Stormwater Report and Calculations

for

The Acton Arboretum Parking Lot Expansion Project

Acton, MA 01720

Date: December 10, 2014

Prepared for:

Town of Acton Conservation Department
472 Main Street
Acton, MA 01720

Prepared by:

Town of Acton Engineering Department
472 Main Street
Acton, MA 01720

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Project Narrative

Project Description

The Acton Arboretum is a popular conservation land located in Acton Center. The Acton Conservation Department is proposing an expansion of the existing parking lot considering the following factors. The existing gravel parking lot is the only parking lot serving the Arboretum. The current parking spaces are limited therefore cannot meet the demand of the park's growing popularity. Throughout the years, the existing parking lot has become more and more difficult to maintain with it's worsen condition. The uneven surface creates puddles after every storm and creates inconvenience for people accessing the park during those times. And last, this new proposed parking lot will meet the handicap accessibility standard which the existing parking does not.

The new paved parking lot will help solve the existing problems. More parking spaces will be available to the public; parking lot maintenance will become easier with the newly paved bituminous concrete surface; the new parking lot will also make accessing the park easier for people with disabilities.

Existing Site Conditions

Soil types on the existing site are identified by the US NRCS (Natural Resources Conservation Services) Soil Web as Woodbridge Fine Sandy Loam (Hydrologic Group C) and Charlton Fine Sandy Loam (Hydrologic Group B), which both types are typically well drained soils.

The existing site contains an 8886 sq ft gravel parking lot with one paved driveway. The current drainage system in the area is mostly through direct infiltration to the ground and a drainage swale across the area that collects the excess runoff from the existing gravel parking lot. The Town is proposing a paved parking lot and a new driveway making the parking lot a one way lot to replace a gravel parking lot.

Proposed Site Conditions

The existing gravel parking lot will be removed. The new 15159 sq ft parking lot will be paved with bituminous concrete. A new 18' wide entrance driveway will be added south side of the parking lot, the existing driveway will be widened and make it an exit driveway only.

A drainage ditch will be put along the Arboretum side of the driveway and parking lot to collect the initial runoff from each designed storms. The excess runoff will be collected by the newly designed Rain Garden that contains two sediment forebays, check dam, rip rap swale and as well as the main rain garden located northeast of the parking lot.

Calculations for both the parking lot and the rain garden have been provided as part of this submittal.

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands Program

Checklist for Stormwater Report

A. Introduction

Important: When filling out forms on the computer, use only the tab key to move your cursor - do not use the return key.

A Stormwater Report must be submitted with the Notice of Intent permit application to document compliance with the Stormwater Management Standards. The following checklist is NOT a substitute for the Stormwater Report (which should provide more substantive and detailed information) but is offered here as a tool to help the applicant organize their Stormwater Management documentation for their Report and for the reviewer to assess this information in a consistent format. As noted in the Checklist, the Stormwater Report must contain the engineering computations and supporting information set forth in Volume 3 of the Massachusetts Stormwater Handbook. The Stormwater Report must be prepared and certified by a Registered Professional Engineer (RPE) licensed in the Commonwealth.

The Stormwater Report must include:

- The Stormwater Checklist completed and stamped by a Registered Professional Engineer (see page 2) that certifies that the Stormwater Report contains all required submittals.[1] This Checklist is to be used as the cover for the completed Stormwater Report.
- Applicant/Project Name
- Project Address
- Name of Firm and Registered Professional Engineer that prepared the Report
- Long-Term Pollution Prevention Plan required by Standards 4-6
- Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan required by Standard 8[2]
- Operation and Maintenance Plan required by Standard 9

In addition to all plans and supporting information, the Stormwater Report must include a brief narrative describing stormwater management practices, including environmentally sensitive site design and LID techniques, along with a diagram depicting runoff through the proposed BMP treatment train. Plans are required to show existing and proposed conditions, identify all wetland resource areas, NRCS soil types, critical areas, Land Uses with Higher Potential Pollutant Loads (LUHPPL), and any areas on the site where infiltration rate is greater than 2.4 inches per hour. The Plans shall identify the drainage areas for both existing and proposed conditions at a scale that enables verification of supporting calculations.

As noted in the Checklist, the Stormwater Management Report shall document compliance with each of the Stormwater Management Standards as provided in the Massachusetts Stormwater Handbook. The soils evaluation and calculations shall be done using the methodologies set forth in Volume 3 of the Massachusetts Stormwater Handbook.

To ensure that the Stormwater Report is complete, applicants are required to fill in the Stormwater Report Checklist by checking the box to indicate that the specified information has been included in the Stormwater Report. If any of the information specified in the checklist has not been submitted, the applicant must provide an explanation. The completed Stormwater Report Checklist and Certification must be submitted with the Stormwater Report.

[1] The Stormwater Report may also include the Illicit Discharge Compliance Statement required by Standard 10. If not included in the Stormwater Report, the Illicit Discharge Compliance Statement must be submitted prior to the discharge of stormwater runoff to the post-construction best management practices.

[2] For some complex projects, it may not be possible to include the Construction Period Erosion and Sedimentation Control Plan in the Stormwater Report. In that event, the issuing authority has the discretion to issue an Order of Conditions that approves the project and includes a condition requiring the proponent to submit the Construction Period Erosion and Sedimentation Control Plan before commencing any land disturbance activity on the site.

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands Program

Checklist for Stormwater Report

B. Stormwater Checklist and Certification

The following checklist is intended to serve as a guide for applicants as to the elements that ordinarily need to be addressed in a complete Stormwater Report. The checklist is also intended to provide conservation commissions and other reviewing authorities with a summary of the components necessary for a comprehensive Stormwater Report that addresses the ten Stormwater Standards.

Note: Because stormwater requirements vary from project to project, it is possible that a complete Stormwater Report may not include information on some of the subjects specified in the Checklist. If it is determined that a specific item does not apply to the project under review, please note that the item is not applicable (N.A.) and provide the reasons for that determination.

A complete checklist must include the Certification set forth below signed by the Registered Professional Engineer who prepared the Stormwater Report.

Registered Professional Engineer's Certification

I have reviewed the Stormwater Report, including the soil evaluation, computations, Long-term Pollution Prevention Plan, the Construction Period Erosion and Sedimentation Control Plan (if included), the Long-term Post-Construction Operation and Maintenance Plan, the Illicit Discharge Compliance Statement (if included) and the plans showing the stormwater management system, and have determined that they have been prepared in accordance with the requirements of the Stormwater Management Standards as further elaborated by the Massachusetts Stormwater Handbook. I have also determined that the information presented in the Stormwater Checklist is accurate and that the information presented in the Stormwater Report accurately reflects conditions at the site as of the date of this permit application.

Registered Professional Engineer Block and Signature

11-26-14
Signature and Date

Checklist

Project Type: Is the application for new development, redevelopment, or a mix of new and redevelopment?

- [x] New development
- [ ] Redevelopment
- [ ] Mix of New Development and Redevelopment

Checklist for Stormwater Report

Checklist (continued)

LID Measures: Stormwater Standards require LID measures to be considered. Document what environmentally sensitive design and LID Techniques were considered during the planning and design of the project:

- ☒ No disturbance to any Wetland Resource Areas
- ☐ Site Design Practices (e.g. clustered development, reduced frontage setbacks)
- ☐ Reduced Impervious Area (Redevelopment Only)
- ☒ Minimizing disturbance to existing trees and shrubs
- ☐ LID Site Design Credit Requested:
  - ☐ Credit 1
  - ☐ Credit 2
  - ☐ Credit 3
- ☒ Use of "country drainage" versus curb and gutter conveyance and pipe
- ☒ Bioretention Cells (includes Rain Gardens)
- ☐ Constructed Stormwater Wetlands (includes Gravel Wetlands designs)
- ☐ Treebox Filter
- ☒ Water Quality Swale
- ☐ Grass Channel
- ☐ Green Roof
- ☐ Other (describe): _____

Standard 1: No New Untreated Discharges

- ☒ No new untreated discharges
- ☐ Outlets have been designed so there is no erosion or scour to wetlands and waters of the Commonwealth
- ☐ Supporting calculations specified in Volume 3 of the Massachusetts Stormwater Handbook included.

Checklist for Stormwater Report

Checklist (continued)

Standard 2: Peak Rate Attenuation

☐ Standard 2 waiver requested because the project is located in land subject to coastal storm flowage and stormwater discharge is to a wetland subject to coastal flooding.

☐ Evaluation provided to determine whether off-site flooding increases during the 100-year 24-hour storm.

☒ Calculations provided to show that post-development peak discharge rates do not exceed pre-development rates for the 2-year and 10-year 24-hour storms. If evaluation shows that off-site flooding increases during the 100-year 24-hour storm, calculations are also provided to show that post-development peak discharge rates do not exceed pre-development rates for the 100-year 24-hour storm.

Standard 3: Recharge

☒ Soil Analysis provided.

☒ Required Recharge Volume calculation provided.

☐ Required Recharge volume reduced through use of the LID site Design Credits.

☒ Sizing the infiltration, BMPs is based on the following method: Check the method used.

☒ Static ☐ Simple Dynamic ☐ Dynamic Field[1]

☒ Runoff from all impervious areas at the site discharging to the infiltration BMP.

☐ Runoff from all impervious areas at the site is *not* discharging to the infiltration BMP and calculations are provided showing that the drainage area contributing runoff to the infiltration BMPs is sufficient to generate the required recharge volume.

☒ Recharge BMPs have been sized to infiltrate the Required Recharge Volume.

☐ Recharge BMPs have been sized to infiltrate the Required Recharge Volume *only* to the maximum extent practicable for the following reason:

- ☐ Site is comprised solely of C and D soils and/or bedrock at the land surface
- ☐ M.G.L. c. 21E sites pursuant to 310 CMR 40.0000
- ☐ Solid Waste Landfill pursuant to 310 CMR 19.000
- ☐ Project is otherwise subject to Stormwater Management Standards only to the maximum extent practicable.

☒ Calculations showing that the infiltration BMPs will drain in 72 hours are provided.

☐ Property includes a M.G.L. c. 21E site or a solid waste landfill and a mounding analysis is included.

[1] 80% TSS removal is required prior to discharge to infiltration BMP if Dynamic Field method is used.

Checklist for Stormwater Report

Checklist (continued)

Standard 3: Recharge (continued)

☒ The infiltration BMP is used to attenuate peak flows during storms greater than or equal to the 10-year 24-hour storm and separation to seasonal high groundwater is less than 4 feet and a mounding analysis is provided.

☐ Documentation is provided showing that infiltration BMPs do not adversely impact nearby wetland resource areas.

Standard 4: Water Quality

The Long-Term Pollution Prevention Plan typically includes the following:

- Good housekeeping practices;
- Provisions for storing materials and waste products inside or under cover;
- Vehicle washing controls;
- Requirements for routine inspections and maintenance of stormwater BMPs;
- Spill prevention and response plans;
- Provisions for maintenance of lawns, gardens, and other landscaped areas;
- Requirements for storage and use of fertilizers, herbicides, and pesticides;
- Pet waste management provisions;
- Provisions for operation and management of septic systems;
- Provisions for solid waste management;
- Snow disposal and plowing plans relative to Wetland Resource Areas;
- Winter Road Salt and/or Sand Use and Storage restrictions;
- Street sweeping schedules;
- Provisions for prevention of illicit discharges to the stormwater management system;
- Documentation that Stormwater BMPs are designed to provide for shutdown and containment in the event of a spill or discharges to or near critical areas or from LUHPPL;
- Training for staff or personnel involved with implementing Long-Term Pollution Prevention Plan;
- List of Emergency contacts for implementing Long-Term Pollution Prevention Plan.

☐ A Long-Term Pollution Prevention Plan is attached to Stormwater Report and is included as an attachment to the Wetlands Notice of Intent.

☐ Treatment BMPs subject to the 44% TSS removal pretreatment requirement and the one inch rule for calculating the water quality volume are included, and discharge:

- ☐ is within the Zone II or Interim Wellhead Protection Area
- ☐ is near or to other critical areas
- ☐ is within soils with a rapid infiltration rate (greater than 2.4 inches per hour)
- ☐ involves runoff from land uses with higher potential pollutant loads.

☐ The Required Water Quality Volume is reduced through use of the LID site Design Credits.

☒ Calculations documenting that the treatment train meets the 80% TSS removal requirement and, if applicable, the 44% TSS removal pretreatment requirement, are provided.

Checklist for Stormwater Report

Checklist (continued)

Standard 4: Water Quality (continued)

☒ The BMP is sized (and calculations provided) based on:

- ☒ The ½" or 1" Water Quality Volume or
- ☐ The equivalent flow rate associated with the Water Quality Volume and documentation is provided showing that the BMP treats the required water quality volume.

☐ The applicant proposes to use proprietary BMPs, and documentation supporting use of proprietary BMP and proposed TSS removal rate is provided. This documentation may be in the form of the propriety BMP checklist found in Volume 2, Chapter 4 of the Massachusetts Stormwater Handbook and submitting copies of the TARP Report, STEP Report, and/or other third party studies verifying performance of the proprietary BMPs.

☐ A TMDL exists that indicates a need to reduce pollutants other than TSS and documentation showing that the BMPs selected are consistent with the TMDL is provided.

Standard 5: Land Uses With Higher Potential Pollutant Loads (LUHPPLs)

☐ The NPDES Multi-Sector General Permit covers the land use and the Stormwater Pollution Prevention Plan (SWPPP) has been included with the Stormwater Report.

☐ The NPDES Multi-Sector General Permit covers the land use and the SWPPP will be submitted ***prior to*** the discharge of stormwater to the post-construction stormwater BMPs.

☒ The NPDES Multi-Sector General Permit does ***not*** cover the land use.

☐ LUHPPLs are located at the site and industry specific source control and pollution prevention measures have been proposed to reduce or eliminate the exposure of LUHPPLs to rain, snow, snow melt and runoff, and been included in the long term Pollution Prevention Plan.

☐ All exposure has been eliminated.

☐ All exposure has ***not*** been eliminated and all BMPs selected are on MassDEP LUHPPL list.

☐ The LUHPPL has the potential to generate runoff with moderate to higher concentrations of oil and grease (e.g. all parking lots with >1000 vehicle trips per day) and the treatment train includes an oil grit separator, a filtering bioretention area, a sand filter or equivalent.

Standard 6: Critical Areas

☐ The discharge is near or to a critical area and the treatment train includes only BMPs that MassDEP has approved for stormwater discharges to or near that particular class of critical area.

☒ Critical areas and BMPs are identified in the Stormwater Report.

Checklist for Stormwater Report

Checklist (continued)

Standard 7: Redevelopments and Other Projects Subject to the Standards only to the maximum extent practicable

☐ The project is subject to the Stormwater Management Standards only to the maximum Extent Practicable as a:

- ☐ Limited Project
- ☐ Small Residential Projects: 5-9 single family houses or 5-9 units in a multi-family development provided there is no discharge that may potentially affect a critical area.
- ☐ Small Residential Projects: 2-4 single family houses or 2-4 units in a multi-family development with a discharge to a critical area
- ☐ Marina and/or boatyard provided the hull painting, service and maintenance areas are protected from exposure to rain, snow, snow melt and runoff
- ☐ Bike Path and/or Foot Path
- ☐ Redevelopment Project
- ☐ Redevelopment portion of mix of new and redevelopment.

☐ Certain standards are not fully met (Standard No. 1, 8, 9, and 10 must always be fully met) and an explanation of why these standards are not met is contained in the Stormwater Report.

☐ The project involves redevelopment and a description of all measures that have been taken to improve existing conditions is provided in the Stormwater Report. The redevelopment checklist found in Volume 2 Chapter 3 of the Massachusetts Stormwater Handbook may be used to document that the proposed stormwater management system (a) complies with Standards 2, 3 and the pretreatment and structural BMP requirements of Standards 4-6 to the maximum extent practicable and (b) improves existing conditions.

Standard 8: Construction Period Pollution Prevention and Erosion and Sedimentation Control

A Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan must include the following information:

- Narrative;
- Construction Period Operation and Maintenance Plan;
- Names of Persons or Entity Responsible for Plan Compliance;
- Construction Period Pollution Prevention Measures;
- Erosion and Sedimentation Control Plan Drawings;
- Detail drawings and specifications for erosion control BMPs, including sizing calculations;
- Vegetation Planning;
- Site Development Plan;
- Construction Sequencing Plan;
- Sequencing of Erosion and Sedimentation Controls;
- Operation and Maintenance of Erosion and Sedimentation Controls;
- Inspection Schedule;
- Maintenance Schedule;
- Inspection and Maintenance Log Form.

☒ A Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan containing the information set forth above has been included in the Stormwater Report.

Checklist for Stormwater Report

Checklist (continued)

Standard 8: Construction Period Pollution Prevention and Erosion and Sedimentation Control (continued)

☐ The project is highly complex and information is included in the Stormwater Report that explains why it is not possible to submit the Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan with the application. A Construction Period Pollution Prevention and Erosion and Sedimentation Control has ***not*** been included in the Stormwater Report but will be submitted ***before*** land disturbance begins.

☐ The project is ***not*** covered by a NPDES Construction General Permit.

☐ The project is covered by a NPDES Construction General Permit and a copy of the SWPPP is in the Stormwater Report.

☐ The project is covered by a NPDES Construction General Permit but no SWPPP been submitted. The SWPPP will be submitted BEFORE land disturbance begins.

Standard 9: Operation and Maintenance Plan

☒ The Post Construction Operation and Maintenance Plan is included in the Stormwater Report and includes the following information:

- ☒ Name of the stormwater management system owners;
- ☒ Party responsible for operation and maintenance;
- ☒ Schedule for implementation of routine and non-routine maintenance tasks;
- ☒ Plan showing the location of all stormwater BMPs maintenance access areas;
- ☐ Description and delineation of public safety features;
- ☐ Estimated operation and maintenance budget; and
- ☐ Operation and Maintenance Log Form.

☐ The responsible party is ***not*** the owner of the parcel where the BMP is located and the Stormwater Report includes the following submissions:

- ☐ A copy of the legal instrument (deed, homeowner's association, utility trust or other legal entity) that establishes the terms of and legal responsibility for the operation and maintenance of the project site stormwater BMPs;
- ☐ A plan and easement deed that allows site access for the legal entity to operate and maintain BMP functions.

Standard 10: Prohibition of Illicit Discharges

☐ The Long-Term Pollution Prevention Plan includes measures to prevent illicit discharges;

☒ An Illicit Discharge Compliance Statement is attached;

☐ NO Illicit Discharge Compliance Statement is attached but will be submitted ***prior to*** the discharge of any stormwater to post-construction BMPs.

Standard 3 - Recharge

Test Pit Ground Elevation = 98.31' 5.5'

A - 0" - 6" → Loamy Sand — No redox
B - 6" - 12" → Loamy Sand — No redox
C 12" - 66" → Loamy Sand — No redox ESHGW < 98.31' - 5.5' = 92.81'

1) Required Volume - R_v

$R_v = F \times$ impervious area

$R_v = \frac{0.35_{in}}{12^{in}/ft} \times 13{,}508\ sf = 393.98\ ft^3 \approx 400\ ft^3 < 1402\ ft^3$ provided below culvert invert

Infiltration Rate = 2.41 in/hr (Loamy Sand)

$Time = \frac{R_v}{K \cdot Bottom\ area}$

$= \frac{393.98}{2.41 \times (1/12) \times 1650} = 1.2$ hours < 72 hours ∴ OK

Standard 4 - Water Quality

$V_{wq} = D_{wq}/12 \times A_{imp}$

$= \left(\frac{1\text{-in}}{12^{in}/ft}\right) \times 13{,}508\ sf = 1125.67\ ft^3 < 1402\ ft^3$ ∴ OK

INSTRUCTIONS:

1. In BMP Column, click on Blue Cell to Activate Drop Down Menu
2. Select BMP from Drop Down Menu
3. After BMP is selected, TSS Removal and other Columns are automatically completed.

Version 1, Automated: Mar. 4, 2008

Location: Arboretum Parking Lot

TSS Removal Calculation Worksheet

B BMP[1]	C TSS Removal Rate[1]	D Starting TSS Load*	E Amount Removed (C*D)	F Remaining Load (D-E)
Water Quality Swale - Dry	0.70	1.00	0.70	0.30
Sediment Forebay	0.25	0.30	0.08	0.23
Rain Garden	0.90	0.23	0.20	0.02
	0.00	0.02	0.00	0.02
	0.00	0.02	0.00	0.02

Total TSS Removal = 98%

Separate Form Needs to be Completed for Each Outlet or BMP Train

Project:

Prepared By:

Date:

*Equals remaining load from previous BMP (E) which enters the BMP

Non-automated TSS Calculation Sheet must be used if Proprietary BMP Proposed

1. From MassDEP Stormwater Handbook Vol. 1

Standard 3- Recharge

Test-Pit Ground Elevation = 98.31' 5.5'

A - 0"-6" → Loamy Sand No redox
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$$= \frac{393.98}{2.41 \times (1/12) \times 1650} = 1.2\ hours < 72\ hours \therefore OK$$

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$V_{wq} = D_{wq}/12 \times A_{imp}$

$= \left(\frac{1\text{-}in}{12^{in}/ft}\right) \times 13{,}508\ sf = 1125.67\ ft^3 < 1402\ ft^3 \therefore OK$

TAYLOR ROAD

UP
UP
UP
UP
103
103
103
104
105
106
106
108
107
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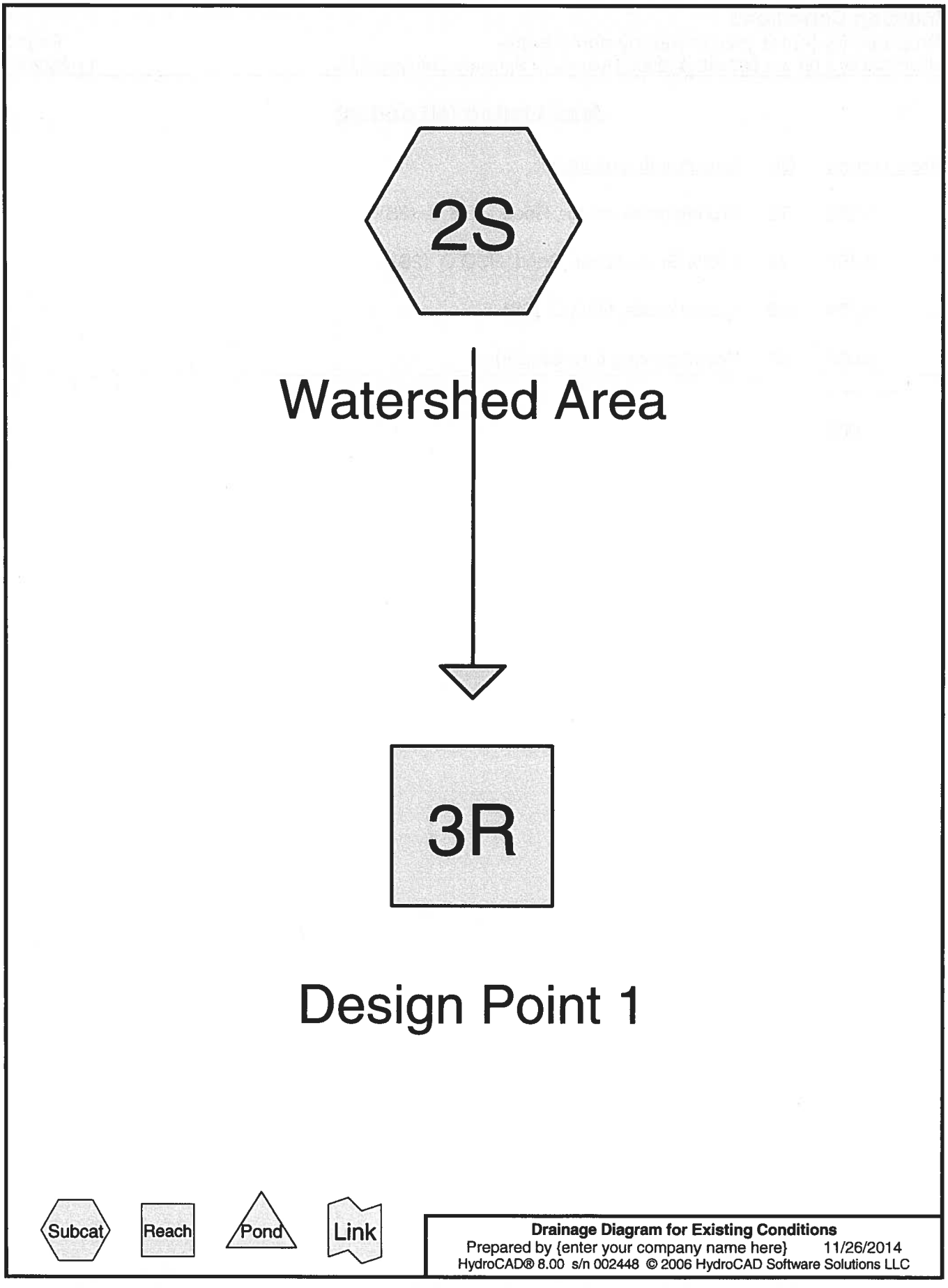
105
104
103
102
101
100
99
99.13
99.14
98.08
98
99
100
LEDGE
LEDGE
LEDGE
EXISTING SIDEWALK
EXISTING HANDICAP PARKING SIGN
EXISTING WOOD RET WALL
EXISTING BIKE RACK
EXISTING EDGE OF GRAVEL PARKING
EXISTING DRAINAGE TRENCH
EXISTING GRAVEL PATH
EXISTING PAVED PATH
EXISTING ADDITIONAL PARKING AREA
EDGE OF TREELINE

SURVEY: PVC/QRP	TOWN OF ACTON ENGINEERING DEPARTMENT	
DESIGN: XXXX	ACTON ARBORETUM PARKING EXPANSION	
DRAFTING: QRP		
CHECKED: PVC	EXISTING CONDITION	
SCALE: 1" = 30'	DRAWING NO: 1	DATE: 7/25/2014

Drawing Name: I:\Drawings\Arboretum\Utility Expansion\Existing Conditions.dwg
Jan 08, 2015 - 13:42pm


2S
Watershed Area
3R
Design Point 1
Subcat
Reach
Pond
Link
Drainage Diagram for Existing Conditions
Prepared by {enter your company name here} 11/26/2014
HydroCAD® 8.00 s/n 002448 © 2006 HydroCAD Software Solutions LLC

Area Listing (all nodes)

Area (acres)	CN	Description (subcats)
0.322	72	Woods/grass comb., Good, HSG C (2S)
0.497	74	>75% Grass cover, Good, HSG C (2S)
0.204	89	Gravel roads, HSG C (2S)
0.038	98	Paved parking & roofs (2S)
1.062		

Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 2S: Watershed Area Runoff Area=46,240 sf Runoff Depth>1.03"
Flow Length=304' Tc=33.6 min CN=77 Runoff=0.73 cfs 0.091 af

Reach 3R: Design Point 1 Inflow=0.73 cfs 0.091 af
Outflow=0.73 cfs 0.091 af

Total Runoff Area = 1.062 ac Runoff Volume = 0.091 af Average Runoff Depth = 1.03"
96.45% Pervious Area = 1.024 ac 3.55% Impervious Area = 0.038 ac

Subcatchment 2S: Watershed Area

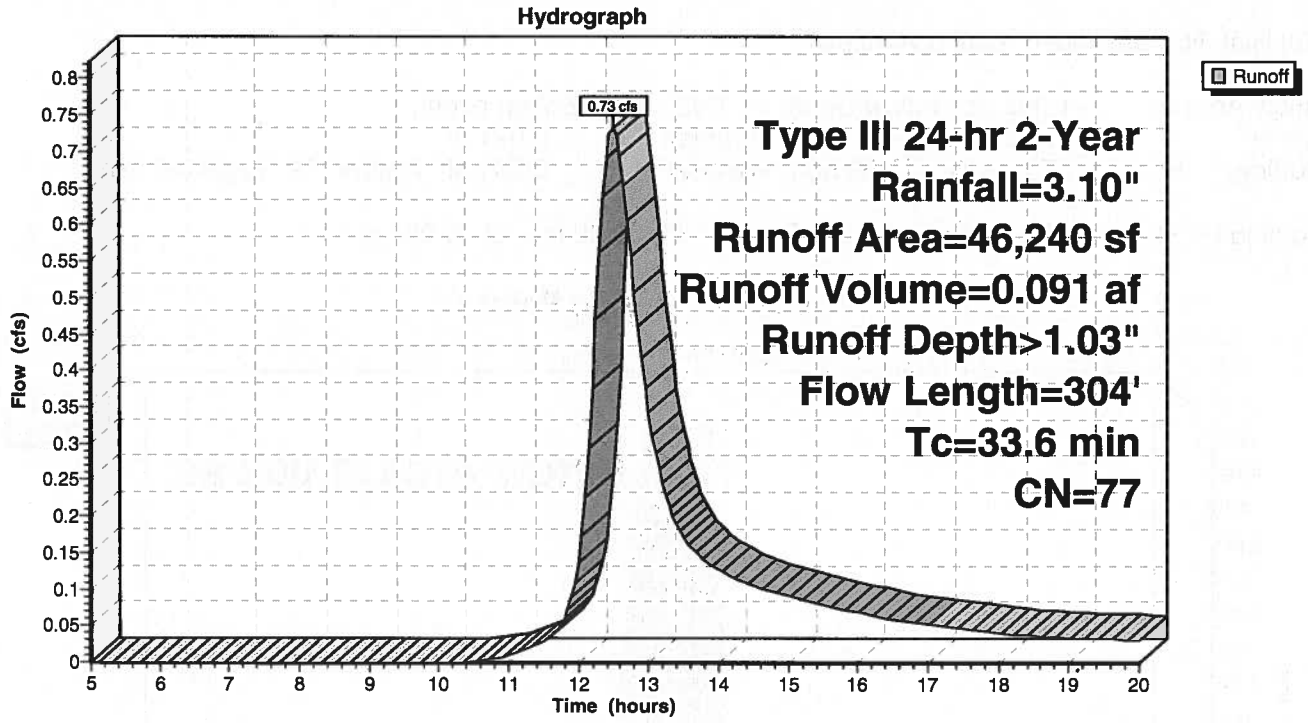
Runoff = 0.73 cfs @ 12.50 hrs, Volume= 0.091 af, Depth> 1.03"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 2-Year Rainfall=3.10"

Area (sf)	CN	Description
1,641	98	Paved parking & roofs
8,907	89	Gravel roads, HSG C
21,651	74	>75% Grass cover, Good, HSG C
14,041	72	Woods/grass comb., Good, HSG C
46,240	77	Weighted Average
44,599		Pervious Area
1,641		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.2	16	0.1000	0.22		**Sheet Flow, Grass** Grass: Short n= 0.150 P2= 3.10"
0.1	6	0.0625	1.22		**Sheet Flow, sidewalk** Smooth surfaces n= 0.011 P2= 3.10"
11.6	27	0.0010	0.04		**Sheet Flow, grass** Grass: Short n= 0.150 P2= 3.10"
14.7	139	0.0010	0.16		**Shallow Concentrated Flow, woodlands** Woodland Kv= 5.0 fps
2.1	64	0.0010	0.51		**Shallow Concentrated Flow, gravel** Unpaved Kv= 16.1 fps
3.9	52	0.0010	0.22		**Shallow Concentrated Flow, grass** Short Grass Pasture Kv= 7.0 fps
33.6	304	Total			

Subcatchment 2S: Watershed Area



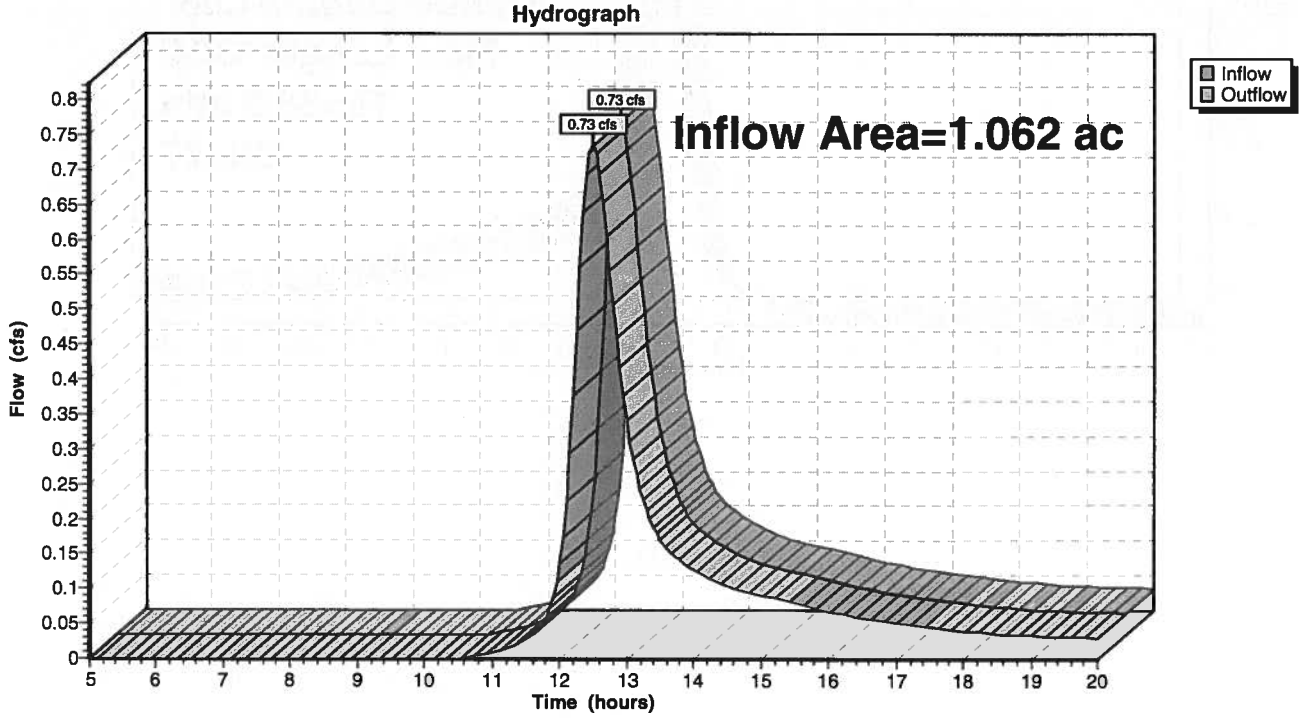
Reach 3R: Design Point 1

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.062 ac, Inflow Depth > 1.03" for 2-Year event
Inflow = 0.73 cfs @ 12.50 hrs, Volume= 0.091 af
Outflow = 0.73 cfs @ 12.50 hrs, Volume= 0.091 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Reach 3R: Design Point 1



Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 2S: Watershed Area Runoff Area=46,240 sf Runoff Depth>2.03"
Flow Length=304' Tc=33.6 min CN=77 Runoff=1.47 cfs 0.180 af

Reach 3R: Design Point 1 Inflow=1.47 cfs 0.180 af
Outflow=1.47 cfs 0.180 af

Total Runoff Area = 1.062 ac Runoff Volume = 0.180 af Average Runoff Depth = 2.03"
96.45% Pervious Area = 1.024 ac 3.55% Impervious Area = 0.038 ac

Subcatchment 2S: Watershed Area

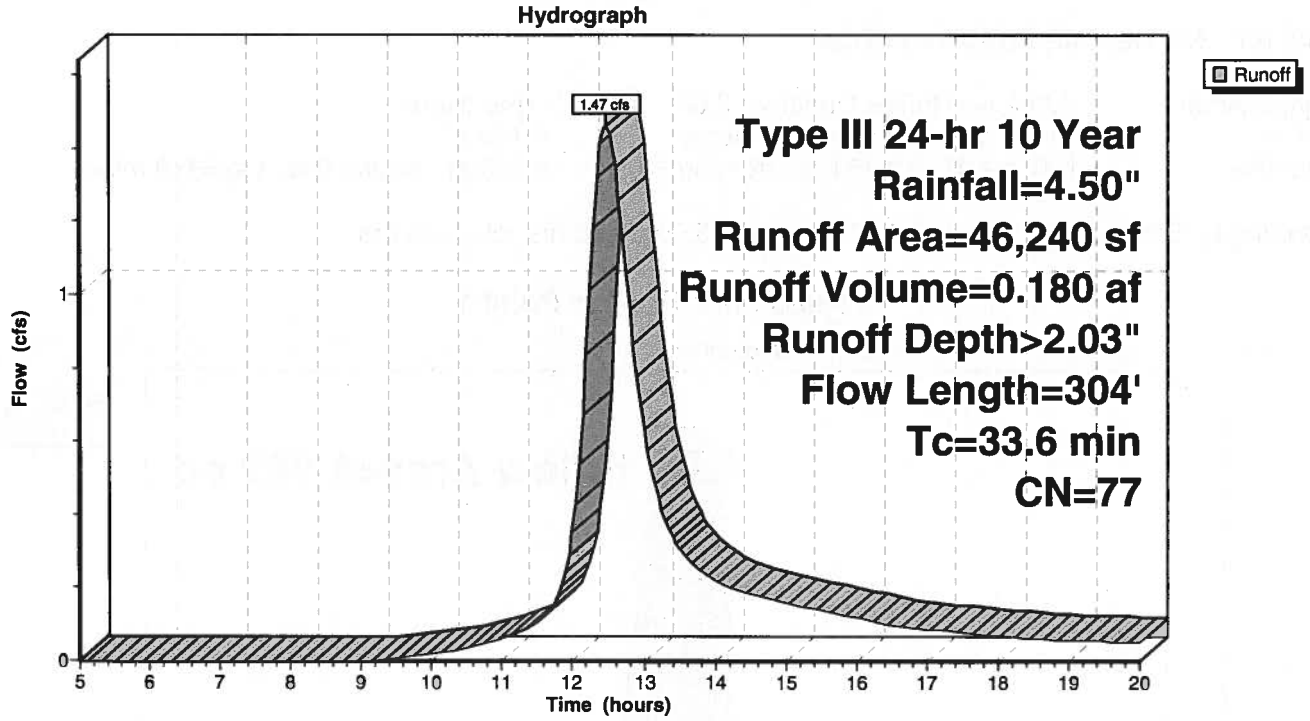
Runoff = 1.47 cfs @ 12.48 hrs, Volume= 0.180 af, Depth> 2.03"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 10 Year Rainfall=4.50"

Area (sf)	CN	Description
1,641	98	Paved parking & roofs
8,907	89	Gravel roads, HSG C
21,651	74	>75% Grass cover, Good, HSG C
14,041	72	Woods/grass comb., Good, HSG C
46,240	77	Weighted Average
44,599		Pervious Area
1,641		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.2	16	0.1000	0.22		**Sheet Flow, Grass** Grass: Short n= 0.150 P2= 3.10"
0.1	6	0.0625	1.22		**Sheet Flow, sidewalk** Smooth surfaces n= 0.011 P2= 3.10"
11.6	27	0.0010	0.04		**Sheet Flow, grass** Grass: Short n= 0.150 P2= 3.10"
14.7	139	0.0010	0.16		**Shallow Concentrated Flow, woodlands** Woodland Kv= 5.0 fps
2.1	64	0.0010	0.51		**Shallow Concentrated Flow, gravel** Unpaved Kv= 16.1 fps
3.9	52	0.0010	0.22		**Shallow Concentrated Flow, grass** Short Grass Pasture Kv= 7.0 fps
33.6	304	Total			

Subcatchment 2S: Watershed Area



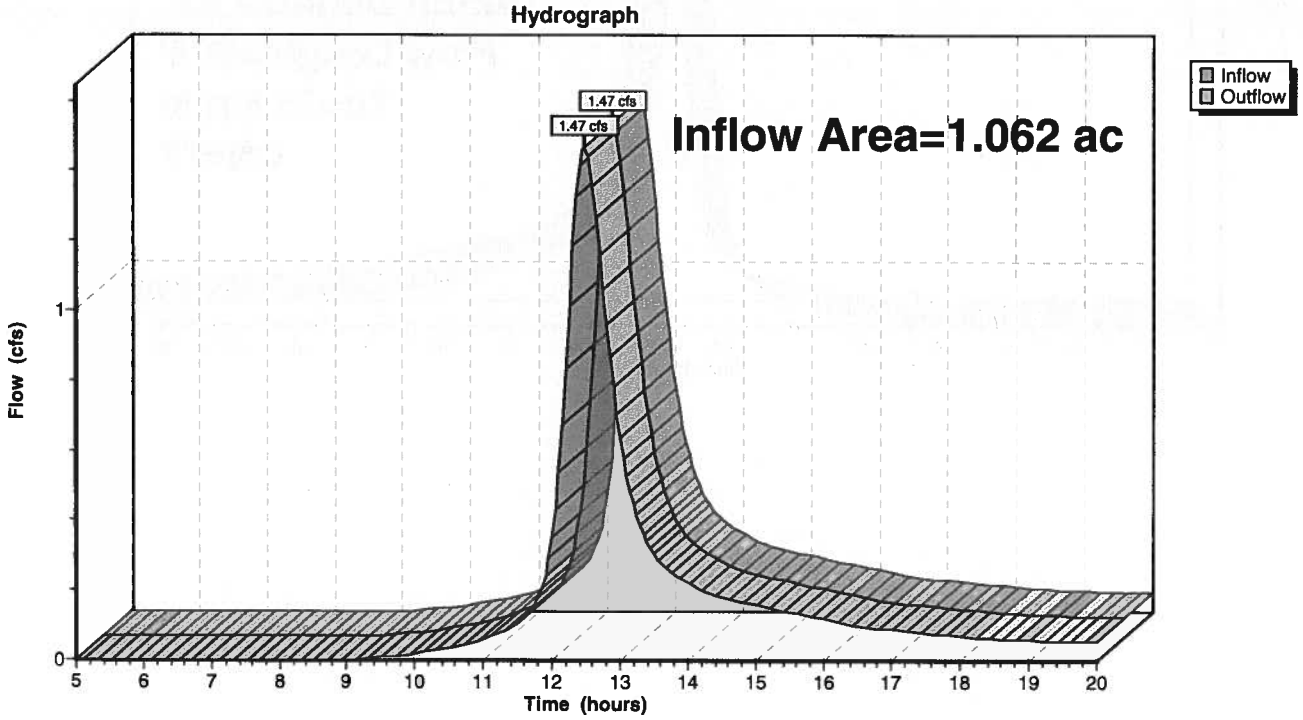
Reach 3R: Design Point 1

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.062 ac, Inflow Depth > 2.03" for 10 Year event
Inflow = 1.47 cfs @ 12.48 hrs, Volume= 0.180 af
Outflow = 1.47 cfs @ 12.48 hrs, Volume= 0.180 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Reach 3R: Design Point 1



Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 2S: Watershed Area Runoff Area=46,240 sf Runoff Depth>2.65"
Flow Length=304' Tc=33.6 min CN=77 Runoff=1.92 cfs 0.235 af

Reach 3R: Design Point 1 Inflow=1.92 cfs 0.235 af
Outflow=1.92 cfs 0.235 af

Total Runoff Area = 1.062 ac Runoff Volume = 0.235 af Average Runoff Depth = 2.65"
96.45% Pervious Area = 1.024 ac 3.55% Impervious Area = 0.038 ac

Subcatchment 2S: Watershed Area

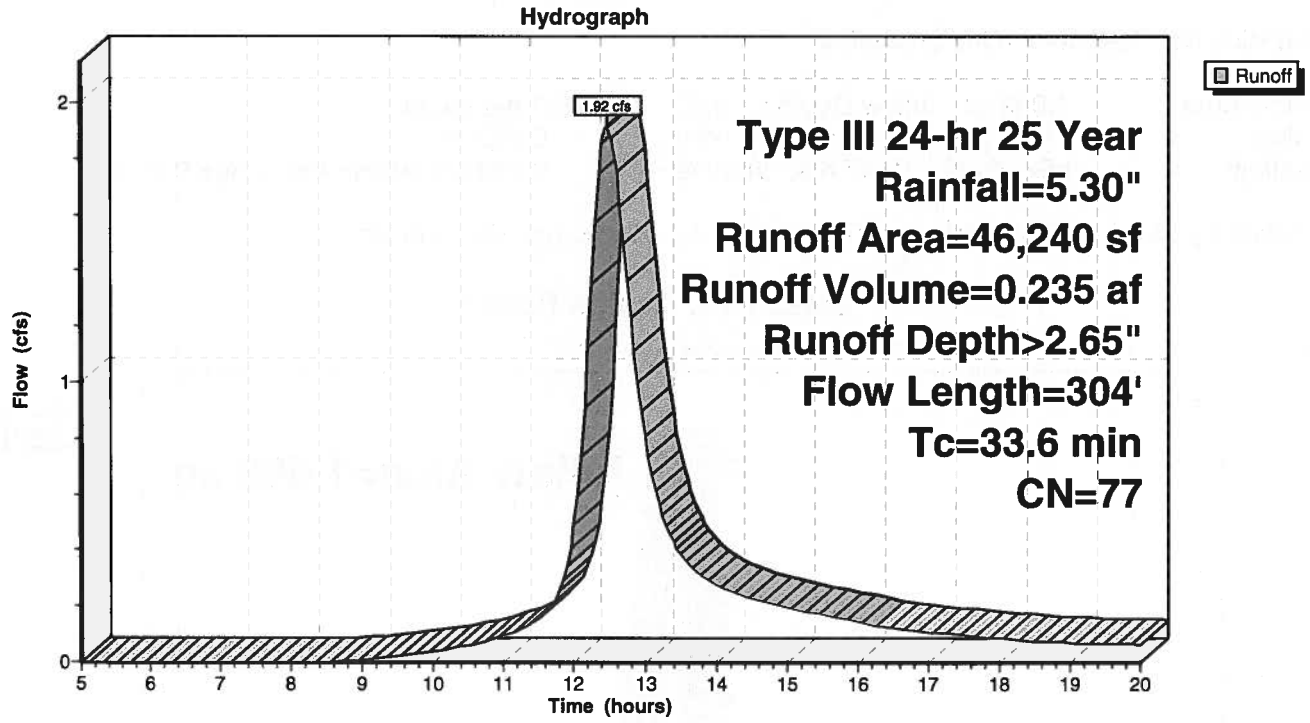
Runoff = 1.92 cfs @ 12.47 hrs, Volume= 0.235 af, Depth> 2.65"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 25 Year Rainfall=5.30"

Area (sf)	CN	Description
1,641	98	Paved parking & roofs
8,907	89	Gravel roads, HSG C
21,651	74	>75% Grass cover, Good, HSG C
14,041	72	Woods/grass comb., Good, HSG C
46,240	77	Weighted Average
44,599		Pervious Area
1,641		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.2	16	0.1000	0.22		**Sheet Flow, Grass** Grass: Short n= 0.150 P2= 3.10"
0.1	6	0.0625	1.22		**Sheet Flow, sidewalk** Smooth surfaces n= 0.011 P2= 3.10"
11.6	27	0.0010	0.04		**Sheet Flow, grass** Grass: Short n= 0.150 P2= 3.10"
14.7	139	0.0010	0.16		**Shallow Concentrated Flow, woodlands** Woodland Kv= 5.0 fps
2.1	64	0.0010	0.51		**Shallow Concentrated Flow, gravel** Unpaved Kv= 16.1 fps
3.9	52	0.0010	0.22		**Shallow Concentrated Flow, grass** Short Grass Pasture Kv= 7.0 fps
33.6	304	Total			

Subcatchment 2S: Watershed Area



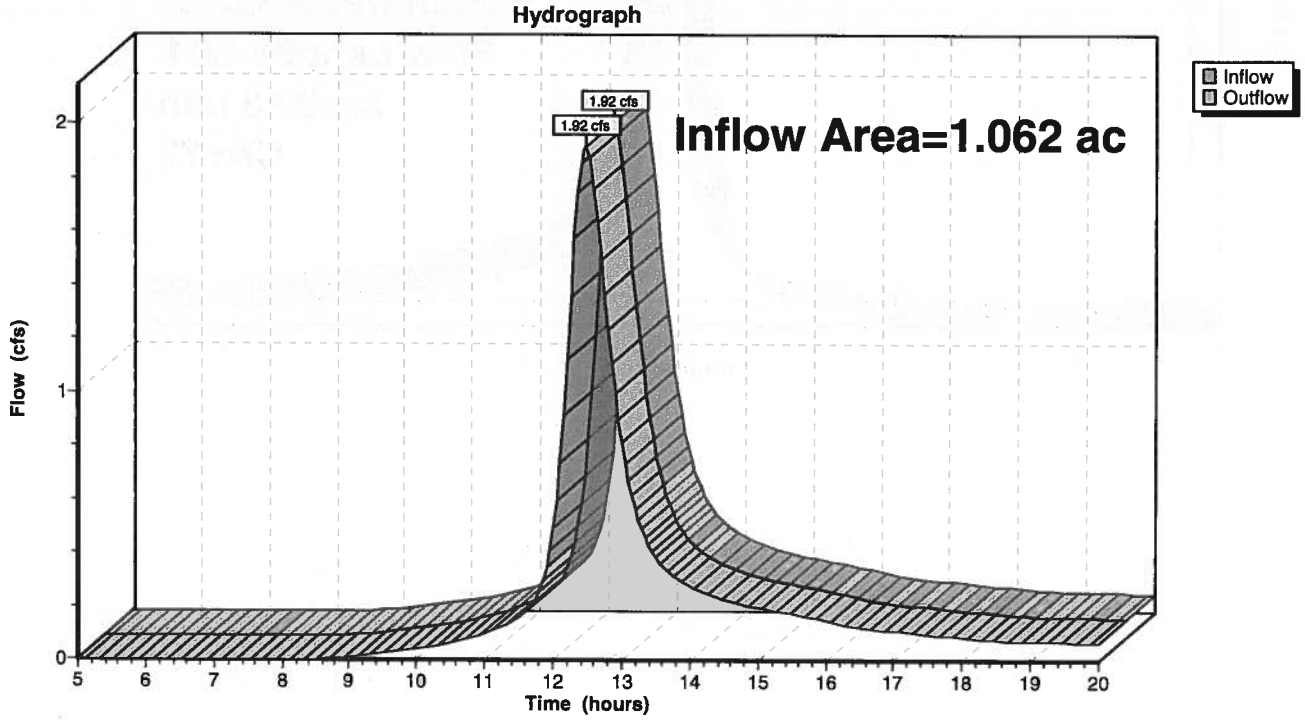
Reach 3R: Design Point 1

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.062 ac, Inflow Depth > 2.65" for 25 Year event
Inflow = 1.92 cfs @ 12.47 hrs, Volume= 0.235 af
Outflow = 1.92 cfs @ 12.47 hrs, Volume= 0.235 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Reach 3R: Design Point 1



Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 2S: Watershed Area Runoff Area=46,240 sf Runoff Depth>3.63"
Flow Length=304' Tc=33.6 min CN=77 Runoff=2.61 cfs 0.321 af

Reach 3R: Design Point 1 Inflow=2.61 cfs 0.321 af
Outflow=2.61 cfs 0.321 af

Total Runoff Area = 1.062 ac Runoff Volume = 0.321 af Average Runoff Depth = 3.63"
96.45% Pervious Area = 1.024 ac 3.55% Impervious Area = 0.038 ac

Subcatchment 2S: Watershed Area

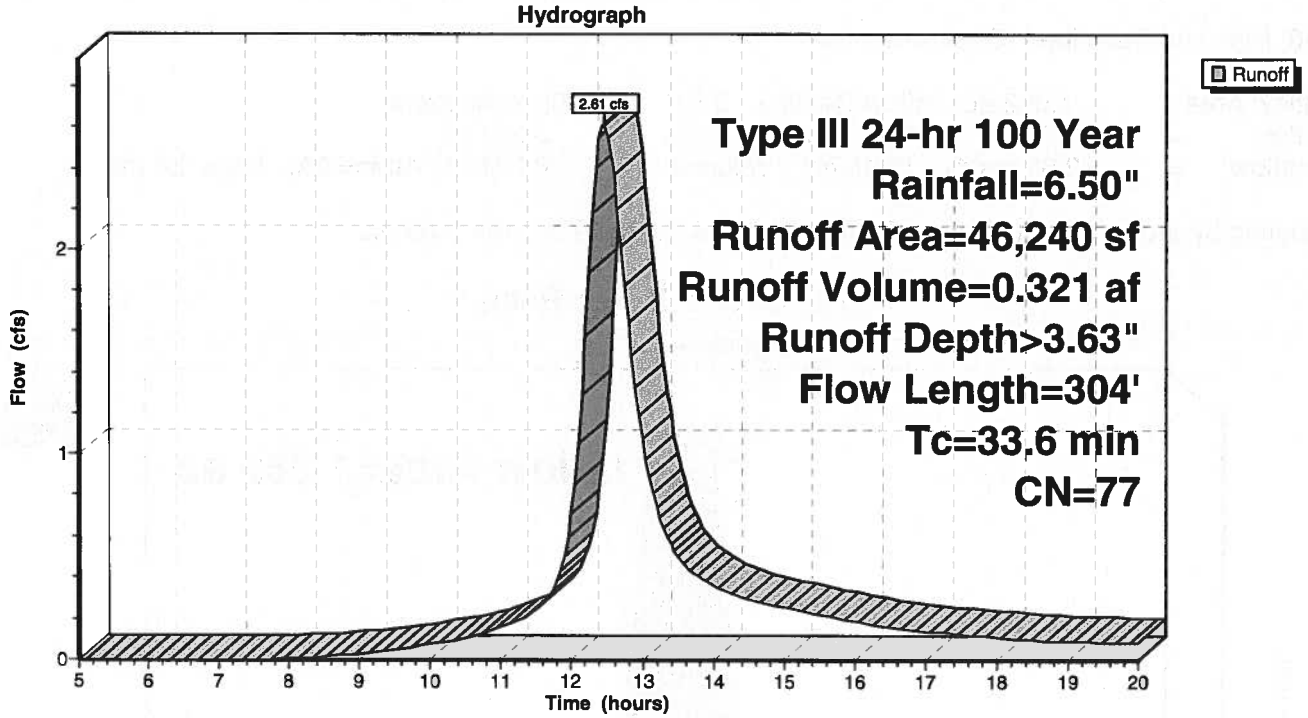
Runoff = 2.61 cfs @ 12.46 hrs, Volume= 0.321 af, Depth> 3.63"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 100 Year Rainfall=6.50"

Area (sf)	CN	Description
1,641	98	Paved parking & roofs
8,907	89	Gravel roads, HSG C
21,651	74	>75% Grass cover, Good, HSG C
14,041	72	Woods/grass comb., Good, HSG C
46,240	77	Weighted Average
44,599		Pervious Area
1,641		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.2	16	0.1000	0.22		**Sheet Flow, Grass** Grass: Short n= 0.150 P2= 3.10"
0.1	6	0.0625	1.22		**Sheet Flow, sidewalk** Smooth surfaces n= 0.011 P2= 3.10"
11.6	27	0.0010	0.04		**Sheet Flow, grass** Grass: Short n= 0.150 P2= 3.10"
14.7	139	0.0010	0.16		**Shallow Concentrated Flow, woodlands** Woodland Kv= 5.0 fps
2.1	64	0.0010	0.51		**Shallow Concentrated Flow, gravel** Unpaved Kv= 16.1 fps
3.9	52	0.0010	0.22		**Shallow Concentrated Flow, grass** Short Grass Pasture Kv= 7.0 fps
33.6	304	Total			

Subcatchment 2S: Watershed Area



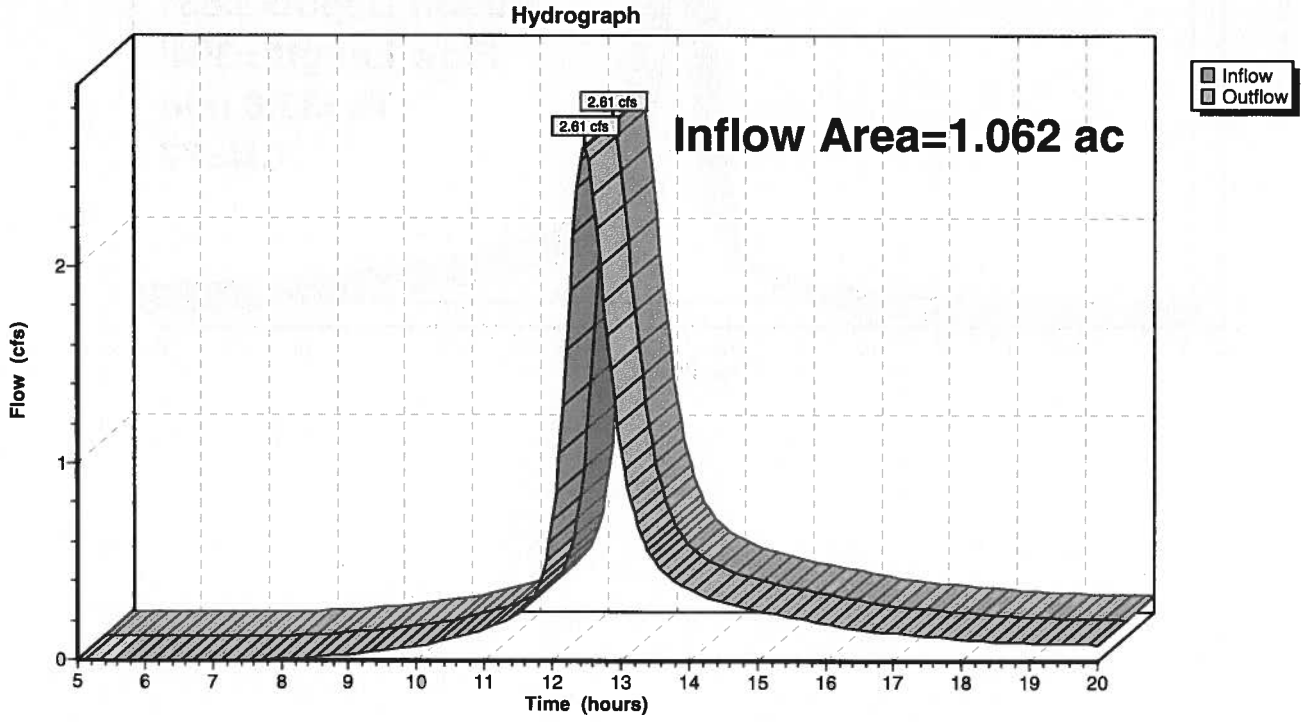
Reach 3R: Design Point 1

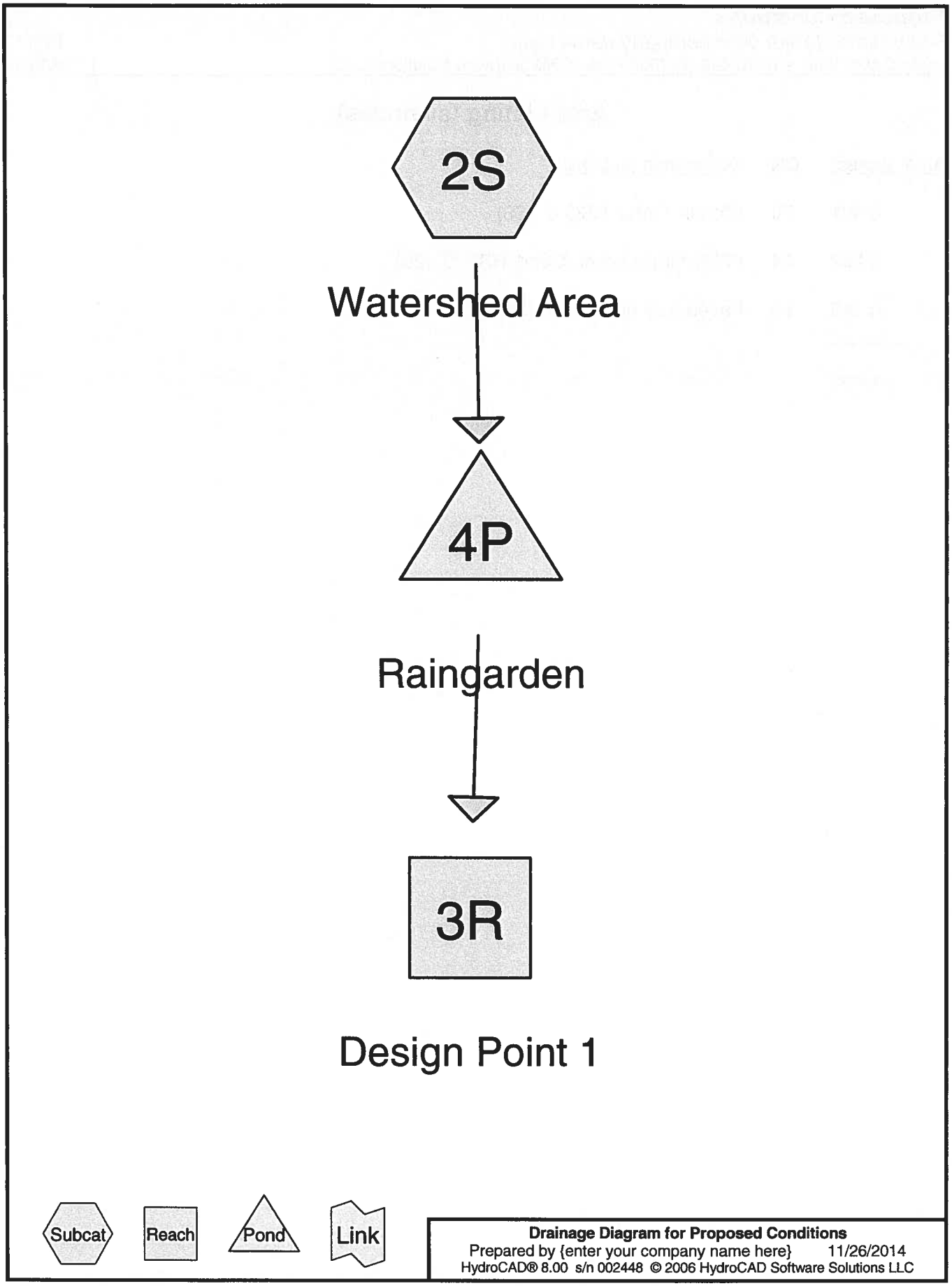
[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.062 ac, Inflow Depth > 3.63" for 100 Year event
Inflow = 2.61 cfs @ 12.46 hrs, Volume= 0.321 af
Outflow = 2.61 cfs @ 12.46 hrs, Volume= 0.321 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Reach 3R: Design Point 1




2S
Watershed Area
4P
Raingarden
3R
Design Point 1
Subcat
Reach
Pond
Link
Drainage Diagram for Proposed Conditions
Prepared by {enter your company name here} 11/26/2014
HydroCAD® 8.00 s/n 002448 © 2006 HydroCAD Software Solutions LLC

Area Listing (all nodes)

Area (acres)	CN	Description (subcats)
0.421	70	Woods, Good, HSG C (2S)
0.292	74	>75% Grass cover, Good, HSG C (2S)
0.348	98	Paved parking & roofs (2S,2S)
1.061		

Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 2S: Watershed Area Runoff Area=46,222 sf Runoff Depth>1.22"
Flow Length=321' Tc=4.8 min CN=80 Runoff=1.64 cfs 0.108 af

Reach 3R: Design Point 1 Inflow=0.16 cfs 0.015 af
Outflow=0.16 cfs 0.015 af

Pond 4P: Raingarden Peak Elev=95.97' Storage=1,876 cf Inflow=1.64 cfs 0.108 af
Discarded=0.12 cfs 0.083 af Primary=0.16 cfs 0.015 af Outflow=0.28 cfs 0.099 af

Total Runoff Area = 1.061 ac Runoff Volume = 0.108 af Average Runoff Depth = 1.22"
67.24% Pervious Area = 0.713 ac 32.76% Impervious Area = 0.348 ac

Subcatchment 2S: Watershed Area

[49] Hint: Tc<2dt may require smaller dt

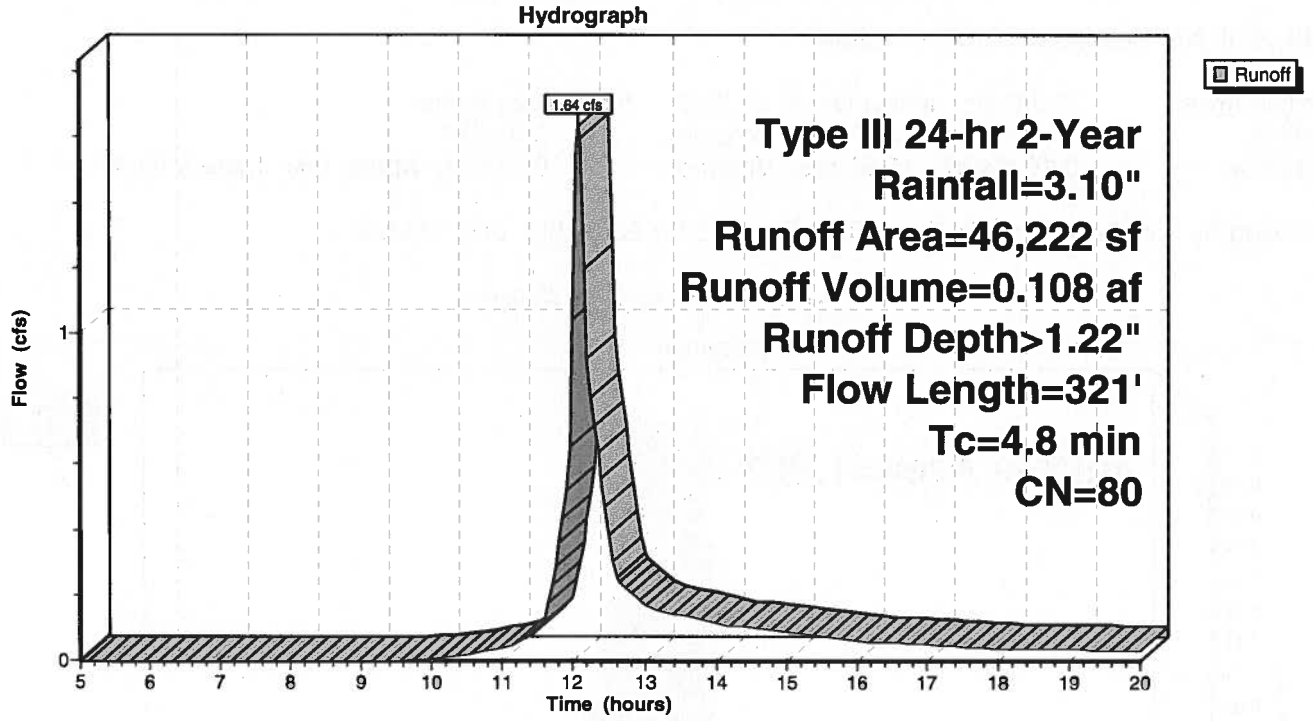
Runoff = 1.64 cfs @ 12.08 hrs, Volume= 0.108 af, Depth> 1.22"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 2-Year Rainfall=3.10"

Area (sf)	CN	Description
13,515	98	Paved parking & roofs
1,627	98	Paved parking & roofs
12,735	74	>75% Grass cover, Good, HSG C
18,345	70	Woods, Good, HSG C
46,222	80	Weighted Average
31,080		Pervious Area
15,142		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.6	23	0.0300	0.15		**Sheet Flow, Grass** Grass: Short n= 0.150 P2= 3.10"
0.1	5	0.0200	0.74		**Sheet Flow, SIDEWALK** Smooth surfaces n= 0.011 P2= 3.10"
2.1	293	0.0250	2.37		**Shallow Concentrated Flow, Grass** Grassed Waterway Kv= 15.0 fps
4.8	321	Total			

Subcatchment 2S: Watershed Area



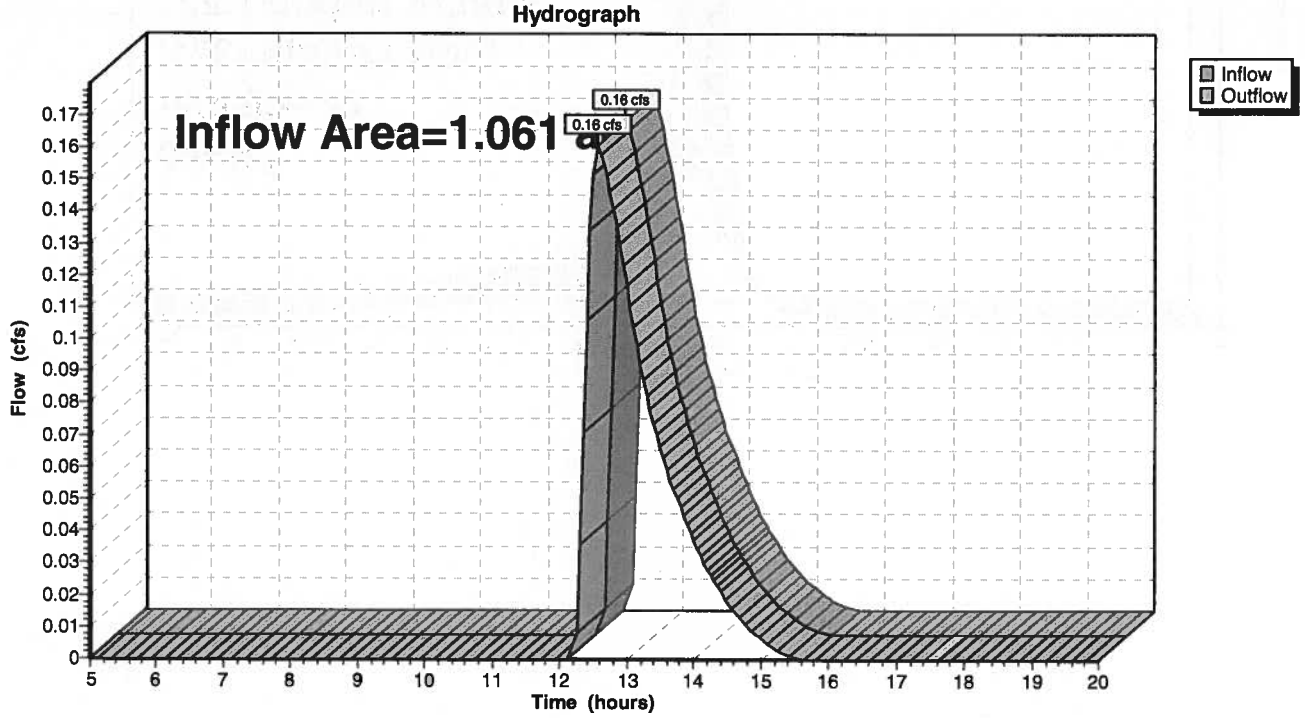
Reach 3R: Design Point 1

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.061 ac, Inflow Depth = 0.17" for 2-Year event
Inflow = 0.16 cfs @ 12.57 hrs, Volume= 0.015 af
Outflow = 0.16 cfs @ 12.57 hrs, Volume= 0.015 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Reach 3R: Design Point 1



Pond 4P: Raingarden

Inflow Area = 1.061 ac, Inflow Depth > 1.22" for 2-Year event
Inflow = 1.64 cfs @ 12.08 hrs, Volume= 0.108 af
Outflow = 0.28 cfs @ 12.57 hrs, Volume= 0.099 af, Atten= 83%, Lag= 29.8 min
Discarded = 0.12 cfs @ 12.57 hrs, Volume= 0.083 af
Primary = 0.16 cfs @ 12.57 hrs, Volume= 0.015 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 95.97' @ 12.57 hrs Surf.Area= 2,215 sf Storage= 1,876 cf

Plug-Flow detention time= 130.9 min calculated for 0.099 af (91% of inflow)
Center-of-Mass det. time= 101.7 min (905.7 - 804.0)

Volume	Invert	Avail.Storage	Storage Description
#1	95.00'	4,517 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

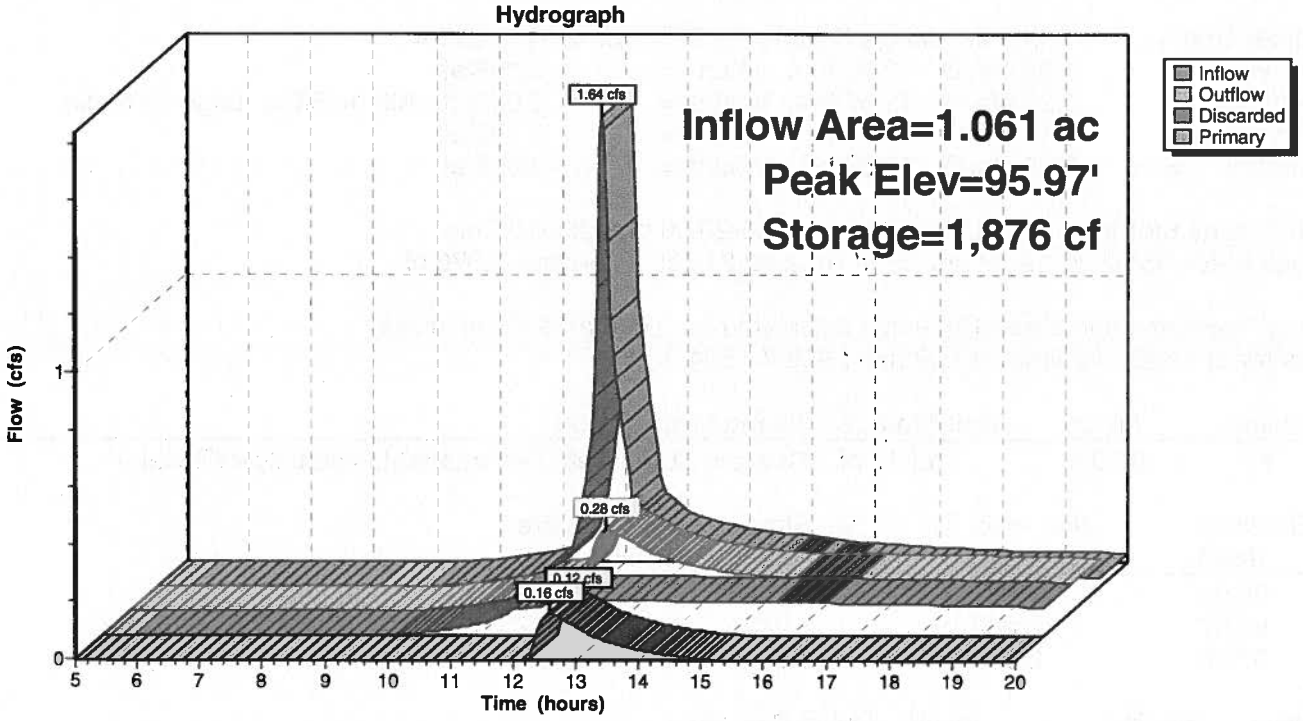
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
95.00	1,651	0	0
96.00	2,232	1,942	1,942
97.00	2,918	2,575	4,517

Device	Routing	Invert	Outlet Devices
#1	Primary	95.75'	**12.0" x 30.0' long Culvert** CMP, square edge headwall, Ke= 0.500 Outlet Invert= 95.60' S= 0.0050 '/' Cc= 0.900 n= 0.011 Concrete pipe, straight & clean
#2	Discarded	0.00'	**2.410 in/hr Exfiltration over Surface area**

Discarded OutFlow Max=0.12 cfs @ 12.57 hrs HW=95.97' (Free Discharge)
↑**2=Exfiltration** (Exfiltration Controls 0.12 cfs)

Primary OutFlow Max=0.16 cfs @ 12.57 hrs HW=95.97' (Free Discharge)
↑**1=Culvert** (Barrel Controls 0.16 cfs @ 1.88 fps)

Pond 4P: Raingarden



Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 2S: Watershed Area Runoff Area=46,222 sf Runoff Depth>2.30"
Flow Length=321' Tc=4.8 min CN=80 Runoff=3.10 cfs 0.203 af

Reach 3R: Design Point 1 Inflow=1.08 cfs 0.085 af
Outflow=1.08 cfs 0.085 af

Pond 4P: Raingarden Peak Elev=96.38' Storage=2,829 cf Inflow=3.10 cfs 0.203 af
Discarded=0.14 cfs 0.097 af Primary=1.08 cfs 0.085 af Outflow=1.22 cfs 0.182 af

Total Runoff Area = 1.061 ac Runoff Volume = 0.203 af Average Runoff Depth = 2.30"
67.24% Pervious Area = 0.713 ac 32.76% Impervious Area = 0.348 ac

Subcatchment 2S: Watershed Area

[49] Hint: Tc<2dt may require smaller dt

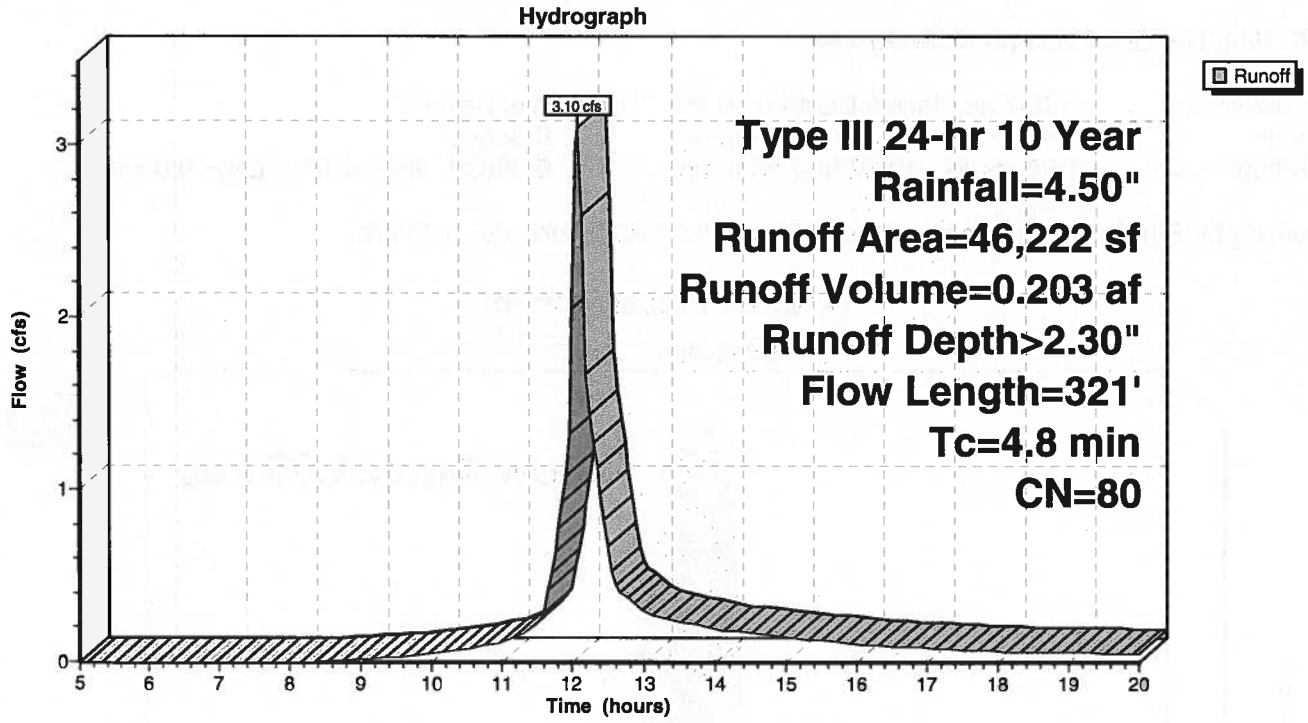
Runoff = 3.10 cfs @ 12.07 hrs, Volume= 0.203 af, Depth> 2.30"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 10 Year Rainfall=4.50"

Area (sf)	CN	Description
13,515	98	Paved parking & roofs
1,627	98	Paved parking & roofs
12,735	74	>75% Grass cover, Good, HSG C
18,345	70	Woods, Good, HSG C
46,222	80	Weighted Average
31,080		Pervious Area
15,142		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.6	23	0.0300	0.15		**Sheet Flow, Grass** Grass: Short n= 0.150 P2= 3.10"
0.1	5	0.0200	0.74		**Sheet Flow, SIDEWALK** Smooth surfaces n= 0.011 P2= 3.10"
2.1	293	0.0250	2.37		**Shallow Concentrated Flow, Grass** Grassed Waterway Kv= 15.0 fps
4.8	321	Total			

Subcatchment 2S: Watershed Area



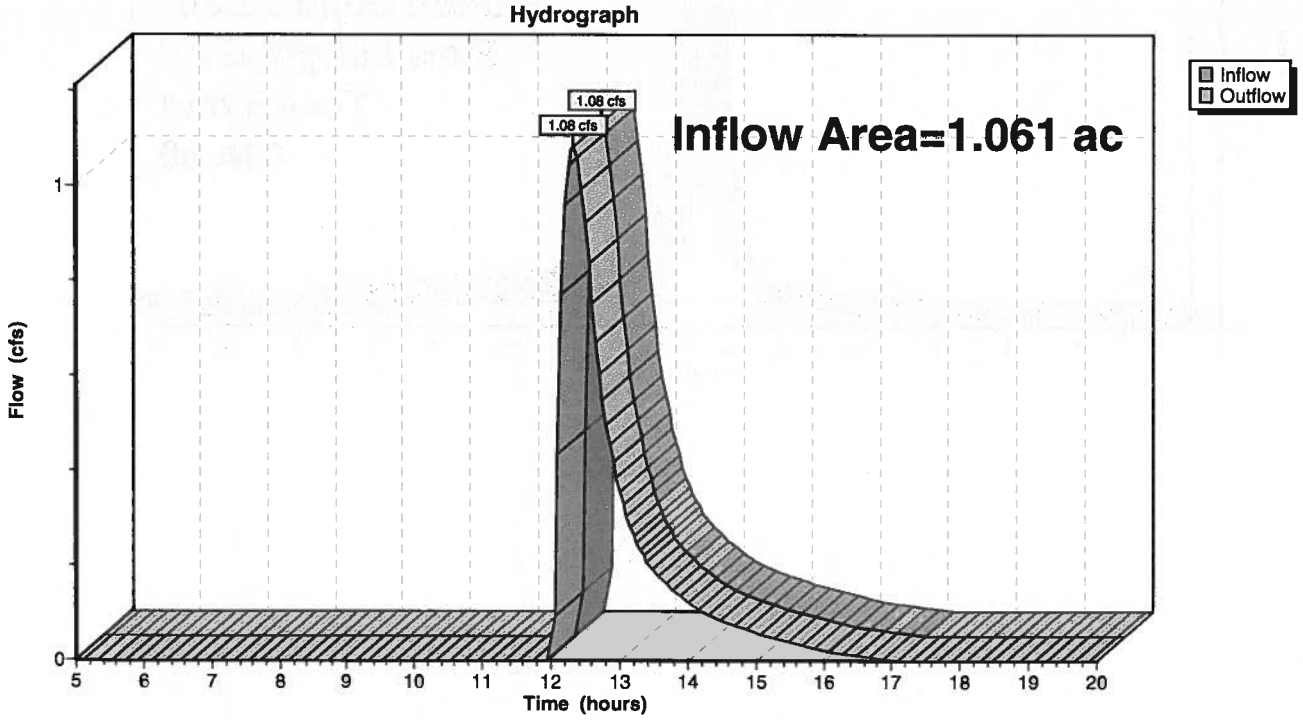
Reach 3R: Design Point 1

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.061 ac, Inflow Depth = 0.96" for 10 Year event
Inflow = 1.08 cfs @ 12.32 hrs, Volume= 0.085 af
Outflow = 1.08 cfs @ 12.32 hrs, Volume= 0.085 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Reach 3R: Design Point 1



Pond 4P: Raingarden

Inflow Area = 1.061 ac, Inflow Depth > 2.30" for 10 Year event
Inflow = 3.10 cfs @ 12.07 hrs, Volume= 0.203 af
Outflow = 1.22 cfs @ 12.32 hrs, Volume= 0.182 af, Atten= 61%, Lag= 14.9 min
Discarded = 0.14 cfs @ 12.32 hrs, Volume= 0.097 af
Primary = 1.08 cfs @ 12.32 hrs, Volume= 0.085 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 96.38' @ 12.32 hrs Surf.Area= 2,490 sf Storage= 2,829 cf

Plug-Flow detention time= 86.0 min calculated for 0.181 af (89% of inflow)
Center-of-Mass det. time= 52.7 min (842.6 - 789.8)

Volume	Invert	Avail.Storage	Storage Description
#1	95.00'	4,517 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

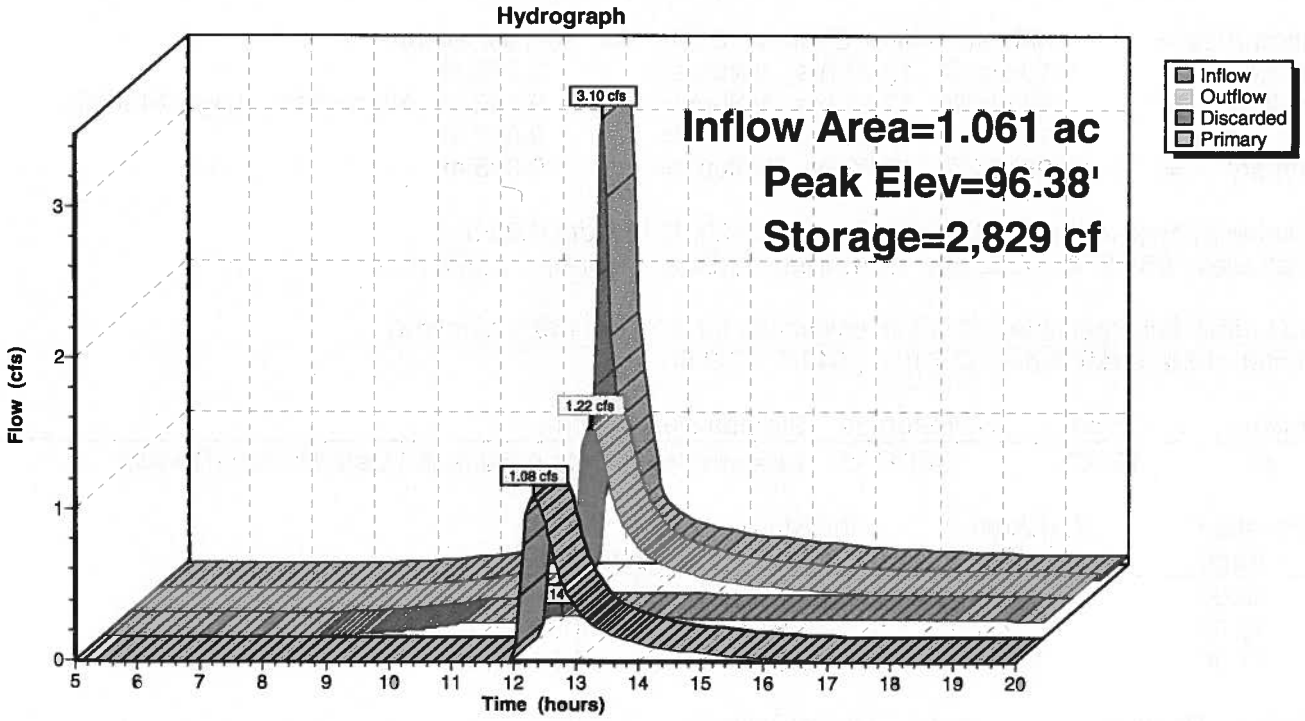
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
95.00	1,651	0	0
96.00	2,232	1,942	1,942
97.00	2,918	2,575	4,517

Device	Routing	Invert	Outlet Devices
#1	Primary	95.75'	**12.0" x 30.0' long Culvert** CMP, square edge headwall, Ke= 0.500 Outlet Invert= 95.60' S= 0.0050 '/' Cc= 0.900 n= 0.011 Concrete pipe, straight & clean
#2	Discarded	0.00'	**2.410 in/hr Exfiltration over Surface area**

Discarded OutFlow Max=0.14 cfs @ 12.32 hrs HW=96.37' (Free Discharge)
↑**2=Exfiltration** (Exfiltration Controls 0.14 cfs)

Primary OutFlow Max=1.08 cfs @ 12.32 hrs HW=96.37' (Free Discharge)
↑**1=Culvert** (Barrel Controls 1.08 cfs @ 2.98 fps)

Pond 4P: Raingarden



Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 2S: Watershed Area Runoff Area=46,222 sf Runoff Depth>2.95"
Flow Length=321' Tc=4.8 min CN=80 Runoff=3.98 cfs 0.261 af

Reach 3R: Design Point 1 Inflow=1.74 cfs 0.132 af
Outflow=1.74 cfs 0.132 af

Pond 4P: Raingarden Peak Elev=96.59' Storage=3,376 cf Inflow=3.98 cfs 0.261 af
Discarded=0.15 cfs 0.103 af Primary=1.74 cfs 0.132 af Outflow=1.89 cfs 0.235 af

Total Runoff Area = 1.061 ac Runoff Volume = 0.261 af Average Runoff Depth = 2.95"
67.24% Pervious Area = 0.713 ac 32.76% Impervious Area = 0.348 ac

Subcatchment 2S: Watershed Area

[49] Hint: Tc<2dt may require smaller dt

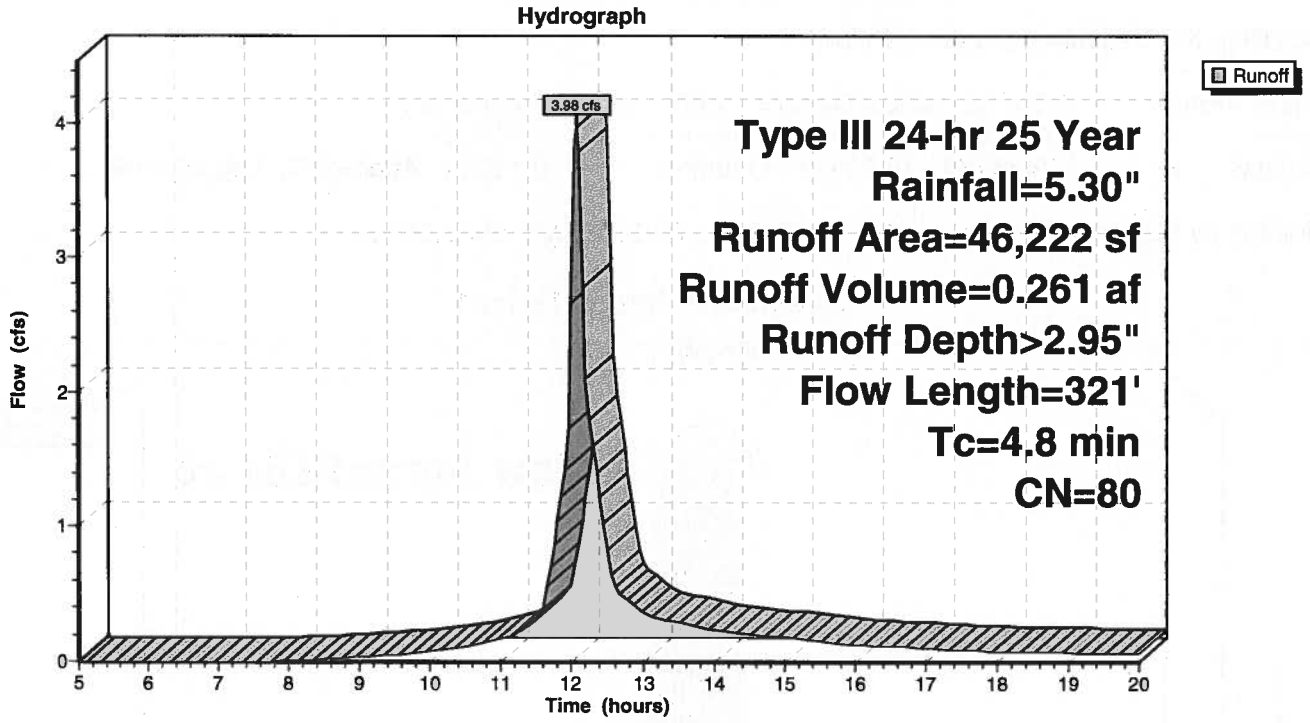
Runoff = 3.98 cfs @ 12.07 hrs, Volume= 0.261 af, Depth> 2.95"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 25 Year Rainfall=5.30"

Area (sf)	CN	Description
13,515	98	Paved parking & roofs
1,627	98	Paved parking & roofs
12,735	74	>75% Grass cover, Good, HSG C
18,345	70	Woods, Good, HSG C
46,222	80	Weighted Average
31,080		Pervious Area
15,142		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.6	23	0.0300	0.15		**Sheet Flow, Grass** Grass: Short n= 0.150 P2= 3.10"
0.1	5	0.0200	0.74		**Sheet Flow, SIDEWALK** Smooth surfaces n= 0.011 P2= 3.10"
2.1	293	0.0250	2.37		**Shallow Concentrated Flow, Grass** Grassed Waterway Kv= 15.0 fps
4.8	321	Total			

Subcatchment 2S: Watershed Area



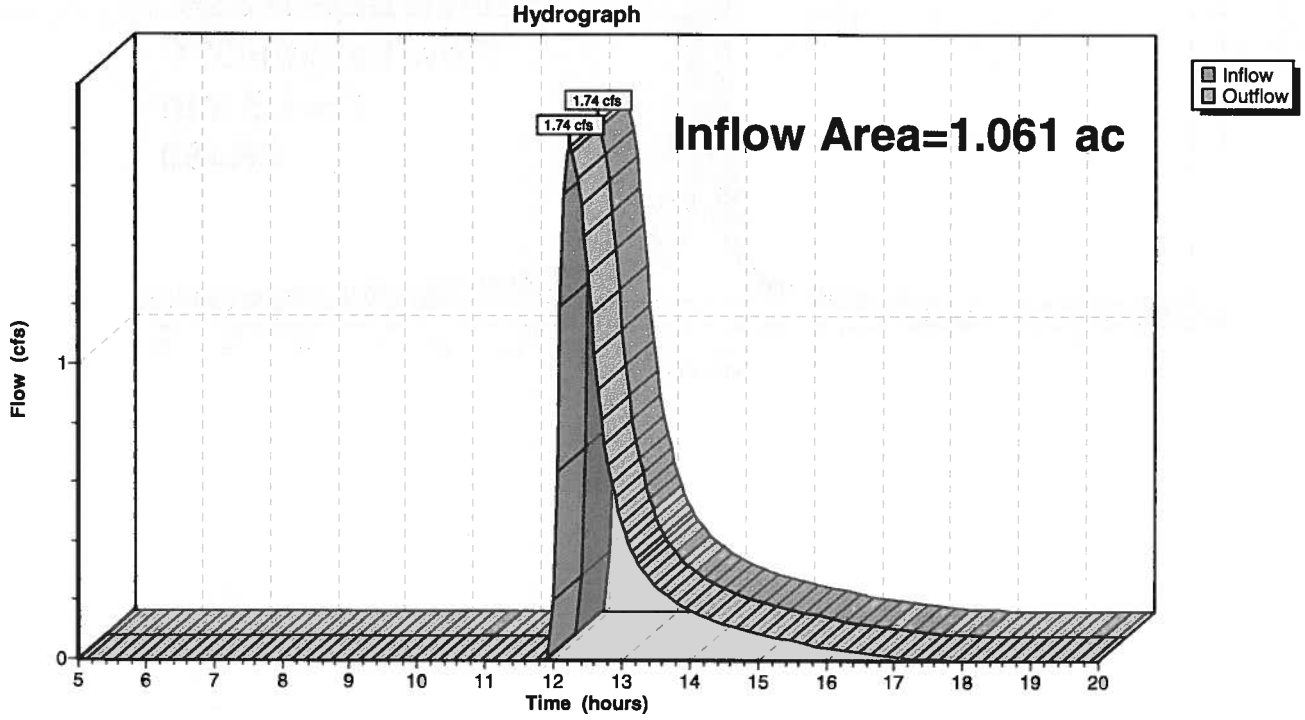
Reach 3R: Design Point 1

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.061 ac, Inflow Depth = 1.50" for 25 Year event
Inflow = 1.74 cfs @ 12.24 hrs, Volume= 0.132 af
Outflow = 1.74 cfs @ 12.24 hrs, Volume= 0.132 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Reach 3R: Design Point 1



Pond 4P: Raingarden

Inflow Area = 1.061 ac, Inflow Depth > 2.95" for 25 Year event
Inflow = 3.98 cfs @ 12.07 hrs, Volume= 0.261 af
Outflow = 1.89 cfs @ 12.24 hrs, Volume= 0.235 af, Atten= 52%, Lag= 10.1 min
Discarded = 0.15 cfs @ 12.24 hrs, Volume= 0.103 af
Primary = 1.74 cfs @ 12.24 hrs, Volume= 0.132 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 96.59' @ 12.24 hrs Surf.Area= 2,636 sf Storage= 3,376 cf

Plug-Flow detention time= 72.8 min calculated for 0.235 af (90% of inflow)
Center-of-Mass det. time= 40.5 min (824.5 - 784.0)

Volume	Invert	Avail.Storage	Storage Description
#1	95.00'	4,517 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

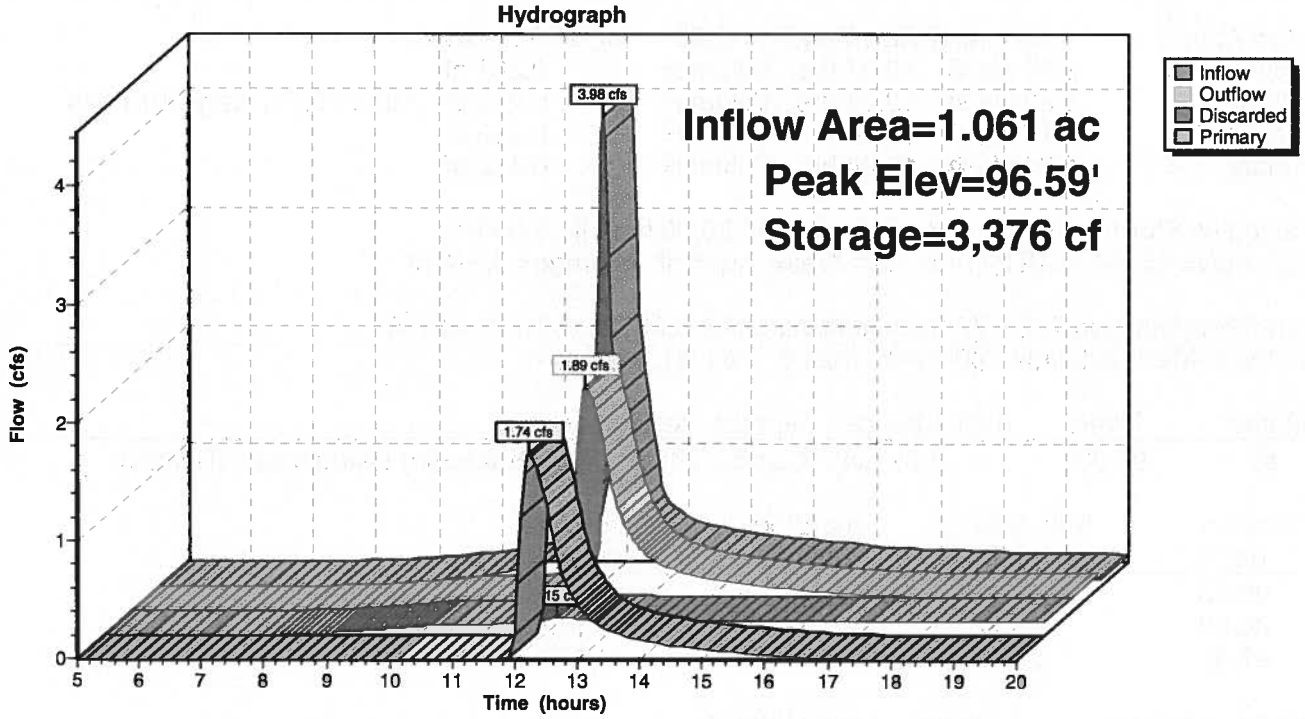
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
95.00	1,651	0	0
96.00	2,232	1,942	1,942
97.00	2,918	2,575	4,517

Device	Routing	Invert	Outlet Devices
#1	Primary	95.75'	**12.0" x 30.0' long Culvert** CMP, square edge headwall, Ke= 0.500 Outlet Invert= 95.60' S= 0.0050 '/' Cc= 0.900 n= 0.011 Concrete pipe, straight & clean
#2	Discarded	0.00'	**2.410 in/hr Exfiltration over Surface area**

Discarded OutFlow Max=0.15 cfs @ 12.24 hrs HW=96.59' (Free Discharge)
↑**2=Exfiltration** (Exfiltration Controls 0.15 cfs)

Primary OutFlow Max=1.74 cfs @ 12.24 hrs HW=96.59' (Free Discharge)
↑**1=Culvert** (Barrel Controls 1.74 cfs @ 3.34 fps)

Pond 4P: Raingarden



Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 2S: Watershed Area Runoff Area=46,222 sf Runoff Depth>3.98"
Flow Length=321' Tc=4.8 min CN=80 Runoff=5.31 cfs 0.352 af

Reach 3R: Design Point 1 Inflow=2.69 cfs 0.209 af
Outflow=2.69 cfs 0.209 af

Pond 4P: Raingarden Peak Elev=96.90' Storage=4,226 cf Inflow=5.31 cfs 0.352 af
Discarded=0.16 cfs 0.112 af Primary=2.69 cfs 0.209 af Outflow=2.84 cfs 0.321 af

Total Runoff Area = 1.061 ac Runoff Volume = 0.352 af Average Runoff Depth = 3.98"
67.24% Pervious Area = 0.713 ac 32.76% Impervious Area = 0.348 ac

Subcatchment 2S: Watershed Area

[49] Hint: Tc<2dt may require smaller dt

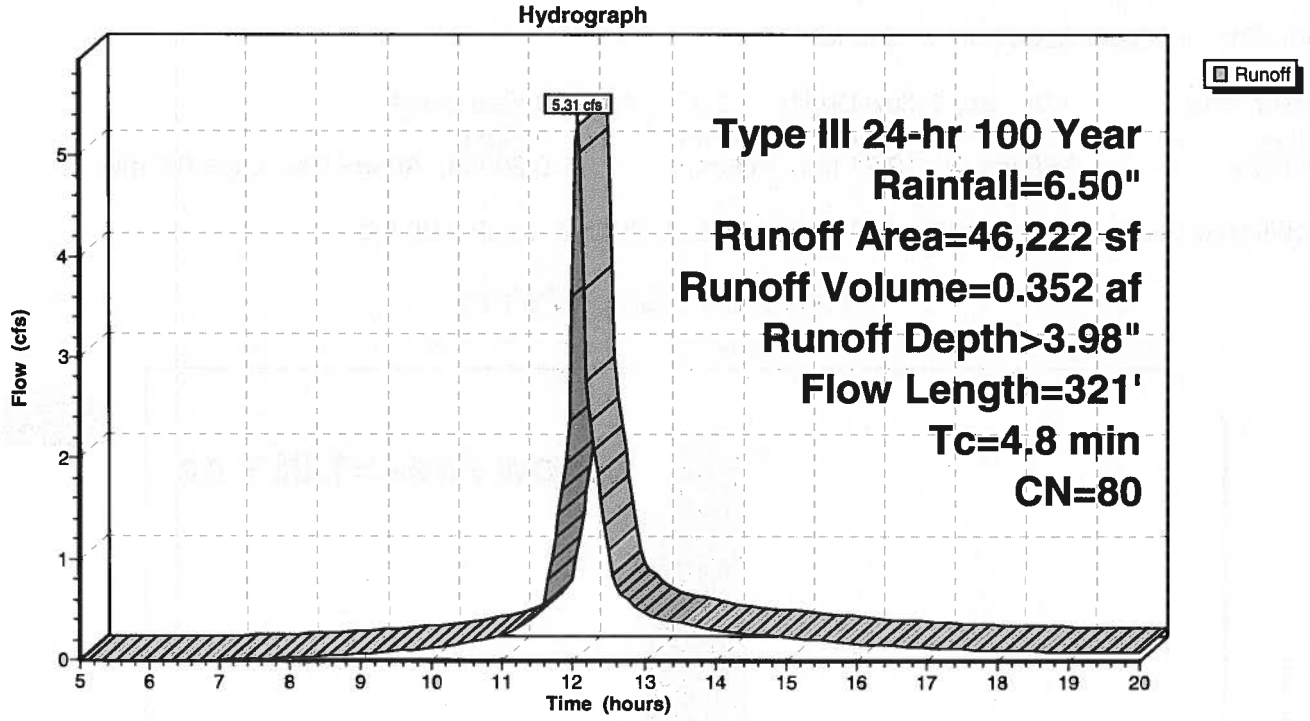
Runoff = 5.31 cfs @ 12.07 hrs, Volume= 0.352 af, Depth> 3.98"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 100 Year Rainfall=6.50"

Area (sf)	CN	Description
13,515	98	Paved parking & roofs
1,627	98	Paved parking & roofs
12,735	74	>75% Grass cover, Good, HSG C
18,345	70	Woods, Good, HSG C
46,222	80	Weighted Average
31,080		Pervious Area
15,142		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.6	23	0.0300	0.15		**Sheet Flow, Grass** Grass: Short n= 0.150 P2= 3.10"
0.1	5	0.0200	0.74		**Sheet Flow, SIDEWALK** Smooth surfaces n= 0.011 P2= 3.10"
2.1	293	0.0250	2.37		**Shallow Concentrated Flow, Grass** Grassed Waterway Kv= 15.0 fps
4.8	321	Total			

Subcatchment 2S: Watershed Area



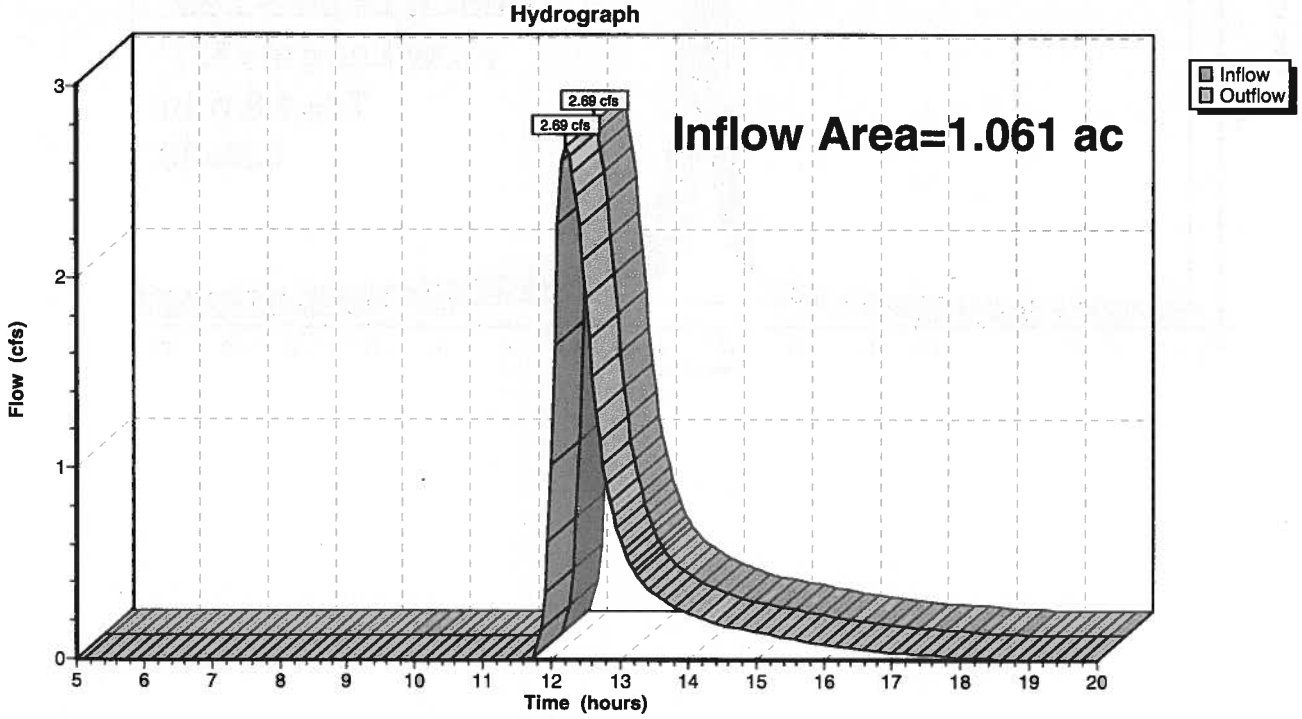
Reach 3R: Design Point 1

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.061 ac, Inflow Depth = 2.37" for 100 Year event
Inflow = 2.69 cfs @ 12.21 hrs, Volume= 0.209 af
Outflow = 2.69 cfs @ 12.21 hrs, Volume= 0.209 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Reach 3R: Design Point 1



Pond 4P: Raingarden

Inflow Area = 1.061 ac, Inflow Depth > 3.98" for 100 Year event
Inflow = 5.31 cfs @ 12.07 hrs, Volume= 0.352 af
Outflow = 2.84 cfs @ 12.21 hrs, Volume= 0.321 af, Atten= 46%, Lag= 8.1 min
Discarded = 0.16 cfs @ 12.21 hrs, Volume= 0.112 af
Primary = 2.69 cfs @ 12.21 hrs, Volume= 0.209 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 96.90' @ 12.21 hrs Surf.Area= 2,849 sf Storage= 4,226 cf

Plug-Flow detention time= 60.7 min calculated for 0.321 af (91% of inflow)
Center-of-Mass det. time= 31.2 min (808.2 - 777.0)

Volume	Invert	Avail.Storage	Storage Description
#1	95.00'	4,517 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

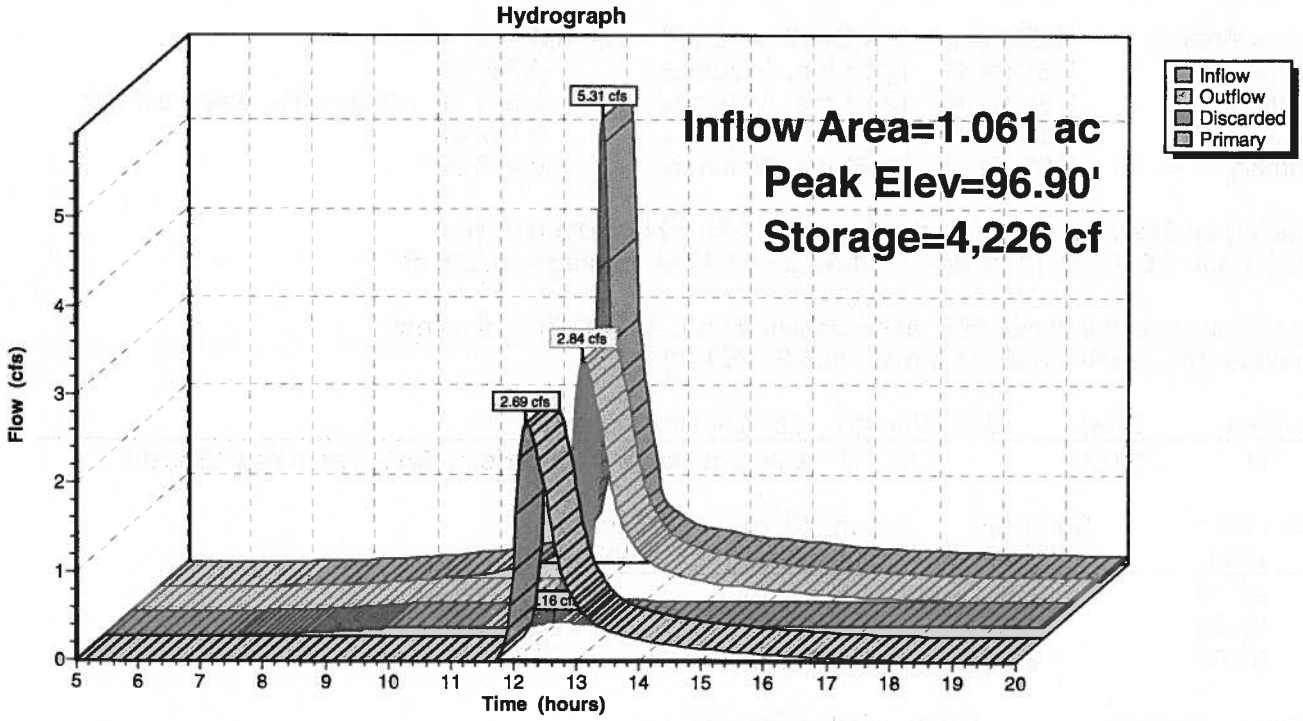
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
95.00	1,651	0	0
96.00	2,232	1,942	1,942
97.00	2,918	2,575	4,517

Device	Routing	Invert	Outlet Devices
#1	Primary	95.75'	**12.0" x 30.0' long Culvert** CMP, square edge headwall, Ke= 0.500 Outlet Invert= 95.60' S= 0.0050 '/' Cc= 0.900 n= 0.011 Concrete pipe, straight & clean
#2	Discarded	0.00'	**2.410 in/hr Exfiltration over Surface area**

Discarded OutFlow Max=0.16 cfs @ 12.21 hrs HW=96.90' (Free Discharge)
↑**2=Exfiltration** (Exfiltration Controls 0.16 cfs)

Primary OutFlow Max=2.68 cfs @ 12.21 hrs HW=96.90' (Free Discharge)
↑**1=Culvert** (Barrel Controls 2.68 cfs @ 3.73 fps)

Pond 4P: Raingarden



Bioretention Areas & Rain Gardens

Description: Bioretention is a technique that uses soils, plants, and microbes to treat stormwater before it is infiltrated and/or discharged. Bioretention cells (also called rain gardens in residential applications) are shallow depressions filled with sandy soil topped with a thick layer of mulch and planted with dense native vegetation. Stormwater runoff is directed into the cell via piped or sheet flow. The runoff percolates through the soil media that acts as a filter.

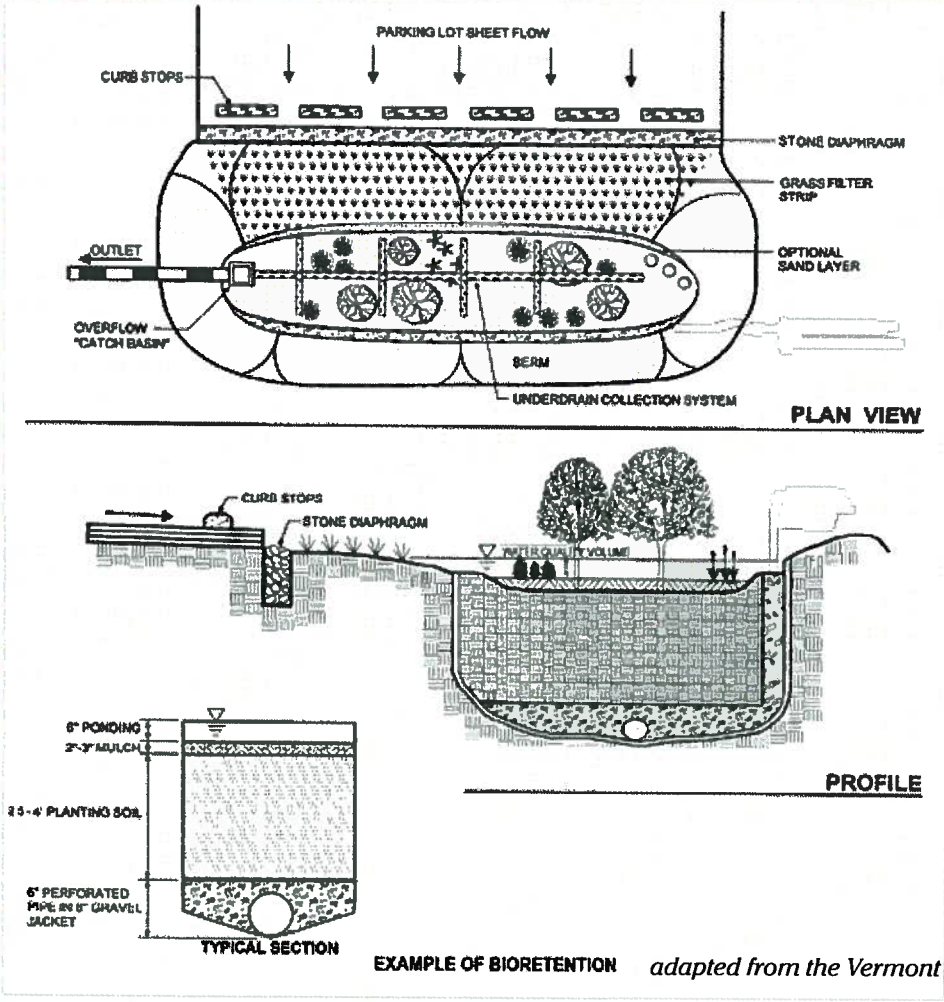
There are two types of bioretention cells: those that are designed solely as an organic filter filtering bioretention areas and those configured to recharge groundwater in addition to acting as a filter exfiltrating bioretention areas. A filtering bioretention area includes an impermeable liner and underdrain that intercepts the runoff before it reaches the water table so that it may be conveyed to a discharge outlet, other best management practices, or the municipal storm drain system. An exfiltrating bioretention area has an underdrain that is designed to enhance exfiltration of runoff into the groundwater.

Ability to meet specific standards

Standard	Description
2 - Peak Flow	N/A
3 - Recharge	An exfiltrating bioretention area provides groundwater recharge.
4 - TSS Removal	90% TSS removal credit with adequate pretreatment
5 - Higher Pollutant Loading	Can be used for certain land uses with higher potential pollutant loads if lined and sealed until adequate pretreatment is provided. Adequate pretreatment must include 44% TSS removal prior to infiltration. For land uses that have the potential to generate runoff with high concentrations of oil and grease such as high intensity use parking lots and gas stations, adequate pretreatment may also include an oil grit separator, sand filter or equivalent. In lieu of an oil grit separator or sand filter, a filtering bioretention area also may be used as a pretreatment device for infiltration practices exfiltrating runoff from land uses with a potential to generate runoff with high concentrations of oil and grease.
6 - Discharges near or to Critical Areas	Good option for discharges near cold-water fisheries. Should not be used near bathing beaches and shellfish growing areas.
7 - Redevelopment	Suitable with appropriate pretreatment

Pollutant Removal Efficiencies

• Total Suspended Solids (TSS)	90% with vegetated filter strip or equivalent
• Total Nitrogen	30% to 50% if soil media at least 30 inches
• Total Phosphorus	30% to 90%
• Metals (copper, lead, zinc, cadmium)	40% to 90%
• Pathogens (coliform, e coli)	Insufficient data



EXAMPLE OF BIORETENTION *adapted from the Vermont Stormwater Manual*

Special Features:

- Can be lined and sealed to prevent recharge where appropriate
- Adequate pretreatment is essential
- Not recommended in areas with steep slope
- Depth of soil media depends on type of vegetation that is proposed
- Soil media must be 30 inches deep to achieve removal of nitrogen

Advantages/Benefits:

- Can be designed to provide groundwater recharge and preserves the natural water balance of the site
- Can be designed to prevent recharge where appropriate
- Supplies shade, absorbs noise, and provides windbreaks
- Can remove other pollutants besides TSS including phosphorus, nitrogen and metals
- Can be used as a stormwater retrofit by modifying existing landscape or if a parking lot is being resurfaced
- Can be used on small lots with space constraints
- Small rain gardens are mosquito death traps
- Little or no hazard for amphibians or other small animals

Disadvantages/Limitations:

- Requires careful landscaping and maintenance
- Not suitable for large drainage areas

Maintenance

Activity	Frequency
Inspect and remove trash	Monthly
Mow	2 to 12 times per year
Mulch	Annually
Fertilize	Annually
Remove dead vegetation	Annually
Prune	Annually

Bioretention Areas & Rain Gardens

Not all bioretention cells are designed to exfiltrate. Only the infiltration requirements are applicable to bioretention cells intended to exfiltrate.

Applicability

Bioretention areas can provide excellent pollutant removal for the "first flush" of stormwater runoff. Properly designed and maintained cells remove suspended solids, metals, and nutrients, and can infiltrate an inch or more of rainfall. Distributed around a property, vegetated bioretention areas can enhance site aesthetics. In residential developments they are often described as "rain gardens" and marketed as property amenities. Routine maintenance is simple and can be handled by homeowners or conventional landscaping companies, with proper direction.

Bioretention systems can be applied to a wide range of commercial, residential, and industrial developments in many geologic conditions; they work well on small sites and on large sites divided into multiple small drainage areas. Bioretention systems are often well suited for ultra-urban settings where little pervious area exists. Although they require significant space (approximately 5% to 7% of the area that drains to them), they can be integrated into parking lots, parking lot islands, median strips, and traffic islands. Sites can be retrofitted with bioretention areas by replacing existing parking lot islands or by re-configuring a parking lot during resurfacing. On residential sites, they are commonly used for rooftop and driveway runoff.

Effectiveness

Bioretention areas remove pollutants through filtration, microbe activity, and uptake by plants; contact with soil and roots provides water quality treatment better than conventional infiltration structures. Studies indicate that bioretention areas can remove from 80% to 90% of TSS. If properly designed and installed, bioretention areas remove phosphorus, nitrogen, metals, organics, and bacteria to varying degrees.

Bioretention areas help reduce stress in watersheds that experience severe low flows due to excessive impervious cover. Low-tech, decentralized bioretention areas are also less costly to design, install, and maintain than conventional stormwater technologies that treat runoff at the end of the pipe. Decentralized bioretention cells can also reduce the size of storm drain pipes, a major component of stormwater treatment costs. Bioretention areas enhance the landscape in a variety of ways: they improve the appearance of developed sites, provide windbreaks, absorb noise, provide wildlife habitat, and reduce the urban heat island effect.

Planning Considerations

Filtering bioretention areas are designed with an impermeable liner and underdrain so that the stormwater may be transported to additional BMPs for treatment and/or discharge. Exfiltrating bioretention areas are designed so that following treatment by the bioretention area the stormwater may recharge the groundwater.

Both types of bioretention areas may be used to treat runoff from land uses with higher potential pollutant loads. However, exfiltrating bioretention areas may be used to treat runoff from land uses with higher potential pollutant loads, only if pretreatment has been provided to achieve TSS removal of at least 44%. If the land use has the potential to generate runoff with high concentrations of oil and grease, other types of pretreatment, i.e., a deep sump catch basin and oil grit separator or a sand filter, is required prior to discharge of runoff to an exfiltrating bioretention area. A filtering bioretention area may also be used as a pretreatment device for an exfiltrating bioretention area or other infiltration practice that exfiltrates runoff from land uses with a potential to generate runoff with high concentrations of oil and grease.

To receive 90% TSS removal credit, adequate pretreatment must be provided. If the flow is piped to the bioretention area a deep sump catch catch basin and sediment forebay should be used to provide pretreatment. For sheet flow, there are a number or pretreatment options. These options include:

- A vegetated filter strip, grass channel or water quality swale designed in accordance with the specifications set forth in Chapter 2.
- A grass and gravel combination. This should consist of at least 8 inches of gravel followed by 3 to 5 feet of sod. (source: North Carolina Stormwater Manual, 2007, http://h2o.enr.state.nc.us/su/documents/Ch12-Bioretention_001.pdf)
- Pea diaphragm combined with a vegetated filter strip specially designed to provide pretreatment for a bioretention area as set forth in the following table. (source: Georgia Stormwater Manual and Claytor and Schuler 1996)

Dimensions for Filter Strip Designed Specially to Provide Pretreatment for Bioretention Area

Parameter	Impervious Area				Pervious Areas (lawns, etc.)			
Maximum inflow approach length (feet)	35		75		75		100	
Filter strip slope (max=6%)	<2%	>2%	<2%	>2%	<2%	>2%	<2%	>2%
Filter strip minimum length (feet)	10	15	20	25	10	12	15	18

Bioretention areas must not be located on slopes greater than 20%. When the bioretention area is designed to exfiltrate, the design must ensure vertical separation of at least 2 feet from the seasonal high groundwater table to the bottom of the bioretention cell.

For residential rain gardens, pick a low spot on the property, and route water from a downspout or sump pump into it. It is best to choose a location with full sun, but if that is not possible, make sure it gets at least a half-day of sunlight.

Do not excavate an extensive rain garden under large trees. Digging up shallow feeder roots can weaken or kill a tree. If the tree is not a species that prefers moisture, the additional groundwater could damage it. Size the bioretention area using the methodology set forth in Volume 3.

Design

Size the bioretention area to be 5% to 7% of the area draining to it. Determine the infiltrative capacity of the underlying native soil by performing a soil evaluation in accordance with Volume 3. Do not use a standard septic system (i.e., Title 5) percolation test to determine soil permeability.

The depth of the soil media must be between 2 and 4 feet. This range reflects the fact that most of the pollutant removal occurs within the first 2 feet of soil and that excavations deeper than 4 feet become expensive. The depth selected should accommodate the vegetation. If the minimum depth is used, only shallow rooted plants and grasses my be used. If there is a Total Maximum Daily Load that requires nitrogen to be removed from the stormwater dischrges, the bioretention area should have a soil media with a depth of at least 30 inches, because nitrogen removal takes place 30 inches below the ground surface. If trees and shrubs are to be planted, the soil media should be at least 3 feet.

Size the cells (based on void space and ponding area) at a minimum to capture and treat the required water quality volume (the first 0.5 inch or 1 inch of runoff) if intended to be used for water quality treatment (Stormwater Standard No. 4), the required recharge volume if used for recharge (Stormwater Standard No. 3), or the larger of the two volumes if used to achieve compliance with both Stormwater Standards 3 and 4.

Cover the bottom of the excavation with coarse gravel, over pea gravel, over sand. Earlier designs used filter fabric as a bottom blanket, but more recent experiences show that filter fabric is prone to clogging. Consequently, do not use fabric filters or sand curtains. Use the Engineered Soil Mix below.

Engineered Soil Mix for Bioretention Systems Designed to Exfiltrate

- The soil mix for bioretention areas should be a mixture of sand compost and soil.
  - o 40 % sand,
  - o 20-30% topsoil, and
  - o 30-40% compost.

- The soil mix must be uniform, free of stones, stumps, roots or similar objects larger than 2 inches. Clay content should not exceed 5%.
- Soil pH should generally be between 5.5-6.5, a range that is optimal for microbial activity and adsorption of nitrogen, phosphorus, and other pollutants.
- Use soils with 1.5% to 3% organic content and maximum 500-ppm soluble salts.
- The sand component should be gravelly sand that meets ASTM D 422.

Sieve Size	Percent Passing
2-inch	100
¾-inch	70-100
¼-inch	50-80
U.S. No. 40	15-40
U.S. No. 200	0-3

- The topsoil component shall be a sandy loam, loamy sand or loam texture.
- The compost component must be processed from yard waste in accordance with MassDEP Guidelines (see http://www.mass.gov/dep/recycle/reduce/leafguid.doc). The compost shall not contain biosolids.

On-site soil mixing or placement is not allowed if soil is saturated or subject to water within 48 hours. Cover and store soil to prevent wetting or saturation.

Test soil for fertility and micro-nutrients and, only if necessary, amend mixture to create optimum conditions for plant establishment and early growth.

Grade the area to allow a ponding depth of 6 to 8 inches; depending on site conditions, more or less ponding may be appropriate.

Cover the soil with 2 to 3 inches of fine-shredded hardwood mulch.

The planting plan shall include a mix of herbaceous perennials, shrubs, and (if conditions permit) understory trees that can tolerate intermittent ponding, occasional saline conditions due to road salt, and extended dry periods. A list of plants that are suitable for bioretention areas can be found at the end of this section. To avoid a monoculture, it is a good practice to include one tree or shrub per 50 square feet of bioretention area, and at least 3 species each of herbaceous perennials and shrubs. Invasive and exotic species are prohibited. The planting plan should also meet any applicable local landscaping requirements.

All exfiltrating bioretention areas must be designed to drain within 72 hours. However, rain gardens are typically designed to drain water within a day and are thus unlikely to breed mosquitoes.

Bioretention cells, including rain gardens, require pretreatment, such as a vegetated filter strip. A stone or pea gravel diaphragm or, even better, a concrete level spreader upstream of a filter strip will enhance sheet flow and sediment removal.
Bioretention cells can be dosed with sheet flow, a surface inlet, or pipe flow. When using a surface inlet, first direct the flow to a sediment forebay. Alternatively, piped flow may be introduced to the bioretention system via an underdrain.

For bioretention cells dosed via sheet flow or surface inlets, include a ponding area to allow water to pond and be stored temporarily while stormwater is exfiltrating through the cell. Where bioretention areas are adjacent to parking areas, allow three inches of freeboard above the ponding depth to prevent flooding.

Most bioretention cells have an overflow drain that allows ponded water above the selected ponding depth to be dosed to an underdrain. If the bioretention system is designed to exfiltrate, the underdrain is not connected to an outlet, but instead terminates in the bioretention cell. If the bioretention area is not designed to exfiltrate, the underdrain is connected to an outlet for discharge or conveyance to additional best management practices.

Construction

During construction, avoid excessively compacting soils around the bioretention areas and accumulating silt around the drain field. To minimize sediment loading in the treatment area, direct runoff to the bioretention area only from areas that are stabilized; always divert construction runoff elsewhere.

To avoid compaction of the parent material, work from the edge of the area proposed as the location of an exfiltrationg bioretention cell. Never direct runoff to the cell until the cell and the contributing drainage areas are fully stabilized.

Place planting soils in 1-foot to 2-foot lifts and compact them with minimal pressure until the desired elevation is reached. Some engineers suggest flooding the cell between each lift placement in lieu of compaction.

Maintenance

Premature failure of bioretention areas is a significant issue caused by lack of regular maintenance. Ensuring long-term maintenance involves sustained public education and deed restrictions or covenants for privately owned cells. Bioretention areas require careful attention while plants are being established

Bioretention Maintenance Schedule

Activity	*Time of Year*	*Frequency*
Inspect & remove trash	Year round	Monthly
Mulch	Spring	Annually
Remove dead vegetation	Fall or Spring	Annually
Replace dead vegetation	Spring	Annually
Prune	Spring or Fall	Annually
Replace entire media & all vegetation	Late Spring/early Summer	As needed*

** Paying careful attention to pretreatment and operation & maintenance can extend the life of the soil media*

and seasonal landscaping maintenance thereafter.

In many cases, a landscaping contractor working elsewhere on the site can complete maintenance tasks. Inspect pretreatment devices and bioretention cells regularly for sediment build-up, structural damage, and standing water.

Inspect soil and repair eroded areas monthly. Re-mulch void areas as needed. Remove litter and debris monthly. Treat diseased vegetation as needed. Remove and replace dead vegetation twice per year (spring and fall).

Proper selection of plant species and support during establishment of vegetation should minimize—if not eliminate—the need for fertilizers and pesticides. Remove invasive species as needed to prevent these species from spreading into the bioretention area. Replace mulch every two years, in the early spring. Upon failure, excavate bioretention area, scarify bottom and sides, replace filter fabric and soil, replant, and mulch. A summary of maintenance activities can be found on the previous page.

Because the soil medium filters contaminants from runoff, the cation exchange capacity of the soil media will eventually be exhausted. When the cation exchange capacity of the soil media decreases, change the soil media to prevent contaminants from migrating to the groundwater, or from being discharged via an underdrain outlet. Using small shrubs and plants instead of larger trees will make it easier to replace the media with clean material when needed.

Plant maintenance is critical. Concentrated salts in roadway runoff may kill plants, necessitating removal of dead vegetation each spring and replanting. The operation and maintenance plan must include measures to make sure the plants are maintained. This is particularly true in residential subdivisions, where the operation and maintenance plan may assign each homeowner the legal responsibility to maintain a bioretention cell or rain garden on his or her property. Including the requirement in the property deed for new subdivisions may alert residential property owners to their legal responsibilities regarding the bioretention cells constructed on their lot.

Cold Climate Considerations

Never store snow in bioretention areas. The Operation and Maintenance plan must specify where on-site snow will be stored. All snow dumps must comply with MassDEP's guidance. When bioretention areas are located along roads, care must be taken during plowing operations to prevent snow from being plowed into the bioretention areas. If snow is plowed into the cells, runoff may bypass the cell and drain into downgradient wetlands without first receiving the required water quality treatment, and without recharging the groundwater.

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U.S. Environmental Protection Agency, 2005, National Management Measures to Control Nonpoint Source Pollution from Urban Areas, Publication Number EPA 841-B-05-004, Pp. 5-29 http://www.epa.gov/nps/urbanmm/

University of North Carolina, www.bae.ncsu.edu/topic/bioretention www.bae.ncsu.edu/stormwater/PublicationFiles/DesigningRainGardens2001.pdf

Plant Species Suitable for Use in Bioretention - Herbaceous Species

Species	Moisture Regime		Tolerance						Morphology			General Characteristics		Comments
Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects/ Disease	Exposure	Form	Height	Root System	Native	Wildlife	
Agrostis alba redtop	FAC	Mesic-Xeric	1-2	H	–	H	H	Shade	Grass	2-3'	Fiberous Shallow	Yes	High	–
Andropogon gerardi bluejoint	FAC	Dry Mesic-Mesic	1-2	–	–	–	–	Sun	Grass	2-3'	Fiberous Shallow	Yes	High	–
Andropogon virginicus broomsedge	–	Wet meadow	1-2	L	–			Full sun	Grass	1-3'		Yes	High	Tolerant of fluctuating water levels and drought.
Carex vulpinoidea fox sedge	OBL	Freshwater marsh	2-4	L	–			Sun to partial sun	Grass	2-3.5'	Rhizome	Yes	High	–
Chelone glabra														
Deschampsia caespitosa tufted hairgrass	FACW	Mesic to wet Mesic	2-4	H	–	H	H	Sun	Grass	2-3'	Fiberous Shallow	Yes	High	May become invasive.
Glycera striata fowl mannagrass, nerved mannagrass	OBL	Freshwater marsh, seeps	1-2	L	–			Partial shade to full shade	Grass	2-4'	Rhizome	Yes	High	–
Hedera helix English ivy	FACU	Mesic	1-2	–	–	–	H	Sun	Evergreen ground cover	–	Fiberous Shallow	No	Low	–
Hibiscus palustris														
Iris kaempferi														

H High Tolerance
M Medium Tolerance
L Low Tolerance

FACU Facultative Upland - Usually occur in non-wetlands, however, occasionally found in wetlands.
FAC Facultative - Equally likely to occur in wetlands and non-wetlands.
FACW Facultative Wetland - Usually occur in wetlands, however, occasionally found in non-wetlands.
OBL Obligate Wetland - Occur almost always in wetlands

Adapted from the Prince George's County Design Manual & the Center for Watershed Protection for the use of bioretention in Stormwater Management

Plant Species Suitable for Use in Bioretention - Herbaceous Species

Species	Moisture Regime		Tolerance						Morphology			General Characteristics		Comments
Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects/ Disease	Exposure	Form	Height	Root System	Native	Wildlife	
Lobelia siphilitica														
Lotus Corniculatus birdsfoot-trefoil	FAC	Mesic-Xeric	1-2	H	L	H	H	Sun	Grass	2-3'	Fiberous Shallow	Yes	High	Member of the legume family
Onoclea sensibilis sensitive fern, beadfern	FACW							Shade		1-3.5'			H	
Pachysandra terminalis Japanese pachysandra	FACU	Mesic	1-2	–	–	–	M	Shade	Evergreen ground cover	–	Fiberous Shallow	No	Low	–
Panicum virgatum switch grass	FAC to FACU	Mesic	2-4	H	–	–	H	Sun or Shade	Grass	4-5'	Fiberous Shallow	Yes	High	Can spread fast and reach height of 6'
Vinca major large periwinkle	FACU	Mesic	1-2	–	–	–	H	Shade	Evergreen ground cover	–	Fiberous Shallow	No	Low	Senstitive to soil compaction and pH changes.
Vinca minor common periwinkle	FACU	Mesic	1-2	–	–	–	H	Shade	Evergreen ground cover	–	Fiberous Shallow	No	Low	–
Indian grass														
Little bluestem														
Deer tongue														
Green coneflower														

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L Low Tolerance

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FACW Facultative Wetland - Usually occur in wetlands, however, occasionally found in non-wetlands.
OBL Obligate Wetland - Occur almost always in wetlands

Adapted from the Prince George's County Design Manual & the Center for Watershed Protection for the use of bioretention in Stormwater Management

Plant Species Suitable for Use in Bioretention - Herbaceous Species

Species	Moisture Regime		Tolerance						Morphology			General Characteristics		Comments
Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects/ Disease	Exposure	Form	Height	Root System	Native	Wildlife	
Aronia arbutifolia (Pyrus arbutifolia) red chokeberry	FACW	Mesic	1-2	H	–	H	M	Sun to partial sun	Deciduous shrub	6-12'	–	Yes	High	Good bank stabilizer. Tolerates drought.
Clethra alnifolia sweet pepperbush	FAC	Mesic to wet Mesic	2-4	H	–	–	H	Sun to partial sun	Ovoid shrub	6-12'	Shallow	Yes	Med	Coastal plain species.
Cornus Stolonifera (Cornus sericea) red osier dogwood	FACW	Mesic-Hydric	2-4	H	H	H	M	Sun or shade	Arching, spreading shrub	8-10'	Shallow	Yes	High	Needs more consistent moisture levels.
Cornus amomum silky dogwood	FAC	Mesic	1-2	L	–	–	M	Sun to partial sun	Broad-leaved	6-12'	–	Yes	High	Good bank stabilizer
Euonymous europeaus spindle-tree	FAC	Mesic	1-2	M	M	M	M	Sun to partial sun	Upright dense oval shrub	10-12'	Shallow	No	No	–
Hamamelis virginiana witch hazel	FAC	Mesic	2-4	M	M	M	M	Sun or shade	Vase-like compact shrub	4-6'	Shallow	Yes	Low	–
Hypercum densiflorum common St. John's wort	FAC	Mesic	2-4	H	M	M	H	Sun	Ovoid shrub	3-6'	Shallow	Yes	Med	–
Ilex glabra inkberry	FACW	Mesic to wet Mesic	2-4	H	H	–	H	Sun to partial sun	Upright dense shrub	6-12'	Shallow	Yes	High	Coastal plain species.
Ilex verticillata winterberry	FACW	Mesic to wet Mesic	2-4	L	M	–	H	Sun to partial sun	Spreading shrub	6-12'	Shallow	Yes	High	–

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Itea virginica tassel-white, Virginia sweetspire	OBL	Mesic	1-2	M	–	–	M	Sun or shade	Broad-leaved, deciduous shrub	6-12'	–	Yes	Low	–
Juniperus communis "compressa" common juniper	FAC	Dry Mesic-Mesic	1-2	M	H	H	M-H	Sun	Mounded shrub	3-6'	Deep taproot	No	High	Evergreen
Juniperus horizontalis "Bar Harbor" creeping juniper	FAC	Dry Mesic-Mesic	1-2	M	H	H	M-H	Sun	Matted shrub	0-3'	Deep taproot	No	High	Evergreen
Lindera benzoin spicebush	FACW	Mesic to wet Mesic	2-4	H	–	–	H	Sun	Upright shrub	6-12'	Deep	Yes	High	–
Myrica pennsylvanica bayberry	FAC	Mesic	2-4	H	M	M	H	Sun to partial sun	Rounded, compact shrub	6-8'	Shallow	Yes	High	Coastal plain species.
Physocarpus opulifolius ninebark	FAC	Dry Mesic to wet Mesic	2-4	M	–	–	H	Sun	Upright shrub	6-12'	Shallow	Yes	Med	May be difficult to locate.
Viburnum cassinoides northern wild raisin	FACW	Mesic	2-4	H	H	H	H	Sun to partial sun	Rounded, compacted shrub	6-8'	Shallow	Yes	High	–
Viburnum dentatum arrow-wood	FAC	Mesic to wet	2-4	H	H	H	H	Sun to partial sun	Upright, multi-stemmed shrub	8-10'	Shallow	Yes	High	–
Viburnum lentago nannyberry	FAC	Mesic	2-4	H	H	H	H	Sun to partial sun	Upright, multi-stemmed shrub	8-10'	Shallow	Yes	High	–

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Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects/ Disease	Exposure	Form	Height	Root System	Native	Wildlife	
Acer rubrum red maple	FAC	Mesic-Hydric	4-8	H	H	H	H	Partial sun	Single to multi-stem tree	50-70'	Shallow	Yes	High	-
Amelanchier canadensis shadbush	FAC	Mesic	2-4	H	M	-	H	Partial sun	Single to multi-stem tree	35-50'	Shallow	Yes	High	Not recommended for full sun.
Betula nigra river birch	FACW	Mesic-Hydric	4-8	-	M	M	H	Partial sun	Single to multi-stem tree	50-75'	Shallow	Yes	High	Not susceptible to bronze birch borer.
Betula populifolia gray birch	FAC	Xeric-Hydric	4-8	H	H	M	H	Partial sun	Single to multi-stem tree	35-50'	Shallow to deep	No	High	Native to New England area.
Fraxinus americana white ash	FAC	Mesic	2-4	M	H	H	H	Sun	Large tree	50-80'	Deep	Yes	Low	-
Fraxinus Pennsylvanica green ash	FACW	Mesic	4-8	M	H	H	H	Partial sun	Large tree	40-65'	Shallow to deep	Yes	Low	-
Ginko biloba Maidenhair tree	FAC	Mesic	2-4	H	H	H	H	Sun	Large tree	50-80'	Shallow to deep	No	Low	Avoid female species-offensive odor from fruit.
Gleditsia triacanthos honeylocust	FAC	Mesic	2-4	H	M	-	M	Sun	Small caopied large tree	50-75'	Shallow to deep variable taproot	Yes	Low	Select thornless variety
Juniperus virginiana eastern red cedar	FACU	Mesic-Xeric	2-4	H	H	-	H	Sun	Dense single stem tree	50-75'	Taproot	Yes	Very high	Evergreen
Liquidambar styraciflua sweet gum	FAC	Mesic	4-8	H	H	H	M	Sun	Large tree	50-70'	Deep taproot	Yes	High	Edge and perimeter; fruit is a maintenance problem
Nyssa sylvatica black gum	FACW	Mesic-Hydric	4-8	H	H	H	H	Sun	Large tree	40-70'	Shallow to deep taproot	Yes	High	-

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Species	Moisture Regime		Tolerance						Morphology			General Characteristics		Comments
Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects/ Disease	Exposure	Form	Height	Root System	Native	Wildlife	
Platanus acerifolia London plane-tree	FACW	Mesic	2-4	H	–	–	M	Sun	Large tree	70-80'	Shallow	No	Low	Tree roots can heave sidewalks.
Platanus occidentalis sycamore	FACW	Mesic-Hydric	4-6	M	M	M	M	Sun	Large tree	70-80'	Shallow	Yes	Med	Edge and perimeter; fruit is a maintennance problem, tree is also prone to windthrow.
Populus deltoides eastern cottonwood	FAC	Xeric-Mesic	4-6	H	H	H	L	Sun	Large tree with spreading branches	75-100'	Shallow	Yes	High	Short lived.
Quercus bicolor Swamp white oak	FACW	Mesic to wet Mesic	4-6	H	–	H	H	Sun to partial sun	Large tree	75-100'	Shallow	Yes	High	One of the faster growing oaks.
Quercus coccinea scarlet oak	FAC	Mesic	1-2	H	M	M	M	Sun	Large tree	50-75'	Shallow to deep	Yes	High	–
Quercus macrocarpa bur oak	FAC	Mesic to wet Mesic	2-4	H	H	H	M	Sun	Large spreading tree	75-100'	Taproot	No	High	Native to Midwest.
Quercus palustris pin oak	FACW	Mesic-Hydric	4-6	H	H	H	M	Sun	Large tree	60-80'	Shallow to deep taproot	Yes	High	–
Quercus phellos willow oak	FACW	Mesic to wet Mesic	4-6	H	–	–	H	Sun	Large tree	55-75'	Shallow	Yes	High	Fast growing oak.
Quercus rubra red oak	FAC	Mesic	2-4	M	H	M	M	Sun to partial sun	Large spreading tree	60-80'	Deep taproot	Yes	High	–
Quercus shumardi Shumard's red oak	FAC	Mesic	2-4	H	H	H	M	Sun to partial sun	Large spreading tree	60-80'	Deep taproot	No	High	Native to Southeast.

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Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects/ Disease	Exposure	Form	Height	Root System	Native	Wildlife	
Sophora japonica Japanese pagoda tree	FAC	Mesic	1-2	M	M	–	M	Sun	Shade tree	40-70'	Shallow	No	Low	Fruit stains sidewalk.
Taxodium distichum bald cypress	FACW	Mesic-Hydric	4-6	–	–	M	H	Sun to partial sun	Typically single stem tree	75-100'	Shallow	Yes	Low	Not well documented for planting in urban areas.
Thuja occidentalis arborvitae	FACW	Mesic to wet Mesic	2-4	M	M	M	H	Sun to partial sun	Dense single stem tree	50-75'	Shallow	No	Low	Evergreen
Zelkova serrata Japanese zelkova	FACU	Mesic	1-2	M	M	–	H	Sun	Dense shade tree	60-70'	Shallow	No	Low	Branches can split easily in storms.

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Sediment Forebays

Description: A sediment forebay is a post-construction practice consisting of an excavated pit, bermed area, or cast structure combined with a weir, designed to slow incoming stormwater runoff and facilitating the gravity separation of suspended solids. This practice is different from a sediment trap used as a construction period BMP.

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Provides no peak flow attenuation
3 - Recharge	Provides no groundwater recharge
4 - TSS Removal	MassDEP requires a sediment forebay as pretreatment before stormwater is discharged to an extended dry detention basin, wet basin, constructed stormwater wetland or infiltration basin. No separate credit is given for the sediment forebay. For example, extended dry detention basins with sediment forebays receive a credit for 50% TSS removal. Wet basins and constructed stormwater wetlands with sediment forebays receive a credit for 80% TSS removal. When they provide pretreatment for other BMPs, sediment forebays receive a 25% TSS removal credit.
5 - Higher Pollutant Loading	Recommended as a pretreatment BMP
6 - Discharges near or to Critical Areas	Recommended as a pretreatment BMP
7 - Redevelopment	Usually not suitable due to land use constraints

Advantages/Benefits:

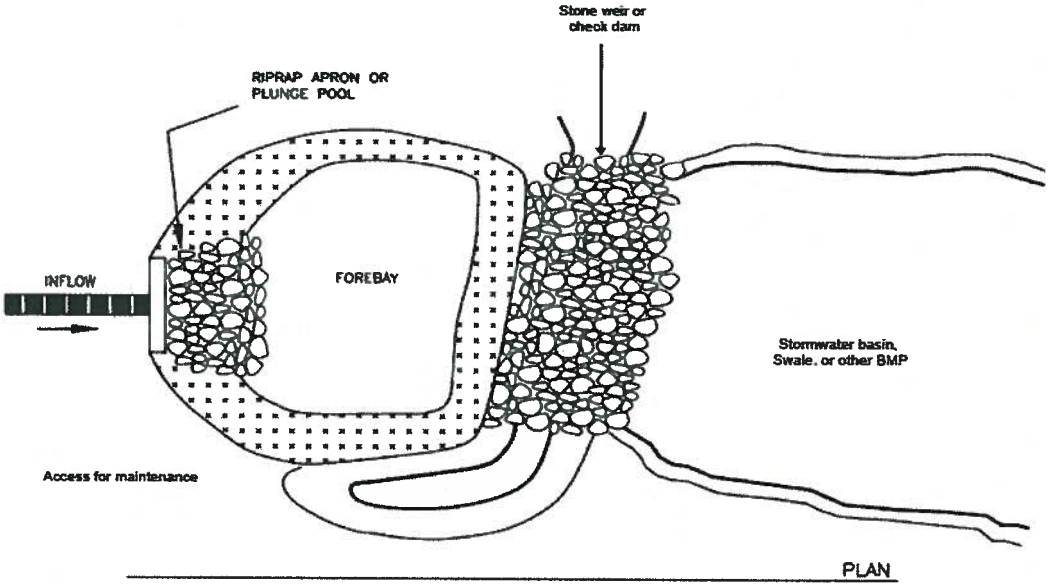
- Provides pretreatment of runoff before delivery to other BMPs.
- Slows velocities of incoming stormwater
- Easily accessed for sediment removal
- Longevity is high with proper maintenance
- Relatively inexpensive compared to other BMPs
- Greater detention time than proprietary separators

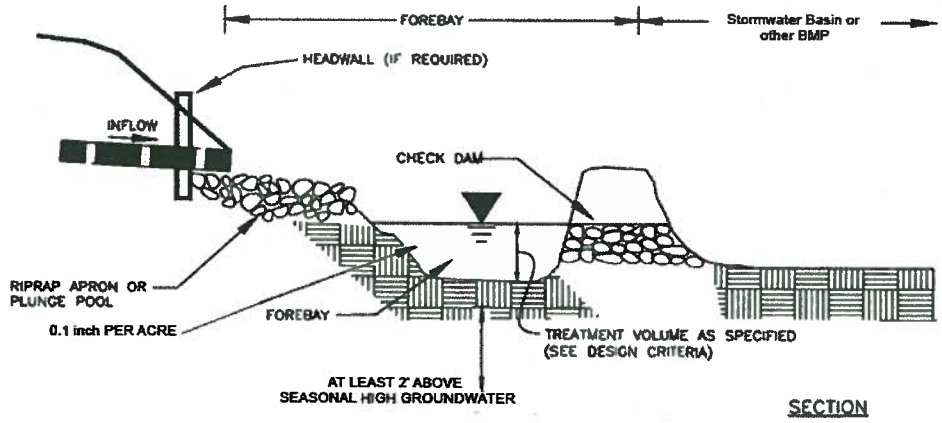
Disadvantages/Limitations:

- Removes only coarse sediment fractions
- No removal of soluble pollutants
- Provides no recharge to groundwater
- No control of the volume of runoff
- Frequent maintenance is essential

Pollutant Removal Efficiencies

- Total Suspended Solids (TSS) - 25%
- Nutrients (Nitrogen, phosphorus) - Insufficient data
- Metals (copper, lead, zinc, cadmium) - Insufficient data
- Pathogens (coliform, e coli) - Insufficient data





adapted from the Vermont Stormwater Handbook

Maintenance

Activity	Frequency
Inspect sediment forebays	Monthly
Clean sediment forebays	Four times per year and when sediment depth is between 3 to 6 feet.

Special Features

MassDEP requires a sediment forebay as pretreatment before discharging to a dry extended detention basin, wet basin, constructed stormwater wetland, or infiltration basin.

MassDEP uses the term sediment forebay for BMPs used to pretreat stormwater after construction is complete and the site is stabilized. MassDEP uses the term sediment trap to refer to BMPs used for erosion and sedimentation control during construction. For information on the design and construction of sediment traps used during construction, consult the Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas: A Guide for Planners, Designers and Municipal Officials.

Sediment Forebays

Design

Sediment forebays are typically on-line units, designed to slow stormwater runoff and settle out sediment.

At a minimum, size the volume of the sediment forebay to hold 0.1-inch/impervious acre to pretreat the water quality volume.

When routing the 2-year and 10-year storms through the sediment forebay, design the forebay to withstand anticipated velocities without scouring.

A typical forebay is excavated below grade with earthen sides and a stone check dam.

Design elevated embankments to meet applicable safety standards.

Stabilize earth slopes and bottoms using grass seed mixes recommended by the NRCS and capable of resisting the anticipated shearing forces associated with velocities to be routed through the forebay. Use only grasses. Using other vegetation will reduce the storage volume in the forebay. Make sure that the selected grasses are able to withstand periodic inundation under water, and drought- tolerant during the summer. MassDEP recommends using a mix of grasses rather than relying upon a single grass species.

Alternatively, the bottom floor may be stabilized with concrete or stone to aid maintenance. Concrete floors or pads, or any hard bottom floor, greatly facilitate the removal of accumulated sediment.

When the bottom floor is vegetated, it may be necessary to remove accumulated sediment by hand, along with re-seeding or re-sodding grasses removed during maintenance.

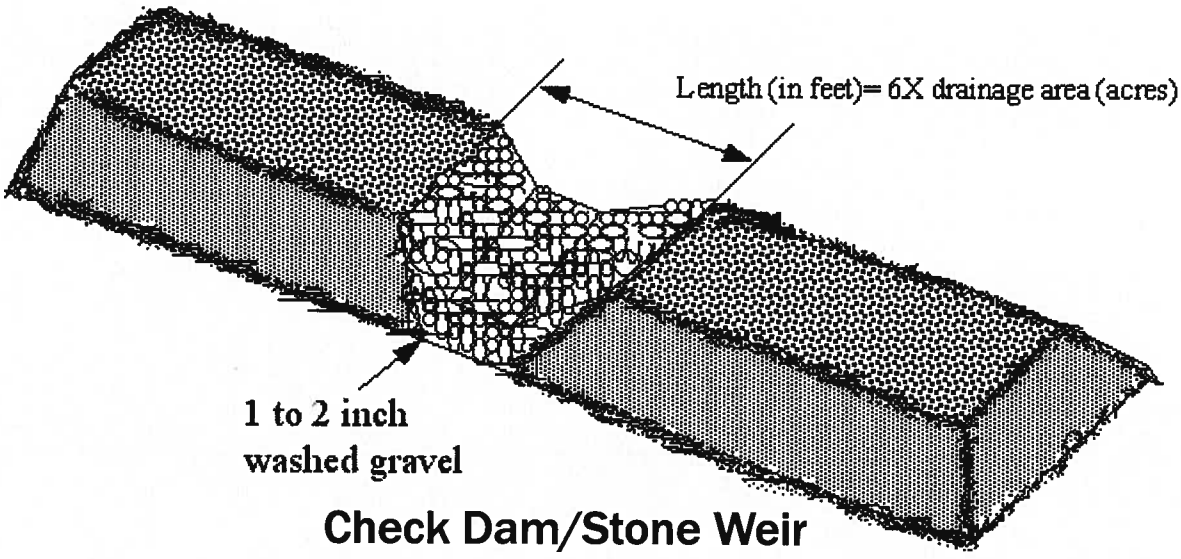
Design sediment forebays to make maintenance accessible and easy. If machinery is required to remove the sediment, carefully incorporate equipment access in the design. Sediment forebays may require excavation so concrete flooring may not always be appropriate.

Include sediment depth markers to simplify inspections. Sediment markers make it easy to determine when the sediment depth is between 3 and 6 feet and needs to be removed. Make the side slopes of sediment forebays no steeper than 3:1. Design the sediment forebay so that the discharge or outflow velocity can control the 2-year peak discharge without scour. Design the channel geometry to prevent erosion from the 2-year peak discharge.

Do not confuse post-construction sediment forebays with the sediment traps used as a construction-period control. Construction-period sediment control traps are sized larger than forebays, because there is a greater amount of suspended solids in construction period runoff. Construction-period sediment traps are sized based on drainage area and not impervious acre. Never use a construction-period sediment trap for post-construction drainage purposes unless it is first brought off-line, thoroughly cleaned (including check dam), and stabilized before being made re-operational.

Refer to the section of this chapter for information on the design of the check dam component of the sediment forebay. Set the minimum elevation of the check dam to hold a volume of 0.1-inch of runoff/ impervious acre. Check dam elevations may be uniform or they may contain a weir (e.g., when the top of the check dam is set to the 2-year or 10-year storm, and the bottom of the weir is set to the top of the 0.1-inch/impervious acre volume). When a weir is included in a stone berm, make sure that the weir is able to hold its shape. Fabric or wire may be required.

Unless part of a wet basin, post construction sediment forebays must be designed to dewater between storms. Set the bottom of the forebay at a minimum of 2 feet above seasonal high groundwater, and place pervious material on the bottom floor to facilitate dewatering between storms. For design purposes, use 72 hours to evaluate dewatering, using the storm that produces either the ½ inch or 1-inch of runoff (water quality volume) in a 24-hour period. A stone check dam can act as a filter berm, allowing water to percolate through the check dam. Depending on the head differential, a stone check dam may allow greater dewatering than an earthen berm.



Check Dam/Stone Weir

MassDEP Stormwater Handbook, 1996

Maintenance

Sediments and associated pollutants are removed only when sediment forebays are actually cleaned out, so regular maintenance is essential. Frequently removing accumulated sediments will make it less likely that sediments will be resuspended. At a minimum, inspect sediment forebays monthly and clean them out at least four times per year. Stabilize the floor and sidewalls of the sediment forebay before making it operational, otherwise the practice will discharge excess amounts of suspended sediments. When mowing grasses, keep the grass height no greater than 6 inches. Set mower blades no lower than 3 to 4 inches. Check for signs of rilling and gullying and repair as needed. After removing the sediment, replace any vegetation damaged during the clean-out by either reseeding or re-sodding. When reseeding, incorporate practices such as hydroseeding with a tackifier, blanket, or similar practice to ensure that no scour occurs in the forebay, while the seeds germinate and develop roots.

Water Quality Swale

Description: Water quality swales are vegetated open channels designed to treat the required water quality volume and to convey runoff from the 10-year storm without causing erosion.

There are two different types of water quality swales that may be used to satisfy the Stormwater Management Standards:

- Dry Swales
- Wet Swales

Unlike drainage channels which are intended to be used only for conveyance, water quality swales and grass channels are designed to treat the required water quality volume and incorporate specific features to enhance their stormwater pollutant removal effectiveness. Water quality swales have higher pollutant removal efficiencies than grass channels.

Ability to meet specific standards

Standard	Description
2 - Peak Flow	With careful design may be able to reduce peak flow at small sites
3 - Recharge	May not be used to satisfy Standard 3
4 - TSS Removal	Wet swales and dry swales achieve 70% TSS removal when provided with a pretreatment device such as a sediment forebay with a check dam.
5 - Higher Pollutant Loading	Dry swale recommended as pretreatment BMP. Must be lined. For some land uses with higher potential pollutant load, an oil grit separator or equivalent may be required before discharge to the swale.
6 - Discharges near or to Critical Areas	Dry and Wet Swales recommended as treatment BMPs for cold-water fisheries. Must be lined unless 44% TSS has been removed before discharge to swale. Should not be used near shellfish growing areas and bathing beaches.
7 - Redevelopment	Recommended for redevelopments and urban applications if sufficient land is available.

Pollutant Removal Efficiencies

- Total Suspended Solids (TSS)
  1. Dry Swale 70%
  2. Wet Swale 70%
- Total Nitrogen - 10% to 90%
- Total Phosphorus 20% to 90%
- Metals (copper, lead, zinc, cadmium) Insufficient data
- Pathogens (coliform, e coli) Insufficient data

Advantages/Benefits:

- May be used to replace more expensive curb and gutter systems.
- Roadside swales provide water quality and quantity control benefits, while reducing driving hazards by keeping stormwater flows away from street surfaces.
- Accents natural landscape.
- Compatible with LID designs
- Can be used to retrofit drainage channels and grass channels
- Little or no entrapment hazard for amphibians or other small animals

Disadvantages/Limitations:

- Higher degree of maintenance required than for curb and gutter systems.
- Roadside swales are subject to damage from off-street parking, snow removal, and winter deicing.
- Subject to erosion during large storms
- Individual dry swales treat a relatively small area
- Impractical in areas with very flat grades, steep topography or poorly drained soils
- Wet swales can produce mosquito breeding habitat
- Should be set back from shellfish growing areas and bathing beaches

Maintenance

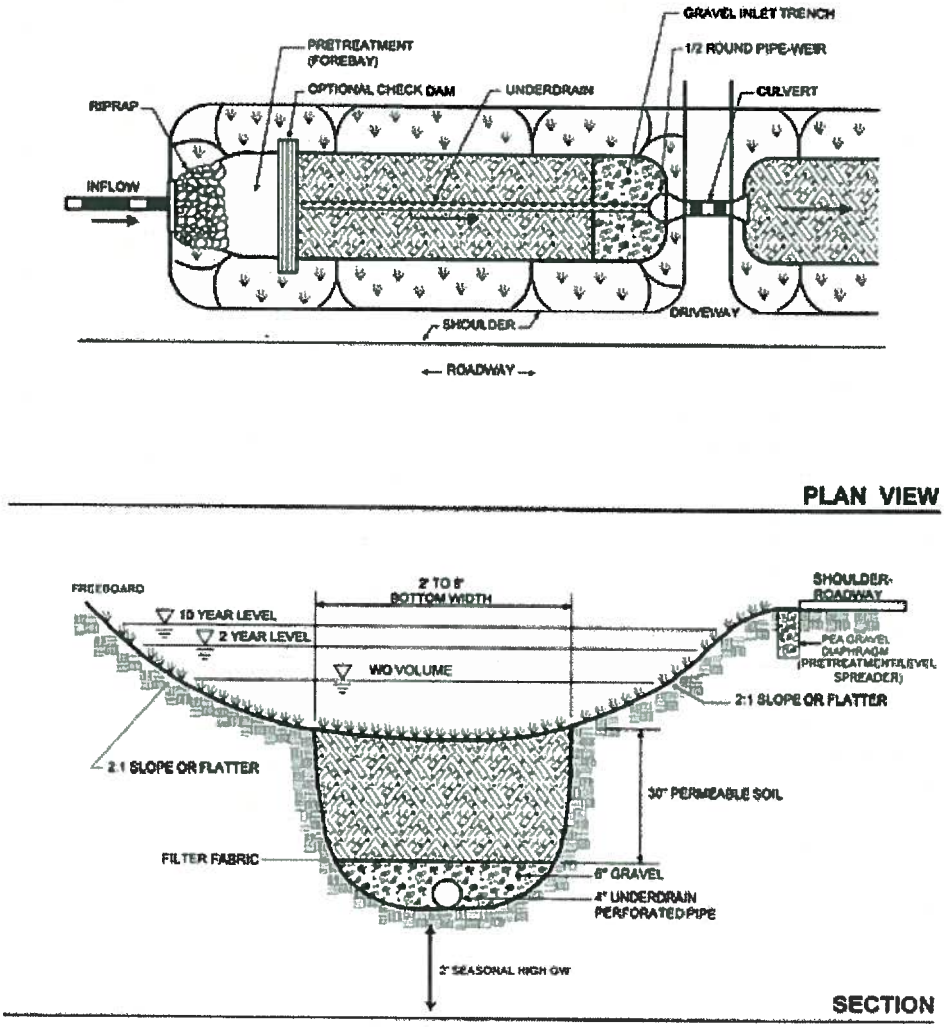
Activity	Frequency
Inspect swales to make sure vegetation is adequate and slopes are not eroding. Check for rilling and gullying. Repair eroded areas and revegetate.	The first few months after construction and twice a year thereafter.
Mow dry swales. Wet swales may not need to be mowed depending on vegetation.	As needed.
Remove sediment and debris manually	At least once a year
Re-seed	As necessary

Special Features

There are two types of swales that may be used to satisfy the Stormwater Management Standards - dry swales and wet swales.

Dry Swale

Dry swales are designed to temporarily hold the water quality volume of a storm in a pool or series of pools created by permanent check dams at culverts or driveway crossings. The soil bed consists of native soils or highly permeable fill material, underlaid by an underdrain system.

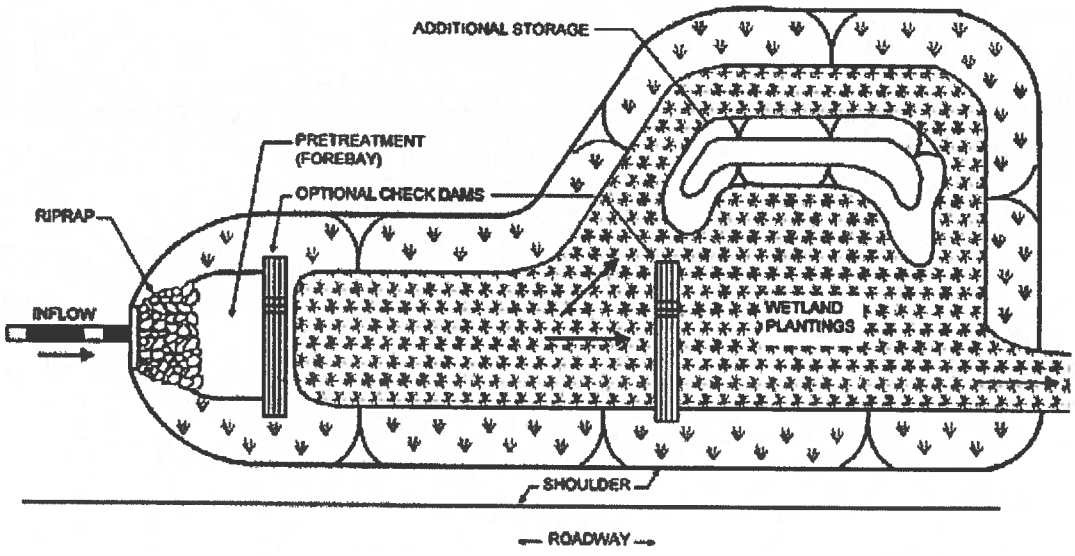


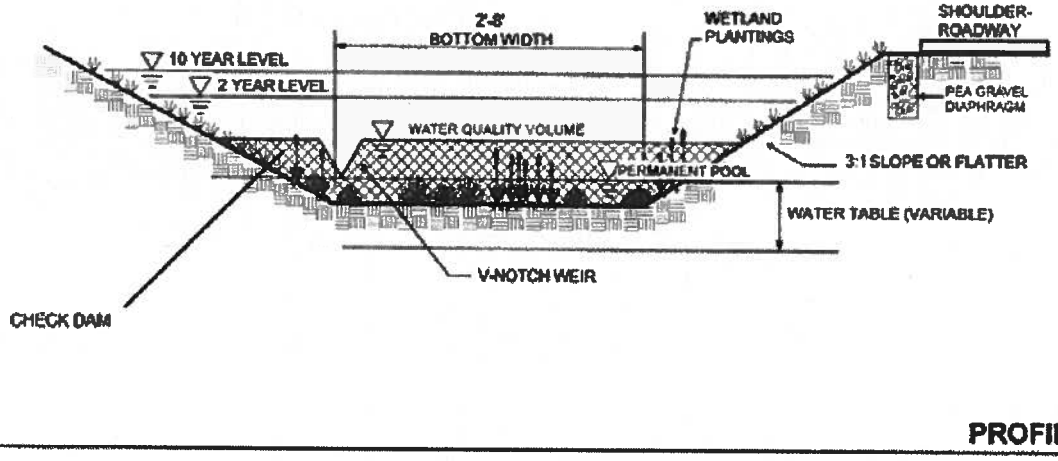
adapted from the Vermont Stormwater Manual

Example of Dry Swale

Wet Swale

Wet swales also temporarily store and treat the required water quality volume. However, unlike dry swales, wet swales are constructed directly within existing soils and are not underlaid by a soil filter bed or underdrain system. Wet swales store the water quality volume within a series of cells within the channel, which may be formed by berms or check dams and may contain wetland vegetation (Metropolitan Council, 2001). The pollutant removal mechanisms in wet swales are similar to those of stormwater wetlands, which rely on sedimentation, adsorption, and microbial breakdown.



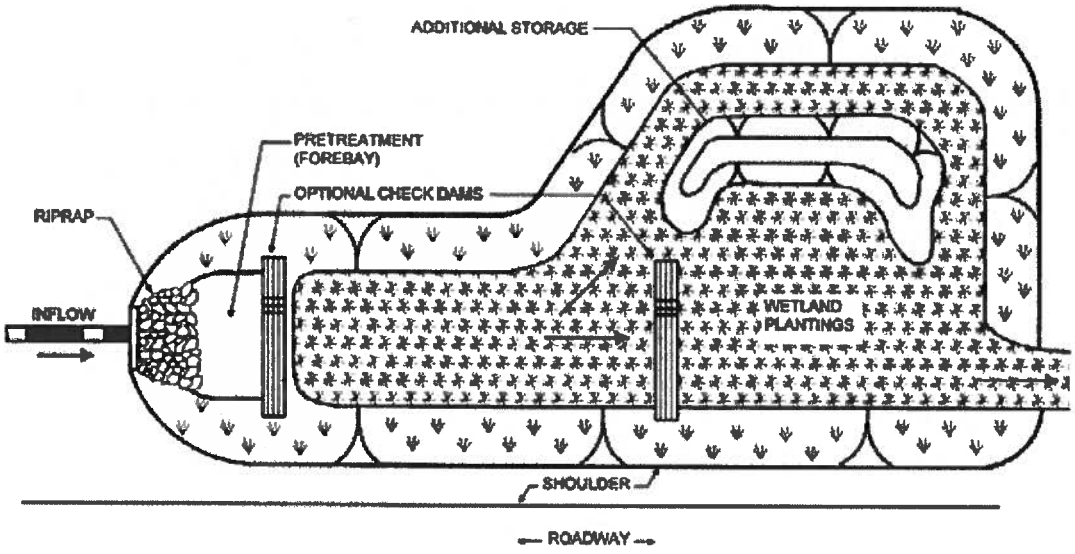


Example of Wet Swale

adapted from the Vermont Stormwater Manual

Wet Swale

Wet swales also temporarily store and treat the required water quality volume. However, unlike dry swales, wet swales are constructed directly within existing soils and are not underlaid by a soil filter bed or underdrain system. Wet swales store the water quality volume within a series of cells within the channel, which may be formed by berms or check dams and may contain wetland vegetation (Metropolitan Council, 2001). The pollutant removal mechanisms in wet swales are similar to those of stormwater wetlands, which rely on sedimentation, adsorption, and microbial breakdown.



Example of Wet Swale

adapted from the Vermont Stormwater Manual

Water Quality Swales

Applicability

Use water quality swales:

- As part of a treatment train
- As one of the best BMPs for areas discharging to cold-water fisheries if they are lined.
- As one of the best BMPs for redevelopments and urban applications.
- For residential and institutional settings (especially dry swales)

Water quality swales have many uses. Dry swales are most applicable to residential and institutional land uses of low to moderate density where the percentage of impervious cover in the contributing areas is relatively low. Wet swales may not be appropriate for some residential applications, such as frontage lots, because they contain standing water that may attract mosquitoes.

Water quality swales may also be used in parking lots to break up areas of impervious cover. Along the edge of small roadways, use water quality swales in place of curb and gutter systems. Water quality swales may not be suitable for sites with many driveway culverts or extensive sidewalk systems. When combining water quality swales with roadways and sidewalks, place the swale between the two impervious areas (e.g. between road and sidewalk or in-between north and south bound lanes of a roadway/highway).

The topography and soils on the site will determine what is appropriate. The topography should provide sufficient slope and cross-sectional area to maintain non-erosive flow velocities. Porous soils are best suited to dry swales, while soils with poor drainage or high groundwater conditions are more suited to wet swales. Design water quality swales to retain and treat the required water quality volume. Because they must also be designed to convey the 2-year and 10-year 24-hour storms, they may have to convey additional runoff volume to other downgradient BMPs.

Planning Considerations

The primary factors to consider when designing a water quality swale are soil characteristics, flow capacity, erosion resistance, and vegetation. Site conditions and design specifications limit the use of water quality swales.

Swale storage capacity should be based on the maximum expected reduction in velocity that occurs during the annual peak growth period. Usually the maximum expected drop in velocity occurs when vegetation is at its maximum growth for the year. Use the minimum level when checking velocity through the swale or the ability of the swale to convey the 2-year 24-hour storm without erosion. This usually occurs during the early growing season and dormant periods.

Other important factors to consider are land availability, maintenance requirements and soil characteristics. The topography of the site should allow for the design of a swale with sufficient slope and cross-sectional area to maintain a non-erosive flow rate, and to retain or detain the required water quality volume. The longitudinal slope of the swale should be as close to zero as possible and not greater than 5%. The grass or vegetation types used in swales should be suited to the soil and water conditions. Wetland hydrophytes (plants adapted to grow in water) or obligate species (i.e., species that occur 99% of the time under natural conditions in wetlands) are generally more water-tolerant than facultative species (i.e., species that occur 67% to 99% of the time under natural conditions in wetlands) and are good selections for wet swales, while dry swales should be planted with species that produce fine and dense cover and are adapted to varying moisture conditions.

Design

See the following for complete design references:
Site Planning for Urban Stream Protection. 1995. Schueler. Center for Watershed Protection.
Watershed Protection Techniques, Volume 2, Number 2, 1996. Center for Watershed Protection.
Biofiltration swale performance, recommendations, and design considerations.
1992. Metro Seattle: Water Pollution Control Department, Seattle,WA.

Access for maintenance must be incorporated into both designs. The maintenance access way must be a minimum of 15 feet wide on at least one longitudinal side of the swale to enable a maintenance truck to drive along the swale and gain access to any one point. When constructed along a highway, the breakdown lane can be used as the access. When constructed in a residential subdivision, an on-street parking lane may double as the maintenance access, provided signs are posted

indicating no parking is allowed during periods when the swales are being maintained.

Dry Swales

- Size dry swales to provide adequate residence time for the required water quality volume. Hydraulic Residence Time (HRT) must be a minimum of 9 minutes. Use Manning's Equation to determine the HRT.
- Dry swales should have a soil bed that is a minimum of 18 inches deep and composed of approximately 50% sand and 50% loam.
- Pretreatment is required to protect the filtering and infiltration capacity of the swale bed. Pretreatment of piped flows is generally a sediment forebay behind a check dam with a pipe inlet. For lateral inflows (sheet flow), use a vegetated filter strip on a gentle slope or a "pea gravel diaphragm."
- Design dry swales to completely empty between storms. Where soils do not permit full dewatering between storms, place a longitudinal perforated underpipe on the bottom of the swale bed. The inter-event period used in design to dewater the swale must be no more than 72 hours.
- Dry swales must have parabolic or trapezoidal cross-sections, with side slopes no greater than 3:1 (horizontal: vertical) and bottom widths ranging from 2 to 8 feet.
- Size dry swales to convey the 10-year storm and design swale slopes and backs to prevent erosion during the 2-year event. At least one foot of freeboard must be provided above the volume expected for the 10-year storm.
- Make sure that the seasonal high water table is not within 2 to 4 feet of the dry swale bottom.
- Use outlet protection at any discharge point from a dry swale to prevent scour at the outlet.

Wet Swales

- Size wet swales to retain the required water quality volume.
- Use wet swales only where the water table is at or near the soil surface or where soil types are poorly drained. When the swale is excavated, keep the swale bed soils.
- Pretreatment is required to protect the filtering and infiltration capacity of the wet swale bed. Pretreatment is generally a sediment forebay behind a check dam with a pipe inlet. For lateral inflows, use gentle slopes or a pea gravel diaphragm.
- Use check dams in wet swales to achieve multiple cells. Use V-notched weirs in the check dams to direct low flow volumes.
- Plant emergent vegetation or place wetland soils on the wet swale bottom for seed stock.
- Wet swales are parabolic or trapezoidal in cross-section, with side slopes no greater than 3:1 (horizontal: vertical) and bottom widths ranging from 2 to 8 feet.
- Size wet swales to convey the 10-year 24-hour storm and design wet swale slopes to prevent erosion during the 2-year 24-hour event.
- Use outlet protection at any discharge point from wet swales to prevent scour at the outlet.

Construction

Use temporary erosion and sediment controls during construction. Select the vegetation mix to suit the characteristics of the site. Seeding will require mulching with appropriate materials, such as mulch matting, straw, and wood chips. Anchor the mulch immediately after seeding. Water new seedlings well until they are established. Refer to "Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas: A Guide for Planners, Designers, and Municipal Officials" for information on seeding and mulching.

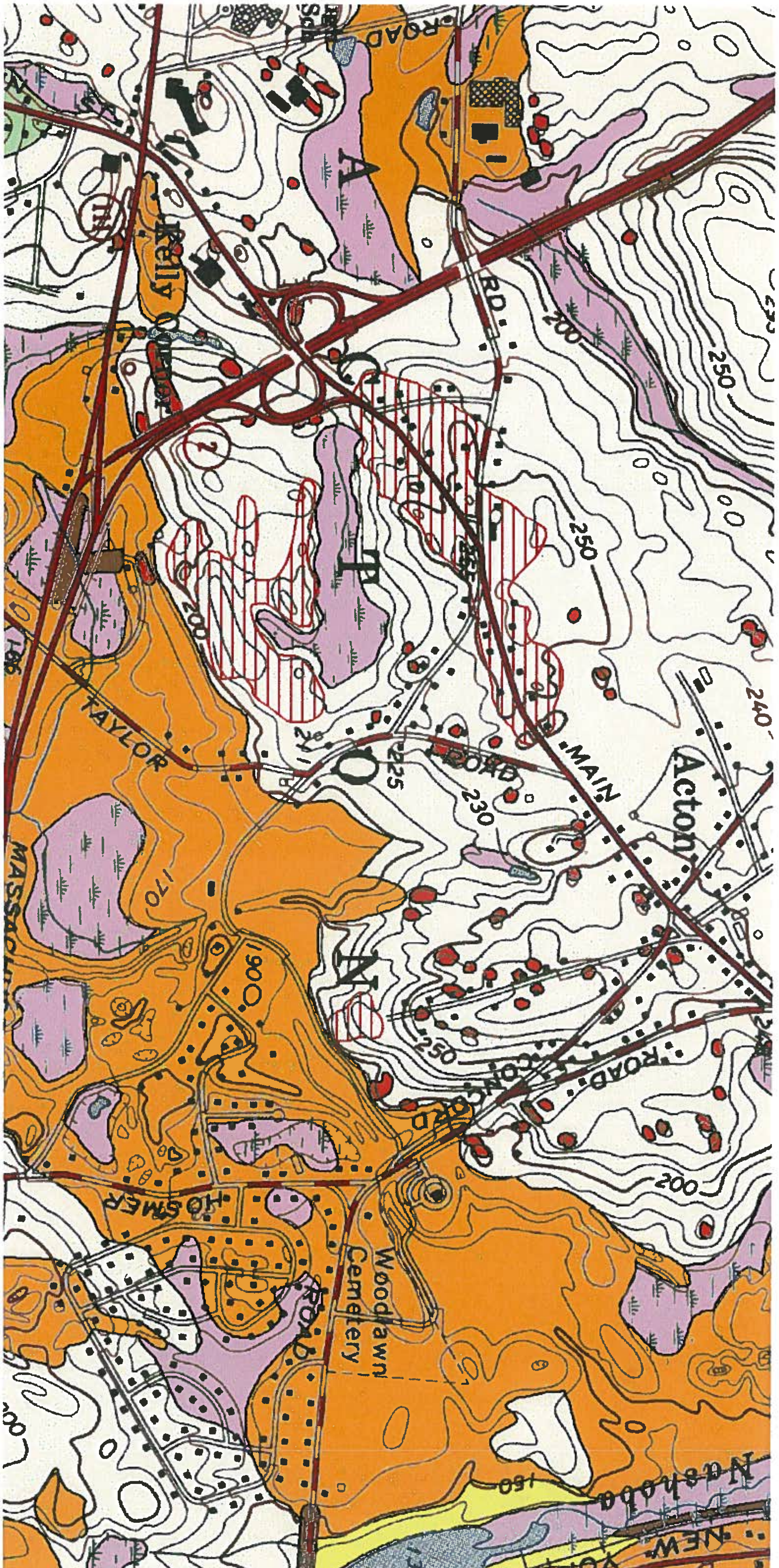
Maintenance

Incorporate a maintenance and inspection schedule into the design to ensure the effectiveness of water quality swales. Inspect swales during the first few months after installation to make sure that the vegetation in the swales becomes adequately established. Thereafter, inspect swales twice a year. During the inspections, check the swales for slope integrity, soil moisture, vegetative health, soil stability, soil compaction, soil erosion, ponding and sedimentation.

Regular maintenance includes mowing, fertilizing, liming, watering, pruning, and weed and pest control. Mow swales at least once per year. Do not cut the grass shorter than three to four inches, otherwise the effectiveness of the vegetation in reducing flow velocity and removing pollutants may be reduced. Do not let grass height exceed 6 inches.

Manually remove sediment and debris at least once per year, and periodically re-seed, if necessary, to maintain a dense growth of vegetation. Take care to protect water quality swales from snow removal and disposal practices and off-street parking. When grass water quality swales are located on private residential property, the operation and maintenance plan must clearly identify the property owner who is responsible for carrying out the required maintenance. If the operation and maintenance plan calls for maintenance of water quality swales on private properties to be accomplished by a public entity or an association (e.g. homeowners association), maintenance easements must be secured.

Attachments



ACTON
Kelly
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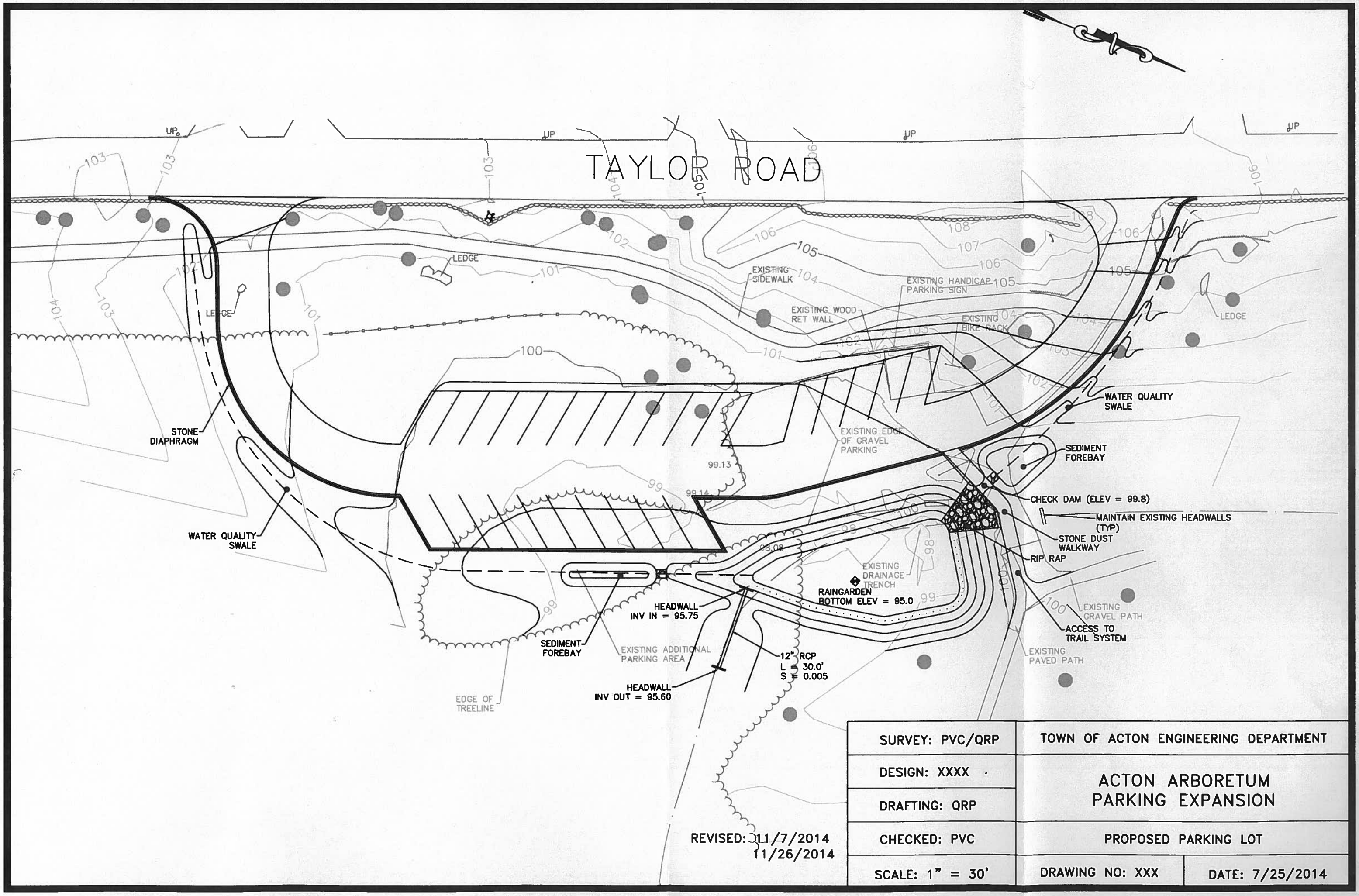
ROAD
TAYLOR
CONCORD
ROAD
HOSMER
Woodlawn
Cemetery
Nashoba
NEW YORK



SURVEY: PVC/QRP	TOWN OF ACTON ENGINEERING DEPARTMENT
DESIGN: XXXX	ACTON ARBORETUM PARKING EXPANSION
DRAFTING: QRP	
CHECKED: PVC	PROPOSED PARKING LOT
SCALE: 1" = 30'	DRAWING NO: XXX / DATE: 7/25/2014

REVISED: 11/7/2014
11/26/2014

Drawing name: P:\Drawings\Arboretum\Parking Expansion\Proposed Conditions.dwg
Jan 15, 2015 - 14:24pm

TAYLOR ROAD

GRASS
SHEET FLOW L=23'

GRASS
SHALLOW CONCENTRATED L=293'

UP

LEDGE

EXISTING SIDEWALK

EXISTING WOOD RET WALL

EXISTING HANDICAP PARKING SIGN

EXISTING BIKE RACK

EXISTING EDGE OF GRAVEL PARKING

STONE DIAPHRAGM

WATER QUALITY SWALE

99.13

99.14

98.08

WATER QUALITY SWALE

SEDIMENT FOREBAY

CHECK DAM (ELEV = 99.8)

MAINTAIN EXISTING HEADWALLS (TYP)

STONE DUST WALKWAY

RIP RAP

EXISTING DRAINAGE TRENCH

RAINGARDEN BOTTOM ELEV = 95.0

EXISTING GRAVEL PATH

ACCESS TO TRAIL SYSTEM

EXISTING PAVED PATH

HEADWALL
INV IN = 95.75

EXISTING ADDITIONAL PARKING AREA

12" RCP
L = 30.0'
S = 0.005

HEADWALL
INV OUT = 95.60

EDGE OF TREELINE

SURVEY: PVC/QRP	TOWN OF ACTON ENGINEERING DEPARTMENT
DESIGN: PVC	ACTON ARBORETUM PARKING LOT EXPANSION
DRAFTING: PVC/QRP	
CHECKED: PVC	WATERSHED AREA MAP
SCALE: 1" = 30'	DRAWING NO: 1 / DATE: 12/1/2014

CODE	SCIENTIFIC NAME	COMMON NAME
RB	Cercis canadensis	Eastern redbud
RMB	Morus rubra	Red mulberry
FG	Fothergilla gardenii	Dwarf fothergilla
EB	Sambucus canadensis	Common elderberry
SG	Liquidambar styraciflua	American sweetgum
W	Salix (sps)	Willow
VB	Viburnum (sps)	Viburnum
NEA	Aster (sps)	New England aster
WT	Chelone	White turtlehead
LI	Liatris	Blazing star
BS	Eupatorium perfoliatum	Boneset
M	Monarda	Bee balm
JP	Eupatorium purpureum	Joe – Pye weed

Ground Covers:

1. Conservation mix – Bigelow Nursery
2. Yellow Sweet Clover ***(Melilotus officinalis)***
3. Upright Sedge ***(Carex stricta)***
4. Indian Grass ***(Sorghastrum nutans)***
5. Cattail ***(Typha latifolia)***

EXISTING HANDICAP PARKING SIGN

EXISTING WOOD RET WALL

EXISTING BIKE RACK

CUT GRASS

CONSERVATION SEED MIX

YELLOW SWEET CLOVER

WHITE CLOVER

INDIAN GRASS

UPRIGHT SEDGE

CATTAIL

EDGE OF TREELINE

SURVEY: PVC/QRP	TOWN OF ACTON ENGINEERING DEPARTMENT
DESIGN: PVC	ACTON ARBORETUM PARKING EXPANSION
DRAFTING: QRP	
CHECKED: PVC	PLANTING PLAN
SCALE: 1" = 20'	DRAWING NO: 1 / DATE: 1/9/2015

REVISED: 11/7/2014
11/26/2014

Drawing name: P:\Drawings\Arboretum\Parking Expansion\Tree Planting Plan.dwg
Jan 15, 2015 - 14:28pm