STORMWATER MANAGEMENT REPORT

Willard Street Drainage Improvements

Cambridge, Massachusetts

Prepared for:

CITY OF CAMBRIDGE

Cambridge Department of Public Works
147 Hampshire Street
Cambridge, MA 02139

Prepared by:

Horsley Witten Group
Sustainable Environmental Solutions
90 Route 6A • Unit 1 • Sandwich, MA 02563
508-833-6600 • horsleywitten.com

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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.

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[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.

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

COMMONWEALTH OF MASSACHUSETTS
RICHARD A.
CLAYTOR
CIVIL
NO. 45116
REGISTERED
PROFESSIONAL ENGINEER

3-21-18

Signature and Date

Checklist

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

☐ New development

☒ Redevelopment

☐ Mix of New Development and Redevelopment

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): Gravel infiltration trenches, Underground infiltration chambers

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 (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 (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.

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

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 (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 (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.

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TABLES

APPENDICES

1.0 STORMWATER AND DRAINAGE OVERVIEW

This Drainage Report provides a summary of the existing stormwater management systems and the proposed stormwater best management practices (BMPs) located within theWillard Street project area in Cambridge, MA as part of an overall drainage, sewer separation, and streetscape improvement project. This report describes the pre- and post-project site conditions, and the practices that will be implemented to reduce the discharge of stormwater-borne pollutants to the combined storm sewer network and the Charles River during and after construction.

As the proposed project is a redevelopment project, the proposeddrainage improvements have been designed to conform to the requirements of the Massachusetts Stormwater Standards (MASWS) (revised January 2008) to the maximum extent practicable. The proposed modifications conform to the Standards and improve water quality by providing stormwater treatment forat least the half an inch (0.5”) of runoff from impervious surfaces that can be captured by BMPs within the project area. This report provides information for the proposed stormwater controls and the operation and maintenance of those controls.

Stormwater runoff quantity was evaluated for the 1-year, 2-year, 10-year, 25-year, 50-year and 100-year Type III, 24-hour storm for both existing and proposed conditions. The stormwater management system was sized to treat the first half inch (0.5”) of runoff for proposed conditions. Existing and proposed conditions were modeled using HydroCAD software (Version 10.0), which combines USDA Soil Conservation Service hydrology and hydraulic techniques (commonly known as SCS TR-55 and TR-20) to generate hydrographs. The rainfall amounts used for calculating runoff for the storm events were obtained from Northeast Regional Climate Center (NRCC).

1.1 Existing Conditions

The Willard Street drainage, sewer separation, and streetscape improvement projectwork site area is approximately 4.50 acres, located within and along segments of Willard Street, Willard Street Court, Foster Street, Dinsmore Court, and Mount Auburn Streets in Cambridge, MA (see figures in Appendix A).The project is considered a “redevelopment” project under the provisions of the MASWS. In addition to the primary work area, two additional off-site stormwater improvement projects are proposed as part of an effort to reduce stormwater pollutant discharges to the combined sewer system: one will be on the grounds of the Cambridge Skating Club, and the other at Longfellow Park.Their work site areas are 0.10 and 0.30 acres, respectively, making the combined work area of the three work sites 4.90 acres. The intersection of Willard and Brattle Streets, the upstream limit of proposed work, is located at latitude: 42° 22' 36" N, and longitude: 71° 07' 40" W. The Willard Street site consists of residential zoning districts A-2, C-1, and C-2; the Skating Club site is in district A-2, and the Longfellow Park site is in an OS (open space) district.

Willard Street is a 28-foot-wide, crowned, asphalt road that runs north-south froman elevation of 15 feet (NAVD 88) at the intersection of Brattle Street to an elevation of 11 feet (NAVD 88) at the intersection of Mount Auburn Street.The existing drainage system consists of deep sump catch basins on both sides of the street, draining to an older drainage pipe. This pipe formerly discharged to the Charles River but currently drains to aflow regulator structure located at the intersection of Willard Street and Mt Auburn Street, and then into the Massachusetts Water Resource Authority

(MWRA) combined sewer in Mt. Auburn Street.The MWRA combined sewer ultimately flows to the Deer Island wastewater treatment facility (WWTF).

Willard Streethas parallel parking along the west side, and a substandard concrete sidewalk with street trees along both sidesthat varies in width from two to five feet. The street is lined mostly with single family homes on lots ofabout an eighth of an acre each. The existing drainage map in **Appendix A** further depicts the surface cover types and the extent of the drainage areas.

According to the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) Soil Survey of Middlesex County, Massachusetts, the site consists of the following soil classification:

- Merrimac-Urban Land Complex (626B), 0 to 8percent slopes, described as “more than 80 inches to a restrictive layer, somewhat excessively drained, with very low runoff class,” Type A.

The soils information and mappingare provided in **Appendix B**.

Observation holes (Geoprobe borings) were conducted onsite to evaluate the subsurface conditions and Estimated Seasonal High Groundwater (ESHGW) on October 27, 2017. Four borings were extended to a depth of approximately 20 feet. Boring B1 was conducted at the Longfellow Park site; B2 at the Skating Club site; B3 on the northeastern edge of Willard Street; and B4 on the northwestern edge of Willard Street. B1 exhibited sand and gravel fill materials down to an appromimately15-foot depth, underlain by silty sand from 15-20 feet. B2 exhibited silty sand fill materials down to a depth of approximately 5 feet that was underlain by peat. B3 and B4 exhibited sand and silty sand fill materials down to an approximately 20-foot depth and underlain by silt. Water depths from the surface were estimated based on redoximorphic features or direct observations at 8 feet (B1), 4 feet (B2), 6 Feet (B3), and 5.5 feet (B4). These depths were used to set the bottom elevations of proposed infiltrating stormwater practices based on the most proximate boring to each practice.

The Soil Borings Report is provided in **Appendix B**.

1.2 Proposed Conditions

The proposed project consists of the following site development and drainage/stormwater management improvements:

- Reconstruction of the existing Willard Street roadway at its current width, and improvements to sidewalks and landscaping, from Mt. Auburn Street to Brattle Street;

- New utilities including gas, sewer, water, new deep sump catchbasins with hoods, and drainage pipe within Willard Street proper to discharge to the restored outfall location to the Charles River south of Memorial Drive. The new drainage pipe will convey runoff from up-gradient of Brattle Street, and west of Willard from Foster and Brown Streets to the restored outfall. This system has been sized for the 10-year frequency storm using the calibrated City-wide Info Works model provided by Stantec, Inc.

- Stormwater treatment systems to manage the west side of Willard Street drainage using both tree trenches (tree pits with underground infiltration trenches), and subsurface gravel infiltration trenches (pre-treatment is provided by deep sump catchbasins). These systems are designed to be off-line and sized to store/infiltrate runoff exceeding ½ inch across the contributing impervious area.

- New piping, catchbasins, and infiltration chambers in Longfellow Park, sized to infiltrate runoff from up to the 10-year storm (pre-treatment is to be provided by deep sump catch basins with hoods and an isolator row within the chamber system). Flows beyond the capacity of chambers overflows to the sewersystem.

- New piping,a drainage inlet/catchbasin and a grass infiltration swale system within the Cambridge Skating Club property to capture runoff exceeding ½ inch across the contributing area (pretreatment by deep sump catch basins with hoods). Flows beyond the capacity of the swale overflow to the sewersystem.

- A permeable pavement strip of 2 feet width in the sidewalk along the western side of Willard Street to enhance infiltration into the underlying gravel trenches and help provide increased watering to the existing and proposed street trees.

- Street trees for both the tree trenches and tree pits as depicted on the landscape plans.

- New outfall structure to the Charles River to replace the existing abandoned outfall structure.

The stormwater management system for the proposed site was designed in accordance with the MASWS.The proposed drainage area map depicting the subcatchments is provided in **Appendix A.**

1.3 Drainage Design Objectives and Methodology

The Stormwater Management System has been designed to accomplish the following major objectives:

- Convey the 10-year frequency storm to the restored Charles River outfall (**Appendix C**);

- Capture and treat, at a minimum, the so-called “first flush” (the first ½-inch of stormwater runoff) from impervious and clay tennis court surfaces at the Skating Club site in order to maintain or improve water quality conditions when compared to existing conditions;

- Recharge groundwater within the limits of Willard Street proper, Longfellow Park, and the Cambridge Skating Club via infiltrating stormwater practices to the extent practicable; and

- Match pre-development runoff peak rates from the post developed condition at the study point (intersection of Mt Auburn Street and Willard Street).

These objectives are met through the use of the following stormwater management measures:

- Deep sump catchbasins with hoods draining to the proposed pipe in Willard Street, sized to convey the 10-year peak discharge;

- 2-foot wide pervious surfaces adjacent to selected sidewalk segments;

- Vegetated tree trenches and subsurface gravel infiltration trenches;
- Grass infiltration swale, and;
- Underground attenuation/recharge chambers.

The proposed Stormwater Management System was designed to replicate pre-development site hydrologic conditions and provide a high level of stormwater treatment for proposed site conditions within the limits of the Willard Street project. Upstream drainage from Brattle Street and Foster Street will be directed to the new drainage pipe and restored outfall to the Charles River. Stormwater runoff quantity was evaluated for the 2-year, 10-year, and 100-year Type III, 24-hour storm events for both pre-development and post-development conditions. The proposed project will result in an increase in impervious cover of 958 square feet, as sidewalks will be widened to provide full accessibility in accordance with local, state, and federal requirements.

Pre-development and post-development conditions were modeled using HydroCAD software, which combines USDA Natural Resources Conservation Service hydrology and hydraulic techniques (commonly known as SCS TR-55 and TR-20) to generate hydrographs (see **Appendix A** for both Existing and Proposed Drainage Area Maps). The rainfall amounts used for calculating runoff for the storm events were obtained from Northeast Regional Climate Center Extreme Precipitation Analysis http://precip.eas.cornell.edu/ (**Appendix D**). A summary table of pre- and post-development runoff peak flow rates and volumes is provided in **Table 1** below.

The HydroCAD modeling results for existing and proposed developed conditions for Peak Flow attenuation (MASWS Standard 3) are provided in **Appendix E.**

Table 1: Peak Flow and Volume Comparison

STUDY POINT 1 (SP1) –INTERSECTION OF MT AUBURN ST AND WILLARD ST

DESIGN STORM	PRE-DEVELOPMENT		POST-DEVELOPMENT	
	PEAK FLOW (CFS)	VOLUME (INCHES)	PEAK FLOW (CFS)	VOLUME (INCHES)
2 Year	1.51	0.64	1.47	0.62
10 Year	4.03	1.57	4.01	1.56
100 Year	11.85	4.47	11.84	4.46

Total impervious surface in post development condition including the road travel lanes, parking lane and sidewalks is approximately 39,037square feet with an increase of 958 square feet over existing conditions, or 0.25% of the pre-developed impervious area within the project limits.

Tree trench and infiltration trenchsizing information can be found in HydroCAD model results in **Appendix E**.

1.4 Construction Activities and Sequence

The plans identify the existing and proposed drainage patterns; areas of soil disturbance; areas that will not be disturbed; the locations where stormwater will discharge (surface and subsurface); and locations of major structural and nonstructural controls identified in this Stormwater Management Report.

Construction activities will involve site preparation and earthworks necessary for construction of the proposed project. These general activities primarily include the following:

- Erosion and sedimentation control installation;
- Excavation, hauling, and stockpiling of excavated soils;
- Rough grading of all disturbed areas;
- Installation of all underground utilities;
- Installation of all drainage systems, including green infrastructure features;
- Completion of site grading and hardscape (pervious pavement, pavement, concrete) installation;
- Finish grading;
- Plantings;and
- Final site stabilization.

Erosion and sediment control measures will be installed per the construction plans and specifications prior to commencement of any soil disturbing activities and will remain in place until final site stabilization is complete.

A summary of the general sequence of project work for the restored outfall is as follows:

1. Confirm existing wetland flagging and replace as necessary;
2. Installation of erosion and sediment control devices around perimeter of project and field marking of the limit of work;
3. Detour the existing bike path around the project work area;
4. Install double floating curtain-drains in the Charles River where indicated;
5. Install steel sheeting cofferdam and dewatering system;
6. Install primary drainage pipe and rip rap at outfall
7. Demolition and disposal of existing pavement;
8. Installation of underground utilities and primary drainage piping;
9. Excavation of all stormwater management areas;
10. Installation of pavement and gravel sub-base;
11. Surface stabilization (vegetation, pavement, stone, or other);
12. Completion of stormwater facilities;
13. Installation of pavement top course;
14. Final site stabilization of disturbed areas; and
15. Removal of remaining erosion & sediment control devices and final cleanup.

2.0 COMPLIANCE WITH STORMWATER STANDARDS

The Massachusetts Stormwater Management Standards (MASWS)were revised in February 2008 to include ten stormwater management standards, established jointly by the MassDEP and the Office of Coastal Zone Management and published in the 2008 update of the Stormwater Management Handbook. Projects that are within the jurisdiction of the Wetlands Protection Act Regulations (310 CMR 10.00) are subject to theMASWS. This project is classified as redevelopment, and is therefore designed to meet the MASWS to the maximum extent practicable.

The following is a list of Stormwater Management Standards (**boldtext**) and accompanying documentation describing compliance of the proposed project with each Standard.

1. No new stormwater conveyances (e.g. outfalls) may discharge untreated stormwater directly to or cause erosion in wetlands or waters of the Commonwealth.

The stormwater management system was designed to treat stormwater runoff from the west side of Willard Street via tree trenches and infiltration trenches. Advanced treatment (deep sump catch basins) of the east side of Willard Street was deemed infeasible due to utility conflicts and limited right of way. Drainage upstream from the project locus (drainage north of Brattle Street and west including Foster and Brown Streets) will be addressed as part of the City of Cambridge's comprehensive stormwater management plan. The restored outfall will discharge to a non-erosive stabilized outfall structure.

Furthermore, the project is being designed to result in long-term improvements in water quality in the Charles River by contributing to the greater goal of reducing the frequency and volume of CSO discharge events to the river. The proposed work at Longfellow Park and the Cambridge Skating Club will result in a direct reduction of rate and volume of stormwater flow to the combined system.

2. Stormwater management systems shall be designed so that post-development peak discharge rates do not exceed pre-development peak discharge rates.

Discharge rates for pre and post-development were calculated using HydroCAD® 2011, an SCS-TR20 based stormwater modeling computer program (calculations are provided). Post-development runoff rates and volumes for the 2-year, 10-year,and 100-year storms are less than or equal to pre-development peak discharge rates for the Willard Street proper project. **Table 1**(above) provides the peak discharge rates and runoff volumes at the study point.

The project fully complies with Stormwater Standard 2.

3. Loss of annual recharge to groundwater shall be eliminated or minimized through the use of infiltration measures including environmentally sensitive site design, low impact development techniques, stormwater best management practices, and good operation and maintenance. At a minimum, the annual recharge from the post-development site shall approximate the annual recharge from pre-development conditions based on soil type. This Standard is met when the stormwater management system is designed to infiltrate the required recharge volume as determined in accordance with the Massachusetts Stormwater Handbook.

The stormwater management system is designed to infiltrate runoff for up to ½ inch of runoff for tree trenches, infiltration trenches (west side of Willard Street), and the Cambridge Staking Club. Runoff draining to the existing combined system in Longfellow Park will infiltrate runoff for up to the 10-year frequency storm. Recharge calculations are provided in **Appendices Dand E**.

The project will result in increased groundwater recharge compared to existing conditions, and therefore fully complies with Stormwater Standard 3.

4. Stormwater management systems shall be designed to remove 80% of the average annual post-construction load of Total Suspended Solids (TSS). This Standard is met when:

- **Suitable practices for source control and pollution prevention are identified in a long-term pollution prevention plan, and thereafter are implemented and maintained;**
- **Structural stormwater best management practices are sized to capture the required water quality volume determined in accordance with the Massachusetts Stormwater Handbook; and**
- **Pretreatment is provided in accordance with the Massachusetts Stormwater Handbook.**

The project is a redevelopment and is required to meet the TSS reduction criterion to the maximum extent practicable. For Willard Street proper, the tree trenches and infiltration trenches proposed for the west side of the street will provide an 80% TSS removal for the areas that drain to these facilities. There are four sub-basins that do not drain to these systems and receive only a 25% TSS reduction for the deep sump catch basins that are provided for these areas. The resulting weighted TSS removal is 48%.

Tree and Infiltration Trenches with Deep Sump CBs:	Recommended design rate:	80%
Deep Sump Catch Basins:	Recommended design rate:	25%

The project complies with Stormwater Standard 4 to the maximum extent practicable.

The proposed Operation and Maintenance Plan is designed to ensure that the stormwater system continues to function as it was designed into the future. TSS removal calculations are provided in **Appendix F.**

5. For land uses with higher potential pollutant loads, source control and pollution prevention shall be implemented in accordance with the Massachusetts Stormwater Handbook to eliminate or reduce the discharge of stormwater runoff from such land uses to the maximum extent practicable. If through source control and/or pollution prevention all land uses with higher potential pollutant loads cannot be completely protected from exposure to rain, snow, snow melt, and stormwater runoff, the proponent shall use the specific structural stormwater BMPs determined by the Department to be suitable for such uses as provided in the Massachusetts Stormwater Handbook. Stormwater discharges from land uses with higher potential pollutant loads shall also comply with the requirements of the Massachusetts Clean Waters Act, M.G.L. c. 21, §§ 26-53 and the regulations promulgated thereunder at 314 CMR 3.00, 314 CMR 4.00 and 314 CMR 5.00.

The proposed project site does not include any land uses with higher potential pollutant loads (LUHPPLs).

6. Stormwater discharges within the Zone II or Interim Wellhead Protection Area of a public water supply, and stormwater discharges near or to any other critical area, require the use of the specific source control and pollution prevention measures and the specific structural stormwater best management practices determined by the Department to be suitable for managing discharges to such areas, as provided in the Massachusetts Stormwater Handbook. A discharge is near a critical area if there is a strong likelihood of a significant impact occurring to said area, taking into account site-specific factors. Stormwater discharges to Outstanding Resource Waters and Special Resource Waters shall be removed and set back from the receiving water or wetland and receive the highest and best practical method of treatment. A "storm water discharge" as defined in 314 CMR 3.04(2)(a)1 or (b) to an Outstanding Resource Water or Special Resource Water shall comply with 314 CMR 3.00 and 314 CMR 4.00. Stormwater discharges to a Zone I or Zone A are prohibited unless essential to the operation of a public water supply.

The site is not located within a Zone II, Interim Wellhead Protection Area, or other critical areas.

7. A redevelopment project is required to meet the following Stormwater Management Standards only to the maximum extent practicable: Standard 2, Standard 3, and the pretreatment and structural best management practice requirements of Standards 4, 5, and 6. Existing stormwater discharges shall comply with Standard 1 only to the maximum extent practicable. A redevelopment project shall also comply with all other requirements of the Stormwater Management Standards and improve existing conditions.

This project is considered a redevelopment project with the goals of improving existing flooding and water quality. The project complies with Stormwater Standards 2 and 3 fully, and complies with Stormwater Standards 1 and 4 to the maximum extent practicable.

8. A plan to control construction-related impacts including erosion, sedimentation and other pollutant sources during construction and land disturbance activities (construction period erosion, sedimentation, and pollution prevention plan) shall be developed and implemented.

Silt-sock/straw wattle is proposed at all down-sloping areas surrounding the project. All drainage catchbasins/yard inlets will be equipped with silt sacks during construction. Disturbed surfaces will be stabilized as soon as possible after installation. The proposed outfall will contain a dewatering system and temporary bulkhead to ensure sediment is retained within the project disturbed limits.

9. A long-term operation and maintenance plan shall be developed and implemented to ensure that stormwater management systems function as designed.

The construction and long-term stormwater Operation &Maintenance Plan is provided within this report.

10. All illicit discharges to the stormwater management system are prohibited.

There will be no illicit discharges to the stormwater management system. A Long-Term Pollution Prevention Plan will be prepared and will include measures to prevent illicit discharges.

3.0 POST-CONSTRUCTION STORMWATER MANAGEMENT

Stormwater treatment and conveyance for the newly constructed areas will be provided by the following proposed BMPs.

3.1 Tree Trenches and Infiltration Trenches

The proposed tree trenches and subsurface infiltration trenches are stormwater management practices to manage and treat stormwater runoff using a stone reservoir and planting soils (within the tree pit). The systems are designed to be off-line; meaning that the water quality treatment volume is diverted into the trenches and an overflow pipe is provided to convey larger storms to the drainage pipe network. The system consists of a perforated inflow pipe, pretreatment via deep sump catchbasins, an overflow pipe out of the catchbasins,the stone (and soil for tree trenches) storage reservoir, and street trees (for the tree trenches).

3.2 Recharge Chambers

Underground stormwater recharge/attenuation chambers at Longfellow Park capture and store stormwater collected from surrounding impervious areas. Drainage structures and pipes convey surface stormwater to interconnected subsurface storage units. Pretreatment is provided by deep sump catchbasins and an “isolator” row within the chamber system. Runoff stored in the chambers is released directly into the ground, mimicking pre-development conditions. An overflow pipe set at the top of the chamber systems diverts high flows back into the combined system pipe. The use of stormwater recharge chambers allows for stored water to infiltrate and recharge groundwater.

3.3 Grass Infiltration Swale

The proposed grass infiltration swale on the Cambridge Skating Club property is designed to store and infiltrate ½-inch of runoff over the contributing impervious area. The system will receive some flows from the adjacent tennis courts via surface runoff and will receive some flows at the bottom of the system via the existing enclosed pipe system within the Skating Club. Similar to the tree trenches/infiltration trenches, this system consists of a stone reservoir and an amended soil system to store and treat runoff prior to infiltration. Pretreatment is provided by a deep sump manhole, which also contains a diversion wall to allow larger flows to be directed back to the combined system. The use of the stone storage reservoir allows for stored water to infiltrate and recharge groundwater.

3.4 Temporary Construction-Phase Pollutant Controls

Perimeter controls will be installed during construction to minimize sediment transportation in stormwater and to protect the adjacent wetland resource and any associated buffers in the vicinity.

3.4.1 Structural Practices

The following are the structural practices that will be implemented as part of the construction activity.

- <u>Silt Fence, Straw Bales, and/or Sediment Silt Sock Barrier</u> will be installed prior to commencement of construction. Barriers will be installed parallel to land slope at the perimeter of the work site where appropriate. This type of practice creates physical barriers to intercept sediment in diffuse runoff, preventing it from reaching storm drain networks or resource areas. The City will be informed upon installation so that they may inspect these barriers prior to construction. Portions of the erosion control barriers will be replaced and/or repaired as necessary to prevent erosion.

- Inlet Protection (Silt Sacks or approved equivalent) will be installed at identified existing catch basins and following construction of new catch basins to prevent sedimentation during any subsequent construction. The Silt Sack will be replaced and disposed of off-site if damage is observed.

- Slope Stabilization will be installed where appropriate in the vicinity of the outfall, upon obtaining final grades as shown on the project site plans. Areas that fail to stabilize will be re-graded to final grade and stabilized as necessary. Amount of land disturbed will be minimized to reduce potential for erosion and sedimentation. Stabilization measures shall be initiated within 14 days following the end of construction at this portion of the site and as soon as practicable.

The entire stormwater management system will be inspected upon completion of construction. Sediment will be removed from all elements of the stormwater management system. All control measures must be installed and maintained in accordance with manufacturer's specifications, good engineering practices, and in accordance with this report (every seven calendar days and after storm events). If inspections show that a control has failed or been installed incorrectly, the operator must replace or modify it within 24 hours.

3.4.2 Stabilization Practices

The amount of land disturbed during construction will be minimized to reduce the potential for erosion and sedimentation. Prompt surface stabilization will be practiced to control erosion in areas where disturbances cannot be avoided during construction. Stabilization measures shall be initiated within 14 days following the end of construction at each portion of the site. Exceptions to this requirement are allowable when snow cover prevents the initiation of stabilization within 14 days, in which case such measures shall be undertaken as soon as possible.

Stabilization measures that will be, or may be, used during construction are described below:

- Temporary Seeding – Temporary seeding of disturbed surfaces with fast-growing grasses (annual rye) to provide greater resistance to stormwater runoff and/or wind erosion for areas where construction has temporarily ceased.

- Permanent Seeding – Permanent seeding of surfaces with vegetation, including but not limited to grass, trees, bushes, and shrubs, to stabilize the soil. Establishing a permanent and sustainable ground cover at a site stabilizes the soil while reducing the sediment content in runoff.

- Permanent Planting – The contractor shall install and adequately establish all planting as required at the completion of the project.

- Mulching – Materials, including, but not limited to straw, grass, woodchips, straw, and gravel will be placed on the soil surface to cover and hold in place disturbed soils.

Temporary seeding or other soil stabilization measures will be provided where construction activities have ceased at the site. Topsoil stockpiles will be temporarily seeded to prevent erosion, and will be surrounded with silt fence. When the site's final grade has been established, permanent vegetation will be planted on the disturbed areas. The vegetation will consist of grass, perennial plants, shrubs, and trees.

3.4.3 Other Types of Controls

Additional controls/practices will be undertaken to reduce pollution in stormwater runoff flows which include, but are not limited to, control of off-site mud tracking from construction site, dust suppression, proper sanitary waste disposal, earthwork procedures timed and conducted in manners aimed to minimize erosion and sedimentation, snow removal plans, proper management of waste materials, proper management of hazardous waste, proper material stockpiling, and spill prevention and control measures.

- Dust Suppression – Water sprays shall be used to control dust during extended dry periods during construction.

- Sanitary Wastes – All sanitary wastes will be collected from the portable units by a licensed sanitary waste management contractor (as required by local regulations).

- Earthwork – The exposure of disturbed surfaces to stormwater and potential stormwater erosion will be minimized by well organized earthwork procedures. Stabilization procedures shall be undertaken in accordance with this report. Grubbing during wet seasons will be avoided if feasible.

- Waste Materials – Dumpsters rented from a licensed solid waste management company will be used to store solid waste and debris that cannot be recycled, reused or salvaged. The dumpsters will meet all local and state solid waste management regulations. Dumpsters will be covered when refuse is not being directly deposited or withdrawn from them. Potentially hazardous wastes will be separated from normal wastes, including segregation of storage areas and proper labeling of containers. Removal of all waste from the site will be performed by licensed contractors in accordance with applicable regulatory requirements and disposed of at either local or regional approved facilities. Waste materials will not be buried on-site. All site personnel will be instructed regarding the correct procedures for waste disposal. Notices stating these procedures will be posted at the site. Solvents and flushing materials used during construction and pre-operational cleaning will be provided, handled, managed, and removed by the contractor for appropriate off-site disposal.

- Hazardous Waste Materials – Any disposal of hazardous materials will be completed using the required paperwork. Copies will be provided to the Engineer and to the City.

- Spill Prevention and Control Measures – To minimize the risk of spills or other accidental exposure of materials and substances to stormwater runoff, the following material management practices will be used throughout the project:

    - An effort will be made to store only enough products required to do the job.
    - All materials stored on-site will be stored in a neat, orderly manner in their appropriate containers and, if possible, under a roof or other enclosure.
    - Products will be kept in their original containers with the original manufacturer's label.
    - Substances will not be mixed with one another unless recommended by the manufacturer.
    - Whenever possible, the maximum amount of a product will be used before disposing of the container.
    - Manufacturers' recommendations for proper use and disposal will be followed.
    - The site superintendent will conduct daily inspections to ensure proper use and disposal of materials.

  To reduce the risk associated with hazardous materials used on the site, the following practices will be used:

    - Products will be kept in original containers unless they are not re-sealable.
    - Original labels and material safety data sheets will be retained and kept on-site; they contain important product information.
    - If surplus product must be disposed of, manufacturers' or local and state recommended methods for proper disposal will be followed.

- Materials List - Materials or substances listed below are expected to be present on-site during construction:

    - Concrete
    - Asphalt
    - Paints (enamel and latex)
    - Wood
    - Tar
    - Adhesives
    - Fertilizers
    - Petroleum Based Products
    - Cleaning Solvents
    - Concrete
    - Sealants

  The following product-specific practices will be followed on-site:

  Petroleum Products– Allon-site vehicles will be monitored for leaks and receive preventative maintenance to reduce the chance of leakage. Petroleum products will be stored in tightly sealed containers which area clearly labeled. Any asphalt substances used on-site will be applied according to the manufacturers' recommendations.

  Fertilizers – Fertilizers used will be applied only in the minimum amounts recommended by the manufacturer. Once applied, fertilizer will be worked into the soil to limit exposure to stormwater. Products will be stored in a covered shed. The contents of any partially used bags of fertilizer will be transferred to a sealable plastic bin to avoid spills.

Paints – All containers will be tightly sealed and stored indoors when not required for use. Excess paint will not be discharged to the storm sewer system but will be properly disposed of according to the manufacturers' instructions or state and local regulations.

Concrete Trucks – Concrete trucks will not be allowed to wash out or discharge surplus concrete or drum wash water on the site.

In addition to the good housekeeping and material management practices discussed in the previous sections of this plan, the following practices will be followed for spill prevention and cleanup:

- Manufacturers' recommended methods for spill cleanup will be clearly posted, and site personnel will be made aware of the procedures and location of the information and cleanup supplies.
- Materials and equipment necessary for spill cleanup will be kept in the material storage area on-site. Equipment and materials will include, but not be limited to, brooms, dust pans, mops, rags, gloves, goggles, speedi-dry, sand, sawdust, and plastic and metal trash containers specifically for this purpose.
- All spills will be cleaned up immediately after discovery. Spills large enough to reach the storm water system will be reported to the National Response Center at 1-800-424-8802.
- The spill area will be kept well ventilated and personnel will wear appropriate protective clothing to prevent injury from contact with a hazardous substance.
- Spills of toxic or hazardous material will be reported to the appropriate state or local government agency, regardless of the size.
- The site superintendent responsible for the day-to-day site operations will be the spill prevention and clean-up coordinator. This individual will designate at least three other site personnel who will receive spill prevention and cleanup training. These individuals will each become responsible for a particular phase of prevention and cleanup. The names of responsible spill personnel will be posted in the material storage area and in the on-site office trailer.

4.0 CONSTRUCTION AND POST-CONSTRUCTION STORMWATER OPERATION AND MAINTENANCE PLAN

All stormwater management and controls identified in the Post Construction Stormwater Management section of this Drainage Report shall be operated and maintained appropriately during the construction phase of the project and during regular operation of the site in the post-construction period. The General Contractor shall provide, inspect, and maintain all control measures. The stormwater controls will be inspected at least once every seven days and within 24 hours of storm events of 0.5 inches or greater, to prevent deficiencies in the effectiveness of the systems due to sediment build-up, damage, or deterioration. A summary of the maintenance plan is presented below.

The stormwater control system will be regularly inspected to ensure proper performance. The following operation and maintenance provisions will be provided:

- Silt fences will be inspected for depth of sediment, tears, and proper fence embedment to determine if the fabric is securely attached to the fence posts, and to determine if the fence posts are firmly in the ground. Silt fence will be replaced when necessary.
- Straw bales shall be inspected for depth of sediment and any breaches will promptly be repaired or replaced when necessary.
- Silt Socks shall be inspected for depth of sediment and any breaches will promptly be repaired or replaced when necessary.
- Sediment shall be removed where accumulation reaches one-third the above ground height of any barrier.
- Once each workday structural control measures receiving flows from areas that have not been stabilized shall be inspected.
- Remedial action shall be taken in areas where temporary and permanent seeding is deemed inefficient through weekly inspections to establish a stabilized surface.
- All BMP's will be cleared of accumulated foreign debris, including leaves and lawn cuttings.
- All BMP's will be inspected for slope integrity and erosion.
- All control measures will be inspected at least once every seven calendar days and within 24 hours after storm events of 0.5 inches or more.
- A maintenance inspection report will be made after each inspection. A copy of the form to be completed by the inspector is located in**Table 2**.
- All measures will be maintained in good working order, if a repair is necessary, it will be initiated within 24 hours of discovery.

The following provides the operation and maintenance plan for the stormwater management system installed for this project. The stormwater controls will be inspected on a routine basis to prevent deficiencies in the effectiveness of the systems due to sediment build-up, damage, or deterioration. Stormwater controls will be operated and maintained appropriately during the construction phase of the project and during regular operation of the site in the post-construction period. The stormwater control system will be regularly inspected to ensure proper performance (see **Table 2**).

Catch Basins/Yard Inlets and Drainage Network: All catch basins, yard inlets and drainage pipe will be inspected at least twice annually (spring & fall) to monitor for proper operation, collection of solids, litter and/or trash, and structural deterioration. The structures will be cleaned when the depth of sediment exceeds one half the sump depth, and repaired when required. Sediments shall be removed by clam-shell or vacuum-truck. Collected sediment will be disposed of properly in a pre-approved off-site location.

Gravel Infiltration Trenches: The inlet structures of these practices will be outfitted with deep sumps, to help prevent clogging of the gravel infiltration reservoir. The structures will be cleaned when the depth of sediment exceeds one half the sump depth, and repaired when required. Sediments shall be removed by clam-shell or vacuum-truck. Collected sediment will be disposed of properly in a pre-approved off-site location. These subsurface infiltration systems will also be equipped with underdrain cleanouts, which can be used to flush the system if it is believed that clogging has occurred. After flushing of an infiltration trench has taken place, care must be taken to remove any sediment or debris that has washed out and into the sump of the inlet structure (catch basin).

Grass Infiltration Swale: This infiltration practice is expected to receive the majority of its stormwater flow from a subsurface pipe network; with respect to this, the primary maintenance concerns are the same as for the other underground infiltration system. However, in addition to subsurface flow, a portion of flow will be directed into the practice via surface runoff from the adjacent clay tennis court. The grass swale should be monitored for sediment build-up and debris, and cleaned whenever the depth of sediment is visibly detectible. Grass should be mowed whenever the nearby lawn is mowed. Do not fertilize grass in or immediately adjacent to stormwater practices to prevent discharge to drainage network.

Tree Trenches: Inspect the stormwater tree trenches annually. Monitor the planting soil bed for proper pH, erosion and aeration. Replace top soil every two years to the original design depth, and remove ill-established, dead or severely diseased plants and replaced as needed. Remove sediment build-up when found during inspection.

Underground Recharge Chambers: The primary maintenance concerns for underground recharge/attenuation are the removal of accumulated sediments within the system and removal of floatable that may become trapped. Therefore, the removal of such material shall occur twice annually or more frequently as needed. Sediments are best removed mechanically from the access manholes prior to reaching the chambers rather than flushing. If flushing is the only option, then great care must be taken not to flush sediments downstream into the receiving waters. Collected sediment will be disposed of properly in a pre-approved off-site location. All inlet and outlet structures shall be inspected, cleaned, and repaired as needed to prevent debris from clogging the system.

Routine Maintenance: Other routine maintenance will include removal of trash and litter from paved and perimeter areas and the drainage system. Annual pavement sweeping will take place after the spring thaw to avoid excessive accumulation of sediment in the drainage system. The pipes draining the project will be inspected annually for proper operation.

4.1 Estimated Operation and Maintenance Budget

The estimated average annual operating and maintenance budget for the proposed stormwater management system is shown below:

Infiltration Swale (1):	**$1,000**
Recharge Chamber System (1)	**$500**
Underground Infiltration Trenches (7)	**$3,500**
Other Routine Maintenance:	**$2,500**
Cleaning	
Drainage network inspections/Cleaning	
Total:	**$7,500**

Note: Estimate does not include other operating expenses (trash collection, mulch replacement, mowing, etc.)

Table 2. Operation and Maintenance Checklist

Operation and Maintenance Checklist

Owner: City of Cambridge
Operator: Cambridge Department of Public Works
Location: Willard Street, Cambridge, MA

Date/Time:

Inspector:

	Description	Maintenance Required? (Y/N)
1. Catch Basins, Drain Manholes, Yard Inlets, Drain Pipe - Inspect twice annually		
Debris Cleanout	Remove all trash, debris, and sediment from all structures twice annually or as needed. Remove all debris from pretreatment structure at least twice annually or when sediment buildup is half the sump depth.	
Structures	Repair as necessary.	
2. Underground Infiltration Trenches		
Sediment Removal	Remove sediment from inlet structure sump when it exceeds half the sump depth	
Vegetation Replacement (Tree Trenches only)	Confirmation of plant materials by landscape professional. Replace dead or dying vegetation as necessary.	
Pruning (Tree Trenches only)	Prune for sight visibility as necessary. Separation of herbaceous vegetation root stock is necessary when over-crowding is observed (1x/3yrs).	
Infiltration Capacity Maintenance	If standing water is observed 48 hrs after a storm event, the infiltration system should be inspected via the cleanout, and flushed if necessary	
3. Underground Recharge/Attenuation Chambers – Inspect twice annually		
General	Maintenance per manufacturer's requirements.	
Debris Cleanout	Remove all trash, debris, and sediment from all structures twice annually or as needed. Remove all debris from chamber and/or galley at least twice annually or when sediment buildup is half the one quarter of the storage.	
Structures	Repair as necessary.	
Sediment Removal	Sediments are to be removed vacuum from the underground chambers where possible.	

	Description	Maintenance Required? (Y/N)
4. Grass Infiltration Swale		
Sediment Removal	Remove sediment from the grass swale when possible to do so	
Vegetation Maintenance	Limit the height of vegetation within the swale to 8”	
5. Routine Maintenance – Perform annually		
Debris Removal	Remove trash from paved and perimeter areas.	
Pavement Sweeping	Sweep pavement after spring thaw.	
Drainage Network	Ensure proper operation.	

Comments:

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Actions to be taken:

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5.0 LONG-TERM POLLUTION PREVENTION PLAN

Stormwater Management System Owner:

City of Cambridge
Department of Public Works
147 Hampshire Street
Cambridge, MA 02139
617.349.4800

Party Responsible for Operation and Maintenance:

City of Cambridge
Department of Public Works
147 Hampshire Street
Cambridge, MA 02139
617.349.4800

Cambridge Skating Club (for this property only)
40 Willard Street
Cambridge, MA 02138
617-354-9427

Long-term pollution prevention measures implemented at the site will further reduce pollutants in stormwater discharges after construction. The following practices will be employed on an on-going basis.

- Spill Prevention and Control Measures – To minimize the risk of spills or other accidental exposure of materials and substances to stormwater runoff, the material management practices as specified.
- Lawn/Landscaping Maintenance – Lawn and landscaping maintenance will be conducted with minimal use of fertilizers and pesticides to protect the nearby wetland and water resources. A drought tolerantgrass mix will be used to minimize fertilization and irrigation needs. Fertilizer will be applied a maximum three times during the growing season, and pesticides will be applied sparingly, as needed, following the manufacturer's directions for application. Any fertilizer/pesticide that lands on paved surfaces such as sidewalks and/or parking areas will be swept up and removed immediately to prevent it from entering the storm drain network. Geese will be discouraged from foraging on the small lawn areas to reduce nutrient and bacteria inputs from their droppings.
- Pet Waste Management – Residents and visitors will be encouraged to pick up after their pets with signage along lawn areas.
- Pavement Sweeping Schedules – The roadways area will be twice monthly from April 1 to December 31.

- Illicit Discharges – No sewer pipes or floor drains will be connected to the drainage network. All wastewater will be connected to the municipal sewer or approved on-site system.

- Personnel Training – All contracted personnel retained for work on site will be given a copy of this Plan and will receive training in applicable practices and implementation to prevent pollutants from entering the stormwater system.

6.0 REFERENCES

1. ASTM (American Society of Testing and Materials). 2003. ASTM D3385-03 Standard test method for field measurement of infiltration rate of soils in field using double-ring infiltrometer.

2. Federal Emergency Management Agency (FEMA). See their homepage at: http://www.fema.gov/

3. Massachusetts Department of Environmental Protection. See their homepage at www.state.ma.gov/dep

4. Massachusetts Department of Environmental Protection. 2008. Massachusetts Stormwater Standards Manual.

5. Massachusetts Office of Geographic and Environmental Information (MassGIS). See their homepage at: http://www.mass.gov/mgis/.

6. Northeast Regional Climate Center –Extreme Precipitation Analysis

7. City of Cambridge Stormwater Management Plan

8. NPDES Phase II Final Rule Notice of Intent and Stormwater Management Plan, City Of Cambridge, Massachusetts. April 2006.

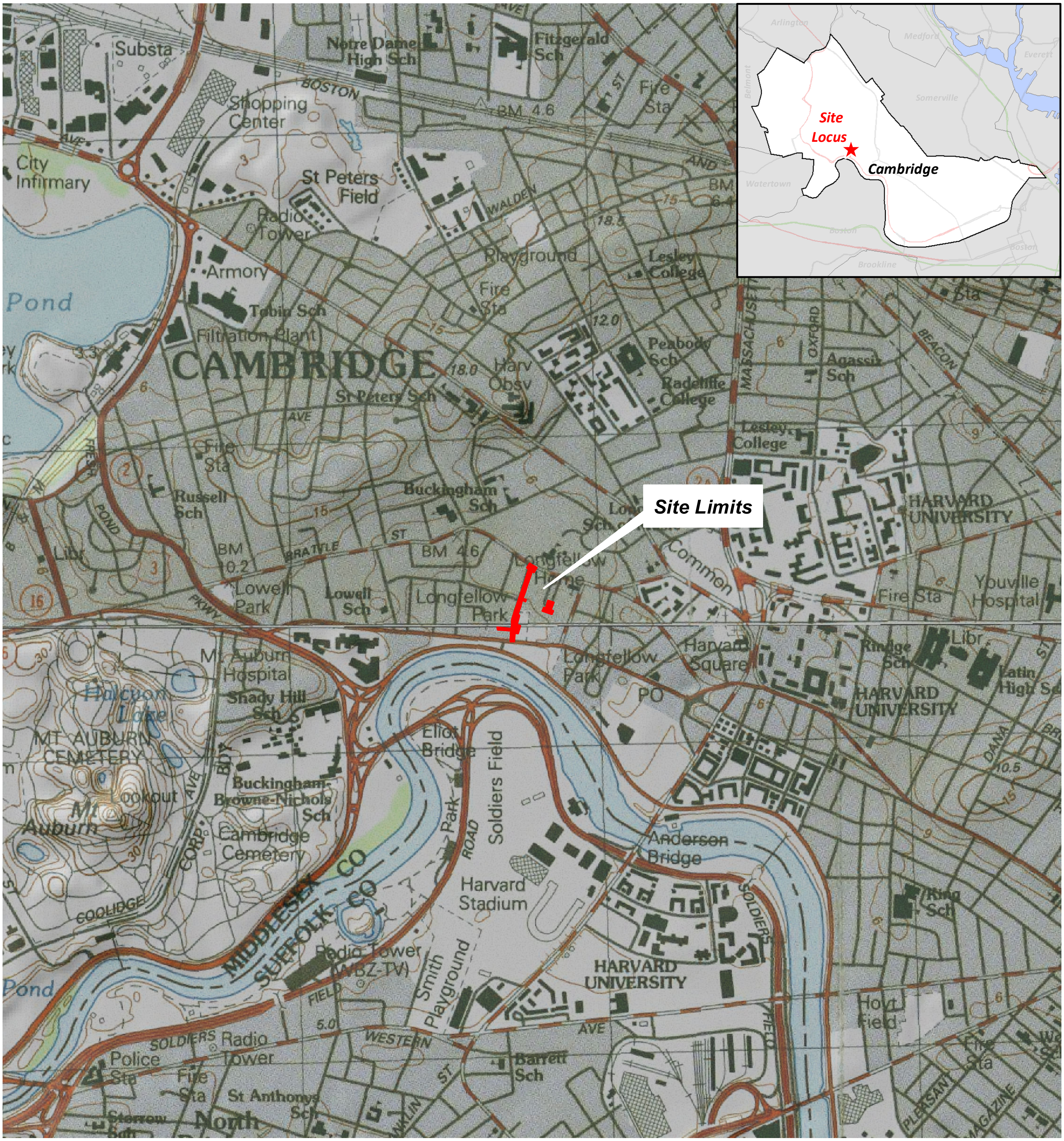
9. Additional resources available at the City of Cambridge Stormwater Management website: https://www.cambridgema.gov/theworks/ourservices/stormwatermanagement.

APPENDIX A

City of Cambridge Existing Site Conditions Maps

USGS Site Location
Aerial Photograph
FEMA National Flood Hazard Layer
Environmental Constraints
Soils

Drainage Area Maps and Land Coverage



Document Path: H:\Projects\2016\16124A HDR_ Willard St Cambridge SW\GIS\Maps\Permiting\Locus.mxd

*Boston North, Boston South, Lexington & Newton Topographic Quadrangles

Legend

Site Limits

N

0 1,500

1" = 1,500 feet

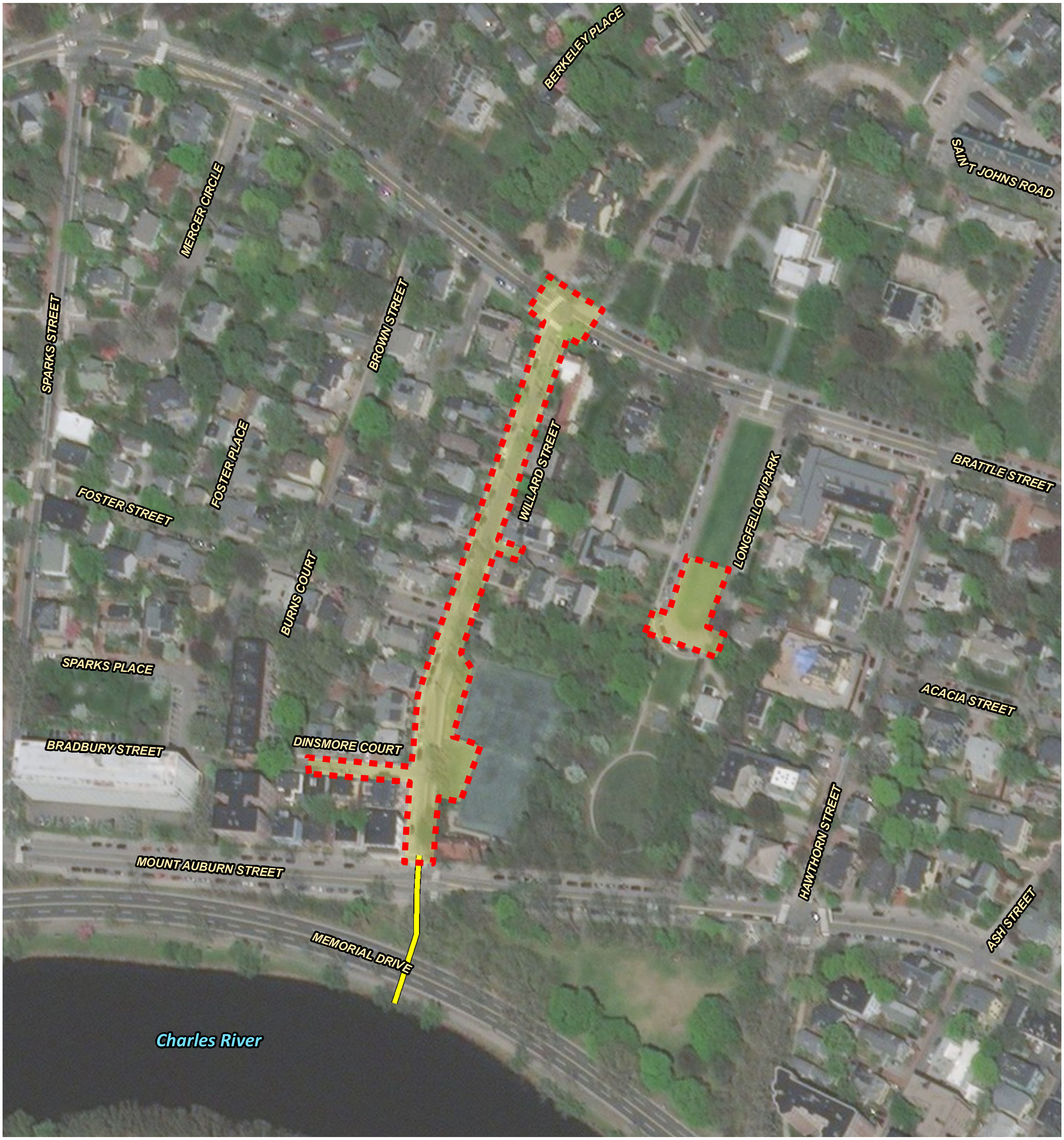
Horsley Witten Group
Sustainable Environmental Solutions
90 Route 6A • Unit 1 • Sandwich, MA 02563
508-833-6600 • horsleywitten.com

USGS Locus
Willard Street
Cambridge, MA

Date: 3/20/2018

Figure 1

*Bureau of Geographic Information (MassGIS), Commonwealth of Massachusetts, Executive Office of Technology and Security Services



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*Aerial Imagery - ESRI 2017

Legend

Site Limits

Restored Outfall

N

0 200

1" = 200 feet

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Sustainable Environmental Solutions
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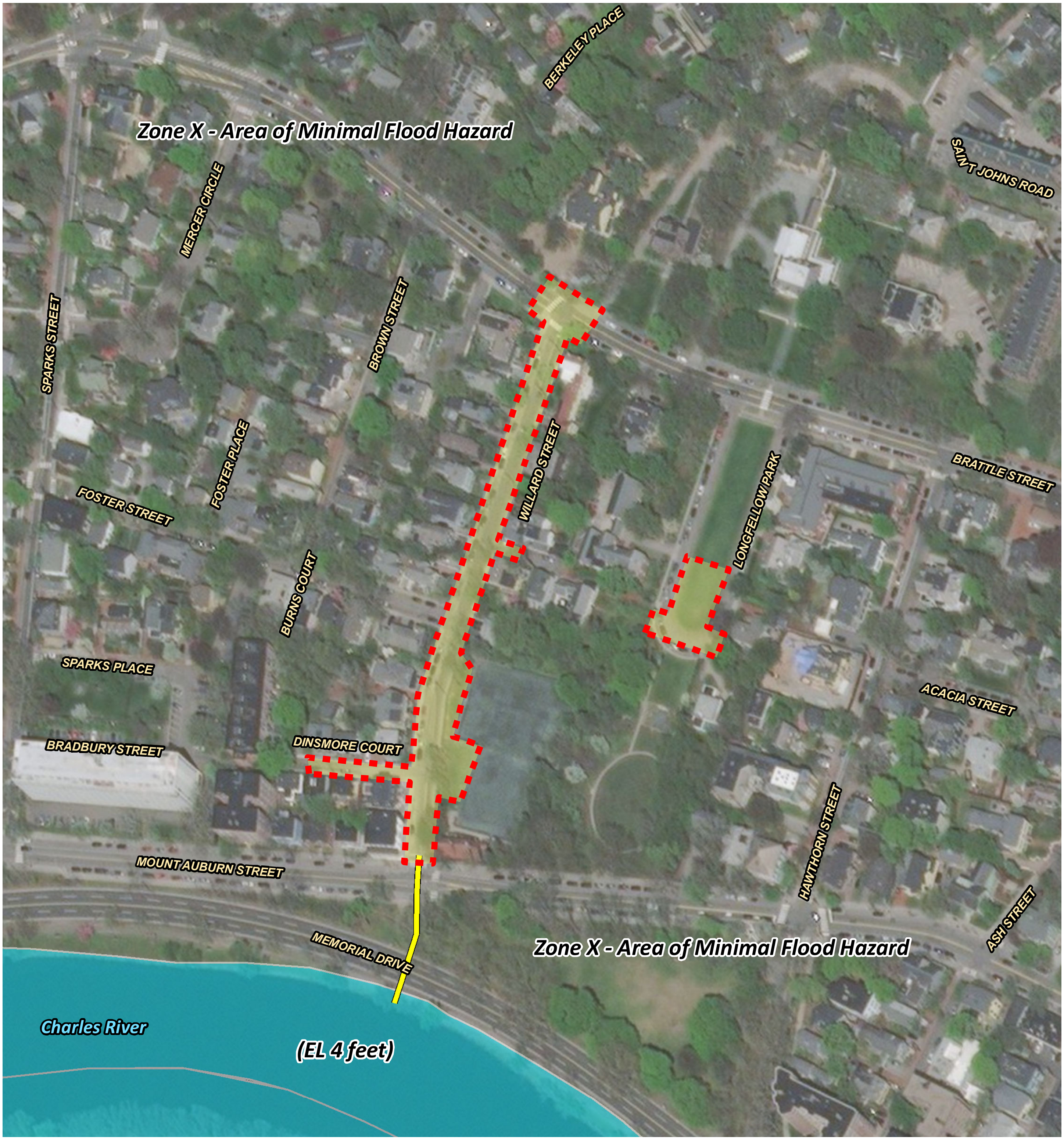
508-833-6600 • horsleywitten.com

Aerial Photo
Willard Street
Cambridge, MA

Date: 3/20/2018

Figure 2

*Bureau of Geographic Information (MassGIS), Commonwealth of Massachusetts, Executive Office of Technology and Security Services



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*Aerial Imagery - ESRI 2017

Legend

Site Limits

Restored Outfall

AE: 1% Annual Chance of Flooding, with BFE

N

0 200

1" = 200 feet

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Sustainable Environmental Solutions
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508-833-6600 • horsleywitten.com

FEMA's National Flood Hazard Layer
Willard Street
Cambridge, MA

Date: 3/20/2018

Figure 3

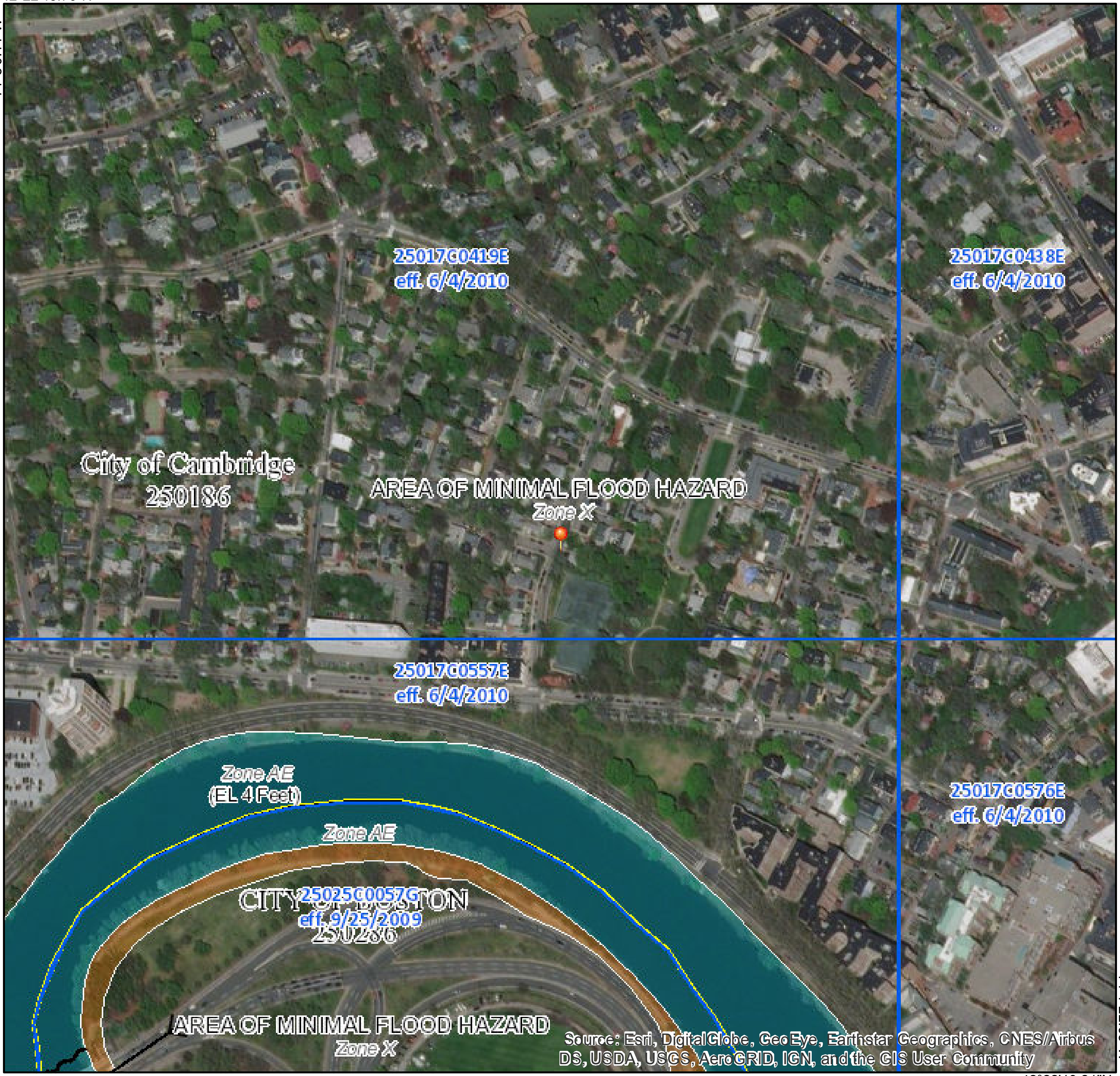
*Bureau of Geographic Information (MassGIS), Commonwealth of Massachusetts, Executive Office of Technology and Security Services

National Flood Hazard Layer FIRMette

FEMA

42°22'45.79"N

71°8'0.14"W



71°7'22.68"W

42°22'19.21"N

Feet

0 250 500 1,000 1,500 2,000

1:6,000

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth
- Regulatory Floodway *Zone AE, AO, AH, VE, AR*

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- B 20.2 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
- 8 Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

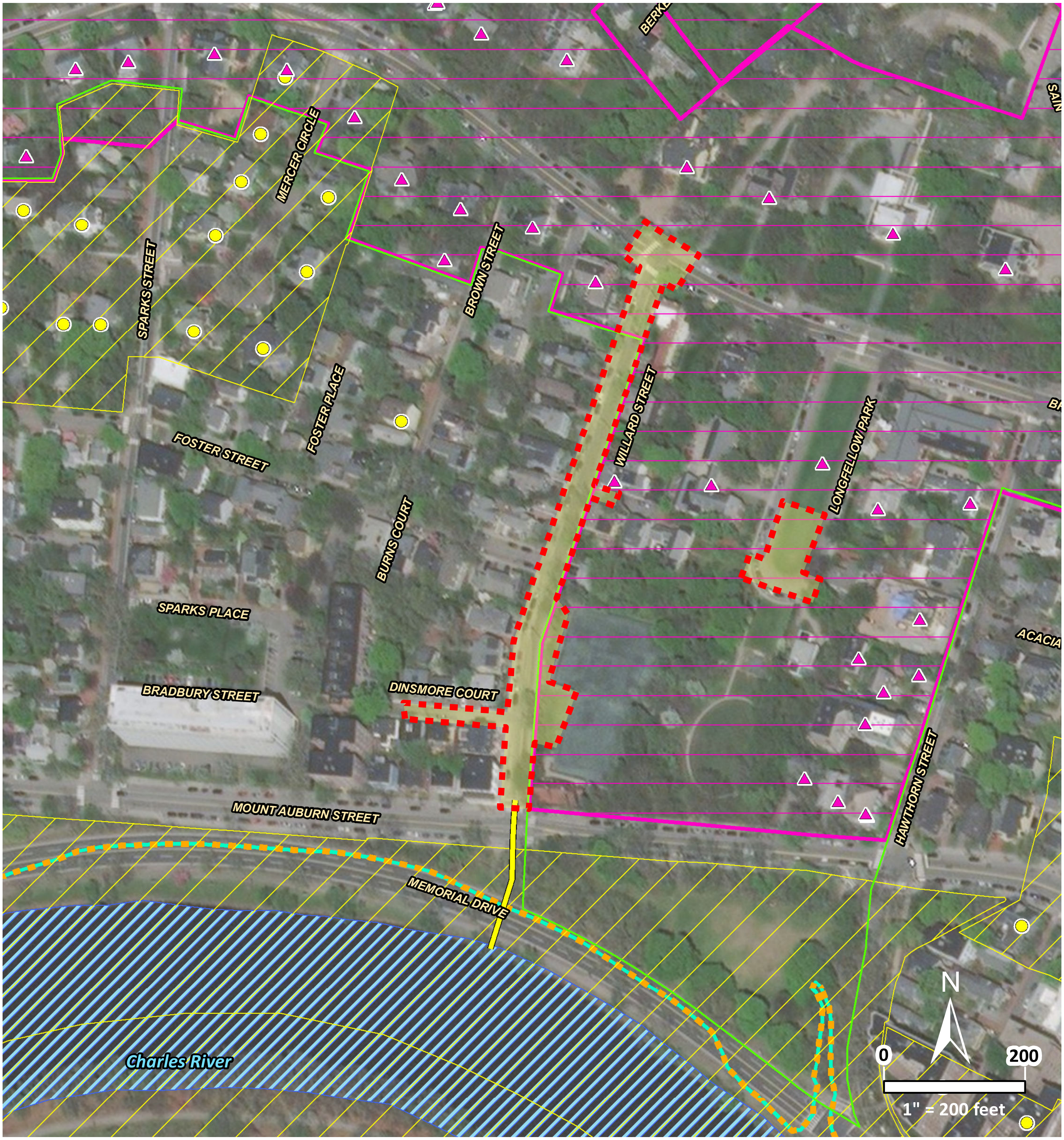
N

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The base map shown complies with FEMA's base map accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 3/20/2018 at 7:39:20 AM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: base map imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

Figure 3A



Document Path: H:\Projects\2016\16124A HDR_Willard St Cambridge SW\GIS\Maps\Permiting\Constraints.mxd

**Aerial Imagery - ESRI 2017*

Legend

Site Limits

Restored Outfall

DEP Wetlands

Open Water

Tidelands Jurisdiction

Jurisdiction

Historic High Water

MHC Historic Inventory

Nat'l Register of Historic Places

Nat'l Register Historic Places & Local Historic District

Local Historic District

Nat''l Registry Historic Places & Local Historic District

Nat'l Register of Historic Places

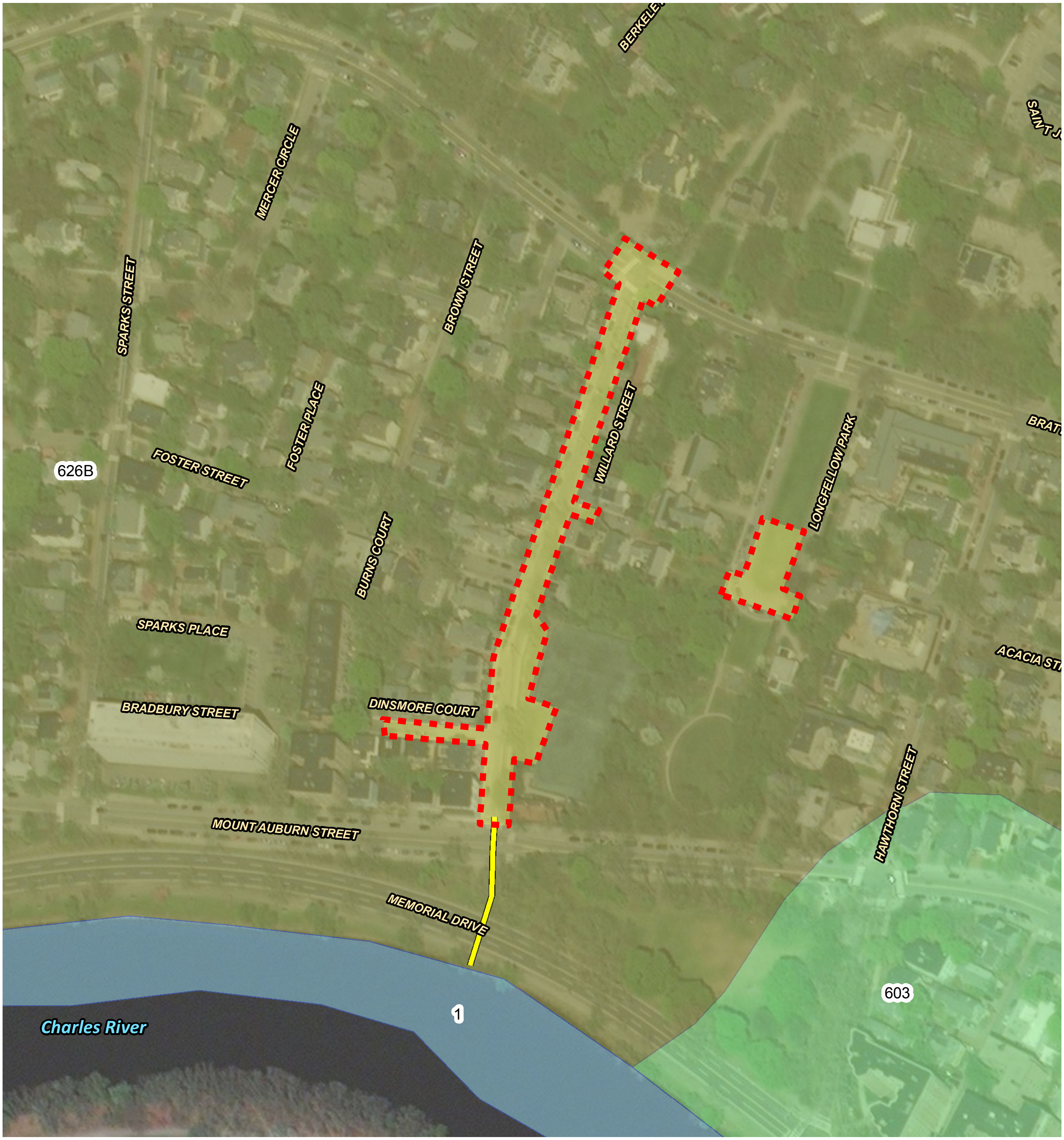
Horsley Witten Group
Sustainable Environmental Solutions
90 Route 6A • Unit 1 • Sandwich, MA 02563
508-833-6600 • horsleywitten.com

Environmental Constraints
Willard Street
Cambridge, MA

Date: 3/21/2018

Figure 4

**Bureau of Geographic Information (MassGIS), Commonwealth of Massachusetts, Executive Office of Technology and Security Services*



Document Path: H:\Projects\2016\16124A HDR_Willard St Cambridge SW\GIS\Maps\Permiting\Soil.mxd

Legend

Site Limits

Restored Outfall

**Aerial Imagery - ESRI 2017*

Map Unit Symbol, Name

1, Water

603, Urban Land, wet substratum

626B, Merrimac - Urban Land

N

0 200

1" = 200 feet

Horsley Witten Group

Sustainable Environmental Solutions

90 Route 6A • Unit 1 • Sandwich, MA 02563
508-833-6600 • horsleywitten.com

NRCS
Middlesex County Soil Map
Willard Street
Cambridge, MA

Date: 3/21/2018

Figure 5

**Bureau of Geographic Information (MassGIS), Commonwealth of Massachusetts, Executive Office of Technology and Security Services*

last modified: 03/20/18 printed: 03/20/18 by ml H:\Projects\2016\16124A HDR_Willard St Cambridge SW\Drawings\MISC\16124 DR.dwg

Revisions

Rev.	Date	By	Appr.	Description

Horsley Witten Group, Inc.
Sustainable Environmental Solutions
90 Route 6A
Sandwich, MA 02563
508-833-6600 voice
508-833-3150 fax

Date: 3/12/18
Design By:
Drawn By: MCL
Checked By: RAC

Plan Set:
WILLARD STREET
INFRASTRUCTURE IMPROVEMENTS
CAMBRIDGE, MASSACHUSETTS

Plan Title:
WATER QUALITY DA MAP

Registration:

Project Number: 16124A

Sheet Number: 1 of 3

Revisions

Rev. | Date | By | Appr. | Description

Horsley Witten Group, Inc.
Sustainable Environmental Solutions
90 Route 6A
Sandwich, MA 02563
508-833-6600 voice
508-833-3150 fax

Date: 3/12/18

Plan Set: WILLARD STREET INFRASTRUCTURE IMPROVEMENTS CAMBRIDGE, MASSACHUSETTS

Plan Title: PRE-CONSTRUCTION DA MAP

Registration:

Project Number: 16124A

Sheet Number: 2 of 3

last modified: 03/20/18 printed: 03/20/18 by ml H:\Projects\2016\16124A HDR_Willard St Cambridge SW\Drawings\MISC\16124 DR.dwg

LEGEND

DRAINAGE AREA BOUNDARY
- WOODS
- ROOFTOPS
- GRASS
- PAVEMENT
- SOIL BOUNDARY
- TIME OF CONCENTRATION FLOW PATH

SOIL TYPES

- 603 URBAN LAND, WET SUBSTRATUM
- 626B MERRIMAC-URBAN LAND COMPLEX (HSG A/D)

Revisions

Rev.	Date	By	Appr.	Description

Horsley Witten Group, Inc.
Sustainable Environmental Solutions
90 Route 6A
Sandwich, MA 02563
508-833-6600 voice
508-833-3150 fax

Date: 3/12/18
Design By:
Drawn By: MCL
Checked By: RAC

Plan Set: WILLARD STREET INFRASTRUCTURE IMPROVEMENTS CAMBRIDGE, MASSACHUSETTS

Plan Title: POST-CONSTRUCTION DA MAP

Registration:

Project Number: 16124A

Sheet Number: 3 of 3

last modified: 03/20/18 printed: 03/20/18 by ml H:\Projects\2016\16124A HDR_Willard St Cambridge SW\Drawings\MISC\16124 DR.dwg

APPENDIX B

Site Soil Report

Soil Boring Logs

United States Department of Agriculture

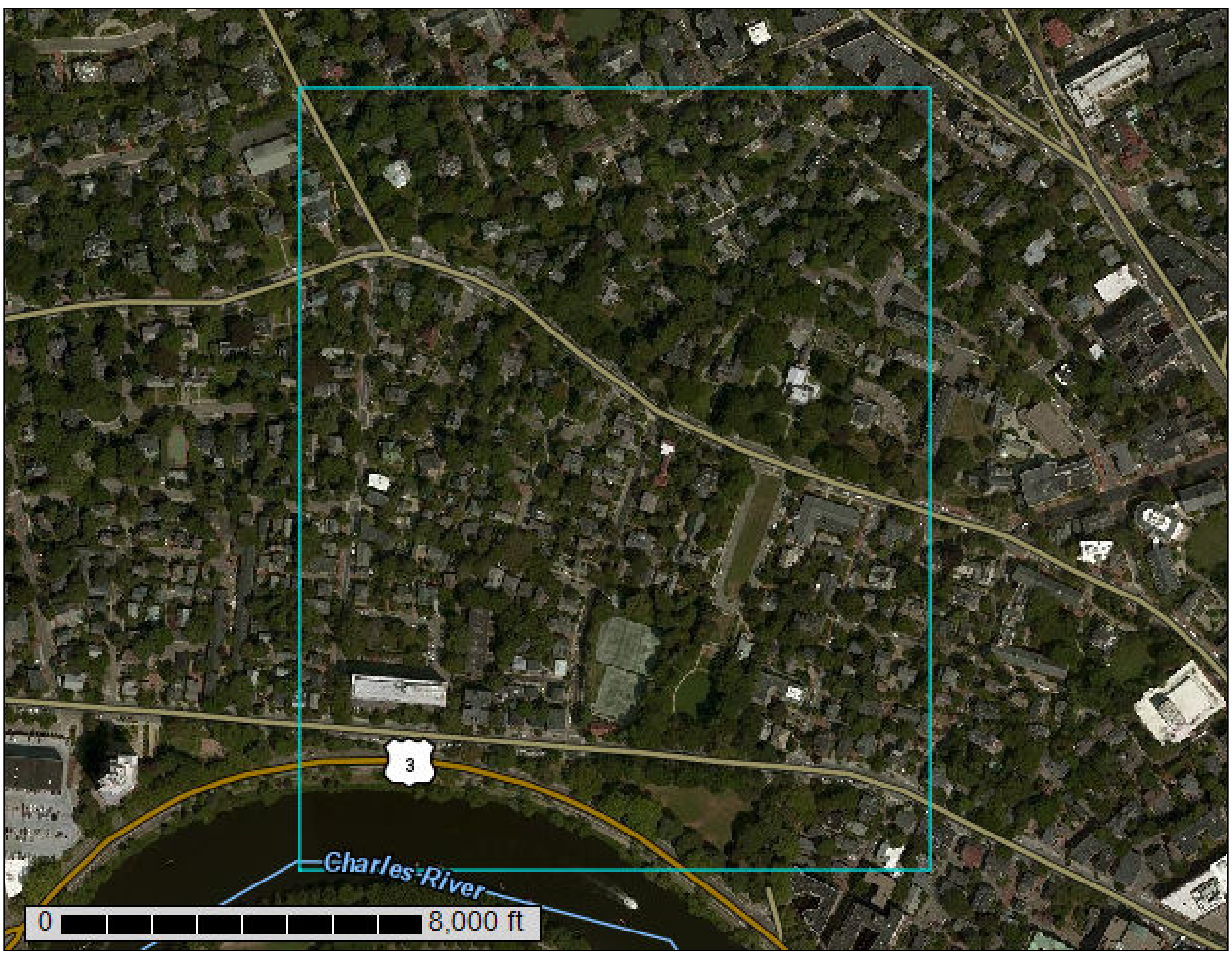
NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for Middlesex County, Massachusetts, and Norfolk and Suffolk Counties, Massachusetts

Willard Street Soils Report



March 18, 2018

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map

Map Scale: 1:3,600 if printed on A portrait (8.5" x 11") sheet.

Meters: 0, 50, 100, 200, 300

Feet: 0, 150, 300, 600, 900

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 19N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Map Unit Polygons

Soil Map Unit Lines

Soil Map Unit Points

Special Point Features

Blowout

Borrow Pit

Clay Spot

Closed Depression

Gravel Pit

Gravelly Spot

Landfill

Lava Flow

Marsh or swamp

Mine or Quarry

Miscellaneous Water

Perennial Water

Rock Outcrop

Saline Spot

Sandy Spot

Severely Eroded Spot

Sinkhole

Slide or Slip

Sodic Spot

Spoil Area

Stony Spot

Very Stony Spot

Wet Spot

Other

Special Line Features

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:25,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Middlesex County, Massachusetts
Survey Area Data: Version 17, Oct 6, 2017

Soil Survey Area: Norfolk and Suffolk Counties, Massachusetts
Survey Area Data: Version 13, Oct 6, 2017

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

MAP LEGEND	MAP INFORMATION
	Soil map units are labeled (as space allows) for map scales 1:50,000 or larger. Date(s) aerial images were photographed: Aug 10, 2014—Aug 11, 2014 The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
1	Water	1.9	2.9%
602	Urban land	1.2	1.9%
603	Urban land, wet substratum	3.9	5.9%
626B	Merrimac-Urban land complex, 0 to 8 percent slopes	58.3	87.8%
Subtotals for Soil Survey Area		**65.3**	**98.4%**
Totals for Area of Interest		**66.4**	**100.0%**

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
1	Water	1.0	1.6%
Subtotals for Soil Survey Area		**1.0**	**1.6%**
Totals for Area of Interest		**66.4**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Middlesex County, Massachusetts

1—Water

Map Unit Setting

National map unit symbol: 996p
Frost-free period: 110 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Water: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Water

Setting

Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Dip
Down-slope shape: Linear
Across-slope shape: Linear

602—Urban land

Map Unit Setting

National map unit symbol: 9950
Elevation: 0 to 3,000 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 110 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Urban land: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Urban Land

Setting

Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Base slope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Excavated and filled land

Minor Components

Rock outcrop

Percent of map unit: 5 percent
Landform: Ledges
Landform position (two-dimensional): Summit

Landform position (three-dimensional): Head slope
Down-slope shape: Concave
Across-slope shape: Concave

Udorthents, wet substratum
Percent of map unit: 5 percent
Hydric soil rating: No

Udorthents, loamy
Percent of map unit: 5 percent
Hydric soil rating: No

603—Urban land, wet substratum

Map Unit Setting
National map unit symbol: 9951
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 110 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition
Urban land: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Urban Land

Setting
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Base slope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Excavated and filled land over alluvium and/or marine deposits

Minor Components

Udorthents, loamy
Percent of map unit: 10 percent
Hydric soil rating: No

Rock outcrop
Percent of map unit: 5 percent
Landform: Ledges
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Head slope
Down-slope shape: Concave
Across-slope shape: Concave

626B—Merrimac-Urban land complex, 0 to 8 percent slopes

Map Unit Setting

National map unit symbol: 2tyr9
Elevation: 0 to 820 feet
Mean annual precipitation: 36 to 71 inches
Mean annual air temperature: 39 to 55 degrees F
Frost-free period: 140 to 250 days
Farmland classification: Not prime farmland

Map Unit Composition

Merrimac and similar soils: 45 percent
Urban land: 40 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Merrimac

Setting

Landform: Eskers, kames, outwash plains, outwash terraces, moraines
Landform position (two-dimensional): Backslope, footslope, shoulder, summit
Landform position (three-dimensional): Side slope, crest, riser, tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy glaciofluvial deposits derived from granite, schist, and gneiss over sandy and gravelly glaciofluvial deposits derived from granite, schist, and gneiss

Typical profile

Ap - 0 to 10 inches: fine sandy loam
Bw1 - 10 to 22 inches: fine sandy loam
Bw2 - 22 to 26 inches: stratified gravel to gravelly loamy sand
2C - 26 to 65 inches: stratified gravel to very gravelly sand

Properties and qualities

Slope: 0 to 8 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Somewhat excessively drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to very high (1.42 to 99.90 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 2 percent
Salinity, maximum in profile: Nonsaline (0.0 to 1.4 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 1.0
Available water storage in profile: Low (about 4.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2e
Hydrologic Soil Group: A
Hydric soil rating: No

Description of Urban Land

Typical profile

M - 0 to 10 inches: cemented material

Properties and qualities

Slope: 0 to 8 percent
Depth to restrictive feature: 0 inches to manufactured layer
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Very low (0.00 to 0.00 in/hr)
Available water storage in profile: Very low (about 0.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8
Hydrologic Soil Group: D
Hydric soil rating: Unranked

Minor Components

Windsor

Percent of map unit: 5 percent
Landform: Deltas, dunes, outwash plains, outwash terraces
Landform position (three-dimensional): Riser, tread
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex
Hydric soil rating: No

Sudbury

Percent of map unit: 5 percent
Landform: Deltas, outwash plains, terraces
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Tread, dip
Down-slope shape: Concave
Across-slope shape: Linear
Hydric soil rating: No

Hinckley

Percent of map unit: 5 percent
Landform: Deltas, eskers, kames, outwash plains
Landform position (two-dimensional): Summit, shoulder, backslope
Landform position (three-dimensional): Nose slope, crest, head slope, side slope, rise
Down-slope shape: Convex
Across-slope shape: Convex, linear
Hydric soil rating: No

Norfolk and Suffolk Counties, Massachusetts

1—Water

Map Unit Setting

National map unit symbol: vkyp
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 120 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Water: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

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Consulting
Engineers and
Scientists

December 1, 2017
Project 1610724

Mr. Roch Larochelle
HDR, Inc.
695 Atlantic Avenue
Boston, MA 02111

Dear Mr. Larochelle:

Re: **Geotechnical Explorations and Testing**
Willard Street Drainage Improvement Project
Cambridge, Massachusetts

This letter report presents the results of our subsurface explorations and laboratory testing performed for the Willard Street Drainage Improvement Project in Cambridge, Massachusetts. The explorations and testing were performed to collect data to support the design of proposed drainage improvement and mast arm traffic signals.

Scope of Work

Our scope of work consisted of the following:

- Reviewed available information.
- Engaged a subcontractor to perform four Geoprobe borings and two Standard Penetration Test (SPT) borings.
- Performed two grain size tests on soil samples collected from the Geoprobe borings.
- Prepared this letter report presenting the results of our explorations and laboratory tests.

Project Description

We understand that the project involves drainage improvements to sections of Willard Street and surrounding streets in Cambridge Massachusetts. The project will also include new overhead traffic signals (mast arms) at the intersection of Sparks Street and Mount Auburn Street.

Exploration Program

Northern Drill Service, Inc. of Northborough, Massachusetts, advanced four direct push Geoprobe borings (B1-B4) and two Standard Penetration Test (SPT) borings (MA-1 and MA-2A) in October 2017. The four Geoprobe borings were performed for proposed drainage improvements on Willard Street and Longfellow park. The two SPT borings were performed for proposed mast arm traffic signals at the intersection of Sparks Street and Mount Auburn Street. The boring locations are shown on Figures 1 to 3. The boring logs are provided in Appendix A.

GEI Consultants, Inc.
400 Unicorn Park Drive, Woburn, MA 01801
781.721.4000 fax: 781.721.4073

The Geoprobe borings were advanced using direct push drilling techniques to depths of about 20 feet. The SPT borings were advanced using rotary drilling techniques with driven casing to depths of 36 feet. Standard Penetration Tests (SPTs) were performed and split-spoon samples were collected continuously in the upper 26 feet of MA-1 and the upper 30 feet of MA-2A (note: boring MA-2 was discontinued after refusal was encountered at 3 feet). The SPTs were performed with an automatic hammer.

Laboratory Testing

We performed two grain size tests on soil samples collected from the Geoprobe borings. The samples were collects from the 5- to 10-foot sampling interval in B1 and B4. The results of the laboratory tests are provided in Appendix B.

Subsurface Conditions

Willard Street Drainage Improvements

The soils encountered in Geoprobe borings B1 and B4 typically consisted of sand and gravel fill, silty in places. B2 and B3 encountered similar fill to depths of about 4 and 18 feet, respectively, overlying peat and organic silt that extended to the Geoprobe termination depth of 20 feet. B1 and B4 were terminated in the sand and gravel fill. B2 and B3 were terminated in the peat and organic silt. Groundwater was encountered at 4 to 8 feet below ground surface.

Mast Arms at Intersection of Sparks Street and Mount Auburn Street

The soils encountered in the mast arm borings consisted of 10 feet of loose to medium-dense granular fill overlying 13 to 19 feet of soft to very soft fibrous peat and organic soil, overlying medium dense sand and gravel. Groundwater was encountered at 8 feet below ground surface.

Recommendations for Drainage Improvements

Soil descriptions on the exploration logs (Appendix A) and on the individual grain size distribution reports (Appendix B) are based on the Unified Soil Classification System. Also included in Appendix B is a figure that provides the results of the grain size analyses based on the United States Department of Agriculture (USDA) Soil Description System. The USDA soil descriptions were used to determine soil texture class, National Resource Conservation Services (NRCS) hydrologic soil group, and estimated infiltration rates (Rawls Rate) as described in the Massachusetts Stormwater Handbook. The soil texture class, hydrologic soil group, and Rawls Rates are provided in Table 1.

Recommendations for Mast Arms

The fill and organic soils are not suitable for support of Mast Arm foundations. We recommend the mast arms be supported on foundations extending into the underlying medium dense sand and gravel layer. The granular fill layer will provide most of the lateral support for the mast arm foundations.

Table 2 provides recommended soil parameters for design based on the guidance provided in the Massachusetts Department of Transportation (MassDOT) Standard Drawings titled "*Overhead Signal Structure and Foundation – Standard Drawings.*" The recommended soil parameters provided in Table 2 are for the granular fill layer and medium dense sand and gravel layer. Based on these findings, we recommend that the mast arm foundations be designed based on the "Loose Wet Sand" soil type and extend a minimum of 3 feet into the medium dense sand layer.

Our professional services for this project have been performed in accordance with generally accepted engineering practices; no warranty, express or implied, is made.

We appreciate the opportunity to work with you on this project. Please call Catherine Johnson at 781-721-4093 if you have any questions.

Sincerely,

GEI CONSULTANTS, INC.

Catherine Johnson

Catherine G. Johnson, PG, LSP.
Project Manager

Stephen J. Sarandis

Stephen J. Sarandis, P.E.
Geotechnical Engineer

SJS/CGJ:mrb

Attachments:

- Table 1 – Exploration Data and Estimated Infiltration Rates
- Table 2 – Soil Parameters for Mast Arms
- Fig. 1 – Site Plan
- Fig. 2 – Mast Arm Boring Location Plan
- Fig. 3 – Geoprobe Boring Location Plan
- Appendix A – Exploration Logs
- Appendix B – Laboratory Tests

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Tables

Table 1. Drainage Improvement Exploration Data and Estimated Infiltration Rates
Willard Street Drainage Improvement Project
Cambridge, Massachusetts

Exploration Number	Approximate Depth to Groundwater (ft)	Field Classification of Soil Based on Unified Soil Classification System [1]	USDA Soil Texture[2]	NRCS Hydrologic Soil Group [3]	Rawls Infiltration Rate (in/hr) [4]
B1	8.0	Narrowly Graded Sand With Gravel (SP)	Sand	A	8.27
B2	4.0	Organic Silt and Peat	--	--	--
B3	6.0	Widely Graded Sand with Silt and Gravel (SW-SM)/ Silty Sand (SM)	--	--	--
B4	5.5	Narrowly Graded Sand with Gravel (SP)	Sand	A	8.27

Notes:
1. Field classification of soils is from samples collected from a depth of 5 to 10 feet.
2. USDA soil texture is from Fig. 2.3.2, of the Massachusetts Stormwater Handbook (Vol 3, Ch. 1) based on the results of grain size tests performed on soil samples collected from the explorations at a depth of 5 to 10 feet.
3. NRCS hydrologic soil group is from Table 2.3.3, of the Massachusetts Stormwater Handbook (Vol. 3, Ch. 1).
4. Rawls Infiltration Rate is based on the National Resources Conservation Service Hydrologic Soil Group encountered in the borings, based on recommendations in Table 2.3.3, of the Massachusetts Stormwater Handbook (Vol. 3, Ch. 1).

Table 2. Soil Parameters for Mast Arms
Willard Street Drainage Improvement Project
Cambridge, Massachusetts

Boring Number	Depth (ft)	Soil Type	Unit Weight (pcf)	Friction Angle	Shear Strength (ksf)
MA-1	0 - 8	Loose Dry Sand	102	33	--
MA-1	8 - 10	Loose Wet Sand	125	33	--
MA-1	**>23**	Dense Wet Sand	135	39	--
MA-2A	0 - 8	Loose Dry Sand	102	33	--
MA-2A	8 - 10	Loose Wet Sand	125	33	--
MA-2A	**>29**	Dense Wet Sand	135	39	--

Notes:

1. Soil Parameters are based on the basis of design table from MassDOT "Overhead Signal Structure & Foundation - Standard Drawings."

Figures

Willard Street Drainage Improvement Cambridge, Massachusetts	GEI Consultants	SITE PLAN	
HDR, Inc. Boston, Massachusetts	Project 1610724	December 2017	Fig. 1

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GOOGLE EARTH IMAGED DATED 4/14/2017.

LEGEND:

BORING BY GEI, 2017

0 25 50
Approximate Scale, Feet

Willard Street Drainage Improvement
Cambridge, Massachusetts

HDR, Inc.
Boston, Massachusetts

GEI Consultants

Project 1610724

MAST BORING PLAN

December 2017

Fig. 2

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LEGEND:

BORING BY GEI, 2017

0 80 160

Approximate Scale, Feet

Willard Street Drainage Improvement Cambridge, Massachusetts	GEI Consultants	GEOPROBE BORING PLAN	
HDR, Inc. Boston, Massachusetts	Project 1610724	December 2017	Fig. 3

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Appendix A

Exploration Logs

BORING INFORMATION

LOCATION: Longfellow Park.

GROUND SURFACE EL. (ft): NM

DATE START/END: 10/23/2017 - 10/27/2017

VERTICAL DATUM: NA

DRILLING COMPANY: Northern Drill Service, Inc.

TOTAL DEPTH (ft): 20.0

DRILLER NAME: C. DeVillers, Z. Fleming

LOGGED BY: L. Tobey

RIG TYPE: Geoprobe 6620DT

BORING B1

PAGE 1 of 1

DRILLING INFORMATION

HAMMER TYPE: NA

CASING I.D./O.D.: 2 inch / 2.5 inch

CORE BARREL TYPE: NA

AUGER I.D./O.D.: NA / NA

DRILL ROD O.D.: NM

CORE BARREL I.D./O.D. NA / NA

DRILLING METHOD: Direct Push

WATER LEVEL DEPTHS (ft): Minimum depth to groundwater estimated at 8 feet based on dampness of soil samples.

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation
= Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample Information: Sample No.	Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
			0 to 5	60		Vac-Ex to ~5'.	FILL/SAND/GRAVEL	Appears to be widely graded sand with gravel. No sample.
	5	S1	5 to 10	60/24		Geoprobe 5-20'.		S1: NARROWLY GRADED SAND WITH GRAVEL (SP); ~80.6% mostly fine to medium sand, ~15.3% subrounded fine gravel up to 1.5", ~4.1% nonplastic fines, brown, moist. <Grain Size>
	10	S2	10 to 15	60/52				S2(0-11"): Similar to S1, but wet. S2(11-52"): NARROWLY GRADED SAND (SP); ~95% fine to medium sand, ~5% nonplastic fines, light brown, red staining at 30", wet.
	15	S3	15 to 20	60/60				S3(0-45"): Similar to S2(11-52") but light brown 0-22", dark brown 22-28", and red 28-45". S3(45-60"): SILTY SAND (SM); ~85% fine sand, ~15% nonplastic fines, light brown.
	20							Bottom of boring 20 feet. Backfilled with cuttings, patched with grass.

NOTES:

PROJECT NAME: Willard Street Drainage Improvement

CITY/STATE: Cambridge, Massachusetts

GEI PROJECT NUMBER: 1610724

GEI Consultants

BORING INFORMATION

LOCATION: Cambridge Tennis Club courts.

GROUND SURFACE EL. (ft): NM

VERTICAL DATUM: NA

TOTAL DEPTH (ft): 20.0

LOGGED BY: L. Tobey

DATE START/END: 10/27/2017 - 10/27/2017

DRILLING COMPANY: Northern Drill Service, Inc.

DRILLER NAME: C. DeVillers, Z. Fleming

RIG TYPE: Geoprobe 6620DT

BORING B2

DRILLING INFORMATION

HAMMER TYPE: NA

AUGER I.D./O.D.: NA / NA

DRILLING METHOD: Direct Push

CASING I.D./O.D.: 2 inch / 2.5 inch

DRILL ROD O.D.: NM

CORE BARREL TYPE: NA

CORE BARREL I.D./O.D. NA / NA

WATER LEVEL DEPTHS (ft): Depth to groundwater estimated at 4 feet based on dampness of soil samples.

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation
= Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
	0	S1	0 to 2.5	30		Hand-dug to ~2.5'.	FILL	S1: SANDY SILT WITH GRAVEL (ML); ~60% nonplastic fines, ~20% fine sand, ~20% subrounded gravel up to 2", brown.
		S2	2.5 to 5	30/26		Geoprobe 2.5-20'.	FILL	S2(0-1"): Similar to S1. S2(1-7"): SILTY SAND (SM); ~60% fine sand, ~40% nonplastic fines, light brown. S2(7-19"): SILT WITH GRAVEL (ML); ~80% low-plasticity fines, ~20% subangular gravel to 0.75", light brown/gray. S2(19-26"): NARROWLY GRADED SAND WITH GRAVEL (SP): ~70% fine to medium sand, ~25% subrounded gravel up to 1.25", ~5% nonplastic fines, wet.
	5	S3	5 to 11	72/14			PEAT/ORGANICS/CLAY	S3(0-2"): Similar to S2(19-26"). S3(2-14"): PEAT (PT); ~100% low-plasticity fines, fibrous, dark gray, moist, organic odor.
	10	S4	11 to 15	48/27			PEAT/ORGANICS/CLAY	S4(0-4"): Similar to S3(2-14"). S4(4-27"): ORGANIC SILT (ML); ~100% low-plasticity fines, trace organics, gray, moist, organic odor.
	15	S5	15 to 20	60/37			PEAT/ORGANICS/CLAY	S5(0-13"): PEAT (PT); ~100% low-plasticity fines, fibrous, dark gray, moist, organic odor. S5(13-37"): ORGANIC SILT (ML); ~100% low-plasticity fines, trace organics, gray, moist, organic odor.
	20							Bottom of boring 20 feet. Backfilled with cuttings, patched with grass.

NOTES:

PROJECT NAME: Willard Street Drainage Improvement

CITY/STATE: Cambridge, Massachusetts

GEI PROJECT NUMBER: 1610724

GEI Consultants

BORING INFORMATION

LOCATION: Willard Street.

GROUND SURFACE EL. (ft): NM | **DATE START/END:** 10/23/2017 - 10/27/2017

VERTICAL DATUM: NA | **DRILLING COMPANY:** Northern Drill Service, Inc.

TOTAL DEPTH (ft): 20.0 | **DRILLER NAME:** C. DeVillers, Z. Fleming

LOGGED BY: L. Tobey | **RIG TYPE:** Geoprobe 6620DT

BORING B3

DRILLING INFORMATION

HAMMER TYPE: NA | **CASING I.D./O.D.:** 2 inch / 2.5 inch | **CORE BARREL TYPE:** NA

AUGER I.D./O.D.: NA / NA | **DRILL ROD O.D.:** NM | **CORE BARREL I.D./O.D.** NA / NA

DRILLING METHOD: Direct Push

WATER LEVEL DEPTHS (ft): Minimum depth to groundwater estimated at 6 feet based on oxidation of soil samples.

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation = Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
	0		0 to 5	60		Vac-Ex to ~5'.	FILL/SAND/GRAVEL	Appears to be widely graded sand with gravel. No sample.
	5	S1	5 to 10	60/38		Geoprobe 5-20'.	FILL/SAND/GRAVEL	S1(0-19"): WIDELY GRADED SAND WITH SILT AND GRAVEL (SW-SM); ~75% sand, ~15% subrounded gravel up to 1", 10% nonplastic fines, reddish brown, signs of oxidation at 10". S1(19-38"): SILTY SAND (SM); ~80% fine to medium sand, ~20% nonplastic fines, light brown.
	10	S2	10 to 15	60/43			FILL/SAND/GRAVEL	S2(0-11"): Similar to S1(19-38"). S2(11-26"): NARROWLY GRADED SAND WITH SILT (SP-SM); ~90% fine sand, 10% nonplastic fines, reddish brown, wet. S2(26-28"): NARROWLY GRADED SAND (SP); ~85% fine to medium sand, ~10% subrounded gravel to 0.25", ~5% nonplastic fines, dark brown, wet. S2(28-43"): SILTY SAND (SM); ~80% fine to medium sand, ~20% nonplastic fines, red, wet.
	15	S3	15 to 20	60/45			FILL/SAND/GRAVEL	S3(0-23"): Similar to S2(28-43") but thick sheen, petroleum-like odor from 0-12". S3(23-38"): WIDELY GRADED SAND (SW); ~85% mostly fine to medium sand, ~10% subrounded gravel up to 0.25", ~5% nonplastic fines, red, wet.
							SILT	S3(38-45"): ORGANIC SILT (ML); ~100% low-plasticity fines, trace organics, gray, moist, organic odor.
	20							Bottom of boring 20 feet. Backfilled with cuttings, topped with Perma-Patch.

NOTES:

PROJECT NAME: Willard Street Drainage Improvement

CITY/STATE: Cambridge, Massachusetts

GEI PROJECT NUMBER: 1610724

GEI Consultants

BORING INFORMATION		BORING B4
LOCATION: Willard Street.		PAGE 1 of 1
GROUND SURFACE EL. (ft): NM	DATE START/END: 10/23/2017 - 10/27/2017	
VERTICAL DATUM: NA	DRILLING COMPANY: Northern Drill Service, Inc.	
TOTAL DEPTH (ft): 20.0	DRILLER NAME: C. DeVillers, Z. Fleming	
LOGGED BY: L. Tobey	RIG TYPE: Geoprobe 6620DT	

DRILLING INFORMATION

HAMMER TYPE: NA	CASING I.D./O.D.: 2 inch / 2.5 inch	CORE BARREL TYPE: NA
AUGER I.D./O.D.: NA / NA	DRILL ROD O.D.: NM	CORE BARREL I.D./O.D. NA / NA

DRILLING METHOD: Direct Push

WATER LEVEL DEPTHS (ft): Depth to groundwater estimated at 5.5 feet based on oxidation of soil samples.

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation = Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
	0		0 to 5	60		Vac-Ex to ~5'.	FILL/SAND/GRAVEL	Appears to be widely graded sand with gravel. No sample.
	5	S1	5 to 10	60/38		Geoprobe 5-20'.		S1(0-36"): NARROWLY GRADED SAND WITH GRAVEL (SP); ~66.7% mostly medium sand, ~30.7% fine gravel up to 1", ~2.6%% nonplastic fines, reddish brown, signs of oxidation at 5". <Grain Size> S1(36-38"): SILTY SAND (SM); ~80% fine to medium sand, ~20% nonplastic fines, light brown, wet.
	10	S2	10 to 15	60/44				S2(0-23"): Similar to S1(36-38"). S2(23-27"): NARROWLY GRADED SAND (SP); ~85% fine to medium sand, ~10% subrounded gravel to 0.25", ~5% nonplastic fines, dark brown, wet. S2(27-31"): WIDELY GRADED SAND WITH SILT AND GRAVEL (SW-SM); ~75% sand, ~15% coarse gravel up to 1", ~10% nonplastic fines, reddish brown, wet. S2(31-44"): SILTY SAND (SM); ~70% fine sand, ~30% nonplastic fines, light brown, wet.
	15	S3	15 to 20	60/48				S3(0-7"): Similar to S2(31-44") but thick sheen, petroleum-like odor. S3(7-16"): NARROWLY GRADED SAND WITH GRAVEL (SP); ~80% fine to medium sand, ~15% subrounded gravel up to 0.5", ~5% nonplastic fines, thick sheen and petroleum-like odor from 7-12", dark brown, wet. S3(16-32"): SILTY SAND (SM); ~70% fine sand, ~30% nonplastic fines, light brown, wet. S3(32-36"): WIDELY GRADED SAND WITH SILT (SW-SM); ~85% sand, ~10% nonplastic fines, ~5% subangular gravel up to 0.25", red, wet. S3(36-48"): SILTY SAND (SM); ~70% fine sand, ~30% nonplastic fines, red, wet.
	20							
	25							Bottom of boring 20 feet. Backfilled with cuttings, topped with Perma-Patch.

NOTES:

PROJECT NAME: Willard Street Drainage Improvement

CITY/STATE: Cambridge, Massachusetts

GEI PROJECT NUMBER: 1610724

GEI Consultants

BORING INFORMATION

LOCATION: Corner of Mt. Auburn and Sparks St. See map.

GROUND SURFACE EL. (ft): NM | **DATE START/END:** 10/18/2017 - 10/20/2017

VERTICAL DATUM: NA | **DRILLING COMPANY:** Northern Drill Service, Inc.

TOTAL DEPTH (ft): 36.0 | **DRILLER NAME:** C. Beirholm, Z. Nader

LOGGED BY: L. Tobey | **RIG TYPE:** Mobile B-57 Truck

BORING MA-1

DRILLING INFORMATION

HAMMER TYPE: Automatic | **CASING I.D./O.D.:** 4 inch / NA | **CORE BARREL TYPE:** NA

AUGER I.D./O.D.: NA / NA | **DRILL ROD O.D.:** NM | **CORE BARREL I.D./O.D.** NA / NA

DRILLING METHOD: Drive and Wash

WATER LEVEL DEPTHS (ft): ▼ 7.8 10/20/2017 9:20 am Measured in casing.

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation = Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
			0 to 6	72		Vac-Ex to ~5.5'.	FILL	~4" Concrete (sidewalk) SILTY SAND WITH GRAVEL (SM); ~70% mostly fine to medium sand, ~15% fine to coarse gravel up to 4", ~15% nonplastic fines, brown, moist. ~1' subangular boulder encountered at 4.5'.
	5							
		S1	6 to 8	24/10	8-8-6-8	Continuous sampling 6-26'.		S1: SILTY SAND (SM); ~75% mostly fine to medium sand, ~15% nonplastic fines, ~10% fine gravel up to 0.25", brown, damp.
		S2	8 to 10	24/11	10-9-5-2			S2: SILTY SAND WITH GRAVEL (SM); ~60% fine to medium sand, ~25% coarse gravel up to 1.5", ~15% nonplastic fines, brown, wet.
	10	S3	10 to 12	24/14	1-WOH-WOH-1		PEAT/ORGANICS/SILT	S3: PEAT (PT); ~100% low-plasticity fines, fibrous, dark gray, organic odor, moist.
		S4	12 to 14	24/8	WOR-2-2-2			S4: PEAT (PT)/ORGANIC SOIL (OL); ~90% low-plasticity fines, ~10% fine sand, dark gray, organic odor, moist.
	15	S5	14 to 16	24/24	WOR-WOH-WOH-2			S5: PEAT (PT); ~100% low-plasticity fines, fibrous, dark gray, organic odor, moist.
		S6	16 to 18	24/6	1-1-1-1			S6: Similar to S5, but wet.
		S7	18 to 20	24/17	WOH-WOH-WOH-1			S7: ORGANIC SILT (ML); ~100% low-plasticity fines, dark gray, moist, trace organics, strong organic odor.
	20	S8	20 to 22	24/22	WOR-WOH-WOH-WOH	First drive had no recovery. Redrove with 3" split spoon.		S8: Similar to S7.

NOTES:

PROJECT NAME: Willard Street Drainage Improvement

CITY/STATE: Cambridge, Massachusetts

GEI PROJECT NUMBER: 1610724

GEI Consultants

LOCATION: Corner of Mt. Auburn and Sparks St. See map.
GROUND SURFACE EL. (ft): NM
VERTICAL DATUM: NA
DATE START/END: 10/18/2017 - 10/20/2017
DRILLING COMPANY: Northern Drill Service, Inc.

BORING MA-1

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		S9	22 to 24	24/24	WOH-1-1-2			S9(0-11"): ORGANIC SILT (ML); ~100% low-plasticity fines, dark gray, moist, trace organics, strong organic odor.
							SILT/SAND/GRAVEL	S9(11-24"): SANDY SILT (ML); ~65% low-plasticity fines, ~30% fine sand, ~5% fine gravel up to 0.25", dark gray, moist.
	25	S10	24 to 26	24/17	5-13-22-14		SILT/SAND/GRAVEL	S10: WIDELY GRADED SAND WITH SILT AND GRAVEL (SW-SM); ~60% sand, ~30% coarse gravel up to 1", ~10% nonplastic fines, gray, wet, slight organic odor.
			26 to 29	36		Pushed 4" casing, begin standard sampling.	SILT/SAND/GRAVEL	
	30	S11	29 to 31	24/13	5-8-10-11		SILT/SAND/GRAVEL	S11(0-3"): WIDELY GRADED SAND (SW); ~95% sand, 5% nonplastic fines, brown/gray, wet. S11(3-9"): WIDELY GRADED GRAVEL WITH SAND (GW); ~70% fine to coarse gravel to 1", ~30% mostly coarse sand, brown/gray, wet.
			31 to 34	36		Pushed 4" casing.	SILT/SAND/GRAVEL	S11(9-13"): NARROWLY GRADED SAND WITH SILT (SP-SM); ~90% fine to medium sand, ~10% nonplastic fines, gray, wet.
	35	S12	34 to 36	24/8	7-11-12-15		SILT/SAND/GRAVEL	S12: Similar to S11(9-13").
	40							Bottom of boring 36 feet. Backfilled with cuttings and gravel, topped with concrete patch.
	45							
	50							

NOTES:

PROJECT NAME: Willard Street Drainage Improvement
CITY/STATE: Cambridge, Massachusetts
GEI PROJECT NUMBER: 1610724

GEI Consultants

BORING INFORMATION

LOCATION: River side of Mt. Auburn St. See map.

GROUND SURFACE EL. (ft): NM | **DATE START/END:** 10/18/2017 - 10/19/2017

VERTICAL DATUM: NA | **DRILLING COMPANY:** Northern Drill Service, Inc.

TOTAL DEPTH (ft): 36.0 | **DRILLER NAME:** C. Beirholm, Z. Nader

LOGGED BY: C. Conlee | **RIG TYPE:** Mobile B-57 Truck

BORING MA-2A

DRILLING INFORMATION

HAMMER TYPE: Automatic | **CASING I.D./O.D.:** 4 inch / NA | **CORE BARREL TYPE:** NA

AUGER I.D./O.D.: NA / NA | **DRILL ROD O.D.:** NM | **CORE BARREL I.D./O.D.** NA / NA

DRILLING METHOD: Drive and Wash

WATER LEVEL DEPTHS (ft): ▼ 7.8 10/19/2017 11:00 am Measured in casing.

ABBREVIATIONS:
Pen. = Penetration Length
Rec. = Recovery Length
RQD = Rock Quality Designation = Length of Sound Cores>4 in / Pen.,%
WOR = Weight of Rods
WOH = Weight of Hammer
S = Split Spoon Sample
C = Core Sample
U = Undisturbed Sample
SC = Sonic Core
DP = Direct Push Sample
HSA = Hollow-Stem Auger
Qp = Pocket Penetrometer Strength
Sv = Pocket Torvane Shear Strength
LL = Liquid Limit
PI = Plasticity Index
PID = Photoionization Detector
I.D./O.D. = Inside Diameter/Outside Diameter
NA, NM = Not Applicable, Not Measured
Blows per 6 in.: 140-lb hammer falling 30 inches to drive a 2-inch-O.D. split spoon sampler.

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
			0 to 6	72		Vac-Ex to ~6.75'. Black rubber tar fragment found at ~2'.	FILL	~4" Concrete (sidewalk). SILTY SAND WITH GRAVEL (SM); ~70% mostly fine to medium sand, ~15% fine to coarse gravel, ~15% nonplastic fines, brown, moist. Cobbles up to ~4".
	5							
		S1	6 to 8	24/7	2-1-2-3	Continuous sampling 6-30'.		S1: SILTY SAND WITH GRAVEL (SM); ~60% mostly fine to medium sand, ~25% nonplastic fines, ~15% mostly fine to medium gravel up to 0.25", brown, wet.
		S2	8 to 10	24/9	4-3-3-4			S2: SILTY SAND (SM); ~75% mostly fine to medium sand, ~15% nonplastic fines, ~10% fine gravel up to 0.25", brown, wet.
	10	S3	10 to 12	24/2	2-1-WOH-WOH	First drive had no recovery. Redrove with 3" split spoon (2-1-WOH-1).	PEAT/ORGANICS/SILT	S3: SILT WITH SAND (ML); ~70% nonplastic fines, ~30% mostly fine sand, trace gravel, dark gray, wet, slight organic odor.
		S4	12 to 14	24/20	1-WOH-1-1			S4(0-5"): Similar to S3. S4(5-20"): PEAT (PT); ~100% low-plasticity fines, fibrous, dark gray, moist, organic odor.
		S5	14 to 16	24/24	1-1-1-1			S5: Similar to S4(5-20").
	15							
		S6	16 to 18	24/24	2-1-1-3			S6: PEAT (PT); ~100% medium-plasticity fines, trace fine gravel 10-12", orange mottling 12-24", dark gray, moist, organic odor.
		S7	18 to 20	24/24	WOR-1-1-1			S7: ORGANIC SOIL (OL); ~100% medium-plasticity fines, trace organic mottling, trace fibers, dark gray, moist, strong organic odors.
	20	S8	20 to 22	24/24	WOR-WOH-1-WOH			S8: Similar to S7.

NOTES:

PROJECT NAME: Willard Street Drainage Improvement

CITY/STATE: Cambridge, Massachusetts

GEI PROJECT NUMBER: 1610724

GEI Consultants

LOCATION: River side of Mt. Auburn St. See map.		BORING MA-2A
GROUND SURFACE EL. (ft): NM	DATE START/END: 10/18/2017 - 10/19/2017	
VERTICAL DATUM: NA	DRILLING COMPANY: Northern Drill Service, Inc.	PAGE 2 of 2

Elev. (ft)	Depth (ft)	Sample No.	Sample Depth (ft)	Pen./ Rec. (in)	Blows per 6 in. or RQD	Drilling Remarks/ Field Test Data	Layer Name	Soil and Rock Description
		S9	22 to 24	24/24	WOR-1-1-1		PEAT/ORGANICS/SILT	S9(0-18"): ORGANIC SOIL (OL); ~100% medium-plasticity fines, trace organic mottling, trace fibers, dark gray, moist, organic odor. S9(18-24"): ORGANIC SILT (ML); ~100% low-plasticity fines, trace organics, dark gray, moist, organic odors.
	25	S10	24 to 26	24/19	2-2-4-1			S10: Similar to S9(18-24").
		S11	26 to 28	24/24	1-WOH-1-1			S11: ORGANIC SILT (ML); ~100% low-plasticity fines, trace organics, dark gray, moist, organic odors.
		S12	28 to 30	24/12	3-9-21-21			S12(0-3"): Similar to S11.
							SAND/GRAVEL	S12(3-12"): WIDELY GRADED SAND WITH SILT AND GRAVEL (SW-SM): ~60% sand, ~30% fine gravel up to 0.25", ~10% nonplastic fines, dark gray, wet.
	30		30 to 34	48		Standard sampling 30-36'. Pushed 4" casing.		
	35	S13	34 to 36	24/19	4-9-13-19			S13(0-10"): WIDELY GRADED SAND (SW); ~95% sand, ~5% nonplastic fines, brown, wet. S13(10-13"): WIDELY GRADED GRAVEL WITH SAND (GW); ~70% gravel up to 0.5", ~30% mostly coarse sand, brown/gray, wet.
								S13(13-19"): NARROWLY GRADED SAND (SP); ~90% mostly fine to medium sand, ~10% nonplastic fines, brown, wet. Bottom of boring 36 feet. Backfilled with cuttings and gravel, topped with concrete patch.
	40							
	45							
	50							

NOTES:

PROJECT NAME: Willard Street Drainage Improvement

CITY/STATE: Cambridge, Massachusetts

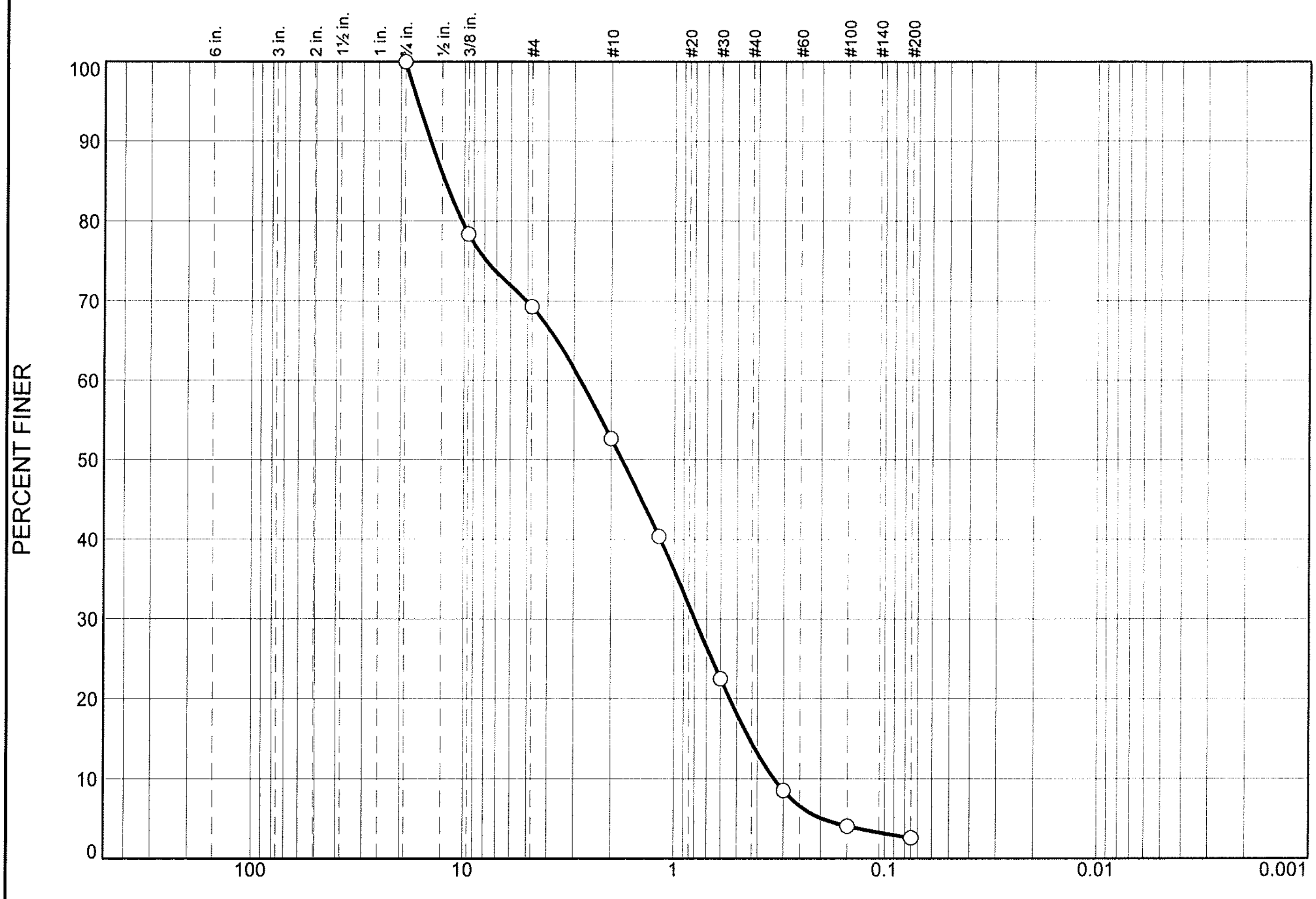
GEI PROJECT NUMBER: 1610724

GEI Consultants

Appendix B

Laboratory Tests

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines
		Coarse	Fine	Coarse	Medium	Fine	
○	0.0	0.0	30.7	16.6	38.2	11.9	2.6

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	-	-	12.2961	2.7963	1.7756	0.7961	0.4357	0.3327	0.68	8.40

Material Description	USCS	AASHTO
○ Narrowly Graded SAND with Gravel	SP	-

Project No. 1610724 **Client:** HDR

Project: Willard Street Drainage

○ **Source of Sample:** B4 **Depth:** 5-10 ft **Sample Number:** S1 (0-36 in)

Remarks:

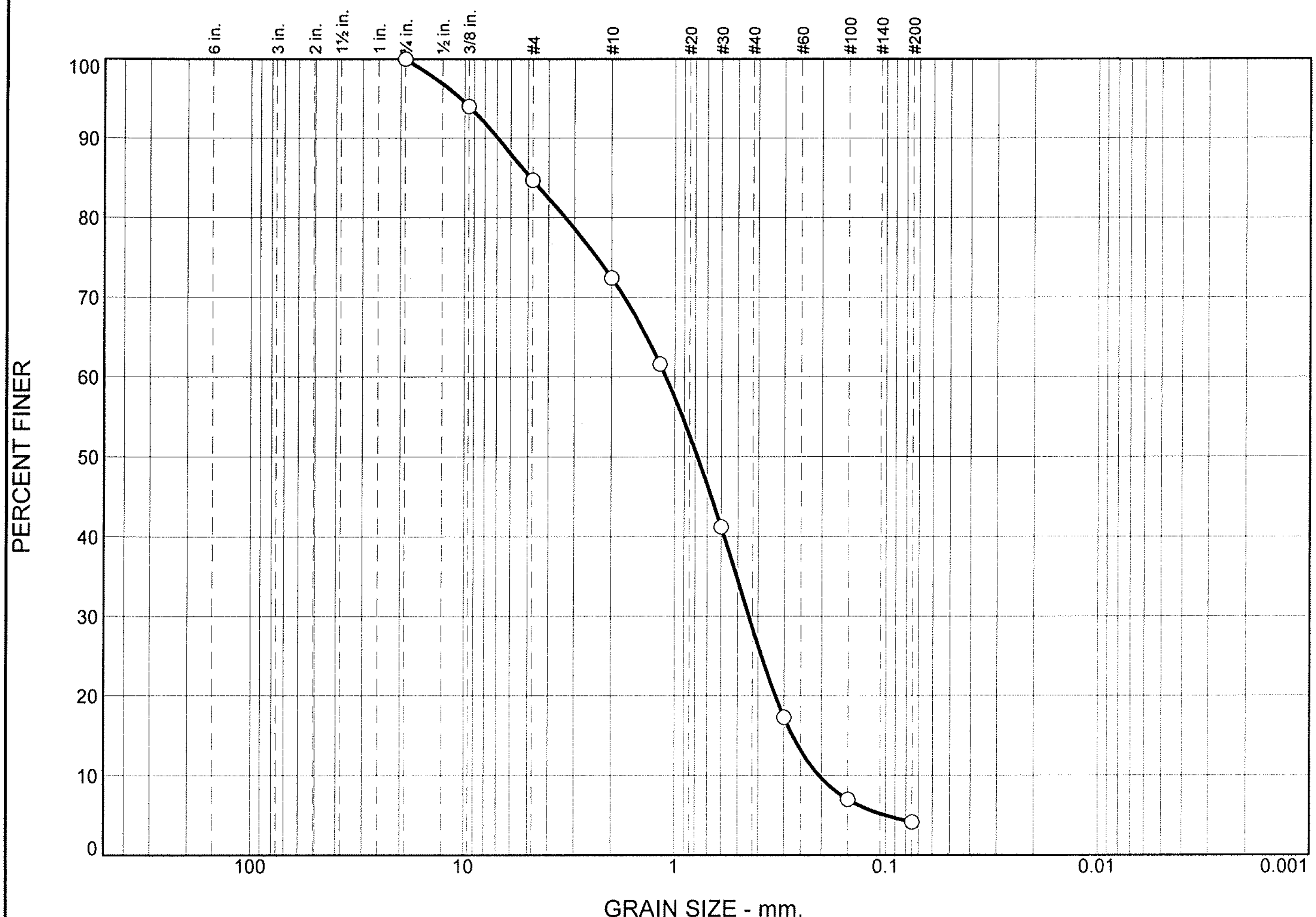
○ As Rec'd WC = 4.0%

GEI Consultants, Inc.
400 Unicorn Park Drive
Woburn, MA 01801

Figure

Tested By: EF

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines
		Coarse	Fine	Coarse	Medium	Fine	
○	0.0	0.0	15.3	12.2	44.0	24.4	4.1

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	-	-	4.8521	1.1066	0.7787	0.4424	0.2730	0.2049	0.86	5.40

Material Description	USCS	AASHTO
○ Narrowly Graded SAND with Gravel	SP	-

Project No. 1610724 **Client:** HDR

Project: Willard Street Drainage

○ **Source of Sample:** B1 **Depth:** 5-10 ft **Sample Number:** S1

Remarks:

○ As Rec'd WC = 7.5%

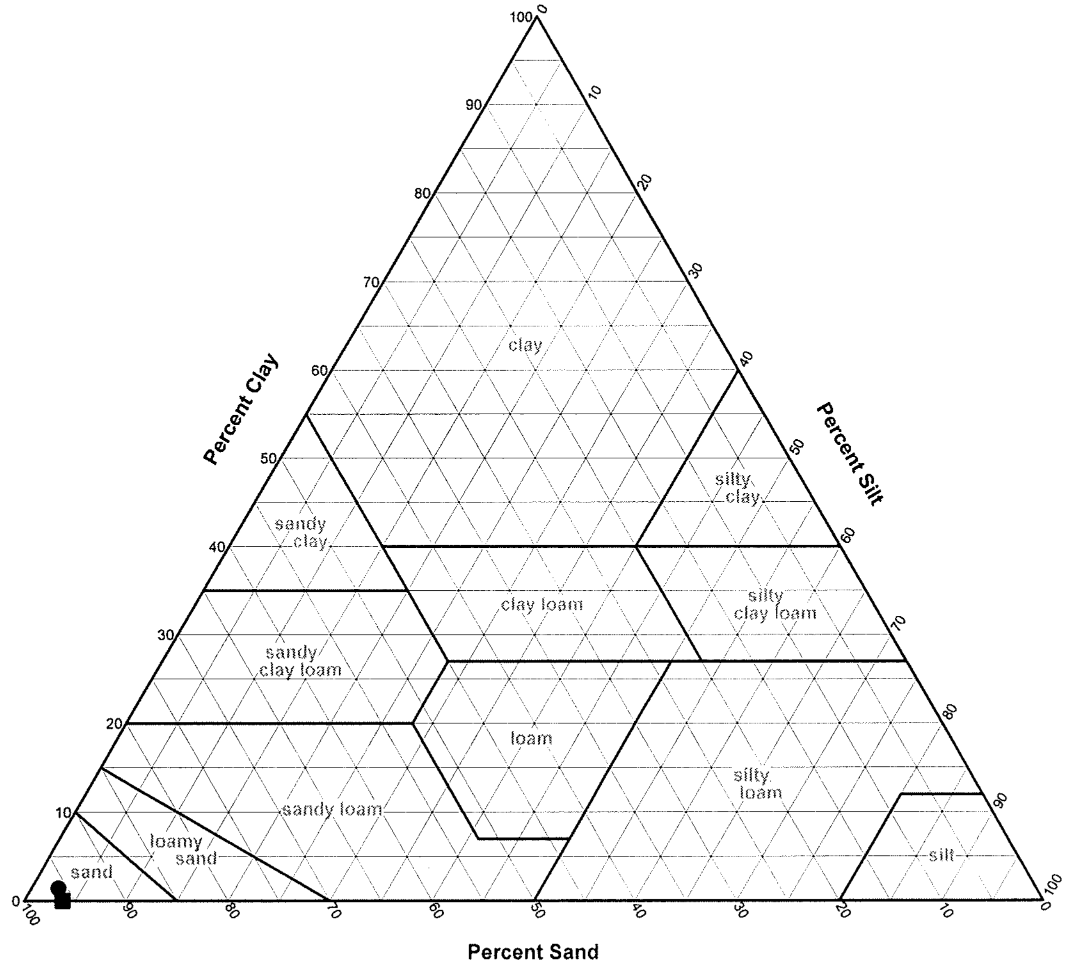
GEI Consultants, Inc.
400 Unicorn Park Drive
Woburn, MA 01801

GEI Consultants

Figure

Tested By: EF **Checked By:** DJA

USDA Soil Classification



SOIL DATA

	Source	Sample No.	Depth	Percentages From Material Passing a #10 Sieve: Sand	Silt	Clay	Classification
●	B1	S1	5-10 ft	95.9	2.8	1.4	Sand
■	B4	S1 (0-36 in)	5-10 ft	96.2	3.8	0.0	Sand

Percentages of silt and clay are based on an extrapolation of the grain size curves beyond the #200 sieve.

GEI Consultants, Inc.
400 Unicorn Park Drive
Woburn, MA 01801

GEI Consultants

Client: HDR

Project: Willard Street Drainage

Project No.: 1610724 **Figure**

APPENDIX C

Pipe Sizing Peak Discharge Calculations

Appendix C: Watershed Hydrology Analysis for Drainage Pipe Sizing – Willard Street from Brattle Street to Discharge to the Charles River (Source: Stantec, Inc., March 2017)

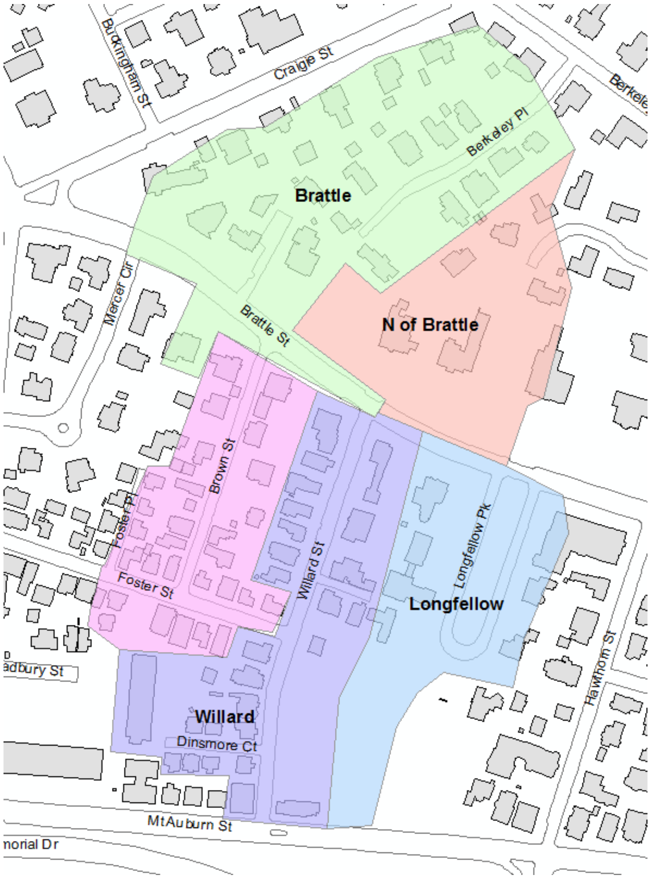


Figure 1: Drainage Area to Willard Street Outfall (Stantec, 2017)

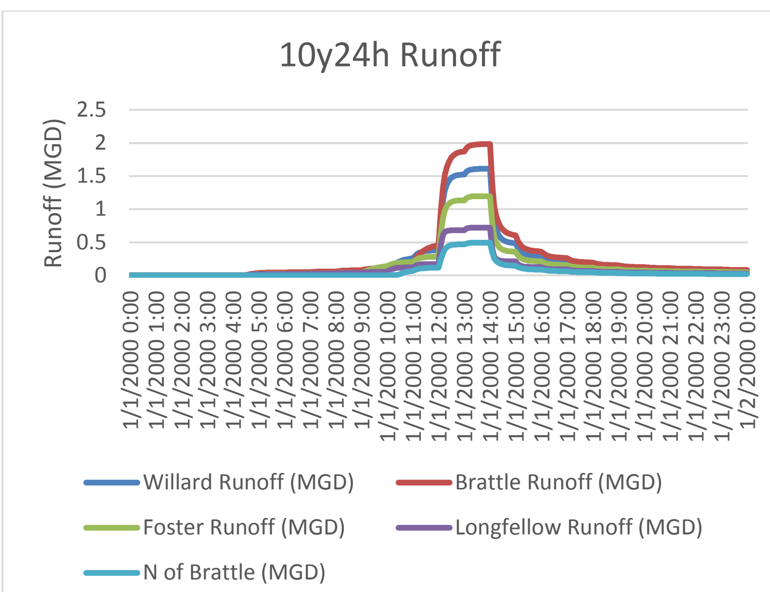


Figure 2: 10-Year Frequency Storm for Pipe Sizing of Main Pipe in Willard Street (Stantec, 2017)

APPENDIX D

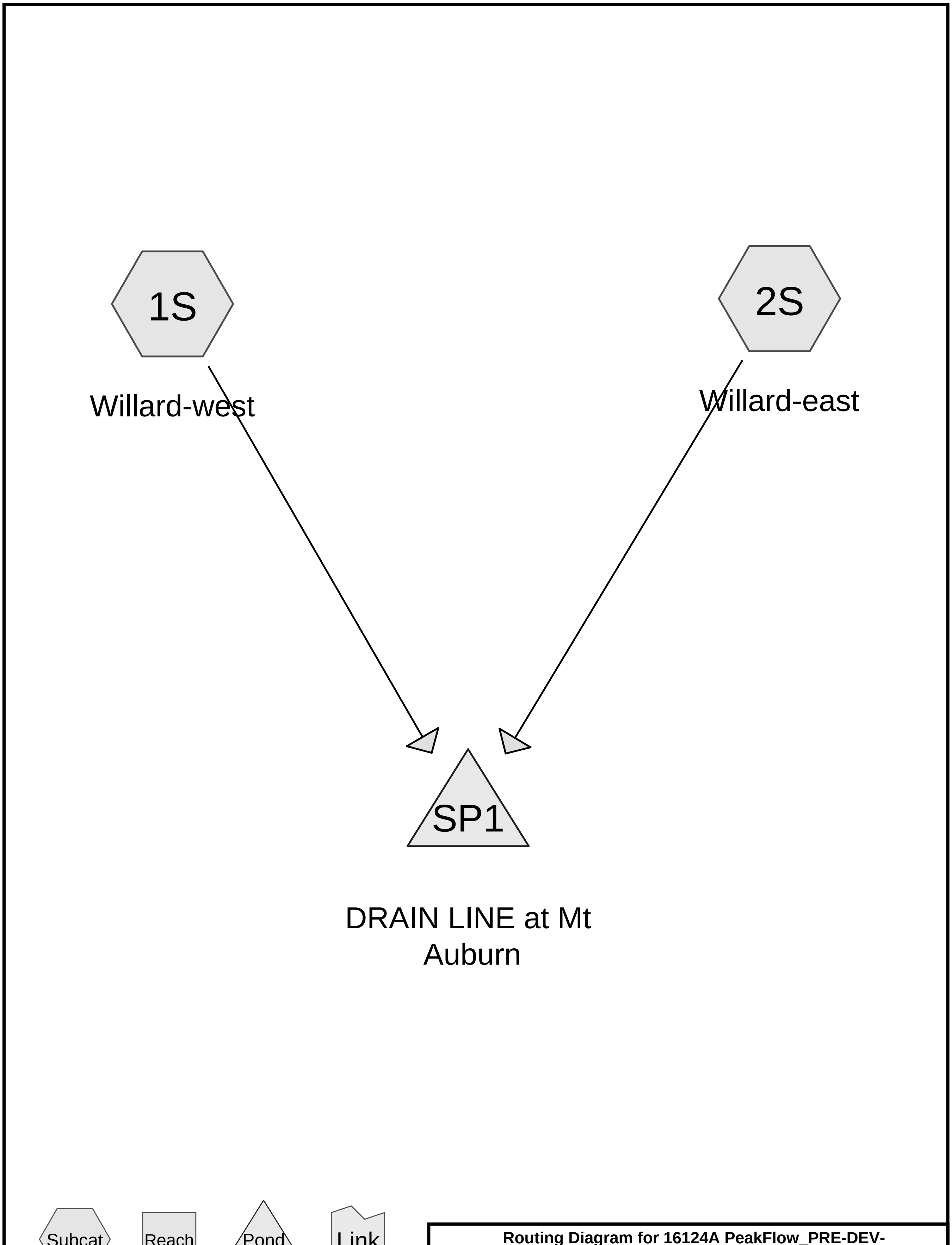
Northeast Regional Climate Center Extreme Precipitation Analysis

HydroCAD® Modeling Results for Peak Flows - Pre and Post Development

NRCC Precipitation Data[1]

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr
1yr	0.29	0.45	0.55	0.72	0.91	1.14	**1yr**	0.78	1.13	1.32	1.68	2.13	2.72	3.15
2yr	0.36	0.56	0.7	0.92	1.16	1.45	**2yr**	1	1.38	1.68	2.09	2.61	3.25	3.65
5yr	0.44	0.69	0.86	1.15	1.47	1.86	**5yr**	1.27	1.77	2.15	2.66	3.28	4.01	4.5
10yr	0.51	0.8	1.01	1.37	1.78	2.25	**10yr**	1.53	2.14	2.6	3.2	3.9	4.71	5.29
25yr	0.61	0.97	1.23	1.7	2.27	2.89	**25yr**	1.96	2.74	3.33	4.07	4.9	5.81	6.54
50yr	0.71	1.13	1.45	2.03	2.73	3.49	**50yr**	2.36	3.31	4.03	4.88	5.81	6.82	7.69
100yr	0.82	1.32	1.7	2.41	3.29	4.21	**100yr**	2.84	4	4.85	5.85	6.9	8.01	9.04
200yr	0.95	1.55	2.01	2.87	3.96	5.08	**200yr**	3.42	4.84	5.84	7	8.19	9.42	10.64
500yr	1.16	1.91	2.5	3.62	5.07	6.51	**500yr**	4.38	6.22	7.47	8.88	10.28	11.66	13.22

(1) Northeast Regional Climate Center (NRCC)/Natural Resources Conservation Service (NRCS).
Extreme Precipitation in New York & New England, An Interactive Web Tool for Extreme Precipitation Analysis. http://precip.eas.cornell.edu/. Accessed May 2016.



Routing Diagram for 16124A PeakFlow_PRE-DEV-
Prepared by Windows User, Printed 3/20/2018

Summary for Subcatchment 1S: Willard-west

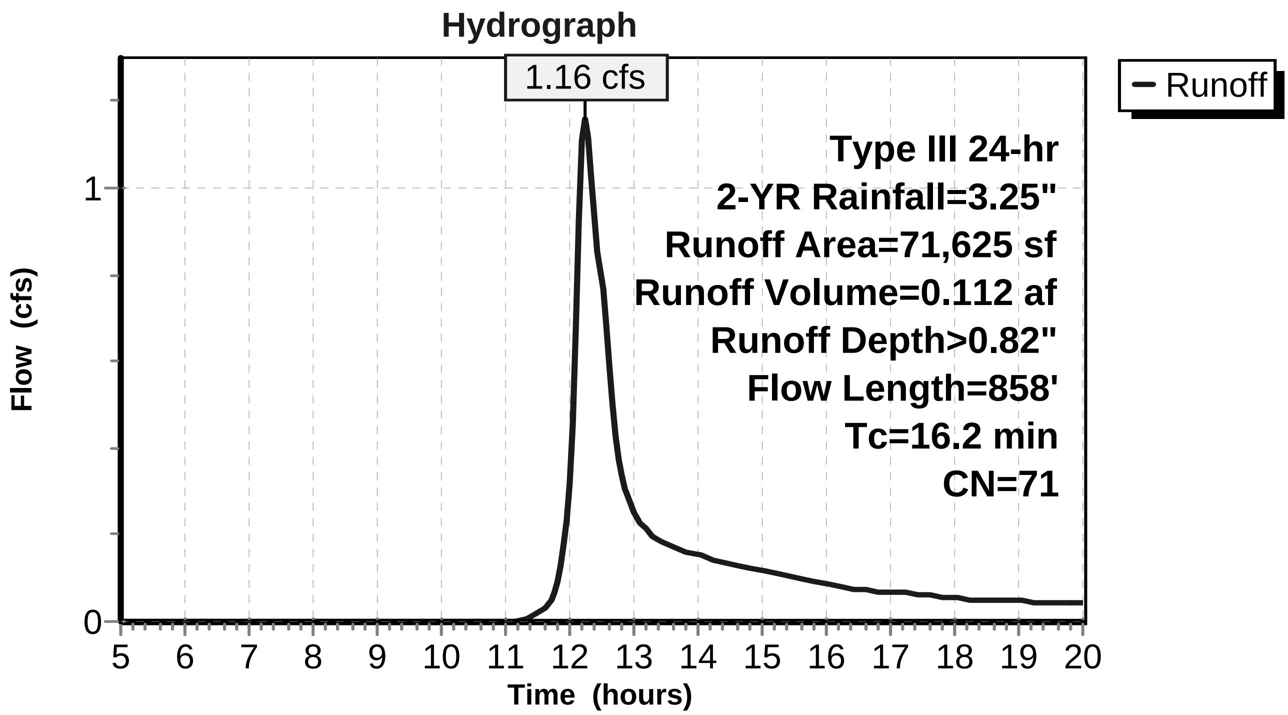
Runoff = 1.16 cfs @ 12.25 hrs, Volume= 0.112 af, Depth> 0.82"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 2-YR Rainfall=3.25"

Area (sf)	CN	Description
16,685	98	Roofs, HSG A
25,790	98	Paved parking, HSG A
4,085	39	>75% Grass cover, Good, HSG A
25,065	30	Woods, Good, HSG A
71,625	71	Weighted Average
29,150		40.70% Pervious Area
42,475		59.30% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.2	40	0.0150	0.13		**Sheet Flow, Lawn** Grass: Short n= 0.150 P2= 3.25"
0.8	58	0.0150	1.22		**Shallow Concentrated Flow, Lawn to driveway** Nearly Bare & Untilled Kv= 10.0 fps
0.5	75	0.0150	2.49		**Shallow Concentrated Flow, Gutter** Paved Kv= 20.3 fps
9.7	685	0.0002	1.18	5.80	**Pipe Channel, Pipe** 30.0" Round Area= 4.9 sf Perim= 7.9' r= 0.63' n= 0.013 Concrete pipe, straight & clean
16.2	858	Total			

Subcatchment 1S: Willard-west



Summary for Subcatchment 2S: Willard-east

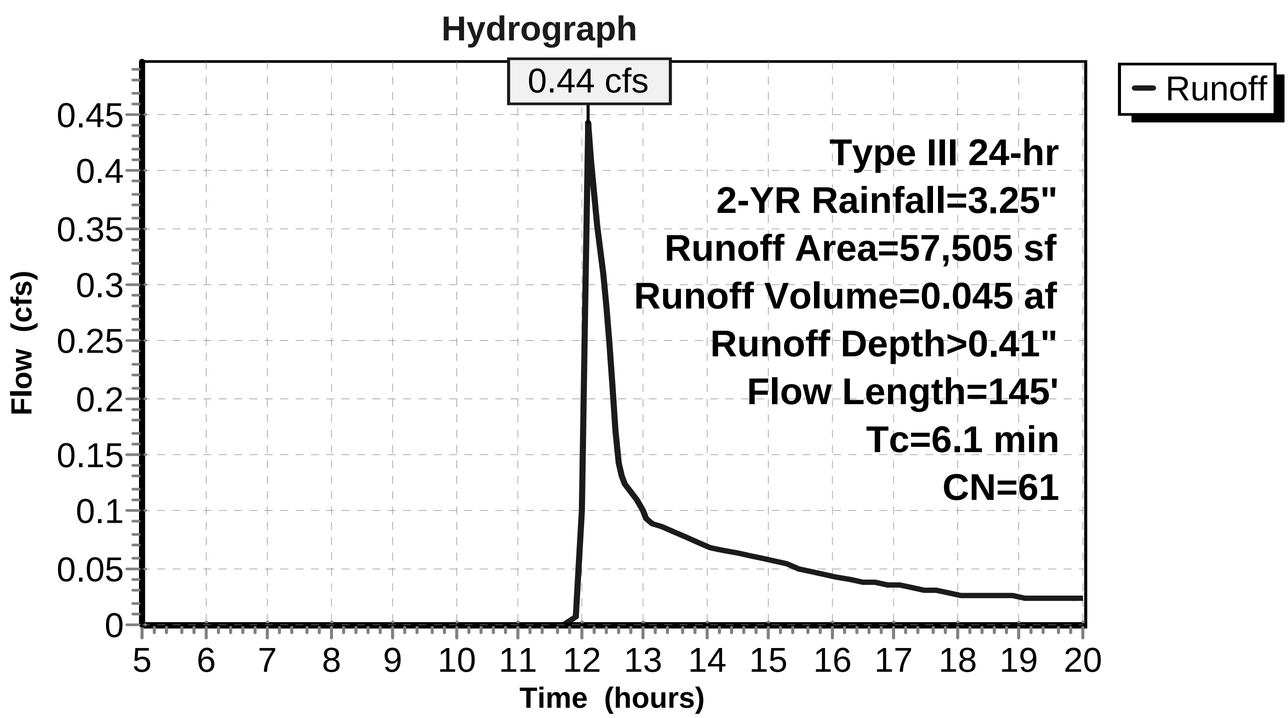
Runoff = 0.44 cfs @ 12.13 hrs, Volume= 0.045 af, Depth> 0.41"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 2-YR Rainfall=3.25"

Area (sf)	CN	Description
15,125	98	Roofs, HSG A
10,262	98	Paved parking, HSG A
1,948	39	>75% Grass cover, Good, HSG A
30,170	32	Woods/grass comb., Good, HSG A
57,505	61	Weighted Average
32,118		55.85% Pervious Area
25,387		44.15% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.2	40	0.0150	0.13		**Sheet Flow, Lawn** Grass: Short n= 0.150 P2= 3.25"
0.5	75	0.0150	2.49		**Shallow Concentrated Flow, Gutter** Paved Kv= 20.3 fps
0.4	30	0.0002	1.18	5.80	**Pipe Channel,** 30.0" Round Area= 4.9 sf Perim= 7.9' r= 0.63' n= 0.013 Concrete pipe, straight & clean
6.1	145	Total			

Subcatchment 2S: Willard-east

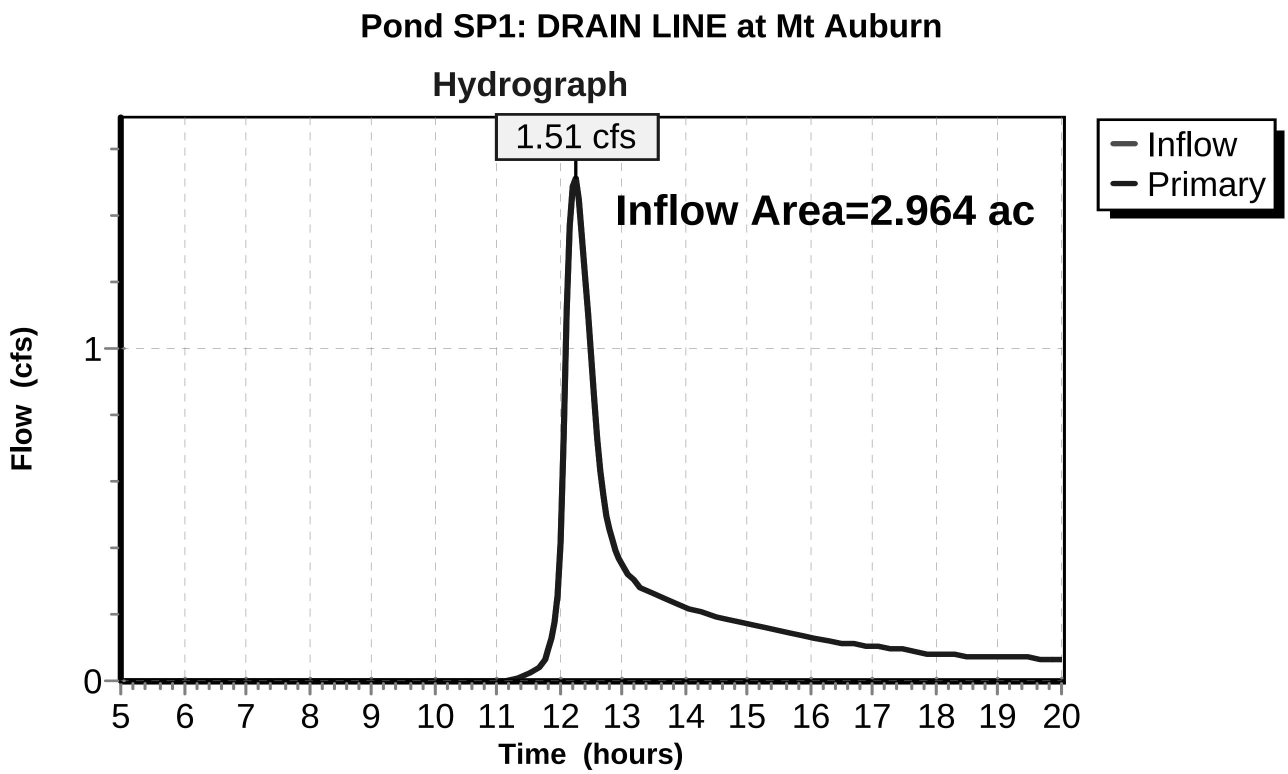


Summary for Pond SP1: DRAIN LINE at Mt Auburn

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

Inflow Area =	2.964 ac,	52.55% Impervious,	Inflow Depth > 0.64"	for 2-YR event	
Inflow =	1.51 cfs @	12.24 hrs,	Volume=	0.157 af	
Primary =	1.51 cfs @	12.24 hrs,	Volume=	0.157 af,	Atten= 0%, Lag= 0.0 min

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



Summary for Subcatchment 1S: Willard-west

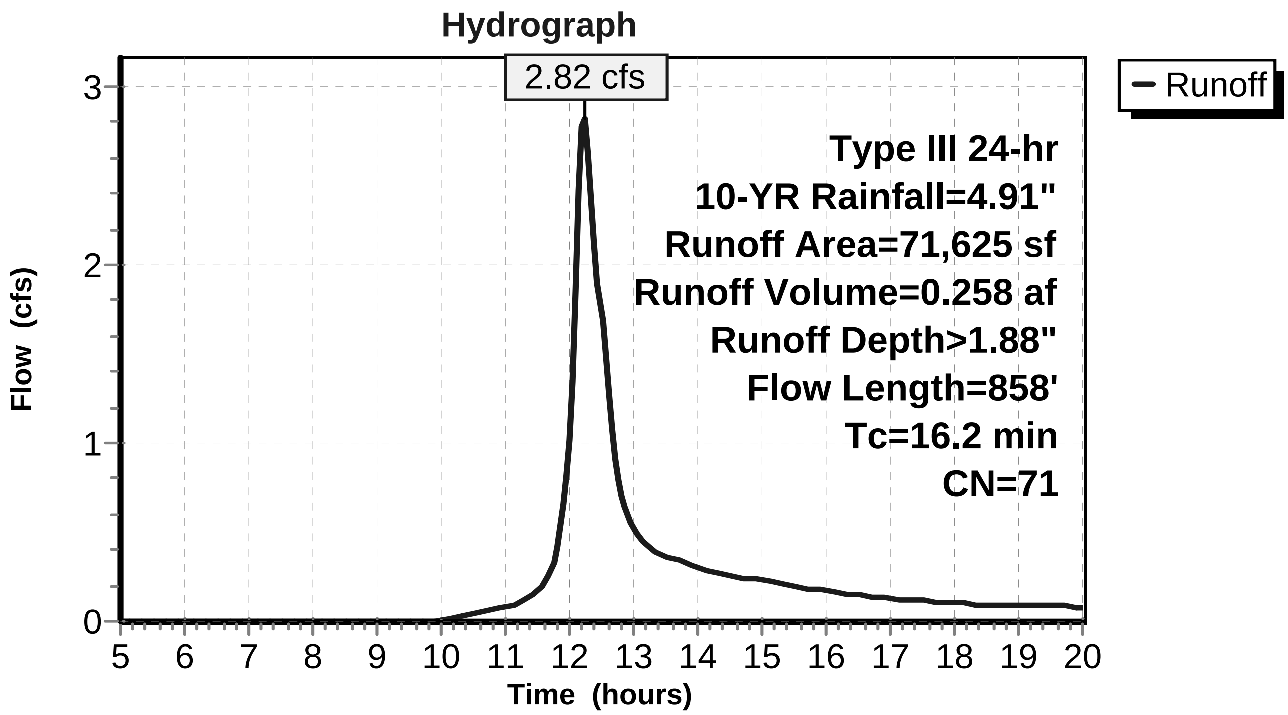
Runoff = 2.82 cfs @ 12.23 hrs, Volume= 0.258 af, Depth> 1.88"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 10-YR Rainfall=4.91"

Area (sf)	CN	Description
16,685	98	Roofs, HSG A
25,790	98	Paved parking, HSG A
4,085	39	>75% Grass cover, Good, HSG A
25,065	30	Woods, Good, HSG A
71,625	71	Weighted Average
29,150		40.70% Pervious Area
42,475		59.30% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.2	40	0.0150	0.13		**Sheet Flow, Lawn** Grass: Short n= 0.150 P2= 3.25"
0.8	58	0.0150	1.22		**Shallow Concentrated Flow, Lawn to driveway** Nearly Bare & Untilled Kv= 10.0 fps
0.5	75	0.0150	2.49		**Shallow Concentrated Flow, Gutter** Paved Kv= 20.3 fps
9.7	685	0.0002	1.18	5.80	**Pipe Channel, Pipe** 30.0" Round Area= 4.9 sf Perim= 7.9' r= 0.63' n= 0.013 Concrete pipe, straight & clean
16.2	858	Total			

Subcatchment 1S: Willard-west



Summary for Subcatchment 2S: Willard-east

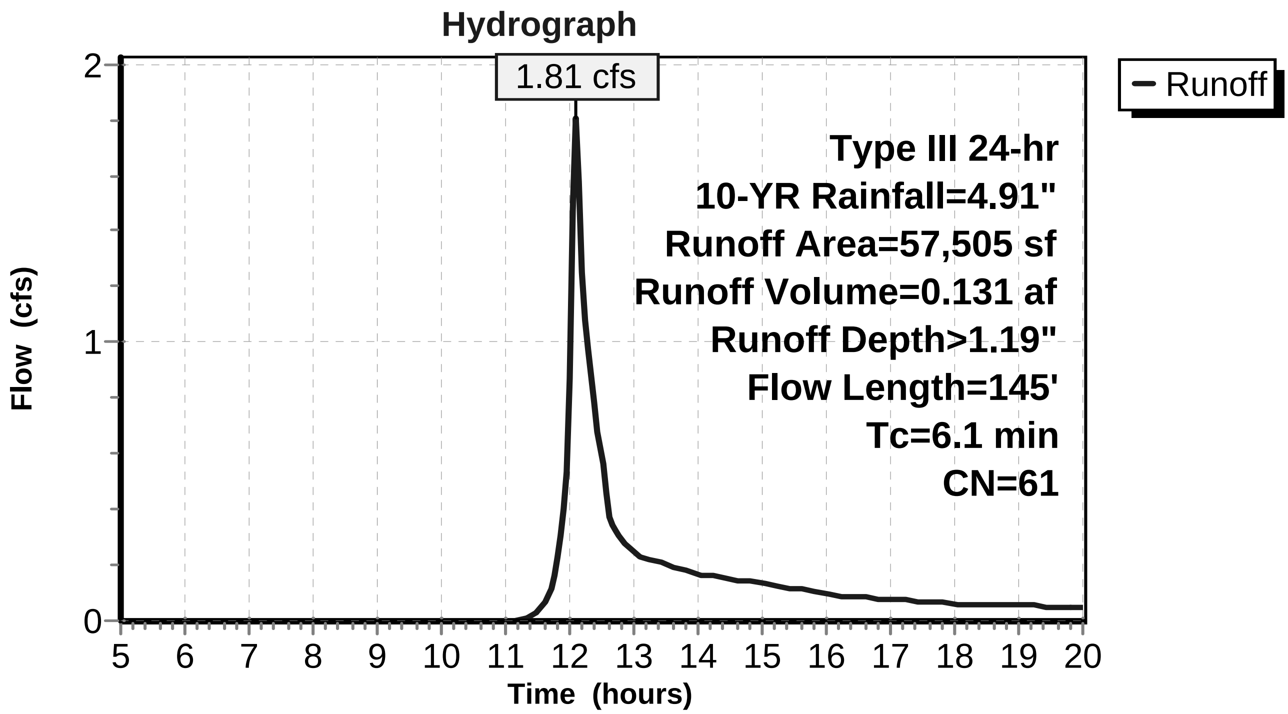
Runoff = 1.81 cfs @ 12.10 hrs, Volume= 0.131 af, Depth> 1.19"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 10-YR Rainfall=4.91"

Area (sf)	CN	Description
15,125	98	Roofs, HSG A
10,262	98	Paved parking, HSG A
1,948	39	>75% Grass cover, Good, HSG A
30,170	32	Woods/grass comb., Good, HSG A
57,505	61	Weighted Average
32,118		55.85% Pervious Area
25,387		44.15% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.2	40	0.0150	0.13		**Sheet Flow, Lawn** Grass: Short n= 0.150 P2= 3.25"
0.5	75	0.0150	2.49		**Shallow Concentrated Flow, Gutter** Paved Kv= 20.3 fps
0.4	30	0.0002	1.18	5.80	**Pipe Channel,** 30.0" Round Area= 4.9 sf Perim= 7.9' r= 0.63' n= 0.013 Concrete pipe, straight & clean
6.1	145	Total			

Subcatchment 2S: Willard-east

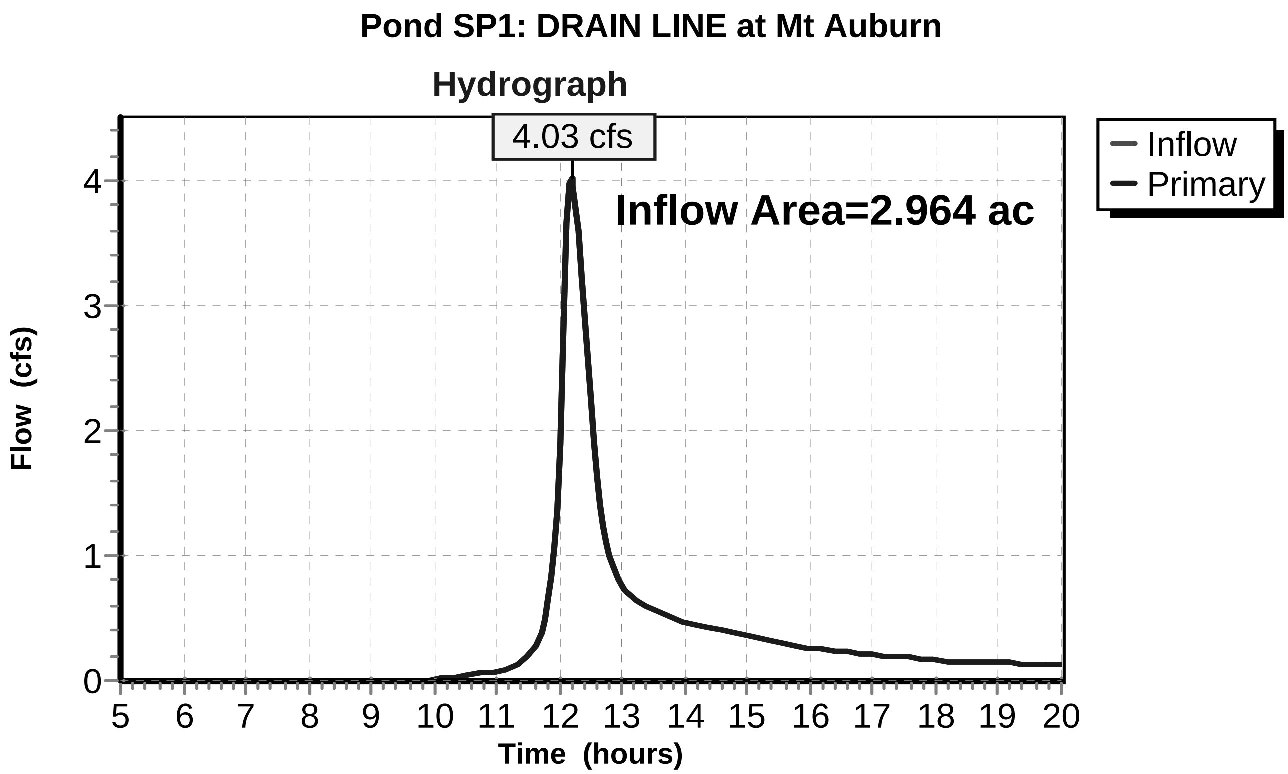


Summary for Pond SP1: DRAIN LINE at Mt Auburn

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

Inflow Area = 2.964 ac, 52.55% Impervious, Inflow Depth > 1.57" for 10-YR event
Inflow = 4.03 cfs @ 12.18 hrs, Volume= 0.389 af
Primary = 4.03 cfs @ 12.18 hrs, Volume= 0.389 af, Atten= 0%, Lag= 0.0 min

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



Summary for Subcatchment 1S: Willard-west

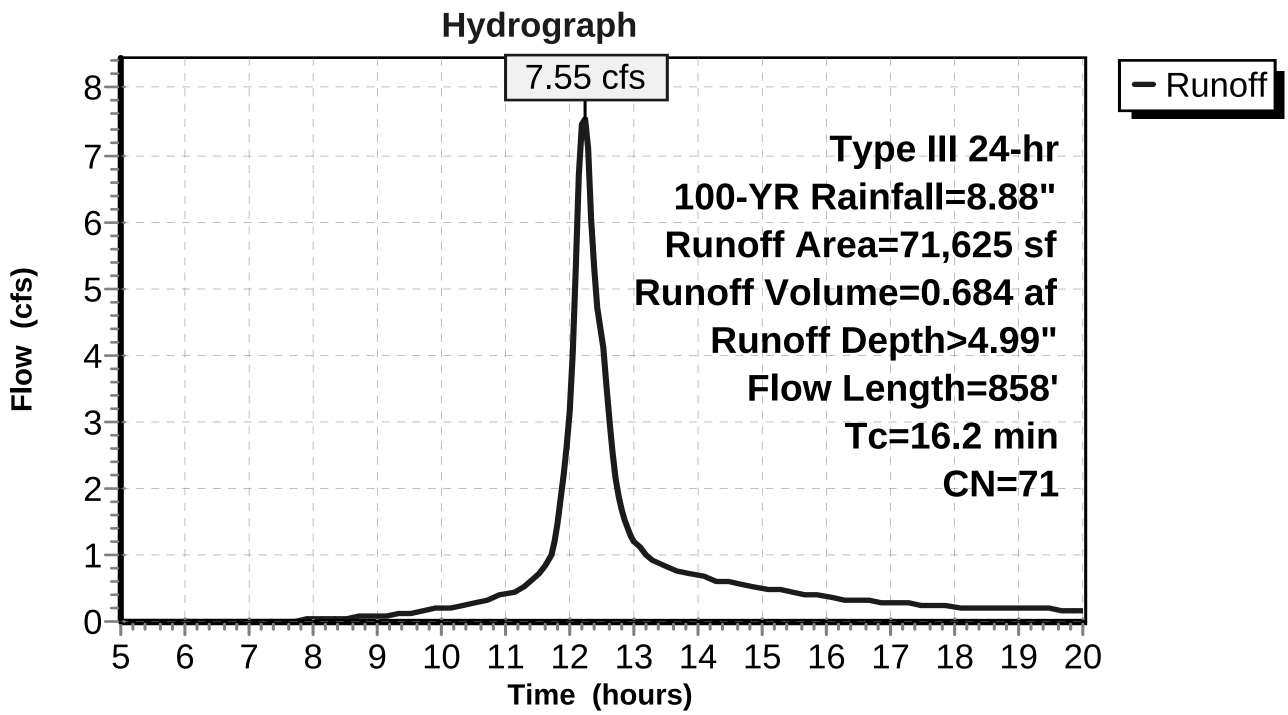
Runoff = 7.55 cfs @ 12.22 hrs, Volume= 0.684 af, Depth> 4.99"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 100-YR Rainfall=8.88"

Area (sf)	CN	Description
16,685	98	Roofs, HSG A
25,790	98	Paved parking, HSG A
4,085	39	>75% Grass cover, Good, HSG A
25,065	30	Woods, Good, HSG A
71,625	71	Weighted Average
29,150		40.70% Pervious Area
42,475		59.30% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.2	40	0.0150	0.13		**Sheet Flow, Lawn** Grass: Short n= 0.150 P2= 3.25"
0.8	58	0.0150	1.22		**Shallow Concentrated Flow, Lawn to driveway** Nearly Bare & Untilled Kv= 10.0 fps
0.5	75	0.0150	2.49		**Shallow Concentrated Flow, Gutter** Paved Kv= 20.3 fps
9.7	685	0.0002	1.18	5.80	**Pipe Channel, Pipe** 30.0" Round Area= 4.9 sf Perim= 7.9' r= 0.63' n= 0.013 Concrete pipe, straight & clean
16.2	858	Total			

Subcatchment 1S: Willard-west



Summary for Subcatchment 2S: Willard-east

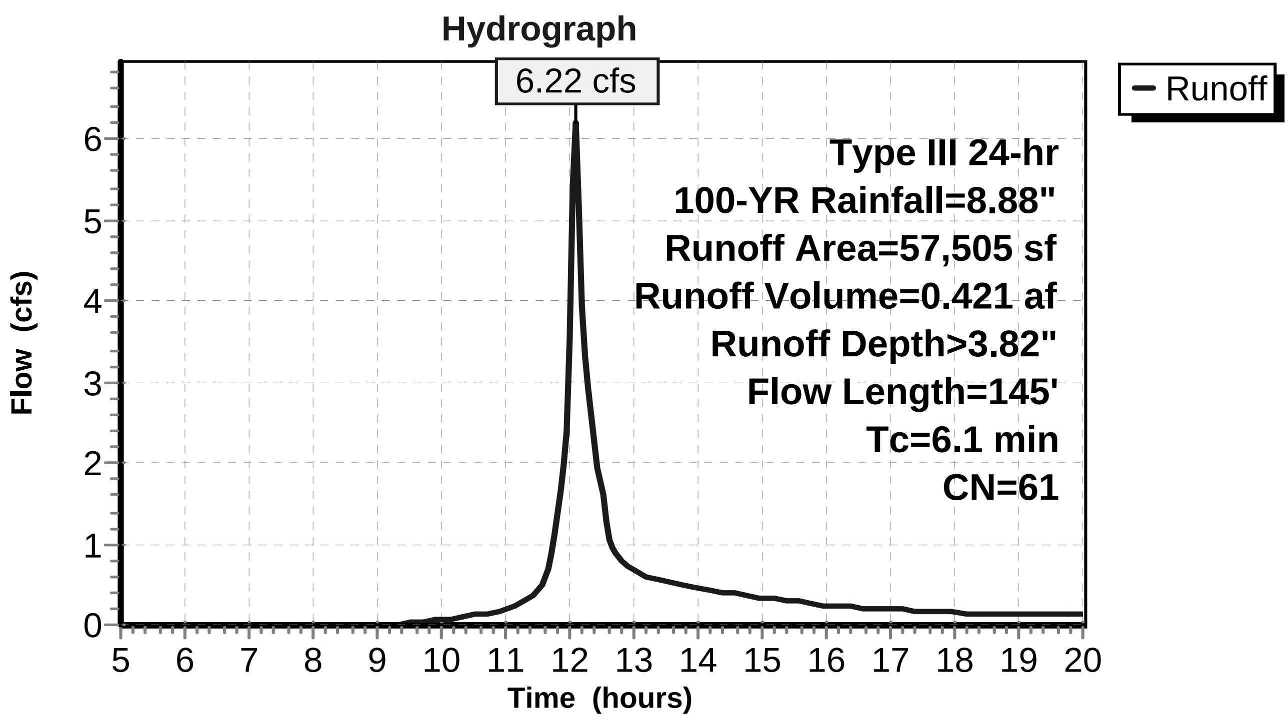
Runoff = 6.22 cfs @ 12.10 hrs, Volume= 0.421 af, Depth> 3.82"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 100-YR Rainfall=8.88"

Area (sf)	CN	Description
15,125	98	Roofs, HSG A
10,262	98	Paved parking, HSG A
1,948	39	>75% Grass cover, Good, HSG A
30,170	32	Woods/grass comb., Good, HSG A
57,505	61	Weighted Average
32,118		55.85% Pervious Area
25,387		44.15% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.2	40	0.0150	0.13		**Sheet Flow, Lawn** Grass: Short n= 0.150 P2= 3.25"
0.5	75	0.0150	2.49		**Shallow Concentrated Flow, Gutter** Paved Kv= 20.3 fps
0.4	30	0.0002	1.18	5.80	**Pipe Channel,** 30.0" Round Area= 4.9 sf Perim= 7.9' r= 0.63' n= 0.013 Concrete pipe, straight & clean
6.1	145	Total			

Subcatchment 2S: Willard-east

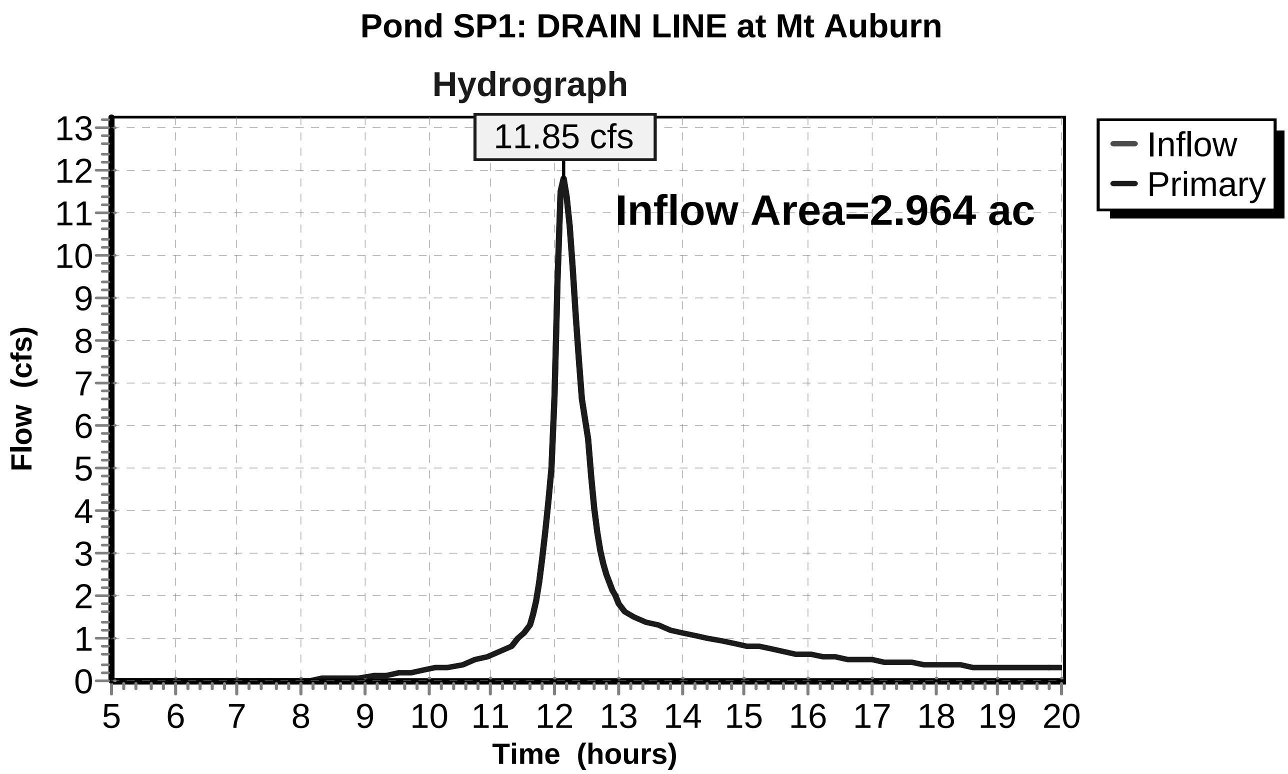


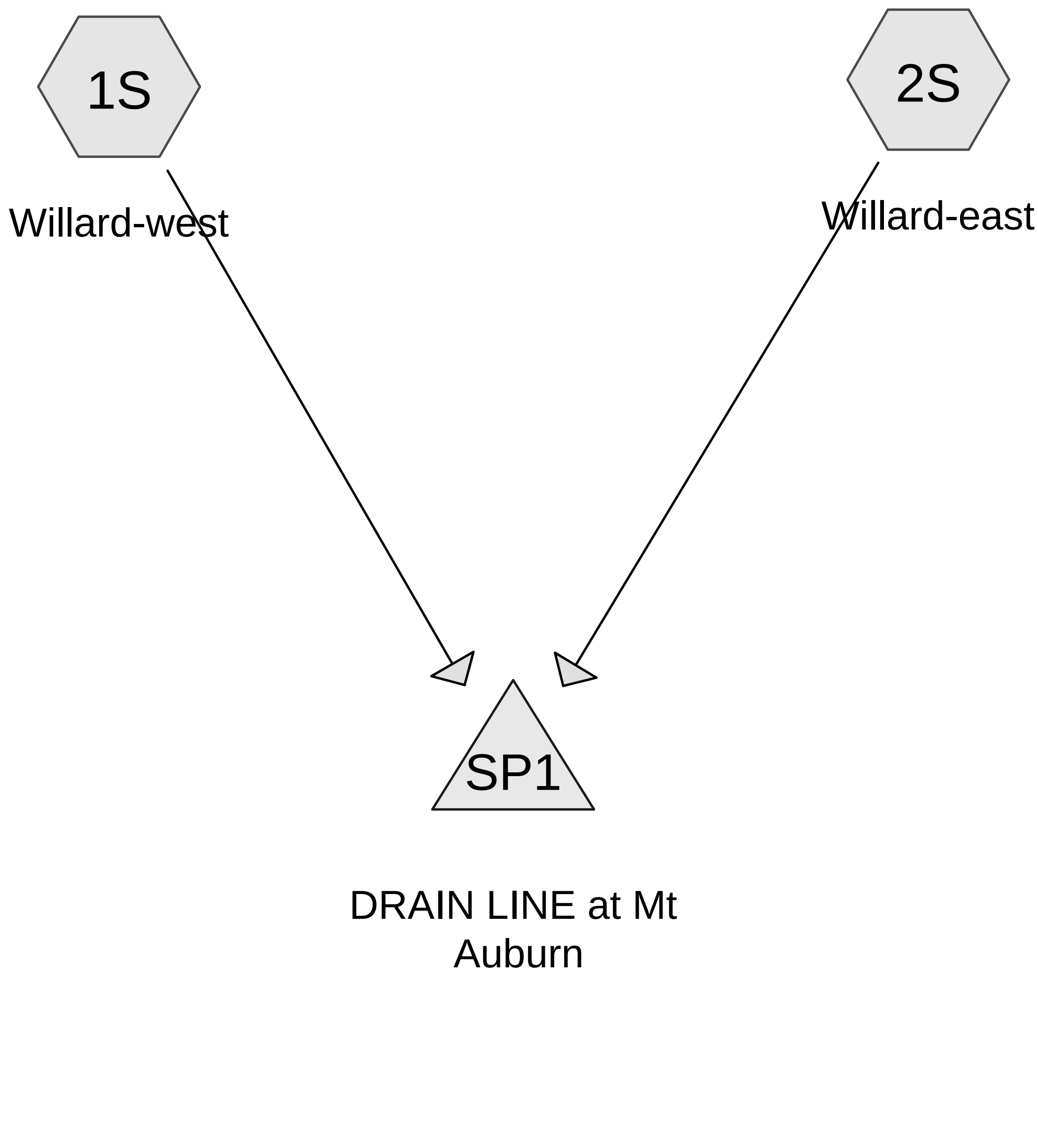
Summary for Pond SP1: DRAIN LINE at Mt Auburn

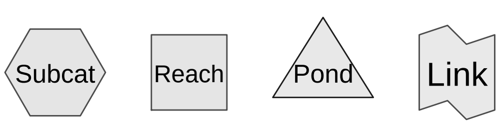
[40] Hint: Not Described (Outflow=Inflow)

Inflow Area =	2.964 ac, 52.55% Impervious,	Inflow Depth > 4.47"	for 100-YR event	
Inflow =	11.85 cfs @	12.15 hrs, Volume=	1.104 af	
Primary =	11.85 cfs @	12.15 hrs, Volume=	1.104 af,	Atten= 0%, Lag= 0.0 min

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







Routing Diagram for 16124A PeakFlow_POST-DEV-
Prepared by Windows User, Printed 3/20/2018
HydroCAD® 10.00-17 s/n 01445 © 2016 HydroCAD Software Solutions LLC

Summary for Subcatchment 1S: Willard-west

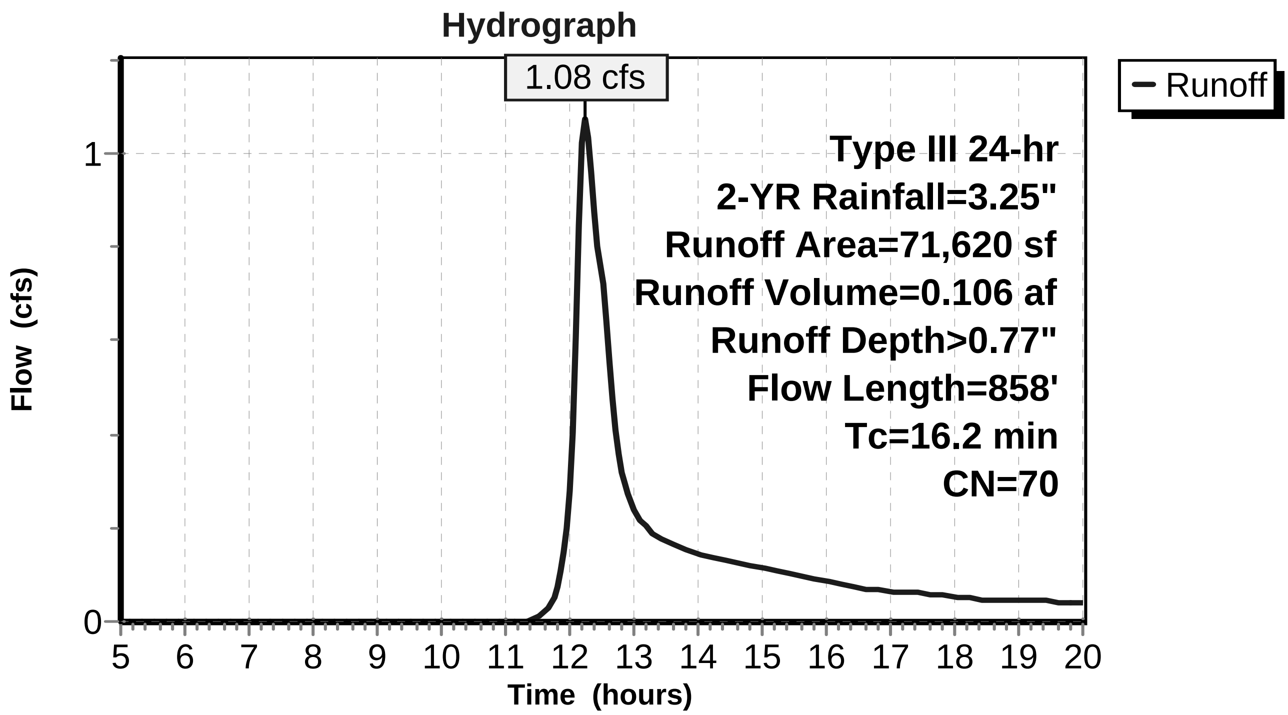
Runoff = 1.08 cfs @ 12.25 hrs, Volume= 0.106 af, Depth> 0.77"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 2-YR Rainfall=3.25"

	Area (sf)	CN	Description
	16,685	98	Roofs, HSG A
	24,600	98	Paved parking, HSG A
	3,730	39	>75% Grass cover, Good, HSG A
	25,065	30	Woods, Good, HSG A
*	1,540	40	Permeable Paving > 12 subbase
	71,620	70	Weighted Average
	30,335		42.36% Pervious Area
	41,285		57.64% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.2	40	0.0150	0.13		**Sheet Flow, Lawn** Grass: Short n= 0.150 P2= 3.25"
0.8	58	0.0150	1.22		**Shallow Concentrated Flow, Lawn to driveway** Nearly Bare & Untilled Kv= 10.0 fps
0.5	75	0.0150	2.49		**Shallow Concentrated Flow, Gutter** Paved Kv= 20.3 fps
9.7	685	0.0002	1.18	5.80	**Pipe Channel, Pipe** 30.0" Round Area= 4.9 sf Perim= 7.9' r= 0.63' n= 0.013 Concrete pipe, straight & clean
16.2	858	Total			

Subcatchment 1S: Willard-west



Summary for Subcatchment 2S: Willard-east

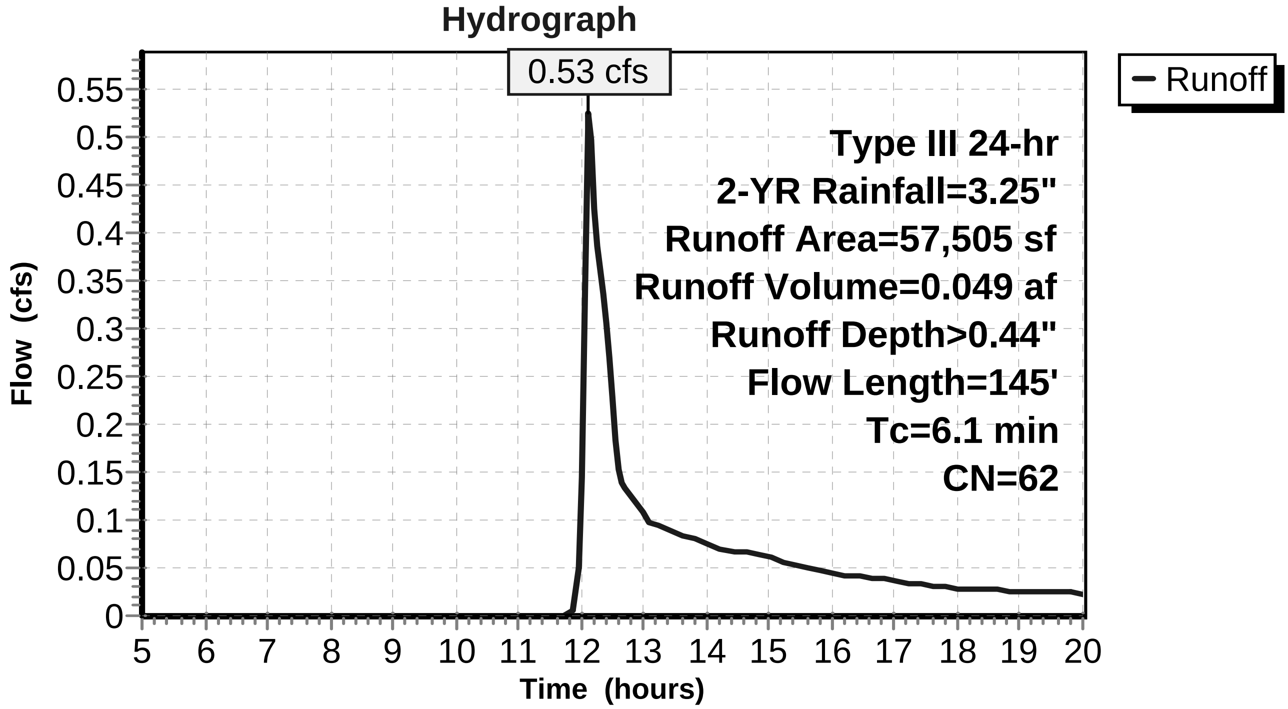
Runoff = 0.53 cfs @ 12.12 hrs, Volume= 0.049 af, Depth> 0.44"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 2-YR Rainfall=3.25"

Area (sf)	CN	Description
15,125	98	Roofs, HSG A
10,865	98	Paved parking, HSG A
1,345	39	>75% Grass cover, Good, HSG A
30,170	32	Woods/grass comb., Good, HSG A
57,505	62	Weighted Average
31,515		54.80% Pervious Area
25,990		45.20% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.2	40	0.0150	0.13		**Sheet Flow, Lawn** Grass: Short n= 0.150 P2= 3.25"
0.5	75	0.0150	2.49		**Shallow Concentrated Flow, Gutter** Paved Kv= 20.3 fps
0.4	30	0.0002	1.18	5.80	**Pipe Channel,** 30.0" Round Area= 4.9 sf Perim= 7.9' r= 0.63' n= 0.013 Concrete pipe, straight & clean
6.1	145	Total			

Subcatchment 2S: Willard-east

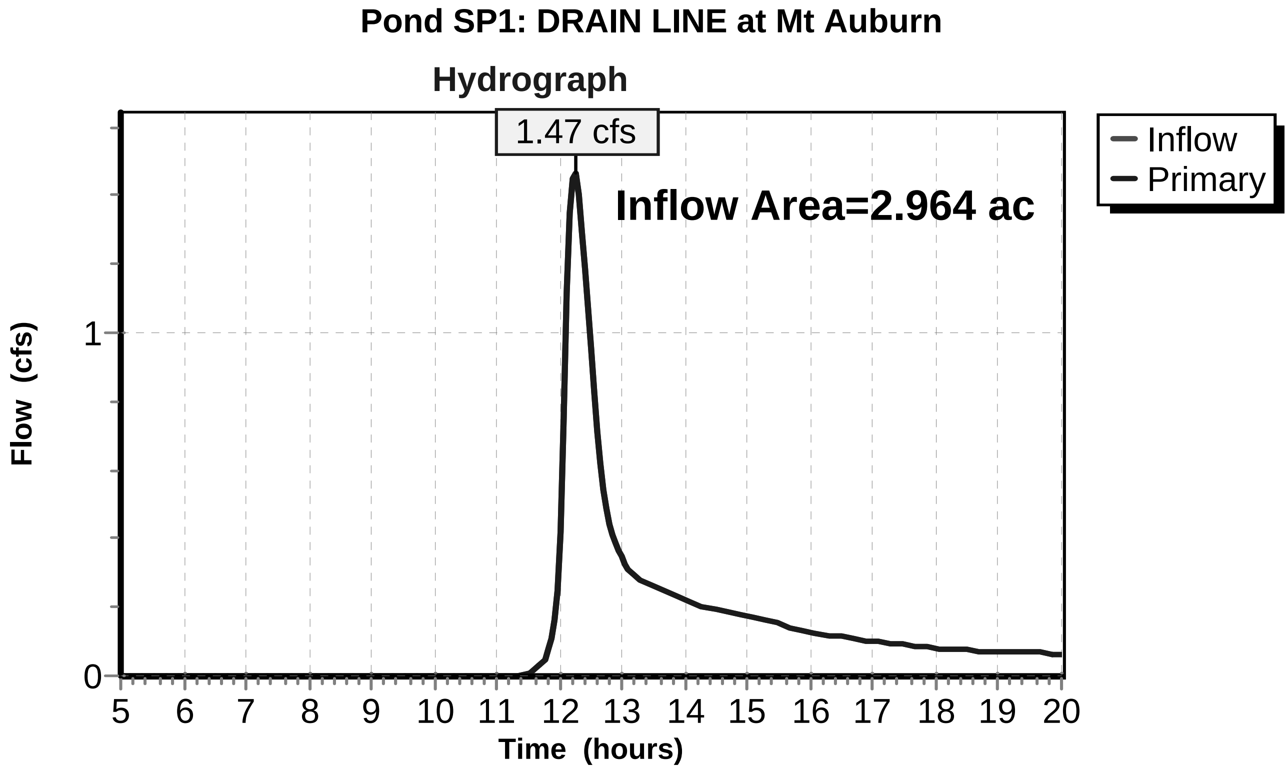


Summary for Pond SP1: DRAIN LINE at Mt Auburn

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

Inflow Area =	2.964 ac,	52.10% Impervious,	Inflow Depth > 0.62"	for 2-YR event	
Inflow =	1.47 cfs @	12.24 hrs,	Volume=	0.154 af	
Primary =	1.47 cfs @	12.24 hrs,	Volume=	0.154 af,	Atten= 0%, Lag= 0.0 min

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



Summary for Subcatchment 1S: Willard-west

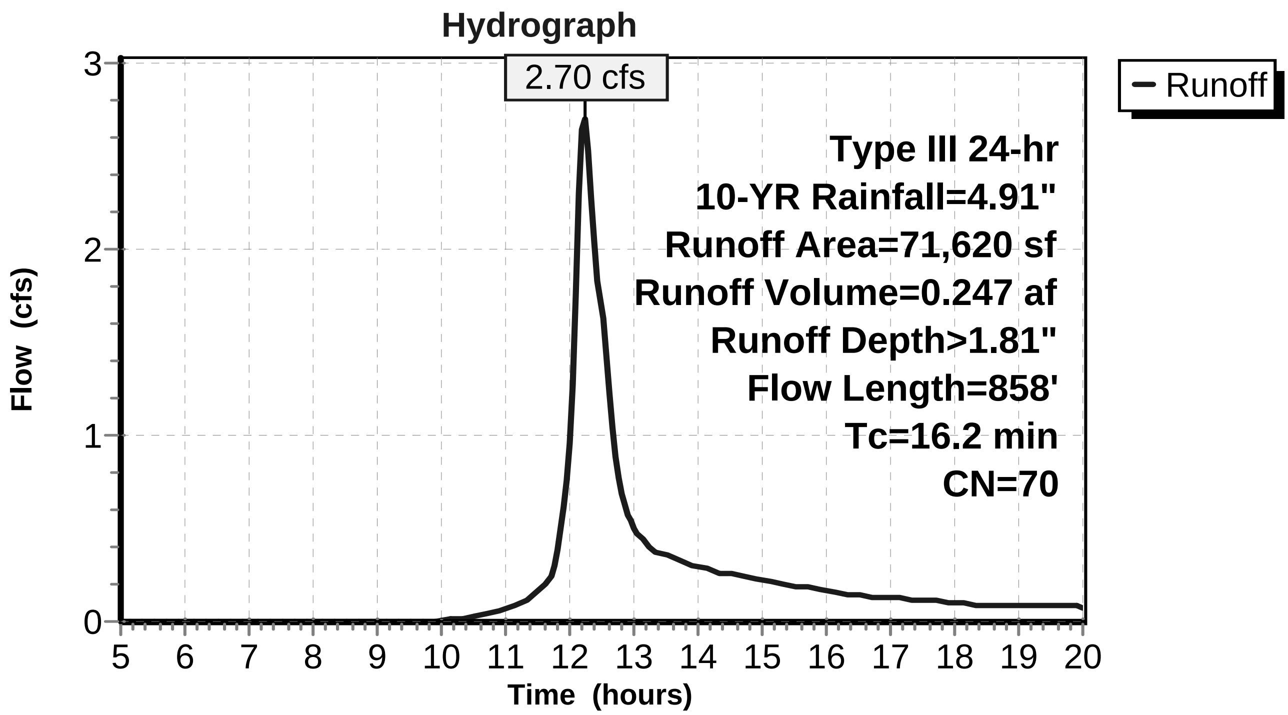
Runoff = 2.70 cfs @ 12.24 hrs, Volume= 0.247 af, Depth> 1.81"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 10-YR Rainfall=4.91"

	Area (sf)	CN	Description
	16,685	98	Roofs, HSG A
	24,600	98	Paved parking, HSG A
	3,730	39	>75% Grass cover, Good, HSG A
	25,065	30	Woods, Good, HSG A
*	1,540	40	Permeable Paving > 12 subbase
	71,620	70	Weighted Average
	30,335		42.36% Pervious Area
	41,285		57.64% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.2	40	0.0150	0.13		**Sheet Flow, Lawn** Grass: Short n= 0.150 P2= 3.25"
0.8	58	0.0150	1.22		**Shallow Concentrated Flow, Lawn to driveway** Nearly Bare & Untilled Kv= 10.0 fps
0.5	75	0.0150	2.49		**Shallow Concentrated Flow, Gutter** Paved Kv= 20.3 fps
9.7	685	0.0002	1.18	5.80	**Pipe Channel, Pipe** 30.0" Round Area= 4.9 sf Perim= 7.9' r= 0.63' n= 0.013 Concrete pipe, straight & clean
16.2	858	Total			

Subcatchment 1S: Willard-west



Summary for Subcatchment 2S: Willard-east

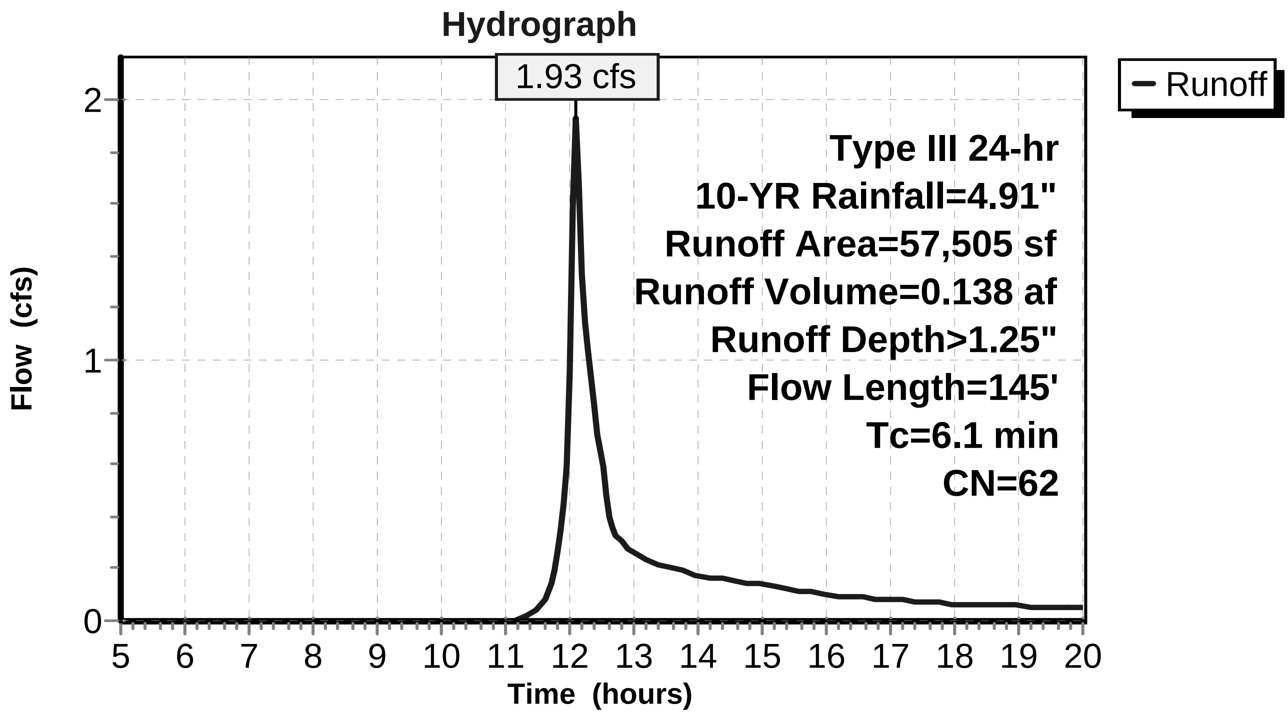
Runoff = 1.93 cfs @ 12.10 hrs, Volume= 0.138 af, Depth> 1.25"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 10-YR Rainfall=4.91"

Area (sf)	CN	Description
15,125	98	Roofs, HSG A
10,865	98	Paved parking, HSG A
1,345	39	>75% Grass cover, Good, HSG A
30,170	32	Woods/grass comb., Good, HSG A
57,505	62	Weighted Average
31,515		54.80% Pervious Area
25,990		45.20% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.2	40	0.0150	0.13		**Sheet Flow, Lawn** Grass: Short n= 0.150 P2= 3.25"
0.5	75	0.0150	2.49		**Shallow Concentrated Flow, Gutter** Paved Kv= 20.3 fps
0.4	30	0.0002	1.18	5.80	**Pipe Channel,** 30.0" Round Area= 4.9 sf Perim= 7.9' r= 0.63' n= 0.013 Concrete pipe, straight & clean
6.1	145	Total			

Subcatchment 2S: Willard-east



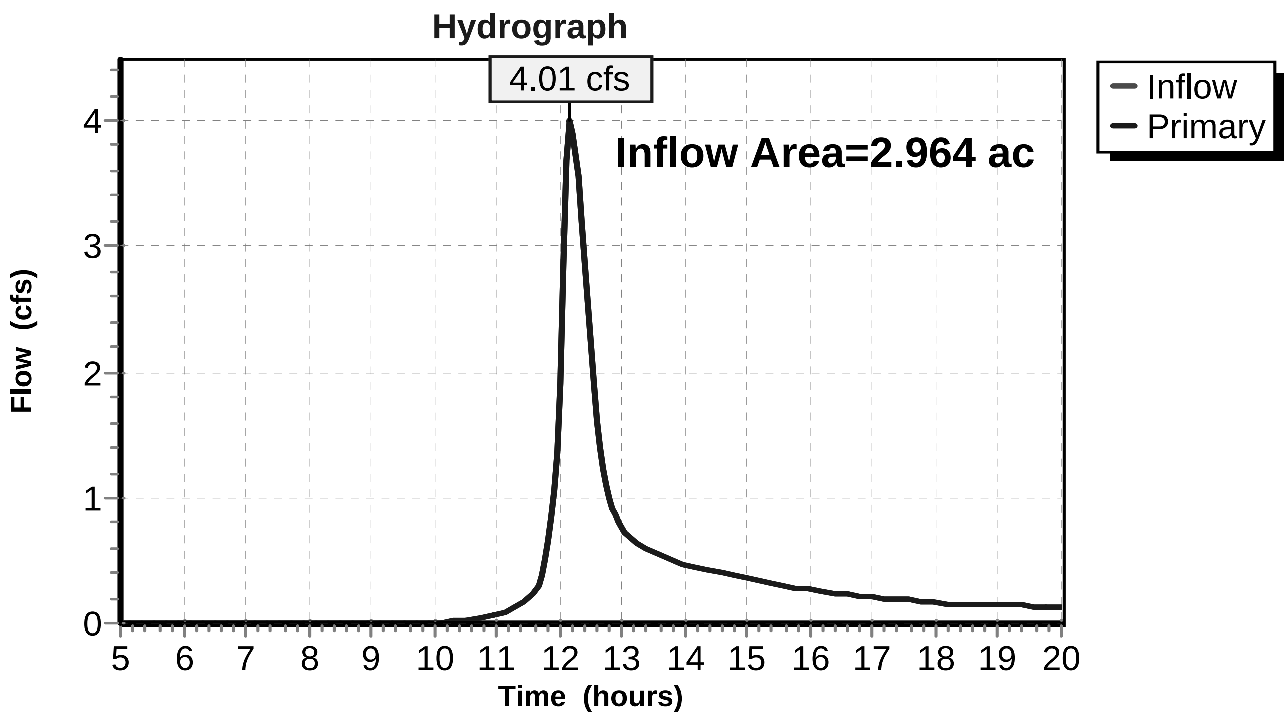
Summary for Pond SP1: DRAIN LINE at Mt Auburn

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

Inflow Area = 2.964 ac, 52.10% Impervious, Inflow Depth > 1.56" for 10-YR event
Inflow = 4.01 cfs @ 12.17 hrs, Volume= 0.385 af
Primary = 4.01 cfs @ 12.17 hrs, Volume= 0.385 af, Atten= 0%, Lag= 0.0 min

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

Pond SP1: DRAIN LINE at Mt Auburn



Summary for Subcatchment 1S: Willard-west

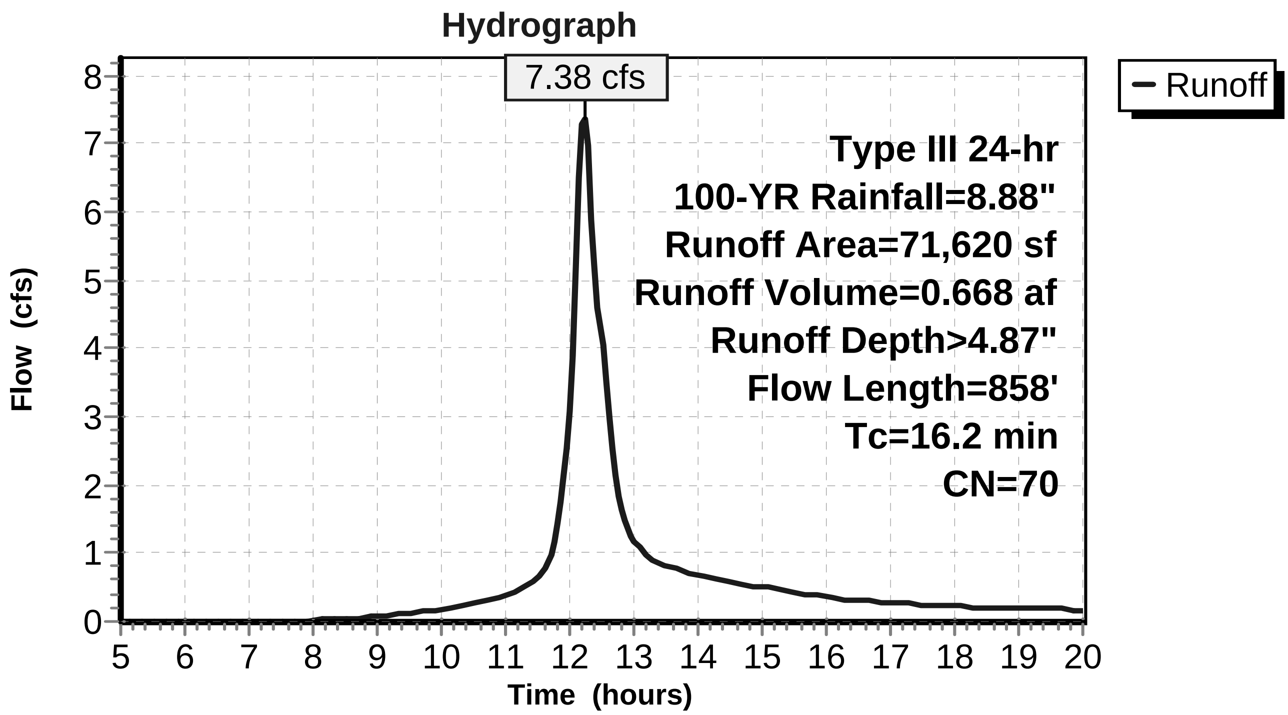
Runoff = 7.38 cfs @ 12.22 hrs, Volume= 0.668 af, Depth> 4.87"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 100-YR Rainfall=8.88"

	Area (sf)	CN	Description
	16,685	98	Roofs, HSG A
	24,600	98	Paved parking, HSG A
	3,730	39	>75% Grass cover, Good, HSG A
	25,065	30	Woods, Good, HSG A
*	1,540	40	Permeable Paving > 12 subbase
	71,620	70	Weighted Average
	30,335		42.36% Pervious Area
	41,285		57.64% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.2	40	0.0150	0.13		**Sheet Flow, Lawn** Grass: Short n= 0.150 P2= 3.25"
0.8	58	0.0150	1.22		**Shallow Concentrated Flow, Lawn to driveway** Nearly Bare & Untilled Kv= 10.0 fps
0.5	75	0.0150	2.49		**Shallow Concentrated Flow, Gutter** Paved Kv= 20.3 fps
9.7	685	0.0002	1.18	5.80	**Pipe Channel, Pipe** 30.0" Round Area= 4.9 sf Perim= 7.9' r= 0.63' n= 0.013 Concrete pipe, straight & clean
16.2	858	Total			

Subcatchment 1S: Willard-west



Summary for Subcatchment 2S: Willard-east

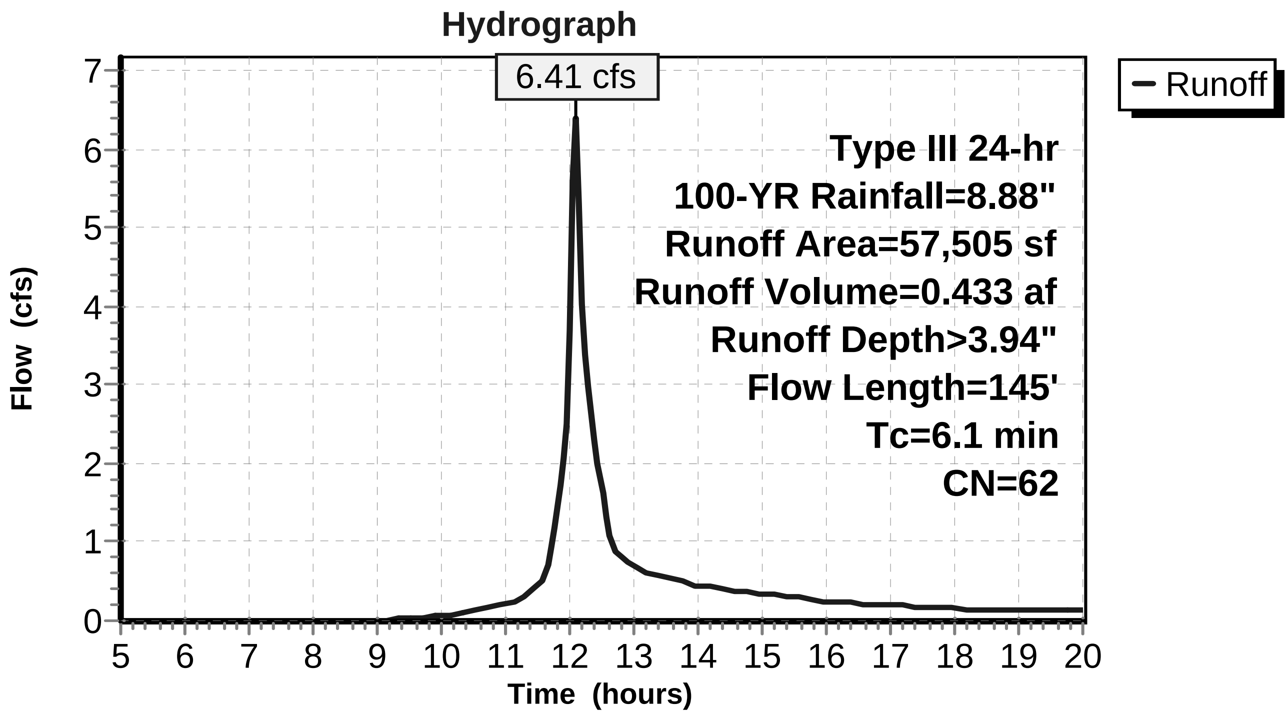
Runoff = 6.41 cfs @ 12.10 hrs, Volume= 0.433 af, Depth> 3.94"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 100-YR Rainfall=8.88"

Area (sf)	CN	Description
15,125	98	Roofs, HSG A
10,865	98	Paved parking, HSG A
1,345	39	>75% Grass cover, Good, HSG A
30,170	32	Woods/grass comb., Good, HSG A
57,505	62	Weighted Average
31,515		54.80% Pervious Area
25,990		45.20% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.2	40	0.0150	0.13		**Sheet Flow, Lawn** Grass: Short n= 0.150 P2= 3.25"
0.5	75	0.0150	2.49		**Shallow Concentrated Flow, Gutter** Paved Kv= 20.3 fps
0.4	30	0.0002	1.18	5.80	**Pipe Channel,** 30.0" Round Area= 4.9 sf Perim= 7.9' r= 0.63' n= 0.013 Concrete pipe, straight & clean
6.1	145	Total			

Subcatchment 2S: Willard-east

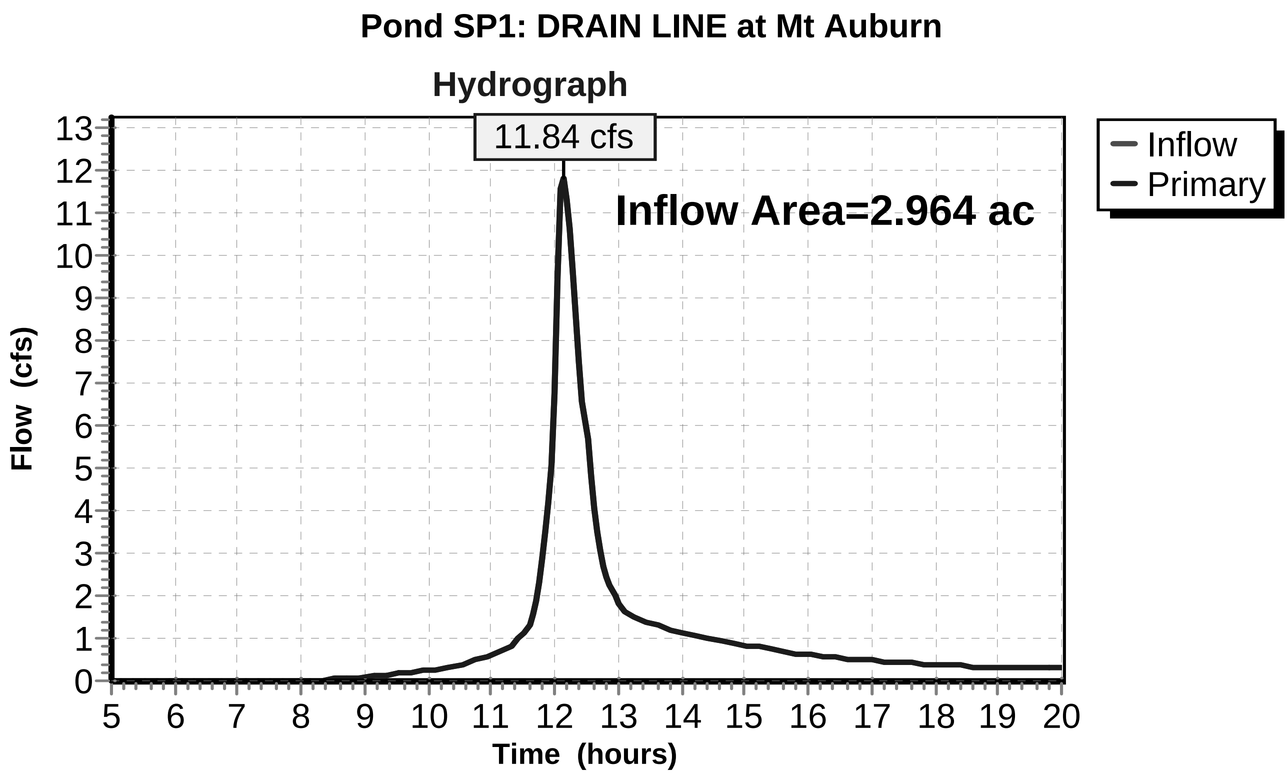


Summary for Pond SP1: DRAIN LINE at Mt Auburn

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

Inflow Area = 2.964 ac, 52.10% Impervious, Inflow Depth > 4.46" for 100-YR event
Inflow = 11.84 cfs @ 12.14 hrs, Volume= 1.101 af
Primary = 11.84 cfs @ 12.14 hrs, Volume= 1.101 af, Atten= 0%, Lag= 0.0 min

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



APPENDIX E

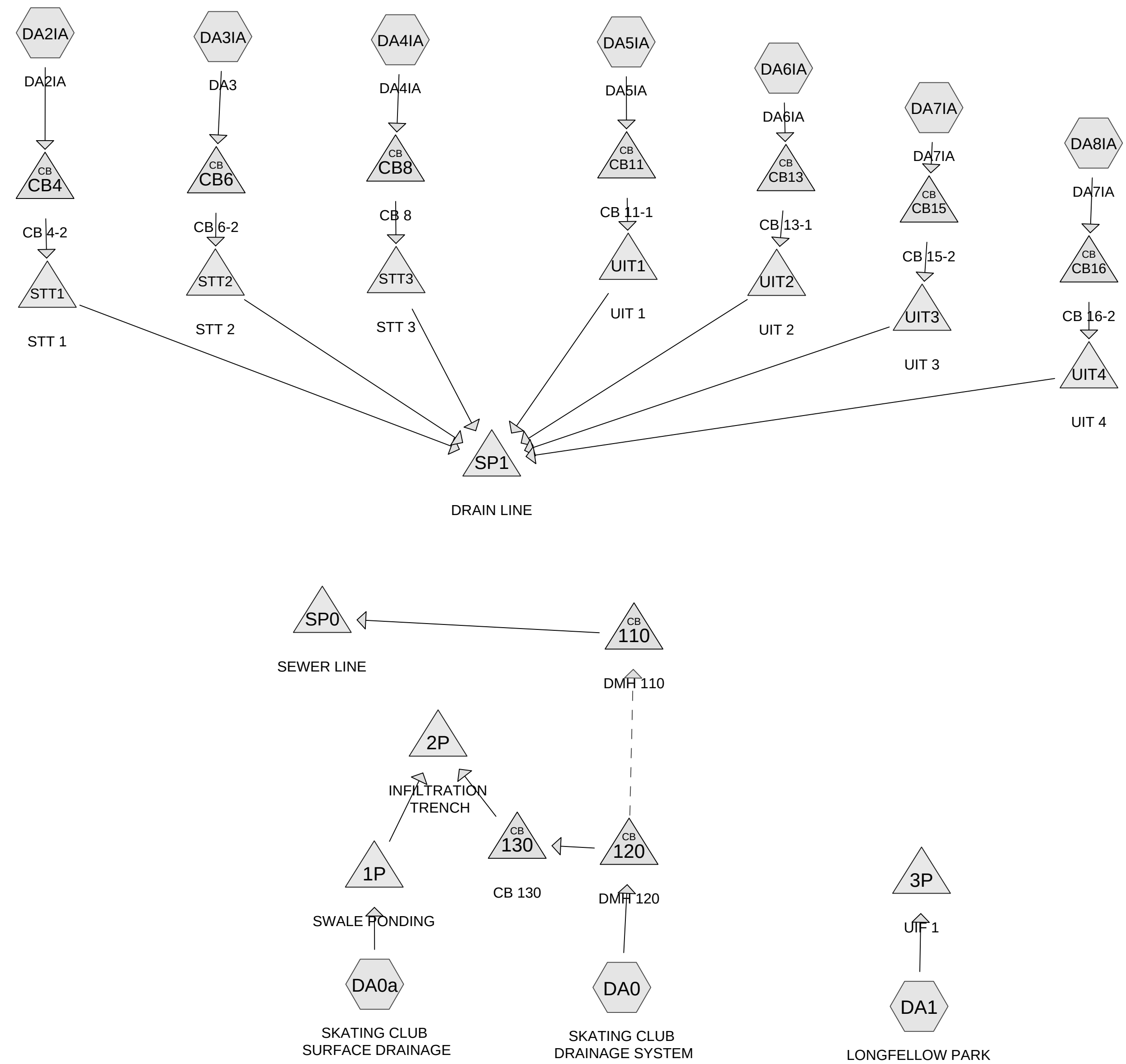
HydroCAD® Water Quality Calculations

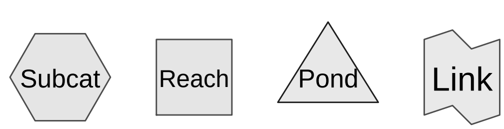
Existing Conditions

2-Year Event
10-Year Event
25-Year Event
100-Year Event

Proposed Conditions

2-Year Event
10-Year Event
25-Year Event
100-Year Event





Routing Diagram for 16124A POST-DEV only impervious areas
Prepared by Windows User, Printed 3/20/2018
HydroCAD® 10.00-17 s/n 01445 © 2016 HydroCAD Software Solutions LLC

Summary for Subcatchment DA0: SKATING CLUB DRAINAGE SYSTEM

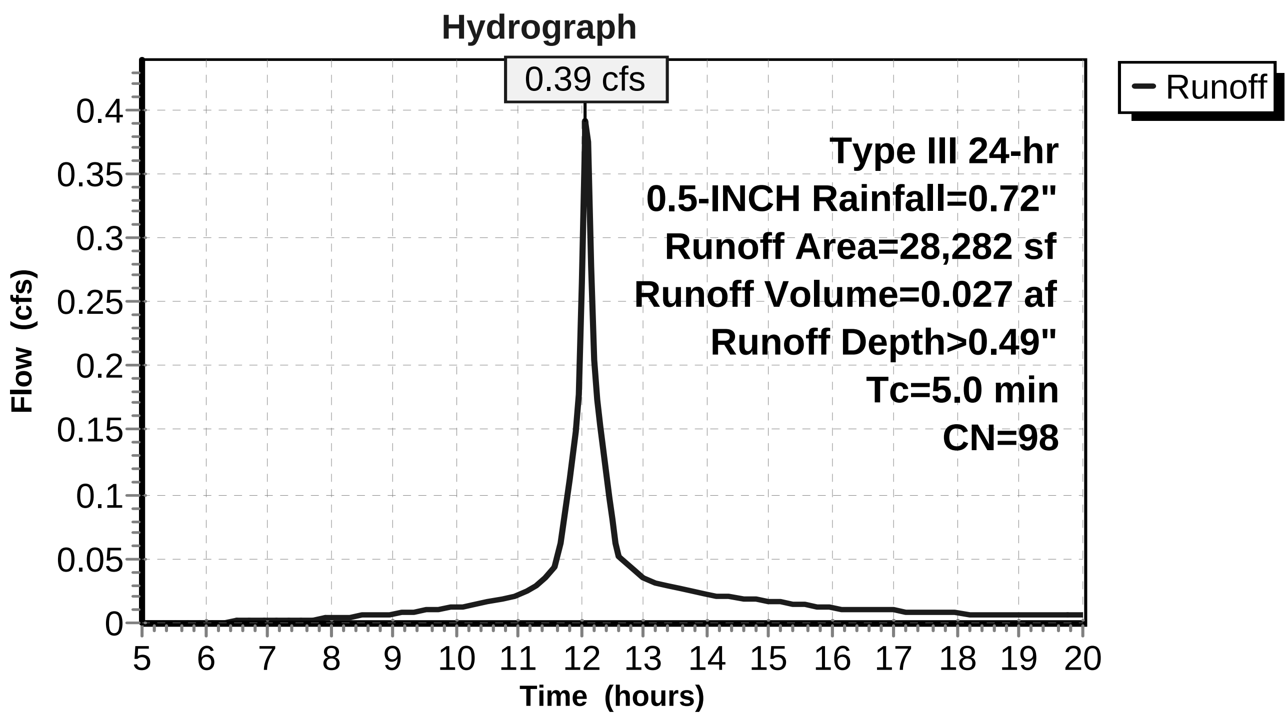
Runoff = 0.39 cfs @ 12.07 hrs, Volume= 0.027 af, Depth> 0.49"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.5-INCH Rainfall=0.72"

Area (sf)	CN	Description
24,898	98	Unconnected pavement, HSG A
3,384	98	Unconnected roofs, HSG A
28,282	98	Weighted Average
28,282		100.00% Impervious Area
28,282		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, 5 MIN**

Subcatchment DA0: SKATING CLUB DRAINAGE SYSTEM



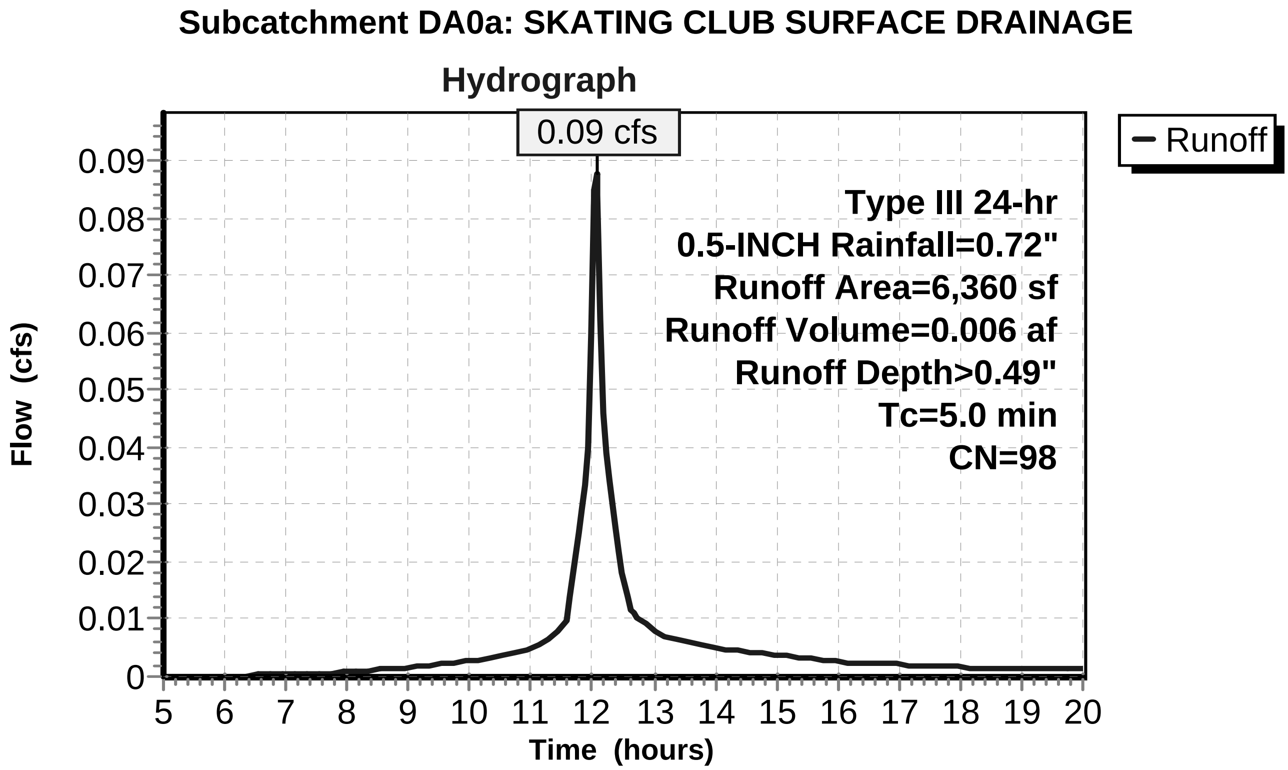
Summary for Subcatchment DA0a: SKATING CLUB SURFACE DRAINAGE

Runoff = 0.09 cfs @ 12.07 hrs, Volume= 0.006 af, Depth> 0.49"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.5-INCH Rainfall=0.72"

Area (sf)	CN	Description
6,360	98	Paved parking, HSG A
6,360		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, 5 MIN**



Summary for Subcatchment DA1: LONGFELLOW PARK

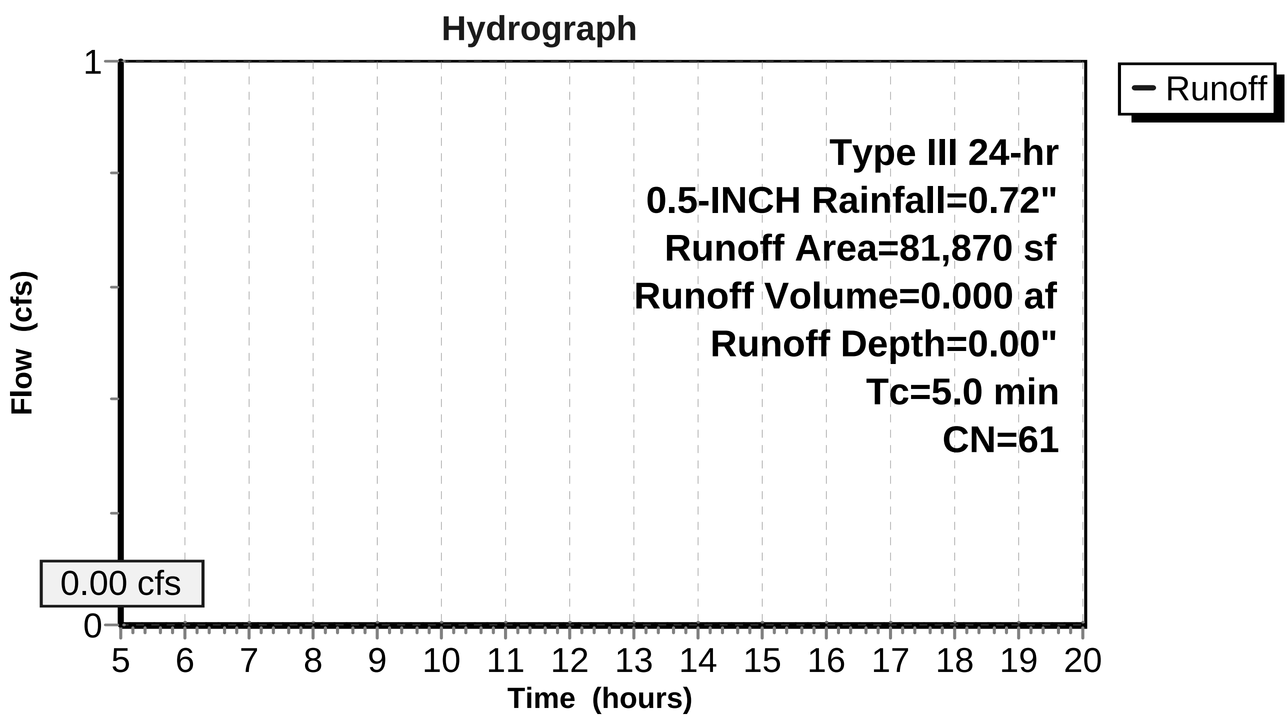
Runoff = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.5-INCH Rainfall=0.72"

Area (sf)	CN	Description
9,410	98	Unconnected roofs, HSG A
23,055	98	Unconnected pavement, HSG A
14,805	32	Woods/grass comb., Good, HSG A
34,600	39	>75% Grass cover, Good, HSG A
81,870	61	Weighted Average
49,405		60.35% Pervious Area
32,465		39.65% Impervious Area
32,465		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, 5 MIN**

Subcatchment DA1: LONGFELLOW PARK



Summary for Subcatchment DA2IA: DA2IA

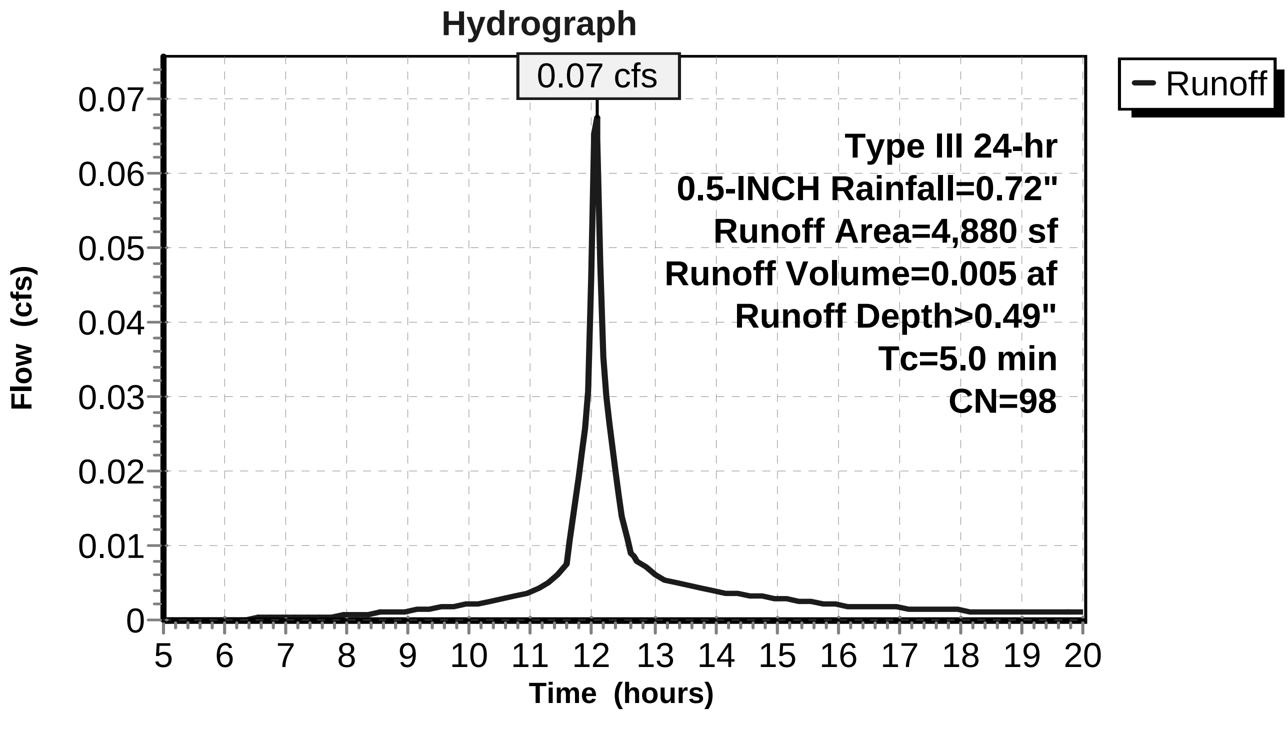
Runoff = 0.07 cfs @ 12.07 hrs, Volume= 0.005 af, Depth> 0.49"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.5-INCH Rainfall=0.72"

Area (sf)	CN	Description
1,530	98	Roofs, HSG A
3,350	98	Paved parking, HSG A
4,880	98	Weighted Average
4,880		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, 5 MIN**

Subcatchment DA2IA: DA2IA



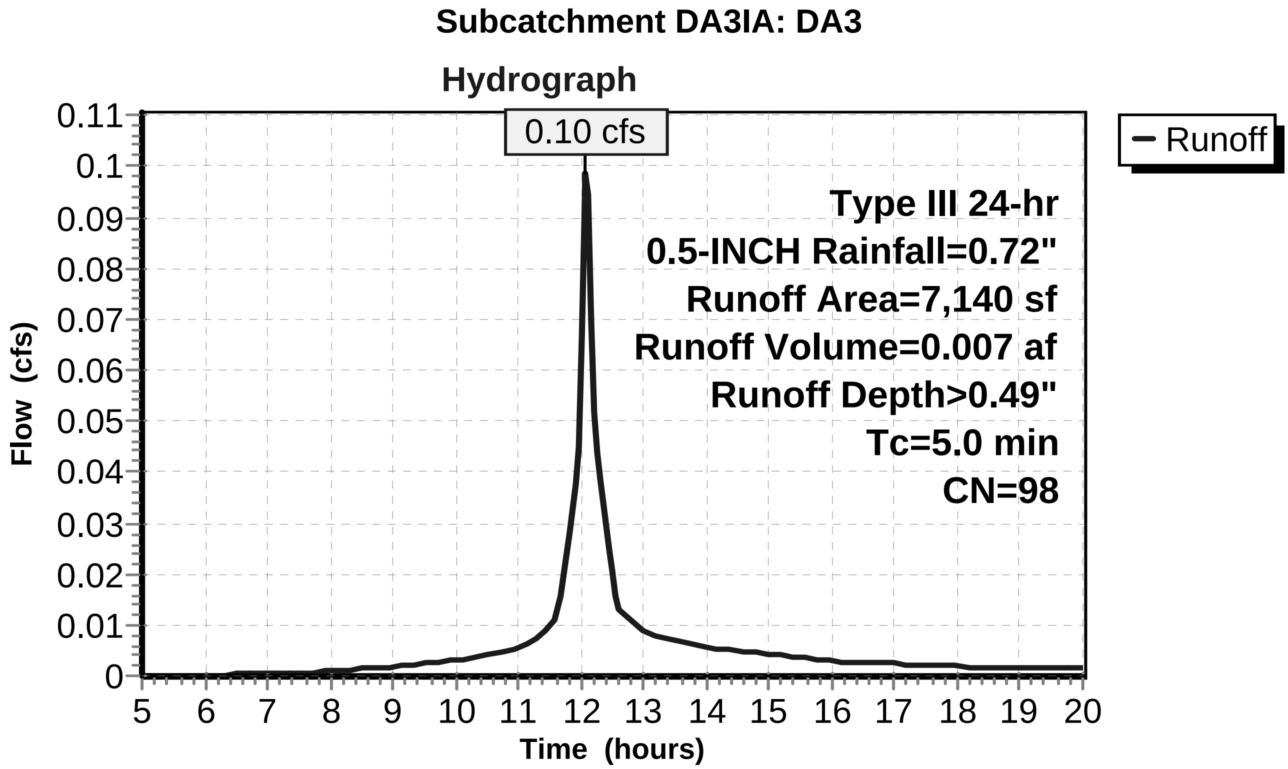
Summary for Subcatchment DA3IA: DA3

Runoff = 0.10 cfs @ 12.07 hrs, Volume= 0.007 af, Depth> 0.49"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.5-INCH Rainfall=0.72"

Area (sf)	CN	Description
2,910	98	Roofs, HSG A
4,230	98	Unconnected pavement, HSG A
7,140	98	Weighted Average
7,140		100.00% Impervious Area
4,230		59.24% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, 5 MIN**



Summary for Subcatchment DA4IA: DA4IA

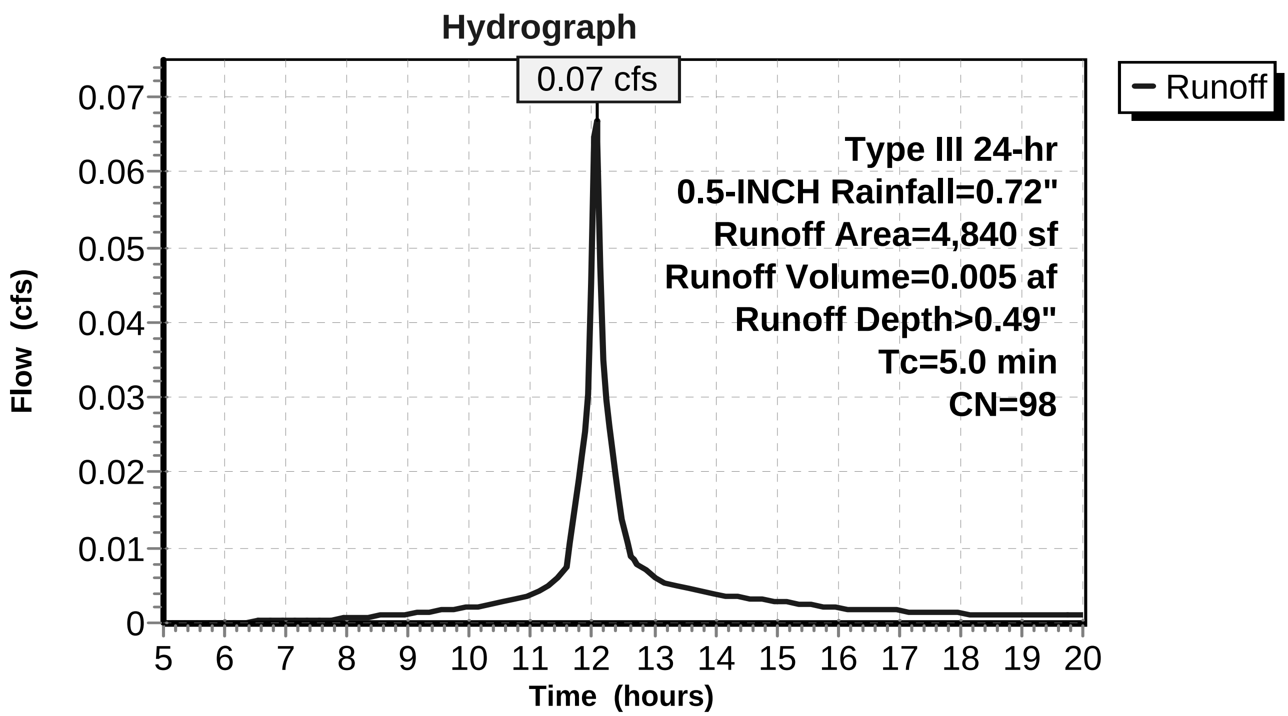
Runoff = 0.07 cfs @ 12.07 hrs, Volume= 0.005 af, Depth> 0.49"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.5-INCH Rainfall=0.72"

Area (sf)	CN	Description
1,820	98	Roofs, HSG A
3,020	98	Unconnected pavement, HSG A
4,840	98	Weighted Average
4,840		100.00% Impervious Area
3,020		62.40% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, 5 MIN**

Subcatchment DA4IA: DA4IA



Summary for Subcatchment DA5IA: DA5IA

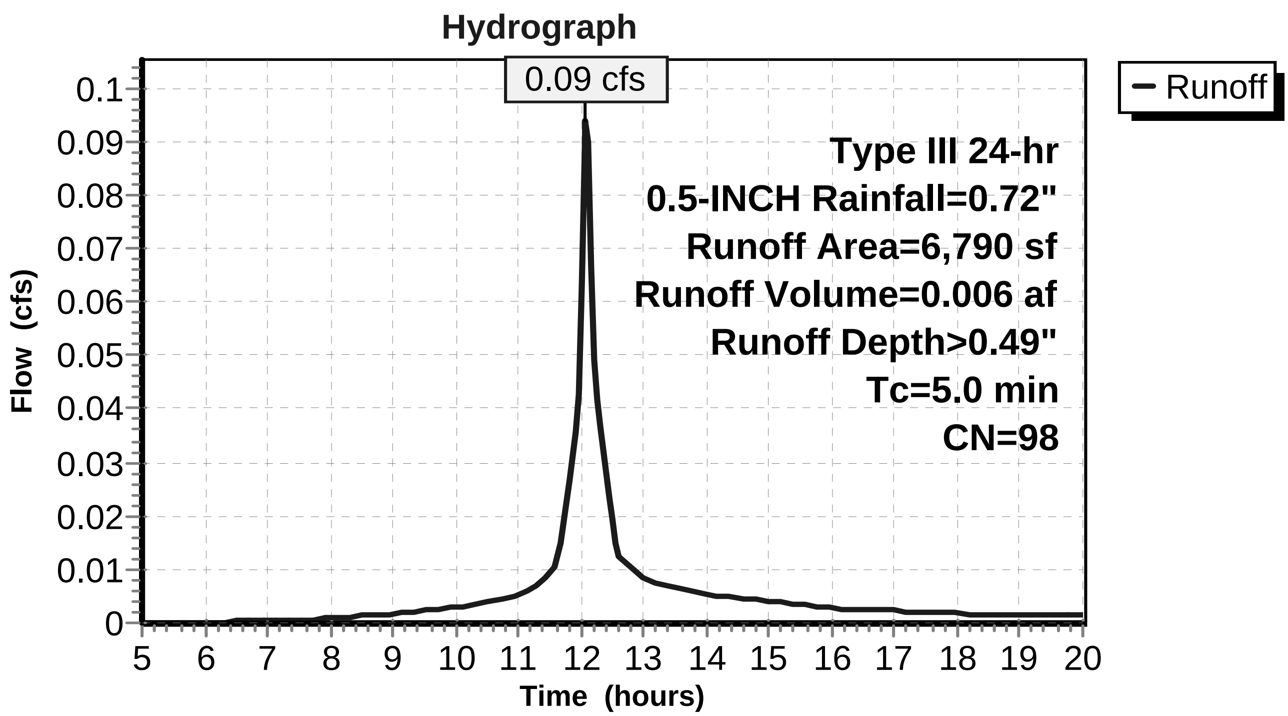
Runoff = 0.09 cfs @ 12.07 hrs, Volume= 0.006 af, Depth> 0.49"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.5-INCH Rainfall=0.72"

Area (sf)	CN	Description
2,345	98	Roofs, HSG A
4,445	98	Unconnected pavement, HSG A
6,790	98	Weighted Average
6,790		100.00% Impervious Area
4,445		65.46% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, 5 MIN**

Subcatchment DA5IA: DA5IA



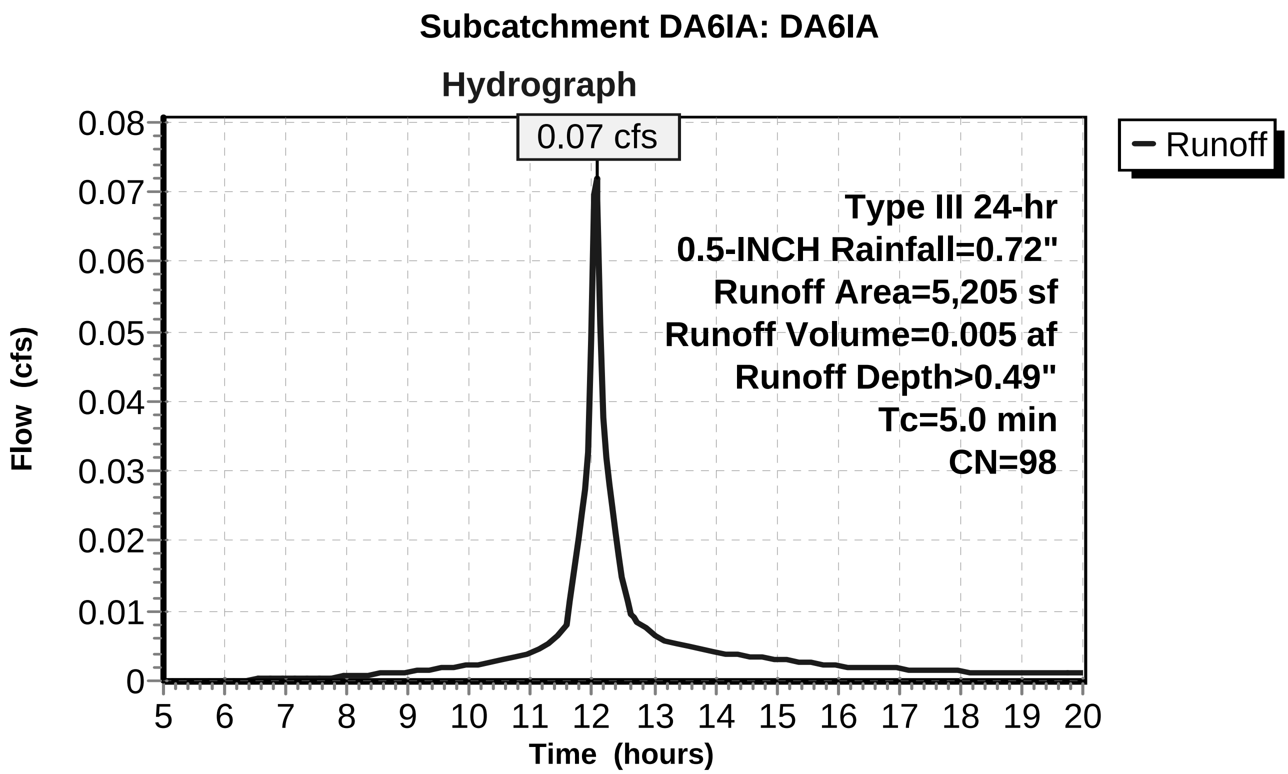
Summary for Subcatchment DA6IA: DA6IA

Runoff = 0.07 cfs @ 12.07 hrs, Volume= 0.005 af, Depth> 0.49"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.5-INCH Rainfall=0.72"

Area (sf)	CN	Description
2,615	98	Roofs, HSG A
2,590	98	Unconnected pavement, HSG A
5,205	98	Weighted Average
5,205		100.00% Impervious Area
2,590		49.76% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, 5 MIN**



Summary for Subcatchment DA7IA: DA7IA

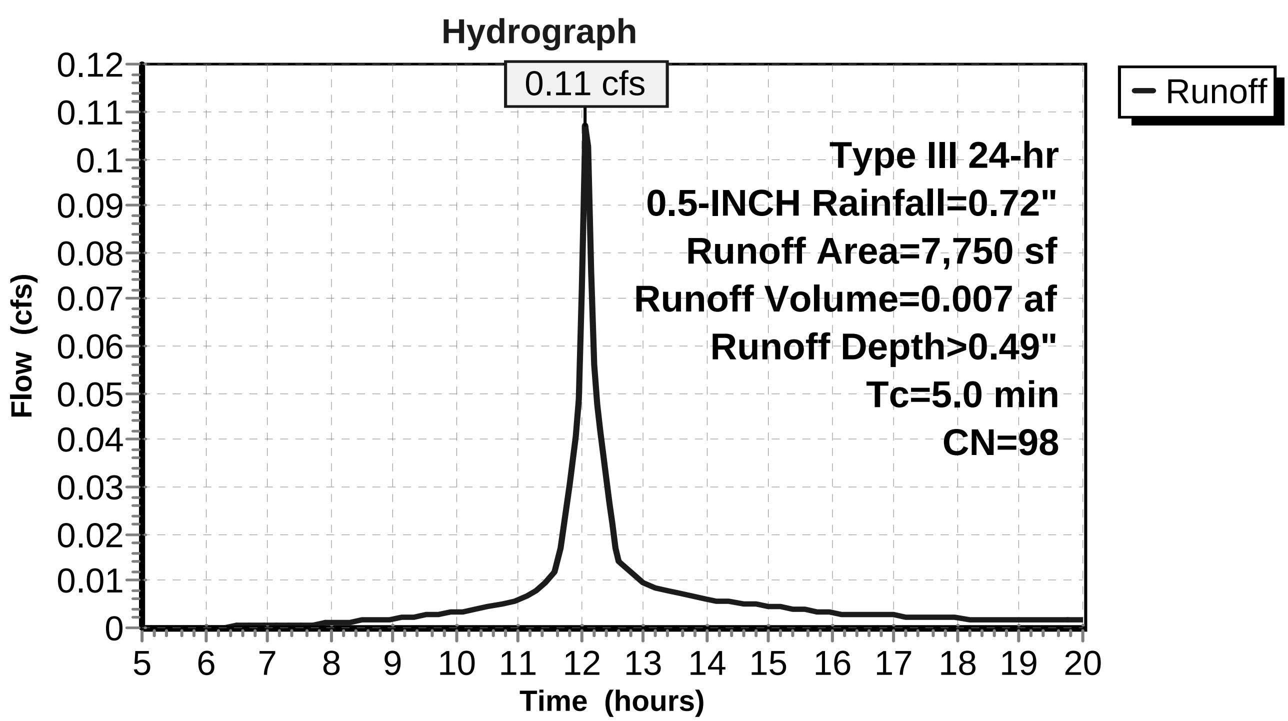
Runoff = 0.11 cfs @ 12.07 hrs, Volume= 0.007 af, Depth> 0.49"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.5-INCH Rainfall=0.72"

Area (sf)	CN	Description
3,150	98	Roofs, HSG A
4,600	98	Unconnected pavement, HSG A
7,750	98	Weighted Average
7,750		100.00% Impervious Area
4,600		59.35% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, 5 MIN**

Subcatchment DA7IA: DA7IA



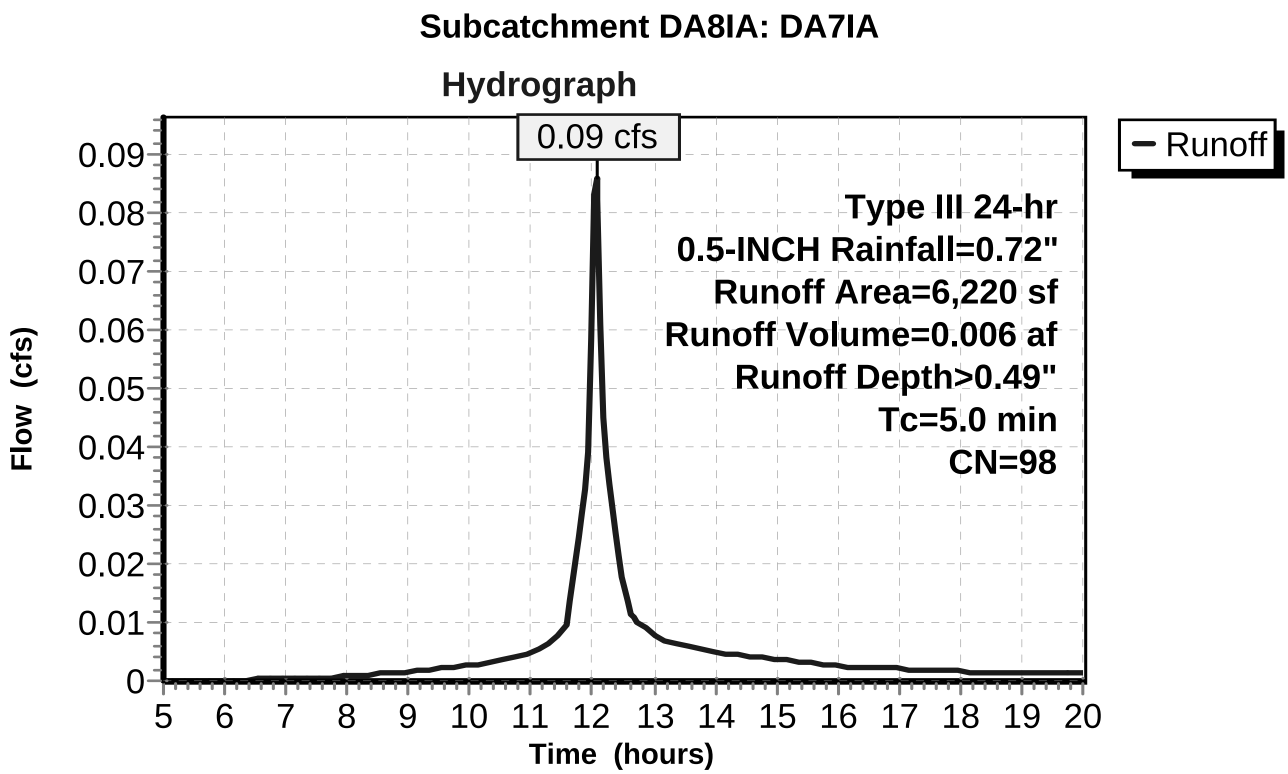
Summary for Subcatchment DA8IA: DA7IA

Runoff = 0.09 cfs @ 12.07 hrs, Volume= 0.006 af, Depth> 0.49"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.5-INCH Rainfall=0.72"

Area (sf)	CN	Description
2,315	98	Roofs, HSG A
3,905	98	Unconnected pavement, HSG A
6,220	98	Weighted Average
6,220		100.00% Impervious Area
3,905		62.78% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, 5 MIN**



Summary for Pond 1P: SWALE PONDING

Inflow Area = 0.146 ac,100.00% Impervious, Inflow Depth > 0.49" for 0.5-INCH event
Inflow = 0.09 cfs @ 12.07 hrs, Volume= 0.006 af
Outflow = 0.06 cfs @ 12.17 hrs, Volume= 0.006 af, Atten= 33%, Lag= 5.6 min
Primary = 0.06 cfs @ 12.17 hrs, Volume= 0.006 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 15.04' @ 12.17 hrs Surf.Area= 308 sf Storage= 30 cf

Plug-Flow detention time= 4.2 min calculated for 0.006 af (100% of inflow)
Center-of-Mass det. time= 4.1 min (771.3 - 767.2)

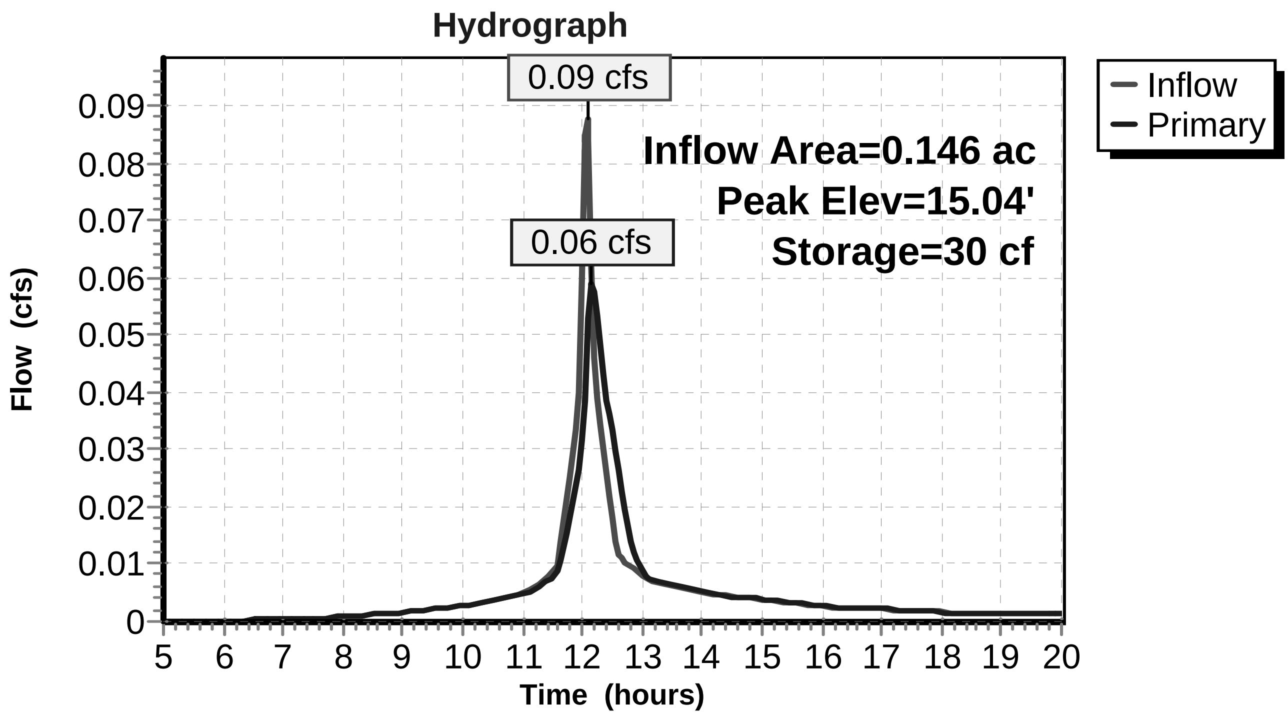
Volume	Invert	Avail.Storage	Storage Description
#1	14.80'	37,985 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
14.80	0	0	0
15.00	204	20	20
15.25	878	135	156
16.00	100,000	37,829	37,985

Device	Routing	Invert	Outlet Devices
#1	Primary	14.80'	**8.270 in/hr Exfiltration over Surface area**

Primary OutFlow Max=0.06 cfs @ 12.17 hrs HW=15.04' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.06 cfs)

Pond 1P: SWALE PONDING



Summary for Pond 2P: INFILTRATION TRENCH

Inflow Area = 0.795 ac,100.00% Impervious, Inflow Depth > 0.36" for 0.5-INCH event
Inflow = 0.42 cfs @ 12.08 hrs, Volume= 0.024 af
Outflow = 0.24 cfs @ 12.22 hrs, Volume= 0.024 af, Atten= 44%, Lag= 8.5 min
Discarded = 0.24 cfs @ 12.22 hrs, Volume= 0.024 af

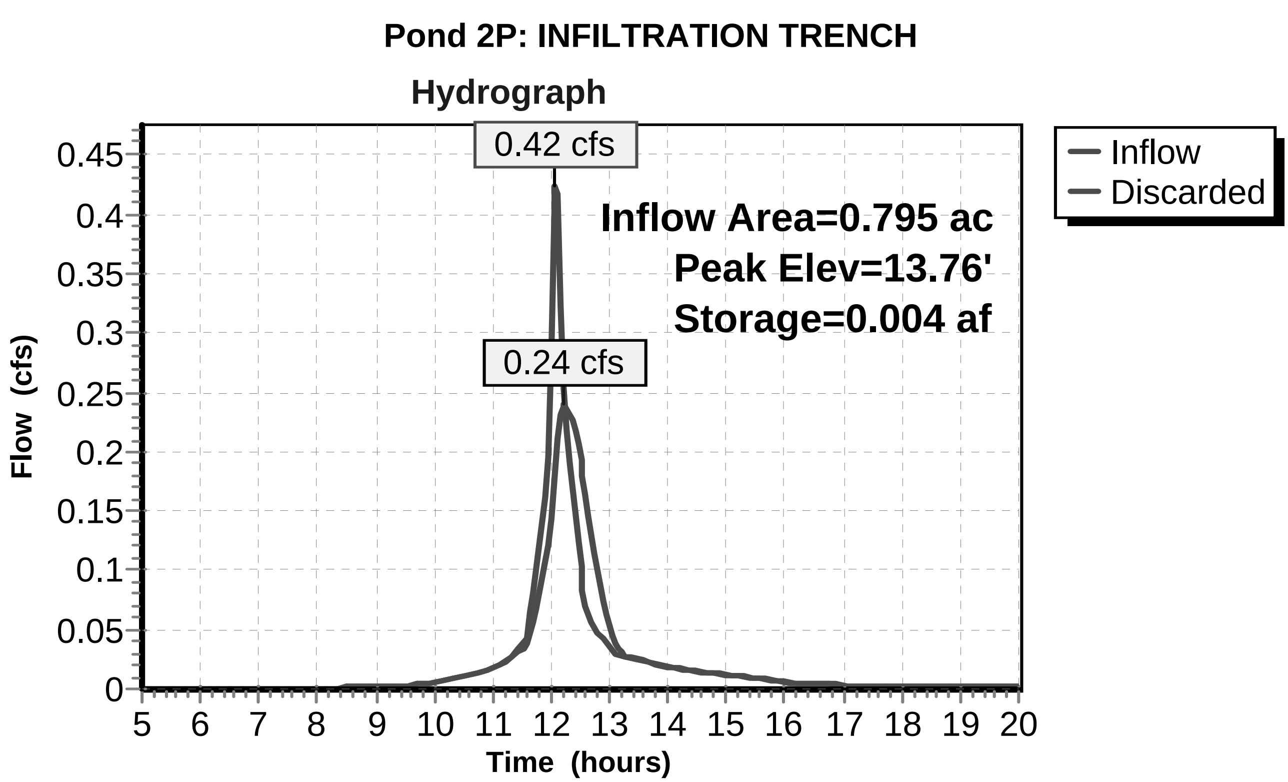
Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 13.76' @ 12.22 hrs Surf.Area= 0.029 ac Storage= 0.004 af

Plug-Flow detention time= 6.5 min calculated for 0.024 af (100% of inflow)
Center-of-Mass det. time= 6.5 min (756.7 - 750.2)

Volume	Invert	Avail.Storage	Storage Description
#1	12.95'	0.026 af	**2.00'W x 70.00'L x 2.05'H Prismatoid Z=8.0** 0.079 af Overall x 33.0% Voids

Device	Routing	Invert	Outlet Devices
#1	Discarded	12.95'	**8.270 in/hr Exfiltration over Surface area**

Discarded OutFlow Max=0.24 cfs @ 12.22 hrs HW=13.76' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.24 cfs)



Summary for Pond 3P: UIF 1

Inflow Area = 1.879 ac, 39.65% Impervious, Inflow Depth = 0.00" for 0.5-INCH event
Inflow = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af
Outflow = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af, Atten= 0%, Lag= 0.0 min
Discarded = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 17.00' @ 5.00 hrs Surf.Area= 0.056 ac Storage= 0.000 af

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

Volume	Invert	Avail.Storage	Storage Description
#1A	17.00'	0.052 af	**30.00'W x 81.94'L x 4.00'H Field A** 0.226 af Overall - 0.070 af Embedded = 0.156 af x 33.0% Voids
#2A	18.00'	0.070 af	**ADS_StormTech SC-740 +Cap** x 66 Inside #1 Effective Size= 44.6"W x 30.0"H => 6.45 sf x 7.12'L = 45.9 cf Overall Size= 51.0"W x 30.0"H x 7.56'L with 0.44' Overlap 6 Rows of 11 Chambers
		0.121 af	Total Available Storage

Storage Group A created with Chamber Wizard

Device	Routing	Invert	Outlet Devices
#1	Discarded	17.00'	**8.270 in/hr Exfiltration over Surface area**

Discarded OutFlow Max=0.00 cfs @ 5.00 hrs HW=17.00' (Free Discharge)
└─**1=Exfiltration** (Passes 0.00 cfs of 0.47 cfs potential flow)

Pond 3P: UIF 1 - Chamber Wizard Field A

Chamber Model = ADS_StormTech SC-740 +Cap (ADS StormTech® SC-740 with cap length)
Effective Size= 44.6"W x 30.0"H => 6.45 sf x 7.12'L = 45.9 cf
Overall Size= 51.0"W x 30.0"H x 7.56'L with 0.44' Overlap

51.0" Wide + 6.0" Spacing = 57.0" C-C Row Spacing

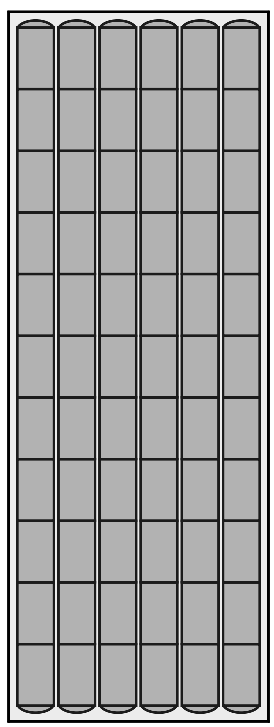
11 Chambers/Row x 7.12' Long +0.81' Cap Length x 2 = 79.94' Row Length +12.0" End Stone x 2 = 81.94' Base Length
6 Rows x 51.0" Wide + 6.0" Spacing x 5 + 12.0" Side Stone x 2 = 30.00' Base Width
12.0" Base + 30.0" Chamber Height + 6.0" Cover = 4.00' Field Height

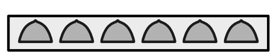
66 Chambers x 45.9 cf = 3,032.0 cf Chamber Storage

9,832.4 cf Field - 3,032.0 cf Chambers = 6,800.4 cf Stone x 33.0% Voids = 2,244.1 cf Stone Storage

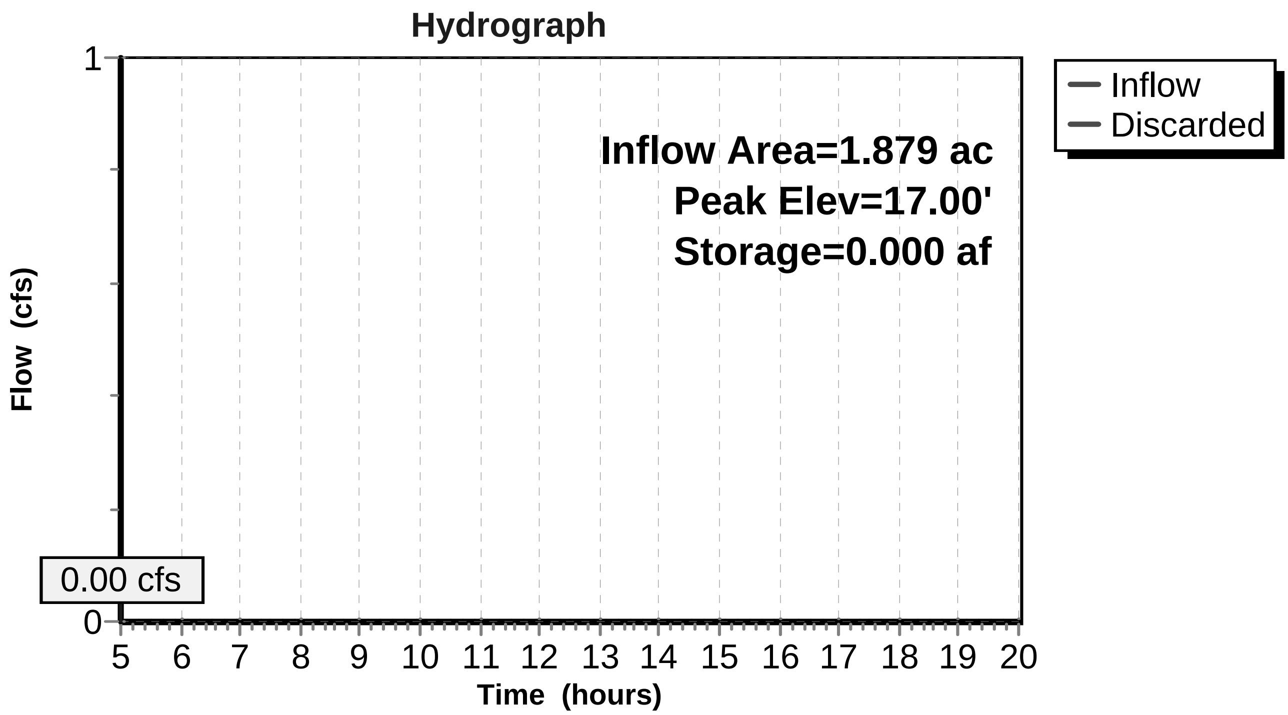
Chamber Storage + Stone Storage = 5,276.2 cf = 0.121 af
Overall Storage Efficiency = 53.7%
Overall System Size = 81.94' x 30.00' x 4.00'

66 Chambers
364.2 cy Field
251.9 cy Stone





Pond 3P: UIF 1


Hydrograph
Inflow
Discarded
Inflow Area=1.879 ac
Peak Elev=17.00'
Storage=0.000 af
0.00 cfs
Flow (cfs)
Time (hours)
1
0
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

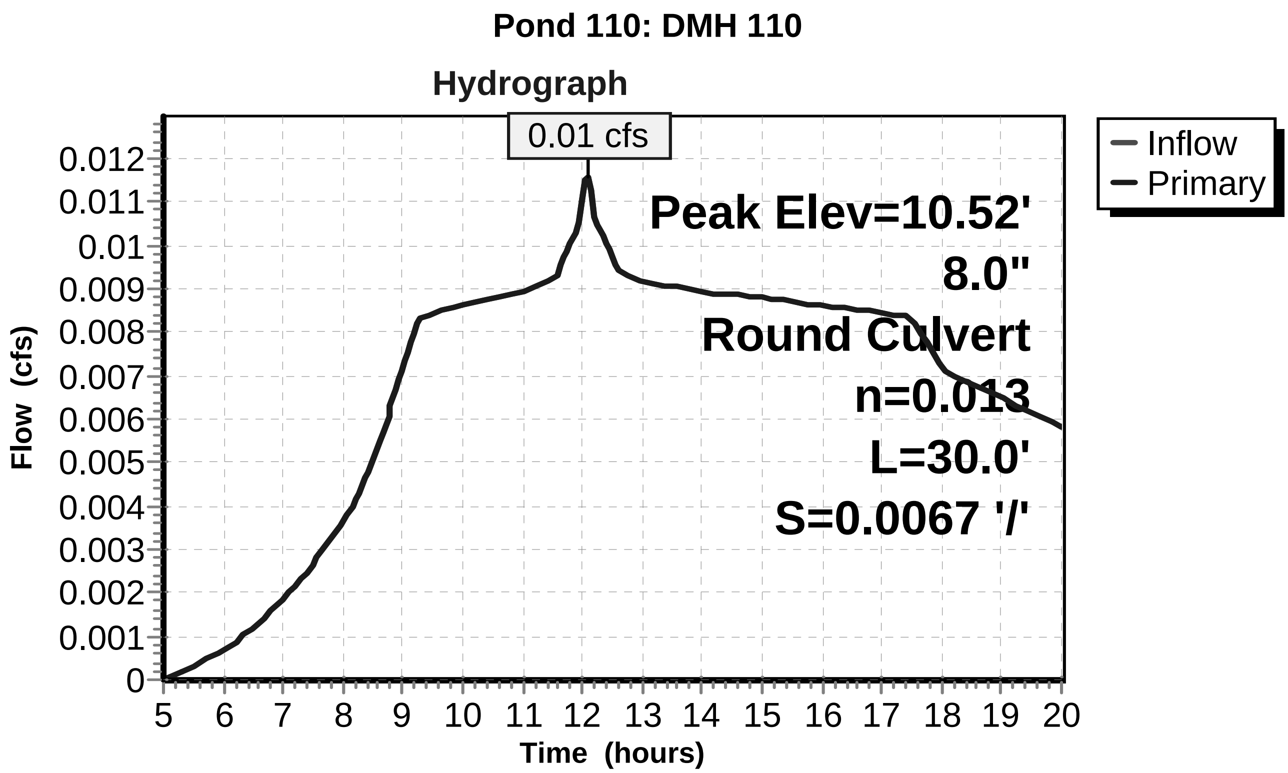
Summary for Pond 110: DMH 110

Inflow	=	0.01 cfs @	12.07 hrs, Volume=	0.008 af	
Outflow	=	0.01 cfs @	12.07 hrs, Volume=	0.008 af,	Atten= 0%, Lag= 0.0 min
Primary	=	0.01 cfs @	12.07 hrs, Volume=	0.008 af	

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 10.52' @ 12.07 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	10.45'	**8.0" Round 8" HDPE** L= 30.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 10.45' / 10.25' S= 0.0067 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.35 sf

Primary OutFlow Max=0.01 cfs @ 12.07 hrs HW=10.52' (Free Discharge)
└─**1=8" HDPE** (Barrel Controls 0.01 cfs @ 0.94 fps)



Summary for Pond 120: DMH 120

Inflow Area = 0.649 ac,100.00% Impervious, Inflow Depth > 0.49" for 0.5-INCH event
Inflow = 0.39 cfs @ 12.07 hrs, Volume= 0.027 af
Outflow = 0.39 cfs @ 12.07 hrs, Volume= 0.027 af, Atten= 0%, Lag= 0.0 min
Primary = 0.38 cfs @ 12.07 hrs, Volume= 0.018 af
Secondary = 0.01 cfs @ 12.07 hrs, Volume= 0.008 af

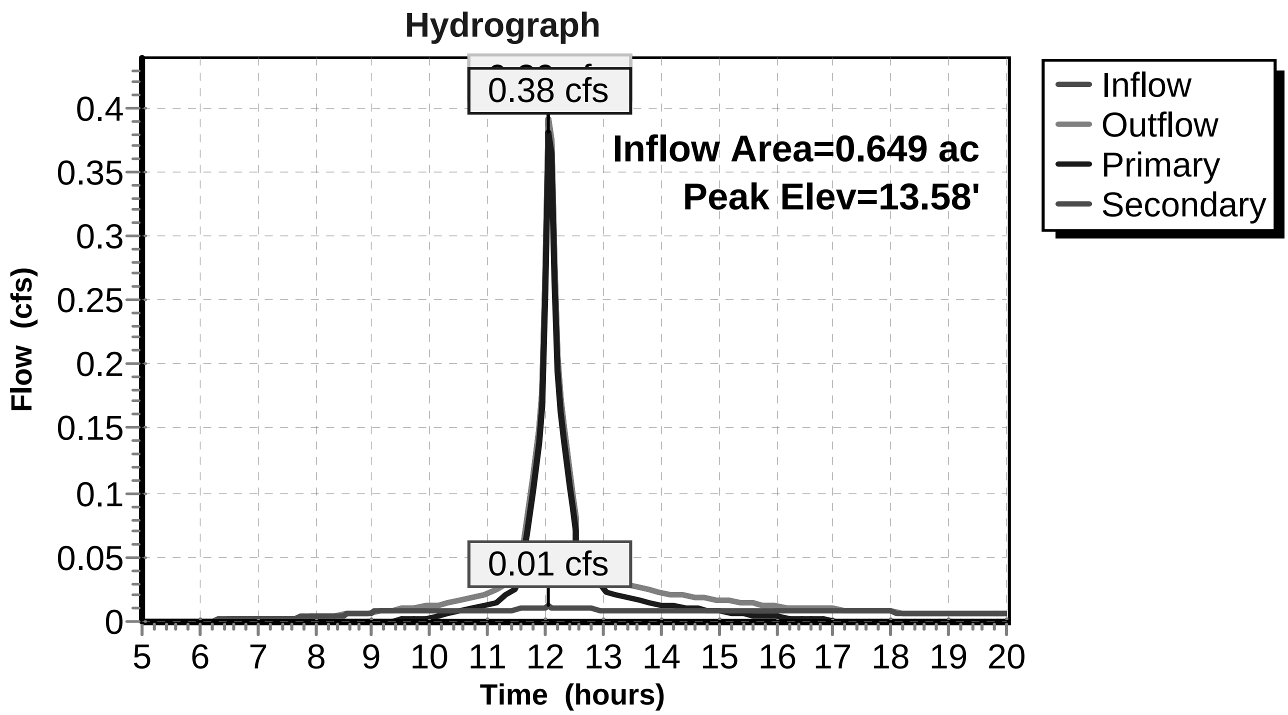
Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 13.58' @ 12.07 hrs

Device	Routing	Invert	Outlet Devices
#1	Device 4	14.00'	**4.0' long x 0.5' breadth Diversion Wall** Head (feet) 0.20 0.40 0.60 0.80 1.00 Coef. (English) 2.80 2.92 3.08 3.30 3.32
#2	Device 4	11.80'	**0.5" Vert. Drawdown Orifice** X 2 rows with 1.0" cc spacing C= 0.600
#3	Primary	13.20'	**8.0" Round 8" HDPE to 130** L= 10.0' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 13.20' / 13.00' S= 0.0200 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.35 sf
#4	Secondary	12.80'	**8.0" Round 8" HDPE to 110** L= 15.0' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 12.80' / 12.00' S= 0.0533 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.35 sf

Primary OutFlow Max=0.37 cfs @ 12.07 hrs HW=13.57' (Free Discharge)
└─**3=8" HDPE to 130** (Inlet Controls 0.37 cfs @ 1.83 fps)

Secondary OutFlow Max=0.01 cfs @ 12.07 hrs HW=13.57' (Free Discharge)
└─**4=8" HDPE to 110** (Passes 0.01 cfs of 0.98 cfs potential flow)
  ├─**1=Diversion Wall** (Controls 0.00 cfs)
  └─**2=Drawdown Orifice** (Orifice Controls 0.01 cfs @ 4.23 fps)

Pond 120: DMH 120



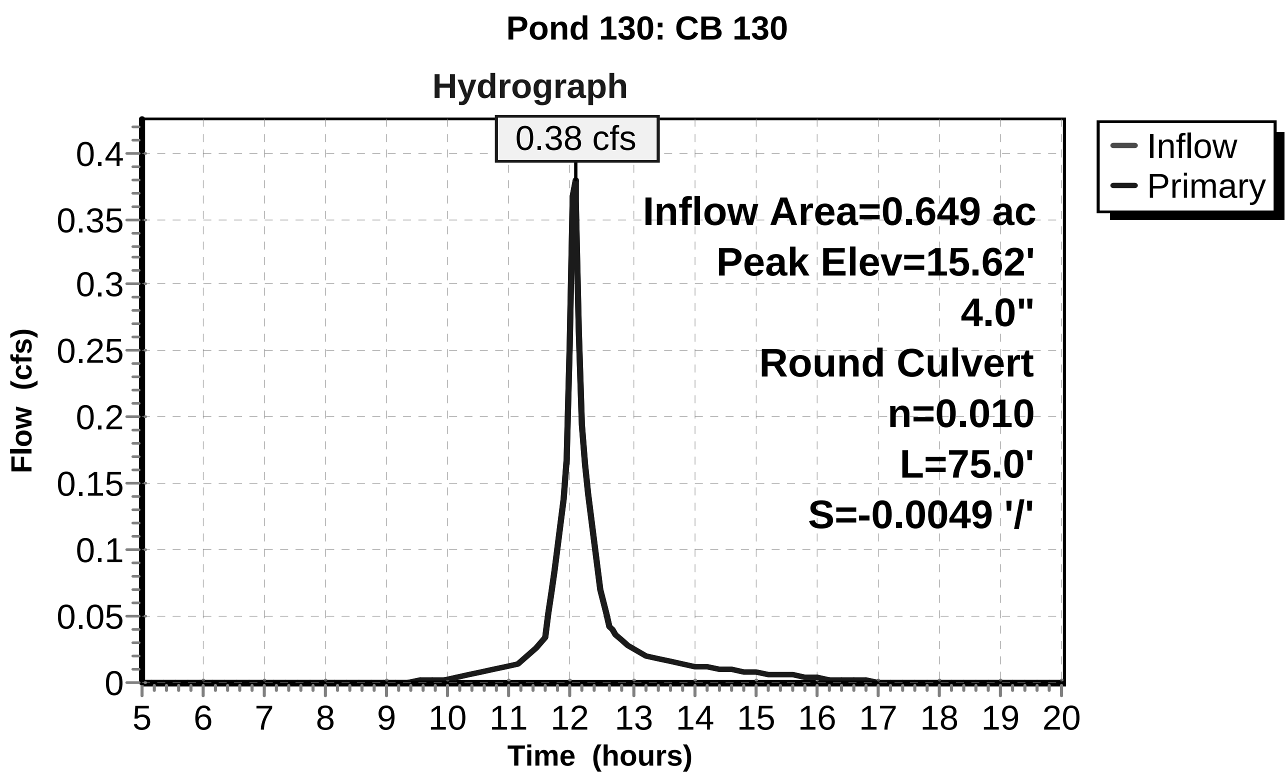
Summary for Pond 130: CB 130

Inflow Area = 0.649 ac,100.00% Impervious, Inflow Depth = 0.34" for 0.5-INCH event
Inflow = 0.38 cfs @ 12.07 hrs, Volume= 0.018 af
Outflow = 0.38 cfs @ 12.07 hrs, Volume= 0.018 af, Atten= 0%, Lag= 0.0 min
Primary = 0.38 cfs @ 12.07 hrs, Volume= 0.018 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 15.62' @ 12.07 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	13.37'	**4.0" Round 4" PVC Underdrain** L= 75.0' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 13.00' / 13.37' S= -0.0049 '/' Cc= 0.900 n= 0.010 PVC, smooth interior, Flow Area= 0.09 sf

Primary OutFlow Max=0.37 cfs @ 12.07 hrs HW=15.47' (Free Discharge)
1=4" PVC Underdrain (Outlet Controls 0.37 cfs @ 4.19 fps)



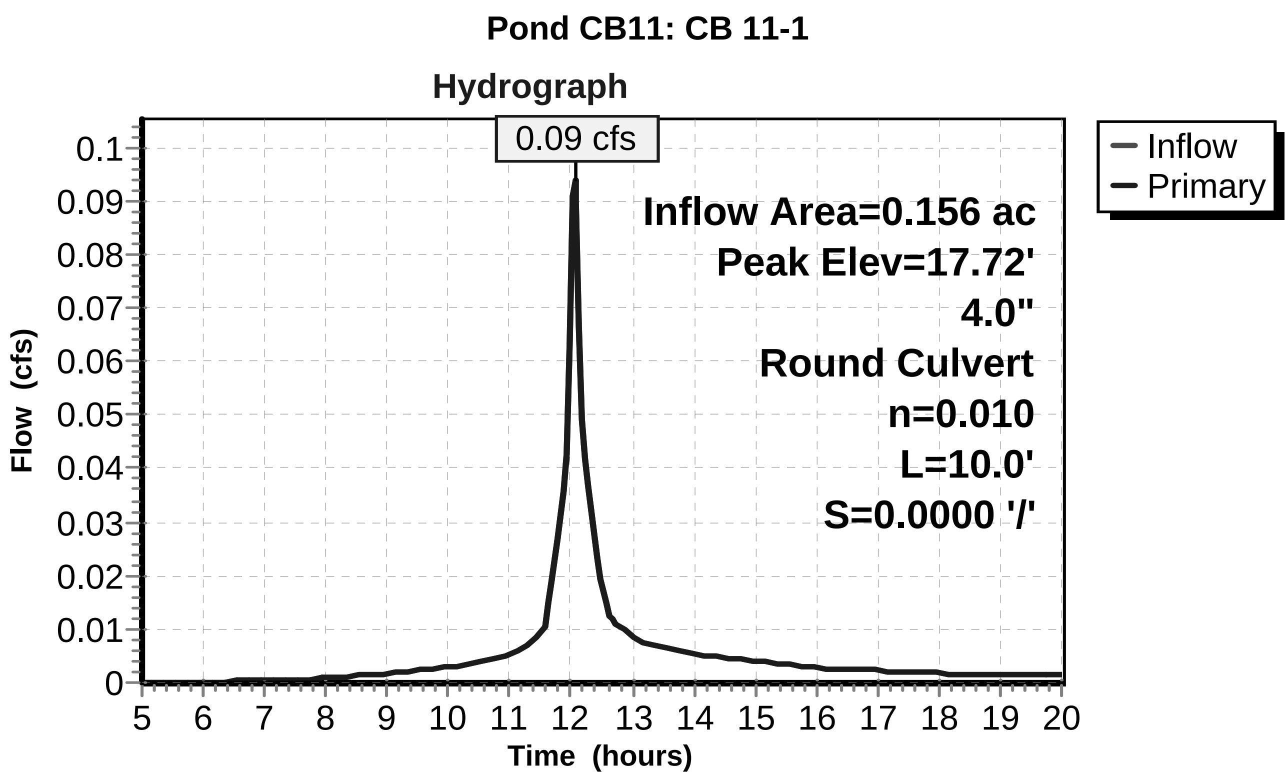
Summary for Pond CB11: CB 11-1

Inflow Area =	0.156 ac,100.00% Impervious,	Inflow Depth > 0.49"	for 0.5-INCH event	
Inflow =	0.09 cfs @	12.07 hrs, Volume=	0.006 af	
Outflow =	0.09 cfs @	12.07 hrs, Volume=	0.006 af,	Atten= 0%, Lag= 0.0 min
Primary =	0.09 cfs @	12.07 hrs, Volume=	0.006 af	

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 17.72' @ 12.07 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	17.40'	**4.0" Round 4" UD OUT** L= 10.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 17.40' / 17.40' S= 0.0000 '/' Cc= 0.900 n= 0.010 PVC, smooth interior, Flow Area= 0.09 sf

Primary OutFlow Max=0.09 cfs @ 12.07 hrs HW=17.71' (Free Discharge)
└─**1=4" UD OUT** (Barrel Controls 0.09 cfs @ 1.40 fps)



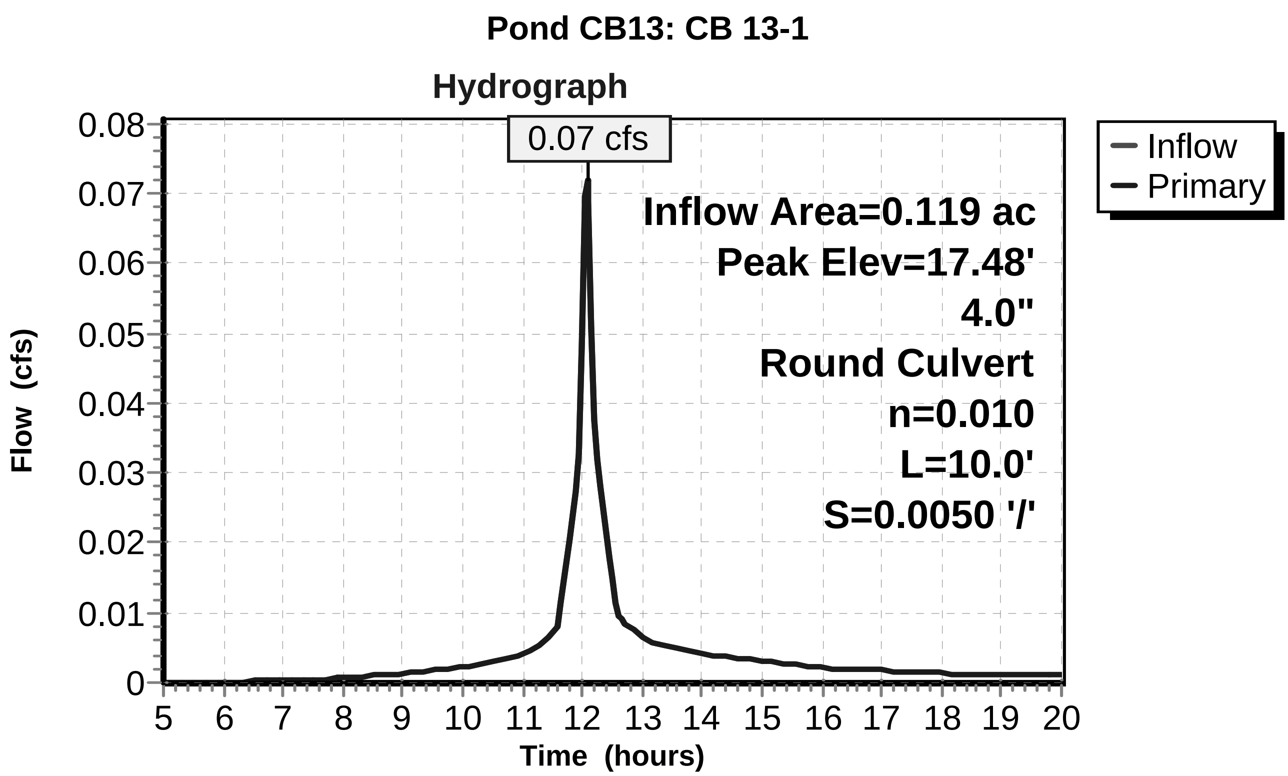
Summary for Pond CB13: CB 13-1

Inflow Area =	0.119 ac,100.00% Impervious,	Inflow Depth > 0.49"	for 0.5-INCH event
Inflow =	0.07 cfs @ 12.07 hrs, Volume=	0.005 af	
Outflow =	0.07 cfs @ 12.07 hrs, Volume=	0.005 af, Atten= 0%, Lag= 0.0 min	
Primary =	0.07 cfs @ 12.07 hrs, Volume=	0.005 af	

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 17.48' @ 12.07 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	17.25'	**4.0" Round 4" UD OUT** L= 10.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 17.25' / 17.20' S= 0.0050 '/' Cc= 0.900 n= 0.010 PVC, smooth interior, Flow Area= 0.09 sf

Primary OutFlow Max=0.07 cfs @ 12.07 hrs HW=17.47' (Free Discharge)
└─**1=4" UD OUT** (Barrel Controls 0.07 cfs @ 1.59 fps)



Summary for Pond CB15: CB 15-2

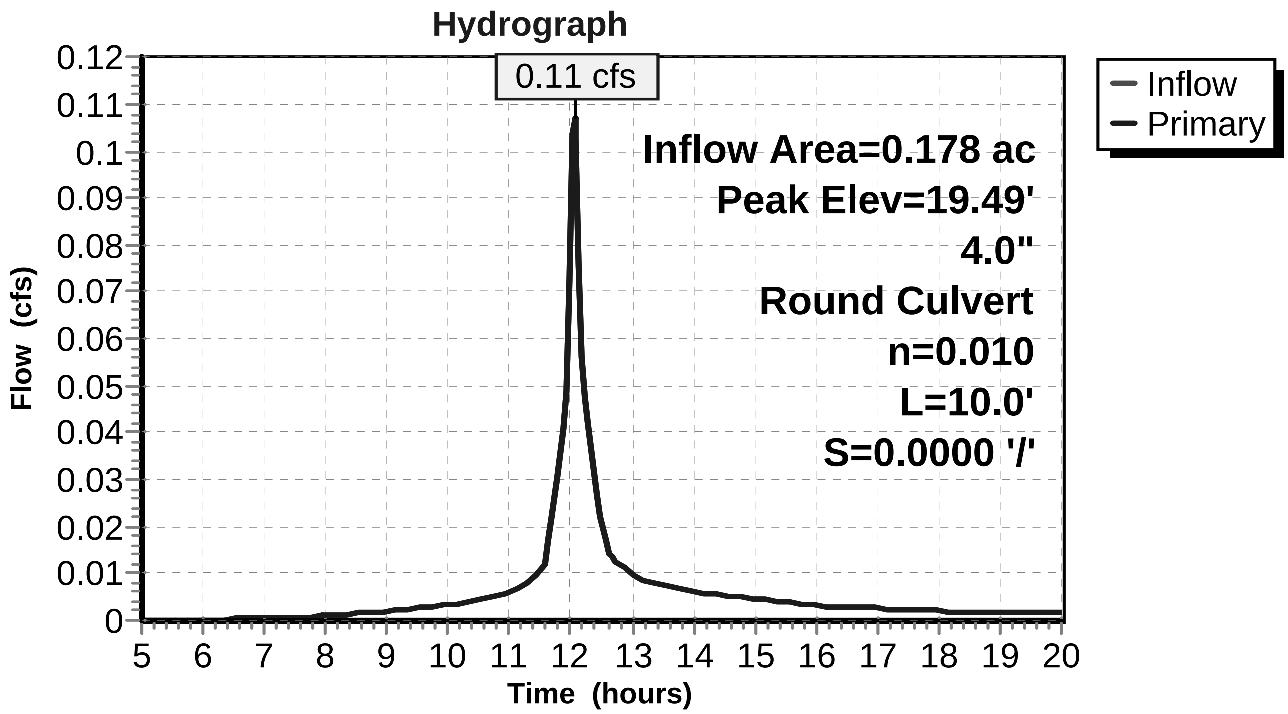
Inflow Area = 0.178 ac,100.00% Impervious, Inflow Depth > 0.49" for 0.5-INCH event
Inflow = 0.11 cfs @ 12.07 hrs, Volume= 0.007 af
Outflow = 0.11 cfs @ 12.07 hrs, Volume= 0.007 af, Atten= 0%, Lag= 0.0 min
Primary = 0.11 cfs @ 12.07 hrs, Volume= 0.007 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 19.49' @ 12.07 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	19.15'	**4.0" Round 4" UD OUT** L= 10.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 19.15' / 19.15' S= 0.0000 '/' Cc= 0.900 n= 0.010 PVC, smooth interior, Flow Area= 0.09 sf

Primary OutFlow Max=0.10 cfs @ 12.07 hrs HW=19.49' (Free Discharge)
└─**1=4" UD OUT** (Barrel Controls 0.10 cfs @ 1.46 fps)

Pond CB15: CB 15-2



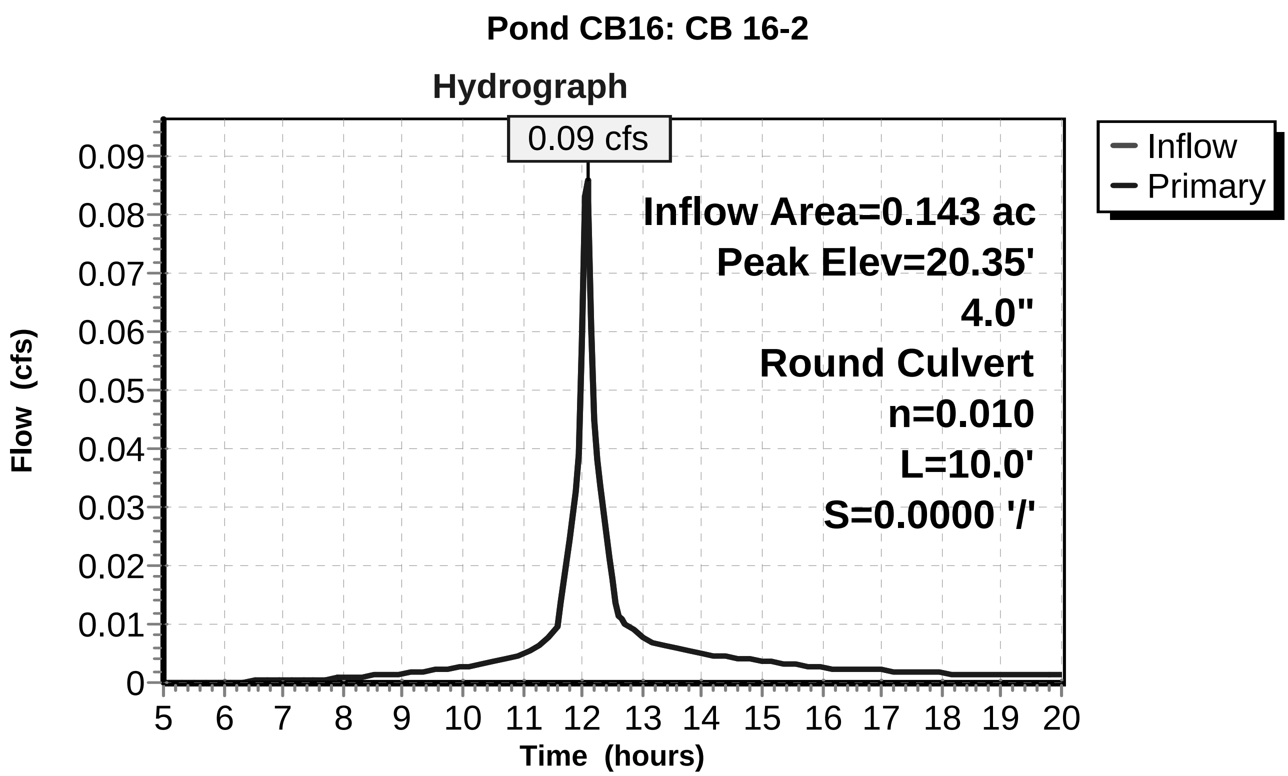
Summary for Pond CB16: CB 16-2

Inflow Area = 0.143 ac,100.00% Impervious, Inflow Depth > 0.49" for 0.5-INCH event
Inflow = 0.09 cfs @ 12.07 hrs, Volume= 0.006 af
Outflow = 0.09 cfs @ 12.07 hrs, Volume= 0.006 af, Atten= 0%, Lag= 0.0 min
Primary = 0.09 cfs @ 12.07 hrs, Volume= 0.006 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 20.35' @ 12.07 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	20.05'	**4.0" Round 4" UD OUT** L= 10.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 20.05' / 20.05' S= 0.0000 '/' Cc= 0.900 n= 0.010 PVC, smooth interior, Flow Area= 0.09 sf

Primary OutFlow Max=0.08 cfs @ 12.07 hrs HW=20.34' (Free Discharge)
└─**1=4" UD OUT** (Barrel Controls 0.08 cfs @ 1.36 fps)



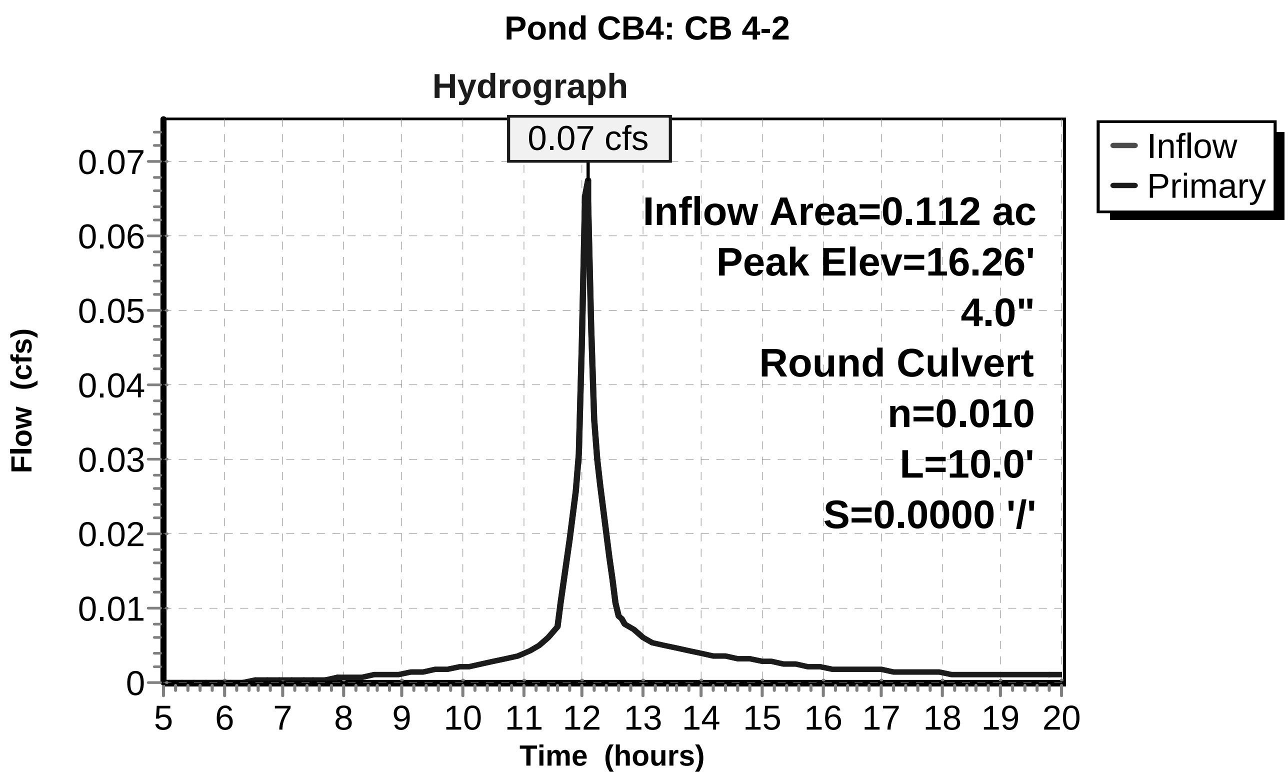
Summary for Pond CB4: CB 4-2

Inflow Area =	0.112 ac,100.00% Impervious,	Inflow Depth > 0.49"	for 0.5-INCH event	
Inflow =	0.07 cfs @	12.07 hrs, Volume=	0.005 af	
Outflow =	0.07 cfs @	12.07 hrs, Volume=	0.005 af,	Atten= 0%, Lag= 0.0 min
Primary =	0.07 cfs @	12.07 hrs, Volume=	0.005 af	

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 16.26' @ 12.07 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	16.00'	**4.0" Round 4" UD OUT** L= 10.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 16.00' / 16.00' S= 0.0000 '/' Cc= 0.900 n= 0.010 PVC, smooth interior, Flow Area= 0.09 sf

Primary OutFlow Max=0.07 cfs @ 12.07 hrs HW=16.26' (Free Discharge)
└─**1=4" UD OUT** (Barrel Controls 0.07 cfs @ 1.25 fps)



Summary for Pond CB6: CB 6-2

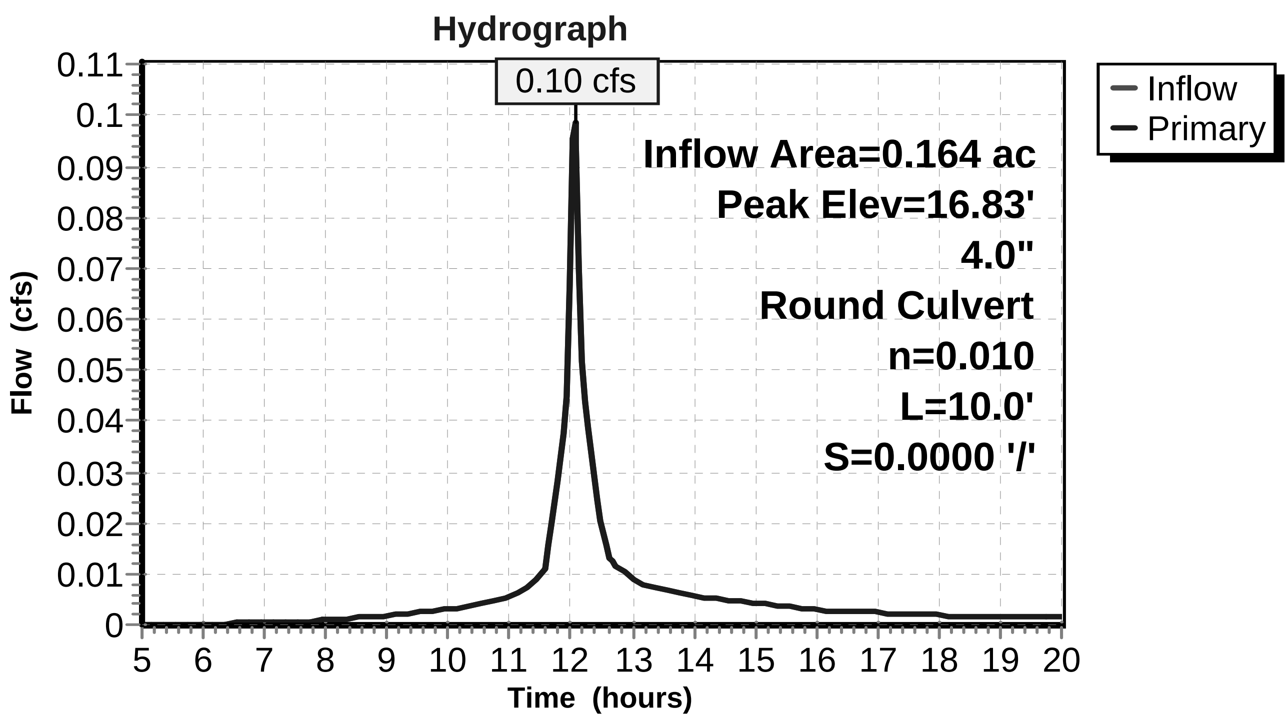
Inflow Area = 0.164 ac,100.00% Impervious, Inflow Depth > 0.49" for 0.5-INCH event
Inflow = 0.10 cfs @ 12.07 hrs, Volume= 0.007 af
Outflow = 0.10 cfs @ 12.07 hrs, Volume= 0.007 af, Atten= 0%, Lag= 0.0 min
Primary = 0.10 cfs @ 12.07 hrs, Volume= 0.007 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 16.83' @ 12.07 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	16.50'	**4.0" Round 4" UD OUT** L= 10.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 16.50' / 16.50' S= 0.0000 '/' Cc= 0.900 n= 0.010 PVC, smooth interior, Flow Area= 0.09 sf

Primary OutFlow Max=0.10 cfs @ 12.07 hrs HW=16.82' (Free Discharge)
└─**1=4" UD OUT** (Barrel Controls 0.10 cfs @ 1.42 fps)

Pond CB6: CB 6-2



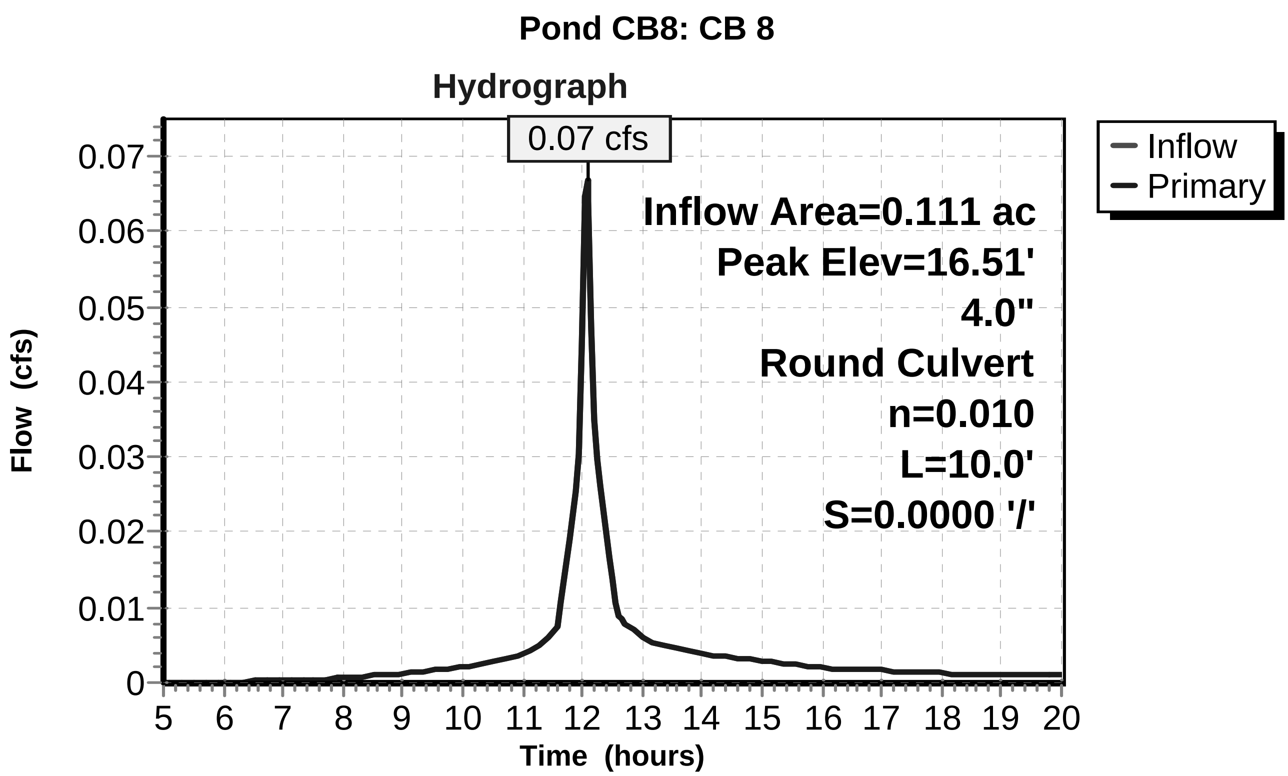
Summary for Pond CB8: CB 8

Inflow Area = 0.111 ac,100.00% Impervious, Inflow Depth > 0.49" for 0.5-INCH event
Inflow = 0.07 cfs @ 12.07 hrs, Volume= 0.005 af
Outflow = 0.07 cfs @ 12.07 hrs, Volume= 0.005 af, Atten= 0%, Lag= 0.0 min
Primary = 0.07 cfs @ 12.07 hrs, Volume= 0.005 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 16.51' @ 12.07 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	16.25'	**4.0" Round 4" UD OUT** L= 10.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 16.25' / 16.25' S= 0.0000 '/' Cc= 0.900 n= 0.010 PVC, smooth interior, Flow Area= 0.09 sf

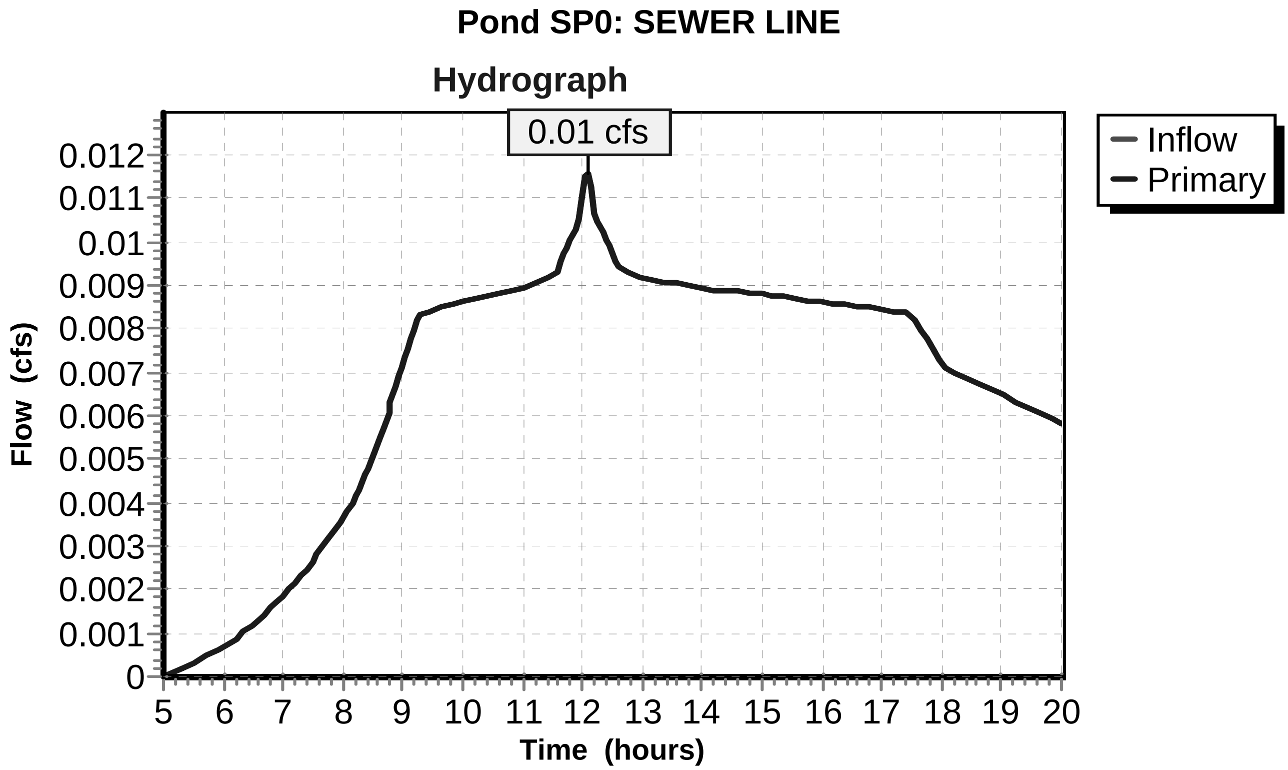
Primary OutFlow Max=0.06 cfs @ 12.07 hrs HW=16.50' (Free Discharge)
1=4" UD OUT (Barrel Controls 0.06 cfs @ 1.25 fps)



Summary for Pond SP0: SEWER LINE

Inflow	=	0.01 cfs @	12.07 hrs,	Volume=	0.008 af
Primary	=	0.01 cfs @	12.07 hrs,	Volume=	0.008 af, Atten= 0%, Lag= 0.0 min

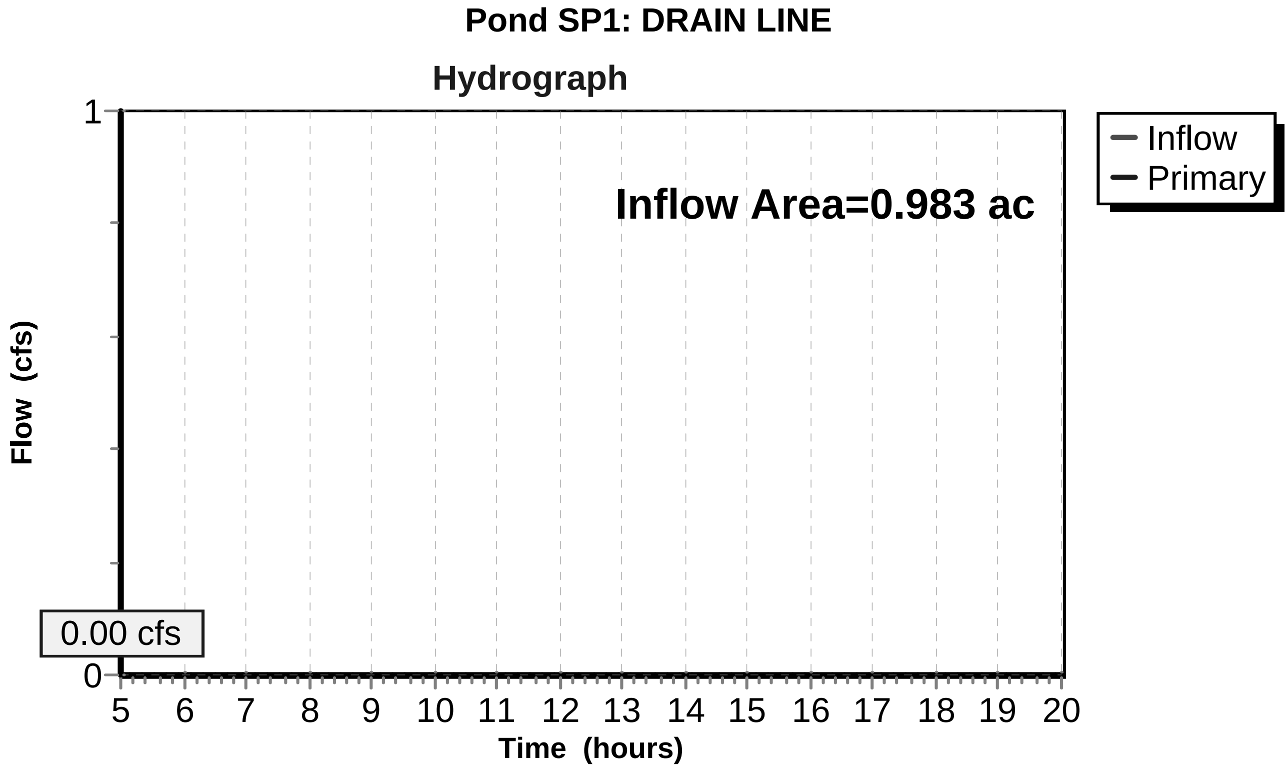
Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs



Summary for Pond SP1: DRAIN LINE

Inflow Area =	0.983 ac,100.00% Impervious,	Inflow Depth = 0.00"	for 0.5-INCH event		
Inflow =	0.00 cfs @	5.00 hrs, Volume=	0.000 af		
Primary =	0.00 cfs @	5.00 hrs, Volume=	0.000 af,	Atten= 0%,	Lag= 0.0 min

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



Summary for Pond STT1: STT 1

Inflow Area = 0.112 ac,100.00% Impervious, Inflow Depth > 0.49" for 0.5-INCH event
Inflow = 0.07 cfs @ 12.07 hrs, Volume= 0.005 af
Outflow = 0.00 cfs @ 11.30 hrs, Volume= 0.003 af, Atten= 95%, Lag= 0.0 min
Discarded = 0.00 cfs @ 11.30 hrs, Volume= 0.003 af
Primary = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 16.11' @ 14.49 hrs Surf.Area= 535 sf Storage= 108 cf

Plug-Flow detention time= 191.5 min calculated for 0.003 af (62% of inflow)
Center-of-Mass det. time= 118.7 min (886.0 - 767.2)

Volume	Invert	Avail.Storage	Storage Description
#1	15.50'	663 cf	**TREE TRENCH (Prismatic)** Listed below (Recalc) 2,010 cf Overall x 33.0% Voids

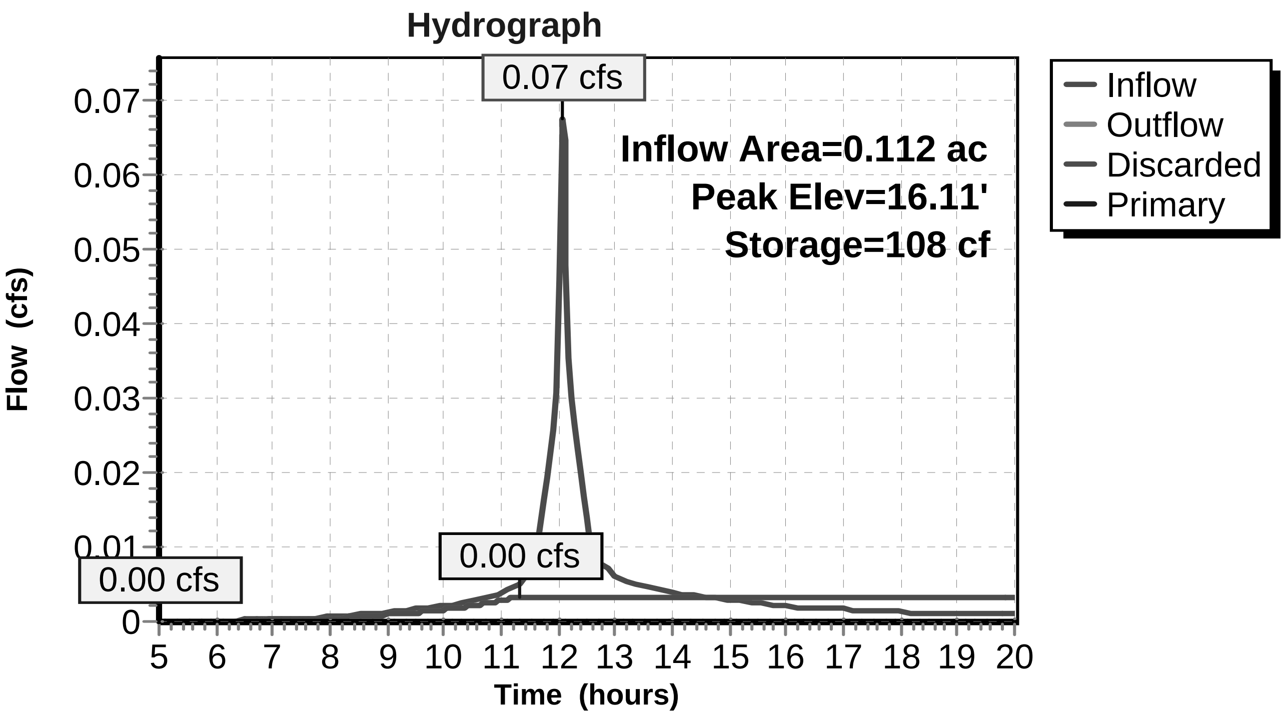
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.50	535	0	0
17.00	535	803	803
18.00	470	503	1,305
19.50	470	705	2,010

Device	Routing	Invert	Outlet Devices
#1	Discarded	15.50'	**0.270 in/hr Exfiltration SILT LOAM over Surface area**
#2	Primary	17.05'	**8.0" Round 12" HDPE OUT** L= 10.0' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 17.05' / 17.00' S= 0.0050 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.35 sf

Discarded OutFlow Max=0.00 cfs @ 11.30 hrs HW=15.54' (Free Discharge)
└─**1=Exfiltration SILT LOAM** (Exfiltration Controls 0.00 cfs)

Primary OutFlow Max=0.00 cfs @ 5.00 hrs HW=15.50' (Free Discharge)
└─**2=12" HDPE OUT** (Controls 0.00 cfs)

Pond STT1: STT 1



Summary for Pond STT2: STT 2

Inflow Area =	0.164 ac,100.00% Impervious,	Inflow Depth > 0.49"	for 0.5-INCH event	
Inflow =	0.10 cfs @	12.07 hrs, Volume=	0.007 af	
Outflow =	0.00 cfs @	11.10 hrs, Volume=	0.004 af,	Atten= 96%, Lag= 0.0 min
Discarded =	0.00 cfs @	11.10 hrs, Volume=	0.004 af	
Primary =	0.00 cfs @	5.00 hrs, Volume=	0.000 af	

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 16.24' @ 15.00 hrs Surf.Area= 680 sf Storage= 166 cf

Plug-Flow detention time= 192.0 min calculated for 0.004 af (55% of inflow)
Center-of-Mass det. time= 112.4 min (879.6 - 767.2)

Volume	Invert	Avail.Storage	Storage Description
#1	15.50'	855 cf	**TREE TRENCH (Prismatic)**Listed below (Recalc) 2,590 cf Overall x 33.0% Voids

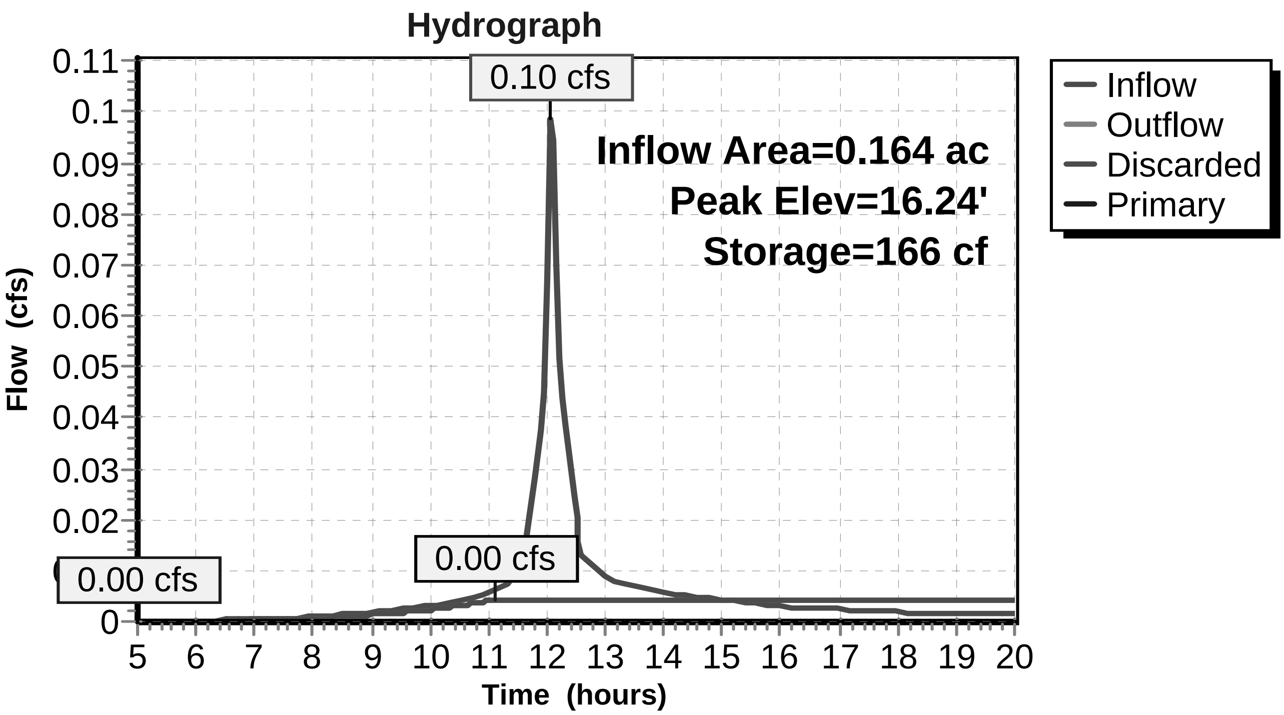
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.50	680	0	0
17.00	680	1,020	1,020
18.00	615	648	1,668
19.00	615	615	2,283
19.50	615	308	2,590

Device	Routing	Invert	Outlet Devices
#1	Discarded	15.50'	**0.270 in/hr Exfiltration SILT LOAM over Surface area**
#2	Primary	17.00'	**8.0" Round 12" HDPE OUT** L= 10.0' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 17.00' / 16.95' S= 0.0050 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.35 sf

Discarded OutFlow Max=0.00 cfs @ 11.10 hrs HW=15.54' (Free Discharge)
└─**1=Exfiltration SILT LOAM** (Exfiltration Controls 0.00 cfs)

Primary OutFlow Max=0.00 cfs @ 5.00 hrs HW=15.50' (Free Discharge)
└─**2=12" HDPE OUT** (Controls 0.00 cfs)

Pond STT2: STT 2



Summary for Pond STT3: STT 3

Inflow Area = 0.111 ac,100.00% Impervious, Inflow Depth > 0.49" for 0.5-INCH event
Inflow = 0.07 cfs @ 12.07 hrs, Volume= 0.005 af
Outflow = 0.00 cfs @ 10.70 hrs, Volume= 0.002 af, Atten= 97%, Lag= 0.0 min
Discarded = 0.00 cfs @ 10.70 hrs, Volume= 0.002 af
Primary = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 16.50' @ 15.67 hrs Surf.Area= 370 sf Storage= 122 cf

Plug-Flow detention time= 191.2 min calculated for 0.002 af (46% of inflow)
Center-of-Mass det. time= 102.5 min (869.8 - 767.2)

Volume	Invert	Avail.Storage	Storage Description
#1	15.50'	446 cf	**TREE TRENCH (Prismatic)**Listed below (Recalc) 1,350 cf Overall x 33.0% Voids

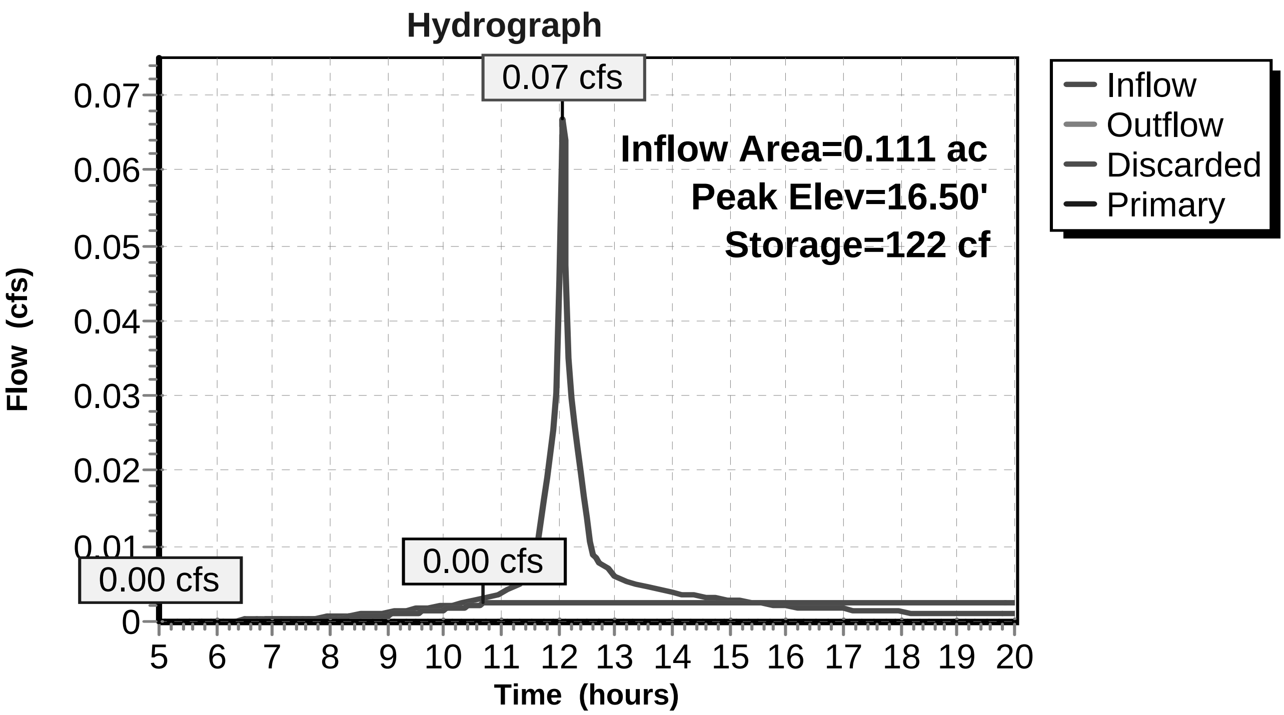
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.50	370	0	0
17.00	370	555	555
18.00	305	338	893
19.50	305	458	1,350

Device	Routing	Invert	Outlet Devices
#1	Discarded	15.50'	**0.270 in/hr Exfiltration SILT LOAM over Surface area**
#2	Primary	17.35'	**8.0" Round 12" HDPE OUT** L= 10.0' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 17.35' / 17.30' S= 0.0050 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.35 sf

Discarded OutFlow Max=0.00 cfs @ 10.70 hrs HW=15.54' (Free Discharge)
└─**1=Exfiltration SILT LOAM** (Exfiltration Controls 0.00 cfs)

Primary OutFlow Max=0.00 cfs @ 5.00 hrs HW=15.50' (Free Discharge)
└─**2=12" HDPE OUT** (Controls 0.00 cfs)

Pond STT3: STT 3



Summary for Pond UIT1: UIT 1

Inflow Area =	0.156 ac,100.00% Impervious,	Inflow Depth > 0.49"	for 0.5-INCH event	
Inflow =	0.09 cfs @	12.07 hrs, Volume=	0.006 af	
Outflow =	0.06 cfs @	12.00 hrs, Volume=	0.006 af,	Atten= 39%, Lag= 0.0 min
Discarded =	0.06 cfs @	12.00 hrs, Volume=	0.006 af	
Primary =	0.00 cfs @	5.00 hrs, Volume=	0.000 af	

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 17.06' @ 12.18 hrs Surf.Area= 300 sf Storage= 16 cf

Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 1.2 min (768.4 - 767.2)

Volume	Invert	Avail.Storage	Storage Description
#1	16.90'	208 cf	**TREE TRENCH (Prismatic)**Listed below (Recalc) 630 cf Overall x 33.0% Voids

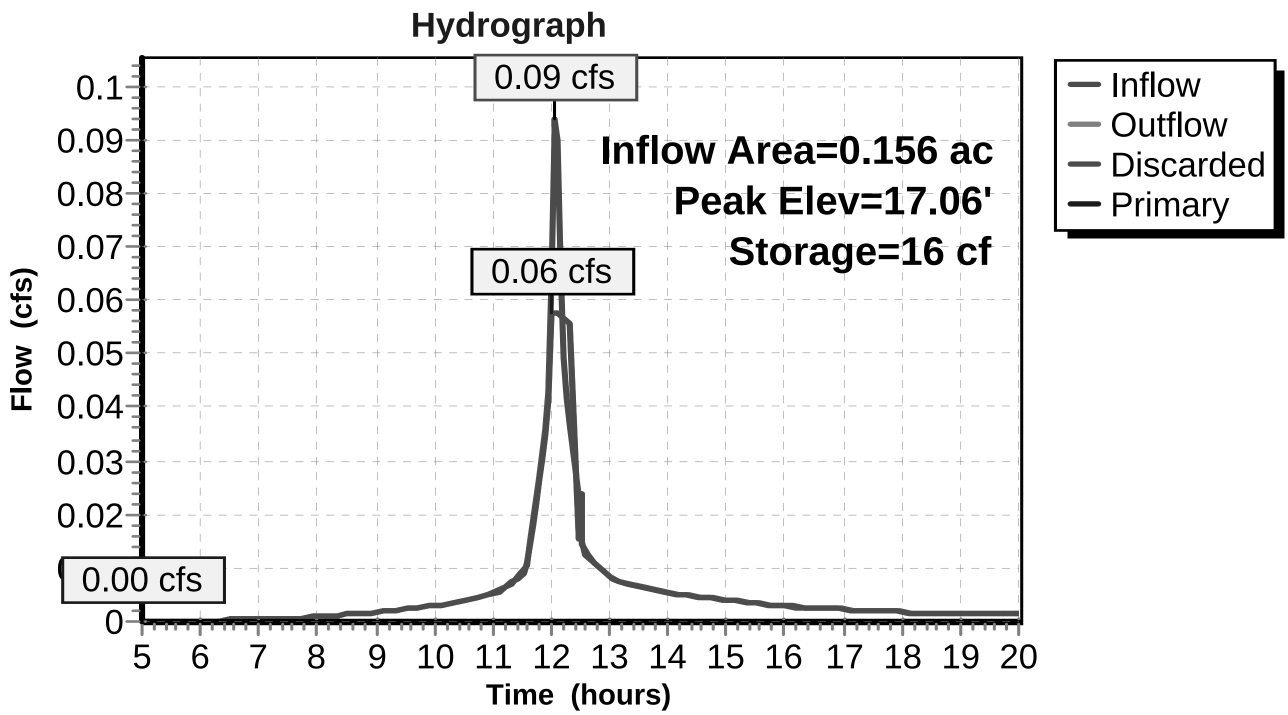
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
16.90	300	0	0
19.00	300	630	630

Device	Routing	Invert	Outlet Devices
#1	Discarded	16.90'	**8.270 in/hr Exfiltration SAND over Surface area**
#2	Primary	17.85'	**8.0" Round 12" HDPE OUT** L= 10.0' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 17.85' / 17.80' S= 0.0050 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.35 sf

Discarded OutFlow Max=0.06 cfs @ 12.00 hrs HW=16.92' (Free Discharge)
└─**1=Exfiltration SAND** (Exfiltration Controls 0.06 cfs)

Primary OutFlow Max=0.00 cfs @ 5.00 hrs HW=16.90' (Free Discharge)
└─**2=12" HDPE OUT** (Controls 0.00 cfs)

Pond UIT1: UIT 1



Summary for Pond UIT2: UIT 2

Inflow Area = 0.119 ac,100.00% Impervious, Inflow Depth > 0.49" for 0.5-INCH event
Inflow = 0.07 cfs @ 12.07 hrs, Volume= 0.005 af
Outflow = 0.07 cfs @ 12.09 hrs, Volume= 0.005 af, Atten= 0%, Lag= 0.7 min
Discarded = 0.07 cfs @ 12.09 hrs, Volume= 0.005 af
Primary = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 17.76' @ 12.09 hrs Surf.Area= 555 sf Storage= 2 cf

Plug-Flow detention time= 0.5 min calculated for 0.005 af (100% of inflow)
Center-of-Mass det. time= 0.4 min (767.6 - 767.2)

Volume	Invert	Avail.Storage	Storage Description
#1	17.75'	229 cf	**TREE TRENCH (Prismatic)** Listed below (Recalc) 694 cf Overall x 33.0% Voids

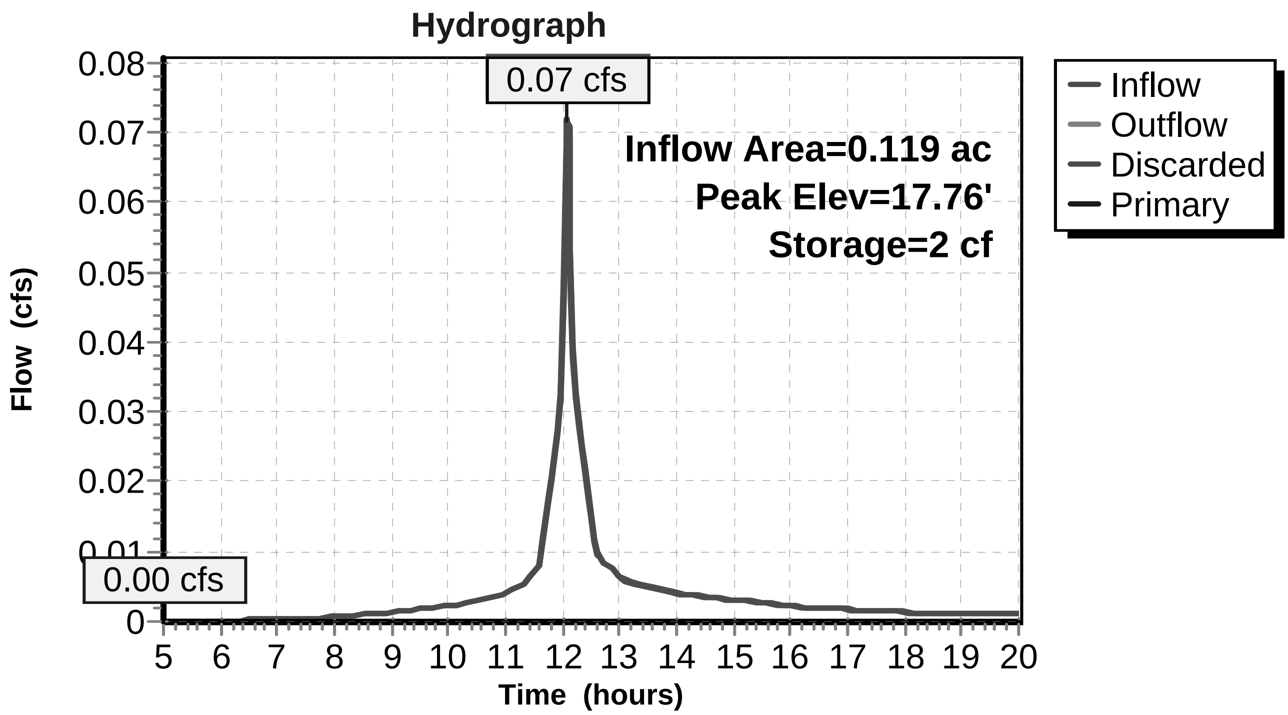
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
17.75	555	0	0
19.00	555	694	694

Device	Routing	Invert	Outlet Devices
#1	Discarded	17.75'	**8.270 in/hr Exfiltration SAND over Surface area**
#2	Primary	18.70'	**8.0" Round 12" HDPE OUT** L= 10.0' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 18.70' / 18.65' S= 0.0050 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.35 sf

Discarded OutFlow Max=0.11 cfs @ 12.09 hrs HW=17.76' (Free Discharge)
└─**1=Exfiltration SAND** (Exfiltration Controls 0.11 cfs)

Primary OutFlow Max=0.00 cfs @ 5.00 hrs HW=17.75' (Free Discharge)
└─**2=12" HDPE OUT** (Controls 0.00 cfs)

Pond UIT2: UIT 2



Summary for Pond UIT3: UIT 3

Inflow Area =	0.178 ac,100.00% Impervious,	Inflow Depth > 0.49"	for 0.5-INCH event	
Inflow =	0.11 cfs @	12.07 hrs, Volume=	0.007 af	
Outflow =	0.04 cfs @	11.95 hrs, Volume=	0.007 af,	Atten= 64%, Lag= 0.0 min
Discarded =	0.04 cfs @	11.95 hrs, Volume=	0.007 af	
Primary =	0.00 cfs @	5.00 hrs, Volume=	0.000 af	

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 18.86' @ 12.34 hrs Surf.Area= 685 sf Storage= 48 cf

Plug-Flow detention time= 6.7 min calculated for 0.007 af (100% of inflow)
Center-of-Mass det. time= 6.5 min (773.7 - 767.2)

Volume	Invert	Avail.Storage	Storage Description
#1	18.65'	305 cf	**TREE TRENCH (Prismatic)**Listed below (Recalc) 925 cf Overall x 33.0% Voids

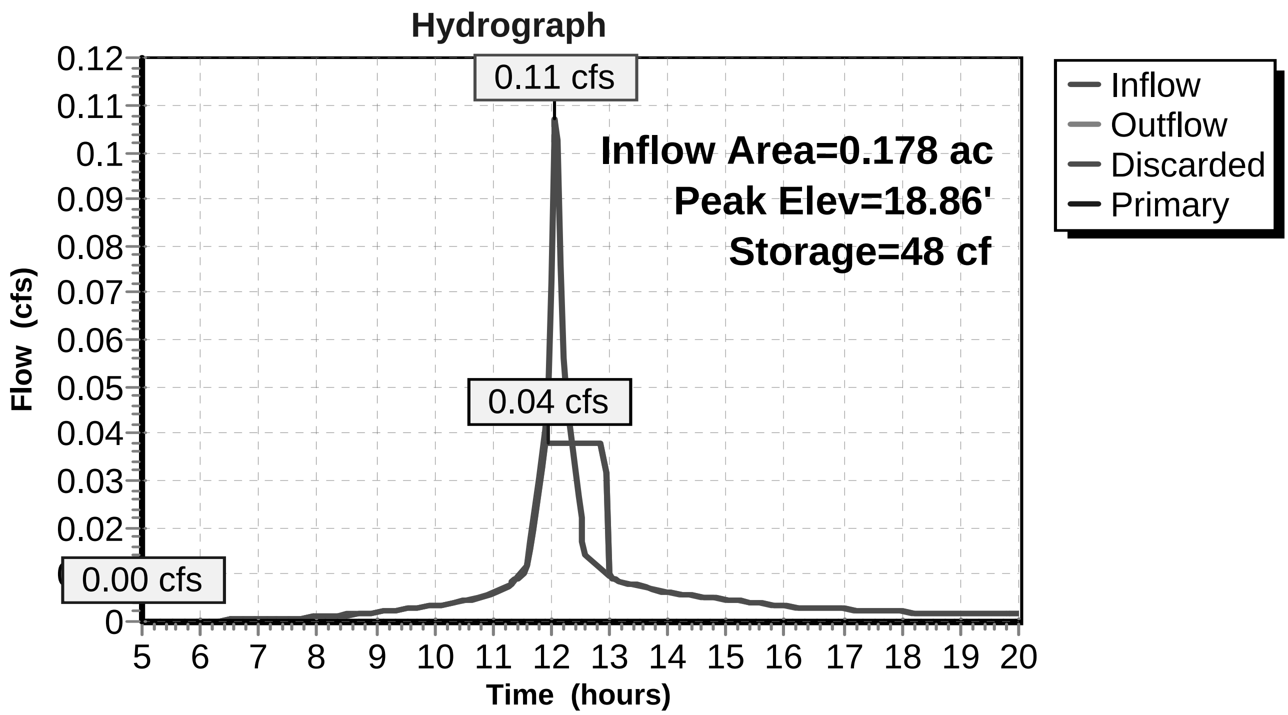
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
18.65	685	0	0
20.00	685	925	925

Device	Routing	Invert	Outlet Devices
#1	Discarded	18.65'	**2.410 in/hr Exfiltration LOAMY SAND over Surface area**
#2	Primary	19.60'	**8.0" Round 12" HDPE OUT** L= 10.0' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 19.60' / 19.55' S= 0.0050 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.35 sf

Discarded OutFlow Max=0.04 cfs @ 11.95 hrs HW=18.67' (Free Discharge)
└─**1=Exfiltration LOAMY SAND** (Exfiltration Controls 0.04 cfs)

Primary OutFlow Max=0.00 cfs @ 5.00 hrs HW=18.65' (Free Discharge)
└─**2=12" HDPE OUT** (Controls 0.00 cfs)

Pond UIT3: UIT 3



Summary for Pond UIT4: UIT 4

Inflow Area = 0.143 ac,100.00% Impervious, Inflow Depth > 0.49" for 0.5-INCH event
Inflow = 0.09 cfs @ 12.07 hrs, Volume= 0.006 af
Outflow = 0.02 cfs @ 11.85 hrs, Volume= 0.006 af, Atten= 72%, Lag= 0.0 min
Discarded = 0.02 cfs @ 11.85 hrs, Volume= 0.006 af
Primary = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 19.90' @ 12.42 hrs Surf.Area= 435 sf Storage= 50 cf

Plug-Flow detention time= 11.3 min calculated for 0.006 af (100% of inflow)
Center-of-Mass det. time= 11.0 min (778.3 - 767.2)

Volume	Invert	Avail.Storage	Storage Description
#1	19.55'	208 cf	**TREE TRENCH (Prismatic)**Listed below (Recalc) 631 cf Overall x 33.0% Voids

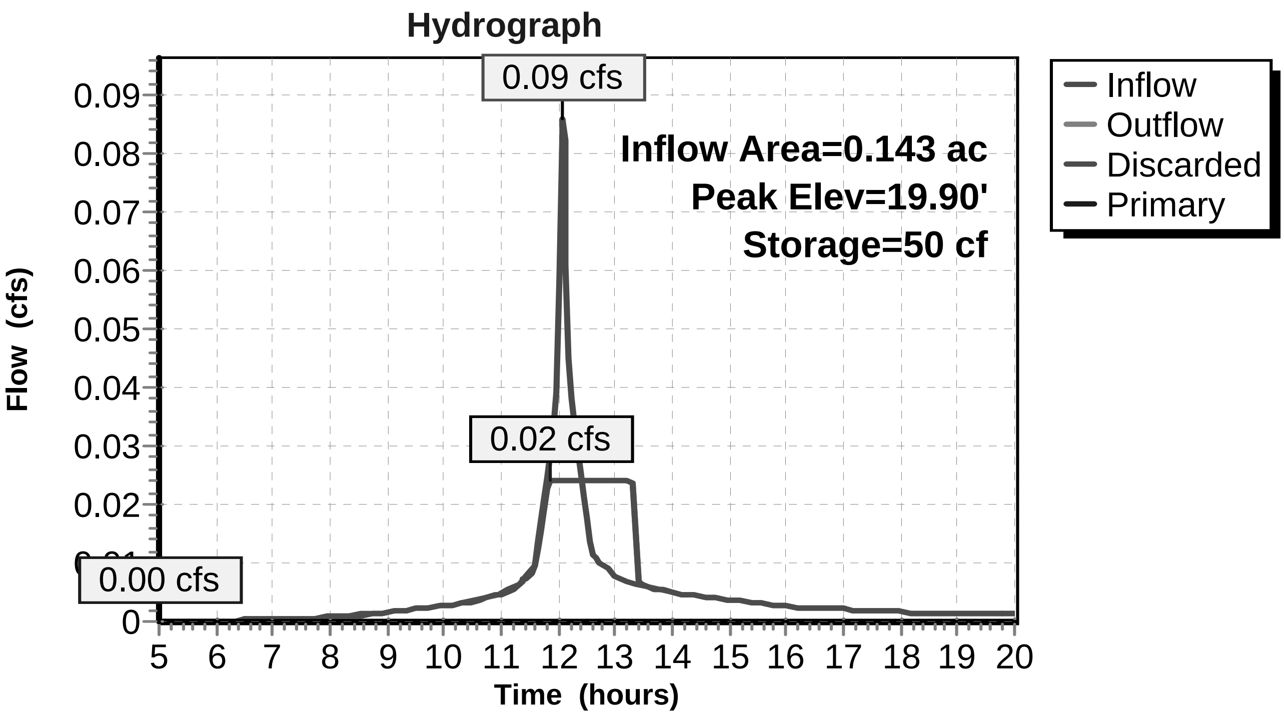
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
19.55	435	0	0
21.00	435	631	631

Device	Routing	Invert	Outlet Devices
#1	Discarded	19.55'	**2.410 in/hr Exfiltration LOAMY SAND over Surface area**
#2	Primary	20.50'	**8.0" Round 12" HDPE OUT** L= 10.0' CPP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 20.50' / 20.45' S= 0.0050 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.35 sf

Discarded OutFlow Max=0.02 cfs @ 11.85 hrs HW=19.57' (Free Discharge)
└─**1=Exfiltration LOAMY SAND** (Exfiltration Controls 0.02 cfs)

Primary OutFlow Max=0.00 cfs @ 5.00 hrs HW=19.55' (Free Discharge)
└─**2=12" HDPE OUT** (Controls 0.00 cfs)

Pond UIT4: UIT 4



APPENDIX F

Water Quality Volume and TSS Removal Calculations

TSS REMOVAL CALCULATIONS

Drainage Area	Roof (*sf*)	Paved (*sf*)	Grass (*sf*)	Woods (*sf*)	Total (*sf*)	Imp. (*sf*)	1/2" (*cf*)	BMP Type	TSS Removal %	Treated (*sf*)
DA2	1,530	3,350	535	0	5,415	4,880	204	INFIL	80	4,332
DA3	2,910	4,230	345	1,430	8,915	7,140	298	INFIL	80	7,132
DA4	1,820	3,020	0	2,270	7,110	4,840	202	INFIL	80	5,688
DA5	2,345	4,445	100	4,485	11,375	6,790	283	INFIL	80	9,100
DA6	2,615	2,590	940	5,710	11,855	5,205	217	INFIL	80	9,484
DA7	3,150	4,600	0	9,020	16,770	7,750	323	INFIL	80	13,416
DA8	2,315	3,905	1,810	2,150	10,180	6,220	260	INFIL	80	8,144
	16,685	26,140	3,730	25,065						
DA100					18,760			DEEP SUMP	25	4,690
DA300					7,430			DEEP SUMP	25	1,858
DA400					9,020			DEEP SUMP	25	2,255
DA600	15125	10865	1345	30170	60,890			DEEP SUMP	25	15,223
					167,720			TOTAL	48	81,321