PRIME ENGINEERING, INC.
CIVIL AND ENVIRONMENTAL ENGINEERING
LAND SURVEYING
P.O. BOX 1088
LAKEVILLE, MA 02347
TEL:(508) 947-0050 FAX: (508) 947-2004

Pipe Design Calculations

PROJECT Cardinal Place

INLET GRATE AND PIPE ANALYSIS - 10 YR STORM - ASBUILT
CALCULATED BY: EKW DATE 7-7-2015
CHECKED BY: DATE

LOCATION		GRATE ANALYSIS						PIPE ANALYSIS							
FROM	TO	(S)ag or (G)utter	FLOW TO GRATE	GRATE CAPACITY	OVER-FLOW	DEPTH OF FLOW	FLOW TO PIPE	PIPE SIZE DIA.	LNGTH FT.	SLOPE FT./FT.	Q CAPACITY cfs	Q ACTUAL cfs	V FULL fps	V ACTUAL fps	CHECK?
CB-1	STC-1	S	1.51	4.43	0.00	0.7"	1.51	12	53	0.0075	3.10	1.51	3.95	3.90	OK
CB-2	STC-1	S	1.45	4.43	0.00	0.7"	1.45	12	47	0.0085	3.30	1.45	4.20	4.04	OK
STC-1	HW-1						2.95	12	67	0.0070	2.99	2.95	3.81	4.25	OK
CB-3	STC-2	G	0.15	0.28	0.00	0.9"	0.15	12	21	0.0210	5.17	0.15	6.58	3.29	OK
CB-4	STC-2	G	0.11	0.23	0.00	0.8"	0.11	12	8	0.0675	9.28	0.11	11.82	5.91	OK
STC-1	PIT						0.26	12	67	0.0070	2.99	0.26	3.81	2.14	OK
SGI-1	STC-3	G	0.05	0.15	0.00	0.6"	0.05	6	37.5	0.0053	0.89	0.05	4.53	2.27	OK
SGI-2	STC-3	G	0.11	0.22	0.00	0.8"	0.11	6	19	0.0105	1.25	0.11	6.37	3.58	OK
STC-3	FES						0.16	12	57.8	0.0088	7.27	0.16	9.26	4.63	OK

COMMONWEALTH OF MASSACHUSETTS
RICHARD J. RHEAUME
No. 28373
CIVIL
REGISTERED PROFESSIONAL ENGINEER

PRIME ENGINEERING INC

Input Values

K Values for grate R-3405-A with a transverse gutter slope of 2%	
LONGITUDINAL SLOPE (%)	K FOR R-3405-A
1	19
1.5	20.75
2	22.5
2.5	24.25
3	26
3.5	27.25
4	28.5
4.5	29.5
5	30.5
5.5	31.5
6	32.5

K Values for grate R-3455-A with a transverse gutter slope of 2%	
LONGITUDINAL SLOPE (%)	K FOR R-3405-A
1	19
1.5	22
2	25
2.5	26.5
3	28
3.5	29.5
4	31
4.5	31.75
5	32.5
5.5	33.25
6	34

ROADWAY PROPERTIES	
Roughness Coefficient of Bituminous Asphalt	0.016
Transverse Slope	0.02

Geometric Values for grate R-3405-A	
Square Dimention (in.)	23.6
Free Area (sq. ft.)	1.3

GUTTER DEPTH OF FLOW

$$D = \left(\frac{QN}{0.56Z\sqrt{S}}\right)^{\frac{3}{8}}$$

Q = Channel flow (cfs)
Z = Reciprocal of transverse slope (ft/ft)
S = Longitudinal Slope
N = Roughness Coefficient
D = Depth (ft)

GUTTER CAPACITY OF GRATE

$$Q = KD^{\frac{5}{3}}$$

Q = Grate capacity (cfs)
K = Grate coef. from "Inlet Grate Capacities Manual"
D = Depth of flow in feet (from previous equation)

ORIFICE FLOW EQUATION

$$Q = .6A\sqrt{2gh}$$

Q = Capacity (cfs)
A = Free open area (sq. ft.)
g = Acceleration of Gravity (32.2 ft/s^2)
h = Head (ft.)

WEIR EQUATION

$$Q = 3.3P(h)^{\frac{3}{2}}$$

Q = Capacity (cfs)
P = Perimeter (ft.)
h = Head (ft.)

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GUTTER INLET CATCH BASINS

STRUCTURE	LONGITUDINAL SLOPE (%)	CONTRIBUTING FLOW (cfs)	CARRYOVER FLOW (cfs)	TOTAL FLOW (cfs)	DEPTH OF FLOW (ft)	WIDTH OF FLOW (ft)	K	CAPACITY (cfs)	OVERFLOW (cfs)	OVERFLOW TO
CB-3	1.6	0.15	0.00	0.15	0.08	2.53	20.75	0.28	0.00	
CB-4	1.6	0.11	0.00	0.11	0.07	2.26	20.75	0.23	0.00	
SGI-1	1.6	0.05	0.00	0.05	0.05	1.70	20.75	0.15	0.00	
SGI-2	1.6	0.11	0.00	0.11	0.07	2.20	20.75	0.22	0.00	

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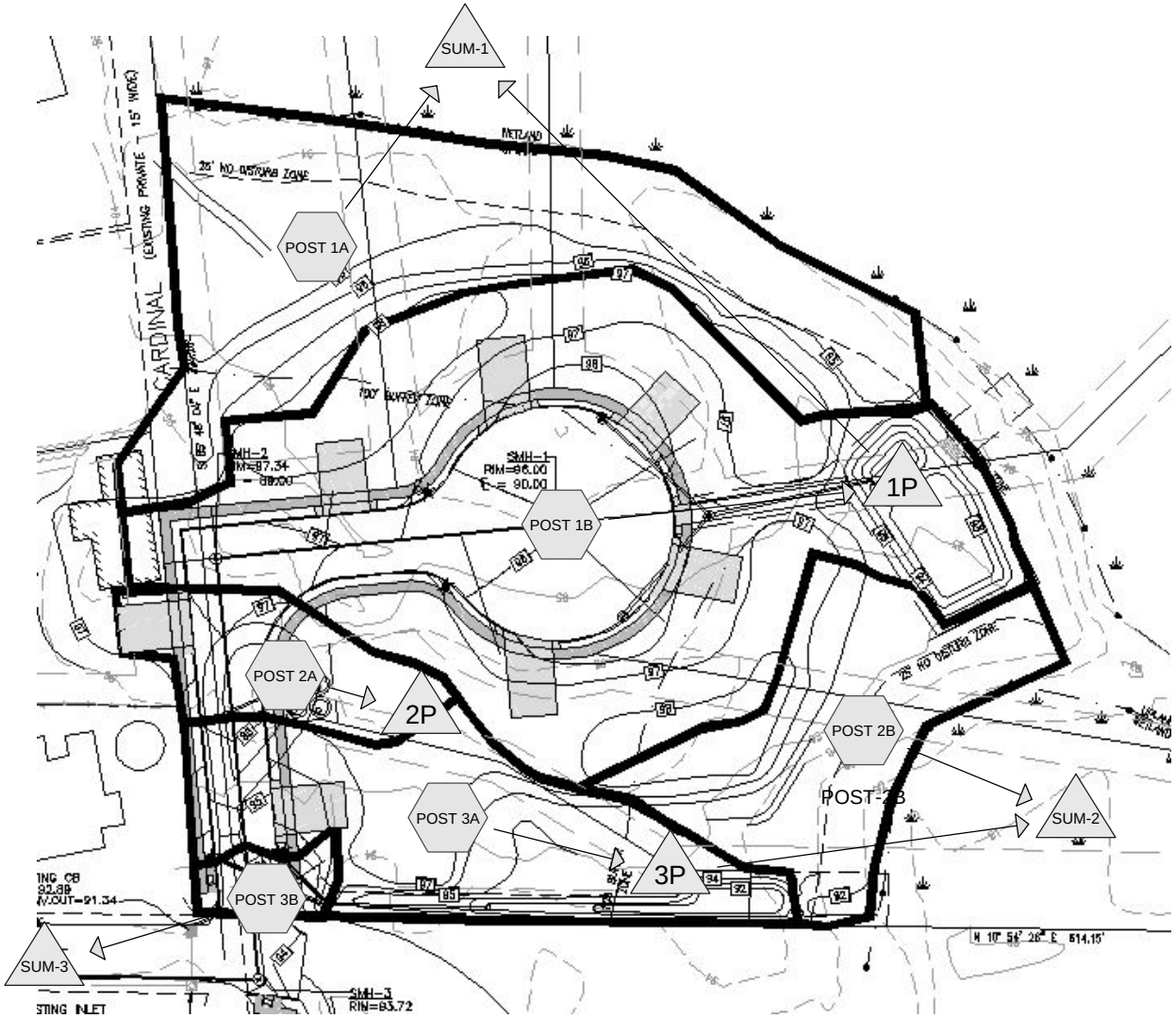
CATCH BASINS IN DEPRESSIONS

STRUCTURE	CONTRIBUTING FLOW (cfs)	CARRYOVER FLOW (cfs)	TOTAL FLOW (cfs)	SIDES ON CURB	(S)INGLE OR (D)OUBLE	P (ft)	HEAD OVER GRATE (ft)	ORIFICE		WEIR		MAX CAPACITY (cfs)	ACTUAL DEPTH (ft)	OVERFLOW (cfs)	OVERFLOW TO
								Q_{MAX} (cfs)	H (ft)	Q_{MAX} (cfs)	H (ft)				
CB-1	1.51	0.00	1.51	1	S	5.9	0.50	4.43	0.06	6.89	0.18	4.43 cfs	0.06 ft.	0.00	-
CB-2	1.45	0.00	1.45	1	S	5.9	0.50	4.43	0.06	6.89	0.18	4.43 cfs	0.06 ft.	0.00	-

RATIONAL METHOD OF FLOWS TOWARD INLET GRATES									
FROM	UNPAVED AREA	UNPAVED COEFFICIENT	PAVE/ROOF AREA	PAVE/ROOF COEFFICIENT	AREA ACRES	WEIGHTED C	TOC MIN.	i 10 yr	Q cfs
CB-1	0.28	0.2	0.29	0.9	0.56	0.56	6	4.8	1.51
CB-2	0.43	0.2	0.24	0.9	0.67	0.45	6	4.8	1.45
CB-3	0.05	0.2	0.02	0.9	0.07	0.43	6	4.8	0.15
CB-4	0.01	0.2	0.02	0.9	0.03	0.69	6	4.8	0.11
SGI-1	0.01	0.2	0.01	0.9	0.02	0.55	6	4.8	0.05
SGI-2	0.02	0.2	0.02	0.9	0.04	0.55	6	4.8	0.11

OPEN CHANEL FLOW CAPACITIES

FROM	TO	PIPE DIA.	FROM INVERT	TO INVERT	PIPE LENGTH	SLOPE FT./FT.	N VALUE	Q FULL cfs
CB-1	STC-1	12	92.10	91.70	53	0.008	0.013	3.10
CB-2	STC-1	12	92.10	91.70	47	0.009	0.013	3.30
STC-1	HW-1	12	91.60	91.13	67	0.007	0.013	2.99
CB-3	STC-2	12	93.00	92.56	21	0.021	0.013	5.17
CB-4	STC-2	12	93.10	92.56	8	0.067	0.013	9.28
STC-2	PITS	12	92.46	92.37	11	0.008	0.013	3.23
SGI-1	STC-3	6	93.40	93.20	37.5	0.005	0.012	0.89
SGI-2	STC-3	6	93.40	93.20	19	0.011	0.012	1.25
		^ TWO 6-INCH						
STC-3	FES	12	93.11	92.60	57.8	0.009	0.012	7.27



Subcat Reach Pond Link

Routing Diagram for POST-development as-built

Prepared by Prime Engineering, Inc, Printed 7/7/2015

HydroCAD® 10.00-13 s/n 01299 © 2014 HydroCAD Software Solutions LLC

Summary for Pond 1P:

Inflow Area = 0.772 ac, 45.58% Impervious, Inflow Depth = 0.75" for 2 yr storm event
Inflow = 0.52 cfs @ 12.13 hrs, Volume= 0.048 af
Outflow = 0.31 cfs @ 12.36 hrs, Volume= 0.048 af, Atten= 41%, Lag= 13.3 min
Discarded = 0.31 cfs @ 12.36 hrs, Volume= 0.048 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Peak Elev= 93.10' @ 12.36 hrs Surf.Area= 1,611 sf Storage= 152 cf

Plug-Flow detention time= 3.1 min calculated for 0.048 af (100% of inflow)
Center-of-Mass det. time= 3.1 min (890.4 - 887.2)

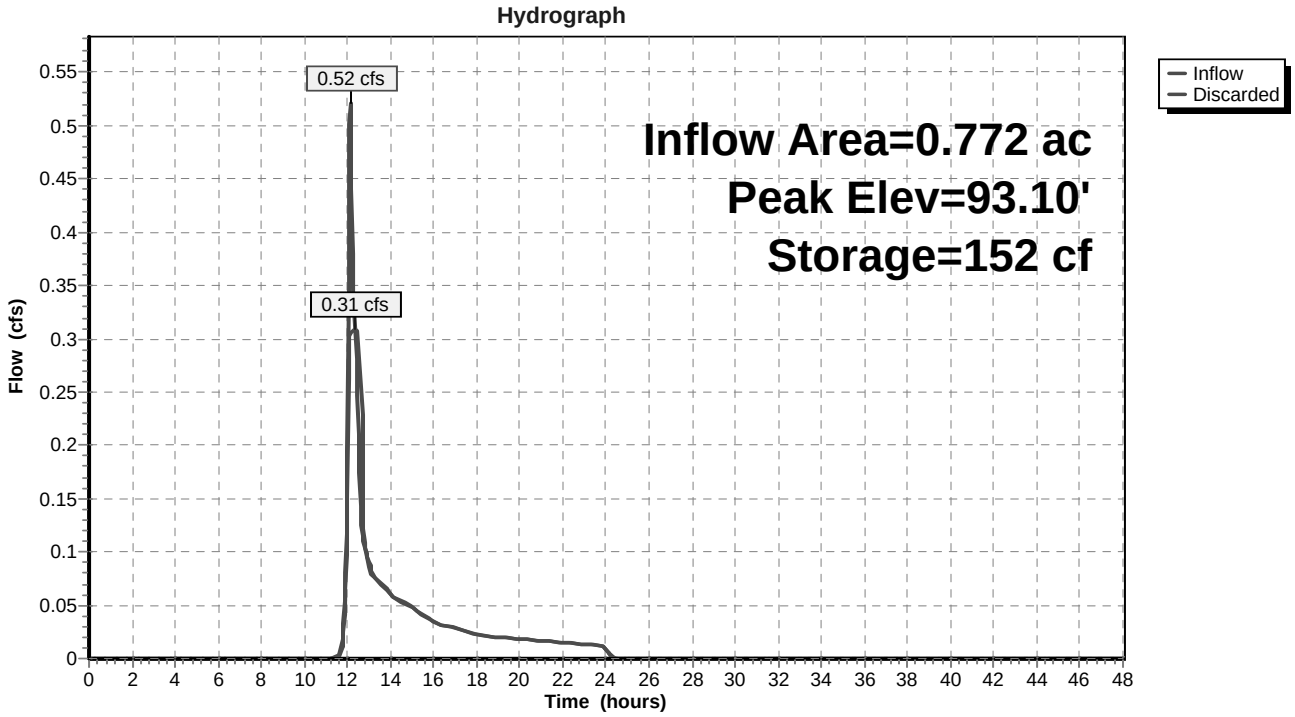
Volume	Invert	Avail.Storage	Storage Description
#1	93.00'	4,121 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
93.00	1,569	0	0
94.00	2,012	1,791	1,791
95.00	2,648	2,330	4,121

Device	Routing	Invert	Outlet Devices
#1	Discarded	93.00'	**8.270 in/hr Exfiltration over Surface area**

Discarded OutFlow Max=0.31 cfs @ 12.36 hrs HW=93.10' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.31 cfs)

Pond 1P:


Hydrograph
Inflow Area=0.772 ac
Peak Elev=93.10'
Storage=152 cf
0.52 cfs
0.31 cfs
Inflow
Discarded
Flow (cfs)
Time (hours)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48

Summary for Pond 3P:

Inflow Area = 0.248 ac, 11.17% Impervious, Inflow Depth = 0.09" for 2 yr storm event
Inflow = 0.00 cfs @ 14.66 hrs, Volume= 0.002 af
Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Atten= 100%, Lag= 0.0 min
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs / 2
Peak Elev= 92.15' @ 24.40 hrs Surf.Area= 557 sf Storage= 78 cf

Plug-Flow detention time= (not calculated: initial storage exceeds outflow)
Center-of-Mass det. time= (not calculated: no outflow)

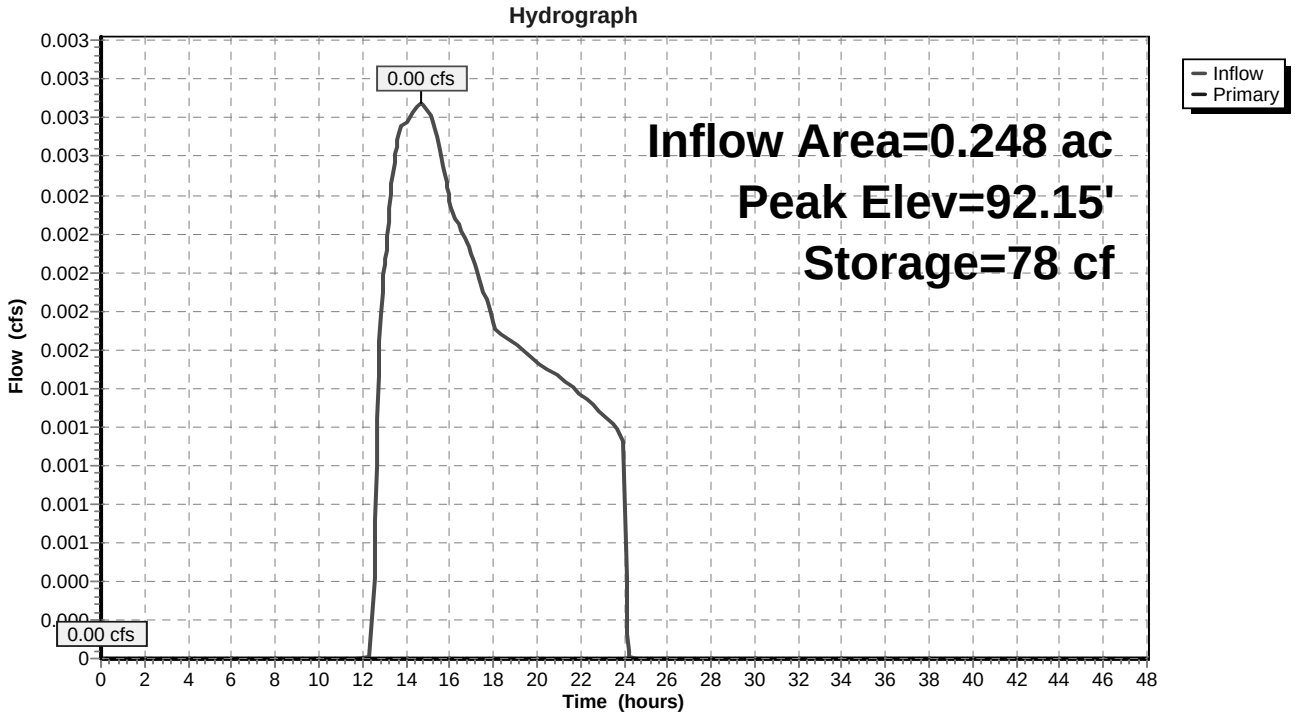
Volume	Invert	Avail.Storage	Storage Description
#1	92.00'	773 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
92.00	462	0	0
93.00	1,084	773	773

Device	Routing	Invert	Outlet Devices
#1	Primary	92.95'	**4.0' long x 4.0' 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) 2.38 2.54 2.69 2.68 2.67 2.67 2.65 2.66 2.66 2.68 2.72 2.73 2.76 2.79 2.88 3.07 3.32

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=92.00' (Free Discharge)
└**1=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 3P:


Hydrograph
Inflow Area=0.248 ac
Peak Elev=92.15'
Storage=78 cf
0.00 cfs
0.00 cfs
Inflow
Primary
Flow (cfs)
Time (hours)

Summary for Pond 1P:

Inflow Area = 0.772 ac, 45.58% Impervious, Inflow Depth = 1.59" for 10 yr storm event
Inflow = 1.27 cfs @ 12.12 hrs, Volume= 0.103 af
Outflow = 0.35 cfs @ 12.55 hrs, Volume= 0.103 af, Atten= 73%, Lag= 26.0 min
Discarded = 0.35 cfs @ 12.55 hrs, Volume= 0.103 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Peak Elev= 93.57' @ 12.55 hrs Surf.Area= 1,821 sf Storage= 965 cf

Plug-Flow detention time= 16.9 min calculated for 0.103 af (100% of inflow)
Center-of-Mass det. time= 16.9 min (879.2 - 862.2)

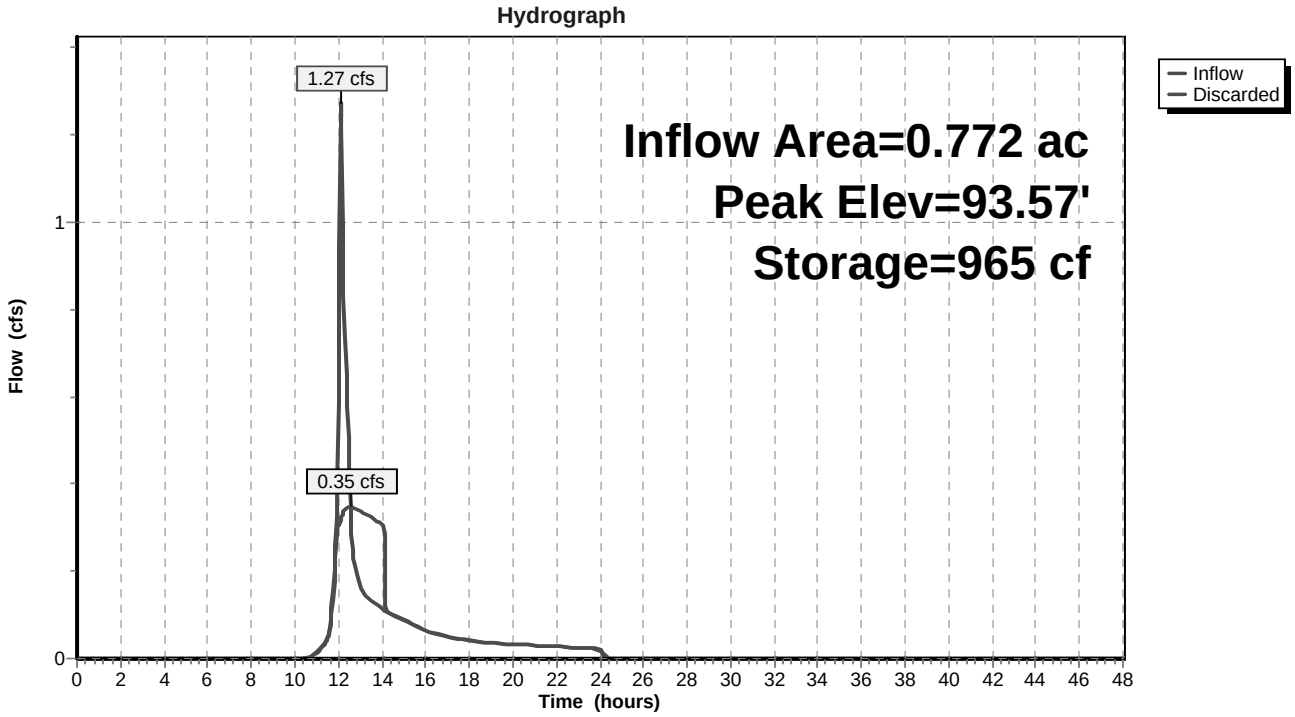
Volume	Invert	Avail.Storage	Storage Description
#1	93.00'	4,121 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
93.00	1,569	0	0
94.00	2,012	1,791	1,791
95.00	2,648	2,330	4,121

Device	Routing	Invert	Outlet Devices
#1	Discarded	93.00'	**8.270 in/hr Exfiltration over Surface area**

Discarded OutFlow Max=0.35 cfs @ 12.55 hrs HW=93.57' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.35 cfs)

Pond 1P:


Hydrograph
1.27 cfs
0.35 cfs
Inflow Area=0.772 ac
Peak Elev=93.57'
Storage=965 cf
Inflow
Discarded
Flow (cfs)
Time (hours)
0
1
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48

Summary for Pond 3P:

Inflow Area = 0.248 ac, 11.17% Impervious, Inflow Depth = 0.42" for 10 yr storm event
Inflow = 0.05 cfs @ 12.30 hrs, Volume= 0.009 af
Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Atten= 100%, Lag= 0.0 min
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs / 2
Peak Elev= 92.59' @ 24.40 hrs Surf.Area= 829 sf Storage= 381 cf

Plug-Flow detention time= (not calculated: initial storage exceeds outflow)
Center-of-Mass det. time= (not calculated: no outflow)

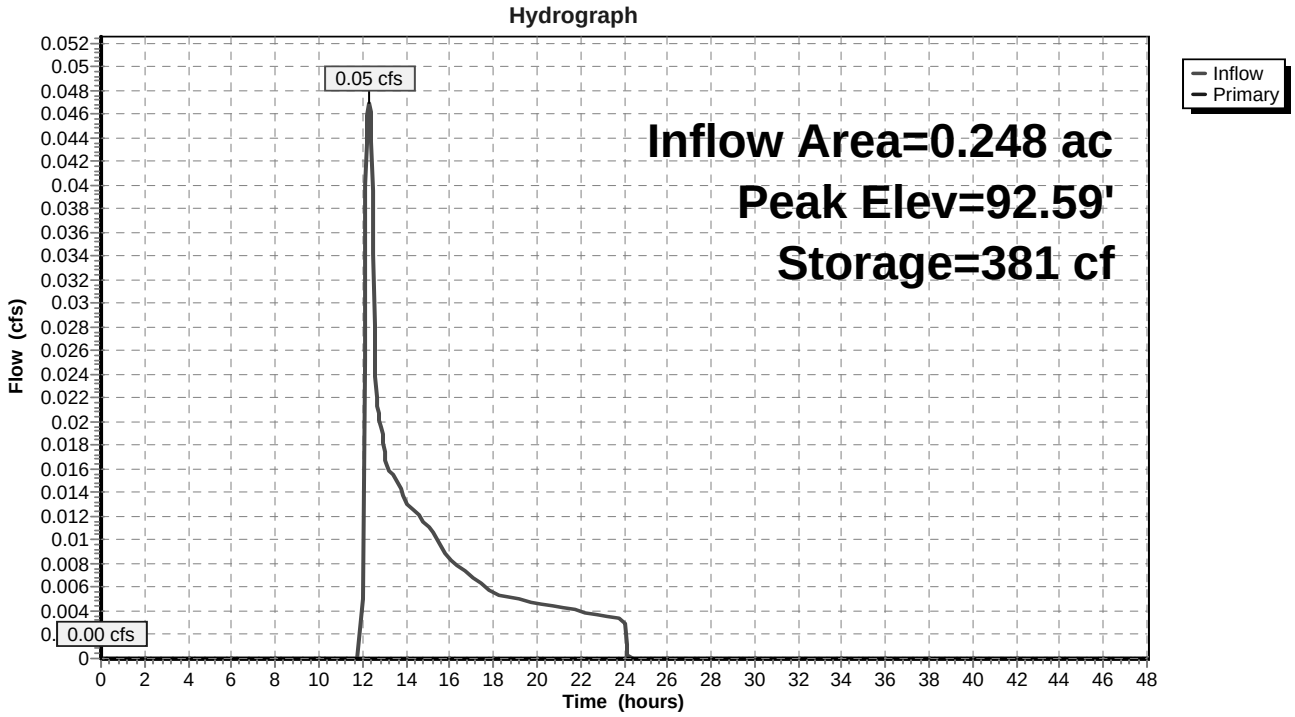
Volume	Invert	Avail.Storage	Storage Description
#1	92.00'	773 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
92.00	462	0	0
93.00	1,084	773	773

Device	Routing	Invert	Outlet Devices
#1	Primary	92.95'	**4.0' long x 4.0' 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) 2.38 2.54 2.69 2.68 2.67 2.67 2.65 2.66 2.66 2.68 2.72 2.73 2.76 2.79 2.88 3.07 3.32

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=92.00' (Free Discharge)
└─**1=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 3P:


Hydrograph
Inflow Area=0.248 ac
Peak Elev=92.59'
Storage=381 cf
0.05 cfs
0.00 cfs
Inflow
Primary
Flow (cfs)
Time (hours)

Summary for Pond 1P:

Inflow Area = 0.772 ac, 45.58% Impervious, Inflow Depth = 3.20" for 100 yr storm event
Inflow = 2.68 cfs @ 12.11 hrs, Volume= 0.206 af
Outflow = 0.45 cfs @ 12.67 hrs, Volume= 0.206 af, Atten= 83%, Lag= 33.5 min
Discarded = 0.45 cfs @ 12.67 hrs, Volume= 0.206 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Peak Elev= 94.50' @ 12.67 hrs Surf.Area= 2,330 sf Storage= 2,875 cf

Plug-Flow detention time= 53.7 min calculated for 0.206 af (100% of inflow)
Center-of-Mass det. time= 53.6 min (894.9 - 841.3)

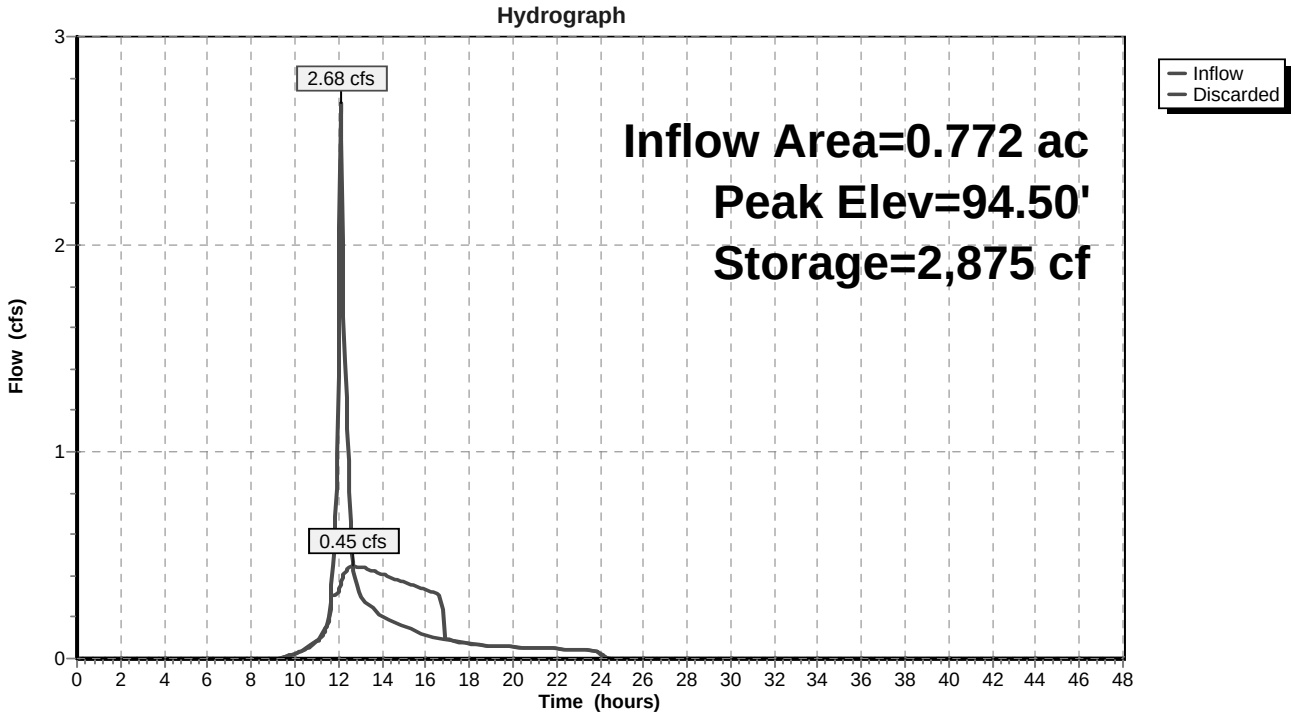
Volume	Invert	Avail.Storage	Storage Description
#1	93.00'	4,121 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
93.00	1,569	0	0
94.00	2,012	1,791	1,791
95.00	2,648	2,330	4,121

Device	Routing	Invert	Outlet Devices
#1	Discarded	93.00'	**8.270 in/hr Exfiltration over Surface area**

Discarded OutFlow Max=0.45 cfs @ 12.67 hrs HW=94.50' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.45 cfs)

Pond 1P:


Hydrograph
Inflow Area=0.772 ac
Peak Elev=94.50'
Storage=2,875 cf
2.68 cfs
0.45 cfs
Inflow
Discarded
Flow (cfs)
Time (hours)
0
1
2
3
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48

Summary for Pond 3P:

Inflow Area = 0.248 ac, 11.17% Impervious, Inflow Depth = 1.32" for 100 yr storm event
Inflow = 0.30 cfs @ 12.11 hrs, Volume= 0.027 af
Outflow = 0.03 cfs @ 15.20 hrs, Volume= 0.011 af, Atten= 91%, Lag= 185.3 min
Primary = 0.03 cfs @ 15.20 hrs, Volume= 0.011 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs / 2
Peak Elev= 92.97' @ 15.20 hrs Surf.Area= 1,065 sf Storage= 741 cf

Plug-Flow detention time= 373.2 min calculated for 0.011 af (39% of inflow)
Center-of-Mass det. time= 215.6 min (1,110.6 - 895.0)

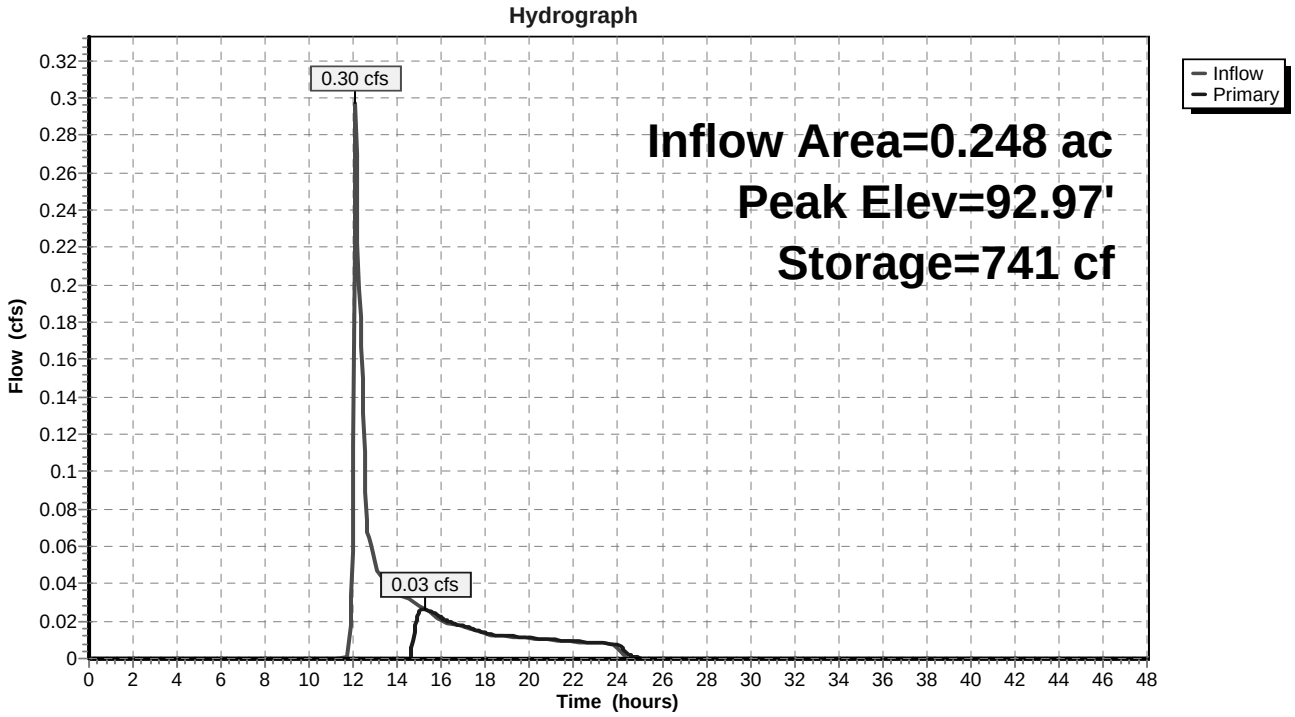
Volume	Invert	Avail.Storage	Storage Description
#1	92.00'	773 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
92.00	462	0	0
93.00	1,084	773	773

Device	Routing	Invert	Outlet Devices
#1	Primary	92.95'	**4.0' long x 4.0' 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) 2.38 2.54 2.69 2.68 2.67 2.67 2.65 2.66 2.66 2.68 2.72 2.73 2.76 2.79 2.88 3.07 3.32

Primary OutFlow Max=0.03 cfs @ 15.20 hrs HW=92.97' (Free Discharge)
└─**1=Broad-Crested Rectangular Weir** (Weir Controls 0.03 cfs @ 0.33 fps)

Pond 3P:


Hydrograph
Inflow Area=0.248 ac
Peak Elev=92.97'
Storage=741 cf
0.30 cfs
0.03 cfs
Inflow
Primary
Flow (cfs)
Time (hours)
0.32
0.3
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48