# ABSTRACT

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As part of an intense effort to clean up the Anacostia River and the Chesapeake Bay region, the Maryland Department of Environment will soon enforce new policies to increase the treatment of impervious area. The University of Maryland's College Park campus needs to identify potential projects in order to meet the pending stormwater regulations as part of the new municipal separate storm sewer systems (MS4) permit for UM-CP. This thesis investigates retrofits a poorly maintained stormwater pond that has maintained itself as a wetland. The 4.89-acre site is located in the north part of campus is a part of the Anacostia watershed and includes the pond, two parking lots, and a wet-

swale. This thesis proposes a stormwater retrofit that includes various state acceptable BMPs including: a constructed wetland, mirco-bioretentions, pervious concrete, and a bio-swale. The BMPs forms a treatment train that reducing runoff by 7%, capturing and treating 113% of a one-year storm of 2.63 inches. This redesign that would provide a range of environmental, recreational, and educational services. While the proposal is site-specific, the model can be adaptable for retrofitting centralized stormwater facilities and by other college campuses within the Chesapeake Bay watershed.

RETHINKING THE ROLE OF STORMWATER MANAGEMENT ON CAMPUS IN COLLEGE PARK, MARYLAND

By
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Thesis submitted to the Faculty of the Graduate School of the University of Maryland, College Park, in partial fulfillment of the requirement for the degree of Master of Landscape Architecture
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## Stormwater and the Environment

Stormwater runoff is generated from an overflow of rain water and snow melts that are runs on impervious surfaces, such as paved streets, parking lots, and building rooftops, and does not soak into the ground (EPA, 2017a). While inside grey infrastructures, like storm sewers, stormwater runoff gathers speed and pollutants as it travels. Thus, the concentrated volume and power blast of the runoff causes streambanks causing erosion and wiping out aquatic habitat. Additionally, the pollutants in the stormwater runoff can harm ecosystems, wildlife, and our potable water (EPA, 2003).

In a natural environment, the stormwater is purified by the vegetation and soil, which allows for the underground aquifers to refill and ultimately flow into nearby water bodies. However, in urban areas, the vast amount of impervious surfaces do not allow the runoff to be infiltrated into the soil, this it will not be purify before entering into a local water body. Figure 1.1 demonstrates water transpires in a natural environment versus an urban environment.

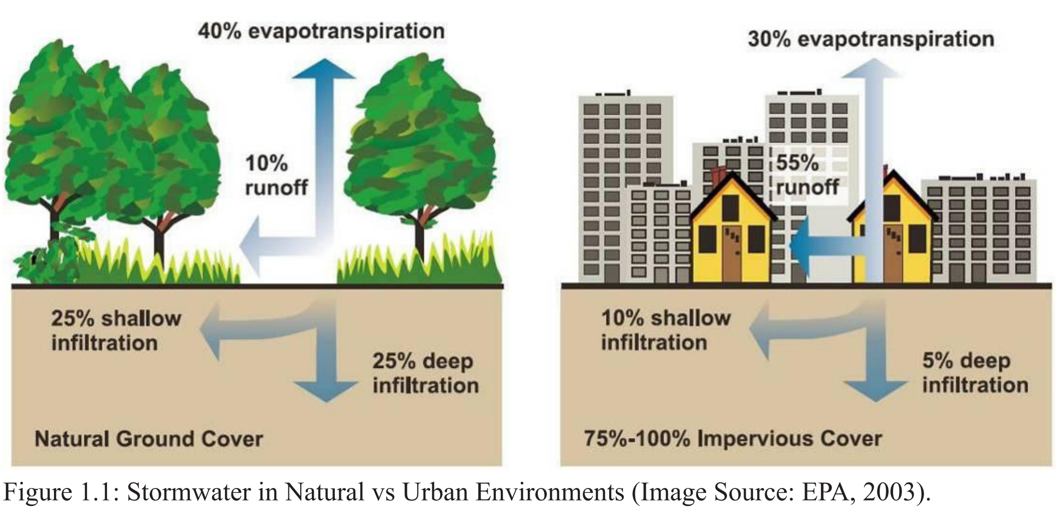



Figure 1.1: Stormwater in Natural vs Urban Environments (Image Source: EPA, 2003).

Between 1982 and 2012, the amount of developed land increased by 58 percent or 42 million acres in 49 states (not including the District of Columbia and Alaska). The Census Bureau estimates that during the same 30-year period, the population of the 49 states grew by more than 82 million people, or 36 percent (EPA, 2017b). Both the endless amounts of impervious surfaces and increase of developed areas have caused the watersheds' impaired conditions. The continued increase of land development and urbanization, will further damage the watersheds. As a result, the protection of bodies of waters is needed through low impact developments (LIDs). LIDs mimic the natural environments by slowing down stormwater run-off, infiltrating, and replenishing the aquifers, and purifying runoff before reaching our drinking water.

**National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permits**

In 1972, Congress passed the Federal Water Pollution Control Act (also known as the Clean Water Act (CWA)) to restore and maintain the integrity of the nation's water. The goals of the CWA are to eliminate the introduction of pollutants into the nation's navigable waters and to achieve fishable and swimmable water quality levels. Section 402 of the CWA is the National Pollutant Discharge Elimination System (NPDES) program states that all facilities must obtain a permit if it is discharging pollutants from any point source into a source of water in the United States. The permit contains limits on what can be discharged, monitoring and reporting requirements, and other provisions to ensure that the discharge does not hurt water quality or people's health (EPA, 2017e). Each permit lasts for five years.

There are two different types of storm sewers systems that can have NPDES permits: a combined sewer system (CSS) and a Municipal Separate Storm Sewer System (MS4). The combined sewer system (CSS) is where the storm sewer from the street is mixed in with wastewater and both are . The municipal separate storm sewer system (MS4) is where the storm sewer is separated from the wastewater that is coming from buildings. Figure 1.2 illustrates how MS4 vs a CSS.

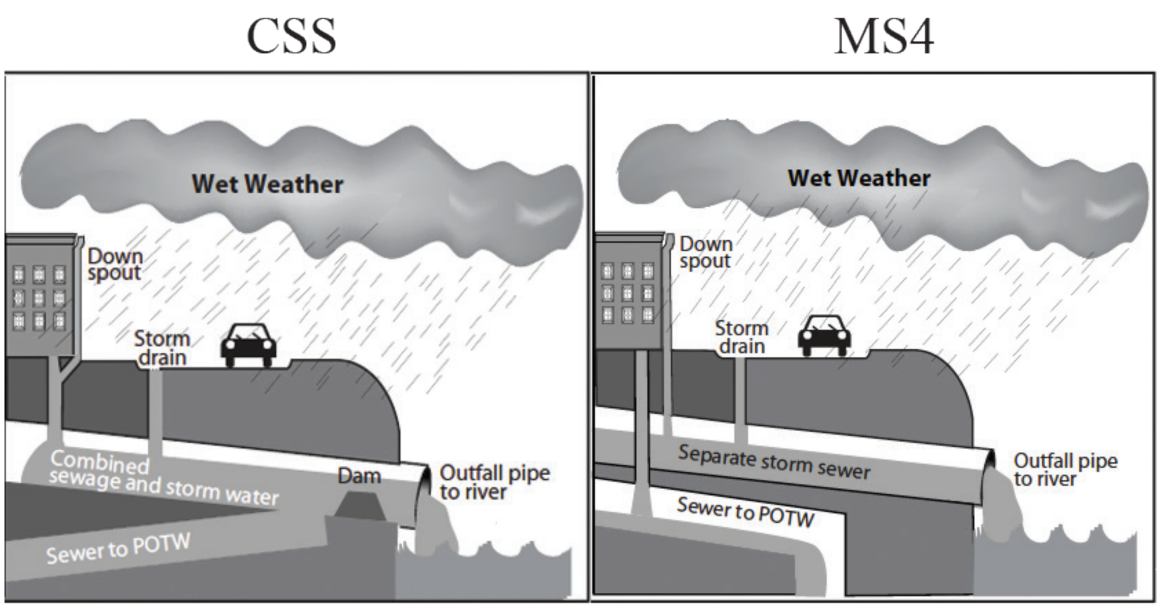



Figure 1.2: CSS vs MS4 (Image Source: EPA, 2004)

There are two different types of permits: Phase I and Phase II. A Phase I permit is broken down by two different sizes of urban areas, large and medium.A Phase I large urban area includes a population that is greater than 250,000, and a medium urban area includes a population that is between 100,000 and 250,000 (MDE, 2017a). A Phase II permit is for a small urban area that has a population that is less than 100,000. To break it down even further, there is a separate MS4 permit for small municipalities, and another for state and federal agencies (MDE, 2017b). Public college and universities are considered as a state property.

### Non-Point Source (NPS) Pollutants

One of the major contributors of stormwater pollutants is non-point source (NPS) pollutants. NPS pollutants come from many different sources that are picked up by runoff from impervious surfaces before heading to bodies of water like rivers, streams, lakes, and coastal waters. NPSs could be trash, chemicals, oils, and sediment. Due to the fact that it does not come from one major contributor like a point source pollutants, e.g. an oil refinery wastewater discharge outlet, NPS pollutants are the main contributor to waterways (EPA, 2017c).

There are eight areas where NPS can come from including agriculture, forestry, Hydromodification and Habitat Alteration, Marinas and Boating, Resource Extraction (Abandoned Mine Drainage), Roads Highways and Bridges, Urban Areas, and Wetland/ Riparian Areas (EPA, 2017d). NPS is the main pollutant in the Anacostia Watershed.

### Maryland Department of Environment (MDE) Stormwater Regulation

The University of Maryland (UMD) falls under a NPDES MS4 Phase II permit, as it is a federal or state owned facility. The current permit MS4 was issued in 2004 and was supposed to be renewed in 2009, but was not. However, the MDE has been managing it administratively since, which makes everything in the old permit still applicable until the EPA issue a new permit.

Although the new permit is not officially in effect, it is under the language and review process. One of the biggest change is the Chesapeake Bay Restoration and addressing the Total Maximum Daily Loads (TMDL) by 2025. This will require Phase II MS4 to commence restoration effect for 20% of existing impervious area. These efforts can include the use of environmental site design (ESD) best management practices (BMPs), structural BMPs, or other alternative restoration practices. Implementation of these permit conditions will establish improved stormwater controls to reduce the discharge of pollutants, protect water quality, and satisfy the water quality requirements of federal regulations under the Clean Water Act. (MDE, 2017b).

The permittee has to determine the total impervious surface area within their jurisdiction and calculate the portion that is treated with acceptable water quality functional BMPs. The portion that is not treated will be the baseline to calculate the twenty percent restoration requirement. For example, if UMD has about 100 acres of impervious surfaces, assuming that 30% of the impervious surface is treated by BMPs, 20% of the remaining impervious area is required to be treated by 2025. Under this scenario, UMD will be required to treat 14 acres of impervious area. The permittee will have to show that current facilities are maintained and functional in able to get credit for it.

**Stormwater Best Management Practices (BMPs)**

In order to handle NPS pollutants, there are best management practices (BMPs). A BMP is used to describe a type of practice or structured approach to prevent pollution (Ellis et al, 2004). The term can be used on both non-structural (e.g. minimizing use of chemical fertilizers and pesticides) and structural (engineered or built infrastructure) attributes. BMPs can include controlling plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage (EPA, 2011).

In the context of stormwater management, BMPs link non-structural methods (e.g., good housekeeping and preventive maintenance) with structural deployments (such as bioretention systems or green infrastructure) to achieve the overall goal of pollutants prevention (Fletcher, 2015).

In everyday practice, the term stormwater BMP is used to describe management practices that aim to deal with water quantity and/or water quality caused by stormwater. By the early 1990s, the term BMP had been adopted in nearly every jurisdiction's stormwater design manual. Consequently, the range of practices described by the general term BMP was implemented across North America, thereby solidifying the customary use of the term. The Maryland Department of Environment (MDE) defined BMP in "1994 Maryland Standards and Specifications for Soil Erosion and Sediment Control" as a structural or non-structural device designed to temporarily store or treat stormwater runoff in order to mitigate flooding, reduce pollution and provide other amenities (MDE, 2000).

**MDE Stormwater Design Manual**

Maryland Stormwater Design Manual is the official guide for stormwater management design, methods, and practices in Maryland. It was originally published in October 2000, and revised in May 2009 (MDE, 2017d). The primary goal of Maryland's stormwater management is to maintain the pre-development runoff characteristics after development. Many current projects on campus are stormwater retrofits. Projects that provide nutrients and sediment reduction on existing development that is currently untreated by any BMP or in inadequately treated by an existing BMP (Bahr et al., 2012). Chapter 3 and 5 in the MDE Stormwater Manual will be examined for design.

*Stormwater Wetland*

Chapter three of the MDE Stormwater Manual outlines criteria, design, treatment, and landscape of structural BMPs that includes stormwater ponds, wetlands, infiltration, filtering systems, and open channels. These practices and designs are mostly for systems that are planned initially with development and then retrofitted. However, when structural BMPs are initial planed, they will come with a buffer. Retrofitted structural BMPs do not have to come with buffer. We will be looking at the section just on stormwater wetlands. Stormwater Wetlands design criteria are listed below:

- Any wetland must demonstrate that it can withstand water in a 30 day drought in the summer
- The surface area of the entire stormwater wetland must be at least 1% of the total drainage area to the facility
- Microtopography is encouraged to enhance wetland diversity
- For the different hydrologic water depth of high and low marshes, it is best it they are irregular or organic shapes
- A minimum of 35% of the total surface area shall have a depth of 6 inches or less and at least 65% of the total surface area shall be shallower than 18 inches.

*Environmental Site Design (ESD) BMPs*

Chapter five of the MDE Stormwater Manual investigates different design processes and planning techniques for implementing ESDs. The basic principle of ESDs is to capturing and retaining enough rainfall so that the runoff leaving a site is reduced to in peak flow. The ultimate goal of implementing ESD is to treat the runoff from 1 inch of rainfall.

The specific ESD practices falls into three broad categories: 1) alternative surfaces, 2) non-structural practices, and 3) micro scale-practices. Appendix A shows a thorough list of different methods within each category.

*Alternative Practices*

In 2014, the MDE recognized that new and innovative approaches to stormwater management were being developed on a continuous basis. As a results, several alternative BMPs are listed that may be used for the purpose of impervious area restoration. Some of these alternative BMPs include: street sweeping, buffer planting, reforestation, and stream restoration. Although these practices do not provide water quality, the main objective is to reduce the pollutant load as close to its source as possible. Because these practices do not hold water, the MDE has to provide a impervious acre equivalent in order to credit theese practice towards.

**MS4 Credits**

The list of practices defined in Chapters 3 and 5 of the manual, and in the MS4 draft are considered as acceptable water quality treatment BMPs for addressing restoration requirements in MS4 permits. The objective for restoration design is to treat the first inch of rainfall for water quality, using the criteria for BMPs defined in the Manual (MDE, 2014). Impervious area treatment credits are granted for the total impervious area within the drainage area when the full water quality is provided. When less than 1 inch of rainfall is treated, impervious area treatment credit will be based on the proportion of the full treatment. When more than 1 inch of rainfall, the credit will increase by 0.1 for every 0.4 inches treated.

Table 1.1: MS4 Credit Gain Scenario

| BMP Design | Catchment Acres | Rainfall Depth Treated | Credit Gain | Remaining Acres to Treat |
|---|---|---|---|---|
| None | 1 | 0 | 0 | 14 |
| Rain Garden | 1 | 1 | 1 | 13 |
| Rain Garden | 1 | 2.6 | 1.4 | 13.6 |
| Rain Garden | 2 | 2.6 | 2.8 | 11.2 |

The credits that are gain from retrofit design are toward the 20% requirement inside the upcoming MS4 permit. Using the scenario of University of Maryland from before, we need to treat 14 acres of impervious surfaces, however, we can treat less based off the rainfall depth that is treated. The table below shows different scenarios on credits gain through a BMP.

**Sustainability and Stormwater Education**

University and college campuses resemble cities because they are on a smaller scale. Therefore, they are an important sites of transformation. Working at this scale is important to implement sustainable development, in part, because there is a bit of freedom on governance structure and local politics are less complex than they are at the scale of the city. With its smaller scale and more structured administration, universities can better reduce the cumulative effect of local environmental problems, which is an area that sometimes struggle with (Finlay and Massey, 2011).

Academic research has grown to incorporate an interdisciplinary curriculum involving the environment, economics, and society (Gibson, 2006). For sustainability to be most effective, it needs to become a part of everyday life on campus. At many institutions, student orientation or classes for first-year students include a sustainability awareness (Finlay and Massey, 2011). Furthermore, students are a driving force behind campus sustainable development, which takes the form of interest groups including: sustainable residences, promises and pledges, jobs, and career fairs (Beringer et al., 2008). Not only do institutions educate and have the potential to impact the environment, they can also influence the local communities (Uhl and Anderson 2001).

Universities worldwide have taken steps to reduce, reuse, and recycle wastewater (USAID 2006). The reasons for undertaking these wastewater reuse initiatives include water shortage in dry climates, and the need to sustain and protect the local watershed. Given the importance of water conservation and reuse worldwide, the main role of universities is to promote effective stormwater management strategies. As college student are an important section of the population and society, it is important to influence future policy-makers (Vedachalam and Mancl, 2012).

## Chapter 2: Site Selection and Methods

The project site is a 4.89 acres located in the north part of campus in the Paint Branch subwatershed. The main elements of the site are a 0.29 acre detention pond and a 572 linear feet swale.

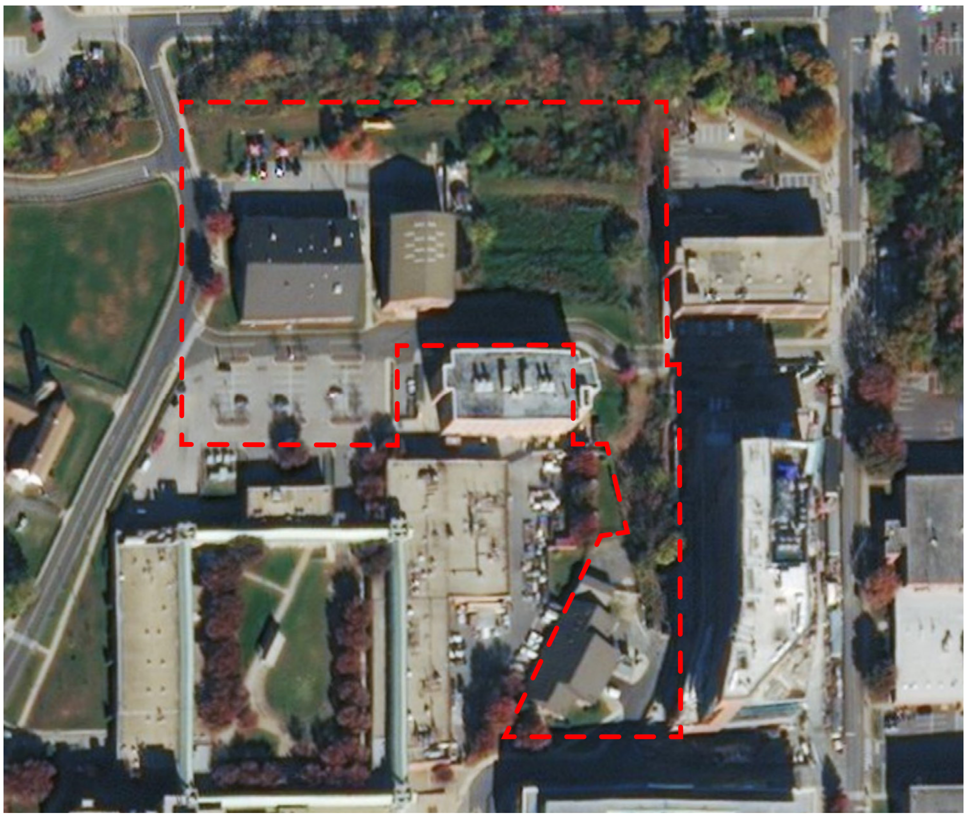


Figure 2.1: Aerial of Site

**History and Context**

The University of Maryland's campus is in the Anacostia Watershed. The Anacostia Watershed starts from the town of Olney in Montgomery County, crosses through Washington D.C, and flows into the Potomac River in Washington D.C. It covers 176 square miles of a large portion Prince George's County and Montgomery County, and eastern half of D.C (AWS, 2017). It has 19 subwatersheds and campus has two of them: Paint Branch and Northeast Branch.


Figure 2.2: Anacostia Watershed vs UMD Context

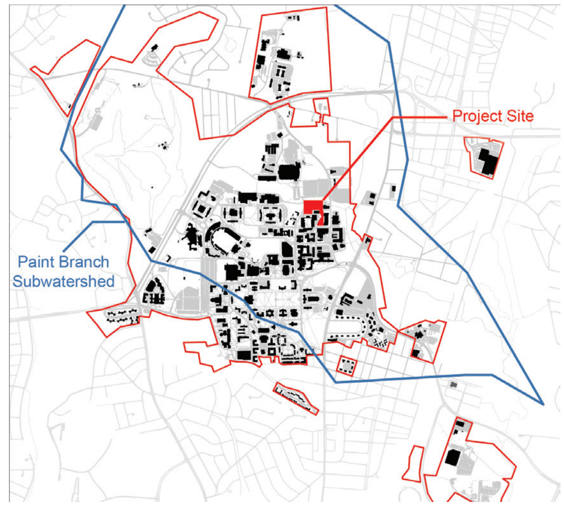



Figure 2.3: Northeast Branch vs UMD Context

The detention pond is called the Neutral Buoyancy pond. In the 1990s, the pond was built to collect from a 1.54-acre parking lot and the Animal Science Complex south and west of the site. The parking lot eventually was split into two halves (FF2 and CC1) due to the construction of the Neutral Buoyancy and the Manufacturing buildings.

Currently, there are a few issues with the pond. First, the gabion wall on the east side of the pond was damaged during nearby construction which caused water to leak from the middle of it. Second, due to a lack of proper maintenance, sediment settled at the bottom of the pond and clogged the low flow pipe to the swale, which has caused the pond to become a retention pond. Last, the amount of as sediment has increased, which has reduced the retention capacity of the pond. As the amount of sediment and nutrients increase, the pond has transition into a wetland that attracted wetland plants, such as cattail (*Typha sp.*), are present.

Detention ponds (or dry pond) serve as important flood control features. They are usually dry except during or after rain or snow melt. Their purpose is to slow down water flow and contain it for a short period of time, i.e. 24 hours. Urban areas rely on these structures to reduce peak runoff rates associated with storms, and decreasing flood damage. Retention pond (or wet pond) have a permanent pool of water that fluctuates in response to precipitation and runoff from the contributing areas. Maintaining a pool of water discourages resuspension and keeps deposited sediments at the bottom of the holding area.

In the early 90s, the swale was built to collect water from the pond, the hill east of the Technology Advancement Building, and an old parking lot that has been recpmstructed into Alfred James Clark Bioengineering Hall (Clark Hall) stands.

The detention pond flows into the swale through the use of an emergency spillway and a low-flow perforated PVC pipe. The swale then flows to campus creek, which is

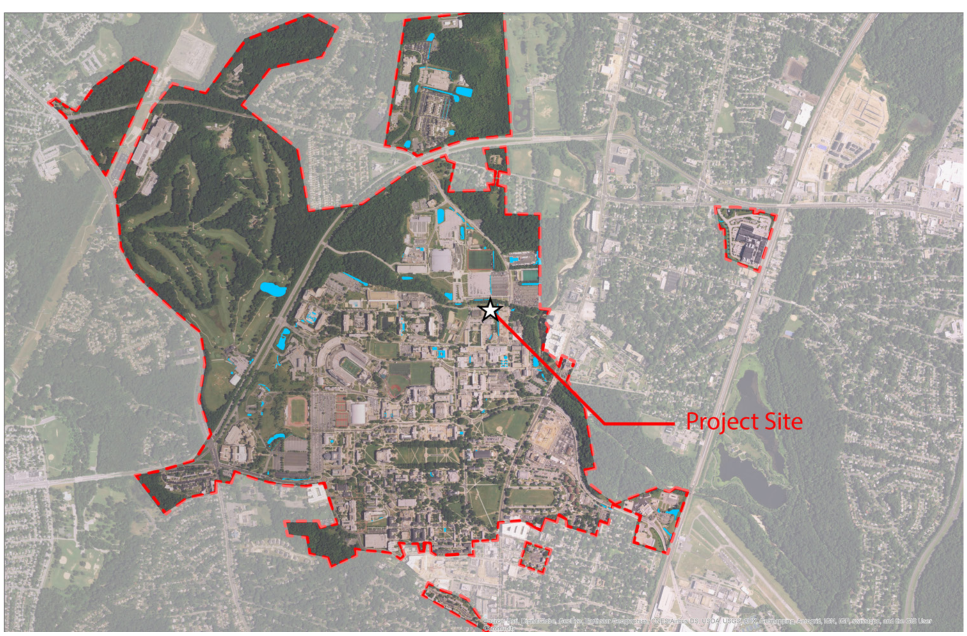



Figure 2.4: Aerial of UMD Stormwater Facilities

approximately 5 miles downstream from the site, will be the start of the Anacostia River.

**Stormwater Management in University of Maryland**

The UMD's campus has an abundant amount of stormwater facilities on campus. It currently has 188 stormwater facilities including bioretention cells, swales, collection ponds, green roofs, permeable pavers, rain gardens, rainwater cisterns, and sand filters Eight facilities have been built within the last year.

In context with the site, 35 stormwater facilities are within a quarter mile, while 18 more are in between a quarter and half-mile. Figure 2.5 shows the stormwater facilities that surround the site by a quarter and half-mile.

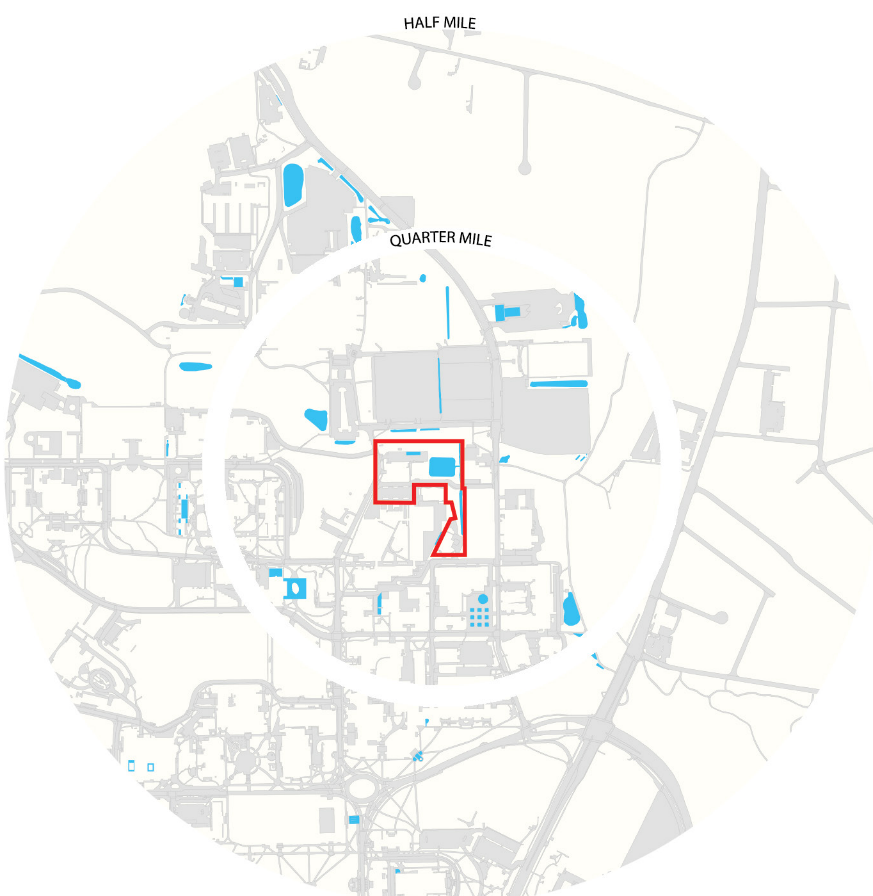



Figure 2.5: Stormwater Facilities around Site

**Why This Site?**

The site was chosen to investigate retrofitting the stormwater pond in order to take advantage of the new MS4 draft that will be available in early 2018. Currently, the stormwater pond will not receive credits since it is not managed well. This proposal will help the University to obtain credits under the new permit.

In addition, this proposal will also provide different BMPs that are not found elsewhere on the UMD campus, which will be beneficial to the ecological component on campus. These BMPs will increase the biodiversity of both plants and animals, and create research opportunities examining their biodiversity.

**UMD and Stormwater**

In the summer of 2007, the University of Maryland's Office of Sustainability was formed. In 2009, the Climate Action Plan (CAP) became an important part of the University's direction to become a more sustainable campus. The plan calculates the amount of carbon footprint that the campus discharges from its inhabitants including faculty, staff and students. The CAP has set objectives in six different sustainability areas to lower the University's carbon footprint to become carbon neutrality in 2050 (UMD Office of Sustainability, 2017). These 6 sustainability areas includes energy, food, green buildings, transportation, waste, and water. Two of these area effects our site in the present and upcoming future.

*Green Building*

The site is located near the new Alfred James Clark Bioengineering Hall, which opened in December 2017. In 2007, a state law was passed known as the, "High Performance Green Building Program" (House Bill 942 – Section 4-809). This law required any new constructed or renovated building with 7,500 of gross square feet or greater build with state funds must be Leadership in Energy and Environmental Design (LEED) Silver Certified. This included the reduction of pollution and increase the energy efficiency goal by 15% (GDS, 2017).

However, due to the building becoming more sustainable, they also need to reduce water efficiency by 50%. In order to fulfill this requirement, there are bioretentions around Clark Hall to capture rooftop and sheet flow runoff. The bioretention behind the building is next to the wet swale of the site, and has a holding capacity of about 3,250 cu ft of water. Any overflow will discharge into the swale.

*Stormwater*

The University of Maryland has several water goals to achieve by the year 2020 which include: reducing the purchase of potable water use 20%, increasing water capture, treatment, and re-use, decreasing stormwater runoff, and capturing the first one-inch of rainfall from 50% of all impervious surface area. Overall, the University is committed to minimizing all campus water uses and discharges, improving discharge water quality, and promoting water reuse. Below are recommended objections to address these goals:

- Design projects, programs, and initiatives to reduce water consumption
- Reuse water when possible
- Reduce wastewater production and improve wastewater quality
- Reduce the volume and improve the quality of stormwater runoff created on

University land; and

- Identify and minimize sources of surface and groundwater contamination and pollution, including nonpoint source pollution, and improve the quality of stormwater runoff as it moves through and off University land.

## Chapter 3: Precedents

The following precedents showcase a range of examples of utilizing stormwater treatment as an artful or educational tool. There are numerous school that are pursuing to becoming a more sustainable campus in varies area of energy, food, green building, transportation, waste, and water. They provide elements that serves as a precedent for design ideas.

**The Dell, University of Virginia, Charlottesville, VA**

Completed in 2004 by Nelson Byrd Woltz Landscape Architect, this project was primary goals of the design were to restore and daylight the Meadow Creek to a more ecologically productive. This 1,200 linear foot captures sediment and solids, reducing sediments load downstream, before channeling and flowing into a 0.75 acre, two-tiered, 12-foot deep stormwater pond that can hold up to 194,000 cu ft of stormwater. After the water reached the second tier, by overflow in the first, it will discharge to the storm sewer at a controlled rate.

This 11-acres site was organized into three major ecological habitat zones of Virginia: Upland Mountain, Intermedia Piedmont, and Lower Coastal Plain. This space also developed a space that would become a passive and active recreation, and educational amenity in the center of the campus by having benches around the pond.

The Dell serves as a precedent because it redeveloped an unattractive stormwater feature while providing recreational and educational amenity in a narrow corridor on a college campus.

Figure 3.1: Bioretention looking at University
Image Source: Nelson Byrd Woltz

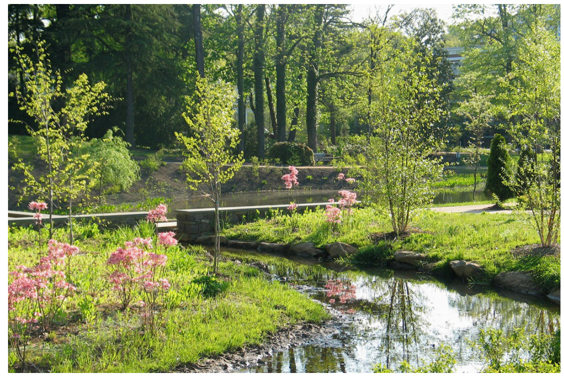


Figure 3.2: Restored stream meander through rain gardens. Image source: Artful Rainwater

**Shoemaker Green, University of Pennsylvania, Philadelphia, PA**

Designed by Andropogon, this 2.75 acre of welcoming open grassy area is one of the gateway entrance to the University of Penn campus from the east. The stormwater management concept is convey, cleanse, and infiltrate, or reuse for irrigation. Rooftop runoff flows from all uphill surrounding buildings and water is guided into trench drains, which will either travel to the lawn or to a rain garden depending on the location. The grassy lawn is actually an infiltration basin that accepts runoff from trench drains, then a network of drain pipes conveys it to a 20,000 gallon cistern.

Although the stormwater features is not visible, it does provide a precedent of using multiple BMPs and storage.

Figure 3.3: Shoemaker Green. Image Source:
Image Source: Andropogon Associate

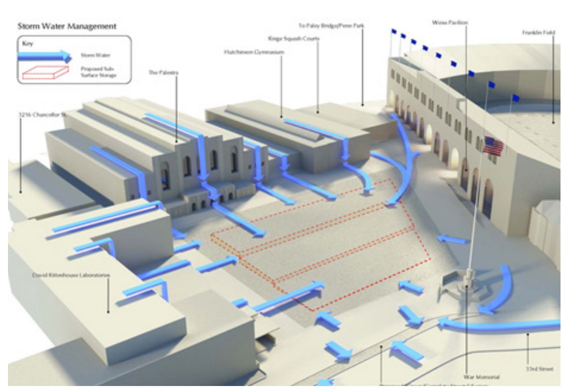



Figure 3.4: Diagram of Stormwater Management.
Image Source: Andropogon Associate

**Southwest Recreation Center Expansion, University of Florida, Gainesville, FL**

Completed in 2010 by RDG Planning and Design, after the Southwest Recreation Center was expanded, the remaining space was used to build a bio-swale on the south side of the building. About 20,000 sq ft of rooftop runoff will flow into downspouts into a cast bowls at the base of the building facade. When the water overflow, it flows into pebble-filled trench drains that funnels into the series of bio-swales filled with Florida native plants and boulders. This allows to stormwater to slow down before heading into the St. Johns River Watershed. The seven tiered of rain gardens in total are about 10,700 sq ft (RDG, 2017). This site is visually shows stormwater runoff by having statues at each of the downspouts that also serves as lamps, which glows blue when it is raining.

Similar to Shoemaker Green, this project also serves as a precedent by bringing rooftop runoff to an acceptable BMP. Another precedent from this project is visually showing the stormwater management to the public by possibility using lights, educational signage, and water flowing into BMPs. This method was mentioned by Finlay and Massey earlier that for sustainability to be most effective, it needs to become a part of everyday life on campus.

Figure 3.5: Overlooking the Series of Bio-Swales.
Image source: Artful Rainwater

Figure 3.6: Runnels that carries water into Bio-Swales.
Source: Artful Rainwater

# Chapter 4: Site Analysis

## Land Cover and Tree Canopy

A large portion of the 4.89 acres of land cover area is open lawn. The pond and swale are on the eastern side of the site and collectivily utilize 0.64 acres. There are also pervious pavers in the Lot FF2. With the elements of open lawn, water, and the permable pavers, the site is 55.5% pervious. With the remaining 44.5% impervious surfaces includes: two parking lots, two academic buildings, and sidewalks. Figure 4.1 illustrates the land cover, while figure 4.2 breaks down the acres of the site into elements on site.

Beginning with tree canopy (on the northern side of the site), there is a riparian buffer protecting Campus Creek that ranges from 34’ to 95’ wide. Secondly (south of the riperian buffer), there are a number of deciduous trees such as Sweetbay Magnolias (*Magnolia virginiana*) and American Sweetgum (*Liquidambar styraciflua*). Third (south of the eastern part of the buffer and north of the pond), there is a bush of tall shrubs and trees. Inside the parking lot CC1, there are a number of Japanese Zelkova (*Zelkova serrata*) within the islands throughout the parking lot. Covering a portion of the swale

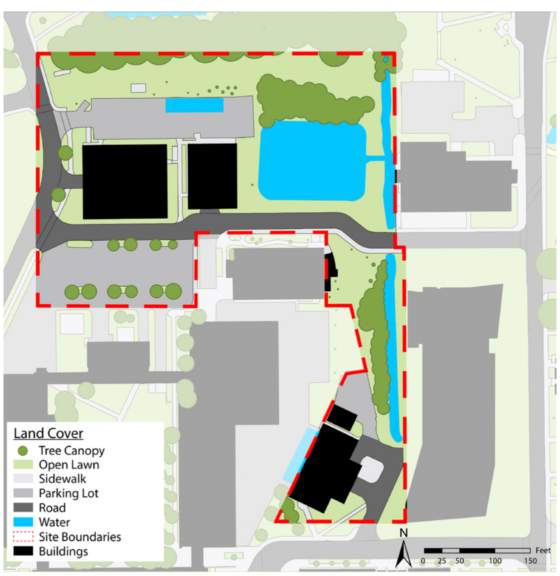



Figure 4.1: Land Cover on Site

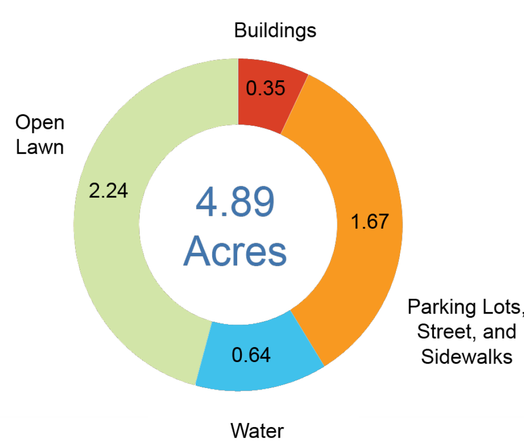



Figure 4.2: Acres of Land Cover

is a number of trees including, Sweetbay Magnolia, Kwanzan Cherry (*Prunus serrulata* 'Kanzan'), and Pin Oaks (*Quercus palustris*). Unfortunately, the site only has about 9.1% tree canopy.

### Elevation and Slope

The highest topographical point of the site is 82 feet above sea level, which is in CC1. The lowest point on the site is in the swale, which is at 64 feet above sea level. Figure 4.3 is the relief map of the site.

In addition to our site, the campus is a fairly flat and walkable. The steepest slope is near the pond and swale where the land descends towards those the stormwater features. The overall slope is moving towards the northeast. The average slope from highest point to the lowest point is 2.8%. Figure 4.4 shows the slope map.

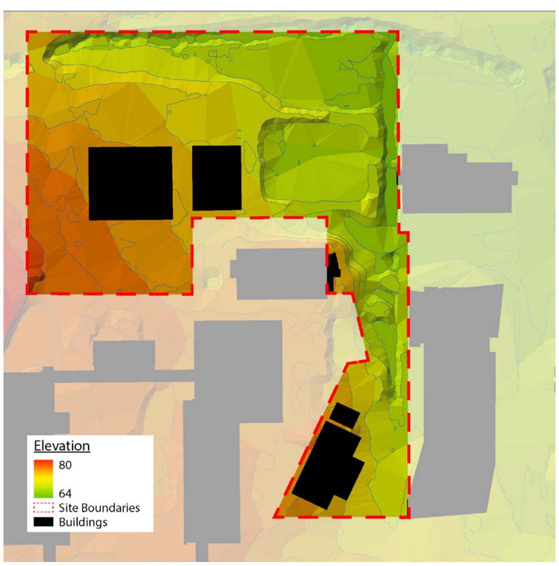



Figure 4.3: Relief Map

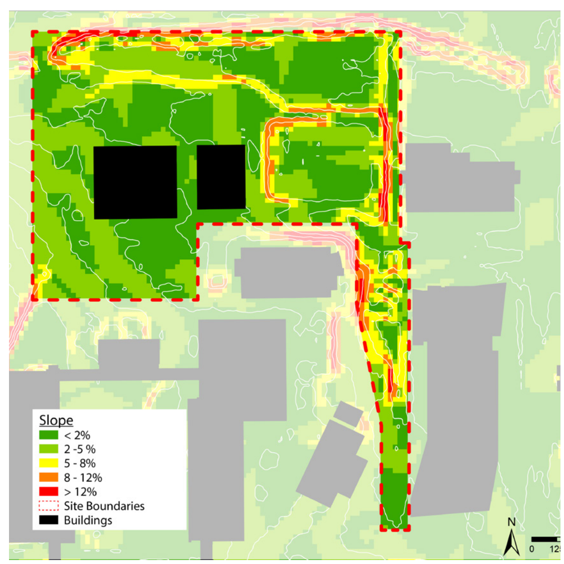



Figure 4.4: Slope Map

### Soils

There are five different types of soils on site, the majority of the site is Urban Land - Issue Complex. Hydrologic groups were designated by the Natural Resources

Conservation Service (NRCS) which are based on measured rainfall, runoff, and infiltration data (USDA NRCS, 2007). About 98.5% of the site is in hydrologic group D, which means the soil has low infiltration rates and high runoff potential. Figure 4.6 indicate the locations of the different soil type on site. Table 4.1 lists each of the soil types with their specific name and hydrologic group rating.

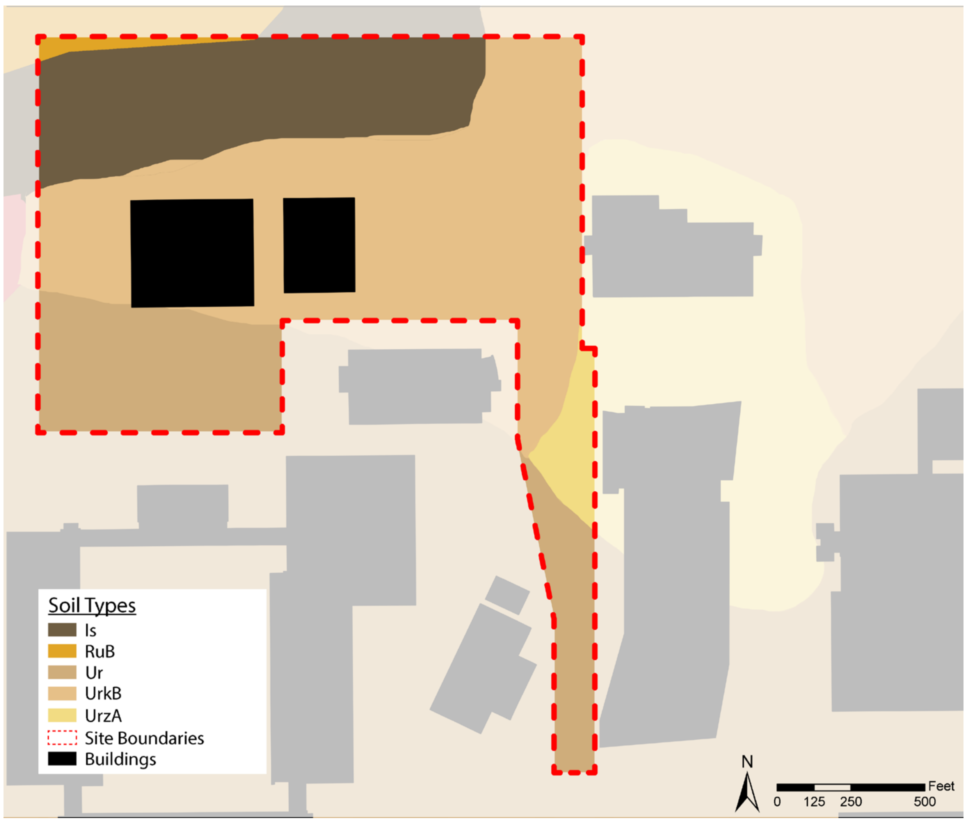



Figure 4.5: Soil Map. Information from USDA NRCS 2017

Table 4.1: Soil Description. Information from USDA NRCS 2017

| Map Soil Symbol | Soil Description | Hydrologic Group |
|---|---|---|
| Is | Issue Silt Loam, Occasionally Flooded | D |
| RuB | Russett-Christiana-Urban Land Complex, 0 to 5 percent slopes | C |
| Ur | Urban Land | D |
| UrkB | Urban Land-Issue Complex, 0 to 5 percent slopes, Occasionally flooded | D |
| UrzA | Urban Land-Zekiah Complex, 0 to 2 percent slopes, Frequently flooded | D |

**Hydrology**

The entire catchment area is 8.62 acres and has 60 percent impervious surfaces that consist of rooftops, concrete sidewalks, and streets. In a one year, 24-hour storm event of 2.63 inches, the entire catchment area will accumulate 57,028 cu ft (426,599 gallons) of runoff. In order to understand where most of the flow was coming from, the catchment area was divided into three subcatchment area: Storm Drain, Pond Surface Flow, and Swale.

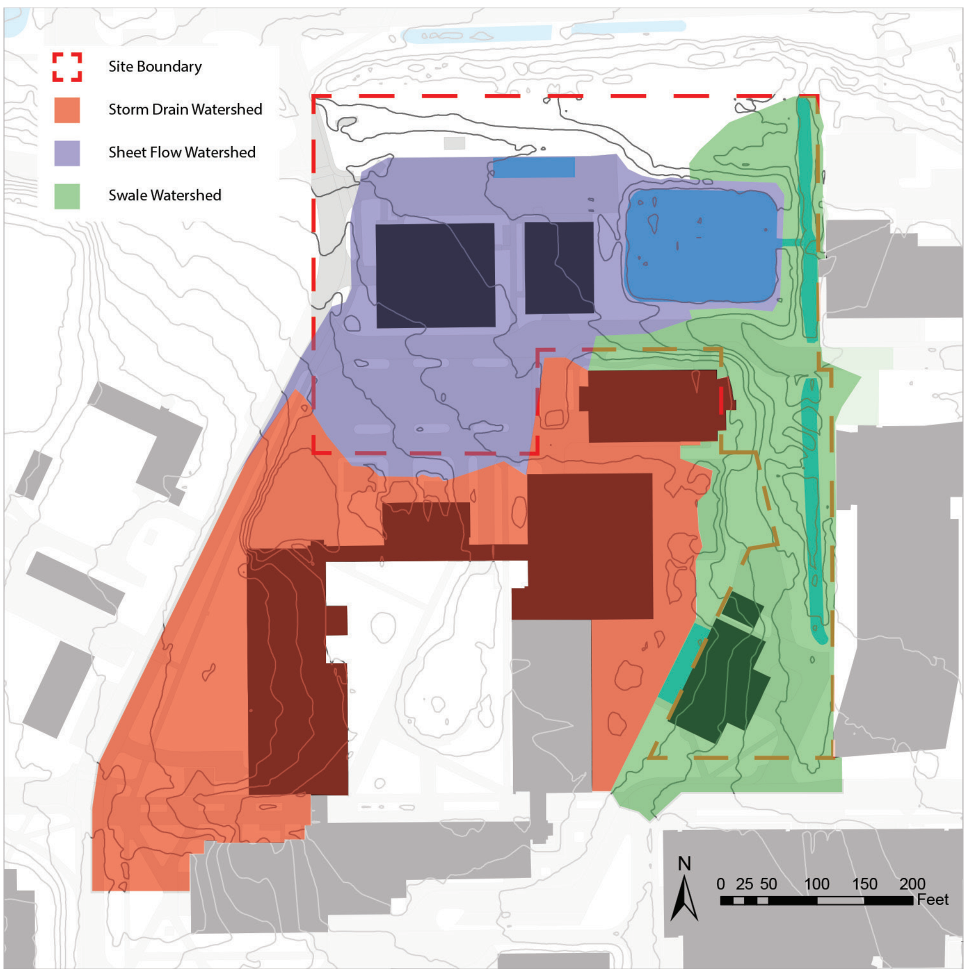


Figure 4.6: Subcatchment Area

The Storm Drain subcatchment area contains the unmanageable amount of water that is captured outside of the site boundaries by the storm drain inlets on Regent Drive and around the Animal Science Complex. The storm drain connects to one inlet, to another, and then channel to the pond. This subcatchment area accumulates 31,853 cu ft of runoff from a one-year storm. Even after proposing the new design, this amount of runoff will remain the same due to inlet being outside of the site boundaries.

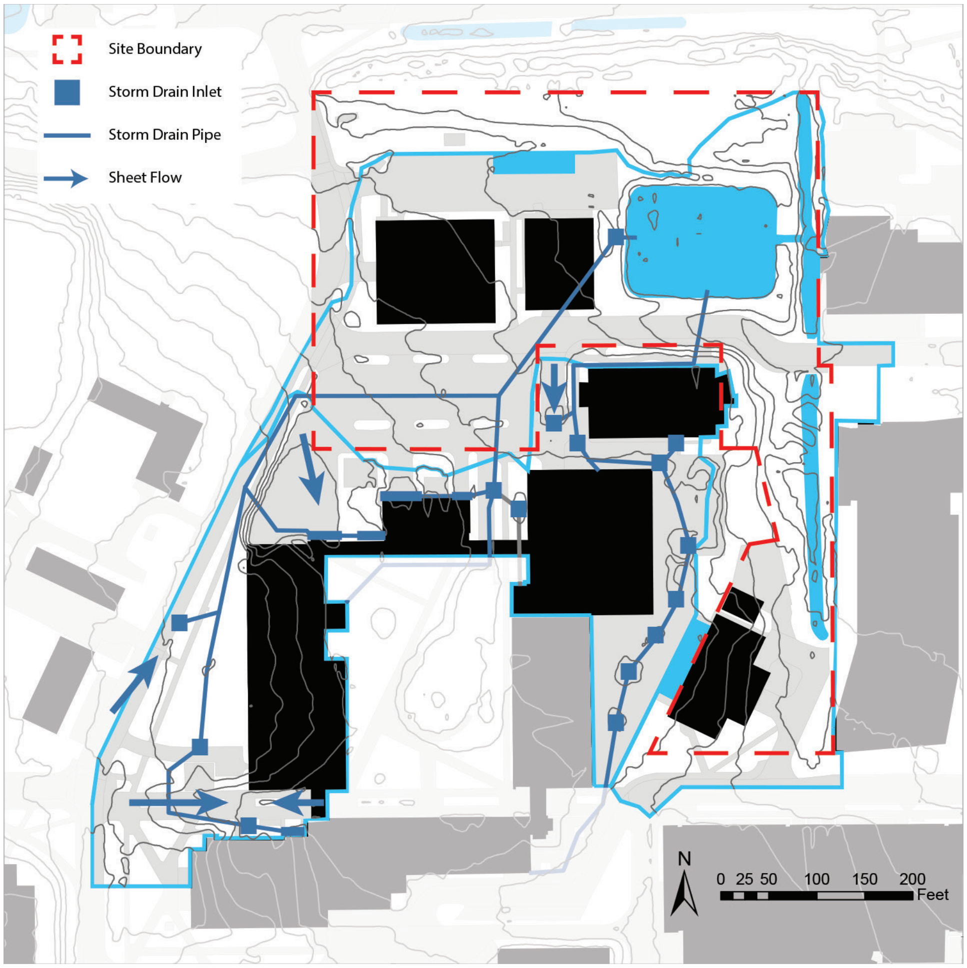



Figure 4.7: Storm Drain Inlet and Pipe

The Pond Surface Flow subcatchment area is the amount of water flow above the ground that drains into the pond. This catchment area includes both Regent Drive, 385 linear feet of Technology Drive, both parking lots, and rooftop runoff from Manufacturing and Neutral Buoyancy Building. Runoff from Lot CC1 will flow northeast to join the flow from Technology Drive and flow into a inlet which empties out into the


Figure 4.8: Technology Drive Inlet

Figure 4.9: Lot FF2 Sheet Flow

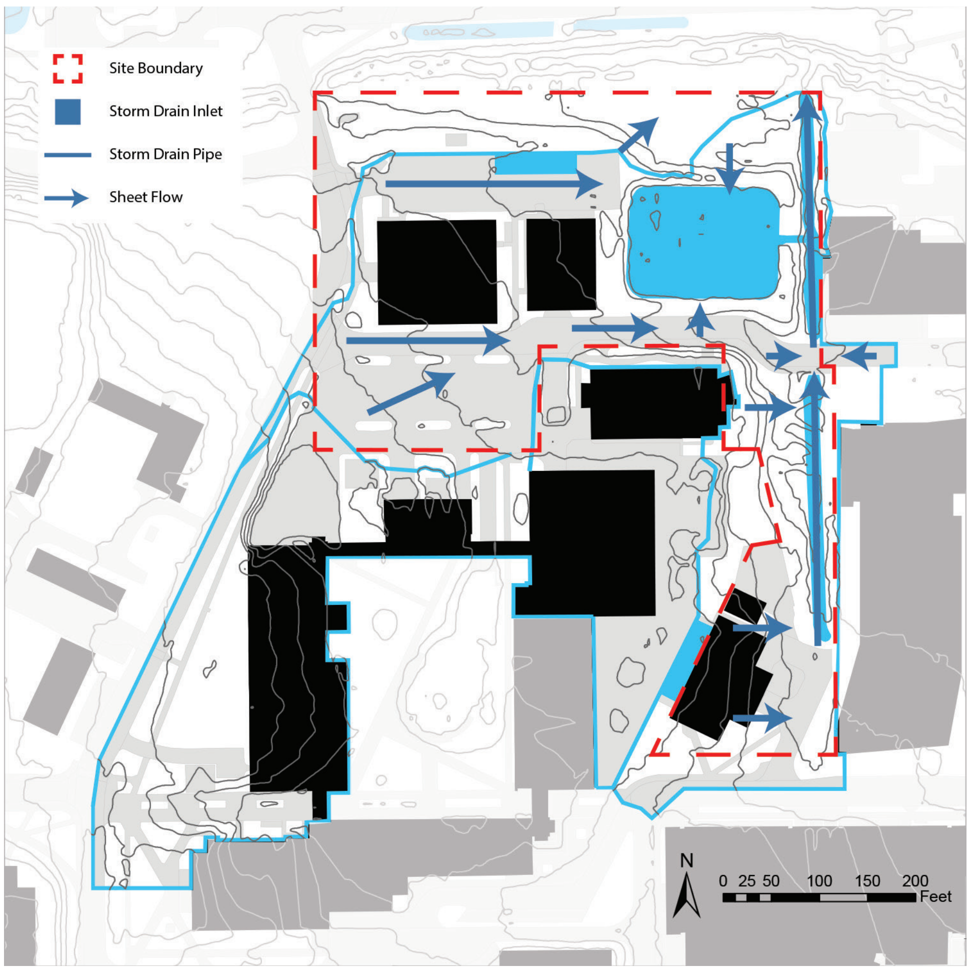



Figure 4.10: Surface flow in Pond Sheet and Swale subcatchment area

pond. Runoff from Lot FF2 will flow eastward and into an eroded channel which empties out into a open inlet that connects to the pond. This subcatchment accumulates 14,609 cu ft of runoff from a one-year storm.

The Swale subcatchment area is the amount of water that flow directly into the swale. South of Technology Drive contains rooftop runoff from Technology Advancement Building and Central Animal Resource Facility, portion of Engineering Drive, and leftover runoff that exceed the storage of the bioretention behind Clark. The remaining 225 linear feet of Technology Drive, east of the inlet, flows into a curb cut that flows into the swale. This subcatchment accumulates 10,566 cu ft of runoff from a one-year storm.


Figure 4.11:

Figure 4.12: Technology Drive curb cut

**Circulation**

*Parking Lots*

Within a quarter mile from our site, there are numerous parking lots that are designated for staff/faculty, students, and visitors. Within the site boundaries, there are two faculty parking lots that have 62 regular space, plus three handicap and two meter spaces. Table 4.2 shows the number of parking lots that are designated for faculty/staff, students, and visitor. Appendix B will breakdown the rules between them. Directly outside the quarter mile radius of our site, there are Regents Drive and Terrapin Trail Parking Garages, which will add to the number of existing spaces. Due to the numerous of future projects on campus, the campus's has predicted a loss of 3,125 parking spaces after the fall semester of 2018 (UMD DOTS, 2015).

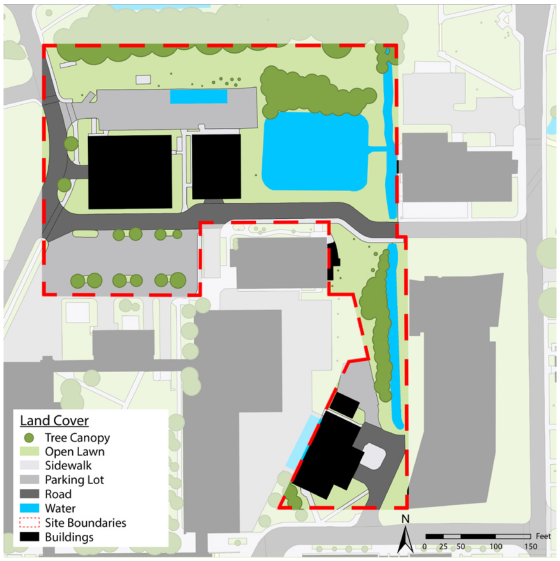



Figure 4.13: Parking Lots within ¼ Mile

Table 4.2: Number of Parking Spaces within ¼ Mile

| | Spaces |
|---|---|
| Student | 1696 |
| Facility/Staff | 2107 |
| Restricted | 95 |
| Visitor/Metered | 347 |
| **Total** | **4245** |

*UMD Shuttle Bus*

There are 22 UMD shuttles buses that run throughout campus from 5:30 am to 3:30 am. All but one bus stops at either of the two main hub locations: Regents Parking Garage or the Adele Stamp Student Union. In the quarter mile radius of the site, there are 11 bus stops that belong to 17 buses (including commuter routes), which take students to nearby cities including Silver Spring and Greenbelt, MD. Directly outside of the quarter mile radius would be the Regent Parking Garage Hub, which contains more buses.

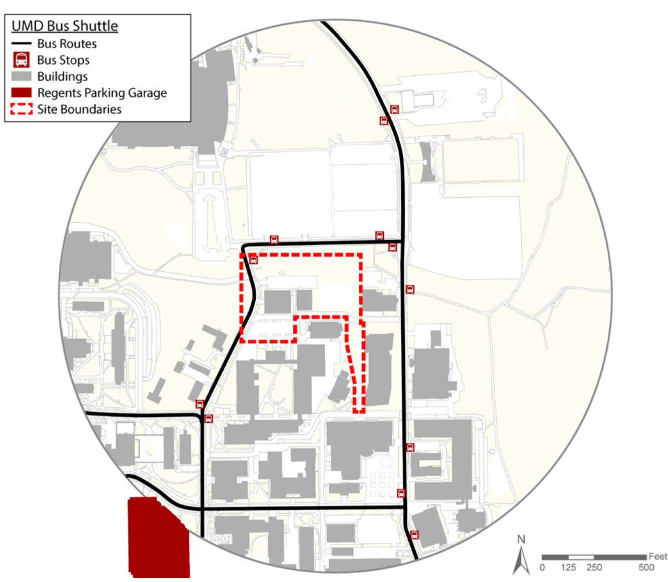



Figure 4.14: UMD Shuttle Routes and Stops in ¼ mile radius

*Pedestrian Circulation*

UMD is a walkable campus, therefore there are plenty of sidewalks for pedestrian circulation. Of course, pedestrians have priority of the roads within crosswalks, which can be cause traffic congestion during class changes in the middle of the campus. However, since this part of campus is away from academic building, this part of campus does not have much congestion. Figure 4.8 shows the sidewalk, crosswalk, and building entrance near our site. On the east side of the map, there is a multi-use path that leads off campus.

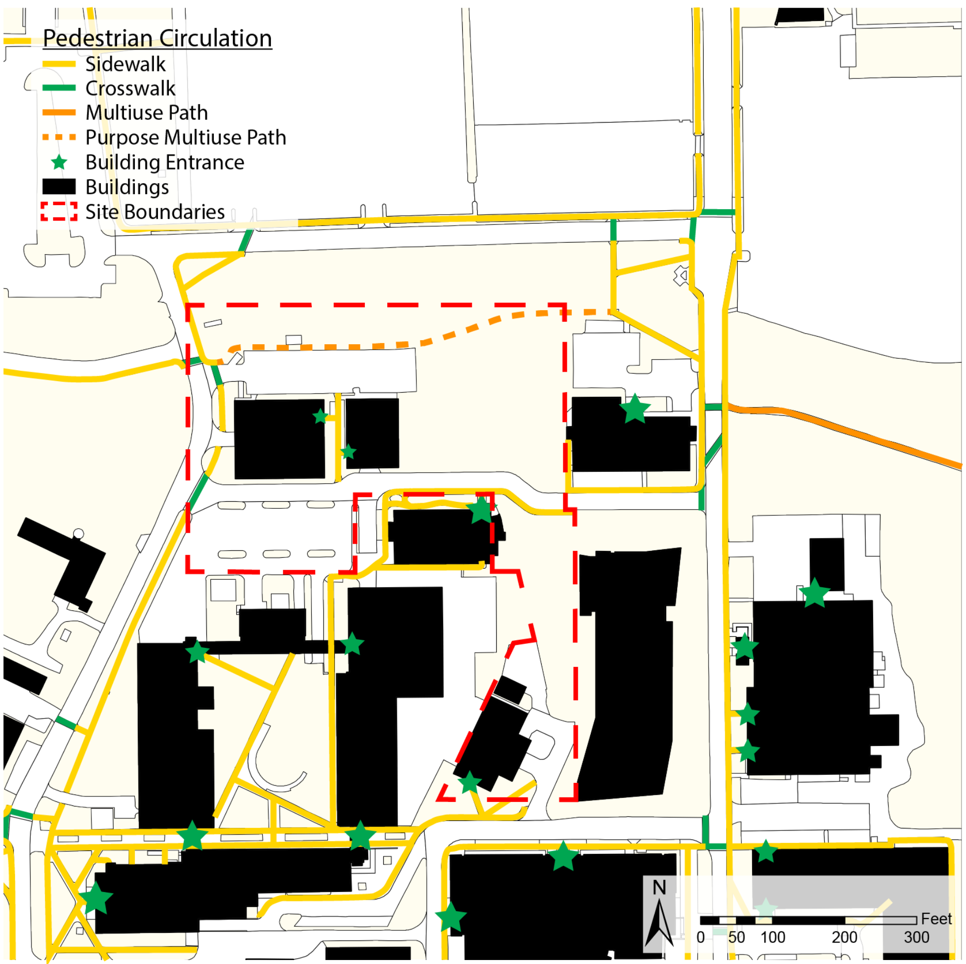



Figure 4.15: Pedestrian Routes around Site

## Future Projects

*Shared Use Path*

In 2011, the university released the 2011 - 2030 Facilities Master Plan (FMP). The FMP Plan is a document of proposed building and the renovation of buildings, corridor through green spaces, enhancing gateways, and the appeal of open space throughout the campus (UMD Facility Management, 2011). Every ten years, they will update a new version for the next 20 years. With this being the third update, there is a new section about improving the campus bicycle routes. In the planning period 2 (2021-2030), the University is proposing a shared use path north of the pond (shown in Figure 4.15).

*Alfred James Clark Bioengineering Hall*

Currently, Phase 1 of the Clark Hall is finished, but there are plans to extend Clark Hall into an L shape along Engineering Drive, and converted Engineering Drive into a plaza (Figure). However, since Phase 2 doesn't have a start date, it can be safe to assume that this project will not happen anytime soon or at all. The step of the project is what the designer called Phase 1.5. Phase 1.5 will replace the Central Animal Resources Facility building with a 20 space parking lot, which the designer will called "Clark Parking Lot". The destruction of the building is in the 2015 update to the recent UMD's FMP (UMD Facility Management, 2015). The parking lot design is not from the designer or University's Department of Facilities.

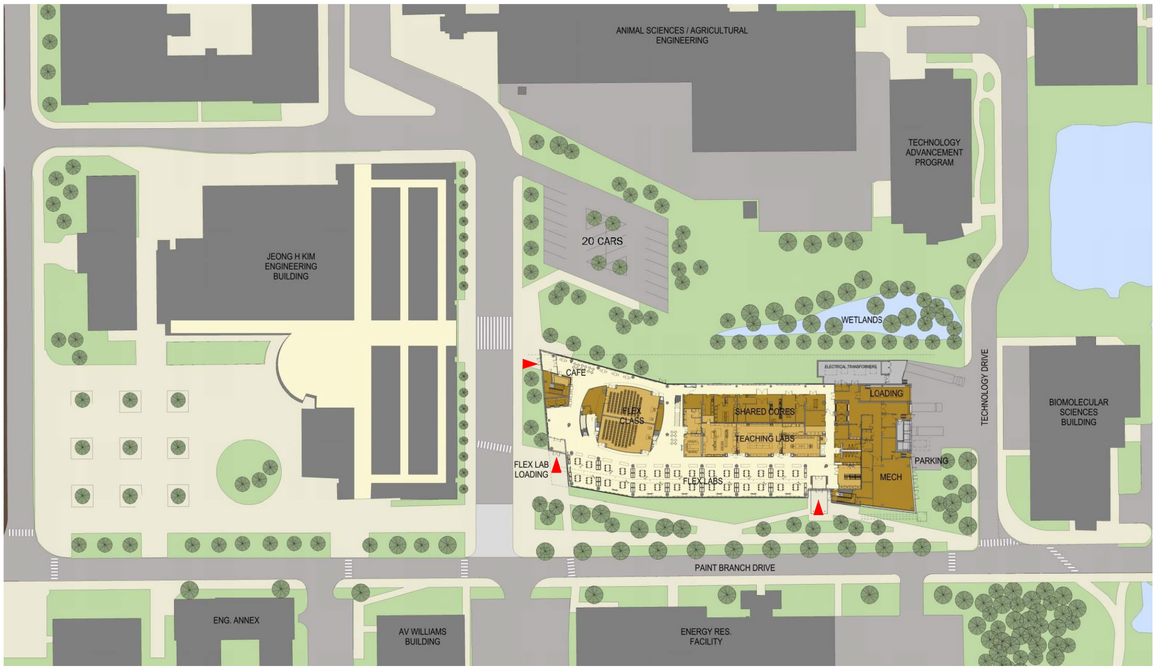



Figure 4.16: “Phase 1.5” of Clark Building. Image from Ballinger Presentation June 6, 2014

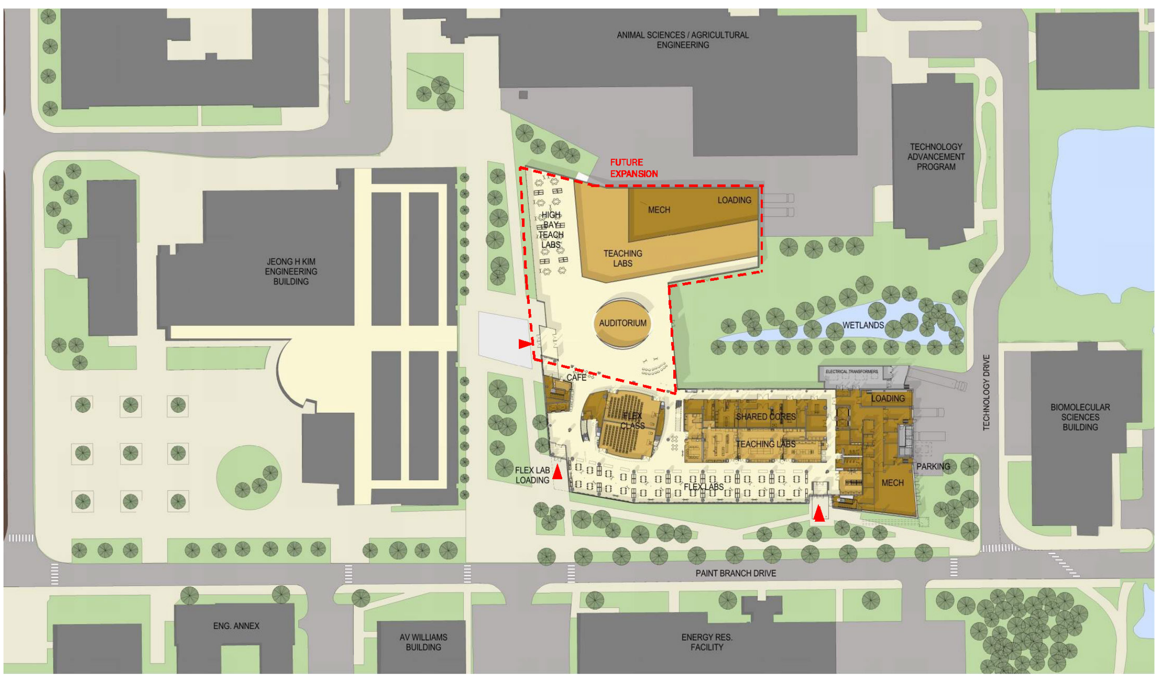



Figure 4.17: Phase 2 of Clark Building. Image from Ballinger Presentation June 6, 2014

## Chapter 5: Design Process and Proposal

### Stakeholder Involvement

Throughout the design process, the University's faculty and staff were included for more insight, to determine goals, and critique the design. The list of people includes Steven Reid, Environmental Planner; Michael Carmichael, SWM Facilities Maintenance Coordinator; Mark Stewart, Senior Project Manager at UMD's Office of Sustainability; and Dr. Peter May, Senior Soil Scientist with Biohabitats and an instructor of Environmental Science and Technology.

### Goals and Design Thinking

After gathering information from stakeholders and examining the site inventory and analysis, the goals of the design as follows:

- Capture and treat the 1 year storm to gain credits for the MS4 permit
- Increase tree canopy
- Improve pedestrian connections
- Create research and education opportunities

The first goal of capturing and treating stormwater for both water quantity and quality, would be for the one-year storm of 2.63 inches. The capture of the one-year storm surpass goals of both the MDE (1 inch), and UMD's Office of Sustainability (1 inch of 50% of impervious area). To check that the proposed design meets this standard, the hydrology of the proposed drainage area is modeled using TR-55.

The new design of the pond and swale into MDE with the standard will greatly improve maintenance needs, considering the facilities were built before the MDE manual. The pond itself has a flat floor and does not have a forebay pond to collect sediments.

Therefore, the entire pond needs to be drudge after years of insufficient maintenance.

Secondly, increasing the tree canopy will serve numerous functions: First, an increased tree canopy will slow water down before reaching the stream or swale; second, by expanding the riparian buffer, it has the potential to serve as a pedestrian corridor; and last, increase the infiltration and evapotranspiration rates. The project site is close to Campus Creek, therefore, slowing down the stormwater before reaching the creek can also reduce erosion of it's bed.

Next, improving pedestrian connections will provide access and safety across the site. Around the perimeter of the site, there are numerous ways to access in all directions. However, there is a disconnect within the site of getting people to a walk a clear define path in a east-west direction on Technology Drive. By offering more pedestrian connection throughout the site, the example of sustainability can be apart of the daily live for students who are coming from the nearby parking lot or use the multipurpose path that coming from off campus.

Last, due to the site's location in the Technology Corridor (near the program of Environmental Science and Technology), the site could be used the site for experiments. There are also opportunities to incorporate volunteer participation as the school arrange yearly on Earth Month. Earth Month is during the month of April, the UMD's Office of Sustainability will host a series of events for students, faculty, and staff have even more opportunities to get involved with sustainability. Every year, various spots on campus will be selected for a project. This can include cleaning up a stream or replanting a rain garden. This may be expanded to the City of College Park residents.

As mentioned before, since the pond was created in the early 1990s, which was before the MDE design standard, retrofitting it to constructed stormwater pond/wetland system from Chapter 3 of the Maryland Stormwater Design Manual. This type of BMP would reduced the need for maintenance in the future. A constructed wetland will be the only one of it's kind and has the potential to provide educational opportunities.

The design criteria for water depth was mentioned back in Chapter 1. The following chart will compare the current pond holding capacity to the potential wetland holding capacity based off of the design criteria.

<u>Pond</u>

Area: **17,932 cu ft**

Depth: **5 feet**

Volume: **89,660 cu ft**

Reduction of **52.5%**

<u>Constructed Wetland</u>

minumum 35% of 6" or less:
**= 3,138 cu ft**

minumum 30% of 18" of less:
**= 8,092 cu ft**

maximum 35% more than 18"
**= 31,360 cu ft**

**= 42,588 cu ft**

Figure 5.1: Pond vs Wetland Holding Capacity

The pond was initially designed to hold 89,600 cu ft of water, but in order to retrofit it as a constructed wetland, the holding capacity will reduce to 42,588 cu ft of water, which is a reduction of 52.5%. This holding capacity is less than the accumulated runoff from the Storm Drain and Pond Sheet Flow subcatchments (46,462 cu ft). Since the Storm Drain subcatchment area amount cannot change (31,853 cu ft), the Pond Sheet Flow subcatchment area (14,609 cu ft) amount will have to be reduce by surface change and storage.

## The Design Proposal

The design proposal separates the sites into three different areas: Parking Lot CC1, Constructed Wetland, and the Wet Swale are treated with multiple ESDs including micro-bioretention, permeable concrete, and  constructed wetland, and a wet swale.

**Parking Lot CC1 Micro-Bioretention**

Figure 5.3: Parking Lot CC1 redesign

Parking Lot CC1 is at the southwest corner of the site. As mentioned before, Parking Lot CC1 and FF2 was used to be one parking lot before the construction of the two buildings. Currently, there are 35 spaces including two handicap spaces. The aisle of the parking lot is constructed in three vertical aisle with a 10 feet island at both ends of each aisle. The new design connects the end of islands together and retrofits them into micro-bioretentions with curb cuts. The parking was change into one-way horizontal aisle.  Although the new design of Lot CC1 will lose two parking spot, a final count of 33, connecting the islands will provides more environmental benefits including green space and tree canopy.

Since the water is flowing from southwest to northeast, the southern bioretention width was reduced to five feet and replaced with a permeable concrete path south of the northern bioretention. This path will serves as a pedestrian walkway that connects from Regent Drive to Paint Branch Drive, alongside Technology Drive and to the front of the Technology Advancement Program Building. Although Technology Drive does not have a lot of traffic, this will provide pedestrian a path that is safer than walking in the parking lot or on Technology Drive.

Finally, trees were added in both bioretentions. On the north side, each tree has a 30 foot spread, and is space part by 30 feet off-center allow each tree 900 cu ft of soil. On the south side, each tree has a 20 feet spread, and is space apart by 26 feet off-center, to give each tree about 390 cu ft of soil. Both recommendation are from Bartlett (Smiley, 2017) for urban trees growth for street trees.


Figure 5.4: Section Perpective of Parking Lot CC1

**Constructed Wetland**

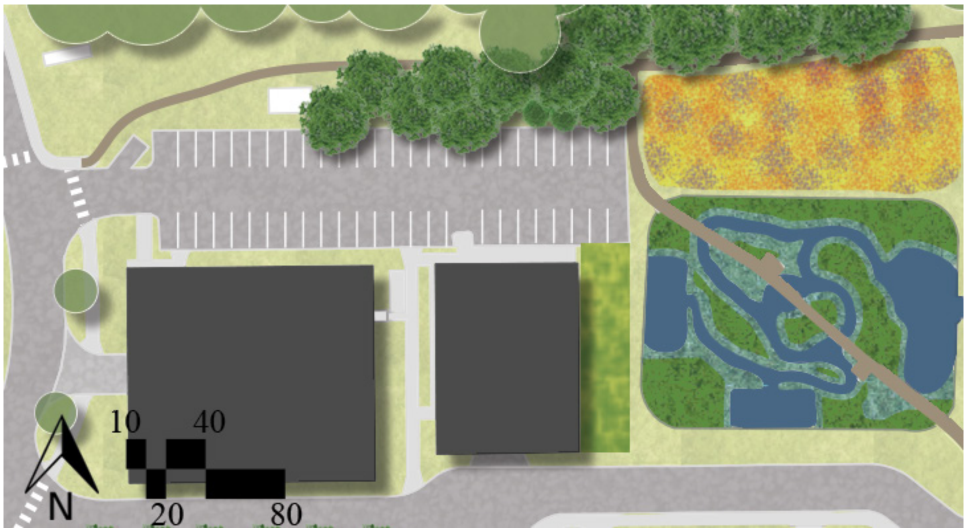



Figure 5.5: Constructed Wetland area redesign

The Construction Wetland is the largest area out of three spaces on the site. It contains the constructed wetland, Lot FF2, Technology Drive, and the Riparian Buffer south of Campus Creek. As mentioned before the pond was retrofitted into a constructed wetland to the MDE standard.

To begin with the area, two pedestrian paths were added. The first path is a shared use path that coordinates with the UMD 2010 - 2030 Facility Master Plan. This shared use path will connect to a crosswalk on the west that will lead to Wellness Way and connects to a concrete sidewalk that connect is north of the parking lot of the Biomolecular Science Building. The other pedestrian paths is a new boardwalk that connects the northwest corner of the constructed wetland to the southeast corner. Also, two bump outs are along the boardwalk and they are inside zone where they connect with all three hydrological zones.

On the east side of Neutral Buoyancy Building, there is a bioretention that will capture water from two different ways. First, it will capture 50% of the Neutral Buoyancy Building rooftop runoff by the way of downspouts. Second, it will also capture the Lot FF2 runoff. A meadow is planted north of the pond and south of the shared use path to encourage infiltration and reducing water flow into the pond.

Finally, additional trees were added on both sides of the shared use path to add more environmental and aesthetic benefits. On the northern side of the path, it will expand the riparian buffer to reduce the stormwater amount and flow before reaching the Campus Creek. By slowing down the stormwater, it will reduce the amount of soil erosion of the Campus Creek's bed. On the southern side, it will create a visual corridor for pedestrian traffic.

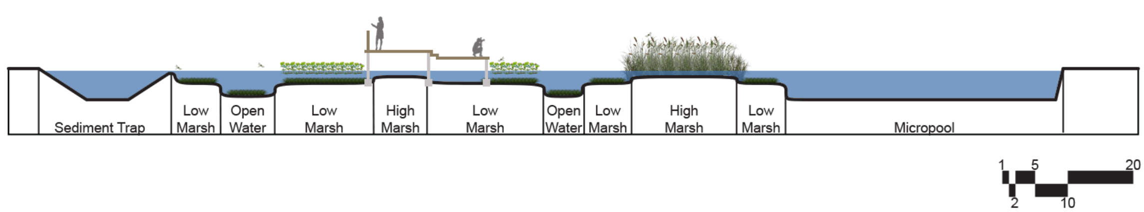



Figure 5.6: Section through Consructed Wetland

**Bio-Swale**

The last area of the design contains the entire wet swale and the Clark parking lot that is replacing the Central Animal Resource Facility Building. Water from the Clark parking lot will flow eastward to a new portion of the swale through curb cuts. Water is then carry northward to the existing swale. Inside the swale, there will weirs every 75 feet with a one foot drop intervals.

A shared use path has been proposed alongside the swale from Engineering Drive to the end of the swale on the north side of the site connecting to the other proposed shared use path. Alongside this both sides of the path would be ornamental grasses. On the west, uphill side of the path, additional trees would be planted. Both the trees and ornamental grasses would provide some water quality functions and decrease the speed of water before it goes into the swale.


Figure 5.5: Bio-swale area redesign

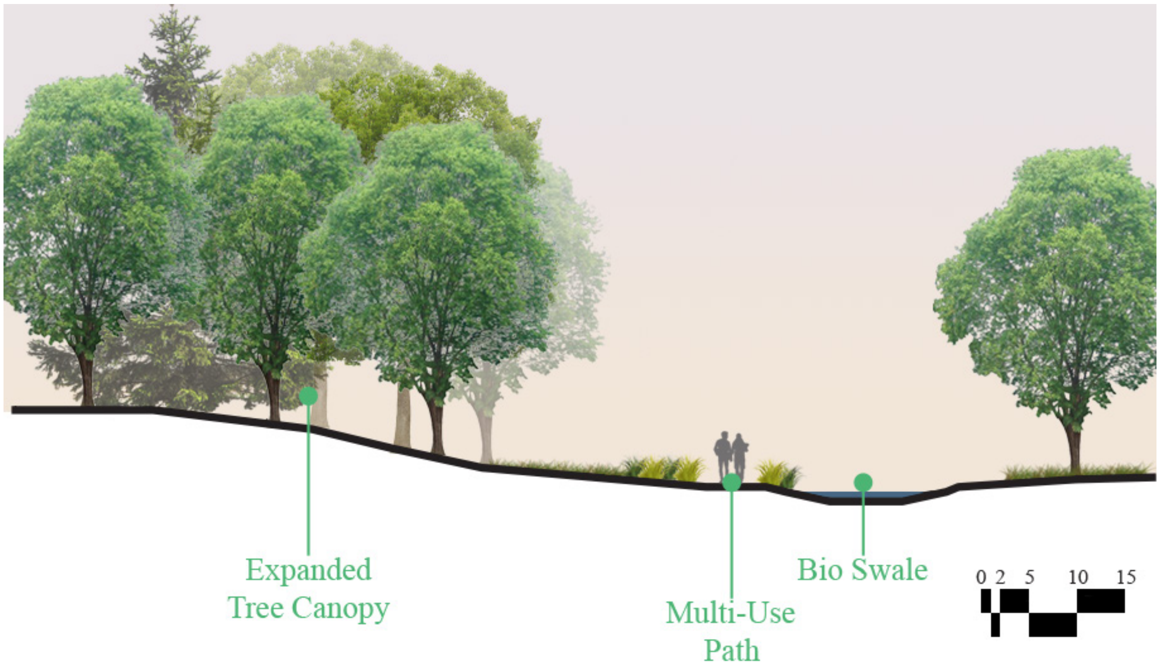



Figure 5.6: Section of Bio-Swale area

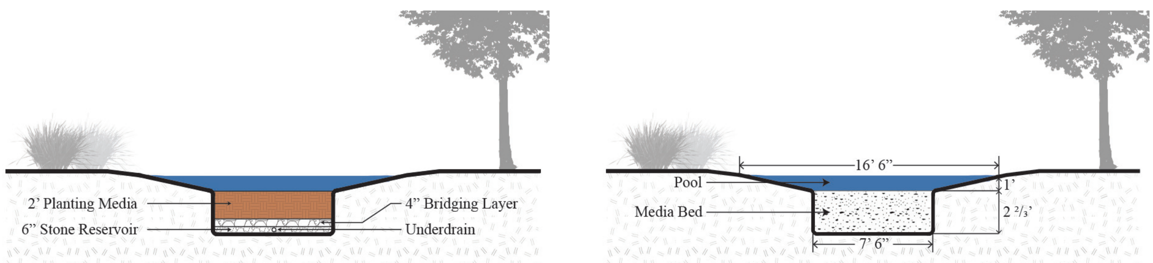



Figure 5.7: Cross-section of Bio-Swale

## Plant Selection

In order to increase biodiversity of the wetland, 5 to 7 species of emergent wetland plants need to be planted, with half of them designated as aggressive colonizers. No more than 25 percent of the high marsh wetland surface area needs to be planted, so the plants will colonizer the rest of the wetland over the next three years (DOEE). The below chart is the plant selection for the proposed site:

Table 5.1: Plant Selection

| Scientific Name | Common Name | Height | Sunlight | Soil Moisture |
|---|---|---|---|---|
| Canopy Trees | | | | |
| *Acer rubra* | Red Maple | 40 - 60’ | | Moist - Wet |
| *Betula nigra* | River Birch | 30 - 50’ | | Moist - Wet |
| *Liquidambar styraciflua* | Sweet Gum | 60 - 80’ | | Moist - Wet |
| *Quercus bicolor* | Swamp White Oak | 60 - 70’ | | Wet |
| *Quercus rubra* | Northern Red Oak | 90’ | | Dry - Moist |
| Understory Trees | | | | |
| *Amelanchier canadensis* | Serviceberry | 35 - 50’ | | Moist - Wet |
| *Cercis canadensis* | Eastern Redbud | 20 - 35’ | | Dry - Moist |
| *Cornus florida* | Flowering Dogwood | 35 - 50’ | | Dry - Moist |
| *Magnolia virginiana* | Sweetbay Magnolia | 30’ | | Moist - Wet |
| Grasses | | | | |
| *Acorus calamus* | Sweet Flag | 2 -3’ | | Moist - Wet |
| *Carex glaucodea* | Blue Wood Sedge | 0.5’ - 2’ | | Dry - Moist |
| *Carex stricta* | Tussock Sedge | 1 - 3’ | | Moist - Wet |
| *Elymus hystrix* | Bottlebrush Grass | 3’ | | Dry - Moist |
| Meadow | | | | |
| *Asclepias tuberosa* | Butterflyweed | 3’ | | Dry - Moist |
| *Aster novi-belgii* | New York Aster | 3 - 4’ | | Moist |
| *Chelone glabra* | White Turtlehead | 3’ | | Moist - Wet |
| *Rudbeckia hirta* | Black-Eyed Susan | 2’ | | Dry - Moist |
| *Tiarella cordoflia* | Foamflower | 1’ | | Moist |
| *Tradescantia virginiana* | Virginia spiderwort | 2 - 3’ | | Moist |
| Wetland | | | | |
| *Elodea canadensis* | Waterweed | 1’ | N/A | Submergent |
| *Iris versicolor* | Blue Flag Iris | 3’ | | Emergent |
| *Nelumbo lutea* | American Lotus | 3 - 6’ | | Emergent |
| ***Saggitaria latifolia*** | **Duck Potato** | 0.5 - 2’ | | Emergent |
| ***Sagittaria lancifolia*** | **Bulltongue Arrowhead** | 1 - 4’ | | Emergent |
| ***Typha latifolia*** | **Broad-Leaved Cattail** | 5 - 7’ | | Emergent |

- Aggressive colonizers are shown in **bold** type

*Dragonfly Habitat*

Currently, there is a mosquito problem at the site because of all the standing water. There has been concern of breeding in stormwater facilities (Maeda, 2017) because of the potential for mosquitoes to spread diseases like West Nile, Chikungunya, and Zika Virus. One method to control and decrease the number of mosquitoes is to provide a habitat for a biological predator: the dragonfly.

There are about 5,000 species of dragonflies and they all belong to the specific Order of Odonata, which mean “toothed one” in Greek, referring to the dragonfly’s serrated teeth (Zielinski, 2011). From the nymph stage to the adult stage, dragonflies provide three benefits for the environment. First, when they hatched as nymph, they feed on aquatic insect larvae such as mosquitoes, tiny fish and tadpoles. When they emerge as adults, they feed on flying insects that are small enough for them to capture including adult mosquitoes, beetles, gnats, and various flies (Berger, 2004). The second benefit is that they are also prey to a few animals, including reptiles, fish, small mammals, frogs, and other insects. Although they are fearful by some insect, they are harmless to people. The third benefits is aesthetics, and they come in many alluring colors and provide a visual accent for freshwater bodies.

For this design, certain plants were chosen to attract dragonflies. The American Lotus (*Nelumbo lutea*) is used to lay dragonfly's eggs on the underside of the plant, Blue Flag Iris (*Iris versicolor*) is used to after the metamorphic stage when they take their first flight, and Cattail (*Typha latifolia*) is used to hide and hunt.

# Chapter 6: Landscape Performance

## Stormwater Management

To establish the water quantity performance, the proposed site surface was changed to reduce runoff, encourage infiltration, and storing water in void spaces in BMPs. The hydrology of the proposed catchment with three subcatchment areas was modeled using the TR-55 software to determine the volume of runoff, which will be compare to the current condition runoff calculations.

The projected reduction of stormwater runoff for the proposed designed reduced the amount of runoff by 7%, from 57,028 cu ft to 53,035 cu ft. Although, that doesn't sound significant, most of the runoff comes from the Storm Drain catchment. Without the Storm Drain subcatchment, the remaining 4.59 acres was reduced by 15.9%.

Table 6.1: Reduction of Runoff

| One year, 24-hour storm volume: **82,294 cu ft** | | | |
|---|---|---|---|
| Current: | Current: | Proposal: | - % |
| Storm Drain Pipes | 31,853 | 31,853 | 0 % |
| Pond Sheet Flow | 14,609 | 13,618 | 6.8 % |
| Swale | 10,566 | 7,564 | 28.4 % |
| **Total:** | **57,028** | **53,035** | 7 % |

However, due to the three BMPs are within the Pond Sheet Flow subcatchment area, two areas were removed from the calculation and given their own capture calculations (Figure 6.1). The first two BMPs are the micro-bioretentions and permeable concrete in Lot CC1, which will capture 0.5 acre of water. The third BMP is the bioretention that is on the east side of the Neutral Buoyancy Building, and it will capture 0.49 acre of water from Lot FF2 and rooftop runoff from the Neutral Buoyancy Building.

Next, the storage volume of both pools and void spaces was calculated in

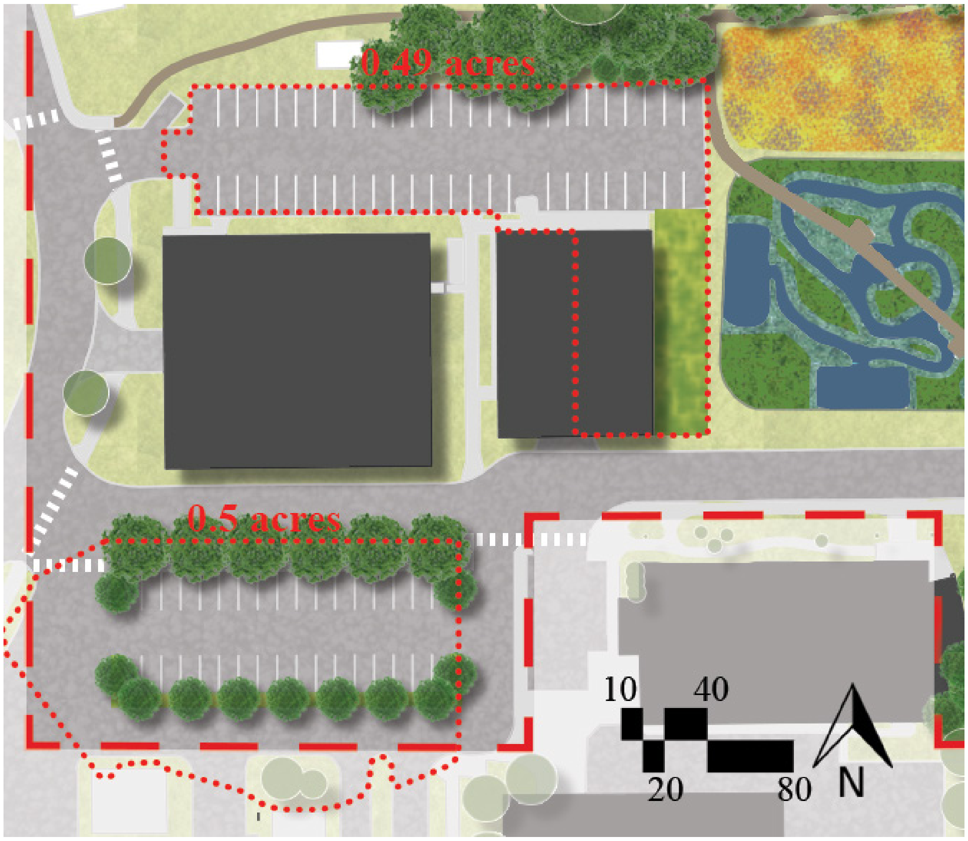


Figure 6.1: BMPs catchment area within subcatchment

cubic feet. The void space was determined by using the soil void space ratio by the Virginia Department of Environmental Quality (DEQ) Stormwater Design Specification (VWRRC, 2011) and the Geotech Gate (Geotechdata.info, 2013).

*Water Quantity Calculation*

Void Space Ratio (Vr)

| | | |
|---|---|---|
| Bioretention Soil Mix Vr | = | 0.25 |
| Sand Course Vr | = | 0.55 |
| Grave and #57 Stone Vr | = | 0.4 |
| Pooling Vr | = | 1 |

Storage Volume

$$SA \times [(D_{SM} \times 0.25) + (D_{CS} \times 0.55) + (D_{GS} \times 0.4)\ (D_P \times 1)]$$

Where:

| | | |
|---|---|---|
| SA | = | Surface Area of Bioretention |
| $D_{SM}$ | = | Depth of Bioretention Soil Mix (in ft) |
| $D_{CS}$ | = | Depth of Course Sand (in ft) |
| $D_{GS}$ | = | Depth of Gravel/Stone (in ft) |
| $D_P$ | = | Depth of Pool (in ft) |

Figure 6.2: Void Space Formula

Now, this equation will be used for all the BMPs:

Parking Lot CC1

Bioretention

$$SA \times [(D_{SM} \times 0.25) + (D_{CS} \times 0.55) + (D_{GS} \times 0.4) + (D_P \times 1)]$$

$$2430 \times [(2 \times 0.25) + (0.33 \times 0.55) + (1.33 \times 0.4) + (0.67 \times 1)]$$

$$2430 \times (0.5 + 0.182 + 0.533 + 0.67) \quad = \quad 4653 \text{ cu ft}$$

Permable Concrete

$$(SA)\ (D_{GS} \times 0.4)$$

$$(1070)\ (0.75 \times 0.4) \quad = \quad 321 \text{ cu ft}$$

**Total Storage = 4974 cu ft**

Figure 6.3: Parking Lot calculation

Neutral Buoyancy Bioretention

SA x [($D_{SM}$ x 0.25) + ($D_{CS}$ x 0.55) + ($D_{GS}$ x 0.4) + ($D_P$ x 1)]

2470 x [(2 x 0.25) + (0.33 x 0.55) + (1.33 x 0.4) + (0.67 x 1)]

2470 x (0.5 + 0.182 + 0.533 + 0.67)

**Total Storage = 4656 cu ft**

Figure 6.4: Neutral Buoyancy Bioretention

The formula for the bio-swale needed to be alter due to the irregular shape of the pooling spaceon top of the infiltration. The shape of the pooling volume is broken down into a triangular prism and 2 triangular pyramid.

Bio-Swale Storage

Storage Volume in Pools

Triangle Prism

1/2 (L) (W) ($D_p$)

1/2 (75) (7.5) (1) = 281 cu ft

Triangular Pyramid

(2) 1/6 (b) (h) ($D_p$)

(2) 1/6 (4.5) (75) (1) = 113 cu ft

Storage Volume in Voids

SA x [($D_{SM}$ x 0.25) + ($D_{GS}$ x 0.4)]

562.5 x [(2 x 0.25) + (0.833 x 0.4)] = 469 cu ft

**Storage per Weir = 863 cu ft**

**9 Weirs Storage = 7767 cu ft**

Figure 6.5: Parking Lot calculation

With these BMPs in place, a treatment train will be implemented as the best means of maximizing pollution removal efficiencies.

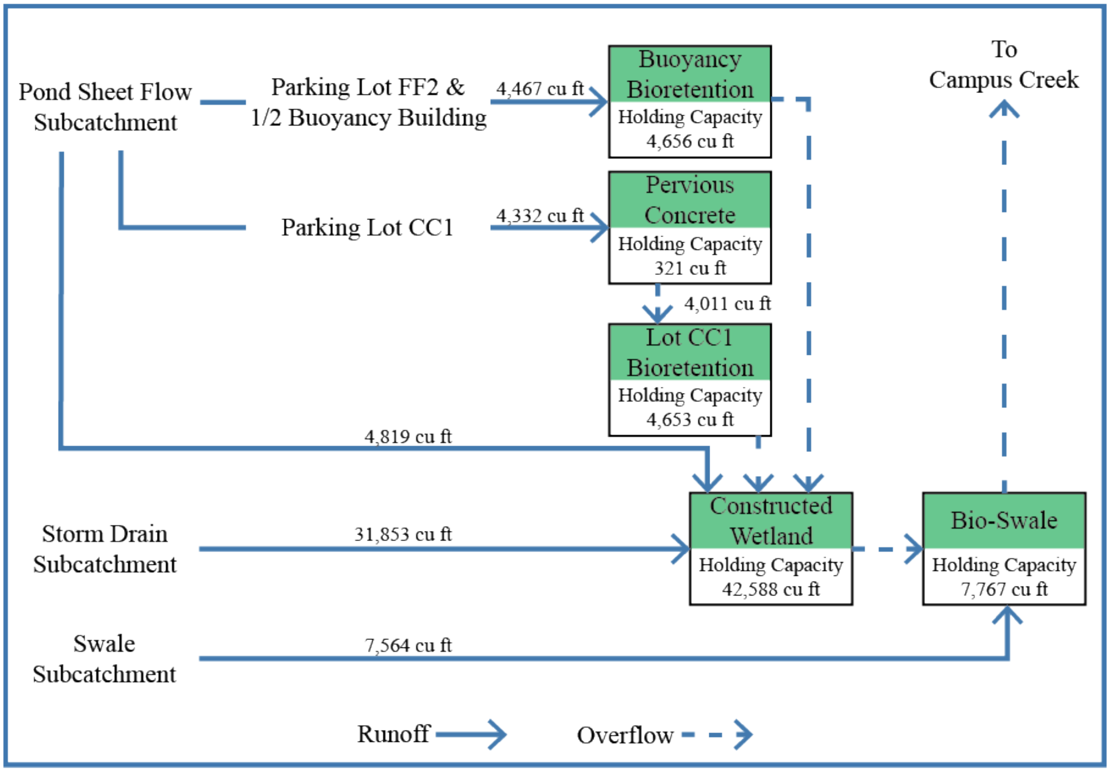


Figure 6.8: Treatment Train of 1-year storm

As a result, the BMPs can capture 59,985 cu ft of water, which is 113% of the one-year storm runoff. Thus, all retrofits will potentially gaining 1.4 of MS4 credits per acre treated.

*Water Quality Calculation*

Lastly, the constructed wetland is classified as a stormwater treatment (ST) practice, while the other BMPs are classified as a runoff reduction (RR) practice. Therefore, the amount of pollutants are determined by the adjustment curved that the MDE turned into Table 6.2 (MD DOE 2014).

Since, the table does not go any higher than 2.5 inches, 2.5 inches was used to for the removal rate. Using the MDE statewide weighted average urban pollutant loading

Table 6.2: Pollutant Removal Rate

| Runoff Depth Treated (inches) | TSS | | TP | | TN | |
|---|---|---|---|---|---|---|
| | ESD/RR | ST | ESD/RR | ST | ESD/RR | ST |
| ***0.00*** | 0% | 0% | 0% | 0% | 0% | 0% |
| ***0.25*** | 40% | 37% | 38% | 29% | 32% | 19% |
| ***0.50*** | 56% | 52% | 52% | 41% | 44% | 26% |
| ***0.75*** | 64% | 60% | 60% | 47% | 52% | 30% |
| ***1.00*** | 70% | 66% | 66% | 52% | 57% | 33% |
| ***1.25*** | 76% | 71% | 70% | 55% | 60% | 35% |
| ***1.50*** | 80% | 74% | 74% | 58% | 64% | 37% |
| ***1.75*** | 83% | 77% | 77% | 61% | 66% | 39% |
| ***2.00*** | 86% | 80% | 80% | 63% | 69% | 40% |
| ***2.25*** | 88% | 83% | 82% | 65% | 71% | 41% |
| ***2.50*** | 90% | 85% | 85% | 66% | 72% | 42% |

Table 6.3: Annual Pollutant Accumulation Volume for Site

| Total Suspended Solids (TSS) | Total Phosphorus (TP) | Total Nitrogen (TN) |
|---|---|---|
| 1.55 tons | 5.86 lbs | 100.85 lbs |

Table 6.4: Annual Pollutant Removal for Site

| | TSS (tons) | TP (lbs) | TN (lbs) |
|---|---|---|---|
| ESDs (RR) | 0.52 | 1.87 | 27.23 |
| Constructed Wetland (ST) | 0.82 | 2.42 | 26.47 |
| **Total** | **1.35** | **4.29** | **53.7** |

rates (MD DOE 2014), the annual pollutant accumulation and removal volumes for the proposed BMPs were calculated.

**Tree Canopy**

With the new design, tree canopy coverage on the site has more than doubled, from 9.1% to 18.4%. By proposing green infrastructure strategies of expanding the riparian buffer, street tree planting, and using tree to slow down water to the bio-swale.

The increase in tree plantings will make the campus more attractive, improve air and water quality, moderate temperature for nearly buildings and pedestrians.

**MS4 Credits**

As stated earlier, the university will gain 1.4 MS4 credits per acre that is treated. In able for the university to get MS4 credit in Reforestation on Previous credits under the Alternative BMP category, the trees that are planted need a survival rate of 100 trees/ acre or greater, and at least 50% of trees have two inch diameter at breast height (DBH) or greater (MDE, 2014).

Table 6.5: MS4 Credit Gain through Propose Design

| BMPs | Rainfall Depth Treated | Credit/Acre | Acres Treated | Credit Earned |
|---|---|---|---|---|
| Netural Buoyancy Bioretention | 2.6 | 1.4 | 0.5 | 0.7 |
| Parking Lot CC1 | 2.6 | 1.4 | 0.5 | 0.7 |
| Constructed Wetland | 2.6 | 1.4 | 5.38 | 7.53 |
| Bio-swale | 2.6 | 1.4 | 2.24 | 3.13 |
| Reforestation on Pervious | N/A | 0.62 | 0.45 | 0.28 |
| **Total** | | | | **12.34** |

Although the number of impervious surface on campus is more than the example from Chapter 1, under these condition, the campus will only have to treat 2.62 acres of impervious surfaces to meet the MS4 requirements.

## Chapter 7: Conclusion

Ultimately, the purpose of this thesis project was to investigate a site that could gain stormwater credits under the upcoming Municipal Separate Storm Sewer Systems (MS4) permit. The main subject of the thesis is a poorly maintained but functional stormwater pond that currently function as a wetland. The design proposal retrofits the stormwater pond into a constructed wetland. It also retrofits the surrounding areas into various state acceptable BMPs including: mirco-bioretentions, pervious concrete, and a bio-swale. The BMPs forms a treatment train that is capable of capturing and treating a one-year storm of 2.63 inches.

Although stormwater management was the main focus, the site has the opportunity for other beneficial services, including: environmental, recreational, and educational. For environmental, BMP will clean up about 87% of total suspended solids (TSS), 73% of total phosphorus (TP), and 53% of total nitrogen (TN). The proposed plant pauete provides a dragonfly habitat to decrease the potential of disease carrying mosquitoes on campus. The dragonfly habitat can also increase the number of animals that prey on dragonflies, which will increase the biodiversity of site.

Next for recreational, the addition of a sidewalk and shared use path will allowed a safer route for pedestrian throughout the site. This shared use path can be use by individuals who are out of a daily run and addition path for campus sponsor runs.

Furthermore for education, this type of BMP is not found anywhere else on campus. For active education, students and faculty of certain major and programs can use this space for an outdoor lab. For passive education, the site and educational signage will be visible for pedestrians that are walking through the site. Being close to on and off campus housing, and the sport arena will provide passerby to look at this site and sign. Making the site more visible to student near student housing and off-campus parking will make the practice of sustainability more effective noted by Finlay and Massey. For students this site has the potential to be seen every day by students.

As most college campus across the United States are public, state-owned facilities, the new MS4 Phase II permit will effective them as well. Therefore, while the design proposal in this thesis is specific to the project site, it has the potential to serve as a model to other college campuses approach to retrofitting stormwater facilities and parking lots to manage and storing stormwater.

**Next Step**

Due to the MDE guideline for permittees to develop planning, funding, and implementation by 2025, the next step will be to give this thesis document to the UMD Facilities Management for possible cost estimation for implementing the project. The designer intends is to keep in contact with the UMD Facilities Management on the process and will give additional help on implication and design challenges.

Appendix A: UMD Parking Restriction

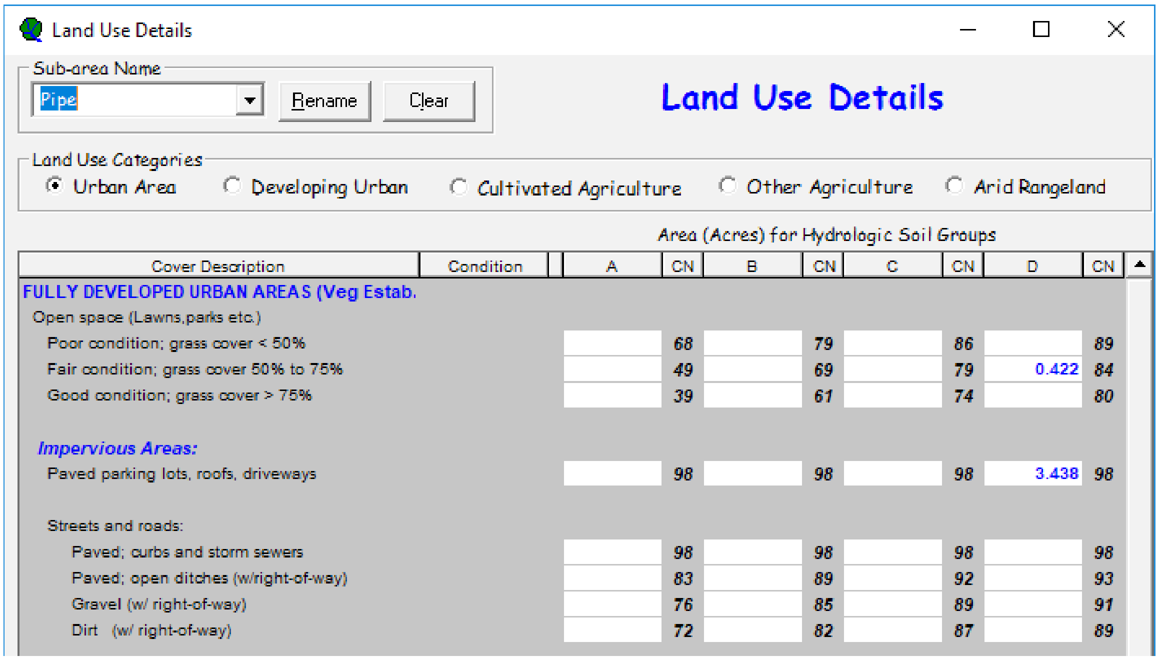
| | Parking Restriction |
|---|---|
| Unrestricted Student<br>Unrestricted Facilities | Free parking 4pm - 7am Mon - Fri, and all day Saturday and Sunday.<br>Commuter registrants may not park overnight Mon - Fri from 3am - 5am. |
| 24 HR Restricted Student<br>24 HR Restricted Facilities | Only individuals with a CLPR/permit corresponding to these lots may park here at anytime. |
| Restricted Facilities | Only faculty/staff with a valid CLPR/permit may park from 4pm - 7am Mon - Fri as well as all day on Saturday and Sunday. |
| Modified Restricted | Only faculty/staff with a valid CLPR/permit may park from 4pm - 8pm and all day on weekends. Anyone may park from 8pm - 7am Monday - Friday. |
| Special Restricted | Requires lot KK Campus License Plate Registration (CLPR) 7am - 8pm Mon - Fri |
| Special Building Parking | Gated Parking that is unaccesbile by General Student and Faculty/Staff |
| Visitor's Parking | $3/HR, 7am - Midnight, Everything |

Chart manupulated from: UMD Transportation Service (2016)

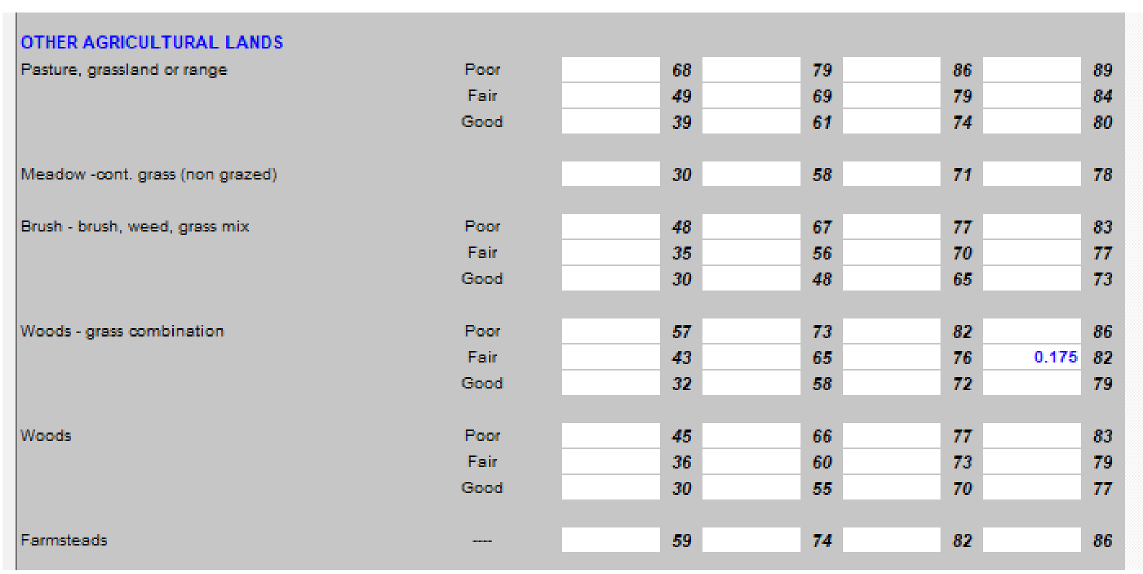
# Appendix B: Hydrologic Modeling with TR-55

## Exisiting Site Hydrology

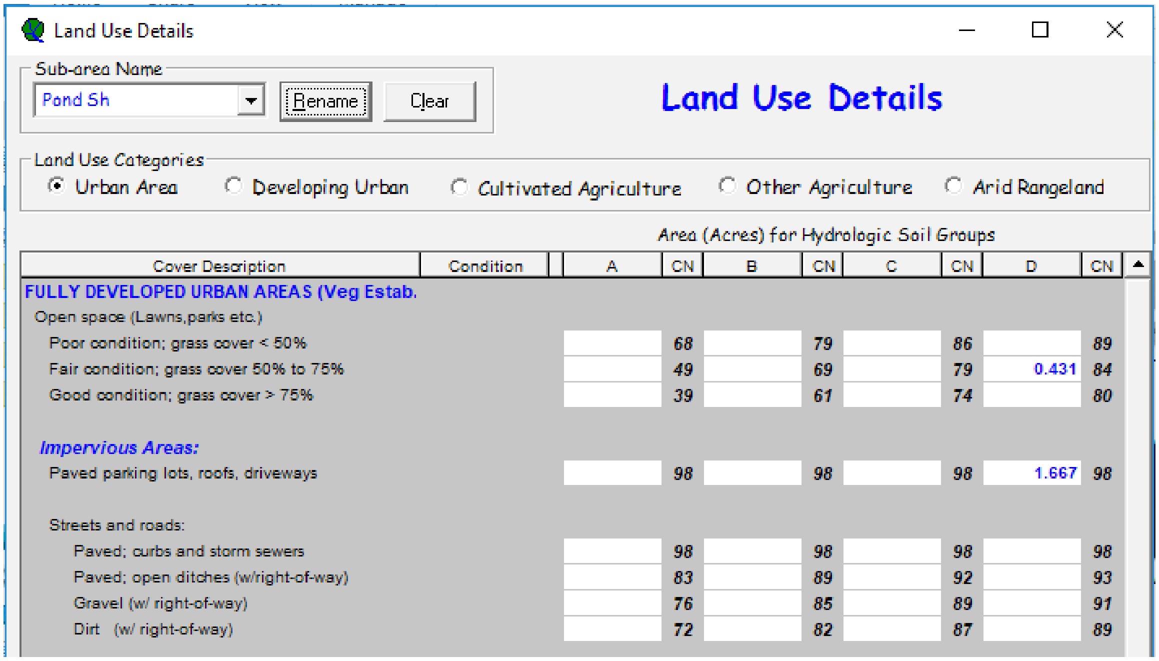
Storm Drain subwatershed is called "Pipe", and Pond Sheet subwatershed is called "Pond Sh".



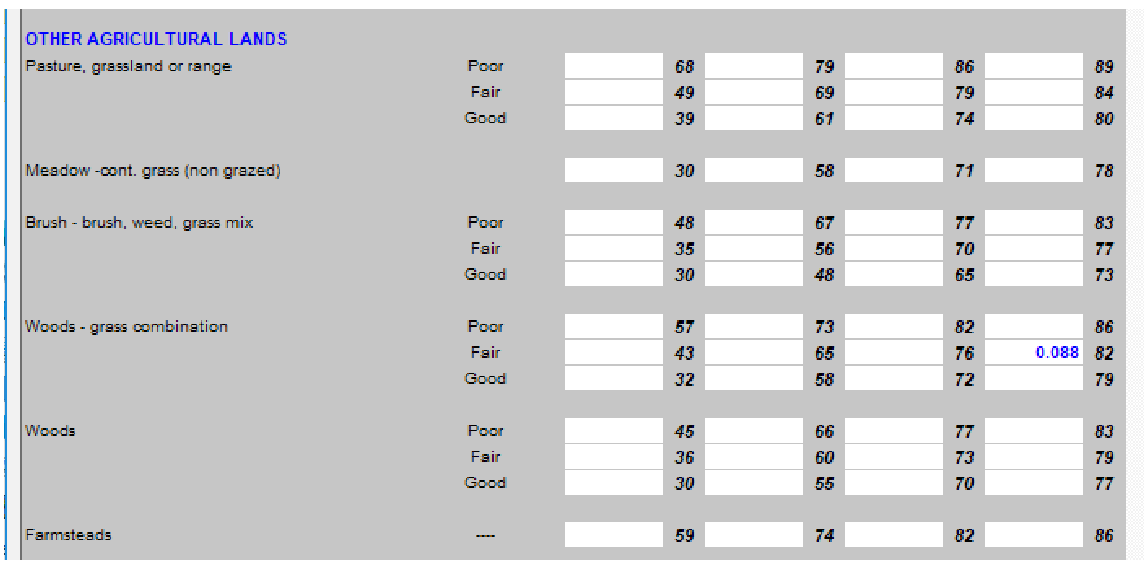

| Cover Description | Condition | A | CN | B | CN | C | CN | D | CN |
|---|---|---|---|---|---|---|---|---|---|
| FULLY DEVELOPED URBAN AREAS (Veg Estab. | | | | | | | | | |
| Open space (Lawns,parks etc.) | | | | | | | | | |
| Poor condition; grass cover < 50% | | | 68 | | 79 | | 86 | | 89 |
| Fair condition; grass cover 50% to 75% | | | 49 | | 69 | | 79 | 0.422 | 84 |
| Good condition; grass cover > 75% | | | 39 | | 61 | | 74 | | 80 |
| *Impervious Areas:* | | | | | | | | | |
| Paved parking lots, roofs, driveways | | | 98 | | 98 | | 98 | 3.438 | 98 |
| Streets and roads: | | | | | | | | | |
| Paved; curbs and storm sewers | | | 98 | | 98 | | 98 | | 98 |
| Paved; open ditches (w/right-of-way) | | | 83 | | 89 | | 92 | | 93 |
| Gravel (w/ right-of-way) | | | 76 | | 85 | | 89 | | 91 |
| Dirt (w/ right-of-way) | | | 72 | | 82 | | 87 | | 89 |



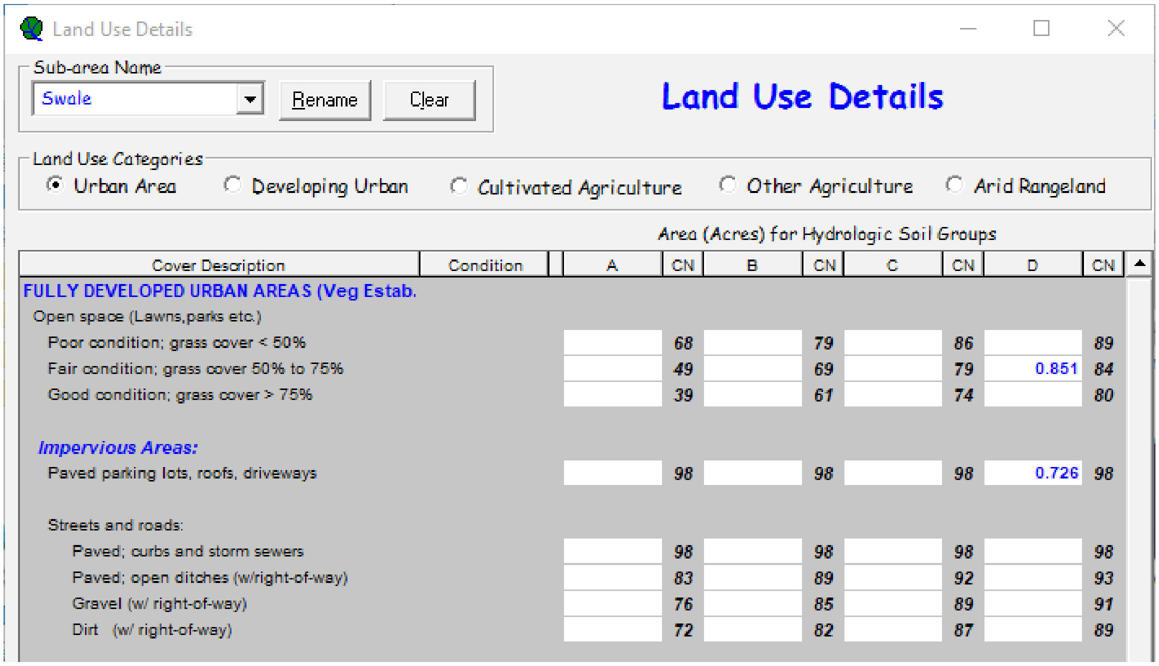
| Cover Description | Condition | A | CN | B | CN | C | CN | D | CN |
|---|---|---|---|---|---|---|---|---|---|
| OTHER AGRICULTURAL LANDS | | | | | | | | | |
| Pasture, grassland or range | Poor | | 68 | | 79 | | 86 | | 89 |
| | Fair | | 49 | | 69 | | 79 | | 84 |
| | Good | | 39 | | 61 | | 74 | | 80 |
| Meadow -cont. grass (non grazed) | | | 30 | | 58 | | 71 | | 78 |
| Brush - brush, weed, grass mix | Poor | | 48 | | 67 | | 77 | | 83 |
| | Fair | | 35 | | 56 | | 70 | | 77 |
| | Good | | 30 | | 48 | | 65 | | 73 |
| Woods - grass combination | Poor | | 57 | | 73 | | 82 | | 86 |
| | Fair | | 43 | | 65 | | 76 | 0.175 | 82 |
| | Good | | 32 | | 58 | | 72 | | 79 |
| Woods | Poor | | 45 | | 66 | | 77 | | 83 |
| | Fair | | 36 | | 60 | | 73 | | 79 |
| | Good | | 30 | | 55 | | 70 | | 77 |
| Farmsteads | ---- | | 59 | | 74 | | 82 | | 86 |




| Cover Description | Condition | A | CN | B | CN | C | CN | D | CN |
|---|---|---|---|---|---|---|---|---|---|
| FULLY DEVELOPED URBAN AREAS (Veg Estab. | | | | | | | | | |
| Open space (Lawns,parks etc.) | | | | | | | | | |
| Poor condition; grass cover < 50% | | | 68 | | 79 | | 86 | | 89 |
| Fair condition; grass cover 50% to 75% | | | 49 | | 69 | | 79 | 0.431 | 84 |
| Good condition; grass cover > 75% | | | 39 | | 61 | | 74 | | 80 |
| *Impervious Areas:* | | | | | | | | | |
| Paved parking lots, roofs, driveways | | | 98 | | 98 | | 98 | 1.667 | 98 |
| Streets and roads: | | | | | | | | | |
| Paved; curbs and storm sewers | | | 98 | | 98 | | 98 | | 98 |
| Paved; open ditches (w/right-of-way) | | | 83 | | 89 | | 92 | | 93 |
| Gravel (w/ right-of-way) | | | 76 | | 85 | | 89 | | 91 |
| Dirt (w/ right-of-way) | | | 72 | | 82 | | 87 | | 89 |



| Cover Description | Condition | A | CN | B | CN | C | CN | D | CN |
|---|---|---|---|---|---|---|---|---|---|
| OTHER AGRICULTURAL LANDS | | | | | | | | | |
| Pasture, grassland or range | Poor | | 68 | | 79 | | 86 | | 89 |
| | Fair | | 49 | | 69 | | 79 | | 84 |
| | Good | | 39 | | 61 | | 74 | | 80 |
| Meadow -cont. grass (non grazed) | | | 30 | | 58 | | 71 | | 78 |
| Brush - brush, weed, grass mix | Poor | | 48 | | 67 | | 77 | | 83 |
| | Fair | | 35 | | 56 | | 70 | | 77 |
| | Good | | 30 | | 48 | | 65 | | 73 |
| Woods - grass combination | Poor | | 57 | | 73 | | 82 | | 86 |
| | Fair | | 43 | | 65 | | 76 | 0.088 | 82 |
| | Good | | 32 | | 58 | | 72 | | 79 |
| Woods | Poor | | 45 | | 66 | | 77 | | 83 |
| | Fair | | 36 | | 60 | | 73 | | 79 |
| | Good | | 30 | | 55 | | 70 | | 77 |
| Farmsteads | ---- | | 59 | | 74 | | 82 | | 86 |



Land Use Details

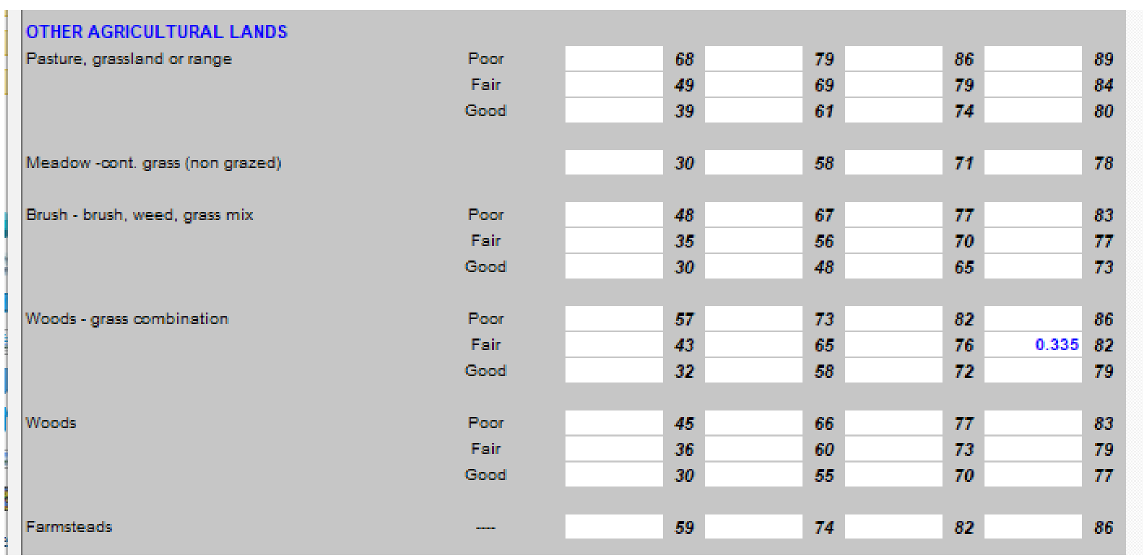
Sub-area Name: Swale | Rename | Clear

**Land Use Details**

Land Use Categories: (•) Urban Area ( ) Developing Urban ( ) Cultivated Agriculture ( ) Other Agriculture ( ) Arid Rangeland

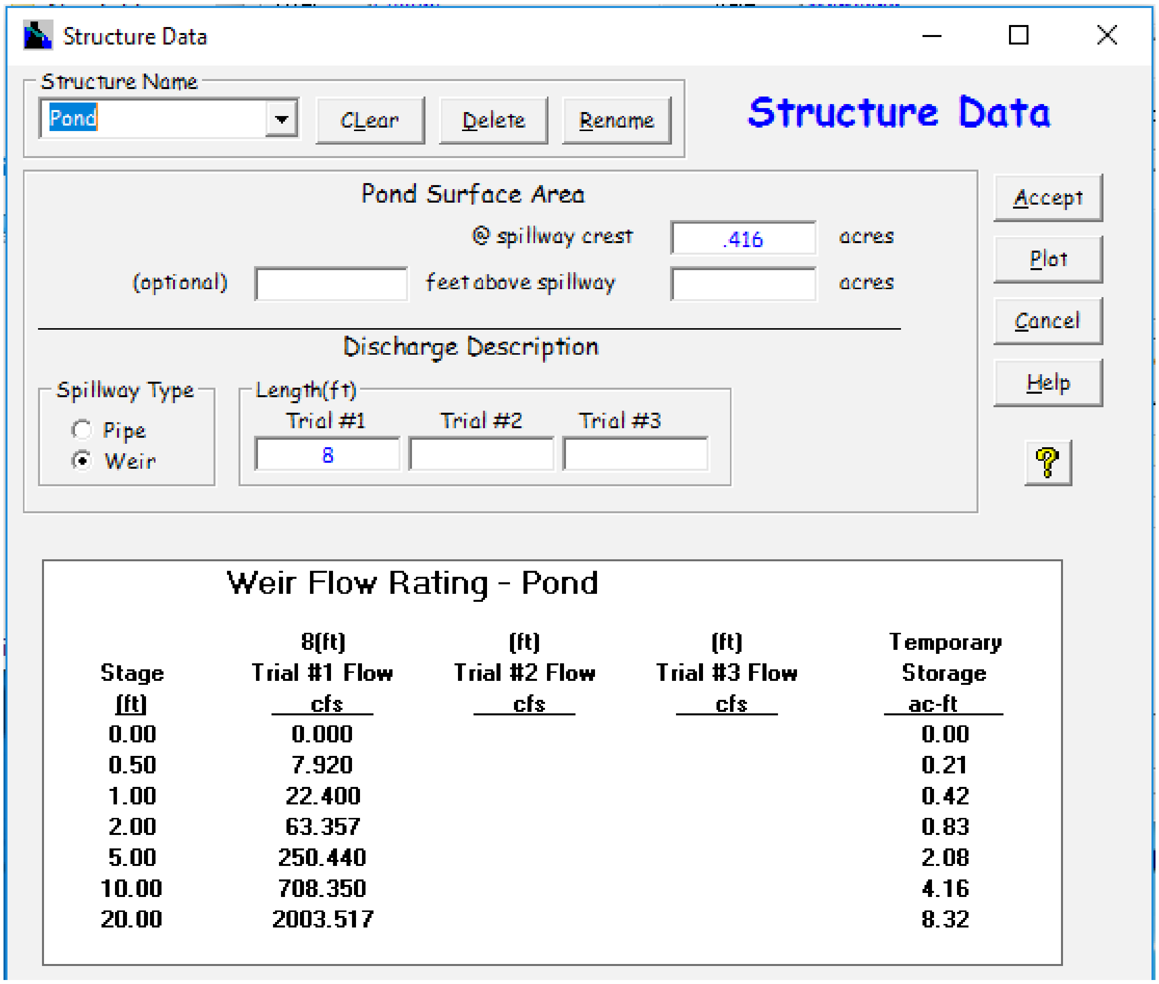
Area (Acres) for Hydrologic Soil Groups

| Cover Description | Condition | A | CN | B | CN | C | CN | D | CN |
|---|---|---|---|---|---|---|---|---|---|
| FULLY DEVELOPED URBAN AREAS (Veg Estab. | | | | | | | | | |
| Open space (Lawns,parks etc.) | | | | | | | | | |
| Poor condition; grass cover < 50% | | | 68 | | 79 | | 86 | | 89 |
| Fair condition; grass cover 50% to 75% | | | 49 | | 69 | | 79 | 0.851 | 84 |
| Good condition; grass cover > 75% | | | 39 | | 61 | | 74 | | 80 |
| *Impervious Areas:* | | | | | | | | | |
| Paved parking lots, roofs, driveways | | | 98 | | 98 | | 98 | 0.726 | 98 |
| Streets and roads: | | | | | | | | | |
| Paved; curbs and storm sewers | | | 98 | | 98 | | 98 | | 98 |
| Paved; open ditches (w/right-of-way) | | | 83 | | 89 | | 92 | | 93 |
| Gravel (w/ right-of-way) | | | 76 | | 85 | | 89 | | 91 |
| Dirt (w/ right-of-way) | | | 72 | | 82 | | 87 | | 89 |

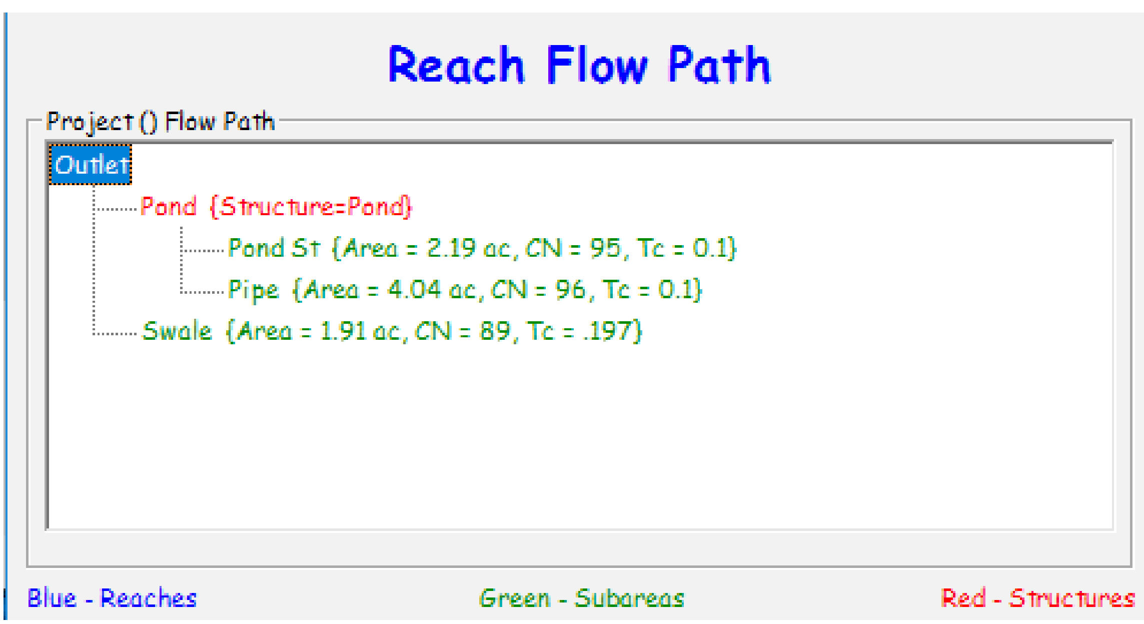


| Cover Description | Condition | A | CN | B | CN | C | CN | D | CN |
|---|---|---|---|---|---|---|---|---|---|
| OTHER AGRICULTURAL LANDS | | | | | | | | | |
| Pasture, grassland or range | Poor | | 68 | | 79 | | 86 | | 89 |
| | Fair | | 49 | | 69 | | 79 | | 84 |
| | Good | | 39 | | 61 | | 74 | | 80 |
| Meadow -cont. grass (non grazed) | | | 30 | | 58 | | 71 | | 78 |
| Brush - brush, weed, grass mix | Poor | | 48 | | 67 | | 77 | | 83 |
| | Fair | | 35 | | 56 | | 70 | | 77 |
| | Good | | 30 | | 48 | | 65 | | 73 |
| Woods - grass combination | Poor | | 57 | | 73 | | 82 | | 86 |
| | Fair | | 43 | | 65 | | 76 | 0.335 | 82 |
| | Good | | 32 | | 58 | | 72 | | 79 |
| Woods | Poor | | 45 | | 66 | | 77 | | 83 |
| | Fair | | 36 | | 60 | | 73 | | 79 |
| | Good | | 30 | | 55 | | 70 | | 77 |
| Farmsteads | ---- | | 59 | | 74 | | 82 | | 86 |

The Storm Drain and Pond Sheet drainage goes through the retention pond before leaving the site. So in TR-55, a structure data was formed to simulate the amount of water going in and leaving the structure.




| Stage (ft) | 8(ft) Trial #1 Flow cfs | (ft) Trial #2 Flow cfs | (ft) Trial #3 Flow cfs | Temporary Storage ac-ft |
|---|---|---|---|---|
| 0.00 | 0.000 | | | 0.00 |
| 0.50 | 7.920 | | | 0.21 |
| 1.00 | 22.400 | | | 0.42 |
| 2.00 | 63.357 | | | 0.83 |
| 5.00 | 250.440 | | | 2.08 |
| 10.00 | 708.350 | | | 4.16 |
| 20.00 | 2003.517 | | | 8.32 |



| Area or Reach Identifier | Drainage Area (sq mi) | Rain Gage ID or Location | Runoff Amount (in) | Peak Flow Elevation (ft) | Peak Flow Time (hr) | Peak Flow Rate (cfs) | Peak Flow Rate (csm) |
|---|---|---|---|---|---|---|---|
| Pipe | 0.006 | | 2.173 | | 12.12 | 14.38 | 2279.07 |

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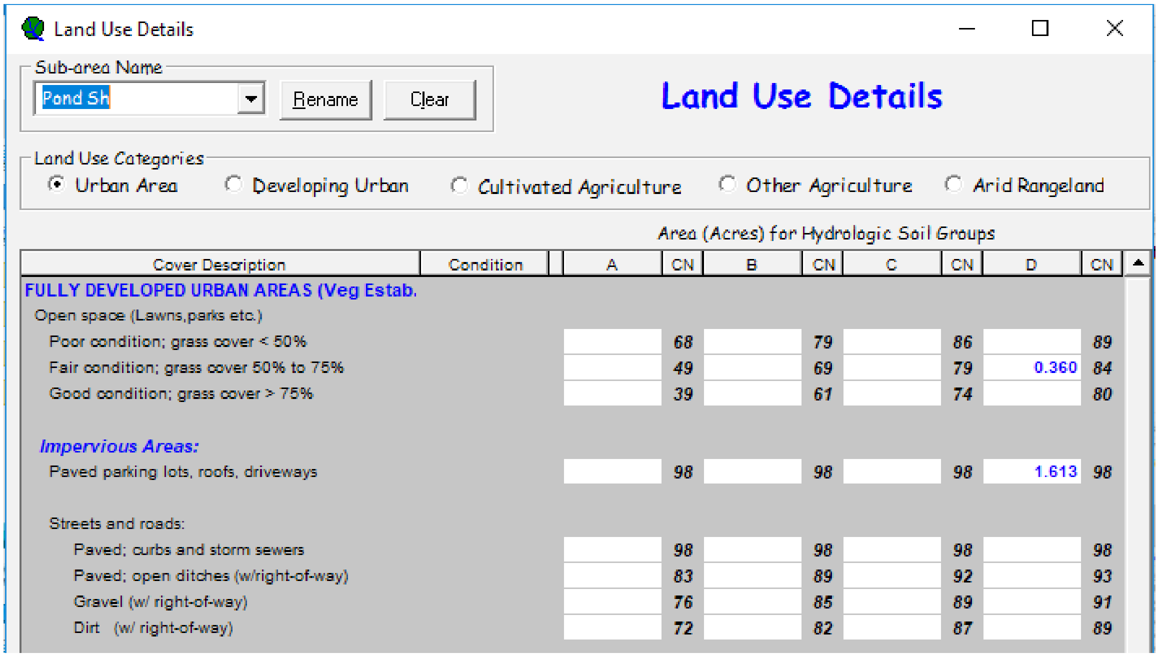
| Area or Reach Identifier | Drainage Area (sq mi) | Rain Gage ID or Location | Runoff Amount (in) | Peak Flow Elevation (ft) | Peak Flow Time (hr) | Peak Flow Rate (cfs) | Peak Flow Rate (csm) |
|---|---|---|---|---|---|---|---|
| Pond Sh | 0.003 | | 1.998 | | 12.12 | 7.58 | 2215.58 |

| Area or Reach Identifier | Drainage Area (sq mi) | Rain Gage ID or Location | Runoff Amount (in) | Peak Flow Elevation (ft) | Peak Flow Time (hr) | Peak Flow Rate (cfs) | Peak Flow Rate (csm) |
|---|---|---|---|---|---|---|---|
| Pond | 0.010 | Downstream | 2.106 | 0.66 | 12.20 | 11.71 | 1203.56 |

| Area or Reach Identifier | Drainage Area (sq mi) | Rain Gage ID or Location | Runoff Amount (in) | Peak Flow Elevation (ft) | Peak Flow Time (hr) | Peak Flow Rate (cfs) | Peak Flow Rate (csm) |
|---|---|---|---|---|---|---|---|
| Swale | 0.003 | | 1.438 | | 12.17 | 4.23 | 1419.91 |

Storm Drain subwatershed information will not be presented for post information because it will not change.



Land Use Details

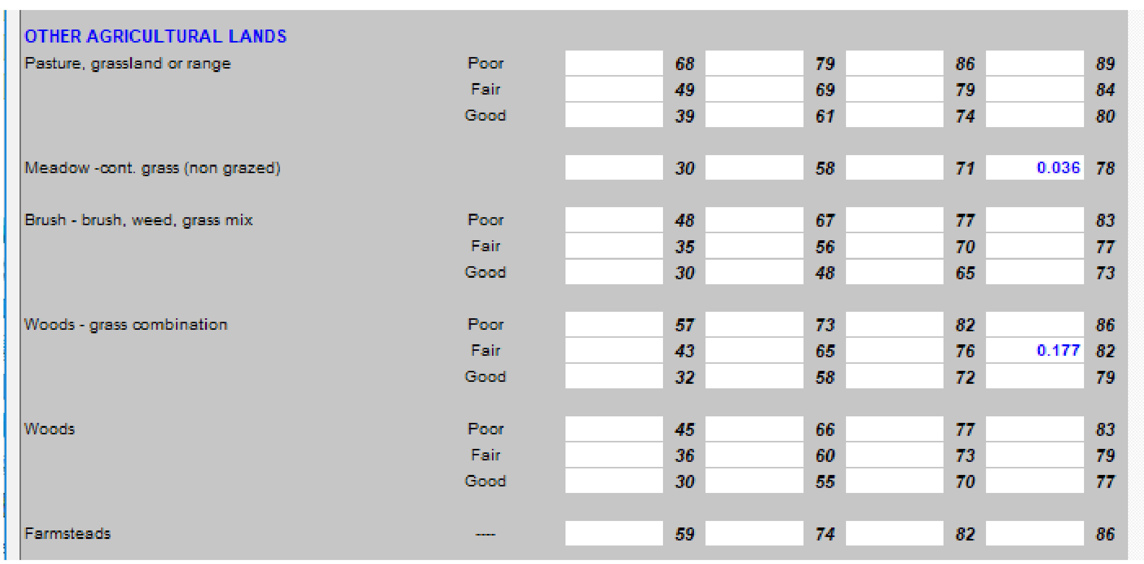
Sub-area Name: Pond Sh — Rename — Clear

**Land Use Details**

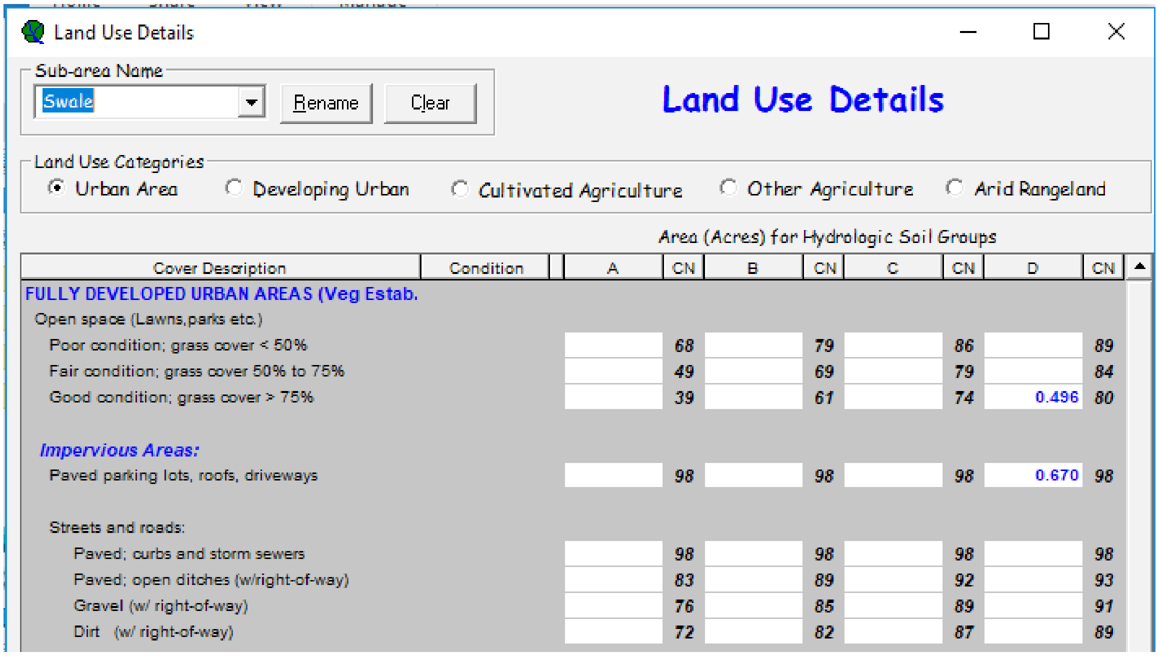
Land Use Categories: (•) Urban Area ( ) Developing Urban ( ) Cultivated Agriculture ( ) Other Agriculture ( ) Arid Rangeland

Area (Acres) for Hydrologic Soil Groups

| Cover Description | Condition | A | CN | B | CN | C | CN | D | CN |
|---|---|---|---|---|---|---|---|---|---|
| FULLY DEVELOPED URBAN AREAS (Veg Estab. | | | | | | | | | |
| Open space (Lawns,parks etc.) | | | | | | | | | |
| Poor condition; grass cover < 50% | | | 68 | | 79 | | 86 | | 89 |
| Fair condition; grass cover 50% to 75% | | | 49 | | 69 | | 79 | 0.360 | 84 |
| Good condition; grass cover > 75% | | | 39 | | 61 | | 74 | | 80 |
| *Impervious Areas:* | | | | | | | | | |
| Paved parking lots, roofs, driveways | | | 98 | | 98 | | 98 | 1.613 | 98 |
| Streets and roads: | | | | | | | | | |
| Paved; curbs and storm sewers | | | 98 | | 98 | | 98 | | 98 |
| Paved; open ditches (w/right-of-way) | | | 83 | | 89 | | 92 | | 93 |
| Gravel (w/ right-of-way) | | | 76 | | 85 | | 89 | | 91 |
| Dirt (w/ right-of-way) | | | 72 | | 82 | | 87 | | 89 |



| Cover Description | Condition | A | CN | B | CN | C | CN | D | CN |
|---|---|---|---|---|---|---|---|---|---|
| OTHER AGRICULTURAL LANDS | | | | | | | | | |
| Pasture, grassland or range | Poor | | 68 | | 79 | | 86 | | 89 |
| | Fair | | 49 | | 69 | | 79 | | 84 |
| | Good | | 39 | | 61 | | 74 | | 80 |
| Meadow -cont. grass (non grazed) | | | 30 | | 58 | | 71 | 0.036 | 78 |
| Brush - brush, weed, grass mix | Poor | | 48 | | 67 | | 77 | | 83 |
| | Fair | | 35 | | 56 | | 70 | | 77 |
| | Good | | 30 | | 48 | | 65 | | 73 |
| Woods - grass combination | Poor | | 57 | | 73 | | 82 | | 86 |
| | Fair | | 43 | | 65 | | 76 | 0.177 | 82 |
| | Good | | 32 | | 58 | | 72 | | 79 |
| Woods | Poor | | 45 | | 66 | | 77 | | 83 |
| | Fair | | 36 | | 60 | | 73 | | 79 |
| | Good | | 30 | | 55 | | 70 | | 77 |
| Farmsteads | ---- | | 59 | | 74 | | 82 | | 86 |



Land Use Details

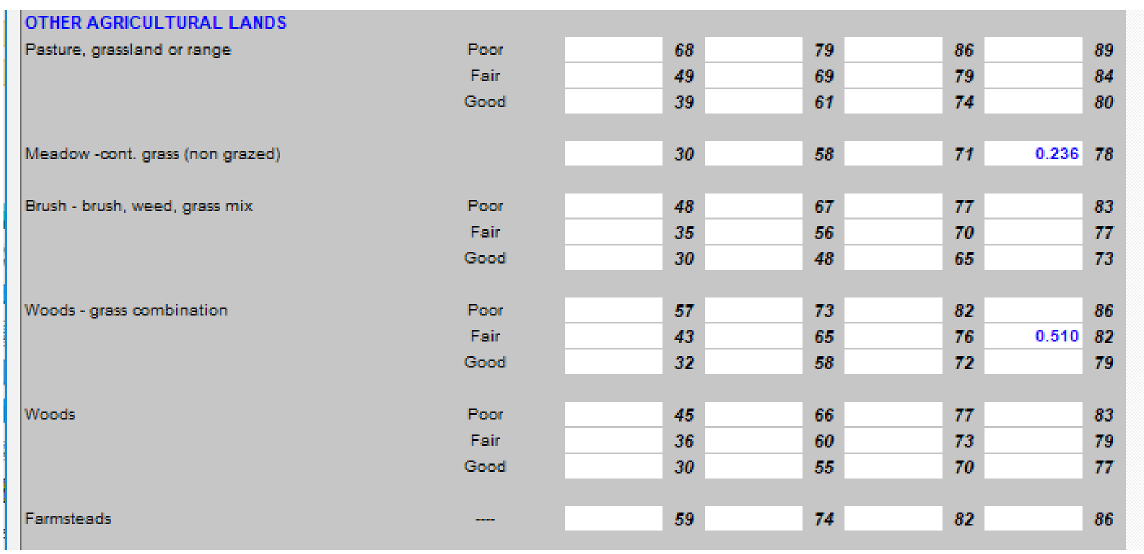
Sub-area Name: Swale | Rename | Clear

**Land Use Details**

Land Use Categories: (•) Urban Area ( ) Developing Urban ( ) Cultivated Agriculture ( ) Other Agriculture ( ) Arid Rangeland

Area (Acres) for Hydrologic Soil Groups

| Cover Description | Condition | A | CN | B | CN | C | CN | D | CN |
|---|---|---|---|---|---|---|---|---|---|
| FULLY DEVELOPED URBAN AREAS (Veg Estab. | | | | | | | | | |
| Open space (Lawns,parks etc.) | | | | | | | | | |
| Poor condition; grass cover < 50% | | | 68 | | 79 | | 86 | | 89 |
| Fair condition; grass cover 50% to 75% | | | 49 | | 69 | | 79 | | 84 |
| Good condition; grass cover > 75% | | | 39 | | 61 | | 74 | 0.496 | 80 |
| *Impervious Areas:* | | | | | | | | | |
| Paved parking lots, roofs, driveways | | | 98 | | 98 | | 98 | 0.670 | 98 |
| Streets and roads: | | | | | | | | | |
| Paved; curbs and storm sewers | | | 98 | | 98 | | 98 | | 98 |
| Paved; open ditches (w/right-of-way) | | | 83 | | 89 | | 92 | | 93 |
| Gravel (w/ right-of-way) | | | 76 | | 85 | | 89 | | 91 |
| Dirt (w/ right-of-way) | | | 72 | | 82 | | 87 | | 89 |



| Cover Description | Condition | A | CN | B | CN | C | CN | D | CN |
|---|---|---|---|---|---|---|---|---|---|
| OTHER AGRICULTURAL LANDS | | | | | | | | | |
| Pasture, grassland or range | Poor | | 68 | | 79 | | 86 | | 89 |
| | Fair | | 49 | | 69 | | 79 | | 84 |
| | Good | | 39 | | 61 | | 74 | | 80 |
| Meadow -cont. grass (non grazed) | | | 30 | | 58 | | 71 | 0.236 | 78 |
| Brush - brush, weed, grass mix | Poor | | 48 | | 67 | | 77 | | 83 |
| | Fair | | 35 | | 56 | | 70 | | 77 |
| | Good | | 30 | | 48 | | 65 | | 73 |
| Woods - grass combination | Poor | | 57 | | 73 | | 82 | | 86 |
| | Fair | | 43 | | 65 | | 76 | 0.510 | 82 |
| | Good | | 32 | | 58 | | 72 | | 79 |
| Woods | Poor | | 45 | | 66 | | 77 | | 83 |
| | Fair | | 36 | | 60 | | 73 | | 79 |
| | Good | | 30 | | 55 | | 70 | | 77 |
| Farmsteads | ---- | | 59 | | 74 | | 82 | | 86 |

STORM 1-Yr

| Area or Reach Identifier | Drainage Area (sq mi) | Rain Gage ID or Location | Runoff Amount (in) | Peak Flow Elevation (ft) | Peak Flow Time (hr) | Peak Flow Rate (cfs) | Peak Flow Rate (csm) |
|---|---|---|---|---|---|---|---|
| Pond Sh | 0.003 | | 1.951 | | 12.08 | 4.57 | 1335.98 |

| Area or Reach Identifier | Drainage Area (sq mi) | Rain Gage ID or Location | Runoff Amount (in) | Peak Flow Elevation (ft) | Peak Flow Time (hr) | Peak Flow Rate (cfs) | Peak Flow Rate (csm) |
|---|---|---|---|---|---|---|---|
| Pond | 0.010 | Downstream | 2.106 | 0.66 | 12.20 | 11.71 | 1203.56 |

| Area or Reach Identifier | Drainage Area (sq mi) | Rain Gage ID or Location | Runoff Amount (in) | Peak Flow Elevation (ft) | Peak Flow Time (hr) | Peak Flow Rate (cfs) | Peak Flow Rate (csm) |
|---|---|---|---|---|---|---|---|
| Swale | 0.003 | | 1.361 | | 12.01 | 3.62 | 1214.57 |

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