i></p> <p><i>Sources:</i></p> <p><i>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</i></p> <p><i>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</i></p>	

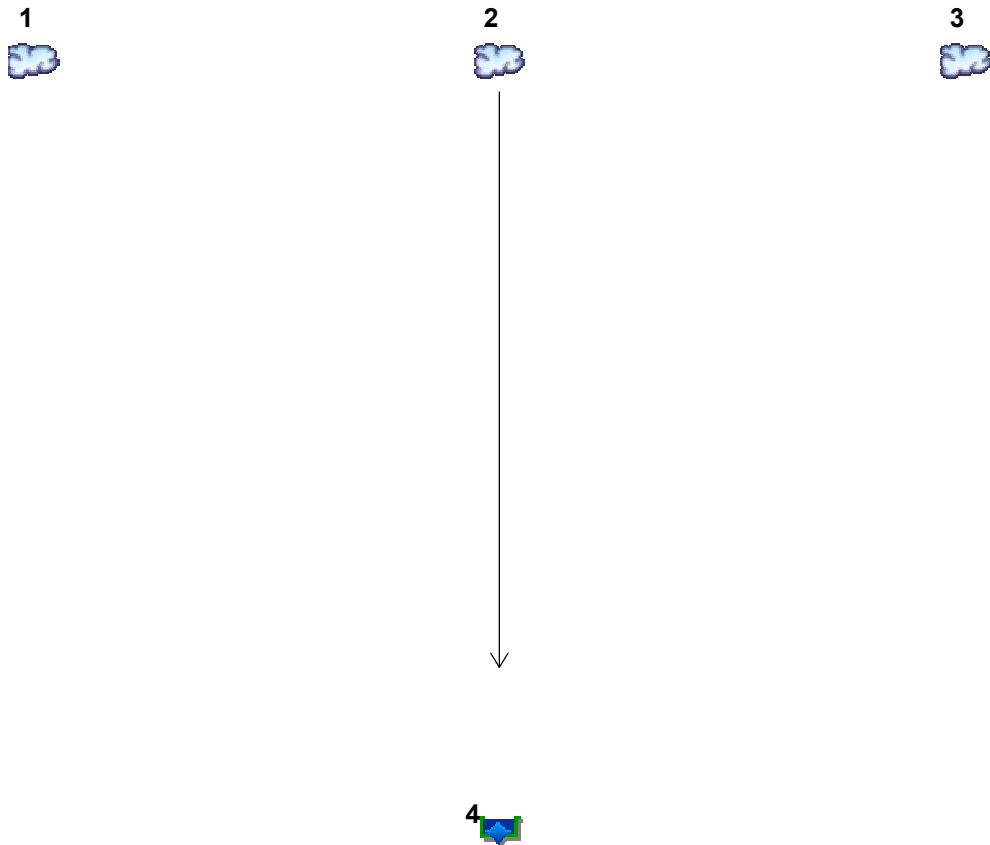
Table 2 – Manning's n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's n value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's n value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

Hyd.	Origin	Description
1	SCS Runoff	DA-FR-118C PRE
2	SCS Runoff	DA-FR-118C POST
3	SCS Runoff	DA-FR-118C Pre-Forested
4	Reservoir	WB Soil Amendment

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	2.438	1	721	6,226	-----	-----	-----	DA-FR-118C PRE
2	SCS Runoff	2.438	1	721	6,226	-----	-----	-----	DA-FR-118C POST
3	SCS Runoff	2.106	1	721	5,529	-----	-----	-----	DA-FR-118C Pre-Forested
4	Reservoir	2.223	1	724	5,356	2	921.61	1,134	WB Soil Amendment
DA-FR-118c.gpw					Return Period: 1 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

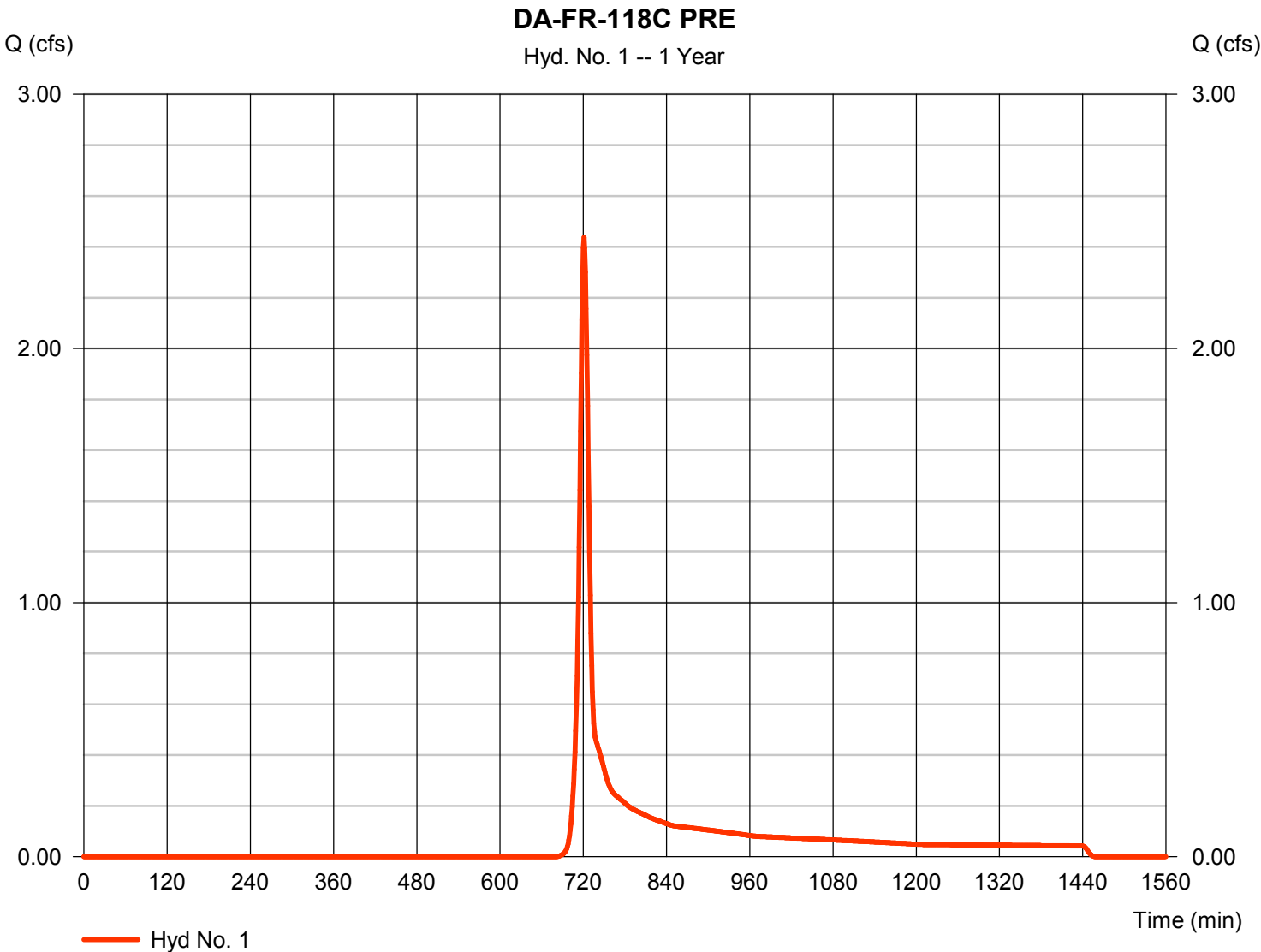
Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-FR-118C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 2.438 cfs
Storm frequency	= 1 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 6,226 cuft
Drainage area	= 1.900 ac	Curve number	= 70*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.40 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.029 x 85) + (0.105 x 89) + (0.068 x 58) + (0.751 x 71) + (0.179 x 55) + (0.770 x 70)] / 1.900



TR55 Tc Worksheet

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Hyd. No. 1

DA-FR-118C PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 10.70	0.00	0.00				
Travel Time (min)	= 10.21	+	0.00	+	0.00	=	10.21
Shallow Concentrated Flow							
Flow length (ft)	= 401.70	0.00	0.00				
Watercourse slope (%)	= 12.50	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.70	0.00	0.00				
Travel Time (min)	= 1.17	+	0.00	+	0.00	=	1.17
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	= 0.040	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				11.40 min			

Hydrograph Report

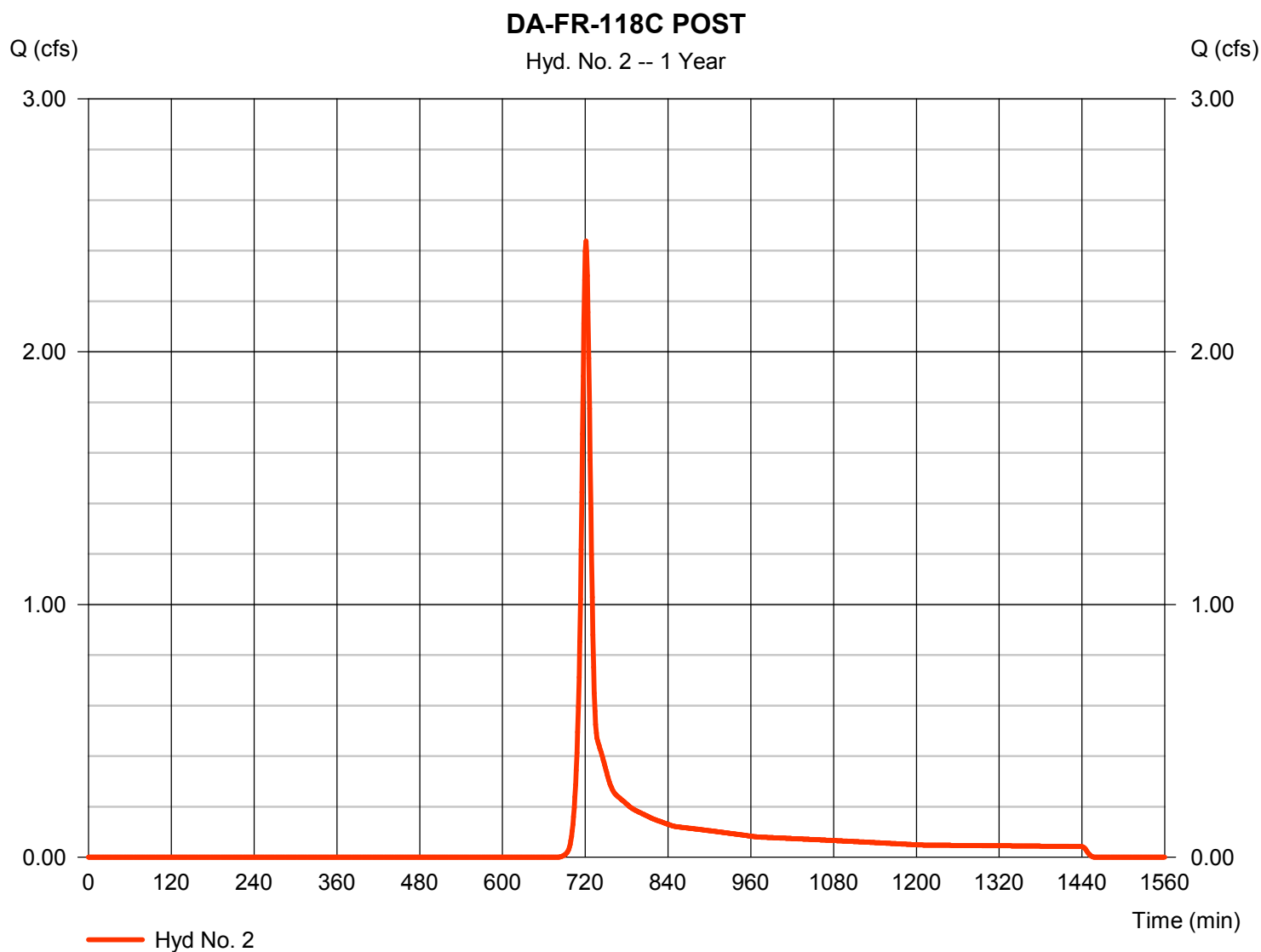
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-FR-118C POST

Hydrograph type	= SCS Runoff	Peak discharge	= 2.438 cfs
Storm frequency	= 1 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 6,226 cuft
Drainage area	= 1.900 ac	Curve number	= 70*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.50 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.900 \times 70)] / 1.900$ 

TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-118C POST

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.800	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 10.70	0.00	0.00				
Travel Time (min)	= 10.21	+	0.00	+	0.00	=	10.21
Shallow Concentrated Flow							
Flow length (ft)	= 127.10	271.60	0.00				
Watercourse slope (%)	= 12.30	12.30	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=5.66	5.66	0.00				
Travel Time (min)	= 0.37	+	0.80	+	0.00	=	1.17
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86						
		0.00					
			0.00				
Flow length (ft)	(0)20.5	0.0	0.0				
Travel Time (min)	= 0.07	+	0.00	+	0.00	=	0.07
Total Travel Time, Tc					11.50 min		

Hydrograph Report

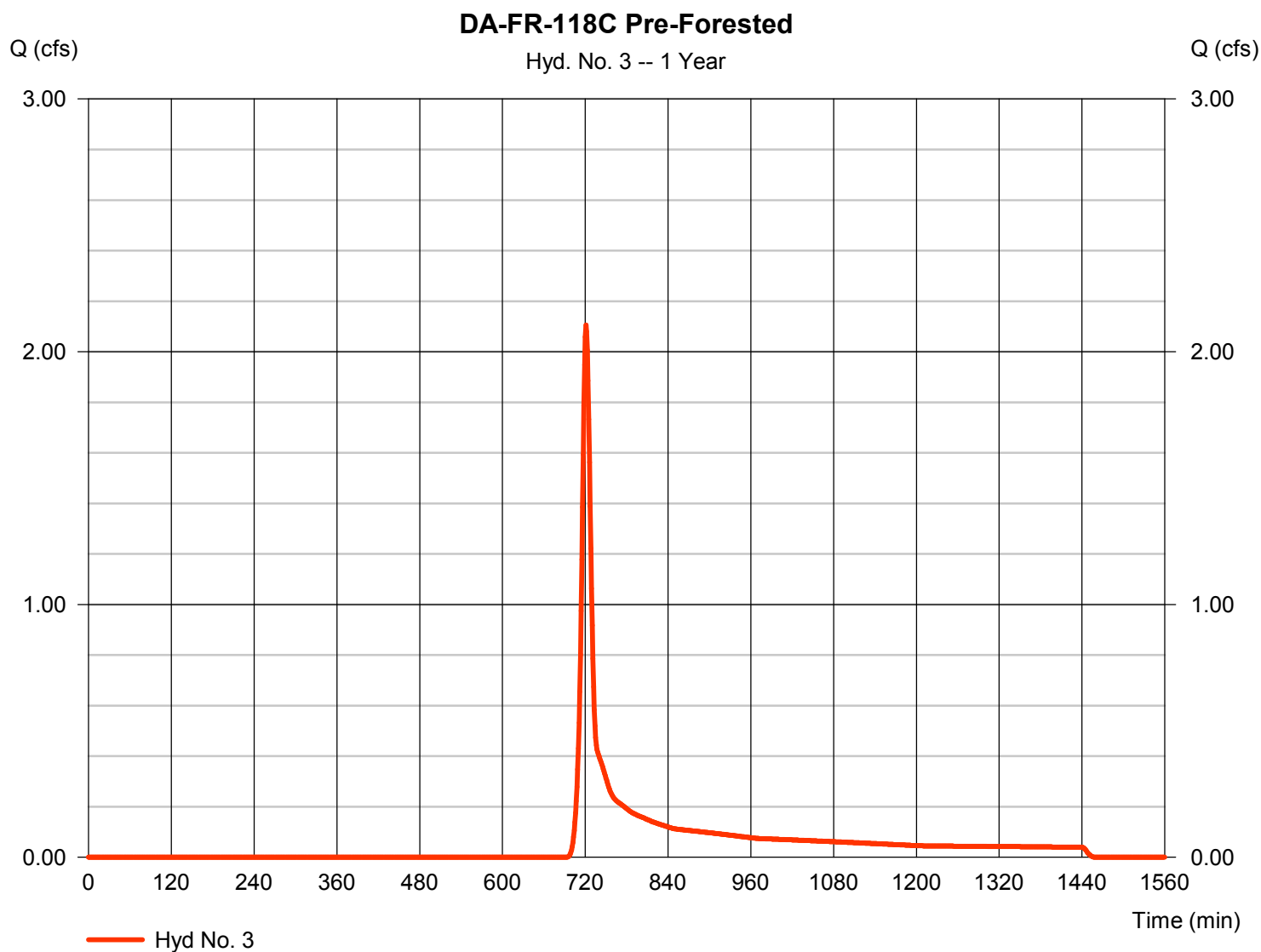
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Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-FR-118C Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 2.106 cfs
Storm frequency	= 1 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 5,529 cuft
Drainage area	= 1.900 ac	Curve number	= 68*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.40 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.280 \times 55) + (1.620 \times 70)] / 1.900$ 

TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-118C Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 10.70	0.00	0.00	
Travel Time (min)	= 10.21	+ 0.00	+ 0.00	= 10.21
Shallow Concentrated Flow				
Flow length (ft)	= 401.70	0.00	0.00	
Watercourse slope (%)	= 12.50	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=5.70	0.00	0.00	
Travel Time (min)	= 1.17	+ 0.00	+ 0.00	= 1.17
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	= 0.030	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				11.40 min

Hydrograph Report

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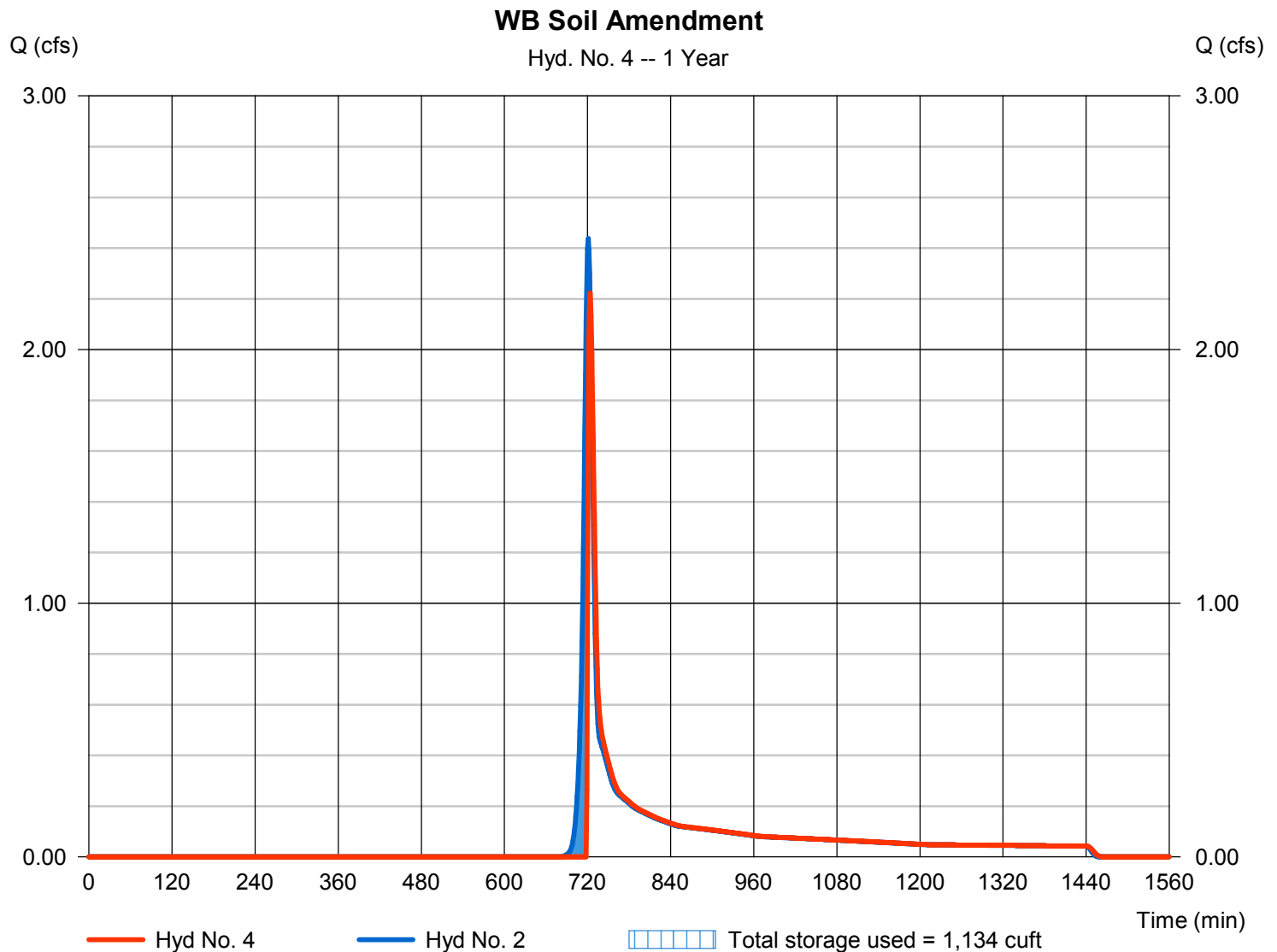
Wednesday, 08 / 16 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 2.223 cfs
Storm frequency	= 1 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 5,356 cuft
Inflow hyd. No.	= 2 - DA-FR-118C POST	Max. Elevation	= 921.61 ft
Reservoir name	= Waterbar Soil Amendment	Max. Storage	= 1,134 cuft

Storage Indication method used.



Pond No. 1 - Waterbar Soil Amendment

Pond Data

Pond storage is based on user-defined values.

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	920.00	n/a	0	0
0.50	920.50	n/a	90	90
1.00	921.00	n/a	90	180
1.50	921.50	n/a	690	870
2.00	922.00	n/a	1,194	2,064

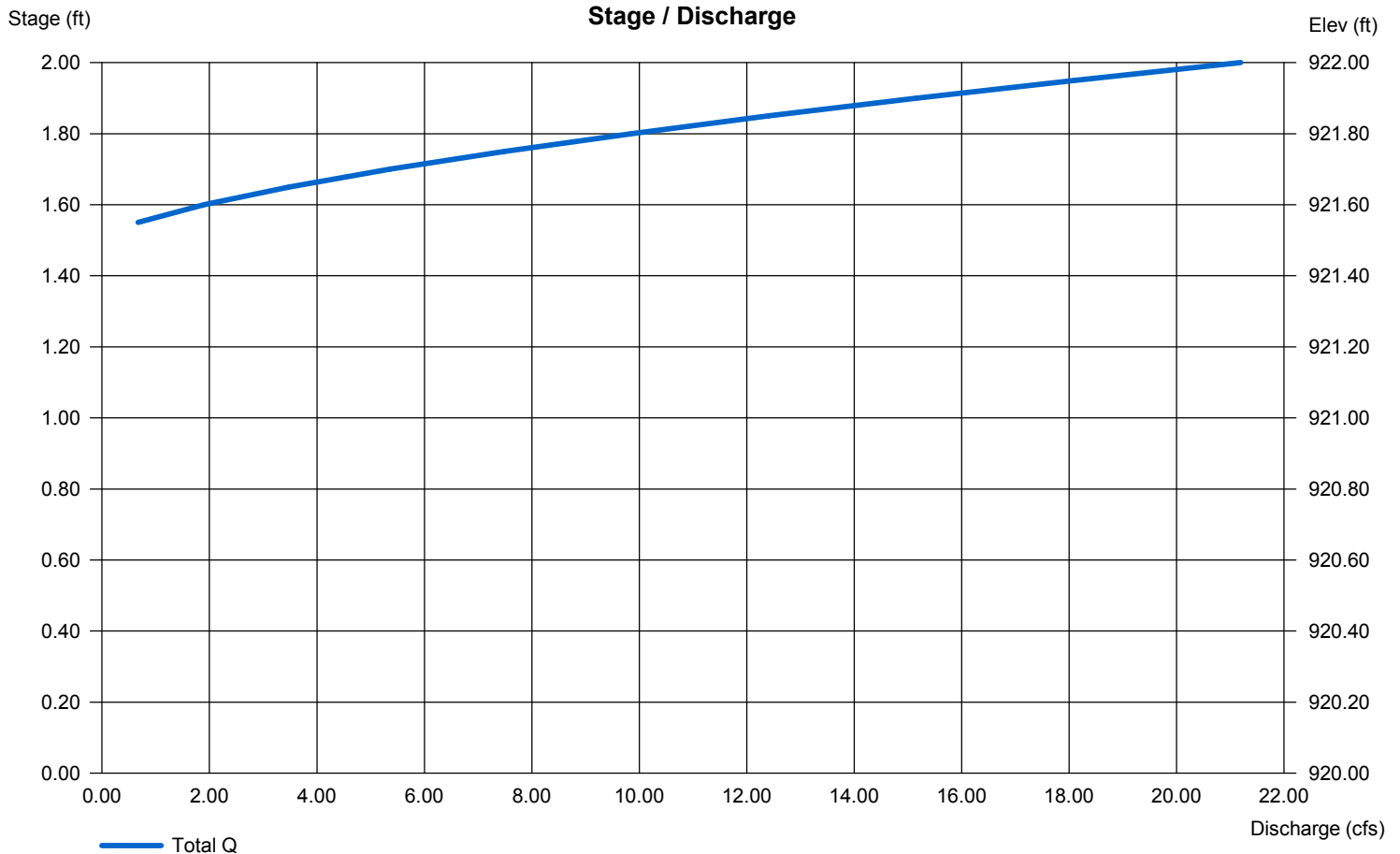
Culvert / Orifice Structures

	[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)	= 18.00	0.00	0.00	0.00
Crest El. (ft)	= 921.50	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= Rect	---	---	---
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).



Hydrograph Summary Report

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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	3.188	1	721	7,959	-----	-----	-----	DA-FR-118C PRE
2	SCS Runoff	3.188	1	721	7,959	-----	-----	-----	DA-FR-118C POST
3	SCS Runoff	2.817	1	721	7,158	-----	-----	-----	DA-FR-118C Pre-Forested
4	Reservoir	3.087	1	722	7,089	2	921.64	1,199	WB Soil Amendment
DA-FR-118c.gpw					Return Period: 2 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

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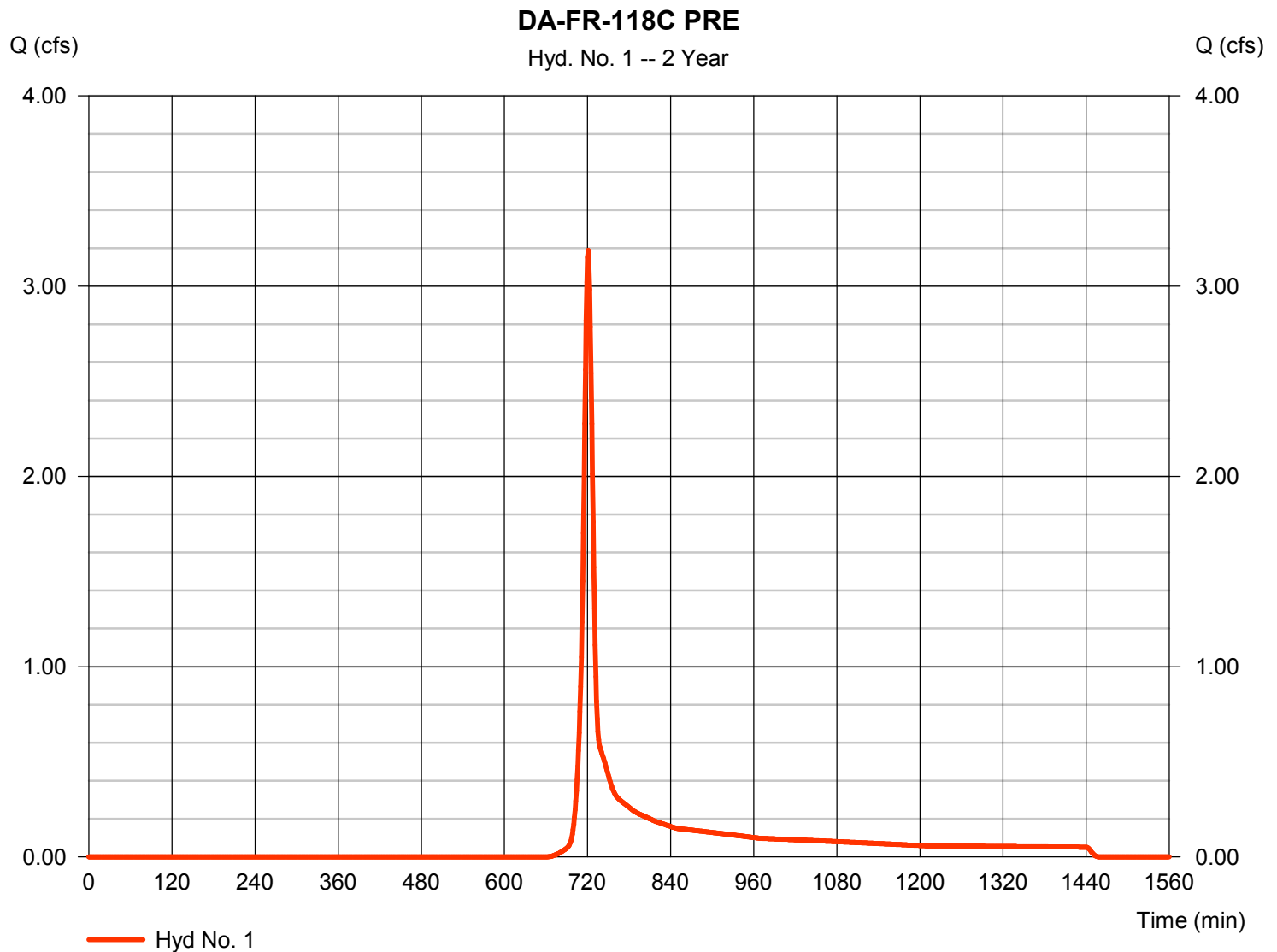
Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-FR-118C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 3.188 cfs
Storm frequency	= 2 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 7,959 cuft
Drainage area	= 1.900 ac	Curve number	= 70*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.40 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.029 \times 85) + (0.105 \times 89) + (0.068 \times 58) + (0.751 \times 71) + (0.179 \times 55) + (0.770 \times 70)] / 1.900$



Hydrograph Report

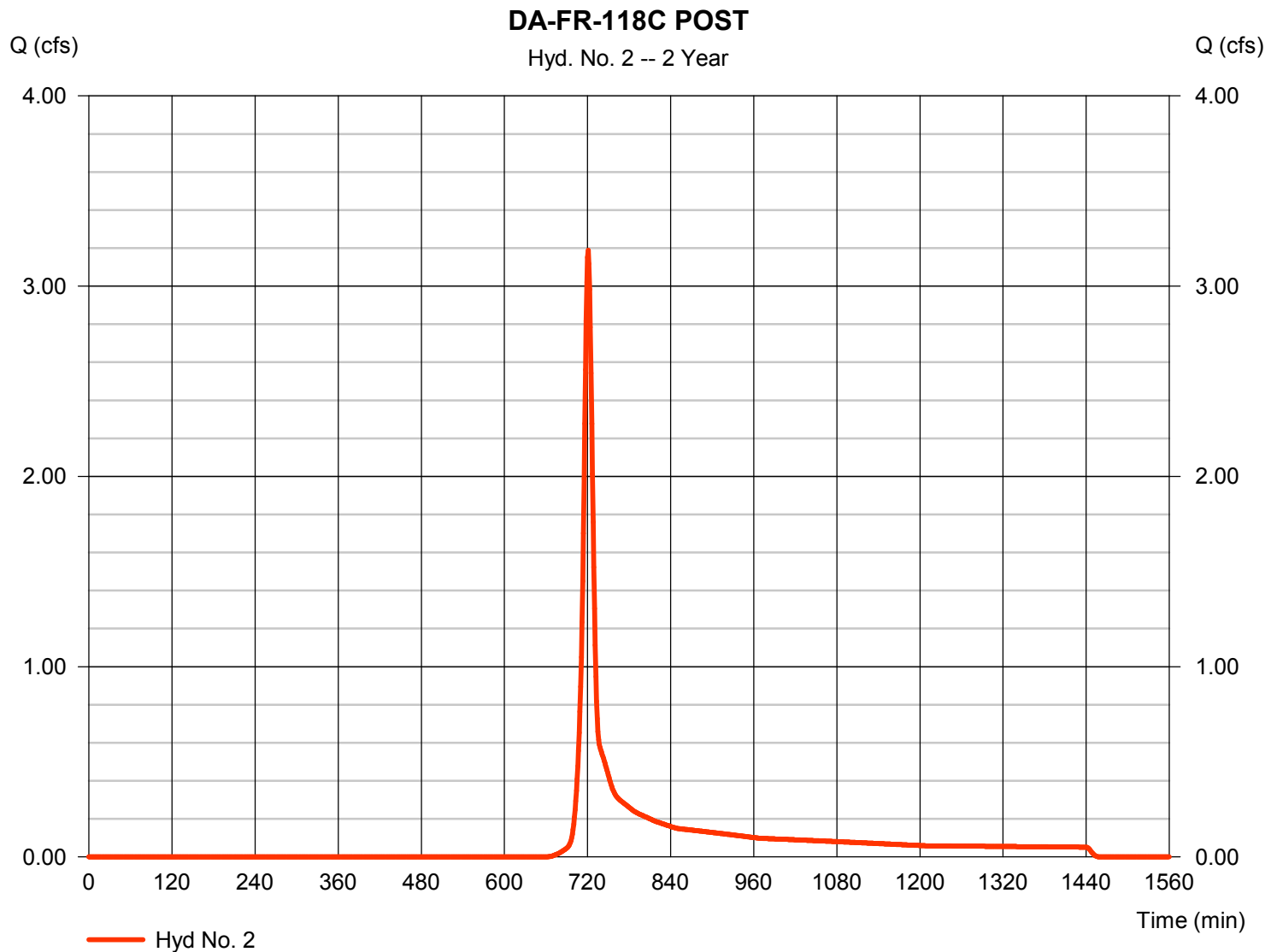
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Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-FR-118C POST

Hydrograph type	= SCS Runoff	Peak discharge	= 3.188 cfs
Storm frequency	= 2 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 7,959 cuft
Drainage area	= 1.900 ac	Curve number	= 70*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.50 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.900 \times 70)] / 1.900$ 

Hydrograph Report

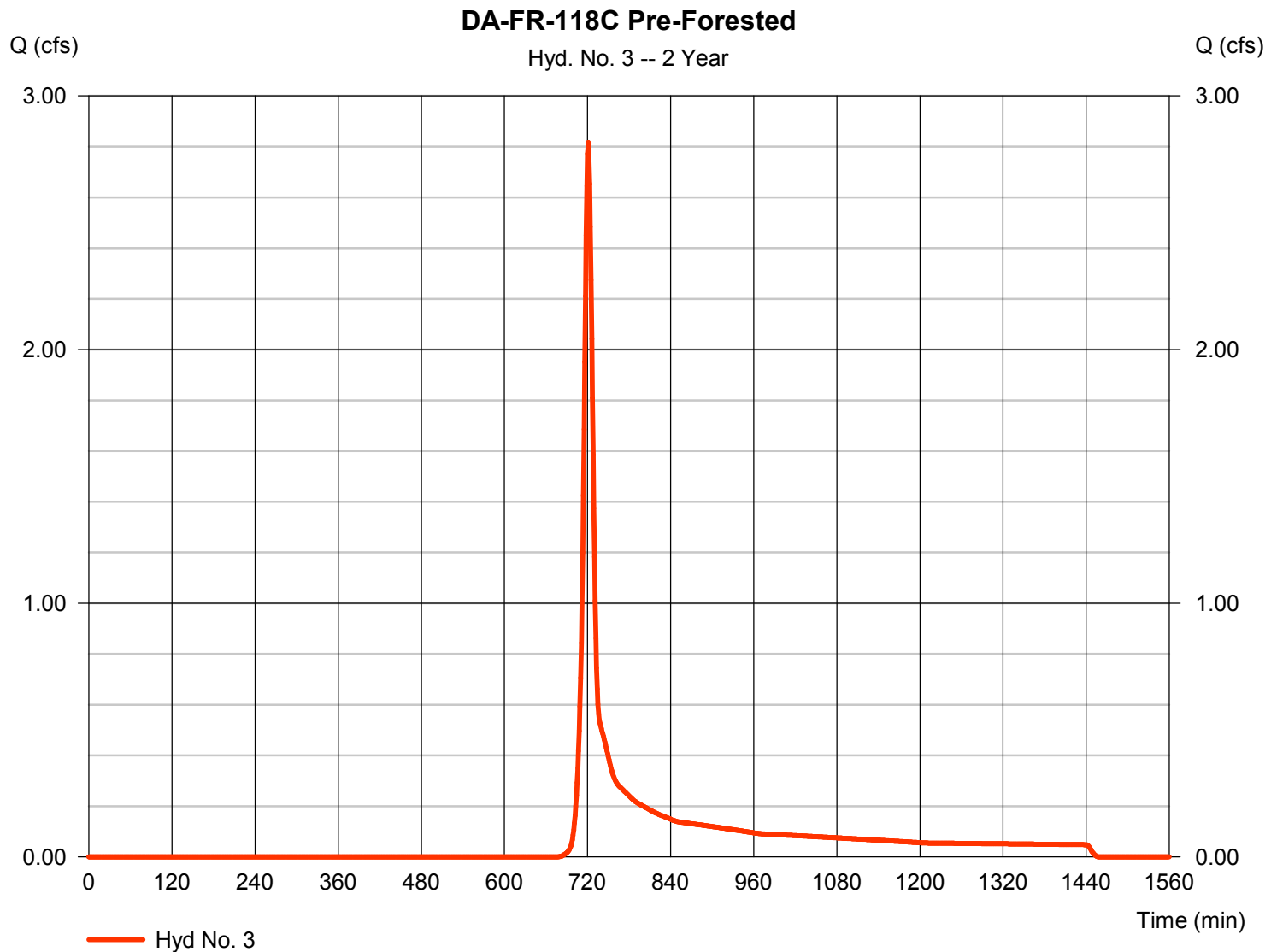
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Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-FR-118C Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 2.817 cfs
Storm frequency	= 2 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 7,158 cuft
Drainage area	= 1.900 ac	Curve number	= 68*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.40 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.280 \times 55) + (1.620 \times 70)] / 1.900$ 

Hydrograph Report

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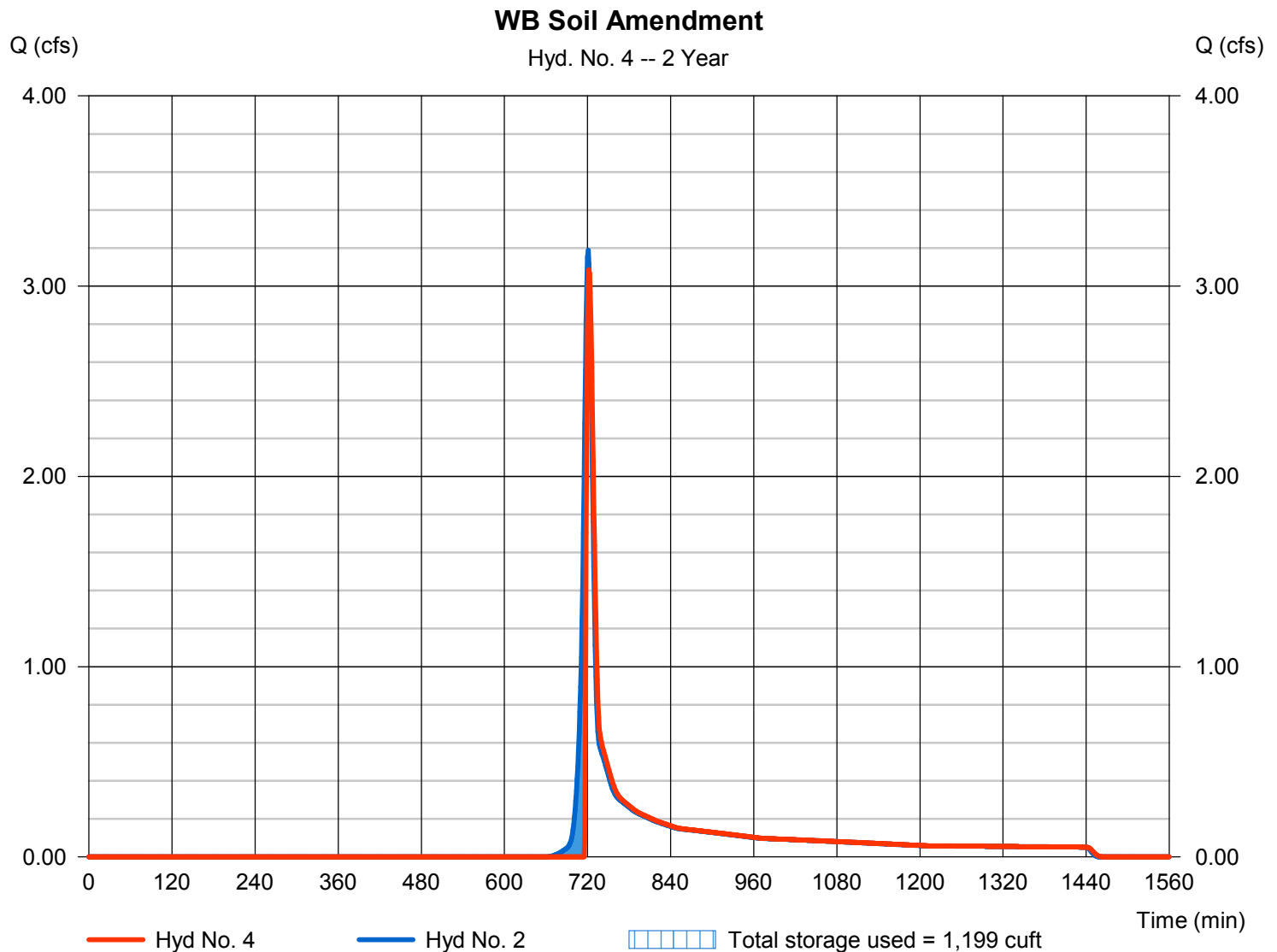
Wednesday, 08 / 16 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 3.087 cfs
Storm frequency	= 2 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 7,089 cuft
Inflow hyd. No.	= 2 - DA-FR-118C POST	Max. Elevation	= 921.64 ft
Reservoir name	= Waterbar Soil Amendment	Max. Storage	= 1,199 cuft

Storage Indication method used.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	7.444	1	720	18,036	-----	-----	-----	DA-FR-118C PRE
2	SCS Runoff	7.444	1	720	18,036	-----	-----	-----	DA-FR-118C POST
3	SCS Runoff	6.916	1	721	16,797	-----	-----	-----	DA-FR-118C Pre-Forested
4	Reservoir	7.366	1	721	17,166	2	921.75	1,460	WB Soil Amendment
DA-FR-118c.gpw					Return Period: 10 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

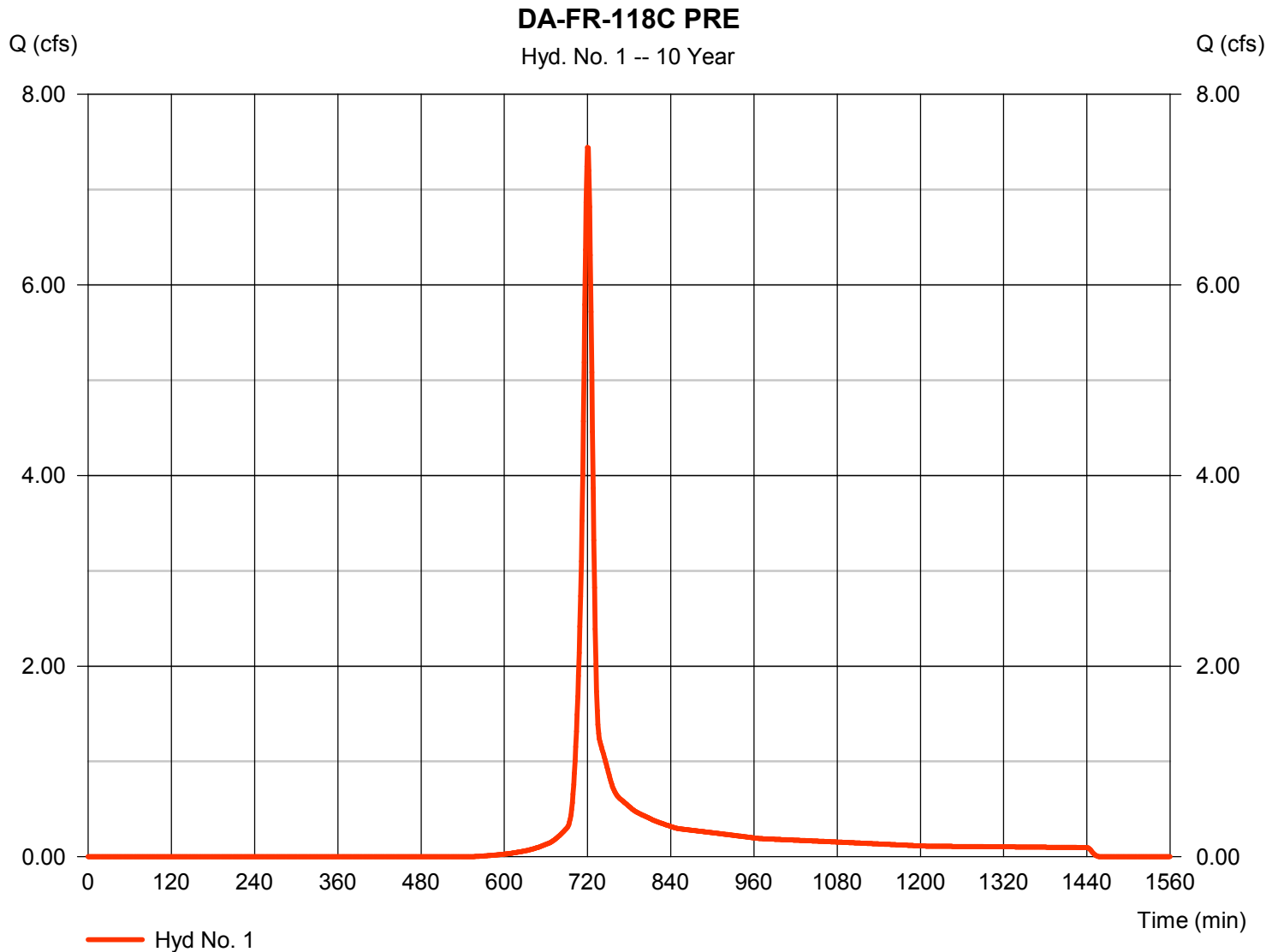
Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-FR-118C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 7.444 cfs
Storm frequency	= 10 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 18,036 cuft
Drainage area	= 1.900 ac	Curve number	= 70*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.40 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.029 \times 85) + (0.105 \times 89) + (0.068 \times 58) + (0.751 \times 71) + (0.179 \times 55) + (0.770 \times 70)] / 1.900$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

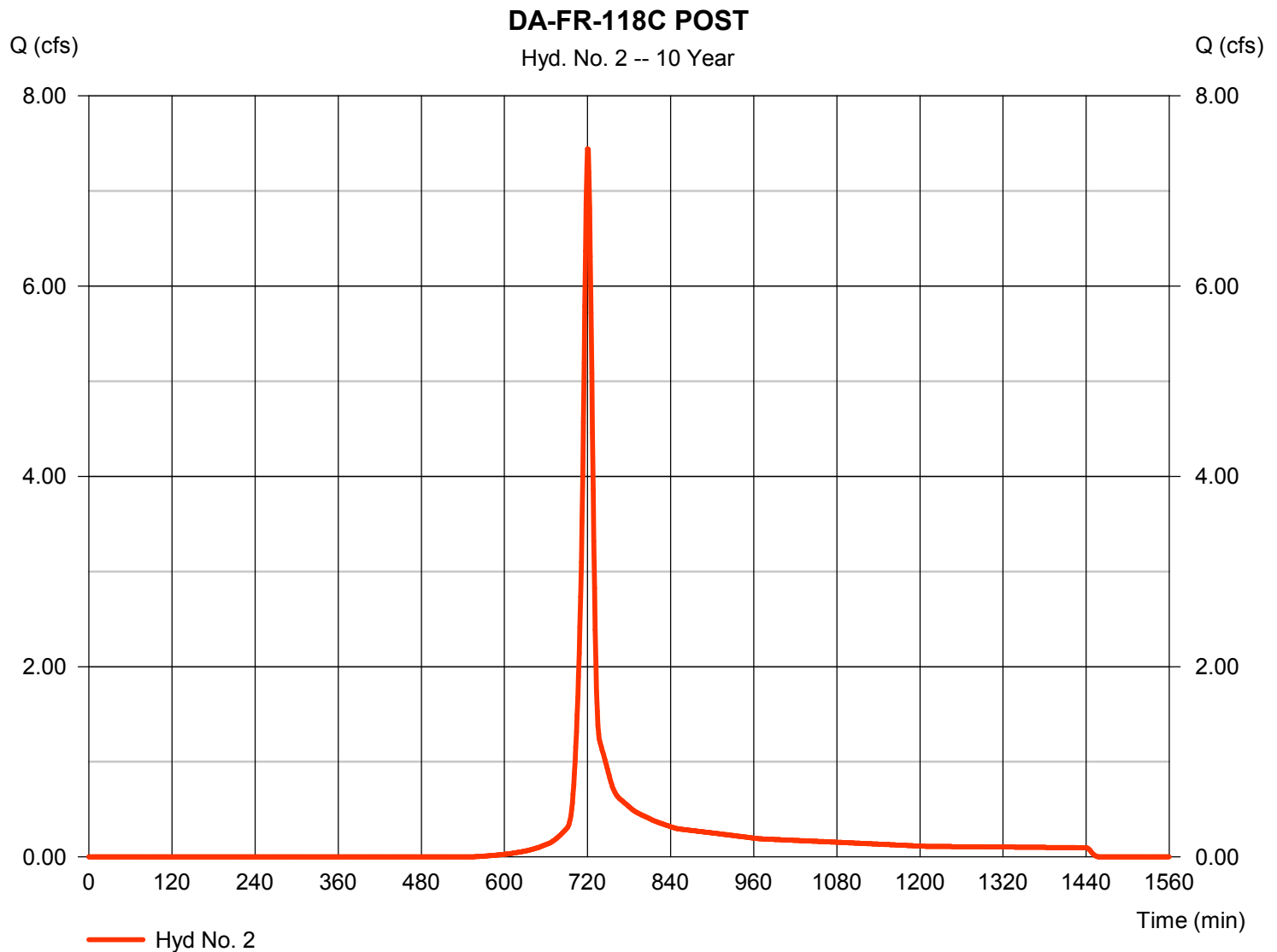
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-FR-118C POST

Hydrograph type	= SCS Runoff	Peak discharge	= 7.444 cfs
Storm frequency	= 10 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 18,036 cuft
Drainage area	= 1.900 ac	Curve number	= 70*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.50 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.900 x 70)] / 1.900



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

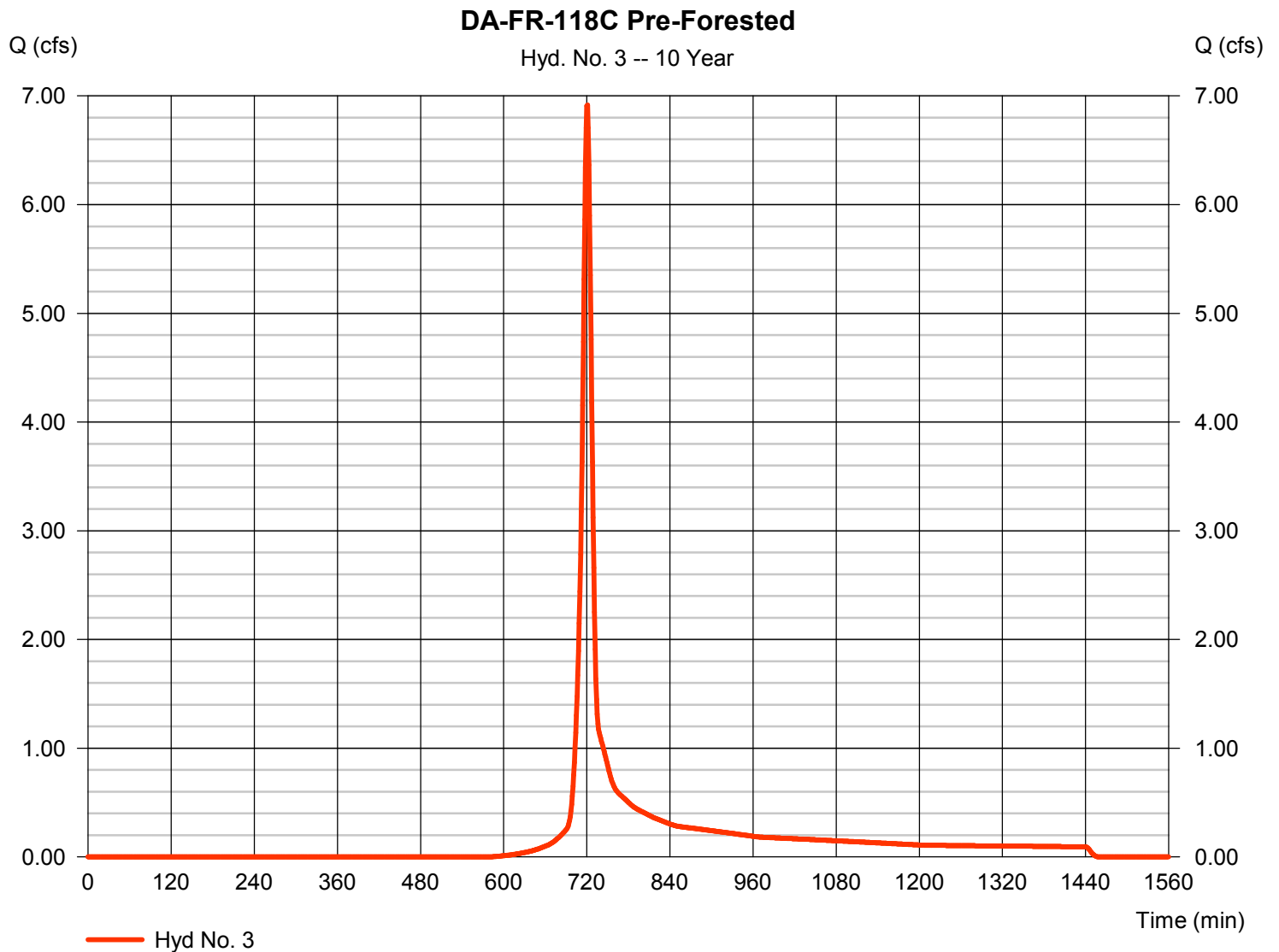
Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-FR-118C Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 6.916 cfs
Storm frequency	= 10 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 16,797 cuft
Drainage area	= 1.900 ac	Curve number	= 68*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.40 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.280 \times 55) + (1.620 \times 70)] / 1.900$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

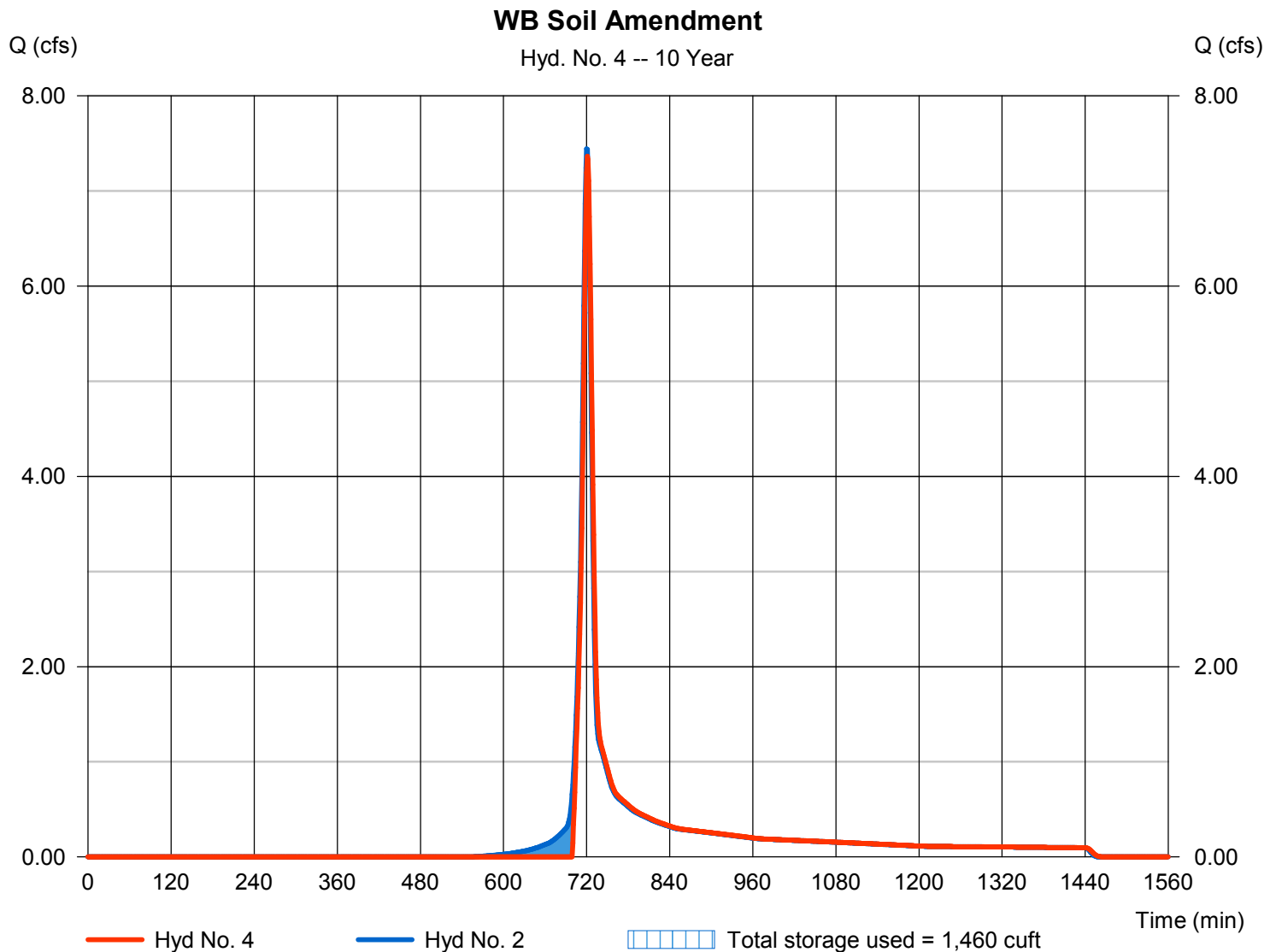
Wednesday, 08 / 16 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 7.366 cfs
Storm frequency	= 10 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 17,166 cuft
Inflow hyd. No.	= 2 - DA-FR-118C POST	Max. Elevation	= 921.75 ft
Reservoir name	= Waterbar Soil Amendment	Max. Storage	= 1,460 cuft

Storage Indication method used.



DA-FR-118D

ENERGY BALANCE METHOD

Inputs:

1-Yr Event		
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	3.890	12967
Developed Condition	3.890	12967
Pre-Developed (Forest) Condition	3.134	10931

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 1

Calculations:

Check #1: $Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->

Q (cfs)		Q (cfs)
3.890	≤	3.890
	OK	

Check #2: $Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->

3.890	≤	3.890
	OK	

Check #3: $Q_{\text{developed}}$ shall not be required to be ≤ $(Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ ---->

3.890	<u>shall not</u> be required to be ≤	2.642
-------	--------------------------------------	-------

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p><i>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</i></p> <p><i>For Paved Road land surface types a Manning’s n value of 0.011 was used.</i></p> <p><i>Sources:</i></p> <p><i>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</i></p> <p><i>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</i></p>	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

1



2



3



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-118D PRE
2	SCS Runoff	DA-FR-118D POST
3	SCS Runoff	DA-FR-118D Pre-Forested

Hydrograph Return Period Recap

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

[illegible]

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	3.890	1	726	12,967	-----	-----	-----	DA-FR-118D PRE
2	SCS Runoff	3.890	1	726	12,967	-----	-----	-----	DA-FR-118D POST
3	SCS Runoff	3.134	1	726	10,931	-----	-----	-----	DA-FR-118D Pre-Forested
DA-FR-118d.gpw					Return Period: 1 Year			Monday, 08 / 14 / 2017	

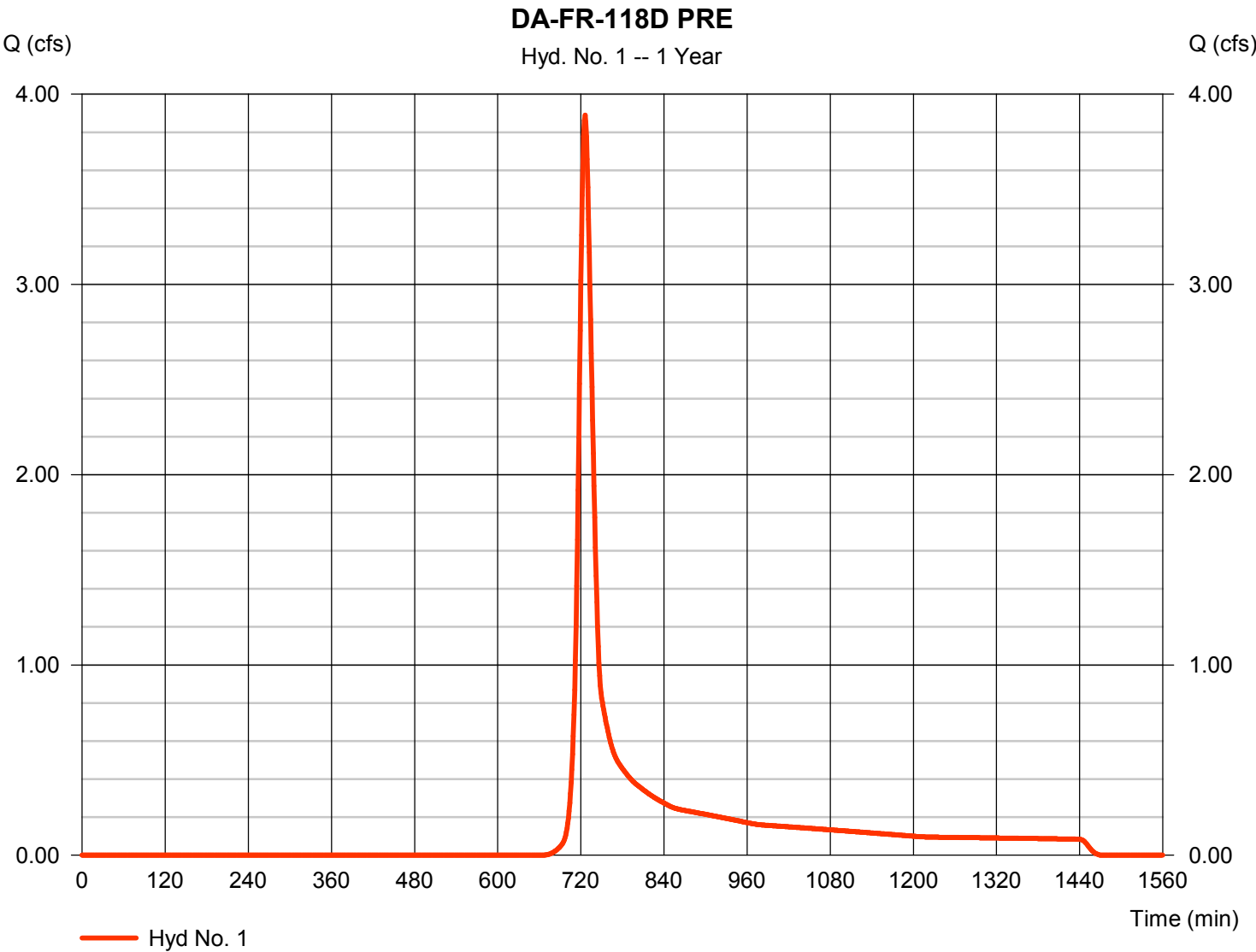
Hydrograph Report

Hyd. No. 1

DA-FR-118D PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 3.890 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 12,967 cuft
Drainage area	= 3.600 ac	Curve number	= 72*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.00 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.001 x 85) + (0.318 x 89) + (0.211 x 58) + (3.067 x 71)] / 3.600



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-118D PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 3.10	0.00	0.00	
Travel Time (min)	= 16.76	+ 0.00	+ 0.00	= 16.76
Shallow Concentrated Flow				
Flow length (ft)	= 602.20	0.00	0.00	
Watercourse slope (%)	= 3.60	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=3.06	0.00	0.00	
Travel Time (min)	= 3.28	+ 0.00	+ 0.00	= 3.28
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	= 0.040	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				20.00 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

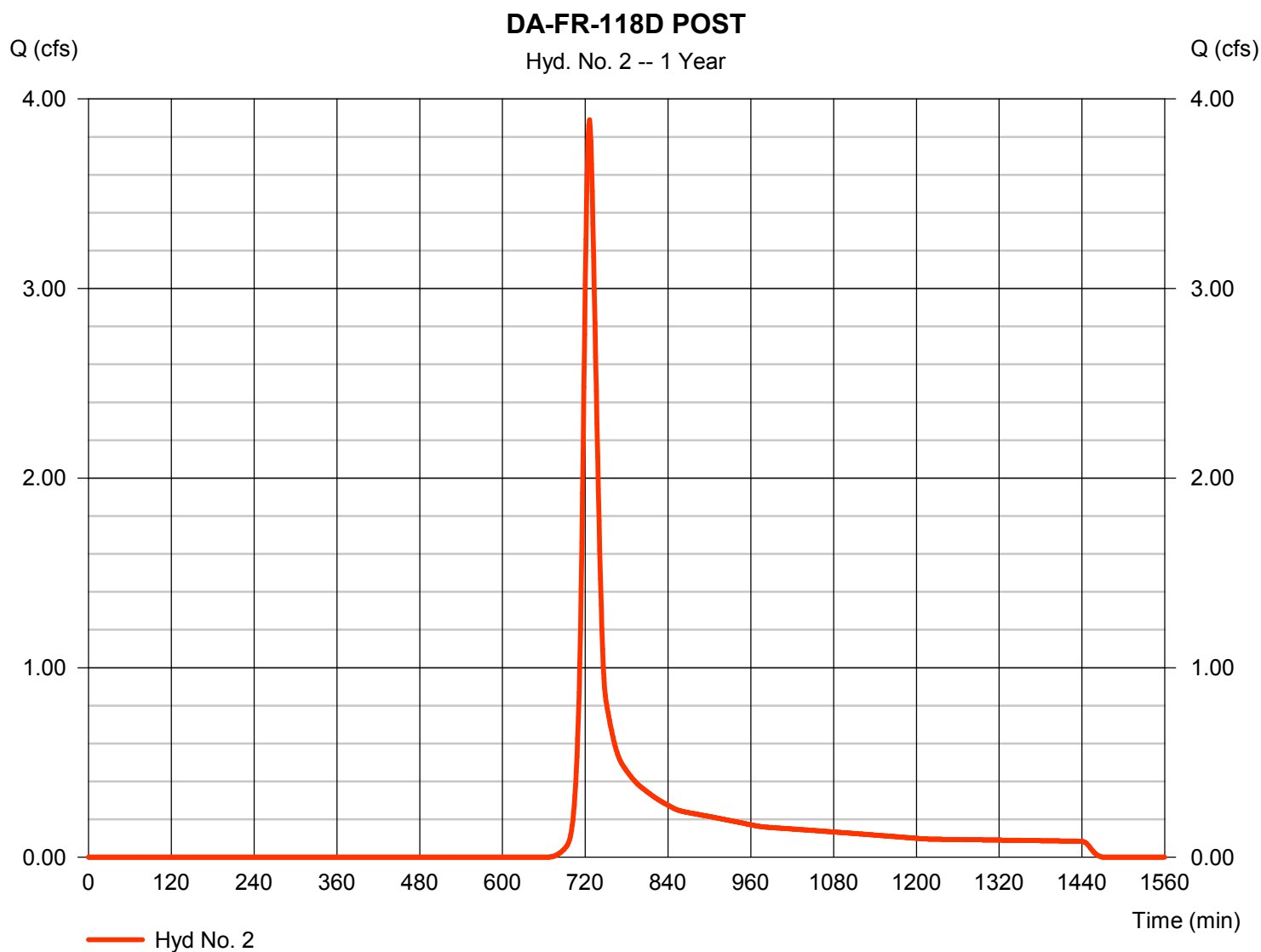
Monday, 08 / 14 / 2017

Hyd. No. 2

DA-FR-118D POST

Hydrograph type	= SCS Runoff	Peak discharge	= 3.890 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 12,967 cuft
Drainage area	= 3.600 ac	Curve number	= 72*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.00 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = + (0.320 x 89) + (0.210 x 58) + (3.070 x 71)] / 3.600



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-118D POST

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.800	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 3.10	0.00	0.00				
Travel Time (min)	= 16.76	+	0.00	+	0.00	=	16.76
Shallow Concentrated Flow							
Flow length (ft)	= 602.20	0.00	0.00				
Watercourse slope (%)	= 3.60	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=3.06	0.00	0.00				
Travel Time (min)	= 3.28	+	0.00	+	0.00	=	3.28
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	= 0.040	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				20.00 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

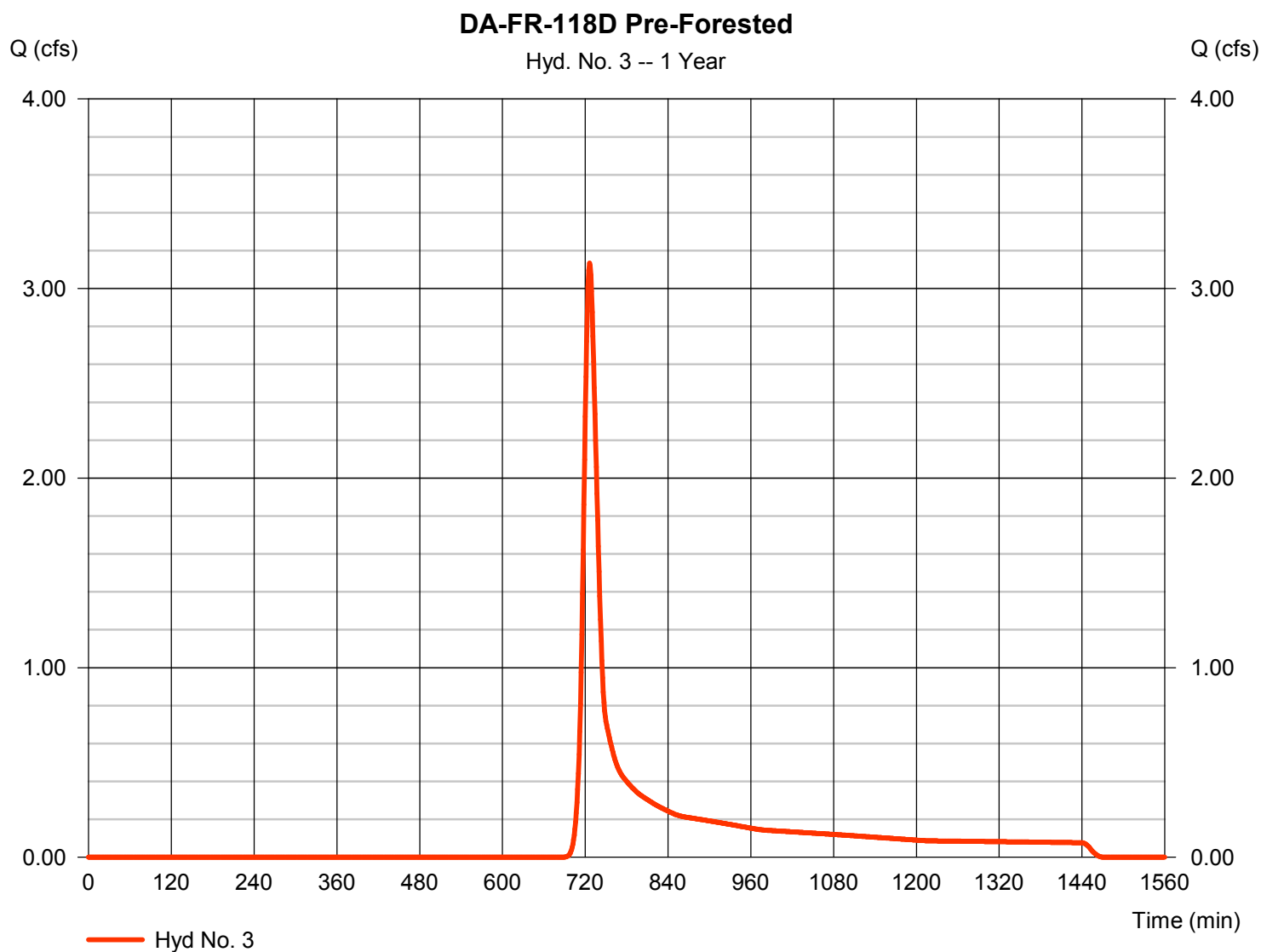
Monday, 08 / 14 / 2017

Hyd. No. 3

DA-FR-118D Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 3.134 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 10,931 cuft
Drainage area	= 3.600 ac	Curve number	= 69*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.00 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.212 \times 55) + (3.385 \times 70)] / 3.600$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-118D Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 3.10	0.00	0.00	
Travel Time (min)	= 16.76	+ 0.00	+ 0.00	= 16.76
Shallow Concentrated Flow				
Flow length (ft)	= 602.20	0.00	0.00	
Watercourse slope (%)	= 3.60	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=3.06	0.00	0.00	
Travel Time (min)	= 3.28	+ 0.00	+ 0.00	= 3.28
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	= 0.030	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				20.00 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	5.029	1	726	16,384	-----	-----	-----	DA-FR-118D PRE
2	SCS Runoff	5.029	1	726	16,384	-----	-----	-----	DA-FR-118D POST
3	SCS Runoff	4.186	1	726	14,060	-----	-----	-----	DA-FR-118D Pre-Forested
DA-FR-118d.gpw					Return Period: 2 Year			Monday, 08 / 14 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

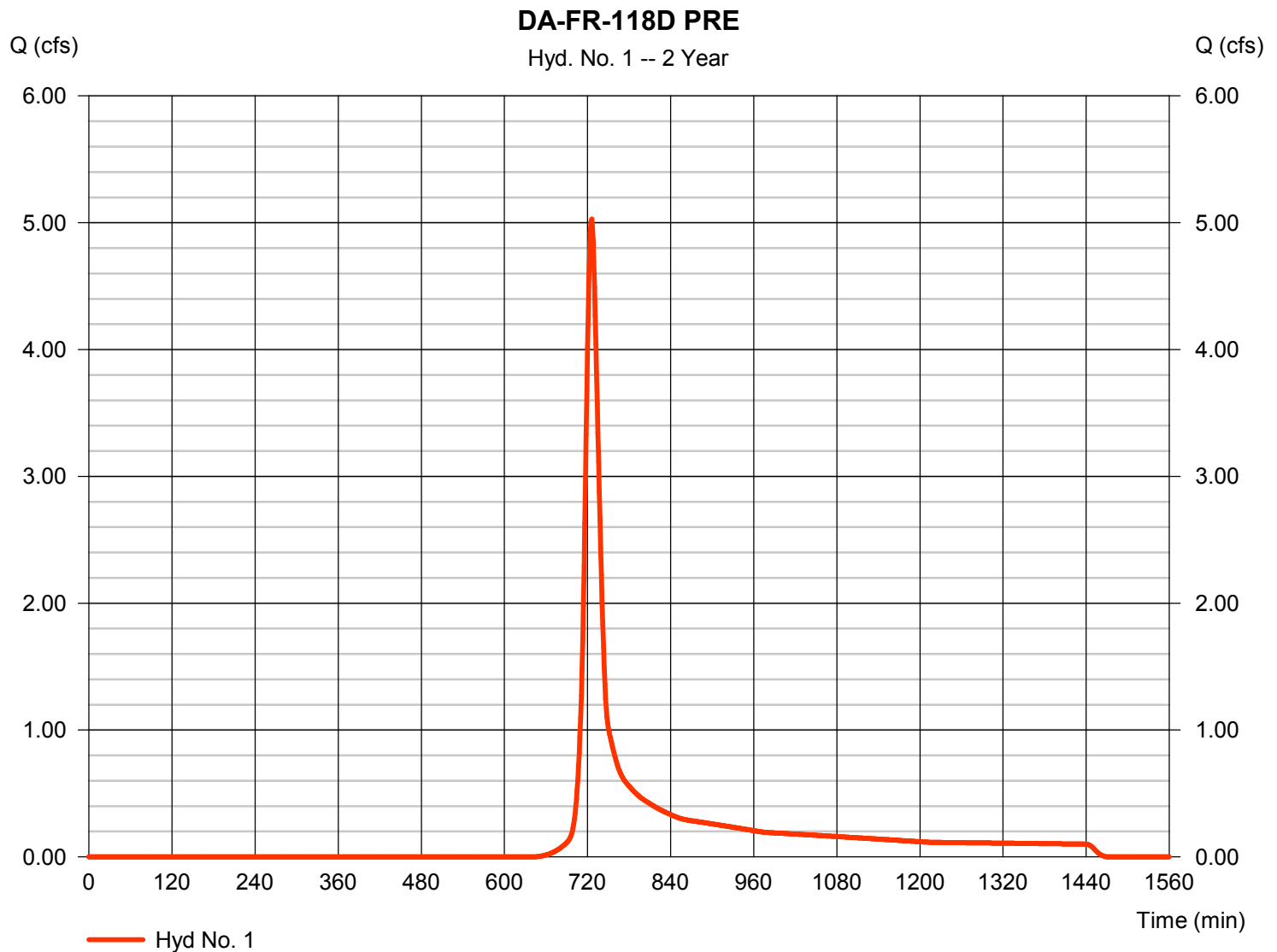
Monday, 08 / 14 / 2017

Hyd. No. 1

DA-FR-118D PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 5.029 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 16,384 cuft
Drainage area	= 3.600 ac	Curve number	= 72*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.00 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.001 \times 85) + (0.318 \times 89) + (0.211 \times 58) + (3.067 \times 71)] / 3.600$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

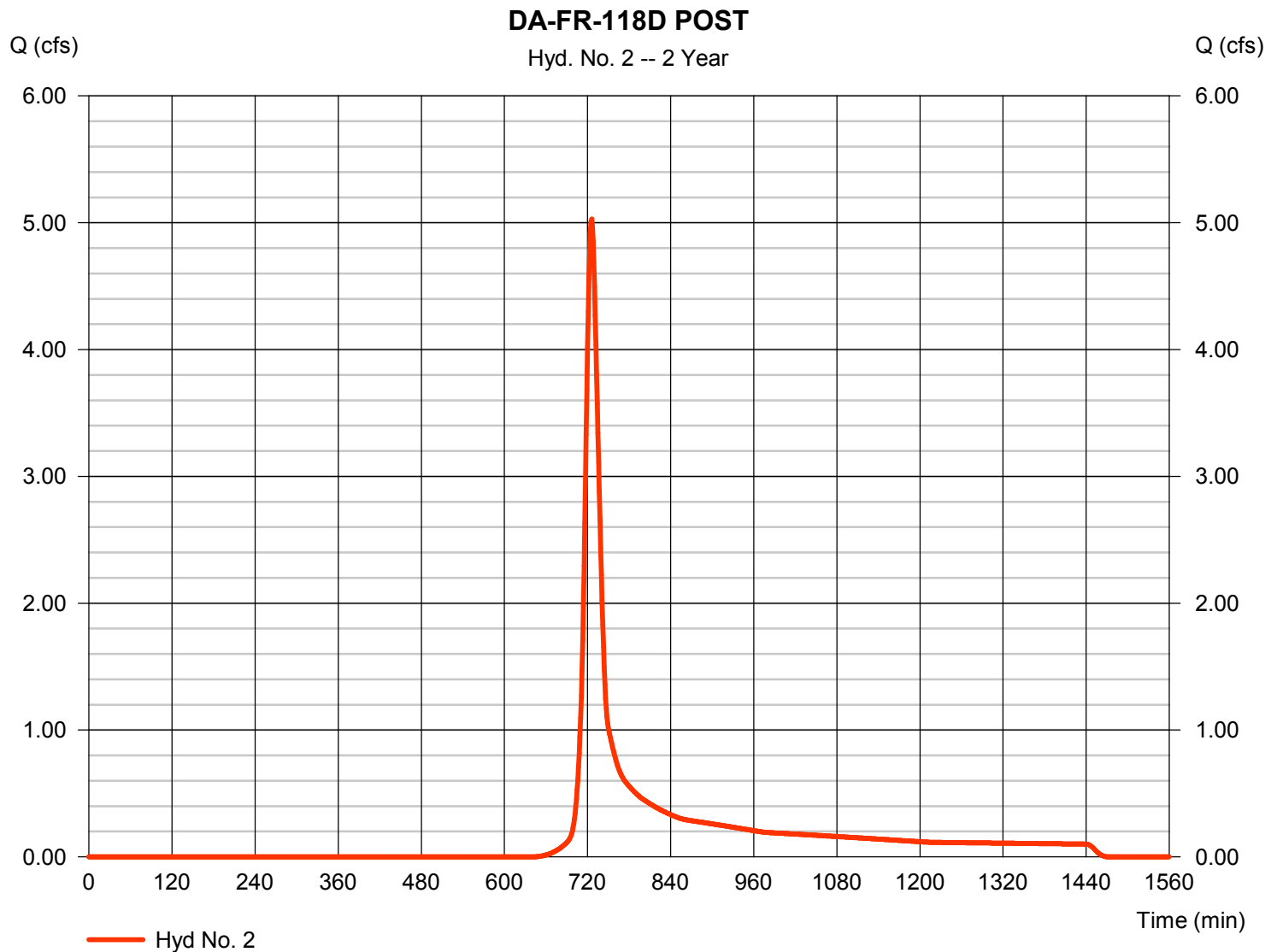
Monday, 08 / 14 / 2017

Hyd. No. 2

DA-FR-118D POST

Hydrograph type	= SCS Runoff	Peak discharge	= 5.029 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 16,384 cuft
Drainage area	= 3.600 ac	Curve number	= 72*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.00 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = + (0.320 x 89) + (0.210 x 58) + (3.070 x 71)] / 3.600



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

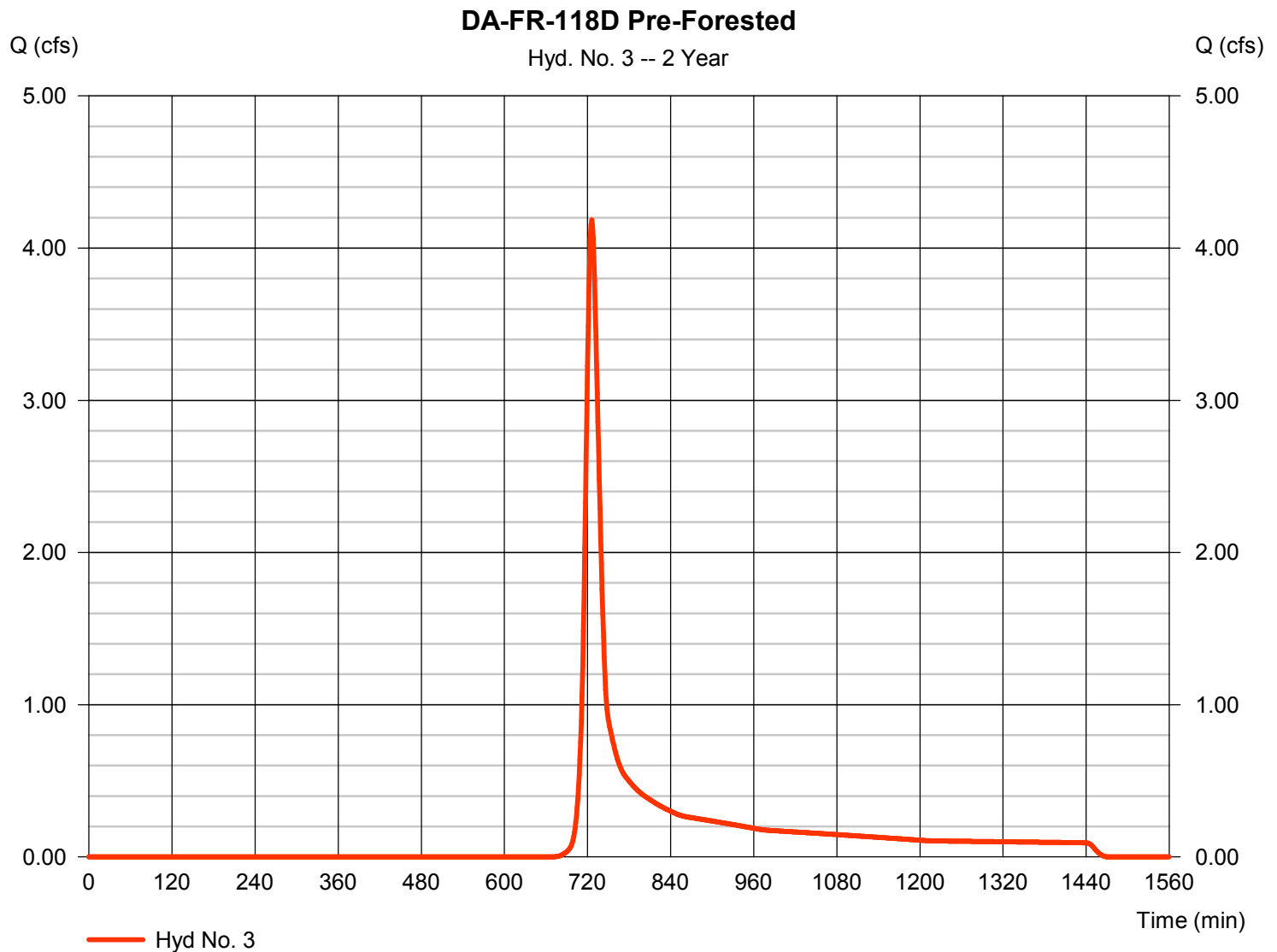
Monday, 08 / 14 / 2017

Hyd. No. 3

DA-FR-118D Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 4.186 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 14,060 cuft
Drainage area	= 3.600 ac	Curve number	= 69*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.00 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.212 \times 55) + (3.385 \times 70)] / 3.600$



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	11.46	1	725	35,934	-----	-----	-----	DA-FR-118D PRE
2	SCS Runoff	11.46	1	725	35,934	-----	-----	-----	DA-FR-118D POST
3	SCS Runoff	10.26	1	725	32,415	-----	-----	-----	DA-FR-118D Pre-Forested
DA-FR-118d.gpw					Return Period: 10 Year			Monday, 08 / 14 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

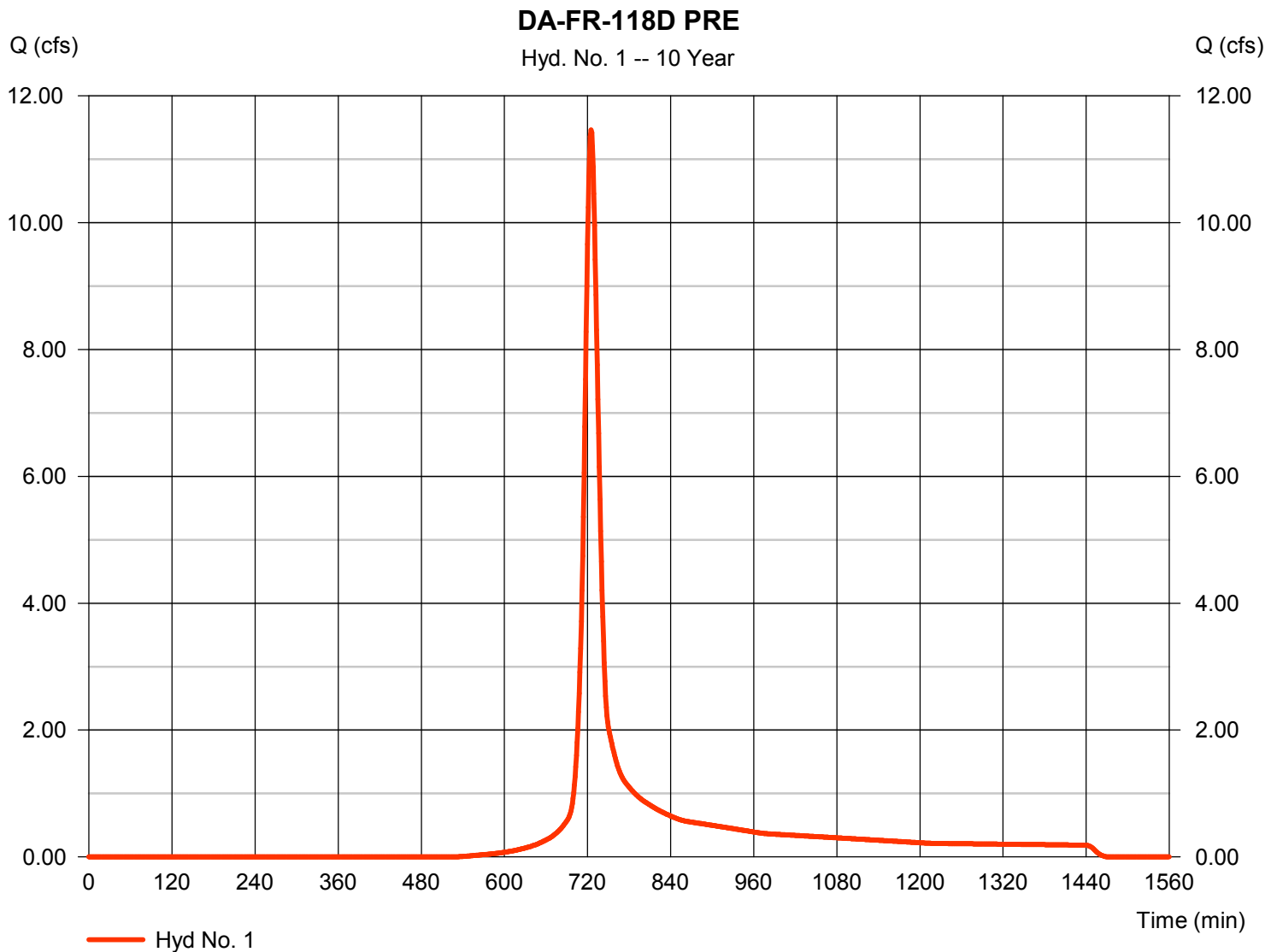
Monday, 08 / 14 / 2017

Hyd. No. 1

DA-FR-118D PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 11.46 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 35,934 cuft
Drainage area	= 3.600 ac	Curve number	= 72*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.00 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.001 \times 85) + (0.318 \times 89) + (0.211 \times 58) + (3.067 \times 71)] / 3.600$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

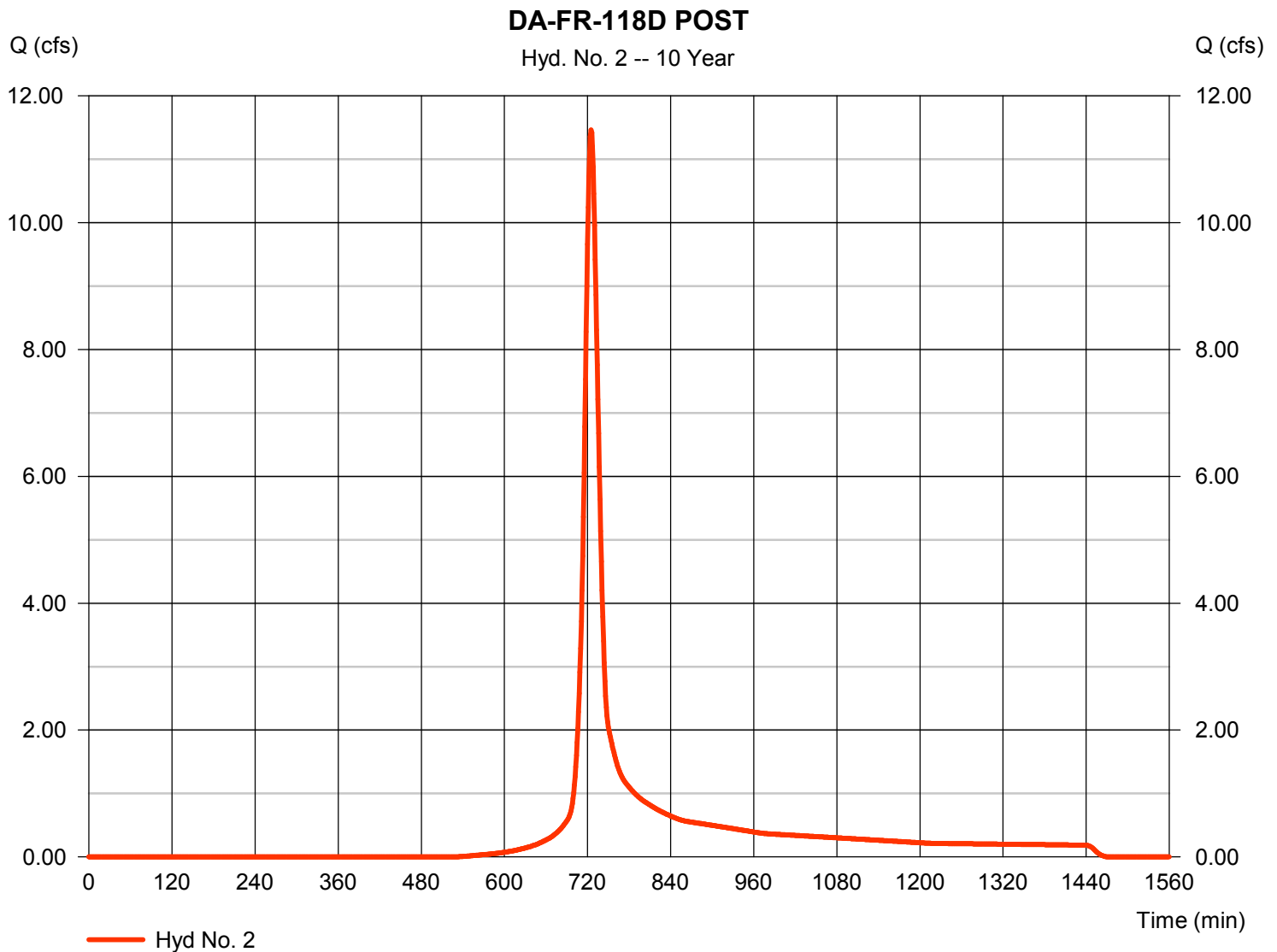
Monday, 08 / 14 / 2017

Hyd. No. 2

DA-FR-118D POST

Hydrograph type	= SCS Runoff	Peak discharge	= 11.46 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 35,934 cuft
Drainage area	= 3.600 ac	Curve number	= 72*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.00 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = + (0.320 x 89) + (0.210 x 58) + (3.070 x 71)] / 3.600



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

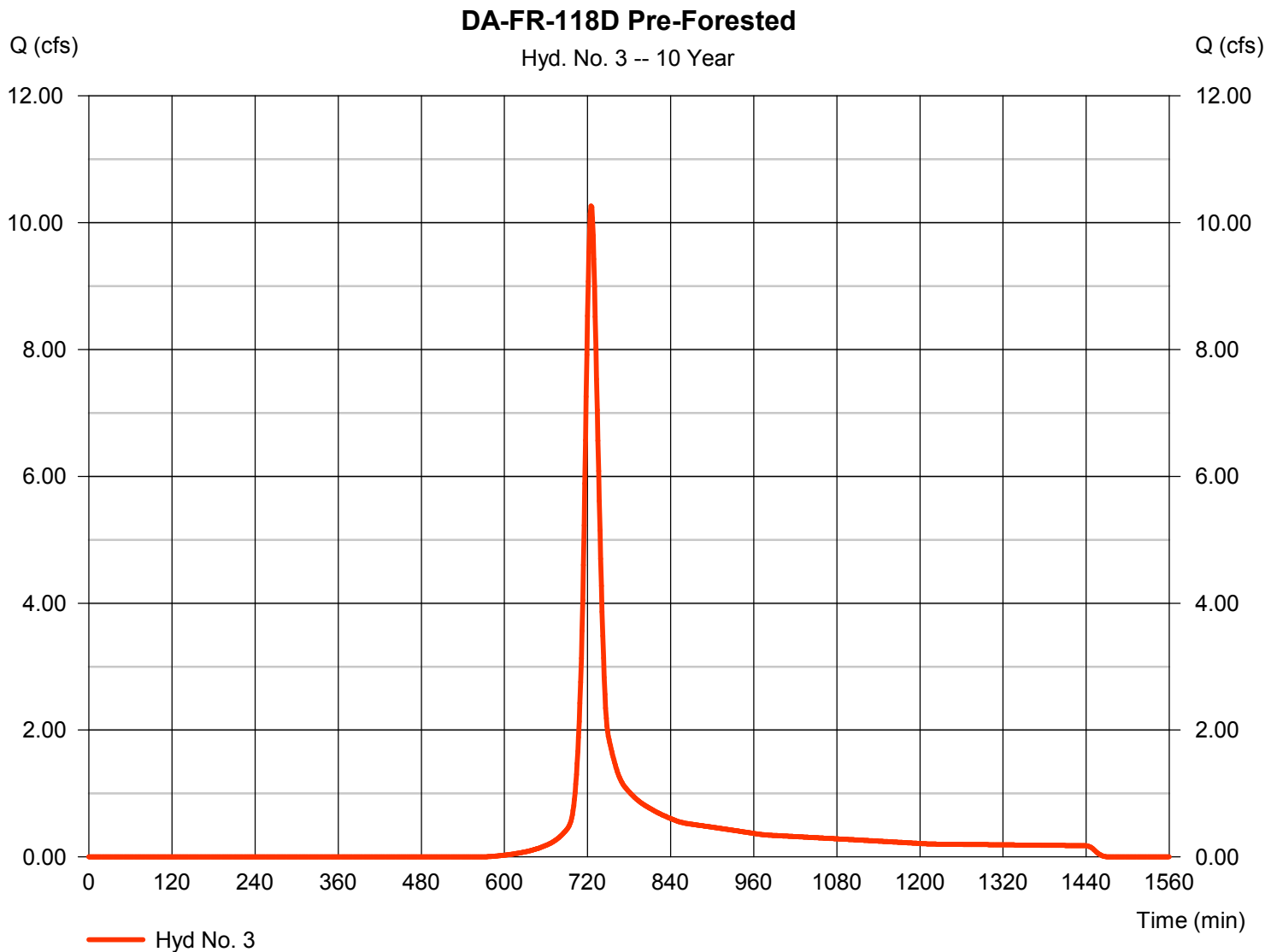
Monday, 08 / 14 / 2017

Hyd. No. 3

DA-FR-118D Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 10.26 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 32,415 cuft
Drainage area	= 3.600 ac	Curve number	= 69*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.00 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.212 \times 55) + (3.385 \times 70)] / 3.600$



DA-FR-118E

ENERGY BALANCE METHOD

Inputs:

1-Yr Event		
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.491	1771
Developed Condition	0.491	1771
Pre-Developed (Forest) Condition	0.398	1500

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF =

1

Calculations:

Check #1: $Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->

Q (cfs)

0.491

≤

Q (cfs)

0.491

OK

Check #2: $Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->

0.491

≤

0.491

OK

Check #3: $Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ --->

0.491

shall not be required to be ≤

0.337

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p><i>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</i></p> <p><i>For Paved Road land surface types a Manning’s n value of 0.011 was used.</i></p> <p><i>Sources:</i></p> <p><i>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</i></p> <p><i>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</i></p>	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-118E PRE
2	SCS Runoff	DA-FR-118E POST
3	SCS Runoff	DA-FR-118E Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.491	1	728	1,771	-----	-----	-----	DA-FR-118E PRE
2	SCS Runoff	0.491	1	728	1,771	-----	-----	-----	DA-FR-118E POST
3	SCS Runoff	0.398	1	728	1,500	-----	-----	-----	DA-FR-118E Pre-Forested
DA-FR-118e.gpw					Return Period: 1 Year			Tuesday, 08 / 15 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

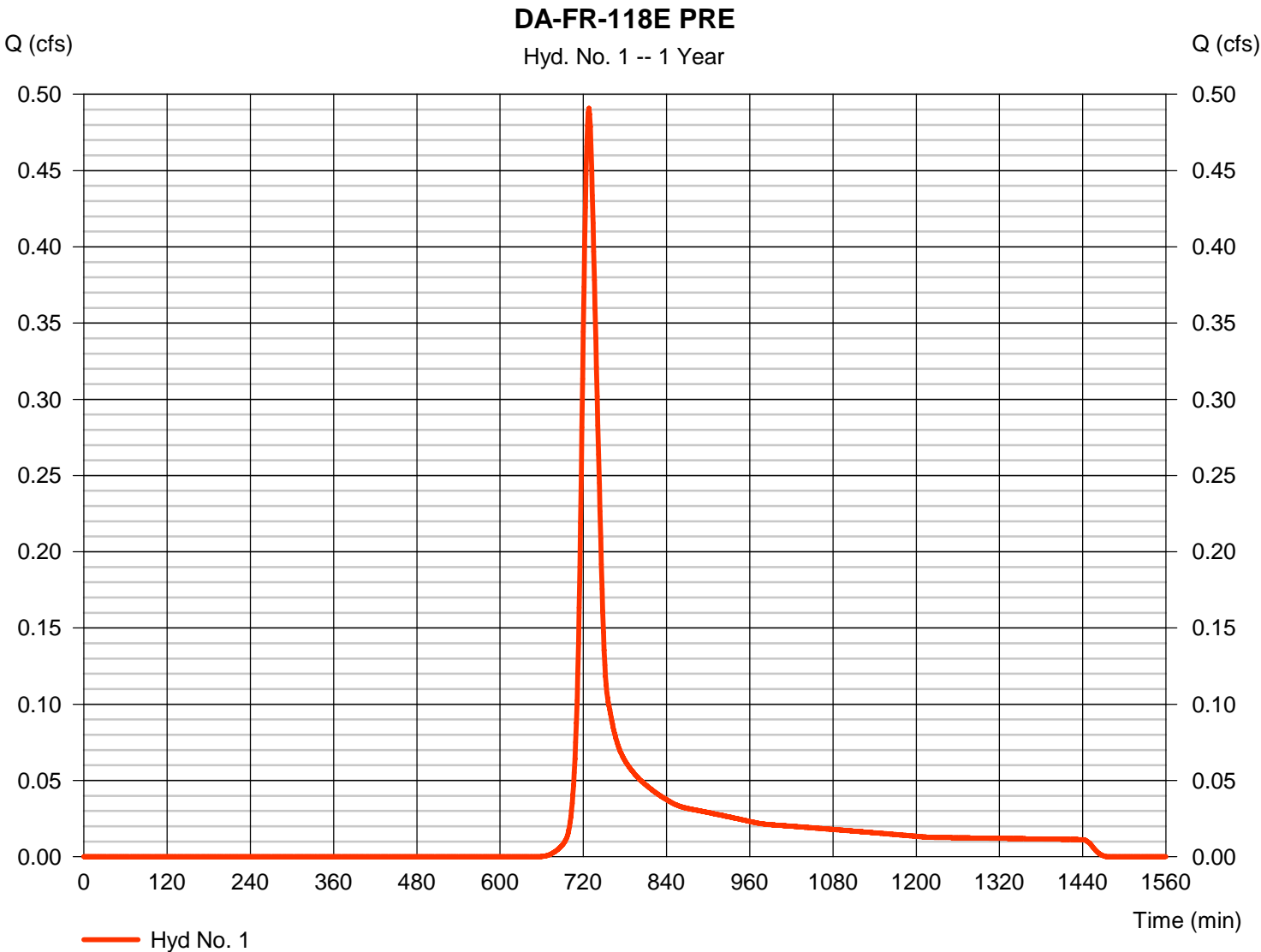
Tuesday, 08 / 15 / 2017

Hyd. No. 1

DA-FR-118E PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.491 cfs
Storm frequency	=	1 yrs	Time to peak	=	728 min
Time interval	=	1 min	Hyd. volume	=	1,771 cuft
Drainage area	=	0.470 ac	Curve number	=	73*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	23.30 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.050 x 89) + (0.420 x 71)] / 0.470



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-118E PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 1.40	0.00	0.00				
Travel Time (min)	= 23.03	+	0.00	+	0.00	=	23.03
Shallow Concentrated Flow							
Flow length (ft)	= 52.80	0.00	0.00				
Watercourse slope (%)	= 3.60	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=3.06	0.00	0.00				
Travel Time (min)	= 0.29	+	0.00	+	0.00	=	0.29
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	= 0.040	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				23.30 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Tuesday, 08 / 15 / 2017

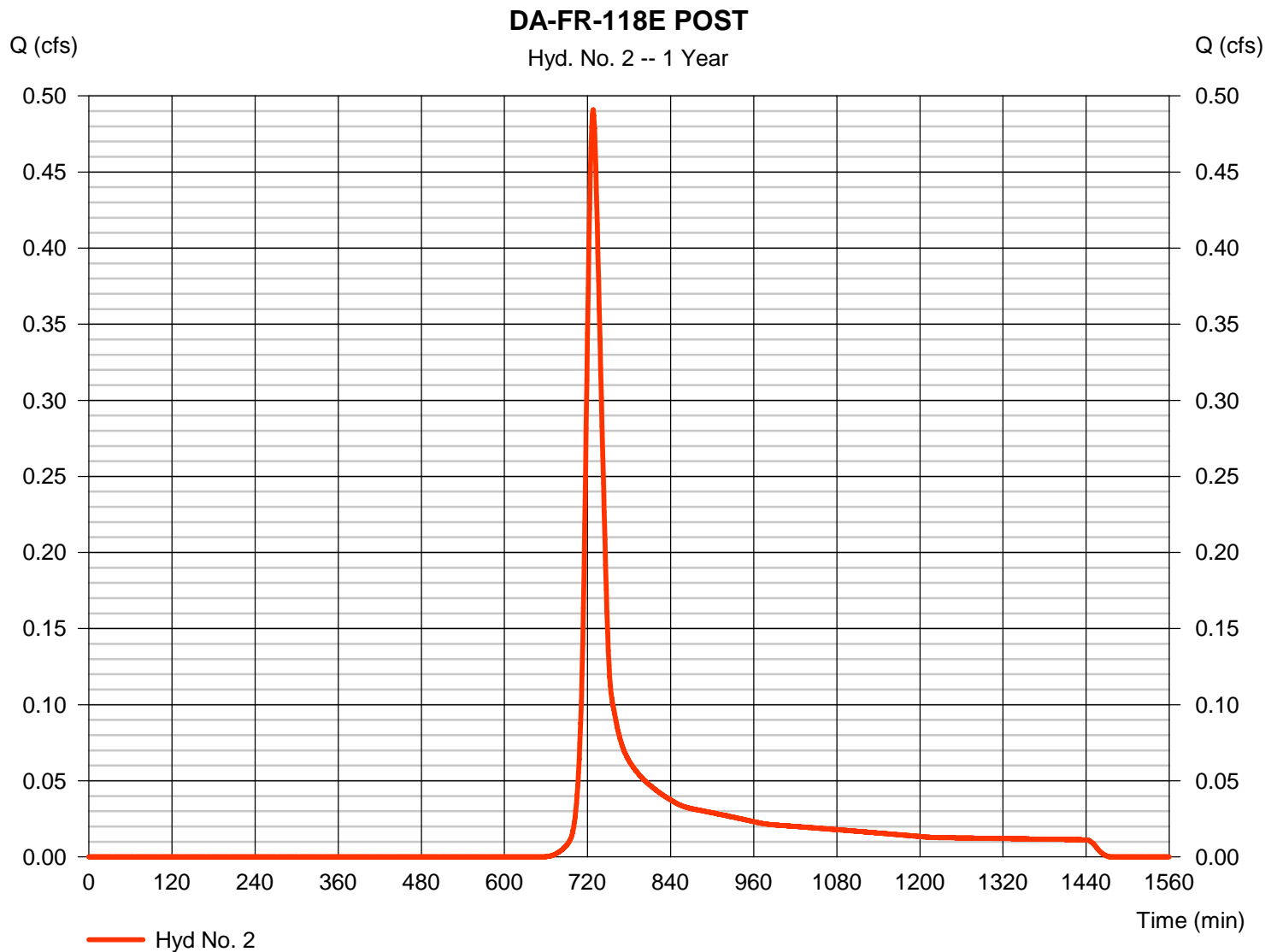
Hyd. No. 2

DA-FR-118E POST

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 0.470 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.30 in
 Storm duration = 24 hrs

Peak discharge = 0.491 cfs
 Time to peak = 728 min
 Hyd. volume = 1,771 cuft
 Curve number = 73*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 23.30 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(0.050 \times 89) + (0.420 \times 71)] / 0.470$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-118E POST

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.800	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 1.40	0.00	0.00	
Travel Time (min)	= 23.03	+ 0.00	+ 0.00	= 23.03
Shallow Concentrated Flow				
Flow length (ft)	= 52.80	0.00	0.00	
Watercourse slope (%)	= 3.60	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=3.06	0.00	0.00	
Travel Time (min)	= 0.29	+ 0.00	+ 0.00	= 0.29
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	= 0.040	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				23.30 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Tuesday, 08 / 15 / 2017

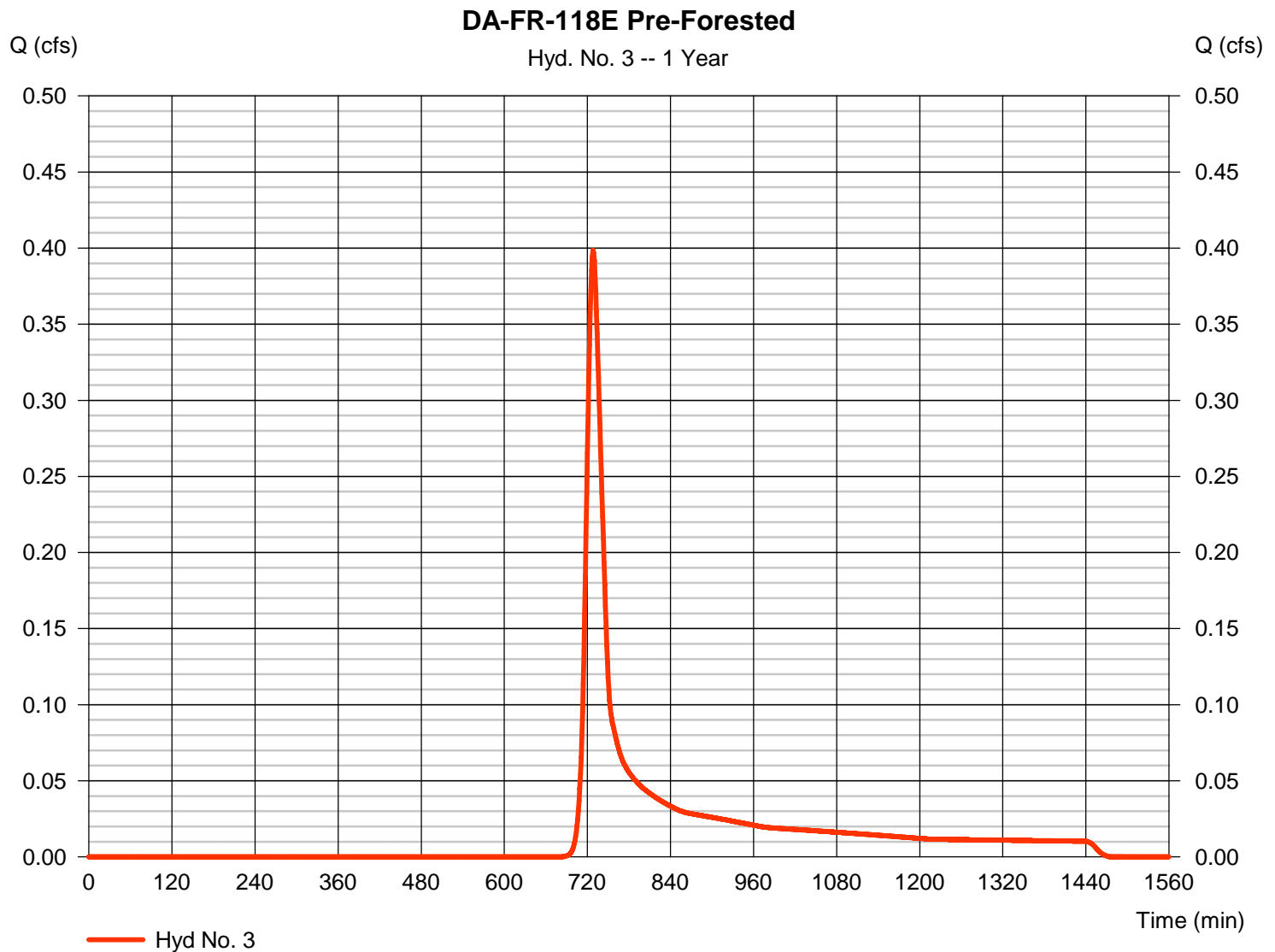
Hyd. No. 3

DA-FR-118E Pre-Forested

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 0.470 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.30 in
 Storm duration = 24 hrs

Peak discharge = 0.398 cfs
 Time to peak = 728 min
 Hyd. volume = 1,500 cuft
 Curve number = 70*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 23.30 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(0.470 \times 70)] / 0.470$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-118E Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 1.40	0.00	0.00				
Travel Time (min)	= 23.03	+	0.00	+	0.00	=	23.03
Shallow Concentrated Flow							
Flow length (ft)	= 52.80	0.00	0.00				
Watercourse slope (%)	= 3.60	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=3.06	0.00	0.00				
Travel Time (min)	= 0.29	+	0.00	+	0.00	=	0.29
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	= 0.030	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				23.30 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.630	1	728	2,225	-----	-----	-----	DA-FR-118E PRE
2	SCS Runoff	0.630	1	728	2,225	-----	-----	-----	DA-FR-118E POST
3	SCS Runoff	0.527	1	728	1,917	-----	-----	-----	DA-FR-118E Pre-Forested
DA-FR-118e.gpw					Return Period: 2 Year			Tuesday, 08 / 15 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

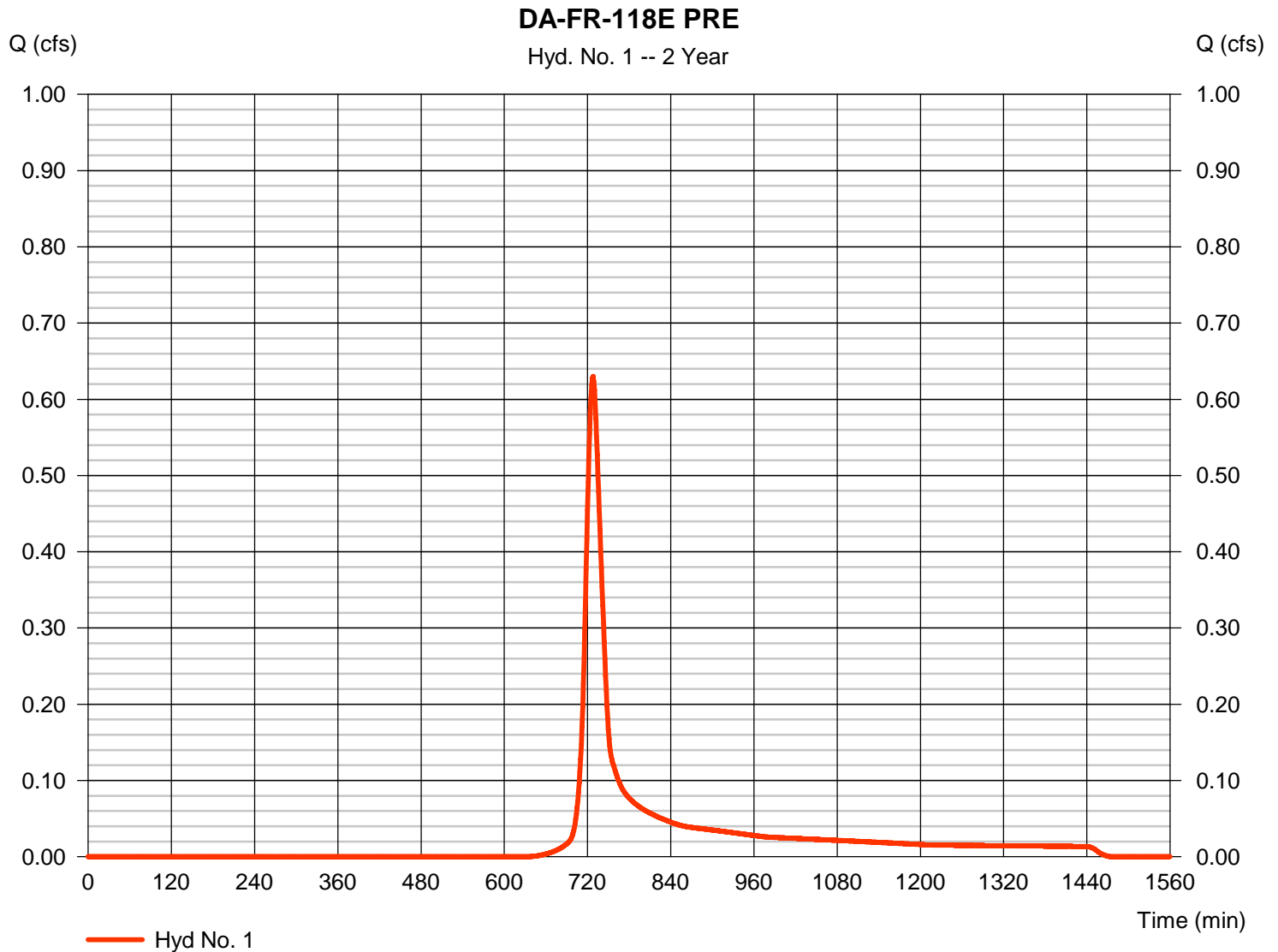
Tuesday, 08 / 15 / 2017

Hyd. No. 1

DA-FR-118E PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.630 cfs
Storm frequency	= 2 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 2,225 cuft
Drainage area	= 0.470 ac	Curve number	= 73*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 23.30 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.050 \times 89) + (0.420 \times 71)] / 0.470$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Tuesday, 08 / 15 / 2017

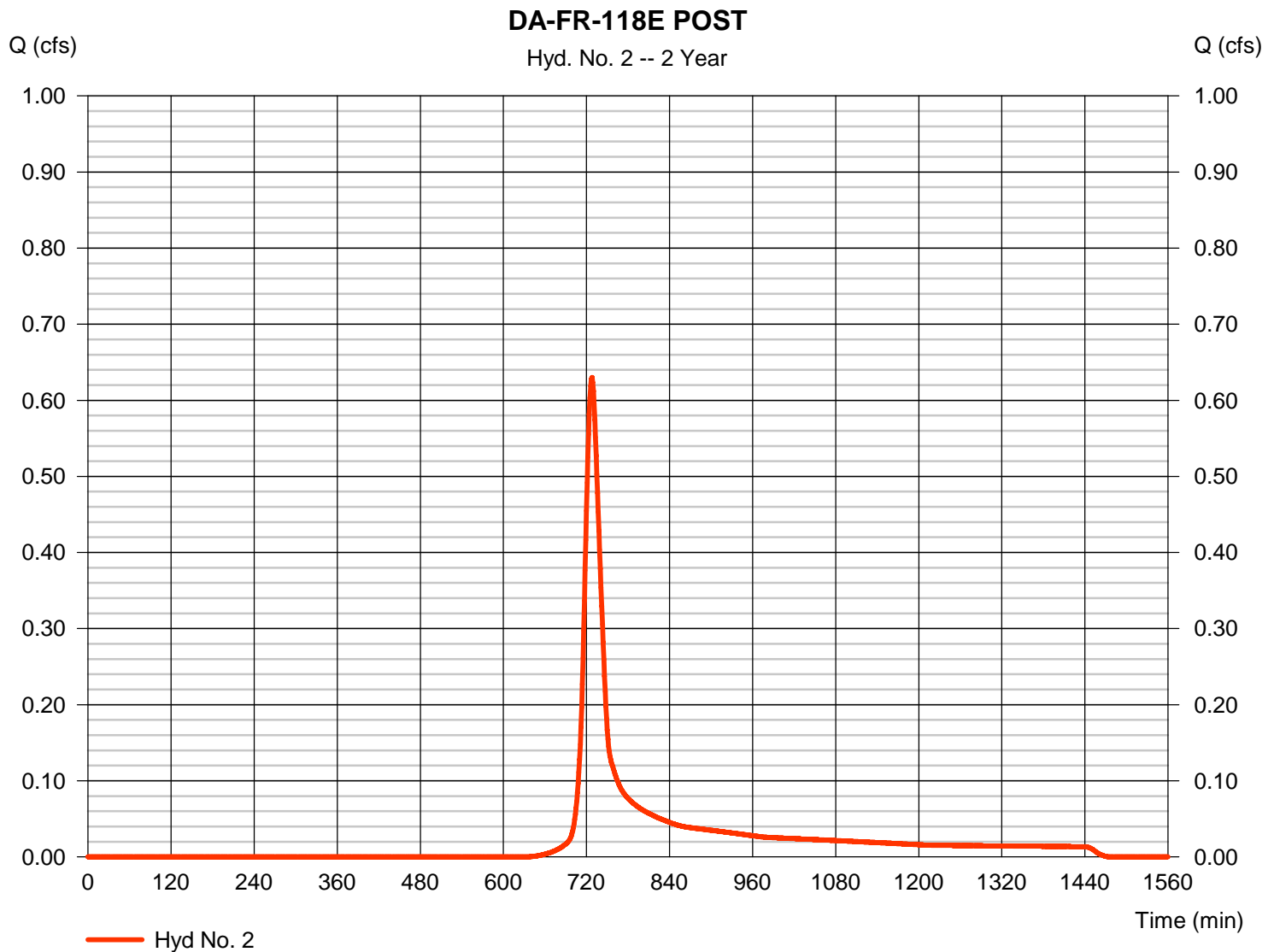
Hyd. No. 2

DA-FR-118E POST

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 0.470 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.630 cfs
 Time to peak = 728 min
 Hyd. volume = 2,225 cuft
 Curve number = 73*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 23.30 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(0.050 \times 89) + (0.420 \times 71)] / 0.470$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Tuesday, 08 / 15 / 2017

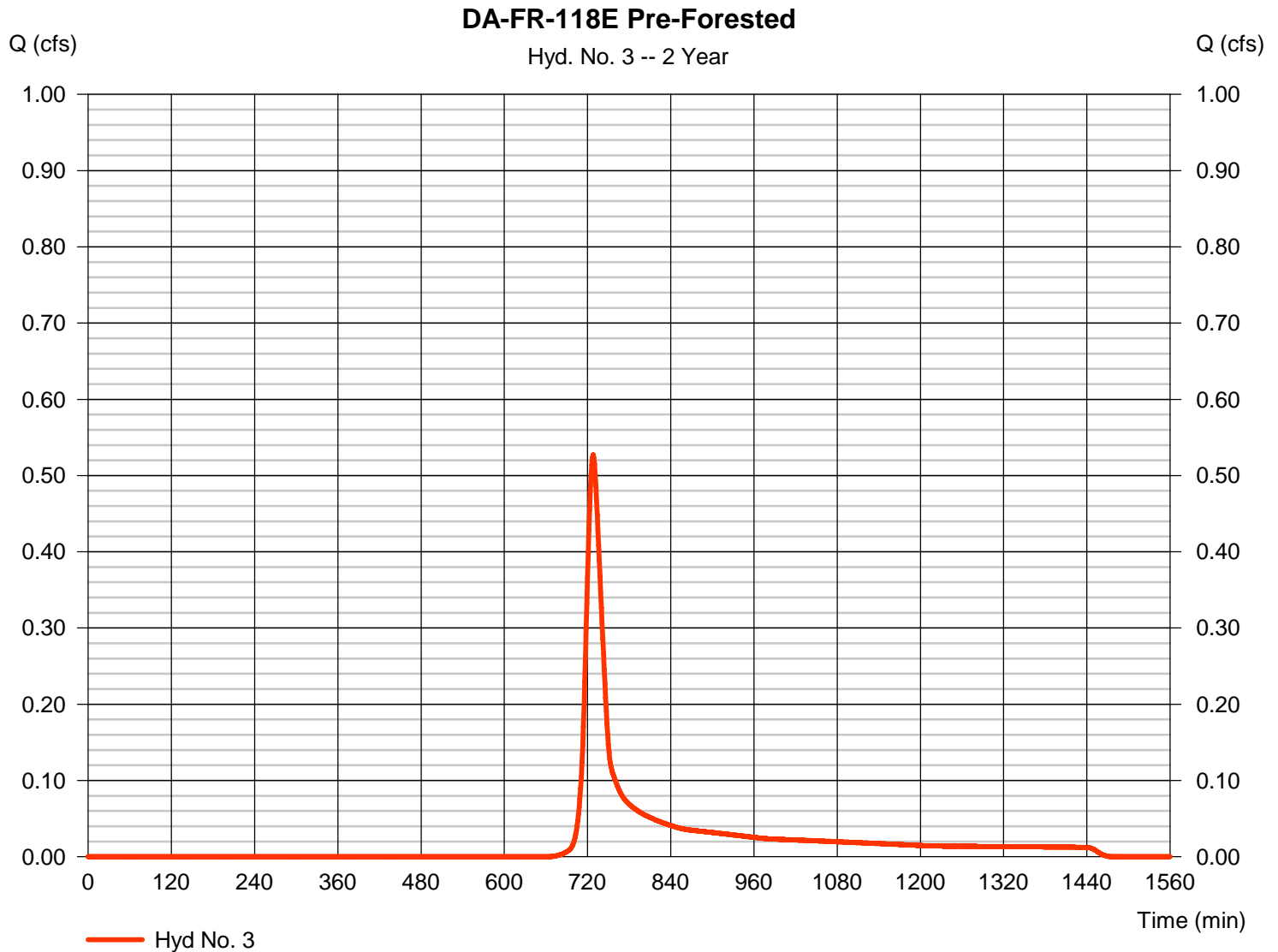
Hyd. No. 3

DA-FR-118E Pre-Forested

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 0.470 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.527 cfs
 Time to peak = 728 min
 Hyd. volume = 1,917 cuft
 Curve number = 70*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 23.30 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(0.470 \times 70)] / 0.470$



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	1.411	1	727	4,805	-----	-----	-----	DA-FR-118E PRE
2	SCS Runoff	1.411	1	727	4,805	-----	-----	-----	DA-FR-118E POST
3	SCS Runoff	1.266	1	727	4,344	-----	-----	-----	DA-FR-118E Pre-Forested
DA-FR-118e.gpw					Return Period: 10 Year			Tuesday, 08 / 15 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

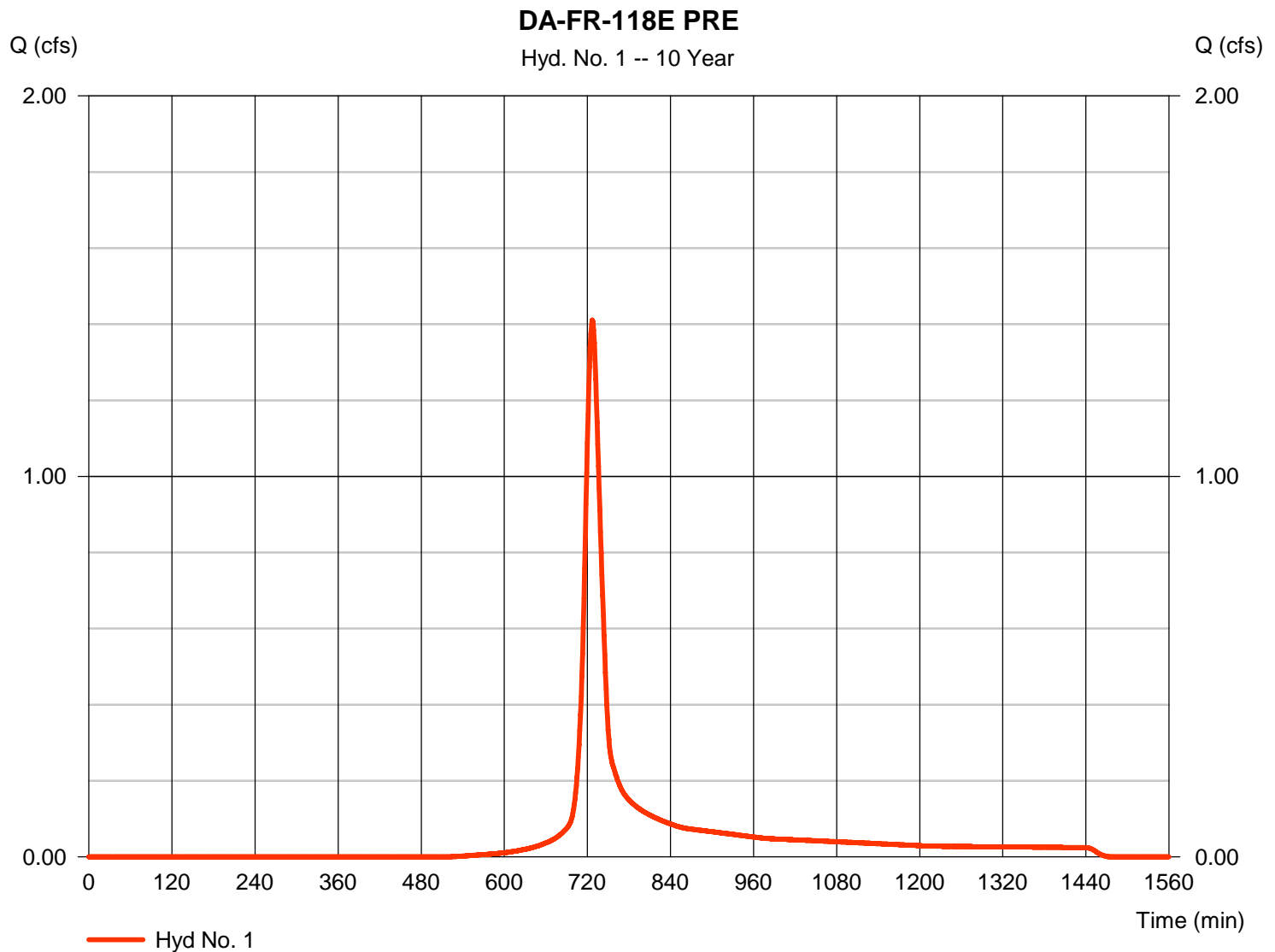
Tuesday, 08 / 15 / 2017

Hyd. No. 1

DA-FR-118E PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 1.411 cfs
Storm frequency	= 10 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 4,805 cuft
Drainage area	= 0.470 ac	Curve number	= 73*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 23.30 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.050 \times 89) + (0.420 \times 71)] / 0.470$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

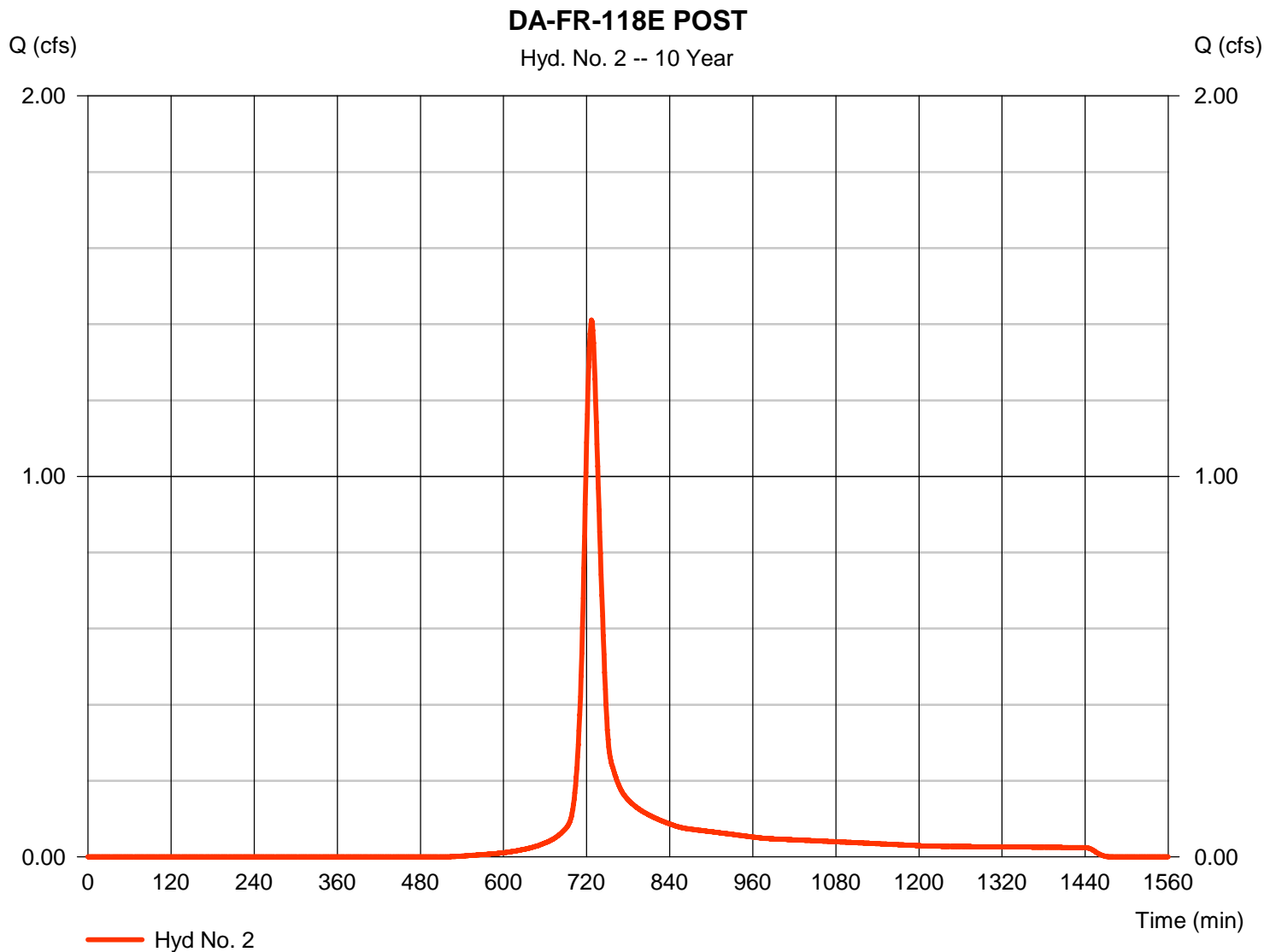
Tuesday, 08 / 15 / 2017

Hyd. No. 2

DA-FR-118E POST

Hydrograph type	= SCS Runoff	Peak discharge	= 1.411 cfs
Storm frequency	= 10 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 4,805 cuft
Drainage area	= 0.470 ac	Curve number	= 73*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 23.30 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.050 \times 89) + (0.420 \times 71)] / 0.470$



Hydrograph Report

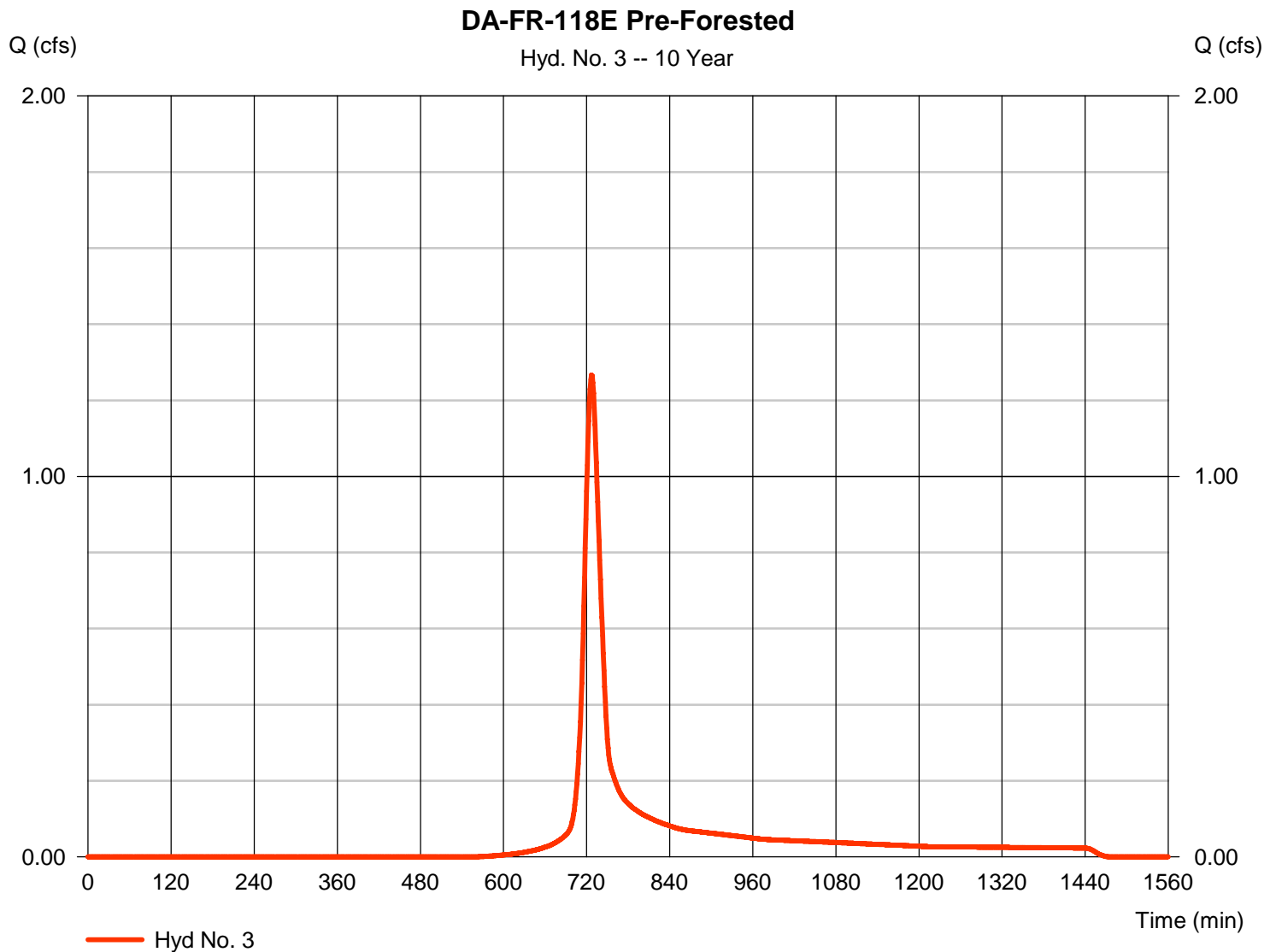
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Tuesday, 08 / 15 / 2017

Hyd. No. 3

DA-FR-118E Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.266 cfs
Storm frequency	=	10 yrs	Time to peak	=	727 min
Time interval	=	1 min	Hyd. volume	=	4,344 cuft
Drainage area	=	0.470 ac	Curve number	=	70*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	23.30 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(0.470 \times 70)] / 0.470$ 

DA-FR-119

DA-FR-119 is located in a meadow and forested areas with rolling to hilly slopes and contains agricultural land, existing dirt road and gravel road. Multiple points of analysis were evaluated within DA-FR-119 to evaluate the effects on each receiving stream/channel following construction. Specifically, DA-FR-119 was divided into four sub-drainage areas (sub-areas A to D).

Pre-construction agricultural areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction. In non-agricultural areas, land use will be restored following construction as noted in the Stormwater Management (SWM) Narrative and the Annual Standards and Specifications. Agricultural areas within the limits of disturbance (LOD) are included in the SWM quality analysis and the total permanent right-of-way is analyzed via VRRM; in these calculations agricultural areas are considered "Forest/Open Space". The total phosphorus load reduction required for DA-FR-119 is -0.37 lb/yr.

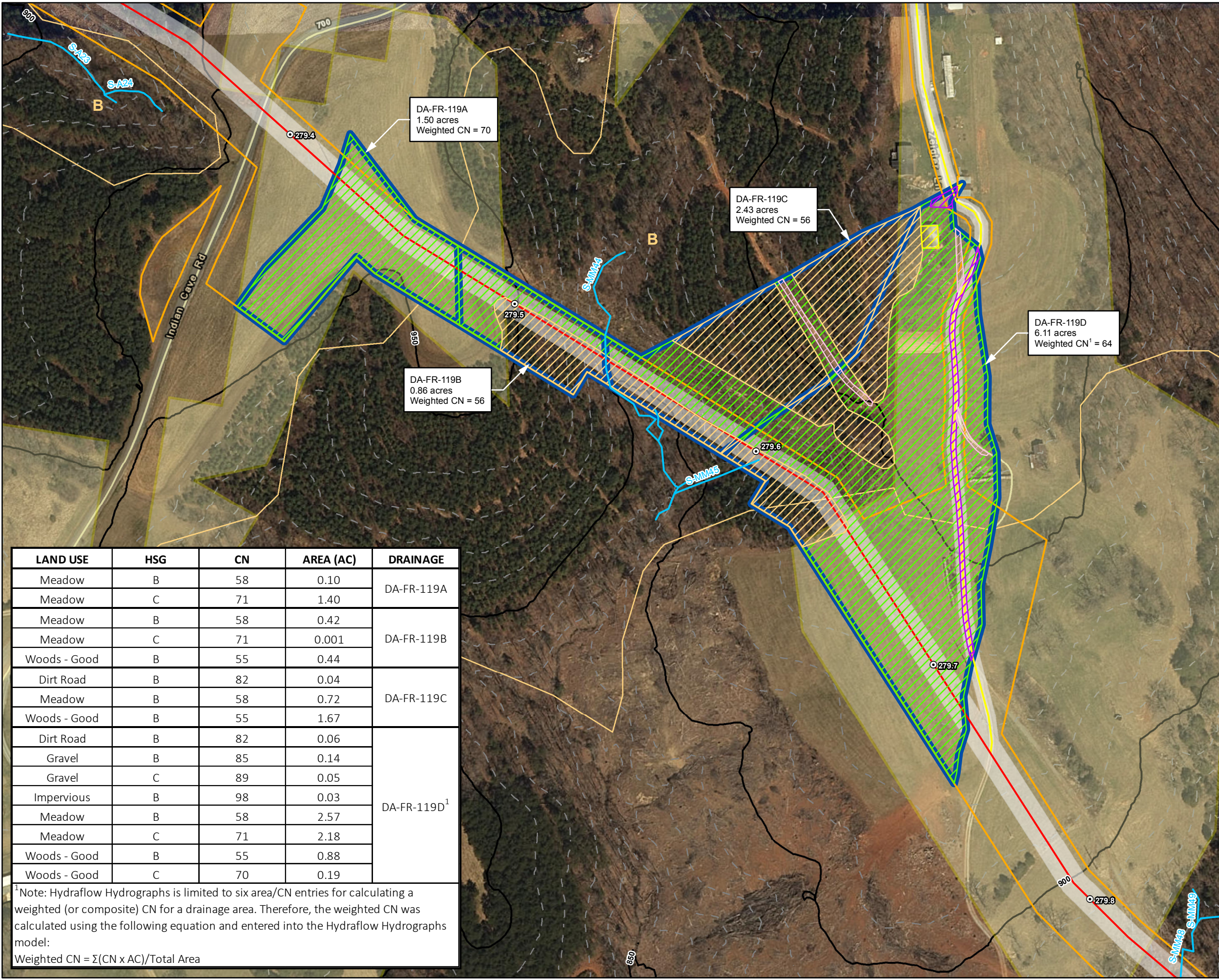
Agricultural areas/fields that will be returned to crop production, in identical condition, upon completion of pipeline construction are exempt from meeting the VA water quality (9VAC25-870-63) and the VA water quantity (9VAC25-870-66) requirements per § 62.1-44.15:34 and 9VAC25-870-300. Therefore, the provisions of water quality design criteria requirements and permanent stormwater management controls for DA-FR-119A are exempt and no stormwater BMPs are required.

Stormwater quantity is met via the energy balance method for DA-FR-119B and DA-FR-119D. In addition to the energy balance method, storm water quantity in sub-area DA-FR-119C is met by two 2 ft by 50 ft compost amended water bar areas (See General Detail MVP-ES38 for a full schedule). Sub-area DA-FR-119C contains entirely non-agricultural areas within the LOD, therefore an Improvement Factor of 0.8 is used when applying the Energy Balance Method per 9VAC25-870-66.B.3.a. Sub-areas DA-FR-119B and DA-FR-119D contain both agricultural and non-agricultural areas within the LOD. For SWM quantity, agricultural areas within the study area are considered/included but an Improvement Factor of 1.0 is used when applying the Energy Balance Method to account for the exemption of agricultural areas (§ 62.1-44.15:34 and 9VAC25-870-300) since such areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction.

The Hydraflow 10-year 24-hour peak discharge results indicate a reduction in flows ranging from 0 to 0.12 cfs for sub-drainage areas DA-FR-119 B to D (as seen in the following table).

Sub-Area	Pre Peak Flow, 10-yr Q (cfs)	Post Peak Flow, 10-yr Q (cfs)	Flow Differential
DA-FR-119B	1.96	1.84	-0.12
DA-FR-119C	4.26	4.24	-0.02
DA-FR-119D	15.73	15.73	0.00

Figures and calculations for each of the sub-areas for DA-FR-119 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.



Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Agricultural Area
- Dirt Road
- Gravel
- Impervious
- Meadow
- Woods
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)
1:2,100

17587.50175

Feet

N

W

S

E

LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Meadow	B	58	0.10	DA-FR-119A
Meadow	C	71	1.40	
Meadow	B	58	0.42	DA-FR-119B
Meadow	C	71	0.001	
Woods - Good	B	55	0.44	DA-FR-119C
Dirt Road	B	82	0.04	
Meadow	B	58	0.72	
Woods - Good	B	55	1.67	DA-FR-119D ¹
Dirt Road	B	82	0.06	
Gravel	B	85	0.14	
Gravel	C	89	0.05	
Impervious	B	98	0.03	
Meadow	B	58	2.57	
Meadow	C	71	2.18	
Woods - Good	B	55	0.88	
Woods - Good	C	70	0.19	

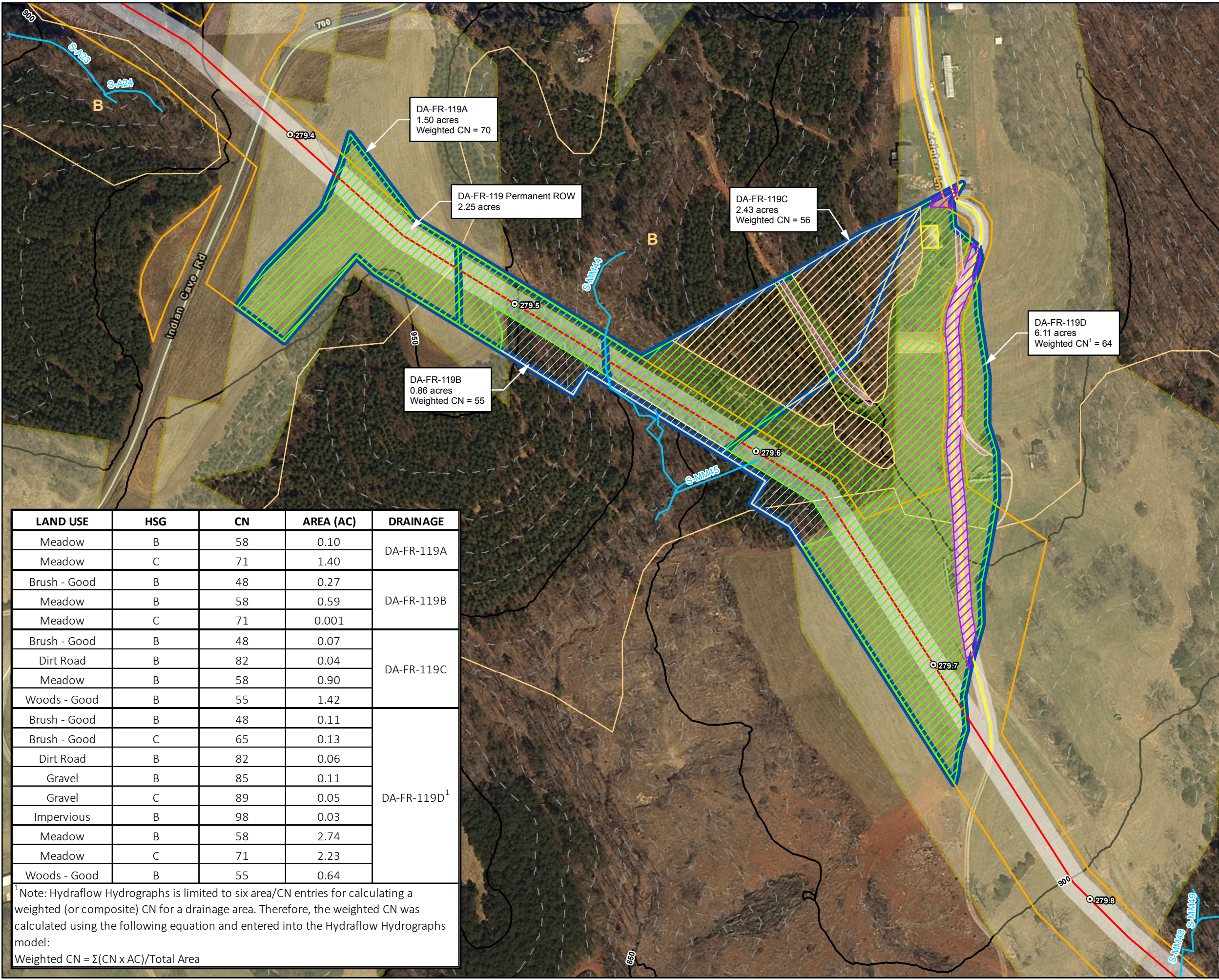
¹Note: Hydraflow Hydrographs is limited to six area/CN entries for calculating a weighted (or composite) CN for a drainage area. Therefore, the weighted CN was calculated using the following equation and entered into the Hydraflow Hydrographs model:
Weighted CN = $\sum(CN \times AC) / \text{Total Area}$



Mountain Valley Pipeline Project

Pre-Construction Drainage Area Map
DA-FR-119
Spread 11
Figure 1
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.



Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Agricultural Area
- Brush
- Dirt Road
- Gravel
- Impervious
- Meadow
- Woods
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:2,100

175 87.5 0 175 Feet

LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Meadow	B	58	0.10	DA-FR-119A
Meadow	C	71	1.40	
Brush - Good	B	48	0.27	DA-FR-119B
Meadow	B	58	0.59	
Meadow	C	71	0.001	DA-FR-119C
Brush - Good	B	48	0.07	
Dirt Road	B	82	0.04	DA-FR-119C
Meadow	B	58	0.90	
Woods - Good	B	55	1.42	DA-FR-119D ¹
Brush - Good	B	48	0.11	
Brush - Good	C	65	0.13	
Dirt Road	B	82	0.06	
Gravel	B	85	0.11	
Gravel	C	89	0.05	
Impervious	B	98	0.03	
Meadow	B	58	2.74	
Meadow	C	71	2.23	
Woods - Good	B	55	0.64	

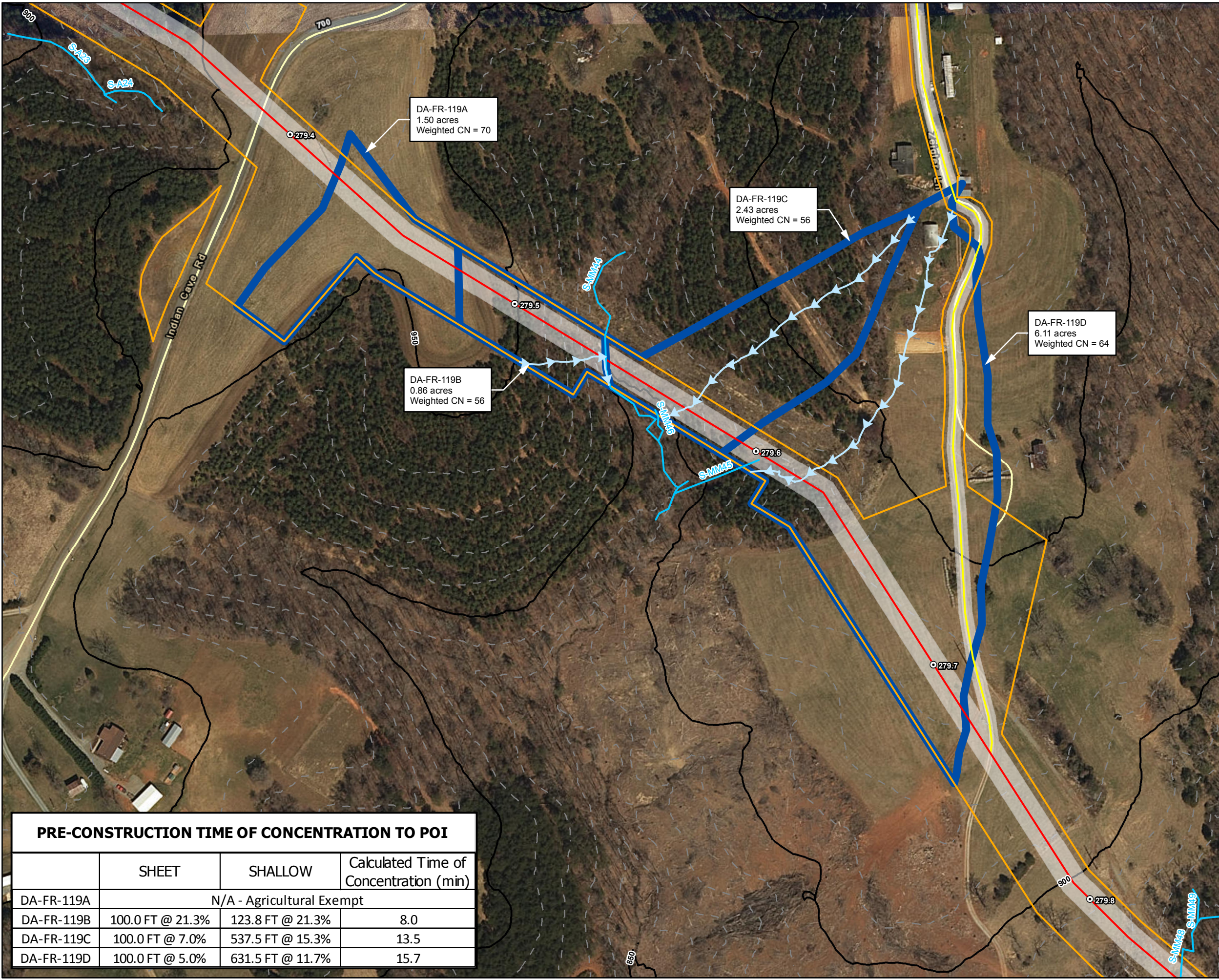
¹Note: Hydraflow Hydrographs is limited to six area/CN entries for calculating a weighted (or composite) CN for a drainage area. Therefore, the weighted CN was calculated using the following equation and entered into the Hydraflow Hydrographs model:
Weighted CN = $\sum(CN \times AC) / \text{Total Area}$



Mountain Valley Pipeline Project**Post-Construction Drainage Area Map**
DA-FR-119
Spread 11
Figure 2
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

Document Path: P:\GIS\EQ1_MVP\Mapdocs\Drainage\MXD\FranklinMVP_PCSM_DA-FR-119_Post.mxd



Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:2,100

175 87.5 0 175 Feet



PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI			
	SHEET	SHALLOW	Calculated Time of Concentration (min)
DA-FR-119A	N/A - Agricultural Exempt		
DA-FR-119B	100.0 FT @ 21.3%	123.8 FT @ 21.3%	8.0
DA-FR-119C	100.0 FT @ 7.0%	537.5 FT @ 15.3%	13.5
DA-FR-119D	100.0 FT @ 5.0%	631.5 FT @ 11.7%	15.7

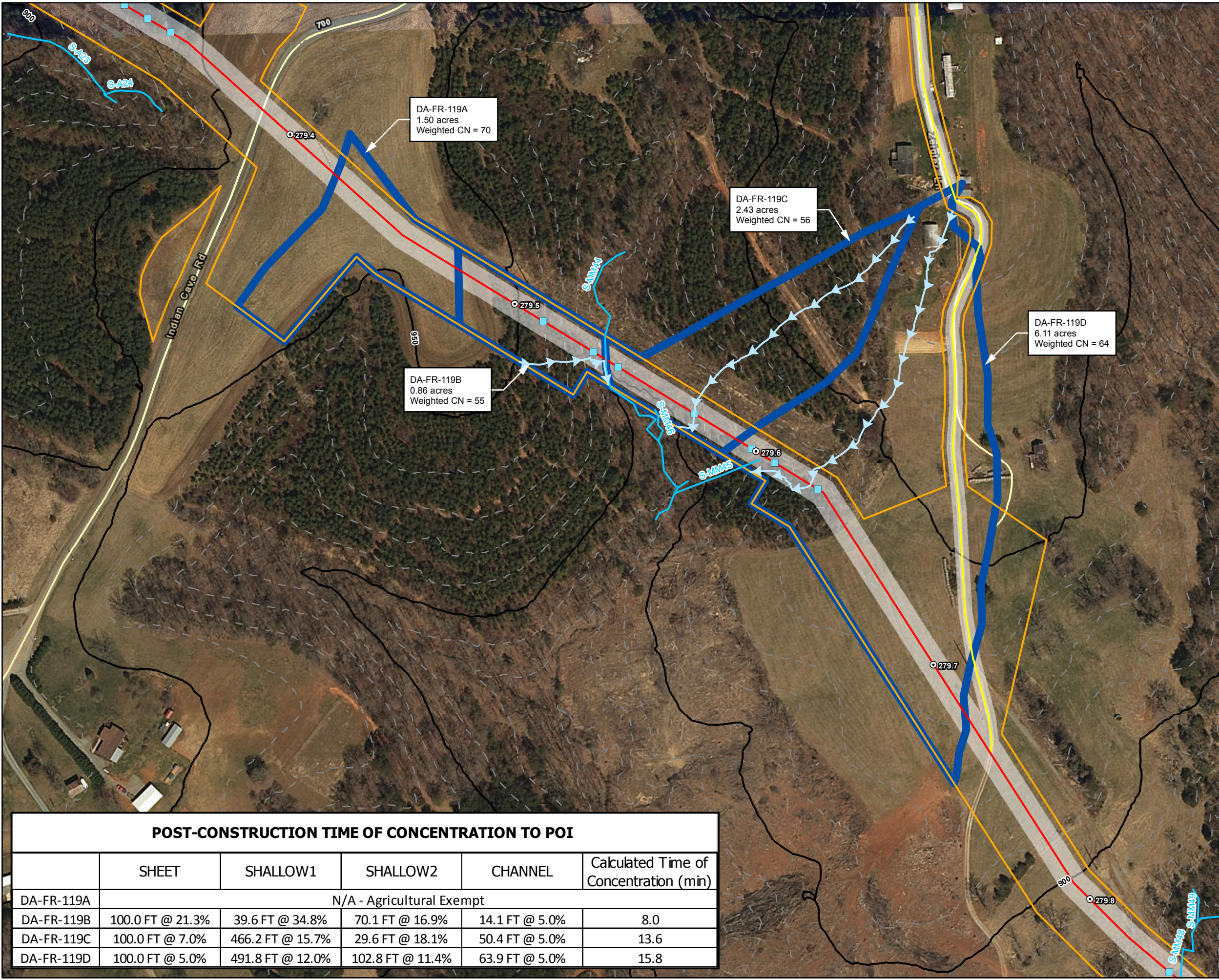
Mountain Valley Pipeline Project



Pre-Construction Drainage Area and Time of Concentration
DA-FR-119
Spread 11

Figure 3
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.



Legend

- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:2,100

175 87.5 0 175 Feet

Mountain Valley Pipeline Project

Post-Construction Drainage Area and Time of Concentration
DA-FR-119
Spread 11
Figure 4
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.

POST-CONSTRUCTION TIME OF CONCENTRATION TO POI					
	SHEET	SHALLOW1	SHALLOW2	CHANNEL	Calculated Time of Concentration (min)
DA-FR-119A	N/A - Agricultural Exempt				
DA-FR-119B	100.0 FT @ 21.3%	39.6 FT @ 34.8%	70.1 FT @ 16.9%	14.1 FT @ 5.0%	8.0
DA-FR-119C	100.0 FT @ 7.0%	466.2 FT @ 15.7%	29.6 FT @ 18.1%	50.4 FT @ 5.0%	13.6
DA-FR-119D	100.0 FT @ 5.0%	491.8 FT @ 12.0%	102.8 FT @ 11.4%	63.9 FT @ 5.0%	15.8

DEQ Virginia Runoff Reduction Method Re-Development Compliance Spreadsheet - Version 3.0

BMP Design Specifications List: 2013 Draft Stds & Specs

Site Summary - Linear Development Project***

Total Rainfall (in):	43
Total Disturbed Acreage:	2.25

Site Land Cover Summary

Pre-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	1.12	0.95	0.00	2.07	92
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.13	0.05	0.00	0.18	8
					2.25	100

Post-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	1.12	0.95	0.00	2.07	92
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.13	0.05	0.00	0.18	8
					2.25	100

* Forest/Open Space areas must be protected in accordance with the Virginia Runoff Reduction Method

Site Tv and Land Cover Nutrient Loads

	Final Post-Development (Post-ReDevelopment & New Impervious)	Post- ReDevelopment	Post- Development (New Impervious)	Adjusted Pre- ReDevelopment
Site Rv	0.11	0.11	--	0.11
Treatment Volume (ft ³)	881	881	--	881
TP Load (lb/yr)	0.55	0.55	--	0.55

Baseline TP Load (lb/yr): 0.9225* **Reduction below new development load limitation not required*

Pre- ReDevelopment TP Load per acre (lb/acre/yr)	Final Post-Development TP Load per acre (lb/acre/yr)	Post-ReDevelopment TP Load per acre (lb/acre/yr)
0.25	0.25	0.25

Total TP Load Reduction Required (lb/yr)	-0.37	N/A***	N/A***
--	-------	--------	--------

***This is a linear development project

	Final Post-Development Load (Post-ReDevelopment & New Impervious)	Pre- ReDevelopment
TN Load (lb/yr)	3.96	3.96

Site Compliance Summary - ***Linear Development Project

Maximum % Reduction Required Below Pre-ReDevelopment Load	20%
--	-----

** Note: % Reduction will reduce post-development TP load to less than or equal to baseline load of 0.92 lb/yr (0.41 lb/ac/yr)
[Post-Dev Reduction Requirement = Post-Dev TP load - baseline load of 0.92 lb/yr], baseline load = site area x 0.41 lb/ac/yr*

Total Runoff Volume Reduction (ft ³)	0
Total TP Load Reduction Achieved (lb/yr)	0.00
Total TN Load Reduction Achieved (lb/yr)	0.00
Remaining Post Development TP Load (lb/yr)	0.55
Remaining TP Load Reduction (lb/yr) Required	0.00

**** TARGET TP REDUCTION EXCEEDED BY 0.37 LB/YEAR ****

**Reduction below new development load limitation not required*

DA-FR-119B

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.256	949
Developed Condition	0.204	856
Pre-Developed (Forest) Condition	0.204	856

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF =

1

Calculations:

Check #1:

$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->

Q (cfs)

0.204

≤

OK

Q (cfs)

0.284

Check #2:

$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->

0.204

≤

OK

0.256

Check #3:

$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ --->

0.204

shall not be required to be ≤

0.204

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p><i>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</i></p> <p><i>For Paved Road land surface types a Manning’s n value of 0.011 was used.</i></p> <p><i>Sources:</i></p> <p><i>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</i></p> <p><i>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</i></p>	

Table 2 – Manning's n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's n value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's n value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

1



2



3



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-119B PRE
2	SCS Runoff	DA-FR-119B POST
3	SCS Runoff	DA-FR-119B Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.256	1	721	949	-----	-----	-----	DA-FR-119B PRE
2	SCS Runoff	0.204	1	721	856	-----	-----	-----	DA-FR-119B POST
3	SCS Runoff	0.204	1	721	856	-----	-----	-----	DA-FR-119B Pre-Forested
DA-FR-119b.gpw					Return Period: 1 Year			Monday, 08 / 14 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

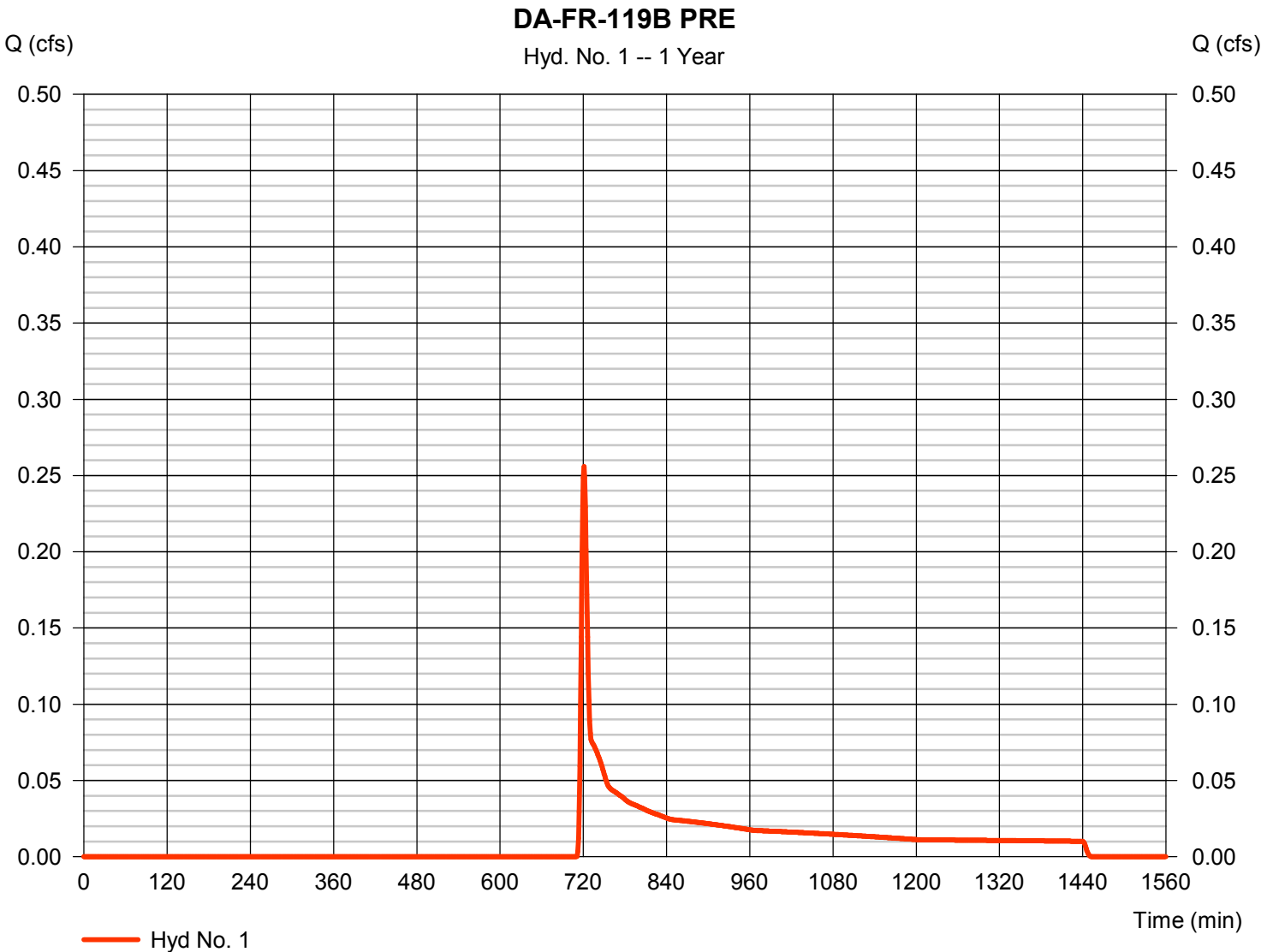
Monday, 08 / 14 / 2017

Hyd. No. 1

DA-FR-119B PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.256 cfs
Storm frequency	=	1 yrs	Time to peak	=	721 min
Time interval	=	1 min	Hyd. volume	=	949 cuft
Drainage area	=	0.860 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	8.00 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.421 x 58) + (0.001 x 71) + (0.439 x 55)] / 0.860



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-119B PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 21.30	0.00	0.00				
Travel Time (min)	= 7.75	+	0.00	+	0.00	=	7.75
Shallow Concentrated Flow							
Flow length (ft)	= 123.80	0.00	0.00				
Watercourse slope (%)	= 21.30	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=7.45	0.00	0.00				
Travel Time (min)	= 0.28	+	0.00	+	0.00	=	0.28
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	= 0.040	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				8.00 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

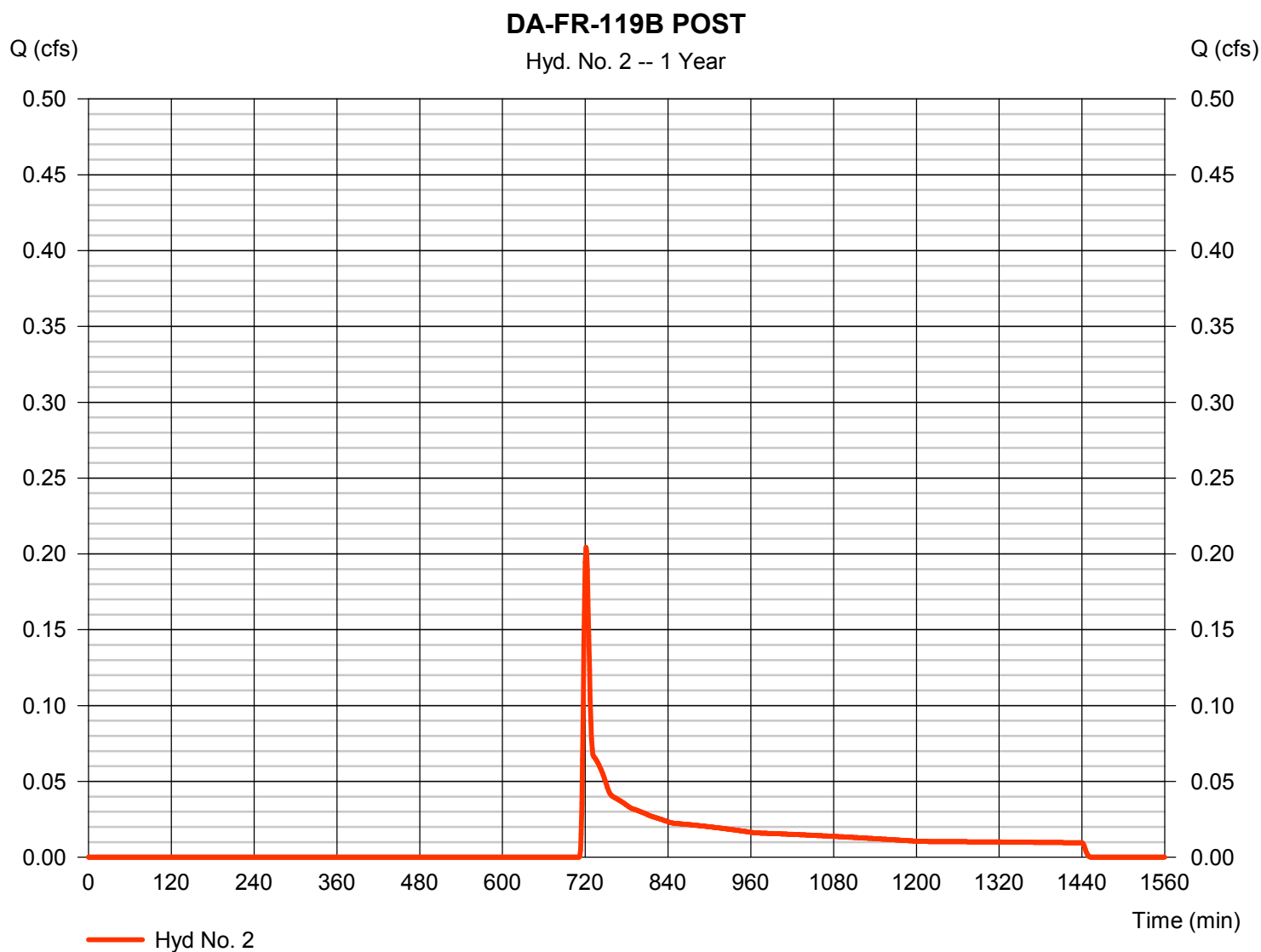
Monday, 08 / 14 / 2017

Hyd. No. 2

DA-FR-119B POST

Hydrograph type	= SCS Runoff	Peak discharge	= 0.204 cfs
Storm frequency	= 1 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 856 cuft
Drainage area	= 0.860 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.00 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.271 \times 48) + (0.589 \times 58) + (0.001 \times 71)] / 0.860$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-119B POST

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.800	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 21.30	0.00	0.00				
Travel Time (min)	= 7.75	+	0.00	+	0.00	=	7.75
Shallow Concentrated Flow							
Flow length (ft)	= 39.60	70.10	0.00				
Watercourse slope (%)	= 34.80	16.90	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=9.52	6.63	0.00				
Travel Time (min)	= 0.07	+	0.18	+	0.00	=	0.25
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	(0)14.1	0.0	0.0				
Travel Time (min)	= 0.05	+	0.00	+	0.00	=	0.05
Total Travel Time, Tc				8.00 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

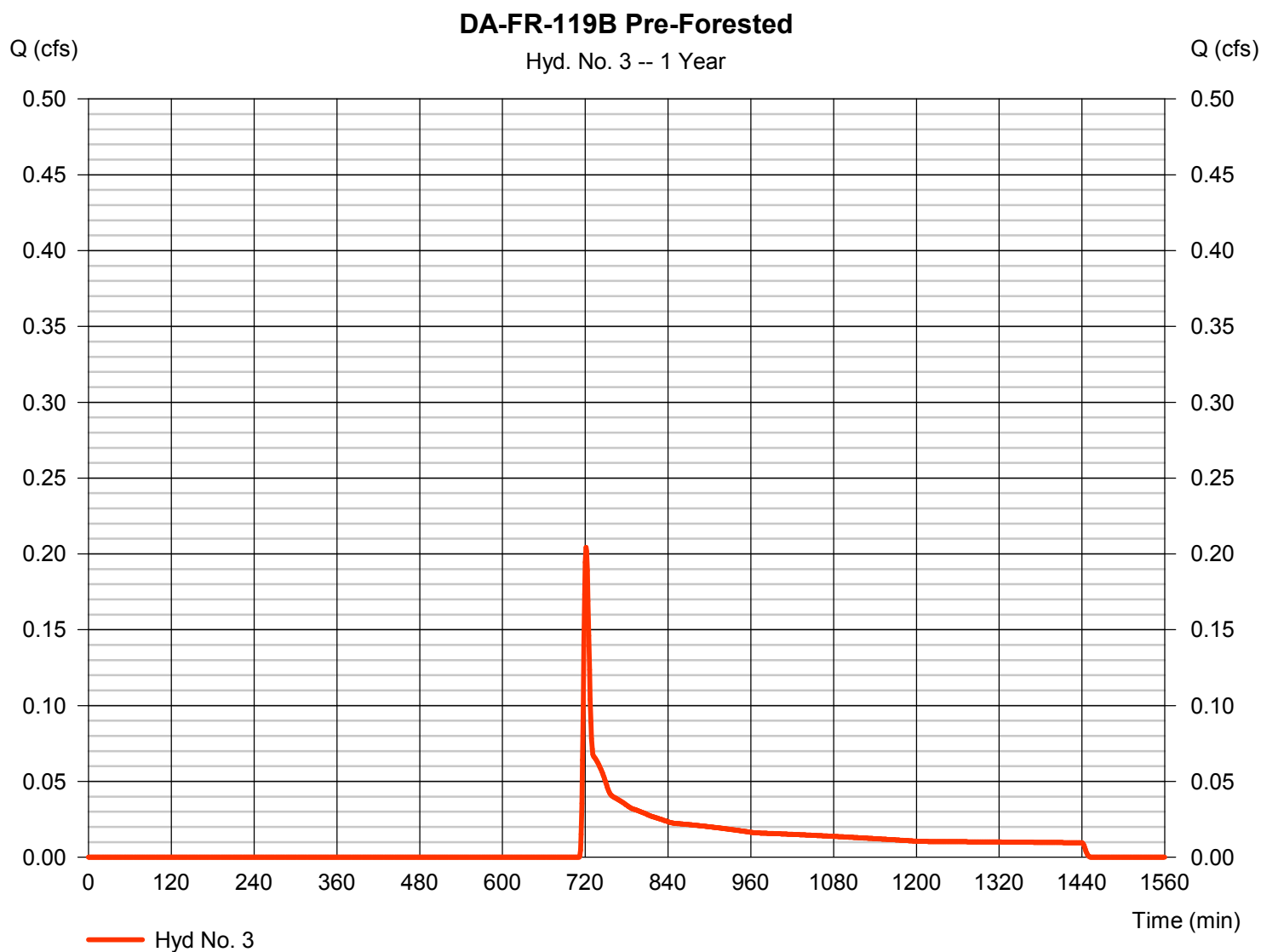
Monday, 08 / 14 / 2017

Hyd. No. 3

DA-FR-119B Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.204 cfs
Storm frequency	= 1 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 856 cuft
Drainage area	= 0.860 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.00 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.860 \times 55) + (0.001 \times 70)] / 0.860$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-119B Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 21.30	0.00	0.00				
Travel Time (min)	= 7.75	+	0.00	+	0.00	=	7.75
Shallow Concentrated Flow							
Flow length (ft)	= 123.80	0.00	0.00				
Watercourse slope (%)	= 21.30	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=7.45	0.00	0.00				
Travel Time (min)	= 0.28	+	0.00	+	0.00	=	0.28
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	= 0.030	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				8.00 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.468	1	720	1,381	-----	-----	-----	DA-FR-119B PRE
2	SCS Runoff	0.399	1	721	1,265	-----	-----	-----	DA-FR-119B POST
3	SCS Runoff	0.399	1	721	1,265	-----	-----	-----	DA-FR-119B Pre-Forested
DA-FR-119b.gpw					Return Period: 2 Year			Monday, 08 / 14 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

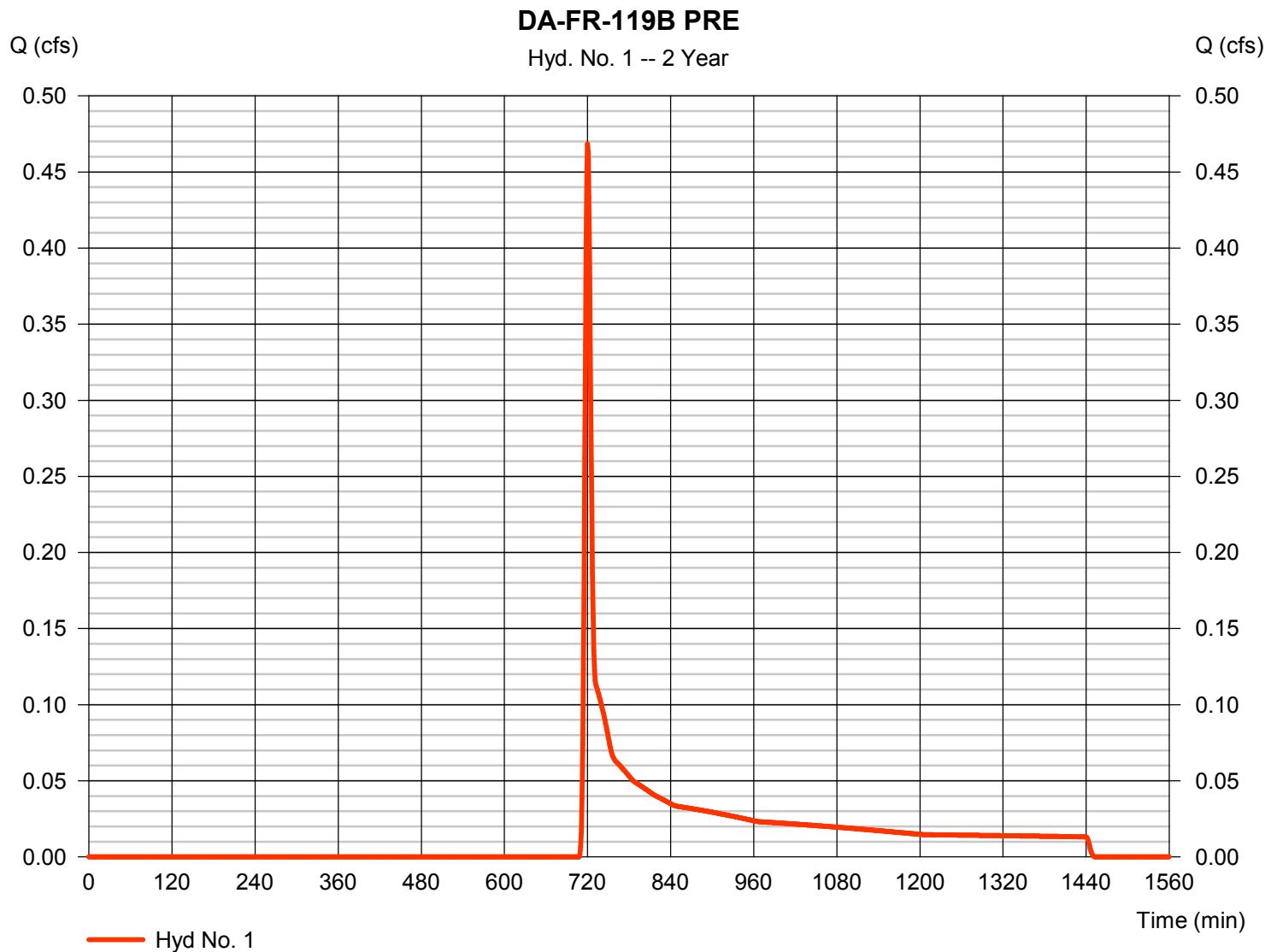
Monday, 08 / 14 / 2017

Hyd. No. 1

DA-FR-119B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.468 cfs
Storm frequency	= 2 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 1,381 cuft
Drainage area	= 0.860 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.00 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.421 \times 58) + (0.001 \times 71) + (0.439 \times 55)] / 0.860$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

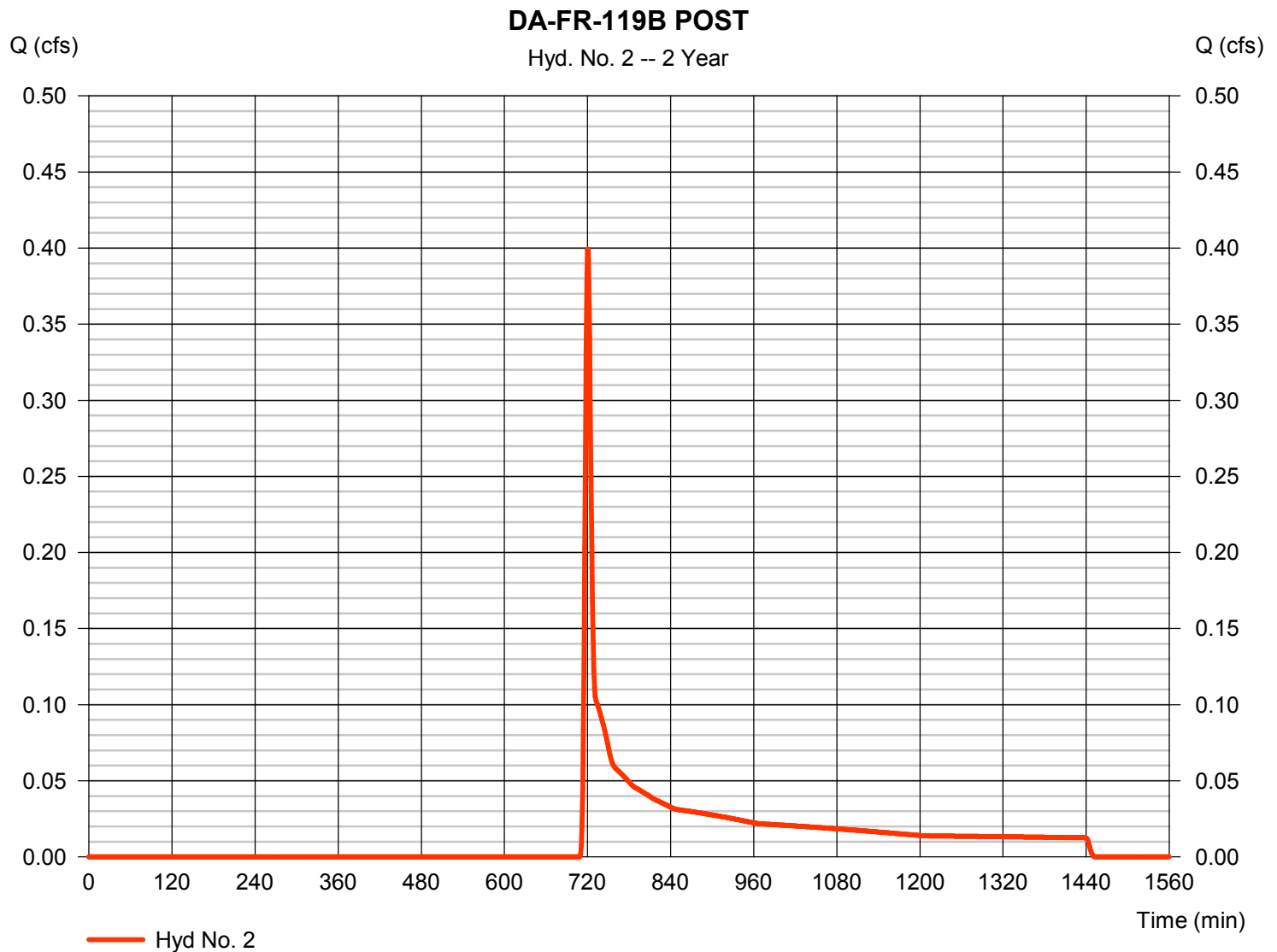
Monday, 08 / 14 / 2017

Hyd. No. 2

DA-FR-119B POST

Hydrograph type	= SCS Runoff	Peak discharge	= 0.399 cfs
Storm frequency	= 2 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 1,265 cuft
Drainage area	= 0.860 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.00 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.271 \times 48) + (0.589 \times 58) + (0.001 \times 71)] / 0.860$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

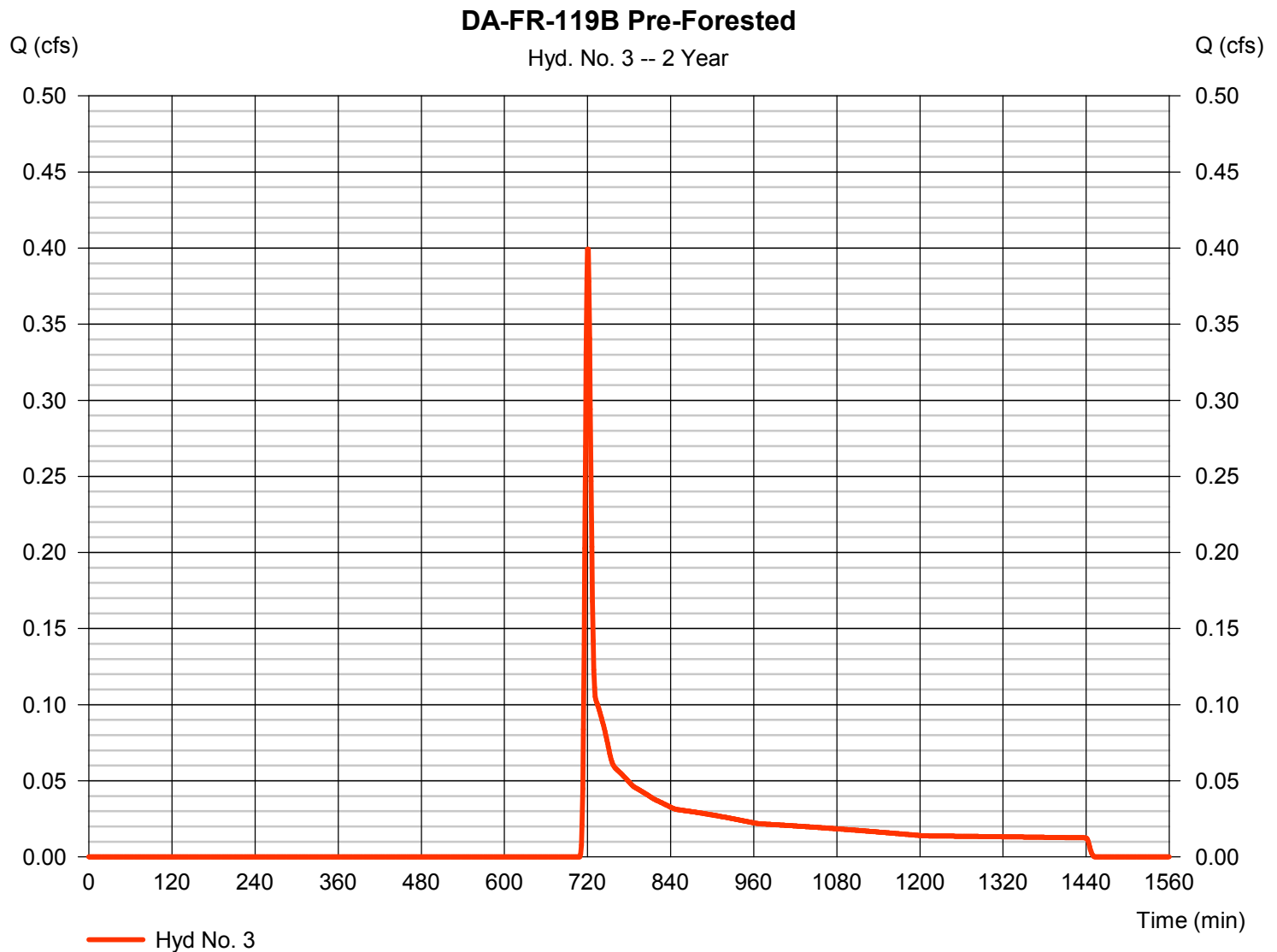
Monday, 08 / 14 / 2017

Hyd. No. 3

DA-FR-119B Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.399 cfs
Storm frequency	= 2 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 1,265 cuft
Drainage area	= 0.860 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.00 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.860 \times 55) + (0.001 \times 70)] / 0.860$



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	1.963	1	719	4,329	-----	-----	-----	DA-FR-119B PRE
2	SCS Runoff	1.841	1	719	4,105	-----	-----	-----	DA-FR-119B POST
3	SCS Runoff	1.841	1	719	4,105	-----	-----	-----	DA-FR-119B Pre-Forested
DA-FR-119b.gpw					Return Period: 10 Year			Monday, 08 / 14 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

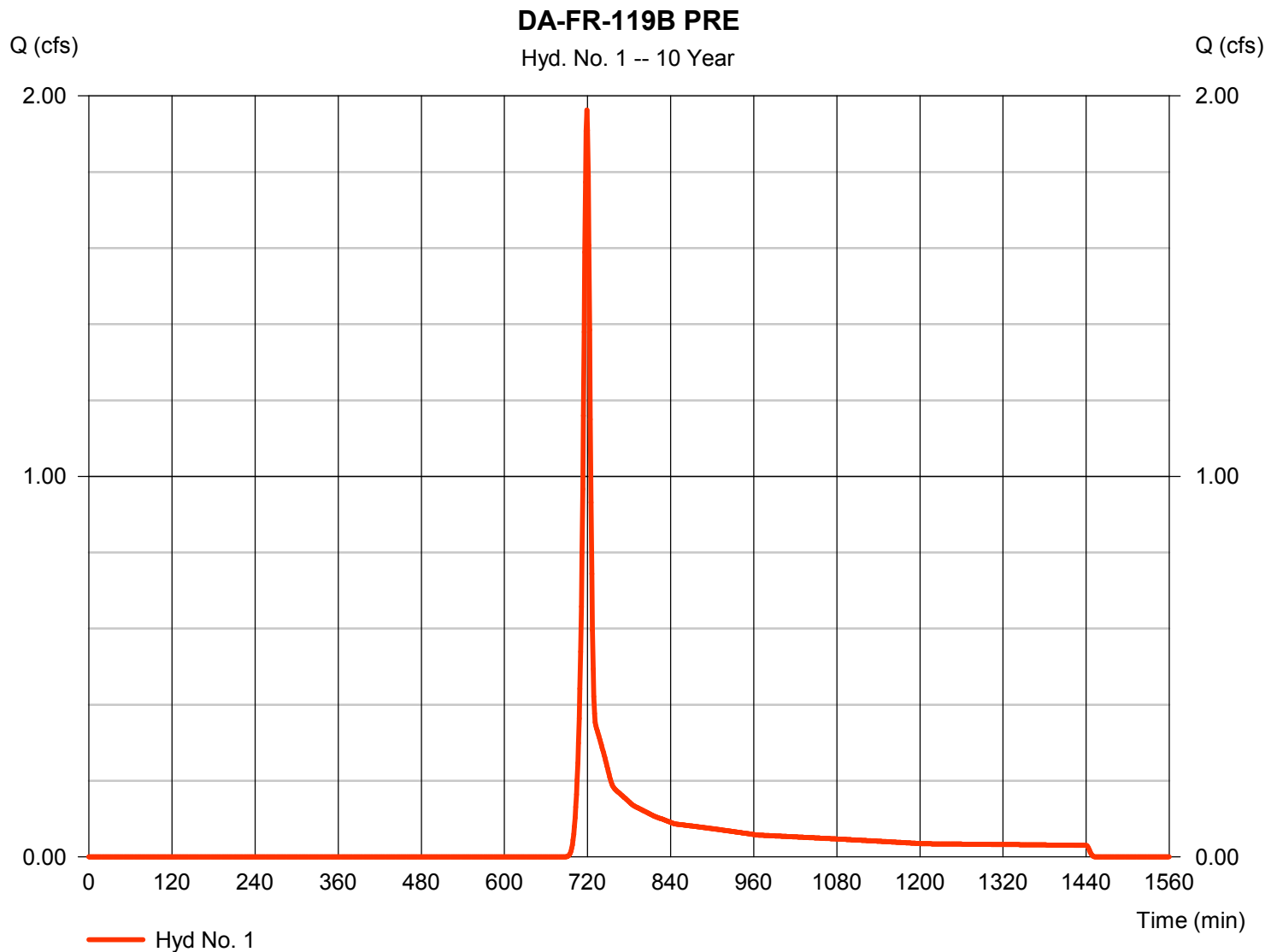
Monday, 08 / 14 / 2017

Hyd. No. 1

DA-FR-119B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 1.963 cfs
Storm frequency	= 10 yrs	Time to peak	= 719 min
Time interval	= 1 min	Hyd. volume	= 4,329 cuft
Drainage area	= 0.860 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.00 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.421 \times 58) + (0.001 \times 71) + (0.439 \times 55)] / 0.860$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

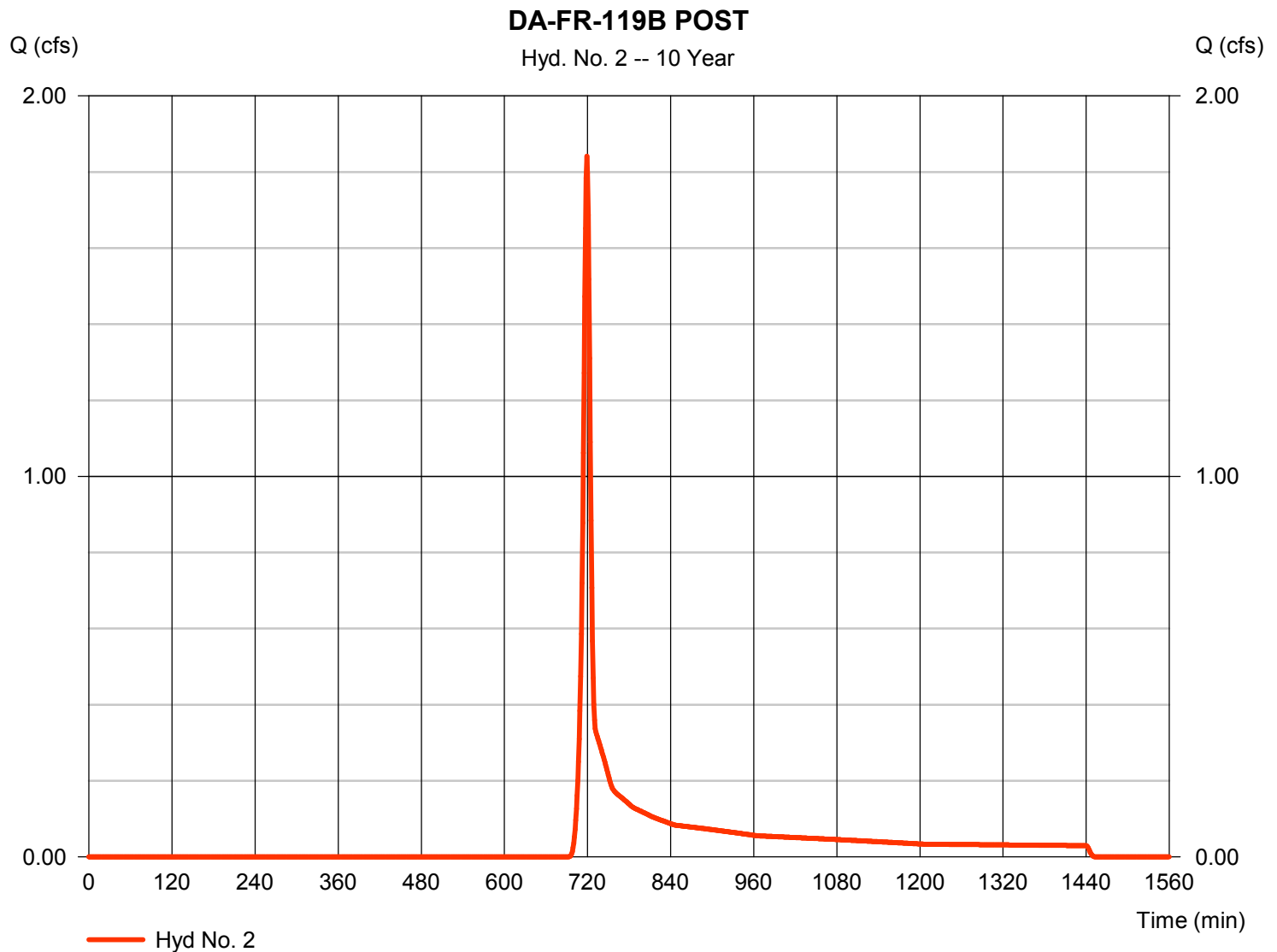
Monday, 08 / 14 / 2017

Hyd. No. 2

DA-FR-119B POST

Hydrograph type	= SCS Runoff	Peak discharge	= 1.841 cfs
Storm frequency	= 10 yrs	Time to peak	= 719 min
Time interval	= 1 min	Hyd. volume	= 4,105 cuft
Drainage area	= 0.860 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.00 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.271 \times 48) + (0.589 \times 58) + (0.001 \times 71)] / 0.860$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

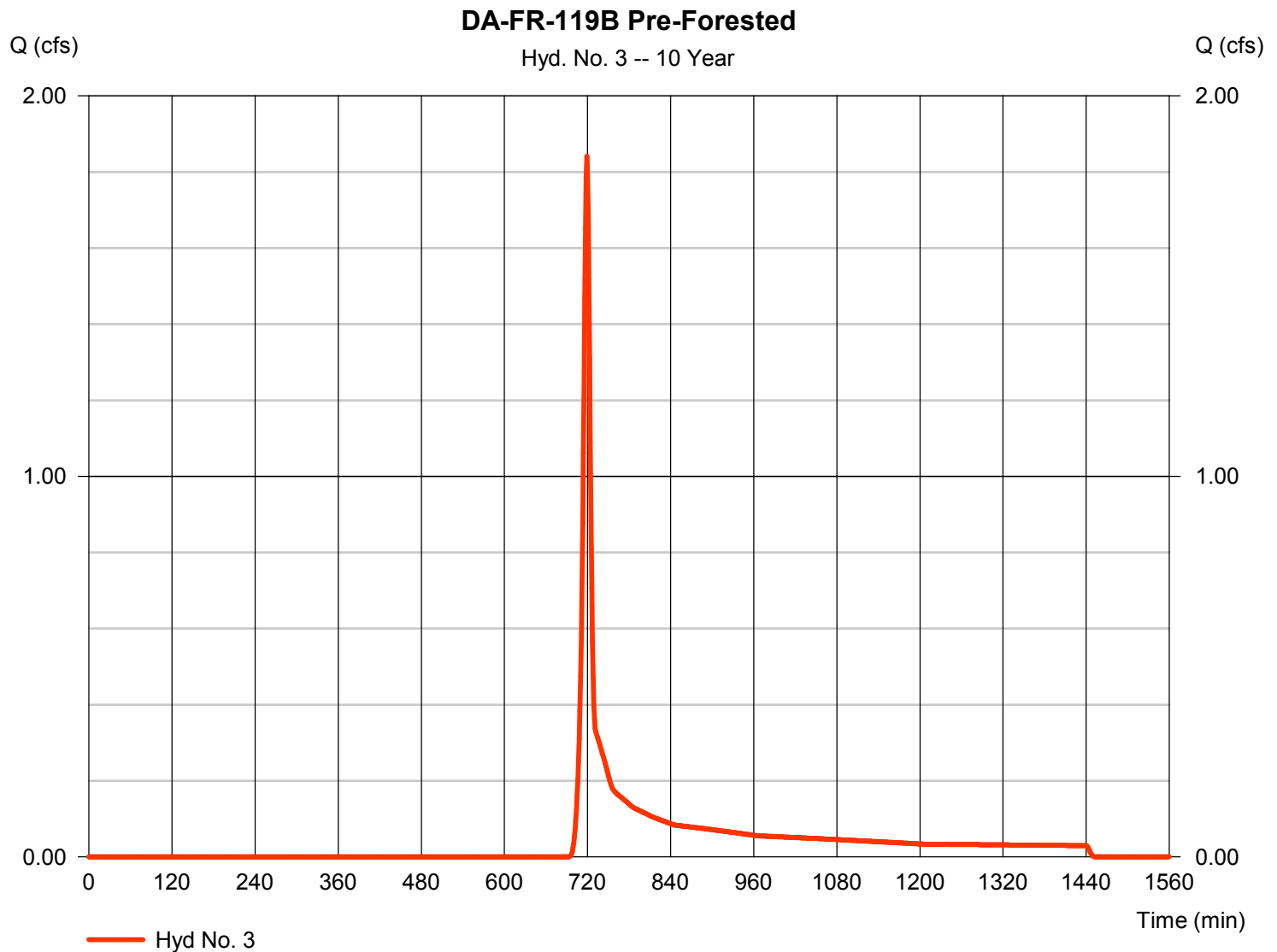
Monday, 08 / 14 / 2017

Hyd. No. 3

DA-FR-119B Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 1.841 cfs
Storm frequency	= 10 yrs	Time to peak	= 719 min
Time interval	= 1 min	Hyd. volume	= 4,105 cuft
Drainage area	= 0.860 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.00 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.860 \times 55) + (0.001 \times 70)] / 0.860$



DA-FR-119C

STORAGE VOLUME OF WATERBAR WITH SOIL COMPOST AMENDMENT AREA

Equations Used:

¹ $V_{\text{gravel storage}} = L * W * D_{\text{gravel}} * (40/100)$

² $V_{\text{soil storage}} = L * W * D_{\text{soil}} * (20/100)$

³ $V_{\text{surface storage}} = [W * S * D^2 * 2] + [L * S * D^2 * 2] + [W * L * D] + [(2 * S * D)^2 * D] / 3]$

¹Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that gravel is made up of 40% voids.

²Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that soil compost amendment is made up of 20% voids.

³Equation #1 under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, but calculation also takes into account surface side slopes.

Inputs:	Depth of Gravel Layer, D_{gravel} (ft) =	0	
	Depth of Soil Amendment Area, D_{soil} (ft) =	1	Refer to Table 4.3 in VA DEQ Stormwater Design Specification No. 4; Note that compost amendment may not be necessary for HSG A/B soils Assume max. length of 50' for waterbar soil amendment areas (i.e., limited to permanent ROW)
	Length of Waterbar Soil Amendment Area, L (ft) =	50	
	Width of Waterbar Soil Amendment Area, W (ft) =	2	
	Inside Embankment Side Slopes, S (H:V) =	2	
	Number of Perm. Waterbars in Drainage Area, n =	2	Assume 2H:1V surface side slopes for waterbars
	Design Infiltration Rate, IR (in/hr) =	0.2	Min. rate of 0.30 in/hr for HSG A soils and 0.15-0.30 in/hr for HSG B soils (see Chap. 4, p. 4-30 in VA Stormwater Management Handbook Volume II (First Edition, 1999)
	Surface Ponding Depth, D (ft) =	0.5	Assume 0.5' CFS height at the end of waterbars

Calculations:	Total Storage Depth per BMP (ft) =	1.5
	Surface Storage Volume per BMP (cf) =	76.66666667
	Subsurface Storage Volume per BMP (cf) =	20
	Total Storage Volume per BMP (cf) =	96.66666667
	Total BMP Storage Volume in Drainage Area (cf) =	193.3333333
	Calculated Infiltration Period per BMP (hr) =	58

Depth-Storage Data				
Depth (ft)	Width (ft)	Length (ft)	Storage Volume per BMP (cf)	Storage Volume in Drainage Area (cf)
0	2	50	0	0
0.5	2	50	10	20
1	2	50	20	40
1.5	4	52	96.66666667	193.3333333
2	6	54	229.3333333	458.6666667

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.502	2749
Developed Condition	0.431	2555
Pre-Developed (Forest) Condition	0.401	2479

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1: $Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->

Q (cfs)		Q (cfs)
0.431	≤	0.432
	OK	

Check #2: $Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->

0.431	≤	0.502
	OK	

Check #3: $Q_{\text{developed}}$ shall not be required to be ≤ $(Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ ---->

0.431	<u>shall not</u> be required to be ≤	0.389
-------	--------------------------------------	-------

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p><i>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</i></p> <p><i>For Paved Road land surface types a Manning’s n value of 0.011 was used.</i></p> <p><i>Sources:</i></p> <p><i>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</i></p> <p><i>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</i></p>	

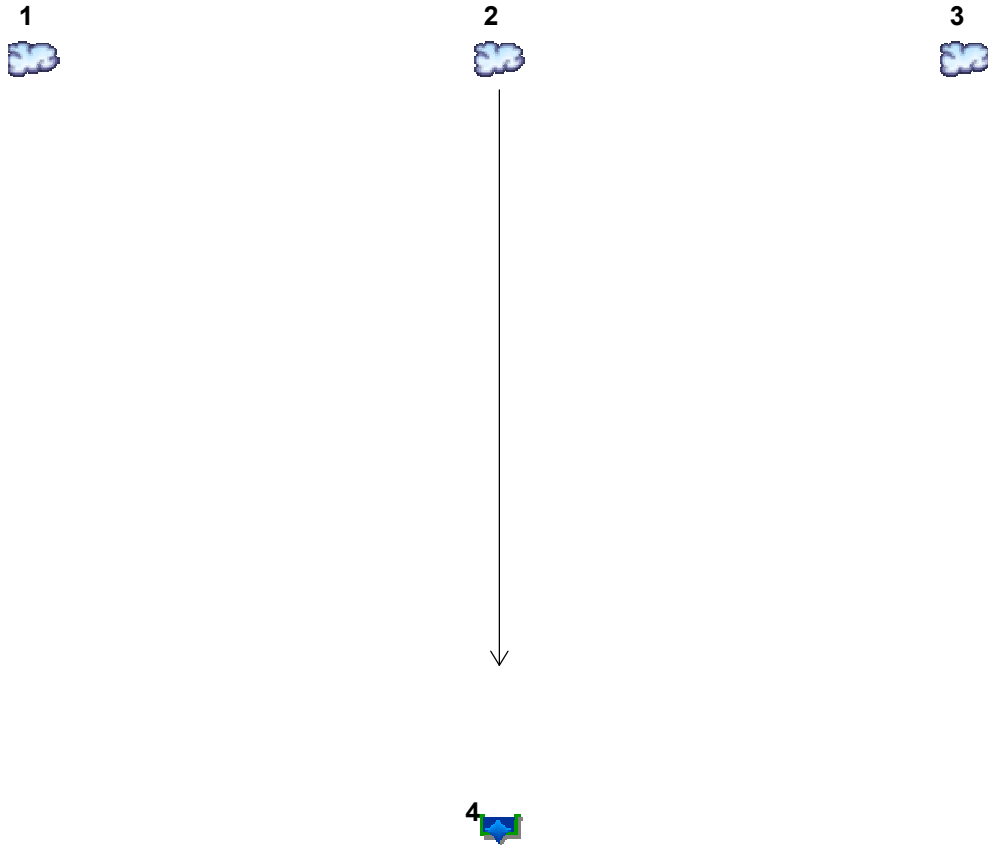
Table 2 – Manning's n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's n value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's n value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-119C PRE
2	SCS Runoff	DA-FR-119C POST
3	SCS Runoff	DA-FR-119C Pre-Forested
4	Reservoir	WB Soil Amendment

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.502	1	726	2,749	-----	-----	-----	DA-FR-119C PRE
2	SCS Runoff	0.502	1	726	2,749	-----	-----	-----	DA-FR-119C POST
3	SCS Runoff	0.401	1	726	2,479	-----	-----	-----	DA-FR-119C Pre-Forested
4	Reservoir	0.431	1	731	2,555	2	907.60	247	WB Soil Amendment
DA-FR-119c.gpw					Return Period: 1 Year			Wednesday, 08 / 16 / 2017	

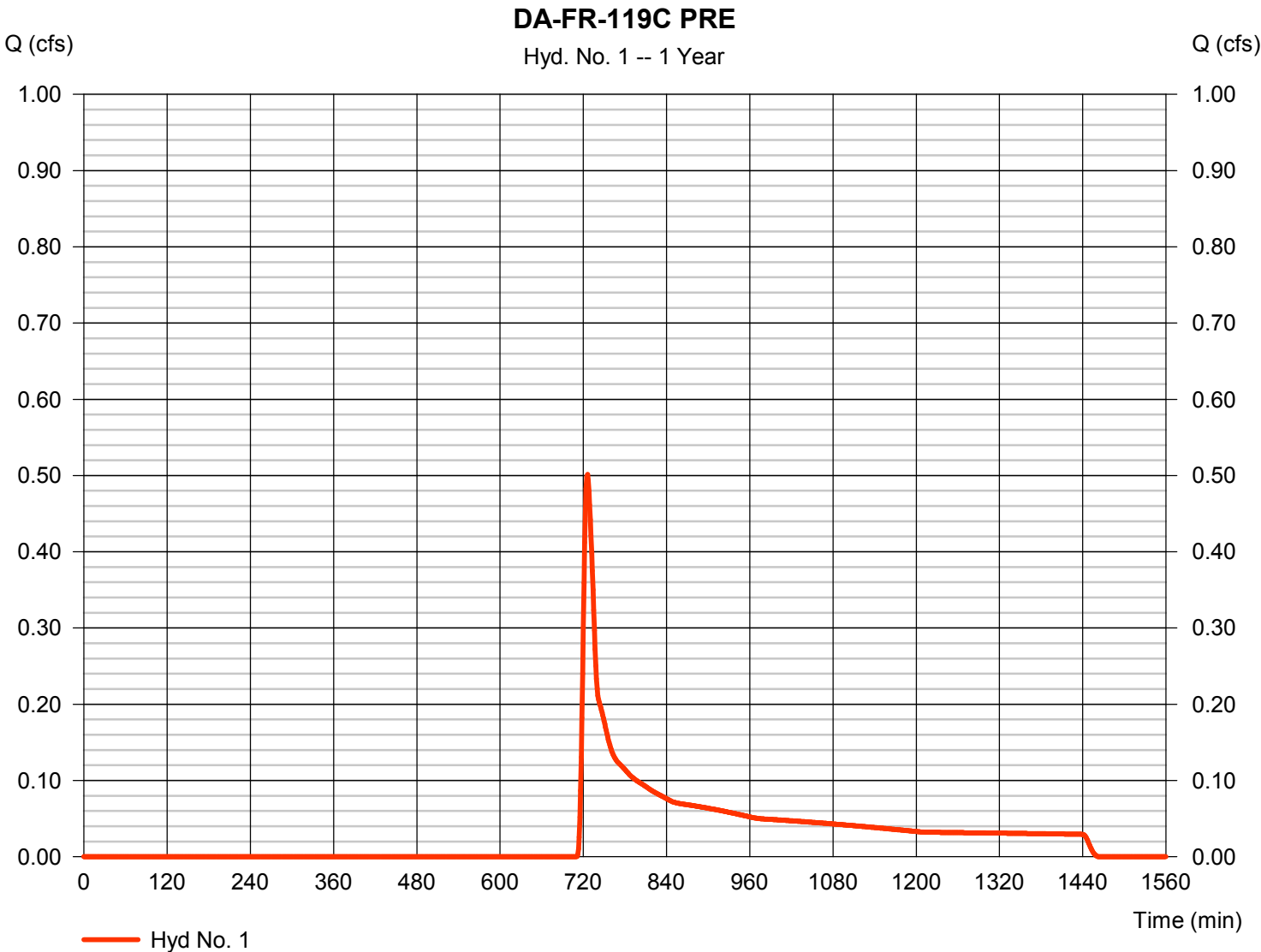
Hydrograph Report

Hyd. No. 1

DA-FR-119C PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.502 cfs
Storm frequency	=	1 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	2,749 cuft
Drainage area	=	2.430 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	13.50 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.040 x 82) + (0.720 x 58) + (1.670 x 55)] / 2.430



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-119C PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 7.00	0.00	0.00				
Travel Time (min)	= 12.10	+	0.00	+	0.00	=	12.10
Shallow Concentrated Flow							
Flow length (ft)	= 537.50	0.00	0.00				
Watercourse slope (%)	= 15.60	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=6.37	0.00	0.00				
Travel Time (min)	= 1.41	+	0.00	+	0.00	=	1.41
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	= 0.040	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				13.50 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

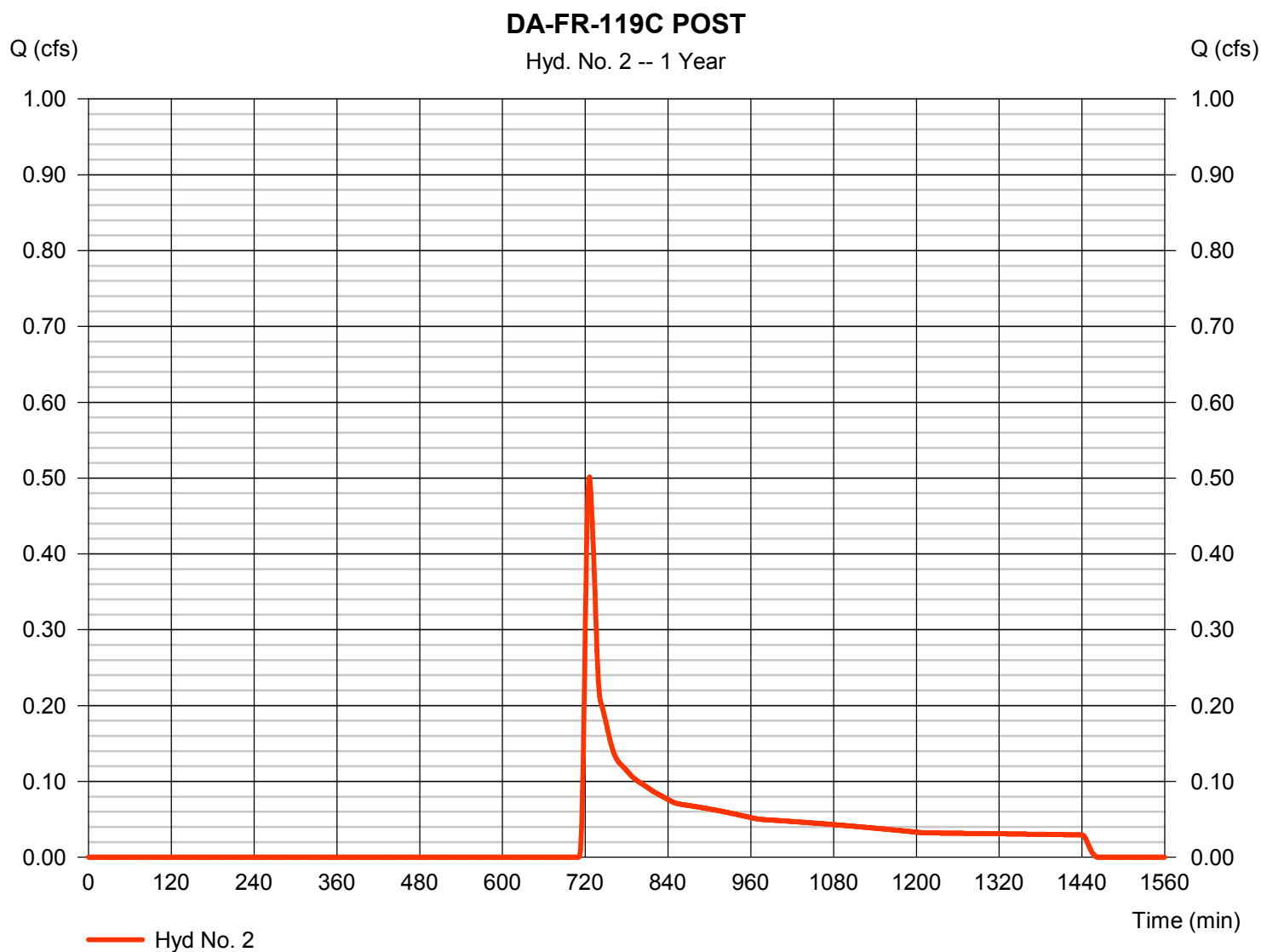
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-FR-119C POST

Hydrograph type	= SCS Runoff	Peak discharge	= 0.502 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 2,749 cuft
Drainage area	= 2.430 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.60 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.070 \times 48) + (0.040 \times 82) + (0.900 \times 58) + (1.420 \times 55)] / 2.430$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-119C POST

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.800	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 7.00	0.00	0.00				
Travel Time (min)	= 12.10	+	0.00	+	0.00	=	12.10
Shallow Concentrated Flow							
Flow length (ft)	= 466.20	29.60	0.00				
Watercourse slope (%)	= 15.70	18.10	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=6.39	6.86	0.00				
Travel Time (min)	= 1.22	+	0.07	+	0.00	=	1.29
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	(0)}50.4	0.0	0.0				
Travel Time (min)	= 0.17	+	0.00	+	0.00	=	0.17
Total Travel Time, Tc				13.60 min			

Hydrograph Report

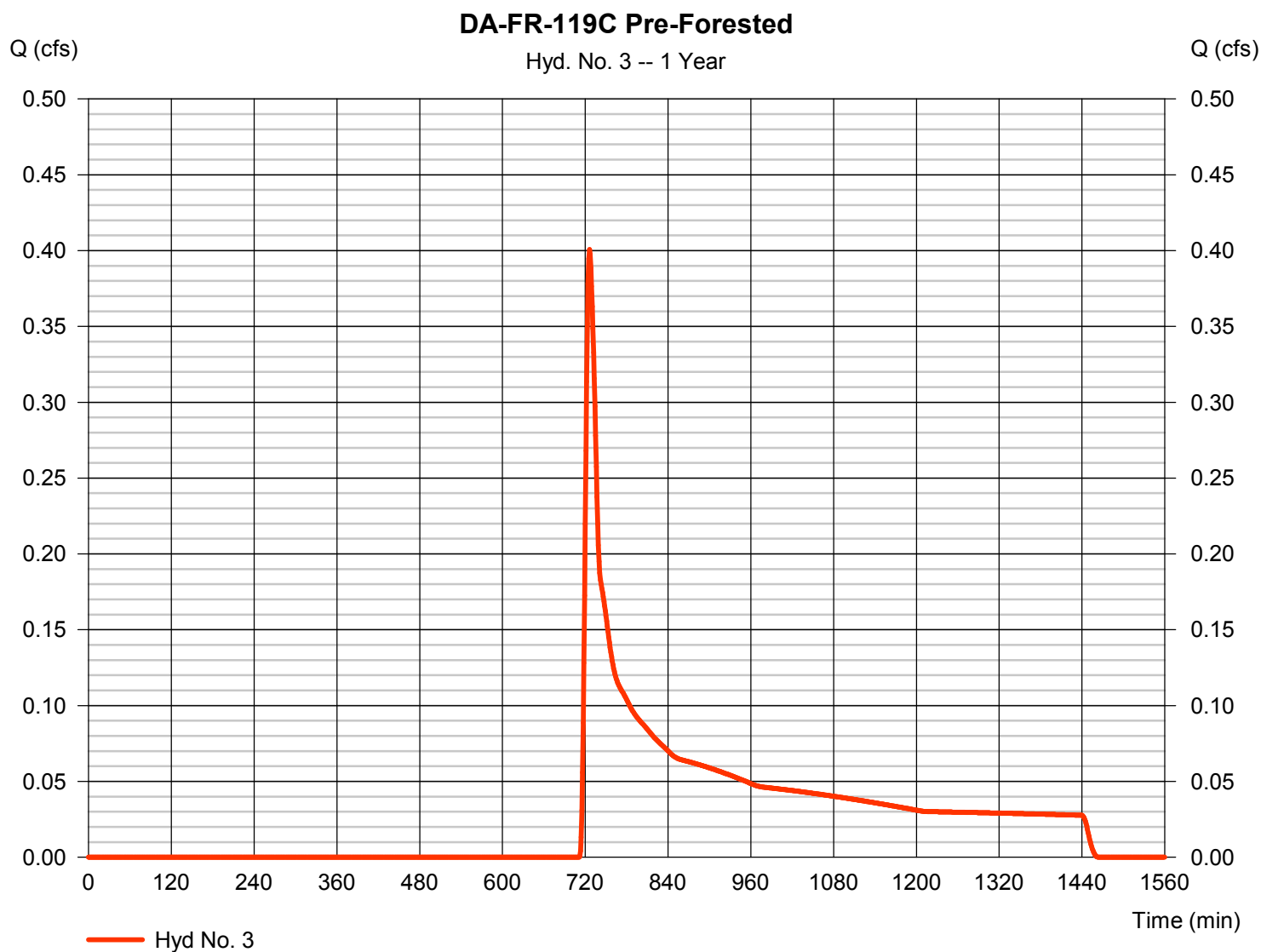
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-FR-119C Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.401 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 2,479 cuft
Drainage area	= 2.430 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.50 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.430 \times 55)] / 2.430$ 

TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-119C Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 7.00	0.00	0.00	
Travel Time (min)	= 12.10	+ 0.00	+ 0.00	= 12.10
Shallow Concentrated Flow				
Flow length (ft)	= 537.50	0.00	0.00	
Watercourse slope (%)	= 15.60	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=6.37	0.00	0.00	
Travel Time (min)	= 1.41	+ 0.00	+ 0.00	= 1.41
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	= 0.030	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				13.50 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

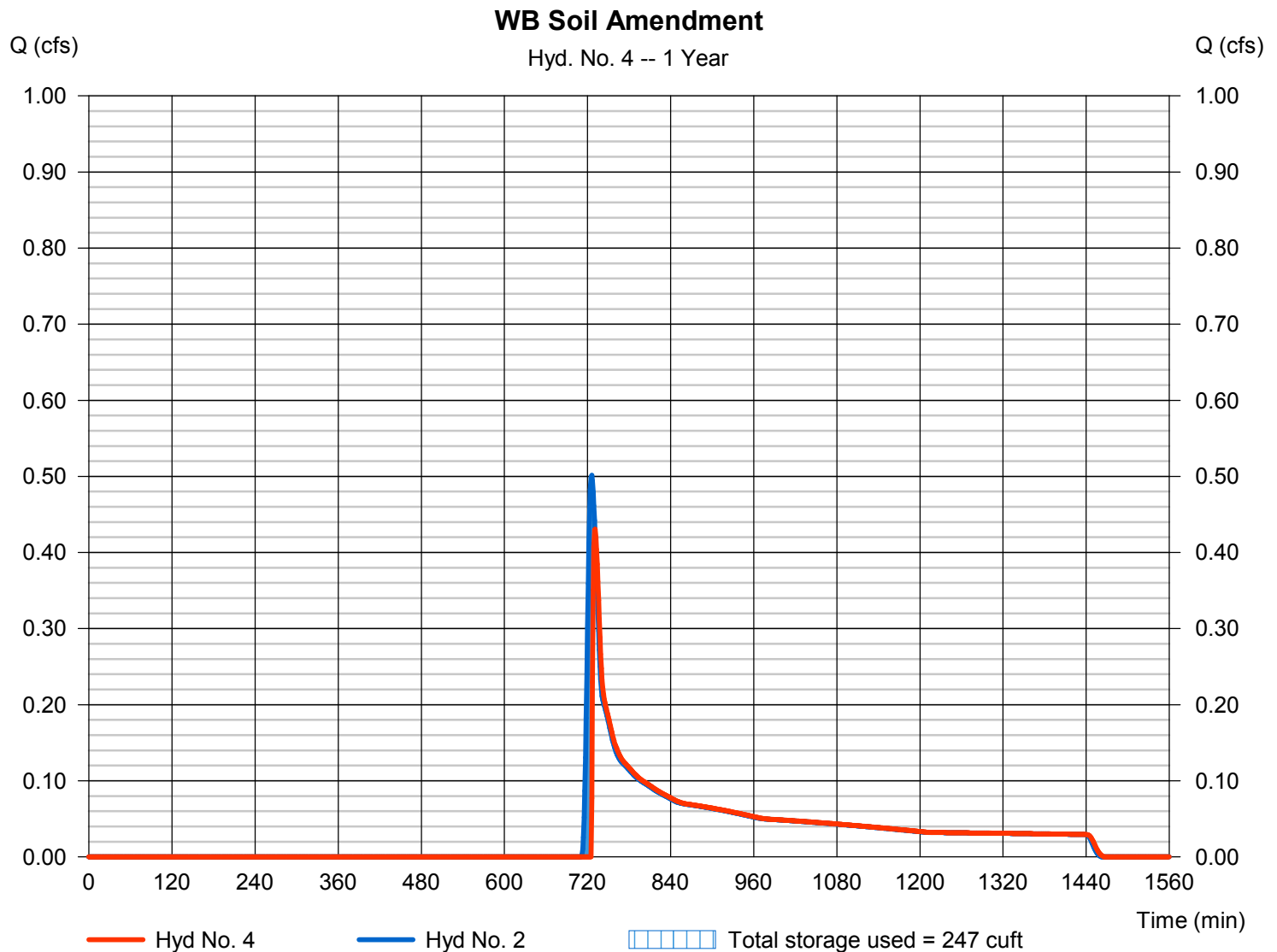
Wednesday, 08 / 16 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 0.431 cfs
Storm frequency	= 1 yrs	Time to peak	= 731 min
Time interval	= 1 min	Hyd. volume	= 2,555 cuft
Inflow hyd. No.	= 2 - DA-FR-119C POST	Max. Elevation	= 907.60 ft
Reservoir name	= Waterbar Soil Amendment	Max. Storage	= 247 cuft

Storage Indication method used.



Pond No. 1 - Waterbar Soil Amendment

Pond Data

Pond storage is based on user-defined values.

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	906.00	n/a	0	0
0.50	906.50	n/a	20	20
1.00	907.00	n/a	20	40
1.50	907.50	n/a	153	193
2.00	908.00	n/a	265	459

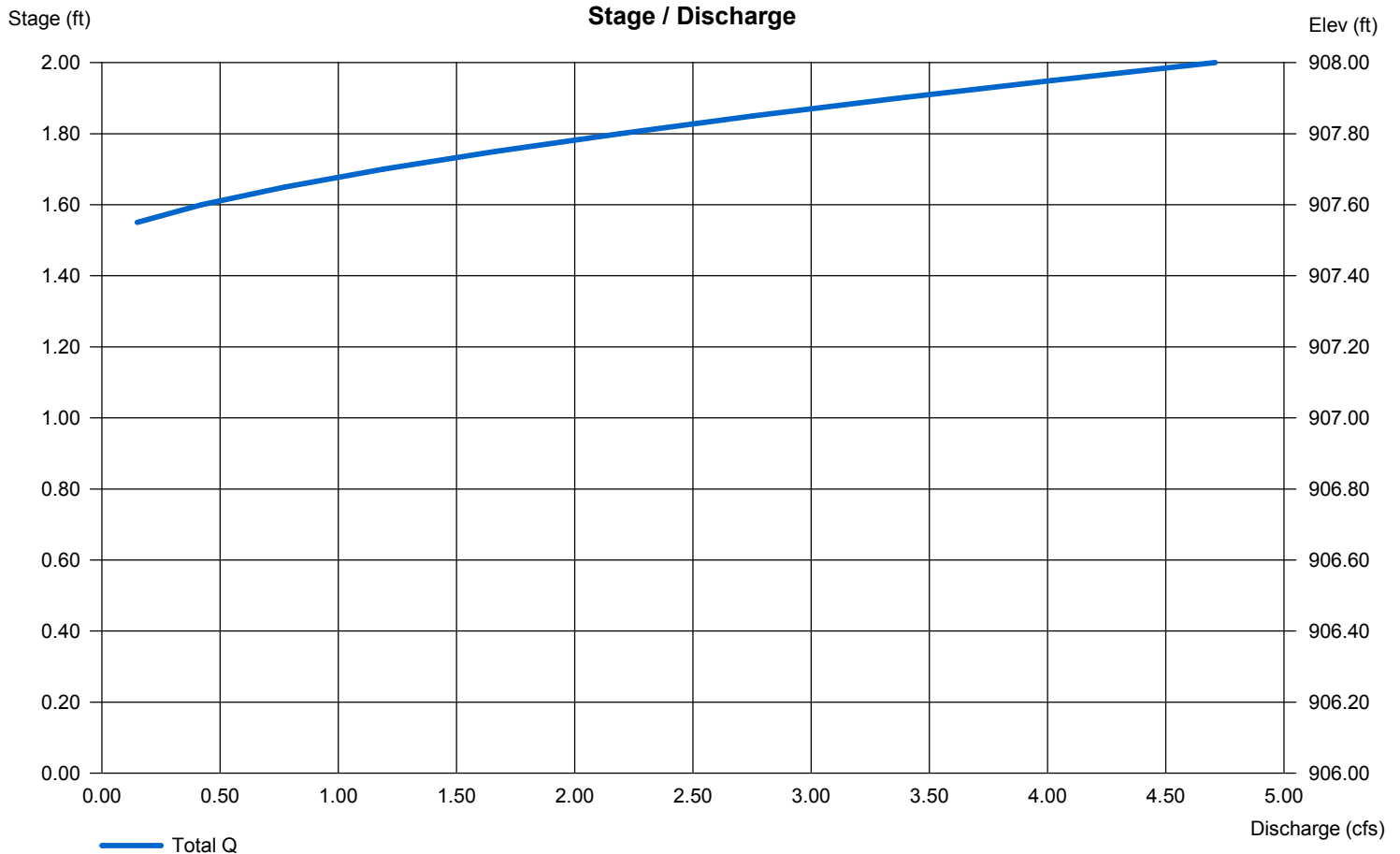
Culvert / Orifice Structures

	[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)	= 4.00	0.00	0.00	0.00
Crest El. (ft)	= 907.50	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= Rect	---	---	---
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).



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.938	1	725	4,002	-----	-----	-----	DA-FR-119C PRE
2	SCS Runoff	0.938	1	725	4,002	-----	-----	-----	DA-FR-119C POST
3	SCS Runoff	0.797	1	725	3,666	-----	-----	-----	DA-FR-119C Pre-Forested
4	Reservoir	0.912	1	727	3,808	2	907.67	282	WB Soil Amendment
DA-FR-119c.gpw					Return Period: 2 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

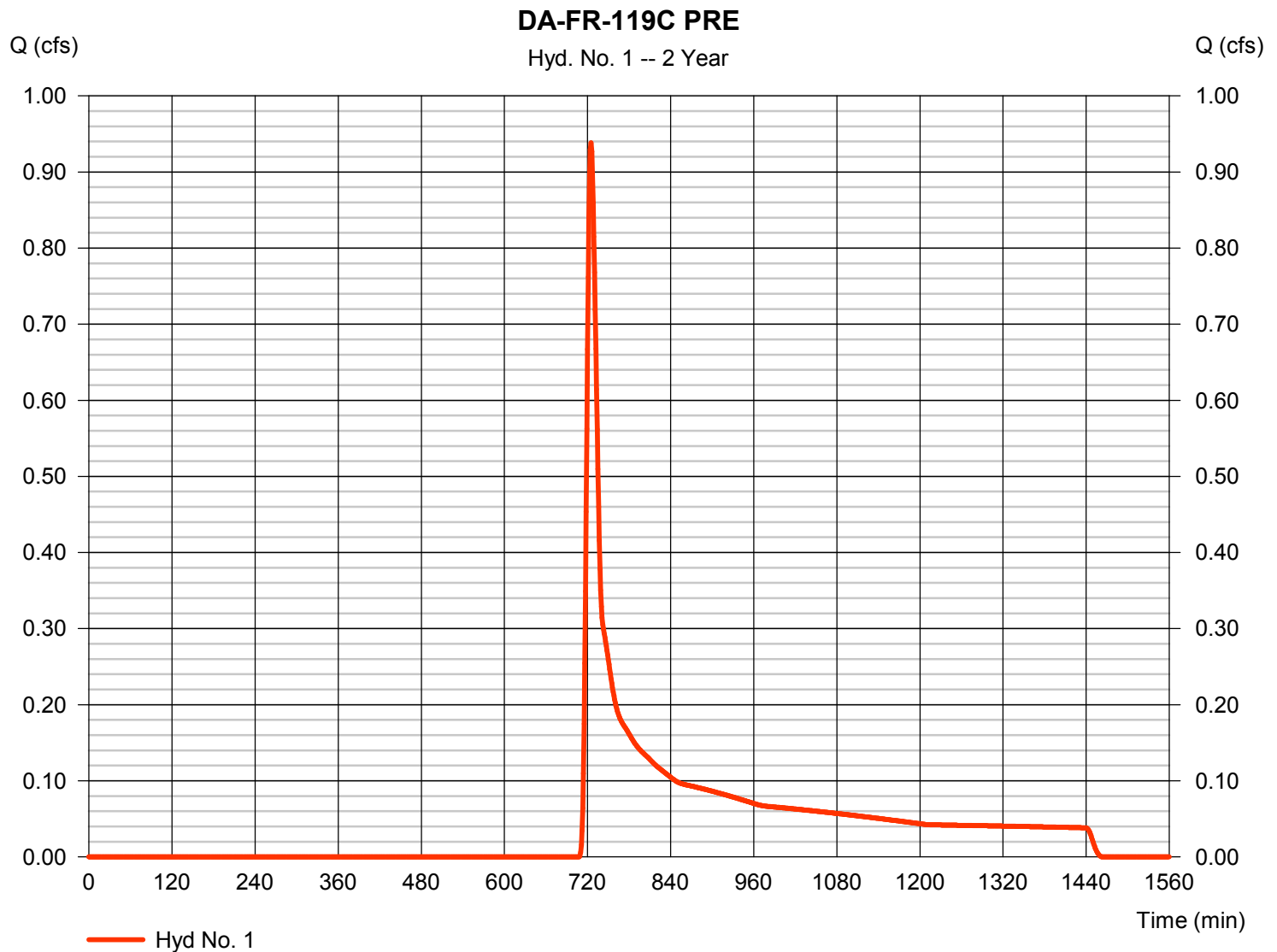
Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-FR-119C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.938 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 4,002 cuft
Drainage area	= 2.430 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.50 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.040 \times 82) + (0.720 \times 58) + (1.670 \times 55)] / 2.430$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

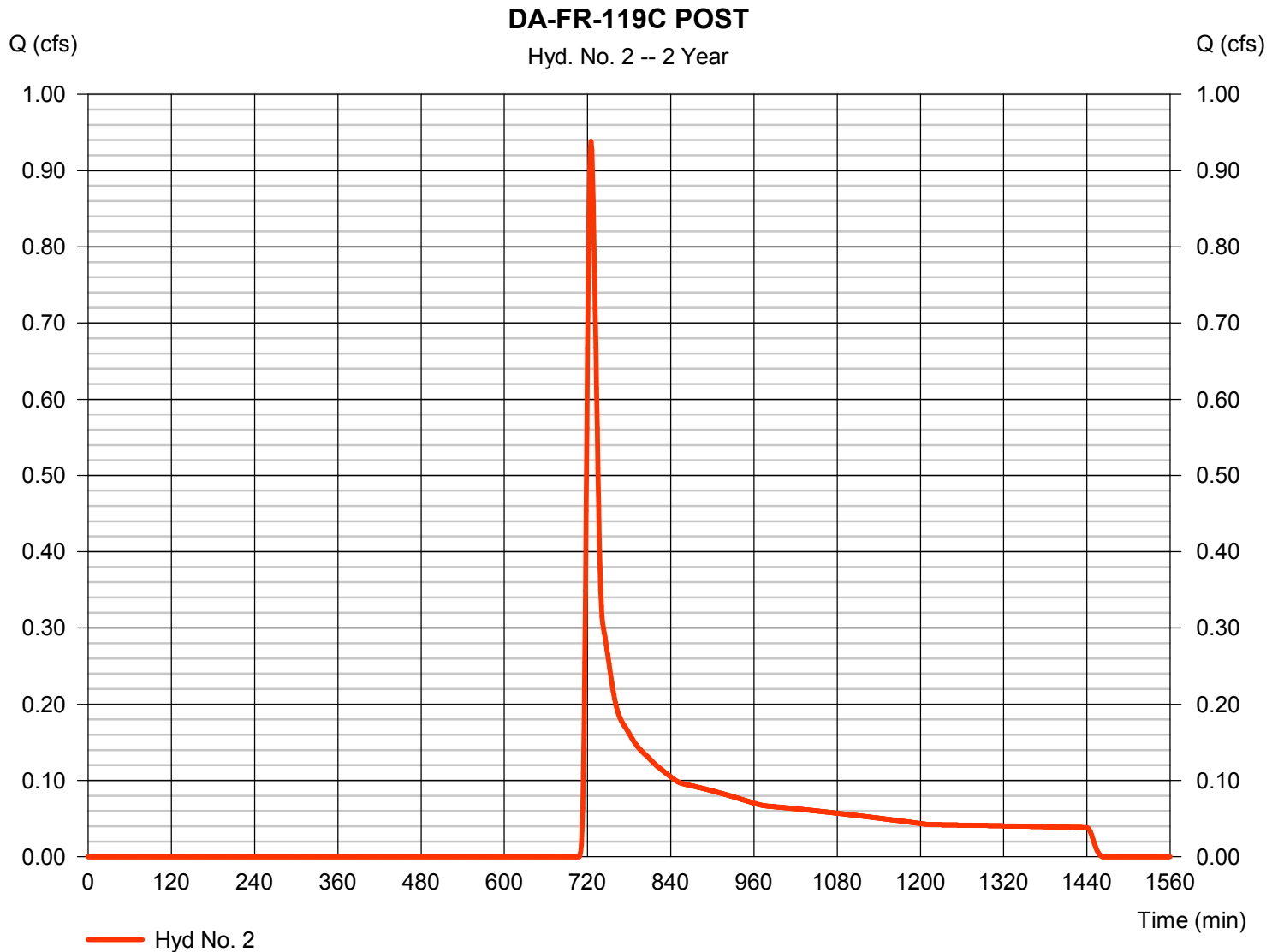
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-FR-119C POST

Hydrograph type	= SCS Runoff	Peak discharge	= 0.938 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 4,002 cuft
Drainage area	= 2.430 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.60 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.070 \times 48) + (0.040 \times 82) + (0.900 \times 58) + (1.420 \times 55)] / 2.430$



Hydrograph Report

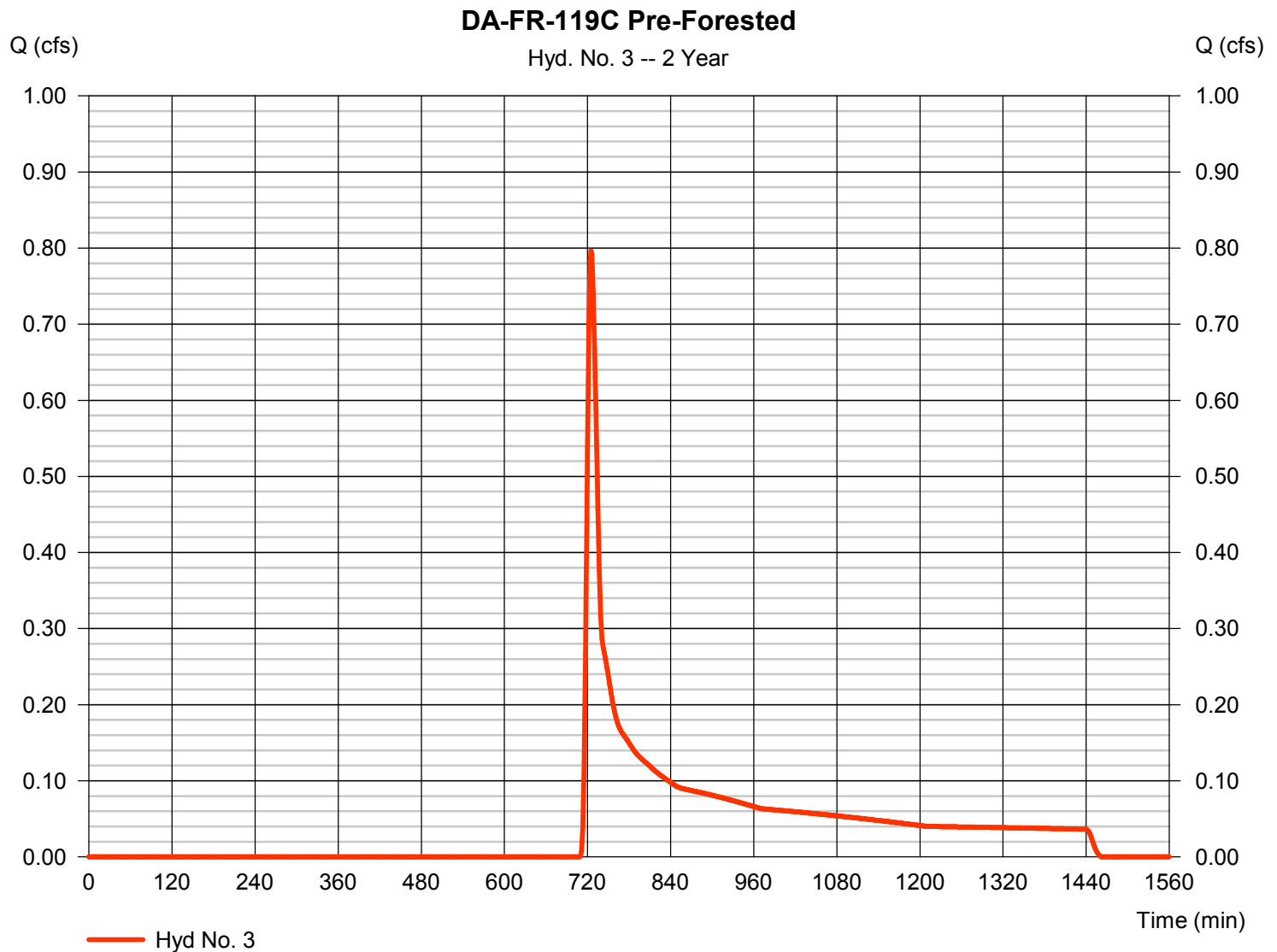
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-FR-119C Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.797 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 3,666 cuft
Drainage area	= 2.430 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.50 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.430 \times 55)] / 2.430$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

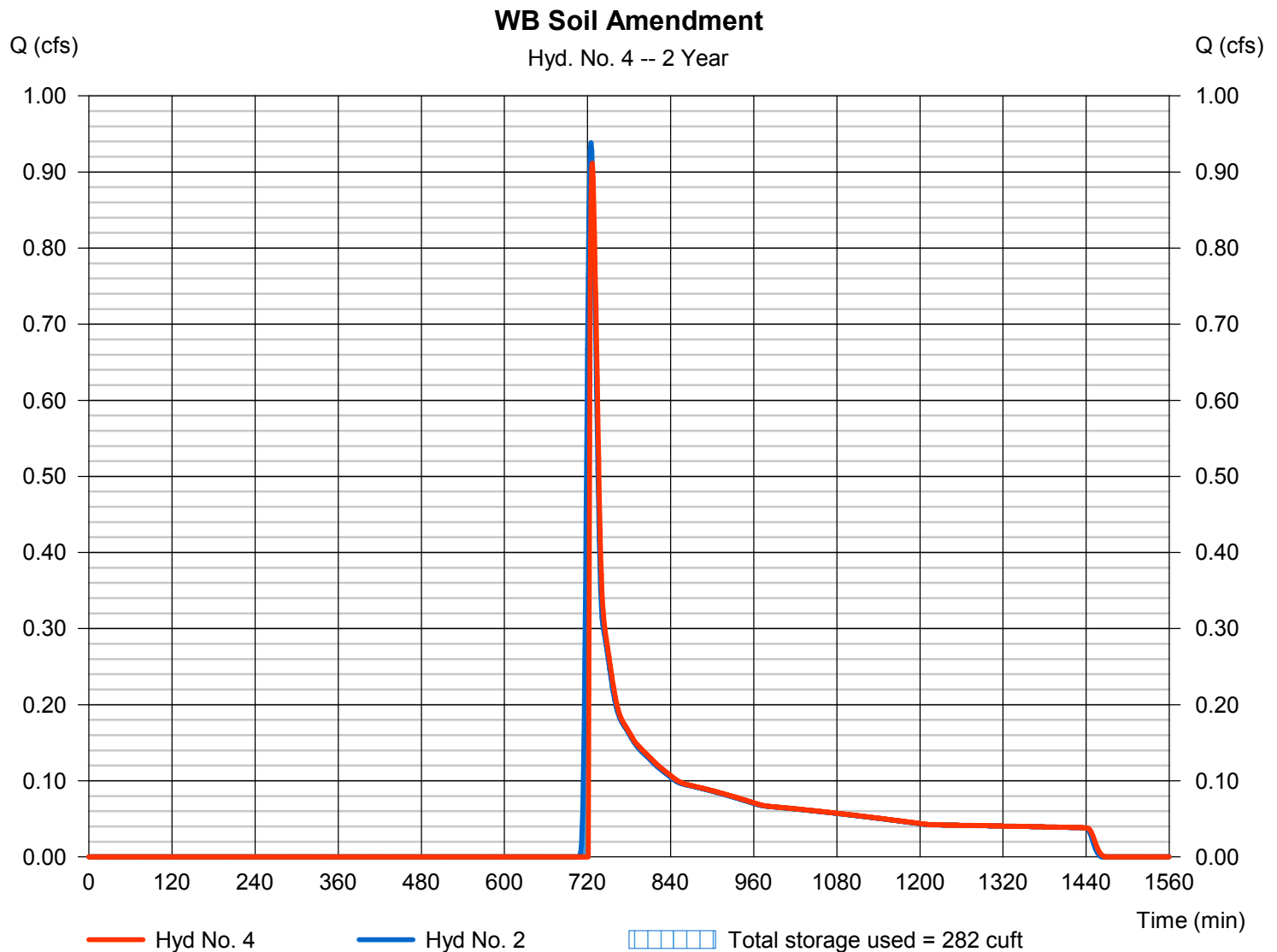
Wednesday, 08 / 16 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 0.912 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 3,808 cuft
Inflow hyd. No.	= 2 - DA-FR-119C POST	Max. Elevation	= 907.67 ft
Reservoir name	= Waterbar Soil Amendment	Max. Storage	= 282 cuft

Storage Indication method used.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	4.263	1	723	12,544	-----	-----	-----	DA-FR-119C PRE
2	SCS Runoff	4.263	1	723	12,544	-----	-----	-----	DA-FR-119C POST
3	SCS Runoff	3.980	1	723	11,895	-----	-----	-----	DA-FR-119C Pre-Forested
4	Reservoir	4.237	1	724	12,351	2	907.97	441	WB Soil Amendment
DA-FR-119c.gpw					Return Period: 10 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

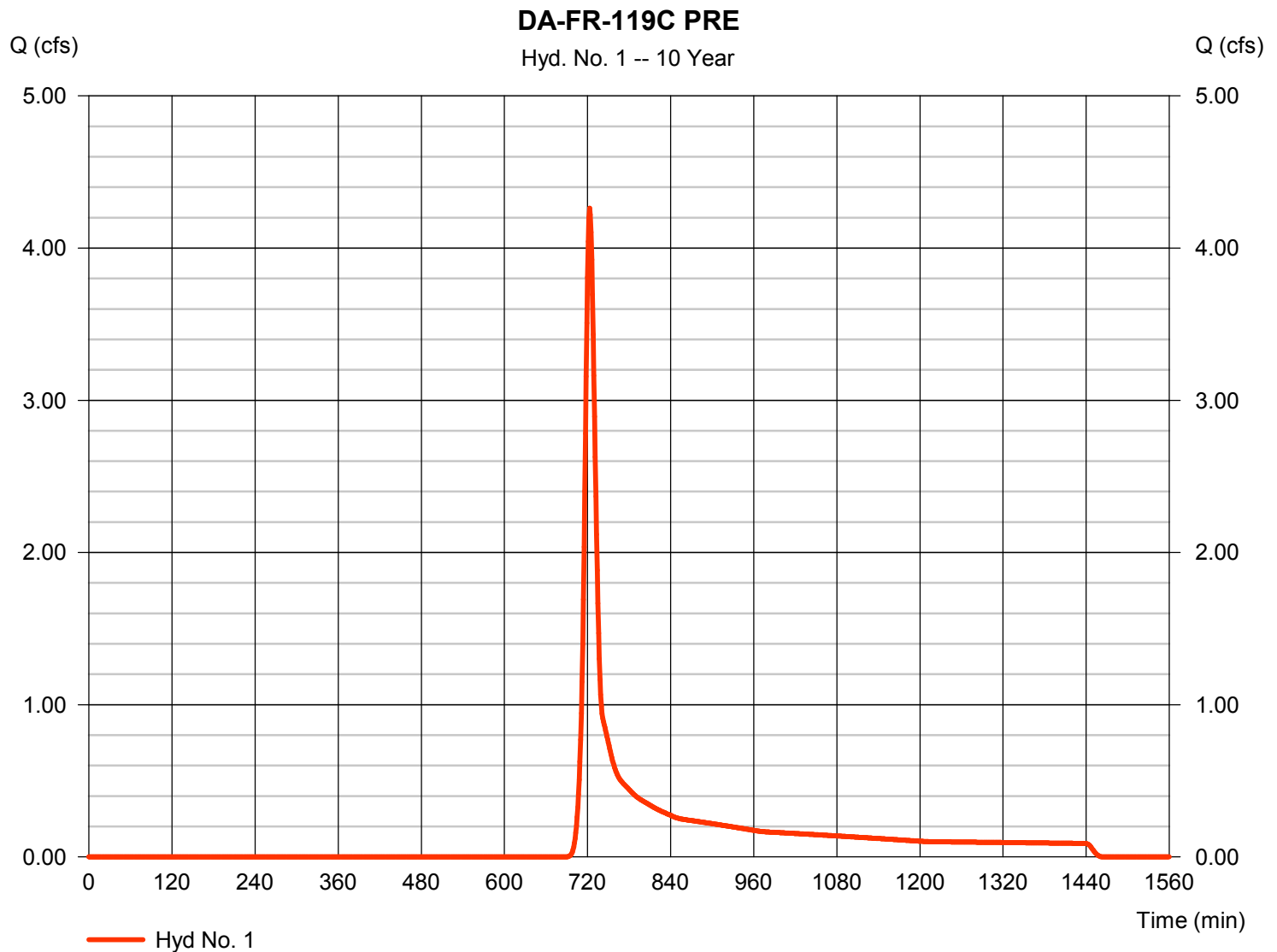
Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-FR-119C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 4.263 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 12,544 cuft
Drainage area	= 2.430 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.50 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.040 \times 82) + (0.720 \times 58) + (1.670 \times 55)] / 2.430$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

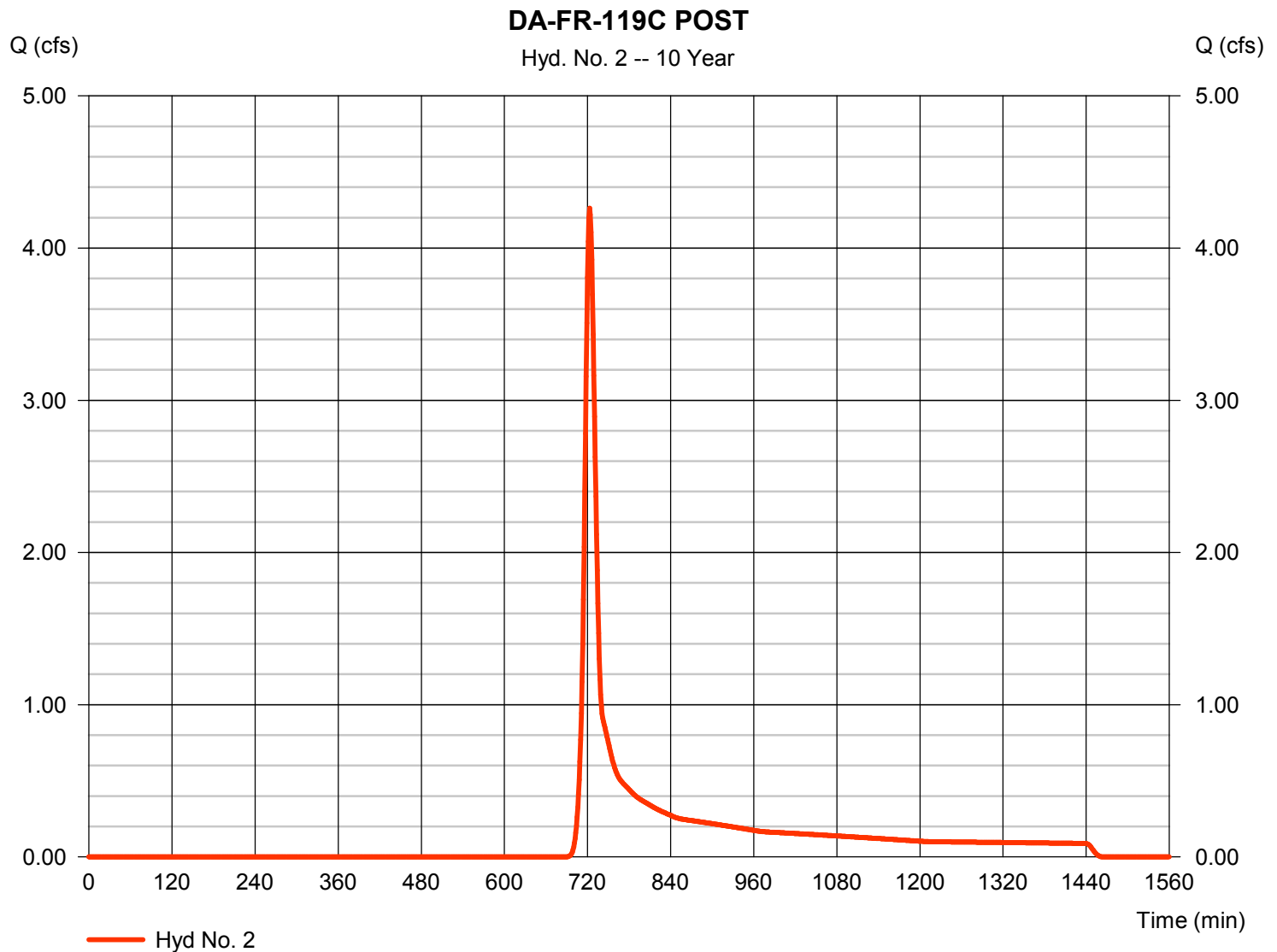
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-FR-119C POST

Hydrograph type	= SCS Runoff	Peak discharge	= 4.263 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 12,544 cuft
Drainage area	= 2.430 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.60 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.070 \times 48) + (0.040 \times 82) + (0.900 \times 58) + (1.420 \times 55)] / 2.430$



Hydrograph Report

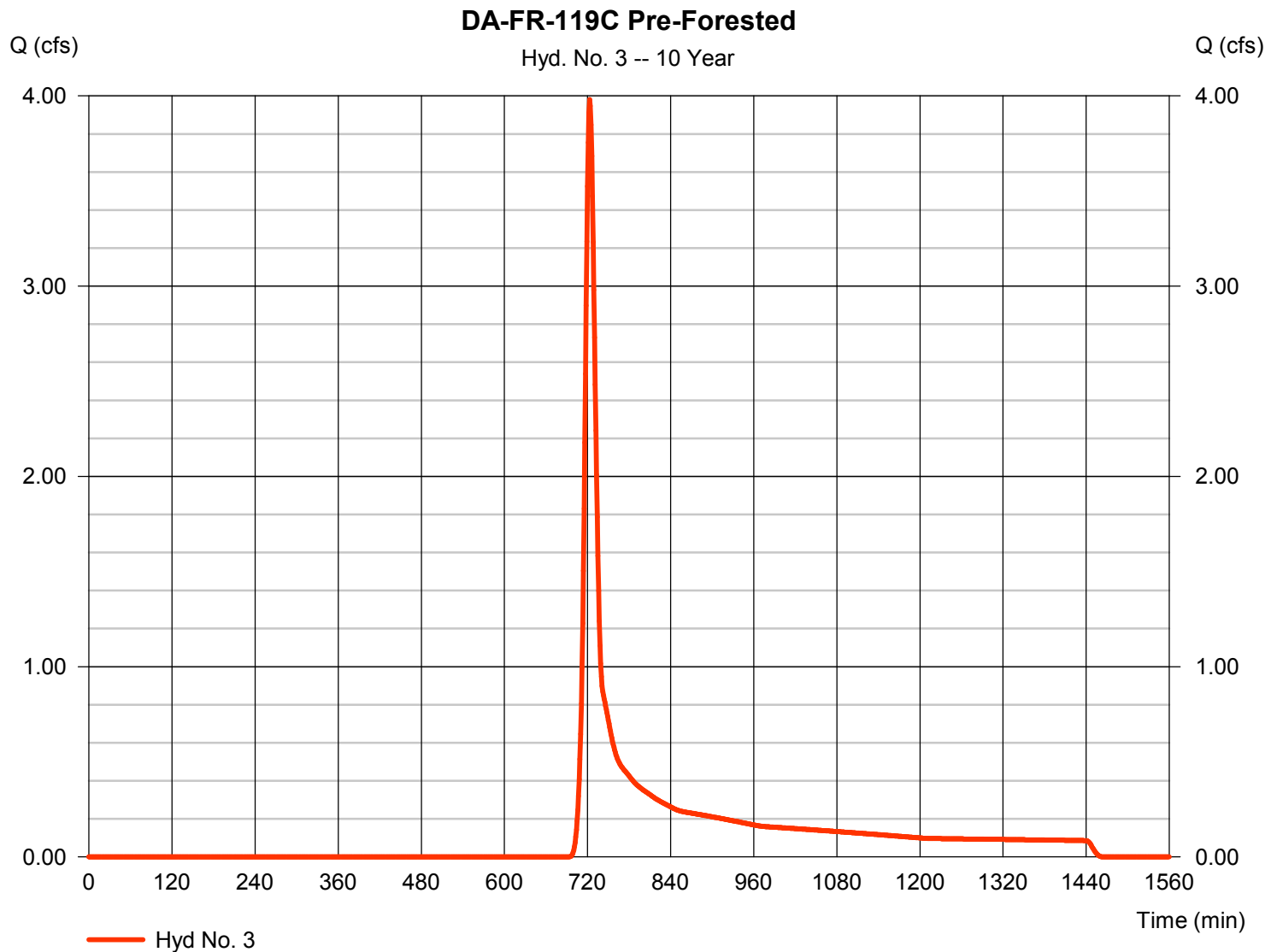
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-FR-119C Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 3.980 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 11,895 cuft
Drainage area	= 2.430 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.50 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.430 \times 55)] / 2.430$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

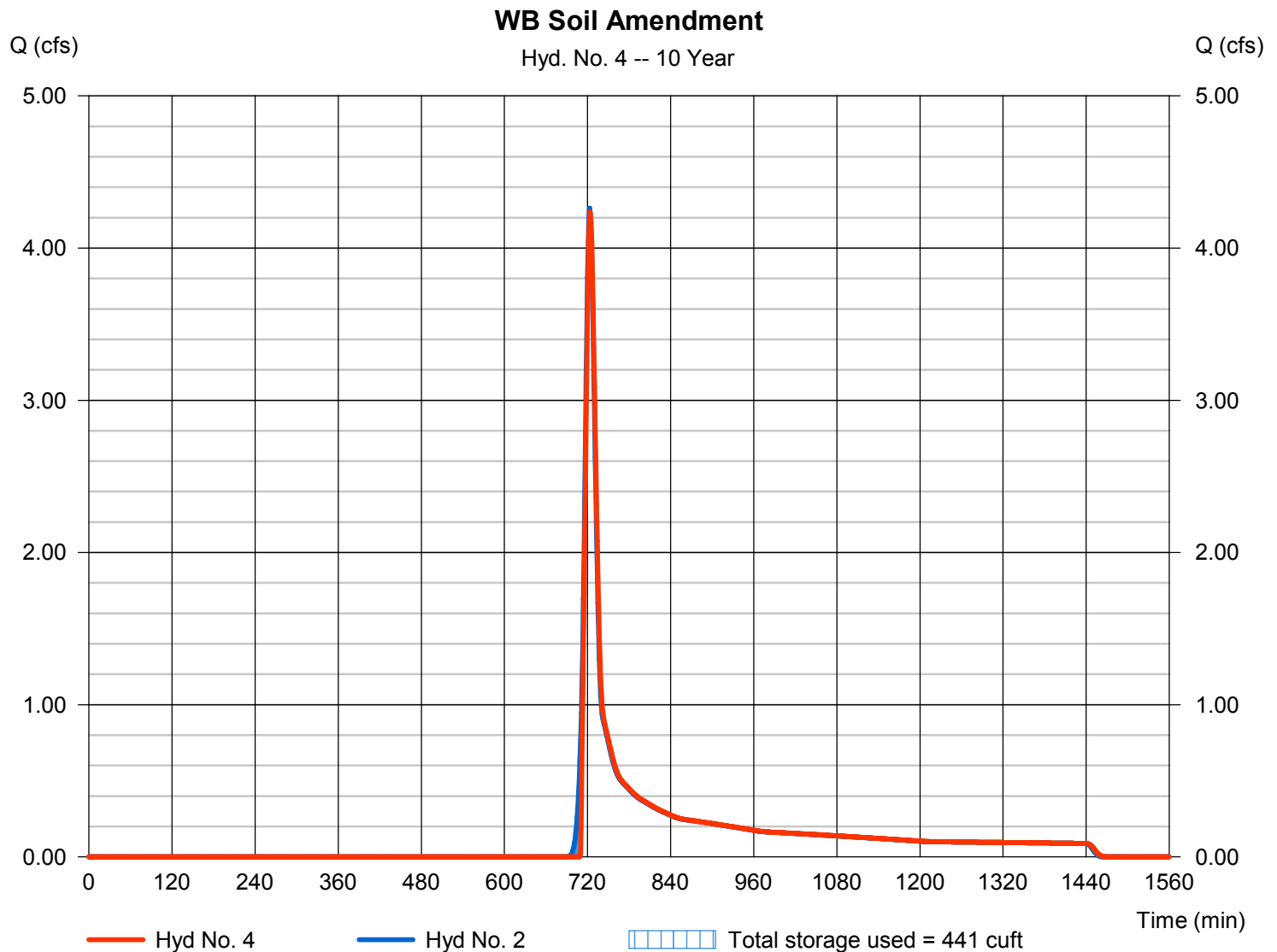
Wednesday, 08 / 16 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 4.237 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 12,351 cuft
Inflow hyd. No.	= 2 - DA-FR-119C POST	Max. Elevation	= 907.97 ft
Reservoir name	= Waterbar Soil Amendment	Max. Storage	= 441 cuft

Storage Indication method used.



Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	-----
2	69.8703	13.1000	0.8658	-----
3	0.0000	0.0000	0.0000	-----
5	79.2597	14.6000	0.8369	-----
10	88.2351	15.5000	0.8279	-----
25	102.6072	16.5000	0.8217	-----
50	114.8193	17.2000	0.8199	-----
100	127.1596	17.8000	0.8186	-----

File name: SampleFHA.idf

$$\text{Intensity} = B / (T_c + D)^E$$

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5.69	4.61	3.89	3.38	2.99	2.69	2.44	2.24	2.07	1.93	1.81	1.70
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	6.57	5.43	4.65	4.08	3.65	3.30	3.02	2.79	2.59	2.42	2.27	2.15
10	7.24	6.04	5.21	4.59	4.12	3.74	3.43	3.17	2.95	2.77	2.60	2.46
25	8.25	6.95	6.03	5.34	4.80	4.38	4.02	3.73	3.48	3.26	3.07	2.91
50	9.04	7.65	6.66	5.92	5.34	4.87	4.49	4.16	3.88	3.65	3.44	3.25
100	9.83	8.36	7.30	6.50	5.87	5.36	4.94	4.59	4.29	4.03	3.80	3.60

Tc = time in minutes. Values may exceed 60.

Precip. file name: P:\MVP ESC&SWM Review\Engineering\SW Calculations\Franklin County.pcp

[illegible]

DA-FR-119D

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	3.833	13619
Developed Condition	3.833	13619
Pre-Developed (Forest) Condition	2.694	10904

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 1

Calculations:

Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	<u>Q (cfs)</u> 3.833	\leq OK	<u>Q (cfs)</u> 3.833
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	3.833	\leq OK	3.833
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ ---->	3.833	<u>shall not</u> be required to be \leq	2.157

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p><i>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</i></p> <p><i>For Paved Road land surface types a Manning’s n value of 0.011 was used.</i></p> <p><i>Sources:</i></p> <p><i>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</i></p> <p><i>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</i></p>	

Table 2 – Manning's n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's n value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's n value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

1



2



3



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-119D PRE
2	SCS Runoff	DA-FR-119D POST
3	SCS Runoff	DA-FR-119D Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	3.833	1	725	13,619	-----	-----	-----	DA-FR-119D PRE
2	SCS Runoff	3.833	1	725	13,619	-----	-----	-----	DA-FR-119D POST
3	SCS Runoff	2.694	1	726	10,904	-----	-----	-----	DA-FR-119D Pre-Forested
DA-FR-119D.gpw					Return Period: 1 Year			Wednesday, 08 / 30 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

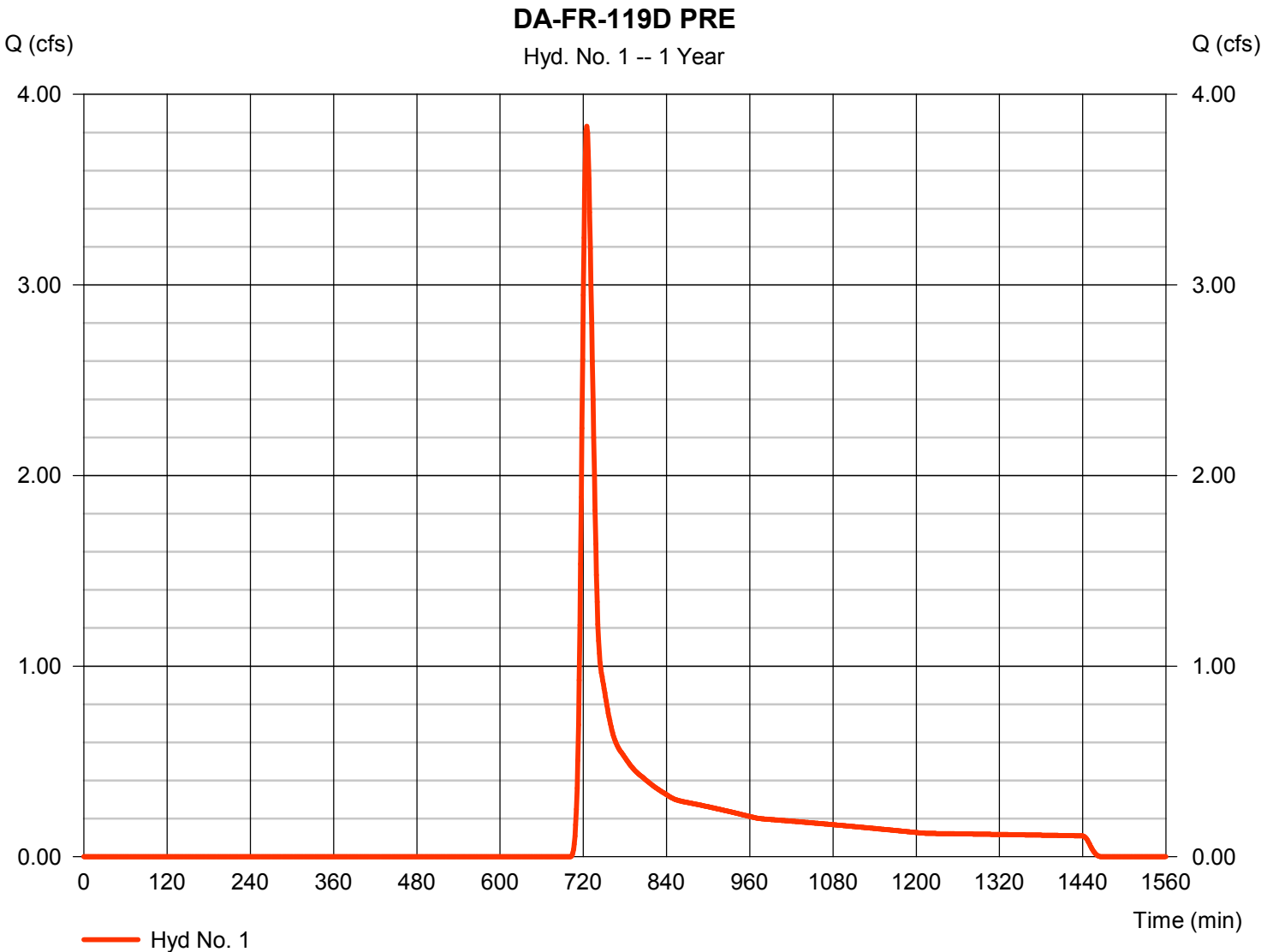
Wednesday, 08 / 30 / 2017

Hyd. No. 1

DA-FR-119D PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 3.833 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 13,619 cuft
Drainage area	= 6.110 ac	Curve number	= 64*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(6.110 x 64)] / 6.110



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-119D PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 5.00	0.00	0.00				
Travel Time (min)	= 13.84	+	0.00	+	0.00	=	13.84
Shallow Concentrated Flow							
Flow length (ft)	= 631.50	0.00	0.00				
Watercourse slope (%)	= 11.70	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.52	0.00	0.00				
Travel Time (min)	= 1.91	+	0.00	+	0.00	=	1.91
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	= 0.040	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				15.70 min			

Hydrograph Report

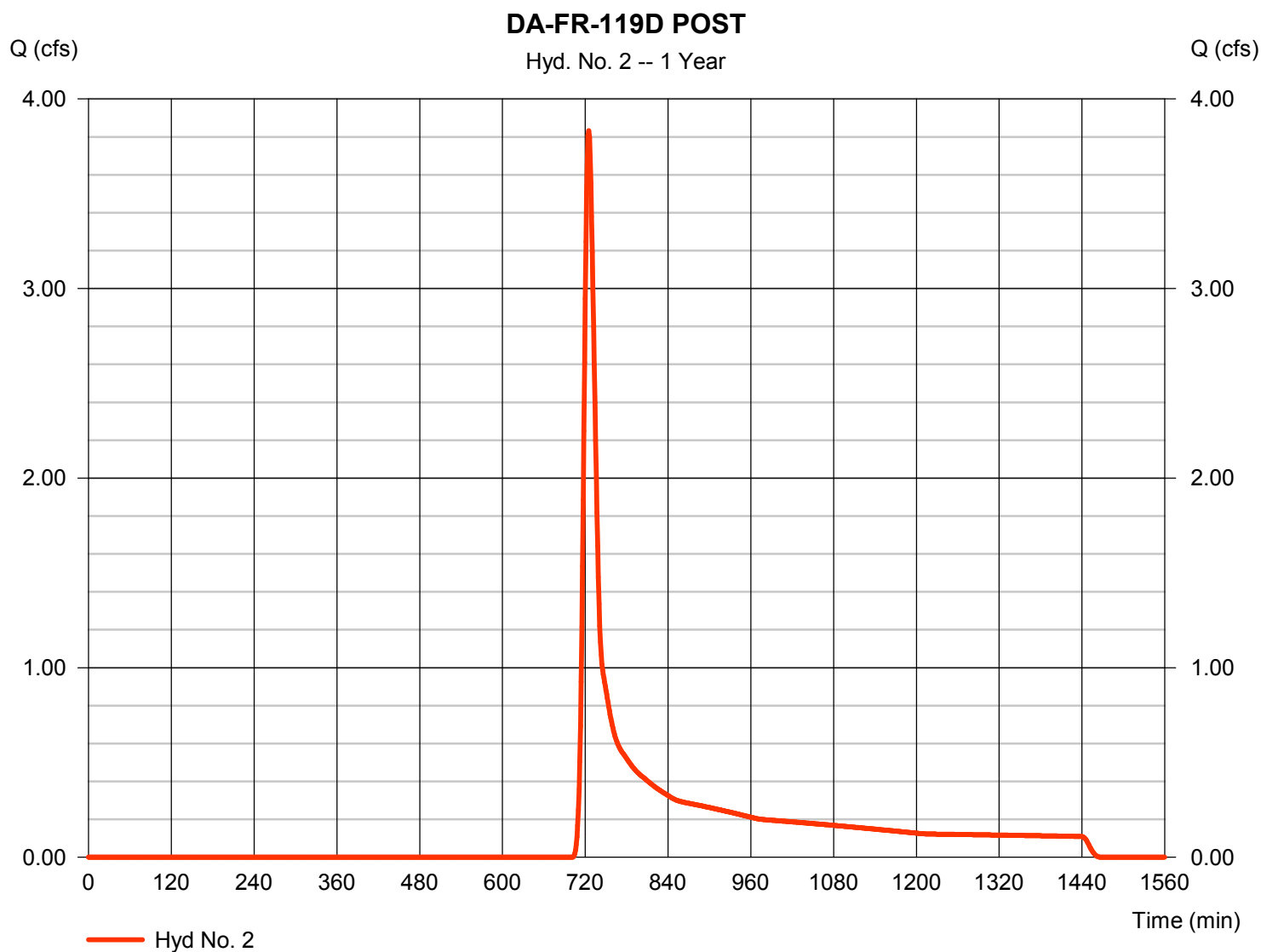
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 08 / 30 / 2017

Hyd. No. 2

DA-FR-119D POST

Hydrograph type	= SCS Runoff	Peak discharge	= 3.833 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 13,619 cuft
Drainage area	= 6.110 ac	Curve number	= 64*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.80 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(6.110 \times 64)] / 6.110$ 

TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-119D POST

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.800	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 5.00	0.00	0.00				
Travel Time (min)	= 13.84	+	0.00	+	0.00	=	13.84
Shallow Concentrated Flow							
Flow length (ft)	= 491.80	102.80	0.00				
Watercourse slope (%)	= 12.00	11.40	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=5.59	5.45	0.00				
Travel Time (min)	= 1.47	+	0.31	+	0.00	=	1.78
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	(\{0\})63.9	0.0	0.0				
Travel Time (min)	= 0.22	+	0.00	+	0.00	=	0.22
Total Travel Time, Tc				15.80 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

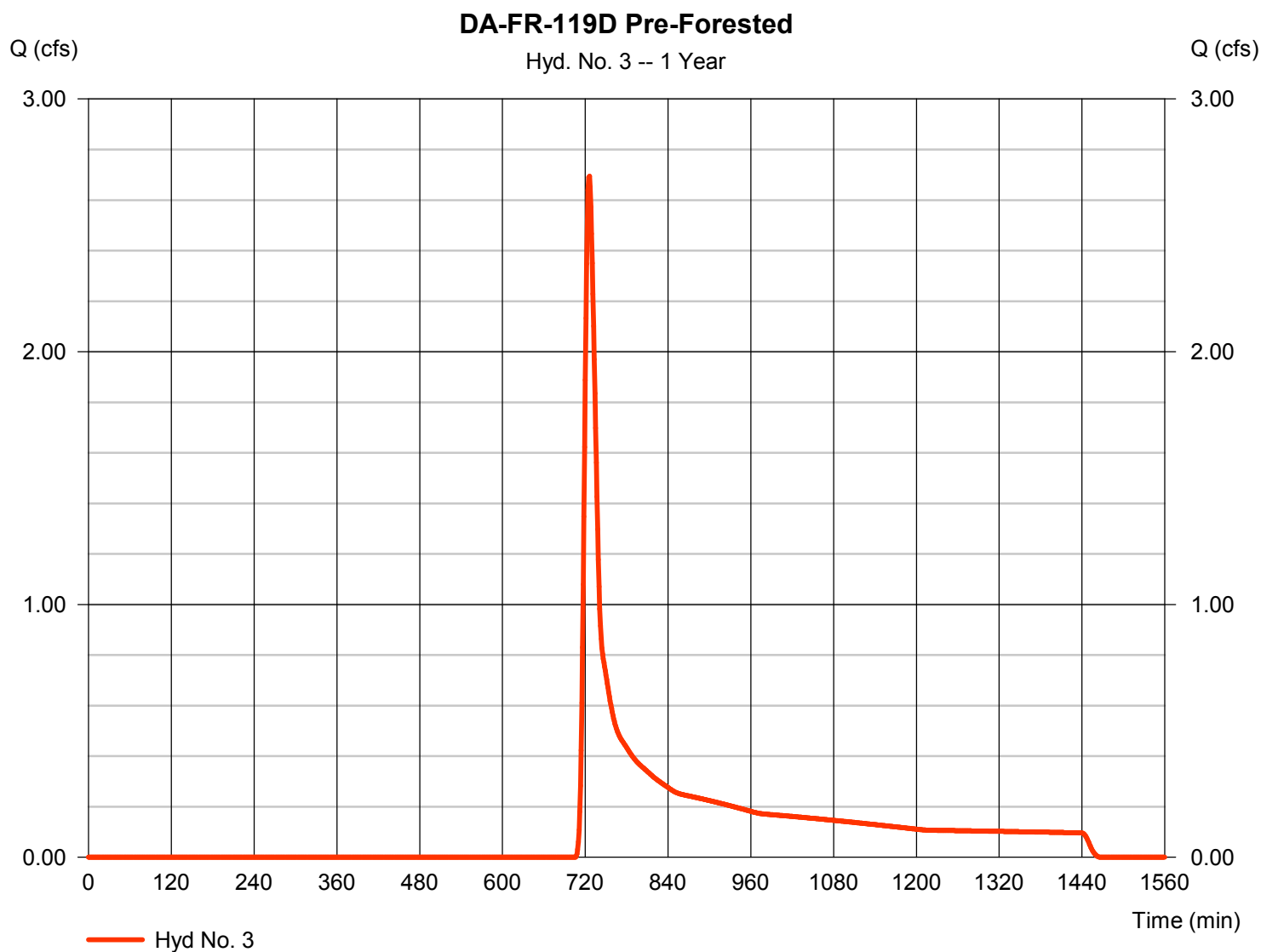
Wednesday, 08 / 30 / 2017

Hyd. No. 3

DA-FR-119D Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 2.694 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 10,904 cuft
Drainage area	= 6.110 ac	Curve number	= 61*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(3.690 \times 55) + (2.420 \times 70)] / 6.110$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-119D Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 5.00	0.00	0.00				
Travel Time (min)	= 13.84	+	0.00	+	0.00	=	13.84
Shallow Concentrated Flow							
Flow length (ft)	= 631.50	0.00	0.00				
Watercourse slope (%)	= 11.70	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.52	0.00	0.00				
Travel Time (min)	= 1.91	+	0.00	+	0.00	=	1.91
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	= 0.030	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				15.70 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	5.503	1	724	18,158	-----	-----	-----	DA-FR-119D PRE
2	SCS Runoff	5.503	1	724	18,158	-----	-----	-----	DA-FR-119D POST
3	SCS Runoff	4.157	1	725	14,936	-----	-----	-----	DA-FR-119D Pre-Forested
DA-FR-119D.gpw					Return Period: 2 Year			Wednesday, 08 / 30 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 08 / 30 / 2017

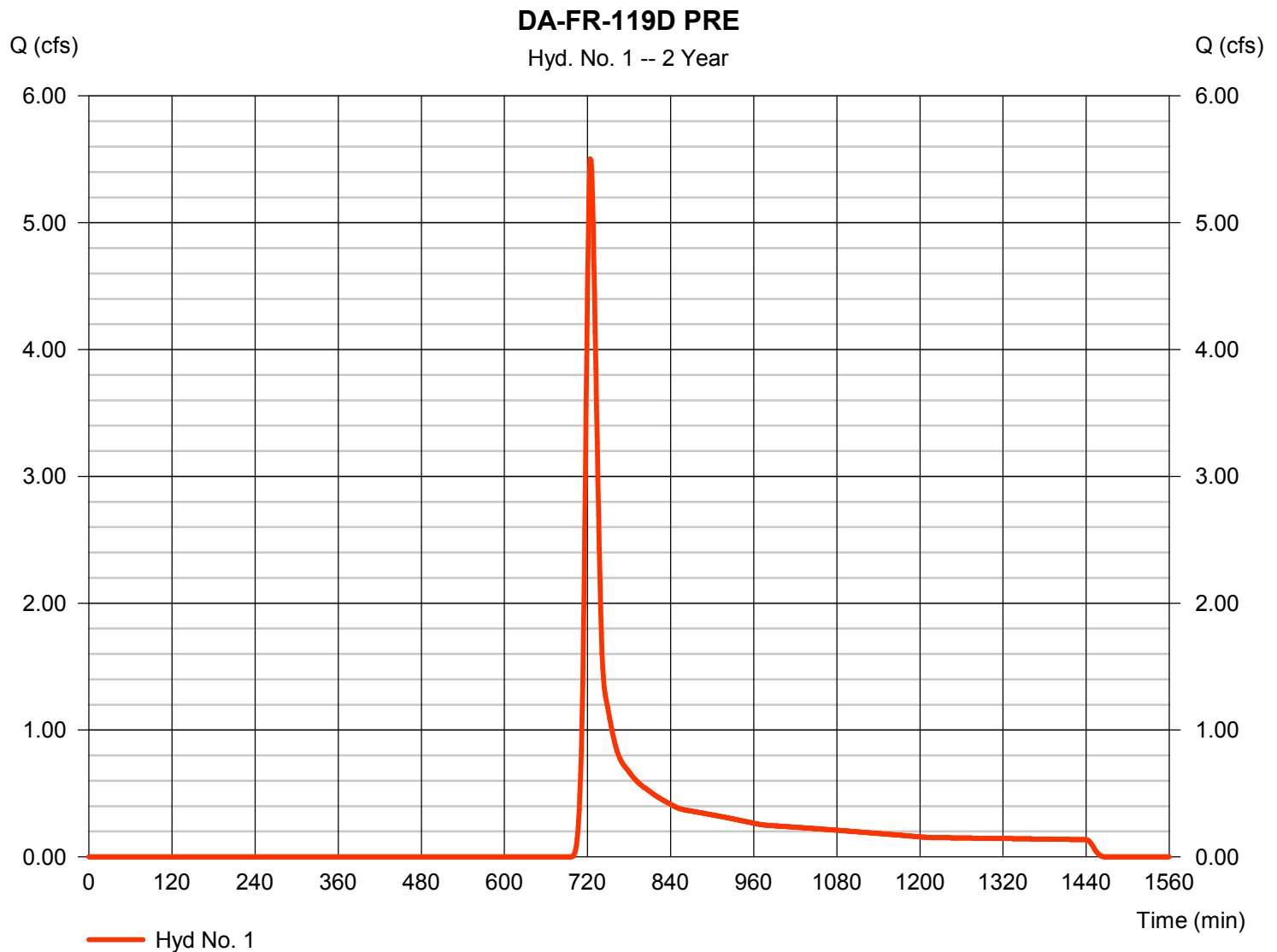
Hyd. No. 1

DA-FR-119D PRE

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 6.110 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 5.503 cfs
 Time to peak = 724 min
 Hyd. volume = 18,158 cuft
 Curve number = 64*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.70 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(6.110 \times 64)] / 6.110$



Hydrograph Report

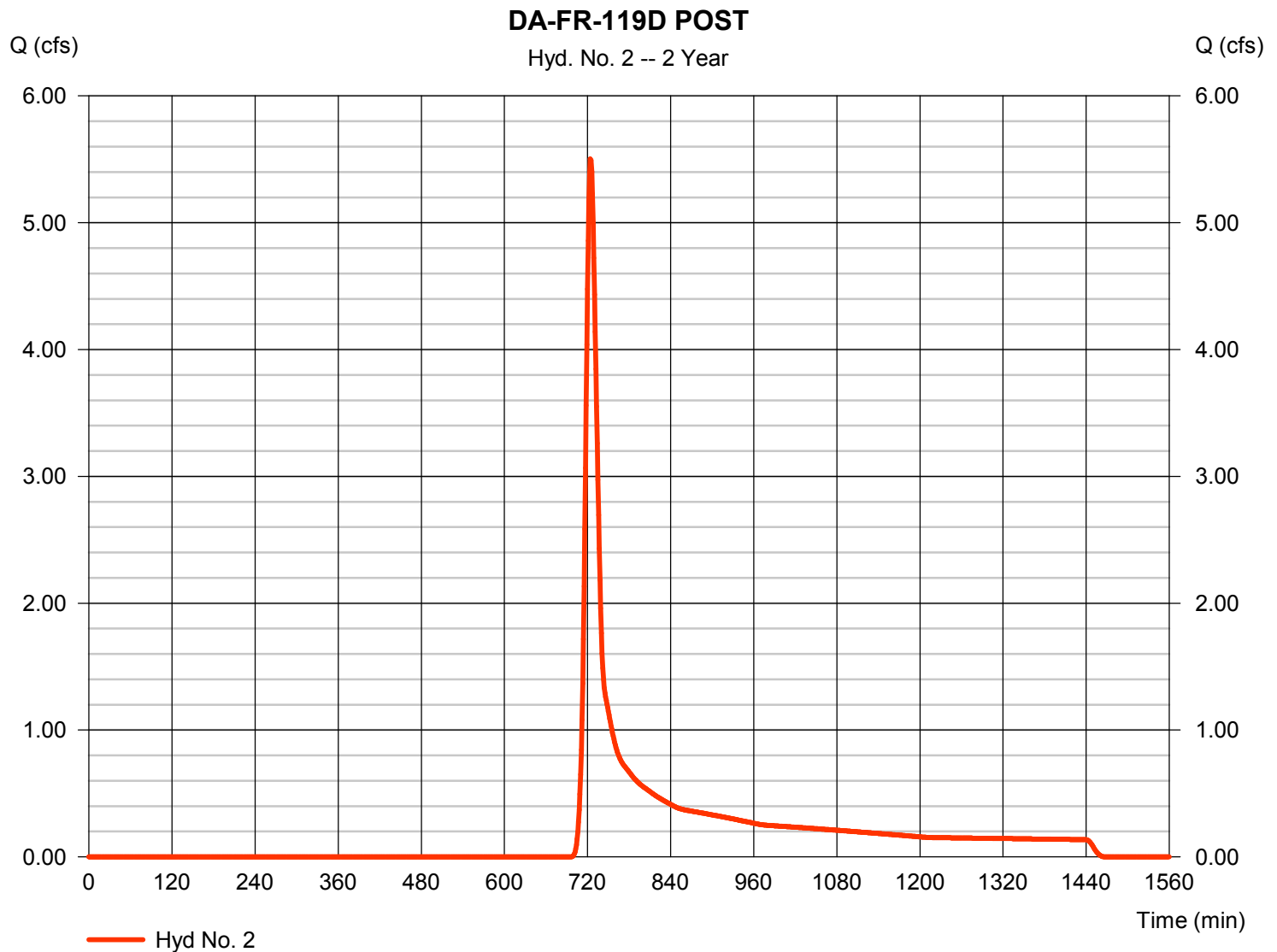
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 08 / 30 / 2017

Hyd. No. 2

DA-FR-119D POST

Hydrograph type	= SCS Runoff	Peak discharge	= 5.503 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 18,158 cuft
Drainage area	= 6.110 ac	Curve number	= 64*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.80 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(6.110 \times 64)] / 6.110$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

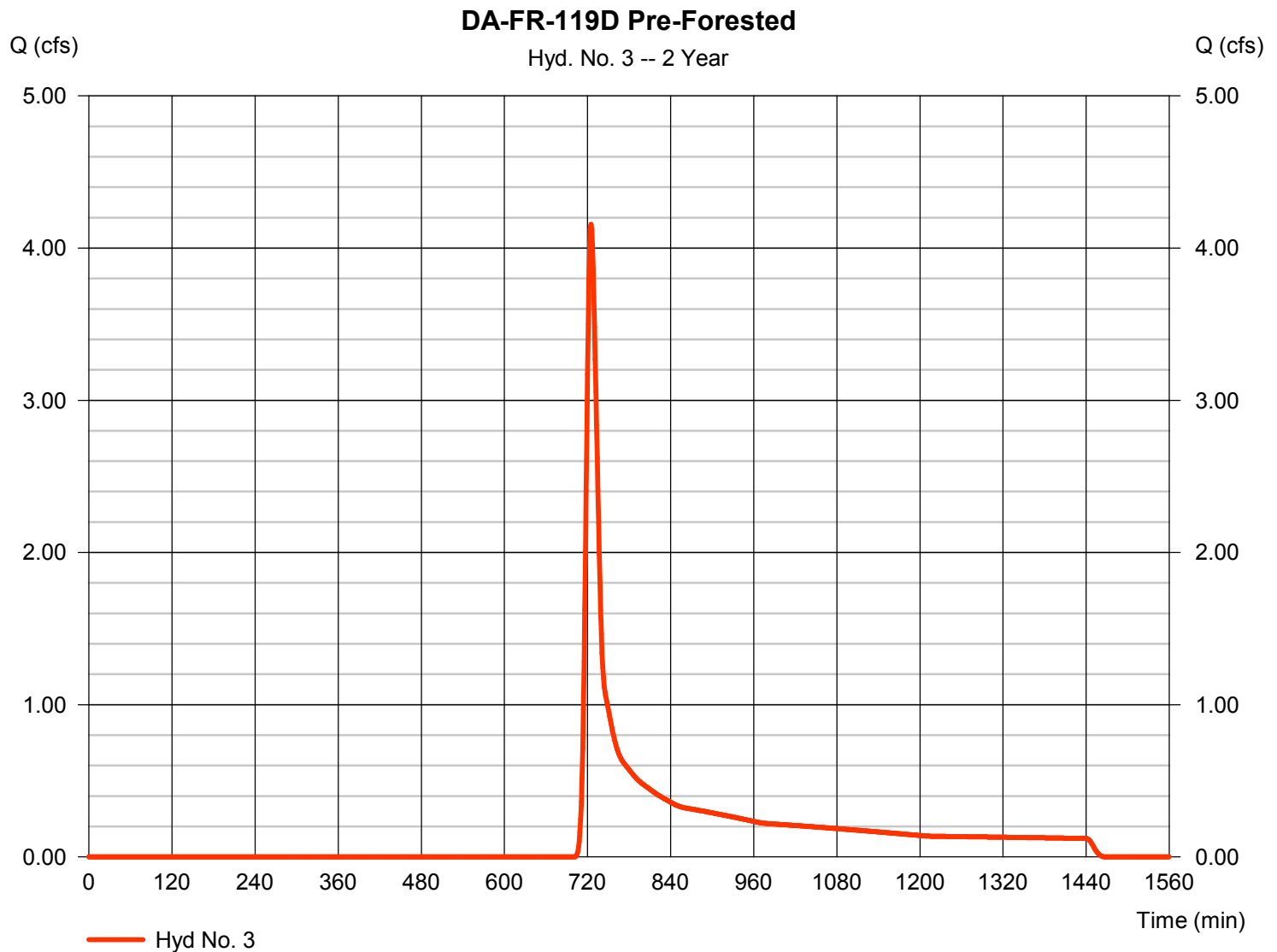
Wednesday, 08 / 30 / 2017

Hyd. No. 3

DA-FR-119D Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 4.157 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 14,936 cuft
Drainage area	= 6.110 ac	Curve number	= 61*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(3.690 \times 55) + (2.420 \times 70)] / 6.110$



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	15.73	1	724	46,081	-----	-----	-----	DA-FR-119D PRE
2	SCS Runoff	15.73	1	724	46,081	-----	-----	-----	DA-FR-119D POST
3	SCS Runoff	13.60	1	724	40,591	-----	-----	-----	DA-FR-119D Pre-Forested
DA-FR-119D.gpw					Return Period: 10 Year			Wednesday, 08 / 30 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

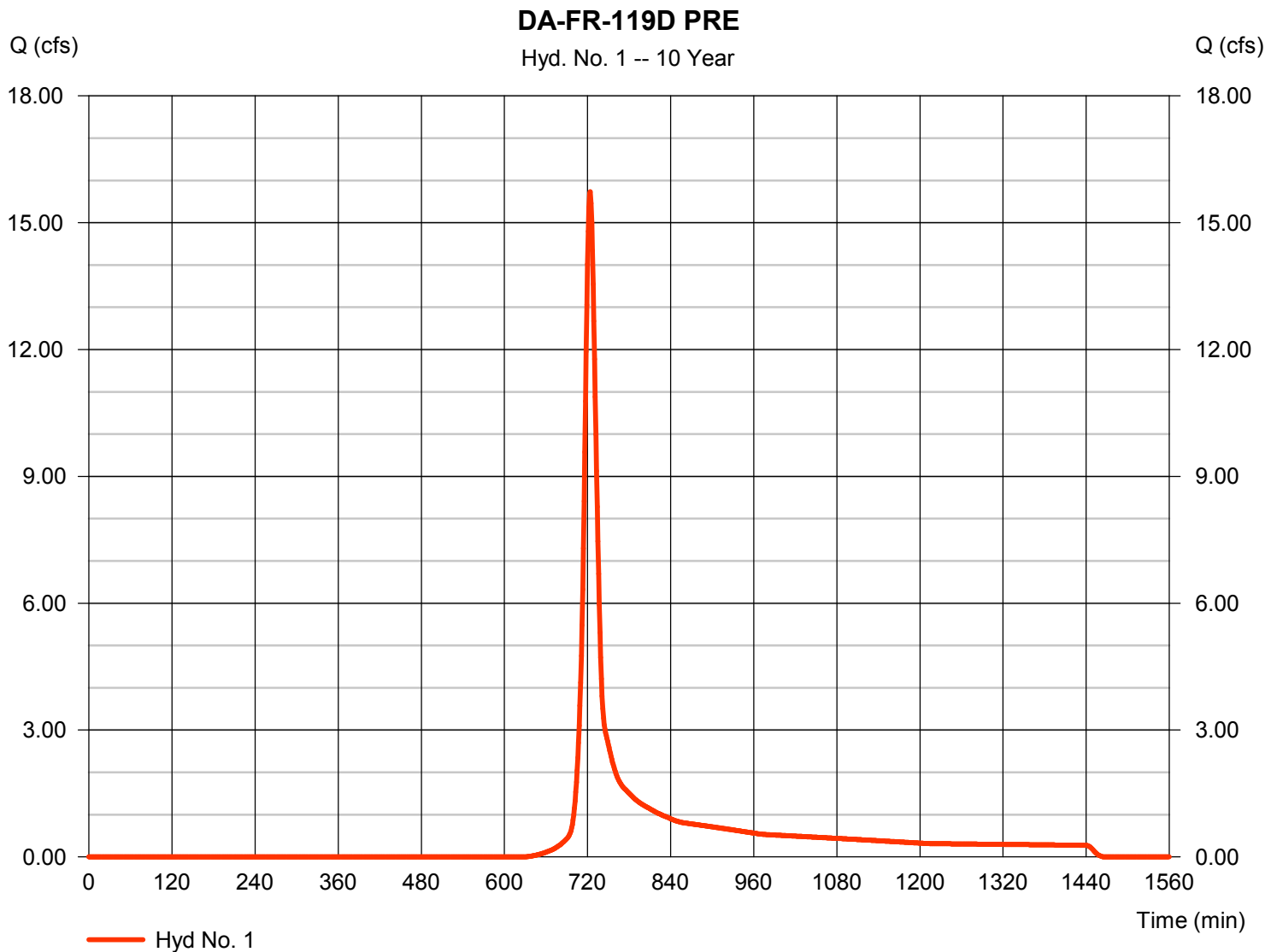
Wednesday, 08 / 30 / 2017

Hyd. No. 1

DA-FR-119D PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 15.73 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 46,081 cuft
Drainage area	= 6.110 ac	Curve number	= 64*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(6.110 x 64)] / 6.110



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

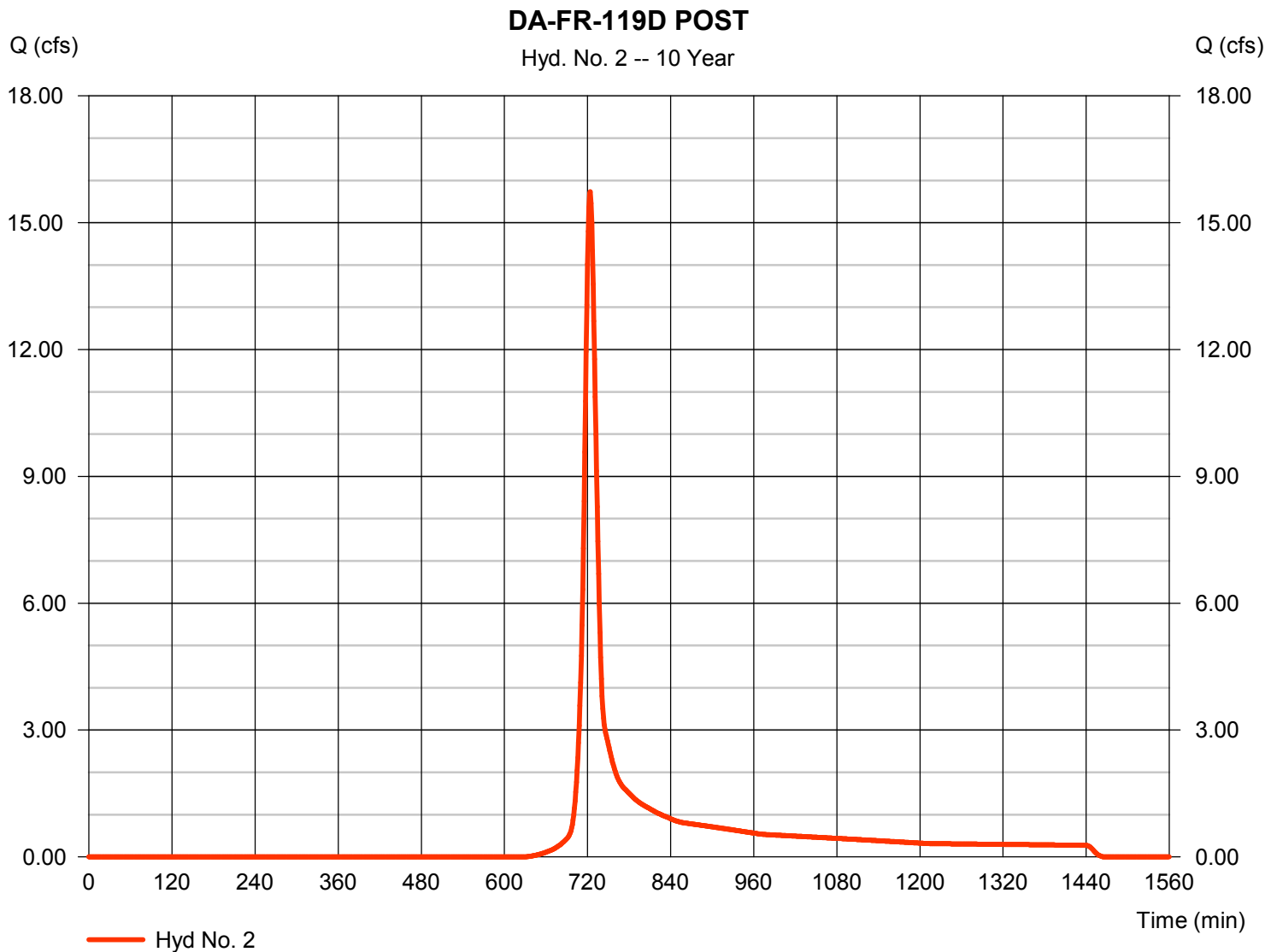
Wednesday, 08 / 30 / 2017

Hyd. No. 2

DA-FR-119D POST

Hydrograph type	= SCS Runoff	Peak discharge	= 15.73 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 46,081 cuft
Drainage area	= 6.110 ac	Curve number	= 64*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.80 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(6.110 x 64)] / 6.110



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

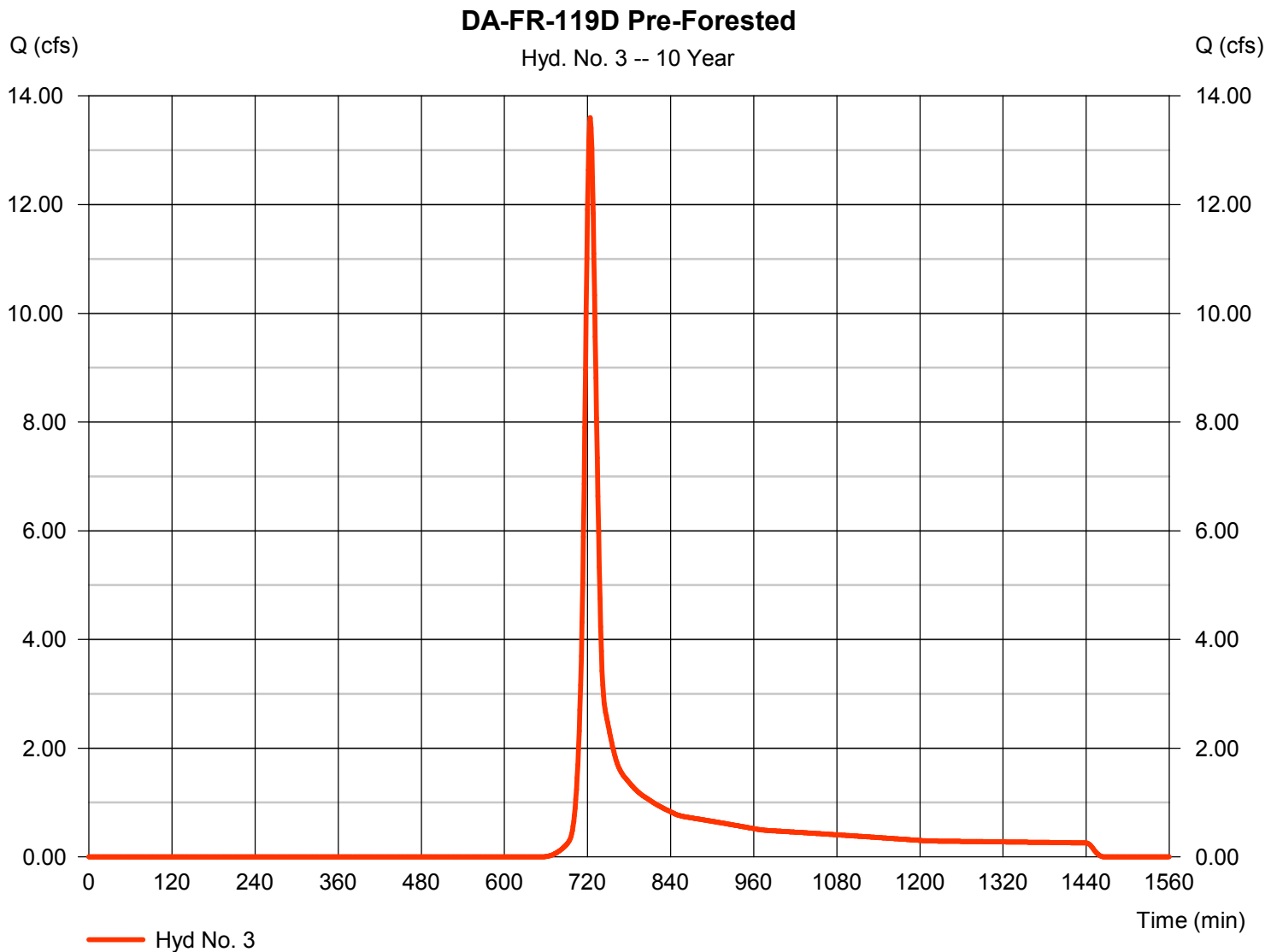
Wednesday, 08 / 30 / 2017

Hyd. No. 3

DA-FR-119D Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 13.60 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 40,591 cuft
Drainage area	= 6.110 ac	Curve number	= 61*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(3.690 \times 55) + (2.420 \times 70)] / 6.110$



DA-FR-120

DA-FR-120 is located in a meadow and forested areas with rolling slopes and contains agricultural land, existing dirt road and gravel road. A stream crosses the drainage area. No new impervious area is proposed within DA-FR-120. The total phosphorus load reduction required for DA-FR-120 is -0.64 lb/yr. Multiple points of analysis were evaluated within DA-FR-120 to evaluate the effects on each receiving stream/channel following construction. Specifically, DA-FR-120 was sub-divided into six sub-drainage areas (sub-areas A through F).

Sub-areas 120A and 120F contain both agricultural and non-agricultural areas within the limits of disturbance (LOD). Pre-construction agricultural areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction. In non-agricultural areas, land use will be restored following construction as noted in the Stormwater Management (SWM) Narrative and the Annual Standards and Specifications. Agricultural areas within the LOD are included in the SWM quality analysis and the total permanent Right of Way (ROW) is analyzed via VRRM; in these calculations agricultural areas are considered "Forest/Open Space".

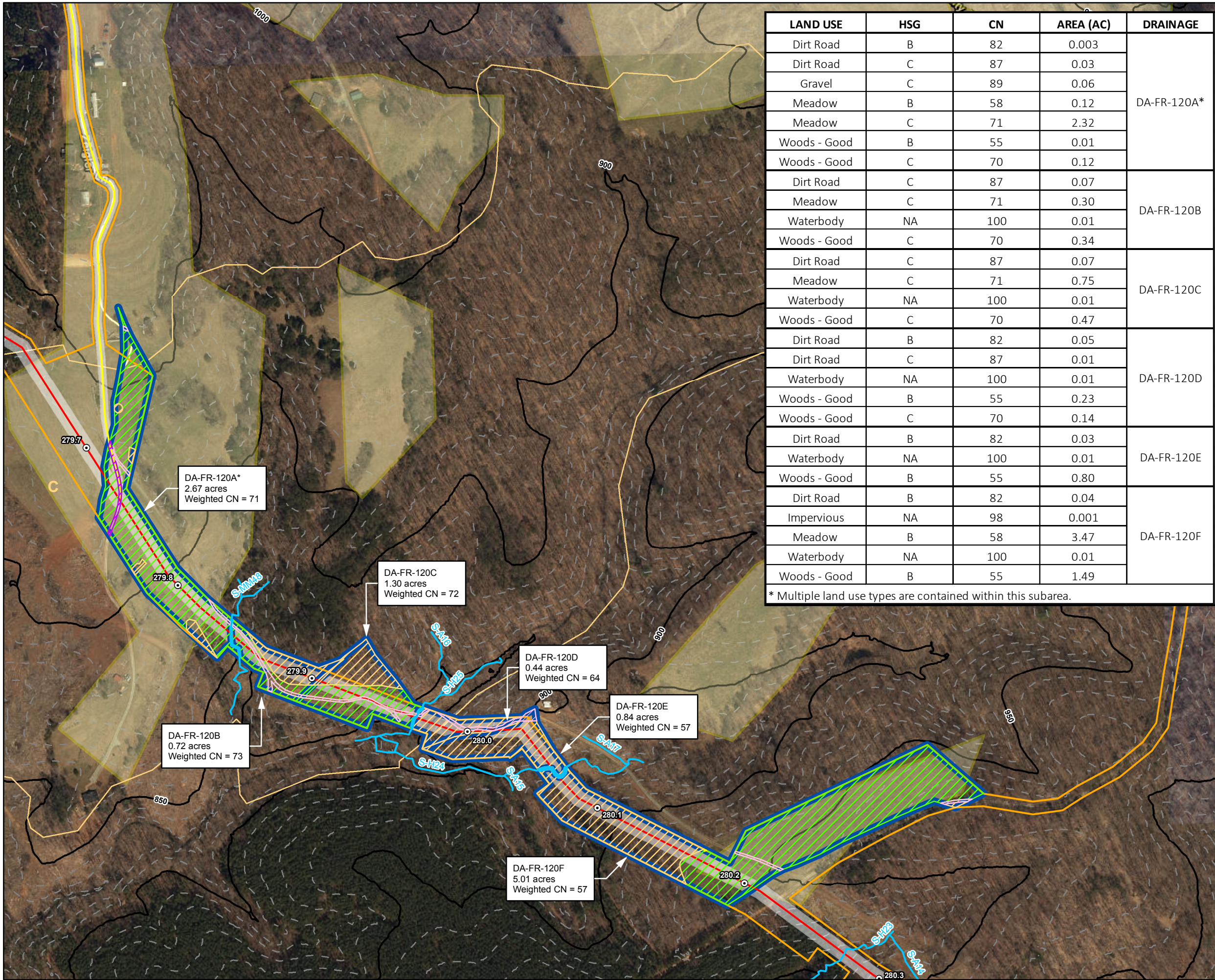
Stormwater quantity is met via the energy balance method for each of the six sub-areas DA-FR-120A through DA-FR-120F. Agricultural areas within the study area are included in the SWM analysis, but an Improvement Factor (IF) of 1.0 is used when applying the Energy Balance Method. This improvement factor is used to account for the exemption of agricultural areas (§ 62.1-44.15:34 and 9VAC25-870-300) since such areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction. BMPs utilized in the sub-areas included four water bars for 120B, five water bars for 120C and five water bars for 120F.

In addition, the Hydraflow Hydrograph's 10-year 24-hour peak discharge results indicate a reduction in flows ranging from 0.00 to 0.56 cfs for all of the sub-drainage areas (as seen in table below).

Sub Area	Pre Peak Flow, 10-yr Q (cfs)	Post Peak Flow, Q 10-yr (cfs)	Flow differential
DA-FR-120A	9.57	9.57	0.00
DA-FR-120B	2.67	2.65	-0.02
DA-FR-120C	5.46	5.39	-0.07
DA-FR-120D	1.44	1.38	-0.06
DA-FR-120E	2.04	1.48	-0.56
DA-FR-120F	8.87	8.80	-0.07

Figures and calculations for each of the sub-areas for DA-FR-120 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.

Note that the sub-area 120A had a time of concentration flow path for the Post-Construction condition that accounted for a permanent water bar that is not cited within the drainage area. This permanent water bar was removed because it was cited in an agricultural area, and resulting changes to the stormwater calculations were flagged during the QA/QC review process. This change was considered to be inconsequential because no stormwater BMPs are sited in DA-FR-120A, so the resulting changes were not made to the stormwater calculations prior to submittal.



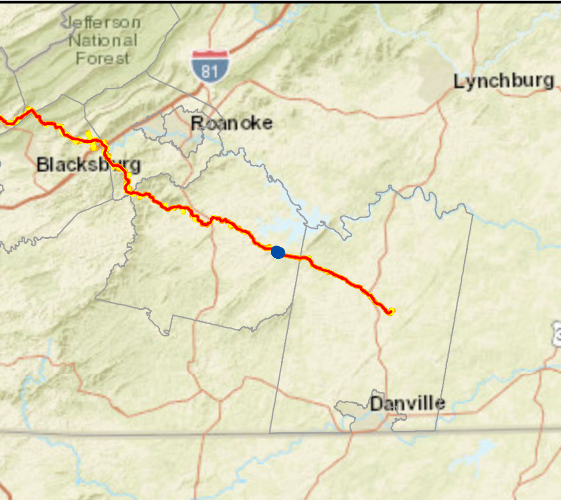
LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Dirt Road	B	82	0.003	DA-FR-120A*
Dirt Road	C	87	0.03	
Gravel	C	89	0.06	
Meadow	B	58	0.12	
Meadow	C	71	2.32	
Woods - Good	B	55	0.01	
Woods - Good	C	70	0.12	
Dirt Road	C	87	0.07	DA-FR-120B
Meadow	C	71	0.30	
Waterbody	NA	100	0.01	
Woods - Good	C	70	0.34	
Dirt Road	C	87	0.07	DA-FR-120C
Meadow	C	71	0.75	
Waterbody	NA	100	0.01	
Woods - Good	C	70	0.47	
Dirt Road	B	82	0.05	DA-FR-120D
Dirt Road	C	87	0.01	
Waterbody	NA	100	0.01	
Woods - Good	B	55	0.23	
Woods - Good	C	70	0.14	DA-FR-120E
Dirt Road	B	82	0.03	
Waterbody	NA	100	0.01	
Woods - Good	B	55	0.80	
Dirt Road	B	82	0.04	DA-FR-120F
Impervious	NA	98	0.001	
Meadow	B	58	3.47	
Waterbody	NA	100	0.01	
Woods - Good	B	55	1.49	

* Multiple land use types are contained within this subarea.

Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Dirt Road
- Gravel
- Impervious
- Meadow
- Waterbody
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)
1:3,600



Mountain Valley Pipeline Project

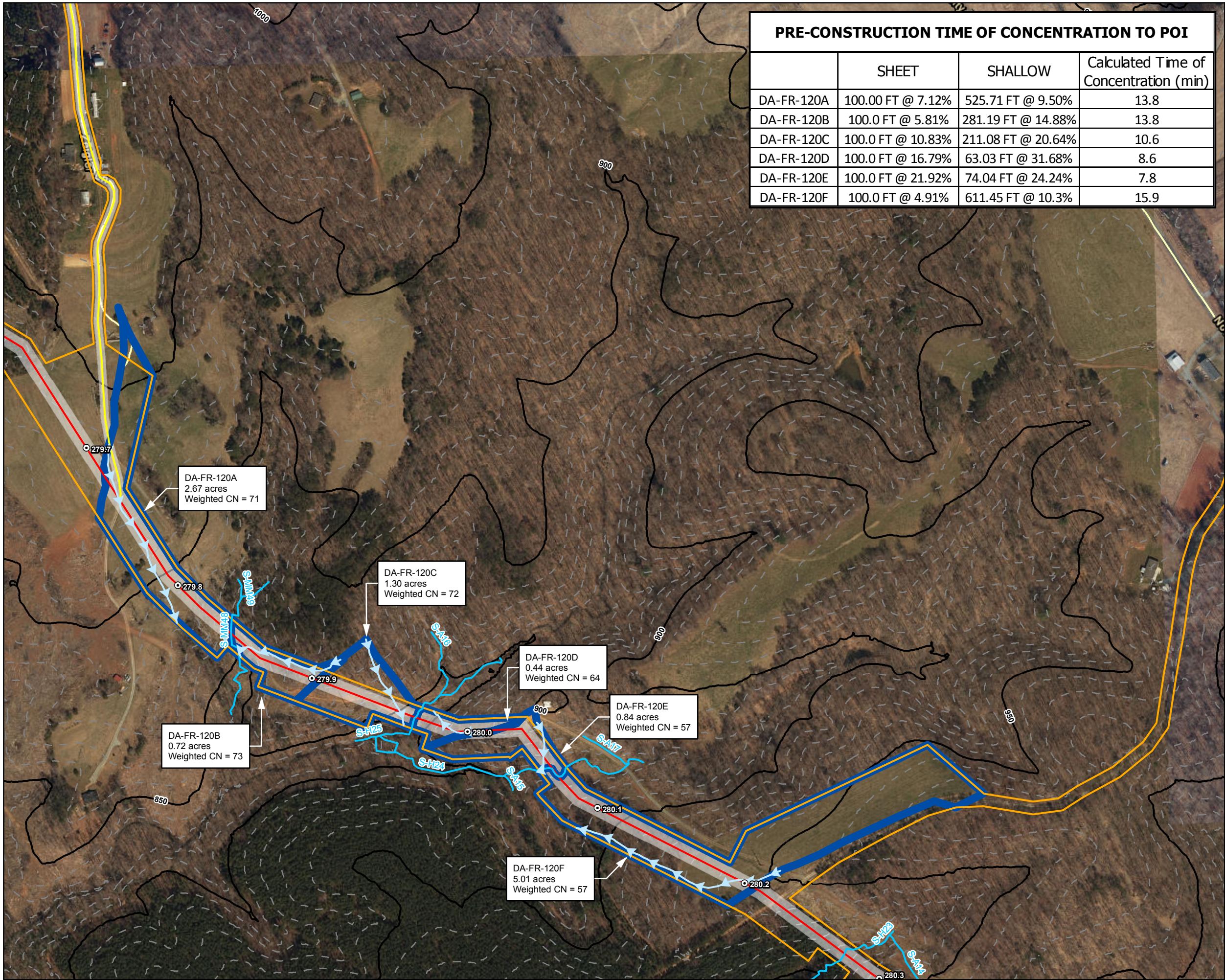


Pre-Construction Drainage Area Map
DA-FR-120
Spread 11

Figure 1
Franklin County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.



PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI			
	SHEET	SHALLOW	Calculated Time of Concentration (min)
DA-FR-120A	100.00 FT @ 7.12%	525.71 FT @ 9.50%	13.8
DA-FR-120B	100.0 FT @ 5.81%	281.19 FT @ 14.88%	13.8
DA-FR-120C	100.0 FT @ 10.83%	211.08 FT @ 20.64%	10.6
DA-FR-120D	100.0 FT @ 16.79%	63.03 FT @ 31.68%	8.6
DA-FR-120E	100.0 FT @ 21.92%	74.04 FT @ 24.24%	7.8
DA-FR-120F	100.0 FT @ 4.91%	611.45 FT @ 10.3%	15.9

Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:3,600

300 150 0 300 Feet

Mountain Valley Pipeline Project

Pre-Construction Drainage Area and Time of Concentration
DA-FR-120
Spread 11
Figure 3
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database

POST-CONSTRUCTION TIME OF CONCENTRATION TO POI							
	SHEET 1	SHEET 2	SHEET 3	SHALLOW1	SHALLOW2	CHANNEL	Calculated Time of Concentration (min)
DA-FR-120A	100.00 FT @ 7.12%	-	-	219.49 FT @ 7.18%	294.17 FT @ 11.30%	19.02 FT @ 4.94%	13.8
DA-FR-120B	100.00 FT @ 5.81%	-	-	107.26 FT @ 13.76%	121.84 FT @ 18.47%	46.67 FT @ 6.73%	13.8
DA-FR-120C	100.00 FT @ 10.83%	-	-	211.08 FT @ 20.64%	-	-	10.6
DA-FR-120D	100.00 FT @ 16.79%	-	-	63.03 FT @ 31.68%	-	-	8.6
DA-FR-120E	55.04 FT @ 22.76%	25.08 FT @ 22.63%	17.50 FT @ 18.40%	22.37 FT @ 27.99%	-	40.16 FT @ 6.41%	11.3
DA-FR-120F	100.00 FT @ 4.91%	-	-	36.93 FT @ 5.85%	549.32 FT @ 10.62%	28.74 FT @ 4.99%	15.9

Legend

- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:3,600

300 150 0 300 Feet



Mountain Valley Pipeline Project



Post-Construction Drainage Area and Time of Concentration
DA-FR-120
Spread 11

Figure 4
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database

Document Path: P:\GIS\REQ\MVP\Mapdocs\Drainage\MXD\Franklin\Figures 3-4\MVP_PCSM_DA-FR-120_4.mxd

DEQ Virginia Runoff Reduction Method Re-Development Compliance Spreadsheet - Version 3.0

BMP Design Specifications List: 2013 Draft Stds & Specs

Site Summary - Linear Development Project***

Total Rainfall (in):	43
Total Disturbed Acreage:	3.02

Site Land Cover Summary

Pre-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	1.30	1.54	0.00	2.84	94
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.04	0.13	0.00	0.17	6
					3.01	100

Post-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	1.30	1.54	0.00	2.84	94
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.04	0.13	0.00	0.17	6
					3.01	100

* Forest/Open Space areas must be protected in accordance with the Virginia Runoff Reduction Method

Site Tv and Land Cover Nutrient Loads

	Final Post-Development (Post-ReDevelopment & New Impervious)	Post- ReDevelopment	Post- Development (New Impervious)	Adjusted Pre- ReDevelopment
Site Rv	0.09	0.09	--	0.09
Treatment Volume (ft ³)	951	951	--	951
TP Load (lb/yr)	0.60	0.60	--	0.60

Baseline TP Load (lb/yr): 1.2341* *Reduction below new development load limitation not required

Pre- ReDevelopment TP Load per acre (lb/acre/yr)	Final Post-Development TP Load per acre (lb/acre/yr)	Post-ReDevelopment TP Load per acre (lb/acre/yr)
0.20	0.20	0.20

Total TP Load Reduction Required (lb/yr)	-0.64	N/A***	N/A***
--	-------	--------	--------

***This is a linear development project

	Final Post-Development Load (Post-ReDevelopment & New Impervious)	Pre- ReDevelopment
TN Load (lb/yr)	4.28	4.28

Site Compliance Summary - ***Linear Development Project

Maximum % Reduction Required Below Pre-ReDevelopment Load	20%
--	-----

* Note: % Reduction will reduce post-development TP load to less than or equal to baseline load of 1.23 lb/yr (0.41 lb/ac/yr)
 [Post-Dev Reduction Requirement = Post-Dev TP load - baseline load of 1.23 lb/yr], baseline load = site area x 0.41 lb/ac/yr

Total Runoff Volume Reduction (ft ³)	0
--	---

Total TP Load Reduction Achieved (lb/yr)	0.00
Total TN Load Reduction Achieved (lb/yr)	0.00
Remaining Post Development TP Load (lb/yr)	0.60
Remaining TP Load Reduction (lb/yr) Required	0.00

**** TARGET TP REDUCTION EXCEEDED BY 0.64 LB/YEAR ****

**Reduction below new development load limitation not required*

DA-FR-120A

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	3.190	9099
Developed Condition	3.190	9099
Pre-Developed (Forest) Condition	0.440	2724

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 1

Calculations:

Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	3.190	\leq	3.190
			OK	
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	3.190	\leq	3.190
			OK	
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ ---->	3.190	<u>shall not</u> be required to be \leq	0.132

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s n value of 0.011 was used.</p> <p><i>Sources:</i></p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

Table 2 – Manning's *n* Values for Open Channel Flow

Channel Type	Manning <i>n</i>		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's <i>n</i> value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's <i>n</i> value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-120A PRE
2	SCS Runoff	DA-FR-120A DEV
3	SCS Runoff	DA-FR-120A FOR

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

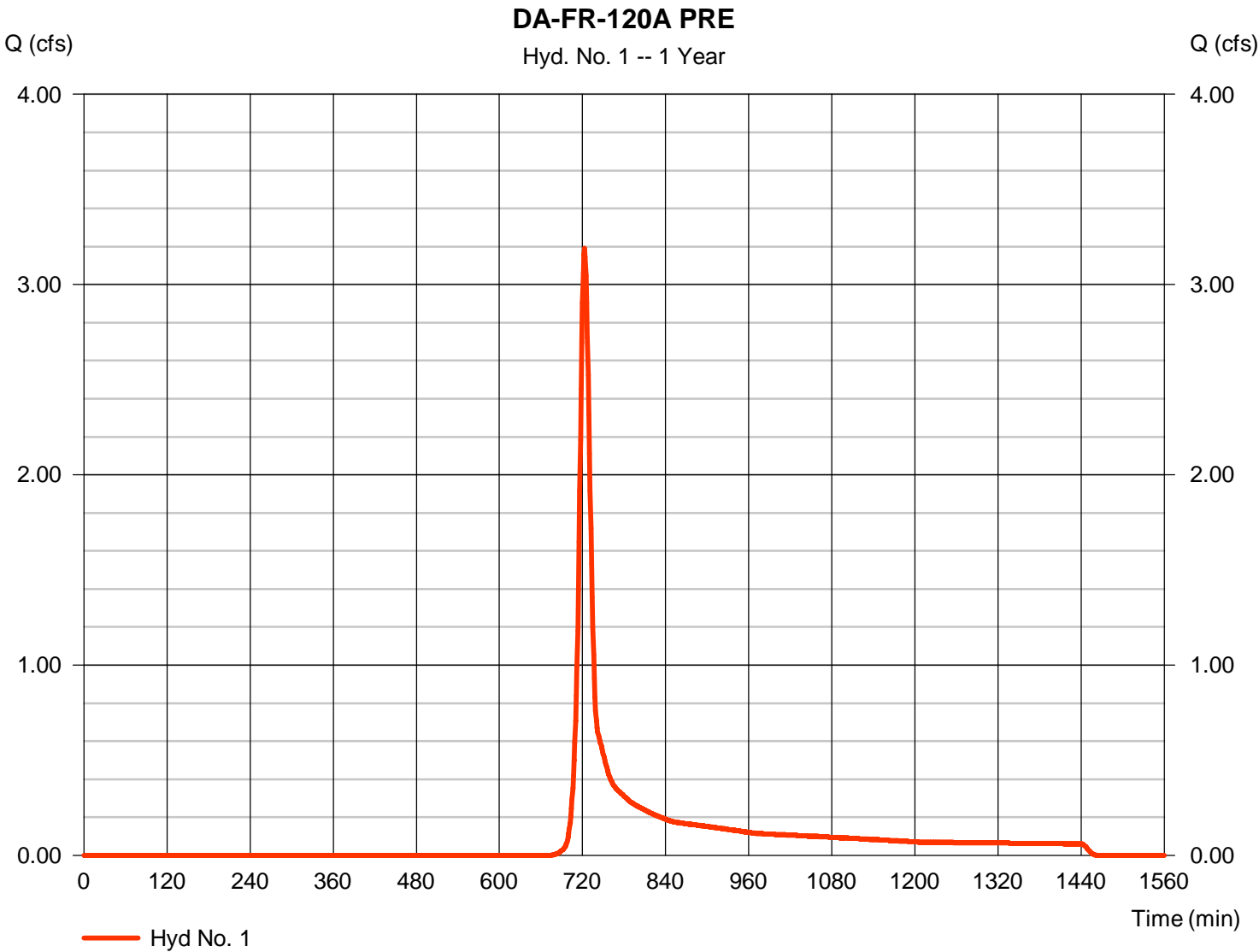
Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	3.190	1	723	9,099	-----	-----	-----	DA-FR-120A PRE
2	SCS Runoff	3.190	1	723	9,099	-----	-----	-----	DA-FR-120A DEV
3	SCS Runoff	0.440	1	726	2,724	-----	-----	-----	DA-FR-120A FOR
DA-FR-120A_Hydraflow.gpw					Return Period: 1 Year			Friday, 08 / 18 / 2017	

Hydrograph Report

Hyd. No. 1

DA-FR-120A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 3.190 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 9,099 cuft
Drainage area	= 2.670 ac	Curve number	= 71
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.80 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-120A PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 7.12	0.00	0.00				
Travel Time (min)	= 12.02	+	0.00	+	0.00	=	12.02
Shallow Concentrated Flow							
Flow length (ft)	= 525.71	0.00	0.00				
Watercourse slope (%)	= 9.50	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=4.97	0.00	0.00				
Travel Time (min)	= 1.76	+	0.00	+	0.00	=	1.76
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				13.80 min			

Hydrograph Report

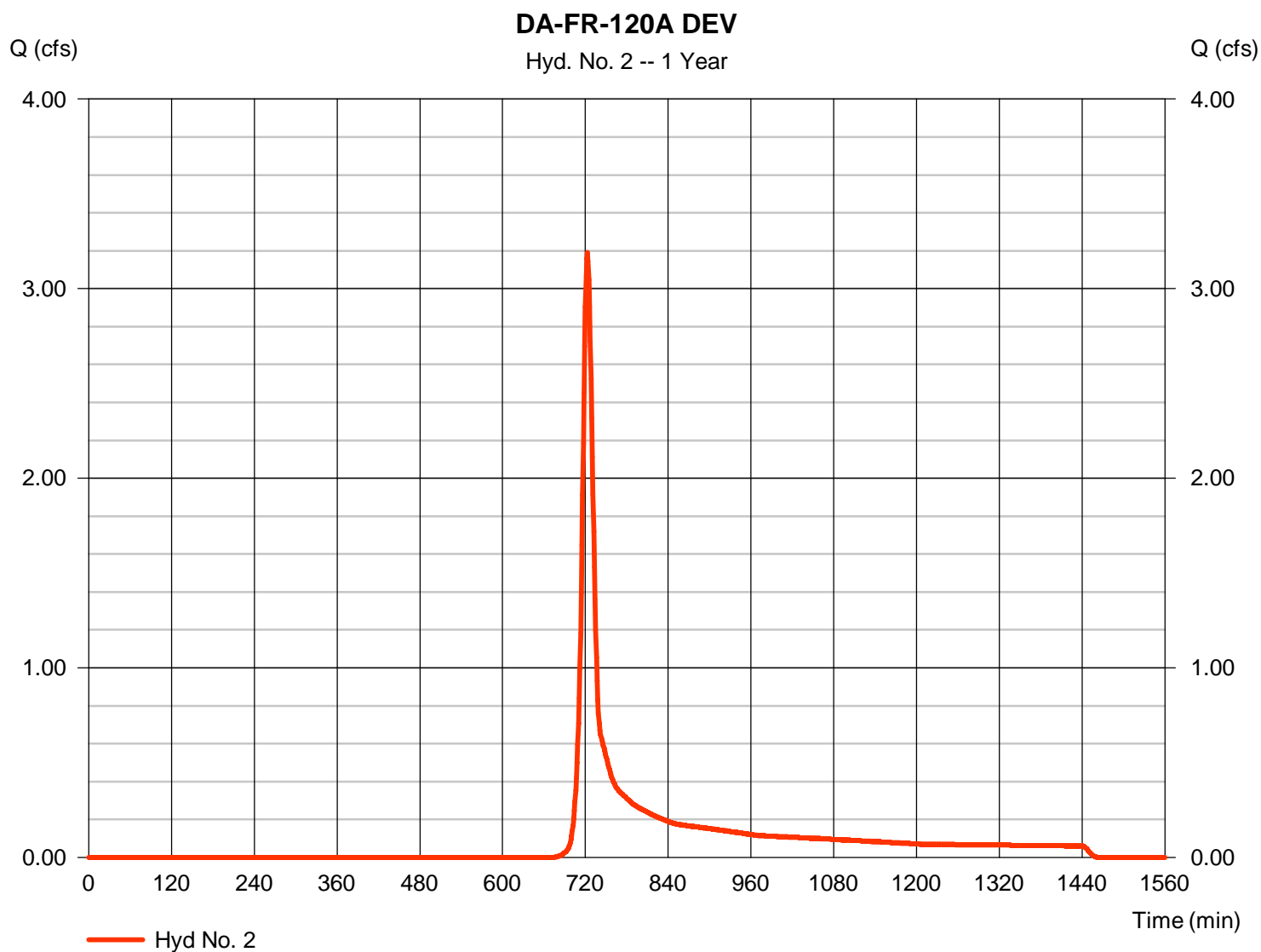
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Friday, 08 / 18 / 2017

Hyd. No. 2

DA-FR-120A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 3.190 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 9,099 cuft
Drainage area	= 2.670 ac	Curve number	= 71
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.80 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-120A DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 7.12	0.00	0.00				
Travel Time (min)	= 12.02	+	0.00	+	0.00	=	12.02
Shallow Concentrated Flow							
Flow length (ft)	= 219.49	294.17	0.00				
Watercourse slope (%)	= 7.18	11.30	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=4.32	5.42	0.00				
Travel Time (min)	= 0.85	+	0.90	+	0.00	=	1.75
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	(\{0\})19.0	0.0	0.0				
Travel Time (min)	= 0.07	+	0.00	+	0.00	=	0.07
Total Travel Time, Tc				13.80 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

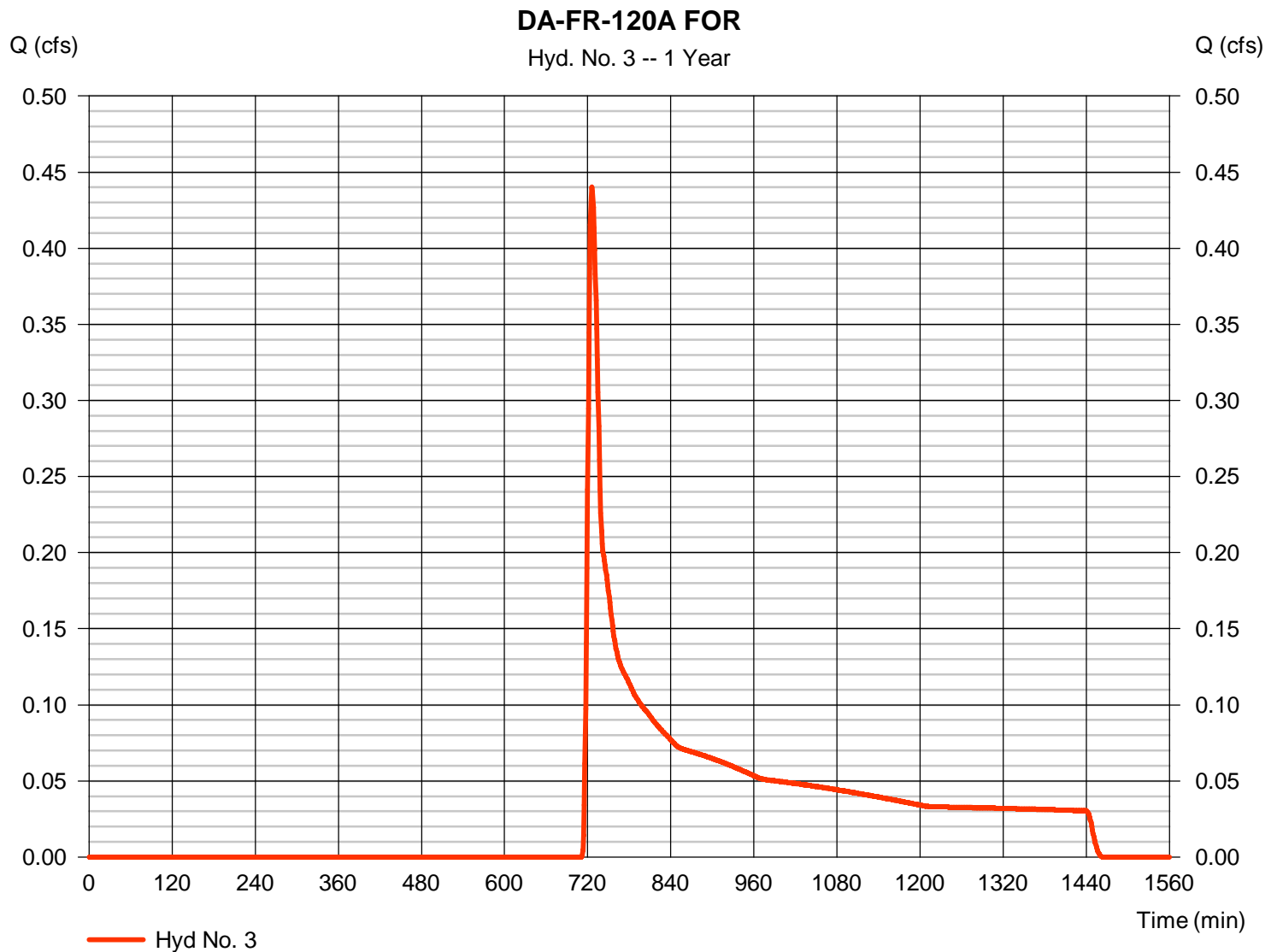
Friday, 08 / 18 / 2017

Hyd. No. 3

DA-FR-120A FOR

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 2.670 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.30 in
 Storm duration = 24 hrs

Peak discharge = 0.440 cfs
 Time to peak = 726 min
 Hyd. volume = 2,724 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 13.80 min
 Distribution = Type II
 Shape factor = 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-120A FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 7.12	0.00	0.00				
Travel Time (min)	= 12.02	+	0.00	+	0.00	=	12.02
Shallow Concentrated Flow							
Flow length (ft)	= 525.71	0.00	0.00				
Watercourse slope (%)	= 9.50	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=4.97	0.00	0.00				
Travel Time (min)	= 1.76	+	0.00	+	0.00	=	1.76
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	= 0.400	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				13.80 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	4.144	1	723	11,563	-----	-----	-----	DA-FR-120A PRE
2	SCS Runoff	4.144	1	723	11,563	-----	-----	-----	DA-FR-120A DEV
3	SCS Runoff	0.875	1	725	4,028	-----	-----	-----	DA-FR-120A FOR
DA-FR-120A_Hydraflow.gpw					Return Period: 2 Year			Friday, 08 / 18 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

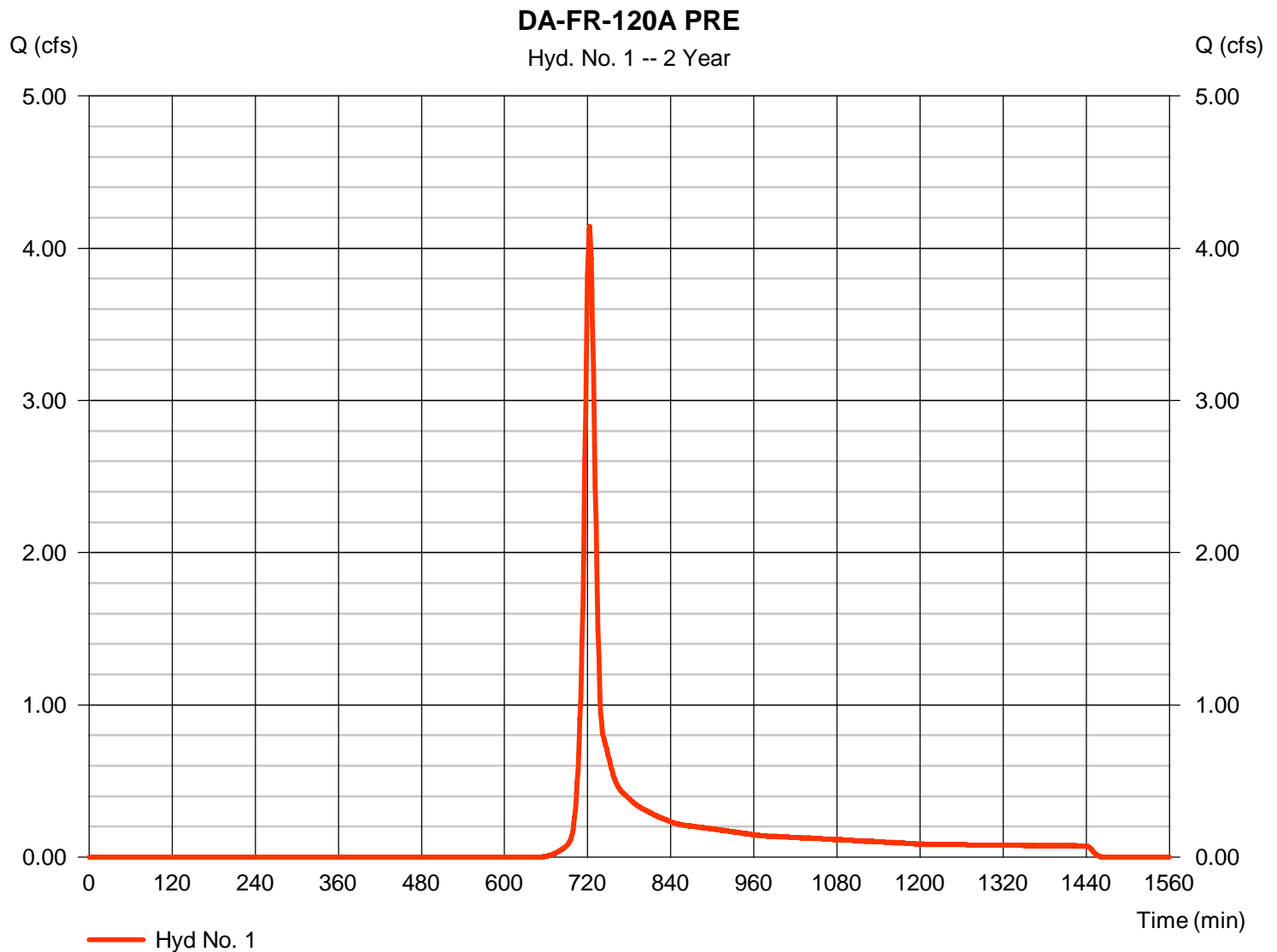
Friday, 08 / 18 / 2017

Hyd. No. 1

DA-FR-120A PRE

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 2.670 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 4.144 cfs
 Time to peak = 723 min
 Hyd. volume = 11,563 cuft
 Curve number = 71
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 13.80 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

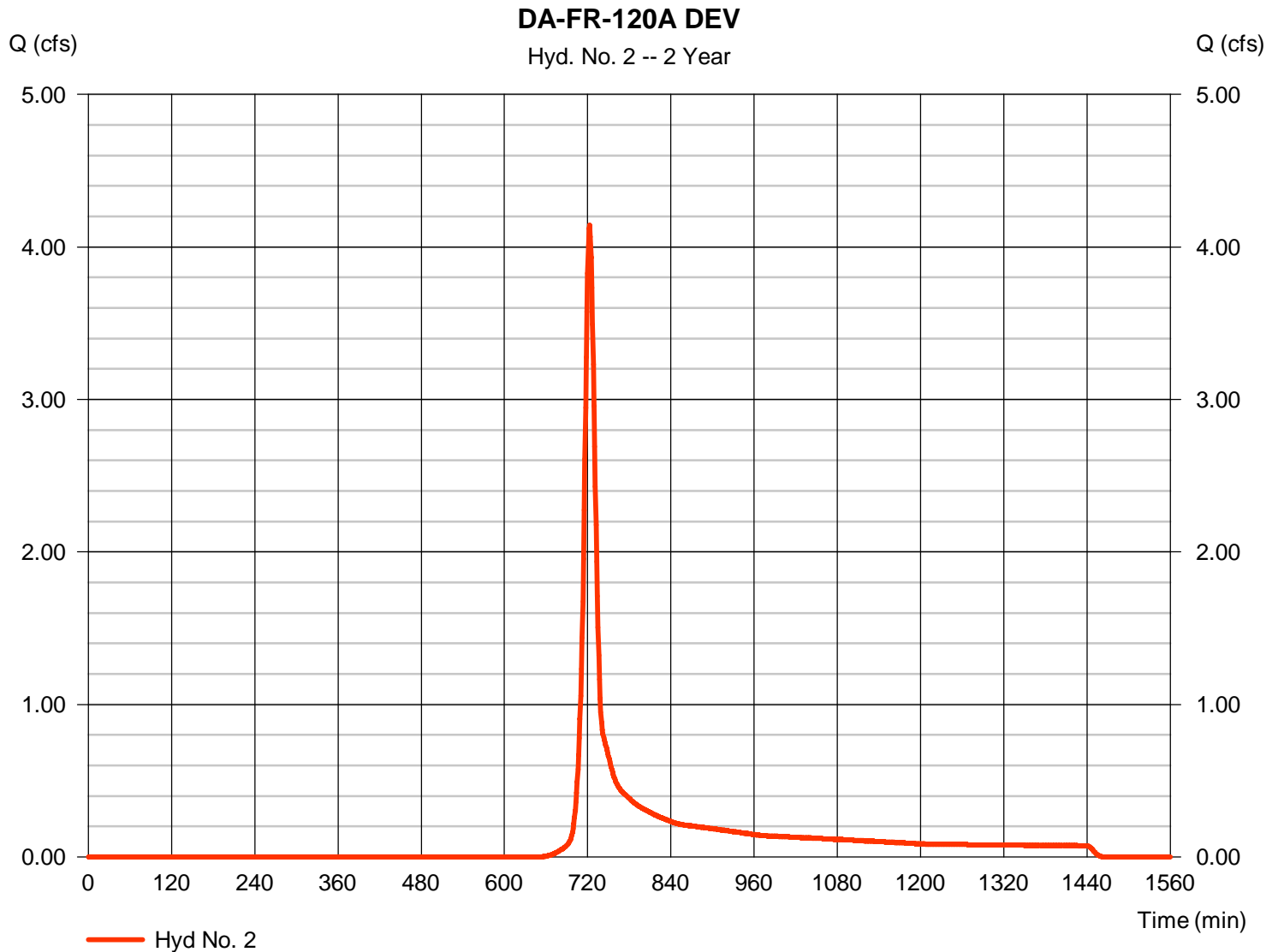
Friday, 08 / 18 / 2017

Hyd. No. 2

DA-FR-120A DEV

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 2.670 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 4.144 cfs
 Time to peak = 723 min
 Hyd. volume = 11,563 cuft
 Curve number = 71
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 13.80 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

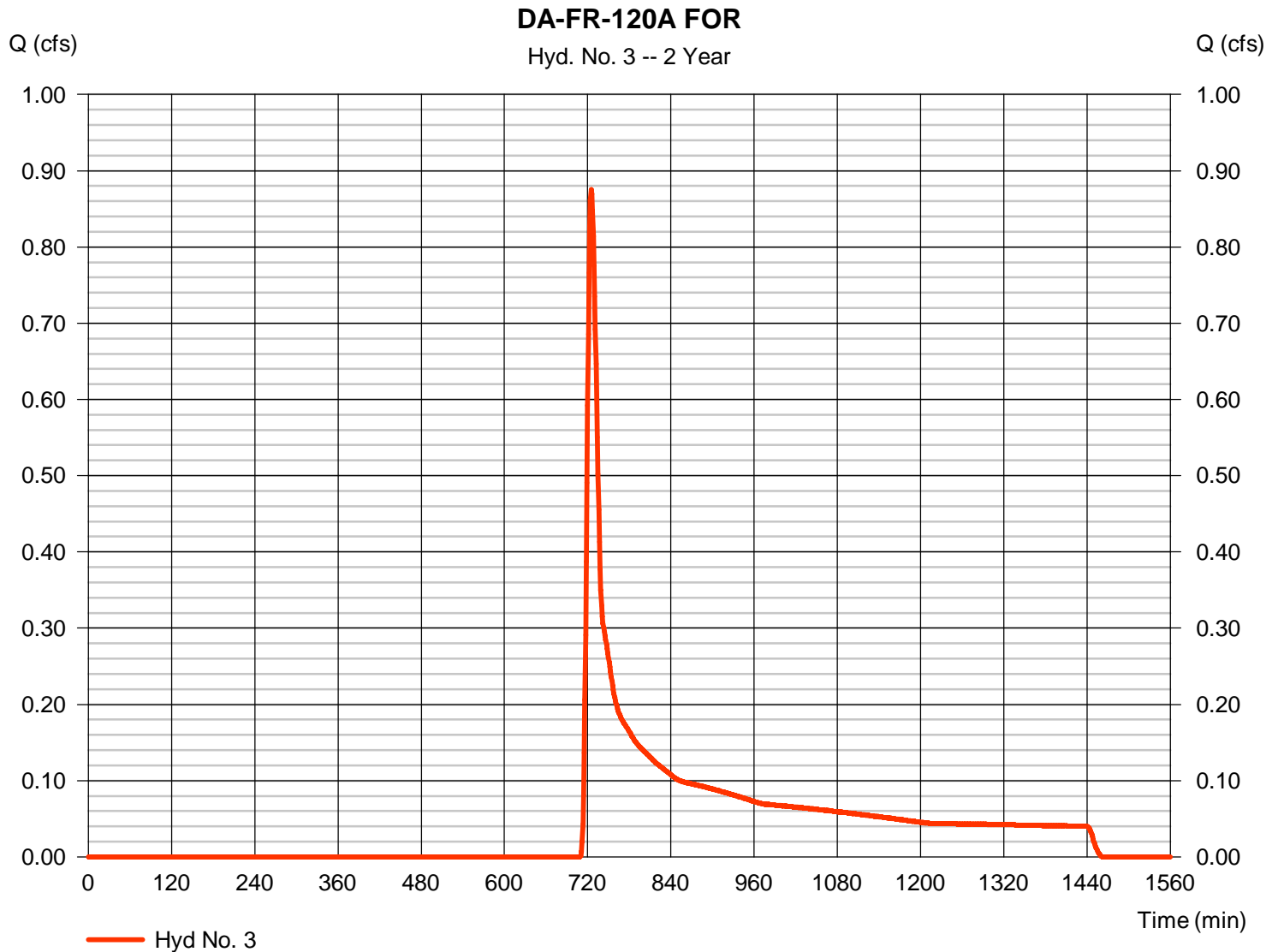
Friday, 08 / 18 / 2017

Hyd. No. 3

DA-FR-120A FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 2.670 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.875 cfs
 Time to peak = 725 min
 Hyd. volume = 4,028 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 13.80 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	9.565	1	722	25,771	-----	-----	-----	DA-FR-120A PRE
2	SCS Runoff	9.565	1	722	25,771	-----	-----	-----	DA-FR-120A DEV
3	SCS Runoff	4.374	1	723	13,070	-----	-----	-----	DA-FR-120A FOR
DA-FR-120A_Hydraflow.gpw					Return Period: 10 Year			Friday, 08 / 18 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

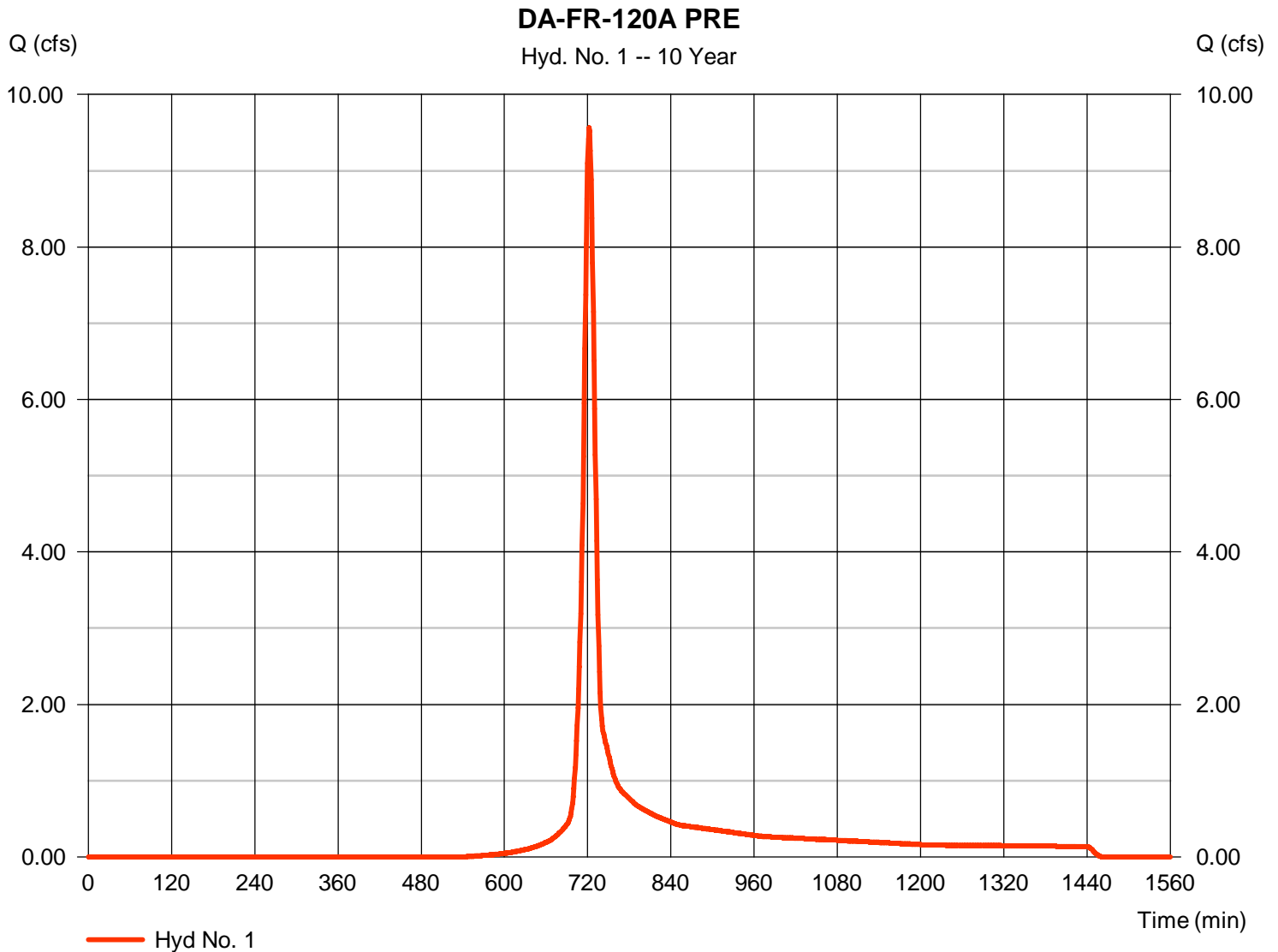
Friday, 08 / 18 / 2017

Hyd. No. 1

DA-FR-120A PRE

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 2.670 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 9.565 cfs
 Time to peak = 722 min
 Hyd. volume = 25,771 cuft
 Curve number = 71
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 13.80 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

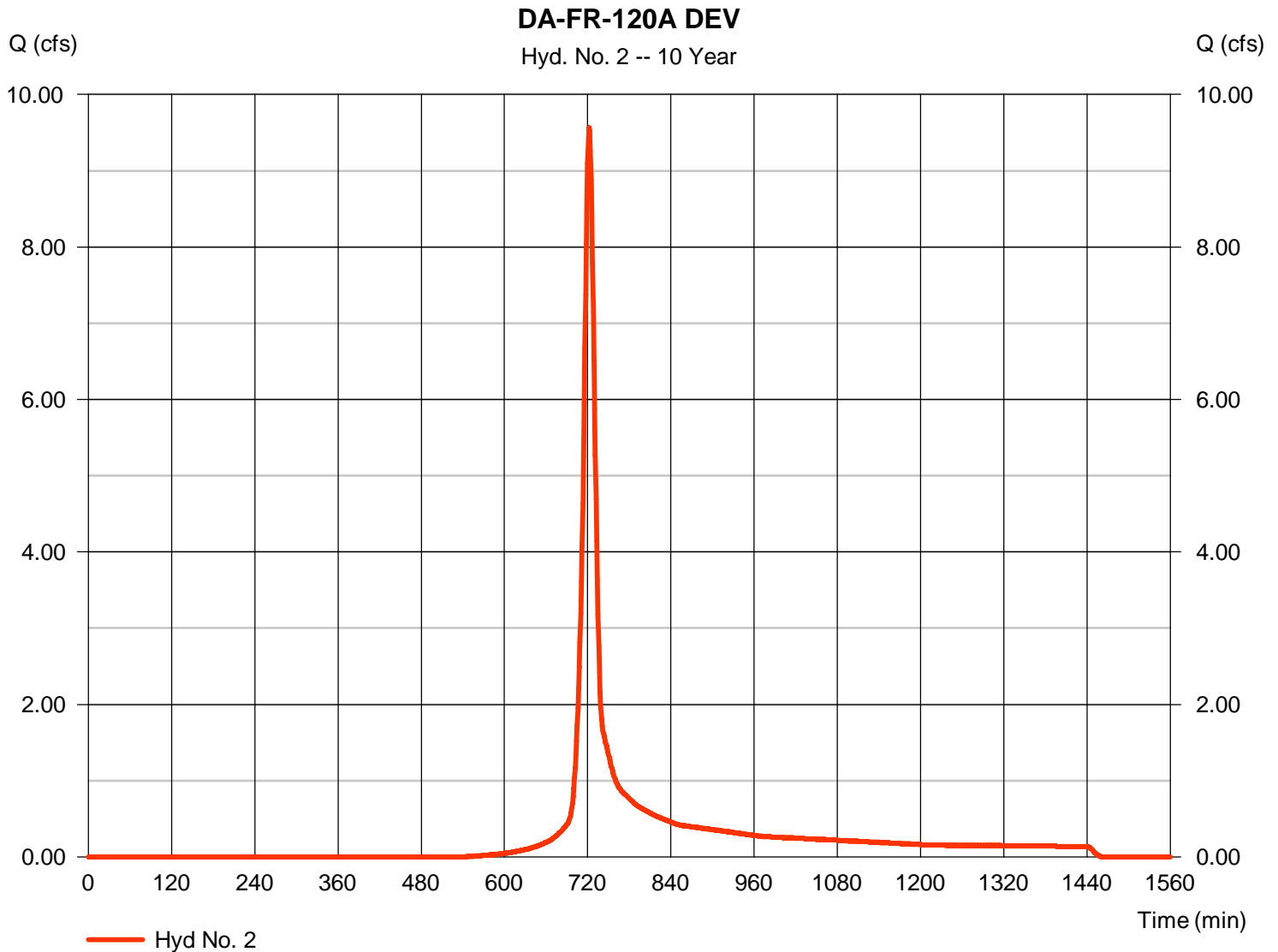
Friday, 08 / 18 / 2017

Hyd. No. 2

DA-FR-120A DEV

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 2.670 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 9.565 cfs
 Time to peak = 722 min
 Hyd. volume = 25,771 cuft
 Curve number = 71
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 13.80 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

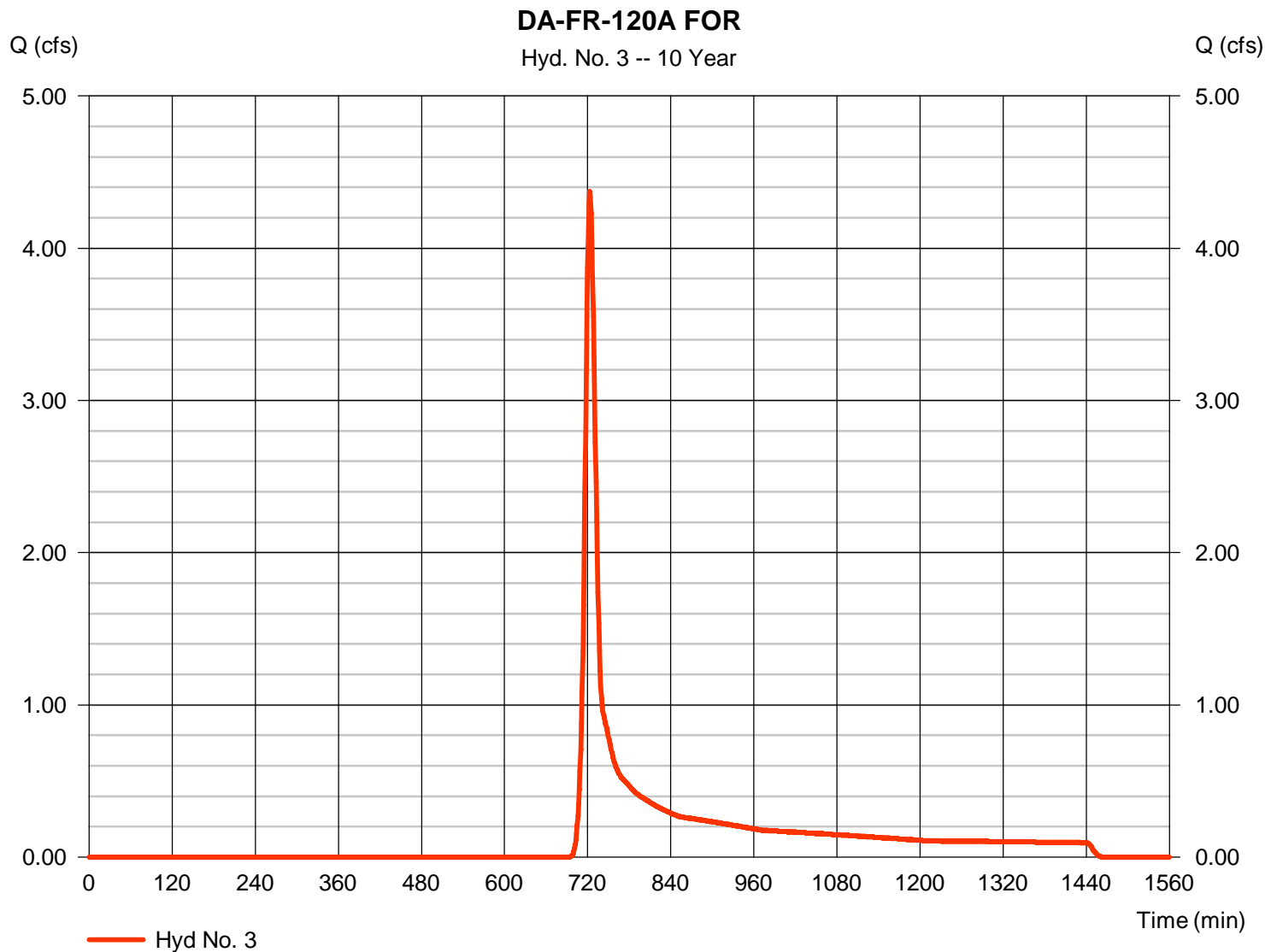
Friday, 08 / 18 / 2017

Hyd. No. 3

DA-FR-120A FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 2.670 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 4.374 cfs
 Time to peak = 723 min
 Hyd. volume = 13,070 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 13.80 min
 Distribution = Type II
 Shape factor = 484



DA-FR-120B

STORAGE VOLUME OF WATERBAR WITH SOIL COMPOST AMENDMENT AREA

Equations Used:

¹V_{gravel} storage = L*W*D_{gravel}*(40/100)

²V_{soil} storage = L*W*D_{soil}*(20/100)

³V_{surface} storage = [W*S*D²/2]+[L*S*D²/2]+[W*L*D]+[(2*S*D)/2*D]/3]

¹Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that gravel is made up of 40% voids.

²Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that soil compost amendment is made up of 20% voids.

³Equation #1 under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, but calculation also takes into account surface side slopes.

Inputs:

Depth of Gravel Layer, D _{gravel} (ft) =	0	
Depth of Soil Amendment Area, D _{soil} (ft) =	1	Refer to Table 4.3 in VA DEQ Stormwater Design Specification No. 4; Note that compost amendment may not be necessary for HSG A/B soils
Length of Waterbar Soil Amendment Area, L (ft) =	40	Assume max. length of 50' for waterbar soil amendment areas (i.e., limited to permanent ROW)
Width of Waterbar Soil Amendment Area, W (ft) =	3	
Inside Embankment Side Slopes, S (H:V) =	2	Assume 2H:1V surface side slopes for waterbars
Number of Perm. Waterbars in Drainage Area, n =	4	
Design Infiltration Rate, IR (in/hr) =	0.2	Min. rate of 0.30 in/hr for HSG A soils and 0.15-0.30 in/hr for HSG B soils (see Chap. 4, p. 4-30 in VA Stormwater Management Handbook Volume II (First Edition, 1999)
Surface Ponding Depth, D (ft) =	0.5	Assume 0.5' CFS height at the end of waterbars

Calculations:

Total Storage Depth per BMP (ft) =	1.5
Surface Storage Volume per BMP (cf) =	82
Subsurface Storage Volume per BMP (cf) =	24
Total Storage Volume per BMP (cf) =	106
Total BMP Storage Volume in Drainage Area (cf) =	425
Calculated Infiltration Period per BMP (hr) =	53

Depth (ft)	Width (ft)	Depth-Storage Data		Storage Volume in Drainage Area (cf)
		Length (ft)	Storage Volume per BMP (cf)	
0	3	40	0	0
0.5	3	40	12	48
1	3	40	24	96
1.5	5	42	106	425
2	7	44	235	941

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.919	2593
Developed Condition	0.835	2168
Pre-Developed (Forest) Condition	0.119	735

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.9

Calculations:

Check #1:	$Q_{developed} \leq IF \times [(Q_{pre-developed} \times RV_{pre-developed}) / RV_{developed}]$ ----->	0.835	≤	0.989
			OK	
Check #2:	$Q_{developed} \leq Q_{pre-developed}$ ----->	0.835	≤	0.919
			OK	
Check #3:	$Q_{developed} \text{ shall not be required to be } \leq (Q_{forest} \times RV_{forest}) / RV_{developed}$ ---->	0.835	<u>shall not</u> be required to be ≤	0.040

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p><i>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</i></p> <p><i>For Paved Road land surface types a Manning’s n value of 0.011 was used.</i></p> <p><i>Sources:</i></p> <p><i>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</i></p> <p><i>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</i></p>	

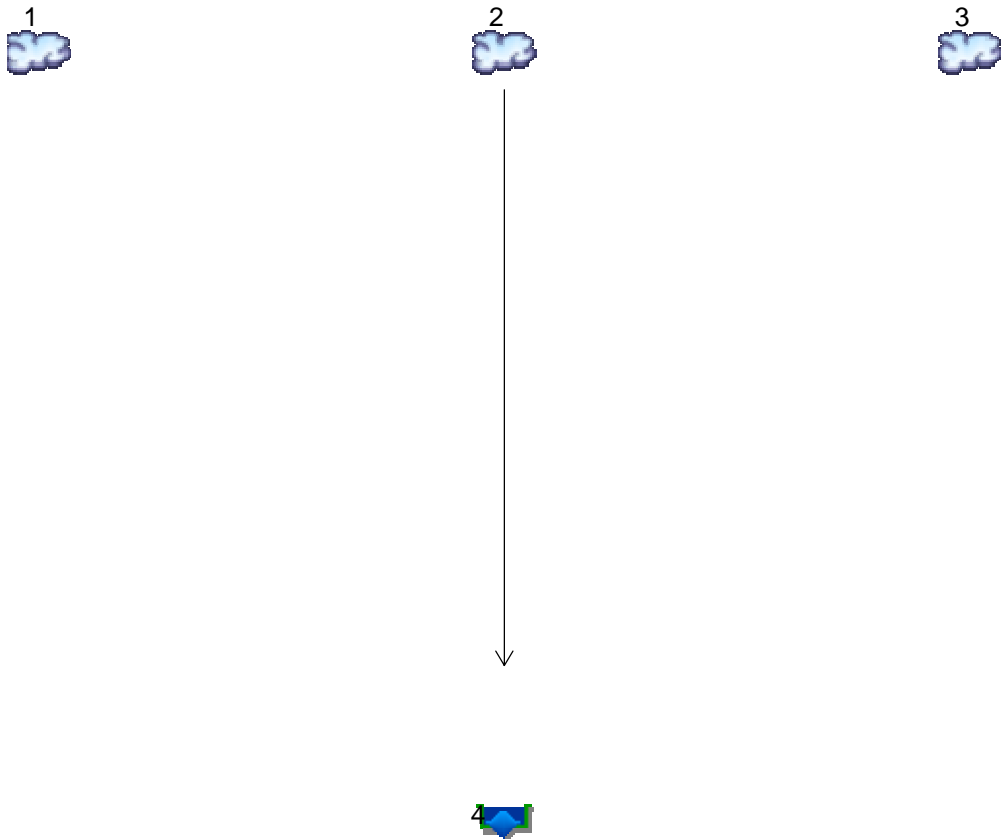
Table 2 – Manning's *n* Values for Open Channel Flow

Channel Type	Manning <i>n</i>		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's <i>n</i> value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's <i>n</i> value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

Hyd.	Origin	Description
1	SCS Runoff	DA-FR-120B PRE
2	SCS Runoff	DA-FR-120B DEV
3	SCS Runoff	DA-FR-120B FOR
4	Reservoir	WB Soil Amendments

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.919	1	723	2,593	-----	-----	-----	DA-FR-120B PRE
2	SCS Runoff	0.919	1	723	2,593	-----	-----	-----	DA-FR-120B DEV
3	SCS Runoff	0.119	1	726	735	-----	-----	-----	DA-FR-120B FOR
4	Reservoir	0.835	1	726	2,168	2	101.60	528	WB Soil Amendments
DA-FR-120B_Hydraflow.gpw					Return Period: 1 Year			Friday, 08 / 18 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

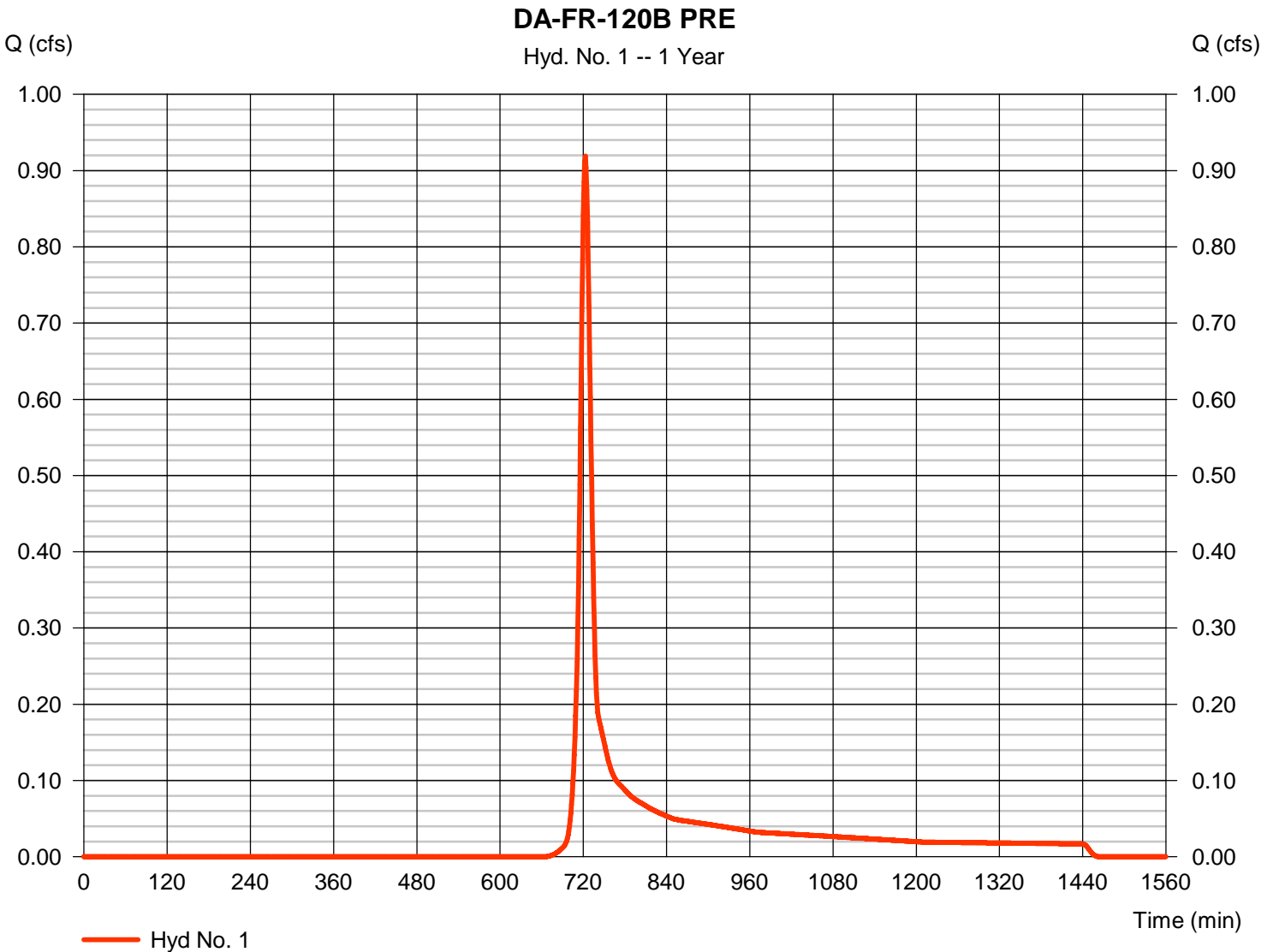
Friday, 08 / 18 / 2017

Hyd. No. 1

DA-FR-120B PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.919 cfs
Storm frequency	=	1 yrs	Time to peak	=	723 min
Time interval	=	1 min	Hyd. volume	=	2,593 cuft
Drainage area	=	0.720 ac	Curve number	=	72*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	13.80 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.070 x 87) + (0.300 x 71) + (0.010 x 100) + (0.340 x 70)] / 0.720



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-120B PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 5.81	0.00	0.00	
Travel Time (min)	= 13.04	+ 0.00	+ 0.00	= 13.04
Shallow Concentrated Flow				
Flow length (ft)	= 281.19	0.00	0.00	
Watercourse slope (%)	= 14.88	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=6.22	0.00	0.00	
Travel Time (min)	= 0.75	+ 0.00	+ 0.00	= 0.75
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				13.80 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

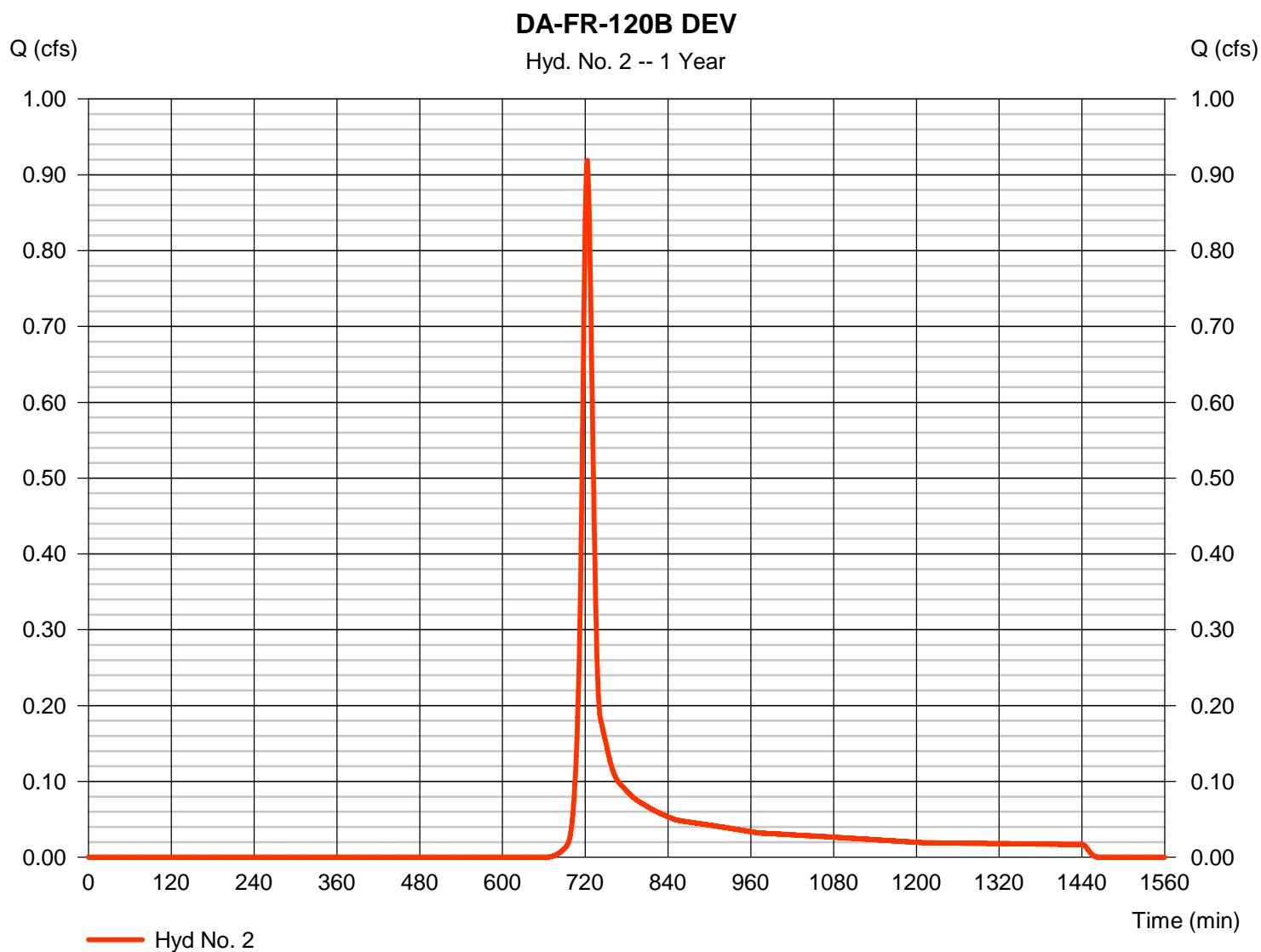
Friday, 08 / 18 / 2017

Hyd. No. 2

DA-FR-120B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.919 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 2,593 cuft
Drainage area	= 0.720 ac	Curve number	= 72*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.80 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.110 \times 65) + (0.070 \times 87) + (0.510 \times 71) + (0.010 \times 100) + (0.020 \times 70)] / 0.720$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-120B DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 5.81	0.00	0.00				
Travel Time (min)	= 13.04	+	0.00	+	0.00	=	13.04
Shallow Concentrated Flow							
Flow length (ft)	= 107.26	121.84	0.00				
Watercourse slope (%)	= 13.76	18.47	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=5.99	6.93	0.00				
Travel Time (min)	= 0.30	+	0.29	+	0.00	=	0.59
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	((0})46.7	0.0	0.0				
Travel Time (min)	= 0.16	+	0.00	+	0.00	=	0.16
Total Travel Time, Tc				13.80 min			

Hydrograph Report

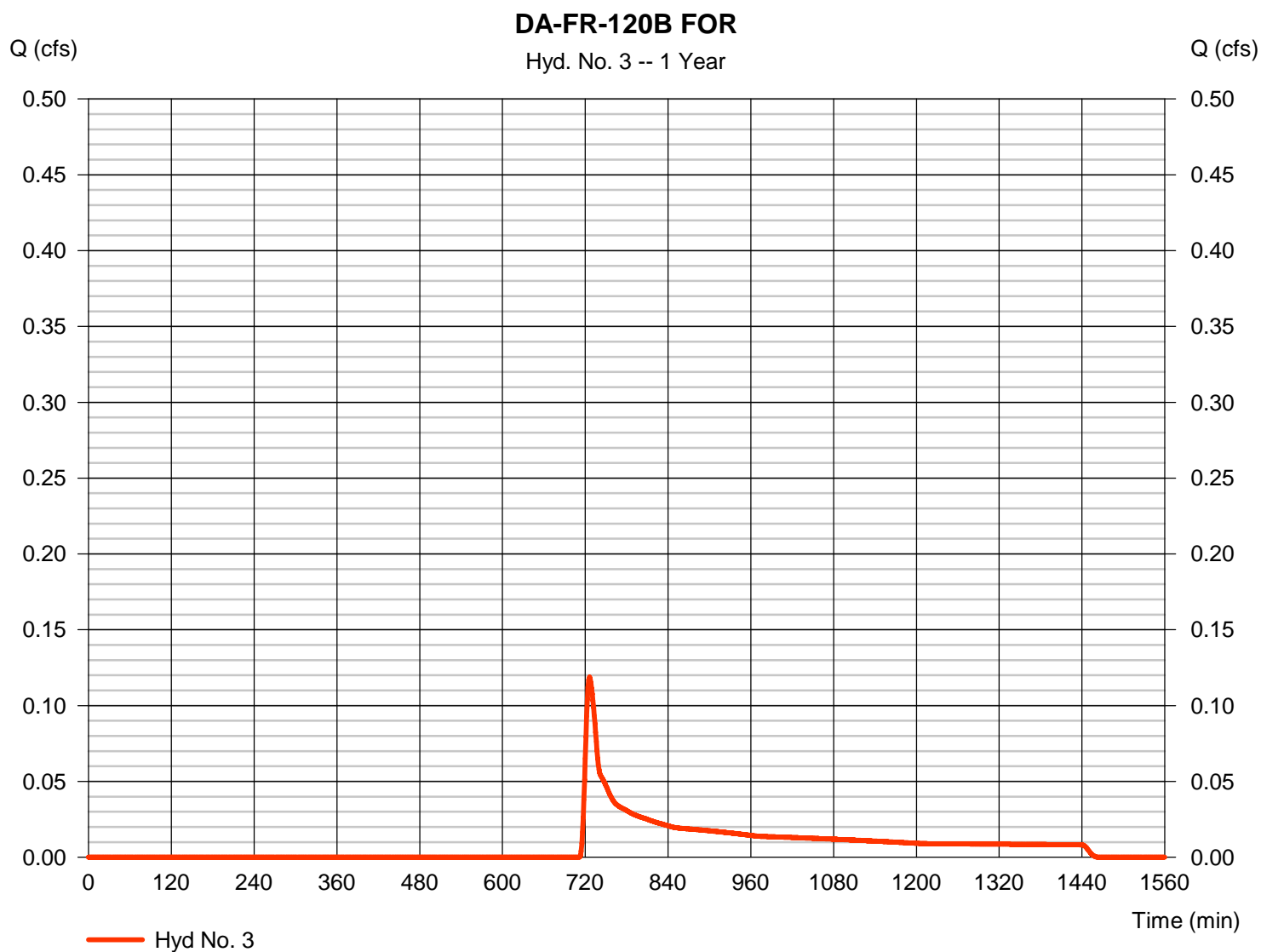
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Friday, 08 / 18 / 2017

Hyd. No. 3

DA-FR-120B FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.119 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 735 cuft
Drainage area	= 0.720 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.80 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-120B FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 5.81	0.00	0.00				
Travel Time (min)	= 13.04	+	0.00	+	0.00	=	13.04
Shallow Concentrated Flow							
Flow length (ft)	= 281.19	0.00	0.00				
Watercourse slope (%)	= 14.88	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=6.22	0.00	0.00				
Travel Time (min)	= 0.75	+	0.00	+	0.00	=	0.75
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				13.80 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

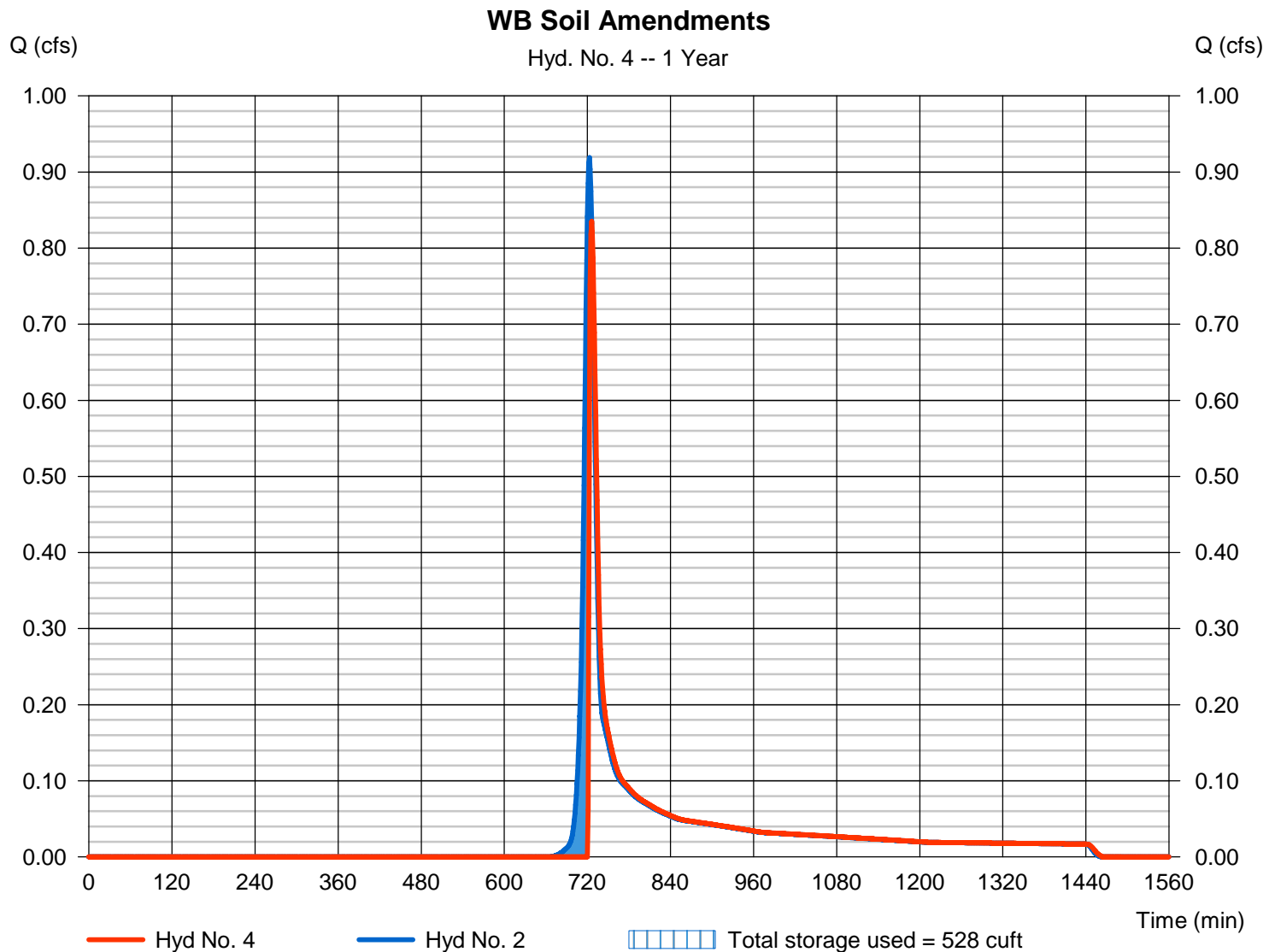
Friday, 08 / 18 / 2017

Hyd. No. 4

WB Soil Amendments

Hydrograph type	= Reservoir	Peak discharge	= 0.835 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 2,168 cuft
Inflow hyd. No.	= 2 - DA-FR-120B DEV	Max. Elevation	= 101.60 ft
Reservoir name	= Waterbar Soil Amendments	Max. Storage	= 528 cuft

Storage Indication method used.



Pond No. 1 - Waterbar Soil Amendments

Pond Data

Pond storage is based on user-defined values.

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	100.00	n/a	0	0
0.50	100.50	n/a	48	48
1.00	101.00	n/a	48	96
1.50	101.50	n/a	329	425
2.00	102.00	n/a	516	941

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)	= 8.00	0.00	0.00	0.00
Crest El. (ft)	= 101.50	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= Rect	---	---	---
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	100.00	---	---	---	---	0.00	---	---	---	---	---	0.000
0.05	5	100.05	---	---	---	---	0.00	---	---	---	---	---	0.000
0.10	10	100.10	---	---	---	---	0.00	---	---	---	---	---	0.000
0.15	14	100.15	---	---	---	---	0.00	---	---	---	---	---	0.000
0.20	19	100.20	---	---	---	---	0.00	---	---	---	---	---	0.000
0.25	24	100.25	---	---	---	---	0.00	---	---	---	---	---	0.000
0.30	29	100.30	---	---	---	---	0.00	---	---	---	---	---	0.000
0.35	34	100.35	---	---	---	---	0.00	---	---	---	---	---	0.000
0.40	38	100.40	---	---	---	---	0.00	---	---	---	---	---	0.000
0.45	43	100.45	---	---	---	---	0.00	---	---	---	---	---	0.000
0.50	48	100.50	---	---	---	---	0.00	---	---	---	---	---	0.000
0.55	53	100.55	---	---	---	---	0.00	---	---	---	---	---	0.000
0.60	58	100.60	---	---	---	---	0.00	---	---	---	---	---	0.000
0.65	62	100.65	---	---	---	---	0.00	---	---	---	---	---	0.000
0.70	67	100.70	---	---	---	---	0.00	---	---	---	---	---	0.000
0.75	72	100.75	---	---	---	---	0.00	---	---	---	---	---	0.000
0.80	77	100.80	---	---	---	---	0.00	---	---	---	---	---	0.000
0.85	82	100.85	---	---	---	---	0.00	---	---	---	---	---	0.000
0.90	86	100.90	---	---	---	---	0.00	---	---	---	---	---	0.000
0.95	91	100.95	---	---	---	---	0.00	---	---	---	---	---	0.000
1.00	96	101.00	---	---	---	---	0.00	---	---	---	---	---	0.000
1.05	129	101.05	---	---	---	---	0.00	---	---	---	---	---	0.000
1.10	162	101.10	---	---	---	---	0.00	---	---	---	---	---	0.000
1.15	195	101.15	---	---	---	---	0.00	---	---	---	---	---	0.000
1.20	228	101.20	---	---	---	---	0.00	---	---	---	---	---	0.000
1.25	260	101.25	---	---	---	---	0.00	---	---	---	---	---	0.000
1.30	293	101.30	---	---	---	---	0.00	---	---	---	---	---	0.000
1.35	326	101.35	---	---	---	---	0.00	---	---	---	---	---	0.000
1.40	359	101.40	---	---	---	---	0.00	---	---	---	---	---	0.000
1.45	392	101.45	---	---	---	---	0.00	---	---	---	---	---	0.000
1.50	425	101.50	---	---	---	---	0.00	---	---	---	---	---	0.000
1.55	477	101.55	---	---	---	---	0.30	---	---	---	---	---	0.298
1.60	528	101.60	---	---	---	---	0.84	---	---	---	---	---	0.843
1.65	580	101.65	---	---	---	---	1.55	---	---	---	---	---	1.548
1.70	631	101.70	---	---	---	---	2.38	---	---	---	---	---	2.383
1.75	683	101.75	---	---	---	---	3.33	---	---	---	---	---	3.330
1.80	735	101.80	---	---	---	---	4.38	---	---	---	---	---	4.378
1.85	786	101.85	---	---	---	---	5.52	---	---	---	---	---	5.517
1.90	838	101.90	---	---	---	---	6.74	---	---	---	---	---	6.740

Continues on next page...

Waterbar Soil Amendments

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
1.95	889	101.95	---	---	---	---	8.04	---	---	---	---	---	8.043
2.00	941	102.00	---	---	---	---	9.42	---	---	---	---	---	9.419

...End

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	1.183	1	723	3,277	-----	-----	-----	DA-FR-120B PRE
2	SCS Runoff	1.183	1	723	3,277	-----	-----	-----	DA-FR-120B DEV
3	SCS Runoff	0.236	1	725	1,086	-----	-----	-----	DA-FR-120B FOR
4	Reservoir	1.153	1	724	2,852	2	101.62	551	WB Soil Amendments
DA-FR-120B_Hydraflow.gpw					Return Period: 2 Year			Friday, 08 / 18 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

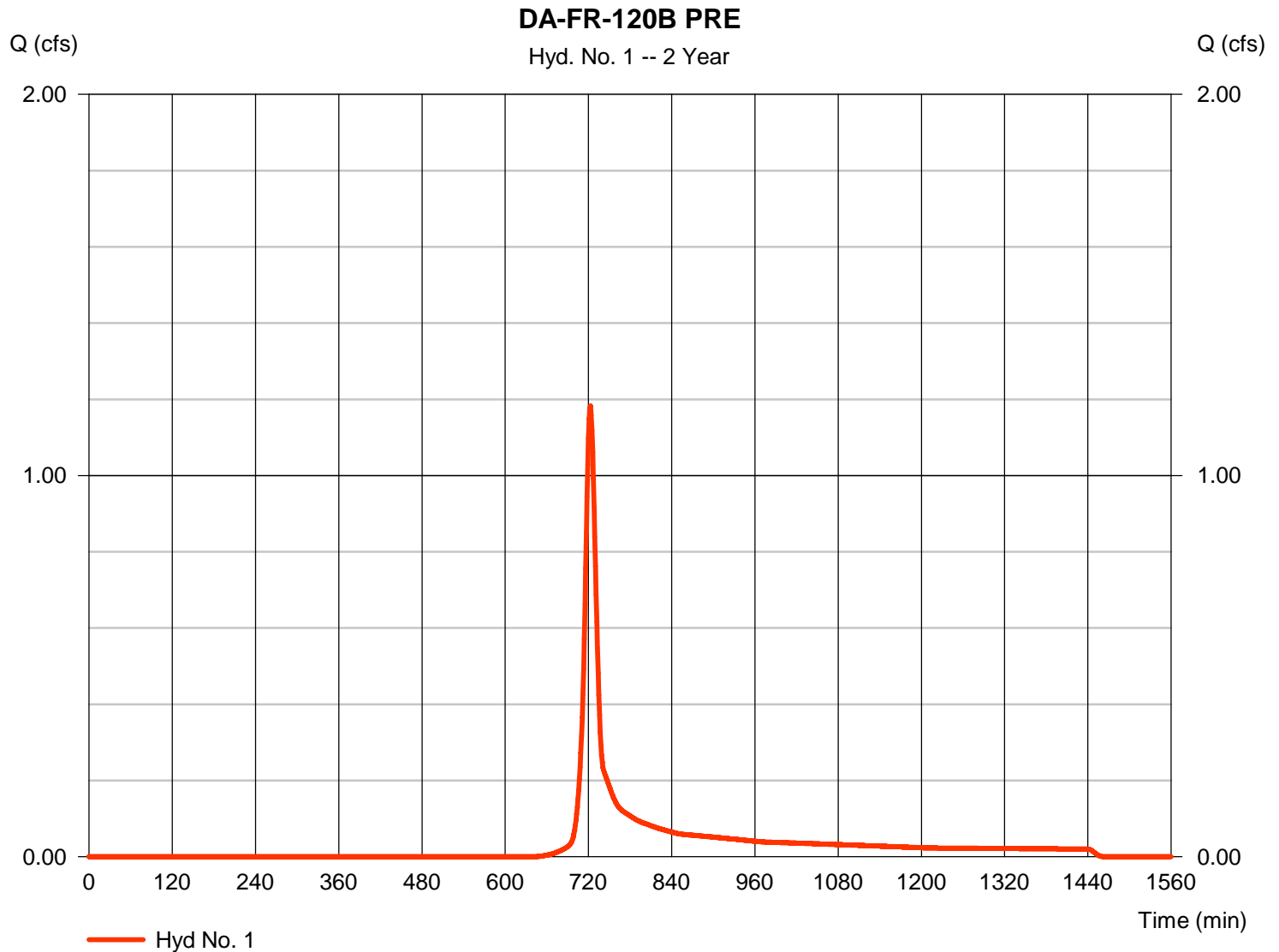
Friday, 08 / 18 / 2017

Hyd. No. 1

DA-FR-120B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 1.183 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 3,277 cuft
Drainage area	= 0.720 ac	Curve number	= 72*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.80 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.070 \times 87) + (0.300 \times 71) + (0.010 \times 100) + (0.340 \times 70)] / 0.720$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

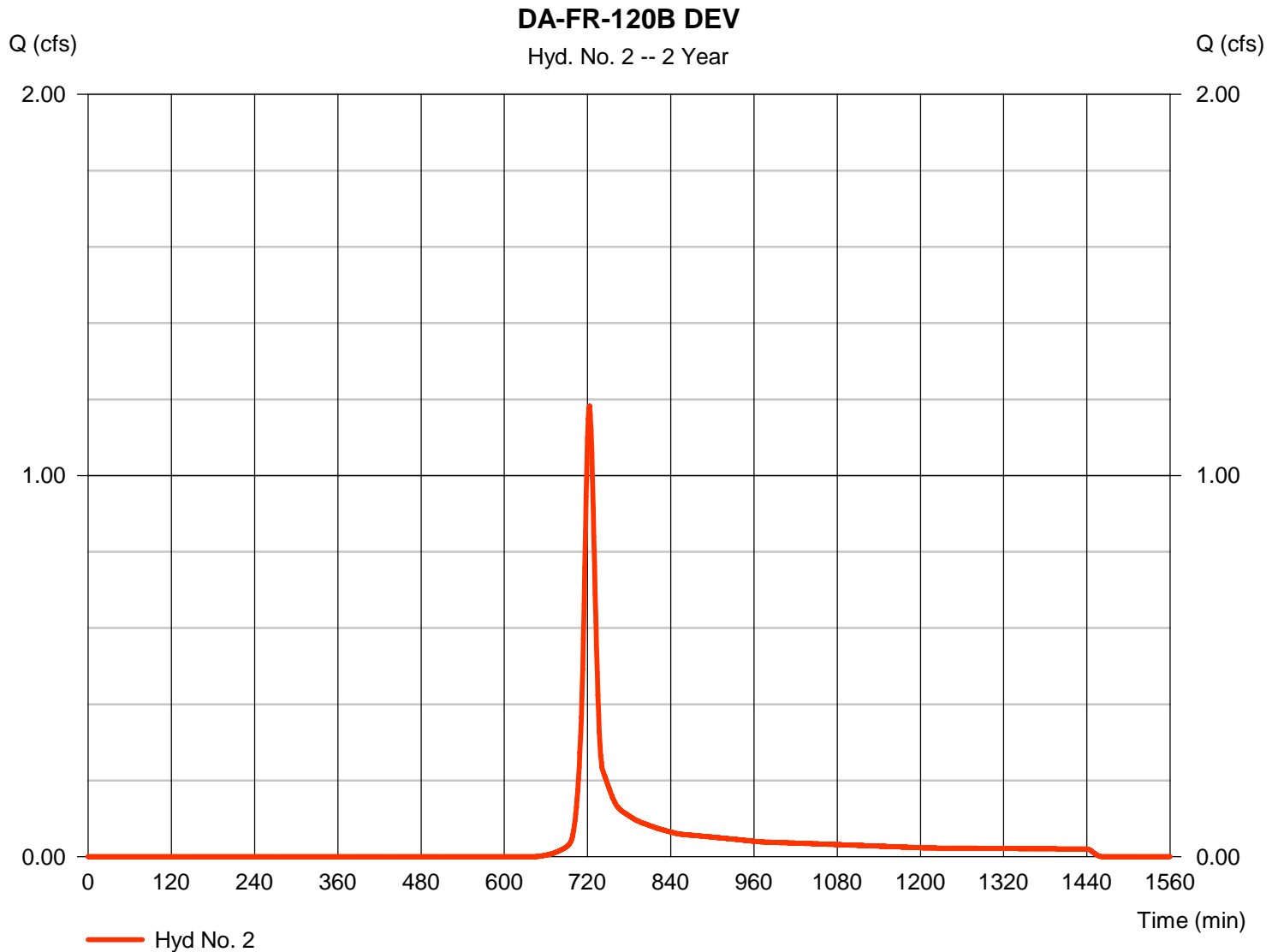
Friday, 08 / 18 / 2017

Hyd. No. 2

DA-FR-120B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 1.183 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 3,277 cuft
Drainage area	= 0.720 ac	Curve number	= 72*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.80 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.110 \times 65) + (0.070 \times 87) + (0.510 \times 71) + (0.010 \times 100) + (0.020 \times 70)] / 0.720$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

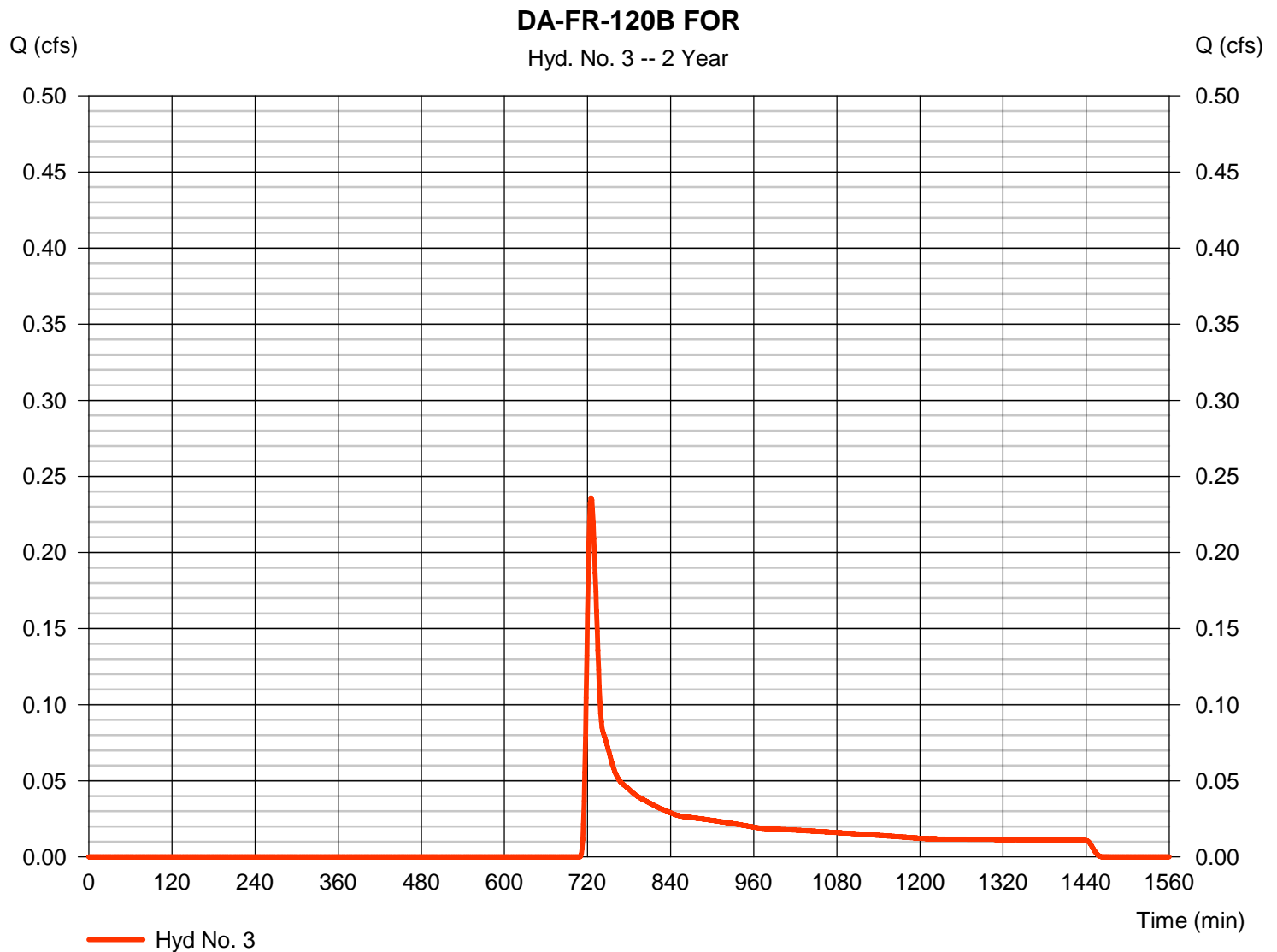
Friday, 08 / 18 / 2017

Hyd. No. 3

DA-FR-120B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 0.720 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.236 cfs
 Time to peak = 725 min
 Hyd. volume = 1,086 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 13.80 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

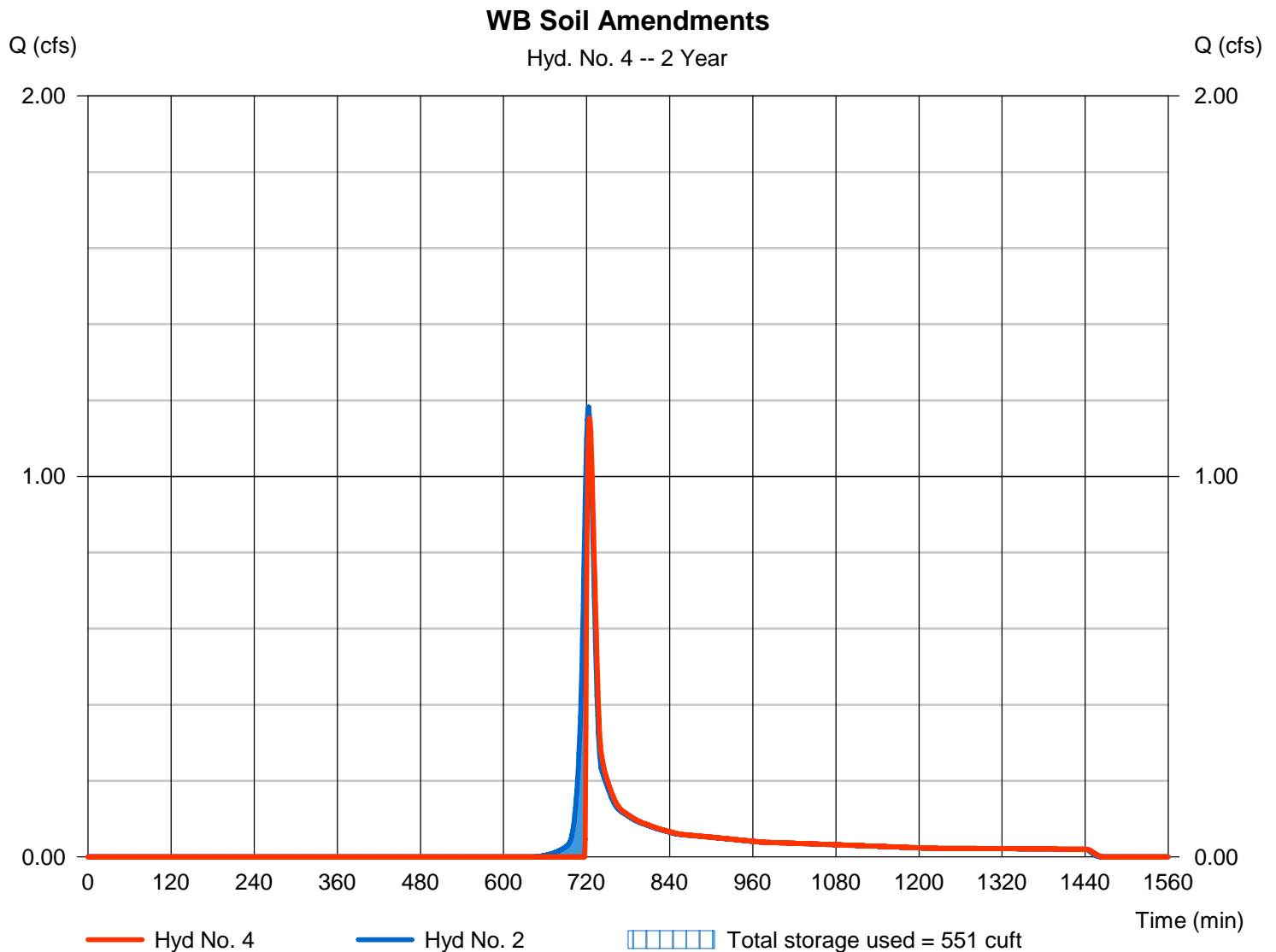
Friday, 08 / 18 / 2017

Hyd. No. 4

WB Soil Amendments

Hydrograph type	= Reservoir	Peak discharge	= 1.153 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 2,852 cuft
Inflow hyd. No.	= 2 - DA-FR-120B DEV	Max. Elevation	= 101.62 ft
Reservoir name	= Waterbar Soil Amendments	Max. Storage	= 551 cuft

Storage Indication method used.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	2.671	1	722	7,187	-----	-----	-----	DA-FR-120B PRE
2	SCS Runoff	2.671	1	722	7,187	-----	-----	-----	DA-FR-120B DEV
3	SCS Runoff	1.179	1	723	3,524	-----	-----	-----	DA-FR-120B FOR
4	Reservoir	2.650	1	723	6,762	2	101.71	646	WB Soil Amendments
DA-FR-120B_Hydraflow.gpw					Return Period: 10 Year			Friday, 08 / 18 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

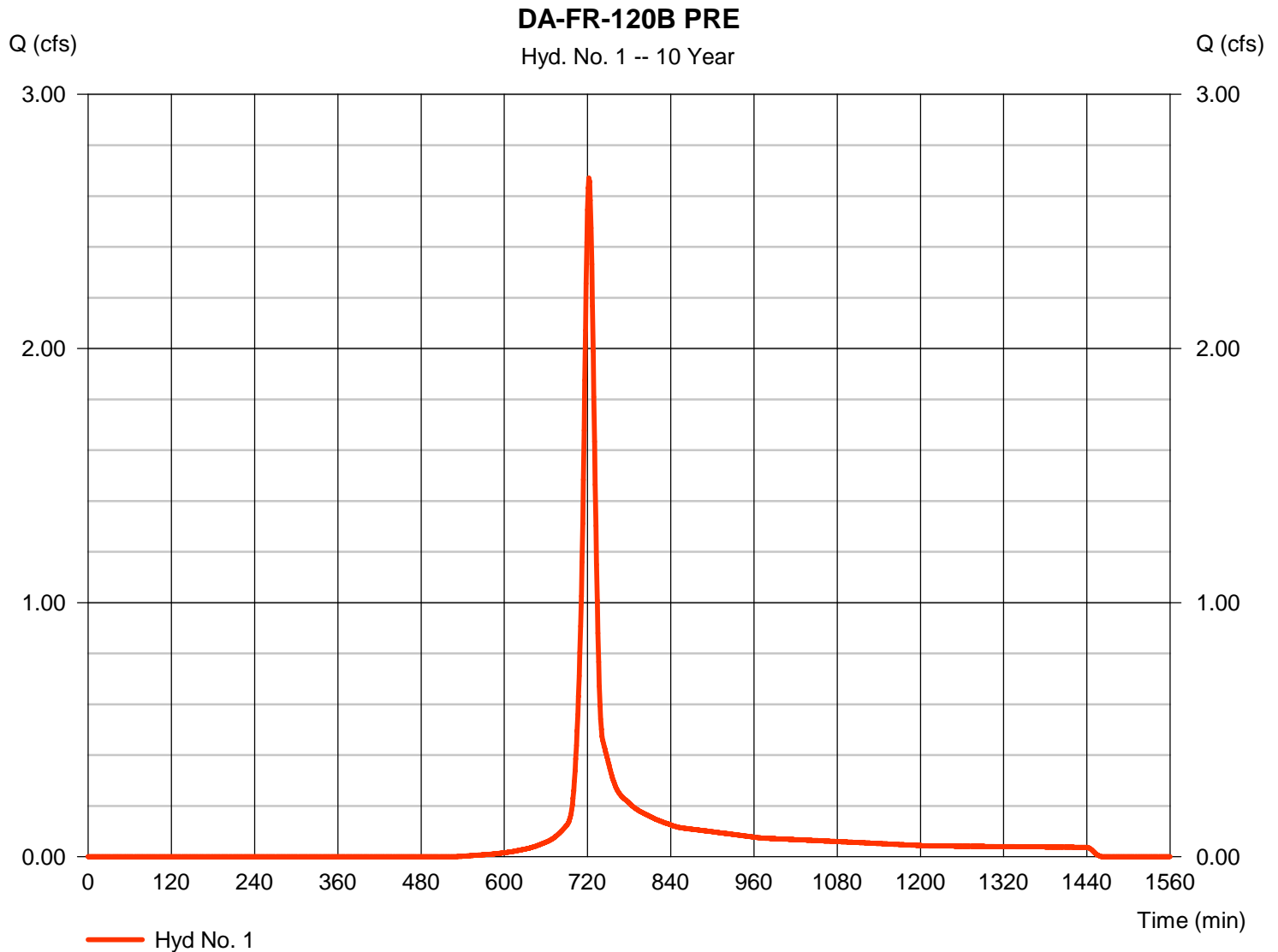
Friday, 08 / 18 / 2017

Hyd. No. 1

DA-FR-120B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 2.671 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 7,187 cuft
Drainage area	= 0.720 ac	Curve number	= 72*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.80 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.070 \times 87) + (0.300 \times 71) + (0.010 \times 100) + (0.340 \times 70)] / 0.720$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

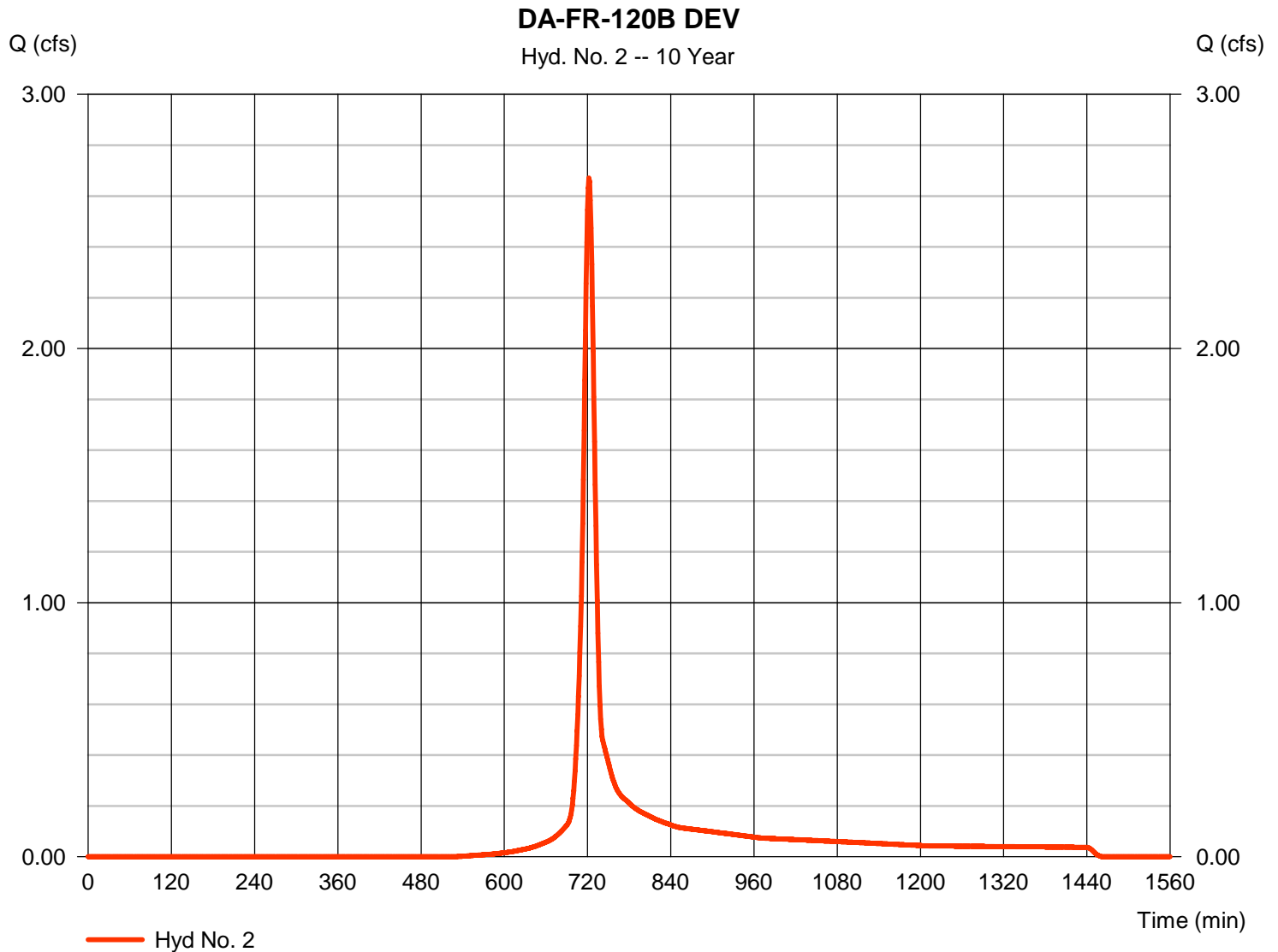
Friday, 08 / 18 / 2017

Hyd. No. 2

DA-FR-120B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 2.671 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 7,187 cuft
Drainage area	= 0.720 ac	Curve number	= 72*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.80 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.110 \times 65) + (0.070 \times 87) + (0.510 \times 71) + (0.010 \times 100) + (0.020 \times 70)] / 0.720$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

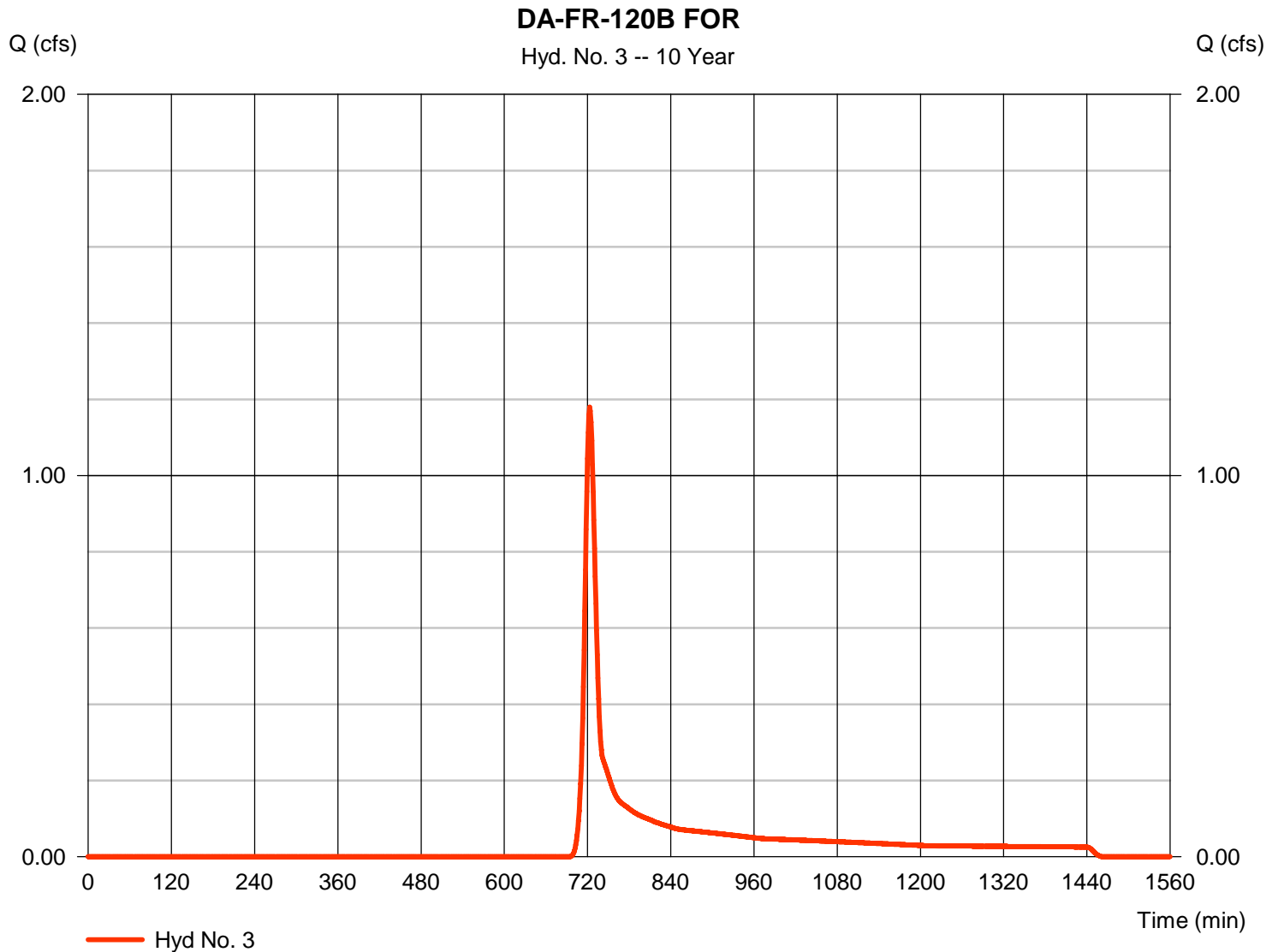
Friday, 08 / 18 / 2017

Hyd. No. 3

DA-FR-120B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 0.720 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 1.179 cfs
 Time to peak = 723 min
 Hyd. volume = 3,524 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 13.80 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

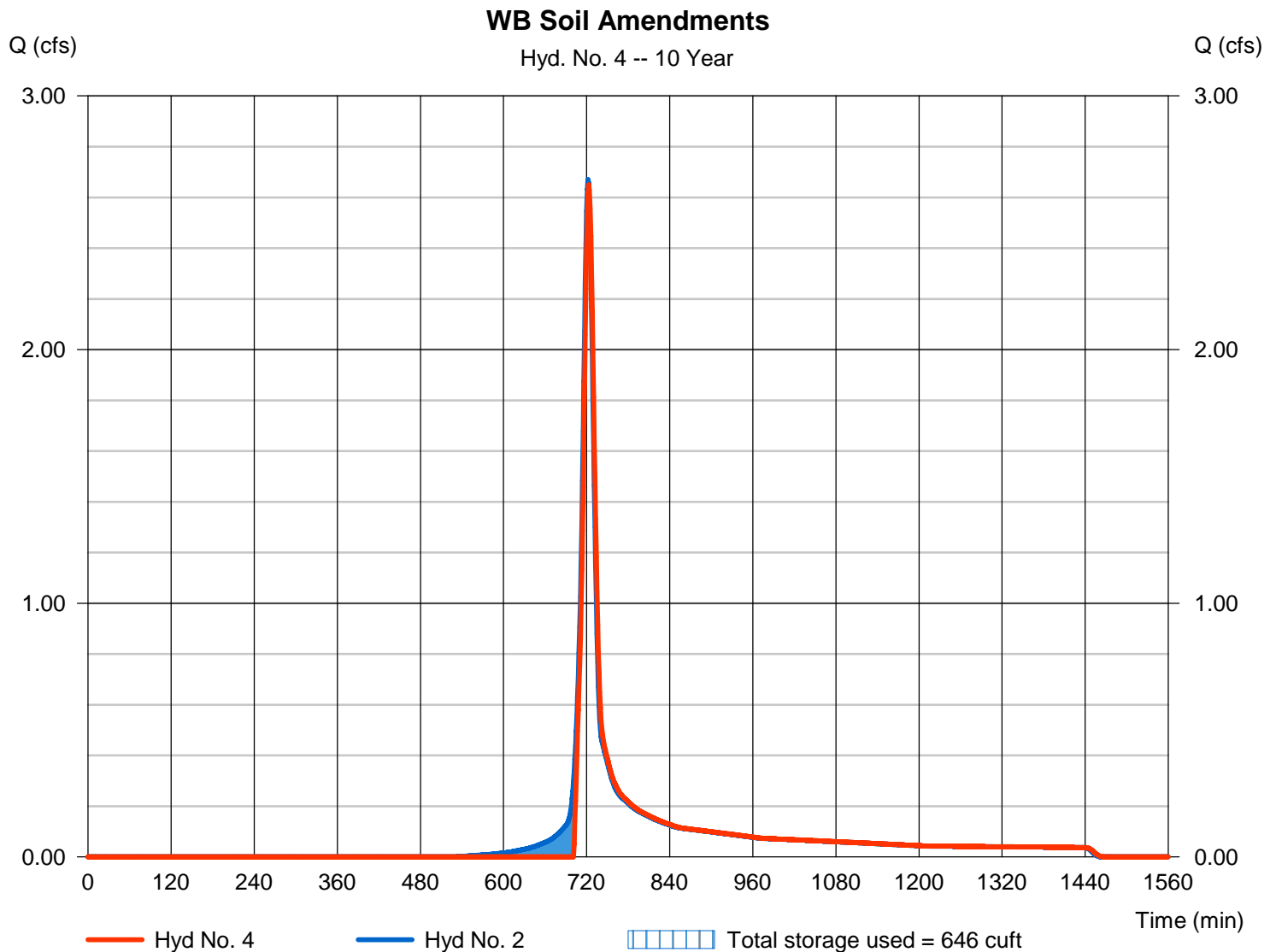
Friday, 08 / 18 / 2017

Hyd. No. 4

WB Soil Amendments

Hydrograph type	= Reservoir	Peak discharge	= 2.650 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 6,762 cuft
Inflow hyd. No.	= 2 - DA-FR-120B DEV	Max. Elevation	= 101.71 ft
Reservoir name	= Waterbar Soil Amendments	Max. Storage	= 646 cuft

Storage Indication method used.



DA-FR-120C

STORAGE VOLUME OF WATERBAR WITH SOIL COMPOST AMENDMENT AREA

Equations Used:

¹V_{gravel} storage = L*W*D_{gravel}*(40/100)

²V_{soil} storage = L*W*D_{soil}*(20/100)

³V_{surface} storage = [W*S*D²/2]+[L*S*D²/2]+[W*L*D]+[(2*S*D)/2*D]/3]

¹Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that gravel is made up of 40% voids.

²Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that soil compost amendment is made up of 20% voids.

³Equation #1 under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, but calculation also takes into account surface side slopes.

Inputs:

Depth of Gravel Layer, D _{gravel} (ft) =	0	
Depth of Soil Amendment Area, D _{soil} (ft) =	1	Refer to Table 4.3 in VA DEQ Stormwater Design Specification No. 4; Note that compost amendment may not be necessary for HSG A/B soils
Length of Waterbar Soil Amendment Area, L (ft) =	50	Assume max. length of 50' for waterbar soil amendment areas (i.e., limited to permanent ROW)
Width of Waterbar Soil Amendment Area, W (ft) =	3	
Inside Embankment Side Slopes, S (H:V) =	2	Assume 2H:1V surface side slopes for waterbars
Number of Perm. Waterbars in Drainage Area, n =	5	
Design Infiltration Rate, IR (in/hr) =	0.2	Min. rate of 0.30 in/hr for HSG A soils and 0.15-0.30 in/hr for HSG B soils (see Chap. 4, p. 4-30 in VA Stormwater Management Handbook Volume II (First Edition, 1999)
Surface Ponding Depth, D (ft) =	0.5	Assume 0.5' CFS height at the end of waterbars

Calculations:

Total Storage Depth per BMP (ft) =	1.5
Surface Storage Volume per BMP (cf) =	102
Subsurface Storage Volume per BMP (cf) =	30
Total Storage Volume per BMP (cf) =	132
Total BMP Storage Volume in Drainage Area (cf) =	661
Calculated Infiltration Period per BMP (hr) =	53

Depth (ft)	Width (ft)	Depth-Storage Data		Storage Volume in Drainage Area (cf)
		Length (ft)	Storage Volume per BMP (cf)	
0	3	50	0	0
0.5	3	50	15	75
1	3	50	30	150
1.5	5	52	132	661
2	7	54	291	1457

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	1.904	4766
Developed Condition	1.764	4105
Pre-Developed (Forest) Condition	0.254	1350

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{developed} \leq IF \times [(Q_{pre-developed} \times RV_{pre-developed}) / RV_{developed}]$ ----->	1.764	≤	1.768
			OK	
Check #2:	$Q_{developed} \leq Q_{pre-developed}$ ----->	1.764	≤	1.904
			OK	
Check #3:	$Q_{developed} \text{ shall not be required to be } \leq (Q_{forest} \times RV_{forest}) / RV_{developed}$ ---->	1.764	<u>shall not</u> be required to be ≤	0.084

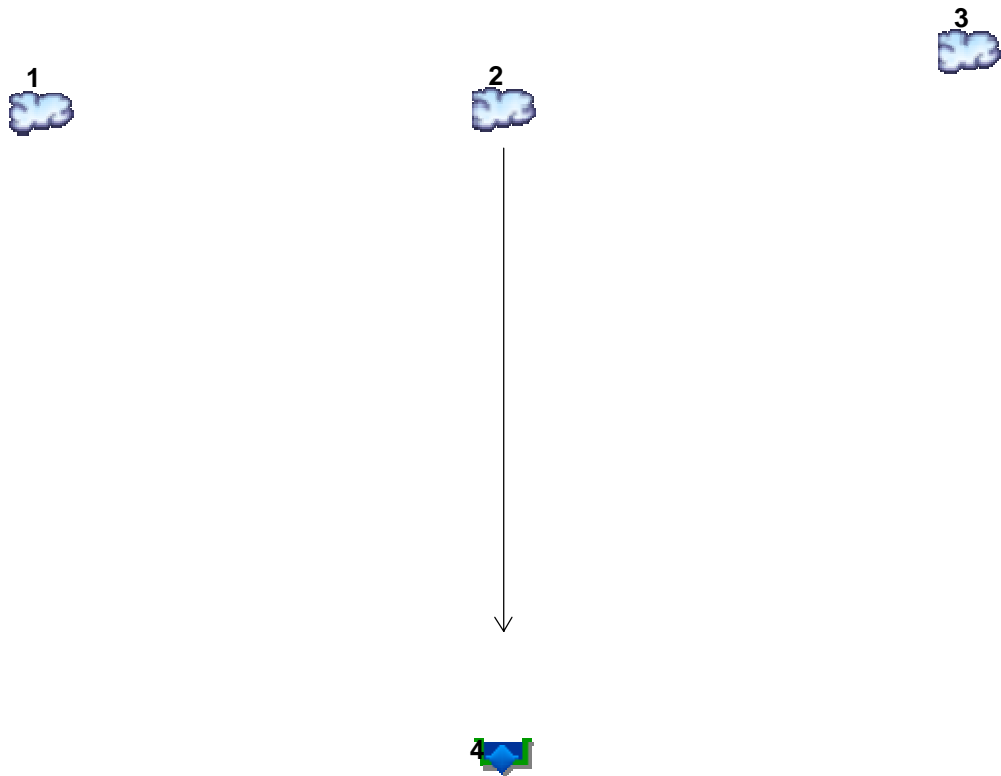
Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p><i>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</i></p> <p><i>For Paved Road land surface types a Manning’s n value of 0.011 was used.</i></p> <p><i>Sources:</i></p> <p><i>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</i></p> <p><i>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</i></p>	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

Hyd.	Origin	Description
1	SCS Runoff	DA-FR-120C PRE
2	SCS Runoff	DA-FR-120C DEV
3	SCS Runoff	DA-FR-120C FOR
4	Reservoir	WB Soil Amendments

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	1.904	1	721	4,766	-----	-----	-----	DA-FR-120C PRE
2	SCS Runoff	1.904	1	721	4,766	-----	-----	-----	DA-FR-120C DEV
3	SCS Runoff	0.254	1	724	1,350	-----	-----	-----	DA-FR-120C FOR
4	Reservoir	1.764	1	723	4,105	2	101.64	884	WB Soil Amendments
DA-FR-120C_Hydraflow.gpw					Return Period: 1 Year			Friday, 08 / 18 / 2017	

Hydrograph Report

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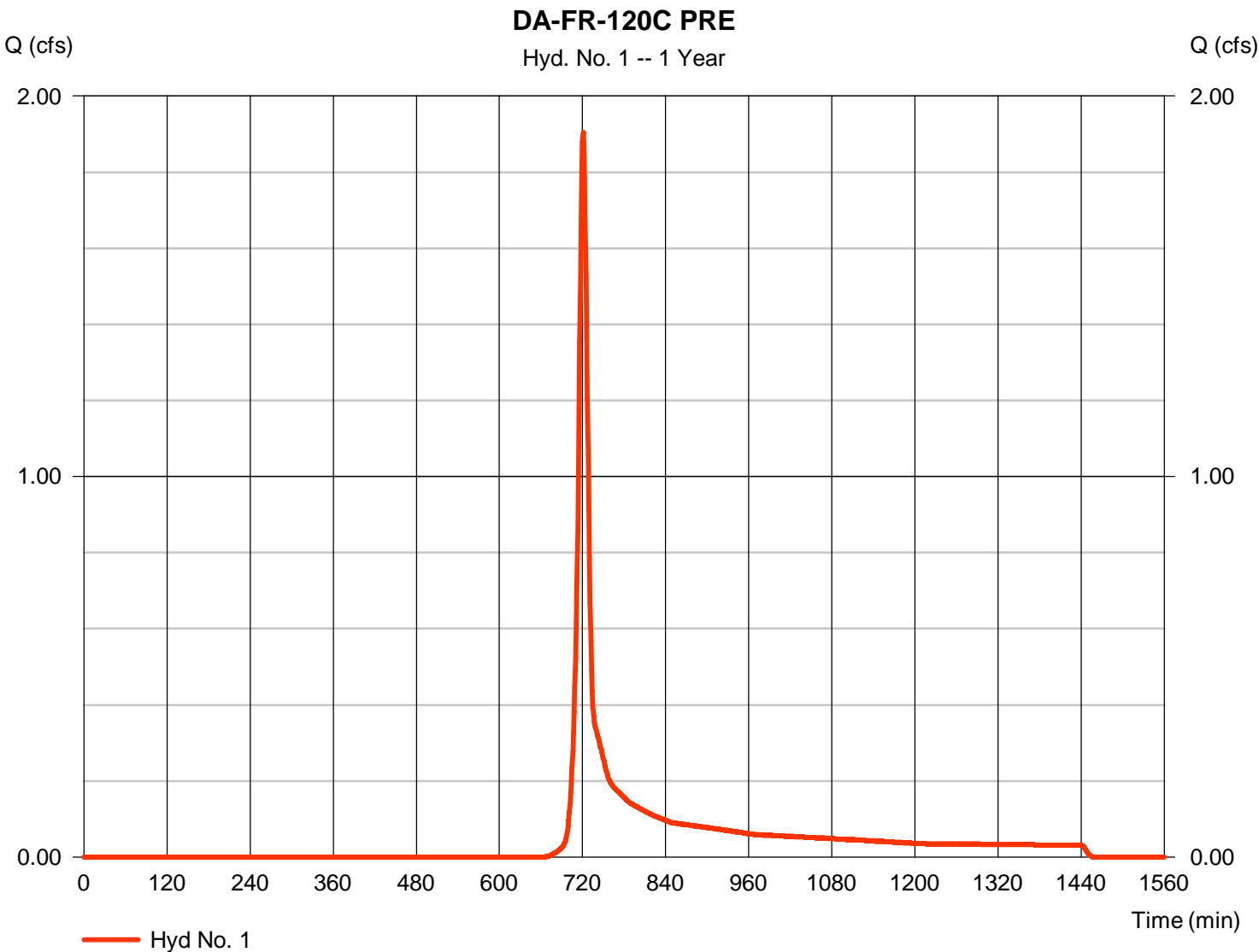
Friday, 08 / 18 / 2017

Hyd. No. 1

DA-FR-120C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 1.904 cfs
Storm frequency	= 1 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 4,766 cuft
Drainage area	= 1.300 ac	Curve number	= 72*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 10.60 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.072 x 87) + (0.748 x 71) + (0.007 x 100) + (0.471 x 70)] / 1.300



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-120C PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 10.83	0.00	0.00				
Travel Time (min)	= 10.16	+	0.00	+	0.00	=	10.16
Shallow Concentrated Flow							
Flow length (ft)	= 211.08	0.00	0.00				
Watercourse slope (%)	= 20.64	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=7.33	0.00	0.00				
Travel Time (min)	= 0.48	+	0.00	+	0.00	=	0.48
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				10.60 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

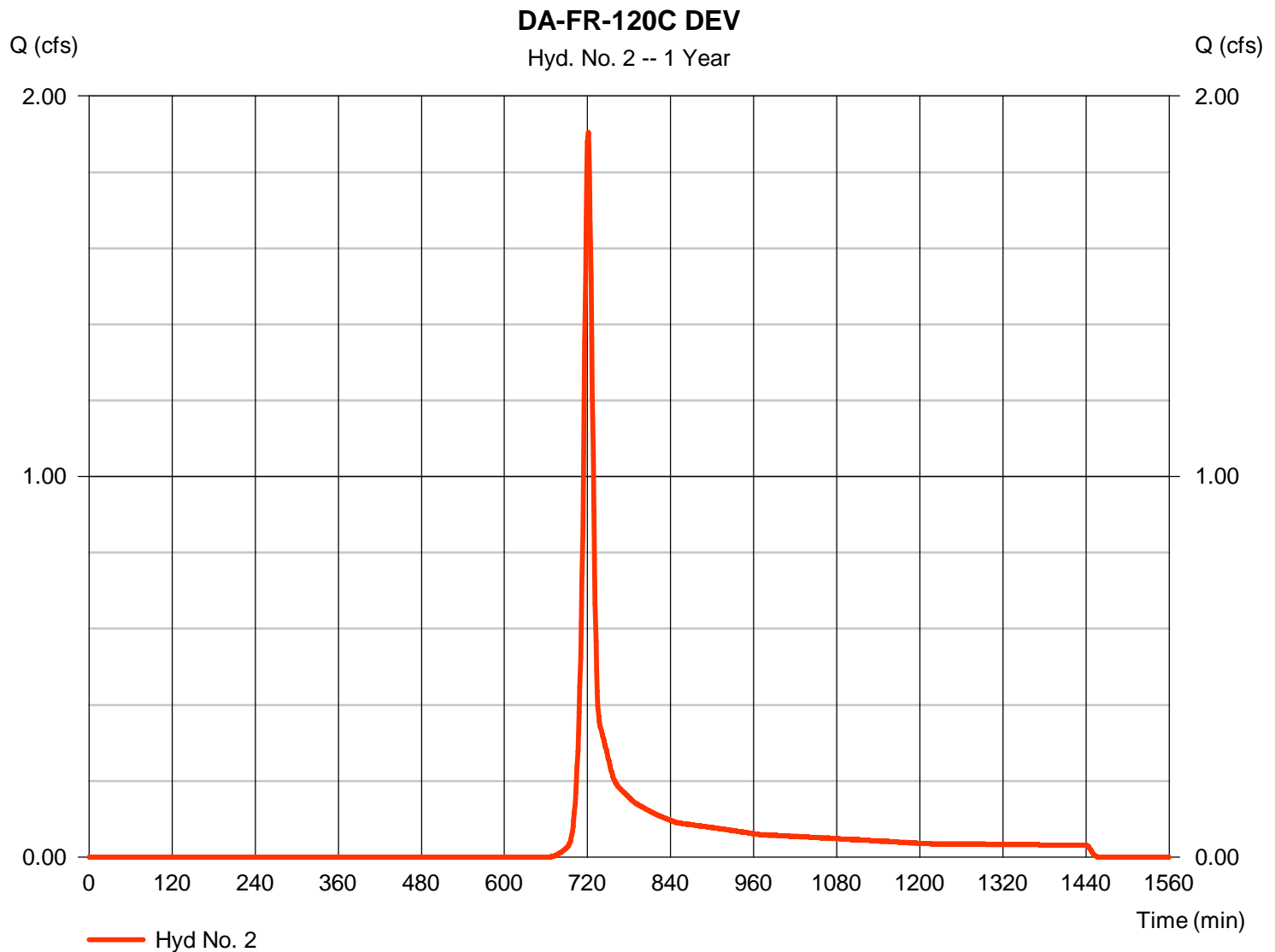
Friday, 08 / 18 / 2017

Hyd. No. 2

DA-FR-120C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 1.904 cfs
Storm frequency	= 1 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 4,766 cuft
Drainage area	= 1.300 ac	Curve number	= 72*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 10.60 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.033 \times 65) + (0.072 \times 87) + (0.796 \times 71) + (0.007 \times 100) + (0.391 \times 70)] / 1.300$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-120C DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 10.83	0.00	0.00	
Travel Time (min)	= 10.16	+ 0.00	+ 0.00	= 10.16
Shallow Concentrated Flow				
Flow length (ft)	= 211.08	0.00	0.00	
Watercourse slope (%)	= 20.64	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=7.33	0.00	0.00	
Travel Time (min)	= 0.48	+ 0.00	+ 0.00	= 0.48
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	
Travel Time (min)	= 0.00	+ 0.00	+ 0.00	= 0.00
Total Travel Time, Tc				10.60 min

Hydrograph Report

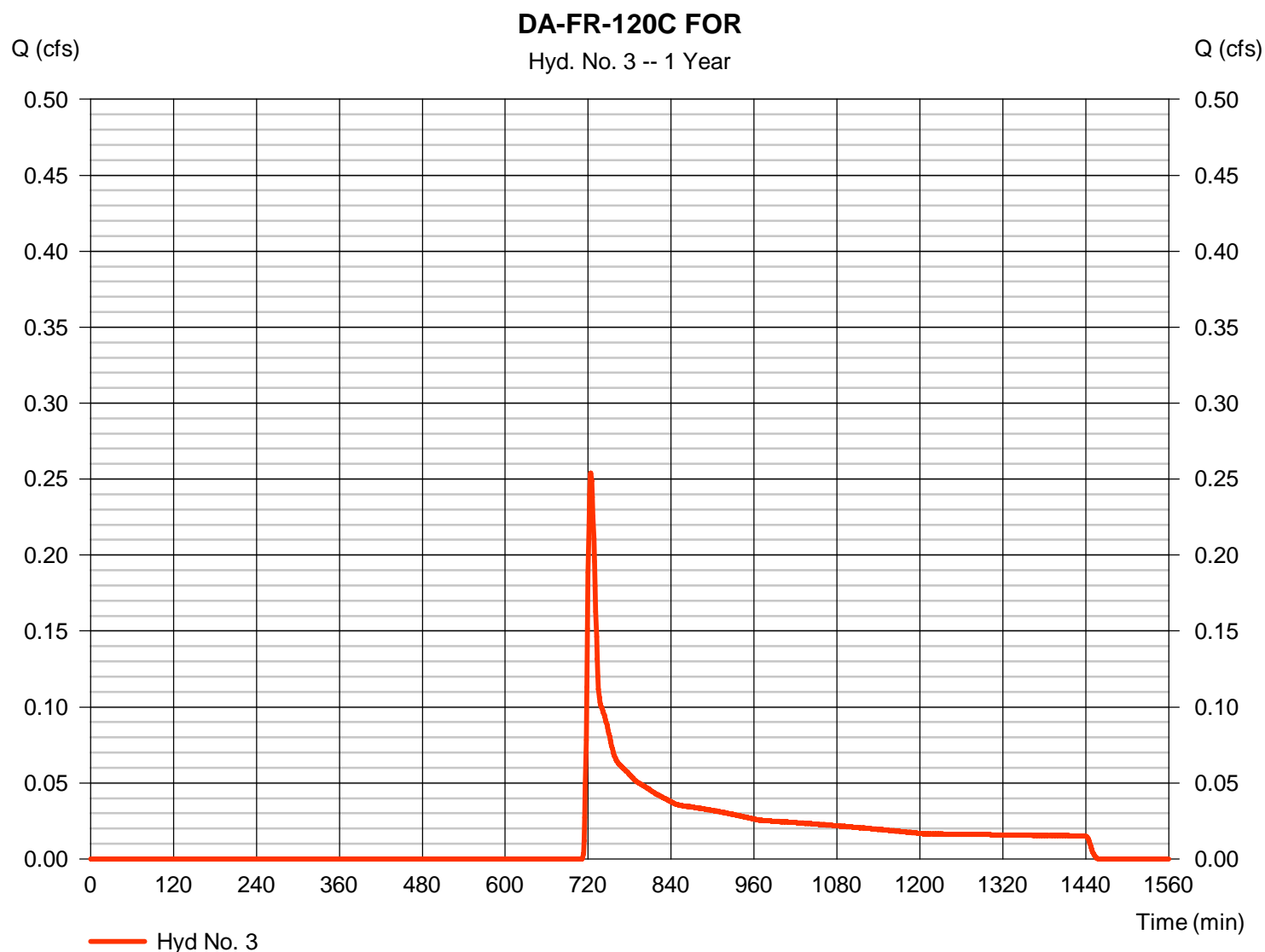
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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Hyd. No. 3

DA-FR-120C FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.254 cfs
Storm frequency	= 1 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 1,350 cuft
Drainage area	= 1.300 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 10.60 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-120C FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 10.83	0.00	0.00	
Travel Time (min)	= 10.16	+ 0.00	+ 0.00	= 10.16
Shallow Concentrated Flow				
Flow length (ft)	= 211.08	0.00	0.00	
Watercourse slope (%)	= 20.64	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=7.33	0.00	0.00	
Travel Time (min)	= 0.48	+ 0.00	+ 0.00	= 0.48
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				10.60 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

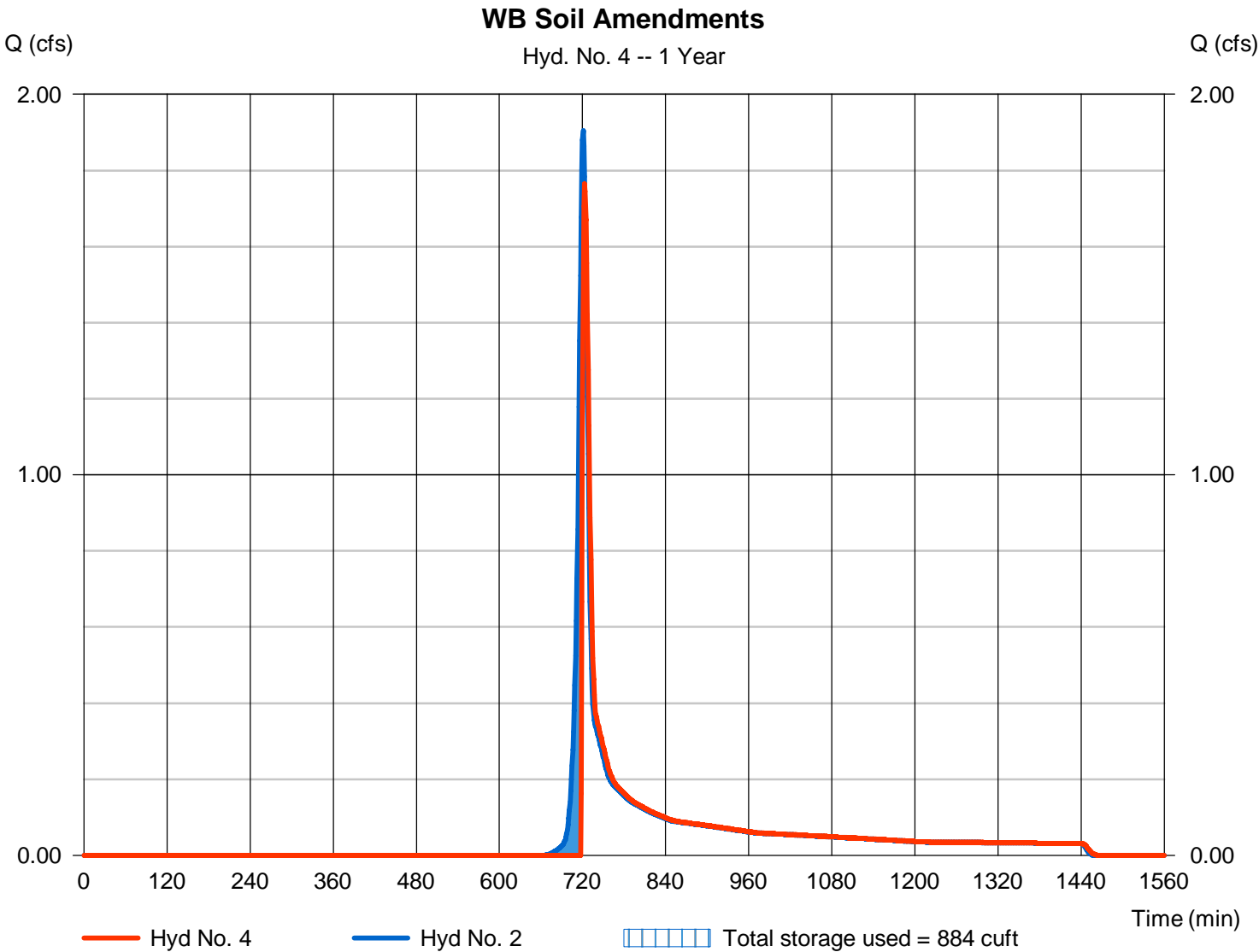
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Hyd. No. 4

WB Soil Amendments

Hydrograph type	= Reservoir	Peak discharge	= 1.764 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 4,105 cuft
Inflow hyd. No.	= 2 - DA-FR-120C DEV	Max. Elevation	= 101.64 ft
Reservoir name	= Waterbar Soil Amendments	Max. Storage	= 884 cuft

Storage Indication method used.



Pond No. 1 - Waterbar Soil Amendments

Pond Data

Pond storage is based on user-defined values.

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	100.00	n/a	0	0
0.50	100.50	n/a	75	75
1.00	101.00	n/a	75	150
1.50	101.50	n/a	511	661
2.00	102.00	n/a	796	1,457

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)	= 10.00	0.00	0.00	0.00
Crest El. (ft)	= 101.50	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= Rect	---	---	---
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	100.00	---	---	---	---	0.00	---	---	---	---	---	0.000
0.05	8	100.05	---	---	---	---	0.00	---	---	---	---	---	0.000
0.10	15	100.10	---	---	---	---	0.00	---	---	---	---	---	0.000
0.15	23	100.15	---	---	---	---	0.00	---	---	---	---	---	0.000
0.20	30	100.20	---	---	---	---	0.00	---	---	---	---	---	0.000
0.25	38	100.25	---	---	---	---	0.00	---	---	---	---	---	0.000
0.30	45	100.30	---	---	---	---	0.00	---	---	---	---	---	0.000
0.35	53	100.35	---	---	---	---	0.00	---	---	---	---	---	0.000
0.40	60	100.40	---	---	---	---	0.00	---	---	---	---	---	0.000
0.45	68	100.45	---	---	---	---	0.00	---	---	---	---	---	0.000
0.50	75	100.50	---	---	---	---	0.00	---	---	---	---	---	0.000
0.55	83	100.55	---	---	---	---	0.00	---	---	---	---	---	0.000
0.60	90	100.60	---	---	---	---	0.00	---	---	---	---	---	0.000
0.65	98	100.65	---	---	---	---	0.00	---	---	---	---	---	0.000
0.70	105	100.70	---	---	---	---	0.00	---	---	---	---	---	0.000
0.75	113	100.75	---	---	---	---	0.00	---	---	---	---	---	0.000
0.80	120	100.80	---	---	---	---	0.00	---	---	---	---	---	0.000
0.85	128	100.85	---	---	---	---	0.00	---	---	---	---	---	0.000
0.90	135	100.90	---	---	---	---	0.00	---	---	---	---	---	0.000
0.95	143	100.95	---	---	---	---	0.00	---	---	---	---	---	0.000
1.00	150	101.00	---	---	---	---	0.00	---	---	---	---	---	0.000
1.05	201	101.05	---	---	---	---	0.00	---	---	---	---	---	0.000
1.10	252	101.10	---	---	---	---	0.00	---	---	---	---	---	0.000
1.15	303	101.15	---	---	---	---	0.00	---	---	---	---	---	0.000
1.20	354	101.20	---	---	---	---	0.00	---	---	---	---	---	0.000
1.25	406	101.25	---	---	---	---	0.00	---	---	---	---	---	0.000
1.30	457	101.30	---	---	---	---	0.00	---	---	---	---	---	0.000
1.35	508	101.35	---	---	---	---	0.00	---	---	---	---	---	0.000
1.40	559	101.40	---	---	---	---	0.00	---	---	---	---	---	0.000
1.45	610	101.45	---	---	---	---	0.00	---	---	---	---	---	0.000
1.50	661	101.50	---	---	---	---	0.00	---	---	---	---	---	0.000
1.55	741	101.55	---	---	---	---	0.37	---	---	---	---	---	0.372
1.60	820	101.60	---	---	---	---	1.05	---	---	---	---	---	1.053
1.65	900	101.65	---	---	---	---	1.93	---	---	---	---	---	1.935
1.70	979	101.70	---	---	---	---	2.98	---	---	---	---	---	2.979
1.75	1,059	101.75	---	---	---	---	4.16	---	---	---	---	---	4.163
1.80	1,139	101.80	---	---	---	---	5.47	---	---	---	---	---	5.472
1.85	1,218	101.85	---	---	---	---	6.90	---	---	---	---	---	6.896
1.90	1,298	101.90	---	---	---	---	8.43	---	---	---	---	---	8.425

Continues on next page...

Waterbar Soil Amendments

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
1.95	1,377	101.95	---	---	---	---	10.05	---	---	---	---	---	10.05
2.00	1,457	102.00	---	---	---	---	11.77	---	---	---	---	---	11.77

...End

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	2.443	1	721	6,022	-----	-----	-----	DA-FR-120C PRE
2	SCS Runoff	2.443	1	721	6,022	-----	-----	-----	DA-FR-120C DEV
3	SCS Runoff	0.506	1	723	1,996	-----	-----	-----	DA-FR-120C FOR
4	Reservoir	2.373	1	722	5,361	2	101.67	933	WB Soil Amendments
DA-FR-120C_Hydraflow.gpw					Return Period: 2 Year			Friday, 08 / 18 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

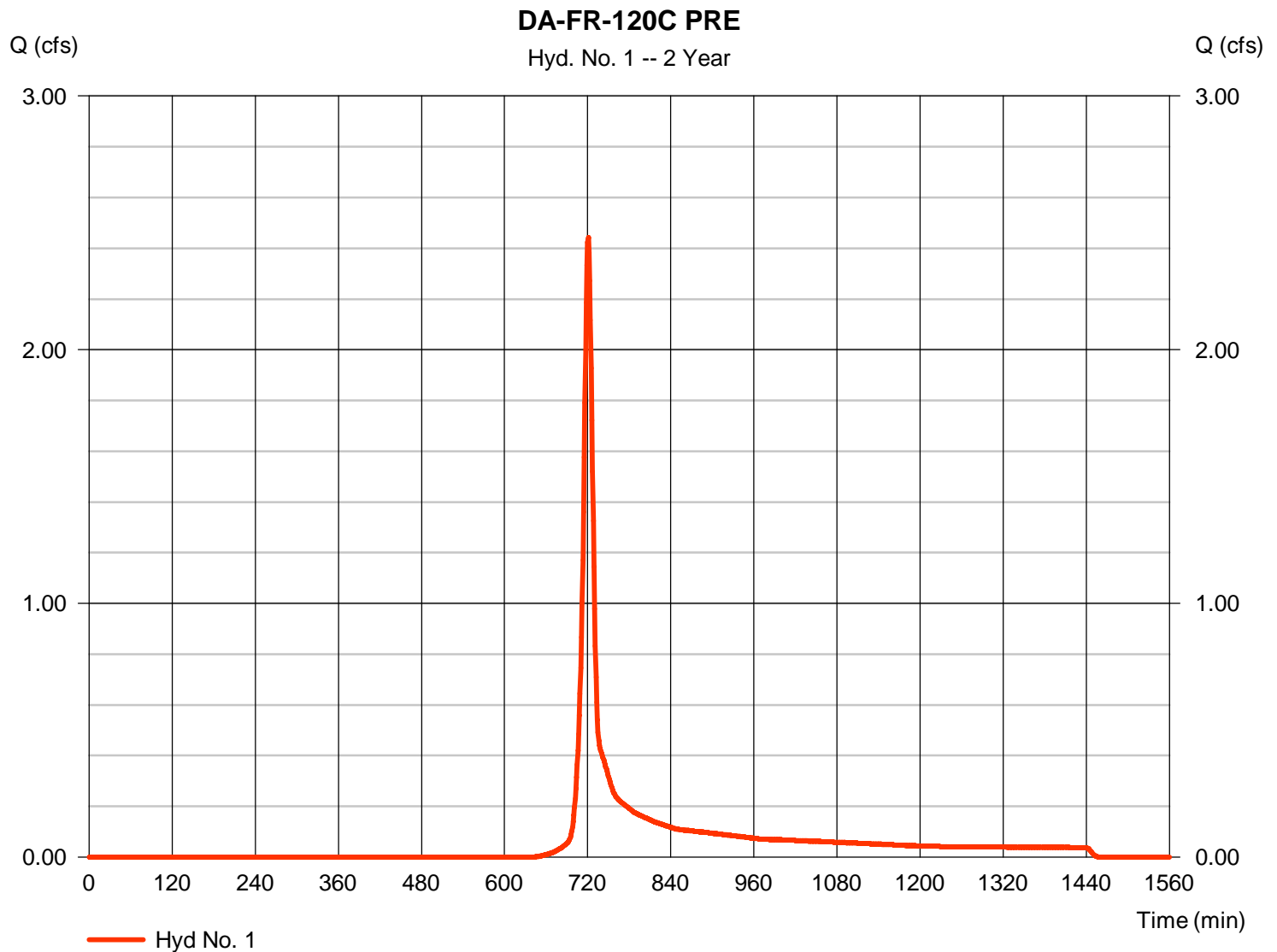
Friday, 08 / 18 / 2017

Hyd. No. 1

DA-FR-120C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 2.443 cfs
Storm frequency	= 2 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 6,022 cuft
Drainage area	= 1.300 ac	Curve number	= 72*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 10.60 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.072 \times 87) + (0.748 \times 71) + (0.007 \times 100) + (0.471 \times 70)] / 1.300$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

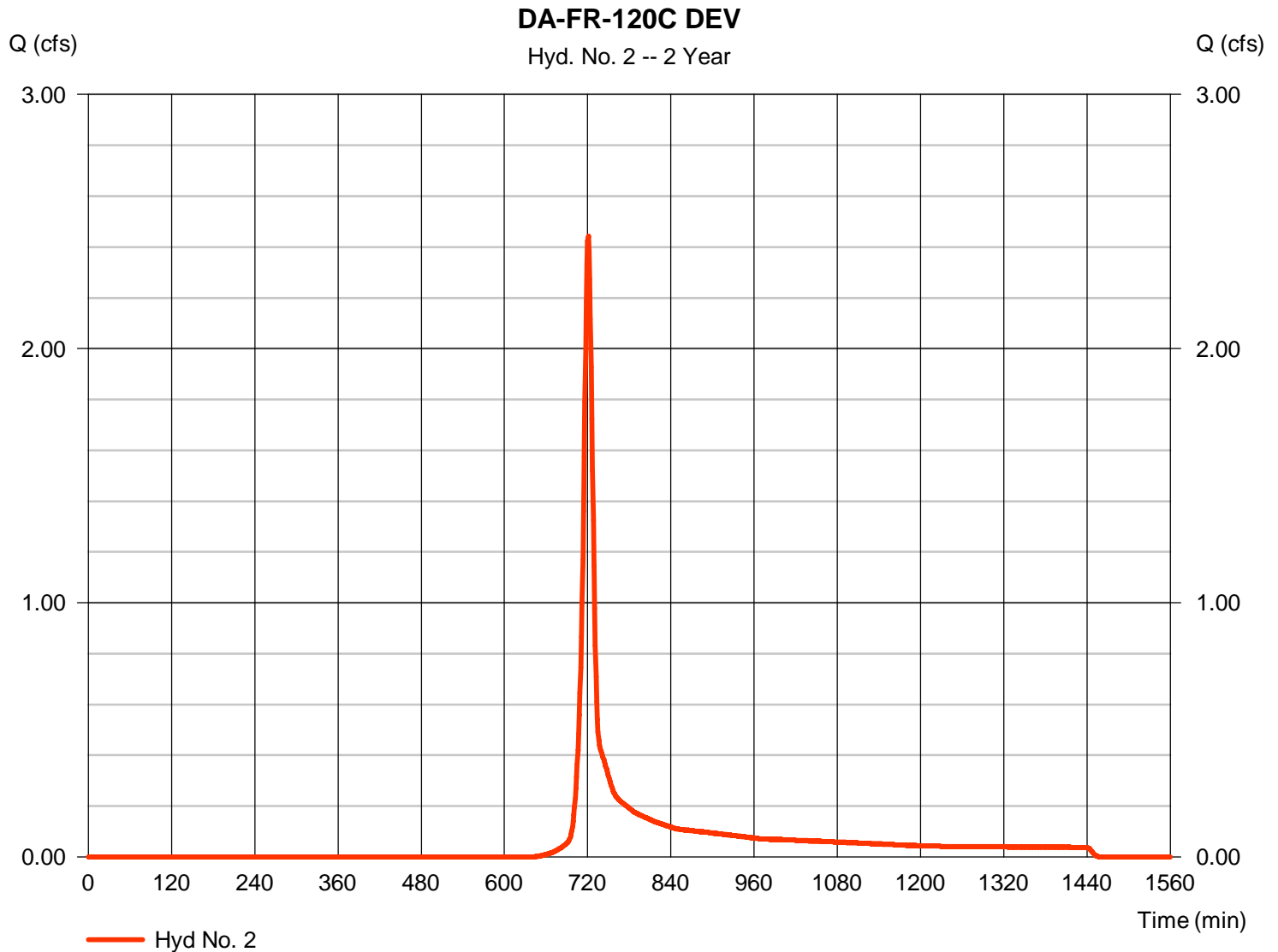
Friday, 08 / 18 / 2017

Hyd. No. 2

DA-FR-120C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 2.443 cfs
Storm frequency	= 2 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 6,022 cuft
Drainage area	= 1.300 ac	Curve number	= 72*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 10.60 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.033 \times 65) + (0.072 \times 87) + (0.796 \times 71) + (0.007 \times 100) + (0.391 \times 70)] / 1.300$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

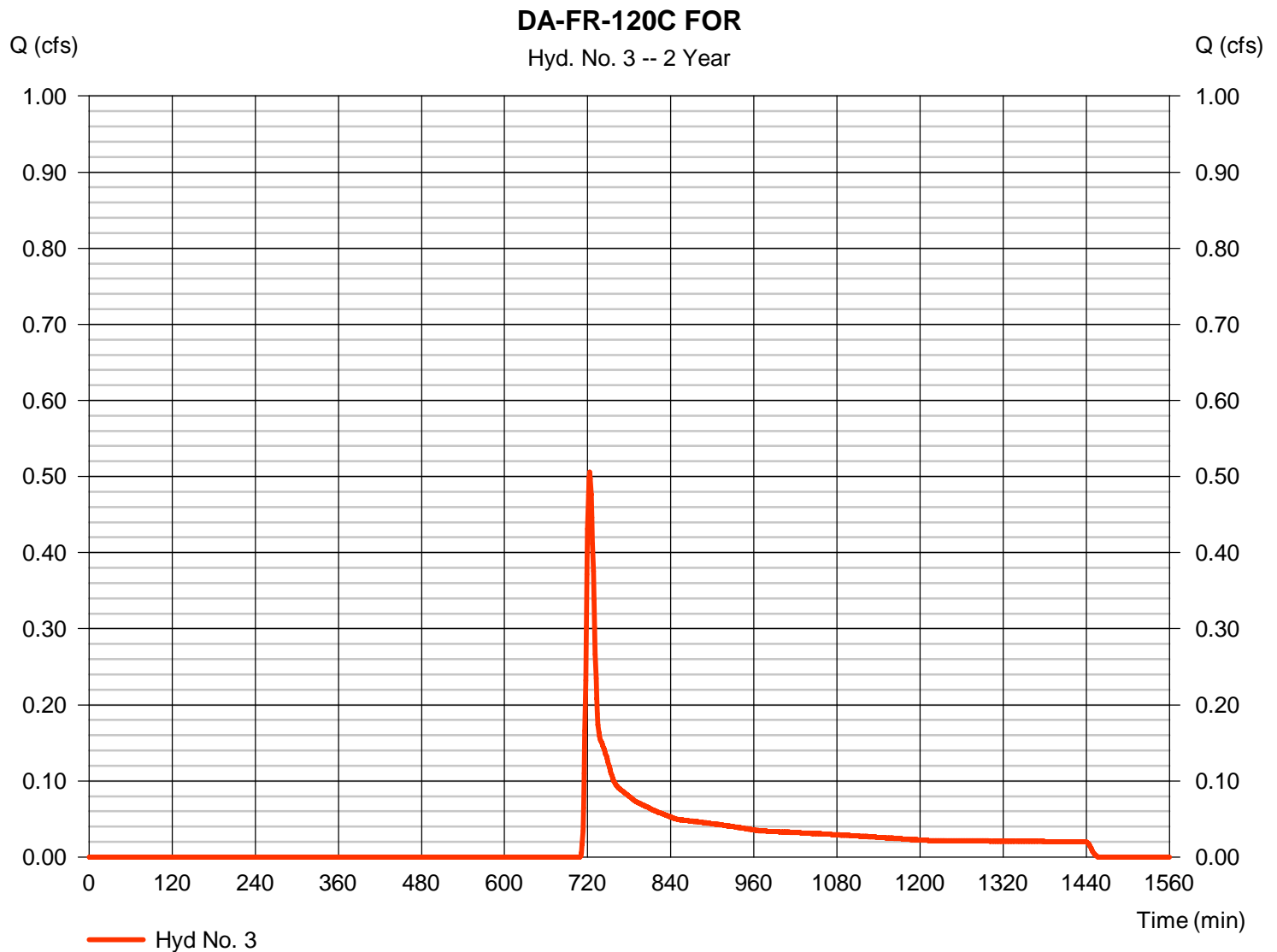
Friday, 08 / 18 / 2017

Hyd. No. 3

DA-FR-120C FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 1.300 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.506 cfs
 Time to peak = 723 min
 Hyd. volume = 1,996 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 10.60 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

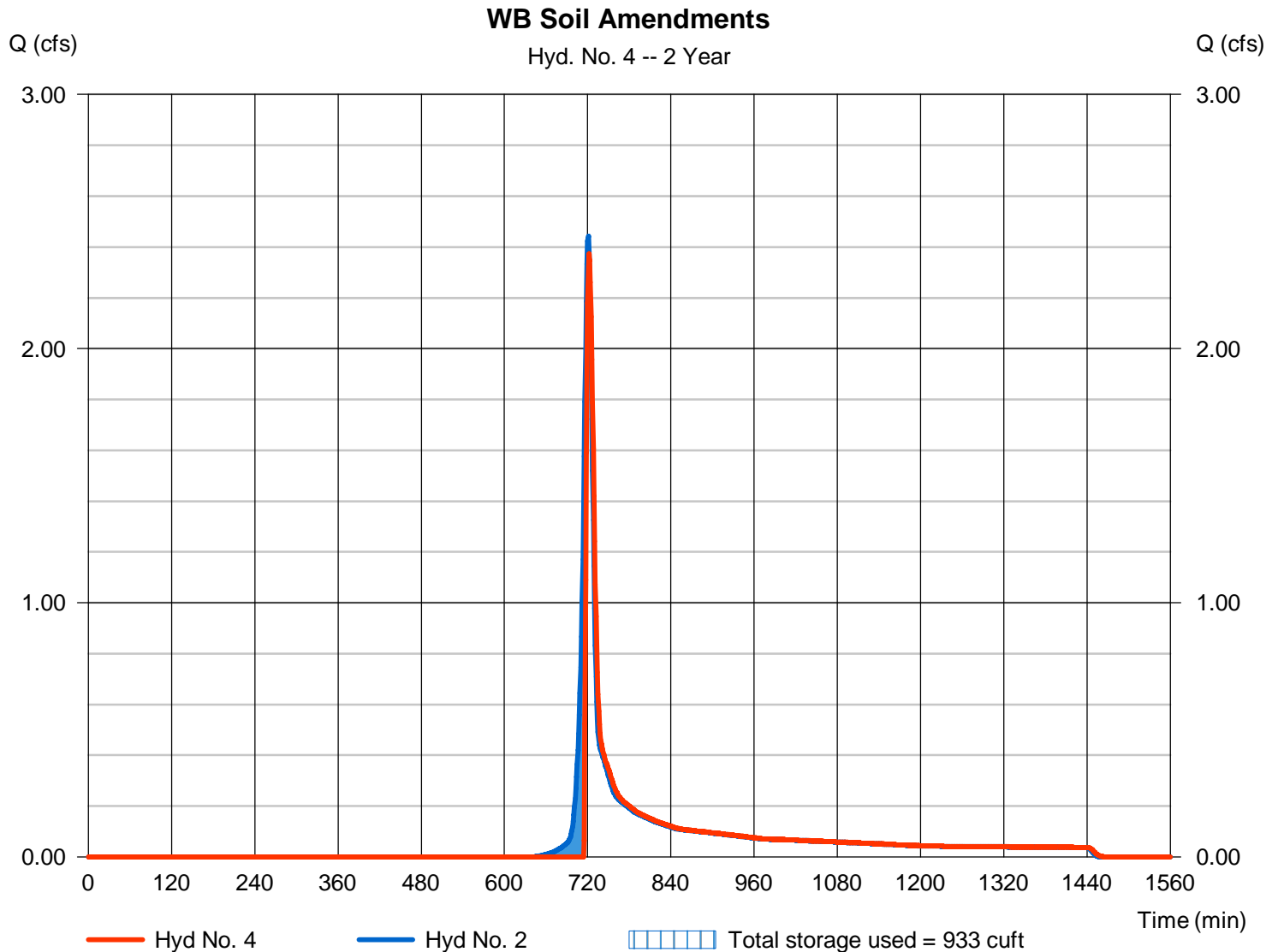
Friday, 08 / 18 / 2017

Hyd. No. 4

WB Soil Amendments

Hydrograph type	= Reservoir	Peak discharge	= 2.373 cfs
Storm frequency	= 2 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 5,361 cuft
Inflow hyd. No.	= 2 - DA-FR-120C DEV	Max. Elevation	= 101.67 ft
Reservoir name	= Waterbar Soil Amendments	Max. Storage	= 933 cuft

Storage Indication method used.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	5.461	1	720	13,208	-----	-----	-----	DA-FR-120C PRE
2	SCS Runoff	5.461	1	720	13,208	-----	-----	-----	DA-FR-120C DEV
3	SCS Runoff	2.461	1	721	6,477	-----	-----	-----	DA-FR-120C FOR
4	Reservoir	5.389	1	721	12,547	2	101.80	1,134	WB Soil Amendments
DA-FR-120C_Hydraflow.gpw					Return Period: 10 Year			Friday, 08 / 18 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

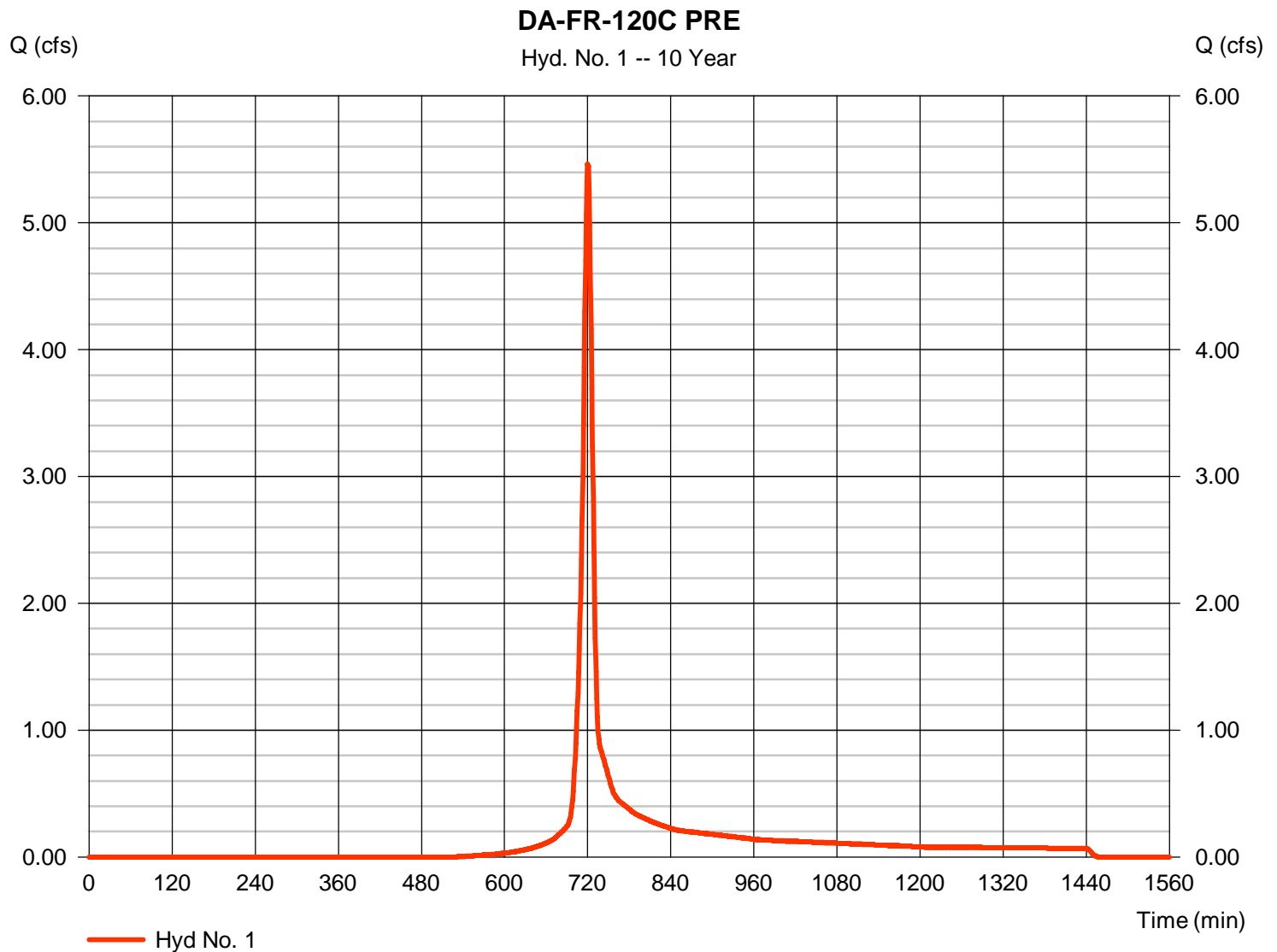
Friday, 08 / 18 / 2017

Hyd. No. 1

DA-FR-120C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 5.461 cfs
Storm frequency	= 10 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 13,208 cuft
Drainage area	= 1.300 ac	Curve number	= 72*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 10.60 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.072 \times 87) + (0.748 \times 71) + (0.007 \times 100) + (0.471 \times 70)] / 1.300$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

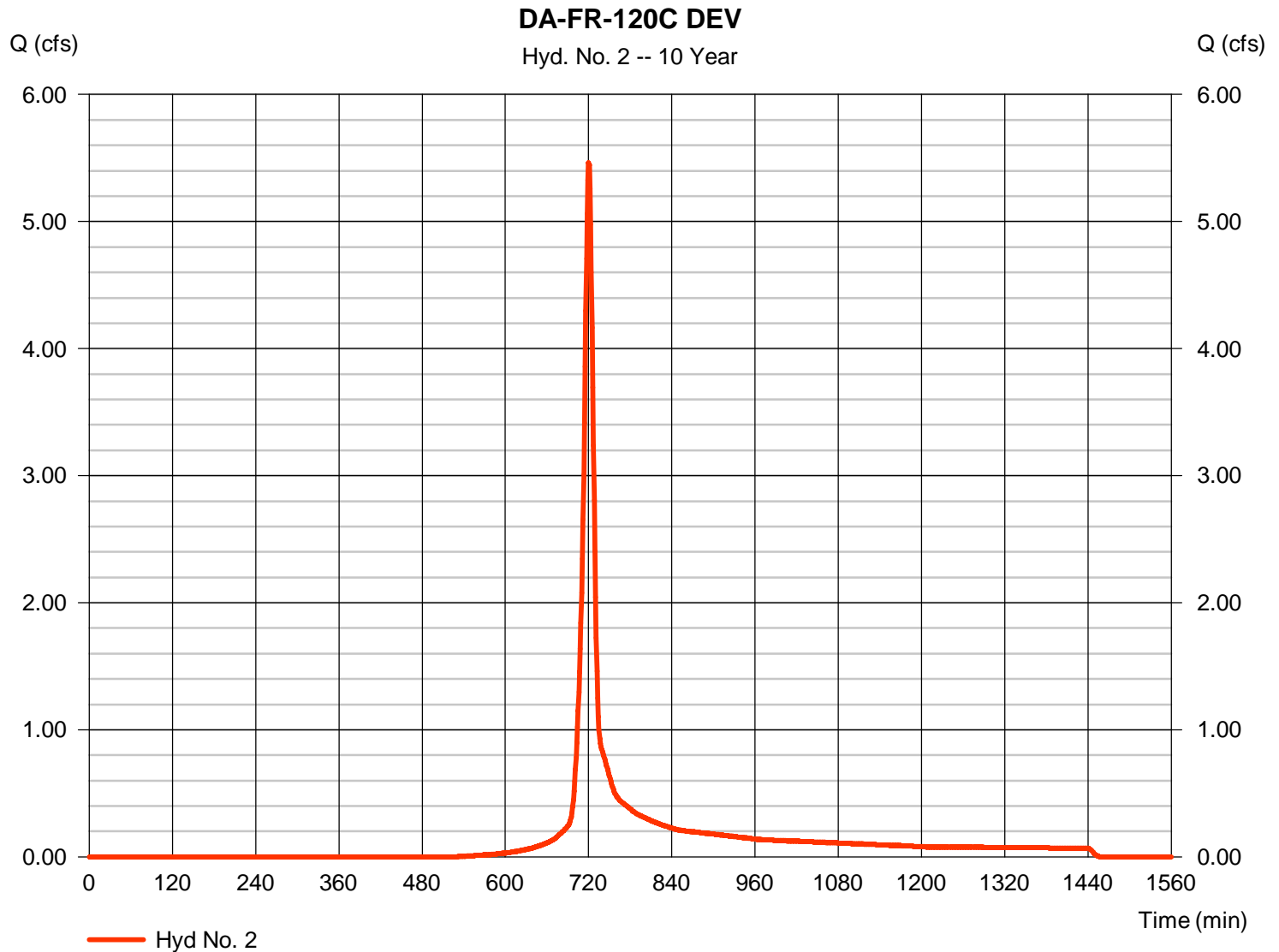
Friday, 08 / 18 / 2017

Hyd. No. 2

DA-FR-120C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 5.461 cfs
Storm frequency	= 10 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 13,208 cuft
Drainage area	= 1.300 ac	Curve number	= 72*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 10.60 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.033 \times 65) + (0.072 \times 87) + (0.796 \times 71) + (0.007 \times 100) + (0.391 \times 70)] / 1.300$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

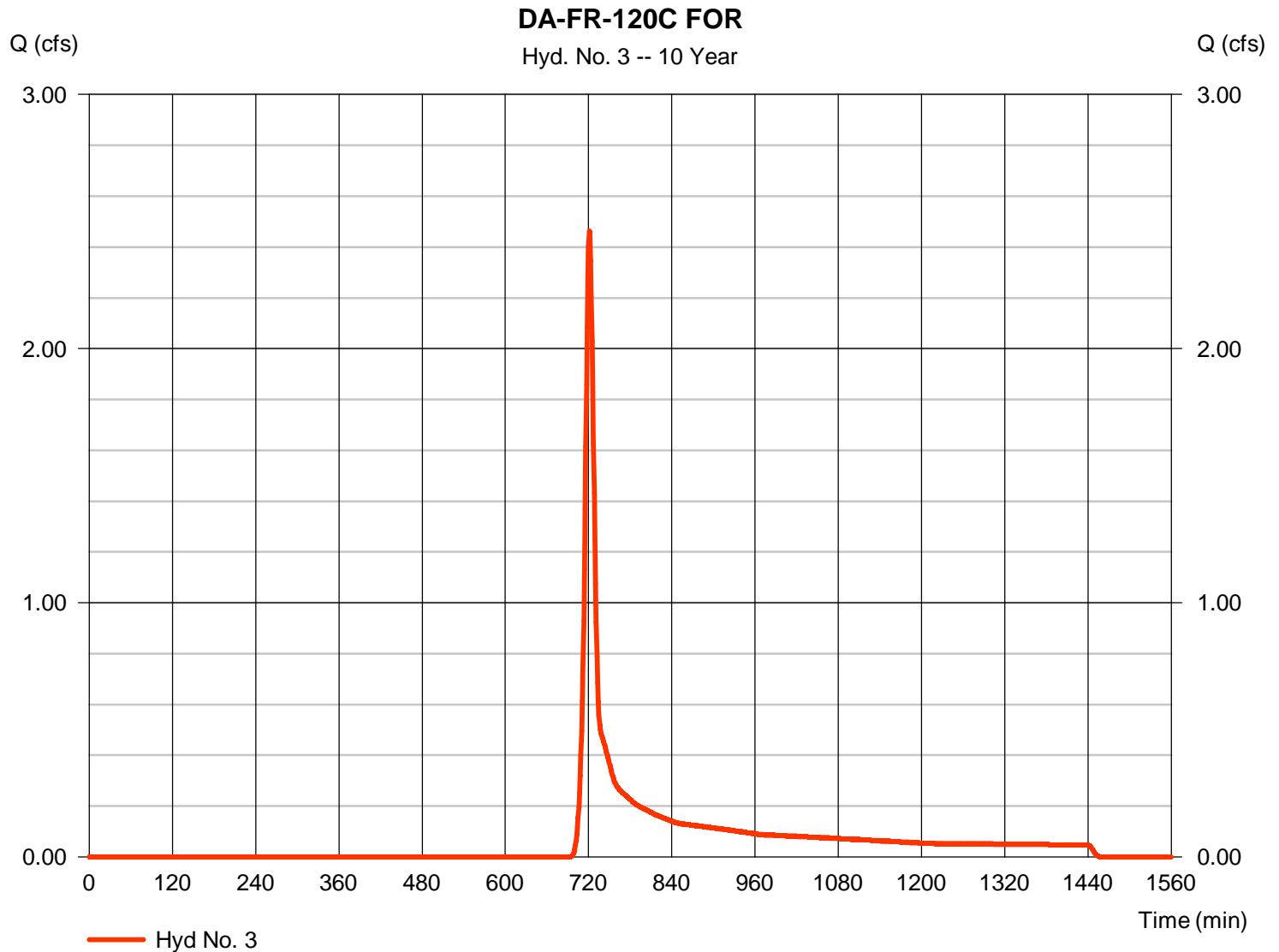
Friday, 08 / 18 / 2017

Hyd. No. 3

DA-FR-120C FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 1.300 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 2.461 cfs
 Time to peak = 721 min
 Hyd. volume = 6,477 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 10.60 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

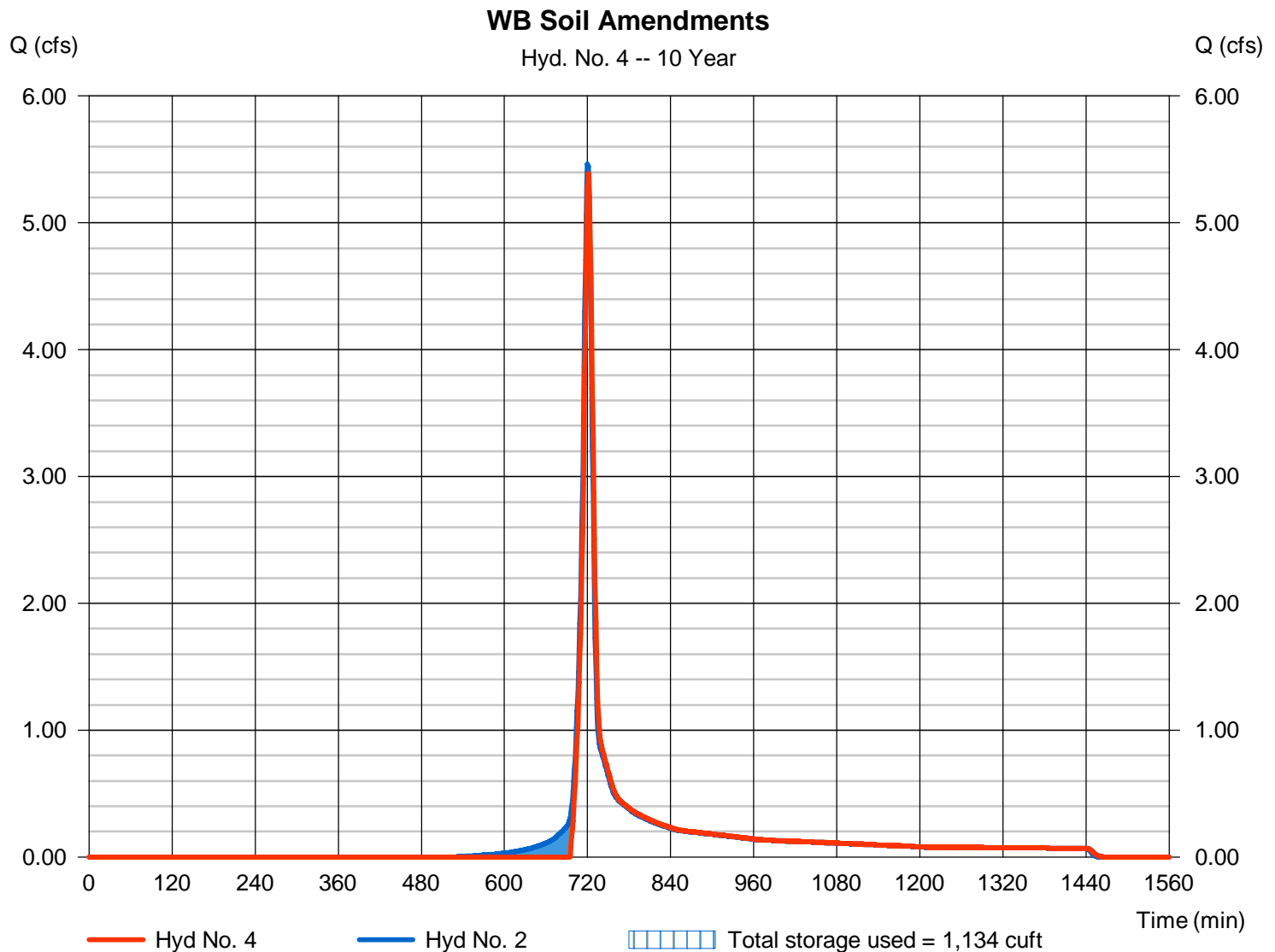
Friday, 08 / 18 / 2017

Hyd. No. 4

WB Soil Amendments

Hydrograph type	= Reservoir	Peak discharge	= 5.389 cfs
Storm frequency	= 10 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 12,547 cuft
Inflow hyd. No.	= 2 - DA-FR-120C DEV	Max. Elevation	= 101.80 ft
Reservoir name	= Waterbar Soil Amendments	Max. Storage	= 1,134 cuft

Storage Indication method used.



DA-FR-120D

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.368	969
Developed Condition	0.333	902
Pre-Developed (Forest) Condition	0.094	449

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.9

Calculations:

Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	0.333	\leq OK	0.356
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.333	\leq OK	0.368
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ ---->	0.333	<u>shall not</u> be required to be \leq	0.047

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s n value of 0.011 was used.</p> <p><i>Sources:</i></p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-120D PRE
2	SCS Runoff	DA-FR-120D DEV
3	SCS Runoff	DA-FR-120D FOR

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.368	1	720	969	-----	-----	-----	DA-FR-120D PRE
2	SCS Runoff	0.333	1	721	902	-----	-----	-----	DA-FR-120D DEV
3	SCS Runoff	0.094	1	723	449	-----	-----	-----	DA-FR-120D FOR
DA-FR-120D_Hydraflow.gpw					Return Period: 1 Year			Friday, 08 / 18 / 2017	

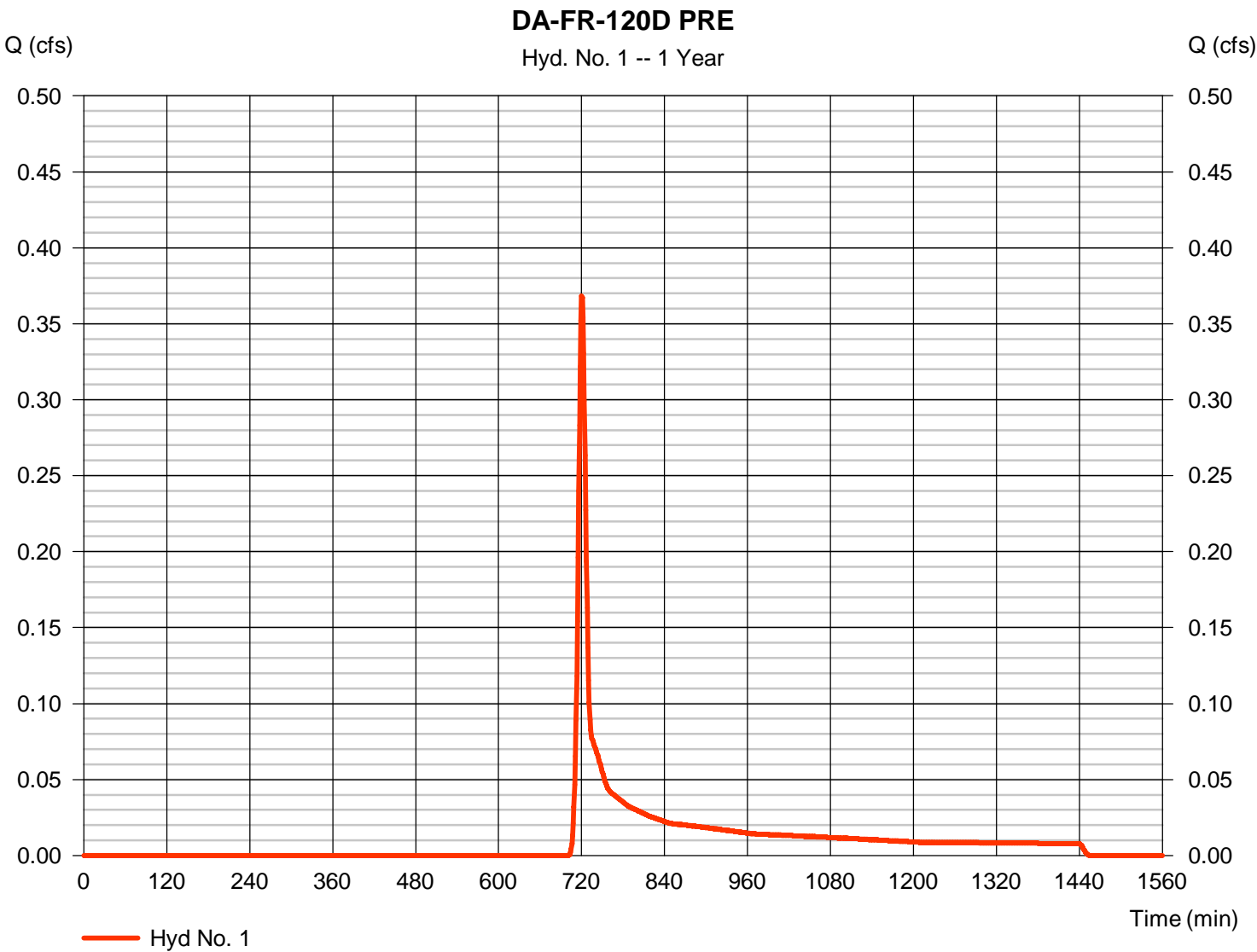
Hydrograph Report

Hyd. No. 1

DA-FR-120D PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.368 cfs
Storm frequency	= 1 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 969 cuft
Drainage area	= 0.440 ac	Curve number	= 64*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.60 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.052 x 82) + (0.012 x 87) + (0.006 x 100) + (0.229 x 55) + (0.136 x 70)] / 0.440



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-120D PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 16.79	0.00	0.00				
Travel Time (min)	= 8.53	+	0.00	+	0.00	=	8.53
Shallow Concentrated Flow							
Flow length (ft)	= 63.03	0.00	0.00				
Watercourse slope (%)	= 31.68	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=9.08	0.00	0.00				
Travel Time (min)	= 0.12	+	0.00	+	0.00	=	0.12
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				8.60 min			

Hydrograph Report

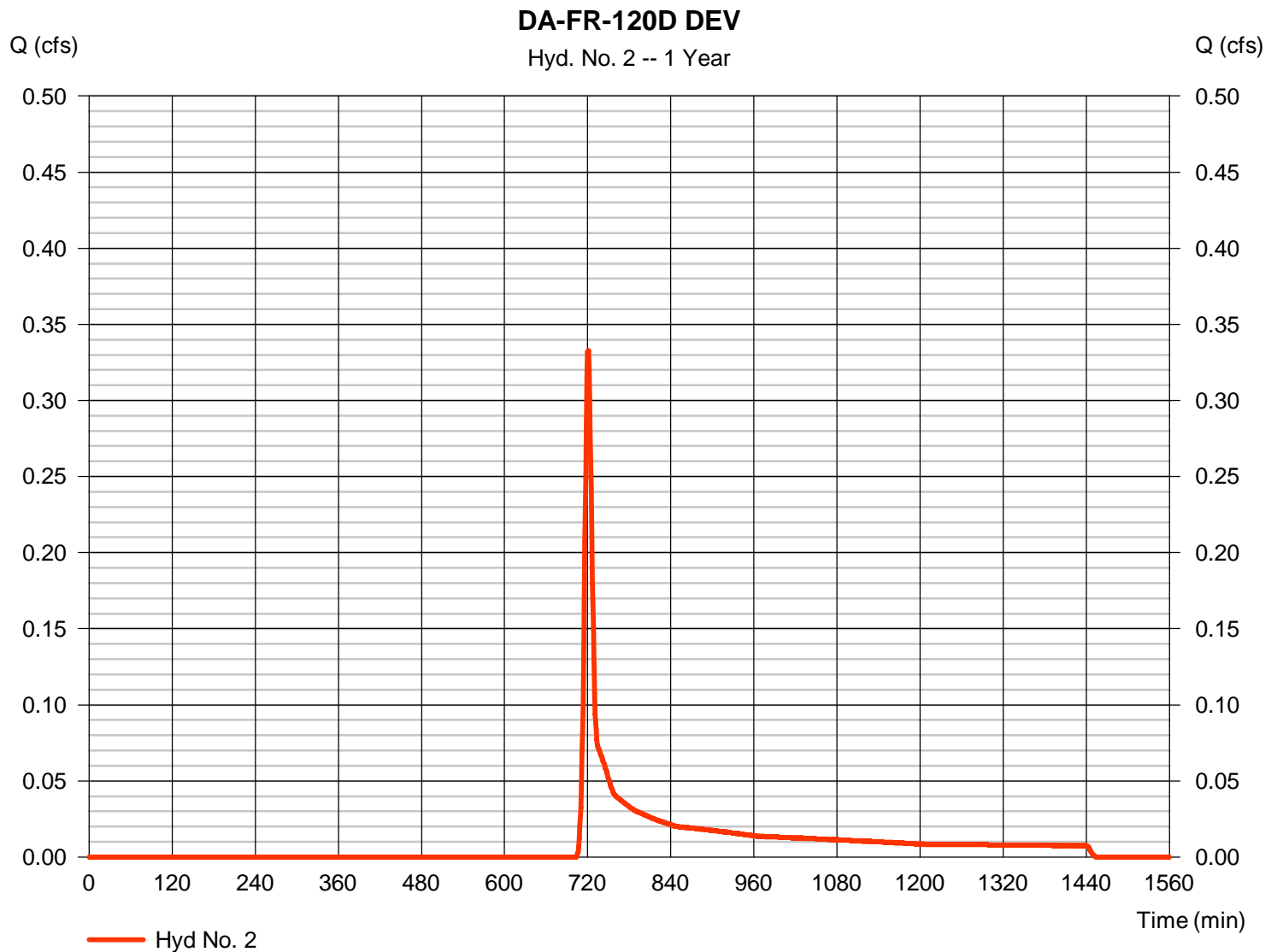
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Friday, 08 / 18 / 2017

Hyd. No. 2

DA-FR-120D DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.333 cfs
Storm frequency	= 1 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 902 cuft
Drainage area	= 0.440 ac	Curve number	= 63
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.60 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-120D DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 16.79	0.00	0.00				
Travel Time (min)	= 8.53	+	0.00	+	0.00	=	8.53
Shallow Concentrated Flow							
Flow length (ft)	= 63.03	0.00	0.00				
Watercourse slope (%)	= 31.68	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=9.08	0.00	0.00				
Travel Time (min)	= 0.12	+	0.00	+	0.00	=	0.12
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	= 0.400	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				8.60 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

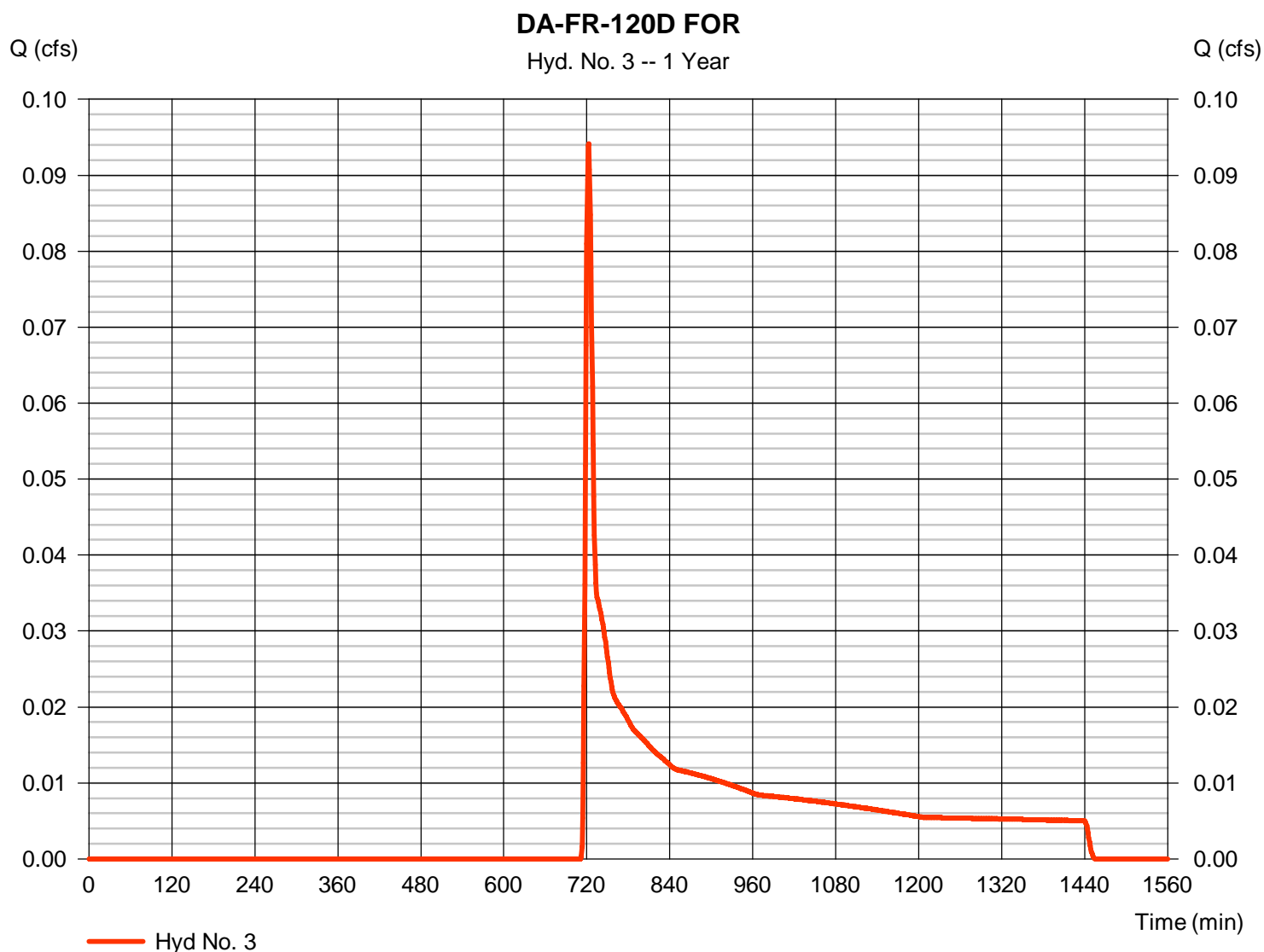
Friday, 08 / 18 / 2017

Hyd. No. 3

DA-FR-120D FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.094 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 449 cuft
Drainage area	= 0.440 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.60 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.050 \times 82) + (0.010 \times 87) + (0.010 \times 100) + (0.230 \times 55) + (0.140 \times 70)] / 0.440$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-120D FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 16.79	0.00	0.00				
Travel Time (min)	= 8.53	+	0.00	+	0.00	=	8.53
Shallow Concentrated Flow							
Flow length (ft)	= 63.03	0.00	0.00				
Watercourse slope (%)	= 31.68	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=9.08	0.00	0.00				
Travel Time (min)	= 0.12	+	0.00	+	0.00	=	0.12
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	= 0.400	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				8.60 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.522	1	720	1,291	-----	-----	-----	DA-FR-120D PRE
2	SCS Runoff	0.481	1	720	1,213	-----	-----	-----	DA-FR-120D DEV
3	SCS Runoff	0.187	1	722	664	-----	-----	-----	DA-FR-120D FOR
DA-FR-120D_Hydraflow.gpw					Return Period: 2 Year			Friday, 08 / 18 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

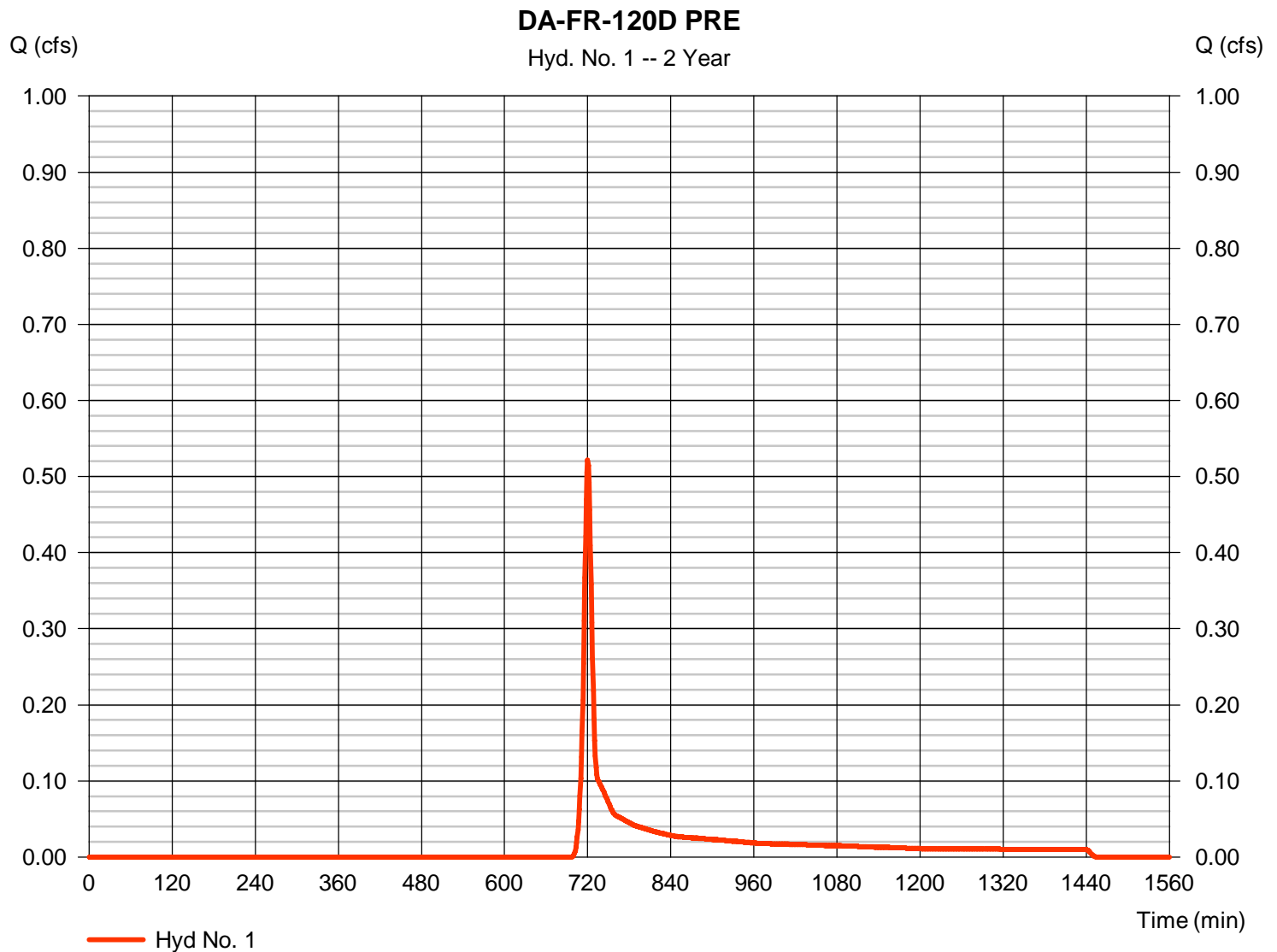
Friday, 08 / 18 / 2017

Hyd. No. 1

DA-FR-120D PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.522 cfs
Storm frequency	= 2 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 1,291 cuft
Drainage area	= 0.440 ac	Curve number	= 64*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.60 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.052 \times 82) + (0.012 \times 87) + (0.006 \times 100) + (0.229 \times 55) + (0.136 \times 70)] / 0.440$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

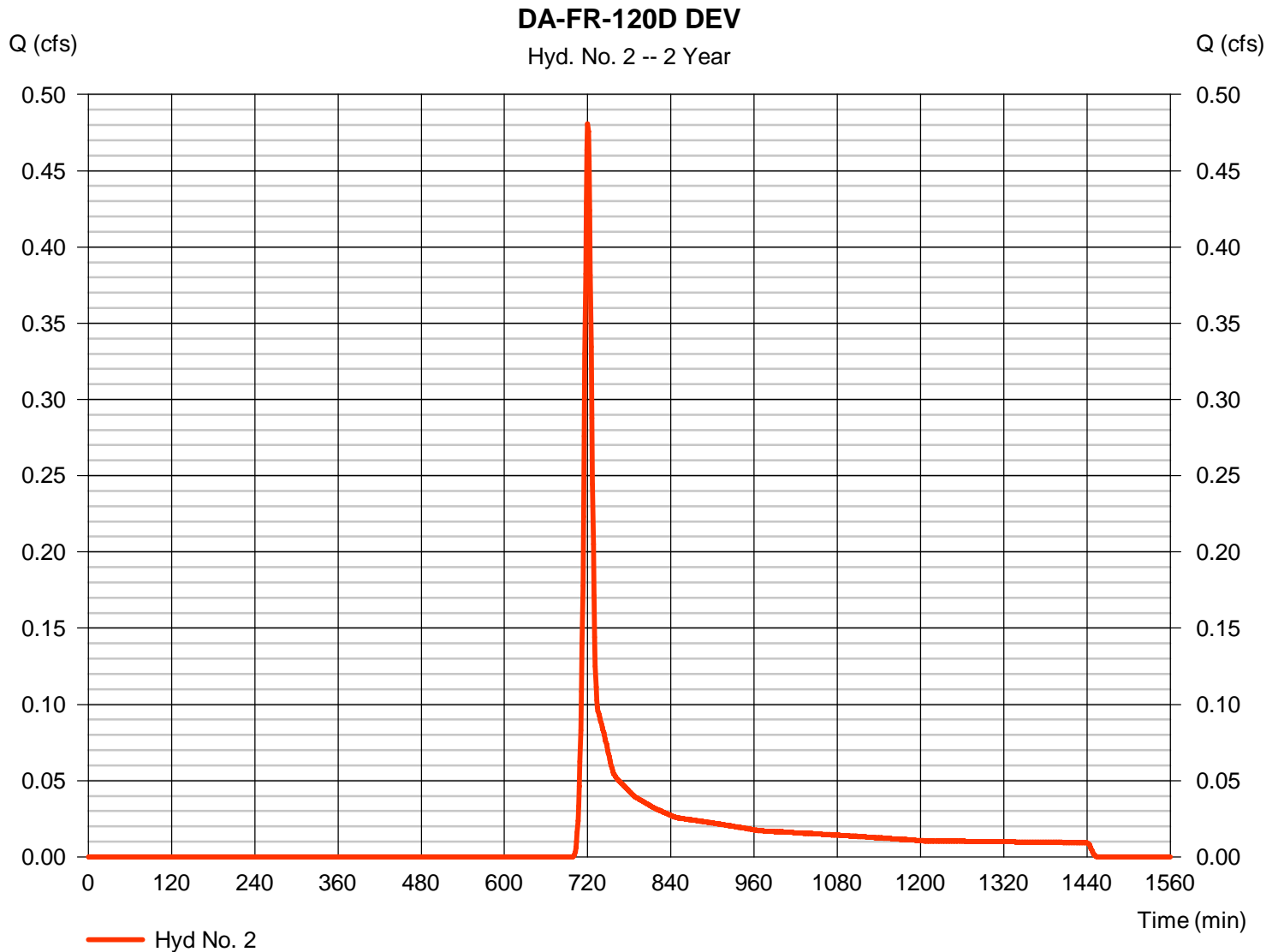
Friday, 08 / 18 / 2017

Hyd. No. 2

DA-FR-120D DEV

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 0.440 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.481 cfs
 Time to peak = 720 min
 Hyd. volume = 1,213 cuft
 Curve number = 63
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 8.60 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

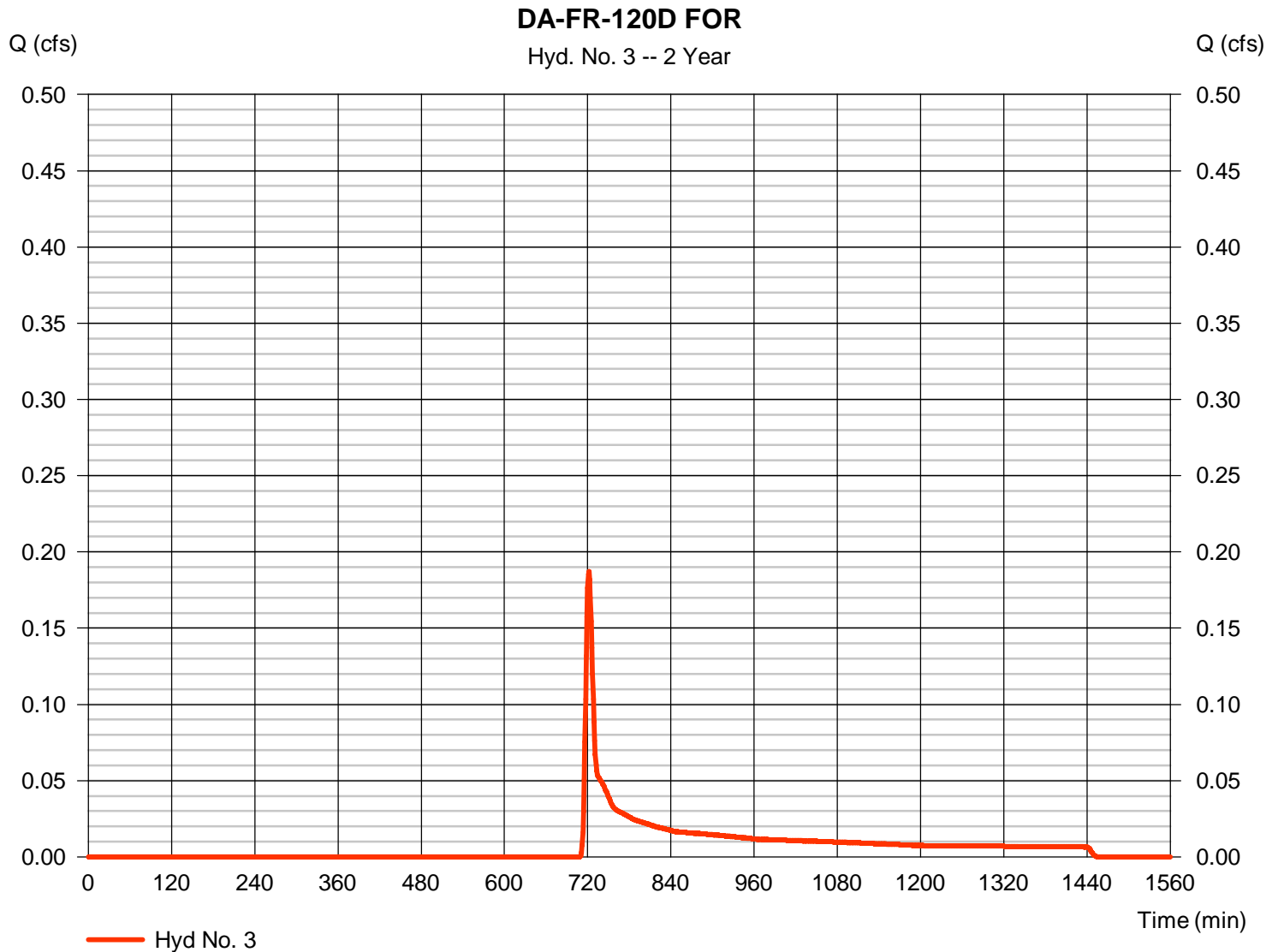
Friday, 08 / 18 / 2017

Hyd. No. 3

DA-FR-120D FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.187 cfs
Storm frequency	= 2 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 664 cuft
Drainage area	= 0.440 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.60 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.050 \times 82) + (0.010 \times 87) + (0.010 \times 100) + (0.230 \times 55) + (0.140 \times 70)] / 0.440$



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	1.439	1	720	3,277	-----	-----	-----	DA-FR-120D PRE
2	SCS Runoff	1.377	1	720	3,146	-----	-----	-----	DA-FR-120D DEV
3	SCS Runoff	0.889	1	720	2,154	-----	-----	-----	DA-FR-120D FOR
DA-FR-120D_Hydraflow.gpw					Return Period: 10 Year			Friday, 08 / 18 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

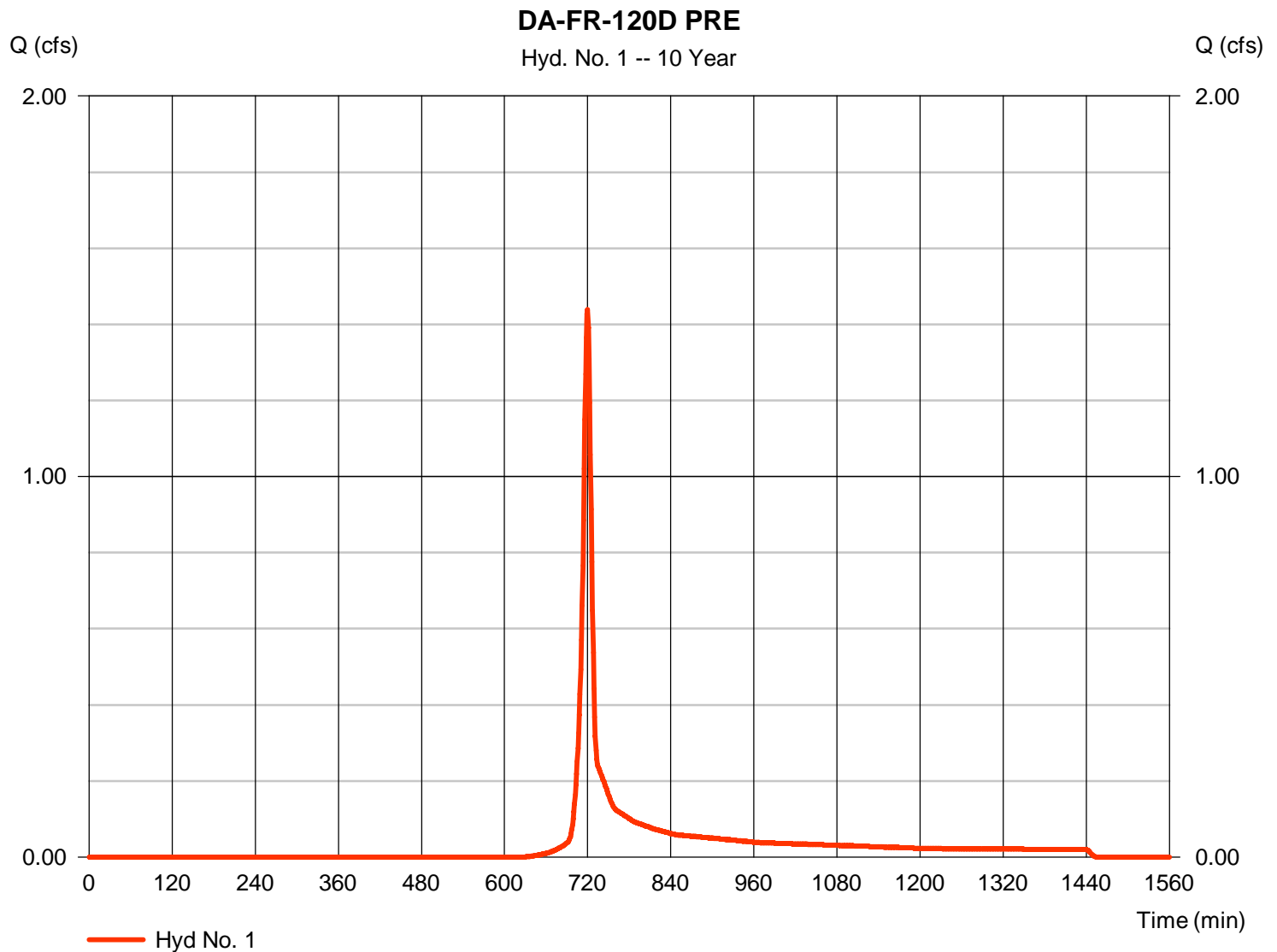
Friday, 08 / 18 / 2017

Hyd. No. 1

DA-FR-120D PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 1.439 cfs
Storm frequency	= 10 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 3,277 cuft
Drainage area	= 0.440 ac	Curve number	= 64*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.60 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.052 \times 82) + (0.012 \times 87) + (0.006 \times 100) + (0.229 \times 55) + (0.136 \times 70)] / 0.440$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

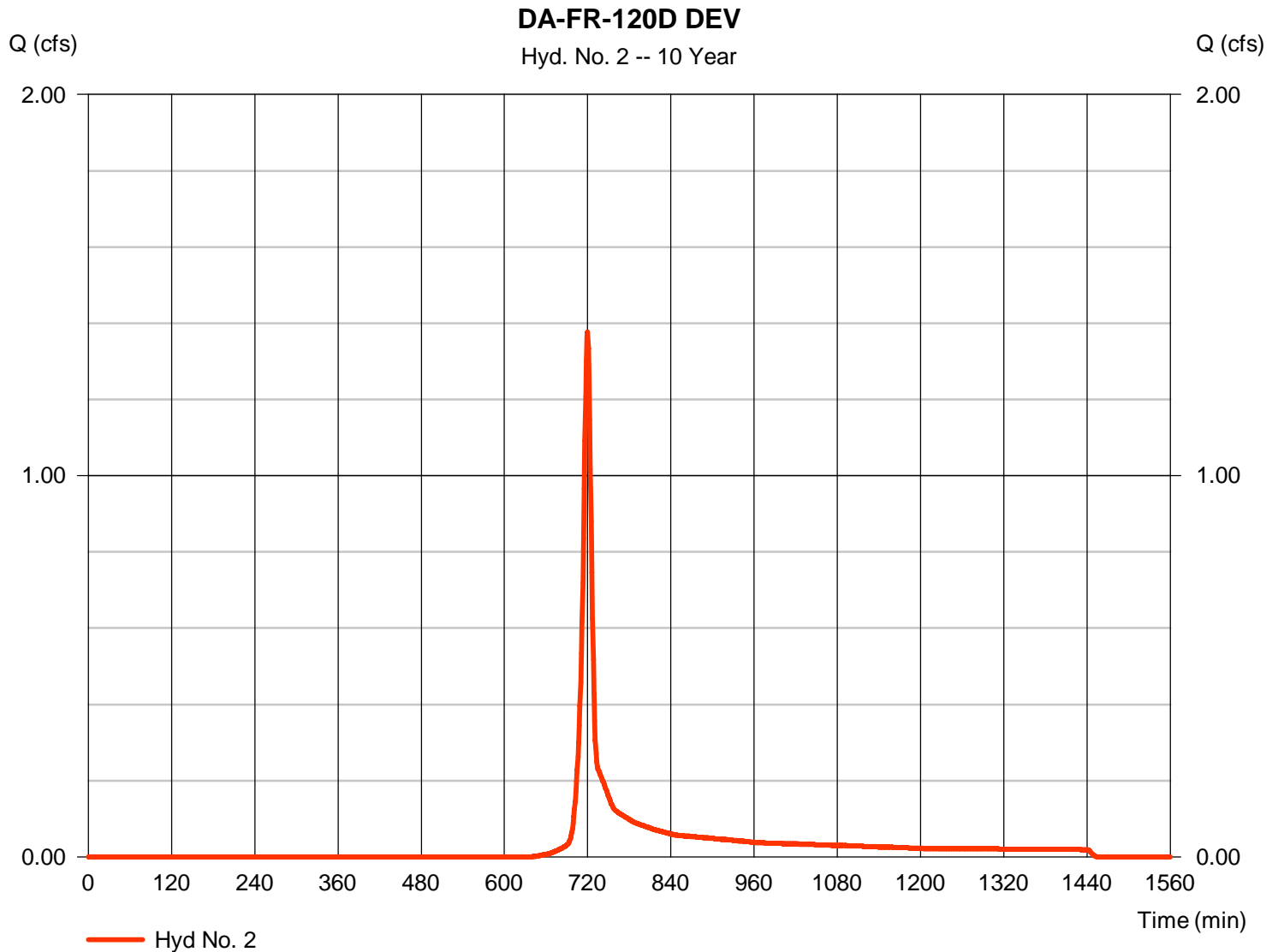
Friday, 08 / 18 / 2017

Hyd. No. 2

DA-FR-120D DEV

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 0.440 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 1.377 cfs
 Time to peak = 720 min
 Hyd. volume = 3,146 cuft
 Curve number = 63
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 8.60 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

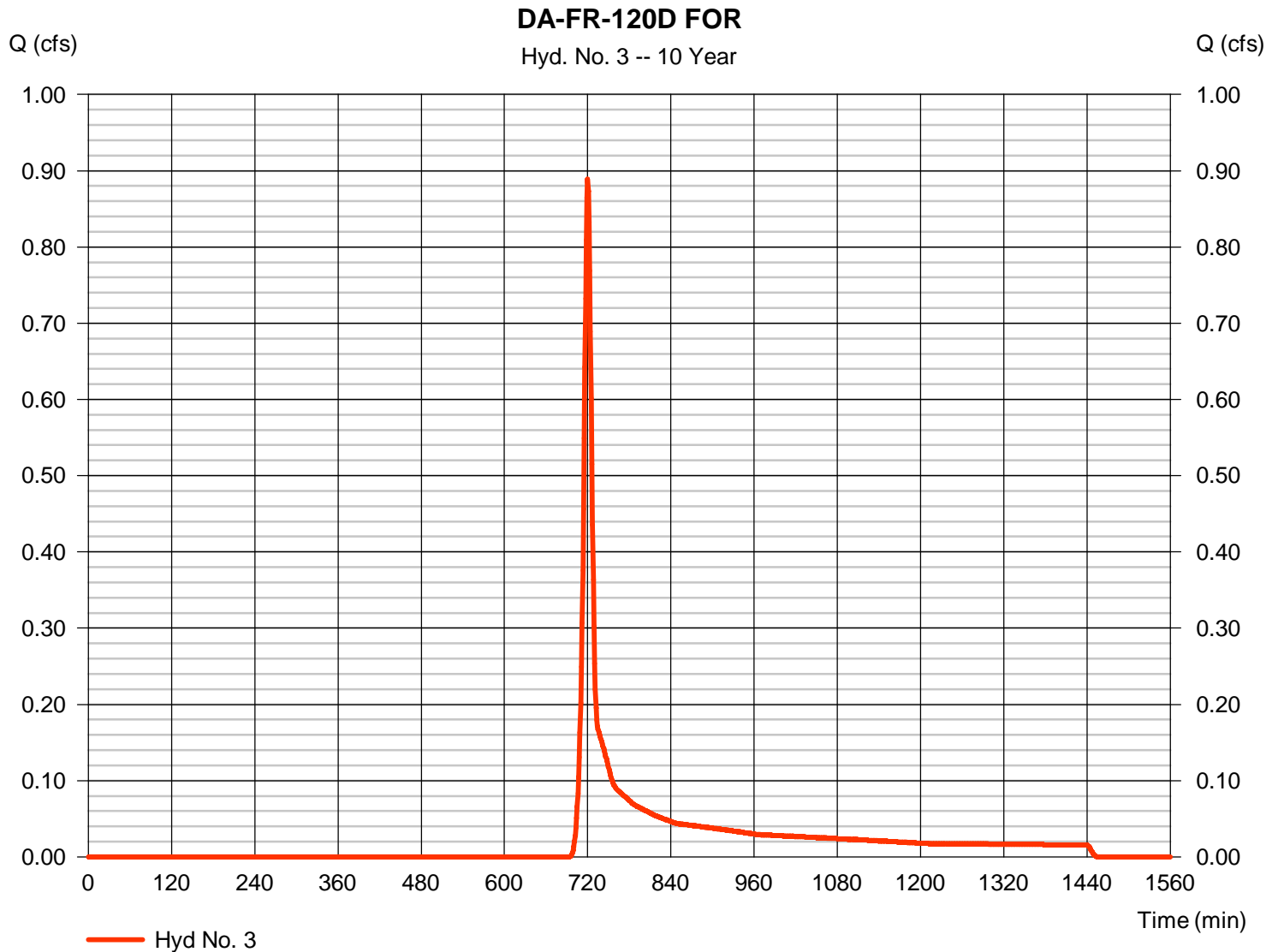
Friday, 08 / 18 / 2017

Hyd. No. 3

DA-FR-120D FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.889 cfs
Storm frequency	= 10 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 2,154 cuft
Drainage area	= 0.440 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.60 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.050 \times 82) + (0.010 \times 87) + (0.010 \times 100) + (0.230 \times 55) + (0.140 \times 70)] / 0.440$



DA-FR-120E

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.303	1022
Developed Condition	0.127	782
Pre-Developed (Forest) Condition	0.200	836

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.9

Calculations:

Check #1:	$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	0.127	\leq OK	0.356
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.127	\leq OK	0.303
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ ---->	0.127	<u>shall not</u> be required to be \leq	0.214

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s n value of 0.011 was used.</p> <p>Sources:</p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

Table 2 – Manning's *n* Values for Open Channel Flow

Channel Type	Manning <i>n</i>		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's <i>n</i> value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's <i>n</i> value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-120E PRE
2	SCS Runoff	DA-FR-120E DEV
3	SCS Runoff	DA-FR-120E FOR

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.303	1	721	1,022	-----	-----	-----	DA-FR-120E PRE
2	SCS Runoff	0.127	1	724	782	-----	-----	-----	DA-FR-120E DEV
3	SCS Runoff	0.200	1	721	836	-----	-----	-----	DA-FR-120E FOR
DA-FR-120E_Hydraflow.gpw					Return Period: 1 Year			Friday, 08 / 18 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

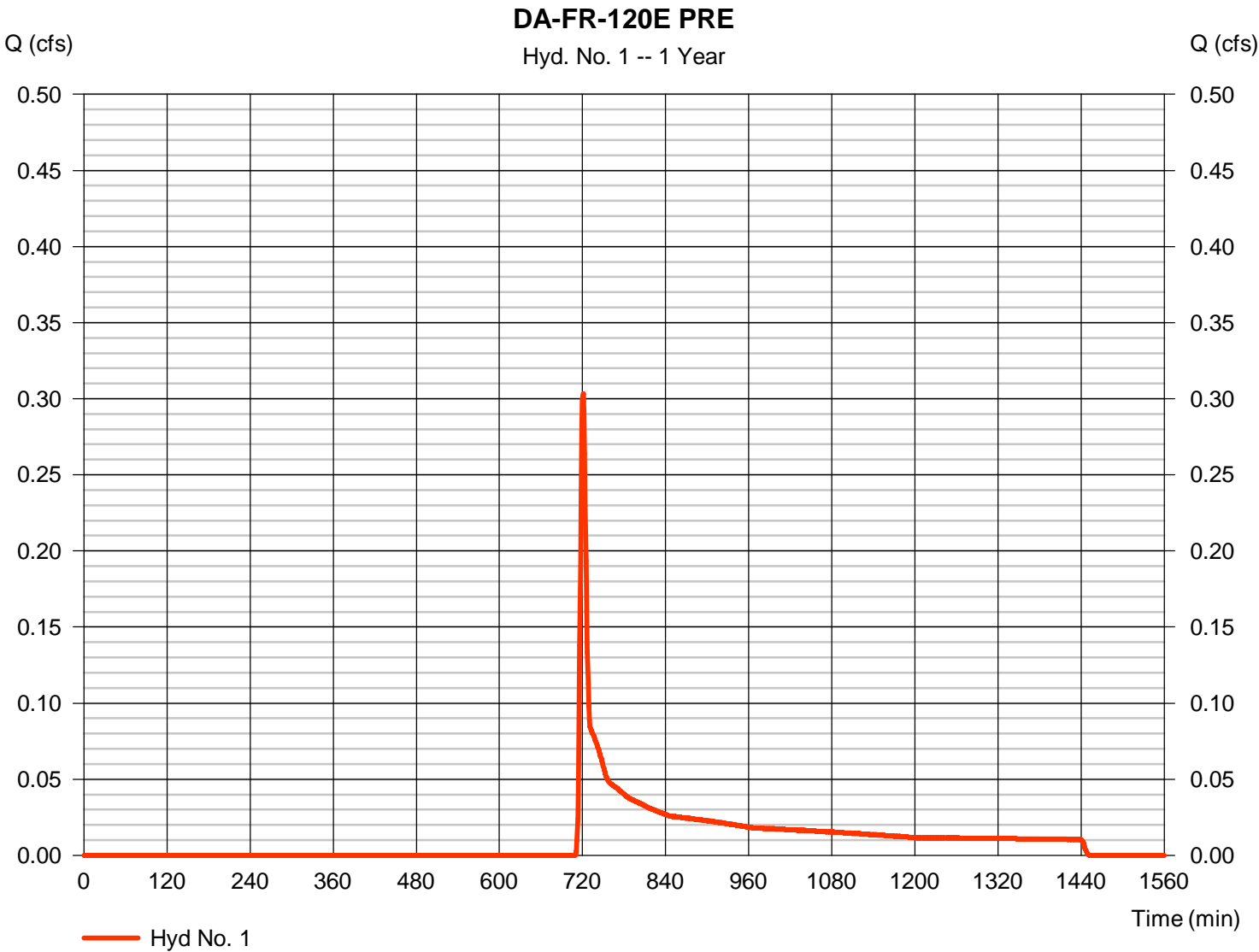
Friday, 08 / 18 / 2017

Hyd. No. 1

DA-FR-120E PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.303 cfs
Storm frequency	= 1 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 1,022 cuft
Drainage area	= 0.840 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 7.80 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.030 x 82) + (0.010 x 100) + (0.800 x 55)] / 0.840



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-120E PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 21.92	0.00	0.00				
Travel Time (min)	= 7.66	+	0.00	+	0.00	=	7.66
Shallow Concentrated Flow							
Flow length (ft)	= 74.04	0.00	0.00				
Watercourse slope (%)	= 24.24	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=7.94	0.00	0.00				
Travel Time (min)	= 0.16	+	0.00	+	0.00	=	0.16
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				7.80 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

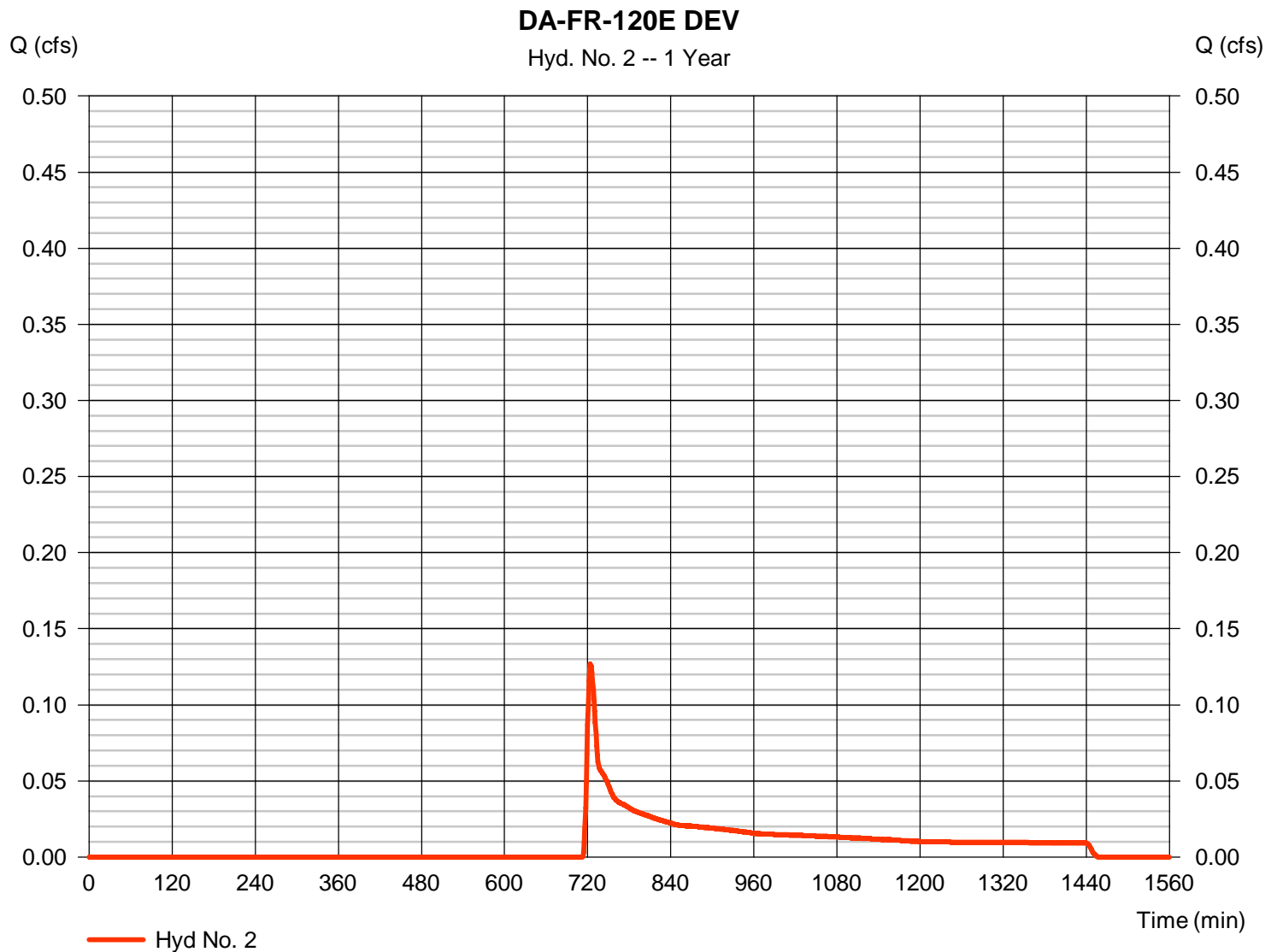
Friday, 08 / 18 / 2017

Hyd. No. 2

DA-FR-120E DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.127 cfs
Storm frequency	= 1 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 782 cuft
Drainage area	= 0.840 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.30 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.466 \times 48) + (0.030 \times 82) + (0.314 \times 58) + (0.013 \times 100) + (0.020 \times 55)] / 0.840$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-120E DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.800	0.400	
Flow length (ft)	= 55.0	25.1	17.5	
Two-year 24-hr precip. (in)	= 3.70	3.70	3.70	
Land slope (%)	= 22.76	22.63	18.40	
Travel Time (min)	= 4.68	+	4.36	+
			2.04	= 11.08
Shallow Concentrated Flow				
Flow length (ft)	= 22.37	0.00	0.00	
Watercourse slope (%)	= 27.99	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=8.54	0.00	0.00	
Travel Time (min)	= 0.04	+	0.00	+
			0.00	= 0.04
Channel Flow				
X sectional flow area (sqft)	= 2.00	0.00	0.00	
Wetted perimeter (ft)	= 4.47	0.00	0.00	
Channel slope (%)	= 5.00	0.00	0.00	
Manning's n-value	= 0.040	0.015	0.015	
Velocity (ft/s)	=4.86	0.00	0.00	
Flow length (ft)	({})40.2	0.0	0.0	
Travel Time (min)	= 0.14	+	0.00	+
			0.00	= 0.14
Total Travel Time, Tc				11.30 min

Hydrograph Report

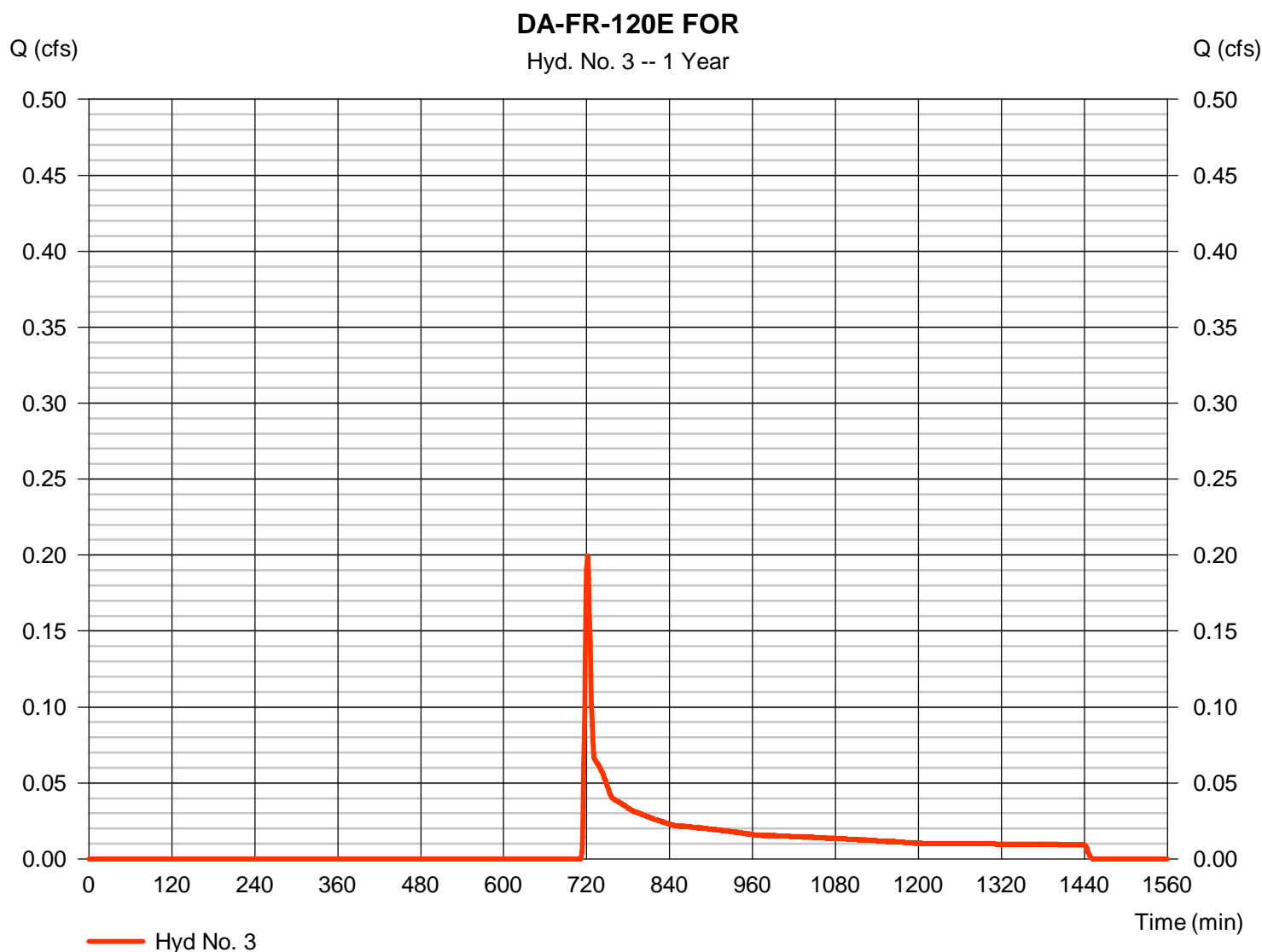
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Friday, 08 / 18 / 2017

Hyd. No. 3

DA-FR-120E FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.200 cfs
Storm frequency	= 1 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 836 cuft
Drainage area	= 0.840 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 7.80 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-120E FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 21.92	0.00	0.00				
Travel Time (min)	= 7.66	+	0.00	+	0.00	=	7.66
Shallow Concentrated Flow							
Flow length (ft)	= 74.04	0.00	0.00				
Watercourse slope (%)	= 24.24	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=7.94	0.00	0.00				
Travel Time (min)	= 0.16	+	0.00	+	0.00	=	0.16
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				7.80 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.526	1	720	1,466	-----	-----	-----	DA-FR-120E PRE
2	SCS Runoff	0.273	1	723	1,176	-----	-----	-----	DA-FR-120E DEV
3	SCS Runoff	0.390	1	721	1,236	-----	-----	-----	DA-FR-120E FOR
DA-FR-120E_Hydraflow.gpw					Return Period: 2 Year			Friday, 08 / 18 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

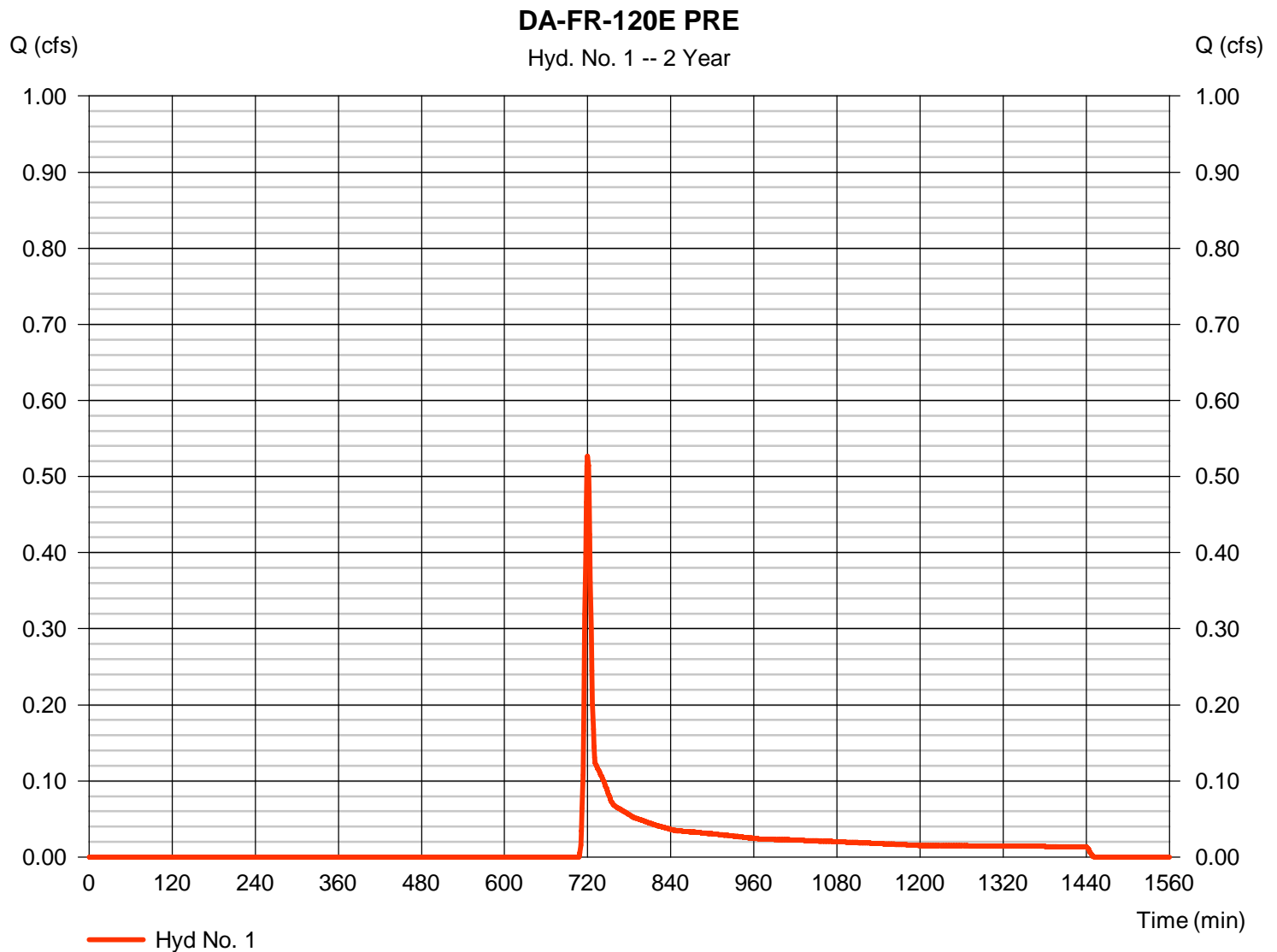
Friday, 08 / 18 / 2017

Hyd. No. 1

DA-FR-120E PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.526 cfs
Storm frequency	= 2 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 1,466 cuft
Drainage area	= 0.840 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 7.80 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.030 \times 82) + (0.010 \times 100) + (0.800 \times 55)] / 0.840$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

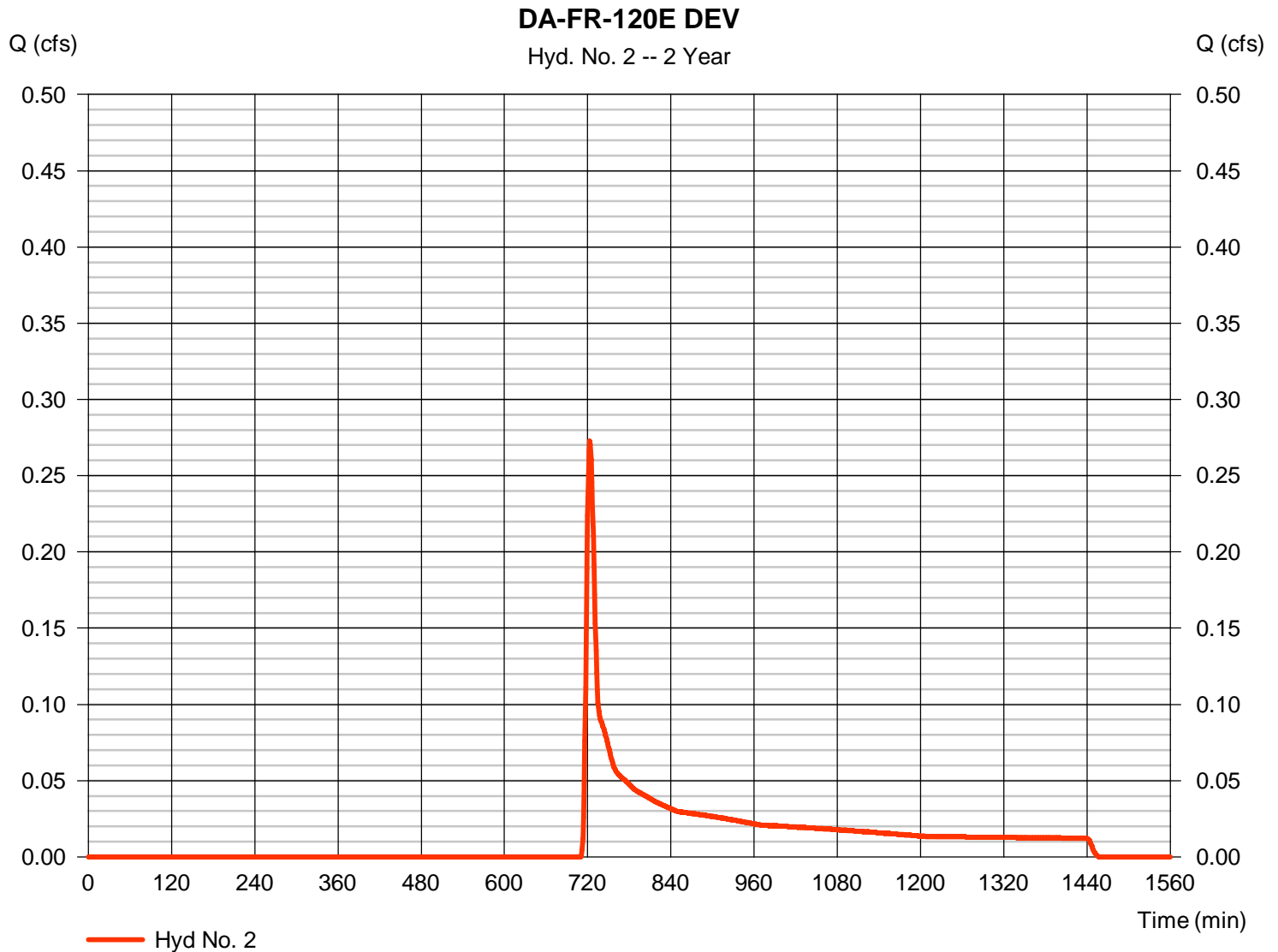
Friday, 08 / 18 / 2017

Hyd. No. 2

DA-FR-120E DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.273 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 1,176 cuft
Drainage area	= 0.840 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.30 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.466 \times 48) + (0.030 \times 82) + (0.314 \times 58) + (0.013 \times 100) + (0.020 \times 55)] / 0.840$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

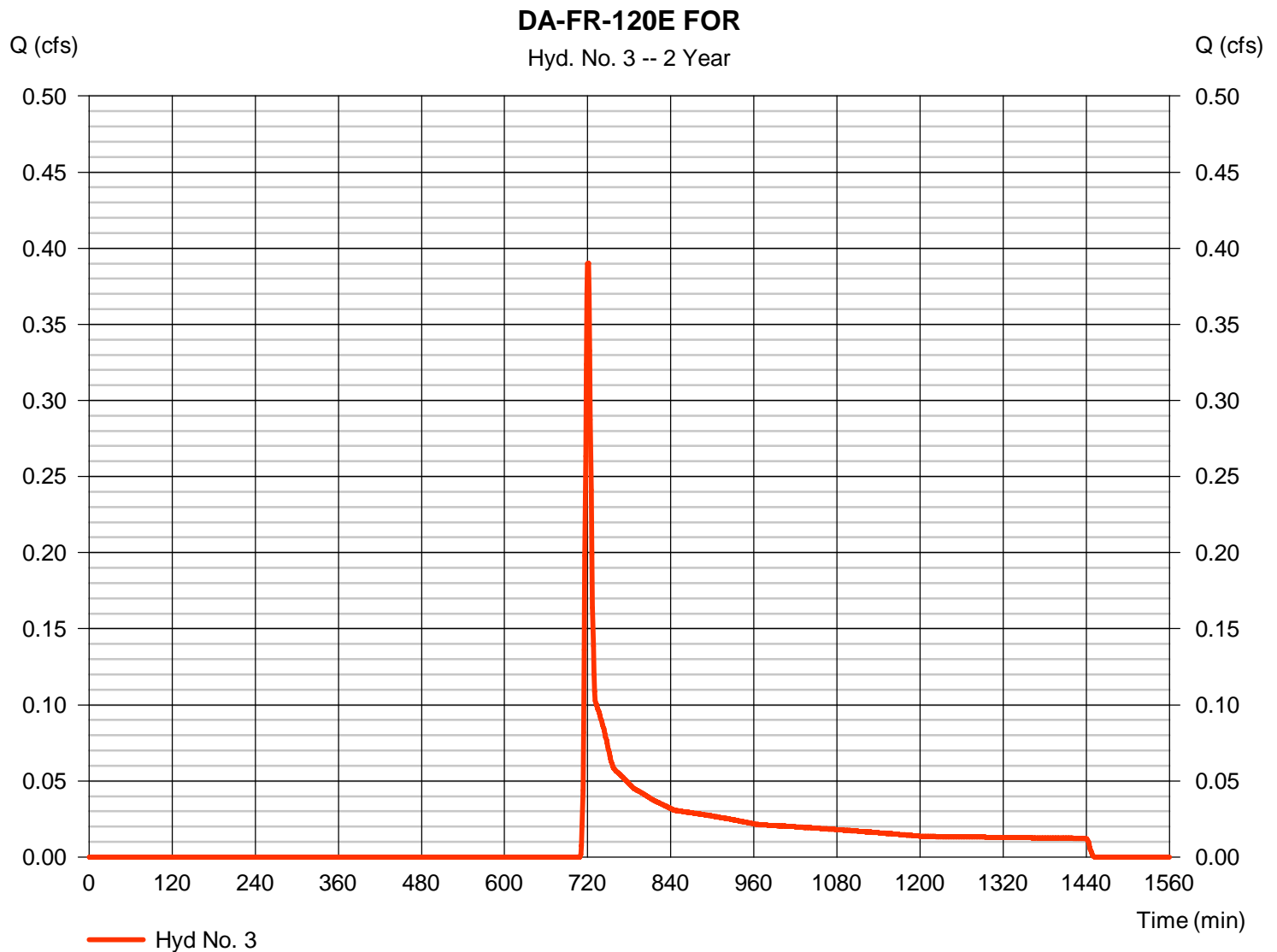
Friday, 08 / 18 / 2017

Hyd. No. 3

DA-FR-120E FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 0.840 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.390 cfs
 Time to peak = 721 min
 Hyd. volume = 1,236 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 7.80 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	2.036	1	719	4,450	-----	-----	-----	DA-FR-120E PRE
2	SCS Runoff	1.481	1	721	3,961	-----	-----	-----	DA-FR-120E DEV
3	SCS Runoff	1.799	1	719	4,009	-----	-----	-----	DA-FR-120E FOR
DA-FR-120E_Hydraflow.gpw					Return Period: 10 Year			Friday, 08 / 18 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

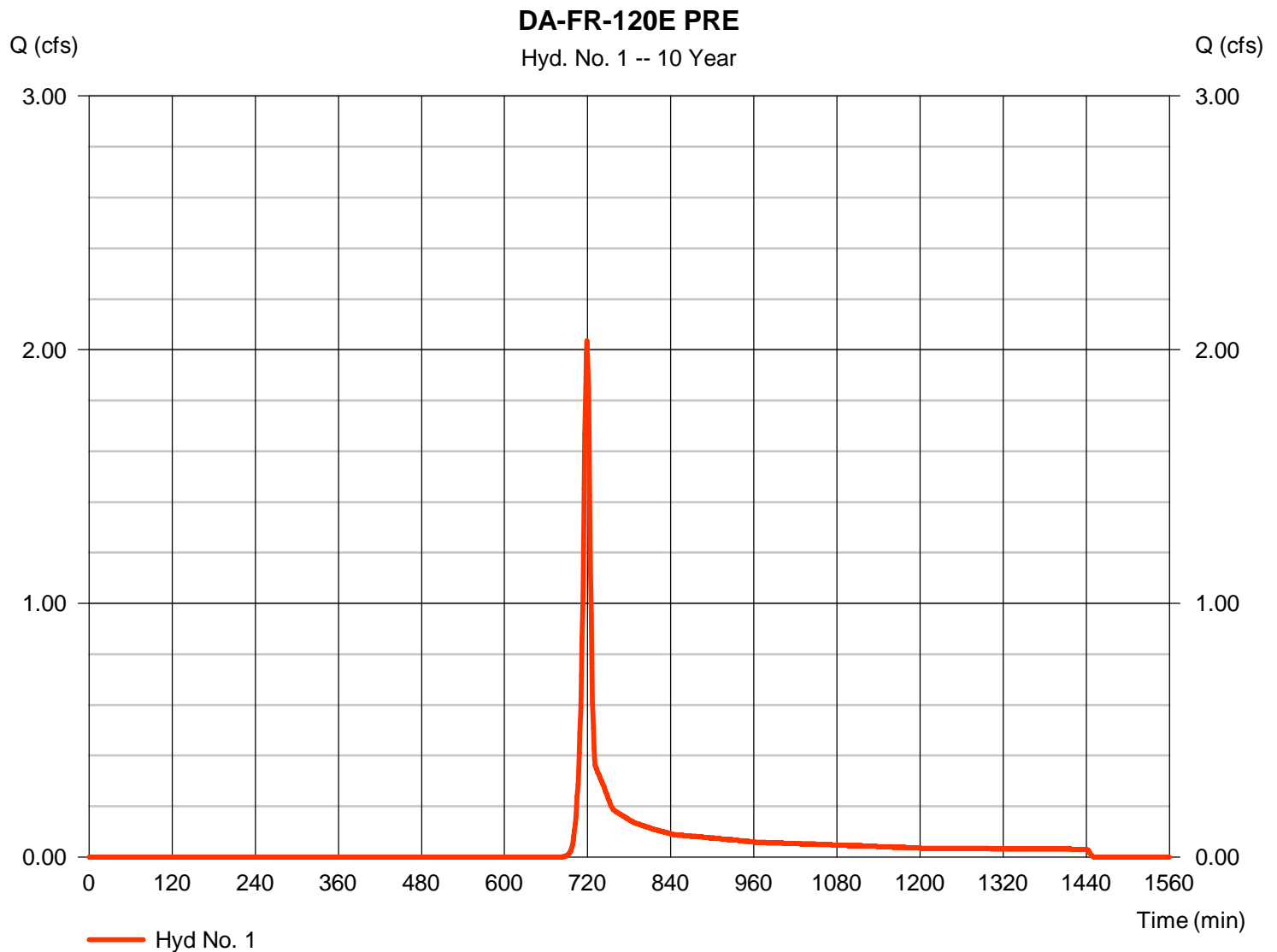
Friday, 08 / 18 / 2017

Hyd. No. 1

DA-FR-120E PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 2.036 cfs
Storm frequency	= 10 yrs	Time to peak	= 719 min
Time interval	= 1 min	Hyd. volume	= 4,450 cuft
Drainage area	= 0.840 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 7.80 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.030 \times 82) + (0.010 \times 100) + (0.800 \times 55)] / 0.840$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

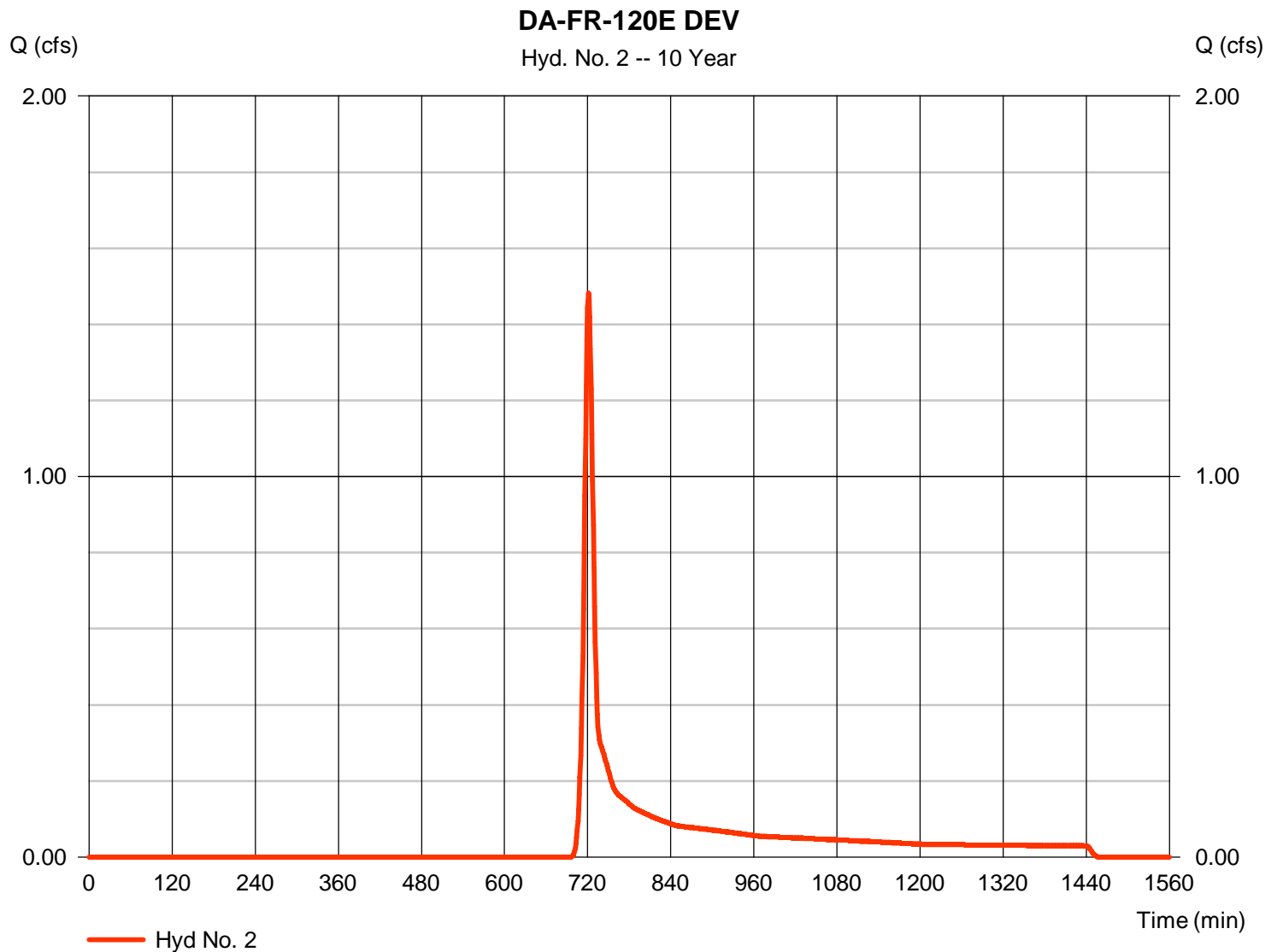
Friday, 08 / 18 / 2017

Hyd. No. 2

DA-FR-120E DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 1.481 cfs
Storm frequency	= 10 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 3,961 cuft
Drainage area	= 0.840 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.30 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.466 \times 48) + (0.030 \times 82) + (0.314 \times 58) + (0.013 \times 100) + (0.020 \times 55)] / 0.840$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

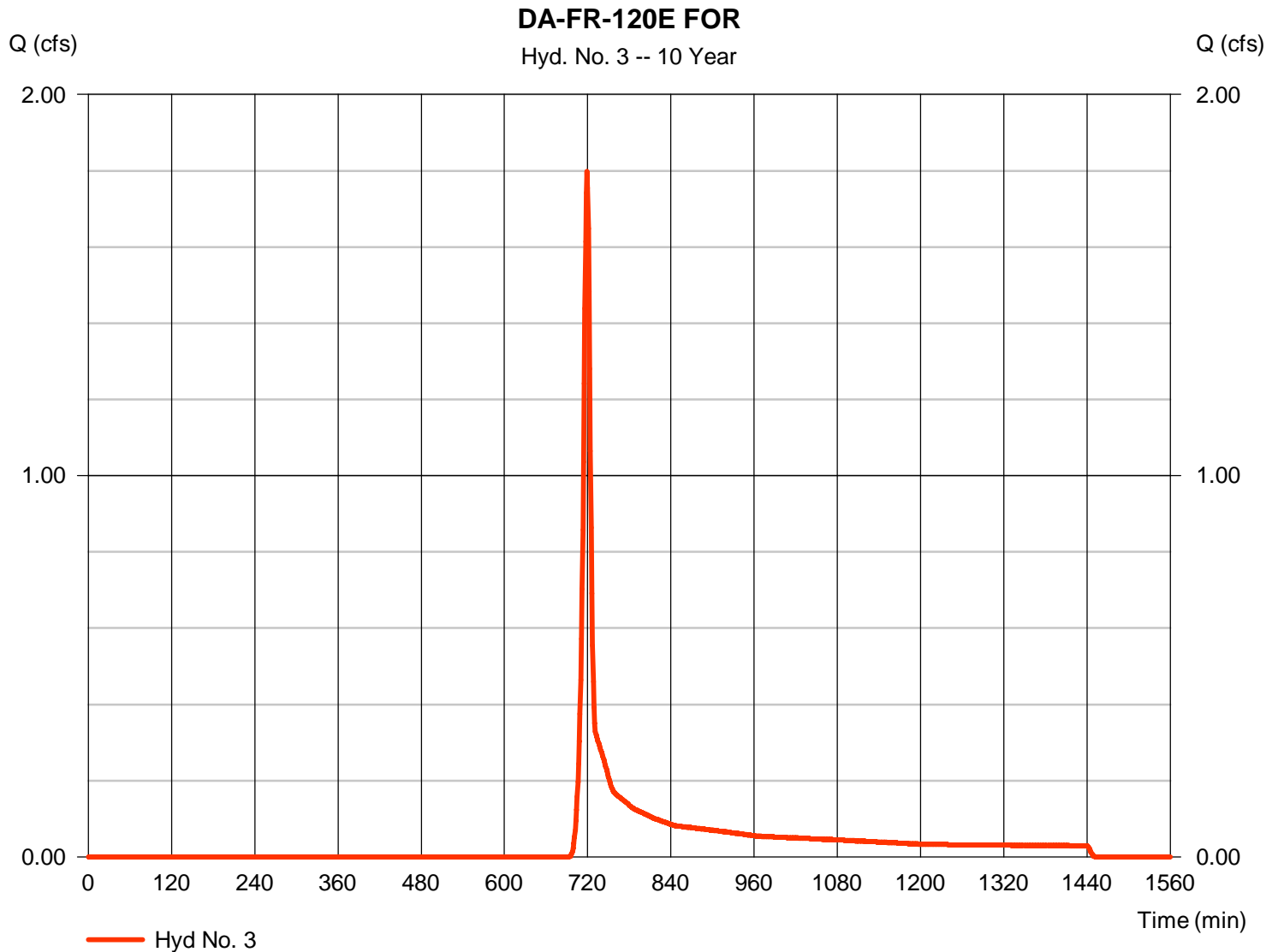
Friday, 08 / 18 / 2017

Hyd. No. 3

DA-FR-120E FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 0.840 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 1.799 cfs
 Time to peak = 719 min
 Hyd. volume = 4,009 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 7.80 min
 Distribution = Type II
 Shape factor = 484



DA-FR-120F

STORAGE VOLUME OF WATERBAR WITH SOIL COMPOST AMENDMENT AREA

Equations Used:

¹V_{gravel} storage = L*W*D_{gravel}*(40/100)

²V_{soil} storage = L*W*D_{soil}*(20/100)

³V_{surface} storage = [W*S*D²/2]+[L*S*D²/2]+[W*L*D]+[(2*S*D)/2+D]/3]

¹Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that gravel is made up of 40% voids.

²Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that soil compost amendment is made up of 20% voids.

³Equation #1 under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, but calculation also takes into account surface side slopes.

Inputs:

Depth of Gravel Layer, D _{gravel} (ft) =	0	
Depth of Soil Amendment Area, D _{soil} (ft) =	1	Refer to Table 4.3 in VA DEQ Stormwater Design Specification No. 4; Note that compost amendment may not be necessary for HSG A/B soils
Length of Waterbar Soil Amendment Area, L (ft) =	50	Assume max. length of 50' for waterbar soil amendment areas (i.e., limited to permanent ROW)
Width of Waterbar Soil Amendment Area, W (ft) =	3	
Inside Embankment Side Slopes, S (H:V) =	2	Assume 2H:1V surface side slopes for waterbars
Number of Perm. Waterbars in Drainage Area, n =	5	
Design Infiltration Rate, IR (in/hr) =	0.2	Min. rate of 0.30 in/hr for HSG A soils and 0.15-0.30 in/hr for HSG B soils (see Chap. 4, p. 4-30 in VA Stormwater Management Handbook Volume II (First Edition, 1999)
Surface Ponding Depth, D (ft) =	0.5	Assume 0.5' CFS height at the end of waterbars

Calculations:

Total Storage Depth per BMP (ft) =	1.5
Surface Storage Volume per BMP (cf) =	102
Subsurface Storage Volume per BMP (cf) =	30
Total Storage Volume per BMP (cf) =	132
Total BMP Storage Volume in Drainage Area (cf) =	661
Calculated Infiltration Period per BMP (hr) =	53

Depth (ft)	Width (ft)	Depth-Storage Data		Storage Volume in Drainage Area (cf)
		Length (ft)	Storage Volume per BMP (cf)	
0	3	50	0	0
0.5	3	50	15	75
1	3	50	30	150
1.5	5	52	132	661
2	7	54	291	1457

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	1.178	6327
Developed Condition	0.905	5666
Pre-Developed (Forest) Condition	0.771	5176

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{developed} \leq IF \times [(Q_{pre-developed} \times RV_{pre-developed}) / RV_{developed}]$ ----->	0.905	≤	1.052
			OK	
Check #2:	$Q_{developed} \leq Q_{pre-developed}$ ----->	0.905	≤	1.178
			OK	
Check #3:	$Q_{developed}$ <u>shall not</u> be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ ---->	0.905	<u>shall not</u> be required to be ≤	0.704

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s n value of 0.011 was used.</p> <p><i>Sources:</i></p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

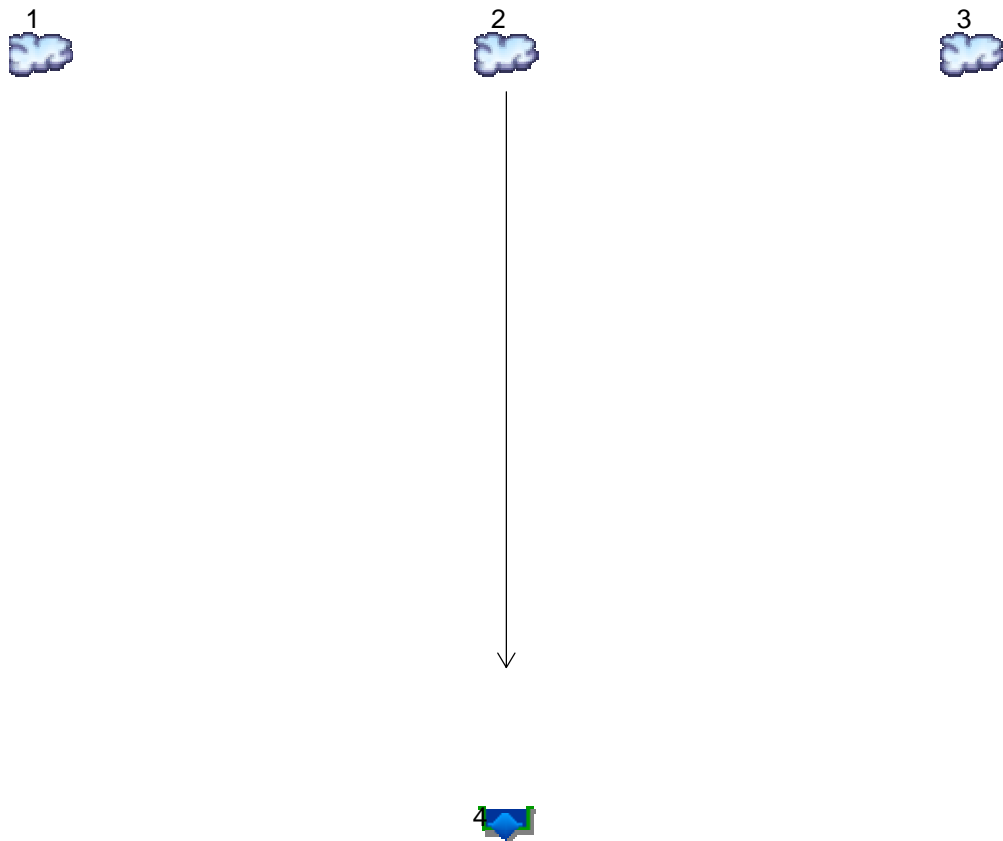
Table 2 – Manning's *n* Values for Open Channel Flow

Channel Type	Manning <i>n</i>		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's <i>n</i> value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's <i>n</i> value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

Hyd.	Origin	Description
1	SCS Runoff	DA-FR-120F PRE
2	SCS Runoff	DA-FR-120F DEV
3	SCS Runoff	DA-FR-120F FOR
4	Reservoir	WB Soil Amendments

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	1.178	1	727	6,327	-----	-----	-----	DA-FR-120F PRE
2	SCS Runoff	1.178	1	727	6,327	-----	-----	-----	DA-FR-120F DEV
3	SCS Runoff	0.771	1	727	5,176	-----	-----	-----	DA-FR-120F FOR
4	Reservoir	0.905	1	734	5,666	2	101.59	803	WB Soil Amendments
DA-FR-120F_Hydraflow.gpw					Return Period: 1 Year			Wednesday, 08 / 30 / 2017	

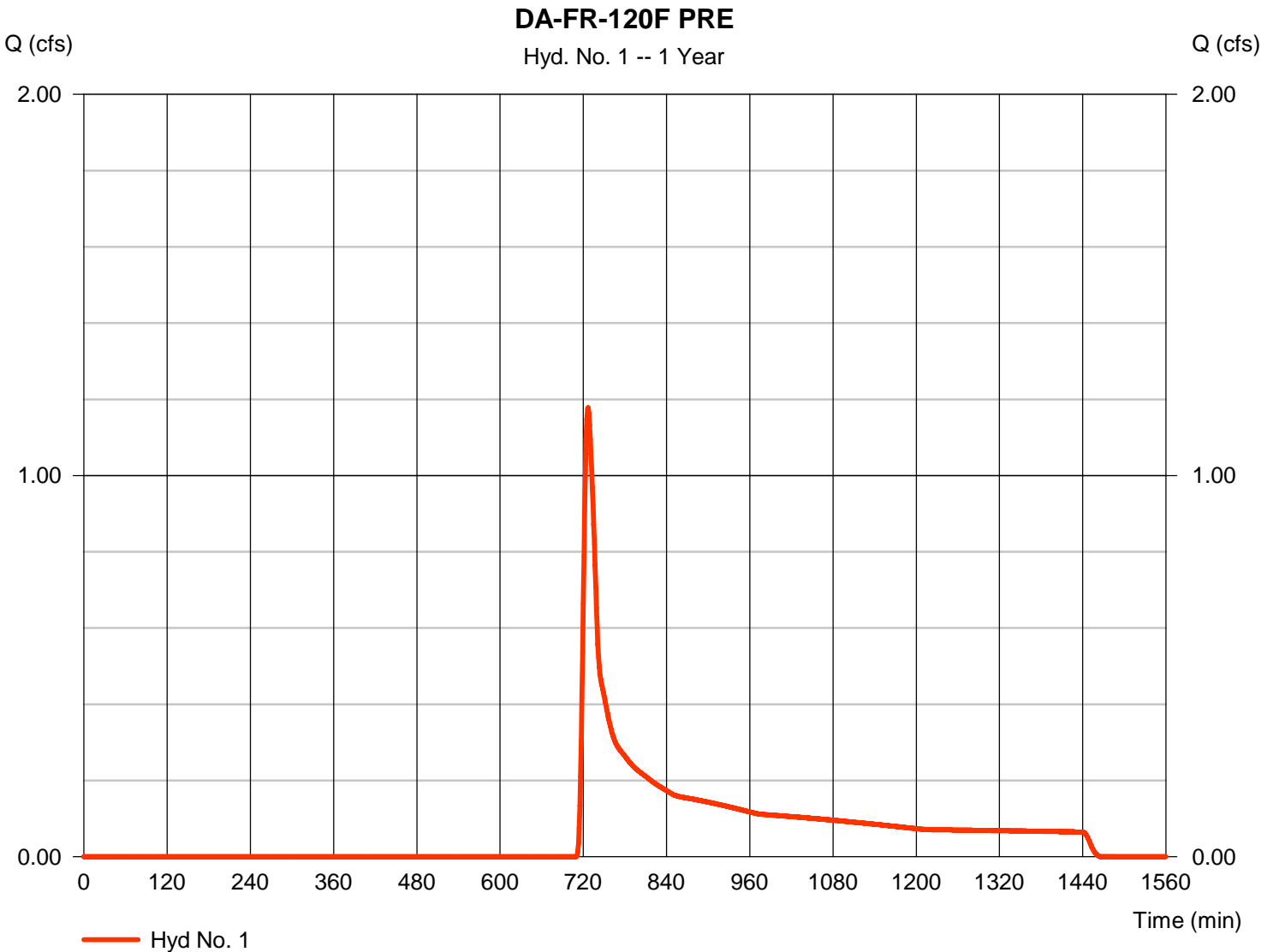
Hydrograph Report

Hyd. No. 1

DA-FR-120F PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 1.178 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 6,327 cuft
Drainage area	= 5.010 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.040 x 65) + (0.001 x 98) + (3.466 x 58) + (0.014 x 100) + (1.494 x 55)] / 5.010



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-120F PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 4.91	0.00	0.00	
Travel Time (min)	= 13.94	+ 0.00	+ 0.00	= 13.94
Shallow Concentrated Flow				
Flow length (ft)	= 611.45	0.00	0.00	
Watercourse slope (%)	= 10.13	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=5.14	0.00	0.00	
Travel Time (min)	= 1.98	+ 0.00	+ 0.00	= 1.98
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				15.90 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

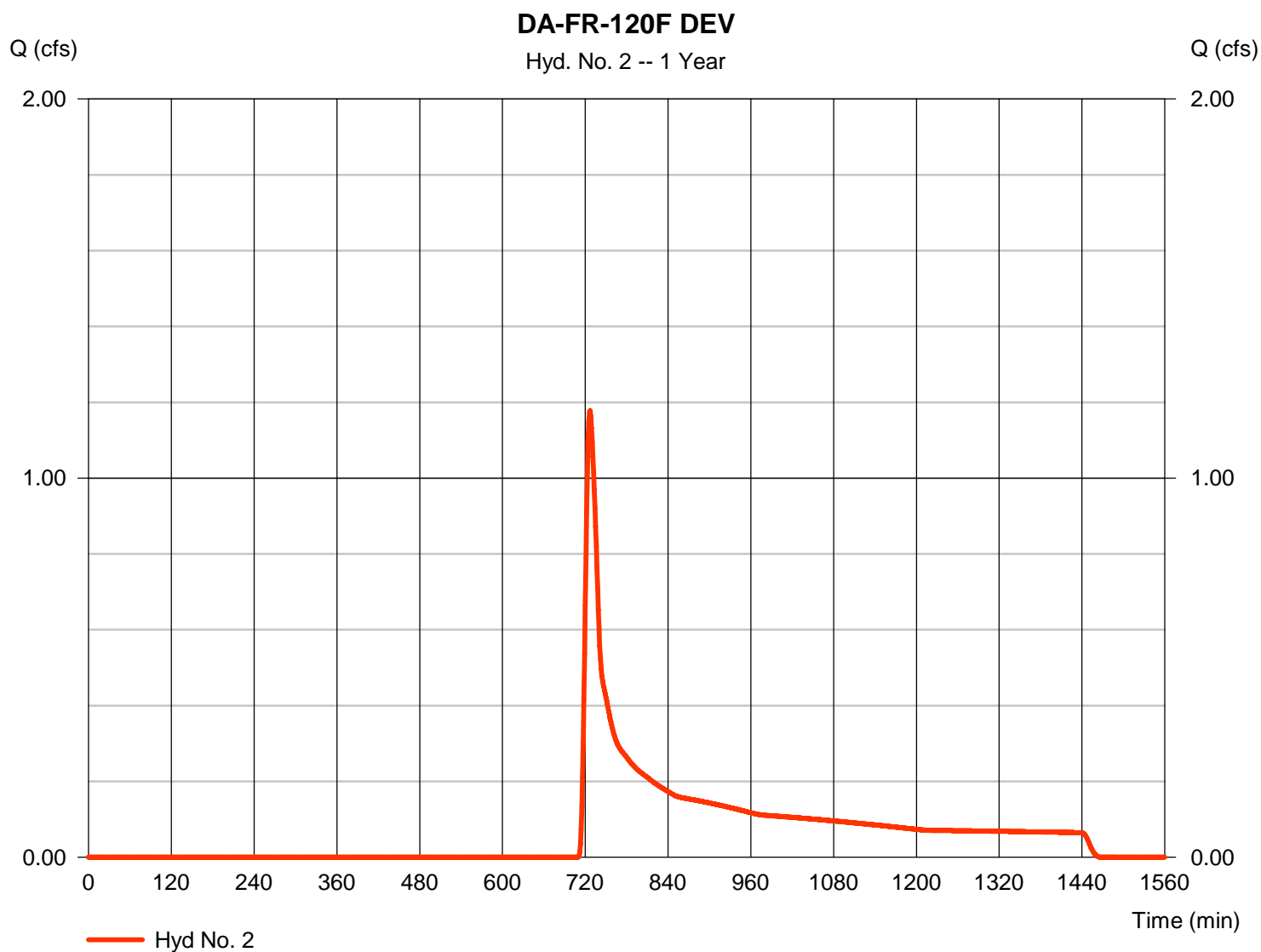
Wednesday, 08 / 30 / 2017

Hyd. No. 2

DA-FR-120F DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 1.178 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 6,327 cuft
Drainage area	= 5.010 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.900 \times 48) + (0.040 \times 82) + (0.001 \times 98) + (4.045 \times 58) + (0.014 \times 100) + (0.014 \times 55)] / 5.010$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-120F DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 4.91	0.00	0.00				
Travel Time (min)	= 13.94	+	0.00	+	0.00	=	13.94
Shallow Concentrated Flow							
Flow length (ft)	= 36.93	549.32	0.00				
Watercourse slope (%)	= 5.85	10.60	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=3.90	5.25	0.00				
Travel Time (min)	= 0.16	+	1.74	+	0.00	=	1.90
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	((0))28.7	0.0	0.0				
Travel Time (min)	= 0.10	+	0.00	+	0.00	=	0.10
Total Travel Time, Tc					15.90 min		

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

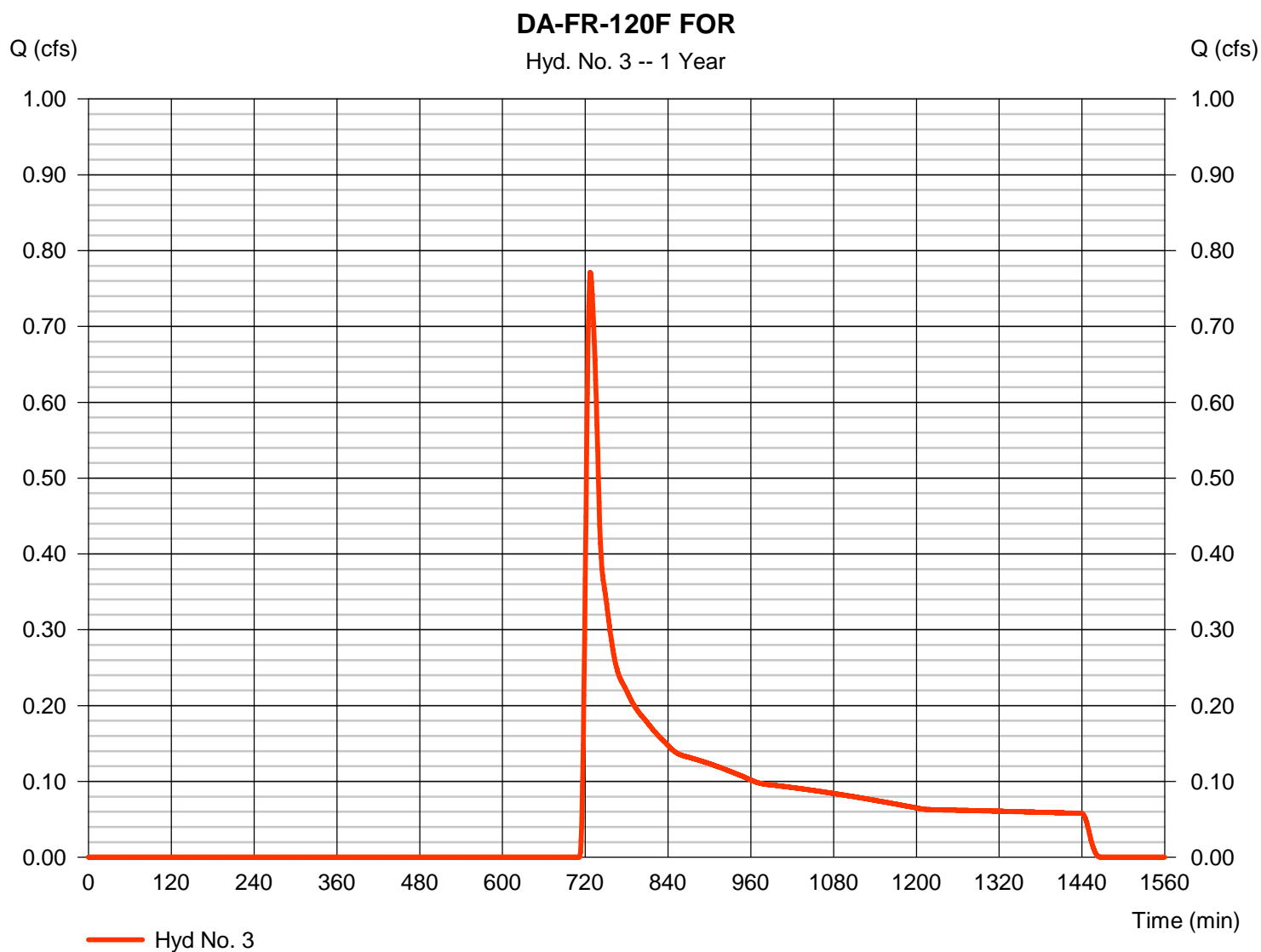
Wednesday, 08 / 30 / 2017

Hyd. No. 3

DA-FR-120F FOR

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 5.010 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.30 in
 Storm duration = 24 hrs

Peak discharge = 0.771 cfs
 Time to peak = 727 min
 Hyd. volume = 5,176 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.90 min
 Distribution = Type II
 Shape factor = 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-120F FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 4.91	0.00	0.00				
Travel Time (min)	= 13.94	+	0.00	+	0.00	=	13.94
Shallow Concentrated Flow							
Flow length (ft)	= 611.45	0.00	0.00				
Watercourse slope (%)	= 10.13	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.14	0.00	0.00				
Travel Time (min)	= 1.98	+	0.00	+	0.00	=	1.98
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				15.90 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

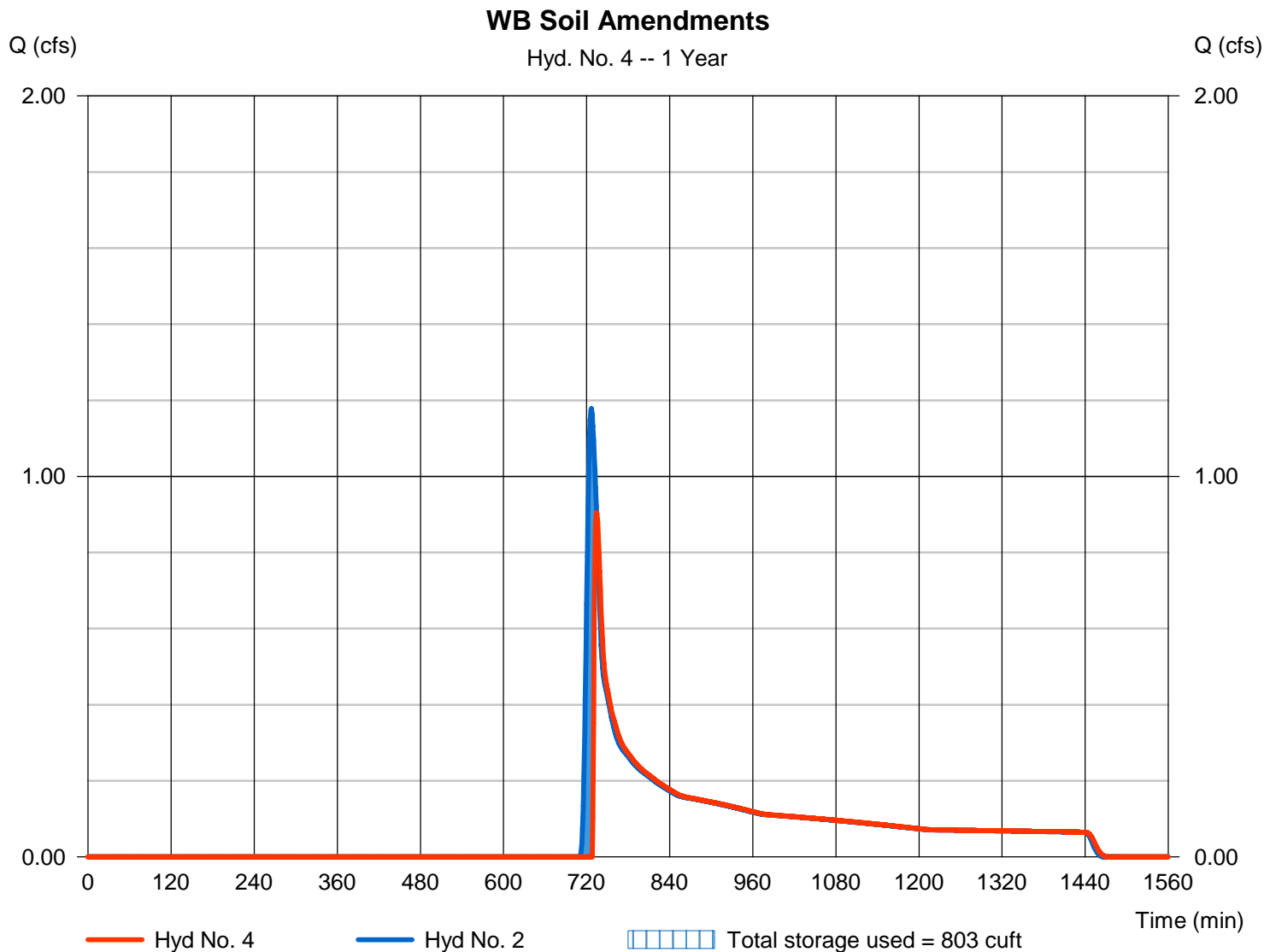
Wednesday, 08 / 30 / 2017

Hyd. No. 4

WB Soil Amendments

Hydrograph type	= Reservoir	Peak discharge	= 0.905 cfs
Storm frequency	= 1 yrs	Time to peak	= 734 min
Time interval	= 1 min	Hyd. volume	= 5,666 cuft
Inflow hyd. No.	= 2 - DA-FR-120F DEV	Max. Elevation	= 101.59 ft
Reservoir name	= Waterbar Soil Amendments	Max. Storage	= 803 cuft

Storage Indication method used.



Pond Report

11

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 08 / 30 / 2017

Pond No. 1 - Waterbar Soil Amendments

Pond Data

Pond storage is based on user-defined values.

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	100.00	n/a	0	0
0.50	100.50	n/a	75	75
1.00	101.00	n/a	75	150
1.50	101.50	n/a	511	661
2.00	102.00	n/a	796	1,457

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)	= 10.00	0.00	0.00	0.00
Crest El. (ft)	= 101.50	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= Rect	---	---	---
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	100.00	---	---	---	---	0.00	---	---	---	---	---	0.000
0.05	8	100.05	---	---	---	---	0.00	---	---	---	---	---	0.000
0.10	15	100.10	---	---	---	---	0.00	---	---	---	---	---	0.000
0.15	23	100.15	---	---	---	---	0.00	---	---	---	---	---	0.000
0.20	30	100.20	---	---	---	---	0.00	---	---	---	---	---	0.000
0.25	38	100.25	---	---	---	---	0.00	---	---	---	---	---	0.000
0.30	45	100.30	---	---	---	---	0.00	---	---	---	---	---	0.000
0.35	53	100.35	---	---	---	---	0.00	---	---	---	---	---	0.000
0.40	60	100.40	---	---	---	---	0.00	---	---	---	---	---	0.000
0.45	68	100.45	---	---	---	---	0.00	---	---	---	---	---	0.000
0.50	75	100.50	---	---	---	---	0.00	---	---	---	---	---	0.000
0.55	83	100.55	---	---	---	---	0.00	---	---	---	---	---	0.000
0.60	90	100.60	---	---	---	---	0.00	---	---	---	---	---	0.000
0.65	98	100.65	---	---	---	---	0.00	---	---	---	---	---	0.000
0.70	105	100.70	---	---	---	---	0.00	---	---	---	---	---	0.000
0.75	113	100.75	---	---	---	---	0.00	---	---	---	---	---	0.000
0.80	120	100.80	---	---	---	---	0.00	---	---	---	---	---	0.000
0.85	128	100.85	---	---	---	---	0.00	---	---	---	---	---	0.000
0.90	135	100.90	---	---	---	---	0.00	---	---	---	---	---	0.000
0.95	143	100.95	---	---	---	---	0.00	---	---	---	---	---	0.000
1.00	150	101.00	---	---	---	---	0.00	---	---	---	---	---	0.000
1.05	201	101.05	---	---	---	---	0.00	---	---	---	---	---	0.000
1.10	252	101.10	---	---	---	---	0.00	---	---	---	---	---	0.000
1.15	303	101.15	---	---	---	---	0.00	---	---	---	---	---	0.000
1.20	354	101.20	---	---	---	---	0.00	---	---	---	---	---	0.000
1.25	406	101.25	---	---	---	---	0.00	---	---	---	---	---	0.000
1.30	457	101.30	---	---	---	---	0.00	---	---	---	---	---	0.000
1.35	508	101.35	---	---	---	---	0.00	---	---	---	---	---	0.000
1.40	559	101.40	---	---	---	---	0.00	---	---	---	---	---	0.000
1.45	610	101.45	---	---	---	---	0.00	---	---	---	---	---	0.000
1.50	661	101.50	---	---	---	---	0.00	---	---	---	---	---	0.000
1.55	741	101.55	---	---	---	---	0.37	---	---	---	---	---	0.372
1.60	820	101.60	---	---	---	---	1.05	---	---	---	---	---	1.053
1.65	900	101.65	---	---	---	---	1.93	---	---	---	---	---	1.935
1.70	979	101.70	---	---	---	---	2.98	---	---	---	---	---	2.979
1.75	1,059	101.75	---	---	---	---	4.16	---	---	---	---	---	4.163
1.80	1,139	101.80	---	---	---	---	5.47	---	---	---	---	---	5.472
1.85	1,218	101.85	---	---	---	---	6.90	---	---	---	---	---	6.896
1.90	1,298	101.90	---	---	---	---	8.43	---	---	---	---	---	8.425

Continues on next page...

Waterbar Soil Amendments

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
1.95	1,377	101.95	---	---	---	---	10.05	---	---	---	---	---	10.05
2.00	1,457	102.00	---	---	---	---	11.77	---	---	---	---	---	11.77

...End

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	2.095	1	726	9,080	-----	-----	-----	DA-FR-120F PRE
2	SCS Runoff	2.095	1	726	9,080	-----	-----	-----	DA-FR-120F DEV
3	SCS Runoff	1.531	1	726	7,652	-----	-----	-----	DA-FR-120F FOR
4	Reservoir	1.950	1	729	8,419	2	101.65	901	WB Soil Amendments
DA-FR-120F_Hydraflow.gpw					Return Period: 2 Year			Wednesday, 08 / 30 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

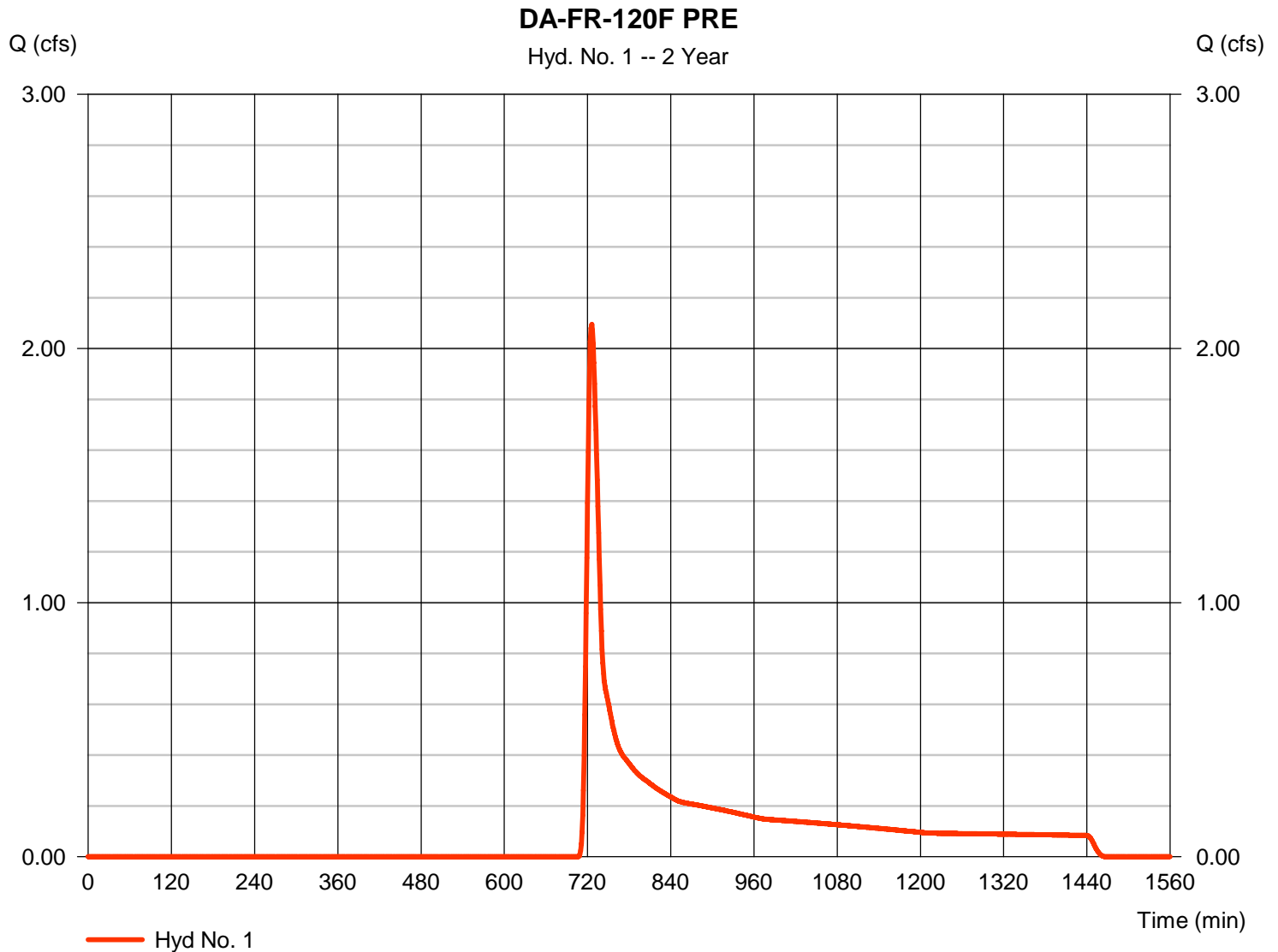
Wednesday, 08 / 30 / 2017

Hyd. No. 1

DA-FR-120F PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 2.095 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 9,080 cuft
Drainage area	= 5.010 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.040 x 65) + (0.001 x 98) + (3.466 x 58) + (0.014 x 100) + (1.494 x 55)] / 5.010



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

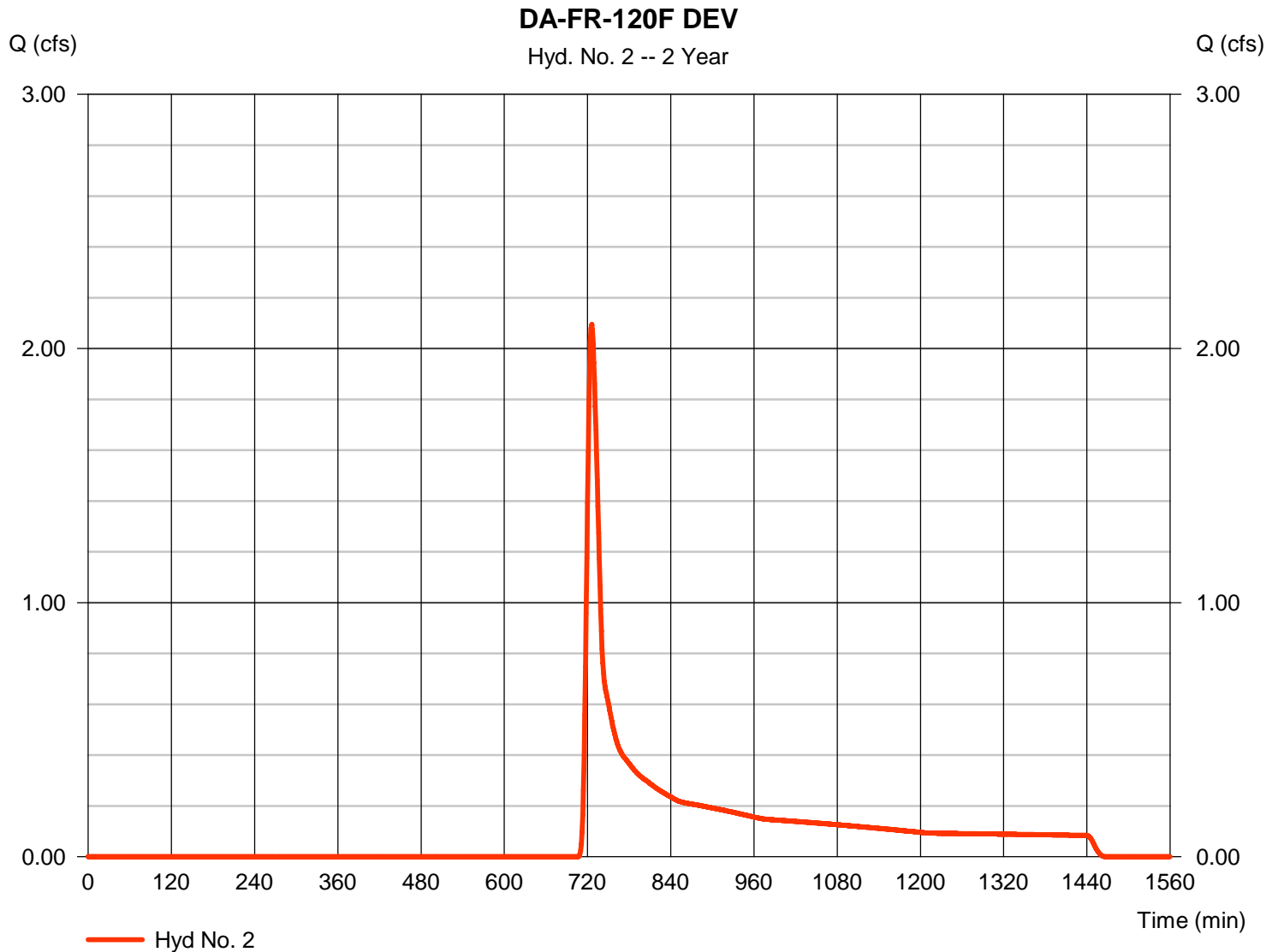
Wednesday, 08 / 30 / 2017

Hyd. No. 2

DA-FR-120F DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 2.095 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 9,080 cuft
Drainage area	= 5.010 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.900 \times 48) + (0.040 \times 82) + (0.001 \times 98) + (4.045 \times 58) + (0.014 \times 100) + (0.014 \times 55)] / 5.010$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

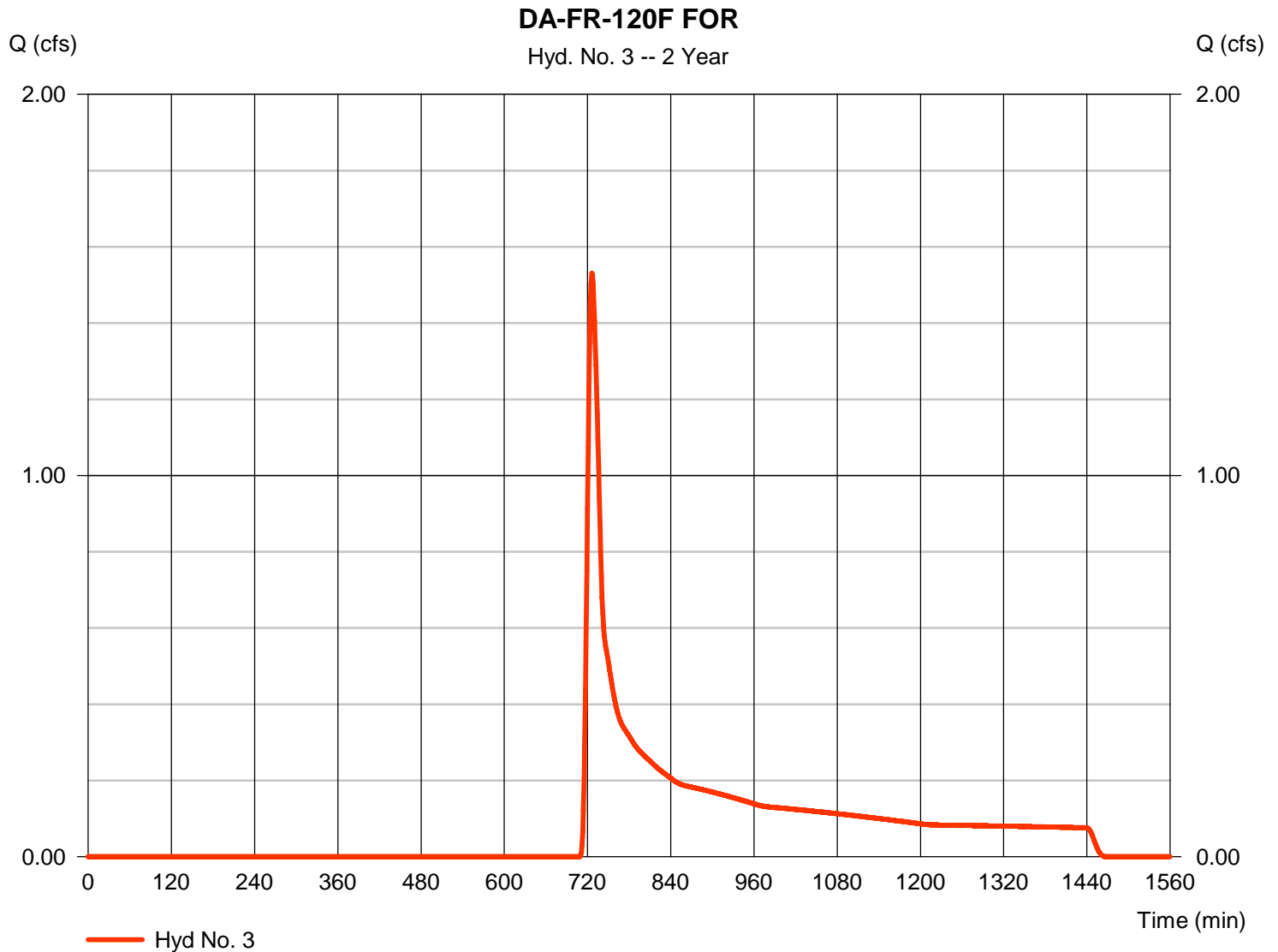
Wednesday, 08 / 30 / 2017

Hyd. No. 3

DA-FR-120F FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 5.010 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 1.531 cfs
 Time to peak = 726 min
 Hyd. volume = 7,652 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.90 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

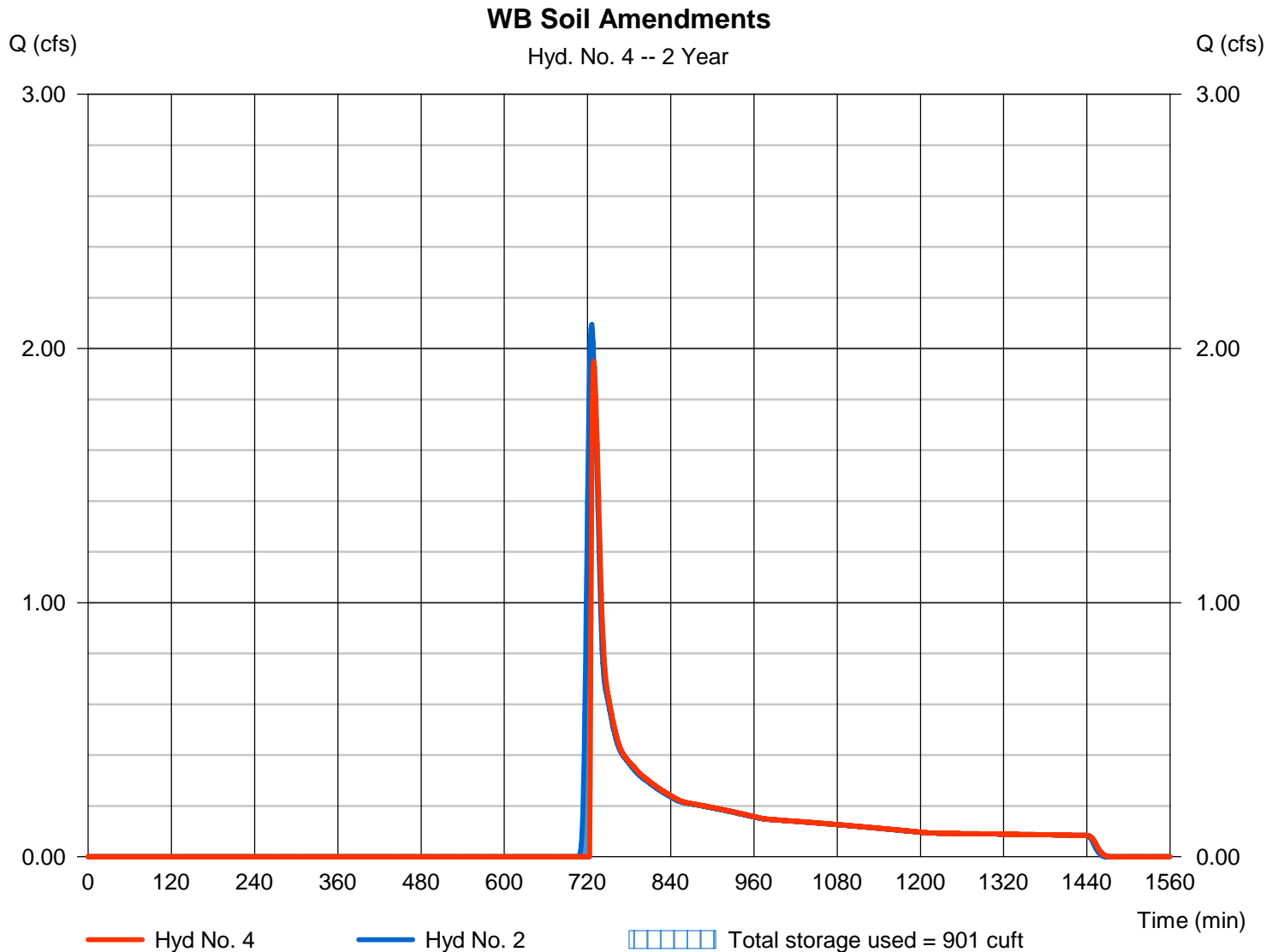
Wednesday, 08 / 30 / 2017

Hyd. No. 4

WB Soil Amendments

Hydrograph type	= Reservoir	Peak discharge	= 1.950 cfs
Storm frequency	= 2 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 8,419 cuft
Inflow hyd. No.	= 2 - DA-FR-120F DEV	Max. Elevation	= 101.65 ft
Reservoir name	= Waterbar Soil Amendments	Max. Storage	= 901 cuft

Storage Indication method used.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	8.865	1	724	27,564	-----	-----	-----	DA-FR-120F PRE
2	SCS Runoff	8.865	1	724	27,564	-----	-----	-----	DA-FR-120F DEV
3	SCS Runoff	7.742	1	724	24,831	-----	-----	-----	DA-FR-120F FOR
4	Reservoir	8.803	1	725	26,902	2	101.91	1,316	WB Soil Amendments
DA-FR-120F_Hydraflow.gpw					Return Period: 10 Year			Wednesday, 08 / 30 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

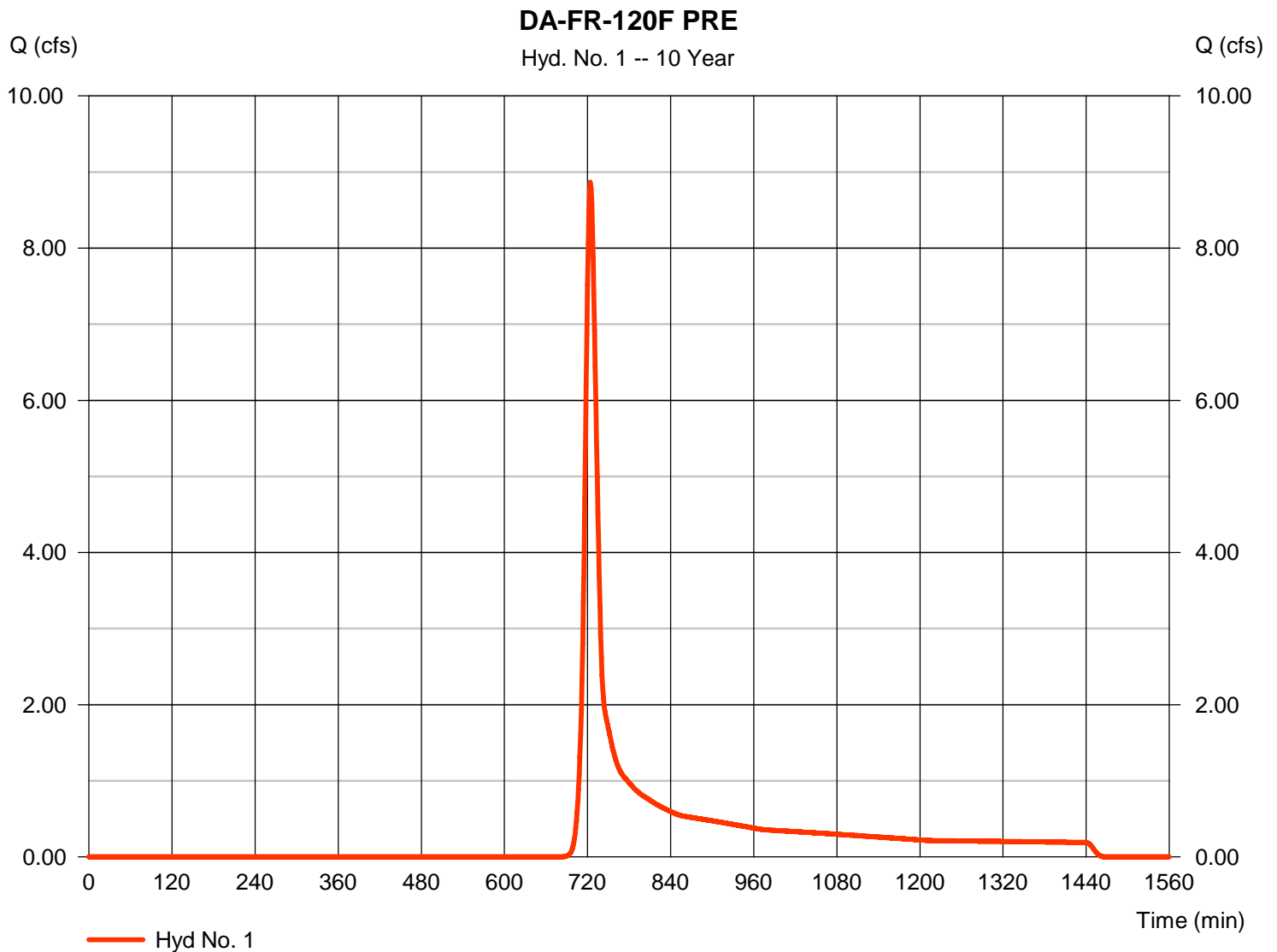
Wednesday, 08 / 30 / 2017

Hyd. No. 1

DA-FR-120F PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 8.865 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 27,564 cuft
Drainage area	= 5.010 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.040 \times 65) + (0.001 \times 98) + (3.466 \times 58) + (0.014 \times 100) + (1.494 \times 55)] / 5.010$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

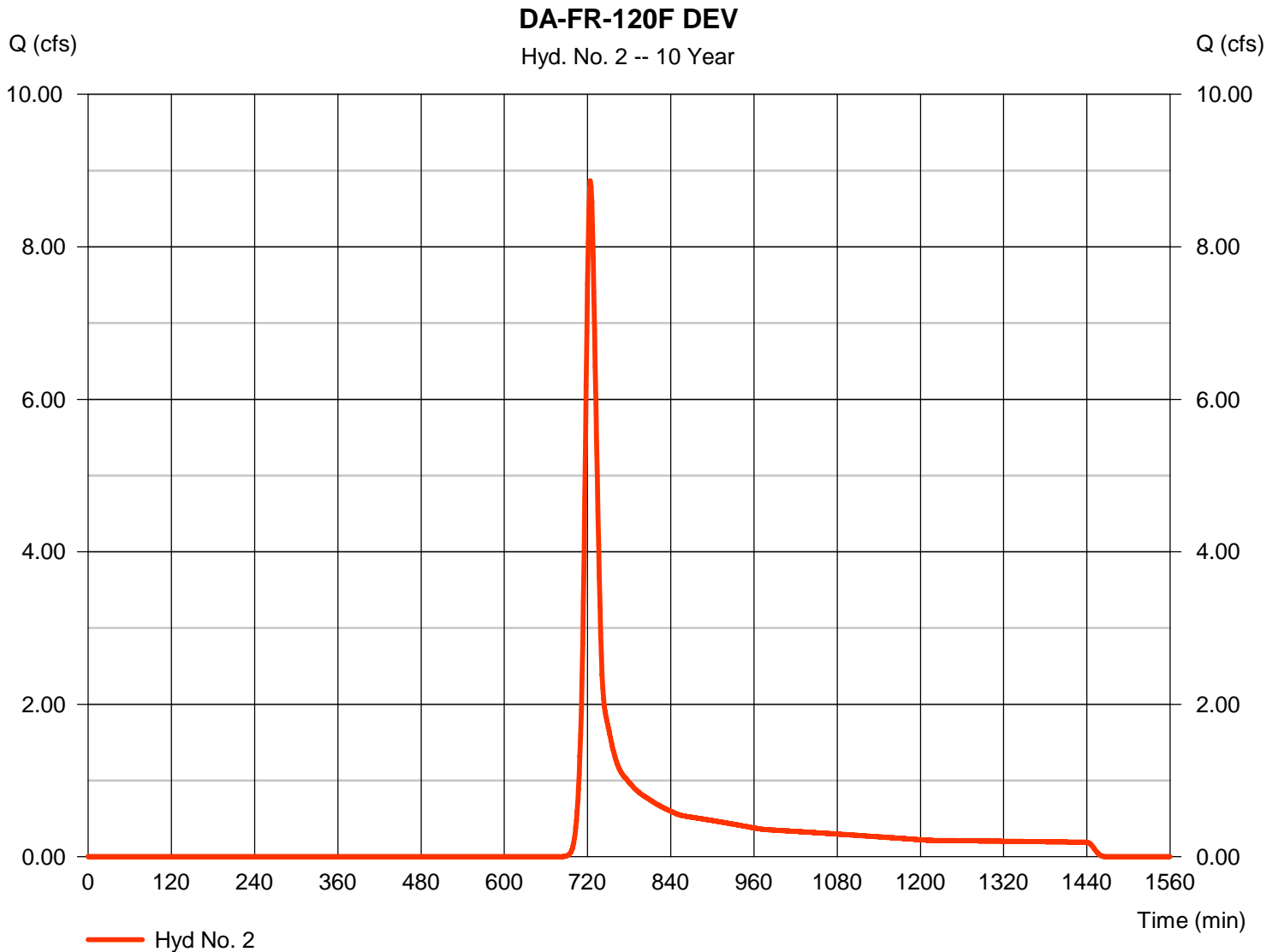
Wednesday, 08 / 30 / 2017

Hyd. No. 2

DA-FR-120F DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 8.865 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 27,564 cuft
Drainage area	= 5.010 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.900 \times 48) + (0.040 \times 82) + (0.001 \times 98) + (4.045 \times 58) + (0.014 \times 100) + (0.014 \times 55)] / 5.010$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

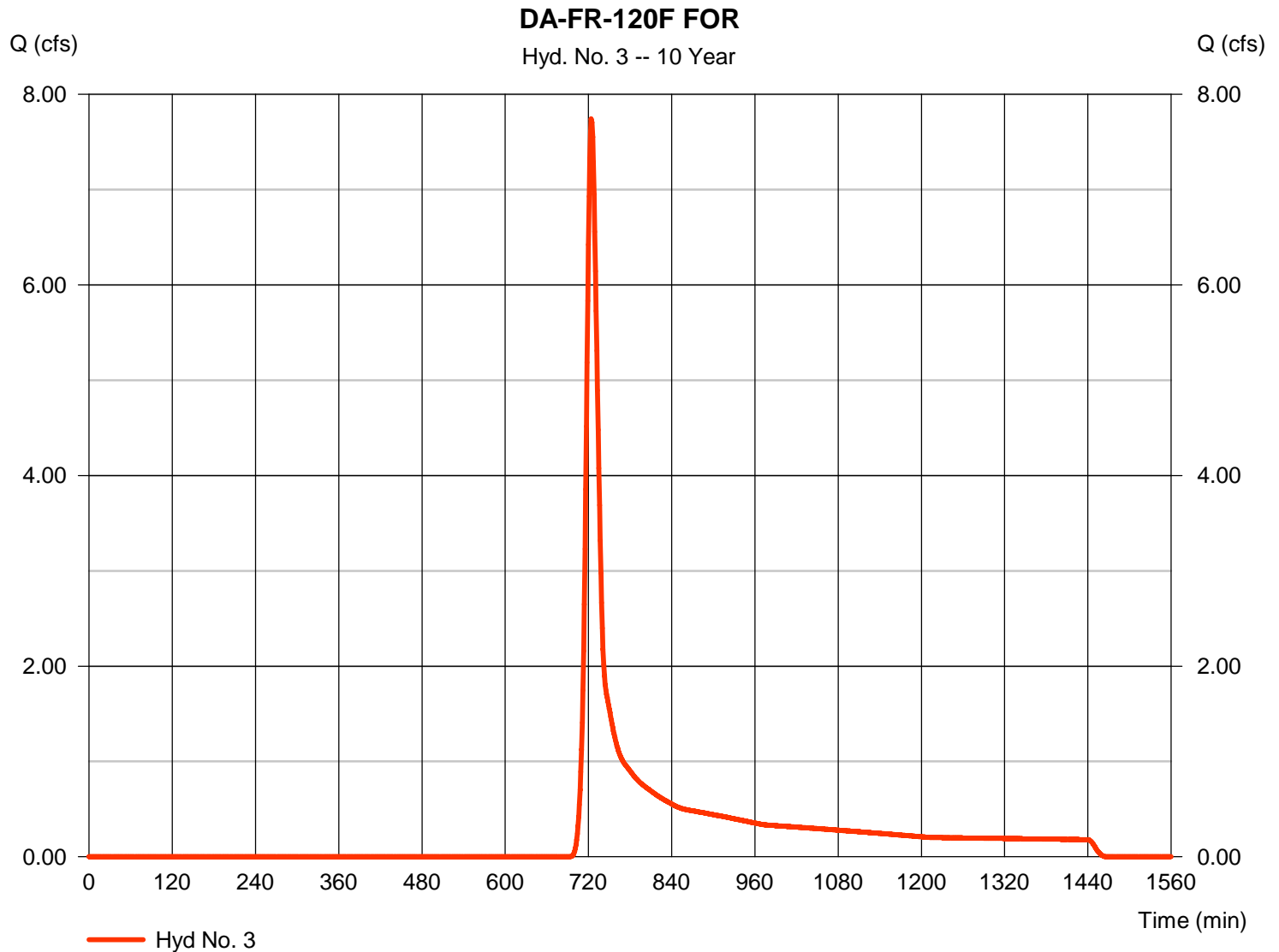
Wednesday, 08 / 30 / 2017

Hyd. No. 3

DA-FR-120F FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 5.010 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 7.742 cfs
 Time to peak = 724 min
 Hyd. volume = 24,831 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.90 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

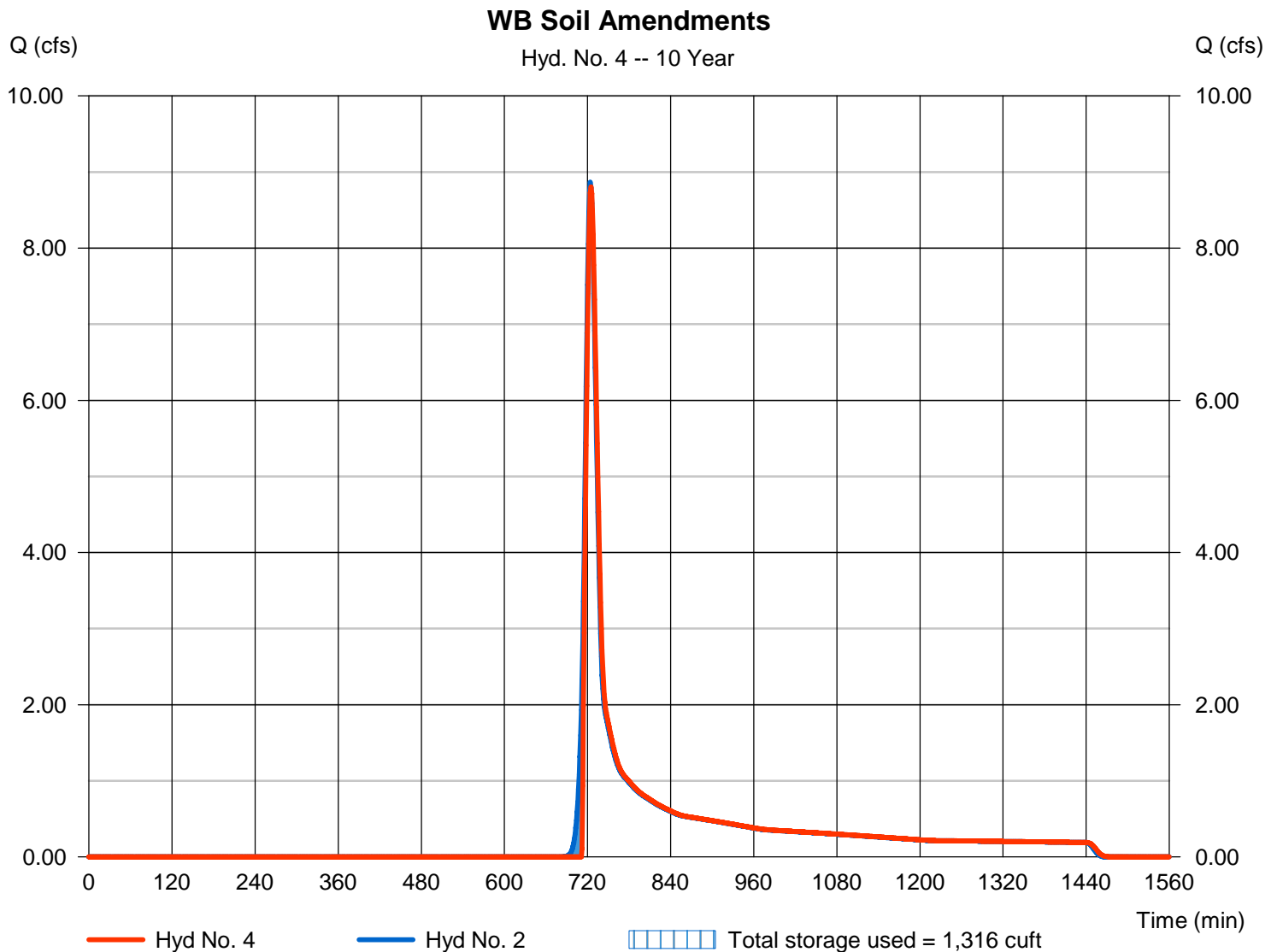
Wednesday, 08 / 30 / 2017

Hyd. No. 4

WB Soil Amendments

Hydrograph type	= Reservoir	Peak discharge	= 8.803 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 26,902 cuft
Inflow hyd. No.	= 2 - DA-FR-120F DEV	Max. Elevation	= 101.91 ft
Reservoir name	= Waterbar Soil Amendments	Max. Storage	= 1,316 cuft

Storage Indication method used.



DA-FR-121

DA-FR-121 is located in a meadow and forested areas with rolling slopes and contains agricultural land, existing dirt road and gravel road. No new impervious area is proposed within DA-FR-121. The total phosphorus load reduction required for DA-FR-121 is -0.28 lb/yr. Multiple points of analysis were evaluated within DA-FR-121 to evaluate the effects on each receiving stream/channel following construction. Specifically, DA-FR-121 was sub-divided into three sub-drainage areas (sub areas A through C).

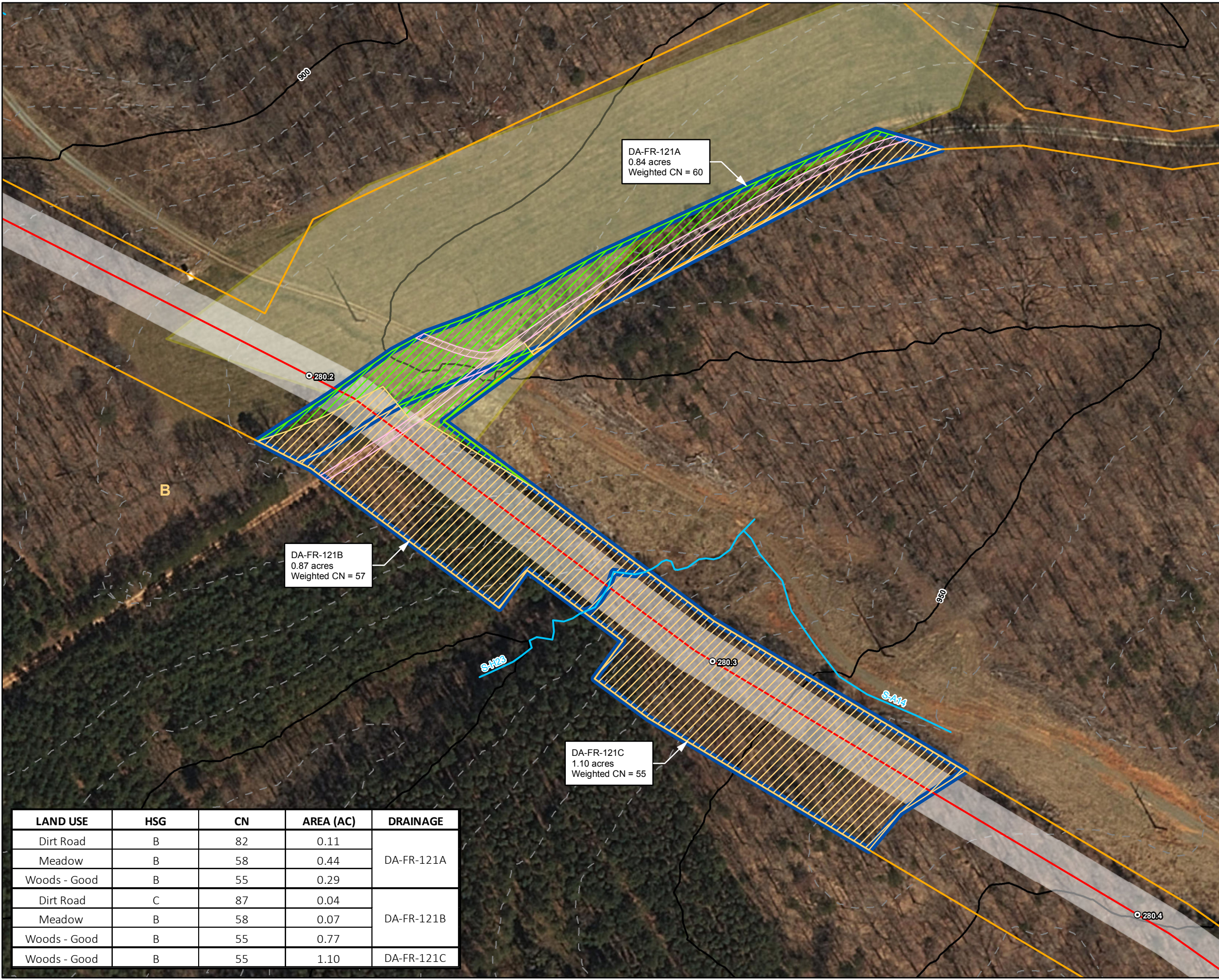
Sub-areas 121A and 121B contain both agricultural and non-agricultural areas within the limits of disturbance (LOD). Pre-construction agricultural areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction. In non-agricultural areas, land use will be restored following construction as noted in the Stormwater Management (SWM) Narrative and the Annual Standards and Specifications. Agricultural areas within the LOD are included in the SWM quality analysis and the total permanent Right of Way (ROW) is analyzed via VRRM; in these calculations agricultural areas are considered "Forest/Open Space".

Stormwater quantity is met via the energy balance method for each of the three sub-areas DA-FR-121A, DA-FR-121B and DA-FR-121C. Agricultural areas within the study area are included in the SWM analysis, but an Improvement Factor (IF) of 1.0 is used when applying the Energy Balance Method. This improvement factor is used to account for the exemption of agricultural areas (§ 62.1-44.15:34 and 9VAC25-870-300) since such areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction.

In addition, the Hydraflow Hydrograph's 10-year 24-hour peak discharge results indicate a reduction in flows ranging from 0.36 to 0.81 cfs for all drainage areas (as seen in table below).

Sub Area	Pre Peak Flow, 10-yr Q (cfs)	Post Peak Flow, Q 10-yr (cfs)	Flow differential
DA-FR-121A	2.56	2.16	-0.40
DA-FR-121B	2.00	1.64	-0.36
DA-FR-121C	1.70	0.89	-0.81

Figures and calculations for each of the sub-areas for DA-FR-121 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.



LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Dirt Road	B	82	0.11	DA-FR-121A
Meadow	B	58	0.44	
Woods - Good	B	55	0.29	
Dirt Road	C	87	0.04	DA-FR-121B
Meadow	B	58	0.07	
Woods - Good	B	55	0.77	
Woods - Good	B	55	1.10	DA-FR-121C

Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Dirt Road
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:1,200

100 50 0 100 Feet

N


W

E

S

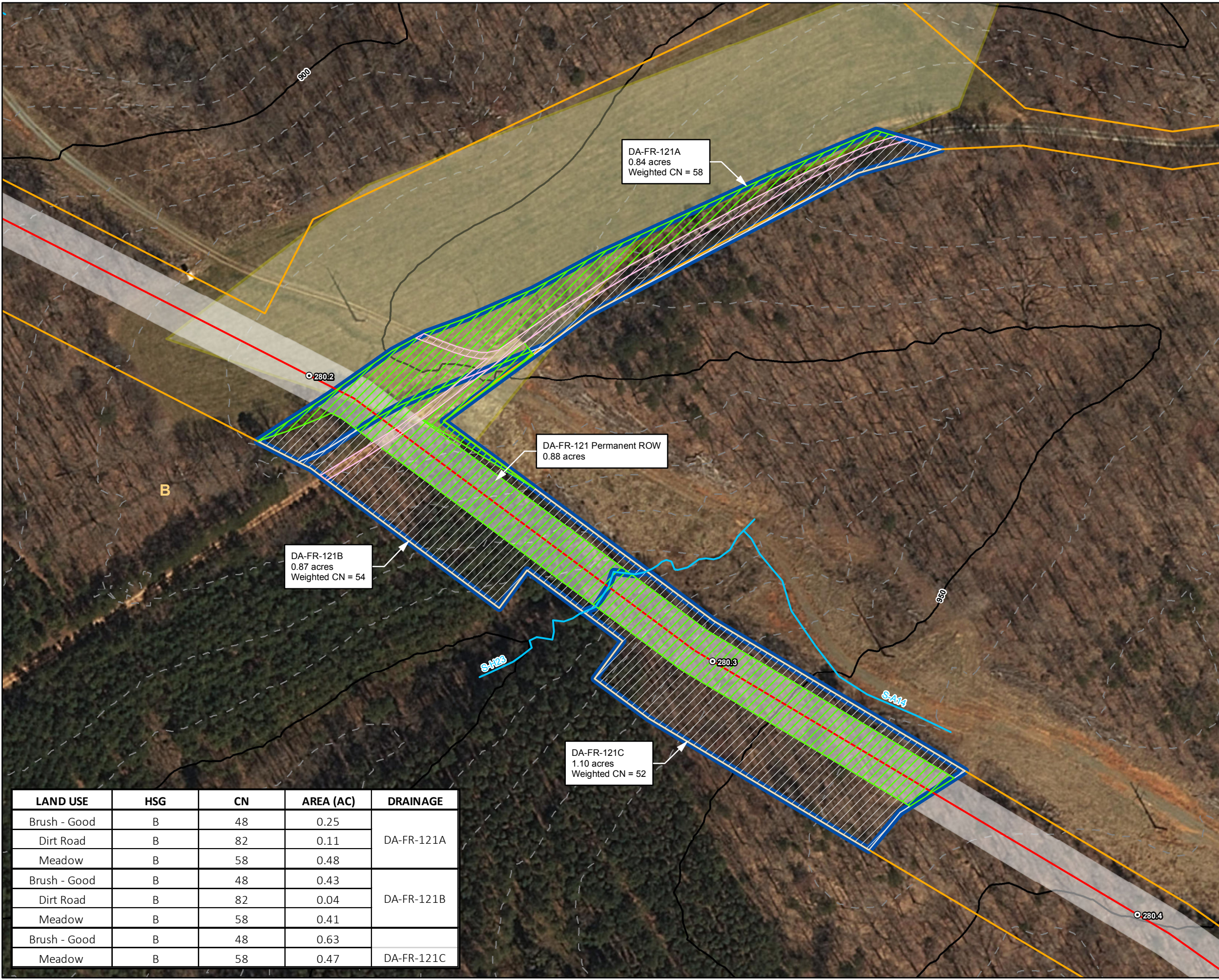


Mountain Valley Pipeline Project

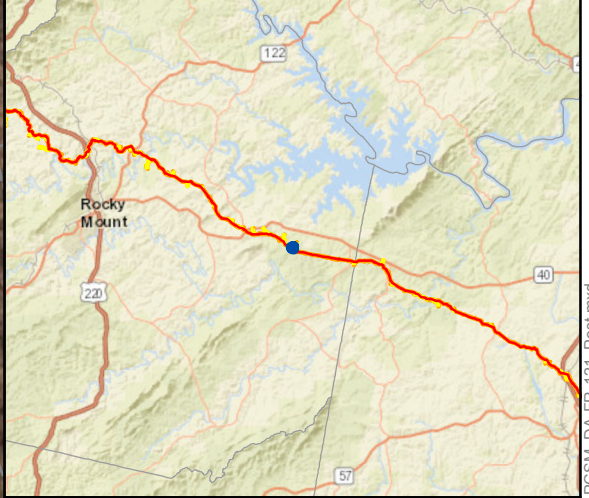
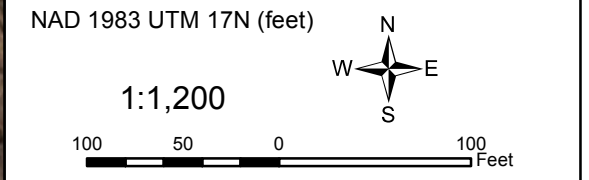


Pre-Construction Drainage Area Map
DA-FR-121
Spread 11
Figure 1
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Elevation data derived from LiDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.



- Legend**
- Milepost
 - Delineated Stream
 - Existing 50' Contour
 - - Existing 10' Contour
 - Alignment Centerline
 - Limit of Disturbance
 - Permanent Right-of-Way
 - ▨ Brush
 - ▨ Dirt Road
 - ▨ Meadow
 - ▨ Agricultural Area
 - Drainage Area
 - Hydrologic Soil Groups

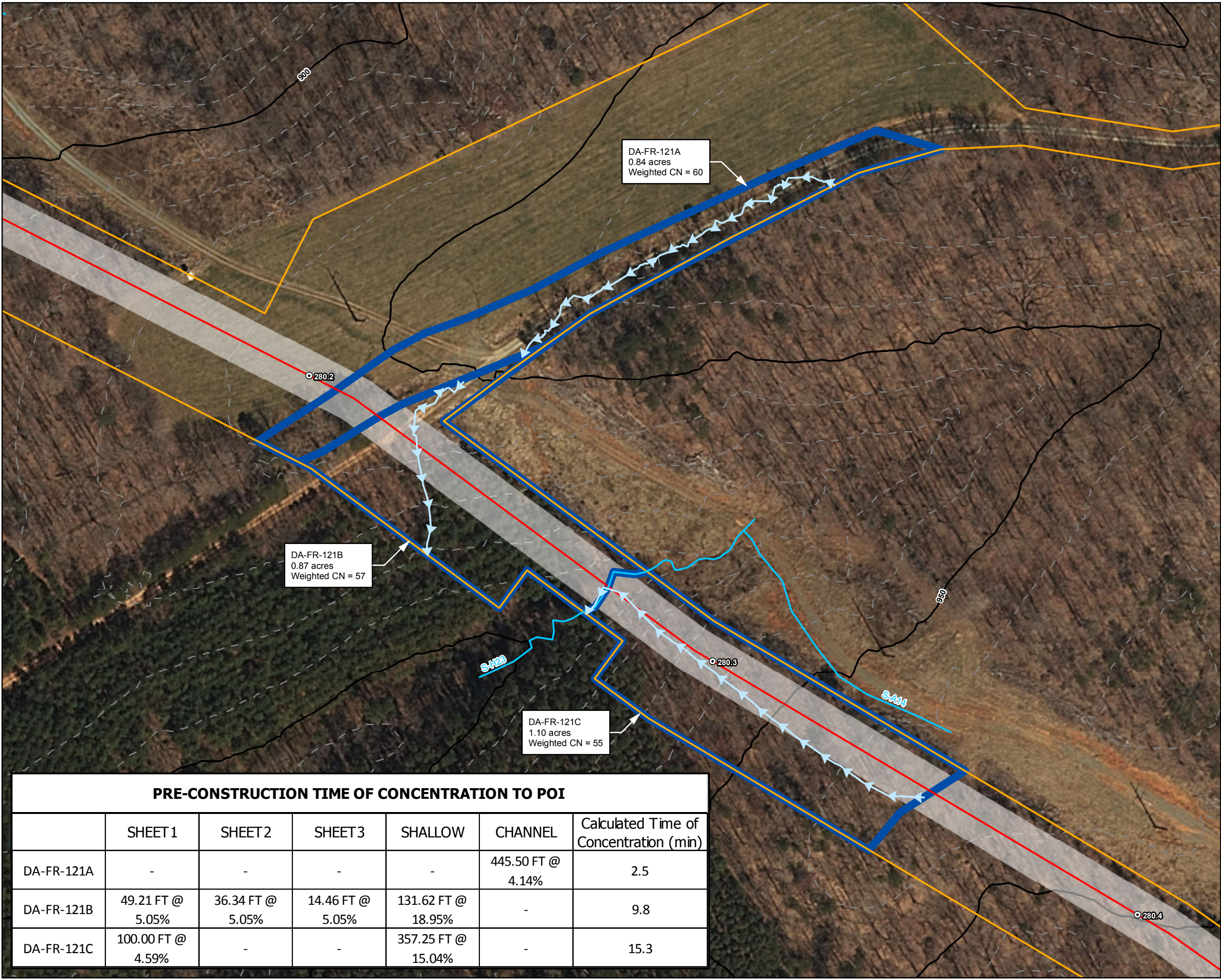


LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Brush - Good	B	48	0.25	DA-FR-121A
Dirt Road	B	82	0.11	
Meadow	B	58	0.48	
Brush - Good	B	48	0.43	DA-FR-121B
Dirt Road	B	82	0.04	
Meadow	B	58	0.41	
Brush - Good	B	48	0.63	DA-FR-121C
Meadow	B	58	0.47	

Mountain Valley Pipeline Project

Post-Construction Drainage Area Map
DA-FR-121
Spread 11
Figure 2
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Elevation data derived from LiDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.



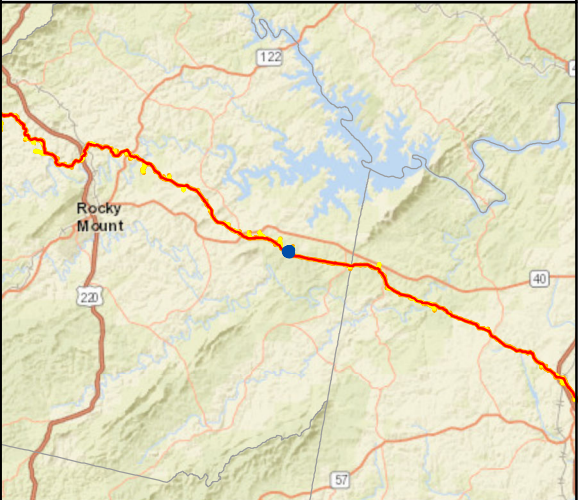
Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- - Existing 10' Contour
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:1,200

100 50 0 100 Feet



Mountain Valley Pipeline Project



**Pre-Construction Drainage Area
and Time of Concentration
DA-FR-121
Spread 11**

Figure 3
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Elevation data derived from LiDAR provided by EQT 2016.

PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET 1	SHEET 2	SHEET 3	SHALLOW	CHANNEL	Calculated Time of Concentration (min)
DA-FR-121A	-	-	-	-	445.50 FT @ 4.14%	2.5
DA-FR-121B	49.21 FT @ 5.05%	36.34 FT @ 5.05%	14.46 FT @ 5.05%	131.62 FT @ 18.95%	-	9.8
DA-FR-121C	100.00 FT @ 4.59%	-	-	357.25 FT @ 15.04%	-	15.3

POST-CONSTRUCTION TIME OF CONCENTRATION TO POI							
	SHEET 1	SHEET 2	SHEET 3	SHALLOW1	SHALLOW2	CHANNEL	Calculated Time of Concentration (min)
DA-FR-120A	100.00 FT @ 7.12%	-	-	219.49 FT @ 7.18%	294.17 FT @ 11.30%	19.02 FT @ 4.94%	13.8
DA-FR-120B	100.00 FT @ 5.81%	-	-	107.26 FT @ 13.76%	121.84 FT @ 18.47%	46.67 FT @ 6.73%	13.8
DA-FR-120C	100.00 FT @ 10.83%	-	-	211.08 FT @ 20.64%	-	-	10.6
DA-FR-120D	100.00 FT @ 16.79%	-	-	63.03 FT @ 31.68%	-	-	8.6
DA-FR-120E	55.04 FT @ 22.76%	25.08 FT @ 22.63%	17.50 FT @ 18.40%	22.37 FT @ 27.99%	-	40.16 FT @ 6.41%	11.3
DA-FR-120F	100.00 FT @ 4.91%	-	-	36.93 FT @ 5.85%	549.32 FT @ 10.62%	28.74 FT @ 4.99%	15.9

Legend

- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:3,600

300 150 0 300 Feet



Mountain Valley Pipeline Project



Post-Construction Drainage Area and Time of Concentration
DA-FR-120
Spread 11

Figure 4
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database

DEQ Virginia Runoff Reduction Method Re-Development Compliance Spreadsheet - Version 3.0

BMP Design Specifications List: 2013 Draft Stds & Specs

Site Summary - Linear Development Project***

Total Rainfall (in):	43
Total Disturbed Acreage:	0.88

Site Land Cover Summary

Pre-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	0.87	0.00	0.00	0.87	99
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.01	0.00	0.00	0.01	1
					0.88	100

Post-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	0.87	0.00	0.00	0.87	99
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.01	0.00	0.00	0.01	1
					0.88	100

* Forest/Open Space areas must be protected in accordance with the Virginia Runoff Reduction Method

Site Tv and Land Cover Nutrient Loads

	Final Post-Development (Post-ReDevelopment & New Impervious)	Post- ReDevelopment	Post- Development (New Impervious)	Adjusted Pre- ReDevelopment
Site Rv	0.04	0.04	--	0.04
Treatment Volume (ft ³)	129	129	--	129
TP Load (lb/yr)	0.08	0.08	--	0.08

Baseline TP Load (lb/yr): 0.3608* *Reduction below new development load limitation not required

Pre- ReDevelopment TP Load per acre (lb/acre/yr)	Final Post-Development TP Load per acre (lb/acre/yr)	Post-ReDevelopment TP Load per acre (lb/acre/yr)
0.09	0.09	0.09

Total TP Load Reduction Required (lb/yr)	-0.28	N/A***	N/A***
--	-------	--------	--------

***This is a linear development project

	Final Post-Development Load (Post-ReDevelopment & New Impervious)	Pre- ReDevelopment
TN Load (lb/yr)	0.58	0.58

Site Compliance Summary - ***Linear Development Project

Maximum % Reduction Required Below Pre-ReDevelopment Load	20%
--	-----

* Note: % Reduction will reduce post-development TP load to less than or equal to baseline load of 0.36 lb/yr (0.41 lb/ac/yr)
 [Post-Dev Reduction Requirement = Post-Dev TP load - baseline load of 0.36 lb/yr], baseline load = site area x 0.41 lb/ac/yr

Total Runoff Volume Reduction (ft ³)	0
--	---

Total TP Load Reduction Achieved (lb/yr)	0.00
Total TN Load Reduction Achieved (lb/yr)	0.00
Remaining Post Development TP Load (lb/yr)	0.08
Remaining TP Load Reduction (lb/yr) Required	0.00

**** TARGET TP REDUCTION EXCEEDED BY 0.28 LB/YEAR ****

**Reduction below new development load limitation not required*

DA-FR-121A

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.605	1281
Developed Condition	0.454	1078
Pre-Developed (Forest) Condition	0.263	804

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	0.454	\leq OK	0.575
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.454	\leq OK	0.605
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ ---->	0.454	<u>shall not</u> be required to be \leq	0.196

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 2 – Manning's *n* Values for Open Channel Flow

Channel Type	Manning <i>n</i>		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's <i>n</i> value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's <i>n</i> value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

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Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-121A DEV
2	SCS Runoff	DA-FR-121A FOR
9	SCS Runoff	DA-FR-121A PRE

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.454	1	716	1,078	-----	-----	-----	DA-FR-121A DEV
2	SCS Runoff	0.263	1	718	804	-----	-----	-----	DA-FR-121A FOR
9	SCS Runoff	0.605	1	716	1,281	-----	-----	-----	DA-FR-121A PRE
DA-FR-121A.gpw					Return Period: 1 Year			Wednesday, 08 / 30 / 2017	

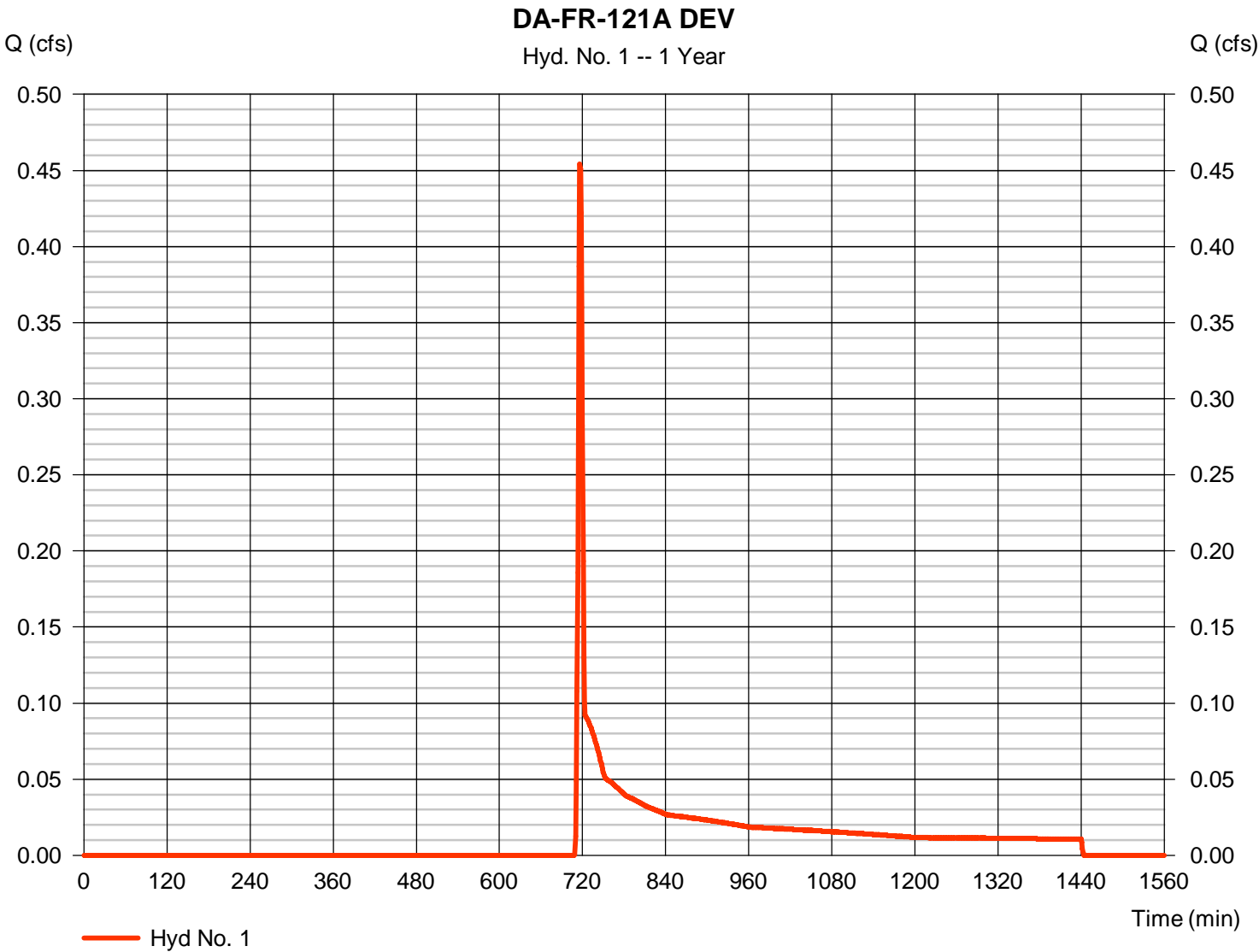
Hydrograph Report

Hyd. No. 1

DA-FR-121A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.454 cfs
Storm frequency	= 1 yrs	Time to peak	= 716 min
Time interval	= 1 min	Hyd. volume	= 1,078 cuft
Drainage area	= 0.840 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 2.50 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.250 x 48) + (0.114 x 82) + (0.476 x 58)] / 0.840



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-121A DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.011	0.011	0.011				
Flow length (ft)	= 0.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 0.00	0.00	0.00				
Land slope (%)	= 0.00	0.00	0.00				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Shallow Concentrated Flow							
Flow length (ft)	= 0.00	0.00	0.00				
Watercourse slope (%)	= 0.00	0.00	0.00				
Surface description	= Paved	Paved	Paved				
Average velocity (ft/s)	=0.00	0.00	0.00				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Channel Flow							
X sectional flow area (sqft)	= 2.52	0.00	0.00				
Wetted perimeter (ft)	= 15.63	0.00	0.00				
Channel slope (%)	= 4.14	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=2.98	0.00	0.00				
Flow length (ft)	(0)445.5	0.0	0.0				
Travel Time (min)	= 2.50	+	0.00	+	0.00	=	2.50
Total Travel Time, Tc				2.50 min			

Hydrograph Report

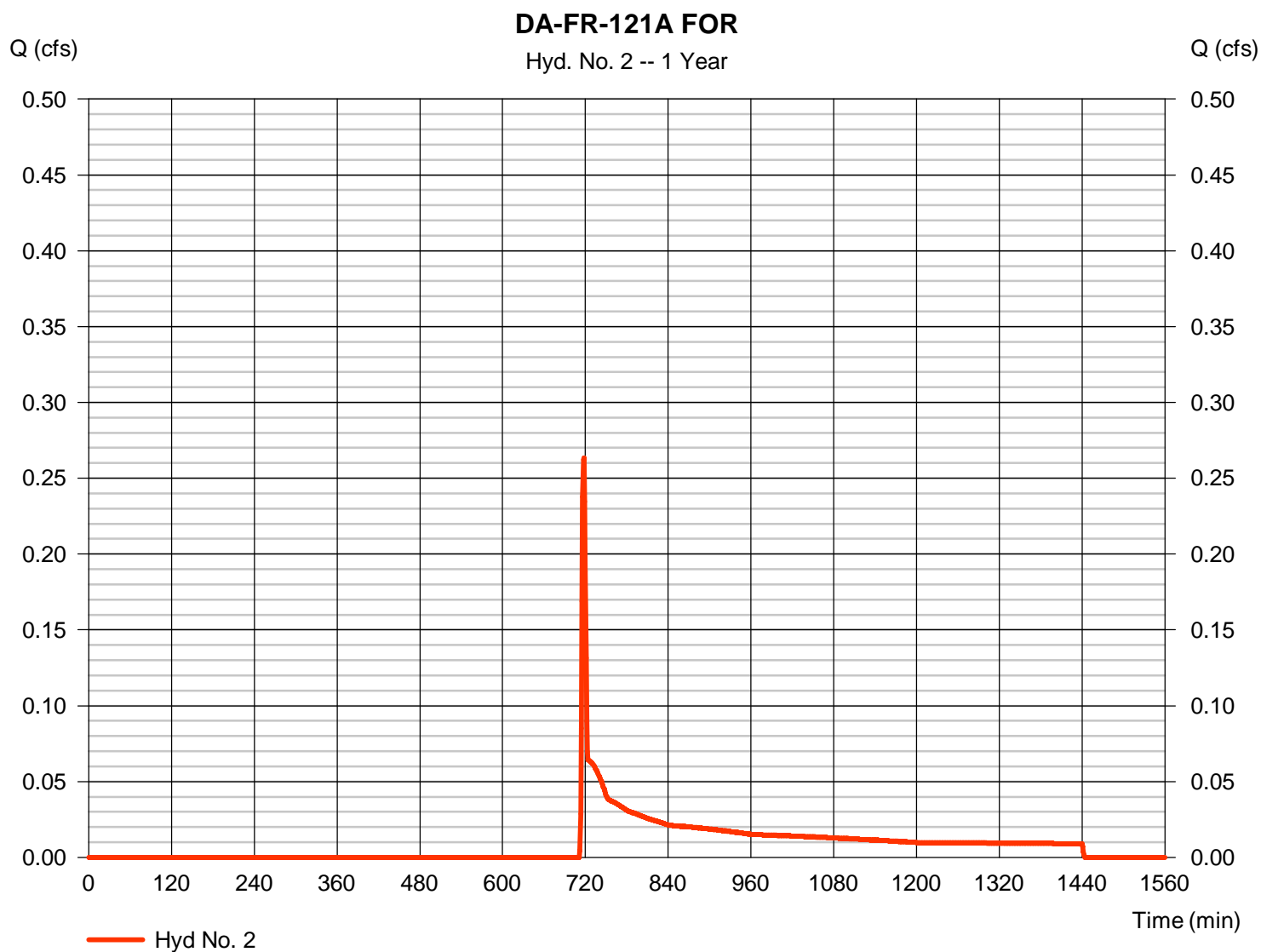
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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Hyd. No. 2

DA-FR-121A FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.263 cfs
Storm frequency	= 1 yrs	Time to peak	= 718 min
Time interval	= 1 min	Hyd. volume	= 804 cuft
Drainage area	= 0.840 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 2.50 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-121A FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.011	0.011	0.011	
Flow length (ft)	= 0.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 0.00	0.00	0.00	
Land slope (%)	= 0.00	0.00	0.00	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Shallow Concentrated Flow				
Flow length (ft)	= 0.00	0.00	0.00	
Watercourse slope (%)	= 0.00	0.00	0.00	
Surface description	= Paved	Paved	Paved	
Average velocity (ft/s)	=0.00	0.00	0.00	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Channel Flow				
X sectional flow area (sqft)	= 2.52	0.00	0.00	
Wetted perimeter (ft)	= 15.63	0.00	0.00	
Channel slope (%)	= 4.14	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=2.98	0.00	0.00	
			0.00	
Flow length (ft)	(\{0\})445.5	0.0	0.0	
Travel Time (min)	= 2.50	+	0.00	+
			0.00	= 2.50
Total Travel Time, Tc				2.50 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

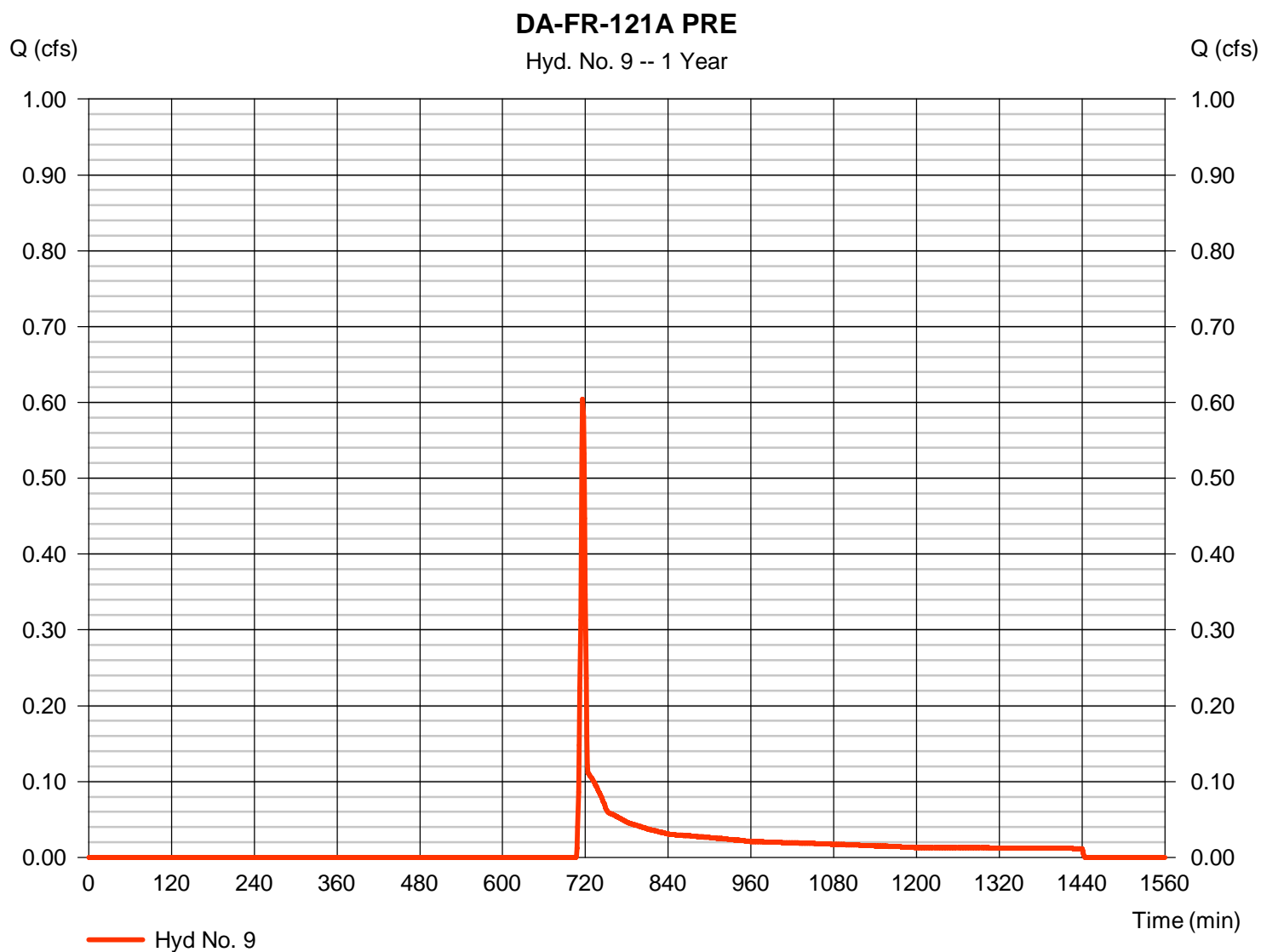
Wednesday, 08 / 30 / 2017

Hyd. No. 9

DA-FR-121A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.605 cfs
Storm frequency	= 1 yrs	Time to peak	= 716 min
Time interval	= 1 min	Hyd. volume	= 1,281 cuft
Drainage area	= 0.840 ac	Curve number	= 60*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 2.50 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.114 \times 82) + (0.441 \times 58) + (0.286 \times 55)] / 0.840$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 9

DA-FR-121A PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.011	0.011	0.011				
Flow length (ft)	= 0.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 0.00	0.00	0.00				
Land slope (%)	= 0.00	0.00	0.00				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Shallow Concentrated Flow							
Flow length (ft)	= 0.00	0.00	0.00				
Watercourse slope (%)	= 0.00	0.00	0.00				
Surface description	= Paved	Paved	Paved				
Average velocity (ft/s)	=0.00	0.00	0.00				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Channel Flow							
X sectional flow area (sqft)	= 2.52	0.00	0.00				
Wetted perimeter (ft)	= 15.63	0.00	0.00				
Channel slope (%)	= 4.14	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=2.98	0.00	0.00				
Flow length (ft)	(0)445.5	0.0	0.0				
Travel Time (min)	= 2.50	+	0.00	+	0.00	=	2.50
Total Travel Time, Tc				2.50 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.743	1	716	1,527	-----	-----	-----	DA-FR-121A DEV
2	SCS Runoff	0.494	1	716	1,188	-----	-----	-----	DA-FR-121A FOR
9	SCS Runoff	0.916	1	716	1,772	-----	-----	-----	DA-FR-121A PRE
DA-FR-121A.gpw					Return Period: 2 Year			Wednesday, 08 / 30 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

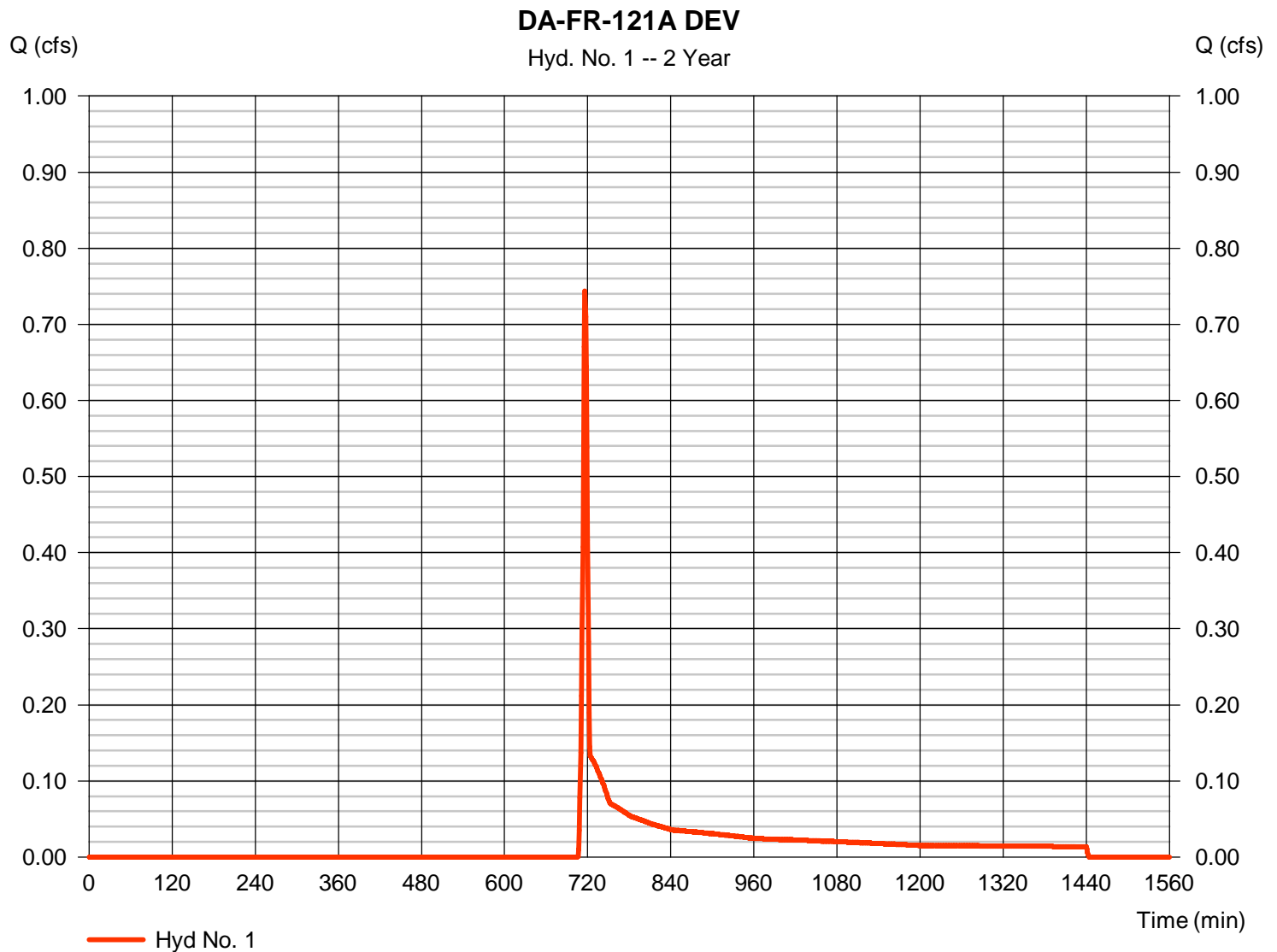
Wednesday, 08 / 30 / 2017

Hyd. No. 1

DA-FR-121A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.743 cfs
Storm frequency	= 2 yrs	Time to peak	= 716 min
Time interval	= 1 min	Hyd. volume	= 1,527 cuft
Drainage area	= 0.840 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 2.50 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.250 \times 48) + (0.114 \times 82) + (0.476 \times 58)] / 0.840$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

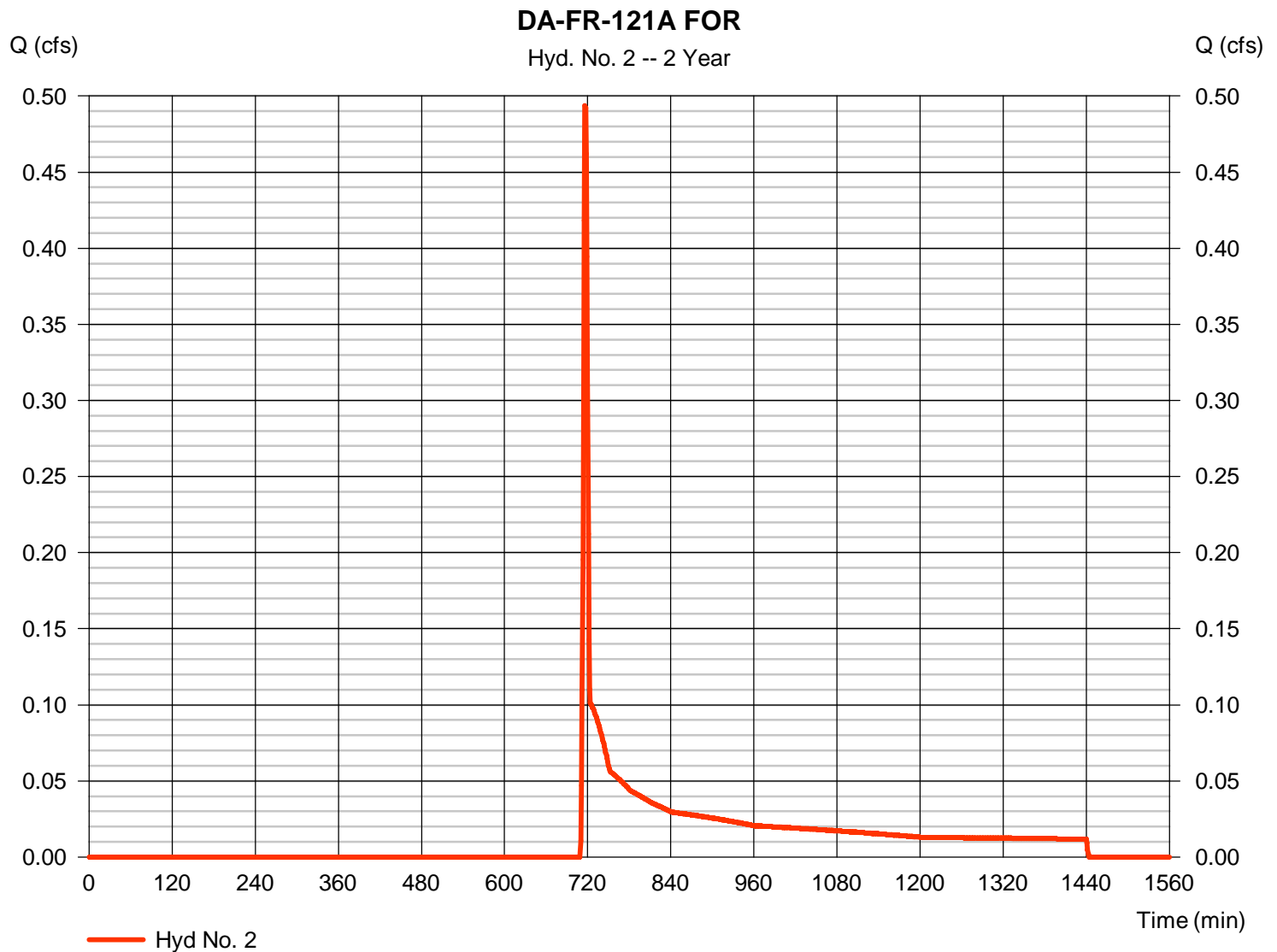
Wednesday, 08 / 30 / 2017

Hyd. No. 2

DA-FR-121A FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 0.840 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.494 cfs
 Time to peak = 716 min
 Hyd. volume = 1,188 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 2.50 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

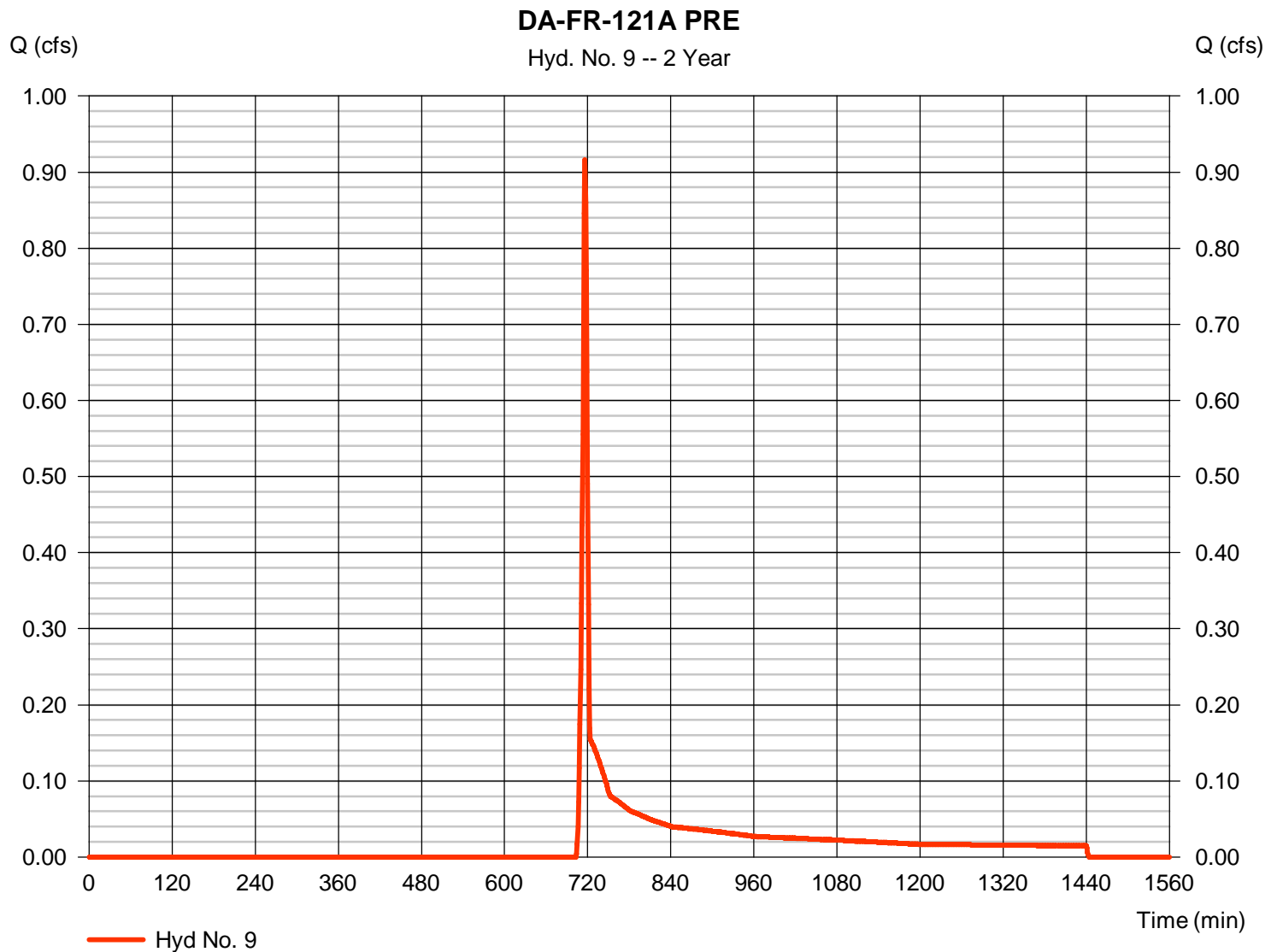
Wednesday, 08 / 30 / 2017

Hyd. No. 9

DA-FR-121A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.916 cfs
Storm frequency	= 2 yrs	Time to peak	= 716 min
Time interval	= 1 min	Hyd. volume	= 1,772 cuft
Drainage area	= 0.840 ac	Curve number	= 60*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 2.50 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.114 \times 82) + (0.441 \times 58) + (0.286 \times 55)] / 0.840$



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	2.559	1	716	4,496	-----	-----	-----	DA-FR-121A DEV
2	SCS Runoff	2.157	1	716	3,855	-----	-----	-----	DA-FR-121A FOR
9	SCS Runoff	2.830	1	716	4,940	-----	-----	-----	DA-FR-121A PRE
DA-FR-121A.gpw					Return Period: 10 Year			Wednesday, 08 / 30 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

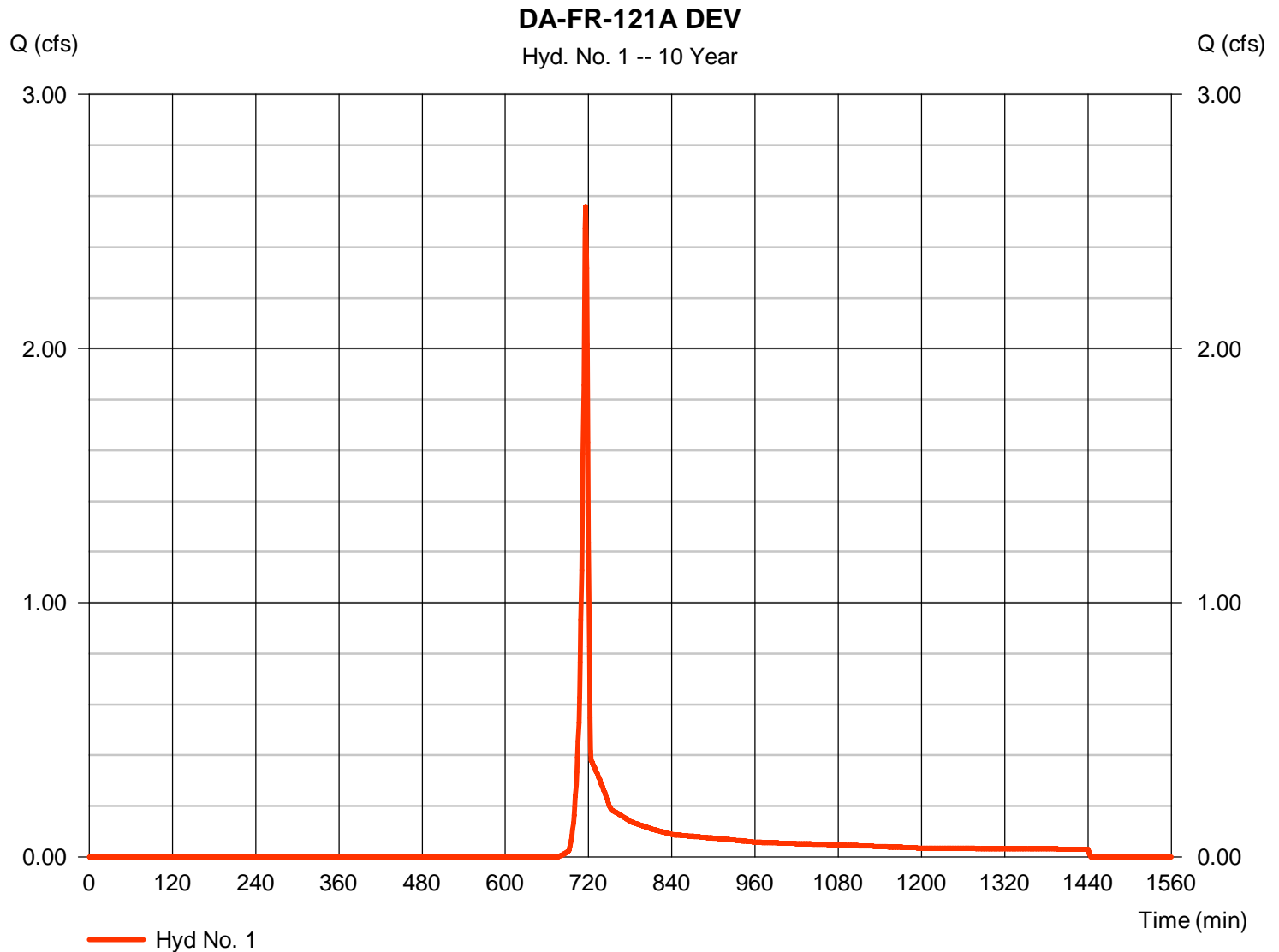
Wednesday, 08 / 30 / 2017

Hyd. No. 1

DA-FR-121A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 2.559 cfs
Storm frequency	= 10 yrs	Time to peak	= 716 min
Time interval	= 1 min	Hyd. volume	= 4,496 cuft
Drainage area	= 0.840 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 2.50 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.250 \times 48) + (0.114 \times 82) + (0.476 \times 58)] / 0.840$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

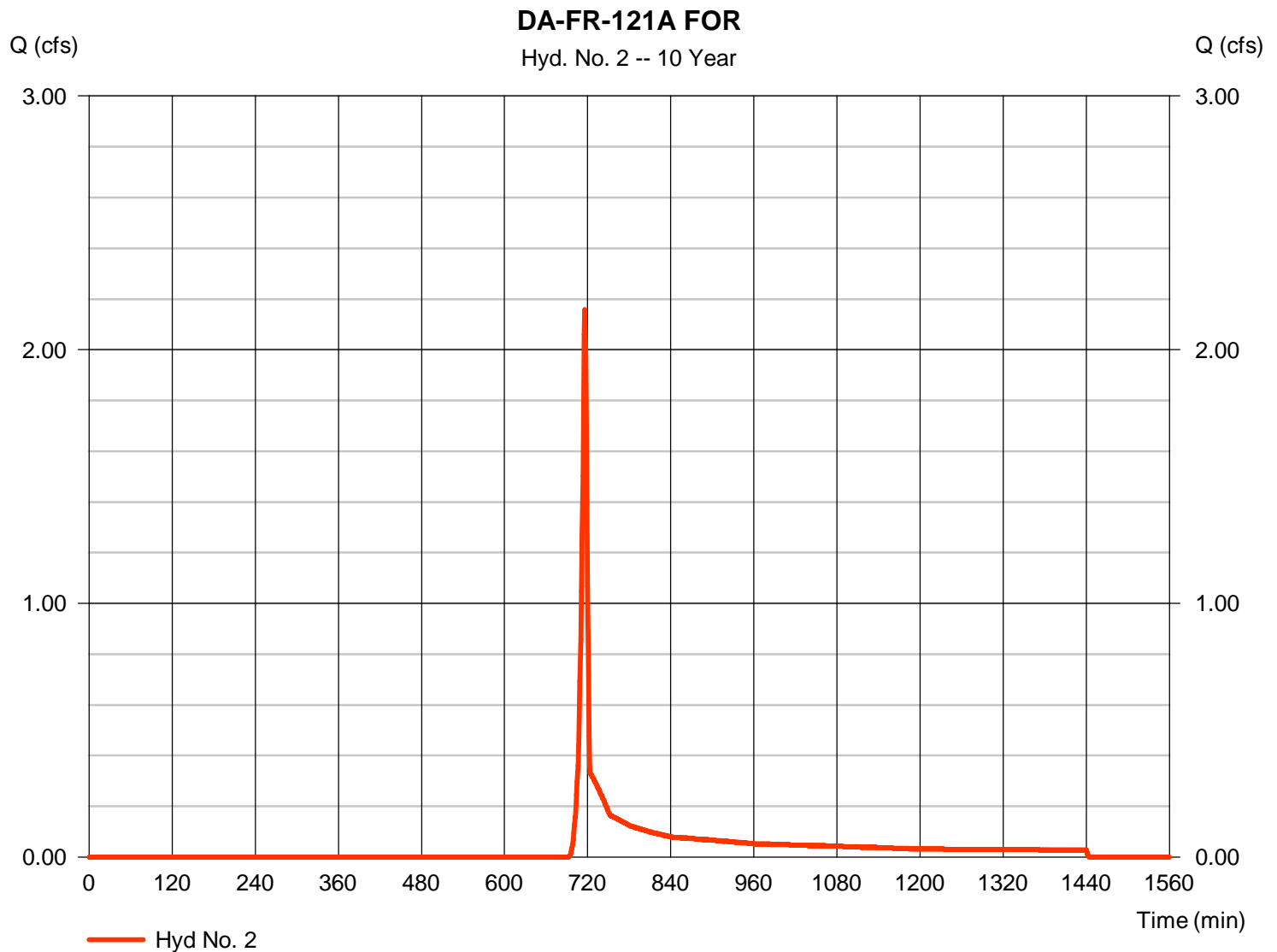
Wednesday, 08 / 30 / 2017

Hyd. No. 2

DA-FR-121A FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 0.840 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 2.157 cfs
 Time to peak = 716 min
 Hyd. volume = 3,855 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 2.50 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

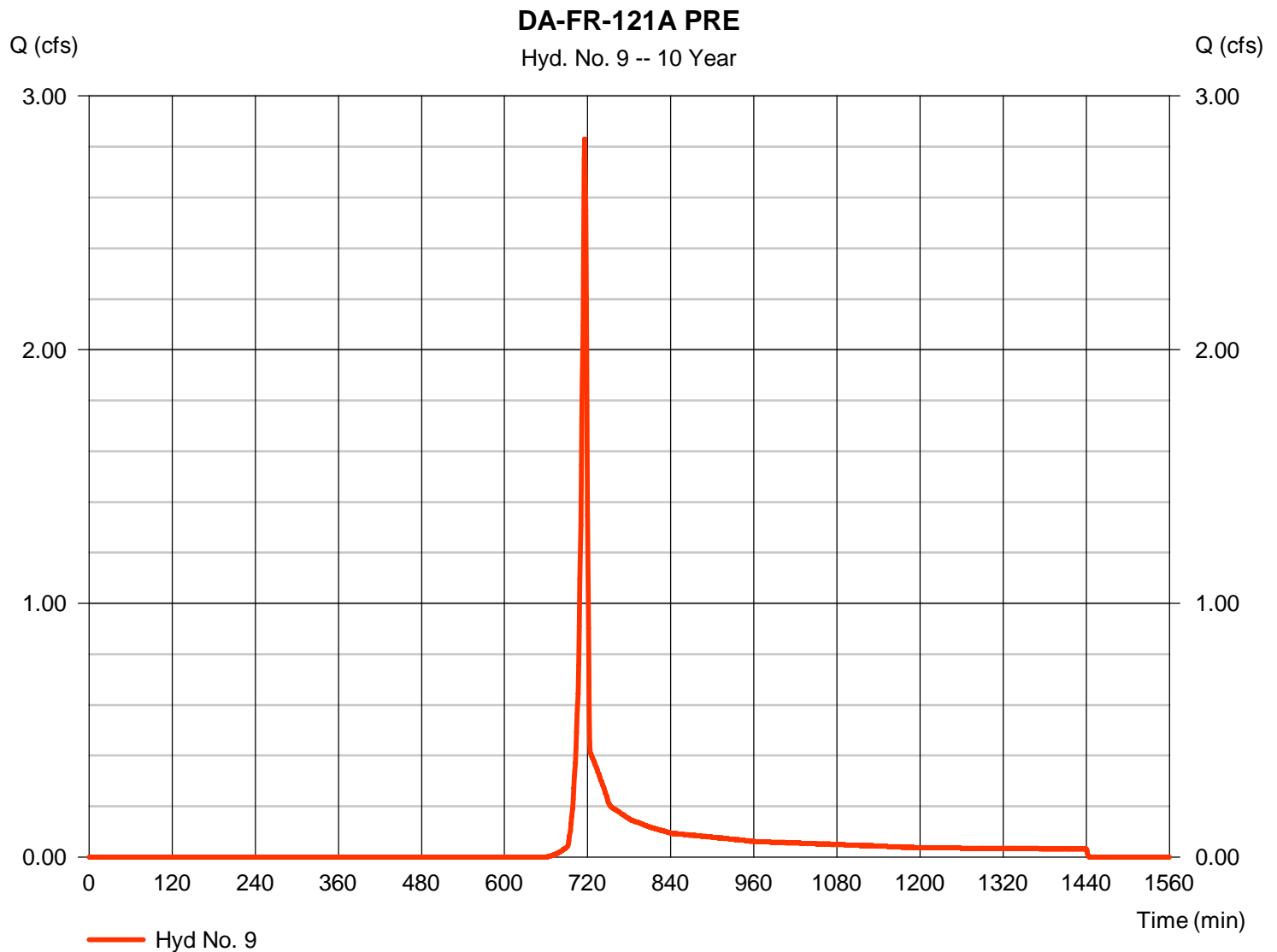
Wednesday, 08 / 30 / 2017

Hyd. No. 9

DA-FR-121A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 2.830 cfs
Storm frequency	= 10 yrs	Time to peak	= 716 min
Time interval	= 1 min	Hyd. volume	= 4,940 cuft
Drainage area	= 0.840 ac	Curve number	= 60*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 2.50 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.114 \times 82) + (0.441 \times 58) + (0.286 \times 55)] / 0.840$



DA-FR-121B

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.286	1085
Developed Condition	0.144	796
Pre-Developed (Forest) Condition	0.143	888

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	0.144	\leq OK	0.312
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.144	\leq OK	0.286
Check #3:	$Q_{\text{developed}} \underline{\text{shall not}}$ be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ --->	0.144	$\underline{\text{shall not}}$ be required to be \leq	0.160

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s n value of 0.011 was used.</p> <p><i>Sources:</i></p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-121B PRE
2	SCS Runoff	DA-FR-121B DEV
3	SCS Runoff	DA-FR-121B FOR

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

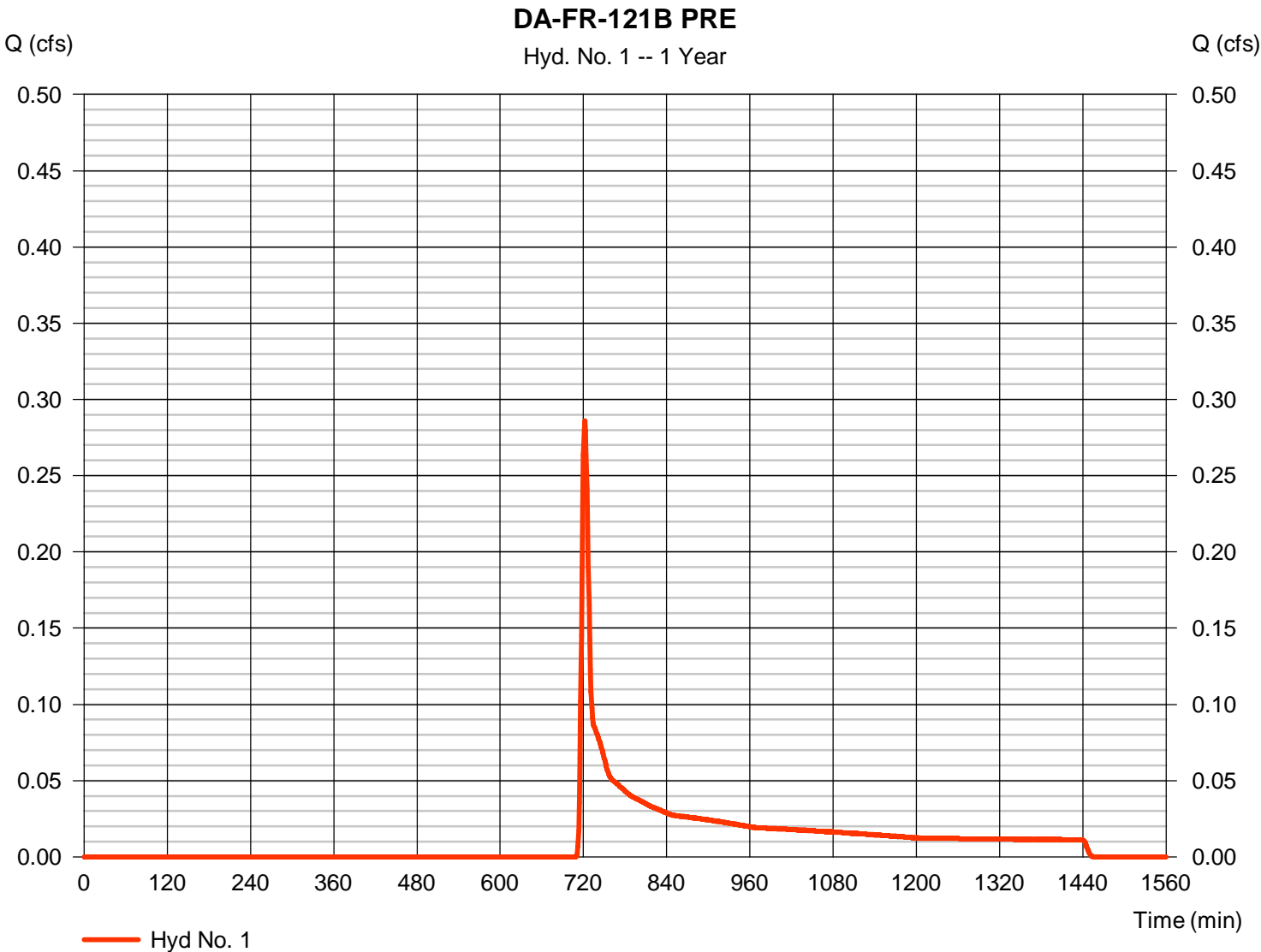
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-121B PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.286 cfs
Storm frequency	=	1 yrs	Time to peak	=	722 min
Time interval	=	1 min	Hyd. volume	=	1,085 cuft
Drainage area	=	0.870 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	9.80 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.038 x 87) + (0.071 x 58) + (0.766 x 55)] / 0.870



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-121B PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.011	0.400	0.400				
Flow length (ft)	= 49.2	36.3	14.5				
Two-year 24-hr precip. (in)	= 3.70	3.70	3.70				
Land slope (%)	= 5.05	5.05	5.05				
Travel Time (min)	= 0.44	+	6.13	+	2.94	=	9.51
Shallow Concentrated Flow							
Flow length (ft)	= 131.62	0.00	0.00				
Watercourse slope (%)	= 18.95	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=7.02	0.00	0.00				
Travel Time (min)	= 0.31	+	0.00	+	0.00	=	0.31
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							9.80 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

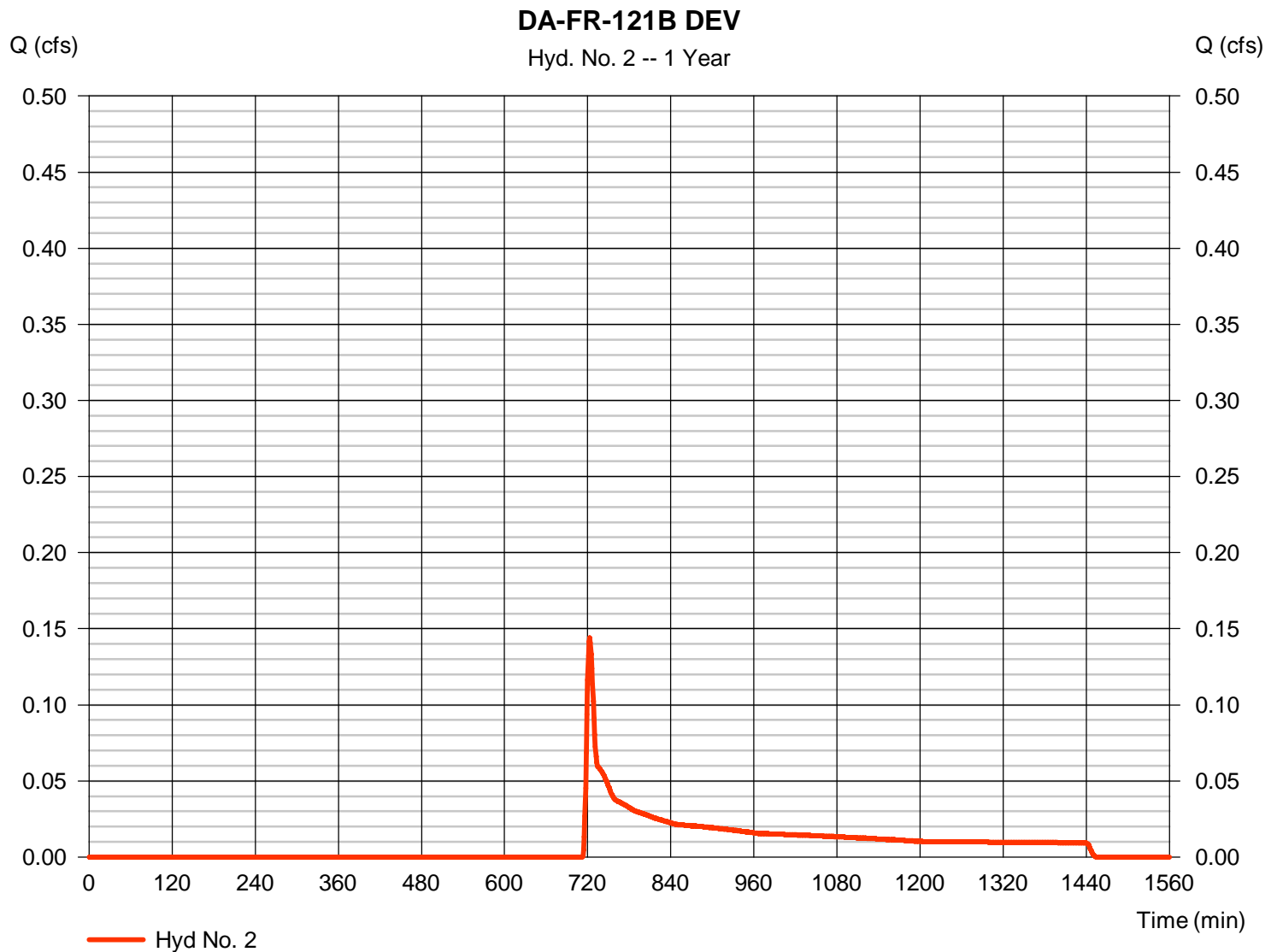
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-121B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.144 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 796 cuft
Drainage area	= 0.870 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 9.80 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.428 \times 48) + (0.038 \times 82) + (0.408 \times 58)] / 0.870$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-121B DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.011	0.400	0.400	
Flow length (ft)	= 49.2	36.3	14.5	
Two-year 24-hr precip. (in)	= 3.70	3.70	3.70	
Land slope (%)	= 5.05	5.05	5.05	
Travel Time (min)	= 0.44	+	6.13	+
			2.94	= 9.51
Shallow Concentrated Flow				
Flow length (ft)	= 131.62	0.00	0.00	
Watercourse slope (%)	= 18.95	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=7.02	0.00	0.00	
Travel Time (min)	= 0.31	+	0.00	+
			0.00	= 0.31
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				9.80 min

Hydrograph Report

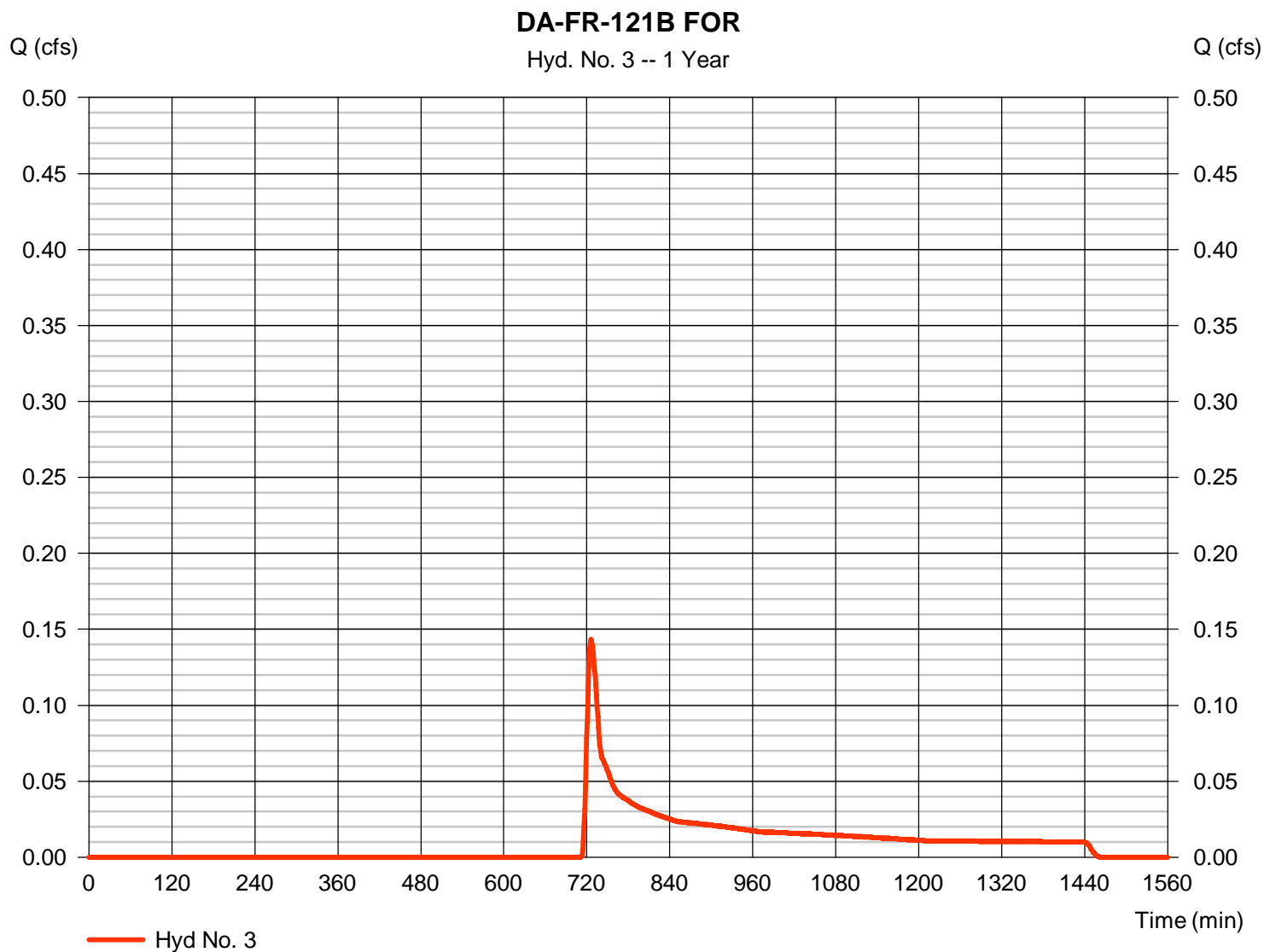
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-121B FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.143 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 888 cuft
Drainage area	= 0.870 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.10 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-121B FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 5.05	0.00	0.00	
Travel Time (min)	= 13.79	+ 0.00	+ 0.00	= 13.79
Shallow Concentrated Flow				
Flow length (ft)	= 131.62	0.00	0.00	
Watercourse slope (%)	= 18.95	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=7.02	0.00	0.00	
Travel Time (min)	= 0.31	+ 0.00	+ 0.00	= 0.31
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				14.10 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

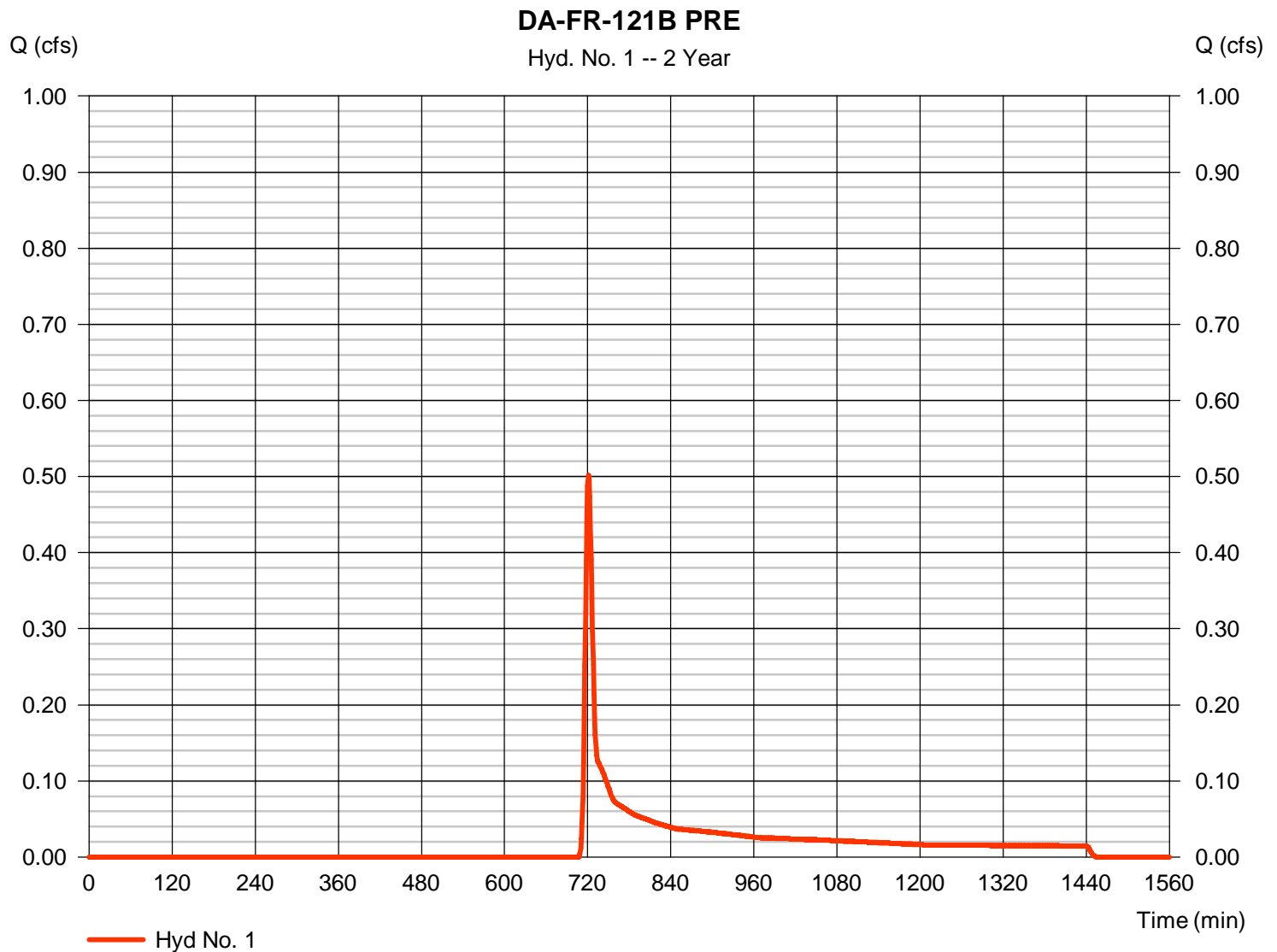
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-121B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.501 cfs
Storm frequency	= 2 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 1,557 cuft
Drainage area	= 0.870 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 9.80 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.038 \times 87) + (0.071 \times 58) + (0.766 \times 55)] / 0.870$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

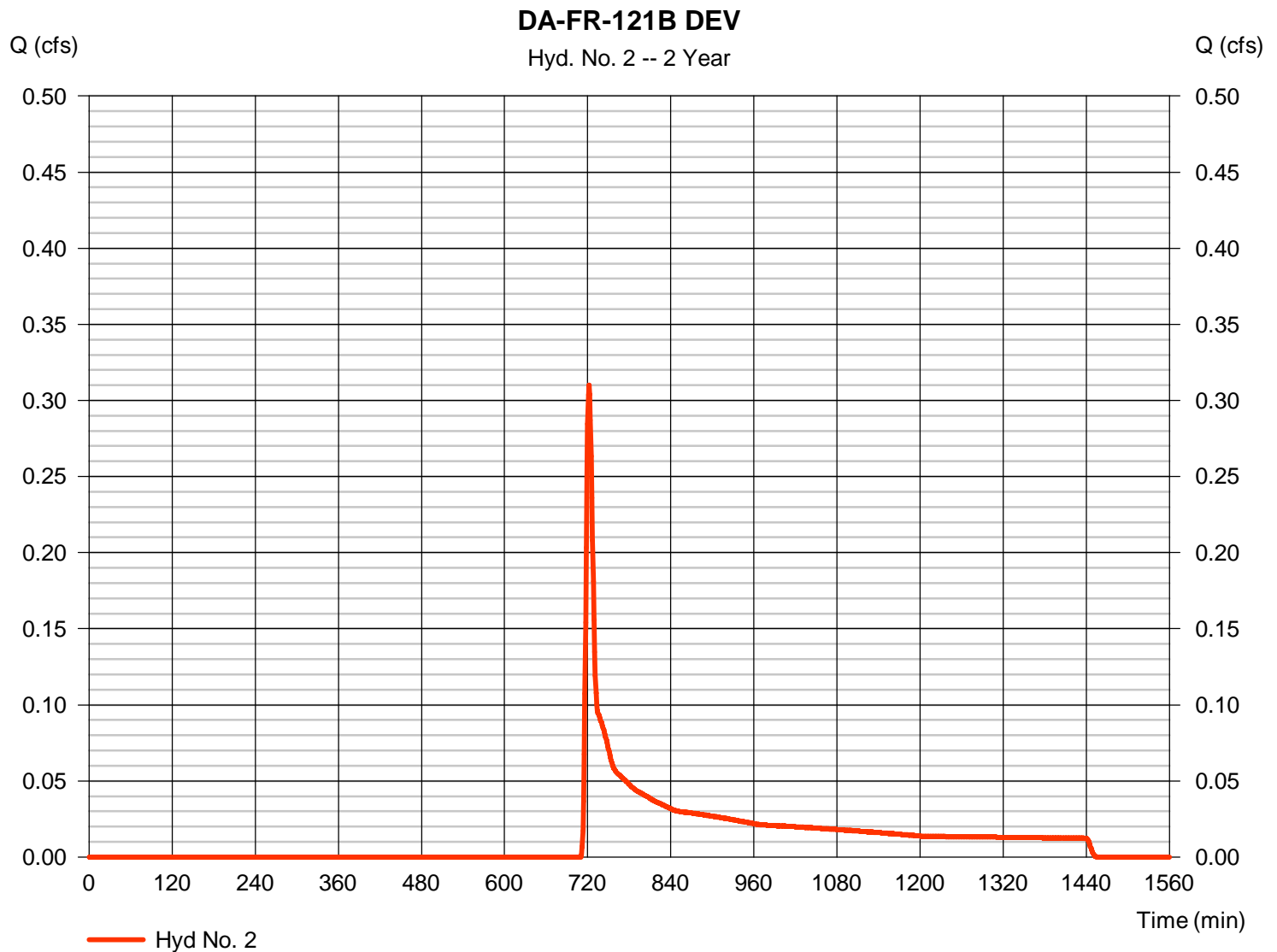
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-121B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.310 cfs
Storm frequency	= 2 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 1,197 cuft
Drainage area	= 0.870 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 9.80 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.428 \times 48) + (0.038 \times 82) + (0.408 \times 58)] / 0.870$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

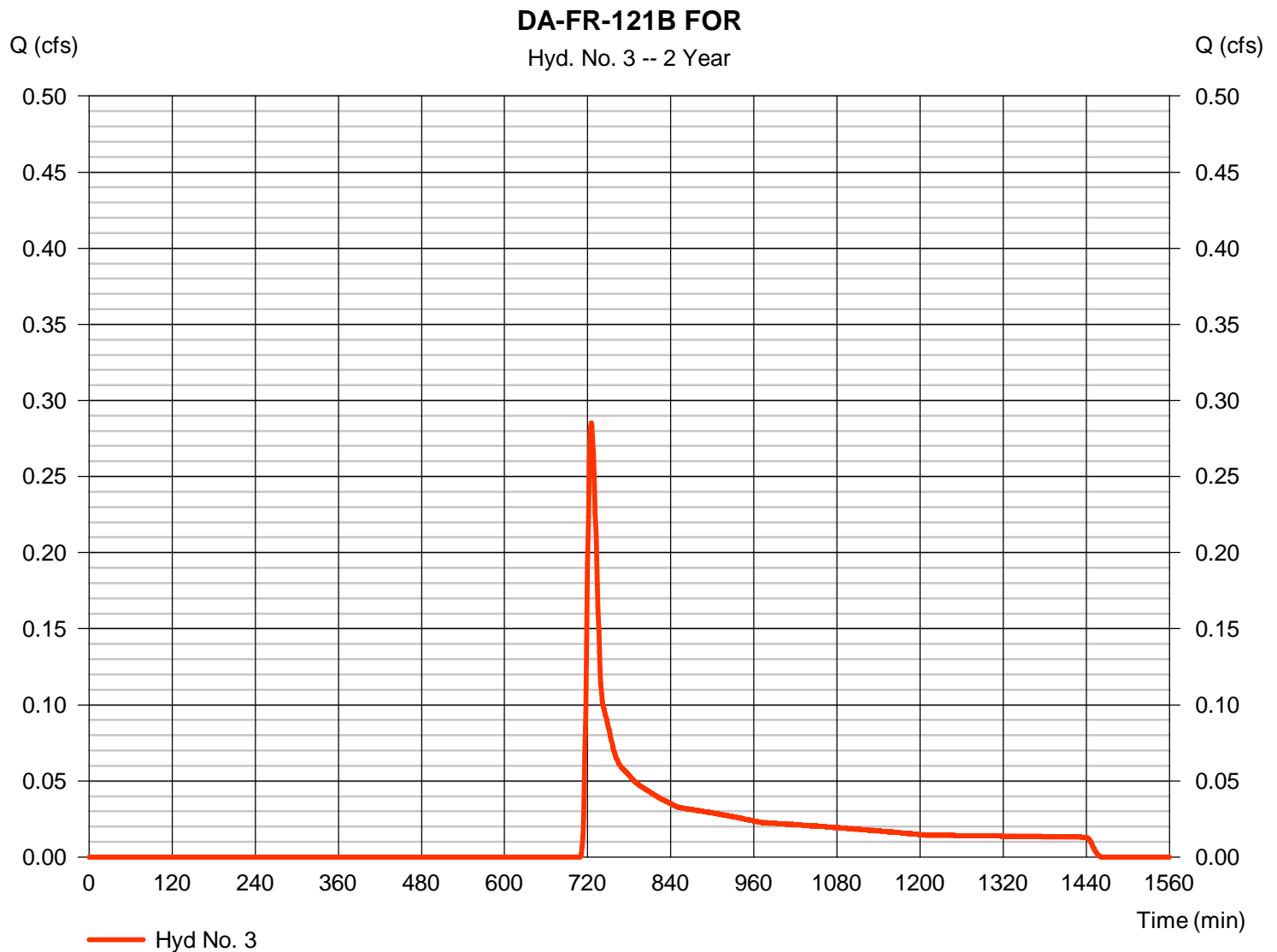
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-121B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 0.870 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.285 cfs
 Time to peak = 725 min
 Hyd. volume = 1,312 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 14.10 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

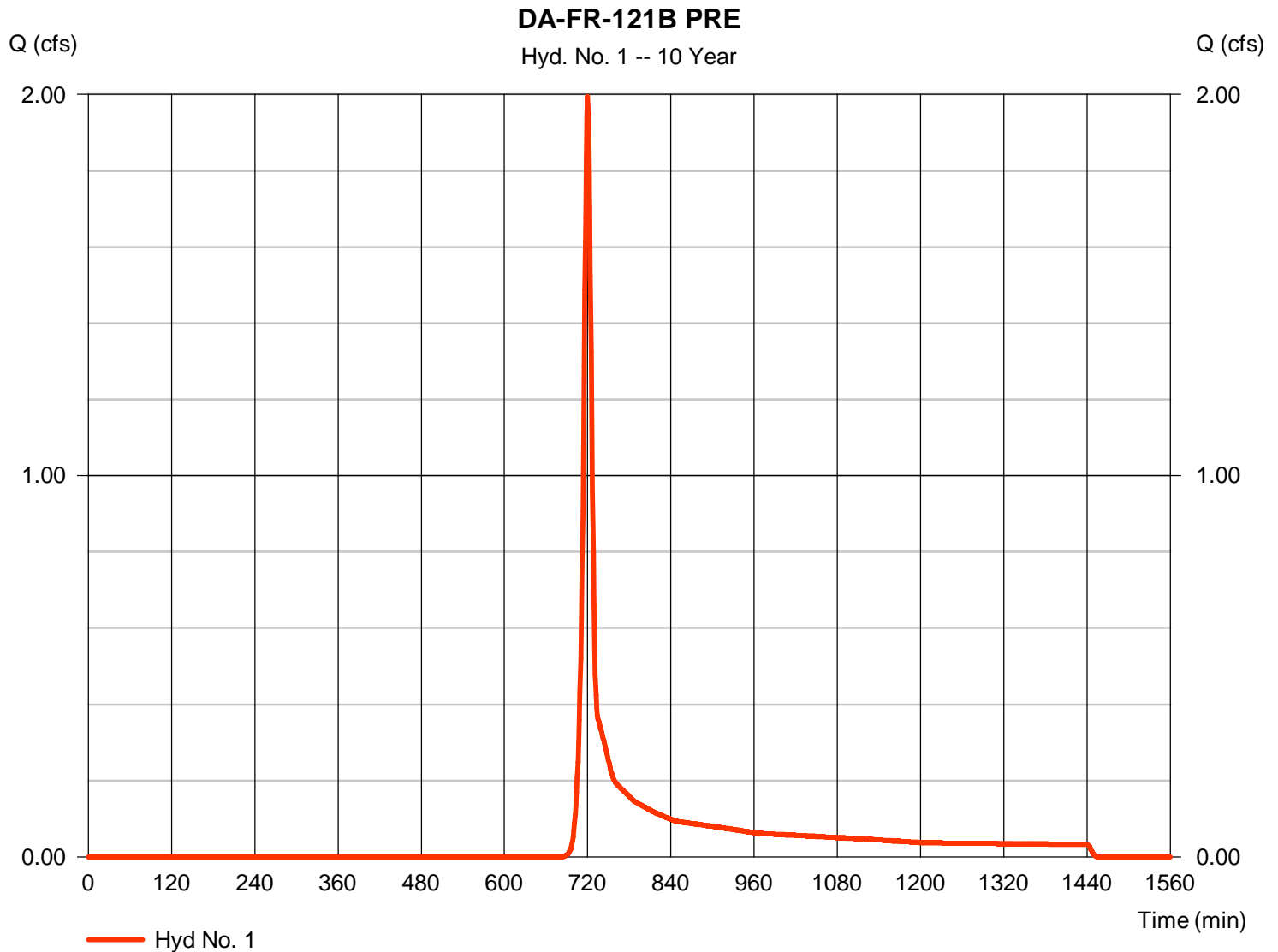
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-121B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 1.995 cfs
Storm frequency	= 10 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 4,727 cuft
Drainage area	= 0.870 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 9.80 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.038 \times 87) + (0.071 \times 58) + (0.766 \times 55)] / 0.870$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

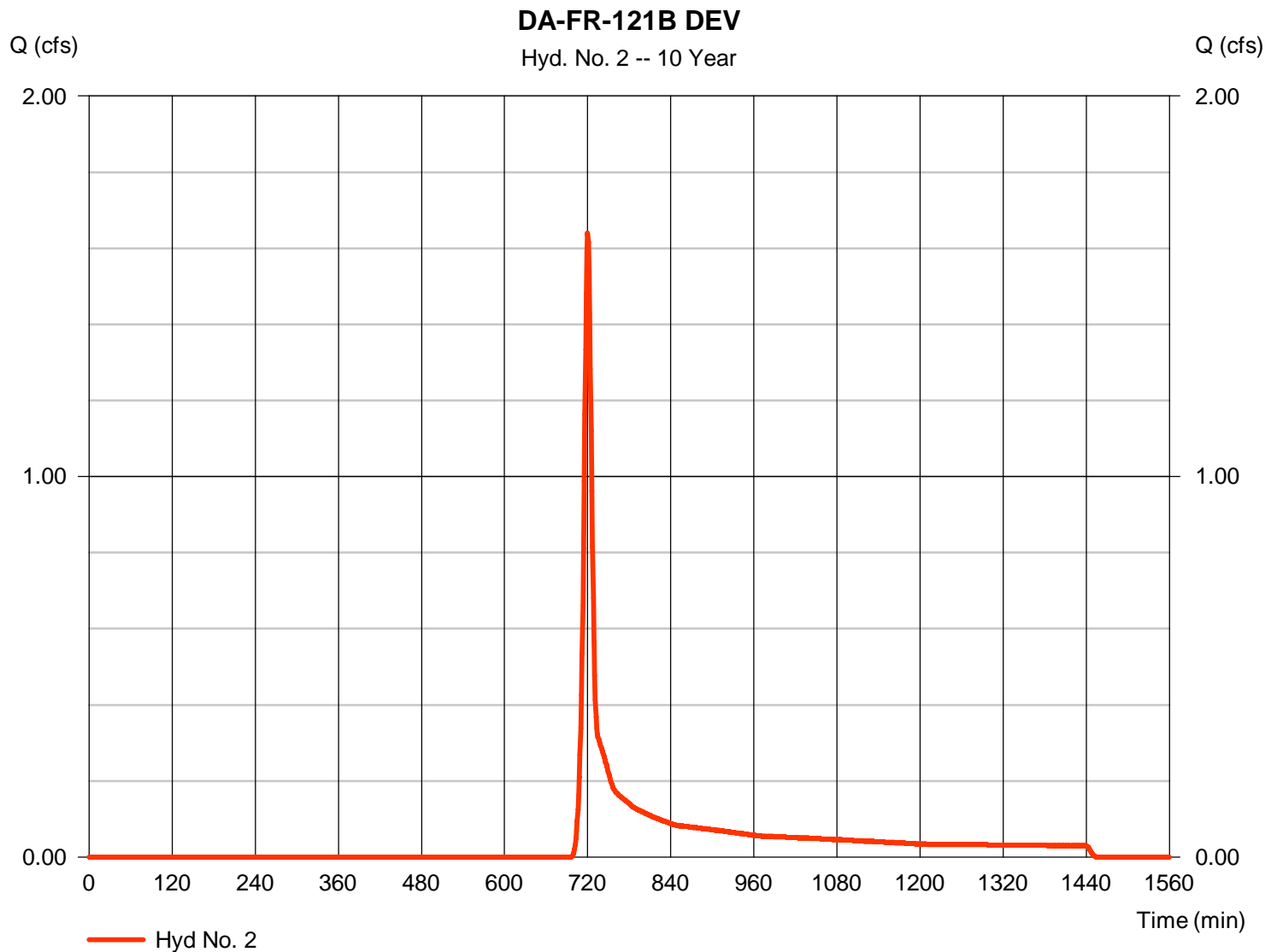
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-121B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 1.639 cfs
Storm frequency	= 10 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 4,030 cuft
Drainage area	= 0.870 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 9.80 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.428 \times 48) + (0.038 \times 82) + (0.408 \times 58)] / 0.870$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

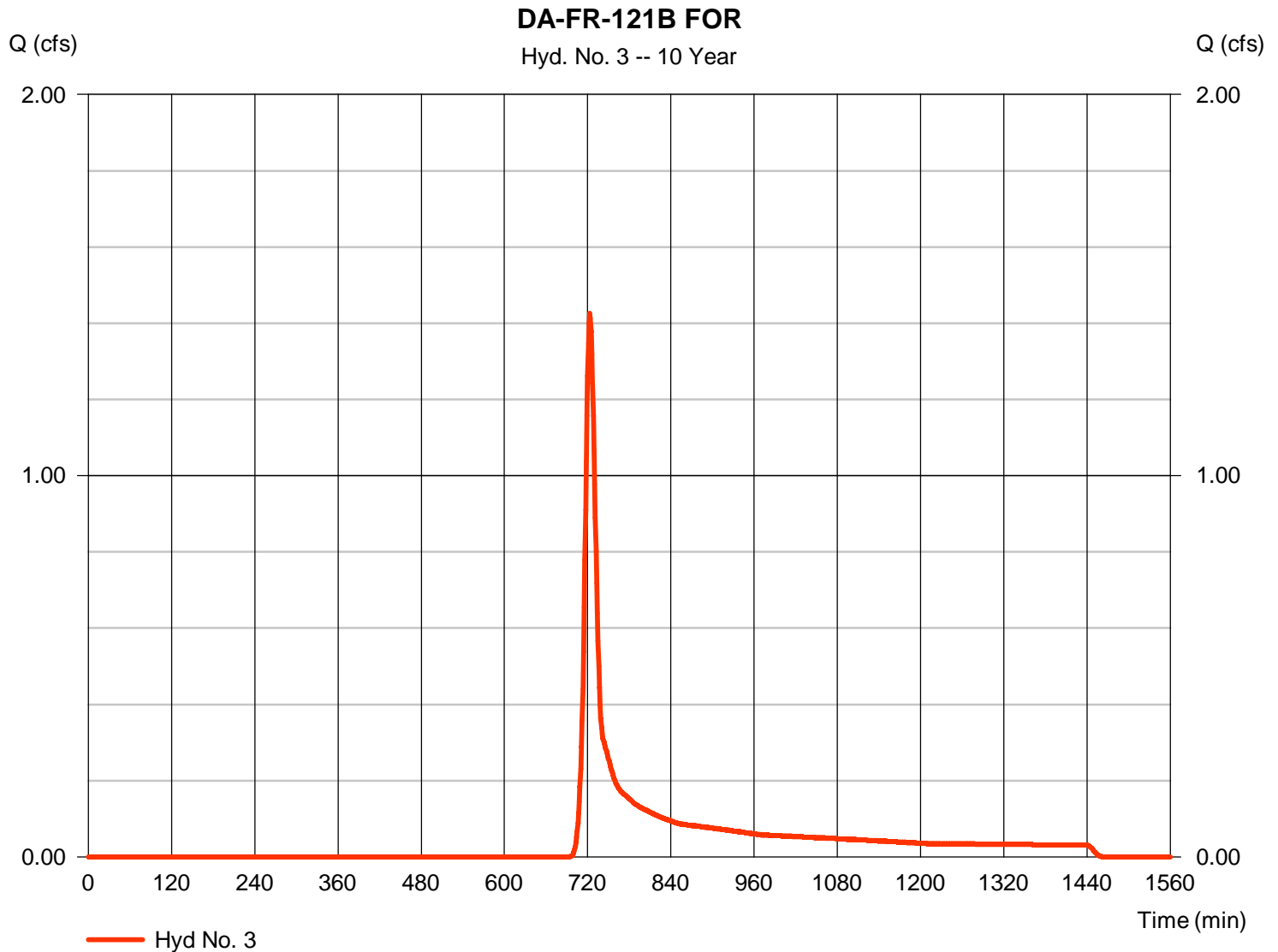
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-121B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 0.870 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 1.425 cfs
 Time to peak = 723 min
 Hyd. volume = 4,259 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 14.10 min
 Distribution = Type II
 Shape factor = 484



Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	-----
2	69.8703	13.1000	0.8658	-----
3	0.0000	0.0000	0.0000	-----
5	79.2597	14.6000	0.8369	-----
10	88.2351	15.5000	0.8279	-----
25	102.6072	16.5000	0.8217	-----
50	114.8193	17.2000	0.8199	-----
100	127.1596	17.8000	0.8186	-----

File name: SampleFHA.idf

$$\text{Intensity} = B / (Tc + D)^E$$

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5.69	4.61	3.89	3.38	2.99	2.69	2.44	2.24	2.07	1.93	1.81	1.70
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	6.57	5.43	4.65	4.08	3.65	3.30	3.02	2.79	2.59	2.42	2.27	2.15
10	7.24	6.04	5.21	4.59	4.12	3.74	3.43	3.17	2.95	2.77	2.60	2.46
25	8.25	6.95	6.03	5.34	4.80	4.38	4.02	3.73	3.48	3.26	3.07	2.91
50	9.04	7.65	6.66	5.92	5.34	4.87	4.49	4.16	3.88	3.65	3.44	3.25
100	9.83	8.36	7.30	6.50	5.87	5.36	4.94	4.59	4.29	4.03	3.80	3.60

Tc = time in minutes. Values may exceed 60.

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[illegible]

DA-FR-121C

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.169	1134
Developed Condition	0.056	790
Pre-Developed (Forest) Condition	0.169	1136

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	0.056	\leq	0.194
			N/A - See Check #3	
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.056	\leq	0.169
			N/A - See Check #3	
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ ---->	0.056	<u>shall not</u> be required to be \leq	0.243

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s n value of 0.011 was used.</p> <p><i>Sources:</i></p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

Table 2 – Manning's *n* Values for Open Channel Flow

Channel Type	Manning <i>n</i>		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's <i>n</i> value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's <i>n</i> value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-121C PRE
2	SCS Runoff	DA-FR-121C DEV
3	SCS Runoff	DA-FR-121C FOR

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

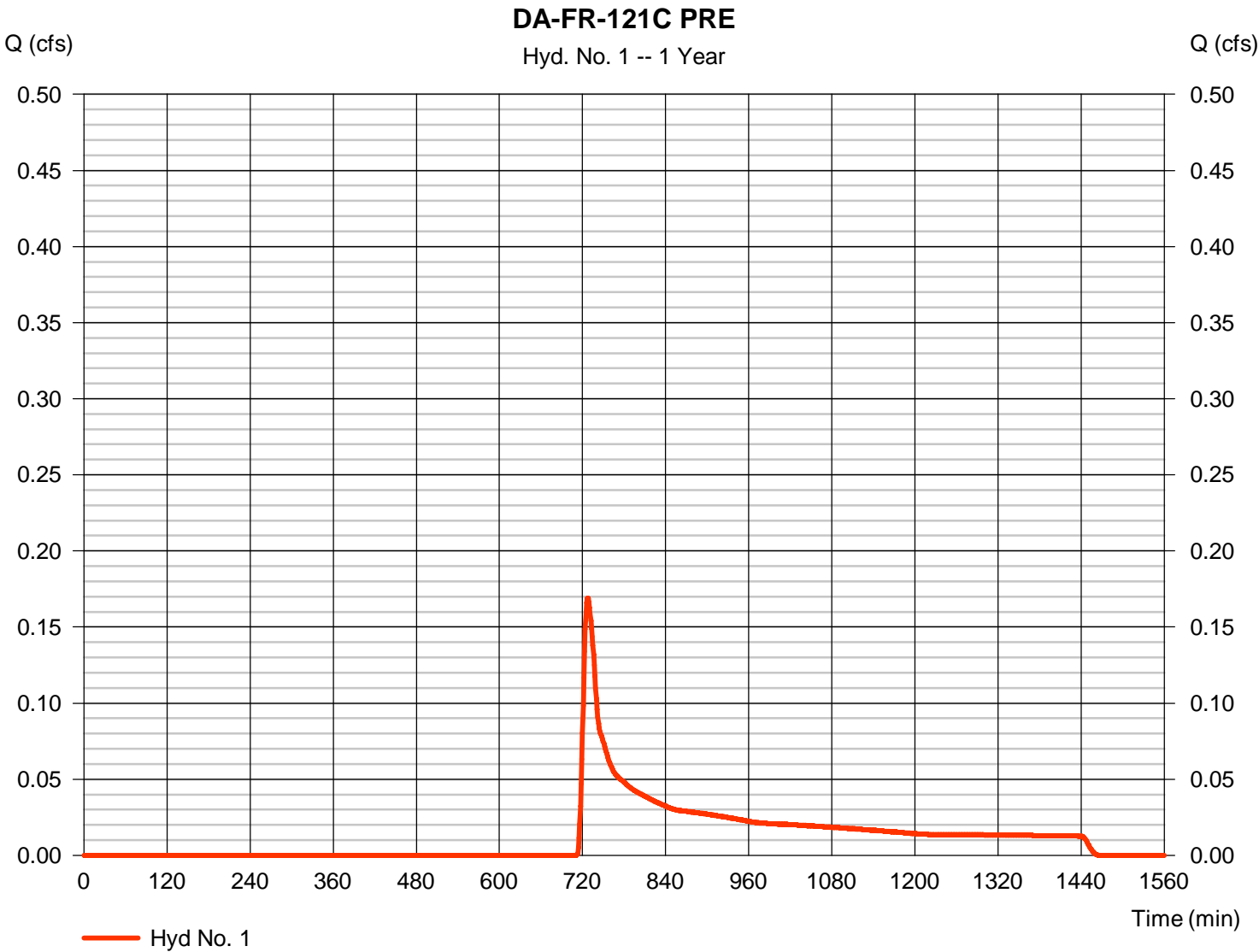
Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.169	1	727	1,134	-----	-----	-----	DA-FR-121C PRE
2	SCS Runoff	0.056	1	749	790	-----	-----	-----	DA-FR-121C DEV
3	SCS Runoff	0.169	1	727	1,136	-----	-----	-----	DA-FR-121C FOR
DA-FR-121C_Hydraflow.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hyd. No. 1

DA-FR-121C PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.169 cfs
Storm frequency	=	1 yrs	Time to peak	=	727 min
Time interval	=	1 min	Hyd. volume	=	1,134 cuft
Drainage area	=	1.098 ac	Curve number	=	55
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	15.30 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-121C PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 4.59	0.00	0.00				
Travel Time (min)	= 14.32	+	0.00	+	0.00	=	14.32
Shallow Concentrated Flow							
Flow length (ft)	= 357.25	0.00	0.00				
Watercourse slope (%)	= 15.04	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=6.26	0.00	0.00				
Travel Time (min)	= 0.95	+	0.00	+	0.00	=	0.95
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				15.30 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

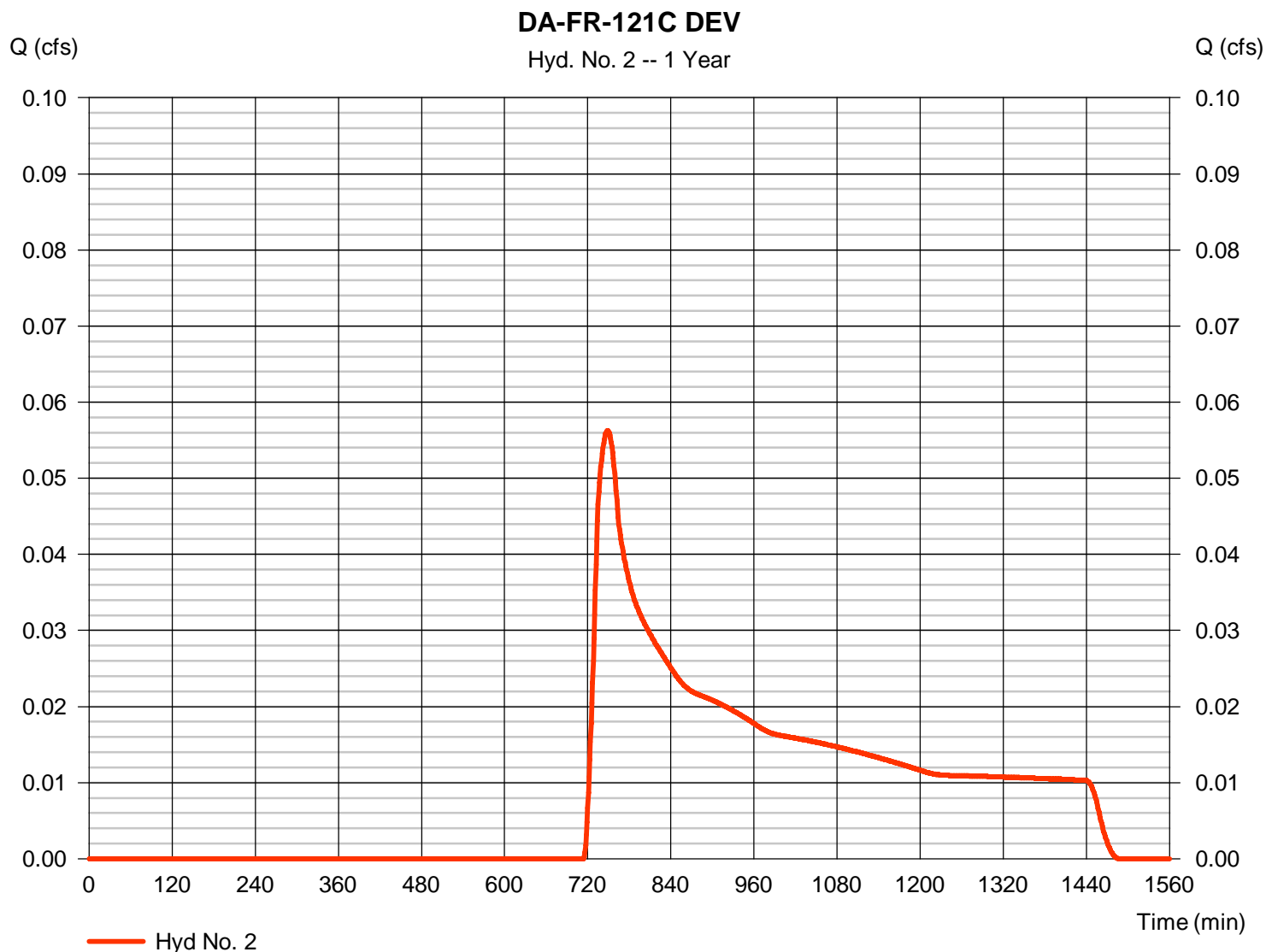
Hyd. No. 2

DA-FR-121C DEV

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 1.100 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.30 in
 Storm duration = 24 hrs

Peak discharge = 0.056 cfs
 Time to peak = 749 min
 Hyd. volume = 790 cuft
 Curve number = 52*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 29.20 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(0.628 \times 48) + (0.470 \times 58)] / 1.100$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-121C DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.800	0.011	
Flow length (ft)	= 33.2	66.8	0.0	
Two-year 24-hr precip. (in)	= 3.70	3.70	0.00	
Land slope (%)	= 0.70	6.52	0.00	
Travel Time (min)	= 12.59	+	15.69	+
			0.00	= 28.28
Shallow Concentrated Flow				
Flow length (ft)	= 107.61	186.36	35.18	
Watercourse slope (%)	= 11.46	20.75	6.12	
Surface description	= Unpaved	Unpaved	Unpaved	
Average velocity (ft/s)	=5.46	7.35	3.99	
Travel Time (min)	= 0.33	+	0.42	+
			0.15	= 0.90
Channel Flow				
X sectional flow area (sqft)	= 2.00	2.00	0.00	
Wetted perimeter (ft)	= 4.47	4.47	0.00	
Channel slope (%)	= 5.00	5.00	0.00	
Manning's n-value	= 0.040	0.040	0.015	
Velocity (ft/s)	=4.86	4.86	0.00	
Flow length (ft)	({})8.5	4.1	0.0	
Travel Time (min)	= 0.03	+	0.01	+
			0.00	= 0.04
Total Travel Time, Tc				29.20 min

Hydrograph Report

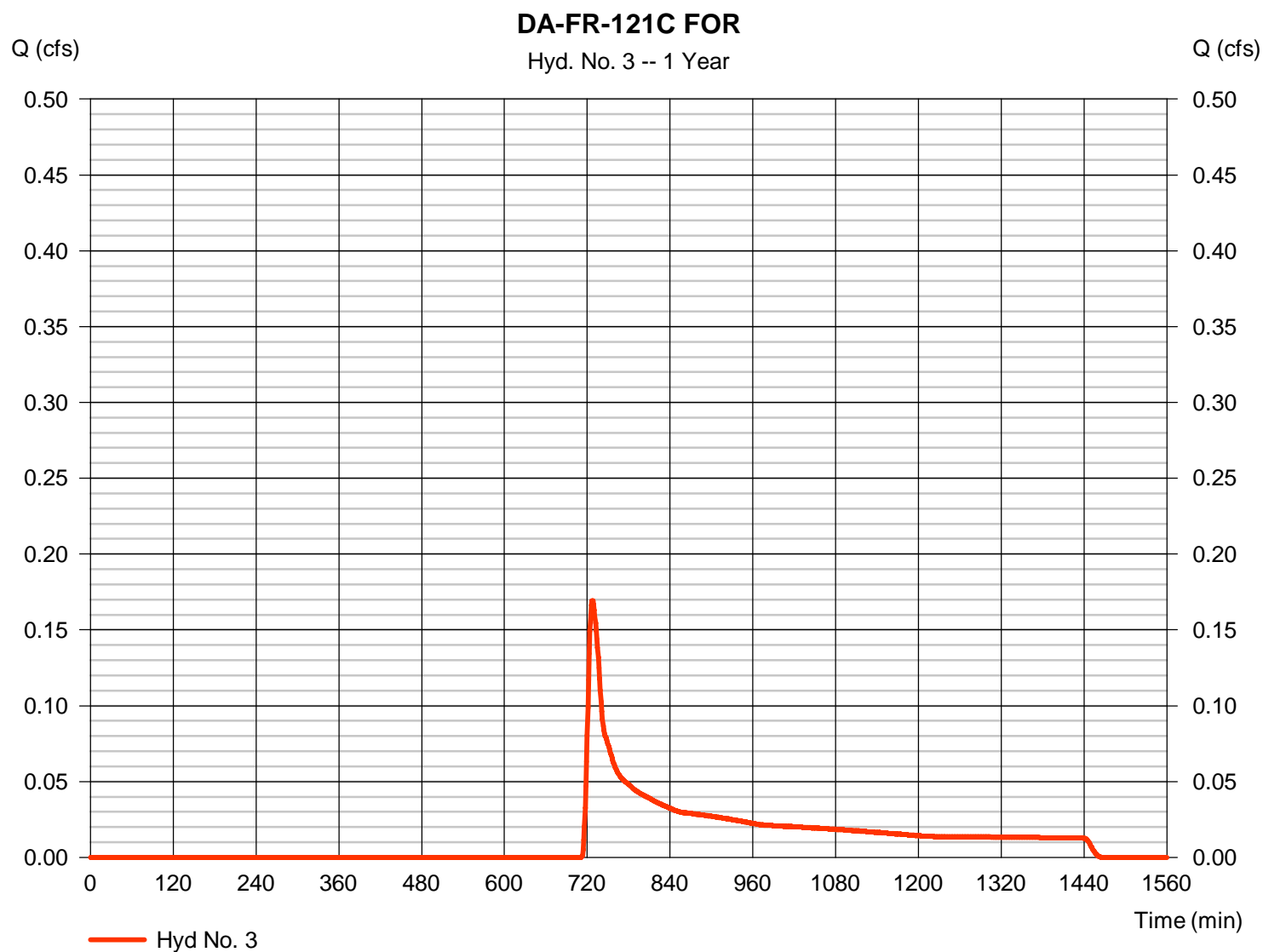
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-121C FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.169 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 1,136 cuft
Drainage area	= 1.100 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.30 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-121C FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 4.59	0.00	0.00	
Travel Time (min)	= 14.32	+ 0.00	+ 0.00	= 14.32
Shallow Concentrated Flow				
Flow length (ft)	= 357.25	0.00	0.00	
Watercourse slope (%)	= 15.04	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=6.26	0.00	0.00	
Travel Time (min)	= 0.95	+ 0.00	+ 0.00	= 0.95
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	
Travel Time (min)	= 0.00	+ 0.00	+ 0.00	= 0.00
Total Travel Time, Tc				15.30 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.335	1	726	1,677	-----	-----	-----	DA-FR-121C PRE
2	SCS Runoff	0.126	1	740	1,238	-----	-----	-----	DA-FR-121C DEV
3	SCS Runoff	0.336	1	726	1,680	-----	-----	-----	DA-FR-121C FOR
DA-FR-121C_Hydraflow.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

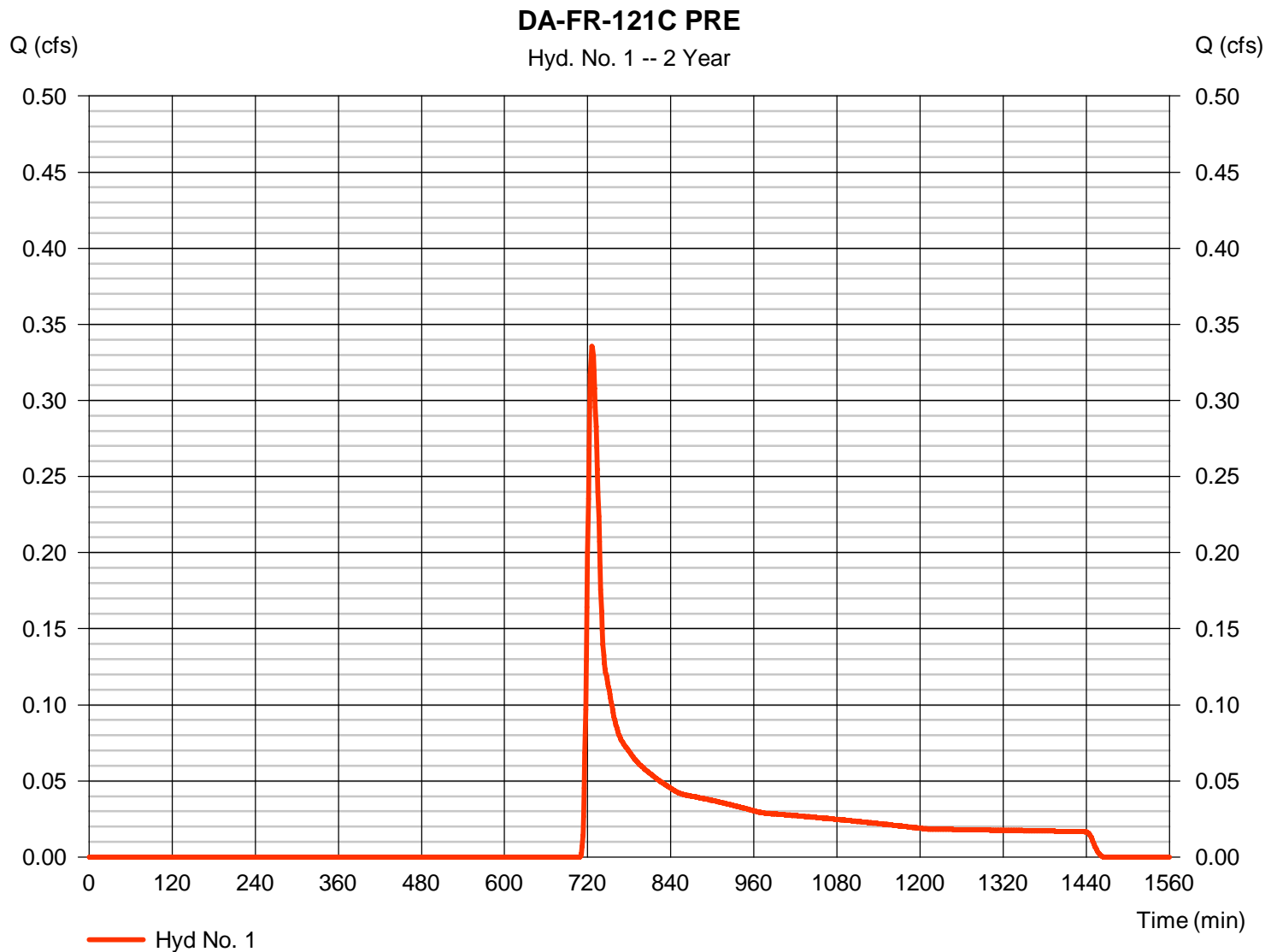
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-121C PRE

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 1.098 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.335 cfs
 Time to peak = 726 min
 Hyd. volume = 1,677 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.30 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

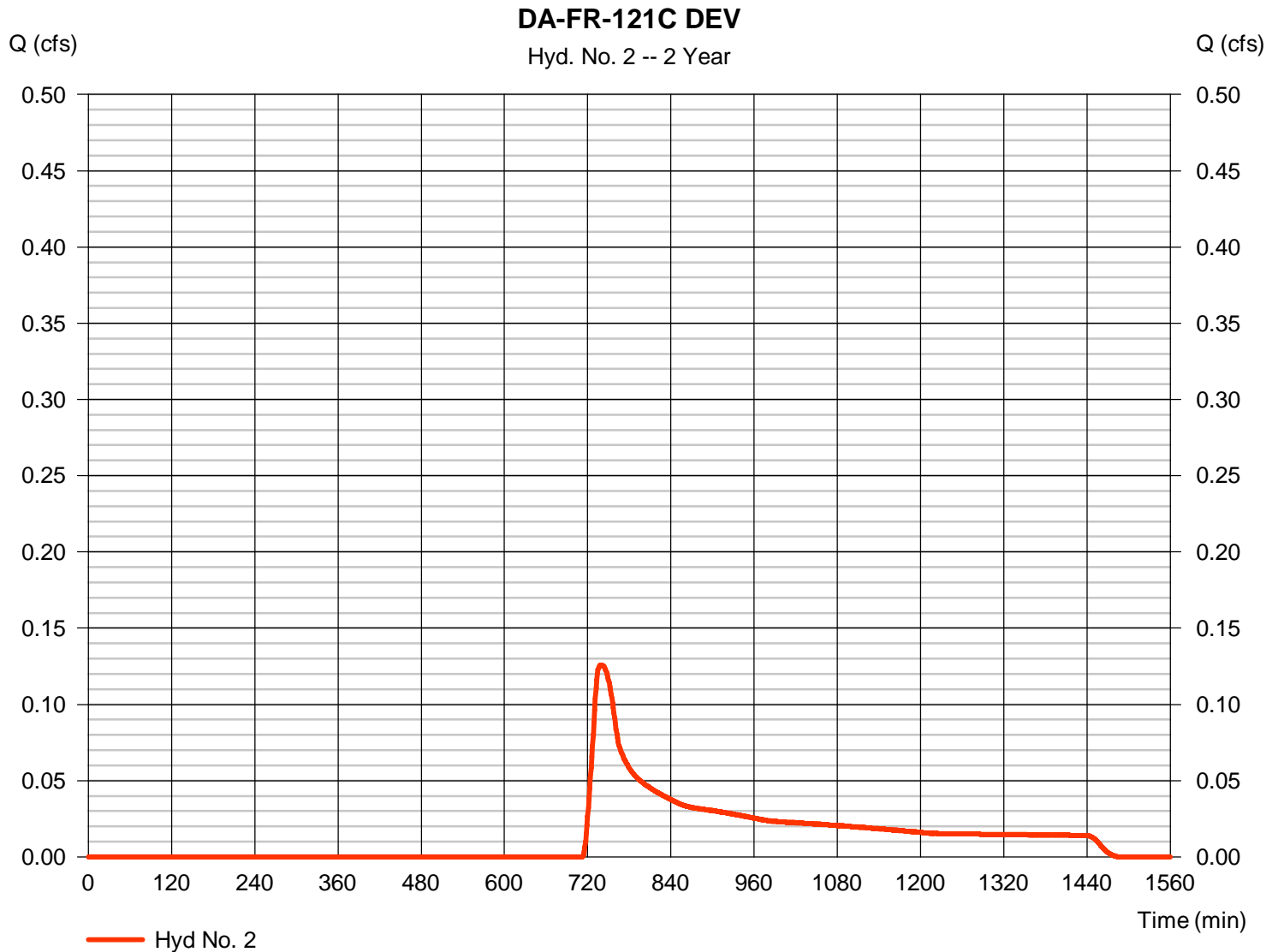
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-121C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.126 cfs
Storm frequency	= 2 yrs	Time to peak	= 740 min
Time interval	= 1 min	Hyd. volume	= 1,238 cuft
Drainage area	= 1.100 ac	Curve number	= 52*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 29.20 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.628 \times 48) + (0.470 \times 58)] / 1.100$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

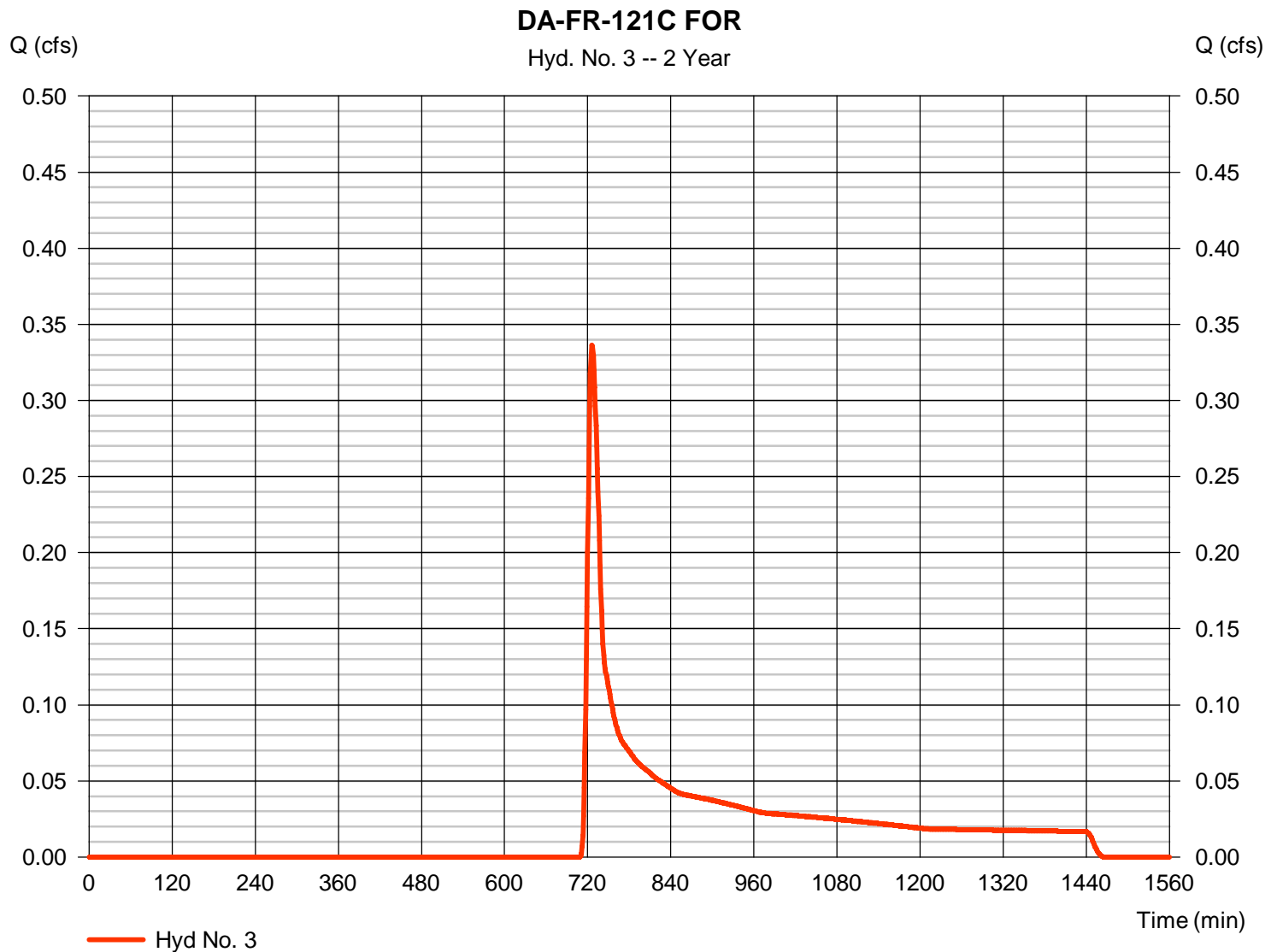
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-121C FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 1.100 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.336 cfs
 Time to peak = 726 min
 Hyd. volume = 1,680 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.30 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	1.697	1	724	5,441	-----	-----	-----	DA-FR-121C PRE
2	SCS Runoff	0.891	1	734	4,532	-----	-----	-----	DA-FR-121C DEV
3	SCS Runoff	1.700	1	724	5,452	-----	-----	-----	DA-FR-121C FOR
DA-FR-121C_Hydraflow.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

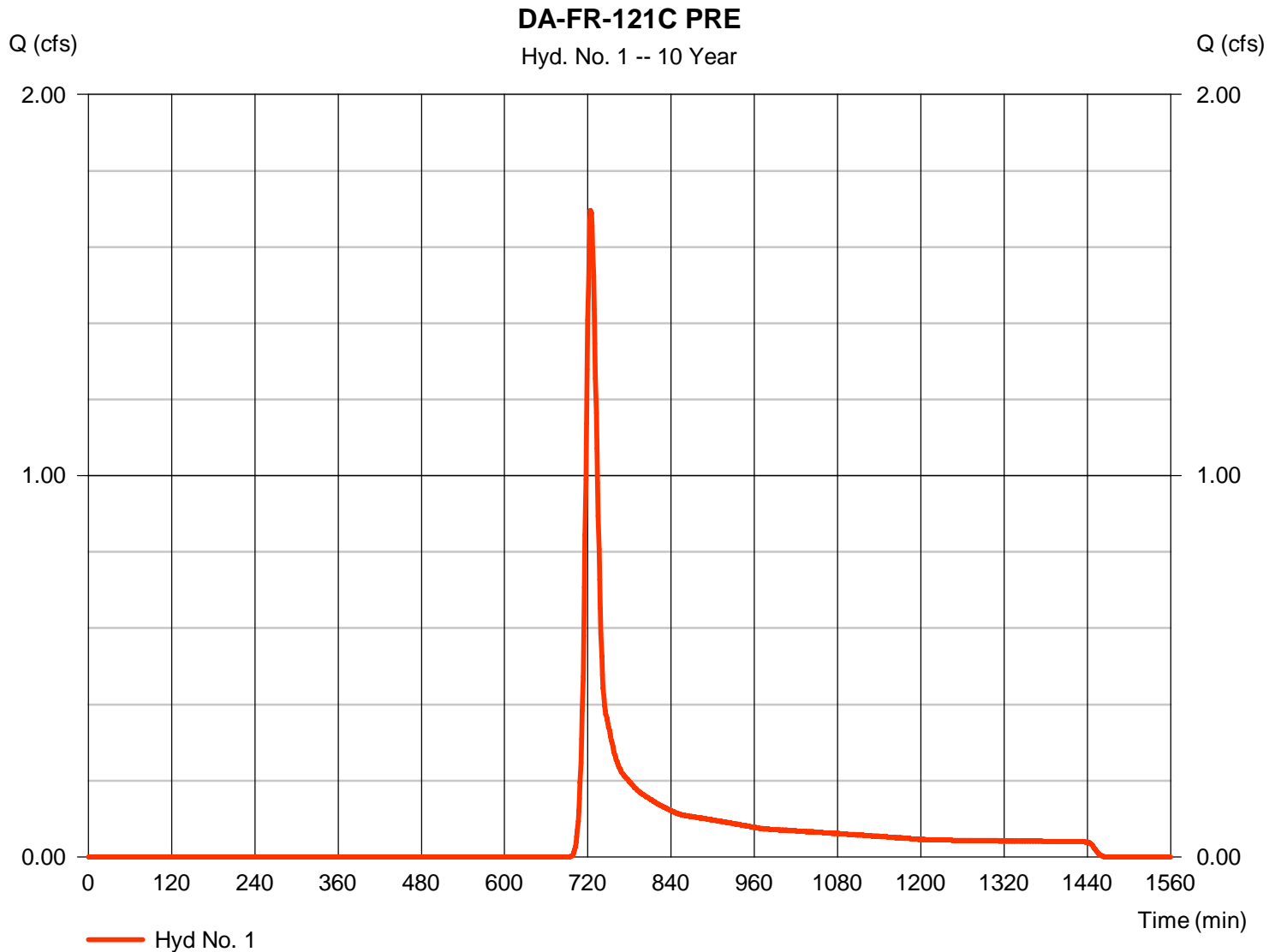
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-121C PRE

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 1.098 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 1.697 cfs
 Time to peak = 724 min
 Hyd. volume = 5,441 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.30 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

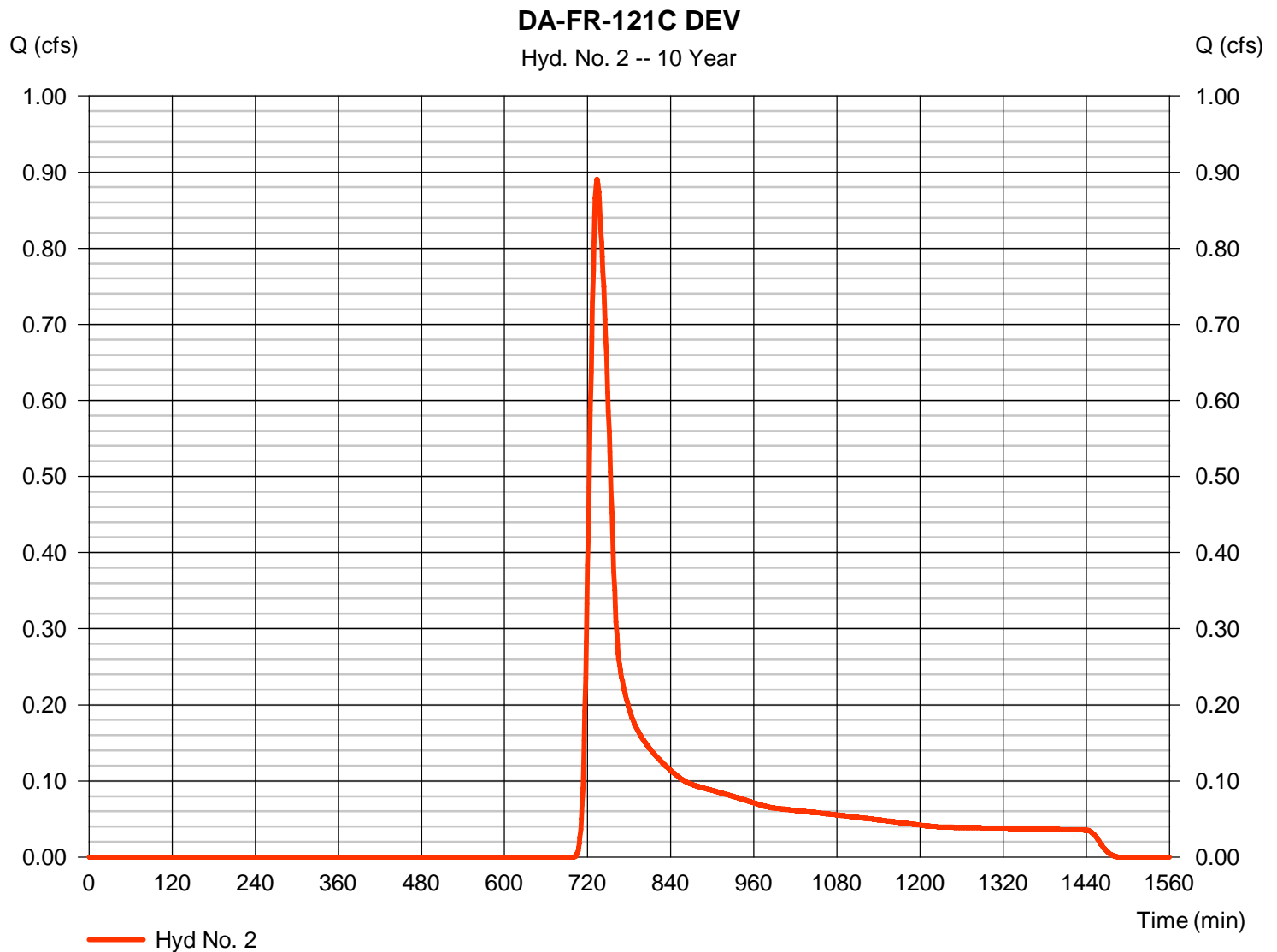
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-121C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.891 cfs
Storm frequency	= 10 yrs	Time to peak	= 734 min
Time interval	= 1 min	Hyd. volume	= 4,532 cuft
Drainage area	= 1.100 ac	Curve number	= 52*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 29.20 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.628 \times 48) + (0.470 \times 58)] / 1.100$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

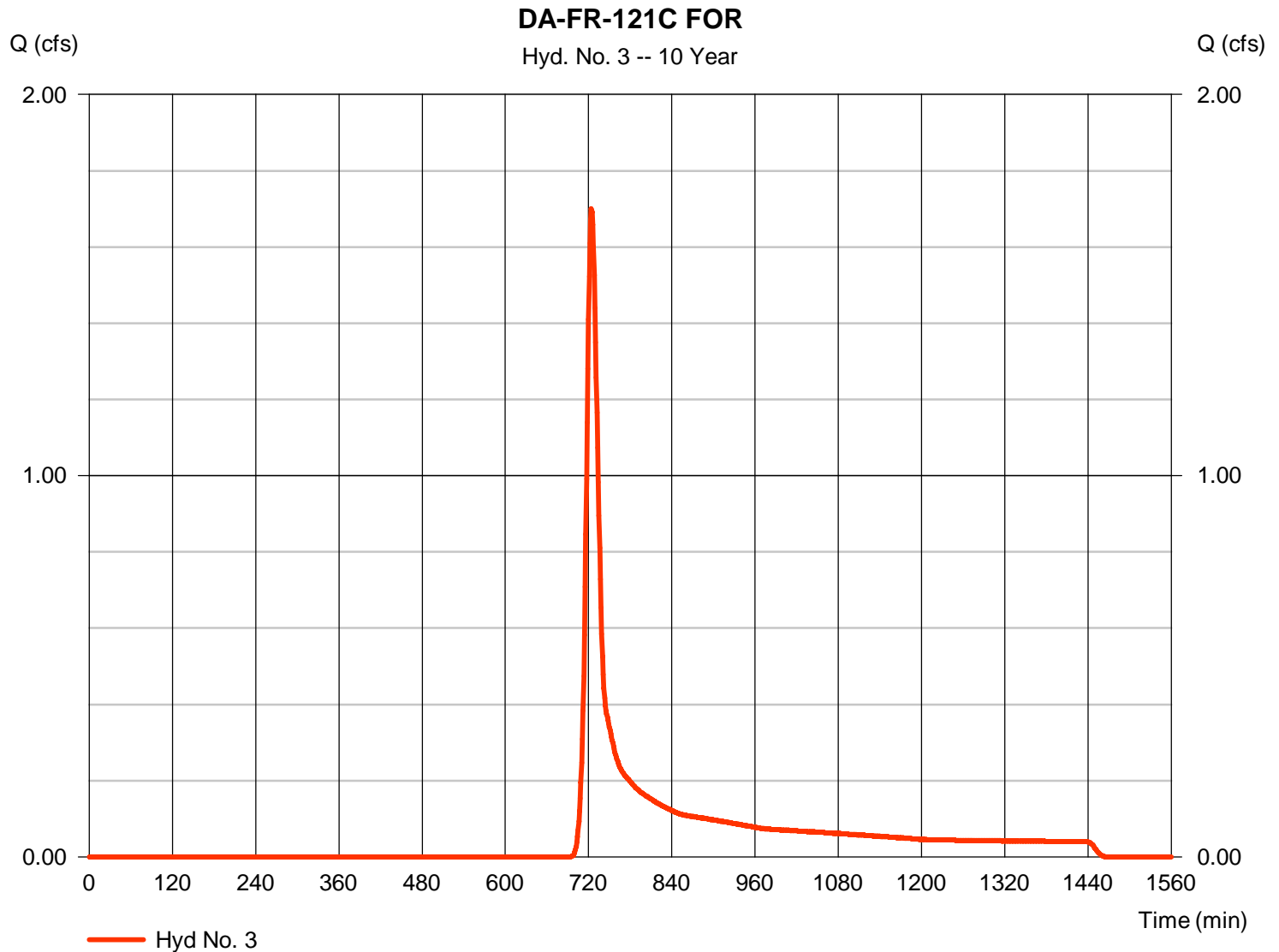
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-121C FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 1.100 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 1.700 cfs
 Time to peak = 724 min
 Hyd. volume = 5,452 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.30 min
 Distribution = Type II
 Shape factor = 484



DA-FR-122

DA-FR-122 is located in a meadow and forested areas with rolling slopes and contains existing dirt road and houses. The total phosphorus load reduction required for DA-FR-122 is -1.02 lb/yr. Total phosphorus load reduction is not required for DA-FR-122.

Multiple points of analysis were evaluated within DA-FR-122 to evaluate the effects on each receiving stream/channel following construction. Specifically, DA-FR-122 was subdivided into six sub-drainage areas (sub-areas A through F).

Sub-areas 122E and 122F contain both agricultural and non-agricultural areas within the limits of disturbance (LOD). Pre-construction agricultural areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction. In non-agricultural areas, land use will be restored following construction as noted in the Stormwater Management (SWM) Narrative and the Annual Standards and Specifications. Agricultural areas within the LOD are included in the SWM quality analysis and the total permanent Right of Way (ROW) is analyzed via VRRM; in these calculations agricultural areas are considered "Forest/Open Space".

Stormwater quantity is met via the energy balance method for each of the six sub-areas DA-FR-122A through DA-FR-122F. Agricultural areas within the study area are included in the SWM analysis, but an Improvement Factor (IF) of 1.0 is used when applying the Energy Balance Method. This improvement factor is used to account for the exemption of agricultural areas (§ 62.1-44.15:34 and 9VAC25-870-300) since such areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction.

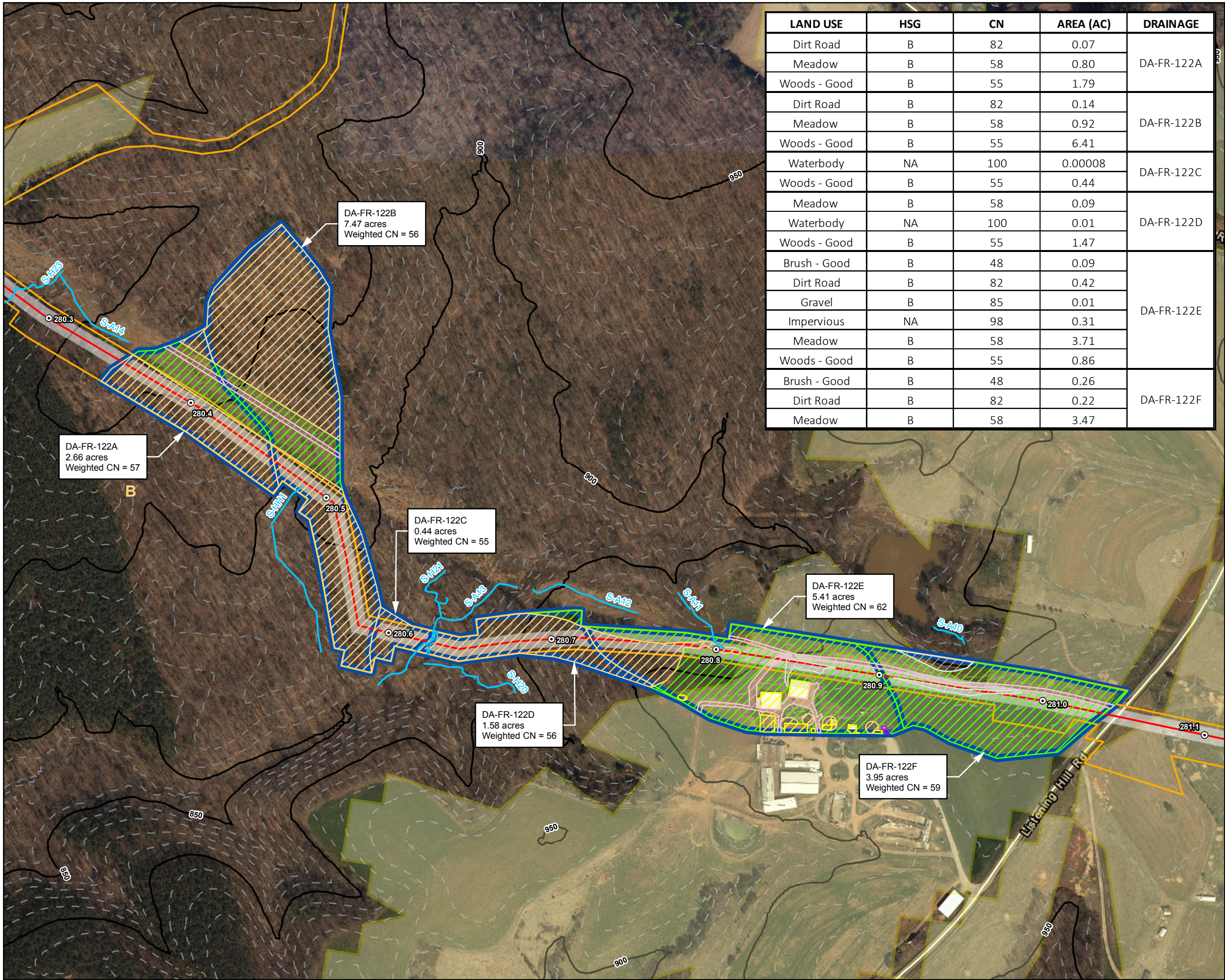
In addition, the Hydraflow Hydrograph's 10-year 24-hour peak discharge results indicate a reduction in flows ranging from 0 to 0.84 cfs for all drainage areas (as seen in table below).

Sub Area	Pre Peak Flow, 10-yr Q (cfs)	Post Peak Flow, Q 10-yr (cfs)	Flow differential
DA-FR-122A	4.98	4.36	-0.62
DA-FR-122B	12.38	11.54	-0.84
DA-FR-122C	0.89	0.77	-0.12
DA-FR-122D	3.20	2.56	-0.64
DA-FR-122E	13.34	13.34	0
DA-FR-122F	7.89	7.89	0

Figures and calculations for each of the sub-areas for DA-FR-122 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.

Note that the sub-areas 122E and 122F had time of concentration flow paths for the Post-Construction condition that accounted for a permanent water bar that is not cited within the drainage area. This permanent water bar was removed because it was cited

in an agricultural area, and resulting changes to the stormwater calculations were flagged during the QA/QC review process. This change was considered to be inconsequential because no stormwater BMPs are sited in DA-FR-122E or 122F, so the resulting changes were not made to the stormwater calculations prior to submittal.



LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Dirt Road	B	82	0.07	DA-FR-122A
Meadow	B	58	0.80	
Woods - Good	B	55	1.79	
Dirt Road	B	82	0.14	DA-FR-122B
Meadow	B	58	0.92	
Woods - Good	B	55	6.41	
Waterbody	NA	100	0.00008	DA-FR-122C
Woods - Good	B	55	0.44	
Meadow	B	58	0.09	
Waterbody	NA	100	0.01	DA-FR-122D
Woods - Good	B	55	1.47	
Brush - Good	B	48	0.09	
Dirt Road	B	82	0.42	DA-FR-122E
Gravel	B	85	0.01	
Impervious	NA	98	0.31	
Meadow	B	58	3.71	
Woods - Good	B	55	0.86	
Brush - Good	B	48	0.26	
Dirt Road	B	82	0.22	DA-FR-122F
Meadow	B	58	3.47	

Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Dirt Road
- Gravel
- Impervious
- Meadow
- Waterbody
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)
1:3,600

300 150 0 300 Feet



Mountain Valley Pipeline Project

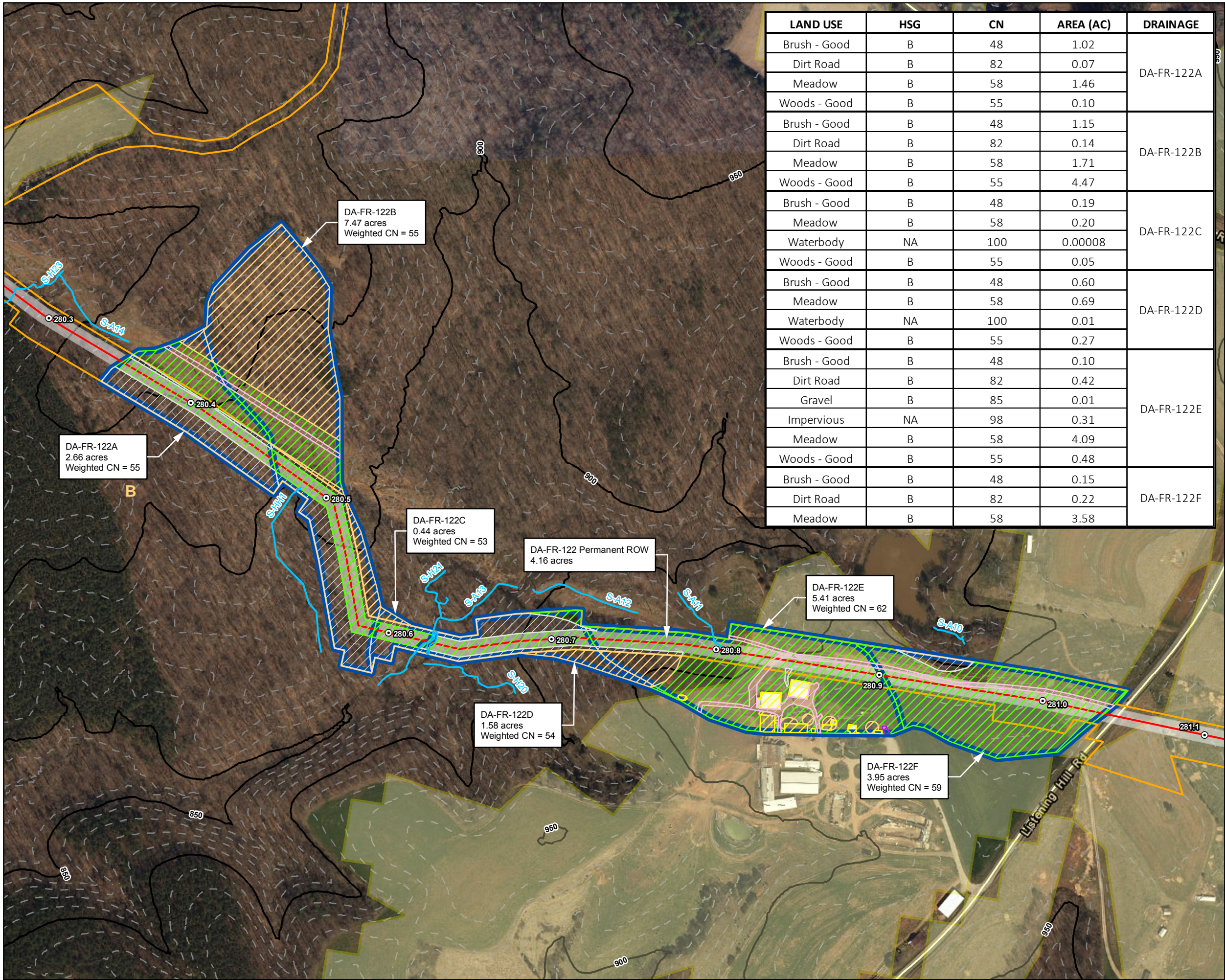


Pre-Construction Drainage Area Map
DA-FR-122
Spread 11

Figure 1
Franklin County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.



LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Brush - Good	B	48	1.02	DA-FR-122A
Dirt Road	B	82	0.07	
Meadow	B	58	1.46	
Woods - Good	B	55	0.10	DA-FR-122B
Brush - Good	B	48	1.15	
Dirt Road	B	82	0.14	
Meadow	B	58	1.71	
Woods - Good	B	55	4.47	DA-FR-122C
Brush - Good	B	48	0.19	
Meadow	B	58	0.20	
Waterbody	NA	100	0.00008	
Woods - Good	B	55	0.05	DA-FR-122D
Brush - Good	B	48	0.60	
Meadow	B	58	0.69	
Waterbody	NA	100	0.01	
Woods - Good	B	55	0.27	DA-FR-122E
Brush - Good	B	48	0.10	
Dirt Road	B	82	0.42	
Gravel	B	85	0.01	
Impervious	NA	98	0.31	
Meadow	B	58	4.09	DA-FR-122F
Woods - Good	B	55	0.48	
Brush - Good	B	48	0.15	
Dirt Road	B	82	0.22	
Meadow	B	58	3.58	

Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Dirt Road
- Gravel
- Impervious
- Meadow
- Waterbody
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)
1:3,600

300 150 0 300 Feet

W N E S



Mountain Valley Pipeline Project

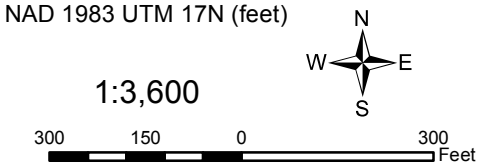
Post-Construction Drainage Area Map
DA-FR-122
Spread 11
Figure 2
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

Document Path: P:\GIS\EQ1_MVP\MapDocs\Drainage\Franklin\WVP_PCSM_DA-FR-122_Post.mxd

PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI						
	SHEET 1	SHEET 2	SHEET 3	SHALLOW	CHANNEL	Calculated Time of Concentration (min)
DA-FR-122A	57.29 FT @ 4.08%	31.16 FT @ 11.70%	11.55 FT @ 0.87%	396.55 FT @ 10.69%	-	15.0
DA-FR-122B	100.00 FT @ 6.89%	-	-	332.22 FT @ 11.77%	472.64 FT @ 5.94%	15.5
DA-FR-122C	100.00 FT @ 16.09%	-	-	101.97 FT @ 15.18%	-	8.9
DA-FR-122D	100.00 FT @ 9.41%	-	-	267.64 FT @ 12.69%	-	11.5
DA-FR-122E	100.00 FT @ 5.94%	-	-	474.48 FT @ 9.97%	-	14.5
DA-FR-122F	100.00 FT @ 4.12%	-	-	297.54 FT @ 12.41%	-	15.8

- Legend**
- Milepost
 - Delineated Stream
 - Existing 50' Contour
 - Existing 10' Contour
 - Road Centerline
 - Alignment Centerline
 - Limit of Disturbance
 - Permanent Right-of-Way
 - Time of Concentration
 - Drainage Area



Mountain Valley Pipeline Project



**Pre-Construction Drainage Area
and Time of Concentration
DA-FR-122
Spread 11**

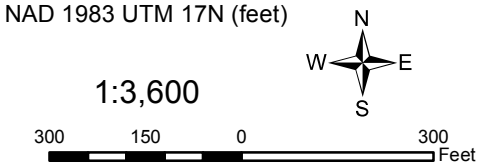
Figure 3
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.

Document Path: P:\GIS\EQ1_MVP\Mapdocs\Drainage\Figures 3-4\MVP_PCSM_DA-FR-122_3.mxd

POST-CONSTRUCTION TIME OF CONCENTRATION TO POI									
	SHEET 1	SHEET 2	SHEET 3	SHALLOW1	SHALLOW2	SHALLOW3	CHANNEL1	CHANNEL2	Calculated Time of Concentration (min)
DA-FR-122A	57.29 FT @ 4.08%	31.16 FT @ 11.70%	11.55 FT @ 0.87%	396.55 FT @ 10.69%	-	-	-	-	15.0
DA-FR-122B	100.00 FT @ 6.89%	-	-	332.33 FT @ 11.77%	-	-	472.64 FT @ 5.94%	-	15.5
DA-FR-122C	100.00 FT @ 16.09%	-	-	101.97 FT @ 15.18%	-	-	-	-	8.9
DA-FR-122D	100.00 FT @ 9.41%	-	-	219.47 FT @ 6.34%	88.01 FT @ 13.62%	-	31.65 FT @ 5.09%	-	12.0
DA-FR-122E	100.00 FT @ 5.94%	-	-	233.55 FT @ 8.98%	143.58 FT @ 16.60%	-	21.31 FT @ 3.31%	-	14.2
DA-FR-122F	100.00 FT @ 4.12%	-	-	27.04 FT @ 6.98%	145.41 FT @ 8.62%	123.95 FT @ 16.16%	55.79 FT @ 4.20%	5.84 FT @ 2.46%	16.1

- Legend
- Milepost
 - Permanent Waterbars
 - Delineated Stream
 - Existing 50' Contour
 - Existing 10' Contour
 - Road Centerline
 - Alignment Centerline
 - Limit of Disturbance
 - Permanent Right-of-Way
 - Time of Concentration
 - Drainage Area



Mountain Valley Pipeline Project



Post-Construction Drainage Area and Time of Concentration
DA-FR-122
Spread 11

Figure 4
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.

Document Path: P:\GIS\EQT_MVP\MapDocs\Drainage\Figures 3-4\MVP_PCSM_DA-FR-122_4.mxd

DEQ Virginia Runoff Reduction Method Re-Development Compliance Spreadsheet - Version 3.0

BMP Design Specifications List: 2013 Draft Stds & Specs

Site Summary - Linear Development Project***

Total Rainfall (in):	43
Total Disturbed Acreage:	4.16

Site Land Cover Summary

Pre-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	3.97	0.00	0.00	3.97	95
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.19	0.00	0.00	0.19	5
					4.16	100

Post-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	3.97	0.00	0.00	3.97	95
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.19	0.00	0.00	0.19	5
					4.16	100

* Forest/Open Space areas must be protected in accordance with the Virginia Runoff Reduction Method

Site Tv and Land Cover Nutrient Loads

	Final Post-Development (Post-ReDevelopment & New Impervious)	Post- ReDevelopment	Post- Development (New Impervious)	Adjusted Pre- ReDevelopment
Site Rv	0.07	0.07	--	0.07
Treatment Volume (ft ³)	1,088	1,088	--	1,088
TP Load (lb/yr)	0.68	0.68	--	0.68

Baseline TP Load (lb/yr): 1.7056* *Reduction below new development load limitation not required

Pre- ReDevelopment TP Load per acre (lb/acre/yr)	Final Post-Development TP Load per acre (lb/acre/yr)	Post-ReDevelopment TP Load per acre (lb/acre/yr)
0.16	0.16	0.16

Total TP Load Reduction Required (lb/yr)	-1.02	N/A***	N/A***
--	-------	--------	--------

***This is a linear development project

	Final Post-Development Load (Post-ReDevelopment & New Impervious)	Pre- ReDevelopment
TN Load (lb/yr)	4.89	4.89

Site Compliance Summary - ***Linear Development Project

Maximum % Reduction Required Below Pre-ReDevelopment Load	20%
--	-----

* Note: % Reduction will reduce post-development TP load to less than or equal to baseline load of 1.71 lb/yr (0.41 lb/ac/yr)
 [Post-Dev Reduction Requirement = Post-Dev TP load - baseline load of 1.71 lb/yr], baseline load = site area x 0.41 lb/ac/yr

Total Runoff Volume Reduction (ft ³)	0
--	---

Total TP Load Reduction Achieved (lb/yr)	0.00
Total TN Load Reduction Achieved (lb/yr)	0.00
Remaining Post Development TP Load (lb/yr)	0.68
Remaining TP Load Reduction (lb/yr) Required	0.00

**** TARGET TP REDUCTION EXCEEDED BY 1.02 LB/YEAR ****

**Reduction below new development load limitation not required*

DA-FR-122A

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.670	3318
Developed Condition	0.439	2714
Pre-Developed (Forest) Condition	0.439	2714

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	0.439	\leq OK	0.655
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.439	\leq OK	0.670
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ ---->	0.439	<u>shall not</u> be required to be \leq	0.439

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s n value of 0.011 was used.</p> <p><i>Sources:</i></p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-122A PRE
2	SCS Runoff	DA-FR-122A DEV
3	SCS Runoff	DA-FR-122A FOR

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.670	1	725	3,318	-----	-----	-----	DA-FR-122A PRE
2	SCS Runoff	0.439	1	726	2,714	-----	-----	-----	DA-FR-122A DEV
3	SCS Runoff	0.439	1	726	2,714	-----	-----	-----	DA-FR-122A FOR
DA-FR-122A_Hydraflow.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

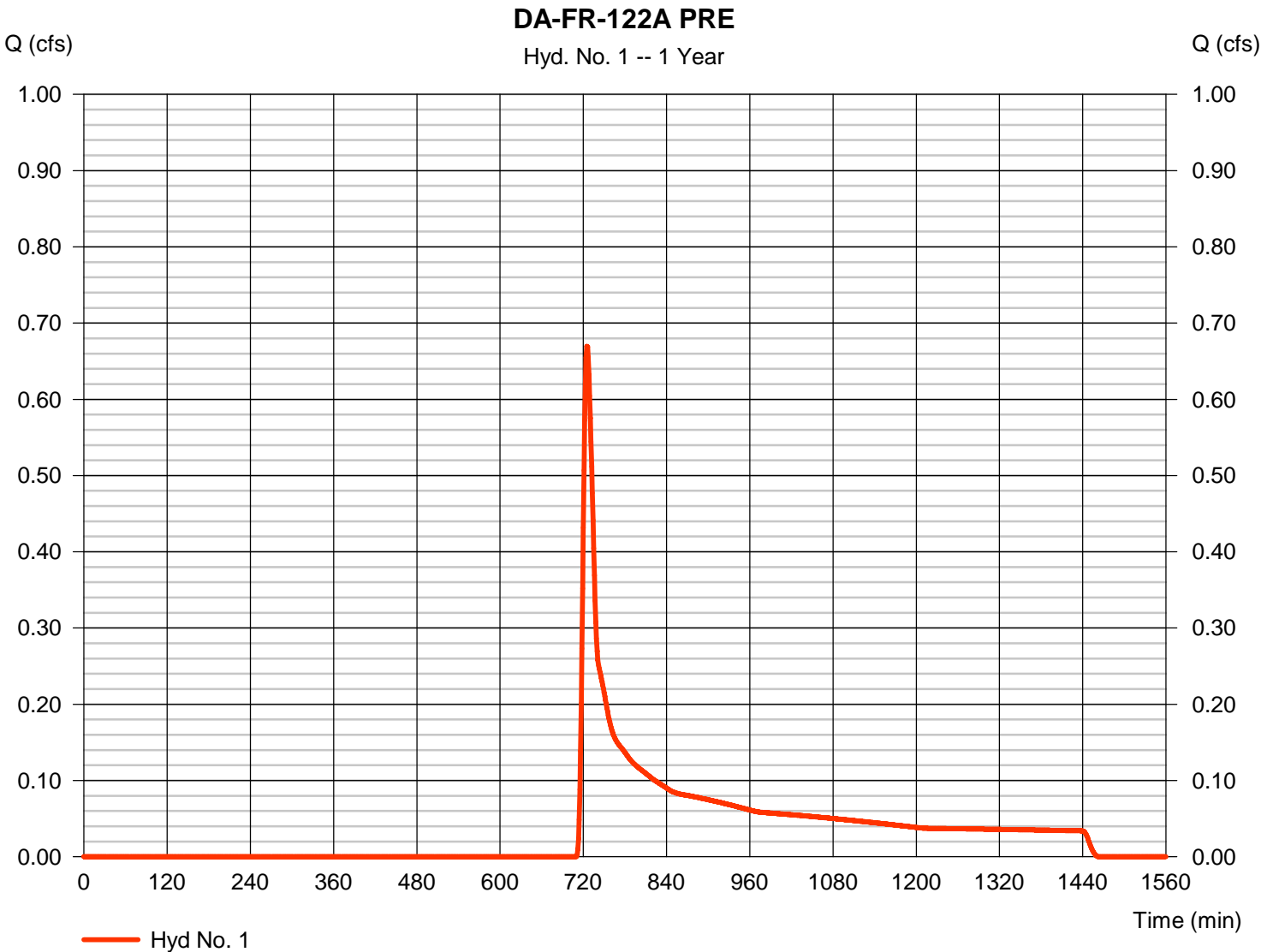
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-122A PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.670 cfs
Storm frequency	=	1 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	3,318 cuft
Drainage area	=	2.660 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	15.00 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.072 x 82) + (0.799 x 58) + (1.788 x 55)] / 2.660



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-122A PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.011				
Flow length (ft)	= 57.3	31.2	11.6				
Two-year 24-hr precip. (in)	= 3.70	3.70	3.70				
Land slope (%)	= 4.08	11.70	0.87				
Travel Time (min)	= 9.62	+	3.88	+	0.28	=	13.77
Shallow Concentrated Flow							
Flow length (ft)	= 396.53	0.00	0.00				
Watercourse slope (%)	= 10.69	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.28	0.00	0.00				
Travel Time (min)	= 1.25	+	0.00	+	0.00	=	1.25
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				15.00 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

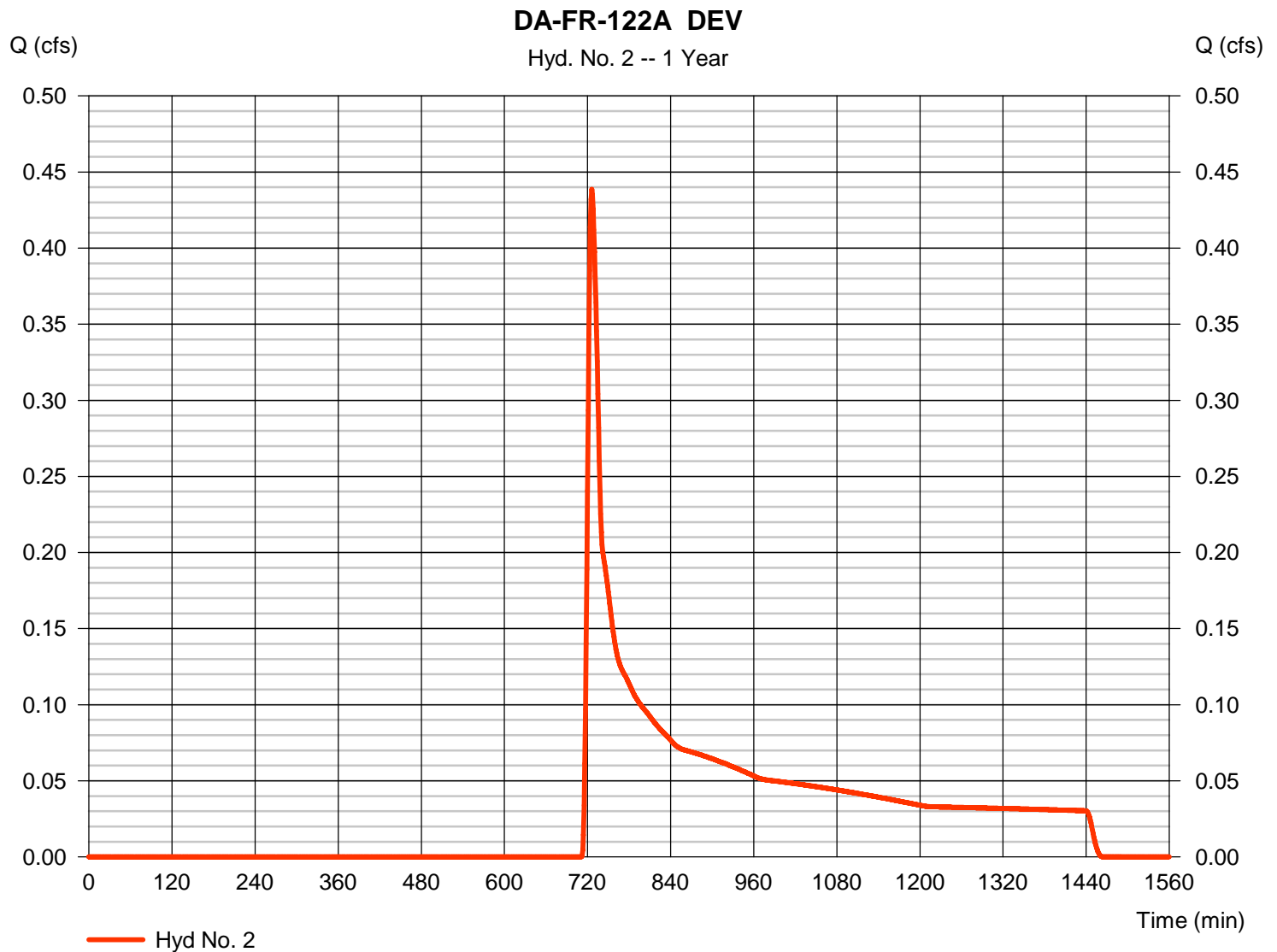
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-122A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.439 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 2,714 cuft
Drainage area	= 2.660 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.00 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.022 \times 48) + (0.072 \times 82) + (1.461 \times 58) + (0.104 \times 55)] / 2.660$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-122A DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.400	0.011	
Flow length (ft)	= 57.3	31.2	11.6	
Two-year 24-hr precip. (in)	= 3.70	3.70	3.70	
Land slope (%)	= 4.08	11.70	0.87	
Travel Time (min)	= 9.62	+	3.88	+
			0.28	= 13.77
Shallow Concentrated Flow				
Flow length (ft)	= 396.55	0.00	0.00	
Watercourse slope (%)	= 10.69	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=5.28	0.00	0.00	
Travel Time (min)	= 1.25	+	0.00	+
			0.00	= 1.25
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				15.00 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

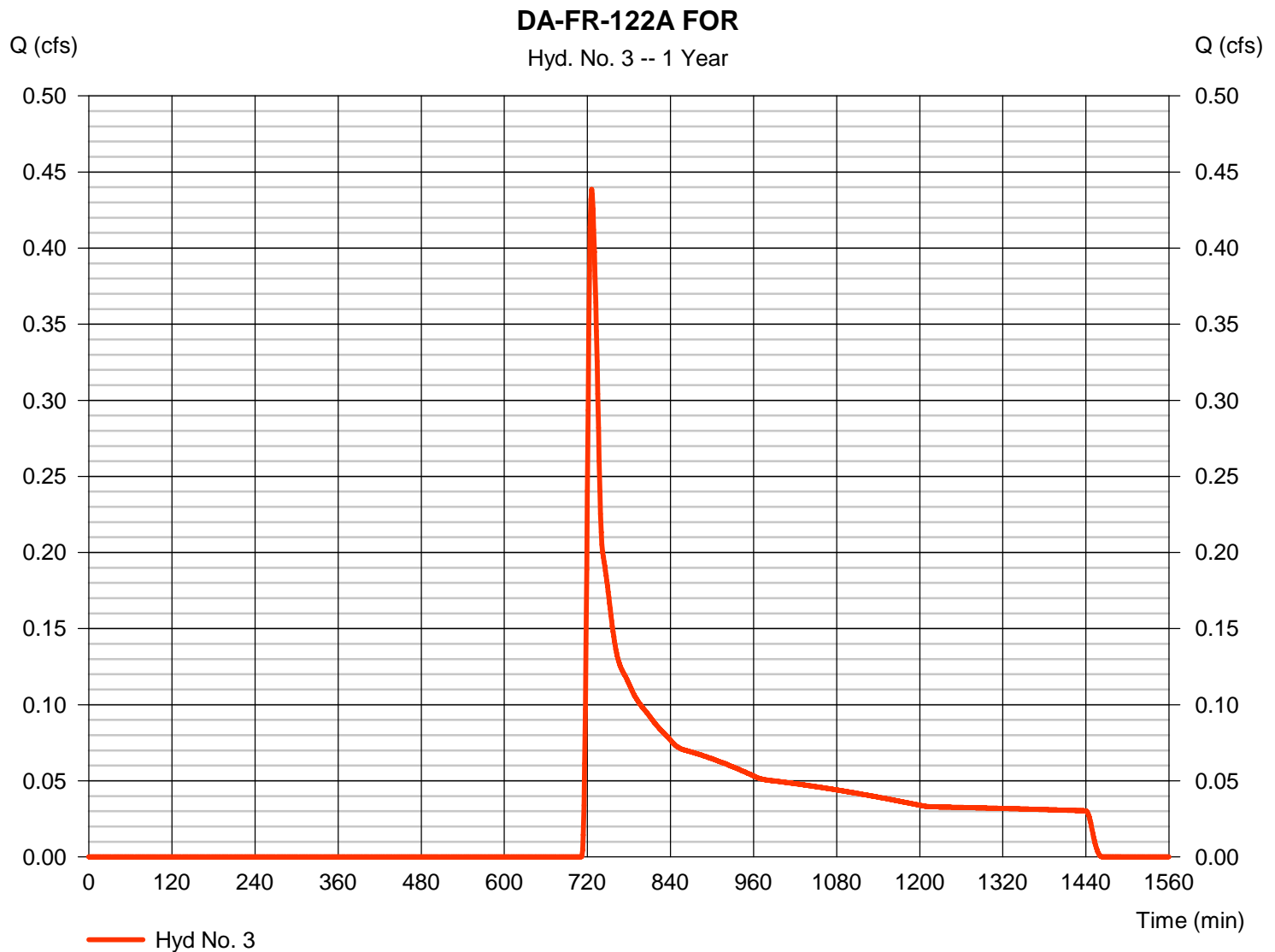
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-122A FOR

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 2.660 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.30 in
 Storm duration = 24 hrs

Peak discharge = 0.439 cfs
 Time to peak = 726 min
 Hyd. volume = 2,714 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.00 min
 Distribution = Type II
 Shape factor = 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-122A FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.011				
Flow length (ft)	= 57.3	31.2	11.6				
Two-year 24-hr precip. (in)	= 3.70	3.70	3.70				
Land slope (%)	= 4.08	11.70	0.87				
Travel Time (min)	= 9.62	+	3.88	+	0.28	=	13.77
Shallow Concentrated Flow							
Flow length (ft)	= 396.53	0.00	0.00				
Watercourse slope (%)	= 10.69	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.28	0.00	0.00				
Travel Time (min)	= 1.25	+	0.00	+	0.00	=	1.25
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				15.00 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	1.190	1	725	4,762	-----	-----	-----	DA-FR-122A PRE
2	SCS Runoff	0.872	1	725	4,013	-----	-----	-----	DA-FR-122A DEV
3	SCS Runoff	0.872	1	725	4,013	-----	-----	-----	DA-FR-122A FOR
DA-FR-122A_Hydraflow.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

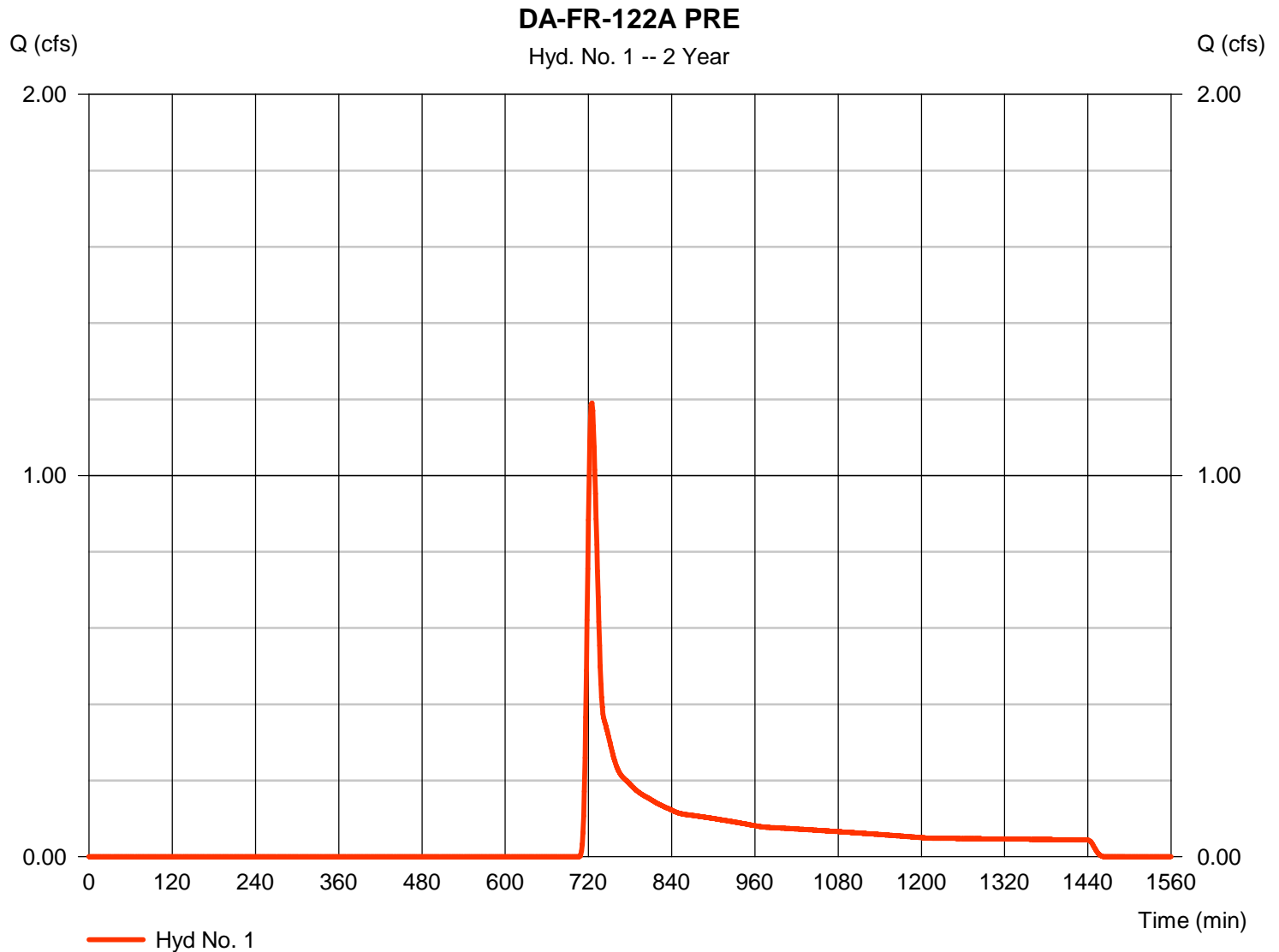
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-122A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 1.190 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 4,762 cuft
Drainage area	= 2.660 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.00 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.072 \times 82) + (0.799 \times 58) + (1.788 \times 55)] / 2.660$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

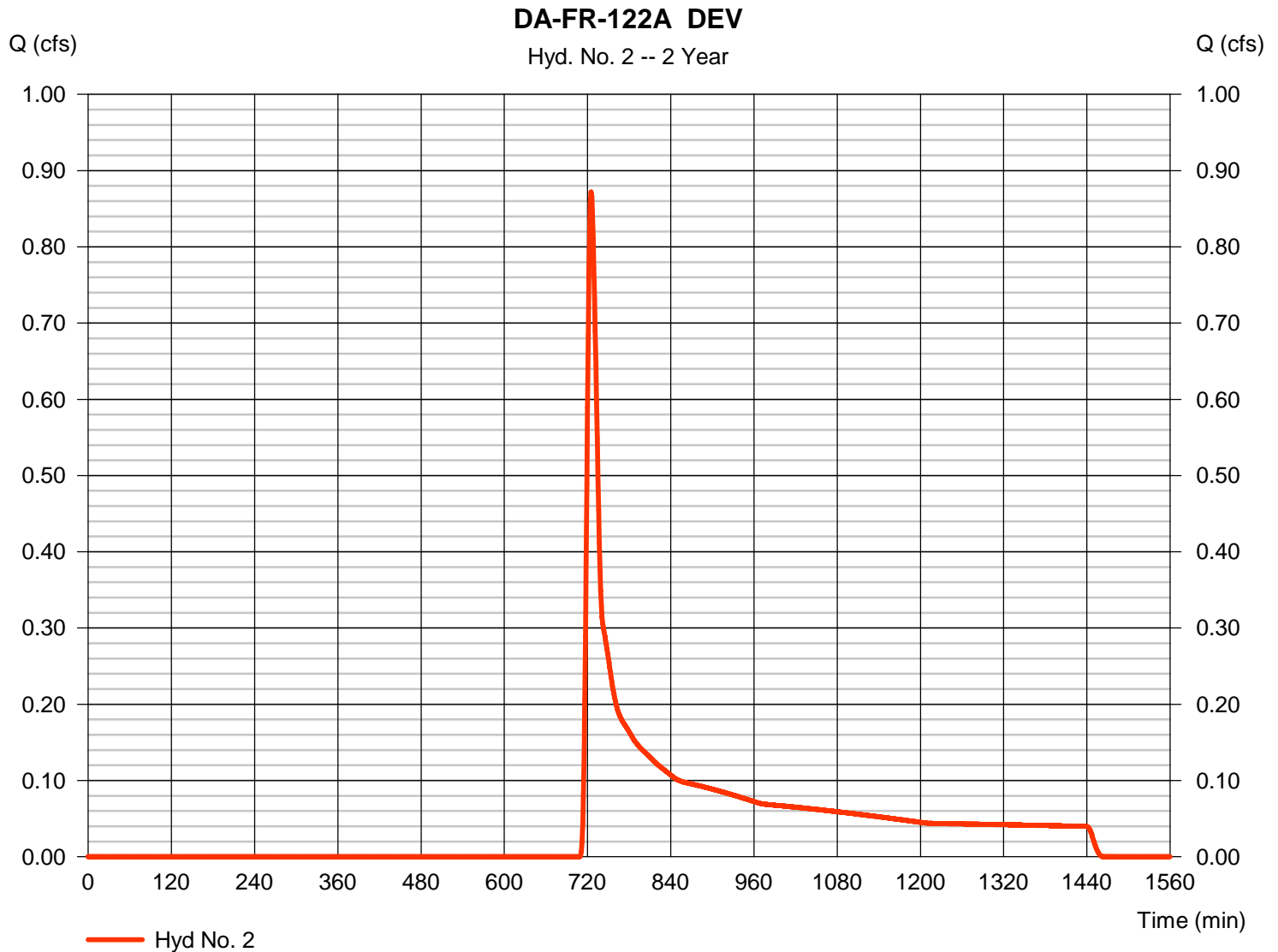
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-122A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.872 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 4,013 cuft
Drainage area	= 2.660 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.00 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.022 \times 48) + (0.072 \times 82) + (1.461 \times 58) + (0.104 \times 55)] / 2.660$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

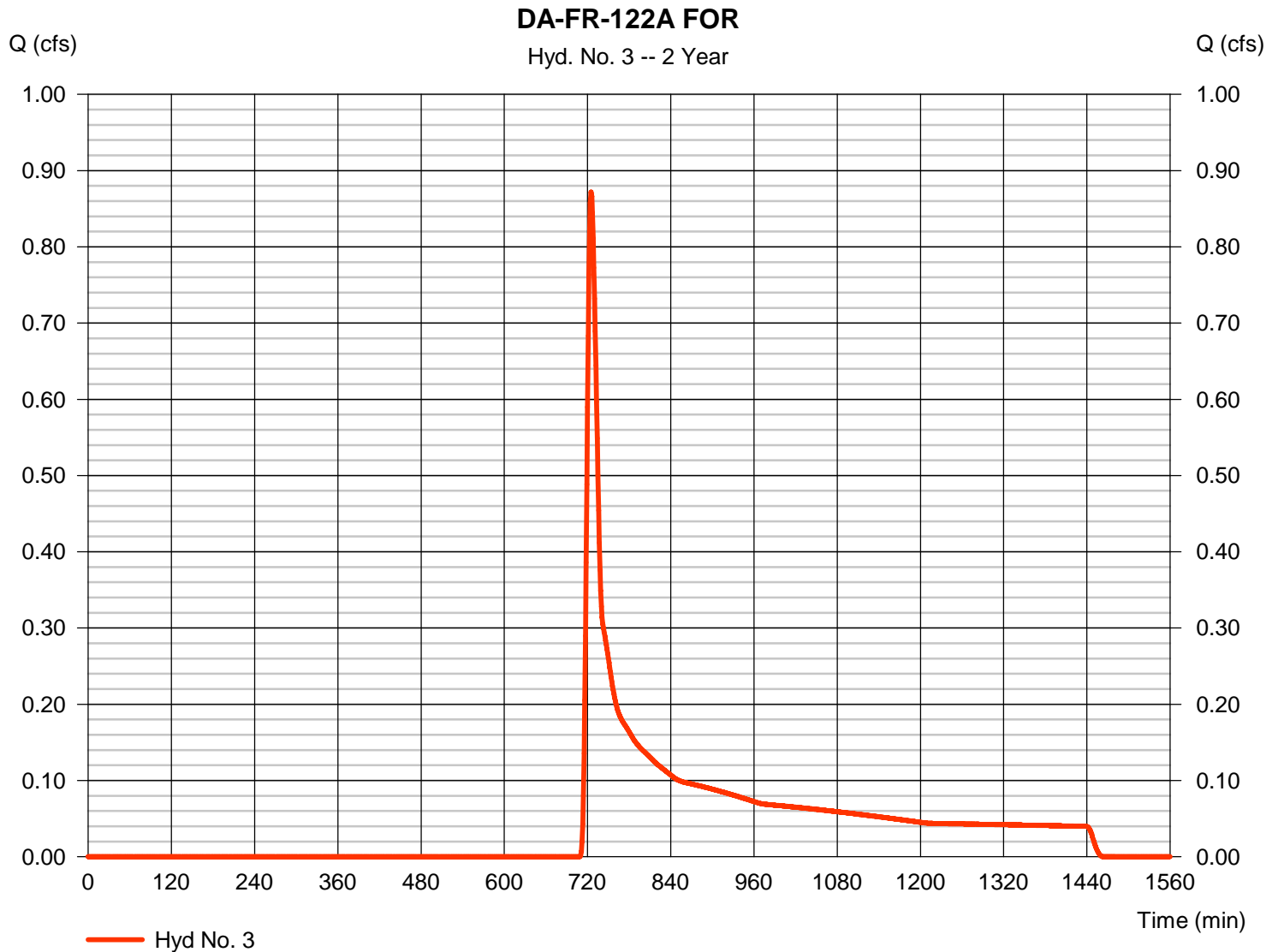
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-122A FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 2.660 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.872 cfs
 Time to peak = 725 min
 Hyd. volume = 4,013 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.00 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	4.977	1	723	14,454	-----	-----	-----	DA-FR-122A PRE
2	SCS Runoff	4.357	1	723	13,021	-----	-----	-----	DA-FR-122A DEV
3	SCS Runoff	4.357	1	723	13,021	-----	-----	-----	DA-FR-122A FOR
DA-FR-122A_Hydraflow.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

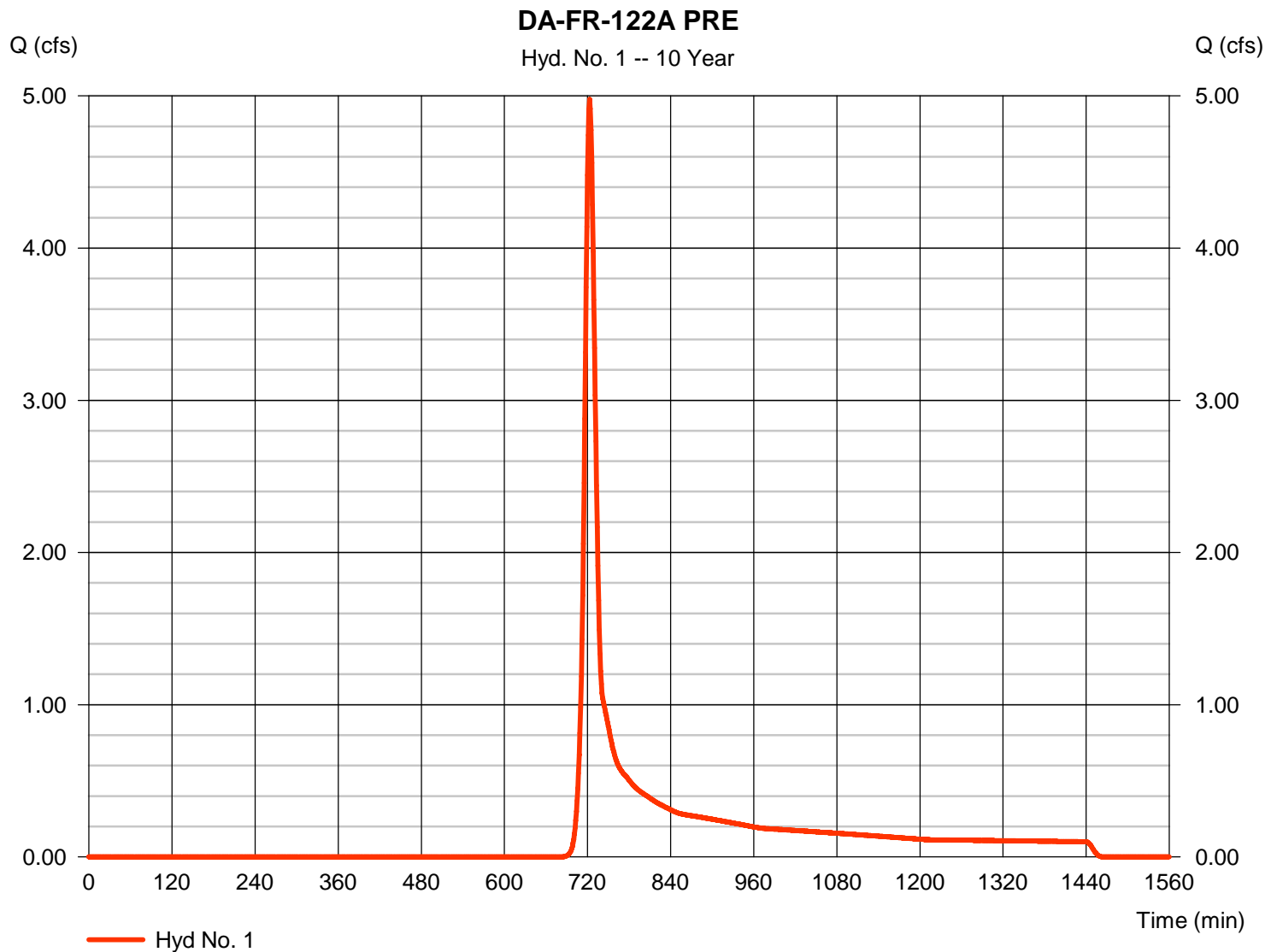
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-122A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 4.977 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 14,454 cuft
Drainage area	= 2.660 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.00 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.072 \times 82) + (0.799 \times 58) + (1.788 \times 55)] / 2.660$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

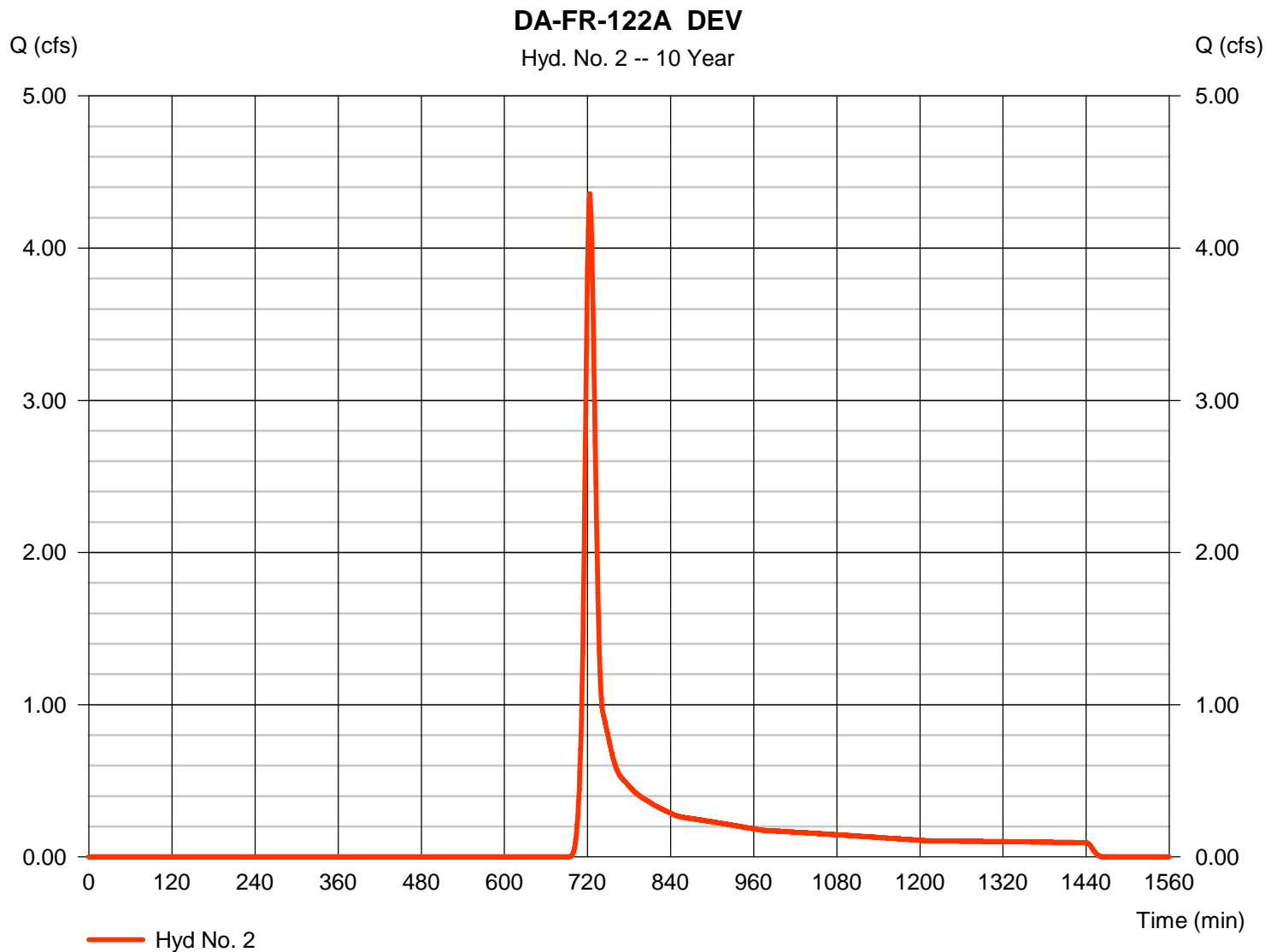
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-122A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 4.357 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 13,021 cuft
Drainage area	= 2.660 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.00 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.022 \times 48) + (0.072 \times 82) + (1.461 \times 58) + (0.104 \times 55)] / 2.660$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

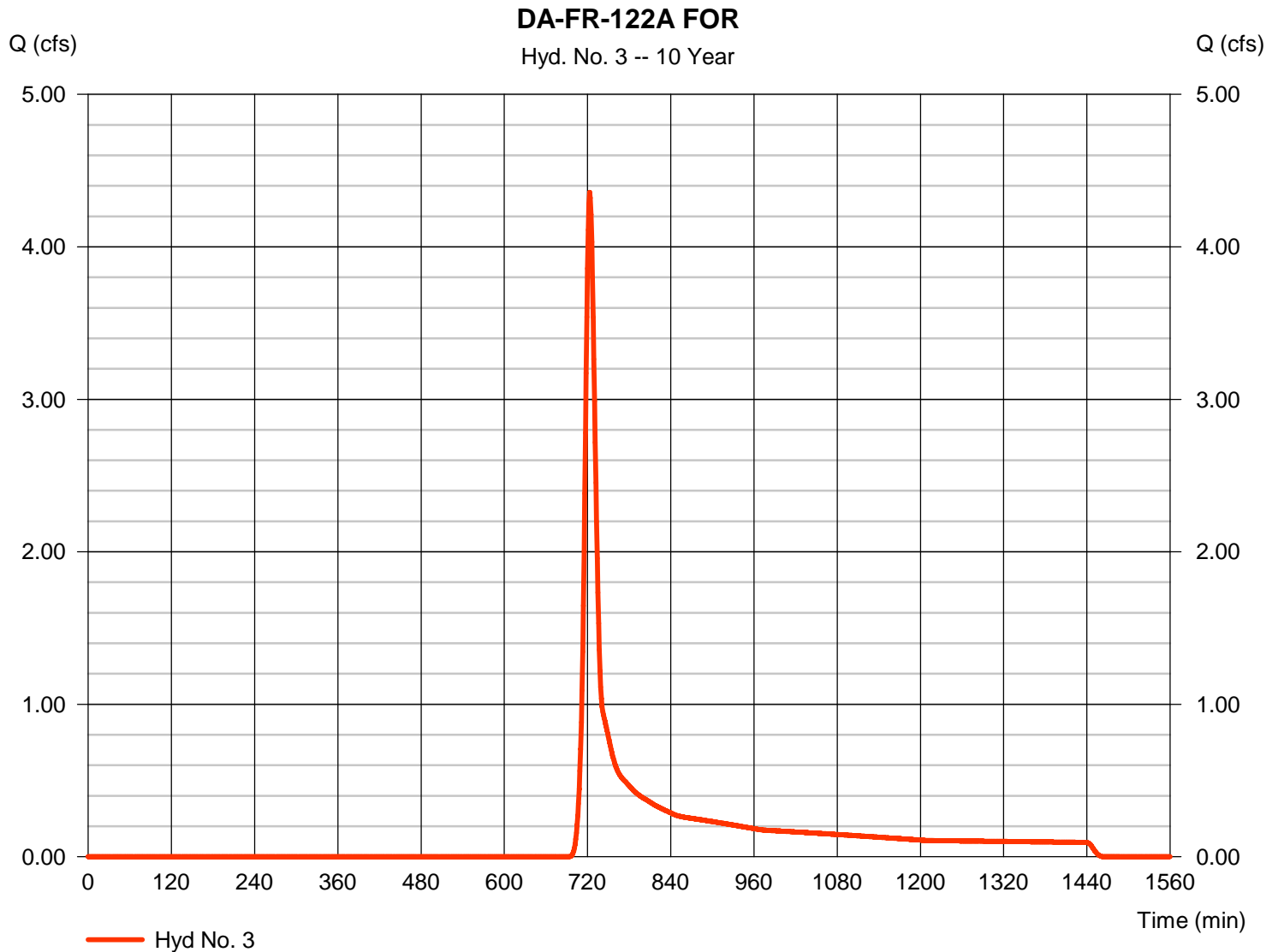
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-122A FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 2.660 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 4.357 cfs
 Time to peak = 723 min
 Hyd. volume = 13,021 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.00 min
 Distribution = Type II
 Shape factor = 484



DA-FR-122B

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	1.441	8556
Developed Condition	1.150	7717
Pre-Developed (Forest) Condition	0.633	7622

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	1.150	\leq OK	1.278
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	1.150	\leq OK	1.441
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ ---->	1.150	<u>shall not</u> be required to be \leq	0.625

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p><i>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</i></p> <p><i>For Paved Road land surface types a Manning’s n value of 0.011 was used.</i></p> <p><i>Sources:</i></p> <p><i>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</i></p> <p><i>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</i></p>	

Table 2 – Manning's *n* Values for Open Channel Flow

Channel Type	Manning <i>n</i>		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's <i>n</i> value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's <i>n</i> value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-122B PRE
2	SCS Runoff	DA-FR-122B DEV
3	SCS Runoff	DA-FR-122B FOR

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	1.441	1	727	8,556	-----	-----	-----	DA-FR-122B PRE
2	SCS Runoff	1.150	1	727	7,717	-----	-----	-----	DA-FR-122B DEV
3	SCS Runoff	0.633	1	755	7,622	-----	-----	-----	DA-FR-122B FOR
DA-FR-122B_Hydraflow.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

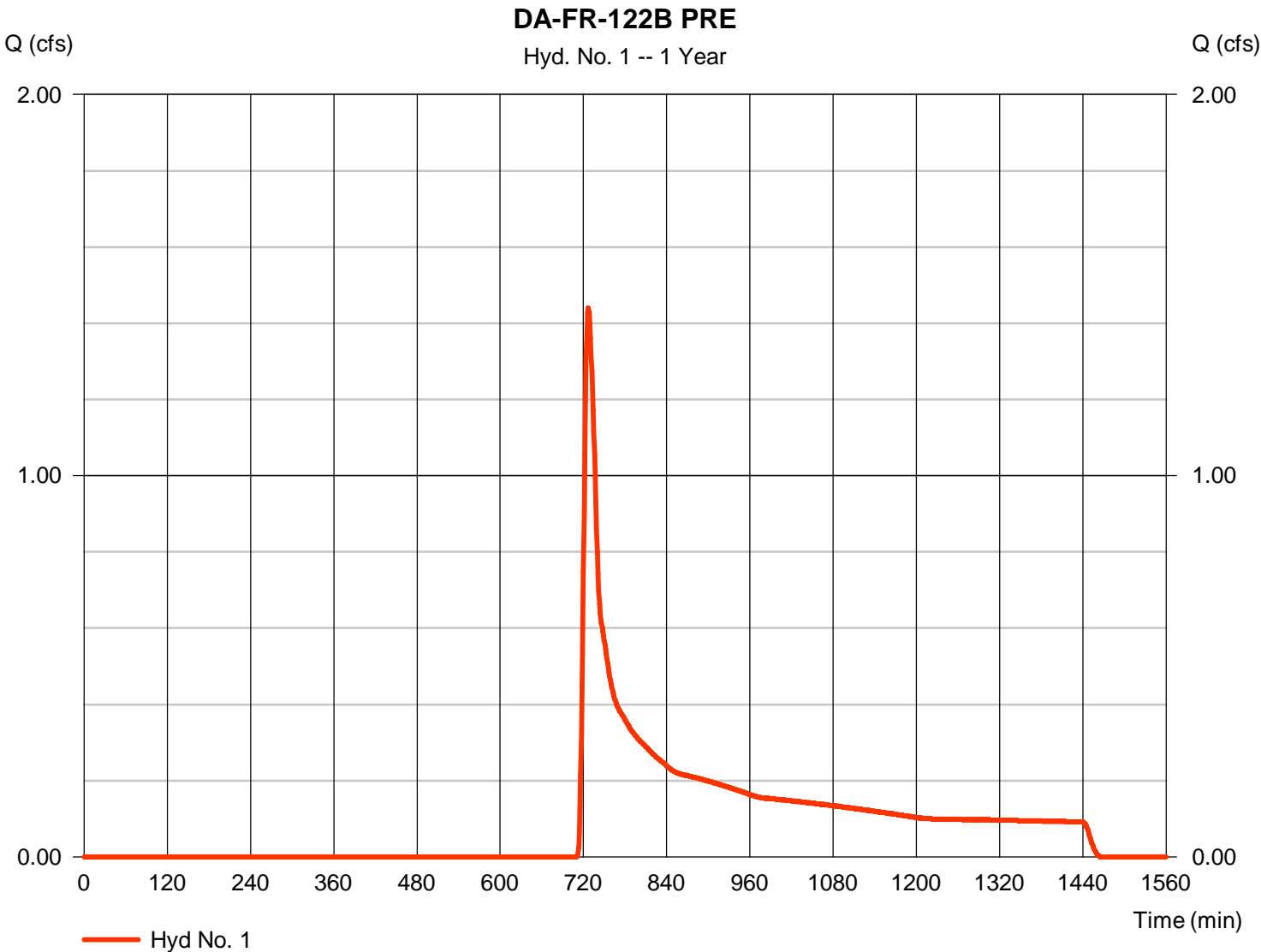
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-122B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 1.441 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 8,556 cuft
Drainage area	= 7.470 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.50 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.140 x 82) + (0.917 x 58) + (6.412 x 55)] / 7.470



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-122B PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 6.89	0.00	0.00	
Travel Time (min)	= 12.18	+	0.00	+
			0.00	= 12.18
Shallow Concentrated Flow				
Flow length (ft)	= 332.22	0.00	0.00	
Watercourse slope (%)	= 11.77	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=5.54	0.00	0.00	
Travel Time (min)	= 1.00	+	0.00	+
			0.00	= 1.00
Channel Flow				
X sectional flow area (sqft)	= 2.11	0.00	0.00	
Wetted perimeter (ft)	= 14.58	0.00	0.00	
Channel slope (%)	= 5.94	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=3.32	0.00	0.00	
			0.00	
Flow length (ft)	(\{0\})472.6	0.0	0.0	
Travel Time (min)	= 2.37	+	0.00	+
			0.00	= 2.37
Total Travel Time, Tc				15.50 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

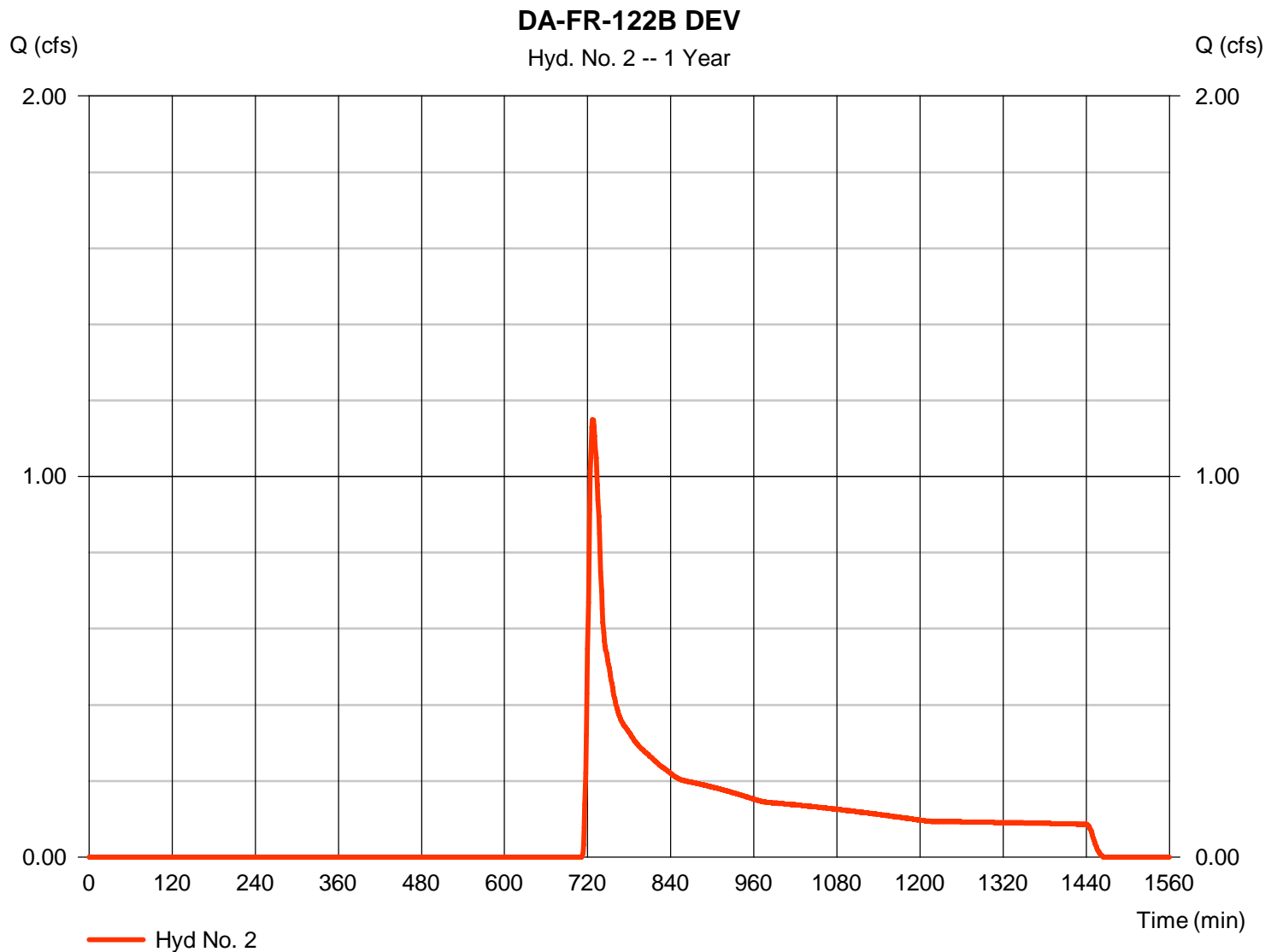
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-122B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 1.150 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 7,717 cuft
Drainage area	= 7.470 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.50 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.147 \times 48) + (0.140 \times 82) + (1.707 \times 58) + (4.475 \times 55)] / 7.470$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-122B DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 6.89	0.00	0.00	
Travel Time (min)	= 12.18	+	0.00	+
			0.00	= 12.18
Shallow Concentrated Flow				
Flow length (ft)	= 332.22	0.00	0.00	
Watercourse slope (%)	= 11.77	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=5.54	0.00	0.00	
Travel Time (min)	= 1.00	+	0.00	+
			0.00	= 1.00
Channel Flow				
X sectional flow area (sqft)	= 2.11	0.00	0.00	
Wetted perimeter (ft)	= 14.58	0.00	0.00	
Channel slope (%)	= 5.94	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=3.32	0.00	0.00	
			0.00	
Flow length (ft)	({})472.6	0.0	0.0	
Travel Time (min)	= 2.37	+	0.00	+
			0.00	= 2.37
Total Travel Time, Tc				15.50 min

Hydrograph Report

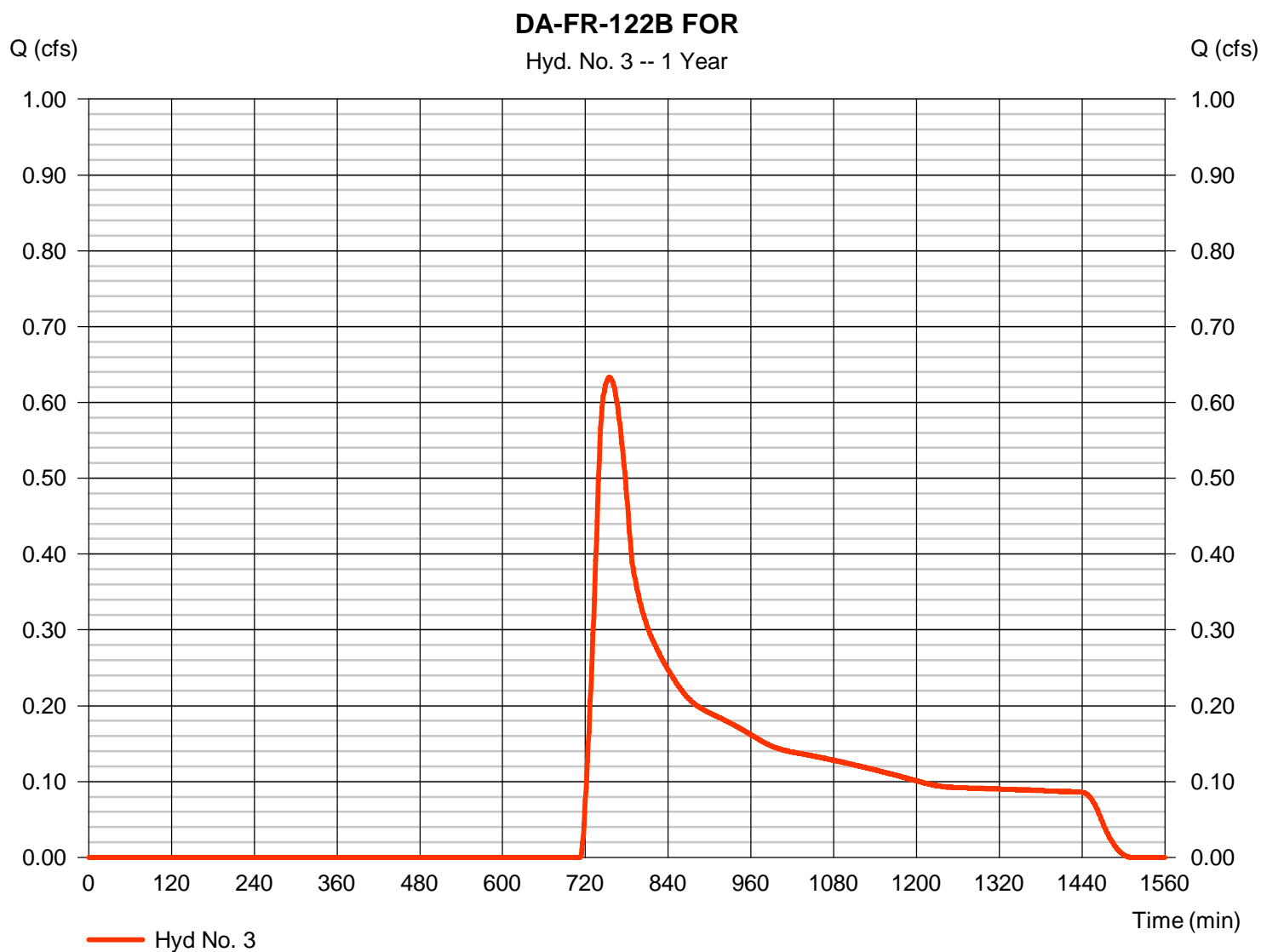
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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Hyd. No. 3

DA-FR-122B FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.633 cfs
Storm frequency	= 1 yrs	Time to peak	= 755 min
Time interval	= 1 min	Hyd. volume	= 7,622 cuft
Drainage area	= 7.470 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 44.80 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-122B FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 6.89	0.00	0.00				
Travel Time (min)	= 12.18	+	0.00	+	0.00	=	12.18
Shallow Concentrated Flow							
Flow length (ft)	= 332.22	0.00	0.00				
Watercourse slope (%)	= 11.77	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.54	0.00	0.00				
Travel Time (min)	= 1.00	+	0.00	+	0.00	=	1.00
Channel Flow							
X sectional flow area (sqft)	= 2.11	0.00	0.00				
Wetted perimeter (ft)	= 14.58	0.00	0.00				
Channel slope (%)	= 5.94	0.00	0.00				
Manning's n-value	= 0.400	0.015	0.015				
Velocity (ft/s)	=0.25	0.00	0.00				
Flow length (ft)	({0})472.6	0.0	0.0				
Travel Time (min)	= 31.65	+	0.00	+	0.00	=	31.65
Total Travel Time, Tc				44.80 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	2.692	1	726	12,455	-----	-----	-----	DA-FR-122B PRE
2	SCS Runoff	2.283	1	726	11,410	-----	-----	-----	DA-FR-122B DEV
3	SCS Runoff	1.159	1	749	11,269	-----	-----	-----	DA-FR-122B FOR
DA-FR-122B_Hydraflow.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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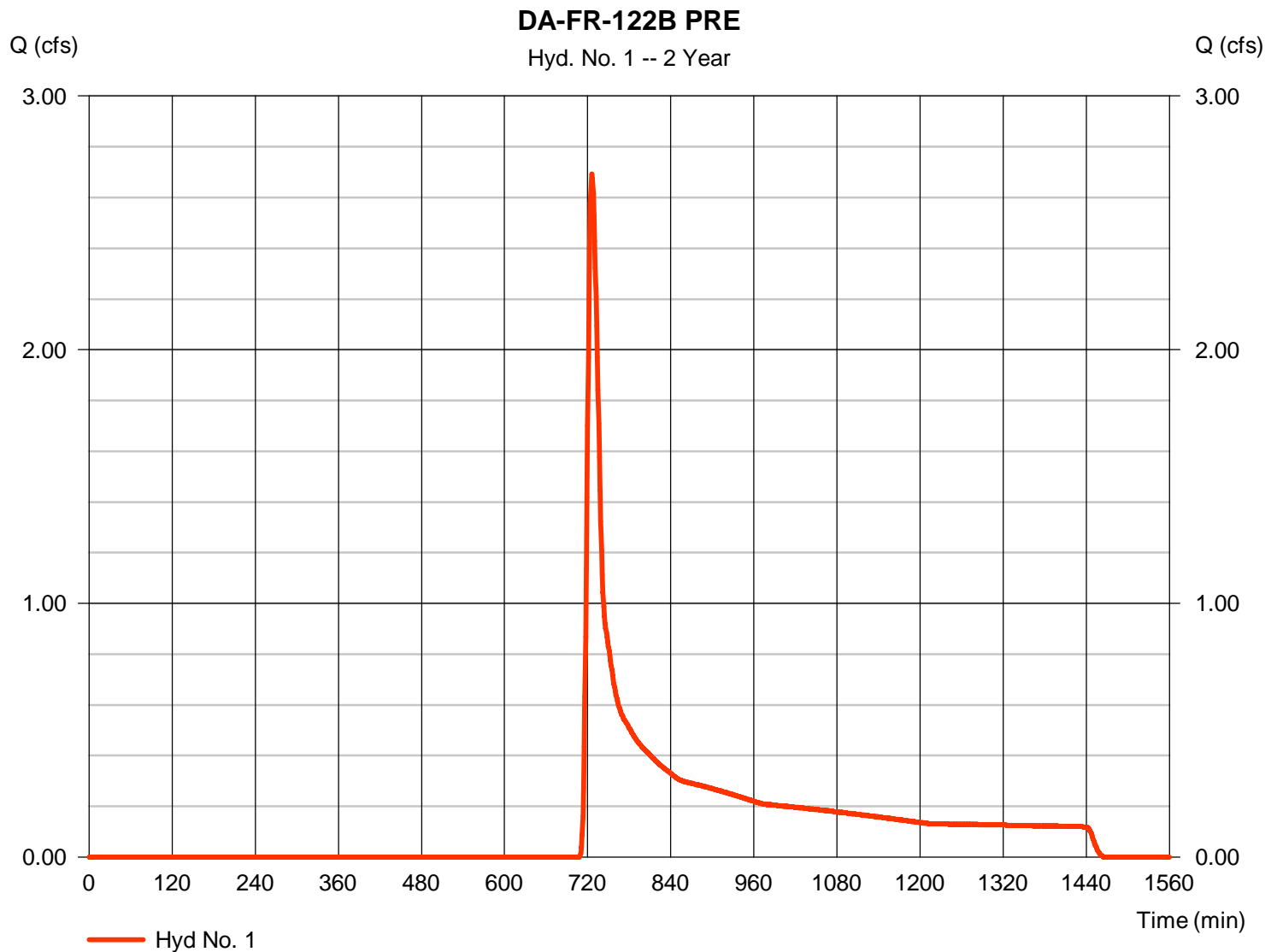
Hyd. No. 1

DA-FR-122B PRE

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 7.470 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 2.692 cfs
 Time to peak = 726 min
 Hyd. volume = 12,455 cuft
 Curve number = 56*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.50 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(0.140 \times 82) + (0.917 \times 58) + (6.412 \times 55)] / 7.470$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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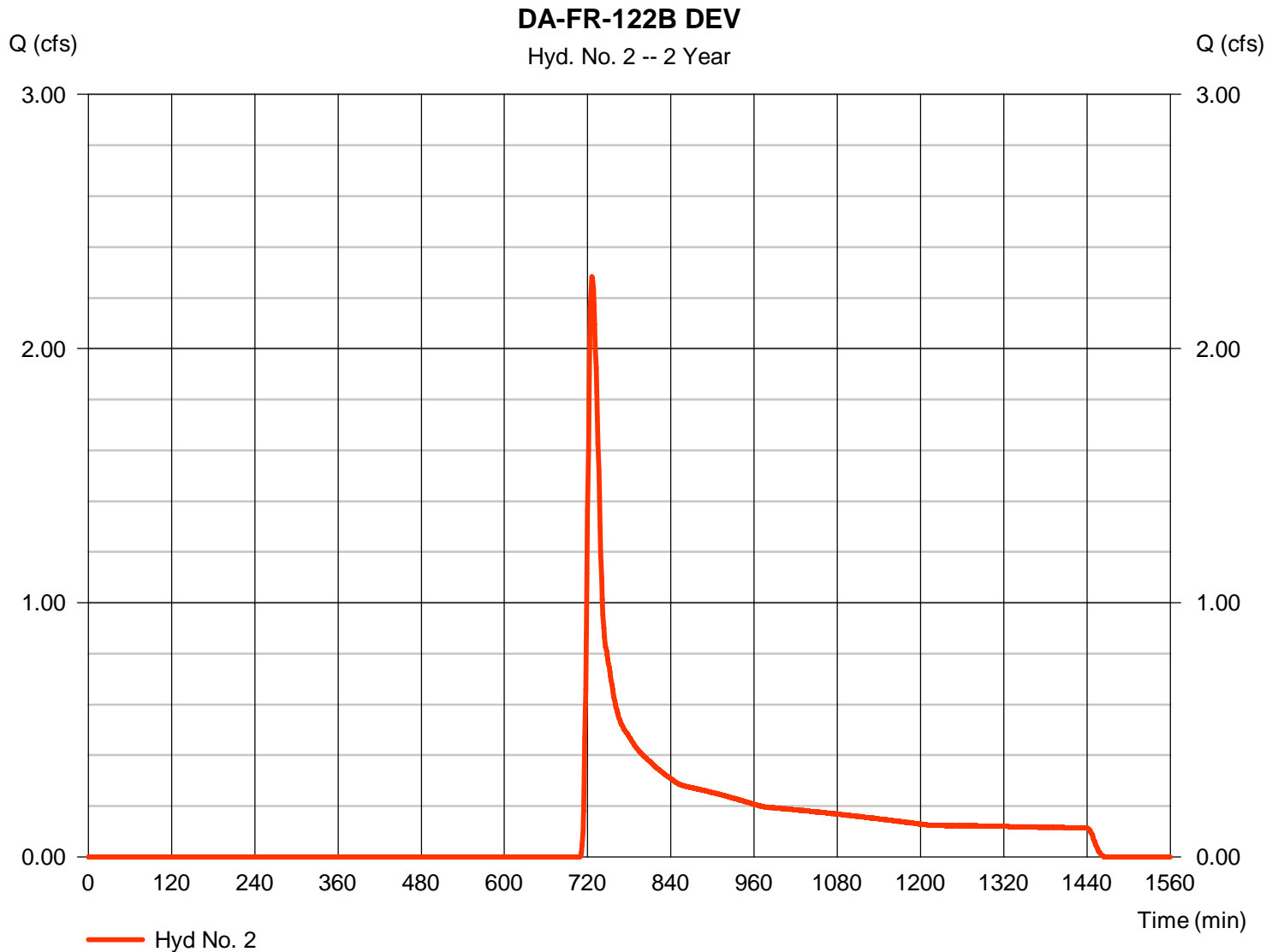
Hyd. No. 2

DA-FR-122B DEV

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 7.470 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 2.283 cfs
 Time to peak = 726 min
 Hyd. volume = 11,410 cuft
 Curve number = 55*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.50 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(1.147 \times 48) + (0.140 \times 82) + (1.707 \times 58) + (4.475 \times 55)] / 7.470$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

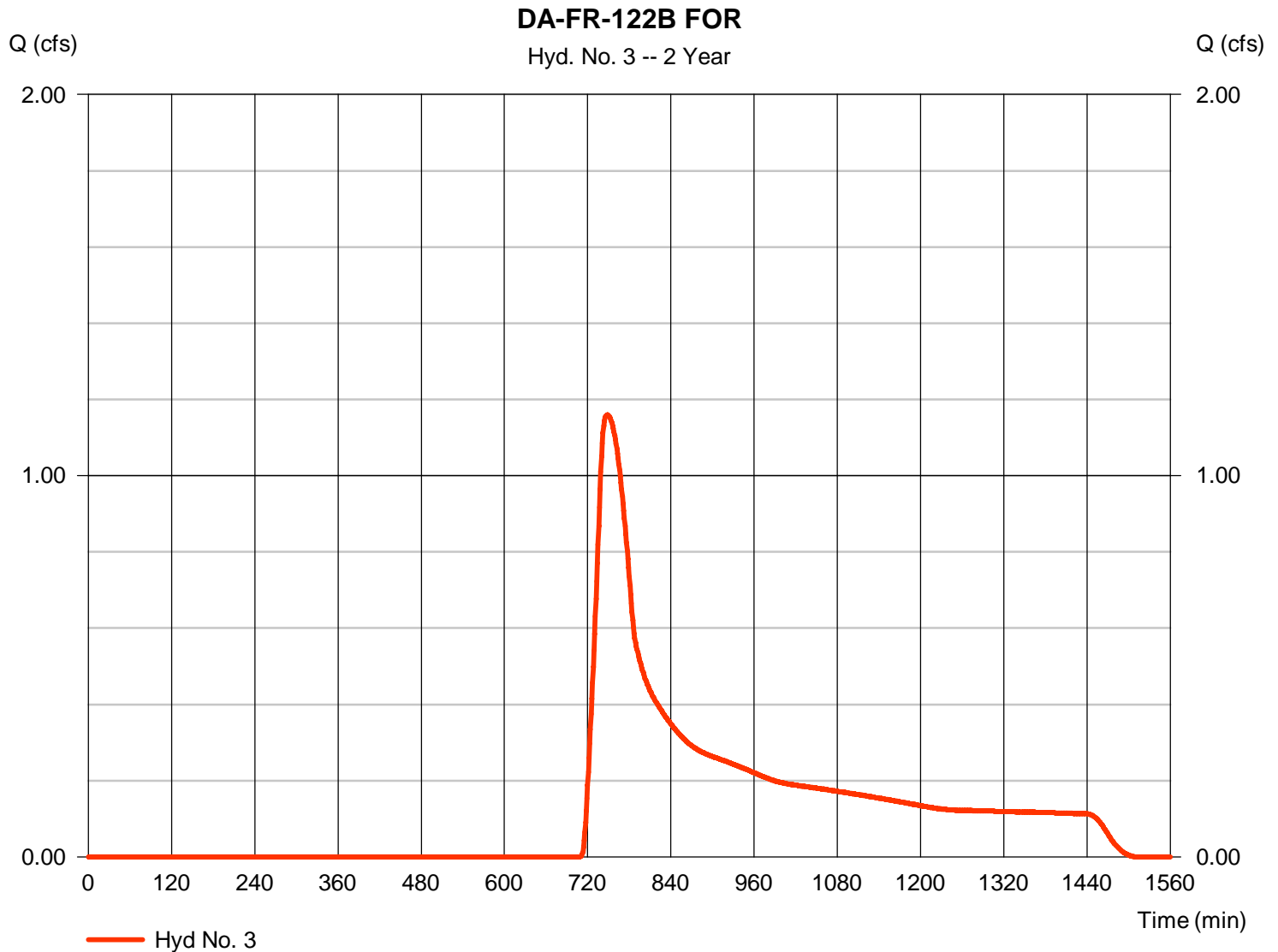
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-122B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 7.470 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 1.159 cfs
 Time to peak = 749 min
 Hyd. volume = 11,269 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 44.80 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	12.38	1	724	39,044	-----	-----	-----	DA-FR-122B PRE
2	SCS Runoff	11.54	1	724	37,023	-----	-----	-----	DA-FR-122B DEV
3	SCS Runoff	5.784	1	743	36,566	-----	-----	-----	DA-FR-122B FOR
DA-FR-122B_Hydraflow.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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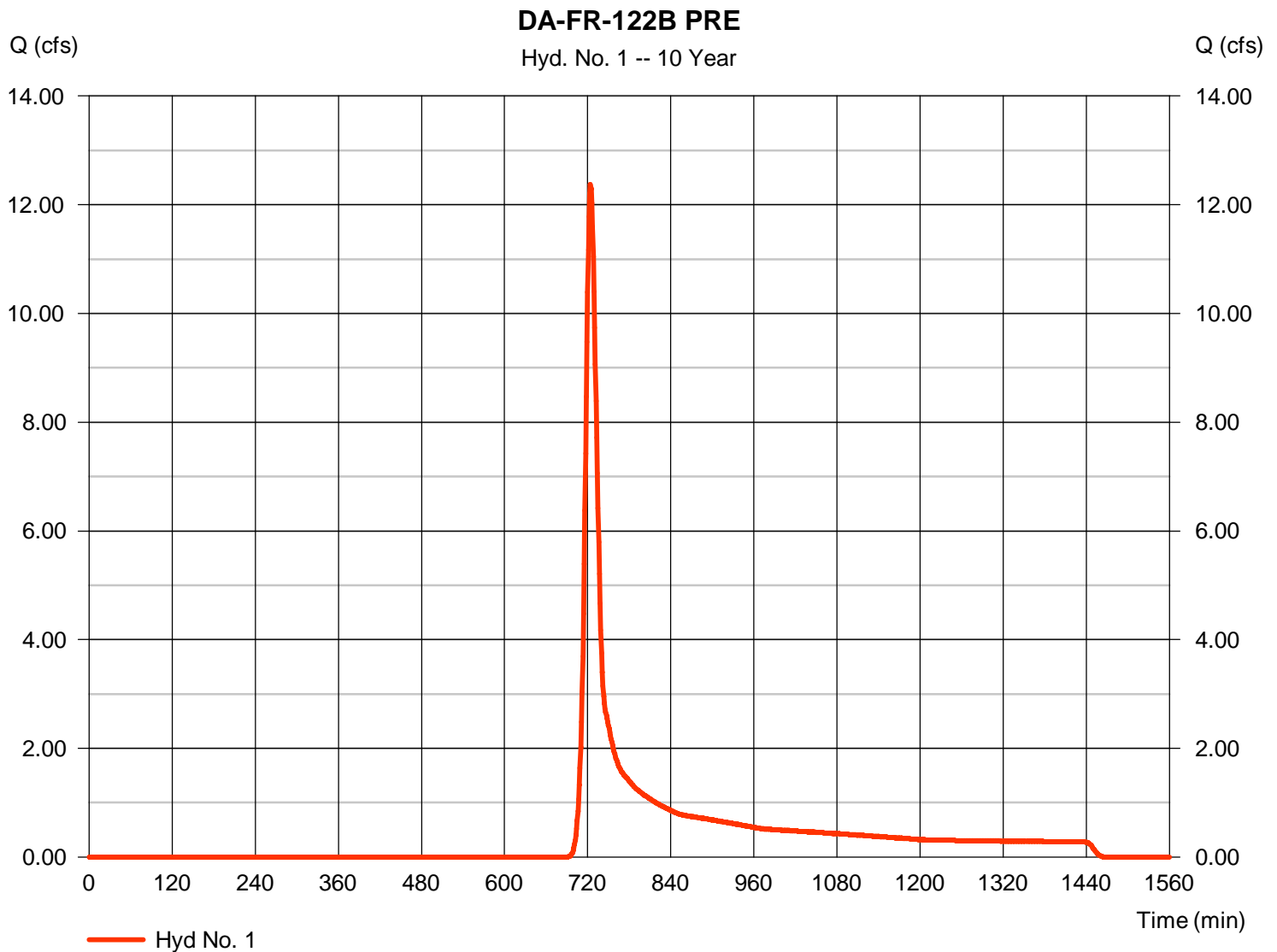
Hyd. No. 1

DA-FR-122B PRE

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 7.470 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 12.38 cfs
 Time to peak = 724 min
 Hyd. volume = 39,044 cuft
 Curve number = 56*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.50 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(0.140 \times 82) + (0.917 \times 58) + (6.412 \times 55)] / 7.470$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

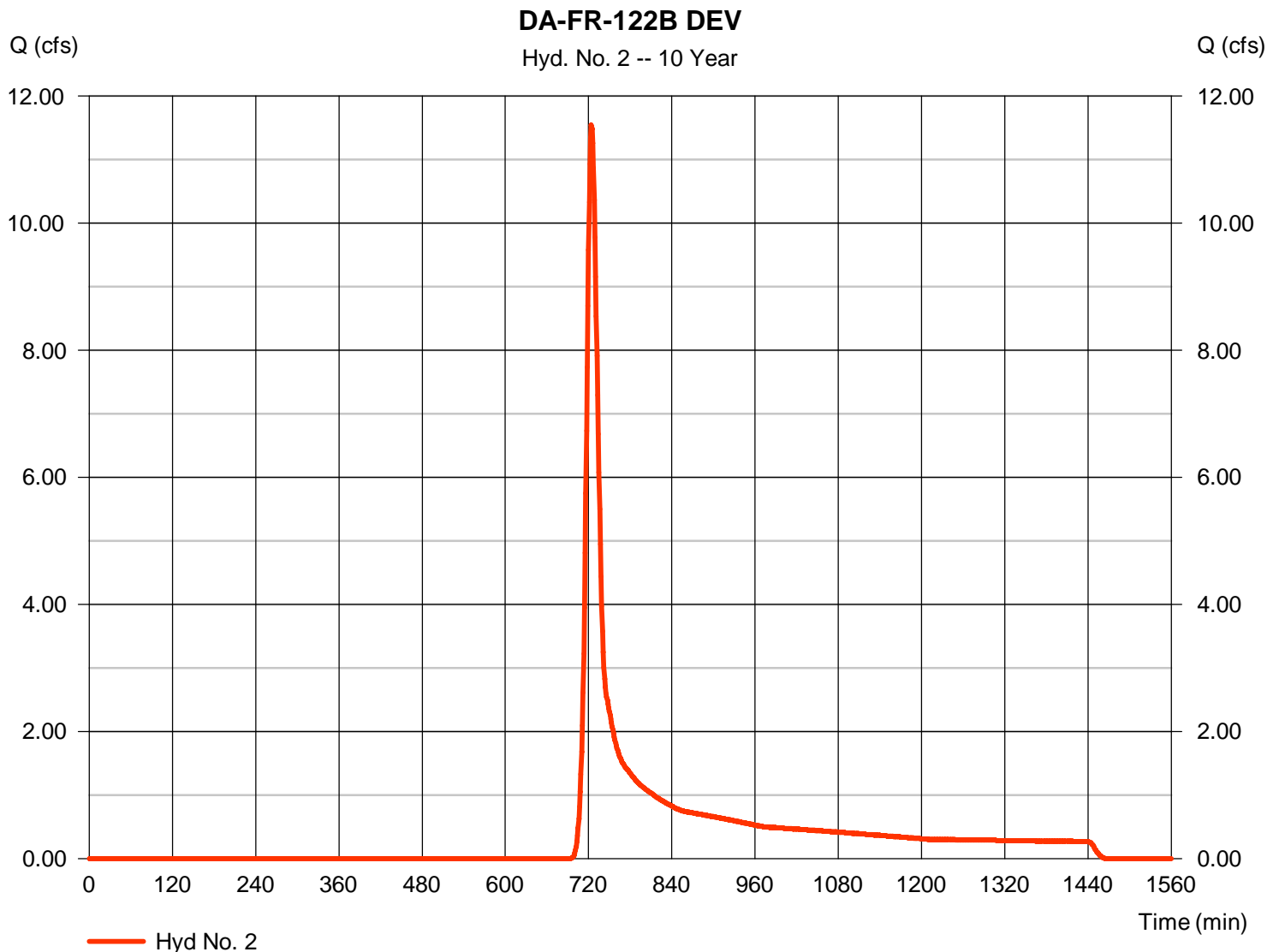
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-122B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 11.54 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 37,023 cuft
Drainage area	= 7.470 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.50 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.147 \times 48) + (0.140 \times 82) + (1.707 \times 58) + (4.475 \times 55)] / 7.470$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

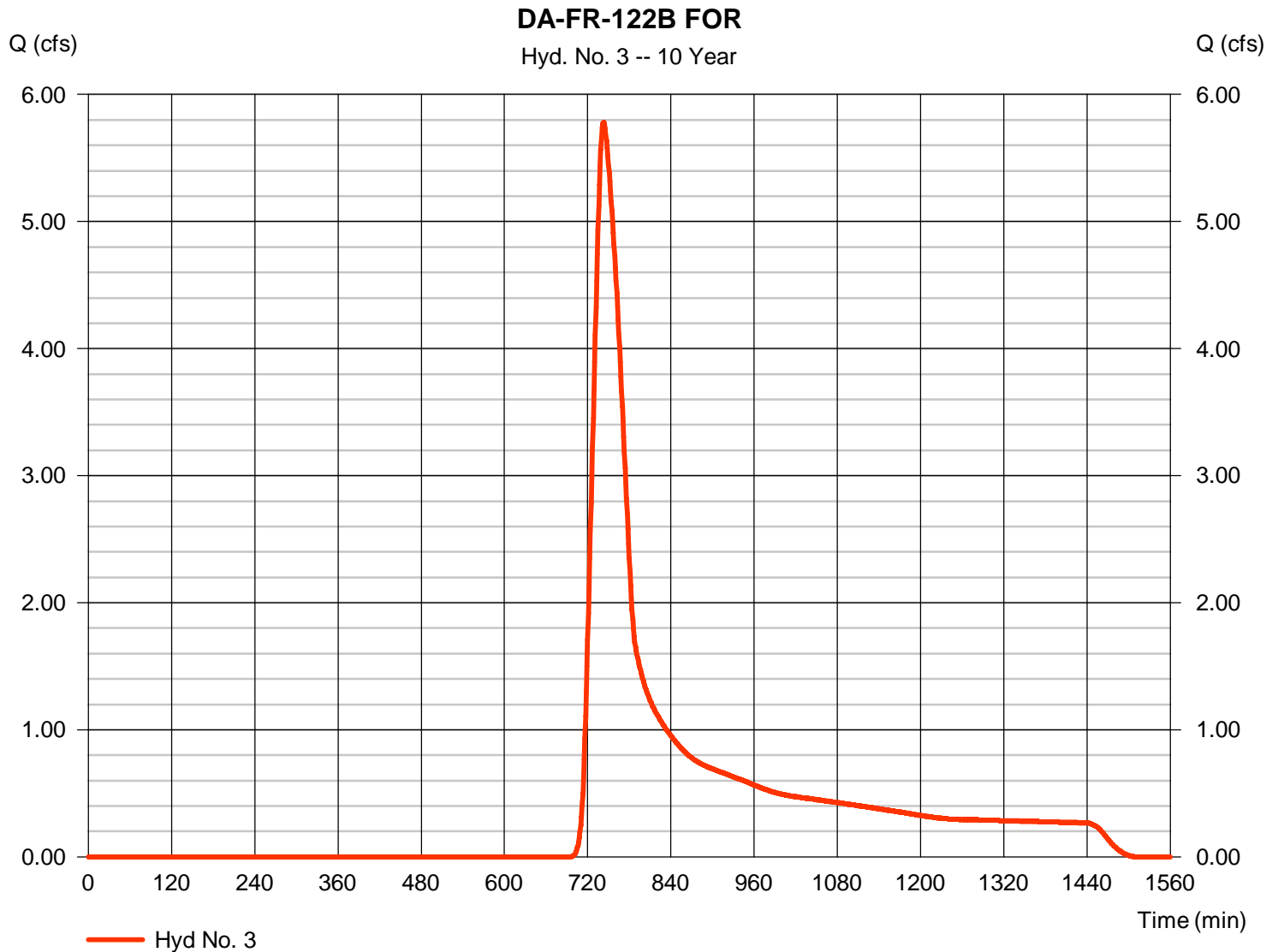
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-122B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 7.470 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 5.784 cfs
 Time to peak = 743 min
 Hyd. volume = 36,566 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 44.80 min
 Distribution = Type II
 Shape factor = 484



DA-FR-122C

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.094	449
Developed Condition	0.054	358
Pre-Developed (Forest) Condition	0.094	449

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.9

Calculations:

Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	0.054	\leq	0.106
			N/A - See Check #3	
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.054	\leq	0.094
			N/A - See Check #3	
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ ---->	0.054	<u>shall not</u> be required to be \leq	0.118

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s n value of 0.011 was used.</p> <p><i>Sources:</i></p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-122C PRE
2	SCS Runoff	DA-FR-122C DEV
3	SCS Runoff	DA-FR-122C FOR

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.094	1	723	449	-----	-----	-----	DA-FR-122C PRE
2	SCS Runoff	0.054	1	723	358	-----	-----	-----	DA-FR-122C DEV
3	SCS Runoff	0.094	1	723	449	-----	-----	-----	DA-FR-122C FOR
DA-FR-122C_Hydraflow.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

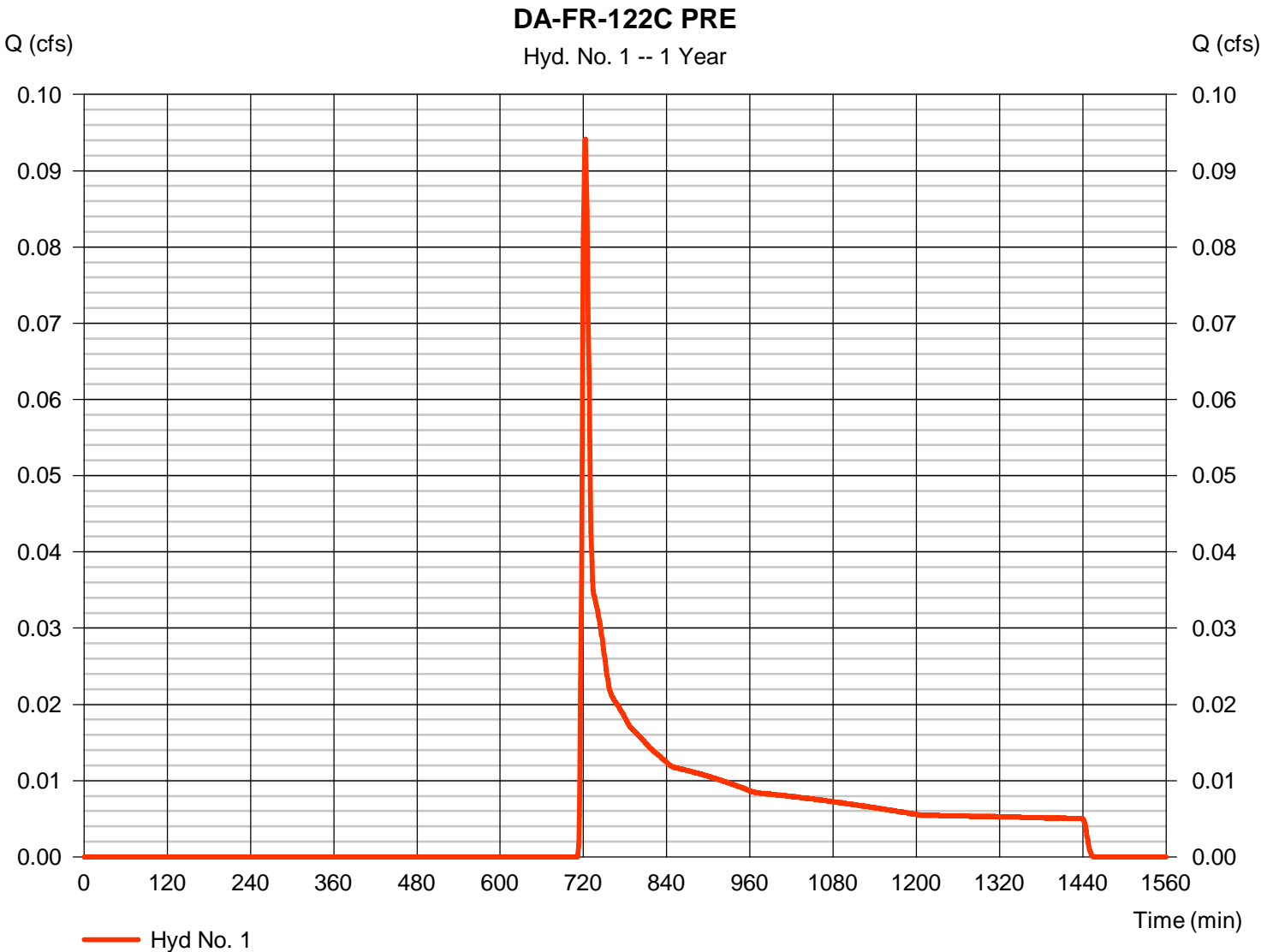
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-122C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.094 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 449 cuft
Drainage area	= 0.440 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.437 x 55) + (0.000 x 100)] / 0.440



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-122C PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 16.09	0.00	0.00				
Travel Time (min)	= 8.67	+	0.00	+	0.00	=	8.67
Shallow Concentrated Flow							
Flow length (ft)	= 101.97	0.00	0.00				
Watercourse slope (%)	= 15.18	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=6.29	0.00	0.00				
Travel Time (min)	= 0.27	+	0.00	+	0.00	=	0.27
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				8.90 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

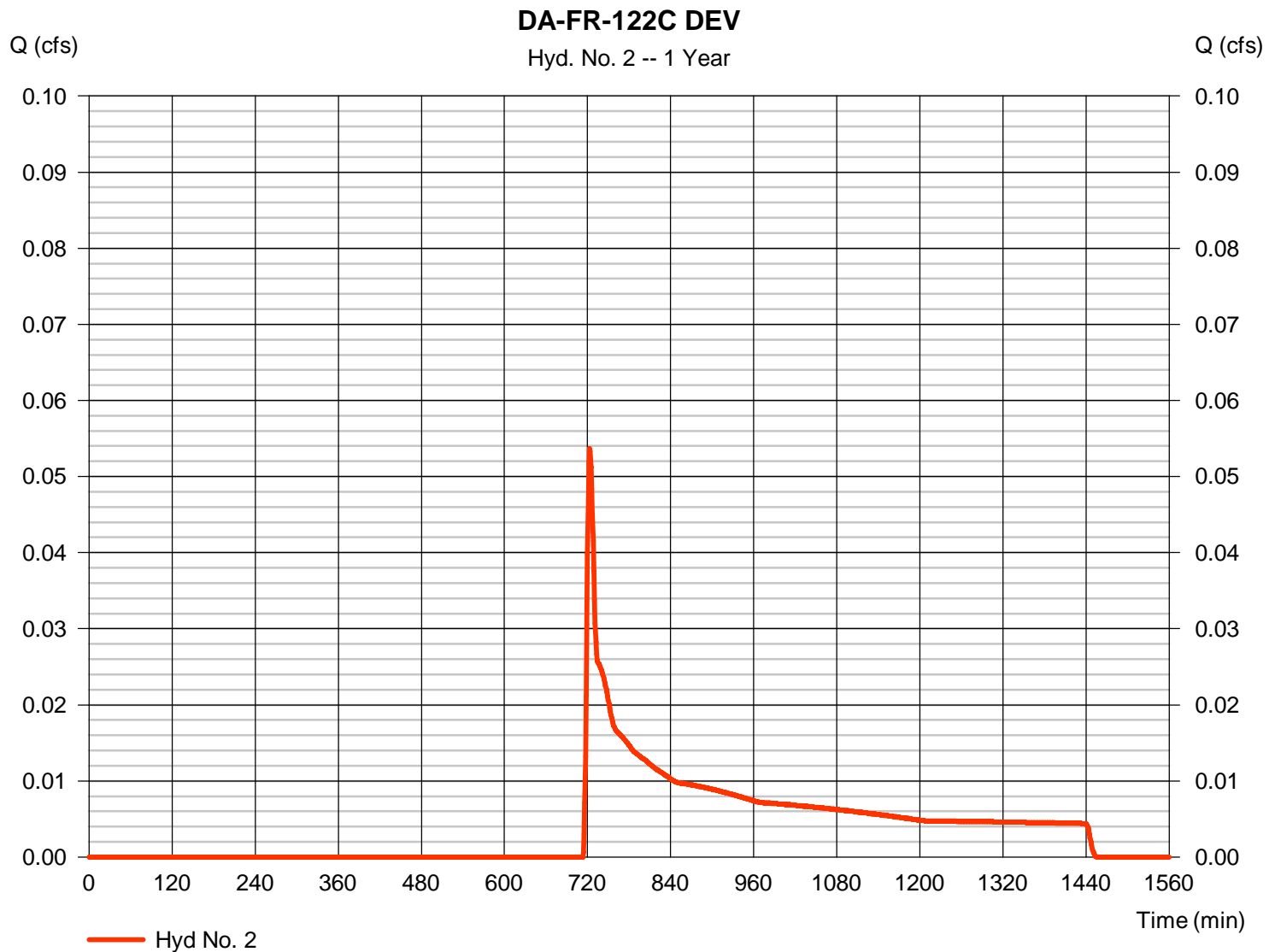
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-122C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.054 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 358 cuft
Drainage area	= 0.440 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.189 \times 48) + (0.200 \times 58) + (0.000 \times 100) + (0.047 \times 55)] / 0.440$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-122C DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 16.09	0.00	0.00				
Travel Time (min)	= 8.67	+	0.00	+	0.00	=	8.67
Shallow Concentrated Flow							
Flow length (ft)	= 101.97	0.00	0.00				
Watercourse slope (%)	= 15.18	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=6.29	0.00	0.00				
Travel Time (min)	= 0.27	+	0.00	+	0.00	=	0.27
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				8.90 min			

Hydrograph Report

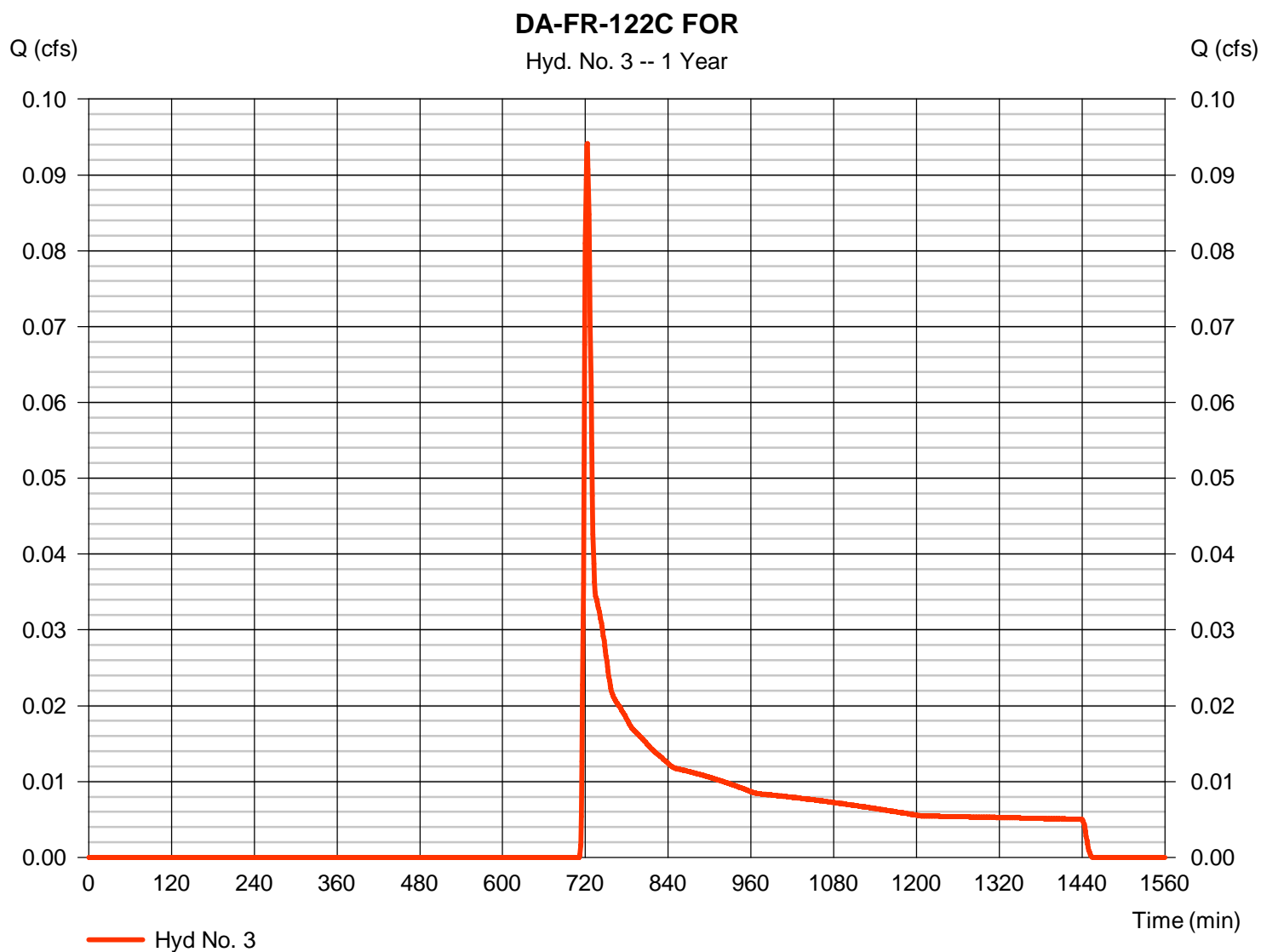
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-122C FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.094 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 449 cuft
Drainage area	= 0.440 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-122C FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 16.09	0.00	0.00				
Travel Time (min)	= 8.67	+	0.00	+	0.00	=	8.67
Shallow Concentrated Flow							
Flow length (ft)	= 101.97	0.00	0.00				
Watercourse slope (%)	= 15.18	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=6.29	0.00	0.00				
Travel Time (min)	= 0.27	+	0.00	+	0.00	=	0.27
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				8.90 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.187	1	722	664	-----	-----	-----	DA-FR-122C PRE
2	SCS Runoff	0.128	1	722	549	-----	-----	-----	DA-FR-122C DEV
3	SCS Runoff	0.187	1	722	664	-----	-----	-----	DA-FR-122C FOR
DA-FR-122C_Hydraflow.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

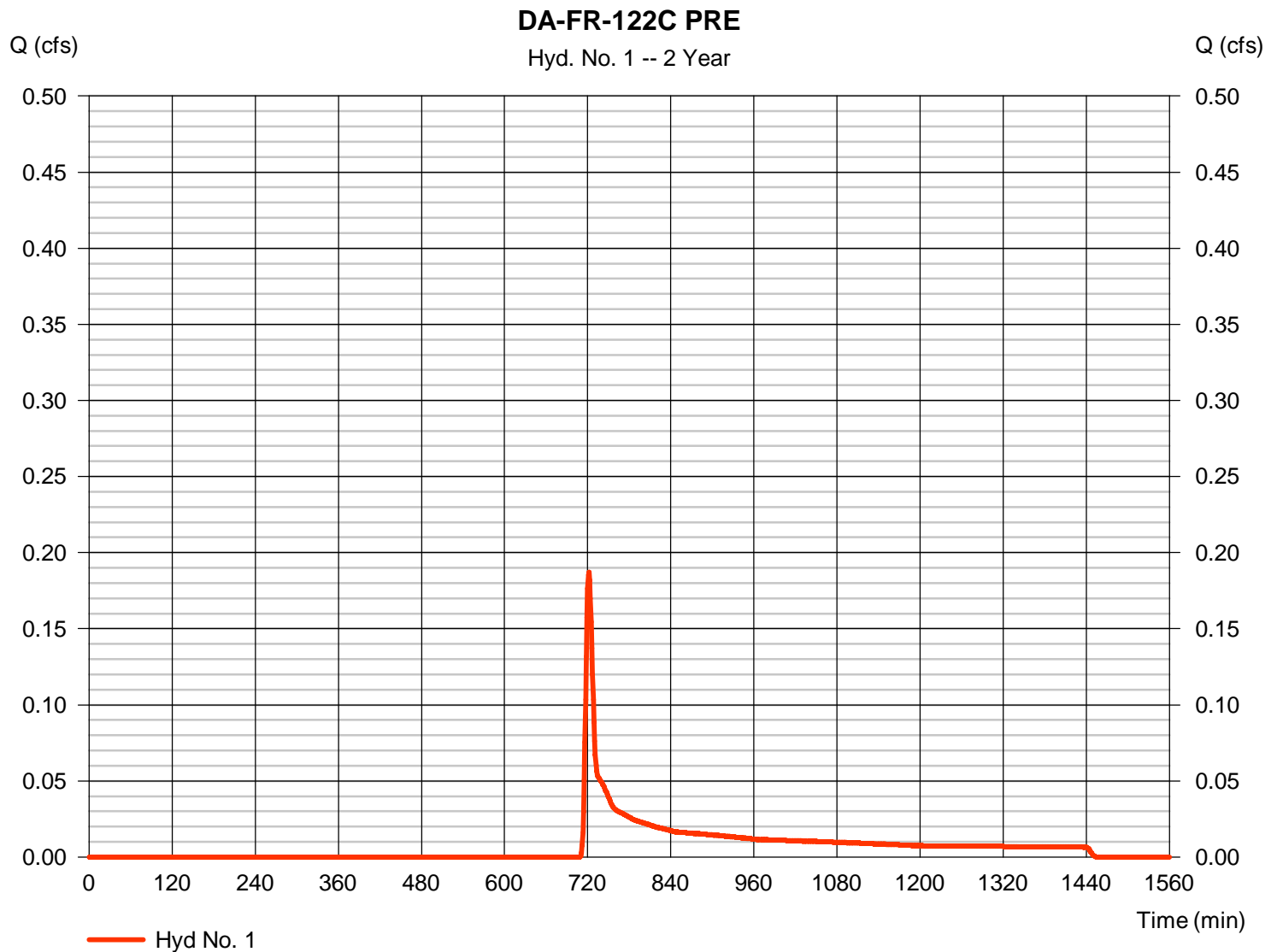
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-122C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.187 cfs
Storm frequency	= 2 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 664 cuft
Drainage area	= 0.440 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.437 \times 55) + (0.000 \times 100)] / 0.440$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

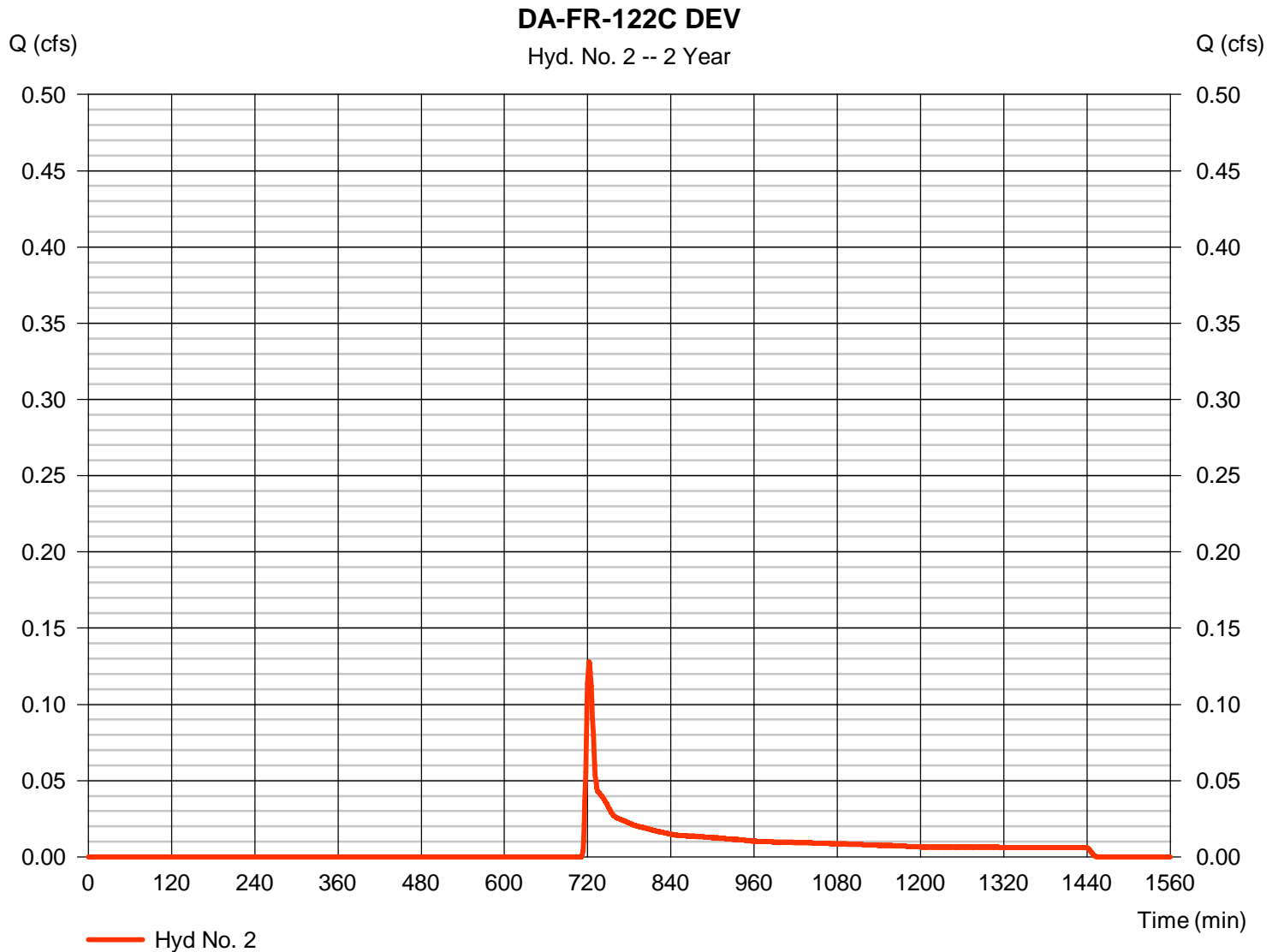
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Hyd. No. 2

DA-FR-122C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.128 cfs
Storm frequency	= 2 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 549 cuft
Drainage area	= 0.440 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.189 \times 48) + (0.200 \times 58) + (0.000 \times 100) + (0.047 \times 55)] / 0.440$



Hydrograph Report

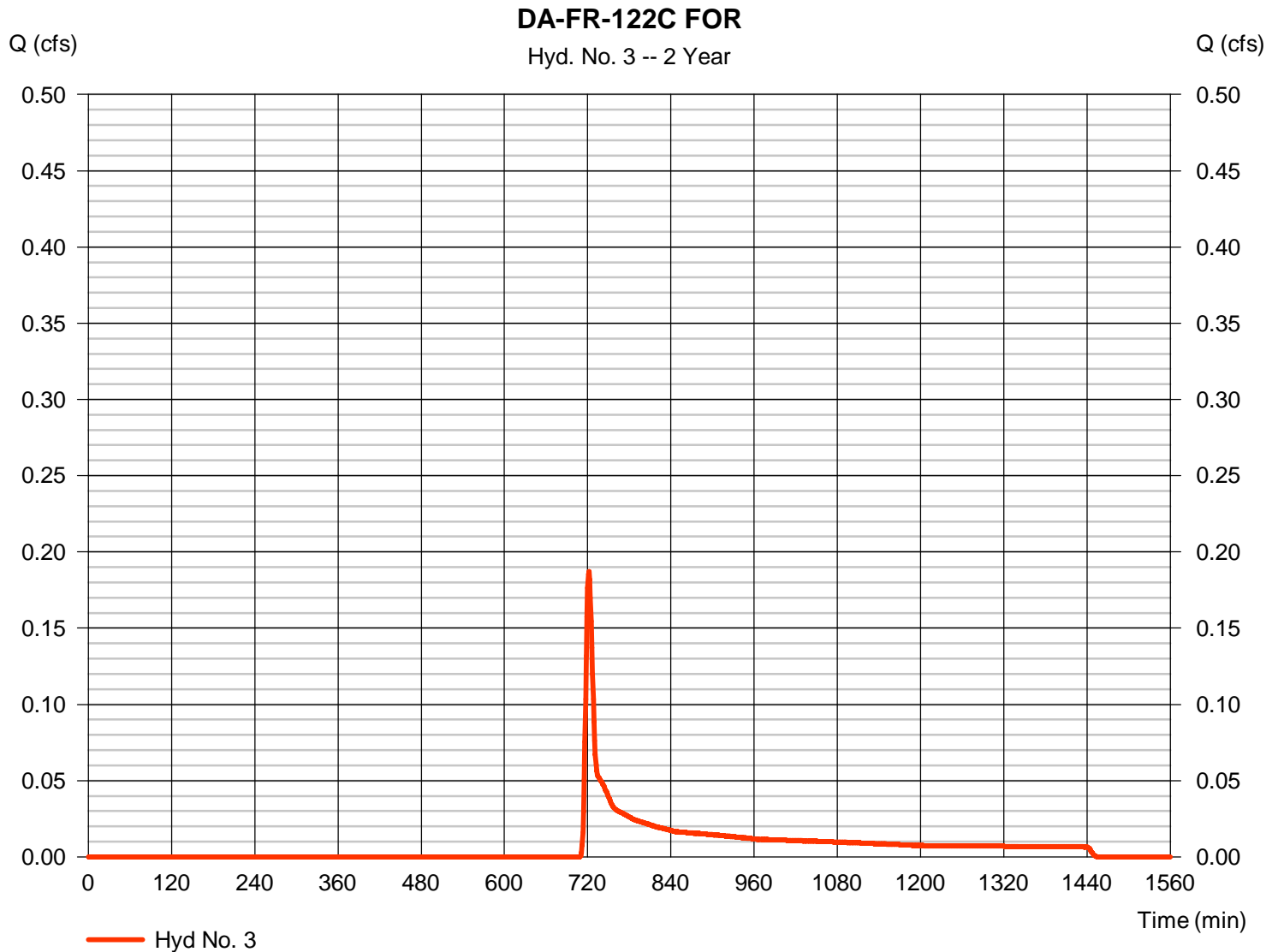
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-122C FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.187 cfs
Storm frequency	= 2 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 664 cuft
Drainage area	= 0.440 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.889	1	720	2,154	-----	-----	-----	DA-FR-122C PRE
2	SCS Runoff	0.770	1	720	1,925	-----	-----	-----	DA-FR-122C DEV
3	SCS Runoff	0.889	1	720	2,154	-----	-----	-----	DA-FR-122C FOR
DA-FR-122C_Hydraflow.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

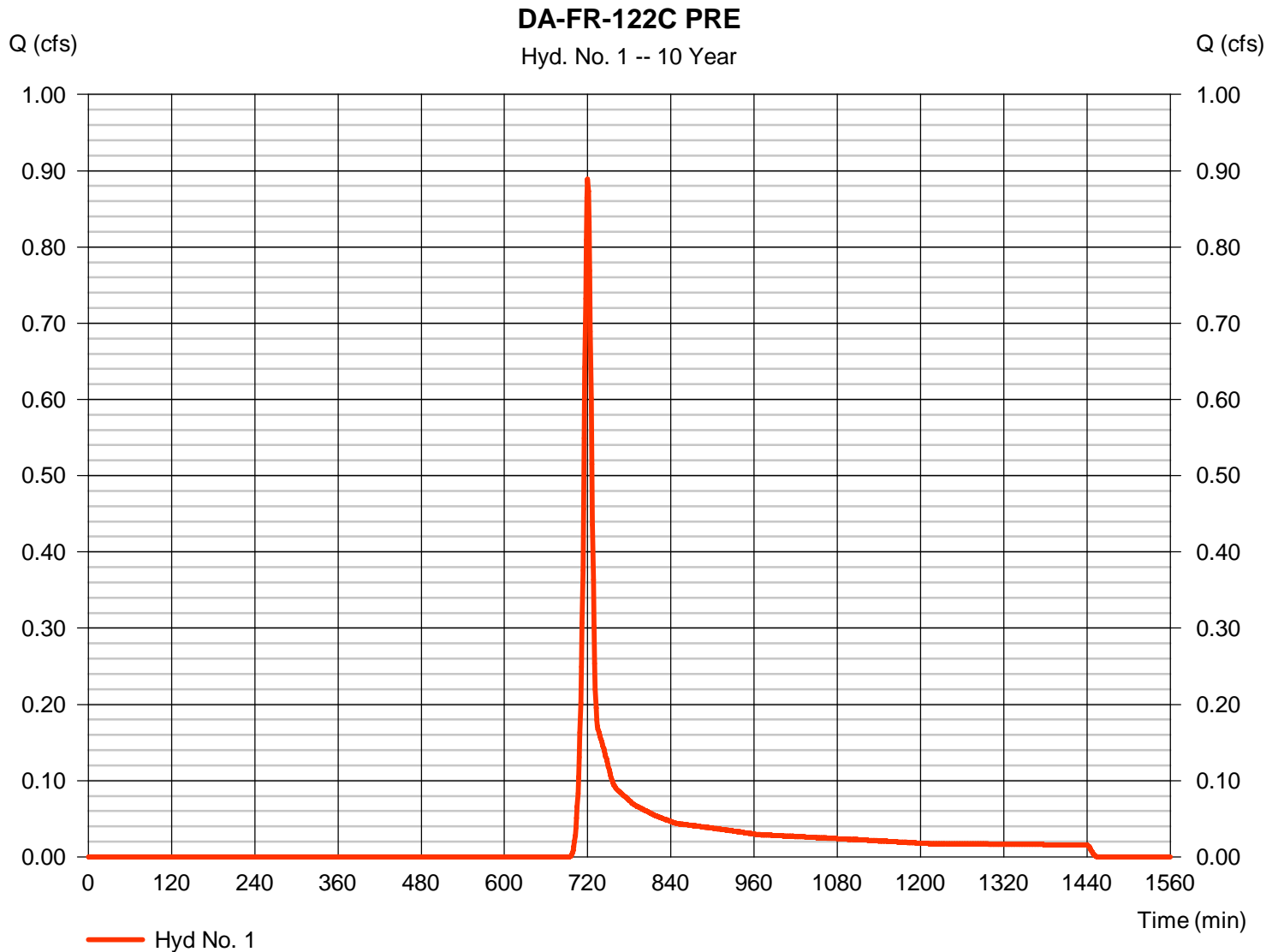
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-122C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.889 cfs
Storm frequency	= 10 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 2,154 cuft
Drainage area	= 0.440 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.437 \times 55) + (0.000 \times 100)] / 0.440$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

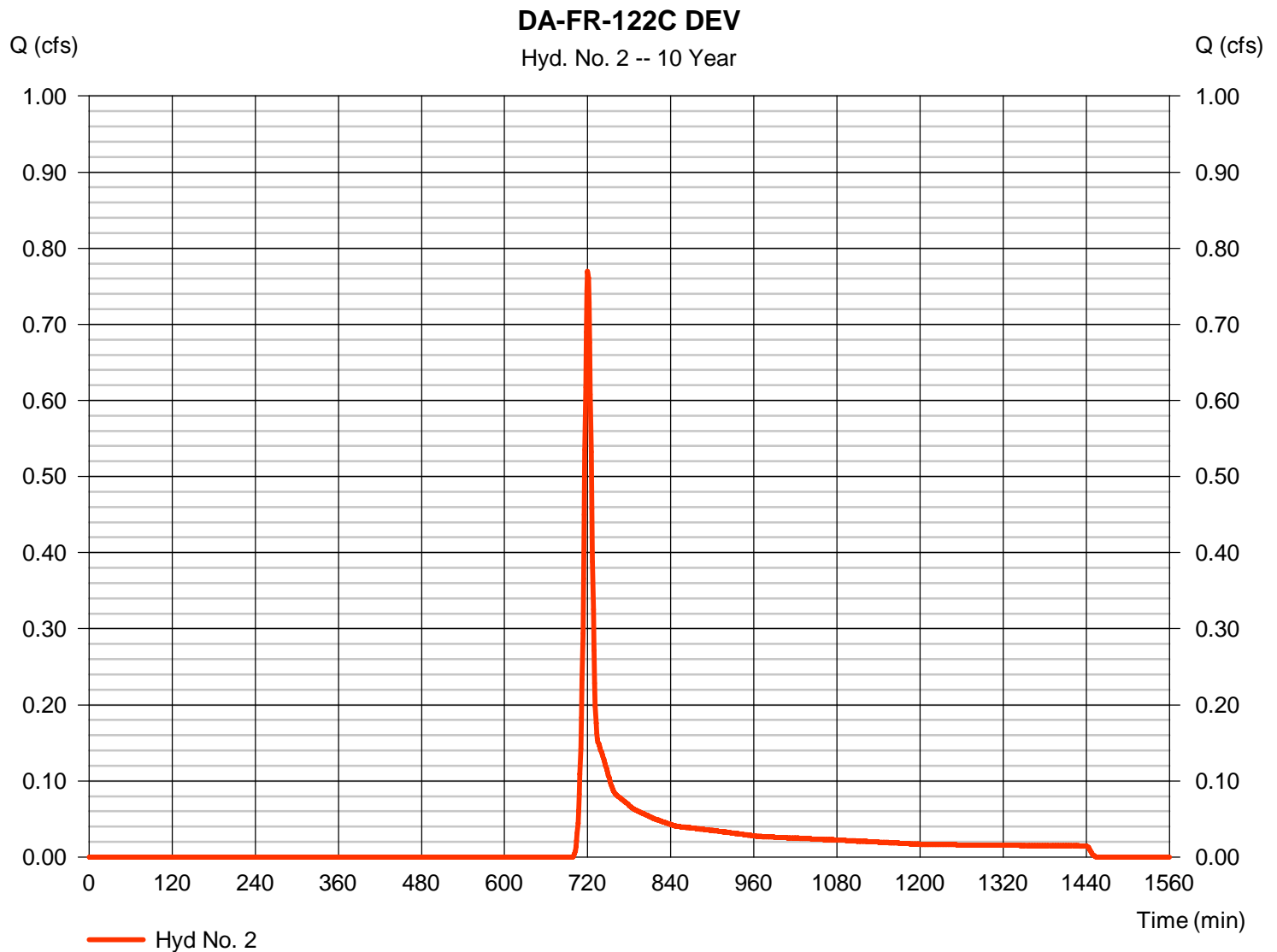
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-122C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.770 cfs
Storm frequency	= 10 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 1,925 cuft
Drainage area	= 0.440 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.90 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.189 \times 48) + (0.200 \times 58) + (0.000 \times 100) + (0.047 \times 55)] / 0.440$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

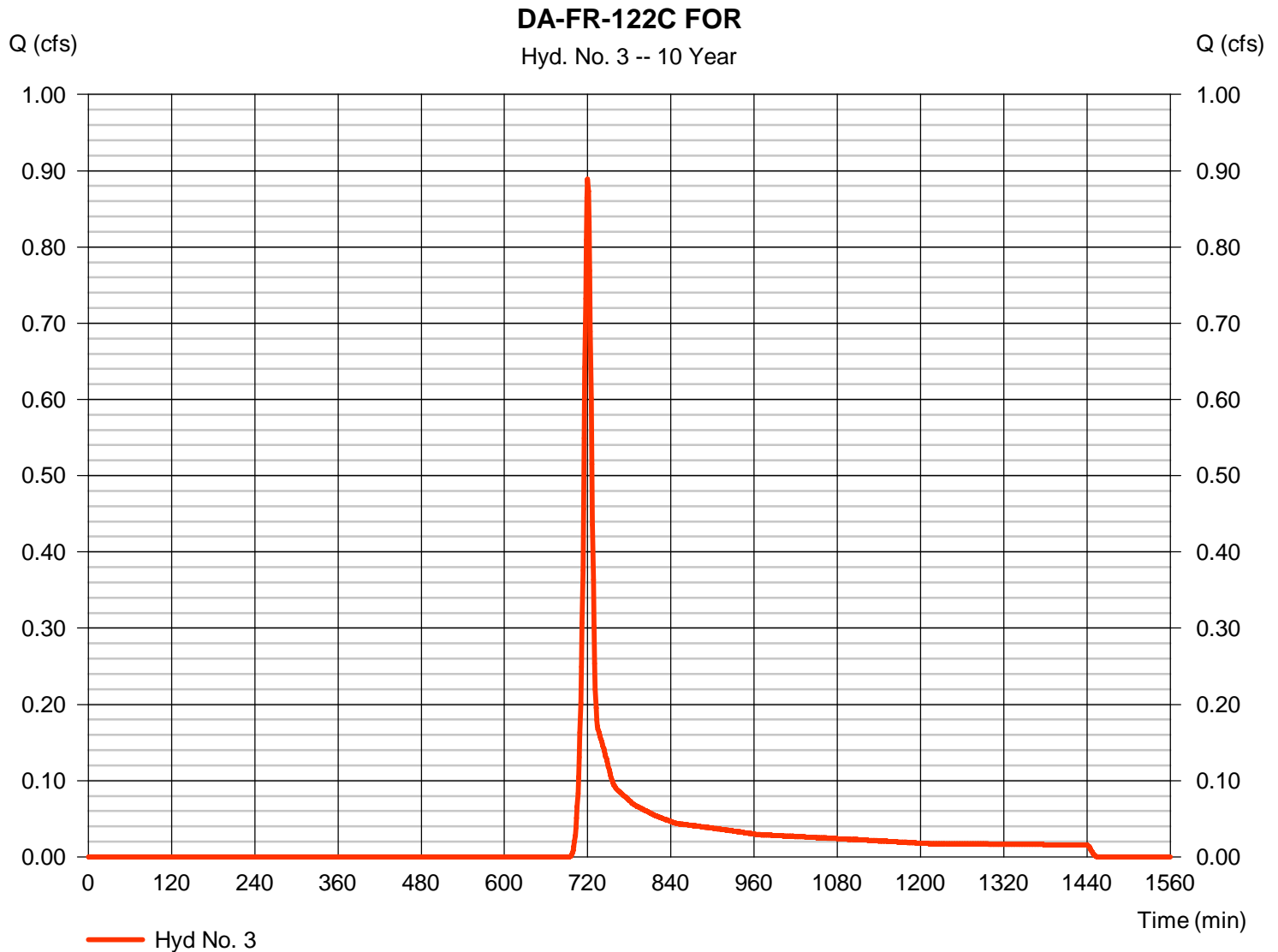
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-122C FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 0.440 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 0.889 cfs
 Time to peak = 720 min
 Hyd. volume = 2,154 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 8.90 min
 Distribution = Type II
 Shape factor = 484



DA-FR-122D

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.386	1819
Developed Condition	0.217	1422
Pre-Developed (Forest) Condition	0.309	1641

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	0.217	\leq OK	0.395
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.217	\leq OK	0.386
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ --->	0.217	<u>shall not</u> be required to be \leq	0.357

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s n value of 0.011 was used.</p> <p><i>Sources:</i></p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

Table 2 – Manning's *n* Values for Open Channel Flow

Channel Type	Manning <i>n</i>		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's <i>n</i> value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's <i>n</i> value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-122D PRE
2	SCS Runoff	DA-FR-122D DEV
3	SCS Runoff	DA-FR-122D FOR

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.386	1	723	1,819	-----	-----	-----	DA-FR-122D PRE
2	SCS Runoff	0.217	1	725	1,422	-----	-----	-----	DA-FR-122D DEV
3	SCS Runoff	0.309	1	724	1,641	-----	-----	-----	DA-FR-122D FOR
DA-FR-122D_Hydraflow.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

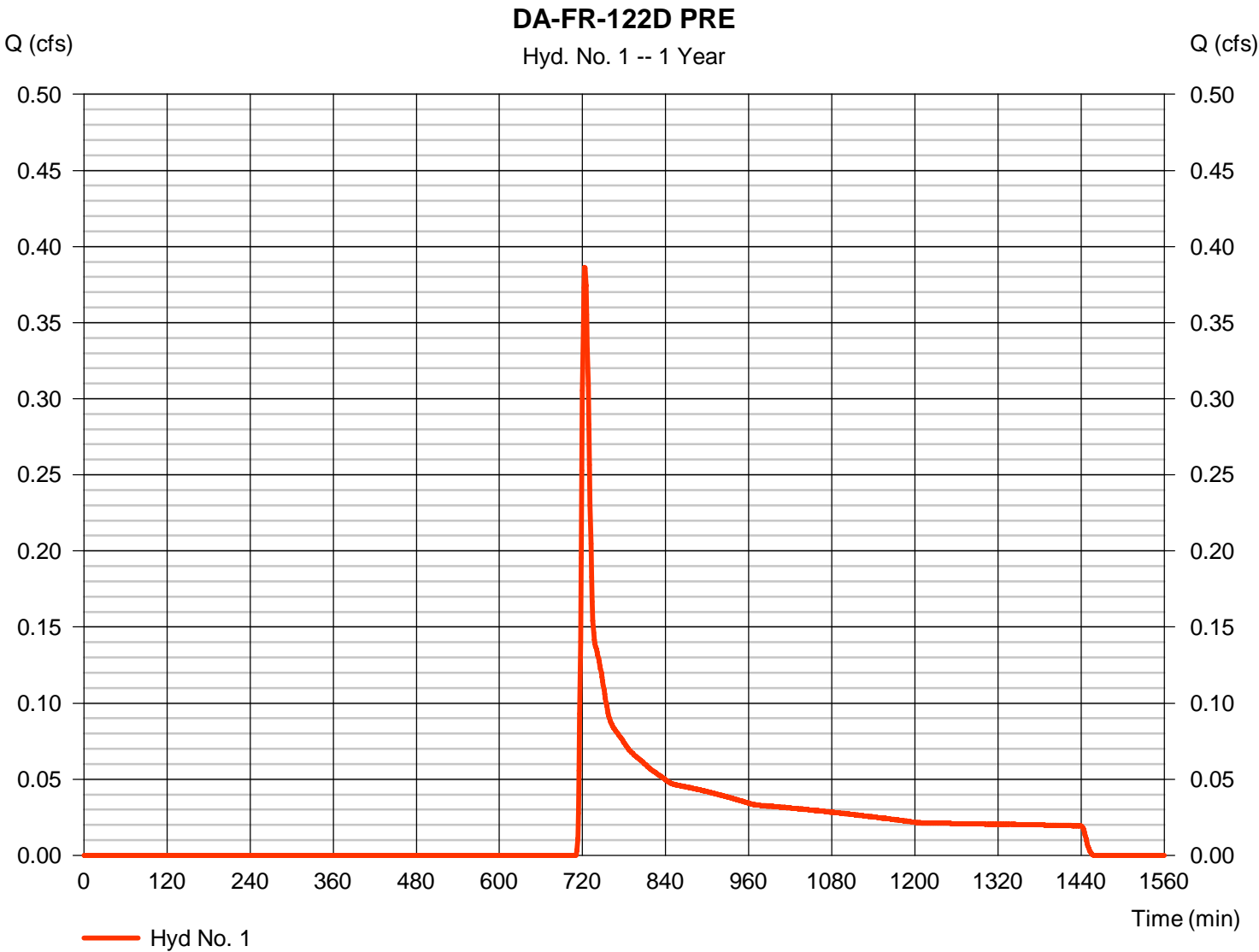
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-122D PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.386 cfs
Storm frequency	=	1 yrs	Time to peak	=	723 min
Time interval	=	1 min	Hyd. volume	=	1,819 cuft
Drainage area	=	1.580 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	11.50 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.093 x 58) + (0.014 x 100) + (1.473 x 55)] / 1.580



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-122D PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 9.41	0.00	0.00				
Travel Time (min)	= 10.75	+	0.00	+	0.00	=	10.75
Shallow Concentrated Flow							
Flow length (ft)	= 267.64	0.00	0.00				
Watercourse slope (%)	= 12.69	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.75	0.00	0.00				
Travel Time (min)	= 0.78	+	0.00	+	0.00	=	0.78
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				11.50 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

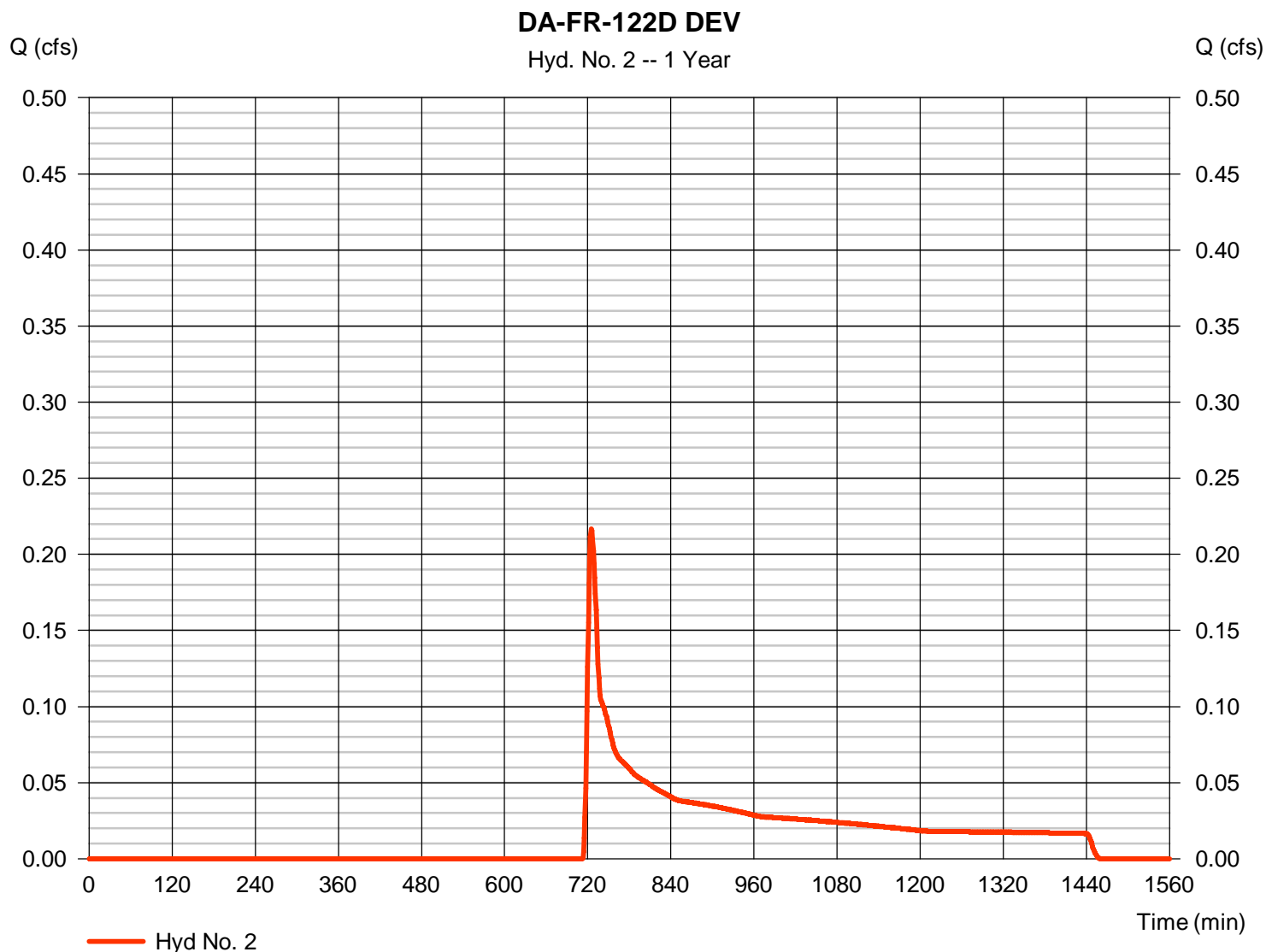
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-122D DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.217 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 1,422 cuft
Drainage area	= 1.580 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.00 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.605 \times 48) + (0.688 \times 58) + (0.014 \times 100) + (0.274 \times 55)] / 1.580$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-122D DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 9.41	0.00	0.00	
Travel Time (min)	= 10.75	+	0.00	+
			0.00	= 10.75
Shallow Concentrated Flow				
Flow length (ft)	= 219.47	88.01	0.00	
Watercourse slope (%)	= 6.34	13.62	0.00	
Surface description	= Unpaved	Unpaved	Paved	
Average velocity (ft/s)	=4.06	5.95	0.00	
Travel Time (min)	= 0.90	+	0.25	+
			0.00	= 1.15
Channel Flow				
X sectional flow area (sqft)	= 2.00	0.00	0.00	
Wetted perimeter (ft)	= 4.47	0.00	0.00	
Channel slope (%)	= 5.00	0.00	0.00	
Manning's n-value	= 0.040	0.015	0.015	
Velocity (ft/s)	=4.86	0.00	0.00	
Flow length (ft)	({})31.6	0.0	0.0	
Travel Time (min)	= 0.11	+	0.00	+
			0.00	= 0.11
Total Travel Time, Tc				12.00 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

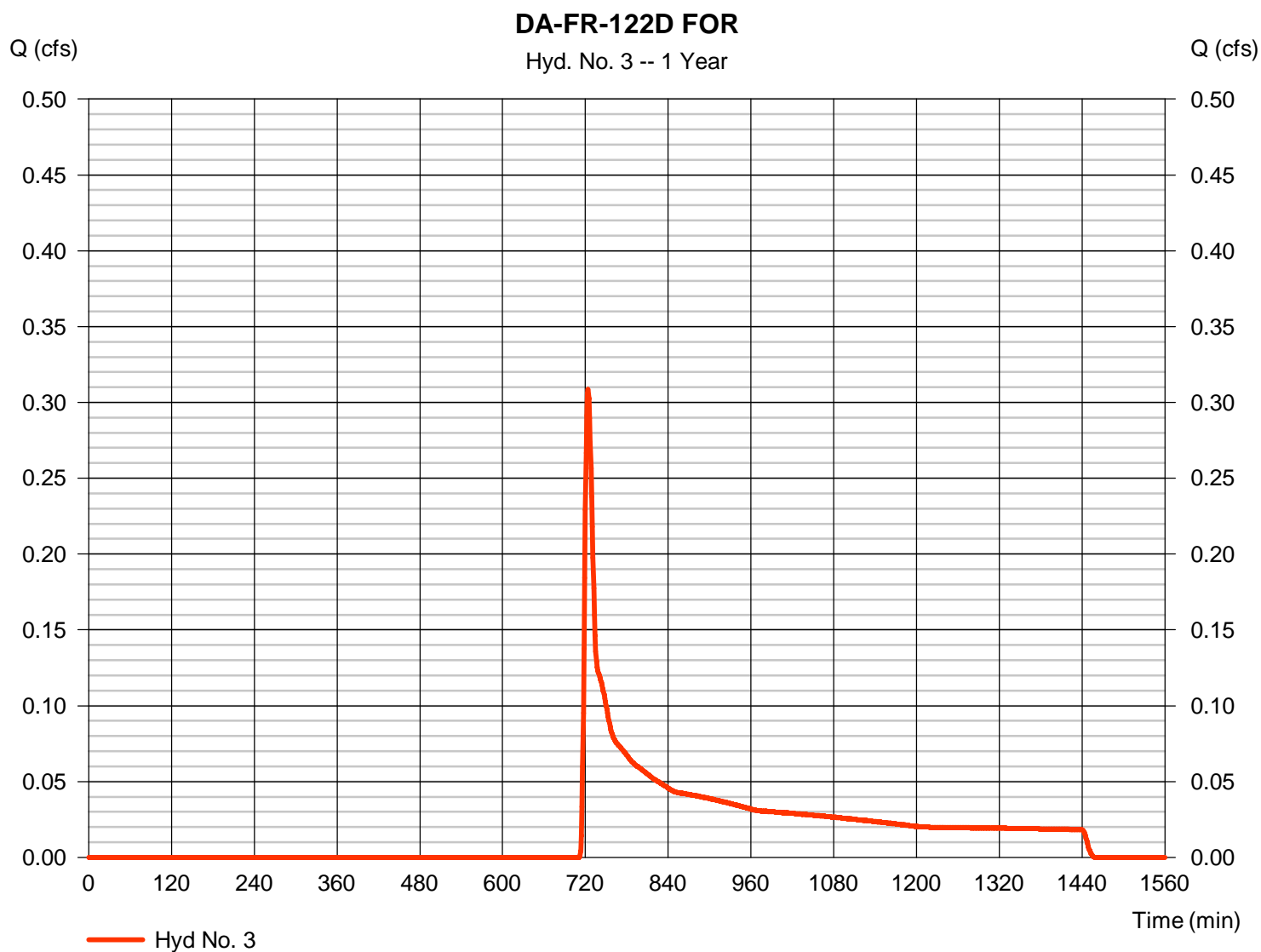
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-122D FOR

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 1.580 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.30 in
 Storm duration = 24 hrs

Peak discharge = 0.309 cfs
 Time to peak = 724 min
 Hyd. volume = 1,641 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 11.50 min
 Distribution = Type II
 Shape factor = 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-122D FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 9.41	0.00	0.00				
Travel Time (min)	= 10.75	+	0.00	+	0.00	=	10.75
Shallow Concentrated Flow							
Flow length (ft)	= 267.64	0.00	0.00				
Watercourse slope (%)	= 12.69	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.75	0.00	0.00				
Travel Time (min)	= 0.78	+	0.00	+	0.00	=	0.78
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				11.50 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.722	1	723	2,648	-----	-----	-----	DA-FR-122D PRE
2	SCS Runoff	0.466	1	724	2,139	-----	-----	-----	DA-FR-122D DEV
3	SCS Runoff	0.615	1	723	2,426	-----	-----	-----	DA-FR-122D FOR
DA-FR-122D_Hydraflow.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

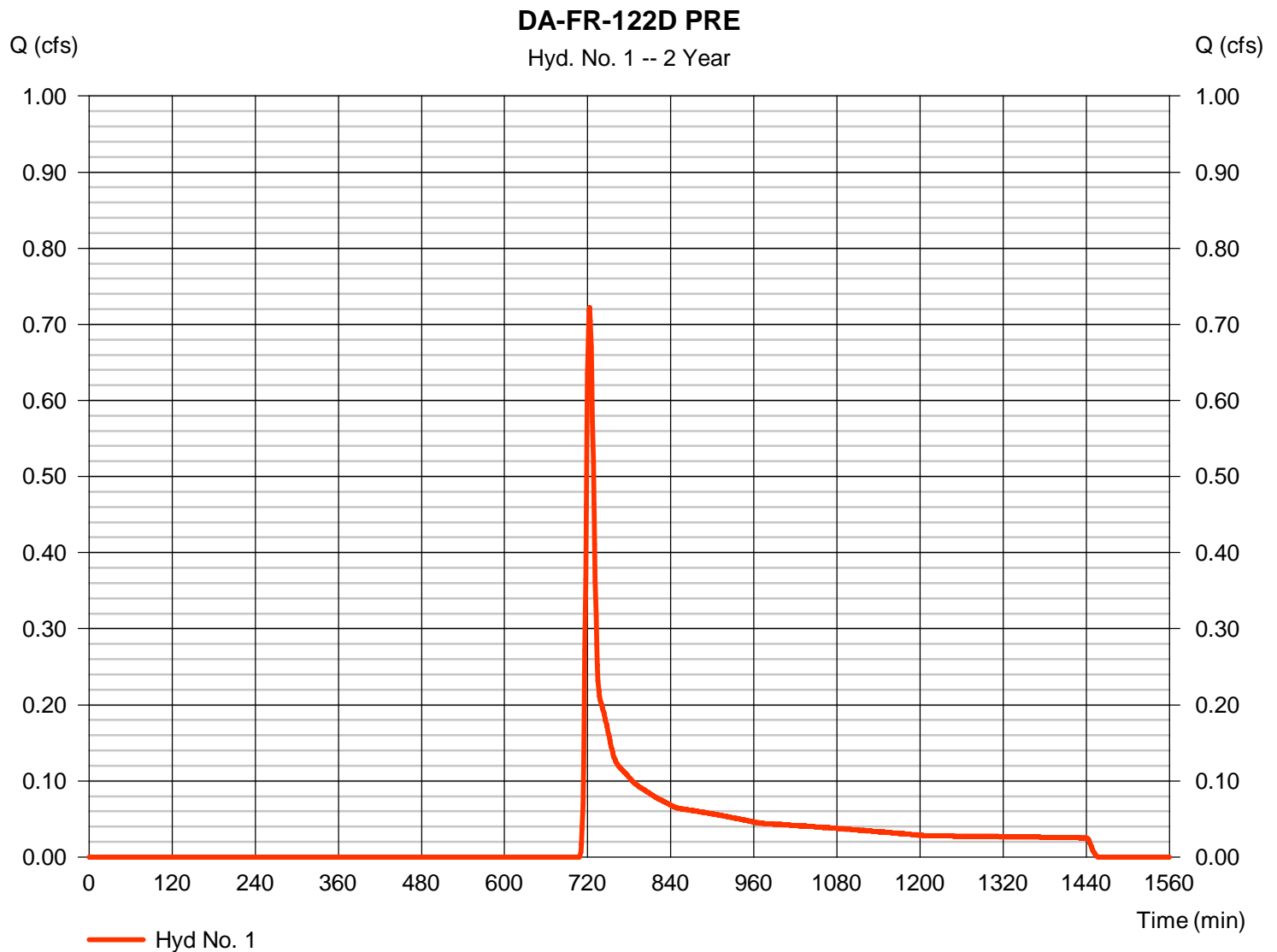
Hyd. No. 1

DA-FR-122D PRE

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 1.580 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.722 cfs
 Time to peak = 723 min
 Hyd. volume = 2,648 cuft
 Curve number = 56*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 11.50 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(0.093 \times 58) + (0.014 \times 100) + (1.473 \times 55)] / 1.580$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

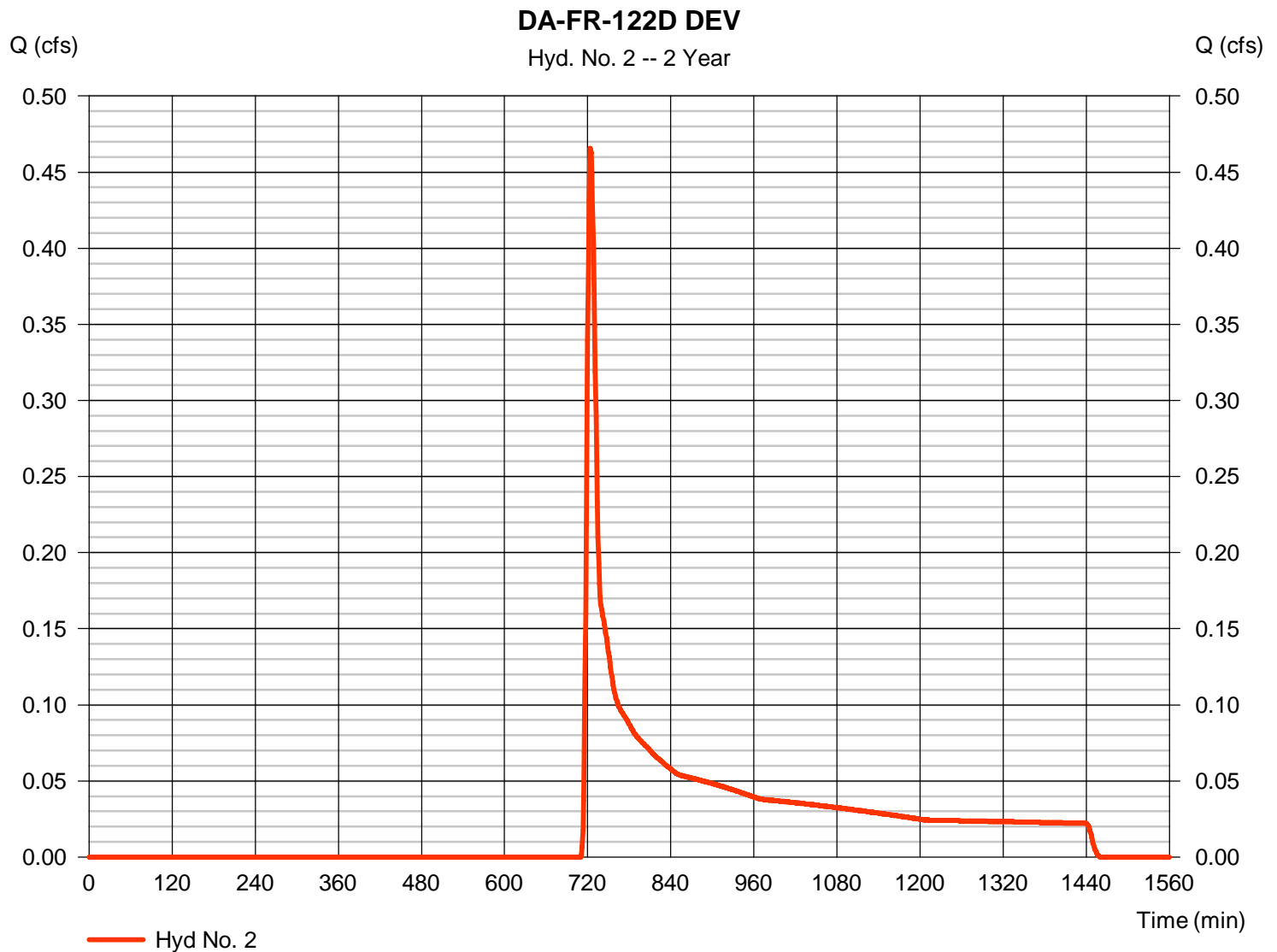
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-122D DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.466 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 2,139 cuft
Drainage area	= 1.580 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.00 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.605 \times 48) + (0.688 \times 58) + (0.014 \times 100) + (0.274 \times 55)] / 1.580$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

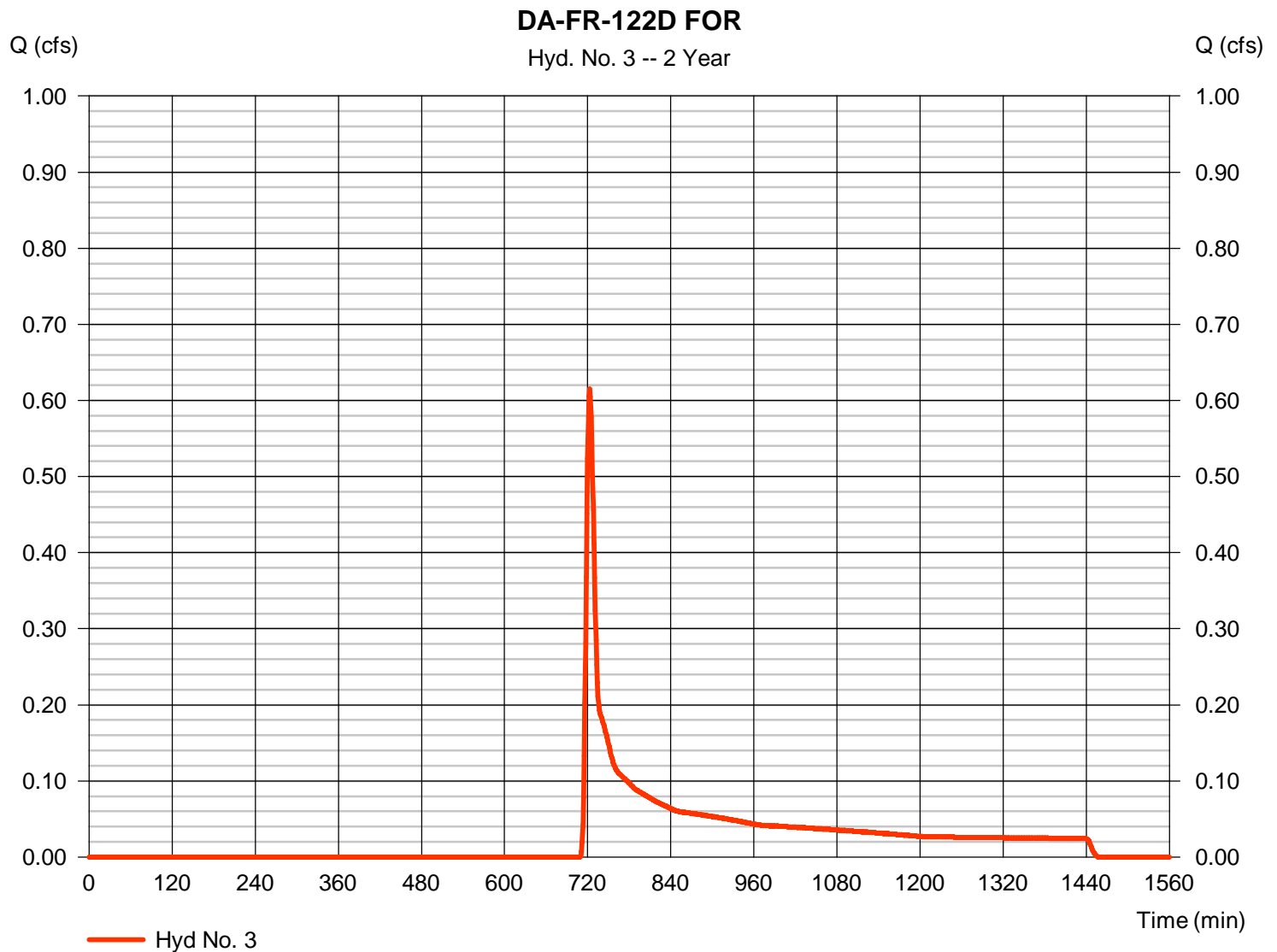
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-122D FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 1.580 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.615 cfs
 Time to peak = 723 min
 Hyd. volume = 2,426 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 11.50 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	3.198	1	721	8,302	-----	-----	-----	DA-FR-122D PRE
2	SCS Runoff	2.557	1	722	7,205	-----	-----	-----	DA-FR-122D DEV
3	SCS Runoff	2.991	1	721	7,872	-----	-----	-----	DA-FR-122D FOR
DA-FR-122D_Hydraflow.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

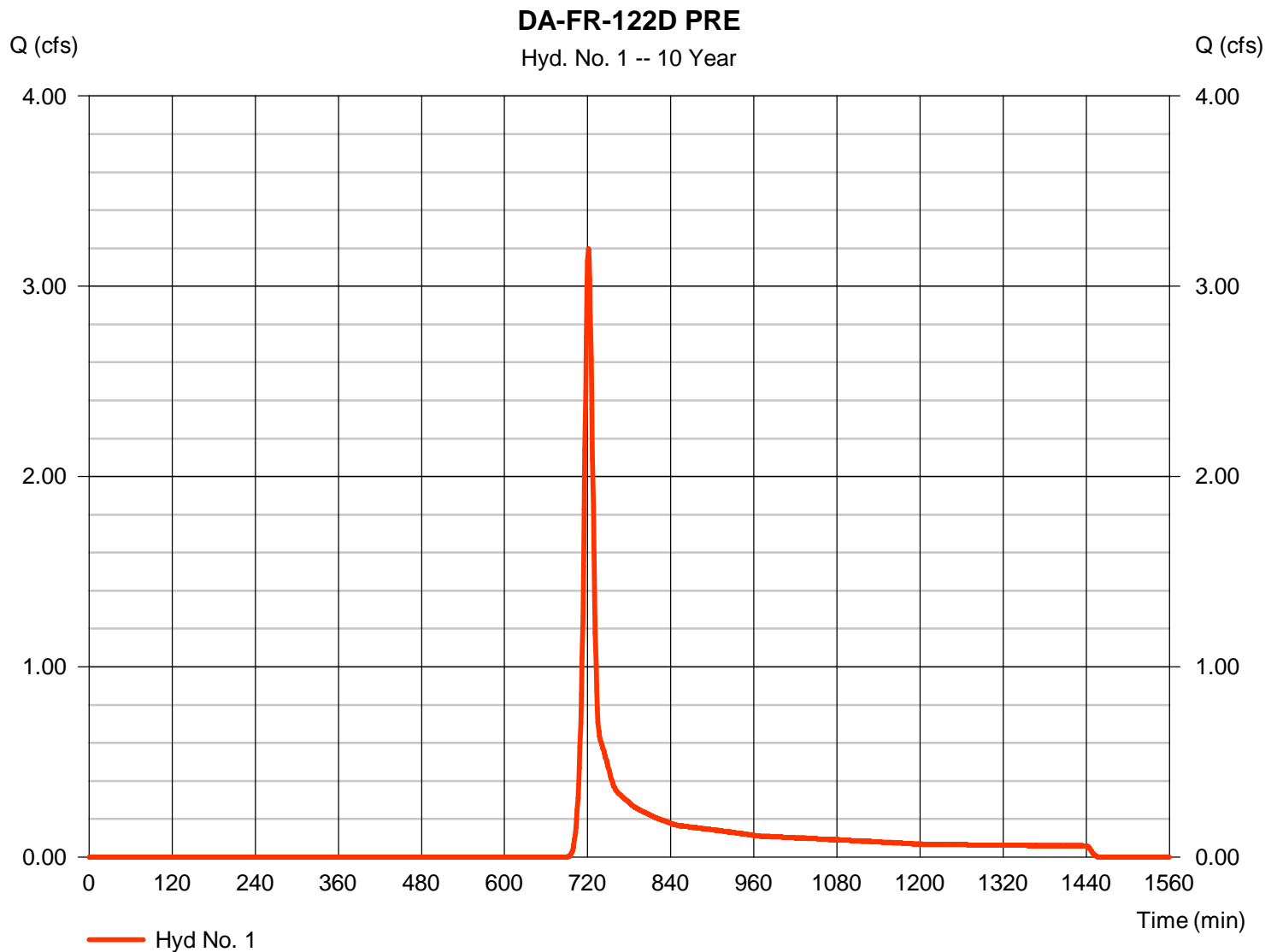
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-122D PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 3.198 cfs
Storm frequency	= 10 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 8,302 cuft
Drainage area	= 1.580 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.50 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.093 \times 58) + (0.014 \times 100) + (1.473 \times 55)] / 1.580$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

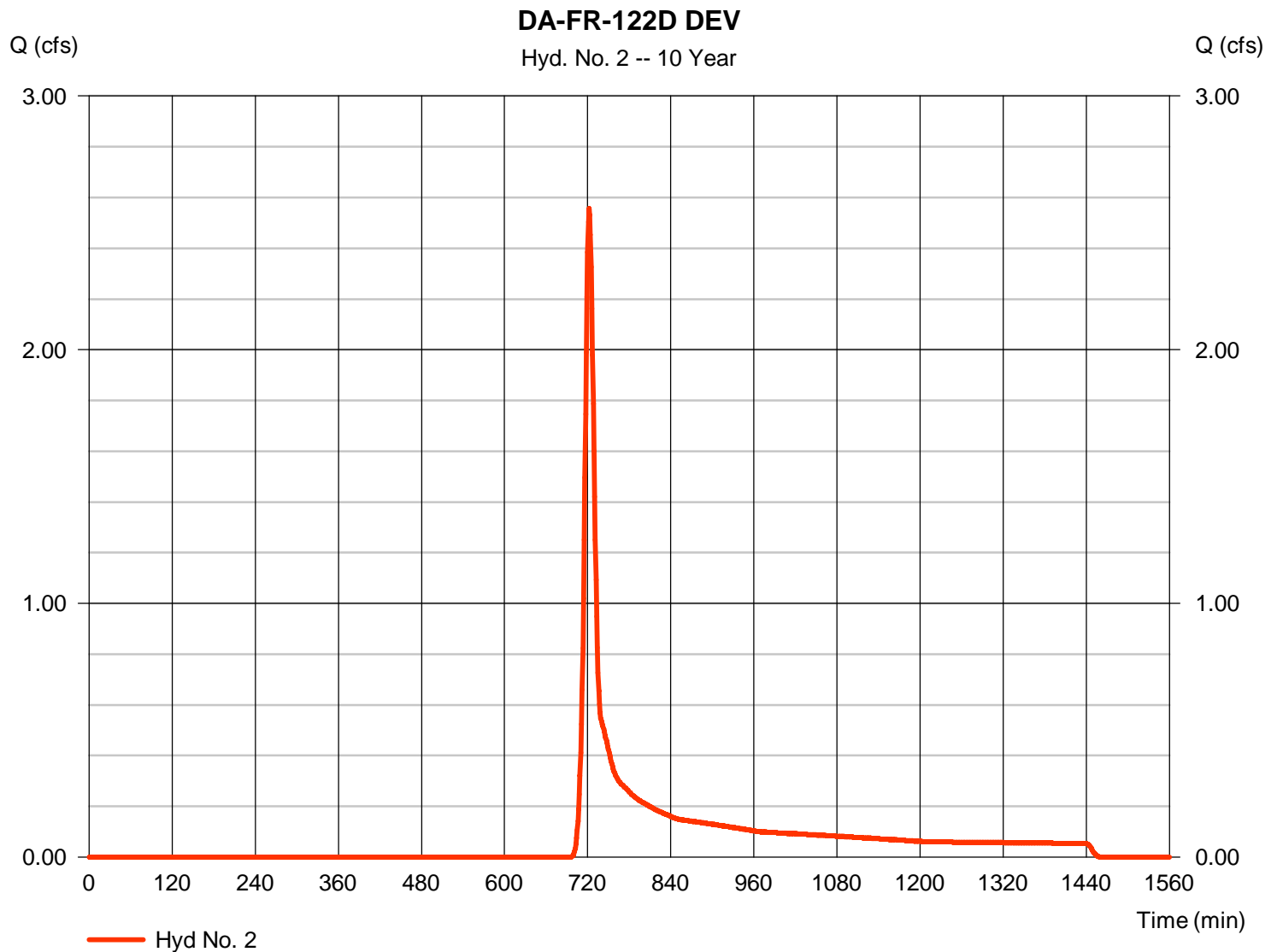
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-122D DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 2.557 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 7,205 cuft
Drainage area	= 1.580 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.00 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.605 \times 48) + (0.688 \times 58) + (0.014 \times 100) + (0.274 \times 55)] / 1.580$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

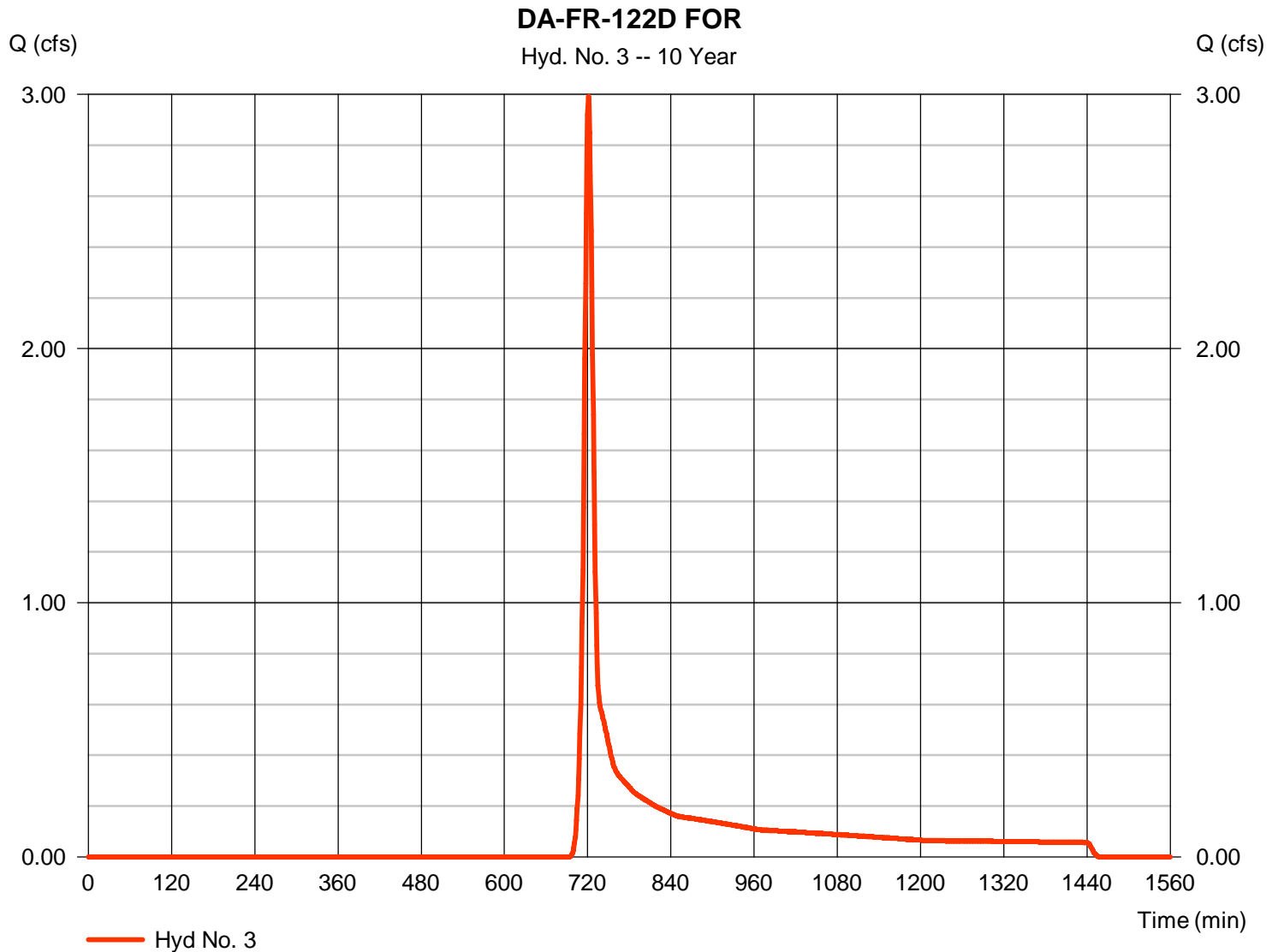
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-122D FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 1.580 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 2.991 cfs
 Time to peak = 721 min
 Hyd. volume = 7,872 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 11.50 min
 Distribution = Type II
 Shape factor = 484



DA-FR-122E

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	2.894	10299
Developed Condition	2.894	10299
Pre-Developed (Forest) Condition	0.892	5520

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF =

1

Calculations:

Check #1:	$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	2.894	\leq OK	2.894
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	2.894	\leq OK	2.894
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ --->	2.894	<u>shall not</u> be required to be \leq	0.478

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s n value of 0.011 was used.</p> <p><i>Sources:</i></p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

Table 2 – Manning's *n* Values for Open Channel Flow

Channel Type	Manning <i>n</i>		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's <i>n</i> value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's <i>n</i> value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-122E PRE
2	SCS Runoff	DA-FR-122E DEV
3	SCS Runoff	DA-FR-122E FOR

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	2.894	1	724	10,299	-----	-----	-----	DA-FR-122E PRE
2	SCS Runoff	2.894	1	724	10,299	-----	-----	-----	DA-FR-122E DEV
3	SCS Runoff	0.892	1	726	5,520	-----	-----	-----	DA-FR-122E FOR
DA-FR-122E_Hydraflow.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

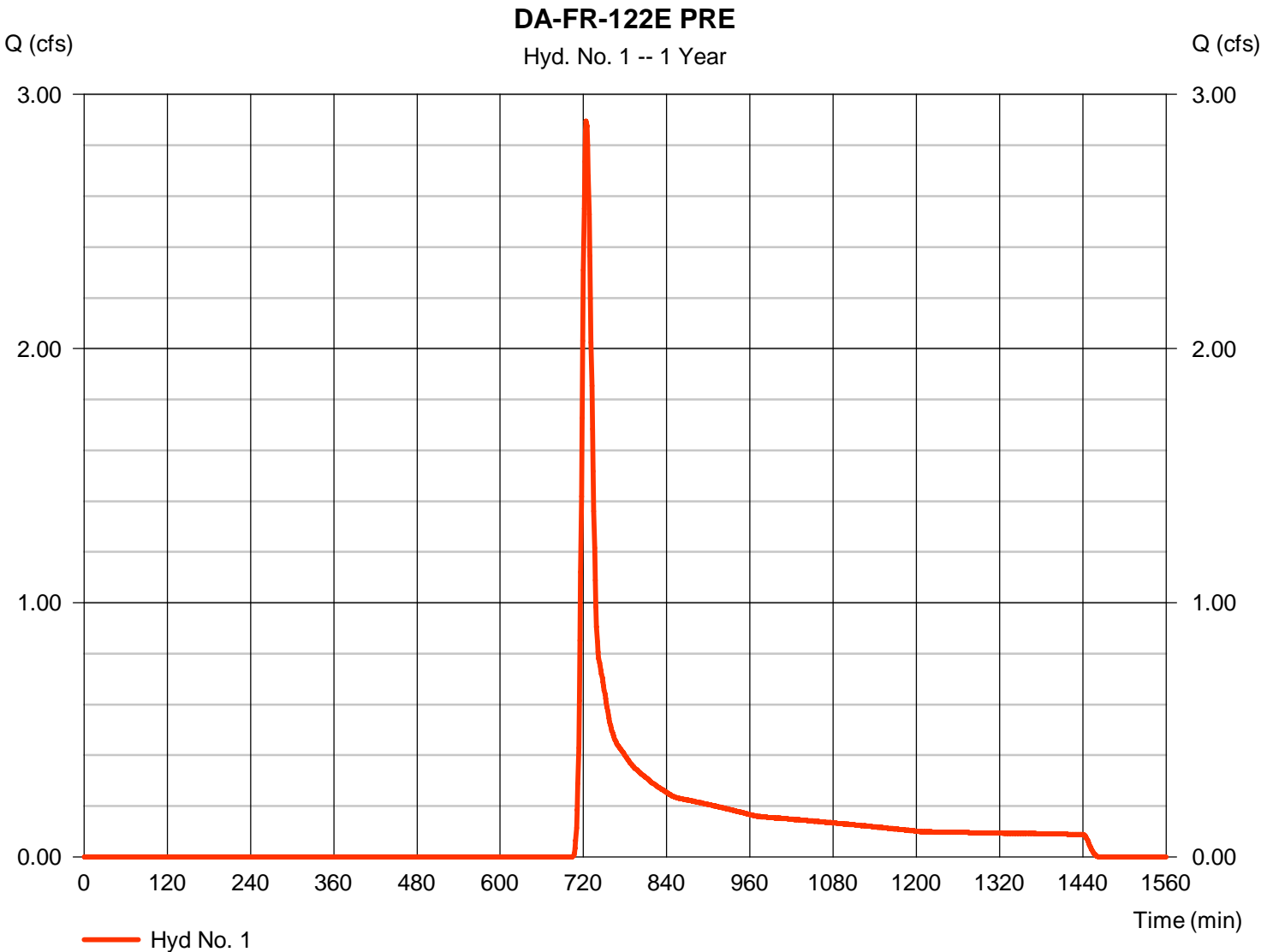
Hydrograph Report

Hyd. No. 1

DA-FR-122E PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 2.894 cfs
Storm frequency	= 1 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 10,299 cuft
Drainage area	= 5.410 ac	Curve number	= 62*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.50 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.090 x 48) + (0.424 x 82) + (0.009 x 85) + (0.313 x 98) + (3.715 x 58) + (0.859 x 55)] / 5.410



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-122E PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 5.94	0.00	0.00				
Travel Time (min)	= 12.92	+	0.00	+	0.00	=	12.92
Shallow Concentrated Flow							
Flow length (ft)	= 474.48	0.00	0.00				
Watercourse slope (%)	= 9.97	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.09	0.00	0.00				
Travel Time (min)	= 1.55	+	0.00	+	0.00	=	1.55
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				14.50 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

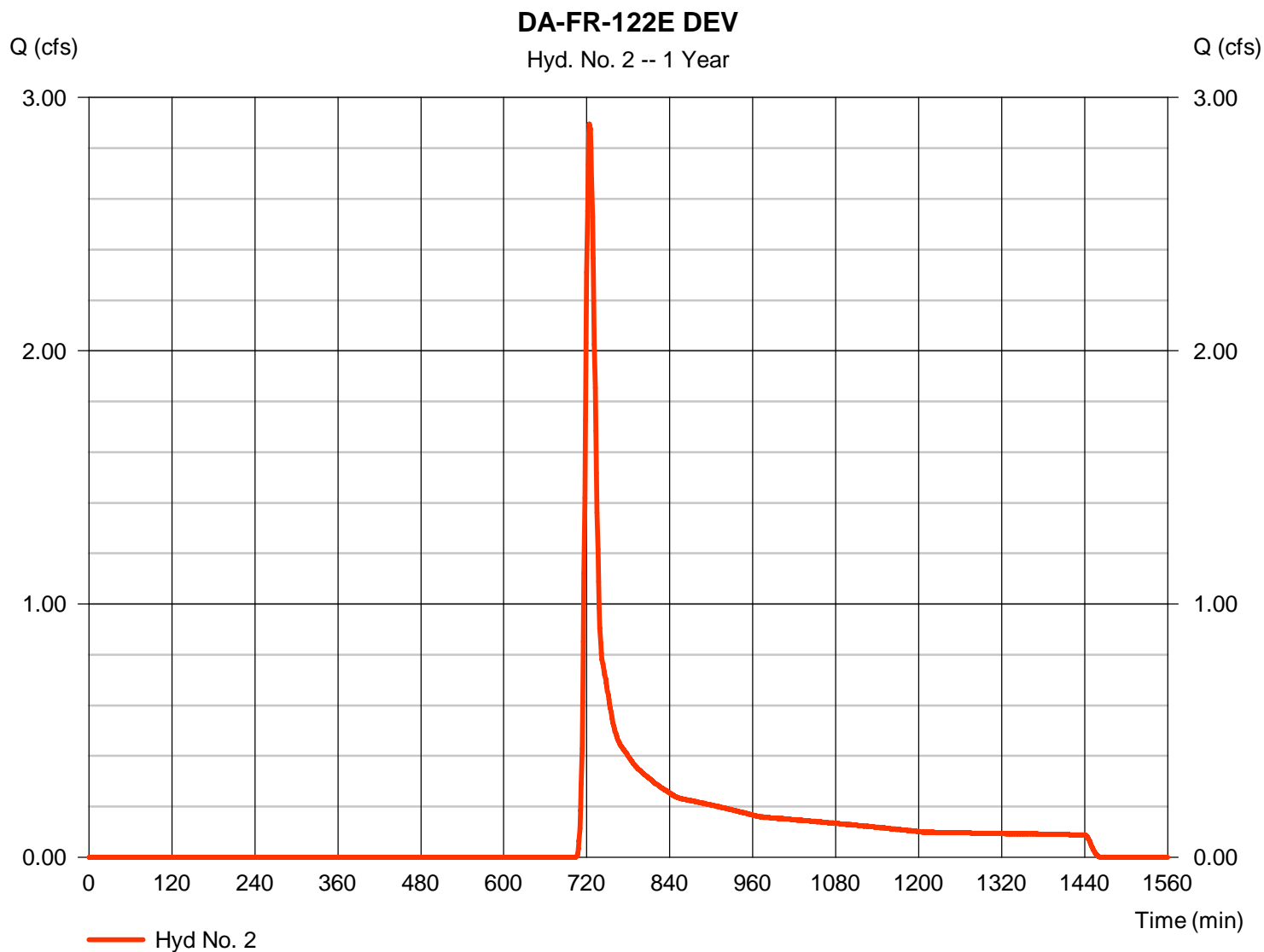
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-122E DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 2.894 cfs
Storm frequency	= 1 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 10,299 cuft
Drainage area	= 5.410 ac	Curve number	= 62*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.20 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.096 x 48) + (0.424 x 82) + (0.009 x 85) + (0.313 x 98) + (4.085 x 58) + (0.483 x 55)] / 5.410



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-122E DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 5.94	0.00	0.00				
Travel Time (min)	= 12.92	+	0.00	+	0.00	=	12.92
Shallow Concentrated Flow							
Flow length (ft)	= 233.55	143.58	0.00				
Watercourse slope (%)	= 8.98	16.60	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=4.83	6.57	0.00				
Travel Time (min)	= 0.81	+	0.36	+	0.00	=	1.17
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	(\{0\})21.3	0.0	0.0				
Travel Time (min)	= 0.07	+	0.00	+	0.00	=	0.07
Total Travel Time, Tc				14.20 min			

Hydrograph Report

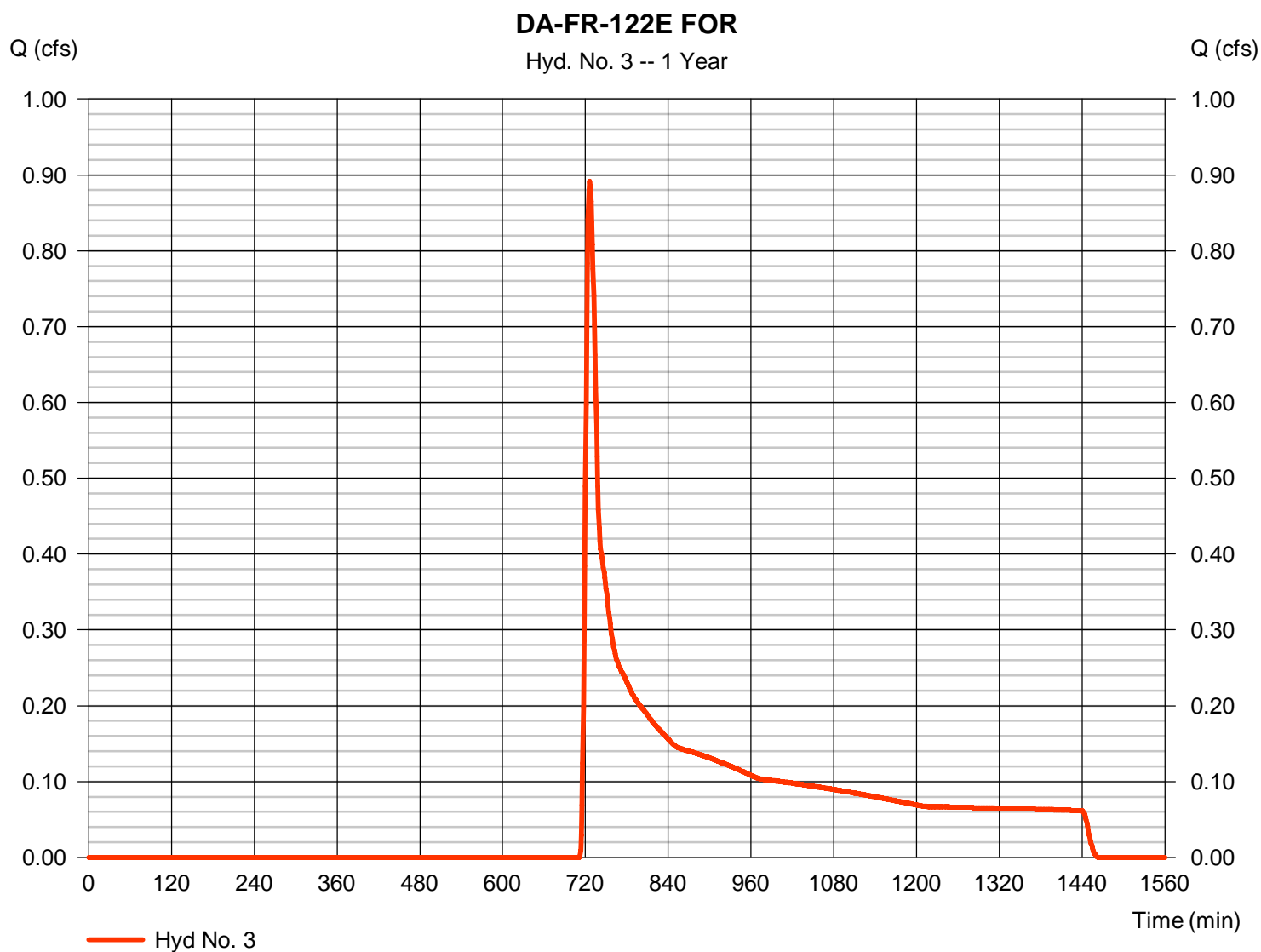
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Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-122E FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.892 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 5,520 cuft
Drainage area	= 5.410 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.50 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-122E FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 5.94	0.00	0.00	
Travel Time (min)	= 12.92	+ 0.00	+ 0.00	= 12.92
Shallow Concentrated Flow				
Flow length (ft)	= 474.48	0.00	0.00	
Watercourse slope (%)	= 9.97	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=5.09	0.00	0.00	
Travel Time (min)	= 1.55	+ 0.00	+ 0.00	= 1.55
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				14.50 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	4.325	1	724	13,973	-----	-----	-----	DA-FR-122E PRE
2	SCS Runoff	4.325	1	724	13,973	-----	-----	-----	DA-FR-122E DEV
3	SCS Runoff	1.773	1	725	8,161	-----	-----	-----	DA-FR-122E FOR
DA-FR-122E_Hydraflow.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

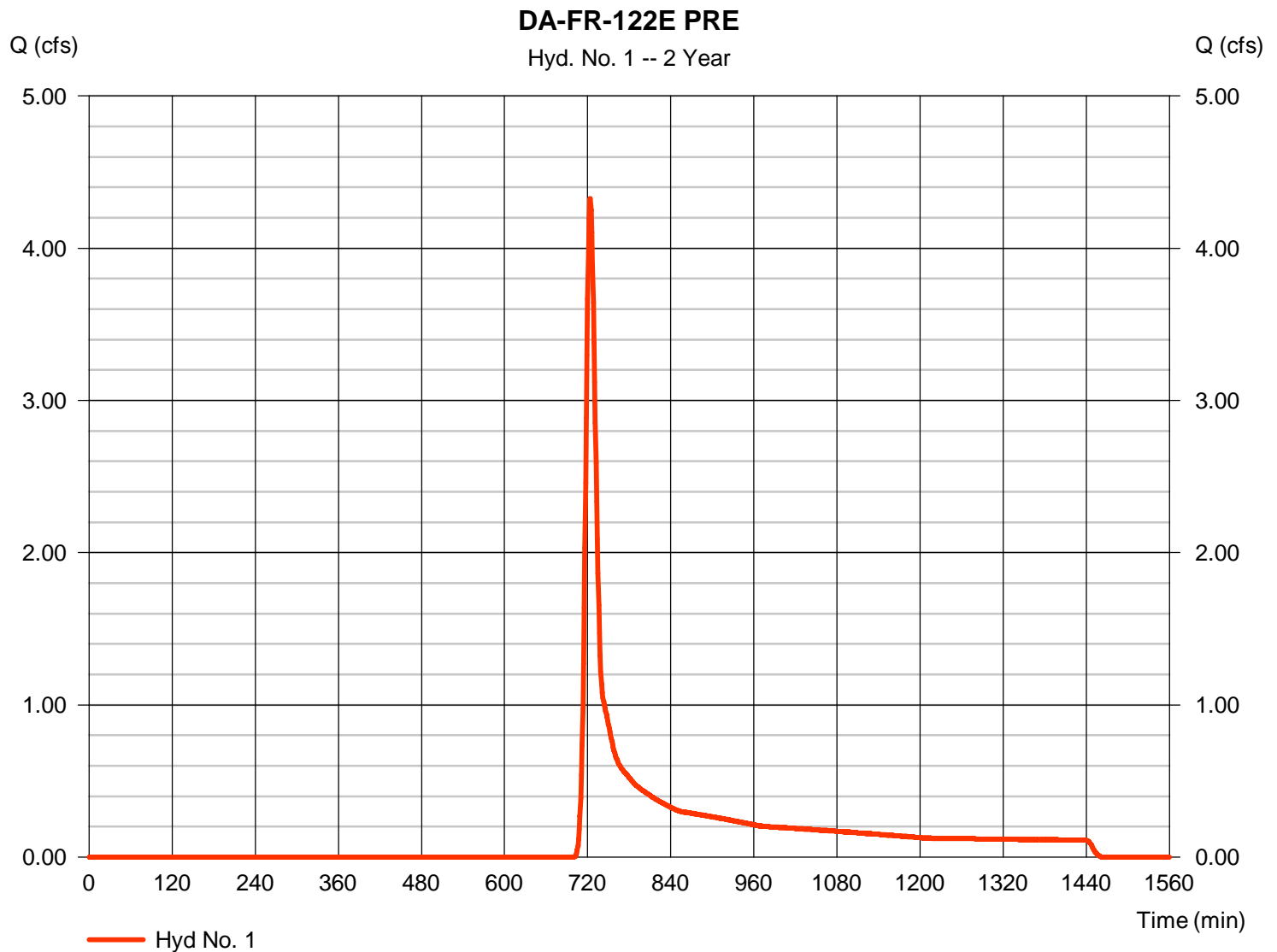
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-122E PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 4.325 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 13,973 cuft
Drainage area	= 5.410 ac	Curve number	= 62*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.50 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.090 \times 48) + (0.424 \times 82) + (0.009 \times 85) + (0.313 \times 98) + (3.715 \times 58) + (0.859 \times 55)] / 5.410$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

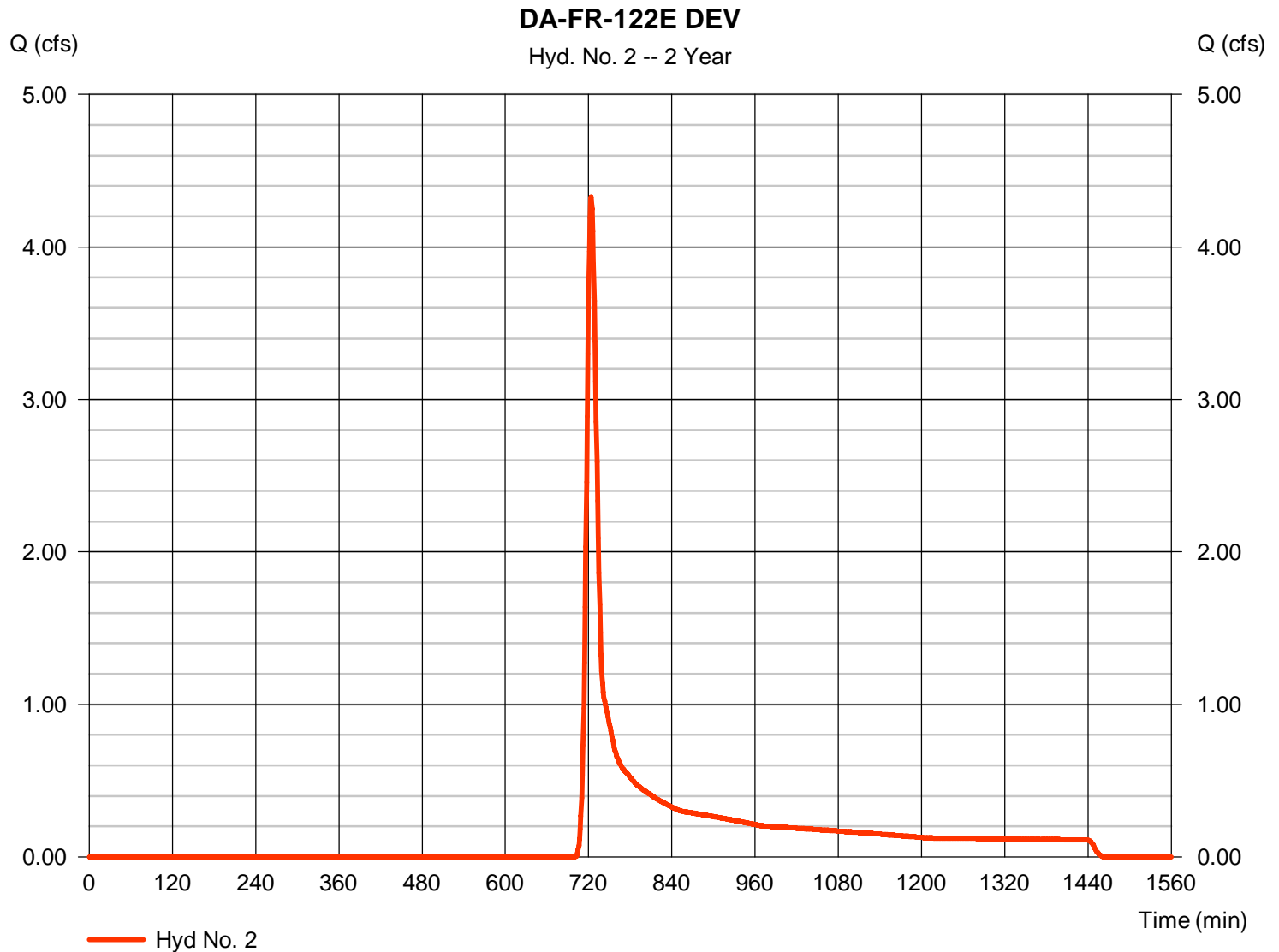
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-122E DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 4.325 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 13,973 cuft
Drainage area	= 5.410 ac	Curve number	= 62*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.20 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.096 \times 48) + (0.424 \times 82) + (0.009 \times 85) + (0.313 \times 98) + (4.085 \times 58) + (0.483 \times 55)] / 5.410$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

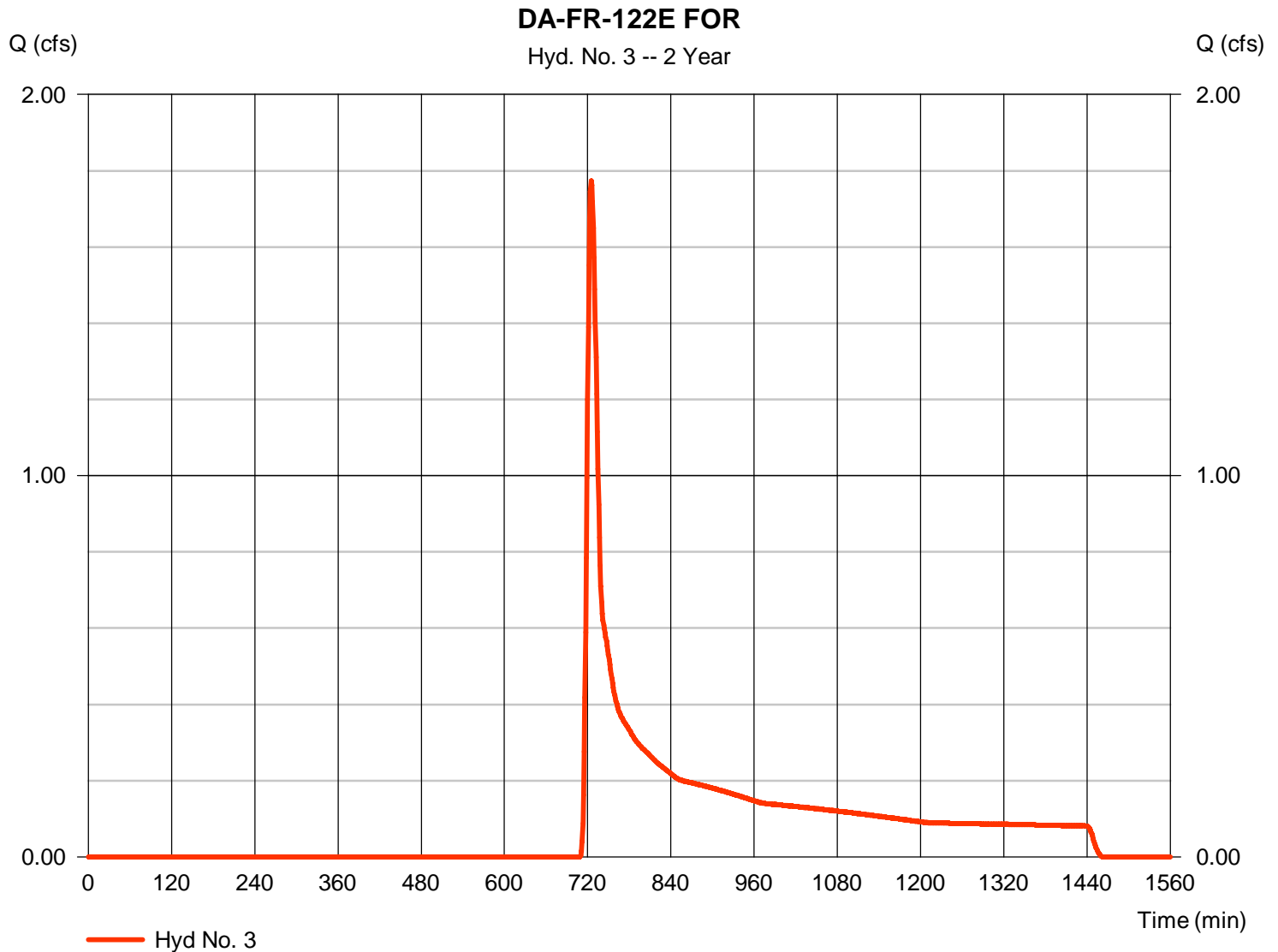
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-122E FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 5.410 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 1.773 cfs
 Time to peak = 725 min
 Hyd. volume = 8,161 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 14.50 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	13.34	1	723	37,076	-----	-----	-----	DA-FR-122E PRE
2	SCS Runoff	13.34	1	723	37,076	-----	-----	-----	DA-FR-122E DEV
3	SCS Runoff	8.862	1	723	26,482	-----	-----	-----	DA-FR-122E FOR
DA-FR-122E_Hydraflow.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

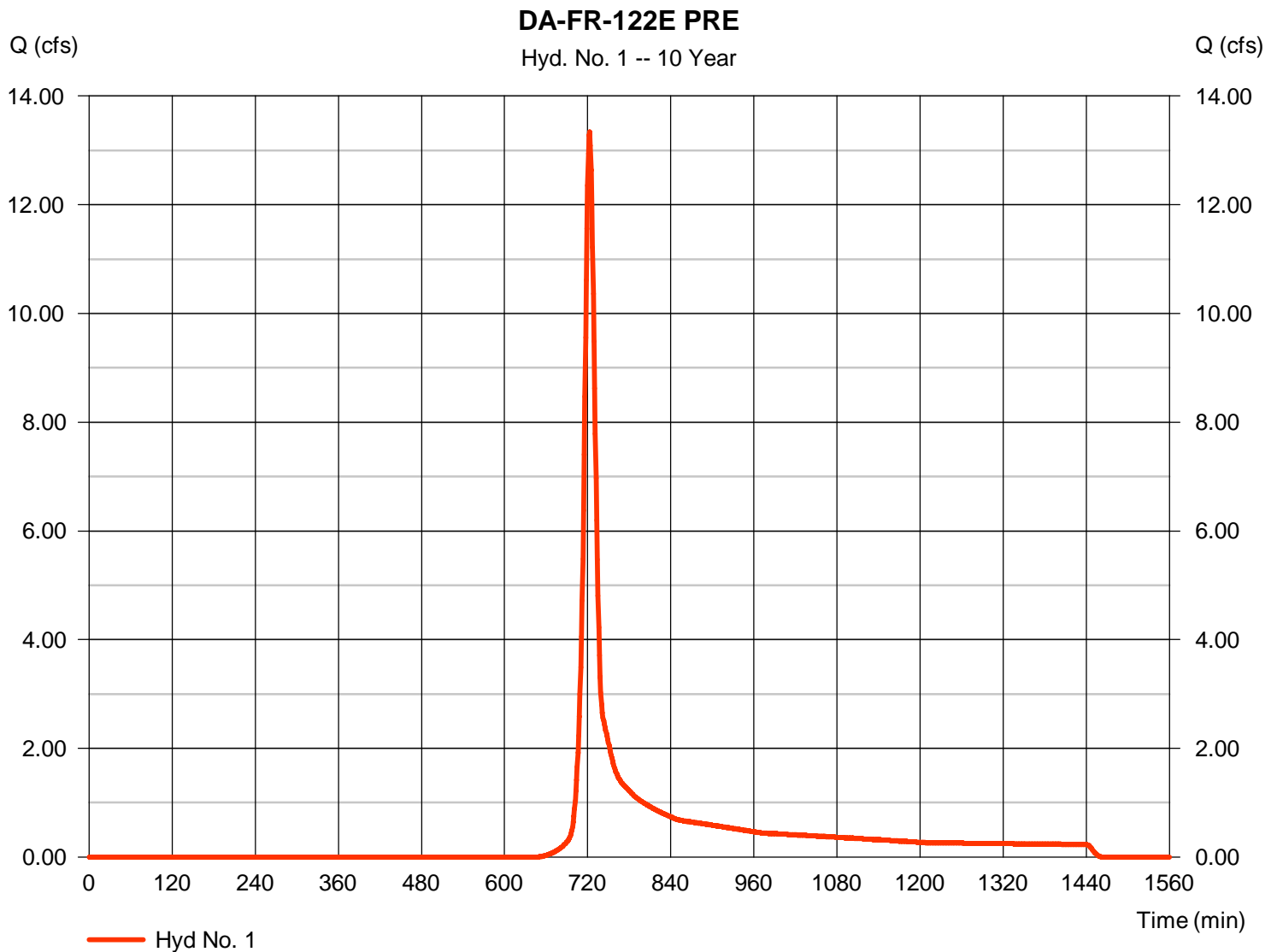
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-122E PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 13.34 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 37,076 cuft
Drainage area	= 5.410 ac	Curve number	= 62*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.50 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.090 \times 48) + (0.424 \times 82) + (0.009 \times 85) + (0.313 \times 98) + (3.715 \times 58) + (0.859 \times 55)] / 5.410$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

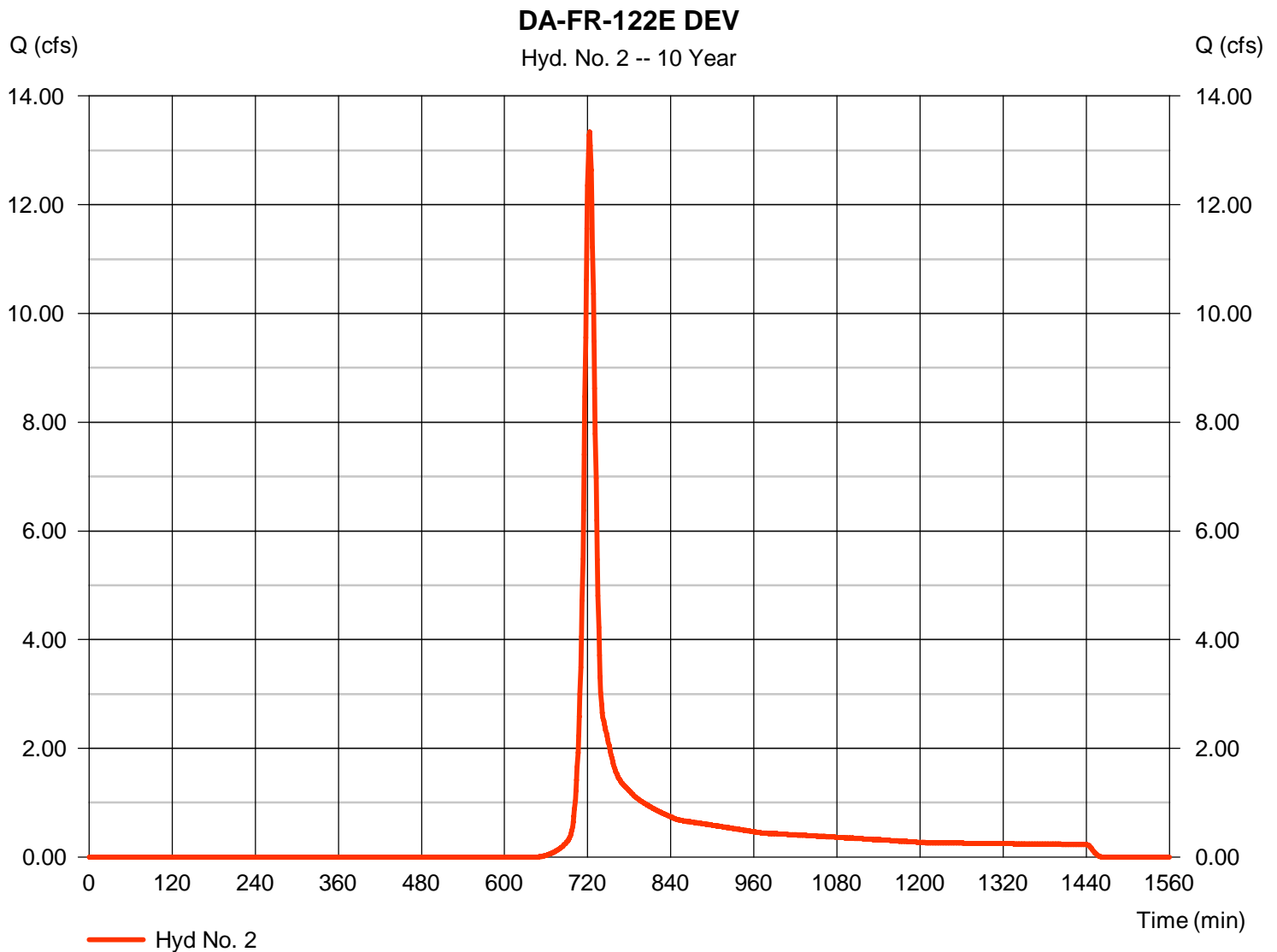
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-122E DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 13.34 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 37,076 cuft
Drainage area	= 5.410 ac	Curve number	= 62*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.20 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.096 \times 48) + (0.424 \times 82) + (0.009 \times 85) + (0.313 \times 98) + (4.085 \times 58) + (0.483 \times 55)] / 5.410$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

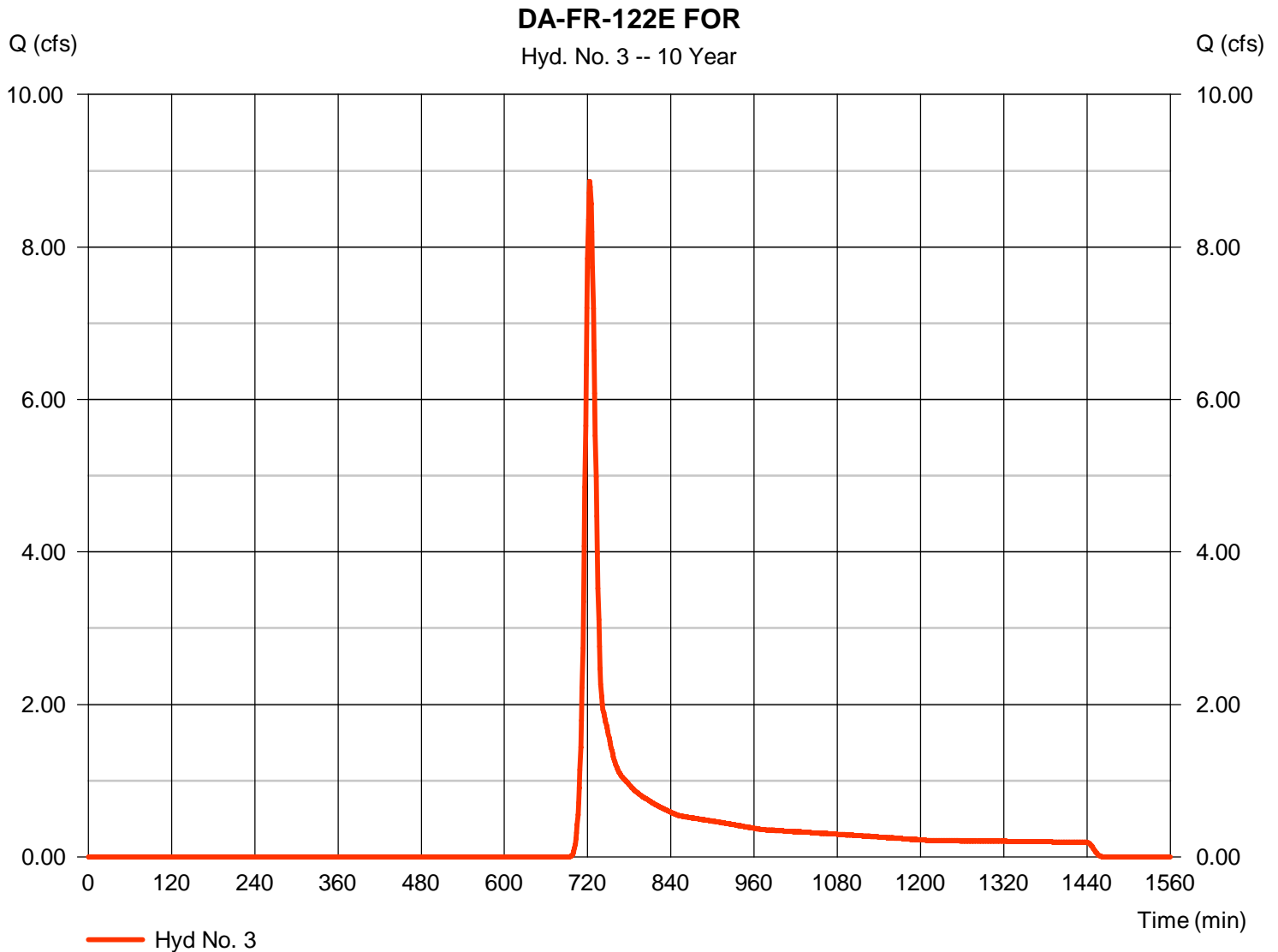
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-122E FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 5.410 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 8.862 cfs
 Time to peak = 723 min
 Hyd. volume = 26,482 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 14.50 min
 Distribution = Type II
 Shape factor = 484



DA-FR-122F

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	1.311	5978
Developed Condition	1.311	5978
Pre-Developed (Forest) Condition	0.608	4081

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 1

Calculations:

Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	1.311	\leq OK	1.311
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	1.311	\leq OK	1.311
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ ---->	1.311	<u>shall not</u> be required to be \leq	0.415

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s n value of 0.011 was used.</p> <p><i>Sources:</i></p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

Table 2 – Manning's *n* Values for Open Channel Flow

Channel Type	Manning <i>n</i>		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's <i>n</i> value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's <i>n</i> value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-122F PRE
2	SCS Runoff	DA-FR-122F DEV
3	SCS Runoff	DA-FR-122F FOR

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	1.311	1	726	5,978	-----	-----	-----	DA-FR-122F PRE
2	SCS Runoff	1.311	1	726	5,978	-----	-----	-----	DA-FR-122F DEV
3	SCS Runoff	0.608	1	727	4,081	-----	-----	-----	DA-FR-122F FOR
DA-FR-122F_Hydraflow.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

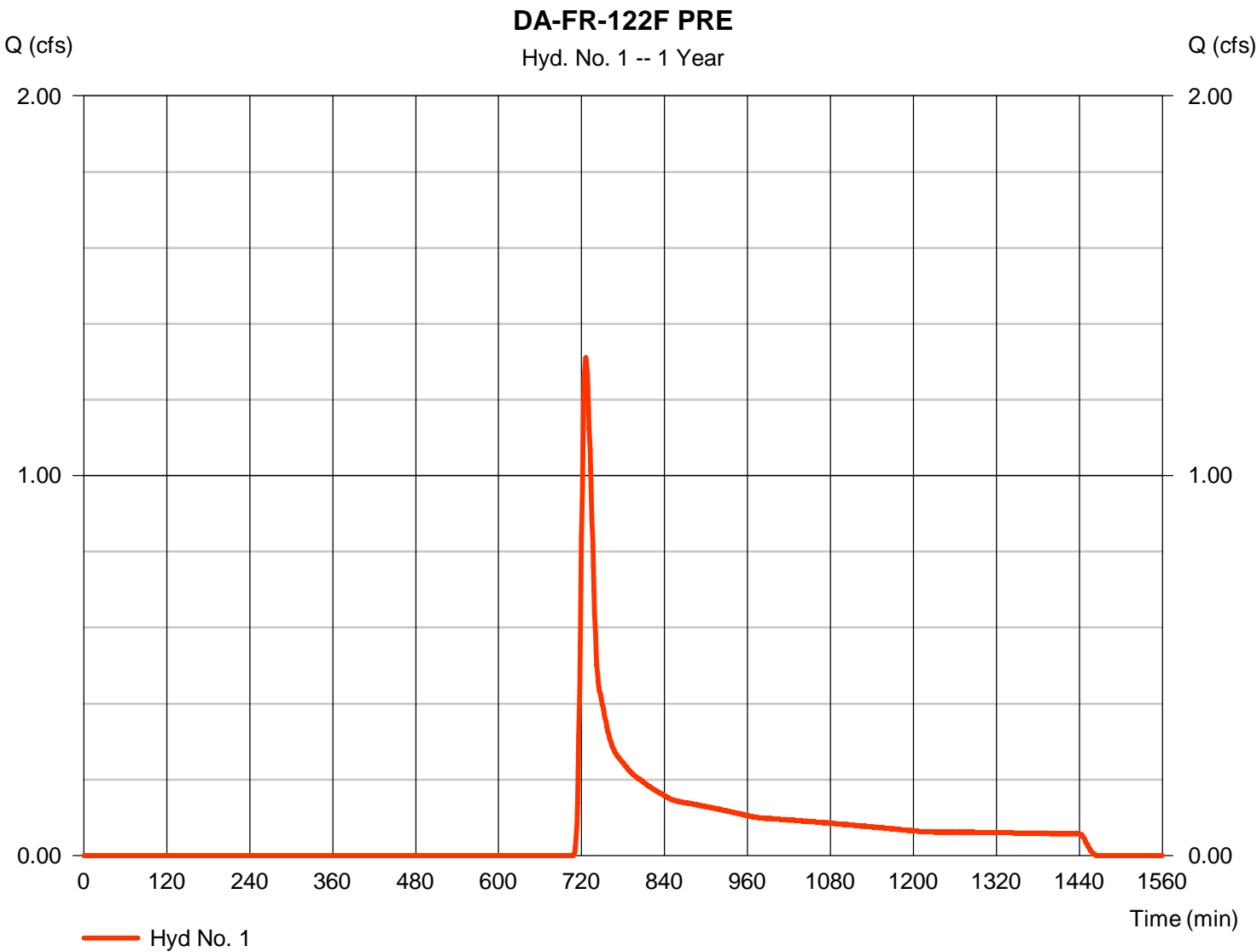
Hydrograph Report

Hyd. No. 1

DA-FR-122F PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 1.311 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 5,978 cuft
Drainage area	= 3.950 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.80 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.259 x 48) + (0.215 x 82) + (3.473 x 58)] / 3.950



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-122F PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 4.12	0.00	0.00	
Travel Time (min)	= 14.96	+ 0.00	+ 0.00	= 14.96
Shallow Concentrated Flow				
Flow length (ft)	= 297.54	0.00	0.00	
Watercourse slope (%)	= 12.41	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=5.68	0.00	0.00	
Travel Time (min)	= 0.87	+ 0.00	+ 0.00	= 0.87
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				15.80 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

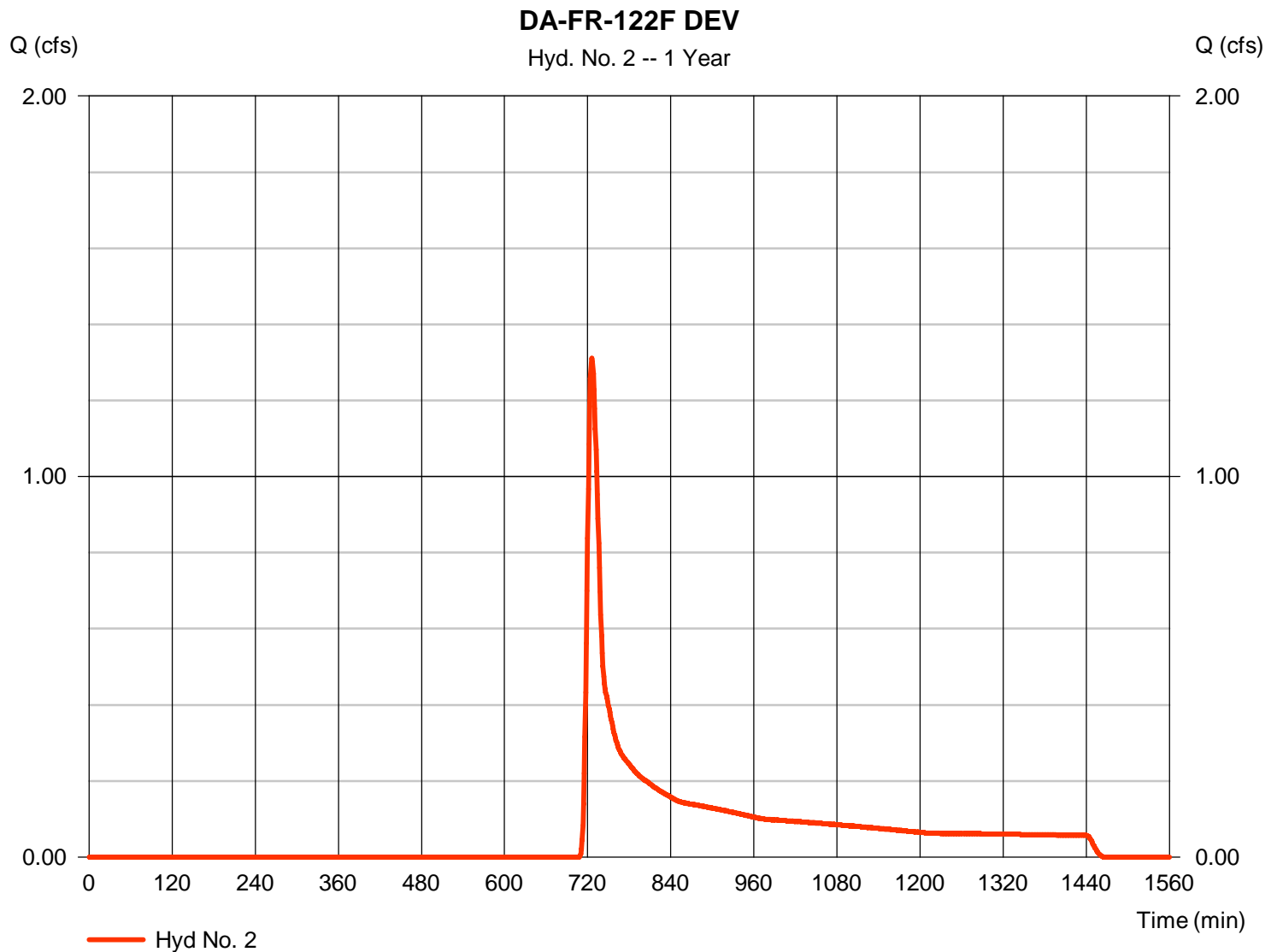
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-122F DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 1.311 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 5,978 cuft
Drainage area	= 3.950 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.10 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.151 \times 48) + (0.215 \times 82) + (3.581 \times 58)] / 3.950$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-122F DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 4.12	0.00	0.00				
Travel Time (min)	= 14.96	+	0.00	+	0.00	=	14.96
Shallow Concentrated Flow							
Flow length (ft)	= 27.04	145.41	123.95				
Watercourse slope (%)	= 6.98	8.62	16.16				
Surface description	= Unpaved	Unpaved	Unpaved				
Average velocity (ft/s)	=4.26	4.74	6.49				
Travel Time (min)	= 0.11	+	0.51	+	0.32	=	0.94
Channel Flow							
X sectional flow area (sqft)	= 2.00	2.00	0.00				
Wetted perimeter (ft)	= 4.47	4.47	0.00				
Channel slope (%)	= 5.00	5.00	0.00				
Manning's n-value	= 0.040	0.040	0.015				
Velocity (ft/s)	=4.86	4.86	0.00				
Flow length (ft)	({}))55.8	5.8	0.0				
Travel Time (min)	= 0.19	+	0.02	+	0.00	=	0.21
Total Travel Time, Tc					16.10 min		

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

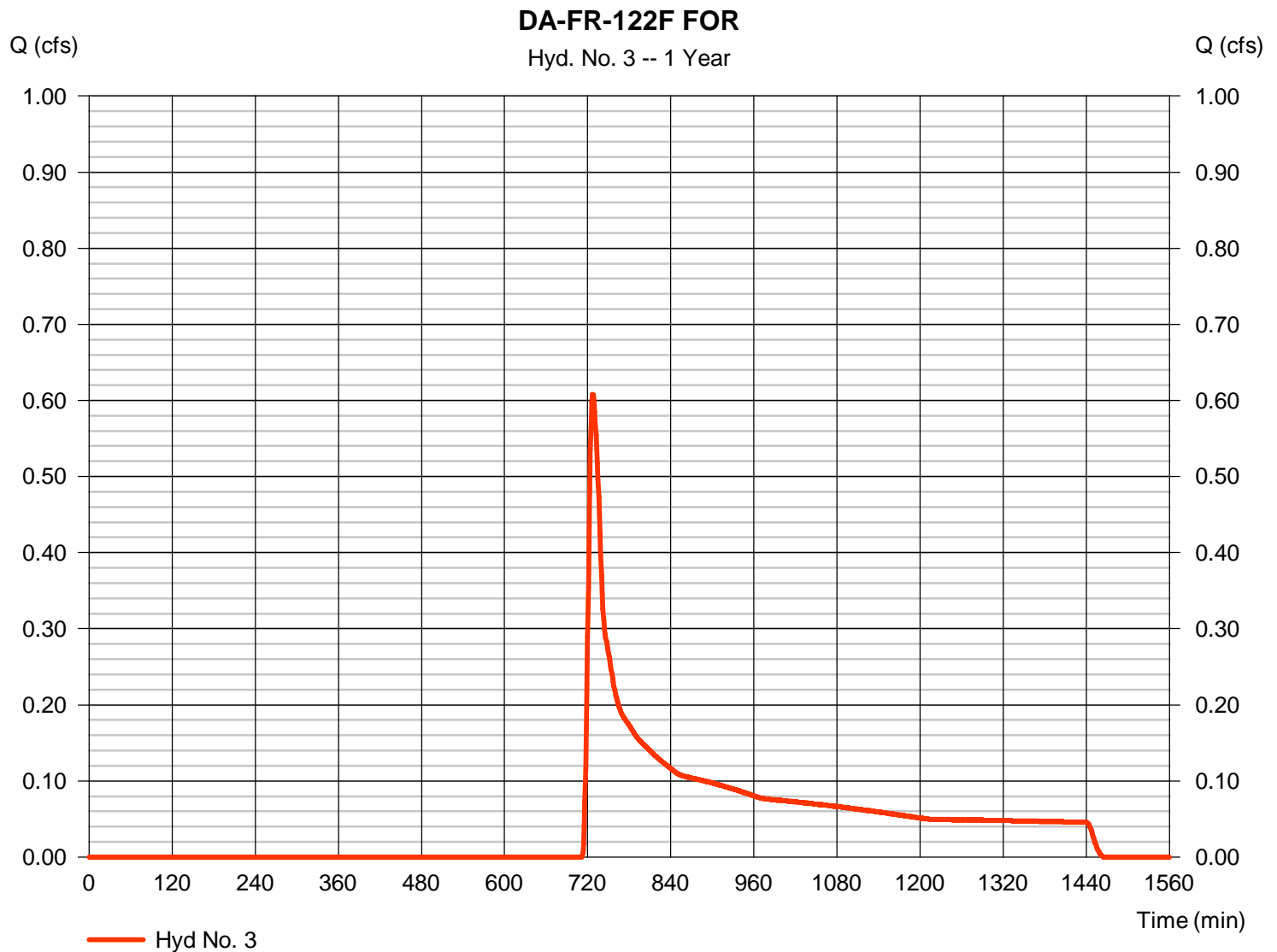
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-122F FOR

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 3.950 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.30 in
 Storm duration = 24 hrs

Peak discharge = 0.608 cfs
 Time to peak = 727 min
 Hyd. volume = 4,081 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.80 min
 Distribution = Type II
 Shape factor = 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-122F FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 4.12	0.00	0.00	
Travel Time (min)	= 14.96	+ 0.00	+ 0.00	= 14.96
Shallow Concentrated Flow				
Flow length (ft)	= 297.54	0.00	0.00	
Watercourse slope (%)	= 12.41	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=5.68	0.00	0.00	
Travel Time (min)	= 0.87	+ 0.00	+ 0.00	= 0.87
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				15.80 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	2.145	1	725	8,368	-----	-----	-----	DA-FR-122F PRE
2	SCS Runoff	2.145	1	725	8,368	-----	-----	-----	DA-FR-122F DEV
3	SCS Runoff	1.207	1	726	6,033	-----	-----	-----	DA-FR-122F FOR
DA-FR-122F_Hydraflow.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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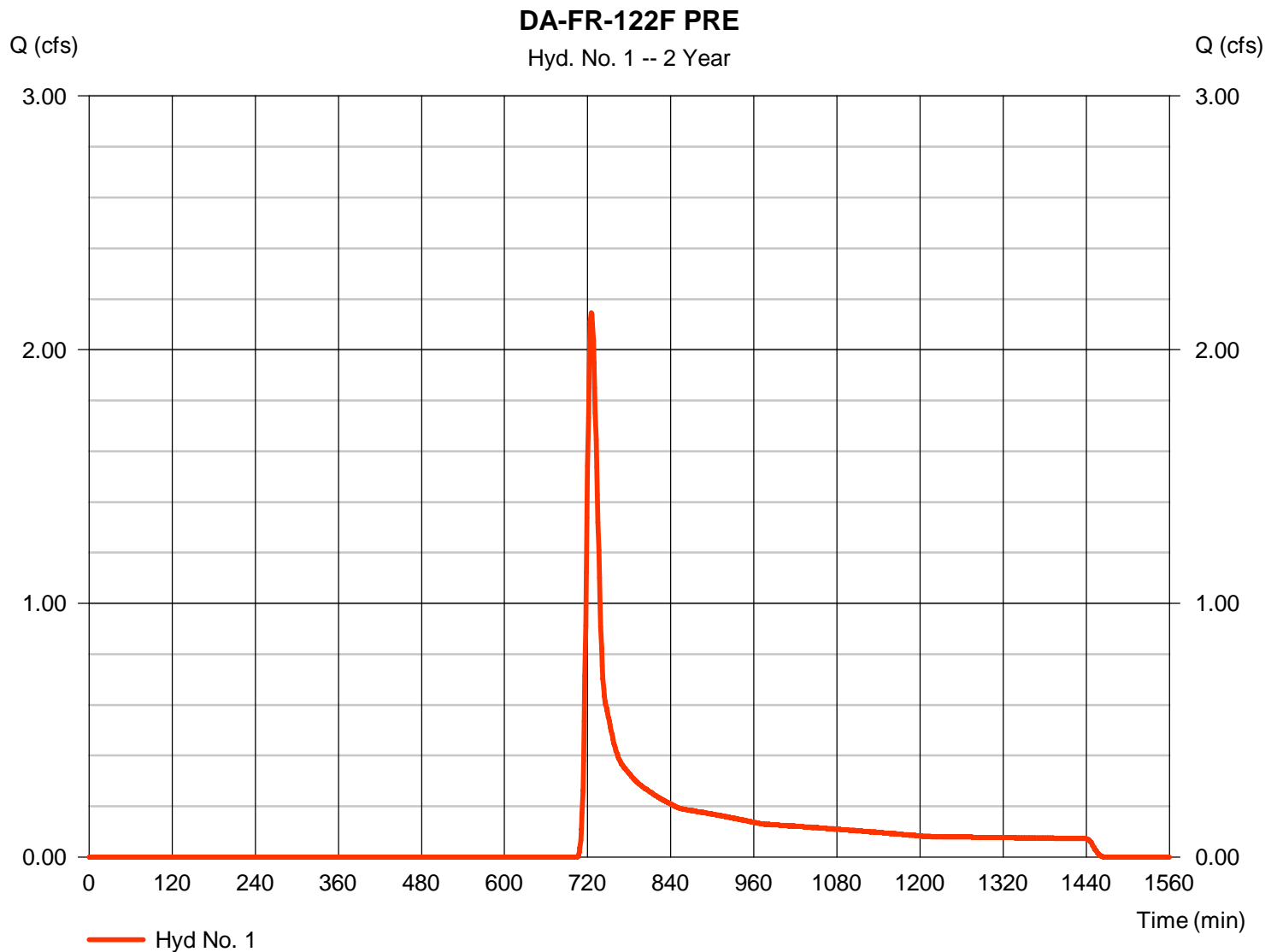
Hyd. No. 1

DA-FR-122F PRE

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 3.950 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 2.145 cfs
 Time to peak = 725 min
 Hyd. volume = 8,368 cuft
 Curve number = 59*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.80 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(0.259 \times 48) + (0.215 \times 82) + (3.473 \times 58)] / 3.950$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

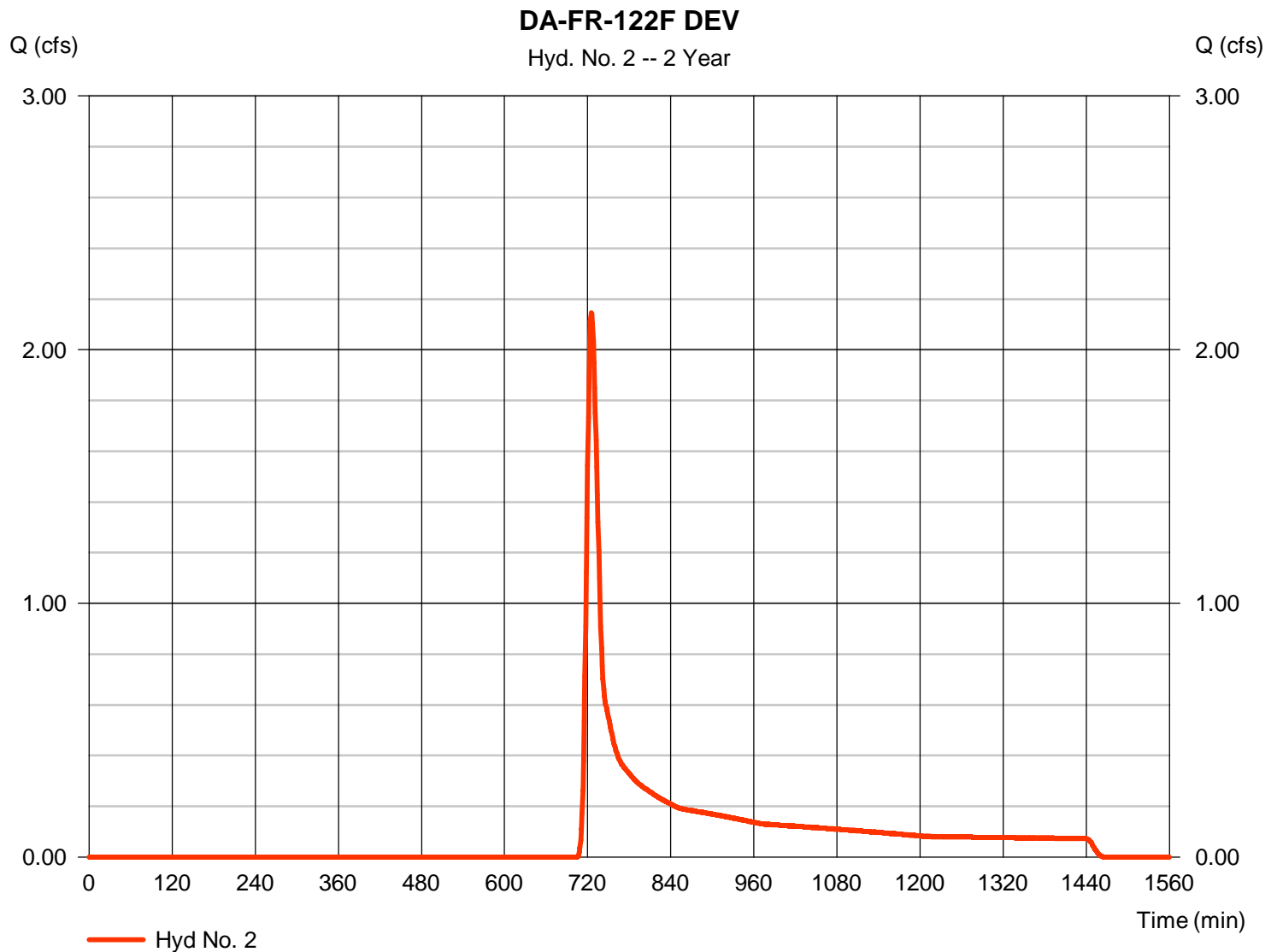
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-122F DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 2.145 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 8,368 cuft
Drainage area	= 3.950 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.10 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.151 \times 48) + (0.215 \times 82) + (3.581 \times 58)] / 3.950$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

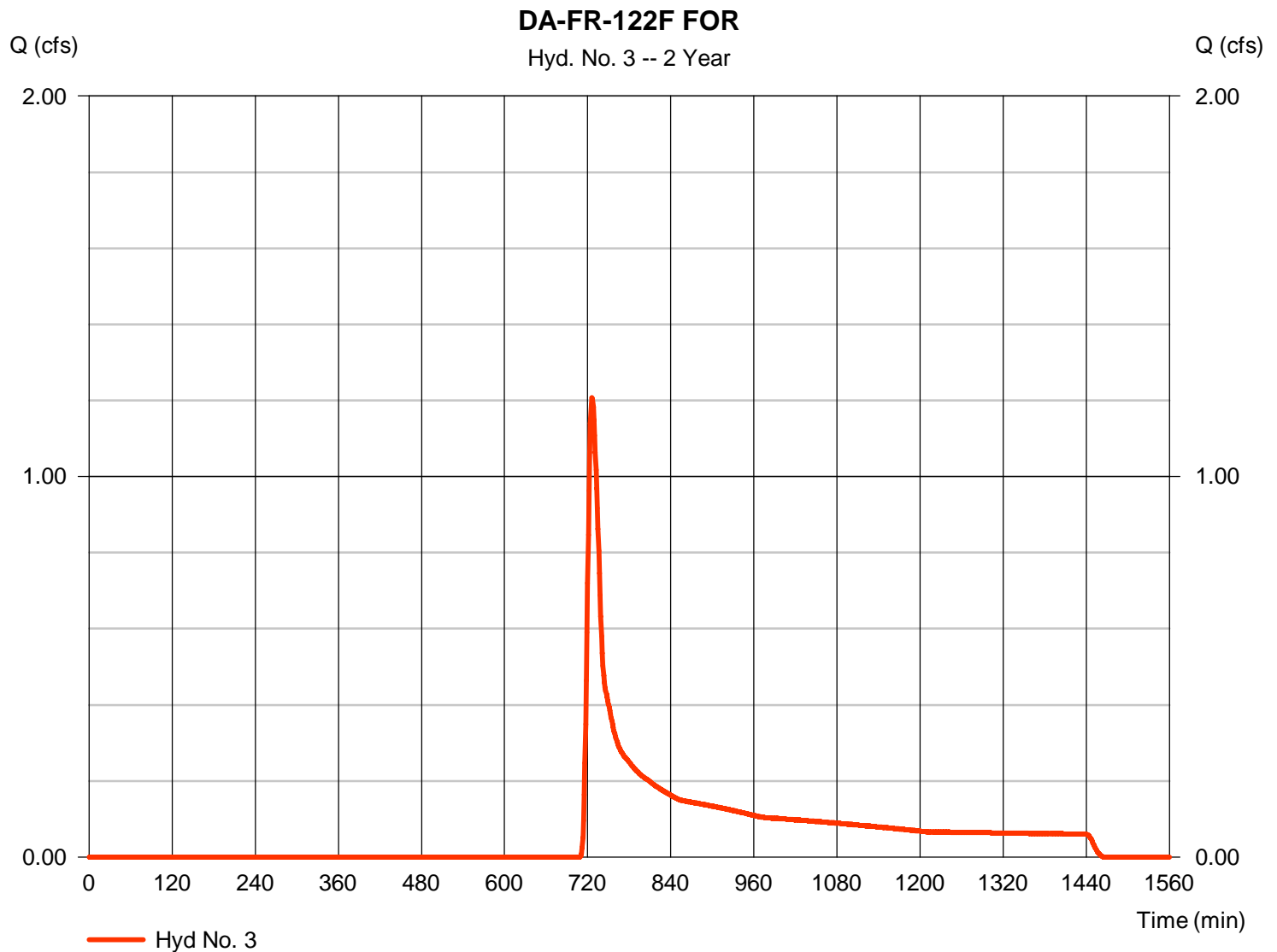
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-122F FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 3.950 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 1.207 cfs
 Time to peak = 726 min
 Hyd. volume = 6,033 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.80 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	7.886	1	724	23,954	-----	-----	-----	DA-FR-122F PRE
2	SCS Runoff	7.886	1	724	23,954	-----	-----	-----	DA-FR-122F DEV
3	SCS Runoff	6.104	1	724	19,577	-----	-----	-----	DA-FR-122F FOR
DA-FR-122F_Hydraflow.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

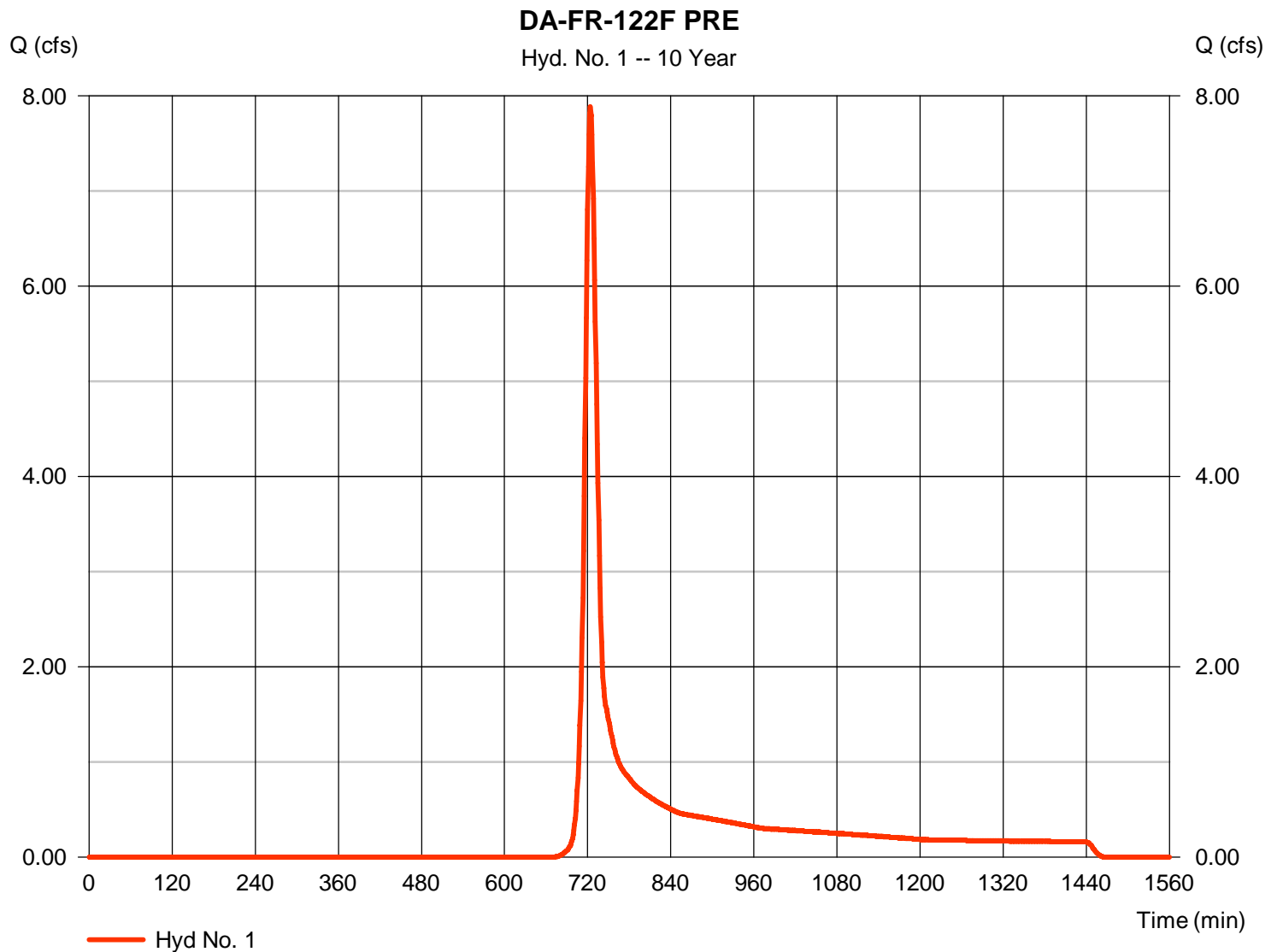
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-122F PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 7.886 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 23,954 cuft
Drainage area	= 3.950 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.80 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.259 \times 48) + (0.215 \times 82) + (3.473 \times 58)] / 3.950$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

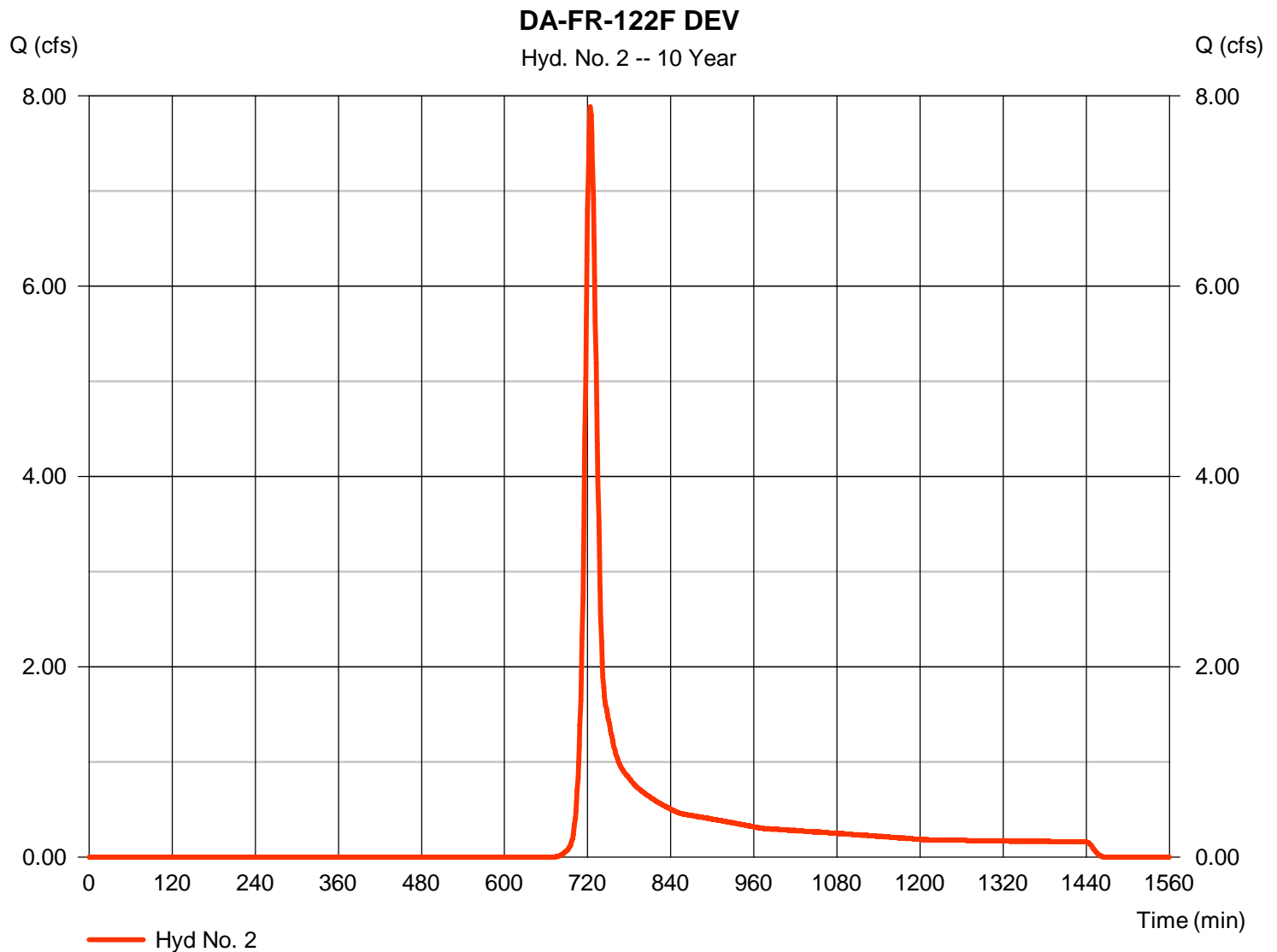
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-122F DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 7.886 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 23,954 cuft
Drainage area	= 3.950 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.10 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.151 \times 48) + (0.215 \times 82) + (3.581 \times 58)] / 3.950$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

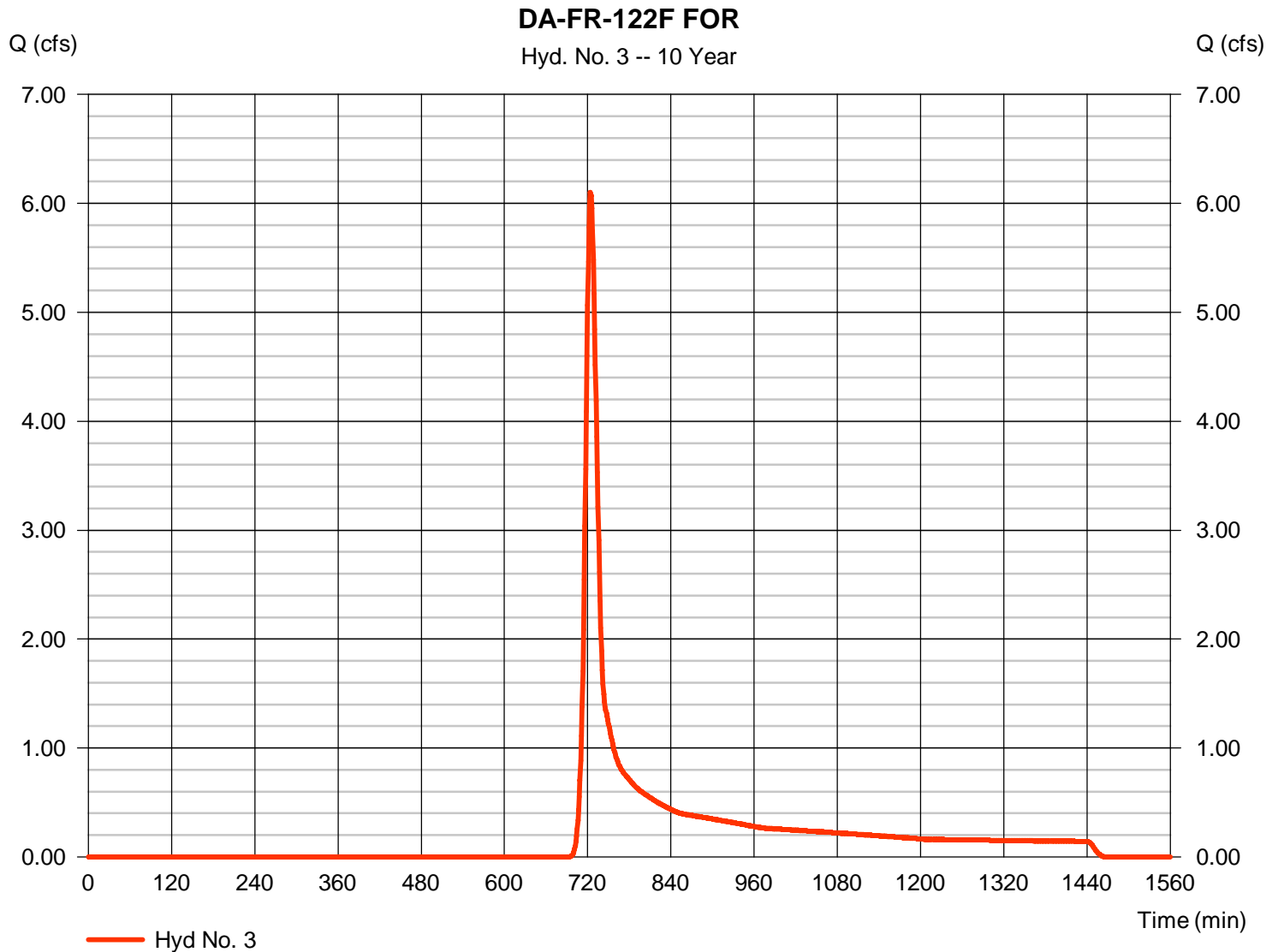
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-122F FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 3.950 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 6.104 cfs
 Time to peak = 724 min
 Hyd. volume = 19,577 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.80 min
 Distribution = Type II
 Shape factor = 484



DA-FR-123

DA-FR-123 is located in a meadow and forested areas with rolling slopes and contains agricultural land, Listening Hill Road, existing dirt road and gravel road. A stream crosses the drainage area. The total phosphorus load reduction required for DA-FR-123 is -0.52 lb/yr. Total phosphorus load reduction is not required for DA-FR-123. Multiple points of analysis were evaluated within DA-FR-123 to evaluate the effects on each receiving stream/channel following construction. Specifically, DA-FR-123 was subdivided into two sub-drainage areas (sub-areas A and B).

Sub-areas 123A and 123B contain both agricultural and non-agricultural areas within the limits of disturbance (LOD). Pre-construction agricultural areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction. In non-agricultural areas, land use will be restored following construction as noted in the Stormwater Management (SWM) Narrative and the Annual Standards and Specifications. Agricultural areas within the LOD are included in the SWM quality analysis and the total permanent Right of Way (ROW) is analyzed via VRRM; in these calculations agricultural areas are considered "Forest/Open Space".

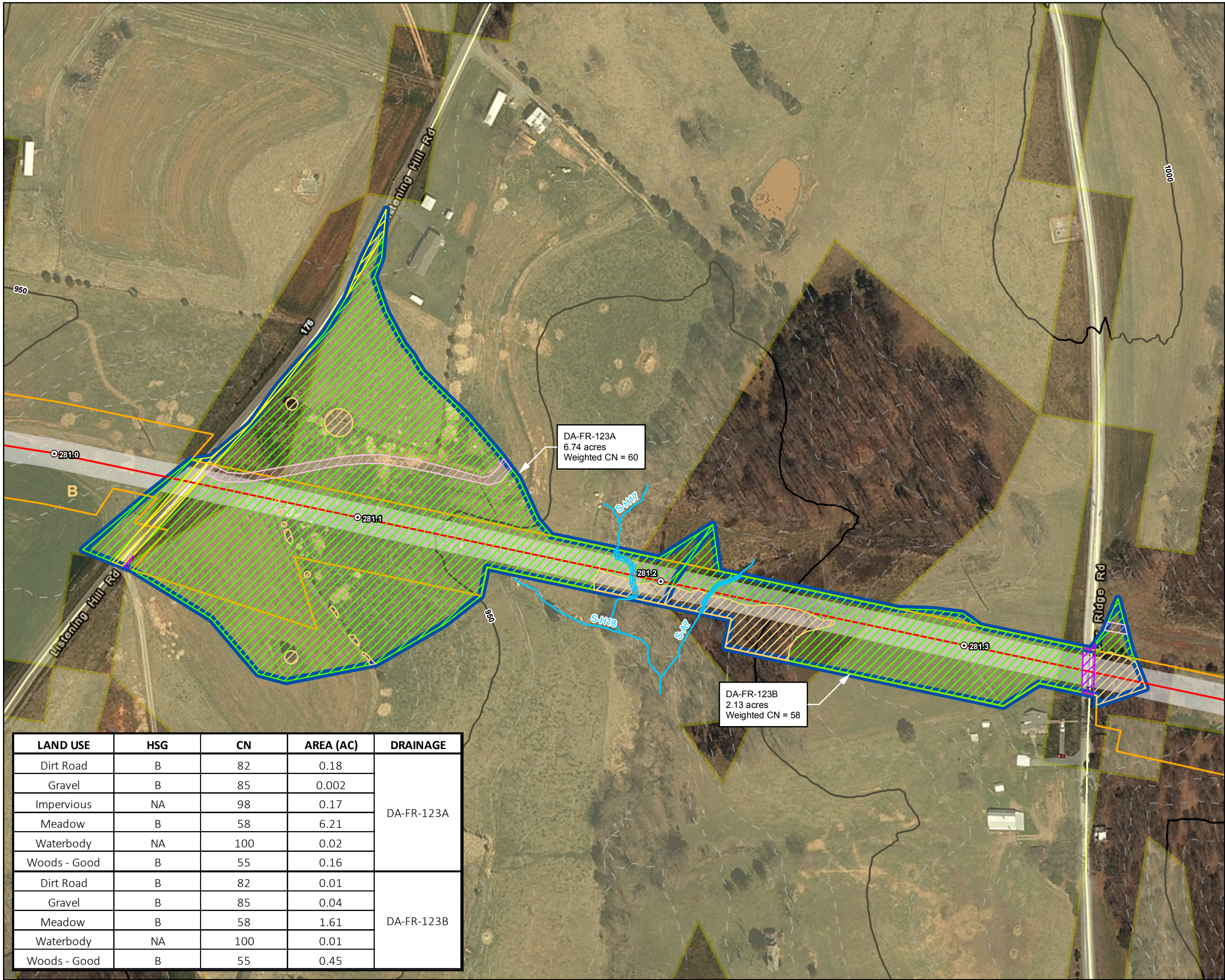
Stormwater quantity is met via the energy balance method for each of the two sub-areas – DA-FR-123A and DA-FR-123B. Agricultural areas within the study area are included in the SWM analysis, but an Improvement Factor (IF) of 1.0 is used when applying the Energy Balance Method. This improvement factor is used to account for the exemption of agricultural areas (§ 62.1-44.15:34 and 9VAC25-870-300) since such areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction.

In addition, the Hydraflow Hydrograph's 10-year 24-hour peak discharge results indicate no reduction in flows for all drainage areas (as seen in table below).

Sub Area	Pre Peak Flow, 10-yr Q (cfs)	Post Peak Flow, Q 10-yr (cfs)	Flow differential
DA-FR-123A	13.33	13.33	0
DA-FR-123B	4.24	4.24	0

Figures and calculations for each of the sub-areas for DA-FR-123 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.

Note that the sub-areas 123A and 123B had time of concentration flow paths for the Post-Construction condition that accounted for a permanent water bar that is not cited within the drainage area. This permanent water bar was removed because it was cited in an agricultural area, and resulting changes to the stormwater calculations were flagged during the QA/QC review process. This change was considered to be inconsequential because no stormwater BMPs are sited in DA-FR-123A or 123B, so the resulting changes were not made to the stormwater calculations prior to submittal.



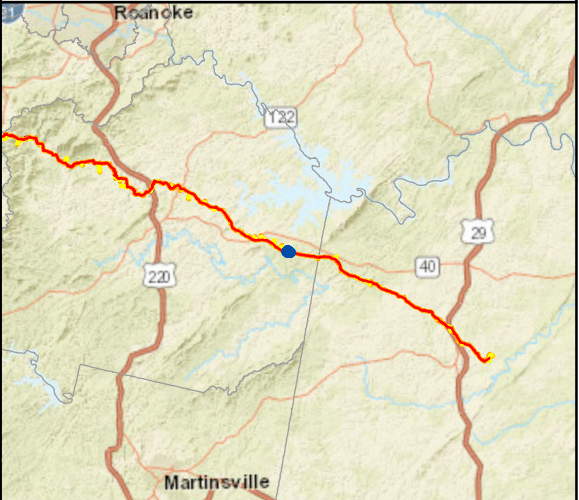
Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Dirt Road
- Gravel
- Impervious
- Meadow
- Waterbody
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:1,920

160 80 0 160 Feet



Mountain Valley Pipeline Project



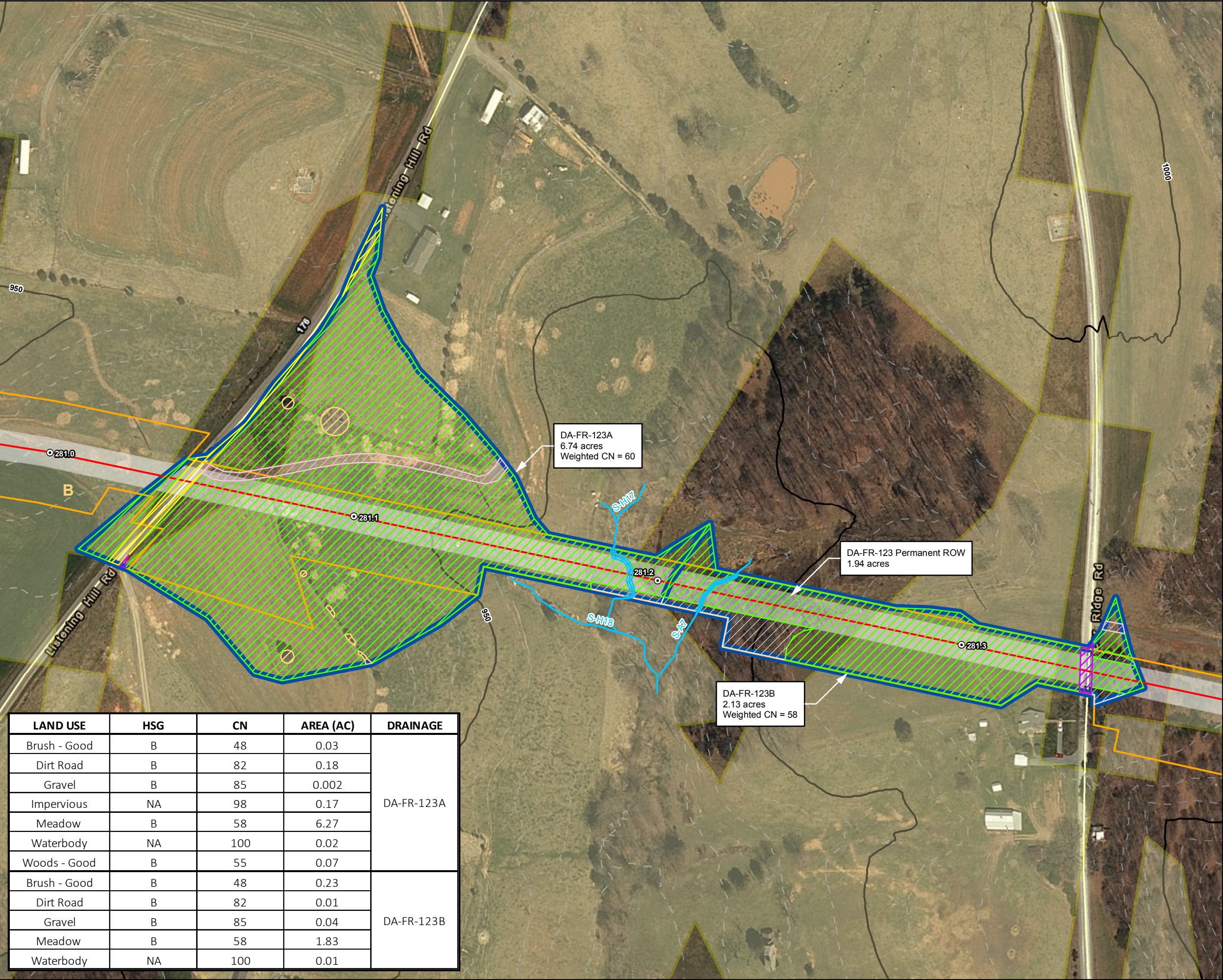
Pre-Construction Drainage Area Map
DA-FR-123
Spread 11

Figure 1
Franklin County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Dirt Road	B	82	0.18	DA-FR-123A
Gravel	B	85	0.002	
Impervious	NA	98	0.17	
Meadow	B	58	6.21	
Waterbody	NA	100	0.02	
Woods - Good	B	55	0.16	
Dirt Road	B	82	0.01	DA-FR-123B
Gravel	B	85	0.04	
Meadow	B	58	1.61	
Waterbody	NA	100	0.01	
Woods - Good	B	55	0.45	



Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Dirt Road
- Gravel
- Impervious
- Meadow
- Waterbody
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)
1:1,920

160 80 0 160 Feet



LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Brush - Good	B	48	0.03	DA-FR-123A
Dirt Road	B	82	0.18	
Gravel	B	85	0.002	
Impervious	NA	98	0.17	
Meadow	B	58	6.27	
Waterbody	NA	100	0.02	
Woods - Good	B	55	0.07	
Brush - Good	B	48	0.23	DA-FR-123B
Dirt Road	B	82	0.01	
Gravel	B	85	0.04	
Meadow	B	58	1.83	
Waterbody	NA	100	0.01	

Mountain Valley Pipeline Project

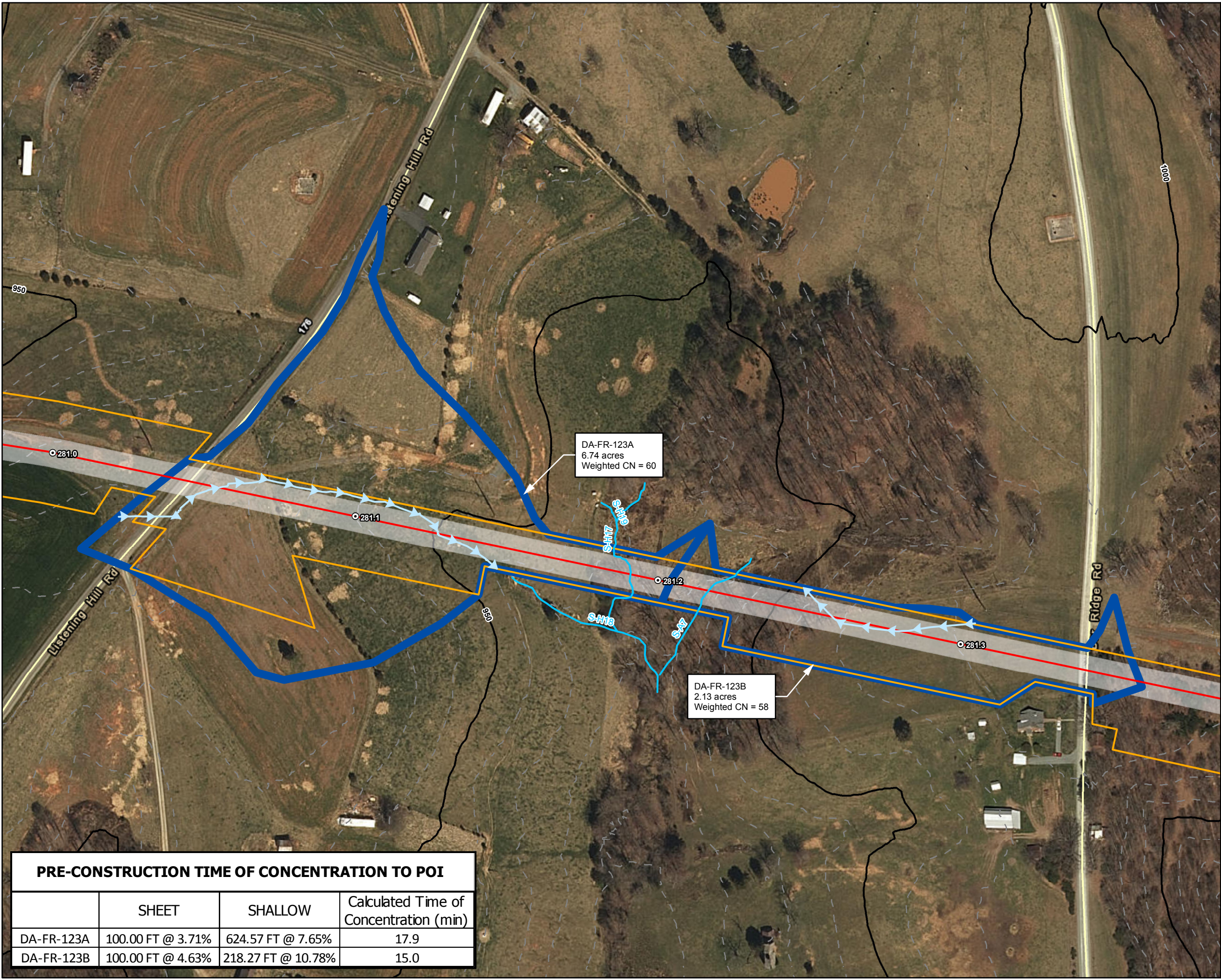


Post-Construction Drainage Area Map
DA-FR-123
Spread 11

Figure 2
Franklin County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.



Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- - Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:1,920

160 80 0 160 Feet



Mountain Valley Pipeline Project



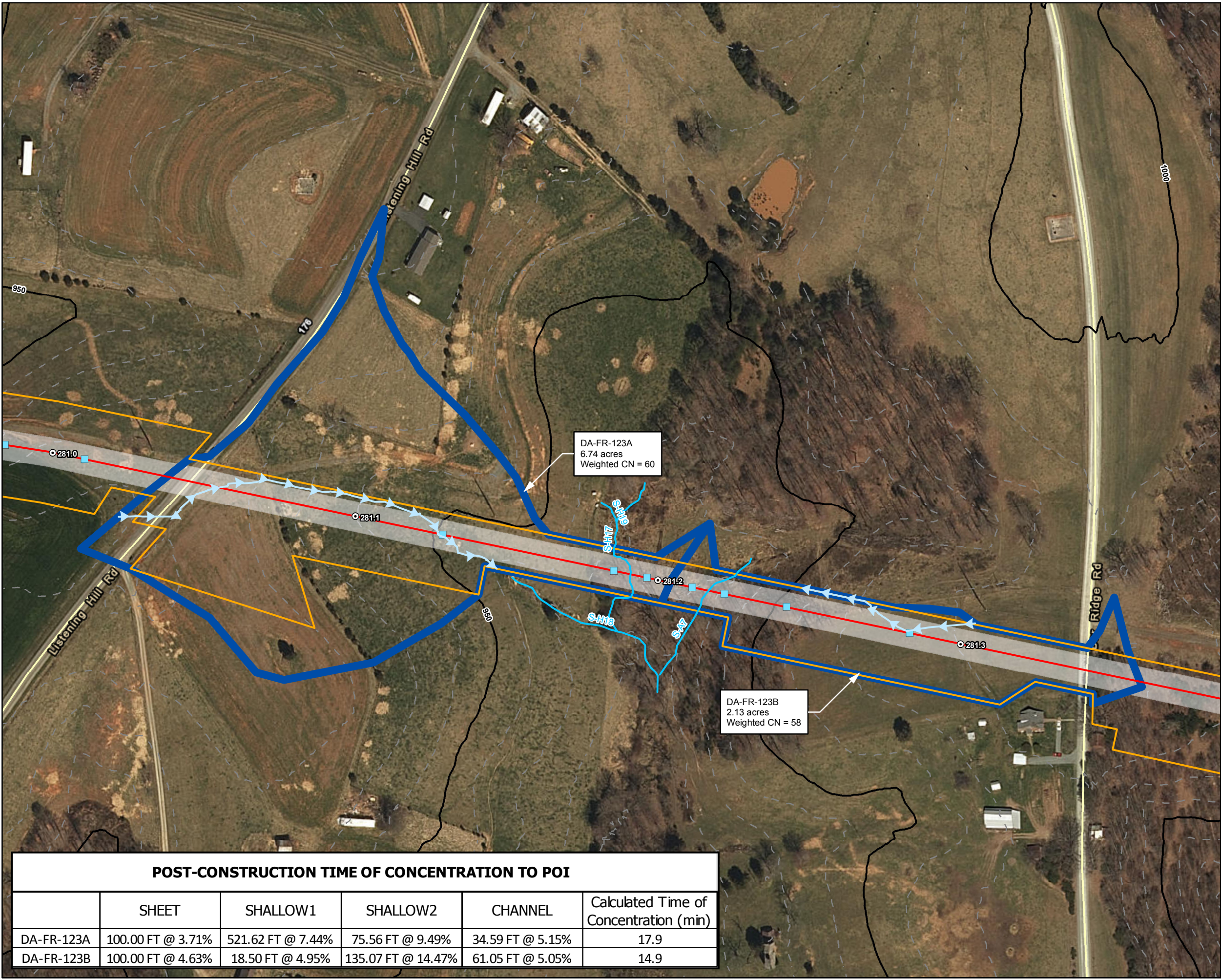
**Pre-Construction Drainage Area
and Time of Concentration
DA-FR-123
Spread 11**

Figure 3
Franklin County, Virginia
September, 2017

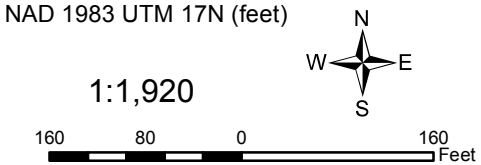
PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET	SHALLOW	Calculated Time of Concentration (min)
DA-FR-123A	100.00 FT @ 3.71%	624.57 FT @ 7.65%	17.9
DA-FR-123B	100.00 FT @ 4.63%	218.27 FT @ 10.78%	15.0

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.



- Legend**
- Milepost
 - Permanent Waterbars
 - Delineated Stream
 - Existing 50' Contour
 - - Existing 10' Contour
 - Road Centerline
 - Alignment Centerline
 - Limit of Disturbance
 - Permanent Right-of-Way
 - Time of Concentration
 - Drainage Area



Mountain Valley Pipeline Project



**Post-Construction Drainage Area
and Time of Concentration
DA-FR-123
Spread 11**

Figure 4
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.

POST-CONSTRUCTION TIME OF CONCENTRATION TO POI					
	SHEET	SHALLOW1	SHALLOW2	CHANNEL	Calculated Time of Concentration (min)
DA-FR-123A	100.00 FT @ 3.71%	521.62 FT @ 7.44%	75.56 FT @ 9.49%	34.59 FT @ 5.15%	17.9
DA-FR-123B	100.00 FT @ 4.63%	18.50 FT @ 4.95%	135.07 FT @ 14.47%	61.05 FT @ 5.05%	14.9

DEQ Virginia Runoff Reduction Method Re-Development Compliance Spreadsheet - Version 3.0

BMP Design Specifications List: 2013 Draft Stds & Specs

Site Summary - Linear Development Project***

Total Rainfall (in):	43
Total Disturbed Acreage:	1.94

Site Land Cover Summary

Pre-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	1.87	0.00	0.00	1.87	96
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.07	0.00	0.00	0.07	4
					1.94	100

Post-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	1.87	0.00	0.00	1.87	96
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.07	0.00	0.00	0.07	4
					1.94	100

* Forest/Open Space areas must be protected in accordance with the Virginia Runoff Reduction Method

Site Tv and Land Cover Nutrient Loads

	Final Post-Development (Post-ReDevelopment & New Impervious)	Post- ReDevelopment	Post- Development (New Impervious)	Adjusted Pre- ReDevelopment
Site Rv	0.06	0.06	--	0.06
Treatment Volume (ft ³)	445	445	--	445
TP Load (lb/yr)	0.28	0.28	--	0.28

Baseline TP Load (lb/yr): 0.7954* *Reduction below new development load limitation not required

Pre- ReDevelopment TP Load per acre (lb/acre/yr)	Final Post-Development TP Load per acre (lb/acre/yr)	Post-ReDevelopment TP Load per acre (lb/acre/yr)
0.14	0.14	0.14

Total TP Load Reduction Required (lb/yr)	-0.52	N/A***	N/A***
--	-------	--------	--------

***This is a linear development project

	Final Post-Development Load (Post-ReDevelopment & New Impervious)	Pre- ReDevelopment
TN Load (lb/yr)	2.00	2.00

Site Compliance Summary - ***Linear Development Project

Maximum % Reduction Required Below Pre-ReDevelopment Load	20%
--	-----

* Note: % Reduction will reduce post-development TP load to less than or equal to baseline load of 0.8 lb/yr (0.41 lb/ac/yr)
 [Post-Dev Reduction Requirement = Post-Dev TP load - baseline load of 0.8 lb/yr], baseline load = site area x 0.41 lb/ac/yr

Total Runoff Volume Reduction (ft ³)	0
--	---

Total TP Load Reduction Achieved (lb/yr)	0.00
Total TN Load Reduction Achieved (lb/yr)	0.00
Remaining Post Development TP Load (lb/yr)	0.28
Remaining TP Load Reduction (lb/yr) Required	0.00

**** TARGET TP REDUCTION EXCEEDED BY 0.52 LB/YEAR ****

**Reduction below new development load limitation not required*

DA-FR-123A

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	2.417	10836
Developed Condition	2.417	10836
Pre-Developed (Forest) Condition	0.969	6799

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF =

1

Calculations:

Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	2.417	\leq OK	2.417
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	2.417	\leq OK	2.417
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ --->	2.417	<u>shall not</u> be required to be \leq	0.608

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s n value of 0.011 was used.</p> <p><i>Sources:</i></p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

Table 2 – Manning's *n* Values for Open Channel Flow

Channel Type	Manning <i>n</i>		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's <i>n</i> value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's <i>n</i> value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-123A PRE
2	SCS Runoff	DA-FR-123A DEV
3	SCS Runoff	DA-FR-123A FOR

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	2.417	1	727	10,836	-----	-----	-----	DA-FR-123A PRE
2	SCS Runoff	2.417	1	727	10,836	-----	-----	-----	DA-FR-123A DEV
3	SCS Runoff	0.969	1	729	6,799	-----	-----	-----	DA-FR-123A FOR
DA-FR-123A_Hydraflow.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

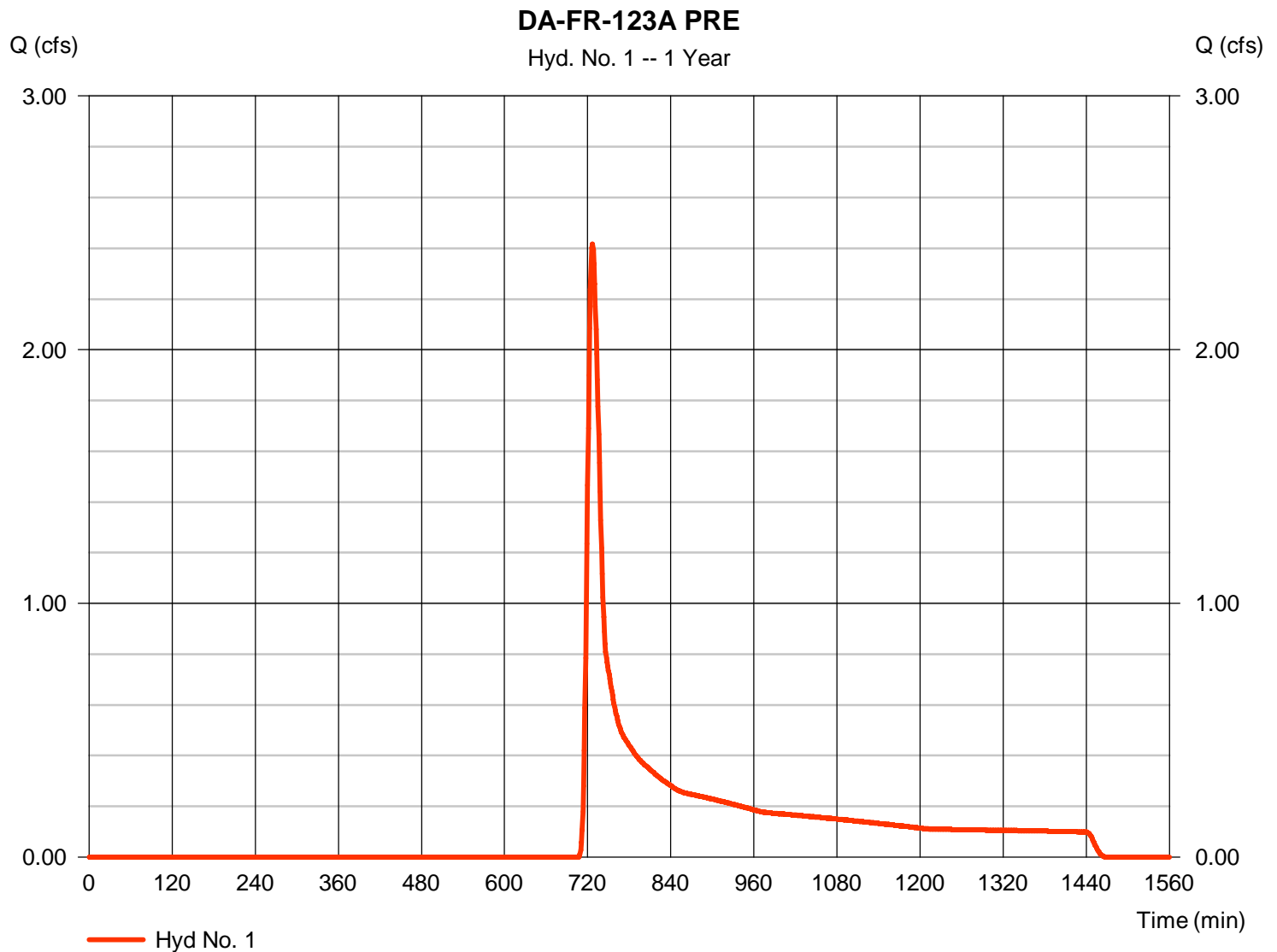
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-123A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 2.417 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 10,836 cuft
Drainage area	= 6.740 ac	Curve number	= 60*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.183 \times 82) + (0.002 \times 85) + (0.171 \times 98) + (6.209 \times 58) + (0.018 \times 100) + (0.159 \times 55)] / 6.740$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-123A PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 3.71	0.00	0.00	
Travel Time (min)	= 15.60	+ 0.00	+ 0.00	= 15.60
Shallow Concentrated Flow				
Flow length (ft)	= 624.57	0.00	0.00	
Watercourse slope (%)	= 7.65	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=4.46	0.00	0.00	
Travel Time (min)	= 2.33	+ 0.00	+ 0.00	= 2.33
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				17.90 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

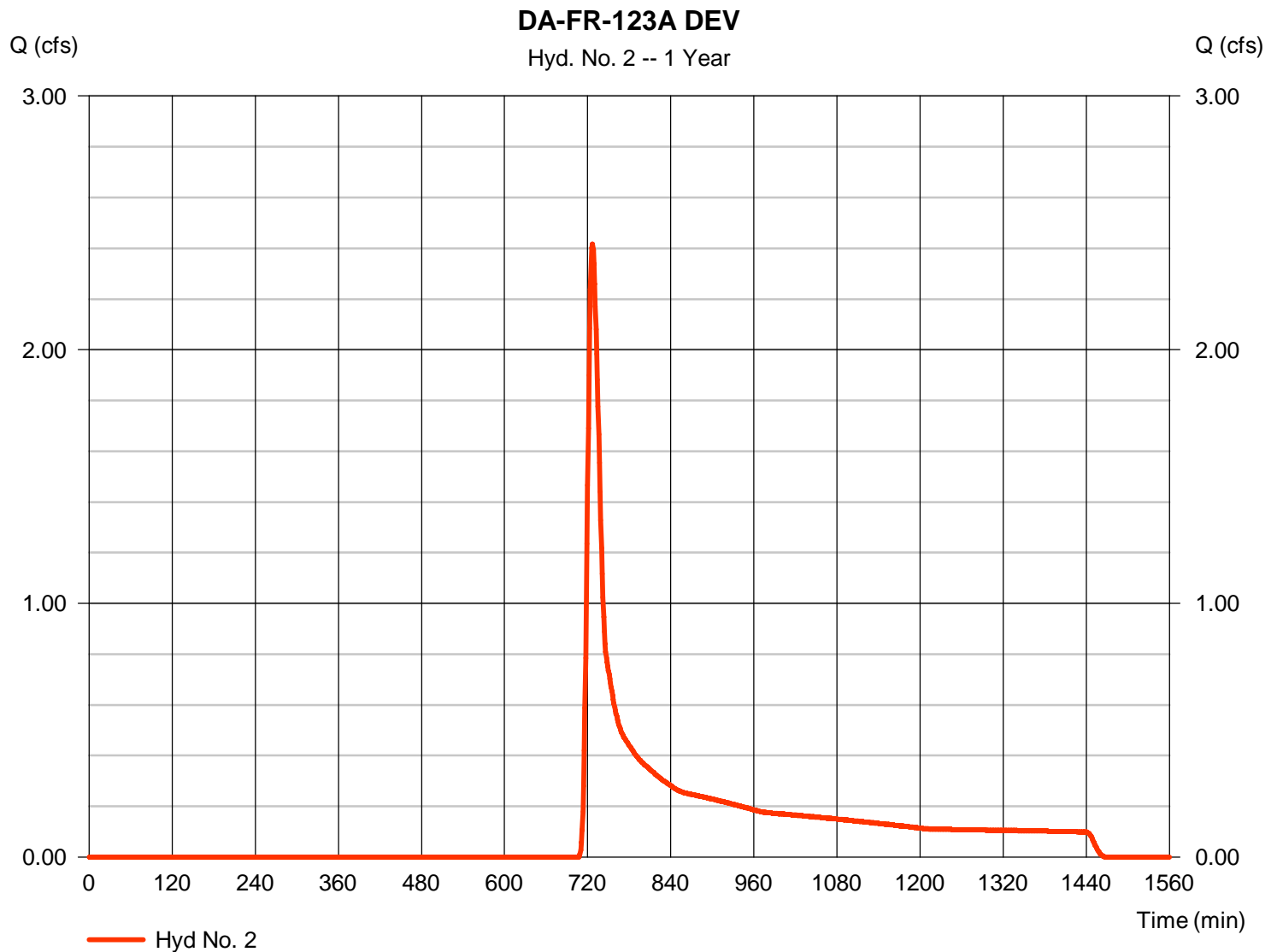
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-123A DEV

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 6.740 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.30 in
 Storm duration = 24 hrs

Peak discharge = 2.417 cfs
 Time to peak = 727 min
 Hyd. volume = 10,836 cuft
 Curve number = 60
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 17.90 min
 Distribution = Type II
 Shape factor = 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-123A DEV

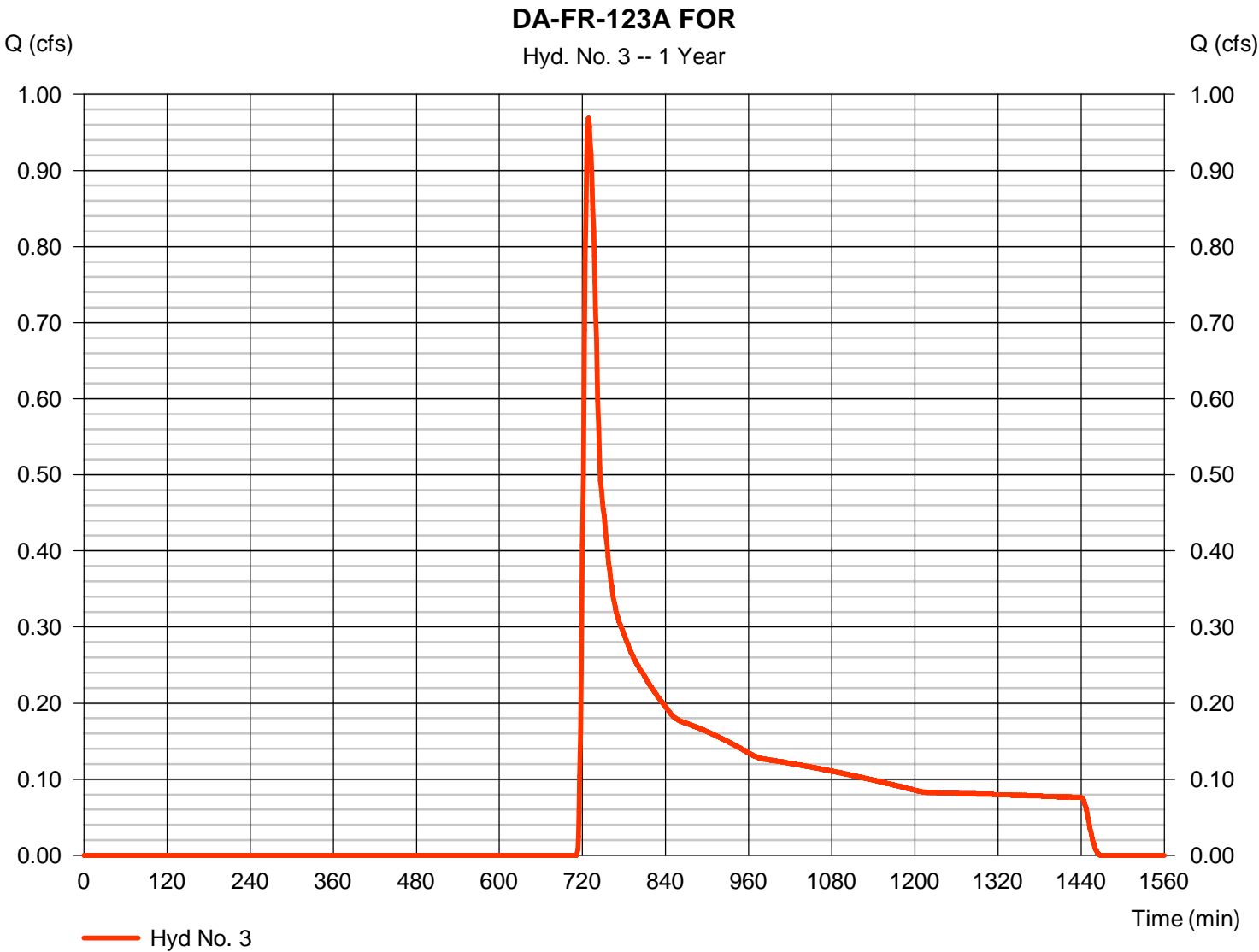
<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 3.71	0.00	0.00				
Travel Time (min)	= 15.60	+	0.00	+	0.00	=	15.60
Shallow Concentrated Flow							
Flow length (ft)	= 521.62	75.56	0.00				
Watercourse slope (%)	= 7.44	9.49	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=4.40	4.97	0.00				
Travel Time (min)	= 1.98	+	0.25	+	0.00	=	2.23
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	({}))34.6	0.0	0.0				
Travel Time (min)	= 0.12	+	0.00	+	0.00	=	0.12
Total Travel Time, Tc					17.90 min		

Hydrograph Report

Hyd. No. 3

DA-FR-123A FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.969 cfs
Storm frequency	= 1 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 6,799 cuft
Drainage area	= 6.740 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-123A FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 3.71	0.00	0.00	
Travel Time (min)	= 15.60	+ 0.00	+ 0.00	= 15.60
Shallow Concentrated Flow				
Flow length (ft)	= 624.57	0.00	0.00	
Watercourse slope (%)	= 7.65	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=4.46	0.00	0.00	
Travel Time (min)	= 2.33	+ 0.00	+ 0.00	= 2.33
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				17.90 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	3.834	1	726	14,997	-----	-----	-----	DA-FR-123A PRE
2	SCS Runoff	3.834	1	726	14,997	-----	-----	-----	DA-FR-123A DEV
3	SCS Runoff	1.918	1	727	10,052	-----	-----	-----	DA-FR-123A FOR
DA-FR-123A_Hydraflow.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

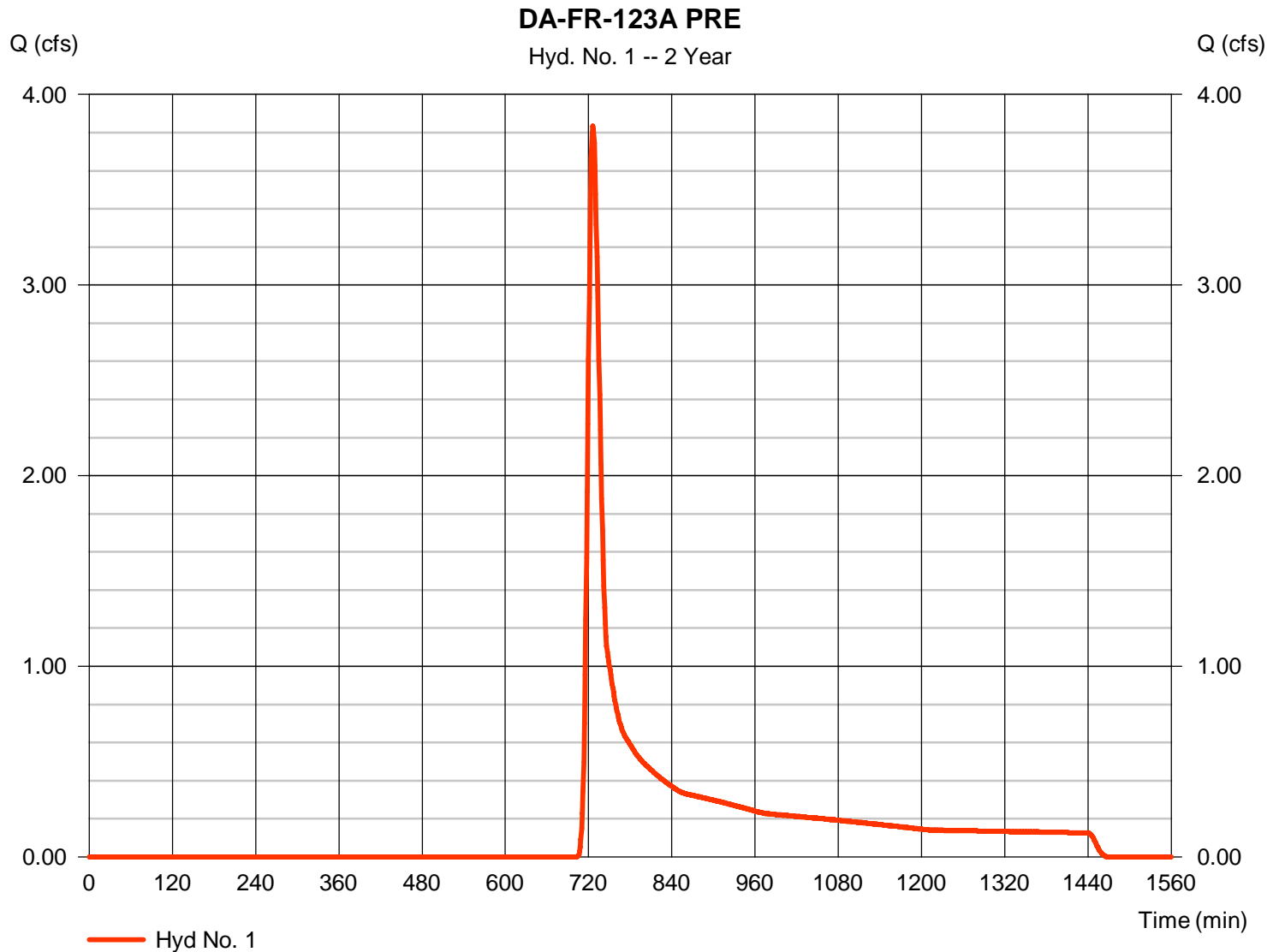
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-123A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 3.834 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 14,997 cuft
Drainage area	= 6.740 ac	Curve number	= 60*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.90 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.183 \times 82) + (0.002 \times 85) + (0.171 \times 98) + (6.209 \times 58) + (0.018 \times 100) + (0.159 \times 55)] / 6.740$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

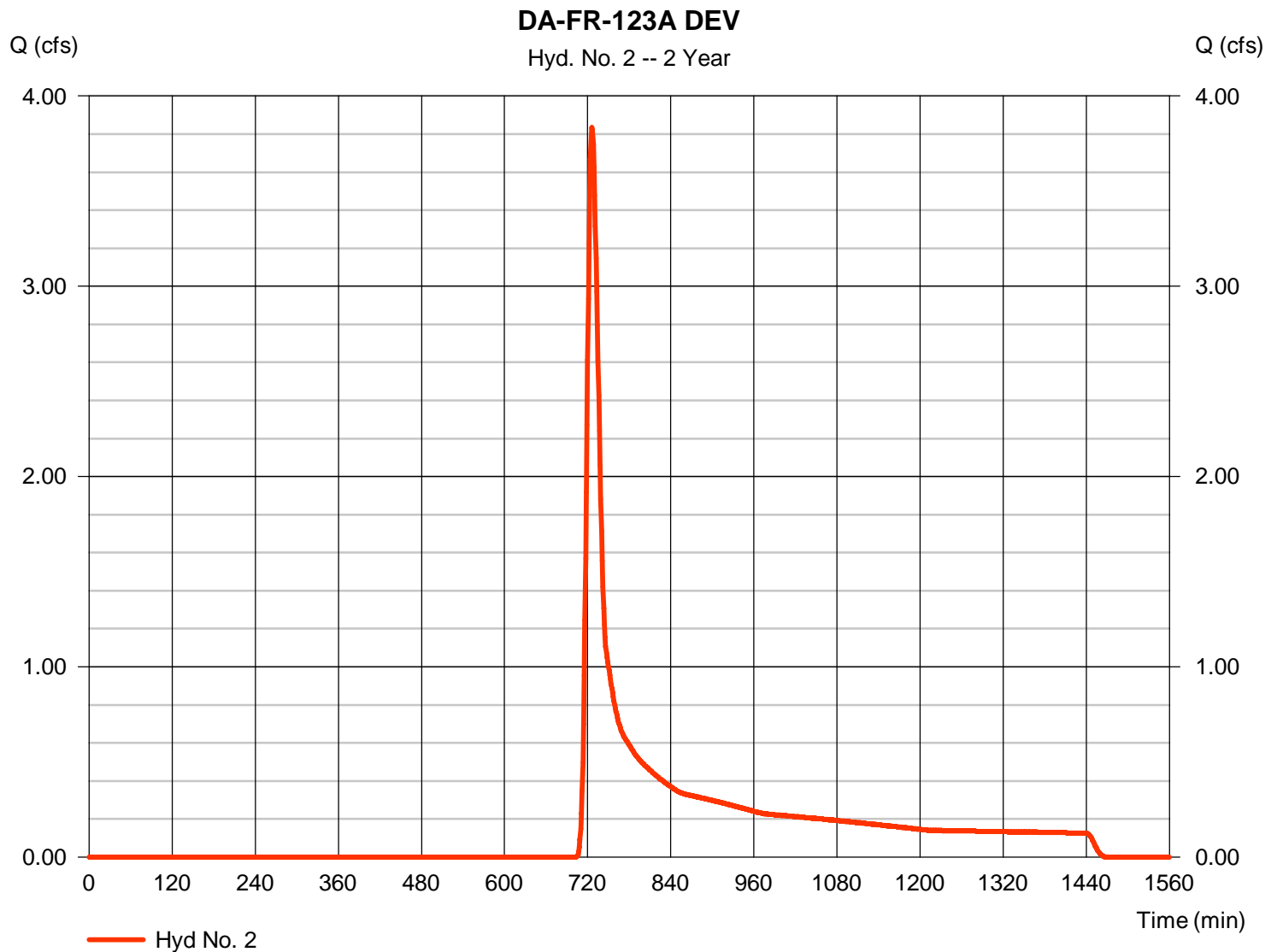
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-123A DEV

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 6.740 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 3.834 cfs
 Time to peak = 726 min
 Hyd. volume = 14,997 cuft
 Curve number = 60
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 17.90 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

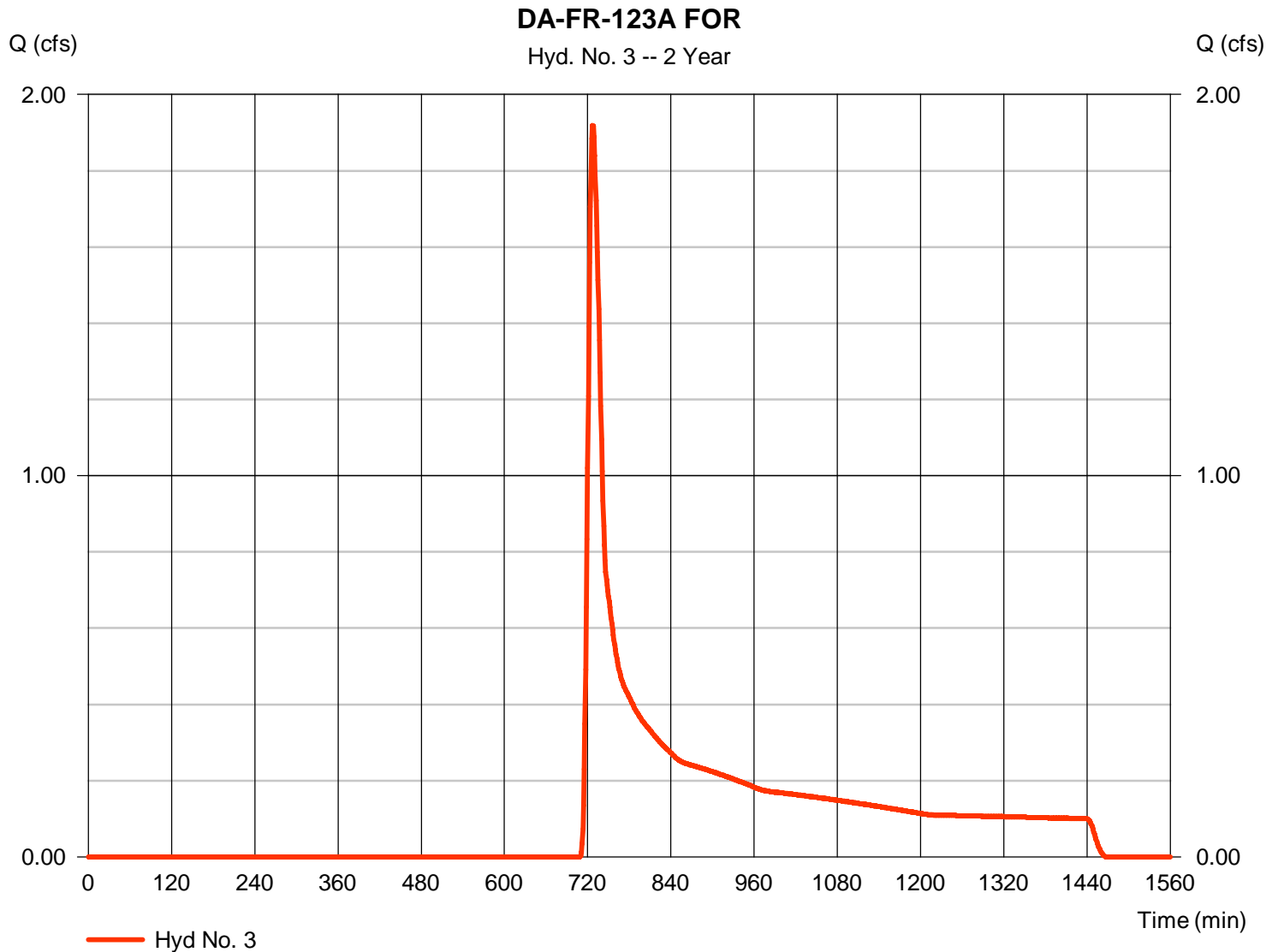
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-123A FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 6.740 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 1.918 cfs
 Time to peak = 727 min
 Hyd. volume = 10,052 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 17.90 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	13.33	1	725	41,802	-----	-----	-----	DA-FR-123A PRE
2	SCS Runoff	13.33	1	725	41,802	-----	-----	-----	DA-FR-123A DEV
3	SCS Runoff	9.738	1	725	32,618	-----	-----	-----	DA-FR-123A FOR
DA-FR-123A_Hydraflow.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

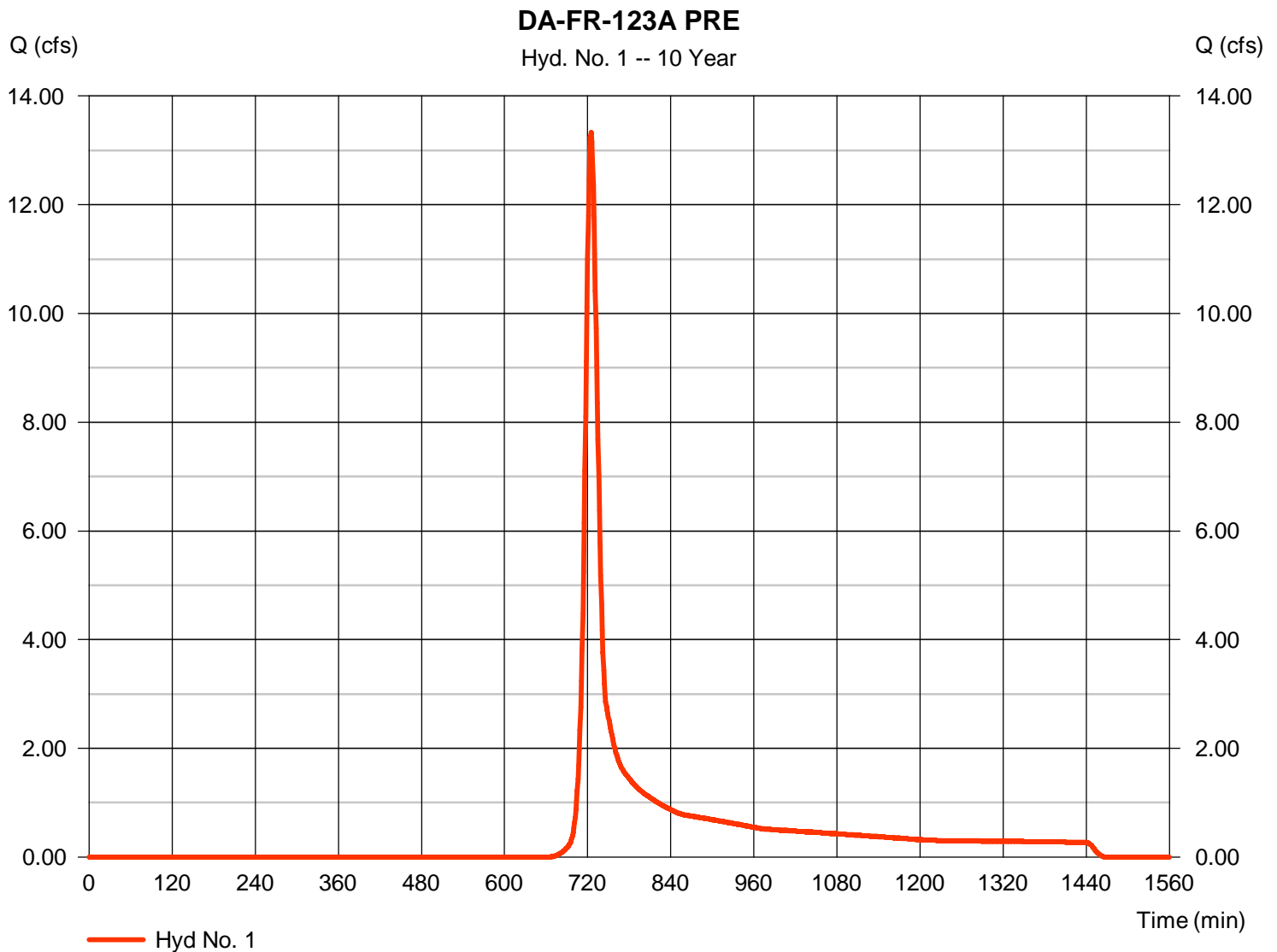
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-123A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 13.33 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 41,802 cuft
Drainage area	= 6.740 ac	Curve number	= 60*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.90 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.183 \times 82) + (0.002 \times 85) + (0.171 \times 98) + (6.209 \times 58) + (0.018 \times 100) + (0.159 \times 55)] / 6.740$



Hydrograph Report

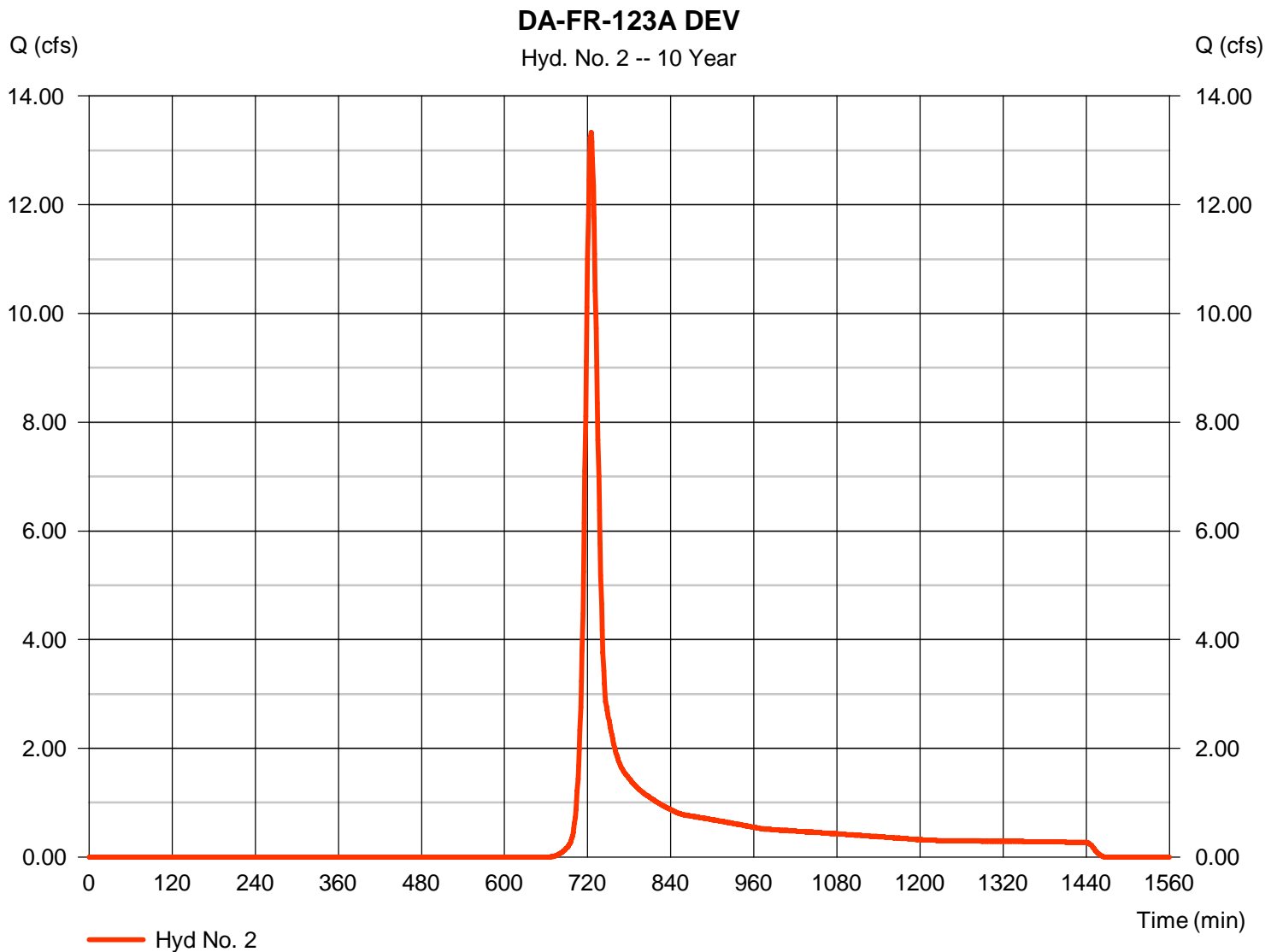
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-123A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 13.33 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 41,802 cuft
Drainage area	= 6.740 ac	Curve number	= 60
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.90 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

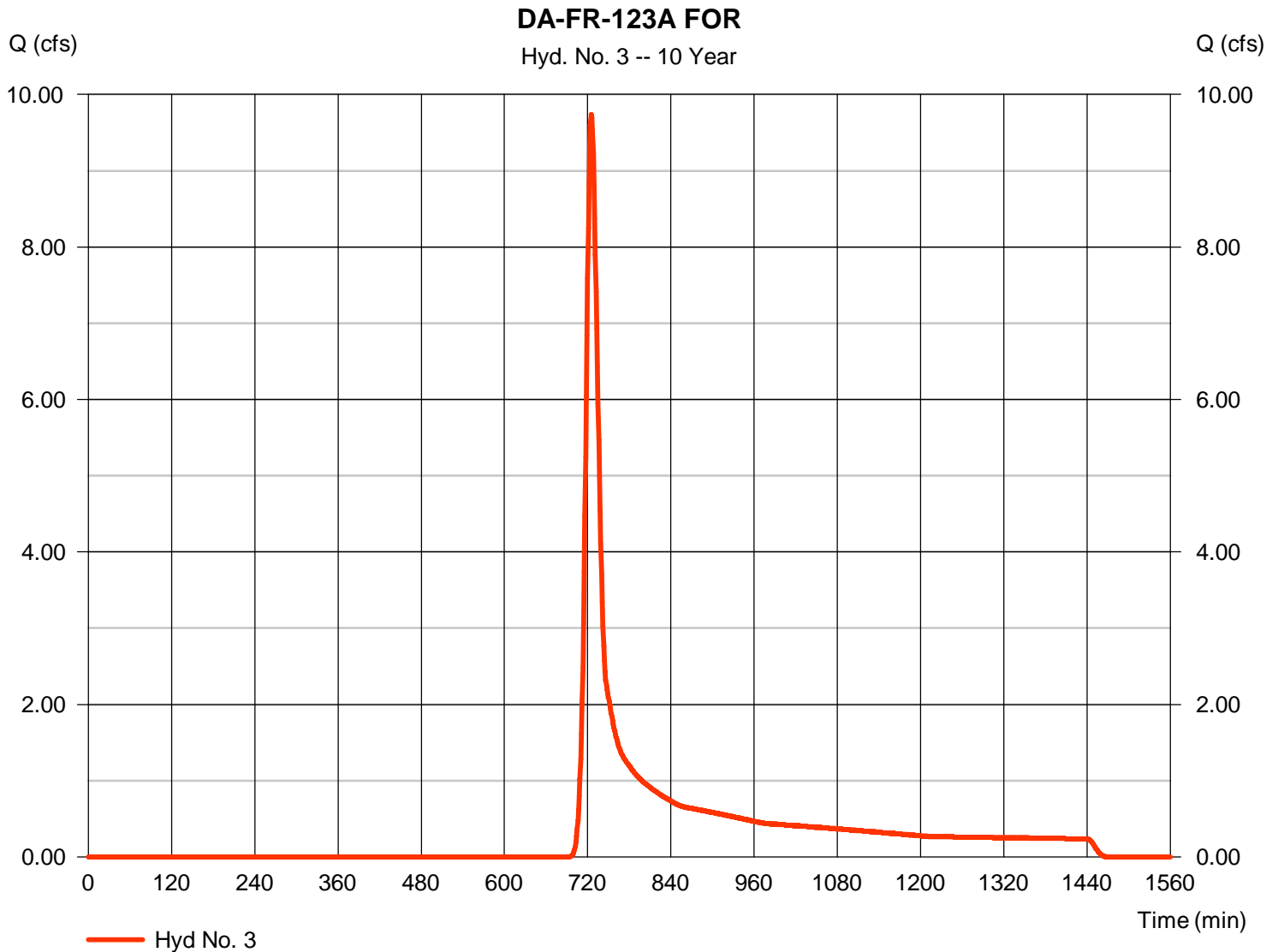
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-123A FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 6.740 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 9.738 cfs
 Time to peak = 725 min
 Hyd. volume = 32,618 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 17.90 min
 Distribution = Type II
 Shape factor = 484



Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	-----
2	69.8703	13.1000	0.8658	-----
3	0.0000	0.0000	0.0000	-----
5	79.2597	14.6000	0.8369	-----
10	88.2351	15.5000	0.8279	-----
25	102.6072	16.5000	0.8217	-----
50	114.8193	17.2000	0.8199	-----
100	127.1596	17.8000	0.8186	-----

File name: SampleFHA.idf

$$\text{Intensity} = B / (Tc + D)^E$$

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5.69	4.61	3.89	3.38	2.99	2.69	2.44	2.24	2.07	1.93	1.81	1.70
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	6.57	5.43	4.65	4.08	3.65	3.30	3.02	2.79	2.59	2.42	2.27	2.15
10	7.24	6.04	5.21	4.59	4.12	3.74	3.43	3.17	2.95	2.77	2.60	2.46
25	8.25	6.95	6.03	5.34	4.80	4.38	4.02	3.73	3.48	3.26	3.07	2.91
50	9.04	7.65	6.66	5.92	5.34	4.87	4.49	4.16	3.88	3.65	3.44	3.25
100	9.83	8.36	7.30	6.50	5.87	5.36	4.94	4.59	4.29	4.03	3.80	3.60

Tc = time in minutes. Values may exceed 60.

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[illegible]

DA-FR-123B

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.643	2915
Developed Condition	0.643	2915
Pre-Developed (Forest) Condition	0.351	2173

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF =

1

Calculations:

Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	0.643	\leq OK	0.643
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.643	\leq OK	0.643
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ --->	0.643	<u>shall not</u> be required to be \leq	0.262

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s n value of 0.011 was used.</p> <p><i>Sources:</i></p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

Table 2 – Manning's *n* Values for Open Channel Flow

Channel Type	Manning <i>n</i>		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's <i>n</i> value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's <i>n</i> value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-123B PRE
2	SCS Runoff	DA-FR-123B DEV
3	SCS Runoff	DA-FR-123B FOR

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.643	1	725	2,915	-----	-----	-----	DA-FR-123B PRE
2	SCS Runoff	0.643	1	725	2,915	-----	-----	-----	DA-FR-123B DEV
3	SCS Runoff	0.351	1	726	2,173	-----	-----	-----	DA-FR-123B FOR
DA-FR-123B_Hydraflow.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

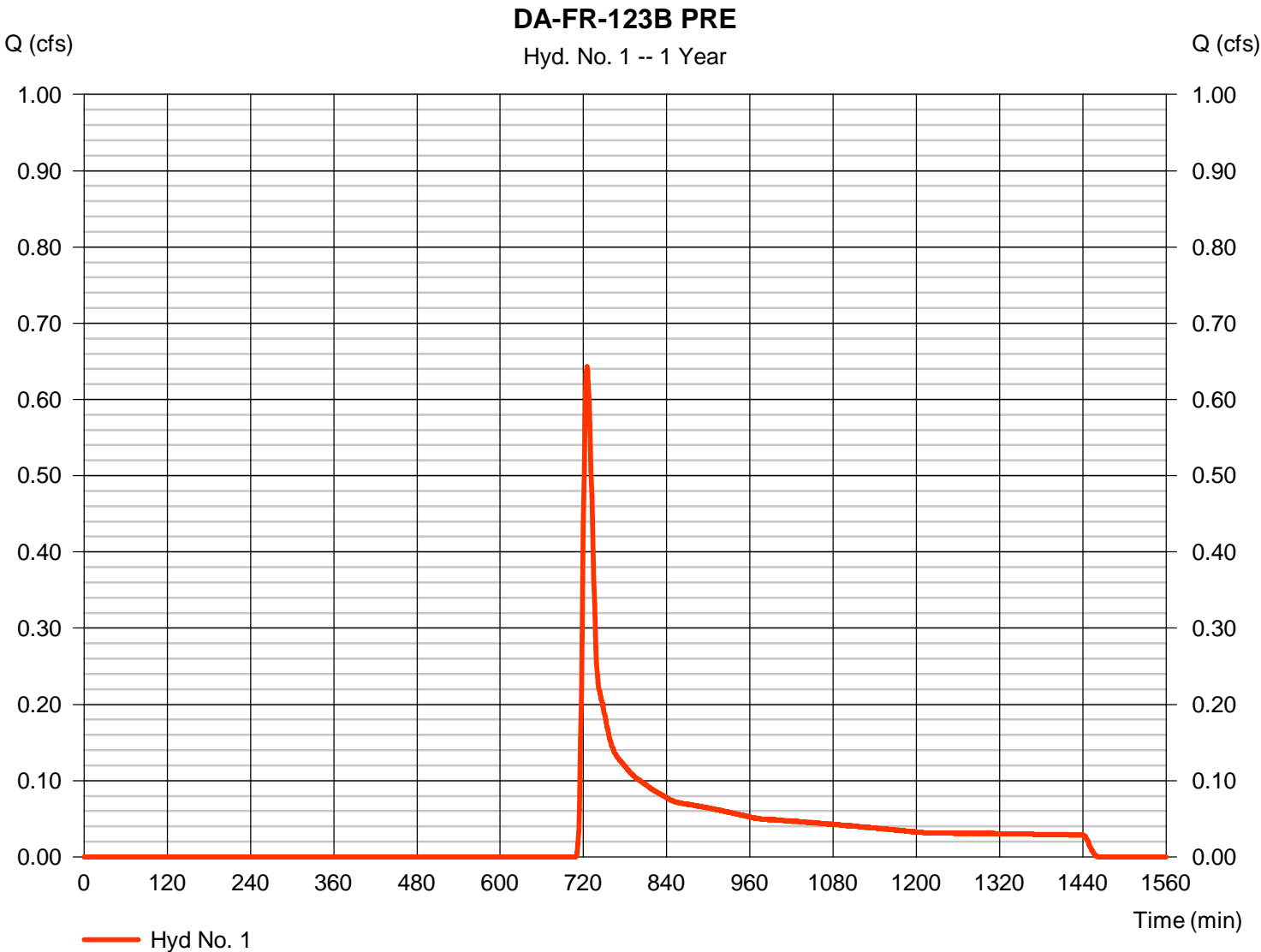
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-123B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.643 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 2,915 cuft
Drainage area	= 2.130 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.00 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.012 x 82) + (0.037 x 85) + (1.614 x 58) + (0.013 x 100) + (0.453 x 55)] / 2.130



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-123B PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 4.63	0.00	0.00				
Travel Time (min)	= 14.27	+	0.00	+	0.00	=	14.27
Shallow Concentrated Flow							
Flow length (ft)	= 218.27	0.00	0.00				
Watercourse slope (%)	= 10.78	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.30	0.00	0.00				
Travel Time (min)	= 0.69	+	0.00	+	0.00	=	0.69
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				15.00 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

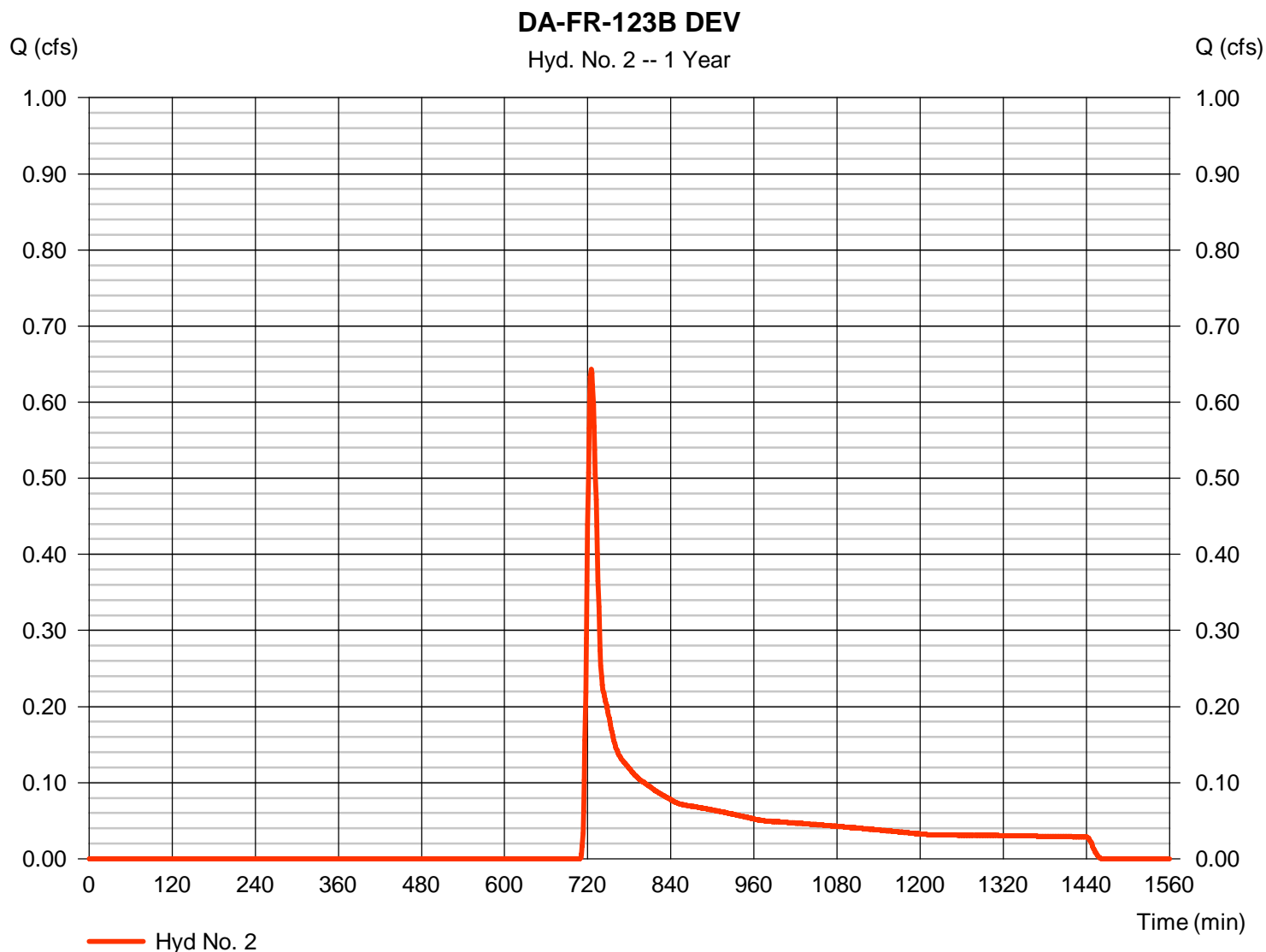
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-123B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.643 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 2,915 cuft
Drainage area	= 2.130 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.233 \times 48) + (0.012 \times 82) + (0.037 \times 85) + (1.834 \times 58) + (0.013 \times 100)] / 2.130$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-123B DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 4.63	0.00	0.00				
Travel Time (min)	= 14.27	+	0.00	+	0.00	=	14.27
Shallow Concentrated Flow							
Flow length (ft)	= 18.50	135.07	0.00				
Watercourse slope (%)	= 4.95	14.47	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=3.59	6.14	0.00				
Travel Time (min)	= 0.09	+	0.37	+	0.00	=	0.45
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	(0)61.0	0.0	0.0				
Travel Time (min)	= 0.21	+	0.00	+	0.00	=	0.21
Total Travel Time, Tc					14.90 min		

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

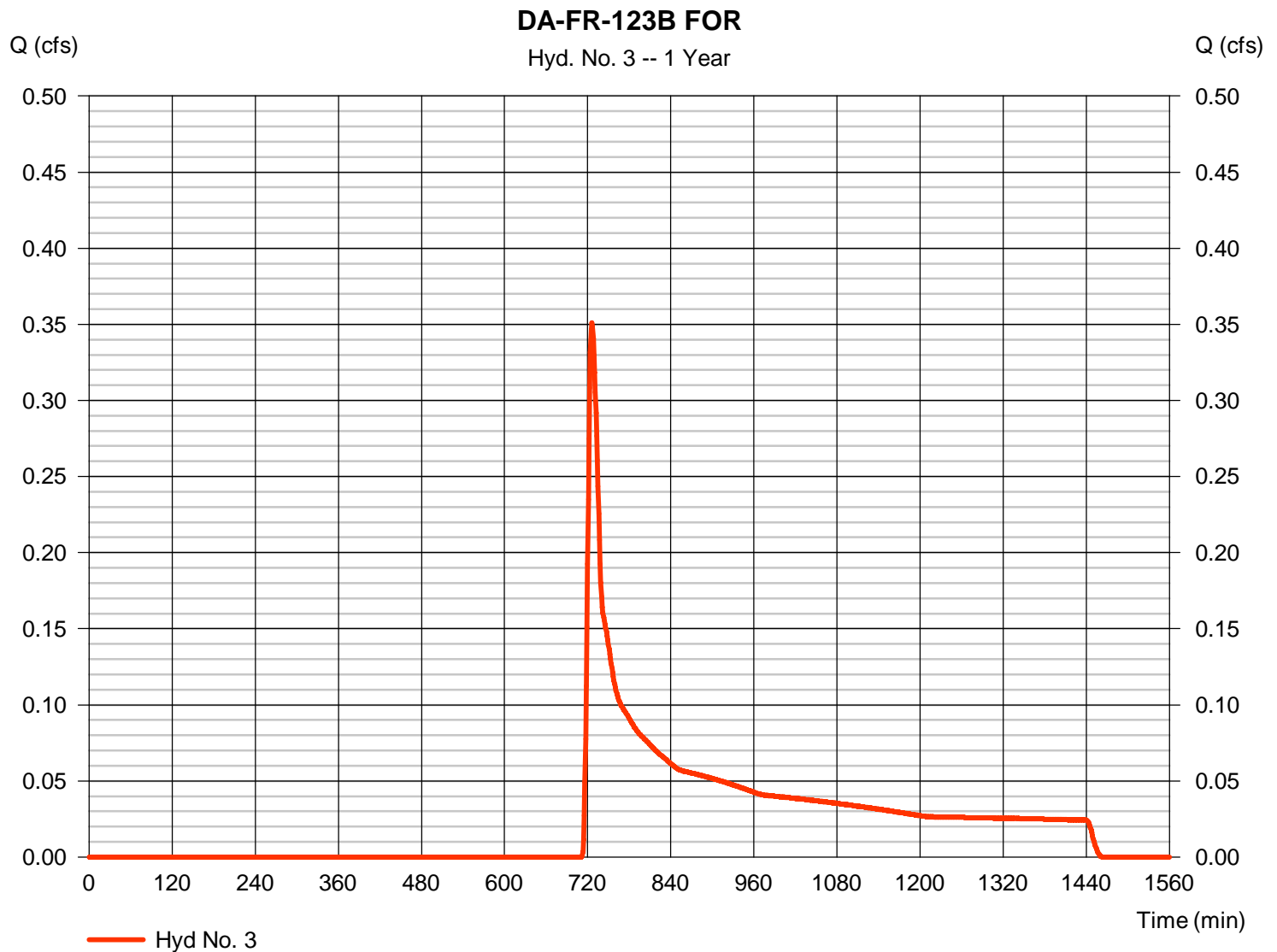
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-123B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 2.130 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.30 in
 Storm duration = 24 hrs

Peak discharge = 0.351 cfs
 Time to peak = 726 min
 Hyd. volume = 2,173 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.00 min
 Distribution = Type II
 Shape factor = 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-123B FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 4.63	0.00	0.00				
Travel Time (min)	= 14.27	+	0.00	+	0.00	=	14.27
Shallow Concentrated Flow							
Flow length (ft)	= 218.27	0.00	0.00				
Watercourse slope (%)	= 10.78	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.30	0.00	0.00				
Travel Time (min)	= 0.69	+	0.00	+	0.00	=	0.69
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				15.00 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	1.090	1	724	4,129	-----	-----	-----	DA-FR-123B PRE
2	SCS Runoff	1.090	1	724	4,129	-----	-----	-----	DA-FR-123B DEV
3	SCS Runoff	0.698	1	725	3,213	-----	-----	-----	DA-FR-123B FOR
DA-FR-123B_Hydraflow.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

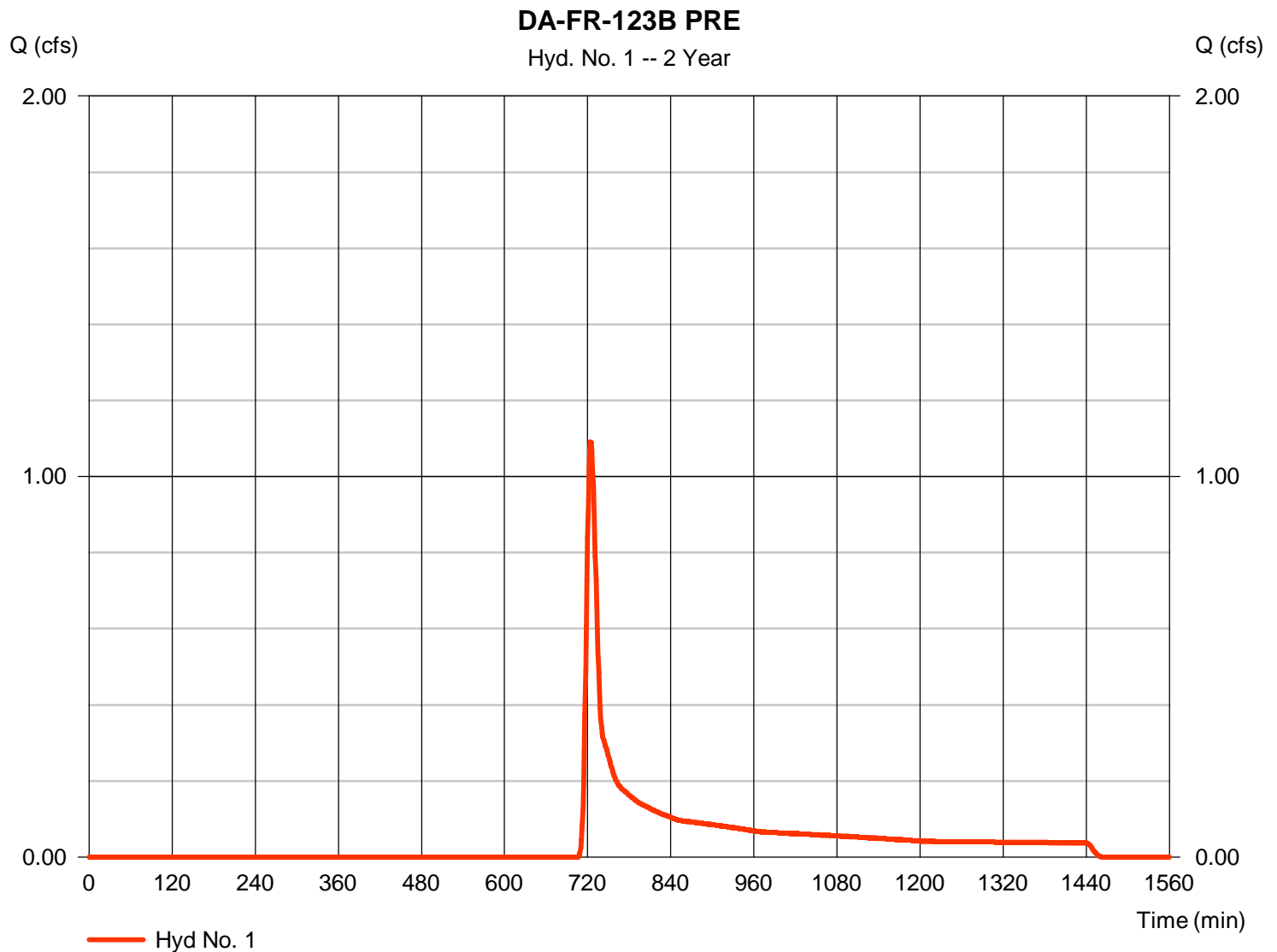
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-123B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 1.090 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 4,129 cuft
Drainage area	= 2.130 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.00 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.012 \times 82) + (0.037 \times 85) + (1.614 \times 58) + (0.013 \times 100) + (0.453 \times 55)] / 2.130$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

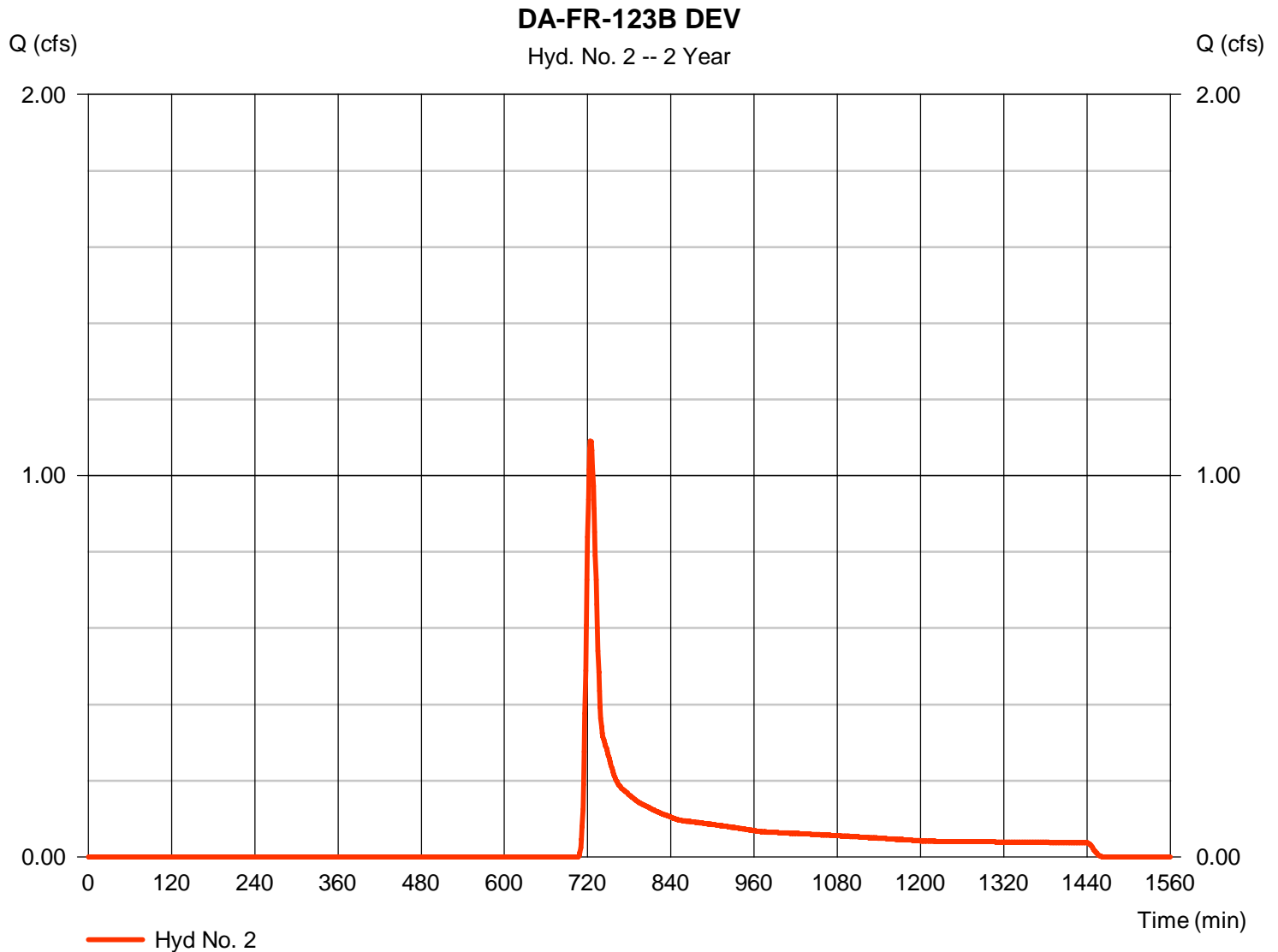
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-123B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 1.090 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 4,129 cuft
Drainage area	= 2.130 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.90 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.233 \times 48) + (0.012 \times 82) + (0.037 \times 85) + (1.834 \times 58) + (0.013 \times 100)] / 2.130$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

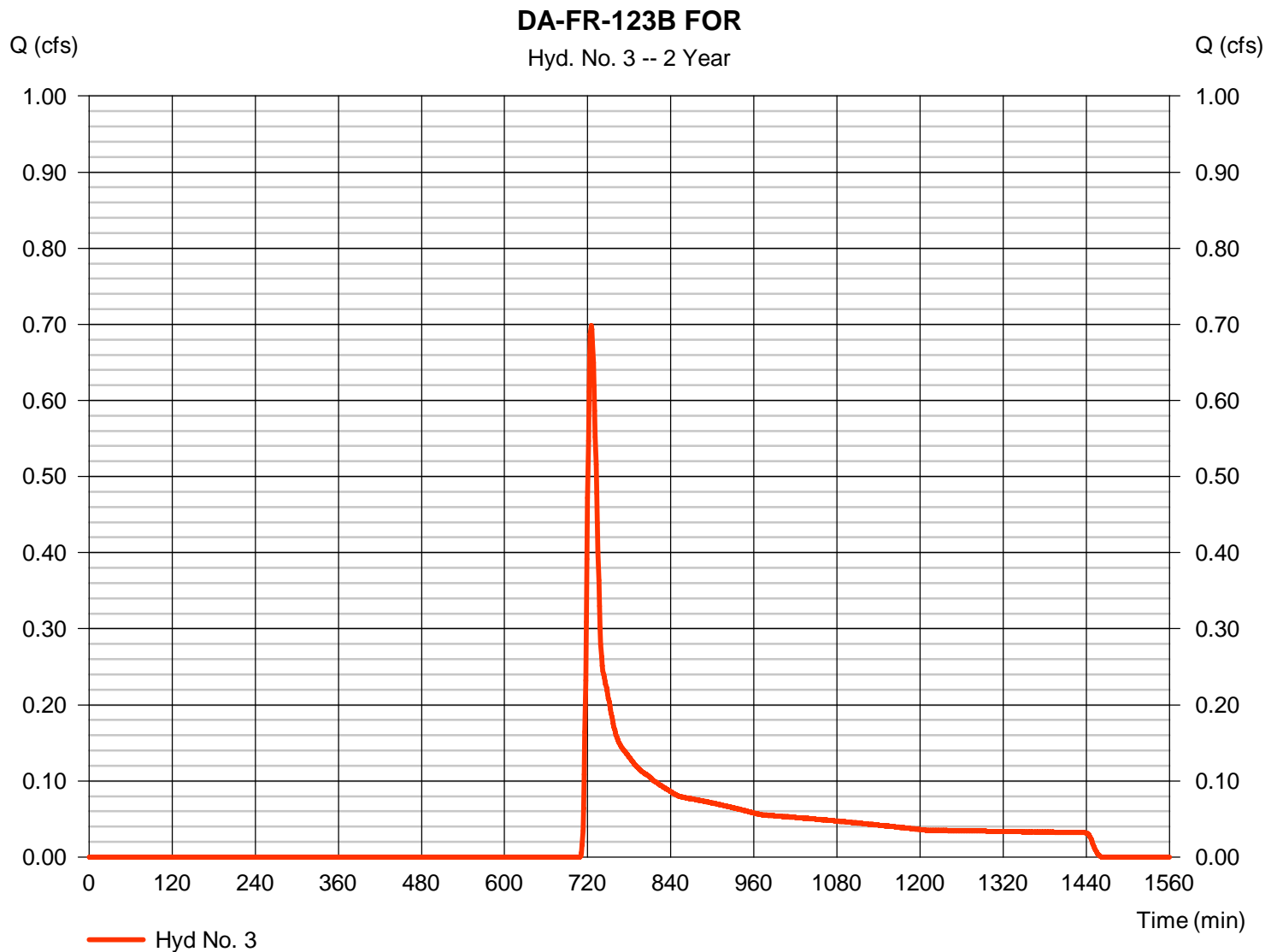
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-123B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 2.130 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.698 cfs
 Time to peak = 725 min
 Hyd. volume = 3,213 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.00 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	4.236	1	723	12,161	-----	-----	-----	DA-FR-123B PRE
2	SCS Runoff	4.236	1	723	12,161	-----	-----	-----	DA-FR-123B DEV
3	SCS Runoff	3.489	1	723	10,427	-----	-----	-----	DA-FR-123B FOR
DA-FR-123B_Hydraflow.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

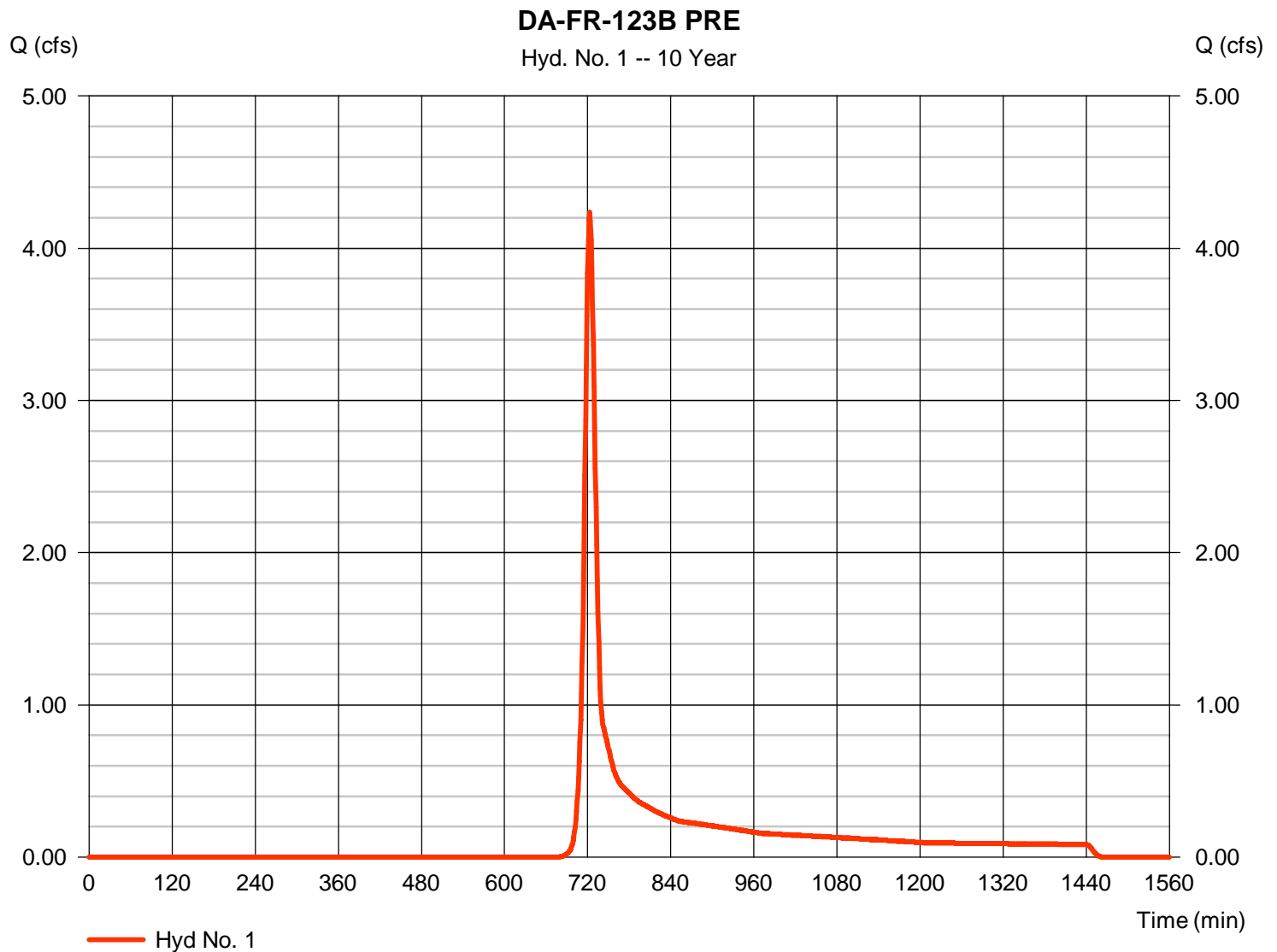
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-123B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 4.236 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 12,161 cuft
Drainage area	= 2.130 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.00 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.012 \times 82) + (0.037 \times 85) + (1.614 \times 58) + (0.013 \times 100) + (0.453 \times 55)] / 2.130$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

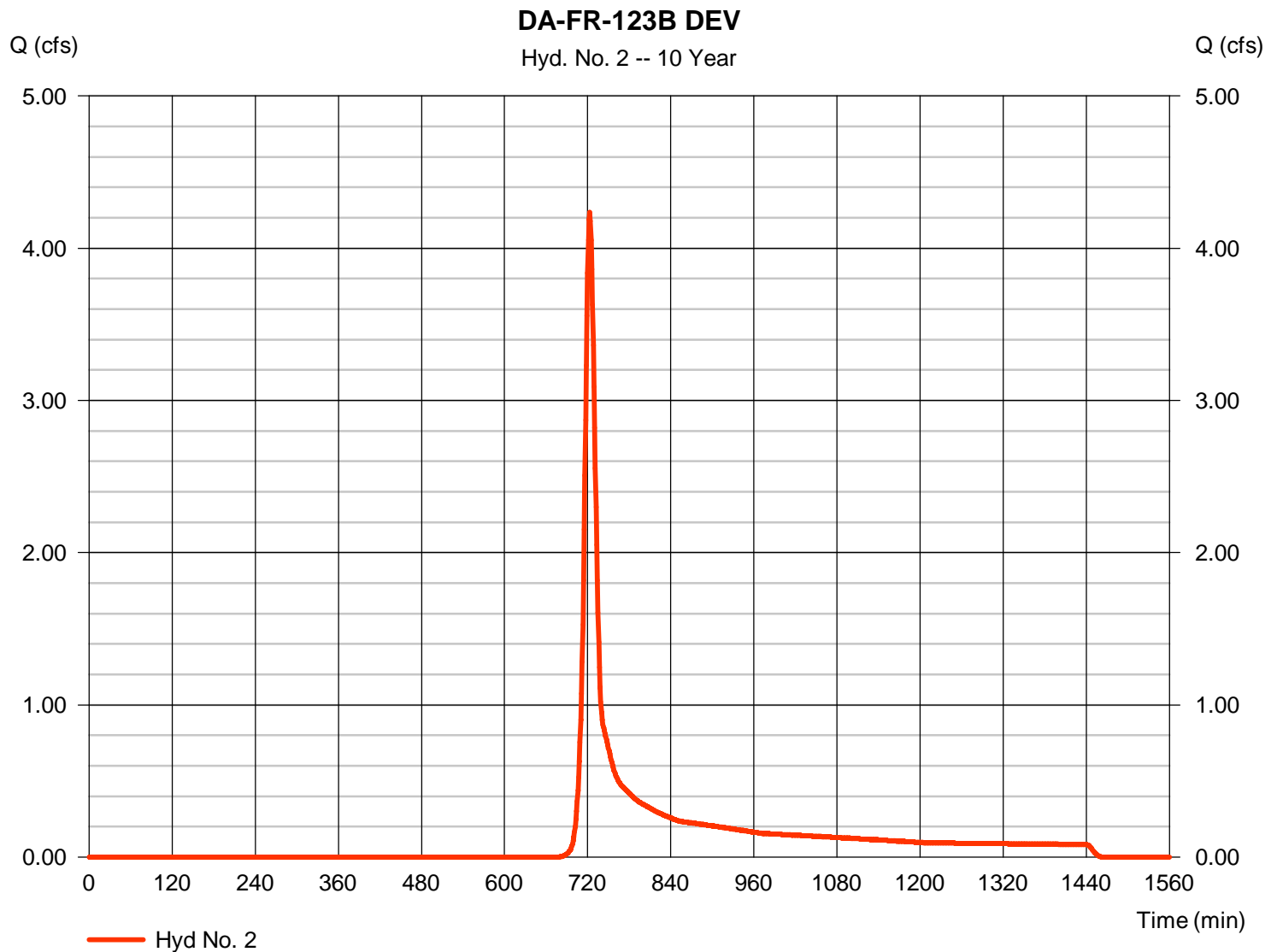
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-123B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 4.236 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 12,161 cuft
Drainage area	= 2.130 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.90 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.233 \times 48) + (0.012 \times 82) + (0.037 \times 85) + (1.834 \times 58) + (0.013 \times 100)] / 2.130$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

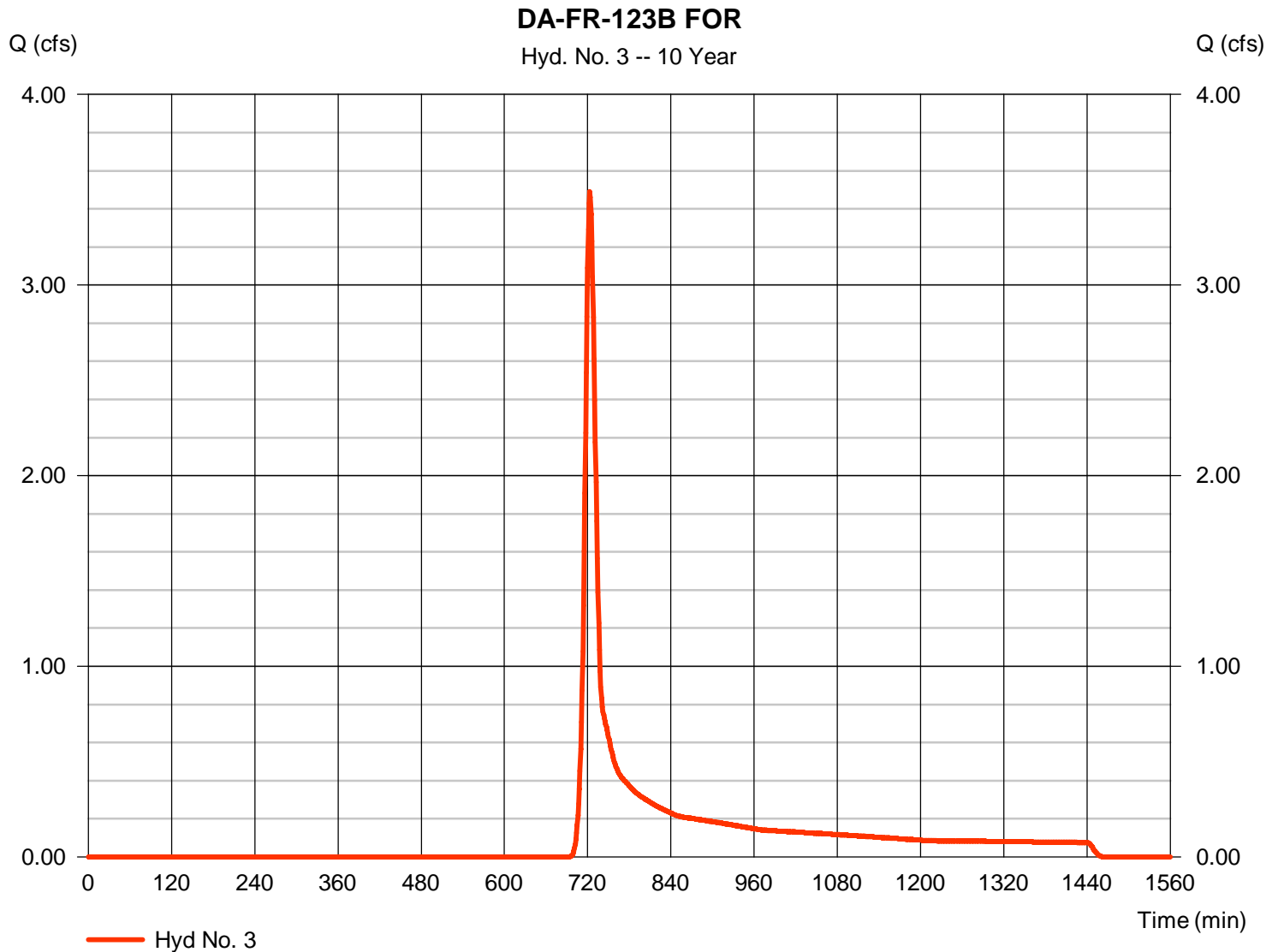
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-123B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 2.130 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 3.489 cfs
 Time to peak = 723 min
 Hyd. volume = 10,427 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.00 min
 Distribution = Type II
 Shape factor = 484



DA-FR-124

DA-FR-124 is located in a meadow and forested areas with hilly slopes. No new impervious area is proposed within DA-FR-124. The total phosphorus load reduction required for DA-FR-124 is -0.62 lb/yr. Multiple points of analysis were evaluated within DA-FR-124 to evaluate the effects on each receiving stream/channel following construction. Specifically, DA-FR-124 was sub-divided into two sub-drainage areas (sub areas A and B).

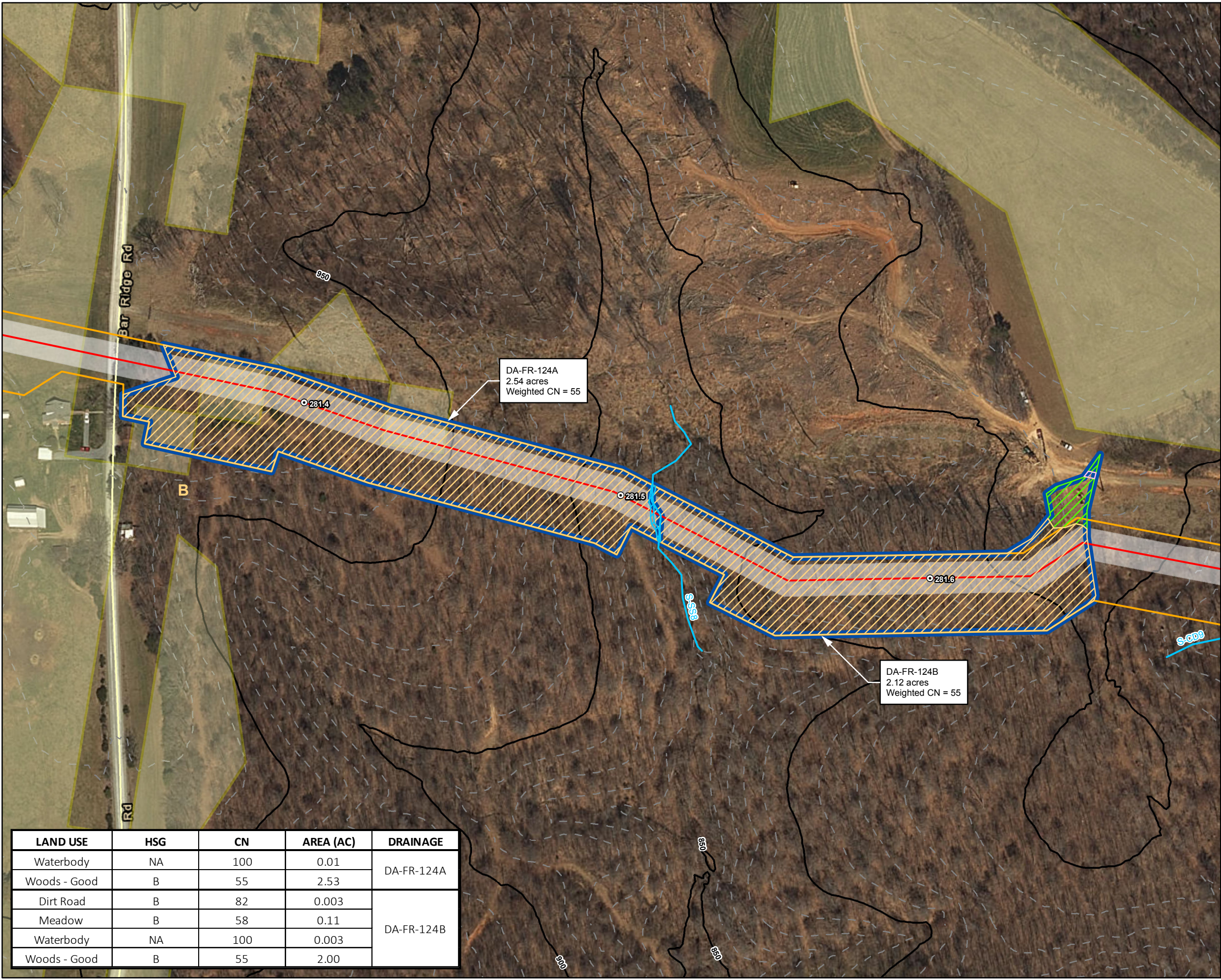
Sub-area 124A contains both agricultural and non-agricultural areas within the limits of disturbance (LOD). Pre-construction agricultural areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction. In non-agricultural areas, land use will be restored following construction as noted in the Stormwater Management (SWM) Narrative and the Annual Standards and Specifications. Agricultural areas within the LOD are included in the SWM quality analysis and the total permanent Right of Way (ROW) is analyzed via VRRM; in these calculations agricultural areas are considered "Forest/Open Space".

Stormwater quantity is met via the energy balance method for each of the two sub-areas DA-FR-124A and DA-FR-124B. Agricultural areas within the study area are included in the SWM analysis, but an Improvement Factor (IF) of 1.0 is used when applying the Energy Balance Method. This improvement factor is used to account for the exemption of agricultural areas (§ 62.1-44.15:34 and 9VAC25-870-300) since such areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction.

In addition, the Hydraflow Hydrograph's 10-year 24-hour peak discharge results indicate a reduction in flows ranging from 0.67 to 0.93 cfs for all drainage areas (as seen in table below).

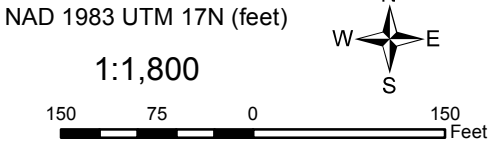
Sub Area	Pre Peak Flow, 10-yr Q (cfs)	Post Peak Flow, Q 10-yr (cfs)	Flow differential
DA-FR-124A	3.67	2.74	-0.93
DA-FR-124B	2.91	2.24	-0.67

Figures and calculations for each of the sub-areas for DA-FR-124 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.



Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- - Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Dirt Road
- Meadow
- Waterbody
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups



Mountain Valley Pipeline Project



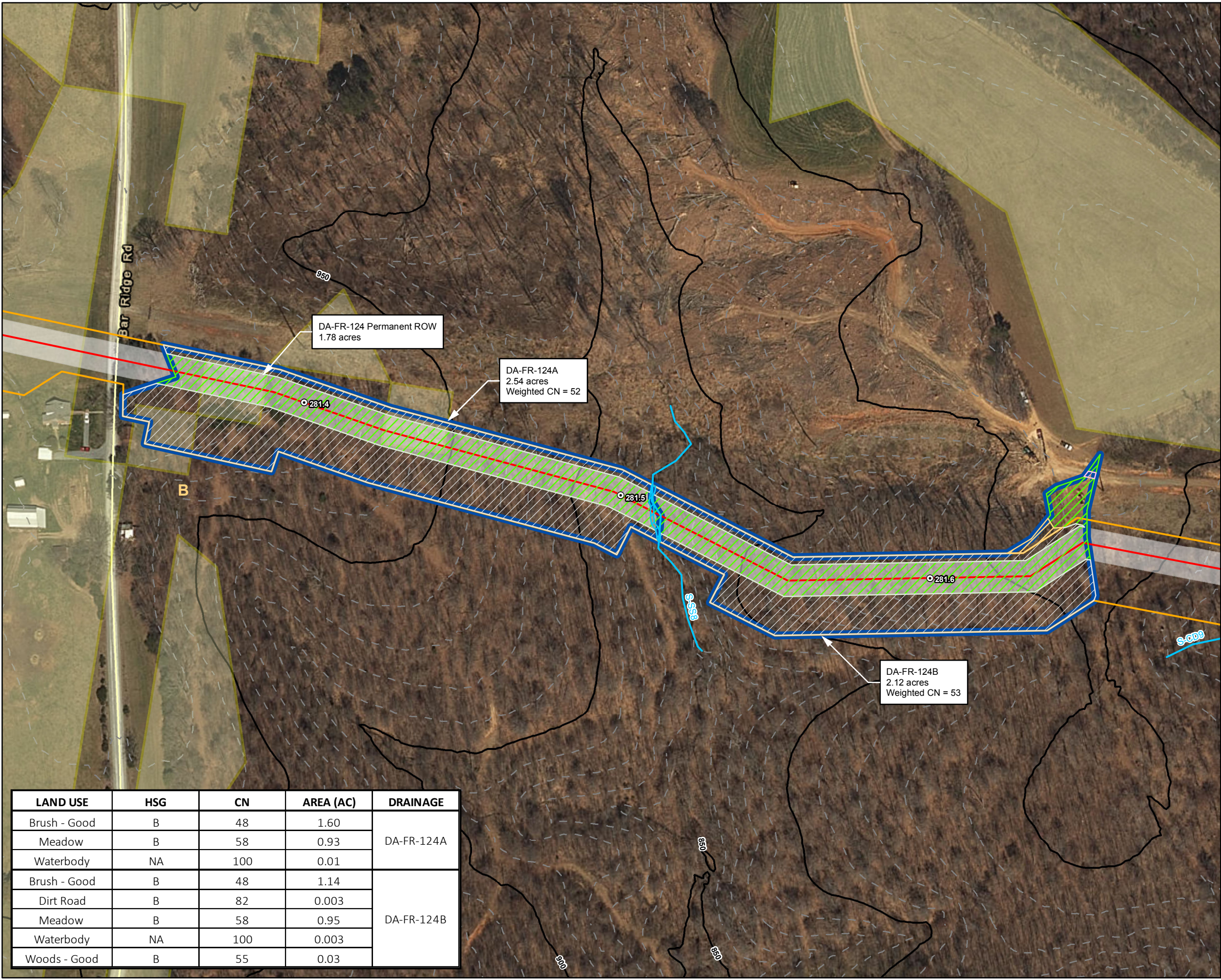
**Pre-Construction Drainage Area Map
DA-FR-124
Spread 11**

Figure 1
Franklin County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Waterbody	NA	100	0.01	DA-FR-124A
Woods - Good	B	55	2.53	
Dirt Road	B	82	0.003	DA-FR-124B
Meadow	B	58	0.11	
Waterbody	NA	100	0.003	
Woods - Good	B	55	2.00	



Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Dirt Road
- Meadow
- Waterbody
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)
1:1,800

150750

Feet

N

W

E

S

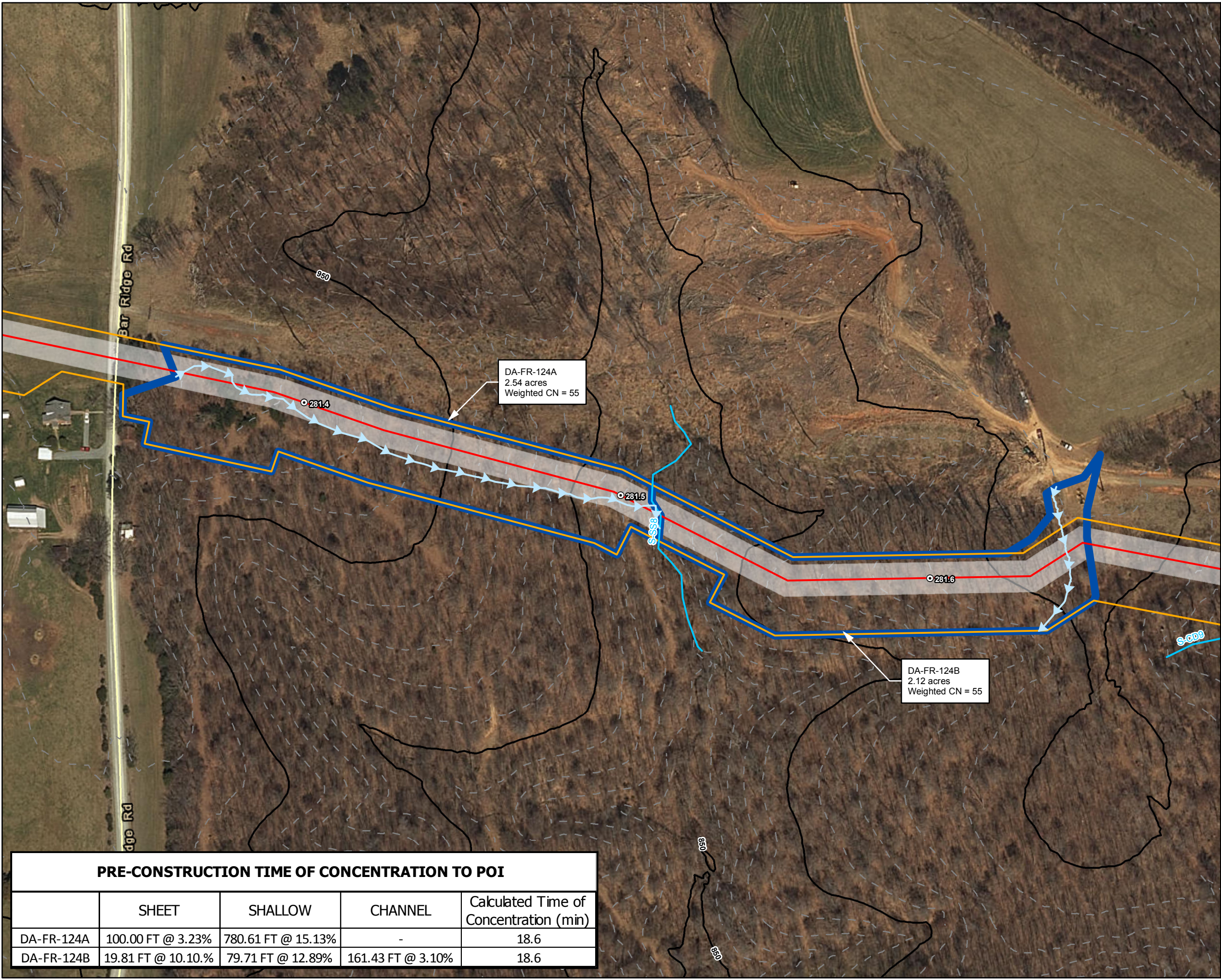


LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Brush - Good	B	48	1.60	DA-FR-124A
Meadow	B	58	0.93	
Waterbody	NA	100	0.01	
Brush - Good	B	48	1.14	DA-FR-124B
Dirt Road	B	82	0.003	
Meadow	B	58	0.95	
Waterbody	NA	100	0.003	
Woods - Good	B	55	0.03	

Mountain Valley Pipeline Project

Post-Construction Drainage Area Map
DA-FR-124
Spread 11
Figure 2
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.



Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:1,800

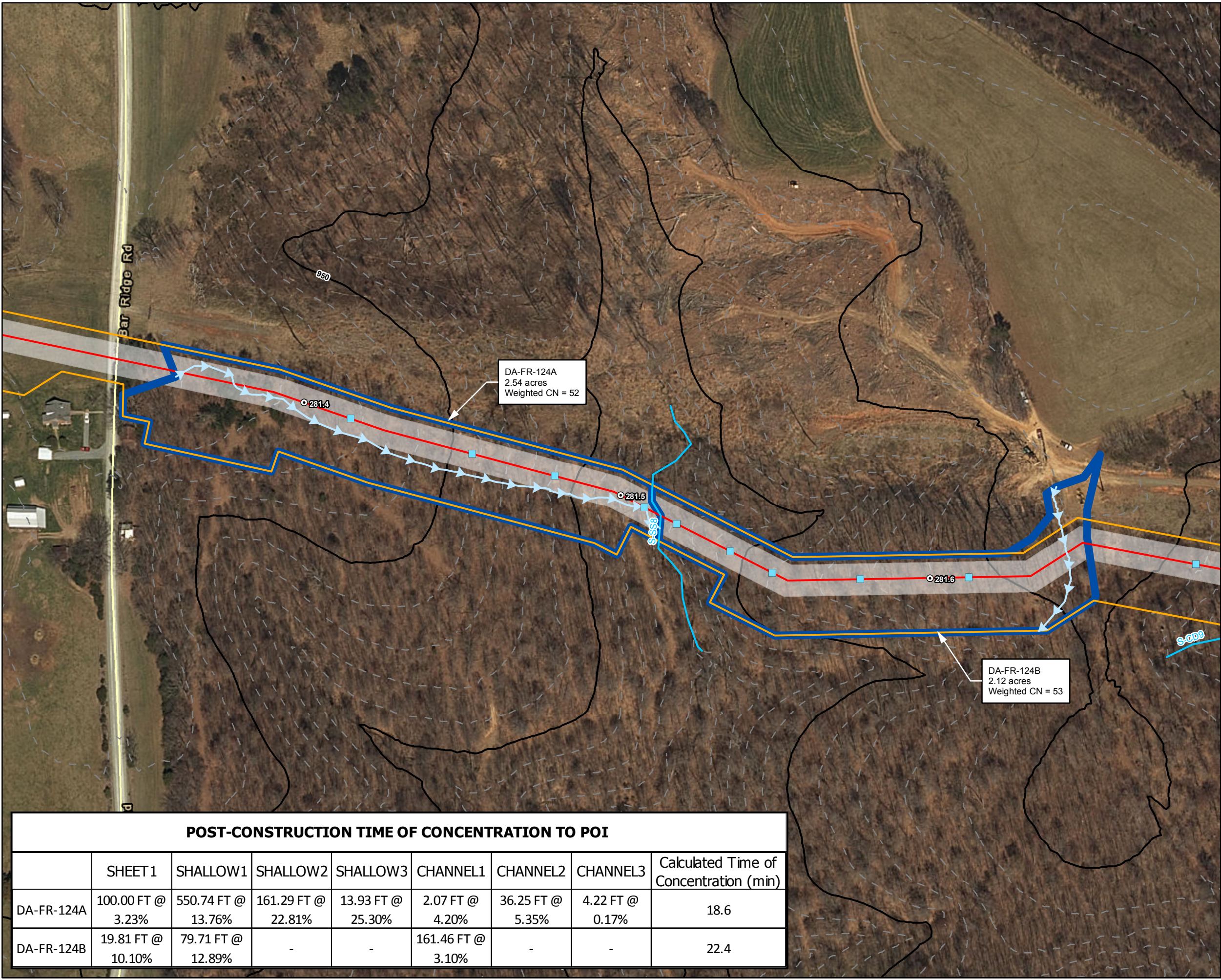
150 75 0 150 Feet

Mountain Valley Pipeline Project

Pre-Construction Drainage Area and Time of Concentration
DA-FR-124
Spread 11
Figure 3
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.

PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI				
	SHEET	SHALLOW	CHANNEL	Calculated Time of Concentration (min)
DA-FR-124A	100.00 FT @ 3.23%	780.61 FT @ 15.13%	-	18.6
DA-FR-124B	19.81 FT @ 10.10.%	79.71 FT @ 12.89%	161.43 FT @ 3.10%	18.6



Legend

- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:1,800

150 75 0 150 Feet

Mountain Valley Pipeline Project

Mountain Valley
PIPELINE

**Post-Construction Drainage Area
and Time of Concentration**
DA-FR-124
Spread 11

Figure 4
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.

POST-CONSTRUCTION TIME OF CONCENTRATION TO POI								
	SHEET 1	SHALLOW1	SHALLOW2	SHALLOW3	CHANNEL1	CHANNEL2	CHANNEL3	Calculated Time of Concentration (min)
DA-FR-124A	100.00 FT @ 3.23%	550.74 FT @ 13.76%	161.29 FT @ 22.81%	13.93 FT @ 25.30%	2.07 FT @ 4.20%	36.25 FT @ 5.35%	4.22 FT @ 0.17%	18.6
DA-FR-124B	19.81 FT @ 10.10%	79.71 FT @ 12.89%	-	-	161.46 FT @ 3.10%	-	-	22.4

Virginia Runoff Reduction Method New Development Worksheet - v2.8 - June 2014

Site Data Summary

Total Rainfall = 45 inches

Site Land Cover Summary

	A Soils	B Soils	C Soils	D Soils	Total	% of Total
Forest (acres)	0.00	1.78	0.07	0.00	1.85	100.00
Turf (acres)	0.00	0.00	0.00	0.00	0.00	0.00
Impervious (acres)	0.00	0.00	0.00	0.00	0.00	0.00
					1.85	100.00

Site Rv	0.03
Post Development Treatment Volume (ft3)	204
Post Development TP Load (lb/yr)	0.13
Post Development TN Load (lb/yr)	0.96
Total TP Load Reduction Required (lb/yr)	-0.62

Total Runoff Volume Reduction (ft ³)	0
Total TP Load Reduction Achieved (lb/yr)	0
Total TN Load Reduction Achieved (lb/yr)	0.00
Adjusted Post Development TP Load (lb/yr)	0.13
Remaining Phosphorous Load Reduction (Lb/yr) Required	0.00

Drainage Area Summary

	D.A. A	D.A. B	D.A. C	D.A. D	D.A. E	Total
Forest (acres)	1.78	0.00	0.00	0.00	0.00	1.78
Turf (acres)	0.00	0.00	0.00	0.00	0.00	0.00
Impervious (acres)	0.00	0.00	0.00	0.00	0.00	0.00
						1.78

Drainage Area Compliance Summary

	D.A. A	D.A. B	D.A. C	D.A. D	D.A. E	Total
TP Load Red. (lb/yr)	0.00	0.00	0.00	0.00	0.00	0.00
TN Load Red. (lb/yr)	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-124A

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.365	2562
Developed Condition	0.149	1823
Pre-Developed (Forest) Condition	0.365	2562

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	0.149	\leq	0.410
			N/A - See Check #3	
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.149	\leq	0.365
			N/A - See Check #3	
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ ---->	0.149	<u>shall not</u> be required to be \leq	0.513

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p><i>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</i></p> <p><i>For Paved Road land surface types a Manning’s n value of 0.011 was used.</i></p> <p><i>Sources:</i></p> <p><i>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</i></p> <p><i>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</i></p>	

Table 2 – Manning's *n* Values for Open Channel Flow

Channel Type	Manning <i>n</i>		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's <i>n</i> value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's <i>n</i> value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-124A PRE
2	SCS Runoff	DA-FR-124A DEV
3	SCS Runoff	DA-FR-124A FOR

Hydrograph Return Period Recap

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)								Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	-----	0.365	0.723	-----	-----	3.670	-----	-----	-----	DA-FR-124A PRE
2	SCS Runoff	-----	0.149	0.374	-----	-----	2.735	-----	-----	-----	DA-FR-124A DEV
3	SCS Runoff	-----	0.365	0.723	-----	-----	3.670	-----	-----	-----	DA-FR-124A FOR
Proj. file: DA-FR-124A_Hydraflow.gpw											Thursday, 08 / 31 / 2017

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.365	1	729	2,562	-----	-----	-----	DA-FR-124A PRE
2	SCS Runoff	0.149	1	736	1,823	-----	-----	-----	DA-FR-124A DEV
3	SCS Runoff	0.365	1	729	2,562	-----	-----	-----	DA-FR-124A FOR
DA-FR-124A_Hydraflow.gpw					Return Period: 1 Year			Thursday, 08 / 31 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

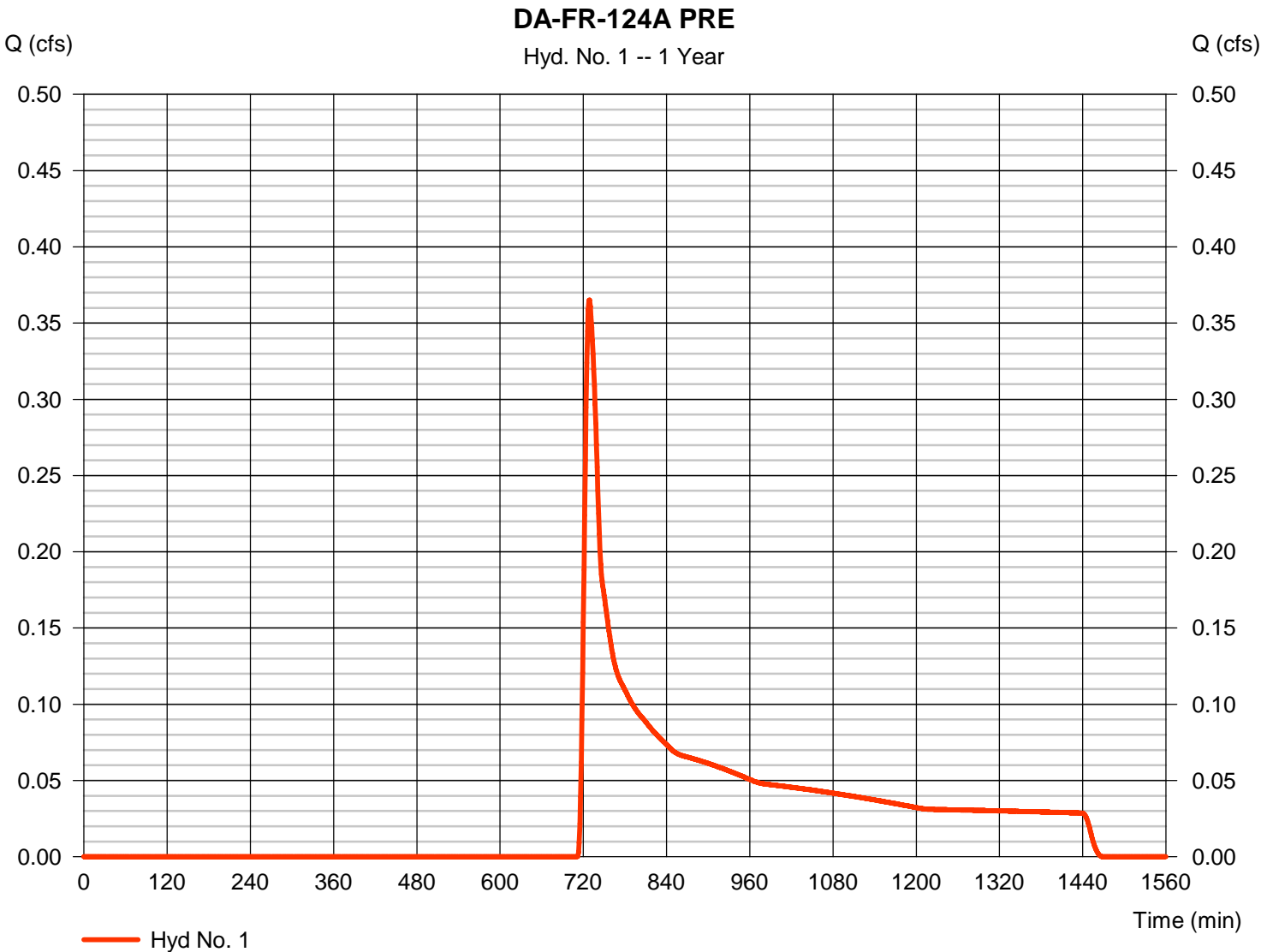
Thursday, 08 / 31 / 2017

Hyd. No. 1

DA-FR-124A PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.365 cfs
Storm frequency	=	1 yrs	Time to peak	=	729 min
Time interval	=	1 min	Hyd. volume	=	2,562 cuft
Drainage area	=	2.540 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.50 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.009 x 100) + (2.532 x 55)] / 2.540



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-124A PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 3.23	0.00	0.00	
Travel Time (min)	= 16.49	+ 0.00	+ 0.00	= 16.49
Shallow Concentrated Flow				
Flow length (ft)	= 741.93	0.00	0.00	
Watercourse slope (%)	= 15.70	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=6.39	0.00	0.00	
Travel Time (min)	= 1.93	+ 0.00	+ 0.00	= 1.93
Channel Flow				
X sectional flow area (sqft)	= 2.93	0.00	0.00	
Wetted perimeter (ft)	= 7.93	0.00	0.00	
Channel slope (%)	= 4.32	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=5.30	0.00	0.00	
Flow length (ft)	({})38.7	0.0	0.0	
Travel Time (min)	= 0.12	+ 0.00	+ 0.00	= 0.12
Total Travel Time, Tc				18.50 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

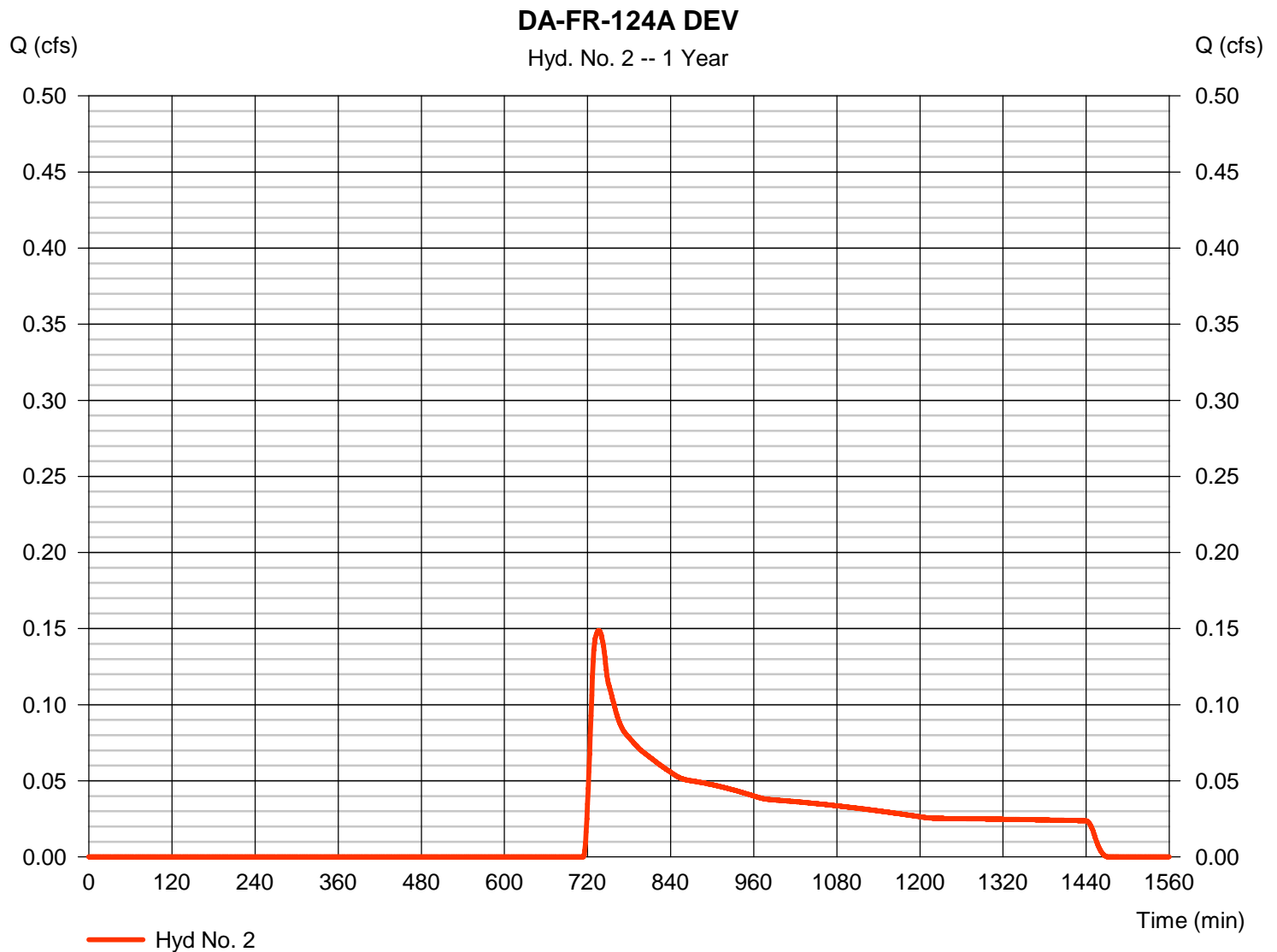
Thursday, 08 / 31 / 2017

Hyd. No. 2

DA-FR-124A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.149 cfs
Storm frequency	= 1 yrs	Time to peak	= 736 min
Time interval	= 1 min	Hyd. volume	= 1,823 cuft
Drainage area	= 2.540 ac	Curve number	= 52*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.60 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.603 \times 48) + (0.929 \times 58) + (0.009 \times 100)] / 2.540$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-124A DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 3.23	0.00	0.00				
Travel Time (min)	= 16.49	+	0.00	+	0.00	=	16.49
Shallow Concentrated Flow							
Flow length (ft)	= 550.74	161.29	13.93				
Watercourse slope (%)	= 13.76	22.81	25.30				
Surface description	= Unpaved	Unpaved	Unpaved				
Average velocity (ft/s)	=5.99	7.71	8.12				
Travel Time (min)	= 1.53	+	0.35	+	0.03	=	1.91
Channel Flow							
X sectional flow area (sqft)	= 2.00	2.00	2.93				
Wetted perimeter (ft)	= 4.47	4.47	7.93				
Channel slope (%)	= 5.00	5.00	0.17				
Manning's n-value	= 0.040	0.040	0.030				
Velocity (ft/s)	=4.86	4.86	1.05				
Flow length (ft)	((0})2.1	36.3	4.2				
Travel Time (min)	= 0.01	+	0.12	+	0.07	=	0.20
Total Travel Time, Tc				18.60 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

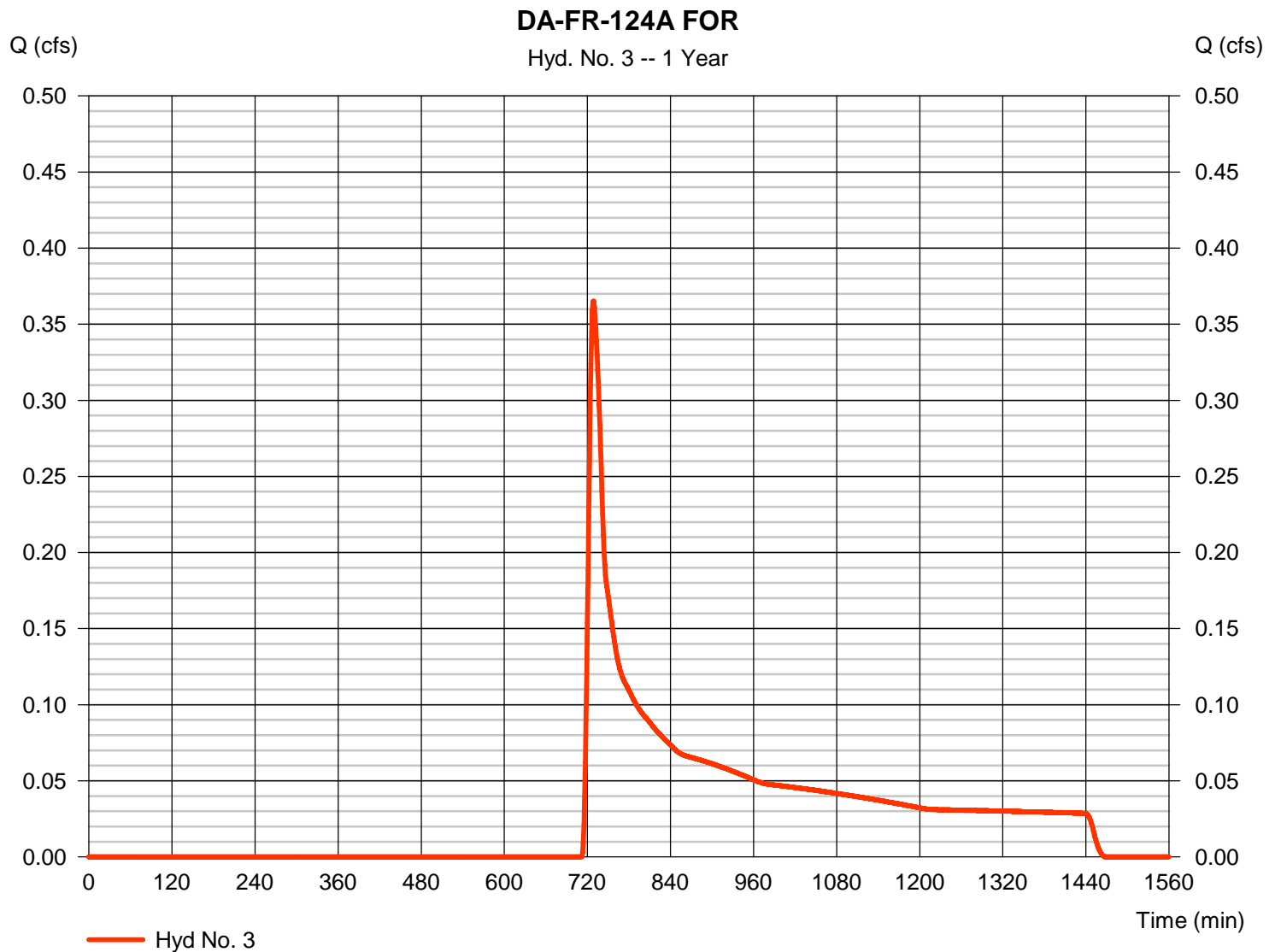
Thursday, 08 / 31 / 2017

Hyd. No. 3

DA-FR-124A FOR

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 2.540 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.30 in
 Storm duration = 24 hrs

Peak discharge = 0.365 cfs
 Time to peak = 729 min
 Hyd. volume = 2,562 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 18.50 min
 Distribution = Type II
 Shape factor = 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-124A FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 3.23	0.00	0.00				
Travel Time (min)	= 16.49	+	0.00	+	0.00	=	16.49
Shallow Concentrated Flow							
Flow length (ft)	= 741.93	0.00	0.00				
Watercourse slope (%)	= 15.70	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=6.39	0.00	0.00				
Travel Time (min)	= 1.93	+	0.00	+	0.00	=	1.93
Channel Flow							
X sectional flow area (sqft)	= 2.93	0.00	0.00				
Wetted perimeter (ft)	= 7.93	0.00	0.00				
Channel slope (%)	= 4.32	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=5.30	0.00	0.00				
Flow length (ft)	((0))38.7	0.0	0.0				
Travel Time (min)	= 0.12	+	0.00	+	0.00	=	0.12
Total Travel Time, Tc				18.50 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.723	1	727	3,788	-----	-----	-----	DA-FR-124A PRE
2	SCS Runoff	0.374	1	730	2,858	-----	-----	-----	DA-FR-124A DEV
3	SCS Runoff	0.723	1	727	3,788	-----	-----	-----	DA-FR-124A FOR
DA-FR-124A_Hydraflow.gpw					Return Period: 2 Year			Thursday, 08 / 31 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

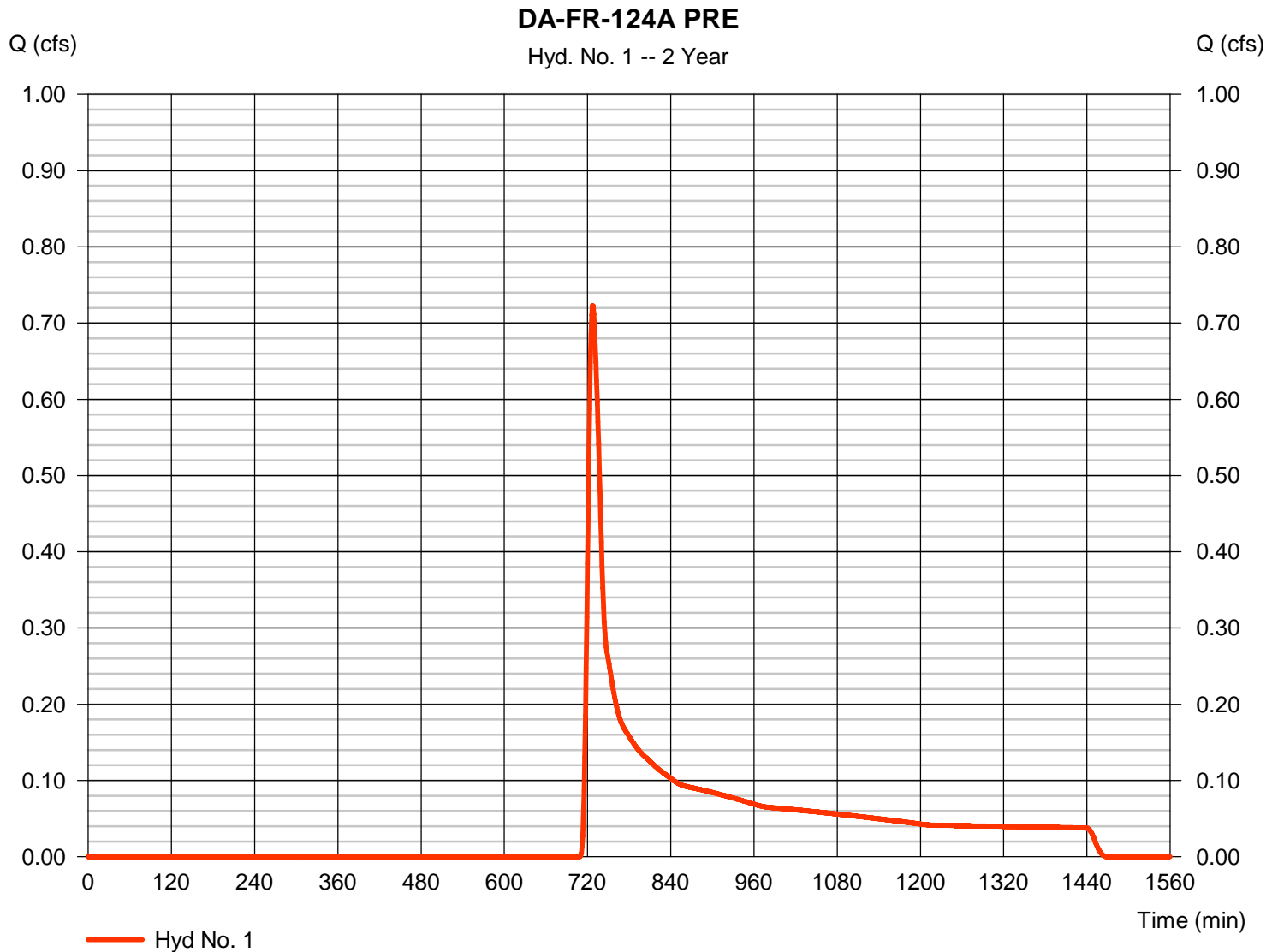
Thursday, 08 / 31 / 2017

Hyd. No. 1

DA-FR-124A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.723 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 3,788 cuft
Drainage area	= 2.540 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.50 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.009 \times 100) + (2.532 \times 55)] / 2.540$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

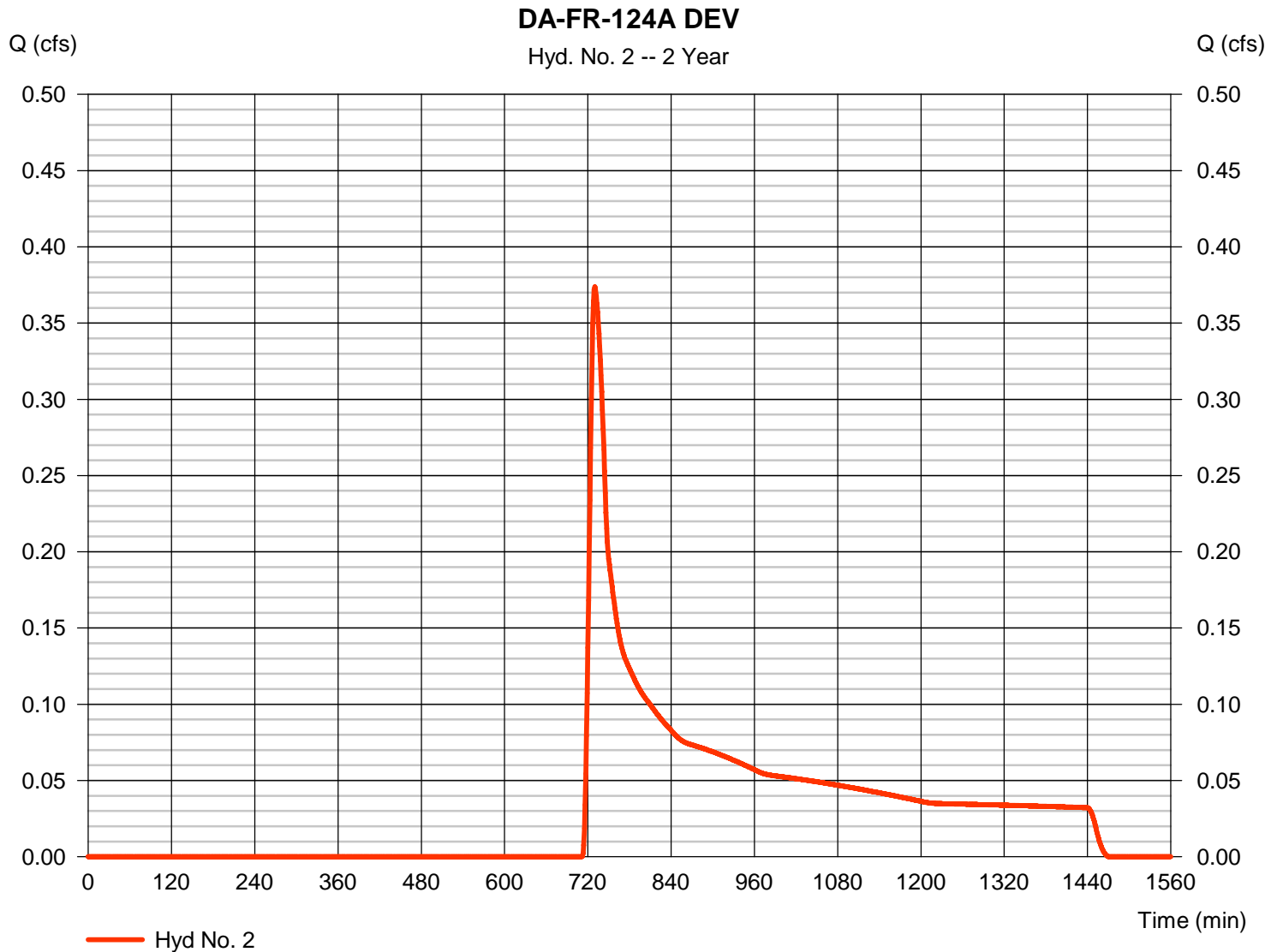
Thursday, 08 / 31 / 2017

Hyd. No. 2

DA-FR-124A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.374 cfs
Storm frequency	= 2 yrs	Time to peak	= 730 min
Time interval	= 1 min	Hyd. volume	= 2,858 cuft
Drainage area	= 2.540 ac	Curve number	= 52*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.60 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.603 \times 48) + (0.929 \times 58) + (0.009 \times 100)] / 2.540$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

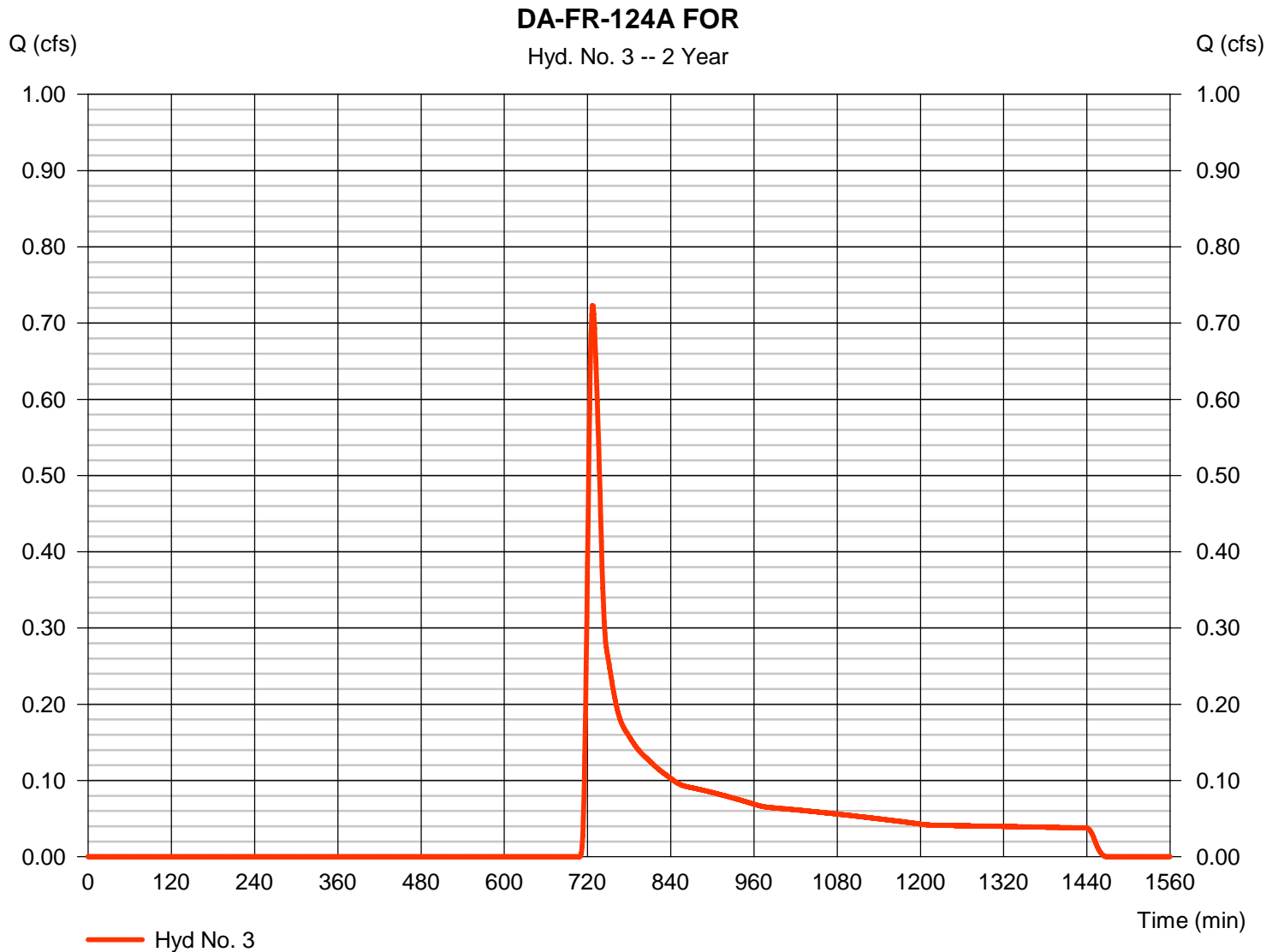
Thursday, 08 / 31 / 2017

Hyd. No. 3

DA-FR-124A FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 2.540 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.723 cfs
 Time to peak = 727 min
 Hyd. volume = 3,788 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 18.50 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	3.670	1	725	12,292	-----	-----	-----	DA-FR-124A PRE
2	SCS Runoff	2.735	1	727	10,465	-----	-----	-----	DA-FR-124A DEV
3	SCS Runoff	3.670	1	725	12,292	-----	-----	-----	DA-FR-124A FOR
DA-FR-124A_Hydraflow.gpw					Return Period: 10 Year			Thursday, 08 / 31 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

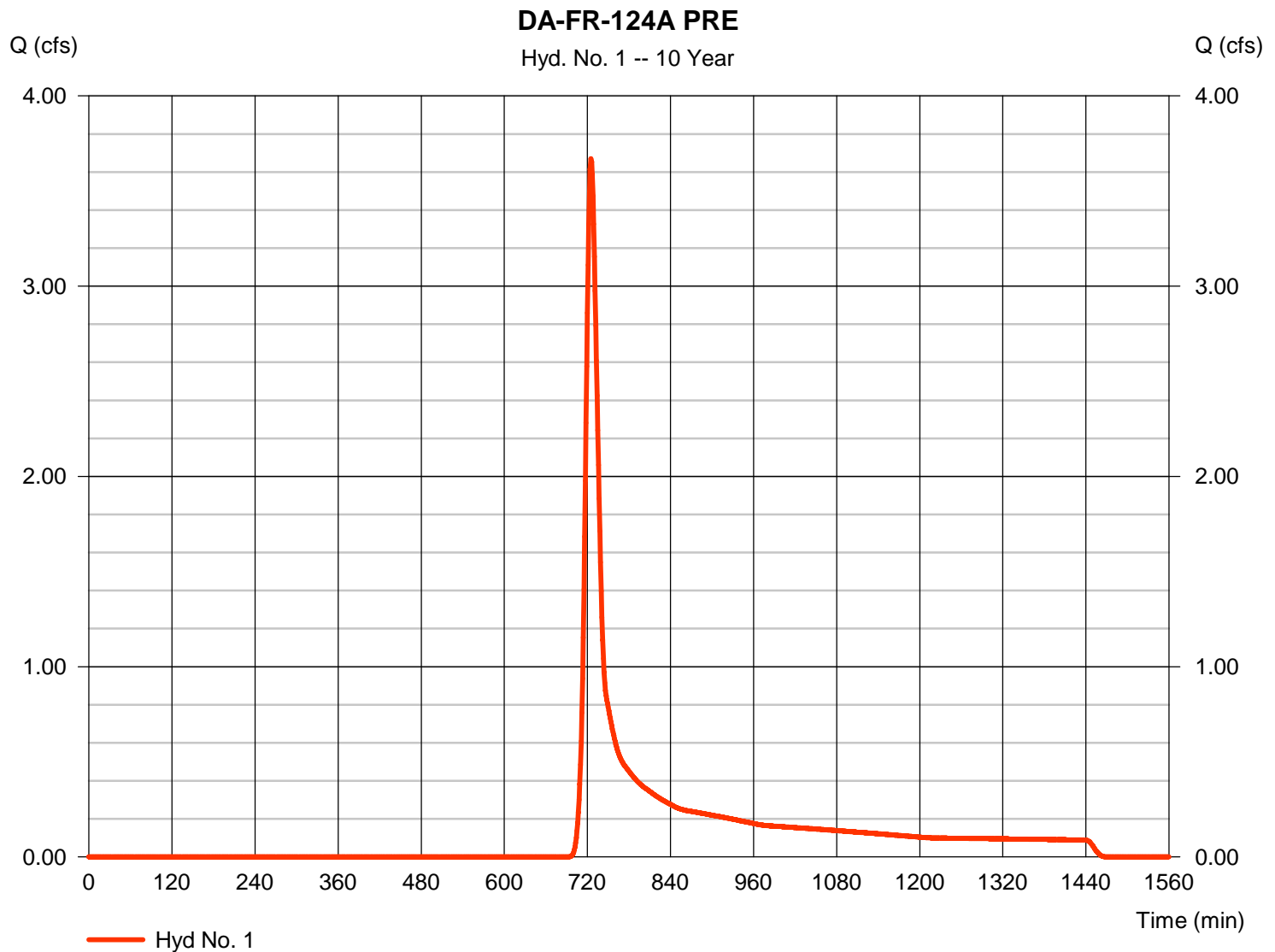
Thursday, 08 / 31 / 2017

Hyd. No. 1

DA-FR-124A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 3.670 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 12,292 cuft
Drainage area	= 2.540 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.50 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.009 \times 100) + (2.532 \times 55)] / 2.540$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

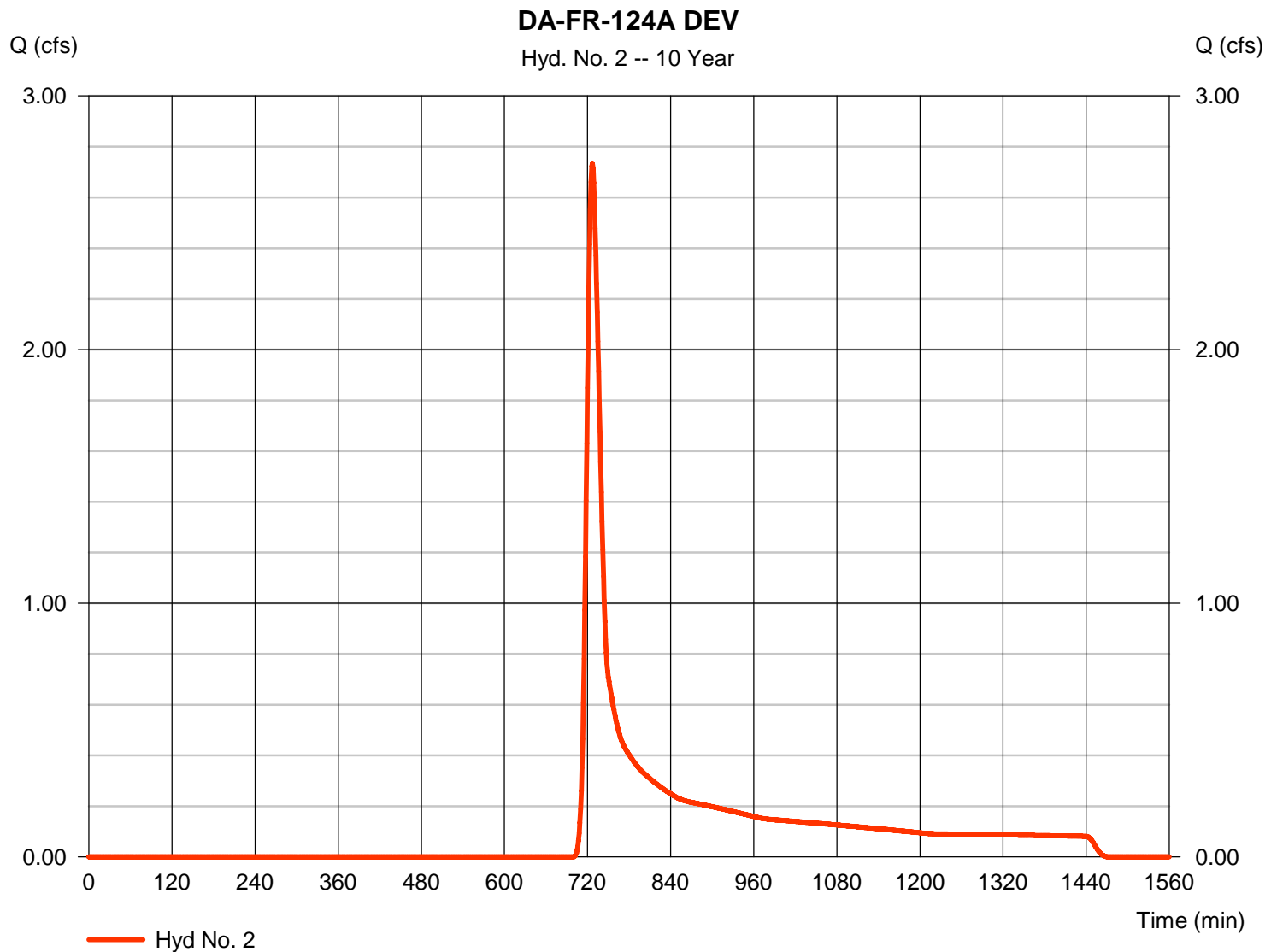
Thursday, 08 / 31 / 2017

Hyd. No. 2

DA-FR-124A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 2.735 cfs
Storm frequency	= 10 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 10,465 cuft
Drainage area	= 2.540 ac	Curve number	= 52*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.60 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.603 \times 48) + (0.929 \times 58) + (0.009 \times 100)] / 2.540$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

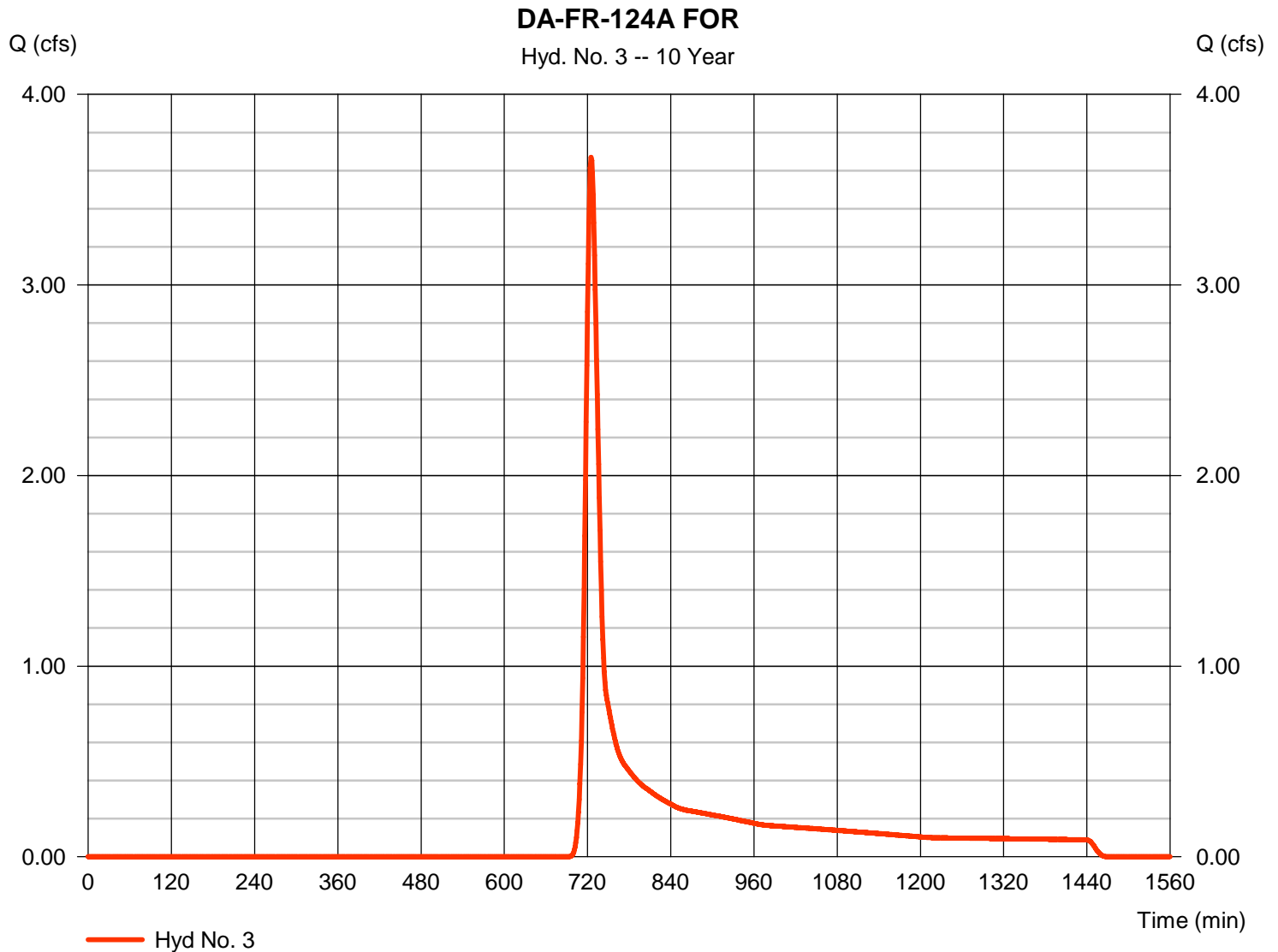
Thursday, 08 / 31 / 2017

Hyd. No. 3

DA-FR-124A FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 2.540 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 3.670 cfs
 Time to peak = 725 min
 Hyd. volume = 12,292 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 18.50 min
 Distribution = Type II
 Shape factor = 484



DA-FR-124B

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.289	2163
Developed Condition	0.156	1710
Pre-Developed (Forest) Condition	0.250	2163

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	0.156	\leq	0.292
			N/A - See Check #3	
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.156	\leq	0.289
			N/A - See Check #3	
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ ---->	0.156	<u>shall not</u> be required to be \leq	0.316

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s *n* Values for Sheet Flow

Land Surface Type	Manning <i>n</i>
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s <i>n</i> values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s <i>n</i> value of 0.011 was used.</p> <p>Sources:</p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

Table 2 – Manning's *n* Values for Open Channel Flow

Channel Type	Manning <i>n</i>		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's <i>n</i> value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's <i>n</i> value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-124B PRE
2	SCS Runoff	DA-FR-124B DEV
3	SCS Runoff	DA-FR-124B FOR

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.289	1	730	2,163	-----	-----	-----	DA-FR-124B PRE
2	SCS Runoff	0.156	1	737	1,710	-----	-----	-----	DA-FR-124B DEV
3	SCS Runoff	0.250	1	734	2,163	-----	-----	-----	DA-FR-124B FOR
DA-FR-124B_Hydraflow.gpw					Return Period: 1 Year			Thursday, 08 / 31 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

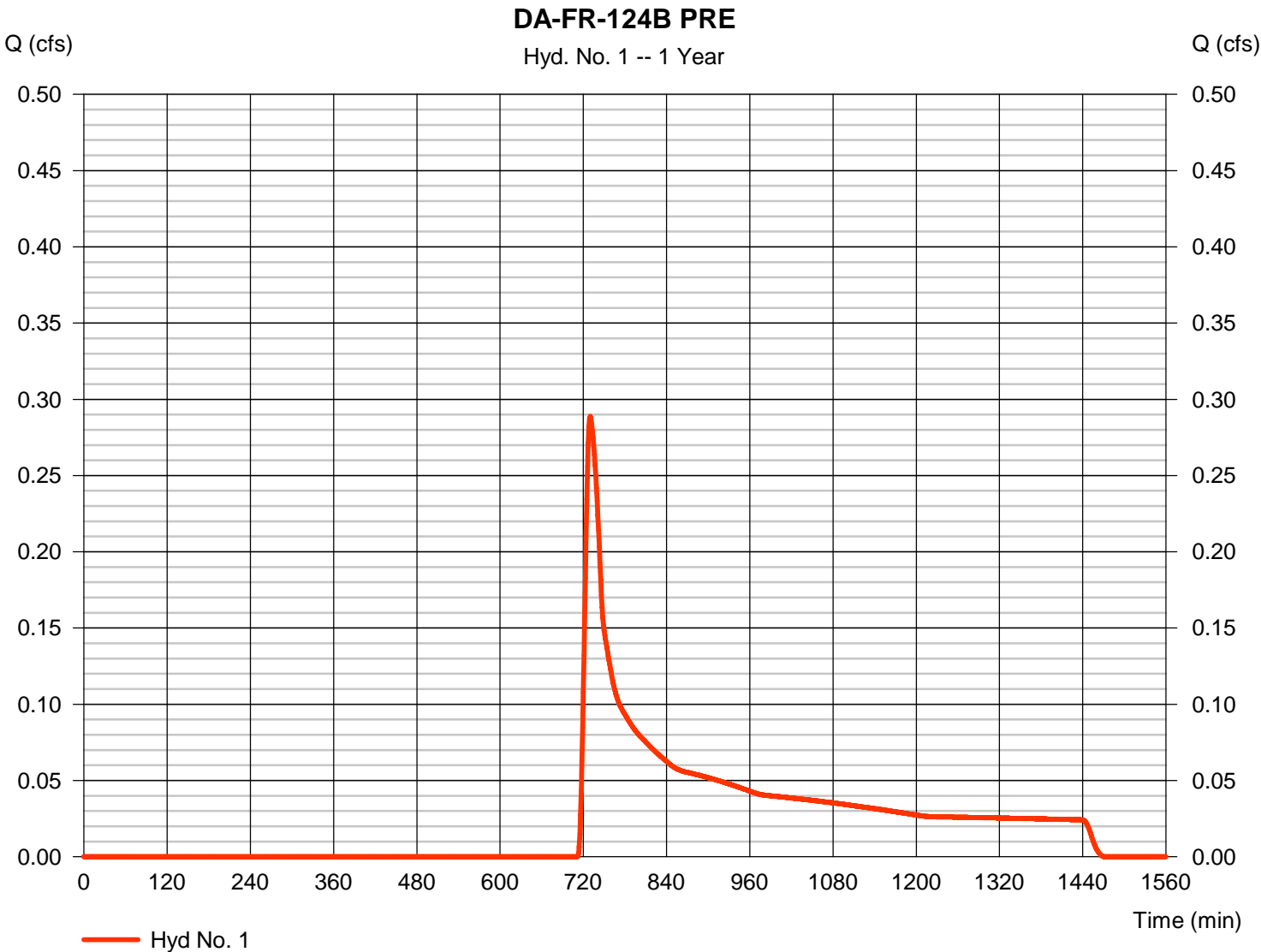
Thursday, 08 / 31 / 2017

Hyd. No. 1

DA-FR-124B PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.289 cfs
Storm frequency	=	1 yrs	Time to peak	=	730 min
Time interval	=	1 min	Hyd. volume	=	2,163 cuft
Drainage area	=	2.120 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.60 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.003 x 82) + (0.109 x 58) + (0.003 x 100) + (2.003 x 55)] / 2.120



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-124B PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 19.8	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 10.10	0.00	0.00				
Travel Time (min)	= 2.86	+	0.00	+	0.00	=	2.86
Shallow Concentrated Flow							
Flow length (ft)	= 79.71	0.00	0.00				
Watercourse slope (%)	= 12.89	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.79	0.00	0.00				
Travel Time (min)	= 0.23	+	0.00	+	0.00	=	0.23
Channel Flow							
X sectional flow area (sqft)	= 0.01	0.00	0.00				
Wetted perimeter (ft)	= 3.47	0.00	0.00				
Channel slope (%)	= 3.10	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.17	0.00	0.00				
Flow length (ft)	(0)161.5	0.0	0.0				
Travel Time (min)	= 15.50	+	0.00	+	0.00	=	15.50
Total Travel Time, Tc				18.60 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

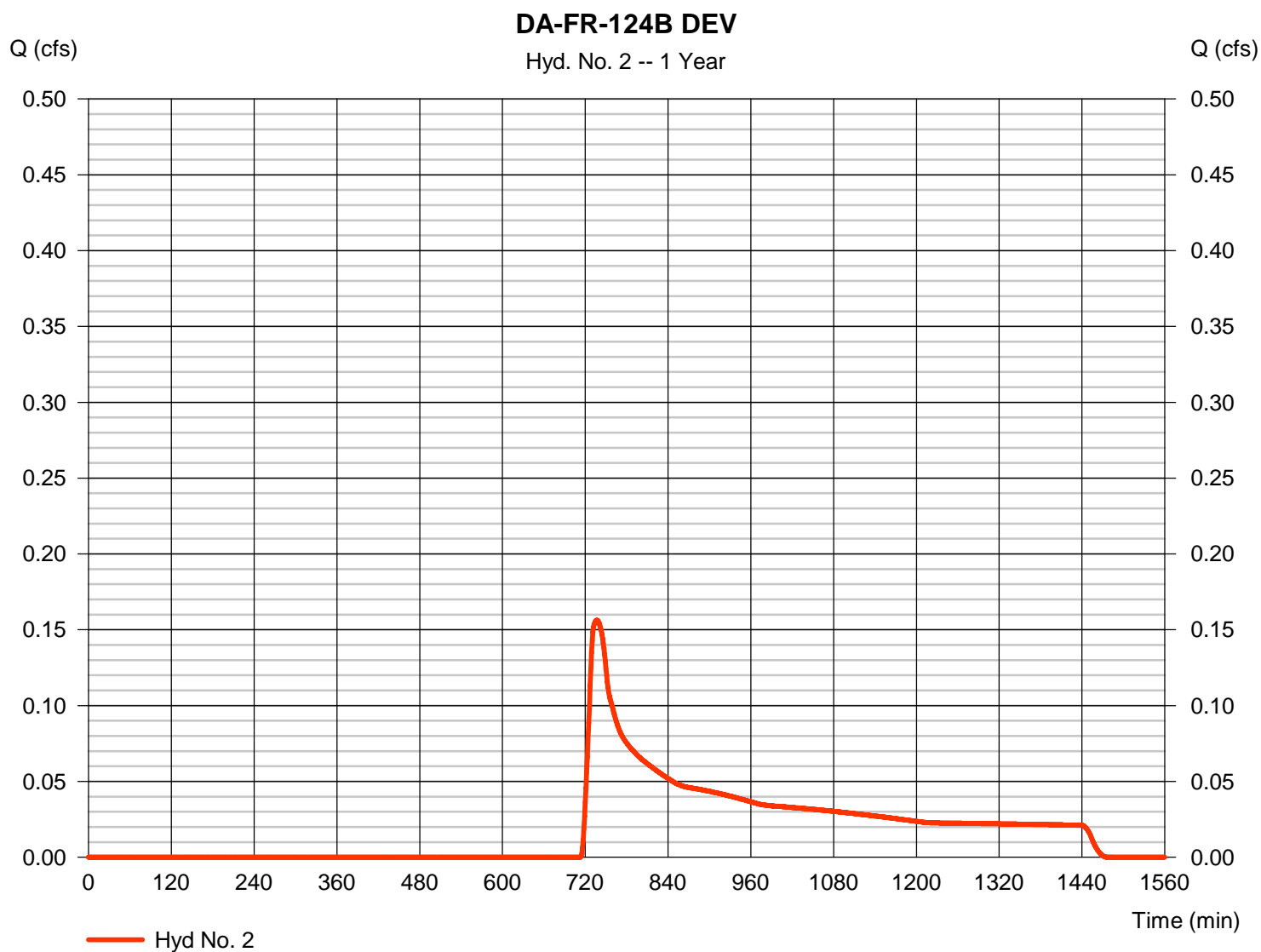
Thursday, 08 / 31 / 2017

Hyd. No. 2

DA-FR-124B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.156 cfs
Storm frequency	= 1 yrs	Time to peak	= 737 min
Time interval	= 1 min	Hyd. volume	= 1,710 cuft
Drainage area	= 2.120 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 22.40 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.137 \times 48) + (0.003 \times 82) + (0.948 \times 58) + (0.003 \times 100) + (0.028 \times 55)] / 2.120$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-124B DEV

Description	A	B	C	Totals
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 19.8	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 10.10	0.00	0.00	
Travel Time (min)	= 2.86	+	0.00	+
			0.00	= 2.86
Shallow Concentrated Flow				
Flow length (ft)	= 79.71	0.00	0.00	
Watercourse slope (%)	= 12.89	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=5.79	0.00	0.00	
Travel Time (min)	= 0.23	+	0.00	+
			0.00	= 0.23
Channel Flow				
X sectional flow area (sqft)	= 0.01	0.00	0.00	
Wetted perimeter (ft)	= 3.47	0.00	0.00	
Channel slope (%)	= 3.10	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.14	0.00	0.00	
Flow length (ft)	({})161.5	0.0	0.0	
Travel Time (min)	= 19.32	+	0.00	+
			0.00	= 19.32
Total Travel Time, Tc				22.40 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

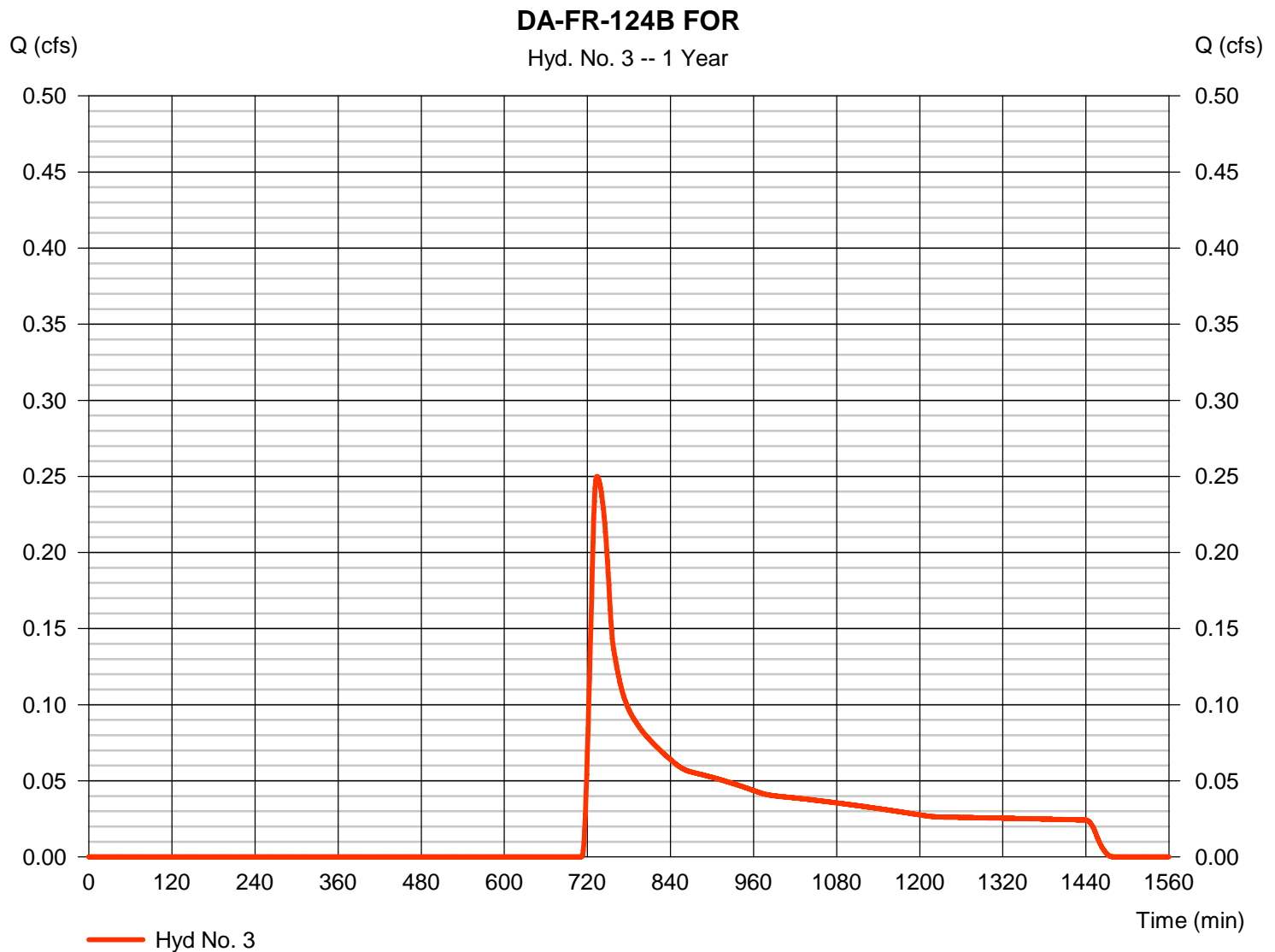
Thursday, 08 / 31 / 2017

Hyd. No. 3

DA-FR-124B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 2.120 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.30 in
 Storm duration = 24 hrs

Peak discharge = 0.250 cfs
 Time to peak = 734 min
 Hyd. volume = 2,163 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 23.80 min
 Distribution = Type II
 Shape factor = 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-124B FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 19.8	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 10.10	0.00	0.00				
Travel Time (min)	= 2.86	+	0.00	+	0.00	=	2.86
Shallow Concentrated Flow							
Flow length (ft)	= 79.71	0.00	0.00				
Watercourse slope (%)	= 12.89	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.79	0.00	0.00				
Travel Time (min)	= 0.23	+	0.00	+	0.00	=	0.23
Channel Flow							
X sectional flow area (sqft)	= 0.01	0.00	0.00				
Wetted perimeter (ft)	= 3.47	0.00	0.00				
Channel slope (%)	= 3.10	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=0.13	0.00	0.00				
Flow length (ft)	(0)161.5	0.0	0.0				
Travel Time (min)	= 20.67	+	0.00	+	0.00	=	20.67
Total Travel Time, Tc				23.80 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.570	1	729	3,198	-----	-----	-----	DA-FR-124B PRE
2	SCS Runoff	0.351	1	732	2,621	-----	-----	-----	DA-FR-124B DEV
3	SCS Runoff	0.489	1	732	3,198	-----	-----	-----	DA-FR-124B FOR
DA-FR-124B_Hydraflow.gpw					Return Period: 2 Year			Thursday, 08 / 31 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

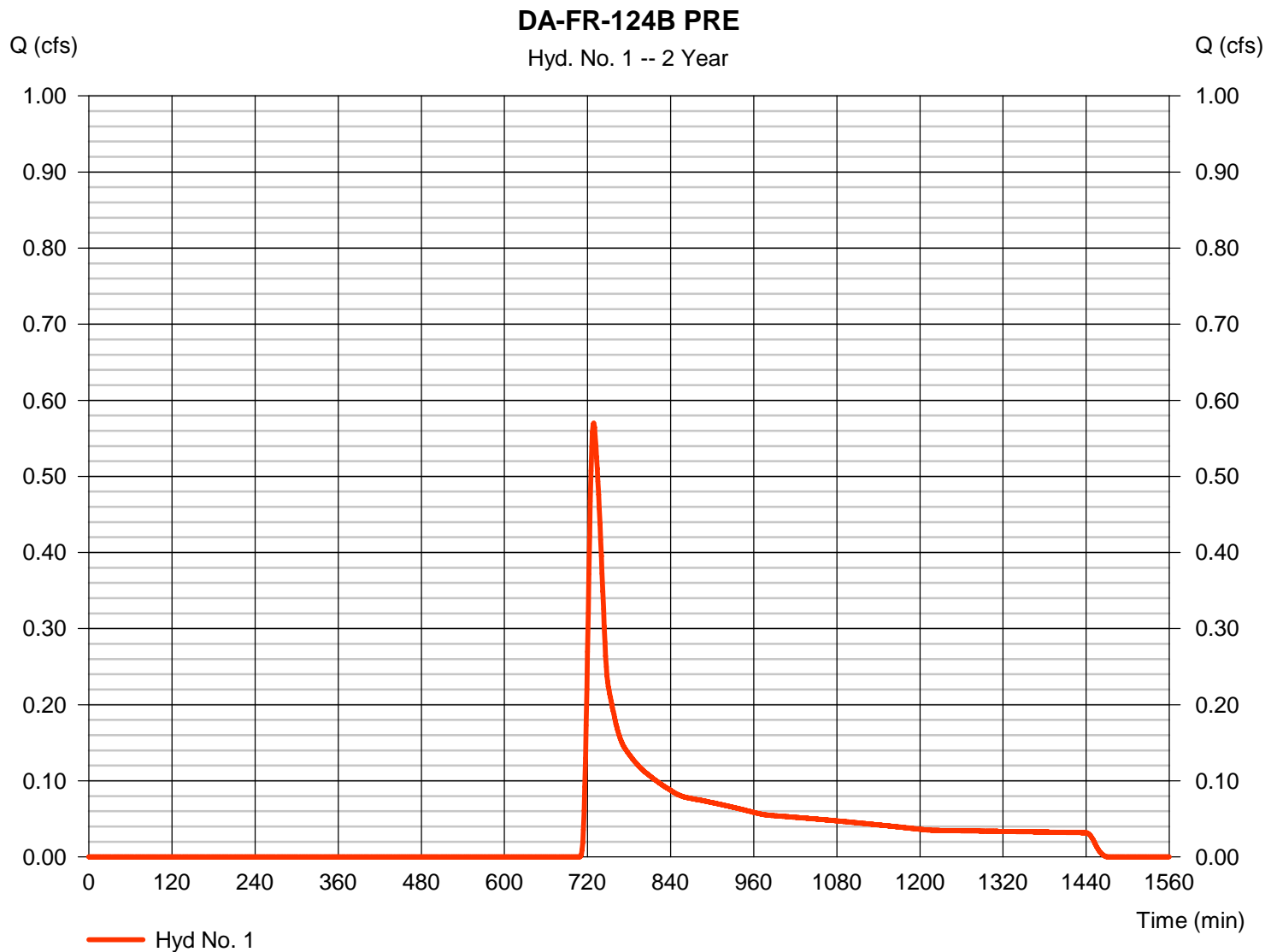
Thursday, 08 / 31 / 2017

Hyd. No. 1

DA-FR-124B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.570 cfs
Storm frequency	= 2 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 3,198 cuft
Drainage area	= 2.120 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.60 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.003 \times 82) + (0.109 \times 58) + (0.003 \times 100) + (2.003 \times 55)] / 2.120$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

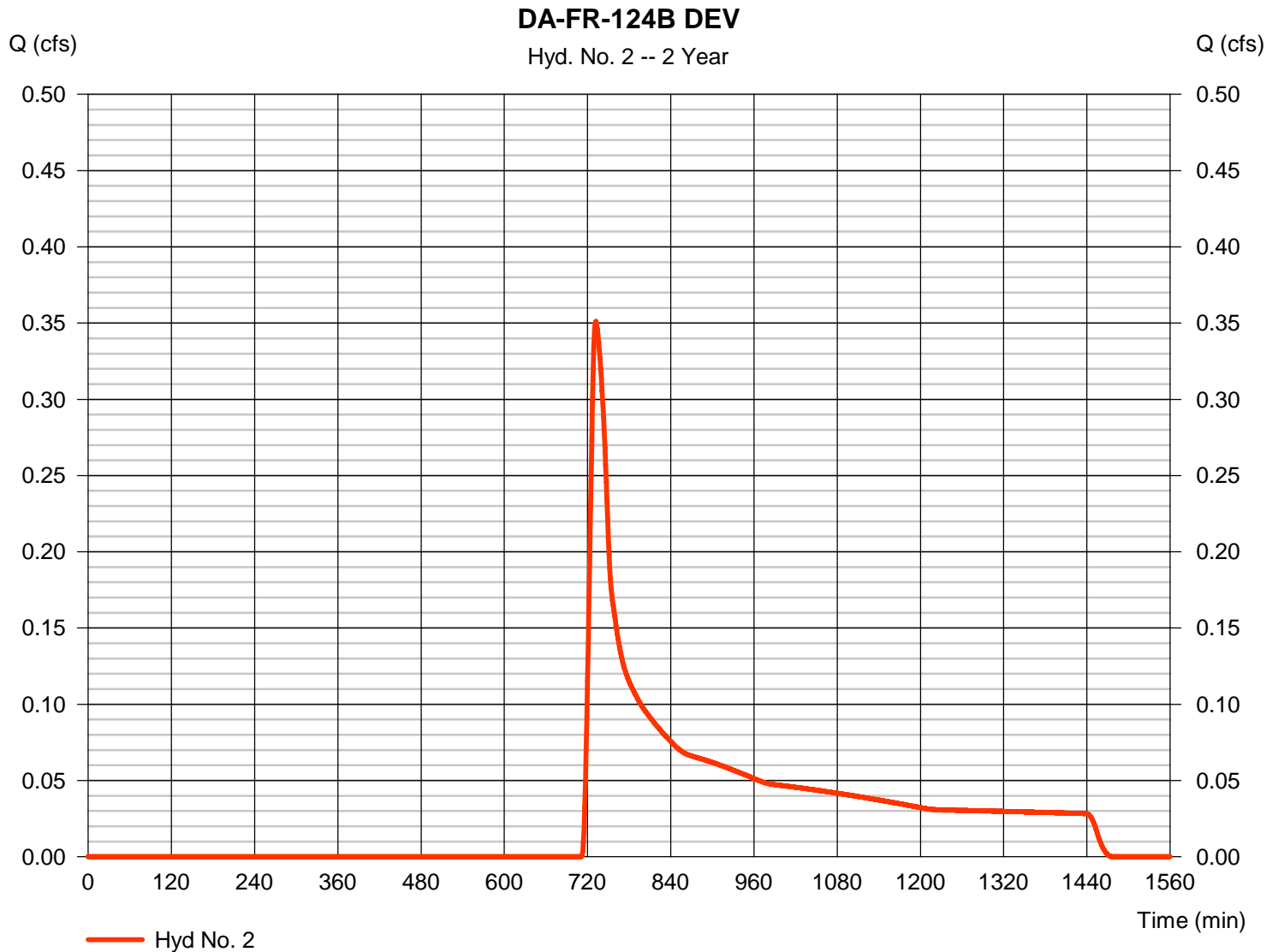
Thursday, 08 / 31 / 2017

Hyd. No. 2

DA-FR-124B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.351 cfs
Storm frequency	= 2 yrs	Time to peak	= 732 min
Time interval	= 1 min	Hyd. volume	= 2,621 cuft
Drainage area	= 2.120 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 22.40 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.137 x 48) + (0.003 x 82) + (0.948 x 58) + (0.003 x 100) + (0.028 x 55)] / 2.120



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

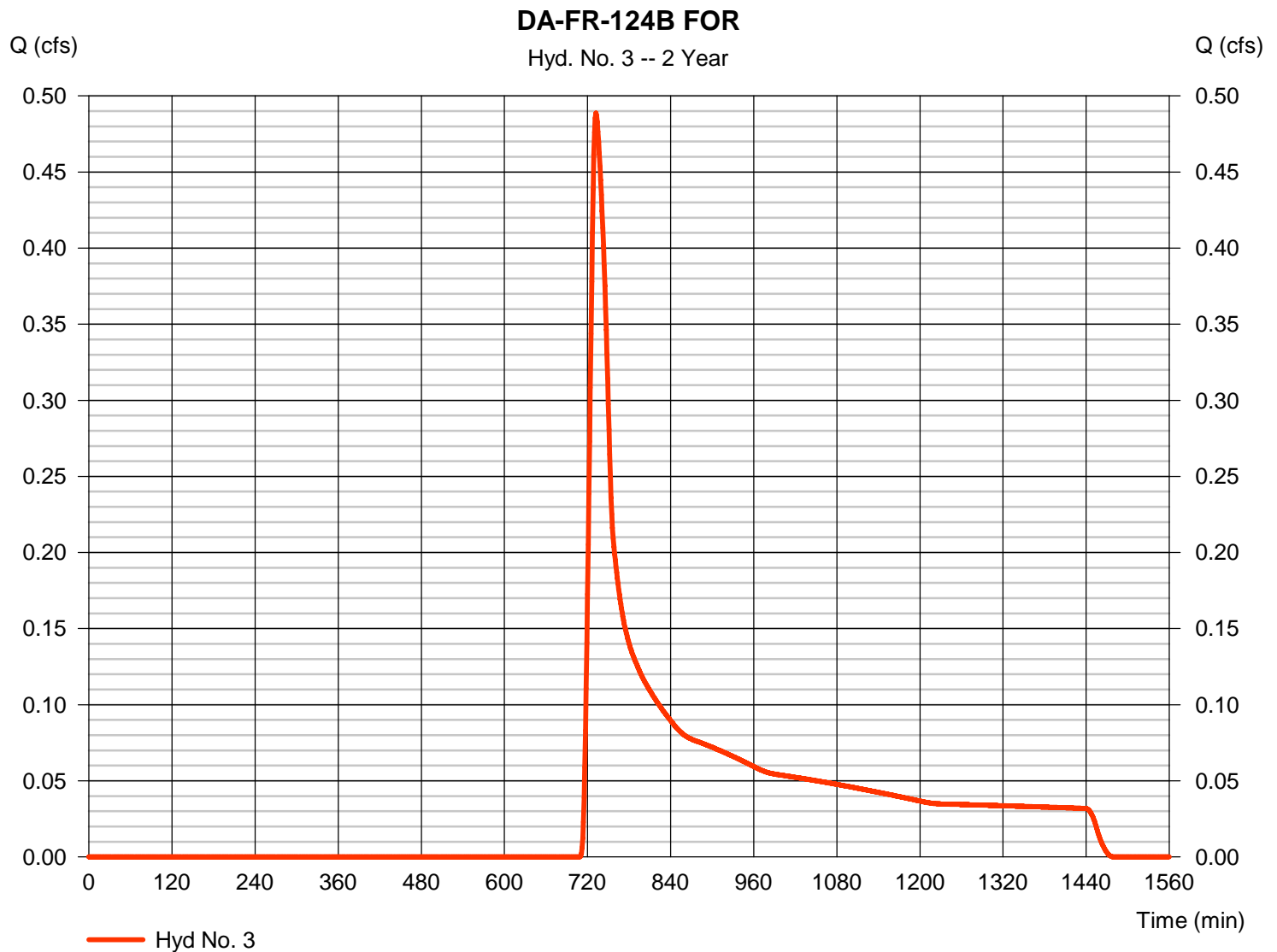
Thursday, 08 / 31 / 2017

Hyd. No. 3

DA-FR-124B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 2.120 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.489 cfs
 Time to peak = 732 min
 Hyd. volume = 3,198 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 23.80 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	2.907	1	726	10,378	-----	-----	-----	DA-FR-124B PRE
2	SCS Runoff	2.235	1	729	9,190	-----	-----	-----	DA-FR-124B DEV
3	SCS Runoff	2.503	1	730	10,378	-----	-----	-----	DA-FR-124B FOR
DA-FR-124B_Hydraflow.gpw					Return Period: 10 Year			Thursday, 08 / 31 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

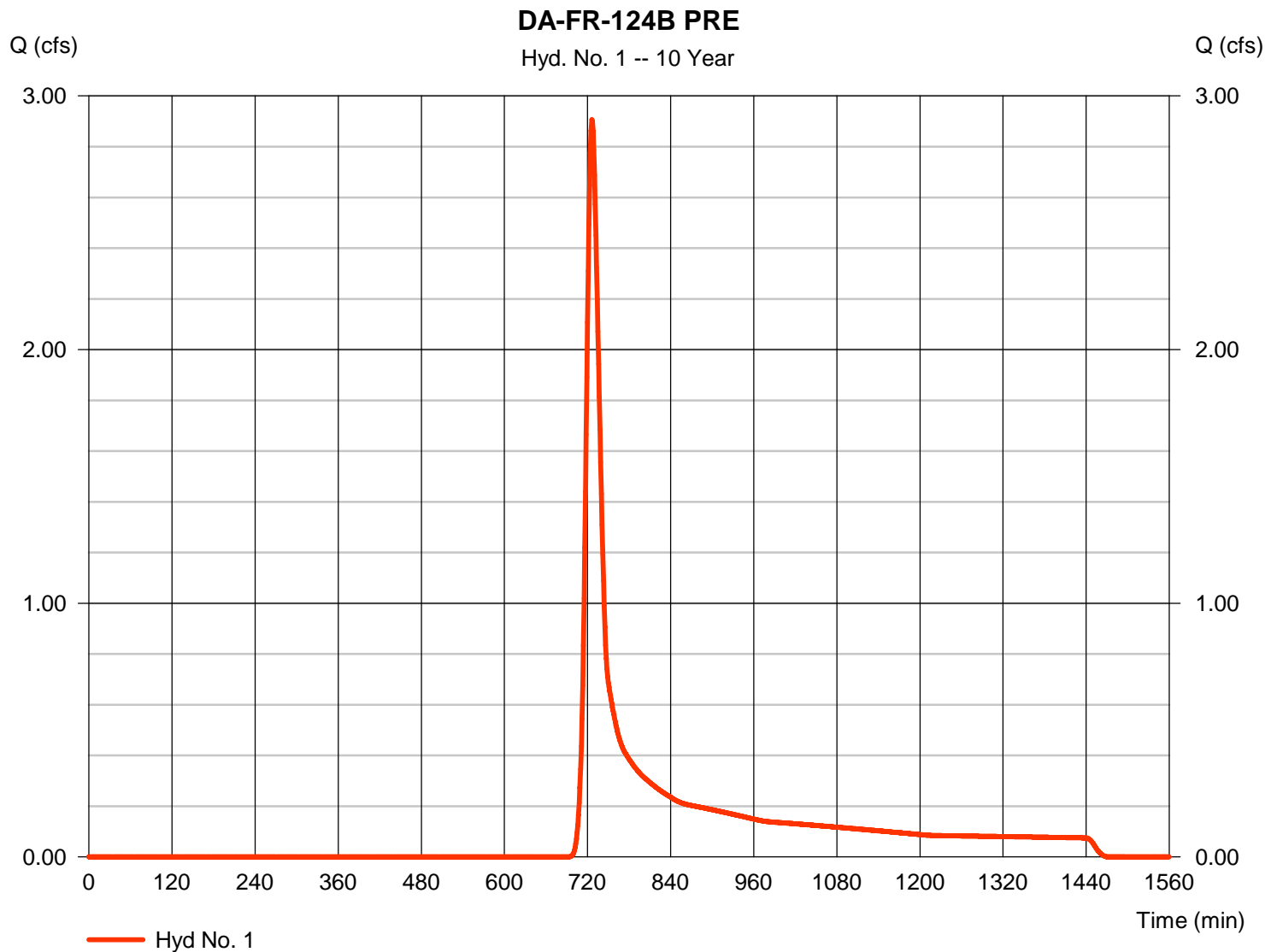
Thursday, 08 / 31 / 2017

Hyd. No. 1

DA-FR-124B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 2.907 cfs
Storm frequency	= 10 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 10,378 cuft
Drainage area	= 2.120 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.60 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.003 \times 82) + (0.109 \times 58) + (0.003 \times 100) + (2.003 \times 55)] / 2.120$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

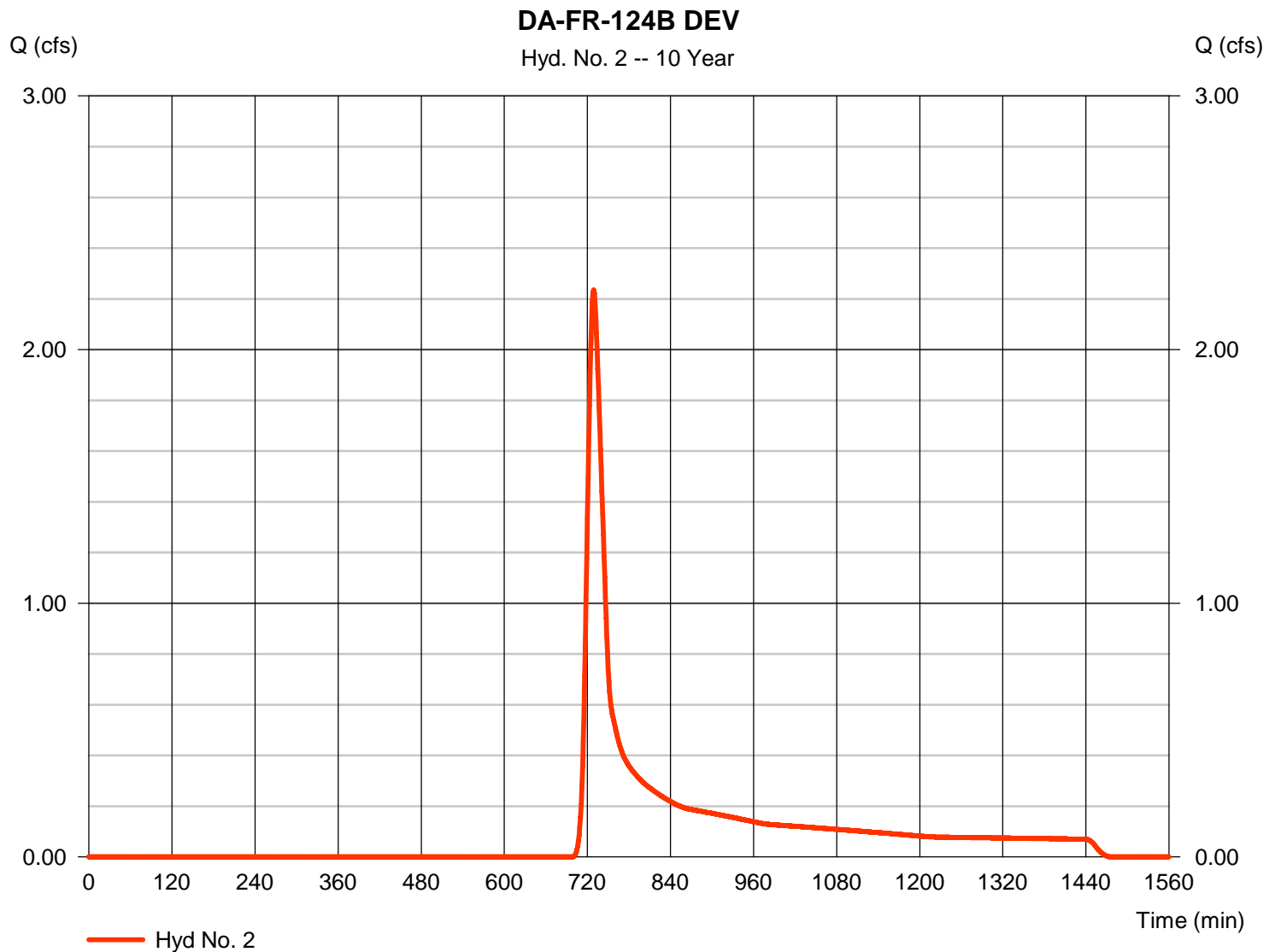
Thursday, 08 / 31 / 2017

Hyd. No. 2

DA-FR-124B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 2.235 cfs
Storm frequency	= 10 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 9,190 cuft
Drainage area	= 2.120 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 22.40 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.137 \times 48) + (0.003 \times 82) + (0.948 \times 58) + (0.003 \times 100) + (0.028 \times 55)] / 2.120$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

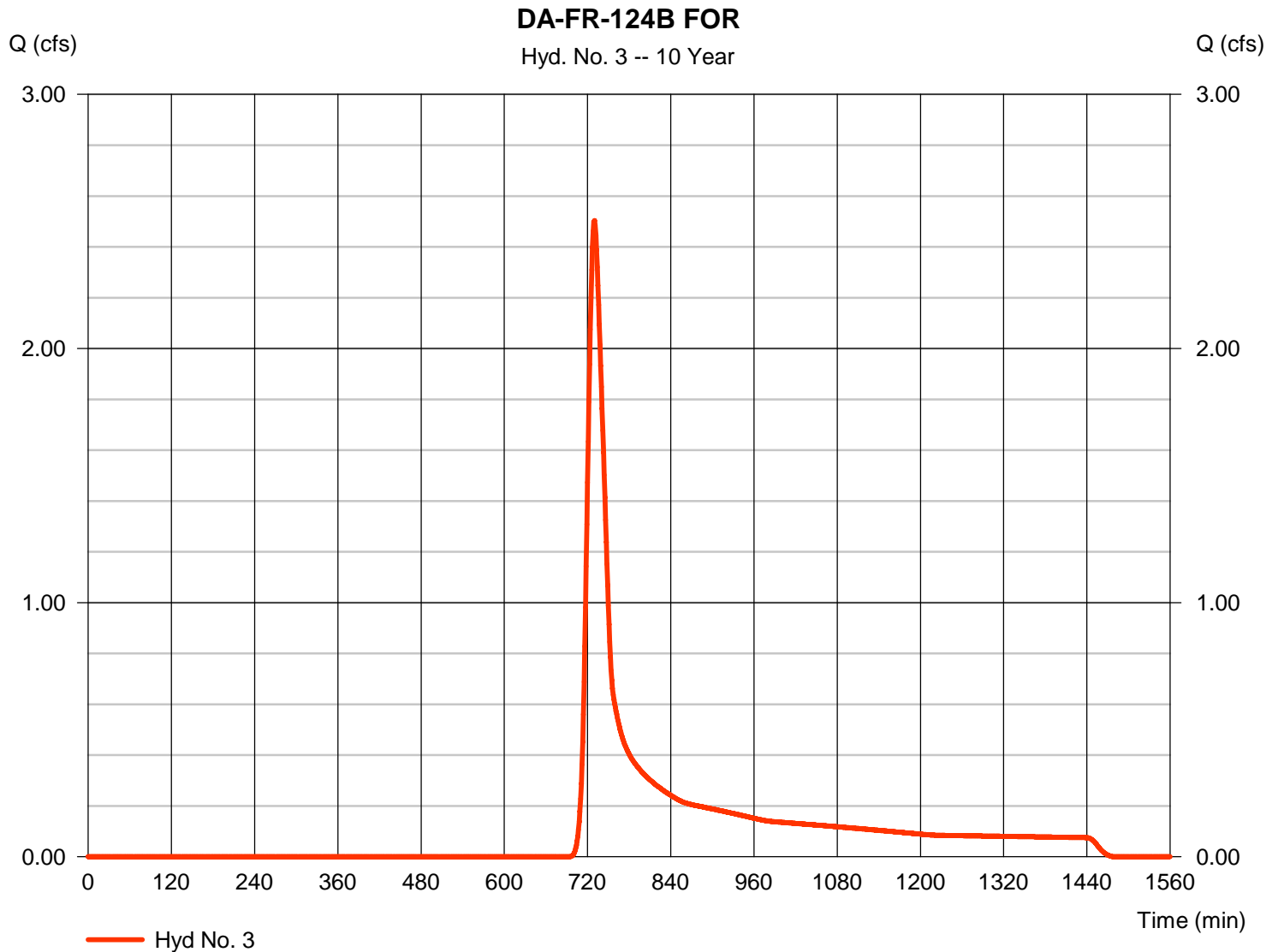
Thursday, 08 / 31 / 2017

Hyd. No. 3

DA-FR-124B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 2.120 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 2.503 cfs
 Time to peak = 730 min
 Hyd. volume = 10,378 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 23.80 min
 Distribution = Type II
 Shape factor = 484



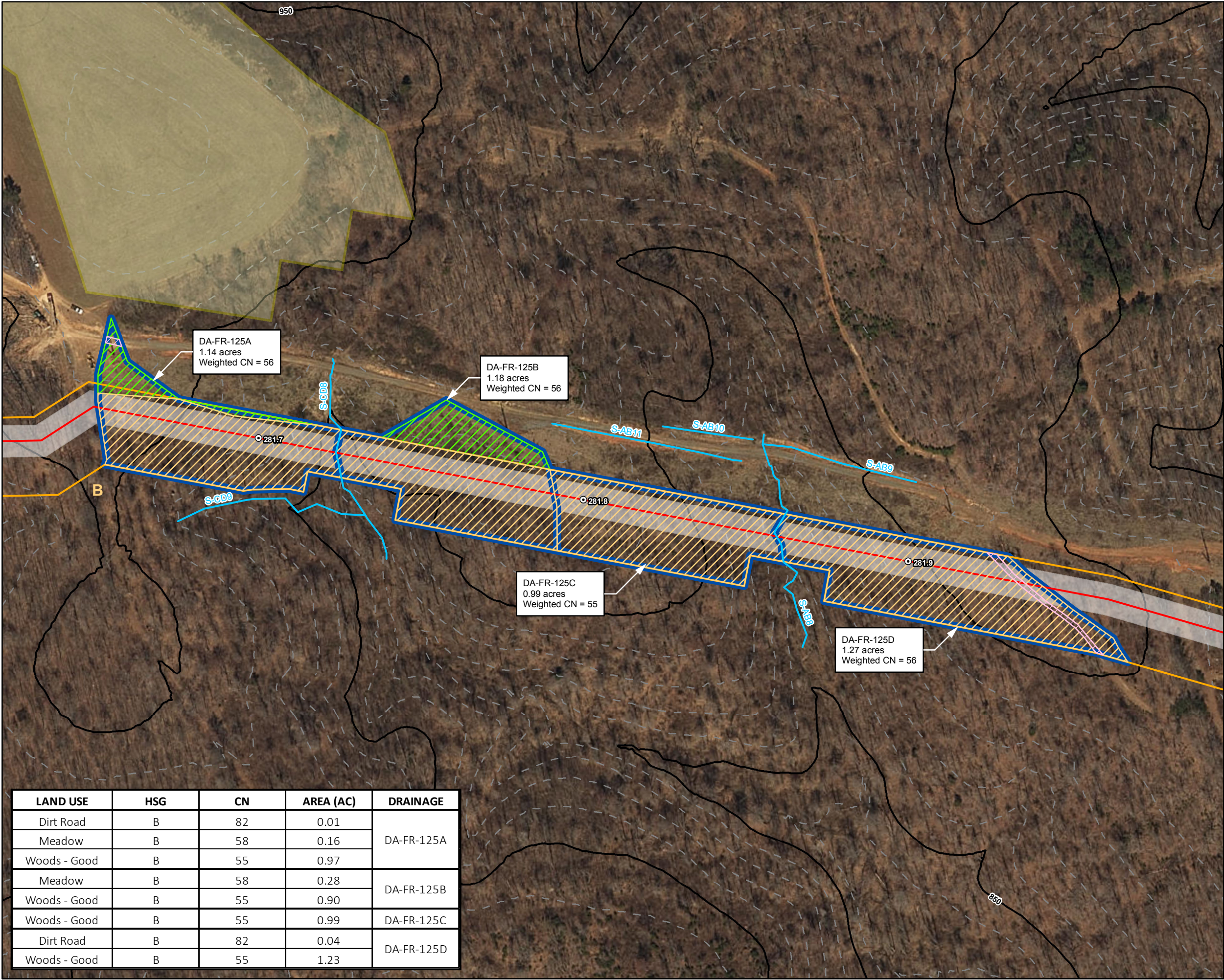
DA-FR-125

DA-FR-125 is located in a meadow and forested areas with hilly slopes and contains an existing gravel road. No new impervious area is proposed within DA-FR-125. The total phosphorus load reduction required for DA-FR-125 is -0.56 lb/yr. Multiple points of analysis were evaluated within DA-FR-125 to evaluate the effects on each receiving stream/channel following construction. Specifically, DA-FR-125 was sub-divided into four sub-drainage areas (sub-areas A through D).

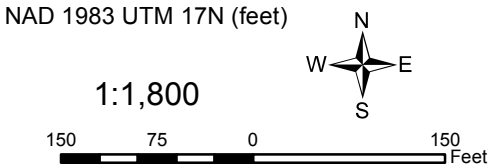
Stormwater quantity is met via the energy balance method for each of the four sub-areas DA-FR-125A, DA-FR-125B, DA-FR-125C and DA-FR-125D. In addition, the Hydraflow Hydrograph's 10-year 24-hour peak discharge results indicate a reduction in flows ranging from 0.27 to 0.68 cfs for all drainage areas (as seen in table below).

Sub Area	Pre Peak Flow, 10-yr Q (cfs)	Post Peak Flow, Q 10-yr (cfs)	Flow differential
DA-FR-125A	2.10	1.51	-0.59
DA-FR-125B	2.07	1.80	-0.27
DA-FR-125C	1.43	0.87	-0.56
DA-FR-125D	2.76	2.08	-0.68

Figures and calculations for each of the sub-areas for DA-FR-125 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.



- Legend**
- Milepost
 - Delineated Stream
 - Existing 50' Contour
 - - Existing 10' Contour
 - Alignment Centerline
 - Limit of Disturbance
 - Permanent Right-of-Way
 - Dirt Road
 - Meadow
 - Woods
 - Agricultural Area
 - Drainage Area
 - Hydrologic Soil Groups



Mountain Valley Pipeline Project



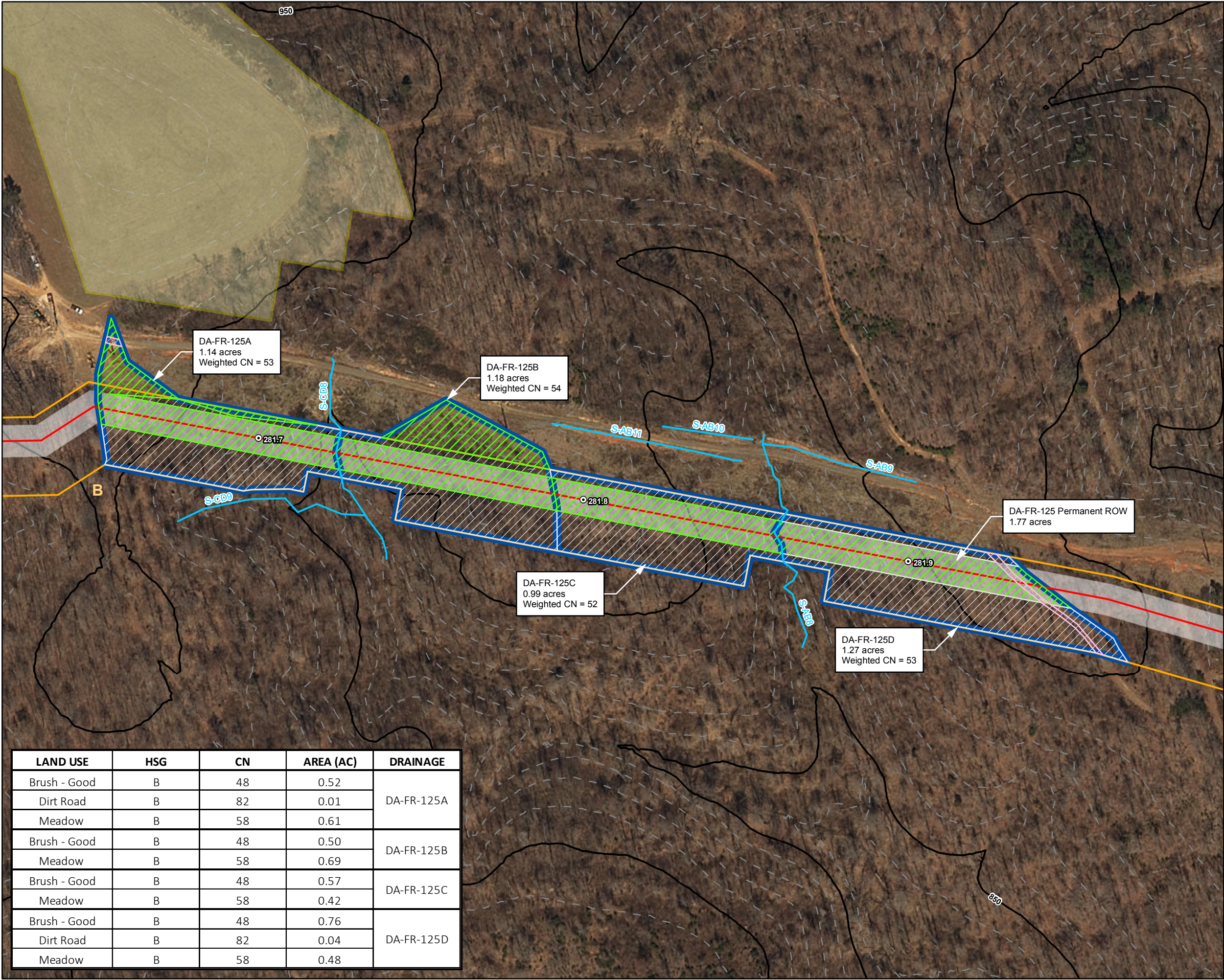
Pre-Construction Drainage Area Map
DA-FR-125
Spread 11

Figure 1
Franklin County, Virginia

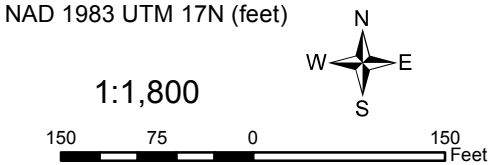
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Elevation data derived from LiDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Dirt Road	B	82	0.01	DA-FR-125A
Meadow	B	58	0.16	
Woods - Good	B	55	0.97	
Meadow	B	58	0.28	DA-FR-125B
Woods - Good	B	55	0.90	
Woods - Good	B	55	0.99	DA-FR-125C
Dirt Road	B	82	0.04	DA-FR-125D
Woods - Good	B	55	1.23	



- Legend**
- Milepost
 - Delineated Stream
 - Existing 50' Contour
 - - Existing 10' Contour
 - Alignment Centerline
 - Limit of Disturbance
 - Permanent Right-of-Way
 - Brush
 - Dirt Road
 - Meadow
 - Agricultural Area
 - Drainage Area
 - Hydrologic Soil Groups



Mountain Valley Pipeline Project



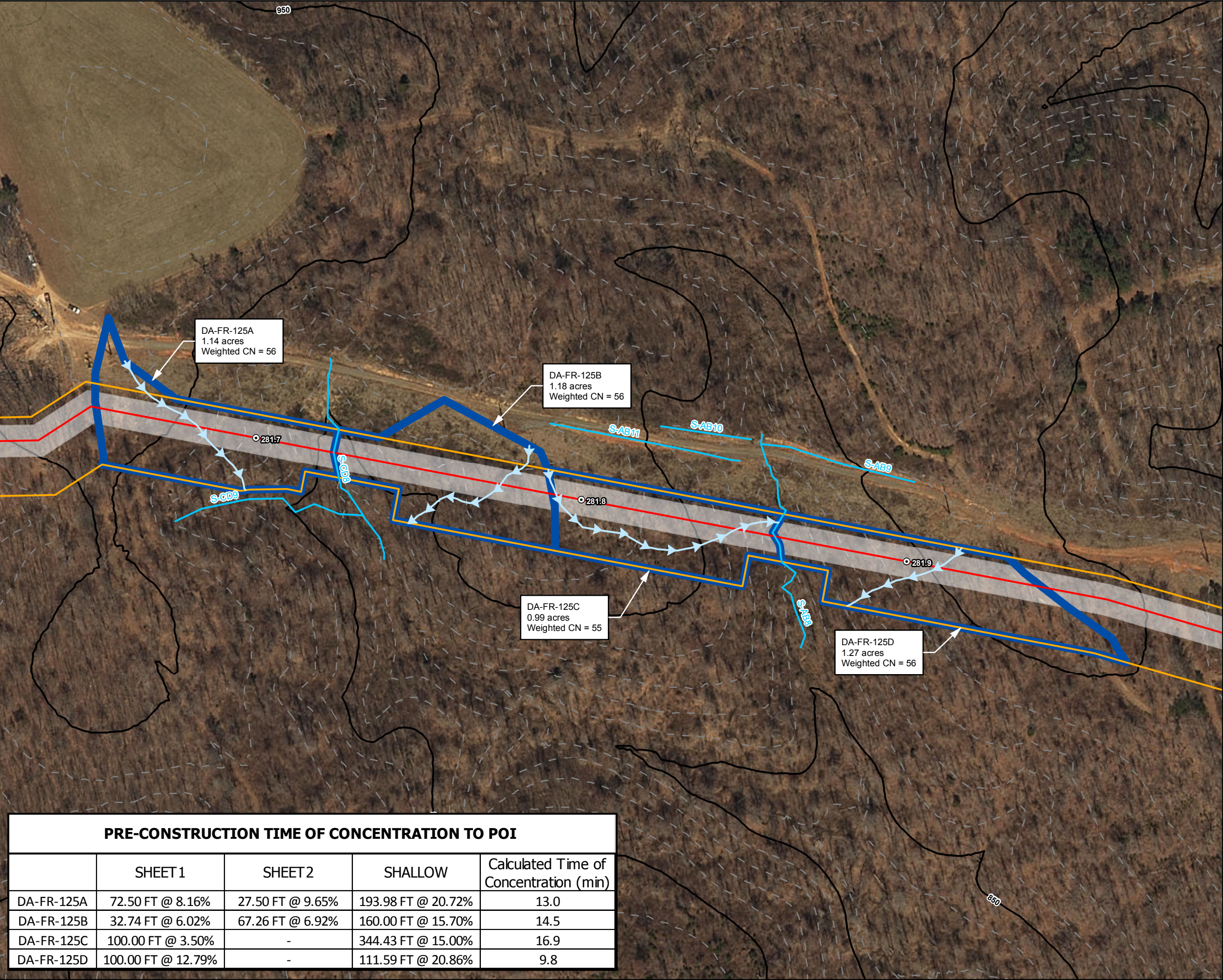
Post-Construction Drainage Area Map
DA-FR-125
Spread 11

Figure 2
Franklin County, Virginia

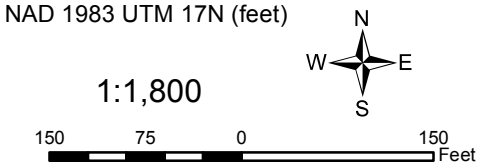
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Elevation data derived from LiDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Brush - Good	B	48	0.52	DA-FR-125A
Dirt Road	B	82	0.01	
Meadow	B	58	0.61	
Brush - Good	B	48	0.50	DA-FR-125B
Meadow	B	58	0.69	
Brush - Good	B	48	0.57	DA-FR-125C
Meadow	B	58	0.42	
Brush - Good	B	48	0.76	DA-FR-125D
Dirt Road	B	82	0.04	
Meadow	B	58	0.48	



- Legend**
- Milepost
 - Delineated Stream
 - Existing 50' Contour
 - - Existing 10' Contour
 - Alignment Centerline
 - Limit of Disturbance
 - Permanent Right-of-Way
 - Time of Concentration
 - Drainage Area



Mountain Valley Pipeline Project

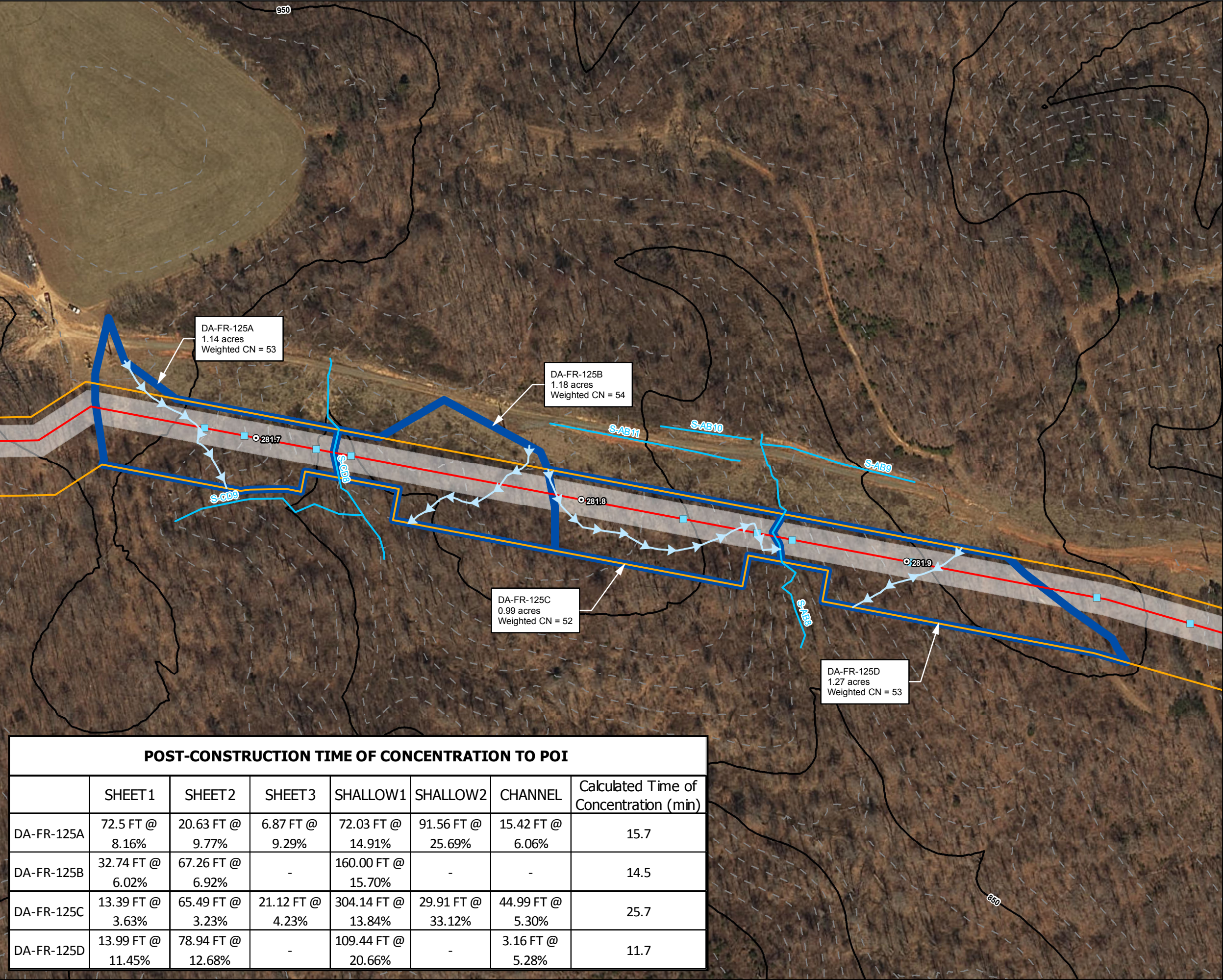


**Pre-Construction Drainage Area
and Time of Concentration
DA-FR-125
Spread 11**

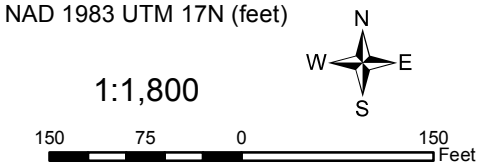
Figure 3
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Elevation data derived from LiDAR provided by EQT 2016.

PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI				
	SHEET 1	SHEET 2	SHALLOW	Calculated Time of Concentration (min)
DA-FR-125A	72.50 FT @ 8.16%	27.50 FT @ 9.65%	193.98 FT @ 20.72%	13.0
DA-FR-125B	32.74 FT @ 6.02%	67.26 FT @ 6.92%	160.00 FT @ 15.70%	14.5
DA-FR-125C	100.00 FT @ 3.50%	-	344.43 FT @ 15.00%	16.9
DA-FR-125D	100.00 FT @ 12.79%	-	111.59 FT @ 20.86%	9.8



- Legend**
- Milepost
 - Permanent Waterbars
 - Delineated Stream
 - Existing 50' Contour
 - Existing 10' Contour
 - Alignment Centerline
 - Limit of Disturbance
 - Permanent Right-of-Way
 - Time of Concentration
 - Drainage Area



Mountain Valley Pipeline Project



**Post-Construction Drainage Area
and Time of Concentration
DA-FR-125
Spread 11**

Figure 4
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Elevation data derived from LiDAR provided by EQT 2016.

DEQ Virginia Runoff Reduction Method Re-Development Compliance Spreadsheet - Version 3.0

BMP Design Specifications List: 2013 Draft Stds & Specs

Site Summary - Linear Development Project***

Total Rainfall (in):	43
Total Disturbed Acreage:	1.77

Site Land Cover Summary

Pre-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	1.75	0.00	0.00	1.75	99
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.02	0.00	0.00	0.02	1
					1.77	100

Post-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	1.75	0.00	0.00	1.75	99
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.02	0.00	0.00	0.02	1
					1.77	100

* Forest/Open Space areas must be protected in accordance with the Virginia Runoff Reduction Method

Site Tv and Land Cover Nutrient Loads

	Final Post-Development (Post-ReDevelopment & New Impervious)	Post- ReDevelopment	Post- Development (New Impervious)	Adjusted Pre- ReDevelopment
Site Rv	0.04	0.04	--	0.04
Treatment Volume (ft ³)	260	260	--	260
TP Load (lb/yr)	0.16	0.16	--	0.16

Baseline TP Load (lb/yr): 0.7257* *Reduction below new development load limitation not required

Pre- ReDevelopment TP Load per acre (lb/acre/yr)	Final Post-Development TP Load per acre (lb/acre/yr)	Post-ReDevelopment TP Load per acre (lb/acre/yr)
0.09	0.09	0.09

Total TP Load Reduction Required (lb/yr)	-0.56	N/A***	N/A***
--	-------	--------	--------

***This is a linear development project

	Final Post-Development Load (Post-ReDevelopment & New Impervious)	Pre- ReDevelopment
TN Load (lb/yr)	1.17	1.17

Site Compliance Summary - ***Linear Development Project

Maximum % Reduction Required Below Pre-ReDevelopment Load	20%
--	-----

* Note: % Reduction will reduce post-development TP load to less than or equal to baseline load of 0.73 lb/yr (0.41 lb/ac/yr)
 [Post-Dev Reduction Requirement = Post-Dev TP load - baseline load of 0.73 lb/yr], baseline load = site area x 0.41 lb/ac/yr

Total Runoff Volume Reduction (ft ³)	0
--	---

Total TP Load Reduction Achieved (lb/yr)	0.00
Total TN Load Reduction Achieved (lb/yr)	0.00
Remaining Post Development TP Load (lb/yr)	0.16
Remaining TP Load Reduction (lb/yr) Required	0.00

**** TARGET TP REDUCTION EXCEEDED BY 0.56 LB/YEAR ****

**Reduction below new development load limitation not required*

DA-FR-125A

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.251	1258
Developed Condition	0.101	939
Pre-Developed (Forest) Condition	0.202	1145

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	0.101	\leq OK	0.269
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.101	\leq OK	0.251
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ --->	0.101	<u>shall not</u> be required to be \leq	0.246

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s n value of 0.011 was used.</p> <p><i>Sources:</i></p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-125A PRE
2	SCS Runoff	DA-FR-125A DEV
3	SCS Runoff	DA-FR-125A FOR

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.251	1	725	1,258	-----	-----	-----	DA-FR-125A PRE
2	SCS Runoff	0.101	1	729	939	-----	-----	-----	DA-FR-125A DEV
3	SCS Runoff	0.202	1	725	1,145	-----	-----	-----	DA-FR-125A FOR
DA-FR-125A_Hydraflow.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

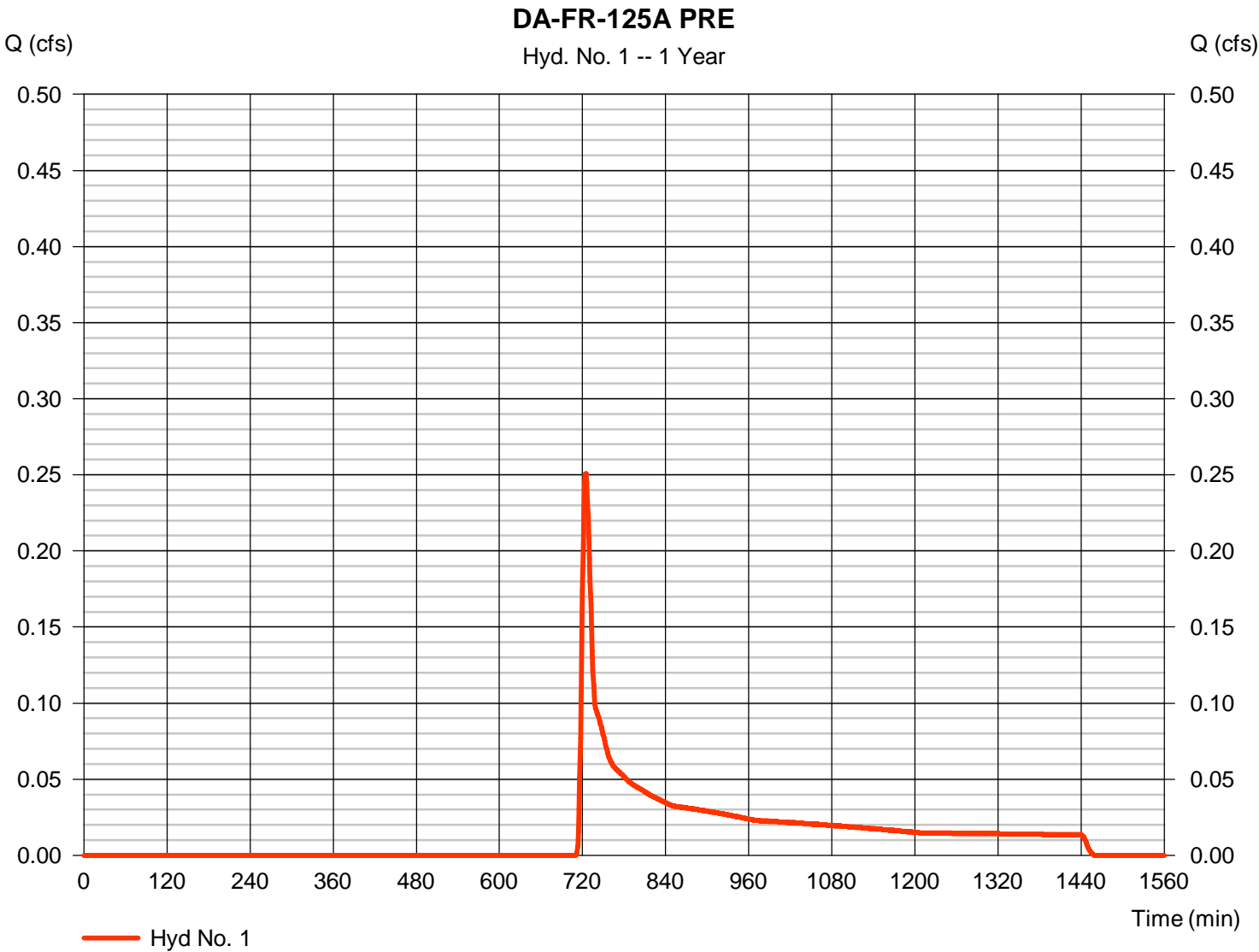
Hydrograph Report

Hyd. No. 1

DA-FR-125A PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.251 cfs
Storm frequency	=	1 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	1,258 cuft
Drainage area	=	1.130 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	13.00 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.005 x 82) + (0.161 x 58) + (0.968 x 55)] / 1.130



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-125A PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.011				
Flow length (ft)	= 72.5	27.5	0.0				
Two-year 24-hr precip. (in)	= 3.70	3.70	0.00				
Land slope (%)	= 8.16	9.65	0.00				
Travel Time (min)	= 8.80	+	3.79	+	0.00	=	12.59
Shallow Concentrated Flow							
Flow length (ft)	= 193.98	0.00	0.00				
Watercourse slope (%)	= 20.72	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=7.34	0.00	0.00				
Travel Time (min)	= 0.44	+	0.00	+	0.00	=	0.44
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					13.00 min		

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

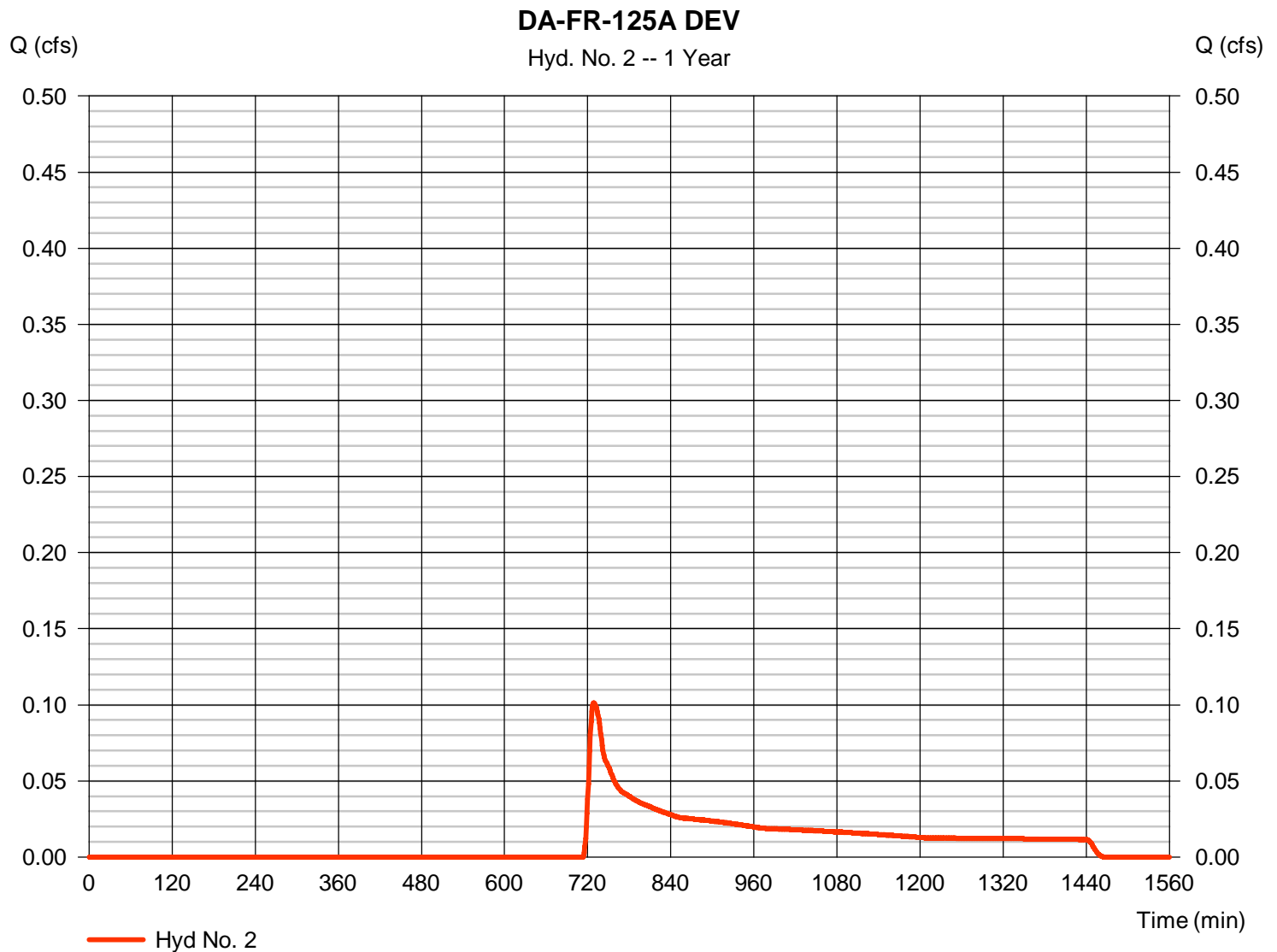
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-125A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.101 cfs
Storm frequency	= 1 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 939 cuft
Drainage area	= 1.140 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.525 \times 48) + (0.005 \times 82) + (0.606 \times 58)] / 1.140$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-125A DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.800	0.400				
Flow length (ft)	= 72.5	20.6	6.9				
Two-year 24-hr precip. (in)	= 3.70	3.70	3.70				
Land slope (%)	= 8.16	9.77	9.29				
Travel Time (min)	= 8.80	+	5.22	+	1.27	=	15.28
Shallow Concentrated Flow							
Flow length (ft)	= 72.03	91.56	0.00				
Watercourse slope (%)	= 14.91	25.69	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=6.23	8.18	0.00				
Travel Time (min)	= 0.19	+	0.19	+	0.00	=	0.38
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	(\{0\})15.4	0.0	0.0				
Travel Time (min)	= 0.05	+	0.00	+	0.00	=	0.05
Total Travel Time, Tc					15.70 min		

Hydrograph Report

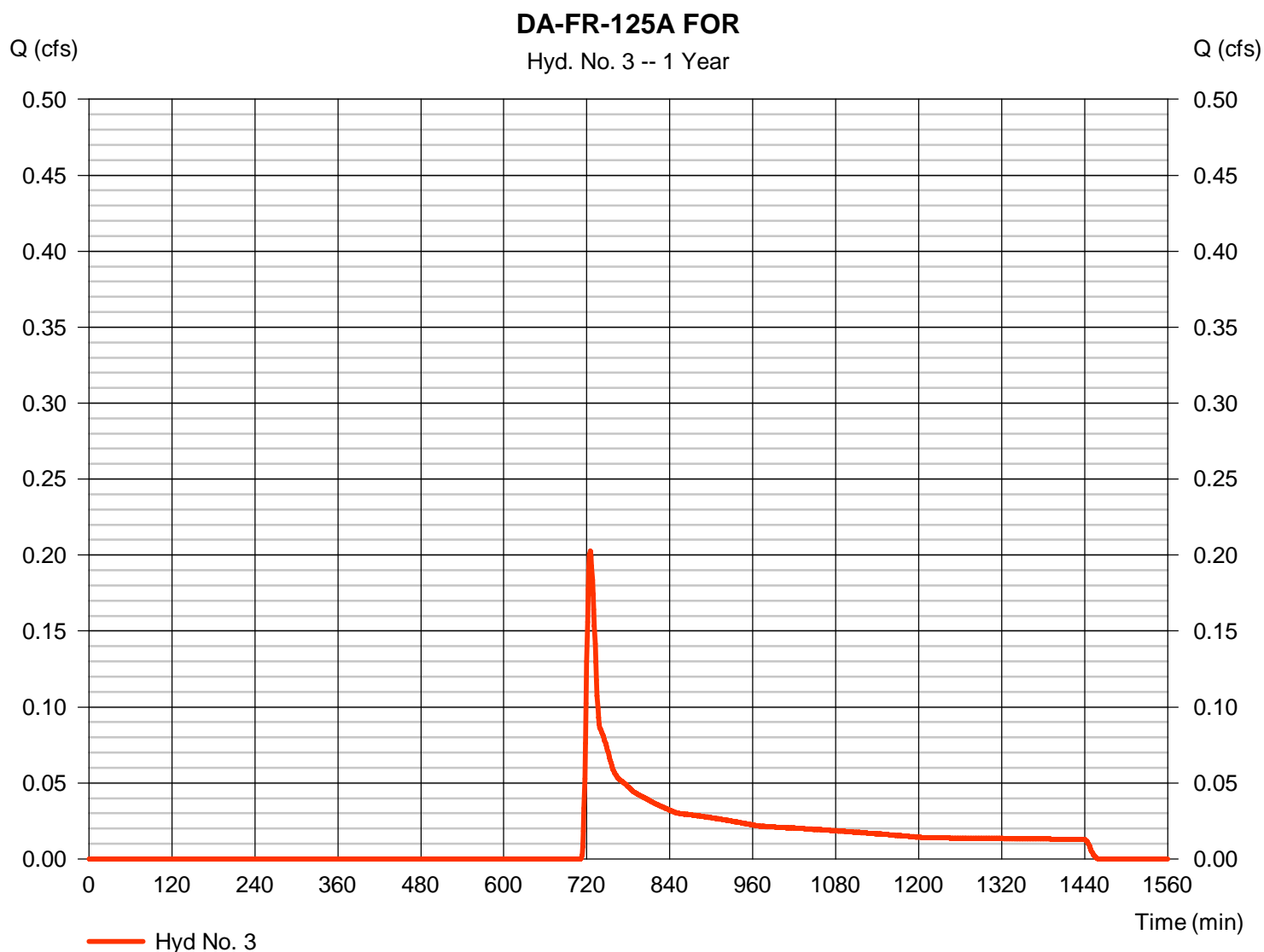
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-125A FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.202 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 1,145 cuft
Drainage area	= 1.140 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.00 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-125A FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.400	0.011	
Flow length (ft)	= 72.5	27.5	0.0	
Two-year 24-hr precip. (in)	= 3.70	3.70	0.00	
Land slope (%)	= 8.16	9.65	0.00	
Travel Time (min)	= 8.80	+	3.79	+
			0.00	= 12.59
Shallow Concentrated Flow				
Flow length (ft)	= 193.98	0.00	0.00	
Watercourse slope (%)	= 20.72	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=7.34	0.00	0.00	
Travel Time (min)	= 0.44	+	0.00	+
			0.00	= 0.44
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				13.00 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.469	1	724	1,832	-----	-----	-----	DA-FR-125A PRE
2	SCS Runoff	0.238	1	727	1,440	-----	-----	-----	DA-FR-125A DEV
3	SCS Runoff	0.403	1	724	1,693	-----	-----	-----	DA-FR-125A FOR
DA-FR-125A_Hydraflow.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

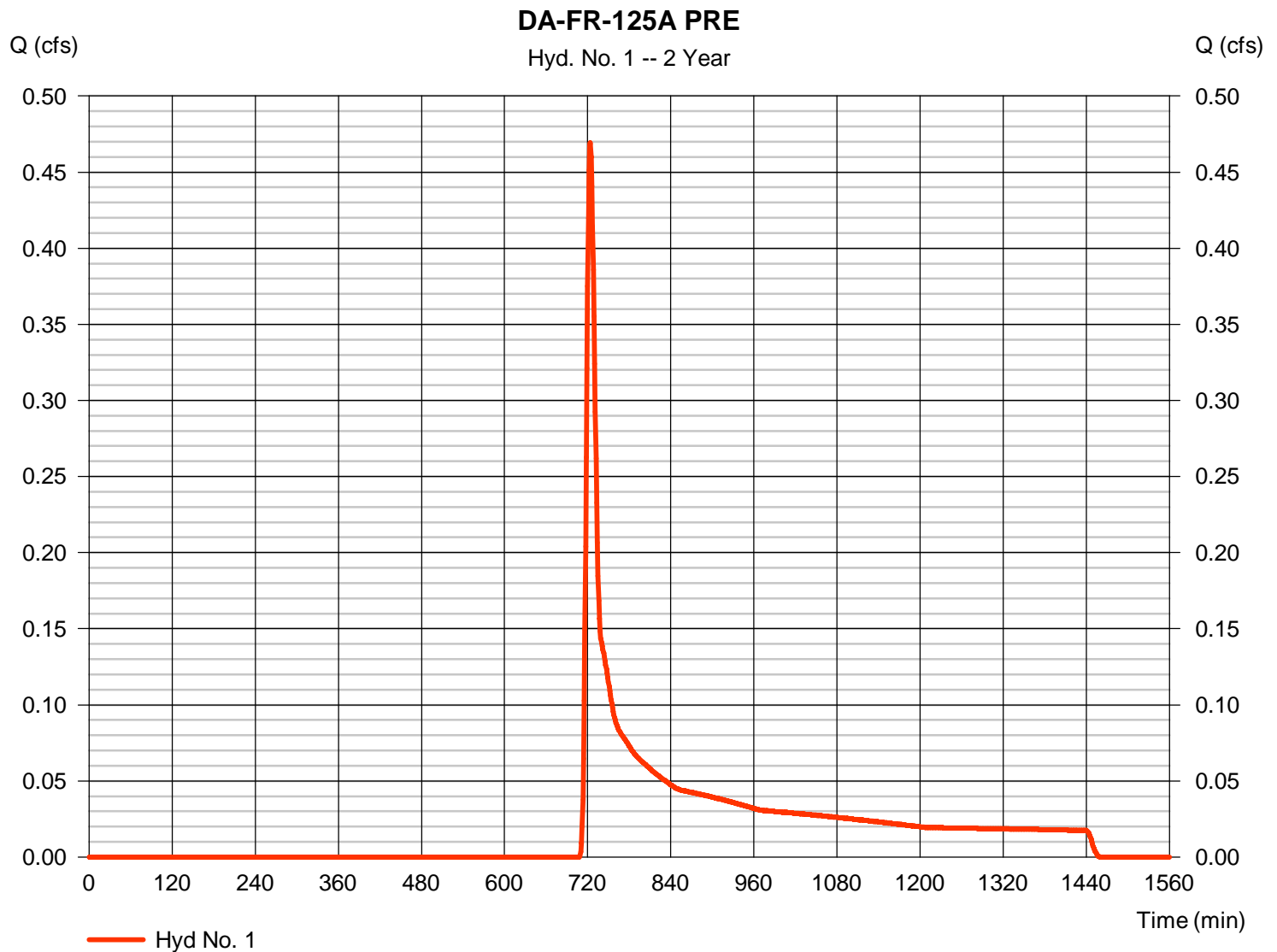
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-125A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.469 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 1,832 cuft
Drainage area	= 1.130 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.00 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.005 \times 82) + (0.161 \times 58) + (0.968 \times 55)] / 1.130$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

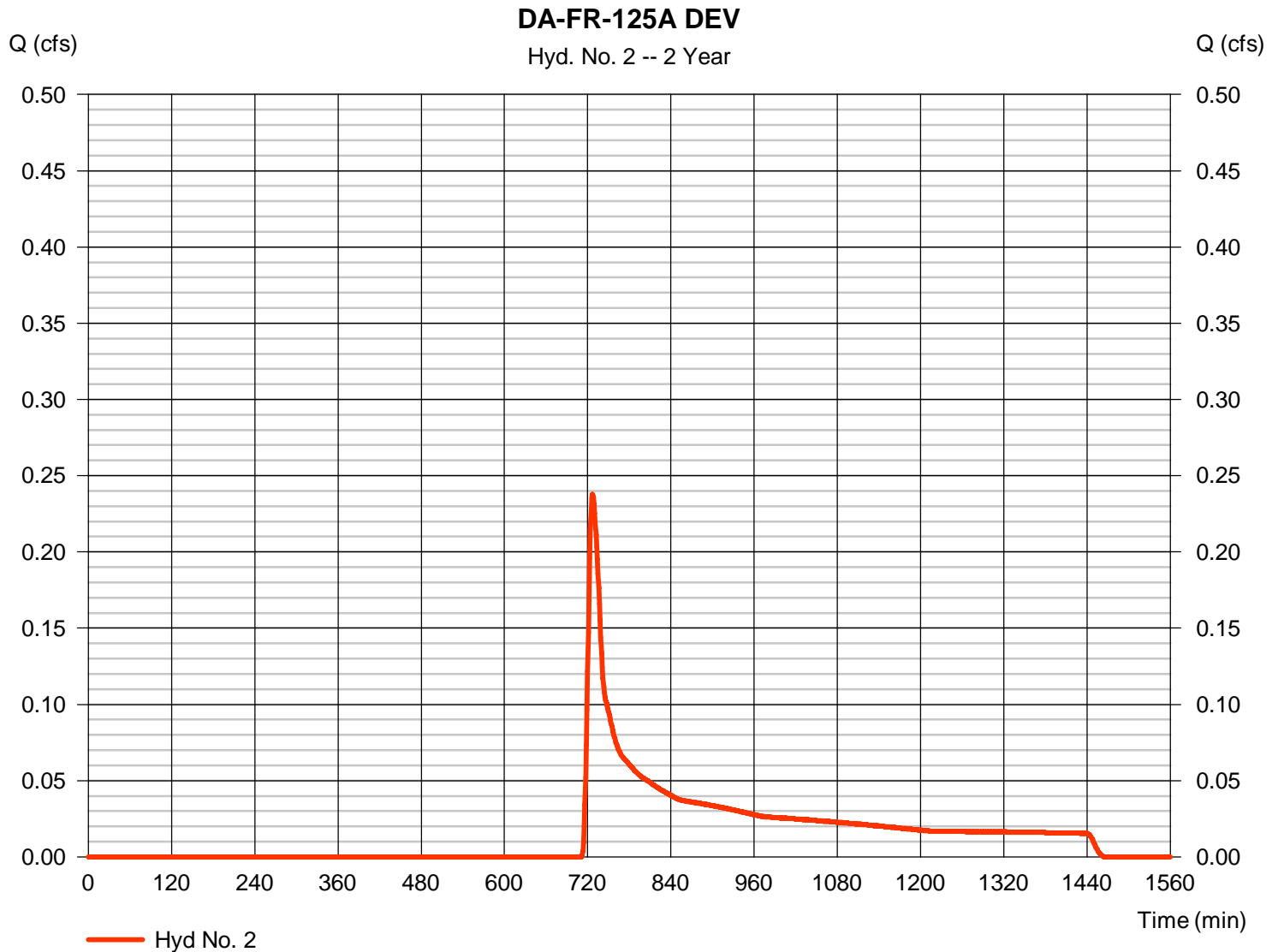
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-125A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.238 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 1,440 cuft
Drainage area	= 1.140 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.525 \times 48) + (0.005 \times 82) + (0.606 \times 58)] / 1.140$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

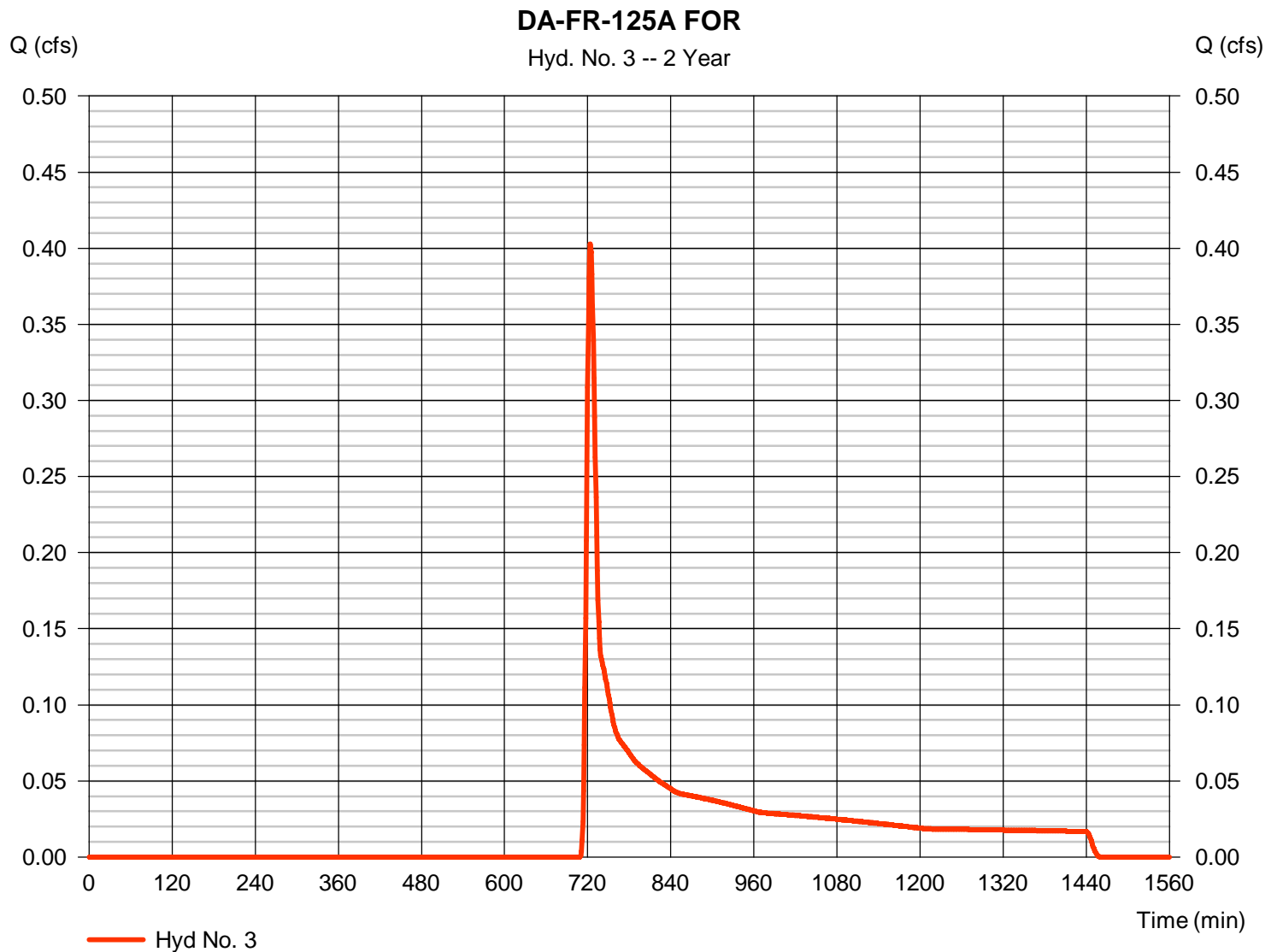
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-125A FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 1.140 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.403 cfs
 Time to peak = 724 min
 Hyd. volume = 1,693 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 13.00 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	2.101	1	722	5,742	-----	-----	-----	DA-FR-125A PRE
2	SCS Runoff	1.510	1	724	5,049	-----	-----	-----	DA-FR-125A DEV
3	SCS Runoff	1.982	1	722	5,493	-----	-----	-----	DA-FR-125A FOR
DA-FR-125A_Hydraflow.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

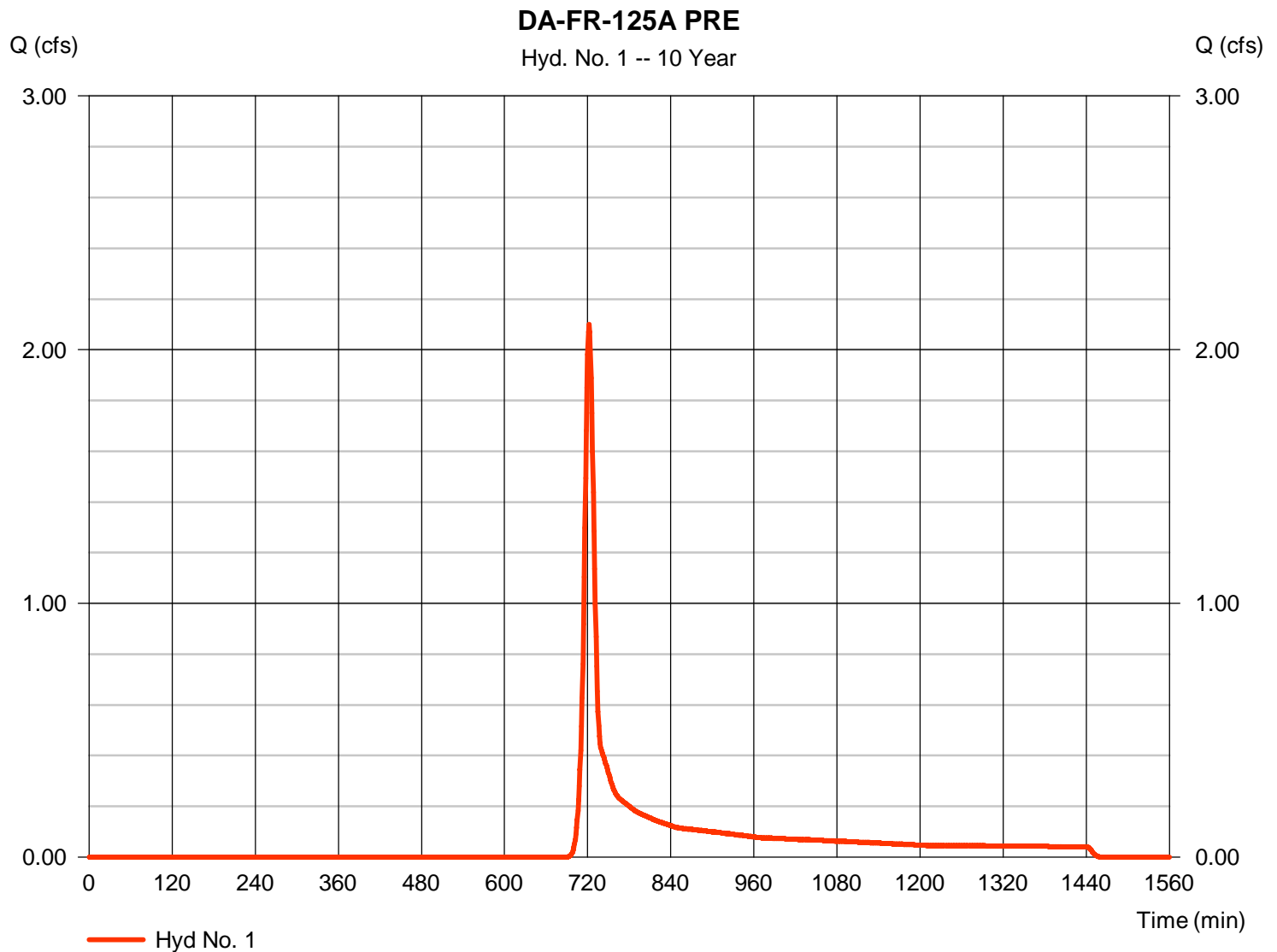
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-125A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 2.101 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 5,742 cuft
Drainage area	= 1.130 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.00 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.005 \times 82) + (0.161 \times 58) + (0.968 \times 55)] / 1.130$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

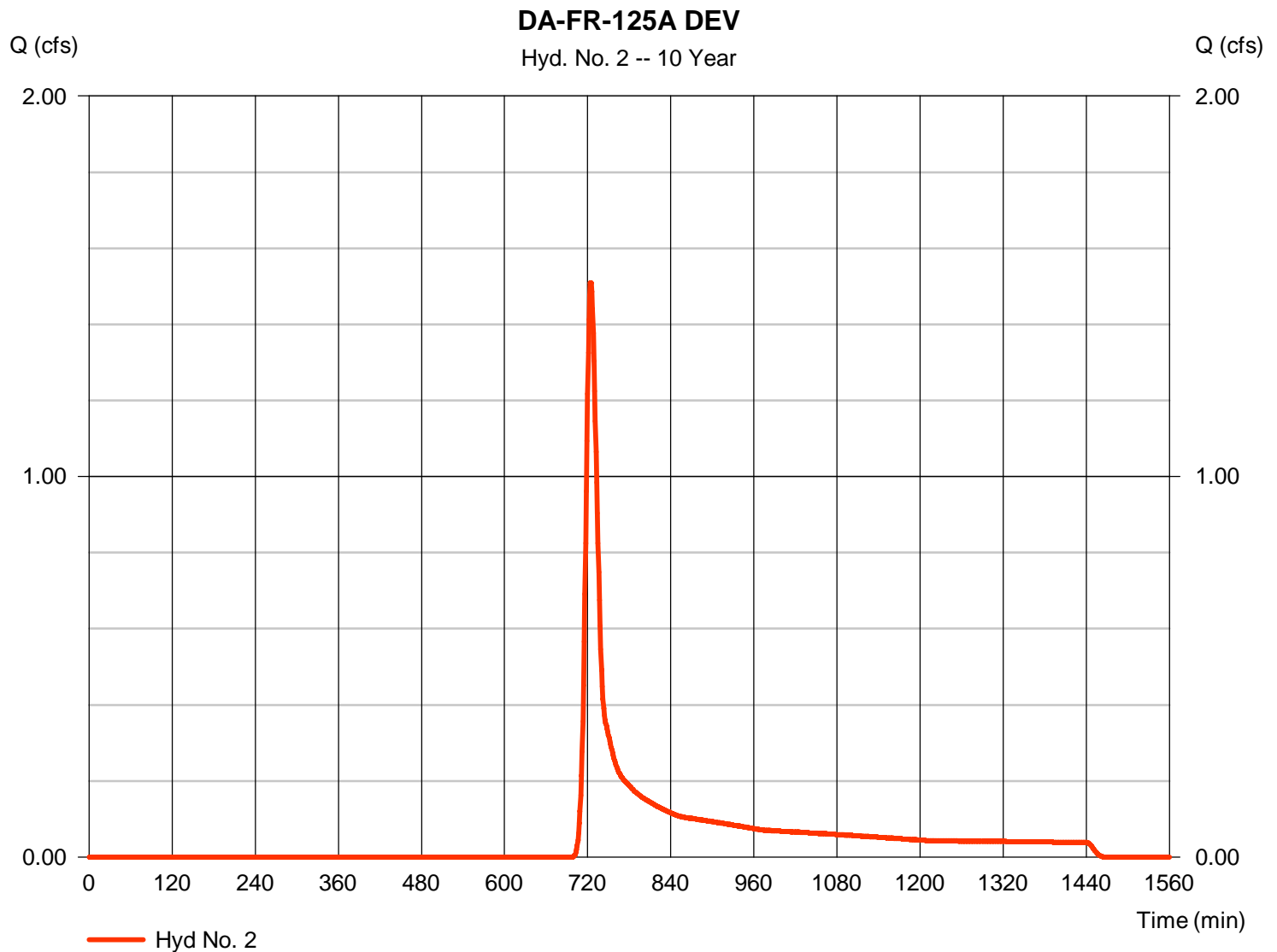
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-125A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 1.510 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 5,049 cuft
Drainage area	= 1.140 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.525 \times 48) + (0.005 \times 82) + (0.606 \times 58)] / 1.140$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

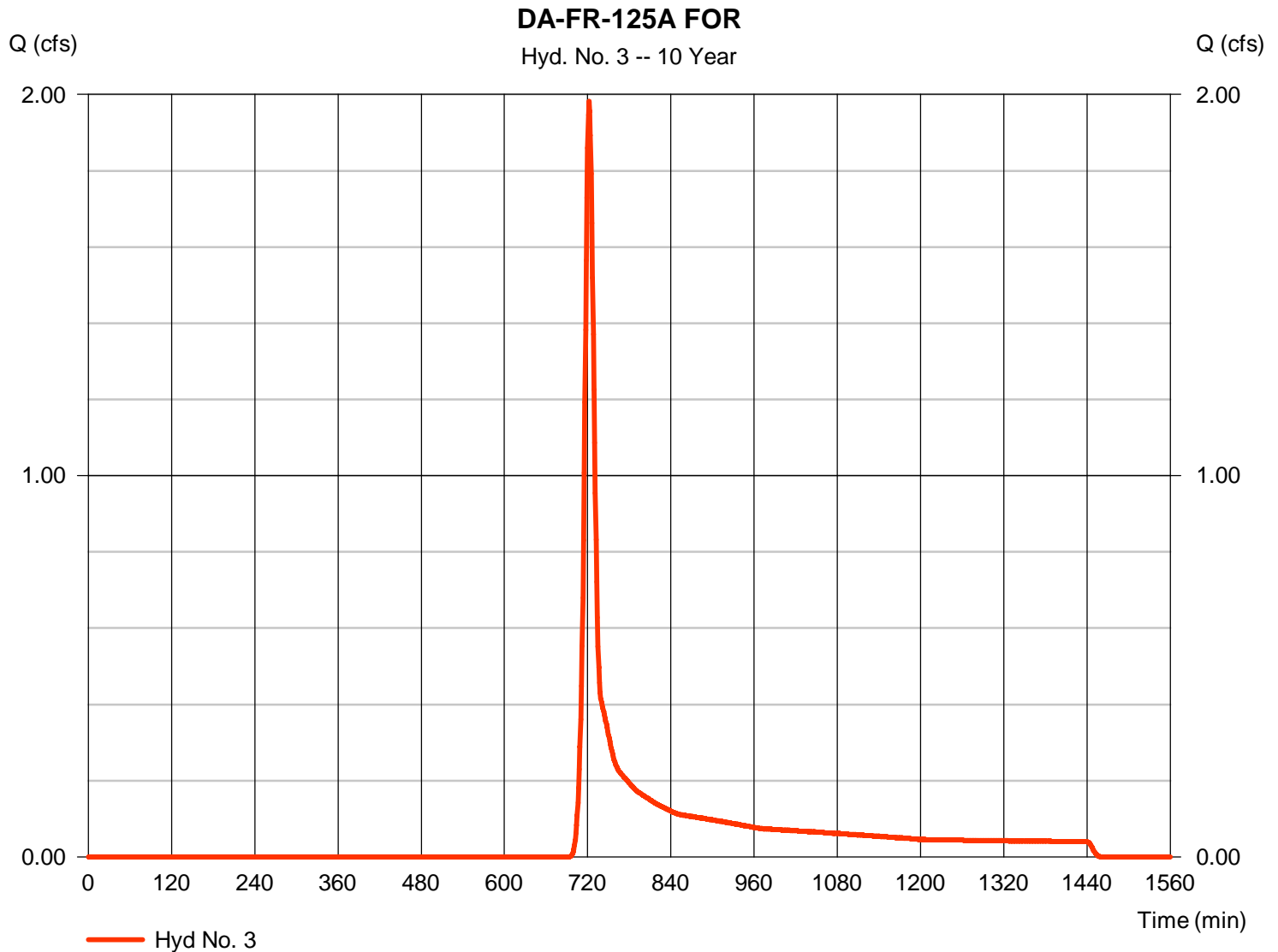
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-125A FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 1.140 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 1.982 cfs
 Time to peak = 722 min
 Hyd. volume = 5,493 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 13.00 min
 Distribution = Type II
 Shape factor = 484



DA-FR-125B

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.244	1335
Developed Condition	0.150	1079
Pre-Developed (Forest) Condition	0.195	1204

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	0.150	\leq OK	0.242
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.150	\leq OK	0.244
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ --->	0.150	<u>shall not</u> be required to be \leq	0.218

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s *n* Values for Sheet Flow

Land Surface Type	Manning <i>n</i>
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s <i>n</i> values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s <i>n</i> value of 0.011 was used.</p> <p>Sources:</p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-125B PRE
2	SCS Runoff	DA-FR-125B DEV
3	SCS Runoff	DA-FR-125B FOR

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.244	1	726	1,335	-----	-----	-----	DA-FR-125B PRE
2	SCS Runoff	0.150	1	727	1,079	-----	-----	-----	DA-FR-125B DEV
3	SCS Runoff	0.195	1	726	1,204	-----	-----	-----	DA-FR-125B FOR
DA-FR-125B_Hydraflow.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

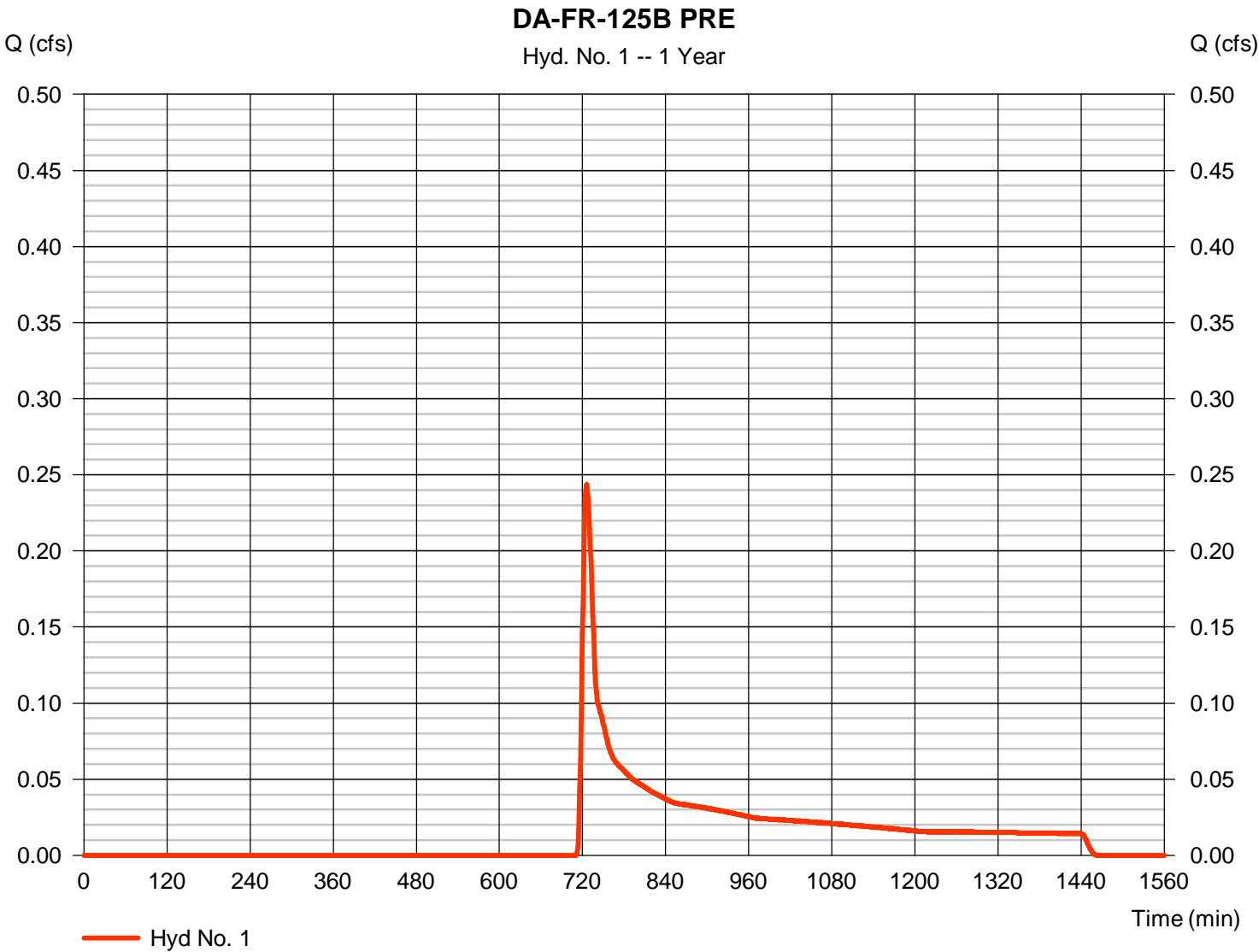
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-125B PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.244 cfs
Storm frequency	=	1 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	1,335 cuft
Drainage area	=	1.180 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	14.50 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.283 x 58) + (0.899 x 55)] / 1.180



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-125B PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.011				
Flow length (ft)	= 32.7	67.3	0.0				
Two-year 24-hr precip. (in)	= 3.70	3.70	0.00				
Land slope (%)	= 6.02	6.92	0.00				
Travel Time (min)	= 5.26	+	8.85	+	0.00	=	14.11
Shallow Concentrated Flow							
Flow length (ft)	= 160.00	0.00	0.00				
Watercourse slope (%)	= 15.70	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=6.39	0.00	0.00				
Travel Time (min)	= 0.42	+	0.00	+	0.00	=	0.42
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				14.50 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

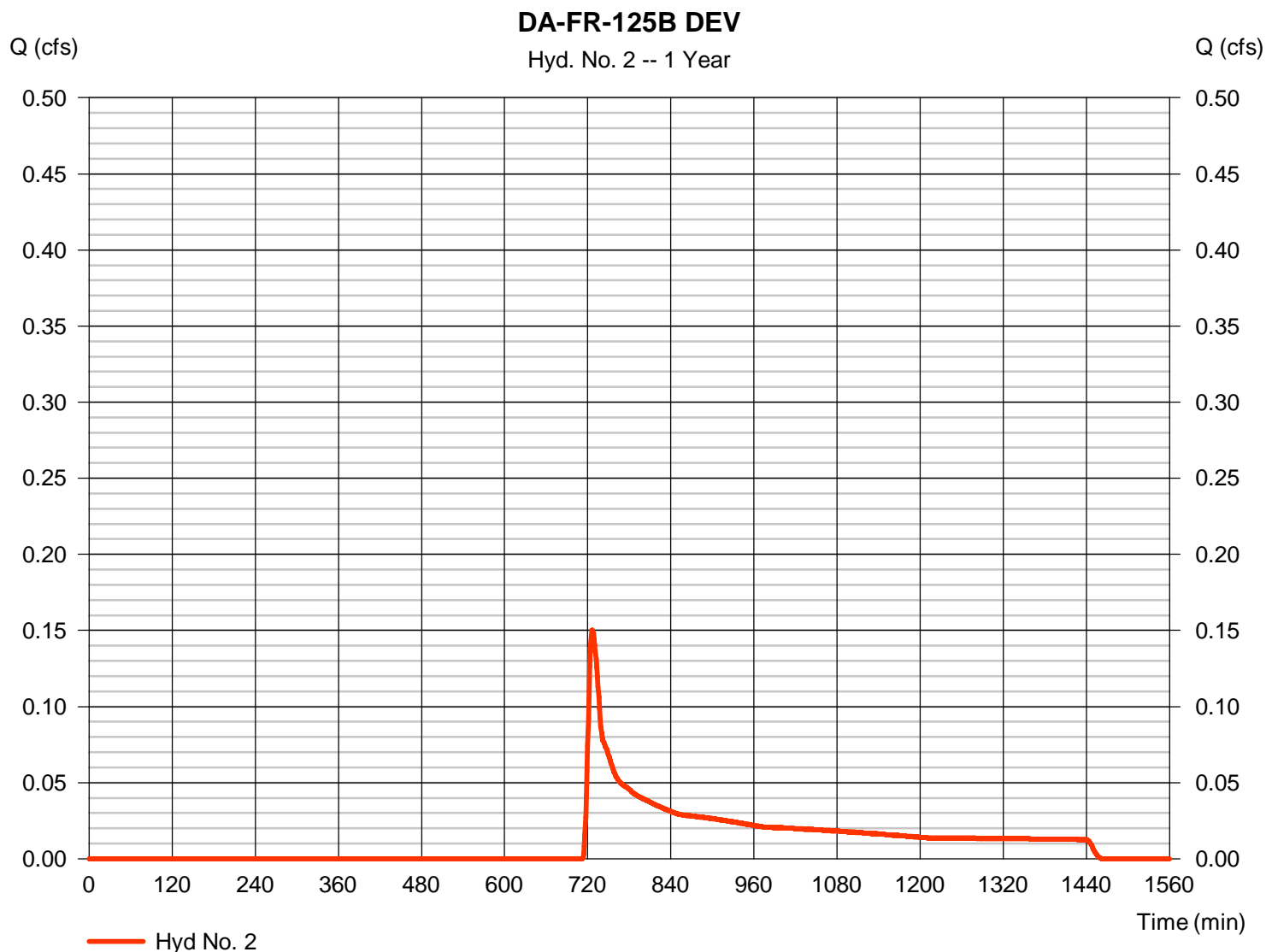
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-125B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.150 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 1,079 cuft
Drainage area	= 1.180 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.50 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.495 \times 48) + (0.687 \times 58)] / 1.180$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-125B DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.400	0.011	
Flow length (ft)	= 32.7	67.3	0.0	
Two-year 24-hr precip. (in)	= 3.70	3.70	0.00	
Land slope (%)	= 6.02	6.92	0.00	
Travel Time (min)	= 5.26	+	8.85	+
			0.00	= 14.11
Shallow Concentrated Flow				
Flow length (ft)	= 160.00	0.00	0.00	
Watercourse slope (%)	= 15.70	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=6.39	0.00	0.00	
Travel Time (min)	= 0.42	+	0.00	+
			0.00	= 0.42
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				14.50 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

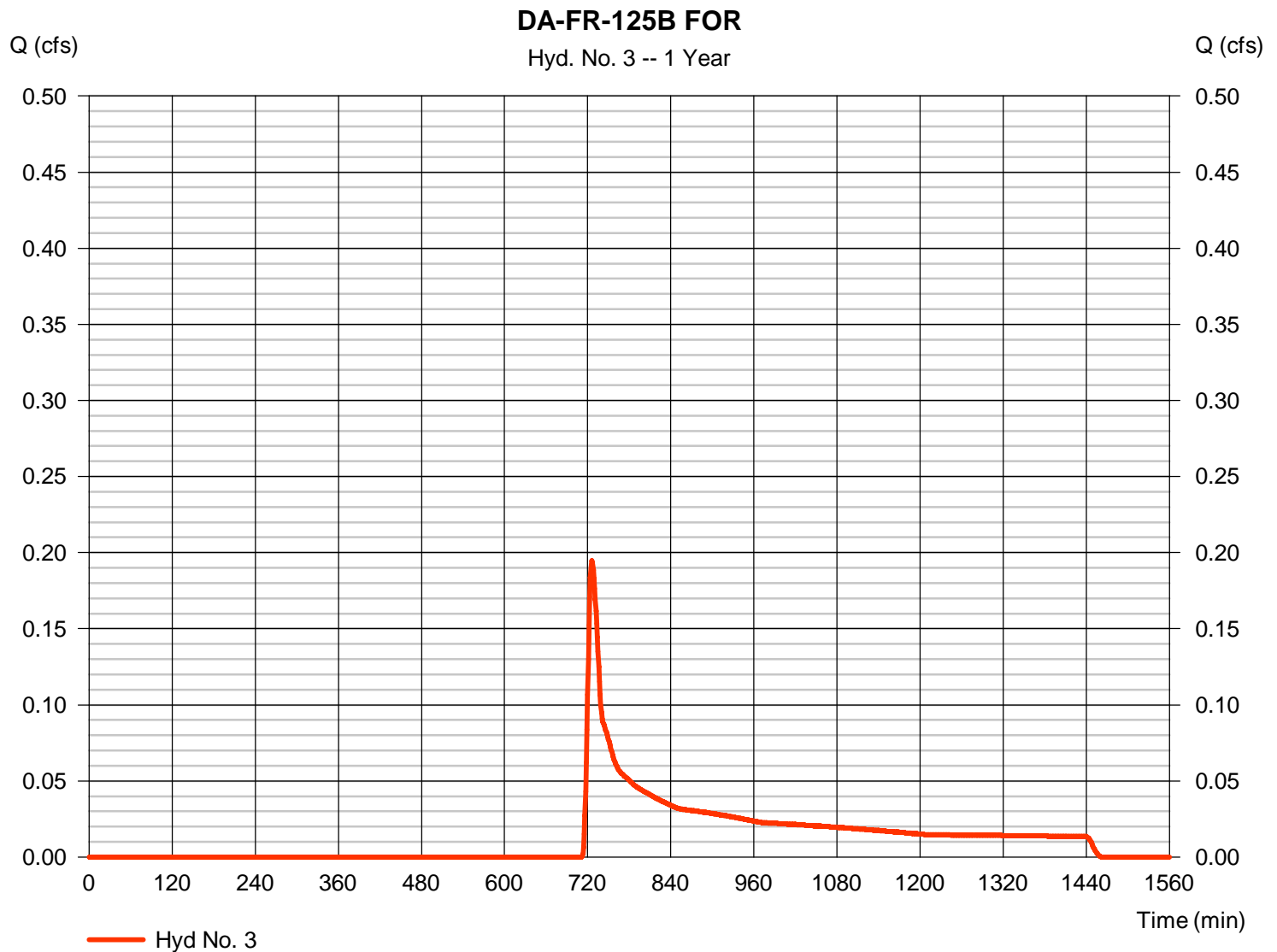
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-125B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 1.180 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.30 in
 Storm duration = 24 hrs

Peak discharge = 0.195 cfs
 Time to peak = 726 min
 Hyd. volume = 1,204 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 14.50 min
 Distribution = Type II
 Shape factor = 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-125B FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.011				
Flow length (ft)	= 32.7	67.3	0.0				
Two-year 24-hr precip. (in)	= 3.70	3.70	0.00				
Land slope (%)	= 6.02	6.92	0.00				
Travel Time (min)	= 5.26	+	8.85	+	0.00	=	14.11
Shallow Concentrated Flow							
Flow length (ft)	= 160.00	0.00	0.00				
Watercourse slope (%)	= 15.70	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=6.39	0.00	0.00				
Travel Time (min)	= 0.42	+	0.00	+	0.00	=	0.42
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				14.50 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.456	1	725	1,943	-----	-----	-----	DA-FR-125B PRE
2	SCS Runoff	0.322	1	725	1,623	-----	-----	-----	DA-FR-125B DEV
3	SCS Runoff	0.387	1	725	1,780	-----	-----	-----	DA-FR-125B FOR
DA-FR-125B_Hydraflow.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

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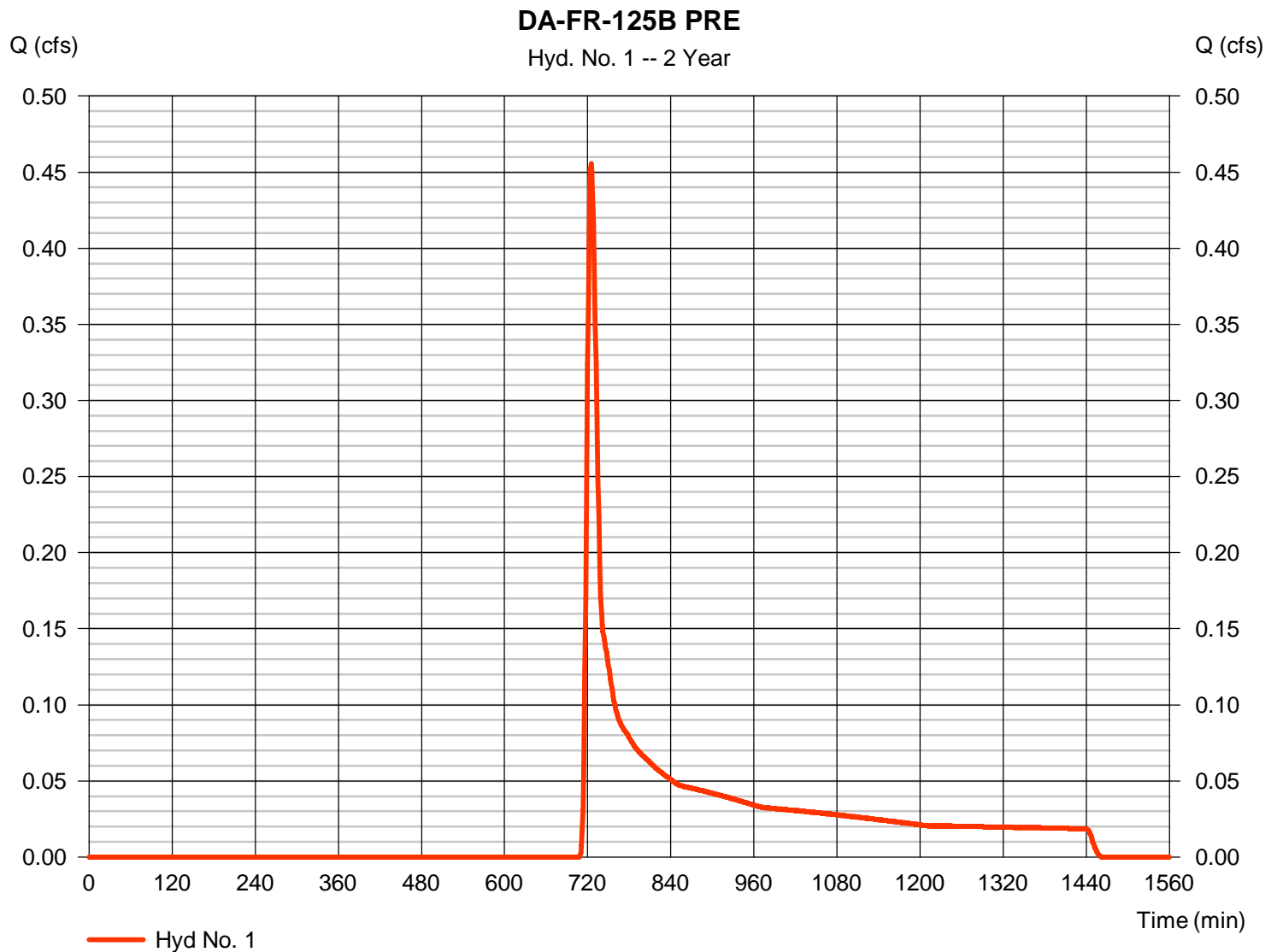
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-125B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.456 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 1,943 cuft
Drainage area	= 1.180 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.50 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.283 \times 58) + (0.899 \times 55)] / 1.180$



Hydrograph Report

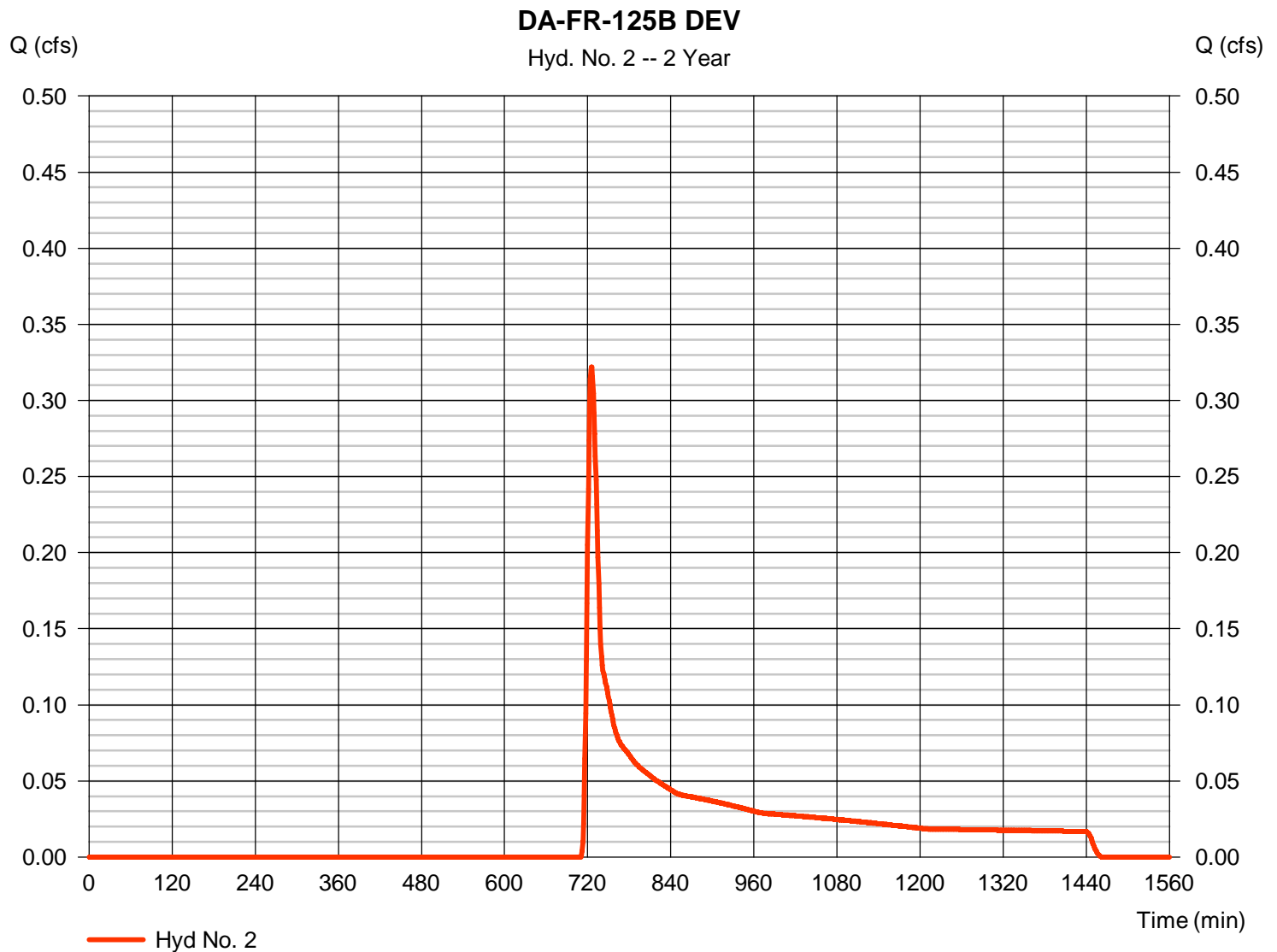
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Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-125B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.322 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 1,623 cuft
Drainage area	= 1.180 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.50 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.495 \times 48) + (0.687 \times 58)] / 1.180$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

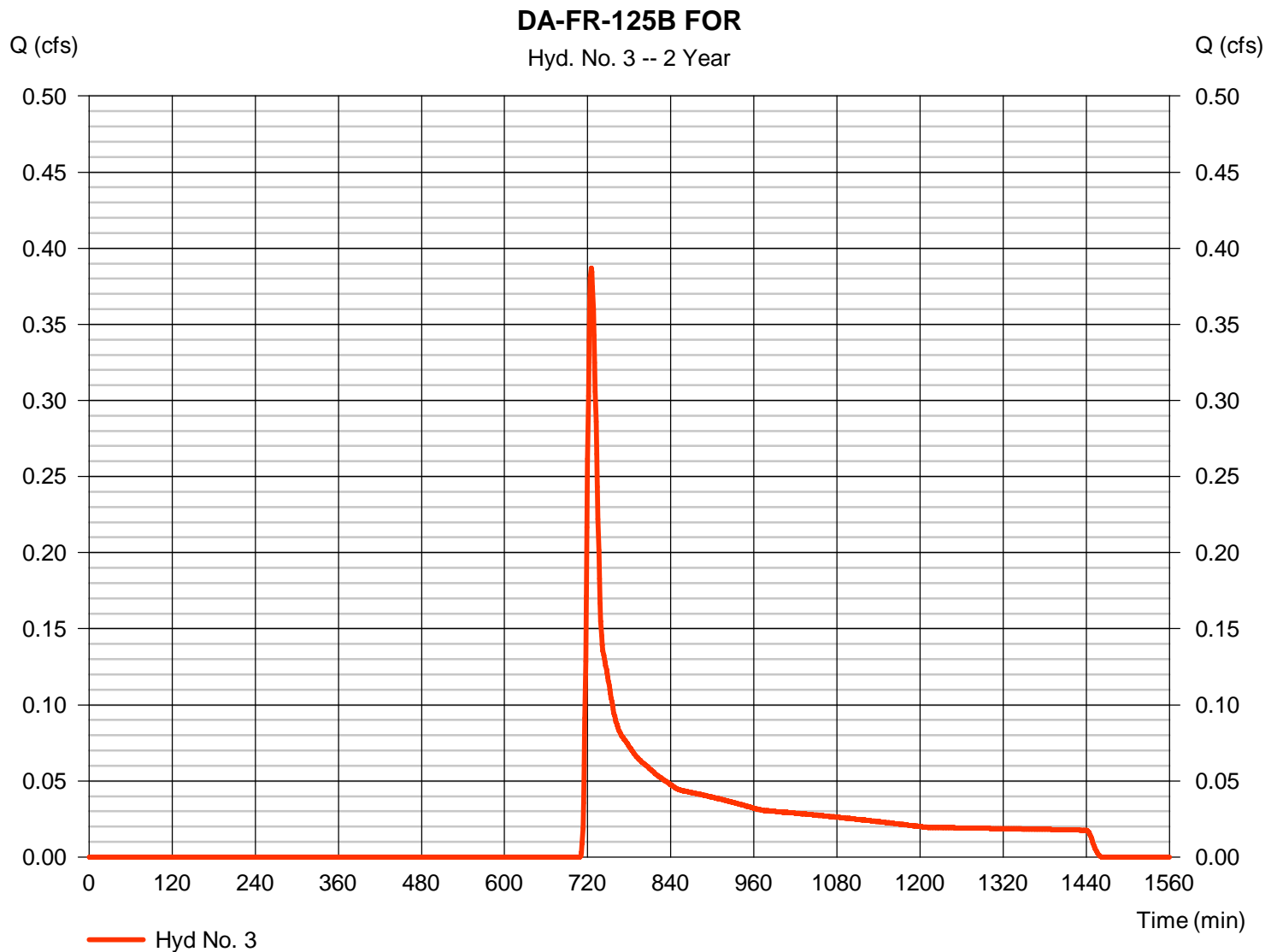
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-125B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 1.180 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.387 cfs
 Time to peak = 725 min
 Hyd. volume = 1,780 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 14.50 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	2.070	1	723	6,091	-----	-----	-----	DA-FR-125B PRE
2	SCS Runoff	1.797	1	723	5,466	-----	-----	-----	DA-FR-125B DEV
3	SCS Runoff	1.933	1	723	5,776	-----	-----	-----	DA-FR-125B FOR
DA-FR-125B_Hydraflow.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

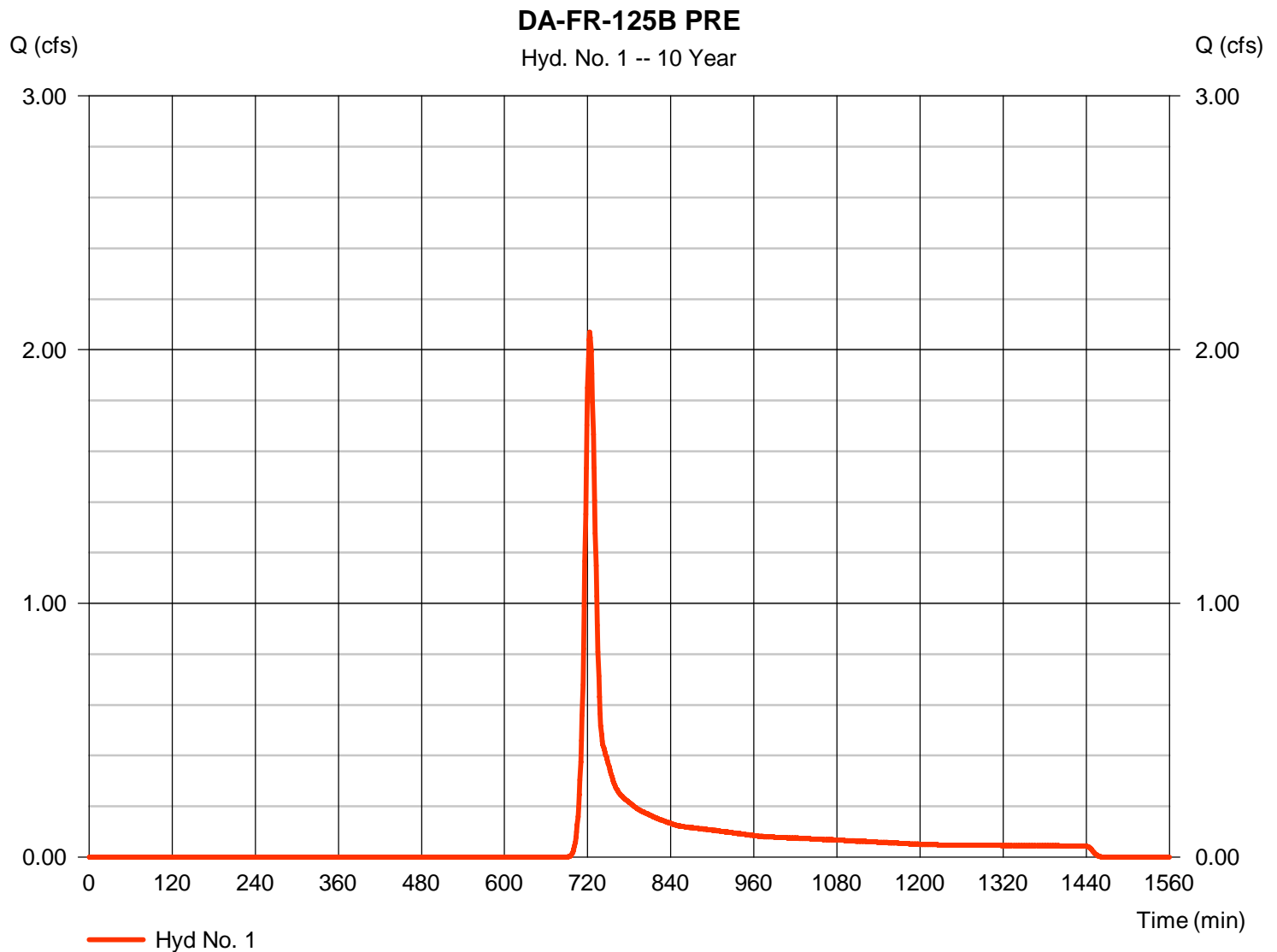
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Hyd. No. 1

DA-FR-125B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 2.070 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 6,091 cuft
Drainage area	= 1.180 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.50 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.283 \times 58) + (0.899 \times 55)] / 1.180$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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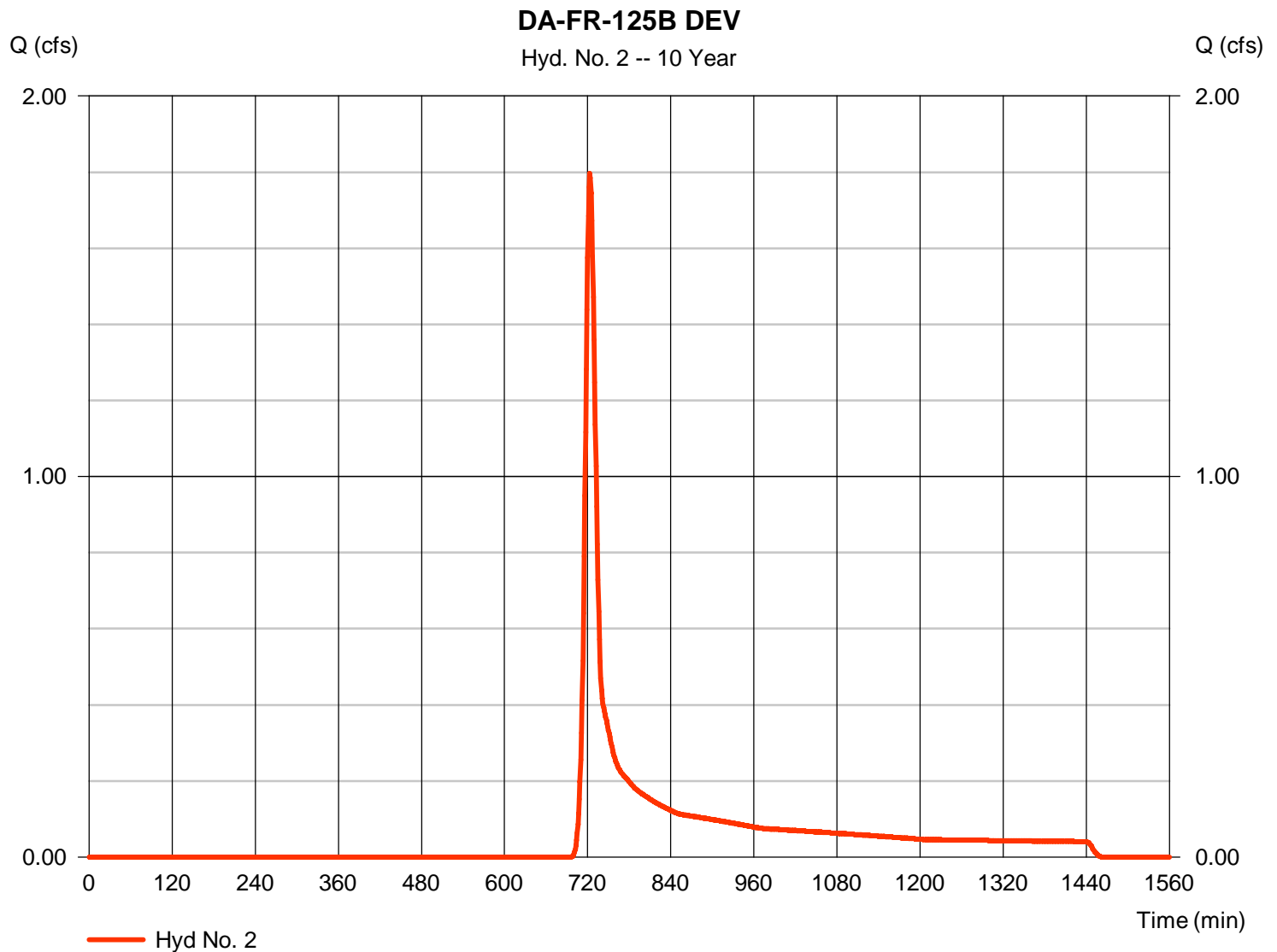
Hyd. No. 2

DA-FR-125B DEV

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 1.180 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 1.797 cfs
 Time to peak = 723 min
 Hyd. volume = 5,466 cuft
 Curve number = 54*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 14.50 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(0.495 \times 48) + (0.687 \times 58)] / 1.180$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

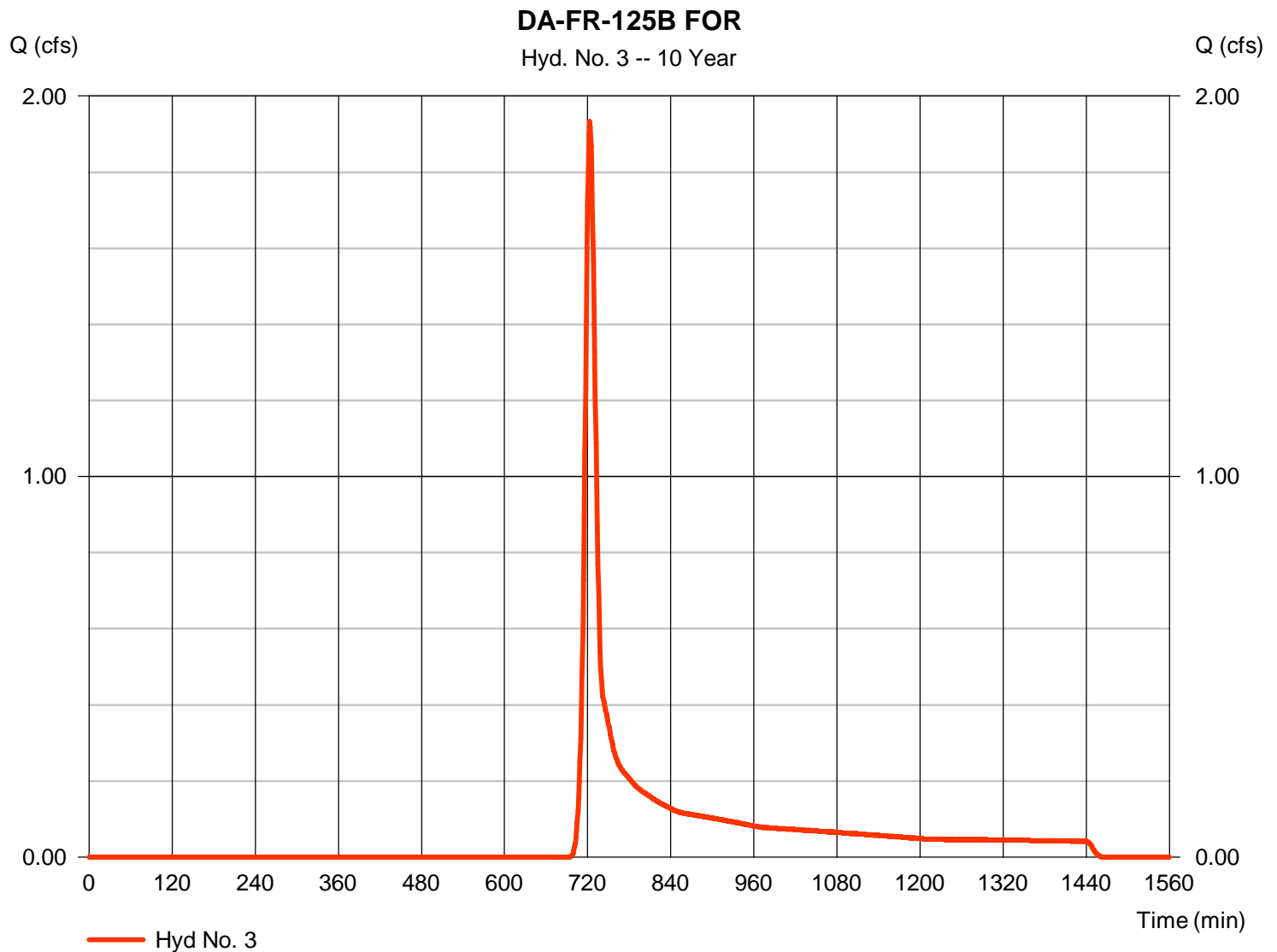
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Hyd. No. 3

DA-FR-125B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 1.180 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 1.933 cfs
 Time to peak = 723 min
 Hyd. volume = 5,776 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 14.50 min
 Distribution = Type II
 Shape factor = 484



DA-FR-125C

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.142	995
Developed Condition	0.053	716
Pre-Developed (Forest) Condition	0.142	999

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.9

Calculations:

Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	0.053	\leq	0.178
			N/A - See Check #3	
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.053	\leq	0.142
			N/A - See Check #3	
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ ---->	0.053	<u>shall not</u> be required to be \leq	0.198

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s n value of 0.011 was used.</p> <p>Sources:</p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

Table 2 – Manning's *n* Values for Open Channel Flow

Channel Type	Manning <i>n</i>		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's <i>n</i> value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's <i>n</i> value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-125C PRE
2	SCS Runoff	DA-FR-125C DEV
3	SCS Runoff	DA-FR-125C FOR

Hydrograph Return Period Recap

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)								Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	-----	0.142	0.281	-----	-----	1.426	-----	-----	-----	DA-FR-125C PRE
2	SCS Runoff	-----	0.053	0.122	-----	-----	0.874	-----	-----	-----	DA-FR-125C DEV
3	SCS Runoff	-----	0.142	0.282	-----	-----	1.430	-----	-----	-----	DA-FR-125C FOR
Proj. file: DA-FR-125C_Hydraflow.gpw									Monday, 08 / 21 / 2017		

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.142	1	729	995	-----	-----	-----	DA-FR-125C PRE
2	SCS Runoff	0.053	1	745	716	-----	-----	-----	DA-FR-125C DEV
3	SCS Runoff	0.142	1	729	999	-----	-----	-----	DA-FR-125C FOR
DA-FR-125C_Hydraflow.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

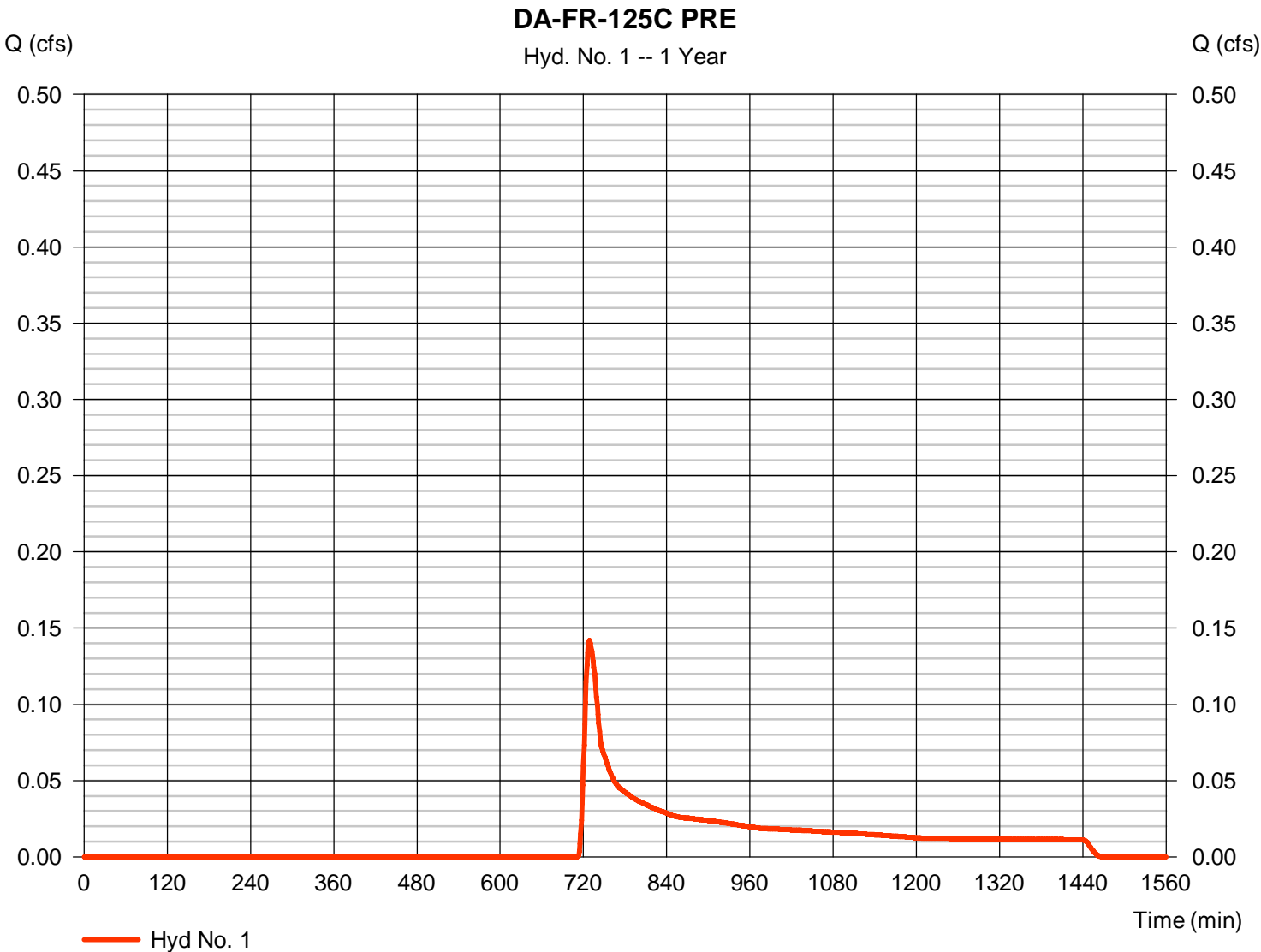
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-125C PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.142 cfs
Storm frequency	=	1 yrs	Time to peak	=	729 min
Time interval	=	1 min	Hyd. volume	=	995 cuft
Drainage area	=	0.987 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	16.90 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.568 x 48) + (0.419 x 58)] / 0.987



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-125C PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 3.50	0.00	0.00	
Travel Time (min)	= 15.97	+ 0.00	+ 0.00	= 15.97
Shallow Concentrated Flow				
Flow length (ft)	= 344.43	0.00	0.00	
Watercourse slope (%)	= 15.00	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=6.25	0.00	0.00	
Travel Time (min)	= 0.92	+ 0.00	+ 0.00	= 0.92
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				16.90 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

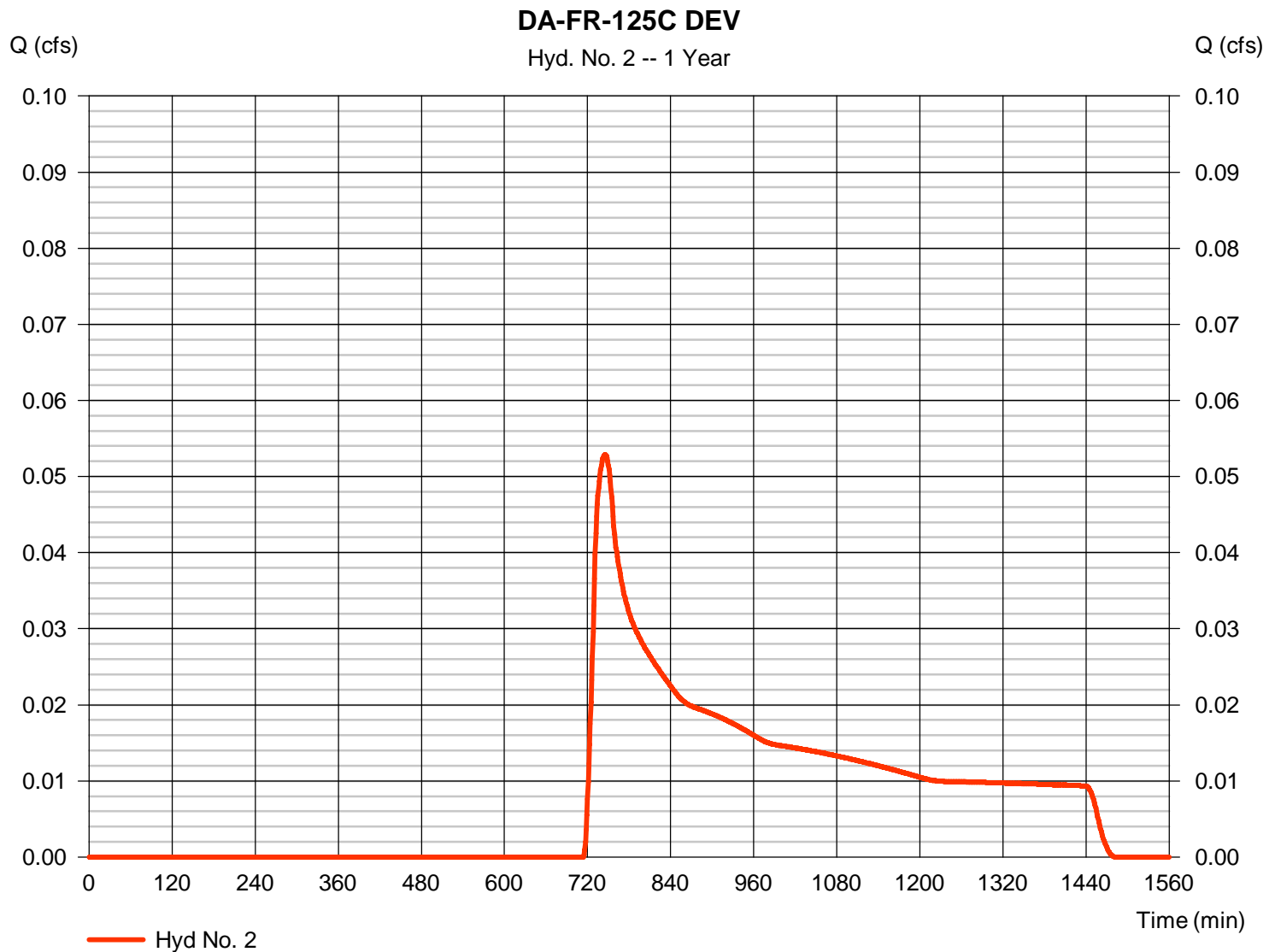
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-125C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.053 cfs
Storm frequency	= 1 yrs	Time to peak	= 745 min
Time interval	= 1 min	Hyd. volume	= 716 cuft
Drainage area	= 0.990 ac	Curve number	= 52*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 25.70 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.568 \times 48) + (0.419 \times 58)] / 0.990$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-125C DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.800	0.400	0.800				
Flow length (ft)	= 13.4	65.5	21.1				
Two-year 24-hr precip. (in)	= 3.70	3.70	3.70				
Land slope (%)	= 3.63	3.23	4.23				
Travel Time (min)	= 5.48	+	11.75	+	7.43	=	24.66
Shallow Concentrated Flow							
Flow length (ft)	= 304.14	29.91	0.00				
Watercourse slope (%)	= 13.84	33.12	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=6.00	9.29	0.00				
Travel Time (min)	= 0.84	+	0.05	+	0.00	=	0.90
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	({}))45.0	0.0	0.0				
Travel Time (min)	= 0.15	+	0.00	+	0.00	=	0.15
Total Travel Time, Tc					25.70 min		

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

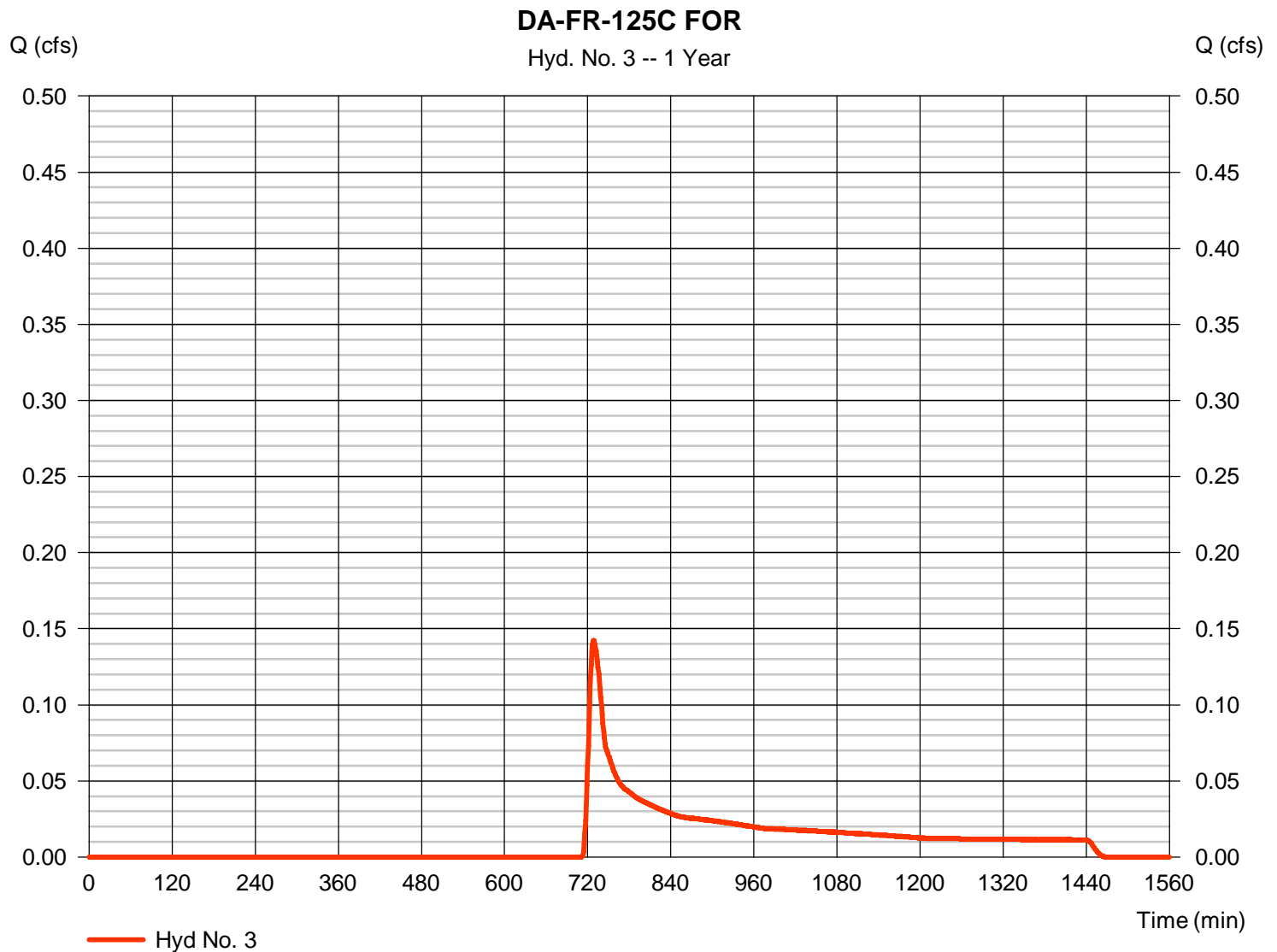
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-125C FOR

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 0.990 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.30 in
 Storm duration = 24 hrs

Peak discharge = 0.142 cfs
 Time to peak = 729 min
 Hyd. volume = 999 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 16.90 min
 Distribution = Type II
 Shape factor = 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-125C FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 3.50	0.00	0.00	
Travel Time (min)	= 15.97	+ 0.00	+ 0.00	= 15.97
Shallow Concentrated Flow				
Flow length (ft)	= 344.43	0.00	0.00	
Watercourse slope (%)	= 15.00	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=6.25	0.00	0.00	
Travel Time (min)	= 0.92	+ 0.00	+ 0.00	= 0.92
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				16.90 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.281	1	727	1,472	-----	-----	-----	DA-FR-125C PRE
2	SCS Runoff	0.122	1	736	1,123	-----	-----	-----	DA-FR-125C DEV
3	SCS Runoff	0.282	1	727	1,477	-----	-----	-----	DA-FR-125C FOR
DA-FR-125C_Hydraflow.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

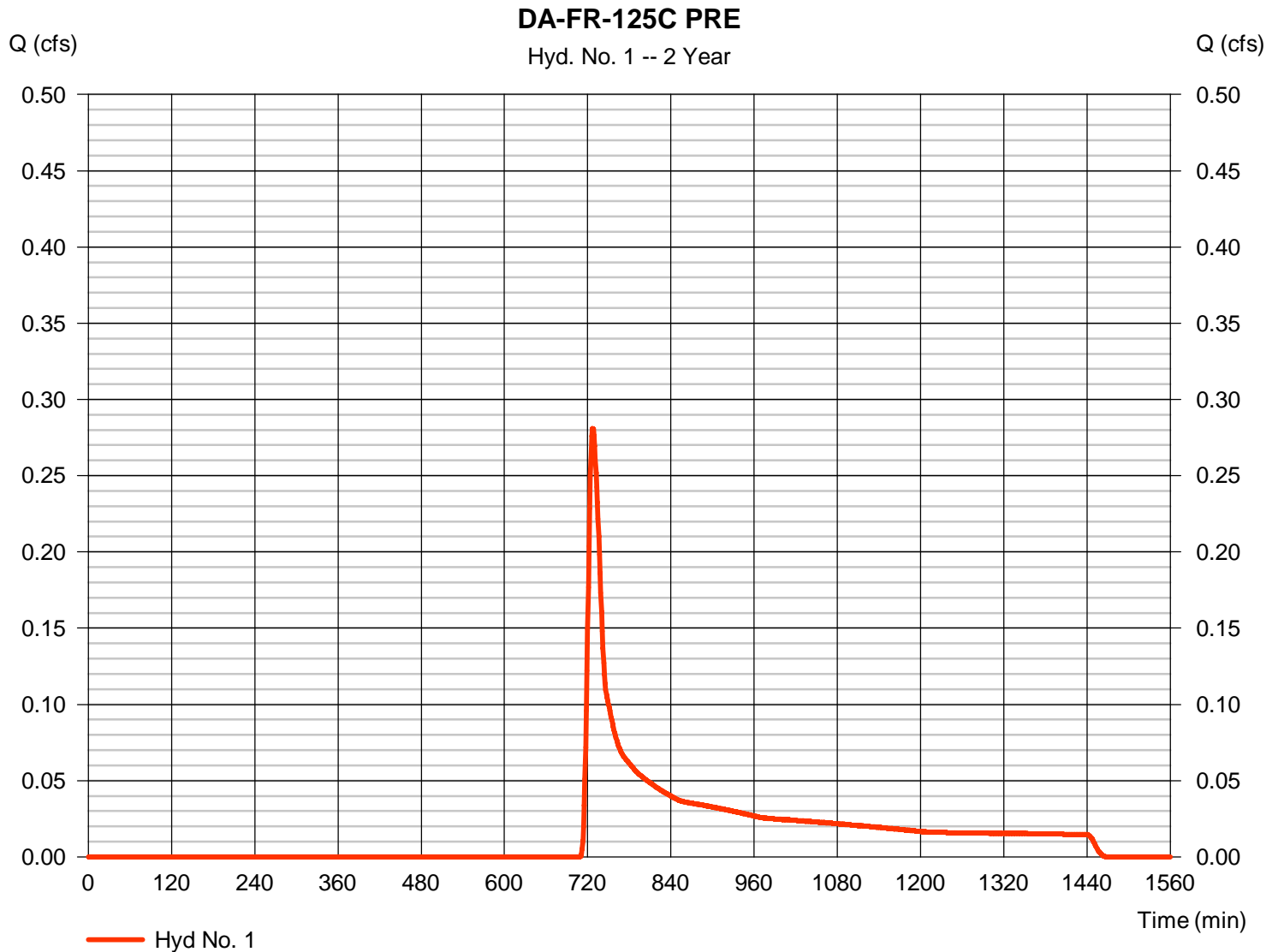
Hyd. No. 1

DA-FR-125C PRE

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 0.987 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.281 cfs
 Time to peak = 727 min
 Hyd. volume = 1,472 cuft
 Curve number = 55*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 16.90 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(0.568 \times 48) + (0.419 \times 58)] / 0.987$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

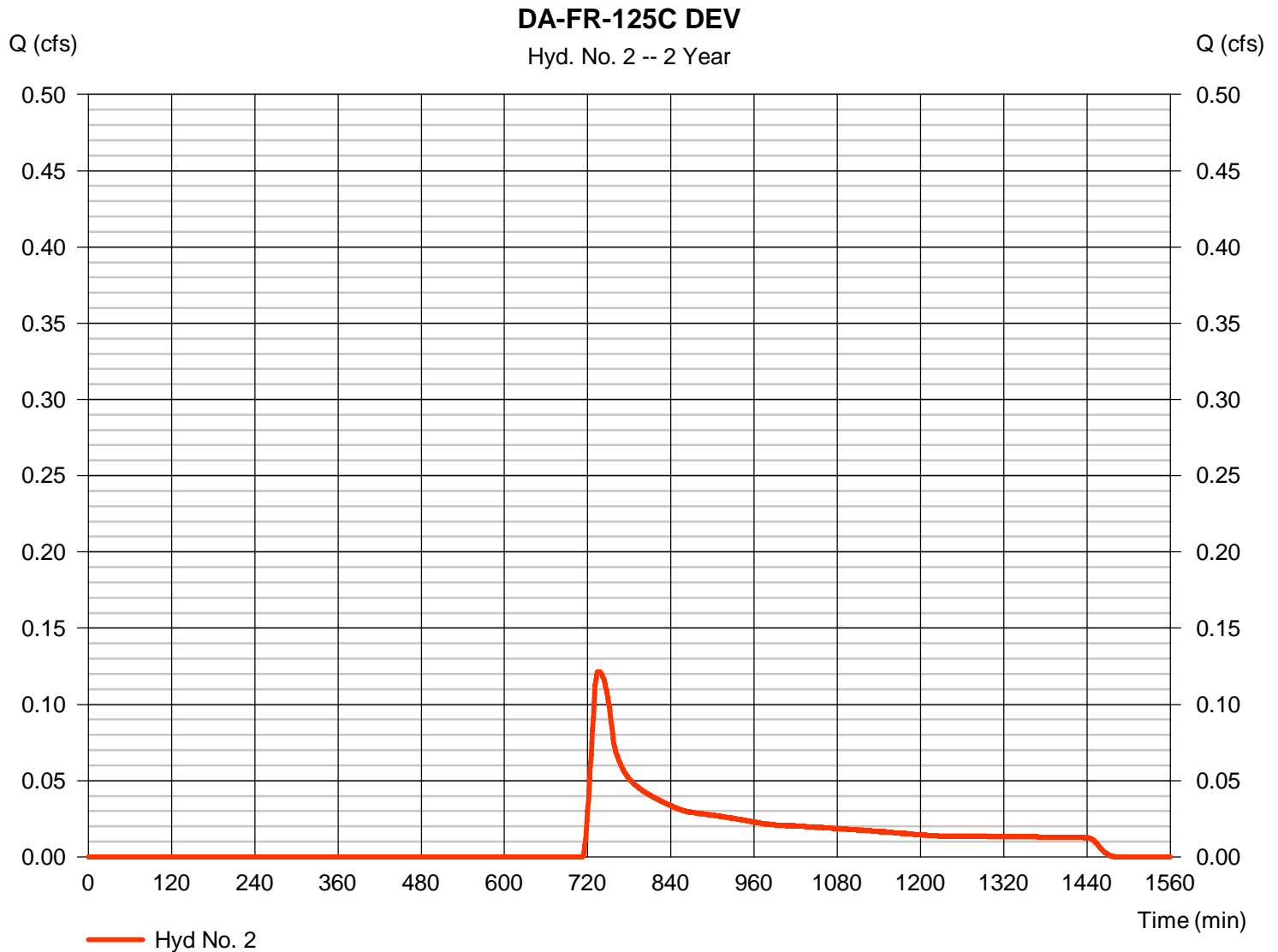
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-125C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.122 cfs
Storm frequency	= 2 yrs	Time to peak	= 736 min
Time interval	= 1 min	Hyd. volume	= 1,123 cuft
Drainage area	= 0.990 ac	Curve number	= 52*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 25.70 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.568 \times 48) + (0.419 \times 58)] / 0.990$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

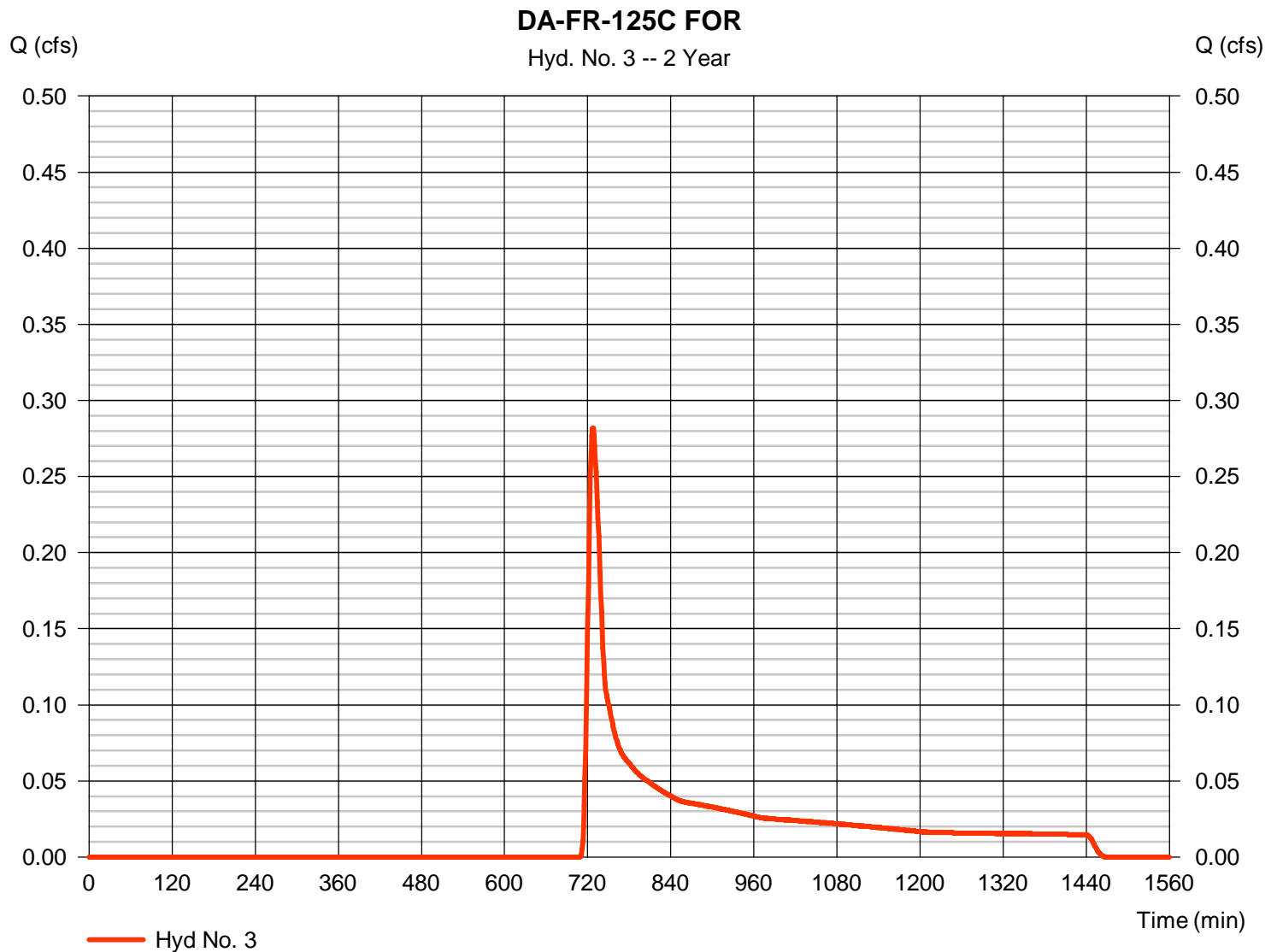
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-125C FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 0.990 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.282 cfs
 Time to peak = 727 min
 Hyd. volume = 1,477 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 16.90 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	1.426	1	725	4,775	-----	-----	-----	DA-FR-125C PRE
2	SCS Runoff	0.874	1	731	4,111	-----	-----	-----	DA-FR-125C DEV
3	SCS Runoff	1.430	1	725	4,791	-----	-----	-----	DA-FR-125C FOR
DA-FR-125C_Hydraflow.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

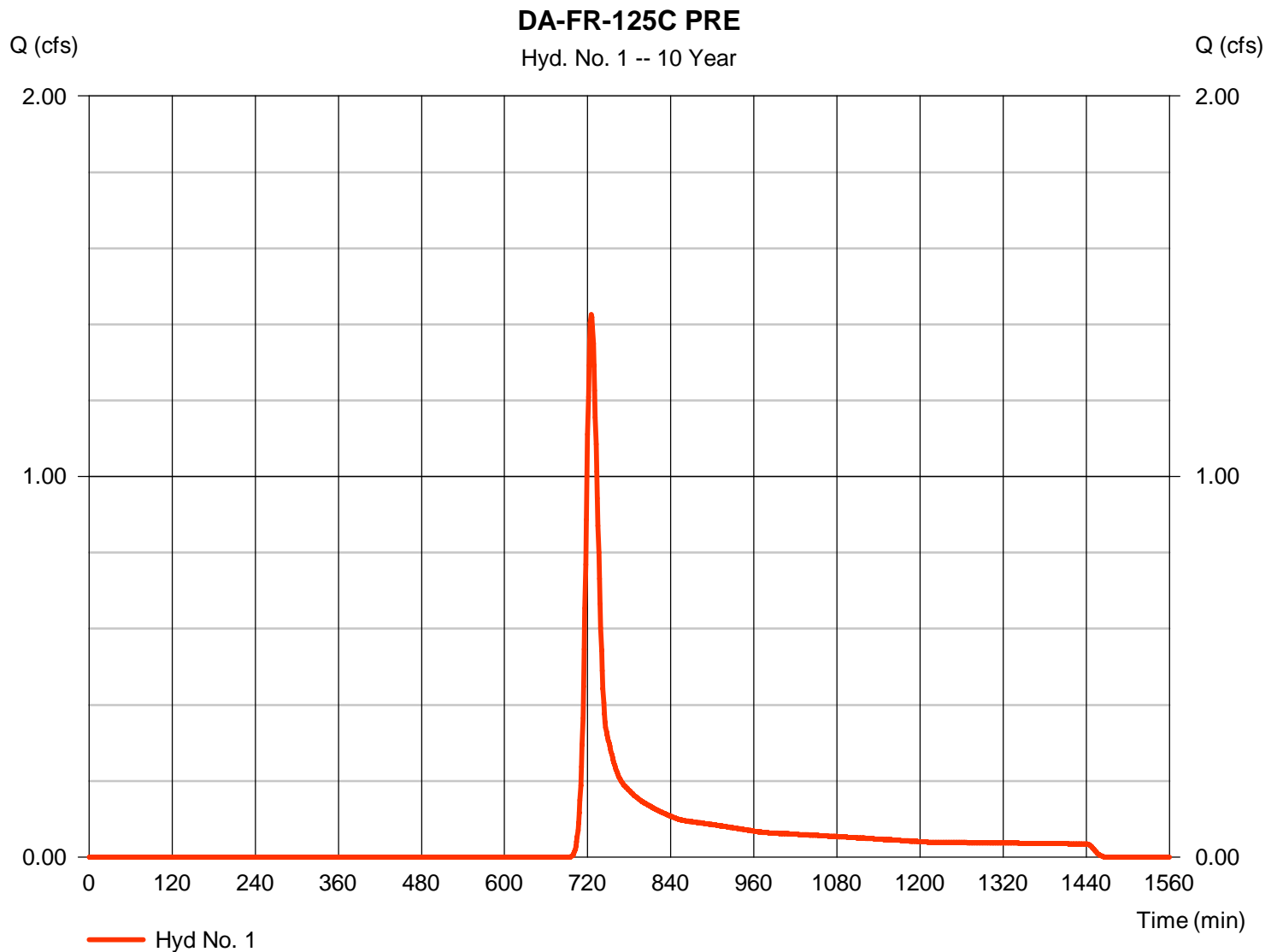
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-125C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 1.426 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 4,775 cuft
Drainage area	= 0.987 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.90 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.568 \times 48) + (0.419 \times 58)] / 0.987$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

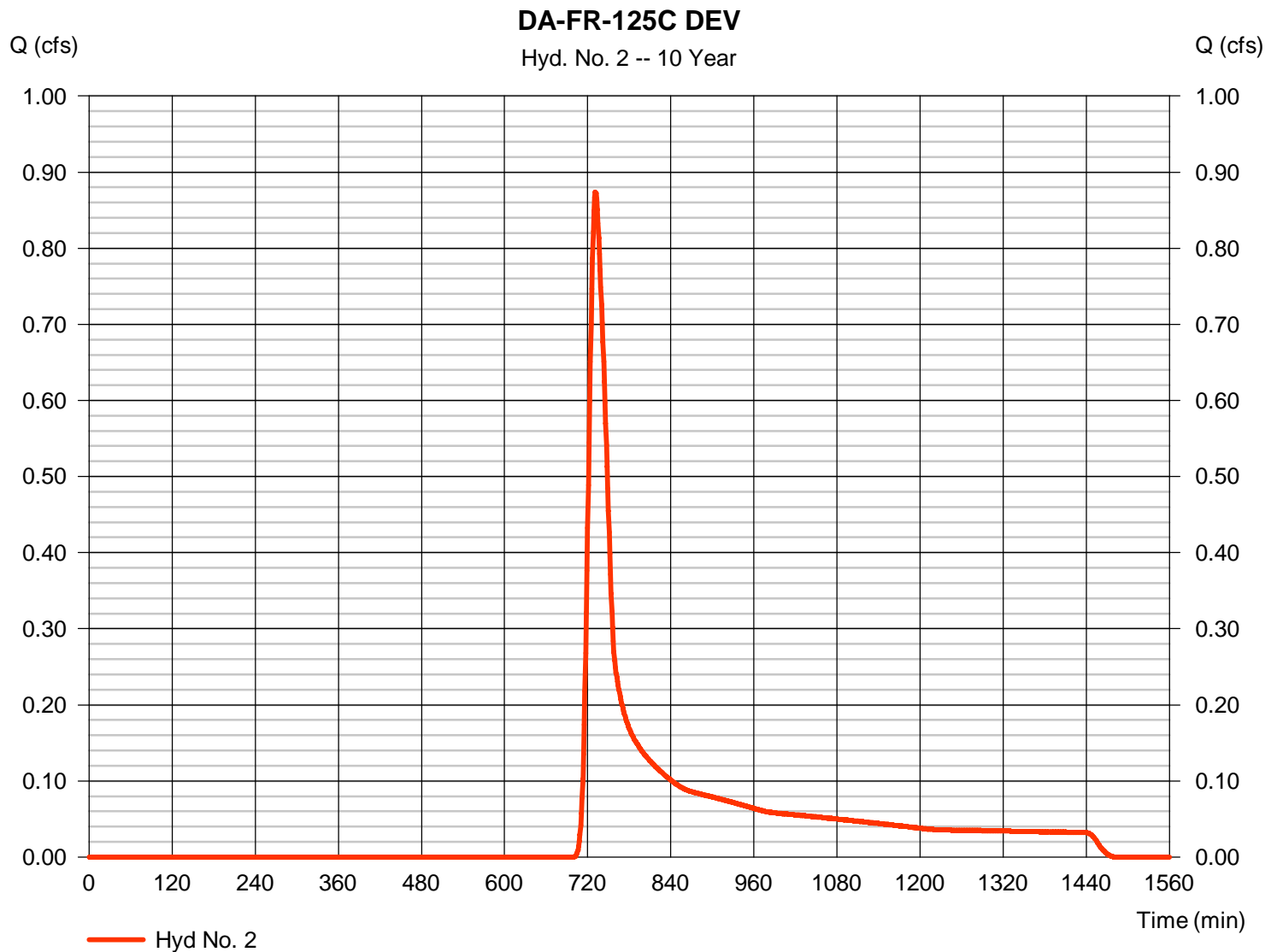
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-125C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.874 cfs
Storm frequency	= 10 yrs	Time to peak	= 731 min
Time interval	= 1 min	Hyd. volume	= 4,111 cuft
Drainage area	= 0.990 ac	Curve number	= 52*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 25.70 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.568 \times 48) + (0.419 \times 58)] / 0.990$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

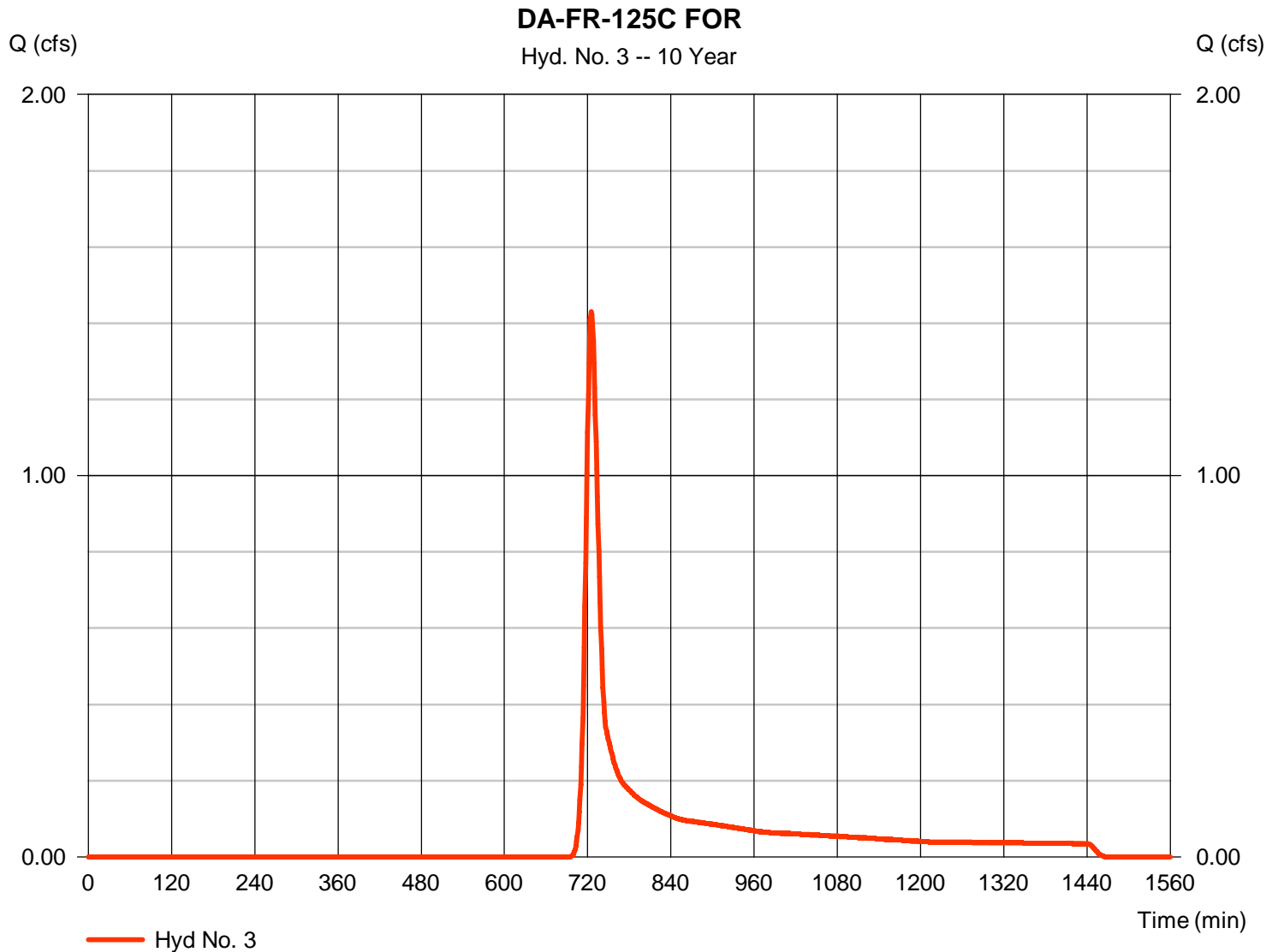
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-125C FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 0.990 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 1.430 cfs
 Time to peak = 725 min
 Hyd. volume = 4,791 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 16.90 min
 Distribution = Type II
 Shape factor = 484



Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	-----
2	69.8703	13.1000	0.8658	-----
3	0.0000	0.0000	0.0000	-----
5	79.2597	14.6000	0.8369	-----
10	88.2351	15.5000	0.8279	-----
25	102.6072	16.5000	0.8217	-----
50	114.8193	17.2000	0.8199	-----
100	127.1596	17.8000	0.8186	-----

File name: SampleFHA.idf

$$\text{Intensity} = B / (Tc + D)^E$$

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5.69	4.61	3.89	3.38	2.99	2.69	2.44	2.24	2.07	1.93	1.81	1.70
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	6.57	5.43	4.65	4.08	3.65	3.30	3.02	2.79	2.59	2.42	2.27	2.15
10	7.24	6.04	5.21	4.59	4.12	3.74	3.43	3.17	2.95	2.77	2.60	2.46
25	8.25	6.95	6.03	5.34	4.80	4.38	4.02	3.73	3.48	3.26	3.07	2.91
50	9.04	7.65	6.66	5.92	5.34	4.87	4.49	4.16	3.88	3.65	3.44	3.25
100	9.83	8.36	7.30	6.50	5.87	5.36	4.94	4.59	4.29	4.03	3.80	3.60

Tc = time in minutes. Values may exceed 60.

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[illegible]

DA-FR-125D

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.344	1448
Developed Condition	0.141	1052
Pre-Developed (Forest) Condition	0.272	1296

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	0.141	\leq OK	0.379
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.141	\leq OK	0.344
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ --->	0.141	<u>shall not</u> be required to be \leq	0.335

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s n value of 0.011 was used.</p> <p>Sources:</p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

Table 2 – Manning's *n* Values for Open Channel Flow

Channel Type	Manning <i>n</i>		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's <i>n</i> value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's <i>n</i> value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-125D PRE
2	SCS Runoff	DA-FR-125D DEV
3	SCS Runoff	DA-FR-125D FOR

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.344	1	722	1,448	-----	-----	-----	DA-FR-125D PRE
2	SCS Runoff	0.141	1	725	1,052	-----	-----	-----	DA-FR-125D DEV
3	SCS Runoff	0.272	1	723	1,296	-----	-----	-----	DA-FR-125D FOR
DA-FR-125D_Hydraflow.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

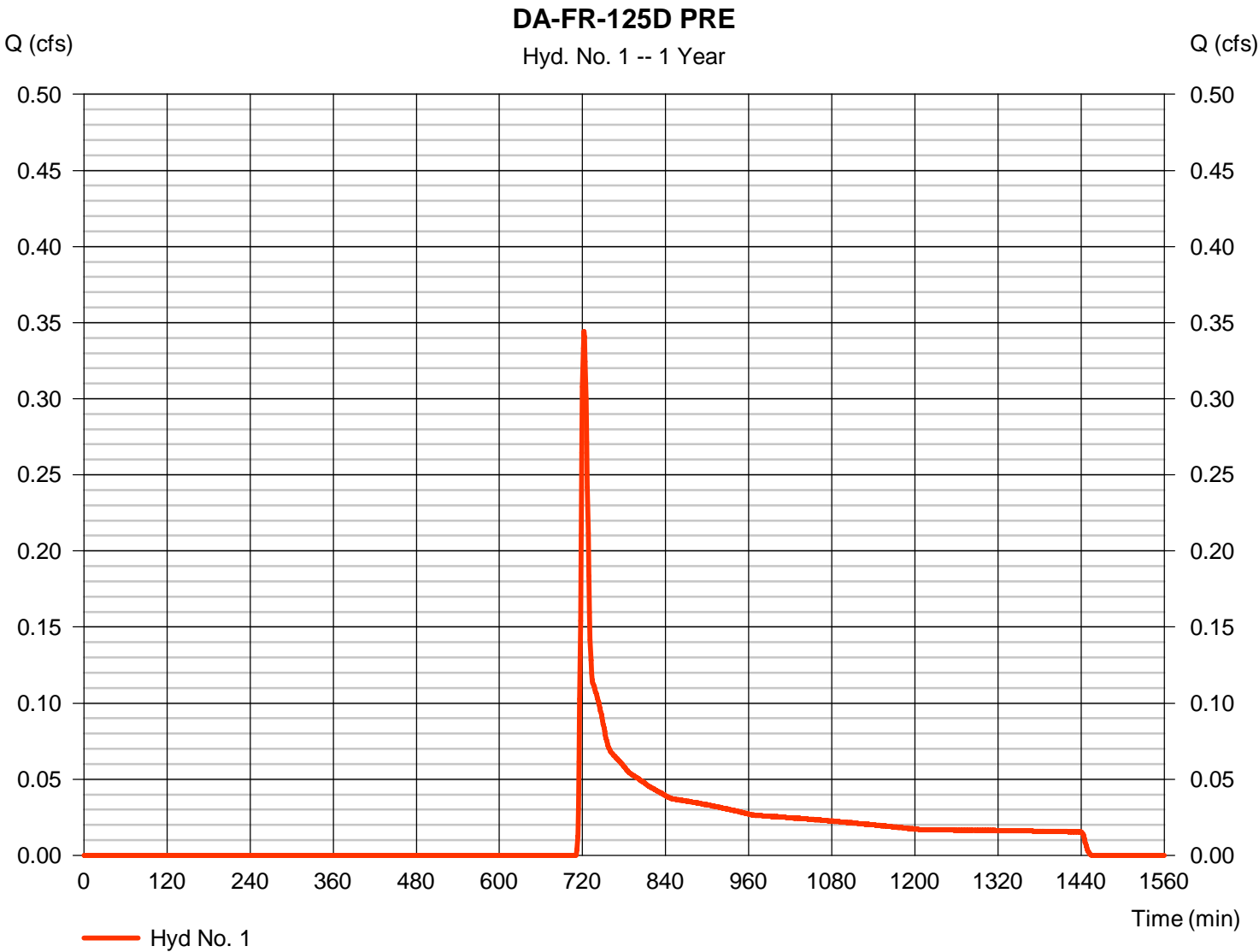
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-125D PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.344 cfs
Storm frequency	=	1 yrs	Time to peak	=	722 min
Time interval	=	1 min	Hyd. volume	=	1,448 cuft
Drainage area	=	1.280 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	9.80 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.038 x 82) + (1.239 x 55)] / 1.280



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-125D PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 12.79	0.00	0.00				
Travel Time (min)	= 9.51	+	0.00	+	0.00	=	9.51
Shallow Concentrated Flow							
Flow length (ft)	= 111.59	0.00	0.00				
Watercourse slope (%)	= 20.86	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=7.37	0.00	0.00				
Travel Time (min)	= 0.25	+	0.00	+	0.00	=	0.25
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				9.80 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

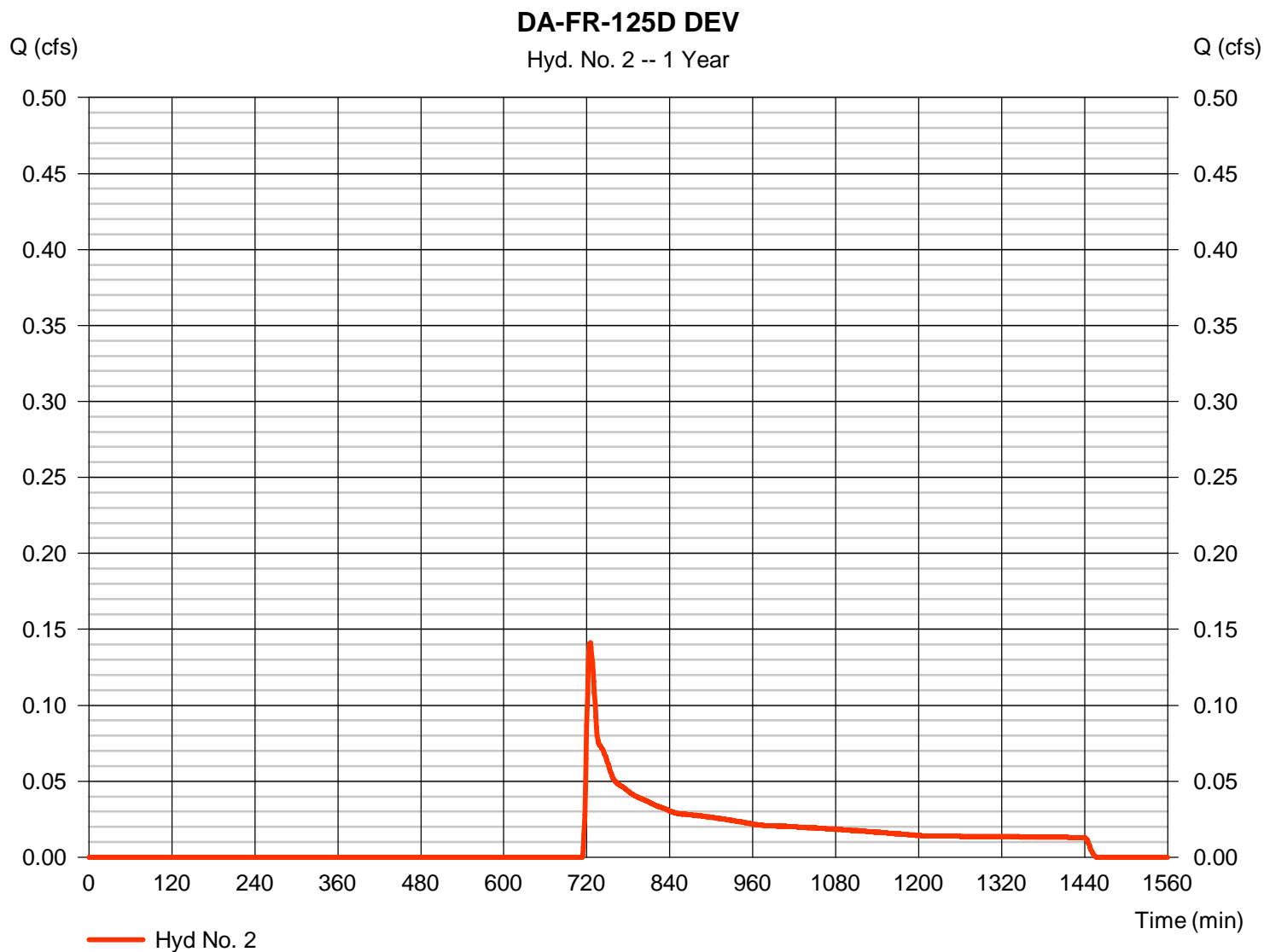
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-125D DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.141 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 1,052 cuft
Drainage area	= 1.270 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.70 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.756 \times 48) + (0.038 \times 82) + (0.478 \times 58)] / 1.270$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-125D DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.800	0.400	0.400	
Flow length (ft)	= 14.0	78.9	0.0	
Two-year 24-hr precip. (in)	= 3.70	3.70	0.00	
Land slope (%)	= 11.45	12.68	12.68	
Travel Time (min)	= 3.59	+	7.90	+
			0.00	= 11.48
Shallow Concentrated Flow				
Flow length (ft)	= 0.00	109.44	0.00	
Watercourse slope (%)	= 0.00	20.66	0.00	
Surface description	= Unpaved	Unpaved	Paved	
Average velocity (ft/s)	=0.00	7.33	0.00	
Travel Time (min)	= 0.00	+	0.25	+
			0.00	= 0.25
Channel Flow				
X sectional flow area (sqft)	= 2.00	0.00	0.00	
Wetted perimeter (ft)	= 4.47	0.00	0.00	
Channel slope (%)	= 5.00	0.00	0.00	
Manning's n-value	= 0.040	0.015	0.015	
Velocity (ft/s)	=4.86	0.00	0.00	
Flow length (ft)	({})3.2	0.0	0.0	
Travel Time (min)	= 0.01	+	0.00	+
			0.00	= 0.01
Total Travel Time, Tc				11.70 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

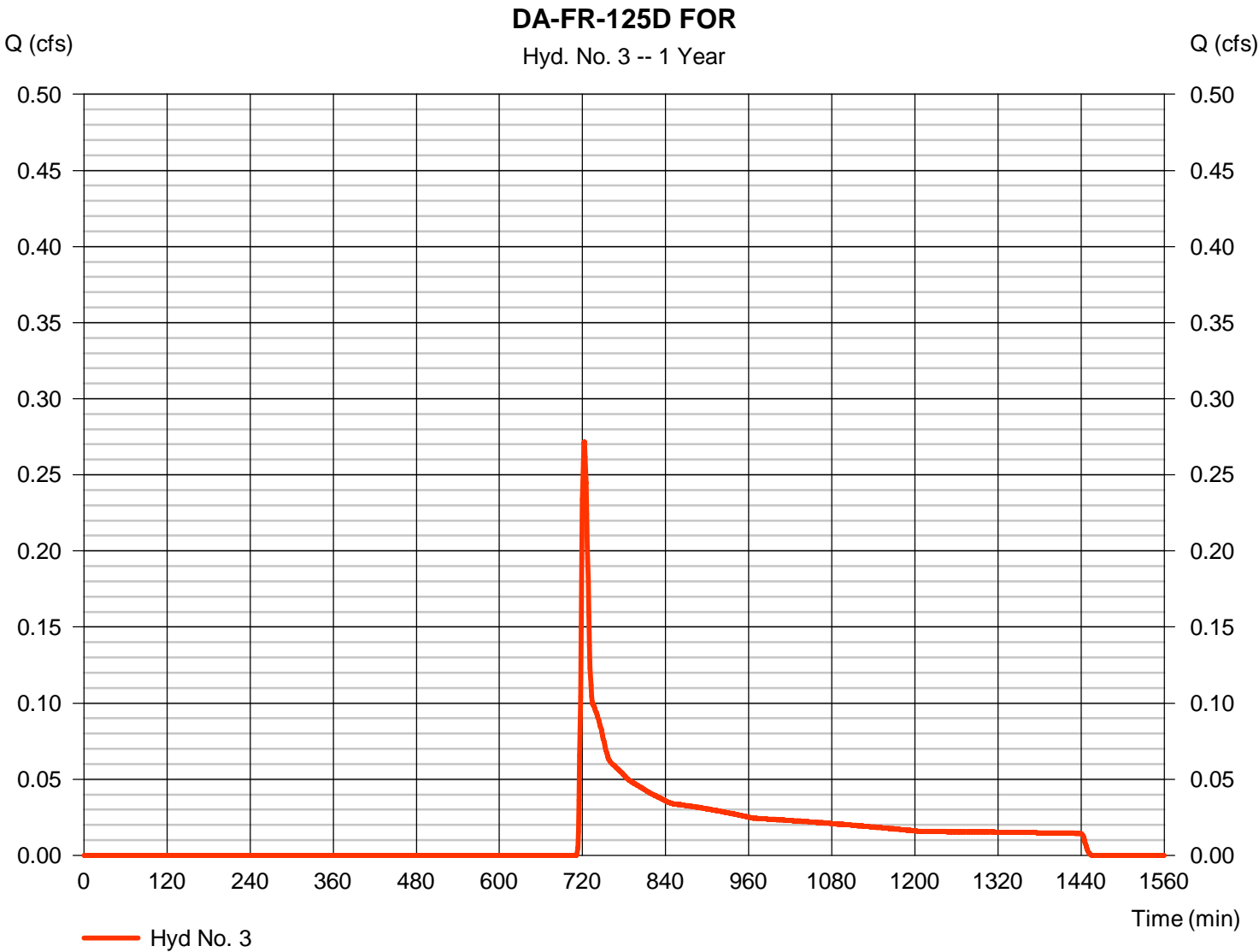
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-125D FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.272 cfs
Storm frequency	=	1 yrs	Time to peak	=	723 min
Time interval	=	1 min	Hyd. volume	=	1,296 cuft
Drainage area	=	1.270 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	9.80 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.038 x 82) + (1.234 x 55)] / 1.270



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-125D FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 12.79	0.00	0.00				
Travel Time (min)	= 9.51	+	0.00	+	0.00	=	9.51
Shallow Concentrated Flow							
Flow length (ft)	= 111.59	0.00	0.00				
Watercourse slope (%)	= 20.86	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=7.37	0.00	0.00				
Travel Time (min)	= 0.25	+	0.00	+	0.00	=	0.25
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				9.80 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.637	1	721	2,108	-----	-----	-----	DA-FR-125D PRE
2	SCS Runoff	0.336	1	724	1,612	-----	-----	-----	DA-FR-125D DEV
3	SCS Runoff	0.540	1	722	1,916	-----	-----	-----	DA-FR-125D FOR
DA-FR-125D_Hydraflow.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

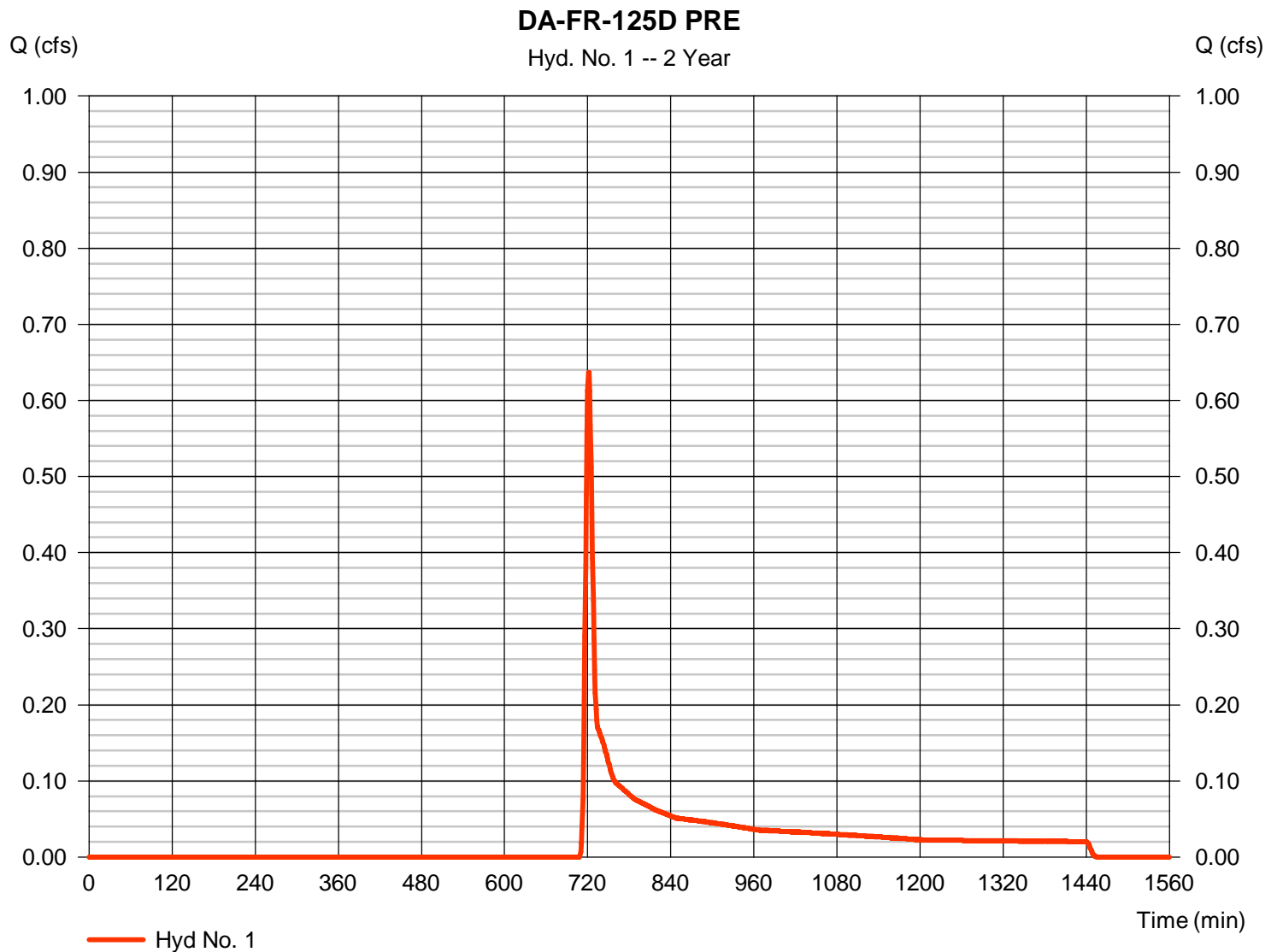
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-125D PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.637 cfs
Storm frequency	= 2 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 2,108 cuft
Drainage area	= 1.280 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 9.80 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.038 \times 82) + (1.239 \times 55)] / 1.280$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

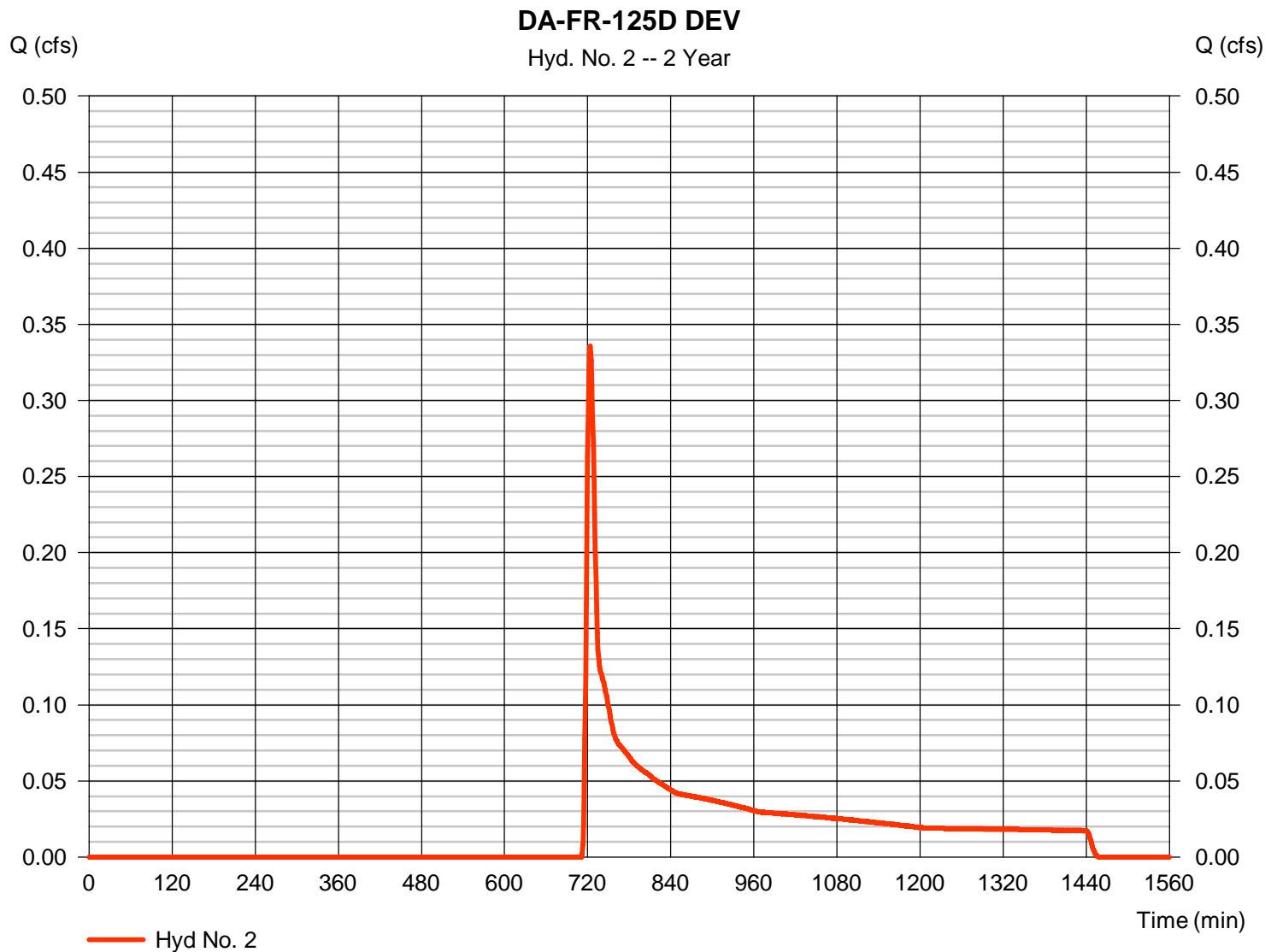
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-125D DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.336 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 1,612 cuft
Drainage area	= 1.270 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.70 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.756 \times 48) + (0.038 \times 82) + (0.478 \times 58)] / 1.270$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

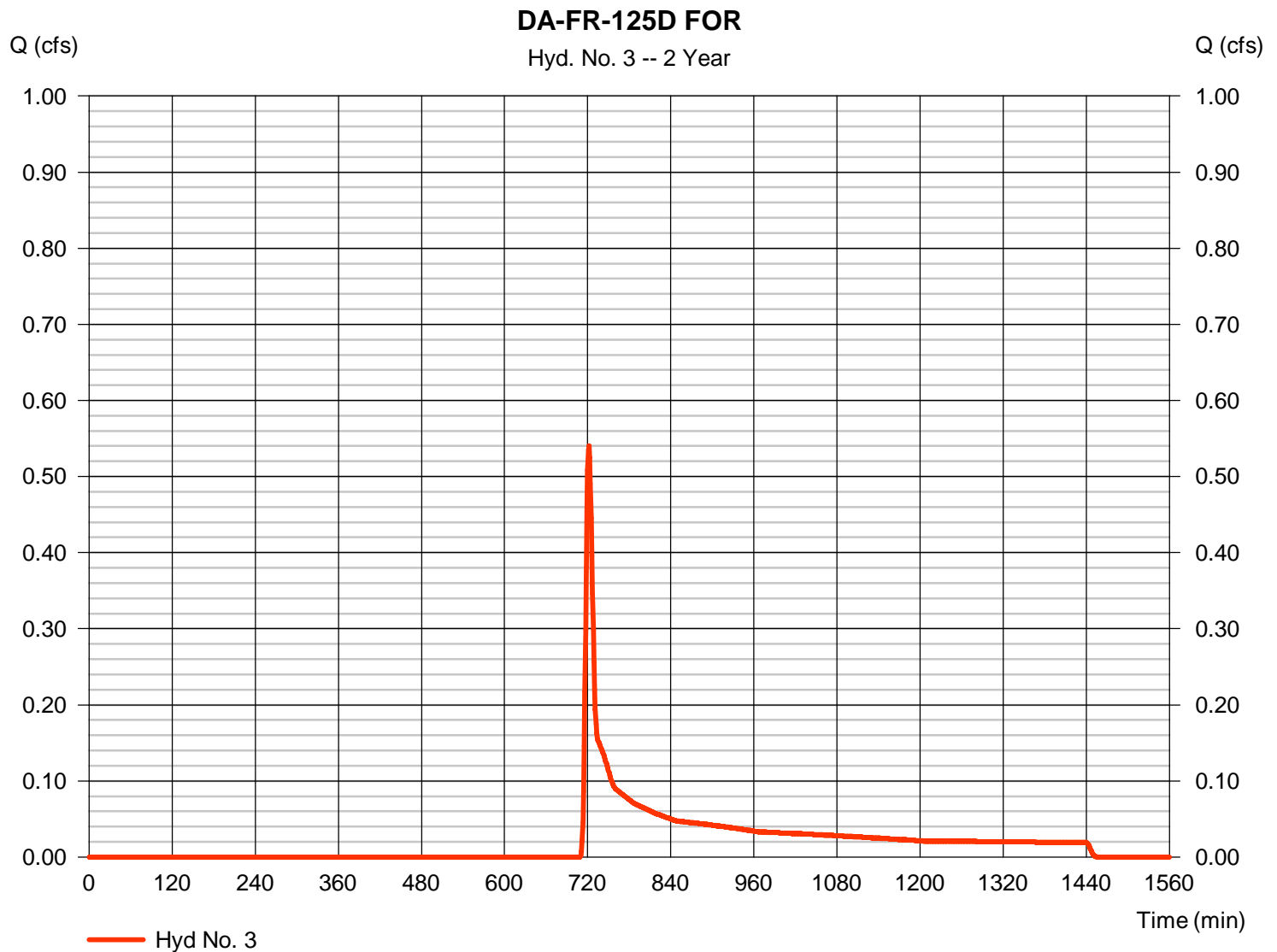
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-125D FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.540 cfs
Storm frequency	= 2 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 1,916 cuft
Drainage area	= 1.270 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 9.80 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.038 \times 82) + (1.234 \times 55)] / 1.270$



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	2.760	1	720	6,608	-----	-----	-----	DA-FR-125D PRE
2	SCS Runoff	2.076	1	721	5,654	-----	-----	-----	DA-FR-125D DEV
3	SCS Runoff	2.565	1	720	6,217	-----	-----	-----	DA-FR-125D FOR
DA-FR-125D_Hydraflow.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

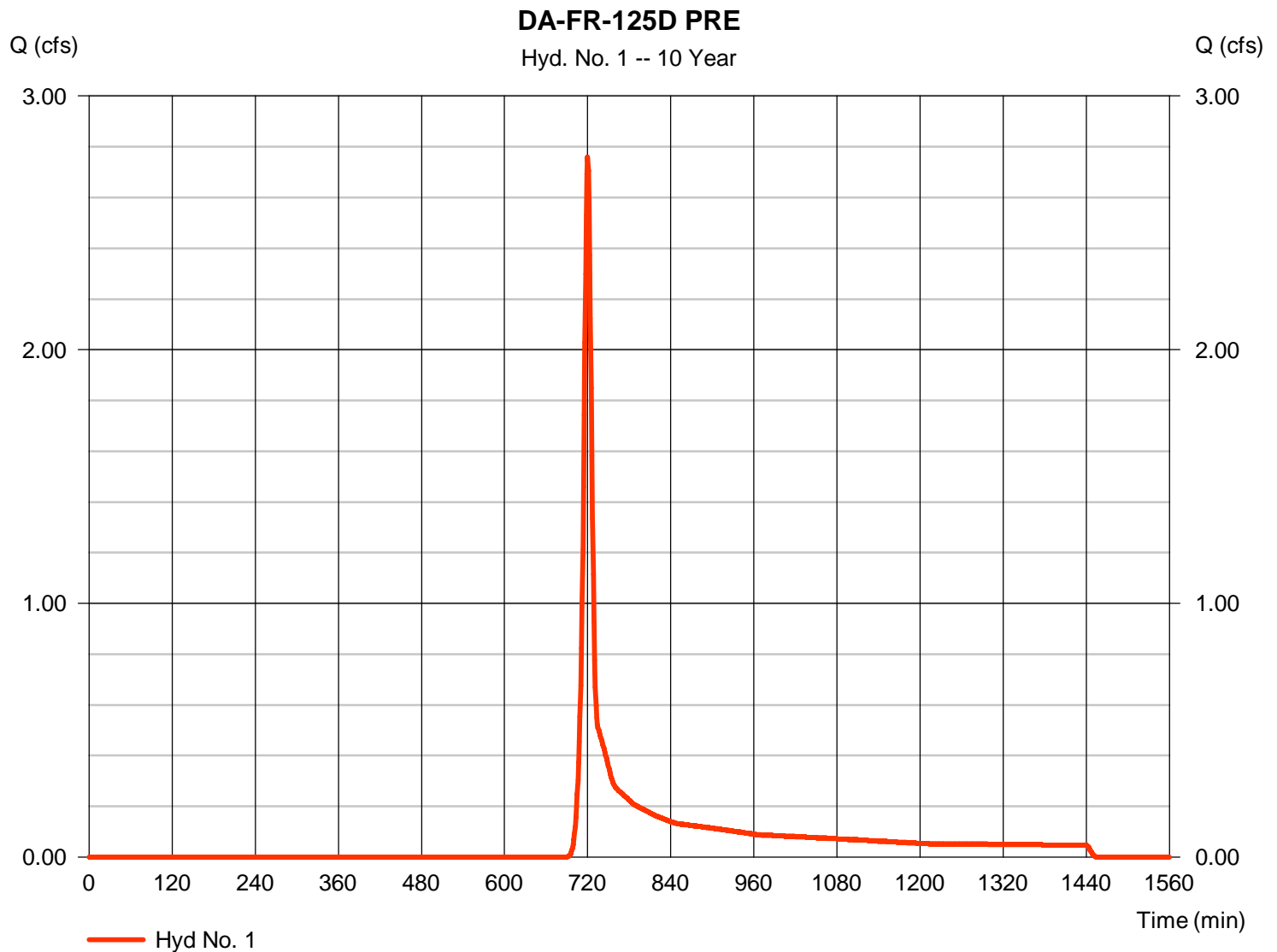
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-125D PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 2.760 cfs
Storm frequency	= 10 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 6,608 cuft
Drainage area	= 1.280 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 9.80 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.038 \times 82) + (1.239 \times 55)] / 1.280$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

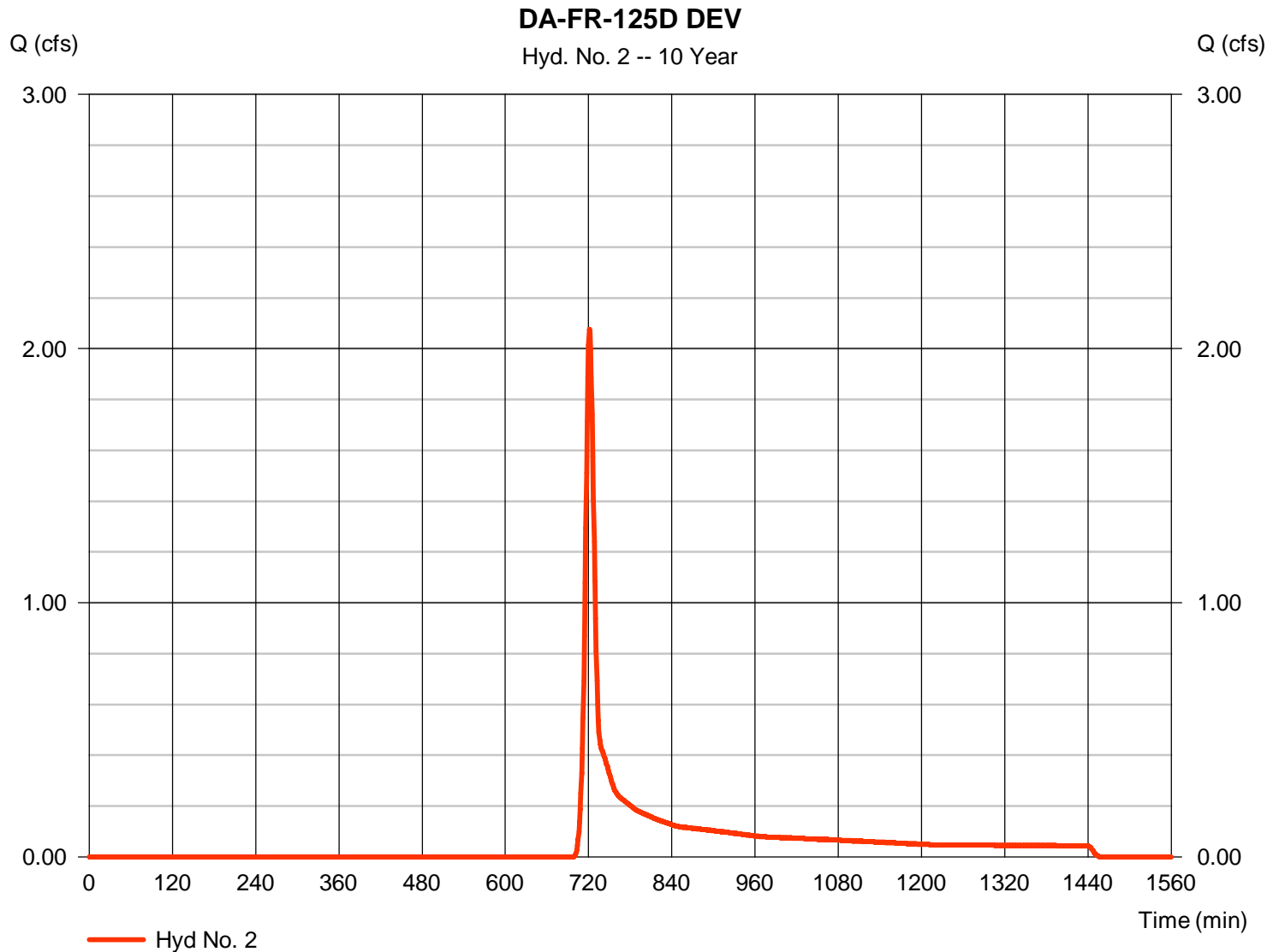
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-125D DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 2.076 cfs
Storm frequency	= 10 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 5,654 cuft
Drainage area	= 1.270 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.70 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.756 \times 48) + (0.038 \times 82) + (0.478 \times 58)] / 1.270$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

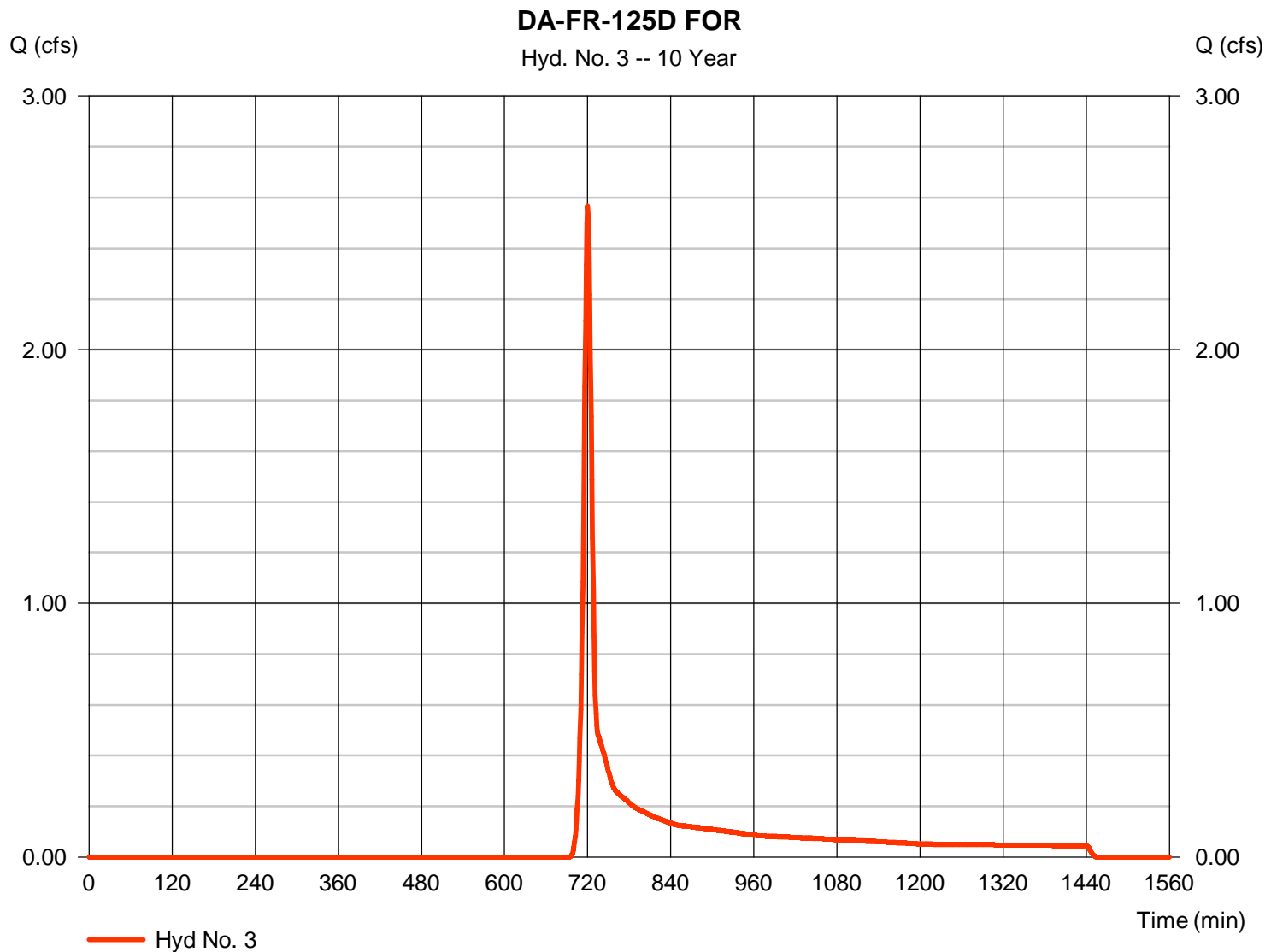
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-125D FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 2.565 cfs
Storm frequency	= 10 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 6,217 cuft
Drainage area	= 1.270 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 9.80 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.038 \times 82) + (1.234 \times 55)] / 1.270$



Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	-----
2	69.8703	13.1000	0.8658	-----
3	0.0000	0.0000	0.0000	-----
5	79.2597	14.6000	0.8369	-----
10	88.2351	15.5000	0.8279	-----
25	102.6072	16.5000	0.8217	-----
50	114.8193	17.2000	0.8199	-----
100	127.1596	17.8000	0.8186	-----

File name: SampleFHA.idf

$$\text{Intensity} = B / (Tc + D)^E$$

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5.69	4.61	3.89	3.38	2.99	2.69	2.44	2.24	2.07	1.93	1.81	1.70
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	6.57	5.43	4.65	4.08	3.65	3.30	3.02	2.79	2.59	2.42	2.27	2.15
10	7.24	6.04	5.21	4.59	4.12	3.74	3.43	3.17	2.95	2.77	2.60	2.46
25	8.25	6.95	6.03	5.34	4.80	4.38	4.02	3.73	3.48	3.26	3.07	2.91
50	9.04	7.65	6.66	5.92	5.34	4.87	4.49	4.16	3.88	3.65	3.44	3.25
100	9.83	8.36	7.30	6.50	5.87	5.36	4.94	4.59	4.29	4.03	3.80	3.60

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

[illegible]

DA-FR-126

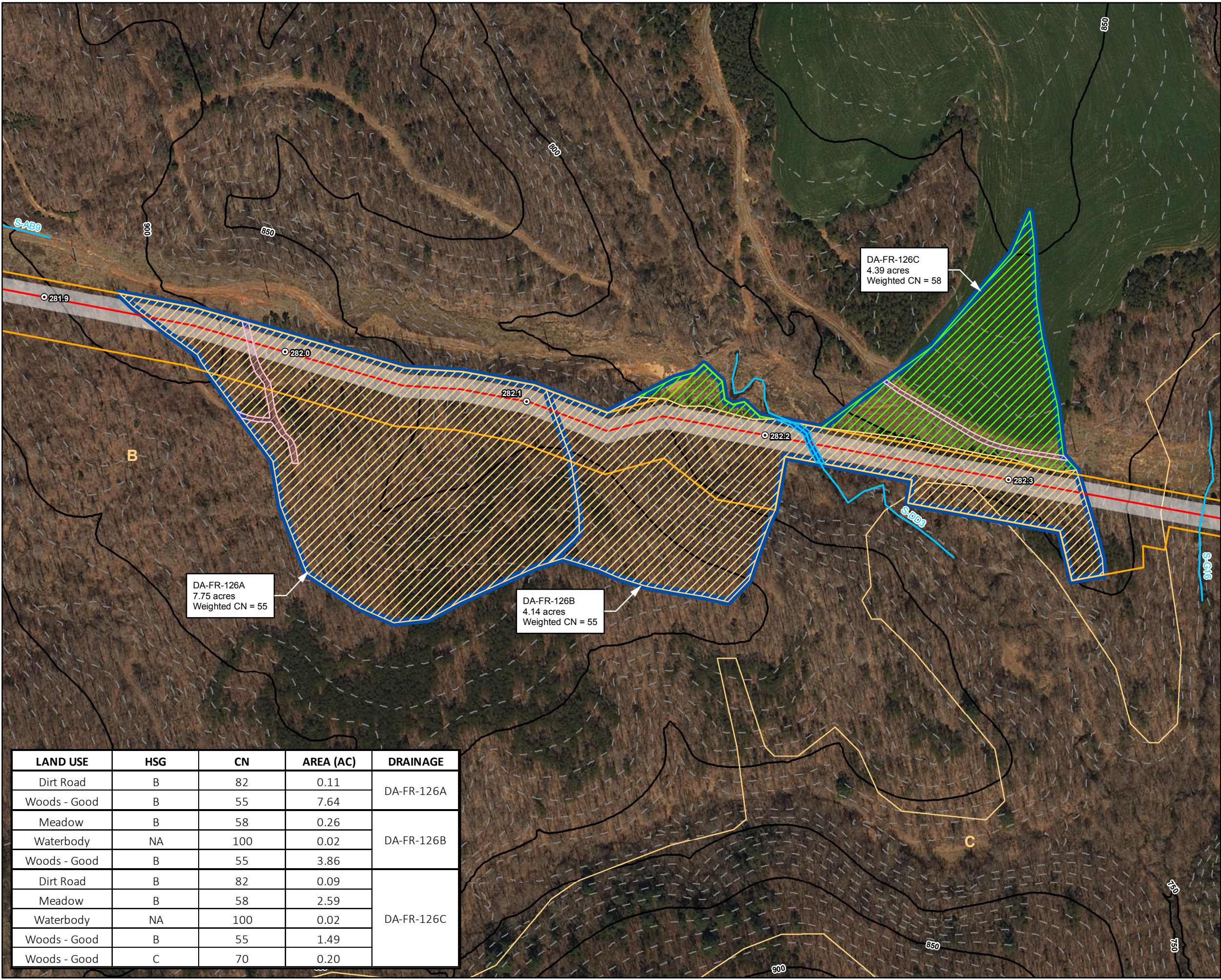
DA-FR-126 is located in a meadow and forested areas with hilly slopes and contains an existing gravel road. No new impervious area is proposed within DA-FR-126. The total phosphorus load reduction required for DA-FR-126 is -0.76 lb/yr. Multiple points of analysis were evaluated within DA-FR-126 to evaluate the effects on each receiving stream/channel following construction. Specifically, DA-FR-126 was sub-divided into three sub-drainage areas (sub areas A through C).

Stormwater quantity is met via the energy balance method for each of the three sub-areas DA-FR-126A, DA-FR-126B and DA-FR-126C. BMPs utilized in sub-area 126A included six water bars and associated soil amendments.

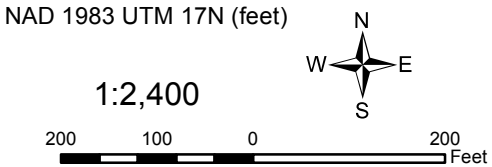
In addition, the Hydraflow Hydrograph's 10-year 24-hour peak discharge results indicate a reduction in flows ranging from 0.05 to 0.50 cfs for all drainage areas (as seen in table below).

Sub Area	Pre Peak Flow, 10-yr Q (cfs)	Post Peak Flow, Q 10-yr (cfs)	Flow differential
DA-FR-126A	10.63	10.58	-0.05
DA-FR-126B	6.78	6.30	-0.48
DA-FR-126C	8.27	7.77	-0.50

Figures and calculations for each of the sub-areas for DA-FR-126 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.



- Legend**
- Milepost
 - Delineated Stream
 - Existing 50' Contour
 - - Existing 10' Contour
 - Alignment Centerline
 - Limit of Disturbance
 - Permanent Right-of-Way
 - Dirt Road
 - Meadow
 - Waterbody
 - Woods
 - Drainage Area
 - Hydrologic Soil Groups



Mountain Valley Pipeline Project



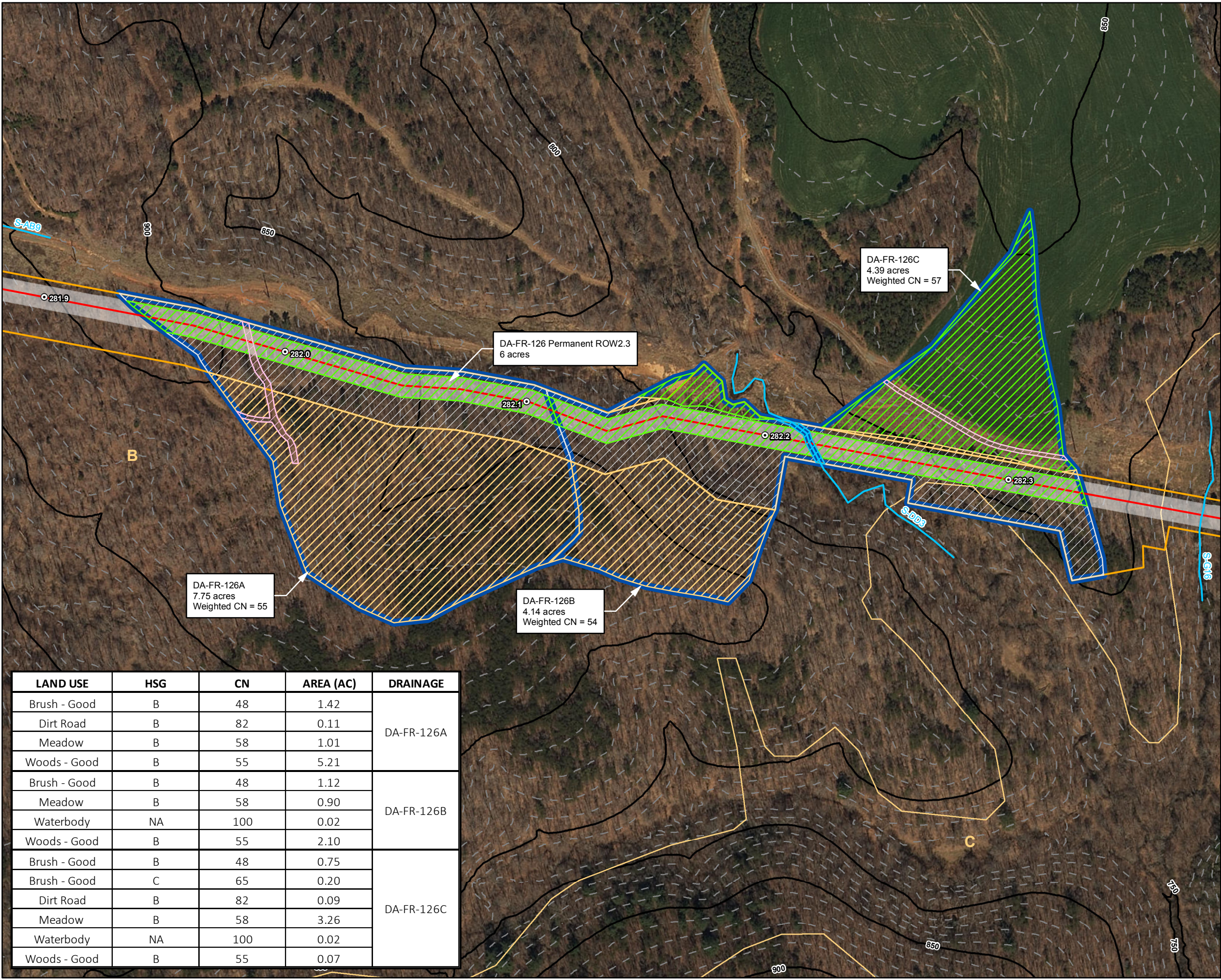
Pre-Construction Drainage Area Map
DA-FR-126
Spread 11

Figure 1
Franklin County, Virginia

September, 2017

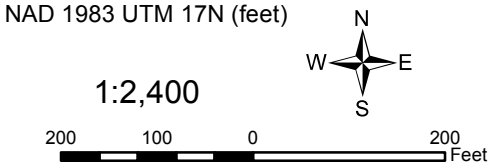
Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Elevation data derived from LiDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Dirt Road	B	82	0.11	DA-FR-126A
Woods - Good	B	55	7.64	
Meadow	B	58	0.26	DA-FR-126B
Waterbody	NA	100	0.02	
Woods - Good	B	55	3.86	DA-FR-126C
Dirt Road	B	82	0.09	
Meadow	B	58	2.59	
Waterbody	NA	100	0.02	
Woods - Good	B	55	1.49	
Woods - Good	C	70	0.20	



LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Brush - Good	B	48	1.42	DA-FR-126A
Dirt Road	B	82	0.11	
Meadow	B	58	1.01	
Woods - Good	B	55	5.21	DA-FR-126B
Brush - Good	B	48	1.12	
Meadow	B	58	0.90	
Waterbody	NA	100	0.02	
Woods - Good	B	55	2.10	DA-FR-126C
Brush - Good	B	48	0.75	
Brush - Good	C	65	0.20	
Dirt Road	B	82	0.09	
Meadow	B	58	3.26	
Waterbody	NA	100	0.02	
Woods - Good	B	55	0.07	

- Legend**
- Milepost
 - Delineated Stream
 - Existing 50' Contour
 - - Existing 10' Contour
 - Alignment Centerline
 - Limit of Disturbance
 - Permanent Right-of-Way
 - Brush
 - Dirt Road
 - Meadow
 - Waterbody
 - Woods
 - Drainage Area
 - Hydrologic Soil Groups



Mountain Valley Pipeline Project

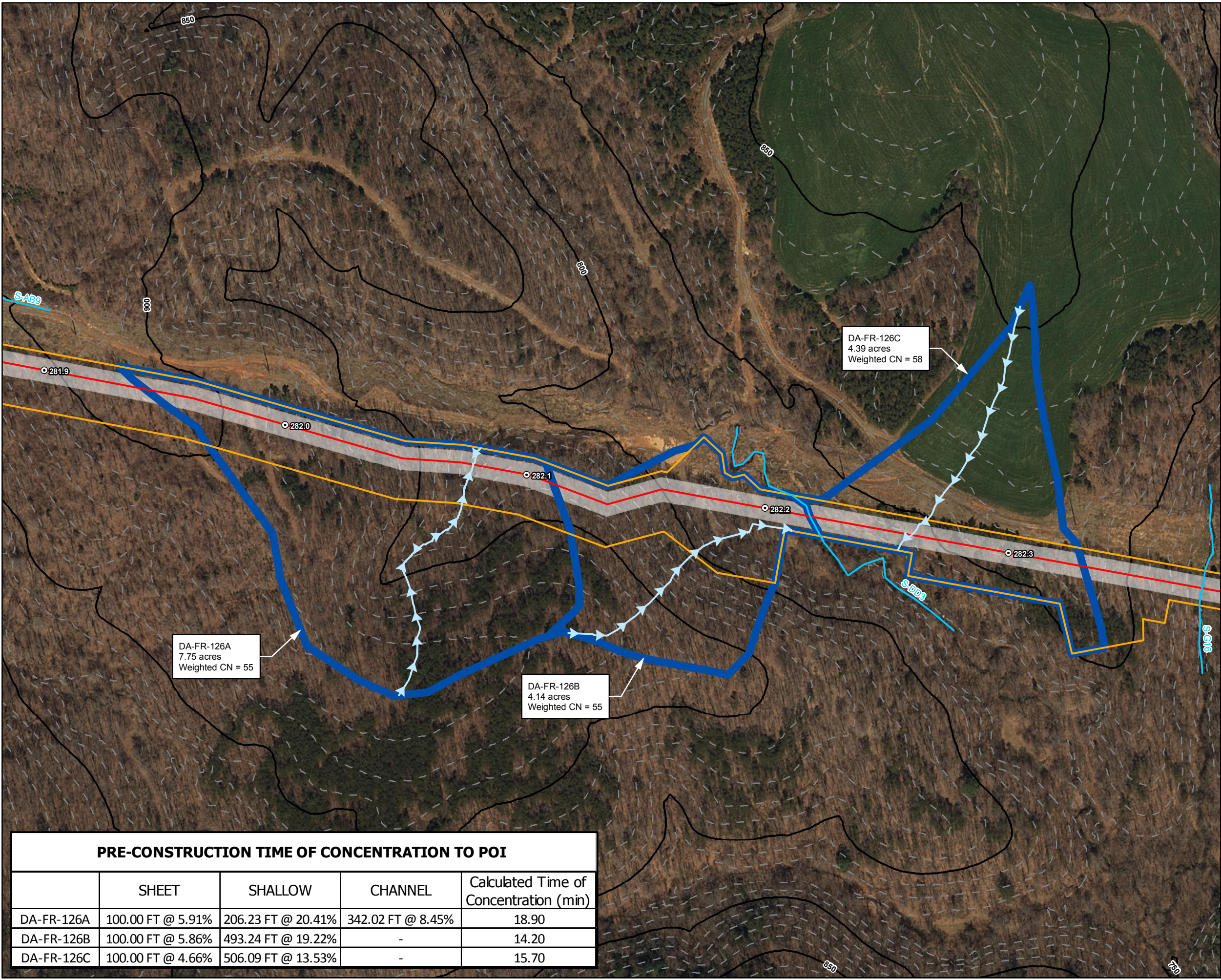


Post-Construction Drainage Area Map
DA-FR-126
Spread 11

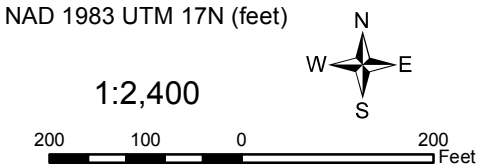
Figure 2
Franklin County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Elevation data derived from LiDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.



- Legend**
- Milepost
 - Delineated Stream
 - Existing 50' Contour
 - - Existing 10' Contour
 - Alignment Centerline
 - Limit of Disturbance
 - Permanent Right-of-Way
 - Time of Concentration
 - Drainage Area



Mountain Valley Pipeline Project

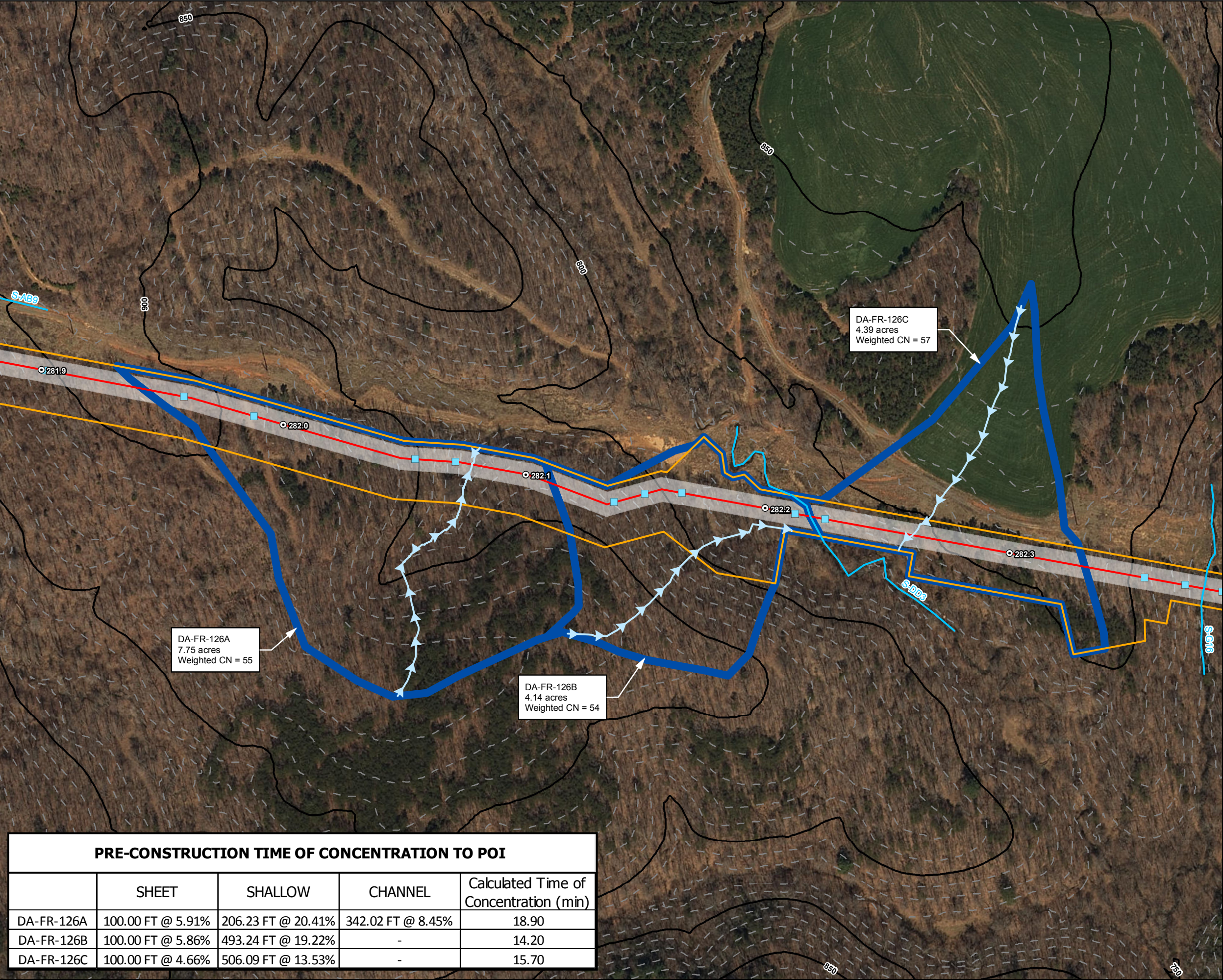


**Pre-Construction Drainage Area
and Time of Concentration
DA-FR-126
Spread 11**

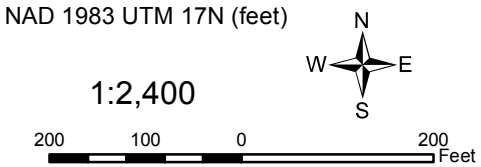
Figure 3
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Elevation data derived from LiDAR provided by EQT 2016.

PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI				
	SHEET	SHALLOW	CHANNEL	Calculated Time of Concentration (min)
DA-FR-126A	100.00 FT @ 5.91%	206.23 FT @ 20.41%	342.02 FT @ 8.45%	18.90
DA-FR-126B	100.00 FT @ 5.86%	493.24 FT @ 19.22%	-	14.20
DA-FR-126C	100.00 FT @ 4.66%	506.09 FT @ 13.53%	-	15.70



- Legend**
- Milepost
 - Permanent Waterbars
 - Delineated Stream
 - Existing 50' Contour
 - - Existing 10' Contour
 - Alignment Centerline
 - Limit of Disturbance
 - Permanent Right-of-Way
 - Time of Concentration
 - ▭ Drainage Area



Mountain Valley Pipeline Project



**Post-Construction Drainage Area
and Time of Concentration
DA-FR-126
Spread 11**

Figure 4
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Elevation data derived from LiDAR provided by EQT 2016.

PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI				
	SHEET	SHALLOW	CHANNEL	Calculated Time of Concentration (min)
DA-FR-126A	100.00 FT @ 5.91%	206.23 FT @ 20.41%	342.02 FT @ 8.45%	18.90
DA-FR-126B	100.00 FT @ 5.86%	493.24 FT @ 19.22%	-	14.20
DA-FR-126C	100.00 FT @ 4.66%	506.09 FT @ 13.53%	-	15.70

DEQ Virginia Runoff Reduction Method Re-Development Compliance Spreadsheet - Version 3.0

BMP Design Specifications List: 2013 Draft Stds & Specs

Site Summary - Linear Development Project***

Total Rainfall (in):	43
Total Disturbed Acreage:	2.36

Site Land Cover Summary

Pre-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	2.34	0.00	0.00	2.34	99
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.02	0.00	0.00	0.02	1
					2.36	100

Post-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	2.34	0.00	0.00	2.34	99
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.02	0.00	0.00	0.02	1
					2.36	100

* Forest/Open Space areas must be protected in accordance with the Virginia Runoff Reduction Method

Site Tv and Land Cover Nutrient Loads

	Final Post-Development (Post-ReDevelopment & New Impervious)	Post- ReDevelopment	Post- Development (New Impervious)	Adjusted Pre- ReDevelopment
Site Rv	0.04	0.04	--	0.04
Treatment Volume (ft ³)	324	324	--	324
TP Load (lb/yr)	0.20	0.20	--	0.20

Baseline TP Load (lb/yr): 0.9676* *Reduction below new development load limitation not required

Pre- ReDevelopment TP Load per acre (lb/acre/yr)	Final Post-Development TP Load per acre (lb/acre/yr)	Post-ReDevelopment TP Load per acre (lb/acre/yr)
0.09	0.09	0.09

Total TP Load Reduction Required (lb/yr)	-0.76	N/A***	N/A***
--	-------	--------	--------

***This is a linear development project

	Final Post-Development Load (Post-ReDevelopment & New Impervious)	Pre- ReDevelopment
TN Load (lb/yr)	1.46	1.46

Site Compliance Summary - ***Linear Development Project

Maximum % Reduction Required Below Pre-ReDevelopment Load	20%
--	-----

* Note: % Reduction will reduce post-development TP load to less than or equal to baseline load of 0.97 lb/yr (0.41 lb/ac/yr)
 [Post-Dev Reduction Requirement = Post-Dev TP load - baseline load of 0.97 lb/yr], baseline load = site area x 0.41 lb/ac/yr

Total Runoff Volume Reduction (ft ³)	0
--	---

Total TP Load Reduction Achieved (lb/yr)	0.00
Total TN Load Reduction Achieved (lb/yr)	0.00
Remaining Post Development TP Load (lb/yr)	0.20
Remaining TP Load Reduction (lb/yr) Required	0.00

**** TARGET TP REDUCTION EXCEEDED BY 0.76 LB/YEAR ****

**Reduction below new development load limitation not required*

DA-FR-126A

STORAGE VOLUME OF WATERBAR WITH SOIL COMPOST AMENDMENT AREA

Equations Used:

¹V_{gravel storage} = L*W*D_{gravel}*(40/100)

²V_{soil storage} = L*W*D_{soil}*(20/100)

³V_{surface storage} = [W*S*D^2]/[L*S*D^2]+[W*L*D]+[((2*S*D)^2*D)/3]

¹Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that gravel is made up of 40% voids.

²Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that soil compost amendment is made up of 20% voids.

³Equation #1 under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, but calculation also takes into account surface side slopes.

Inputs:	Depth of Gravel Layer, D _{gravel} (ft) =	0	
	Depth of Soil Amendment Area, D _{soil} (ft) =	1	Refer to Table 4.3 in VA DEQ Stormwater Design Specification No. 4; Note that compost amendment may not be necessary for HSG A/B soils
	Length of Waterbar Soil Amendment Area, L (ft) =	50	Assume max. length of 50' for waterbar soil amendment areas (i.e., limited to permanent ROW)
	Width of Waterbar Soil Amendment Area, W (ft) =	3	
	Inside Embankment Side Slopes, S (H:V) =	2	Assume 2H:1V surface side slopes for waterbars
	Number of Perm. Waterbars in Drainage Area, n =	6	
	Design Infiltration Rate, IR (in/hr) =	0.2	Min. rate of 0.30 in/hr for HSG A soils and 0.15-0.30 in/hr for HSG B soils (see Chap. 4, p. 4-30 in VA Stormwater Management Handbook Volume II (First Edition, 1999))
Calculations:	Surface Ponding Depth, D (ft) =	0.5	Assume 0.5' CFS height at the end of waterbars
	Total Storage Depth per BMP (ft) =	1.5	
	Surface Storage Volume per BMP (cf) =	102	
	Subsurface Storage Volume per BMP (cf) =	30	
	Total Storage Volume per BMP (cf) =	132	
	Total BMP Storage Volume in Drainage Area (cf) =	793	
	Calculated Infiltration Period per BMP (hr) =	53	

Depth-Storage Data				
Depth (ft)	Width (ft)	Length (ft)	Storage Volume per BMP (cf)	Storage Volume in Drainage Area (cf)
0	3	50	0	0
0.5	3	50	15	90
1	3	50	30	180
1.5	5	52	132	793
2	7	54	291	1748

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	1.056	7908
Developed Condition	0.837	7114
Pre-Developed (Forest) Condition	0.467	7908

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:	Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	0.837	≤	0.939
				OK	
	Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.837	≤	1.056
				OK	
	Check #3:	$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ --->	0.837	<u>shall not</u> be required to be ≤	0.519

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s n value of 0.011 was used.</p> <p><i>Sources:</i></p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

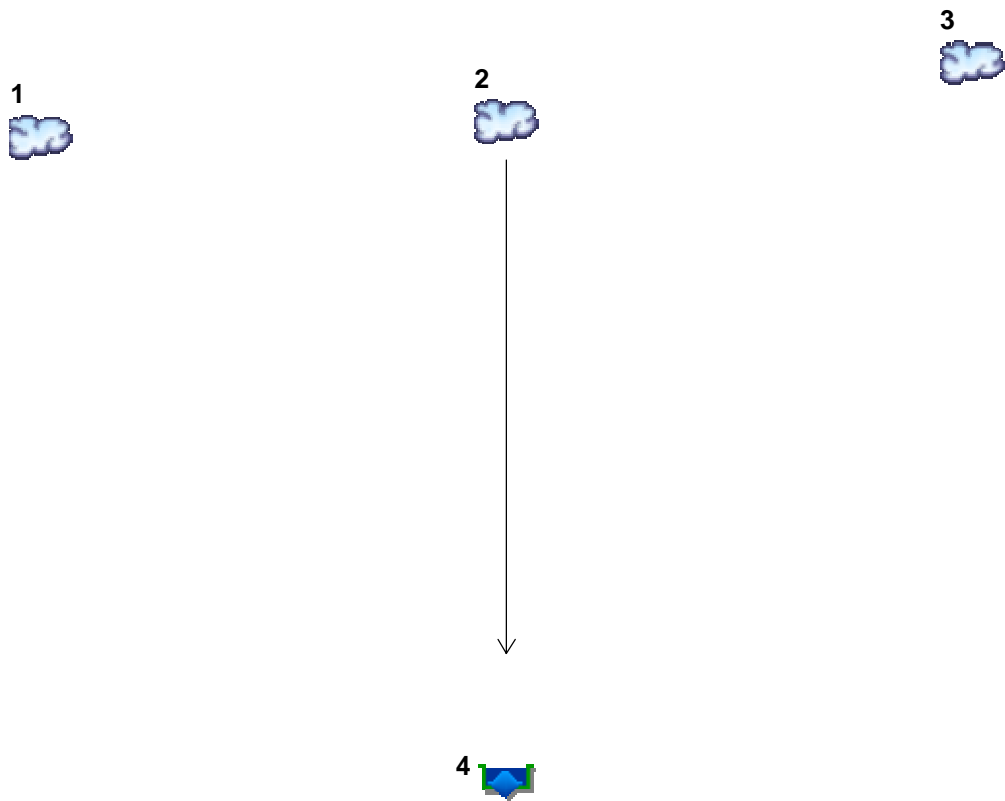
Table 2 – Manning's *n* Values for Open Channel Flow

Channel Type	Manning <i>n</i>		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's <i>n</i> value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar or grass channel. ² For the pre-developed condition (if applicable), a Manning's <i>n</i> value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), <i>Gravity Sanitary Sewer Design and Construction</i> , ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), <i>Open Channel Hydraulics</i> , McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

Hyd.	Origin	Description
1	SCS Runoff	DA-FR-126B PRE
2	SCS Runoff	DA-FR-126B DEV
3	SCS Runoff	DA-FR-126B FOR
4	Reservoir	WB Soil Amendments

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	1.056	1	730	7,908	-----	-----	-----	DA-FR-126B PRE
2	SCS Runoff	1.056	1	730	7,908	-----	-----	-----	DA-FR-126B DEV
3	SCS Runoff	0.467	1	793	7,908	-----	-----	-----	DA-FR-126B FOR
4	Reservoir	0.837	1	740	7,114	2	101.57	934	WB Soil Amendments
DA-FR-126A_Hydraflow.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

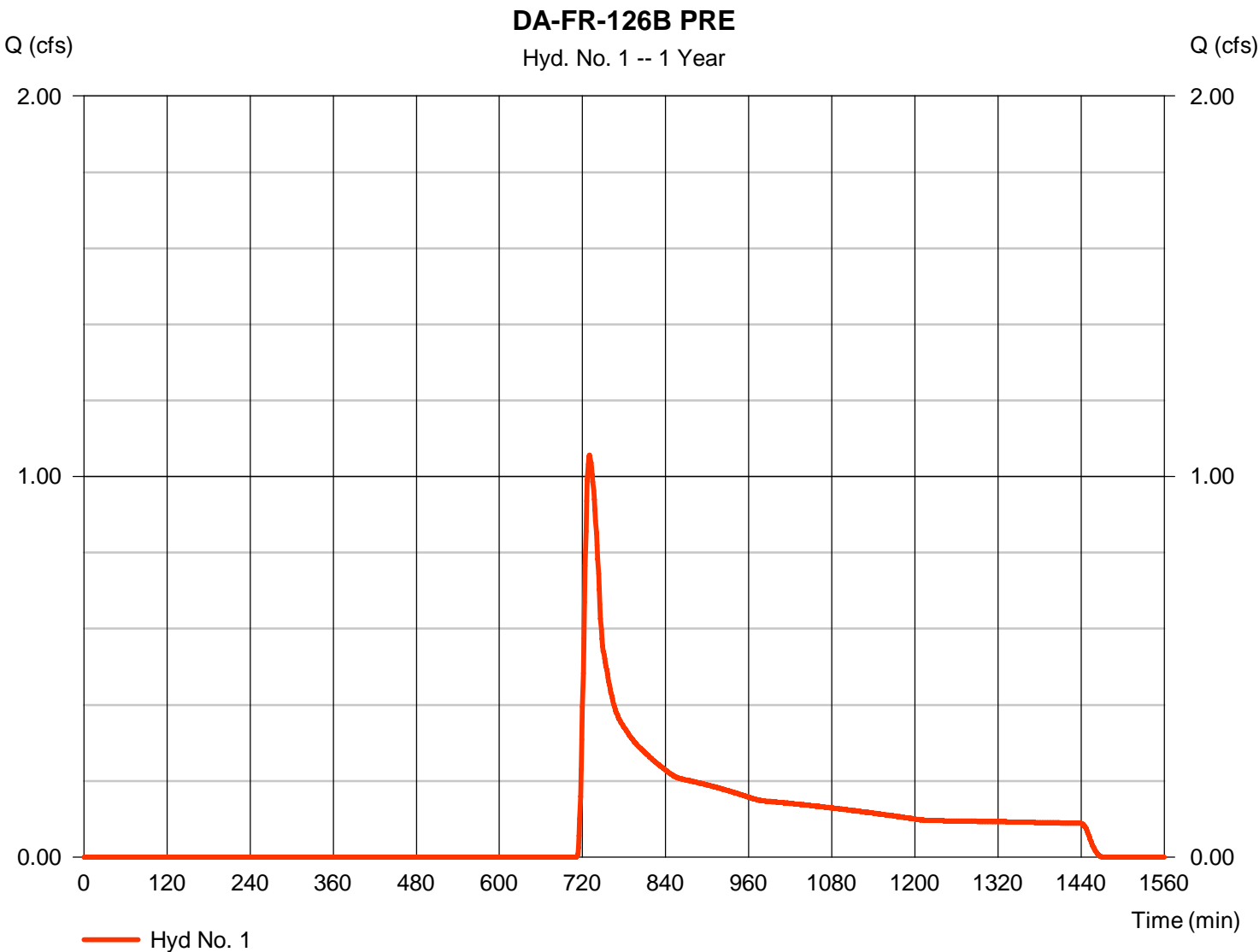
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-126B PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.056 cfs
Storm frequency	=	1 yrs	Time to peak	=	730 min
Time interval	=	1 min	Hyd. volume	=	7,908 cuft
Drainage area	=	7.750 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.90 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.112 x 82) + (7.642 x 55)] / 7.750



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-126B PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 5.91	0.00	0.00	
Travel Time (min)	= 12.95	+	0.00	+
			0.00	= 12.95
Shallow Concentrated Flow				
Flow length (ft)	= 206.23	0.00	0.00	
Watercourse slope (%)	= 20.41	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=7.29	0.00	0.00	
Travel Time (min)	= 0.47	+	0.00	+
			0.00	= 0.47
Channel Flow				
X sectional flow area (sqft)	= 0.13	0.00	0.00	
Wetted perimeter (ft)	= 6.51	0.00	0.00	
Channel slope (%)	= 8.45	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=1.05	0.00	0.00	
			0.00	
Flow length (ft)	({})342.0	0.0	0.0	
Travel Time (min)	= 5.43	+	0.00	+
			0.00	= 5.43
Total Travel Time, Tc				18.90 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

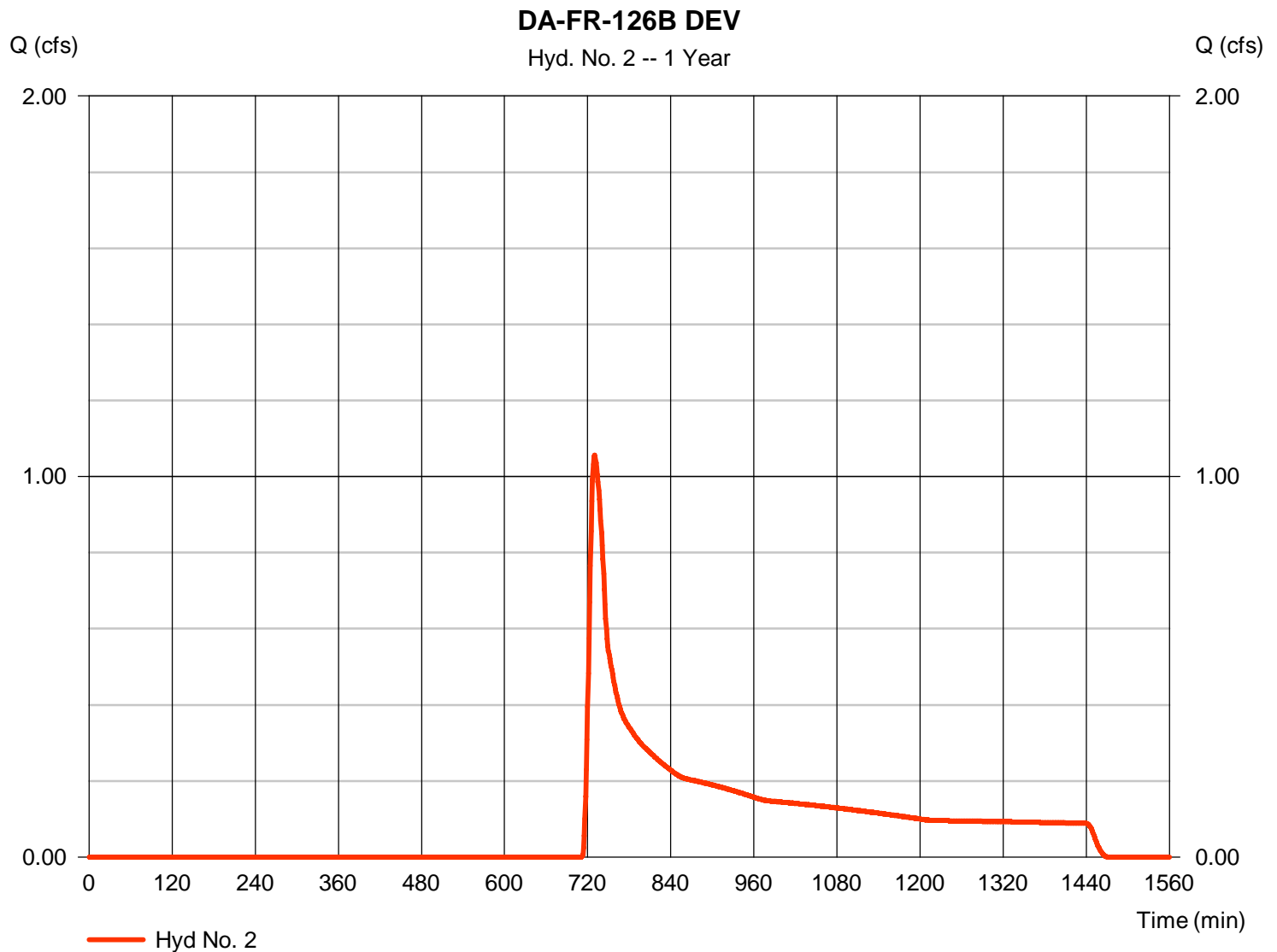
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-126B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 1.056 cfs
Storm frequency	= 1 yrs	Time to peak	= 730 min
Time interval	= 1 min	Hyd. volume	= 7,908 cuft
Drainage area	= 7.750 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.419 \times 48) + (0.112 \times 82) + (1.012 \times 58) + (5.210 \times 55)] / 7.750$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-126B DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 5.91	0.00	0.00	
Travel Time (min)	= 12.95	+	0.00	+
			0.00	= 12.95
Shallow Concentrated Flow				
Flow length (ft)	= 206.23	0.00	0.00	
Watercourse slope (%)	= 20.41	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=7.29	0.00	0.00	
Travel Time (min)	= 0.47	+	0.00	+
			0.00	= 0.47
Channel Flow				
X sectional flow area (sqft)	= 0.13	0.00	0.00	
Wetted perimeter (ft)	= 6.51	0.00	0.00	
Channel slope (%)	= 8.45	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=1.05	0.00	0.00	
			0.00	
Flow length (ft)	({})342.0	0.0	0.0	
Travel Time (min)	= 5.43	+	0.00	+
			0.00	= 5.43
Total Travel Time, Tc				18.90 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

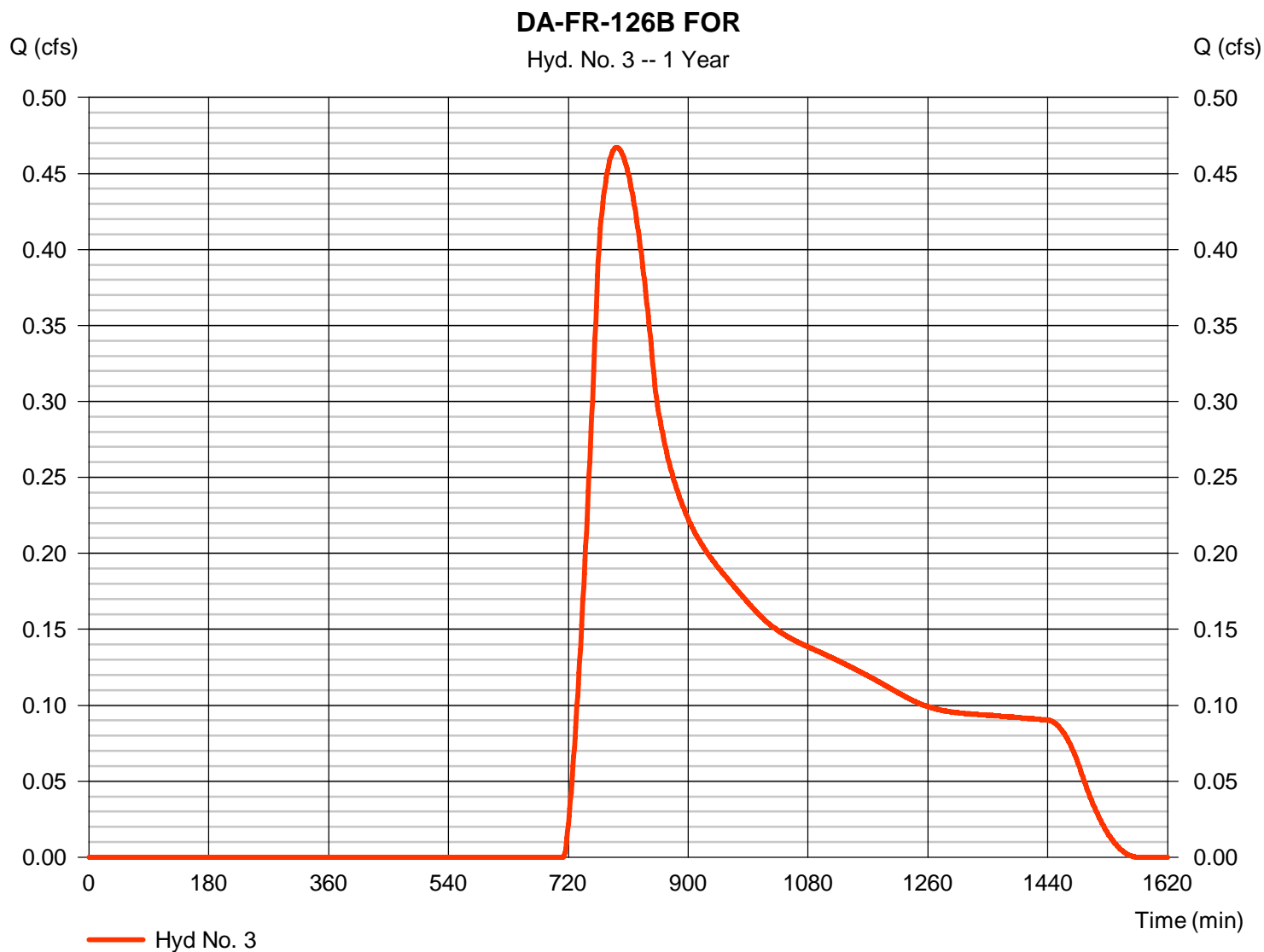
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-126B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 7.750 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.30 in
 Storm duration = 24 hrs

Peak discharge = 0.467 cfs
 Time to peak = 793 min
 Hyd. volume = 7,908 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 85.90 min
 Distribution = Type II
 Shape factor = 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-126B FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 5.91	0.00	0.00				
Travel Time (min)	= 12.95	+	0.00	+	0.00	=	12.95
Shallow Concentrated Flow							
Flow length (ft)	= 206.23	0.00	0.00				
Watercourse slope (%)	= 20.41	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=7.29	0.00	0.00				
Travel Time (min)	= 0.47	+	0.00	+	0.00	=	0.47
Channel Flow							
X sectional flow area (sqft)	= 0.13	0.00	0.00				
Wetted perimeter (ft)	= 6.51	0.00	0.00				
Channel slope (%)	= 8.45	0.00	0.00				
Manning's n-value	= 0.400	0.015	0.015				
Velocity (ft/s)	=0.08	0.00	0.00				
Flow length (ft)	(0)342.0	0.0	0.0				
Travel Time (min)	= 72.47	+	0.00	+	0.00	=	72.47
Total Travel Time, Tc				85.90 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

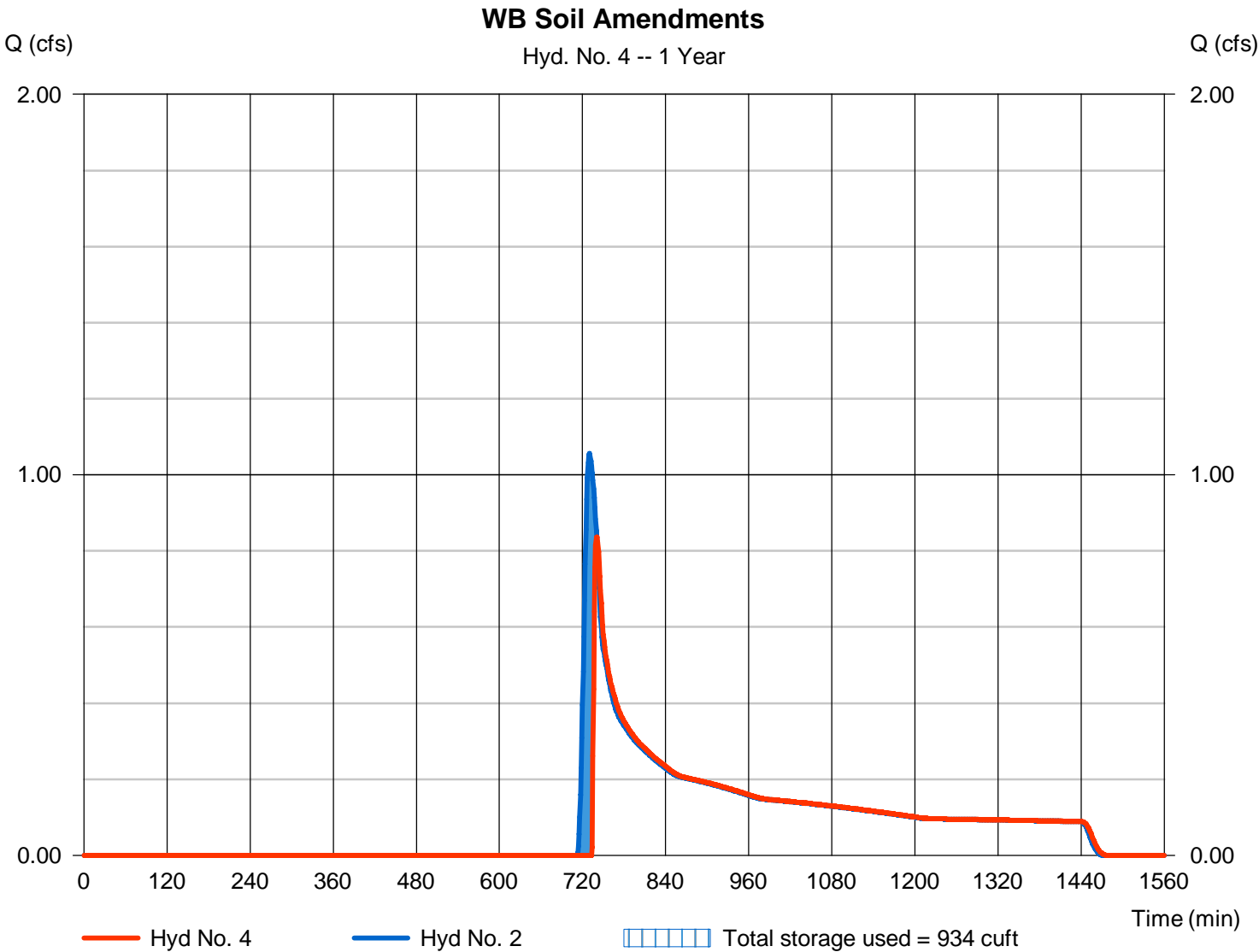
Monday, 08 / 21 / 2017

Hyd. No. 4

WB Soil Amendments

Hydrograph type	= Reservoir	Peak discharge	= 0.837 cfs
Storm frequency	= 1 yrs	Time to peak	= 740 min
Time interval	= 1 min	Hyd. volume	= 7,114 cuft
Inflow hyd. No.	= 2 - DA-FR-126B DEV	Max. Elevation	= 101.57 ft
Reservoir name	= Waterbar Soil Amendments	Max. Storage	= 934 cuft

Storage Indication method used.



Pond No. 1 - Waterbar Soil Amendments

Pond Data

Pond storage is based on user-defined values.

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	100.00	n/a	0	0
0.50	100.50	n/a	90	90
1.00	101.00	n/a	90	180
1.50	101.50	n/a	613	793
2.00	102.00	n/a	955	1,748

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)	= 12.00	0.00	0.00	0.00
Crest El. (ft)	= 101.50	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= Rect	---	---	---
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	100.00	---	---	---	---	0.00	---	---	---	---	---	0.000
0.05	9	100.05	---	---	---	---	0.00	---	---	---	---	---	0.000
0.10	18	100.10	---	---	---	---	0.00	---	---	---	---	---	0.000
0.15	27	100.15	---	---	---	---	0.00	---	---	---	---	---	0.000
0.20	36	100.20	---	---	---	---	0.00	---	---	---	---	---	0.000
0.25	45	100.25	---	---	---	---	0.00	---	---	---	---	---	0.000
0.30	54	100.30	---	---	---	---	0.00	---	---	---	---	---	0.000
0.35	63	100.35	---	---	---	---	0.00	---	---	---	---	---	0.000
0.40	72	100.40	---	---	---	---	0.00	---	---	---	---	---	0.000
0.45	81	100.45	---	---	---	---	0.00	---	---	---	---	---	0.000
0.50	90	100.50	---	---	---	---	0.00	---	---	---	---	---	0.000
0.55	99	100.55	---	---	---	---	0.00	---	---	---	---	---	0.000
0.60	108	100.60	---	---	---	---	0.00	---	---	---	---	---	0.000
0.65	117	100.65	---	---	---	---	0.00	---	---	---	---	---	0.000
0.70	126	100.70	---	---	---	---	0.00	---	---	---	---	---	0.000
0.75	135	100.75	---	---	---	---	0.00	---	---	---	---	---	0.000
0.80	144	100.80	---	---	---	---	0.00	---	---	---	---	---	0.000
0.85	153	100.85	---	---	---	---	0.00	---	---	---	---	---	0.000
0.90	162	100.90	---	---	---	---	0.00	---	---	---	---	---	0.000
0.95	171	100.95	---	---	---	---	0.00	---	---	---	---	---	0.000
1.00	180	101.00	---	---	---	---	0.00	---	---	---	---	---	0.000
1.05	241	101.05	---	---	---	---	0.00	---	---	---	---	---	0.000
1.10	303	101.10	---	---	---	---	0.00	---	---	---	---	---	0.000
1.15	364	101.15	---	---	---	---	0.00	---	---	---	---	---	0.000
1.20	425	101.20	---	---	---	---	0.00	---	---	---	---	---	0.000
1.25	486	101.25	---	---	---	---	0.00	---	---	---	---	---	0.000
1.30	548	101.30	---	---	---	---	0.00	---	---	---	---	---	0.000
1.35	609	101.35	---	---	---	---	0.00	---	---	---	---	---	0.000
1.40	670	101.40	---	---	---	---	0.00	---	---	---	---	---	0.000
1.45	732	101.45	---	---	---	---	0.00	---	---	---	---	---	0.000
1.50	793	101.50	---	---	---	---	0.00	---	---	---	---	---	0.000
1.55	889	101.55	---	---	---	---	0.45	---	---	---	---	---	0.447
1.60	984	101.60	---	---	---	---	1.26	---	---	---	---	---	1.264
1.65	1,080	101.65	---	---	---	---	2.32	---	---	---	---	---	2.322
1.70	1,175	101.70	---	---	---	---	3.57	---	---	---	---	---	3.574
1.75	1,271	101.75	---	---	---	---	5.00	---	---	---	---	---	4.995
1.80	1,366	101.80	---	---	---	---	6.57	---	---	---	---	---	6.567
1.85	1,462	101.85	---	---	---	---	8.27	---	---	---	---	---	8.275
1.90	1,557	101.90	---	---	---	---	10.11	---	---	---	---	---	10.11

Continues on next page...

Waterbar Soil Amendments

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
1.95	1,653	101.95	---	---	---	---	12.06	---	---	---	---	---	12.06
2.00	1,748	102.00	---	---	---	---	14.13	---	---	---	---	---	14.13

...End

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	2.084	1	729	11,691	-----	-----	-----	DA-FR-126B PRE
2	SCS Runoff	2.084	1	729	11,691	-----	-----	-----	DA-FR-126B DEV
3	SCS Runoff	0.808	1	784	11,691	-----	-----	-----	DA-FR-126B FOR
4	Reservoir	1.946	1	733	10,898	2	101.63	1,046	WB Soil Amendments
DA-FR-126A_Hydraflow.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

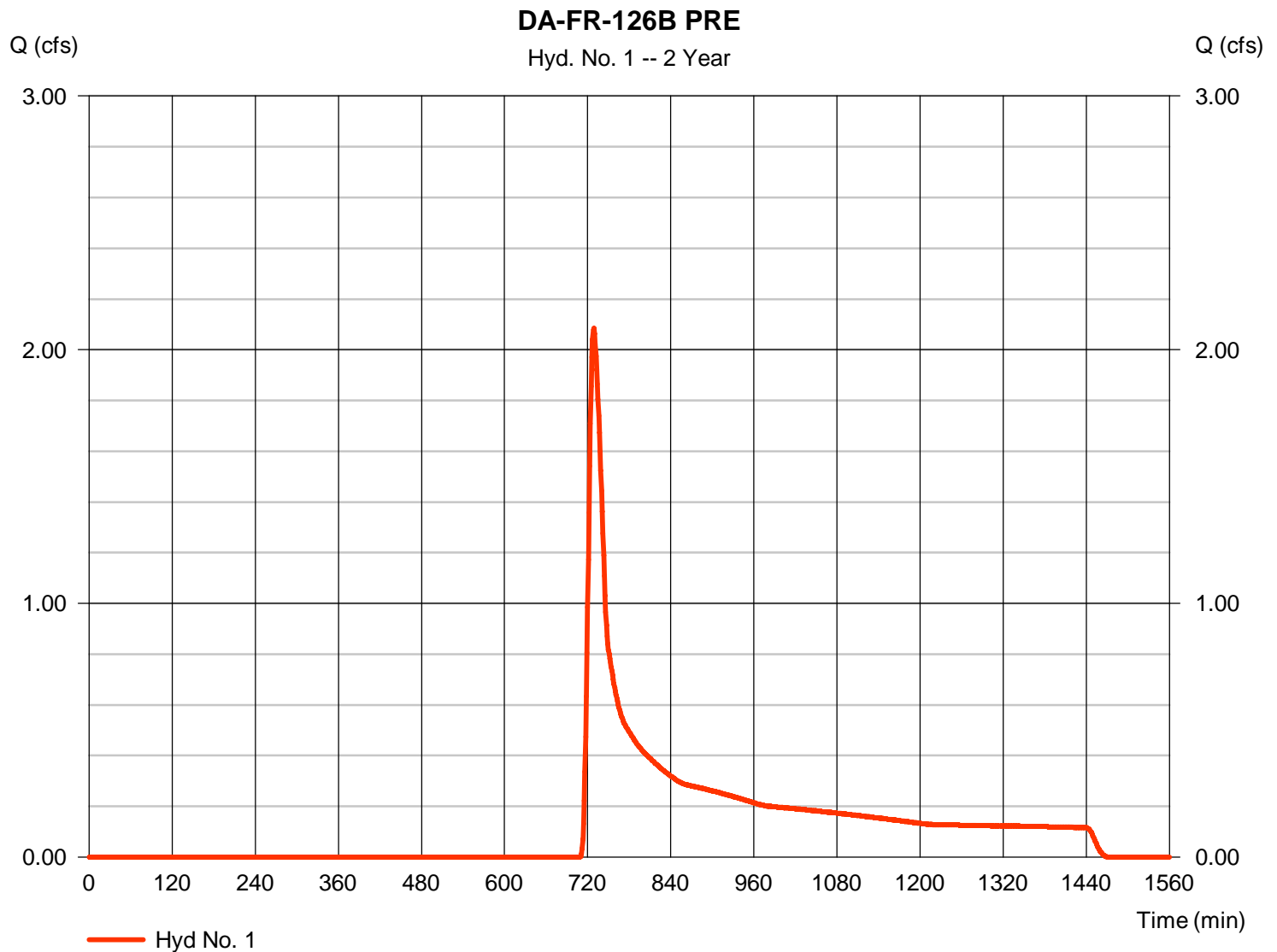
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-126B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 2.084 cfs
Storm frequency	= 2 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 11,691 cuft
Drainage area	= 7.750 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.90 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.112 \times 82) + (7.642 \times 55)] / 7.750$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

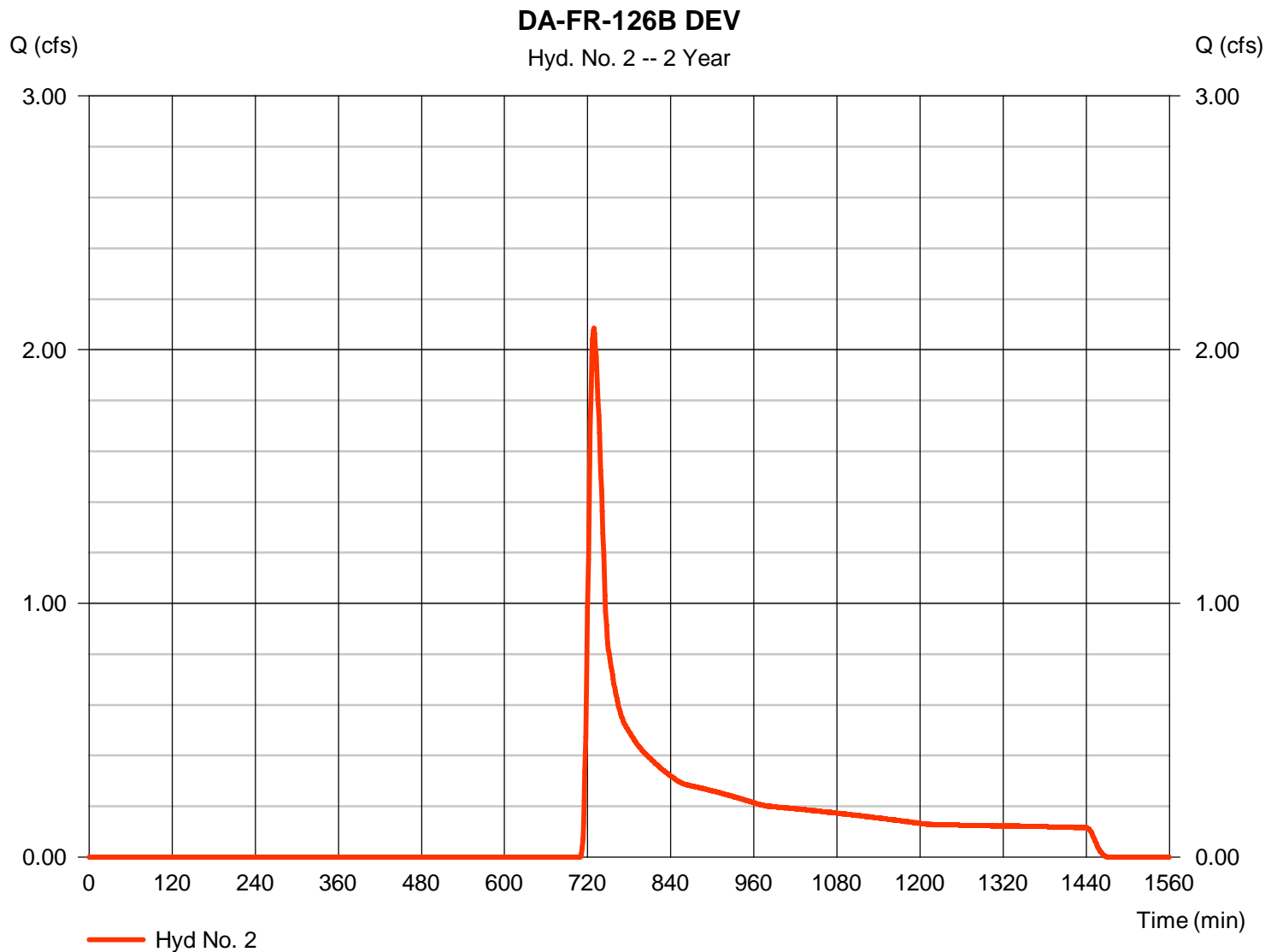
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-126B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 2.084 cfs
Storm frequency	= 2 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 11,691 cuft
Drainage area	= 7.750 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.90 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.419 \times 48) + (0.112 \times 82) + (1.012 \times 58) + (5.210 \times 55)] / 7.750$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

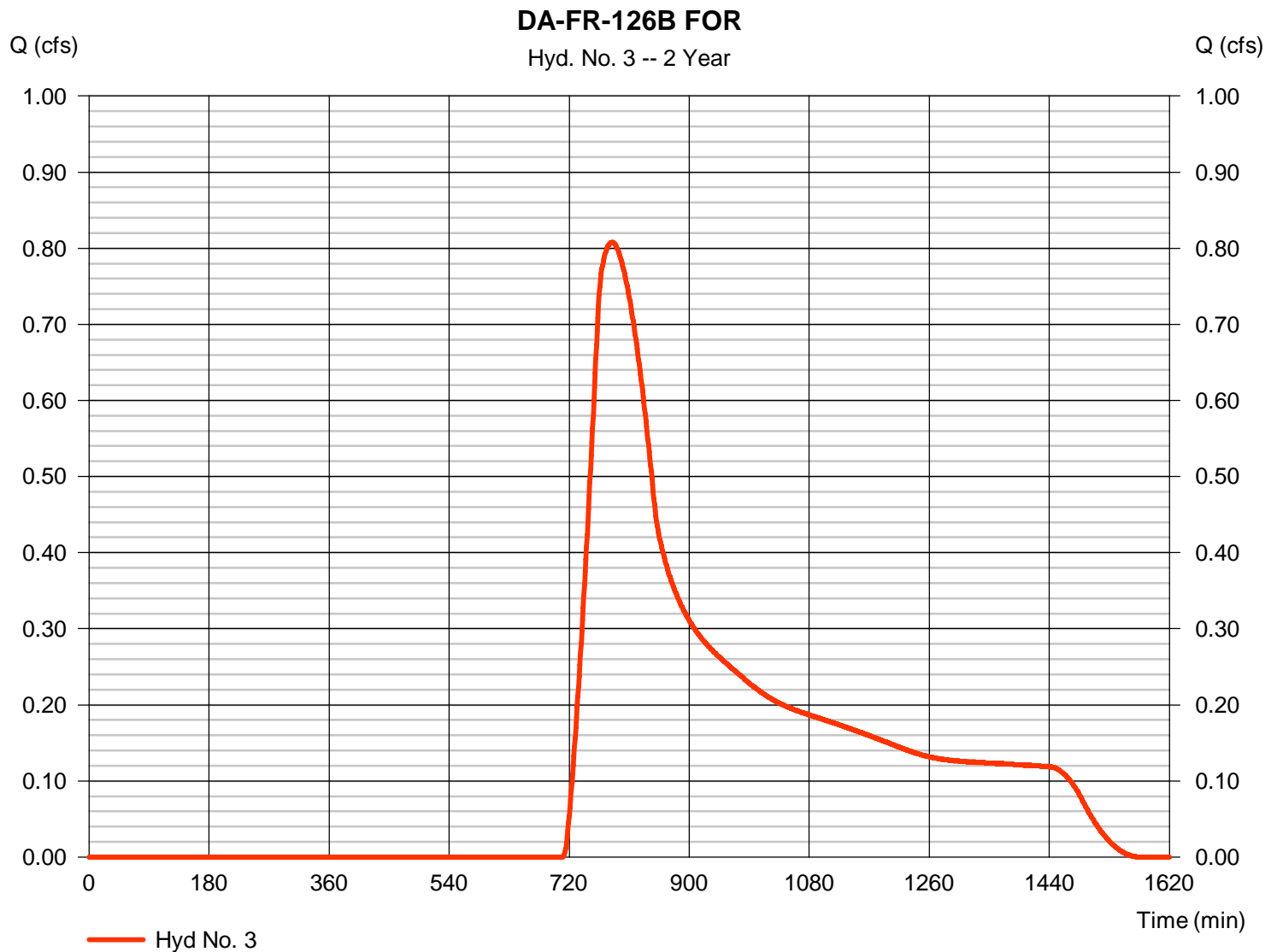
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-126B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 7.750 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 0.808 cfs
 Time to peak = 784 min
 Hyd. volume = 11,691 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 85.90 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

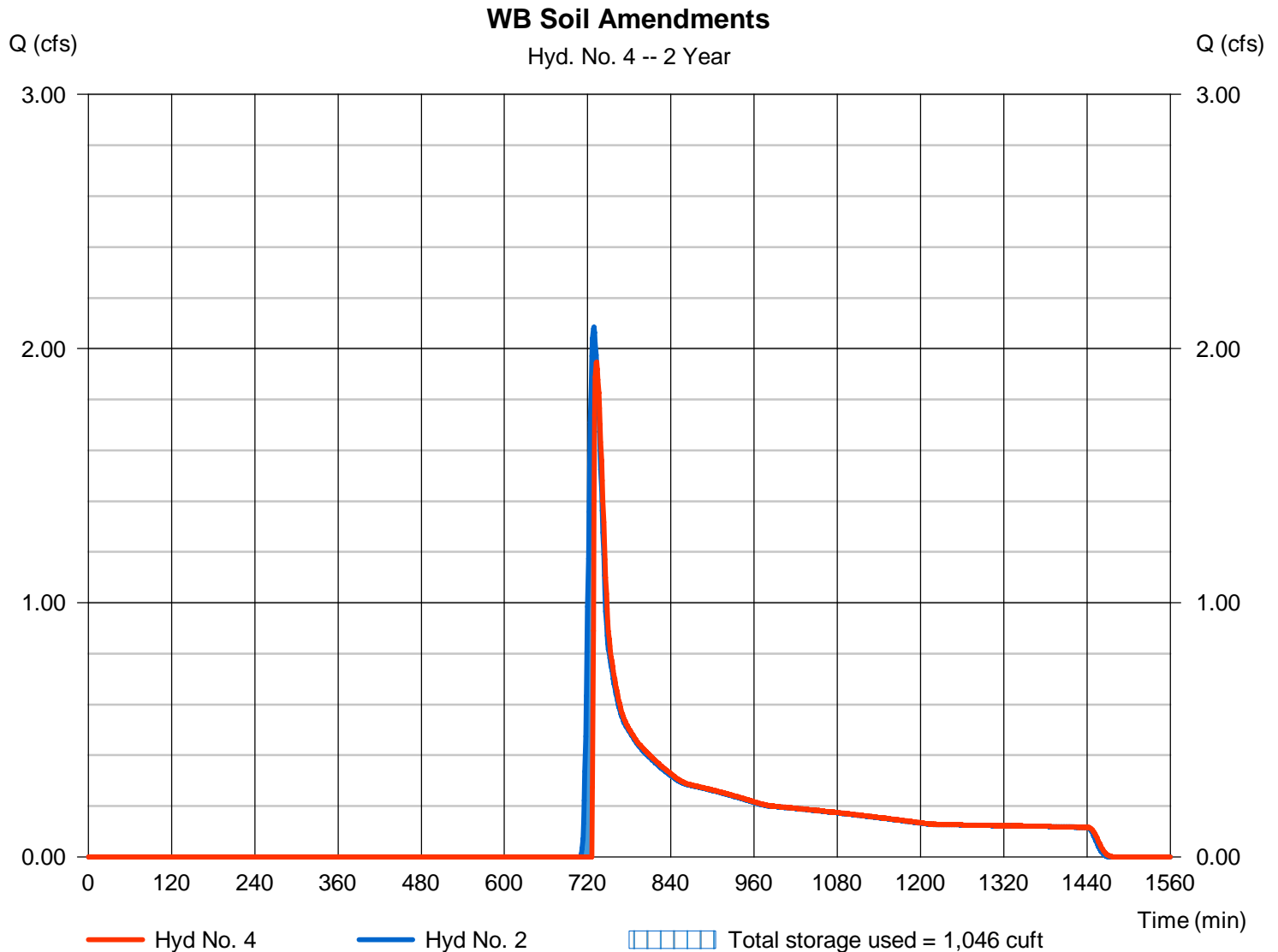
Monday, 08 / 21 / 2017

Hyd. No. 4

WB Soil Amendments

Hydrograph type	= Reservoir	Peak discharge	= 1.946 cfs
Storm frequency	= 2 yrs	Time to peak	= 733 min
Time interval	= 1 min	Hyd. volume	= 10,898 cuft
Inflow hyd. No.	= 2 - DA-FR-126B DEV	Max. Elevation	= 101.63 ft
Reservoir name	= Waterbar Soil Amendments	Max. Storage	= 1,046 cuft

Storage Indication method used.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	10.63	1	726	37,937	-----	-----	-----	DA-FR-126B PRE
2	SCS Runoff	10.63	1	726	37,937	-----	-----	-----	DA-FR-126B DEV
3	SCS Runoff	3.717	1	769	37,937	-----	-----	-----	DA-FR-126B FOR
4	Reservoir	10.58	1	727	37,144	2	101.91	1,580	WB Soil Amendments
DA-FR-126A_Hydraflow.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

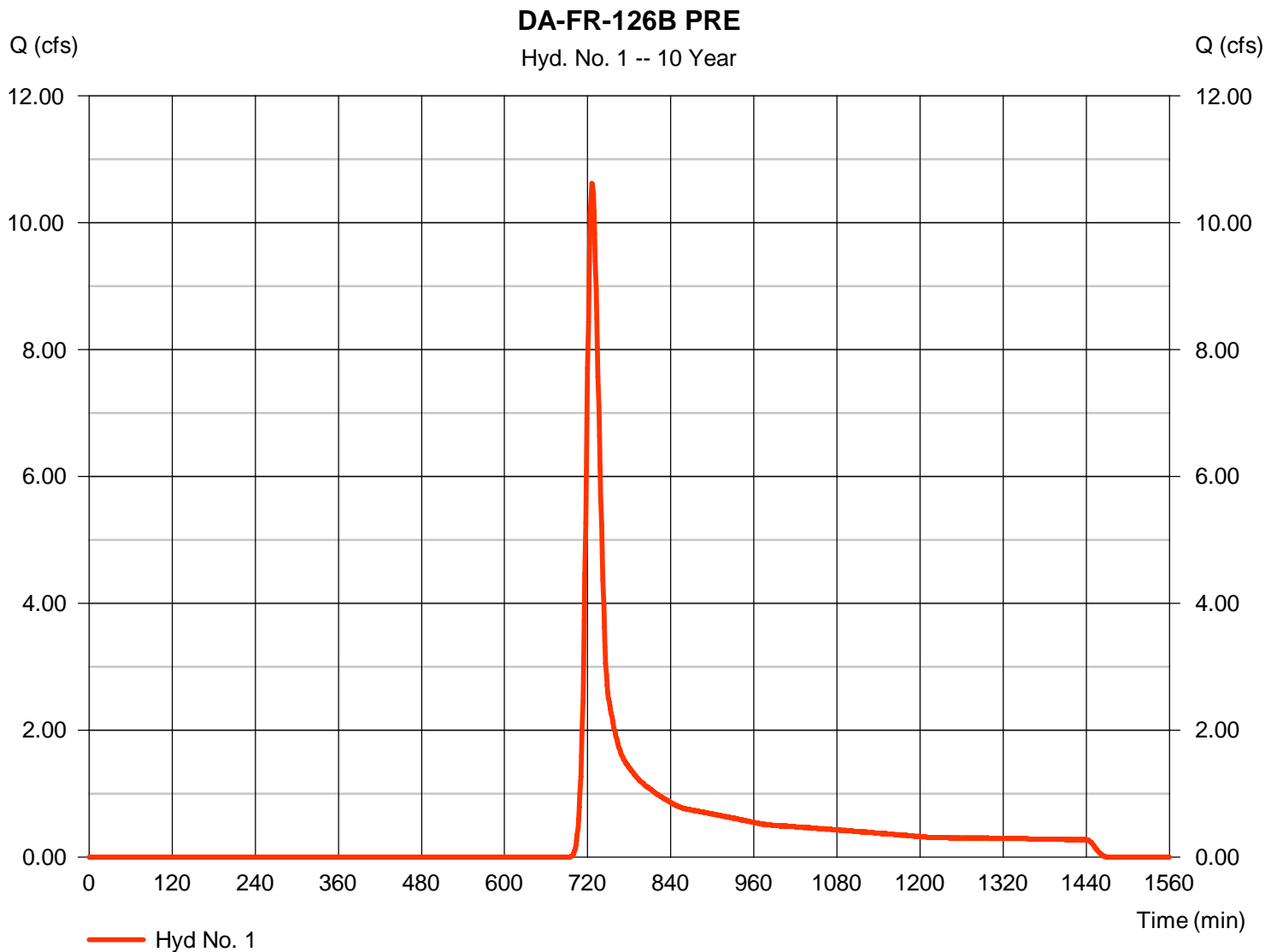
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-126B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 10.63 cfs
Storm frequency	= 10 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 37,937 cuft
Drainage area	= 7.750 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.90 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.112 \times 82) + (7.642 \times 55)] / 7.750$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

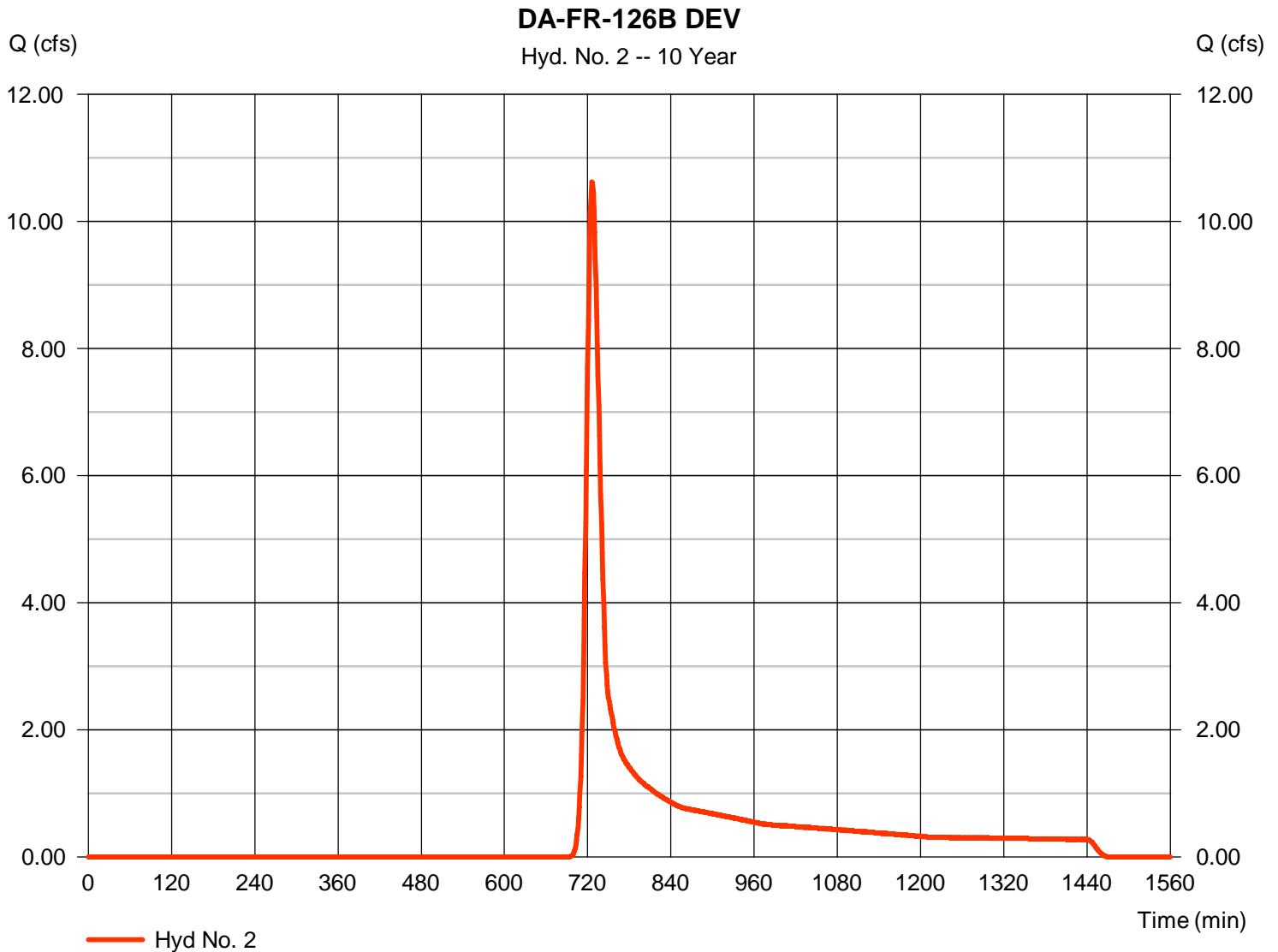
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-126B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 10.63 cfs
Storm frequency	= 10 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 37,937 cuft
Drainage area	= 7.750 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.90 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.419 \times 48) + (0.112 \times 82) + (1.012 \times 58) + (5.210 \times 55)] / 7.750$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

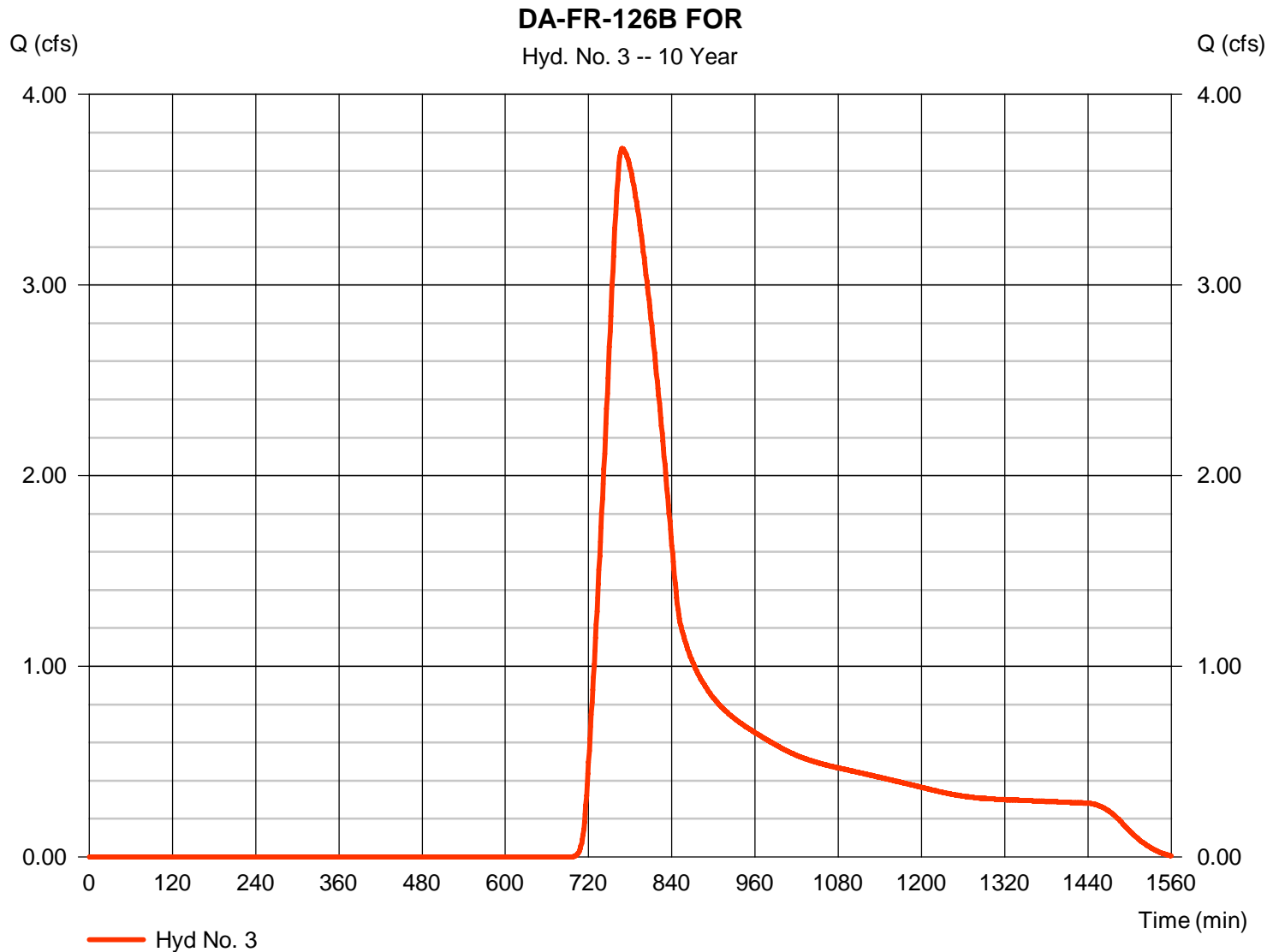
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-126B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 7.750 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 3.717 cfs
 Time to peak = 769 min
 Hyd. volume = 37,937 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 85.90 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

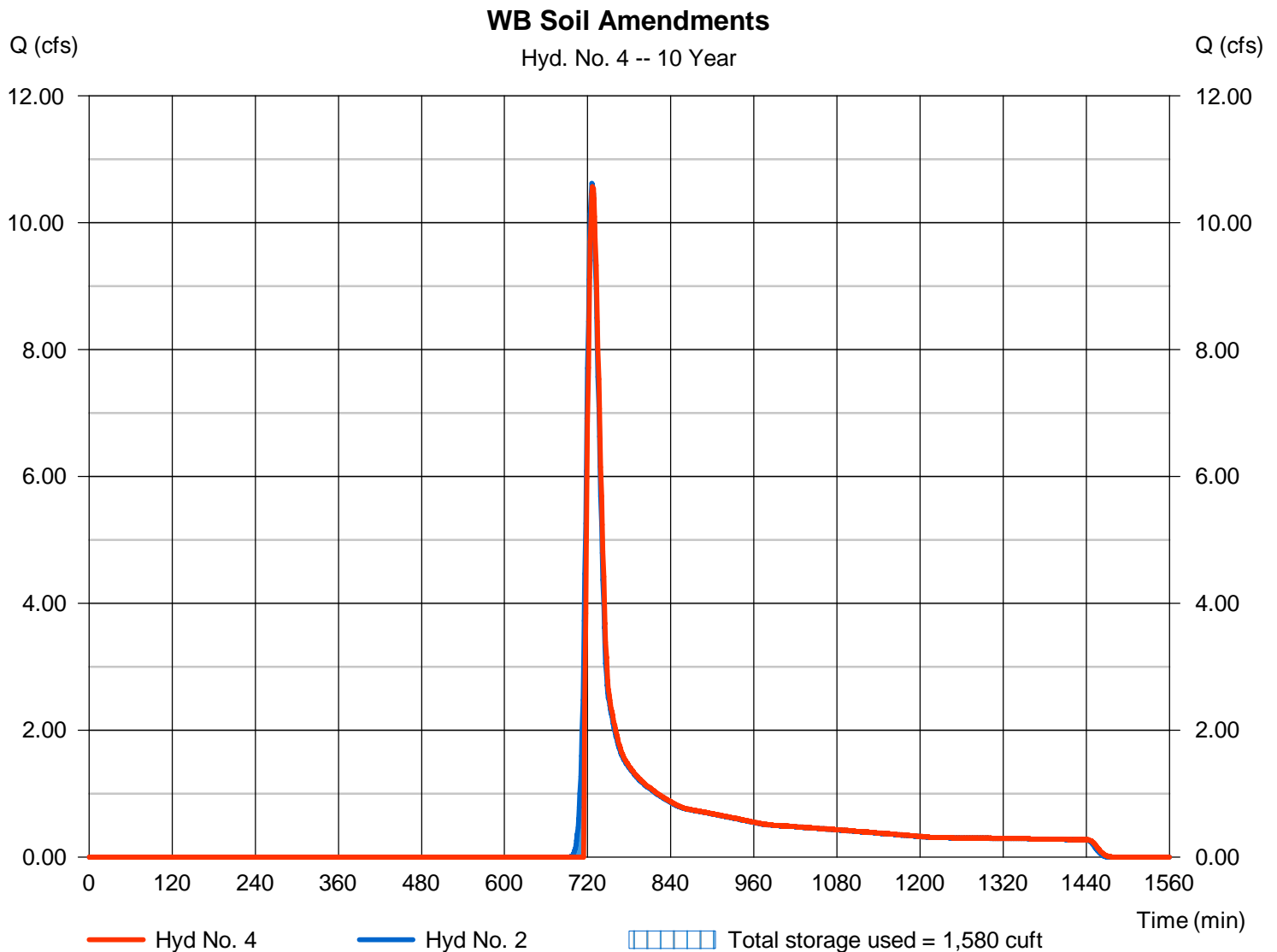
Monday, 08 / 21 / 2017

Hyd. No. 4

WB Soil Amendments

Hydrograph type	= Reservoir	Peak discharge	= 10.58 cfs
Storm frequency	= 10 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 37,144 cuft
Inflow hyd. No.	= 2 - DA-FR-126B DEV	Max. Elevation	= 101.91 ft
Reservoir name	= Waterbar Soil Amendments	Max. Storage	= 1,580 cuft

Storage Indication method used.



Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	-----
2	69.8703	13.1000	0.8658	-----
3	0.0000	0.0000	0.0000	-----
5	79.2597	14.6000	0.8369	-----
10	88.2351	15.5000	0.8279	-----
25	102.6072	16.5000	0.8217	-----
50	114.8193	17.2000	0.8199	-----
100	127.1596	17.8000	0.8186	-----

File name: SampleFHA.idf

$$\text{Intensity} = B / (T_c + D)^E$$

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5.69	4.61	3.89	3.38	2.99	2.69	2.44	2.24	2.07	1.93	1.81	1.70
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	6.57	5.43	4.65	4.08	3.65	3.30	3.02	2.79	2.59	2.42	2.27	2.15
10	7.24	6.04	5.21	4.59	4.12	3.74	3.43	3.17	2.95	2.77	2.60	2.46
25	8.25	6.95	6.03	5.34	4.80	4.38	4.02	3.73	3.48	3.26	3.07	2.91
50	9.04	7.65	6.66	5.92	5.34	4.87	4.49	4.16	3.88	3.65	3.44	3.25
100	9.83	8.36	7.30	6.50	5.87	5.36	4.94	4.59	4.29	4.03	3.80	3.60

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

[illegible]

DA-FR-126B

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.683	4224
Developed Condition	0.527	3786
Pre-Developed (Forest) Condition	0.683	4224

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	0.527	\leq	0.610
			N/A - See Check #3	
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.527	\leq	0.683
			N/A - See Check #3	
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ --->	0.527	<u>shall not</u> be required to be \leq	0.762

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</p> <p>For Paved Road land surface types a Manning’s n value of 0.011 was used.</p> <p><i>Sources:</i></p> <p>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</p> <p>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</p>	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-126B PRE
2	SCS Runoff	DA-FR-126B DEV
3	SCS Runoff	DA-FR-126B FOR

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	0.683	1	726	4,224	-----	-----	-----	DA-FR-126B PRE
2	SCS Runoff	0.527	1	727	3,786	-----	-----	-----	DA-FR-126B DEV
3	SCS Runoff	0.683	1	726	4,224	-----	-----	-----	DA-FR-126B FOR
DA-FR-126B_Hydraflow.gpw					Return Period: 1 Year			Thursday, 08 / 31 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

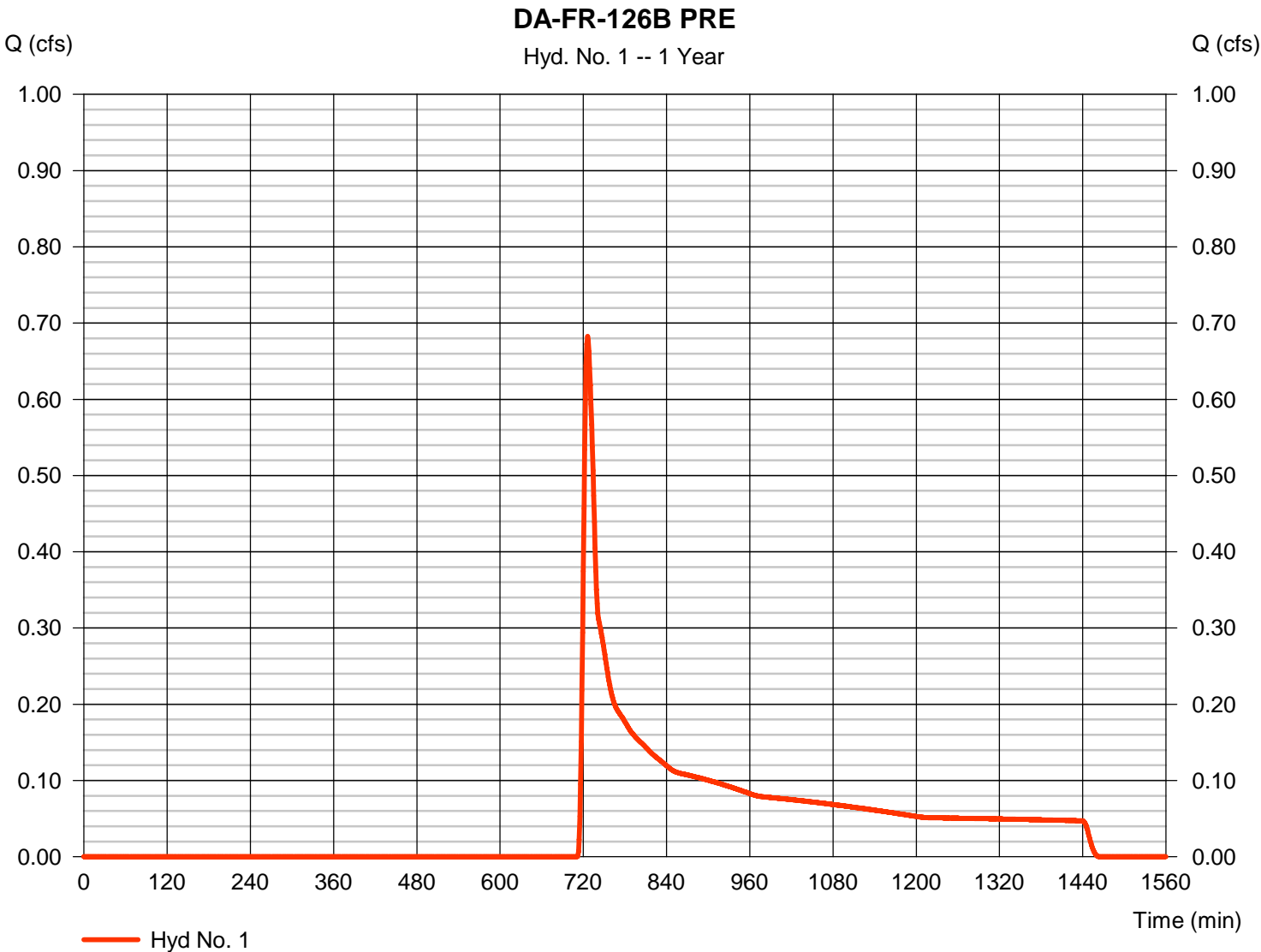
Thursday, 08 / 31 / 2017

Hyd. No. 1

DA-FR-126B PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.683 cfs
Storm frequency	=	1 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	4,224 cuft
Drainage area	=	4.140 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	14.20 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.258 x 58) + (0.021 x 100) + (3.858 x 55)] / 4.140



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-126B PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	3.70	3.70				
Land slope (%)	= 5.86	0.00	0.00				
Travel Time (min)	= 12.99	+	0.00	+	0.00	=	12.99
Shallow Concentrated Flow							
Flow length (ft)	= 493.24	0.00	0.00				
Watercourse slope (%)	= 19.22	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=7.07	0.00	0.00				
Travel Time (min)	= 1.16	+	0.00	+	0.00	=	1.16
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				14.20 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

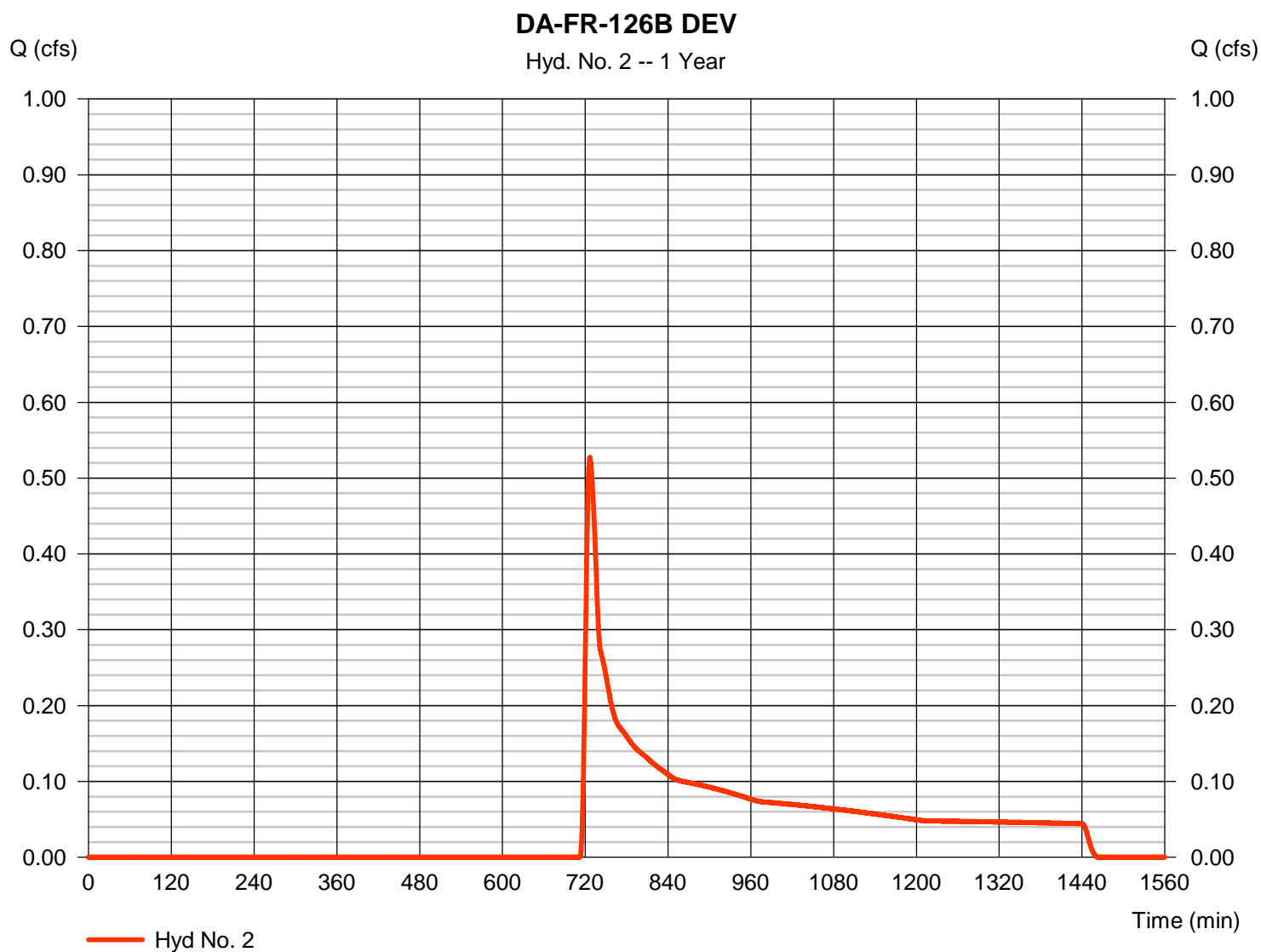
Thursday, 08 / 31 / 2017

Hyd. No. 2

DA-FR-126B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.527 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 3,786 cuft
Drainage area	= 4.140 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.20 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.120 \times 48) + (0.895 \times 58) + (0.021 \times 100) + (2.101 \times 55)] / 4.140$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-126B DEV

Description	A	B	C	Totals
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 5.86	0.00	0.00	
Travel Time (min)	= 12.99	+	0.00	+
			0.00	= 12.99
Shallow Concentrated Flow				
Flow length (ft)	= 493.24	0.00	0.00	
Watercourse slope (%)	= 19.22	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=7.07	0.00	0.00	
Travel Time (min)	= 1.16	+	0.00	+
			0.00	= 1.16
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	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Total Travel Time, Tc				14.20 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

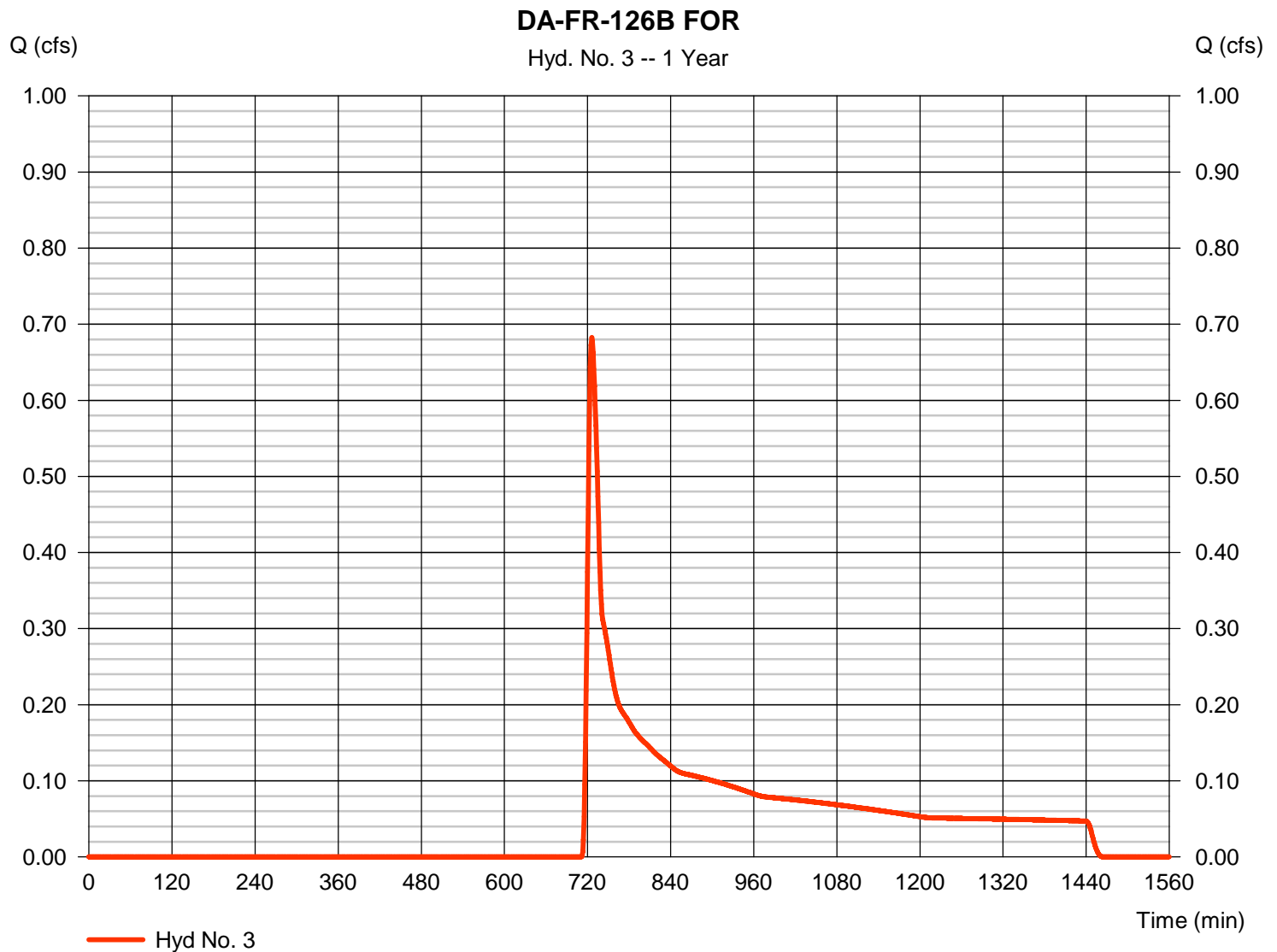
Thursday, 08 / 31 / 2017

Hyd. No. 3

DA-FR-126B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 4.140 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.30 in
 Storm duration = 24 hrs

Peak discharge = 0.683 cfs
 Time to peak = 726 min
 Hyd. volume = 4,224 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 14.20 min
 Distribution = Type II
 Shape factor = 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-126B FOR

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	3.70	3.70	
Land slope (%)	= 5.86	0.00	0.00	
Travel Time (min)	= 12.99	+ 0.00	+ 0.00	= 12.99
Shallow Concentrated Flow				
Flow length (ft)	= 493.24	0.00	0.00	
Watercourse slope (%)	= 19.22	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=7.07	0.00	0.00	
Travel Time (min)	= 1.16	+ 0.00	+ 0.00	= 1.16
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				14.20 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	1.357	1	725	6,245	-----	-----	-----	DA-FR-126B PRE
2	SCS Runoff	1.130	1	725	5,694	-----	-----	-----	DA-FR-126B DEV
3	SCS Runoff	1.357	1	725	6,245	-----	-----	-----	DA-FR-126B FOR
DA-FR-126B_Hydraflow.gpw					Return Period: 2 Year			Thursday, 08 / 31 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

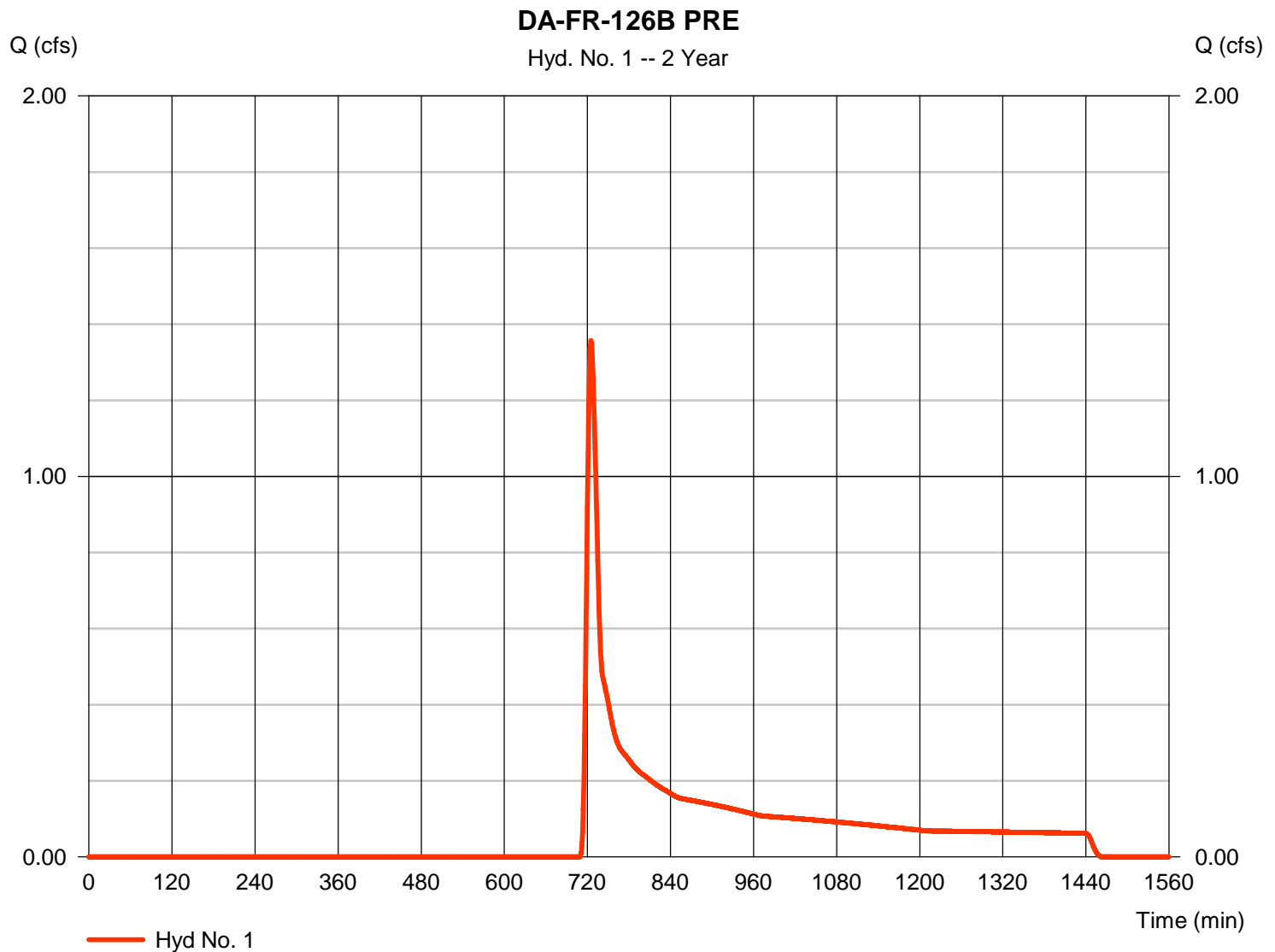
Thursday, 08 / 31 / 2017

Hyd. No. 1

DA-FR-126B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 1.357 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 6,245 cuft
Drainage area	= 4.140 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.20 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.258 \times 58) + (0.021 \times 100) + (3.858 \times 55)] / 4.140$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

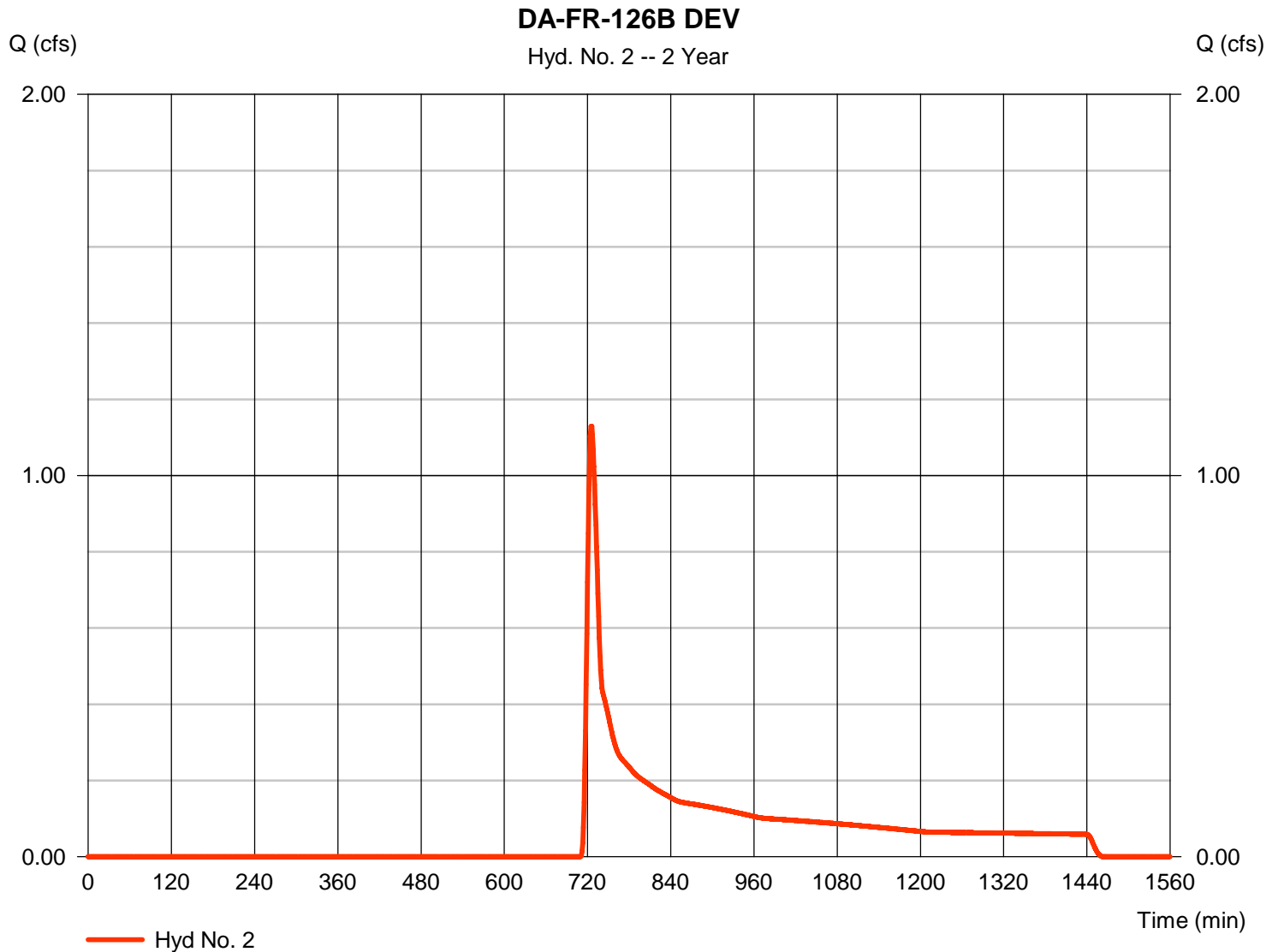
Thursday, 08 / 31 / 2017

Hyd. No. 2

DA-FR-126B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 1.130 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 5,694 cuft
Drainage area	= 4.140 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.20 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.120 \times 48) + (0.895 \times 58) + (0.021 \times 100) + (2.101 \times 55)] / 4.140$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

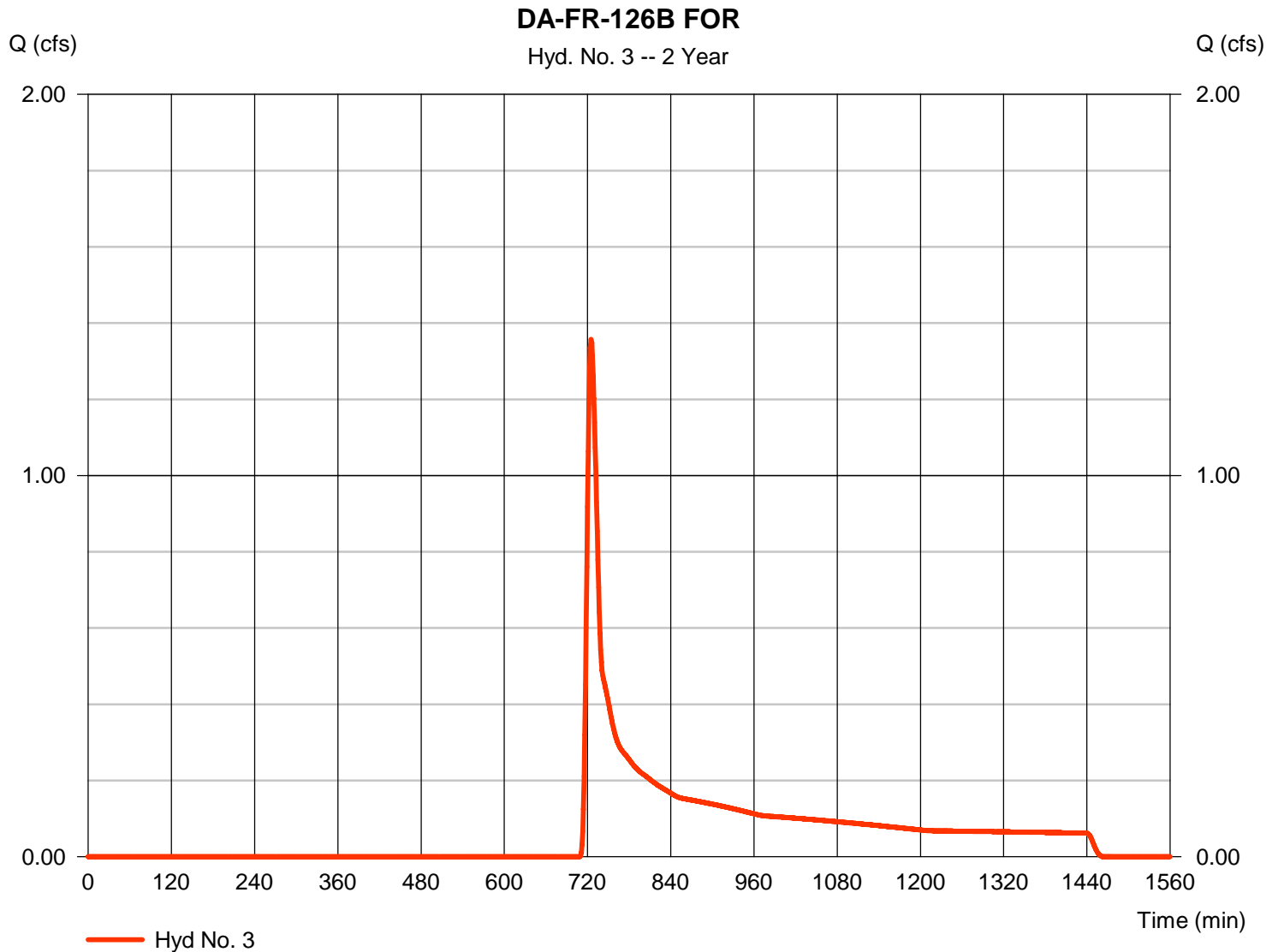
Thursday, 08 / 31 / 2017

Hyd. No. 3

DA-FR-126B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 4.140 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 1.357 cfs
 Time to peak = 725 min
 Hyd. volume = 6,245 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 14.20 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	6.781	1	723	20,266	-----	-----	-----	DA-FR-126B PRE
2	SCS Runoff	6.303	1	723	19,177	-----	-----	-----	DA-FR-126B DEV
3	SCS Runoff	6.781	1	723	20,266	-----	-----	-----	DA-FR-126B FOR
DA-FR-126B_Hydraflow.gpw					Return Period: 10 Year			Thursday, 08 / 31 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

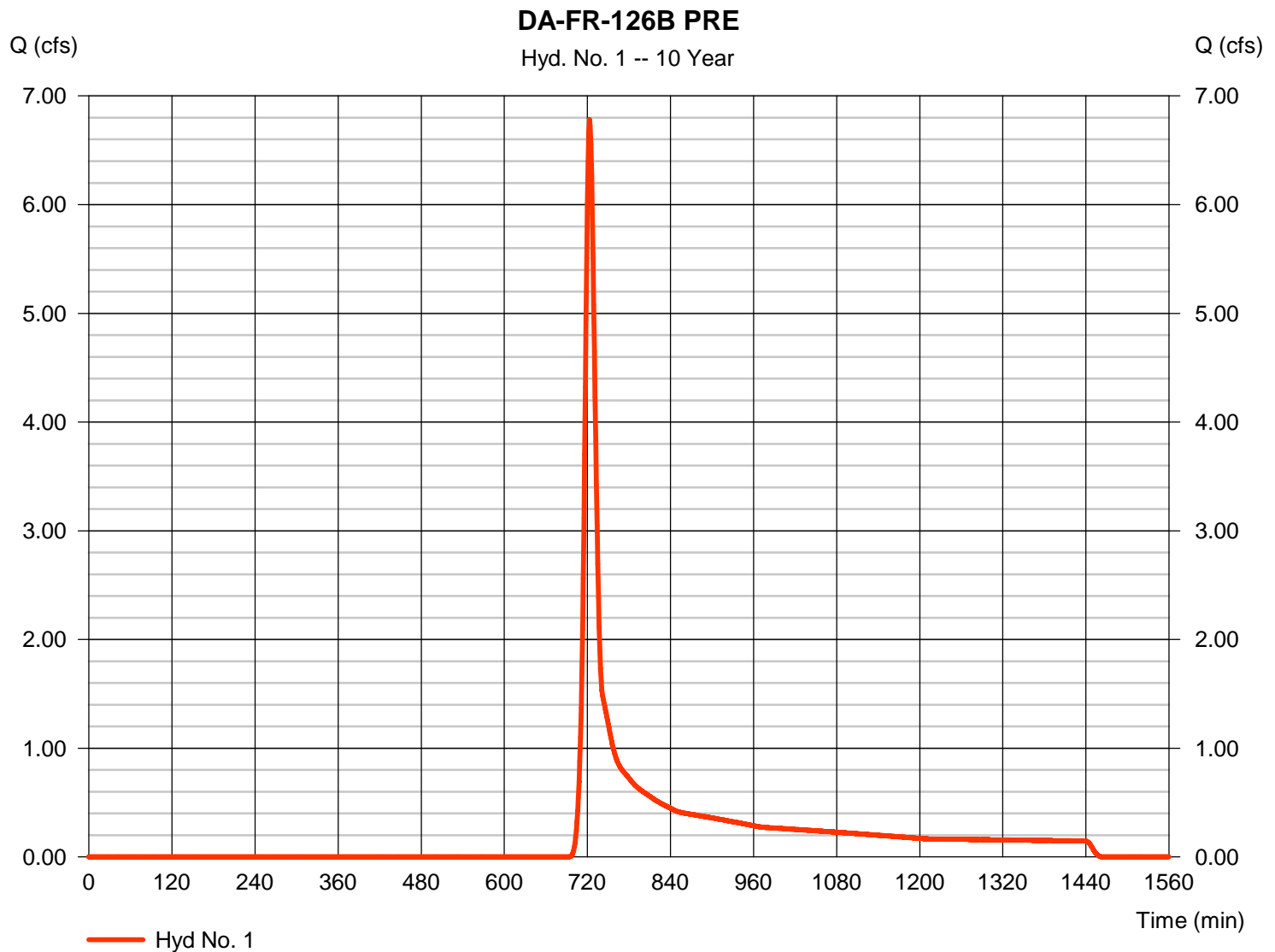
Thursday, 08 / 31 / 2017

Hyd. No. 1

DA-FR-126B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 6.781 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 20,266 cuft
Drainage area	= 4.140 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.20 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.258 \times 58) + (0.021 \times 100) + (3.858 \times 55)] / 4.140$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

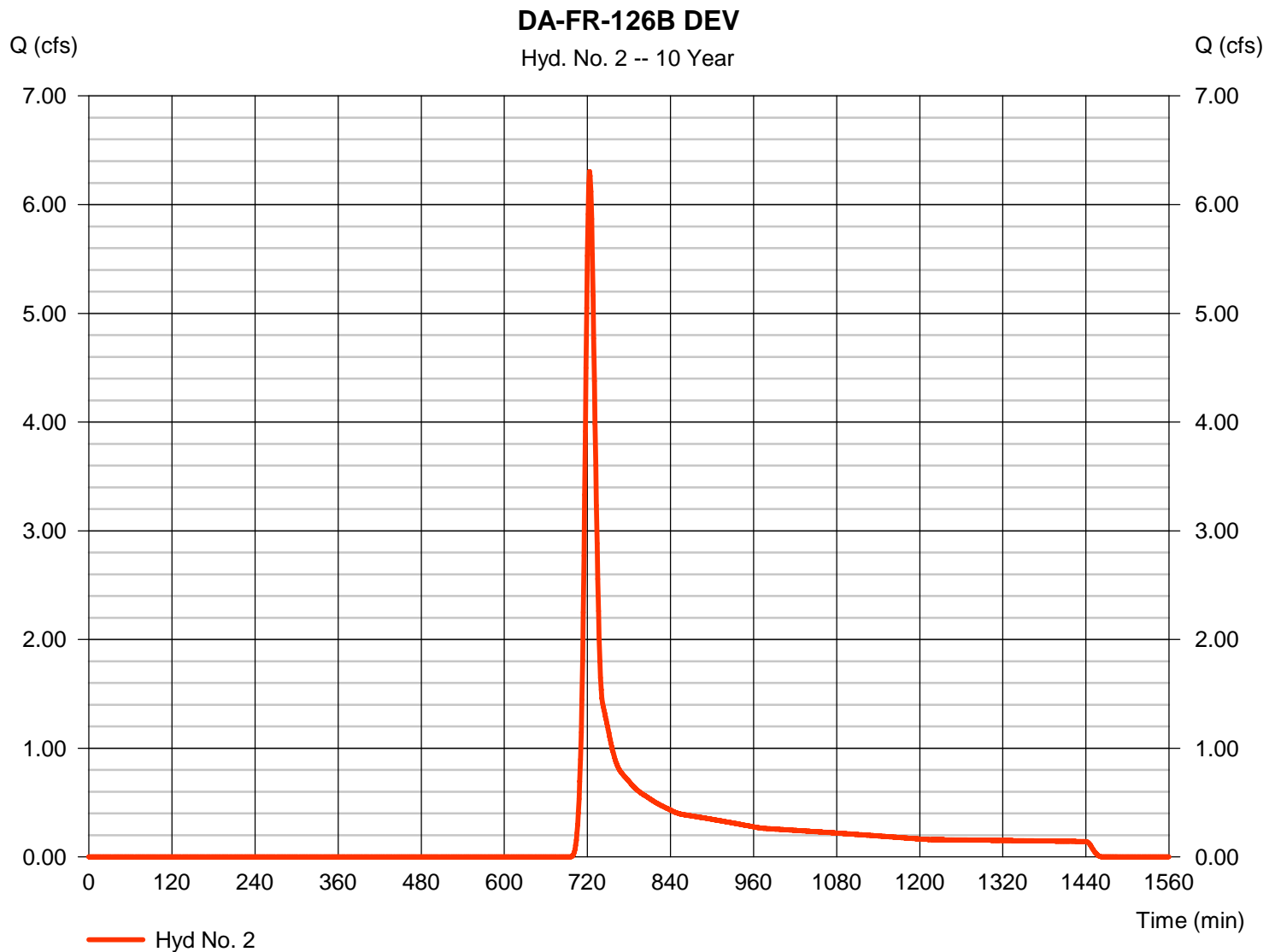
Thursday, 08 / 31 / 2017

Hyd. No. 2

DA-FR-126B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 6.303 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 19,177 cuft
Drainage area	= 4.140 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.20 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.120 \times 48) + (0.895 \times 58) + (0.021 \times 100) + (2.101 \times 55)] / 4.140$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

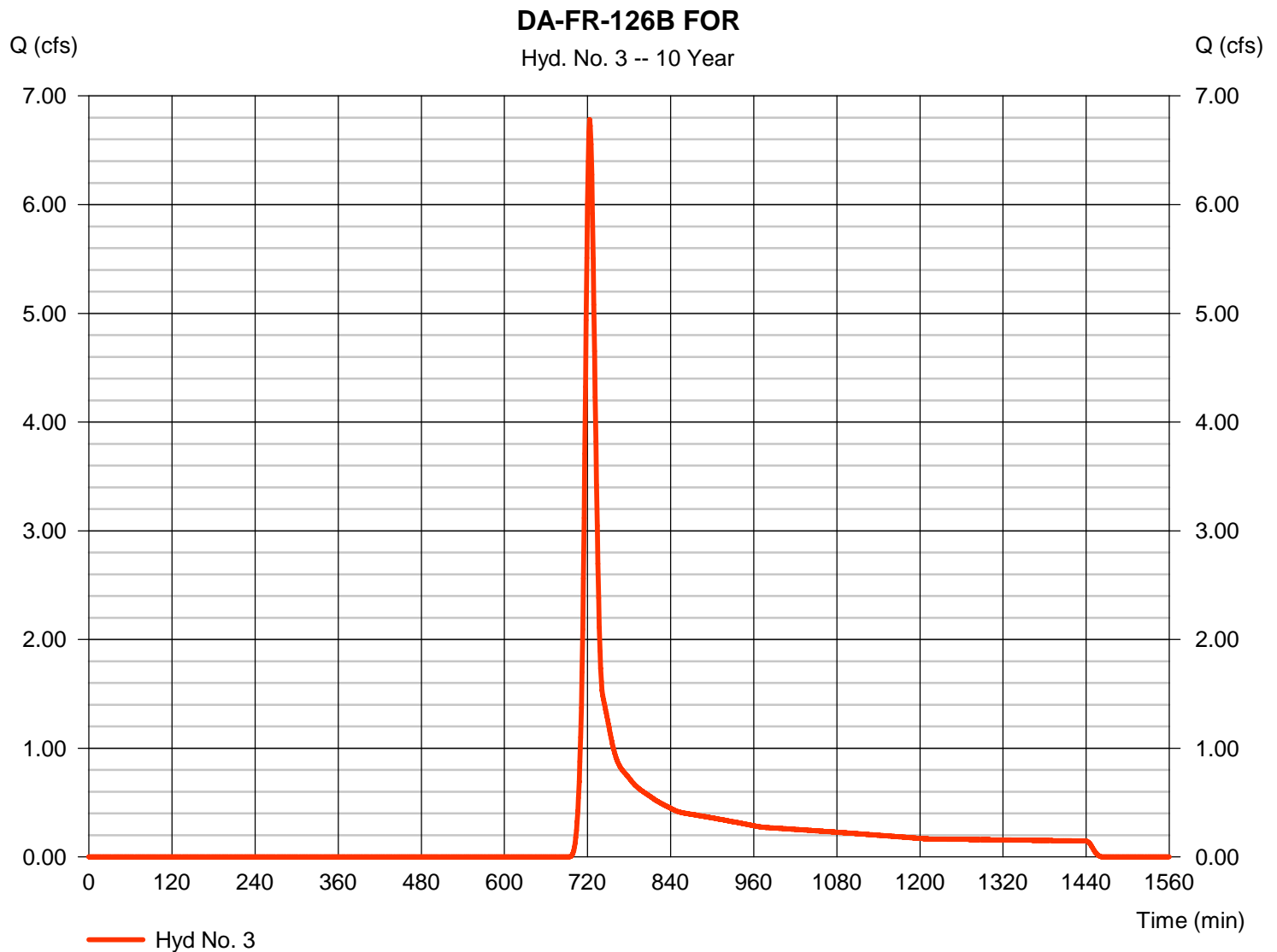
Thursday, 08 / 31 / 2017

Hyd. No. 3

DA-FR-126B FOR

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 4.140 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 6.781 cfs
 Time to peak = 723 min
 Hyd. volume = 20,266 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 14.20 min
 Distribution = Type II
 Shape factor = 484



DA-FR-126C

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	1.236	6083
Developed Condition	1.033	5544
Pre-Developed (Forest) Condition	0.676	4535

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	1.033	\leq OK	1.085
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	1.033	\leq OK	1.236
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ --->	1.033	<u>shall not</u> be required to be \leq	0.553

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning’s n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<p><i>Note:</i></p> <p><i>Manning’s n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</i></p> <p><i>For Paved Road land surface types a Manning’s n value of 0.011 was used.</i></p> <p><i>Sources:</i></p> <p><i>-USACE, 1998, HEC-1 Flood Hydrograph Package User’s Manual, Hydrologic Engineering Center, Davis, CA</i></p> <p><i>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</i></p>	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-FR-126C PRE
2	SCS Runoff	DA-FR-126C DEV
3	SCS Runoff	DA-FR-126C for

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	1.236	1	726	6,083	-----	-----	-----	DA-FR-126C PRE
2	SCS Runoff	1.033	1	727	5,544	-----	-----	-----	DA-FR-126C DEV
3	SCS Runoff	0.676	1	727	4,535	-----	-----	-----	DA-FR-126C for
DA-FR-126C_Hydraflow.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

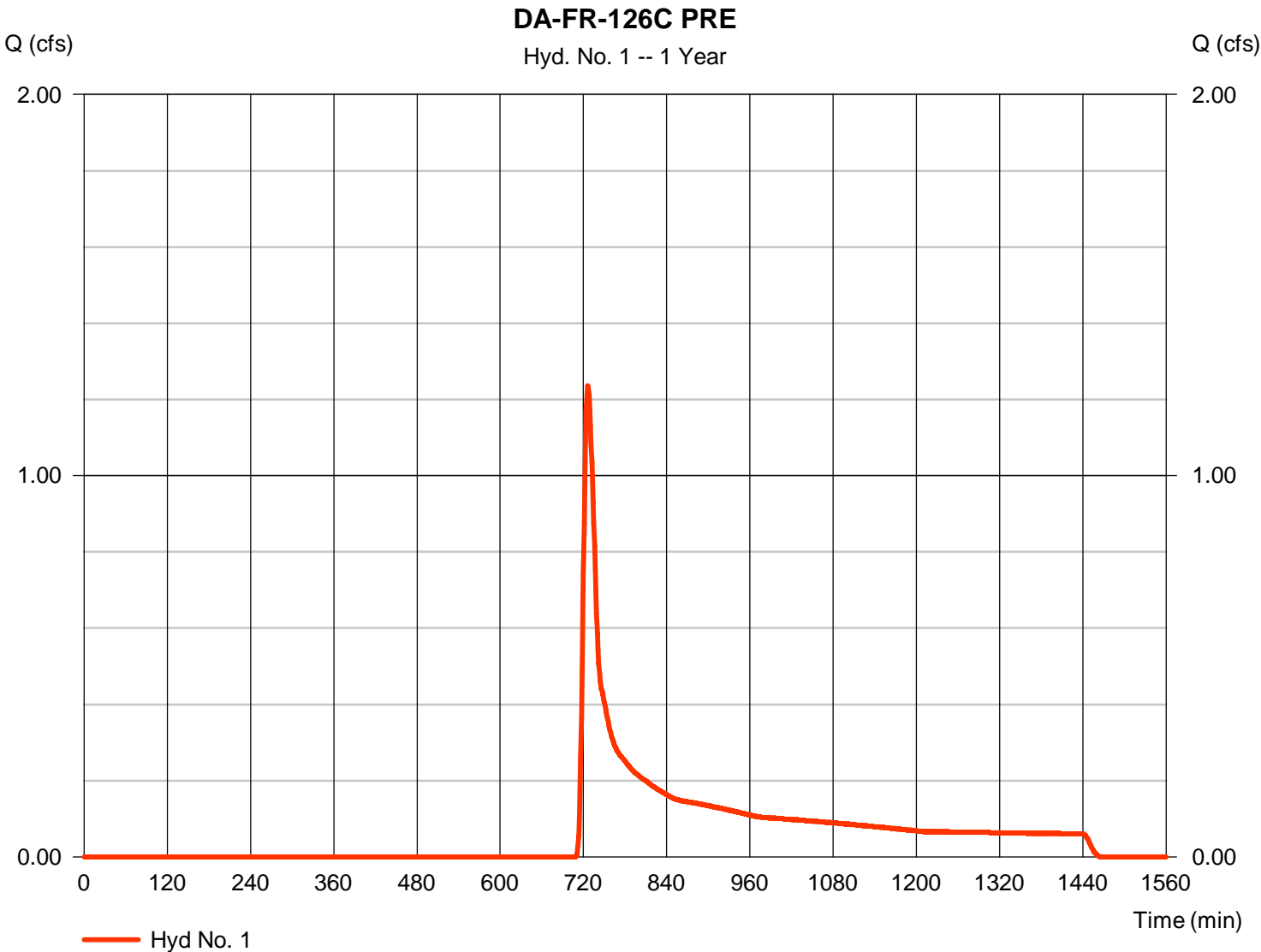
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-126C PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.236 cfs
Storm frequency	=	1 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	6,083 cuft
Drainage area	=	4.390 ac	Curve number	=	58*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	15.70 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.090 x 82) + (2.590 x 58) + (0.018 x 100) + (1.488 x 55) + (0.204 x 70)] / 4.390



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-FR-126C PRE

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 4.66	0.00	0.00				
Travel Time (min)	= 14.24	+	0.00	+	0.00	=	14.24
Shallow Concentrated Flow							
Flow length (ft)	= 506.09	0.00	0.00				
Watercourse slope (%)	= 13.53	0.00	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=5.93	0.00	0.00				
Travel Time (min)	= 1.42	+	0.00	+	0.00	=	1.42
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				15.70 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

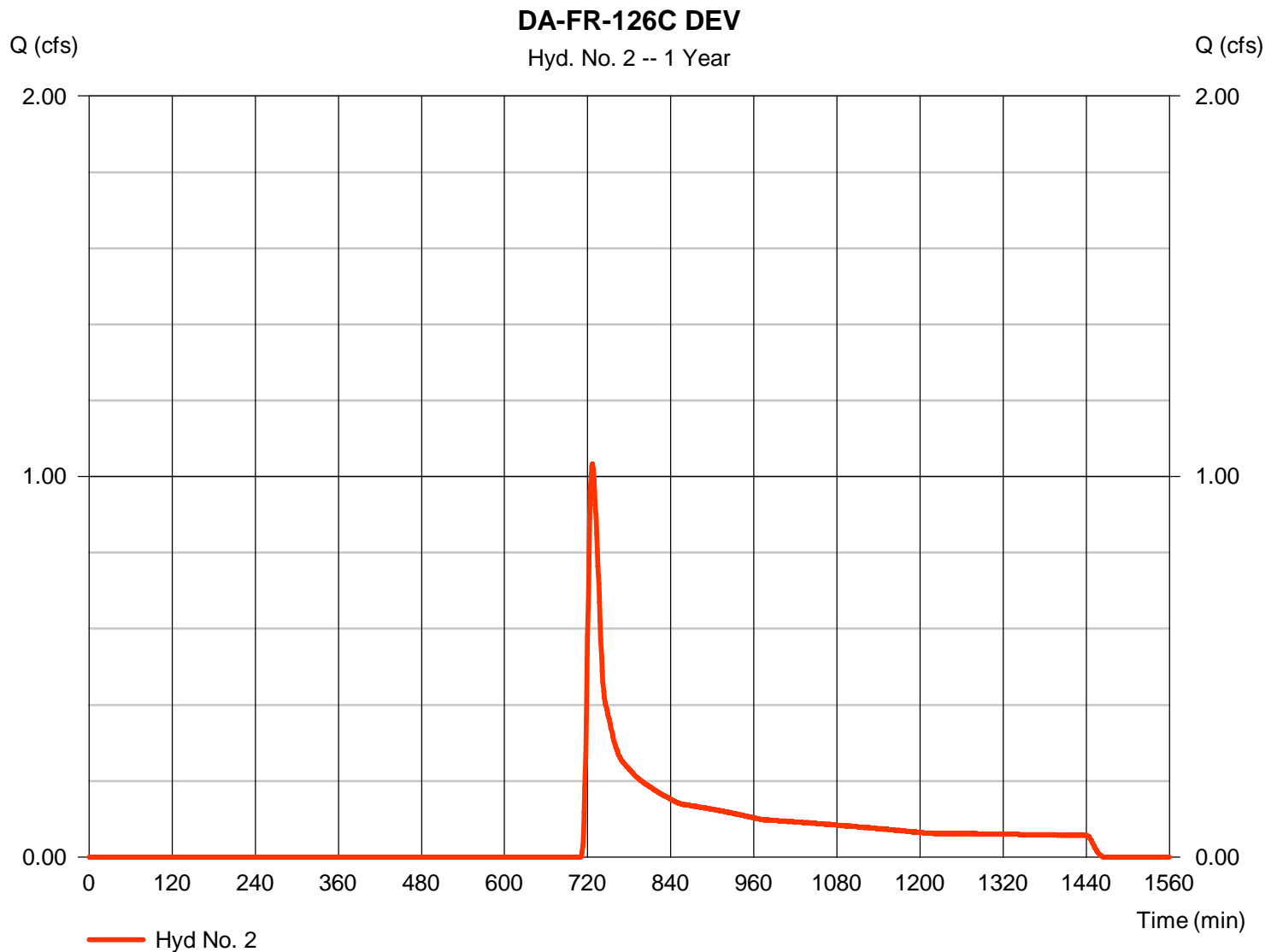
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-126C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 1.033 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 5,544 cuft
Drainage area	= 4.390 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.746 \times 48) + (0.204 \times 65) + (0.090 \times 82) + (3.259 \times 58) + (0.018 \times 100) + (0.073 \times 55)] / 4.390$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-FR-126C DEV

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.800	0.800	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00	
Land slope (%)	= 4.66	0.00	0.00	
Travel Time (min)	= 14.24	+	0.00	+
			0.00	= 14.24
Shallow Concentrated Flow				
Flow length (ft)	= 506.09	0.00	0.00	
Watercourse slope (%)	= 13.53	0.00	0.00	
Surface description	= Unpaved	Unpaved	Unpaved	
Average velocity (ft/s)	=5.93	0.00	0.00	
Travel Time (min)	= 1.42	+	0.00	+
			0.00	= 1.42
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				15.70 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

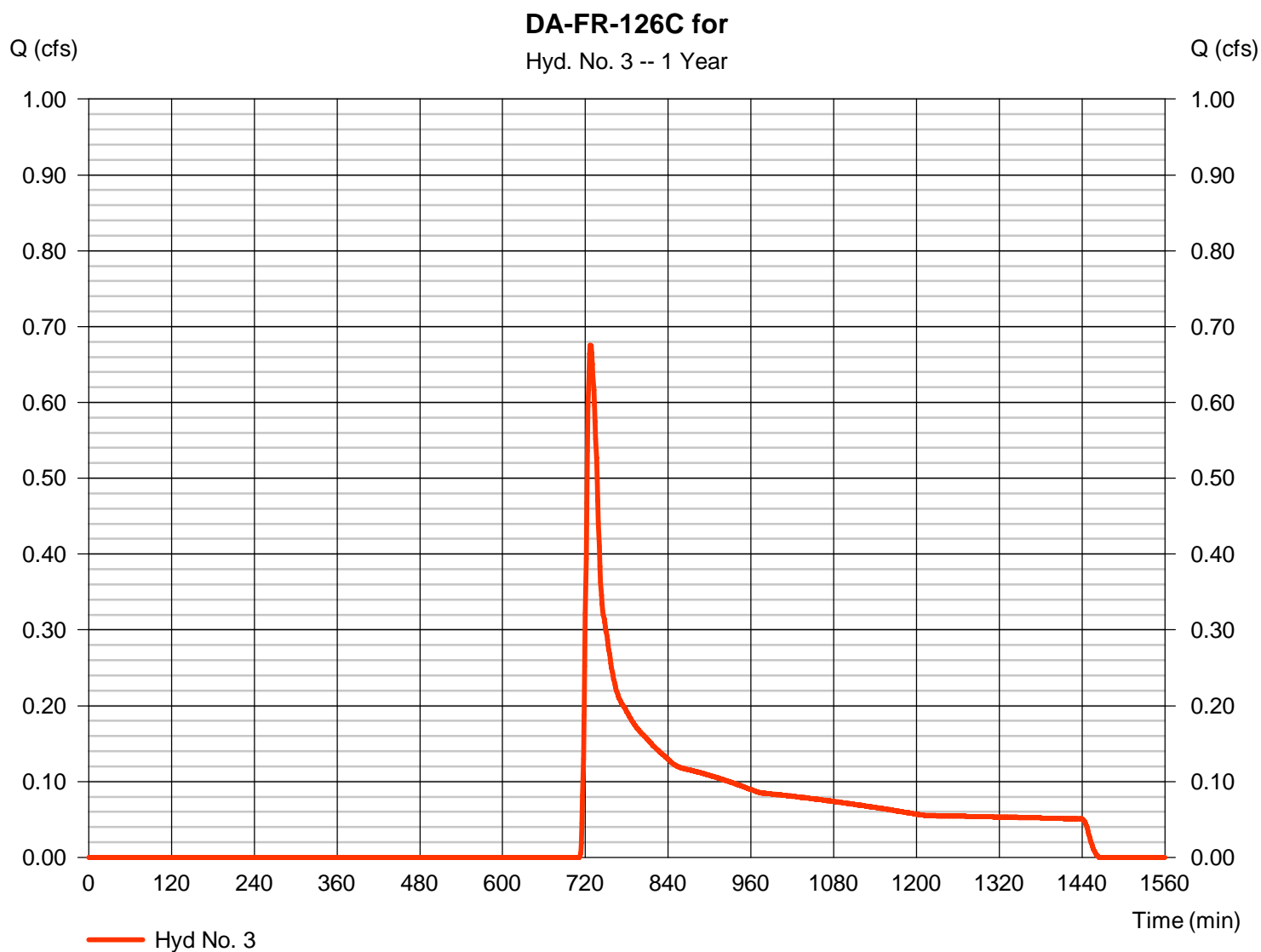
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-126C for

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 4.390 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.30 in
 Storm duration = 24 hrs

Peak discharge = 0.676 cfs
 Time to peak = 727 min
 Hyd. volume = 4,535 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.70 min
 Distribution = Type II
 Shape factor = 484



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-FR-126C for

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.70	0.00	0.00				
Land slope (%)	= 4.66	0.00	0.00				
Travel Time (min)	= 14.24	+	0.00	+	0.00	=	14.24
Shallow Concentrated Flow							
Flow length (ft)	= 506.09	0.00	0.00				
Watercourse slope (%)	= 13.53	0.00	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=5.93	0.00	0.00				
Travel Time (min)	= 1.42	+	0.00	+	0.00	=	1.42
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				15.70 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	2.103	1	726	8,617	-----	-----	-----	DA-FR-126C PRE
2	SCS Runoff	1.836	1	726	7,957	-----	-----	-----	DA-FR-126C DEV
3	SCS Runoff	1.341	1	726	6,705	-----	-----	-----	DA-FR-126C for
DA-FR-126C_Hydraflow.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

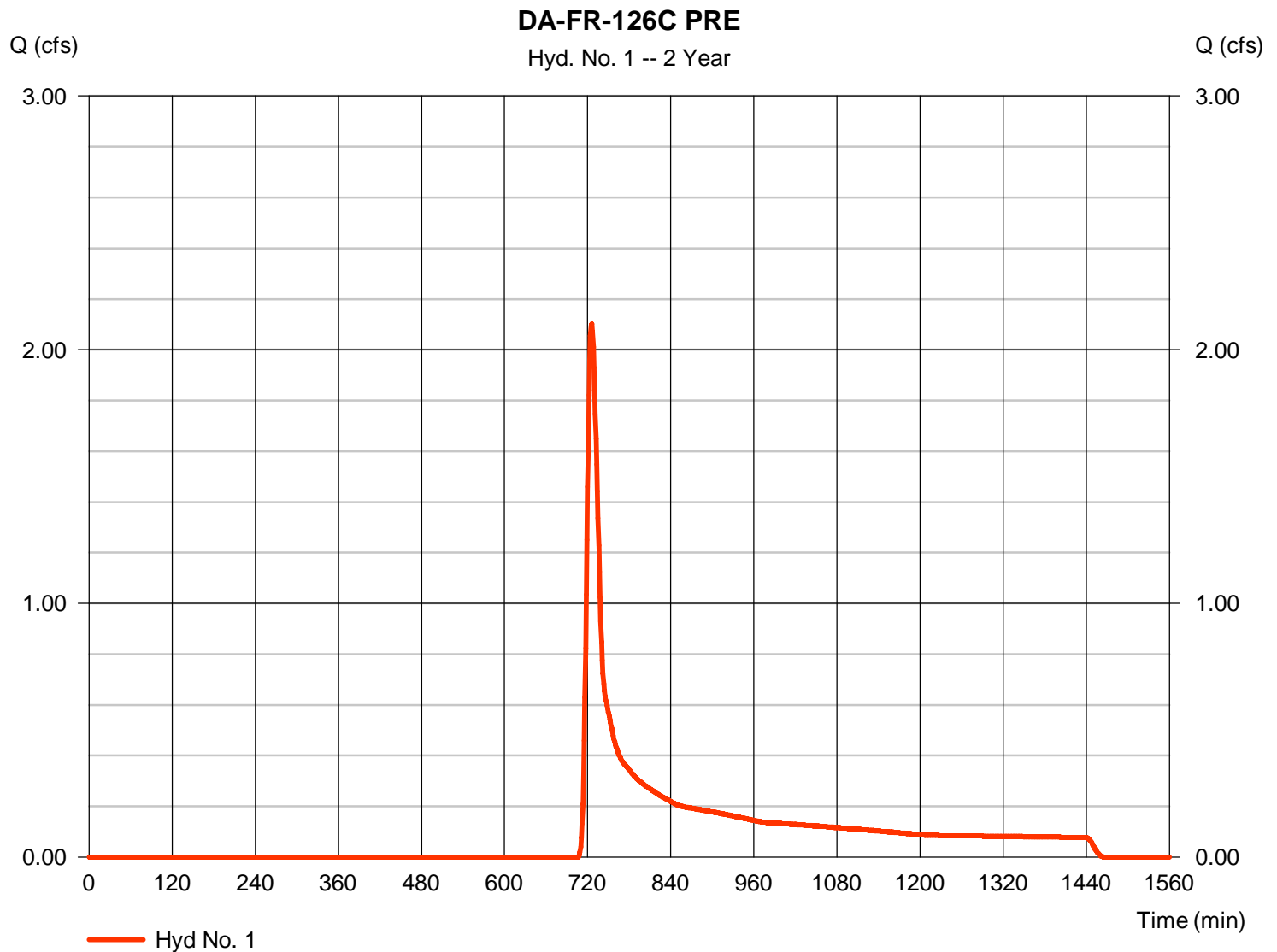
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-126C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 2.103 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 8,617 cuft
Drainage area	= 4.390 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.090 \times 82) + (2.590 \times 58) + (0.018 \times 100) + (1.488 \times 55) + (0.204 \times 70)] / 4.390$



Hydrograph Report

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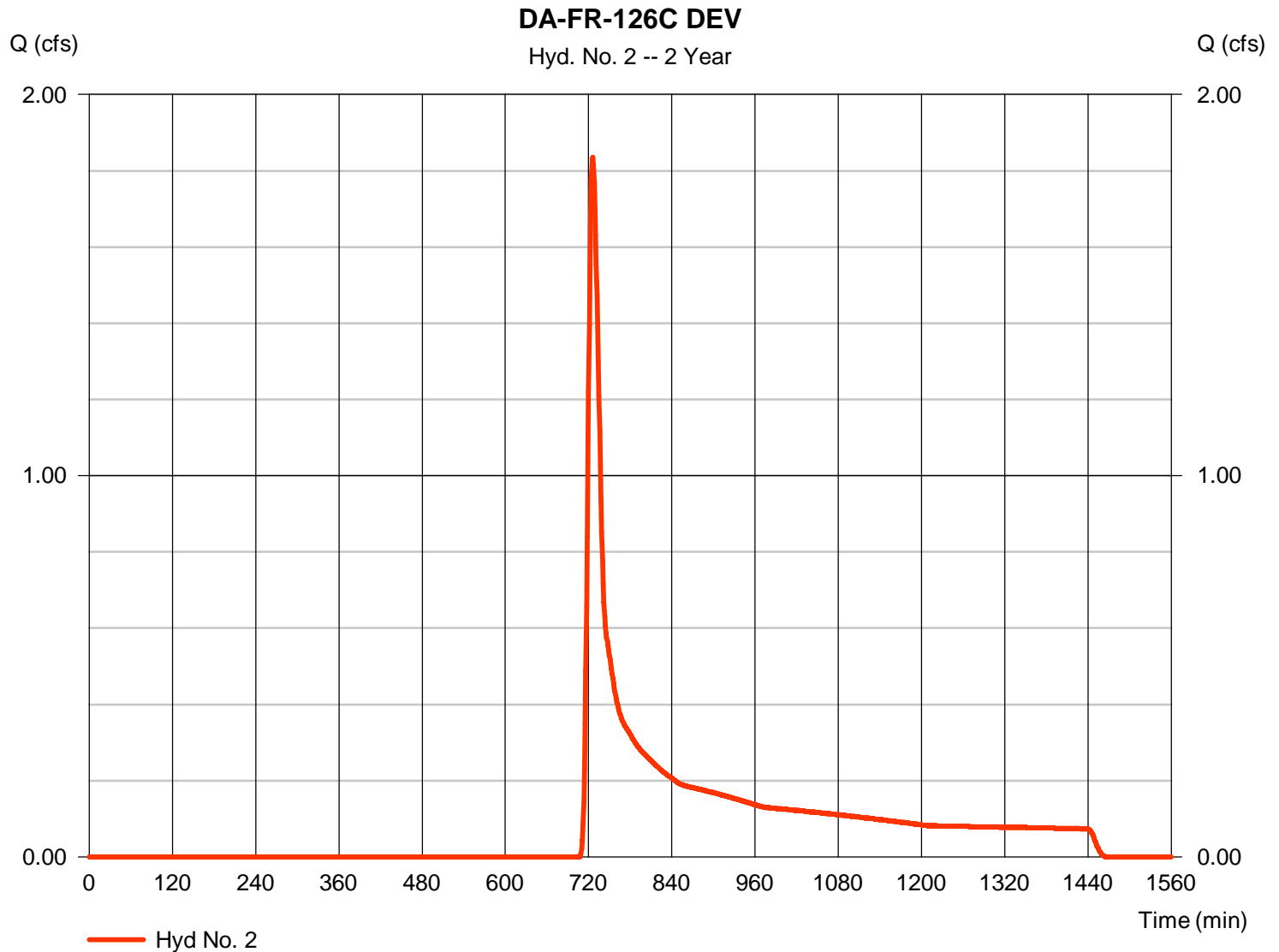
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-126C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 1.836 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 7,957 cuft
Drainage area	= 4.390 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.746 \times 48) + (0.204 \times 65) + (0.090 \times 82) + (3.259 \times 58) + (0.018 \times 100) + (0.073 \times 55)] / 4.390$



Hydrograph Report

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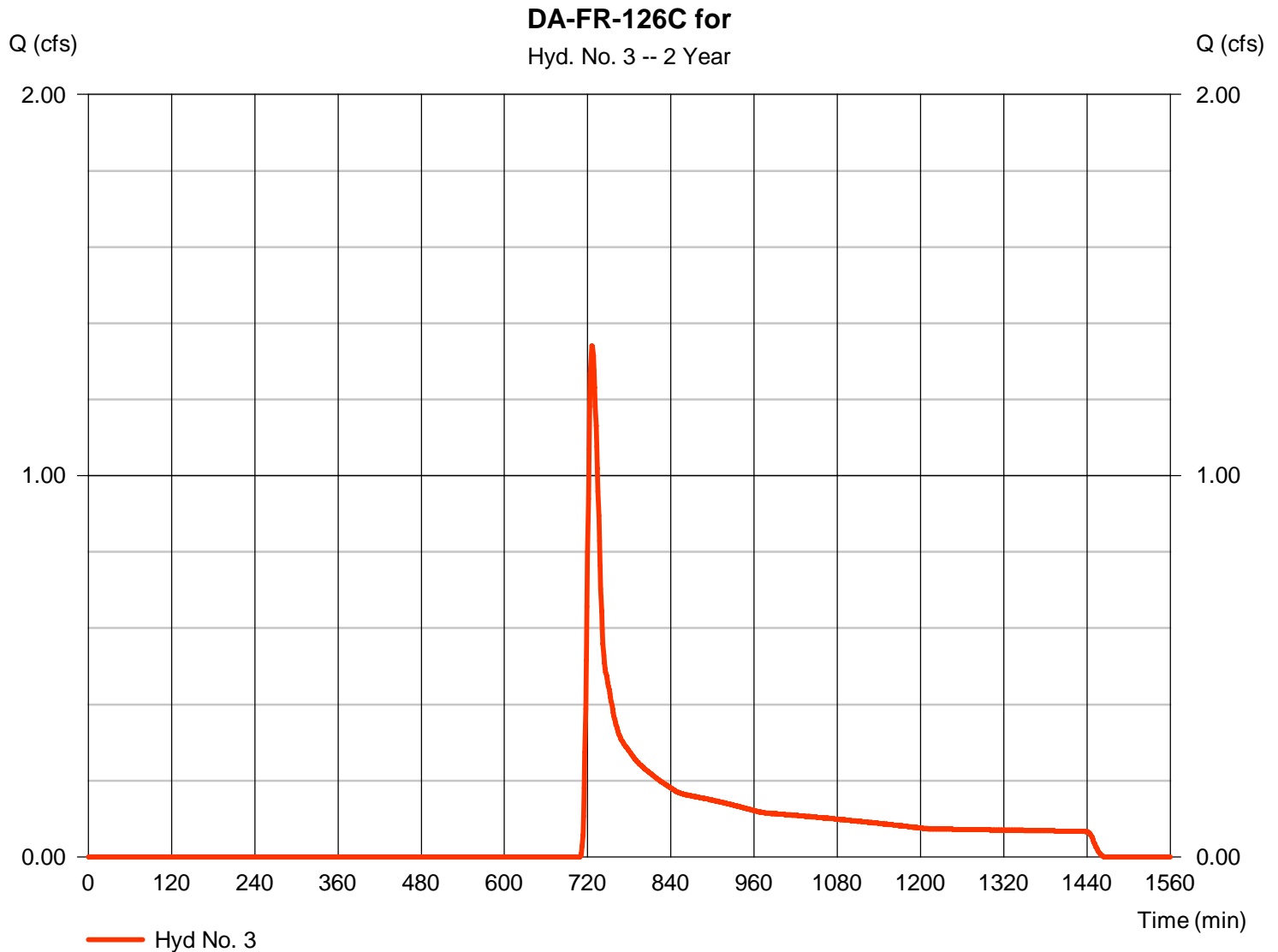
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-126C for

Hydrograph type = SCS Runoff
 Storm frequency = 2 yrs
 Time interval = 1 min
 Drainage area = 4.390 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 3.70 in
 Storm duration = 24 hrs

Peak discharge = 1.341 cfs
 Time to peak = 726 min
 Hyd. volume = 6,705 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.70 min
 Distribution = Type II
 Shape factor = 484



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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	8.265	1	724	25,378	-----	-----	-----	DA-FR-126C PRE
2	SCS Runoff	7.768	1	724	24,153	-----	-----	-----	DA-FR-126C DEV
3	SCS Runoff	6.784	1	724	21,758	-----	-----	-----	DA-FR-126C for
DA-FR-126C_Hydraflow.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

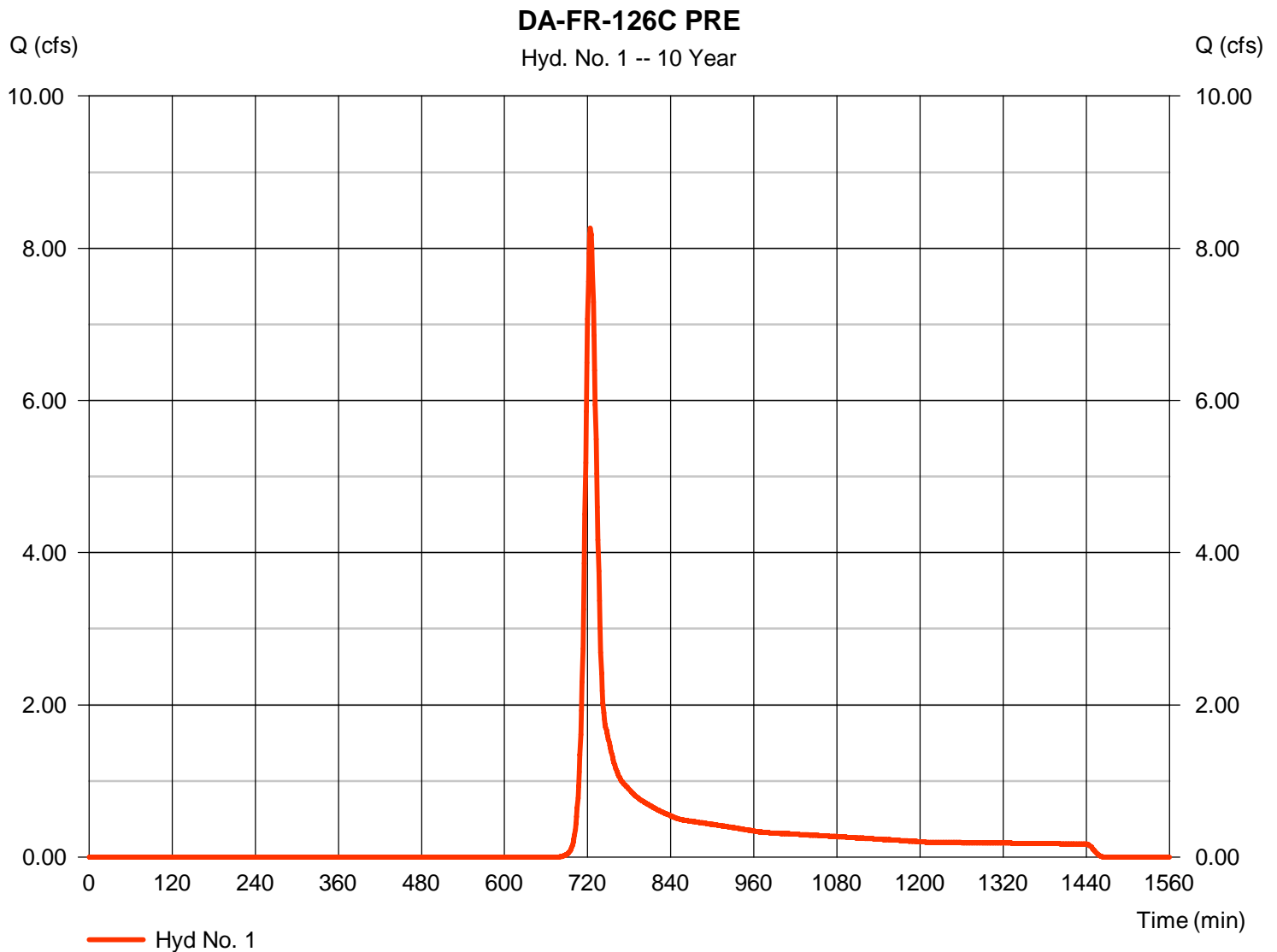
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-FR-126C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 8.265 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 25,378 cuft
Drainage area	= 4.390 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.090 \times 82) + (2.590 \times 58) + (0.018 \times 100) + (1.488 \times 55) + (0.204 \times 70)] / 4.390$



Hydrograph Report

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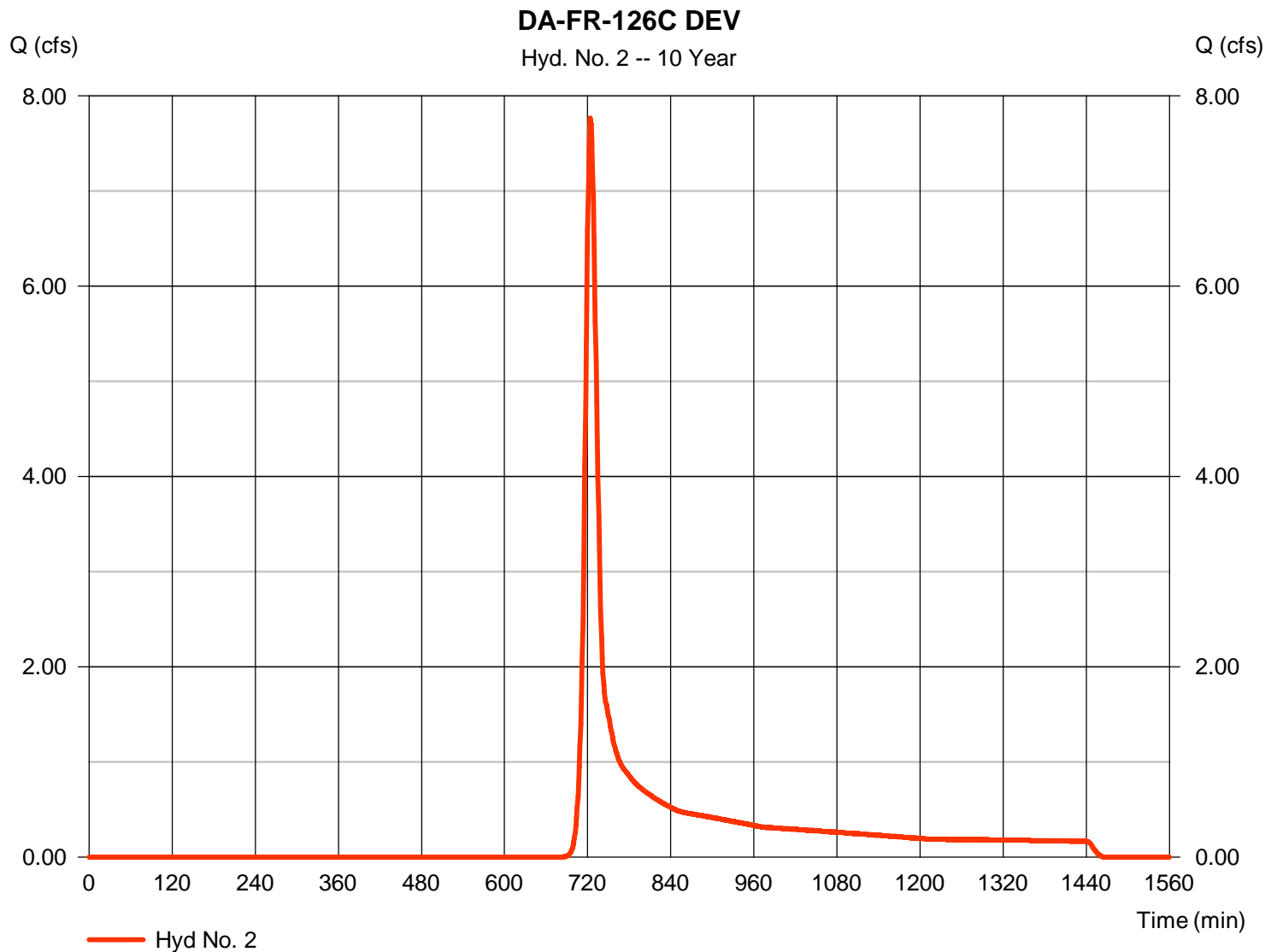
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-FR-126C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 7.768 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 24,153 cuft
Drainage area	= 4.390 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.746 \times 48) + (0.204 \times 65) + (0.090 \times 82) + (3.259 \times 58) + (0.018 \times 100) + (0.073 \times 55)] / 4.390$



Hydrograph Report

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Monday, 08 / 21 / 2017

Hyd. No. 3

DA-FR-126C for

Hydrograph type = SCS Runoff
 Storm frequency = 10 yrs
 Time interval = 1 min
 Drainage area = 4.390 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 5.70 in
 Storm duration = 24 hrs

Peak discharge = 6.784 cfs
 Time to peak = 724 min
 Hyd. volume = 21,758 cuft
 Curve number = 55
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 15.70 min
 Distribution = Type II
 Shape factor = 484

