TENNESSEE GAS PIPELINE COMPANY, L.L.C.

HYDROLOGIC AND HYDRAULIC CALCULATIONS FOR ACCESS ROADS ALONG THE

CONNECTICUT PIPELINE EXPANSION PROJECT

CONNECTICUT LOOP

Submitted by:

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Houston, TX 77002

APRIL 2015

The attached hydrologic and hydraulic calculations were performed for all field surveyed waterbodies crossed by the Connecticut Pipeline Extension (Project) Hartford County Connecticut. The Project would consist of installing approximately 13.3 miles of pipeline looping: 1.4 Miles of 36-inch Pipeline Loop in Albany County, New York ("NY Loop") 3.8 Miles of 36-inch Pipeline Loop in Berkshire County, Massachusetts ("MA Loop"). 8.15 Miles of 24-inch Pipeline Loop in Hampden County, Massachusetts and Hartford County, Connecticut ("CT Loop)".

The primary objective of the attached calculations was to evaluate the amount of runoff due to the construction of permanent access roadways to the pipeline, and to size flume pipes at each waterbody crossing to convey, at a minimum, normal flow safely under the access roads. A typical flume installation will consist of sand bag cofferdams placed at the upstream and downstream limits of the construction workspace and the installation of the pipe specified in the design.

DESIGN CRITERIA AND METHODOLOGY

The following design criteria and methodology was used to perform the calculations:

1. **Hydrologic Methodology**

Hydrologic calculations were performed using a combination of the Rational Method, the NRCS (SCS) Peak Flow Method, USGS StreamStats, and USGS StreamStats with HydroCAD v.10.0. The specific method used to calculate the design flows for each waterbody varied based on parameters such as the watershed size, waterbody slope, basin elevation, and ground cover type (e.g. pasture, forest, urban).

a. Rational Method: Q=CIA

- Q = flow (cubic feet per second - cfs)
  C = runoff coefficient
  A = drainage area (acres – ac)
  I = rainfall intensity (inches per hour – in/hr)
- This method was used for drainage areas up to 200 acres in size
- NOAA Technical Memorandum NWS Hydro-35 was used to determine "I" in Connecticut County of Hartford.
- The following Runoff Coefficients were used:

Cover Type	Slope Range (%)	Hydrologic Soil Group*	Runoff Coefficient
Pasture	0% - 6%	D	0.20
Forest	0% – 20 %	D	0.32
Forest	> 20 %	D	0.38
Gravel	0%-3%	N/A	0.80

*Hydrologic Soil Group D was used for a conservative approach.

- Time of Concentrations were calculated using the following:
  - **Sheet Flow:**
    Manning's Kinematic Solution
    Maximum (max) sheet flow length of 150ft

- **Shallow Concentrated Flow**
  The travel time for shallow concentrated flow was calculated by dividing the travel path length by a calculated velocity. The velocity for specific cover types were calculated using Manning's equation.

- **Channel Flow**
  As upstream channel morphology is not constant, the travel time for Channel flow was calculated by assuming a channel velocity of 15.00 ft/s and applying it to the shallow concentrated flow formula.

b. NRCS (SCS) Peak Flow Method:

The computer program HydroCAD, Version 10.0, was used to determine the peak flow discharges for the watershed. HydroCAD is a program which employs TR-20 methodology which uses the unit-hydrograph runoff procedure. As with TR-20, the HydroCAD peak flow discharges are dependent upon parameters such as watershed size, the curve number for a given watershed, time of concentration, available flood storage, rainfall storm type, rainfall intensity and storm duration.

- The following curve numbers were used:

Cover Type	Hydrologic Soil Group*	Curve Number (CN)
Woods	D	83
Pasture	D	89
Urban	D	98

*Hydrologic Soil Group D was used for poor soil conditions, and a conservative approach.

- Depths were used in conjunction with a 24-hour storm duration.
- The Time of Concentration was calculated using the same methodology used for the Rational Method.

c. USGS StreamStats for Connecticut

StreamStats is a Web-based tool developed by the USGS and Environmental Systems Research Institute, Inc. (ESRI). This map-based Web application was designed to make it easy for users to obtain stream flow statistics, drainage-basin characteristics, and other information for user-selected sites. StreamStats utilizes previously published information from gaging stations and previously gathered basin characteristics to develop stream flow statistics utilizing the

appropriate regression equations to compute the stream flows. The StreamStats flows will only be utilized where the drainage area falls within the acceptable ranges for Mean/Base-Flow or for Peak Flow. Drainage areas outside the acceptable ranges generate flows that are based on extrapolations with unknown errors.

d. Design Frequency:

The design frequency utilized in the design varied based on the U.S. Weather Bureau Technical Paper 40. A 2-year design, a 5-year, and a 10-year maximum design storm were utilized for all watershed classifications. Average daily flow calculations were also performed for larger watersheds where the 2- and 5-year storms resulted in flows that cannot be completely passed within the designed pipes and it is unlikely that a 2-year or 5-year storm event will occur during the crossing.

2. Hydraulic Calculations

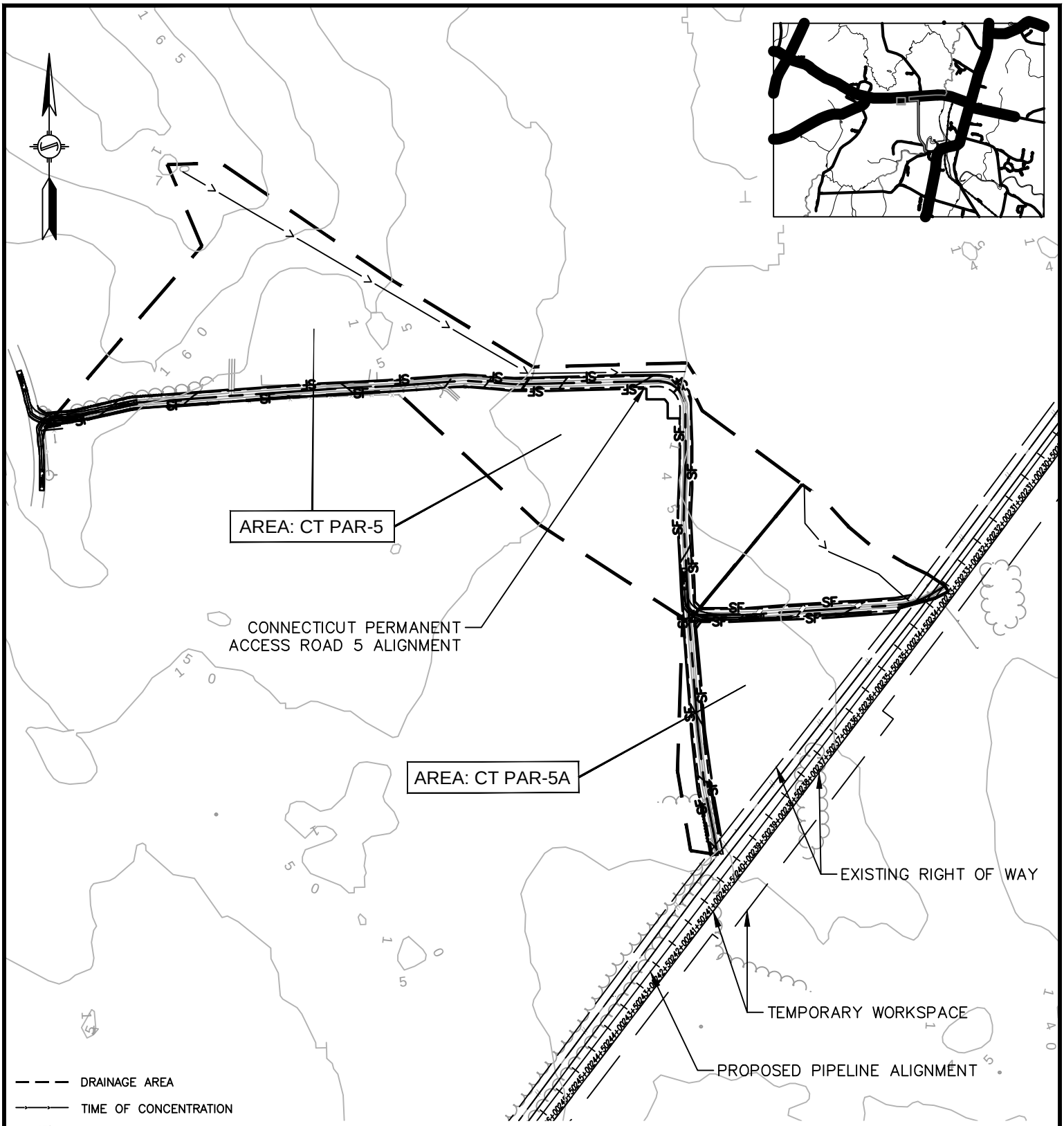
The temporary flume pipes were sized using the Federal Highway Administration (FHWA) HY-8 computer program. HY-8 is a culvert analysis program that automates the design methods described in HDS No. 5, "Hydraulic Design of Highway Culverts".

3. Summary and Results

The post construction hydrology of the access road areas are not significantly altered by the construction of the access roadways. The flows, summarized in the table below, are not significantly higher due to the construction of the access roadways and will not negatively impact the surrounding areas. See attached table on the next page, for flume pipe and stream crossing details.

CT PAR-05

	Pre-Development Flow (cfs)	Post-Development Flow (cfs)	Difference (cfs)	Difference (%)
2-Year	5.39	5.79	0.40	7.4
10-Year	7.89	8.48	0.59	7.5
100-Year	13.76	14.78	1.02	7.4



NO.	DATE	BY	DESCRIPTION	PROJ. ID	APPR.

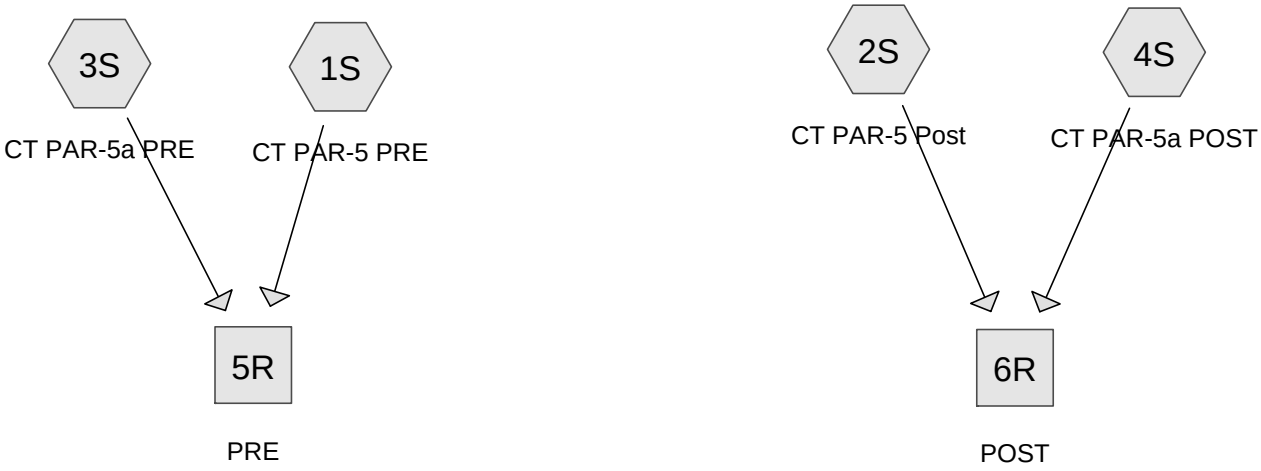
REVISIONS

Division:	Op. Area:	
St.:	Co./Par.:	
Section:	Township:	Range:
Dft: JMS	Date: 07/08/14	Project ID:
Chk: –	Date: –	Scale:
Appr: –	Date: –	Filename:

CONNECTICUT EXPANSION
CONNECTICUT LOOP
PROPOSED NATURAL GAS PIPELINE
TOWN OF SUFFIELD
HARTFORD COUNTY, CONNECTICUT

Tennessee Gas Pipeline Company, L.L.C.
a Kinder Morgan company

Sheet: of
Type:



Subcat Reach Pond Link

Routing Diagram for C-ENG-14C4781CT-PAR05
Prepared by BL Companies, Printed 7/20/2014
HydroCAD® 10.00 s/n 01334 © 2013 HydroCAD Software Solutions LLC

Time span=0.00-3.00 hrs, dt=0.01 hrs, 301 points
Runoff by Rational method, Rise/Fall=1.0/1.0 xTc
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: CT PAR-5 PRE Runoff Area=9.480 ac 0.85% Impervious Runoff Depth=0.33"
Flow Length=1,047' Tc=29.6 min C=0.32 Runoff=4.67 cfs 0.264 af

Subcatchment 2S: CT PAR-5 Post Runoff Area=9.480 ac 0.85% Impervious Runoff Depth=0.35"
Flow Length=1,047' Tc=29.6 min C=0.34 Runoff=4.96 cfs 0.280 af

Subcatchment 3S: CT PAR-5a PRE Runoff Area=1.414 ac 0.00% Impervious Runoff Depth=0.34"
Flow Length=319' Tc=13.5 min C=0.33 Runoff=0.72 cfs 0.041 af

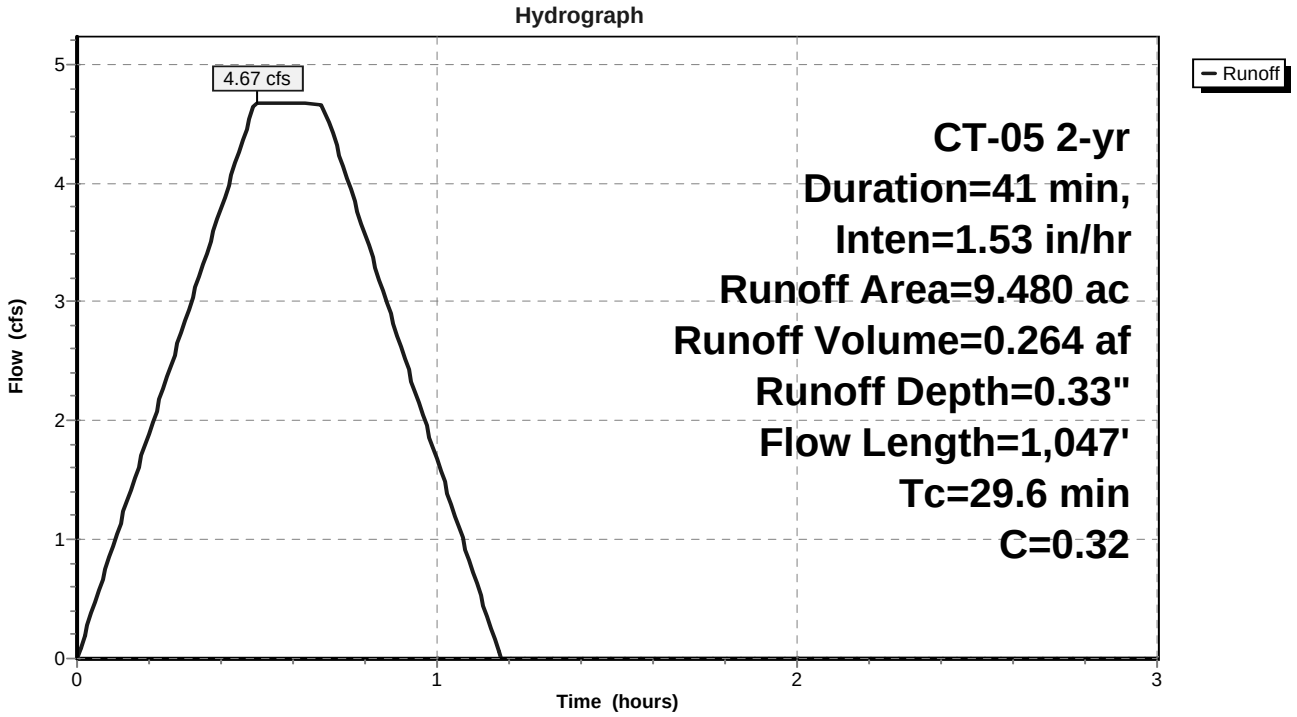
Subcatchment 4S: CT PAR-5a POST Runoff Area=1.414 ac 0.00% Impervious Runoff Depth=0.40"
Flow Length=319' Tc=13.5 min C=0.38 Runoff=0.83 cfs 0.047 af

Reach 5R: PRE Inflow=5.39 cfs 0.304 af
Outflow=5.39 cfs 0.304 af

Reach 6R: POST Inflow=5.79 cfs 0.327 af
Outflow=5.79 cfs 0.327 af

Total Runoff Area = 21.788 ac Runoff Volume = 0.631 af Average Runoff Depth = 0.35"
99.26% Pervious = 21.626 ac 0.74% Impervious = 0.162 ac

Subcatchment 1S: CT PAR-5 PRE



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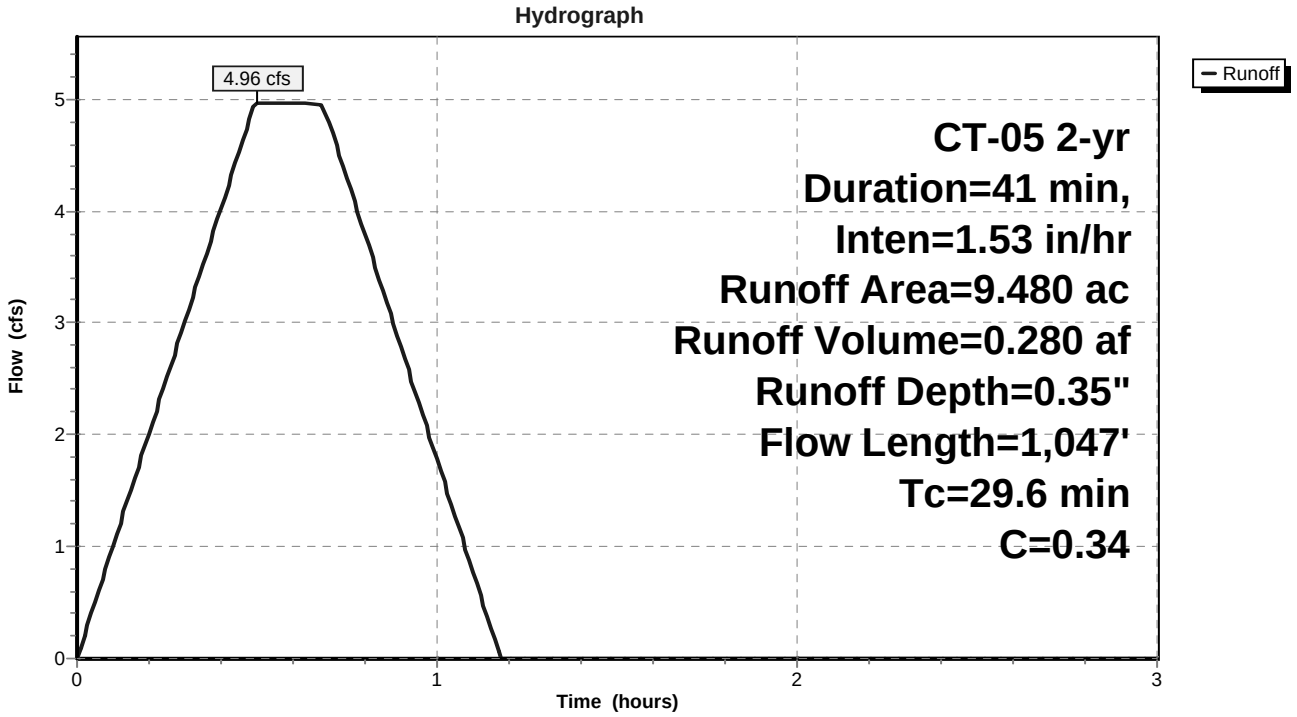

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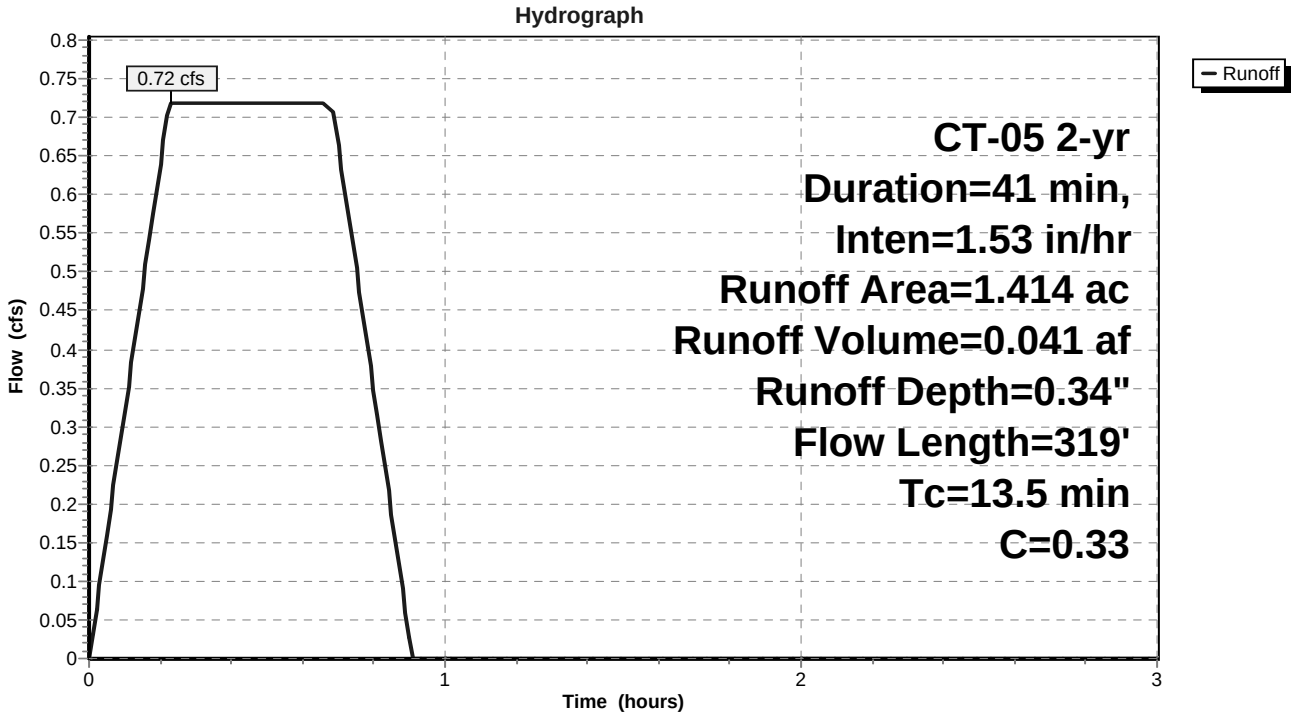

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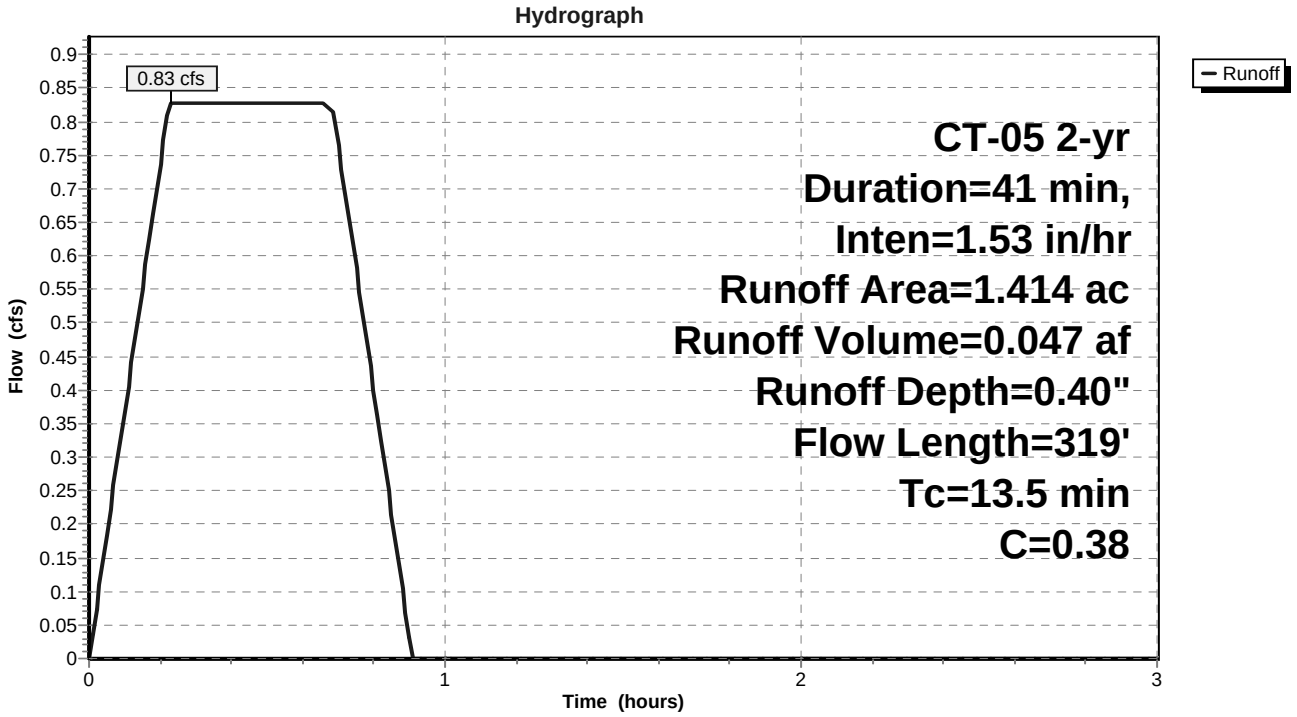
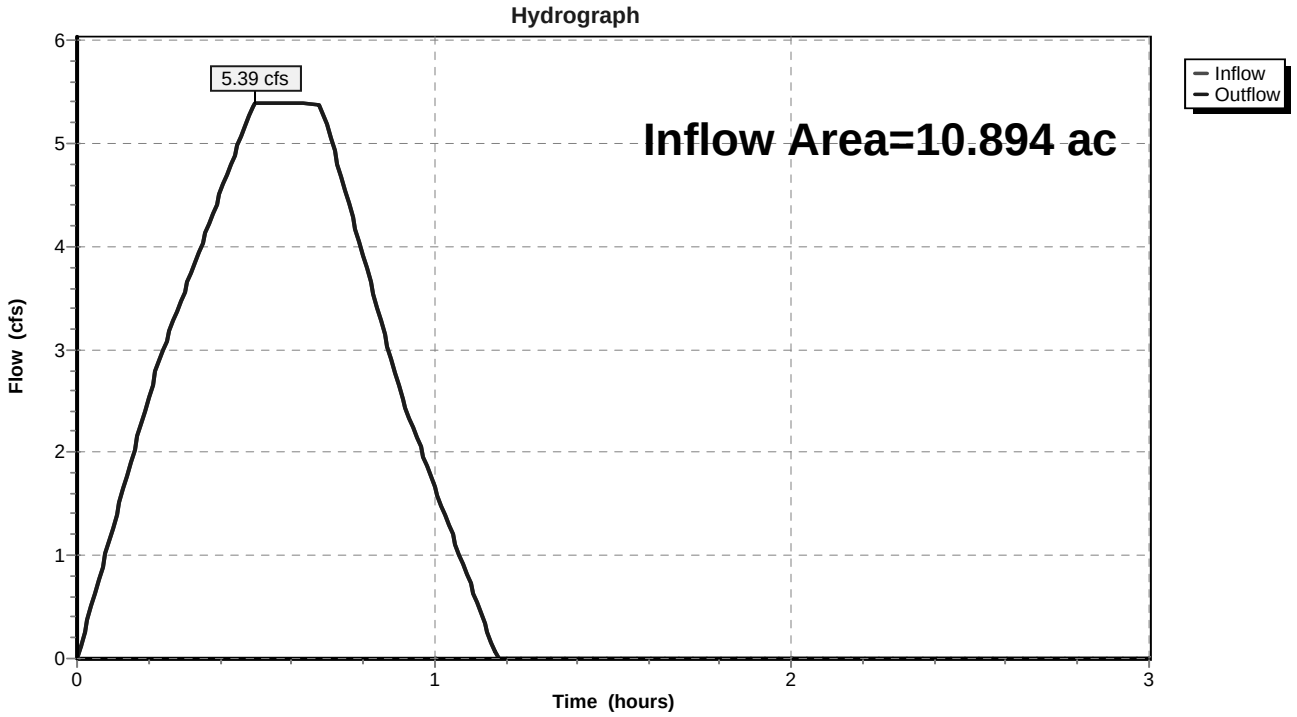


Reach 5R: PRE


Hydrograph
5.39 cfs
Inflow Area=10.894 ac
Inflow
Outflow
Flow (cfs)
Time (hours)
0
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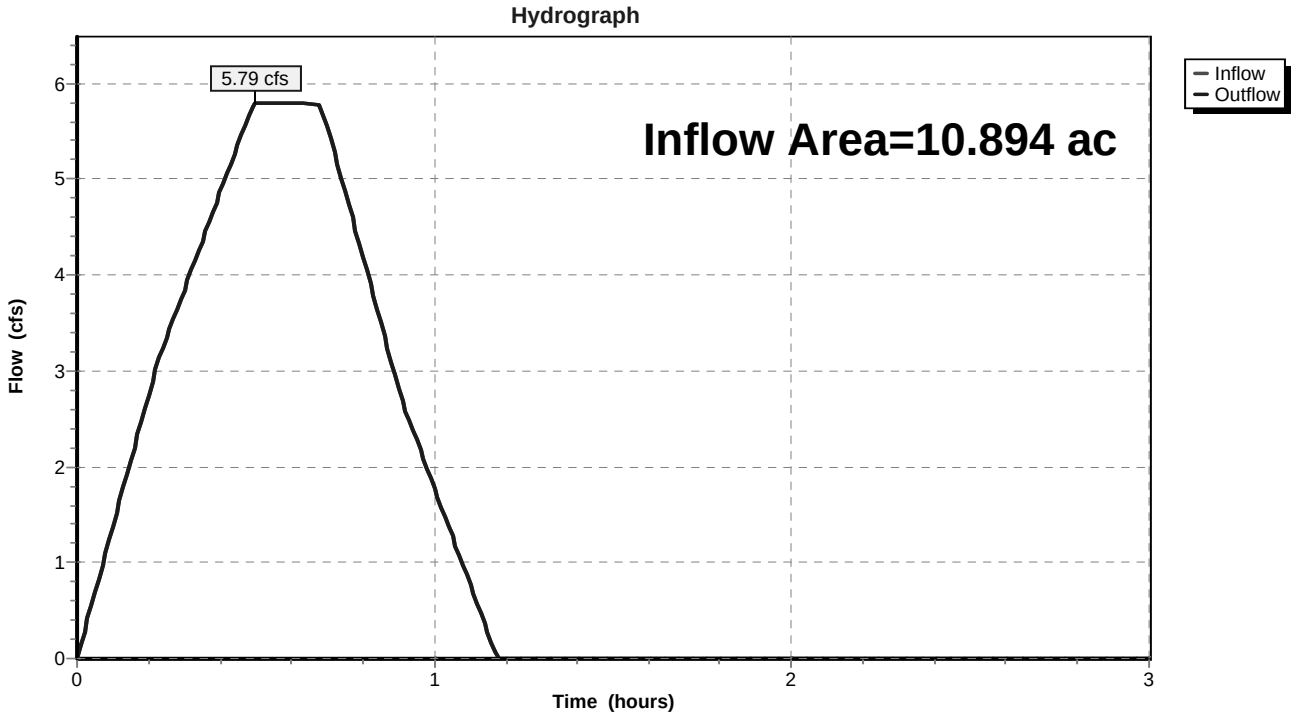
Reach 6R: POST



Time span=0.00-3.00 hrs, dt=0.01 hrs, 301 points
Runoff by Rational method, Rise/Fall=1.0/1.0 xTc
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: CT PAR-5 PRE Runoff Area=9.480 ac 0.85% Impervious Runoff Depth=0.49"
Flow Length=1,047' Tc=29.6 min C=0.32 Runoff=6.84 cfs 0.386 af

Subcatchment 2S: CT PAR-5 Post Runoff Area=9.480 ac 0.85% Impervious Runoff Depth=0.52"
Flow Length=1,047' Tc=29.6 min C=0.34 Runoff=7.27 cfs 0.410 af

Subcatchment 3S: CT PAR-5a PRE Runoff Area=1.414 ac 0.00% Impervious Runoff Depth=0.50"
Flow Length=319' Tc=13.5 min C=0.33 Runoff=1.05 cfs 0.059 af

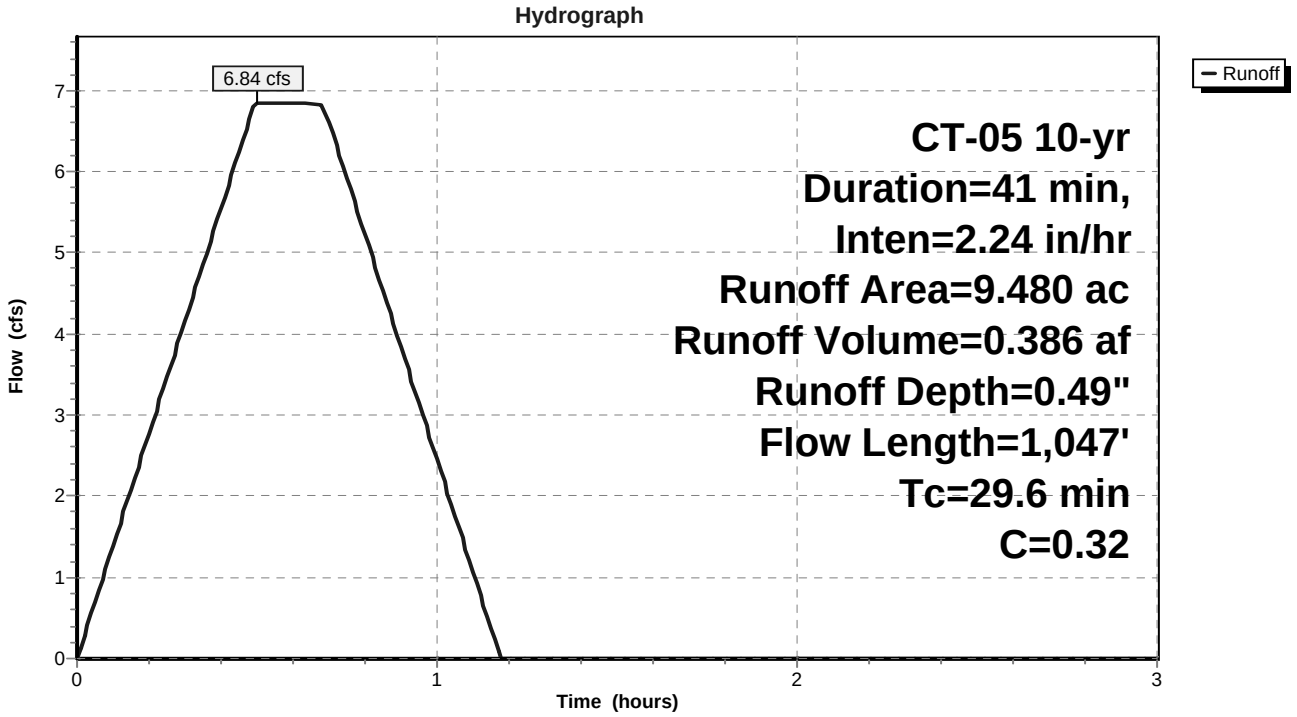
Subcatchment 4S: CT PAR-5a POST Runoff Area=1.414 ac 0.00% Impervious Runoff Depth=0.58"
Flow Length=319' Tc=13.5 min C=0.38 Runoff=1.21 cfs 0.068 af

Reach 5R: PRE Inflow=7.89 cfs 0.446 af
Outflow=7.89 cfs 0.446 af

Reach 6R: POST Inflow=8.48 cfs 0.479 af
Outflow=8.48 cfs 0.479 af

Total Runoff Area = 21.788 ac Runoff Volume = 0.924 af Average Runoff Depth = 0.51"
99.26% Pervious = 21.626 ac 0.74% Impervious = 0.162 ac

Subcatchment 1S: CT PAR-5 PRE



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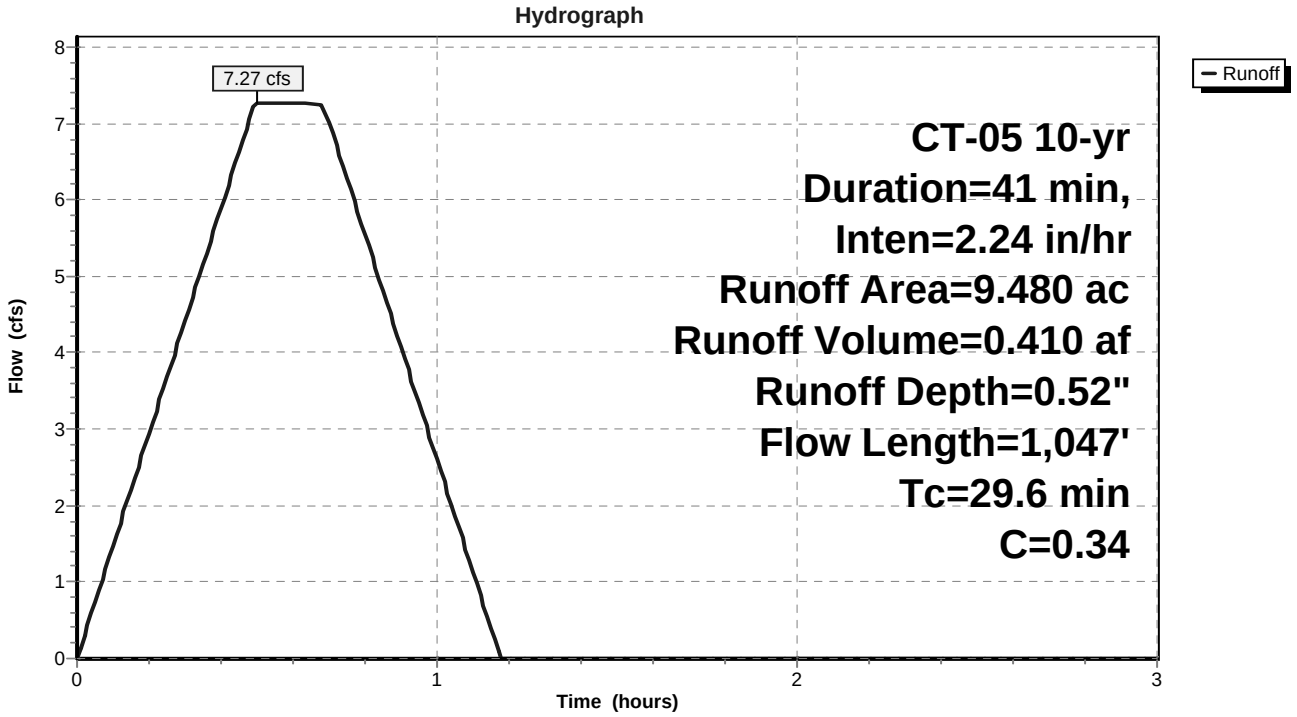
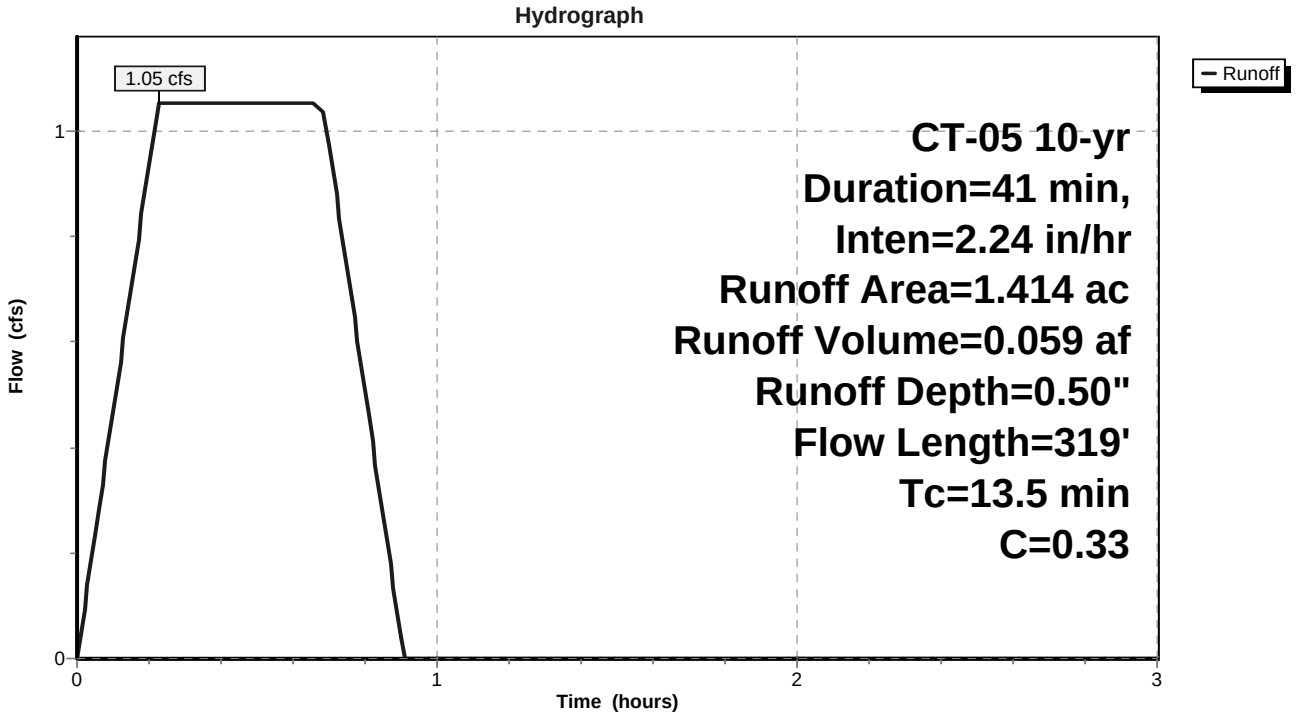


Subcatchment 3S: CT PAR-5a PRE



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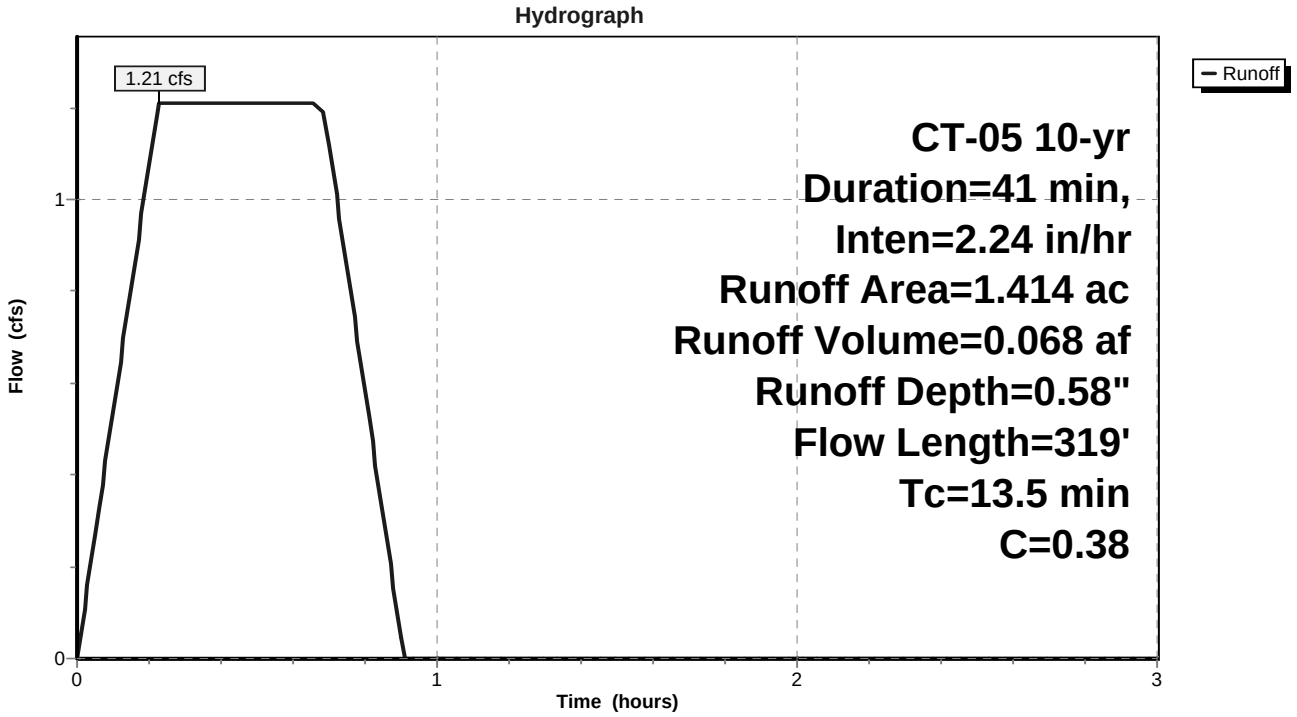
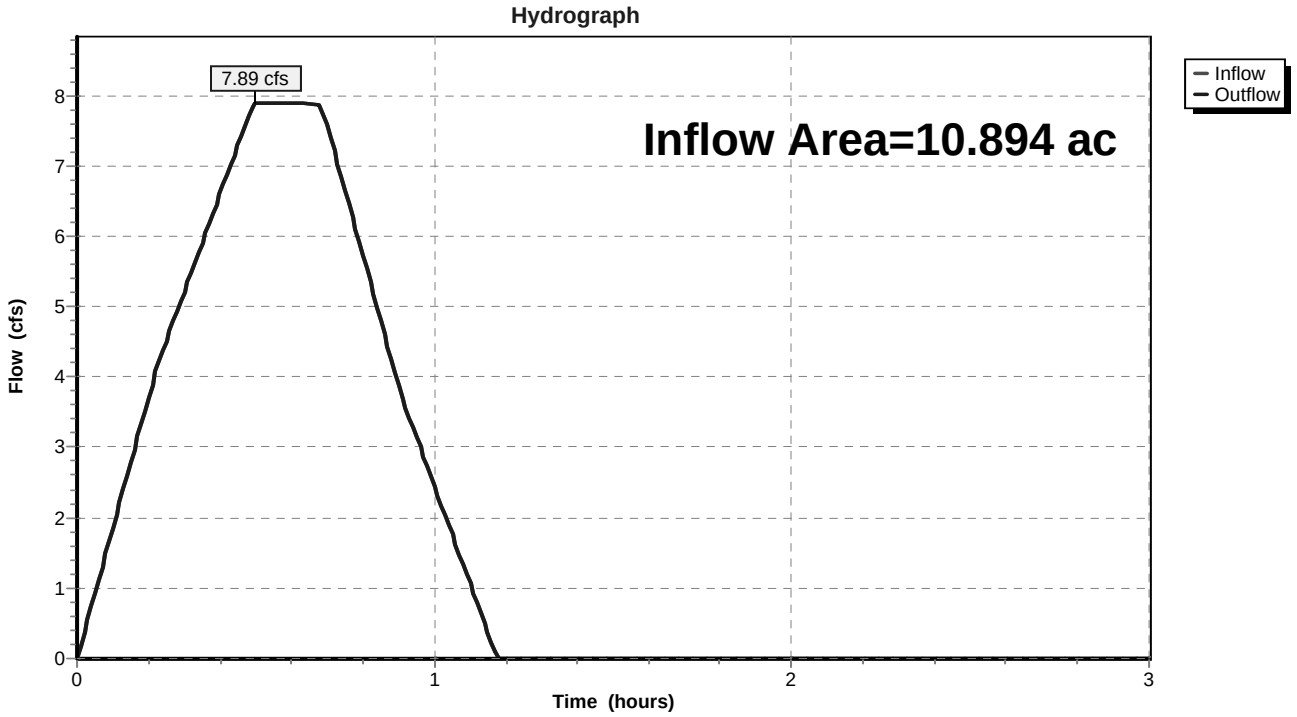


Reach 5R: PRE


Hydrograph
7.89 cfs
Inflow Area=10.894 ac
Inflow
Outflow
Flow (cfs)
Time (hours)
0
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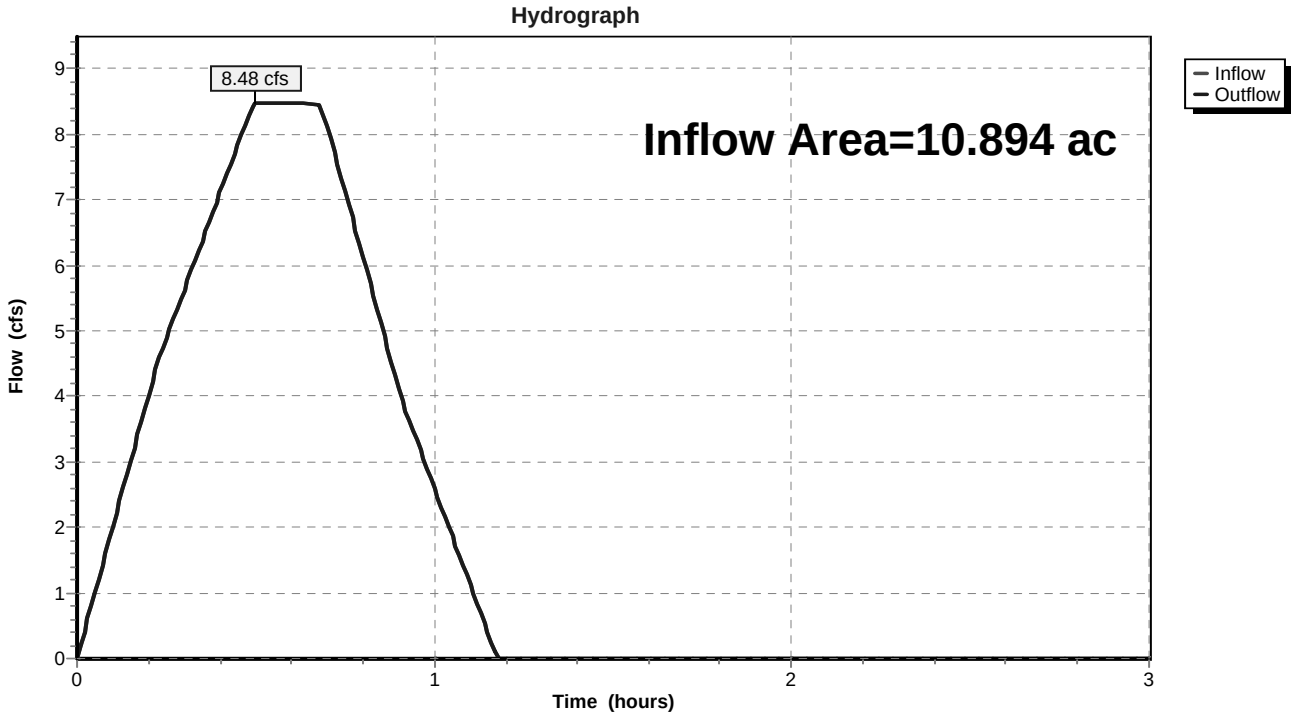
Reach 6R: POST



Time span=0.00-3.00 hrs, dt=0.01 hrs, 301 points
Runoff by Rational method, Rise/Fall=1.0/1.0 xTc
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: CT PAR-5 PRE Runoff Area=9.480 ac 0.85% Impervious Runoff Depth=0.85"
Flow Length=1,047' Tc=29.6 min C=0.32 Runoff=11.93 cfs 0.673 af

Subcatchment 2S: CT PAR-5 Post Runoff Area=9.480 ac 0.85% Impervious Runoff Depth=0.91"
Flow Length=1,047' Tc=29.6 min C=0.34 Runoff=12.67 cfs 0.716 af

Subcatchment 3S: CT PAR-5a PRE Runoff Area=1.414 ac 0.00% Impervious Runoff Depth=0.88"
Flow Length=319' Tc=13.5 min C=0.33 Runoff=1.83 cfs 0.104 af

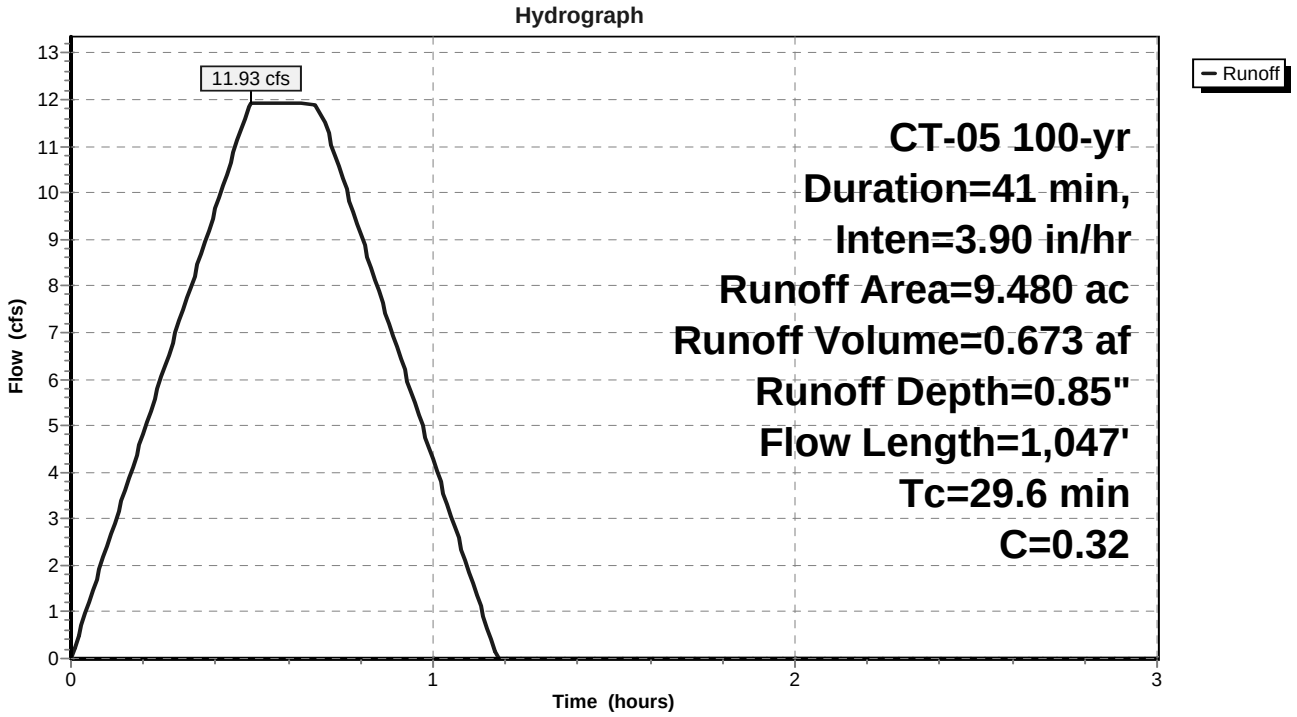
Subcatchment 4S: CT PAR-5a POST Runoff Area=1.414 ac 0.00% Impervious Runoff Depth=1.01"
Flow Length=319' Tc=13.5 min C=0.38 Runoff=2.11 cfs 0.119 af

Reach 5R: PRE Inflow=13.76 cfs 0.777 af
Outflow=13.76 cfs 0.777 af

Reach 6R: POST Inflow=14.78 cfs 0.835 af
Outflow=14.78 cfs 0.835 af

Total Runoff Area = 21.788 ac Runoff Volume = 1.612 af Average Runoff Depth = 0.89"
99.26% Pervious = 21.626 ac 0.74% Impervious = 0.162 ac

Subcatchment 1S: CT PAR-5 PRE



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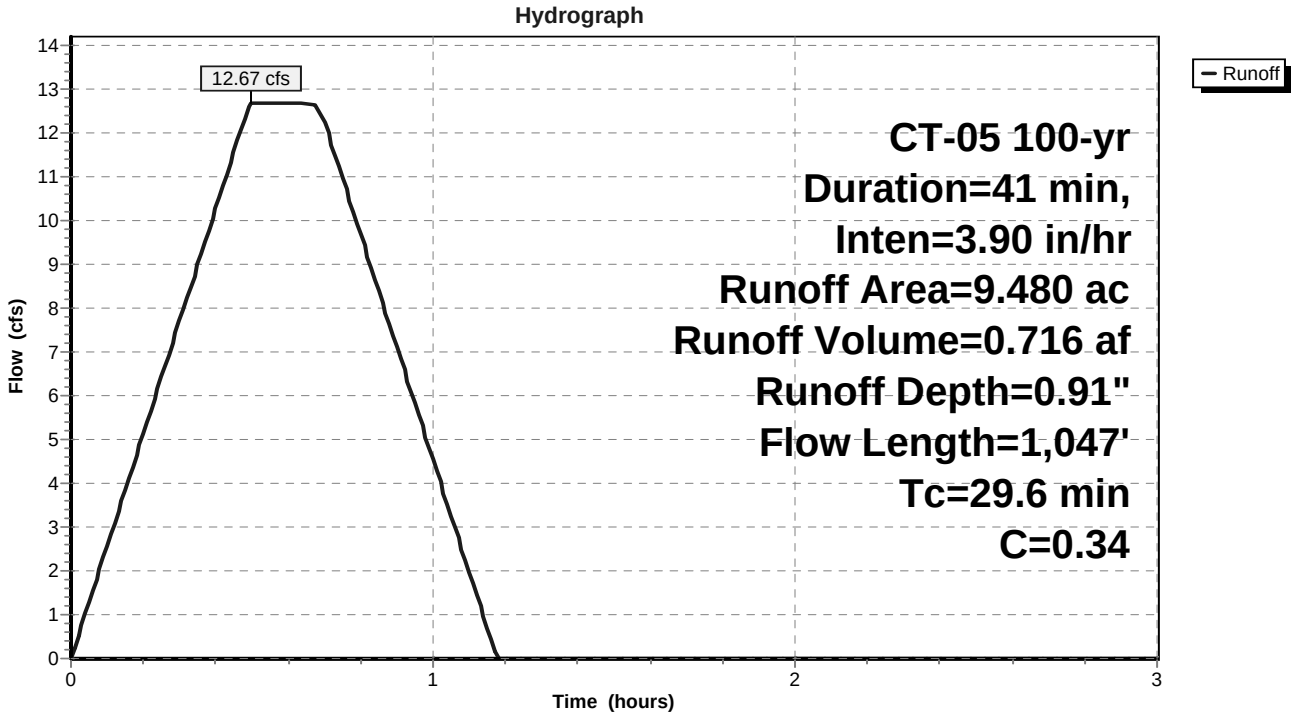
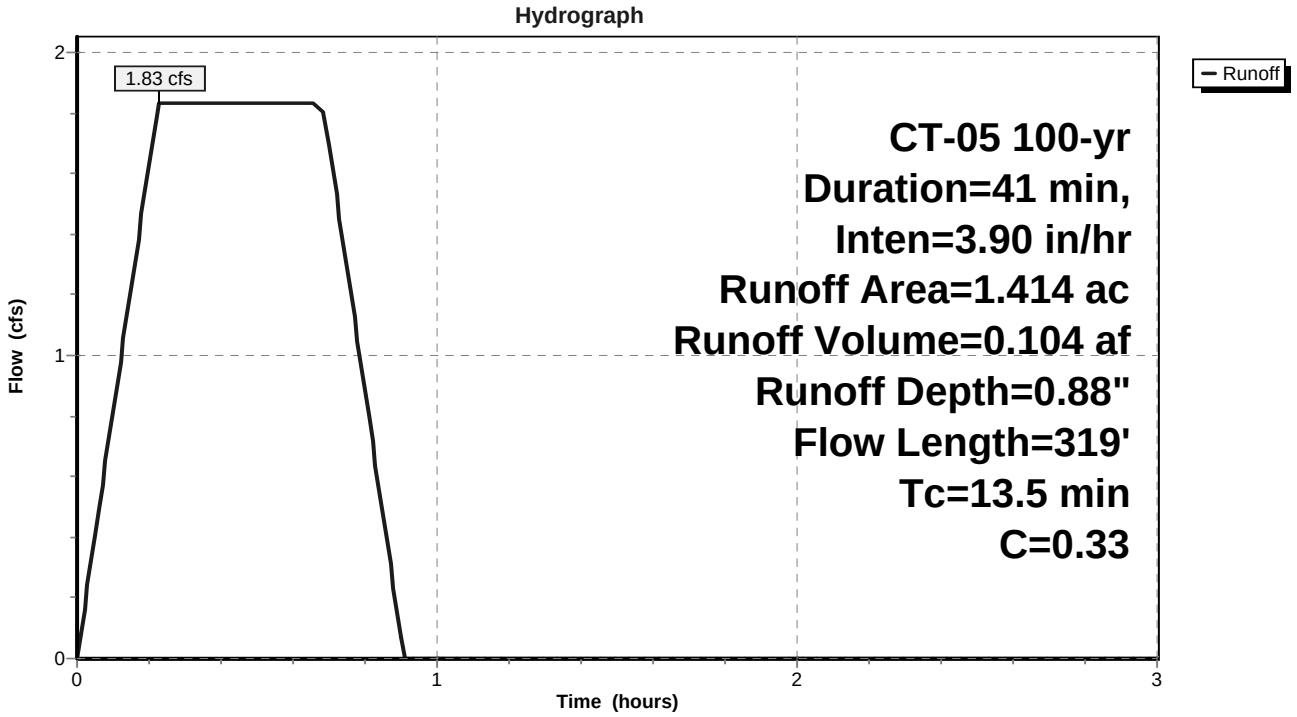
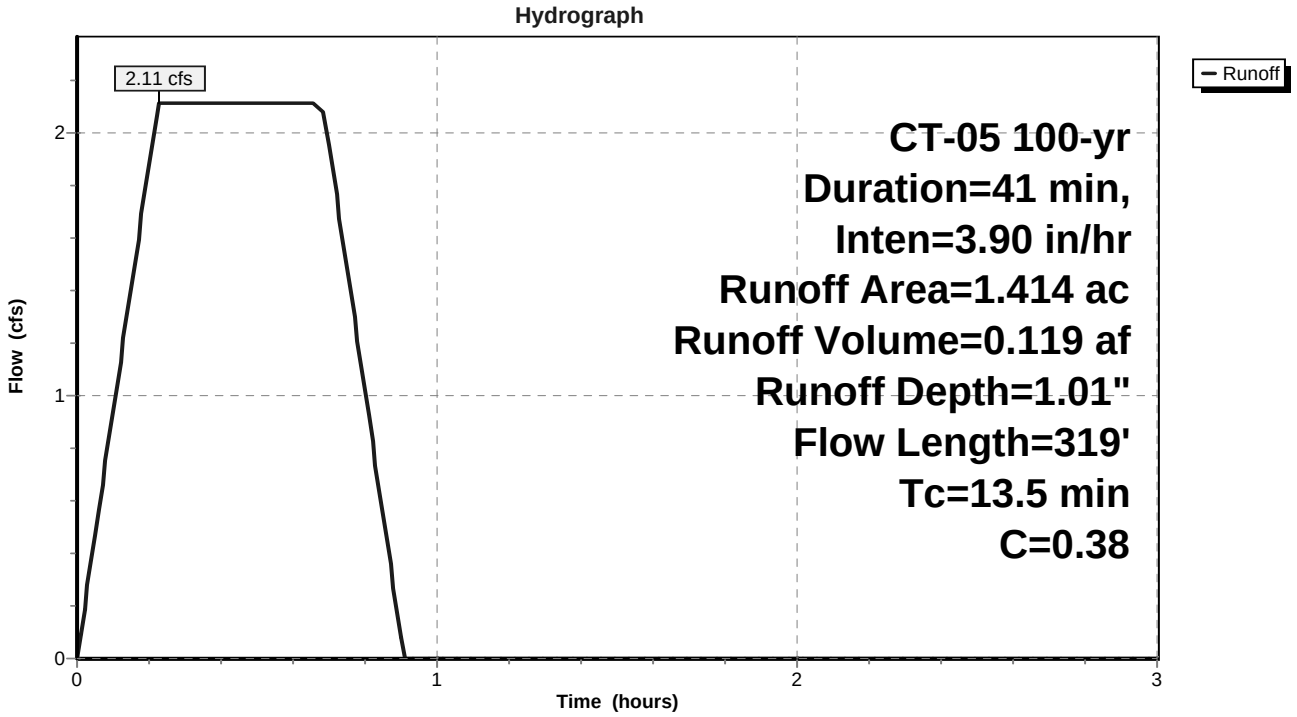


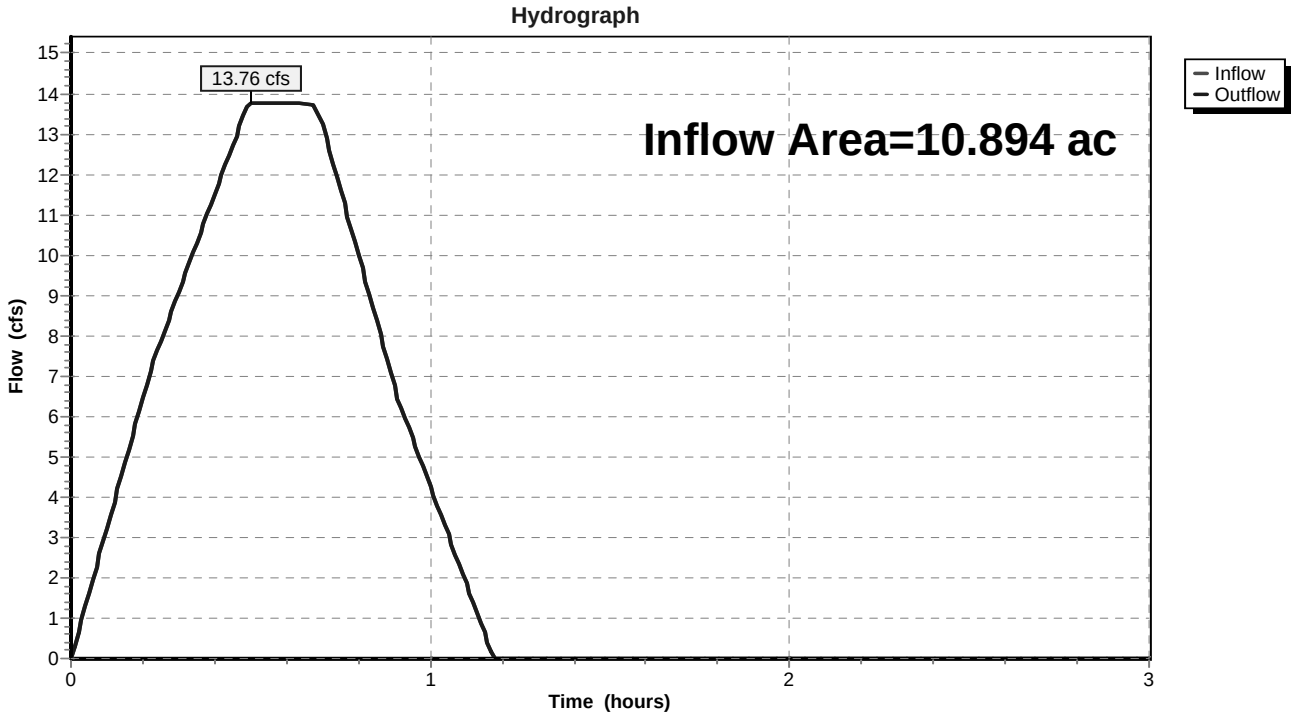
Subcatchment 3S: CT PAR-5a PRE



Subcatchment 4S: CT PAR-5a POST



Reach 5R: PRE


Hydrograph
13.76 cfs
Inflow Area=10.894 ac
Inflow
Outflow
Flow (cfs)
Time (hours)
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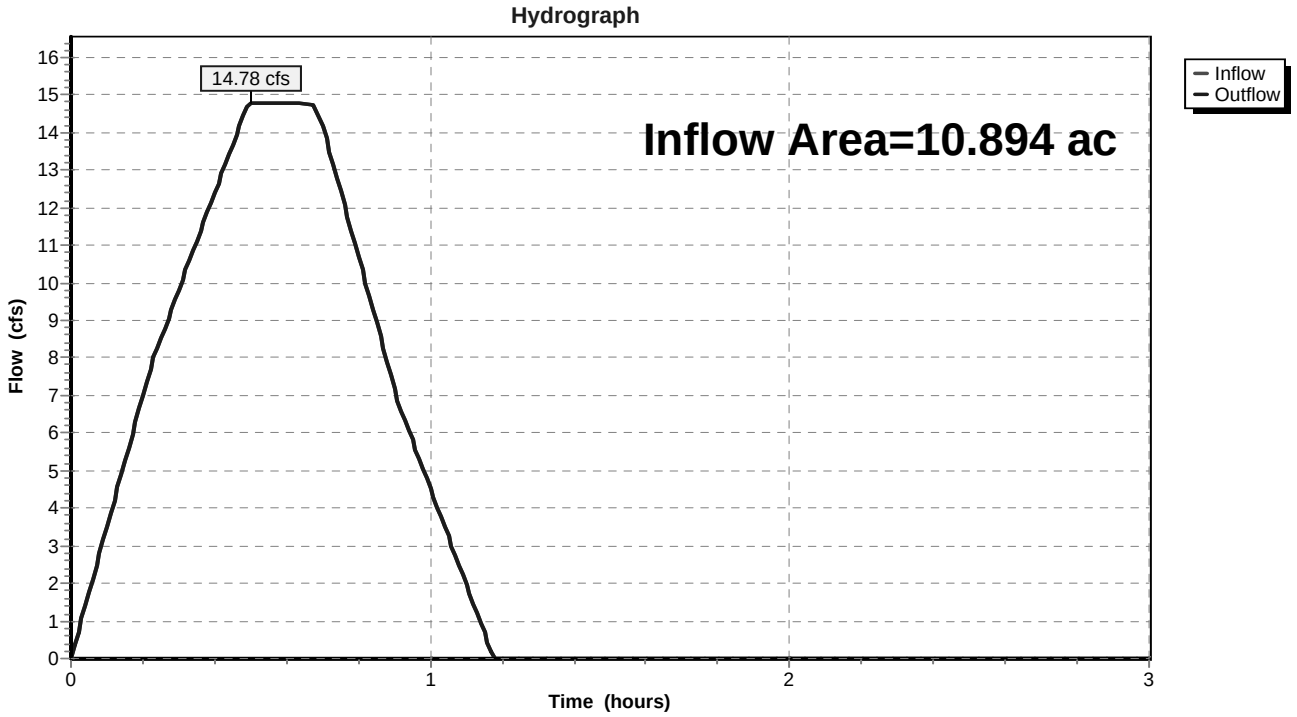
Reach 6R: POST