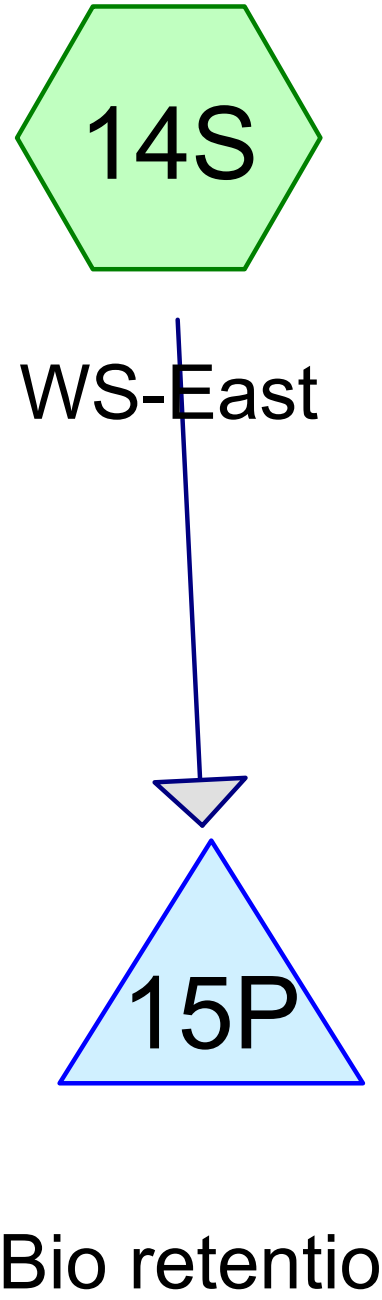
Bioretention Swale Modeling



Subcat Reach Pond Link

Routing Diagram for Borden St
Prepared by Krebs & Lansing Consulting Engineers, Inc., Printed 5/19/2023
HydroCAD® 10.00 s/n 06429 © 2013 HydroCAD Software Solutions LLC

NOAA Atlas 14, Volume 10, Version 3
Location name: Richmond, Vermont, USA*
Latitude: 44.405°, Longitude: -72.9968°
Elevation: 311 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sandra Pavlovic, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Orlan Wilhite

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.308 (0.240-0.392)	0.362 (0.282-0.461)	0.450 (0.349-0.575)	0.523 (0.404-0.672)	0.624 (0.464-0.830)	0.702 (0.510-0.951)	0.779 (0.548-1.09)	0.857 (0.578-1.24)	0.960 (0.623-1.43)	1.04 (0.657-1.58)
10-min	0.437 (0.340-0.556)	0.513 (0.399-0.653)	0.638 (0.495-0.815)	0.741 (0.572-0.953)	0.884 (0.658-1.18)	0.994 (0.723-1.35)	1.10 (0.776-1.54)	1.21 (0.819-1.75)	1.36 (0.883-2.03)	1.47 (0.931-2.24)
15-min	0.514 (0.401-0.654)	0.604 (0.470-0.769)	0.751 (0.582-0.959)	0.872 (0.673-1.12)	1.04 (0.774-1.38)	1.17 (0.850-1.58)	1.30 (0.913-1.81)	1.43 (0.963-2.06)	1.60 (1.04-2.39)	1.73 (1.10-2.63)
30-min	0.696 (0.542-0.885)	0.817 (0.636-1.04)	1.02 (0.787-1.30)	1.18 (0.909-1.51)	1.40 (1.05-1.87)	1.58 (1.15-2.14)	1.75 (1.23-2.45)	1.93 (1.30-2.78)	2.16 (1.40-3.22)	2.34 (1.48-3.56)
60-min	0.877 (0.684-1.12)	1.03 (0.802-1.31)	1.28 (0.992-1.64)	1.49 (1.15-1.91)	1.77 (1.32-2.36)	1.99 (1.45-2.70)	2.21 (1.55-3.08)	2.43 (1.64-3.51)	2.72 (1.77-4.06)	2.94 (1.86-4.48)
2-hr	1.09 (0.858-1.38)	1.28 (1.00-1.62)	1.58 (1.24-2.01)	1.84 (1.42-2.34)	2.18 (1.64-2.89)	2.45 (1.80-3.31)	2.72 (1.93-3.80)	3.01 (2.04-4.32)	3.41 (2.22-5.06)	3.73 (2.37-5.65)
3-hr	1.23 (0.966-1.54)	1.44 (1.13-1.81)	1.78 (1.39-2.25)	2.06 (1.60-2.62)	2.45 (1.85-3.24)	2.74 (2.02-3.70)	3.05 (2.18-4.26)	3.39 (2.30-4.85)	3.88 (2.53-5.73)	4.27 (2.72-6.44)
6-hr	1.46 (1.16-1.83)	1.72 (1.36-2.15)	2.14 (1.68-2.68)	2.48 (1.95-3.14)	2.96 (2.25-3.91)	3.32 (2.47-4.47)	3.70 (2.68-5.18)	4.15 (2.82-5.90)	4.80 (3.14-7.06)	5.34 (3.41-8.01)
12-hr	1.70 (1.36-2.11)	2.02 (1.61-2.51)	2.54 (2.01-3.16)	2.96 (2.34-3.72)	3.56 (2.72-4.66)	4.00 (2.99-5.36)	4.47 (3.25-6.23)	5.03 (3.44-7.11)	5.87 (3.85-8.59)	6.59 (4.22-9.82)
24-hr	1.98 (1.59-2.44)	2.35 (1.89-2.90)	2.96 (2.37-3.67)	3.47 (2.76-4.33)	4.17 (3.21-5.44)	4.69 (3.54-6.26)	5.25 (3.84-7.28)	5.92 (4.06-8.32)	6.92 (4.55-10.1)	7.76 (4.99-11.5)
2-day	2.33 (1.88-2.86)	2.75 (2.22-3.37)	3.43 (2.76-4.22)	4.00 (3.20-4.95)	4.78 (3.70-6.18)	5.37 (4.06-7.09)	5.99 (4.39-8.22)	6.71 (4.63-9.37)	7.78 (5.14-11.2)	8.67 (5.59-12.8)
3-day	2.60 (2.10-3.17)	3.04 (2.46-3.71)	3.76 (3.03-4.60)	4.35 (3.49-5.37)	5.18 (4.01-6.66)	5.79 (4.39-7.61)	6.44 (4.73-8.79)	7.19 (4.97-10.0)	8.28 (5.49-11.9)	9.18 (5.93-13.5)
4-day	2.82 (2.29-3.43)	3.28 (2.66-4.00)	4.03 (3.26-4.92)	4.65 (3.74-5.72)	5.51 (4.28-7.06)	6.15 (4.67-8.05)	6.83 (5.02-9.27)	7.60 (5.26-10.5)	8.70 (5.78-12.5)	9.62 (6.22-14.1)
7-day	3.40 (2.78-4.12)	3.91 (3.20-4.74)	4.75 (3.86-5.77)	5.44 (4.40-6.64)	6.39 (4.98-8.13)	7.11 (5.41-9.23)	7.85 (5.78-10.6)	8.68 (6.04-12.0)	9.86 (6.57-14.1)	10.8 (7.02-15.8)
10-day	3.96 (3.25-4.78)	4.52 (3.70-5.45)	5.43 (4.43-6.58)	6.18 (5.02-7.53)	7.23 (5.65-9.15)	8.01 (6.12-10.4)	8.83 (6.50-11.8)	9.72 (6.78-13.4)	11.0 (7.32-15.6)	12.0 (7.77-17.4)
20-day	5.67 (4.68-6.79)	6.36 (5.25-7.63)	7.50 (6.16-9.02)	8.44 (6.89-10.2)	9.74 (7.65-12.2)	10.7 (8.22-13.7)	11.7 (8.65-15.5)	12.8 (8.96-17.4)	14.2 (9.53-20.1)	15.3 (9.97-22.1)
30-day	7.12 (5.91-8.49)	7.92 (6.56-9.45)	9.22 (7.61-11.0)	10.3 (8.45-12.4)	11.8 (9.30-14.7)	12.9 (9.94-16.5)	14.1 (10.4-18.5)	15.3 (10.7-20.7)	16.8 (11.3-23.6)	18.0 (11.7-25.8)
45-day	8.95 (7.45-10.6)	9.86 (8.20-11.7)	11.4 (9.41-13.6)	12.6 (10.4-15.1)	14.3 (11.3-17.8)	15.6 (12.0-19.8)	16.9 (12.5-22.1)	18.2 (12.9-24.7)	19.9 (13.4-27.9)	21.1 (13.8-30.3)
60-day	10.5 (8.76-12.4)	11.5 (9.59-13.6)	13.1 (10.9-15.6)	14.5 (12.0-17.4)	16.4 (13.0-20.3)	17.9 (13.8-22.5)	19.3 (14.3-25.0)	20.7 (14.6-27.9)	22.4 (15.1-31.3)	23.7 (15.5-33.8)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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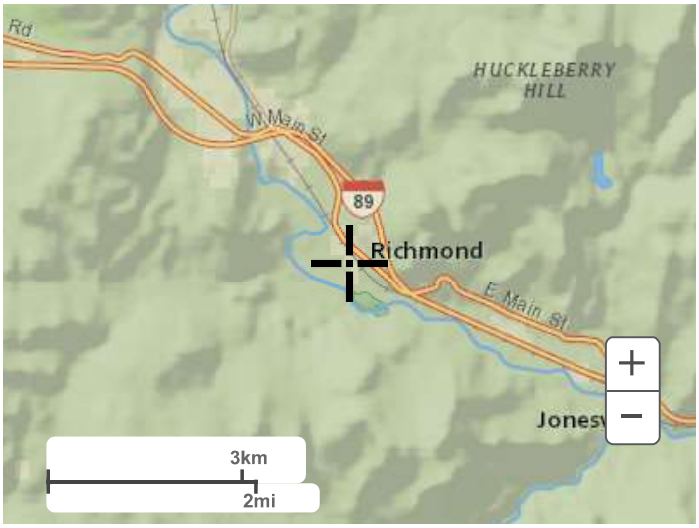
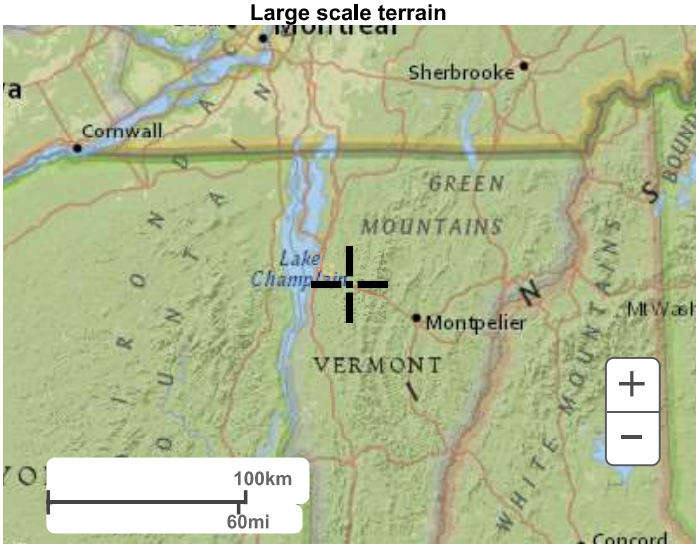
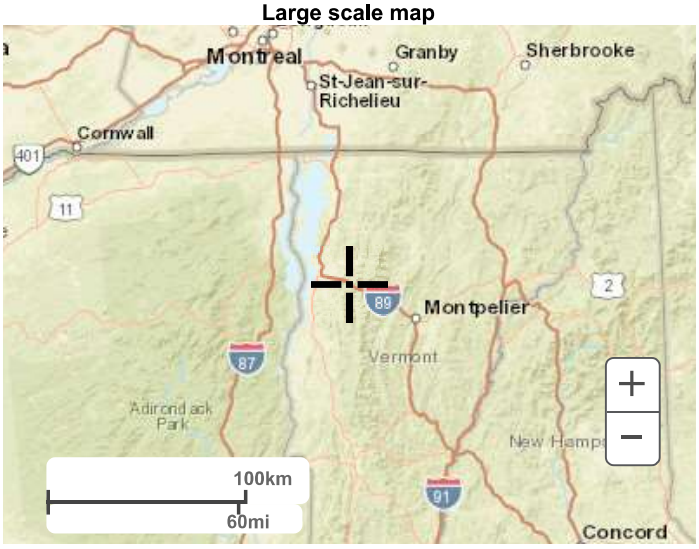
PF graphical



Large scale terrain



Large scale map



Large scale aerial

Version: 11/24/2020

Project Name:	**Richmond Village Housing**
Discharge Point:	**1**
Bioretention #	**1**

Bioretention (4.3.1)

	Practice Drainage Area	For Permit Coverage	Not for Permit Coverage	Total to Practice
1	Total Area (acres)	0.780	0.000	0.780
2	New Impervious (acres)	0.000	0.000	0.000
3	Redeveloped Impervious	0.510	0.000	0.510
		WQ_V for credit	WQ_V not for credit	Total WQ_V
4	WQ_V to practice	0.0208	0.0000	0.0208

Modified CN for WQ (1.0") storm	90

5	Designed to Infiltrate?	◯ Yes ◯ No
6*	Design Volume for Infiltration T_V (acre-feet)	
7	Designed to Infiltrate >WQ_V?	◯ n/a ◯ No ◯ Yes

Note: If the practice is designed to infiltrate the WQ_V, then $T_V = WQ_V$. Designers may use the Practice Drainage Area Runoff Calculator (second tab) for calculation of practice-specific runoff volumes for other treatment standards. Sizing of the filter bed area/swale bottom need to consider the desired treatment volume (see treatment section). Some design requirements will change based on the size of storm the practice is designed to treat.

** Questions preceded by an asterix (*) may change based on previously entered values*

	Feasibility (4.3.1.1)	**Response**	**Attachment location**
8*	Is the SHGWT at or below the bottom of the practice?	◯ Yes ◯ No	
9*	Has the infiltration rate (fc) of the underlying soil been confirmed to be at least 0.2 inches per hour by the soil testing requirements in Section 4.3.3.2?	◯ Yes ◯ No	
10*		◯ Yes ◯ No	

	Conveyance (4.3.1.2)	**Response**	**Attachment location**
11	Has an underdrain been provided? (required if the underlying soils have an infiltration rate of less than 0.2 inches per hour)	◯ Yes ◯ No	
12*		◯ Yes ◯ No	
13	Have the outfalls and the conveyance to the discharge point been designed/protected to avoid erosive velocities?	◯ Yes ◯ No	

Practice Drainage Area Runoff Calculator

Project Name:	**Richmond Village Housing**
Discharge Point:	**1**
Bioretention #	**1**

This tool may be used to calculate the required treatment volumes for the area draining to an individual practice where the practices drainage area is only a portion of of the area draining to a discharge point. Where the practice receives runoff from the entire area to a discharge point, this calculator will give the same information as the Standards Compliance Workbook.

Precipitation Data * Preciptation values shall be obtained from NOAA Atlas 14

Storm	**WQ Storm**	**1 yr, 24 hr**	**10 yr, 24 hr**	**100 yr, 24 hr**
Precipitation (inches)	1.00	1.98	3.47	5.25

Drainage Area Information

Pre Development Land Use (acres)

	Hydrologic Soil Group				
Landuse	A	B	C	D	Total (acres)
Grass	0.270	0.000	0.000	0.000	**0.270**
Meadow	0.000	0.000	0.000	0.000	**0.000**
Woods	0.000	0.000	0.000	0.000	**0.000**
Pavement, roofs, and other impervious	0.510	0.000	0.000	0.000	**0.510**
Total	**0.780**	**0.000**	**0.000**	**0.000**	**0.780**

Post Development Land Use (acres)

	Hydrologic Soil Group				
Landuse	A	B	C	D	Total (acres)
Grass	0.270	0.000	0.000	0.000	**0.270**
Meadow	0.000	0.000	0.000	0.000	**0.000**
Woods	0.000	0.000	0.000	0.000	**0.000**
Pavement, roofs, and other impervious	0.510	0.000	0.000	0.000	**0.510**
Total	**0.780**	**0.000**	**0.000**	**0.000**	**0.780**

T_V of upstream practices: 0.000 ac-ft T_V credit of this practice: 0.000 ac-ft

Treatment Standard	**Required Treatment Volume**	Post Development Runoff Volume	Pre-development Runoff Volume	Post Composite CN (to practice)	CN_{Adj} (with T_V practice credit)	Pre Composite CN
Channel Protection (Hydrologic Condition Method)	**0.0000**	0.0746	0.0746	91	91	91
Overbank Flood	**0.0000**	0.1377	0.1377	87	87	87
Extreme Flood	**0.0000**	0.2187	0.2187	83	83	83

Information for Calculating T_C by the Watershed Lag Method

Average Catchment Slope, Y (%)	Hydraulic Length, l (ft)	Time of Concentration, T_C (min)		
		1 yr	10 yr	100 yr

Pre Development	7.00%	275.00	2.9	3.4	3.9
Post Development, upstream of practice	7.00%	275.00	2.9	3.4	3.9
Post Development, with T_V credit from practice	0.00%	0.00	0.0	0.0	0.0

Project Notes

Richmond Village Housing
Stormwater Modeling

Area Listing (selected nodes)

Area (acres)	CN	Description (subcatchment-numbers)
0.780	90	Worksheet (14S)
0.780	**90**	**TOTAL AREA**

Time span=1.00-120.00 hrs, dt=0.01 hrs, 11901 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-Q
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 14S: WS-East Runoff Area=0.780 ac 0.00% Impervious Runoff Depth=0.32"
Flow Length=275' Slope=0.0700 '/' Tc=3.0 min CN=90 Runoff=0.50 cfs 0.021 af

Pond 15P: Bio retention Peak Elev=309.72' Storage=410 cf Inflow=0.50 cfs 0.021 af
Discarded=0.00 cfs 0.012 af Primary=0.04 cfs 0.008 af Outflow=0.04 cfs 0.021 af

Total Runoff Area = 0.780 ac Runoff Volume = 0.021 af Average Runoff Depth = 0.32"
100.00% Pervious = 0.780 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment 14S: WS-East

Runoff = 0.50 cfs @ 11.94 hrs, Volume= 0.021 af, Depth= 0.32"

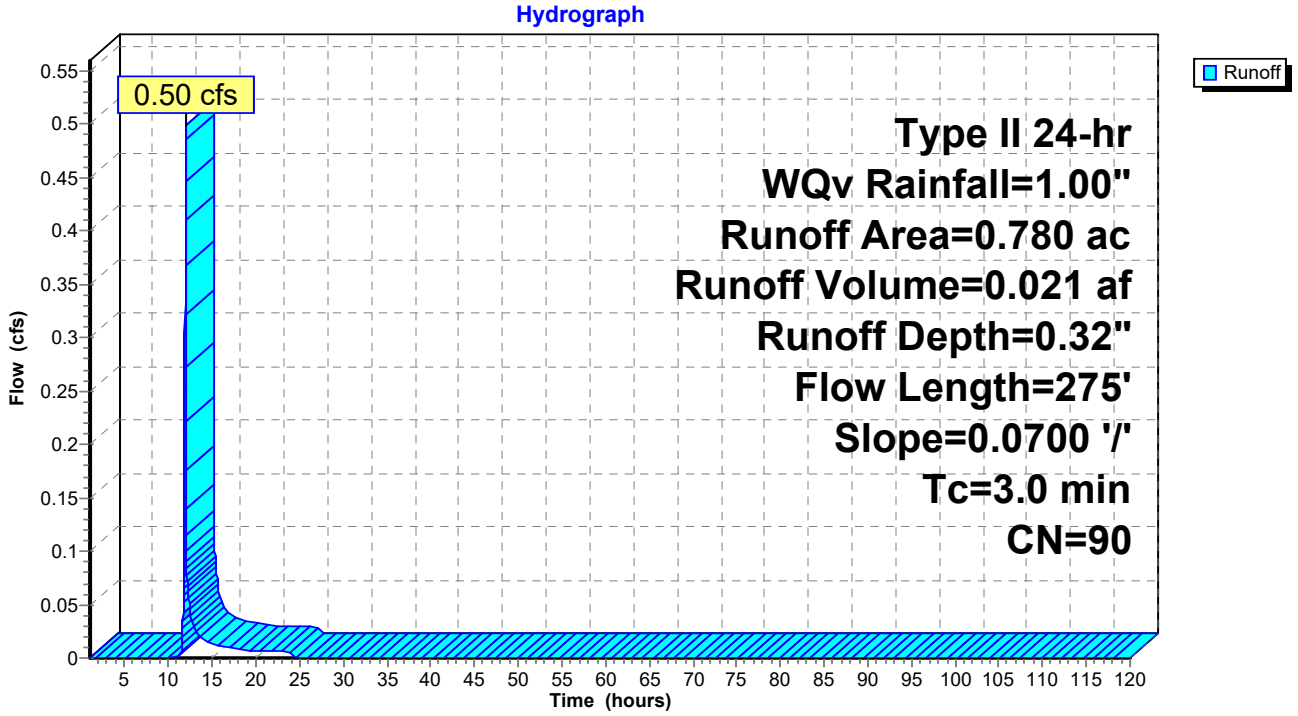
Runoff by SCS TR-20 method, UH=SCS, Weighted-Q, Time Span= 1.00-120.00 hrs, dt= 0.01 hrs
Type II 24-hr WQv Rainfall=1.00"

From Worksheet

	Area (ac)	CN	Description
*	0.780	90	Worksheet
	0.780		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.0	275	0.0700	1.53		**Lag/CN Method, Tc Lag**

Subcatchment 14S: WS-East



Summary for Pond 15P: Bio retention

Inflow Area = 0.780 ac, 0.00% Impervious, Inflow Depth = 0.32" for WQv event
Inflow = 0.50 cfs @ 11.94 hrs, Volume= 0.021 af
Outflow = 0.04 cfs @ 12.46 hrs, Volume= 0.021 af, Atten= 91%, Lag= 31.1 min
Discarded = 0.00 cfs @ 11.39 hrs, Volume= 0.012 af
Primary = 0.04 cfs @ 12.46 hrs, Volume= 0.008 af

Runoff volume reduction from Bioretention Swale

Routing by Stor-Ind method, Time Span= 1.00-120.00 hrs, dt= 0.01 hrs
Peak Elev= 309.72' @ 12.46 hrs Surf.Area= 914 sf Storage= 410 cf

Plug-Flow detention time= 775.4 min calculated for 0.021 af (100% of inflow)
Center-of-Mass det. time= 775.5 min (1,632.2 - 856.7)

Volume	Invert	Avail.Storage	Storage Description
#1	309.00'	769 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

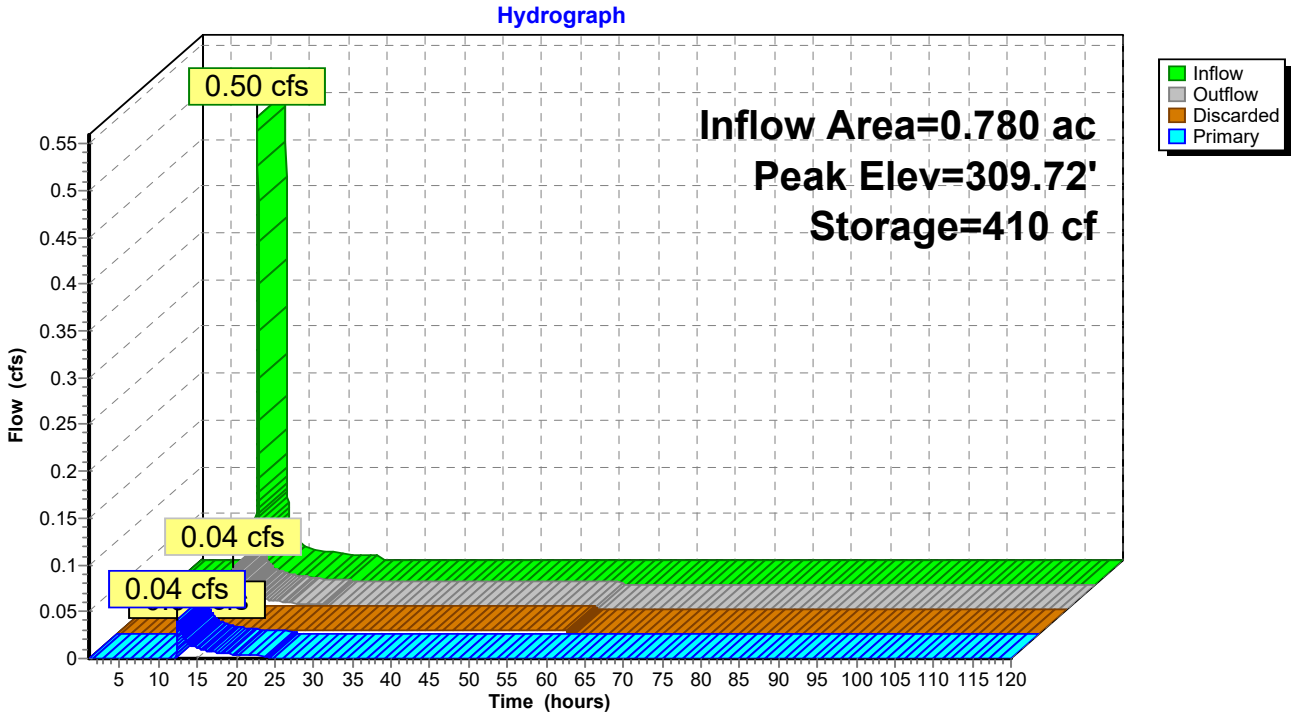
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
309.00	260	0	0
309.70	860	392	392
310.00	1,650	377	769

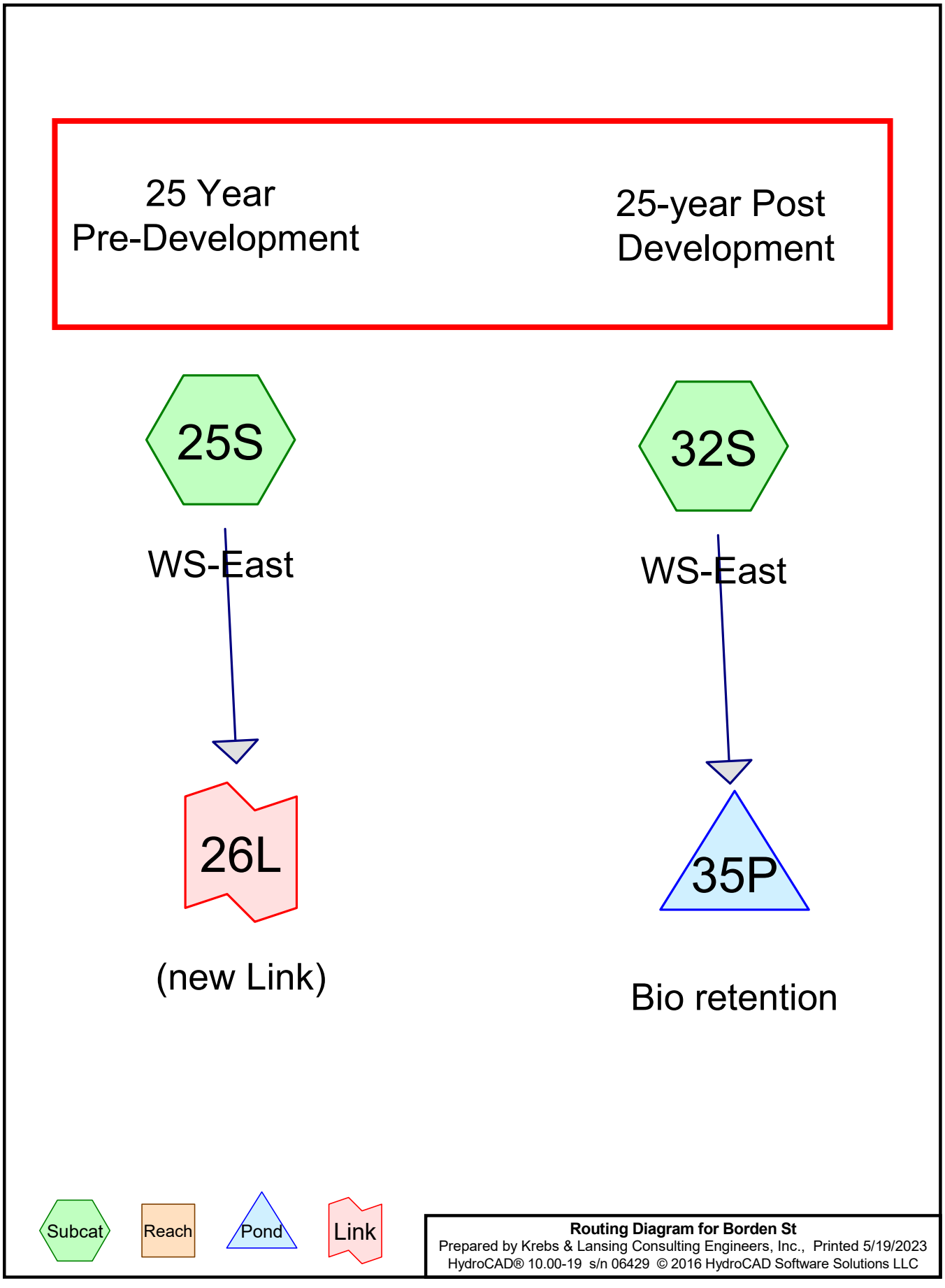
Device	Routing	Invert	Outlet Devices
#1	Discarded	309.00'	**0.500 in/hr Exfiltration over Surface area below 309.01'**
#2	Primary	309.70'	**6.0' long x 5.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.34 2.50 2.70 2.68 2.68 2.66 2.65 2.65 2.65 2.65 2.67 2.66 2.68 2.70 2.74 2.79 2.88

Discarded OutFlow Max=0.00 cfs @ 11.39 hrs HW=309.01' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.00 cfs)

Primary OutFlow Max=0.04 cfs @ 12.46 hrs HW=309.72' (Free Discharge)
↑—**2=Broad-Crested Rectangular Weir** (Weir Controls 0.04 cfs @ 0.33 fps)

Pond 15P: Bio retention




25 Year
Pre-Development
25-year Post
Development
25S
WS-East
26L
(new Link)
32S
WS-East
35P
Bio retention
Subcat
Reach
Pond
Link
Routing Diagram for Borden St
Prepared by Krebs & Lansing Consulting Engineers, Inc., Printed 5/19/2023
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Project Notes

Richmond Village Housing
Stormwater Modeling

Area Listing (selected nodes)

Area (acres)	CN	Description (subcatchment-numbers)
1.560	85	Worksheet - Interpolated (25S, 32S)
1.560	**85**	**TOTAL AREA**

Time span=1.00-120.00 hrs, dt=0.01 hrs, 11901 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-Q
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 25S: WS-East Runoff Area=0.780 ac 0.00% Impervious Runoff Depth=2.61"
Tc=3.7 min CN=85 Runoff=3.86 cfs 0.170 af

Subcatchment 32S: WS-East Runoff Area=0.780 ac 0.00% Impervious Runoff Depth=2.61"
Tc=3.7 min CN=85 Runoff=3.86 cfs 0.170 af

Pond 35P: Bio retention Peak Elev=310.03' Storage=753 cf Inflow=3.86 cfs 0.170 af
Discarded=0.00 cfs 0.013 af Primary=3.71 cfs 0.156 af Outflow=3.71 cfs 0.170 af

Link 26L: (new Link) Inflow=3.86 cfs 0.170 af
Primary=3.86 cfs 0.170 af

Total Runoff Area = 1.560 ac Runoff Volume = 0.339 af Average Runoff Depth = 2.61"
100.00% Pervious = 1.560 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment 25S: WS-East

Runoff = 3.86 cfs @ 11.94 hrs, Volume= 0.170 af, Depth= 2.61"

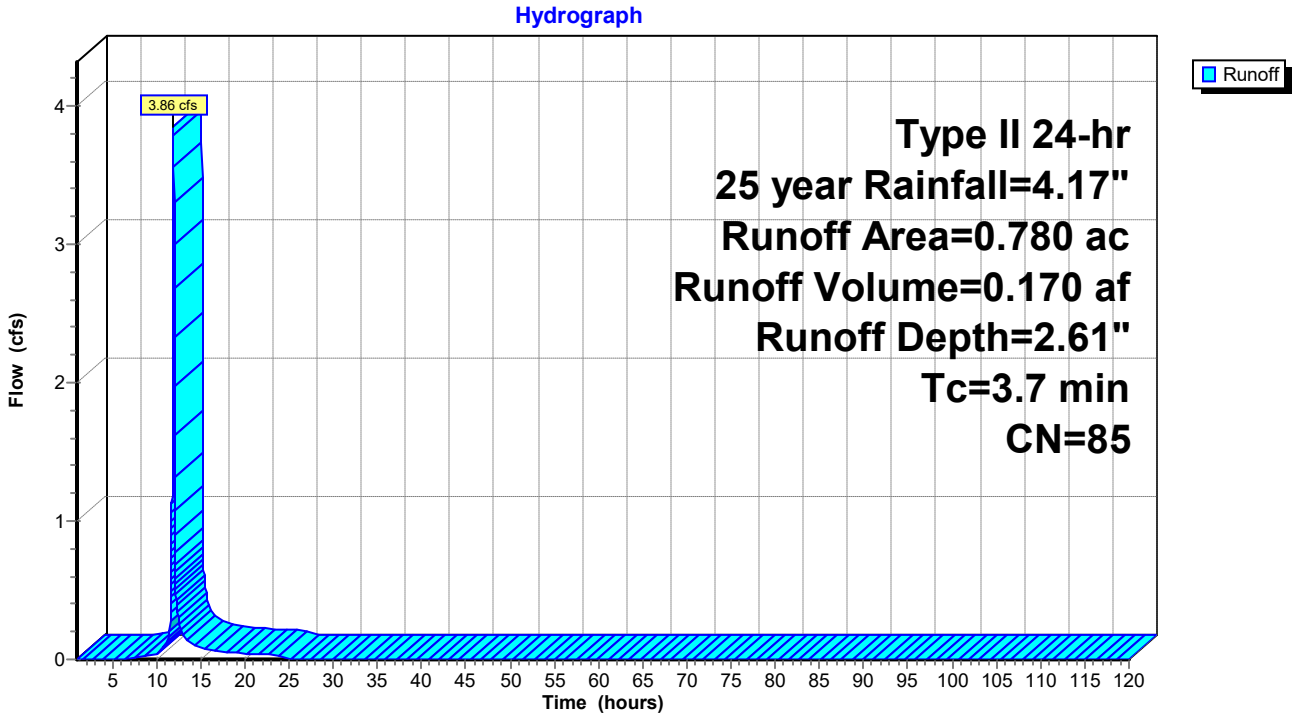
Runoff by SCS TR-20 method, UH=SCS, Weighted-Q, Time Span= 1.00-120.00 hrs, dt= 0.01 hrs
Type II 24-hr 25 year Rainfall=4.17"

CN and Tc interpolated between 10 year and 100 year worksheet calculation

	Area (ac)	CN	Description
*	0.780	85	Worksheet - Interpolated
	0.780		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.7					**Direct Entry, Tc from Worksheet - Interpolated**

Subcatchment 25S: WS-East



Summary for Subcatchment 32S: WS-East

Runoff = 3.86 cfs @ 11.94 hrs, Volume= 0.170 af, Depth= 2.61"

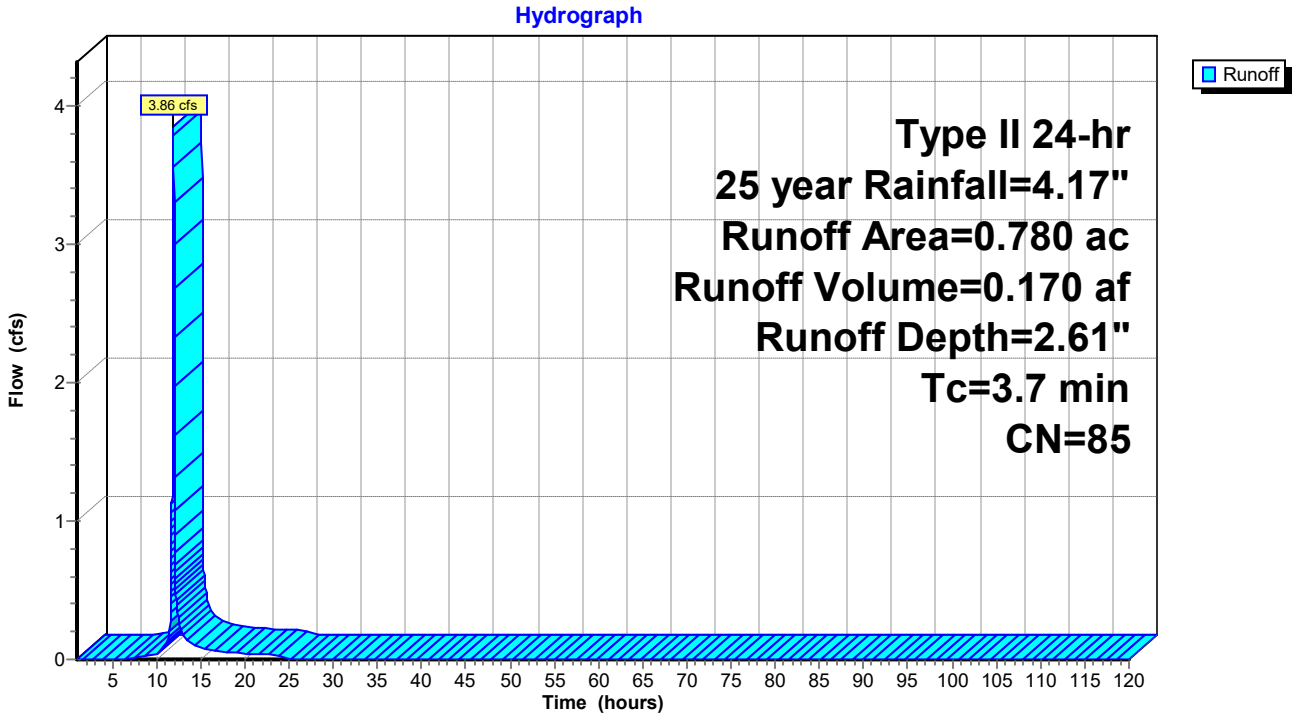
Runoff by SCS TR-20 method, UH=SCS, Weighted-Q, Time Span= 1.00-120.00 hrs, dt= 0.01 hrs
Type II 24-hr 25 year Rainfall=4.17"

CN and Tc interpolated between 10 year and 100 year worksheet calculation

	Area (ac)	CN	Description
*	0.780	85	Worksheet - Interpolated
	0.780		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.7					**Direct Entry, Tc from Worksheet - Interpolated**

Subcatchment 32S: WS-East



25 year storm Post Development Peak Discharge Rate

Summary for Pond 35P: Bio retention

Inflow Area = 0.780 ac, 0.00% Impervious, Inflow Depth = 2.61" for 25 year event
Inflow = 3.86 cfs @ 11.94 hrs, Volume= 0.170 af
Outflow = 3.71 cfs @ 11.96 hrs, Volume= 0.170 af, Atten= 4%, Lag= 1.0 min
Discarded = 0.00 cfs @ 7.19 hrs, Volume= 0.013 af
Primary = 3.71 cfs @ 11.96 hrs, Volume= 0.156 af

Routing by Stor-Ind method, Time Span= 1.00-120.00 hrs, dt= 0.01 hrs
Peak Elev= 310.03' @ 11.96 hrs Surf.Area= 1,330 sf Storage= 753 cf

Plug-Flow detention time= 104.5 min calculated for 0.170 af (100% of inflow)
Center-of-Mass det. time= 104.7 min (914.3 - 809.6)

Volume	Invert	Avail.Storage	Storage Description
#1	309.00'	1,536 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

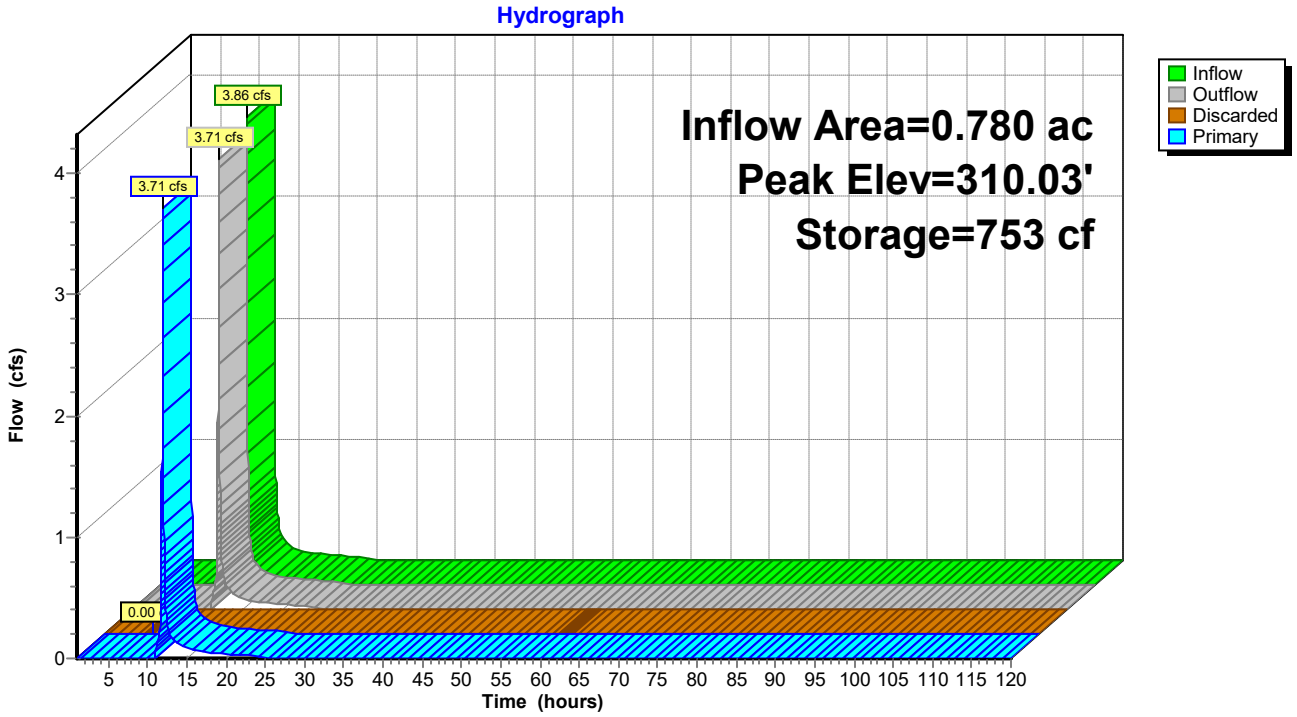
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
309.00	260	0	0
309.70	860	392	392
310.50	2,000	1,144	1,536

Device	Routing	Invert	Outlet Devices
#1	Discarded	309.00'	**0.500 in/hr Exfiltration over Surface area below 309.01'**
#2	Primary	309.70'	**8.0' long x 5.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.34 2.50 2.70 2.68 2.68 2.66 2.65 2.65 2.65 2.65 2.67 2.66 2.68 2.70 2.74 2.79 2.88

Discarded OutFlow Max=0.00 cfs @ 7.19 hrs HW=309.02' (Free Discharge)
└**1=Exfiltration** (Exfiltration Controls 0.00 cfs)

Primary OutFlow Max=3.70 cfs @ 11.96 hrs HW=310.03' (Free Discharge)
└**2=Broad-Crested Rectangular Weir** (Weir Controls 3.70 cfs @ 1.40 fps)

Pond 35P: Bio retention



25 year storm
Predevelopment peak
discharge rate

Summary for Link 26L: (new Link)

Inflow Area = 0.780 ac, 0.00% Impervious, Inflow Depth = 2.61" for 25 year event
Inflow = 3.86 cfs @ 11.94 hrs, Volume= 0.170 af
Primary = 3.86 cfs @ 11.94 hrs, Volume= 0.170 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 1.00-120.00 hrs, dt= 0.01 hrs

Link 26L: (new Link)