Mitigation of Stormwater Runoff from Ivy and Emmet Street Redevelopment Site

A Technical Report
presented to the faculty of the
School of Engineering and Applied Science
University of Virginia

by

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with

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

Signed: ____

Approved: ____________________________________ Date ______________________
Teresa Culver, Department of Civil Engineering

Table of Contents

Section 1

Overall Development Proposal

Overview

We were asked to design a site layout and an onsite stormwater system that can serve as a gateway to the University of Virginia grounds at the Ivy Corridor Project Area, taking into account environmental concerns and historical flood risks. The goals of the Ivy Corridor Strategic Planning Study should be honored including: improve arrival experience to Grounds, improve connectivity to North Grounds, and enhance stormwater ecology and mixed-use on the site. The minimum site requirements include: maintain the Ivy Parking Garage, provide at least 200-bed hotel space with 5,000 square feet of conference space, provide at least 20,000 square feet of retail space, and provide at least 20% of open space on the site.

Our design is centered around the existing stream and a large pond, with ample open space provided for the University community to congregate and take advantage of. Upon arriving to Grounds, visitors will see the pond and greenery when driving down Emmet Street. The proposed buildings provide plenty of academic space for classes to be held for students, while also consisting of retail space and a large hotel for visitors. The stormwater will be maintained using Best Management Practices (BMP's) that also contribute to the scenery and green space, particularly with a bioretention system that will have a variety of native plants and shrubs. Our unique design fulfills all the requirements while maintaining the goals and desires outlined to create a space welcoming to everyone in the University community.

Site Layout Plan

Our recommended site development plan maintains the Existing Ivy Parking Garage and includes:

Building Floors and Square Footage

Building Type	Number of Floors	Total Square Footage
Academic Building 1	3	60,000
Retail Space	1	28,000
Academic Building 2	4	110,000
Academic Building 3	4	115,000
Hotel (with Conference Space)	4	150,000

Rentable Square Footage (RSF) consists of the Retail Space square footage of 28,000 square feet. The Gross Square Footage (GSF) is 463,000 square feet, and the breakdown for each building is shown above. The stormwater management features, or BMP's, that will also serve aesthetic purposes include a pond, bioretention, and dry swale. The pond is located next to the Emmet and Ivy Road intersection to serve as a nice aesthetic feature for those driving down Emmet Street to the University of Virginia. Walking paths are provided around the pond with access to the nearby Academic Building 1 and Retail Space for easy pedestrian access. The dry swale is located next to the Hotel with the bioretention closeby in the provided open space near the Hotel and Academic Building 3.

The Academic Building 1 and Retail Space are closest to Emmet Street near the Ivy Parking Garage. The area surrounding the pond serves as open space for use by University pedestrians. The natural stream will stay preserved with wooded tree buffers and flow from just beyond the Ivy Parking Garage to the pond. Academic Building 2 is off of Ivy Road and situated between the existing road entrance into the Ivy Parking Garage and the proposed road. The backside of the building looks onto the natural stream and open space. Academic Building 3 is off of Ivy Road and situated to the left of the proposed road. The backside of the building looks onto the bioretention. The Hotel (with Conference Space) is next to Copeley Road and will have a parking deck on the first level to easily accommodate visitors with cars. This decision was made in order to not put in surface parking lots, which would sacrifice green space on the project site. On the 2nd level, 25% of the floor will be dedicated to conference space to allow for 9,000 square feet of meeting rooms which will overlook the green area with the bioretention and dry swale. The top 2 levels of the hotel and half of the 2nd level, accounting for 93,750 square feet, allow for approximately 230 bedrooms (based upon a 400 square foot bedroom). The proposed road runs between Academic Building 2 and Academic Building 3 and provides an additional entrance to the Ivy Parking Garage (which will enter onto the 2nd floor of the garage due to topography) and an exit onto Copeley Road to easily accommodate visitors from the hotel. Due to poor site distance, the exit onto Copeley Road will be right-turn only. A UVA bus stop is proposed to be located near the bioretention, with easy walkability to both the Ivy Parking Garage and Hotel, since the current bus stop in front of the Ivy Parking Garage needs to be moved.

Open space accounts for 7 acres, or 42%, of the 16.6 acre site, which more than doubles the minimum project requirements. The areas surrounding the pond, stream, and bioretention provide for significant aesthetic and recreational space for individuals of the community to take advantage of. The open space is spread out throughout the site, with areas available for use near all buildings to enhance the usage of the outdoors by students, faculty, and visitors alike.

The land use comparison between current site and proposed site (site area = 16.6 acres):

Land Use (acres)

	Current Site	Proposed Site
Building Coverage	3.2	5.0
Green Space*	5.7	8.5
Impervious Area	7.7	3.1

*Note green space includes BMP’s

Site Topographic Plan

The site topographic plan follows the existing topography as much as possible in order to minimize the cut and fill required. In general, the highest elevation is located at the western end of the site where the Hotel is located near Copeley Road and the land slopes downward to its lowest elevation at the eastern end of the site near Emmet Street where the pond is placed.

The finished floor elevations (FFE) for the buildings are listed in the table below:

Building FFE

Building Type	FFE
Academic Building 1	504’
Retail Space	504’

Building (With Retaining Walls) FFE

Building Type	FFE 1	FFE 2
Academic Building 2	506’	526’
Academic Building 3	532’	542’
Hotel	540’	552’

Academic Building 1 and the Retail Space drain to the pond, which is at 494’, and the drainage from Academic Building 2 will be routed to the pond. Academic Building 3 drains to the bioretention which sits at 530’ and the runoff from the Hotel will go to the dry swale that is at 538’. There is a retaining wall for the western access to the Ivy Parking Garage, which allows for entrance to the second floor of the garage. The proposed road provides an exit onto Copeley Road, but will be right-turn only given the poor site distance and steep grade.

Earthwork Calculations

For a cut and fill factor of 1.0, the amount of cut and fill is in the table below.

Cut and Fill (Cu. Yd.)

Cut	Fill	Net
44850.75	46419.64	1568.90 <fill>

As the project site is not balanced for cut and fill, possible adjustments could be made with the grading and site design to avoid trucking fill material as would be needed if constructed as currently designed. Suggestions include enlarging the pond or using recycled asphalt product (RAP) from the existing parking lots which are to be demolished.

Erosion and Sediment Control Plan

The erosion and sediment control plan consists of 4 phases. A summary of each phase follows. The current stage of construction of other plan facilities at the site includes: The Cavalier Inn and The Villa Diner, with their respective surface parking, have been demolished and a grassy field planted. No other progress has been noted with regards to construction of remaining facilities still present on the site.

Phase 1

Phase 1 includes the construction of all perimeter controls. The limits of disturbance surround the entire site, except for the existing Ivy Road Parking Garage and existing road entrance off of Ivy Road which remain outside it. Two temporary construction entrances will be located off of Ivy Road. The first temporary construction entrance is close to the Emmet Street/Ivy Road intersection to provide access to Academic Building 1, Retail Space, and pond. The second temporary construction entrance is where the proposed road will be put to provide access to Academic Building 2, Academic Building 3, and the Hotel. Silt fence will be installed on the eastern portion of the site near the Emmet Street/Ivy Road intersection as it sits at the lowest elevation. Silt fence will also be put around the entire stream. Safety fence (noted as tree protection on plans) will be installed around the rest of the site to mark off the construction zone and tree protection will be put in place around the indicated ‘tree save’ areas that are clustered around the stream and behind the Ivy Parking Garage. These measures will ensure better protection of the stream and tree areas throughout construction. A temporary sediment basin that will then be turned into the pond and a temporary sediment trap that is located near Academic Building 2 will be used. Inlet protections are located along Emmet Street, Ivy Road, and Copeley Road where all existing inlets are.

Phase 2

Phase 2 consists of the construction of the Hotel and dry swale. A staging area will be located where Academic Building 3 is set to be built. Two diversion ditches will divert runoff to the temporary sediment trap. One diversion ditch runs along the southern edge of the site in front of the Hotel and Academic Building 3 and the other diversion ditch is along the northern edge of the site past the proposed road, running through where the retaining wall for the Ivy Parking Garage will be. The dry swale will be built during the last stage of Phase 2, once the site has been stabilized diverting runoff to the dry swale for stormwater treatment.

Phase 3

Phase 3 involves the construction of Academic Building 1, Retail Space, Academic Building 2, and Academic Building 3. For the construction of Academic Building 1 and the Retail Space, two diversion ditches will run and empty into the temporary sediment basin. One diversion ditch runs along the north-east corner of the site to the right of Academic Building 1. The second diversion ditch is along the south edge to the left of the first temporary construction entrance. A staging area is located just above the second diversion ditch to service this construction zone. Note the temporary sediment basin will be converted into the pond at the end of this phase. For the construction of Academic Building 2 and Academic Building 3, the two diversion ditches from Phase 2 will remain. A staging area is located to the right of the dry swale.

Phase 4

Phase 4 constructs the bioretention, proposed road, and retaining wall for the Ivy Parking Garage. Two diversion ditches will divert runoff to the temporary sediment trap. One diversion ditch is along the northern edge of the site past the proposed road, running down the western end of the Ivy Parking Garage. The second diversion ditch runs alongside the north-west corner of Academic Building 2. A staging area is located to the right of the dry swale. Silt fence is placed around the dry swale to mitigate the risk of sediment intrusion. The bioretention will be built in the last stage of construction for Phase 4.

Section 2

Site Layout Design Plan

A pdf plan set in full size, 24” x 36” sheets, is separately submitted. The plan set includes:

1) Layout Plan
2) Topographic Plan
3) Erosion and Sediment Control Plan (in 4 phases)
4) BMP Plans
    a) Bioretention Detail
    b) Dry Swale Detail

Narrative explanations and justifications for the site design can be found in the Overall Development Proposal, and narrative descriptions for the BMP designs are provided in the Best Management Practice (BMP) Design Proposal. A Wet Pond Detail was not included as only two BMP designs were required for this proposal.

The Earthwork Calculations are summarized in the below table:

Cut/Fill Report

Volume Summary

Name	Type	Cut Factor	Fill Factor	2d Area (Sq. Ft.)	Cut (Cu. Yd.)	Fill (Cu. Yd.)	Net (Cu. Yd.)
Earthwork	full	1.000	1.000	664784.75	44850.75	46419.64	1568.90<Fill>

Totals

	2d Area (Sq. Ft.)	Cut (Cu. Yd.)	Fill (Cu. Yd.)	Net (Cu. Yd.)
Total	664784.75	44850.75	46419.64	1568.90<Fill>

* Value adjusted by cut or fill factor other than 1.0

Section 3

Virginia Runoff Reduction Method Worksheets

Preliminary Assumptions:

In lieu of conducting an infiltration test on various points in the Ivy Corridor, we accessed USGS's online Web Soil Survey and selected our Area of Interest (AOI) to match our proposed Limits of Disturbance (LOD). Although the generated report was not able to explicitly provide information of the distribution of Hydrologic Soil Groups (HSGs), it indicated that 69.4% of the existing soil is classified as urban land, which the Survey instructions dictate to automatically assign to HSG D. The survey also indicated that 30.6% of land that was classified as "[u]dorthents, loamy, 2 to 25 percent slopes". As the term "udorthents" does not necessarily imply a specific HSG, we turned to the description of loam in order to make a prediction.

After researching the wide array of combinations of sand, silt, clay and loam, we were tasked to make an assumption on what HSG we were most likely to find on this site. We settled on the conservative assumption that the remaining 30.6% of soil is HSG D for two reasons; our site exists in a relatively developed area so the underlying soil is more likely to be compacted with a lower permeability and group D is the "worst case scenario" so assuming that this is the case ensures that we meet pollutant/volume reductions later on in the design process

Design Decisions and Findings:

We decided only to have one drainage area for our VRRM spreadsheets as we were very attracted to the idea of having the pond be a fixture of our open space. The Best Management Practice (BMP) Clearinghouse recommends a drainage area of at least 10-15 acres for a wet pond to ensure adequate base flow during periods of no runoff, but the envisioned topography of our site made this next to impossible. In order to ensure such a baseflow, we developed the site to only have one drainage area so that all water that landed on site would eventually make it to the pond. This was achieved by including a pipe that would transfer treated stormwater from the swale and bioretention basin to the stream which ultimately carries it to the pond.

The breakdown of predevelopment land cover (open space, managed turf, impervious cover) was adapted from the information on page 23 of the Ivy Corridor Strategic Planning Study developed by the Office of the Architect in 2016 and the BMPS employed during this time were deduced from the GIS file provided at the outset of the project.

Overall, our redevelopment was found to be in compliance, as confirmed by the summary tab of the VRRM spreadsheets (included in an electronic appendix) by exceeding the Total Phosphorus (TP) reduction of 6.22 pounds per year by 8.9 pounds per year.

VRRM Summary Sheets:

Please find the full VRRM Excel sheets in the accompanying electronic appendix.

Site Summary

Project Title: Ivy Corridor Test

Date: NA

Total Rainfall (in):	43
Total Disturbed Acreage:	16.63

Site Land Cover Summary

Pre-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	0.00	0.00	3.48	3.48	21
Managed Turf (acres)	0.00	0.00	0.00	4.08	4.08	25
Impervious Cover (acres)	0.00	0.00	0.00	9.07	9.07	55
					16.63	100

Post-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	0.00	0.00	0.00	0.00	0
Managed Turf (acres)	0.00	0.00	0.00	7.44	7.44	45
Impervious Cover (acres)	0.00	0.00	0.00	9.19	9.19	55
					16.63	100

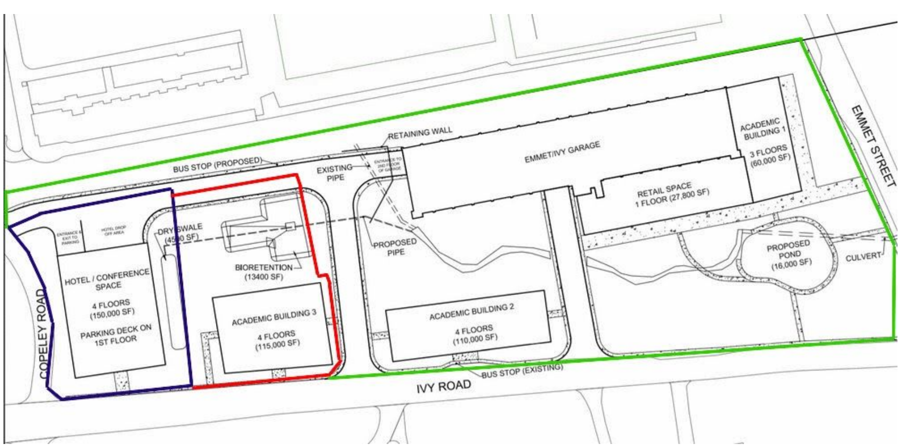
Site Compliance Summary

Maximum % Reduction Required Below Pre-ReDevelopment Load	20%

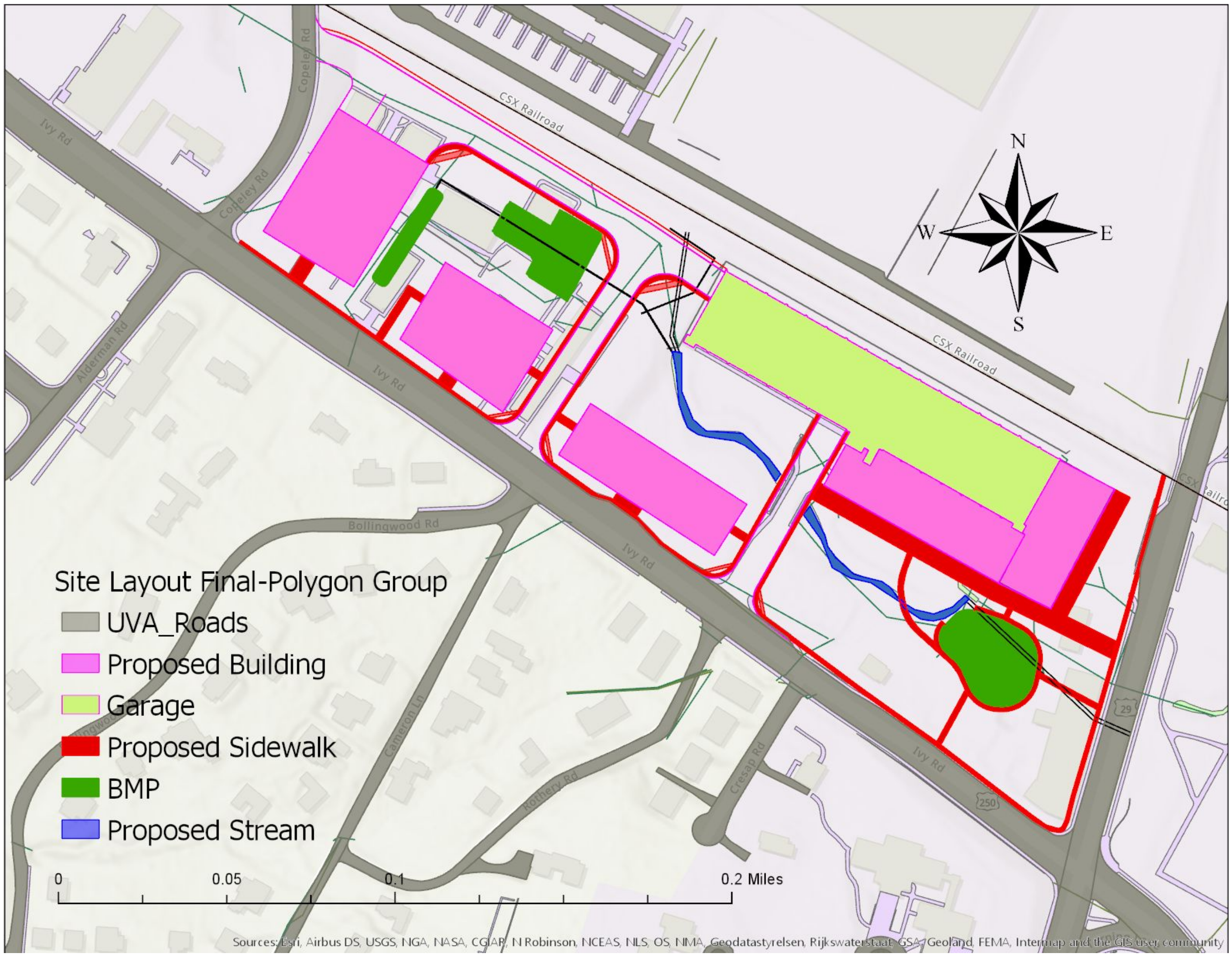
Total Runoff Volume Reduction (ft^3)	8,201
Total TP Load Reduction Achieved (lb/yr)	15.12
Total TN Load Reduction Achieved (lb/yr)	82.41
Remaining Post Development TP Load (lb/yr)	9.03
Remaining TP Load Reduction (lb/yr) Required	0.00

** TARGET TP REDUCTION EXCEEDED BY 8.9 LB/YEAR **

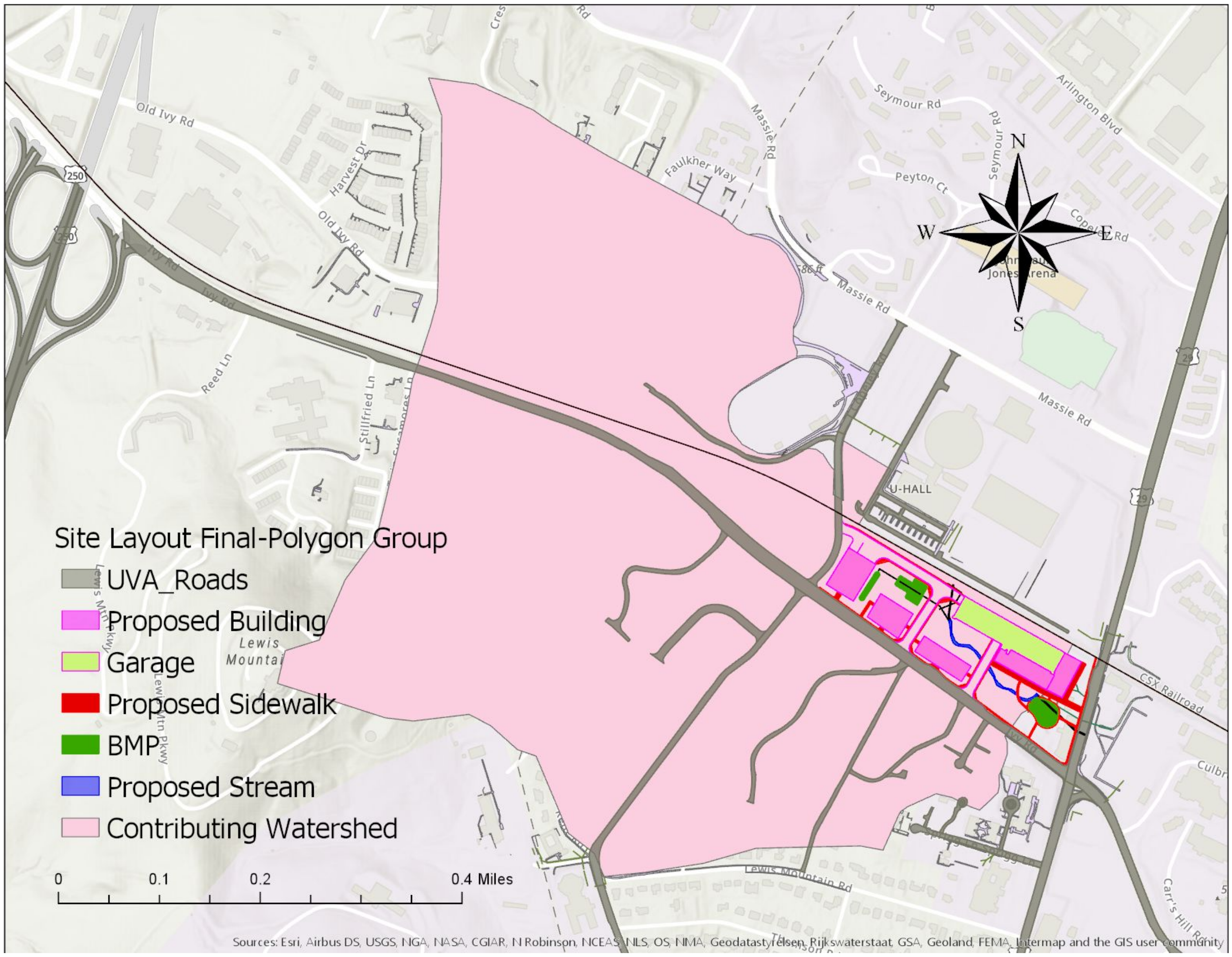
VRRM BMP Drainage Areas:



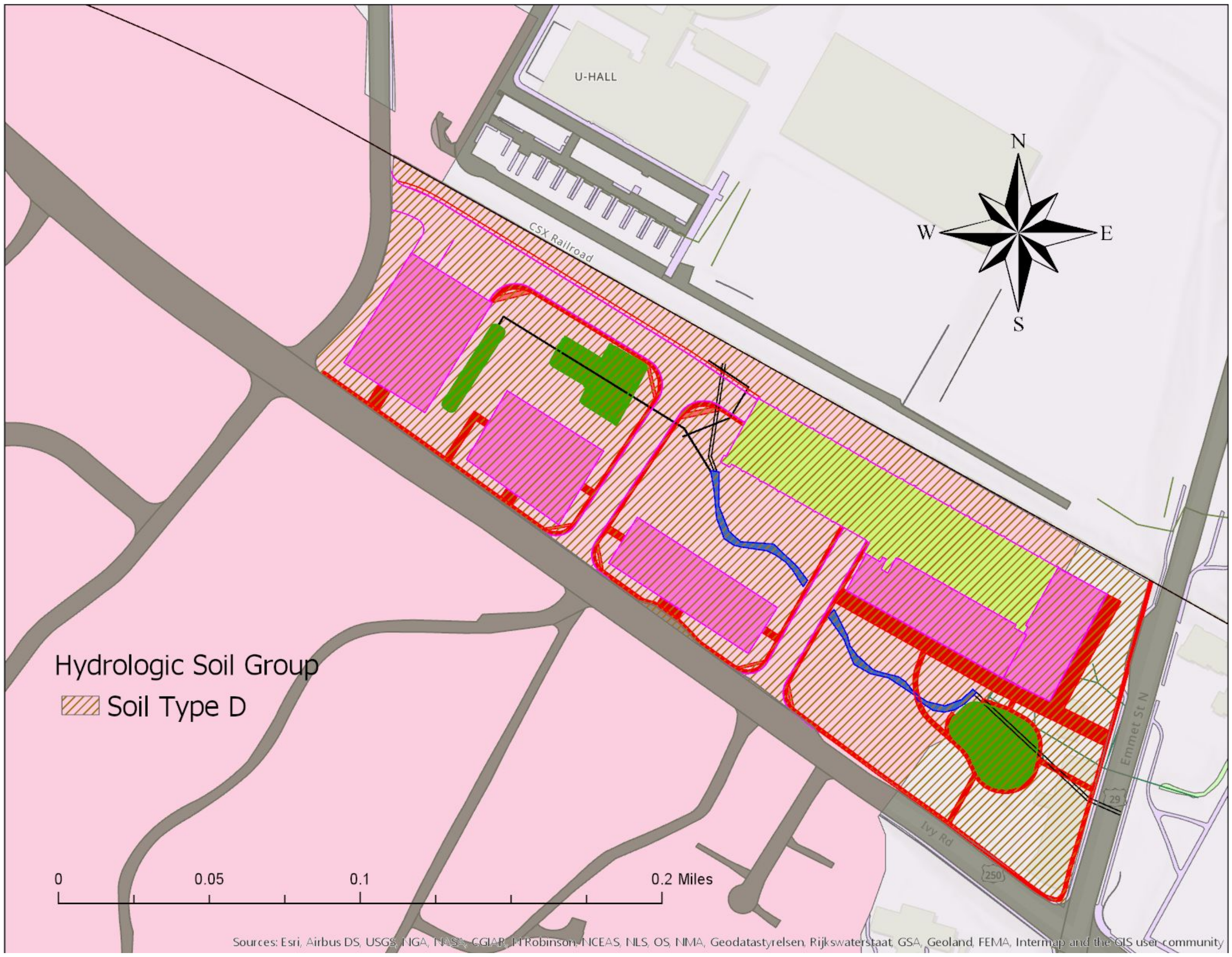
Map of Proposed Land Use



Map of Contributing Watershed



Map of Soil Types on Site



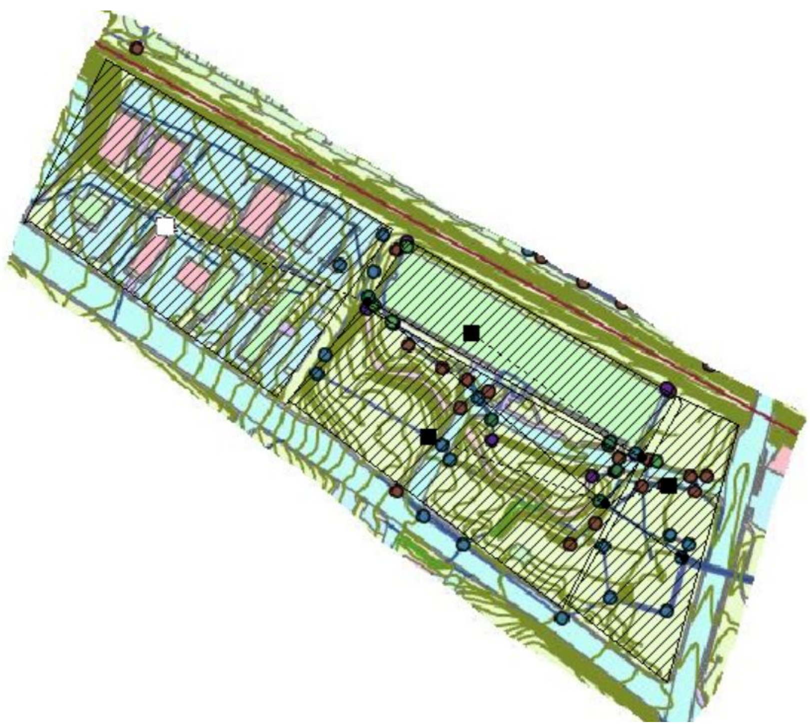
Section 4

Hydrological Modeling

Site Pre-Development:

To model the Emmet-Ivy site pre-development conditions, the Environmental Protection Agency's Stormwater Management Model was used. The existing site was broken into four subcatchments based on current land use and topography conditions. Given the site layout the curve numbers for each of the subcatchments were determined using the NRCS's manual Urban Hydrology for Small Watersheds (TR-55). For all impervious areas a curve number of 98 was used. For pervious areas a CN of 80 was used, modeling them as a good-conditioned open space with soil type D. The model routes runoff from the four subwatersheds into the drop-down structure just upstream of the culvert that goes beneath Emmet St, and then into an outlet that represents the upstream invert of the culvert.

To model existing conduits on the site, the HEC-RAS Hydraulic Reference Manual was used. All of the site's existing pipes are RCP, so a Manning's n value of 0.013 was used. Rain data for Charlottesville was found on the National Oceanic and Atmospheric Administration's website, and was used to simulate the 1-year, 2-year, 10-year, and 100-year storms spanning 24 hours.



Pre-development Model

To determine the site's runoff, the model was run under each of the four design storms. The total inflow for each of the storms was measured at the site's outfall node. Hydrographs for each of our models under 1-year, 2-year, 10-year, and 100-year design storms can be found in the appendix.

Pre-development Site Runoff

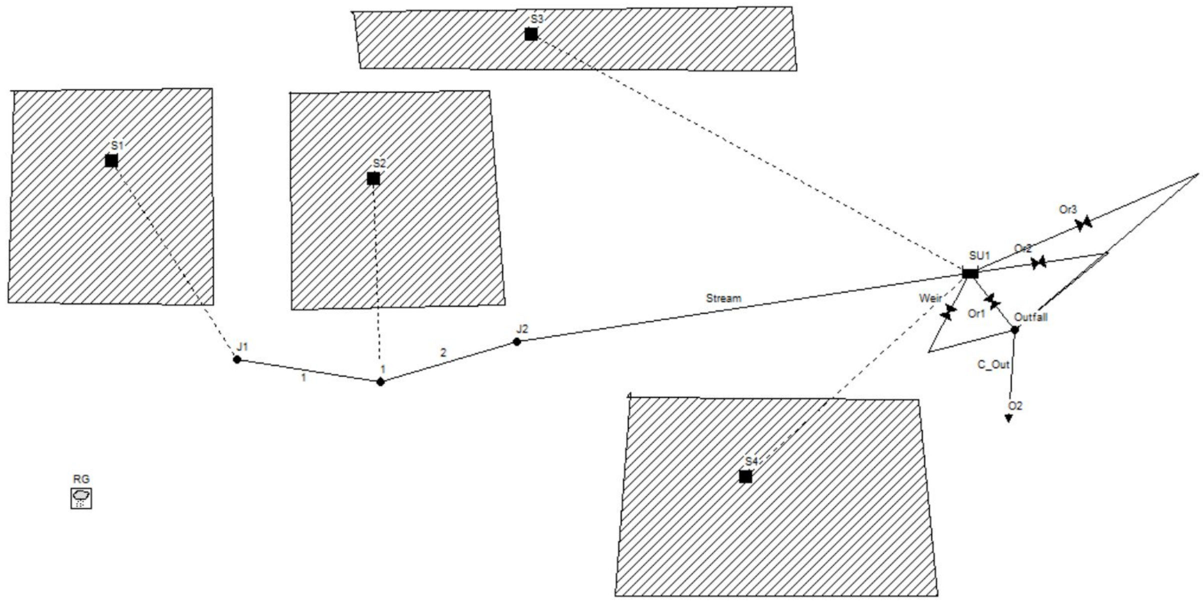
Design Storm (24 hrs)	Peak Runoff (CFS)	Total Volume (10^6 gal)
1-year	18	1.0
2-year	22	1.3
10-year	36	2.1
100-year	62	3.6

Site Post-development:

To model the Emmet-Ivy site post-development conditions, the proposed site was broken into four subcatchments. Given the site layout and conditions, the curve numbers for each of the subcatchments were determined using the NRCS's manual Urban Hydrology for Small Watersheds. For all impervious areas a curve number of 98 was used. For pervious areas a CN of 80 was used, modeling them as a good-conditioned open space with soil type D.

To model the proposed stream and conduits on site, the HEC-RAS Hydraulic Reference Manual was used. For the proposed open stream a Manning's n value of 0.031 was used. For all pipes 0.013 was used.

Rain data for Charlottesville was found on the National Oceanic and Atmospheric Administration's website. It was used to simulate the 1-year, 2-year, 10-year, and 100-year storms spanning 24 hours.



Post-development Model

To determine the site's runoff, each of the four design storms was run. The total inflow for each of the storms was measured at the junction labeled "Outfall".

Post-development Site Runoff

Design Storm (24 hrs)	Peak Runoff (CFS)	Total Volume (10^6 gal)
1-year	11	1.0
2-year	16	1.2
10-year	30	2.0
100-year	55	3.6

To model the wet pond and orifices the SWMM Applications Manual was used. The pond's storage curve and orifices were calculated and sized simultaneously. The storage curve was calibrated to maintain a 4:1 slope throughout. The orifices were sized to decrease the peak runoff from the predevelopment storm scenarios as shown in the above table. Orifice 1 is placed at the bottom of the pond and is constantly discharging water. Orifice 2 comes online when the system undergoes a storm larger than the 24-hr 1-year storm. Orifice 3 begins discharging during the 24-hr 2-year storm. During the 10 and 100-year storms the weir also comes online.

Pond Storage Curve

Depth (ft)	Storage (sqft)
0.00	4,000
2.61	6,000
2.7	12,000
6.0	16,000

Orifice and Weir Design

Name	Type	Discharge Coefficient	Inlet Offset (feet)	Size (feet)
Orifice 1	Circular	0.65	0.0	0.4 (Diameter)
Orifice 2	Rectangular	0.65	2.0	1.2x5
Orifice 3	Rectangular	0.65	2.7	0.5x5
Weir	Transverse	3.33	3.1	2.9x5

Pre-development Site with Contributing Watershed:

Approach

To model the development site and its contributing watershed area, the EPA Storm Water Management Model (SWMM) version 5.1 was employed in combination with GIS data and as-builts from both the University and the City of Charlottesville. To model the contributing watershed, we identified a feature class in the GIS data that we were given by the school that delineated the area, roughly 203 acres, of the watershed contributing runoff to our site. Once the contributing area was identified, it was used to clip the storm line and city pipes feature classes, as well as all roads, buildings, and walkways. To simplify the model, the attribute table for pipes of interest was sorted based on diameter, then all pipes with a diameter of eighteen inches or greater were selected and extracted into their own feature class. The contributing watershed was then broken into 10 subwatersheds based on topography, land use, and the locations of the existing pipes of interest to be modeled in SWMM.

To approximate the impervious cover of our 10 subwatersheds, a hybridized version of the direct method and land use methods were used. For the direct method approach, we summed the areas of all impervious cover (roads, buildings, sidewalks) for each subwatershed and divided by the total area of the subwatershed. Land use was incorporated in that it was noted that the GIS layers used did not include feature classes for parking lots, so the calculated values of imperviousness were corrected using conservative estimates from aerial imagery of the additional impervious area added by parking lots. The subwatersheds directly west of the development site were affected the most by these corrections as they contained large, open parking lots.

All pipes in our model are made of RCP so a manning roughness coefficient of 0.013 was used. Invert elevations, lengths of flow paths, areas and widths of subwatersheds and nodes were all measured or taken from attribute tables of University and City data in GIS
NOAA data for Charlottesville was input into time series in SWMM and linked to rain gauges for modeling the 1yr, 2yr, 10yr, and 100yr storm.

Pre-development Site with Contributing Watershed Model

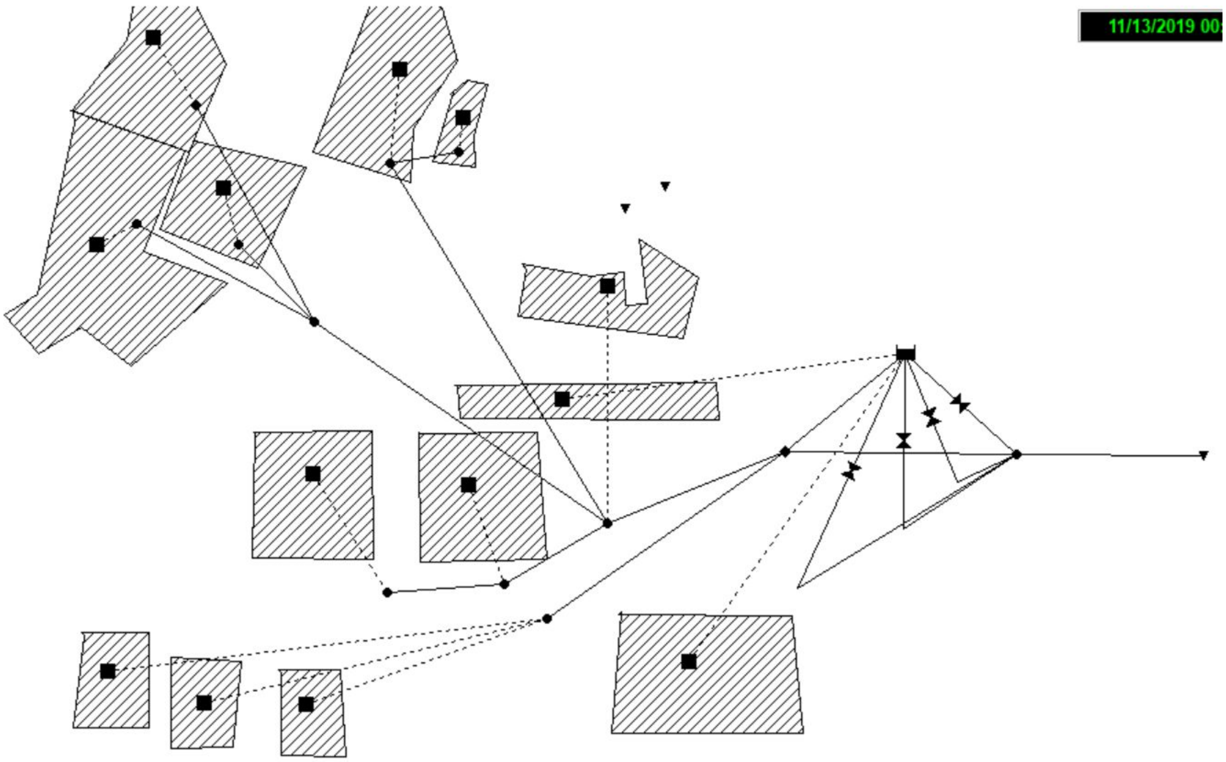
Pre-development with Contributing Watershed Site Runoff

Design Storm (24 hrs)	Peak Runoff (CFS)	Total Volume (10^6 gal)
1-year	186.13	11.5
2-year	231.20	14.4
10-year	349.3	23.2
100-year	486.22	37.5

Post-development Site with Contributing Watershed:

Approach

To model the post-development site with the contributing watershed, the contributing watershed model for pre-development conditions was used, but the subcatchment of that model representing our development site was replaced with our post-development site model. The results are shown in the table below, revealing reduced peak runoff and volume reduction for all storm events analyzed.



Post-development Site with Contributing Watershed Model

Post-development with Contributing Watershed Site Runoff

Design Storm (24 hrs)	Peak Runoff (CFS)	Total Volume (10^6 gal)
1-year	170.57	10.5
2-year	213.14	13.2
10-year	325.84	21.5
100-year	464.38	35.2

Section 5
Culvert Analysis and Design Proposal

Approach:

To assess the capacity of the downstream culvert beneath Emmet St., the SWMM models with the contributing watershed for both pre and post-development conditions were used to model flooding. The culvert was modeled in SWMM as a conduit link, and culvert dimensions as well as invert elevations were taken from university GIS data and the city's as-built for the culvert. Our model shows that under existing site conditions, even during a one-year storm the existing culvert is at risk of flooding. While site runoff is reduced in the post-development model, the model still showed flooding in the existing culvert during the two, ten, and one hundred year storms. The following tables show the relative likelihood and extents of flooding in the existing culvert for both pre and post development site conditions.

Existing Culvert Pre-Development:

Design Storm	Likelihood (% chance in a year)	Hours Flooded	Max cfs	Total Flood Volume (10^6 gal)
1-year	100%	0.51	44.58	0.379
2-year	50%	0.86	89.66	1.29
10-year	10%	1.45	207.75	4.752
100-year	1%	2.11	344.68	10.725

Existing Culvert Post-Development:

Design Storm	Likelihood (% chance in a year)	Hours Flooded	Max cfs	Total Flood Volume (10^6 gal)
1-year	100%	0	0	0
2-year	50%	0.46	39.55	.252
10-year	10%	1.09	154.89	2.896
100-year	1%	1.97	311.72	8.265

Recommendations:

Given the fact that our models showed extensive flooding in the existing culvert, we considered and modeled several different design changes to the culvert to recommend for redevelopment. The culvert modification that we are recommending is for the 48’ RCP pipe culvert beneath Emmet St, as well as the segment of 48’ RCP pipe that currently carries water from the constructed wetland to the culvert’s inlet, to both be replaced with a 5’x6’ three-sided box culvert. The section of pipe that carries water from the constructed wetland to the culvert inlet is 250’ , and the culvert itself is an additional 106’ of pipe, so the recommended replacement will require 356’ of 5’x6’ box culvert to be purchased and installed. A model of the proposed culvert replacement shows no potential for flooding under any of the design storms, as can be seen in the following table.

Proposed Culvert Replacement Post-Development:

Design Storm	Likelihood (% chance in a year)	Hours Flooded	Max cfs	Total Flood Volume (10^6 gal)
1-year	100%	0	0	0
2-year	50%	0	0	0
10-year	10%	0	0	0
100-year	1%	0	0	0

Recommendation Considerations:

In modeling and discussing the possible ways to augment the existing culvert, there were several considerations that ultimately affected our decision to recommend a 5’x6’ three-sided box culvert. Initially, we had considered increasing the number of barrels of 48’ RCP pipe to fix the culvert’s flooding problem. While this redevelopment would solve the flooding problem, it would greatly increase the wetted perimeter of the pipe system, which would introduce frictional losses and result in decreased hydraulic capacity of the culvert. To solve the wetted perimeter problem, the culvert was instead modeled as a box culvert. Different dimensions were then modeled, and our model showed that a 5’x6’ box culvert would solve the problem of flooding even during a 100-year storm. Further considerations for recommending a box culvert include choosing a three-sided culvert as opposed to a four-sided one. We are recommending a three-sided box culvert to allow the natural stream bed to remain intact, and to facilitate safer passage of animals through the culvert. Research suggests that wildlife are more likely to travel through culverts with a natural substrate, as opposed to concrete or metal pipe material.

Additionally, circular RCP pipe culverts would require routine maintenance and need to be replaced much earlier than a box culvert, so it is likely that a box culvert would save UVA money in the long term.

An additional consideration moving forward would be the rise of the proposed box culvert. At 5’x6’, the recommended culvert has a rise 1’ greater than the existing 48” RCP, so existing utilities would need to be explored in more depth to ensure that they would not be impacted.

Section 6

Best Management Practice (BMP) Design Proposal

Overview:

As a general approach, we wanted to incorporate BMPs that not only met the pollutant reduction requirements but also added aesthetic utility to the site to enhance its overall connectivity and functionality as a gateway from Northern to Central Grounds. The BMPs that most served this purpose given the nuances of this site, we decided to rely on two infiltration practices (a dry swale and a bioretention basin) and a wet pond. As per the RFP, the design parameters for the two infiltration practices are detailed in this section.

Bioretention:

General Design Requirements per BMP Clearinghouse (DEQ):

Recommended contributing drainage area = 2.5 acres (up to 5 with local approval)

Maximum Ponding Depth = 6” to 12”

Filter Media Depth minimum = 36”; Recommended Maximum = 48”

Media and Surface Content must be supplied by the vendor and tested for acceptable permeability and phosphorus content

Underdrain: Schedule 40 PVC with cleanouts and minimum 12” stone sump below the invert

Length of shortest flow path / length of most distant inlet to outlet > 0.8

10’ building setbacks if down gradient from buildings

Soil Porosities

Bioretention soil media porosity (η) = .25

Gravel η = .40

Surface storage η = 1.0

Equivalent Bioretention Level 2 Design Storage Depth and Surface Area

Bioretention Specifications: 6” max surface ponding depth and 3” gravel sump below underdrain, 36” media depth, 2.02 acre contributing drainage area

Effective Depth = (3 ft Bio Soil)(.25) + (1 ft Gravel)(.40) + (.5 ft surface)(1.0) = 1.65 ft

Required Surface Area = Treatment Volume/Depth

SA = T_{VBMP}/(1.65ft)

T_{VBMP} (from Clearinghouse) in $ft^3 = 1.25[(1.0 \text{ in})(R_v)(A)/12]$

Where R_v (-) is the runoff coefficient and A (ft^2) is the drainage area. The calculation of R_v is done using the standard outlined in the BMP Clearinghouse that stipulates an R_v of .95 for impervious surface and .21 for managed turf. The percentage of total area in the calculation of weighted R_v comes from the VRRM Spreadsheet.

Weighted $R_v = (.95)(.604) + (.21)(.396) = .65$

Calculations

$T_{VBMP} = 1.25[\ (1.0 \text{ in})(.65)(2.02 \text{ Acres})(43{,}560 \text{ ft}^2/\text{Acre})/12] = 5957.8 \text{ ft}^3$

$SA_{MIN} = 1.25(5{,}957.8 \text{ ft}^3\ /\ 1.65 \text{ ft}) = 4{,}513 \text{ ft}^2$

Actual Design Bioretention Basin SA = 8,800 SF (with pretreatment, 13,400 SF)

SFP/L = 1 (inlet at western most edge of bio retention facility, i.e. length of basin is the same as the shortest flow path to maximize infiltration)

Shape and Oversizing

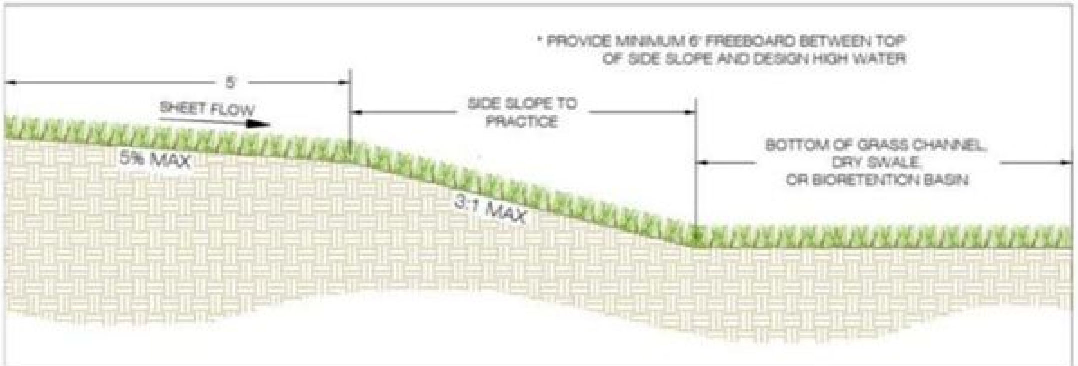
A T-shaped design was chosen not only to maximize the right angle created by the joining roads at the north-east end of the basin, but also encourage as much infiltration as possible by routing the water a longer distance to the outlet at the eastern end. We also feel that this design mimics a more natural meadow and further adds a more pleasant look to the BMP when paired with the right vegetation, to be discussed later.

It is clear that the bioretention facility is oversized by almost a factor of two. This is a function of both the uncertainty of the underlying soil affecting adjacent infiltration and how much runoff is actually expected to reach the facility. More specifically, because we are employing two infiltration practices, oversizing the downstream one further decreases the likelihood of flooding. Another component that needs to be satisfied is the BMP's agreement with the proposed topography. The facility needs to have a certain amount of length on the top of the T due to that side's comparatively lower elevation and simply putting a rectangular bioretention facility along this road would diminish the natural meadow we are going for. Another added dimension is how this site will perform under the effects of climate change; with rainfall frequency and intensity expected to increase over the coming decades, we want to ensure a resilient site that meets future runoff demand as well as the current compliance standards.

Pretreatment and Overflow

Grass filter strips (as per the following figure) applied before the bioretention basin at a slope of 5% (20:1) and 4:1 along the side slopes of the basin.

Stone flow spreader placed at the North end of the academic building immediately south of the facility at the outflow of downspouts. Conveyance from north-west corner of building to west end of basin.



Grass Filter Strip Pretreatment (VADEQ, 2013)

Filter Media and Surface Cover

Goal: the soil media mixture has a porosity that maintains the desired permeability but also contains sufficient organic matter to support plant growth and absorb phosphorus and other stormwater contaminants. Initial seasons of plant growth and establishment must not overload the system with excessive nutrients (may leach nutrients or clog soil media mixture), yet support adequate plant growth to stabilize the facility for the growth cycles in the coming years and decades.

Filter Media Physical Composition:

Coarse sand with no more than 10% clay, no more than 20% silt + clay, and at least 75% of the sand fraction should be coarse or very coarse sand. Mix should also contain at least 10% soil fines (silt and clay) while also meeting previous specifications. Media should contain 3% to 5% organic matter by conventional Walkley-Black soil organic matter determination method. Ultimate performance goal is a verified soil permeability (saturated hydraulic conductivity) of 1 to 2 inches per hour, minimum.

Sand must meet grain size distribution described in the following figure.

Sieve	Size	% Passing
3/8 in	9.50 mm	100
No. 4	4.75 mm	95 to 100
No. 8	2.36 mm	80 to 100
No. 16	1.18 mm	45 to 85
No. 30	0.6 mm	15 to 60
No. 50	0.3 mm	3 to 15
No. 100	0.15 mm	0 to 4
Effective Particle size (D10) > 0.3mm		
Uniformity Coefficient (D60/D10) < 4.0		

Mandatory Grain Size Distribution for Filter Media (VADEQ, 2013)

Topsoil must be carefully selected so that the ingredients (sand, fines, organic matter) so as not to exceed any previously outlined limit. Topsoil defined as loamy sand, sandy loam, or loam is often used to meet these criteria.

Organic matter should consist of well-decomposed natural C-containing organic materials like: peat moss, humus, compost, pine bark fines, or other organic soil conditioning materials.

Plant-available soil P should be within the range of Low$^+$(L^+) to Medium (M) defined in Table 2.2 of DCR (2005) Virginia Nutrient Managements Standards and Criteria, about 15 mg/kg P – 18 mg/kg P.

Cation Exchange Capacity (CEC) refers to the ability of soils to retain nutrient cations like Ca and K. Minimum CEC of bioretention soil media (total number of positively charged ions that a soil can hold per unit dry mass) is 5.0 meq/100g.

The BMP clearinghouse recommends a 2 to 3-inch layer of (hardwood) mulch placed on the filter bed encourages plant growth and pretreats runoff. However, after consideration of the performance of mulch over time, this bioretention will be constructed with a layer of geomesh fabric as the top layer.

Choice of filter media is as followed to meet the criteria.

Underdrain

3-inch sump below the invert of the underdrain

Bottom of storage layer must be 2 feet above seasonally high water table, consisting of washed #57 stone. Sump dewaters by percolating into native soils. Run of pipe comprising the underdrain includes cleanouts at 45-degree horizontal beds set a minimal grade. Bioretention must include observation wells tying into any T or Y shaped connections in the underdrain.

Plant Selection for Performance and Aesthetic Utility

An herbaceous meadow, low maintenance, vegetative style will be used to establish a natural look in the area.

Wet footed species are to be placed near the center and upland species around the edge of the basin. Herbaceous plants will be placed in clusters in the basin. Due to snow activity in Charlottesville, consideration of salt-tolerant herbaceous perennial plants will be taken.

Albemarle native plant species to be predominantly featured, including: Virginia Wild Rye (*Elymus virginicus*), Switchgrass (*Panicum virgatum*), Joe Pye Weed (*Eupatorium purpureum*), Indian Grass (*Sorghastrum nutans*).

Albemarle native shrubs to be implemented : Common Winterberry (*Ilex verticillatta*) and Arrowwood (*Virburum dentatum*)

Further detail on plant and shrub selection can be found under the "Bioretention Plant Selection" section of the Appendix.

Construction/Inspections

Construction will proceed in the methodology outlined by the DEQ in the BMP Clearinghouse, also included in the Bioretention Construction Procedure section of the Appendix.

A detailed inspection will be conducted by qualified individuals periodically during and immediately following the construction of the bioretention basin. Items of particular importance during these inspections include: proper coverage of plants and soil media, properly installed and stabilized filter strips, the stability of the outfall/energy dissipator.

Maintenance

Maintenance will follow Appendix C of Chapter 9 of the *Virginia Stormwater Management Handbook*, and will be most important during the year after installation. Common maintenance during this period includes: unclogging inflows, removing sediment buildup, replacing the Coir Matting if needed, replacing dead vegetation, checking for excessive ponding, and stabilizing bare soil patches. The frequency of common maintenance tasks is outlined in the following table.

Required Maintenance with Recommended Frequency (VADEQ, 2013)

Maintenance Tasks	Frequency
• Mowing of grass filter strips and bioretention turf cover	At least 4 times a year
• Spot weeding, erosion repair, trash removal, and mulch raking	Twice during growing season
• Add reinforcement planting to maintain desired the vegetation density • Remove invasive plants using recommended control methods • Stabilize the contributing drainage area to prevent erosion	As needed
• Spring inspection and cleanup • Supplement mulch to maintain a 3 inch layer • Prune trees and shrubs	Annually
• Remove sediment in pre-treatment cells and inflow points	Once every 2 to 3 years
• Replace the mulch layer	Every 3 years

Dry Swale:

Dry Swale Feasibility per BMP Clearinghouse (VADEQ)

Footprint is small, so dry swales can fit into relatively narrow corridors between utilities, roads, parking areas, and other site restraints. They should be at least 3% to 5% of the contributing drainage area (subject to site specific limitations and land cover).

Check dams are to be used to reduce the effective slope of the swale and lengthen the contact time to enhance filtering and infiltration.

Maximum drainage area for a dry swale is 5 acres, preferably lower to limit flow velocity and erosion of the channel.

In general, 3 to 4 feet of elevation above the outlet invert is needed to create the hydraulic head needed to drive stormwater through the proposed filter bed.

Design Criteria

Accepted porosities (η) for filter media:

Dry Swale Soil Media	$\eta = 0.25$
Gravel	$\eta = 0.40$
Surface Storage behind check dams	$\eta = 1.0$

Dry Swale Level 2 Design Storage Depth

$(2.0 \text{ ft})(.25) + (1.0 \text{ ft})(.40) = .9 \text{ ft}$

Sizing the Dry Swale

T_{vBMP} (BMP Design Treatment Volume – ft^3) = $[(0.5 \text{ in})(R_v)(A)/12]$

Where R_v (-) is the runoff coefficient and A (ft^2) is the contributing drainage area. The calculation of R_v is done using the standard outlined in the BMP Clearinghouse that stipulates an R_v of .95 for impervious surface and .21 for managed turf. The percentage of total area in the calculation of weighted R_v comes from the VRRM Spreadsheet as follows:

$R_v = (.21)(.53) + (.47)(.95) = .58$

A = 3.39 Acres

$SA_{MIN} = [((1.1)(T_{vBMP}) - \text{volume of surface storage})/ 0.9 \text{ ft}]$

For the sake of ease, we will be designing assuming we will not need any additional surface storage.

Calculations

$T_{vBMP} = [(.5 \text{ in})(.58)(3.39 \text{ Acres})(43{,}560 \text{ ft}^2 / \text{Acre})/12] = 3{,}568 \text{ ft}^3$

$SA_{MIN} = [(1.1)(3{,}568 \text{ ft}^3)/ 0.9 \text{ ft}] = 4{,}360 \text{ ft}^2$

Design Surface Area = 4,500 SF

Underdrain

Underdrains are provided in dry swales to ensure that they drain properly after storms.

• The underdrain should have a minimum diameter of 4 inches (or larger as required by the T_v design flow) and be encased in a 12-inch deep gravel bed.

• Two layers of stone should be used. A choker stone layer, consisting of #8 or #78 stone at least 3 inches deep, should be installed immediately below the filter media. Below the choker stone layer, the main underdrain layer should be at least 12 inches deep and composed on #57 double washed stone.

• The underdrain pipe should be set at least 3 inches above the bottom of the stone layer to create a sump.

Slopes and Check Dams

Side slopes of dry swales should be no steeper than 3H:1V and flatter slopes are recommended where adequate space is available to enhance pre-treatment of sheet flows entering the swale.

Design side slope of our swale is 4H:1V

Check dams are constructed of timbers, concrete, gabions, or other durable (non-erodible) material and serve to hold pockets of runoff at the swale surface that will eventually filter throughout the soil media to the underdrain.

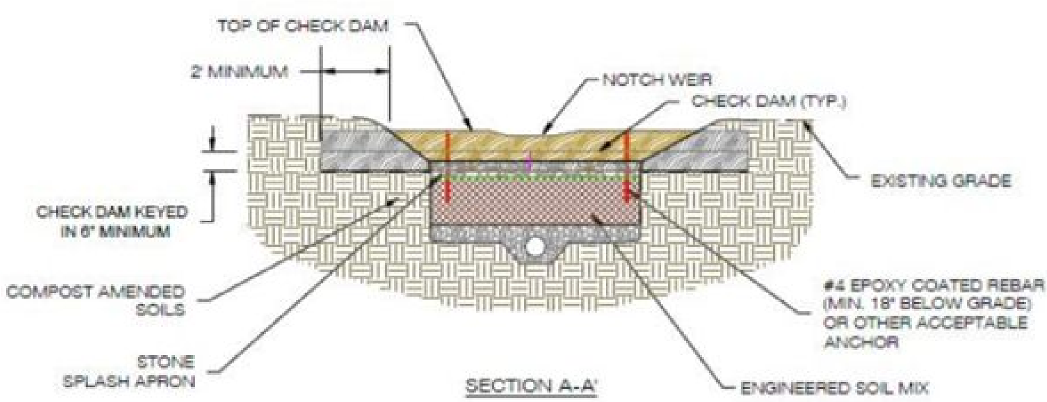
Check dams must be firmly anchored into the side-slopes to prevent outflanking during the maximum design flow (typically the 10-year frequency event unless designed to be an off-line practice

The height of the check dam relative to the normal channel elevation should not exceed 12 inches.

Armoring may be needed on the downhill side of the check dam overflow section to prevent erosion. The combined overflow section and armoring must be designed to spread runoff evenly over the dry swale's filter bed surface.

The top weir of each check dam should include a contained overflow section to pass the design storms safely with no erosion in compliance with the figure on the next page.

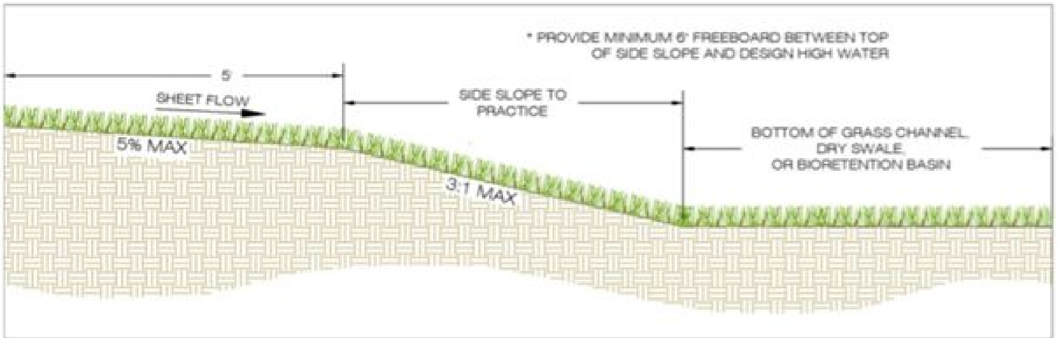
As the length of our dry swale is 165' and has a natural slope of 1%, check dams will be placed every 50', starting from the inflow point on the southern end of the swale, for a total of three dams. The check dams will be designed according to the accompanying plan set. The weirs atop the dams will be constructed as per VADEQ standards, shown in the figure on the next page, with particular attention paid to how deep the wood is buried to prevent undercutting (as per mentor recommendation).



Dam Weir Detail (VADEQ, 2013)

Pretreatment

A Grass Filter Strip (detailed in the following figure) will be used for pretreatment of sheet flow into the swale to limit erosion.



Grass Filter Strip Specifications (VADEQ, 2013)

Filter Media

All filter material detailed in the plan set will be in compliance with the chart outlined in the BMP Clearinghouse, included in the Appendix under "Dry Swale Filter Media Notes and Specifications".

Observation Well

The cleanout closest to the outlet will also double as a monitoring well to ensure adequate swale performance. The well will be constructed to the standards outlined by the VADEQ regulations as stipulated in the Clearinghouse.

Choice of Vegetation

Designers should choose native grasses, herbaceous plants, or trees that can withstand both wet and dry periods and relatively high velocity flows for planting within the channel. Salt tolerant grass species should be chosen for dry swales located along roads. Taller and denser grasses are preferable, although the species is less important than good stabilization and dense vegetative cover. Grass species should have the following characteristics: a deep root system to resist scouring; a high stem density with well-branched top growth; water-tolerance; resistance to being flattened by runoff; and an ability to recover growth following inundation. Given these criteria from the clearinghouse, the grass chosen will be the Albemarle native *Juncus effusus*, soft rush: grass, sedge, and weed.

References:

Virginia Department of Environmental Quality (VADEQ). (2013). Virginia DCR Stormwater Design Specification No. 10: Dry Swales, Ver. 2.0. retrieved from: https://www.swbmp.vwrrc.vt.edu/wp-content/uploads/BMP_Spec_No_10_DRY_SWALE.pdf

Virginia Department of Environmental Quality (VADEQ). (2013). Virginia DCR Stormwater Design Specification No. 9: Bioretention, Ver. 2.0. retrieved from: https://www.swbmp.vwrrc.vt.edu/wp-content/uploads/BMP_Spec_No_9_BIORETENTION.pdf

Section 7

Cost Proposal

Erosion and Sediment Control

Item	Quantity	Unit	Unit Price	Cost
Silt Fence	2565	LF	$5	$12,825
Tree Protection Fencing	6125	LF	$3	$18,375
Diversion Dike	2275	LF	$8	$18,200
Construction Entrance	2	EA	$4,000	$8,000
Inlet Protection	4	EA	$175	$700
Sediment Trap	1	EA	$4,000	$4,000
Sediment Basin	1	EA	$15,000	$15,000

Sub-Total: $77,150
Contingency (10%): $7,715
Total: $84,865

BMPs

Bioretention

Bioretention Calculations:

Item	Area (SF)	Thickness (FT)	Volume (CF)	Volume (CY)
36” soil media	8,800	3	26,400	978
3” pea gravel	8,800	0.25	2,200	82

Item	Area (SF)	Thickness (FT)	Volume (CF)	Volume (Ton)
12” No. 57 stone	8,800	1	8,800	455

Bioretention Construction Costs:

Category	Item	Quantity	Unit	Unit Price	Cost
Construction	36” soil media	980	CY	$65	$63,700
	6” PVC underdrain	151	LF	$40	$6,040
	3” pea gravel	85	CY	$40	$3,400
	12” No. 57 stone	455	Ton	$30	$13,650
	Geotextile	980	SY	$10	$9,800
	PVC clean-outs	3	EA	$200	$600
Earthwork	Fill soil	2612.52	CY	$30	$78,376

Sub-Total: $175,566
Contingency (10%): $17,557
Total: $193,123

Bioretention Annualized Costs:

TP Nutrient Removal = 2.79 lb — Cost = $69,220 / lb TP removed
TN Nutrient Removal = 20.38 lb — Cost = $9,476 / lb TN removed
Volume Reduction = 3,947 cu.ft — Cost = $49 / cu.ft. volume reduced

Dry Swale

Dry Swale Calculations:

Item	Area (SF)	Thickness (FT)	Volume (CF)	Volume (CY)
3” pea gravel	4,500	0.25	1,125	42
24” soil media	4,500	2	9,000	333

Item	Area (SF)	Thickness (FT)	Volume (CF)	Volume (Ton)
13” No. 57 stone	4,500	1.083	4,875	250

Dry Swale Construction Costs:

Category	Item	Quantity	Unit	Unit Price	Cost
Construction	Rock check dam	3	EA	$500	$1,500
	4” PVC cleanouts	3	EA	$200	$600
	4” PVC underdrain	165	LF	$40	$6,600
	3” pea gravel	45	CY	$40	$1,800
	Geotextile	500	SY	$10	$5,000
	13” No. 57 stone	250	Ton	$30	$7,500
	24” soil media	335	CY	$65	$21,775
Earthwork	Fill soil	184.58	CY	$30	$5,537

Sub-Total: $50,312
Contingency (10%): $5,031
Total: $55,343

Dry Swale Annualized Costs:

TP Nutrient Removal: 3.38 lb — Cost = $16,374 / lb TP removed
TN Nutrient Removal: 23.56 lb — Cost = $2,349 / lb TN removed
Volume Reduction: 4,255 cu.ft. — Cost = $13 / cu.ft. volume reduced

<u>Culvert Work</u>

Category	Item	Quantity	Unit	Unit Price	Cost
Replacement	Box Culvert 5’ x 6’	356	LF	$1000	$356,000

Sub-Total: $356,000
Contingency (10%): $35,600
Total: $391,600

Section 8

Schedule

Before Winter Break:

9/22/19	12/1/19	12/1/19	12/6/19	*Winter Break*
Site Visit	**SPLAYO (Layout Plan)**	**VRRM Post-development**	**SPGRAD (Topo Plan)**	
	Iteration 1: Discussion and revisions (9/30/19-10/2/19)	Determine land type and area (10/14/19-10/25/19)	Research how-to (10/25/19-11/8/19)	
	Iteration 2: Discussion and revisions (10/2/19-10/10/19)	Determine drainage areas (10/14/19-10/25/19)	Workshop/Tutorial Meeting (11/22/19)	
	Iteration 3: Discussion and revisions (10/10/19-10/16/19)	Determine runoff amount to BMPs (10/14/19-10/25/19)	Iteration 1: Discussion and revisions (11/22/19-12/6/19)	
	Iteration 4: Discussion and revisions (10/16/19-10/20/19)	GIS-generated maps of land uses, soil types and contributing drainage areas (10/25/19-11/8/19)	**SPEROS (Erosion and Sediment Control Plan)**	
	Iteration 5: Discussion and revisions (11/1/19-11/4/19)	Completed VRRM spreadsheets, with summary tables (10/25/19-12/1/19)	Research how-to (11/15/19-12/06/19)	
	Iteration 6: Discussion and revisions (11/22/19-12/1/19)	VRRM narrative description of inputs and results of analysis (11/1/19-12/1/19)	**Hydrological Modeling**	
			SWMM introduction/orientation (10/20/19-11/2/19)	
			SWMM data collection (10/25/19-11/2/19)	
			SWMM pre-development modeling (10/27/19-12/6/19)	
			SWMM post-development modeling (10/27/19-12/6/19)	

After Winter Break:

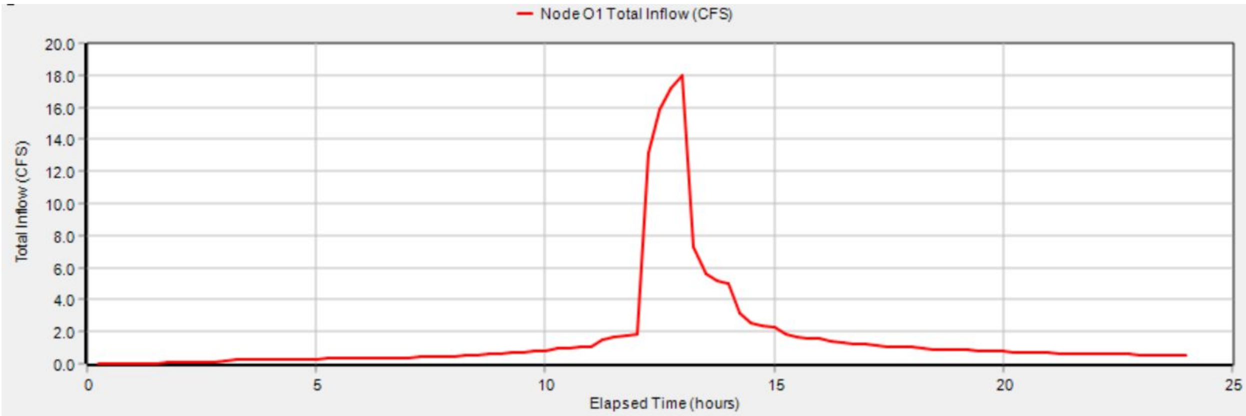
2/11/20	3/3/20	3/24/20	4/15/20	4/21/20	4/23/20
Hydrological Modeling	**Hydrological Modeling**	**Site Layout Design Plan**	**Proposal Written Response (Draft)**	**Final Proposal Written Response**	**Presentation**
SWMM pre and post development modeling finalized	GIS-generated map with contributing drainage area	Finalized design elements: site layout, topo, earthwork calcs, and E&S			
SWMM Results (Select summary tabular results)	SWMM narrative description (methods, inputs, assumptions)	**Cost Proposal**			
SPEROS (Erosion and Sediment Control Plan)	SWMM Hydrographs before/after stormflows	Construction and maintenance costs for:			
Iteration 1: Discussion and revisions	**SPEROS (Erosion and Sediment Control Plan)**	- Stormwater/hydraulic infrastructure			
Iteration 2: Discussion and revisions	Iteration 3: Discussion and Revisions	- BMPs (bioretention, dry swale, pond)			
SPGRAD (Topo Plan)	**SPGRAD (Topo Plan)**	- Culvert work			
Iteration 2: Discussion and revisions	Iteration 4: Discussion and Revisions	**Dry Swale Design**			
Iteration 3: Discussion and revisions	**SPLAYO (Site Layout)**	Verify minimum design requirements			
Narrative Description of BMPs	**Earthwork Calculations**	Quantitative description (area, depth, volume, slope)			
Verify minimum design requirements (Bio and Swale)	**Culvert Analysis**	Material choice (including veg)			
Updated Schedule	Culvert modeling pre-development	Design plan and diagrams			
Updated VRRM	Culvert modeling post-development	**Overall Development Proposal**			
	Redevelopment culvert sizing	**Updated Schedule**			
	Culvert Analysis Narrative Description				
	Bioretention Design				
	Verify minimum design requirements				
	Quantitative description (area, depth, volume, slope)				
	Material choice (including veg)				
	Design plan and diagrams				
	Updated Schedule				
	Updated VRRM				

Section 9

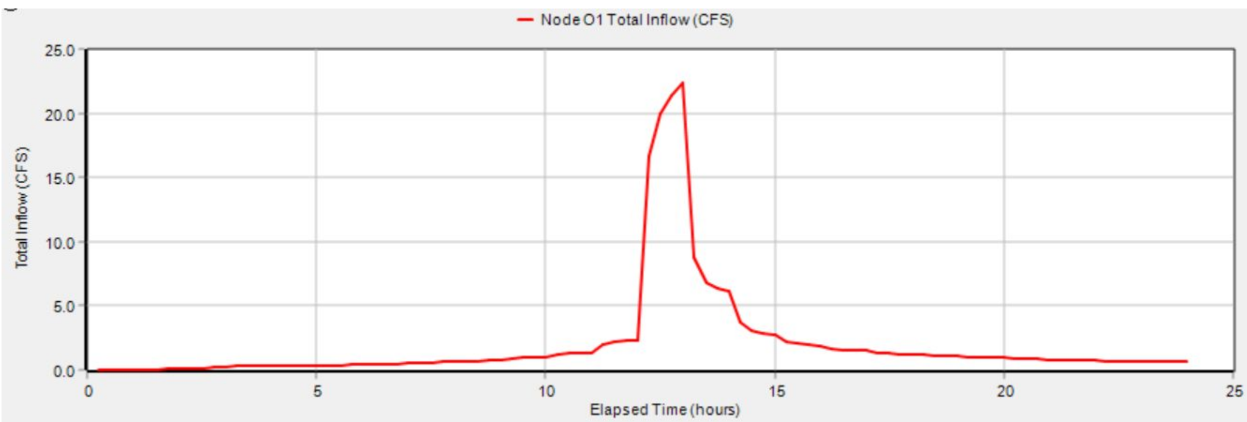
Appendix

Site Pre-Development Design Storm Hydrographs:

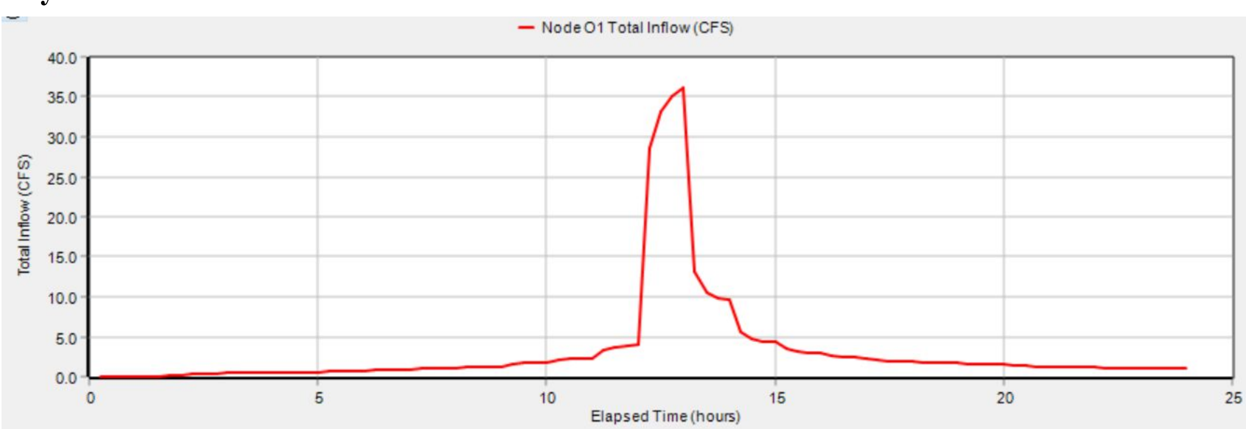
1-year



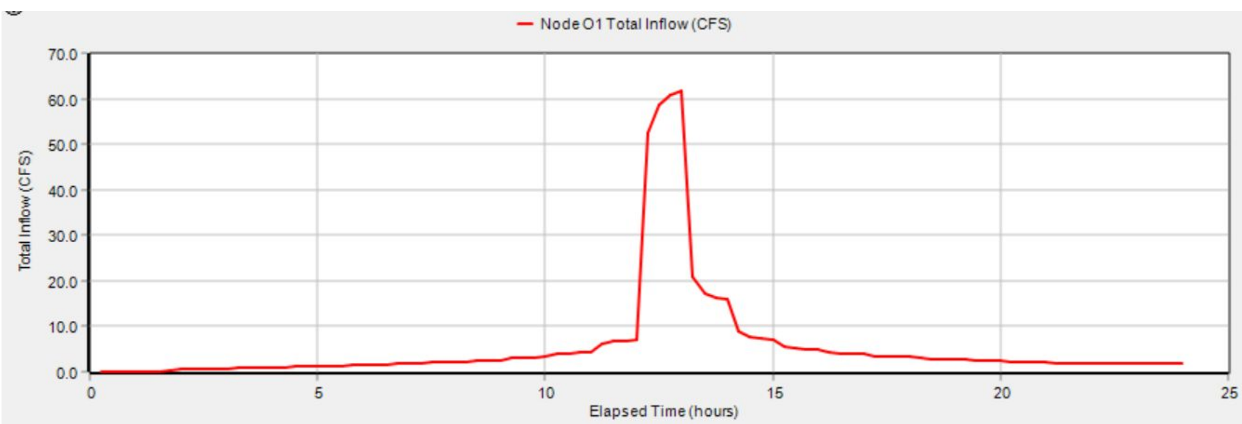
2-year



10-year

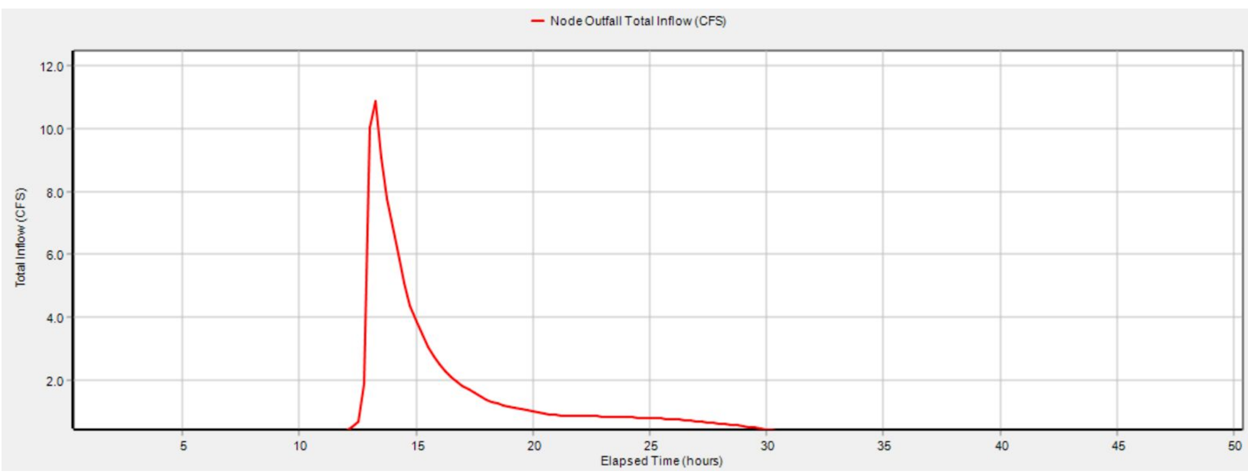


100-yr

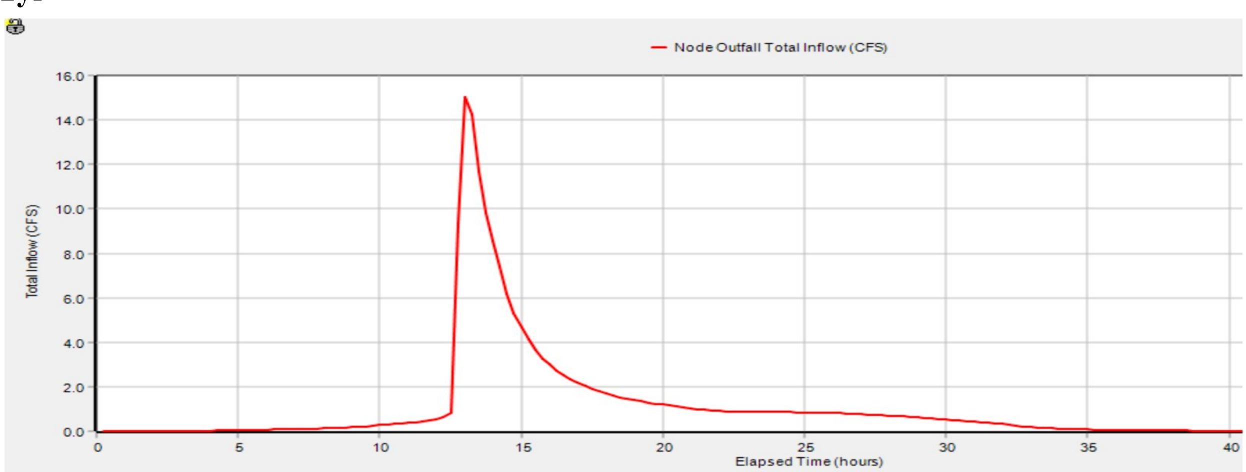


Site Post-development Design Storm Hydrographs:

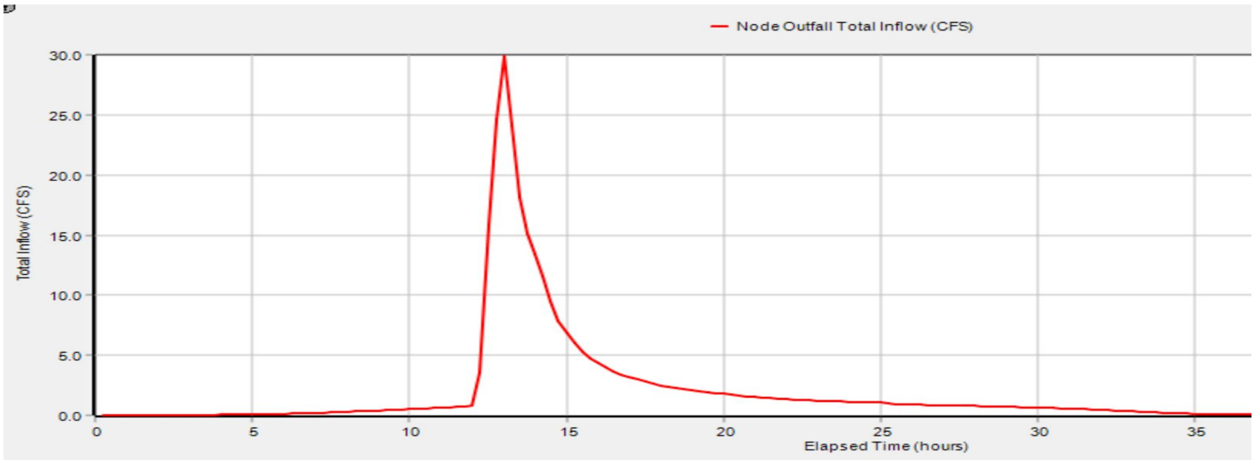
1yr



2yr

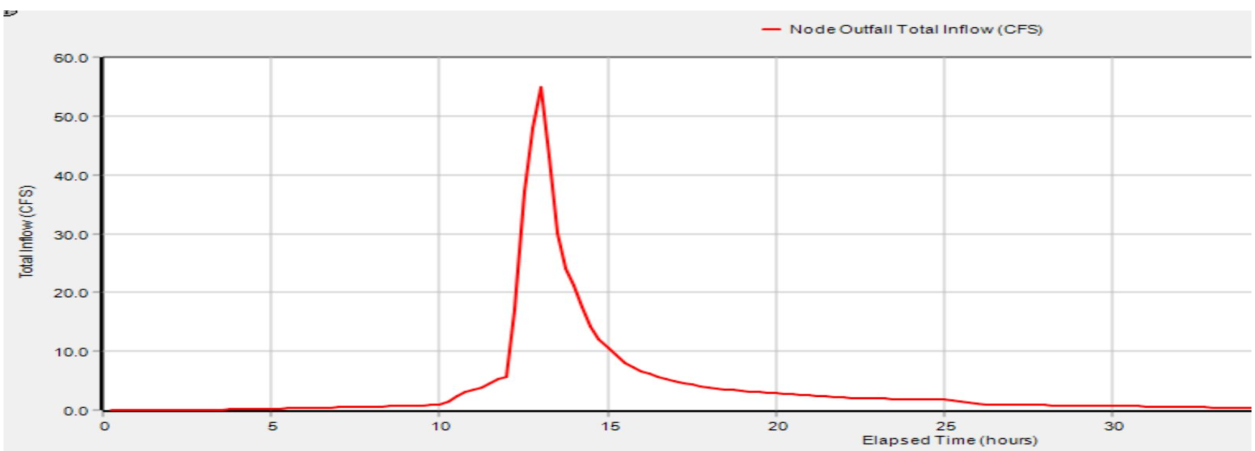


10yr



Node Outfall Total Inflow (CFS)
Total Inflow (CFS)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
5
10
15
20
25
30
35
Elapsed Time (hours)

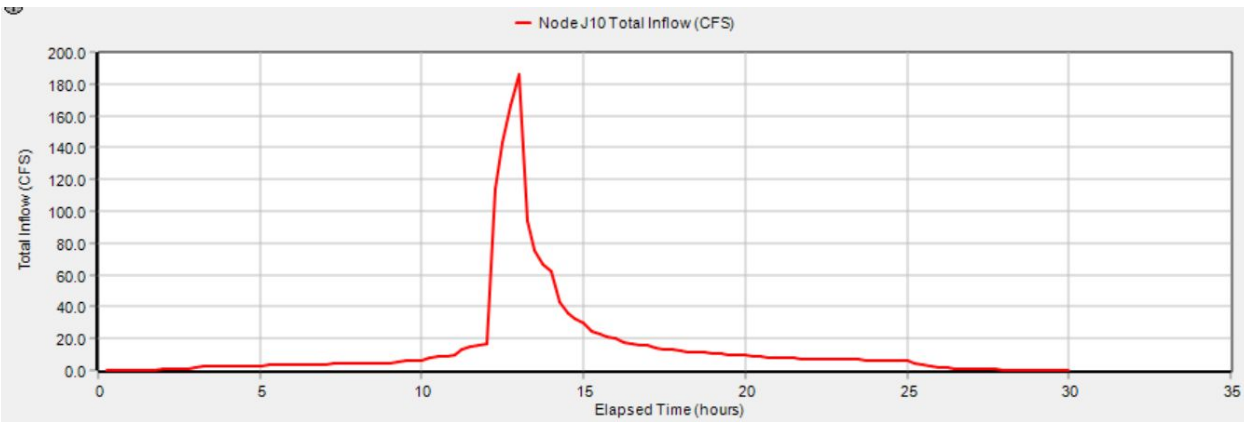
100yr



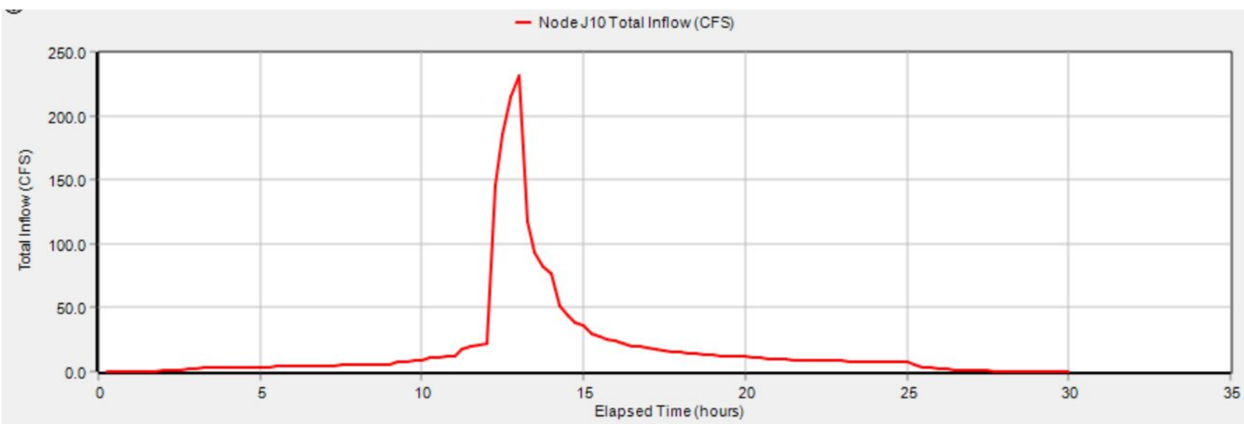
Node Outfall Total Inflow (CFS)
Total Inflow (CFS)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
5
10
15
20
25
30
Elapsed Time (hours)

Site Pre-development with Contributing Watershed Design Storm Hydrographs:

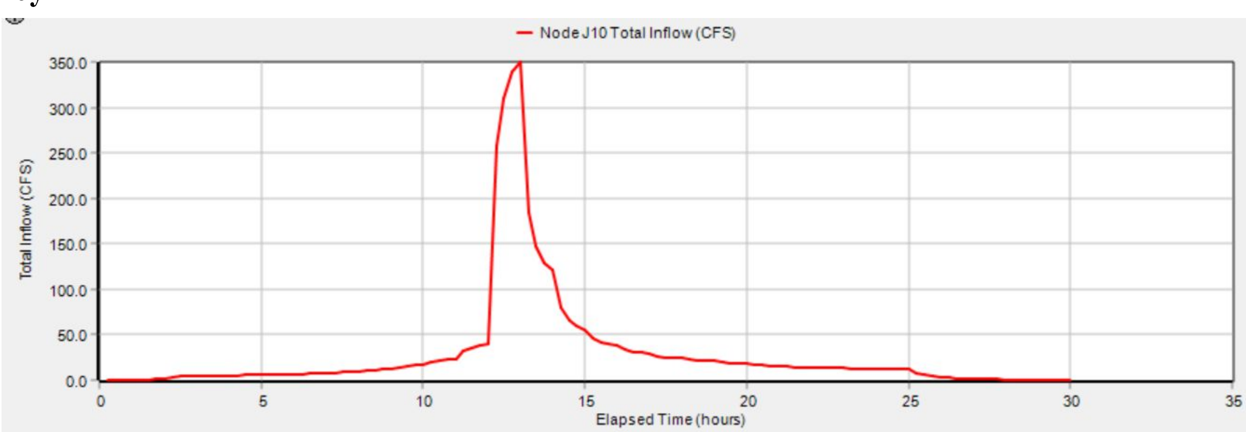
1yr



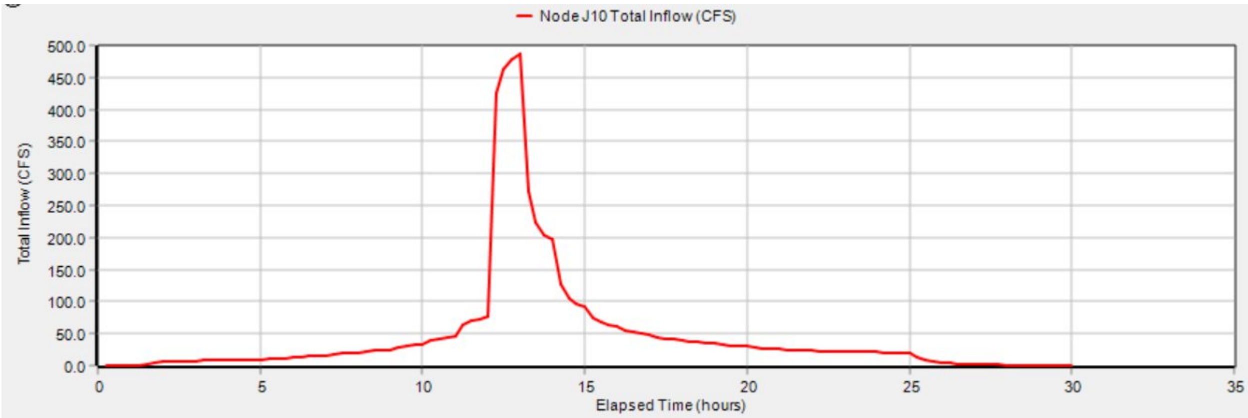
2yr



10yr

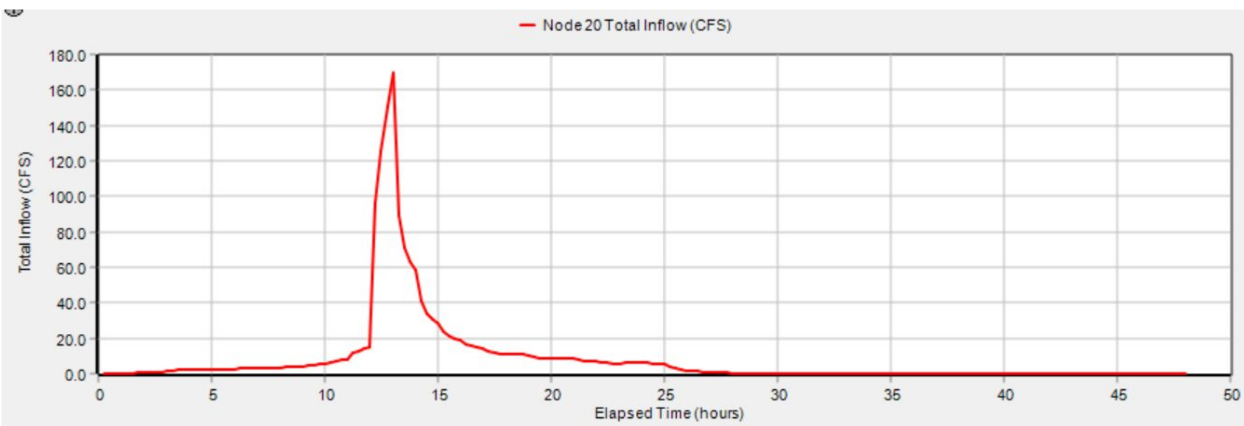


100yr

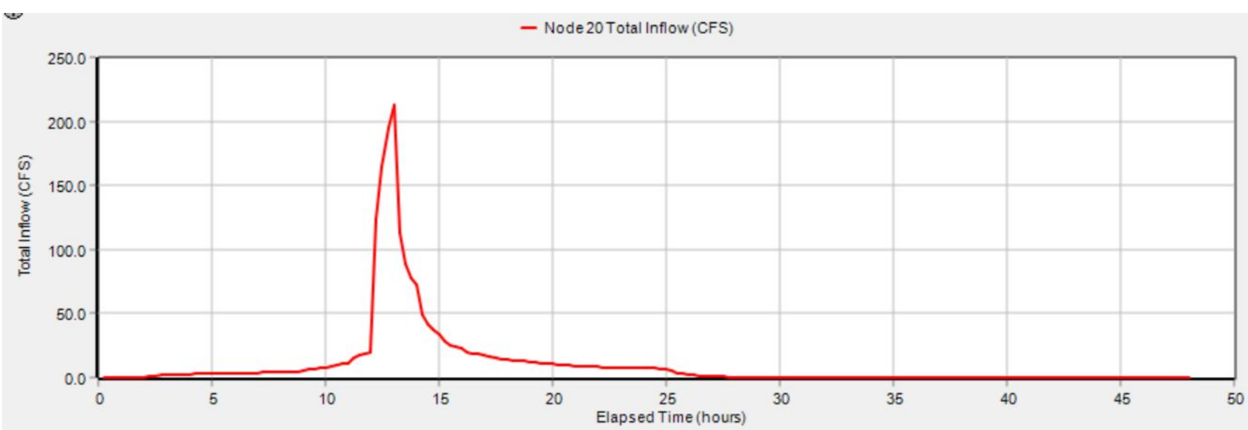


Site Post-development with Contributing Watershed Design Storm Hydrographs:

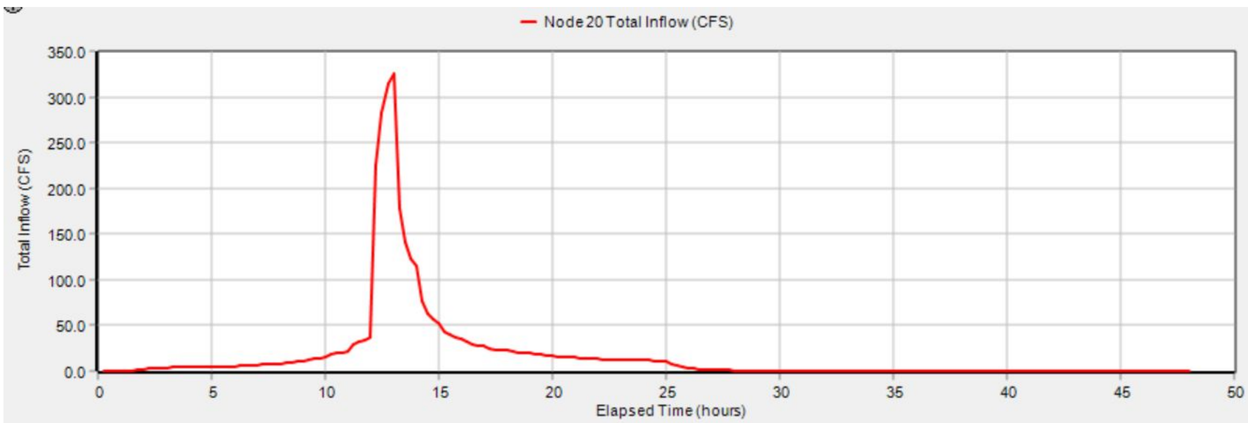
1yr



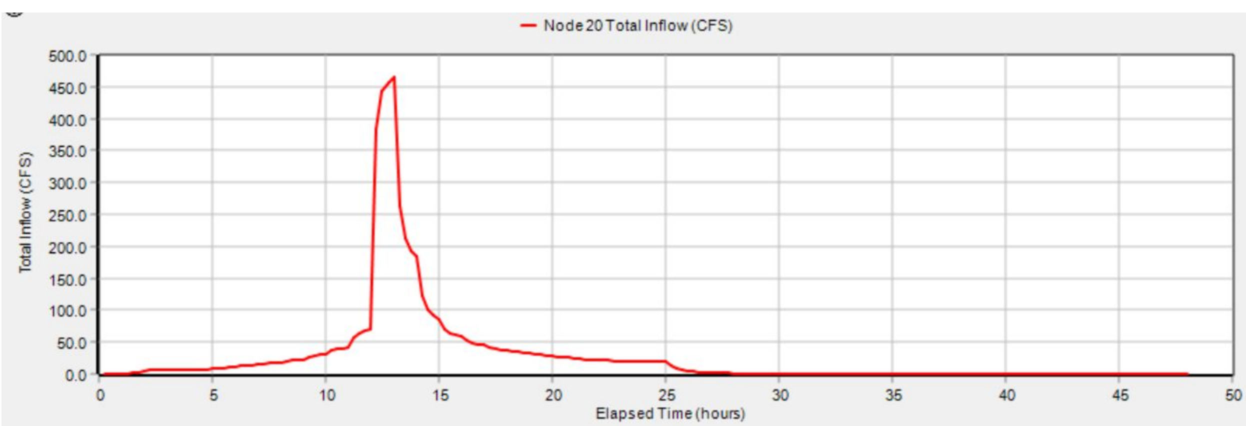
2yr



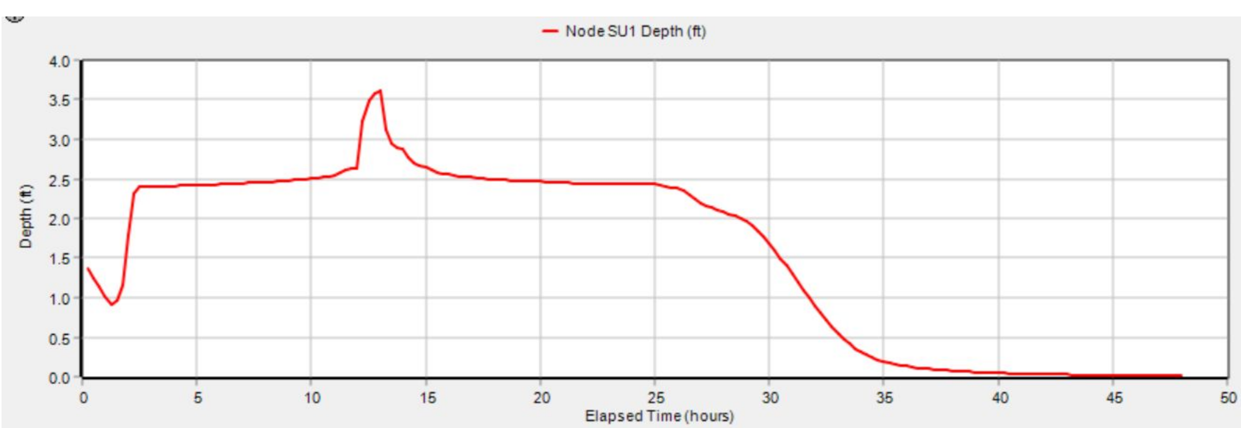
10yr



100yr



<u>Pond Depth during 100yr Storm:</u>



Bioretention Plant Selection:

Plants

Scientific/Common Name	Stormwater Facilities	Recommended Uses	Plant Needs	Characteristics
Panicum virgatum switch grass Grass, Sedge & Reed Albemarle/Charlottesville Native Recommended More details? Plant Question?	Swale Rain Garden Bioretention Basin Detention Basin (Dry Pond) Stream Buffer	Host plants for Lepidoptera Wildlife Landscape Horticulture	Dry Moderate Moisture High Moisture Full Light Partial Shade	**Flower Color:** Pink **Bloom Time:** Jul,Aug,Sep,Oct,Nov,Jan,Feb Spreads Rapidly Deer Resistant Est Height: 36"-60" Est Spread: 24"-36"
Eupatorium purpureum sweetscented joe pye weed Wildflower Albemarle/Charlottesville Native Recommended More details? Plant Question?	Rain Garden Bioretention Basin	Host plants for Lepidoptera		
Sorghastrum nutans Indian grass Grass, Sedge & Reed Albemarle/Charlottesville Native Recommended More details? Plant Question?	Rain Garden Bioretention Basin Detention Basin (Dry Pond)	Host plants for Lepidoptera Wildlife Erosion Landscape	Dry Moderate Moisture Full Light Partial Shade	**Foliage Color:** Green **Flower Color:** Yellow, Red **Bloom Time:** Aug,Sep,Oct Spreads Rapidly Deer Resistant Est Height: 3'-8'
Elymus virginicus Virginia wild rye Grass, Sedge & Reed Albemarle/Charlottesville Native Recommended More details? Plant Question?	Swale Rain Garden Bioretention Basin	Host plants for Lepidoptera Habitat Wildlife Erosion	Dry Moderate Moisture Partial Shade Shade	**Flower Color:** Yellow **Bloom Time:** May,Jun Est Height: 18"-36" Est Spread: 12"-24"

Shrubs

Scientific/Common Name	**Stormwater Facilities**	**Recommended Uses**	**Plant Needs**	**Characteristics**
Viburnum dentatum southern arrow-wood viburnum Shrub Albemarle/Charlottesville Native Recommended More details? Plant Question?	Swale Rain Garden Bioretention Basin Retention Basin (Wet Pond) Detention Basin (Dry Pond)	Host plants for Lepidoptera Habitat Wildlife Landscape Horticulture	Dry Moderate Moisture Partial Shade Shade	**Foliage Color:** Green to Reddish-Purple **Flower Color:** White **Bloom Time:** May,Jun Deer Resistant Est Height: 6'-10' Est Spread: 4'-8'
Ilex verticillata winterberry holly Shrub Albemarle/Charlottesville Native Recommended More details? Plant Question?	Swale Rain Garden Bioretention Basin Detention Basin (Dry Pond) Stream Buffer	Host plants for Lepidoptera Wildlife Landscape Horticulture	Moderate Moisture High Moisture Partial Shade Shade	**Foliage Color:** Evergreen **Flower Color:** Greenish-White, White **Bloom Time:** May,Jun Est Height: 6'-10' Est Spread: 6"-8"

Bioretention Construction Procedure:

Step 1. Construction of the bioretention area may only begin after the entire contributing drainage area has been stabilized with vegetation. It may be necessary to block or dirvert certain curb or other inlets while the bioretention area is being constructed. The proposed site should be checked for existing utilities prior to any excavation.

Step 2. The designer and the installer should have a preconstruction meeting, checking the boundaries of the contributing drainage area and the actual inlet elevations to ensure they conform to original design. Since other contractors may be responsible for constructing portions of the site, it is quite common to find subtle differences in site grading, drainage and paving elevations that can produce hydraulically important differences for the proposed bioretention area. The designer should clearly communicate, in writing, any project changes determined during the preconstruction meeting to the installer and the plan review/inspection authority.

Step 3. Temporary E&S controls are needed during construction of the bioretention area to divert stormwater away from the bioretention area until it is completed. Special protection measures such as erosion control fabrics may be needed to protect vulnerable side slopes from erosion during the construction process.

Step 4. Any pre-treatment cells should be excavated first and then sealed to trap sediments.

Step 5. Excavators or backhoes should work from the sides to excavate the bioretention area to its appropriate design depth and dimensions. Excavating equipment should have scoops with adequate reach so they do not have to sit inside the footprint of the bioretention area. Contractors should use a cell construction approach in larger bioretention basins, whereby the basin is split into 500 to 1,000 sq. ft. temporary cells with a 10-15 foot earth bridge in between, so that cells can be excavated from the side.

Step 6. It may be necessary to rip the bottom soils to a depth of 6 to 12 inches to promote greater infiltration.

Step 7. Place geotextile fabric on the sides of the bioretention area with a 6-inch overlap on the sides. If a stone storage layer will be used, place the appropriate depth of #57 stone on the bottom, install the perforated underdrain pipe, pack #57 stone to 3 inches above the underdrain pipe, and add approximately 3 inches of choker stone/pea gravel as a filter between the underdrain and the soil media layer. If no stone storage layer is used, start with 6 inches of #57 stone on the bottom, and proceed with the layering as described above.

Step 8. Obtain soil the media from a qualified vendor, and store it on an adjacent impervious area or plastic sheeting. After verifying that the media meets the specifications, apply the media in 12- inch lifts until the desired top elevation of the bioretention area is achieved. Wait a few days to check for settlement, and add additional media, as needed, to achieve the design elevation.

Step 9. Prepare planting holes for any trees and shrubs, install the vegetation, and water accordingly. Install any temporary irrigation.

Dry Swale Filter Media Notes and Specifications:

Material	**Specification(s)**	**Notes**
Filter Media Composition	Filter Media to contain (specific media component composition is described in **Section 6.6** of **Spec No. 9**: • 85-88% sand • 8-12% soil fines • 3-5% qualified organic matter	The volume of filter media for construction should be is based on 110% of the plan volume to account for settling.
Filter Media Testing	Available P between 7 and 23 mg/kg.; CEC greater than 10 (to the extent possible)	The media should be certified by the supplier as meeting the intent of these specifications (refer to **Stormwater Design Spec No. 9: Bioretention**, for additional soil media information.
Surface Cover	Turf, river stone, select bioretention landscaping.	
Top Soil	4 inch surface depth of loamy sand or sandy loam texture, with less than 5% clay content, a corrected pH of 6 to 7, and at least 2% organic matter.	
Filter Fabric	Use an appropriate material for the application based on AASHTO M288-06. Fabric should have a flow rate of > 125 gpm/sq. ft. (ASTM D4491), and an Apparent Opening Size (AOS) equivalent to a US # 70 or # 80 sieve (ASTM D4751). The geotextile AOS selection is based on the percent passing the No. 200 sieve in "A" Soil subgrade, using FHWA or AASHTO selection criteria. Apply on the sides and immediately above the underdrain only.] For hotspots and certain karst sites only, use an appropriate liner on the bottom.	
Choking Layer	A 2 to 4 inch layer of sand over a 2 inch layer of choker stone (typically #8 or # 89 washed gravel) laid above the underdrain stone.	
Stone and/or Storage Layer	1 inch stone should be double-washed and clean and free of all fines (e.g., VDOT #57 stone).	A 9 to 18 inch layer (depending on the desired depth of the storage layer)
Underdrains, Cleanouts, and Observation Wells	6-inch rigid schedule 40 PVC pipe, with 3/8-inch perforations(or equivalent corrugated HDPE), with 3/8-inch perforations at 6 inches on center;	Install perforated pipe for the full length of the dry swale cell. Use non-perforated pipe, as needed, to connect with the storm drain system.
Vegetation	Plant species as as specified on the landscaping plan	
Check Dams	Use non-erosive material such as wood, gabions, riprap, or concrete. All check dams should be underlain with filter fabric, and include weep holes. Wood used for check dams should consist of pressure-treated logs or timbers, or water-resistant tree species such as cedar, hemlock, swamp oak or locust.	
Erosion Control Fabric	Where flow velocities dictate, use woven biodegradable erosion control fabric or mats (EC3) that are durable enough to last at least 2 growing seasons.	