STORMWATER MANAGEMENT PLAN

FOR

KASOTA AVENUE TRAILER STORAGE

2495 KASOTA AVENUE

SAINT PAUL, MN

PREPARED BY:

EMILY CASTANIAS

CHAD AYERS, PE

10/01/2019

PROJECT INTRODUCTION

The proposed project is a development of an existing site on the north-west corner of Kasota Avenue and Highway 280 in Saint Paul. The redevelopment will include the addition of a parking lot for trailer storage, as well as the addition of a rate control basin. The project is within the jurisdiction of the Mississippi Watershed Management Organization (MWMO). It is the intent of the project to meet the stormwater management requirement of the of City of Saint Paul and the MWMO through the construction of a rate control basin and a Contech StormFilter proprietary filtration device.

EXISTING CONDITIONS

The existing 1.85-acre site is undeveloped. The Geotechnical Report prepared by AET shows soils onsite to be primarily silty sands which may be classified as HSG type B soils. An Environmental Investigation performed by Landmark Environmental also determined that the soils on-site are largely contaminated. The north end of the site drains uncontrolled to the west where it runs along the adjacent railroad and enters an existing wetland basin south of the site. The southern end of the drains into an existing stormwater pond before discharging into the wetland south of the site. The site ultimately discharges into the Mississippi River approximately 1.75 miles away.

PROPOSED CONDITIONS

The proposed site includes the addition of 1.058 acres of impervious for the proposed parking lot. The majority of the site is captured and discharged into a rate control basin at the southwest end of the site. The rate control basin discharges into a Contech StormFilter device for treatment before discharging into the existing wetland south of the site. The western edge of the site runs off uncontrolled to the west where it runs along the adjacent railroad and enters an existing wetland basin south of the site.

RATE CONTROL AND WATER QUALITY

The City of Saint Paul requires post development discharge rates not exceed predevelopment discharge rates for the 2-, 10-, 100-year 24-hour rainfall events for all discharge points from the site. The City of Saint Paul also requires that runoff from a 5.9-inch Type II 24-hour event not exceed 1.64 cubic feet per second per acre of disturbed area. HydroCAD was used to model the existing and proposed site runoff. For the model, a curve number of 61 and 98 were used for the pervious and impervious areas respectively. Times of concentration (Tcs) were calculated with the use of the Lag method within HydroCAD. The results of the analysis are below. Detailed calculations may be found in the appendices.

The project was run through the MWMO Design Sequence Flow Chart, and due to the contaminated materials on site the project fell under *Flexible Treatment Option 2*. This option requires volume reduction to the maximum extent practicable, 60% removal of total phosphorus (TP), and consideration of relocating project elements to address varying soil conditions. Due to the contaminated soils, infiltration, sand filtration with underdrain, and rainwater reuse on site was not feasible. Contaminated materials were found throughout the site, so BMP relocation would not improve site conditions. In addition, the project site was graded in order to minimize disturbance of contaminated material. In order to meet MPCA and MWMO water quality requirements, a StormFilter proprietary filtration is proposed to treat water discharging from the rate control basin. Studies have shown the StormFilter device created by Contech can remove over 60% of total phosphorus. Preliminary sizing for the StormFilter Device as well as the relevant removal studies are included in the appendices.

Existing Drainage Areas Information

Existing DAs	Total Area [sf]	Impervious Area [sf]	Pervious Area [sf]	Tc [min]
CN	-	98	61	-
3S, On-Site UC Runoff	25538	0	25538	5.5
1S, On-Site to Pond	55086	2109	52977	13.1
4S, Off-Site UC Runoff	2787	0	2787	5.7
2S, Off-Site to Pond	17388	8225	9163	7.2

Proposed Drainage Area Information

Proposed DAs	Total Area [sf]	Impervious Area [sf]	Pervious Area [sf]	Tc [min]
CN	-	98	61	-
8S, On-Site UC Runoff	11207	0	11207	5.7
6S, On-Site To Pond	69428	45474	23954	10.6
5S, Off-Site from Street	10864	8225	2638	6.7
7S, Off-Site To Pond	9302	377	8925	20.3

$$Q_{Max}(cfs) = 1.64\ (cfs/ac) * Site\ Area\ (ac) + Offsite\ Flow\ (cfs)$$

$$Q_{Max}(cfs) = 1.64\ (cfs/ac) * 1.851\ (ac) + 2.41(cfs) = \mathbf{5.45\ cfs}$$

Maximum Rate of Runoff (cfs)

Storm Event	Total Existing	Total Proposed
2-year	1.10	1.08
10-year	3.50	2.07
50-year	6.90	3.69
100-year	8.11	4.57
Saint Paul 100-year	6.54	**3.40**

Proposed Rate Control Basin Details	
Max Depth	4-ft
Area	0.15-ac
Max Volume	0.448-af
100-year Depth	3.73-ft
100-year volume	0.408-af

EMERGENCY OVERFLOW

In the event of a clog in the system or a rainfall event larger than the design events water will overflow from the rate control basin at an elevation of 882.5-ft. The pond was designed to overtop the EOF in the 50- and 100-year rainfall events. Water passing through the EOF will overflow into Kasota Avenue where it will either enter the adjacent storm sewer and enter the wetland to the south or continue to flow west down Kasota Avenue.

STORMWATER SYSTEM OPERATIONS & MAINTENANCE

An operations & maintenance agreement will be prepared for the project.

EROSION & SEDIMENT CONTROL

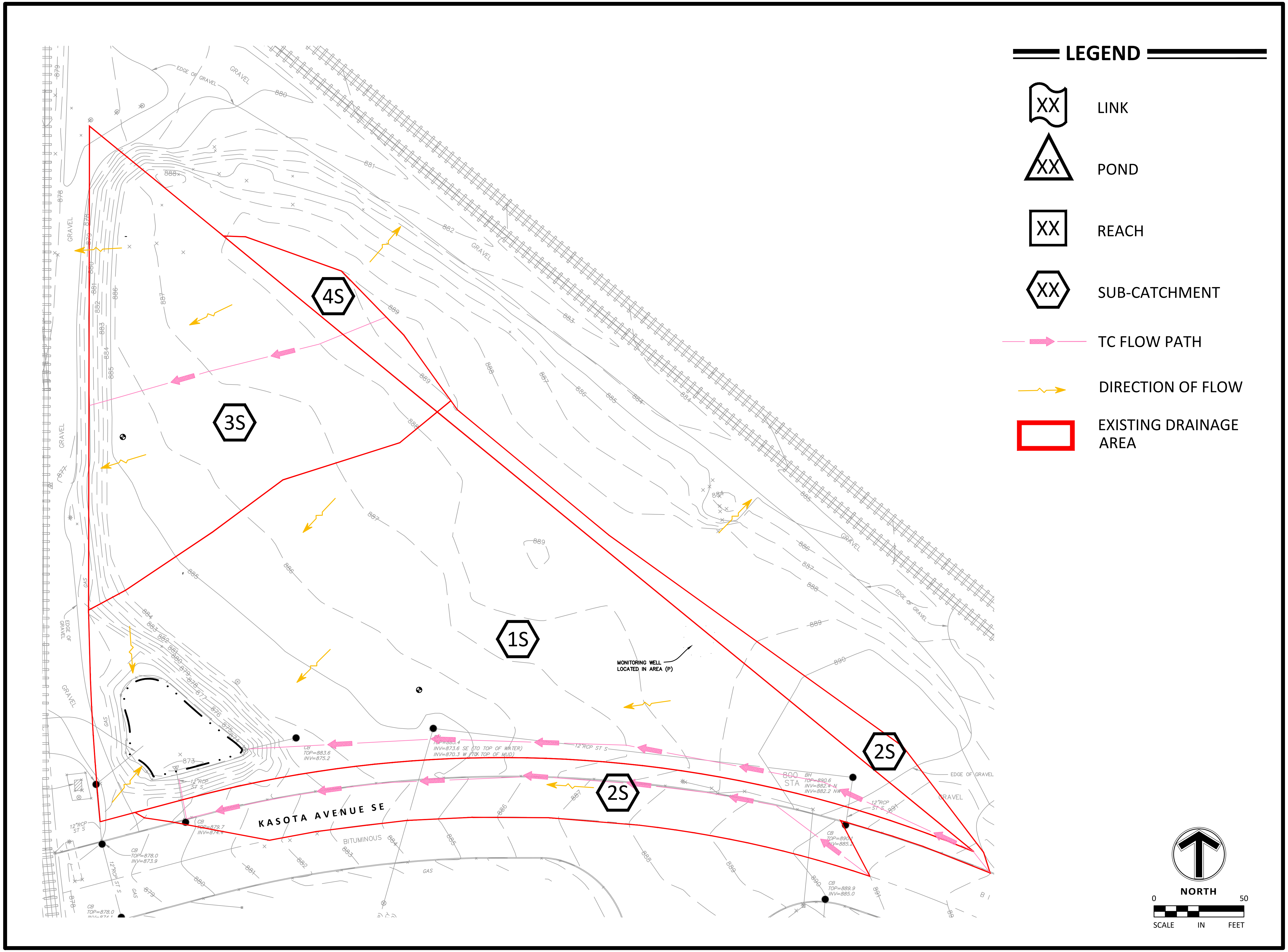
A comprehensive Stormwater Pollution Prevention Plan (SWPPP) meeting the requirements of the 2018 MPCA NPDES permit will be developed as a part of the proposed plans.

SUMMARY

The proposed Kasota Avenue Trailer Storage project will meet the requirements of the City of Saint Paul, and the MPCA through construction of a rate control basin and a Contech StormFilter proprietary filtration device. These BMPs will provide the required rate control and water quality improvements prior to discharging stormwater runoff from the site to downstream receiving waters.

If you have any questions, comments, or additional information regarding this report, please contact me at CAyers@sambatek.com or 763.259.6697

APPENDIX A – DRAINAGE MAPS



Oct 01, 2019 - 4:05pm - User:ecastanias L:\PROJECTS\21625\CAD\Xrefs\21625-DRNBASE.dwg

Sambatek
www.sambatek.com

12800 Whitewater Drive, Suite 300
Minnetonka, MN 55343

763.476.6010 telephone
763.476.8532 facsimile

Engineering | Surveying | Planning | Environmental

Client

VENTURE PASS PARTNERS

Project

RHON INDUSTRIES TRAILER STORAGE

Location

ST PAUL, MN

Certification

Summary

Approved: CA Drawn: EC

Revision History

No. Date By Submittal / Rev.

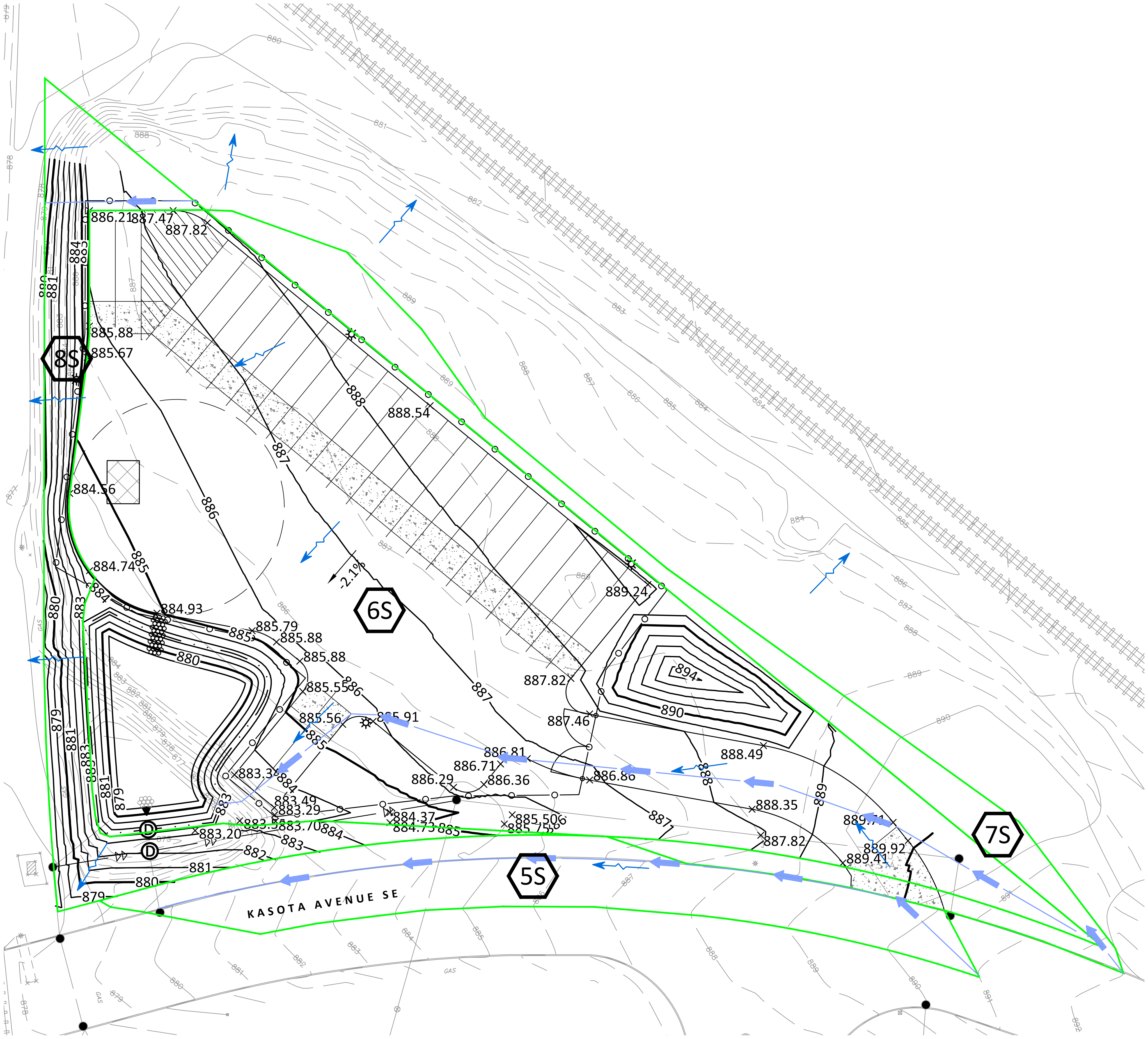
Sheet Title

EXISTING DRAINAGE MAP

Sheet No. Revision

1/2

Project No. 21625



LEGEND

XX LINK

XX POND

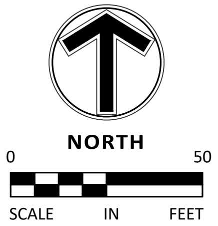
XX REACH

XX SUB-CATCHMENT

TC FLOW PATH

DIRECTION OF FLOW

🟩 PROPOSED DRAINAGE AREA



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PROPOSED DRAINAGE MAP

Sheet No. Revision

2/2

Project No. 21625

APPENDIX B – TIME OF CONCENTRATION CALCULATIONS

Appendix B - Time of Concentration Calculations

The times of concentration (Tcs) for the HydroCAD model were calculated within HydroCAD using the Lag method. The following tables summarize the drainage area information used to calculate the Tcs.

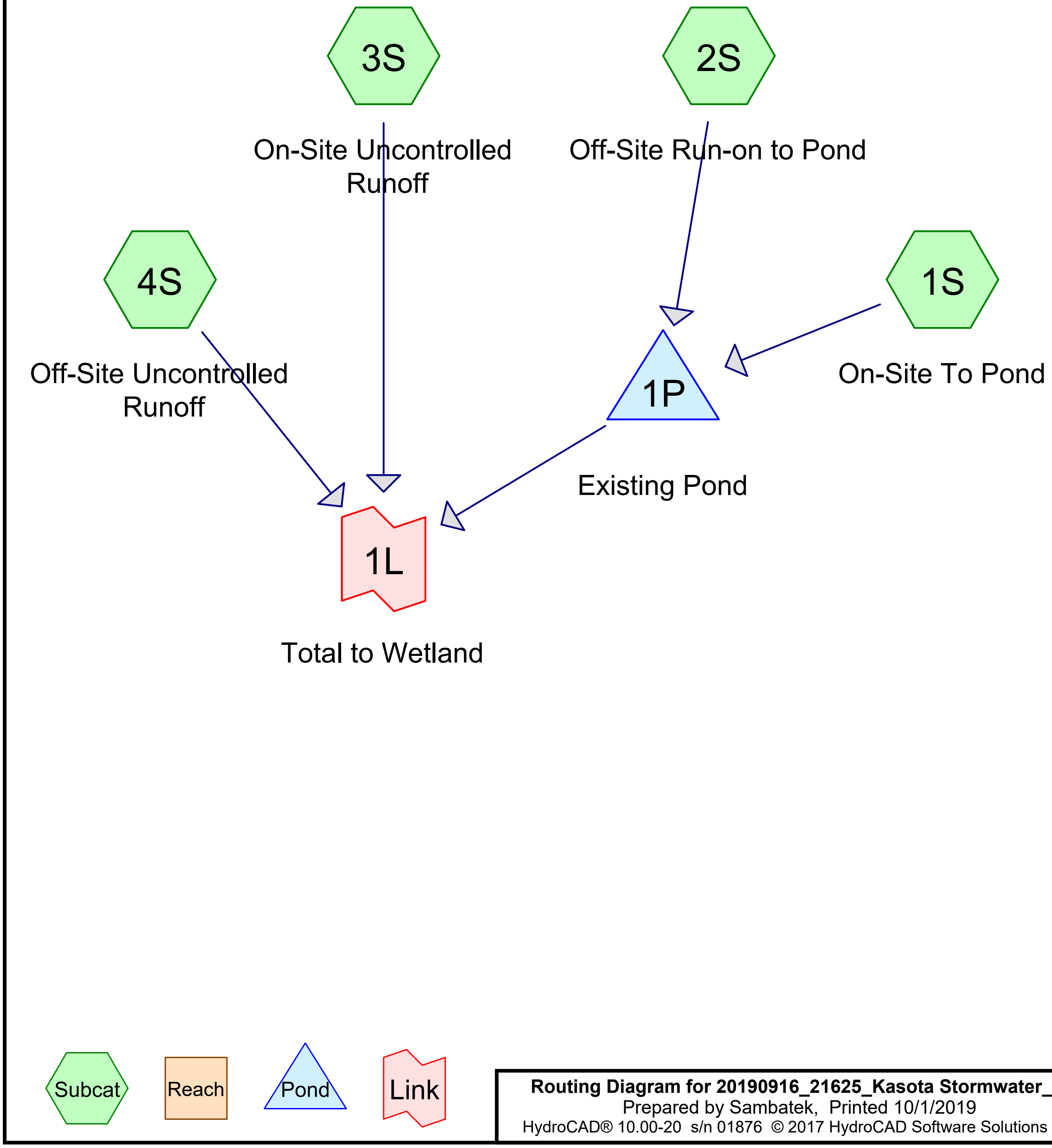
EXISTING DRAINAGE AREAS

DA	Flow Path Length	High Contour	Low Contour	Slope of Path	Tc
3S	146	888.5	882.0	0.0444	5.5
1S	413	891.0	875.0	0.0387	13.1
4S	172	889.0	880.0	0.0523	5.7
2S	382	892.0	875.0	0.0445	7.2

PROPOSED DRAINAGE AREAS

DA	Flow Path Length	High Contour	Low Contour	Slope of Path	Tc
8S	153	884.8	878.0	0.0441	5.7
6S	448	891.0	883.0	0.0179	10.6
5S	398	891.0	880.0	0.0276	6.7
7S	463	892	883	0.0194	20.3

APPENDIX C – HYDROCAD MODELS



Routing Diagram for 20190916_21625_Kasota Stormwater_Lag
Prepared by Sambatek, Printed 10/1/2019
HydroCAD® 10.00-20 s/n 01876 © 2017 HydroCAD Software Solutions LLC

Area Listing (selected nodes)

Area (acres)	CN	Description (subcatchment-numbers)
2.077	61	>75% Grass cover, Good, HSG B (1S, 2S, 3S, 4S)
0.189	98	Paved parking, HSG B (2S)
0.048	98	Water Surface, HSG D (1S)
2.314	**65**	**TOTAL AREA**

Soil Listing (selected nodes)

Area (acres)	Soil Group	Subcatchment Numbers
0.000	HSG A	
2.266	HSG B	1S, 2S, 3S, 4S
0.000	HSG C	
0.048	HSG D	1S
0.000	Other	
2.314		**TOTAL AREA**

Ground Covers (selected nodes)

HSG-A (acres)	HSG-B (acres)	HSG-C (acres)	HSG-D (acres)	Other (acres)	Total (acres)	Ground Cover	Subcatchment Numbers
0.000	2.077	0.000	0.000	0.000	2.077	>75% Grass cover, Good	1S, 2S, 3S, 4S
0.000	0.189	0.000	0.000	0.000	0.189	Paved parking	2S
0.000	0.000	0.000	0.048	0.000	0.048	Water Surface	1S
0.000	**2.266**	**0.000**	**0.048**	**0.000**	**2.314**	**TOTAL AREA**	

Pipe Listing (selected nodes)

Line#	Node Number	In-Invert (feet)	Out-Invert (feet)	Length (feet)	Slope (ft/ft)	n	Diam/Width (inches)	Height (inches)	Inside-Fill (inches)
1	1P	871.90	871.90	30.0	0.0000	0.011	12.0	0.0	0.0

Time span=0.00-72.00 hrs, dt=0.01 hrs, 7201 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

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Subcatchment1S: On-Site To Pond          Runoff Area=55,086 sf   3.83% Impervious   Runoff Depth=0.33"
                         Flow Length=413'   Slope=0.0387 '/'   Tc=13.1 min   CN=62   Runoff=0.35 cfs  0.034 af

Subcatchment2S: Off-Site Run-on to Pond  Runoff Area=17,388 sf   47.30% Impervious   Runoff Depth=1.05"
                          Flow Length=418'   Slope=0.0407 '/'   Tc=8.1 min   CN=79   Runoff=0.71 cfs  0.035 af

Subcatchment3S: On-Site Uncontrolled     Runoff Area=25,538 sf   0.00% Impervious   Runoff Depth=0.30"
                          Flow Length=146'   Slope=0.0444 '/'   Tc=5.5 min   CN=61   Runoff=0.21 cfs  0.014 af

Subcatchment4S: Off-Site Uncontrolled     Runoff Area=2,787 sf   0.00% Impervious   Runoff Depth=0.30"
                          Flow Length=172'   Slope=0.0523 '/'   Tc=5.7 min   CN=61   Runoff=0.02 cfs  0.002 af

Pond 1P: Existing Pond                        Peak Elev=873.81'  Storage=17 cf   Inflow=0.91 cfs  0.069 af
                 12.0"  Round Culvert  n=0.011  L=30.0'  S=0.0000 '/'   Outflow=0.90 cfs  0.069 af

Link 1L: Total to Wetland                                                      Inflow=1.10 cfs  0.085 af
                                                                              Primary=1.10 cfs  0.085 af

          Total Runoff Area = 2.314 ac   Runoff Volume = 0.085 af   Average Runoff Depth = 0.44"
                                    89.75% Pervious = 2.077 ac     10.25% Impervious = 0.237 ac
```

Summary for Subcatchment 1S: On-Site To Pond

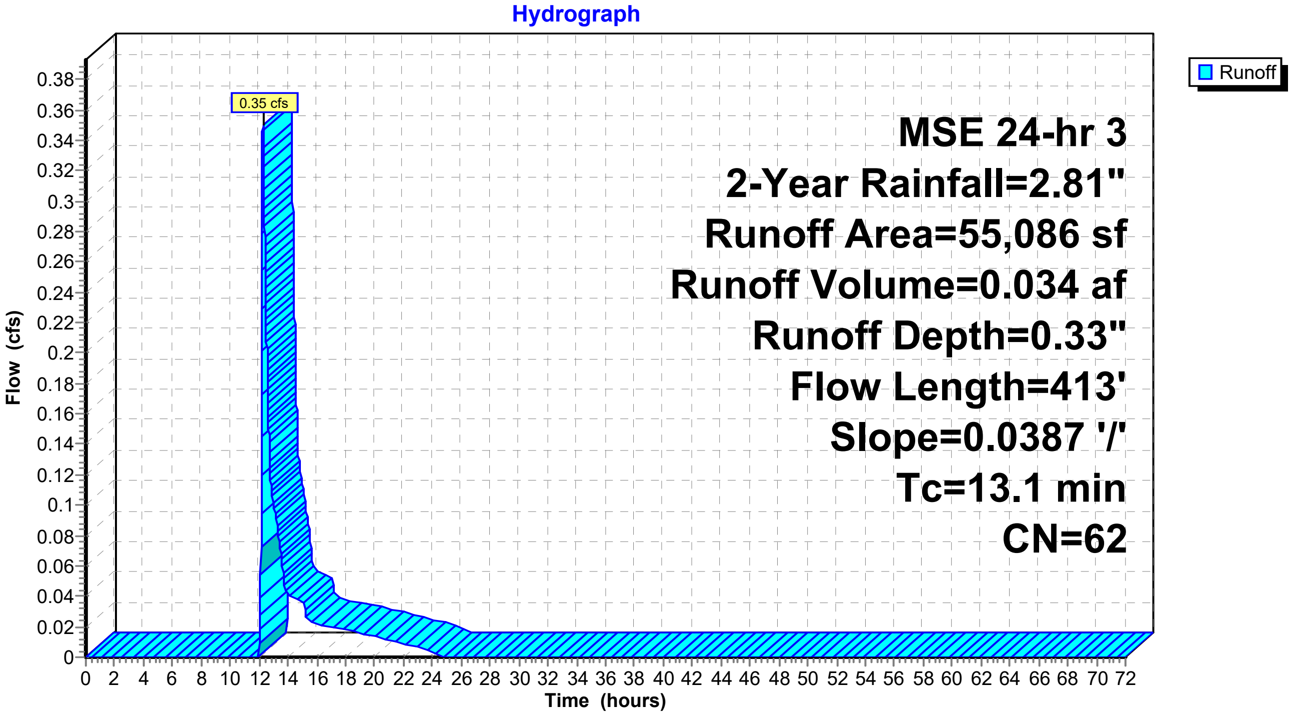
Runoff = 0.35 cfs @ 12.27 hrs, Volume= 0.034 af, Depth= 0.33"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 2-Year Rainfall=2.81"

Area (sf)	CN	Description
52,977	61	>75% Grass cover, Good, HSG B
2,109	98	Water Surface, HSG D
55,086	62	Weighted Average
52,977		96.17% Pervious Area
2,109		3.83% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.1	413	0.0387	0.53		**Lag/CN Method,**

Subcatchment 1S: On-Site To Pond



Summary for Subcatchment 2S: Off-Site Run-on to Pond

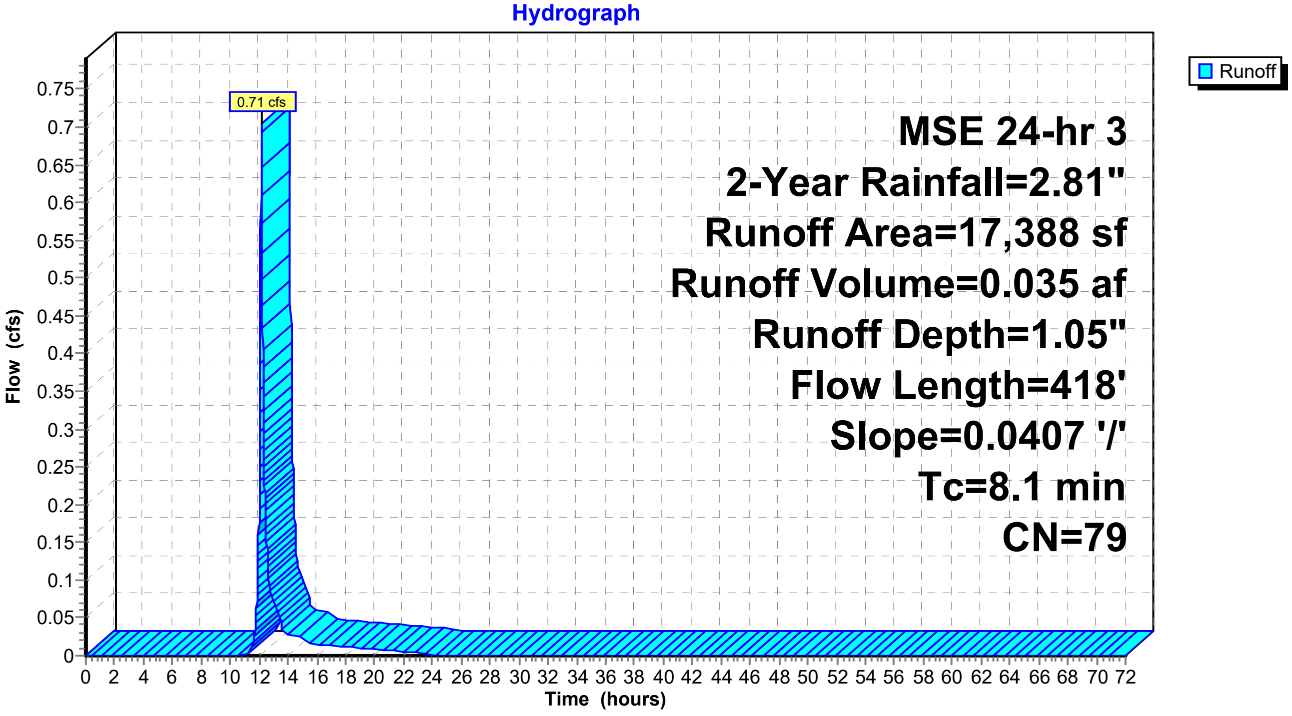
Runoff = 0.71 cfs @ 12.16 hrs, Volume= 0.035 af, Depth= 1.05"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 2-Year Rainfall=2.81"

Area (sf)	CN	Description
9,163	61	>75% Grass cover, Good, HSG B
8,225	98	Paved parking, HSG B
17,388	79	Weighted Average
9,163		52.70% Pervious Area
8,225		47.30% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.1	418	0.0407	0.86		**Lag/CN Method,**

Subcatchment 2S: Off-Site Run-on to Pond



Summary for Subcatchment 3S: On-Site Uncontrolled Runoff

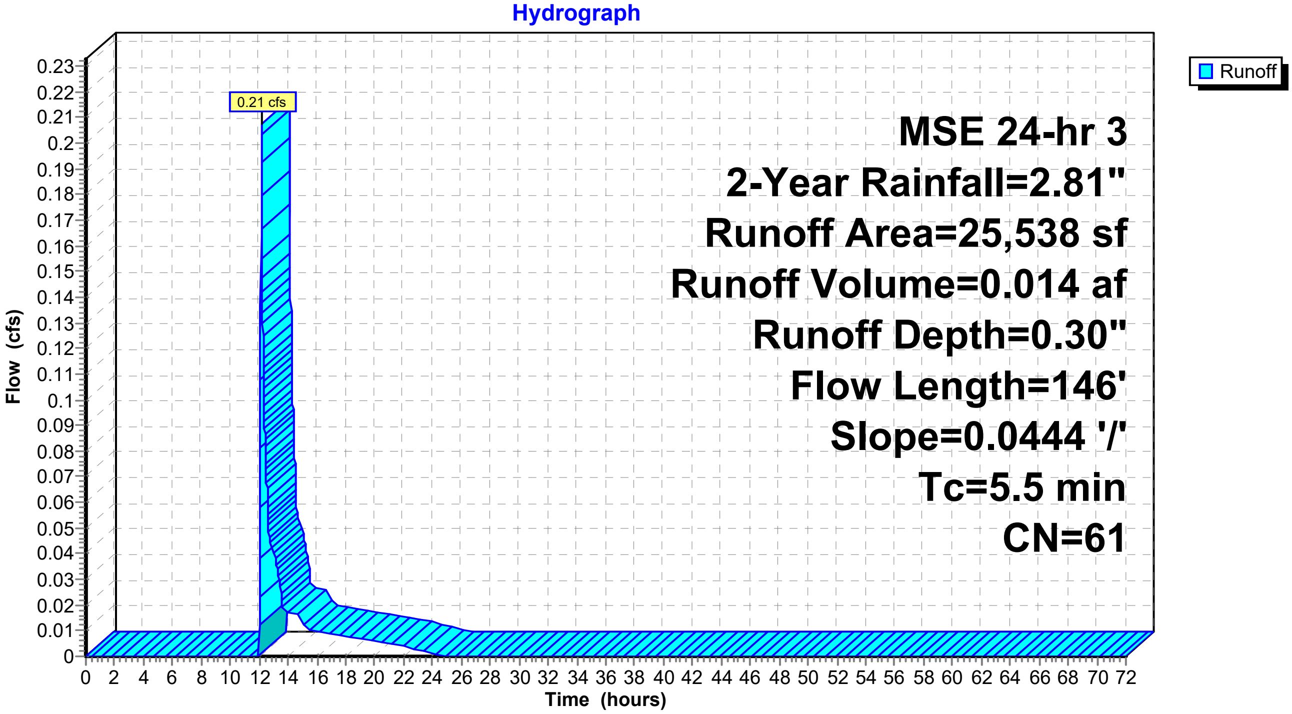
Runoff = 0.21 cfs @ 12.15 hrs, Volume= 0.014 af, Depth= 0.30"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 2-Year Rainfall=2.81"

Area (sf)	CN	Description
25,538	61	>75% Grass cover, Good, HSG B
25,538		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.5	146	0.0444	0.45		**Lag/CN Method,**

Subcatchment 3S: On-Site Uncontrolled Runoff



Summary for Subcatchment 4S: Off-Site Uncontrolled Runoff

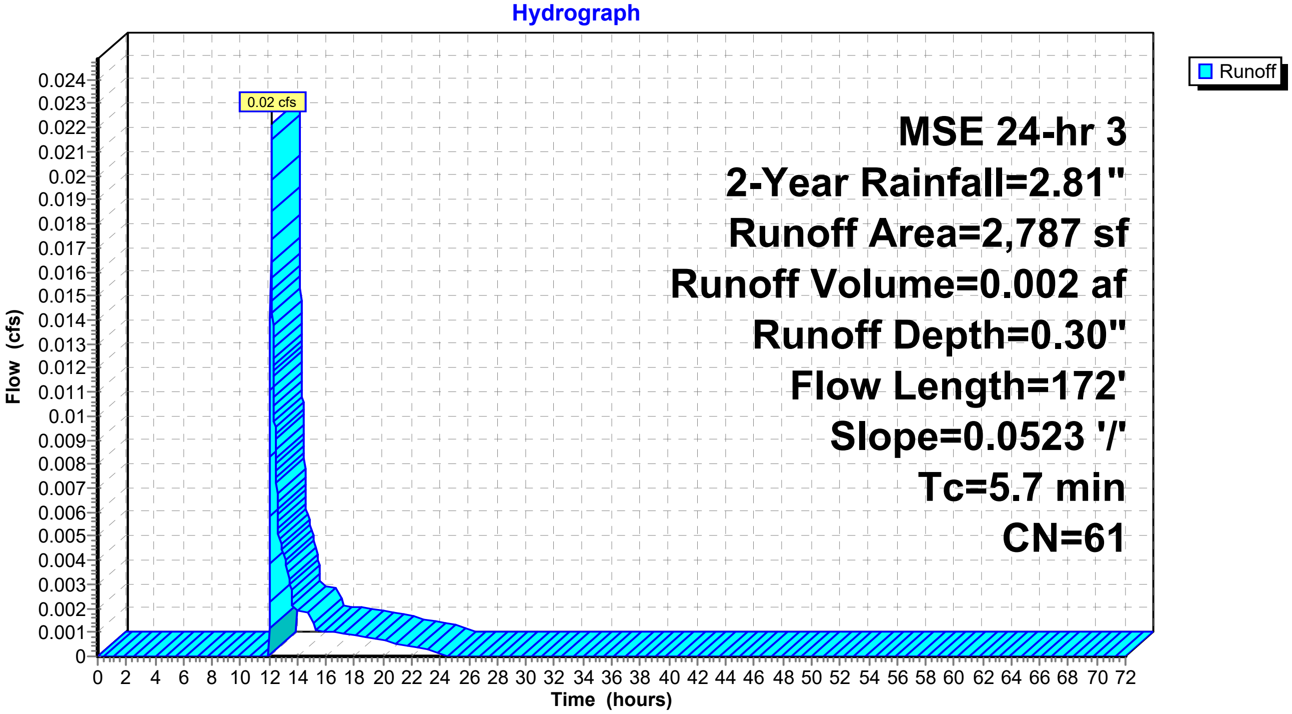
Runoff = 0.02 cfs @ 12.15 hrs, Volume= 0.002 af, Depth= 0.30"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 2-Year Rainfall=2.81"

Area (sf)	CN	Description
2,787	61	>75% Grass cover, Good, HSG B
2,787		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.7	172	0.0523	0.50		**Lag/CN Method,**

Subcatchment 4S: Off-Site Uncontrolled Runoff



Summary for Pond 1P: Existing Pond

Inflow Area = 1.664 ac, 14.26% Impervious, Inflow Depth = 0.50" for 2-Year event
Inflow = 0.91 cfs @ 12.18 hrs, Volume= 0.069 af
Outflow = 0.90 cfs @ 12.19 hrs, Volume= 0.069 af, Atten= 0%, Lag= 0.3 min
Primary = 0.90 cfs @ 12.19 hrs, Volume= 0.069 af

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Peak Elev= 873.81' @ 12.19 hrs Surf.Area= 2,476 sf Storage= 17 cf

Plug-Flow detention time= 0.3 min calculated for 0.069 af (100% of inflow)
Center-of-Mass det. time= 0.3 min (854.4 - 854.0)

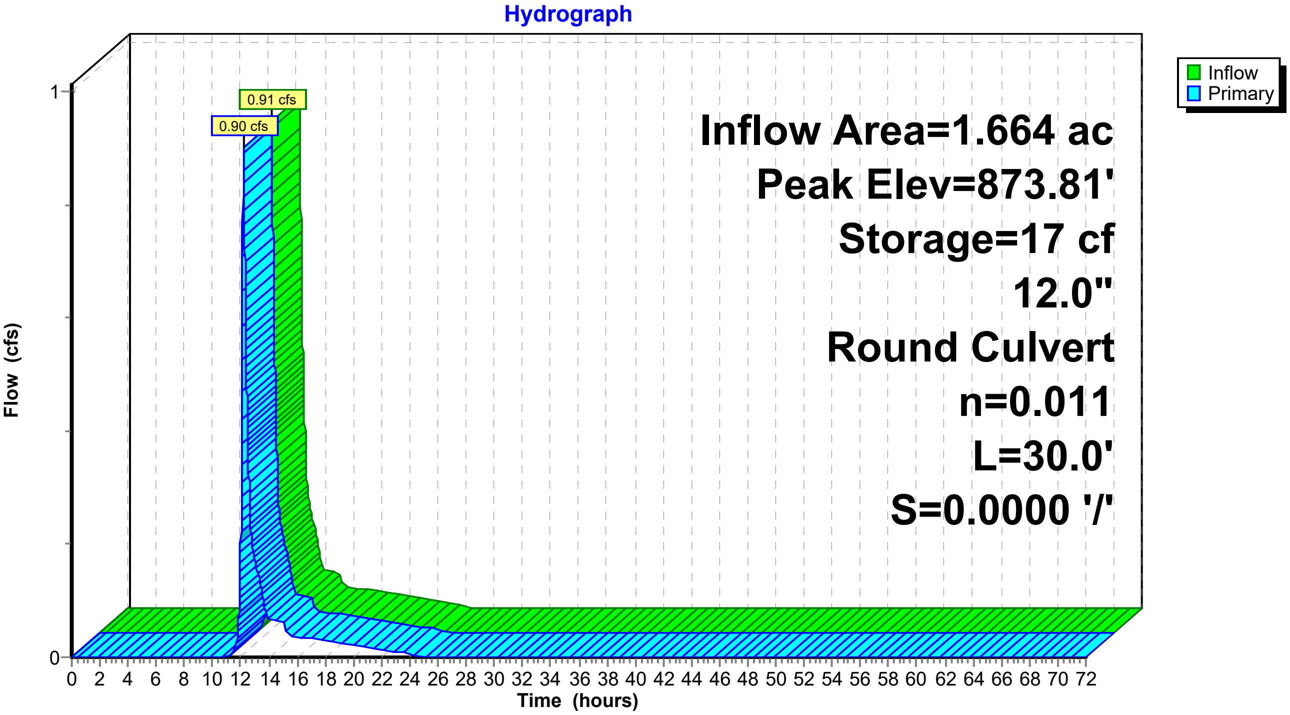
Volume	Invert	Avail.Storage	Storage Description
#1	873.80'	10,998 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
873.80	2,472	0	0
876.00	3,710	6,800	6,800
877.00	4,686	4,198	10,998

Device	Routing	Invert	Outlet Devices
#1	Primary	871.90'	**12.0" Round Culvert** L= 30.0' Ke= 0.500 Inlet / Outlet Invert= 871.90' / 871.90' S= 0.0000 '/' Cc= 0.900 n= 0.011 Concrete pipe, straight & clean, Flow Area= 0.79 sf

Primary OutFlow Max=4.07 cfs @ 12.19 hrs HW=873.81' (Free Discharge)
↑—**1=Culvert** (Barrel Controls 4.07 cfs @ 5.18 fps)

Pond 1P: Existing Pond

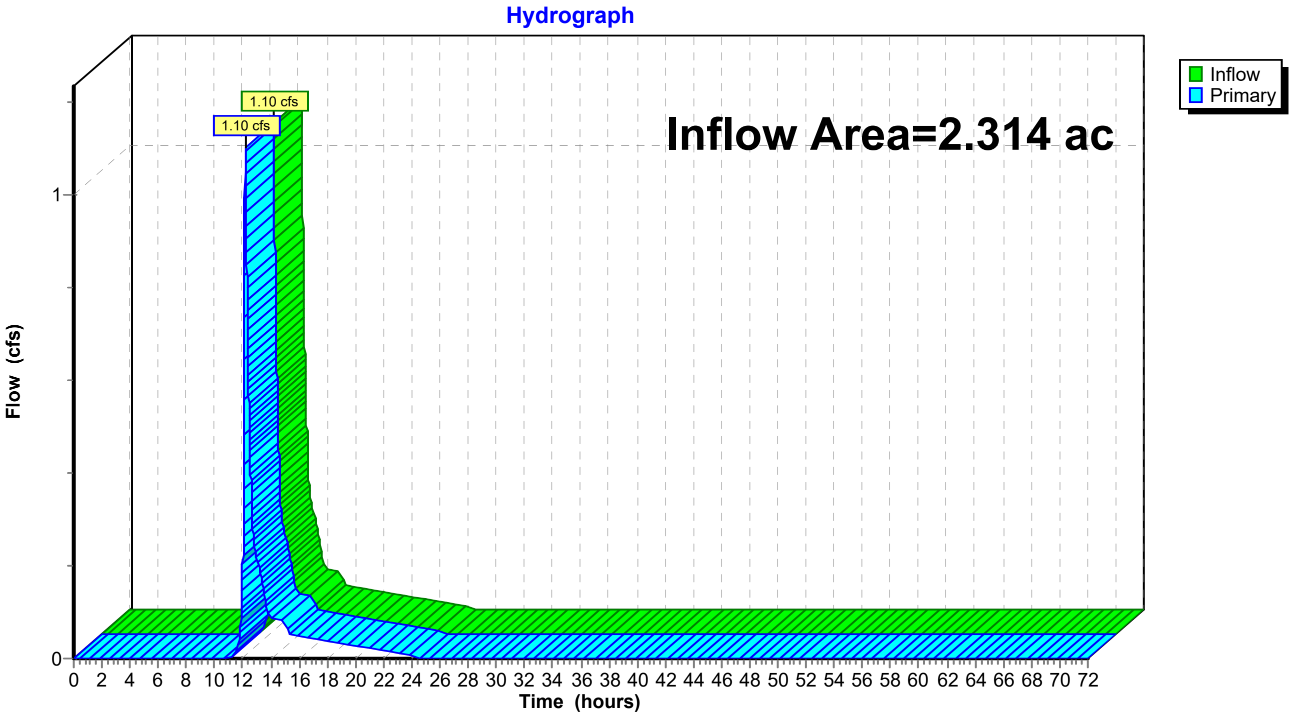


Summary for Link 1L: Total to Wetland

Inflow Area = 2.314 ac, 10.25% Impervious, Inflow Depth = 0.44" for 2-Year event
Inflow = 1.10 cfs @ 12.17 hrs, Volume= 0.085 af
Primary = 1.10 cfs @ 12.17 hrs, Volume= 0.085 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs

Link 1L: Total to Wetland



Time span=0.00-72.00 hrs, dt=0.01 hrs, 7201 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment1S: On-Site To Pond Runoff Area=55,086 sf 3.83% Impervious Runoff Depth=0.97"
Flow Length=413' Slope=0.0387 '/' Tc=13.1 min CN=62 Runoff=1.51 cfs 0.102 af

Subcatchment2S: Off-Site Run-on to Pond Runoff Area=17,388 sf 47.30% Impervious Runoff Depth=2.12"
Flow Length=418' Slope=0.0407 '/' Tc=8.1 min CN=79 Runoff=1.43 cfs 0.070 af

Subcatchment3S: On-Site Uncontrolled Runoff Area=25,538 sf 0.00% Impervious Runoff Depth=0.91"
Flow Length=146' Slope=0.0444 '/' Tc=5.5 min CN=61 Runoff=0.95 cfs 0.045 af

Subcatchment4S: Off-Site Uncontrolled Runoff Area=2,787 sf 0.00% Impervious Runoff Depth=0.91"
Flow Length=172' Slope=0.0523 '/' Tc=5.7 min CN=61 Runoff=0.10 cfs 0.005 af

Pond 1P: Existing Pond Peak Elev=873.82' Storage=51 cf Inflow=2.68 cfs 0.172 af
12.0" Round Culvert n=0.011 L=30.0' S=0.0000 '/' Outflow=2.67 cfs 0.172 af

Link 1L: Total to Wetland Inflow=3.50 cfs 0.222 af
Primary=3.50 cfs 0.222 af

Total Runoff Area = 2.314 ac Runoff Volume = 0.222 af Average Runoff Depth = 1.15"
89.75% Pervious = 2.077 ac 10.25% Impervious = 0.237 ac

Summary for Subcatchment 1S: On-Site To Pond

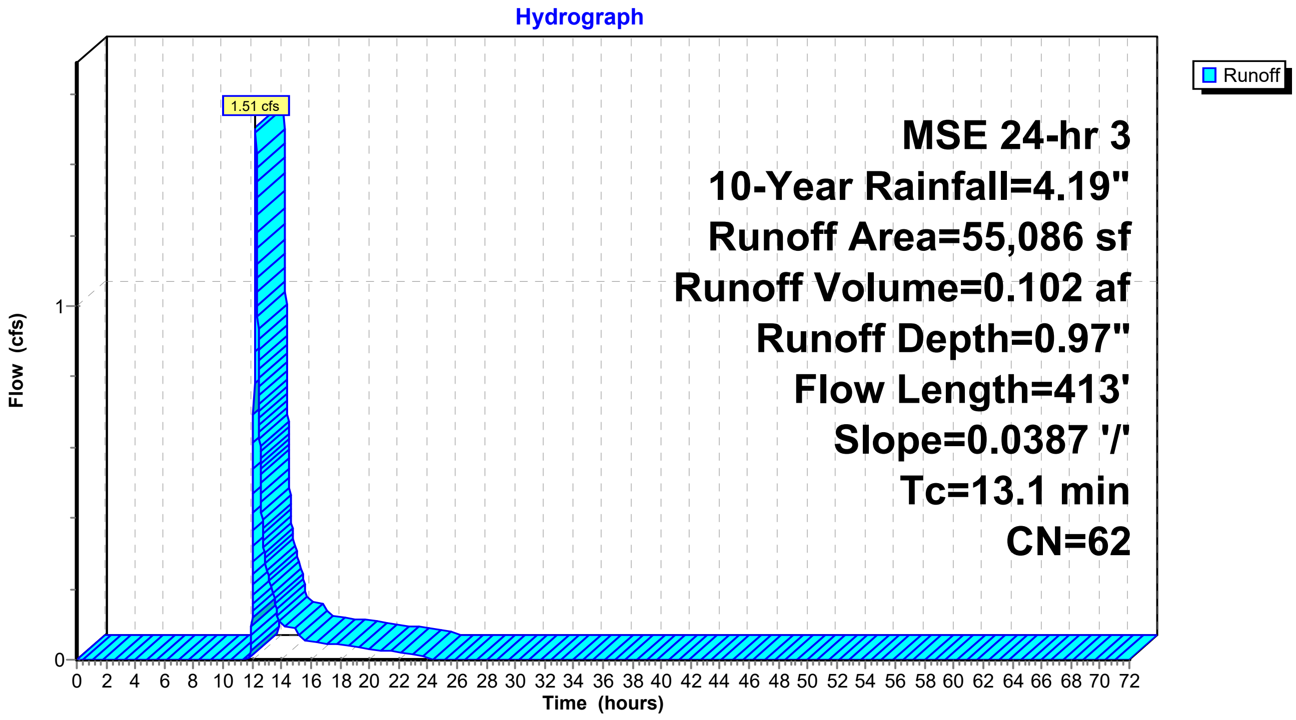
Runoff = 1.51 cfs @ 12.23 hrs, Volume= 0.102 af, Depth= 0.97"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 10-Year Rainfall=4.19"

Area (sf)	CN	Description
52,977	61	>75% Grass cover, Good, HSG B
2,109	98	Water Surface, HSG D
55,086	62	Weighted Average
52,977		96.17% Pervious Area
2,109		3.83% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.1	413	0.0387	0.53		**Lag/CN Method,**

Subcatchment 1S: On-Site To Pond



Summary for Subcatchment 2S: Off-Site Run-on to Pond

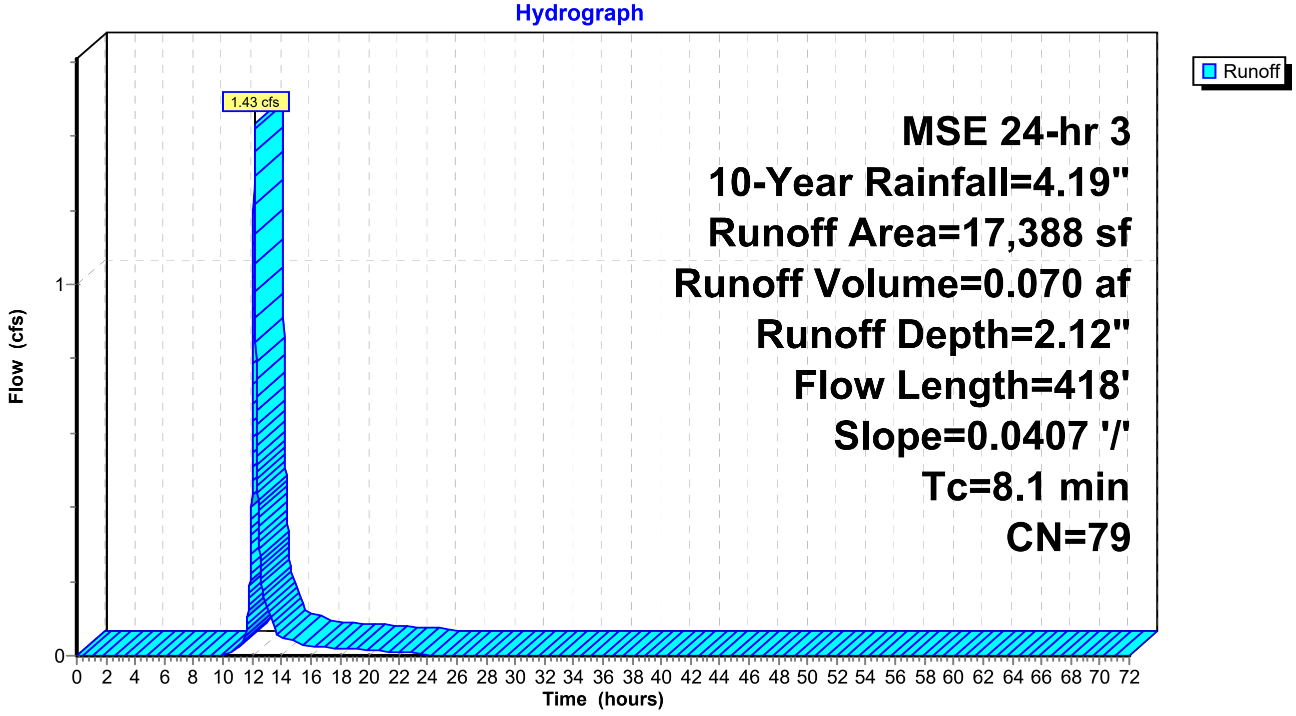
Runoff = 1.43 cfs @ 12.16 hrs, Volume= 0.070 af, Depth= 2.12"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 10-Year Rainfall=4.19"

Area (sf)	CN	Description
9,163	61	>75% Grass cover, Good, HSG B
8,225	98	Paved parking, HSG B
17,388	79	Weighted Average
9,163		52.70% Pervious Area
8,225		47.30% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.1	418	0.0407	0.86		**Lag/CN Method,**

Subcatchment 2S: Off-Site Run-on to Pond



Summary for Subcatchment 3S: On-Site Uncontrolled Runoff

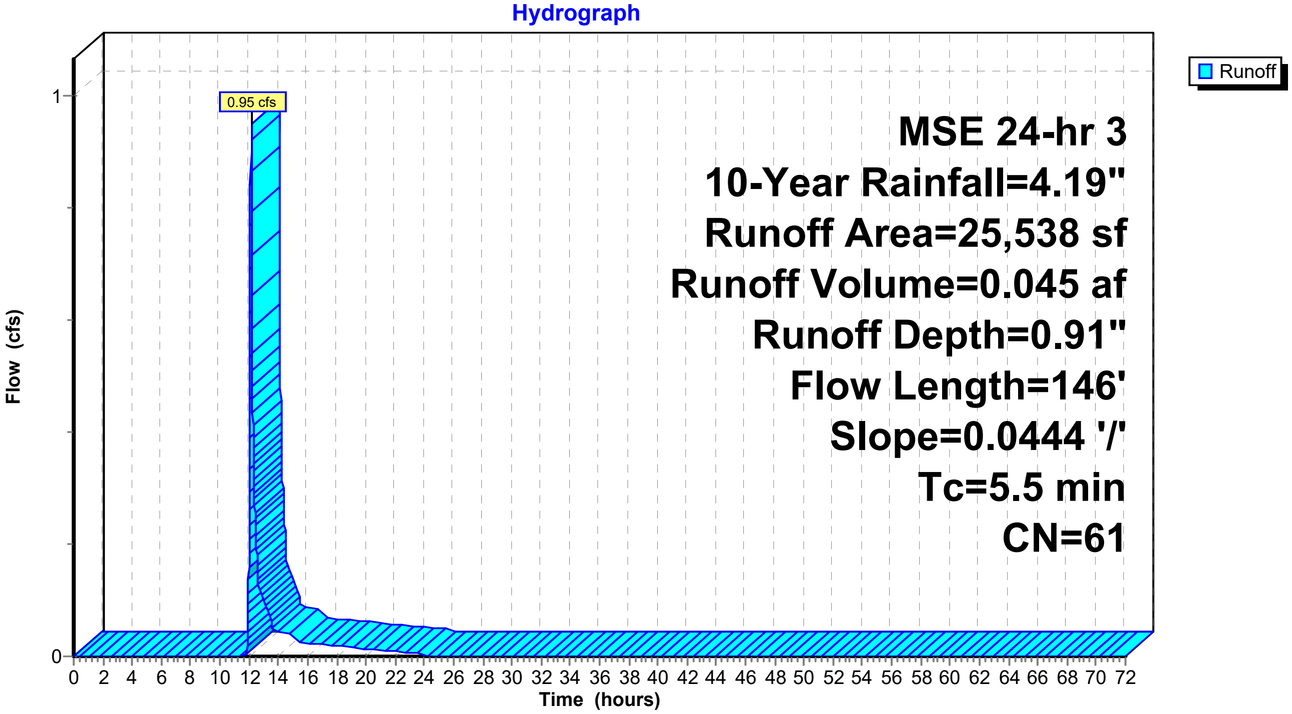
Runoff = 0.95 cfs @ 12.14 hrs, Volume= 0.045 af, Depth= 0.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 10-Year Rainfall=4.19"

Area (sf)	CN	Description
25,538	61	>75% Grass cover, Good, HSG B
25,538		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.5	146	0.0444	0.45		**Lag/CN Method,**

Subcatchment 3S: On-Site Uncontrolled Runoff



Summary for Subcatchment 4S: Off-Site Uncontrolled Runoff

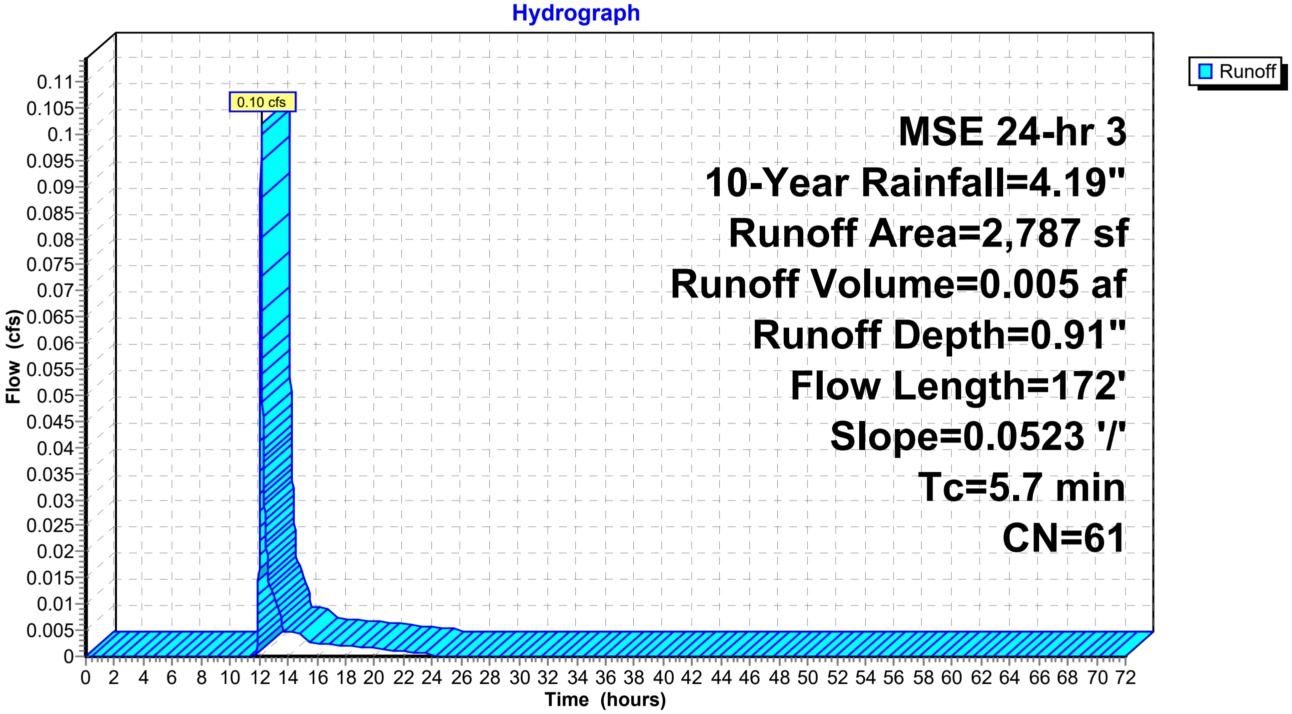
Runoff = 0.10 cfs @ 12.14 hrs, Volume= 0.005 af, Depth= 0.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 10-Year Rainfall=4.19"

Area (sf)	CN	Description
2,787	61	>75% Grass cover, Good, HSG B
2,787		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.7	172	0.0523	0.50		**Lag/CN Method,**

Subcatchment 4S: Off-Site Uncontrolled Runoff



Summary for Pond 1P: Existing Pond

Inflow Area = 1.664 ac, 14.26% Impervious, Inflow Depth = 1.24" for 10-Year event
Inflow = 2.68 cfs @ 12.18 hrs, Volume= 0.172 af
Outflow = 2.67 cfs @ 12.19 hrs, Volume= 0.172 af, Atten= 0%, Lag= 0.4 min
Primary = 2.67 cfs @ 12.19 hrs, Volume= 0.172 af

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Peak Elev= 873.82' @ 12.19 hrs Surf.Area= 2,484 sf Storage= 51 cf

Plug-Flow detention time= 0.3 min calculated for 0.172 af (100% of inflow)
Center-of-Mass det. time= 0.3 min (833.9 - 833.5)

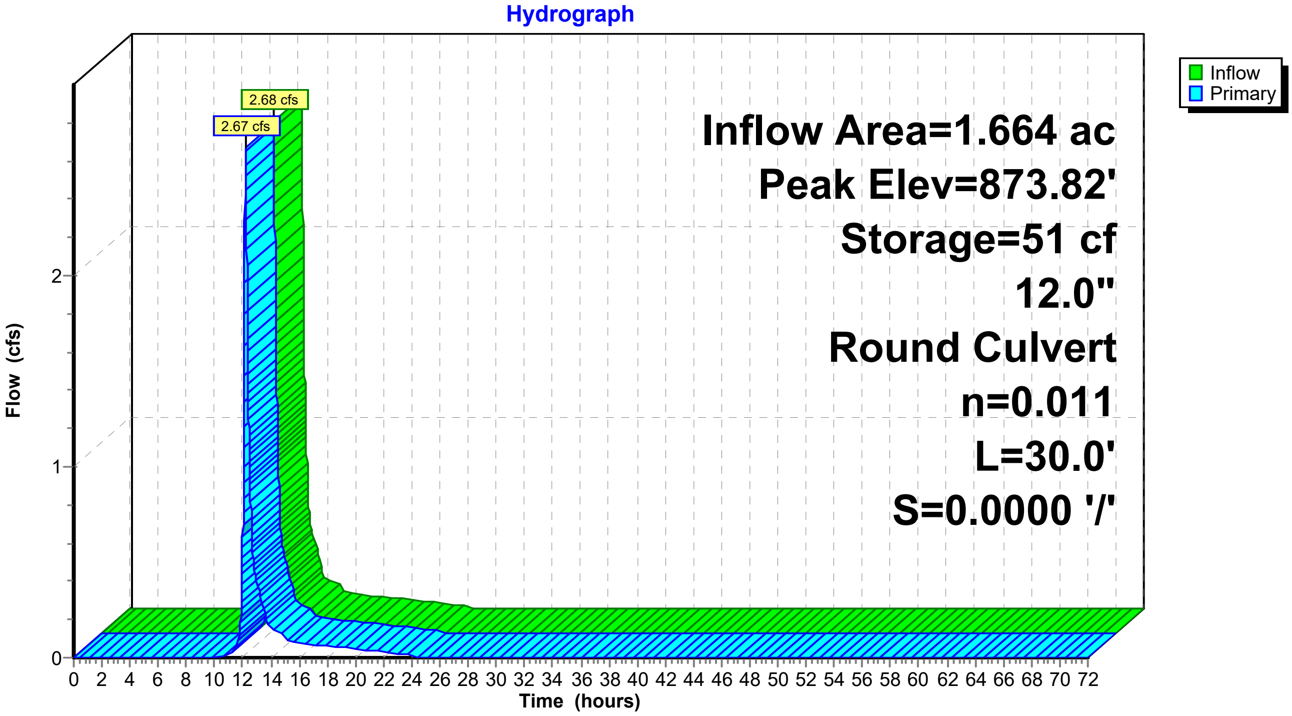
Volume	Invert	Avail.Storage	Storage Description
#1	873.80'	10,998 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
873.80	2,472	0	0
876.00	3,710	6,800	6,800
877.00	4,686	4,198	10,998

Device	Routing	Invert	Outlet Devices
#1	Primary	871.90'	**12.0" Round Culvert** L= 30.0' Ke= 0.500 Inlet / Outlet Invert= 871.90' / 871.90' S= 0.0000 '/' Cc= 0.900 n= 0.011 Concrete pipe, straight & clean, Flow Area= 0.79 sf

Primary OutFlow Max=4.10 cfs @ 12.19 hrs HW=873.82' (Free Discharge)
↰**1=Culvert** (Barrel Controls 4.10 cfs @ 5.22 fps)

Pond 1P: Existing Pond

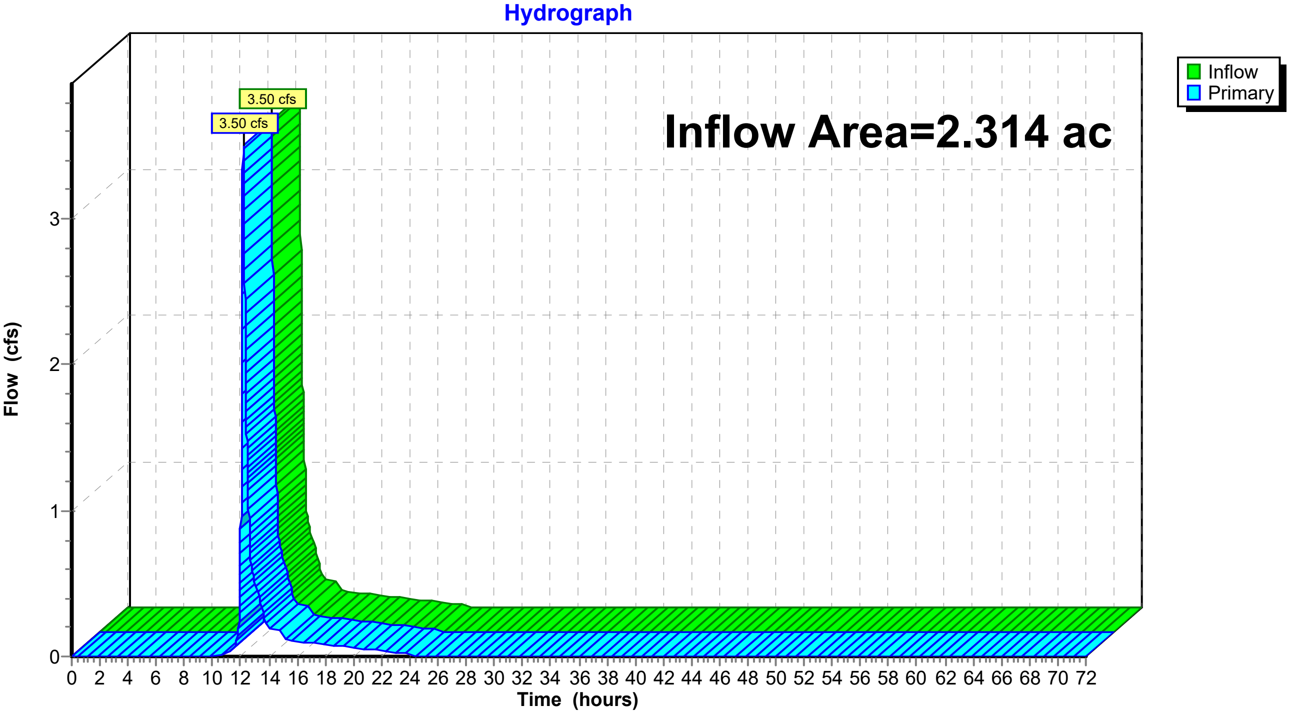


Summary for Link 1L: Total to Wetland

Inflow Area =	2.314 ac,	10.25% Impervious,	Inflow Depth = 1.15"	for 10-Year event
Inflow =	3.50 cfs @	12.16 hrs, Volume=	0.222 af	
Primary =	3.50 cfs @	12.16 hrs, Volume=	0.222 af,	Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs

Link 1L: Total to Wetland



```
                    Time span=0.00-72.00 hrs, dt=0.01 hrs, 7201 points
                       Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
             Reach routing by Stor-Ind+Trans method  -  Pond routing by Stor-Ind method

Subcatchment1S: On-Site To Pond             Runoff Area=55,086 sf   3.83% Impervious   Runoff Depth=2.28"
                             Flow Length=413'   Slope=0.0387 '/'   Tc=13.1 min   CN=62   Runoff=3.89 cfs  0.240 af

Subcatchment2S: Off-Site Run-on to Pond Runoff Area=17,388 sf   47.30% Impervious   Runoff Depth=3.92"
                              Flow Length=418'   Slope=0.0407 '/'   Tc=8.1 min   CN=79   Runoff=2.61 cfs  0.130 af

Subcatchment3S: On-Site Uncontrolled        Runoff Area=25,538 sf   0.00% Impervious   Runoff Depth=2.19"
                              Flow Length=146'   Slope=0.0444 '/'   Tc=5.5 min   CN=61   Runoff=2.45 cfs  0.107 af

Subcatchment4S: Off-Site Uncontrolled         Runoff Area=2,787 sf   0.00% Impervious   Runoff Depth=2.19"
                              Flow Length=172'   Slope=0.0523 '/'   Tc=5.7 min   CN=61   Runoff=0.26 cfs  0.012 af

Pond 1P: Existing Pond                          Peak Elev=874.09'  Storage=741 cf   Inflow=6.07 cfs  0.370 af
                          12.0"  Round Culvert  n=0.011  L=30.0'  S=0.0000 '/'   Outflow=4.66 cfs  0.370 af

Link 1L: Total to Wetland                                                           Inflow=6.90 cfs  0.489 af
                                                                                   Primary=6.90 cfs  0.489 af

              Total Runoff Area = 2.314 ac   Runoff Volume = 0.489 af   Average Runoff Depth = 2.54"
                                           89.75% Pervious = 2.077 ac     10.25% Impervious = 0.237 ac
```

Summary for Subcatchment 1S: On-Site To Pond

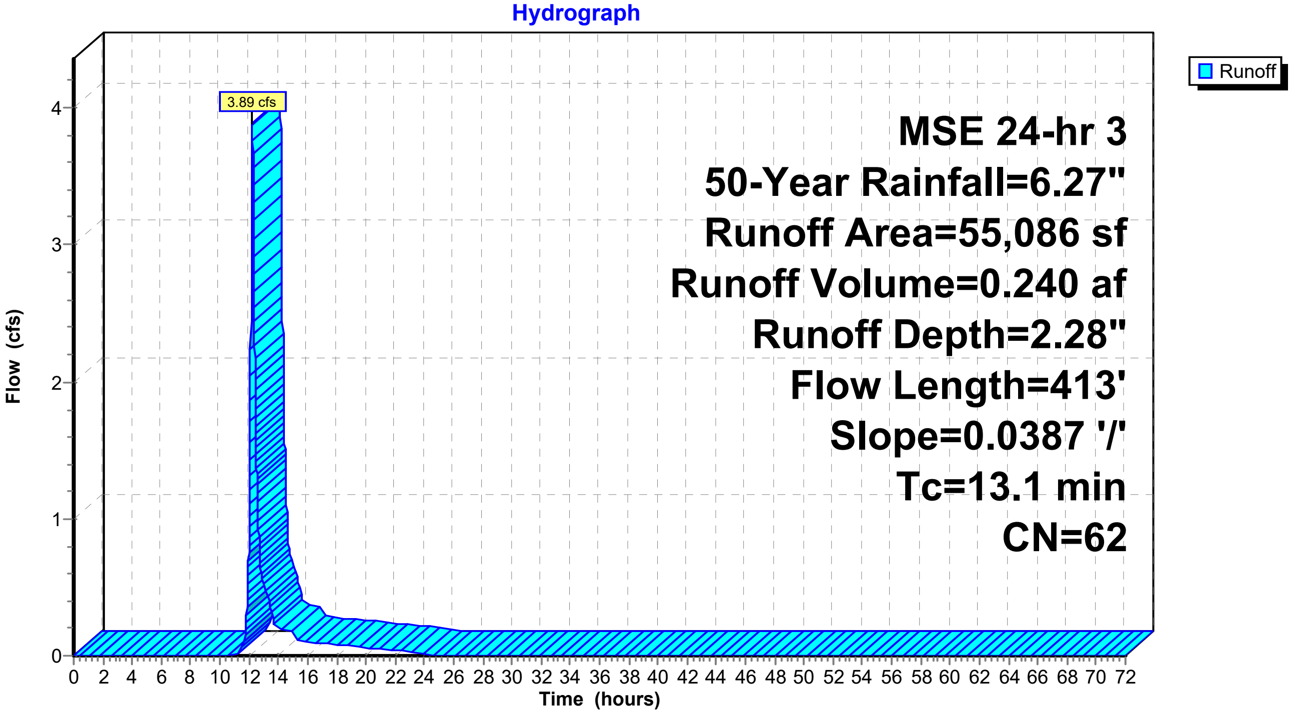
Runoff = 3.89 cfs @ 12.22 hrs, Volume= 0.240 af, Depth= 2.28"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 50-Year Rainfall=6.27"

Area (sf)	CN	Description
52,977	61	>75% Grass cover, Good, HSG B
2,109	98	Water Surface, HSG D
55,086	62	Weighted Average
52,977		96.17% Pervious Area
2,109		3.83% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.1	413	0.0387	0.53		**Lag/CN Method,**

Subcatchment 1S: On-Site To Pond



Summary for Subcatchment 2S: Off-Site Run-on to Pond

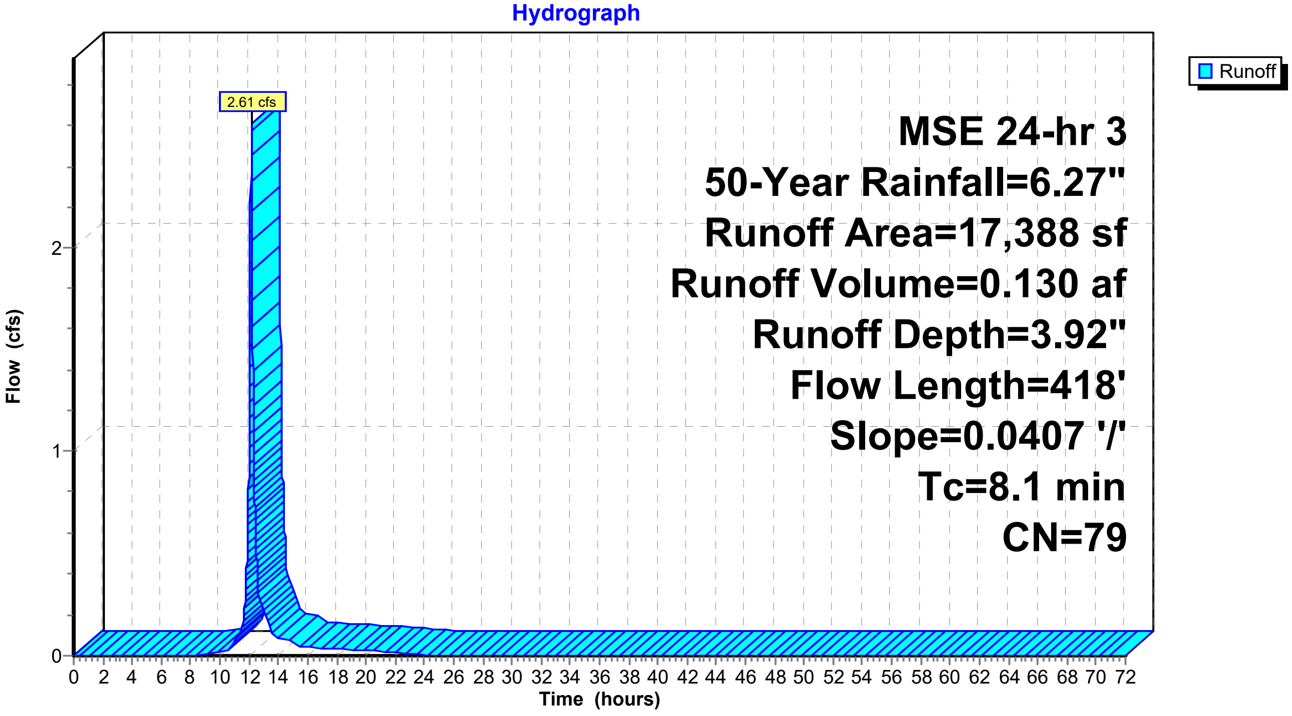
Runoff = 2.61 cfs @ 12.15 hrs, Volume= 0.130 af, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 50-Year Rainfall=6.27"

Area (sf)	CN	Description
9,163	61	>75% Grass cover, Good, HSG B
8,225	98	Paved parking, HSG B
17,388	79	Weighted Average
9,163		52.70% Pervious Area
8,225		47.30% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.1	418	0.0407	0.86		**Lag/CN Method,**

Subcatchment 2S: Off-Site Run-on to Pond



Summary for Subcatchment 3S: On-Site Uncontrolled Runoff

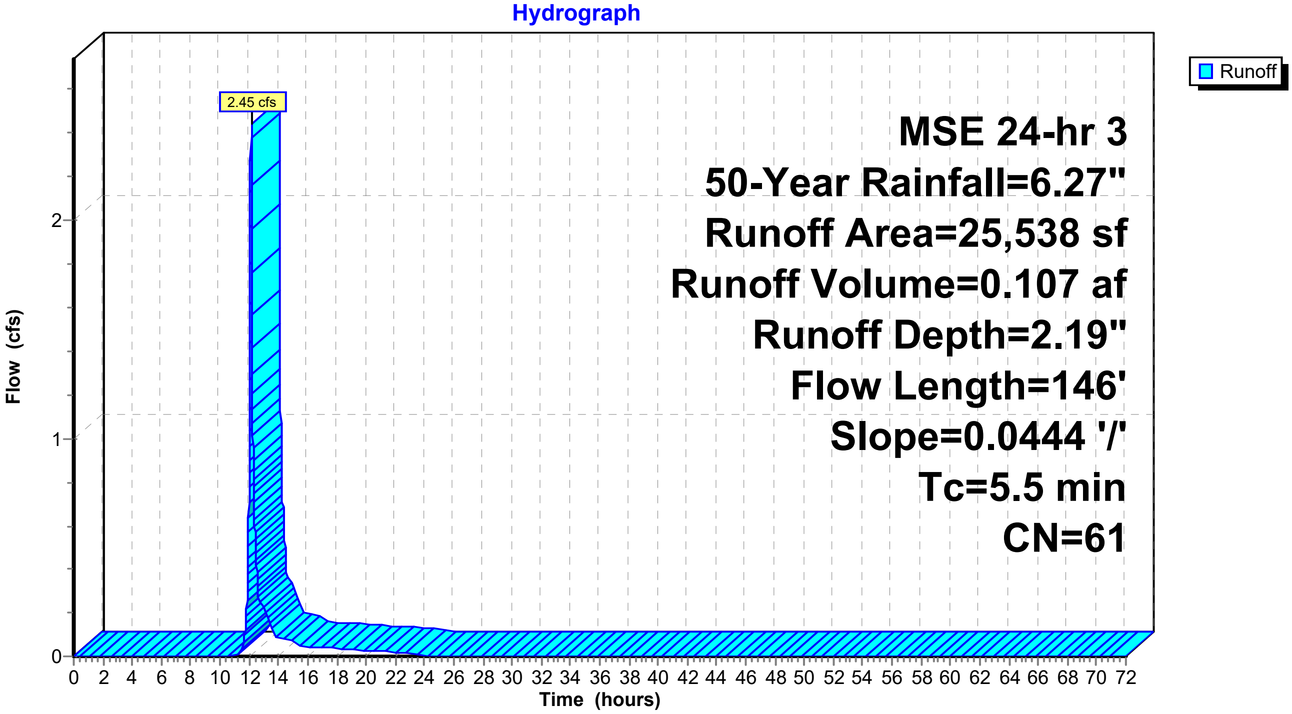
Runoff = 2.45 cfs @ 12.13 hrs, Volume= 0.107 af, Depth= 2.19"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 50-Year Rainfall=6.27"

Area (sf)	CN	Description
25,538	61	>75% Grass cover, Good, HSG B
25,538		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.5	146	0.0444	0.45		**Lag/CN Method,**

Subcatchment 3S: On-Site Uncontrolled Runoff



Summary for Subcatchment 4S: Off-Site Uncontrolled Runoff

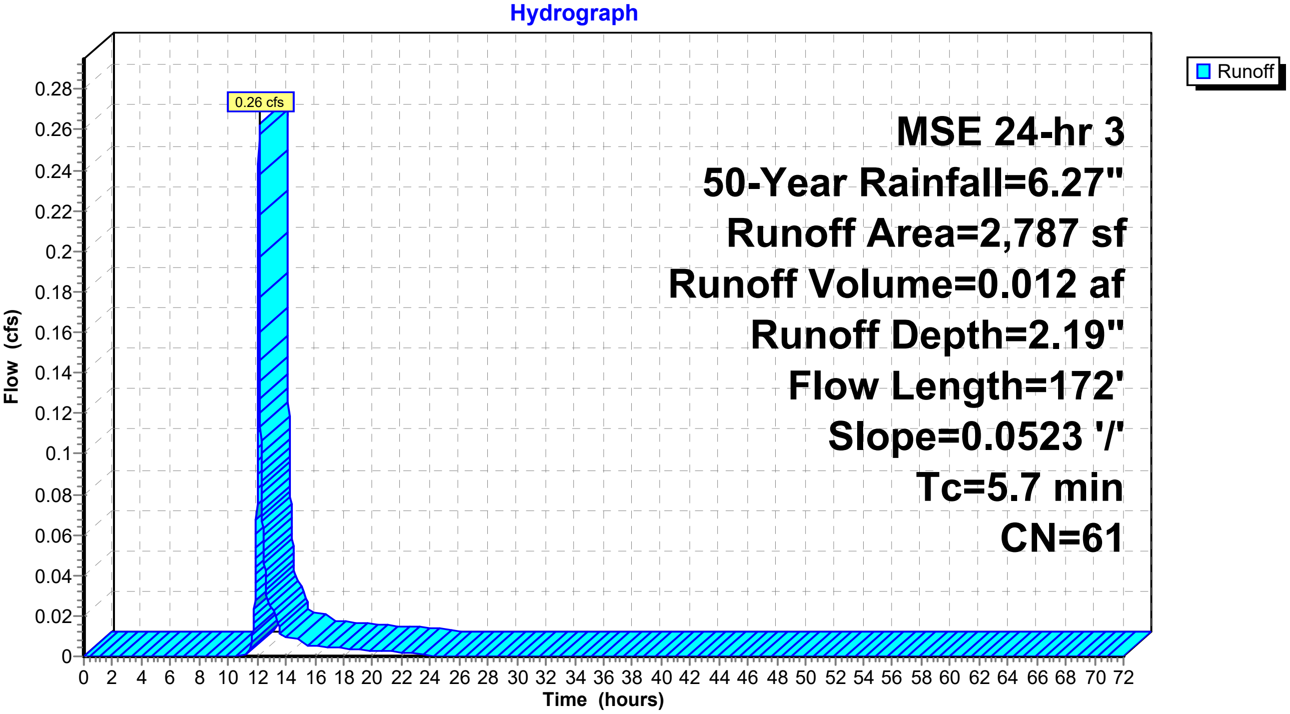
Runoff = 0.26 cfs @ 12.13 hrs, Volume= 0.012 af, Depth= 2.19"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 50-Year Rainfall=6.27"

Area (sf)	CN	Description
2,787	61	>75% Grass cover, Good, HSG B
2,787		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.7	172	0.0523	0.50		**Lag/CN Method,**

Subcatchment 4S: Off-Site Uncontrolled Runoff



Summary for Pond 1P: Existing Pond

```
Inflow Area =          1.664 ac,  14.26% Impervious,  Inflow Depth =   2.67"    for  50-Year event
Inflow      =        6.07 cfs @   12.18 hrs,  Volume=          0.370 af
Outflow     =        4.66 cfs @   12.28 hrs,  Volume=          0.370 af,  Atten= 23%,  Lag= 5.8 min
Primary     =        4.66 cfs @   12.28 hrs,  Volume=          0.370 af
```

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Peak Elev= 874.09' @ 12.28 hrs Surf.Area= 2,635 sf Storage= 741 cf

Plug-Flow detention time= 0.8 min calculated for 0.370 af (100% of inflow)
Center-of-Mass det. time= 0.8 min (818.9 - 818.1)

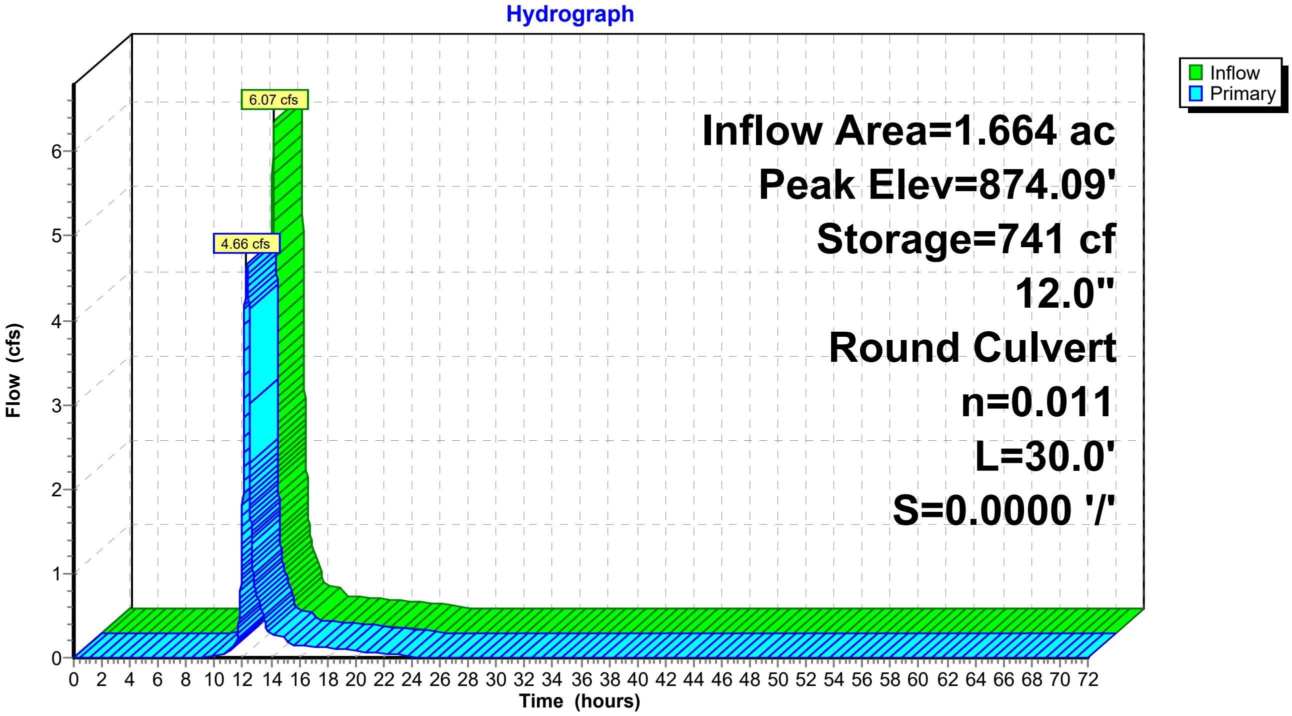
Volume	Invert	Avail.Storage	Storage Description
#1	873.80'	10,998 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
873.80	2,472	0	0
876.00	3,710	6,800	6,800
877.00	4,686	4,198	10,998

Device	Routing	Invert	Outlet Devices
#1	Primary	871.90'	**12.0" Round Culvert** L= 30.0' Ke= 0.500 Inlet / Outlet Invert= 871.90' / 871.90' S= 0.0000 '/' Cc= 0.900 n= 0.011 Concrete pipe, straight & clean, Flow Area= 0.79 sf

Primary OutFlow Max=4.66 cfs @ 12.28 hrs HW=874.09' (Free Discharge)
↑—**1=Culvert** (Barrel Controls 4.66 cfs @ 5.94 fps)

Pond 1P: Existing Pond

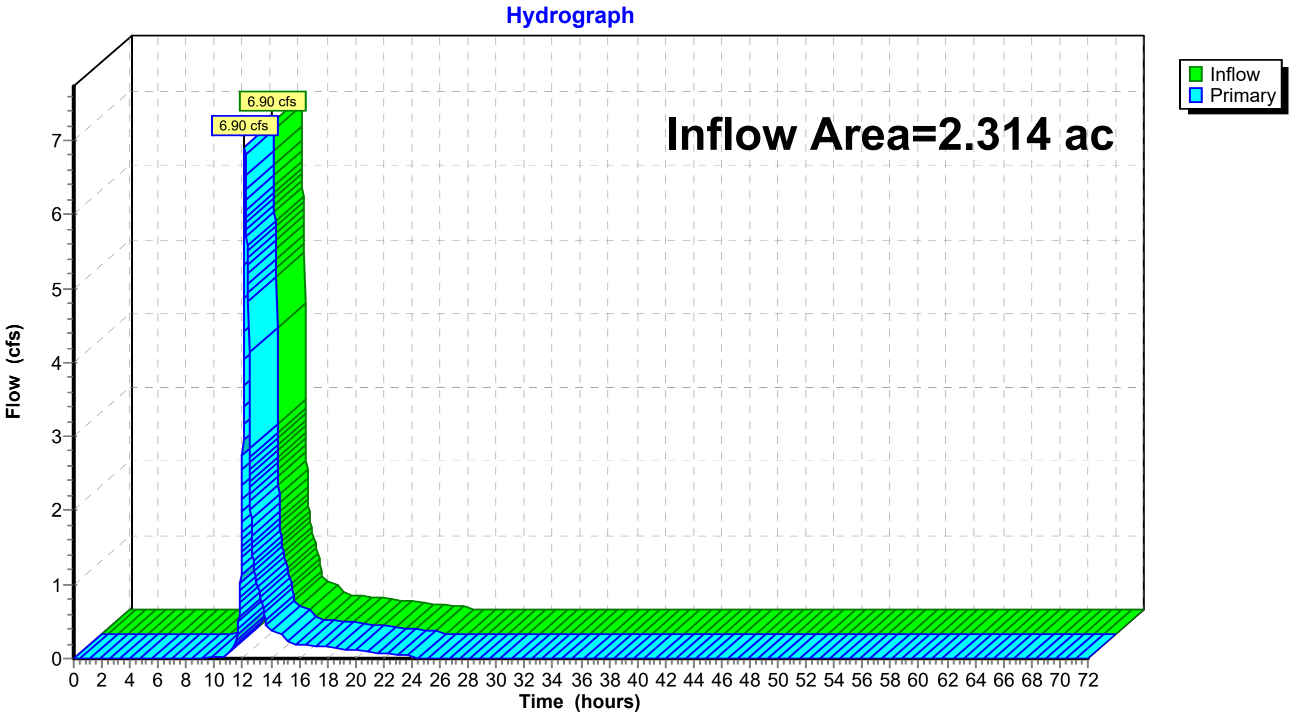


Summary for Link 1L: Total to Wetland

Inflow Area = 2.314 ac, 10.25% Impervious, Inflow Depth = 2.54" for 50-Year event
Inflow = 6.90 cfs @ 12.14 hrs, Volume= 0.489 af
Primary = 6.90 cfs @ 12.14 hrs, Volume= 0.489 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs

Link 1L: Total to Wetland



Time span=0.00-72.00 hrs, dt=0.01 hrs, 7201 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment1S: On-Site To Pond Runoff Area=55,086 sf 3.83% Impervious Runoff Depth=3.07"
Flow Length=413' Slope=0.0387 '/' Tc=13.1 min CN=62 Runoff=5.32 cfs 0.323 af

Subcatchment2S: Off-Site Run-on to Pond Runoff Area=17,388 sf 47.30% Impervious Runoff Depth=4.91"
Flow Length=418' Slope=0.0407 '/' Tc=8.1 min CN=79 Runoff=3.24 cfs 0.163 af

Subcatchment3S: On-Site Uncontrolled Runoff Area=25,538 sf 0.00% Impervious Runoff Depth=2.96"
Flow Length=146' Slope=0.0444 '/' Tc=5.5 min CN=61 Runoff=3.33 cfs 0.145 af

Subcatchment4S: Off-Site Uncontrolled Runoff Area=2,787 sf 0.00% Impervious Runoff Depth=2.96"
Flow Length=172' Slope=0.0523 '/' Tc=5.7 min CN=61 Runoff=0.36 cfs 0.016 af

Pond 1P: Existing Pond Peak Elev=874.46' Storage=1,755 cf Inflow=8.03 cfs 0.487 af
12.0" Round Culvert n=0.011 L=30.0' S=0.0000 '/' Outflow=5.34 cfs 0.487 af

Link 1L: Total to Wetland Inflow=8.11 cfs 0.647 af
Primary=8.11 cfs 0.647 af

Total Runoff Area = 2.314 ac Runoff Volume = 0.647 af Average Runoff Depth = 3.36"
89.75% Pervious = 2.077 ac 10.25% Impervious = 0.237 ac

Summary for Subcatchment 1S: On-Site To Pond

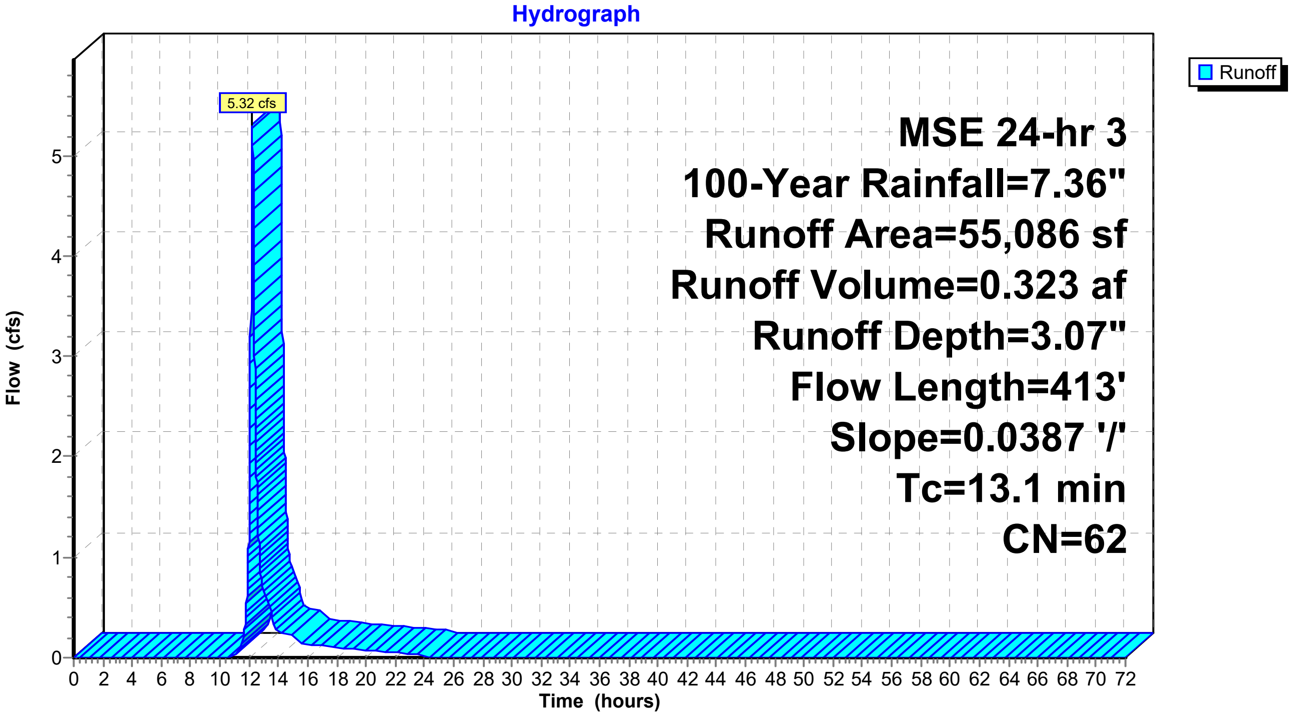
Runoff = 5.32 cfs @ 12.22 hrs, Volume= 0.323 af, Depth= 3.07"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 100-Year Rainfall=7.36"

Area (sf)	CN	Description
52,977	61	>75% Grass cover, Good, HSG B
2,109	98	Water Surface, HSG D
55,086	62	Weighted Average
52,977		96.17% Pervious Area
2,109		3.83% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.1	413	0.0387	0.53		**Lag/CN Method,**

Subcatchment 1S: On-Site To Pond



Summary for Subcatchment 2S: Off-Site Run-on to Pond

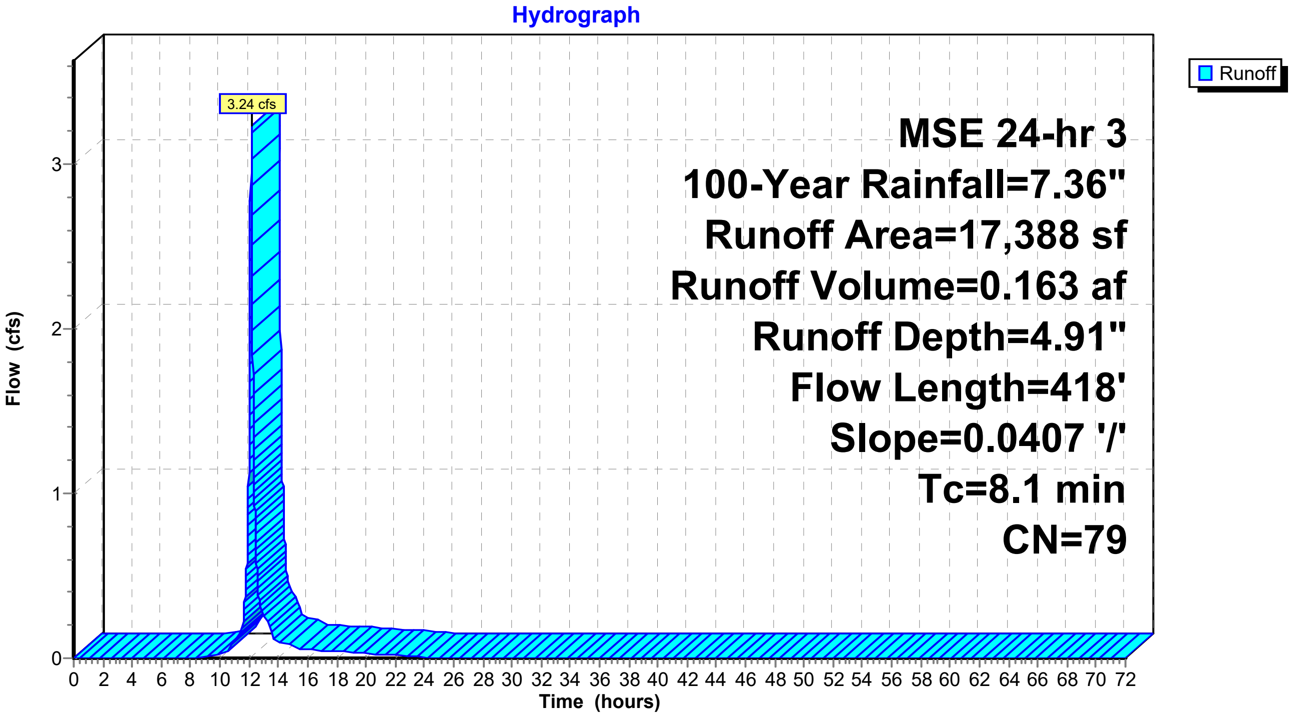
Runoff = 3.24 cfs @ 12.15 hrs, Volume= 0.163 af, Depth= 4.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 100-Year Rainfall=7.36"

Area (sf)	CN	Description
9,163	61	>75% Grass cover, Good, HSG B
8,225	98	Paved parking, HSG B
17,388	79	Weighted Average
9,163		52.70% Pervious Area
8,225		47.30% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.1	418	0.0407	0.86		**Lag/CN Method,**

Subcatchment 2S: Off-Site Run-on to Pond



Summary for Subcatchment 3S: On-Site Uncontrolled Runoff

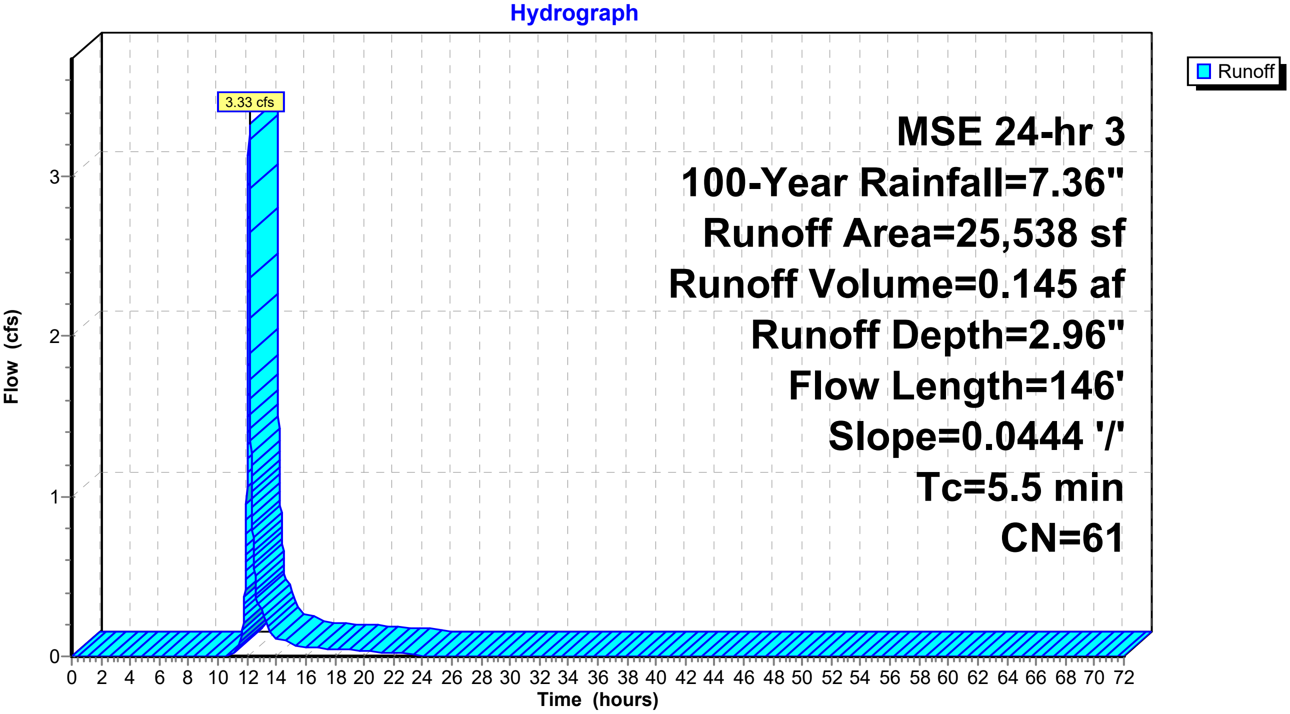
Runoff = 3.33 cfs @ 12.13 hrs, Volume= 0.145 af, Depth= 2.96"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 100-Year Rainfall=7.36"

Area (sf)	CN	Description
25,538	61	>75% Grass cover, Good, HSG B
25,538		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.5	146	0.0444	0.45		**Lag/CN Method,**

Subcatchment 3S: On-Site Uncontrolled Runoff



Summary for Subcatchment 4S: Off-Site Uncontrolled Runoff

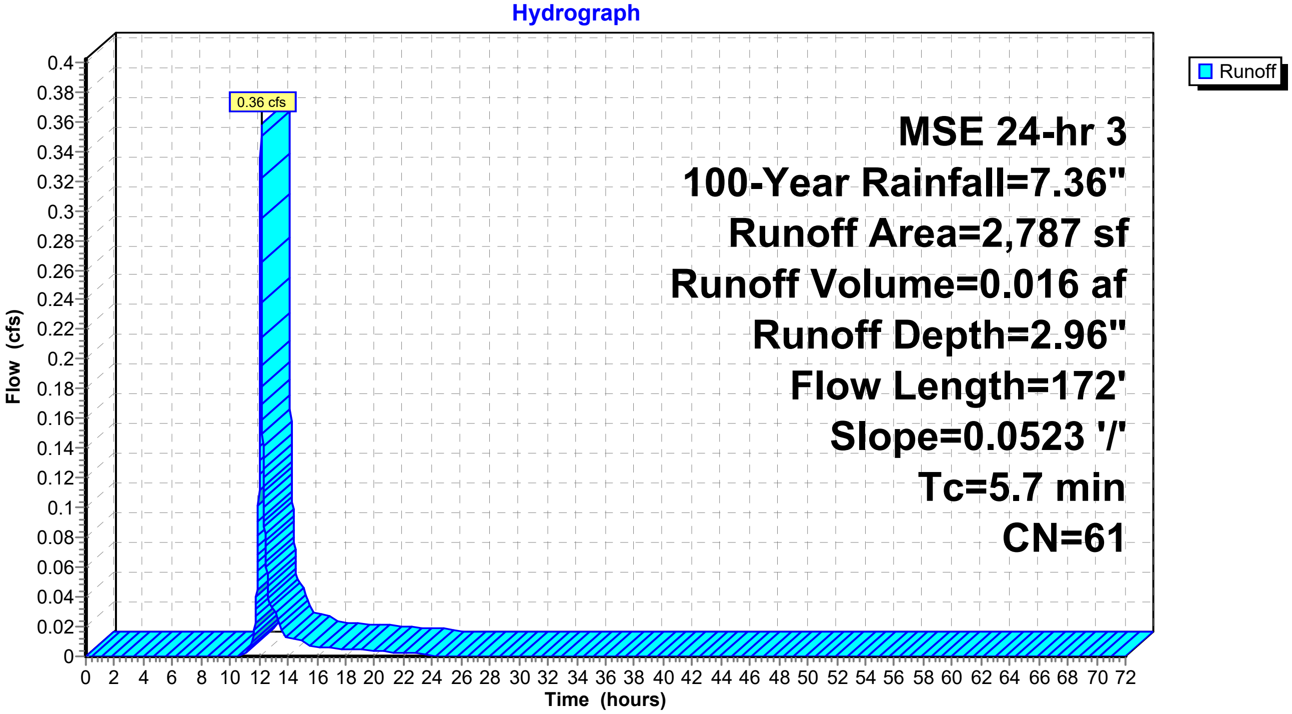
Runoff = 0.36 cfs @ 12.13 hrs, Volume= 0.016 af, Depth= 2.96"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 100-Year Rainfall=7.36"

Area (sf)	CN	Description
2,787	61	>75% Grass cover, Good, HSG B
2,787		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.7	172	0.0523	0.50		**Lag/CN Method,**

Subcatchment 4S: Off-Site Uncontrolled Runoff



Summary for Pond 1P: Existing Pond

```
Inflow Area =        1.664 ac,  14.26% Impervious,  Inflow Depth =   3.51"    for  100-Year event
Inflow      =        8.03 cfs @   12.18 hrs,  Volume=           0.487 af
Outflow     =        5.34 cfs @   12.31 hrs,  Volume=           0.487 af,  Atten= 33%,  Lag= 7.6 min
Primary     =        5.34 cfs @   12.31 hrs,  Volume=           0.487 af
```

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Peak Elev= 874.46' @ 12.31 hrs Surf.Area= 2,844 sf Storage= 1,755 cf

Plug-Flow detention time= 1.7 min calculated for 0.487 af (100% of inflow)
Center-of-Mass det. time= 1.7 min (814.5 - 812.8)

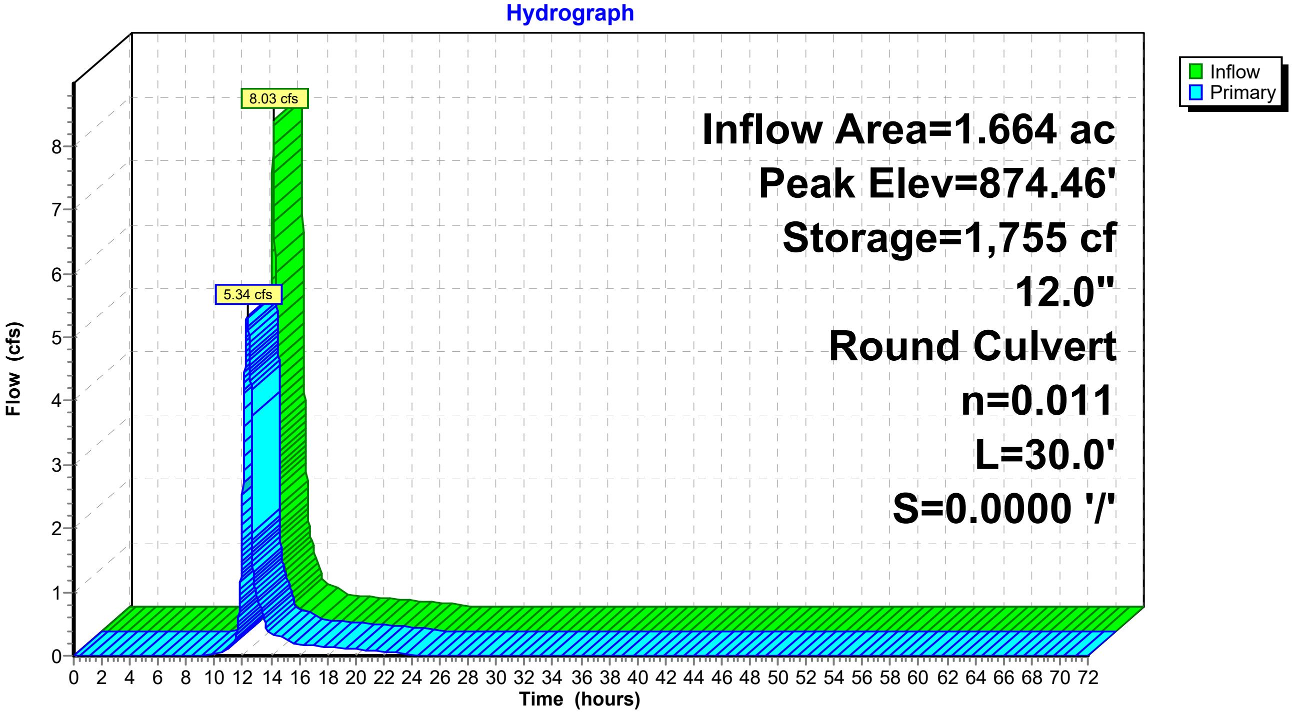
Volume	Invert	Avail.Storage	Storage Description
#1	873.80'	10,998 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
873.80	2,472	0	0
876.00	3,710	6,800	6,800
877.00	4,686	4,198	10,998

Device	Routing	Invert	Outlet Devices
#1	Primary	871.90'	**12.0" Round Culvert** L= 30.0' Ke= 0.500 Inlet / Outlet Invert= 871.90' / 871.90' S= 0.0000 '/' Cc= 0.900 n= 0.011 Concrete pipe, straight & clean, Flow Area= 0.79 sf

Primary OutFlow Max=5.34 cfs @ 12.31 hrs HW=874.46' (Free Discharge)
↑—**1=Culvert** (Barrel Controls 5.34 cfs @ 6.80 fps)

Pond 1P: Existing Pond

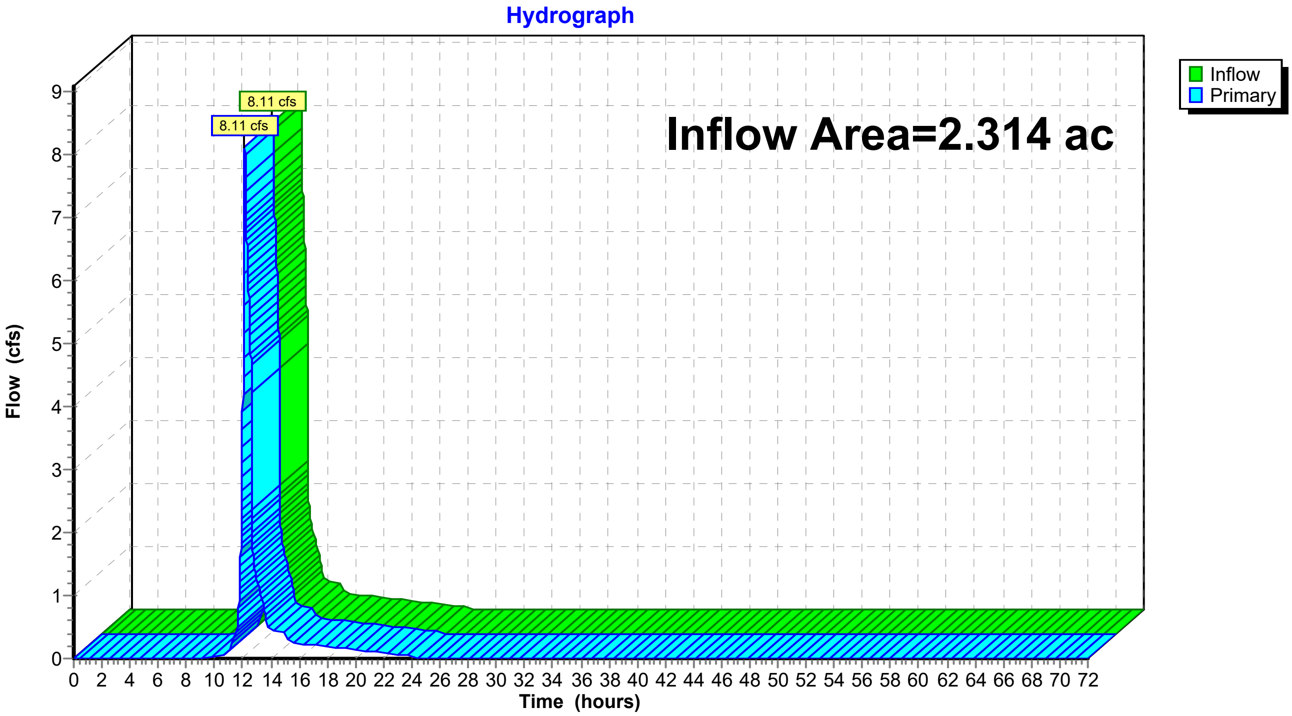


Summary for Link 1L: Total to Wetland

```
Inflow Area =      2.314 ac,  10.25% Impervious,  Inflow Depth =   3.36"    for  100-Year event
Inflow       =     8.11 cfs @   12.14 hrs,  Volume=            0.647 af
Primary      =     8.11 cfs @   12.14 hrs,  Volume=            0.647 af,  Atten= 0%,  Lag= 0.0 min
```

Primary outflow = Inflow, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs

Link 1L: Total to Wetland



```
                  Time span=0.00-72.00 hrs, dt=0.01 hrs, 7201 points
                 Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
        Reach routing by Stor-Ind+Trans method  -  Pond routing by Stor-Ind method

Subcatchment1S: On-Site To Pond         Runoff Area=55,086 sf   3.83% Impervious   Runoff Depth=2.02"
                        Flow Length=413'   Slope=0.0387 '/'   Tc=13.1 min   CN=62   Runoff=3.43 cfs  0.213 af

Subcatchment2S: Off-Site Run-on to Pond Runoff Area=17,388 sf   47.30% Impervious   Runoff Depth=3.59"
                         Flow Length=418'   Slope=0.0407 '/'   Tc=8.1 min   CN=79   Runoff=2.40 cfs  0.119 af

Subcatchment3S: On-Site Uncontrolled    Runoff Area=25,538 sf   0.00% Impervious   Runoff Depth=1.94"
                         Flow Length=146'   Slope=0.0444 '/'   Tc=5.5 min   CN=61   Runoff=2.16 cfs  0.095 af

Subcatchment4S: Off-Site Uncontrolled     Runoff Area=2,787 sf   0.00% Impervious   Runoff Depth=1.94"
                         Flow Length=172'   Slope=0.0523 '/'   Tc=5.7 min   CN=61   Runoff=0.23 cfs  0.010 af

Pond 1P: Existing Pond                      Peak Elev=873.98'  Storage=462 cf   Inflow=5.43 cfs  0.333 af
                   12.0"  Round Culvert  n=0.011  L=30.0'  S=0.0000 '/'   Outflow=4.45 cfs  0.333 af

Link 1L: Total to Wetland                                                    Inflow=6.54 cfs  0.438 af
                                                                            Primary=6.54 cfs  0.438 af

         Total Runoff Area = 2.314 ac   Runoff Volume = 0.438 af   Average Runoff Depth = 2.27"
                                   89.75% Pervious = 2.077 ac     10.25% Impervious = 0.237 ac
```

Summary for Subcatchment 1S: On-Site To Pond

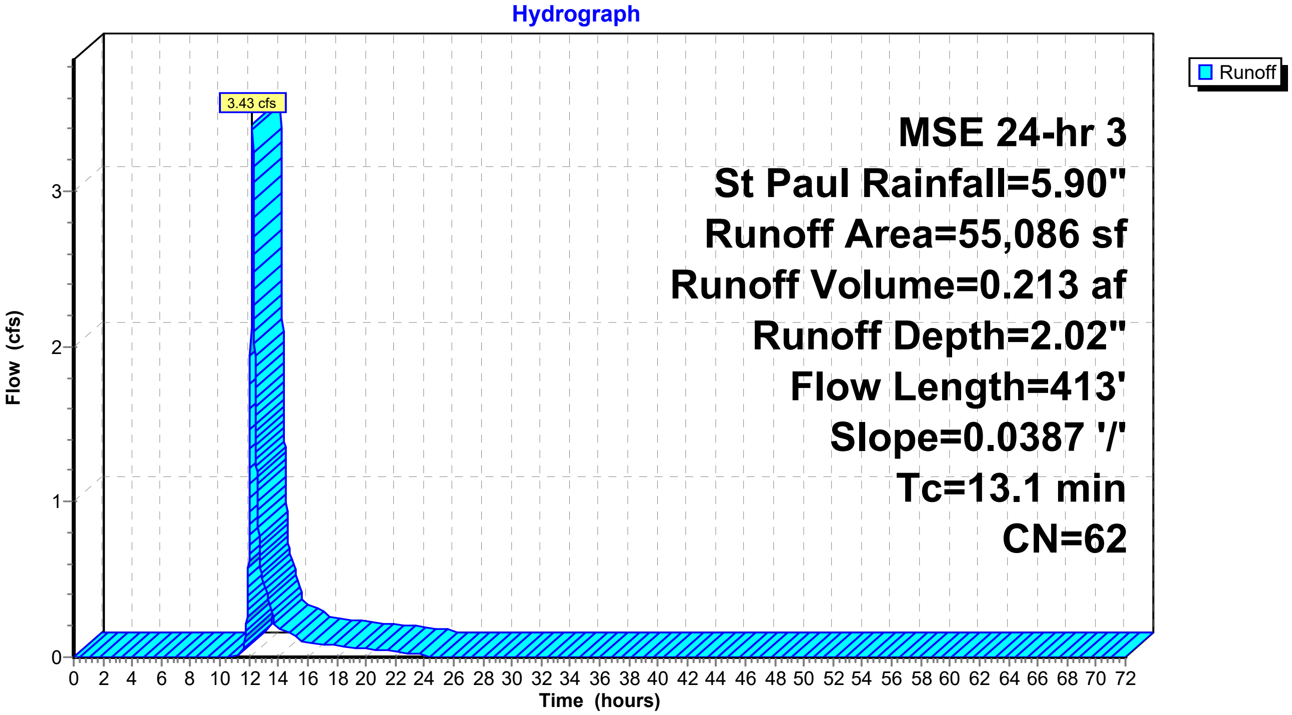
Runoff = 3.43 cfs @ 12.22 hrs, Volume= 0.213 af, Depth= 2.02"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 St Paul Rainfall=5.90"

Area (sf)	CN	Description
52,977	61	>75% Grass cover, Good, HSG B
2,109	98	Water Surface, HSG D
55,086	62	Weighted Average
52,977		96.17% Pervious Area
2,109		3.83% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.1	413	0.0387	0.53		**Lag/CN Method,**

Subcatchment 1S: On-Site To Pond



Summary for Subcatchment 2S: Off-Site Run-on to Pond

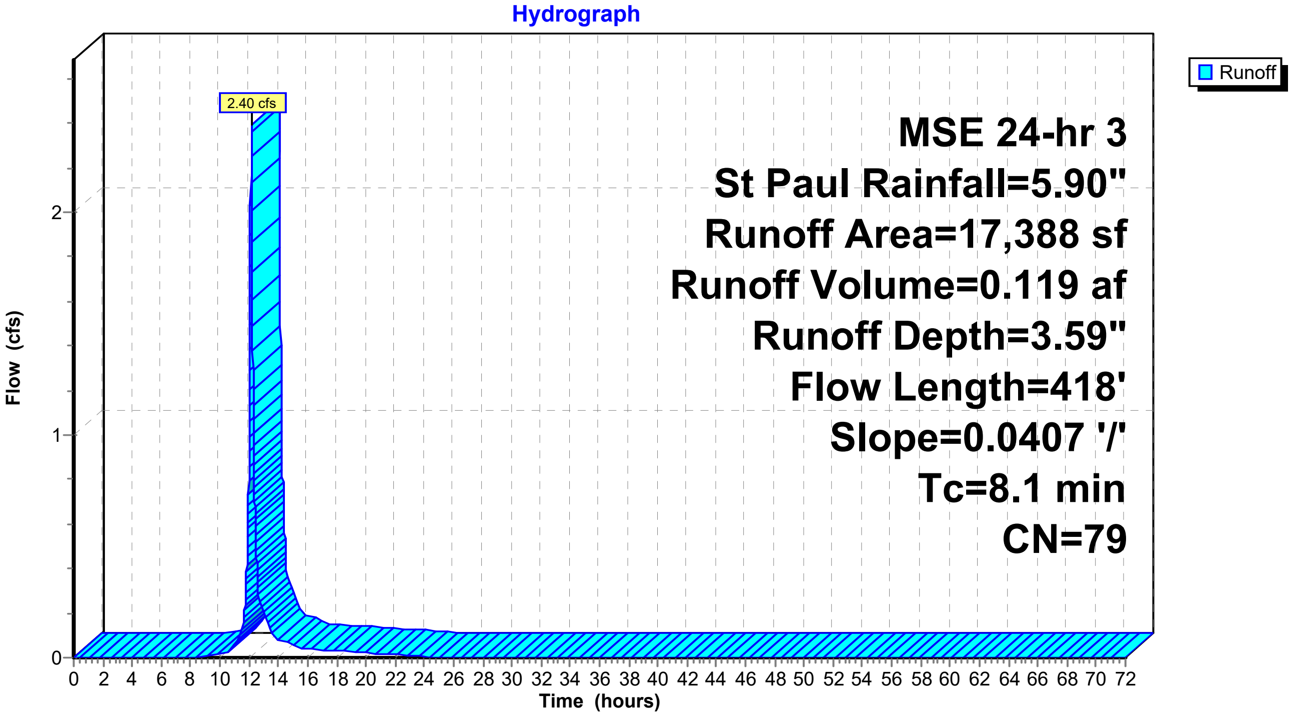
Runoff = 2.40 cfs @ 12.15 hrs, Volume= 0.119 af, Depth= 3.59"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 St Paul Rainfall=5.90"

Area (sf)	CN	Description
9,163	61	>75% Grass cover, Good, HSG B
8,225	98	Paved parking, HSG B
17,388	79	Weighted Average
9,163		52.70% Pervious Area
8,225		47.30% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.1	418	0.0407	0.86		**Lag/CN Method,**

Subcatchment 2S: Off-Site Run-on to Pond



Summary for Subcatchment 3S: On-Site Uncontrolled Runoff

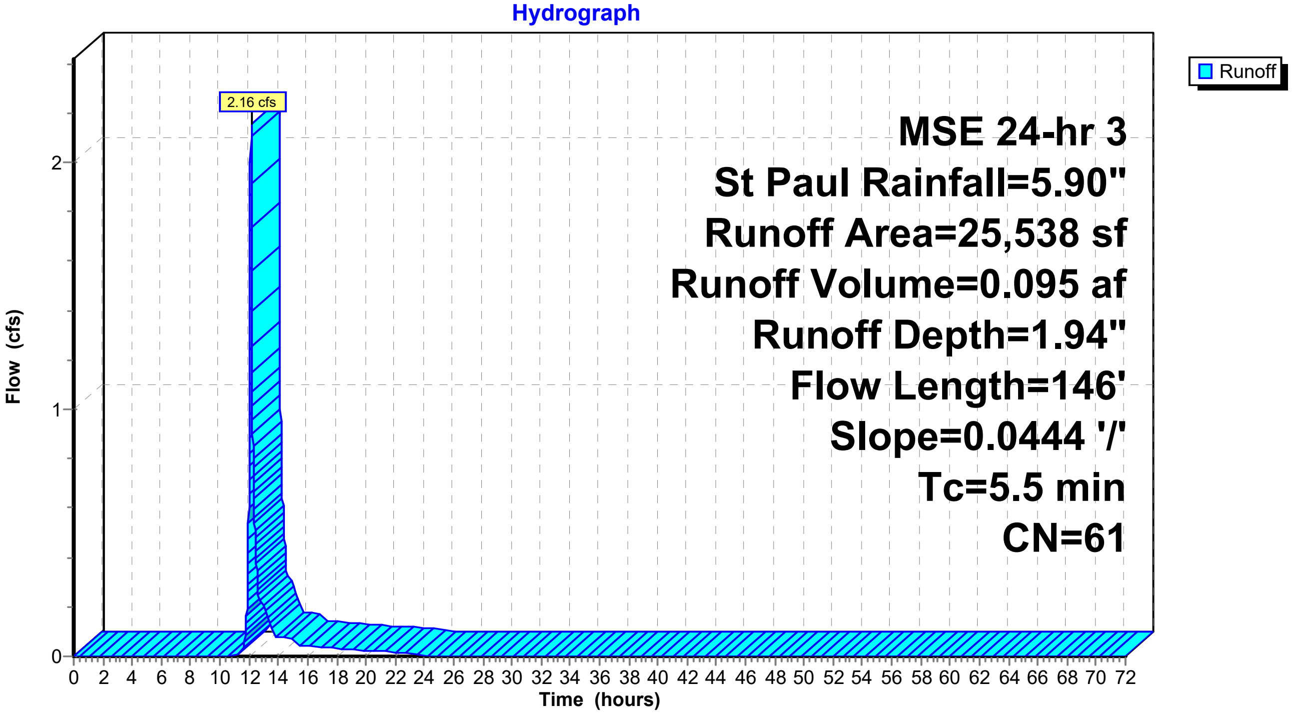
Runoff = 2.16 cfs @ 12.13 hrs, Volume= 0.095 af, Depth= 1.94"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 St Paul Rainfall=5.90"

Area (sf)	CN	Description
25,538	61	>75% Grass cover, Good, HSG B
25,538		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.5	146	0.0444	0.45		**Lag/CN Method,**

Subcatchment 3S: On-Site Uncontrolled Runoff



Summary for Subcatchment 4S: Off-Site Uncontrolled Runoff

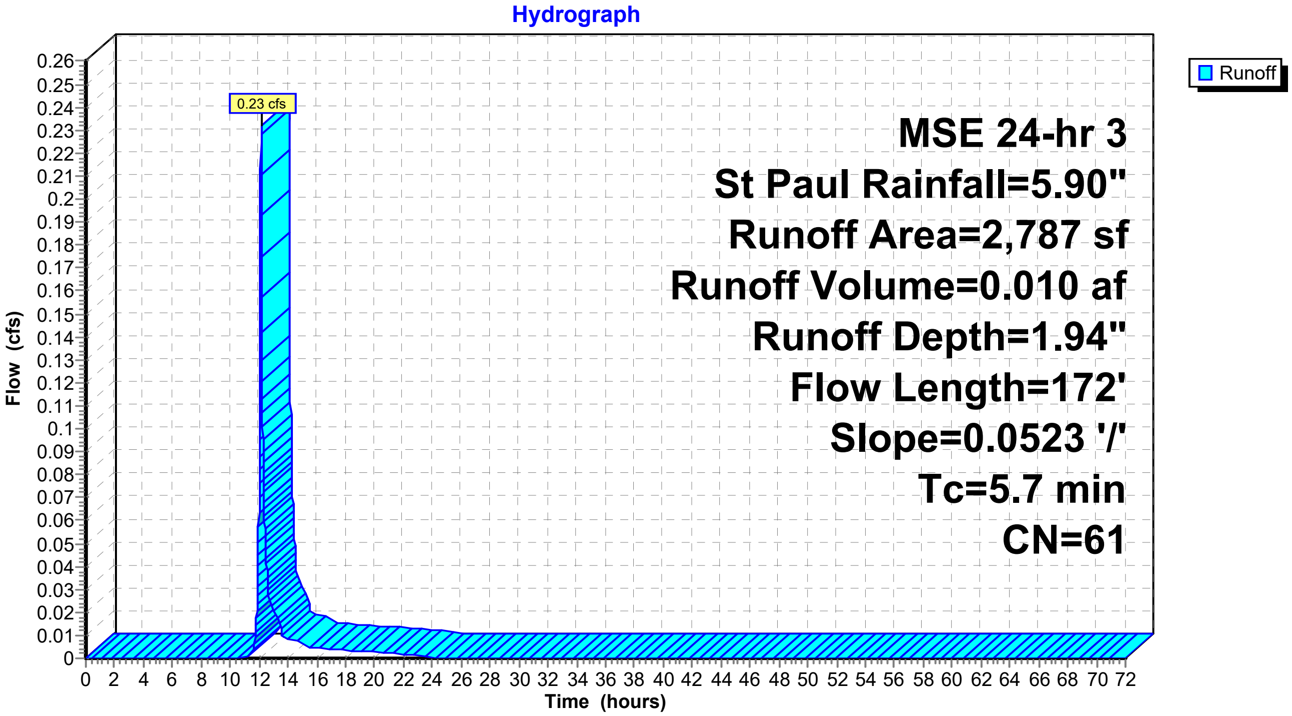
Runoff = 0.23 cfs @ 12.14 hrs, Volume= 0.010 af, Depth= 1.94"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 St Paul Rainfall=5.90"

Area (sf)	CN	Description
2,787	61	>75% Grass cover, Good, HSG B
2,787		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.7	172	0.0523	0.50		**Lag/CN Method,**

Subcatchment 4S: Off-Site Uncontrolled Runoff



Summary for Pond 1P: Existing Pond

```
Inflow Area =       1.664 ac,  14.26% Impervious,  Inflow Depth =  2.40"   for  St Paul event
Inflow      =       5.43 cfs @  12.18 hrs,  Volume=          0.333 af
Outflow     =       4.45 cfs @  12.27 hrs,  Volume=          0.333 af,  Atten= 18%,  Lag= 4.9 min
Primary     =       4.45 cfs @  12.27 hrs,  Volume=          0.333 af

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Peak Elev= 873.98' @ 12.27 hrs   Surf.Area= 2,575 sf   Storage= 462 cf

Plug-Flow detention time= 0.6 min calculated for 0.333 af (100% of inflow)
Center-of-Mass det. time= 0.6 min ( 820.8 - 820.2 )
```

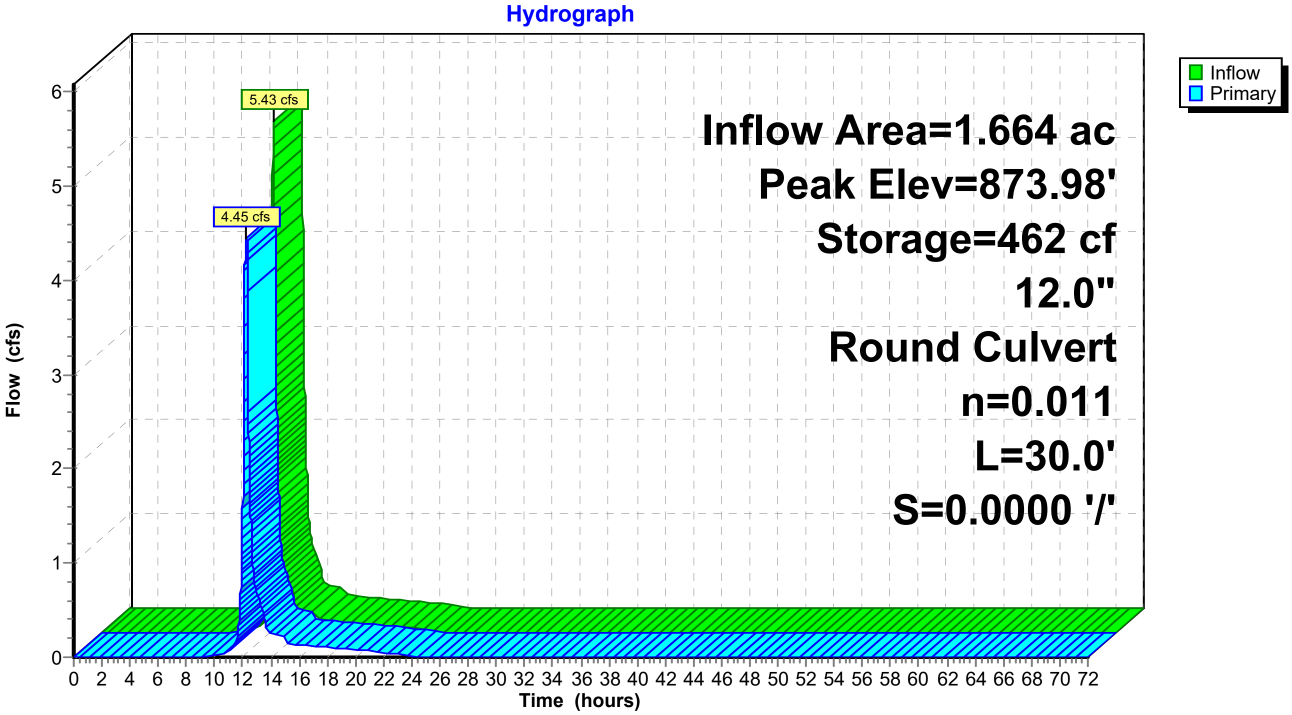
Volume	Invert	Avail.Storage	Storage Description
#1	873.80'	10,998 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
873.80	2,472	0	0
876.00	3,710	6,800	6,800
877.00	4,686	4,198	10,998

Device	Routing	Invert	Outlet Devices
#1	Primary	871.90'	**12.0" Round Culvert** L= 30.0' Ke= 0.500 Inlet / Outlet Invert= 871.90' / 871.90' S= 0.0000 '/' Cc= 0.900 n= 0.011 Concrete pipe, straight & clean, Flow Area= 0.79 sf

Primary OutFlow Max=4.45 cfs @ 12.27 hrs HW=873.98' (Free Discharge)
↑—**1=Culvert** (Barrel Controls 4.45 cfs @ 5.66 fps)

Pond 1P: Existing Pond

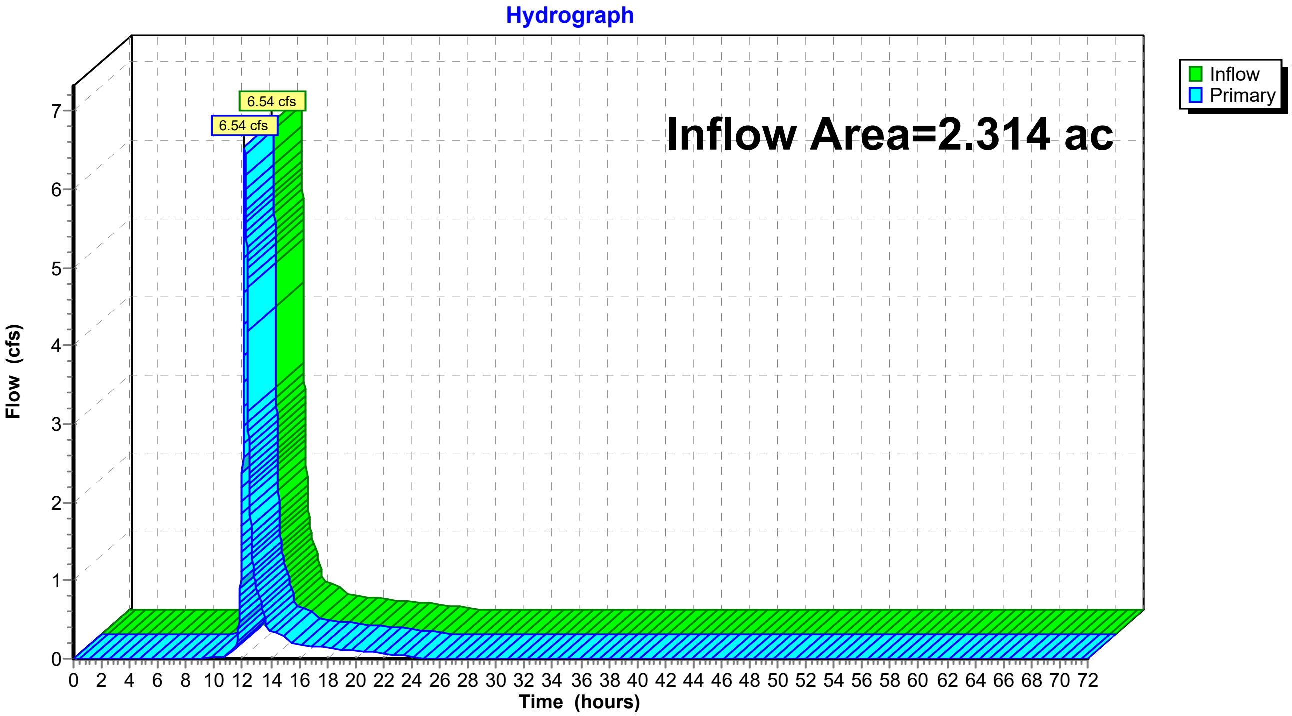


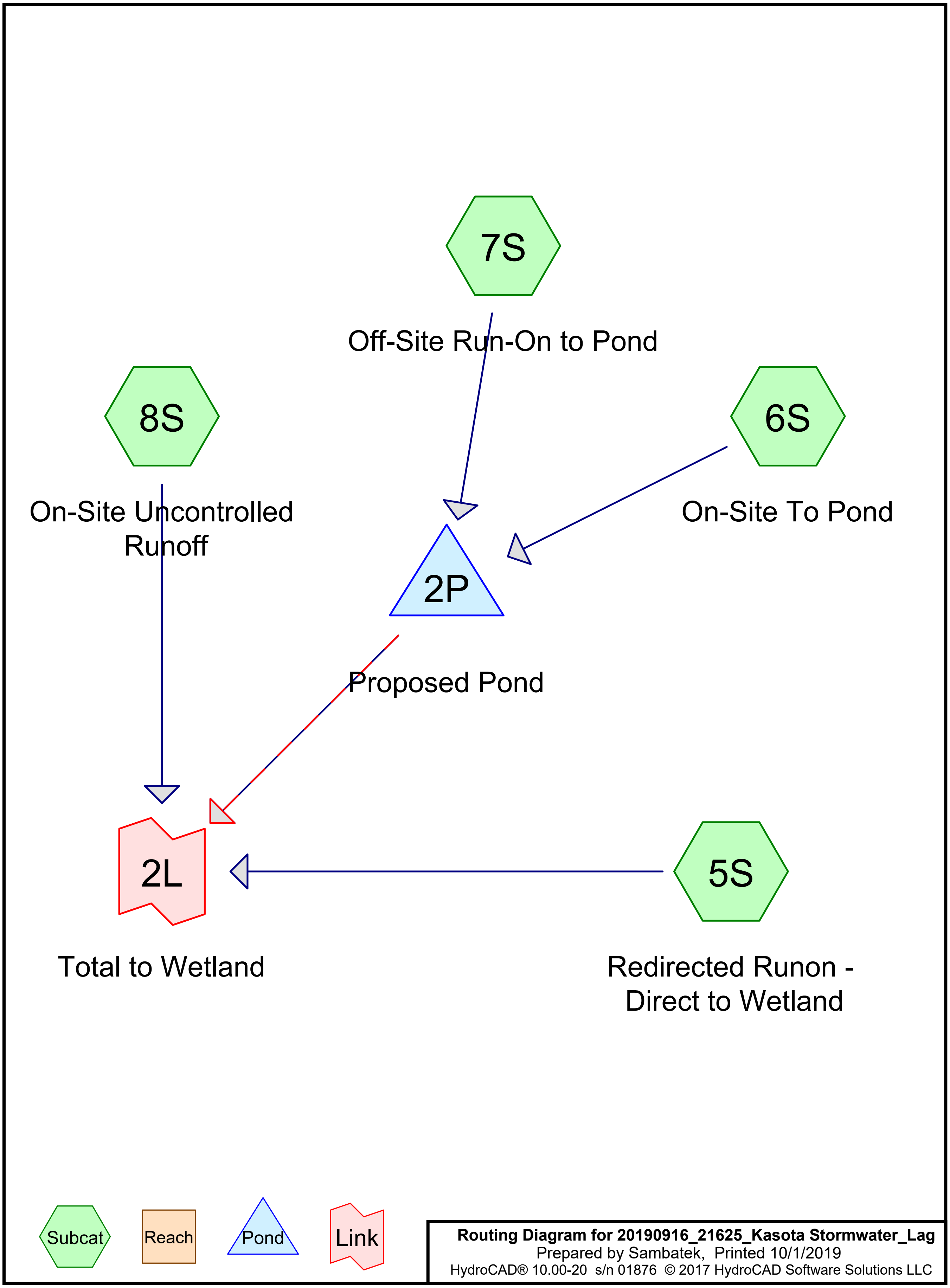
Summary for Link 1L: Total to Wetland

Inflow Area = 2.314 ac, 10.25% Impervious, Inflow Depth = 2.27" for St Paul event
Inflow = 6.54 cfs @ 12.14 hrs, Volume= 0.438 af
Primary = 6.54 cfs @ 12.14 hrs, Volume= 0.438 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs

Link 1L: Total to Wetland





Routing Diagram for 20190916_21625_Kasota Stormwater_Lag
Prepared by Sambatek, Printed 10/1/2019
HydroCAD® 10.00-20 s/n 01876 © 2017 HydroCAD Software Solutions LLC

Area Listing (selected nodes)

Area (acres)	CN	Description (subcatchment-numbers)
1.073	61	>75% Grass cover, Good, HSG B (5S, 6S, 7S, 8S)
1.241	98	Paved parking, HSG B (5S, 6S, 7S)
2.314	**81**	**TOTAL AREA**

Soil Listing (selected nodes)

Area (acres)	Soil Group	Subcatchment Numbers
0.000	HSG A	
2.314	HSG B	5S, 6S, 7S, 8S
0.000	HSG C	
0.000	HSG D	
0.000	Other	
2.314		**TOTAL AREA**

Ground Covers (selected nodes)

HSG-A (acres)	HSG-B (acres)	HSG-C (acres)	HSG-D (acres)	Other (acres)	Total (acres)	Ground Cover	Subcatchment Numbers
0.000	1.073	0.000	0.000	0.000	1.073	>75% Grass cover, Good	5S, 6S, 7S, 8S
0.000	1.241	0.000	0.000	0.000	1.241	Paved parking	5S, 6S, 7S
0.000	**2.314**	**0.000**	**0.000**	**0.000**	**2.314**	**TOTAL AREA**	

Pipe Listing (selected nodes)

Line#	Node Number	In-Invert (feet)	Out-Invert (feet)	Length (feet)	Slope (ft/ft)	n	Diam/Width (inches)	Height (inches)	Inside-Fill (inches)
1	2P	873.00	872.85	20.0	0.0075	0.011	12.0	0.0	0.0

Time span=0.00-72.00 hrs, dt=0.01 hrs, 7201 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment5S: Redirected Runon - Runoff Area=10,863 sf 75.72% Impervious Runoff Depth=4.64"
Flow Length=398' Slope=0.0276 '/' Tc=6.7 min CN=89 Runoff=1.95 cfs 0.096 af

Subcatchment6S: On-Site To Pond Runoff Area=69,428 sf 65.50% Impervious Runoff Depth=4.21"
Flow Length=448' Slope=0.0179 '/' Tc=10.6 min CN=85 Runoff=9.88 cfs 0.559 af

Subcatchment7S: Off-Site Run-On to Pond Runoff Area=9,302 sf 4.05% Impervious Runoff Depth=2.02"
Flow Length=463' Slope=0.0194 '/' Tc=20.3 min CN=62 Runoff=0.46 cfs 0.036 af

Subcatchment8S: On-Site Uncontrolled Runoff Area=11,207 sf 0.00% Impervious Runoff Depth=1.94"
Flow Length=71' Slope=0.1100 '/' Tc=1.9 min CN=61 Runoff=1.11 cfs 0.042 af

Pond 2P: Proposed Pond Peak Elev=882.32' Storage=15,256 cf Inflow=10.18 cfs 0.595 af
Primary=0.75 cfs 0.595 af Secondary=0.00 cfs 0.000 af Outflow=0.75 cfs 0.595 af

Link 2L: Total to Wetland Inflow=3.40 cfs 0.733 af
Primary=3.40 cfs 0.733 af

Total Runoff Area = 2.314 ac Runoff Volume = 0.733 af Average Runoff Depth = 3.80"
46.35% Pervious = 1.073 ac 53.65% Impervious = 1.241 ac

Summary for Subcatchment 5S: Redirected Runon - Direct to Wetland

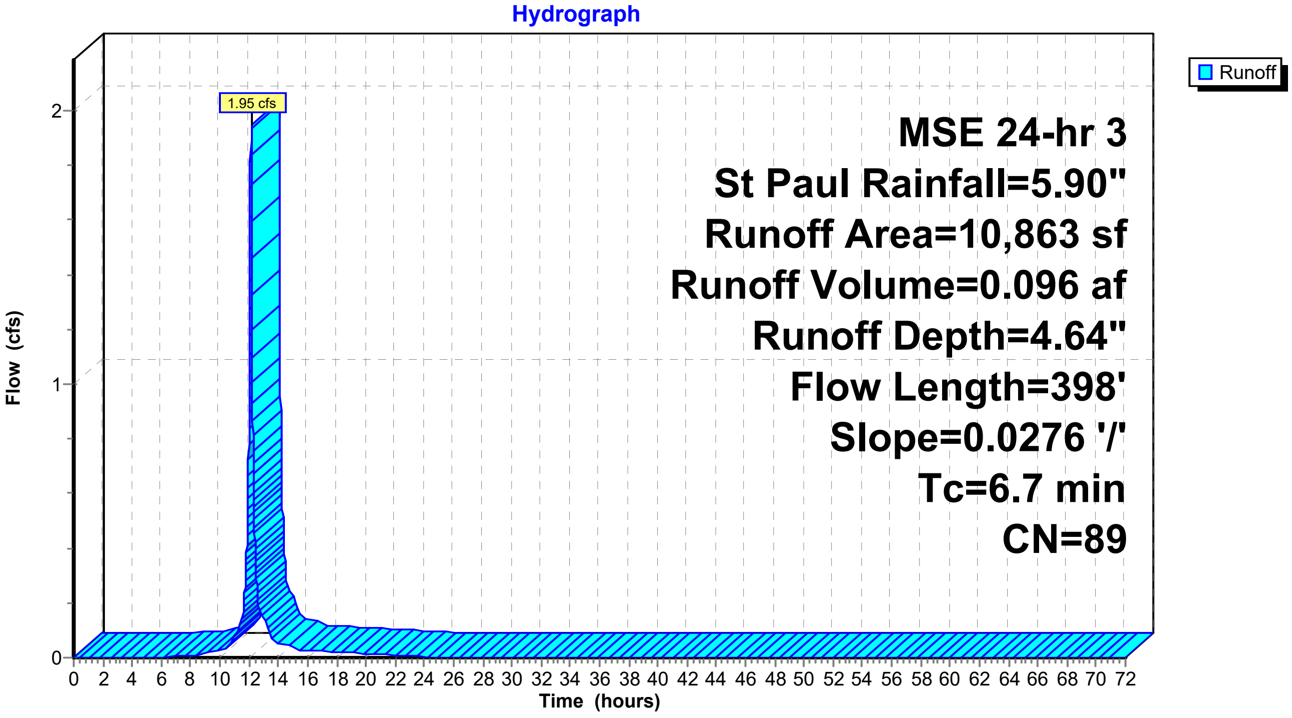
Runoff = 1.95 cfs @ 12.14 hrs, Volume= 0.096 af, Depth= 4.64"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 St Paul Rainfall=5.90"

Area (sf)	CN	Description
8,225	98	Paved parking, HSG B
2,638	61	>75% Grass cover, Good, HSG B
10,863	89	Weighted Average
2,638		24.28% Pervious Area
8,225		75.72% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.7	398	0.0276	0.99		**Lag/CN Method,**

Subcatchment 5S: Redirected Runon - Direct to Wetland



Summary for Subcatchment 6S: On-Site To Pond

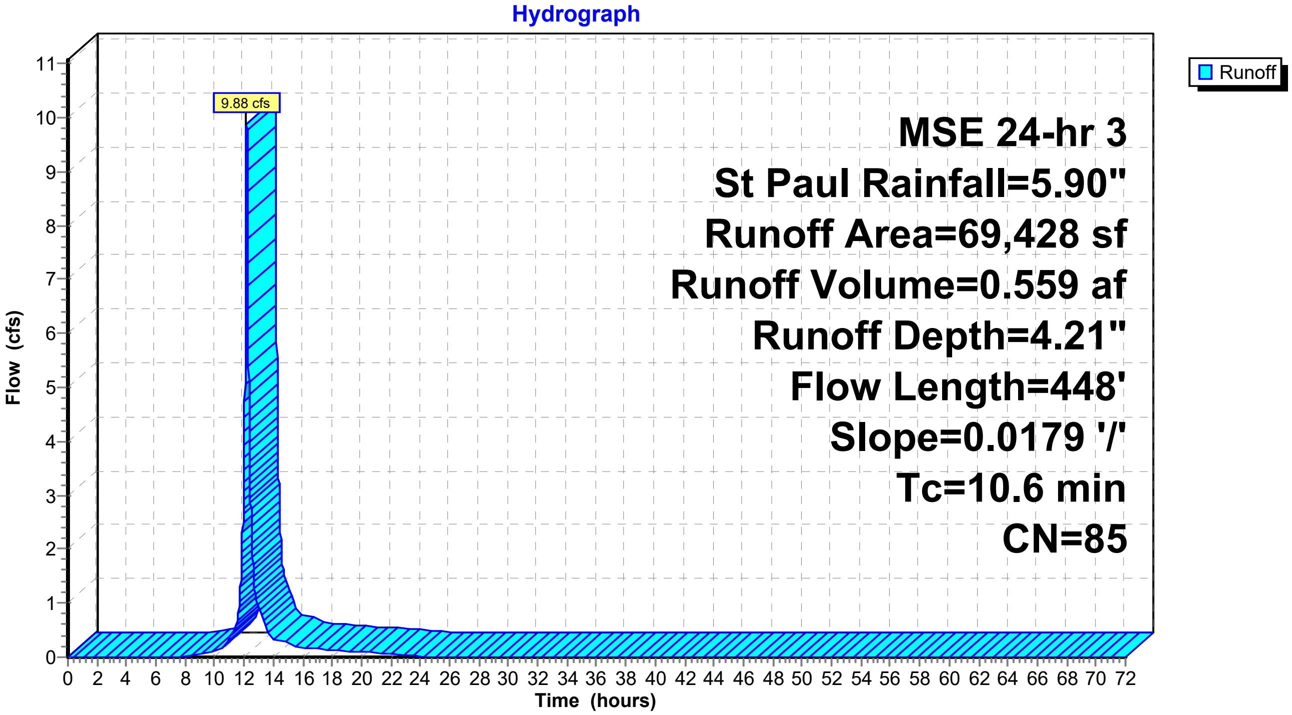
Runoff = 9.88 cfs @ 12.18 hrs, Volume= 0.559 af, Depth= 4.21"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 St Paul Rainfall=5.90"

Area (sf)	CN	Description
45,474	98	Paved parking, HSG B
23,954	61	>75% Grass cover, Good, HSG B
69,428	85	Weighted Average
23,954		34.50% Pervious Area
45,474		65.50% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.6	448	0.0179	0.70		**Lag/CN Method,**

Subcatchment 6S: On-Site To Pond



Summary for Subcatchment 7S: Off-Site Run-On to Pond

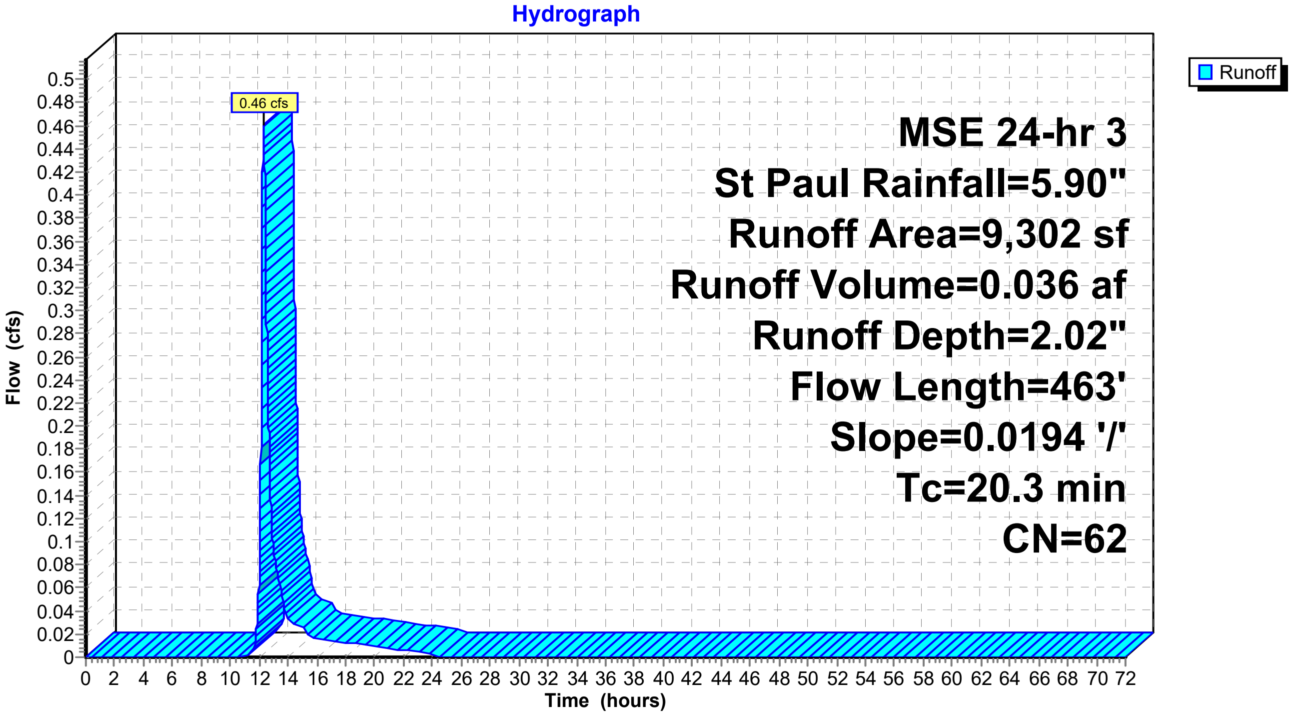
Runoff = 0.46 cfs @ 12.32 hrs, Volume= 0.036 af, Depth= 2.02"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 St Paul Rainfall=5.90"

Area (sf)	CN	Description
8,925	61	>75% Grass cover, Good, HSG B
377	98	Paved parking, HSG B
9,302	62	Weighted Average
8,925		95.95% Pervious Area
377		4.05% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
20.3	463	0.0194	0.38		**Lag/CN Method,**

Subcatchment 7S: Off-Site Run-On to Pond



Summary for Subcatchment 8S: On-Site Uncontrolled Runoff

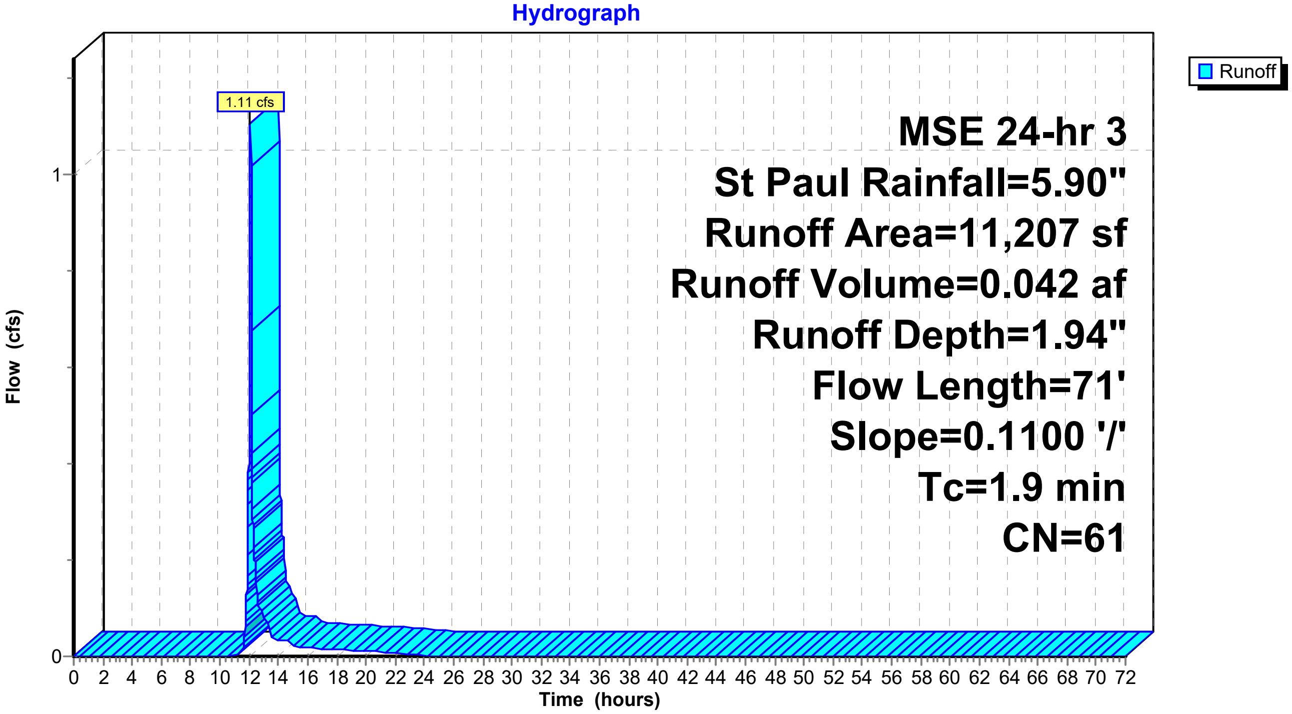
Runoff = 1.11 cfs @ 12.10 hrs, Volume= 0.042 af, Depth= 1.94"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
MSE 24-hr 3 St Paul Rainfall=5.90"

Area (sf)	CN	Description
11,207	61	>75% Grass cover, Good, HSG B
11,207		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.9	71	0.1100	0.61		**Lag/CN Method,**

Subcatchment 8S: On-Site Uncontrolled Runoff



Summary for Pond 2P: Proposed Pond

Inflow Area = 1.807 ac, 58.24% Impervious, Inflow Depth = 3.95" for St Paul event
Inflow = 10.18 cfs @ 12.18 hrs, Volume= 0.595 af
Outflow = 0.75 cfs @ 13.35 hrs, Volume= 0.595 af, Atten= 93%, Lag= 70.0 min
Primary = 0.75 cfs @ 13.35 hrs, Volume= 0.595 af
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Peak Elev= 882.32' @ 13.35 hrs Surf.Area= 5,995 sf Storage= 15,256 cf
Flood Elev= 883.00' Surf.Area= 6,569 sf Storage= 19,532 cf

Plug-Flow detention time= 247.3 min calculated for 0.595 af (100% of inflow)
Center-of-Mass det. time= 247.2 min (1,039.6 - 792.3)

Volume	Invert	Avail.Storage	Storage Description
#1	879.00'	19,532 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

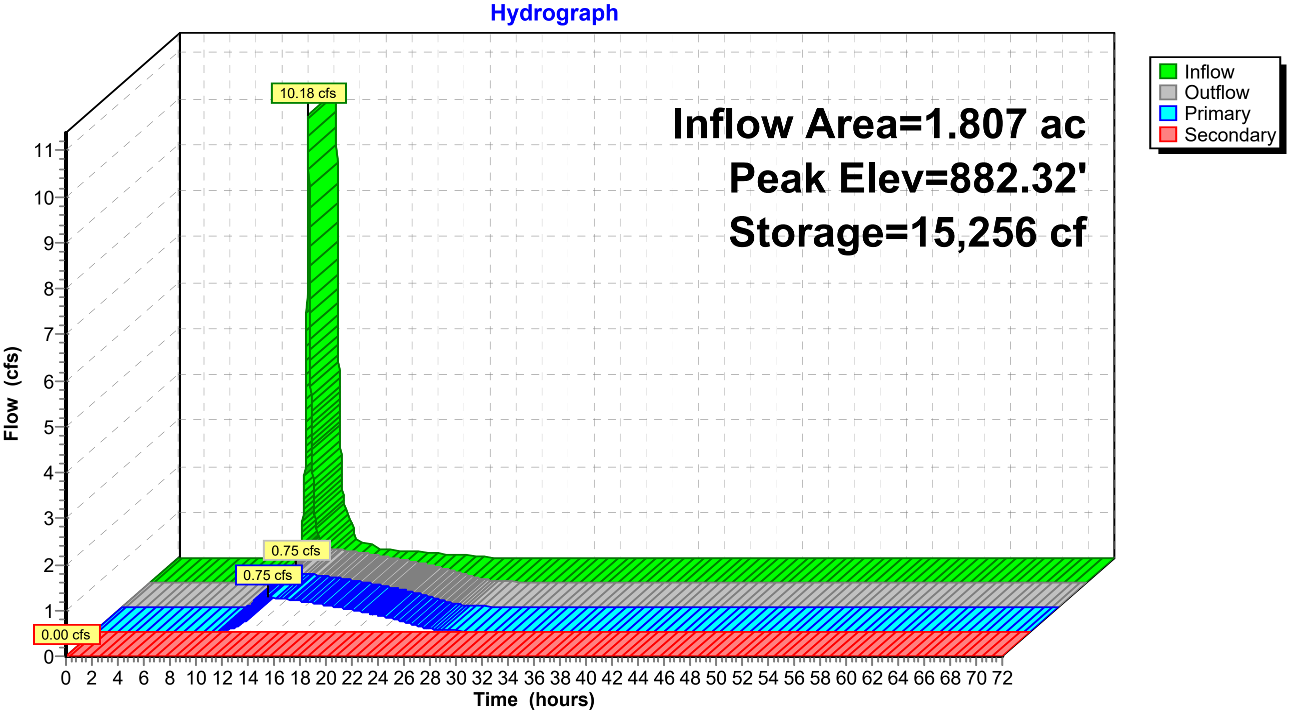
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
879.00	3,197	0	0
883.00	6,569	19,532	19,532

Device	Routing	Invert	Outlet Devices
#1	Primary	873.00'	**12.0" Round Culvert** L= 20.0' Ke= 0.500 Inlet / Outlet Invert= 873.00' / 872.85' S= 0.0075 '/' Cc= 0.900 n= 0.011 Concrete pipe, straight & clean, Flow Area= 0.79 sf
#2	Device 1	879.00'	**4.0" Vert. Orifice/Grate** C= 0.600
#3	Secondary	882.50'	**10.0' long x 10.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.49 2.56 2.70 2.69 2.68 2.69 2.67 2.64

Primary OutFlow Max=0.75 cfs @ 13.35 hrs HW=882.32' (Free Discharge)
↑—**1=Culvert** (Passes 0.75 cfs of 11.23 cfs potential flow)
  ↑—**2=Orifice/Grate** (Orifice Controls 0.75 cfs @ 8.55 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=879.00' (Free Discharge)
↑—**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 2P: Proposed Pond

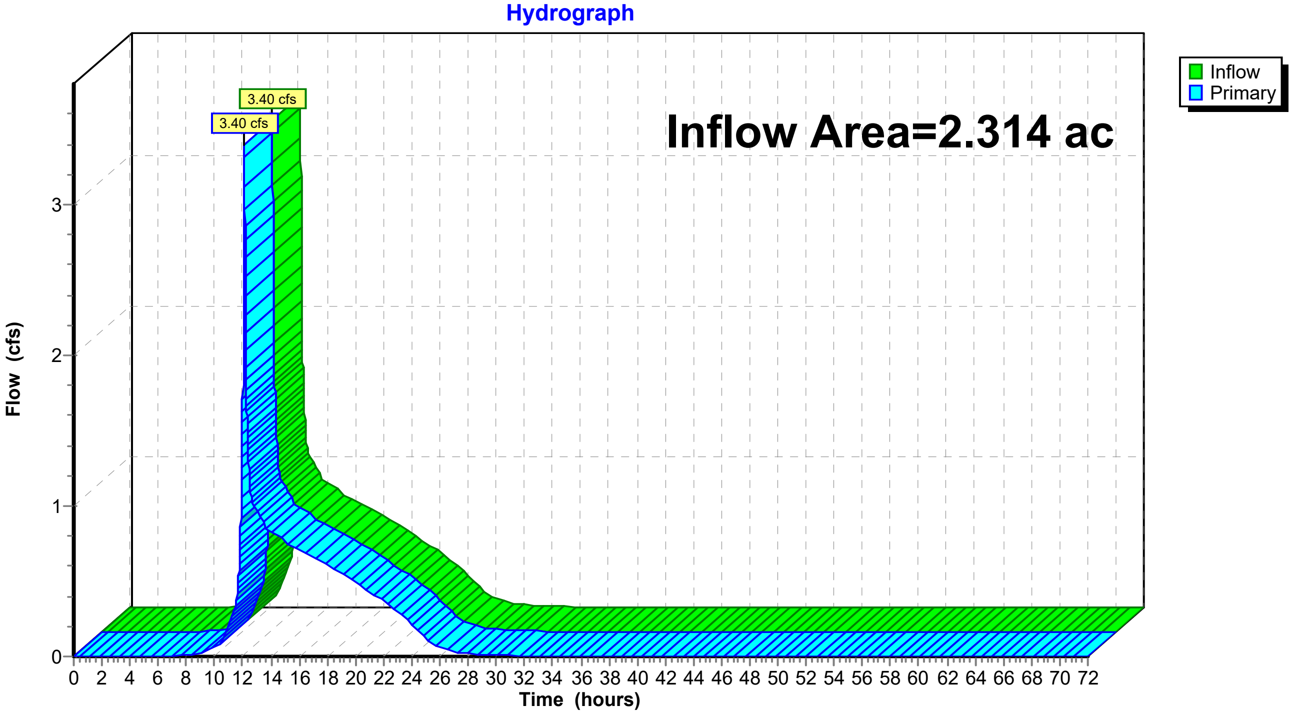


Summary for Link 2L: Total to Wetland

```
Inflow Area =       2.314 ac, 53.65% Impervious, Inflow Depth =  3.80"   for  St Paul event
Inflow      =      3.40 cfs @  12.11 hrs, Volume=          0.733 af
Primary     =      3.40 cfs @  12.11 hrs, Volume=          0.733 af, Atten= 0%, Lag= 0.0 min
```

Primary outflow = Inflow, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs

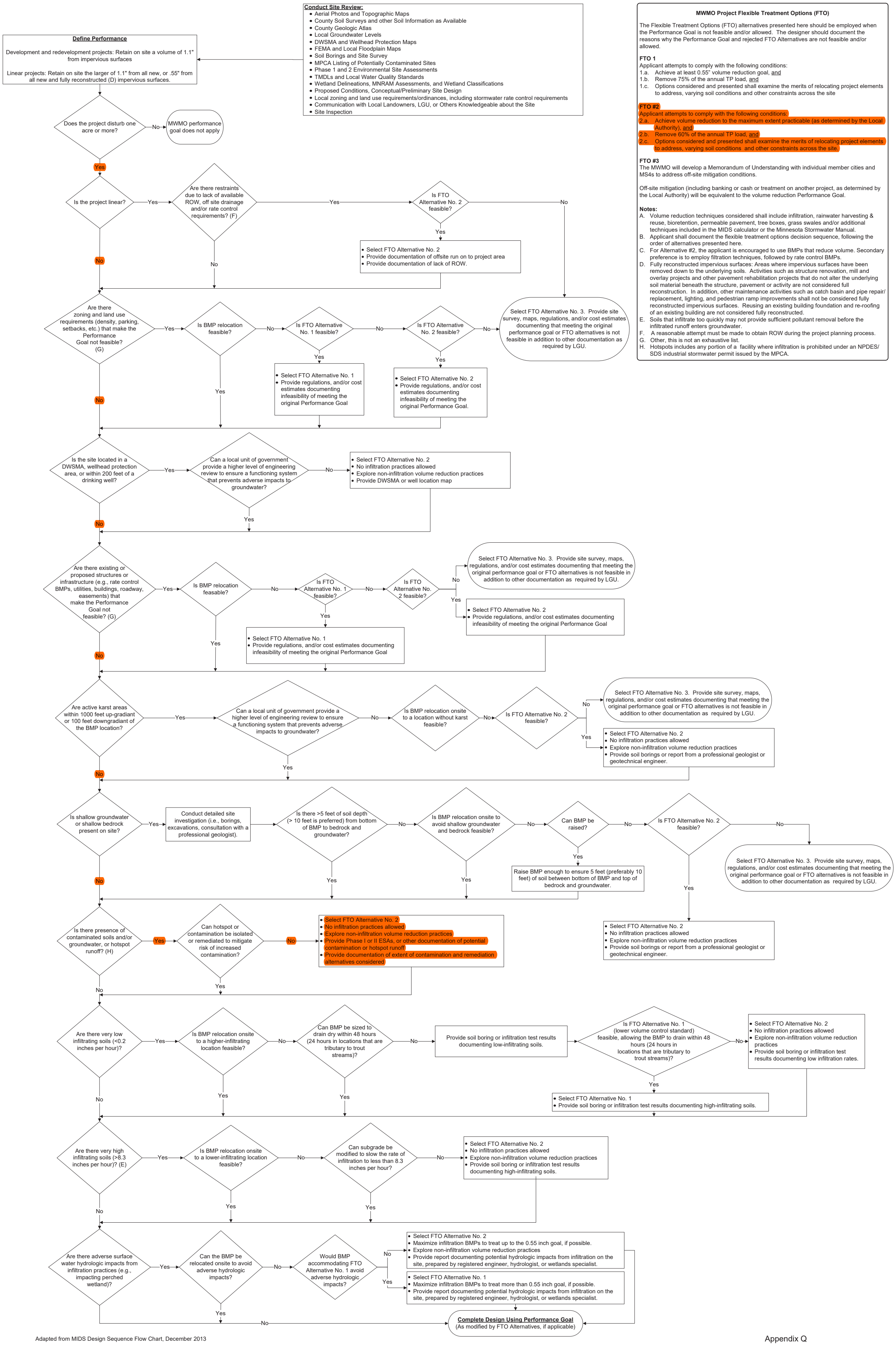
Link 2L: Total to Wetland



APPENDIX D – MWMO FLEXIBLE TREATMENT OPTIONS

version 5.12.2015

MWMO DESIGN SEQUENCE FLOW CHART



MWMO Project Flexible Treatment Options (FTO)

The Flexible Treatment Options (FTO) alternatives presented here should be employed when the Performance Goal is not feasible and/or allowed. The designer should document the reasons why the Performance Goal and rejected FTO Alternatives are not feasible and/or allowed.

FTO 1
Applicant attempts to comply with the following conditions:
1.a. Achieve at least 0.55" volume reduction goal, and
1.b. Remove 75% of the annual TP load, and
1.c. Options considered and presented shall examine the merits of relocating project elements to address, varying soil conditions and other constraints across the site

FTO #2
Applicant attempts to comply with the following conditions:
2.a. Achieve volume reduction to the maximum extent practicable (as determined by the Local Authority), and
2.b. Remove 60% of the annual TP load, and
2.c. Options considered and presented shall examine the merits of relocating project elements to address, varying soil conditions and other constraints across the site.

FTO #3
The MWMO will develop a Memorandum of Understanding with individual member cities and MS4s to address off-site mitigation conditions.

Off-site mitigation (including banking or cash or treatment on another project, as determined by the Local Authority) will be equivalent to the volume reduction Performance Goal.

Notes:
A. Volume reduction techniques considered shall include infiltration, rainwater harvesting & reuse, bioretention, permeable pavement, tree boxes, grass swales and/or additional techniques included in the MIDS calculator or the Minnesota Stormwater Manual.
B. Applicant shall document the flexible treatment options decision sequence, following the order of alternatives presented here.
C. For Alternative #2, the applicant is encouraged to use BMPs that reduce volume. Secondary preference is to employ filtration techniques, followed by rate control BMPs.
D. Fully reconstructed impervious surfaces: Areas where impervious surfaces have been removed down to the underlying soils. Activities such as structure renovation, mill and overlay projects and other pavement rehabilitation projects that do not alter the underlying soil material beneath the structure, pavement or activity are not considered full reconstruction. In addition, other maintenance activities such as catch basin and pipe repair/ replacement, lighting, and pedestrian ramp improvements shall not be considered fully reconstructed impervious surfaces. Reusing an existing building foundation and re-roofing of an existing building are not considered fully reconstructed.
E. Soils that infiltrate too quickly may not provide sufficient pollutant removal before the infiltrated runoff enters groundwater.
F. A reasonable attempt must be made to obtain ROW during the project planning process.
G. Other, this is not an exhaustive list.
H. Hotspots includes any portion of a facility where infiltration is prohibited under an NPDES/ SDS industrial stormwater permit issued by the MPCA.

Adapted from MIDS Design Sequence Flow Chart, December 2013

APPENDIX E – GEOTECHNICAL REPORT

Geotechnical Evaluation Report

Proposed Pavements
280 Trailer Storage
Kasota Avenue and Hwy 280 South Entrance Ramp
St. Paul, Minnesota

Prepared for

Venture Pass Partners, LLC or assigns and Mason Holdings III, LLC or assigns

Professional Certification:
I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly licensed Professional Engineer under the laws of the State of Minnesota.

Robert J. Janssen, PE
President - Principal Engineer
License Number: 19943
June 21, 2019

ROBERT J. JANSSEN
19943

Project B1905336

Braun Intertec Corporation

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Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

June 21, 2019

Project B1905336

Mr. Randy Rauwerdink
Venture Pass Partners, LLC or assigns
and Mason Holdings III, LLC or assigns
19620 Waterford Court
Shorewood, MN 55331

Re: Geotechnical Evaluation
Proposed Pavements
280 Trailer Storage
Kasota Avenue and Hwy 280 South Entrance Ramp
St. Paul, Minnesota

Dear Mr. Rauwerdink:

We are pleased to present this Geotechnical Evaluation Report for the proposed parking lot at in the northwest quadrant of Kasota Avenue and Highway 280 in St. Paul, Minnesota.

Thank you for making Braun Intertec your geotechnical consultant for this project. If you have questions about this report, or if there are other services that we can provide in support of our work to date, please contact Belick Pha at 612.750.2148 (bpha@braunintertec.com) or Bob Janssen at 612.865.8786 (bjanssen@braunintertec.com).

Sincerely,

BRAUN INTERTEC CORPORATION

Rannie Dudero for
Belick Pha, EIT
Staff Engineer

Robert J. Janssen, PE
President - Principal Engineer

c: Mr. Jerry Mullin, Landmark Environmental
Mr. Chad Ayers, Sambatek

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Appendix

A. Introduction

A.1. Project Description

This Geotechnical Evaluation Report addresses the proposed design and construction of a new trailer parking lot located at the junction of MN 280 and Kasota Avenue in Saint Paul, Minnesota. The project will include the construction of a bituminous paved parking lot for semi-truck trailers. Table 1 provides project details.

Table 1. Site Aspects and Grading Description

Aspect	Description
Pavement type(s)	Bituminous or concrete with concrete dolly pads
Assumed pavement loads	Heavy-duty: 150,000 ESALs*
Grade changes	2 (provided)

*Equivalent 43,000-lb multi-axle loads based on 15 semitrailers per day for a 20-year design life.

The figure below shows an illustration of the proposed site layout.

Figure 1. Site Layout

Figure provided by Google Earth© dated June 2019. Approximate property line denoted in solid red lines.

A.2. Site Conditions and History

Currently, the site exists as undeveloped property. The surface is generally populated with vegetation including grass and trees with no structures currently existing on site. Generally, the site is flat, increasing in elevation from the southwest to northeast.

Correspondences with Venture Pass Partners, LLC indicated the site had previously been used as a landfill. No further documents were provided about the site's use history, except for those mentioned in section A.4.

A.3. Purpose

The purpose of our evaluation was to characterize subsurface geologic conditions at selected exploration locations, evaluate their impact and provide recommendations for use in the design and construction of the proposed parking lot.

A.4. Background Information and Reference Documents

We reviewed the following information:

- Topographic map and Concept Plan 4 prepared by Sambatek, Inc.
- Previous geotechnical report prepared by Braun Intertec (Project No. BAAX-95-849) and dated January 15, 1996. As part of that evaluation, 6 soil borings were performed on this site. The approximate locations of those borings are shown on the sketch and those boring logs are included with this report.
- Communications with Venture Pass Partners, LLC regarding test pit locations and scheduling.
- Discussions with you, along with the Civil Engineers with Sambatek and the Environmental consultants with Landmark to discuss design details.

In addition to the provided sources, we have used several publicly available sources of information.

We have described our understanding of the proposed construction and site to the extent others reported it to us. Depending on the extent of available information, we may have made assumptions based on our experience with similar projects. If we have not correctly recorded or interpreted the project details, the project team should notify us. New or changed information could require additional evaluation, analyses and/or recommendations.

A.5. Scope of Services

We performed our scope of services for the project in accordance with our Proposal to Venture Park Pass, LLC, dated May 17, 2019. The following list describes the geotechnical tasks completed in accordance with our authorized scope of services.

- Reviewing the background information and reference documents previously cited.

- Landmark Environmental (Landmark) selected the new test pit locations. We acquired the surface elevations and locations with Landmark GPS technology using the Universal Transverse Mercator (UTM) coordinate system NAD83/UTM 15T. The attached Sketch shows the approximate locations of the test pits, along with the locations of the previously performed soil borings.

- Performing 8 test pits, denoted as TP-1 to TP-8, to nominal depths of 5 feet below grade across the site.

- Preparing this report containing a test pit location sketch, logs of test pits, a summary of the soils encountered, and recommendations for pavement subgrade preparation and the design and pavements.

Our scope of services did not include environmental services or testing. Environmental testing and services were provided by Landmark Environmental (Landmark). When the test pits were excavated, an environmental scientist was present from Landmark.

B. Results

B.1. Geologic Overview

We based the geologic origins used in this report on the soil types and available common knowledge of the geological history of the site.

B.2. Test Pit and Previous Boring Results

We performed 6 soil borings at this site in 1995. Borings ST-1 to ST-6 are in the area of the proposed parking lot footprint. The borings were extended to nominal depths of 25 1/2 to 80 feet. Logs of the previous borings are included in the Appendix.

Table 2 provides a summary of the test pits and previous soil boring results, in the general order we encountered the strata. Please refer to the Log of Test Pits and Boring sheets in the Appendix for additional details. The Descriptive Terminology sheet in the Appendix includes definitions of abbreviations used in Table 2.

Table 2. Subsurface Profile Summary*

Strata	Soil Type - ASTM Classification	Range of Penetration Resistances	Commentary and Details
Topsoil Fill	SM		▪ Predominantly SM. ▪ Generally black. ▪ Topsoil fill not present at all borings and was measured to be less than 1 foot when observed. ▪ Moisture condition generally moist.
Fill	SM, CL, OL, PT	Weight of hammer to 39 blows per foot (BPF)	▪ General penetration resistance of 4 to 15 BPF. ▪ Intermixed layers of dark brown, dark gray, and black. ▪ Moisture condition generally moist to wet. ▪ Thicknesses at soil boring locations varied from 16 to 22 feet. ▪ Highly variable, soils intermixed; layers of organic clay and peat observed in Boring ST-1. ▪ Existing fill contained variable amounts of gravel and debris, including glass, bricks, metal, concrete and bituminous. ▪ Possible cobbles and boulders.
Swamp deposits	OL	1 to 4 BPF	▪ A 3-foot layer was observed in Boring ST-5. ▪ Generally black. ▪ Moisture condition generally wet. ▪ Swamp deposits not observed in test pits.
Alluvial	CL	4 BPF	▪ Moisture condition generally wet. ▪ Only observed beneath the fill in Borings ST-3/ST-3A and ST-6. ▪ Alluvial soils not observed in test pits.
Glacial deposits	SP, SP-SM, SM	2 to 58 BPF	▪ Intermixed layers of glacial outwash and till. ▪ Variable amounts of gravel; may contain cobbles. ▪ Moisture condition generally wet. ▪ Glacial deposits not observed in test pits.
	SC, CL, ML	4 to 20 BPF	
Bedrock	Shale	17 to 44 BPF	▪ Top of bedrock observed at depth of 80 feet. ▪ Generally bluish gray. ▪ Bedrock not observed in test pits.

*Abbreviations defined in the attached Descriptive Terminology sheet.

B.3. Groundwater

While excavating the test pits, water was observed seeping into 3 of the test pits. Table 3 summarizes the depths where we observed groundwater while excavating test pits. Table 3 also summarizes groundwater observed while advancing previous soil borings. The attached Log of Test Pits and Log of Borings in the Appendix also include this information and additional details.

Table 3. Groundwater Summary

Location	Measured or Estimated Depth to Groundwater (ft)
TP-1	Not observed in test pit to 5 feet
TP-2	Not observed in test pit to 5 1/2 feet
TP-3	Not observed in test pit to 5 feet
TP-4	2
TP-5	Not observed in test pit to 5 feet
TP-6	Not observed in test pit to 5 feet
TP-7	1.1/2
TP-8	1 1/2
ST-1	Not observed in boring to 25.5 feet
ST-2/ST-2A	19 1/2
ST-3/ST-3A	Not observed in boring to 80 feet
ST-4	16
ST-5	18
ST-6	21.2

Groundwater observed in test pits were relatively shallow and likely due to perched water conditions. Precipitation or seasonal changes, such as thawing, will increase perched water conditions in sand seams in the fill.

Based on the available data, it appears that at the time those borings were performed, the hydrostatic water level will be below excavations for the proposed parking lot.

C. Recommendations

C.1. Site Grading and Subgrade Preparation

C.1.a. Existing Fill

As indicated by the soil borings and test pit data, the on-site soils consist of significant amounts of fill materials consisting of variable soils types which are intermixed with miscellaneous debris and organic soils, and the penetration resistances recorded in the soil borings indicate that some of the fill is very soft or loose. Ideally, and to reduce risks of long-term differential settlement, all or a significant portion of the existing fill would have to be removed from beneath the proposed pavements. However, because of the environmental concerns associated with the removal of the existing fill and considering that some risk of long-term settlements associated with pavements can typically be tolerated, the significant costs associated with the removal of significant amounts of the existing fill can likely not be tolerated. As such, the recommendations we are providing in this report assumes that the risk of long-term differential settlement to the pavements can be tolerated. Within this report, we will provide design and earthwork recommendations to reduce risks associated with adverse amounts of long-term settlement.

As discussed in more detail in the following sections, our recommendations include the removal of the surficial topsoil, scarifying and compacting the in place soils prior to placement of fill or pavement areas, removing any exposed large-sized or compressible debris, and placement of geogrid beneath the recommended pavement designs.

C.1.b. Reuse of On-Site Soils

With the exception of the topsoil and unsuitable debris, assuming that the soils are acceptable per the Response Action Plan (RAP) that is being prepared by Landmark, it is our opinion that much of the excavated soils on site will be suitable to be reused for subgrade fill material. Any on-site soils with an organic content greater that 3 percent, or debris or boulders larger than 4 inches in diameter should be considered unsuitable for use as pavement fill material. Those materials should be placed in a green area or hauled off site. Furthermore, much of the soils on this site are moisture sensitive, and it is likely that some moisture conditioning (wetting or drying) will be necessary to reuse the on-site soils as compacted backfill.

C.1.c. Excavated Slopes

Based on the borings, we anticipate on-site soils in excavations will consist of silty sands intermixed with clay. These soils are typically considered Type B Soil under OSHA (Occupational Safety and Health

Administration) guidelines. OSHA guidelines indicate unsupported excavations in Type B soils should have a gradient no steeper than 1H:1V. Slopes constructed in this manner may still exhibit surface sloughing. OSHA requires an engineer to evaluate slopes or excavations over 20 feet in depth.

An OSHA-approved qualified person should review the soil classification in the field. Excavations must comply with the requirements of OSHA 29 CFR, Part 1926, Subpart P, “Excavations and Trenches.” This document states excavation safety is the responsibility of the contractor. The project specifications should reference these OSHA requirements.

C.1.d. Excavation Dewatering

We recommend removing groundwater from the excavations. Project planning should include temporary sumps and pumps for excavations in low-permeability soils, such as clays. If it is necessary to pump water from excavations, that work should be done in accordance with the RAP.

C.1.e. Pavement and Exterior Slab Subgrade Preparation

We recommend the following steps for pavement and exterior slab subgrade preparation, understanding the site will have a grade change of 2 feet or less. Note that project planning may need to require additional subcuts to limit frost heave.

1. Strip unsuitable soils consisting of surficial vegetation and soils with an organic content greater than 3 percent any existing structures and pavements that exists within2 feet of the surface of the proposed pavement subgrade. At depths greater than 2 feet, assuming the surficial organic materials are removed and the underlying soils can be stabilized as addressed below, the existing soils can remain in place.

2. Have a geotechnical representative observe the excavated subgrade to evaluate if additional subgrade improvements are necessary.

3. Prior to placement of fill or the pavement materials, Scarify the exposed soils to a depth of 10 inches, moisture condition the soils to near optimum moisture content and then compact the soils to the relative densities indicated in Table 5.

4. Place pavement engineered fill to grade and compact in accordance with Section C.1.g. to bottom of pavement.

5. Proofroll the pavement or exterior slab subgrade as described in Section C.1.f.

Along with the earthwork correction recommendations previously provided and because much of the existing fill that will be left in place beneath the pavement areas are very soft/loose and contain organic soils and debris, to improve long-term pavement performance of the pavement, we recommend incorporating biaxial geogrid at the interface of the prepared subgrade and aggregate base layer.

C.1.f. Pavement Subgrade Proofroll

After preparing the subgrade as described above and prior to the placement of the geogrid and aggregate base, we recommend proofrolling the subgrade soils with a fully loaded tandem-axle truck. We also recommend having a geotechnical representative observe the proofroll. Areas that fail the proofroll likely indicate soft or weak areas that will require additional soil correction work to support pavements.

The contractor should correct areas that display excessive yielding or rutting during the proofroll, as determined by the geotechnical representative. Possible options for subgrade correction include moisture conditioning and recompaction, subcutting and replacement with soil or crushed aggregate, chemical stabilization and/or geotextiles. We recommend performing a second proofroll after the aggregate base material is in place, and prior to placing bituminous or concrete pavement.

C.1.g. Engineered Fill Materials and Compaction

The engineered fill materials placed in proposed pavement areas should consist of on-site soils as addressed previously in Section C.1.b or imported soils consisting of soils classified as sands or clays with an organic content less than 3 percent containing a plastic index less than 25 percent. We recommend placing an aggregate base below the pavement to provide a suitable subgrade for pavement, reduce faulting and help dissipate loads.

Table 4 provides recommended subgrade relative compaction of fill based on depth and location.

Table 4. Compaction Recommendations Summary

Reference	Relative Compaction, percent (ASTM D698 – Standard Proctor)	Moisture Content Variance from Optimum, percentage points	
		< 12% Passing #200 Sieve (typically SP, SP-SM)	> 12% Passing #200 Sieve (typically CL, SC, ML, SM)
Within 3 feet of pavement subgrade	100	±2	-1 to +2
More than 3 feet below pavement subgrade	95	±3	±3
Below landscaped surfaces	90	±5	±4

*Increase compaction requirement to meet compaction required for structure supported by this engineered fill.

The project documents should not allow the contractor to use frozen material as engineered fill or to place engineered fill on frozen material. Frost should not penetrate under foundations during construction.

We recommend performing density tests in engineered fill to evaluate if the contractors are effectively compacting the soil and meeting project requirements.

C.2. Pavements and Exterior Slabs

C.2.a. Design Sections

Based on the previous year's average load and estimated average daily traffic, provided by Venture Pass Partners, LLC., and test pit observations, we recommend pavement design assume an R-value of 12. We based the concrete pavement designs on a modulus of subgrade reaction (k) of 75 pci.

Note the contractor may need to perform limited removal of unsuitable or less suitable soils to achieve this value.

Table 5 provides recommended pavement sections, based on the soils support and traffic loads.

Table 5. Recommended Bituminous and Concrete Pavement Sections

	Component Thicknesses (inches)	
	Heavy-duty	
Material Component	Bituminous[a]	Concrete
Bituminous Wear	2	—
Bituminous Non-wear	2	—
Bituminous Non-wear	2	—
Concrete	—	6
Aggregate Base	8	6
Geotextile Grid	Yes (see Section C.2.e)	No

C.2.b. Aggregate Base Materials

We recommend specifying crushed aggregate base meeting the requirements of Minnesota Department of Transportation (MnDOT) Specification 3138 for Class 5.

Table 6 shows recommended Minnesota Department of Transportation (MnDOT) Class 5 and Class 6 base aggregate gradations. Gradation recommendations assume base aggregate will contain less than 25 percent, by weight, recycled aggregate.

Table 6. MnDOT Class 5 and 6 Aggregate*

Base Aggregate**	% passing 1 1/2" Sieve	% passing 3/4" Sieve	% passing 3/8" Sieve	% passing #4 Sieve	% passing #10 Sieve	% passing #40 Sieve	% passing #200 Sieve
Class 5	100	70 - 100	45 - 90	35 - 80	20 - 65	10 - 35	3.0 - 10.0
Class 6	100	70 - 100	45 - 85	35 - 70	20 - 55	10 - 30	3.0 - 7.0

*Gradations based on Minnesota Department of Transportation (MnDOT) 2018 Standard Specification for Construction section 3138.
**Percent passing value should be total percent passing by weight.

We recommend that the aggregate base be compacted to a minimum of 100 percent of its maximum standard Proctor dry density at a moisture content within 1 percentage point of its optimum moisture content.

C.2.c. Bituminous Pavement Materials

We recommend that the bituminous wear and base courses meet the requirements of Minnesota Department of Transportation Specification 2360, Type SP. We recommend the aggregate gradations for the asphalt mixes meet Gradation B for the non-wear and wear courses. We recommend that the light- and heavy-duty bituminous mixes incorporate Traffic Level 3. With that, we recommend using the following mix designations for heavy- duty pavements:

- Heavy-duty Non-Wear: SPNWB330E; Asphalt Binder Grade PG 58H-28 (PG 64-28)
- Heavy-duty Wear: SPWEB340E; Asphalt Binder Grade PG 58H-28 (PG 64-28)

We recommend that the bituminous pavement be compacted to an average density of at least 92 percent (per the core method) of the maximum theoretical Rice density, with no core test result being less than 90 percent and no core test result being greater than 97 percent.

C.2.d. Concrete Pavement Materials

We assumed the concrete pavement sections in Table 5 will have edge support. We recommend placing an aggregate base below the pavement to provide a suitable subgrade for concrete placement, reduce faulting and help dissipate loads. Appropriate mix designs, panel sizing, jointing, doweling, and edge reinforcement are critical to performance of rigid pavements.

We recommend specifying concrete for pavements that has a minimum 28-day compressive strength of 4,000 psi, and a modulus of rupture (M_r) of at least 600 psi. We also recommend Type I cement meeting the requirements of ASTM C 150. We recommend specifying 5 to 7 percent entrained air for exposed concrete to provide resistance to freeze-thaw deterioration. We also recommend using a water/cement ratio of 0.45 or less for concrete exposed to deicers.

C.2.e. Geotextile Grid

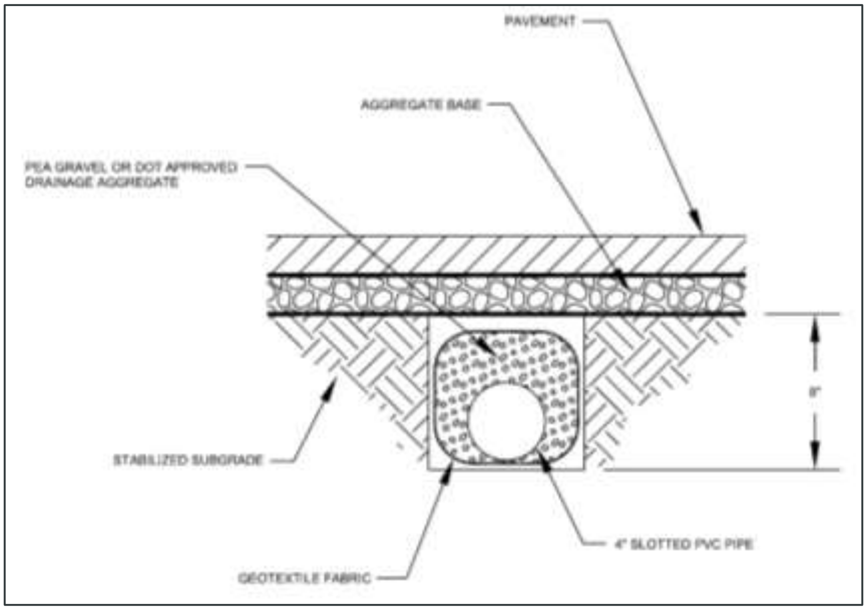
We recommend placing Tensar® Biaxial Geogrid BX1200 or equivalent directly below the aggregate base layer.

C.2.f. Subgrade Drainage

We recommend installing plastic perforated drainpipes throughout pavement areas at low points and about catch basins. The drainpipes should be placed in small trenches extended at least 8 inches below the aggregate base material. A cross-section illustration of a drainage trench is shown below in Figure 2. We recommend installing the draintile at a pitch of no less than 1/4 percent. We recommend routing the draintile to nearby storm sewer or other suitable outlet.

We suggest that we work with the civil engineer to determine the spacing of drainpipes.

Figure 2. Draintile Illustration



C.2.g. Performance and Maintenance

We based the above pavement designs on a 20-year performance life for bituminous and a 20-year life for concrete. This is the amount of time before we anticipate the pavement will require reconstruction. This performance life assumes routine maintenance, such as seal coating and crack sealing. The actual pavement life will vary depending on variations in weather, traffic conditions and maintenance.

It is common to place the non-wear course of bituminous and then delay placement of wear course. For this situation, we recommend evaluating if the reduced pavement section will have sufficient structure to support construction traffic.

Many conditions affect the overall performance of the exterior slabs and pavements. Some of these conditions include the environment, loading conditions and the level of ongoing maintenance. With regard to bituminous pavements in particular, it is common to have thermal cracking develop within the first one to two years of placement, and continue throughout the life of the pavement. We recommend developing a regular maintenance plan for filling cracks in exterior slabs and pavements to lessen the potential impacts for cold weather distress due to frost heave or warm weather distress due to wetting and softening of the subgrade.

C.3. Utilities

C.3.a. Subgrade Stabilization

For exterior utilities, we anticipate the soils at typical invert elevations will generally be suitable for utility support. However, if construction encounters unfavorable conditions such as soft clay, organic soils, perched water or large debris within 2 feet of invert grades, the unsuitable soils should be removed and replaced with sand or crushed rock to prepare a proper subgrade for pipe support. Project design and construction should not place utilities within the 1H:1V oversizing of foundations.

C.3.b. Corrosion Potential

Based on our experience, the soils encountered by the borings are moderately corrosive to metallic conduits, but only marginally corrosive to concrete. We recommend specifying non-corrosive materials or providing corrosion protection, unless project planning chooses to perform additional tests to demonstrate the soils are not corrosive.

D. Procedures

D.1. Exploratory Test Pits

Frattalone excavated the test pits with a Bobcat E85 backhoe, under the direction and observation of our staff, Landmark, and Venture Pass Partners, Inc. We prepared Test Pit Logs by visually examining the sidewalls of the test pits and classifying the materials brought to the surface by the backhoe bucket. We measured strata boundary depths with a steel tape and generally rounded to the nearest 1/2-foot.

D.2. Exploration Logs

D.2.a. Log of Test Pit and Previous Boring Sheets

The Appendix includes Log of Test Pit sheets as well as Logs of Borings from previous projects. The logs classify and describe the geologic materials exposed in the sidewalls and bottoms of the pits, present the results of laboratory tests performed on bulk samples obtained from them, and depict groundwater measurements.

D.2.b. Geologic Origins

We assigned geologic origins to the materials shown on the logs and referenced within this report, based on: (1) a review of the background information and reference documents cited above, (2) visual classification of the various geologic material samples retrieved during the course of our subsurface exploration, (3) penetration resistance and other in-situ testing performed for the project, and (4) available common knowledge of the geologic processes and environments that have impacted the site and surrounding area in the past.

D.3. Material Classification and Testing

D.3.a. Visual and Manual Classification

We visually and manually classified the geologic materials encountered based on ASTM D2488. When we performed laboratory classification tests, we used the results to classify the geologic materials in accordance with ASTM D2487. The Appendix includes a chart explaining the classification system we used.

D.3.b. Laboratory Testing

The exploration logs in the Appendix note the results of the laboratory tests performed on geologic material samples. We performed the tests in general accordance with ASTM or AASHTO procedures.

D.4. Groundwater Measurements

While excavating the test pits and at the termination depths, our field personnel observed the sides and bottoms of the excavation for evidence of groundwater seepage and/or accumulation.

E. Qualifications

E.1. Variations in Subsurface Conditions

E.1.a. Material Strata

We developed our evaluation, analyses and recommendations from a limited amount of site and subsurface information. It is not standard engineering practice to retrieve material samples from exploration locations continuously with depth. Therefore, we must infer strata boundaries and thicknesses to some extent. Strata boundaries may also be gradual transitions, and project planning should expect the strata to vary in depth, elevation and thickness, away from the exploration locations.

Variations in subsurface conditions present between exploration locations may not be revealed until performing additional exploration work, or starting construction. If future activity for this project reveals any such variations, you should notify us so that we may reevaluate our recommendations. Such variations could increase construction costs, and we recommend including a contingency to accommodate them.

E.1.b. Groundwater Levels

We made groundwater measurements under the conditions reported herein and shown on the exploration logs, and interpreted in the text of this report. Note that the observation periods were relatively short, and project planning can expect groundwater levels to fluctuate in response to rainfall, flooding, irrigation, seasonal freezing and thawing, surface drainage modifications and other seasonal and annual factors.

E.2. Continuity of Professional Responsibility

E.2.a. Plan Review

We based this report on a limited amount of information, and we made a number of assumptions to help us develop our recommendations. We should be retained to review the geotechnical aspects of the designs and specifications. This review will allow us to evaluate whether we anticipated the design correctly, if any design changes affect the validity of our recommendations, and if the design and specifications correctly interpret and implement our recommendations.

E.2.b. Construction Observations and Testing

We recommend retaining us to perform the required observations and testing during construction as part of the ongoing geotechnical evaluation. This will allow us to correlate the subsurface conditions exposed during construction with those encountered by the borings and provide professional continuity from the design phase to the construction phase. If we do not perform observations and testing during construction, it becomes the responsibility of others to validate the assumption made during the preparation of this report and to accept the construction-related geotechnical engineer-of-record responsibilities.

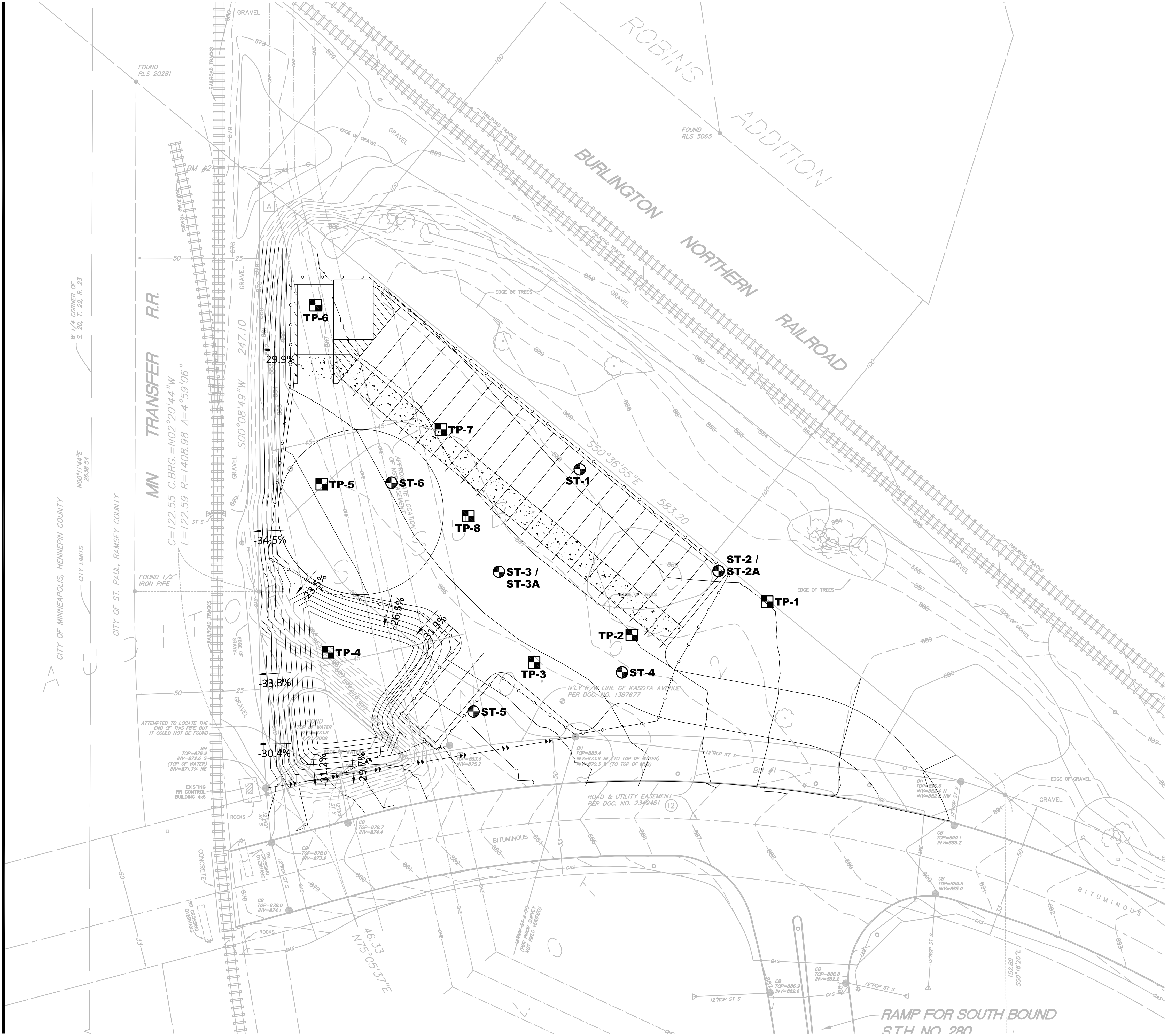
E.3. Use of Report

This report is for the exclusive use of the addressed parties. Without written approval, we assume no responsibility to other parties regarding this report. Our evaluation, analyses and recommendations may not be appropriate for other parties or projects.

E.4. Standard of Care

In performing its services, Braun Intertec used that degree of care and skill ordinarily exercised under similar circumstances by reputable members of its profession currently practicing in the same locality. No warranty, express or implied, is made.

Appendix



▨ **DENOTES APPROXIMATE LOCATION OF TEST PIT**

◐ **DENOTES APPROXIMATE LOCATION OF PREVIOUSLY COMPLETED SOIL BORING**

N

30' 0 60'

SCALE: 1" = 60'

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Minneapolis, MN 55438
952.995.2000
braunintertec.com

Base Drawing Provided By

Sambatek

Drawing Information

Project No:
B1905336

Drawing No:
B1905336

Drawn By:	BJB
Date Drawn:	6/14/19
Checked By:	BP
Last Modified:	6/14/19

Project Information

280 Trailer Storage

Kasota Avenue, west of Highway 280

Saint Paul, Minnesota

Test Pit and Soil Boring Location Sketch

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LOG OF TEST PIT

See Descriptive Terminology sheet for explanation of abbreviations

Project Number B1905336 **Geotechnical Evaluation** **280 Trailer Storage** **Kasota Avenue and Hwy 280 South Entrance Ramp** **Saint Paul, Minnesota**		TEST PIT:	**TP-1**
		LOCATION: Coordinate datum uses NAD83/UTM Zone 15N. Elevations estimated from Concept 4 plans, CP-4, prepared by Sambatek. See attached sketch.	
		NORTHING: 4980523	EASTING: 483893.0
EXCAVATOR: Frattalone	LOGGED BY: B. Pha	START DATE: 05/30/19	END DATE: 05/30/19
SURFACE ELEVATION: 889.0 ft	RIG: Excavator	SURFACING: Grass	WEATHER: Cloudy
METHOD:			

Elev./ Depth ft	Water Level	Description of Materials (Soil-ASTM D2488 or 2487; Rock-USACE EM 1110-1-2908)	Sample	Sample Blows Recovery	q_p tsf	MC %	Tests or Remarks
888.2 0.8		SILTY SAND (SM), fine to medium sand, trace Gravel, black, moist (TOPSOIL)					Soil consisted of approximately 5 to 10 percent debris
884.0 5.0		FILL: SILTY SAND (SM), fine to medium sand, with Gravel, and debris, dark brown to dark gray, moist, debris includes glass, brick, plastic, wooden beams, and wood chips *Soil dark gray and contained odor below 2 1/2 feet* 5					
		END OF TEST PIT Test pit then backfilled with spoils					Water not observed with 5.0 feet of tooling in the ground while drilling.
		10					

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LOG OF TEST PIT

See Descriptive Terminology sheet for explanation of abbreviations

Project Number B1905336
Geotechnical Evaluation
280 Trailer Storage
Kasota Avenue and Hwy 280 South Entrance Ramp
Saint Paul, Minnesota

TEST PIT: **TP-2**

LOCATION: Coordinate datum uses NAD83/UTM Zone 15N. Elevations estimated from Concept 4 plans, CP-4, prepared by Sambatek. See attached sketch.

NORTHING:	4980517	EASTING:	483868.0
EXCAVATOR:	Frattalone	LOGGED BY:	B. Pha
START DATE:	05/30/19	END DATE:	05/30/19
SURFACE ELEVATION:	887.0 ft	RIG:	Excavator
METHOD:		SURFACING:	Grass
WEATHER:	Cloudy		

Elev./ Depth ft	Water Level	Description of Materials (Soil-ASTM D2488 or 2487; Rock-USACE EM 1110-1-2908)	Sample	Sample Blows Recovery	qₚ tsf	MC %	Tests or Remarks
886.6 0.4		SILTY SAND (SM), fine to medium sand, with Gravel, and roots, black, moist (TOPSOIL)					Soil consisted of approximately 5 to 10 percent debris
881.5 5.5		FILL: SILTY SAND (SM), fine to medium sand, with Gravel, and debris, dark brown to dark gray, moist, debris includes glass, brick, plastic, rubber, wood chips, wooden beams, and cinders *Soil dark gray and contained odor below 4 feet*					
		END OF TEST PIT Test pit then backfilled with spoils					Water not observed with 5.5 feet of tooling in the ground while drilling.

LOG OF TEST PIT

See Descriptive Terminology sheet for explanation of abbreviations

Project Number B1905336
Geotechnical Evaluation
280 Trailer Storage
Kasota Avenue and Hwy 280 South Entrance Ramp
Saint Paul, Minnesota

TEST PIT: **TP-3**

LOCATION: Coordinate datum uses NAD83/UTM Zone 15N. Elevations estimated from Concept 4 plans, CP-4, prepared by Sambatek. See attached sketch.

NORTHING:	4980512	EASTING:	483850.0
EXCAVATOR:	Frattalone	LOGGED BY:	B. Pha
START DATE:	05/30/19	END DATE:	05/30/19
SURFACE ELEVATION:	886.0 ft	RIG:	Excavator
METHOD:			
SURFACING:	Grass	WEATHER:	Cloudy

Elev./ Depth ft	Water Level		Description of Materials (Soil-ASTM D2488 or 2487; Rock-USACE EM 1110-1-2908)	Sample	Sample Blows Recovery	q_p tsf	MC %	Tests or Remarks
885.5 0.5			SILTY SAND (SM), fine to medium sand, with Gravel, and roots, black, moist (TOPSOIL)					Soil consisted of approximately 5 to 10 percent debris *8-inch thick concrete slabs greater than 20"x20" encountered
881.0 5.0			FILL: SILTY SAND (SM), fine to medium sand, with Gravel, and debris, dark brown to dark gray, moist, debris includes glass, brick, plastic, rubber chips, rubber hoses, wood chips, wooden beams, cinders, and concrete *Soil dark gray and contained odor below 3 feet*					
			END OF TEST PIT Test pit then backfilled with spoils					Water not observed with 5.0 feet of tooling in the ground while drilling.

LOG OF TEST PIT

See Descriptive Terminology sheet for explanation of abbreviations

Project Number B1905336
Geotechnical Evaluation
280 Trailer Storage
Kasota Avenue and Hwy 280 South Entrance Ramp
Saint Paul, Minnesota

TEST PIT:	**TP-4**		
LOCATION: Coordinate datum uses NAD83/UTM Zone 15N. Elevations estimated from Concept 4 plans, CP-4, prepared by Sambatek. See attached sketch.			
NORTHING:	4980514	EASTING:	483812.0
EXCAVATOR:	Frattalone	LOGGED BY:	B. Pha
START DATE:	05/30/19	END DATE:	05/30/19
SURFACE ELEVATION:	884.0 ft	RIG:	Excavator
METHOD:			
SURFACING:	Grass	WEATHER:	Mostly cloudy

Elev./ Depth ft	Water Level	Description of Materials (Soil-ASTM D2488 or 2487; Rock-USACE EM 1110-1-2908)	Sample	Sample Blows Recovery	q_p tsf	MC %	Tests or Remarks
883.0 1.0		SILTY SAND (SM), with Gravel, and roots, trace debris, black, moist, debris includes glass and plastic (TOPSOIL)					Soil consisted of approximately 5 to 10 percent debris
879.0 5.0	▽	FILL: SILTY SAND (SM), fine to medium sand, with Gravel, and Clay seams, with debris, dark brown to dark gray, moist to wet, debris includes glass, brick, plastic, rubber, metal pipes and nails, wood, and cinders *Soil dark gray and contained odor below 3 feet* 5					Water observed at 2.0 feet with 5.0 feet of tooling in the ground while drilling. Water observed likely perched.
		END OF TEST PIT Test pit then backfilled with spoils 10					

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LOG OF TEST PIT

See Descriptive Terminology sheet for explanation of abbreviations

Project Number B1905336
Geotechnical Evaluation
280 Trailer Storage
Kasota Avenue and Hwy 280 South Entrance Ramp
Saint Paul, Minnesota

TEST PIT:	**TP-5**		
LOCATION: Coordinate datum uses NAD83/UTM Zone 15N. Elevations estimated from Concept 4 plans, CP-4, prepared by Sambatek. See attached sketch.			
NORTHING:	4980545	EASTING:	483811.0
START DATE:	05/30/19	END DATE:	05/30/19
SURFACING:	Grass	WEATHER:	Mostly cloudy

EXCAVATOR:	Frattalone	LOGGED BY:	B. Pha
SURFACE ELEVATION:	886.0 ft	RIG: Excavator	METHOD:

Elev./ Depth ft	Water Level		Description of Materials (Soil-ASTM D2488 or 2487; Rock-USACE EM 1110-1-2908)	Sample	Sample Blows Recovery	q_p tsf	MC %	Tests or Remarks
		▨	FILL: SILTY SAND (SM), fine to medium sand, with Gravel, and debris, dark brown to dark gray, moist, debris includes glass, brick, plastic, rubber, metal, concrete, wood chips, wooden beams, and cinders *Soil dark gray and contained odor below 3 1/2 feet*					Soil consisted of approximately 5 to 10 percent debris
881.0 5.0			5 END OF TEST PIT Test pit then backfilled with spoils 10					Water not observed with 5.0 feet of tooling in the ground while drilling.

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LOG OF TEST PIT

See Descriptive Terminology sheet for explanation of abbreviations

Project Number B1905336
Geotechnical Evaluation
280 Trailer Storage
Kasota Avenue and Hwy 280 South Entrance Ramp
Saint Paul, Minnesota

TEST PIT: **TP-6**

LOCATION: Coordinate datum uses NAD83/UTM Zone 15N. Elevations estimated from Concept 4 plans, CP-4, prepared by Sambatek. See attached sketch.

NORTHING:	4980578	EASTING:	483810.0
EXCAVATOR:	Frattalone	LOGGED BY:	B. Pha
START DATE:	05/30/19	END DATE:	05/30/19
SURFACE ELEVATION:	887.0 ft	RIG:	Excavator
METHOD:		SURFACING:	Grass
WEATHER:	Mostly cloudy		

Elev./ Depth ft	Water Level		Description of Materials (Soil-ASTM D2488 or 2487; Rock-USACE EM 1110-1-2908)	Sample	Sample Blows Recovery	q_p tsf	MC %	Tests or Remarks
		▨	FILL: SILTY SAND (SM), fine to medium sand, with Gravel, roots, and debris, dark brown to dark gray, moist, debris includes glass, brick, plastic, rubber, metal, concrete, wood chips, wooden beams, and cinders *Soil dark gray and contained odor below 3 feet*					Soil consisted of approximately 5 to 10 percent debris
882.0 5.0			5 END OF TEST PIT Test pit then backfilled with spoils					Water not observed with 5.0 feet of tooling in the ground while drilling.
			10					

LOG OF TEST PIT

See Descriptive Terminology sheet for explanation of abbreviations

Project Number B1905336
Geotechnical Evaluation
280 Trailer Storage
Kasota Avenue and Hwy 280 South Entrance Ramp
Saint Paul, Minnesota

TEST PIT: **TP-7**

LOCATION: Coordinate datum uses NAD83/UTM Zone 15N. Elevations estimated from Concept 4 plans, CP-4, prepared by Sambatek. See attached sketch.

NORTHING:	4980555	EASTING:	483833.0
EXCAVATOR:	Frattalone	LOGGED BY:	B. Pha
START DATE:	05/30/19	END DATE:	05/30/19
SURFACE ELEVATION:	887.0 ft	RIG:	Excavator
METHOD:			
SURFACING:	Grass	WEATHER:	Mostly cloudy

Elev./ Depth ft	Water Level	Description of Materials (Soil-ASTM D2488 or 2487; Rock-USACE EM 1110-1-2908)	Sample	Sample Blows Recovery	qₚ tsf	MC %	Tests or Remarks
886.4 0.6		SILTY SAND (SM), fine to medium sand, with Gravel, and roots, black, moist (TOPSOIL)					Soil consisted of approximately 5 to 10 percent debris
882.0 5.0	▽	FILL: SILTY SAND (SM), fine to medium sand, with Gravel, and debris, brown to dark gray, moist to wet, debris includes glass, brick, plastic, rubber, metal, concrete, and wood chips *Soil dark gray and contained odor below 3 feet*					
		END OF TEST PIT Test pit then backfilled with spoils					Water observed at 1.5 feet with 5.0 feet of tooling in the ground while drilling. Water observed likely perched.

5

10

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LOG OF TEST PIT

See Descriptive Terminology sheet for explanation of abbreviations

Project Number B1905336
Geotechnical Evaluation
280 Trailer Storage
Kasota Avenue and Hwy 280 South Entrance Ramp
Saint Paul, Minnesota

TEST PIT:	**TP-8**		
LOCATION: Coordinate datum uses NAD83/UTM Zone 15N. Elevations estimated from Concept 4 plans, CP-4, prepared by Sambatek. See attached sketch.			
NORTHING:	4980539	EASTING:	483838.0
EXCAVATOR:	Frattalone	LOGGED BY:	B. Pha
START DATE:	05/30/19	END DATE:	05/30/19
SURFACE ELEVATION:	886.0 ft	RIG:	Excavator
METHOD:			
SURFACING:	Grass	WEATHER:	Mostly cloudy

Elev./ Depth ft	Water Level		Description of Materials (Soil-ASTM D2488 or 2487; Rock-USACE EM 1110-1-2908)	Sample	Sample Blows Recovery	q_p tsf	MC %	Tests or Remarks
885.0 1.0			SILTY SAND (SM), fine to medium sand, with Gravel, and roots, black, moist (TOPSOIL)					Soil consisted of approximately 5 to 10 percent debris
881.0 5.0	▽		FILL: SILTY SAND (SM), with Gravel, and debris, contains seams of Poorly Graded Sand, dark brown to dark gray, moist to wet, debris includes glass, bricks, plastic, rubber, metal, concrete, and wood *Soil dark gray and contained odor below 3 feet*					
			END OF TEST PIT Test pit then backfilled with spoils					Water observed at 1.5 feet with 5.0 feet of tooling in the ground while drilling. Water observed likely perched.

5

10

LOG OF BORING

PROJECT: **BABX-95-849**
PRELIMINARY GEOTECHNICAL EVALUATION
Proposed Manufacturing Building
Northwest of Kasota Avenue & Minnesota Highway 280
St. Paul, Minnesota

BORING: **ST-1**

LOCATION:
See attached sketch.

DRILLER: M. Rowland

METHOD: 3 1/4" HSA

DATE: 10/31/95

SCALE: 1" = 4'

Elev. 98.2	Depth 0.0	ASTM Symbol	Description of Materials	BPF	WL	Tests or Notes
84.2	14.0	FILL	FILL: Silty Sand mixed with glass, concrete, Gravel, brick, wood, cinders, paper and peat, black and dark brown, moist to wet.	4 8 10 3 5		Strong fuel odor.
82.2	16.0	FILL	FILL: Organic Clay mixed with glass, black and gray, wet.	2		
76.2	22.0	FILL	FILL: Peat mixed with Organic Clay and Silt with a trace of glass, black and gray, wet.	5 7		
72.7	25.5	CL	SANDY LEAN CLAY, with a trace of Gravel, brow, wet, medium to rather stiff. (Glacial Till)	7 9		
			END OF BORING. Water not observed with 24' of hollow-stem auger in the ground. Boring grouted to the surface.			Elevation Reference: Top of catch basin on north side of Kasota Avenue east of the southbound highway 280 entrance ramp. Elevation assumed to be 100.0.

LOG OF BORING

PROJECT: **BABX-95-849** **PRELIMINARY GEOTECHNICAL EVALUATION** **Proposed Manufacturing Building** **Northwest of Kasota Avenue & Minnesota Highway 280** **St. Paul, Minnesota**	BORING: **ST-2** LOCATION: See attached sketch.
DRILLER: M. Niesen — METHOD: 3 1/4" HSA	DATE: 10/30/95 — SCALE: 1" = 4'

Elev. 98.2	Depth 0.0	ASTM Symbol	Description of Materials	BPF	WL	Tests or Notes
80.2	18.0	FILL	FILL: Silty Sand mixed with brick rubble, wood, metal, Organic Clay and glass, black and dark brown, moist to 10' then wet.	9 14 6 10 13 19 10 10 4 5 2 4 1 5 WH 6 4 8		
72.2	26.0	CL	SANDY LEAN CLAY, with a trace of Gravel and seams and layers of Sand, brown, wet, rather soft to very stiff. (Glacial Till)	4 6 5 17 12 17	▼ ▽	

END OF BORING.

Water down 22 1/2' with 24' of hollow-stem auger in the ground.

Water down 19 1/2' with cave-in at 21 1/2'.

Boring then grouted to surface.

LOG OF BORING

PROJECT: **BABX-95-849**
PRELIMINARY GEOTECHNICAL EVALUATION
Proposed Manufacturing Building
Northwest of Kasota Avenue & Minnesota Highway 280
St. Paul, Minnesota

BORING: **ST-2A**

LOCATION:
Same as Boring ST-2 - redrilled.

DRILLER: M. Niesen

METHOD: 3 1/4" HSA

DATE: 12/21/95

SCALE: 1" = 4'

Elev. 98.2	Depth 0.0	ASTM Symbol	Description of Materials	BPF	WL	Tests or Notes
80.2	18.0	FILL	FILL: Silty Sand mixed with brick rubble, wood, metal, Organic Clay and glass, black and dark brown, moist to 10' then wet.			
72.2	26.0	CL	SANDY LEAN CLAY, with a trace of Gravel and seams and layers of Sand, brown, wet, rather soft to very stiff. (Glacial Till)	20		
70.2	28.0	SC	CLAYEY SAND, with a trace of Gravel, brown, wet, very stiff. (Glacial Till)			
66.2	32.0	SC	CLAYEY SAND, with a trace of Gravel, grayish brown, wet, medium. (Glacial Till)	8		

LOG OF BORING

PROJECT: BABX-95-849
PRELIMINARY GEOTECHNICAL EVALUATION
Proposed Manufacturing Building
Northwest of Kasota Avenue & Minnesota Highway 280
St. Paul, Minnesota

BORING: **ST-2A (cont.)**

LOCATION:
Same as Boring ST-2 - redrilled.

DRILLER: M. Niesen

METHOD: 3 1/4" HSA

DATE: 12/21/95

SCALE: 1" = 4'

Elev.	Depth	ASTM Symbol	Description of Materials	BPF	WL	Tests or Notes
60.2	38.0	SP	POORLY GRADED SAND, mostly medium-grained, brown, waterbearing, very loose. (Glacial Outwash)	3		
50.2	48.0	SP	POORLY GRADED SAND, fine- to coarse-grained, with fine to coarse Gravel, brown, waterbearing, medium dense. (Glacial Outwash)	20 24		
39.2	59.0	SP	POORLY GRADED SAND, mostly fine- to medium-grained, with a trace of fine to coarse Gravel, brown, waterbearing, medium dense. (Glacial Outwash)	12 14		
34.2	64.0	SC	CLAYEY SAND, with a trace of fine to coarse Gravel, brown, wet, hard. (Glacial Till) (Continued on next page)	32		

LOG OF BORING

PROJECT: **BABX-95-849**
PRELIMINARY GEOTECHNICAL EVALUATION
Proposed Manufacturing Building
Northwest of Kasota Avenue & Minnesota Highway 280
St. Paul, Minnesota

BORING: **ST-2A (cont.)**

LOCATION:
Same as Boring ST-2 - redrilled.

DRILLER: M. Niesen

METHOD: 3 1/4" HSA

DATE: 12/21/95

SCALE: 1" = 4'

Elev.	Depth	ASTM Symbol	Description of Materials	BPF	WL	Tests or Notes
		SC	(Continued from previous page) CLAYEY SAND, brown, wet, hard. (Glacial Till)	42		
				58		
27.7	70.5					
			END OF BORING. Boring immediately grouted to the surface.			

LOG OF BORING

PROJECT: **BABX-95-849**
PRELIMINARY GEOTECHNICAL EVALUATION
Proposed Manufacturing Building
Northwest of Kasota Avenue & Minnesota Highway 280
St. Paul, Minnesota

BORING: **ST-3**

LOCATION:
See attached sketch.

DRILLER: M. Rowland

METHOD: 3 1/4" HSA

DATE: 10/31/95

SCALE: 1" = 4'

Elev. 97.2	Depth 0.0	ASTM Symbol	Description of Materials	BPF	WL	Tests or Notes
		FILL	FILL: Sandy Lean Clay mixed with Peat, Gravel, glass, concrete and brick debris, black, moist to wet.	2		
				8		
				6		OC = 9% MC = 40%
				3		
				4		
				3		
				39		
77.2	20.0			4		
		CL	LEAN CLAY, gray, wet, rather soft. (Alluvium)			
75.2	22.0					
		CL	SANDY LEAN CLAY, with seams and layers of Sand and a trace of Gravel, brown, wet, stiff. (Glacial Till)	14		
71.7	25.5					
			END OF BORING. Water not observed with 24' of hollow-stem auger in the ground. Boring grouted to surface.			

LOG OF BORING

PROJECT: **BABX-95-849** **PRELIMINARY GEOTECHNICAL EVALUATION** **Proposed Manufacturing Building** **Northwest of Kasota Avenue & Minnesota Highway 280** **St. Paul, Minnesota**	BORING: **ST-3A** LOCATION: **Same as Boring ST-3 - redrilled.**

DRILLER: M. Niesen	METHOD: 3 1/4" HSA	DATE: 12/21/95	SCALE: 1" = 4'

Elev. 97.2	Depth 0.0	ASTM Symbol	Description of Materials	BPF	WL	Tests or Notes
77.2	20.0	FILL	FILL: Sandy Lean Clay mixed with Peat, Gravel, glass, concrete and brick debris, black, moist to wet. (Redrilled, augered to 25-foot depth.)			
75.2	22.0	CL	LEAN CLAY, gray, wet, rather soft. (Alluvium)			
72.2	25.0	CL	SANDY LEAN CLAY, with seams and layers of Sand and a trace of Gravel, brown, wet, stiff. (Glacial Till)	9		
69.2	28.0	CL	SANDY LEAN CLAY, with a trace of Gravel and layers of Sand, brown, wet, rather stiff. (Glacial Till)			
65.2	32.0	SC	CLAYEY SAND, with a trace of fine to medium Gravel, brown, wet, stiff. (Glacial Till) (Continued on next page)	16		

LOG OF BORING

PROJECT: **BABX-95-849** **PRELIMINARY GEOTECHNICAL EVALUATION** **Proposed Manufacturing Building** **Northwest of Kasota Avenue & Minnesota Highway 280** **St. Paul, Minnesota**	BORING: ST-3A (cont.) LOCATION: **Same as Boring ST-3 - redrilled.**
DRILLER: M. Niesen — METHOD: 3 1/4" HSA	DATE: 12/21/95 — SCALE: 1" = 4'

Elev.	Depth	ASTM Symbol	Description of Materials	BPF	WL	Tests or Notes
64.2	33.0	SC	(Continued from previous page) CLAYEY SAND, with a trace of fine to medium Gravel, brown, wet, stiff. (Glacial Till)			
53.2	44.0	CL	SANDY LEAN CLAY, with a trace of fine to medium Gravel, brown, wet, medium to stiff. (Glacial Till)	8 13		
44.2	53.0	SP	POORLY GRADED SAND, mostly fine- to medium-grained, brown, waterbearing, very loose to medium dense. (Glacial Outwash)	2 16		
39.2	58.0	SP	POORLY GRADED SAND, mostly fine- to medium-grained, with a trace of Gravel and layers of Clayey Sand, brown, waterbearing, medium dense. (Glacial Outwash)	25		
33.2	64.0	CL	LEAN CLAY, Shale, bluish gray, moist, very stiff to hard. (Bedrock) (Continued on next page)	17		

LOG OF BORING

PROJECT: **BABX-95-849** **PRELIMINARY GEOTECHNICAL EVALUATION** **Proposed Manufacturing Building** **Northwest of Kasota Avenue & Minnesota Highway 280** **St. Paul, Minnesota**	BORING: **ST-3A (cont.)** LOCATION: **Same as Boring ST-3 - redrilled.**

DRILLER: M. Niesen	METHOD: 3 1/4" HSA	DATE: 12/21/95	SCALE: 1" = 4'

Elev.	Depth	ASTM Symbol	Description of Materials	BPF	WL	Tests or Notes
		CL	(Continued from previous page) LEAN CLAY, Shale, bluish gray, moist, very stiff to hard. (Bedrock)	40		
				30		
				42		
17.2	80.0			44		
			END OF BORING. Boring immediately grouted to surface.			

LOG OF BORING

PROJECT: **BABX-95-849**
PRELIMINARY GEOTECHNICAL EVALUATION
Proposed Manufacturing Building
Northwest of Kasota Avenue & Minnesota Highway 280
St. Paul, Minnesota

BORING: **ST-4**

LOCATION:
Drilled 5' north of staked location. See attached sketch.

DRILLER: M. Niesen

METHOD: 3 1/4" HSA

DATE: 10/30/95

SCALE: 1" = 4'

Elev. 97.4	Depth 0.0	ASTM Symbol	Description of Materials	BPF	WL	Tests or Notes
80.4	17.0	FILL	FILL: Silty Sand mixed with Gravel, wood, paper, glass and metal debris, black and dark brown, moist to 14' then wet.	15 5 2	▼	Strong fuel odor.
71.9	25.5	CL	SANDY LEAN CLAY, with a trace of Gravel, brown, wet, rather soft to rather stiff. (Glacial Till)	4 6 12		
			END OF BORING. Water not observed with 24' of hollow-stem auger in the ground. Water down 16' with cave-in at 23'. Boring then grouted to the surface.			

LOG OF BORING

PROJECT: **BABX-95-849** **PRELIMINARY GEOTECHNICAL EVALUATION** **Proposed Manufacturing Building** **Northwest of Kasota Avenue & Minnesota Highway 280** **St. Paul, Minnesota**	BORING: **ST-5** LOCATION: **See attached sketch.**
DRILLER: M. Niesen — METHOD: 3 1/4" HSA	DATE: 10/30/95 — SCALE: 1" = 4'

Elev. 96.5	Depth 0.0	ASTM Symbol	Description of Materials	BPF	WL	Tests or Notes
80.5	16.0	FILL	FILL: Silty Sand mixed with Organic Clay, glass, concrete, Gravel, brick, wood, paper and a trace of coal, black and dark brown, moist to wet.	5 8 6 7 9 16 27 30 11 7 5 5 1 2 3 6		
77.5	19.0	OL	ORGANIC CLAY, black, wet. (Swamp Deposit)	4 2 1	▽ ▼	
70.5	26.0	CL	SANDY LEAN CLAY, with a trace of Gravel, and seams and layers of Sand, wet, rather soft to very stiff. (Glacial Till)	5 4 7 14 29		
			END OF BORING. Water down 16 1/2' with 24' of hollow-stem auger in the ground. Water down 18' immediately after withdrawal of auger with cave-in at 23'.*			Boring then grouted to the surface.

LOG OF BORING

PROJECT:	BORING: ST-6
BABX-95-849 **PRELIMINARY GEOTECHNICAL EVALUATION** **Proposed Manufacturing Building** **Northwest of Kasota Avenue & Minnesota Highway 280** **St. Paul, Minnesota**	LOCATION: **See attached sketch.**

DRILLER: M. Rowland	METHOD: 3 1/4" HSA	DATE: 10/31/95	SCALE: 1" = 4'

Elev. 96.2	Depth 0.0	ASTM Symbol	Description of Materials	BPF	WL	Tests or Notes
74.2	22.0	FILL	FILL: Mixed Silty Sand, Clayey Sand, Organic Clay, Peat, glass, concrete, Gravel, wood, metal and brick rubble, black, moist to wet.	5 4 9 8 3 3 5 13 11 12 16 15 10 8 5 4 5 7 3 2 4 4	∇	
72.2	24.0	ML	SILT, with a trace of shells, gray, wet, very loose. (Alluvium)	4 4		
70.2	26.0	SM	SILTY SAND, mostly fine-grained, with a trace of Gravel, gray, waterbearing, medium dense. (Glacial Till)	14 16		
			END OF BORING. Water down 21.2' with 24' of hollow-stem auger in the ground. Boring grouted to the surface.			

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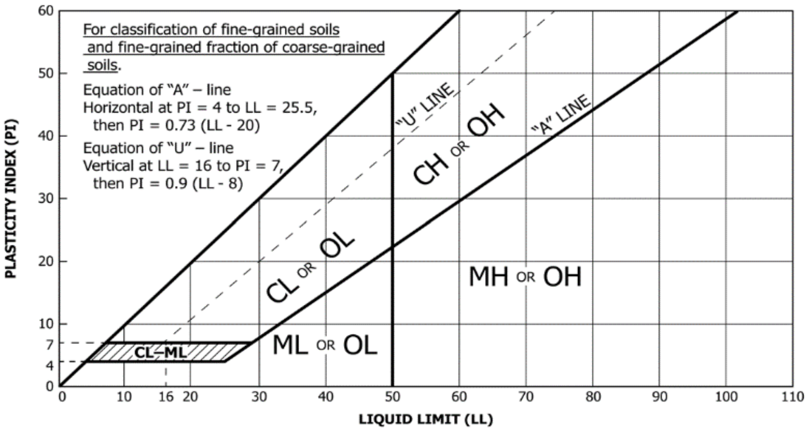
Descriptive Terminology of Soil

Based on Standards ASTM D2487/2488
(Unified Soil Classification System)

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests^A				Soil Classification	
				Group Symbol	Group Name^B
Coarse-grained Soils (more than 50% retained on No. 200 sieve)	**Gravels** (More than 50% of coarse fraction retained on No. 4 sieve)	**Clean Gravels** (Less than 5% fines^C)	$C_u \geq 4$ and $1 \leq C_c \leq 3^D$	GW	Well-graded gravel^E
			$C_u < 4$ and/or ($C_c < 1$ or $C_c > 3$)^D	GP	Poorly graded gravel^E
		Gravels with Fines (More than 12% fines^C)	Fines classify as ML or MH	GM	Silty gravel$^{E\ F\ G}$
			Fines Classify as CL or CH	GC	Clayey gravel$^{E\ F\ G}$
	Sands (50% or more coarse fraction passes No. 4 sieve)	**Clean Sands** (Less than 5% fines^H)	$C_u \geq 6$ and $1 \leq C_c \leq 3^D$	SW	Well-graded sand^I
			$C_u < 6$ and/or ($C_c < 1$ or $C_c > 3$)^D	SP	Poorly graded sand^I
		Sands with Fines (More than 12% fines^H)	Fines classify as ML or MH	SM	Silty sand$^{F\ G\ I}$
			Fines classify as CL or CH	SC	Clayey sand$^{F\ G\ I}$
Fine-grained Soils (50% or more passes the No. 200 sieve)	**Silts and Clays** (Liquid limit less than 50)	Inorganic	PI > 7 and plots on or above "A" line^J	CL	Lean clay$^{K\ L\ M}$
			PI < 4 or plots below "A" line^J	ML	Silt$^{K\ L\ M}$
		Organic	$\frac{\text{Liquid Limit – oven dried}}{\text{Liquid Limit – not dried}} <0.75$	OL	Organic clay$^{K\ L\ M\ N}$ Organic silt$^{K\ L\ M\ O}$
	Silts and Clays (Liquid limit 50 or more)	Inorganic	PI plots on or above "A" line	CH	Fat clay$^{K\ L\ M}$
			PI plots below "A" line	MH	Elastic silt$^{K\ L\ M}$
		Organic	$\frac{\text{Liquid Limit – oven dried}}{\text{Liquid Limit – not dried}} <0.75$	OH	Organic clay$^{K\ L\ M\ P}$ Organic silt$^{K\ L\ M\ Q}$
Highly Organic Soils		Primarily organic matter, dark in color, and organic odor		PT	Peat

A. Based on the material passing the 3-inch (75-mm) sieve.
B. If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.
C. Gravels with 5 to 12% fines require dual symbols:
    GW-GM well-graded gravel with silt
    GW-GC well-graded gravel with clay
    GP-GM poorly graded gravel with silt
    GP-GC poorly graded gravel with clay
D. $C_u = D_{60} / D_{10}$ $\qquad C_c = (D_{30})^2 / (D_{10}\ x\ D_{60})$
E. If soil contains ≥ 15% sand, add "with sand" to group name.
F. If fines classify as CL-ML, use dual symbol GC-GM or SC-SM.
G. If fines are organic, add "with organic fines" to group name.
H. Sands with 5 to 12% fines require dual symbols:
    SW-SM well-graded sand with silt
    SW-SC well-graded sand with clay
    SP-SM poorly graded sand with silt
    SP-SC poorly graded sand with clay
I. If soil contains ≥ 15% gravel, add "with gravel" to group name.
J. If Atterberg limits plot in hatched area, soil is CL-ML, silty clay.
K. If soil contains 15 to < 30% plus No. 200, add "with sand" or "with gravel", whichever is predominant.
L. If soil contains ≥ 30% plus No. 200, predominantly sand, add "sandy" to group name.
M. If soil contains ≥ 30% plus No. 200 predominantly gravel, add "gravelly" to group name.
N. PI ≥ 4 and plots on or above "A" line.
O. PI < 4 or plots below "A" line.
P. PI plots on or above "A" line.
Q. PI plots below "A" line.



Particle Size Identification

Boulders............. over 12"
Cobbles............... 3" to 12"
Gravel
    Coarse............ 3/4" to 3" (19.00 mm to 75.00 mm)
    Fine................ No. 4 to 3/4" (4.75 mm to 19.00 mm)
Sand
    Coarse............. No. 10 to No. 4 (2.00 mm to 4.75 mm)
    Medium........... No. 40 to No. 10 (0.425 mm to 2.00 mm)
    Fine................. No. 200 to No. 40 (0.075 mm to 0.425 mm)
Silt....................... No. 200 (0.075 mm) to .005 mm
Clay..................... < .005 mm

Relative Proportions$^{L,\ M}$

trace............................ 0 to 5%
little............................. 6 to 14%
with............................. ≥ 15%

Inclusion Thicknesses

lens.............................. 0 to 1/8"
seam............................ 1/8" to 1"
layer............................. over 1"

Apparent Relative Density of Cohesionless Soils

Very loose .... 0 to 4 BPF
Loose .... 5 to 10 BPF
Medium dense............. 11 to 30 BPF
Dense........................... 31 to 50 BPF
Very dense................... over 50 BPF

Consistency of Cohesive Soils	**Blows Per Foot**	**Approximate Unconfined Compressive Strength**
Very soft	0 to 1 BPF	< 0.25 tsf
Soft	2 to 4 BPF	0.25 to 0.5 tsf
Medium	5 to 8 BPF	0.5 to 1 tsf
Stiff	9 to 15 BPF	1 to 2 tsf
Very Stiff	16 to 30 BPF	2 to 4 tsf
Hard	over 30 BPF	> 4 tsf

Moisture Content:

Dry: Absence of moisture, dusty, dry to the touch.
Moist: Damp but no visible water.
Wet: Visible free water, usually soil is below water table.

Drilling Notes:

Blows/N-value: Blows indicate the driving resistance recorded for each 6-inch interval. The reported N-value is the blows per foot recorded by summing the second and third interval in accordance with the Standard Penetration Test, ASTM D1586.

Partial Penetration: If the sampler could not be driven through a full 6-inch interval, the number of blows for that partial penetration is shown as #/x" (i.e. 50/2"). The N-value is reported as "REF" indicating refusal.

Recovery: Indicates the inches of sample recovered from the sampled interval. For a standard penetration test, full recovery is 18", and is 24" for a thinwall/shelby tube sample.

WOH: Indicates the sampler penetrated soil under weight of hammer and rods alone; driving not required.

WOR: Indicates the sampler penetrated soil under weight of rods alone; hammer weight and driving not required.

Water Level: Indicates the water level measured by the drillers either while drilling (▽), at the end of drilling (▼), or at some time after drilling (▼).

Laboratory Tests

DD	Dry density, pcf	**OC**	Organic content, %	**LL**	Liquid limit
WD	Wet density, pcf	**q_p**	Pocket penetrometer strength, tsf	**PL**	Plastic limit
P200	% Passing #200 sieve	**MC**	Moisture content, %	**PI**	Plasticity index
		q_U	Unconfined compression test, tsf		

APPENDIX F – CONTECH STORMFILTER DEVICE SIZING

Determining Number of Cartridges for Systems Downstream of Detention

CONTECH Stormwater Solutions Inc. Engineer:	GRB	Blue Cells =	Input
Date	9/24/2019	Black Cells =	Calculation

Site Information

Project Name	Rohn Project	
Project State	St. Paul	
Project Location	MN	
Drainage Area, Ad	1.78	ac
Impervious Area, Ai	1.05	ac
Pervious Area, Ap	0.73	
% Impervious	59%	
Runoff Coefficient, Rc	0.58	

Mass loading calculations

Mean Annual Rainfall, P	30	in
Agency required % removal	90%	
Percent Runoff Capture	90%	
Mean Annual Runoff,V_t	101,342	ft^3
Event Mean Concentration of Pollutant, EMC	70	mg/l
Annual Mass Load, M_{total}	442.59	lbs

Filter System

Filtration brand	StormFilter	
Cartridge height	27	in
Specific Flow Rate	1.0	gpm/ft^2

Number of cartridges - mass loading

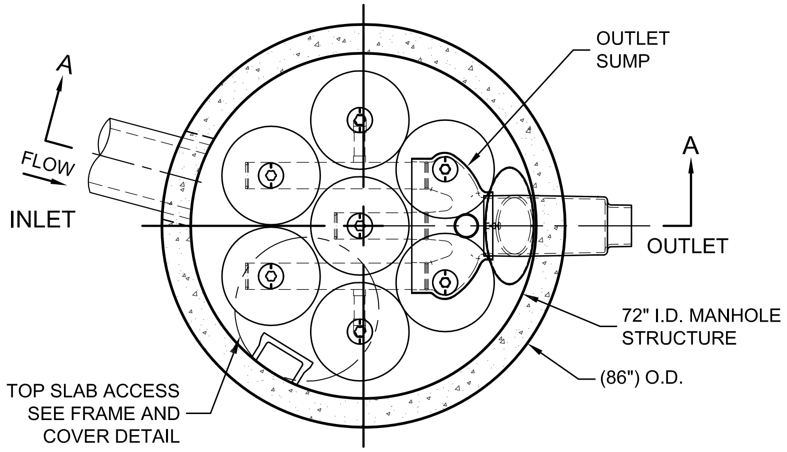
Mass removed by pretreatment system, M_{pre}	100.00	lbs
Mass load to filters after pretreatment, M_{pass1}	342.59	lbs
Estimate the required filter efficiency, E_{filter}	0.90	
Mass to be captured by filters, M_{filter}	308.33	lbs
Allowable Cartridge Flow rate, Q_{cart}	11.25	
Mass load per cartridge, M_{cart} (lbs)	54.00	lbs
Number of Cartridges required, N_{mass}	6	
Treatment Capacity	0.15	cfs

Determine Critical Sizing Value

Number of Cartridges using $Q_{release\ treat}$, N_{flow}	0
Method to Use:	MASS-LOADING

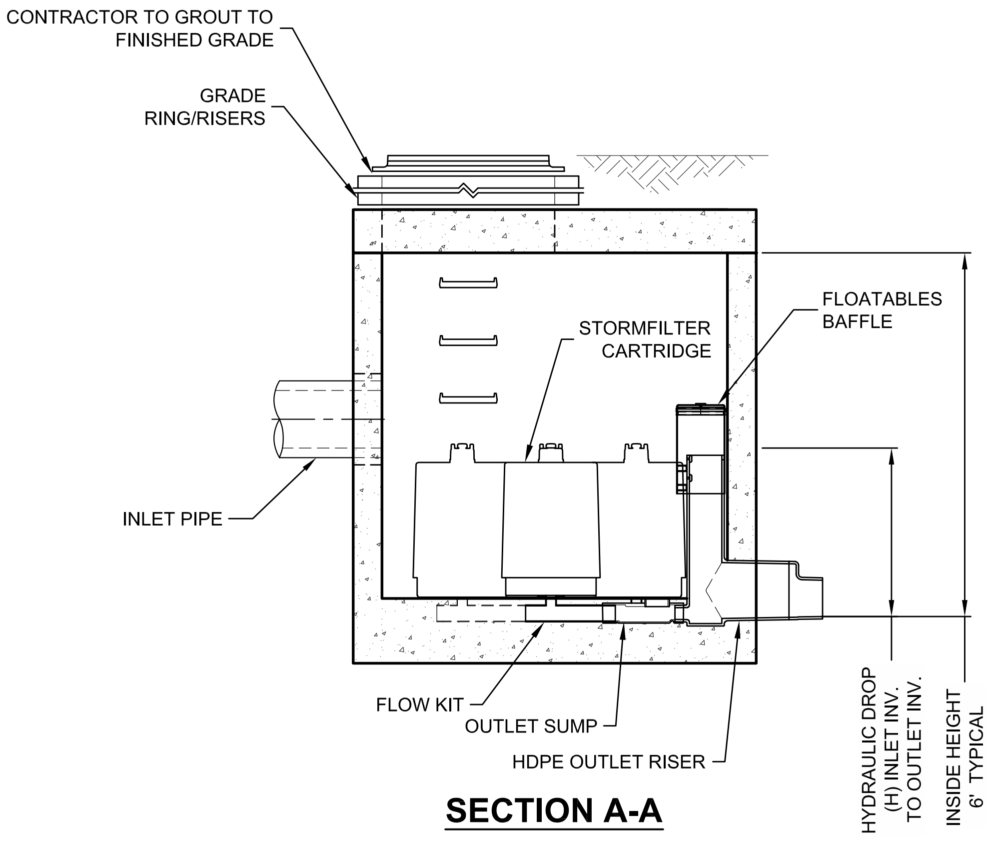
SUMMARY

Treatment Flow Rate, cfs	0.15
Cartridge Flow Rate, gpm	11.3
Number of Cartridges	6



PLAN VIEW

STANDARD OUTLET RISER
FLOWKIT: 42A



SECTION A-A

The Stormwater Management
StormFilter®
THIS PRODUCT MAY BE PROTECTED BY ONE OR MORE OF THE FOLLOWING U.S. PATENTS: 5,322,629; 5,524,576; 5,707,527; 5,985,157; 6,027,639; 6,649,048; RELATED FOREIGN PATENTS, OR OTHER PATENTS PENDING.

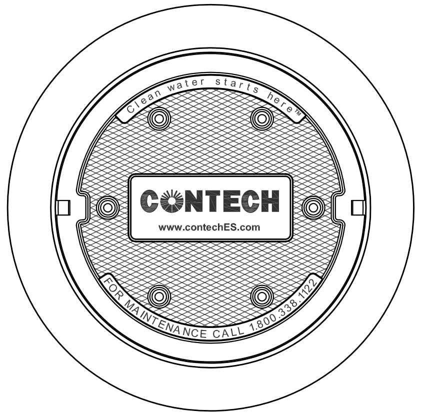
STORMFILTER DESIGN NOTES

STORMFILTER TREATMENT CAPACITY IS A FUNCTION OF THE CARTRIDGE SELECTION AND THE NUMBER OF CARTRIDGES. THE STANDARD MANHOLE STYLE IS SHOWN WITH THE MAXIMUM NUMBER OF CARTRIDGES (7). VOLUME SYSTEM IS ALSO AVAILABLE WITH MAXIMUM 7 CARTRIDGES.
Ø72" MANHOLE STORMFILTER PEAK HYDRAULIC CAPACITY IS 1.5 CFS. IF THE SITE CONDITIONS EXCEED 1.5 CFS AN UPSTREAM BYPASS STRUCTURE IS REQUIRED.

CARTRIDGE SELECTION

CARTRIDGE HEIGHT	27"			18"			LOW DROP		
RECOMMENDED HYDRAULIC DROP (H)	3.05'			2.3'			1.8'		
SPECIFIC FLOW RATE (gpm/sf)	2 gpm/sf	1.67* gpm/sf	1 gpm/sf	2 gpm/sf	1.67* gpm/sf	1 gpm/sf	2 gpm/sf	1.67* gpm/sf	1 gpm/sf
CARTRIDGE FLOW RATE (gpm)	22.5	18.79	11.25	15	12.53	7.5	10	8.35	5

* 1.67 gpm/sf SPECIFIC FLOW RATE IS APPROVED WITH PHOSPHOSORB® (PSORB) MEDIA ONLY



FRAME AND COVER

(DIAMETER VARIES)
N.T.S.

SITE SPECIFIC DATA REQUIREMENTS

STRUCTURE ID	*
WATER QUALITY FLOW RATE (cfs)	*
PEAK FLOW RATE (cfs)	*
RETURN PERIOD OF PEAK FLOW (yrs)	*
CARTRIDGE HEIGHT (27", 18", LOW DROP(LD))	*
NUMBER OF CARTRIDGES REQUIRED	*
CARTRIDGE FLOW RATE	*
MEDIA TYPE (PERLITE, ZPG,PSORB)	*

PIPE DATA:	I.E.	MATERIAL	DIAMETER
INLET PIPE #1	*	*	*
INLET PIPE #2	*	*	*
OUTLET PIPE	*	*	*

RIM ELEVATION	*

ANTI-FLOTATION BALLAST	WIDTH	HEIGHT
	*	*

NOTES/SPECIAL REQUIREMENTS:

* PER ENGINEER OF RECORD

GENERAL NOTES

1. CONTECH TO PROVIDE ALL MATERIALS UNLESS NOTED OTHERWISE.
2. DIMENSIONS MARKED WITH ( ) ARE REFERENCE DIMENSIONS. ACTUAL DIMENSIONS MAY VARY.
3. FOR SITE SPECIFIC DRAWINGS WITH DETAILED VAULT DIMENSIONS AND WEIGHTS, PLEASE CONTACT YOUR CONTECH ENGINEERED SOLUTIONS LLC REPRESENTATIVE. www.ContechES.com
4. STORMFILTER WATER QUALITY STRUCTURE SHALL BE IN ACCORDANCE WITH ALL DESIGN DATA AND INFORMATION CONTAINED IN THIS DRAWING.
5. STRUCTURE SHALL MEET AASHTO HS-20 LOAD RATING, ASSUMING EARTH COVER OF 0' - 5' AND GROUNDWATER ELEVATION AT, OR BELOW, THE OUTLET PIPE INVERT ELEVATION. ENGINEER OF RECORD TO CONFIRM ACTUAL GROUNDWATER ELEVATION. CASTINGS SHALL MEET AASHTO M306 AND BE CAST WITH THE CONTECH LOGO.
6. FILTER CARTRIDGES SHALL BE MEDIA-FILLED, PASSIVE, SIPHON ACTUATED, RADIAL FLOW, AND SELF CLEANING. RADIAL MEDIA DEPTH SHALL BE 7-INCHES. FILTER MEDIA CONTACT TIME SHALL BE AT LEAST 38 SECONDS.
7. SPECIFIC FLOW RATE IS EQUAL TO THE FILTER TREATMENT CAPACITY (gpm) DIVIDED BY THE FILTER CONTACT SURFACE AREA (sq ft).
8. STORMFILTER STRUCTURE SHALL BE PRECAST CONCRETE CONFORMING TO ASTM C-478 AND AASHTO LOAD FACTOR DESIGN METHOD.

INSTALLATION NOTES

A. ANY SUB-BASE, BACKFILL DEPTH, AND/OR ANTI-FLOTATION PROVISIONS ARE SITE-SPECIFIC DESIGN CONSIDERATIONS AND SHALL BE SPECIFIED BY ENGINEER OF RECORD.
B. CONTRACTOR TO PROVIDE EQUIPMENT WITH SUFFICIENT LIFTING AND REACH CAPACITY TO LIFT AND SET THE STORMFILTER STRUCTURE (LIFTING CLUTCHES PROVIDED).
C. CONTRACTOR TO INSTALL JOINT SEALANT BETWEEN ALL STRUCTURE SECTIONS AND ASSEMBLE STRUCTURE.
D. CONTRACTOR TO PROVIDE, INSTALL, AND GROUT INLET PIPE(S).
E. CONTRACTOR TO PROVIDE AND INSTALL CONNECTOR TO THE OUTLET RISER STUB. STORMFILTER EQUIPPED WITH A DUAL DIAMETER HDPE OUTLET STUB AND SAND COLLAR. IF OUTLET PIPE IS LARGER THAN 8 INCHES, CONTRACTOR TO REMOVE THE 8 INCH OUTLET STUB AT MOLDED IN CUT LINE. COUPLING BY FERNCO OR EQUAL AND PROVIDED BY CONTRACTOR.
F. CONTRACTOR TO TAKE APPROPRIATE MEASURES TO PROTECT CARTRIDGES FROM CONSTRUCTION-RELATED EROSION RUNOFF.

CONTECH®
ENGINEERED SOLUTIONS LLC
www.contechES.com
9025 Centre Pointe Dr., Suite 400, West Chester, OH 45069
800-338-1122 513-645-7000 513-645-7993 FAX

SFMH72
STORMFILTER
STANDARD DETAIL

APPENDIX G – CONTECH STORMFILTER REMOVAL STUDIES

Appendix G - Contech StormFilter Removal Studies

Four different studies were analyzed to determine the TP and TSS removal efficiencies for the StormFilter device. These studies were performed by Contech Engineered Solutions, Mitchell Community College, and Washington State Department of Ecology. The following table summarizes removal efficiencies determined by these studies.

CONTECH STORMFILTER STUDIES

Study	TSS Removal %	TP Removal %	DP Removal %
Contech Engineered Solutions	88	73	27
Mitchell Community College (ER Efficiency)	90.4	86.1	74.2
Mitchell Community College (SOL Efficiency)	90.9	87.1	67.3
Washington State Department of Ecology	85	67	50
Average Removal	**89%**	**78%**	**55%**

The Stormwater Management StormFilter® PhosphoSorb® at a Specific Flow Rate of 1.67 gpm/ft^2

General Use Level Designation

Technical Evaluation Report

Prepared by

CONTECH Engineered Solutions
11815 NE Glenn Widing Drive
Portland, OR 97220
Telephone: 800-548-4667

October 9, 2015

Table of Contents

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1.0 Executive Summary

A performance evaluation of The Stormwater Management StormFilter® with PhosphoSorb® media operating at a specific flow rate of 1.67 gpm/ft^2 was performed at a roadway site in Zigzag, Oregon. The field evaluation began in January 2012 and sampling continued through February 2015. The approved Quality Assurance Project Plan (QAPP) for this evaluation follows the procedures and guidelines described in the Guidance for Evaluating Emerging Stormwater Treatment Technologies Technology Assessment Protocol Ecology (Ecology, 2011). This document has been prepared with a goal of receiving a General Use Level Designation for basic and phosphorus treatment.

1.1 Technology Description

The Stormwater Management StormFilter (StormFilter) is a Best Management Practice (BMP) that is provided by Contech Engineered Solutions, LLC (Contech). The StormFilter improves the quality of stormwater runoff before it enters receiving waterways through the use of its customizable filter media, which removes non-point source pollutants. The StormFilter is typically comprised of a vault that houses rechargeable, media-filled filter cartridges. Stormwater entering the system percolates through these media-filled cartridges, which trap particulates and remove pollutants. Once filtered through the media, the treated stormwater is discharged through an outlet pipe to a storm sewer system or receiving water.

Depending on the treatment requirements and pollutant characteristics of the influent stream at an individual site, the filtration rate through a typical StormFilter cartridge at the design driving head can be adjusted. The flow rate is individually controlled for each cartridge by a restrictor disc located at the connection point between the cartridge and the underdrain manifold.

The StormFilter is offered in multiple configurations including plastic, steel, and concrete catch basin, precast manhole, precast vault, panel vault, CON/SPAN, box culvert, and curb inlet. These configurations can include up to 3 different cartridge heights at 12, 18, and 27 inches. Increasing the height of the cartridge allows for an increase in the available surface area and volume of the media per cartridge, but also requires a greater hydraulic drop (head loss) across the system.

The StormFilter cartridge can house different types of media including perlite, zeolite, granular activated carbon (GAC), CSF® leaf media, MetalRx™, PhosphoSorb® or various media blends such as ZPG™ (perlite, zeolite, GAC). All of the media use physical straining to remove solids. Active inorganic media provide additional treatment mechanisms such as cation exchange capacity and/or adsorption, and organic media (CSF leaf, MetalRx) provide chelation.

1.2 Sampling Procedures

Influent and effluent flows were measured using Large 60°V Trapezoidal Flumes in conjunction with individual ISCO 750 Bubbler Flow Modules. Influent and effluent flows were monitored continuously throughout the evaluation period on a 5 minute time step data interval.

Discrete flow-sampling was used to collect influent and effluent samples using individual ISCO 6712 Portable Automated Samplers configured for standard, individual, round, wide-mouth 1-L HDPE bottles sample bottles. Sample tubing, 3/8” ID Acutech Duality FEP/LDPE tubing, was routed from each automated sampler to influent and effluent sample locations. Sample intakes were located at the invert of both the influent and effluent sample locations.

1.3 TSS and Total Phosphorus Data Summary

A total of 17 qualified storm events have been evaluated to provide field data for a General Use Level Designation for basic and phosphorus treatment. Overall Total Suspended Solids (TSS) data showed a removal efficiency of 88% with a mean influent concentration of 380 mg/L. Total phosphorus removal efficiency is 73% with a mean influent concentration of 0.33 mg/L for the qualified events sampled.

Data was analyzed using the 2011-08 TAPE bootstrap confidence interval calculator for TSS and total phosphorus. The lower 95% confidence interval for TSS removal efficiency was 85%. The lower 95% confidence interval for total phosphorus removal efficiency was 67%. The upper 95% confidence interval for total phosphorus effluent concentration was 0.084 mg/L.

A performance assessment was also included for suspended solids less than 500 microns (SSC<500 µm) and the silt and clay fraction. SSC<500 microns had a mean influent concentration of 325 mg/L and a mean removal efficiency of 87%. The lower 95% confidence interval for SSC<500 µm was 85%. The silt and clay fraction, representing suspended solid concentrations less than 62.5 microns, was also evaluated with a mean influent concentration of 153 mg/L and a removal efficiency of 78%. The lower 95% confidence interval for the silt and clay fraction removal efficiency was 73%.

1.4 Hydraulic Evaluation Summary

Over the entire 37 month evaluation period, the total effluent volume recorded at the site was 376,244 gallons. There were some data gaps due to weather, equipment issues, and back-up data storage errors. A total of 14,060 gallons were bypassed through the system accounting for 4% of the total recorded volume. A total of 26 events contained bypass flow. Three (of 26) bypass events were a result of media occlusion impairing the ability of the system to meet the hydraulic capacity requirements.

Five of the 17 qualified events evaluated contained bypass flow and a water quality treatment flow rate greater than 100% design rate (specific flow rate of 1.67 gpm/ft^2). Four of the five qualified events satisfied the basic and phosphorus treatment goals.

2.0 Introduction

Contech requests a General Use Level Designation for the Stormwater Management StormFilter® (StormFilter) with PhosphoSorb® media operating at a specific flow rate of 1.67 gpm/ft^2. A field evaluation of the StormFilter with PhosphoSorb media, operating at a 12.5 gpm for an 18-inch cartridge, was initiated in January 2012. Seventeen storm events were collected following the approved Quality Assurance Project Plan (QAPP) and show an average TSS removal efficiency of 88% with a mean influent concentration of 380 mg/L. Total phosphorus removal efficiency was 73% with a mean influent concentration of 0.33 mg/L.

The enclosed report, and supporting appendices, follows the Guidance for Evaluating Emerging Stormwater Treatment Technologies Technology Assessment Protocol Ecology (TAPE, 2011) reporting guidelines for a Technical Evaluation Report (TER).

3.0 Technology Description

The Stormwater Management StormFilter® (StormFilter) cleans stormwater through a patented passive filtration process, effectively removing pollutants to meet stringent regulatory requirements. Highly reliable, easy to install and maintain, and with proven performance over time, the StormFilter system is recognized as a versatile BMP for removing a variety of pollutants, such as sediments, oil and grease, metals, organics, and nutrients. The StormFilter comes in variable configurations to match local conditions and is designed for prolonged maintenance intervals to ensure long-term performance and reduce operating costs.

3.1 Physical Description

The StormFilter (Figure 1) is typically comprised of a vault that houses rechargeable, media-filled filter cartridges. Stormwater enters the system and percolates through the cartridges, which trap particulates and remove pollutants such as dissolved metals, nutrients, and hydrocarbons. Once filtered through the media, the treated stormwater is discharge through and outlet pipe to a storm sewer system or a receiving water body.

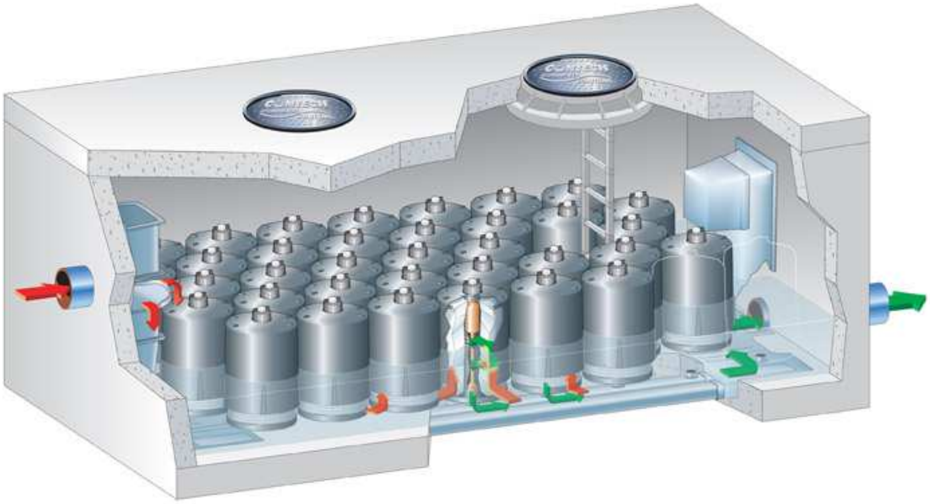

Figure 1. The precast Stormwater Management StormFilter®

Cartridge media can be customized for each site and jurisdiction to target and remove the desired levels of sediments, oils and greases, dissolved metals, nutrients, and organics using different media. In many cases, a combination of media may be recommended to maximize the stormwater pollutant removal.

3.1.1 Operation

During a storm, runoff passes through the filtration media and starts filling the cartridge center tube. Air below the hood is purged through a one-way check valve as the water rises. When water reaches the top of the float, buoyant forces pull the float free and allow filtered water to drain through the cartridge media.

After the storm, the water level in the structure starts falling. A hanging water column remains under the cartridge hood until the water level reaches the scrubbing regulators. Air then rushes through the regulators releasing water and creating air bubbles that agitate the surface of the filter media, causing accumulated sediment to drop to the vault floor. This patented surface-cleaning mechanism helps restore the filter's permeability between storm events.

3.1.2 Cartridge Operation

As the water level in the filtration bay begins to rise, stormwater enters the StormFilter cartridge (Figure 2). Stormwater in the cartridge percolates horizontally through the filter media and passes into the cartridge's center tube, where the float in the cartridge is in a closed (downward) position. As the water level in the filtration bay continues to rise, more water passes through the filter media and into the cartridge's center tube. The air in the cartridge is displaced by the water and purged from beneath the filter hood through the one-way check valve located in the cap.

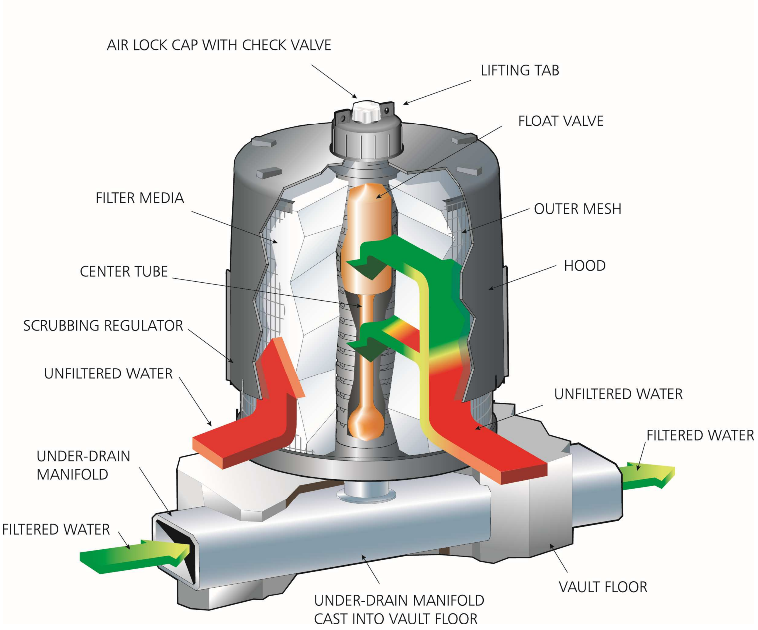

Figure 2. The StormFilter cartridge

Once the center tube is filled with water, there is enough buoyant force on the float to open the float valve and allow the treated water to flow into the under drain manifold. As the treated water drains, it tries to pull in air behind it. This causes the check valve to close, initiating a siphon that draws polluted water throughout the full surface area and volume of the filter media. Thus, the entire filter cartridge is used to filter water throughout the duration of the storm, regardless of the water surface elevation in the filtration bay.

This continues until the water surface elevation drops to the elevation of the scrubbing regulators and the float returns to a closed position. At this point, the siphon begins to break and air is quickly drawn beneath the hood through the scrubbing regulators, causing high-energy turbulence between the inner surface of the hood and the outer surface of the filter. This turbulence agitates the surface of the filter, releasing accumulated sediments on the surface, flushing them from beneath the hood, and allowing them to settle to the vault floor. This surface-cleaning mechanism maintains the permeability of the filter surface and enhances the overall performance and longevity of the system.

3.1.3 Media Choices

The StormFilter can be customized with different filter media to target site-specific pollutants. A combination of media is often recommended to maximize pollutant removal effectiveness. Table 1 shows typical media and associated target pollutants.

CSF® Leaf Media and MetalRx™ use a feed stock of pure deciduous leaf compost that does not contain mixed yard debris (pruning or grass). Mature stable compost is processed into an organic granular media or pellet. CSF is a coarse media with a high hydraulic capacity. MetalRx is a finer media with a lower hydraulic capacity. Both are effective at removing soluble metals, TSS, oil and grease, and buffering acid rain. Both media types are very effective at soluble metals removal, and MetalRx is the most effective.

Granular Activated Carbon (GAC) has a micro-porous structure with an extensive surface area to provide high levels of adsorption. It is primarily used to remove oil and grease and organics such as PAHs and phthalates.

Perlite is a naturally occurring heat-expanded volcanic rock. It is effective for removing TSS, oil and grease.

PhosphoSorb® is comprised of a heat expanded volcanic rock and activated alumina. The lightweight expanded rock provides exceptional removal of fine particulate and the activated alumina allows for adsorption of soluble phosphorus.

Zeolite is a naturally occurring mineral used to remove soluble metals, ammonium and some organics.

ZPG™ is a media blend of perlite, zeolite and granular activated carbon. It is an all-purpose media that is ideal for sites that require removal of the most common pollutants.

Table 1. Typical media and targeted pollutants.

	Perlite	CSF® leaf	MetalRx™	PhosphoSorb®	Zeolite	GAC
Sediment	X	X		X		
Oil & Grease	X	X	X	X		
Soluble Metals		X	X		X	
Organics		X	X			X
Nutrients	X	X	X	X	X	

Note: Indicated media are most effective for pollutant type.
Other media may treat pollutants but to a lesser degree.

3.1.4 Adjustable Flow Rate

Depending on the treatment requirements and the pollutant characteristics of the influent stream at an individual site, the filtration rate through a typical StormFilter cartridge at the design driving head can be adjusted. The flow rate is individually controlled for each cartridge by a restrictor disc located at the connection point between the cartridge and the underdrain manifold. Consisting of a simple orifice disc of a specified diameter, the flow rate through the cartridges can be adjusted to a level that coincides with treatment requirements.

A reduction in flow rate affects the performance of the StormFilter system with regards to both sediment and soluble pollutants. For solids, Stokes' Law predicts the movement of sediment in a fluid and it has been proven that a reduction in the flow velocity through the system will facilitate increased settling and capture of sediments. In addition, some media types have the ability to remove soluble pollutants through chemical processes such as ion exchange. A reduction in the flow velocity through the cartridge will increase the contact time between the stormwater and the media, thereby increasing removal efficiency by increasing the time for a chemical process to take place.

3.1.5 Cartridge Heights

Three different cartridge heights are available at 12, 18, and 27 inches. Increasing the height of the cartridge (ranging from 18 to 27 inches) allows for an increase in the available surface area and volume of the media per cartridge, but also requires a greater hydraulic drop (head loss) across the system. Similarly, decreasing the cartridge effective height will result in a reduction in the required hydraulic drop but a corresponding reduction in the media surface area and volume per cartridge. Since each cartridge contains an individual orifice control – the calibrated restrictor disc – a consistent specific flow rate is sustained for all cartridge heights.

Projects that have additional hydraulic drop available can opt for a taller cartridge design and gain the benefit of a smaller number of required cartridges and therefore a smaller system footprint, Figure 3. Projects with limited available hydraulic drop can select the Low Drop StormFilter, which is an 18" cartridge containing 12" float. However, more cartridges may be required to provide the required media surface area, which results in a larger system footprint.

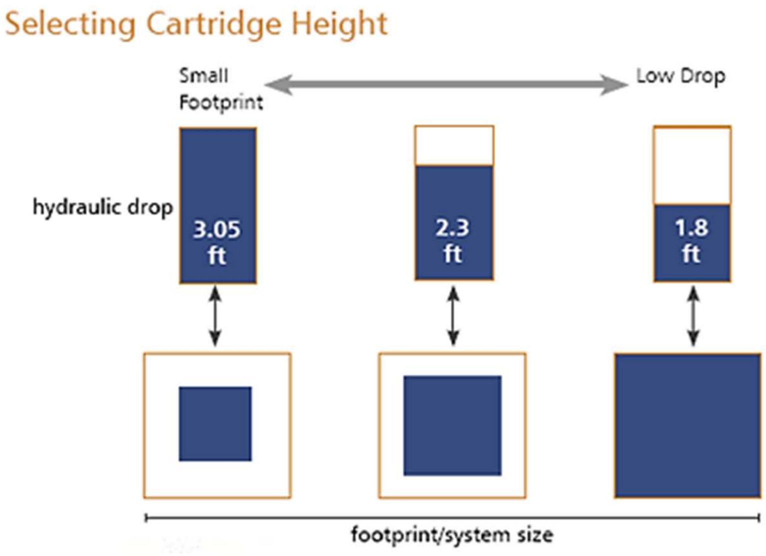

Figure 3. Relationship between cartridge height and system size.

3.1.6 Configurations

Table 2 provides a summary of the available configurations with the StormFilter.

Table 2. Configurations

Model	Description	Photo
Vault/Manhole	• Treats small to medium sized sites • Simple installation; arrives on-site fully assembled	
High Flow	• Treats flows from large sites • Consists of large, precast components designed for easy assembly on-site • Several configurations available, including: CON/SPAN, Panel Vault, Box Culvert, or Cast-In-Place	
Drywell	• Provides treatment and infiltration in one structure • Available for new construction and retrofit applications • Easy installation	
CatchBasin	• Provides a low cost, low drop, point-of-entry configuration • Treats sheet flow from small sites • Uses drop from the inlet grate to conveyance pipe to drive the passive filtration cartridges	
Volume	• Meets volume-based stormwater treatment regulations • Captures and treats site specific Water Quality Volume (WQv) • StormFilter cartridges provide treatment and control the discharge rate • Can be designed to capture all, or a portion, of the WQv	
Curb-Inlet	• Provides a low drop, point-of-entry configuration • Accommodates curb inlet openings from 3 to 10 feet long • Uses drop from the curb inlet to the conveyance pipe to drive the passive filtration cartridges	

3.1.7 Design Drawings

Standard design drawings for the StormFilter are available at ContechES.com and upon request.

3.1.8 Treatment Mechanisms

The StormFilter system utilizes several unit processes to remove pollutants from stormwater. This section includes a brief summary of the media type and the unit process employed in the StormFilter system for each specific contaminant.

Physical Separation

The primary component of the StormFilter is the filtration bay with media-filled cartridges. Residence time within a vault varies with cartridge flow rate and vault size, but as a rule of thumb, is a minimum of 6 minutes. This allows for large solids (coarse sand and grit) to drop to the floor of the system.

Pollutant Removal by the Media-Filled Cartridge

The StormFilter cartridge is the central treatment device within the system. The cartridges are filled with various media depending on the site's runoff and targeted pollutant removal. Removal associated with the media is promoted through physical straining, ion exchange, and adsorption. Physical straining is the primary removal mechanism for suspended solids. Depending on the media used, dissolved pollutant removal is either associated with ion exchange, chelation, or adsorption reactions.

Physical Straining

Physical straining through the media promotes solids removal by trapping solids within interstitial spaces throughout the filtration media. Removal of suspended particles occurs through physical straining as water passes through filtration media. The straining results in the trapping of suspended particles within the media matrix either in microchannels or dead end pores. All Contech media options utilize physical straining.

Also, physical straining promotes non-dissolved metals removal due to the binding of metals to particles. Other attached pollutants removed through straining include total phosphorus and total nitrogen. All Contech media options utilize physical straining for total metals and nutrients.

Cation Exchange

As implied, cation exchange is the exchange of a cation (positively charged atom) for another cation. The process involves the displacement of an atom within the media matrix by an atom within the water column. The displacement occurs if the incoming atom's affinity for the exchange site is higher than that of the current occupying atom. In general, most media have a preference for small hydrated ions with a greater positive charge over larger hydrated ions with a single positive charge.

For commonly found metals in stormwater runoff, predictions can be made using a periodic table of elements. Staying within the same row of the table and proceeding left to right produces an increasing affinity for cation exchange. This trend is promoted due to the metal atom remaining in the same valence state (charge) while the overall diameter of the atom decreases. Since the diameter decreases, the "apparent charge" of the atom increases, thus producing the driving mechanism for cation exchange. For most purposes the following affinity series is true:

$$Al^{3+} > H^{+} > Zn^{2+} > Cu^{2+} > Ni^{2+} > Fe^{2+} > Cr^{2+} > Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$$

The media-bound ions utilized with cation exchange filtration are calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) with calcium and magnesium being the primary exchange ions due to their abundance within the media matrix. As presented above, zinc, copper and iron (as well as others) will force the displacement of the calcium and magnesium ions from the media. Media promoting cation exchange include: CSF leaf media (93.8 meq/100-grams) and Zeolite (125 meq/100 grams).

Chelation

Chelation refers to the process of a metal being bound by a ligand to form a cyclic compound. Essentially it is the binding of a metal ion to a chemical or complex within the media. Some describe the process as a 'crab claw' grabbing onto a metal ion and holding onto it. Media promoting metal chelation include: CSF leaf media and MetalRx media

Adsorption

Adsorption is the attraction and adhesion of a dissolved contaminant to the media surface. This occurs at the surface as well as within the pores of the media granule. Adsorption requires that a contaminant come in contact with an active surface site on the media and time must be allowed for the contaminant to adhere. These reactions are usually promoted by polar interactions between the media and the pollutant. Adsorption can also occur within the dead end pores and channels of the media but is generally slower than a surface reaction due to limits of the contaminants diffusion into the pore. The contaminant's molecular size will limit diffusion in that the media’s pore opening must be larger than the dissolved contaminant.

Commonly adsorbed pollutants include: gasoline, oil, grease, TNT, polar organics or organically bound metals and nutrients. Media promoting adsorption reactions include: CSF leaf media, PhosphoSorb, Perlite, and Granular Activated Carbon.

3.1.9 Hydraulic Capacity

The StormFilter is typically designed to treat the peak flow of a specified water quality design storm. The on-line or off-line water quality treatment design rate is utilized in conjunction with Ecology’s allowed hydraulic loading rate for the StormFilter system to determine the number of cartridges required.

Since the StormFilter is designed to accommodate the water quality design flow, three situations could occur during a given storm event: 1) flows below the design flow; 2) flows at the design flow; and 3) flows in excess of the design flow. These situations can sometimes occur all within a single storm event.

1) Flows below the design flow: The predetermined flow rate through the StormFilter cartridge is the maximum filtration rate of the cartridge. The head and tail ends of a storm event may have minimal flows. If these low flows don’t provide enough volume to raise the water surface elevation in the vault, these smaller flows may not activate the siphon mechanism of the cartridges (see Figure 4). Stormwater entering the unit will still be treated at a lower flow rate. An increase in performance results due to longer residence time, reduced flow rate, and increased media contact for storms below the water quality design.

2) Flows at the design flow: Once event flows reach the design flow rate, the siphon mechanism of the cartridges is activated and the flow is treated at design capacity for the duration of the event.

3) Flows in excess of the design flow: Flows exceeding the design flows can be bypassed internally through an overflow riser for an on-line system or by using an upstream, external, flow splitter, such as the

StormGate, an adjustable weir for off-line systems. Each StormFilter unit has design guidelines for the maximum allowable internal bypass, which varies by configuration.

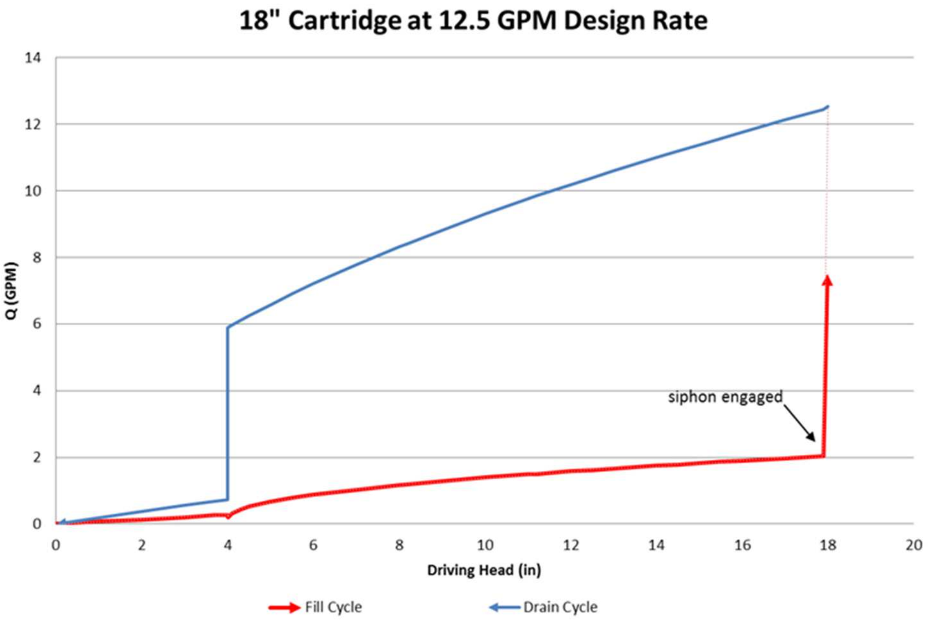

Figure 4. StormFilter fill and drain cycle at 12.5 gpm for an 18" tall cartridge.

3.2 Site Requirements

The following sections address the site requirements for StormFilter applications.

Soil characteristics

The StormFilter typically consists of an underground structure, such as steel catch basins or concrete manholes or vaults. If stabilization of the vault can be assured, soil conditions are not relevant.

Hydraulic grade requirements

Hydraulic grade requirements for the StormFilter vary, depending on the cartridge height used. The following table summarizes the hydraulic drop required for each of the three cartridge heights available.

Table 3. Cartridge Heights

Cartridge Type	Hydraulic Drop
StormFilter 27"	3.05'
StormFilter 18"	2.30'
StormFilter Low Drop	1.80'

Depth to groundwater limitations

Buoyancy calculations relative to groundwater level should be performed to determine if vault flotation is a concern.

Applications that the manufacturer recommends for the technology

The StormFilter can be used for a variety of land uses such as residential, commercial, industrial, and roadway. Depending on the type of land use pretreatment and media selection should be evaluated for each individual project.

Pretreatment requirements

Pretreatment of TSS and oil and grease may be necessary and shall be provided as recommended by local site requirements. Guidance includes evaluating sites that contain high amounts of oil and grease, such as vehicle maintenance yards, and pre-settling of sediment to reduce loading. An example of recommendations for determining the need for pretreatment sedimentation is below.

Table 4. Pretreatment Requirements

Site Type	Recommendation
Roadways with no curb and gutter	Required
Roadways with curb and gutter	Recommended
Development with steep slopes and erosive soils	Required
Single Family Developments	Recommended
Multi-family Developments	Optional
Small 2 acre or less commercial	Optional

List of facilities installed in the US. Include location, land use, and size of each facility.

There have been six StormFilter systems with PhosphoSorb media operating at 1.67 gpm/ft^2 installed in Washington State under a Conditional Use Level Designation. An installation list has been previously provided to Ecology in March 2015.

Other site characteristics:

- Steep slopes: A retaining wall may be required. Evaluate the site for maintenance access.
- High groundwater: If discharge is to infiltration, evaluate the system for potential backwater effects. Also, evaluate for buoyancy concerns
- Seepage or base flows: These may need to be bypassed around the StormFilter. These constant, low flows may cause the growth of algae on filtration media.
- Tidal action: Systems should be evaluated for the potential of tidal action to cause backwater into the system. The impact on design may vary with the amplitude and frequency of tidal action as compared to the frequency and depth of filter inundation. Although tidal valves have been used for these applications in the past, they are typically not recommended due to the additional head required to get flow out of the StormFilter.
- Proximity to wells, septic systems and buildings: Groundwater calculations should be buoyancy issues. Access for maintenance should be evaluated. Refer to receiving water recommendations for selecting media type within wellhead protection zones.
- Facility depth limits for access and safety: StormFilter units have been installed up to a depth of 17 feet, thus far. Access and safety requirements may include standard OSHA confined space entry procedures.

- Risk of hazardous material spills: The StormFilter can be equipped with downstream valves to prevent the loss of material spills. However, the StormFilter is not designed for containment of spills.
- Driving head requirements: Hydraulic grade requirements are dictated by cartridge height and are defined above. These requirements may be adjusted in some circumstances with more knowledge of backwater effects, pipe diameters, and acceptability of pipe submergence.
- Power availability: No power is required for typical applications. For areas that have limited drop, a pump and power source may be required.

3.3 Sizing Methodology

For jurisdictional authorities in Western Washington without a specified water quality design method, the Western Washington Continuous Simulation Hydrology Model (WWHM) will be used to size the StormFilter system in accordance with the latest Washington State Department of Ecology (Ecology) Stormwater Management Manual. For jurisdictions with other design methodologies, such as King County, the StormFilter system will be designed according to their design methodology (for example, KCRTS method outlined in King County).

The primary design methodology for Washington is the flow-based methodology. In general, the StormFilter sizing is based on the water quality design storm designated by the regulatory agency. Water quality flow rates from the design storm are used to calculate the number of cartridges required to accommodate the flow rate. The per-cartridge flow rate is specified by the Use Level Designation. Once the required number of cartridges has been calculated, the size of the facility to accommodate those cartridges can be determined.

Other possible design methods include: volume-based designs, mass-loading designs, and downstream of detention designs.

3.3.1 Design criteria – Expected pollutant removal

Under influent conditions typical of municipal projects in the Pacific Northwest region, the StormFilter with PhosphoSorb media is expected to achieve 80% removal of TSS and greater than 50% total phosphorus at the design flow.

3.3.2 Design criteria – Design hydraulics

Typically, the StormFilter is sized to treat the peak flow of a water quality design storm. The on-line or off-line water quality treatment design rate from WWHM is utilized in conjunction with Ecology's allowed hydraulic loading rate for the StormFilter system to determine the number of cartridges required. The following table summarizes the available cartridge hydraulic loading rates.

Table 5. Hydraulic Loading Rate per Cartridge Height and Specific Flow Rate

StormFilter Cartridge Type	Per Cartridge Flow Rate at 2 gpm/ft^2	Per Cartridge Flow Rate at 1.67 gpm/ft^2	Per Cartridge Flow Rate at 1 gpm/ft^2	Hydraulic Drop Required
Low Drop	10 gpm	8.4 gpm	5 gpm	3.05'
18"	15 gpm	12.5 gpm	7.5 gpm	2.3'
27"	22.5 gpm	18.8 gpm	11.3 gpm	1.8'

Since the StormFilter is designed to the water quality design flow, three conditions exist for incoming storms: flows are below the water quality design flow, equal to the water quality design flow, or in excess of the water quality design flow. All three conditions could occur within a single storm event.

For events producing flows below the water quality design flow (or for the portion of an event, such as the head and tail ends of the hydrograph), the siphon mechanism of the cartridges may not be activated, since the depth of water in the vault may not reach the kick-point of the cartridges. Stormwater entering the unit can only exit through the cartridges, and will be treated at a lower flow rate. An increase in performance could result due to the lower flow rate and thus longer residence time in the system and increased media contact time.

For events producing flows equal to the water quality design flow, the cartridge siphon mechanisms will be activated and the flow will be treated at the design capacity for the duration of the event.

For events producing flows in excess of the water quality design flow, the cartridge siphon mechanisms will be activated, and the system will treat at the design capacity. Once the inflow exceeds the cartridge capacity, additional flows will be diverted through the internal or external flow splitters (depending on which is available). This additional flow will not be treated by the cartridges, but also shall be diverted to prevent resuspension of previously accumulated sediment. Each StormFilter unit has specific design guidelines for the maximum allowable internal bypass capacity to minimize resuspension and/or scour.

3.3.3 Design criteria – Residence time and velocities

As a rule of thumb, the average residence time in the StormFilter system is approximately six minutes. However, the performance of the system is primarily dictated by contact time with the filtration media rather than system residence time.

3.3.4 Design criteria – Treatment limitations

The potential for biofilm development on the media is reduced by preventing standing water within the cartridge bay. This allows the media to dry out between storm events. Also, each StormFilter cartridge has a cartridge hood cover with perforations at the base (scrubbing regulators). As the storm event subsides, and the water surface elevation in the vault drops, air enters the scrubbing regulators and the siphon collapses. The turbulent interchange of water under the cartridge hood being displaced by bubbles entering through the scrubbing regulators agitates and displaces accumulated pollutants on the surface of the filtration media. This provides additional protection from development of biofilm and fouling.

3.3.5 Design criteria – Specific media flow rate

The StormFilter can be designed at multiple media flow rates. The two primary design flow rates are 1 and 2 gpm/ft^2. StormFilter with PhosphoSorb media has been evaluated at 1.67 gpm/ft^2 for this application. Cartridge flow rates vary depending on the application, regulatory approval and targeted pollutants.

3.3.6 Design criteria – Media head loss curves

The nature of the StormFilter cartridge and its operation create a constant radial flow rate throughout the cartridge. Throughout most of the life of the cartridge, flow through the cartridge is controlled by the cartridge restrictor disc and is relatively independent of the media head loss. The total dynamic head loss through the system depends on the cartridge height in use. These losses are summarized in the table in Section 3.3.2 above. The hydraulic drop required is determined from the upstream water surface elevation to the downstream water surface elevation. Over time, as the media begins to occlude, the media head loss could begin to dictate the flow through the cartridge. At this point, the system may need evaluation for determining maintenance.

3.3.7 Design criteria – Media contact time and thickness

The StormFilter cartridges all have the same diameter regardless of height and flow rate. Therefore, the media thickness is consistently 7 inches. Cartridge media volume varies with cartridge height. The filtration media contact time also varies, depending on cartridge flow rate. The StormFilter with PhosphoSorb media operating at a specific flow rate of 1.67 gpm/ft^2 has a media contact time of approximately 46 seconds.

3.3.8 Design criteria – Estimated design life

The design life of the concrete structures is typically 50 years. The design life of the steel structures is typically 20 years. The design life of the cartridges is typically 20 years, assuming annual maintenance has been performed.

3.3.9 Design criteria – Media specifications

Media specifications for the PhosphoSorb media are included in Appendix A.

3.3.10 Western Washington Sizing

In Western Washington, the StormFilter system must be sized to meet applicable performance goals at the design flow rate coinciding with treating at least 91 percent of the total annual runoff volume, using an Ecology-approved continuous simulation model such as WWHM, KCRTS, or MGS Flood. Depending on the configuration of the StormFilter and bypass, the on-line or off-line flow rate should be used as applicable.

If the StormFilter system is located downstream of a detention facility, it must be sized to meet the full 2-year release rate of the detention facility.

3.3.11 Eastern Washington Sizing

In Eastern Washington, the StormFilter typically will be sized to treat the runoff flow predicted for the proposed development condition from the short-duration (3-hour) storm with a 6-month return frequency.

If the StormFilter system is located downstream of a detention facility, it must be sized to meet the full 2-year release rate of the detention facility.

3.4 Installation

3.4.1 Installation Requirements

For precast StormFilter units (such as the vault, manhole, and curb-inlet configurations), the StormFilter is typically delivered to the site with the underdrain manifold in place, as well as internal components including cartridges, flow spreaders, and energy dissipators as specified. The contractor is responsible for base preparation, for providing equipment as needed, and for setting the precast unit as specified. The influent and effluent pipes are then connected by the contractor. If required, the contractor shall also provide ballast as specified on the plans. Backfill material and placement shall be in accordance with the plans. Many precast units are delivered to the site with construction bypass lines in place. Once construction is complete, landscaping is in place, and the site has been stabilized, the contractor is responsible for activating the StormFilter system. Depending on the method of protecting the system from construction runoff, this step may include installation of the cartridges, removal of any inlet pipe plugs, and installation of construction bypass plugs.

For cast-in-place, CON/SPAN, or other high flow units, the contractor is responsible for constructing or installing the vault as specified on the site drawings. Once the vault is complete, the flow kit will be ready for installation. The contractor is responsible for setting the underdrain manifold as specified in the plans; location and spacing of the manifold are critical. The underdrain manifold is then cast in place using a secondary concrete pour by the contractor. Other internal components including cartridges, flow spreaders and energy dissipators shall be installed by the contractor as specified.

3.4.2 Provisions for other factors (structural integrity, water tightness, buoyancy)

- Structural integrity: Most StormFilter systems are designed for an H-20 load rating. For precast units, stamped structural calculations can be provided upon request. For cast-in-place units, structural calculations are the responsibility of the site engineer or contractor.
- Water tightness: For precast units, structure joints are typically filled with Conseal. If applied correctly, vaults can be considered watertight.
- Buoyancy: Buoyancy calculations can be performed for vaults that will be located in areas with suspected high groundwater levels, upon request.

3.4.3 Potential problems that can occur during design and installation

Potential design issues:

- Backwater: If downstream hydraulic conditions are not evaluated during the design process, backwater conditions may impact the filtration capacity of the StormFilter
- Base flows: Base flows or seepage flows should be bypassed around the cartridges to ensure proper functioning and design life of the cartridges and filtration media.
- Excessive solids loading: Usually high sediment loading should be addressed during the design phase of the project to determine if pretreatment is needed.

Potential installation issues:

- Invert elevations: Correct installation of the StormFilter inlet and outlet piping is crucial for proper operation of the system.
- Construction sediment: If the StormFilter is placed online before the site is stabilized, construction sediment may reduce the capacity of the cartridges for the design goal of removing post-construction sediment. If construction sediment is allowed to enter the system, more frequent maintenance of the system may be required.
- Vault placement and floor leveling: It is necessary for the vault to be set or constructed level to ensure proper functioning of the cartridges.

3.4.4 Methods for diagnosing and correcting potential problems

- The Engineering and Customer Service Department at Contech offers full technical support for all applications of our products. During the design phase, Stormwater Design Engineers offer to assist with plan preparation and can provide a technical review of the system. This review provides an opportunity to review elevation requirements, system sizing and placement, backwater evaluation, as well as maintenance access.
- Contech also provides design overview and construction support directly to the contractor and/or owner during the bidding and construction phases of the project.
- If there are problems with the structure or components during delivery, Contech will work to resolve these issues prior to installation of the system.

- If problems develop during or due to the installation of the system, Contech will work with the contractor to effect repairs to ensure proper operation of the system.

3.4.5 Impacts to effectiveness if problems are not corrected

- Backwater: Backwater will reduce the driving head across the filter and will reduce treatment flow. Backwater may also saturate the filtration media for extended periods of time, increasing the possibility of microbial occlusion of the media.
- Base flows: If base flows enter the system, the filtration media may become exhausted prematurely. This could also result in microbial occlusion of the media. This will affect the life of the cartridges and more frequent maintenance will be required. In some cases, base flow bypasses can be installed retroactively.
- Excessive solids loading: Heavy solids loading without pretreatment may cause premature occlusion of the cartridges. Required maintenance frequency may increase in this case.
- Invert elevations: If the StormFilter is incorrectly installed and insufficient drop is provided across the system, the system may experience early bypass and may not be able to fully treat the design flow rate.
- Vault placement and floor leveling: If the unit is not installed level, the design flow rate through the cartridges may not be achieved before early bypass. In addition, some cartridges may treat a disproportionate amount of the flow and thus may occlude more quickly than others.

3.4.6 Technology availability (sourcing and lead time)

- Precast units: For precast units, the concrete structures can be provided by many precasters throughout the region. Typical lead time required is 4 to 6 weeks from shop drawing approval by the contractor to vault delivery.
- Catch basin units: Steel catch basin units are sourced from a supplier in Portland, Oregon. Typical lead time required is 2 to 4 weeks from shop drawing approval by the contractor to catch basin delivery.
- StormFilter components: The cartridges, underdrain manifold, flow spreaders and energy dissipators are supplied by Contech. These components typically require 2 to 3 weeks lead time.

3.5 Operation and Maintenance Requirements

3.5.1 Inspections – Frequency and methodology

At least one scheduled inspection should take place per year with maintenance following as warranted. An inspection should be performed prior to the winter season. During the inspection, the need for maintenance should be determined by checking the accumulated materials in the system. It is also important to check the condition of the StormFilter after major storms for potential damage caused by high flows and for sediment accumulation that may be caused by localized erosion in the drainage area. It may be necessary to adjust the inspection/maintenance schedule depending on the actual operating conditions encountered by the system. In general, inspection activities can be conducted at any time, and maintenance should occur, if warranted in late summer or early fall when flows into the system are less likely to be present.

3.5.2 Maintenance triggers and rationale

The need for maintenance is typically based on results of an inspection. The following criteria should be used as a guideline for when maintenance is required:

- Sediment loading on vault floor could be an indication that the mass loading capacity of the system has been reached. If there is greater than 4” of accumulated sediment, maintenance is required.
- Sediment loading on top of the cartridges could be an indication that the influent water is not passing through the cartridges at the design flow rate (suspended sediment has time to settle out instead of passing through the filtration media). If there is greater than ¼” of accumulated sediment on top of the cartridges, maintenance is required.
- Submerged cartridges could indicate that the cartridges are completely plugged. However, this could also be due to backwater conditions caused by high groundwater, plugged pipes, or high hydraulic grade lines. Completely plugged cartridges could also be associated with heavy oil and grease loading, which might require additional source control measures. If there is greater than 4” of static water in the cartridge compartment for more than 24 hours after the end of the rain event, maintenance is required.
- Plugged media could be an indication that the mass loading capacity of the system has been reached. If pore space between the media granules is absent, maintenance is required.
- Prolonged bypass flow could indicate that the cartridges are in bypass and that the mass loading capacity of the system has been reached. If inspection is conducted during an average rainfall event and the StormFilter remains in bypass condition (water over the internal outlet baffle wall or submerged cartridges), maintenance is required.
- The presence of hazardous materials could indicate a spill. If hazardous material release (automotive fluids or other) is reported, maintenance is required.
- The presence of a pronounced scum line could indicate excessive bypass. If a pronounced scum line (greater than ¼” thick) is present about cartridge top cap, maintenance is required.
- Finally, a history of the maintenance should be kept in maintenance files. This helps provide an understanding of maintenance requirements over time. If a system has not been maintained for 3 years, maintenance is required.

3.5.3 Maintenance methodology

Depending on the configuration of the particular system, maintenance personnel may be required to enter the system to perform maintenance. If this is required, OSHA rules for confined space entry must be followed.

The first step in maintaining the StormFilter system is to open and vent the system (as applicable) and then perform a visual inspection of the system, both internally and externally. Next, the cartridges and spent media are removed from the system. This may be accomplished in several ways: 1) the full cartridges can be detached from the underdrain manifold and removed the vault using appropriate lifting equipment, 2) the cartridges can be detached from the underdrain manifold, tipped to the side to dump the spent media onto the floor of the vault, and then the empty cartridges are manually removed from the vault, or 3) the cartridges can be detached from the underdrain manifold, media from the cartridge is removed directly from the vacuum hose, and then the empty cartridges are manually removed from the vault. Once the cartridges have been removed, the remaining accumulated sediment (and/or spent media) on the floor of the vault and in the forebay (if applicable) are removed. Typically, this is most easily achieved using a vactor truck. The structure should then be inspected for structural conditions and new cartridges are lowered into the system and connected to the underdrain manifold. This is most easily achieved with lifting equipment.

Collected sediment and spent media should then be disposed of in accordance with applicable regulations. Consideration should be made for disposal of both liquid and solid wastes. Empty cartridges are returned to Contech to be cleaned, refurbished, and/or updated for use at another site.

3.5.4 Maintenance area accessibility by people and equipment

Depending on the type of StormFilter system installed, confined space entry may be required. If this is the case, personnel should follow appropriate confined space entry procedures and use appropriate equipment.

Maintenance equipment, such as vactor trucks and/or lifting equipment should have full access to the system.

3.5.5 Estimated maintenance frequency and basis for determination

Generally, the design maintenance frequency for the StormFilter is once per year, based on extensive experience with rainfall conditions, typical site loadings, and multiple system installations in the Pacific Northwest. On a site-by-site basis however, maintenance frequency should be determined during the site evaluation and inspection process.

Additionally, maintenance should be performed in the event of a spill or other unusual loading event.

3.5.6 Estimated media capacity for pollutant removal

All filtration systems have a limited capacity for pollutant removal before a reduction in performance occurs. Typically, sediment is the limiting pollutant for stormwater treatment applications. For the StormFilter, the sediment mass load capacity of the cartridge is inversely proportional to the design flow rate of the cartridge. The lower the filtration rate of the cartridge, the more mass load is removed by that cartridge, due to the increased residence time (and thus settling time) in the structure. The following table summarizes the mass load capacity design parameters for StormFilter.

Table 6. StormFilter Sediment Mass Load Capacities

StormFilter Cartridge Type	Mass Capacity at 2 gpm/ft^2	Mass Capacity at 1.67 gpm/ft^2	Mass Capacity at 1 gpm/ft^2
Low Drop	15 lbs	19 lbs	24 lbs
18”	23 lbs	29 lbs	36 lbs
27”	34 lbs	44 lbs	54 lbs

3.5.7 Estimated design life of facility and components

The design life of the concrete structures is typically 50 years. The design life of the steel structures is typically 20 years. The design life of the cartridges is typically 20 years, assuming annual maintenance has been performed.

3.5.8 Maintenance equipment and materials

Maintenance equipment and materials typically include:

- Equipment for removal of both solid and liquid wastes, such as a vactor truck
- Pump for removal of water due to complete system occlusion, if needed
- Shovel for removal of sediment from structure

- Lifting equipment for removal of old cartridges and installation of new cartridges. A lifting cap (4" PVC threaded end cap with lifting ring) for installations prior to 2004) or a lifting hook for raising or lowering cartridges in the vault.
- Very large systems may assess the need for a boom truck or crane.

3.5.9 Maintenance service contract availability

Maintenance service contracts are available through a list of Preferred Maintenance Service Providers. These providers have been trained to provide inspections and maintenance of all StormFilter systems. Contech can offer replacement cartridges directly to the owner, or to the service provider. The service provider typically provides all field services related to maintenance. Costs vary by size and type of the system, as well as location of the site, and are managed by the service provider.

As a rule of thumb, for a system with greater than 50 cartridges, the cost (2015) of a full-service maintenance is approximately $200 per cartridge for ZPG media. Costs may vary for other filtration media options.

3.5.10 Solids and media disposal

Solids and spent media are analyzed for total metals (Cu, Zn, Pb, As, Hg, Cd, Mo, Ni, Se) and total petroleum hydrocarbons (NWTPH-Dx) as necessary to comply with local disposal regulations and permit requirements. Except in the case of hazardous spills, all disposals have generally been to standard landfills.

3.5.11 Impacts of delayed maintenance

Delayed maintenance has no effect on the performance of the system, with the exception of reduced hydraulic capacity. Restoration of the system typically involves simply removing the accumulated sediments and replacing the cartridges.

3.5.12 History, availability of materials and parts from manufacturer

The history of Contech is available at www.ContechES.com and has been in business for over 100 years. The media-filled cartridges are the primary component required to keep the system functioning properly. Cartridges can be filled with a variety of non-proprietary filtration media that the owner can find "off-the-shelf" and can use to recharge the system to proper working order. Maintenance of the system can be performed by any vactor-truck service provider. In the event that Contech should no longer exist, these maintenance service providers will be able to assist the owners in maintenance of the system.

3.6 Reliability

3.6.1 Other factors that affect performance

Excessive solids loading due to unaccounted sources (such as vehicle washing, disposal of materials in upstream catch basins, generally poor housekeeping on a site) could affect the performance of the system. Addition of surfactants to the influent stream could also prevent the media from providing removal of pollutants as expected.

3.6.2 Circumstances in which the technology can add, transform or release pollutants

Accumulated pollutants may be released during extreme events, as with all treatment systems, unless the system contains an external bypass. However, the first flush from extreme events will be treated through the filtration media even though the entire event runoff may not be treated.

3.6.3 Media decomposition or bacterial growth issues

No filtration media utilized by the StormFilter decompose. In a standard application, since the system drains down completely between rainfall events, the filtration media are not subject to slime or bacterial growth. However, if there are continuous base flows at the site, or if the cartridges remain in standing water due to backwater conditions or occlusion, a biofilm may develop on the cartridges. In order to prevent this condition, a low-flow bypass can be installed.

3.6.4 Sensitivity to sediment loading and pretreatment requirements

Sites with heavy loadings of sediment should provide pretreatment upstream of the StormFilter to prolong the life of the cartridges. This is typically evaluated during the design phase of the project. Pretreatment is not required for every site. Pretreatment should be considered based on land usage and/or for sites that produce heavy oil and grease loadings or high solids loadings.

3.6.5 Diagnosis of underperformance and response

Performance in relation to pollutant removal can be addressed through the use of an alternate media. Finer grain sizes of media can also be selected to provide more surface area and increased pollutant removal capabilities. The cartridge flow rates can also be adjusted to vary the contact time with the media and increase or decrease the pollutant removal efficiency accordingly.

3.6.6 Warranty

A detailed warranty is available at www.ContechES.com.

3.6.7 Provision of user support

Contech provides complete support of all StormFilter systems. This includes support throughout system design phase, product delivery, and installation of the system. Once the system is online, support is also available. The support may pertain to engineering, maintenance, research, or other aspects depending on client's needs.

3.7 Other Benefits or Challenges

3.7.1 Other benefits or challenges in other potentially relevant areas, such as groundwater recharge, thermal effects on surface waters, habitat creation, aesthetics, vectors, safety, community acceptance, recreational use, and efficacy on redevelopment sites.

- The StormFilter does not impact groundwater recharge.
- The StormFilter does not have thermal effects on surface waters.
- The StormFilter does not provide habitat creation.
- The StormFilter can increase the clarity of water and reduce odor associated with anaerobic conditions from standing water, which would benefit aesthetics. Additionally, the use of the StormFilter has prevented the destruction of habitat since when it was used instead of larger, above-ground systems.
- The StormFilter can provide vector control options if needed.
- The StormFilter does not create a safety issue since the vaults are typically underground, completely closed and require a tool for opening access ports.
- Community acceptance of the StormFilter is very strong.
- The StormFilter has been used for recreational sites such as marinas and boatyard applications to reduce toxicity.
- The StormFilter has frequently been used in redevelopment and retrofit applications.

3.7.2 Copper, lead or zinc components

There are no copper, leads or zinc components of the standard StormFilter system that may be exposed to stormwater runoff and could potentially leach into the effluent.

3.7.3 Concrete components

There is no evidence that the concrete vault impacts the pH or causes pH fluctuations in the effluent.

4.0 Results from Previous Studies

A summary of previous studies has been provided to demonstrate the StormFilter with PhosphoSorb media and its ability to remove dissolved phosphorus and Sil-Co-Sil 106 in the laboratory; and field testing using a volume-based StormFilter in North Carolina for TSS, total phosphorus, and total nitrogen.

4.1 Bench testing

In bench testing, PhosphoSorb achieved an average of 50% removal of dissolved phosphorus for the first 1,000 treated bed volumes (CES, 2011). Significant removal was provided through 2,000 treated bed volumes (CES, 2011). In the same test using GAC media, 30% removal was achieved through 1,000 bed volumes.

4.2 Sil-Co-Sil 106 testing

PhosphoSorb media was tested in a StormFilter cartridge to assess its ability to remove suspended solids and decrease turbidity from simulated stormwater. The contaminant surrogate used for these tests was Sil Co Sil 106®, which has a silt texture (25% sand, 65% silt, 10% clay). Utilizing a standardized contaminant surrogate eliminates contaminant characteristics as a variable, thereby allowing comparison of StormFilter performance test results involving different media or treatment systems that used the same contaminant surrogate.

The test included 8 runoff simulations at 7.5 gpm (28 L/min) and 7 simulations at 15 gpm (56 L/min) using influent variable event mean concentrations (EMCs) between 0 and 300 mg/L (Ma, 2009). Regression statistics were used to determine the mean suspended solids concentration (SSC) removal efficiency for each flow rate. For the test at 7.5 gpm, this was calculated as 88% (P=0.05: L1=87%, L2=89%) and for the test at 15 gpm was calculated as 82% (P=0.05: L1=80 %, L2=84%).

4.3 Field Testing

Results from the twenty month field study in North Carolina, representing a total of 13 storm events and 27.73 inches of precipitation, show that the StormFilter system effectively removed solids and nutrients from stormwater runoff. The StormFilter system tested was designed to capture and treat the 1-inch water quality volume, typical for the Piedmont region of North Carolina, at a cartridge specific flow rate of 1 gpm/ft^2 with PhosphoSorb media. The StormFilter system was also designed on a mass-loading basis to meet the annual pollutant loading requirements of the site with a minimum expected interval of 1 year.

Significant reductions for solid and nutrient pollutants were observed between influent and effluent. The Efficiency Ratio calculation method resulted in TSS removal of 90%, total phosphorus removal of 86%, and total nitrogen removal of 56%. The Summation of Load (SOL) efficiency calculation resulted in TSS removal of 91%, total phosphorus removal of 87%, and total nitrogen removal of 50%.

5.0 Sampling Procedures

5.1 Site Description and Vicinity Map

The Lolo Pass Road evaluation site is located in Zigzag, Oregon and is situated at the west protruding end of Zigzag Mountain in the foothills of Mt. Hood, which is part of the Cascade Mountain Range. The site, located on Lolo Pass Road at Bear Creek Bridge, is a 100% impervious medium use road which sits approximately 1400 feet above sea level. The 0.063 acre (2800 square feet) contributing drainage area is comprised of bridge deck and is located at the intersection of Lolo Pass Road and US Highway 26 (Lat: 45.34420862, Lon: -121.94275218). The bridge and adjacent roadway are managed by the Clackamas County Department of Transportation and Development. An aerial view of the site from 2005 is shown in Figure 5.

The site is swept periodically, but significant amounts of sediment and organic debris are typically present on site. Sanding, graveling, and deicing occur on site as necessary during the winter to control ice accumulation and to assist with tire traction. The time of concentration (t_c) on the site is estimated to be 1.4 minutes. A view of the treatment area for the Lolo Pass Site can be seen in Figure 6.

The StormFilter system evaluated at the Lolo Pass Road site is a flow-based treatment unit with no upstream detention or pretreatment. It is located within a larger preexisting vault on site which was modified to house flow monitoring equipment as well. The system is in an online configuration where bypass is directed through the treatment system. A photo of the exterior of the StormFilter system at Lolo Pass Road can be seen in Figure 7.

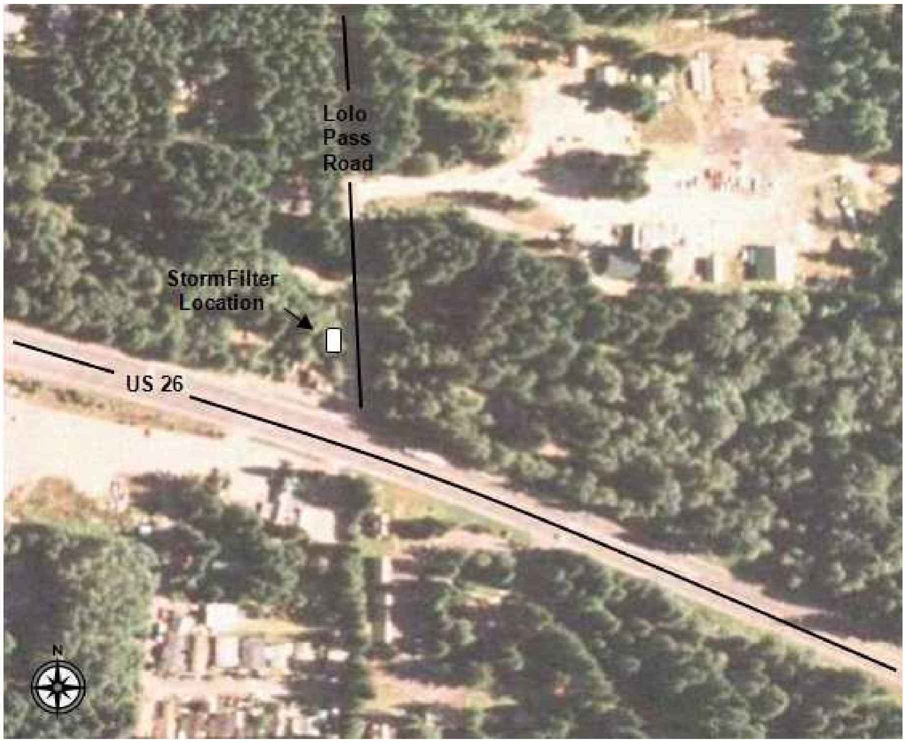

Figure 5. Aerial view of the Lolo Pass Site.

Figure 6. View of the drainage area of the Lolo Pass Site looking south towards US26.

Figure 7. External view of the StormFilter system at Lolo Pass Road.

5.2 Treatment System Description and Sizing

Stormwater treatment for the site is provided by a StormFilter system containing one 18-inch StormFilter cartridge with PhosphoSorb media operating at a specific flow rate 1.67 gpm/ ft^2 or 12.5 gpm per 18-inch tall cartridge. The TAPE (2011) has placed additional emphasis on analyzing the pollutant removal as a function of flow rate. Previous testing at the site evaluated a system with a higher design flow rate. To facilitate evaluation over a range of treatment flow rates, a single cartridge with a design operating rate of 12.5 gpm was selected. Details on the hydraulic flow rate evaluation, mass loading considerations, and cumulative load analysis are provided in the approved QAPP (Appendix B). In summary, the anticipated load from the site would result in a mass load sizing that was 4 times greater (i.e. 4 cartridges).

5.3 Monitoring Information and Equipment Locations

The equipment and sampling techniques used for this study are in accordance with the 2011 version of the Washington Department of Ecology TAPE (TAPE, 2011). Contech personnel were responsible for the installation, operation, and maintenance of sampling equipment, sample retrieval and system reset, and sample submittal activities. Water sample processing and analysis was performed by Test America and APEX Labs (Analytical Laboratory), both located in Beaverton, Oregon.

Influent and effluent samples were collected using individual ISCO 6712 Portable Automated Samplers configured for standard, individual, round, wide-mouth 1-L HDPE bottles sample bottles. The samplers were connected to individual 12VDC deep cycle batteries that were replaced periodically throughout the project. Influent and effluent flows were measured using Large 60°V Trapezoidal Flumes (primary measurement device) in conjunction with individual ISCO 730 Bubbler Flow Modules (secondary measurement devices). Influent and effluent flow was monitored continuously throughout the evaluation period in 5-minute data intervals. Figure 8 shows the flow measurement locations, flow path within the system, and sampling locations.

Each sampler was also connected to an ISCO SPA 1489 Digital Cell Phone Modem System to allow for remote communication and data access. Rainfall was measured using a 0.01-in resolution Texas Electronics tipping bucket-type rain gage. The location of the rain gage at the monitoring site can be seen in Figure 7. Sample tubing, 3/8” ID Acutech Duality FEP/LDPE tubing, was routed from each automated sampler to influent and effluent sample locations. Sample intakes were located at the invert of both the influent and effluent sample locations.

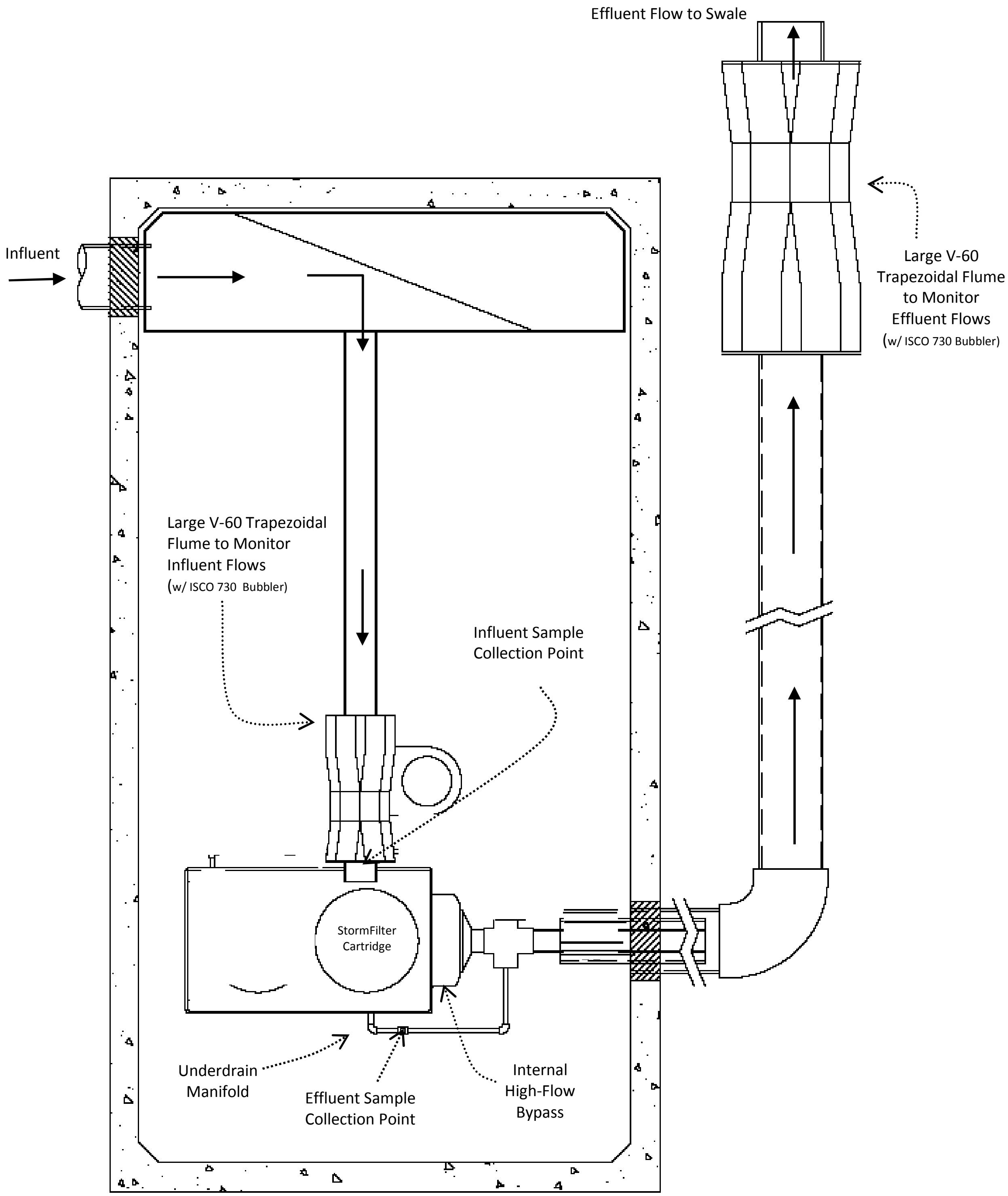

Figure 8. Flow path through the StormFilter system at Lolo Pass Road.

5.4 Approved QAPP

A copy of the approved QAPP can be found in Appendix B of this report.

5.5 Deviations from Approved QAPP

There were no deviations to the water sampling methods from the approved QAPP. Residual solids assessment from the material in the system was not conducted during maintenance. The TAPE (2011) lists sediment sampling as optional.

5.6 Summary of Challenges

There were numerous challenges encountered during the evaluation. A summary of unanticipated events and challenges are below:

- Construction activities from a bridge replacement project downstream (2012). Bridge was washed out by high flows.
- Equipment: Multiple thefts of solar panels which were used to increase battery power during cold weather. Measures to restrict battery power were implemented.
- Analytical laboratory change to obtain consistent lower detection limits for key analytes.
- Data storage drives (network, computer, and replicate storage) malfunction causing loss of hydraulic and precipitation data.

6.0 Data Summaries and Analysis

The section summarizes the water quality data collected during the evaluation. Data have been compiled and compared to the guidelines provided in the TAPE (2011) and outlined in the approved QAPP (Appendix B). None of the events monitored were disqualified due to a storm event criteria variance, however, seven storm events were disqualified due to variance from the sample collection criteria. One additional event, LPR021012, was disqualified as the system had not yet stabilized from a February 2, 2012 maintenance event. A low intensity, small volume event occurred on February 8, 2012 that did not produce sufficient volume to stabilize the media bed.

6.1 Storm Event Criteria

A total of 25 events were sampled at the site from February 2012 to February 2015. Field Recordkeeping forms for these events can be seen in Appendix C. There were zero disqualifications to the sample population (n=25) related to the storm event criteria. Six events did contain an antecedent dry period that was less than 6 hours. Table 7 provides a summary of storm event criteria.

The following findings summarize compliance with the storm event criteria:

- Storm event depth was greater than 0.15-inches for all events sampled.
- Minimum storm duration was greater than 1-hour for all events sampled.
- A range of average rainfall intensities were observed from 0.01 to 0.1 inches per hour.
- Antecedent times greater than 6 hours for pre-storm and post-storm satisfied the 6 hours with rainfall less than 0.04 inches with exception of:
    - Pre-storm: LPR052412, LPR060412, LPR062513, and LPR013014
    - Post-storm: LPR060412 and LPR062513

The antecedent condition criteria are intended to allow pollutant concentrations to build-up on the site for evaluation purposes. These events contained influent concentrations within the targeted concentration ranges; therefore, the data were included in the performance evaluation.

6.2 Sampling Collection Criteria

The sample collection criteria were satisfied for 17 storm events. Seven events were disqualified as the 75% storm event coverage criteria were not satisfied. These events are LPR022012, LPR031012, LPR032912, LPR111112, LPR112312, LPR030814, and LPR042214. Appendix D contains Individual Storm Reports for each event (n=25).

- A minimum of 10 aliquots were collected for each event with exception to event LPR021412.
- A minimum storm event coverage goal of 75% was met for each event listed in Table 7, with exception of LPR051713 which was 74% for the influent.
- The sampling duration was less than 36 hours for all events sampled.
- The minimum number of samples exceeded 12 storm events.

Table 7: Summary of Storm Event and Sampling Requirement Criteria.

	Storm Event Guidelines						Sample Collection Criteria					
	Precipitation				Antecedent Dry Period		Number of Aliquots		Storm Event Coverage		Sampling Duration	
Event ID	Total Depth (in)	Max. Intensity (in/hour)	Avg. Intensity (in/hour)	Duration (hours)	Before Event (hours)	Post Event (hours)	Influent	Effluent	Influent	Effluent	Influent (hours)	Effluent (hours)
LPR021412	0.34	0.06	0.01	18	21	36	7	7	81%	78%	14	14
LPR021712	1.34	0.14	0.02	46	18	14	40	32	94%	97%	29	31
LPR022412	0.80	0.13	0.04	11	31	11	23	17	100%	91%	10	10
LPR031212	0.44	0.10	0.03	6	28	16	14	12	83%	95%	6	6
LPR052412	0.48	0.13	0.04	5	4	48	13	15	85%	80%	2	3
LPR060112	0.86	0.15	0.08	7	104	10	32	37	97%	99%	5	5
LPR060412	0.77	0.15	0.04	13	5	5	24	25	84%	96%	9	10
LPR060712	0.73	0.14	0.04	12	36	8	24	25	96%	87%	12	12
LPR110612	0.47	0.36	0.03	7	117	55	13	16	99%	94%	7	7
LPR113012	0.69	0.26	0.03	16	7	9	27	15	79%	100%	15	15
LPR051713	0.26	0.07	0.02	9	13	9	16	13	74%	77%	13	13
LPR052113	0.70	0.18	0.08	6	9	7	35	28	99%	98%	7	5
LPR062513	0.71	0.29	0.10	4	2	2	26	24	93%	96%	3	3
LPR013014	0.51	0.09	0.02	21	5	8	36	41	96%	94%	23	23
LPR030314	0.76	0.30	0.05	9	6	9	31	43	100%	100%	9	11
LPR011815	2.62	0.24	0.07	26	18	8	35	38	97%	98%	15	18
LPR020215	0.43	0.12	0.04	5	13	21	16	14	91%	90%	5	5
Min	0.26	0.06	0.01	4	2	2	7	7	74%	77%	2	3
Max	2.62	0.36	0.10	46	117	55	40	43	100%	100%	29	31
Mean	0.76	0.17	0.04	13	26	16	24	24	91%	92%	11	11

One event, LPR051713, contained 74% influent storm event coverage. This event contained a small amount of precipitation approximately 3 hours before the first influent and effluent aliquot was sampled. The small amount of precipitation resulted in flow lower than the threshold that was needed to trigger the automated samplers. The paired influent and effluent samples were representative of the entire event and all other storm event and sampling criteria were satisfied. The 1% variance to the storm event coverage was deemed to meet the intent of the criterion.

One event, LPR021412, contained seven influent and effluent aliquots. However, the storm event criteria and all other sample collection requirements were satisfied for this event. The aliquot pacing was representative and greater than 80% storm event coverage was attained for the LPR021412 event. As such, the data were included in the performance evaluation.

6.3 Hydraulic Data

The hydraulic evaluation of the StormFilter with PhosphoSorb includes analysis of the volume and bypass associated with sampled events as well as the entire evaluation period.

6.3.1 Hydraulic Data for Sampled Events

As shown in Table 8, the volume recorded for the sampled events (n=17) ranged between 442 and 3,565 gallons. The grand total volume for all sample events was 24,575 gallons with a mean of 1,446 gallons per event. A grand total of 1,453 gallons were bypassed through the system from 5 of the 17 events. A majority of the bypass was from a single event, LPR062513, with 891 gallons.

Table 8. Hydraulic Data for the 17 events sampled.

		Peak Flow		Average Flow		Bypass	
Event ID	Total Volume (gal)	Influent (gpm)	Effluent (gpm)	Influent (gpm)	Effluent (gpm)	Volume (gal)	Percent Treated
LPR021412	442	7	4	0.3	0.3	0	---
LPR021712	2,127	8	5	0.6	0.5	0	---
LPR022412	1,149	9	6	1.0	0.8	0	---
LPR031212	890	6	5	1.1	0.8	0	---
LPR052412	572	5	5	0.9	1.1	0	---
LPR060112	1,637	12	8	2.5	2.8	0	---
LPR060412	1,319	20	13	1.2	1.2	95	93%
LPR060712	645	31	17	0.6	0.8	89	86%
LPR110612	971	10	9	1.1	1.4	0	---
LPR113012	1,695	12	10	1.0	0.7	0	---
LPR051713	1,208	7	6	1.3	1.0	0	---
LPR052113	1,300	9	9	2.4	1.8	0	---
LPR062513	2,876	80	59	6.8	5.7	891	69%
LPR013014	1,829	15	9	0.9	1.0	0	---
LPR030314	1,648	25	24	1.7	1.7	359	78%
LPR011815	3,565	16	17	1.8	2.0	19	99%
LPR020215	701	5	4	1.2	1.0	0	---
Min	442	5	4	0.3	0.3	0	69%
Max	3,565	80	59	6.8	5.7	891	99%
Mean	1,446	16	12	1.6	1.5	85	85%
Median	1,300	10	9	1.1	1.0		
Sum	24,575					1,453	94%

The influent average flow rates through the system for sampled events ranged from 0.3 to 6.8 gpm, with a mean of 1.6 gpm and a median of 1.1 gpm. The influent peak flow rates through the system for sampled events ranged from 5 to 80 gpm, with a mean of 16 and a median of 10 gpm.

The effluent average flow rates through the system for sampled events ranged from 0.3 to 5.7 gpm, with a mean of 1.5 gpm and a median of 1.0 gpm. The effluent peak flow rates through the system for sampled events ranged from 4 to 59 gpm, with a mean of 12 and a median of 9 gpm.

6.3.2 Overall Hydraulic Data

Over the entire 37 month evaluation period, the total effluent volume recorded was 376,244 gallons. There were several data gaps due to weather, equipment issues, and back-up data storage errors, which are identified in Table 9.

Table 9. Total Volume and Bypass

Date	Total Volume (gal)	Bypass Volume[1] (gal)	Bypass Volume (%)
Feb-12	12,164	155	1%
Mar-12	18,630	114	1%
Apr-12	7,655	128	2%
May-12	3,444	0	0%
Jun-12	12,977	355	3%
Jul-12	0	0	0%
Aug-12	0	0	0%
Sep-12	0	0	0%
Oct-12	105,241	9,739	17%
Nov-12	33,990	775	2%
Dec-12[a]	4,403	0	0%
Jan-13[b]	---	---	---
Feb-13[b]	---	---	---
Mar-13	10,352	411	4%
Apr-13	18,333	0	0%
May-13	9,705	42	0%
Jun-13	21,290	1,664	8%
Jul-13[c] thru Dec-13[c]	Data Gap		
Jan-14[c]	Data Gap		
Feb-14[c]			
Mar-14	39,846	435	1%
Apr-14	30,181	0	0%
May-14[d]	6,369	0	0%
Jun-14[e]	---	---	---
Jul-14[e]	---	---	---
Aug-14[e]	---	---	---
Sep-14[e]	---	---	---
Oct-14	9,070	0	0%
Nov-14	20,691	222	1%
Dec-14[b]	---	---	---
Jan-15	8,062	19	0%
Feb-15[f]	3,840	0	0%
SUM	**376,244**	**14,060**	**4%**

[1] An internal weir with a single station horizontal switch was used to calculate volume.

[a] Data covers December 1-3, 2012

[b] Monitoring equipment offline due to severe winter weather conditions

[c] Hydraulic and precipitation data were lost due to back-up storage issue.

[d] Data covers May 1-7, 2014

[e] June to September 2014 monitoring equipment was offline.

[f] Data covers February 1-9, 2015

A total of 14,060 gallons were bypassed through the system accounting for 4% of the total recorded volume. A total of 26 events contained bypass flow. A total of three bypass events were a result of media occlusion impairing the ability of the system to meet the hydraulic capacity requirements. The March 2012 event recorded a flow rate of 4.5 gpm and the March 2013 events recorded flow rates of 7.0 and 6.8 gpm at the point of bypass. Maintenance was performed 7-14 days after each occurrence. Additional information regarding maintenance and flow rate during bypass is available in section 7.2.

6.4 Individual Storm Reports

The Individual Storm Reports (ISRs) for the 17 storm events sampled during this evaluation are attached in Appendix D. Appendix D also contains the 8 storm events that were disqualified as these events did not meet the sample collection criteria (per section 6.2). Each ISR contains general site and system information, hydrology information for the specific event, and all raw analytical data collected for the storm event.

6.5 Laboratory Quality Control

Data were reviewed and validated according to the approved QAPP (Appendix B). A detailed quality control/quality assurance analysis is enclosed in Appendix E. The 17 storm events used to evaluate performance did not contain any disqualified data.

6.6 Performance Evaluation

Total Suspended Solids (TSS) and total phosphorus were the primary performance evaluation objectives for the StormFilter with PhosphoSorb investigation. A copy of the raw data in tabular form for all of the parameters evaluated can be seen in Appendix F. Appendix G contains copies of the analytical laboratory reports for each event.

6.6.1 Suspended Solids

A total of 17 events were sampled from February 2012 and February 2015. TSS, Suspended Sediment Concentration less than 500 microns (SSC<500 µm), and solids representing the silt and clay fraction (SSC less than 62.5-µm) from these 17 events are shown in Table 10. Additional solids data can be found in the ISRs for each event in Appendix D.

For the 17 events sampled influent Event Mean Concentrations (EMCs) for TSS ranged from 40 mg/L to 780 mg/L with a median of 389 mg/L and a mean of 380 mg/L. Corresponding effluent EMCs ranged from 6 mg/L to 120 mg/L with a median of 32 mg/L and a mean of 40 mg/L.

Influent SSC<500 µm EMCs (n=15) ranged from 41 mg/L to 670 mg/L with a median of 309 mg/L and a mean of 325 mg/L. Corresponding effluent EMCs ranged from 4 mg/L to 120 mg/L with a median of 32 mg/L and a mean of 40 mg/L.

Influent silt and clay EMCs (n=16) ranged from 19 mg/L to 399 mg/L with a median of 156 mg/L and a mean of 153 mg/L. Corresponding effluent EMCs ranged from 5 mg/L to 110 mg/L with a median of 21 mg/L and a mean of 31 mg/L.

Table 10. Suspended Solids (Raw Data) for the 17 Events Sampled.

	TSS-SM				SSC<500 µm				Silt and Clay*			
Event ID	Influent (mg/L)	Effluent (mg/L)	MRL (mg/L)	Removal (%)	Influent (mg/L)	Effluent (mg/L)	MRL (mg/L)	Removal (%)	Influent (mg/L)	Effluent (mg/L)	MRL (mg/L)	Removal (%)
LPR021412	539	32	10	94%		*Not Tested*			*163*	*30*	3.7	*82%*
LPR021712	387	48	10	88%	270	52	5	81%	*208*	*44*	5	*79%*
LPR022412	512	43	10	92%	309	52	2.9	83%	*148*	*46*	3.98	*69%*
LPR031212	150	18	10	88%	190	ND	27	86%	*88*	*ND*	20	*69%*
LPR052412	510	43	10	92%	400	47	22	88%	*200*	*41*	37	*80%*
LPR060112	780	16	10	98%	540	ND	41	92%	*220*	*ND*	40	*80%*
LPR060412	580	32	10	94%	670	28	22	96%	*230*	*23*	22	*90%*
LPR060712	570	120	10	79%	470	120	42	74%	*240*	*110*	47	*54%*
LPR110612	40	10	10	75%	41	9	3	77%	*19*	*6.6*	3	*65%*
LPR113012	230	17	10	93%	150	15	3	90%	*49*	*9.5*	*2.9*	*81%*
LPR051713	94	6	5	94%	94	4	4.1	95%	49	5.0	5	90%
LPR052113	389	24	10	94%	243	22	3.4	91%	121	20	3.4	84%
LPR062513	308	21	10	93%	421	32	3.3	92%	172	15	4.7	91%
LPR013014	170	17	5	90%	131	17	3.2	87%	115	11	3.6	91%
LPR030314	280	95	5	66%		*Not Tested*				*Not Tested*		
LPR011815	529	73	5	86%	536	72	3.7	87%	399	63	10	84%
LPR020215	397	67	5	83%	405	53	4.6	87%	33	14	0.6	58%
Min	40	6	5	66%	41	4	3	74%	19	5	0.6	54%
Max	780	120	10	98%	670	120	42	96%	399	110	47	91%
Median	389	32	10	92%	309	32	4	87%	156	21	5	80%
Mean	380	40	9	88%	325	40	13	87%	153	31	13	78%

*Silt and clay fraction is represented by suspended solid concentrations less than 62.5-um. Events sampled in 2012 were not tested for SSC <62.5-um thus SSC<50-um results are used as a substitute for these events and are shown in italics.

6.6.2 Phosphorus

Total phosphorus and soluble phosphorus results for the 17 events sampled are shown in Table 11. Each sampled event was analyzed for total phosphorus (TP), ortho-phosphate and dissolved phosphorus concentrations. Due to a high occurrence of events with non-detect concentrations for ortho-phosphate and dissolved phosphorus, the two data sets were combined into one set (n=9) and referred to as soluble phosphorus, as seen in Table 11.

For the 17 events, sampled influent EMCs for TP ranged from 0.07 mg/L to 0.69 mg/L with a median of 0.28 mg/L and a mean of 0.33 mg/L. Corresponding effluent EMCs ranged from 0.03 mg/L to 0.14 mg/L with a median of 0.06 mg/L and a mean of 0.07 mg/L.

For the 17events sampled influent EMCs for soluble phosphorus ranged from 0.01 mg/L to 0.099 mg/L with a median of 0.026 mg/L and a mean of 0.051 mg/L. Corresponding effluent EMCs ranged from 0.01 mg/L to 0.012 mg/L with a median of 0.012 mg/L and a mean of 0.011 mg/L.

Table 11. Phosphorus (raw data) for the 17 Sampled Events.

	Total Phosphorus				Soluble Phosphorus				
Event ID	Influent (mg/L)	Effluent (mg/L)	MRL (mg/L)	Removal (%)	Influent (mg/L)	Effluent (mg/L)	MRL (mg/L)	Analyte	Removal (%)
LPR021412	0.22	0.06	0.10	72%	ND	ND	0.010	ORP	
LPR021712	0.31	0.07	0.10	78%	ND	ND	0.010	ORP	
LPR022412	0.42	0.07	0.20	83%	ND	ND	0.010	ORP	
LPR031212	0.15	0.04	0.02	75%	ND	ND	0.010	ORP	
LPR052412	0.17	0.07	0.02	59%	ND	ND	0.010	ORP	
LPR060112	0.20	0.04	0.02	83%	ND	ND	0.010	ORP	
LPR060412	0.21	0.04	0.02	80%	ND	ND	0.010	ORP	
LPR060712	0.17	0.14	0.02	18%	ND	ND	0.010	ORP	
LPR110612	0.07	ND	0.05	26%	0.093	ND	0.050	ORP	46%
LPR113012	0.17	ND	0.05	71%	0.099	ND	0.050	ORP	49%
LPR051713	0.28	0.03	0.01	90%	*0.0260*	*0.0110*	*0.010*	DP	58%
LPR052113	0.56	0.05	0.01	91%	*0.0190*	*0.0118*	*0.010*	DP	38%
LPR062513	0.58	0.05	0.01	92%	ND	ND	0.010	ORP	
LPR013014	0.32	0.05	0.01	83%	ND	0.012	0.010	ORP	-20%
LPR030314	0.42	0.13	0.01	68%	ND	ND	0.010	ORP	
LPR011815	0.65	0.12	0.01	81%	*ND*	*0.0116*	*0.010*	DP	-16%
LPR020215	0.69	0.10	0.05	86%	*0.0156*	*ND*	*0.010*	DP	36%
Min	0.07	0.03	0.01	18%	0.016	0.011	0.01		-20%
Max	0.69	0.14	0.20	92%	0.099	0.012	0.05		58%
Median	0.28	0.06	0.02	80%	0.026	0.012	0.01		38%
Mean	0.33	0.07	0.04	73%	0.051	0.012	0.01		27%

Note: Soluble Phosphorus is defined as either Ortho-Phosphorus (ORP) or Dissolved Phosphorus (DP).
ND - Non-detect

6.7 Statistical comparison of influent and effluent pollutant concentrations

The StormFilter with PhosphoSorb media operating at a specific flow rate of 1.67 gpm/ft^2 was analyzed to determine whether there are significant differences in pollutant concentrations between the influent and effluent across individual storm events. The specific null hypothesis (H_o) and alternative hypothesis (H_a) for these analyses are as follows:

H_o: Effluent pollutant concentrations are equal to or greater than influent concentrations

H_a: Effluent concentrations are less than influent concentrations

A one-tailed Wilcoxon signed-rank test performed on qualified TSS and total phosphorus data indicated there was a statistically significant difference between the influent and effluent concentrations for both parameters based on an alpha (α) level of 0.05. Complete results for this test can be seen in Appendix H.

6.8 Pollutant removal efficiency calculations

Pollutant removal efficiencies for the 17 sampled storm events have been calculated using TAPE Method #1: Individual Storm Reduction in Pollutant Concentration (TAPE, 2011). This method calculates the individual storm reductions in pollutant concentration assuming no water losses in the treatment system between the influent and effluent sampling points.

Individual event removal efficiencies per TAPE Method #1 for TSS for the 17 events can be found in Table 10. The mean and median individual storm reductions for TSS are 88% and 92%, respectively.
The mean and median individual storm reductions for SSC<500 µm are 87%. The silt and clay fraction (less than 62.5 µm) individual storm reductions were also analyzed with a mean and median removal efficiency of 78% and 80%, respectively.

Individual event removal efficiencies per TAPE Method #1 for total phosphorus and soluble phosphorus can be seen in Table 11. The mean individual storm reductions for total phosphorus and soluble phosphorus are 73% and 27%, respectively. The median individual storm reductions for total phosphorus and soluble phosphorus are 80% and 38%, respectively.

Table 12. Basic Treatment Performance (TSS results)

Basic Treatment	Influent: <100 mg/L; Effluent: ≤ 20 mg/L			Influent: 100-200 mg/L; ≥ 80% Removal			Influent: >200 mg/L; ≥ 80% Removal		
Event ID	Influent (mg/L)	Effluent (mg/L)	Removal (%)	Influent (mg/L)	Effluent (mg/L)	Removal (%)	Influent (mg/L)	Effluent (mg/L)	Removal (%)
LPR021412							539	32	94%
LPR021712							387	48	88%
LPR022412							512	43	92%
LPR031212				150	18	88%			
LPR052412							510	43	92%
LPR060112							780	16	98%
LPR060412							580	32	94%
LPR060712							570	120	79%
LPR110612	40	10	75%						
LPR113012							230	17	93%
LPR051713	94	6	94%						
LPR052113							389	24	94%
LPR062513							308	21	93%
LPR013014				170	17	90%			
LPR030314							280	95	66%
LPR011815							529	73	86%
LPR020215							397	67	83%
Min	40	6	75%	150	17	88%	230	16	66%
Max	94	10	94%	170	18	90%	780	120	98%
Median	67	8	84%	160	18	89%	510	43	92%
Mean	67	8	84%	160	18	89%	462	49	89%

6.8.1 Basic Treatment

The basic treatment performance goal is defined as 80% TSS removal for influent concentrations and an effluent TSS concentration of 20 mg/L or less for influent concentrations from 20 to 100 mg/L. Table 12 shows TSS performance for the 17 events grouped by TSS influent concentration. Two of the 17 events had influent TSS concentrations below 100 mg/L. Both of these events had effluent concentrations at 10 mg/L or lower.

Two of the 17 events had an influent TSS concentration between 100 mg/L and 200 mg/L. Both of these events resulted in 88% or greater TSS removal.

Thirteen of the 17 events had influent TSS concentrations greater than 200 mg/L. Of those 13 events, 11 showed removal greater than 80%. The mean and median removal efficiency for the 13 events with influent TSS concentrations greater than 200 mg/L are 89% and 92% respectively.

6.8.2 Suspended Solids Performance

In addition to TSS, a performance assessment was included for suspended solids less than 500 microns (SSC<500 µm) and the silt and clay fraction (SSC<62.5 µm).

The SSC<500 µm fraction with influent concentrations less than 100 mg/L (n=2) resulted in an effluent of 9 mg/L or less. The SSC<500 µm fraction with influent concentrations between 100 and 200 mg/L (n=3) demonstrated 86% removal or greater. The SSC<500 µm fraction with influent concentrations greater than 200 mg/L (n=10) demonstrated a mean and median removal efficiency of 87% and 88%, respectively.

Table 13. SSC < 500 µm Performance

Basic Treatment	Influent: <100 mg/L; Effluent: ≤ 20 mg/L			Influent: 100-200 mg/L; ≥ 80% Removal			Influent: >200 mg/L; ≥ 80% Removal		
Event ID	Influent (mg/L)	Effluent (mg/L)	Removal (%)	Influent (mg/L)	Effluent (mg/L)	Removal (%)	Influent (mg/L)	Effluent (mg/L)	Removal (%)
LPR021412								*Not Tested*	
LPR021712							270	52	81%
LPR022412							309	52	83%
LPR031212				190	**ND**	86%			
LPR052412							400	47	88%
LPR060112							540	**ND**	91%
LPR060412							670	28	96%
LPR060712							470	120	74%
LPR110612	41	9	77%						
LPR113012				150	15	90%			
LPR051713	94	4	95%						
LPR052113							243	22	91%
LPR062513							421	32	92%
LPR013014				131	17	87%			
LPR030314								*Not Tested*	
LPR011815							536	72	87%
LPR020215							405	53	87%
Min	41	4	77%	131	15	86%	243	22	74%
Max	94	9	95%	190	17	90%	670	120	96%
Median	68	7	86%	150	16	87%	413	52	88%
Mean	68	7	86%	157	16	88%	426	53	87%

ND = Non-Detect

Table 14. Silt and Clay Performance

Basic Treatment	Influent: <100 mg/L; Effluent: ≤ 20 mg/L			Influent: 100-200 mg/L; ≥ 80% Removal			Influent: >200 mg/L; ≥ 80% Removal		
Event ID	Influent (mg/L)	Effluent (mg/L)	Removal (%)	Influent (mg/L)	Effluent (mg/L)	Removal (%)	Influent (mg/L)	Effluent (mg/L)	Removal (%)
LPR021412				163	30	82%			
LPR021712							208	44	79%
LPR022412				148	46	69%			
LPR031212	88	ND	69%						
LPR052412				200	41	80%			
LPR060112							220	ND	80%
LPR060412							230	23	90%
LPR060712							240	110	54%
LPR110612	19	7	65%						
LPR113012	49	10	81%						
LPR051713	49	5	90%						
LPR052113				121	20	84%			
LPR062513				172	15	91%			
LPR013014				115	11	91%			
LPR030314					*Not Tested*				
LPR011815							399	63	84%
LPR020215	33	14	58%						
Min	19	5	58%	115	11	69%	208	23	54%
Max	88	14	90%	200	46	91%	399	110	90%
Median	49	8	69%	156	25	83%	230	53	80%
Mean	48	9	73%	153	27	83%	259	60	78%

ND = Non-Detect

The silt and clay fraction is represented of suspended solids less than 62.5 microns. Events sampled in 2012 were not tested for SSC<62.5 µm. SSC<50 µm results are used as a substitute for the 2012 data set.

Five events had silt and clay fraction less than 100 mg/L with a mean effluent concentration of 9 mg/L. Six events had a silt and clay fraction between 100 mg/L and 200 mg/L with a mean and median removal efficiency of 83%. Five events had a silt and clay fraction above 200 mg/L with a mean and median removal efficiency of 78% and 80%, respectively.

6.8.3 Phosphorus Treatment

Phosphorus treatment performance goals include meeting all basic treatment goals as well as demonstrating at least 50% total phosphorus removal for events with influent concentrations between 0.1 and 0.5 mg/L. Table 15 shows total phosphorus removal results for the 17 events grouped by influent concentration range.

One storm event, LPR110612, had an influent concentration less than 0.1 mg/L total phosphorus. Twelve events had an influent total phosphorus concentration between 0.1 and 0.5 mg/L. Four events contained total phosphorus influent concentrations greater than 0.5 mg/L. These four higher concentration events were included in the performance evaluation with a substituted influent value of 0.5 mg/L. A total of 16 events were analyzed for the phosphorus treatment goal.

Fifteen of the 16 storm events with influent concentrations between 0.1 to 0.5 mg/L demonstrated greater than 50% removal. The mean and median total phosphorus removal efficiency for influent concentrations between 0.1 and 0.5 mg/L was 75% and 79%, respectively.

Table 15. Phosphorus Treatment Results

Phosphorus Treatment	Influent < 0.1 mg/L; (no defined goal)			Influent 0.1mg/L to 0.5 mg/L; ≥50% removal			Influent > 0.5 mg/L;		
Event ID	Influent (mg/L)	Effluent (mg/L)	Removal (%)	Influent (mg/L)	Effluent (mg/L)	Removal (%)	Influent (mg/L)	Effluent (mg/L)	Removal (%)
LPR021412				0.22	0.06	72%			
LPR021712				0.31	0.07	78%			
LPR022412				0.42	0.07	83%			
LPR031212				0.15	0.04	75%			
LPR052412				0.17	0.07	59%			
LPR060112				0.20	0.04	83%			
LPR060412				0.21	0.04	80%			
LPR060712				0.17	0.14	18%			
LPR110612	0.07	ND	26%						
LPR113012				0.17	ND	71%			
LPR051713				0.28	0.03	90%			
LPR052113				**0.50**	0.05	**90%**	0.56	0.05	91%
LPR062513				**0.50**	0.05	**91%**	0.58	0.05	92%
LPR013014				0.32	0.05	83%			
LPR030314				0.42	0.13	68%			
LPR011815				**0.50**	0.12	**75%**	0.65	0.12	81%
LPR020215				**0.50**	0.10	**80%**	0.69	0.10	86%
Min	0.07	0.05	26%	0.15	0.03	18%	0.56	0.05	81%
Max	0.07	0.05	26%	0.50	0.14	91%	0.69	0.12	92%
Median	0.07	0.05	26%	0.30	0.06	79%	0.62	0.07	88%
Mean	0.07	0.05	26%	0.32	0.07	75%	0.62	0.08	87%

BOLD - Influent concentrations greater than 0.5 mg/L were substituted with 0.5 mg/L.

6.9 Statistical evaluation of performance goals

The TAPE (2011) requires bootstrapping to be used to compute the lower one-sided 95% confidence limit (LCL95) for pollutant removal efficiency for all parameters associated with the project specific performance goals. This calculated limit is then compared to the associated performance goal for that specific analyte. If the computed limit is higher than the treatment goal, it can be concluded that the stormwater treatment system met the specified performance goal with the required 95% confidence. Data from the 17 events were analyzed using the 2011-08 TAPE bootstrap confidence interval calculator (bootstrap calculator) for TSS (Basic Treatment) and total phosphorus (Phosphorus Treatment). Printed screenshots showing the TSS bootstrap calculator results can be seen in Appendix I.

Fifteen events had influent TSS concentrations greater than 100 mg/L and the LCL95 for TSS removal efficiency was 85% per the bootstrap calculator. Since this computed limit is higher than the basic treatment goal of greater than or equal to 80%, it is concluded that the basic performance goal for this project was met.

Of the 17 events sampled, 12 had influent total phosphorus concentrations between 0.1 and 0.5 mg/L. Additionally, 4 events had influent total phosphorus concentrations greater than 0.5 mg/L. These 4 events were added to the data set used in the bootstrap calculator. For these four events, an influent concentration of 0.5 mg/L was substituted for the reported concentration to allow for a conservative addition of these data points.

For these 16 events, the LCL95 for total phosphorus removal efficiency was 67%. The upper 95% confidence interval (UCL95) for effluent concentration was 0.084 mg/L per the bootstrap calculator. Since the computed LCL95 is higher than the specified treatment goal of greater than or equal to 50%, it is concluded that the Phosphorus Treatment goal for this project was met. Printed screenshots showing the total phosphorus bootstrap results can be seen in Appendix I.

6.10 Pollutant Removal as a Function of Flow Rate

To evaluate pollutant removal as a function of flow rate, as per the TAPE (2011), individual event EMCs for both TSS and total phosphorus were compared to the corresponding aliquot-weighted influent flow rate for each of the 17 sampled events. The aliquot-weighted influent flow rate was calculated by determining the influent flow rate at the time each influent aliquot was collected and then taking an average of these values (TAPE, 2011). Removal efficiencies are plotted versus aliquot-weighted influent flow rate for TSS and total phosphorus in Figures 9 and 11 respectively.

The Lolo Pass Road StormFilter has a design treatment flow rate of 12.5 gpm with an internal bypass set to bypass all flows exceeding 13.5 gpm. Treated flows greater than 90% design (11.25 gpm) were observed in 8 of the 17 events and the peak treatment flow measured without bypass was 14.6 gpm during LPR013014. The flow rate at the point of bypass was greater than 13.5 gpm for all five bypass events that were sampled. Relying on the analysis of aliquot-weighted influent flow rates versus EMC removal efficiencies alone does not show what happens during the times of operation at or near peak design capacity. In an effort to better understand operation during peak flows, EMC removal efficiencies for TSS and total phosphorus were also compared to the corresponding peak influent flow recorded for each of the sampled events. Figures 10 and 12 show the maximum recorded influent flow rate versus TSS and total phosphorus EMC removal efficiencies, respectively. In addition, Figures 10 and 12 also show TSS and total phosphorus removal efficiencies versus the effluent flow rate at the time bypass occurred for the five sampled events with bypass. These five bypass events were isolated to illustrate the effluent flow rate at the time that bypass occurred (i.e. treated rate at bypass). These five additional bypass data points (treated rate at bypass) are included in Figures 10 and 12, but are not included in the linear regression analysis (too few data points).

Section 7.2 and Figure 14 provide the flow rate at the time of bypass for the 26 occurrences throughout the evaluation. Only three events were lower than the design rate and the system was maintained within 7-14 days of these observations.

6.10.1 Flow Rate Determination - Basic Treatment

Figure 9 shows the relationship between the TSS removal efficiency for each event (n=17) and the corresponding aliquot-weighted influent flow rate. Two of the events contained influent concentrations less than 100 mg/L. Five of the sampled events contain bypass.

Figure 10 shows the relationship between TSS removal efficiency for each event and the corresponding maximum recorded influent flow rate for the event. The maximum flow rate analysis demonstrates that the system was able to achieve greater than the 100% designed treatment rate for six events. Figure 10 also shows the TSS removal efficiency versus the effluent flow rate (treated rate at bypass) at the time bypass occurred for the five sampled events with bypass. Bypass did not occur for the other 13 events.

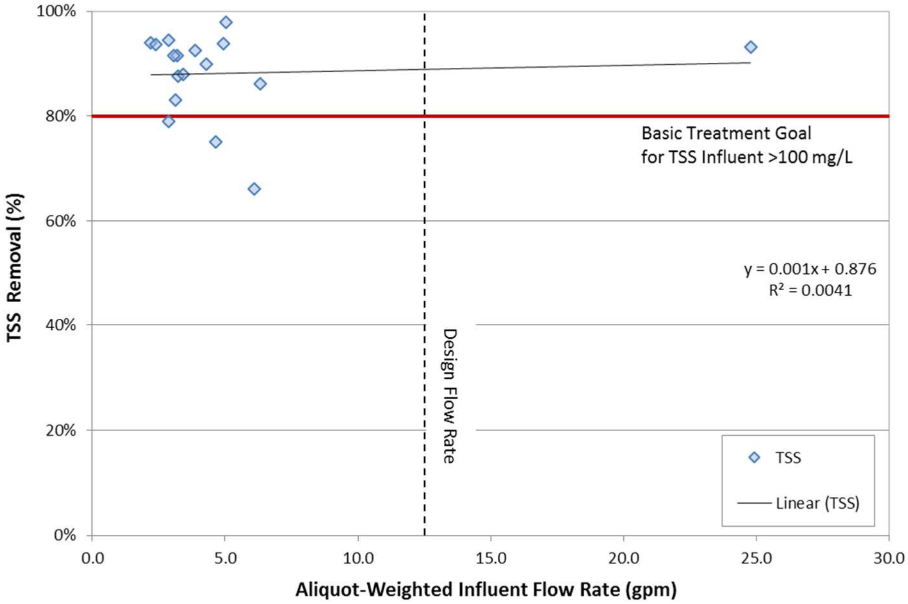

Figure 9. TSS removal (%) as a function of aliquot-weighted influent flow rate (n=17).

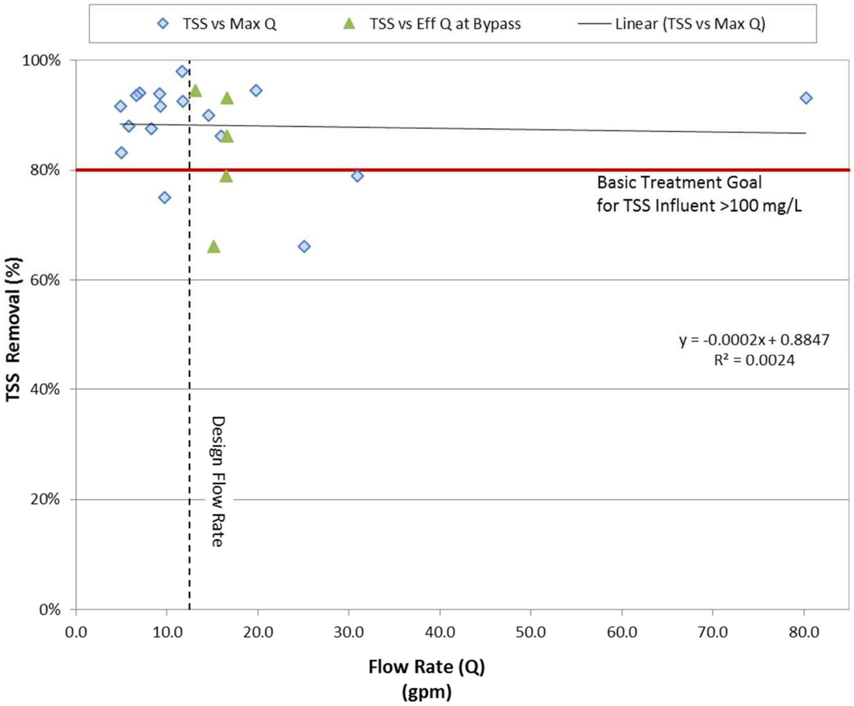

Figure 10. TSS removal (%) as a function of maximum influent flow rate (n=17) and TSS removal (%) as a function of effluent flow rate at the time of bypass (treated rate at bypass) (n=5).

6.10.2 Flow Rate Determination - Phosphorus Treatment

Figure 11 shows the relationship between total phosphorus efficiency for each event (n=17) and the corresponding aliquot-weighted influent flow rate. One event contained influent concentrations less than 0.1 mg/L. Bypass occurred in five events.

Figure 12 shows the relationship between total phosphorus removal efficiency for each event and the corresponding maximum recorded influent flow rate for the event. The maximum flow rate analysis demonstrates that the system was able to achieve greater than the 100% designed treatment rate for six events. Figure 12 also shows the total phosphorus removal efficiency versus the effluent flow rate (treated rate at bypass) at the time bypass occurred for the five sampled events with bypass. Bypass did not occur for the other 12 events.

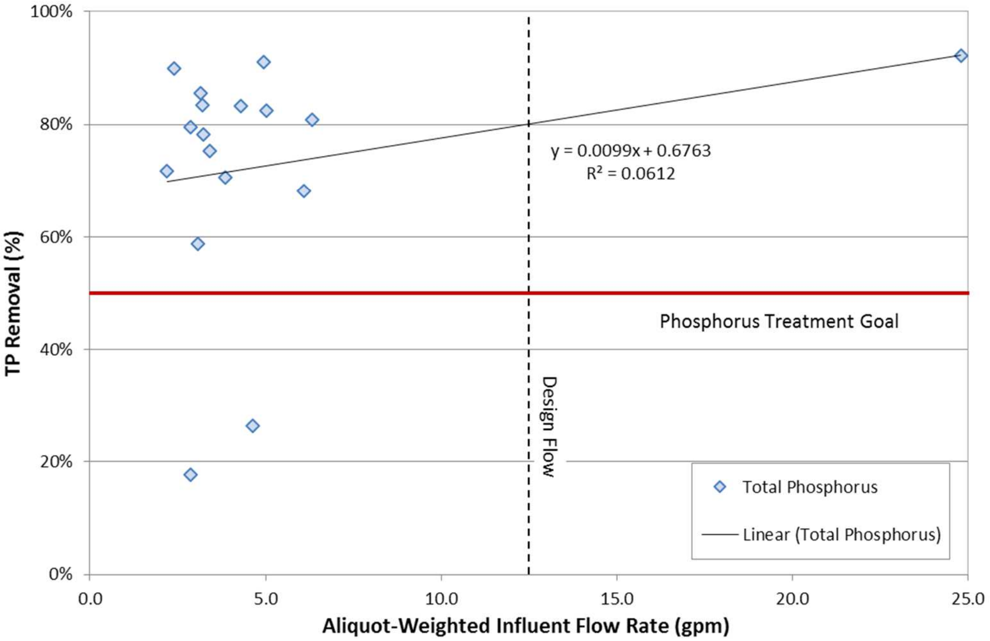

Figure 11. Total Phosphorus removal efficiencies versus corresponding aliquot-weighted influent flow rate for each qualified event sampled (n=17).

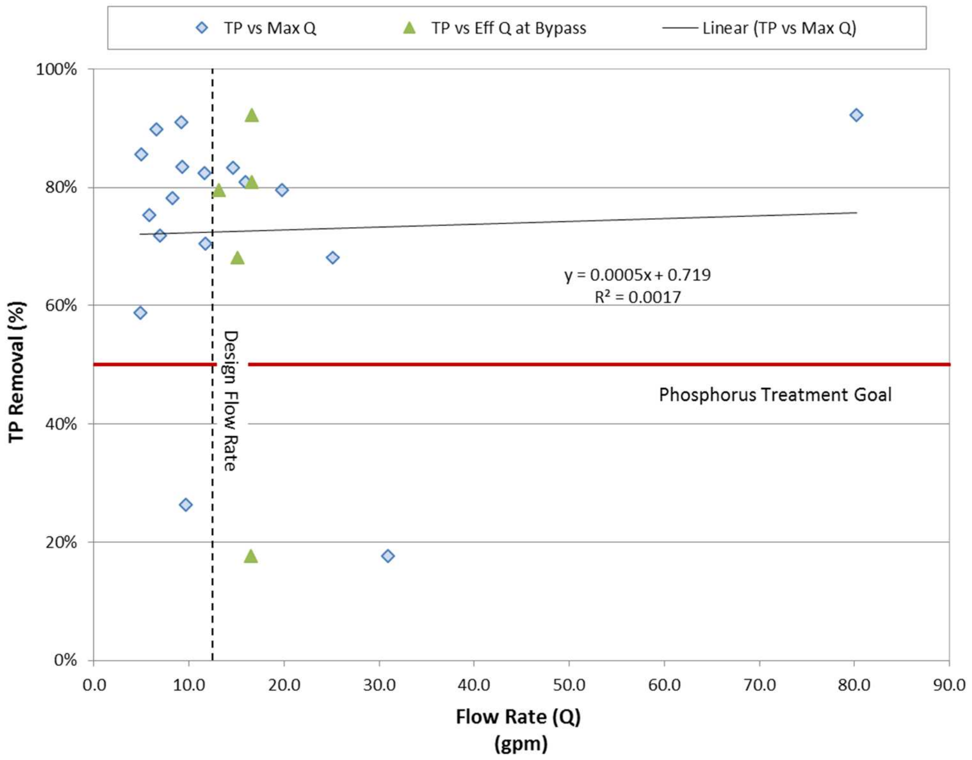

Figure 12. Total phosphorus removal (%) as a function of maximum influent flow rate (n=17) and total phosphorus removal (%) as a function of effluent flow rate at the time of bypass (treated rate at bypass) (n=5).

6.10.3 Regression Analysis

The TAPE (2011) requires regression analysis on the pollutant removal as a function of the influent flow rates. Figures 9 thru 12 contain linear regressions without any modifications to the dataset. The diagnostic reports (scatter plots, residuals, constant variance, etc.) used to determine the suitability for using regression are in Appendix J. Several iterations of the linear regressions were explored in Appendix J. The results of the regression (and each iteration) indicated there is no significant relationship between performance and influent flow rates.

6.11 Particle Size Distribution

Particle Size Distribution (PSD) is listed in the TAPE (2011) as a screening parameter and was required to be sampled for a minimum of three events. The TAPE PSD method is a modification of ASTM Method D3977-97 and defines particles as larger than 250 µm, between 250 and 62.5 µm, and smaller than 62.5 µm in size. Three TAPE influent PSD samples (LPR030814, LPR011815, LPR020215) showed an average of 72% sand and 28% silt with 8% of the silt fraction estimated as clay as seen in Figure 13. Storm event LPR030814 was disqualified for the performance evaluation due to inadequate effluent coverage. However, storm event guidelines and influent sample collection criteria were met thus it was deemed acceptable for the purpose including the data in the PSD analysis, and satisfying the PSD screening parameter. Table 16 shows the storm event and sampling collection characteristics of the event.

Table 16. Storm Event Guidelines and Sample Collection Criteria for LPR030814

	Storm Event Guidelines						Sample Collection Criteria					
	Precipitation				Antecedent Dry		Number of Aliquots		Storm Event		Sampling Duration	
Event ID	Total Depth (in)	Max. Intensity (in/hour)	Avg. Intensity (in/hour)	Duration (hours)	Before Event (hours)	Post Event (hours)	Influent	Effluent	Influent	Effluent	Influent (hours)	Effluent (hours)
LPR030814	1.89	0.36	0.08	18	27	11	47	48	83%	70%	13	9

In addition to the TAPE PSD method, a second PSD procedure – serial filtration, was utilized for the PSD characterization per the QAPP (Appendix B). Samples from 17 events were analyzed for influent PSD using this alternative procedure. For this serial filtration procedure a composite sample was split into subsamples using a cone splitter with different sieves at each outlet. The storm by storm analysis was conducted to understand removal effectiveness on the entire range of particles, 50-µm, 62.5-µm, 100-µm, 250-µm, 500-µm, and 2000-µm sieves were evaluated. Samples passing through each sieve were analyzed using the ASTM D3977-97 method. PSD results utilizing this method showed an average of 61% sand and 39% silt with 10% of the silt fraction estimated as clay, as seen in Figure 13.

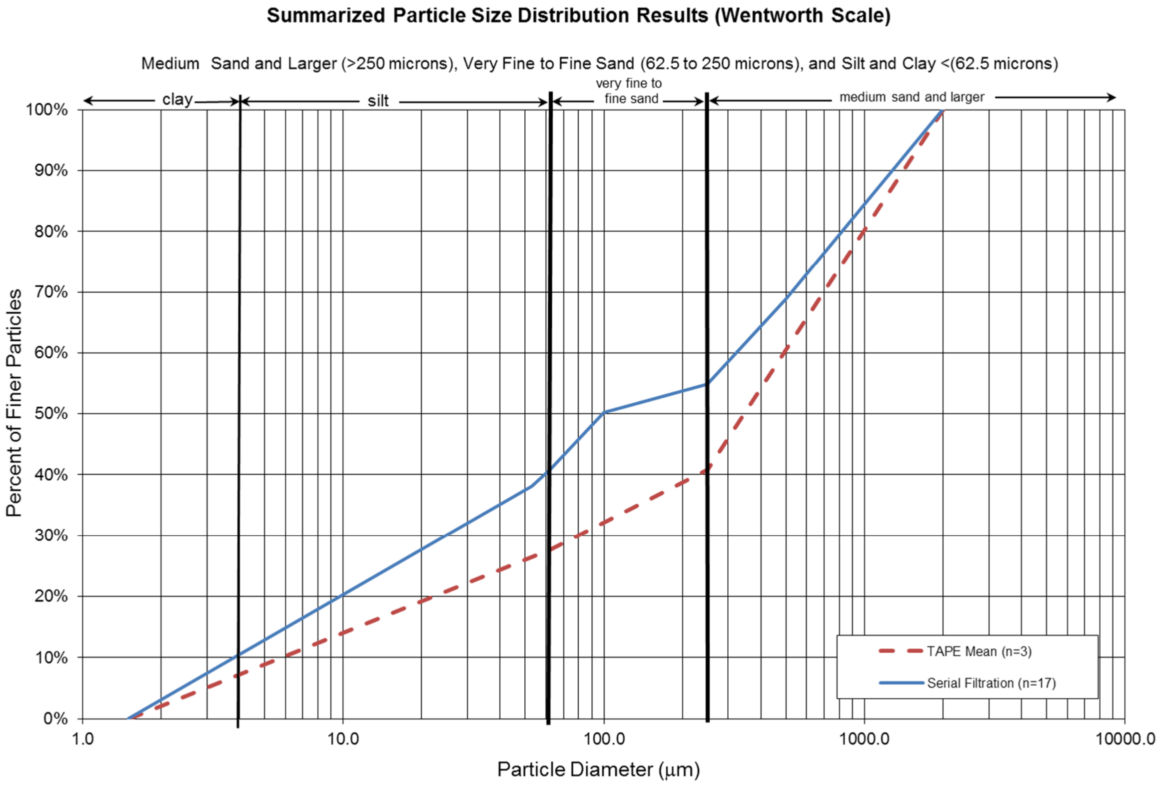

Figure 13. Particle Size Distribution results, plotted on the TAPE (2011) defined scale

Appendix K explores several variations of the particle size distribution data including each individual event, and sub-500 microns PSD characterization. In summary, evaluation of the sub-500 micron data set contained 54% of the suspended solids in the silt and clay sized fraction and resulted in a bootstrap lower 95% confidence limit of 85% removal. Performance of the silt and clay fraction (only) with an average influent concentration of 153 mg/L resulted in an average of 78% removal and a bootstrap 95% confidence lower limit of 73% removal.

In addition, Appendix L contains a memorandum on the deicing applications in the adjacent upstream roadway section that was discussed as a potential link to the coarse sediment. A majority of the deicing applications were not related to sampled events. Another theory to the amount of coarse sediment (greater than 500 microns) was construction activity associated with a bridge replacement one mile downstream in 2012.

7.0 Operation and Maintenance Information

7.1 System Maintenance

Full maintenance of the system was performed on February 2, 2012 marking the beginning of the monitoring period for the Lolo Pass Road StormFilter. Maintenance involved removal of sediment from the unit and replacement of the StormFilter cartridge. Following maintenance, monitoring equipment was installed and the field evaluation was initiated.

The system was maintained four times throughout the 37 month evaluation period. Each of the maintenance events involved the removal of sediment within the system, removal of the used cartridge, and the installation of a new cartridge. Maintenance was performed on March 27, 2012, March 28, 2013, January 17, 2014, and October 10, 2014. With the exception to the March 27, 2012 maintenance event, maintenances were 10 to 12 months apart. Field recordkeeping forms for all maintenance events can be seen in Appendix M. The Operation and Maintenance Manual is in Appendix N.

The March 27, 2012 maintenance event occurred two months after monitoring began. This was the result of a large and unusual precipitation event in the area. A bridge located one mile downstream from the evaluation site washed out. In the weeks following this event, numerous construction vehicles were present within the drainage area being tested. Large amounts of sand and gravel were deposited in the drainage area. Approximately 13 inches of sediment accumulated within the system and the system was maintained.

7.2 Bypass

The StormFilter system contains an internal bypass allowing larger flows to pass through the system untreated. The system goes into bypass when the water level in the unit rises to approximately 3 inches above the top of the StormFilter cartridge. The StormFilter has a calibrated orifice at the base of the cartridge that controls the flow rate until the media becomes occluded. The 3 inches of driving head increases the operating rate of the system from 12.5 gpm to 13.5 gpm before bypass.

Bypass was recorded using an internal weir and a single station horizontal switch. The upper range of flow capacity limit for the cartridge was calculated to be 13.5 gpm, with flows exceeding 13.5 gpm bypassing treatment. The single station horizontal switch measured the duration that the water surface elevation exceeded 21 inches. When the measured effluent flow exceeded 13.5 gpm and the water surface elevation exceeded 21 inches, the system was in bypass and reported as bypass volume.

Over the 37 months of the evaluation period there were some data gaps. Monitoring equipment was offline from January 2013 to February 2013, and December 2014 due to extreme winter weather. The monitoring equipment and system were also offline from June 2014 to September 2014. Hydraulic data from July 2013 to February 2014 (not sampled storm related) were lost due to a malfunction of the network, computer, and replicate storage systems.

Of the data available, a total of 26 events had bypass flow. The flow recorded after the single station horizontal switch was initiated is reported in Figure 14. Figure 14 contains each maintenance event, each period that was off-line, and any data gaps during the evaluation period.

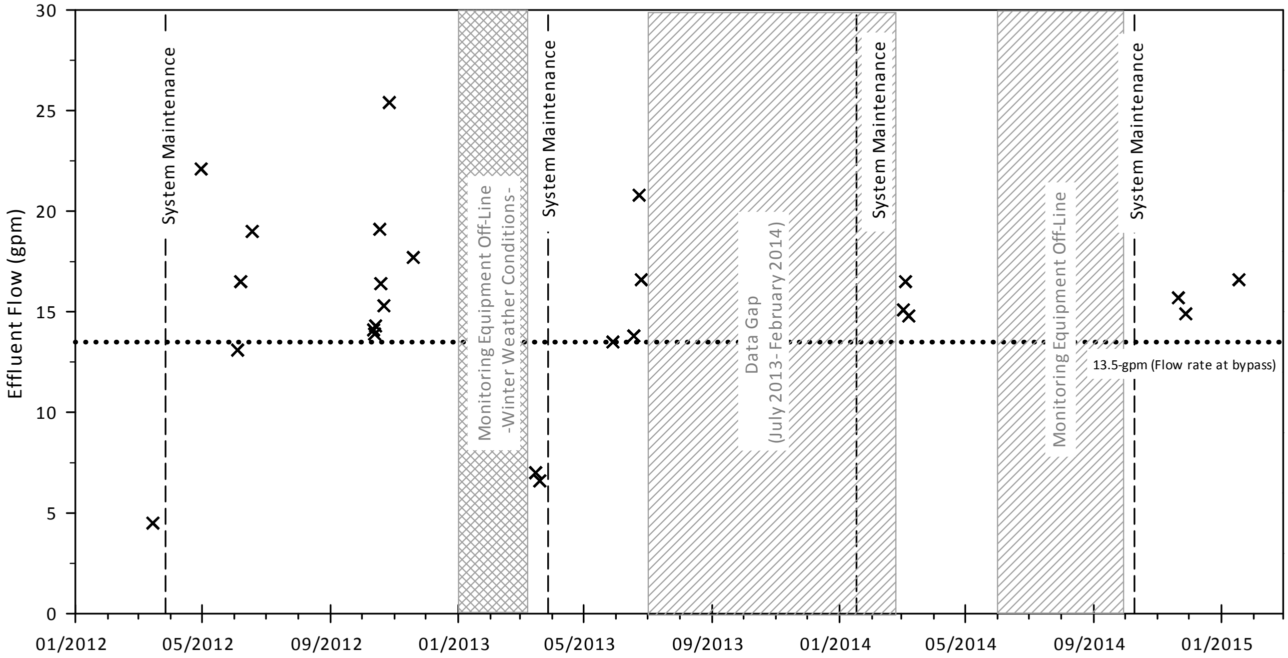

Figure 14. Flow rate at the time of bypass during the evaluation period.

7.3 Screening Parameter Results

Screening parameters were collected for a minimum of 3 sampled events. The analytes evaluated for Basic and Phosphorus Treatment were PSD, pH, total phosphorus, total and dissolved copper, total and dissolved zinc, orthophosphate, and hardness.

The above listed screening parameters were evaluated for five runoff events; LPR060112, LPR060712, LPR013014, LPR030314, and LPR011815. One additional event, LPR030814, did not meet the sample collection criterion for storm event effluent coverage (70%). Results for all screening parameters tested, with the exception of PSD, can be seen in Tables 17 and 18. PSD results are discussed in Section 6.10.

With the exception of three incidences, all screening parameter results showed removal of the specified pollutants for all five sampled events. LPR030314, an event with bypass, showed a release of total phosphorus. LPR011815, an event with bypass, showed a minimal release of both orthophosphate and dissolved zinc. There was a nominal difference between influent and effluent pH of -0.5%.

Table 17. Screening parameter results from the Lolo Pass Road evaluation site for TSS, total phosphorus, orthophosphate, hardness, and pH.

Event	Parameter									
	TSS (mg/L)		Total Phos (mg/L)		Ortho-Phos (mg/L)		Hardness (mg CaCO3/L)		pH	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
LPR060112	780	16.0	0.24	0.036	ND	ND	39	5.8	6.56	6.66
LPR060712	570	120	0.22	0.14	ND	ND	41	14	6.74	6.61
LPR013014	170	17.0	0.301	0.0588	0.042	0.012	44.5	39.6	6.81	6.87
LPR030314	280	95.0	0.128	0.419	ND	ND	18.6	7.22	6.79	6.93
LPR030814	173	26.0	0.264	0.0518	ND	ND	16.4	3.56	6.63	6.63
LPR011815	397	67.0	0.635	0.125	ND	0.006	29.0	11.0	NT	NT

Table 18. Screening parameter results from the Lolo Pass Road evaluation site for total copper, dissolved copper, total zinc, and dissolved zinc.

Event	Parameter							
	Total Cu (mg/L)		Diss Cu (mg/L)		Total Zn (mg/L)		Diss Zn (mg/L)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
LPR060112	0.037	0.0026	ND	ND	0.21	0.012	ND	ND
LPR060712	0.03	0.0096	0.0045	0.0025	0.17	0.049	ND	ND
LPR013014	0.0209	0.00488	0.00224	0.00190	0.109	0.0264	0.0154	0.0131
LPR030314	0.0196	0.00542	ND	ND	0.107	0.0273	0.0079	0.00648
LPR030814	0.0179	0.00220	0.00293	ND	0.0952	0.0114	0.00661	ND
LPR011815	0.0561	0.0079	0.00309	0.00268	0.155	0.0381	0.0118	0.0123

7.4 Sediment Depth Measurements

Sediment depth measurements were taken prior to each full maintenance of the system, with the exception of the maintenance event on February 2, 2012 which marked the beginning of the monitoring period. Average sediment depth measurements were taken on March 27, 2012, March 13, 2013, January 17, 2014, and October 10, 2014. The average recorded sediment depths were 13 inches, 9 inches, 11 inches, and 6 inches respectively. The average recorded sediment depth accumulation between each maintenance event was 9.75 inches. Sediment samples were not collected and analyzed.

7.5 Cumulative Load

Event mean concentration data and measured volume were used to estimate cumulative pollutant load over the entire evaluation period (n=25). Results for estimated mass retained by the system for SSC, total phosphorus, total zinc, and total copper are shown in Table 19. The values listed in Table 19 do not account for flow volume that may have occurred between July 2013 and December 2014.

Table 19. Estimated mass retained throughout evaluation period.

Maintenance Period	SSC (kg)			Total Phosphorus (kg)			Total Zinc (kg)			Total Copper (kg)		
	Influent	Effluent	Retained	Influent	Effluent	Retained	Influent	Effluent	Retained	Influent	Effluent	Retained
Feb 2, 2012 - Mar 27, 2012	37	5.3	32	0.02	0.01	0.02	0.013	0.003	0.010	0.002	0.001	0.002
Mar 28, 2012 - Mar 28, 2013	288	25	262	0.09	0.05	0.04	0.066	0.014	0.052	0.011	0.003	0.008
Mar 29, 2013 - Jan 17, 2014	80	1.9	79	0.08	0.00	0.08	0.018	0.002	0.016	0.004	0.001	0.004
Jan 18, 2014 - Oct 10, 2014	128	13	115	0.12	0.02	0.10	0.034	0.007	0.028	0.007	0.001	0.006
Oct 11, 2014 - Feb 9, 2015	179	7.7	171	0.17	0.01	0.16	0.043	0.005	0.039	0.012	0.001	0.011
Project Total:	**712**	**53**	**659**	**0.49**	**0.10**	**0.39**	**0.175**	**0.031**	**0.145**	**0.036**	**0.006**	**0.030**

8.0 Discussion

The TAPE (2011) requires the following information to be in the discussion section.

8.1 Statistical Data Evaluation

A one-tailed Wilcoxon signed-rank test performed on qualified TSS and total phosphorus data indicated there was a statistically significant difference between the influent and effluent concentrations for both parameters based on an alpha (α) level of 0.05.

The lower 95% confidence limit (LCL95) mean percent reduction for TSS and total phosphorus was 85% and 67%, respectively. The LCL95 mean percent reduction for sub-500 µm solids was 85% and the silt and clay fraction was 73%.

8.2 Explanation of any deviations from sampling procedures

There were no deviations from water sampling procedures. An optional sediment sampling procedure was not implemented as listed in the QAPP.

8.3 Information about anticipated performance in relation to climate, design storm, or site conditions.

As described in the QAPP, the site was selected for evaluation because previous TAPE investigations had shown; a silt loam soil texture; a high frequency of total phosphorus influent concentrations within the range of 0.1 to 0.5 mg/L; and high frequency of TSS influent concentrations in the 200 to 300 mg/L. The system was undersized based on mass load and treatment rate to increase the frequency of bypass. A full range of operating rates were experienced throughout the evaluation to demonstrate performance.

8.4 Information on recommended operation and maintenance schedules

Excluding the first maintenance event, the system exhibited an operational and maintenance cycle of 10 to 12 months. The preliminary design recommendations were for four StormFilter cartridges based on the expected load. The initial recommendations were too conservative, but the estimation tool can be used to conservatively design for an annual maintenance frequency.

8.5 Identification of any special disposal requirements.

There were no special disposal requirements associated with the captured materials in the system. Materials can be disposed of in any municipal solid waste landfills.

9.0 Conclusions

The StormFilter with PhosphoSorb media operating at a specific flow rate of 1.67 gpm/ft^2 was evaluated at a roadway site in ZigZag, OR. Over a 37 months evaluation period, 25 storm events were sampled. Of these 25 events, 17 met the storm event and sampling collection criteria.

Seventeen storm events satisfied the storm event and sampling collection criteria for total suspended solids (TSS). For TSS influent concentrations greater than 100 mg/L, the mean TSS removal efficiency was 88%. The TSS LCL95 mean percent removal was 85%. Additional suspended solid analysis on sub-500 microns and silt and clay fractions showed mean removal efficiencies of 87% and 78% respectively. LCL95 of the mean removal efficiency for sub-500 microns was 85%. The system exhibited greater than 80% removal TSS removal on average for storms with flow rates up to and exceeding the 12.5 gpm design flow.

Thirteen storm events satisfied the storm event criterion, sampling collection criterion, and target total phosphorus influent concentration range of 0.1 to 0.5 mg/L. An additional 4 events had total phosphorus influent concentrations greater than 0.5 mg/L. These events were included in the performance evaluation with a substituted influent value of 0.5 mg/L. The seventeen events demonstrated a total phosphorus mean removal efficiency of 73%. The total phosphorus LCL95 of the mean removal efficiency was 67%. The system exhibited greater than 50% total phosphorus removal for storms with peak flow rates up to and exceeding the 12.5 gpm design flow.

The StormFilter with PhosphoSorb media achieved the Basic and Phosphorus Treatment goals at a specific flow rate of 1.67 gpm/ft^2. The flow-based system was designed in an online configuration. The flow-based system can be configured as either an on-line system with internal bypass or as an off-line configuration with external bypass. Either the Western Washington Hydrology Model (WWHM) or Eastern Washington Manual (using a single event model) can be used to configure the system and achieve the basic and phosphorus treatment goals. The hydraulic loading rate, specific flow rate, and hydraulic drop for each cartridge height are shown in Table 20.

Table 20. Hydraulic Loading Rate per Cartridge Height and Specific Flow Rate

StormFilter Cartridge Type	Per Cartridge Flow Rate at 1.67 gpm/ft^2	Hydraulic Drop Required
Low Drop	8.4 gpm	3.05’
18”	12.5 gpm	2.3’
27”	18.8 gpm	1.8’

Recommendations for designing with pretreatment, mass load, downstream of detention and maintenance frequency should be the same as the StormFilter with ZPG media GULD, which is consistent with The Stormwater Management StormFilter Product Design Manual.

10.0 Appendices

- Appendix A – Media Specifications
- Appendix B – Approved QAPP
- Appendix C – Field Recordkeeping Forms, all 25 events
- Appendix D – Individual Storm Reports, all 25 events
- Appendix E – Quality Control
- Appendix F – Raw Data Tables
- Appendix G – Analytical Laboratory Reports
- Appendix H – Wilcoxon Results
- Appendix I – Bootstrap Results
- Appendix J – Statistics
- Appendix K – Particle Size Distribution
- Appendix L – Deicer Application
- Appendix M – Field Maintenance Recordkeeping Forms
- Appendix N – Operation and Maintenance Manual

11.0 References

Contech Engineered Solutions (CES). 2011. Evaluation of the Removal of Sil-Co-Sil 106 by PhosphoSorb™ in the Stormwater Management StormFilter® at 7.5 gpm (28 L/min) and 15 gpm (56 L/min). Portland, OR Author.

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North Carolina Department of Environment and Natural Resources Division of Water Quality Preliminary Evaluation Period Program Field Evaluation:

Stormwater Management StormFilter® Stormwater Treatment System
Mitchell Community College
Mooresville, NC

Abstract

This paper presents the results of a twenty month field study conducted at the Mitchell Community College testing site located in the Town of Mooresville, NC. The study was conducted in an effort to demonstrate the effectiveness of The Stormwater Management StormFilter® (StormFilter) Stormwater Treatment System (system) in treating stormwater runoff with respect to the removal of solid and nutrient pollutants.

Testing of the StormFilter system was conducted for Total Suspended Solids (TSS), Suspended Sediment Concentration (SSC), Total Volatile Suspended Solids (TVSS), Total Phosphorus (TP), Dissolved Phosphorus (Diss. P), Ortho-phosphate (Ortho-P), Particulate Phosphorus (PP), Ammonia (NH3+), Total Kjeldahl Nitrogen (TKN), Nitrate plus Nitrite (NO2- plus NO3-), Total Nitrogen (TN), and Organic Nitrogen (ON) in accordance with the approved Project Plan, (Contech, 2010) as well as the conditions outlined in the North Carolina Department of Environment and Natural Resources (NCDENR) Division of Water Quality (DWQ) Preliminary Evaluation Period (PEP) program, (NCDENR, 2007).

Results from the twenty month study, that represented a total of 13 storm events and 27.73 inches of precipitation, show that the StormFilter system tested was effective in removing solid and nutrient pollutants from stormwater runoff. The study was completed using the recommended design criteria of a maximum cartridge specific flow rate of 1gpm/ft^2, a coated perlite media, and a volume based design methodology. The StormFilter system was designed to capture and treat the 1-inch water quality volume, typical for the Piedmont region of North Carolina. The StormFilter system was also designed on a mass-loading basis to meet the annual pollutant loading requirements of the site with a minimum expected interval between maintenance of 1 year.

Significant reductions for solid and nutrient pollutants were observed between influent and effluent sampling locations using the Efficiency Ratio (ER) efficiency calculation (TSS 90.4%, TP 86.1%, and TN 55.9%) and Summation of Load (SOL) efficiency calculation methods (TSS 90.9%, TP 87.1%, and TN 50.2 %).

The study concluded that the StormFilter system successfully treated stormwater runoff with respect to removal of solid and nutrient pollutants and was able to meet North Carolina’s 85% TSS pollutant removal requirement, and provide excellent reductions of TP and TN to meet nutrient sensitive watershed nutrient goals (NCDENR, 2007).

Keywords

BMP; stormwater; TP; TN; TSS; NCDENR DWQ PEP; StormFilter; media filter cartridge

Introduction

Contech Engineered Solutions LLC (formerly Contech Construction Products Inc., Stormwater360 Inc., and Stormwater Management Inc.) is the leading provider of innovative, long-term, stormwater treatment solutions, offering a variety of products, maintenance, and laboratory and engineering support to meet stormwater treatment needs. Contech Engineered Solutions LLC's patented product, the Stormwater Management StormFilter® (StormFilter) Stormwater Treatment System (system) is a Best Management Practice (BMP) designed to meet federal, state, and local requirements for treating stormwater runoff in compliance with the Clean Water Act. The StormFilter system improves the quality of stormwater runoff before it enters receiving waterways through the use of customizable filter media, which removes non-point source pollutants, including sediment particles, oil and grease, soluble metals, nutrients, and organics.

The StormFilter system, as seen in Figure 1, is typically comprised of a vault that houses rechargeable, media-filled, filter cartridges. Stormwater entering the system percolates horizontally through these media-filled cartridges, where pollutant removal processes occur. Once filtered through the media, the treated stormwater is directed to a collection pipe and discharged to an open channel drainage way or stormsewer.

The StormFilter system is offered in a variety of configurations or containers depending on the specific application and site conditions: precast vault, box culvert vault, panel vault, manhole, and cast-in-place concrete. The StormFilter system is also offered in a steel catch basin or a concrete curb inlet configuration. The precast, manhole, and inlet configuration models utilize standard pre-manufactured units and arrive at the construction site with the filter cartridges and other internal components already in place to ease the installation process; the box culvert, panel vault, and cast-in-place units are customized for larger flows and require installation of cartridges at the site.

Contech Engineered Solutions LLC (Contech) applied to the NCDENR DWQ for conditional approval of the StormFilter system in December of 1997. This conditional approval allowed for participation in the Preliminary Evaluation Period (PEP) program. The PEP program is utilized by NCDENR DWQ to evaluate innovative and proprietary stormwater treatment technologies. In general, the PEP program allows for a limited number of installations in order for NCDENR DWQ to evaluate the performance of the technology and develop appropriate permitting criteria.

The StormFilter system PEP program application was approved by NCDENR DWQ in March of 2001, and the first PEP program field evaluation of the StormFilter system was conducted at the Currituck Gas House installation located in Barco, North Carolina. The objective of the study was to demonstrate the solid pollutant removal performance of the StormFilter system as compared to North Carolina's 85% TSS pollutant removal requirement (NCDENR, 2007). The Currituck Gas House StormFilter system study was successfully completed in March of 2007. The results obtained from this study were determined to be inconclusive with respect to meeting North Carolina's 85% TSS pollutant removal requirement.

Contech was granted approval for continued participation in the PEP program in June of 2009. The approval allowed for a limited number of additional installations in order for NCDENR DWQ to evaluate the performance of the StormFilter system. The primary goal was to collect performance data in order to support the approval of the StormFilter system and its potential inclusion into the North Carolina Stormwater BMP Manual. A major condition of the approval for continued participation in the PEP program was the execution of an additional field evaluation in accordance with the conditions outlined in the PEP program.

A Project Plan was completed in September of 2010, resulting in the commencement of field evaluation activities. The field evaluation was initiated in October of 2010 following the general acceptance of the Project Plan by stakeholders.

Pursuant to the approval for continued participation in the PEP program, the Mitchell Community College StormFilter system installation (located in Mooresville, NC) was evaluated over a twenty month period following system maintenance in November of 2010. This project was managed by Contech in cooperation with the site owner and the NCDENR DWQ. Independent oversight of all aspects of the project was provided by Ryan Winston, M.S., Extension Associate Engineer in the Department of Biological and Agricultural Engineering at North Carolina State University. Sample handling services were provided by Pace Analytical Services (Pace) of Huntersville, NC, and laboratory work was conducted by Pace and Test America of Beaverton, OR. Monitoring over a twenty month period resulted in the collection of 13 storm events representing 23.73 inches of cumulative precipitation.

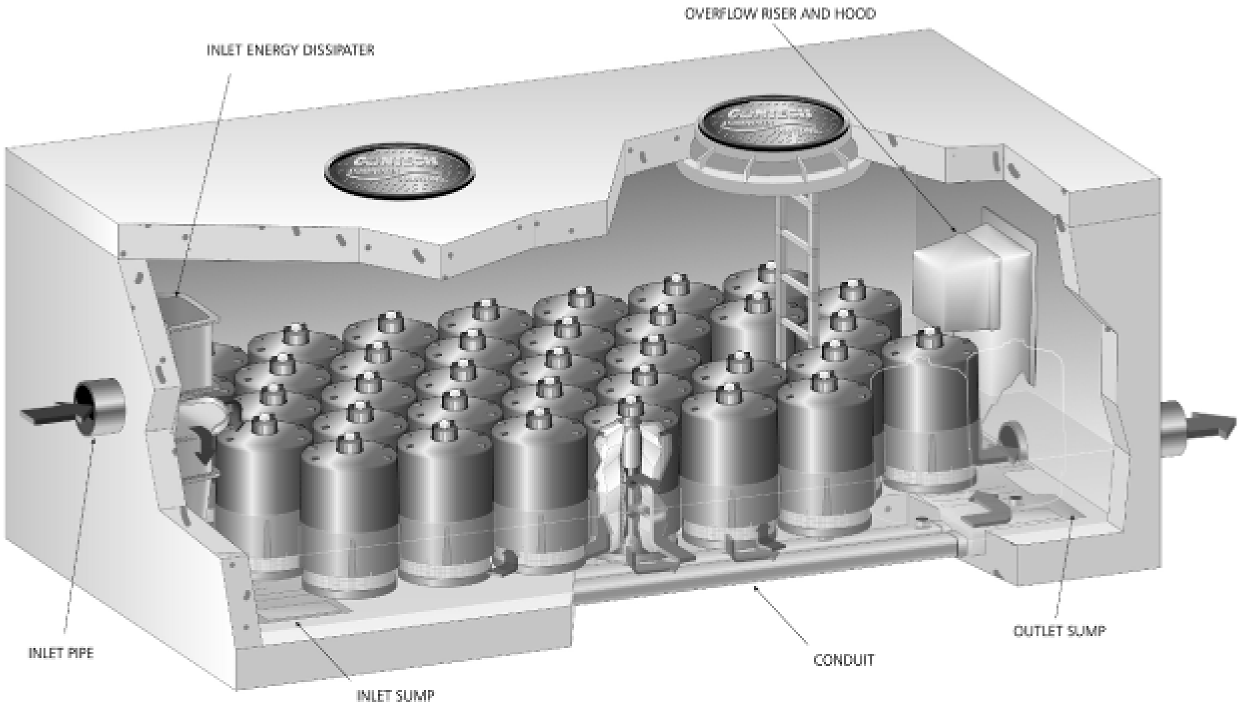

Figure 1. Standard StormFilter® System Illustration.

Site and System Description

The Mitchell Community College testing site is located in the Town of Mooresville, NC. Mooresville is located in southern Iredell County in the Piedmont region of North Carolina. The town is located between the Charlotte metropolitan area and the city of Statesville, the County seat. Mooresville is located within 15 miles of three interstate highways and is approximately 23 miles from the Charlotte-Douglas International Airport. The testing site was located at the intersection of West Moore Avenue and North Academy Street, (Lat: 35°35'3.60"N, Lon: 80°48'47.76"W, Elevation AMSL: 862ft). The site was owned and operated by Mitchell Community College and used for parking. The site was swept periodically, however minor amounts of sediment and organic debris were typically present on site. Based on information provided by the design engineer, the site was 68% impervious and the total drainage area for the site was 1.08 acres. A view of the finished parking lot located on site can be seen in Figure 2. An aerial view of the site from 2010 is shown in Figure 3. Stormwater runoff from the contributing drainage area was directed to the StormFilter system before eventually discharging into Reed's Creek Basin and ultimately Lake Norman.

Stormwater treatment for the site was provided by a StormFilter system, designed as a capture-and-treat system. The storage component of the system (tank) was comprised of a 30 inch diameter corrugated metal pipe (CMP) network designed to capture 75% of the calculated water quality volume (i.e. the runoff volume associated with the 1.0 inch event). The treatment component (StormFilter) was designed on a mass-loading basis required to meet the annual pollutant loading requirements of the site with a minimum estimated interval between maintenance of 1 year. The StormFilter contained a total of eight 18 inch, media filled filter cartridges operating at a specific flow rate of 1 gpm/ft^2.

Figure 2. View of finished parking lot at the Mitchell Community College testing site.

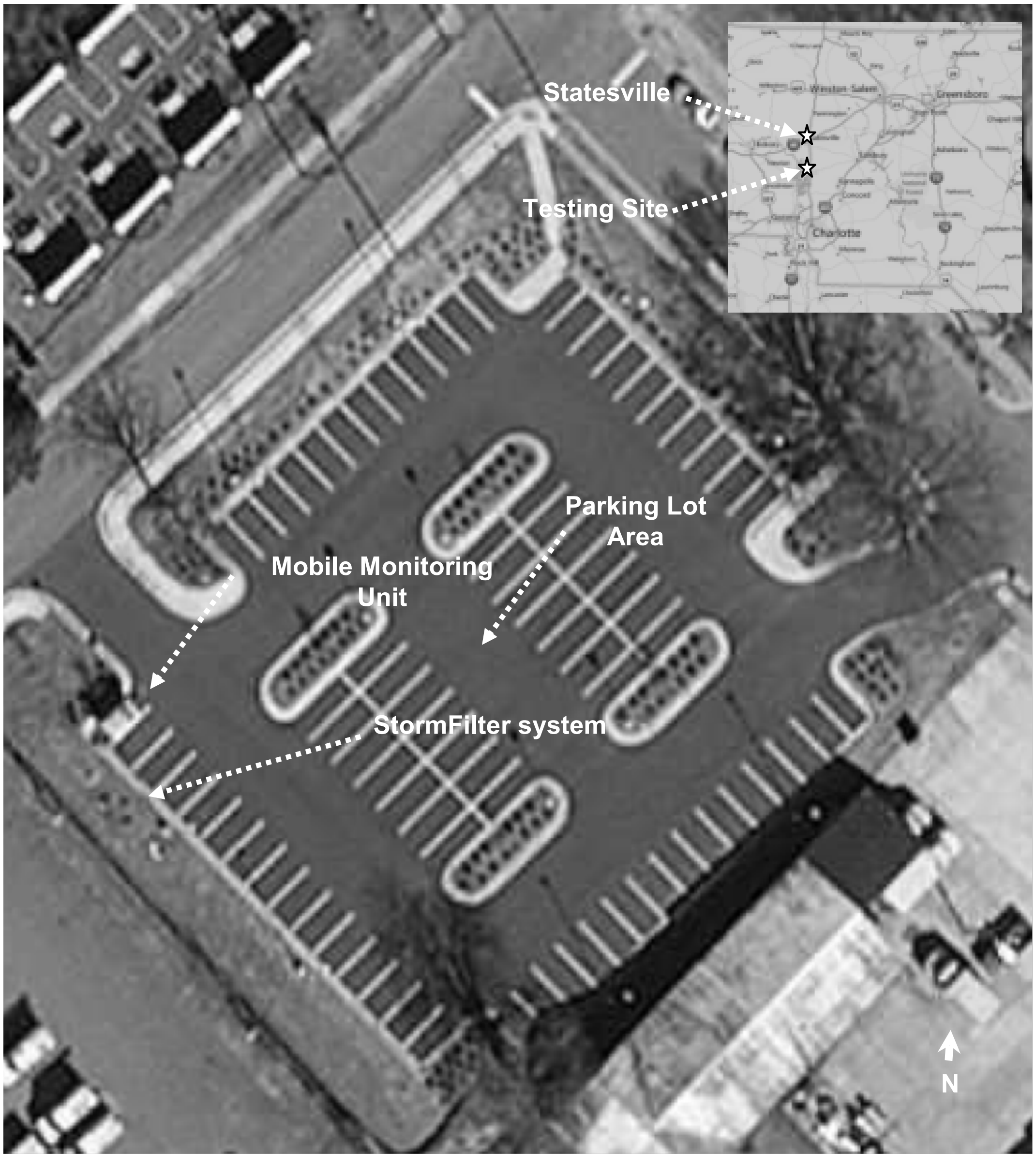

Figure 3. Aerial view of the Mitchell Community College testing site.

Each of the filter cartridges was filled with a perlite media. The perlite media used for this study was coated with activated alumina; this was done to aid in the attenuation and/or capture nutrient pollutants. With the exception of the surface coating, the coated and uncoated perlite media are essentially identical with respect to physical characteristics. Given that the primary pollutant removal mechanism employed by the media is physical straining, the coated perlite (PhosphoSorb) and uncoated perlite (Perlite) media should be considered equivalent with respect to expected solids removal performance. However, given that the secondary pollutant mechanism employed by the media is adsorption, the coated perlite (PhosphoSorb) and uncoated perlite (Perlite) media should not be considered equivalent with respect to expected nutrient pollutant removal performance. Therefore, the two media types were differentiated when determining nutrient removal performance.

Sampling Design

The equipment and sampling techniques used for this study were in accordance with the Project Plan (Contech, 2010) developed by Contech in consultation with NCDENR DWQ. The Project Plan met the conditions outlined in the PEP program. Contech personnel were responsible for the installation, operation, and maintenance of the sampling equipment. Pace provided sample retrieval, system reset, and sample submittal activities. Water sample processing and analysis was performed by Pace and Test America.

A Mobile Monitoring Unit (MMU) was provided, installed, maintained, and operated by Contech for sampling purposes. The MMU is a towable, fully enclosed, self-contained stormwater monitoring system specially designed and built by Contech for remote, extended-deployment stormwater monitoring. The design allows for remote control of sampling equipment, eliminates confined space entry requirements, and streamlines the sample and data collection process. The MMU installed at the Mitchell Community College testing site is shown in Figure 4.

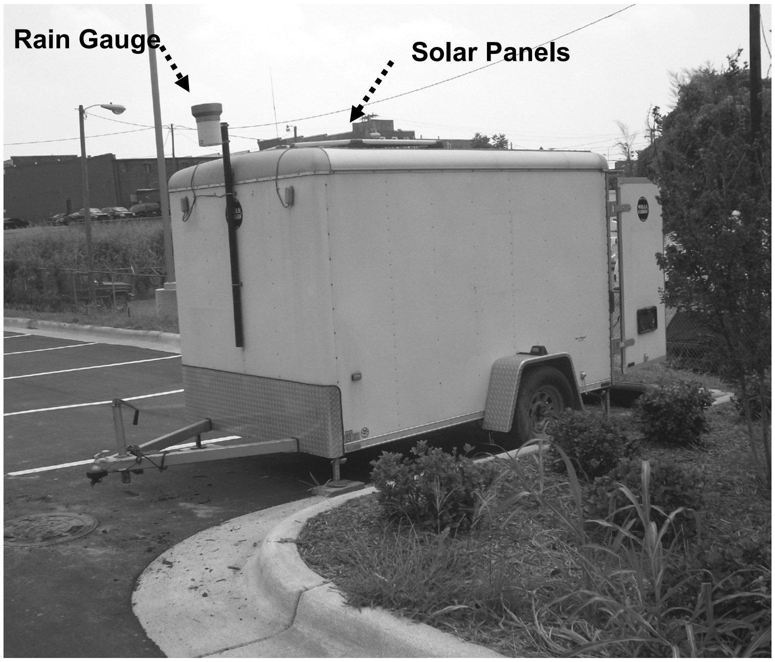

Figure 4. View of the Mobile Monitoring Unit (MMU) installed at the Mitchell Community College testing site.

Influent and effluent water quality samples were collected using individual ISCO 6712 Portable Automated Samplers configured for 1 liter wide-mouth HDPE bottles with sample bottles in the 1 through 12 positions for sample collection. The samplers were connected to individual 12V DC batteries recharged with solar panels. The influent sampler was equipped with an ISCO 750 Area Velocity Flow Module with a Low Profile Area Velocity Flow Sensor for flow analysis and influent sample pacing. The effluent sampler was equipped with an ISCO 730 Bubbler Flow Module used in conjunction with a 6 inch diameter Thel-Mar Weir for flow analysis and effluent sample pacing. Each sampler was also connected to an ISCO SPA 1489 Digital Cell Phone Modem to allow for remote communication and data access. Rainfall was measured using a 0.01-in resolution Texas Electronics TR-4 tipping bucket-type rain gauge. The sample intake for each automated sampler was connected to a stainless steel sample strainer (9/16″ diameter, 6″ length, with multiple ¼″ openings) via a length of

3/8″ ID Acutech Duality FEP/LDPE tubing. Sample strainers and flow measurement equipment were secured to the invert of the influent and effluent pipes using stainless steel spring rings.

Samplers were programmed to enable the sampling program when the flow rate exceeded 5 gpm. Once enabled, the samplers collected flow-proportional samples allowing the specified pacing volume to pass before taking a sample. The sample collection program was a one-part program developed to maximize the number of water quality samples collected as well as the coverage of the storm event. Influent and effluent sample collection programs were configured to collect up to four 250-mL aliquots per bottle spread between up to 12 1-L HDPE bottles. Due to the variability among precipitation events, the sample pacing specifications were varied in consultation with the most up-to-date precipitation forecasts.

Following a precipitation event, Contech personnel remotely communicated with the automated sampling equipment to confirm sample collection and dispatch personnel from Pace to retrieve the samples and reset the automated sampling equipment. Samples were delivered to Pace and Test America on ice (<4 degrees C) and accompanied by chain-of-custody documentation.

In situations where samples associated with multiple storm events were collected by the automated sampler, samples were composited using only those samples associated with independent individual storm events based on the hydrograph. Associated sample bottles were combined by Pace to create composite samples. Sample bottles were thoroughly shaken and sieved through a 2000µm sieve. Sample bottles were then emptied into a cone splitter to obtain a single, composite sample (USGS, 1980). Composite samples were then submitted for analysis according to the analytical methods specified in Table 1. The field monitoring methods used for this study represent the current state-of-the practice, and are very similar to those used by researchers in North Carolina to evaluate Stormwater BMPs.

Table 1. Analytical methods used for analytical parameters of interest.

Parameter	Analytical Method
Total Suspended Solids (TSS)	SM2540 D
Suspended Sediment Conc. (SSC)	ASTM D3977
Total Volatile Suspended Solids (TVSS)	EPA 160.4
Total Phosphorus (TP)	EPA 365.1
Dissolved Phosphorus (Diss. P)	EPA 365.1
Ortho-phosphate (Ortho-P)	EPA 365.1
Total Kjeldahl Nitrogen (TKN)	EPA 351.2
Ammonia (NH3+)	EPA 350.1
Nitrate plus Nitrite (NO2- plus NO3-)	EPA 353.2

As per the Project Plan, the following quality control samples were used to assess the quality of both field sampling and analytical activities: equipment rinsate blanks, equipment field blanks, method blank, and duplicate analysis. Sample processing blank samples were not taken. Except for solids analyses that employ the use of the whole sample volume (SSC), all method blanks and duplicate analyses were handled by Pace and Test America. Since solids analyses that employ the use of whole sample volume (SSC) consume the entire sample volume, replicate samples were prepared in place of duplicate samples and analyzed to allow for the assessment of analytical accuracy. The results of equipment rinsate blanks and equipment field blanks are shown in Table 2 accompanied by associated decisions and action items for instances of detection. Equipment rinsate blanks and equipment field blanks were submitted for analysis of the following parameters TSS, TVSS, TP, TKN, NH3+, and NO2- plus NO3-.

Table 2. Instances of detection in equipment rinsate blank and equipment field blank samples.

Date	Blank Type	Detections	Action	% of Sample Pairs Affected
7/8/2011	Rinsate	None	None	0
6/28/2011	Field	None	None	0
6/14/2012	Field	None	None	0

Precipitation Measurement

Precipitation was measured with a Texas Electronics TR-4 tipping bucket-type rain gauge. The rain gauge was connected to an ISCO 6712 Automated Sampler programmed to record the total number of tips (0.01 inch per tip) every 5 minutes. Equipment calibrations performed on site during the monitoring period indicated that the rain gauge was working properly.

A comparison of monthly precipitation totals measured at the NOAA NWS COOP weather station in Statesville, NC during the monitoring period to the 30 year monthly mean precipitation totals shows that precipitation in the area was below normal in 15 of the 20 months studied (Table 3). Rainfall was above normal in March (2011), July (2011), September (2011), November (2011), and May (2012) as seen in Table 3.

A total of 13 storm events were successfully sampled during the monitoring period Individual storm reports are included in Appendix A. Collection of storm events commenced after the review and conditional approval of the Project Plan by project stakeholders.

For sampled storm events, rainfall durations ranged from 8 to 36 hours, rainfall depth ranged from 0.85 to 4.41 inches, and 15 and 30 minute maximum intensities were 3.28 and 1.90 inches/hour respectively. Based on design information provided by the design engineer, runoff was calculated using the Curve Number Method using a CN of 89. Calculated runoff volumes ranged from 5796 to 94,133 gallons as seen in Table 4.

Table 3. Monthly precipitation totals compared to 30 year monthly mean precipitation totals (NOAA NWS COOP Weather Station Statesville, NC)

Month	NOAA NWS COOP Station Statesville, NC Precipitation Total (in.)	Percent of Monthly Precipitation Total Normal (%)	30 Year Monthly Precipitation Total Normal (in.)
November (2010)	1.08	33	3.30
December (2010)	2.63	72	3.64
January (2011)	1.59	42	3.83
February (2011)	1.76	50	3.55
March (2011)	5.66	127	4.45
April (2011)	2.72	80	3.42
May (2011)	3.82	92	4.15
June (2011)	1.78	40	4.49
July (2011)	6.26	158	3.95
August (2011)	3.29	90	3.67
September (2011)	4.89	120	4.07
October (2011)	2.39	69	3.45
November (2011)	4.14	125	3.30
December (2011)	3.32	91	3.64
January (2012)	1.8	47	3.83
February (2012)	1.81	51	3.55
March (2012)	2.64	59	4.45
April (2012)	1.77	52	3.42
May (2012)	6.43	155	4.15
June (2012)	4.36	97	4.49

Table 4. Precipitation and runoff statistics for sampled events at the Mitchell Community College testing site.

Event ID	Duration of storm event (hours)	Total Precipitation (in.)	P15 (in/hr)	P30 (in/hr)	Calculated Runoff Volume (gal)
MCC041611	8	1.04	1.32	0.96	9086
MCC051011	8	0.93	1.24	0.80	7126
MCC051611	22	1.04	0.40	0.26	9086
MCC062811	24	2.06	1.36	1.00	31611
MCC070811	13	4.41	3.28	1.90	94133
MCC073111	19	1.37	2.04	1.88	15674
MCC090511	36	1.94	1.92	0.96	28694
MCC092111	13	3.75	2.16	1.60	75933
MCC110311	24	1.40	0.56	0.50	16316
MCC111611	14	1.01	1.68	1.34	8538
MCC051312	21	1.82	1.28	0.92	25828
MCC052112	30	0.85	1.68	0.86	5796
MCC060612	30	2.11	1.00	0.88	32841

Flow Measurement

An ISCO 750 Area Velocity Flow Module with a Low Profile Area Velocity Flow Sensor was used to measure flow and pace sample collection at the influent sample location. Level measurements were adjusted by applying corrections that reflected differences between recorded and measured water surface elevations in the influent pipe where the Low Profile Area Velocity Flow Sensor was installed. On average, 182% of the calculated total rainfall volume as runoff was measured for the events monitored (Table 5).

An ISCO 730 Bubbler Flow Module was used in conjunction with a 6 inch diameter Thel-Mar Weir to measure flow and pace sample collection at the effluent sample location. Level measurements were adjusted by applying corrections that reflected differences between recorded and measured water surface elevations in the effluent pipe where the 6 inch diameter Thel-Mar Weir was installed. On average, 105% of the calculated total rainfall volume as runoff was measured as outflow for the monitored events (Table 5).

Table 5. Percentage of calculated rainfall runoff volumes measured at the Mitchell Community College testing site.

Event ID	Calculated Runoff Volume (gal)	Influent Volume (gal)	Influent Volume / Calc. Runoff Volume (%)	Effluent Volume (gal)	Effluent Volume / Calc. Runoff Volume (%)
MCC041611	9086	19897	219	12748	140
MCC051011	7126	11180	157	9392	132
MCC051611	9086	20358	224	18104	199
MCC062811	31611	35556	112	26364	83
MCC070811	94133	180699	192	49090	52
MCC073111	15674	20865	133	16093	103
MCC090511	28694	56344	196	35039	122
MCC092111	75933	125432	165	67321	89
MCC110311	16316	51869	318	20220	124
MCC111611	8538	18858	221	9926	116
MCC051312	25828	38451	149	13154	51
MCC052112	5796	9130	158	4879	84
MCC060612	32841	40865	124	21569	66

Stormwater Data Collection Requirements

Of the 13 qualifying storm events sampled between November of 2010 and June of 2012; 1) the total rainfall was greater than 0.1 inches for all storm events sampled, 2) the minimum inter-event period was greater than 6 hours for all storm events sampled, 3) the minimum number of influent and effluent aliquots collected per storm event was ≥ 5, 4) influent flow-weighted composite samples covered ≥ 50% of the total storm flow for all storm events sampled with the exception of the MCC070811, MCC090511, MCC092111, MCC110311,MCC051312, and MCC060612 events, and 5) effluent flow-weighted composite samples covered ≥ 50% of the total storm flow for all storm events sampled. All events have been determined to meet the conditions outlined in the PEP program as shown in Table 6.

Table 6. Stormwater data collection requirement results.

Event ID	Influent Coverage	Effluent Coverage	Influent Number of Aliquots	Effluent Number of Aliquots	Antecedent Dry Period > 6 hours	Event Depth (in.)
MCC041611	101%	100%	18	14	√	1.04
MCC051011	91%	79%	6	6	√	0.93
MCC051611	79%	90%	8	8	√	1.04
MCC062811	98%	97%	19	13	√	2.06
MCC070811	41%	98%	24	24	√	4.41
MCC073111	97%	98%	16	16	√	1.37
MCC090511	46%	90%	29	26	√	1.94
MCC092111	49%	93%	48	48	√	3.75
MCC110311	34%	60%	48	48	√	1.40
MCC111611	100%	100%	39	40	√	1.01
MCC051312	36%	92%	28	48	√	1.82
MCC052112	100%	74%	31	5	√	0.85
MCC060612	46%	73%	42	48	√	2.11

Data Analysis

Of the 13 storm events captured data verification and validation did not lead to the outright disqualification of any events due to obvious monitoring, handling or analytical errors, or the substantial exceedance of the design operating parameters. Event Mean Concentrations (EMC) from influent and effluent samples are summarized in Table 7-10.

Appendix A details system performance on an individual storm event basis using the Washington State Department of Ecology Individual Storm Reduction in Pollutant Concentration (ISRPC) method. This provides information on the performance of the system over the course of a single storm event based upon EMC (WADOE, 2003). Hydrograph and rainfall data from each event are also shown in Appendix A.

Using SSC (<500µm) EMC results, the percent of corresponding SSC (<2000µm) EMC results was calculated. The calculated percentages of corresponding SSC (<2000µm) EMC results indicated the portion of material that was less than 500µm in size and are summarized in Table 11.

Using TVSS EMC results, the percent of corresponding SSC results was calculated. The calculated percentages of corresponding SSC (<2000µm) and SSC (<500µm) results indicated the percent of combustible materials that are assumed to be organic in nature and are summarized in Table 12.

Non-parametric statistical methods were used to evaluate correlations and differences between non-transformed influent and effluent EMCs since influent and effluent EMCs were generally not from the same statistical distribution. To test for positive correlations between influent and effluent EMCs, the Spearman Rank Order Correlation test was used (USGS, 1991). To evaluate the significance of differences between influent and effluent EMCs, the Mann-Whitney Rank Sum Test was used (USGS, 1991). For the Mann-Whitney Rank Sum Test the null hypothesis was that the two samples were not drawn from populations with different medians. A significant difference between influent and effluent EMCs was concluded when P<0.05.

Detectible concentrations were observed for all parameters analyzed except for TSS for the MCC051011, MCC051611, MCC062811, MCC073111, MCC090511, MCC092111, MCC110311, and MCC060612 events; SSC (<2000µm) for the MCC073111, MCC051312, and MCC060612 events; SSC (<500µm) for the MCC051611, MCC051312, and MCC060612 events; TVSS (<2000µm) for the MCC111611 event; TVSS (<500µm) for the MCC110311 and MCC111611 events; TP for the MCC05161, MCC062811, MCC070811, MCC092111, MCC110311, MCC111611, MCC051312, MCC052112, and MCC060612 events ; Diss. P for the MCC041611, MCC062811, MCC070811, MCC073111, MCC092111, MCC110311, MCC111611, MCC051312, and MCC060612 events; Ortho-P for the MCC041611, MCC062811, MCC070811, MCC073111, MCC092111, MCC110311, MCC111611, MCC051312, and MCC060612 events; TKN for the MCC062811, MCC070811, MCC073111, MCC092111, MCC110311, MCC111611, MCC051312, and MCC060612 events; NH3+ for the MCC062811, MCC073111, MCC092111, MCC110311, MCC111611, MCC051312, and MCC060612 events; and NO2- plus NO3- for the MCC062811, MCC070811, MCC092111, MCC110311, MCC111611, and MCC051312 events; For values that were reported as non-detect, substitutions were made using half of the Method Reporting Limit (MRL) for statistical testing and calculation of efficiencies. For calculated parameters values calculated as ≤ 0 were reported as 0 for statistical testing and calculation of efficiencies.

Performance was calculated using the Efficiency Ratio (ER) efficiency calculation method. The ER method defines the efficiency as the average event mean concentration of pollutants over some time period.

$$ER = 1 - \frac{mean\ effluent\ EMC}{mean\ influent\ EMC}$$

The ER method assumes; 1) The weight of all storm events is equal regardless of the relative magnitude of the storm event and 2) that if all storm events at the site had been monitored, the average inlet and outlet EMCs would be similar to those that were monitored (URS/ EPA 1999). ER efficiency calculations for the 13 events sampled at the Mitchell Community College testing site are summarized in Tables 7-10.

Performance was also calculated using the Summation of Loads (SOL) efficiency calculation method. The SOL method defines the efficiency as a percentage based on the ratio of the summation of all influent loads to the summation of all effluent loads.

$$SOL = 1 - \frac{sum\ of\ all\ effluent\ loads}{sum\ of\ all\ influent\ loads}$$

The SOL method assumes; 1) monitoring data accurately represents the actual entire total loads in and out of the BMP for a period long enough to overshadow any temporary storage or export of pollutants and 2) any significant storm events that were not monitored had a ratio of inlet to effluent loads similar to the storms events that were monitored (URS/ EPA 1999). In an effort to eliminate the introduction of potential bias associated with observed discrepancies between influent and effluent measured volumes it was assumed that the influent volume was equal to the effluent volume. Measured effluent volume was used to calculate loads for both the influent and effluent sample locations. SOL efficiency calculations for the 13 events sampled at the Mitchell Community College testing site are summarized in Tables 13,- 16.

Results

Based on the use of the Spearman Rank Order correlation test, positive correlations ($P<0.05$) were determined between influent and effluent EMCs for Ortho-P and NH3+.

Based on the use of the Mann-Whitney Rank Sum test, the difference in the median values between the influent and effluent EMCs is greater than would be expected by chance. Therefore, a statistically significant difference ($P<0.05$) was observed for TSS, SSC (<2000µm), SSC (<500µm), TVSS (<2000µm), TP, PP, TKN, TN, and ON as seen in Tables 7 -10.

Based on the use of the Mann-Whitney Rank Sum test, a statistically significant difference ($P> 0.05$) was *not* observed for TVSS (<500µm), Diss. P, Ortho-P, NH3+, and NO2- plus NO3- as seen in Tables 7-10.

Suspended Solids Parameters

Influent EMCs for TSS ranged from 10.3 mg/l to 98.2 mg/l with a median of 27.6 mg/l and a mean of 34.6 mg/l. Corresponding effluent EMCs ranged from 1.3 mg/l to 6.6 mg/l with a median of 2.8 mg/l and a mean of 3.3 mg/l, resulting in an ER efficiency of 90.4%. Total event loadings for the study were 32.7 kg at the influent and 3.0 kg at the effluent sampling location, resulting in an SOL efficiency of 90.9%.

Influent EMCs for SSC (<2000µm) ranged from 17.7 mg/l to 2080.0 mg/l with a median of 53.4 mg/l and a mean of 231.0 mg/l. Corresponding effluent EMCs ranged from 1.9 mg/l to 7.2 mg/l with a median of 3.4 mg/l and a mean of 3.9 mg/l, resulting in an ER efficiency of 98.3%.Total event loadings for the study were 222.0 kg at the influent and 3.9 kg at the effluent sampling location, resulting in an SOL efficiency of 98.3%. In general, the relationship between TSS and SSC (<2000µm) was determined not to be significant based on the linear regression results for both influent (R^2 =0.0130) and effluent (R^2 =0.410) EMCs.

Influent EMCs for SSC (<500µm) ranged from 9.0 mg/l to 393.0 mg/l with a median of 28.6 mg/l and a mean of 66.1 mg/l. Corresponding effluent EMCs ranged from 1.7 mg/l to 10.0 mg/l with a median of 2.8 mg/l and a mean of 4.4 mg/l, resulting in an ER efficiency of 93.4%.Total event loadings for the study were 63.3 kg at the influent and 4.0 kg at the effluent sampling location, resulting in an SOL efficiency of 93.7%. For each storm event, the percent of SSC (<2000µm) represented by SSC (<500 µm) was calculated (Table 11). Influent and effluent median percentages of SSC (<2000µm) were 68.0% and 94.2%, respectively. The percentage of corresponding SSC (<2000µm) results indicated the portion of material that were less than 500µm in size.

Volatile Suspended Solids Parameters

Influent EMCs for TVSS (<2000µm) ranged from 1.1 mg/l to 99.2 mg/l with a median of 11.9 mg/l and a mean of 23.8 mg/l. Corresponding effluent EMCs ranged from 0.5 mg/l to 6.7 mg/l with a median of 3.0 mg/l and a mean of 2.9 mg/l, resulting in an ER efficiency of 87.7%.Total event loadings for the study were 24.6 kg at the influent and 2.9 kg at the effluent sampling location, resulting in an SOL efficiency of 88.2%. For each storm event, the percent of SSC (<2000 µm) represented by TVSS (<2000µm) was calculated (Table 12). Influent and effluent median percentages of SSC (<2000µm) were 29.0% and 65.1%, respectively. Percentage of corresponding SSC (<2000µm) results indicated the percent of combustible materials that were assumed to be organic in nature.

Influent EMCs for TVSS (<500µm) ranged from 1.1 mg/l to 48.0 mg/l with a median of 7.3 mg/l and a mean of 11.6 mg/l. Corresponding effluent EMCs ranged from 0.6 mg/l to 5.3 mg/l with a median of 3.4 mg/l and a mean of 3.1 mg/l, resulting in an ER efficiency of 73.4%.Total event loadings for the study were 9.9 kg at the influent and 3.3 kg at the effluent sampling location, resulting in an SOL efficiency of 67.1%. For each storm event, the percent of SSC (<500µm) represented by TVSS (<500µm) was calculated (Table 12). Influent and effluent median percentages of SSC (<500µm) were 31.4% and 86.4% respectively. Percentage of corresponding SSC (<500µm) results indicated the percent of combustible materials that were assumed to be organic in nature.

Phosphorus Parameters

Influent EMCs for TP ranged from 0.07 mg/l to 0.90 mg/l with a median of 0.14 mg/l and a mean of 0.22 mg/l. Corresponding effluent EMCs ranged from 0.03 mg/l to 0.06 mg/l with a median of 0.03 mg/l and a mean of 0.03 mg/l, resulting in an ER efficiency of 86.1%. Total event loadings for the study were 218.6 g at the influent and 28.1 g at the effluent sampling location, resulting in an SOL efficiency of 87.1%.

Influent EMCs for Diss. P ranged from 0.03 mg/l to 0.85 mg/l with a median of 0.05 mg/l and a mean of 0.16 mg/l. Corresponding effluent EMCs ranged from 0.03 mg/l to 0.16 mg/l with a median of 0.05 mg/l and a mean of 0.04 mg/l, resulting in an ER efficiency of 74.2%. Total event loadings for the study were 109.6 g at the influent and 35.9 g at the effluent sampling location, resulting in an SOL efficiency of 67.3%.

Influent EMCs for Ortho-P ranged from 0.03 mg/l to 0.86 mg/l with a median of 0.03 mg/l and a mean of 0.14 mg/l. Corresponding effluent EMCs ranged from 0.03 mg/l to 0.03 mg/l with a median of 0.03 mg/l and a mean of 0.03 mg/l, resulting in an ER efficiency of 82.5%. Total event loadings for the study were 102.8 g at the influent and 22.4 g at the effluent sampling location, resulting in an SOL efficiency of 78.2%.

Calculated influent EMCs for PP, calculated as the difference between TP and Diss. P, ranged from 0.02 mg/l to 0.23 mg/l with a median of 0.06 mg/l and a mean of 0.08 mg/l. Corresponding effluent EMCs ranged from 0.03 mg/l to 0.00 mg/l with a median of 0.00 mg/l and a mean of 0.01 mg/l, resulting in an ER efficiency of 91.3%. Total event loadings for the study were 97.7 g at the influent and 3.5 g at the effluent sampling location, resulting in an SOL efficiency of 96.4%.

Nitrogen Parameters

Influent EMCs for NH3+ ranged from 0.05 mg/l to 0.72 mg/l with a median of 0.21 mg/l and a mean of 0.27 mg/l. Corresponding effluent EMCs ranged from 0.05 mg/l to 0.24 mg/l with a median of 0.05 mg/l and a mean of 0.10 mg/l, resulting in an ER efficiency of 62.8%. Total event loadings for the study were 205.0 g at the influent and 82.0 g at the effluent sampling location, resulting in an SOL efficiency of 60.0%.

Influent EMCs for TKN ranged from 0.25 mg/l to 2.70 mg/l with a median of 0.72 mg/l and a mean of 0.94 mg/l. Corresponding effluent EMCs ranged from 0.25 mg/l to 0.58 mg/l with a median of 0.25 mg/l and a mean of 0.28 mg/l, resulting in an ER efficiency of 70.2%. Total event loadings for the study were 686.2 g at the influent and 268.2 g at the effluent sampling location, resulting in an SOL efficiency of 60.9%.

Influent EMCs for NO2- plus NO3- ranged from 0.10 mg/l to 0.30 mg/l with a median of 0.16 mg/l and a mean of 0.17 mg/l. Corresponding effluent EMCs ranged from 0.10 mg/l to 0.35 mg/l with a median of 0.10 mg/l and a mean of 0.16 mg/l, resulting in an ER efficiency of 9.8%. Total event loadings for the study were 150.7 g at the influent and 133.9 g at the effluent sampling location, resulting in an SOL efficiency of 11.2%.

Calculated influent EMCs for TN, calculated as the sum of TKN and NO2- plus NO3- , ranged from 0.35 mg/l to 2.95 mg/l with a median of 0.85 mg/l and a mean of 1.00 mg/l. Corresponding effluent EMCs ranged from 0.35 mg/l to 0.82 mg/l with a median of 0.35 mg/l and a mean of 0.44 mg/l, resulting in an ER efficiency of 55.9%. Total event loadings for the study were 798.1 g at the influent and 397.4 g at the effluent sampling location, resulting in an SOL efficiency of 50.2%.

Calculated influent EMCs for ON, calculated as the difference between TKN and NH3+ results, ranged from 0.00 mg/l to 1.98 mg/l with a median of 0.063 mg/l and a mean of 0.67 mg/l. Corresponding effluent EMCs ranged from 0.03 mg/l to 0.34 mg/l with a median of 0.20 mg/l and a mean of 0.18 mg/l, resulting in an ER efficiency of 73.1%. Total event loadings for the study were 481.2 g at the influent and 186.1 g at the effluent sampling location, resulting in an SOL efficiency of 61.3%.

Table 7. Suspended Solids Efficiency Ratio (ER) Calculations and Statistical Testing for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TSS (mg/l)		SSC (<2000μm) (mg/l)		SSC (<500μm) (mg/l)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
MCC041611	21.2	6.2	55.7	7.2	45.8	7.3
MCC051011	98.2	5.1	90.6	4.6	104.0	5.1
MCC051611	21.8	2.8	51.0	6.2	9.6	1.9
MCC062811	10.3	1.4	18.0	3.0	9.0	2.6
MCC070811	18.2	3.3	29.7	3.8	16.0	3.0
MCC073111	28.4	2.5	17.7	2.7	29.1	4.0
MCC090511	25.1	2.5	81.8	2.5	74.5	2.4
MCC092111	27.6	1.3	86.0	1.9	20.4	1.7
MCC110311	23.6	1.3	2080.0	2.4	393.0	1.8
MCC111611	56.9	3.4	186.0	2.7	16.3	2.5
MCC051312	52.4	5.7	27.0	5.0	28.0	10.0
MCC052112	28.2	6.6	NT	NT	NT	NT
MCC060612	38.0	1.3	48.0	5.0	48.0	10.0
Min	10.3	1.3	17.7	1.9	9.0	1.7
Max	98.2	6.6	2080.0	7.2	393.0	10.0
Median	27.6	2.8	53.4	3.4	28.6	2.8
Mean	34.6	3.3	231.0	3.9	66.1	4.4
Efficiency Ratio	90.4%		98.3%		93.4%	
Mann-Whitney U statistic	0.000		0.000		4.000	
P value for U statistic	<0.001		<0.001		<0.001	

NT = Not tested

QC DQ = Quality Control Disqualification

Table 8. Total Volatile Suspended Solids Efficiency Ratio (ER) Calculations and Statistical Testing for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TVSS (<2000µm) (mg/l)		TVSS (<500µm) (mg/l)	
	Influent	Effluent	Influent	Effluent
MCC041611	30.8	4.1	24.0	5.3
MCC051011	53.0	6.7	48.0	4.2
MCC051611	13.0	3.1	10.4	3.6
MCC062811	10.8	3.4	4.8	4.3
MCC070811	8.0	2.1	7.6	3.3
MCC073111	19.6	3.8	3.4	3.9
MCC090511	7.4	2.8	4.2	3.4
MCC092111	27.3	1.7	6.1	1.5
MCC110311	99.2	1.6	13.3	1.0
MCC111611	1.1	0.5	1.1	0.6
MCC051312	8.4	3.2	9.2	3.2
MCC052112	NT	NT	NT	NT
MCC060612	7.2	2.2	7.0	2.8
Min	1.1	0.5	1.1	0.6
Max	99.2	6.7	48.0	5.3
Median	11.9	3.0	7.3	3.4
Mean	23.8	2.9	11.6	3.1
Efficiency Ratio	87.7%		73.4%	
Mann-Whitney U statistic	11.000		0.000	
P value for U statistic	<0.001		0.667	

NT = Not tested
QC DQ = Quality Control Disqualification

Table 9. Phosphorus Efficiency Ratio (ER) Calculations and Statistical Testing for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TP (mg/l)		Diss. P (mg/l)		Ortho-P (mg/l)		PP (mg/l)	
	Influent	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**
MCC041611	0.160	0.058	0.025	0.025	0.025	0.025	0.135	0.033
MCC051011	NT	NT	NT	NT	NT	NT	NT	NT
MCC051611	0.110	0.025	NT	NT	NT	NT	NT	NT
MCC062811	0.130	0.025	0.025	0.160	0.025	0.025	0.105	0.000
MCC070811	0.065	0.025	0.025	0.025	0.025	0.025	0.040	0.000
MCC073111	0.140	0.057	0.061	0.025	0.025	0.025	0.079	0.032
MCC090511	NT	NT	NT	NT	NT	NT	NT	NT
MCC092111	0.250	0.025	0.025	0.025	0.025	0.025	0.225	0.000
MCC110311	0.900	0.025	0.850	0.025	0.860	0.025	0.050	0.000
MCC111611	0.100	0.025	0.081	0.025	0.063	0.025	0.019	0.000
MCC051312	0.088	0.025	0.054	0.025	0.025	0.025	0.034	0.000
MCC052112	0.200	0.025	NT	NT	NT	NT	NT	NT
MCC060612	0.310	0.025	0.250	0.025	0.210	0.025	0.060	0.000
Min	0.065	0.025	0.025	0.025	0.025	0.025	0.019	0.000
Max	0.900	0.058	0.850	0.160	0.860	0.025	0.225	0.033
Median	0.140	0.025	0.054	0.025	0.025	0.025	0.060	0.000
Mean	0.223	0.031	0.155	0.040	0.143	0.025	0.083	0.007
Efficiency Ratio	86.1%		74.2%		82.5%		91.3%	
Mann-Whitney U statistic	0.000		23.000		27.000		2.000	
P value for U statistic	<0.001		0.074		0.077		<0.001	

NT = Not tested
QC DQ = Quality Control Disqualification

Table 10. Nitrogen Efficiency Ratio (ER) Calculations and Statistical Testing for the 13 events sampled at the Mitchell Community College testing site.

Event ID	NH3+ (mg/l)		TKN (mg/l)		NO2- plus NO3- (mg/l)		TN (mg/l)		ON (mg/l)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
MCC041611	0.48	0.22	0.64	0.25	0.17	0.16	0.81	0.41	0.16	0.03
MCC051011	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
MCC051611	0.36	0.24	0.99	0.58	0.22	0.24	1.21	0.82	0.63	0.34
MCC062811	0.05	0.05	0.25	0.25	0.25	0.10	0.50	0.35	0.20	0.20
MCC070811	0.25	0.10	0.25	0.25	0.10	0.10	0.35	0.35	0.00	0.15
MCC073111	0.05	0.05	0.72	0.25	0.30	0.35	1.02	0.60	0.67	0.20
MCC090511	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
MCC092111	0.05	0.05	0.25	0.25	0.10	0.10	0.35	0.35	0.20	0.20
MCC110311	0.72	0.05	2.70	0.25	0.25	0.10	2.95	0.35	1.98	0.20
MCC111611	0.11	0.05	0.25	0.25	0.10	0.10	0.35	0.35	0.14	0.20
MCC051312	0.05	0.05	0.79	0.25	0.10	0.10	0.89	0.35	0.74	0.20
MCC052112	0.60	0.18	2.10	0.25	NT	NT	NT	NT	1.50	0.07
MCC060612	0.21	0.05	1.40	0.25	0.15	0.22	1.55	0.47	1.19	0.20
Min	0.05	0.05	0.25	0.25	0.10	0.10	0.35	0.35	0.00	0.03
Max	0.72	0.24	2.70	0.58	0.30	0.35	2.95	0.82	1.98	0.34
Median	0.21	0.05	0.72	0.25	0.16	0.10	0.85	0.35	0.63	0.20
Mean	0.27	0.10	0.94	0.28	0.17	0.16	1.00	0.44	0.67	0.18
Efficiency Ratio	62.8%		70.2%		9.8%		55.9%		73.1%	
Mann-Whitney U statistic	35.000		24.000		40.500		24.000		2.000	
P value for U statistic	0.079		0.006		0.467		0.043		<0.001	

NT = Not tested
QC DQ = Quality Control Disqualification

Table 11. Calculated Percentages of material less than 500µm for the 13 events sampled at the Mitchell Community College testing site.

Event ID	SSC (<500µm)/ SSC (<2000µm) (%)	
	Influent	**Effluent**
MCC041611	82.2	100.0
MCC051011	100.0	100.0
MCC051611	18.9	31.1
MCC062811	49.8	86.0
MCC070811	53.9	79.9
MCC073111	100.0	100.0
MCC090511	91.1	98.4
MCC092111	23.7	85.9
MCC110311	18.9	75.2
MCC111611	8.8	90.1
MCC051312	100.0	100.0
MCC052112	NT	NT
MCC060612	100.0	100.0
Min	8.8	31.1
Max	100.0	100.0
Median	68.0	94.2
Mean	62.3	87.2

NT = Not tested
QC DQ = Quality Control Disqualification

Table 12. Calculated percentages of combustible materials that were assumed to be organic in nature for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TVSS (<2000μm)/ SSC (<2000μm) (%)		TVSS (<500μm)/ SSC (<500μm) (%)	
	Influent	**Effluent**	**Influent**	**Effluent**
MCC041611	55.3	56.9	52.4	72.6
MCC051011	58.5	100.0	46.2	81.9
MCC051611	25.5	50.0	100.0	100.0
MCC062811	60.0	100.0	53.6	100.0
MCC070811	26.9	55.6	47.5	100.0
MCC073111	100.0	100.0	11.7	98.7
MCC090511	9.0	100.0	5.6	100.0
MCC092111	31.7	88.5	29.9	90.9
MCC110311	4.8	66.1	3.4	54.9
MCC111611	0.6	18.3	6.7	22.4
MCC051312	31.1	64.0	32.9	32.0
MCC052112	NT	NT	NT	NT
MCC060612	15.0	44.0	14.6	28.0
Min	0.6	18.3	3.4	22.4
Max	100.0	100.0	100.0	100.0
Median	29.0	65.1	31.4	86.4
Mean	34.9	70.3	33.7	73.5

NT = Not tested
QC DQ = Quality Control Disqualification

Table 13. Suspended Solids Summation of Loads (SOL) Calculations for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TSS (kg)		SSC (<2000µm) (kg)		SSC (<500µm) (kg)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
MCC041611	1.0	0.3	2.7	0.3	2.2	0.4
MCC051011	3.5	0.2	3.2	0.2	3.7	0.2
MCC051611	1.5	0.2	3.5	0.4	0.7	0.1
MCC062811	1.0	0.1	1.8	0.3	0.9	0.3
MCC070811	3.4	0.6	5.5	0.7	3.0	0.6
MCC073111	1.7	0.2	1.1	0.2	1.8	0.2
MCC090511	3.3	0.3	10.8	0.3	9.9	0.3
MCC092111	7.0	0.3	21.9	0.5	5.2	0.4
MCC110311	1.8	0.1	159.2	0.2	30.1	0.1
MCC111611	2.1	0.1	7.0	0.1	0.6	0.1
MCC051312	2.6	0.3	1.3	0.2	1.4	0.5
MCC052112	0.5	0.1	NT	NT	NT	NT
MCC060612	3.1	0.1	3.9	0.4	3.9	0.8
Sum	32.7	3.0	222.0	3.9	63.3	4.0
SOL Efficiency	90.9%		98.3%		93.7%	

NT = Not tested

QC DQ = Quality Control Disqualification

Table 14. Total Volatile Suspended Solids Summation of Loads (SOL) Calculations for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TVSS (<2000µm) (kg)		TVSS (<500µm) (kg)	
	Influent	Effluent	Influent	Effluent
MCC041611	1.5	0.2	1.2	0.3
MCC051011	1.9	0.2	1.7	0.1
MCC051611	0.9	0.2	0.7	0.2
MCC062811	1.1	0.3	0.5	0.4
MCC070811	1.5	0.4	1.4	0.6
MCC073111	1.2	0.2	0.2	0.2
MCC090511	1.0	0.4	0.6	0.5
MCC092111	7.0	0.4	1.6	0.4
MCC110311	7.6	0.1	1.0	0.1
MCC111611	0.0	0.0	0.0	0.0
MCC051312	0.4	0.2	0.5	0.2
MCC052112	NT	NT	NT	NT
MCC060612	0.6	0.2	0.6	0.2
Sum	24.6	2.9	9.9	3.3
SOL Efficiency	88.2%		67.1%	

NT = Not tested
QC DQ = Quality Control Disqualification

Table 15. Phosphorus Summation of Loads (SOL) Calculations for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TP (g)		Diss. P (g)		Ortho-P (g)		PP (g)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
MCC041611	7.7	2.8	1.2	1.2	1.2	1.2	6.5	1.6
MCC051011	NT	NT	NT	NT	NT	NT	NT	NT
MCC051611	7.5	1.7	NT	NT	NT	NT	NT	NT
MCC062811	13.0	2.5	2.5	16.0	2.5	2.5	10.5	0.0
MCC070811	12.1	4.6	4.6	4.6	4.6	4.6	7.4	0.0
MCC073111	8.5	3.5	3.7	1.5	1.5	1.5	4.8	1.9
MCC090511	NT	NT	NT	NT	NT	NT	NT	NT
MCC092111	63.7	6.4	6.4	6.4	6.4	6.4	57.3	0.0
MCC110311	68.9	1.9	65.1	1.9	65.8	1.9	3.8	0.0
MCC111611	3.8	0.9	3.0	0.9	2.4	0.9	0.7	0.0
MCC051312	4.4	1.2	2.7	1.2	1.2	1.2	1.7	0.0
MCC052112	3.7	0.5	NT	NT	NT	NT	NT	NT
MCC060612	25.3	2.0	20.4	2.0	17.1	2.0	4.9	0.0
Sum	218.6	28.1	109.6	35.9	102.8	22.4	97.7	3.5
SOL Efficiency	87.1%		67.3%		78.2%		96.4%	

NT = Not tested

QC DQ = Quality Control Disqualification

Table 16. Nitrogen Summation of Loads (SOL) Calculations for the 13 events sampled at the Mitchell Community College testing site.

Event ID	**NH3+ (g)**		**TKN (g)**		**NO2- plus NO3- (g)**		**TN (g)**		**ON (g)**	
	Influent	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**
MCC041611	23.2	10.6	30.9	12.1	8.2	7.7	39.1	19.8	7.7	1.4
MCC051011	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
MCC051611	24.7	16.4	67.8	39.7	15.1	16.4	82.9	56.2	43.2	23.3
MCC062811	5.0	5.0	24.9	24.9	24.9	10.0	49.9	34.9	20.0	20.0
MCC070811	46.5	18.6	46.5	46.5	18.6	18.6	65.0	65.0	0.0	27.9
MCC073111	3.0	3.0	43.9	15.2	18.3	21.3	62.1	36.6	40.8	12.2
MCC090511	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
MCC092111	12.7	12.7	63.7	63.7	25.5	25.5	89.2	89.2	51.0	51.0
MCC110311	55.1	3.8	206.7	19.1	19.1	7.7	225.8	26.8	151.6	15.3
MCC111611	4.1	1.9	9.4	9.4	3.8	3.8	13.2	13.2	5.3	7.5
MCC051312	2.5	2.5	39.3	12.4	5.0	5.0	44.3	17.4	36.8	10.0
MCC052112	11.1	3.3	38.8	4.6	NT	NT	NT	NT	27.7	1.3
MCC060612	17.1	4.1	114.3	20.4	12.2	18.0	126.6	38.4	97.2	16.3
Sum	205.0	82.0	686.2	268.2	150.7	133.9	798.1	397.4	481.2	186.1
SOL Efficiency	60.0%		60.9%		11.2%		50.2%		61.3%	

NT = Not tested
QC DQ = Quality Control Disqualification

Residual Solids Assessment Results

In an effort to verify the capture of materials by the StormFilter system over the course of the monitoring period, a qualitative assessment of materials captured by the StormFilter system was performed during the site visit conducted on November 3, 2011. The mass of materials contained in the system was estimated using a mean depth measurement and a texture based bulk density estimate. The mean depth of material captured by the StormFilter was determined to be approximately 3 inches. A composite sample of the material captured by the StormFilter was collected and texture was determined in the field by hand texturing of the sample. Hand texture analysis of the composite sample revealed that the materials captured by the StormFilter had a loamy sand texture (USDA classification). The estimated mass of materials contained in the StormFilter, using the mean depth of material captured by the StormFilter and a bulk density assumption for loamy sand texture soils of 1.65 gm/cc, was approximately 150 kg.

Following the maintenance of the system on November 3, 2011 which involved the removal of accumulated solids from the system as well as the replacement of cartridges, a qualitative assessment of materials captured by the StormFilter system was performed during the site visit conducted on June 14, 2012. The mass and texture of materials contained in the system was estimated as described above. The mean depth of material captured by the StormFilter was determined to be approximately 0.5 inches; and had a loamy sand texture (USDA classification). The estimated mass of materials was approximately 25 kg.

The estimated mass of materials captured by the StormFilter system between November (2010) and June (2012) was 175 kg should be considered limited. As compared to the calculated mass of material captured by the system using SSC (<2000µm) results of 218.2 kg (Table 13), the estimated mass of materials captured by the StormFilter system over the course of the monitoring period is within the realm of expectation for the study.

Summary and Conclusion

The primary purpose of this report was to document StormFilter system performance with respect to solid and nutrient pollutant removal and quantify performance in accordance with the conditions outlined in the NCDENR DWQ PEP program.

Between April 2011 and June 2012, a total of 13 storm events were monitored and were determined to meet the storm data collection requirements as per the conditions outlined in the NCDENR DWQ PEP program.

Significant reductions for solid and nutrient pollutant concentrations were observed between influent and effluent sampling locations using the Efficiency Ratio (ER) efficiency calculation method (TSS 90.4%, TP 86.1%, and TN 55.9%) and Summation of Load (SOL) efficiency calculation method (TSS 90.9%, TP 87.1%, and TN 50.2 %).

The capture of solids by the system was verified as part of the residual solids assessment during site visits conducted on November 3, 2011 and June 14, 2012. Comparison of the estimated mass of materials captured by the StormFilter system over the course of the monitoring period to calculated loads using SSC (<2000µm) results was determined to be within the realm of expectations for the study.

Given that the solid performance standard for this project is based solely on TSS removal efficiency, the review of additional data was required to further understand removal efficiency results. In an effort to isolate suspended sediment removal efficiency based on specific particle size ranges, SSC samples were sieved prior to analysis. The particle size ranges that were isolated for this study included 2000µm to 1.5µm and 500µm to 1.5µm. The isolation of suspended solids removal efficiencies based on particles 2000µm to 1.5µm and particles between 500µm and 1.5 µm resulted in an overall removal efficiency of 98.3% and 93.4% respectively using the ER efficiency calculation method and 98.3% and 93.7% respectively using the SOL efficiency calculation method. These results demonstrate performance greater than the performance goal of 85% removal of TSS.

Given that the phosphorus removal performance standard for this project is based solely on TP removal efficiency, the review of additional data was required to further understand removal efficiency results. In an effort to isolate phosphorus removal efficiency based on speciation TP, Diss. P, Ortho-P, and PP results were isolated. TP, Diss. P, and Ortho-P results were provided by the analytical lab. PP was calculated as the difference between TP and Diss. P. Removal efficiencies for TP, Diss. P, Ortho-P, and PP results resulted in overall removal efficiencies of 86.1%, 74.2%, 82.5%, and 91.3% respectively using the ER efficiency calculation method. Removal efficiencies for TP, Diss. P, Ortho-P, and PP results resulted in an overall removal efficiency of 87.1%, 67.3%, 78.2%, and 96.4% using the SOL efficiency calculation method. These results not only demonstrate that the system was able to meet the performance goal but was able to attenuate TP captured by the system over the course of the study.

Given that the nitrogen removal performance standard for this project is based solely on TN removal efficiency, the review of additional data was required to further understand removal efficiency results. In an effort to isolate nitrogen removal efficiency based on the forms of nitrogen used to calculate TN NH3+, NO2- plus NO3-, and ON were isolated. NH3+ and NO2- plus NO3- results were provided by the analytical lab. ON was calculated as the difference between TKN and NH3+ results. Removal efficiencies based on calculated TN results resulted in overall removal efficiency 55.9% using the ER efficiency calculation method and 50.2% using the SOL efficiency calculation method. Removal efficiencies based on NH3+, NO2- plus NO3-, and ON results resulted in overall removal efficiency 62.8 %, 9.8%, and 73.1% respectively using the ER efficiency calculation method. Removal efficiencies based on NH3+, NO2- plus NO3-, and ON and results resulted in an overall removal efficiency of 60.0%, 11.2%, and 61.3% respectively using the SOL efficiency calculation method. Removal efficiencies based on calculated TN results resulted in overall removal efficiency 55.9% using the ER efficiency calculation method and 50.2% using the SOL efficiency calculation method. These results demonstrate that the system was able to successfully meet the performance goal for the study.

Results from the twenty month study, that represented a total of 13 storm events and 27.73 inches of precipitation, show that the StormFilter system tested was effective in removing solid and nutrient pollutants from the stormwater runoff. This study was completed using the recommended design criteria based on a maximum cartridge specific flow rate of 1gpm/ft^2, a coated perlite media, and a volume based design methodology. The StormFilter system was designed to capture and treat 75% of the calculated water quality volume (i.e. the runoff volume associated with the 1.0 inch event). The StormFilter system was also designed on a mass-loading basis to meet the annual pollutant loading requirements of the site with a minimum expected interval between maintenance of 1 year.

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Appendix A

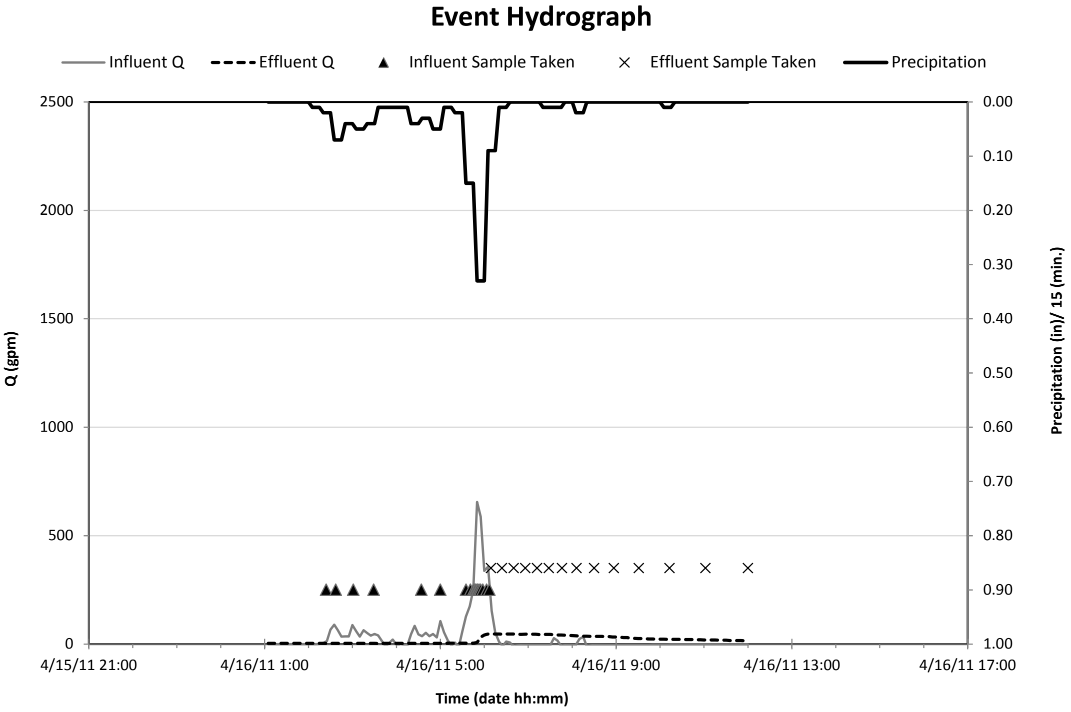
Individual Storm Reports: through 06/2012

General Information

Site: Mitchell Community College (40529), Mooresville, North Carolina
System Description: Volume StormFilter, 8 Cartridges (7.5-gpm)
Media Tested: PSORB
Event Date: 04/16/11 Date of Last Maintenance: 03/17/11
Antecedent Conditions (hr): > 6 hr. Storm Duration (hours): 8

Hydrology

Total Precipitation (in): 1.04
Peak Flow, (gpm): 655 Influent, 46 Effluent
Total Runoff Volume (gal): 19897 Influent, 12748 Effluent
Storm Coverage (%) 100 Influent, 100 Effluent



Analytical

Number of Aliquots:
IN/EFF: 18/14

Parameter	Concentrations (mg/L)		
	Influent EMC	Effluent EMC	ISRPC
TSS	21.2	6.2	71%
SSC (<2000μm)	55.7	7.2	87%
SSC (<500μm)	45.8	7.3	84%
TVSS (<2000μm)	30.8	4.1	87%
TVSS (<500μm)	24	5.3	78%
TP	0.16	0.058	64%
Diss. P	*0.025*	*0.025*	0%
Ortho-P	*0.025*	*0.025*	0%
PP	*0.135*	*0.033*	76%
NH3+	0.48	0.22	54%
TKN	0.64	*0.25*	61%
NO2- plus NO3-	0.17	0.16	6%
TN	0.81	*0.41*	49%
ON	0.16	0.03	81%

Notes

Italicized EMC results defaulted to half of the MRL if result reported as ND.

Appendix A

Individual Storm Reports: through 06/2012

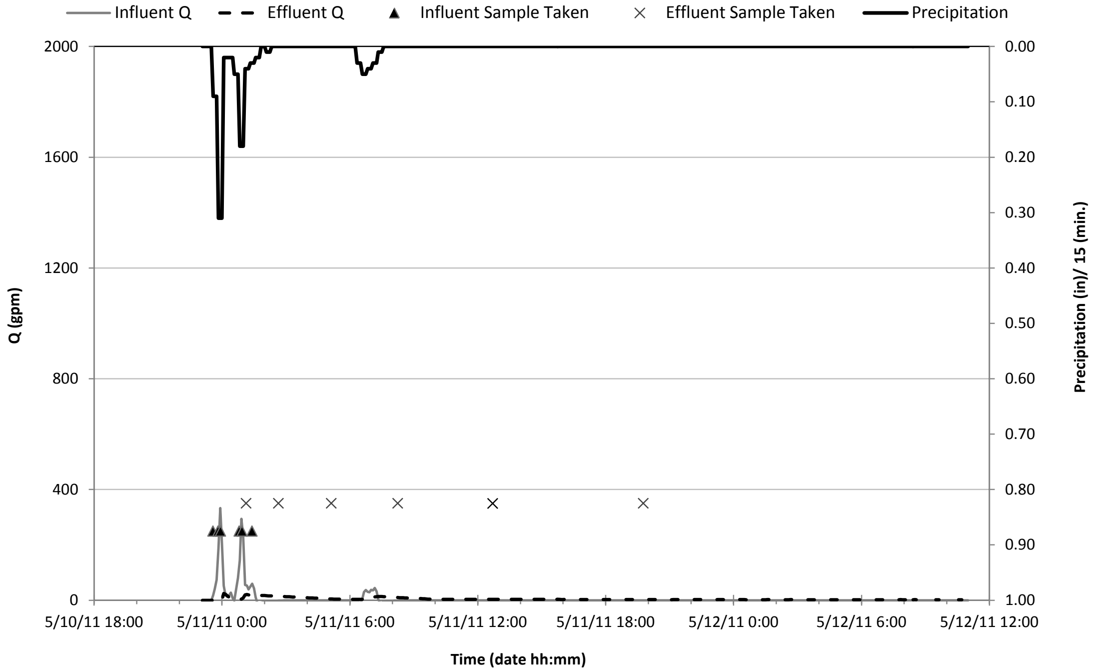
General Information

Site:	Mitchell Community College (40529), Mooresville, North Carolina		
System Description:	Volume StormFilter, 8 Cartridges (7.5-gpm)		
Media Tested:	PSORB		
Event Date:	05/10/11	Date of Last Maintenance:	03/17/11
Antecedent Conditions (hr):	> 6 hr.	Storm Duration (hours):	8

Hydrology

Total Precipitation (in):	0.93
Peak Flow, (gpm):	333 Influent, 24 Effluent
Total Runoff Volume (gal):	11180 Influent, 9392 Effluent
Storm Coverage (%)	91 Influent, 79 Effluent

Event Hydrograph



Analytical

	Parameter	Concentrations (mg/L) Influent EMC	Concentrations (mg/L) Effluent EMC	ISRPC
Number of Aliquots: IN/EFF: 6/6	TSS	98.2	*5.1*	95%
	SSC (<2000µm)	90.6	4.6	95%
	SSC (<500µm)	104	5.13	95%
	TVSS (<2000µm)	53	6.7	87%
	TVSS (<500µm)	48	4.2	91%
	TP	NT	NT	-
	Diss. P	NT	NT	-
	Ortho-P	NT	NT	-
	PP	NT	NT	-
	NH3+	NT	NT	-
	TKN	NT	NT	-
	NO2- plus NO3-	NT	NT	-
	TN	NT	NT	-
	ON	NT	NT	-

Notes

Italicized EMC results defaulted to half of the MRL if result reported as ND.

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Appendix A

Individual Storm Reports: through 06/2012

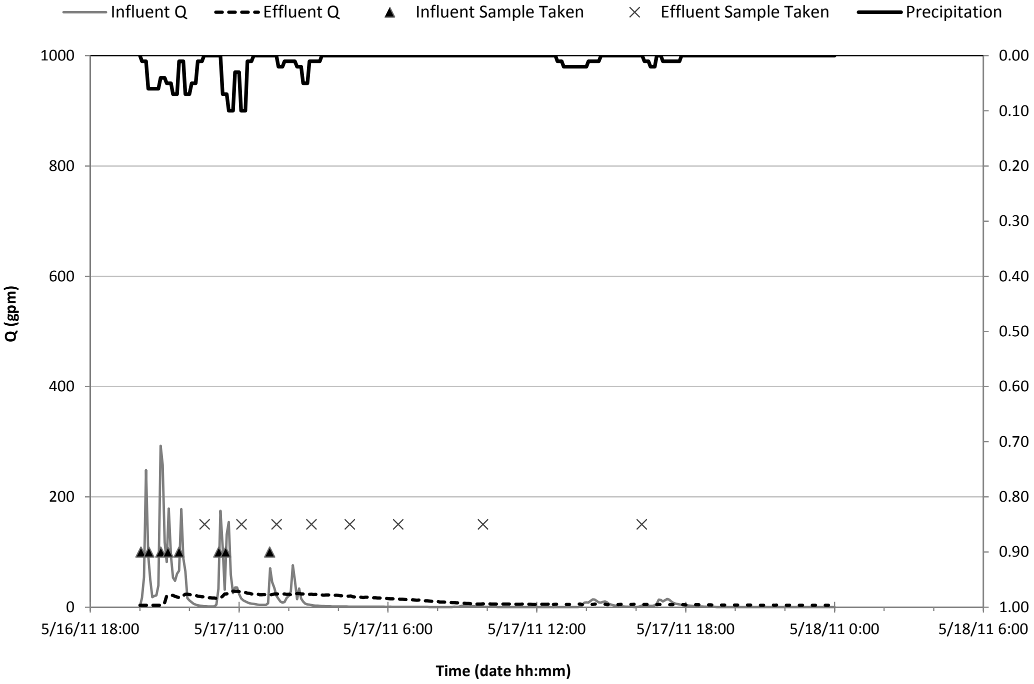
General Information

Site:	Mitchell Community College (40529), Mooresville, North Carolina		
System Description:	Volume StormFilter, 8 Cartridges (7.5-gpm)		
Media Tested:	PSORB		
Event Date:	05/16/11	Date of Last Maintenance:	03/17/11
Antecedent Conditions (hr):	>6 hr.	Storm Duration (hours): 22	

Hydrology

Total Precipitation (in):	1.04
Peak Flow, (gpm):	293 Influent, 29 Effluent
Total Runoff Volume (gal):	20358 Influent, 18104 Effluent
Storm Coverage (%)	79 Influent, 90 Effluent

Event Hydrograph



Analytical

Number of Aliquots:
IN/EFF: 8/8

Parameter	Concentrations (mg/L) Influent EMC	Concentrations (mg/L) Effluent EMC	ISRPC
TSS	21.8	*2.8*	87%
SSC (<2000µm)	51	6.2	88%
SSC (<500µm)	9.64	*1.93*	80%
TVSS (<2000µm)	13	3.1	76%
TVSS (<500µm)	10.4	3.6	65%
TP	0.11	*0.025*	77%
Diss. P	NT	NT	-
Ortho-P	NT	NT	-
PP	NT	NT	-
NH3+	0.36	0.24	33%
TKN	0.99	0.58	41%
NO2- plus NO3-	0.22	0.24	-9%
TN	1.21	0.82	32%
ON	0.63	0.34	46%

Notes

Italicized EMC results defaulted to half of the MRL if result reported as ND.

Appendix A

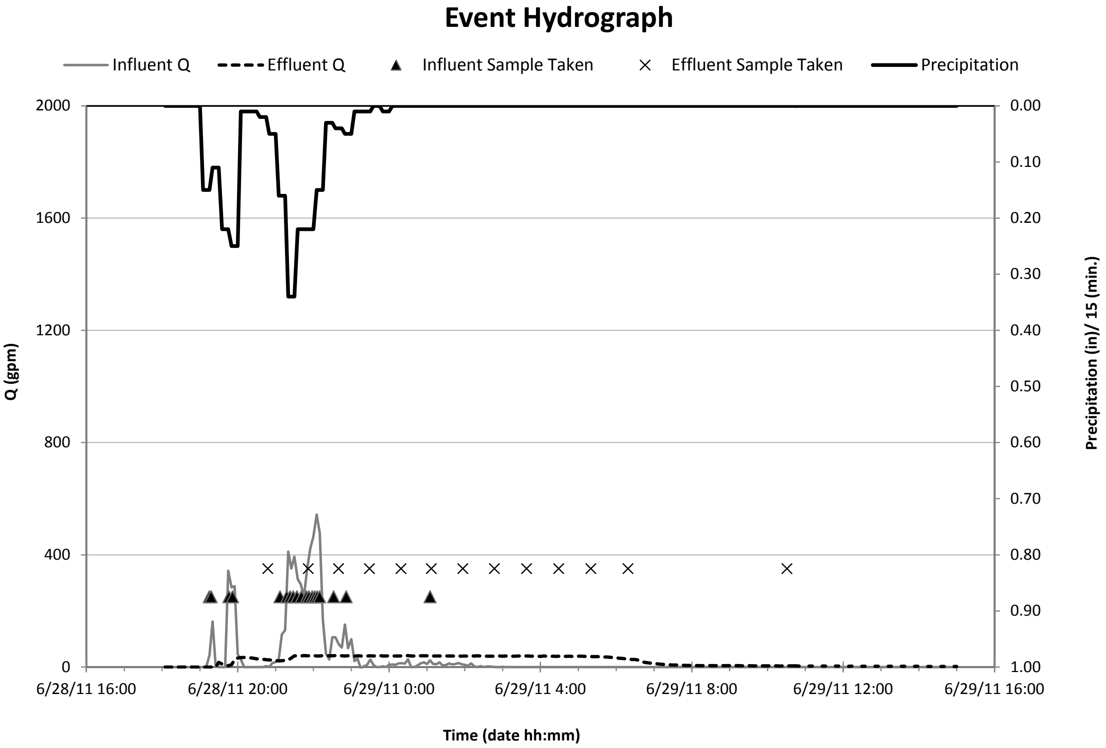
Individual Storm Reports: through 06/2012

General Information

Site: Mitchell Community College (40529), Mooresville, North Carolina
System Description: Volume StormFilter, 8 Cartridges (7.5-gpm)
Media Tested: PSORB
Event Date: 06/28/11 Date of Last Maintenance: 03/17/2011
Antecedent Conditions (hr): >6 hr. Storm Duration (hours): 24

Hydrology

Total Precipitation (in): 2.06
Peak Flow, (gpm): 543 Influent, 41 Effluent
Total Runoff Volume (gal): 35556 Influent, 26364 Effluent
Storm Coverage (%) 98 Influent, 97 Effluent



Analytical

	Parameter	Concentrations (mg/L)		ISRPC
Number of Aliquots:		Influent EMC	Effluent EMC	
IN/EFF: 9/13	TSS	10.3	*1.4*	86%
	SSC (<2000µm)	18	3.01	83%
	SSC (<500µm)	8.96	2.59	71%
	TVSS (<2000µm)	10.8	3.4	69%
	TVSS (<500µm)	4.8	4.3	10%
	TP	0.13	*0.025*	81%
	Diss. P	*0.025*	0.16	-540%
	Ortho-P	*0.025*	*0.025*	0%
	PP	0.105	0	100%
	NH3+	*0.05*	*0.05*	0%
	TKN	*0.25*	*0.25*	0%
	NO2- plus NO3-	0.25	*0.1*	60%
	TN	*0.5*	*0.35*	30%
	ON	*0.2*	*0.2*	0%

Notes

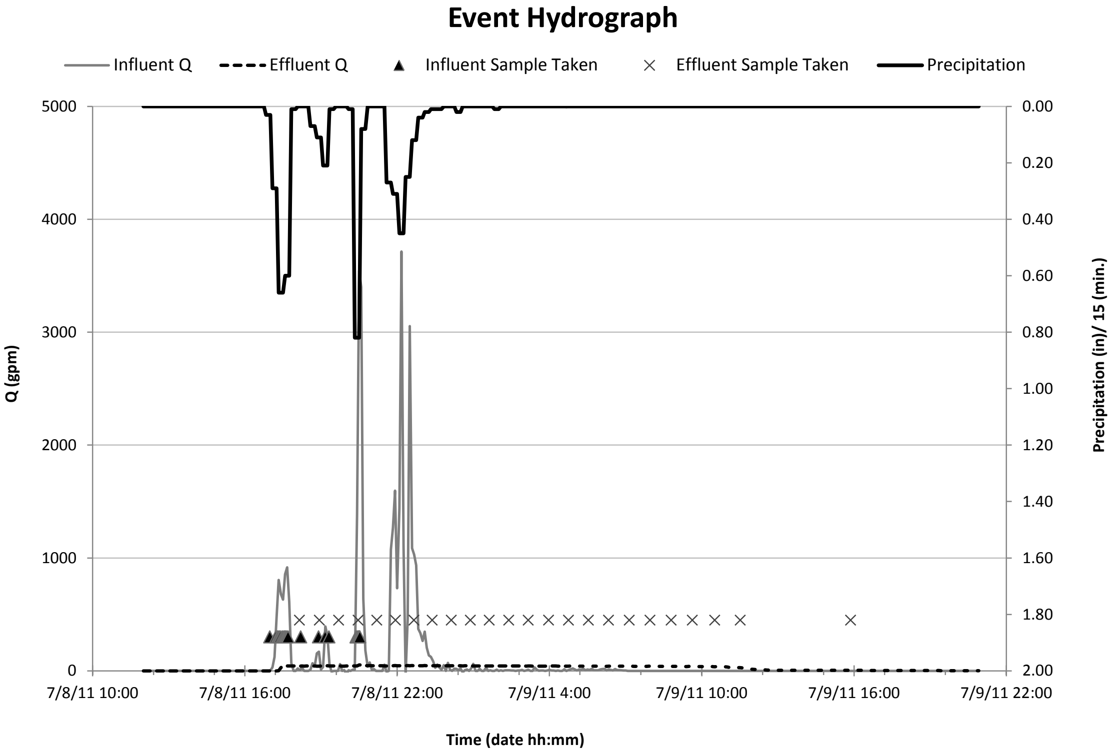
Italicized EMC results defaulted to half of the MRL if result reported as ND.

General Information

Site: Mitchell Community College (40529), Mooresville, North Carolina
System Description: Volume StormFilter, 8 Cartridges (7.5-gpm)
Media Tested: PSORB
Event Date: 07/08/11 Date of Last Maintenance: 03/17/11
Antecedent Conditions (hr): >6 hr. Storm Duration (hours): 13

Hydrology

Total Precipitation (in): 4.41
Peak Flow, (gpm): 3714 Influent, 54 Effluent
Total Runoff Volume (gal): 180699 Influent, 49090 Effluent
Storm Coverage (%) 41 Influent, 98 Effluent



Analytical

Number of Aliquots:	Parameter	Concentrations (mg/L)		ISRPC
		Influent EMC	Effluent EMC	
IN/EFF: 24/24	TSS	18.2	3.3	82%
	SSC (<2000µm)	29.7	3.78	87%
	SSC (<500µm)	16	3.02	81%
	TVSS (<2000µm)	8	2.1	74%
	TVSS (<500µm)	7.6	3.3	57%
	TP	0.065	*0.025*	62%
	Diss. P	*0.025*	*0.025*	0%
	Ortho-P	*0.025*	*0.025*	0%
	PP	0.04	0	100%
	NH3+	0.25	0.1	60%
	TKN	*0.25*	*0.25*	0%
	NO2- plus NO3-	*0.1*	*0.1*	0%
	TN	*0.35*	*0.35*	0%
	ON	*0*	*0.15*	-

Notes

Italicized EMC results defaulted to half of the MRL if result reported as ND.

Appendix A

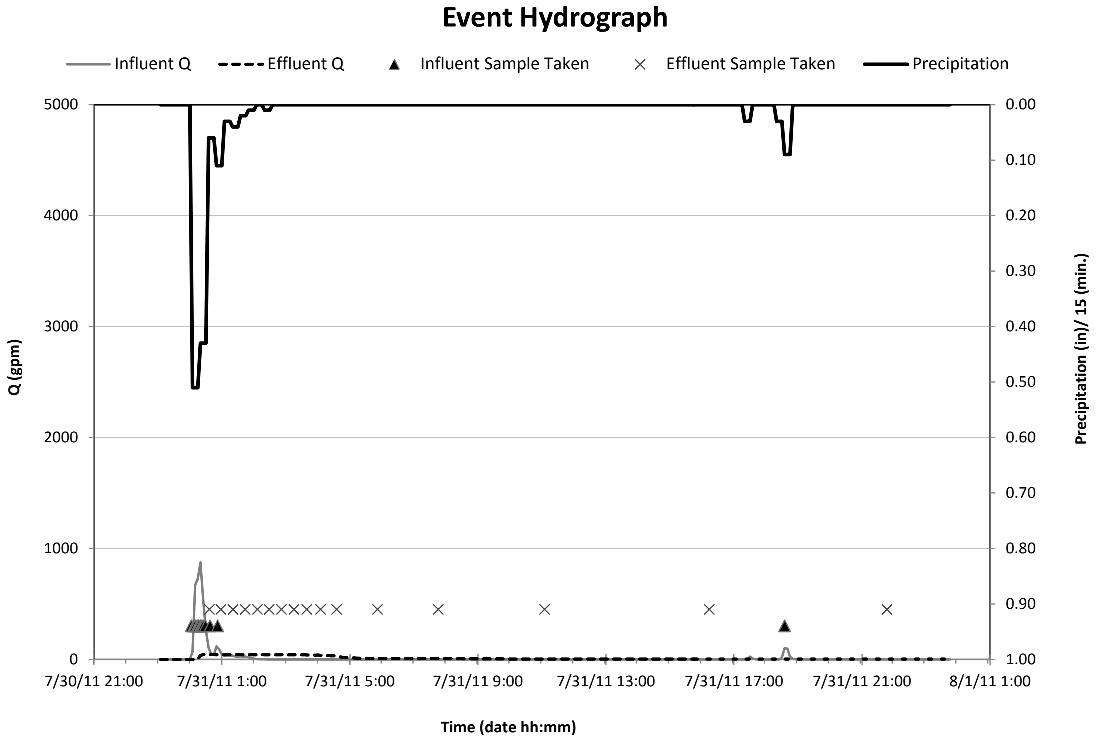
Individual Storm Reports: through 06/2012

General Information

Site:	Mitchell Community College (40529), Mooresville, North Carolina		
System Description:	Volume StormFilter, 8 Cartridges (7.5-gpm)		
Media Tested:	PSORB		
Event Date:	07/31/11	Date of Last Maintenance:	03/17/11
Antecedent Conditions (hr):	>6 hr.	Storm Duration (hours): 19	

Hydrology

Total Precipitation (in):	1.37
Peak Flow, (gpm):	876 Influent, 44 Effluent
Total Runoff Volume (gal):	20865 Influent, 16093 Effluent
Storm Coverage (%)	97 Influent, 98 Effluent



Analytical

Number of Aliquots:
IN/EFF: 16/16

Parameter	Concentrations (mg/L)		ISRPC
	Influent EMC	Effluent EMC	
TSS	28.4	*2.5*	91%
SSC (<2000μm)	17.7	*2.675*	85%
SSC (<500μm)	29.1	3.95	86%
TVSS (<2000μm)	19.6	3.8	81%
TVSS (<500μm)	3.4	3.9	-15%
TP	0.14	0.057	59%
Diss. P	0.061	*0.025*	59%
Ortho-P	*0.025*	*0.025*	0%
PP	0.079	*0.032*	59%
NH3+	*0.05*	*0.05*	0%
TKN	0.72	*0.25*	65%
NO2- plus NO3-	0.3	0.35	-17%
TN	1.02	*0.6*	41%
ON	*0.67*	*0.2*	70%

Notes

Italicized EMC results defaulted to half of the MRL if result reported as ND.

Appendix A

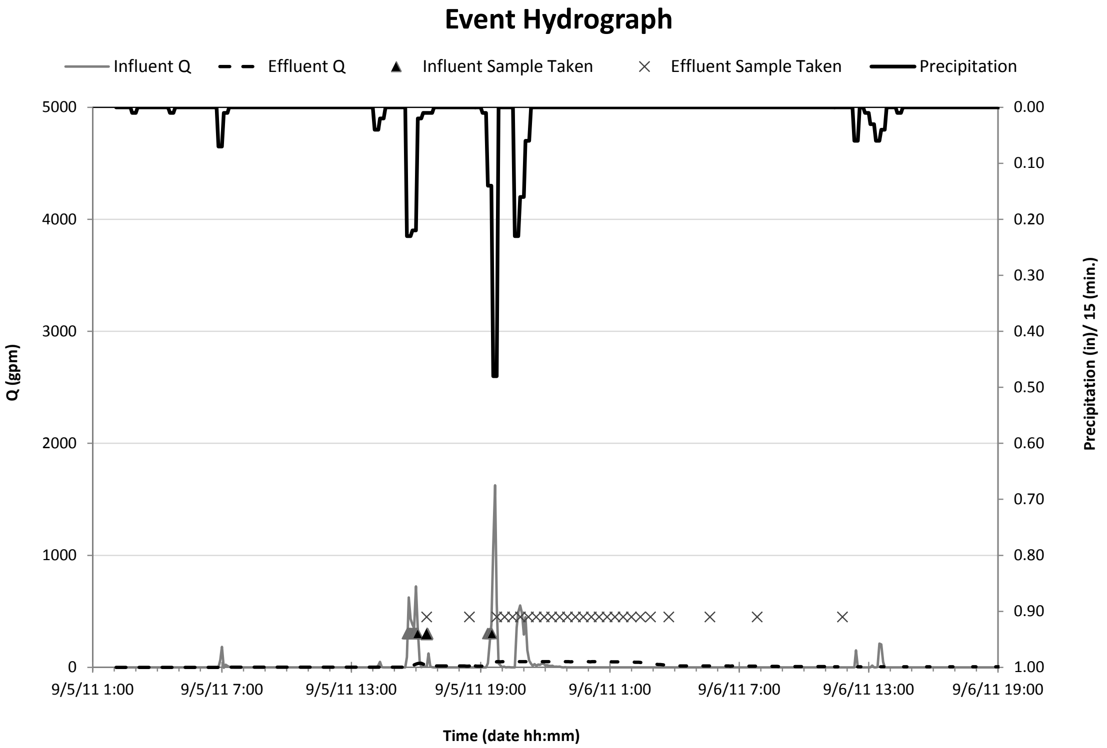
Individual Storm Reports: through 06/2012

General Information

Site: Mitchell Community College (40529), Mooresville, North Carolina
System Description: Volume StormFilter, 8 Cartridges (7.5-gpm)
Media Tested: PSORB
Event Date: 09/05/11 Date of Last Maintenance: 03/17/11
Antecedent Conditions (hr): >6 hr. Storm Duration (hours): 36

Hydrology

Total Precipitation (in): 1.94
Peak Flow, (gpm): 1625 Influent, 52 Effluent
Total Runoff Volume (gal): 56344 Influent, 35039 Effluent
Storm Coverage (%) 46 Influent, 90 Effluent



Analytical

Number of Aliquots:
IN/EFF: 29/36

Parameter	Concentrations (mg/L) Influent EMC	Concentrations (mg/L) Effluent EMC	ISRPC
TSS	25.1	*2.5*	90%
SSC (<2000µm)	81.8	2.45	97%
SSC (<500µm)	74.5	2.41	97%
TVSS (<2000µm)	7.4	2.8	62%
TVSS (<500µm)	4.2	3.4	19%
TP	NT	NT	-
Diss. P	NT	NT	-
Ortho-P	NT	NT	-
PP	NT	NT	-
NH3+	NT	NT	-
TKN	NT	NT	-
NO2- plus NO3-	NT	NT	-
TN	NT	NT	-
ON	NT	NT	-

Notes

Italicized EMC results defaulted to half of the MRL if result reported as ND.

Appendix A

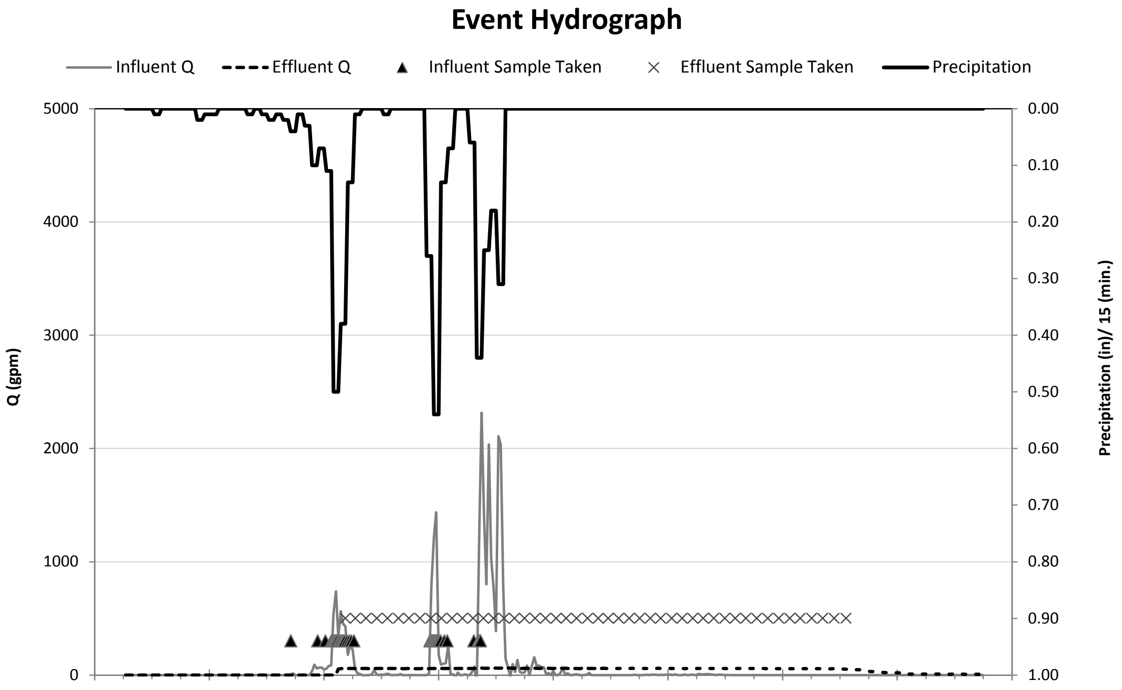
Individual Storm Reports: through 06/2012

General Information

Site:	Mitchell Community College (40529), Mooresville, North Carolina		
System Description:	Volume StormFilter, 8 Cartridges (7.5-gpm)		
Media Tested:	PSORB		
Event Date:	09/21/11	Date of Last Maintenance:	03/17/11
Antecedent Conditions (hr):	>6 hr.	Storm Duration (hours):	13

Hydrology

Total Precipitation (in):	3.75
Peak Flow, (gpm):	2315 Influent, 62 Effluent
Total Runoff Volume (gal):	125432 Influent, 67321 Effluent
Storm Coverage (%)	49 Influent, 93 Effluent



Analytical

Number of Aliquots:
IN/EFF: 48/48

Parameter	Concentrations (mg/L)		ISRPC
	Influent EMC	Effluent EMC	
TSS	27.6	*1.25*	95%
SSC (<2000µm)	86	1.92	98%
SSC (<500µm)	20.4	1.65	92%
TVSS (<2000µm)	27.3	1.7	94%
TVSS (<500µm)	6.1	1.5	75%
TP	0.25	*0.025*	90%
Diss. P	*0.025*	*0.025*	0%
Ortho-P	*0.025*	*0.025*	0%
PP	*0.225*	*0*	100%
NH3+	*0.05*	*0.05*	0%
TKN	*0.25*	*0.25*	0%
NO2- plus NO3-	*0.1*	*0.1*	0%
TN	*0.35*	*0.35*	0%
ON	*0.2*	*0.2*	0%

Notes

Italicized EMC results defaulted to half of the MRL if result reported as ND.

Appendix A

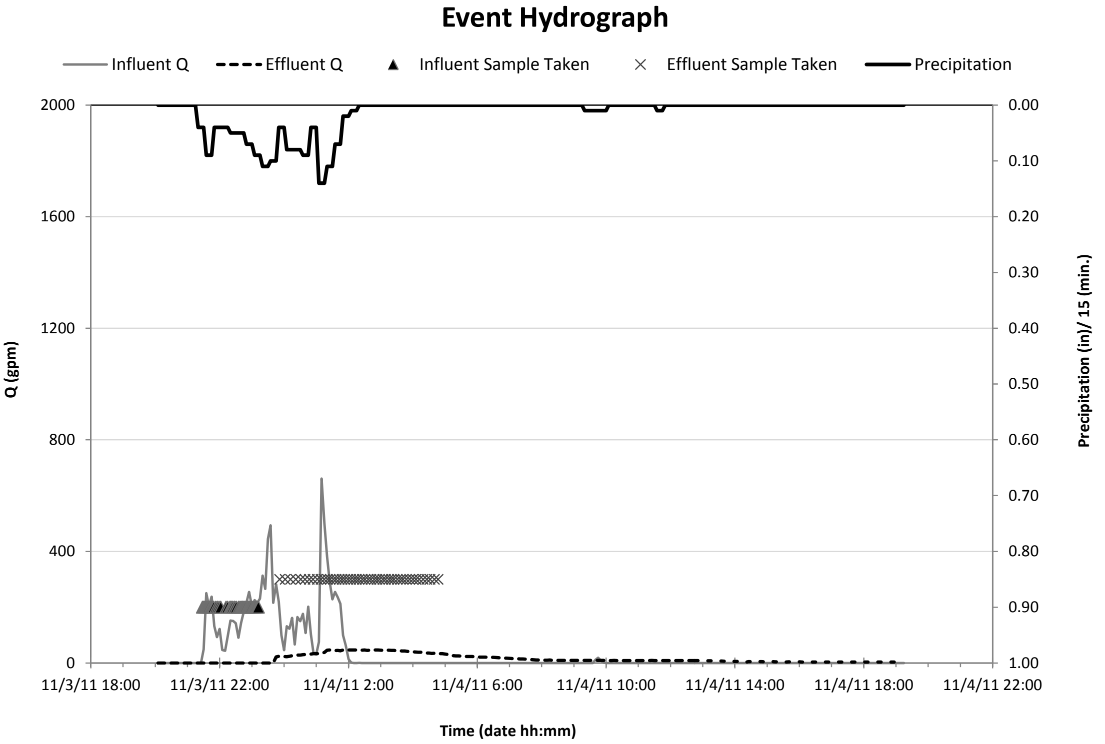
Individual Storm Reports: through 06/2012

General Information

Site: Mitchell Community College (40529), Mooresville, North Carolina
System Description: Volume StormFilter, 8 Cartridges (7.5-gpm)
Media Tested: PSORB
Event Date: 11/03/2011 Date of Last Maintenance: 11/03/2011
Antecedent Conditions (hr): >6 hr. Storm Duration (hours): 24

Hydrology

Total Precipitation (in): 1.40
Peak Flow, (gpm): 661 Influent, 47 Effluent
Total Runoff Volume (gal): 51869 Influent, 20220 Effluent
Storm Coverage (%) 34 Influent, 60 Effluent



Analytical

Number of Aliquots:
IN/EFF: 48/48

Parameter	Concentrations (mg/L)		ISRPC
	Influent EMC	Effluent EMC	
TSS	23.6	*1.25*	95%
SSC (<2000µm)	2080	2.42	100%
SSC (<500µm)	393	1.82	100%
TVSS (<2000µm)	99.2	1.6	98%
TVSS (<500µm)	13.3	*1*	92%
TP	0.9	*0.025*	97%
Diss. P	0.85	*0.025*	97%
Ortho-P	0.86	*0.025*	97%
PP	0.05	*0*	100%
NH3+	0.72	*0.05*	93%
TKN	2.7	*0.25*	91%
NO2- plus NO3-	0.25	*0.1*	60%
TN	2.95	*0.35*	88%
ON	1.98	*0.2*	90%

Notes

Italicized EMC results defaulted to half of the MRL if result reported as ND.

Appendix A

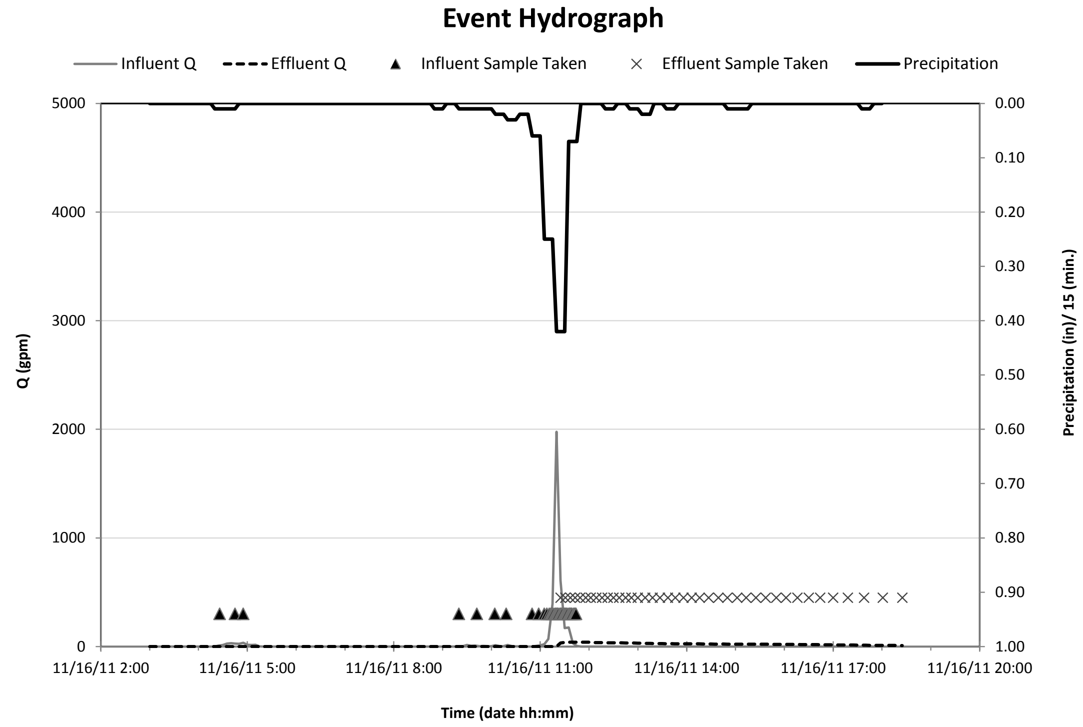
Individual Storm Reports: through 06/2012

General Information

Site:	Mitchell Community College (40529), Mooresville, North Carolina		
System Description:	Volume StormFilter, 8 Cartridges (7.5-gpm)		
Media Tested:	PSORB		
Event Date:	11/16/2011	Date of Last Maintenance:	11/03/2011
Antecedent Conditions (hr):	>6 hr.	Storm Duration (hours): 14	

Hydrology

Total Precipitation (in):	1.01
Peak Flow, (gpm):	1977 Influent, 40 Effluent
Total Runoff Volume (gal):	18858 Influent, 9926 Effluent
Storm Coverage (%)	100 Influent, 100 Effluent



Analytical

	Parameter	Concentrations (mg/L)		
Number of Aliquots:		Influent EMC	Effluent EMC	ISRPC
IN/EFF: 39/40	TSS	56.9	3.4	94%
	SSC (<2000µm)	186	2.73	99%
	SSC (<500µm)	16.3	2.46	85%
	TVSS (<2000µm)	*1.1*	*0.5*	55%
	TVSS (<500µm)	*1.1*	*0.55*	50%
	TP	0.1	*0.025*	75%
	Diss. P	0.081	*0.025*	69%
	Ortho-P	0.063	*0.025*	60%
	PP	0.019	*0*	100%
	NH3+	0.11	*0.05*	55%
	TKN	*0.25*	*0.25*	0%
	NO2- plus NO3-	*0.1*	*0.1*	0%
	TN	*0.35*	*0.35*	0%
	ON	*0.14*	*0.2*	-43%

Notes

Italicized EMC results defaulted to half of the MRL if result reported as ND.

Appendix A

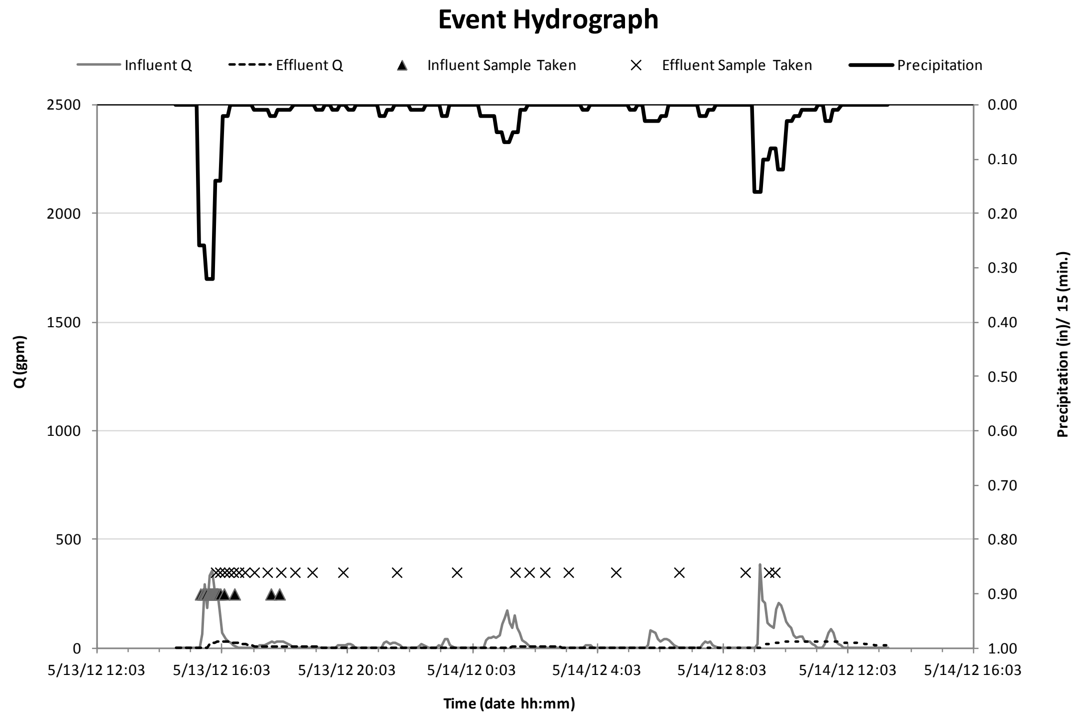
Individual Storm Reports: through 06/2012

General Information

Site:	Mitchell Community College (40529), Mooresville, North Carolina		
System Description:	Volume StormFilter, 8 Cartridges (7.5-gpm)		
Media Tested:	PSORB		
Event Date:	05/13/2012	Date of Last Maintenance:	11/03/2011
Antecedent Conditions (hr):	>6 hr.	Storm Duration (hours): 21	

Hydrology

Total Precipitation (in):	1.82
Peak Flow, (gpm):	384 Influent, 34 Effluent
Total Runoff Volume (gal):	38451 Influent, 13154 Effluent
Storm Coverage (%)	36 Influent, 92 Effluent



Analytical

Number of Aliquots:
IN/EFF: 28/48

Parameter	Concentrations (mg/L) Influent EMC	Concentrations (mg/L) Effluent EMC	ISRPC
TSS	52.4	5.7	89%
SSC (<2000µm)	27	*5*	81%
SSC (<500µm)	28	*10*	64%
TVSS (<2000µm)	8.4	3.2	62%
TVSS (<500µm)	9.2	3.2	65%
TP	0.088	*0.025*	72%
Diss. P	0.054	0.025	54%
Ortho-P	*0.025*	*0.025*	0%
PP	0.034	*0*	100%
NH3+	*0.05*	*0.05*	0%
TKN	0.79	*0.25*	68%
NO2- plus NO3-	*0.1*	*0.1*	0%
TN	*0.89*	*0.35*	61%
ON	*0.74*	*0.2*	73%

Notes

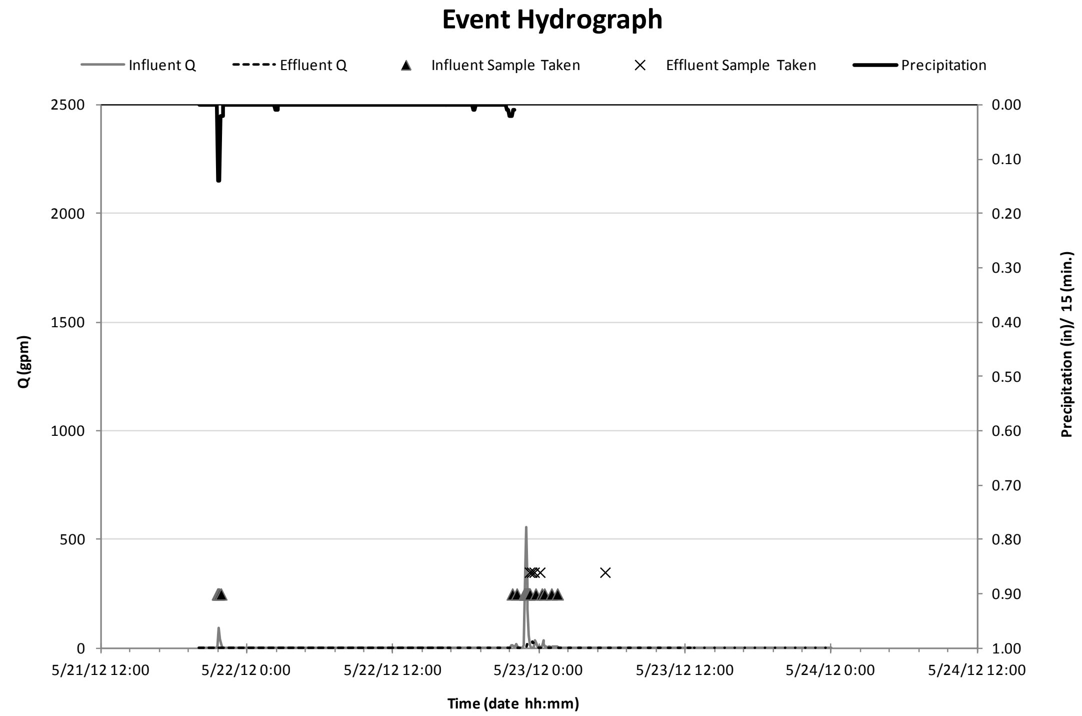
Italicized EMC results defaulted to half of the MRL if result reported as ND.

General Information

Site: Mitchell Community College (40529), Mooresville, North Carolina
System Description: Volume StormFilter, 8 Cartridges (7.5-gpm)
Media Tested: PSORB
Event Date: 05/21/2012 Date of Last Maintenance: 11/03/2011
Antecedent Conditions (hr): >6 hr. Storm Duration (hours): 30

Hydrology

Total Precipitation (in): 0.85
Peak Flow, (gpm): 557 Influent, 33 Effluent
Total Runoff Volume (gal): 9831 Influent, 4879 Effluent
Storm Coverage (%) 100 Influent, 74 Effluent



Analytical

	Parameter	Concentrations (mg/L)		
Number of Aliquots:		Influent EMC	Effluent EMC	ISRPC
IN/EFF:	TSS	28.2	*6.6*	77%
	SSC (<2000µm)	NT	NT	-
	SSC (<500µm)	NT	NT	-
	TVSS (<2000µm)	NT	NT	-
	TVSS (<500µm)	NT	NT	-
	TP	0.2	*0.025*	88%
	Diss. P	NT	NT	-
	Ortho-P	NT	NT	-
	PP	NT	NT	-
	NH3+	0.6	0.18	70%
	TKN	2.1	*0.25*	88%
	NO2- plus NO3-	NT	NT	-
	TN	NT	NT	-
	ON	1.5	*0.07*	95%

Notes

Italicized EMC results defaulted to half of the MRL if result reported as ND.

Appendix A

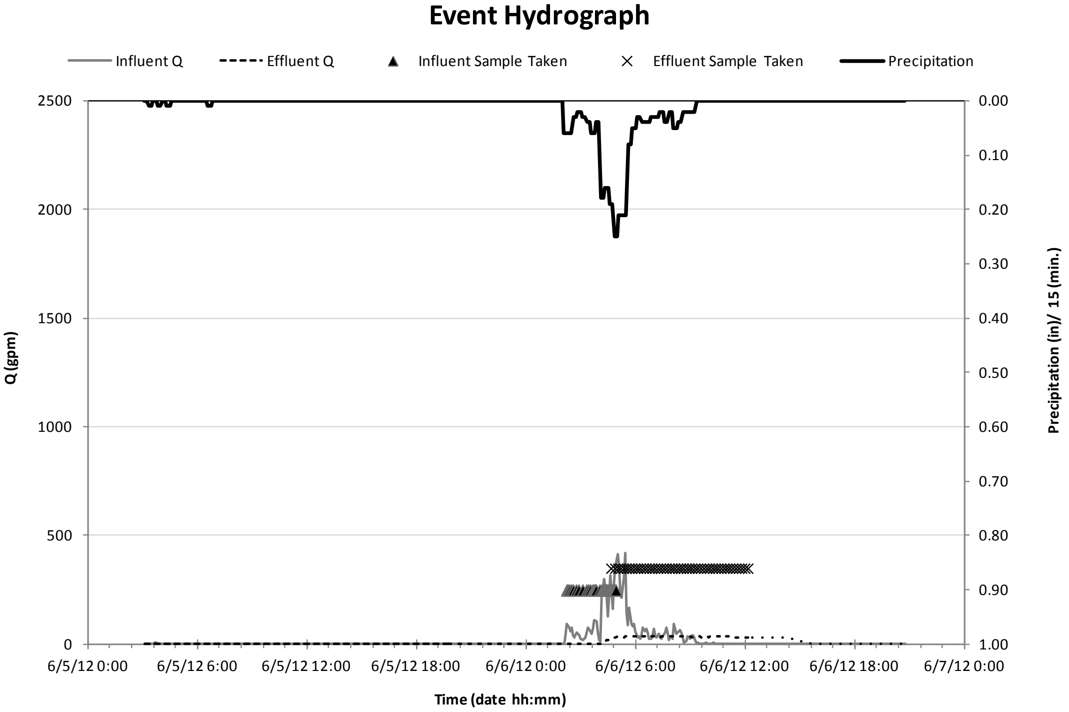
Individual Storm Reports: through 06/2012

General Information

Site:	Mitchell Community College (40529), Mooresville, North Carolina		
System Description:	Volume StormFilter, 8 Cartridges (7.5-gpm)		
Media Tested:	PSORB		
Event Date:	06/06/2012	Date of Last Maintenance:	11/03/2011
Antecedent Conditions (hr):	>6 hr.	Storm Duration (hours): 30	

Hydrology

Total Precipitation (in):	2.11
Peak Flow, (gpm):	417 Influent, 35 Effluent
Total Runoff Volume (gal):	40865 Influent, 21569 Effluent
Storm Coverage (%)	46 Influent, 73 Effluent



Analytical

Number of Aliquots:
IN/EFF: 42/48

Parameter	Concentrations (mg/L) Influent EMC	Effluent EMC	ISRPC
TSS	38	*1.25*	97%
SSC (<2000µm)	48	*5*	90%
SSC (<500µm)	48	*10*	79%
TVSS (<2000µm)	7.2	2.2	69%
TVSS (<500µm)	7	2.8	60%
TP	0.31	*0.025*	92%
Diss. P	0.25	*0.025*	90%
Ortho-P	0.21	*0.025*	88%
PP	0.06	*0*	100%
NH3+	0.21	*0.05*	76%
TKN	1.4	*0.25*	82%
NO2- plus NO3-	0.15	*0.22*	-47%
TN	1.55	*0.47*	70%
ON	1.19	*0.2*	83%

Notes

Italicized EMC results defaulted to half of the MRL if result reported as ND.

Revision History

Original

WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

April 2017

GENERAL USE LEVEL DESIGNATION FOR BASIC (TSS) AND PHOSPHORUS TREATMENT
For
CONTECH Engineered Solutions
Stormwater Management StormFilter®
with PhosphoSorb® media

Ecology's Decision:

1. **Based on Contech Engineered Solutions application, Ecology hereby issues the following use level designation for the Stormwater Management StormFilter® using PhosphoSorb® media cartridges:**

   - **General Use Level Designation (GULD) for Basic Treatment (total suspended solids) and for Phosphorus (total phosphorus) treatment.**
     - **Sized at a hydraulic loading rate of no greater than 1.67 gallon per minute (gpm) per square foot (sq ft.) of media surface, per Table 1.**
     - **Using Contech's PhosphoSorb media. Specifications for the media shall match the specifications provided by the manufacturer and approved by Ecology.**

   Table 1. StormFilter cartridge design flow rates for 18-inch diameter cartridges with PhosphoSorb media operating at 1.67 gpm/sq ft.

Effective cartridge height (in)	Cartridge flow rate (gpm/cartridge)
12	8.35
18	12.53
27	18.79

2. **Ecology approves StormFilter systems containing PhosphoSorb media for treatment at the cartridge flow rate shown in Table 1, and sized based on the water quality design flow rate for an off-line system. Contech designs their StormFilter systems to maintain treatment of the water quality design flow while routing excess flows around the treatment chamber during periods of peak bypass. Calculate the water quality design flow rates using the following procedures:**
    - **Western Washington: For treatment installed upstream of detention or retention, the water quality design flow rate is the peak 15-minute flow rate as calculated using the latest version of the Western Washington Hydrology Model or other Ecology-approved continuous runoff model.**
    - **Eastern Washington: For treatment installed upstream of detention or retention, the water quality design flow rate is the peak 15-minute flow rate as calculated using one of the three methods described in Chapter 2.2.5 of the Stormwater Management Manual for Eastern Washington (SWMMEW) or local manual.**
    - **Entire State: For treatment installed downstream of detention, the water quality design flow rate is the full 2-year release rate of the detention facility.**
3. **The GULD designation has no expiration date but it may be amended or revoked by Ecology and is subject to the conditions specified below.**

Ecology's Conditions of Use:

StormFilter systems containing PhosphoSorb media shall comply with these conditions:

1. **Design, assemble, install, operate, and maintain StormFilter systems containing PhosphoSorb media in accordance with applicable Contech Engineered Solutions manuals, documents, and the Ecology Decision.**
2. **Use sediment loading capacity, in conjunction with the water quality design flow rate, to determine the target maintenance interval.**
3. **Owners shall install StormFilter systems in such a manner that bypass flows exceeding the water quality treatment rate or flows through the system will not re-suspend captured sediments.**
4. **Pretreatment of TSS and oil and grease may be necessary, and designers shall provide pre-treatment in accordance with the most current versions of the CONTECH *Product Design Manual* or the applicable Ecology Stormwater Manual. Design pre-treatment using the performance criteria and pretreatment practices provided in the Stormwater Management Manual for Western Washington (SWMMWW), the Stormwater Management Manual for Eastern Washington (SWMMEW), or on Ecology's "Evaluation of Emerging Stormwater Treatment Technologies" website.**
5. **Maintenance: The required maintenance interval for stormwater treatment devices is often dependent upon the degree of pollutant loading from a particular drainage basin. Therefore, Ecology does not endorse or recommend a "one size fits all" maintenance cycle for a particular model/size of manufactured filter treatment device.**
    - **Typically, CONTECH designs StormFilter systems for a target filter media replacement interval of 12 months. Maintenance includes removing accumulated**

sediment from the vault, and replacing spent cartridges with recharged cartridges.

- **Indications of the need for maintenance include the effluent flow decreasing to below the design flow rate, as indicated by the scumline above the shoulder of the cartridge.**
- **Owners/operators must inspect StormFilter with PhosphoSorb media for a minimum of twelve months from the start of post-construction operation to determine site-specific maintenance schedules and requirements. You must conduct inspections monthly during the wet season, and every other month during the dry season. (According to the *SWMMWW*, the wet season in western Washington is October 1 to April 30. According to *SWMMEW*, the wet season in eastern Washington is October 1 to June 30). After the first year of operation, owners/operators must conduct inspections based on the findings during the first year of inspections.**
- **Conduct inspections by qualified personnel, follow manufacturer's guidelines, and use methods capable of determining either a decrease in treated effluent flowrate and/or a decrease in pollutant removal ability.**
- **When inspections are performed, the following findings typically serve as maintenance triggers:**
    - **Accumulated vault sediment depths exceed an average of 2 inches, or**
    - **Accumulated sediment depths on the tops of the cartridges exceed an average of 0.5 inches, or**
    - **Standing water remains in the vault between rain events, or**
    - **Bypass during storms smaller than the design storm.**
- **Note: If excessive floatables (trash and debris) are present, perform a minor maintenance consisting of gross solids removal, not cartridge replacement.**

6. **Discharges from the StormFilter systems containing PhosphoSorb media shall not cause or contribute to water quality standards violations in receiving waters.**

Applicant:	CONTECH Engineered Solutions
Applicant's Address:	11835 NE Glenn Widing Dr. Portland, OR 97220

Application Documents:

- The Stormwater Management StormFilter, PhosphoSorb at a Specific Flow Rate of 1.67 gpm/ft^2, Conditional Use Level Designation Application. August 2012.
- Quality Assurance Project Plan The Stormwater Management StormFilter® PhosphoSorb® at a Specific Flow Rate of 1.67 gpm/ft^2 Performance Evaluation. August 2012.
- The Stormwater Management StormFilter® PhosphoSorb® at a Specific Flow Rate of 1.67 gpm/ft^2, General Use Level Designation, Technical Evaluation Report. October 2015.

Applicant's Use Level Request:

- General use level designation as a basic (TSS) and phosphorus (total phosphorus) treatment device in accordance with Table 2 of Ecology's 2011 *Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies Technology Assessment Protocol – Ecology (TAPE).*

Applicant's Performance Claims:

Based on results from laboratory and field-testing, the applicant claims:

- The Stormwater Management StormFilter® with PhosphoSorb® media operating at 1.67 gpm/ft^2 is able to remove 80% of Total Suspended Solids (TSS) for influent concentrations greater than 100 mg/L, is able to remove greater than 80% TSS for influent concentrations greater than 200 mg/L, and achieve a 20 mg/L effluent for influent concentrations less than 100 mg/L.
- The StormFilter with PhosphoSorb media is able to remove 50% or greater total phosphorus for influent concentrations between 0.1 to 0.5 mg/L.

Recommendations:

Ecology finds that:

- CONTECH Engineered Solutions has shown Ecology, through laboratory and field testing, that the Stormwater Management StormFilter® with PhosphoSorb® media is capable of attaining Ecology's Basic and Total Phosphorus treatment goals.

Findings of Fact:

Laboratory testing

- A Phosphosorb StormFilter cartridge test unit, operating at 28 L/min (equivalent to 1.0 gpm/ sq. ft.), and subject to SSC with a silt loam texture (25% sand, 65% silt, and 10% clay by mass) originating from SCS 106 provides a mean SSC removal efficiency of 88%;
- A Phosphosorb StormFilter cartridge test unit, operating at 56 L/min (equivalent to 2.0 gpm/sq. ft.), and subject to SSC with a silt loam texture (25% sand, 65% silt, and 10% clay by mass) originating from SCS 106 provides a mean turbidity reduction of 82%;

- Laboratory testing of PhosphoSorb media in a Horizontal Flow Column (HFC; a 1/24th scale of a full cartridge) resulted in 50 percent dissolved phosphorus removal for the first 1,000 bed volumes. Granular activated carbon (GAC) tested under the same conditions resulted in 30 percent removal of dissolved phosphorus.

Field testing

- Contech conducted monitoring of a StormFilter® with PhosphoSorb® media at a site along Lolo Pass Road in Zigzag, Oregon between February 2012 and February 2015. The manufacturer collected flow-weighted influent and effluent composite samples during 17 separate storm events. The system treated approximately 96 percent of the flows recorded during the monitoring period. The applicant sized the system at 1.67 gpm/sq. ft.
    - Influent TSS concentrations for qualifying sampled storm events ranged from 40 to 780 mg/L. For influent concentrations less than 100 mg/L (n=2) the effluent concentration was less than 10 mg/L. For influent concentrations greater than 100 mg/L the bootstrap estimate of the lower 95 percent confidence limit (LCL95) of the mean TSS reduction was 85%.
    - Total phosphorus removal for 16 events with influent TP concentrations in the range of 0.1 to 0.5 mg/L averaged 75 percent. A bootstrap estimate of the lower 95 percent confidence limit (LCL95) of the mean total phosphorus reduction was 67 percent.

Other StormFilter system with PhosphoSorb media items the Company should address:

1. Conduct testing to obtain information about maintenance requirements in order to come up with a maintenance cycle.
2. Conduct loading tests on the filter to determine maximum treatment life of the system.

Technology Description: Download at: http://www.conteches.com/Products/Stormwater-Management/Treatment/Stormwater-Management-StormFilter®.aspx

Contact Information:

Applicant:

Jeremiah Lehman
Contech Engineered Solutions
11815 NE Glenn Widing Drive
Portland, OR, 97220
503-258-3136
jlehman@conteches.com

Applicant website: www.conteches.com

Ecology web link: http://www.ecy.wa.gov/programs/wq/stormwater/newtech/index.html

Ecology: Douglas C. Howie, P.E.
Department of Ecology
Water Quality Program
(360) 407-6444
douglas.howie@ecy.wa.gov

Revision History

Date	**Revision**
December 2012	Original use-level-designation document: CULD for basic and phosphorus treatment.
January 2013	Revised document to match standard formatting
August 2014	Revised TER and expiration dates
November 2015	Approved GULD designation for Basic and Phosphorus treatment
November 2016	Revised Contech contact information
April 2017	Revised sizing language to note sizing based on Off-line calculations

Herrera Environmental Consultants, Inc.

Memorandum

To Douglas Howie, Washington State Department of Ecology

cc Carla Milesi, Washington Stormwater Center
Sean Darcy, Contech Engineered Solutions

From Dylan Ahearn, Herrera Environmental Consultants

Date October 14, 2015

Subject StormFilter with PhosphoSorb TER review and approval

In August 2014, Contech Engineered Solutions LLC (Contech) was re-issued a Conditional Use Level Designation (CULD) from the Washington State Department of Ecology (Ecology) authorizing limited use of the StormFilter with PhosphoSorb for basic and phosphorus treatment in Washington State. From January 2012 to February 2015, a performance evaluation of the system was conducted in Zigzag, Oregon. Herrera Environmental Consultants (Herrera) conducted an independent review of a Data Summary Report in March 2015. In May 2015 Herrera reviewed and commented on the draft Technical Evaluation Report (TER). Finally, in October 2015 Herrera reviewed the final TER submission after comments from the Board of External Reviewers (BER) were incorporated. This memorandum summarizes the result from the TER review and provides a recommendation for the final TER approval.

A detailed review of the data and TER was performed to ensure the specified monitoring procedures conformed to the QAPP and that the resultant data satisfied the requirements of the Technology Assessment Protocol – Ecology (TAPE) (Ecology 2011). Herrera provided review and comments on the following specific elements of the TER:

- The initial bypass analysis was only conducted on sampled events, it is now conducted on all measured events
- Calibration records of the rain gauge and flow gauges were verified
- Sampling and Storm Criteria were verified
- Field notes, lab reports, ISRs, and data tables were cross referenced
- Edits to figures and tables were made to improve clarity
- Numerous editorial revisions to improve clarity
- A review of the particle size distribution analysis was conducted

Herrera submitted consolidated comments on the initial draft of the TER to Contech and subsequently received a revised version with a response to comments (see Attachment A to this memorandum). Representatives from Herrera (Dylan Ahearn) and Contech (Sean Darcy) subsequently participated in a teleconference on June 5, 2015 to discuss and resolve outstanding issues not completely addressed in the response to comments. Finally, on October 14, 2015, Herrera reviewed the response to BER comments and the final TER.

Based on our reading of this TER it is apparent that the system was performing well under very challenging site conditions. The sediment loading was greater than any previously TAPE approved system has encountered, with an average influent TSS concentration of 380 mg/L. This loading consisted of sandy material from nearby construction and road sanding, yet the system only required maintenance 4 times over the 37 month monitoring period. Due to the high influent concentrations and high percentage of coarse suspended solids the BER requested that a treatment efficiency analysis be conducted on two size fractions: suspended solids concentration (SSC) < 500 microns and SSC < 62.5 microns. The mean TSS removal was 88 percent with a lower 95% confidence limit (LCL95) of 85 percent, meeting the 80 percent goal in the TAPE. The mean percent removal for the silt and clay fraction (SSC < 62.5) was 83 and 78 percent for influent concentrations 100 – 200 and >200 mg/L, respectively. There were not enough data available to calculate the LCL95 for these size fractions. The system performed well at removing total phosphorus (TP). With a mean influent TP concentration of 0.33 mg/L, the system achieved a mean treatment efficiency of 73 percent, with a LCL95 of 67 percent, exceeding the TAPE goal of 50 percent TP reduction.

Based on our review of the data and the TER and accounting for Contech's response to our comments, Herrera is satisfied the monitoring conducted on the test system conformed to the requirements for TAPE. The TSS reduction analysis was complicated by the high sediment loading and coarse nature of the suspended solids, however, we feel the proponent provided ample data to indicate that the system would perform as designed under more typical loading conditions. We therefore recommend Ecology approve the specified system in the TER for a GULD for phosphorus and basic treatment at the design flow rate of 1.67 gpm/ft^2 of filtration media.

APPENDIX H – CONTECH STORMFILTER OPERATIONS AND MAINTENANCE

StormFilter Inspection and Maintenance Procedures

The Stormwater Management StormFilter®

Maintenance Guidelines

The primary purpose of the Stormwater Management StormFilter® is to filter and prevent pollutants from entering our waterways. Like any effective filtration system, periodically these pollutants must be removed to restore the StormFilter to its full efficiency and effectiveness.

Maintenance requirements and frequency are dependent on the pollutant load characteristics of each site. Maintenance activities may be required in the event of a chemical spill or due to excessive sediment loading from site erosion or extreme storms. It is a good practice to inspect the system after major storm events.

Maintenance Procedures

Although there are many effective maintenance options, we believe the following procedure to be efficient, using common equipment and existing maintenance protocols. The following two-step procedure is recommended::

1. **Inspection**
   - Inspection of the vault interior to determine the need for maintenance.
2. **Maintenance**
   - Cartridge replacement
   - Sediment removal

Inspection and Maintenance Timing

At least one scheduled inspection should take place per year with maintenance following as warranted.

First, an inspection should be done before the winter season. During the inspection the need for maintenance should be determined and, if disposal during maintenance will be required, samples of the accumulated sediments and media should be obtained.

Second, if warranted, a maintenance (replacement of the filter cartridges and removal of accumulated sediments) should be performed during periods of dry weather.

In addition to these two activities, it is important to check the condition of the StormFilter unit after major storms for potential damage caused by high flows and for high sediment accumulation that may be caused by localized erosion in the drainage area. It may be necessary to adjust the inspection/ maintenance schedule depending on the actual operating conditions encountered by the system. In general, inspection activities can be conducted at any time, and maintenance should occur, if warranted, during dryer months in late summer to early fall.

Maintenance Frequency

The primary factor for determining frequency of maintenance for the StormFilter is sediment loading.

A properly functioning system will remove solids from water by trapping particulates in the porous structure of the filter media inside the cartridges. The flow through the system will naturally decrease as more and more particulates are trapped. Eventually the flow through the cartridges will be low enough to require replacement. It may be possible to extend the usable span of the cartridges by removing sediment from upstream trapping devices on a routine as-needed basis, in order to prevent material from being re-suspended and discharged to the StormFilter treatment system.

The average maintenance lifecycle is approximately 1-5 years. Site conditions greatly influence maintenance requirements. StormFilter units located in areas with erosion or active construction may need to be inspected and maintained more often than those with fully stabilized surface conditions.

Regulatory requirements or a chemical spill can shift maintenance timing as well. The maintenance frequency may be adjusted as additional monitoring information becomes available during the inspection program. Areas that develop known problems should be inspected more frequently than areas that demonstrate no problems, particularly after major storms. Ultimately, inspection and maintenance activities should be scheduled based on the historic records and characteristics of an individual StormFilter system or site. It is recommended that the site owner develop a database to properly manage StormFilter inspection and maintenance programs..

Inspection Procedures

The primary goal of an inspection is to assess the condition of the cartridges relative to the level of visual sediment loading as it relates to decreased treatment capacity. It may be desirable to conduct this inspection during a storm to observe the relative flow through the filter cartridges. If the submerged cartridges are severely plugged, then typically large amounts of sediments will be present and very little flow will be discharged from the drainage pipes. If this is the case, then maintenance is warranted and the cartridges need to be replaced.

Warning: In the case of a spill, the worker should abort inspection activities until the proper guidance is obtained. Notify the local hazard control agency and Contech Engineered Solutions immediately.

To conduct an inspection:

Important: Inspection should be performed by a person who is familiar with the operation and configuration of the StormFilter treatment unit.

1. If applicable, set up safety equipment to protect and notify surrounding vehicle and pedestrian traffic.
2. Visually inspect the external condition of the unit and take notes concerning defects/problems.
3. Open the access portals to the vault and allow the system vent.
4. Without entering the vault, visually inspect the inside of the unit, and note accumulations of liquids and solids.
5. Be sure to record the level of sediment build-up on the floor of the vault, in the forebay, and on top of the cartridges. If flow is occurring, note the flow of water per drainage pipe. Record all observations. Digital pictures are valuable for historical documentation.
6. Close and fasten the access portals.
7. Remove safety equipment.
8. If appropriate, make notes about the local drainage area relative to ongoing construction, erosion problems, or high loading of other materials to the system.
9. Discuss conditions that suggest maintenance and make decision as to weather or not maintenance is needed.

Maintenance Decision Tree

The need for maintenance is typically based on results of the inspection. The following Maintenance Decision Tree should be used as a general guide. (Other factors, such as Regulatory Requirements, may need to be considered)

1. Sediment loading on the vault floor.
    a. If >4" of accumulated sediment, maintenance is required.
2. Sediment loading on top of the cartridge.
    a. If >1/4" of accumulation, maintenance is required.
3. Submerged cartridges.
    a. If >4" of static water above cartridge bottom for more than 24 hours after end of rain event, maintenance is required. (Catch basins have standing water in the cartridge bay.)
4. Plugged media.
    a. If pore space between media granules is absent, maintenance is required.
5. Bypass condition.
    a. If inspection is conducted during an average rain fall event and StormFilter remains in bypass condition (water over the internal outlet baffle wall or submerged cartridges), maintenance is required.
6. Hazardous material release.
    a. If hazardous material release (automotive fluids or other) is reported, maintenance is required.
7. Pronounced scum line.
    a. If pronounced scum line (say ≥ 1/4" thick) is present above top cap, maintenance is required.

Maintenance

Depending on the configuration of the particular system, maintenance personnel will be required to enter the vault to perform the maintenance.

Important: If vault entry is required, OSHA rules for confined space entry must be followed.

Filter cartridge replacement should occur during dry weather. It may be necessary to plug the filter inlet pipe if base flows is occurring.

Replacement cartridges can be delivered to the site or customers facility. Information concerning how to obtain the replacement cartridges is available from Contech Engineered Solutions.

Warning: In the case of a spill, the maintenance personnel should abort maintenance activities until the proper guidance is obtained. Notify the local hazard control agency and Contech Engineered Solutions immediately.

To conduct cartridge replacement and sediment removal maintenance:

1. If applicable, set up safety equipment to protect maintenance personnel and pedestrians from site hazards.
2. Visually inspect the external condition of the unit and take notes concerning defects/problems.
3. Open the doors (access portals) to the vault and allow the system to vent.
4. Without entering the vault, give the inside of the unit, including components, a general condition inspection.
5. Make notes about the external and internal condition of the vault. Give particular attention to recording the level of sediment build-up on the floor of the vault, in the forebay, and on top of the internal components.
6. Using appropriate equipment offload the replacement cartridges (up to 150 lbs. each) and set aside.
7. Remove used cartridges from the vault using one of the following methods:

Method 1:

A. This activity will require that maintenance personnel enter the vault to remove the cartridges from the under drain manifold and place them under the vault opening for lifting (removal). Disconnect each filter cartridge from the underdrain connector by rotating counterclockwise 1/4 of a turn. Roll the loose cartridge, on edge, to a convenient spot beneath the vault access.

Using appropriate hoisting equipment, attach a cable from the boom, crane, or tripod to the loose cartridge. Contact Contech Engineered Solutions for suggested attachment devices.

B. Remove the used cartridges (up to 250 lbs. each) from the vault.

Important: Care must be used to avoid damaging the cartridges during removal and installation. The cost of repairing components damaged during maintenance will be the responsibility of the owner.

C. Set the used cartridge aside or load onto the hauling truck.

D. Continue steps a through c until all cartridges have been removed.

Method 2:

A. This activity will require that maintenance personnel enter the vault to remove the cartridges from the under drain manifold and place them under the vault opening for lifting (removal). Disconnect each filter cartridge from the underdrain connector by rotating counterclockwise 1/4 of a turn. Roll the loose cartridge, on edge, to a convenient spot beneath the vault access.

B. Unscrew the cartridge cap.

C. Remove the cartridge hood and float.

D. At location under structure access, tip the cartridge on its side.

E. Empty the cartridge onto the vault floor. Reassemble the empty cartridge.

F. Set the empty, used cartridge aside or load onto the hauling truck.

G. Continue steps a through e until all cartridges have been removed.

8. Remove accumulated sediment from the floor of the vault and from the forebay. This can most effectively be accomplished by use of a vacuum truck.
9. Once the sediments are removed, assess the condition of the vault and the condition of the connectors.
10. Using the vacuum truck boom, crane, or tripod, lower and install the new cartridges. Once again, take care not to damage connections.
11. Close and fasten the door.
12. Remove safety equipment.
13. Finally, dispose of the accumulated materials in accordance with applicable regulations. Make arrangements to return the used **empty** cartridges to Contech Engineered Solutions.

Related Maintenance Activities - Performed on an as-needed basis

StormFilter units are often just one of many structures in a more comprehensive stormwater drainage and treatment system.

In order for maintenance of the StormFilter to be successful, it is imperative that all other components be properly maintained. The maintenance/repair of upstream facilities should be carried out prior to StormFilter maintenance activities.

In addition to considering upstream facilities, it is also important to correct any problems identified in the drainage area. Drainage area concerns may include: erosion problems, heavy oil loading, and discharges of inappropriate materials.

Material Disposal

The accumulated sediment found in stormwater treatment and conveyance systems must be handled and disposed of in accordance with regulatory protocols. It is possible for sediments to contain measurable concentrations of heavy metals and organic chemicals (such as pesticides and petroleum products). Areas with the greatest potential for high pollutant loading include industrial areas and heavily traveled roads.

Sediments and water must be disposed of in accordance with all applicable waste disposal regulations. When scheduling maintenance, consideration must be made for the disposal of solid and liquid wastes. This typically requires coordination with a local landfill for solid waste disposal. For liquid waste disposal a number of options are available including a municipal vacuum truck decant facility, local waste water treatment plant or on-site treatment and discharge.

Inspection Report

Date: Personnel:

Location:_________________________ System Size: ____

System Type: Vault ☐ Cast-In-Place ☐ Linear Catch Basin ☐ Manhole ☐ Other ☐

Sediment Thickness in Forebay: ______________________________________ Date: ____________

Sediment Depth on Vault Floor: ____

Structural Damage: ____

Estimated Flow from Drainage Pipes (if available):____

Cartridges Submerged: Yes ☐ No ☐ Depth of Standing Water:______________________________

StormFilter Maintenance Activities (check off if done and give description)

☐ Trash and Debris Removal: ____

☐ Minor Structural Repairs: ____

☐ Drainage Area Report ____

Excessive Oil Loading: Yes ☐ No ☐ Source: ______________________________

Sediment Accumulation on Pavement: Yes ☐ No ☐ Source: ______________________________

Erosion of Landscaped Areas: Yes ☐ No ☐ Source: ______________________________

Items Needing Further Work: ____

Owners should contact the local public works department and inquire about how the department disposes of their street waste residuals.

Other Comments:

____

____

____

____

____

____

____

____

Review the condition reports from the previous inspection visits.

StormFilter Maintenance Report

Date: ______________________ Personnel: ______________________

Location: ______________________ System Size: ______________________

System Type: Vault ☐ Cast-In-Place ☐ Linear Catch Basin ☐ Manhole ☐ Other ☐

List Safety Procedures and Equipment Used: ______________________

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System Observations

Months in Service:

Oil in Forebay (if present): Yes ☐ No ☐

Sediment Depth in Forebay (if present): ______________________

Sediment Depth on Vault Floor: ______________________

Structural Damage: ______________________

Drainage Area Report

Excessive Oil Loading: Yes ☐ No ☐ Source: ______________________

Sediment Accumulation on Pavement: Yes ☐ No ☐ Source: ______________________

Erosion of Landscaped Areas: Yes ☐ No ☐ Source: ______________________

StormFilter Cartridge Replacement Maintenance Activities

Remove Trash and Debris: Yes ☐ No ☐ Details: ______________________

Replace Cartridges: Yes ☐ No ☐ Details: ______________________

Sediment Removed: Yes ☐ No ☐ Details: ______________________

Quantity of Sediment Removed (estimate?):

Minor Structural Repairs: Yes ☐ No ☐ Details: ______________________

Residuals (debris, sediment) Disposal Methods: ______________________

Notes:

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