14. VOLUMETRIC REDUCTION STANDARDS

The Stormwater Management rules at N.J.A.C. 7:8-5.6 et seq. incorporate volumetric reduction standards to reduce runoff volume discharged from a major development site. By requiring the reduction of runoff volume generated by more frequent, smaller storm events, communities will experience less frequent localized flooding during more frequent, smaller storm events. Further, less sediment will be transported offsite, which will reduce the required frequency of sediment removal from downstream catch basins, pipes and stormwater management basins. Additionally, less overall, pollutant-carrying stormwater runoff will reach downstream waterbodies, which will serve to improve water quality and reduce fluvial flooding. During larger storm events, since the retained volume of stormwater will not be discharged off-site, less runoff will go into the stream and storm sewer system. The streams and storm sewer system will have more capacity to mitigate the increased runoff from increased precipitation due to climate change and reduce the chance of flooding.

Volumetric Reduction Standards

The volumetric reduction standards at N.J.A.C. 7:8-5.6(d) are as follows:

1. *Stormwater management measures shall be designed to achieve retention of the water quality design storm by incorporating green infrastructure BMPs from Table 5-1 and Table 5-2 unless (d)1i below applies:*

    i. *Where an applicant demonstrates that compliance with this paragraph is technically impracticable as set forth at N.J.A.C. 7:8-4.6(a)1, or the type of stormwater is subject to N.J.A.C. 7:8-5.4(b)3, a major development site shall instead meet the hydrograph requirements at (d)1i(1) and (2) below:*

        (1) *The runoff peak flow rate of the water quality design storm from the site shall be less than the runoff peak flow rate of the water quality design storm from a drainage area equivalent to the size of the disturbed area of the major development, with a woods cover type, in good hydrologic condition and on Hydrologic Soil Group D soil; and*
        (2) *The runoff hydrograph duration of the water quality design storm from the site shall be greater than the runoff hydrograph duration of the water quality design storm from a drainage area equivalent to the size of disturbed areas of the major development, with a woods cover type, in good hydrologic condition, and on Hydrologic Soil Group D soil. For the purposes of this sub-subparagraph, "runoff hydrograph duration" means the duration between the time that the runoff flow rate starts to be greater than zero to the time that the runoff flow rate becomes zero.*

2. *In the alternative of (d)1 above, the applicant may address all or a portion of the volumetric reduction standards, as follows:*

    i. *The applicant shall undertake one or both of the following:*

(1) Removal of existing impervious surface totaling an area equal to or greater than the impervious surface within the disturbed portions of the major development site; and/or

(2) Retention of an equivalent or greater volume of stormwater runoff generated by the water quality design storm required pursuant to (d)1 above at an offsite location. Runoff retained from storms other than the water quality design storm shall not be counted toward compliance with this requirement.

i. Volumetric reduction pursuant to (d)2i above shall occur within the same HUC-14 as the major development, except where the applicant is a public transportation entity that demonstrates providing volumetric reduction within the same HUC-14 is technically impracticable as set forth at N.J.A.C. 7:8-4.6(a)1, in which case the applicant shall provide volumetric reduction within the same Watershed Management Area as the major development, and as close as practicable to the major development.

ii. Any application for a major development that utilizes offsite impervious surface removal or retention to comply with the volumetric reduction standards must be accompanied by sufficient information and property owner permission to fully review and approve the offsite portion of the project along with the major development itself. Applications utilizing offsite impervious surface removal or retention without this information shall not be considered complete. Further, any offsite portions of the project must be constructed prior to, or concurrent with, the major development.

3. The volumetric reduction standards of this subsection shall not be applicable to projects that are undertaken by a public transportation entity in cases where the project meets the definition of major development solely because the project results in increased capacity of an existing stormwater conveyance system.

Retention of runoff by infiltration

N.J.A.C. 7:8-1.2 defines retention as retaining the stormwater runoff generated from development by infiltration, evapotranspiration or reuse of stormwater runoff without the discharge of the stormwater directly or indirectly to surface waters or to a treatment works. Accordingly, the onsite retention of Water Quality Design Standard (WQDS) runoff at N.J.A.C. 7:8-5.6(d)1 can be achieved through stormwater BMPs that infiltrate into subsoil, such as dry wells, small-scale or large-scale bioretention systems, small-scale or large-scale infiltration basins, pervious paving systems, or small-scale or large-scale sand filters. Alternatively, a major development project may retain an equivalent or greater volume of stormwater runoff generated by the water quality design storm required pursuant to N.J.A.C. 7:5-6(d)2 at an offsite location.

Retention of runoff by evapotranspiration or reuse

Stormwater BMPs that retain runoff onsite other than infiltration, such as green roofs, cisterns and GI wet ponds, through evapotranspiration and beneficial reuse can also be utilized to achieve the volumetric reduction standards. The volumetric reduction standards at N.J.A.C. 7:5-6(d)1 can also be met by

beneficial reuse of the runoff onsite through cisterns and GI wet ponds. The runoff volume generated by WQDS from the disturbed area needs to be used onsite in three days to meet the volumetric reduction standards. Ch. 9.1: Cisterns and Ch. 10.5: Wet Ponds (GI) of the BMP Manual provide design criteria and examples.

Extension of the post-construction WQDS runoff hydrograph and attenuate peak flow rates onsite

In some instances, onsite retention cannot be met for engineering, environmental or safety reasons. For example, the subsoil has a tested saturated soil hydraulic conductivity rate less than 1 inch per hour or the site has a very high seasonal high water table (SHWT) that cannot maintain a required SHWT separation. Also, infiltration of runoff is prohibited when the runoff is from areas of high pollutant loading or from an industrial site where the source material is exposed to stormwater as set forth at N.J.A.C. 7:8-7:8-5.4(b)3. When onsite retention cannot be met by infiltration of runoff, the volumetric reduction standards can be met by stormwater BMPs that can attenuate the post-construction WQDS peak flow rate and extend the runoff hydrograph duration to release the runoff as an undisturbed wooded area on Hydrologic Soil Group (HSG) 'D' soil. A runoff hydrograph duration means the duration between the time that the runoff flow rate starts to be greater than zero to the time that the runoff flow rate becomes zero. Stormwater BMPs, such as grass swales, underdrained bioretention systems, underdrained pervious paving systems, underdrained sand filters, vegetative filter strips and standard constructed wetlands can be used to meet the peak flow rate and runoff hydrograph duration requirements at N.J.A.C. 7:8-5.6(d)1i.

Incorporate multiple Stormwater BMPs to meet the volumetric reduction standards

Stormwater BMPs can be arranged in series to achieve the volumetric reduction standards. For example, a site may use a green roof to retain a portion of the roof runoff and use an infiltration type BMP to achieve the onsite retention requirements, or the site may use a green roof in series with a grass swale and underdrained BMP to achieve the peak flowrate and runoff hydrograph duration requirements in N.J.A.C. 7:8-5.6(d)1i. Furthermore, a site may be designed to meet the onsite retention in N.J.A.C. 7:8-5.6(d)1 in a portion of the site but use other types of stormwater BMPs to meet the peak flow rate and runoff hydrograph duration requirements on the other portion of the site, where the portion of the site is technically impracticable to meet the onsite retention or the runoff from the area is prohibited to recharge runoff as set forth at N.J.A.C. 7:8-5.4(b)3.

Remove existing impervious surface to meet N.J.A.C. 7:5-6(d)2

As an alternative to meeting the volume reduction standard, N.J.A.C. 7:5-6(d)2 allows for the removal of existing impervious surface totaling an area equal to or greater than the impervious surface within the disturbed portions of the major development site. The removal of existing impervious surface should be performed in a hierarchical order to provide the greatest pollutant removal and volume reduction benefit as follows, where possible:

1. An impervious surface that is also a motor vehicle surface, where the runoff is not managed by any stormwater measures before the runoff is discharged to environmentally critical areas as defined in N.J.A.C. 7:8-1.2 or into a receiving water that has a Total Maximum Daily Load Established for a stormwater related pollutant.

2. An impervious surface where the runoff discharges to a combined sewer system.

3. An impervious surface that is also a motor vehicle surface, where the runoff discharges to a water body directly or through stormwater conveyance system without any stormwater management.

4. An impervious surface that is not a motor vehicle surface, where the runoff is not managed by any stormwater measures before the runoff is discharged to environmentally critical areas as defined in N.J.A.C. 7:8-1.2 or into a receiving water that has a Total Maximum Daily Load Established for a stormwater related pollutant.

5. An impervious surface that is also not a motor vehicle surface, where the runoff discharges to a water body directly or through stormwater conveyance system without any stormwater management.

6. An impervious surface that is also a motor vehicle surface, where the runoff discharges to a stormwater management measure constructed prior to the current Stormwater Control Ordinance (SCO) or Stormwater Management rules. In this case, older stormwater management measures should be given higher priority. For example, removal of an impervious surface that discharges into a detention basin from 1975 should be given higher priority than removal of an impervious surface that discharges into a detention basin from 2012.

7. An impervious surface that is not a motor vehicle surface, where the runoff discharges to a stormwater management measure constructed prior to the current Stormwater Control Ordinance (SCO) or Stormwater Management rules. In this case, older stormwater management measures should be given higher priority. For example, removal of an impervious surface that discharges into a detention basin from 1975 should be given higher priority than removal of an impervious surface that discharges into a detention basin from 2012.

8. Any other impervious surface.

The impervious surface to be removed offsite shall be within the same HUC-14 as the major development, except the applicant of the major development project is a public transportation entity that demonstrates providing volumetric reduction within the same HUC-14 is technically impracticable as set forth at N.J.A.C. 7:8-4.6(a)1, in which case the applicant shall provide volumetric reduction within the same Watershed Management Area as the major development and as close as practicable to the major development.

The disturbed area associated with the removed impervious surface shall be revegetated within 6 months of the start of work to be qualified as temporary disturbance that will not be counted toward to the threshold of a major development. The removal of the impervious surface may be subject to the New Jersey *Standards for Soil Erosion and Sediment Control* and may need an application to the local Soil Control District.

Design Examples Meeting the Volumetric Reduction Standards

Example 14-1: Retention of the Water Quality Design Storm through Infiltration

A 2-acre wooded area in Morris County is to be developed. The site is on HSG 'C' soil. The proposed development will consist of 1 acre of building area, 0.5 acres of parking area and 0.5 acres of lawn area. The tested permeability of the subsoil is 2 in/hr, which is suitable for an infiltration type BMP. Therefore, a small-scale infiltration basin is proposed to meet the stormwater quantity, quality, groundwater recharge and volumetric reduction standards. Note that the models and calculations presented below only show the design for the volumetric reduction standards. For the design to meet stormwater water quantity, quality and groundwater recharge standards, *Chapters 5*, *6* and *9.8* of the *BMP Manual* provide various examples for detailed calculations.

Per N.J.A.C. 7:8-5.6(d)1, stormwater management measures shall be designed to achieve retention of the water quality design storm by incorporating green infrastructure BMPs from Table 5-1 and Table 5-2. Retention is further defined as retaining the stormwater runoff generated from development by infiltration, evapotranspiration or reuse of stormwater runoff without the discharge of the stormwater directly or indirectly to surface waters or to a treatment works. In this example, the stormwater runoff from the WQDS will be retained via infiltration in the small-scale infiltration basin, which is listed in Table 5-1.

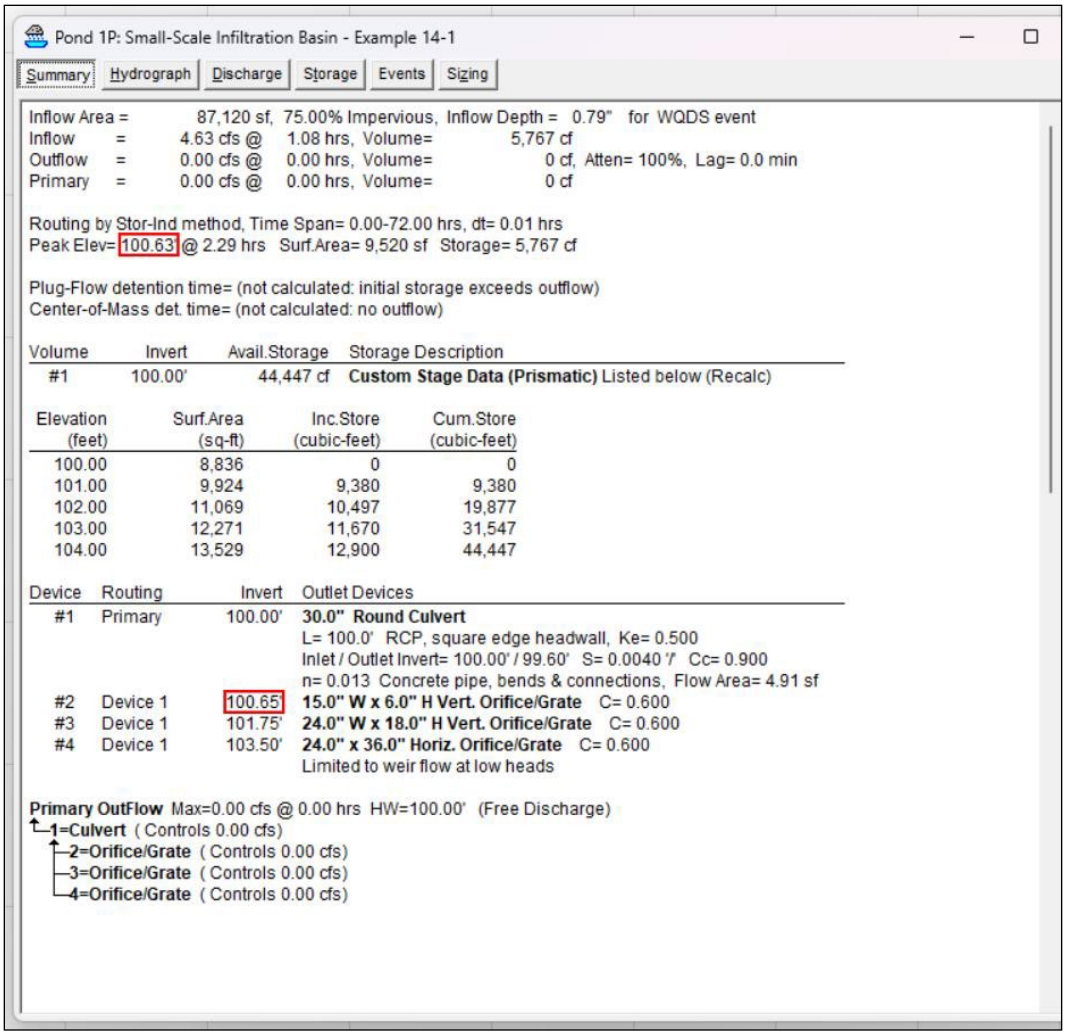
It is important to note that unlike the stormwater quality standards which only apply to the WQDS runoff generated by motor vehicle surface, the volumetric reduction standards apply to the WQDS runoff generated by all surfaces in the disturbed area. All surfaces, regardless of land cover, have the potential to generate WQDS runoff.

Taking this into consideration, and looking at the hydrological and hydraulic model, the three different land covers produce the following WQDS runoff:

1. 1 Acre of Building Area (CN=98) = 3,755 cubic feet of WQDS runoff,
2. 0.5 Acres of Parking Area (CN = 98) = 1,878 cubic feet of WQDS runoff and
3. 0.5 Acres of Lawn Area (CN 74) = 134 cubic feet of WQDS runoff,

for a total of 5,767 cubic feet.

Because all three surfaces generate WQDS runoff, the runoff from all three surfaces needs to be captured and retained by the small-scale infiltration basin. Looking at the model output, the WQDS is at elevation 100.63 feet. Because of this, the first orifice is placed at elevation 100.65 feet. This depth of 0.65 feet is less than the allowed 2 feet, so this is permissible. Putting the first orifice at elevation 100.65 feet allows all of the WQDS runoff from the proposed development to be infiltrated, meeting the volumetric reduction standards.



Pond 1P: Small-Scale Infiltration Basin - Example 14-1

Summary | Hydrograph | Discharge | Storage | Events | Sizing

Inflow Area = 87,120 sf, 75.00% Impervious, Inflow Depth = 0.79" for WQDS event
Inflow = 4.63 cfs @ 1.08 hrs, Volume= 5,767 cf
Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0 cf, Atten= 100%, Lag= 0.0 min
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Peak Elev= 100.63 @ 2.29 hrs Surf.Area= 9,520 sf Storage= 5,767 cf

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

Volume	Invert	Avail.Storage	Storage Description
#1	100.00'	44,447 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
100.00	8,836	0	0
101.00	9,924	9,380	9,380
102.00	11,069	10,497	19,877
103.00	12,271	11,670	31,547
104.00	13,529	12,900	44,447

Device	Routing	Invert	Outlet Devices
#1	Primary	100.00'	**30.0" Round Culvert** L= 100.0' RCP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 100.00' / 99.60' S= 0.0040 '/' Cc= 0.900 n= 0.013 Concrete pipe, bends & connections, Flow Area= 4.91 sf
#2	Device 1	100.65'	**15.0" W x 6.0" H Vert. Orifice/Grate** C= 0.600
#3	Device 1	101.75'	**24.0" W x 18.0" H Vert. Orifice/Grate** C= 0.600
#4	Device 1	103.50'	**24.0" x 36.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=100.00' (Free Discharge)
↑**1=Culvert** (Controls 0.00 cfs)
  ↑**2=Orifice/Grate** (Controls 0.00 cfs)
  ↑**3=Orifice/Grate** (Controls 0.00 cfs)
  ↑**4=Orifice/Grate** (Controls 0.00 cfs)

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Example 14-2: Use of an Underdrained Small-Scale Bioretention System to Meet N.J.A.C. 7:5-6(d)1i(1) and (2)

A 2-acre wooded area in Morris County is to be developed. The site is on HSG 'C' soil. The proposed development will consist of 0.75 acres of building area, 0.5 acres of parking area, 0.25 acres of lawn area and 0.5 acres of undisturbed wooded area. Although the site is on HSG 'C' soil, the tested saturated soil hydraulic conductivity rate of the most restrictive subsoil layer under the proposed stormwater BMP is less than 1 in/hr, which is not suitable for infiltration type BMPs. Therefore, an underdrained small-scale bioretention system is proposed to meet the stormwater quality, stormwater quantity and volumetric reduction standards.

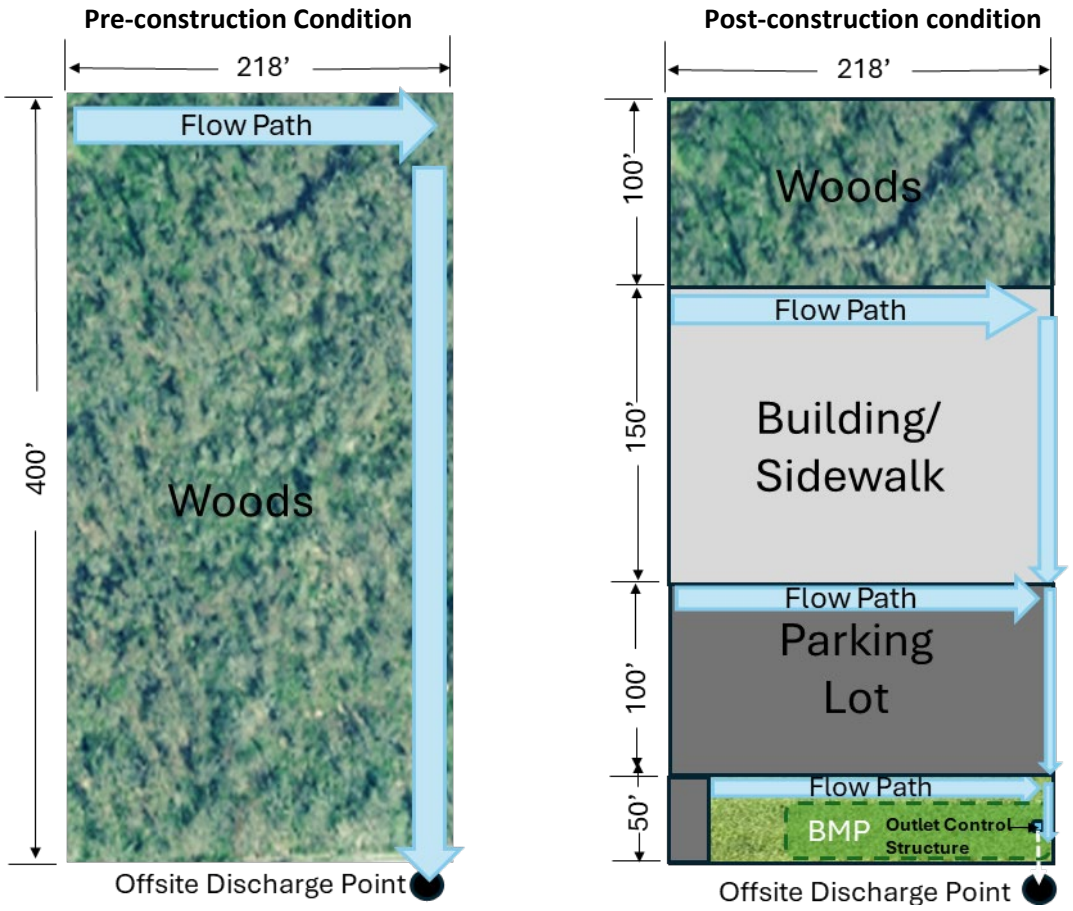
The arrangement of the site and development is as follows:

Wooded area under pre-construction conditions (2 ac):	400 ft by 218 ft
Undisturbed wooded area (0.5 ac):	100 ft by 218 ft
Wooded area to be disturbed (1.5 ac):	300 ft by 218 ft, consisting of
Proposed building (0.75 ac):	150 ft by 218 ft

Proposed parking lot (0.5 ac):	100 ft by 218 ft
Proposed lawn area (0.25 ac):	50 ft by 218 ft

The slope of the site in both pre- and post-construction conditions is 1%.
The runoff at the pre-construction condition will flow toward to the right boundary of the site and then flow down to the south corner of the site before the runoff leaves the site.

Conceptual layouts of the site are illustrated below.



The models and calculations presented below show the design for the volumetric reduction standards only. For the design to meet stormwater water quantity, quality and groundwater recharge standards, *Chapters 5*, *6* and *9.7* of the *BMP Manual* provide detailed calculations and examples.

Step 1: Identify the disturbed area subject to the volumetric reduction standards

In accordance with N.J.A.C. 7:8-5.6(d)1i(1), the post-construction runoff peak flow rate of the WQDS from the site shall be less than the runoff peak flow rate of the WQDS from a drainage area equivalent to the size of the disturbed area of the major development, with a woods cover type, in good hydrologic condition and on HSG 'D' soil. Although the wooded area before the construction is 2 acres, the proposed major development will disturb only 1.5 acres. Therefore, the drainage area to calculate the equivalent

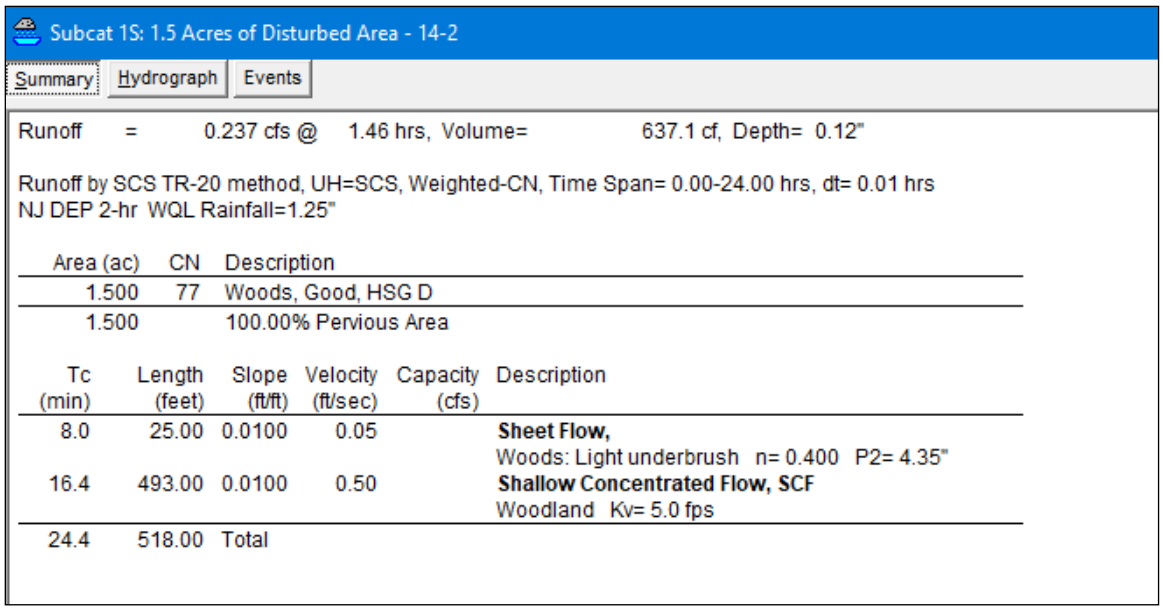
wooded area is 1.5 acres. The hydrologic and hydraulic analysis shall show the peak flow rate for this equivalent 1.5-acre woods.

In accordance with N.J.A.C. 7:8-5.6(d)1i(2), the runoff hydrograph duration of the water quality design storm from the site shall be greater than the runoff hydrograph duration of the water quality design storm from a drainage area equivalent to the size of disturbed areas of the major development, with a woods cover type, in good hydrologic condition, and on HSG 'D' soil. The "runoff hydrograph duration" means the duration between the time that the runoff flow rate starts to be greater than zero to the time that the runoff flow rate becomes zero. Therefore, the hydrologic and hydraulic analysis of the equivalent 1.5-acre woods needs to include the hydrograph and its duration.

Step 2: Hydrologic and hydraulic analysis for the equivalent wooded area

The volumetric reduction standards require the equivalent woods to be analyzed in good hydrologic condition and on HSG D soil. From Table 9-1 in Ch. 9 of the *National Engineering Handbook*, the Curve Number (CN) for a wooded area on HSG 'D' soil in good hydrologic condition is 77.

The flow path of runoff from the equivalent 1.5-acre wooded area to the offsite discharge point follows the flow pattern in the pre-construction condition that flows to the right boundary and down to the south corner of the site. Therefore, the flow path will be 300 feet and 218 feet, which results in 518 feet. Sheet flow length calculated by McCuen-Spiess limitation is 25 feet. The remaining flow path, 493 feet, is shallow concentrated flow. The 2-year storm for the calculation of time of concentration shall use the projected 2-year storm, i.e., 4.53 inches, which is the current 3.54 inches for Morris County multiplied by the respective Future Precipitation Change Factor of 1.23. The hydrologic and hydraulic model for the 1.5-acre woods is shown below. The peak flow rate is 0.237 cfs. The hydrograph starts at 1.10 hours and ends at 3.0 hours. As a result, the runoff hydrograph duration is 1.9 hours.



Subcat 1S: 1.5 Acres of Disturbed Area - 14-2

Summary | Hydrograph | Events

Runoff = 0.237 cfs @ 1.46 hrs, Volume= 637.1 cf, Depth= 0.12"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NJ DEP 2-hr WQL Rainfall=1.25"

Area (ac)	CN	Description
1.500	77	Woods, Good, HSG D
1.500		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.0	25.00	0.0100	0.05		**Sheet Flow,** Woods: Light underbrush n= 0.400 P2= 4.35"
16.4	493.00	0.0100	0.50		**Shallow Concentrated Flow, SCF** Woodland Kv= 5.0 fps
24.4	518.00	Total			

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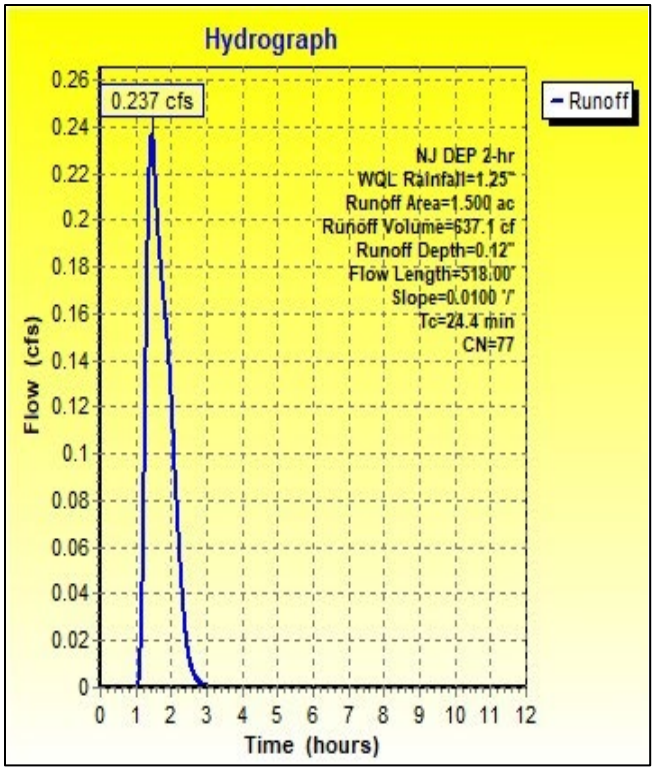


Subcat 1S: 1.5 Acres of Disturbed Area

Summary | Hydrograph | Events

Time (hours)	Precip. (inches)	Excess (inches)	Runoff (cfs)
0.00	0.00	0.00	0.000
0.50	0.10	0.00	0.000
1.00	0.63	0.00	**0.000**
1.50	1.15	0.09	**0.232**
2.00	**1.25**	**0.12**	0.125
2.50	1.25	0.12	0.014
3.00	1.25	0.12	0.001
3.50	1.25	0.12	0.000
4.00	1.25	0.12	0.000
4.50	1.25	0.12	0.000
5.00	1.25	0.12	0.000
5.50	1.25	0.12	0.000
6.00	1.25	0.12	0.000
6.50	1.25	0.12	0.000
7.00	1.25	0.12	0.000
7.50	1.25	0.12	0.000
8.00	1.25	0.12	0.000
8.50	1.25	0.12	0.000
9.00	1.25	0.12	0.000

Source: HydroCAD® Hydrograph Graph and Tabular Report; HydroCAD is a registered trademark of HydroCAD Software Solutions LLC. Used with permission.

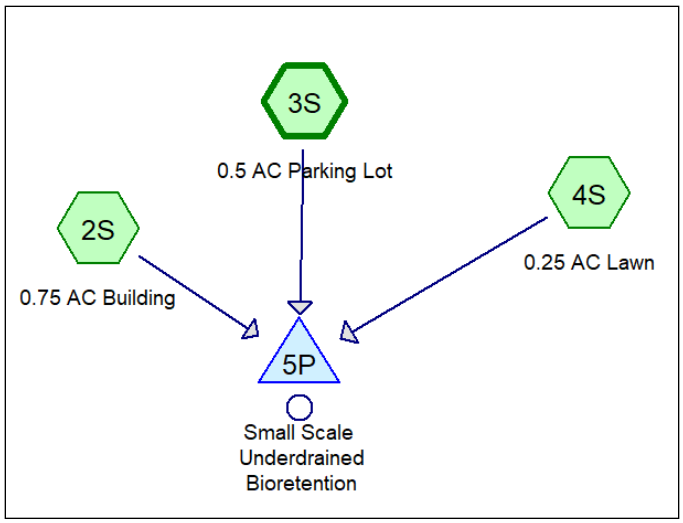
Step 3: Hydrologic and hydraulic analysis for the post-construction condition

The parameters of the hydrologic and hydraulic models for the buidling, parking lot and the lawn area are shown below:

Land Cover	CN	Sheet Flow Length (ft)	Shallow Concentrated Flow Length (ft)	Mannings's n	Slope
Building	98	100	268	0.011	1%
Parking Lot	98	100	218	0.011	1%
Lawn	74	50	218	0.15	1%

The combined peak flow rate from those three sources before entering the proposed bioretention BMP is 3.817 cfs. A 7,600 sf underdrained bioretention BMP is designed to meet the peak flow rate and runoff hydrograph duration requirements of the volumetric reduction standards. The underdrained bioretention BMP is arranged as 47.5 feet wide and 160 feet long. The bioretention BMP is installed with a 150-foot, 4 inch perforated corrogated pipe as the underdrain. The 4 inch perforated pipe is burried within a 1-foot crushed stone bed. The sand layer and the soil bed are 6 inches and 24 inches, respectively, in accordance with the design criteria in Ch. 9.8 of the BMP Manual. A 40% void ratio is assigned to the crushed stone layer where runoff will be drained and provide a temporary storage during the hydraulic modeling. No void ratio is assigned to the sand layer and soil bed because the soil bed is supposed to remain moist to sustain the planting, which significantly reduces the temporary storage during the hydraulic modeling.

The underdrains consist of perforated pipes connected to a outlet control structure. A 2.0 inch orifice is installed to control the flow from the perforated pipe. An 8 inch discharge pipe is connected to the outlet control structure. The invert of the 2.0 inch orifice is at EL 98.5 ft. Take note that the any flow control device, such as an orifice, weir, grate or perforated pipe, at the outlet of the stormwater management measures shall be designed to prevent the clogging of the flow control device while achieving the design and performance standards at N.J.A.C. 7:8-5.4, 5.5, and 5.6. The outlet and underdrain configurations shown in the model below are for example purposes only. Design engineers may have other configurations.



Source: HydroCAD® Diagram; HydroCAD is a registered trademark of HydroCAD Software Solutions LLC. Used with permission. Each numbered element is called a "node."

Inflow Area = 65,340 sf, 83.33% Impervious, Inflow Depth = 0.87" for WQL event
Inflow = 3.817 cfs @ 1.09 hrs, Volume= 4,761 cf
Outflow = 0.235 cfs @ 1.81 hrs, Volume= 4,761 cf, Atten= 94%, Lag= 43.1 min
Primary = 0.235 cfs @ 1.81 hrs, Volume= 4,761 cf

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs / 2
Peak Elev= 103.60' @ 1.81 hrs Surf.Area= 7,600 sf Storage= 3,826 cf

Plug-Flow detention time= 190.7 min calculated for 4,760 cf (100% of inflow)
Center-of-Mass det. time= 190.8 min (259.1 - 68.3)

Volume	Invert	Avail.Storage	Storage Description
#1	100.00'	33,440 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Voids (%)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
100.00	7,600	0.0	0	0
101.00	7,600	40.0	3,040	3,040
101.50	7,600	0.0	0	3,040
103.50	7,600	0.0	0	3,040
104.50	7,600	100.0	7,600	10,640
105.50	7,600	100.0	7,600	18,240
106.50	7,600	100.0	7,600	25,840
107.50	7,600	100.0	7,600	33,440

Device	Routing	Invert	Outlet Devices
#1	Device 2	98.50'	**2.0" Vert. Low Flow Control Device** C= 0.600
#2	Primary	98.50'	**8.0" Round Discharge Pipe** L= 25.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 98.50' / 86.00' S= 0.5000 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 0.35 sf
#3	Device 2	104.13'	**2.5" Vert. 1st Orifice above Soil Bed** C= 0.600
#4	Device 2	105.50'	**4.0" Vert. 2nd Orifice above Soil Bed** C= 0.600
#5	Device 2	106.75'	**20.0' long x 0.5' breadth Top Overflow Weir for 100 Year Storm** Head (feet) 0.20 0.40 0.60 0.80 1.00 Coef. (English) 2.80 2.92 3.08 3.30 3.32
#6	Primary	107.10'	**10.0' long x 5.0' breadth Spillway** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.34 2.50 2.70 2.68 2.68 2.66 2.65 2.65 2.65 2.65 2.67 2.66 2.68 2.70 2.74 2.79 2.88

Primary OutFlow Max=0.235 cfs @ 1.81 hrs HW=103.60' (Free Discharge)
- **2=Discharge Pipe** (Passes 0.235 cfs of 2.898 cfs potential flow)
  - **1=Low Flow Control Device** (Orifice Controls 0.235 cfs @ 10.79 fps)
  - **3=1st Orifice above Soil Bed** (Controls 0.000 cfs)
  - **4=2nd Orifice above Soil Bed** (Controls 0.000 cfs)
  - **5=Top Overflow Weir for 100 Year Storm** (Controls 0.000 cfs)
- **6=Spillway** (Controls 0.000 cfs)

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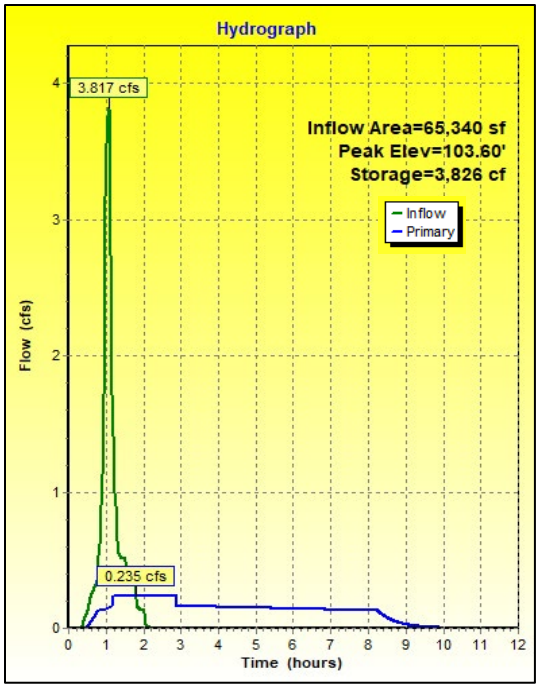

Time (hours)	Inflow (cfs)	Storage (cubic-feet)	Elevation (feet)	Primary (cfs)
0.00	0.000	0	100.00	0.000
0.50	0.120	32	100.01	0.018
1.00	**3.340**	1,111	100.37	0.140
1.50	**0.508**	**3,645**	**103.58**	**0.235**
2.00	0.132	**3,766**	**103.60**	**0.235**
2.50	0.000	3,372	103.54	0.234
3.00	0.000	2,978	100.98	0.163
3.50	0.000	2,688	100.88	0.159
4.00	0.000	2,404	100.79	0.156
4.50	0.000	2,126	100.70	0.153
5.00	0.000	1,854	100.61	0.150
5.50	0.000	1,588	100.52	0.146
6.00	0.000	1,328	100.44	0.143
6.50	0.000	1,073	100.35	0.140
7.00	0.000	825	100.27	0.136
7.50	0.000	582	100.19	0.133
8.00	0.000	345	100.11	0.130
8.50	0.000	138	100.05	0.078
9.00	0.000	50	100.02	0.028
9.50	0.000	18	100.01	0.010
10.00	0.000	7	100.00	0.004
10.50	0.000	2	100.00	0.001
11.00	0.000	1	100.00	0.000
11.50	0.000	0	100.00	0.000

Source: HydroCAD® Hydrograph Graph and Tabular Report; HydroCAD is a registered trademark of HydroCAD Software Solutions LLC. Used with permission.

The hydrologic and hydraulic model shows that the peak flow rate for the WQDS is 0.235 cfs. The hydrograph of the discharge starts at 0.5 hours and ends at 10.50 hours, which results in a runoff hydrograph duration of 10 hours. The hydrologic and hydraulic analysis demostrates that the proposed underdrained bioretention BMP has a smaller peak flow rate and longer runoff hydrograph duration than the equivalent woods on HSG D soil. The volumetric reduction standards are met.

References

USDA Natural Resources Conservation Service. National Engineering Handbook, Part 630, Hydrology. Washington D.C.