Green Infrastructure Solutions to Campus Flooding in Urbana, IL

University of Illinois at Urbana-Champaign

2020

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PROJECT ABSTRACT FORM
WEFTEC® 2020 STUDENT DESIGN COMPETITION

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Project Title: Green Infrastructure Solutions to Flooding in Urbana, IL

University: University of Illinois at Urbana-Champaign

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Abstract

As an esteemed part of the University of Illinois at Urbana-Champaign, the College of Veterinary Medicine attracts many students from around the world. However, poor stormwater management around the facility has led to issues of flooding and even nitrate pollution from agricultural stormwater from the surrounding areas. The purpose of this project was to design green infrastructure systems in order to alleviate flooding around the Vet Med facility and improve general aesthetics. The design featured a rain garden and parking lot bioswales for collection of stormwater runoff in separate water catchments. Analysis of rainfall events, BMP design and optimization, land surveying, and cost estimates were included in the project.

Summary of Project Team Efforts

- Jinglin Duan - Jinglin created 3D models of the rain garden and bioswales using AutoCAD.
- Ryan Moeller - Ryan designed the layout and cross section of the rain garden options in the south green area and performed volume calculations for cost estimates.
- Lindsay Muth - Lindsay worked on the rain garden design and gathered information for cost estimates using RS Means.
- Abhijeet Saraf - Abhijeet researched stormwater reduction design requirements and modeled the detention capacities and stormwater runoff simulations on EPA SWMM .
- Justin Shen - Justin organized group meetings and oversaw progress of design decisions. He performed cost estimates for the design options and gathered information on the parking lot redevelopment.
- Xinyu Teng - Xinyu researched rain garden designs and alternatives.

Project Description

1. Background

1.1 Vet Med

The Veterinary Medicine (Vet Med) Facility at the University of Illinois at Urbana-Champaign was constructed in the late 20th century to accommodate the expansion of the College of Veterinary Medicine. The facility includes space for teaching instruction, animal clinics, and laboratory use. Today, the College is still growing rapidly as an institution renowned for its curriculum, personnel, and excellent programs. As a result, it is imperative that the University maintains an inviting environment for prospective and current students, researchers, and alumni.

Figure 1.11 Main entrance to College of Vet Med

The main entrance to the College of Vet Med is through the large parking lot (which will be referred to as “the south parking lot”) neighboring Lincoln Ave. as shown above in Figure 1.1. When high rainfall events occur, stormwater around the entrance routes in two ways as shown below in Figure 1.2:

- Runoff collected in the north parking lot of Figure 1.1 as well as the green areas north and east of it travel along the blue arrows through a culvert and consequently to the green area west of the south parking lot. The stormwater then travels through a culvert under Hazelwood Drive to the southern dairy farm.

- Runoff collected in the south parking lot of Figure 1.1 enters manholes delineated by the marked circles, and then travels through a storm sewer shown by black arrows. The sewer leads under Hazelwood Drive to the southern dairy farm.

The location of the entire College with regard to the dairy farm is shown in Figure 1.3.

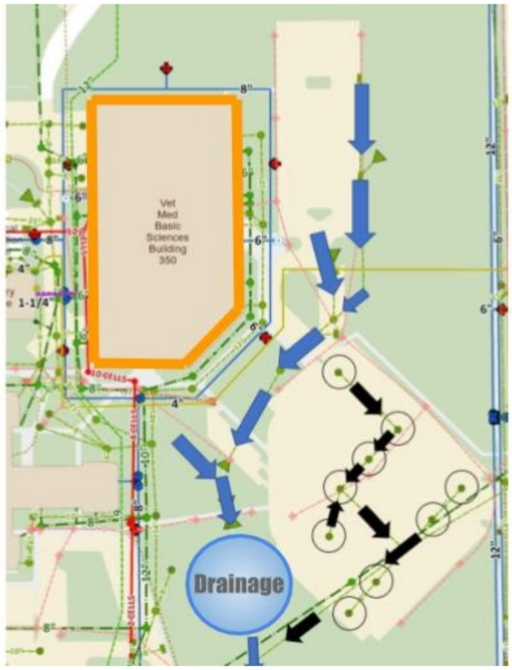

Figure 1.12 Stormwater routing near entrance to College of Vet Med

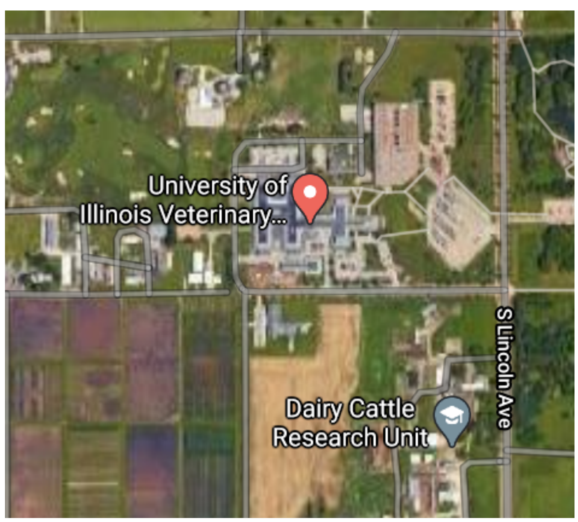

Figure 1.13 Location of College of Vet Med with respect to south dairy farm

At high volumes, stormwater arriving at the dairy farm leaches agricultural nutrients, most notably nitrates, into nearby streams and eventually the Gulf of Mexico via the Embarras, Wabash, Ohio, and Mississippi Rivers, contributing to the hypoxic zone.

1.2 Design Rainfall

For the purpose of assessing reductions in runoff from the facility, arising from our design solutions, two design rainfall parameters were employed:

95th Percentile Rainfall - Section 438 of the Energy Independence and Security Act (EISA) states that a federal facility needs to develop measures to retain 100% volume generated by a 95th percentile rainfall event. This rainfall event represents the amount of rainfall that is higher than the amount of rainfall received in 95% of rainfall events historically.

Historical records of past 13 years were retrieved from National Oceanic and Atmospheric Administration (NOAA) and the precipitation data was plotted using MS-Excel. Using this plot, the 95th percentile rainfall was found to be 2.18 in/day.

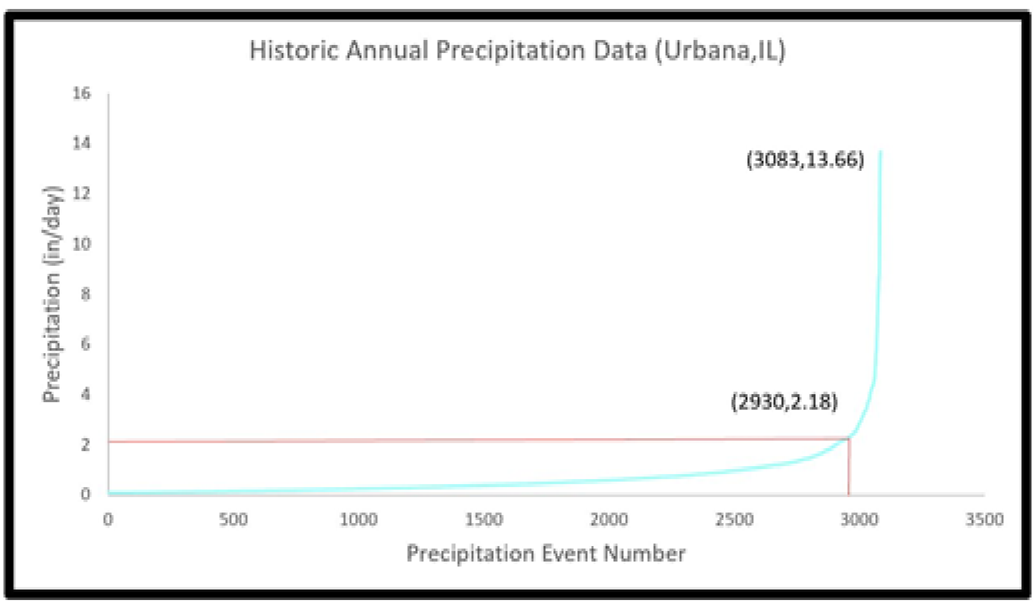

Figure 1.21 Plot to estimate 95th percentile rainfall

24hr-5yr event - As per standard texts such as the New York Stormwater Management Design Manual, the 24hr-5yr event is employed to assess reduction in runoff volume post construction of BMP. This data was retrieved from NOAA and this value was noted to be 3.73 in/hr.

PF tabular | PF graphical | Supplementary information | Print page

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]										
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.409** (0.380-0.443)	**0.485** (0.450-0.527)	**0.576** (0.533-0.626)	**0.647** (0.597-0.702)	**0.741** (0.681-0.803)	**0.813** (0.744-0.880)	**0.885** (0.808-0.957)	**0.961** (0.869-1.04)	**1.06** (0.953-1.15)	**1.14** (1.01-1.23)
10-min	**0.635** (0.590-0.688)	**0.757** (0.703-0.822)	**0.894** (0.828-0.972)	**0.999** (0.922-1.08)	**1.13** (1.04-1.23)	**1.23** (1.13-1.33)	**1.33** (1.21-1.44)	**1.43** (1.30-1.55)	**1.56** (1.40-1.69)	**1.66** (1.48-1.79)
15-min	**0.779** (0.723-0.843)	**0.926** (0.859-1.00)	**1.10** (1.02-1.19)	**1.23** (1.13-1.33)	**1.40** (1.29-1.52)	**1.53** (1.40-1.65)	**1.66** (1.51-1.79)	**1.78** (1.61-1.93)	**1.95** (1.75-2.11)	**2.07** (1.85-2.24)
30-min	**1.03** (0.957-1.12)	**1.24** (1.15-1.35)	**1.50** (1.39-1.64)	**1.71** (1.58-1.85)	**1.98** (1.82-2.14)	**2.18** (2.00-2.36)	**2.39** (2.17-2.58)	**2.60** (2.36-2.81)	**2.89** (2.59-3.12)	**3.11** (2.77-3.35)
60-min	**1.26** (1.17-1.36)	**1.52** (1.41-1.65)	**1.89** (1.75-2.05)	**2.17** (2.00-2.36)	**2.56** (2.36-2.78)	**2.87** (2.63-3.11)	**3.20** (2.91-3.46)	**3.53** (3.20-3.82)	**3.99** (3.58-4.32)	**4.36** (3.89-4.71)
2-hr	**1.50** (1.38-1.63)	**1.81** (1.67-1.97)	**2.23** (2.05-2.42)	**2.57** (2.36-2.80)	**3.08** (2.82-3.34)	**3.52** (3.21-3.81)	**4.02** (3.65-4.34)	**4.58** (4.14-4.95)	**5.43** (4.88-5.87)	**6.19** (5.51-6.69)
3-hr	**1.61** (1.48-1.76)	**1.94** (1.78-2.12)	**2.39** (2.19-2.61)	**2.76** (2.53-3.02)	**3.33** (3.04-3.63)	**3.83** (3.48-4.17)	**4.40** (3.98-4.78)	**5.04** (4.53-5.47)	**6.03** (5.37-6.55)	**6.92** (6.12-7.52)
6-hr	**1.91** (1.75-2.08)	**2.29** (2.10-2.51)	**2.80** (2.58-3.07)	**3.25** (2.98-3.55)	**3.92** (3.57-4.27)	**4.50** (4.08-4.90)	**5.16** (4.65-5.61)	**5.92** (5.30-6.43)	**7.09** (6.29-7.70)	**8.13** (7.16-8.82)
12-hr	**2.22** (2.06-2.41)	**2.67** (2.47-2.90)	**3.25** (3.01-3.53)	**3.75** (3.46-4.08)	**4.49** (4.12-4.86)	**5.14** (4.70-5.55)	**5.87** (5.34-6.34)	**6.70** (6.06-7.23)	**7.98** (7.16-8.61)	**9.11** (8.12-9.83)
24-hr	**2.57** (2.41-2.76)	**3.06** (2.88-3.29)	**3.73** (3.51-4.01)	**4.31** (4.03-4.63)	**5.19** (4.82-5.59)	**5.98** (5.49-6.47)	**6.88** (6.26-7.50)	**7.93** (7.11-8.71)	**9.57** (8.40-10.6)	**11.0** (9.52-12.4)

Figure 1.22 Precipitation data for Urbana,IL (source - NOAA)l

2. Design Problem

Our design goal for the project is to propose green infrastructure solutions to reduce the stormwater runoff from the facility so that the associated leaching of nutrients from the dairy farm located downstream is minimized and water quality of the stormwater runoff is enhanced. Additionally, incorporation of green infrastructure features will also add to the facility aesthetics.

3. Alternative Solutions

Our team researched several green infrastructure features for installation at the facility as a measure to reduce stormwater runoff. These options included -

- Construction of Rain Gardens
- Construction of Bioretention swales
- Incorporation of Permeable Pavements
- Employing planter boxes
- Urban Tree Canopies
- Rainwater Harvesting

After diligent brainstorming, and consideration of efficiency, time constraints and funding requirements, it was decided that two design solutions would be most appropriate:

a) Construction of a Rain Garden in green area adjacent to South Parking lot - The rain garden would capture stormwater runoff from upstream, including the north parking lot and surrounding areas

b) Construction of Bioretention swales in South Parking Lot - The bioretention swales would be built on the subcatchments in the south parking lot and would capture stormwater runoff from the parking lot. Since this parking lot forms the main entrance to the facility, the construction of swales would also aid in aesthetic appeal.

4. Design Recommendation

4.1 Construction of Rain Garden to capture runoff from the north parking lot and surrounding areas

In order to retain runoff during peak storm events, rain gardens in two areas were considered. The north green area directly east of the facility's north parking lot receives runoff from only a single storm sewer, while the south green area receives the remaining flow from the north parking lot and green areas adjacent to the building. Ultimately only the south green area was selected as a candidate for a rain garden. As seen in figure 4.1, the area is divided by a sidewalk, with the larger southern portion ending in a culvert leading under Hazelwood Drive.

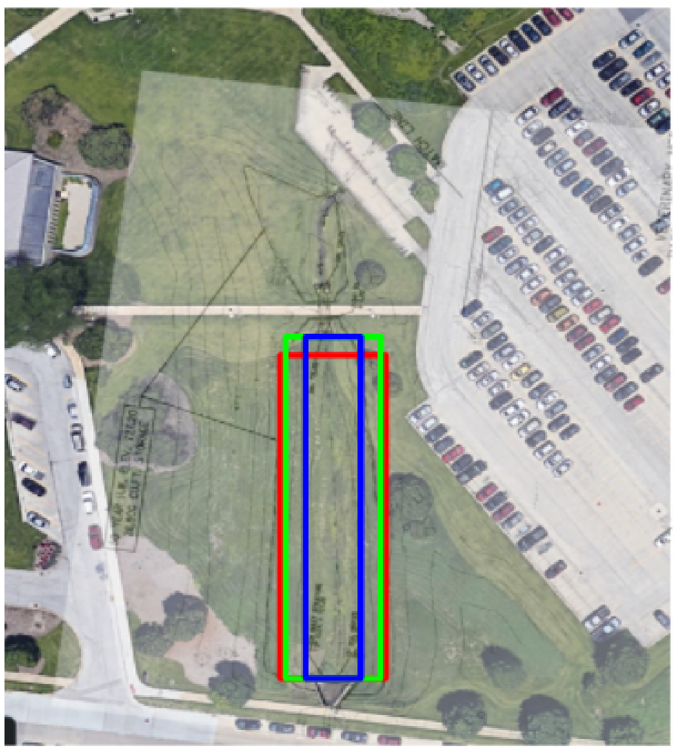

Figure 4.11 Existing contours in south green area

According to climate data from NOAA and the Illinois State Water Survey, a 95th percentile rainfall event would bring roughly 2.18 inches of rain per day to the area, while a 24-hour 5-year event would result in an average of 3.73 inches/hour. Based on EPA SWMM modeling, the catchment basin of the southern green area would receive roughly 30,000 cubic feet of water in this extreme event. To minimize runoff and cost, three designs were evaluated with differing surface area. These designs were created to roughly fit the existing slopes in the area, as efforts to collaborate with students and faculty in the university's landscape architecture department were put on hold after spring classes were moved online mid-March. Rough dimensions for the options are as follows:

Option A: 25'x220'
Option B: 45'x220'
Option C: 50'x210'

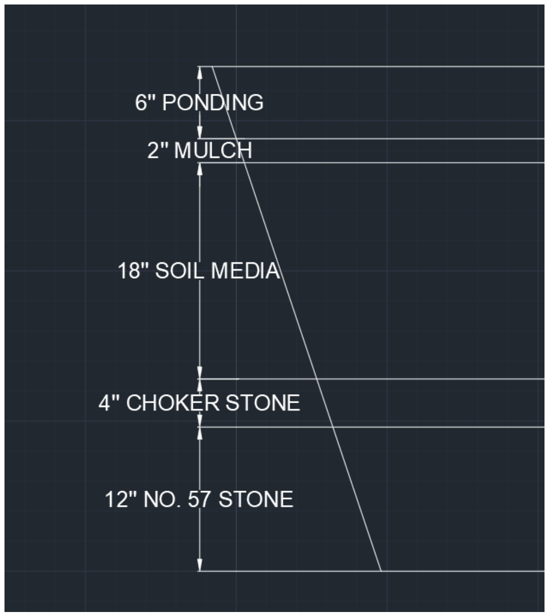

Figure 4.12 Proposed rain garden cross-section

The project will require about three feet of excavation to allow for the shown depths of gravel, soil, and mulch, which amounts to 500 cubic yards for our smallest design or over 1000 for our largest. If soil tests show it is uncontaminated, the soil can remain on site to be reused. Based on soil data the drainage in the area is roughly 14 inches per day, so the existing soil would provide adequate drainage for a rain garden.The rain garden design accounts for 6 inches of ponding on top of the soil media to allow for extra storage if rainfall exceeds soil drainage capacity. Located within the lowest gravel layer, a perforated PVC underdrain, not pictured in Figure 4.12, would help alleviate excess ponding.

	Storage Volume	% Reduction
Option A	12,400 cubic ft.	40.2
Option B	22,500 cubic ft.	73.1
Option C	23,600 cubic ft.	76.6

Table 4.1 Reduction capacity for rain garden options in 24-hr 5-year event

Storage volume was calculated using the cross section shown in Figure 4.12 and the area of each design option. The sloped sides of the rain garden design were taken into consideration, as was the variation in porosities between the layers.

As seen in Table 4.1, the existing rain garden options would not achieve 100% reduction to the design requirements. However, increasing the ponding depth of options B or C from 6 inches to 12 inches would make this goal feasible. At a 12-inch ponding depth, the storage volume of Option C increases to 29,000 cubic feet, just shy of the design requirement. To achieve 100% runoff reduction, the area directly north of the sidewalk could also be incorporated, or a slightly larger surface area could be included when the design is rounded and made more aesthetically pleasing.

4.2 Construction of Bioretention swales to capture water from south parking lot and surrounding area

The south parking lot forms the main entrance of the facility and has an area of nearly 2.5 acres. The total catchment area of the lot is nearly 3 acres including the surrounding green areas. The existing system of stormwater sewers in the lot drains the collected water across hazelwood drive and into the natural channel, that ultimately flows out into the Mississippi river and eventually to the Gulf of Mexico.

The parking lot consists of 10 subcatchments, each of which drain into a manhole. All manholes are interconnected by sewer lines. The plan of existing stormwater sewers was retrieved from the University's Facilities & Services to understand the drainage systems. The figures below illustrate the different subcatchments in the parking lot and also existing drainage system. The illustration on the left shows one subcatchment in blue marking and is from EPA SWMM model used for design.

Figure 4.21 Delineated subcatchment on EPA SWMM windowl

Figure 4.22 Drainage plan retrieved from Facilities & Services Department

In the existing configuration, parking spaces are located on either sides of 4 parking medians, that are marked straight lines running parallel to each other. Parking medians lie along the crest or high-points of subcatchments. Manholes lie along lines parallel to parking medians and form the lowest points in each subcatchment. As shown in the following illustration, the yellow pins represent the manhole and the white lines represent the parking median marks in parking lot.

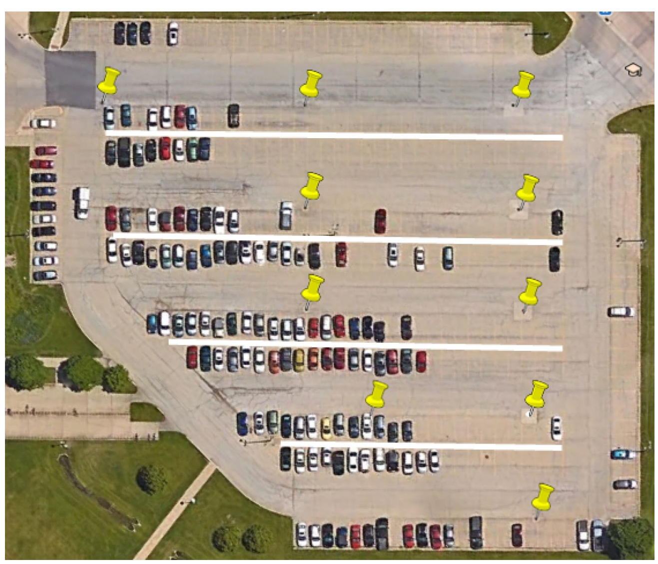

Figure 4.23 Manhole and existing Parking medians at South Parking Lotl

Our redevelopment plan would include construction of bioretention swales running along the parallel lines connecting manholes, thus forming the trough of the subcatchments. In total, there would be 8 new bioretention swales as shown illustration below. The boxed section represent the manholes and hatched rectangle sections each represent swales.

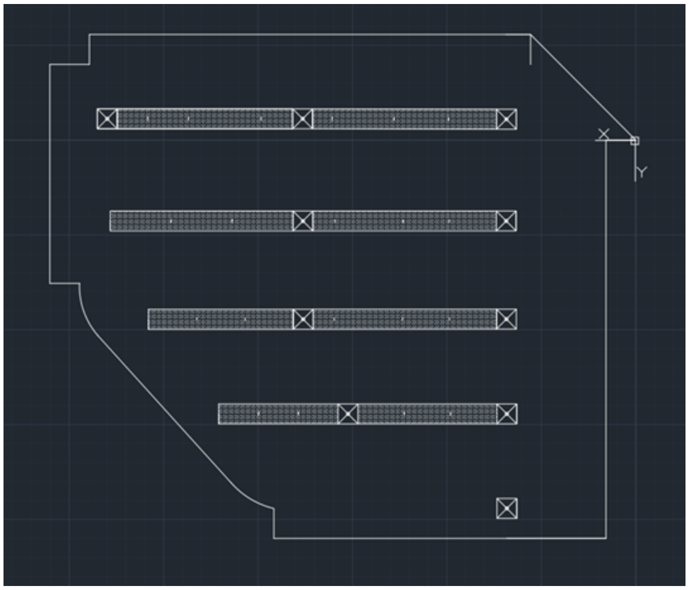

Figure 4.24 Swales Overview

However, multiple subcatchments run across some swales and there exist sub-sections for some swales that convey water to different manholes. An illustration overlaying proposed swales onto the existing parking lot aims to explain this better.

Figure 4.25 Proposed swale sections overlaid on existing plan view of South Parking Lot

Subsections 1 and 2 form one swale together but they both convey water to different manholes. Subsection 1 conveys water to the manhole on the left and subsection 2 conveys water to the manhole on the right. Better idea of the subcatchments was achieved from the elevation data and these were carefully considered while modelling.

For modeling the reduction in runoff due to the design rainfall parameters, EPA SWMM software was used. This software is a standard stormwater management model widely used in the field of water resources and its main features include area subcatchments, manholes, conduits and rain gage for modeling the rainfall.

To model the parking lot in SWMM window, site investigation and level survey were performed to collect better elevation data at the parking lot. Google Earth was employed to measure the length of conduits and the slopes of longest flow paths for individual subcatchments. It was also used to calculate the areas of subcatchments.

The data so collected and prepared, was then input into the SWMM window.

2 EPA SWMM models were prepare for the 2 scenarios - firstly, existing drainage or the pre-development stage and secondly, the post-development scenario post-construction of the bioswales. These models aided in the comparison and estimation of decrease in runoff volume post construction of bioswales.

The bioswales sections were designed in accordance with standard texts such as the Georgia Stormwater Management Manual. The manual was referred for sizing of various components in the proposed bioswale so as to retain the 95th percentile rainfall.

The cross-section of our proposed bioswale is shown in illustration below:

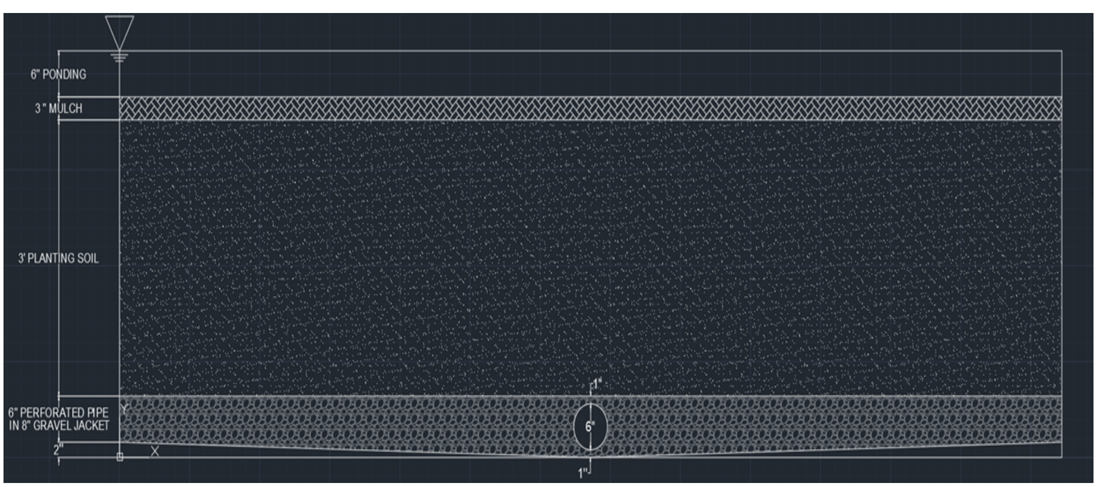

Figure 4.26 Bioretention Swale Section

There will be a 6-inch ponding layer on top, followed by a 3-inch mulch layer, 36 inches of planting soil, and then an 8-inch gravel layer that has a sloping bottom. The 6-inch diameter perforated pipe will be located in the middle of the gravel layer, an inch from both the top and the bottom.

The modeling of the sections was performed using the LID Controls provision on the EPA SWMM window as illustrated below:

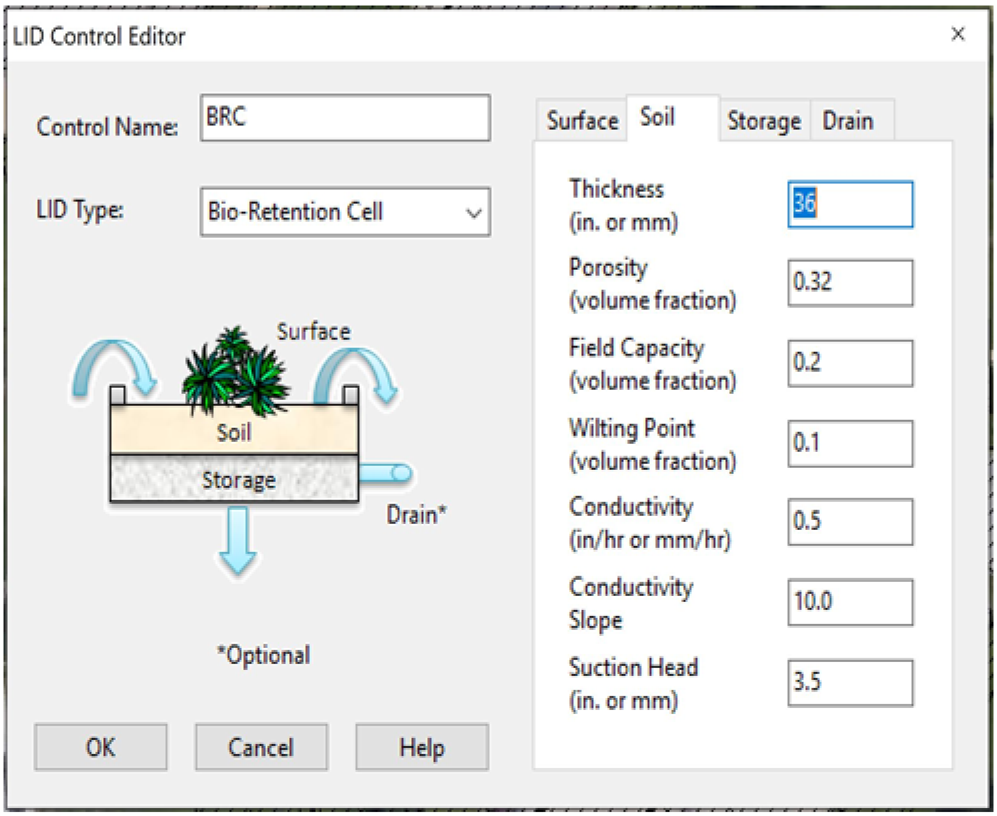

Figure 4.27 Bioretention swales modeling on EPA SWMM window using LID Controls provision

Upon running the simulations for the 95th percentile rainfall, the stormwater runoff out of the swale sections was found to be zero for all sections.

Topic: LID Performance — Click a column header to sort the column.

Subcatchment	LID Control	Total Inflow in	Evap Loss in	Infil Loss in	Surface Outflow in	Drain Outflow in	Initial Storage in	Final Storage in	Continuity Error %
S48	BRC	22.31	0.00	6.97	2.43	0.00	3.60	16.52	0.00
S49	BRC	29.03	0.00	7.43	8.67	0.00	3.60	16.52	0.00
S50	BRC	18.04	0.00	6.45	0.00	0.00	3.60	15.17	0.10
S51	BRC	17.27	0.00	6.32	0.00	0.00	3.60	14.53	0.09
S52	BRC	17.62	0.00	6.38	0.00	0.00	3.60	14.82	0.10
S53	BRC	2.18	0.00	0.00	0.00	0.00	3.60	5.78	0.13
S54	BRC	16.89	0.00	6.26	0.00	0.00	3.60	14.21	0.09
S55	BRC	11.87	0.00	4.68	0.00	0.00	3.60	10.79	0.05
S56	BRC	13.61	0.00	5.54	0.00	0.00	3.60	11.66	0.06

Figure 4.28 EPA SWMM simulation results for runoff from swale sections

For a 24hr-5yr design rainfall event, nearly 200,000 gallons of water either infiltrated or was retained in the bioswale section. This accounted for more than 2% decrease in runoff volume discharged in a 24-hr period. The runoffs from the subcatchments were noted following simulation in EPA SWMM.

Serial Number	Manhole	Subcatchment Draining into it pre-development	Subcatchment Runoff Volume (10^6 gal)	Subcatchment Draining into it post-development	Subcatchment Runoff Volume (10^6 gal)
	J14	S44	0.84	S54	0.8
	J15	S30	0.7	S52	0.69
	J16	S29	0.75	S50	0.73
	J17	S26	0.71	S48	0.64
	J18	S25	1.32	S58	1.29
	J19	S33	0.37	S55	0.41
	J20	S31	0.75	S53	0.72
	J21	S28	0.8	S51	0.69
	J22	S27	0.94	S49	0.95
	J23	S34	0.46	S56	0.52
		Total Runoff (gallons)	7640000	Total Runoff (gallons)	7440000

Net Reduction in Runoff Volume in a 24 hr 5-yr event (gallons)	200000
Net Reduction in Runoff Volume as a percentage of pre-development runoff	2.617801047

Figure 4.29 Reduction in runoff volume for a 24hr-5yr event

Hence, the incorporation of bioretention swales achieves the aim of retention of the entire volume of runoff from a 95th percentile event and also results in significant reductions in gross runoff volume for a 24hr-5yr design event.

4.3 Cost Estimates

Cost estimates were computed using 2011 RS Means due to a lack of access to newer versions, and so costs were inflated to 2020 values. As a result of the limitations with 2011 RS Means, many items were unable to be found in each option considered. Thus, results were evaluated on a scale. As shown in Table 4.31, Option C offers the most detention capacity at the highest cost, with Option B slightly behind in both categories. From the parking lot redevelopment estimate shown in Table 4.32, it can be seen that the bioswale implementation will be much more costly than any of the rain garden construction. However, the rain garden and bioswale offer solutions to stormwater management in different areas, and so both are necessary.

	Option A	Option B	Option C
Cost ($)	20,400	34,800	38,000
Detention Capacity (cubic feet)	12,400	22,500	23,600

Table 4.31 Rain Garden Cost Estimate Scale

Cost ($)	162,000
Detention Capacity (cubic feet)	16,100

Table 4.32 Parking Lot Redevelopment Cost Estimate Scale

4.4 Decision Matrix

The four factors evaluated for our design recommendation were detention capabilities, cost, difficulty of implementation, and aesthetics. The goal of the project was to reduce flooding for the Vet Med Facility, so detention capabilities was the factor with the highest weight. This contributed to the result of **Rain Garden Option C being the best choice of the rain gardens**, whereas the **Parking Lot Redevelopment stood alone in combatting stormwater runoff in the south parking lot**.

Decision Factor	Weight	Parking Lot Redevelopment		Rain Garden Option A		Rain Garden Option B		Rain Garden Option C	
		Raw	Weighted	Raw	Weighted	Raw	Weighted	Raw	Weighted
Detention Capabilities	0.35	1	0.35	5	1.75	3	1.05	2	0.7
Cost	0.30	4	1.2	1	0.3	2	0.6	3	0.9
Difficulty of Implementation	0.20	4	0.8	2	0.4	2	0.4	2	0.4
Aesthetics	0.15	2	0.3	4	0.6	4	0.6	4	0.6
Total	1.00		**2.65**		**3.05**		**2.65**		**2.6**

Table 4.41 Matrix evaluating the different options

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