# STORMWATER MANAGEMENT PLAN

# KENOZA LAKE WATER TREATMENT PLANT COMPREHENSIVE UPGRADES

## PREPARED FOR:
## HAVERHILL WATER DEPARTMENT

## OCTOBER 2016
## REVISED 11/14/2016


WRIGHT-PIERCE
Engineering a Better Environment

# STORMWATER MANAGEMENT
# PLAN
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Attachments

# SECTION 1

# INTRODUCTION

## 1.1 PROJECT OVERVIEW

The Haverhill Water Department will be undertaking a comprehensive upgrade to its water treatment plant in 2017. The plant located at 131 Amesbury Road treats water from Kenoza lake. The improvements are aimed at hydraulic and process improvements that were identified in a 2010 Comprehensive Water System Master Plan completed for the City. The proposed upgrades will enable the plant to provide 12 MGD of hydraulic and treatment capacity and full operational redundancy. The project's construction period is expected to take 2.5 years to complete.

Some of the components of the proposed upgrades include:

- Upgrade of the raw water pumping capacity and electrical systems;
- Reconfiguration of the raw water inlet piping, chemical injection, and mixing system;
- Upgrade of the existing sedimentation process to accommodate a Dissolved Air Flotation process;
- Relocation and expansion of the filter system;
- Construction of an equalization and backwash tank;
- Expansion of the GAC filter system;
- Upgrade of the chemical feed systems;
- Construction of a new clearwell for improved disinfection efficiency;
- Upgrade of all major building systems; and
- Site improvements to include reconfigured parking areas, truck access improvements, updates to the site drainage system, and other site piping improvements.

In accordance with the Massachusetts Stormwater Rules and Regulations, the improvements at the Haverhill Water Treatment plant is considered a redevelopment project. The improvements at the plant have been designed to keep as much of the existing drainage patterns at the site intact with slight modifications where required. The site is located within Surface Water Protection Zone A, due to its proximity to Lake Kenoza, which is defined as the land area within a 400-foot lateral distance from the upper boundary of the bank of a Class A surface water source. Therefore, the entire site is considered an Outstanding Resource Waters. Stormwater discharges are prohibited unless essential to the operation of a public water supply.

The existing and proposed water treatment plant site discharges to two compliance points: (1) wetlands to the north of Amesbury Road; and (2) Kenoza Lake. Existing drainage patterns to each compliance point is as follows:

- Compliance Point 1 (Wetlands North of Amesbury Road): Drainage includes the enclosed storm drain system within the access drive to the plant which conveys drainage to the storm drain system along Amesbury Road and to the northwest corner of the site, there is a series of catch basins that collect runoff from the parking area and directs it to the west where it outlets onto the grassed lawn area which ultimately makes it way to the storm drain system along Amesbury Road.
- Compliance Point 2 (Kenoza Lake): Drainage includes an existing stormwater outfall near the raw water pump station collecting drainage from the existing treatment plant and runoff from the southwest side of the site. A system of underdrains and roof drains at the plant connects in storm drain pipes on the east side of the plant prior to discharging to the lake.

Proposed drainage patterns and stormwater best management practices within each compliance point include:

- Compliance Point 1 (Wetlands North of Amesbury Road): Drainage patterns will mimic existing conditions. Increased flows due to new impervious area from the parking area and buildings will be managed prior to discharge to the existing storm drain system on

Amesbury Road through a detention area on the northeast side of the site adjacent to the entrance.

- Compliance Point 2 (Kenoza Lake): Drainage patterns will mimic existing conditions; however, drainage will be diverted from flowing over the existing boat ramp to prevent migration of fecal matter from water fowl into the receiving water. Further, vegetated swales will be installed between the impervious areas and the lake to provide filtration and potential infiltration prior to discharging into the lake. Roof runoff will be diverted to underdrains which discharge directly to the lake.

The project will be funded through MassDEP's Drinking Water State Revolving Fund (DWSRF) program.

The proposed project schedule is summarized below:

- September 2016: Design Plans and Specifications submitted to MassDEP for approval
- Late 2016: Construction Bids Received for Project
- Winter 2017: Construction Begins on the Project
- Mid to End of 2019: Final Completion of Project

The purpose of that report is to summarize the drainage analysis and erosion and sediment controls for the project area and demonstrate its compliance with the Massachusetts Stormwater Standards, Haverhill Stormwater Regulations and Conservation Commission Rules and Regulations.

# SECTION 2

# REGULATORY STANDARDS

## 2.1 ORGANIZATION OF THE REGULATORY STANDARDS SECTION

This Section of the Stormwater Management Plan (SMP) is organized to describe the Ten Massachusetts Stormwater Standards, consistent with Section 7 of the Stormwater Management By-Law, which are listed below:

Standard #1: No New Untreated Discharges
Standard #2: Post-development Peak Discharge Rates
Standard #3: Recharge to Groundwater
Standard #4: 80% TSS Removal
Standard #5: Higher Potential Pollutant Loads
Standard #6: Protection of Critical Areas
Standard #7: Redevelopment Projects
Standard #8: Erosion & Sedimentation Control Plan
Standard #9: Operation & Maintenance Plan
Standard #10: Illicit Discharges

For redevelopment projects, the project is required to meet these standards to the maximum extent practicable for standards 1 through 6. Other provisions in standards 7 through 10 shall comply with the provisions in the standards.

## 2.2 STANDARD 1: NO NEW UNTREATED DISCHARGES

Under Standard 1, no new untreated discharges are allowed. Under the proposed conditions, no new untreated discharges have been created and all existing discharges will remain and be modified to the extent practicable to provide water quality treatment. Under the proposed conditions, an existing catch basin in the vicinity of the Raw Water Pump Station will be converted to a manhole which will discharge groundwater from subsurface vaults. Runoff which previously

discharged to this catch basin will flow to a level spreader and ultimately to a vegetated swale prior to discharging into Kenoza Lake.

Proposed new discharge to the wetland north of Amesbury Road, will mimic existing conditions with the addition of a small bermed area to the east of the entrance. This bermed area will collect and retain discharge from the existing outfall to allow for filtration and natural percolation into the subsurface.

## 2.3 STANDARD 2: POST-DEVELOPMENT PEAK DISCHARGE RATES

Under Standard 2, the proposed project shall be designed so that post-development peak discharge rates do not exceed the pre-development peak discharge rates for the 2-year, 10-year, and 100-year, 24-hour storm events, to prevent downstream and off-site flooding to the maximum extent practicable. Table 1 presents the pre-development and post-development peak discharge rates to the two compliance points. Drainage delineations and model output are provided as Attachment A.

**TABLE 1**
**PEAK FLOW COMPARISON (CFS)**

| Design Storm | North Wetlands (CP1) | | Kenoza Lake (CP2) | |
|---|---|---|---|---|
| | Pre-Dev | Post-Dev | Pre-Dev | Post-Dev |
| 2-Year, 24-Hour | 1.95 | 0.85 | 5.02 | 5.66 |
| 10-Year, 24-Hour | 4.66 | 3.50 | 10.63 | 11.30 |
| 100-year, 24-Hour | 12.25 | 14.51 | 24.54 | 25.01 |

Based on Table 1, the post-development discharge to the northwestern wetlands across Amesbury Road decreases for both the 2-year and 10-year, 24-hour storm events. Based on information about past storms, it appears that during intense and large storm events the wetlands north of Amesbury Road overtop the road and create flooding at the site. The 100-year, 24-hour event will increase the peak discharge from the site; however, based on past storm events it is more likely that the wetland will become overwhelmed from surrounding flows and the flow from the site will be contained on-site.

Post-development discharges to Kenoza lake have modest increases from the pre-development condition. Due to the proximity of the site within a Zone A Water Supply Protection Area, infiltration stormwater BMPs are not allowed and therefore management practices required to meeting this standard inhibit the ability for it to be met. However, best management practices include a level spreader and vegetated swales have been installed to provide pre-treatment on-site prior to discharging to Kenoza Lake.

Due to the configuration of the existing plant, location adjacent to the lake, and the scope of the needed improvements, little opportunity exists to attenuate runoff rates from the site and all efforts have been made to improve water quality through implementation of best management practices. Impervious surfaces within the 100-foot buffer zone of the lake will not be significantly increased as part of the work. In areas where the impervious area is being increased the runoff is directed to the existing lawn area and connected to the Amesbury Road drainage system where it discharges away from the lake.

## 2.4 STANDARD 3: RECHARGE TO GROUNDWATER

In accordance with the Massachusetts Stormwater Rules and Regulations, "stormwater discharges to a Zone I or Zone A are prohibited unless essential to the operation of the public water supply". Therefore, installation of infiltration BMPs to meet the groundwater recharge requirements under Standard 3 cannot be met.

## 2.5 STANDARD 4: 80% TSS REMOVAL

Standard 4 requires the design of stormwater management features to remove 80% of the average annual post-construction load of total suspended solids (TSS). Since stormwater discharges are prohibited to a Zone A, this criterion cannot be met. However, deep sump catch basins are being proposed which provide 25% TSS removal, in accordance with the Massachusetts Stormwater Handbook. The elimination of the curbing adjacent to the boat ramp area will alleviate a direct surface runoff discharge to the lake. Where the curb is being removed between the raw water pump station and the boat ramp, the area will be regraded to provide a sediment trap before runoff

discharges to the lake. This will improve the current configuration. Drainage is also being directed to grass swales where possible to assist in removing TSS loads.

## 2.6 STANDARD 5: HIGHER POTENTIAL POLLUTANT LOADS

The project site is not considered a land use with higher potential pollutant loads and therefore this standard does not apply.

## 2.7 STANDARD 6: PROTECTION OF CRITICAL AREAS

The project site is considered an Outstanding Resources Waters as defined in 310 CMR 22.02, since the site falls within a Zone A Water Supply Protection Area. Under Standard 6, for Zone A Water Supply Protection Areas, stormwater discharges are prohibited unless essential to the operation of the public water supply. Existing drainage patterns have been maintained to the extent practicable and water quality treatment management practice installed to prevent any impacts from development.

## 2.8 STANDARD 7: REDEVELOPMENT PROJECTS

The project site is considered a redevelopment project, as much of the existing pavement area and building foot prints will remain in place.

## 2.9 STANDARD 8: EROSION & SEDIMENT CONTROL PLAN

### 2.9.1 Implementation of Erosion and Sedimentation Controls

Prior to the start of any earthwork or demolition on the site, the sedimentation and erosion controls shall be installed. Section 2.9.3 provides a listing of controls and a sequence of construction.

### 2.9.2 Inspection and Maintenance of Stormwater Controls

Stormwater controls must be maintained in good operating condition until all disturbed soils are permanently stabilized. To ensure this, the following areas will be inspected by the Contractor every week and after every rainfall event of 0.5 inches or greater:

The following standard maintenance practices will apply to the erosion and sedimentation controls for the project:

- All erosion and sediment control measures will be properly maintained. If repairs or other maintenance is necessary, it will be initiated by the Contractor within 24 hours of report;
- Stabilized construction entrance will be inspected regularly. Adjacent roadways will be inspected for track-out and swept as needed.
- Silt sacks will be installed in catch basins adjacent to the work area and inspected on a regular basis and cleaned as necessary;
- Silt fence will be inspected for depth of sediment, tears, to see if the fabric is securely attached to the fence posts, and to see that the fence posts are firmly in the ground;
- Built up sediment will be removed from silt fence when it has reached one-half the height of the fence and at end of the job;
- Erosion control measures will be maintained for disturbed areas of the site that have not been stabilized;
- Erosion control measures will be installed and maintained for the construction staging area, stockpiles, and material storage areas until those areas have been stabilized after construction; and,
- Temporary and permanent seeding and planting will be inspected for bare spots, washouts, and healthy growth.

If the inspections reveal the need for additional control devices to prevent erosion and sedimentation, the Contractor will promptly install additional protection devices as required. Control devices in need of repair will be repaired promptly after identification. A stockpile of 300 linear feet of silt fence will be maintained on the site and under cover for emergency repairs and routine maintenance.

The Owner (or their representative) will be responsible for preparing an inspection and maintenance report following each inspection and filing completed reports after maintenance action has taken place by the Contractor. The Contractor's superintendent will be responsible for

maintenance and repair activities and completing and signing the maintenance action portion of inspection and maintenance reports.

### 2.9.3 Stormwater Controls for Construction Period

CONSTRUCTION SEQUENCING

The project construction phasing will generally proceed in the following sequence:

1. Furnish and install erosion control measures. This includes at a minimum the placement of silt fencing at the down slope perimeter of all areas proposed for disturbance and installation of silt sack inlet protection in downstream catch basins.
2. Initiate tree removal and clearing and grubbing.
3. Removal and stockpile the existing loam from the area.
4. Begin excavation and construct the building foundations.
5. Commence building structure construction.
6. Start utility construction and site work, including water piping and site stormwater management controls.
7. Finalize building construction and site utility and piping work.
8. Establish finish grades, finalize stormwater management controls, realign driveway and construct the proposed walkways and parking areas.
9. Complete construction of the new driveways, parking areas and walkways with new bituminous asphalt concrete pavement.
10. Stabilize all remaining disturbed areas. Continue to touch-up and maintain all areas that have received loam and seed as needed until a 90% catch of vegetative growth has established.
11. Once the site has become permanently stabilized as determined by the Owner and the Engineer, remove all remaining temporary erosion and sedimentation control measures.

EROSION AND SEDIMENT CONTROLS:

1. Temporary stabilization measures shall be instituted to minimize effects of sedimentation and erosion during construction.
2. Permanent stabilization measures shall be employed to minimize effects of sedimentation and erosion after the completion of construction.

## 2.10 STANDARD 9: OPERATION & MAINTENANCE PLAN

Due to the nature and intensity of the proposed redevelopment project, the site is not anticipated to generate any significant TSS or pollutant loads. As such, inspection activities at the site should be focused on the development or potential for development, of any erosion issues.

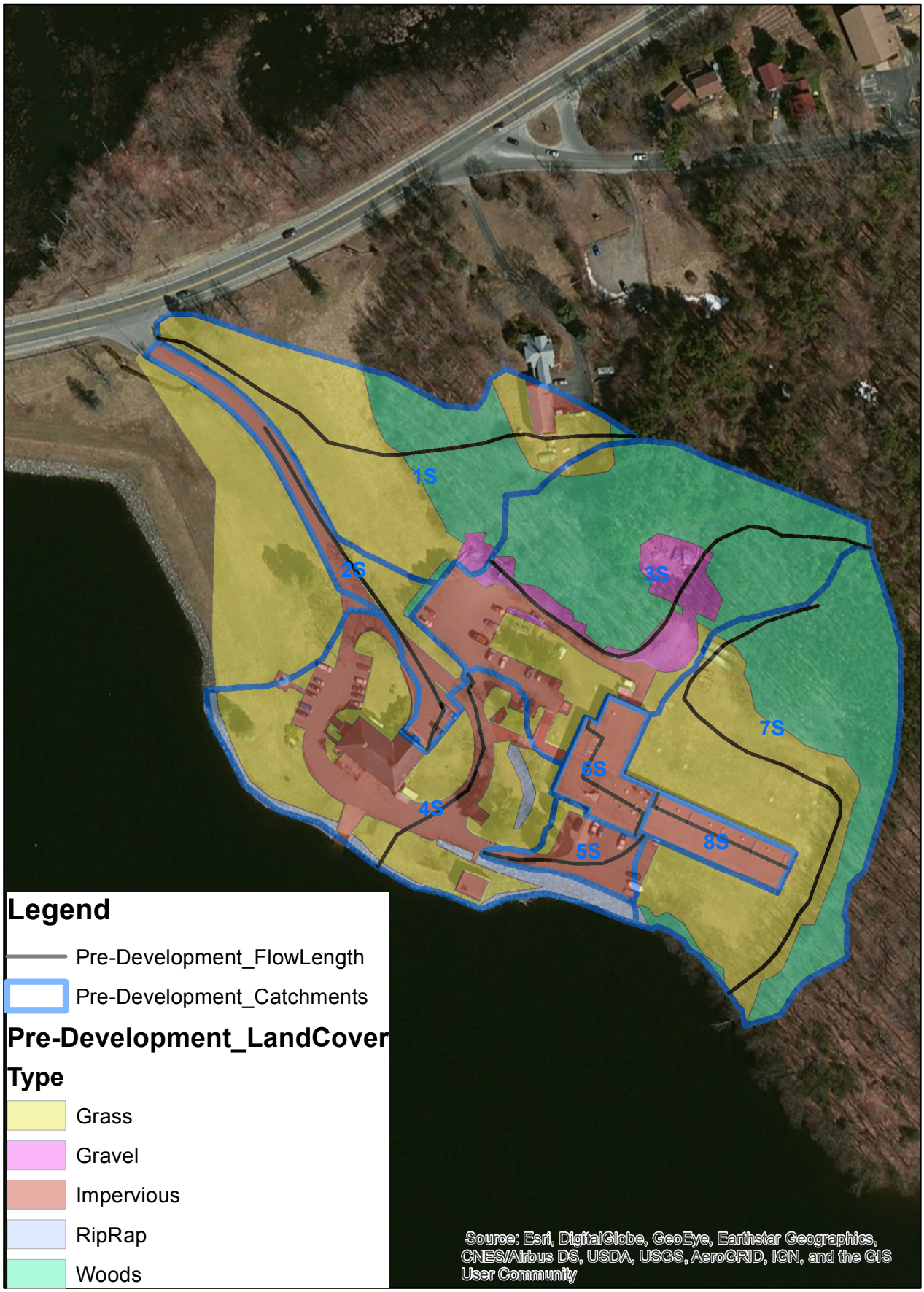
To ensure compliance with all applicable stormwater regulations, and as a measure of good housekeeping, inspection and maintenance personnel shall maintain an operation and maintenance log for the last three years. The operation and maintenance log shall include inspections, repairs, replacements and disposals (for disposals, the log shall indicate the type of material and the disposal location). The operation and maintenance plan is included as Attachment B.

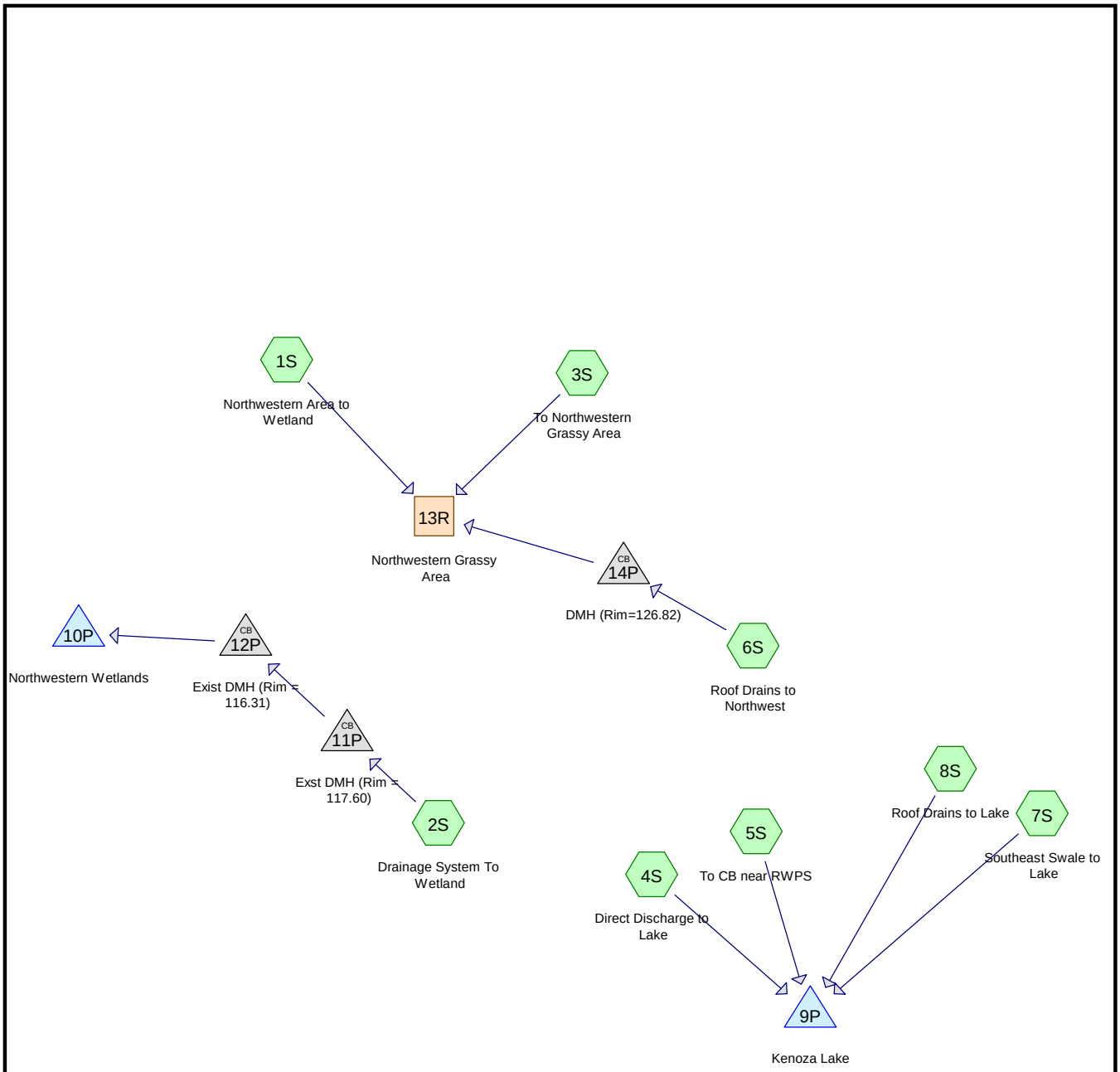
## 2.11 STANDARD 10: ILLICIT DISCHARGES

There are no known illicit discharges in the area of the project. New drainage proposed for the Plant will be constructed and tied into the existing system. Due to the site constraints, there is no future development anticipated that would create an illicit discharge in this area.

# STORMWATER MANAGEMENT REPORT APPENDICES

# APPENDIX A
## Hydrologic Computer Model and Catchment Area Plans


1S
2S
3S
4S
5S
6S
7S
8S
Legend
Pre-Development_FlowLength
Pre-Development_Catchments
Pre-Development_LandCover
Type
Grass
Gravel
Impervious
RipRap
Woods
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community




**Routing Diagram for 13109_WTP-Upgrade_Pre-ConstructionModel**
Prepared by wright-pierce, Printed 11/11/2016

## Area Listing (all nodes)

| Area (acres) | CN | Description (subcatchment-numbers) |
|---|---|---|
| 2.715 | 39 | >75% Grass cover, Good, HSG A (1S, 2S, 3S, 4S, 5S) |
| 1.913 | 74 | >75% Grass cover, Good, HSG C (3S, 4S, 5S, 7S) |
| 0.131 | 76 | Gravel roads, HSG A (1S, 3S) |
| 0.290 | 89 | Gravel roads, HSG C (3S) |
| 2.611 | 98 | Paved parking, HSG A (1S, 2S, 3S, 4S, 5S, 6S, 7S, 8S) |
| 0.275 | 96 | RipRap_Assumed (4S, 7S) |
| 1.170 | 30 | Woods, Good, HSG A (1S, 2S, 3S) |
| 2.442 | 70 | Woods, Good, HSG C (1S, 3S, 7S) |
| **11.547** | **67** | **TOTAL AREA** |

## Summary for Subcatchment 1S: Northwestern Area to Wetland

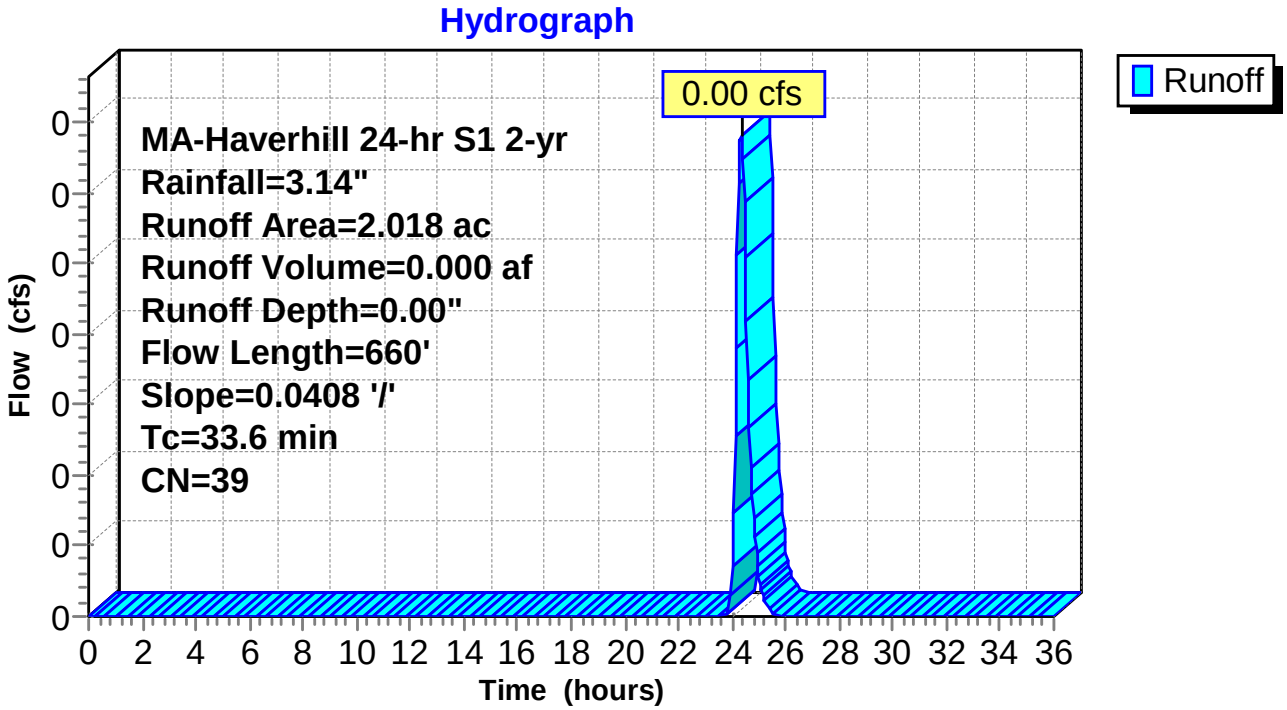
Runoff = 0.00 cfs @ 24.34 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 2-yr Rainfall=3.14"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 1.281 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.042 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.066 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.625 | 30 | Woods, Good, HSG A |
| | 0.004 | 70 | Woods, Good, HSG C |
| | 2.018 | 39 | Weighted Average |
| | 1.952 | | 96.73% Pervious Area |
| | 0.066 | | 3.27% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 33.6 | 660 | 0.0408 | 0.33 | | **Lag/CN Method,** |

### Subcatchment 1S: Northwestern Area to Wetland



## Summary for Subcatchment 2S: Drainage System To Wetland

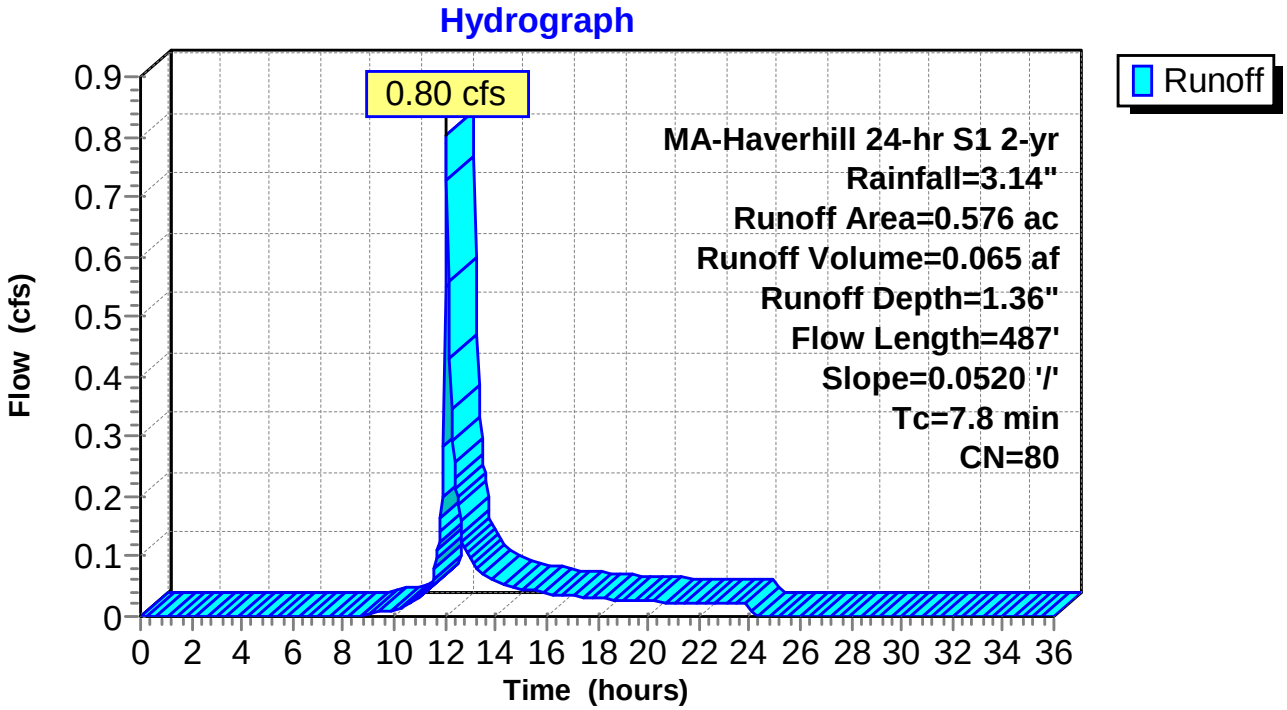
Runoff = 0.80 cfs @ 12.06 hrs, Volume= 0.065 af, Depth= 1.36"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 2-yr Rainfall=3.14"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.159 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.403 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.014 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.576 | 80 | Weighted Average |
| | 0.173 | | 30.03% Pervious Area |
| | 0.403 | | 69.97% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 7.8 | 487 | 0.0520 | 1.04 | | **Lag/CN Method,** |

## Subcatchment 2S: Drainage System To Wetland



## Summary for Subcatchment 3S: To Northwestern Grassy Area

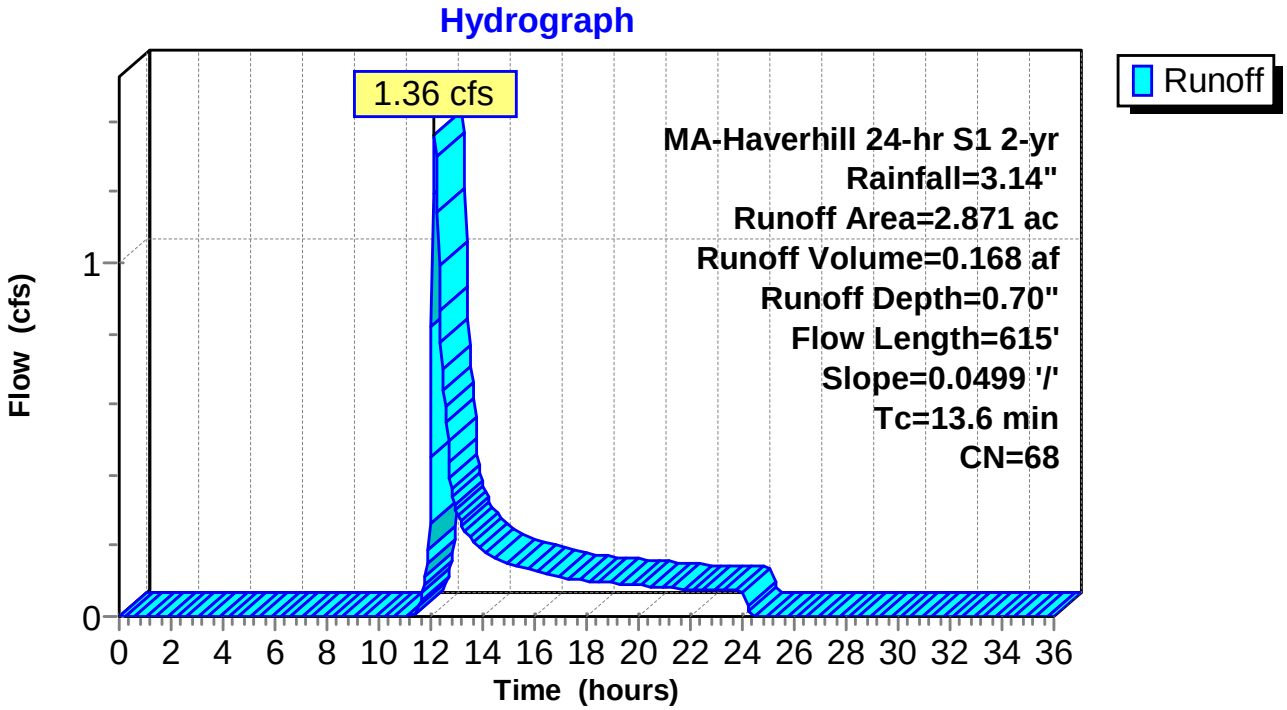
Runoff = 1.36 cfs @ 12.16 hrs, Volume= 0.168 af, Depth= 0.70"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 2-yr Rainfall=3.14"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.174 | 39 | >75% Grass cover, Good, HSG A |
| | 0.196 | 74 | >75% Grass cover, Good, HSG C |
| | 0.089 | 76 | Gravel roads, HSG A |
| | 0.290 | 89 | Gravel roads, HSG C |
| | 0.457 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.531 | 30 | Woods, Good, HSG A |
| | 1.134 | 70 | Woods, Good, HSG C |
| | 2.871 | 68 | Weighted Average |
| | 2.414 | | 84.08% Pervious Area |
| | 0.457 | | 15.92% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 13.6 | 615 | 0.0499 | 0.76 | | **Lag/CN Method,** |

### Subcatchment 3S: To Northwestern Grassy Area



## Summary for Subcatchment 4S: Direct Discharge to Lake

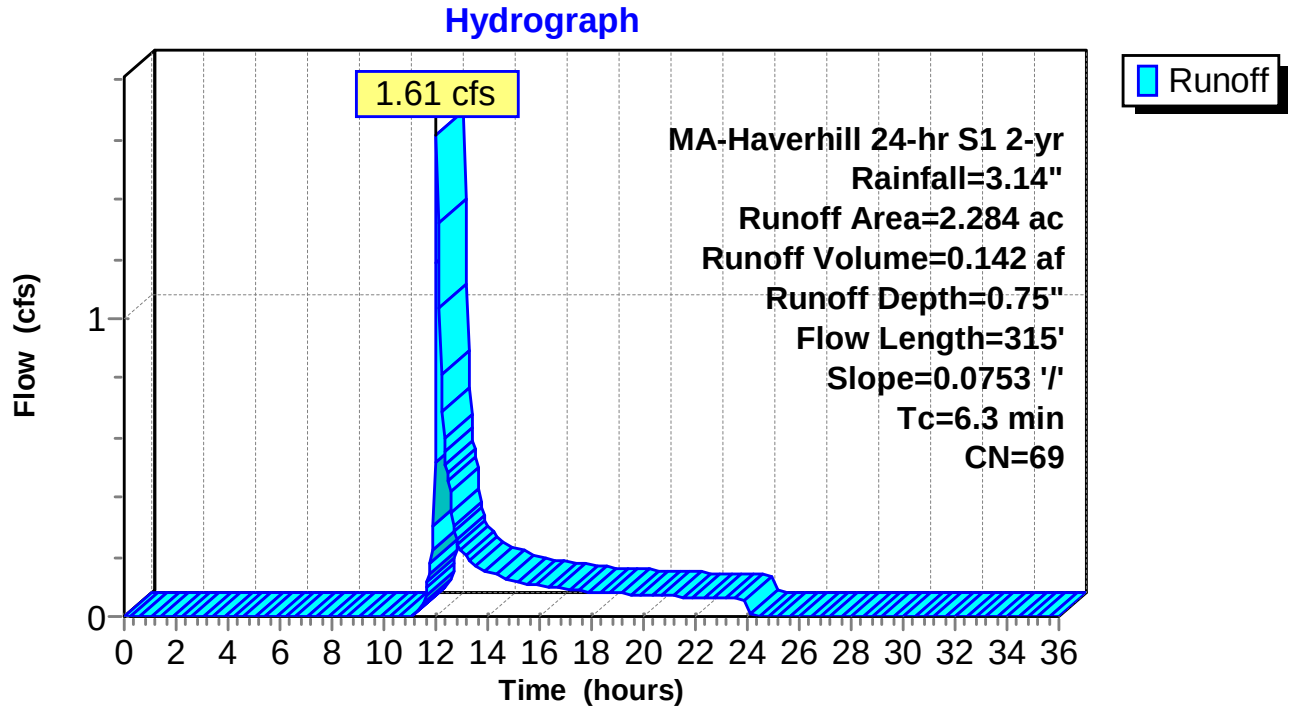
Runoff = 1.61 cfs @ 12.05 hrs, Volume= 0.142 af, Depth= 0.75"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 2-yr Rainfall=3.14"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 1.098 | 39 | >75% Grass cover, Good, HSG A |
| | 0.060 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.858 | 98 | Paved parking, HSG A |
| * | 0.268 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 2.284 | 69 | Weighted Average |
| | 1.426 | | 62.43% Pervious Area |
| | 0.858 | | 37.57% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.3 | 315 | 0.0753 | 0.83 | | **Lag/CN Method,** |

### Subcatchment 4S: Direct Discharge to Lake



## Summary for Subcatchment 5S: To CB near RWPS

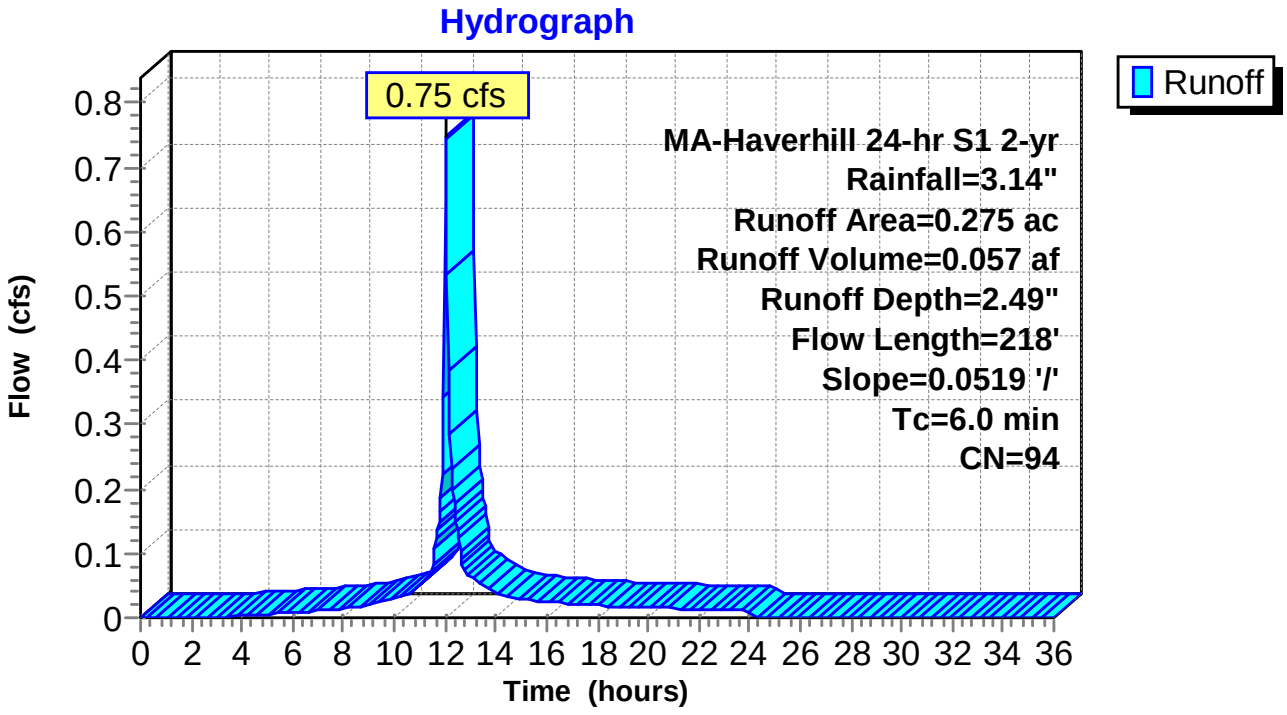
Runoff = 0.75 cfs @ 12.04 hrs, Volume= 0.057 af, Depth= 2.49"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 2-yr Rainfall=3.14"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.003 | 39 | >75% Grass cover, Good, HSG A |
| | 0.033 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.239 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.275 | 94 | Weighted Average |
| | 0.036 | | 13.09% Pervious Area |
| | 0.239 | | 86.91% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 2.4 | 218 | 0.0519 | 1.50 | | **Lag/CN Method,** |
| 2.4 | 218 | Total, Increased to minimum Tc = 6.0 min | | | |

### Subcatchment 5S: To CB near RWPS



## Summary for Subcatchment 6S: Roof Drains to Northwest

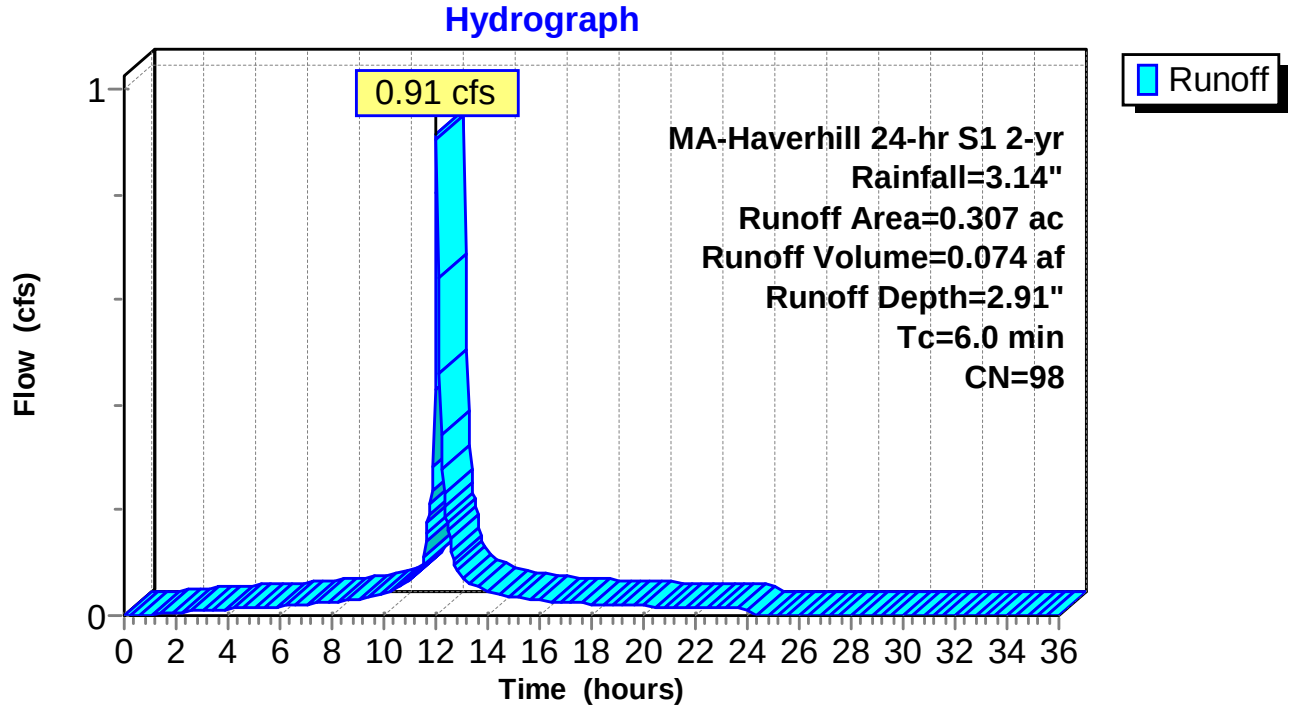
Runoff = 0.91 cfs @ 12.04 hrs, Volume= 0.074 af, Depth= 2.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 2-yr Rainfall=3.14"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.000 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.307 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.307 | 98 | Weighted Average |
| | 0.307 | | 100.00% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.0 | | | | | **Direct Entry, Minimum (Roof)** |

### Subcatchment 6S: Roof Drains to Northwest



## Summary for Subcatchment 7S: Southeast Swale to Lake

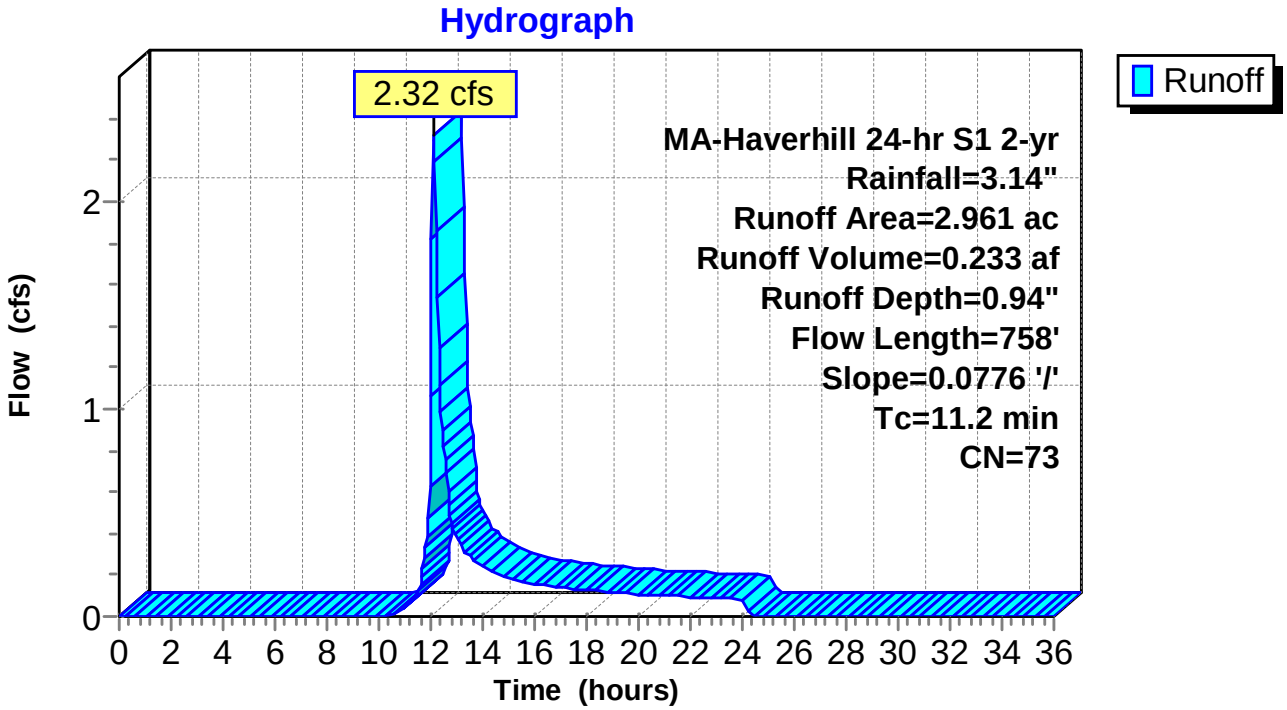
Runoff = 2.32 cfs @ 12.12 hrs, Volume= 0.233 af, Depth= 0.94"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 2-yr Rainfall=3.14"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.000 | 39 | >75% Grass cover, Good, HSG A |
| | 1.624 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.026 | 98 | Paved parking, HSG A |
| * | 0.007 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 1.304 | 70 | Woods, Good, HSG C |
| | 2.961 | 73 | Weighted Average |
| | 2.935 | | 99.12% Pervious Area |
| | 0.026 | | 0.88% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 11.2 | 758 | 0.0776 | 1.12 | | **Lag/CN Method,** |

### Subcatchment 7S: Southeast Swale to Lake



## Summary for Subcatchment 8S: Roof Drains to Lake

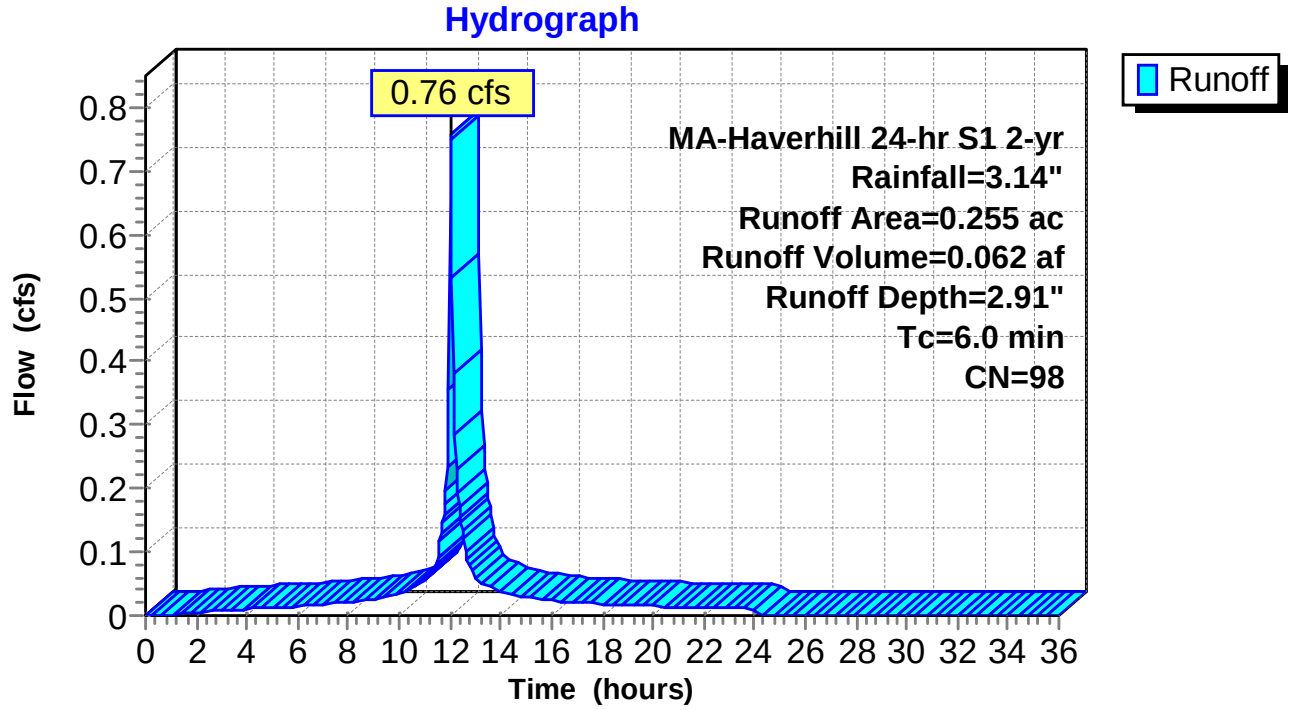
Runoff = 0.76 cfs @ 12.04 hrs, Volume= 0.062 af, Depth= 2.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 2-yr Rainfall=3.14"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.000 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.255 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.255 | 98 | Weighted Average |
| | 0.255 | | 100.00% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.0 | | | | | **Direct Entry, Minimum (Roof)** |

## Subcatchment 8S: Roof Drains to Lake



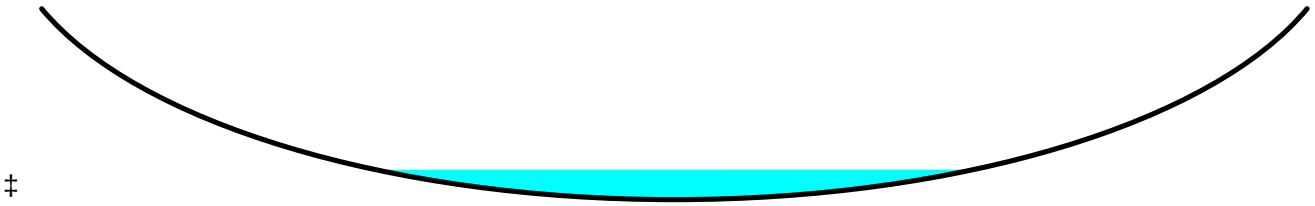
## Summary for Reach 13R: Northwestern Grassy Area

Inflow Area = 5.196 ac, 15.97% Impervious, Inflow Depth = 0.56" for 2-yr event
Inflow = 1.84 cfs @ 12.12 hrs, Volume= 0.242 af
Outflow = 1.66 cfs @ 12.30 hrs, Volume= 0.242 af, Atten= 10%, Lag= 11.2 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.33 fps, Min. Travel Time= 6.3 min
Avg. Velocity = 0.47 fps, Avg. Travel Time= 17.8 min

Peak Storage= 626 cf @ 12.20 hrs
Average Depth at Peak Storage= 0.16'
Bank-Full Depth= 1.00' Flow Area= 20.0 sf, Capacity= 90.86 cfs

30.00' x 1.00' deep Parabolic Channel, n= 0.030 Earth, grassed & winding
Length= 500.0' Slope= 0.0145 '/'
Inlet Invert= 123.50', Outlet Invert= 116.25'



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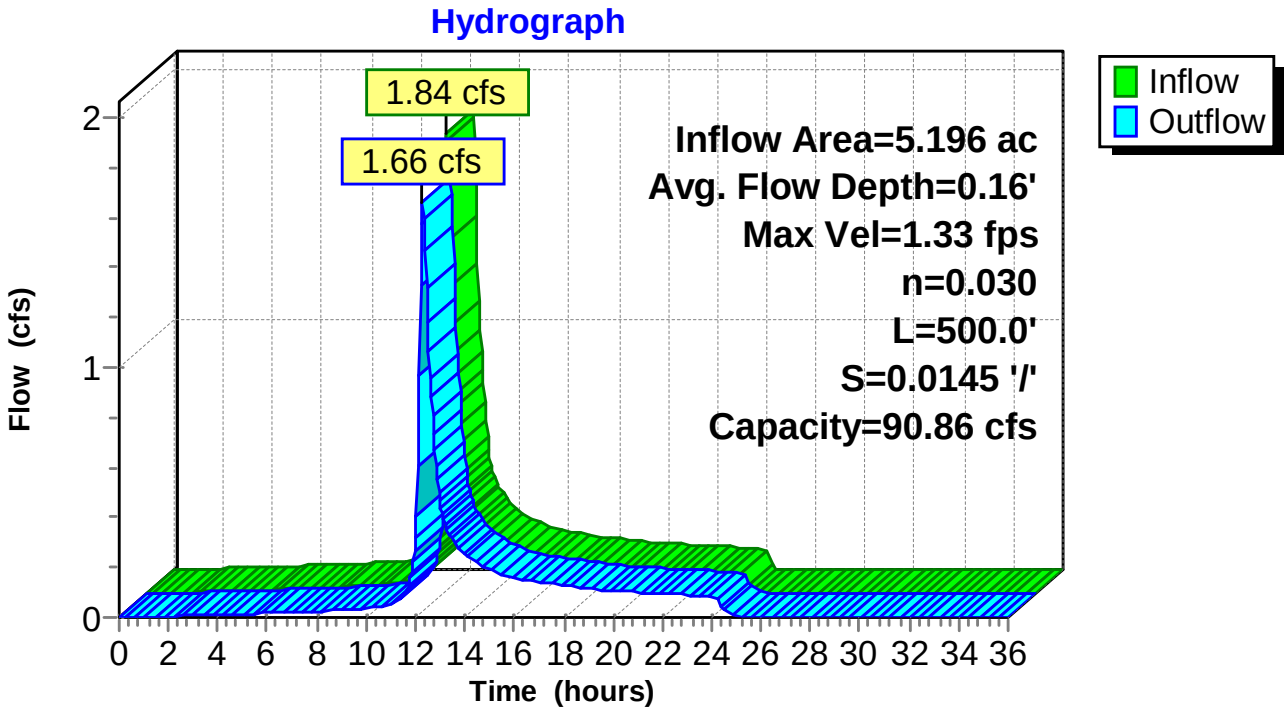
**Reach 13R: Northwestern Grassy Area**

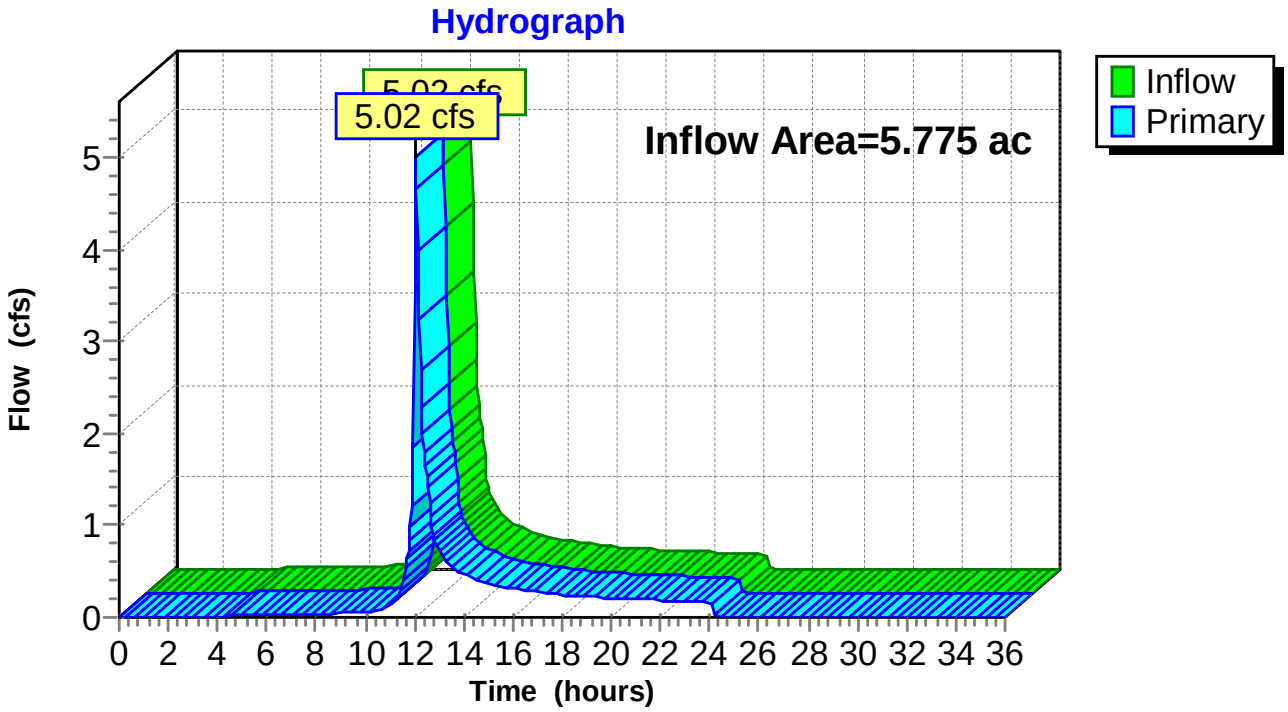


## Summary for Pond 9P: Kenoza Lake

Inflow Area = 5.775 ac, 23.86% Impervious, Inflow Depth = 1.03" for 2-yr event
Inflow = 5.02 cfs @ 12.07 hrs, Volume= 0.494 af
Primary = 5.02 cfs @ 12.07 hrs, Volume= 0.494 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs

### Pond 9P: Kenoza Lake

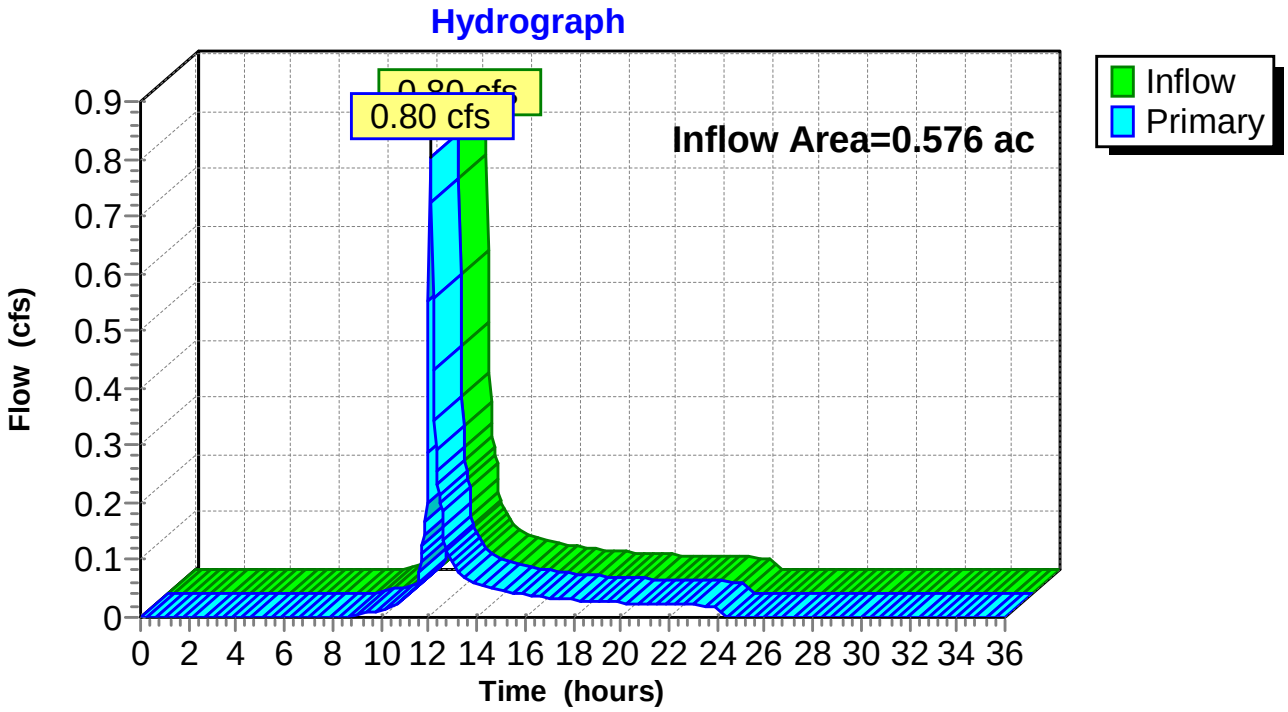


## Summary for Pond 10P: Northwestern Wetlands

Inflow Area = 0.576 ac, 69.97% Impervious, Inflow Depth = 1.36" for 2-yr event
Inflow = 0.80 cfs @ 12.06 hrs, Volume= 0.065 af
Primary = 0.80 cfs @ 12.06 hrs, Volume= 0.065 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs

### Pond 10P: Northwestern Wetlands



## Summary for Pond 11P: Exst DMH (Rim = 117.60)

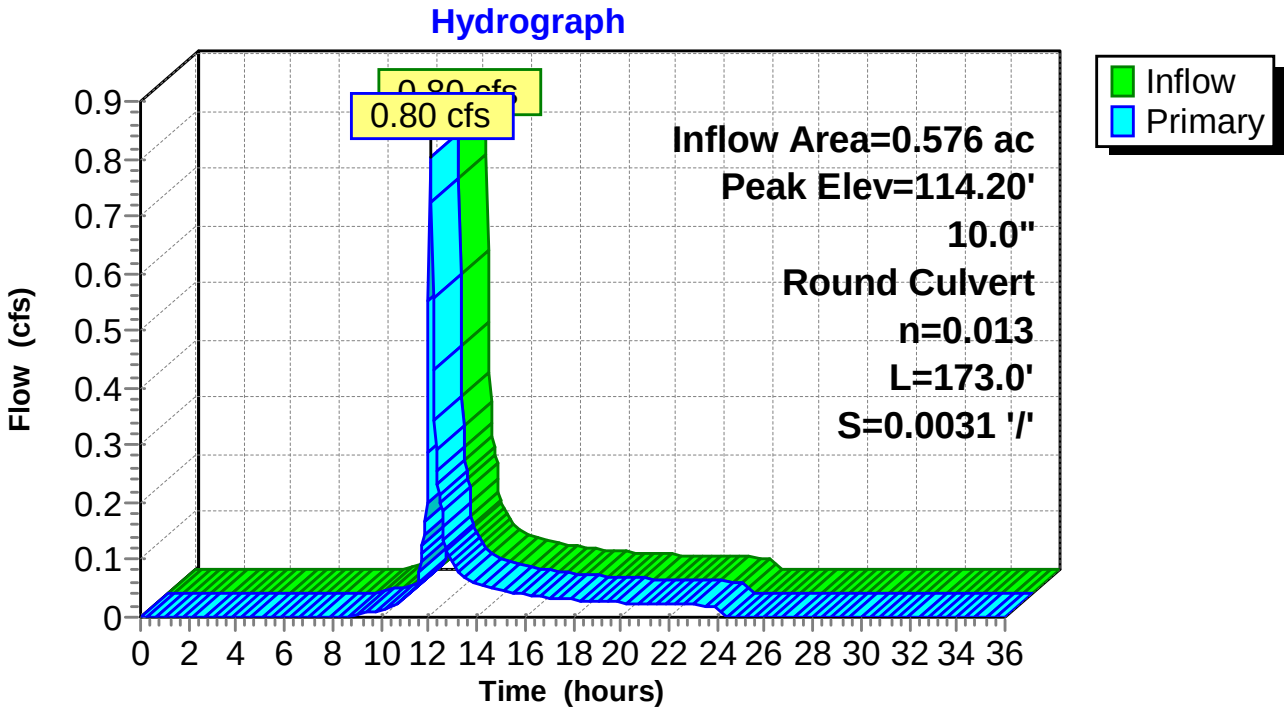
Inflow Area = 0.576 ac, 69.97% Impervious, Inflow Depth = 1.36" for 2-yr event
Inflow = 0.80 cfs @ 12.06 hrs, Volume= 0.065 af
Outflow = 0.80 cfs @ 12.06 hrs, Volume= 0.065 af, Atten= 0%, Lag= 0.0 min
Primary = 0.80 cfs @ 12.06 hrs, Volume= 0.065 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 114.20' @ 12.06 hrs
Flood Elev= 117.60'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 113.55' | **10.0" Round Culvert**<br>L= 173.0' RCP, square edge headwall, Ke= 0.500<br>Inlet / Outlet Invert= 113.55' / 113.01' S= 0.0031 '/' Cc= 0.900<br>n= 0.013, Flow Area= 0.55 sf |

**Primary OutFlow** Max=0.77 cfs @ 12.06 hrs HW=114.18' (Free Discharge)
**1=Culvert** (Barrel Controls 0.77 cfs @ 2.41 fps)

### Pond 11P: Exst DMH (Rim = 117.60)



## Summary for Pond 12P: Exist DMH (Rim = 116.31)

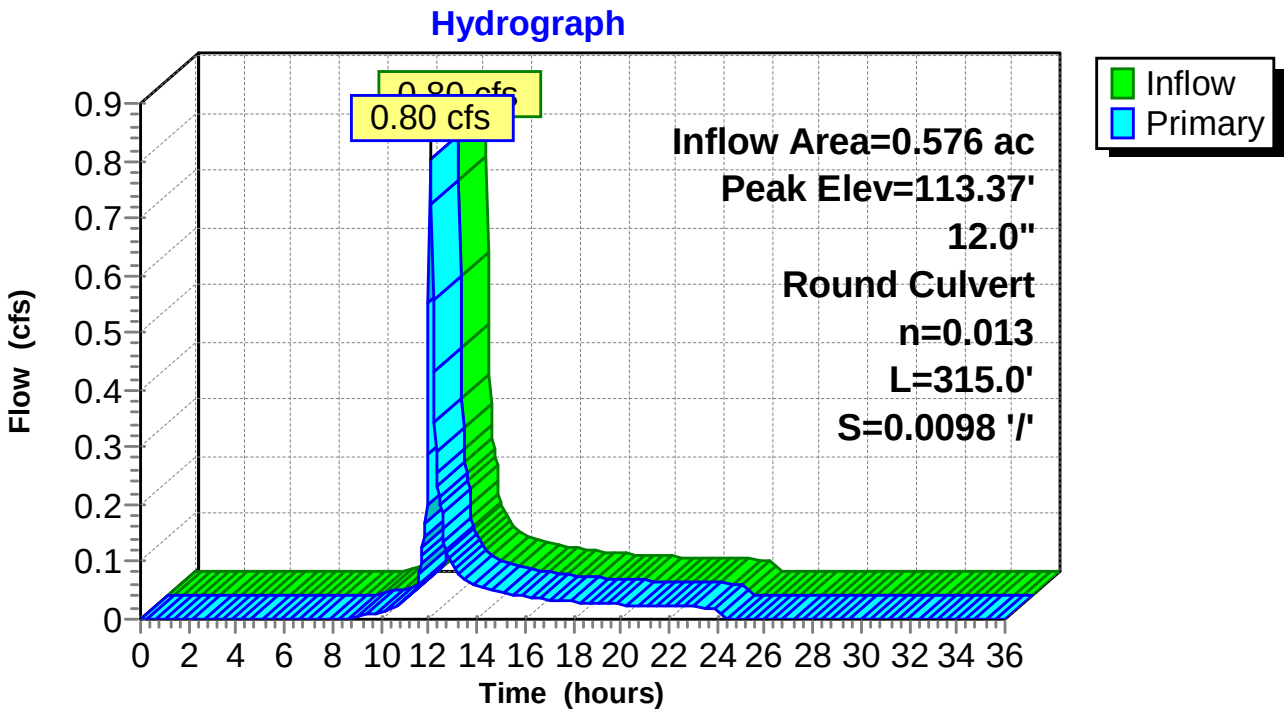
Inflow Area = 0.576 ac, 69.97% Impervious, Inflow Depth = 1.36" for 2-yr event
Inflow = 0.80 cfs @ 12.06 hrs, Volume= 0.065 af
Outflow = 0.80 cfs @ 12.06 hrs, Volume= 0.065 af, Atten= 0%, Lag= 0.0 min
Primary = 0.80 cfs @ 12.06 hrs, Volume= 0.065 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 113.37' @ 12.06 hrs
Flood Elev= 116.31'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 112.91' | **12.0" Round Culvert**<br>L= 315.0' RCP, square edge headwall, Ke= 0.500<br>Inlet / Outlet Invert= 112.91' / 109.82' S= 0.0098 '/' Cc= 0.900<br>n= 0.013, Flow Area= 0.79 sf |

**Primary OutFlow** Max=0.77 cfs @ 12.06 hrs HW=113.36' (Free Discharge)
**1=Culvert** (Inlet Controls 0.77 cfs @ 2.28 fps)

### Pond 12P: Exist DMH (Rim = 116.31)



## Summary for Pond 14P: DMH (Rim=126.82)

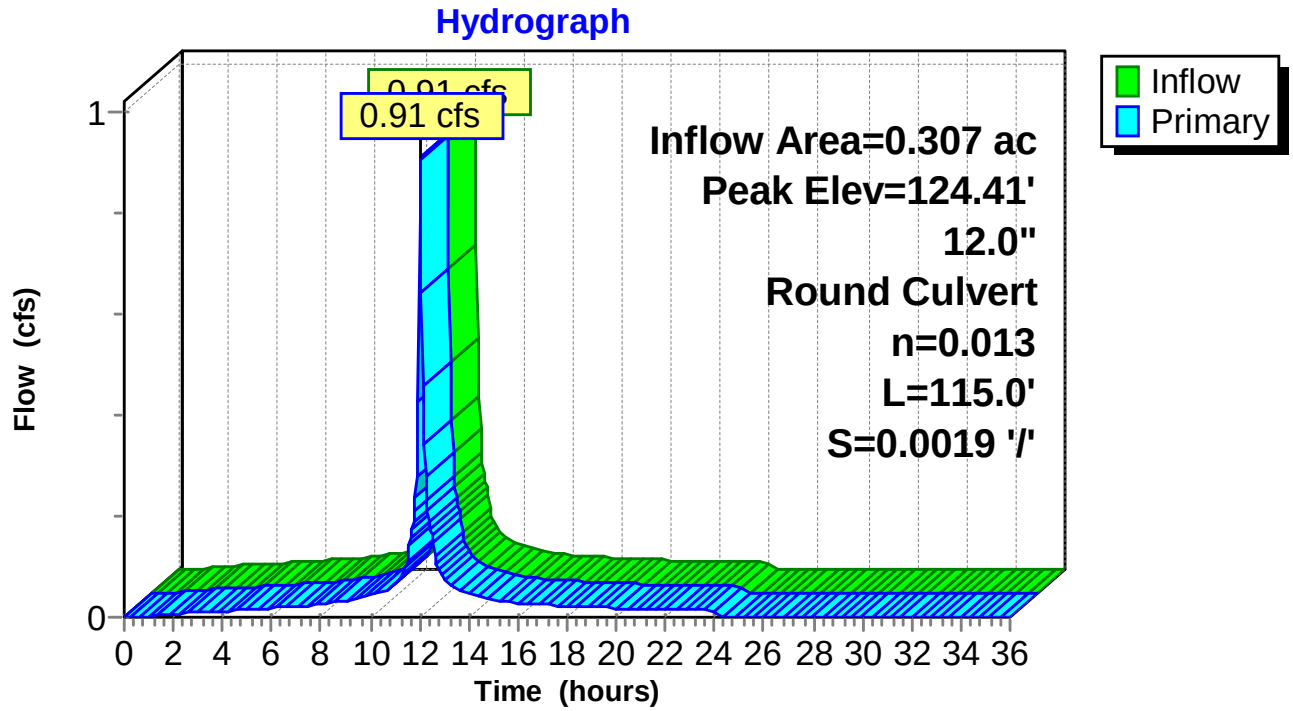
Inflow Area = 0.307 ac,100.00% Impervious, Inflow Depth = 2.91" for 2-yr event
Inflow = 0.91 cfs @ 12.04 hrs, Volume= 0.074 af
Outflow = 0.91 cfs @ 12.04 hrs, Volume= 0.074 af, Atten= 0%, Lag= 0.0 min
Primary = 0.91 cfs @ 12.04 hrs, Volume= 0.074 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 124.41' @ 12.04 hrs
Flood Elev= 126.82'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 123.72' | **12.0" Round Culvert**<br>L= 115.0' RCP, square edge headwall, Ke= 0.500<br>Inlet / Outlet Invert= 123.72' / 123.50' S= 0.0019 '/' Cc= 0.900<br>n= 0.013, Flow Area= 0.79 sf |

**Primary OutFlow** Max=0.88 cfs @ 12.04 hrs HW=124.39' (Free Discharge)
**1=Culvert** (Barrel Controls 0.88 cfs @ 2.22 fps)

### Pond 14P: DMH (Rim=126.82)



## Summary for Subcatchment 1S: Northwestern Area to Wetland

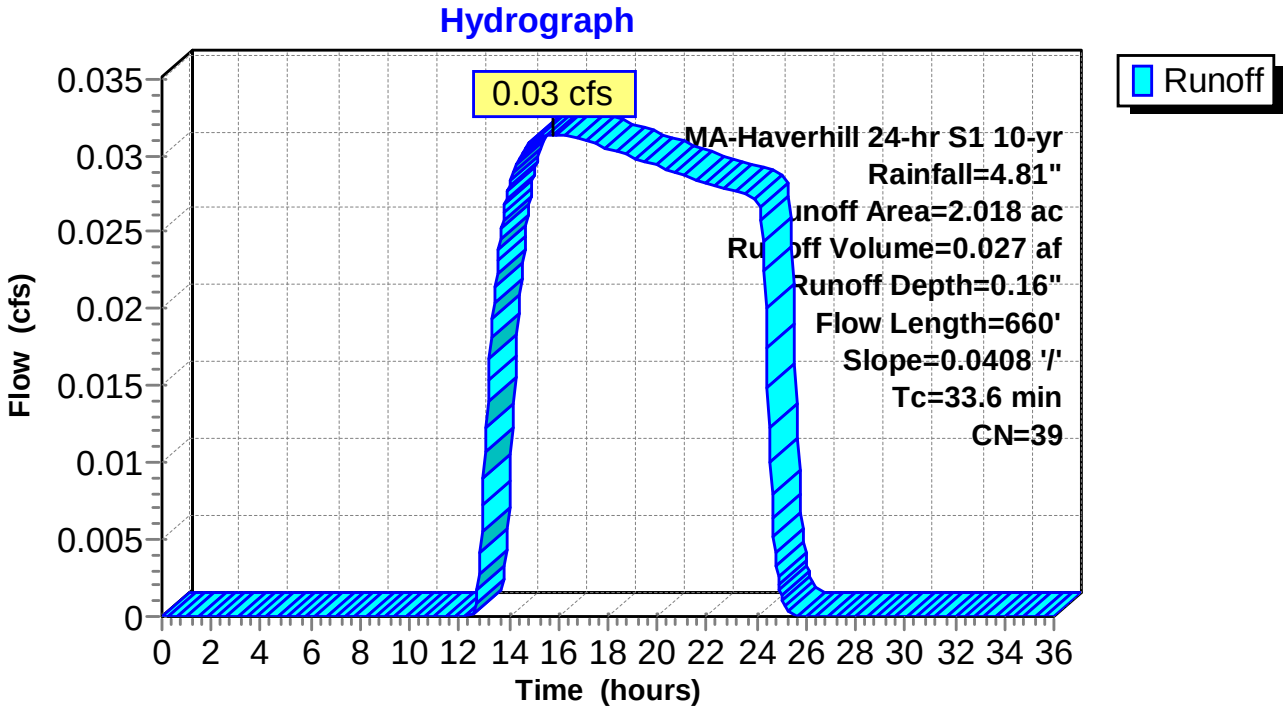
Runoff = 0.03 cfs @ 15.81 hrs, Volume= 0.027 af, Depth= 0.16"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 10-yr Rainfall=4.81"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 1.281 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.042 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.066 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.625 | 30 | Woods, Good, HSG A |
| | 0.004 | 70 | Woods, Good, HSG C |
| | 2.018 | 39 | Weighted Average |
| | 1.952 | | 96.73% Pervious Area |
| | 0.066 | | 3.27% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 33.6 | 660 | 0.0408 | 0.33 | | **Lag/CN Method,** |

### Subcatchment 1S: Northwestern Area to Wetland



## Summary for Subcatchment 2S: Drainage System To Wetland

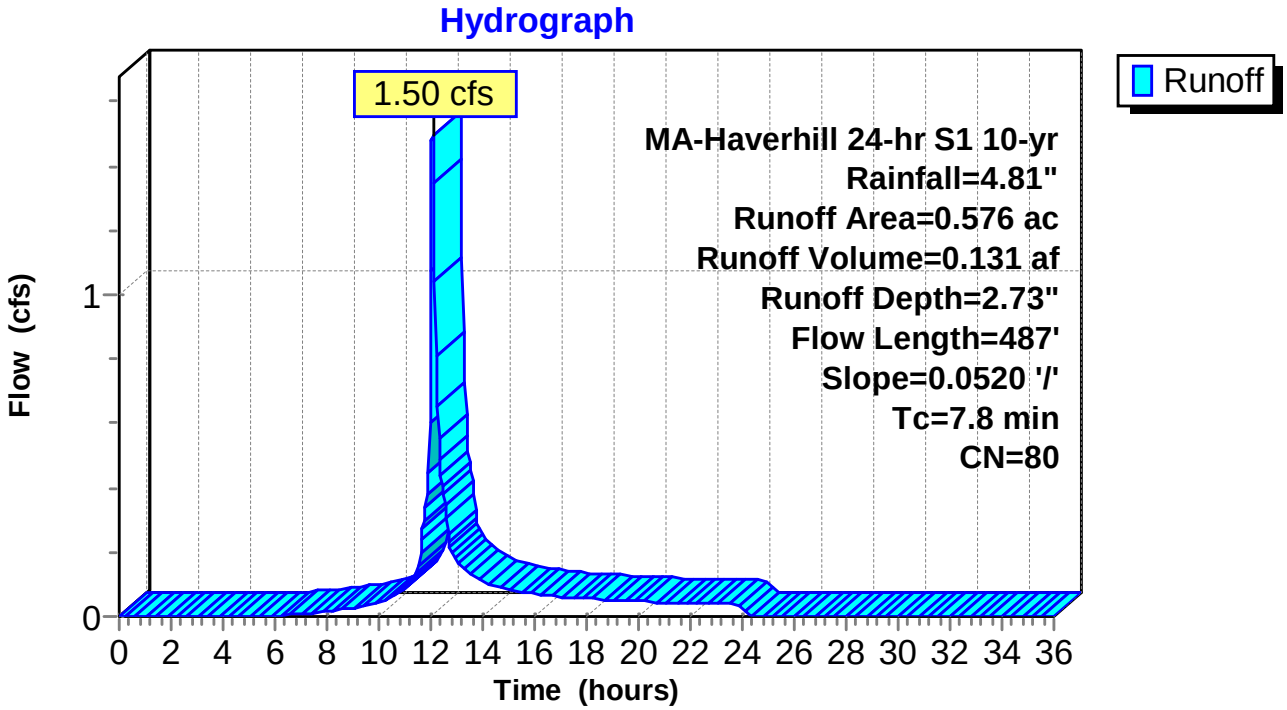
Runoff = 1.50 cfs @ 12.06 hrs, Volume= 0.131 af, Depth= 2.73"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 10-yr Rainfall=4.81"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.159 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.403 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.014 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.576 | 80 | Weighted Average |
| | 0.173 | | 30.03% Pervious Area |
| | 0.403 | | 69.97% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 7.8 | 487 | 0.0520 | 1.04 | | **Lag/CN Method,** |

### Subcatchment 2S: Drainage System To Wetland



## Summary for Subcatchment 3S: To Northwestern Grassy Area

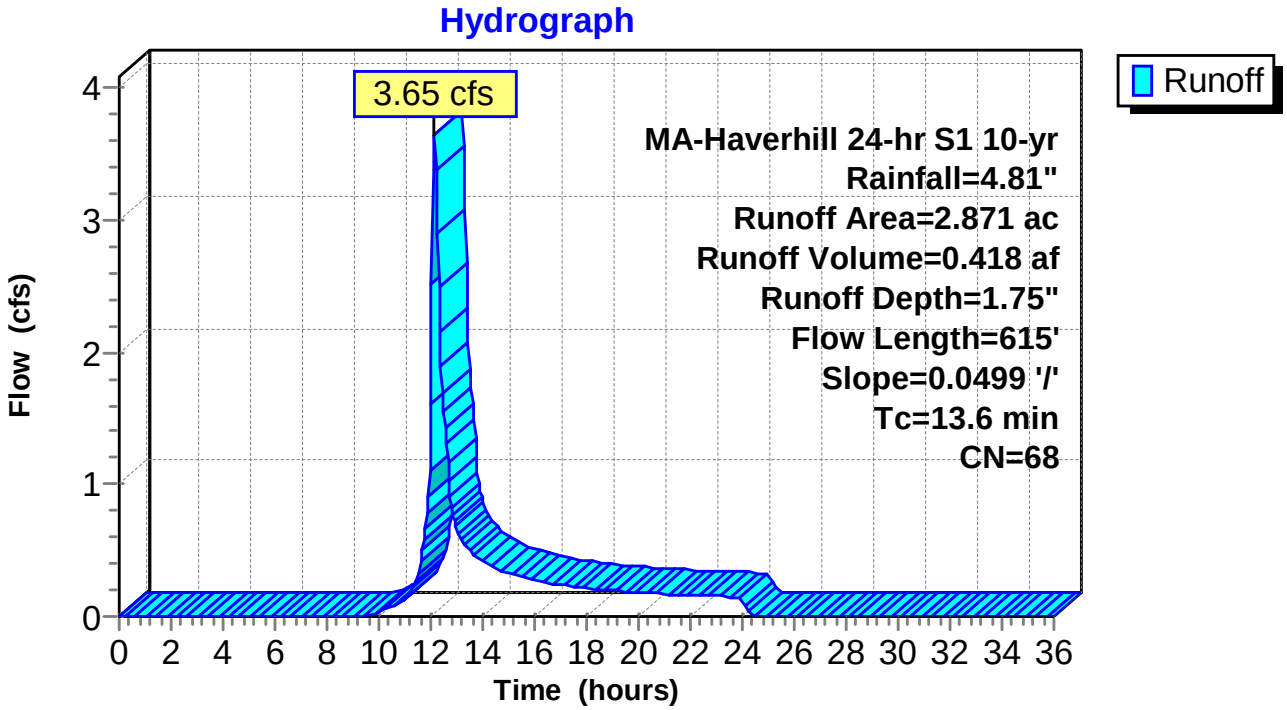
Runoff = 3.65 cfs @ 12.15 hrs, Volume= 0.418 af, Depth= 1.75"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 10-yr Rainfall=4.81"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.174 | 39 | >75% Grass cover, Good, HSG A |
| | 0.196 | 74 | >75% Grass cover, Good, HSG C |
| | 0.089 | 76 | Gravel roads, HSG A |
| | 0.290 | 89 | Gravel roads, HSG C |
| | 0.457 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.531 | 30 | Woods, Good, HSG A |
| | 1.134 | 70 | Woods, Good, HSG C |
| | 2.871 | 68 | Weighted Average |
| | 2.414 | | 84.08% Pervious Area |
| | 0.457 | | 15.92% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 13.6 | 615 | 0.0499 | 0.76 | | **Lag/CN Method,** |

### Subcatchment 3S: To Northwestern Grassy Area



## Summary for Subcatchment 4S: Direct Discharge to Lake

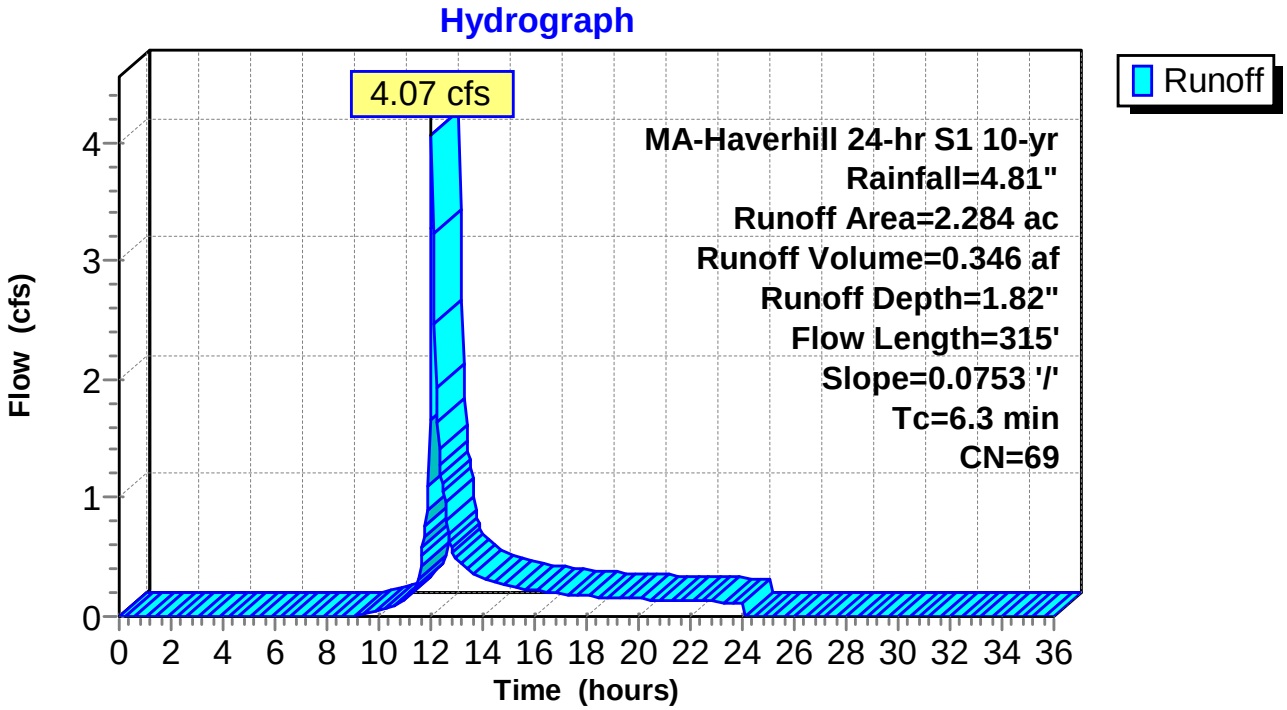
Runoff = 4.07 cfs @ 12.05 hrs, Volume= 0.346 af, Depth= 1.82"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 10-yr Rainfall=4.81"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 1.098 | 39 | >75% Grass cover, Good, HSG A |
| | 0.060 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.858 | 98 | Paved parking, HSG A |
| * | 0.268 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 2.284 | 69 | Weighted Average |
| | 1.426 | | 62.43% Pervious Area |
| | 0.858 | | 37.57% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.3 | 315 | 0.0753 | 0.83 | | **Lag/CN Method,** |

### Subcatchment 4S: Direct Discharge to Lake



## Summary for Subcatchment 5S: To CB near RWPS

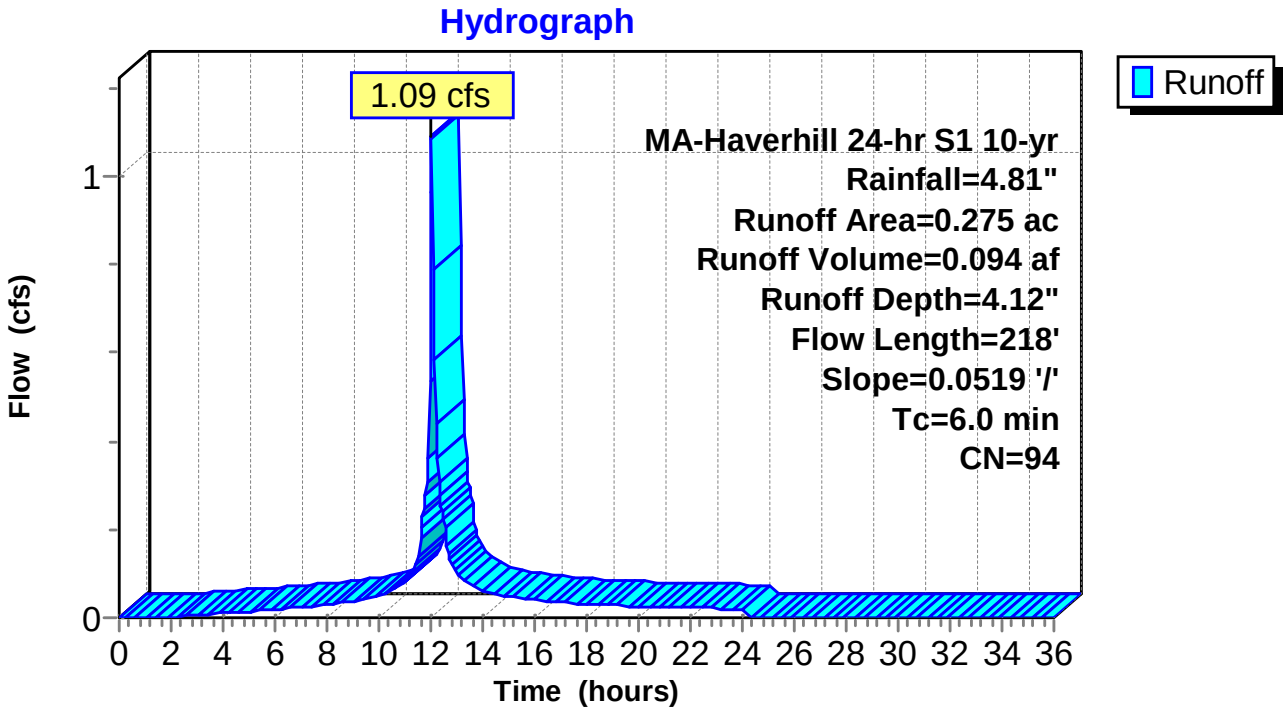
Runoff = 1.09 cfs @ 12.04 hrs, Volume= 0.094 af, Depth= 4.12"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 10-yr Rainfall=4.81"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.003 | 39 | >75% Grass cover, Good, HSG A |
| | 0.033 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.239 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.275 | 94 | Weighted Average |
| | 0.036 | | 13.09% Pervious Area |
| | 0.239 | | 86.91% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 2.4 | 218 | 0.0519 | 1.50 | | **Lag/CN Method,** |
| 2.4 | 218 | Total, Increased to minimum Tc = 6.0 min | | | |

### Subcatchment 5S: To CB near RWPS



## Summary for Subcatchment 6S: Roof Drains to Northwest

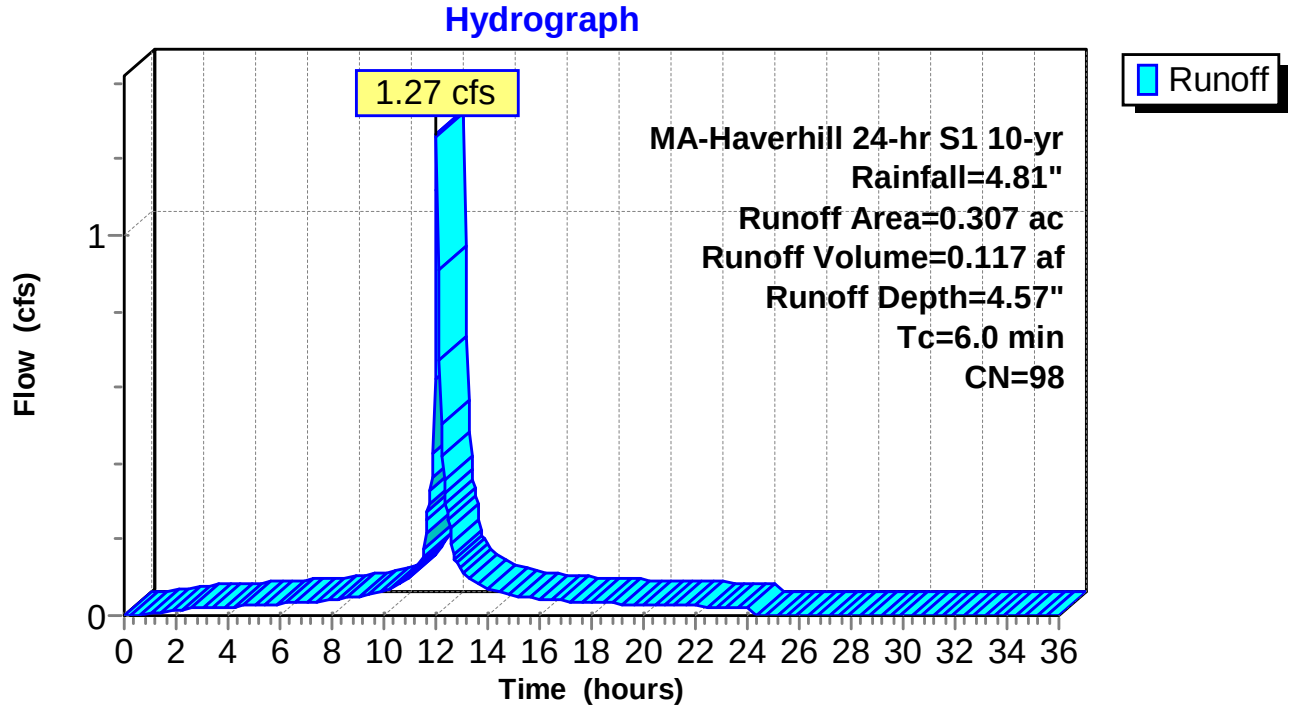
Runoff = 1.27 cfs @ 12.04 hrs, Volume= 0.117 af, Depth= 4.57"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 10-yr Rainfall=4.81"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.000 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.307 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.307 | 98 | Weighted Average |
| | 0.307 | | 100.00% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.0 | | | | | **Direct Entry, Minimum (Roof)** |

## Subcatchment 6S: Roof Drains to Northwest



## Summary for Subcatchment 7S: Southeast Swale to Lake

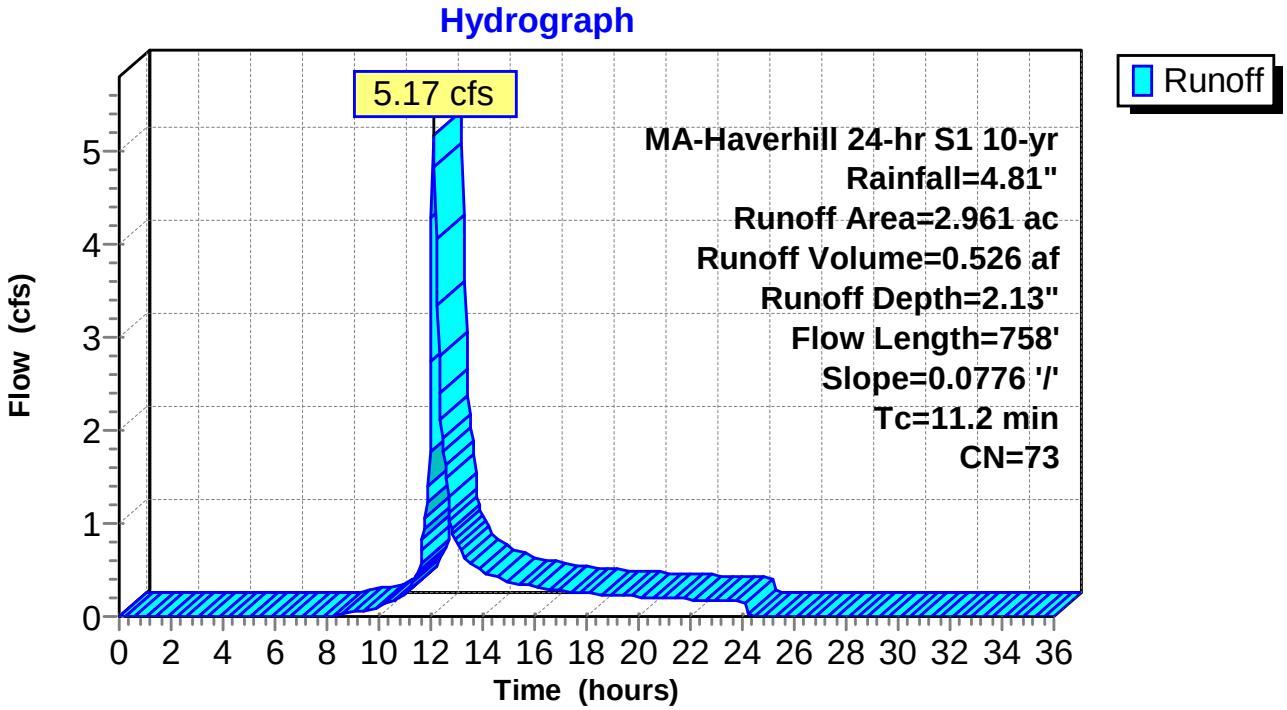
Runoff = 5.17 cfs @ 12.11 hrs, Volume= 0.526 af, Depth= 2.13"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 10-yr Rainfall=4.81"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.000 | 39 | >75% Grass cover, Good, HSG A |
| | 1.624 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.026 | 98 | Paved parking, HSG A |
| * | 0.007 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 1.304 | 70 | Woods, Good, HSG C |
| | 2.961 | 73 | Weighted Average |
| | 2.935 | | 99.12% Pervious Area |
| | 0.026 | | 0.88% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 11.2 | 758 | 0.0776 | 1.12 | | **Lag/CN Method,** |

### Subcatchment 7S: Southeast Swale to Lake



## Summary for Subcatchment 8S: Roof Drains to Lake

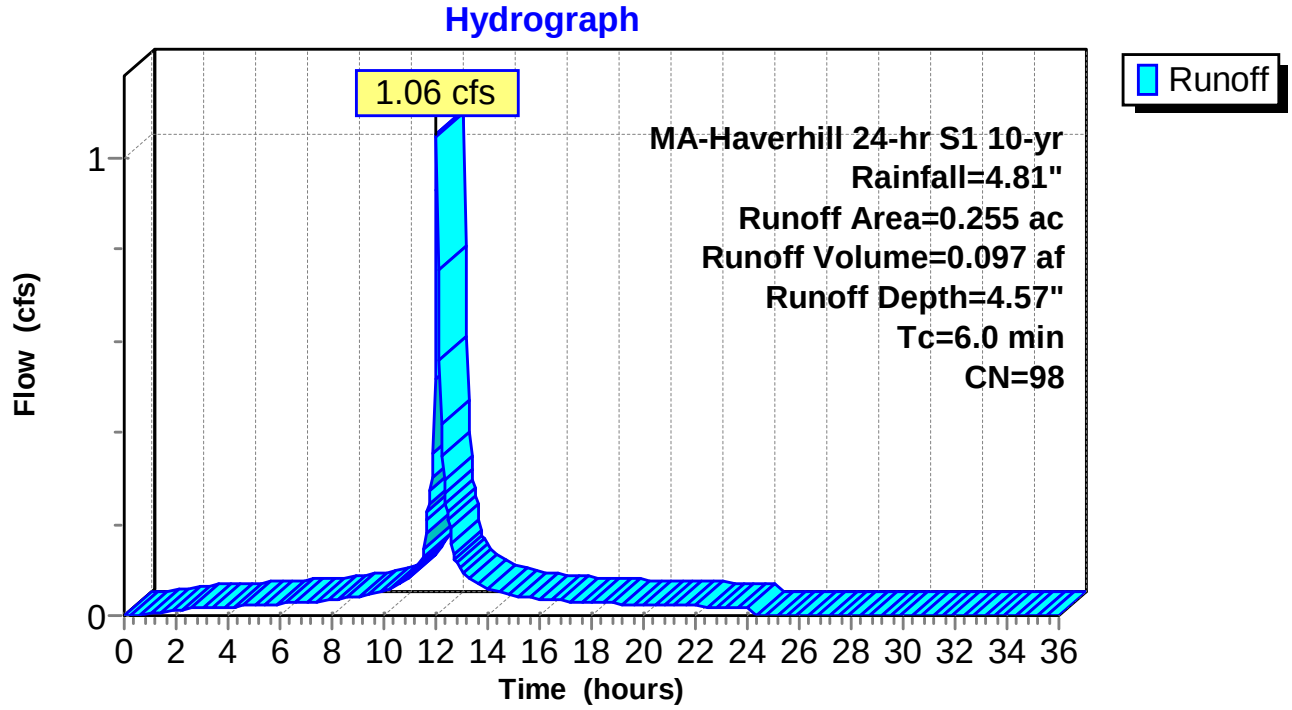
Runoff = 1.06 cfs @ 12.04 hrs, Volume= 0.097 af, Depth= 4.57"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 10-yr Rainfall=4.81"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.000 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.255 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.255 | 98 | Weighted Average |
| | 0.255 | | 100.00% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.0 | | | | | **Direct Entry, Minimum (Roof)** |

## Subcatchment 8S: Roof Drains to Lake



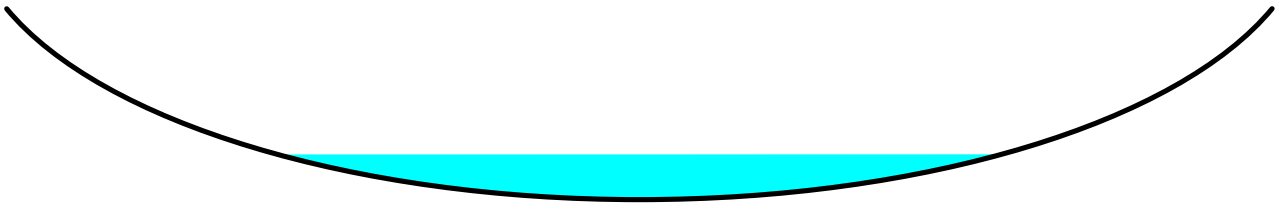
## Summary for Reach 13R: Northwestern Grassy Area

Inflow Area = 5.196 ac, 15.97% Impervious, Inflow Depth = 1.30" for 10-yr event
Inflow = 4.37 cfs @ 12.13 hrs, Volume= 0.562 af
Outflow = 4.03 cfs @ 12.27 hrs, Volume= 0.562 af, Atten= 8%, Lag= 8.4 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.75 fps, Min. Travel Time= 4.8 min
Avg. Velocity = 0.58 fps, Avg. Travel Time= 14.3 min

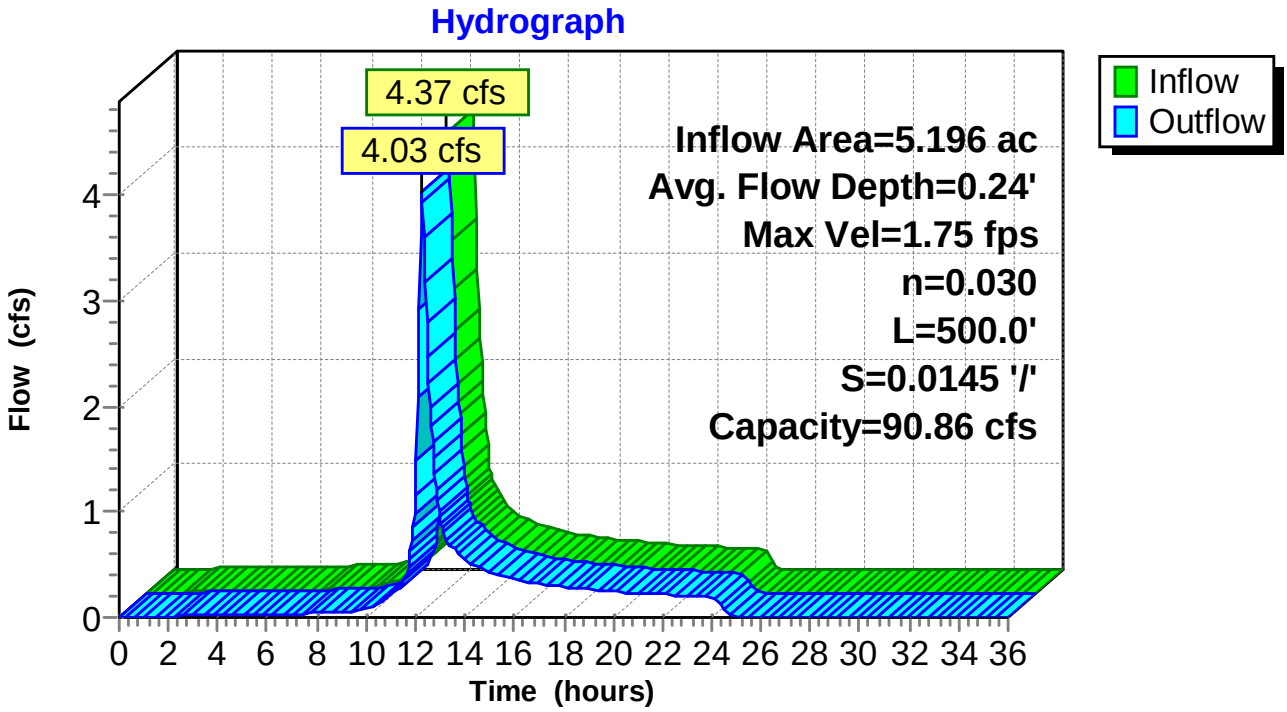
Peak Storage= 1,163 cf @ 12.19 hrs
Average Depth at Peak Storage= 0.24'
Bank-Full Depth= 1.00' Flow Area= 20.0 sf, Capacity= 90.86 cfs

30.00' x 1.00' deep Parabolic Channel, n= 0.030 Earth, grassed & winding
Length= 500.0' Slope= 0.0145 '/'
Inlet Invert= 123.50', Outlet Invert= 116.25'



‡

**Reach 13R: Northwestern Grassy Area**

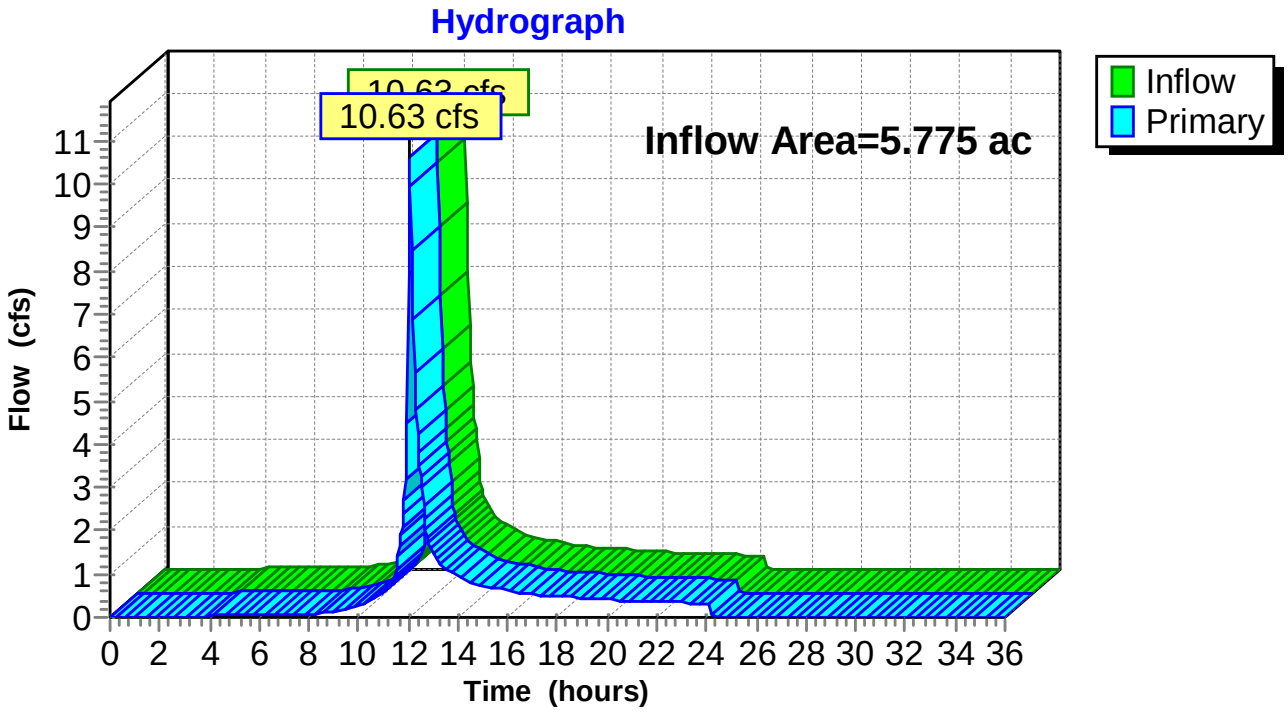


## Summary for Pond 9P: Kenoza Lake

Inflow Area = 5.775 ac, 23.86% Impervious, Inflow Depth = 2.21" for 10-yr event
Inflow = 10.63 cfs @ 12.07 hrs, Volume= 1.064 af
Primary = 10.63 cfs @ 12.07 hrs, Volume= 1.064 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs

### Pond 9P: Kenoza Lake

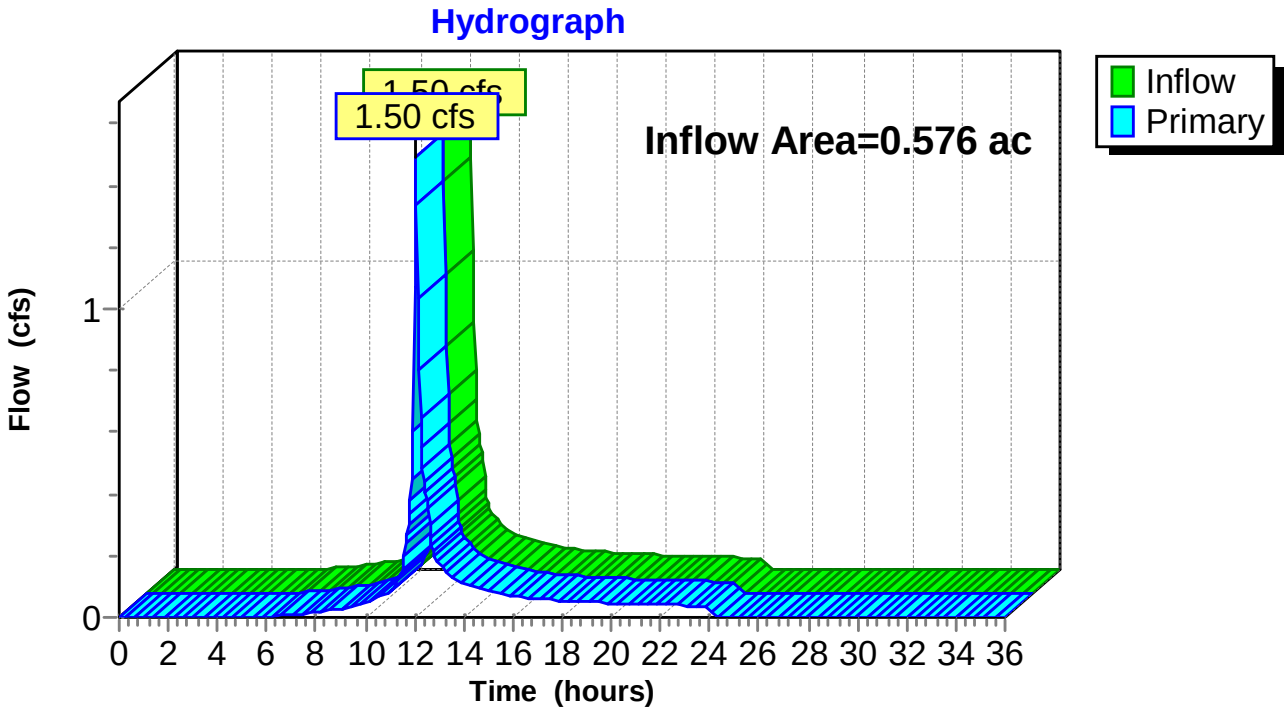


## Summary for Pond 10P: Northwestern Wetlands

Inflow Area = 0.576 ac, 69.97% Impervious, Inflow Depth = 2.73" for 10-yr event
Inflow = 1.50 cfs @ 12.06 hrs, Volume= 0.131 af
Primary = 1.50 cfs @ 12.06 hrs, Volume= 0.131 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs

### Pond 10P: Northwestern Wetlands



## Summary for Pond 11P: Exst DMH (Rim = 117.60)

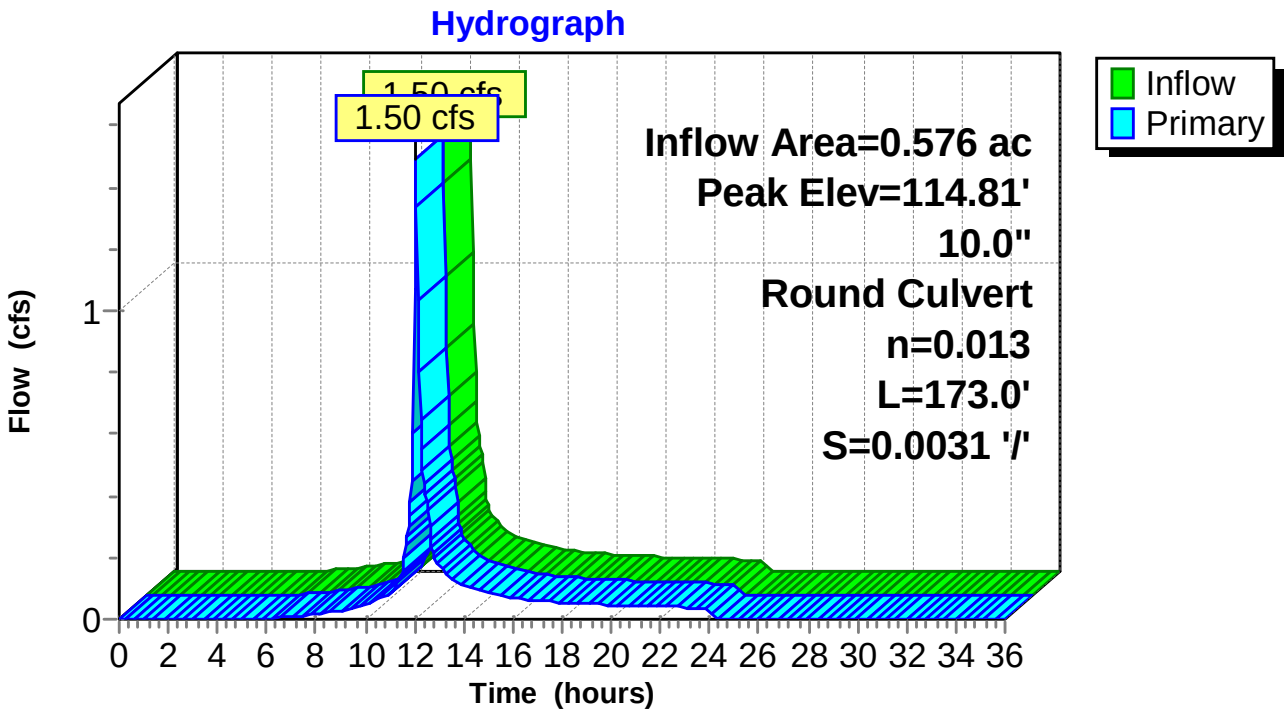
Inflow Area = 0.576 ac, 69.97% Impervious, Inflow Depth = 2.73" for 10-yr event
Inflow = 1.50 cfs @ 12.06 hrs, Volume= 0.131 af
Outflow = 1.50 cfs @ 12.06 hrs, Volume= 0.131 af, Atten= 0%, Lag= 0.0 min
Primary = 1.50 cfs @ 12.06 hrs, Volume= 0.131 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 114.81' @ 12.06 hrs
Flood Elev= 117.60'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 113.55' | **10.0" Round Culvert**<br>L= 173.0' RCP, square edge headwall, Ke= 0.500<br>Inlet / Outlet Invert= 113.55' / 113.01' S= 0.0031 '/' Cc= 0.900<br>n= 0.013, Flow Area= 0.55 sf |

**Primary OutFlow** Max=1.42 cfs @ 12.06 hrs HW=114.73' (Free Discharge)
**1=Culvert** (Barrel Controls 1.42 cfs @ 2.61 fps)

### Pond 11P: Exst DMH (Rim = 117.60)



## Summary for Pond 12P: Exist DMH (Rim = 116.31)

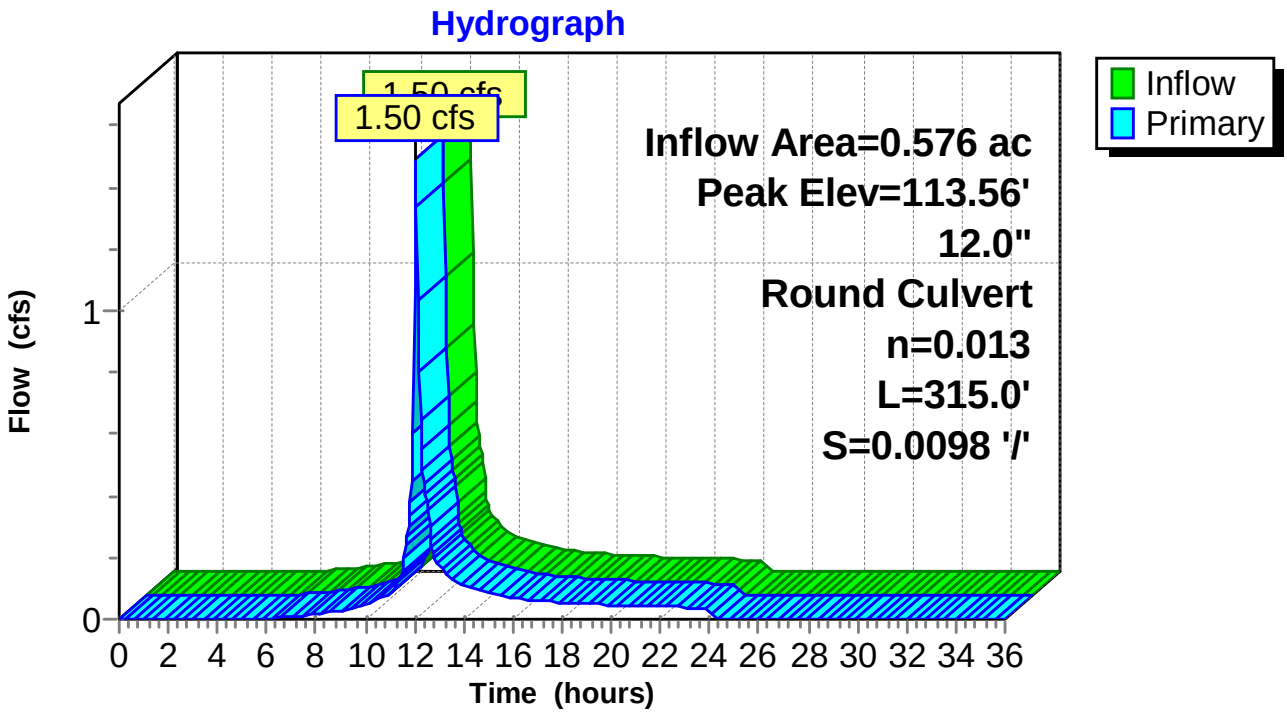
Inflow Area = 0.576 ac, 69.97% Impervious, Inflow Depth = 2.73" for 10-yr event
Inflow = 1.50 cfs @ 12.06 hrs, Volume= 0.131 af
Outflow = 1.50 cfs @ 12.06 hrs, Volume= 0.131 af, Atten= 0%, Lag= 0.0 min
Primary = 1.50 cfs @ 12.06 hrs, Volume= 0.131 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 113.56' @ 12.06 hrs
Flood Elev= 116.31'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 112.91' | **12.0" Round Culvert**<br>L= 315.0' RCP, square edge headwall, Ke= 0.500<br>Inlet / Outlet Invert= 112.91' / 109.82' S= 0.0098 '/' Cc= 0.900<br>n= 0.013, Flow Area= 0.79 sf |

**Primary OutFlow** Max=1.45 cfs @ 12.06 hrs HW=113.55' (Free Discharge)
**1=Culvert** (Inlet Controls 1.45 cfs @ 2.72 fps)

### Pond 12P: Exist DMH (Rim = 116.31)



## Summary for Pond 14P: DMH (Rim=126.82)

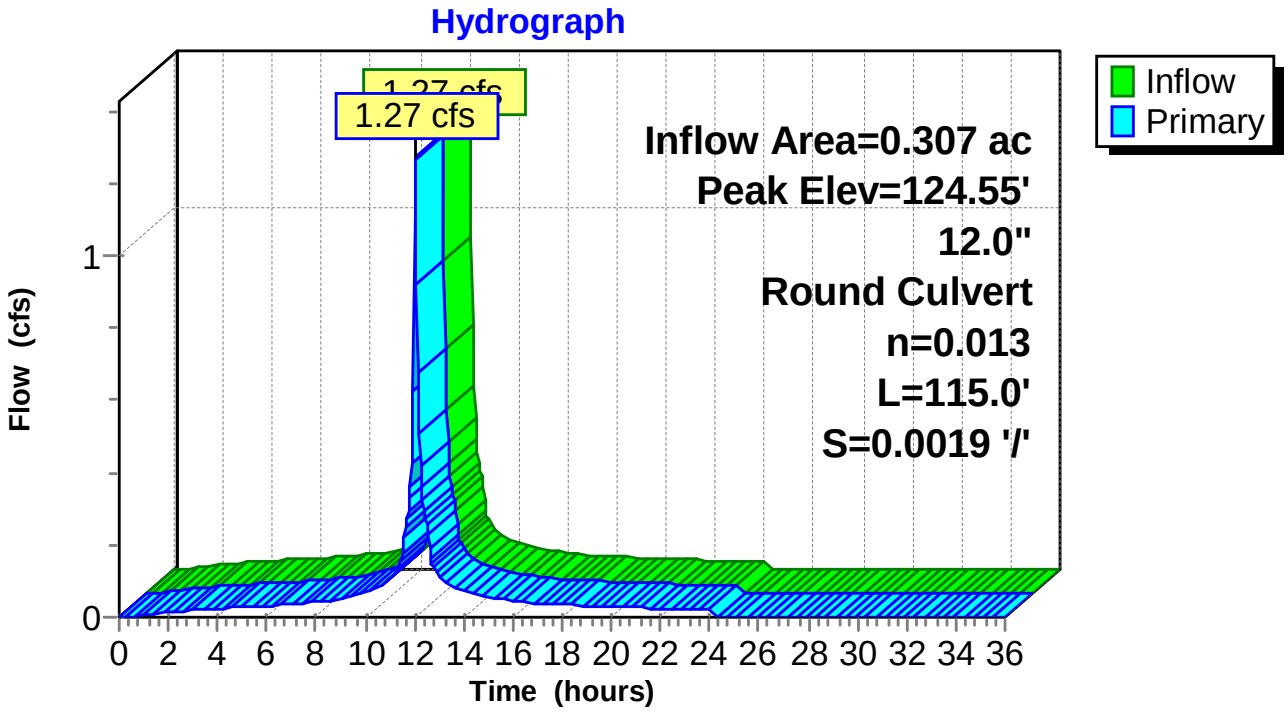
Inflow Area = 0.307 ac,100.00% Impervious, Inflow Depth = 4.57" for 10-yr event
Inflow = 1.27 cfs @ 12.04 hrs, Volume= 0.117 af
Outflow = 1.27 cfs @ 12.04 hrs, Volume= 0.117 af, Atten= 0%, Lag= 0.0 min
Primary = 1.27 cfs @ 12.04 hrs, Volume= 0.117 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 124.55' @ 12.04 hrs
Flood Elev= 126.82'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 123.72' | **12.0" Round Culvert**<br>L= 115.0' RCP, square edge headwall, Ke= 0.500<br>Inlet / Outlet Invert= 123.72' / 123.50' S= 0.0019 '/' Cc= 0.900<br>n= 0.013, Flow Area= 0.79 sf |

**Primary OutFlow** Max=1.23 cfs @ 12.04 hrs HW=124.54' (Free Discharge)
**1=Culvert** (Barrel Controls 1.23 cfs @ 2.44 fps)

### Pond 14P: DMH (Rim=126.82)



## Summary for Subcatchment 1S: Northwestern Area to Wetland

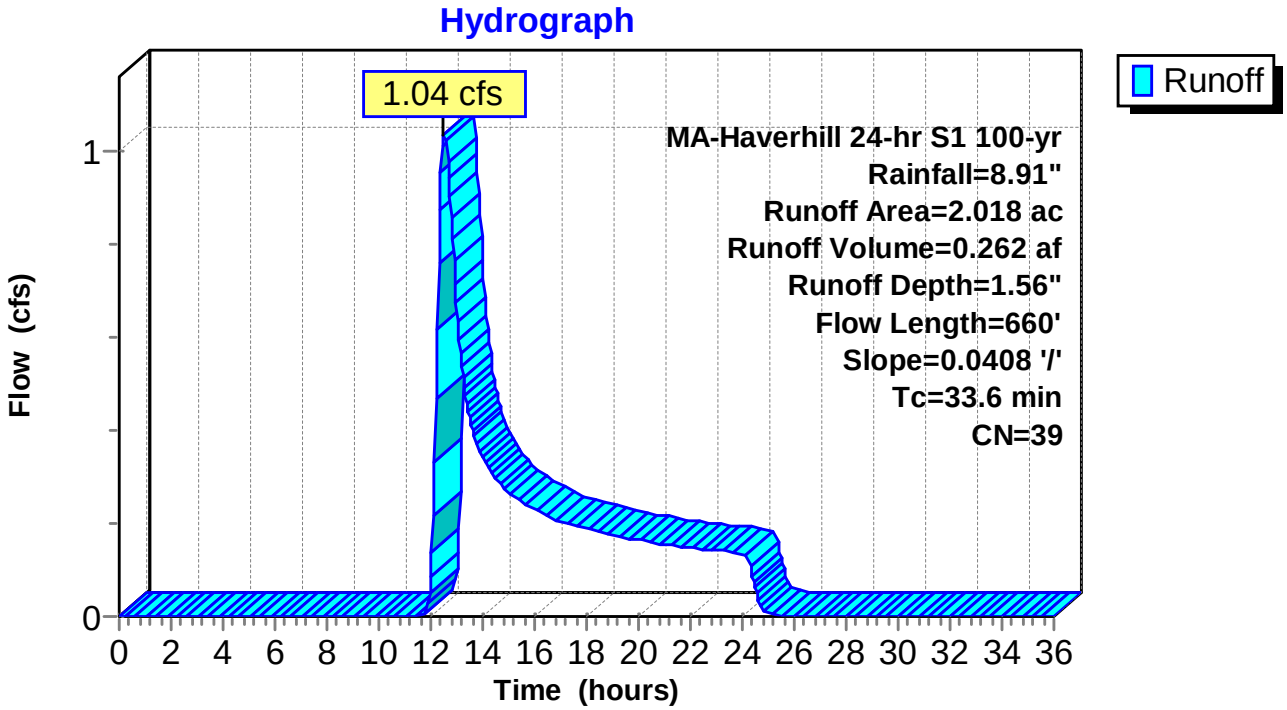
Runoff = 1.04 cfs @ 12.52 hrs, Volume= 0.262 af, Depth= 1.56"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 100-yr Rainfall=8.91"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 1.281 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.042 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.066 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.625 | 30 | Woods, Good, HSG A |
| | 0.004 | 70 | Woods, Good, HSG C |
| | 2.018 | 39 | Weighted Average |
| | 1.952 | | 96.73% Pervious Area |
| | 0.066 | | 3.27% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 33.6 | 660 | 0.0408 | 0.33 | | **Lag/CN Method,** |

## Subcatchment 1S: Northwestern Area to Wetland



## Summary for Subcatchment 2S: Drainage System To Wetland

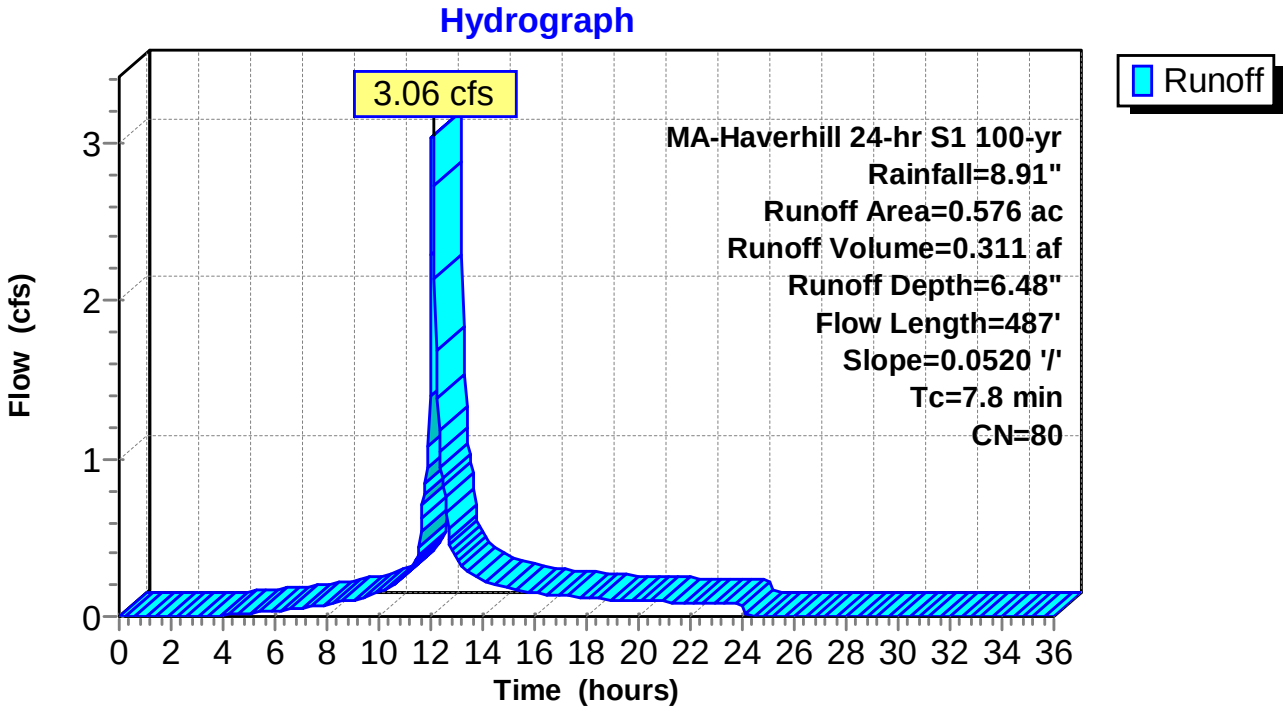
Runoff = 3.06 cfs @ 12.06 hrs, Volume= 0.311 af, Depth= 6.48"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 100-yr Rainfall=8.91"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.159 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.403 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.014 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.576 | 80 | Weighted Average |
| | 0.173 | | 30.03% Pervious Area |
| | 0.403 | | 69.97% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 7.8 | 487 | 0.0520 | 1.04 | | **Lag/CN Method,** |

### Subcatchment 2S: Drainage System To Wetland



## Summary for Subcatchment 3S: To Northwestern Grassy Area

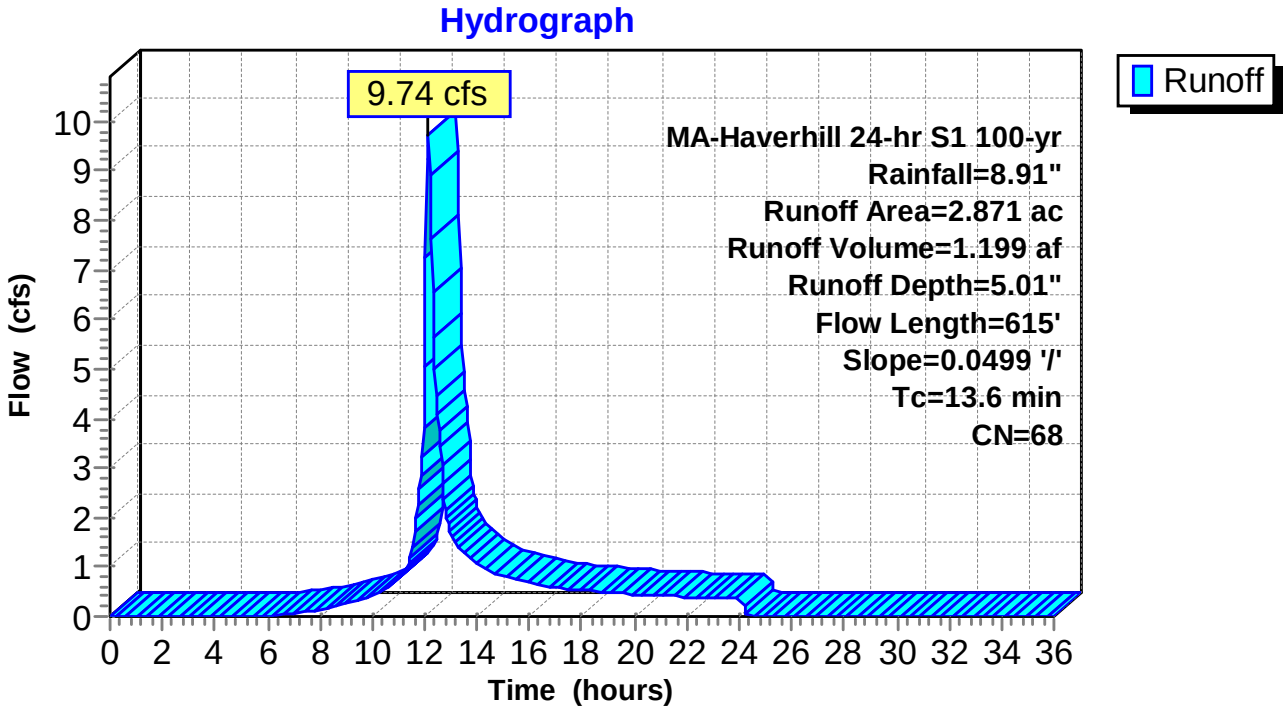
Runoff = 9.74 cfs @ 12.14 hrs, Volume= 1.199 af, Depth= 5.01"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 100-yr Rainfall=8.91"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.174 | 39 | >75% Grass cover, Good, HSG A |
| | 0.196 | 74 | >75% Grass cover, Good, HSG C |
| | 0.089 | 76 | Gravel roads, HSG A |
| | 0.290 | 89 | Gravel roads, HSG C |
| | 0.457 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.531 | 30 | Woods, Good, HSG A |
| | 1.134 | 70 | Woods, Good, HSG C |
| | 2.871 | 68 | Weighted Average |
| | 2.414 | | 84.08% Pervious Area |
| | 0.457 | | 15.92% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 13.6 | 615 | 0.0499 | 0.76 | | **Lag/CN Method,** |

## Subcatchment 3S: To Northwestern Grassy Area



## Summary for Subcatchment 4S: Direct Discharge to Lake

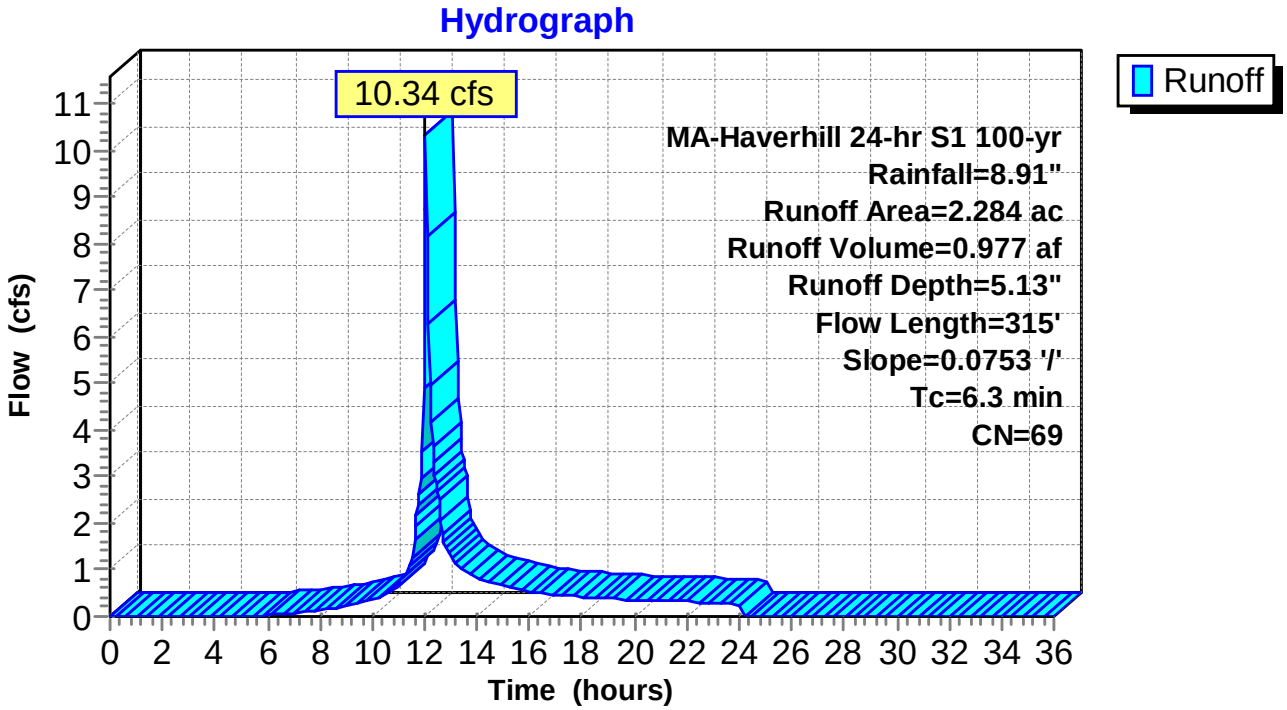
Runoff = 10.34 cfs @ 12.05 hrs, Volume= 0.977 af, Depth= 5.13"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 100-yr Rainfall=8.91"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 1.098 | 39 | >75% Grass cover, Good, HSG A |
| | 0.060 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.858 | 98 | Paved parking, HSG A |
| * | 0.268 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 2.284 | 69 | Weighted Average |
| | 1.426 | | 62.43% Pervious Area |
| | 0.858 | | 37.57% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.3 | 315 | 0.0753 | 0.83 | | **Lag/CN Method,** |

### Subcatchment 4S: Direct Discharge to Lake



## Summary for Subcatchment 5S: To CB near RWPS

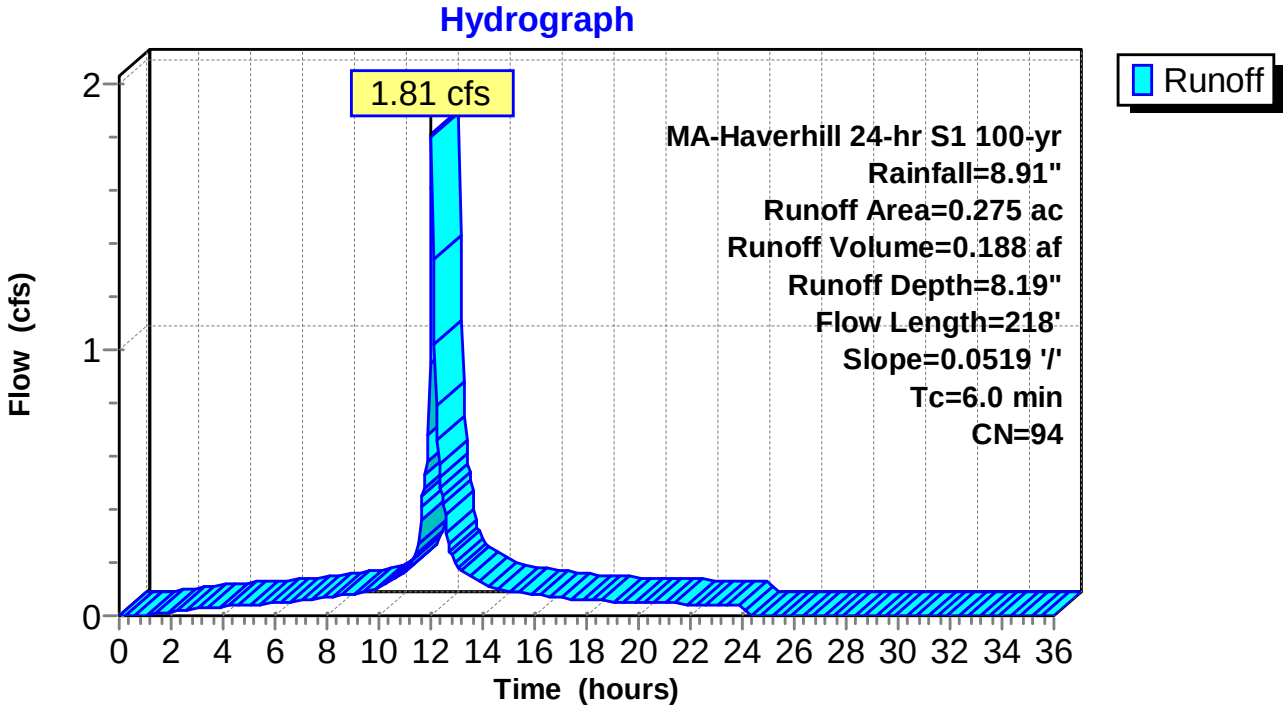
Runoff = 1.81 cfs @ 12.04 hrs, Volume= 0.188 af, Depth= 8.19"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 100-yr Rainfall=8.91"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.003 | 39 | >75% Grass cover, Good, HSG A |
| | 0.033 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.239 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.275 | 94 | Weighted Average |
| | 0.036 | | 13.09% Pervious Area |
| | 0.239 | | 86.91% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 2.4 | 218 | 0.0519 | 1.50 | | **Lag/CN Method,** |
| 2.4 | 218 | Total, Increased to minimum Tc = 6.0 min | | | |

## Subcatchment 5S: To CB near RWPS



## Summary for Subcatchment 6S: Roof Drains to Northwest

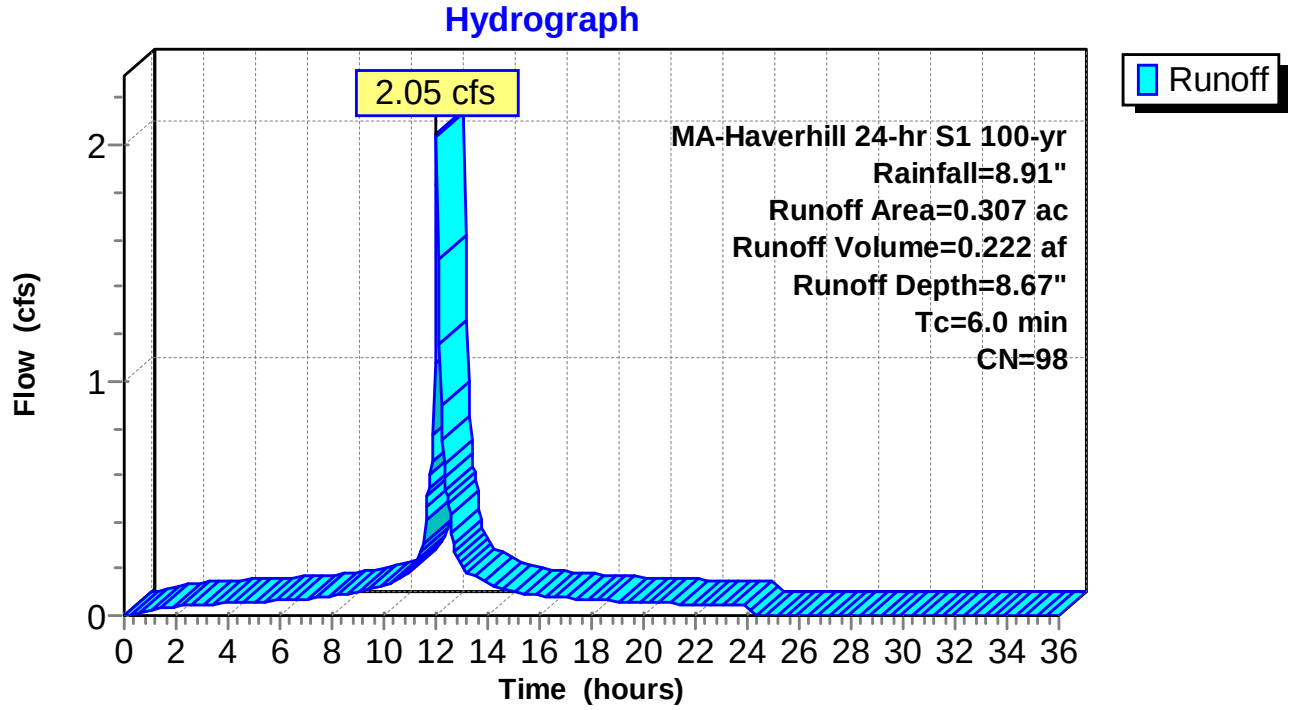
Runoff = 2.05 cfs @ 12.04 hrs, Volume= 0.222 af, Depth= 8.67"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 100-yr Rainfall=8.91"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.000 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.307 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.307 | 98 | Weighted Average |
| | 0.307 | | 100.00% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.0 | | | | | **Direct Entry, Minimum (Roof)** |

## Subcatchment 6S: Roof Drains to Northwest



## Summary for Subcatchment 7S: Southeast Swale to Lake

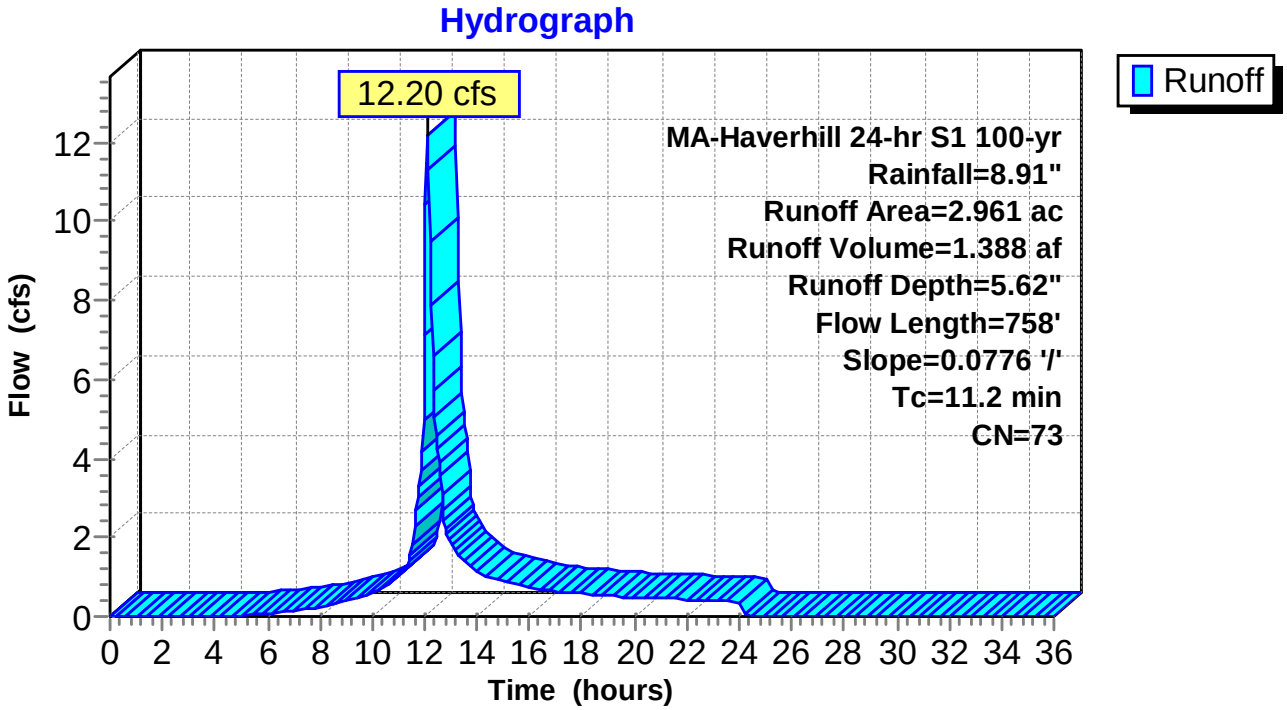
Runoff = 12.20 cfs @ 12.11 hrs, Volume= 1.388 af, Depth= 5.62"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 100-yr Rainfall=8.91"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.000 | 39 | >75% Grass cover, Good, HSG A |
| | 1.624 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.026 | 98 | Paved parking, HSG A |
| * | 0.007 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 1.304 | 70 | Woods, Good, HSG C |
| | 2.961 | 73 | Weighted Average |
| | 2.935 | | 99.12% Pervious Area |
| | 0.026 | | 0.88% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 11.2 | 758 | 0.0776 | 1.12 | | **Lag/CN Method,** |

### Subcatchment 7S: Southeast Swale to Lake



## Summary for Subcatchment 8S: Roof Drains to Lake

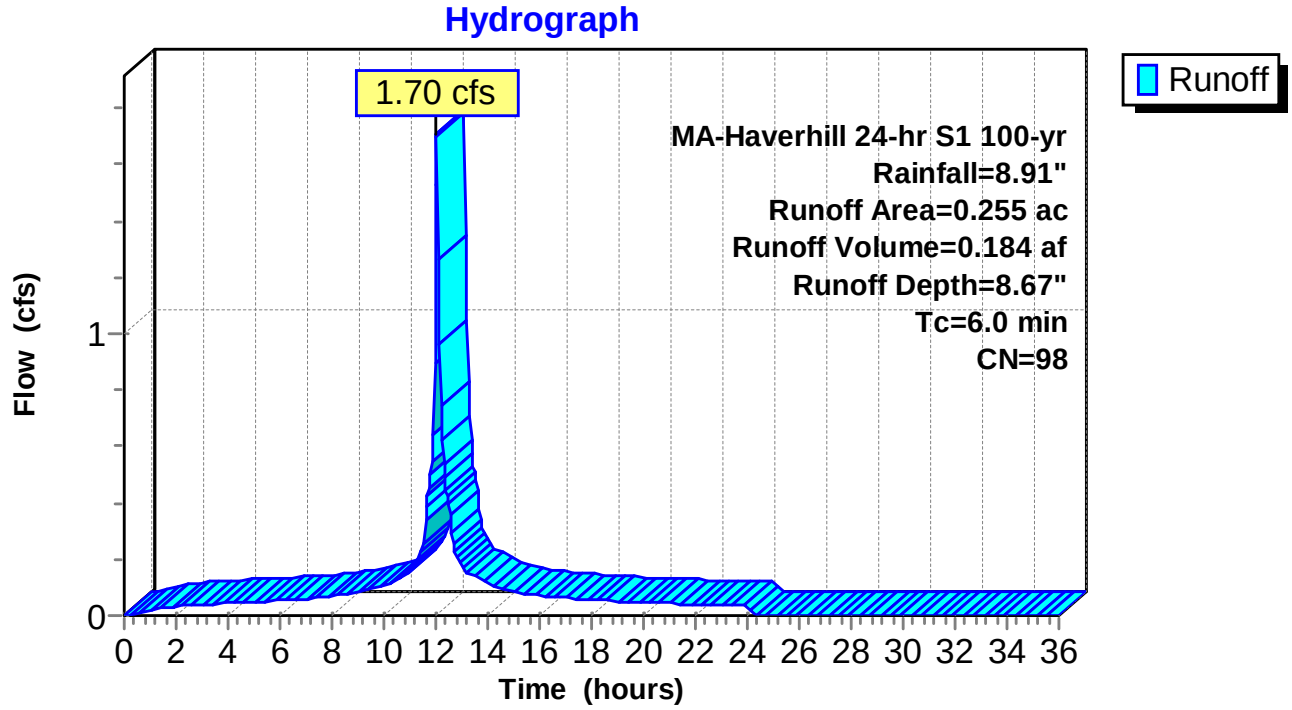
Runoff = 1.70 cfs @ 12.04 hrs, Volume= 0.184 af, Depth= 8.67"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 100-yr Rainfall=8.91"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.000 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.255 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.255 | 98 | Weighted Average |
| | 0.255 | | 100.00% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.0 | | | | | **Direct Entry, Minimum (Roof)** |

## Subcatchment 8S: Roof Drains to Lake



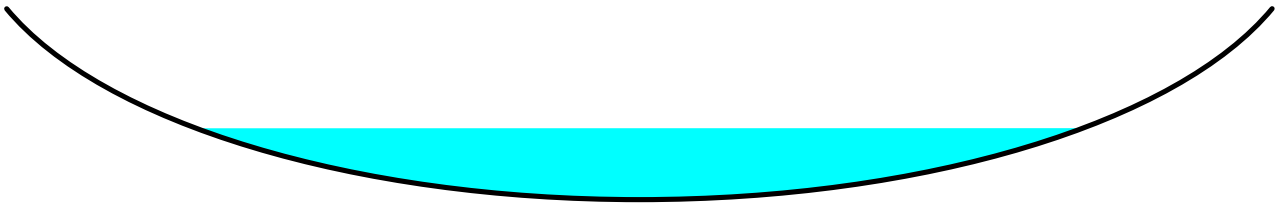
## Summary for Reach 13R: Northwestern Grassy Area

Inflow Area = 5.196 ac, 15.97% Impervious, Inflow Depth = 3.89" for 100-yr event
Inflow = 11.26 cfs @ 12.13 hrs, Volume= 1.683 af
Outflow = 10.73 cfs @ 12.24 hrs, Volume= 1.683 af, Atten= 5%, Lag= 6.3 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.36 fps, Min. Travel Time= 3.5 min
Avg. Velocity = 0.80 fps, Avg. Travel Time= 10.4 min

Peak Storage= 2,288 cf @ 12.18 hrs
Average Depth at Peak Storage= 0.37'
Bank-Full Depth= 1.00' Flow Area= 20.0 sf, Capacity= 90.86 cfs

30.00' x 1.00' deep Parabolic Channel, n= 0.030 Earth, grassed & winding
Length= 500.0' Slope= 0.0145 '/'
Inlet Invert= 123.50', Outlet Invert= 116.25'



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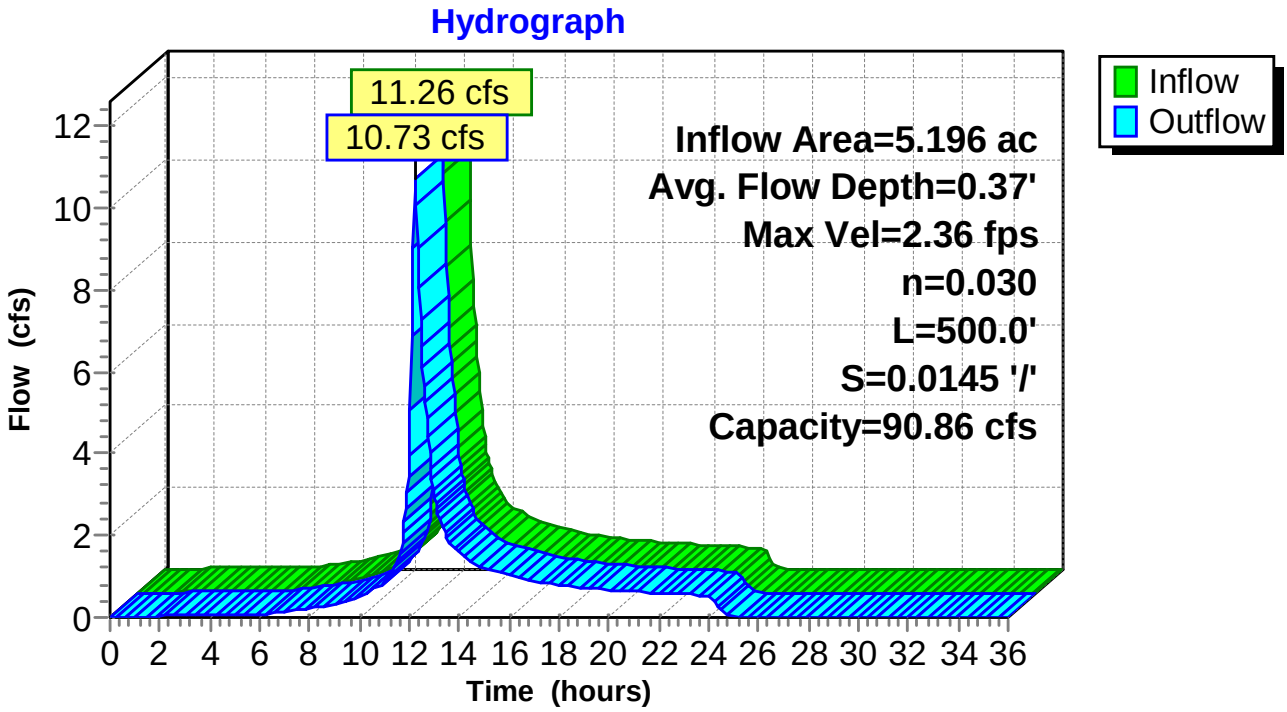
**Reach 13R: Northwestern Grassy Area**

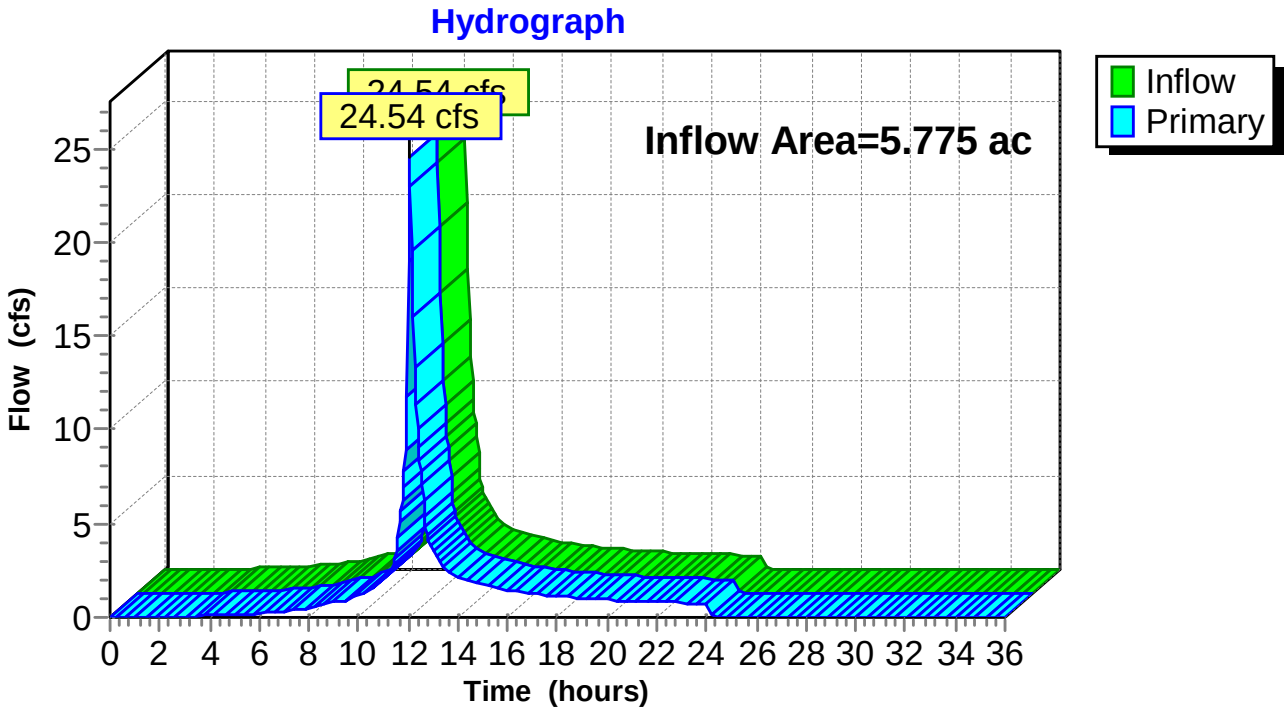


## Summary for Pond 9P: Kenoza Lake

Inflow Area = 5.775 ac, 23.86% Impervious, Inflow Depth = 5.69" for 100-yr event
Inflow = 24.54 cfs @ 12.06 hrs, Volume= 2.737 af
Primary = 24.54 cfs @ 12.06 hrs, Volume= 2.737 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs

### Pond 9P: Kenoza Lake

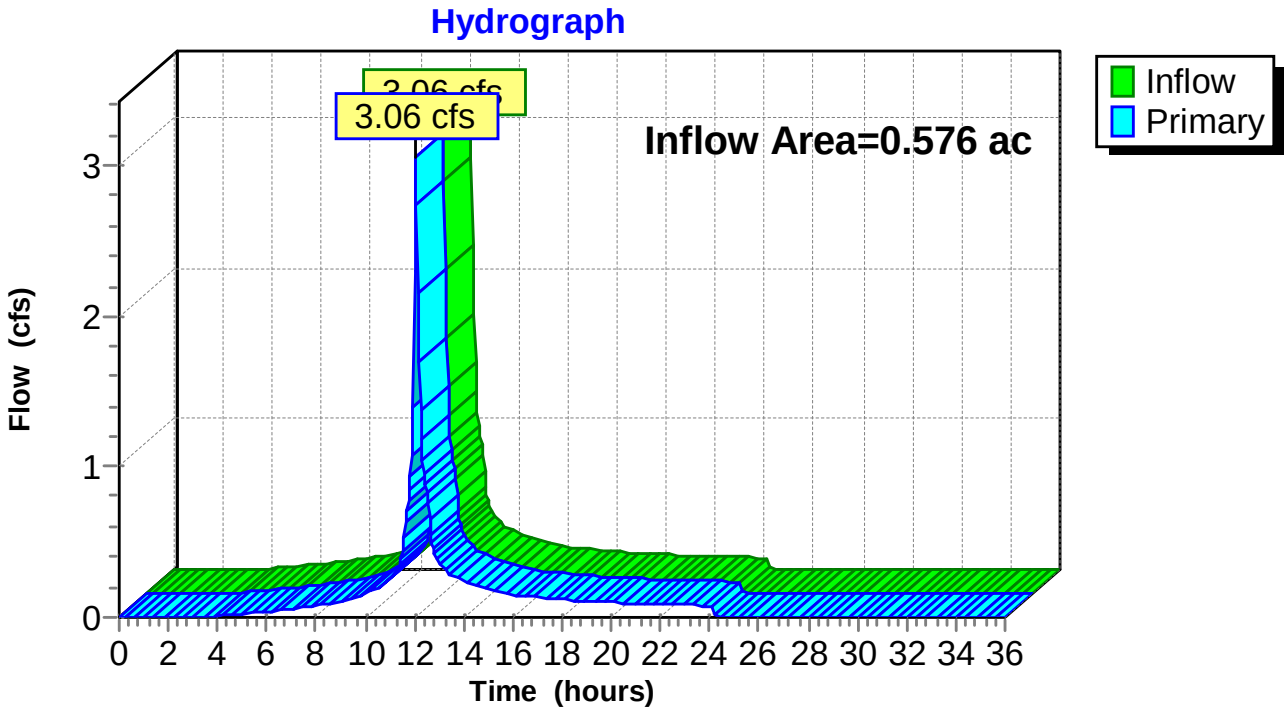


## Summary for Pond 10P: Northwestern Wetlands

Inflow Area = 0.576 ac, 69.97% Impervious, Inflow Depth = 6.48" for 100-yr event
Inflow = 3.06 cfs @ 12.06 hrs, Volume= 0.311 af
Primary = 3.06 cfs @ 12.06 hrs, Volume= 0.311 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs

### Pond 10P: Northwestern Wetlands



## Summary for Pond 11P: Exst DMH (Rim = 117.60)

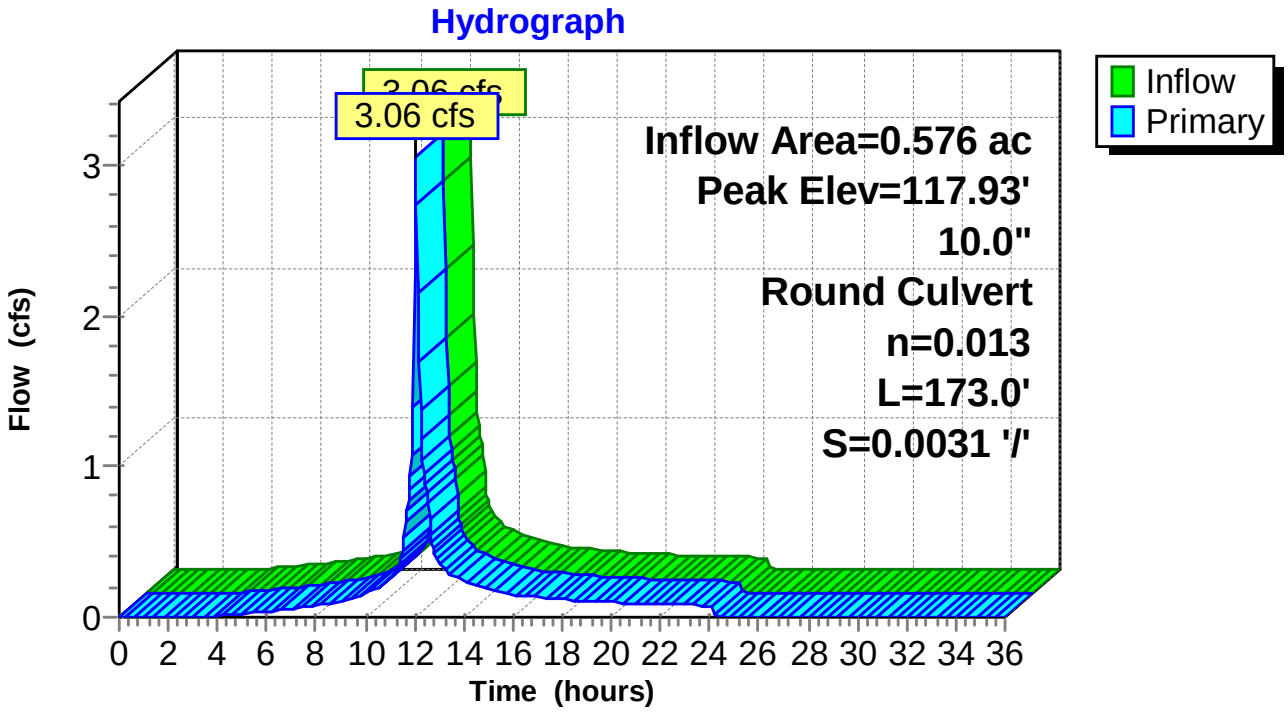
Inflow Area = 0.576 ac, 69.97% Impervious, Inflow Depth = 6.48" for 100-yr event
Inflow = 3.06 cfs @ 12.06 hrs, Volume= 0.311 af
Outflow = 3.06 cfs @ 12.06 hrs, Volume= 0.311 af, Atten= 0%, Lag= 0.0 min
Primary = 3.06 cfs @ 12.06 hrs, Volume= 0.311 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 117.93' @ 12.06 hrs
Flood Elev= 117.60'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 113.55' | **10.0" Round Culvert**<br>L= 173.0' RCP, square edge headwall, Ke= 0.500<br>Inlet / Outlet Invert= 113.55' / 113.01' S= 0.0031 '/' Cc= 0.900<br>n= 0.013, Flow Area= 0.55 sf |

**Primary OutFlow** Max=2.97 cfs @ 12.06 hrs HW=117.72' (Free Discharge)
**1=Culvert** (Barrel Controls 2.97 cfs @ 5.45 fps)

### Pond 11P: Exst DMH (Rim = 117.60)



## Summary for Pond 12P: Exist DMH (Rim = 116.31)

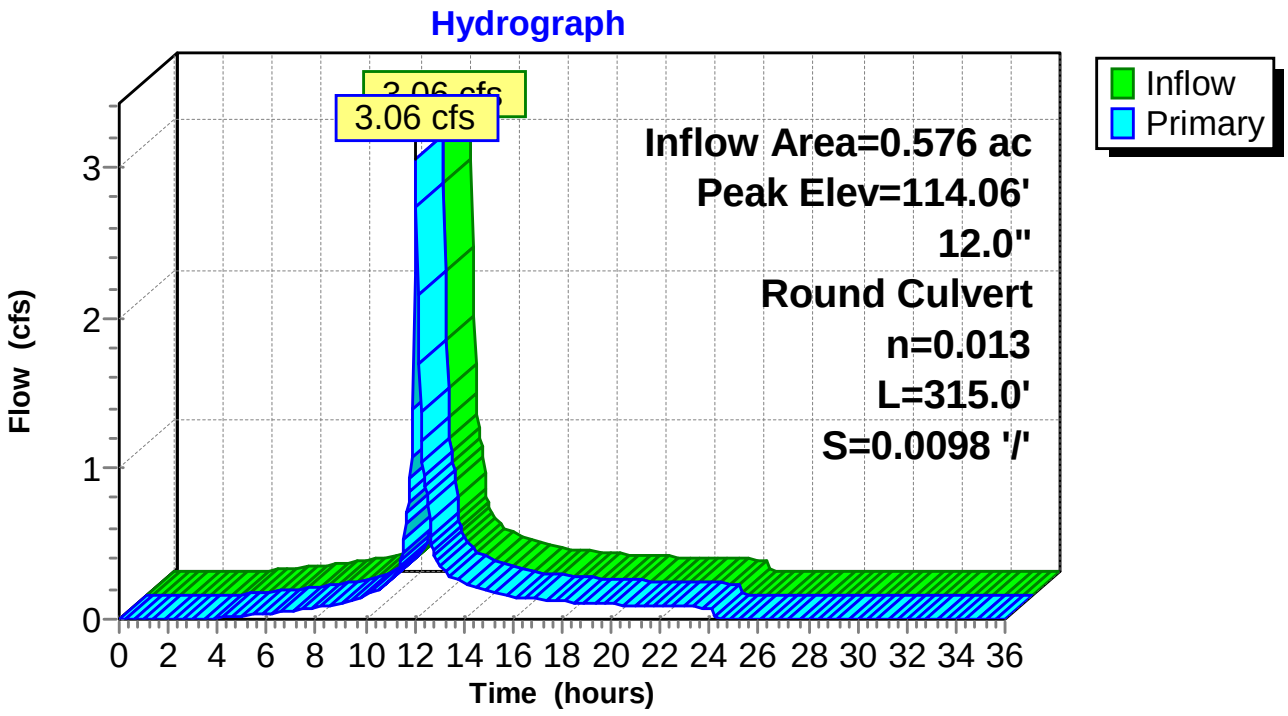
Inflow Area = 0.576 ac, 69.97% Impervious, Inflow Depth = 6.48" for 100-yr event
Inflow = 3.06 cfs @ 12.06 hrs, Volume= 0.311 af
Outflow = 3.06 cfs @ 12.06 hrs, Volume= 0.311 af, Atten= 0%, Lag= 0.0 min
Primary = 3.06 cfs @ 12.06 hrs, Volume= 0.311 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 114.06' @ 12.06 hrs
Flood Elev= 116.31'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 112.91' | **12.0" Round Culvert**<br>L= 315.0' RCP, square edge headwall, Ke= 0.500<br>Inlet / Outlet Invert= 112.91' / 109.82' S= 0.0098 '/' Cc= 0.900<br>n= 0.013, Flow Area= 0.79 sf |

**Primary OutFlow** Max=2.97 cfs @ 12.06 hrs HW=114.03' (Free Discharge)
**1=Culvert** (Inlet Controls 2.97 cfs @ 3.78 fps)

## Pond 12P: Exist DMH (Rim = 116.31)



## Summary for Pond 14P: DMH (Rim=126.82)

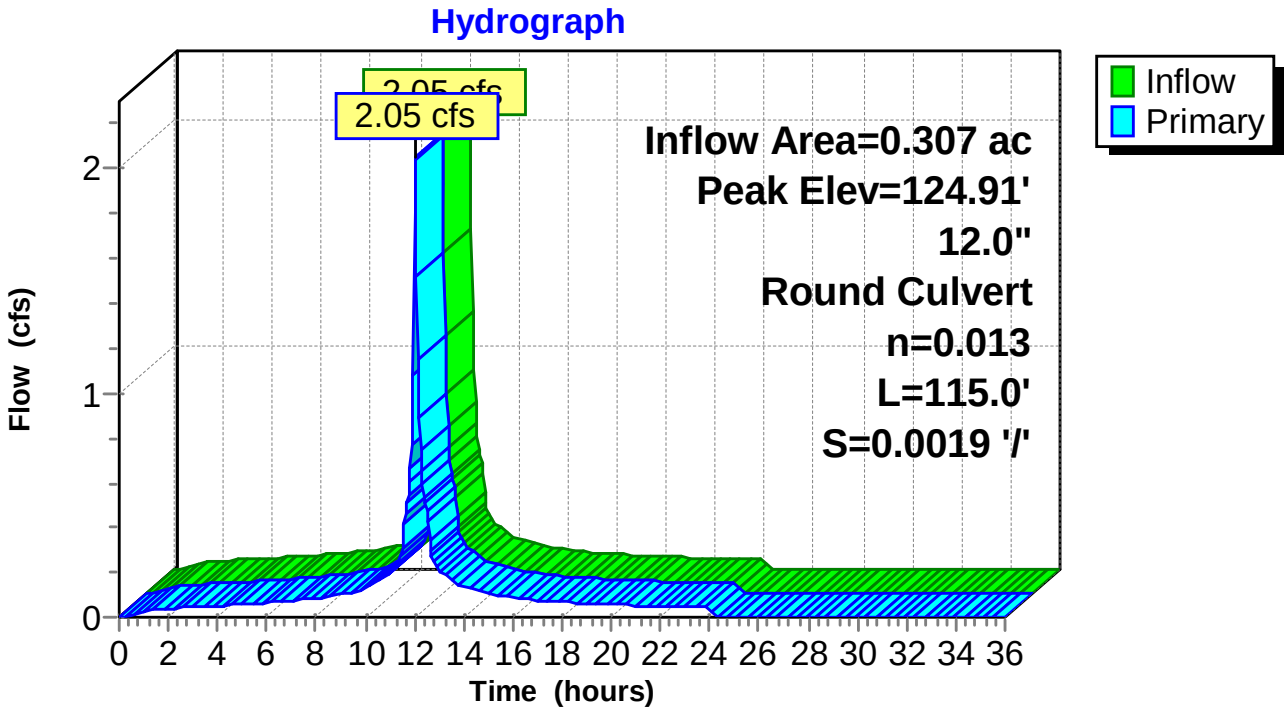
Inflow Area = 0.307 ac,100.00% Impervious, Inflow Depth = 8.67" for 100-yr event
Inflow = 2.05 cfs @ 12.04 hrs, Volume= 0.222 af
Outflow = 2.05 cfs @ 12.04 hrs, Volume= 0.222 af, Atten= 0%, Lag= 0.0 min
Primary = 2.05 cfs @ 12.04 hrs, Volume= 0.222 af

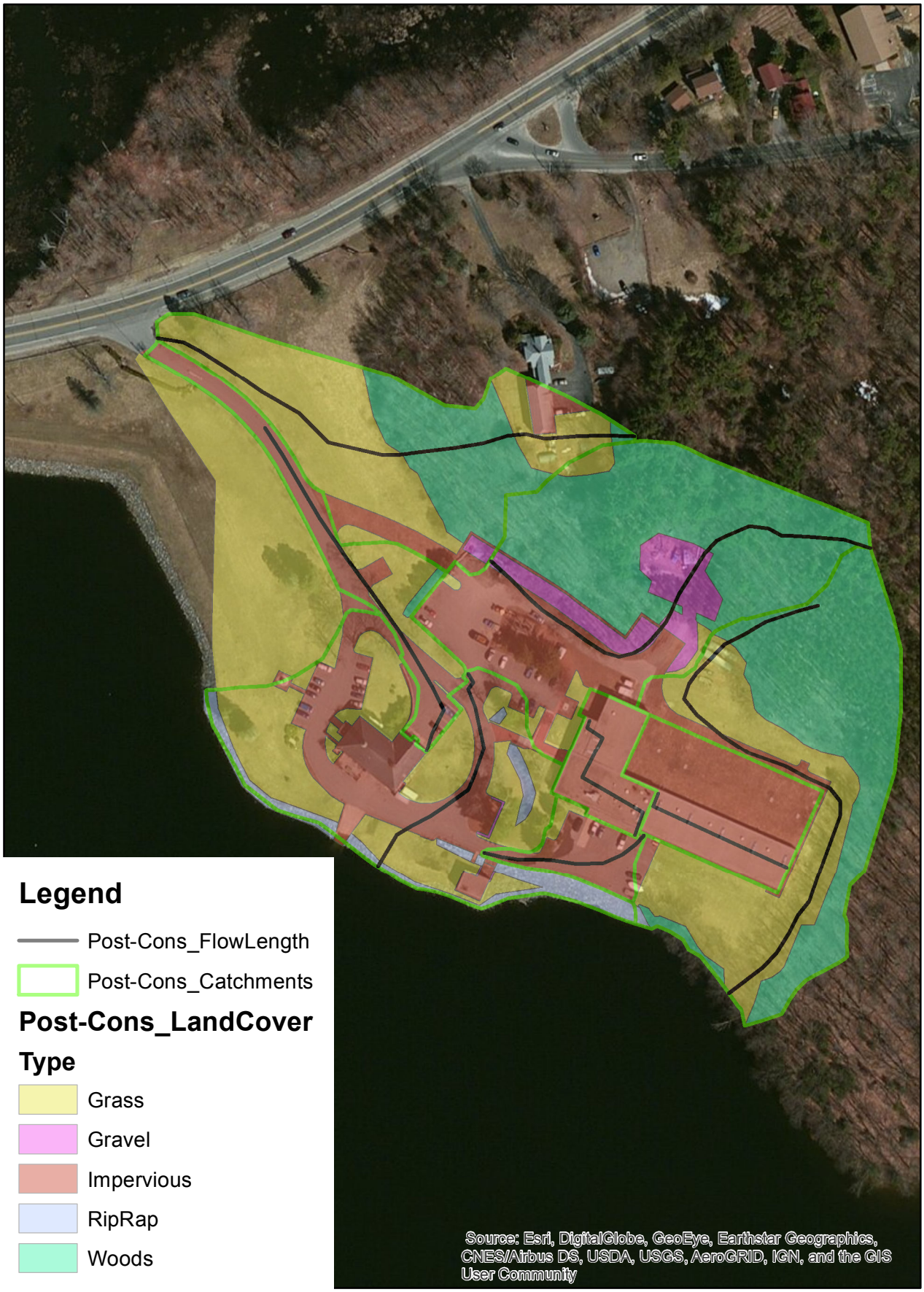
Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 124.91' @ 12.04 hrs
Flood Elev= 126.82'

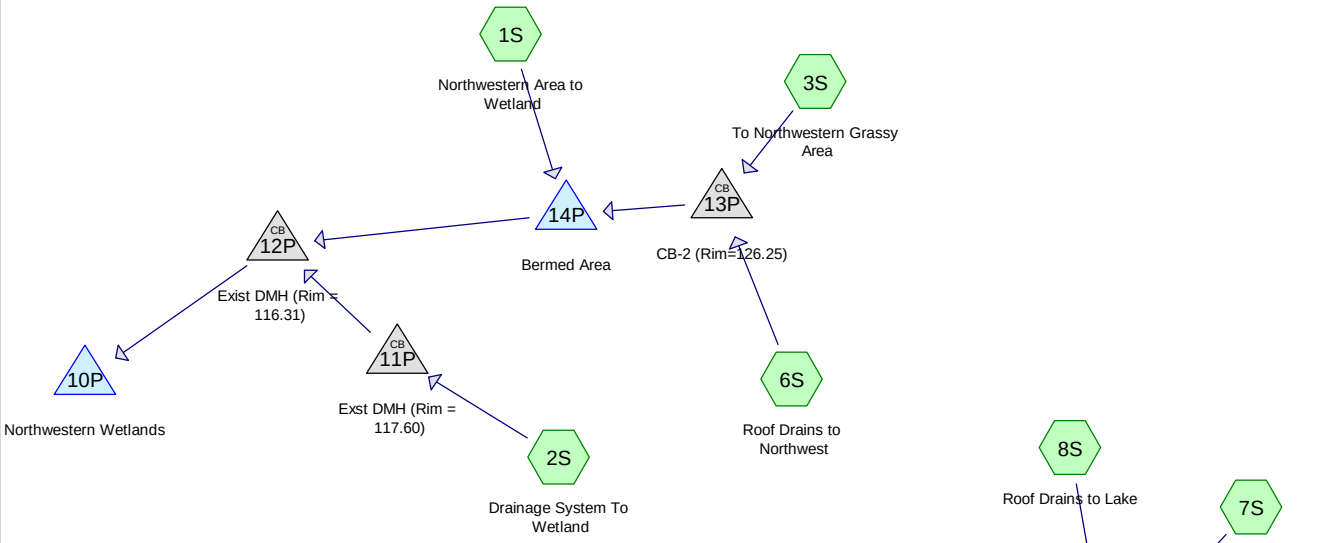
| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 123.72' | **12.0" Round Culvert**<br>L= 115.0' RCP, square edge headwall, Ke= 0.500<br>Inlet / Outlet Invert= 123.72' / 123.50' S= 0.0019 '/' Cc= 0.900<br>n= 0.013, Flow Area= 0.79 sf |

**Primary OutFlow** Max=2.00 cfs @ 12.04 hrs HW=124.88' (Free Discharge)
**1=Culvert** (Barrel Controls 2.00 cfs @ 2.76 fps)

### Pond 14P: DMH (Rim=126.82)




Legend
Post-Cons_FlowLength
Post-Cons_Catchments
Post-Cons_LandCover
Type
Grass
Gravel
Impervious
RipRap
Woods
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community




Subcat Reach Pond Link

**Routing Diagram for 13109_WTP-Upgrade_Post-ConstructionModel**
Prepared by wright-pierce, Printed 11/11/2016

## Area Listing (all nodes)

| Area (acres) | CN | Description (subcatchment-numbers) |
|---|---|---|
| 2.423 | 39 | >75% Grass cover, Good, HSG A (1S, 2S, 3S, 4S) |
| 1.208 | 74 | >75% Grass cover, Good, HSG C (3S, 4S, 7S) |
| 0.106 | 76 | Gravel roads, HSG A (1S, 3S, 4S) |
| 0.279 | 89 | Gravel roads, HSG C (3S) |
| 3.763 | 98 | Paved parking, HSG A (1S, 2S, 3S, 4S, 6S, 7S, 8S) |
| 0.274 | 96 | RipRap_Assumed (4S, 7S) |
| 1.109 | 30 | Woods, Good, HSG A (1S, 2S, 3S) |
| 2.385 | 70 | Woods, Good, HSG C (1S, 3S, 7S) |
| **11.547** | **70** | **TOTAL AREA** |

## Summary for Subcatchment 1S: Northwestern Area to Wetland

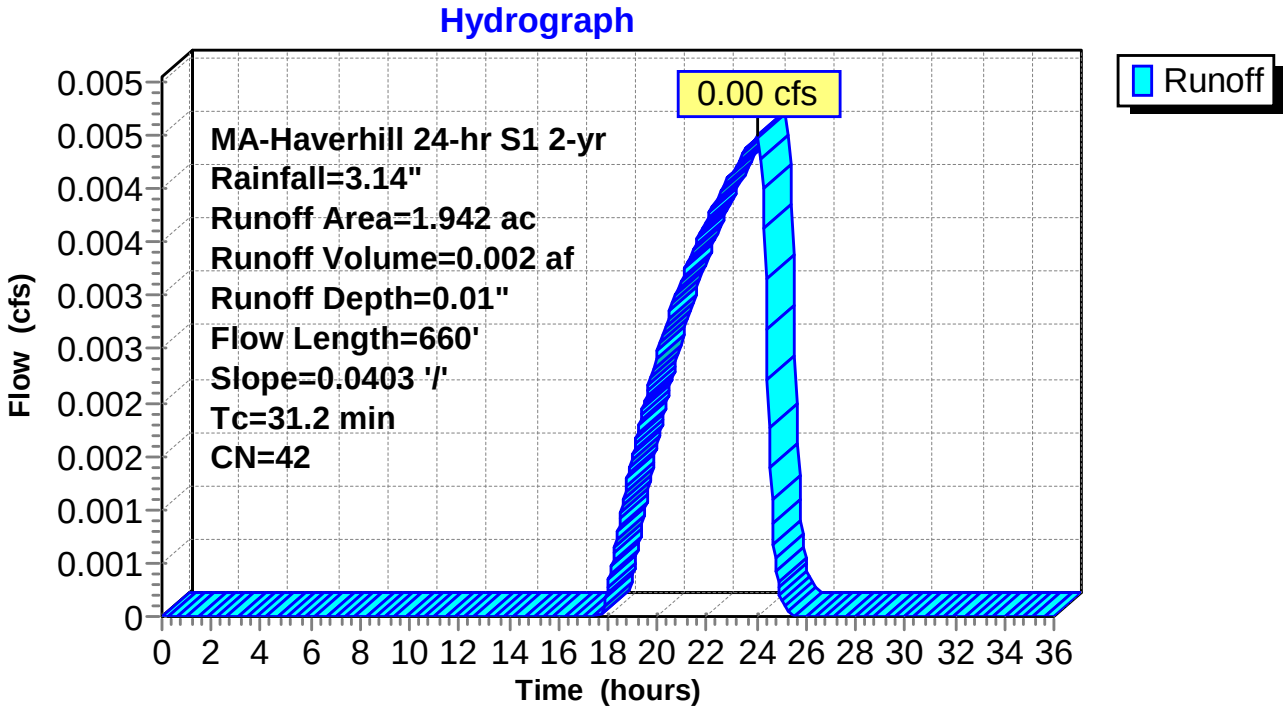
Runoff = 0.00 cfs @ 24.05 hrs, Volume= 0.002 af, Depth= 0.01"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 2-yr Rainfall=3.14"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 1.107 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.019 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.195 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.617 | 30 | Woods, Good, HSG A |
| | 0.004 | 70 | Woods, Good, HSG C |
| | 1.942 | 42 | Weighted Average |
| | 1.747 | | 89.96% Pervious Area |
| | 0.195 | | 10.04% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 31.2 | 660 | 0.0403 | 0.35 | | **Lag/CN Method,** |

### Subcatchment 1S: Northwestern Area to Wetland



## Summary for Subcatchment 2S: Drainage System To Wetland

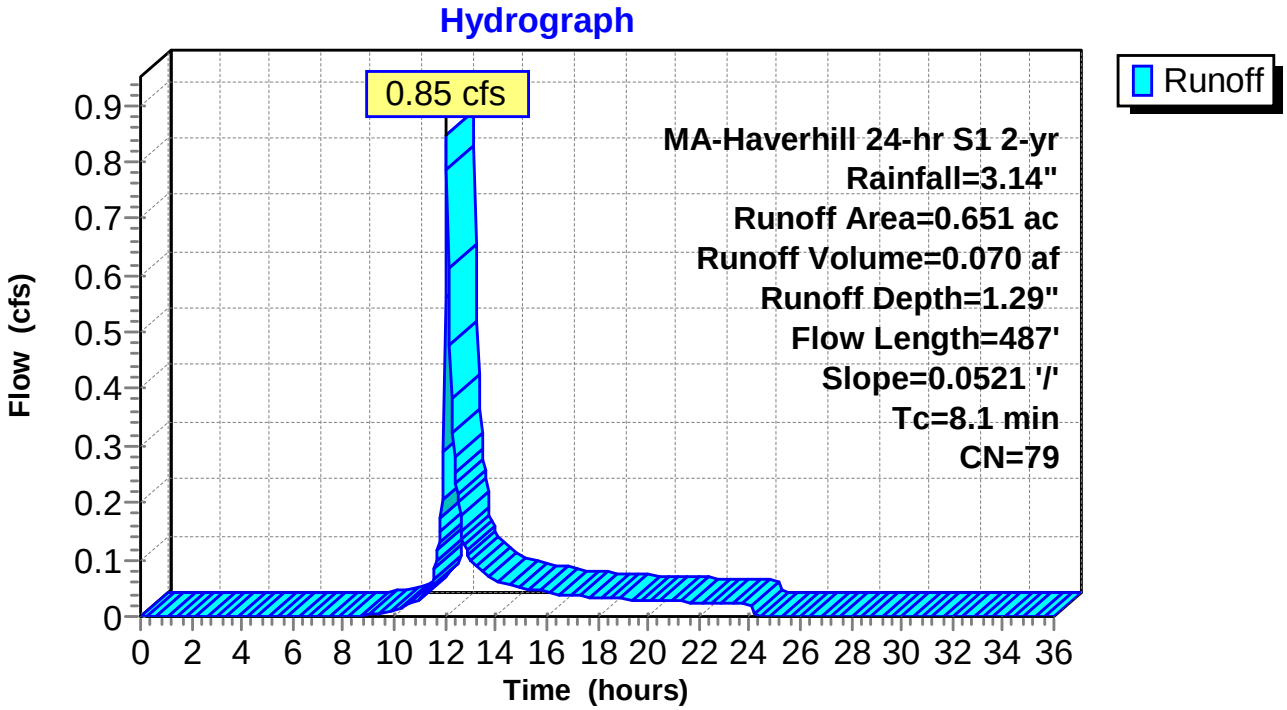
Runoff = 0.85 cfs @ 12.07 hrs, Volume= 0.070 af, Depth= 1.29"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 2-yr Rainfall=3.14"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.192 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.439 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.020 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.651 | 79 | Weighted Average |
| | 0.212 | | 32.57% Pervious Area |
| | 0.439 | | 67.43% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 8.1 | 487 | 0.0521 | 1.01 | | **Lag/CN Method,** |

### Subcatchment 2S: Drainage System To Wetland



## Summary for Subcatchment 3S: To Northwestern Grassy Area

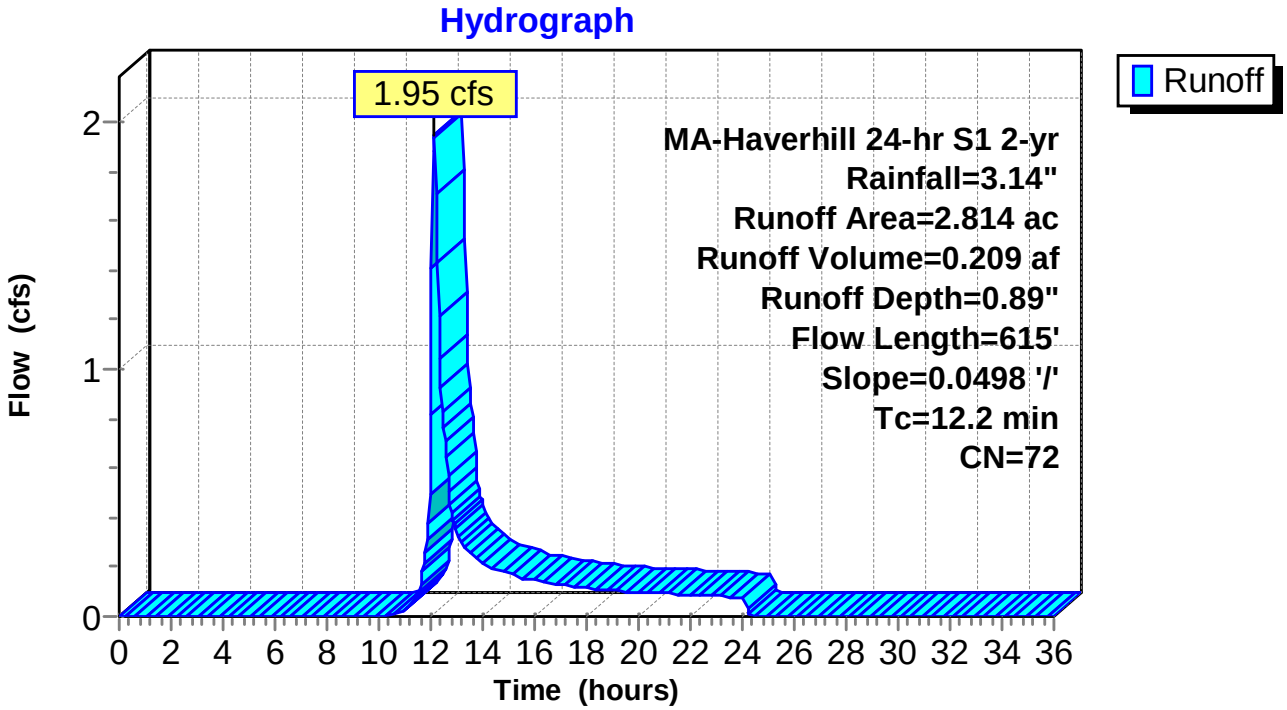
Runoff = 1.95 cfs @ 12.13 hrs, Volume= 0.209 af, Depth= 0.89"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 2-yr Rainfall=3.14"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.058 | 39 | >75% Grass cover, Good, HSG A |
| | 0.076 | 74 | >75% Grass cover, Good, HSG C |
| | 0.080 | 76 | Gravel roads, HSG A |
| | 0.279 | 89 | Gravel roads, HSG C |
| | 0.768 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.472 | 30 | Woods, Good, HSG A |
| | 1.081 | 70 | Woods, Good, HSG C |
| | 2.814 | 72 | Weighted Average |
| | 2.046 | | 72.71% Pervious Area |
| | 0.768 | | 27.29% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 12.2 | 615 | 0.0498 | 0.84 | | **Lag/CN Method,** |

## Subcatchment 3S: To Northwestern Grassy Area



## Summary for Subcatchment 4S: Direct Discharge to Lake

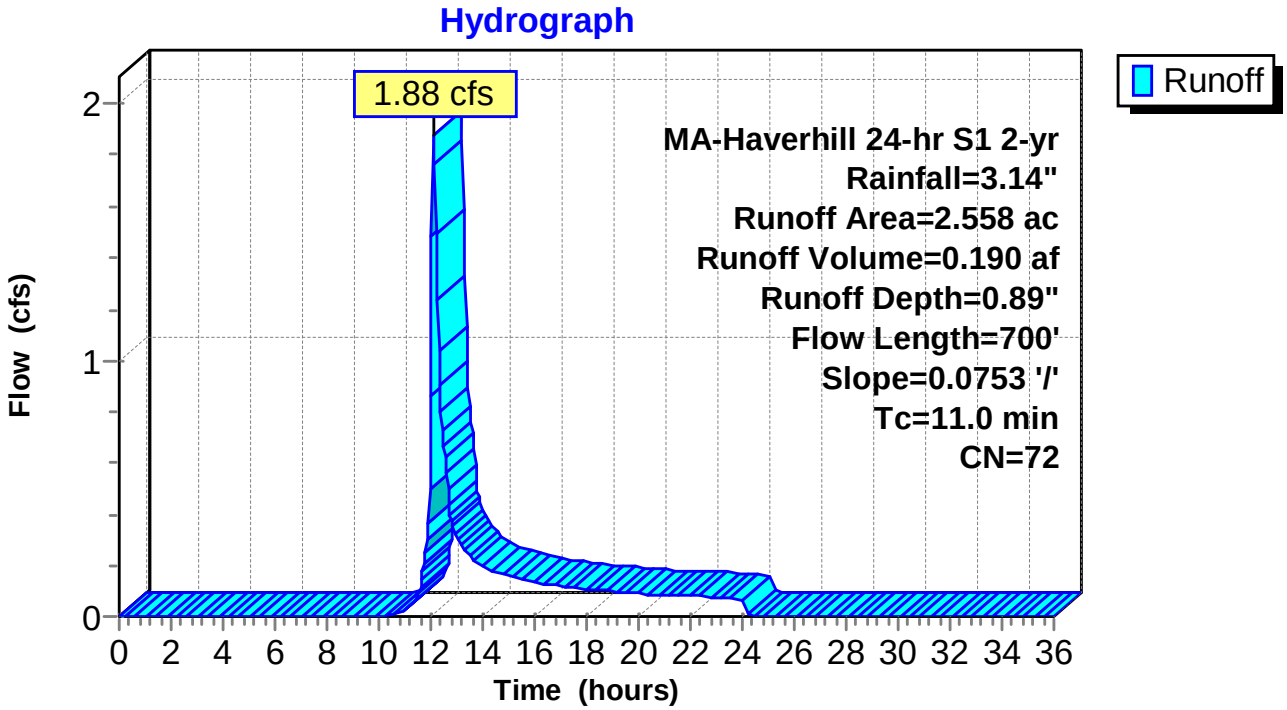
Runoff = 1.88 cfs @ 12.12 hrs, Volume= 0.190 af, Depth= 0.89"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 2-yr Rainfall=3.14"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 1.066 | 39 | >75% Grass cover, Good, HSG A |
| | 0.085 | 74 | >75% Grass cover, Good, HSG C |
| | 0.007 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 1.133 | 98 | Paved parking, HSG A |
| * | 0.267 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 2.558 | 72 | Weighted Average |
| | 1.425 | | 55.71% Pervious Area |
| | 1.133 | | 44.29% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 11.0 | 700 | 0.0753 | 1.06 | | **Lag/CN Method,** |

### Subcatchment 4S: Direct Discharge to Lake



## Summary for Subcatchment 6S: Roof Drains to Northwest

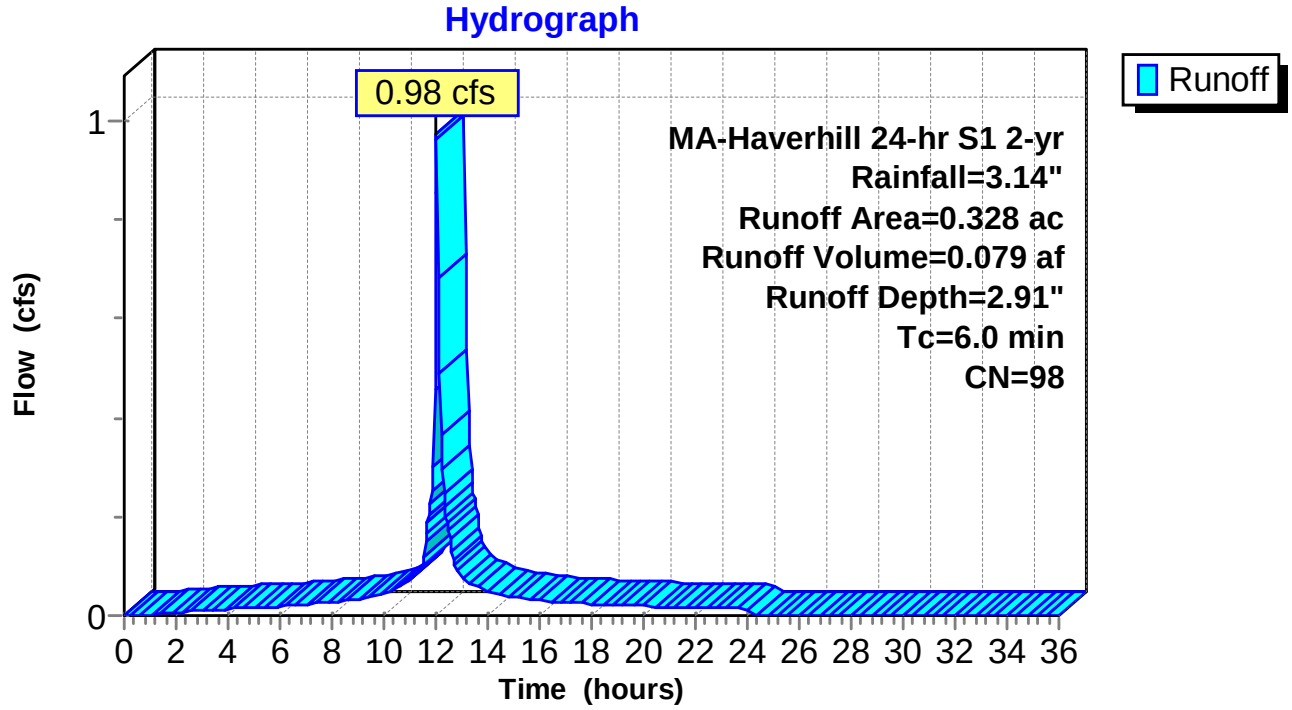
Runoff = 0.98 cfs @ 12.04 hrs, Volume= 0.079 af, Depth= 2.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 2-yr Rainfall=3.14"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.000 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.328 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.328 | 98 | Weighted Average |
| | 0.328 | | 100.00% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.0 | | | | | **Direct Entry, Minimum (Roof)** |

## Subcatchment 6S: Roof Drains to Northwest



## Summary for Subcatchment 7S: Southeast Swale to Lake

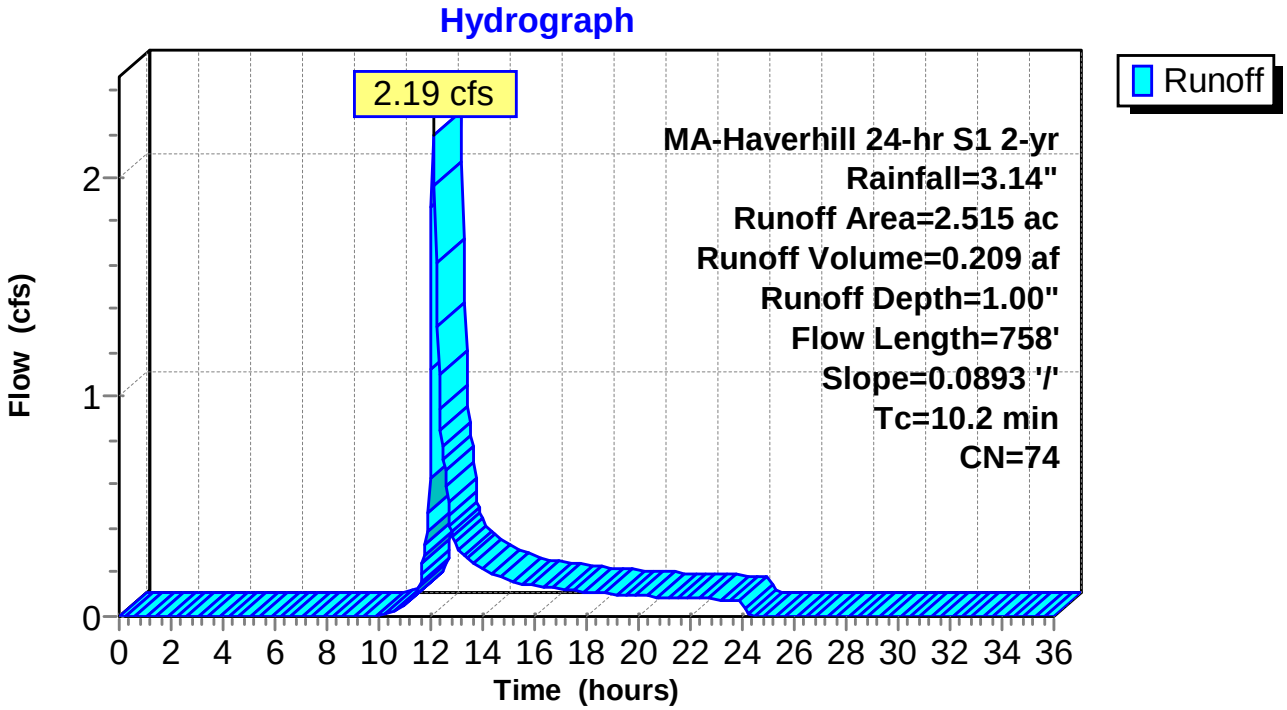
Runoff = 2.19 cfs @ 12.10 hrs, Volume= 0.209 af, Depth= 1.00"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 2-yr Rainfall=3.14"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.000 | 39 | >75% Grass cover, Good, HSG A |
| | 1.047 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.161 | 98 | Paved parking, HSG A |
| * | 0.007 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 1.300 | 70 | Woods, Good, HSG C |
| | 2.515 | 74 | Weighted Average |
| | 2.354 | | 93.60% Pervious Area |
| | 0.161 | | 6.40% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 10.2 | 758 | 0.0893 | 1.24 | | **Lag/CN Method,** |

### Subcatchment 7S: Southeast Swale to Lake



## Summary for Subcatchment 8S: Roof Drains to Lake

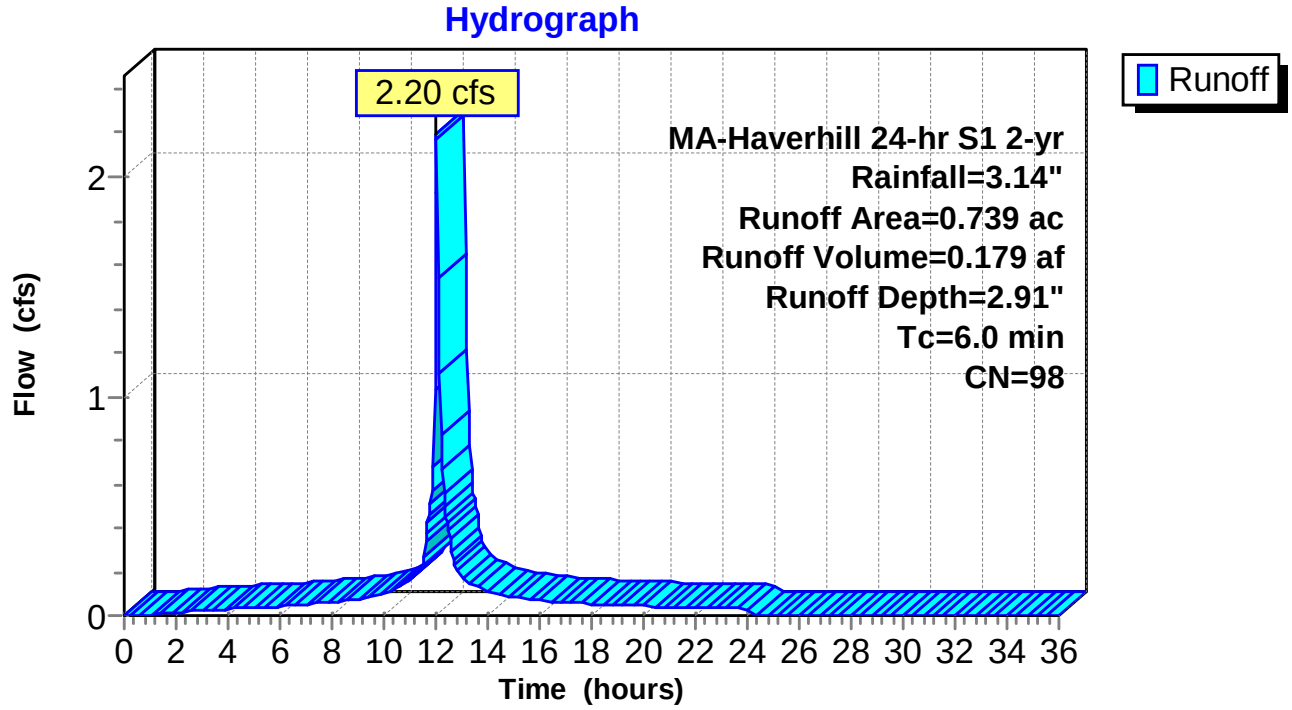
Runoff = 2.20 cfs @ 12.04 hrs, Volume= 0.179 af, Depth= 2.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 2-yr Rainfall=3.14"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.000 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.739 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.739 | 98 | Weighted Average |
| | 0.739 | | 100.00% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.0 | | | | | **Direct Entry, Minimum (Roof)** |

## Subcatchment 8S: Roof Drains to Lake

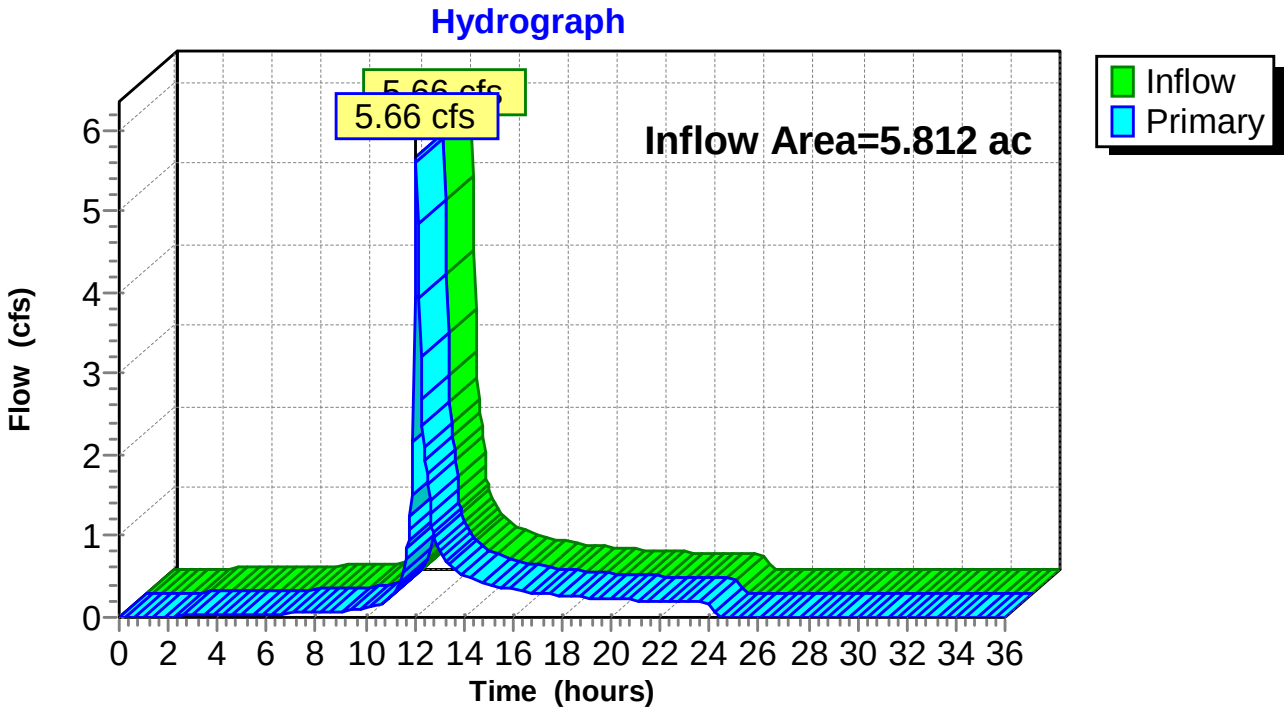


## Summary for Pond 9P: Kenoza Lake

Inflow Area = 5.812 ac, 34.98% Impervious, Inflow Depth = 1.19" for 2-yr event
Inflow = 5.66 cfs @ 12.08 hrs, Volume= 0.579 af
Primary = 5.66 cfs @ 12.08 hrs, Volume= 0.579 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs

### Pond 9P: Kenoza Lake

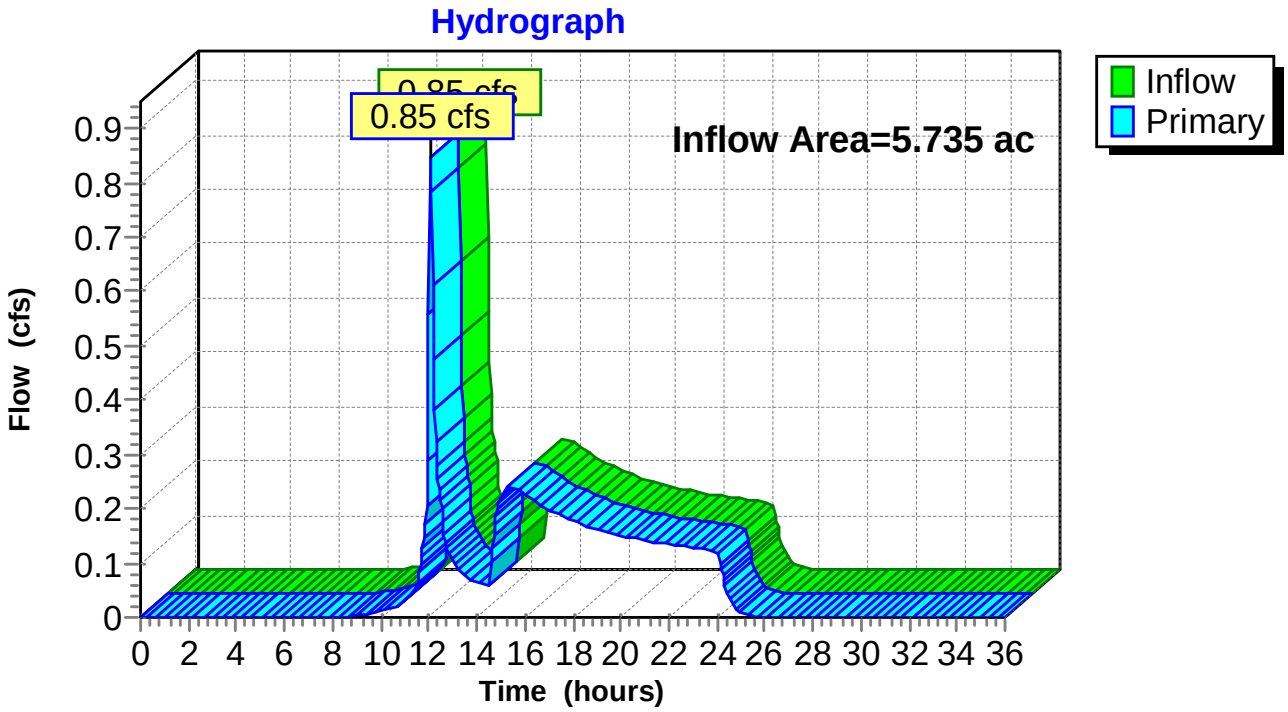


## Summary for Pond 10P: Northwestern Wetlands

Inflow Area = 5.735 ac, 30.17% Impervious, Inflow Depth = 0.37" for 2-yr event
Inflow = 0.85 cfs @ 12.07 hrs, Volume= 0.179 af
Primary = 0.85 cfs @ 12.07 hrs, Volume= 0.179 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs

### Pond 10P: Northwestern Wetlands



## Summary for Pond 11P: Exst DMH (Rim = 117.60)

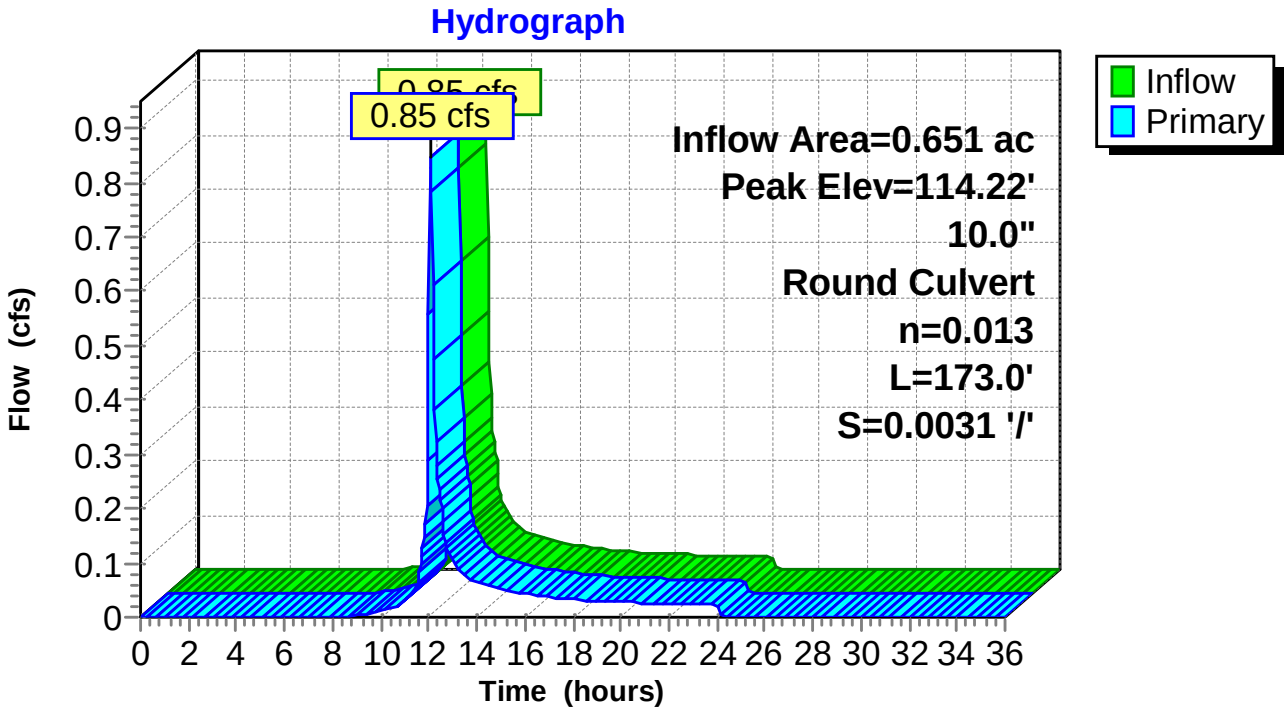
Inflow Area = 0.651 ac, 67.43% Impervious, Inflow Depth = 1.29" for 2-yr event
Inflow = 0.85 cfs @ 12.07 hrs, Volume= 0.070 af
Outflow = 0.85 cfs @ 12.07 hrs, Volume= 0.070 af, Atten= 0%, Lag= 0.0 min
Primary = 0.85 cfs @ 12.07 hrs, Volume= 0.070 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 114.22' @ 12.07 hrs
Flood Elev= 117.60'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 113.55' | **10.0" Round Culvert**<br>L= 173.0' RCP, square edge headwall, Ke= 0.500<br>Inlet / Outlet Invert= 113.55' / 113.01' S= 0.0031 '/' Cc= 0.900<br>n= 0.013, Flow Area= 0.55 sf |

**Primary OutFlow** Max=0.81 cfs @ 12.07 hrs HW=114.20' (Free Discharge)
**1=Culvert** (Barrel Controls 0.81 cfs @ 2.44 fps)

### Pond 11P: Exst DMH (Rim = 117.60)



## Summary for Pond 12P: Exist DMH (Rim = 116.31)

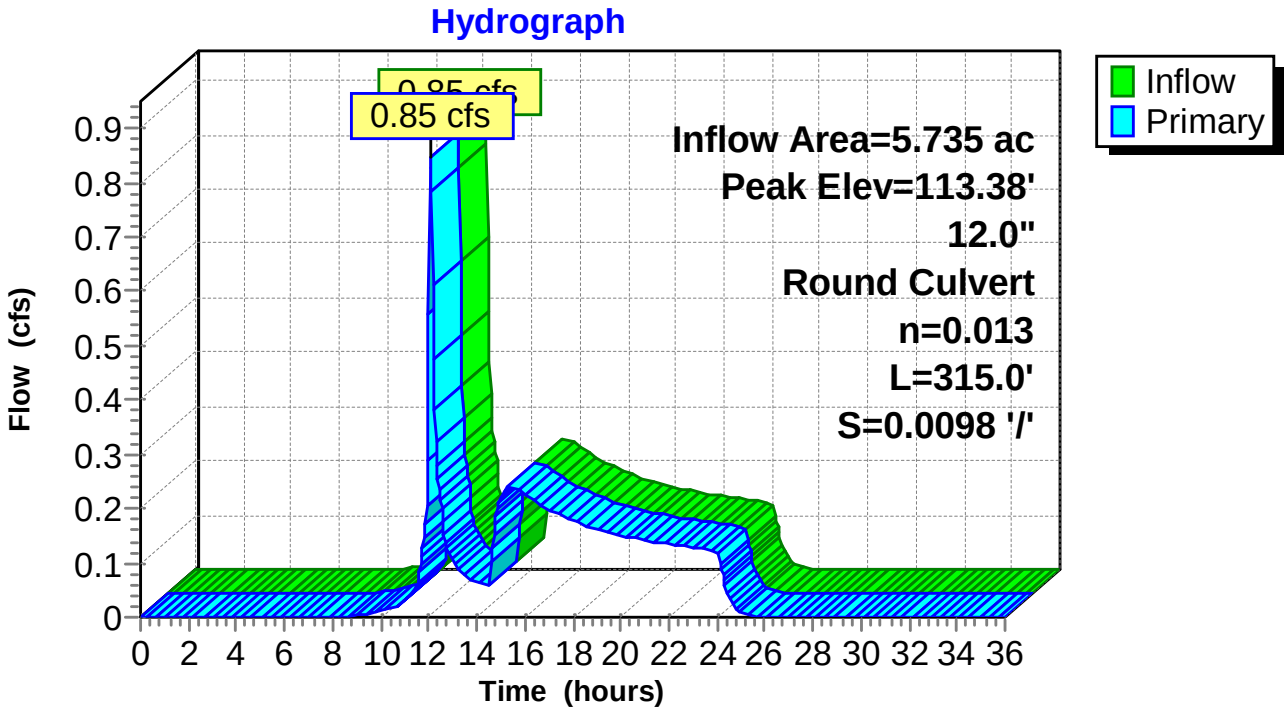
Inflow Area = 5.735 ac, 30.17% Impervious, Inflow Depth = 0.37" for 2-yr event
Inflow = 0.85 cfs @ 12.07 hrs, Volume= 0.179 af
Outflow = 0.85 cfs @ 12.07 hrs, Volume= 0.179 af, Atten= 0%, Lag= 0.0 min
Primary = 0.85 cfs @ 12.07 hrs, Volume= 0.179 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 113.38' @ 12.07 hrs
Flood Elev= 116.31'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 112.91' | **12.0" Round Culvert**<br>L= 315.0' RCP, square edge headwall, Ke= 0.500<br>Inlet / Outlet Invert= 112.91' / 109.82' S= 0.0098 '/' Cc= 0.900<br>n= 0.013, Flow Area= 0.79 sf |

**Primary OutFlow** Max=0.81 cfs @ 12.07 hrs HW=113.37' (Free Discharge)
**1=Culvert** (Inlet Controls 0.81 cfs @ 2.31 fps)

### Pond 12P: Exist DMH (Rim = 116.31)



## Summary for Pond 13P: CB-2 (Rim=126.25)

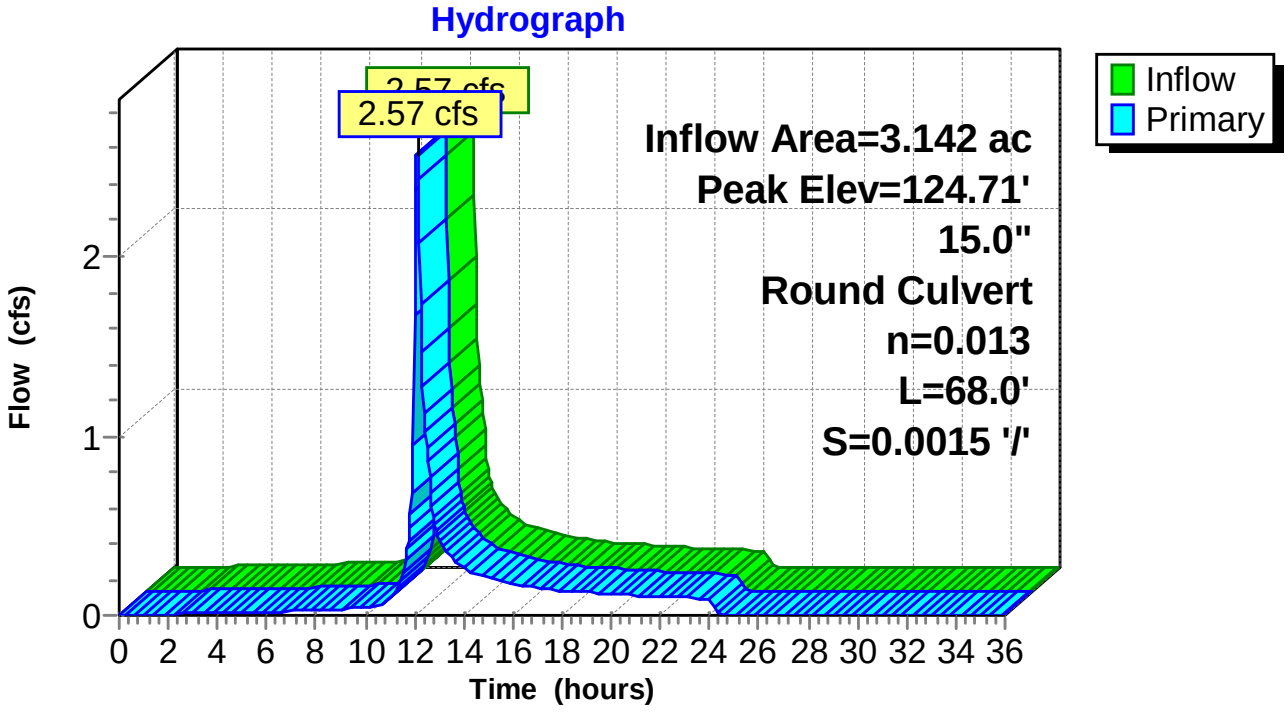
Inflow Area = 3.142 ac, 34.88% Impervious, Inflow Depth = 1.10" for 2-yr event
Inflow = 2.57 cfs @ 12.10 hrs, Volume= 0.289 af
Outflow = 2.57 cfs @ 12.10 hrs, Volume= 0.289 af, Atten= 0%, Lag= 0.0 min
Primary = 2.57 cfs @ 12.10 hrs, Volume= 0.289 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 124.71' @ 12.10 hrs
Flood Elev= 126.25'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 123.60' | **15.0" Round Culvert** L= 68.0' CPP, square edge headwall, Ke= 0.500<br>Inlet / Outlet Invert= 123.60' / 123.50' S= 0.0015 '/' Cc= 0.900<br>n= 0.013, Flow Area= 1.23 sf |

**Primary OutFlow** Max=2.56 cfs @ 12.10 hrs HW=124.71' (Free Discharge)
**1=Culvert** (Barrel Controls 2.56 cfs @ 2.95 fps)

### Pond 13P: CB-2 (Rim=126.25)



## Summary for Pond 14P: Bermed Area

Inflow Area = 5.084 ac, 25.39% Impervious, Inflow Depth = 0.69" for 2-yr event
Inflow = 2.57 cfs @ 12.10 hrs, Volume= 0.290 af
Outflow = 0.19 cfs @ 15.44 hrs, Volume= 0.109 af, Atten= 92%, Lag= 200.1 min
Primary = 0.19 cfs @ 15.44 hrs, Volume= 0.109 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 120.02' @ 15.44 hrs Surf.Area= 8,500 sf Storage= 8,105 cf

Plug-Flow detention time= 461.3 min calculated for 0.109 af (38% of inflow)
Center-of-Mass det. time= 266.6 min ( 1,140.0 - 873.4 )

| Volume | Invert | Avail.Storage | Storage Description |
|---|---|---|---|
| #1 | 118.00' | 12,150 cf | **Custom Stage Data (Prismatic)** Listed below (Recalc) |

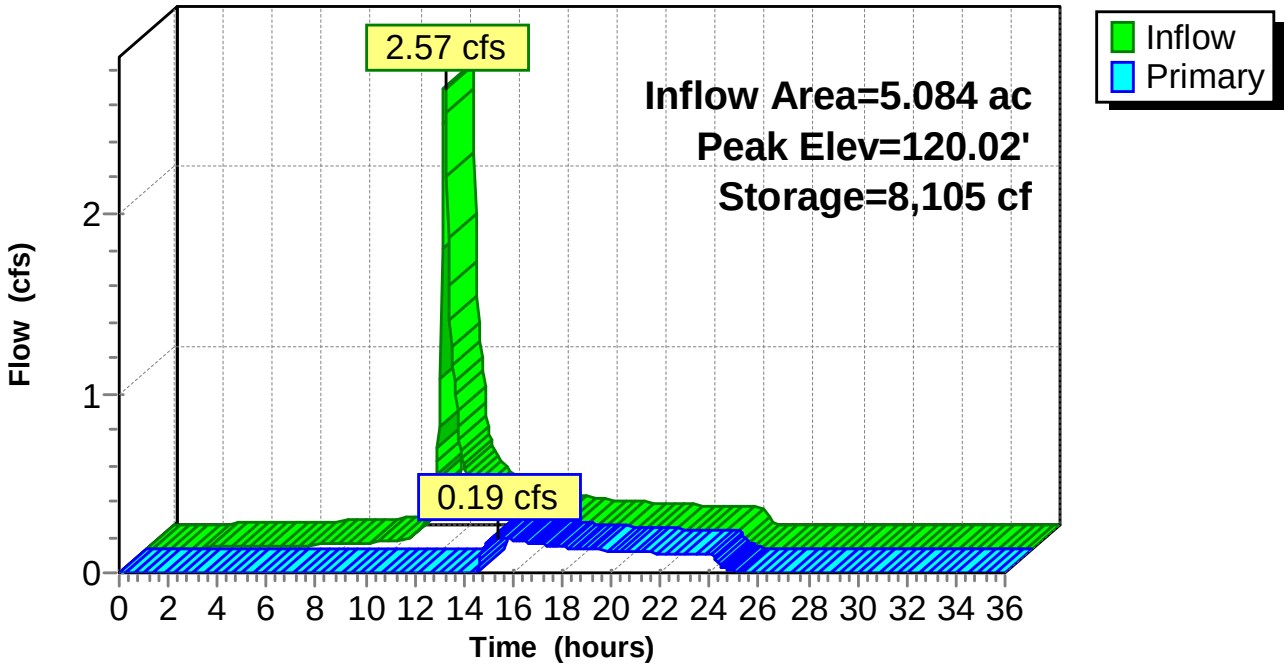
| Elevation (feet) | Surf.Area (sq-ft) | Inc.Store (cubic-feet) | Cum.Store (cubic-feet) |
|---|---|---|---|
| 118.00 | 1,000 | 0 | 0 |
| 119.00 | 3,100 | 2,050 | 2,050 |
| 119.50 | 5,900 | 2,250 | 4,300 |
| 120.00 | 8,500 | 3,600 | 7,900 |
| 120.50 | 8,500 | 4,250 | 12,150 |

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 120.00' | **20.0' long x 2.0' breadth Broad-Crested Rectangular Weir**<br>Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50<br>Coef. (English) 2.54 2.61 2.61 2.60 2.66 2.70 2.77 2.89 2.88 2.85 3.07 3.20 3.32 |

**Primary OutFlow** Max=0.19 cfs @ 15.44 hrs HW=120.02' (Free Discharge)
**1=Broad-Crested Rectangular Weir** (Weir Controls 0.19 cfs @ 0.39 fps)

## Pond 14P: Bermed Area

### Hydrograph



## Summary for Subcatchment 1S: Northwestern Area to Wetland

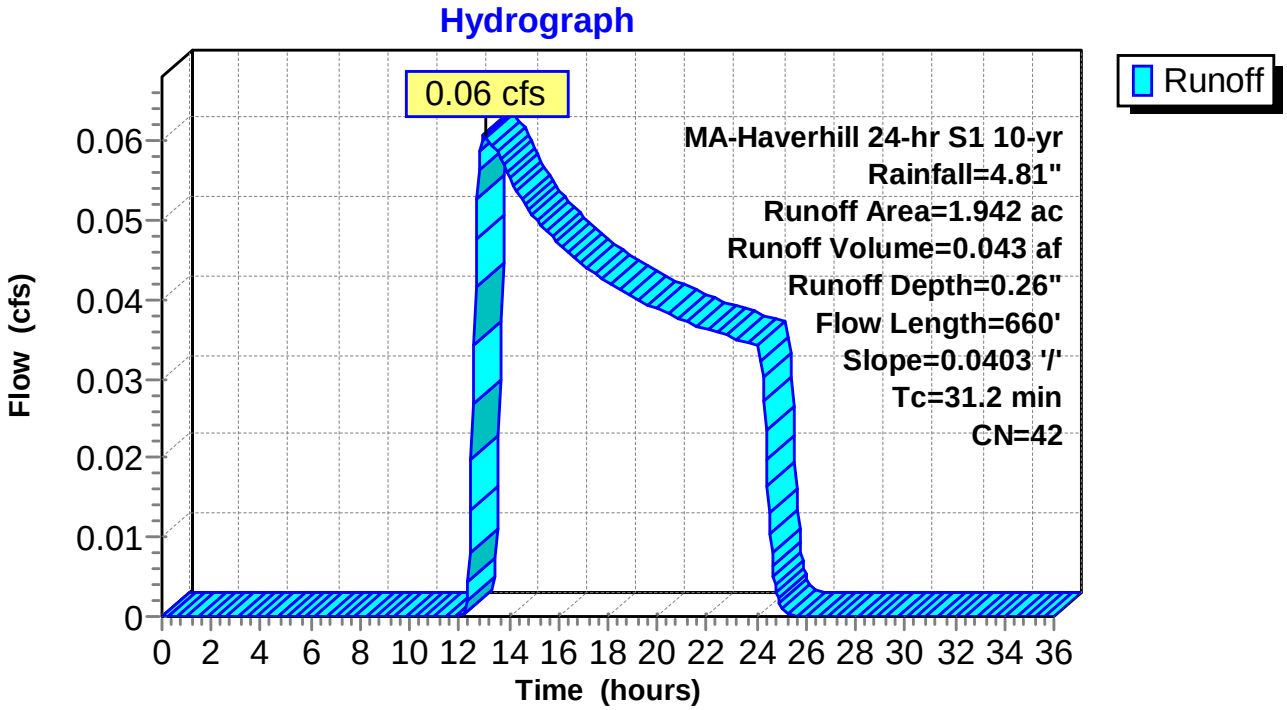
Runoff = 0.06 cfs @ 13.01 hrs, Volume= 0.043 af, Depth= 0.26"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 10-yr Rainfall=4.81"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 1.107 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.019 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.195 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.617 | 30 | Woods, Good, HSG A |
| | 0.004 | 70 | Woods, Good, HSG C |
| | 1.942 | 42 | Weighted Average |
| | 1.747 | | 89.96% Pervious Area |
| | 0.195 | | 10.04% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 31.2 | 660 | 0.0403 | 0.35 | | **Lag/CN Method,** |

### Subcatchment 1S: Northwestern Area to Wetland



## Summary for Subcatchment 2S: Drainage System To Wetland

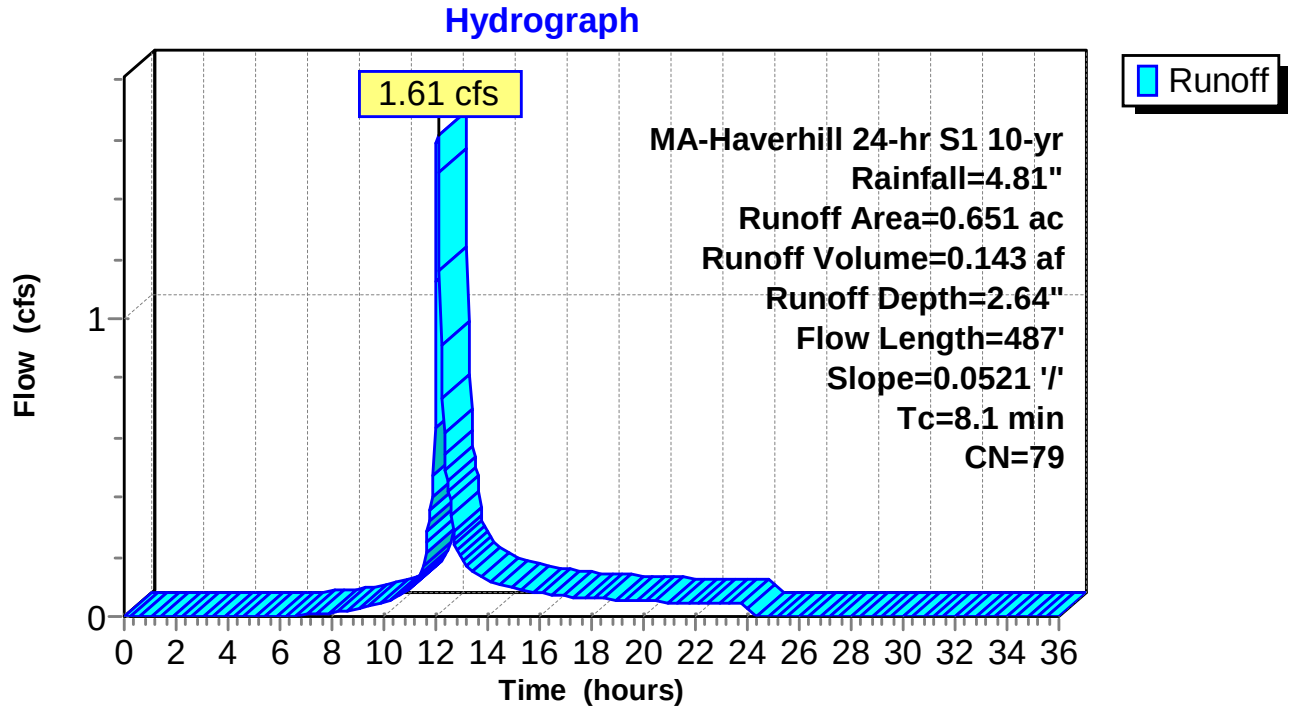
Runoff = 1.61 cfs @ 12.07 hrs, Volume= 0.143 af, Depth= 2.64"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 10-yr Rainfall=4.81"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.192 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.439 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.020 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.651 | 79 | Weighted Average |
| | 0.212 | | 32.57% Pervious Area |
| | 0.439 | | 67.43% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 8.1 | 487 | 0.0521 | 1.01 | | **Lag/CN Method,** |

### Subcatchment 2S: Drainage System To Wetland



## Summary for Subcatchment 3S: To Northwestern Grassy Area

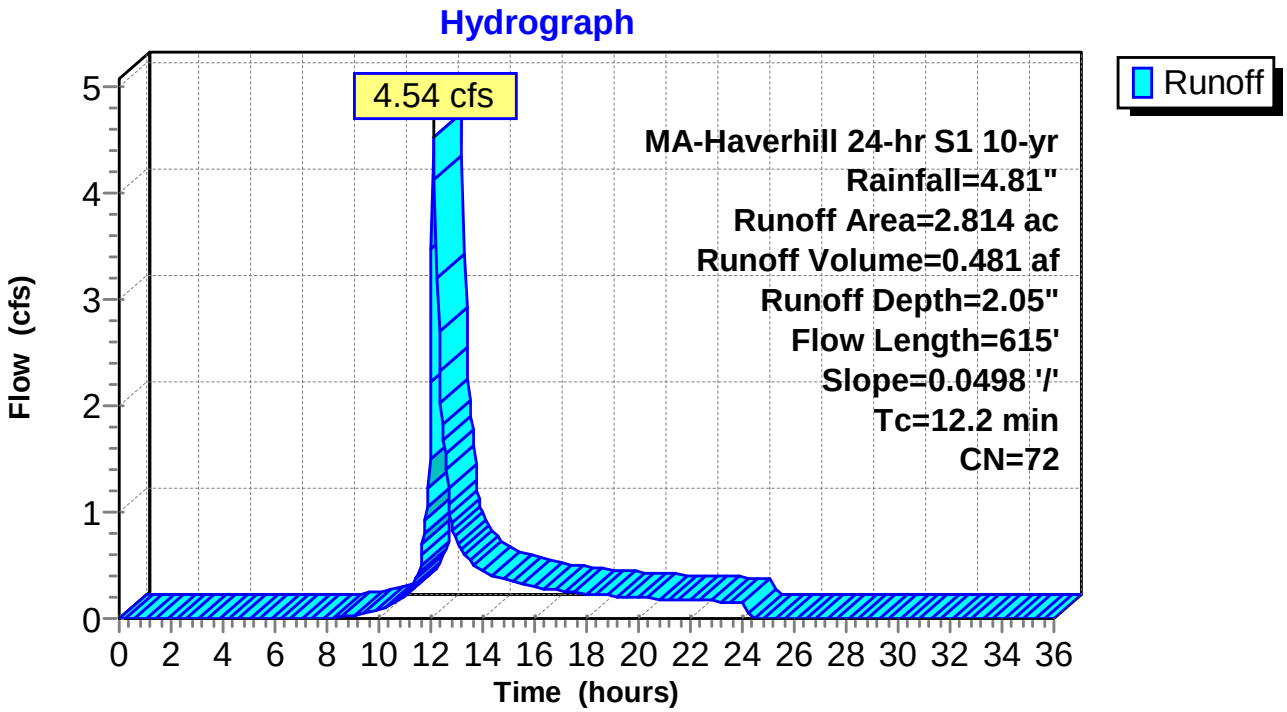
Runoff = 4.54 cfs @ 12.12 hrs, Volume= 0.481 af, Depth= 2.05"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 10-yr Rainfall=4.81"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.058 | 39 | >75% Grass cover, Good, HSG A |
| | 0.076 | 74 | >75% Grass cover, Good, HSG C |
| | 0.080 | 76 | Gravel roads, HSG A |
| | 0.279 | 89 | Gravel roads, HSG C |
| | 0.768 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.472 | 30 | Woods, Good, HSG A |
| | 1.081 | 70 | Woods, Good, HSG C |
| | 2.814 | 72 | Weighted Average |
| | 2.046 | | 72.71% Pervious Area |
| | 0.768 | | 27.29% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 12.2 | 615 | 0.0498 | 0.84 | | **Lag/CN Method,** |

### Subcatchment 3S: To Northwestern Grassy Area



## Summary for Subcatchment 4S: Direct Discharge to Lake

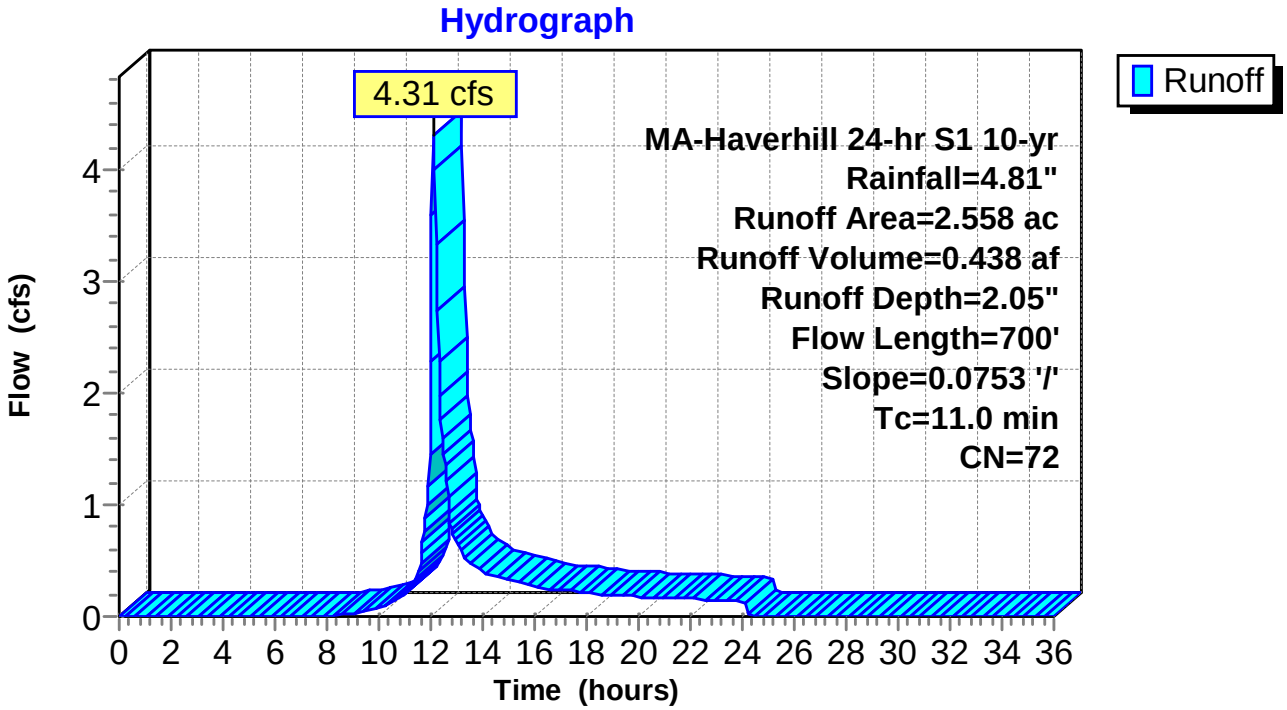
Runoff = 4.31 cfs @ 12.11 hrs, Volume= 0.438 af, Depth= 2.05"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 10-yr Rainfall=4.81"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 1.066 | 39 | >75% Grass cover, Good, HSG A |
| | 0.085 | 74 | >75% Grass cover, Good, HSG C |
| | 0.007 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 1.133 | 98 | Paved parking, HSG A |
| * | 0.267 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 2.558 | 72 | Weighted Average |
| | 1.425 | | 55.71% Pervious Area |
| | 1.133 | | 44.29% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 11.0 | 700 | 0.0753 | 1.06 | | **Lag/CN Method,** |

### Subcatchment 4S: Direct Discharge to Lake



## Summary for Subcatchment 6S: Roof Drains to Northwest

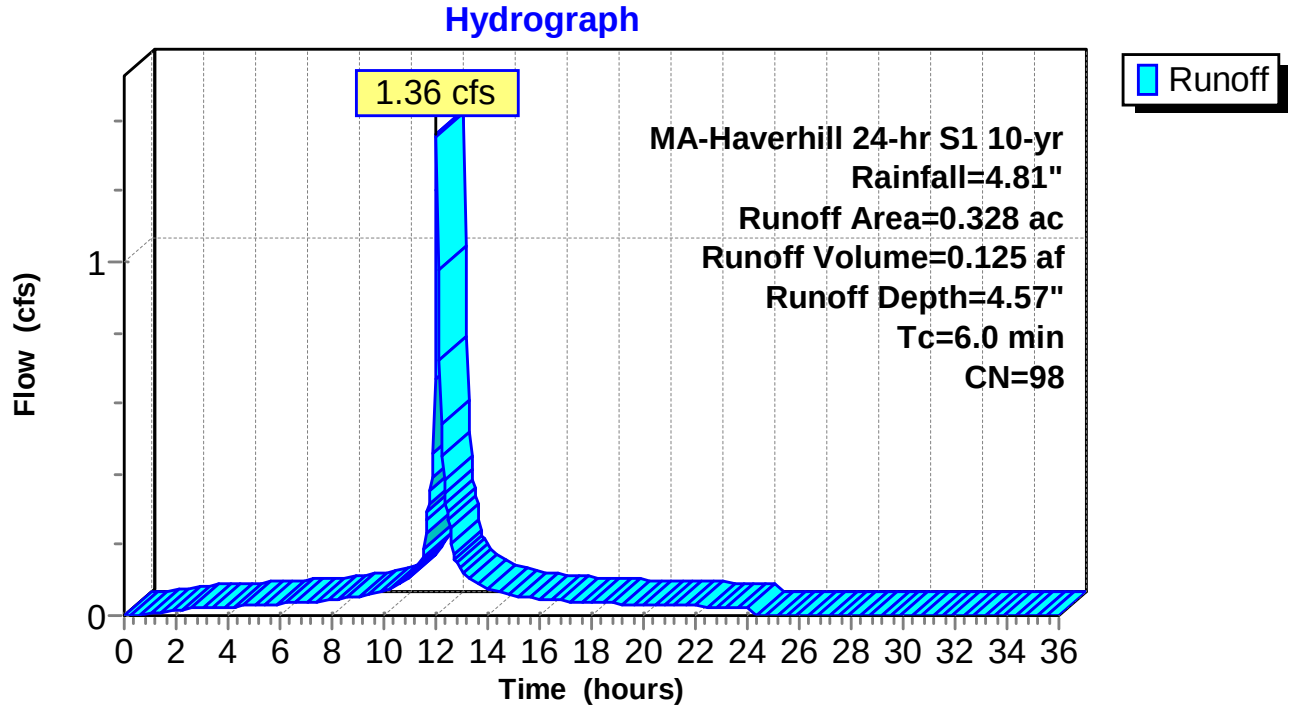
Runoff = 1.36 cfs @ 12.04 hrs, Volume= 0.125 af, Depth= 4.57"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 10-yr Rainfall=4.81"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.000 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.328 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.328 | 98 | Weighted Average |
| | 0.328 | | 100.00% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.0 | | | | | **Direct Entry, Minimum (Roof)** |

## Subcatchment 6S: Roof Drains to Northwest



## Summary for Subcatchment 7S: Southeast Swale to Lake

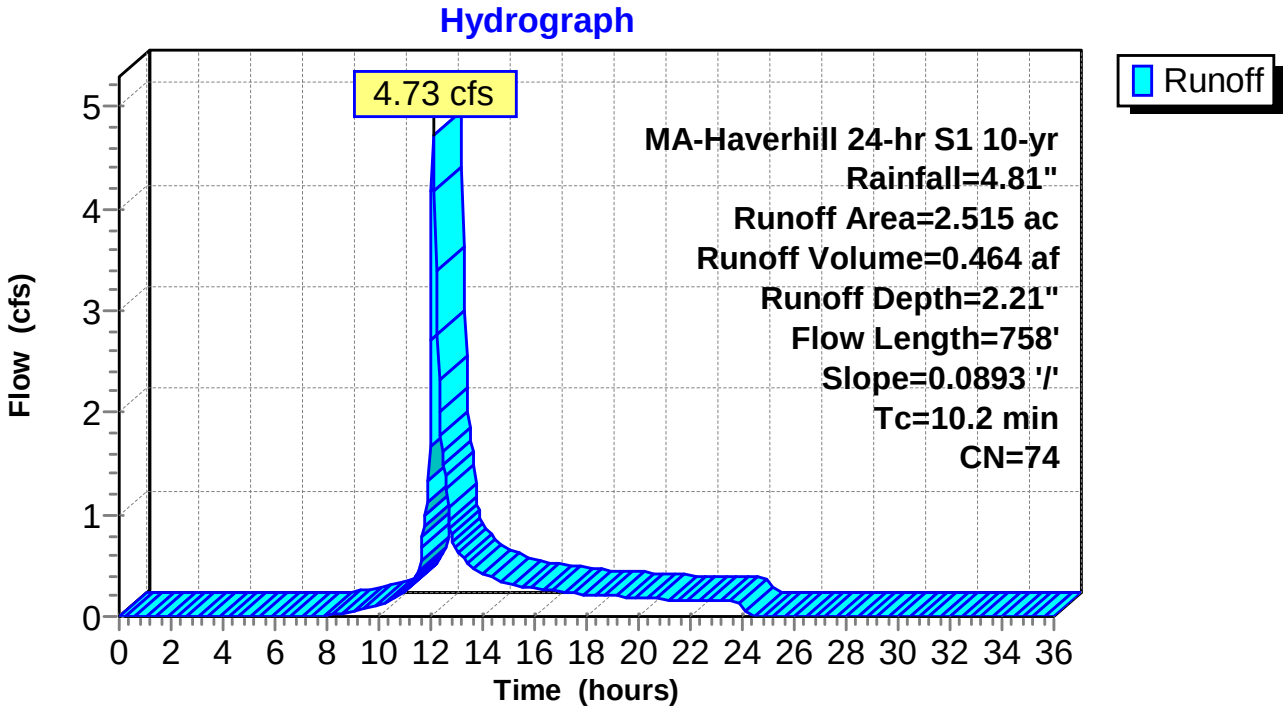
Runoff = 4.73 cfs @ 12.10 hrs, Volume= 0.464 af, Depth= 2.21"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 10-yr Rainfall=4.81"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.000 | 39 | >75% Grass cover, Good, HSG A |
| | 1.047 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.161 | 98 | Paved parking, HSG A |
| * | 0.007 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 1.300 | 70 | Woods, Good, HSG C |
| | 2.515 | 74 | Weighted Average |
| | 2.354 | | 93.60% Pervious Area |
| | 0.161 | | 6.40% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 10.2 | 758 | 0.0893 | 1.24 | | **Lag/CN Method,** |

### Subcatchment 7S: Southeast Swale to Lake



## Summary for Subcatchment 8S: Roof Drains to Lake

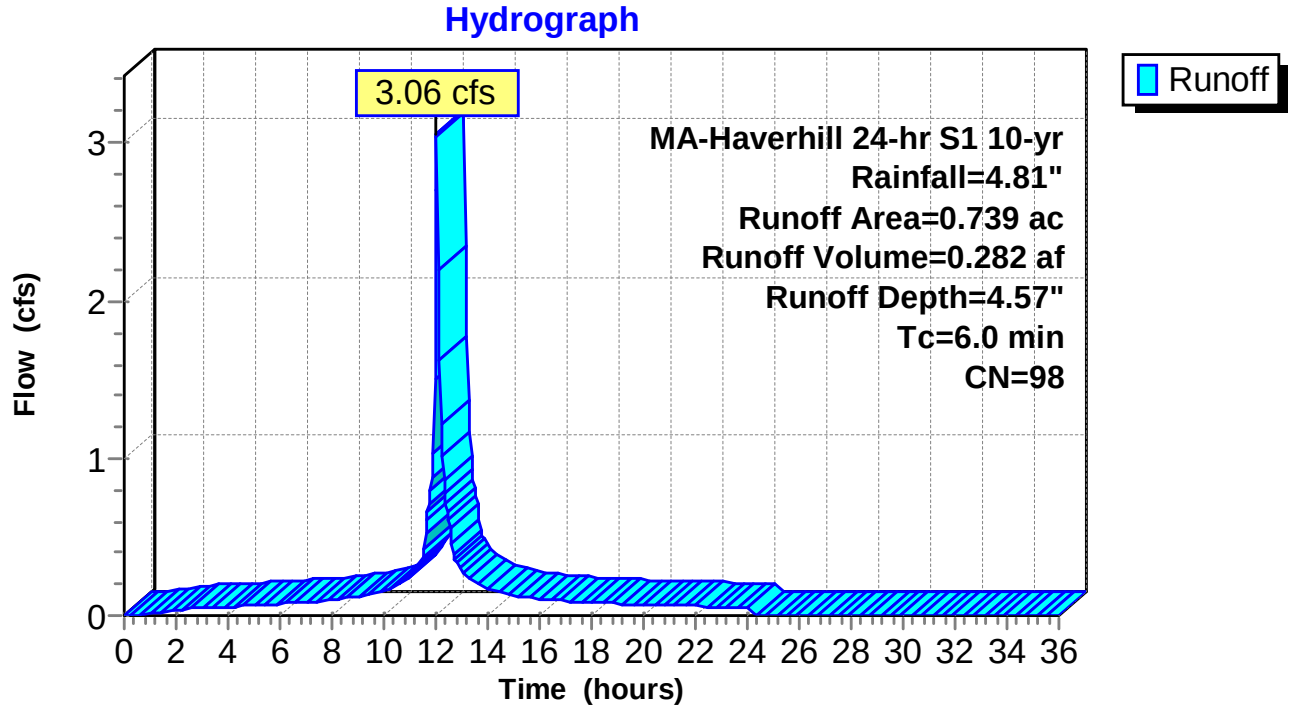
Runoff = 3.06 cfs @ 12.04 hrs, Volume= 0.282 af, Depth= 4.57"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 10-yr Rainfall=4.81"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.000 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.739 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.739 | 98 | Weighted Average |
| | 0.739 | | 100.00% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.0 | | | | | **Direct Entry, Minimum (Roof)** |

## Subcatchment 8S: Roof Drains to Lake

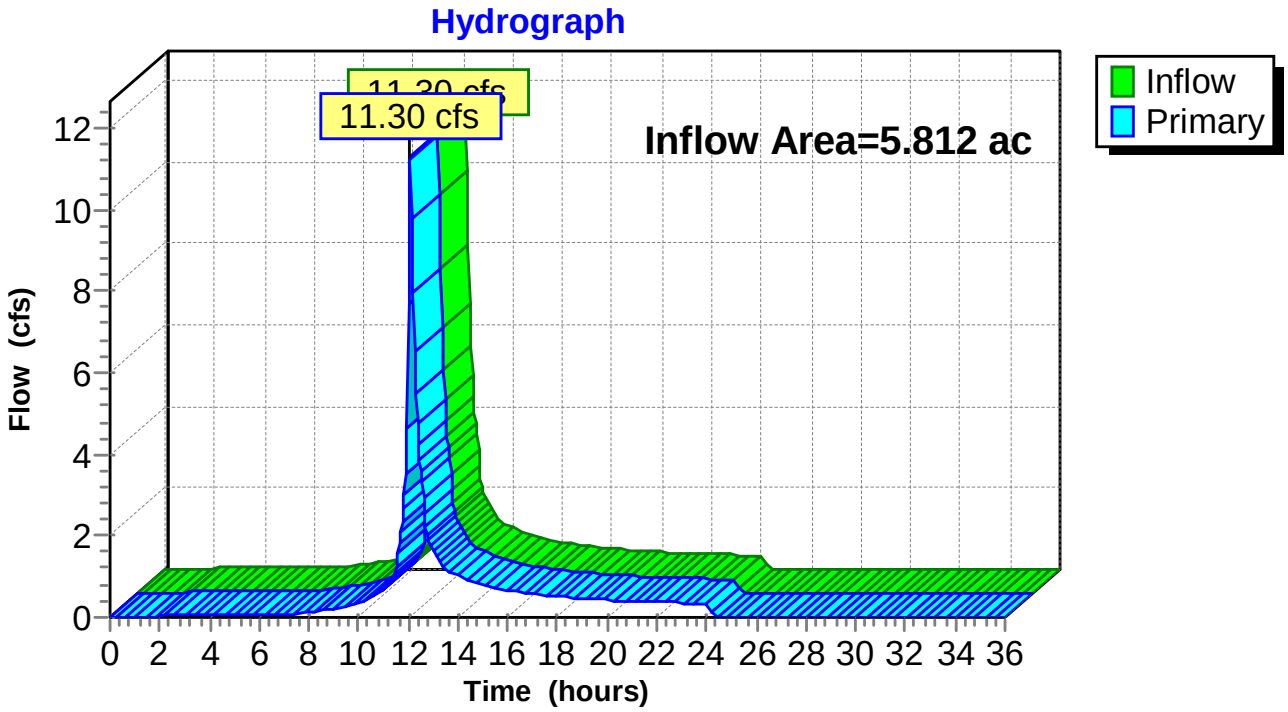


## Summary for Pond 9P: Kenoza Lake

Inflow Area = 5.812 ac, 34.98% Impervious, Inflow Depth = 2.44" for 10-yr event
Inflow = 11.30 cfs @ 12.09 hrs, Volume= 1.183 af
Primary = 11.30 cfs @ 12.09 hrs, Volume= 1.183 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs

### Pond 9P: Kenoza Lake

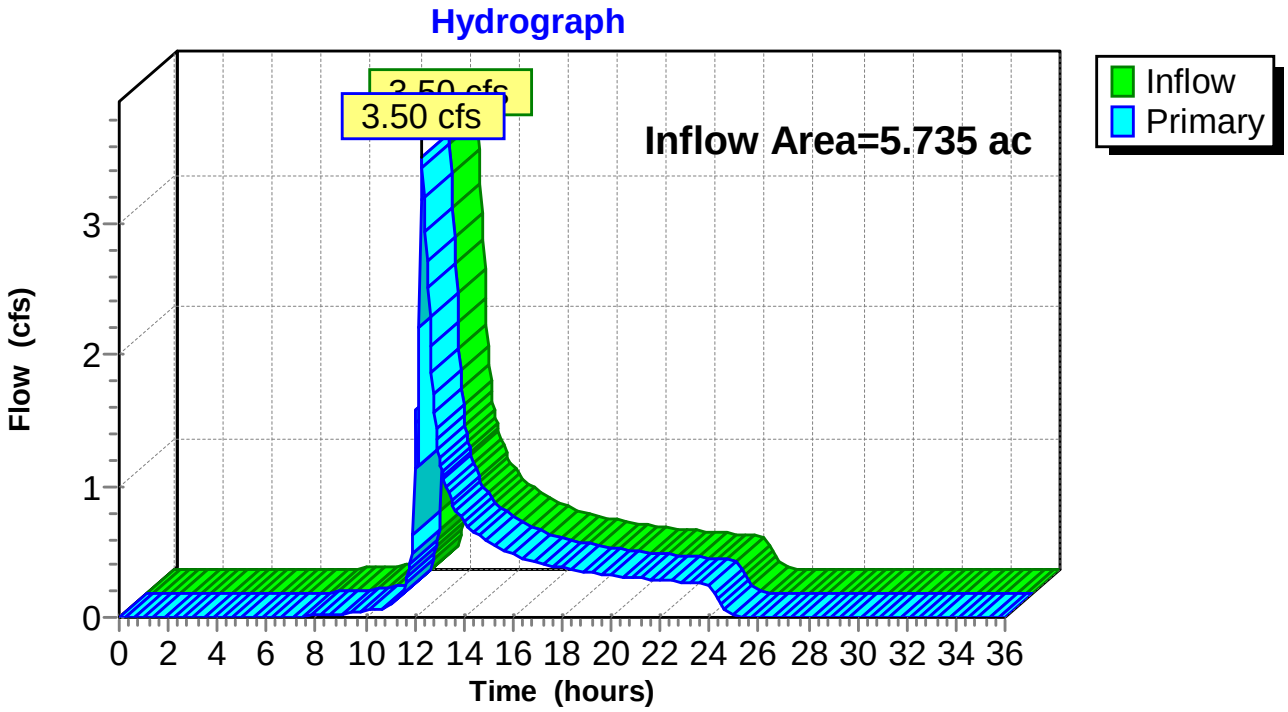


## Summary for Pond 10P: Northwestern Wetlands

Inflow Area = 5.735 ac, 30.17% Impervious, Inflow Depth = 1.28" for 10-yr event
Inflow = 3.50 cfs @ 12.32 hrs, Volume= 0.611 af
Primary = 3.50 cfs @ 12.32 hrs, Volume= 0.611 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs

### Pond 10P: Northwestern Wetlands



## Summary for Pond 11P: Exst DMH (Rim = 117.60)

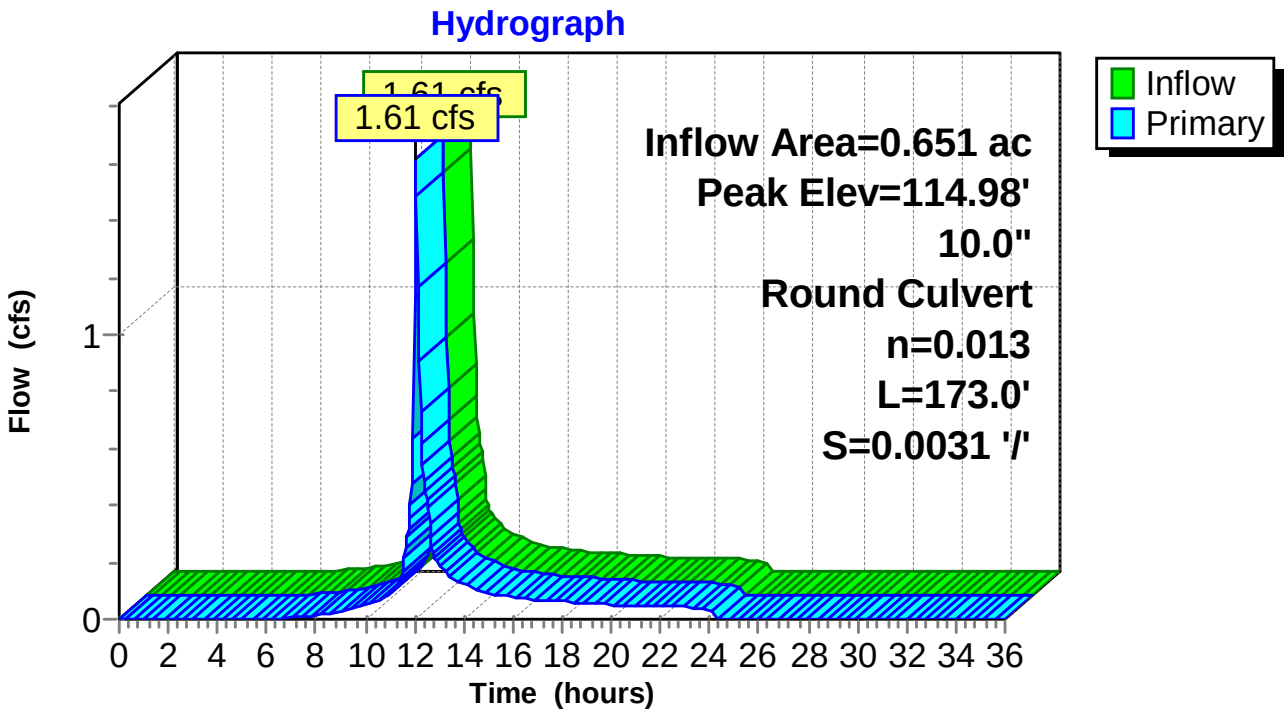
Inflow Area = 0.651 ac, 67.43% Impervious, Inflow Depth = 2.64" for 10-yr event
Inflow = 1.61 cfs @ 12.07 hrs, Volume= 0.143 af
Outflow = 1.61 cfs @ 12.07 hrs, Volume= 0.143 af, Atten= 0%, Lag= 0.0 min
Primary = 1.61 cfs @ 12.07 hrs, Volume= 0.143 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 114.98' @ 12.07 hrs
Flood Elev= 117.60'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 113.55' | **10.0" Round Culvert**<br>L= 173.0' RCP, square edge headwall, Ke= 0.500<br>Inlet / Outlet Invert= 113.55' / 113.01' S= 0.0031 '/' Cc= 0.900<br>n= 0.013, Flow Area= 0.55 sf |

**Primary OutFlow** Max=1.55 cfs @ 12.07 hrs HW=114.91' (Free Discharge)
**1=Culvert** (Barrel Controls 1.55 cfs @ 2.85 fps)

## Pond 11P: Exst DMH (Rim = 117.60)



## Summary for Pond 12P: Exist DMH (Rim = 116.31)

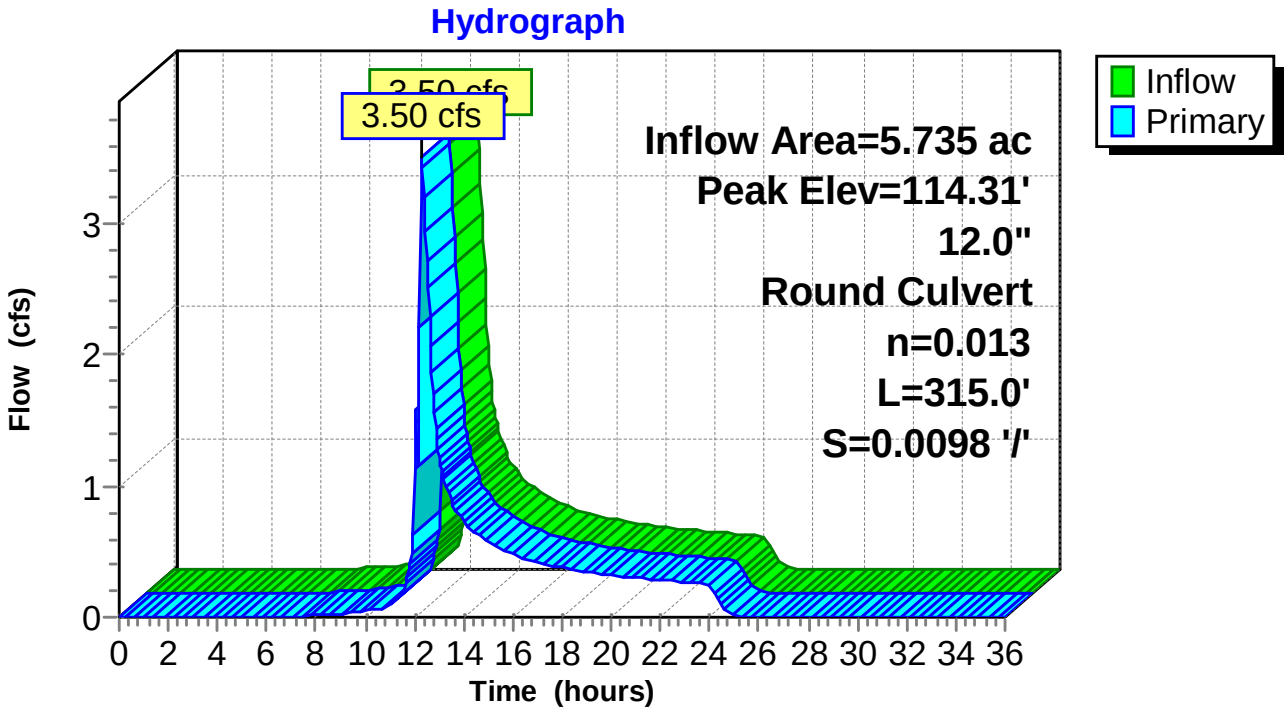
Inflow Area = 5.735 ac, 30.17% Impervious, Inflow Depth = 1.28" for 10-yr event
Inflow = 3.50 cfs @ 12.32 hrs, Volume= 0.611 af
Outflow = 3.50 cfs @ 12.32 hrs, Volume= 0.611 af, Atten= 0%, Lag= 0.0 min
Primary = 3.50 cfs @ 12.32 hrs, Volume= 0.611 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 114.31' @ 12.31 hrs
Flood Elev= 116.31'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 112.91' | **12.0" Round Culvert**<br>L= 315.0' RCP, square edge headwall, Ke= 0.500<br>Inlet / Outlet Invert= 112.91' / 109.82' S= 0.0098 '/' Cc= 0.900<br>n= 0.013, Flow Area= 0.79 sf |

**Primary OutFlow** Max=3.47 cfs @ 12.32 hrs HW=114.28' (Free Discharge)
**1=Culvert** (Barrel Controls 3.47 cfs @ 4.42 fps)

### Pond 12P: Exist DMH (Rim = 116.31)



## Summary for Pond 13P: CB-2 (Rim=126.25)

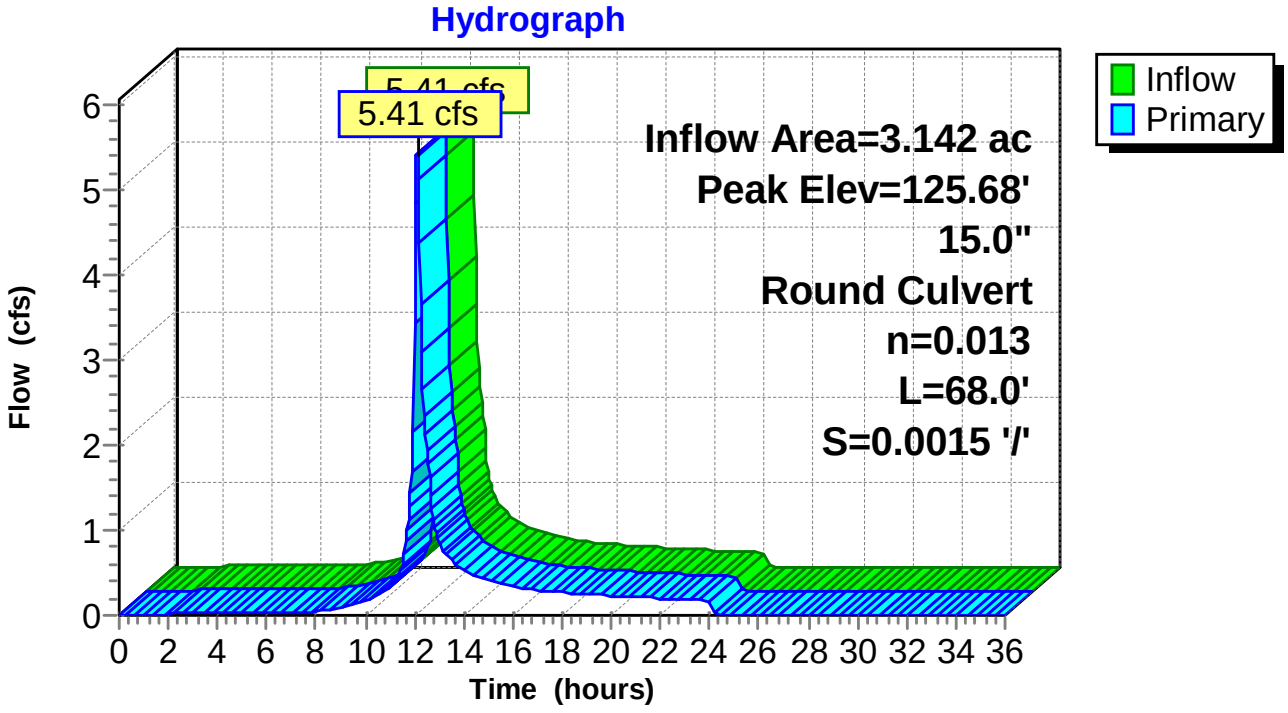
Inflow Area = 3.142 ac, 34.88% Impervious, Inflow Depth = 2.32" for 10-yr event
Inflow = 5.41 cfs @ 12.11 hrs, Volume= 0.606 af
Outflow = 5.41 cfs @ 12.11 hrs, Volume= 0.606 af, Atten= 0%, Lag= 0.0 min
Primary = 5.41 cfs @ 12.11 hrs, Volume= 0.606 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 125.68' @ 12.11 hrs
Flood Elev= 126.25'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 123.60' | **15.0" Round Culvert** L= 68.0' CPP, square edge headwall, Ke= 0.500<br>Inlet / Outlet Invert= 123.60' / 123.50' S= 0.0015 '/' Cc= 0.900<br>n= 0.013, Flow Area= 1.23 sf |

**Primary OutFlow** Max=5.35 cfs @ 12.11 hrs HW=125.66' (Free Discharge)
**1=Culvert** (Barrel Controls 5.35 cfs @ 4.36 fps)

### Pond 13P: CB-2 (Rim=126.25)



## Summary for Pond 14P: Bermed Area

Inflow Area = 5.084 ac, 25.39% Impervious, Inflow Depth = 1.53" for 10-yr event
Inflow = 5.41 cfs @ 12.11 hrs, Volume= 0.649 af
Outflow = 2.89 cfs @ 12.33 hrs, Volume= 0.468 af, Atten= 47%, Lag= 13.0 min
Primary = 2.89 cfs @ 12.33 hrs, Volume= 0.468 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 120.15' @ 12.33 hrs Surf.Area= 8,500 sf Storage= 9,157 cf

Plug-Flow detention time= 218.6 min calculated for 0.467 af (72% of inflow)
Center-of-Mass det. time= 95.8 min ( 966.7 - 870.9 )

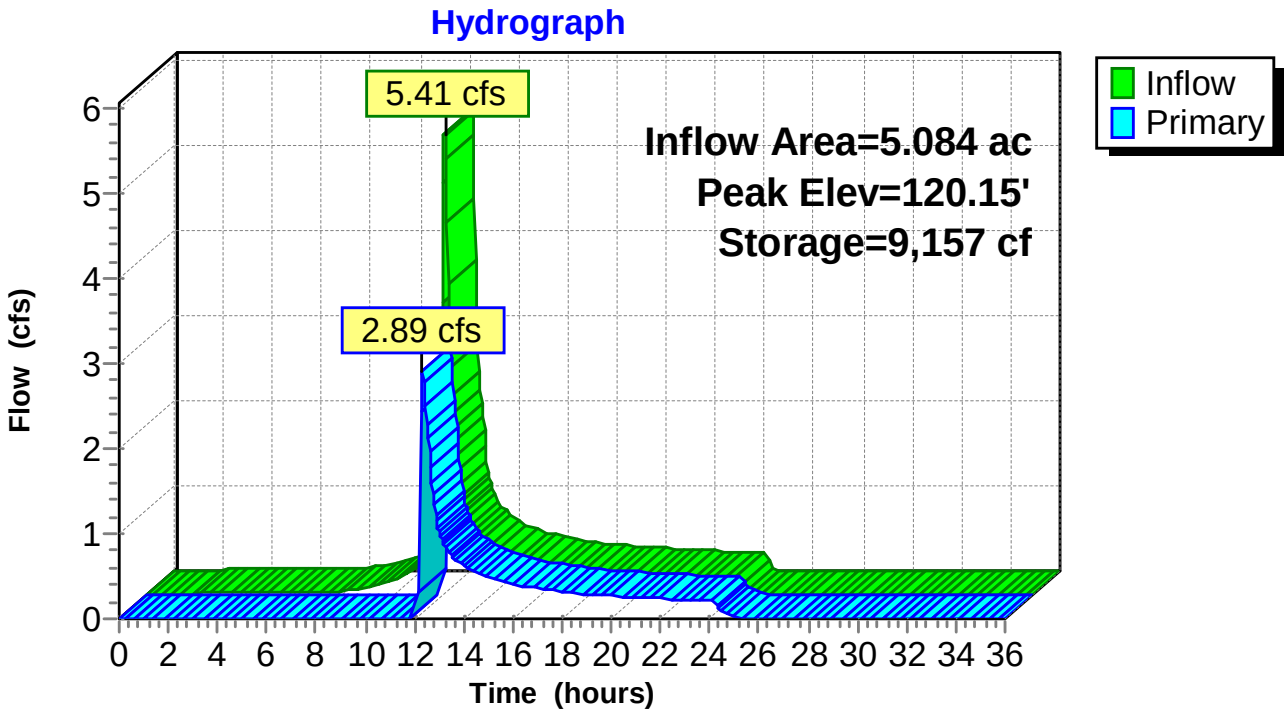
| Volume | Invert | Avail.Storage | Storage Description |
|---|---|---|---|
| #1 | 118.00' | 12,150 cf | **Custom Stage Data (Prismatic)** Listed below (Recalc) |

| Elevation (feet) | Surf.Area (sq-ft) | Inc.Store (cubic-feet) | Cum.Store (cubic-feet) |
|---|---|---|---|
| 118.00 | 1,000 | 0 | 0 |
| 119.00 | 3,100 | 2,050 | 2,050 |
| 119.50 | 5,900 | 2,250 | 4,300 |
| 120.00 | 8,500 | 3,600 | 7,900 |
| 120.50 | 8,500 | 4,250 | 12,150 |

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 120.00' | **20.0' long x 2.0' breadth Broad-Crested Rectangular Weir**<br>Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50<br>Coef. (English) 2.54 2.61 2.61 2.60 2.66 2.70 2.77 2.89 2.88 2.85 3.07 3.20 3.32 |

**Primary OutFlow** Max=2.87 cfs @ 12.33 hrs HW=120.15' (Free Discharge)
**1=Broad-Crested Rectangular Weir** (Weir Controls 2.87 cfs @ 0.97 fps)

## Pond 14P: Bermed Area



## Summary for Subcatchment 1S: Northwestern Area to Wetland

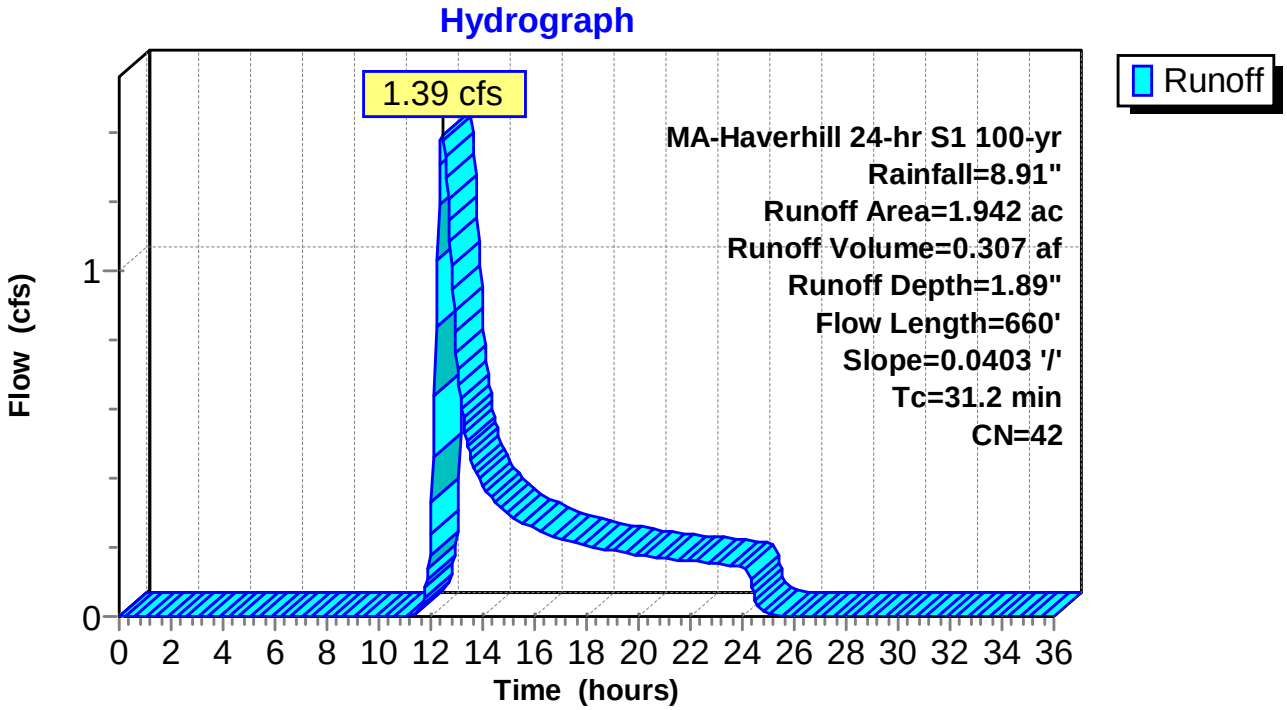
Runoff = 1.39 cfs @ 12.45 hrs, Volume= 0.307 af, Depth= 1.89"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 100-yr Rainfall=8.91"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 1.107 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.019 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.195 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.617 | 30 | Woods, Good, HSG A |
| | 0.004 | 70 | Woods, Good, HSG C |
| | 1.942 | 42 | Weighted Average |
| | 1.747 | | 89.96% Pervious Area |
| | 0.195 | | 10.04% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 31.2 | 660 | 0.0403 | 0.35 | | **Lag/CN Method,** |

## Subcatchment 1S: Northwestern Area to Wetland



## Summary for Subcatchment 2S: Drainage System To Wetland

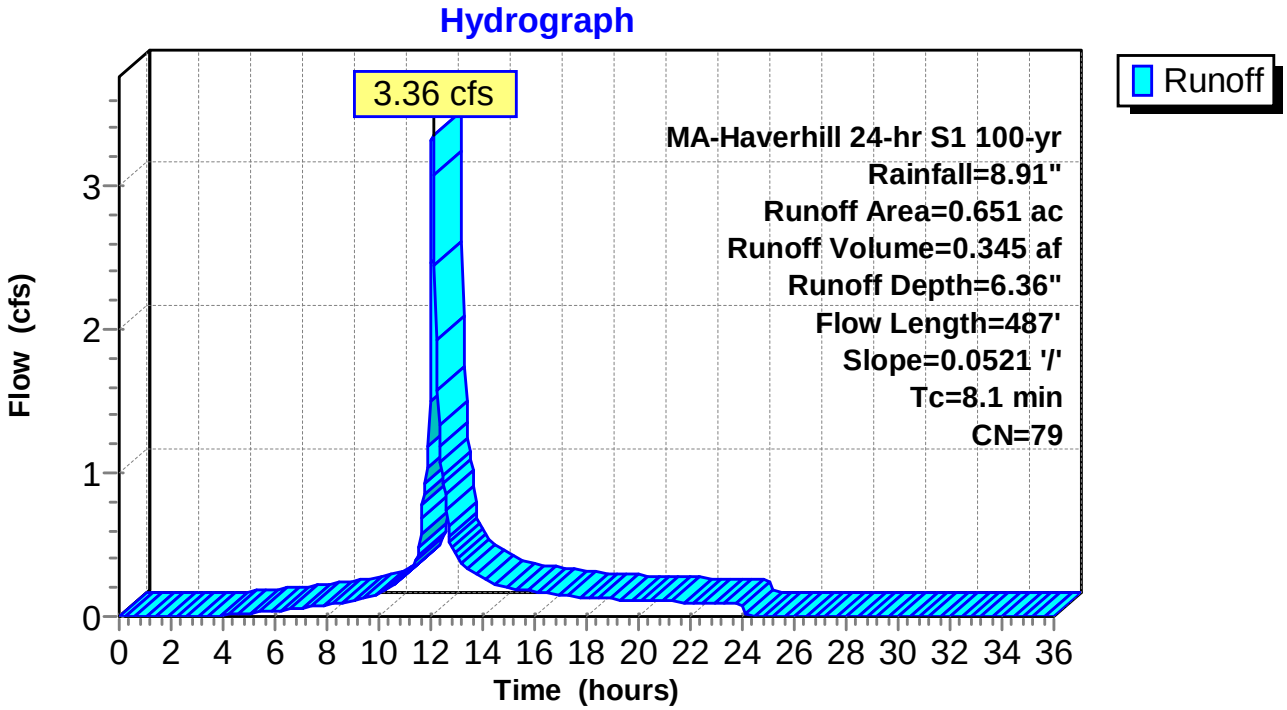
Runoff = 3.36 cfs @ 12.06 hrs, Volume= 0.345 af, Depth= 6.36"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 100-yr Rainfall=8.91"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.192 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.439 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.020 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.651 | 79 | Weighted Average |
| | 0.212 | | 32.57% Pervious Area |
| | 0.439 | | 67.43% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 8.1 | 487 | 0.0521 | 1.01 | | **Lag/CN Method,** |

### Subcatchment 2S: Drainage System To Wetland



## Summary for Subcatchment 3S: To Northwestern Grassy Area

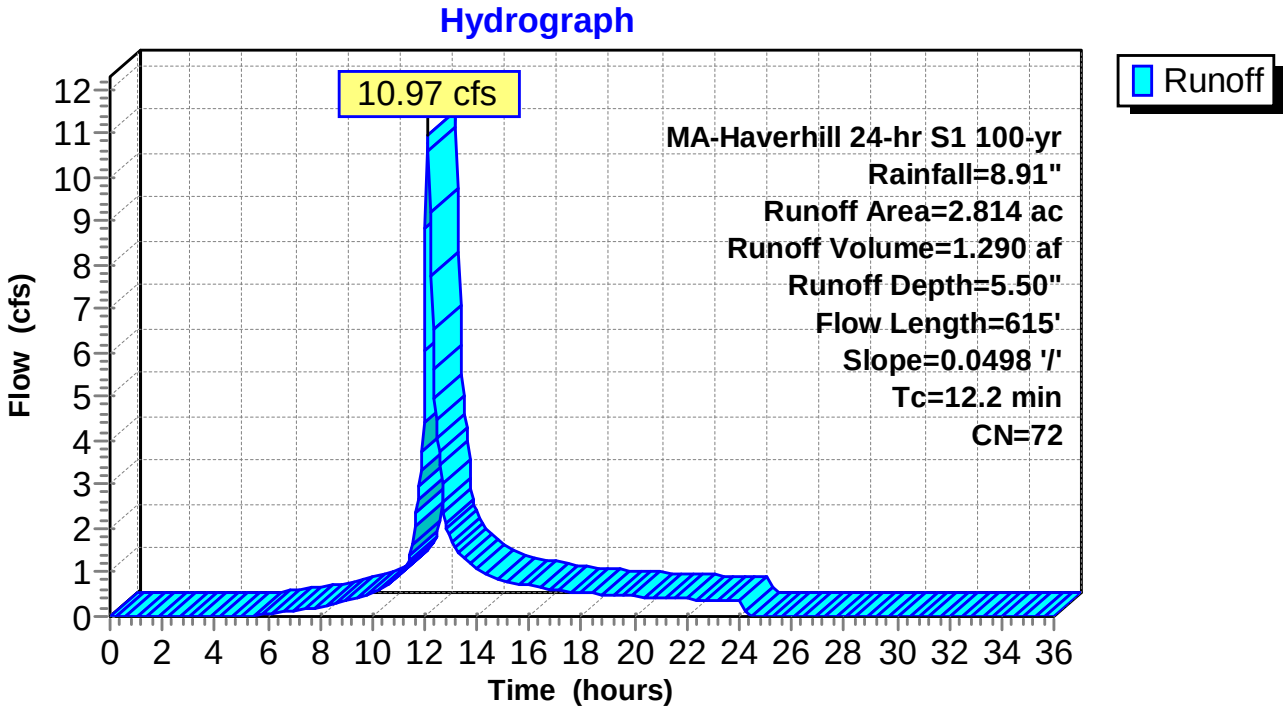
Runoff = 10.97 cfs @ 12.12 hrs, Volume= 1.290 af, Depth= 5.50"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 100-yr Rainfall=8.91"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.058 | 39 | >75% Grass cover, Good, HSG A |
| | 0.076 | 74 | >75% Grass cover, Good, HSG C |
| | 0.080 | 76 | Gravel roads, HSG A |
| | 0.279 | 89 | Gravel roads, HSG C |
| | 0.768 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.472 | 30 | Woods, Good, HSG A |
| | 1.081 | 70 | Woods, Good, HSG C |
| | 2.814 | 72 | Weighted Average |
| | 2.046 | | 72.71% Pervious Area |
| | 0.768 | | 27.29% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 12.2 | 615 | 0.0498 | 0.84 | | **Lag/CN Method,** |

## Subcatchment 3S: To Northwestern Grassy Area



## Summary for Subcatchment 4S: Direct Discharge to Lake

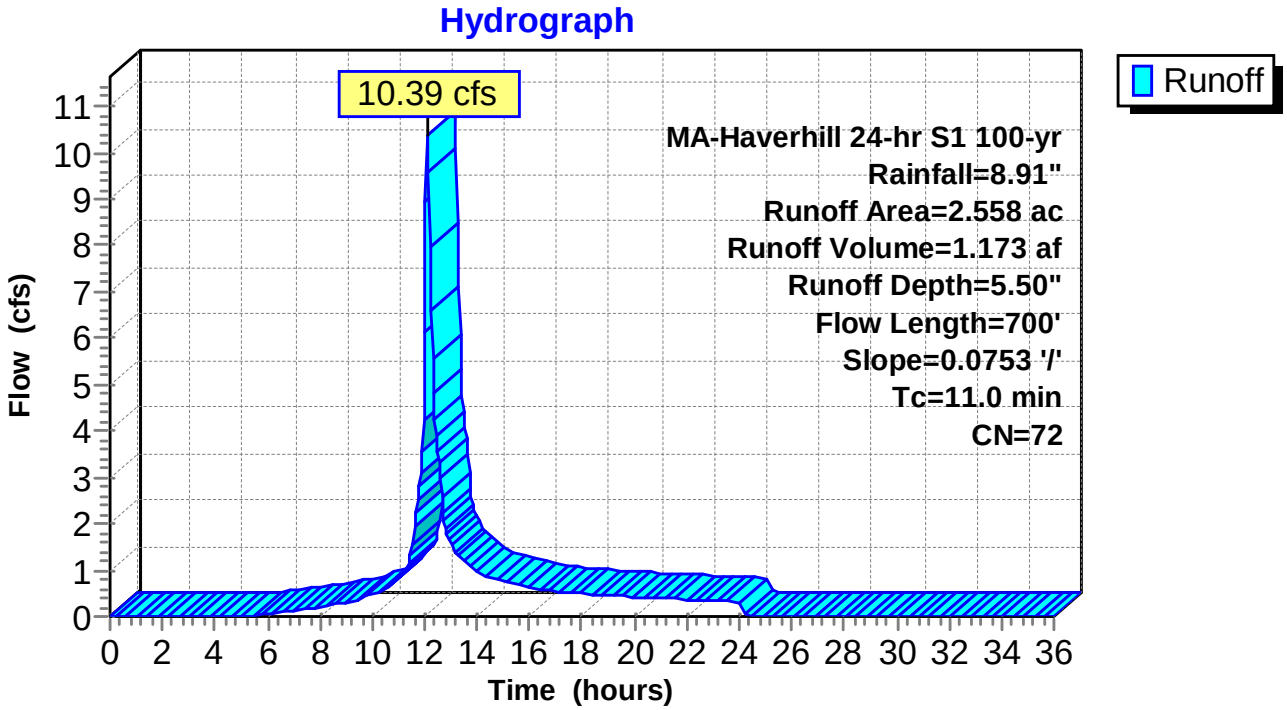
Runoff = 10.39 cfs @ 12.11 hrs, Volume= 1.173 af, Depth= 5.50"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 100-yr Rainfall=8.91"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 1.066 | 39 | >75% Grass cover, Good, HSG A |
| | 0.085 | 74 | >75% Grass cover, Good, HSG C |
| | 0.007 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 1.133 | 98 | Paved parking, HSG A |
| * | 0.267 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 2.558 | 72 | Weighted Average |
| | 1.425 | | 55.71% Pervious Area |
| | 1.133 | | 44.29% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 11.0 | 700 | 0.0753 | 1.06 | | **Lag/CN Method,** |

### Subcatchment 4S: Direct Discharge to Lake



## Summary for Subcatchment 6S: Roof Drains to Northwest

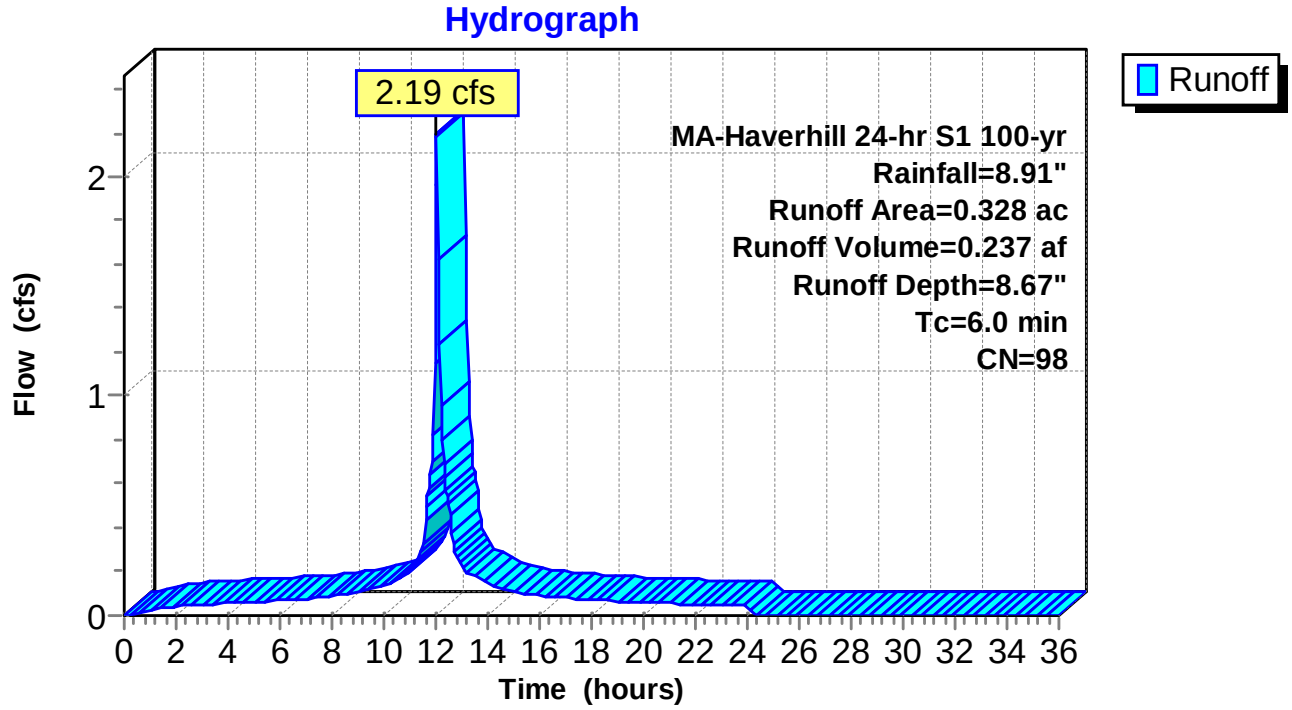
Runoff = 2.19 cfs @ 12.04 hrs, Volume= 0.237 af, Depth= 8.67"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 100-yr Rainfall=8.91"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.000 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.328 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.328 | 98 | Weighted Average |
| | 0.328 | | 100.00% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.0 | | | | | **Direct Entry, Minimum (Roof)** |

## Subcatchment 6S: Roof Drains to Northwest



## Summary for Subcatchment 7S: Southeast Swale to Lake

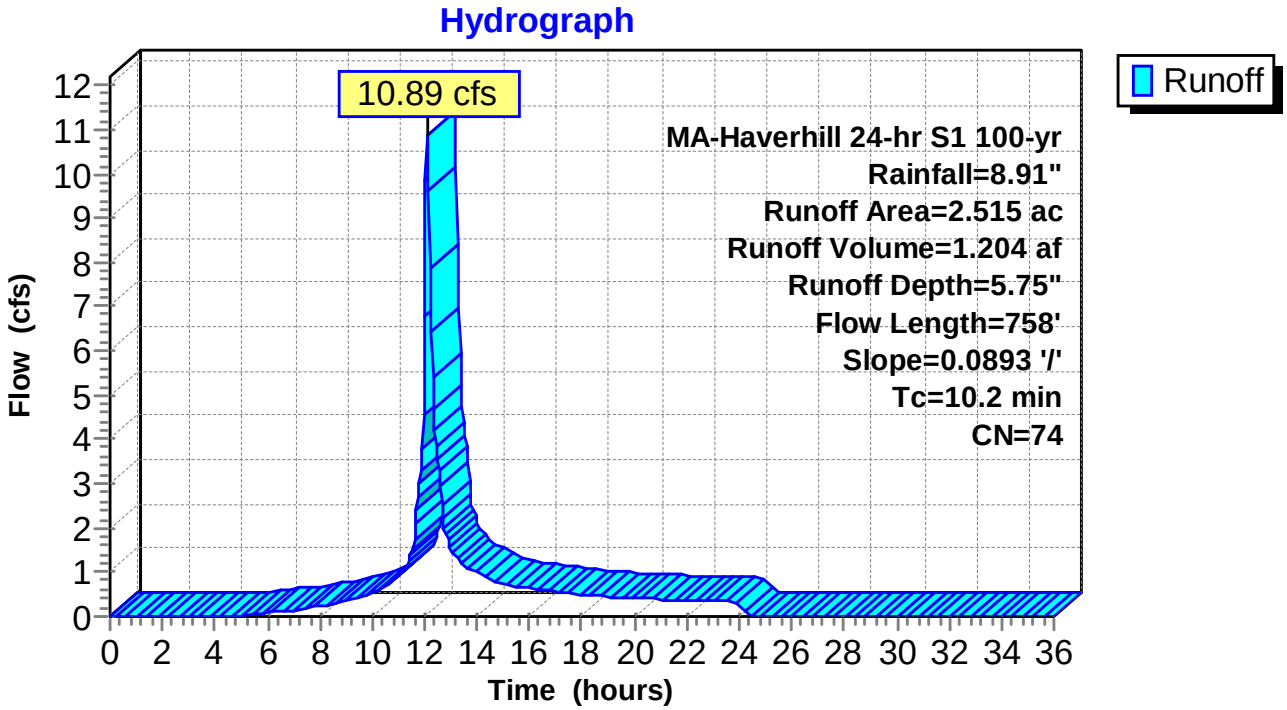
Runoff = 10.89 cfs @ 12.10 hrs, Volume= 1.204 af, Depth= 5.75"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 100-yr Rainfall=8.91"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.000 | 39 | >75% Grass cover, Good, HSG A |
| | 1.047 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.161 | 98 | Paved parking, HSG A |
| * | 0.007 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 1.300 | 70 | Woods, Good, HSG C |
| | 2.515 | 74 | Weighted Average |
| | 2.354 | | 93.60% Pervious Area |
| | 0.161 | | 6.40% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 10.2 | 758 | 0.0893 | 1.24 | | **Lag/CN Method,** |

## Subcatchment 7S: Southeast Swale to Lake



## Summary for Subcatchment 8S: Roof Drains to Lake

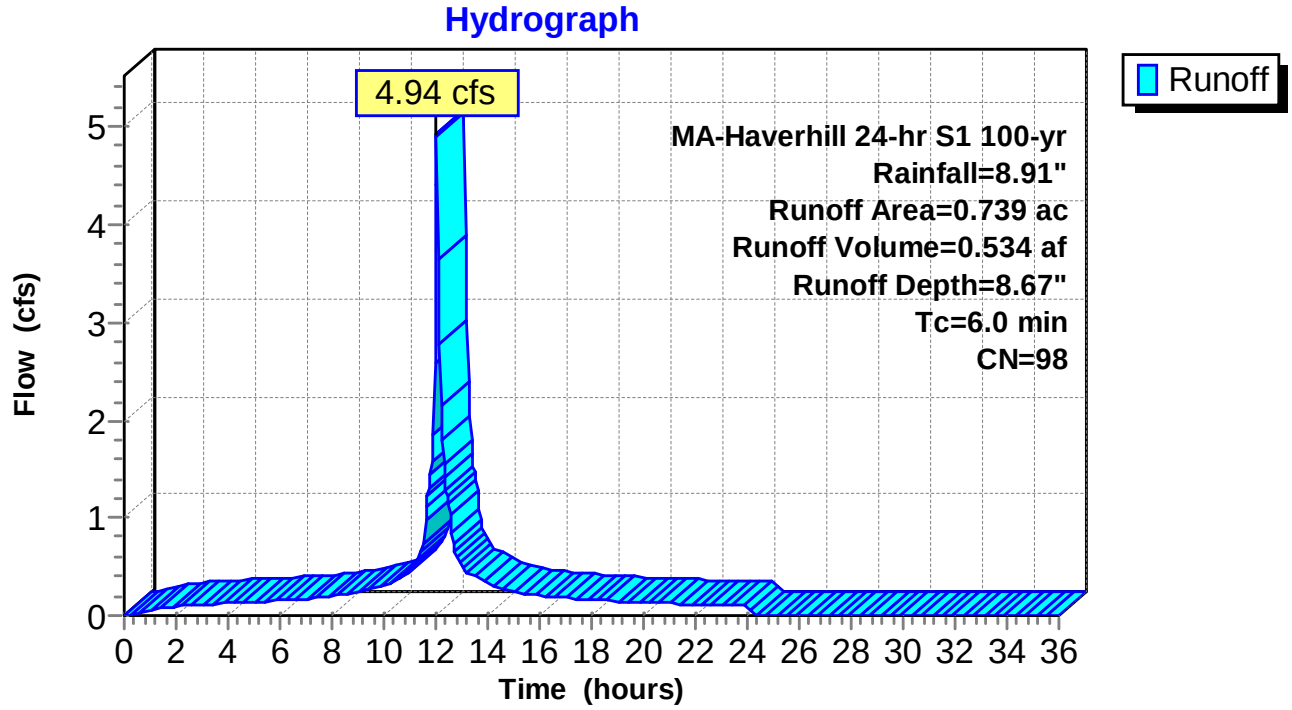
Runoff = 4.94 cfs @ 12.04 hrs, Volume= 0.534 af, Depth= 8.67"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
MA-Haverhill 24-hr S1 100-yr Rainfall=8.91"

| | Area (ac) | CN | Description |
|---|---|---|---|
| | 0.000 | 39 | >75% Grass cover, Good, HSG A |
| | 0.000 | 74 | >75% Grass cover, Good, HSG C |
| | 0.000 | 76 | Gravel roads, HSG A |
| | 0.000 | 89 | Gravel roads, HSG C |
| | 0.739 | 98 | Paved parking, HSG A |
| * | 0.000 | 96 | RipRap_Assumed |
| | 0.000 | 30 | Woods, Good, HSG A |
| | 0.000 | 70 | Woods, Good, HSG C |
| | 0.739 | 98 | Weighted Average |
| | 0.739 | | 100.00% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.0 | | | | | **Direct Entry, Minimum (Roof)** |

## Subcatchment 8S: Roof Drains to Lake

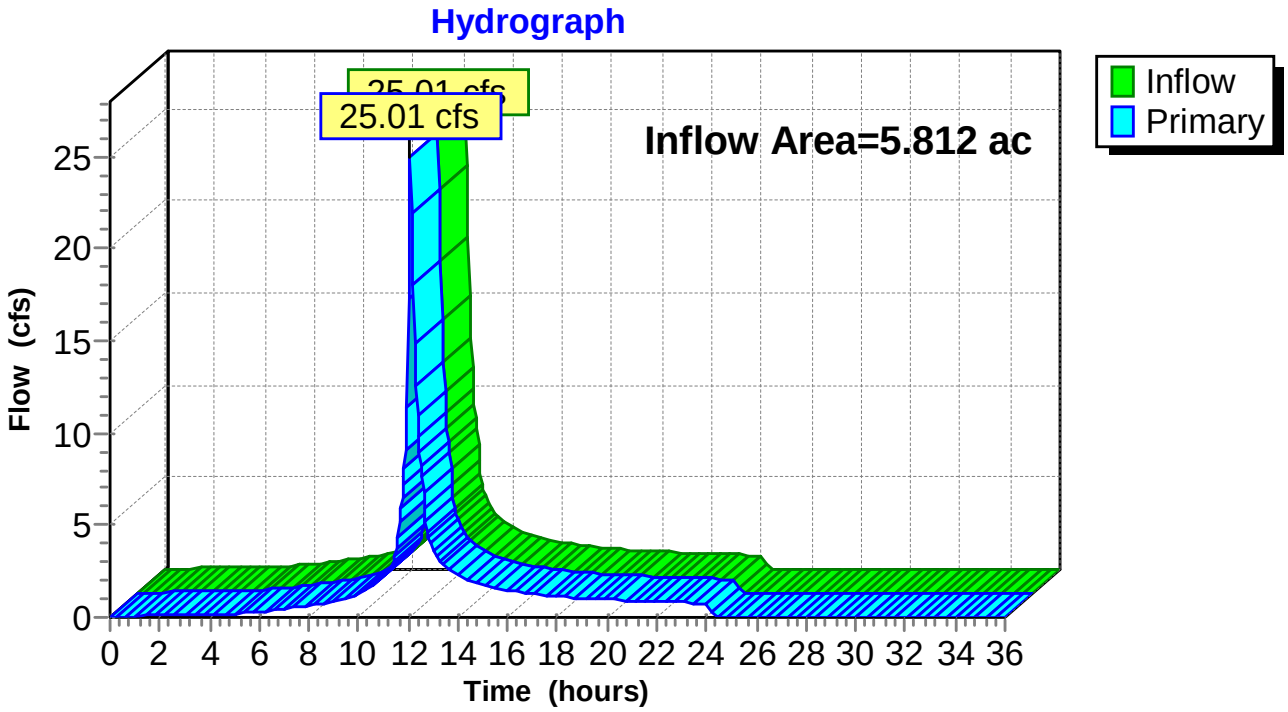


## Summary for Pond 9P: Kenoza Lake

Inflow Area = 5.812 ac, 34.98% Impervious, Inflow Depth = 6.01" for 100-yr event
Inflow = 25.01 cfs @ 12.09 hrs, Volume= 2.911 af
Primary = 25.01 cfs @ 12.09 hrs, Volume= 2.911 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs

### Pond 9P: Kenoza Lake

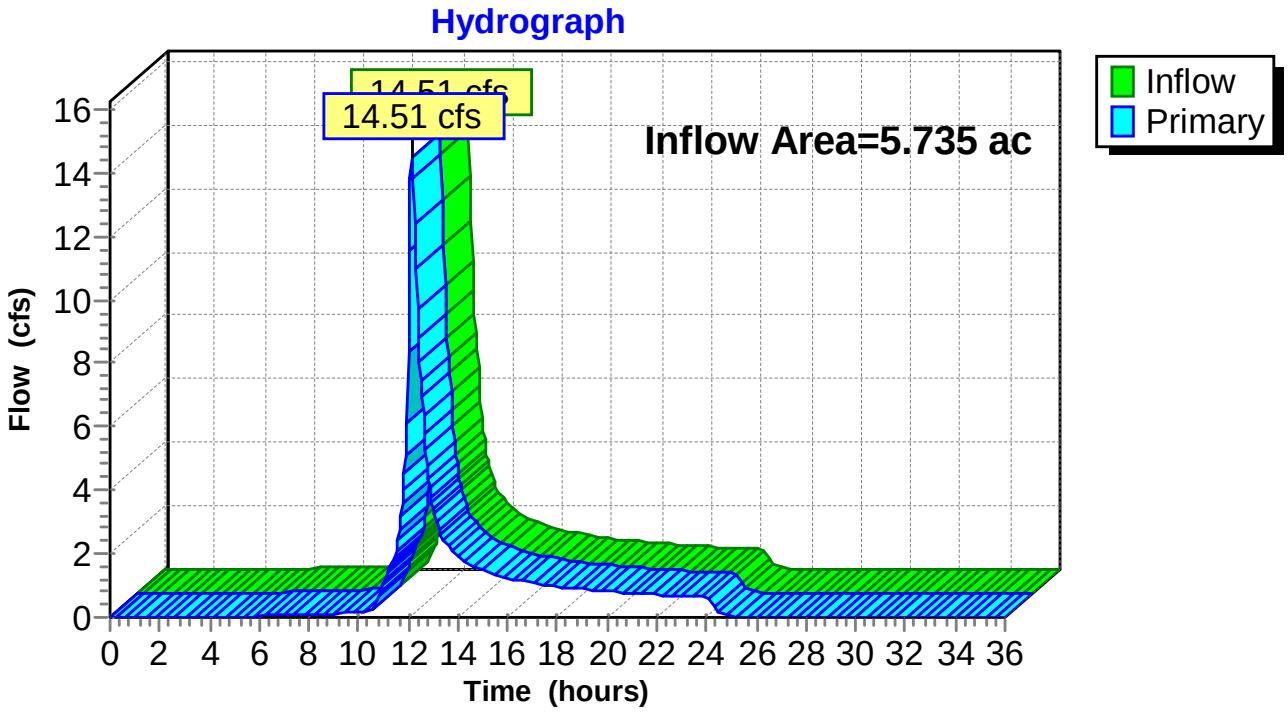


## Summary for Pond 10P: Northwestern Wetlands

Inflow Area = 5.735 ac, 30.17% Impervious, Inflow Depth = 4.18" for 100-yr event
Inflow = 14.51 cfs @ 12.15 hrs, Volume= 1.997 af
Primary = 14.51 cfs @ 12.15 hrs, Volume= 1.997 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs

### Pond 10P: Northwestern Wetlands



## Summary for Pond 11P: Exst DMH (Rim = 117.60)

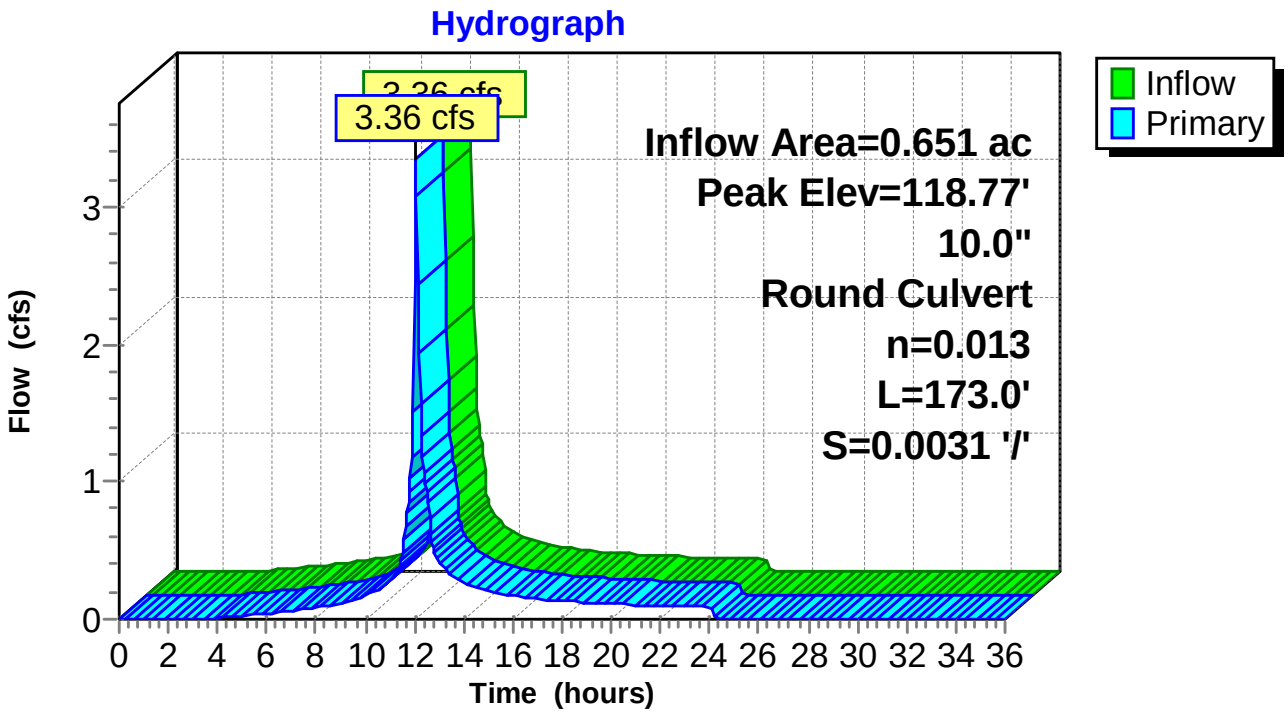
Inflow Area = 0.651 ac, 67.43% Impervious, Inflow Depth = 6.36" for 100-yr event
Inflow = 3.36 cfs @ 12.06 hrs, Volume= 0.345 af
Outflow = 3.36 cfs @ 12.06 hrs, Volume= 0.345 af, Atten= 0%, Lag= 0.0 min
Primary = 3.36 cfs @ 12.06 hrs, Volume= 0.345 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 118.77' @ 12.06 hrs
Flood Elev= 117.60'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 113.55' | **10.0" Round Culvert**<br>L= 173.0' RCP, square edge headwall, Ke= 0.500<br>Inlet / Outlet Invert= 113.55' / 113.01' S= 0.0031 '/' Cc= 0.900<br>n= 0.013, Flow Area= 0.55 sf |

**Primary OutFlow** Max=3.25 cfs @ 12.06 hrs HW=118.48' (Free Discharge)
**1=Culvert** (Barrel Controls 3.25 cfs @ 5.95 fps)

## Pond 11P: Exst DMH (Rim = 117.60)



## Summary for Pond 12P: Exist DMH (Rim = 116.31)

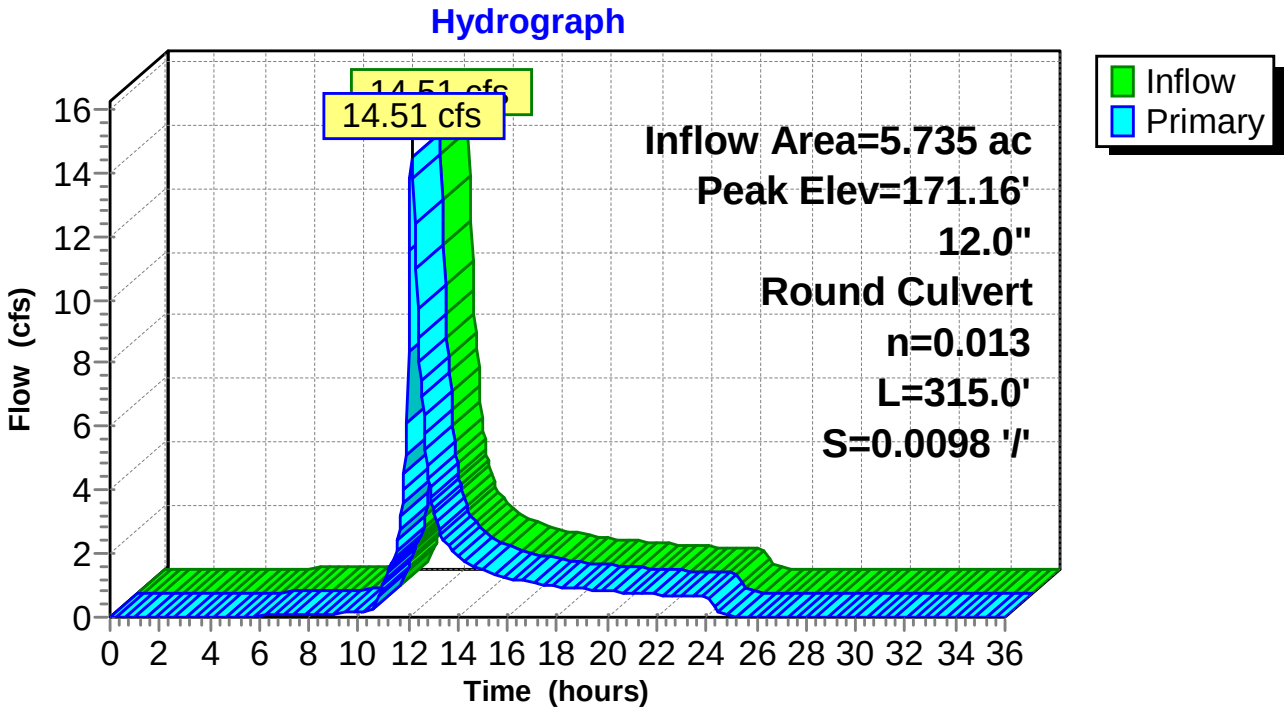
Inflow Area = 5.735 ac, 30.17% Impervious, Inflow Depth = 4.18" for 100-yr event
Inflow = 14.51 cfs @ 12.15 hrs, Volume= 1.997 af
Outflow = 14.51 cfs @ 12.15 hrs, Volume= 1.997 af, Atten= 0%, Lag= 0.0 min
Primary = 14.51 cfs @ 12.15 hrs, Volume= 1.997 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 171.16' @ 12.15 hrs
Flood Elev= 116.31'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 112.91' | **12.0" Round Culvert**<br>L= 315.0' RCP, square edge headwall, Ke= 0.500<br>Inlet / Outlet Invert= 112.91' / 109.82' S= 0.0098 '/' Cc= 0.900<br>n= 0.013, Flow Area= 0.79 sf |

**Primary OutFlow** Max=14.49 cfs @ 12.15 hrs HW=171.03' (Free Discharge)
**1=Culvert** (Barrel Controls 14.49 cfs @ 18.45 fps)

### Pond 12P: Exist DMH (Rim = 116.31)



## Summary for Pond 13P: CB-2 (Rim=126.25)

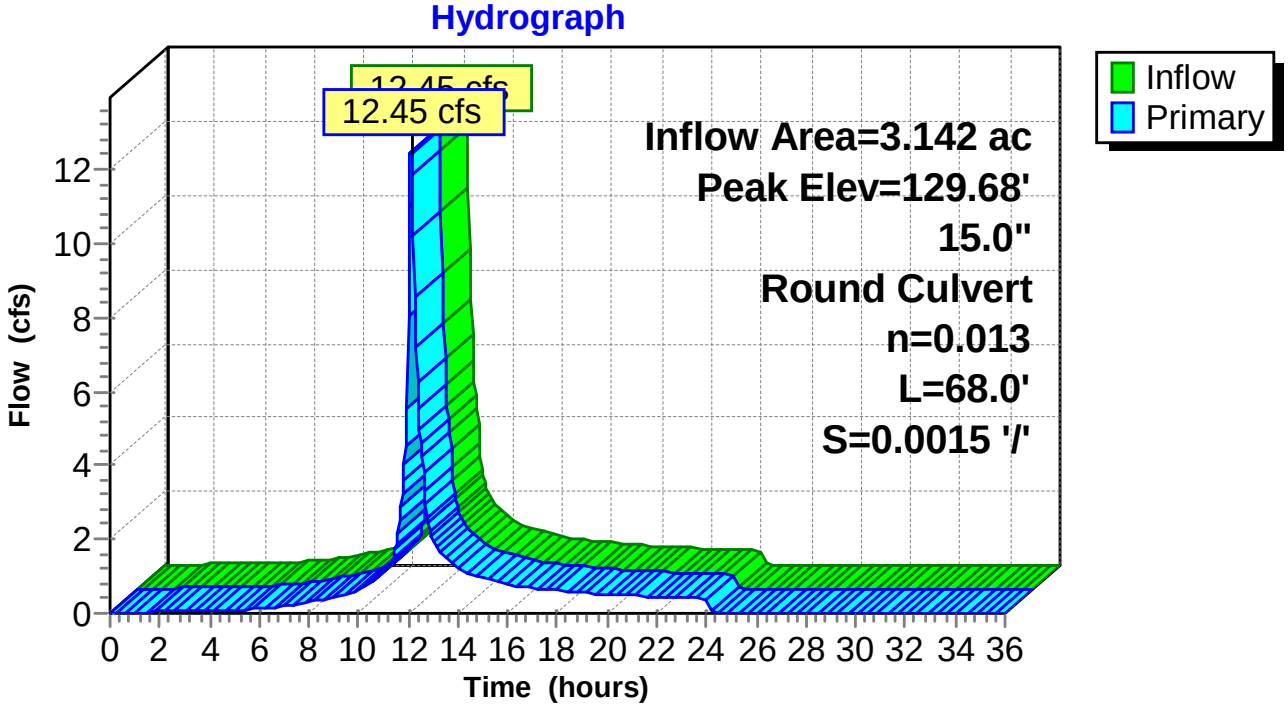
Inflow Area = 3.142 ac, 34.88% Impervious, Inflow Depth = 5.83" for 100-yr event
Inflow = 12.45 cfs @ 12.11 hrs, Volume= 1.527 af
Outflow = 12.45 cfs @ 12.11 hrs, Volume= 1.527 af, Atten= 0%, Lag= 0.0 min
Primary = 12.45 cfs @ 12.11 hrs, Volume= 1.527 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 129.68' @ 12.11 hrs
Flood Elev= 126.25'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 123.60' | **15.0" Round Culvert** L= 68.0' CPP, square edge headwall, Ke= 0.500<br>Inlet / Outlet Invert= 123.60' / 123.50' S= 0.0015 '/' Cc= 0.900<br>n= 0.013, Flow Area= 1.23 sf |

**Primary OutFlow** Max=12.29 cfs @ 12.11 hrs HW=129.56' (Free Discharge)
**1=Culvert** (Barrel Controls 12.29 cfs @ 10.02 fps)

### Pond 13P: CB-2 (Rim=126.25)



## Summary for Pond 14P: Bermed Area

Inflow Area = 5.084 ac, 25.39% Impervious, Inflow Depth = 4.33" for 100-yr event
Inflow = 12.96 cfs @ 12.11 hrs, Volume= 1.834 af
Outflow = 12.16 cfs @ 12.17 hrs, Volume= 1.652 af, Atten= 6%, Lag= 3.2 min
Primary = 12.16 cfs @ 12.17 hrs, Volume= 1.652 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 120.38' @ 12.17 hrs Surf.Area= 8,500 sf Storage= 11,125 cf

Plug-Flow detention time= 100.5 min calculated for 1.652 af (90% of inflow)
Center-of-Mass det. time= 47.0 min ( 901.2 - 854.2 )

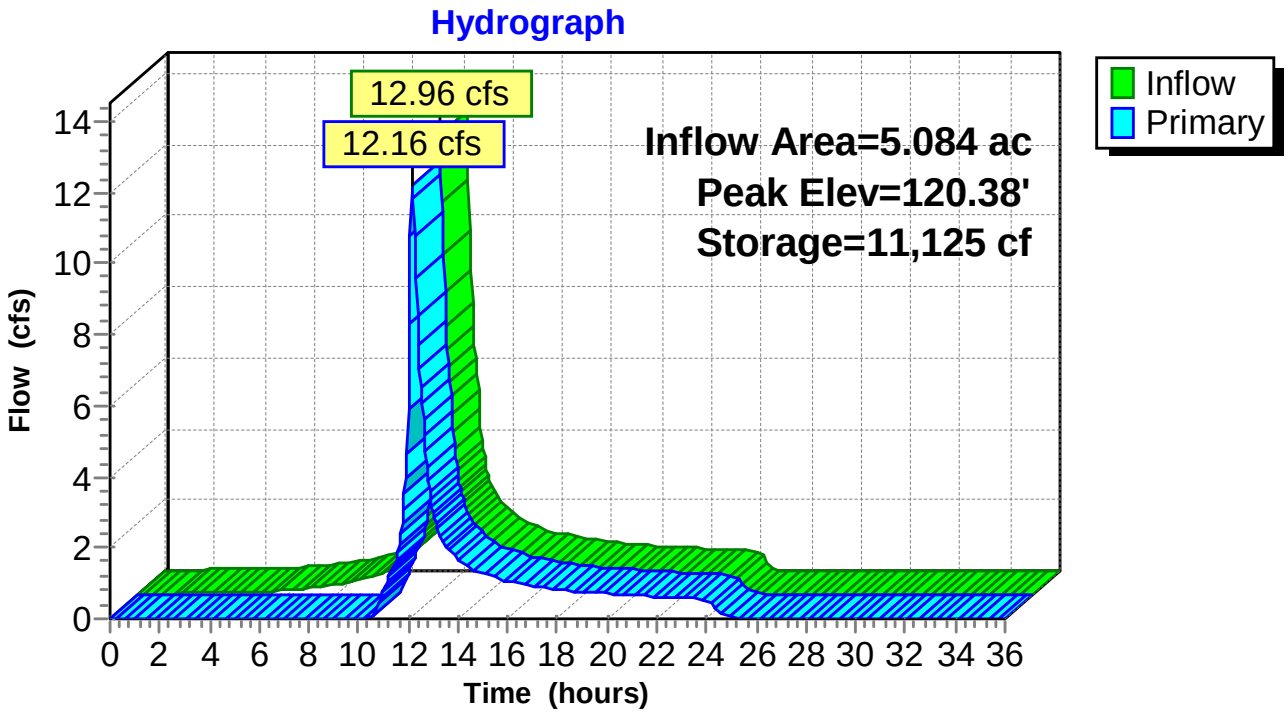
| Volume | Invert | Avail.Storage | Storage Description |
|---|---|---|---|
| #1 | 118.00' | 12,150 cf | **Custom Stage Data (Prismatic)** Listed below (Recalc) |

| Elevation (feet) | Surf.Area (sq-ft) | Inc.Store (cubic-feet) | Cum.Store (cubic-feet) |
|---|---|---|---|
| 118.00 | 1,000 | 0 | 0 |
| 119.00 | 3,100 | 2,050 | 2,050 |
| 119.50 | 5,900 | 2,250 | 4,300 |
| 120.00 | 8,500 | 3,600 | 7,900 |
| 120.50 | 8,500 | 4,250 | 12,150 |

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 120.00' | **20.0' long x 2.0' breadth Broad-Crested Rectangular Weir**<br>Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50<br>Coef. (English) 2.54 2.61 2.61 2.60 2.66 2.70 2.77 2.89 2.88 2.85 3.07 3.20 3.32 |

**Primary OutFlow** Max=11.99 cfs @ 12.17 hrs HW=120.38' (Free Discharge)
**1=Broad-Crested Rectangular Weir** (Weir Controls 11.99 cfs @ 1.59 fps)

## Pond 14P: Bermed Area



# APPENDIX B

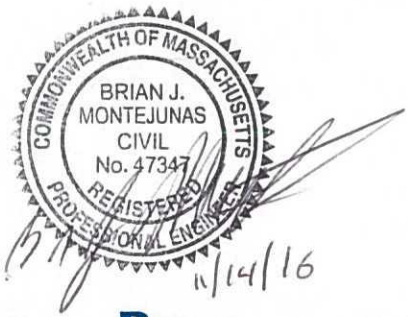
# Long-Term Pollution Prevention and Operation & Maintenance Plan

# STORMWATER OPERATION AND MAINTENANCE PLAN AND LONG TERM POLLUTION PREVENTION PLAN

# KENOZA LAKE WATER TREATMENT PLANT COMPREHENSIVE UPGRADES

## PREPARED FOR:
## HAVERHILL WATER DEPARTMENT

## NOVEMBER 2016




WRIGHT-PIERCE
Engineering a Better Environment

# OPERATION AND MAINTENANCE PLAN

# &

# LONG TERM POLLUTION PREVENTION PLAN

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# SECTION 1

# OPERATION AND MAINTENANCE

This Operation and Maintenance Plan (O&M Plan) was prepared in accordance with the City of Haverhill Stormwater Management Regulations to ensure that all soil erosion and stormwater runoff control facilities and measures are maintained during and after construction. Regular inspections and maintenance are essential for long-term effectiveness of soil erosion and stormwater runoff control facilities and measures. If not properly maintained, these facilities and measures will not operate as designed and will not provide effective treatment of stormwater runoff. The Haverhill Water Department will be responsible for performing the regular inspections and required maintenance for the stormwater treatment practices to be installed as part of the project. The following is an outline of these inspection and maintenance procedures.

## 1.1 BMP OWNERS

The OWNERS of the BMP's shall be the person, persons, trust, corporation, etc., or their successors who have title to the land on which the BMP is located. It is anticipated that all BMP's will be owned and maintained by the City of Haverhill Water Department. Should the title of land upon which they are located is transferred the purchaser of the property, at that time, will assume all responsibilities set forth within this document.

## 1.2 OPERATION AND MAINTENANCE RESPONSIBILITIES

- The party or parties responsible for the funding, operation and maintenance of the BMP's shall be the City of Haverhill Water Department or their designees.
- BMP's each have specific maintenance requirements to ensure long-term effectiveness. These stormwater management systems will be operated, inspected and maintained on a regular basis by a qualified professional with expertise in inspecting drainage system components. All of the stormwater BMP's shall be kept in good working order at all times.
- A maintenance agreement providing for the funding, operation and maintenance of all the stormwater management BMP's shall be provided.

## 1.3 SCHEDULE FOR INSPECTION AND MAINTENANCE

- BMP's each have specific maintenance requirements to ensure long-term effectiveness. These stormwater management systems will be operated, inspected and maintained on a regular basis in accordance with this manual. All of the stormwater BMP's shall be kept in good working order at all times.

- As a minimum, the City of Haverhill Water Department shall follow the general guidelines outlined herein for the BMP's provided on this site.
- An Operation and Maintenance log must be maintained for the last three years, outlining inspections, repairs, replacement and disposal for each Best Management Practice (BMP). In the case of disposal, the log shall indicate the type and material and the disposal location. This rolling log shall be made available to the Mass DEP and/or the Framingham Planning Board (or designated Board or Commission) upon request.

## 1.4 OPERATION OF BEST MANAGEMENT PRACTICES

### 1.4.1 Deep Sump Hooded Catch Basins

Deep sump hooded catch basins are underground concrete structures which are designed to retain removed trash, debris and coarse sediment from stormwater runoff and serve as temporary spill containment devices for floatables such as oil and greases prior to discharge into a storm sewer pipe. The functions of a deep sump hooded catch basin include:

- A grate and/or vertical notch found in the curbing, that allow stormwater to enter the structure while filtering out larger objects such as trash and leaves; and
- A four foot (minimum) sump below the invert of the storm sewer pipe provides an area for detention time which allows sands and other sediments to settle out of the runoff prior to discharge.

### 1.4.2 Storm Drainage Pipes

Storm drainage pipes are made of various materials that provided a predictable flow and structural stability. A minimum diameter of 12" is usually specified in order to facilitate cleaning equipment. Drain pipes should not have any vertical or horizontal bends so that they can be inspected from end to end. Drain pipes have a maximum length to accommodate the limitations of cleaning equipment. The function of culverts and drain lines includes:

- Transport water safely from one point to another

### 1.4.3 Drainage Manholes (DMH)

Drainage manholes are usually made of reinforced concrete and are wide enough inside for a person to enter and work. An access cover and a ladder are provided. The function of manholes includes:

- Inspecting and cleaning of drainage lines
- Provide a means for drain lines to change vertical or horizontal direction.

### 1.4.4 Drainage Outlets

Drainage outlets are armored with riprap lined treatment to prevent erosion of soil at the outlet of culverts and storm drain pipes.

### 1.4.4 Drainage Swales

Vegetated drainage swales are open channels designed to treat and convey stormwater runoff. Vegetated swales provide water quality improvement when compared to traditional drainage pipes. Swales shall be inspected frequently until vegetation has established and following major storm events.

### 1.4.5 Depression Areas

A depression area is an impoundment for the short-term detention of stormwater runoff from a completed development that allows a controlled release from the structure at downstream, pre-development flow rates. Depression detention areas typically control peak runoff for 2-year and 10-year 24-hour storms. They are not specifically designed to provide extended dewatering times, wet pools, or groundwater recharge. Sometimes flows can be controlled using an outlet pipe of the appropriate size but this approach typically cannot control multiple design storms.

### 1.4.7 Level Spreader

A level spreader receives concentrated flow from channels, outlet structures, or other conveyance structures, and converts it to sheet flow where it can disperse uniformly across a stable slope. A level spreader is not a pollutant reduction device. It improves the efficiency of other BMPs, such as vegetated swales, filter strips, or infiltration systems that depend on sheet flow to operate properly.

Level spreaders are used in wide, level areas where concentrated runoff occurs. They should be placed on undisturbed soil that has been stabilized with vegetation. Disturbed soils are more erodible. If the spreader is not absolutely level, flow will concentrate at the low point and may worsen erosion problems. Flows to the level spreader should be relatively free of sediment, or the level spreader could be quickly overwhelmed by sediment and lose its effectiveness.

### 1.4.8 Check Dams

A check dam is a small dam constructed across a drainage ditch, swale, or channel to lower the velocity of flow. Reduced runoff velocity reduces erosion and gullying in the channel and allows sediments to settle out. A check dam may be built from stone, sandbags (filled with pea gravel), logs, or concrete. Check dams are relatively easy and inexpensive to construct. Permanent check dams should be constructed from stone or concrete. Sandbag dams filled with pea gravel or logs are suitable only as temporary practices. Never use a filter fence or a hay bale as a check dam, either on a temporary or permanent basis.

## 1.5 MAINTENANCE

Closed drainage systems in general are designed to be self-cleaning with only a limited amount of regular maintenance being required. So much emphasis is placed on the ability of the system to provide drainage control that it is not realized by most people that the design must also provide for this self-cleaning ability. Catch basin grates are designed to allow as much water as possible to enter the basin without allowing large debris to enter at the same time. Catch basins are typically provided with sumps at the bottom of the basins that collect sand and other heavy debris that gets into the system. Oil hoods are also provided at the basin exit pipes that prevent most oil, and other materials that float to the top, from entering the closed drainage system.

Some sand and debris will inevitably get into the drainage pipes. These pipes are sized to provide a minimum volume and velocity during storms that is capable of lifting and flushing these materials from the system. Drainage pipes are also sized to prevent too high a velocity from exiting the pipes that would create soil erosion problems. In some cases heavy rock or concrete rip rap is provided at the end of these pipes to create turbulence in order to dissipate some of this erosive energy. Drainage pipes are usually a minimum 12" diameter in order to accommodate mechanical cleaning systems.

Pre-treatment and treatment facilities are designed to collect and store sediments and in some cases recharge stored water into the groundwater supply. As a result of their function these facilities require more frequent inspection and maintenance.

### 1.5.1 Deep Sump Hooded Catch Basins and Drain Manholes

At a minimum, deep sump hooded catch basins and drain manholes shall be inspected four times per year. Ideally, inspection should be conducted at the end of the foliage and snow removal seasons, with remaining inspections at regular intervals between these times. Each structure should be cleaned whenever the depth of sediment deposits is greater than or equal to one half the depth of the sump from the bottom of the structure to the bottom of the lowest pipe invert, or at a minimum once per year. Structures shall be inspected for a buildup of sediments, oils and debris, cracks, breaks, or deformations. Any function of the catch basin and drain manhole that is not in working order will be replaced with similar materials, as per the detail, to prevent the storm sewer system from failing.

The catch basins and drain manholes shall be cleaned by means of hand held shovels, scallop shovel and/or vactor truck. The grate opening shall be clear of any foreign or lodged object. Sands and salts used in the winter will be removed from the catch basin sumps in the early spring. Leaves, pine needles, and branches brought down by autumn winds, rain, and cold weather will be removed from the catch basin and drain manhole sumps in the late fall.

Collected sediment and debris will be properly disposed of per local, state and federal requirements. Any sediment and debris removed from a catch basin deemed to be contaminated must be evaluated in accordance with the Hazardous Waste Regulations, 310 CMR 30.000, and handled as hazardous waste.

### 1.5.2 Storm Drainage Pipes

Inspect the drain lines once per year. The drain lines must also be inspected from within the drain manholes. Determine if debris is accumulating in the lines by visual inspection.

If there is an accumulation of debris within the pipe, clean the debris by high pressure flushing. Install haybales at the end of the drain lines to collect sediment. Collected sediment and debris will be properly disposed of per local, state and federal requirements. Any sediment and debris removed from a catch basin deemed to be contaminated must be evaluated in accordance with the Hazardous Waste Regulations, 310 CMR 30.000, and handled as hazardous waste.

### 1.5.3 Drainage Outlets

Inspect riprap after heavy rains to see if there are signs of erosion around or below the riprap. Immediately make all needed repairs to prevent further erosion.

### 1.5.4 Drainage Swales

The grass lined swales shall be mowed as required during the growing season. Any obstructions to flow, or signs of erosion shall be repaired within a week of discovery.

### 1.5.5 Depression Area

At least once per year, inspect wet areas to ensure that they are draining or releasing water as designed. Mow the area regularly during spring, summer and fall. Remove accumulated debris, including leaves from the depression area and any accumulate sediment. Repair vegetation as needed.

### 1.5.6 Level Spreader

Inspect level spreaders regularly, especially after large rainfall events. Note and repair any erosion or low spots in the spreader.

### 1.5.7 Check Dams

Inspect check dams after every significant rainfall event. Repair damage as needed. Remove sediment as needed.

## 1.6 SCHEDULE OF INSPECTION AND MAINTENANCE

**TABLE 1**
**INSPECTION AND MAINTENANCE FREQUENCY**

| BMPs | Inspection & Maintenance Frequency | | |
|---|---|---|---|
| | Spring | Fall | Heavy Rainfall |
| Catch Basins | X | X | X |
| Drain Pipes | X | | X |
| Drainage Manholes | X | | X |
| Drainage Outlets | | | X |
| Drainage Depression | X | X | X |
| Swales | X | X | X |
| Level Spreader | X | X | X |
| Check Dams | | | X |

## 1.7 ESTIMATED O&M BUDGET

**TABLE 2**
**INSPECTION AND MAINTENANCE BUDGET**

| Task | Cost ($) | | | | | Annual Total ($) |
|---|---|---|---|---|---|---|
| | Spring | Summer | Fall | Winter | Occasional | |
| Inspection & Documentation | 500 | | 500 | | 500 | 1,500 |
| Maintenance & Repair | | | | | | |
| Cleaning & Flushing | 500 | | 500 | | | 1,000 |
| Loam, Seed, Mulch | 300 | | 300 | | | 600 |
| Mowing | 300 | 600 | 300 | | | 1,200 |
| Structural | | | | | 1000 | 1,000 |
| | | | | | **Average Cost ($)** | **5,300** |

## 1.8 O&M LOG FORM

## Stormwater BMP Inspection and Maintenance Log

| | |
|---|---|
| Facility Name | |
| Address | |
| Begin Date | End Date |

| Date | BMP ID# | BMP Description | Inspected by: | Cause for Inspection | Exceptions Noted | Comments and Actions Taken |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

Instructions: Record all inspections and maintenance for all treatment BMPs on this form. Use additional log sheets and/or attach extended comments or documentation as necessary. Submit a copy of the completed log with the annual independent inspectors' report to the municipality, and start a new log at that time.

- § BMP ID# — Always use ID# from the Operation and Maintenance Manual.
- § Inspected by — Note all inspections and maintenance on this form, including the required independent annual inspection.
- § Cause for inspection — Note if the inspection is routine, pre-rainy-season, post-storm, annual, or in response to a noted problem or complaint.
- § Exceptions noted — Note any condition that requires correction or indicates a need for maintenance.
- § Comments and actions taken — Describe any maintenance done and need for follow-up.

# SECTION 2

# LONG TERM POLLUTION PREVENTION PLAN

## 2.1 HOUSEKEEPING OPERATIONS

1. Good housekeeping and material management reduce the risk of spills or other accidental exposure of materials and substances to stormwater runoff.
    a. All materials stored on-site must be stored in a neat, orderly manner in their appropriate containers and, if possible, under a roof or other enclosure.
    b. Products shall be kept in their original containers with the original manufacturer's label.
    c. Substances should not be mixed with one another unless recommended by the manufacturer.
    d. Whenever possible, all of a product will be used up before disposing of a container.
    e. Original materials label and material safety data sheets (MSDS) shall be kept by the Owner.
    f. Petroleum products:
        - All on-site vehicles and parking areas shall be monitored weekly for leaks and spills. Spills shall be cleaned immediately.
        - Petroleum products shall be stored under cover and shall be in tightly sealed containers that are clearly labeled.
    g. Fertilizers:
        - Fertilizers shall only be used in the minimum amounts as recommended by the manufacturer.
        - The contents of any un-used fertilizer shall be transferred to a clearly labeled, sealable plastic bin, to avoid spillage.
    h. Paints solvents.
        - All paints and solvents shall be stored in original manufacturer's containers in a covered location.
        - The use of paints and solvents shall, whenever possible, be limited to service or storage bays. Where not possible, the work area shall be protected with impermeable drop clothes or tarps. At no point shall material be used in parking or access ways that are tributaries to the drainage system.

2. Spill Control Practices:
    a. Manufacturer's recommended methods shall be clearly posted for spill clean-up and Water Department personnel shall be made aware of the procedures and the locations of cleanup information and supplies.
    b. Material and equipment necessary for spill clean-up will be kept on-site in a designated material storage area. Equipment will include, but not be limited to, brooms, dust pans, mops, rags, gloves, goggles, absorbent materials, sand,

sawdust and plastic & metal trash containers specifically kept and labeled for this purpose.

c. All spills must be cleaned-up immediately after discovery.
d. Spills of toxic or hazardous material must be reported to the appropriate state, local or federal agency, as required by-law.

3. The washing of vehicles shall be limited to areas within the buildings that are served by a floor drain system and on-site tight tank. Wash water with its combination of solvents, detergents and oil/greases should not be allowed to enter any part of the on-site drainage system.

4. Snow plowing operations shall stockpile snow, ice and accumulated materials in areas where snow melt will flow into the on-site drainage systems, including drainage basins. No plowing or storage of snow is allowed in bio-retention areas or wetland resource areas.

5. During winter conditions sand use site-wide shall be applied to the minimum extent possible to maintain safe conditions.

6. The usage of Sodium Chloride for snow and ice removal shall be used with caution and limited due to the proximity of the site to an outstanding water resource.

7. Pet waste shall be picked up on-site and disposed of in appropriate trash receptacles.

**Emergency Contacts:**

**Haverhill Fire Department: 978-373-8460**
**Haverhill Police Department & Emergency Dispatch: 978-373-1212**