PENNSTATE

Department of Agricultural and Biological Engineering

CREEation Station 4+09
BE 466 Final Project Report
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Executive Summary

The current rate of land development practices have brought stormwater management to the forefront of environmental design. Stormwater runoff is defined as the excess water volume following a storm event which is not infiltrated into the surrounding soil areas. Characterized by poorly infiltrating soils, a high water table, and minimal elevation changes, Cree Manor of Huntingdon County, PA, a 1995 housing development of roughly 27 acres, currently struggles to manage their runoff volume. Through hydrologic study and runoff volume estimations, *CREEation Station 4+09* aims to provide Walker Township Municipality and the homeowners of Cree Manor a final design to reduce runoff volume and convey residual runoff, therefore, reducing flooding within low-lying areas. The methods described within the USDA Technical Reference 55, *Urban Hydrology for Small Watersheds*, were used to determine peak runoff rates and depths for pre and post development stormwater runoff volumes.

Through TR-55, it was found that increased runoff from to land development was localized to the upper portion of the neighborhood and the water issues at lower elevations stemmed from the proximity of the groundwater table to the ground's surface. Due to the complexity of stormwater issues within Cree Manor, *CREEation Station 4+09* developed a system of four best management practices in which to mitigate stormwater: a vegetated swale, a "stream restoration", a pipe diversion and wet pond, and the evaluation and redesign of the culvert located at the corner of Fairgrounds and Station Roads. Although it is recommended that all four solutions be used together, in order to minimize costs, the solutions can be grouped separately such that the vegetated swale and "stream restoration" or the pipe diversion, wet pond, and culvert redesign are implemented together.

In conclusion, Cree Manor experiences stormwater issues unique to its location and site design, but through careful analysis and creative engineering, these issues can be minimized, satisfying both homeowner and municipality.

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1.0 Introduction

Stormwater management is becoming an increasingly important issue as society continues to grow and develop. Historically, water falling during a precipitation event would percolate into the ground, making its way back to the groundwater table. As society advances, more and more buildings, houses, and roads are built, and less and less soil space is available for percolation. Instead of infiltrating into the ground, when precipitation falls on these new structures and designs, the water runs off over the landscape in search of a stream or river. This excess water with nowhere to go is called stormwater runoff. As this water makes its way to streams, its volume and velocity cause many issues including flooding, erosion, pollution, poor water quality, and aquatic habitat degradation. In addition to the desire to decrease flooding and erosion, it is becoming increasingly more common to mitigate environmental impacts as well. Recent EPA and DEP laws require treatment of stormwater before it makes its way to streams and rivers through the use of best management practices (BMPs) for infiltration and attenuation of urban stormwater. Several types of BMPs will be evaluated for implementation in the Cree Manor development in Walker Township of Huntingdon County, Pennsylvania. This neighborhood, built on a hill, is facing increasingly difficult flooding issues as the areas around it continue to develop.

1.1 Initial Problem Statement

Cree Manor is a relatively small development of roughly 27 acres built in 1995 in Huntingdon, PA. This rural neighborhood was built before stormwater laws came into effect, and, therefore, does not have a stormwater management plan. It was built in phases on a hill of about a 3.5 percent slope. This slope, along with the volume of stormwater that runs through the neighborhood, causes major flooding issues. The flooding is exacerbated as the dominant hydrologic soil group of the area, D soil, is characterized by a high runoff potential and slow infiltration rate. In addition, the fast flowing, large volume of water from the top of the development and the storage facility located there cause erosion issues and perpetuate the downstream flooding.The culvert that outlets the water from Cree Manor under Station Road and into Crooked Creek was not designed to support the stormwater volume that the neighborhood produces. In addition, the culvert has some functional issues as its inlet is positioned too high above the discharging swale to allow more than a small trickle of water through. Because of this, water backs up at the bottom of the neighborhood causing flooding and perpetual wet soil. It is unclear how much of the flooding is caused by the stormwater runoff and culvert design issue and how much is due to the fact that the groundwater table is very high at the bottom of the development near Station Road, which could mean that groundwater makes its way to the surface. The sponsor for this project is the Walker Township Municipality. We are working closely with the Secretary, Julie, and township workers in sewer and wastewater, Bill and Kirk. The major issue at hand seems to be overall water volume and velocity. We will work to solve the flooding and erosion issues while balancing the limitations of the environment and keeping the homeowners in mind. A map of the site is shown below as Figure 1. Each of the major project components including the storage shed, natural swale, and culvert are labeled.

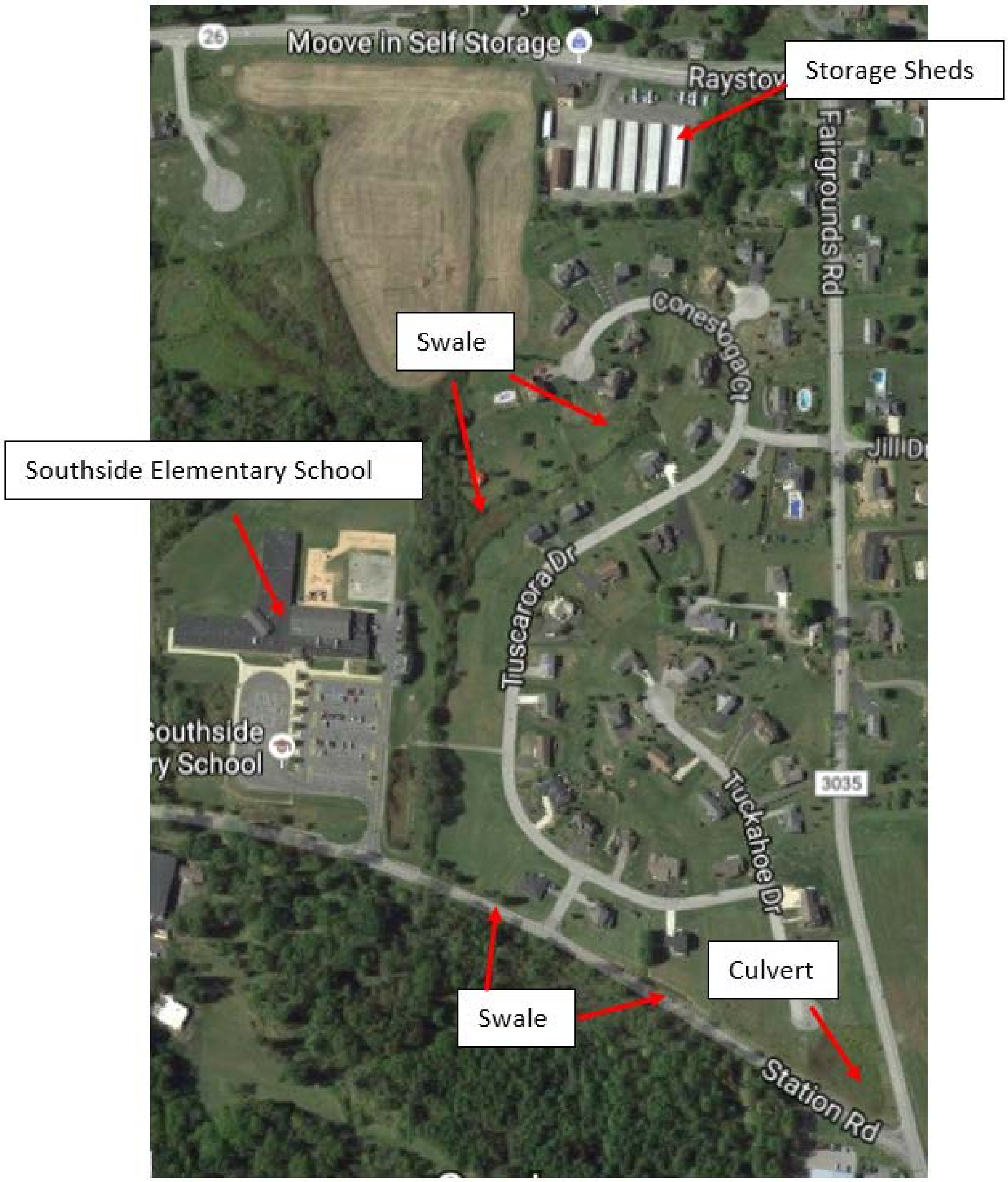

Figure 1: Google Earth image of Cree Manor

1.2 Objectives

The goal of this project is to provide Walker Township Municipality and the homeowners in Cree Manor a final design that ultimately reduces the volume of water flow and therefore, reduces flooding. The scope of this project will focus on three main objectives: to reduce the volume of water that enters the community from the storage site and Shenecoy Manor at the top of the development, to initiate flow in the swale along Station road and direct water to toward the culvert, and to subsequently reduce flooding in Cree Manor. Although the overall goal is volume reduction and flood management, there are several other variables that must be taken into account including cost, ease of implementation, and aesthetics. Different solutions such as infiltration, and various best management practices (BMPs) will be taken into consideration. Additionally, we will investigate the possibility of culvert resizing at Station Road to aid in flood relief. When choosing a solution to the flooding issue, we will largely base the decision on cost, durability and efficiency of water storage and removal of the design. While the primary goal is volume reduction, we will attempt to simultaneously slow the velocity of the water, reduce erosion, and treat the potentially contaminated stormwater before it enters the Chesapeake Bay Watershed system. The final design must also overcome the natural environmental and geological issues including poor soil type, and a high groundwater table.

2.0 Sponsor Needs Assessment

2.1 Gathering Input

On September 13, 2016, the team members of CREEation Station 4+09 met with Walker Township municipal employees to gather first-hand information pertaining to Cree Manor's stormwater and flooding issues. The team's first introduction to the layout of the neighborhood and the location of excess runoff was from studying Cree Manor's construction plans at the Walker Township municipal building. It was at this time that the team learned erosion and sediment control and stormwater management plans were not created during the neighborhood's construction because it was not yet a requirement by law. This lack of planning may have resulted in the waterlogged yards, eroded lawns and flooded streets among other Cree Manor complaints to the municipal office.

Walking the Cree Manor neighborhood and driving through the surrounding area, the team became familiar with the current conditions of stormwater management. Although previous attempts had been made to relocate the volume of runoff by means of conventional stormwater management systems, such as the addition of storm sewer drains, this process had had little effect on the low lying, ponding water.

The township employees believe the culvert at the bottom of the neighborhood is not currently sloping in the correct direction, nor sized for the appropriate volume of water. Upon studying the construction plans of the first section of Cree Manor development, the team agreed this may play a role in the neighborhood's stormwater issues. From observation and lack of documentation for the existing culvert in the neighborhood construction plan, the team concluded the culvert was designed to carry the runoff from Fairgrounds Rd. before surrounding land was developed. Concern about the volume of runoff due to the up gradient neighborhood, Shenecoy Manor, and storage facility were also noted by the team. The township employees hope that our work could help them convince a government agency to amend the existing culvert or assist financially with an improved stormwater management system.

To assure the team is addressing the most pertinent concerns of Cree Manor residents, it is important they have direct access to voice their runoff issues with the team members as well as the municipality. In October, *The Huntingdon Daily News* interviewed the team members and published an article about the project's current progress on diagnosing a solution to Cree Manor's stormwater management. At the end of the article an email address was provided for concerned parties.

2.2 Weighting of Customer Needs

Because there are many facets to stormwater management and the problems facing the residents of Cree Manor, Table 1, a pairwise comparison chart was used to determine the main scope of our project. As seen in Table 1, safety and aesthetics were found to be the least important aspects of the project once speaking with the township employees. Their input and knowledge of the residents' complaints convinced us of the overwhelming need to limit the volume of water currently moving through Cree Manor. For this reason, limiting volume was weighted higher than any other customer need.

Limiting volume was followed in importance by efficiency of water storage and removal, low cost and durability, respectively. A solution for this community will only be effective if it performs well over a long period of time, at little to no effort from the community. Disturbing a large area of ground within the community would place a financial burden on Huntingdon County. The designed solution hopes to avoid this by utilizing management practices with easy implementation and minimal earth disturbance. Although, there are more resident complaints about water volume, the team observed indications of erosion on the pre-existing channel, running through Cree Manor. As erosion would destroy the residents' property, as well as carry sediment downstream through the watershed, the team weighted velocity reduction above aesthetics and safety, but below the more pressing customer needs of volume limitation and cost.

Table 1. Pairwise Comparison Chart to Determine Weighting for Customer Needs as a Means to Determine Main Objectives and Goals for the Project Scope.

Customer Need	**Safe**	**Imp.**	**Dur.**	**Cost**	**Eff.**	**Vol.**	**Vel.**	**Aes..**	**Total**	**Weight**
Safe	1.00	0.50	0.33	0.50	0.33	0.33	0.33	2.00	5.32	0.060
Ease of Implementation	2.00	1.00	0.50	0.50	0.33	0.33	1.00	2.00	7.66	0.087
Durable	3.00	2.00	1.00	0.50	0.50	0.33	2.00	3.00	12.30	0.139
Low Cost	2.00	2.00	2.00	1.00	0.50	0.33	2.00	3.00	12.89	0.146
Efficient	3.00	3.00	2.00	2.00	1.00	0.50	2.00	3.00	16.50	0.187
Limit Volume	3.00	3.00	3.00	3.00	2.00	1.00	3.00	3.00	21.00	0.238
Reduce Velocity	3.00	1.00	0.50	0.50	0.50	0.33	1.00	0.50	7.33	0.083
Aesthetics	0.50	0.50	0.33	0.33	0.33	0.33	2.00	1.00	5.32	0.060

3.0 External Search

Much of the information that will be used in the design of this project was given to the group by the sponsor or was discovered while visiting the site. However, it is still very beneficial to do an outside search so that the group can bring in knowledge of what practices have worked in similar situations in the past. Much of the information below focuses on articles that describe solutions to stormwater problems that were implemented in various locations in the past. These detail what specific problems each practice solves and how well they worked. There are also several government documents that provide more useful information pertaining to the design and installation of Best Management Practices as well as legal guidelines with which our group will comply. Further details about each article may be found below.

3.1 Journal Articles

GIS Methods for Sustainable Stormwater Harvesting and Storage using Remote Sensing for Land Cover Data by Mahmoud et al. (2015) explains the usefulness of GIS in dealing with stormwater problems. It explains how land use, soil type, slope, and other factors play a role in the movement of water in a watershed. The GIS concepts explained in this article can be used to map the watershed in this project and give the group an idea as to where water travels in the development.

Effective Impervious Area for Runoff in Urban Watersheds by Ebrahimian et al. (2016) provides information about the impervious area in a watershed and describes not only why that factor is important but also how to calculate it. In the Cree Manor development, a large portion of the land is covered by impervious surfaces such as driveways, roads, and houses. The information provided by this article will allow the group to determine this area, which can then be used in runoff calculations.

Limitations to Vegetation Establishment and Growth in Biofiltration Swales by Mazer et al, (2001) details different types of plants that can be used to make bioswales more effective. It explains what types of plants are better in different circumstances and states that the more plants there are, the more effective the swale is. One problem with the Cree Manor stormwater system is that the natural bioswale is very ineffective. It is not a designed swale, so it functions as a very eroded, small (6 inches to 1 ft across) channelized "stream" (4-6 inches deep) that overflows its channel during storm events and floods the surrounding areas. The neighbors tend to mow their grass right up to this area. By fixing the channelization, designing an actual swale shape, and utilizing this article's recommendations for plant use and swale lining material, the hope is that the natural swale's function can be improved.

3.2 Industry Standards and Application Notes

The Pennsylvania Department of Environmental Protection website contains a Municipal Stormwater page which provides useful information on permitting and construction of stormwater management systems. This website contains information about Municipal Separate Storm Sewer System, or MS4 forms, and National Pollutant Discharge Elimination System, or NPDES permits, and other documentation that government organizations look at when they analyze stormwater systems. It is important that the group understand state and federal requirements so it may comply with them and create both an effective and legal design. These may be found on the MS4 and NPDES forms. Following these mandates may also help the group obtain funding to implement the design.

The Pennsylvania Best Management Practices (BMP) Manual, which may be found on the Stormwater PA website, is a document produced by the Pennsylvania state government. This document explains how stormwater management systems should be designed and installed and gives more insight on state stormwater design requirements. It primarily focuses on ways to decrease the volume of stormwater runoff and improve the quality of water entering the stream. This manual will be an important tool for the group as it attempts to come up with a design that will help landowners in the development without degrading land and water downstream.

Virginia Runoff Reduction Method Instructions and Documentation is a document published in 2011 by the Virginia Department of Environmental Quality. The primary focus of this article is a method of reducing runoff volume, which is one of the sponsor's most important needs. In addition, it contains equations and tables that are used in Virginia to design stormwater systems. The methodology and information detailed in this article will be useful as the group designs its own system.

3.3 Existing Products or Design Approaches

Grass swales are commonly used to reduce the velocity of water and allow water to infiltrate the soil. Grass swales are long open channels, usually located at the bottom of residential complexes or alongside highways. These grass channels are designed to collect water from the surrounding area and slowly redirect it away from roads and building. Figure 2 shows a grass swale located next to a road. Depending on the location, grass swales do not have to be major depressions in the ground. They just need to be constructed to slow the velocity of water and decrease the amount of discharge within the area. Information concerning the design of swales and rain gardens may be found in sections 6.4.5 and 6.4.8 of the Pennsylvania BMP Manual.

Figure 2: Example of a Grass swale
"Reducing Stormwater Runoff and Pollution through Low Impact Development."

For areas that have limited space, rain gardens are constructed to collect large amounts of water runoff. Rain gardens incorporate a variety of plants to absorb water runoff as seen in Figure 3. Water travels into a rain garden where it is slowed by vegetation and mulch. Since rain gardens are designed for water infiltration, the build-up of water allows vegetation to hold and consume a large amount of water runoff.

Figure 3: Example of a Large Rain Garden
("Pennsylvania Stormwater Best Management Practices Manual")

Dry detention ponds are used for areas that accumulate large amounts of water runoff. These are typically constructed near large buildings, residential developments (Figure 4), and commercial complexes. Detention ponds are built below the surface to retain water runoff. Once water collects into the detention pond, it is briefly stored in the detention pond. After a period of time, water will either infiltrate into the soil or be slowly released by an outlet structure. This prevents any flooding or damage to the environment.

Figure 4: Example of a Dry Detention Pond
("Detention Pond")

3.4 Other Sources

One of the biggest environmental issues concerning runoff that can be seen today is what is occurring in the Chesapeake Bay. Here, the public can witness the damage water runoff can do to the environment. The government does not want to increase this disaster, so that is why strict regulations and calculations must be done before constructing any type of stormwater management structure. Sewage treatment plants, industrial facilities, agricultural fields and lawns are all contributing factors for discarding large amounts of nitrogen and phosphorous into local streams and rivers. The excess nitrogen and phosphorus from the surrounding area is then transported directly into the bay. From an overabundance of nutrients, the water quality drastically decreases and aquatic life is killed.

The Pennsylvania state government has placed more requirements on how to manage the discharge of stormwater runoff. In the past, communities and business would discharge their water runoff into a local stream or river without thinking of any consequences. These practices have now created many environmental issues. As areas increased in population and impervious surfaces, major flooding, erosion, and pollution has affected the environment. Pennsylvania passed legislation to restrict the amount of water runoff and pollutants into streams and rivers. The Federal Clean Water Act, Pennsylvania's Clean Streams Law, the Pennsylvania Stormwater Management Act, and the Chesapeake Bay Total Maximum Daily Load (TMDL) are a few examples that protect the environment and regulate what discharge can be placed into streams and rivers.

In an attempt to abide by the aforementioned state and federal requirements, different calculations and tests must be done to correctly design a stormwater management facilities. Of course, since the development has already been built, these laws do not apply. Team CREEation Station 4+09 would like to attempt to abide by them and meet certain requirements though, as if Cree Manor were to be regulated as built today in 2016. The stormwater management facility must show the same post-development discharge, compared to the the pre-development discharge. This means the environment does not receive any extra outflow after construction. Runoff coefficients, slopes, and rainfall intensity are a few variables for the various equations and charts used to calculate water runoff. Equation 1 and Figure 5 illustrate the different variables used in calculating water runoff. See Appendix Section I, Subsection A for Figure 5, the rainfall intensity for a specific region located in Pennsylvania. Given a certain rain storm and its duration, the rainfall intensity value can be used in Equation 1 listed below.

Equation 1: Rational Method, $Q=CiA$

where Q=peak runoff rate (cfs)

C= runoff coefficient

i=rainfall Intensity(in/hr)

A=watershed area (ac)

4.0 Engineering Specifications

4.1 Establishing Target Specifications and Specification Analysis

In order to solve the Cree Manor stormwater issues, it is important to determine the target specifications that the design should meet. For example, it is imperative the runoff volume be reduced. Ideally, the peak volume should be equal to the peak volume before Cree Manor was built ("Pennsylvania Best Management Practices Manual"). The specifications are displayed below in Table 2 along with their limits and ranges.

Specifications were determined based on the customer needs assessment and the regulatory requirements for current construction. Sediment concentration values are based off of the DEP's classification of healthy limits in a stream, as are pollution values. Runoff rate limits and ideals ranges were chosen due to the results found from Section 8, Hydrologic Analysis. To add to the ease of design and maintenance, the area of the intended design will be kept below 5,000 square feet, in order to eliminate the Pa. Code Title 25 Chapter 102.4b required implementation and maintenance of an Erosion & Sediment Control Plan for the construction site ("Pennsylvania Stormwater Best Management Practices Manual."). Within the industry, it is generally accepted to design structures to hold runoff depths resulting from storms with a 10 year return period. The limits and ideal range of grant funding were defined by the average grant provided by the PA DEP Growing Greener Grant as explained in Section 7.1.

Table 2: Target Specifications

Specification	Limits of range	Ideal range or value	Units
Runoff Rate	78.56	78.56	cfs
Grant Funding	125,000	<125,000	dollars
PA Infiltration	2.67 (2-Yr Storm)	5.92 (50-Yr Storm)	in

Reduction of Pollution Concentration	<10	<1	ppm
Sediment Concentration	1500	500 to 1500	ppm
Risk of Failure	10	10 or 25	storm return period
Area of Disturbance	5,000	<5,000	ft2

4.2 Relating Specifications to Customer Needs

As discussed in the previous section, the final design must meet proposed specifications. The customer needs of safety, ease of implementation, durability, cost, efficiency, ability to limit volume, ability to reduce velocity, aesthetics, combined with the legal specifications of stormwater management, were integrated to make conscious design decisions for Cree Manor’s stormwater management plan.

To better understand the metrics or specifications associated with each customer need, and to gauge how it will be determined if the need was addressed, a need-metrics matrix was developed below as Table 3. For example, the area of disturbance for the design will directly impact the aesthetics of the final design and the ease of implementation. If the design is small, it will most likely be more aesthetically pleasing. However, if a large retention pond is built, the homeowners may not be happy. In addition, the smaller the design, the easier it should be to implement, and the less area it should need to disturb. Different metrics were considered for all of the needs and an evaluation was done to see how each of the metrics would demonstrate whether or not the customer need was met. All of these metrics and their influence on meeting customer needs will be taken into account when choosing and designing the final design solution to Cree Manor’s stormwater issues.

Table 3: Need-Metrics Matrix

Needs \ Metrics	Pollutant Concentration	Sediment Concentration	Grant Funding	Life expectancy of system	Runoff Volume	Area of Disturbance	PA Infiltration Requirement	Time of Concentration	Risk of Failure
Safety	x	x							x
Ease of Implementation						x			
Durability		x		x					
Cost			x						
Efficient					x		x	x	x
Limit Volume					x		x	x	
Reduce Velocity					x				
Aesthetics						x			

5.0 Concept Generation and Selection

5.1 Concept Generation

Several concepts were generated as potential solutions to the stormwater volume and flooding problem. Most of these solutions are types of best management practices (BMPs) that can be implemented. These BMPs can either be implemented in the Cree Manor development itself, or the development directly above it, Shenecoy Manor, as both developments contribute stormwater to the problem. Others suggestions are to redesign a natural swale that runs through the development as a vegetated swale and to redesign an existing culvert.

5.1.1 Concept 1: Wet Pond/Retention Basin

Wet Ponds or Wet Detention Ponds are stormwater basins with the purpose of temporary storage and peak rate mitigation, as well as pollutant removal. Although they are not particularly effective at reducing water volumes, they are effective for large rain storm instances. These structures include a substantial permanent pool for water quality treatment and additional storage capacity above the permanent pool for temporary runoff capture. These structures require forebays to trap sediment and prevent short circuiting. Another key aspect of wet detention ponds is that their goal is not to infiltrate water, but rather to detain it temporarily. Therefore, hydrologic soil groups “C” and “D” are most suitable. There should also be some level of permanent water in these ponds, allowing for sustained vegetation growth. According to Chapter 6 of the Pennsylvania Best Management Practices (BMP) Manual, at least 10 acres of the drainage area should drain to the pond. In addition, steps need to be taken to mitigate the potential for thermal pollution to nearby sensitive waterbodies as wet ponds tend to discharge warm water. As far as Cree Manor, this structure works well with the hydrologic soil group of the area. It also helps to mitigate the large peak flows that most likely cause most of the flooding of the area. Crooked Creek, the ultimate outfall of the development is designated as a warm water fishery so any discharge to it should not impact the aquatic life. See Appendix Section I Subsection B for Figure 6, a typical schematic of a wet detention pond, both in plan view and profile view.

5.1.2 Concept 2: Rain Garden/Bioretention

A rain garden, or bioretention bed is a structure used in both residential and commercial areas to treat and capture runoff. These are shallow depressions in the ground that are filled with a soil mixture designed to promote infiltration and improve water quality. Aesthetically pleasing native plants are then grown in the garden. According Chapter 6 of the PA BMP manual, they have a medium volume reduction capacity, a medium-low peak flow rate control capability, and discharge medium to high quality water. These structures would be well suited for reducing water volume either near homes or in larger, more open areas. A schematic of this structure can be seen below as Figure 7 .

Residents of Cree Manor have often complained about flooding in their yards or even basements. These structures have the ability to capture water from a wide area and infiltrate a large volume of it. Rain gardens that are planted near or between houses can be used to control where water ponds and where excess water is diverted to, which should solve many flooding problems, particularly those in basements. Unfortunately, this type of BMP would be built on residents’ land and would require their approval before construction can begin.

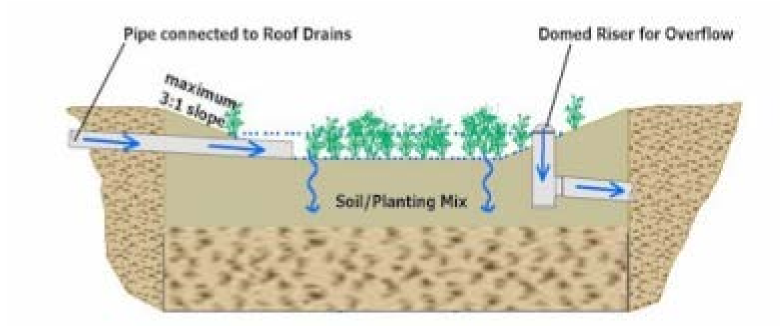

Figure 7: Rain Garden/Bioretention Schematic
("Pennsylvania Stormwater Best Management Practices Manual")

5.1.3 Concept 3: Culvert Pipe Redesign/Resizing

Township officials suggested that much of Cree Manor's flooding problems were due to the poorly designed culvert near the bottom of the development (Figure 8). This structure was implemented before any development was done and as a result it cannot effectively move the greater, post development water volume. This structure was built too high off the ground, causing water to back up and pool in nearby yards. Although it will not reduce volume, redesign may alleviate these issues and satisfy the township by helping transport water more efficiently.

Figure 8: Culvert at the Intersection of Station and Fairgrounds Road
Photo by Michael Henderson

5.1.4 Concept 4: Runoff Capture and Reuse

The term "runoff capture and reuse" is used to describe any of the possible ways to capture precipitation and then reuse it by another means of release. Determining the anticipated inflow and usage is required to create a balanced water budget analysis, ensuring water use and available capacity for capture after each precipitation event. Typical types of capturing units include cisterns, underground tanks, aboveground vertical storage tanks, and rain barrels. Home-owner maintained, rain barrels (Figure 9) are recommended for residential use to supplement garden irrigation, while large units, such as vertical storage tanks, are recommended for urban areas lacking substantial area for infiltration. Placing the capture and reuse unit up gradient of reuse area eliminates the need for pumps. Periodic tank and sump cleanout is required to maintain the efficiency of the storage system.

Runoff capture and reuse has high potential to limit the volume of runoff within the Cree Manor neighborhood. Currently, high volumes up-gradient of Rt. 26 are creating channelized flow through yards within Cree Manor. To be effective, the capture and reuse system would have to be implemented up gradient from the Cree Manor neighborhood in order to capture excess runoff and mediate its release over time. Unfortunately, this concept requires maximum resident involvement managing the water budget and maintaining the system periodically.

Figure 9: Possible rain barrel design with connection to roof runoff from rain gutter ("Pennsylvania Stormwater Best Management Practices Manual")

5.1.5 Concept 5: Infiltration Trench

Infiltration trenches are continuously perforated, or “leaky”, pipes surrounded by gravel with a level bottom. They are best suited to be used at a relatively flat section within a larger storm sewer system or as a part of a stormwater system for a small area. With a minimum of six inches of topsoil above the gravel, stormwater from a small storm event may be significantly reduced to the point of no runoff while large event stormwater volume is partially reduced through conveyance through the pipe. Infiltration trenches are always designed for positive overflow, in which an inlet at the lowest gradient is installed to directly enter the pipe.

By combining an infiltration trench with Cree Manor’s current storm sewer system parallel to Station Rd., troublesome slow moving water, caused by the lack of gradient, could be more quickly moved to the culvert. This water would still reap the benefits of infiltration after small events and residents would be satisfied by volume reduction after large events. This concept could be potentially limited by the hydrological soil group D soils within the majority of Cree Manor which has a limited capacity for infiltration. A schematic of an infiltration trench, Figure 10, can be found in Appendix Section I Subsection C.

5.1.6 Concept 6: Dry Extended Detention Basin

Dry extended detention basins are areas that temporarily store stormwater runoff. These basins are designed to collect as much water runoff as possible, then slowly release the water into a local stream or river. Outlet structures are designed to gradually allow water to drain out of the detention basin. This will control peak runoff rates, reducing the amount of flooding downstream. Dry basins are constructed where the elevation is the lowest. As the water runoff is being discharged, pollutants and larger particles have enough time to settle to the ground. Water will have a higher quality leaving the basin than it does entering. A schematic of a dry extended detention basin, Figure 11, can be found in Appendix Section I, Subsection D.

5.1.7 Concept 7: Vegetated Swale Design

Using vegetated swales will reduce the velocity of water runoff, promote infiltration, and decrease pollutants and sediments in the water. They are usually trapezoidal or parabolic shaped with the middle being filled with native vegetation. The vegetation selected in the swale should be drought and salt tolerant with pollutant removal capabilities. Below the vegetation, swales typically have at least 24 inches of permeable soil. In areas that do not have soil that can infiltrate water well, other design variations can be used. Once example is placing a drainage pipe under the soil with domed riders scattered throughout the length of the vegetated swale. This decreases the amount of water traveling along the surface while storing the rest underneath. Figure 12 is an example of a pipe under a vegetated swale. Water will travel in the swale and in the pipe below the surface.

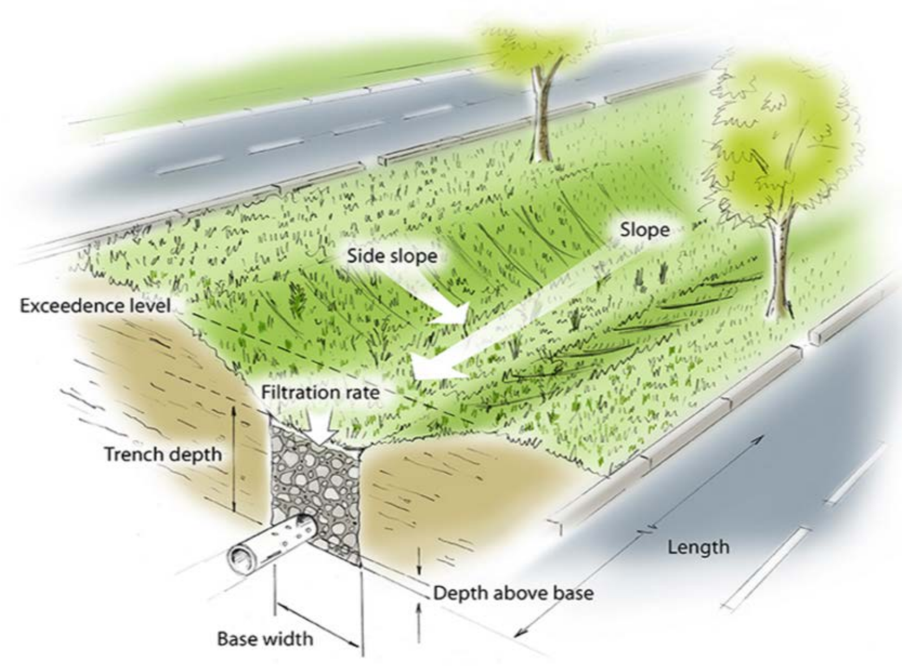

Figure 12 : Vegetated Swale

(*Swale - Xpdrainage 2016 Help Documentation - XP Solutions Resource Center*)

5.2 Concept Selection and Analysis

A Pugh Concept Scoring Chart was utilized to analyze each of the seven design concepts based on customer needs in reference to a particular design. In this case, the reference design was "repairing the existing culvert" because this is something that the sponsor had suggested they would like to be addressed. Each design concept was then rated on the customer needs as whether it would perform better or worse for that need than the reference concept. The results are shown below in Table 4.

Table 4. Pugh Concept Scoring Chart

		Concepts													
		1		2		3 (Ref)		4		5		6		7	
Selection Criteria	Weight	Rati ng	Wgtd. Score	Rating	Wgtd. Score	Rating	Wgtd. Score	Rating	Wgtd. Score	Rating	Wgtd. Score	Rating	Wgtd. Score	Rating	Wgtd. Score
Safe	0.060	2	0.12	3	0.18	3	0.18	5	0.3	3	0.18	2	0.12	3	0.18
Ease of Implementation	0.087	2	0.174	4	0.348	3	0.261	4	0.348	4	0.348	2	0.174	2	0.174
Durable	0.139	3	0.417	2	0.278	3	0.417	2	0.278	2	0.278	2	0.278	2	0.278
Low Cost	0.146	2	0.292	3	0.438	3	0.438	4	0.584	4	0.584	3	0.438	2	0.292
Efficient	0.187	5	0.935	4	0.748	3	0.561	4	0.748	4	0.748	4	0.748	4	0.748
Limit Volume	0.238	5	1.19	4	0.952	3	0.714	5	1.19	4	0.952	4	0.952	4	0.952
Reduce Velocity	0.083	4	0.332	4	0.332	3	0.249	4	0.332	4	0.332	4	0.332	4	0.332
Aesthetics	0.060	4	0.24	5	0.3	3	0.18	3	0.18	3	0.18	4	0.24	5	0.3
	Total Score		3.700		3.576		3.000		3.722		3.602		3.282		3.256
	Rank	2		4		7		1		3		5		6	
	Continue	Yes- Alt. Dsgn		Yes- Alt. Dsgn.		No		Yes-Prim. Dsgn		Yes- Alt. Dsgn		No		No	

Relative Performance	Rating
Much worse than reference	1
Worse than reference	2
Same as reference	3
Better than reference	4
Much better than reference	5

After analyzing the Pugh chart, it became evident that the township's suggestion of redesigning and re-sizing the culvert is expected to be the least effective concept for solving Cree Manor's stormwater problems.Redesigning the culvert does not achieve any of their greatest needs like limiting volume and reducing velocity when used singularly. Although the dry extended detention basin and vegetated swale are not durable or inexpensive, while do help limit volume. In addition, vegetated swales are most effective when used in areas with soils of low infiltration. Analyses on how well the volume is reduced, as well as other important factors may be found in the PA BMP manual and are briefly described in the concept descriptions above.

The Cree Manor development is in parts of three smaller watersheds, so it is important to note that what works in one watershed may not work in others. For example, resizing the culvert would only help the area that drains to the culvert, while building a wet pond below the storage facility would only help reduce volume downstream of that area. For this reason, multiple concepts will have to be used in different watersheds based on the land, the needs of the homeowners, desired runoff volume reduction, and what can realistically be done in each area. An example of this may be putting rain gardens or infiltration trenches near homes to reduce basement flooding but building larger structures like a wet pond in a more open area so that less of the homeowners' land is used.

6.0 Safety Analysis

For the purpose of analyzing the safety concerns for the concepts listed in Section 5, the concepts were broken down into three groups. The first group, consisting of concepts 4 and 3, rain barrels and culvert design, were found to be without any safety risks post installation and left off of Table 5, the hazard analysis for each desired concept group. The second group contains the concepts most likely to acquire stagnant water during their respective lifetime. The concepts within this group are number 2, rain gardens, 5, infiltration trenches, and 7, vegetated swales. The possible hazard associated with stagnant water is the potential for disease transfer due to mosquito populations. Although these concepts already have a relatively low risk of hazard, this will be further lowered due to the Pennsylvania Best Management Practice Manual's requirement that these structures completely drain within 48- 72 hours, the average time between storm events in Pennsylvania. The third and final group is comprised of concepts 1 and 6, wet pond/retention and dry extended basins. The singular safety hazard for this group is the possibility of injury due to steep embankment slopes. By adding fencing around these concepts, this safety hazard can be alleviated.

Through the hazard analysis within Table 5, it was found that the safety hazards associated with the concepts involving basins had a slightly higher hazard, than the concepts requiring more shallow earth work. The risks for all groups was found to be too slight to warrant the elimination of any concept due to its possible hazard.

Table 5: Hazard Analysis for Each Concept Group

Hazard	**Factors contributing to hazard**	**Effect/Injury Potential**	**Quantification**			
			Expo.	**Like.**	**Cons.**	**Total**
Stagnant Water	**Mosquitos**	**Transfer of Diseases**	**5**	**3**	**5**	**75**
Steep Slope	**Lack of Fencing**	**Falling Injury**	**9**	**3**	**3**	**81**

7.0 Special Topics

7.1 Budget Information

Often it is the cost of green infrastructure that limits its implementation. This observation was compounded by the sponsors within Walker Township who wish to solve Cree Manor's stormwater issues at a small cost due to limited funds within the township. For this reason, the Pennsylvania Stormwater Best Management Practices Manual was consulted to estimate the costs associated with each of the concepts' materials and installation as outlined in Section 5. Although there is not set budget, CREEation Station 4+09 hopes to implement designs applicable for federal and state grants promoting improved stormwater management to help alleviate the financial burden felt not only by Walker Township, but many other townships nationwide.

At a one time average cost of $150 per barrel for residential use and no paid maintenance costs, the rain barrel is the least expensive concept outlined in Section 5 as described by the Pennsylvania Stormwater Best Management Practices Manual. One negative of installing rain barrels within or upgradient from Cree Manor is life span. In addition, success is contingent on the cooperation of the land owners now responsible for the stormwater management maintenance.

Although dependent on design configuration, construction, and location costs, infiltration trenches, rain gardens, and vegetated swales are estimated to be the second most cost efficient concepts. As of 2003, an infiltration trench could be built from $4-$9 per cubic foot of storage with annual maintenance costs approximately 5-10% of the capital costs ("Pennsylvania Stormwater Best Management Practices Manual"). As of 2005, rain garden construction costs of $5-$7 per cubic foot of capacity were similar to the construction of an infiltration trench. Additionally, the net cost of a rain garden can be substantially lower than the construction cost as most rain gardens are placed in areas otherwise landscaped with maintenance intensive plantings and can lower the cost for a stormwater conveyance system ("Pennsylvania Stormwater Best Management Practices Manual"). Including the costs associated with the clearing, grubbing, leveling, filling and sodding of a vegetative swale, the Southeastern Wisconsin Regional Planning Commission estimated the cost of installing a vegetated swale to be $8.50 per linear foot. Swales' longer lifespan counteracts the increased costs due to annual operation and maintenance ("Pennsylvania Stormwater Best Management Practices Manual").

According to the Pennsylvania Stormwater Best Management Practices Manual, dry extended detention and wet pond retention basins are the most expensive concepts within Section 5. As of 1997, the typical construction cost of a dry extended detention basin was $41,600 for a single acre-foot pond. In 1999, a typical wet pond retention basin cost $25,000-$50,000 per acre-foot of storage and cost is dependent on the required earth work per basin. The listed costs do not include the cost of the property's loss of value.

7.2 Project Management

Project Team CREEation Station 4+09 consists of a talented group of individuals who each bring their own expertise to the table. There is no "leader" of the team, however, each team member is responsible for his or her own roles in the project. The group works off of checks and balances to ensure that the work is evenly divided and that it is completed in a timely fashion. More specifically the team roles are as follows.

Brittany Ayers serves as the team's public relations representative. She is the point of contact for the sponsor and advisors. She also relays information from sponsors and advisors to the rest of the team. Kaitlyn Morrow serves as the scribe. She records meeting minutes including team assignments and also updates and populates an online meeting minute notebook for all to see. Michael Henderson serves as the librarian. He populates the team's online file with documents such as data, design plans, and scanned copies of physical documentation. Finally, Zach Klueber serves as the team's historian. He finds and relays precedents to the group. He also documented all existing conditions on site.

The team works together to quantify, design, and find solutions to the problem at hand as each team member is capable of completing any of the tasks that arise. For example, each team member has done some work in GIS and VTPSUHM software to quantify the issue. Each member has also researched different design concepts. Some team members have more background knowledge in certain areas, but that knowledge is shared with the team and utilized to progress the project forward. Each Team Member's resume is listed in the Appendix as sections II-V. In addition, a Deliverables Agreement with the team's sponsor for deadlines and project goals can also be found in the Appendix as Section VI.

7.3 Risk Plan

Safety on a job site is the most important aspect during the design and construction phase. Precautions must be followed so workers are not injured. During the construction phase, many risks and safety problems can occur. Implementation is one example for when the probability of risks increase. One solution is to have an on-site engineer. An on-site engineer will answer questions and oversee the project. In order to improve the Cree Manor development, having an on-site engineer will provide more insight on a situation and provide valuable information regarding safety problems.

It is important to think about all types of risk and strategies to prevent them from occurring. Table 6 shows different risks, the actions to minimize the risk, and a fall back strategy. The risks our team thought of were Implementation Issues, Homeowner Dissatisfaction, Erosion and Sediment Loss and finally BMP Maintenance. Each risk is labeled on the severity and its separate fall back strategy.

Table 6: Risk Plan

Risk	Level	Actions to Minimize	Fall Back Strategy
Implementation Issues	Moderate	- make design plans specific to contract - constructing during spring and summer months -have an engineer periodically inspect the site	- have an on-site engineer during the entire process -change design plans to accommodate
Homeowner Dissatisfaction	High	-factor their needs into the design -minimize disruption to their property -communicate with homeowners before construction	-discuss funding and permitting issues with homeowners -explain the need and use of such projects
Erosion and Sediment Loss	Moderate	- constructing during spring and summer months - follow Erosion & Sediment Control (E & S)plans	-install additional E&S BMPs
BMP Maintenance	Low	-designate persons or agencies to maintain the BMPs installed	- have homeowners maintain the area

7.4 Ethics Statement

Team CREEation Station 4+09 is committed to completing this project with the utmost ethical standards and responsibilities. The team will comply with all state and federal regulations. In addition, the homeowners' best interest was held as one of the highest priorities during the concept and design process. Credit for ideas or solutions were given where credit was deserved. In addition, the Pennsylvania BMP Manual was referenced for all major decisions to ensure compliance in design parameters. We relied on professional codes of ethical conduct as described by the National Society of Professional Engineers (NSPE) in conjunction with our own moral standards and opinions. The NSPE code of ethics has seven main points: hold safety paramount, service with competence, issue true statements, act as a faithful agent, reputation by merit, uphold professional honor, and continue professional development ("Code of Ethics."). We worked to ensure that each of these seven points of the code of ethics was followed. This report represents our best work and honest factual findings.

7.5 Sustainability Ethics

Sustainability plays an integral role in all projects related to water management and natural resources. Based on guidelines provided by professionally recognized engineering organizations, we plan to adopt several sustainability ethics. We have abided by the National Association of Environmental Professionals (NAEP) to ensure that all design activities be carried out "in a scientifically objective manner." This means that we have reported true findings no matter what they may be. We also followed their guideline to "incorporate the best principles of the environmental sciences for the mitigation of environmental harm and enhancement of environmental quality." The design solutions proposed in this report will in no way, shape or form, harm the environment or disrupt its function. Additionally, we have made sure that our design plan is a long term fix and not a band-aid on a larger problem. The goal, as the World Federation of Engineering Organizations explains, is to "create and implement engineering solutions for a sustainable future." This means that if the design would solve the flooding issue by displacing the water to the nearby stream, we cannot ethically suggest it as a viable solution to the problem. Not only would it not solve the source of the problem, but it would cause direct harm to the water quality of Crooked Creek, pollution that could cause lasting effects. We evaluated every design possibility and made certain that the designs have no effects on the environment "downstream" of Cree Manor. We all live downstream and we do not want to push the problem on someone else. We also kept in mind, the societal and economic aspects of sustainability when designing our solution. This means that we worked to limit inconveniences on the residents and ensure their safety, while being mindful of the cost of the design and how the project will be funded.

All laws governed by the Pennsylvania Department of Environmental Protection (DEP) and the United States Environmental Protection Agency (EPA) were abided by throughout the duration of this project. Team CREEation Station 4+09 is committed to meeting all environmental standards. The team also followed all laws set forth by the Clean Water Act including the anti-degradation policy for Crooked Creek, which is a warm-water fishery.

7.5.1 Identify Sustainability Issues

In the Cree Manor project, there are some issues that directly relate to sustainability. Based on visual inspection and professional opinion, it was determined that the properties located north of the culvert are wet year round, have cattails and other wetland grasses growing in them, and are therefore, considered a wetland. This is further confirmed by the Environmental Protection Agency's (EPA) definition of a wetland "areas where water covers the soil, or is present either at or near the surface of the soil all year or for varying period of time during the year." Based on the fact that the land above the culvert and along station road is considered a wetland, little can be done to disrupt it. This may cause issues if the township were to attempt to fix the existing culvert where Station Rd. and Fairgrounds Rd. meet. Ethically, and by law, the wetland cannot be disturbed or removed without proper mitigation.

Another sustainability ethics issue that we have run into is the swale along the Station Road. It seems that the water table is very high in this area. So far, the best solution to make the swale direct water to the culvert is to re-grade and redesign it. This idea is not possible, however. If we start digging and hit groundwater, we cannot ethically, or with scientific conscious, continue to dig. This not only puts the integrity of the swale at risk, but could also open the groundwater table up to more outflow, and potentially even contaminate some of the groundwater. Therefore, based on our best engineering judgement, it was decided to leave the swale as is.

Another issue we have encountered is the idea of just moving the water elsewhere. Technically, it seems that this would work in favor of Cree Manor's water issue. It is not, however, ethical to do. Not only could it potentially cause pollution and contamination issues at the discharge point, but could also cause flooding and contamination issues for downstream neighbors. Another sustainability issue has to do with economic sustainability. The township does not have the funds to pay for whatever design we may suggest, but also does not want to have to tax residents to pay for it. We must find a way to fund the project. Sustainability ethics make the problem more interesting to solve, but ensure a design that will meet everyone's needs.

7.5.2 Implementing Sustainability in Design

To incorporate sustainability into the design, CREEation Station 4+09 has several design ideas, that collectively should solve the water issues in the development. Although not legally required, the team looked into reducing the peak runoff rates to pre-development conditions if possible, as it would be required if Cree Manor were to be constructed this year (2017) under PA Act 167 and the PA Stormwater Best Management Practices Manual. Ideally, the BMPs or design components chosen would be able to not only reduce the quantity of water flowing, but also improve quality of the water that flows to Crooked Creek. There is a limitation in Cree Manor, however, since its type-D soils do not lend well to water infiltration. This means that instead of reaching optimal pollutant reduction by infiltration through soil, reduction of water quantity may be the best method of improving the quality of water. Reducing the amount of stormwater runoff will reduce erosion rates and allow less sediment pollution to make its way to Crooked Creek as reduction is usually achieved through detention which allows sediment to settle out.

7.6 Communication and Coordination with Sponsor

Team CREEation Station 4+09 communicated via email with its sponsor once a week, sending a weekly update memo. In addition, the team met with the sponsor in person at least once during the semester. The schedule for Spring 2017 semester is as follows:

- Friday January 13th, 20th, 27th: Memo to Sponsor
- Friday February 3rd, 10th, 17th, 24th: Memo to Sponsor
- Friday March 3rd, 10th, 17th, 24th, 31st: Memo to Sponsor
- Tuesday April 4th: Meet with Sponsor to Discuss and Finalize Design
- Friday April 7th: Finalize Design
- Week of April 24th: Final Presentation

7.7. Timeline

Gantt charts are used to show when certain tasks should be completed by. This Gantt chart documents our anticipated progress throughout the spring semester. It is labeled as Figure 13 and can be found in the Appendix under Section I, Subsection E. Our first milestone for the project will be comparing the pre-development runoff to the post-development. Other milestones consist of BMP sizing, placing BMPs, and creating a final presentation. Smaller tasks to complete the milestones are represented in Table 7. Each member in the group will work together on completing each.

Table 7: Gantt Chart Tasks

	Task Name	Start	End	Duration (days)
*	Pre-Development Analysis and Comparison	1/9/2017	1/20/2017	11
	Delineate Watersheds Pre-development	1/9/2017	1/13/2017	4
	Delineate Watersheds Post-development	1/16/2017	1/20/2017	4
	Compare and Explain Changes	1/16/2017	1/20/2017	4
*	BMP Sizing and Design Calculations	1/23/2017	3/17/2017	53
	Choose the Size of all BMP’s	1/23/2017	2/3/2017	11
	Calculate Design and Impacts of BMP’s	2/6/2017	3/17/2017	39
	Compare Different Designs	3/13/2017	3/17/2017	4
*	Placing BMP’s	3/20/2017	3/31/2017	11
	Where BMP’s should be located	3/20/2017	3/24/2017	4
	Explain why the chosen location	3/27/2017	3/31/2017	4
*	Final Design and PowerPoint Presentation	4/3/2017	4/28/2017	25
	Finalize Design	4/3/2017	4/7/2017	4
	Create PowerPoint Slides	4/10/2017	4/14/2017	4
	Practice Presentation	4/17/2017	4/21/2017	4
	Presentation	4/24/2017	4/28/2017	4

* = Milestones

8.0 Detailed Design

8.1 Detailed Hydrologic Analysis

In order to create a stormwater management solution for Cree Manor, an in-depth hydrologic analysis had to be completed. To understand the water dynamic in the Cree Manor watershed, many hydrologic models and methods were used. The overall goal of this analysis was to determine the peak flow rates and maximum storm depths created in each delineated watershed for a 2-, 5-, 10-, 25-, 50-, and 100-year storm. To determine this information, the TR-55 Method was largely used. This method's input parameters consist of a weighted average curve number, area of watershed, precipitation data, and time of concentration. In order to find these parameters, several other methods were utilized. For example, the TR-55 SCS Segmental method was used to determine the time of concentration, and the Weighted Curve Number Method is largely utilized as method in the design of the TR-55 model. In order to find input values for each of these parametres, data was downloaded from Pennsylvania Spatial Data Access (PASDA) and National Oceanic and Atmospheric Association (NOAA) websites, and subsequent analyses were run via software programs in ArcGIS and VTPSUHM, explained below. The following section details what each software system was utilized for and how the determination and input of parameters into the TR-55 Model eventually output flow data.

8.1.1 ArcGIS

ArcGIS played a large role in understanding the dynamics of Cree Manor. According to ESRI, the parent company responsible for the ArcGIS software, "ArcGIS is a system for the management, analysis, and display of geographic information." Using a world imagery basemap, the Cree Manor development was located and PASDA topography files were added to the system to show the contours and slope in the neighborhood and surrounding areas. ArcGIS was also used to generate watersheds of interest based off of points of interest and the topography of the area. Within these watersheds, flow lines were added to the file by way of Dr. Cibin Raj using the Soil and Water Assessment Tool. These flow lines represent the route that stormwater runoff will take once it hits the ground surface. Overall, this software was utilized to determine the parameters of land use, slope, watershed boundaries, distance for time of concentration, and stormwater runoff flow lines.

8.1.1.1 Watershed Delineation

In order to quantify the amount of runoff that was in Cree Manor, it was first necessary to determine where water entering the development was originating from, and where it was being deposited. This was done by delineating watersheds in the development using ArcGIS. A digital elevation model, or DEM, of the area of interest was downloaded from the PASDA website. This DEM was then opened in ArcGIS. Using the tools in GIS, a flow direction raster was made from the DEM, and a flow accumulation raster was made from the flow direction raster. Then, the display of the flow direction raster was changed so that only the areas with the most flow, or streamlines, were displayed on the map. Next, outlet points were manually placed on the streams in the locations where they left the development; at the culvert near South Side Elementary School, and the culvert by at the intersection of Station Road and Fairgrounds Road. Then, the watersheds tool was used in ArcGIS to generate the boundaries of the watersheds, with the flow direction raster as the input, and the two points by the culverts as the outlet points. These watersheds were then modified slightly to account for flow patterns that the group observed while visiting the site. The watershed by the intersection was designated as Watershed 1, and the Watershed by the school was designated as Watershed 3. There was land in the development between Watersheds 1 and 3 that was not accounted for, but all this water drained to a different outlet point. This area became Watershed 2 by the process described above that was used to delineate Watersheds 1 and 3. The three watersheds can be seen below in Figure 14.

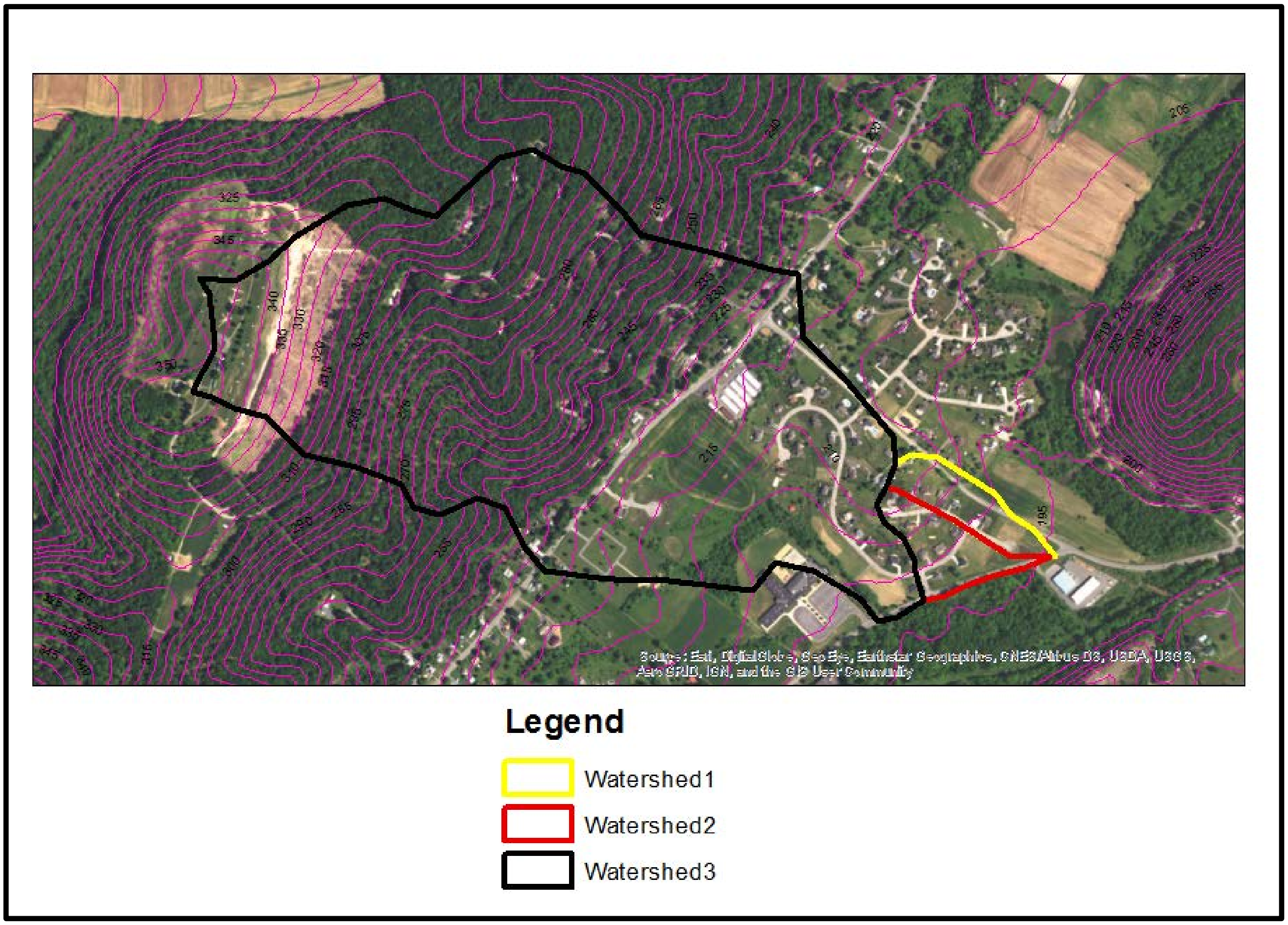

Figure 14: Watershed Boundaries of the Cree Manor Development

8.1.1.2 Evaluating Land Use and Soil Type

In order to eventually determine stormwater flow rates, the weighted curve number needed to be found. The two inputs for the weighted curve number are land use and soil type. Each soil type with a unique land use has its own unique curve number and these curve numbers are weighted by area to find the weighted curve number. The first step in finding the curve number was to use ArcGIS to evaluate land use and soil type. A soil map file of the area, which was taken from the Web Soil Survey site, was added to the ArcGIS file that contained the watershed boundaries. This file was then clipped to each watershed. The three clipped soil files were then further broken up by soil class; individual soil polygons for type A, B, C, and D soil were made for each watershed when applicable. Then a land useage file was downloaded from the PASDA website and clipped to each individual polygon. It can be seen below in Figure 15. By opening the attribute table for each of these clipped land uses, it was possible to find which percentage of each soil type in each watershed was a certain land use value.

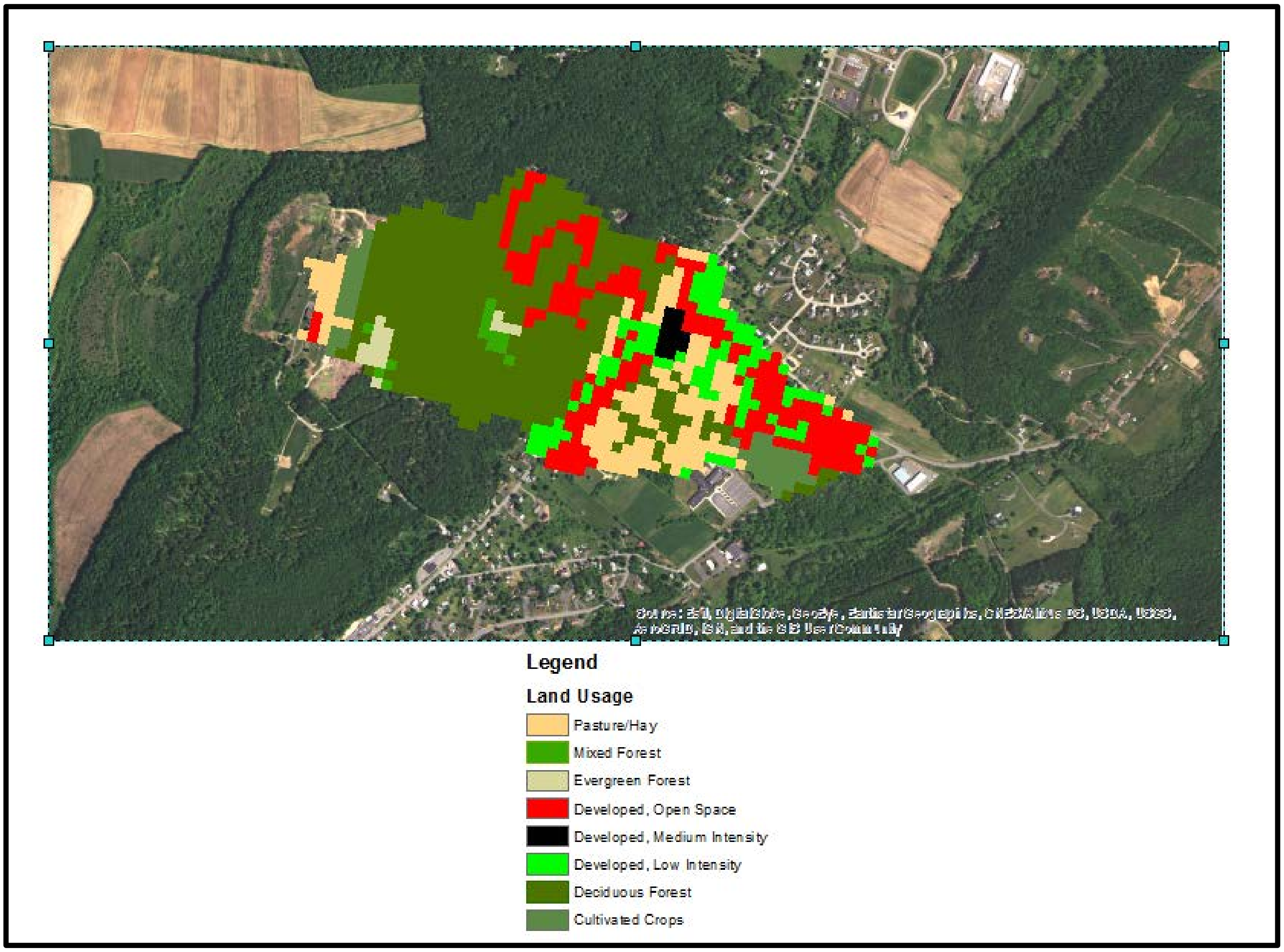

Figure 15: Land Uses in Cree Manor Watersheds

8.1.1.3 Computing the Weighted Curve Number

The land use values are described in an Excel document that comes with the land use file, and these descriptions in turn were then matched with the soil descriptions on page 87 of *Effectively Managing Water* by A.R Jarrett and R.C. Brandt. This table provides a curve number for each land use and soil type. Once these individual curve numbers were found, they could be multiplied by their respective percentages of the watersheds. This resulted in a curve number for each soil type in the watershed. These curve numbers were then multiplied by the percentage of the watershed that each soil type covered. This generated the overall post development weighted curve number for each watershed. To find the pre-development curve numbers, the same methods and soil types were used, except the group assumed that the land use above Raystown Road was all forest in good condition, and the land below Raystown road was all meadow in good condition. The resultant values may be found below in Table 8. CN values range between 0 and 100; the values found are within this range, so they are accurate and can be relied upon.

Table 8: Pre- and Post- Development Curve Numbers

	Area (ac)	Pre-Development CN	Post-Development CN
Watershed 1	6.47	78	80.96
Watershed 2	7.38	78	81.54
Watershed 3	204	45.09	49.26

8.1.1.4 Flow Line Delineation

Before designs concepts were generated, it was necessary to determine where water flows through the development once it hits the surface. This analysis served two purposes; it allowed subbasins to be delineated and it allowed the group to understand where water flows and where management structures could potentially be built. The team ended up delineating one subbasin, which included the storage shed area itself. The flowrates to this area were used to design solutions immediately below the property. Flow lines were generated via the Soil and Water Assessment Tool (SWAT) in ArcGIS. This was done by Dr. Cibin Raj, as he had software that the group did not have access to. These flow lines were added to the ArcGIS file, as shown below in Figure 16. The flow lines in this image are big sky blue colored.

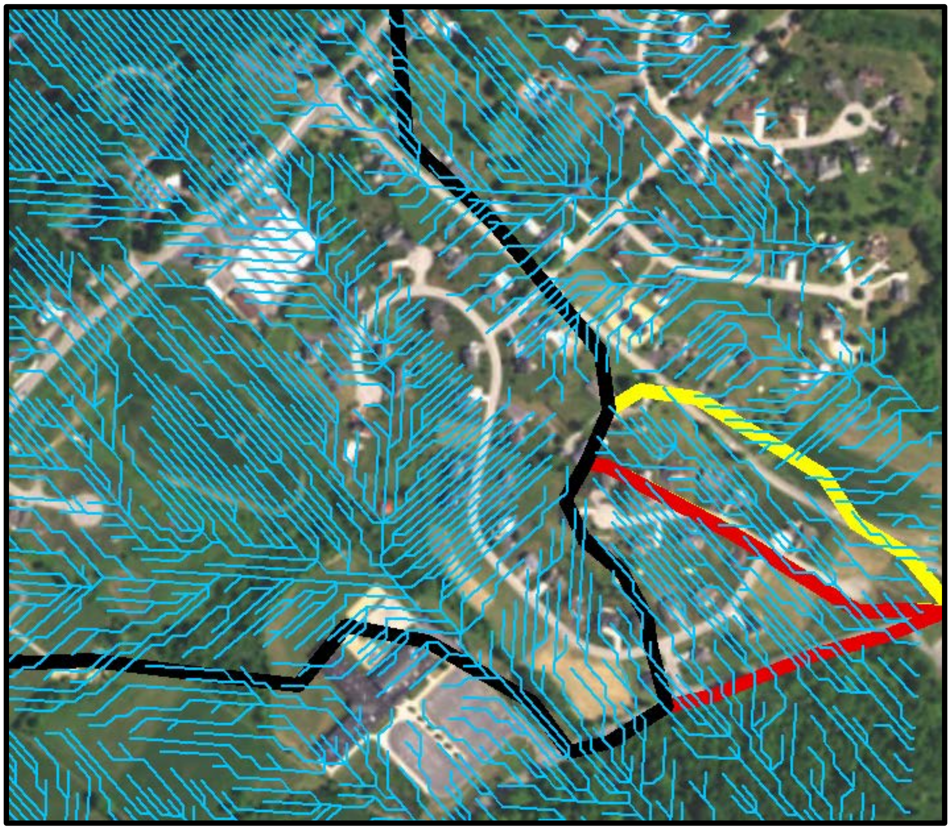

Figure 16. Dr. Cibin Raj's Flow Lines

8.1.2 VTPSUHM

The Virginia Tech, Penn State Urban Hydrology Modeling software (VTPSUHM), named for the universities at which it was developed, was utilized, as its name suggests, to model the urban hydrology of Cree Manor. This software program has TR-55 model computations built directly into it. The software was used to find time of concentration in each watershed, and to ultimately determine flow rates with its TR-55 function for each watershed via the model's three inputs: time of concentration, weighted curve number, and precipitation data. The following section describes these input parameters and the output values obtained via the TR-55 model. It is important to note that the rainfall data was taken from the NOAA website's rainfall intensity chart for a 24-hour storm in Huntingdon County, PA, and that the weighted CN values utilized are the same as shown in Table 8. The resulting flowrates from VTPSUHM"s execution of the TR-55 method will be used to determine the size of the stormwater BMPs that the group will propose to the township.

8.1.2.1 USDA Technical Reference 55 (TR-55)

In the USDA Technical Reference 55, *Urban Hydrology for Small Watersheds*, simplified procedures to predict the peak runoff rates as well as the total volume and depth of water for small watersheds are presented. The methods described, dubbed TR-55, require a variety of inputs from multiple sources such as precipitation, area of interest, weighted curve number, and time concentration. Two sets of data were analyzed for the three respective watersheds to determine possible changes in runoff; pre-development and post-development. The following sections depict the methods implemented to determine the necessary parameters for the TR-55 method and ultimately used to determine peak volume outputs.

8.1.2.2 Time of Concentration

The United States Department of Agriculture- Soil Conservation Service (USDA-SCS), known now as the Natural Resources Conservation Service, defines time of concentration as the time required for surface runoff water to travel from the watershed's most remote point to a point of interest (Jarrett and Brandt). For the Cree Manor project, the culvert at the bottom of the neighborhood was determined to be the point of interest for the three delineated watersheds. The SCS Segmental Method for determining time of concentration was chosen for Cree Manor's pre- and post-development topography as the Soil Conservation Service developed it to be used with the TR-55 runoff volume. This method defines the travel of water through a watershed as three types of flow; sheet flow, shallow concentrated flow, and channel flow.

Immediately following impact onto soil, runoff as it moves from the farthest location from the point of interest as sheet flow for the first 100 feet. Following the first 100 feet, the water is considered shallow concentrated flow. Water travels as shallow concentrated flow for the majority of its path, until converging into a channel described best by Manning's equation (Jarrett and Brandt). The addition of the calculated travel times for each type of flow creates the time of concentration for the watershed.

Determination of individual travel times for sheet, shallow concentrated, and channel flows were dependent on the respective parameters of each flow. Sheet flow was dictated by Manning's roughness coefficient for the study flow path, the length of the flow path (a maximum of 100' for VTPSUHM), the precipitation depth of a 2-year, 24 hour storm event in the given area, and the slope of the reach. The travel time of shallow concentrated flow was dependent on the length of the flow and the flow's velocity. Finally, if concentrated flow was found within the watershed, its travel time was found by defining the length of the flow, the Manning's roughness coefficient of the underlying channel, the hydraulic radius of the channel, and the slope of the channel. Using the developed ArcGIS file, the longest flowline path for a watershed was drawn into the respective watershed and measured using internal program measurement tools. To calculate the average slope for each flow's travel time, the change in elevation over the distance of the respective flow was divided by the flow's length.

Watershed 1 did not outlet at the specified point of interest, the culvert, and so a lag time was calculated to determine the length of time necessary for the runoff to move from the most remote boundary of watershed 1 across the channel parallel to Station Rd. and through the culvert. This was done using the SCS lag time calculation, defined by parameters of length of flow, the average slope of the length, and the potential maximum retention. The travel times for watersheds 1, 2, and 3 were found to be 10.05 minutes, 10.05 minutes, and 58.44 minutes respectively.

8.1.2.3 Peak Runoff Rate Outputs

Having found the parameters detailed in the above sections, the values were entered into the TR-55 Tabular Method table within VTPSUHM. The program then calculated the peak runoff value, runoff depths and corresponding hydrographs for the storm events listed in Tables 9-11 below.

Overall the depth of water after development did not increase significantly for the three watersheds, as seen in Tables 9-11. Watershed 1 and Watershed 2 did not illustrate a major change in depth, as the curve number, shown in Table 8, did not increase significantly after development due to the assumption of soil properties remaining constant throughout development. In this case, the type D soils, limited precipitation infiltration both predevelopment and post development. In Watershed 3, most of the water is infiltrated towards the top of the watershed due to the presence of type A soil in a wooded area. Runoff depth within Watershed 3 increased due to the increase in impervious surfaces added through land development. Although, peak runoff rates are not as high was previously expected within a developed area, these values will be used in designing BMPs and other water control structures.

Table 9: Watershed 1 Peak Volumes (Qpeak) and Depths

Area=6.47 ac	Pre Development		Post Development		
Storm Event	Depth (in)	Qpeak (cfs)	Depth (in)	Qpeak (cfs)	**Depth Change (in)**
2 year	0.88	3.33	1.04	8.02	0.16
5 year	1.34	5.27	1.54	12.11	0.20
10 year	1.74	7.07	1.97	15.71	0.23
25 year	2.36	9.84	2.62	21.13	0.26
50 year	2.91	12.35	3.19	25.79	0.28
100 year	3.51	15.04	3.81	30.82	0.30

Table 10: Watershed 2 Peak Volumes (Qpeak) and Depths

Area=7.83 ac	Pre Development		Post Development		
Storm Event	Depth (in)	Qpeak (cfs)	Depth (in)	Qpeak (cfs)	**Depth Change (in)**
2 year	0.88	4.04	1.04	10.01	0.16
5 year	1.34	6.38	1.54	15.04	0.20
10 year	1.74	8.55	1.97	19.44	0.23
25 year	2.36	11.91	2.62	26.05	0.26
50 year	2.91	14.95	3.19	31.69	0.28
100 year	3.51	18.20	3.81	37.80	0.30

Table 11: Watershed 3 Peak Volumes (Qpeak) and Depths

Area=204 ac	Pre Development		Post Development		
Storm Event	Depth (in)	Qpeak (cfs)	Depth (in)	Qpeak (cfs)	**Depth Change (in)**
2 year	0.00	0.15	0.03	1.6	0.03
5 year	0.06	2.54	0.13	6.73	0.07
10 year	0.14	6.41	0.26	13.16	0.12
25 year	0.32	14.55	0.50	30.68	0.18
50 year	0.52	26.3	0.75	54.96	0.23
100 year	0.78	45.32	1.05	87.66	0.27

8.1.3 Depth Validation with L-THIA

To validate the depth values found with the TR-55 method, the group used the Long Term Hydrologic Impact Analysis, or L-THIA program developed by Purdue University. This program allows the user to input each land use by soil type and area, which had been found in section 8.1.1.2. These could be designated as Current (Pre-Development) or Scenario 1 (Post-Development). This program was run assuming all forested land was forest at all times. For land that was developed, the descriptions from the file that comes with the land use raster that was used in ArcGIS were matched with the most appropriate land use types in L-THIA. This land was assumed to be grass/pasture before development. L-THIA then generated annual runoff volumes and depths once the input data were set. These results can be seen below in Table 12. These values confirm that the numbers found with the TR-55 method are realistic. The runoff depth in each watershed for each major storm are less than the the annual total depth, but over the period of a year the runoff would likely add up to a value close to the annual runoff depth. For this reason, the runoff depths and their associated peak flow rates can be relied upon in calculations.

Table 12: L-THIA Results

Watershed	Pre Development Annual Values		Post Development Annual Values	
	Volume (ac-ft)	Runoff Depth (in)	Volume (ac-ft)	Runoff Depth (in)
1	2.26	4.20	3.39	6.30
2	2.74	4.20	4.11	6.30
3	21.59	1.26	24.21	1.42

8.2 Design Selection Process

This project presented many design challenges and several factors played a role in determining the design of the solution to Cree Manor's water issues. In order to design a congruent solution for the Cree Manor neighborhood, it was necessary to have a complete understand of the challenges influencing design. Once information was gathered on the identified challenges, informed designs were created to mitigate the water issues within Cree Manor.

8.2.1 Design Challenges

There are two hydrologic factors that impacted the design selection process: soil drainage characteristics, and depth to groundwater table. It was brought to our attention by Teresa Smith, Huntingdon County resident and professional hydrogeologist, that the Cree Manor area has always been prone to water problems, "at least partly because it is part of the artesian groundwater discharge zone from Warrior's Ridge recharge area." This means that the water table around Cree Manor is very close to the surface, so close that in some places, groundwater is being pushed up to the surface. This is exacerbating the runoff issue of the development and causing some locations to be constantly wet year-round. In addition, as previously stated, the soil in Cree Manor is not conducive to infiltration, but rather, runoff. These soil and geologic characteristics compounded the runoff issue and limiting design choices.

To better understand the parts of the development that have a high groundwater table, and where the soil is poorly drained, the United States Department of Agriculture (USDA) Web Soil Survey was utilized. The soil map, below, Figure 17, shows the different soil types associated with different locations throughout the development. The subsequent Tables, 13,14, and 15, describe the depth to water table, hydrologic soil group, and drainage class for each of the soil types shown on the soil map.

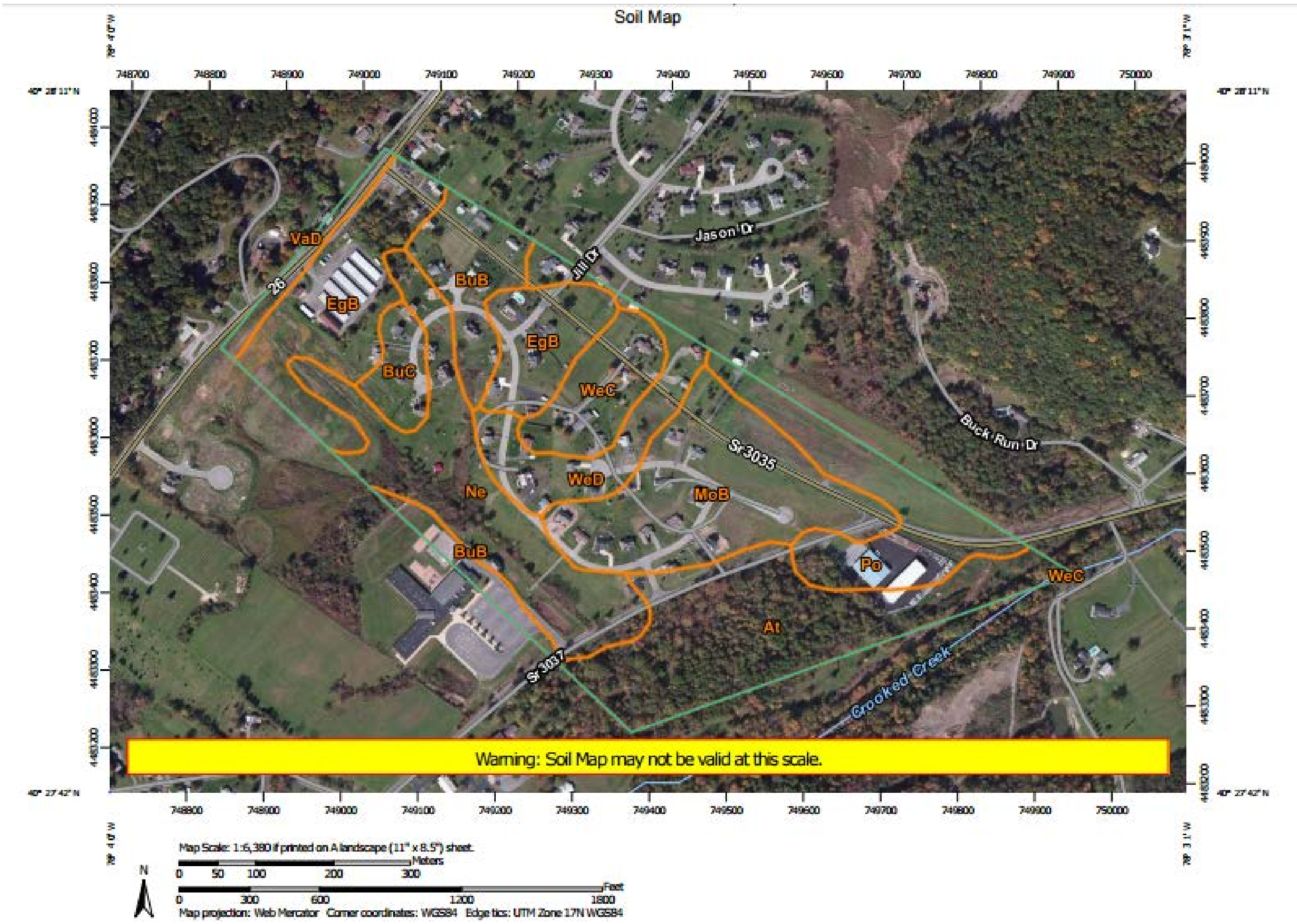

Figure 17: Soil Map of Cree Manor

Table 13: Depth to Water Table Summary

Depth to Water Table— Summary by Map Unit — Huntingdon County, Pennsylvania (PA061)				
Map unit symbol	**Map unit name**	**Rating (centimeters)**	**Acres in AOI**	**Percent of AOI**
At	Atkins silt loam	15	3.4	4.7%
BuB	Buchanan gravelly loam, 3 to 8 percent slopes	53	7.3	10.3%
BuC	Buchanan gravelly loam, 8 to 15 percent slopes	50	2.5	3.5%
EgB	Edom-Weikert complex, 3 to 8 percent slopes	>200	13.3	18.7%
MoB	Monongahela silt loam, 2 to 10 percent slopes	55	14.6	20.6%
Ne	Newark silt loam	31	13.7	19.3%
Po	Philo and Basher silt loams, high bottom	69	3.7	5.2%
VaD	Vanderlip loamy sand, 5 to 25 percent slopes	>200	1.6	2.3%
WeC	Weikert channery silt loam, 8 to 15 percent slopes	>200	4.9	6.8%
WeD	Weikert channery silt loam, 15 to 25 percent slopes	>200	6.1	8.6%
Totals for Area of Interest			**71.2**	**100.0%**

In the context of these results, "water table," according to the Web Soil Survey, refers to a saturated zone in the soil. The estimations on the table above are "representative values" based on observations of the water table at selected sites with the known soil type. The results of Table 13 make it evident why the swale along Station Road, State Route 3037 on the map, is constantly wet. It is classified as Atkins silt loam and has a depth to water table of only 15 centimeters, or 6 inches. In fact, the whole lower section of the development has an average depth to water table of 45 centimeters, or 1.5 feet. This could potentially cause issues with regrading or reconstructing the swale it would only be possible to dig to a depth of 1.5 feet. Because of this, the idea of regrading the swale was excluded as a design consideration.

According to the USDA, the soils in the United States are assigned to four hydrologic soil class groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). They define Group A soils as having a high infiltration rate and low runoff potential, and being composed of excessively drained sands or gravelly sands. Type B soils are defined as having a moderate infiltration rate and consist of soils that have moderately fine texture to moderately coarse texture. Group C soils are described as having a slow infiltration rate and consist primarily of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. Finally, Group D soils are defined as soils having a very slow infiltration rate and high runoff potential, and consist primarily of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. The USDA also explains that if a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes, meaning all dual class soils can be assumed to have characteristics of type D soil. Table 14 below, shows the different hydrologic soil groups for each soil on the soil map (Web Soil Survey).

Table 14: Hydrologic Soil Classes

Hydrologic Soil Group— Summary by Map Unit — Huntingdon County, Pennsylvania (PA061)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
At	Atkins silt loam	B/D	16.5	18.0%
BuB	Buchanan gravelly loam, 3 to 8 percent slopes	D	7.3	7.9%
BuC	Buchanan gravelly loam, 8 to 15 percent slopes	C/D	2.5	2.7%
EgB	Edom-Weikert complex, 3 to 8 percent slopes	B	14.7	16.1%
MoB	Monongahela silt loam, 2 to 10 percent slopes	C/D	14.6	16.0%
Ne	Newark silt loam	B/D	14.0	15.3%
Po	Philo and Basher silt loams, high bottom	B/D	8.9	9.7%
VaD	Vanderlip loamy sand, 5 to 25 percent slopes	A	1.6	1.7%
WeC	Weikert channery silt loam, 8 to 15 percent slopes	D	4.9	5.3%
WeD	Weikert channery silt loam, 15 to 25 percent slopes	D	6.6	7.2%
Totals for Area of Interest			**91.6**	**100.0%**

In addition, Table 15, below, reiterates the already known fact that predominantly type D hydrologic soil group soils of Cree Manor are, poorly, or only moderately well drained. This characteristic of type D soils is most evident in the sections of Cree Manor experiencing the most water ponding issues, mainly along along Station Road to the outlet culvert at the intersection of Station Rd. and Fairgrounds Rd. These USGS maps and tables assisted in the design stage, as

CREEation Station 4+09 was able to to navigate the area and assess where to appropriately place specific design options.

Table 15: Drainage Classes

Drainage Class— Summary by Map Unit — Huntingdon County, Pennsylvania (PA061)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
At	Atkins silt loam	Poorly drained	3.4	4.7%
BuB	Buchanan gravelly loam, 3 to 8 percent slopes	Moderately well drained	7.3	10.3%
BuC	Buchanan gravelly loam, 8 to 15 percent slopes	Moderately well drained	2.5	3.5%
EgB	Edom-Weikert complex, 3 to 8 percent slopes	Well drained	13.3	18.7%
MoB	Monongahela silt loam, 2 to 10 percent slopes	Moderately well drained	14.6	20.6%
Ne	Newark silt loam	Somewhat poorly drained	13.7	19.3%
Po	Philo and Basher silt loams, high bottom	Moderately well drained	3.7	5.2%
VaD	Vanderlip loamy sand, 5 to 25 percent slopes	Well drained	1.6	2.3%
WeC	Weikert channery silt loam, 8 to 15 percent slopes	Somewhat excessively drained	4.9	6.8%
WeD	Weikert channery silt loam, 15 to 25 percent slopes	Somewhat excessively drained	6.1	8.6%
Totals for Area of Interest			**71.2**	**100.0%**

In addition to the type D soils and high groundwater table, there were also some other challenges that the design team faced while designing a solution to Cree Manor’s water issues. In addition to the high groundwater table, as discussed earlier, it was also discovered that the area sits on top of an artesian groundwater discharge zone. This means that not only is the groundwater table high, but the water is actually coming up out of the ground and saturating the surface. Additionally, the wetland area above the culvert created some challenges. We cannot disrupt the wetland, or remove any of it. Instead, we are going to try to work with the wetland, construct it, and use it as a best management practice for stormwater management. The issues with this could be getting permitting to do so. Additionally, if the culvert is to be re-designed and constructed, it could potentially disrupt the wetland. This doesn’t mean that the culvert can’t be fixed, however, it does require an extra step. A permit for temporary disruption of a wetland is likely necessary from the Pennsylvania Department of

Environmental Protection (DEP). The final issue with the current stormwater design in Cree Manor is the swale along Station Road. The water that enters the piped drainage system throughout the neighborhood is discharged into property number 28. The water is then supposed to flow from there, along the swale of Station road, and to the culvert at the intersection of Station and Fairgrounds roads. Based on surveying by Team CREEation Station 4+09, the slope of the swale is only approximately 1%. This means that the land is very flat and that the water is not actually flowing in the swale. There may be some flow, but this water is sitting there and ponding, never making its way to the culvert. This likely means that the biggest issue with the culvert is that water is not getting to it. The best thing to do would be to re-grade the swale to convey the water. However, as previously mentioned the water table in that area is too high for digging into the ground and re-grading.

8.2.2 Eliminated Design Concepts

After discussing the areas with the most flooding, different design concepts for implementing into Cree Manor were suggested. The concepts that were eliminated and its reasons are shown in Table 16. Since Cree Manor has a high water table, seen in Table 13, and Class D soils made it challenging to select the most effective BMP's. Any type of BMP that uses infiltration, such as the infiltration trench, was eliminated due to the Class D soils. Other BMP's that were too costly or required permits were also eliminated to save the township money. Finally, BMP's that homeowners would not approve or dislike were also eliminated from the design process.

Table 16: Eliminated Design Concepts

Concept	Reason for Elimination
Infiltration Trench	● Depth to groundwater table might flood the trench ● Water will not infiltrate into the soils surface
Regrade Swale along Station Road	● Wetland cannot be disturbed without a permit ● Area is only 0.8 feet to water table
Rain Barrels	● Constant management by Homeowners to release water collected
Retention Pond immediately below Storage Units	● Expense and unnecessary with completion of other concepts ● Homeowners will lose some of their land
Install Piping to Crooked Creek	● Very expensive

8.2.3 Selected Design Concepts

Due to the complexity of the water issues Cree Manor faces, several stormwater management designs were created to work together to alleviate specific aspects of Cree Manor's challenges. The four designs include two choices of vegetated swale, a stream restoration of the "natural swale," pipe diversion and wet pond, and an evaluation and re-design of the culvert at the corner of Station and Fairground Roads. Figure 18 shows the relationship of the four designs' locations. For best results, it is recommended that all four of the designs be implemented, but in the interest of cost, the designs can be separated into two groups; vegetated swale and stream restoration or pipe diversion, wet pond, and culvert re-design.

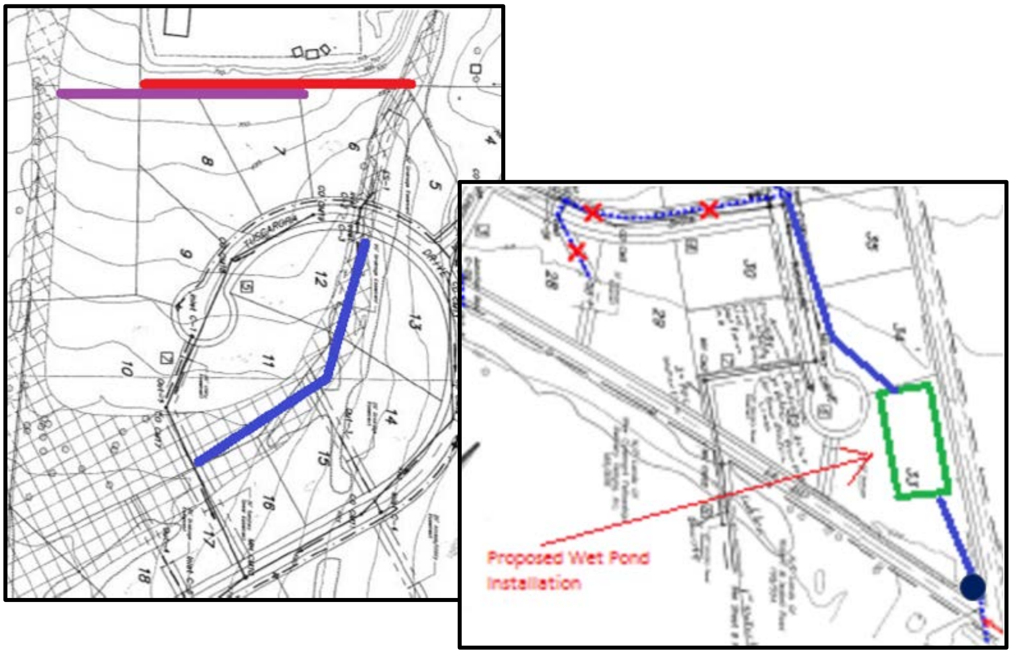

Figure 18: (Left) Illustration of vegetated swale (red or purple) and stream restoration of the "natural swale" (blue). (Right) Illustration of proposed pipe diversion (blue), wet pond (green) and culvert (black).

8.2.3.1 Vegetated Swale

A major stormwater issue in Cree Manor, as described by Walker Township, is surface water runoff from the Storage sheds at the top of the development. The runoff from this area causes water issues in housing lots 7 and 8. For reference, the housing plan map with lot numbers can be found in Appendix VII. In order to alleviate this issue, we are recommended a vegetated swale to convey the water from the storage sheds to the natural swale that runs through the development. There are two options for this swale, as can be seen in Figure 18.

Vegetated swales, according to the Pennsylvania BMP Manual, are broad, shallow channels designed to slow runoff, attenuate and convey stormwater runoff, promote infiltration, and filter pollutants and sediments (PA BMP Manual). They are aesthetically pleasing and easily integrated into a natural landscape. Figure 19, below, shows a suggested vegetated swale cross section as per the PA BMP Manual.

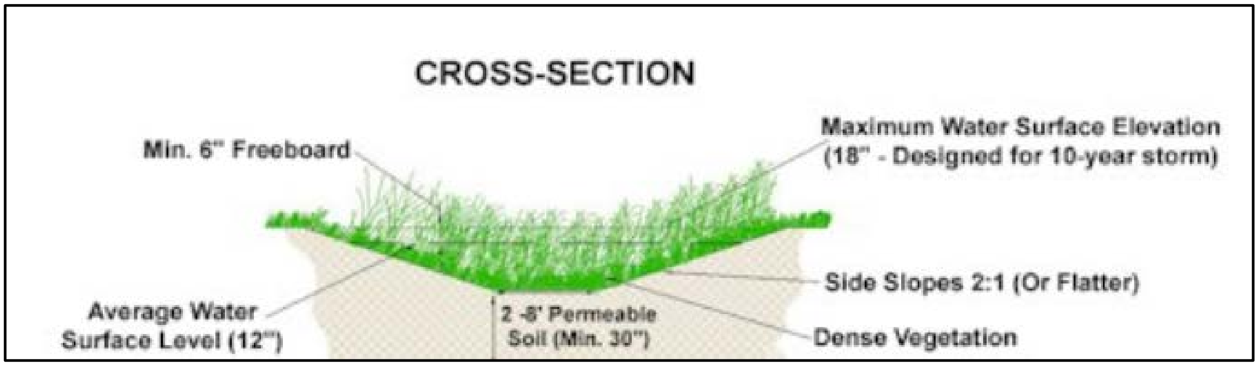

Figure 19: Suggested Cross Section of Vegetated Swale as per PA BMP Manual

It is suggested that each vegetated swale be underlain with 24 inches of permeable soil. Despite the fact that Cree Manor is dominated by type-D soils, the area directly below the storage shed is characterized by type-B soils, which allow infiltration. Each vegetated swale is also designed with a maximum water ponding depth of 18 inches at the discharge point, and an average ponding depth of 12 inches during storm events. They are also designed to be densely planted with shrubs and grasses to promote infiltration, filter pollutants, and consume excess water. The main purpose of a vegetated swale is to temporarily store and infiltrate the 1-inch storm event, while also providing conveyance for up to the 10-year storm with 6 inches of freeboard, without causing erosion (PA BMP Manual). For vegetated swale design purposes, a sub-watershed encompassing the storage shed was delineated, and its values were run through VTPSUHM to find a peak flowrate for design. This subwatershed has an area of 1 acre, a curve number of 91, and a 10-year storm peak flowrate of 4.52 cfs. This means that 4.52 cfs of water is flowing off of the storage sheds and onto the back yards of the residents. As the Pennsylvania BMP manual suggests designing for a 10-year storm peak flow, this value of 4.52 cfs was used.

Taking all of these design considerations into mind, two different vegetated swale options were calculated and designed. The runoff from the right-hand side of the storage sheds naturally flows to the existing natural swale, which then runs through the development. The water from the left-hand side of the storage shed property, however, is what is causing the majority of the issues in lots 7 and 8. Additionally, the natural swale takes two paths through the development. It exists between Cree Manor and the nearby elementary school, but also crosses through lots 11-14, as shown in Figure 18, above. Both of these paths eventually join together behind housing lots 19 and 20. We recommend either having a vegetated swale that captures all of the water and conveys it to the natural swale via the existing natural swale on the right-hand side of the storage shed, or installing a swale that captures the water from the left hand side of the swale and directs it to the natural swale located to the left of the development, between Cree Manor and the elementary school. This would mean that there is no structure installed to convey the water from the right half of the storage sheds, and flow there would continue as it is now. It is worth noting, that upon visual inspection, there was a great deal of sediment movement in this part of the natural swale. Each of the swale designs is described in more detail, below. While there are differences in the design, they each have the same dimensions, as shown below in Figure 20, and summarized in Table 17.

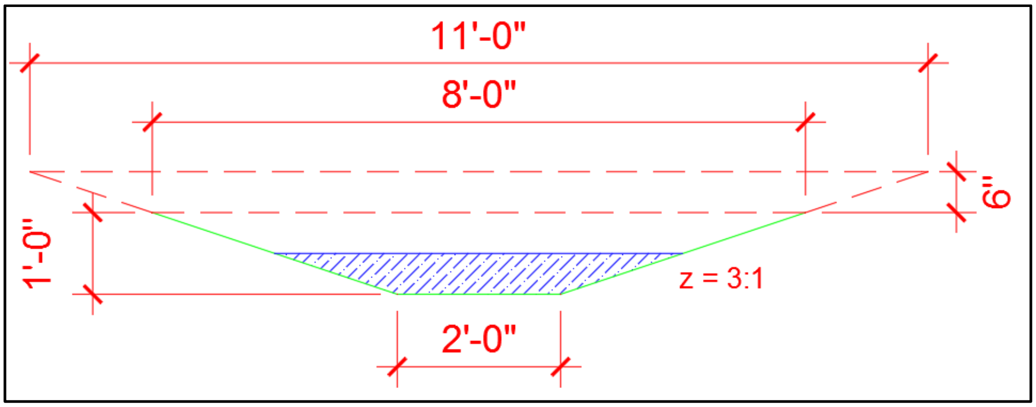

Figure 20: Vegetated Swale Dimensions

Table17: Design Specification of Vegetated Swale

Length	360 or 425 ft.
Vegetation	Switchgrass, Bluegrass, Aster
Allowable Flowrate	22 cfs
10-Year Storm Peak Flowrate	4.52 cfs
Conveyance	10-Year Storm
Longitudinal Slope	2.77% or 2.82%

Each swale option, regardless of direction, was designed with the same dimensions. The swale was minimized to be as small as possible. The PA BMP manual requires a bottom width of 2-8ft. With a bottom width of 2 feet, a water depth of 1 foot, and a side slope of 3:1 feet, it was determined that there is a cross sectional area of 5 square feet in which the water may flow. Recall that this is the smallest design possible given the PA BMP regulations. Additionally, based on these dimensions and calculations from *Effectively Managing Water,* the top width of the swale was determined to be 11 feet, given 6 inches of freeboard. Each swale was also assumed to have a Manning's Roughness coefficient of 0.04 (Jarett, n.a.).

The only major differences between the two swale designs are swale length, longitudinal slope, and direction of flow. The swale to the left has a length of 360 ft, while the swale to the right has a length of 425 ft. The only reason for difference in swale length is length of water conveyance needed from the storage shed to either side of the natural swale. Longitudinal slope is dependent upon the location in the development, the change in elevation from one end of the swale to the other, and the length of the swale. The longitudinal slope for the swale directed to the left is 2.77%, while the longitudinal slope of the swale directed to the right is 2.82%. As both slopes are less than 3%, check dams were not needed to further slow the velocity of the water.

Additionally, given the design flowrate of 4.52 cfs for a 10-year storm, it was determined that for the swale to the left, a cross-sectional area of 1 square feet is needed with a flow velocity of 4.4 cfs. The swale to the right requires a cross sectional area of 1.018 square feet and a flow velocity of 4.44 fps. Recall that the designed swale has a cross sectional area of 5 square feet. It also has a maximum permissible velocity of 7 fps. As both designed swales have areas and velocities less than 5 square feet and 7 fps, respectively, these designed swales are more than capable of handling and conveying a 10-year storm without producing significant erosion. Additionally, the swales are capable of handling approximately 22 cfs of water, well above the 5-year storm flowrate.

Finally, it is suggested that switchgrass, bluegrass and sedge aster be planted as vegetation in the designed swale. The BMP Manual shares that the vegetation needs to be low-growing, native, water resistant, drought and salt tolerant. Switchgrass is a drought tolerant native grass, often used in stormwater BMP designs. It has deep, clump-forming root systems that act as a natural check dam in swales to promote soil infiltration and reduce velocity and erosion potential of runoff water (Fleming, n.a.). Bluegrass serves much the same purpose as switchgrass, but introduces a different species to the swale ecosystem. Additionally, sedge aster is another common plant species utilized in stormwater BMP designs. They produce pretty purple flowers, not only making the swale aesthetically pleasing, but attracting a variety of colorful birds, butterflies and insects, and integrating the swale into the natural landscape.

It is also recommended that there is slight soil remediation. The soil below the storage shed is Edom-Weikert complex soil. It is approximately 0-8 inches of silty clay loam with approximately 8-38 inches of silty clay soil underneath it (USGS Web Soil Survey). The BMP Manual specifies that approximately 12 inches of loamy or sandy soils is needed as an infiltration medium. Therefore, slight soil remediation to increase macropore size and reduce clay content is recommended.

While both swale solutions work, there are slight pros and cons to each. We would, however, recommend the swale to the right. While the swale directed to the right may cost slightly more, as it is longer, and cost for vegetated swales tends to be per linear foot, it is also addressing the water issues from the entire storage shed. A swale directed to the left will only manage half of the flow from the storage sheds. Additionally, a swale to the left may cause increased stormwater issues at the outlet of the natural swale across Station Road near the McConnellstown Church of Nazarene, an issue out of the scope of Cree Manor, but unethical if issues were to arise. It could also cause more sedimentation and erosion of the natural swale near the school, an area where erosion is already evident. A swale to the right may make more hydrological sense as it is not changing the natural flow direction of water. Most of the storage shed already flows to the right, and often best management practices are designed to fit into natural topography and flow direction, not go against it. The swale to the right will also slightly increase the volume and flowrate of water that flow through the natural swale of the development through a storm event. This means that there would be a slightly larger flowrate of water through the natural swale in the back yards of homeowners in lots 11-16. Therefore, it is suggested below that the natural swale be re-designed as well.

8.2.3.2 “Stream Restoration” of Natural Swale

Regardless of the possible influx of water due to the addition of the vegetated below the storage units, the natural swale running through lots 11-16 is not currently equipped to convey storm events. Its current state of channelization is causing bank erosion and movement of sediment, resulting in clogged outlets and higher maintenance costs for Walker Township. Because the United States Geological Survey (USGS) defines a stream as a “watercourse” and defines a watercourse as a “channel or conveyance of surface water having defined bed and banks, whether natural or artificial, with perennial or intermittent flow,” CREEation Station 4+09 recommends a restoring the natural swale as if it were a stream (025 Pa Code & 105.1).

The first sign of erosion within the natural swale is the imbalance of actual and allowable water velocity. The current Manning’s velocity flowing through the natural swale for a 10-year design storm was found to be greater than the allowable velocity for stream beds comprised of silt loam soil (Table 18). This means that the stormwater’s horizontal forces are greater than the bed’s ability to keep sediment particles in place. The natural swale was also found to be suffering from erosion by studying its dimension, cross section, and related parameters, bankfull depth, entrenchment ratio, and width/depth ratio, as described by *Elements of Stream Restoration*. Figure 21 below illustrates the swale’s approximate cross section at maximum bankfull depth, when modeling the stream as a parabolic shaped channel. Table 18 includes the parameters determined from studying the sit’s current conditions. Because surveying of the area surrounding the natural swale was not conducted, to limit intrusion into residents’ property, the current entrenchment ratio could not be calculated. Regardless, the low width to depth ratio of 0.7 indicates “a great deal of energy to move [particles],” (A.R. Jarrett, n. a.).

Table 18: Current natural swale dimensions and related parameters modeled as a parabolic channel

Length	650 ft.
Longitudinal Slope	4.62%
Manning’s Roughness Coefficient	0.039
Cross-sectional area	0.33 ft2
Wetted Perimeter	1.67 ft
Hydraulic Radius	0.20 ft
Manning’s Velocity	2.80 ft/s
Maximum Velocity based on silt loam bed	2.0 ft/s
Bankfull Depth (dbkf)	0.5 ft
Bankfull width at bankfull depth (Wbkf)	0.7 ft
Maximum Bankfull Depth (Dmbkf)	1.0 ft
Entrenchment Ratio	N.A.
Width to Depth Ratio (Wbkf/ Dmbkf)	0.7

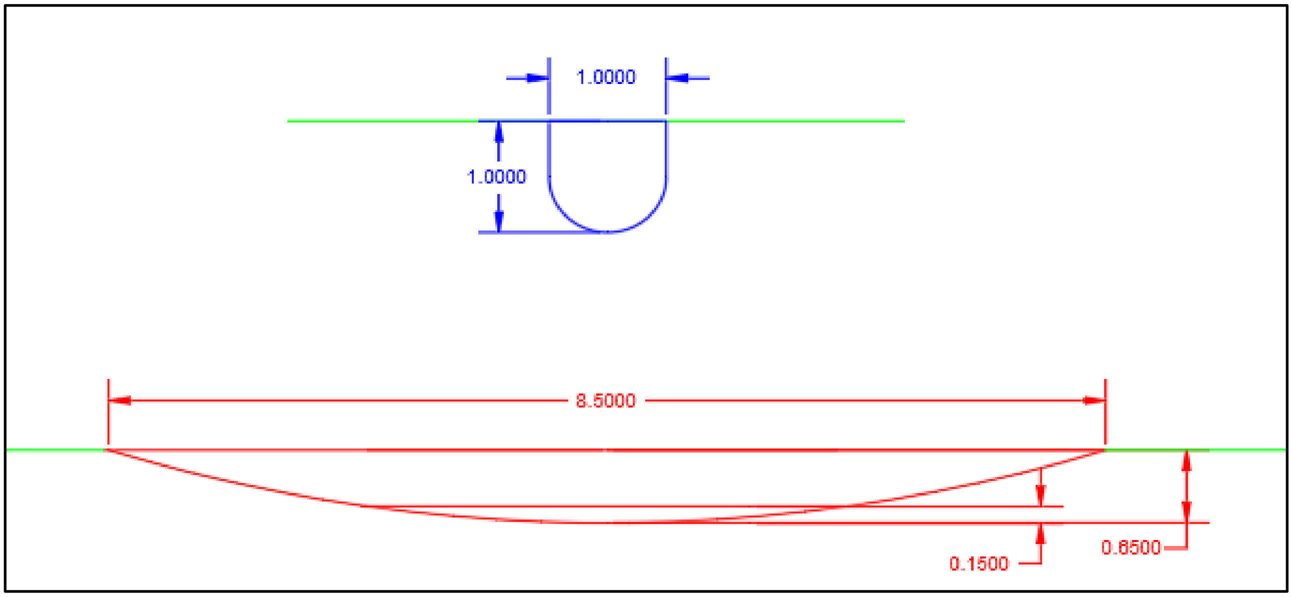

Figure 21: Current Swale (blue) and Stream Restoration (red) Dimensions

In order to design a natural swale channel that would not only convey the current runoff volumes, but the additional runoff from the proposed vegetated swale design, the flowrates resulting from a 10 year storm for the area of interest were found (Table 19). It was assumed that some of the runoff created in the upper portion of Cree Manor would be captured by street drains, and thus only the runoff captured by the channel and lots 11-16 were included in the area of interest. By dividing the 10-year storm flowrate by the maximum allowable velocity for bed's consisting of silt loam soil (A.R. Jarrett, n. a.) the maximum cross sectional area was found. This area was then used to determine the necessary design dimensions of the channel (Figure 21). The width of the channel was maximized and the depth minimized in order to increase the width to depth ratio (Table 19). In doing so, the natural swale would have a more stable, or moderate, ratio (A.R. Jarrett, n.a.).

To limit costs and inconvenience to residents, the proposed natural swale profile was kept similar to its current state. It is also recommended that the residents refrain from mowing their lawns within 5.0 ft of the width at maximum bankfull depth for the 10 year design storm (Table 19). Although this will limit use of a small portion of their lawns, use of a riparian buffer will greatly increase water quality through the neighborhood. By creating a physical barrier with tall grass or plants, sediment is stripted from surface runoff flowing from lawns into the natural swale.

Table 19: Design Specification of Stream Restoration

Length	650 ft.
Longitudinal Slope	4.62%
Manning's Roughness Coefficient	0.039
Allowable Velocity for silt loam bed	2.00 ft/s
Conveyance	10-Year Storm
10-Year Storm Peak Flowrate	1.50 cfs
Cross-sectional area	0.40 ft2
Wetted Perimeter	4.02 ft
Hydraulic Radius	0.01 ft
Manning's Velocity	1.76 ft/s
Maximum Bankfull Depth (Dmbkf) for a 10 year Storm	0.15 ft
Bankfull width at bankfull depth (Wbkf)	4.00 ft
Width to Depth Ratio	26.67

8.2.3.3 Pipe Diversion and Wet Pond

Some of the flooding located along Station Road is due to the development's piping system. Part of Cree Manor's piping system first collects water through an inlet located at the edge of lots 40 and 44. Water is then redirected around lots 46 and 47, where it discharges between lots 28 and 29. Once the water is discharged, it travels parallel to Station Road towards lot 33, where the water finally exits the development via culvert. Rather than the water runoff traveling through multiple pipes in different directions, a different pathway for water runoff followed by a wet pond can be implemented to reduce ponding and potentially increase the land value for the surrounding area.

There is already a pipe system located at the edge of lots 34 and 35. Instead of directing the water around lot 46, water will travel through the pipes near lots 34 and 35 so it can be discharged in lot 33. Lot 33 will then have a designed wet pond for water to be temporarily stored. Once these pipes are placed, the next process will be to create a wet pond.

As stated before, wet ponds are stormwater basins with the purpose of temporary storage and peak rate mitigation, as well as pollutant removal. Designing a wet pond requires a variety of constraints. The PA BMP Manual describes all constraints in detail for a wet pond and should be followed accordingly. In Table 20, highlights the most crucial constraints when designing the wet pond.

Table 20: Contains for Designing a Wet Pond

Constraint	Description
Drainage Area	Should have a drainage area of at least 10 acres
Size of Wet Pond	The area of the Wet Pond is generally 1 to 3 percent of its drainage area
Length to Width ratio	length to width ratio of at least 2:1
Average Depth	An average depth of 3 to 6 feet and a maximum depth of 8 feet
Side Slopes	Slopes in and around Wet Ponds should be 4:1 to 5:1
Location	The Wet Pond should not be constructed within 10 feet from the property line or 50 feet from a private well or septic system

The drainage area for Cree Manor's designed wet pond is about 14 acres. This area is the total area of watershed 1 and 2. Combined, the watersheds are above the minimum drainage of 10 acres meaning a wet pond can be implemented. The size of the wet pond was chosen to be 3% of its drainage area with a length to width ratio of 2:1. Having a higher percentage of the drainage area, the wet pond would be able to retain more water that flows through the development. Since Cree Manor has a higher water table, the depth of the wet pond needed to be as close to the surface as possible. This will prevent water coming from the ground and into the wet pond. The wet pond should have the maximum volume to store water during a rain event.

After all of contains were met, the next process was to dimension the wet pond. Lot 33 was our chosen location since it sits at the bottom of the development and the new piping system would lead into the wet pond. Calculating the total drainage area and seeing what ratio would fit into lot 33, a length to width ratio of 2:1 was selected. These parameters can be found in Table 21.

Table 21: Parameters of the Designed Wet Pond

Parameters	Values	Units
Top Width	97	ft
Base Width	73	ft
Length	193	ft
Depth	3	ft
Slope	2 to 1	ft

Using these parameters, the wet pond will be able to retain about 570,000 gallons of water. Figure 22 shows a representation of the overall size the wet pond would be. This aerial view was done by projecting a section of the property map onto ArcGIS. From there, a shapefile was created with the length and width of the wet pond. From Figure 22, the wet pond is able to fit in lot 33. It is positioned at a safe enough distance from lot 34 and Fairgrounds Road, meeting the wet pond constraints. Figure 23, shows a simple 3D representation of the wet pond's overall shape.

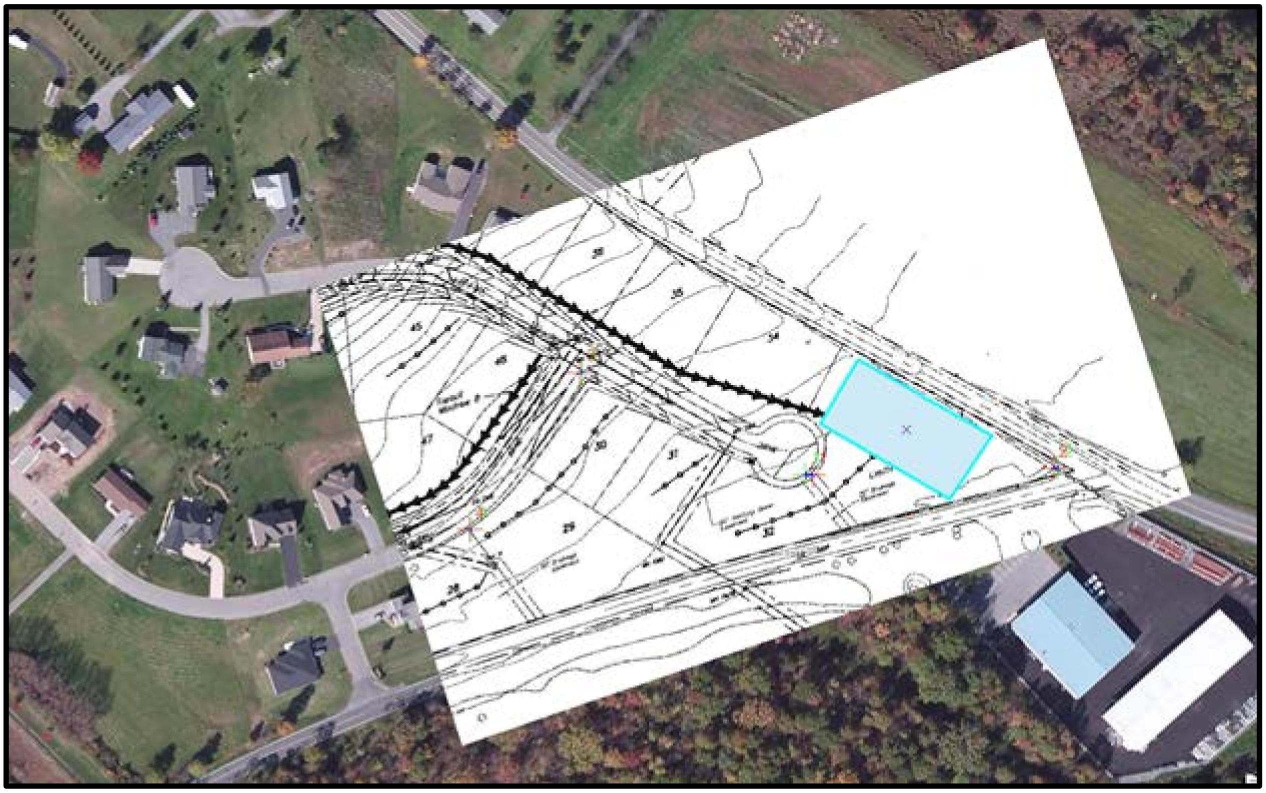

Figure 22: Aerial View of Wet Pond

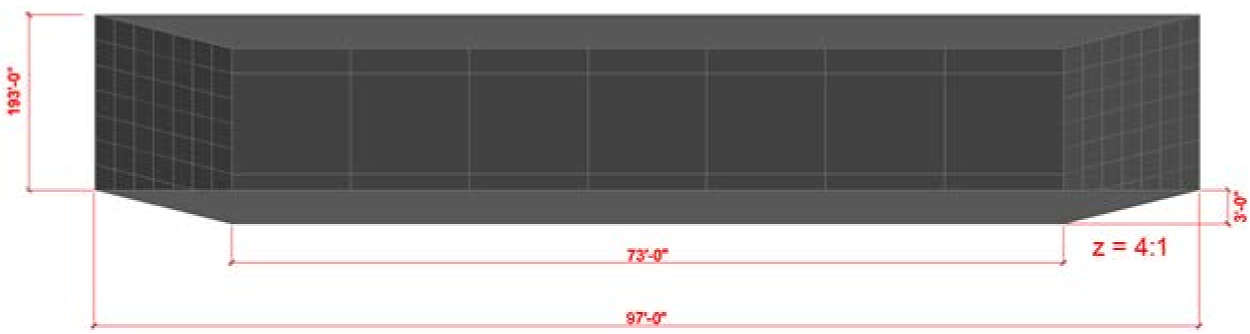

Figure 23: 3D Model of Designed Wet Pond Overall Shape

Wet ponds require certain types of vegetation based on the location's hardness zone and hydrologic zone. These zones, along with descriptions of vegetation, can be found in the PA BMP manual, Appendix B. Vegetation will enhance pollutant removal, limit the amount of erosion, and reduce algal growth. Some examples of suitable vegetation for the wet pond would be Cinnamon Ferns, Milkweed, and Carex stricta grass. Carex stricta grasses are able to withstand being either partially submerged or fully submerged. These grasses would be planted throughout the base of the wet pond in case of a high volume rain storm. Cinnamon Ferns and Milkweed on the other hand can only be partially submerged. The Cinnamon Ferns and Milkweed will be planted along the edges, keeping the wet pond durable.

8.2.3.4 Culvert Evaluation and Re-Design

Walker Township hypothesized that one way to solve the flooding issues at the lowest point of the development was to redesign the culvert. The culvert needed to be 120 feet long in order to transport water under Station Road, and, because the slope of the existing culvert was unknown, the team proposed that the redesigned culvert would have a slope of 2% in order to control the velocity of water exiting the pipe. The team designed a culvert that could handle a 25 year, 24 hour storm using the stormwater management model, or SWMM software, provided by the EPA. This culvert is made of a 2 ft diameter corrugated plastic pipe, a cheap material with a high roughness coefficient of n= 0.015 (Jarrett, n.a.) These design specifications are consistent with the parameters of the existing culvert. Inputs that were used to set up the SWMM file are shown in Table 22 below. The SWMM file itself can be seen in Figure 24.

Table 22. SWMM File Inputs

Parameter	**Value**
Total Runoff Depth for design storm	4.58 inches
Contributing area	14.3 acres
Width of overland flow path	1601.5 ft
Percent slope	1.44
% Impervious	27.65
% Zero Impervious	22.3
N-Imperv	0.055
N-perv	0.1
Dstore-imperv	0.05 ft
Dstore-perv	0.15 ft

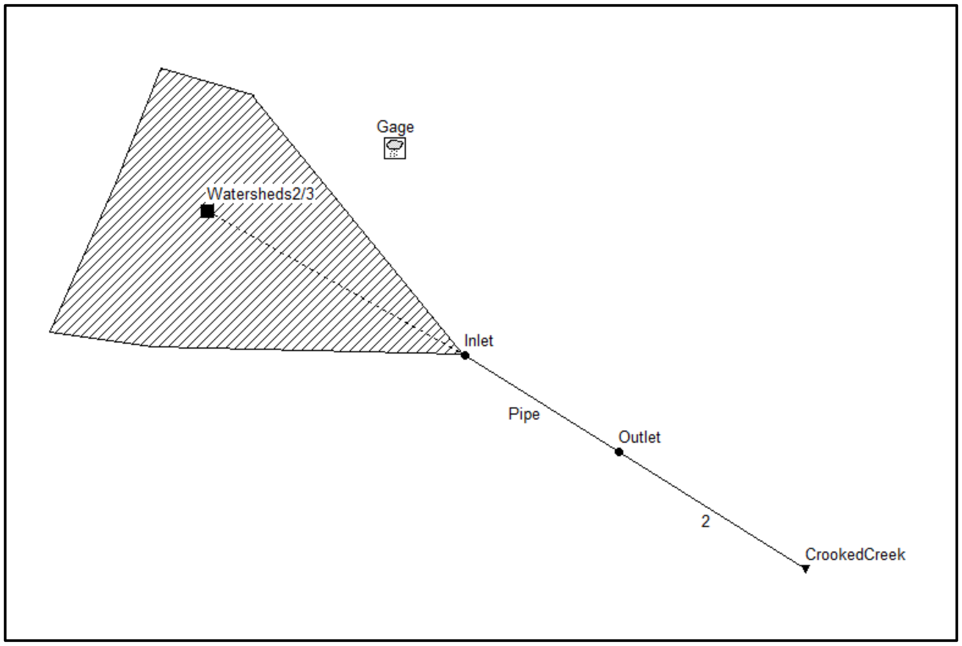

Figure 24: SWMM Project Map

The culvert is designed to manage water from watersheds 2 and 3, which have a combined area of 14.3 ac. The longest flow path, or width, is 1601.5 ft, which was measured using ArcGIS; the percent slope was found the same way. ArcGIS was also used to draw polygons and calculate the total impervious area in the development. Of the total impervious area, only the houses and road were truly totally impervious, with no storage, and the % zero impervious was calculated by dividing the area of the houses by the total impervious area. The N-values were found in *Effectively Managing Water* by Jarrett and Brandt. The depth of storage is the average depth of storage in both the pervious and impervious area, which was found in the SWMM manual. After all theses parameters were put into SWMM, the cross sectional view of the culvert pipe itself could be viewed in Figure 25. Because the existing slope and pipe length were unknown the group estimated the length to be 120 feet by measuring it in ArcGIS. Furthermore, the group assumed a gradual slope of 2%. This pipe was tested with a cumulative 25 year, 24 hour storm, and the inlet flooded for about 15 minutes of the simulation. This is a relatively negligible amount of time, and it proves that the redesigned culvert can reliably transport all the water generated by this and smaller storms. This proves that the existing culvert is large enough to drain the roadside channels near the intersection of Station and Fairgrounds Road, although it needs to be lowered so that the water effluent from the wet pond is able to make its way into the culvert to flow. Currently, the swale sits too high above the ground; water ponds near the culvert and doesn't all flow through. If the inlet of the culvert pipe is at the bottom of the ditch, as seen in figure 25, almost all of the water will be drained out of the ditch. It is necessary to drain the water through the culvert because infiltration cannot be relied upon to drain the ditch due to the high water table and Type D soils in the area. These results prove that a redesigned culvert can alleviate ponding issues at the inlet to the culvert, however this solution will not have much effect on the rest of the ponding and flooding issues in the lower lots of Cree Manor.

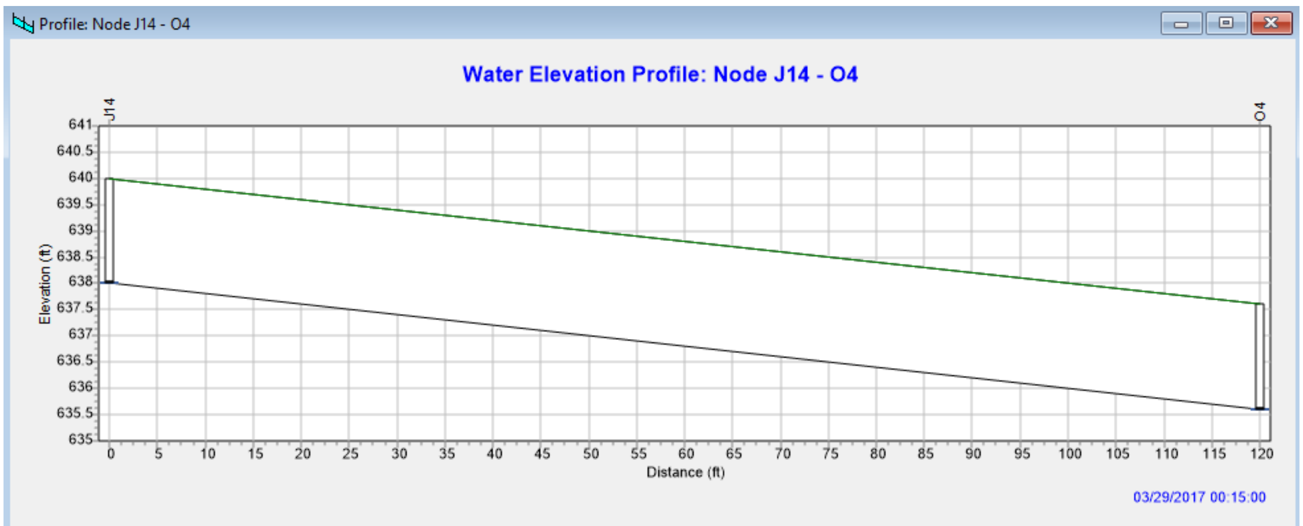

Figure 25. Cross Sectional View of the Redesigned Culvert

8.3 Testing Procedure

Modeling softwares, Storm Water Management Model (SWMM) and Hydrologic Engineering Center- Hydrologic Modeling System (HEC-HMS), were implemented to test our engineering designs and to determine the role of groundwater within the stormwater system, respectively.

8.3.1 SWMM Evaluation

The team wanted to use another program to ensure that its proposed designs would successfully remove water from the development. It was determined that SWMM was the best program to use to validate the team's designs. In the SWMM simulation, Cree Manor was broken down into 19 smaller watersheds or subcatchments in areas of interest around the development. The existing and ditch networks, as well as the stream, were added to the program, which can be seen in Figure 26. Finally, the designs for the vegetative swale, modified culvert, and stream were added to the file so they could be tested. The wet pond was not tested because SWMM is designed to analyze water transport, not detainment structures. The various properties of each of these subcatchments were found by analyzing utility maps or ArcGIS. Two major assumptions made as part of this analysis. Firstly, it was assumed that the impervious area in the forested area uphill of Cree Manor could be negated. Secondly, it was assumed that the initial amount of water in the natural stream and the pipe and ditch network was also negligible. These assumptions were made to make calculations simpler, and should not greatly affect the simulation results. As this evaluation was done as a project for a different class, further detail on the SWMM calculations may be found in the *BE 477 Final Report.*

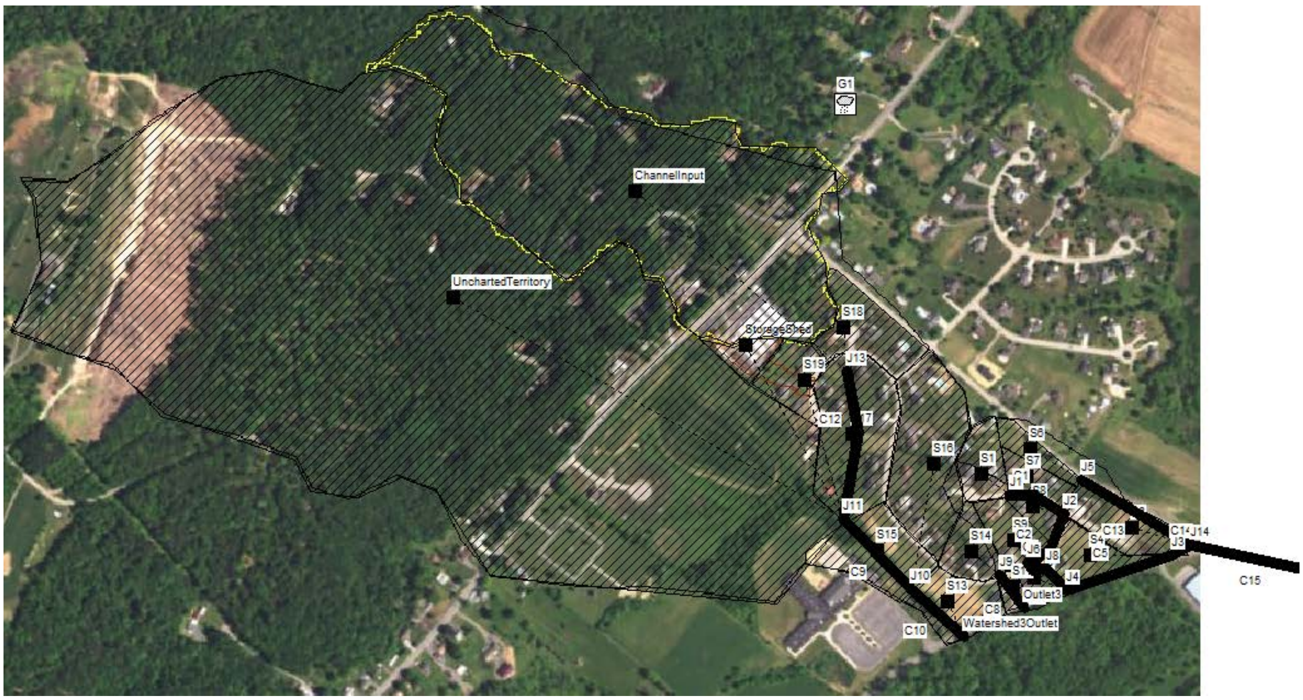

Figure 26: SWMM Program Map Display

8.3.2 HEC-HMS Evaluation

Another modeling software was used in an attempt to model the groundwater flow in Cree Manor. It was assumed that all baseflow in the Juniata River nearby could be equated to groundwater discharge in Cree Manor. Additionally, unlike the SWMM modeling calculations, this did not prove whether or not our designs worked, but rather, allowed us to gain a better understanding of the groundwater contribution to Cree Manor's water issues, and we felt that since assembled and ran the model, it was worth sharing the results.

This modeling was carried out using HEC-HMS, a program developed by the United States Army Corps of Engineers. HEC-HMS stands for "Hydrologic Engineering Center- Hydrologic

Modeling System." It is a surface water hydrology simulation tool. Using this model, a system of runoff routing was created to determine the runoff and base flows that Cree Manor experiences and to determine how they interact with one another to cause flooding and ponding. According to the HEC-HMS Technical Manual, baseflow is fair weather flow due to subsurface runoff and is composed largely of groundwater effluent (Feldman). Since the water table is so high in Cree Manor, it is very likely that groundwater is contributing to baseflow when it reaches the surface, compounding the effects of stormwater runoff, and causing perpetual flooding.

9.0 Final Discussion

9.1 Implementation Process

This was a unique stormwater management project in which more than one best management practice and several designs were suggested as a way to alleviate the flooding and ponding issues in the development. CREEation Station 4+09 has suggested four different designs which would work together to solve the stormwater issues of Cree Manor: a vegetated swale to convey the water away from the storage sheds, a stream restoration of the "natural swale" running through Cree Manor in order to accommodate increased flow and decrease flooding in backyards adjacent to the swale, a pipe diversion and wet pond installation to deal with the ponding along Station Road, and a culvert re-design to outlet the water from the wet pond across the street and eventually to Crooked Creek. When implementing these four designs, keep in mind that some won't work without the other. For example, if the swale to the right is chosen as a design concept, it would likely require the stream restoration as well. This option may cost slightly more, but would solve more ponding issues residents in Cree Manor. Additionally, it isn't worth redirecting the outlet pipe if a wet pond were not to be installed. If neither of these options were implemented, however, the ponding issues in the swale along Station Road would still persist. Lowering the culvert would allow more water to flow through it, no matter what design options were installed. However, lowering the culvert would not solve the overarching issue along Station Road that water doesn't flow to it.

9.1.1 Vegetated Swale

Implementation of the vegetated swale may affect homeowners whose backyards are located directly below the storage shed. Additionally, the design, with a top width of 11 feet, may take up some of the homeowners' property, but will alleviate flooding issues. As per the PA BMP Manual, the following steps are part of the construction and implementation of the vegetated swale by the construction company:

1. Follow Erosion and Sediment Control guidelines for soil and earth movement
2. Roughly grade the vegetated swale, while being sure to avoid excessive compaction or land disturbance. Ensure that excavating equipment is operating from the side of the swale and never on the bottom. Deep plow topsoil into the subgrade in order to penetrate the compacted zone and promote aeration and the formation of macropores.
3. Fine grade the vegetated swale. Accurate grading is crucial for swales as even the smallest nonconformities may compromise flow conditions.
4. Seed, vegetate, and install temporary protective lining as per approved plans and according to final planting list. Be sure to plant the swale at a time of the year when successful establishment without irrigation is most likely.
5. Ensure swale stabilization before allowing it to receive flow.
6. Follow maintenance guidelines and inspect as needed to check for erosion, pools of standing water, sufficient discharge, the need for replanting.

9.1.2 "Stream Restoration" of Natural Swale

Restoring the natural swale to a more stable state may affect homeowners of lots 11-16. A larger bankfull width of 8.5 ft will take up some of the homeowners' property, but will alleviate flooding issues and increase water quality due to the addition of a riparian buffer in this extended width. As per the PA BMP Manual and the Keystone Strem Team, the following steps are part of the construction and implementation of the restoration by the construction company:

1. Apply for the necessary federal and state building permits.
2. Follow Erosion and Sediment Control guidelines for soil and earth movement.
3. Identify specific time windows for construction and the entry or exit points to minimize soil compaction and damage to surrounding riparian buffers.
4. Walk the stream channel, marking the new maximum bankfull depth and width along the stream profile with construction flags.

5. Roughly grade the channel, while being sure to avoid excessive compaction or land disturbance working from upstream to downstream.
6. Fine grade the natural swale to the desired dimensions.
7. Seed, vegetate, mulch, and install bank stabilization matting as per approved plans and according to final planting list to ensure bank stability. Matting and mulch will provide bank stability and cover as plants develop their rooting system.
8. Follow maintenance guidelines and inspect as needed to check for erosion, pools of standing water, sufficient discharge, the need for replanting.

9.1.3 Pipe Diversion and Wet Pond

Before constructing the wet pond, additional pipes may be need. With some pipes already in place, the only requirement is to convey the water runoff from the existing pipes into the designed wet pond. This might include additional pipes or re-grading the existing ones. From there the construction of the wet pond can begin. Listed below is the construction process for building a wet pond, stated from the PA BMP Wet Pond/Retention Basin Manual.

1. Separate wet pond area from contributing area:
    a. All channels/pipes conveying flows to the WP should be routed away from the WP area until it is completed and stabilized.
    2. The area immediately adjacent to the WP should be stabilized in accordance with the PADEP’s Erosion and Sediment Pollution Control Program Manual (2000 or latest edition) prior to construction of the WP.

2.Clearing and Grubbing:

    a. Clear the area to be excavated of all vegetation.
    b. Remove all tree roots, rocks, and boulders.
    c. Fill all stump holes, crevices and similar areas with impermeable materials.

3. Excavate bottom of WP to desired elevation (Rough Grading).
4. Install surrounding embankments and inlet and outlet control structures.
5. Grade and prepare subsoil.
6. Apply and grade planting soil.

a. Matching design grades is crucial because aquatic plants can be very sensitive to depth.

7. Apply erosion-control measures.
8. Seed, plant and mulch according to Planting Plan
9. Install any anti-grazing measures, if necessary
10. Follow required maintenance and monitoring guidelines.

9.1.4 Culvert Re-Design

Implementation of the culvert, like other culvert information, largely depends on what will be done to the road by outside contractors or the government when it is redone. Once the road is removed above the culvert, material above the pipe and the pipe itself will need to be removed. Then, material will need to be removed to make the bottom of the excavated ditch level with the ditch that will outlet into the culvert. The excavated ditch will then be graded along the specified culvert pipe slope, and the new pipe will be secured in place. Then, the excavated ditch can be backfilled and paved over.

9.2 Test Results and Discussion

This is a discussion on how well your design fared during the testing phase. Answer the question of whether or not it passed your expectations as well as meeting the customer's needs and specifications. Summarize your data with the major results here. Include <u>all</u> of your data in the Appendix.

9.2.1 SWMM Evaluation Results

SWMM was used to evaluate the efficiency of the redesigned culvert and stream, as well as the proposed vegetative swale.The SWMM program analyzed the efficiency of these structures to handle runoff generated by a 10 year, 24 hour storm. This storm event was used because it was the design storm used to design the tested structures, with the exception of the culvert. When the culvert was tested for this event, its maximum flow depth was 3.12 inches of a possible 2 feet of flow depth. Because so little of the culvert was flooded, it is very reasonable to assume that the culvert could handle runoff from a 25-year storm or larger events. A cross section of the pipe network leading into the culvert may be seen in Figure 27.

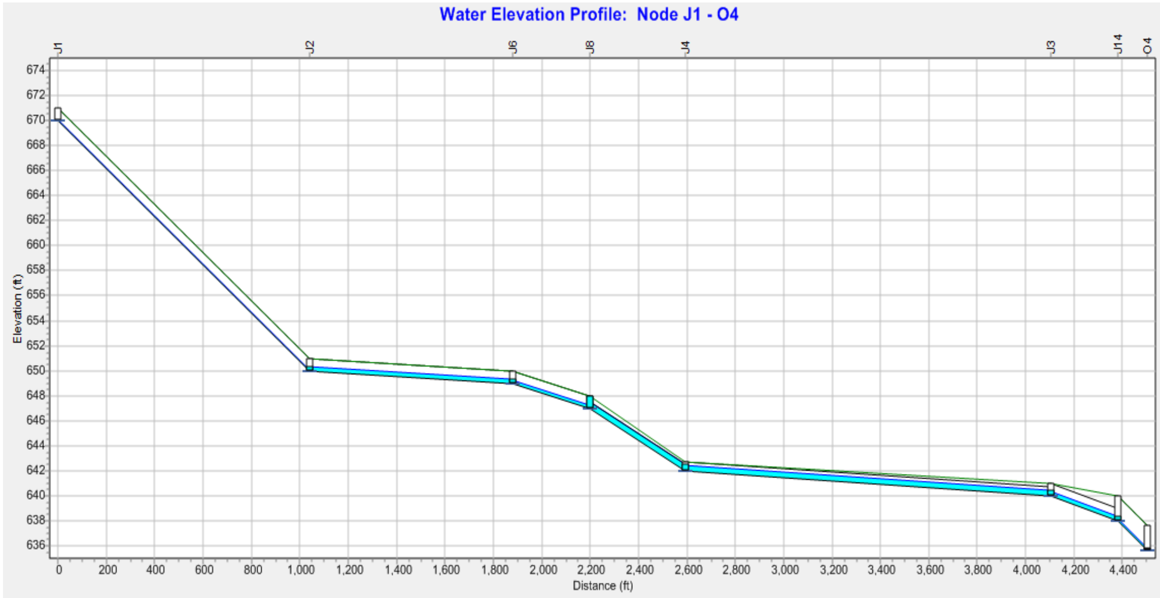

Figure 27. Pipe Network leading to Culvert

The redesigned stream was modeled somewhat conservatively in the SWMM file, as only overland flow into the stream was taken into account, and it was assumed that no water entered the pipe network in watershed 3 and was drained in a different area in order to simplify calculations. It was also assumed that the initial water level in the stream was negligible. This is a valid assumption because some portions of the stream were dry when they were observed in the field, and the parts that contained water only had a very small amount flowing through them. The SWMM model generated a cross sectional view of the stream that may be seen in Figure 28. This simulation proved that the stream was successful because it maximum flow depth in any segment was only 92% of the possible total flow depth. When the SWMM model was run, the maximum depth in any part of the redesigned stream was only 92% of its full flow depth. This indicated that the stream performed as expected and did not overflow into residential yards during a hypothetical 10 year 24-hour storm event.

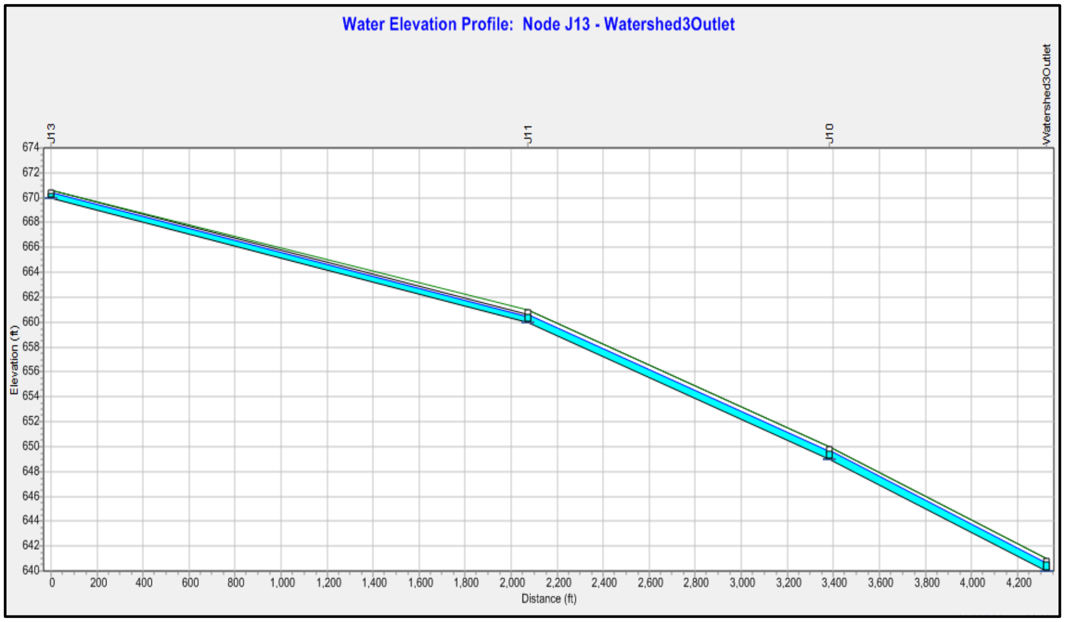

Figure 28. Cross Section of Proposed Stream in Watershed 3

There were two options for the design of the swale. One design diverted half of the water to the left, where it would eventually reach J11, and the other carried all of the water from the storage sheds to the right, where it outlet near J13. The team chose to analyze the design sloping to the right because it carried a larger volume. A cross section of the swale can be seen in figure 29. The maximum depth of water in the swale was only 10% of the potential full flow depth, meaning the swale can easily handle water from a 10 year 24-hour storm. However, this caused the maximum flow depth in the stream below J13 to be 98% of its full flow depth. This means that the swale can be designed to the right or the left, as neither will cause the swale to overflow its banks or stream to overflow their banks.

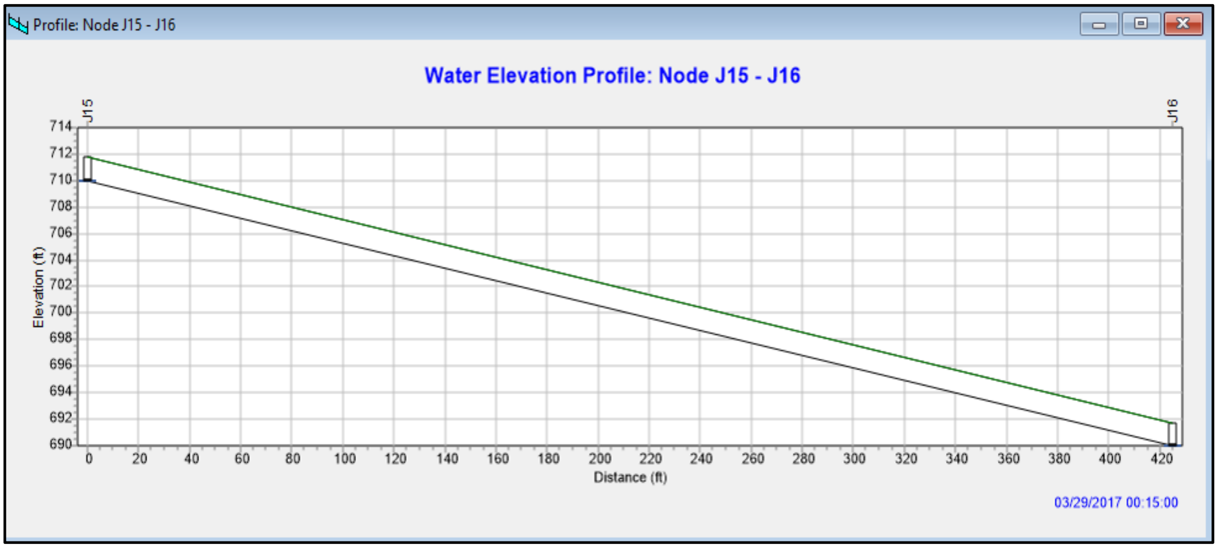

Figure 29. Cross Section of Swale below Storage Sheds

9.2.2 HEC-HMS Evaluation Results

The goal of this analysis was to understand how baseflow combined with stormwater runoff leads to the flooding issues in Cree Manor. To do this, USGS gaging station data and the stream network from the Upper Juniata Subbasin of the Lower Susquehanna Watershed was used. This stream network, set up via ArcGIS is shown below as Figure 30, below.

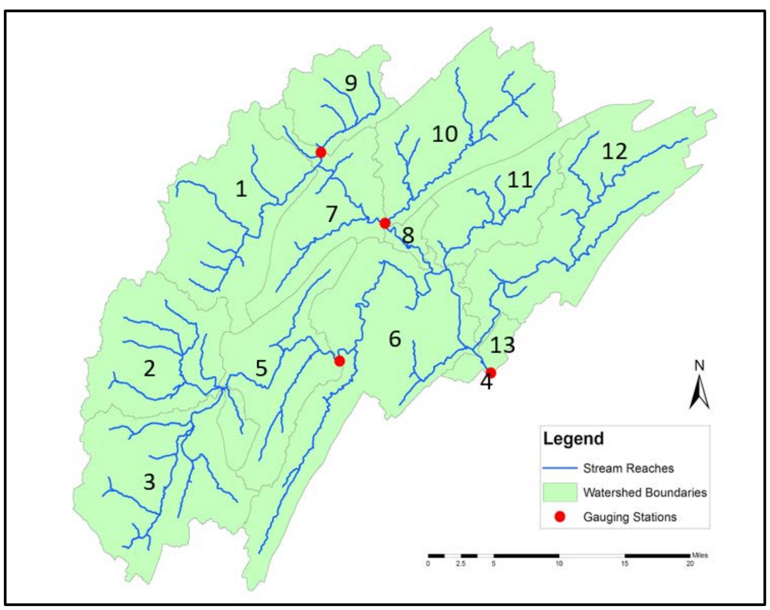

Figure 30: Stream Network via ArcGIS

In Figure 30, above, it is assumed that the flow making its way to the gaging station near subbasin 13 is representative of Cree Manor. The program outputs total flow based on baseflow values and precipitation. It was first run with no precipitation input. Therefore, the output showed only baseflow in the area. Figure 31, below shows the average baseflow in the Upper Juniata Subbasin as a constant, unvarying flow of 48.1 cubic meters per second (cms).

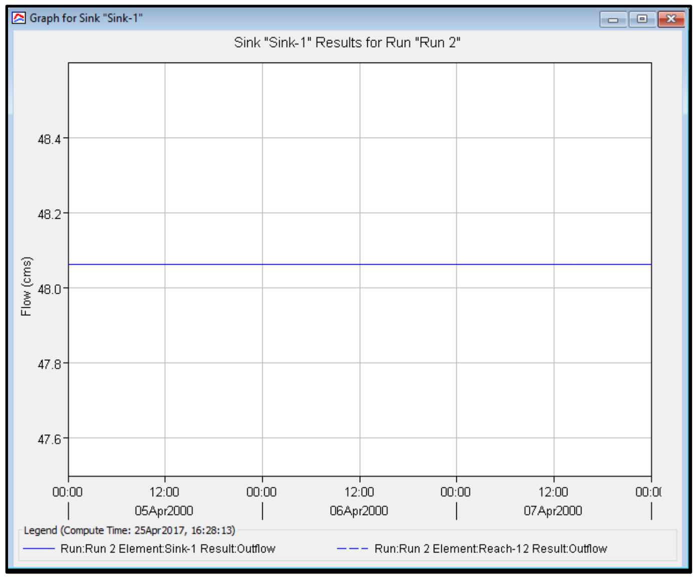

Figure 31: Constant Baseflow

The program was then run with precipitation inputs for a 2-,5-,10,2-, and 50-year storm. HEC-HMS output total peak flowrates, including the sum of baseflow and surface runoff, for the outlet point of the entire Upper Juniata Subbasin. To scale this down to Cree Manor, the values were multiplied by the percentage of the Juniata Subbasin comprised of Cree Manor and it's three watersheds. Given the estimated surface runoff flowrates that were calculated for this project during the design phase, the estimated baseflow of the area was found by subtracting surface runoff flowrates from total flowrates. A summary of these values is shown below in Table 23. It was estimated that the baseflow, or groundwater to surface flow for all three watersheds delineated in the Cree Manor (Figure 14) is approximately 0.0175 cms. This equates to approximately 400,000 gallons of water per day that could potentially come to the surface and run across the 217.85 acres of Cree Manor's watersheds. This value is likely an overestimate, as the values are based off of baseflow in a river located nearby to the development, and the flow in the neighborhood is not as significant.

Table 23: Summary of Flowrate Data

Storm Type	Total Peak Flowrate For Juniata Subbasin (cms)	Estimated Total Peak Flowrate For Cree Manor (cms)	TR-55 Estimated Surface Runoff Flowrate for Cree Manor (cms)	Estimated Baseflow via HEC-HMS and TR-55 (cms)
2	596.6	0.2066	0.1853	0.0213
5	976.3	0.3381	0.3198	0.0183
10	1362.2	0.4718	0.4560	0.0158
25	1947.6	0.6745	0.7349	-0.0604
50	2518	0.8721	1.0613	-0.1892

10.0 Cost Analysis

10.1 Vegetated Swale

A rough cost estimate of a vegetated swale, according to the PA BMP Manual is $5-20 per linear foot. With varying lengths of 360 or 425 feet depending on swale option chosen, the price could be anywhere from $1,800 to $8,500. The price of the swale will also likely increase due to the cost of vegetation planted, and varying labor rates as per the construction company hired. Additionally, slight maintenance may be required.

10.2 Stream Restoration of Natural Swale

A possible solution for finding alternate funds to finance Cree Manor's improved stormwater management through stream restoration is applying for the Pennsylvania Department of Environmental Protection's Growing Greener Grant which aims to address Pennsylvania's many environmental impacts such as farmland preservation, watershed restoration and stormwater and wastewater infrastructure ("watershed grants"). The stormwater runoff leaving Cree Manor can be defined as a type of nonpoint source pollution because of its ability to acquire and transport toxins from roadways and lawns. Improving the stormwater management within this area with a plan to implement green infrastructure to promote water quality and reduce runoff within Cree Manor could make Walker Township, PA eligible to apply for this federal grant. The Growing Greener Grant typically awards $125,000 per project which covers the average construction cost of $107.6 per lineal foot of stream restoration for streams in north central Pennsylvania ("Guidelines for Developing Cost Guidelines for Developing Cost Ranges of a Natural Stream Channel Ranges of a Natural Stream Channel Design Project"). Although this cost does not include the cost of engineering field and design work, it was estimated from projects much larger than the proposed project within Cree Manor and so $125,000 would likely cover much of the total costs.

10.3 Pipe Diversion and Wet Pond

It is difficult to estimate the cost for diverting water from lot 46 into lot 33. These cost are dependent on the construction company, materials need to repair land and road damages, and labor costs. On the other hand, the PA BMP manual provides a rough estimate when building a wet pond. From the PA BMP manual, in 2004 the cost to build a wet pond was anywhere from $25,000 to $50,000 per acre-foot of storage. The acre-foot of storage for this wet pond is around 1.8 acre feet. This means the cost in 2017 would be anywhere from $56,700 to $114,700 to construct this particular wet pond.

10.4 Culvert Evaluation and Re-Design

It was somewhat difficult to predict the cost associated with redesigning the culvert. The necessary material can be found on numerous websites such as Agri Supply, where it costs $2736 for the required 120 ft of corrugated plastic pipe with a 2 ft diameter. While the cost of material can be found online, the cost of labor is unknown. To minimize labor costs, it is sensible to install a new culvert pipe in 2018 when the road is being re-done. However, the scope of the work on the road is unknown, so it is not possible to tell how much additional labor or material will be needed as this information largely depends on what specifically will be done to the road when the culvert will be installed.

11.0 Ethics Analysis

There are many ethical issues that are part of a program with a scope as broad as the stormwater problems in Cree Manor. One obvious issue is the status of land, both sold and unsold. For example, implementing projects such as building a swale below the storage shed or redesigning the stream could help reduce flooding for some residents but temporarily damage yards of others. Additionally, building structures such as the wet pond on unsold land will greatly reduce the ability of that lot to be sold, but it would have the potential to solve flooding issues in surrounding lots, which may improve their value. Furthermore, it is important to consider what will happen downstream of Cree Manor, as design considerations forced the team to move water out of the development, rather than infiltrate it, as erosion and channelization near the school or church on Station Road could occur.

11.1 Ethical Issue(s)

The majority of the lots within the lower half of Cree Manor, Figure 32, are currently uninhabited due to the soil's constant saturation. This saturation makes them unsuitable for traditional basement construction and susceptible to water damage in the future due to this area's the high water table. The current engineering design solutions propose the diversion of stormwater discharges in a wet pond within lot 33. Although this is a prime location for the wet pond due to its proximity to the culvert outlet, constructing the wet pond within one of the neighborhood lots would mean losing the property value of lot 33. It is possible that by diverting water into this wet pond would reduce flooding and ponding issues within the surrounding lots, making them more suitable for development. It is also important to note the apparent presence of wetlands in this area, possibly due to the development within the area.

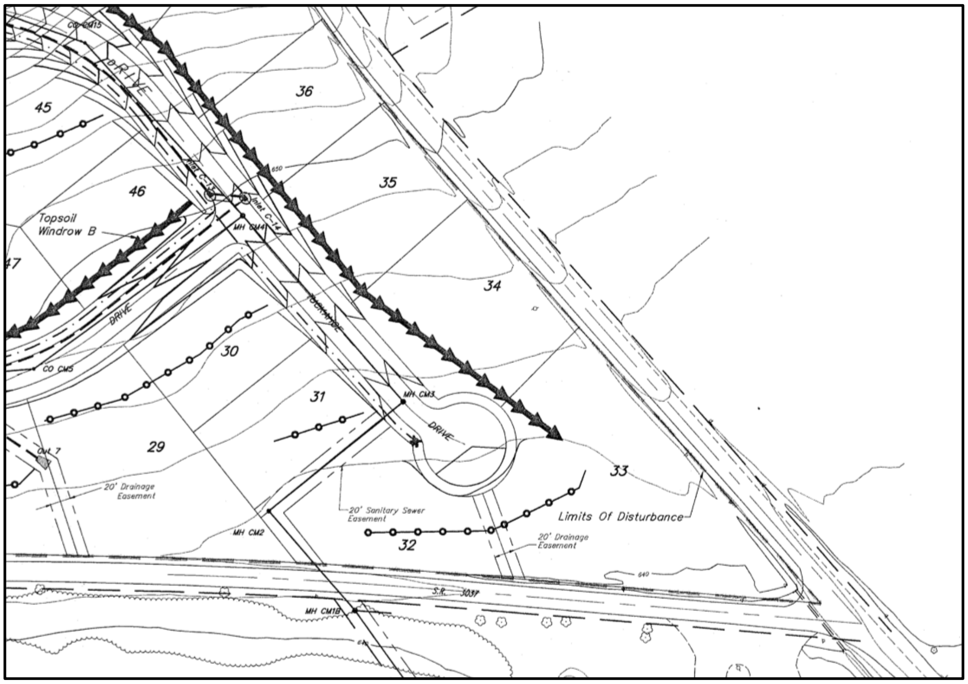

Figure 32: Detailed Illustration of Cree Manor Lots 29-36

11.2 Stakeholders

The stakeholders invested in the construction of lot 33 are the property owner, the future land owner, the current residents of Cree Manor, and the water flowing through Cree Manor and into Crooked Creek. The property owner would be both harmed and benefit from the construction of a wet pond within lot 33. Although the owner would lose the value of lot 33, if the wet pond is created, there is chance of profit recovery from selling the remaining properties surrounding lot 33. The future land owner of lot 33 would be harmed due to the loss of this property but would benefit from saving the inevitable expenses due to water damage. The current residents of Cree Manor would benefit from their stormwater outletting into the wet pond instead of the current outlet on Station Road. This would reduce ponding and flooding in the backyards of current residents.

11.3 Values

There are a couple values being jeopardized by the ethical issues. The first value is based on the ethic of care. We do not wish for the stakeholders to suffer from flooded basements. It becomes a fanatical problem for the stakeholders, especially if they are trying to buy or sell a home. This means that if the wet pond does make adjacent lots sellable, it is still recommended they be built out of the ground, not dug into. Not only do we care about their investments, but also the treatment of the water. Sediment and pollutants leaving Cree Manor will only harm the environment downstream. BMP's placed throughout Cree Manor will reduce the amount of pollutants leaving the area. The second value is based on the ethic of justice. Even though the channel along Station Road and lot 33 are not considered a wetland, it shows every sign of being classified as one. Lot 33 will have a lot of legal issues when trying to construct a residential house if a wetland classification is placed. The final value that is being jeopardized is based on the ethics of profession. Water runoff from properties at a higher elevation should not affect properties downstream. Different BMPs will reduce the amount of flooding for houses dispersed in Cree Manor.

11.4 Potential Solutions

Cree Manor has multiple issues across the entire development. With multiple issues, there are a variety of solutions that can help alleviate Cree Manors flooding. One solution in particular is the addition of a wet pond in lot 33. This would improve water quality and minimize stormwater issues in the surrounding areas. The assumptions for this method is the stakeholder that has already investing in lot 33 would have surrender their investments for the greater good of the development. Other solutions could entail smaller ponds scattered throughout Cree Manor. This will eliminate the need to use an entire lot, but more stakeholders would have to give up a small portion of their land.

12.0 Conclusions and Recommendations

Cree Manor's water issues were not an easy or simple problem to solve. There is not one sole cause of the flooding and ponding that residents in the area experience, and therefore there is no "quick fix". Team CREEation Station 4+09 worked diligently throughout the semester to investigate the water issues of the neighborhood, to identify the cause, and propose a suitable solution. The final design solution includes four different recommendations: a vegetated swale, stream restoration of the "natural swale," pipe diversion and wet pond installation, and culvert re-design. We believe that these solutions meet the needs of Walker Township and the residents of Cree Manor. Possibly the most important need that was met was safety. None of the proposed structures are very dangerous for residents, the only safety risk is a resident getting injured falling into the wet pond or the stream. These structures are also very aesthetically pleasing with the exception of the culvert, which is simply a pipe below a road. Some structures, such as the wet pond and swale, indirectly reduce volume of water in parts of the development. Volume reduction was not a major part of the team's solution because the best way to reduce flooding issues was to ensure that water easily exited the development in a manner that prevented both erosion and ponding. The system of solutions is very efficient and structures like the stream and wet pond reduce the velocity of water in the development.These structures are very durable as well, although they could be damaged by outstanding events, such as 100-year storms. They will be relatively inexpensive to install. The culvert can be replaced when the road above it is redone in 2018 in order to save money, and cost of installation of the swale, wet pond, and restored stream may be reduced if government assistance, such as the Growing Greener Grant, is obtained. Unfortunately, because of the scope of this project and the various challenges associated with each structure, it may be somewhat difficult to install the team's solutions.

Table 24. Customer Needs Satisfaction Chart

Customer need	**Satisfaction rating (1-10)**
Safe	9
Ease of Implementation	5
Durable	8
Low Cost	7
Efficient	9
Limit Volume	6
Reduce Velocity	9
Aesthetics	9

The aforementioned design concepts are based on the information and data possessed by the team. In the future, a professional in-depth survey of the land may prove to be beneficial, and may offer some additional insight to design parameter specifications. The overarching mechanisms behind the designs, however, should stay the same: increase the retention time of the water, slow the velocity, reduce erosion, and filter out pollutants. We believe that the design solutions presented in this report reflect the best possible solutions to the Cree Manor water issue. It is recommended that all designs be implemented in order to truly alleviate the flooding and ponding issues. We realize that cost is a concern, however, so we would recommend that when implementing designs, Walker Township refer to Section 9.1 of this report, “Implementation Analysis.” It was a pleasure to work with Walker Township and to put our classroom knowledge into real-world practice by tackling the water issues of Cree Manor.

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Appendix

I. Reference Images

II. Brittany Ayers' Resume

III. Michael Henderson's Resume

IV. Kaitlyn Morrow's Resume

V. Zach Klueber's Resume

VI. Sponsor Deliverables Agreement

VII. Cree Manor Utility Map Reference

Section I

Subsection A

Region 1								
Rainfall Total								
	1-Yr Storm	2-Yr Storm	5-Yr Storm	10-Yr Storm	25-Yr Storm	50-Yr Storm	100-Yr Storm	500-Yr Storm
Duration (Min)	in	in	in	in	in	in	in	in
5	0.28	0.33	0.39	0.45	0.51	0.55	0.58	
10	0.43	0.51	0.61	0.69	0.78	0.83	0.87	
15	0.53	0.63	0.75	0.85	0.96	1.03	1.09	
30	0.70	0.84	1.03	1.18	1.36	1.47	1.57	
60	0.85	1.03	1.30	1.50	1.76	1.94	2.10	
120	0.99	1.19	1.49	1.74	2.08	2.35	2.62	
180	1.09	1.31	1.63	1.90	2.28	2.58	2.89	
360	1.37	1.64	2.04	2.37	2.84	3.19	3.56	
720	1.69	2.02	2.49	2.91	3.52	3.97	4.46	
1440	2.04	2.44	2.99	3.44	4.09	4.65	5.24	6.74

Figure 5: Five (5) minute through twenty-four (24) hour storm totals for Region 1 ("Pennsylvania Design Rainfall Intensity Charts")

Subsection B.

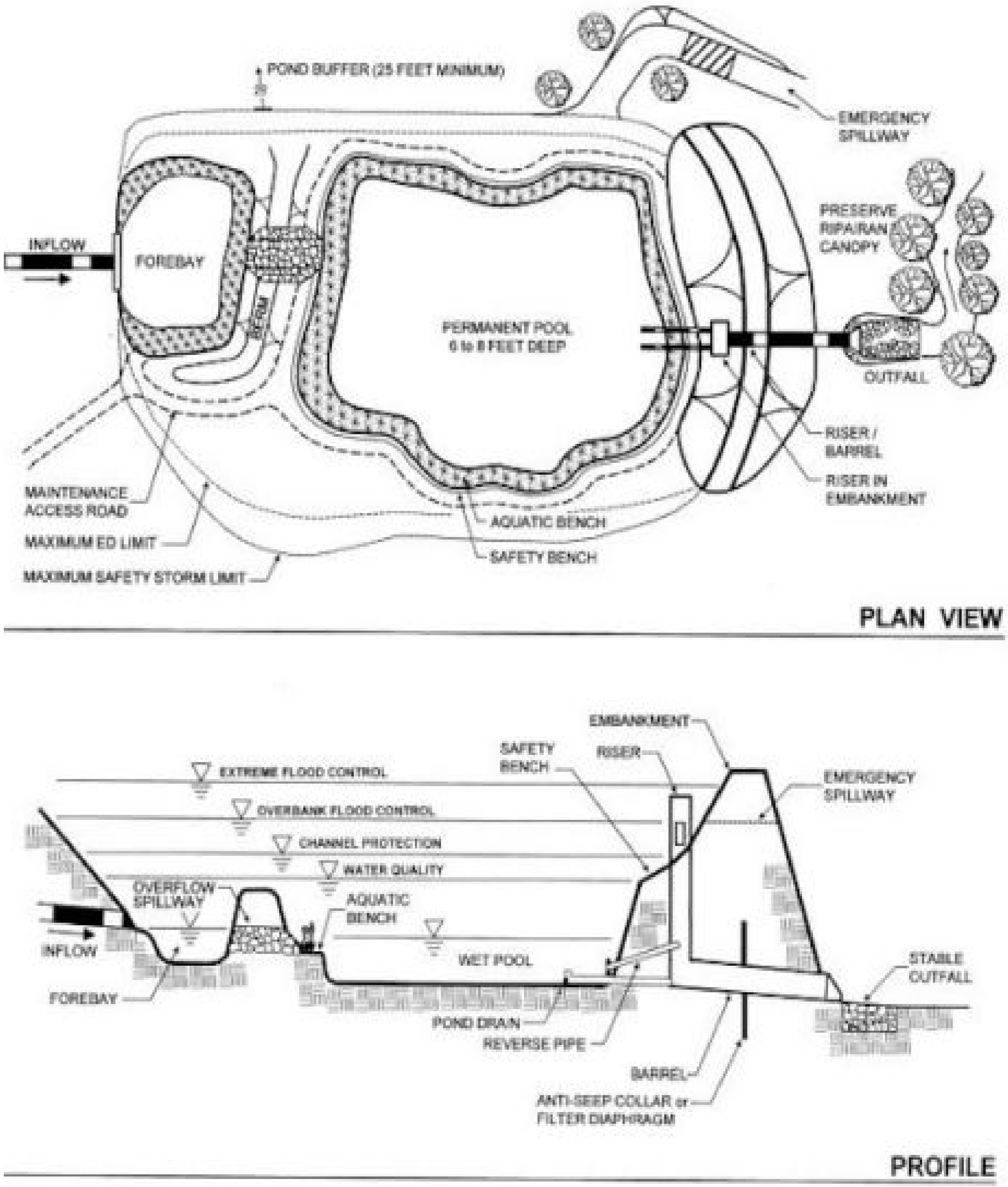


Figure 6: Typical Wet Detention Pond Schematic

("Pennsylvania Stormwater Best Management Practices Manual")

Subsection C.

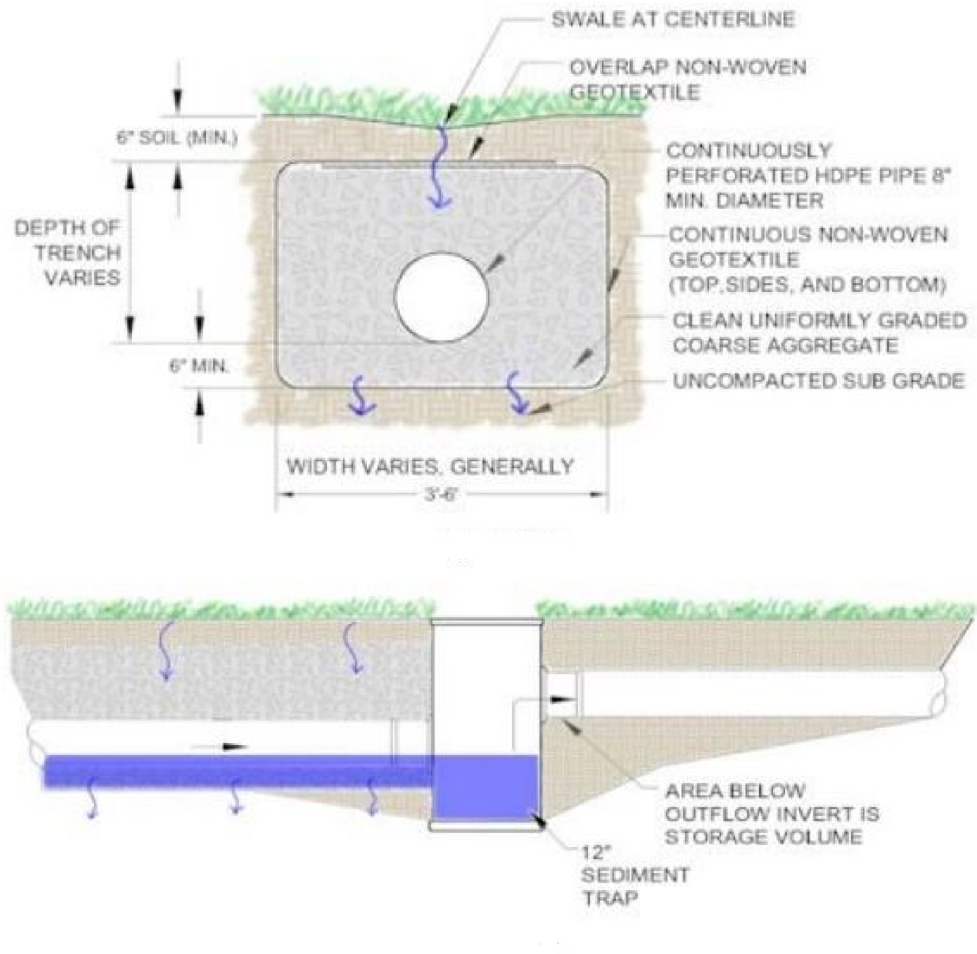


Figure 10. Typical infiltration trench construction sequence
("Pennsylvania Stormwater Best Management Practices Manual")

Subsection D.

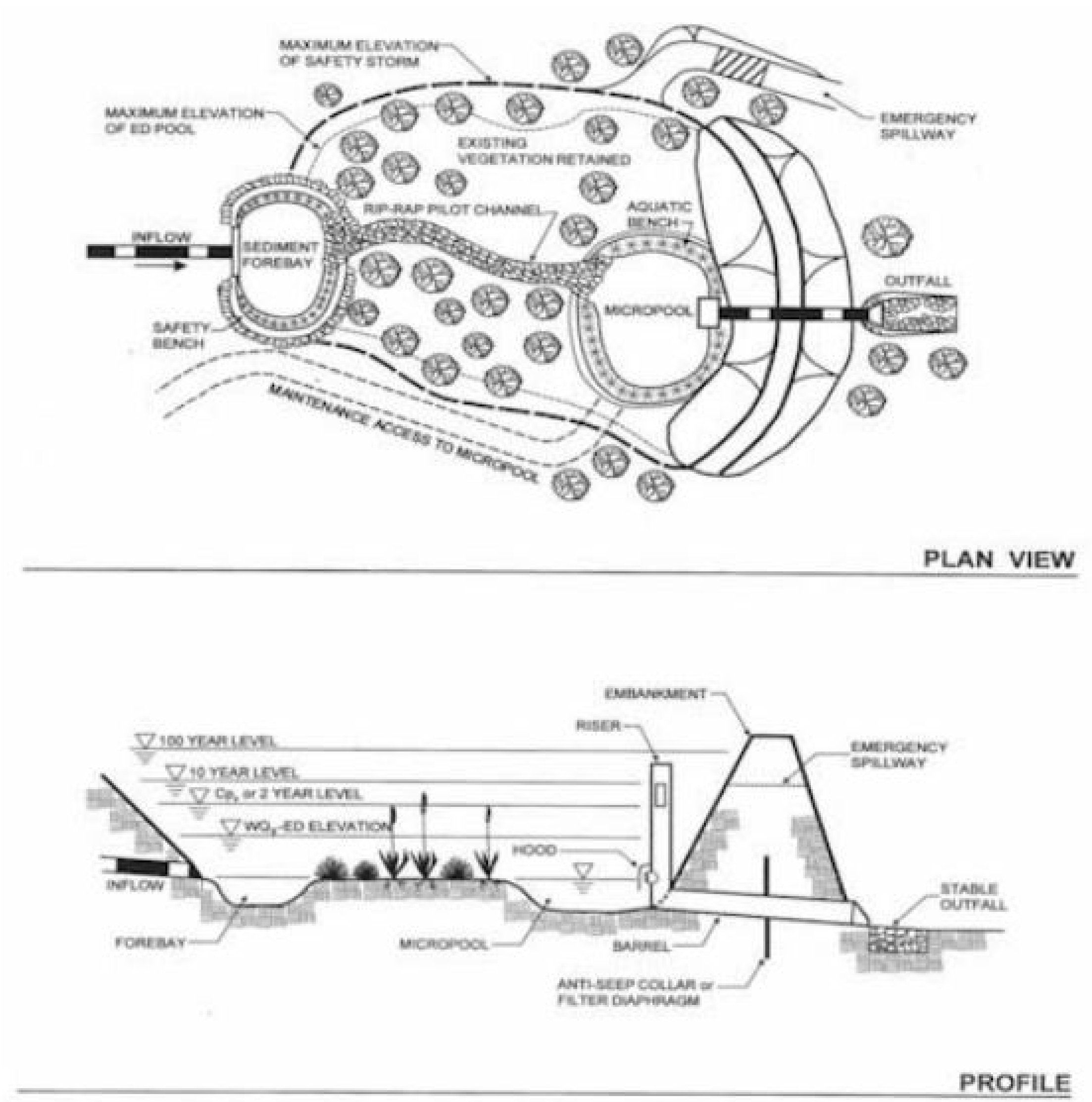
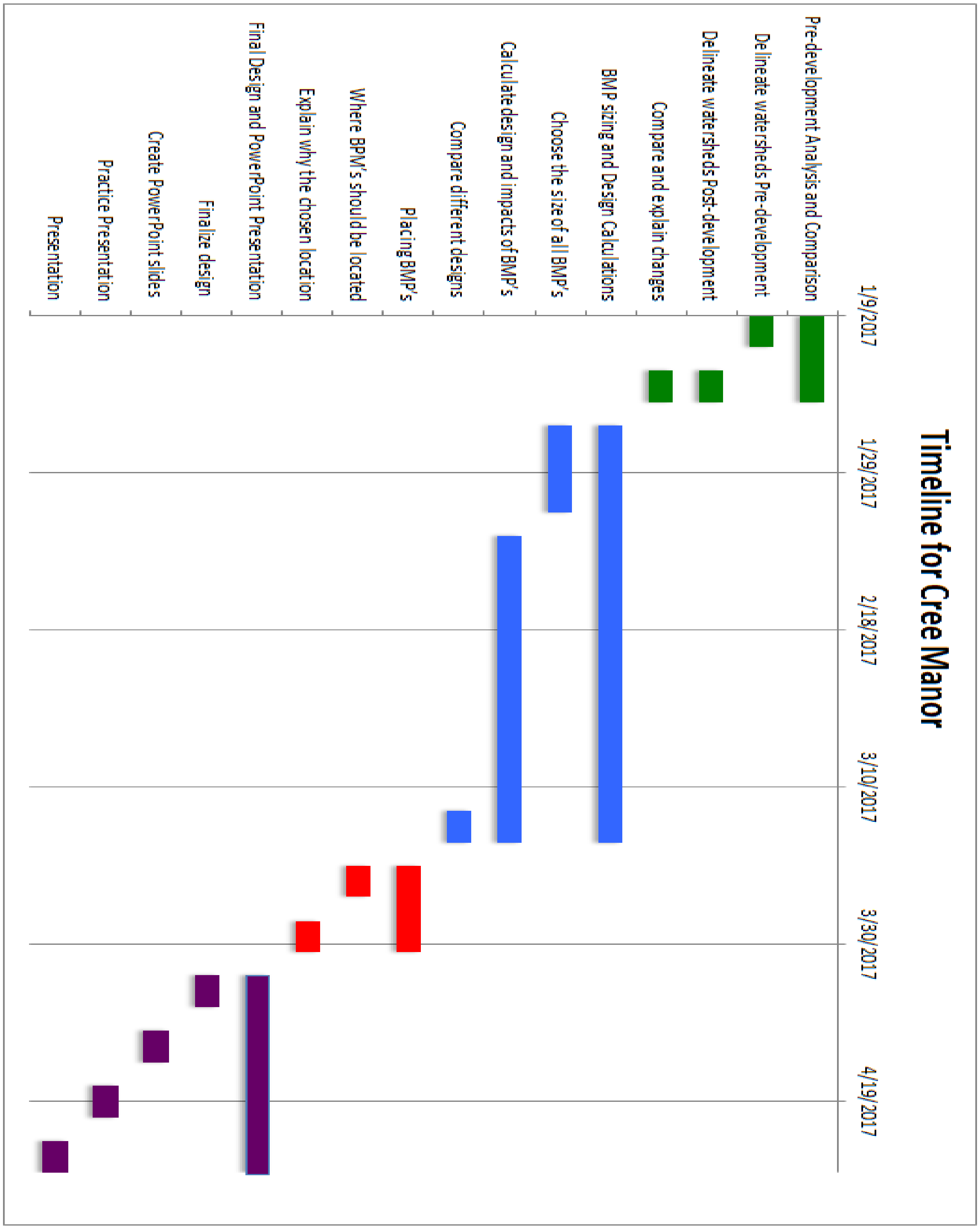


Figure 11: Extended Detention Basin
("Pennsylvania Stormwater Best Management Practices Manual")

Subsection E



Section II

Permanent Address:
138 Spruce St.
Mountain Top, PA, 18707

Brittany Ayers
boa5134@psu.edu
(570)-814-8337

Current Address:
506 West College Ave., Apt 2
University Park, PA, 16801

EDUCATION

The Pennsylvania State University — **University Park, PA**
College of Engineering — Graduation May 2017
Bachelor of Science in Biological Engineering — **GPA: 3.53/4.0**
Minor in Environmental Engineering
Minor in Watersheds and Water Resources
Schreyer Honors College- 34 Honors Credits

Study Abroad Experience
Lincoln University, New Zealand
A 2 week embedded program traversing the South Island to learn about sustainability and natural resources.

WORK EXPERIENCE

Whitney Bailey Cox & Magnani (WBCM) — **Towson, MD**
Intern — May 2015/16- July 2015/16

- Utilized ArcGIS to map the location of vegetated swales in Prince George's County, MD
- Learned about Erosion and Sediment Control practices and guidelines and best management practices
- Gained a working understanding of consulting firm operations
- Obtained exposure to watershed delineation and hydrograph modeling
- Became familiar with laws and regulations such as NPDES and MS4 permits and TMDL's in the Chesapeake Watershed
- Worked on a team to conduct field visits and data analysis

Ayers Towing Service, Inc. — **Mountain Top, PA**
Secretary — Sept 2011 – Aug 2014

- Answered customer calls and dispatched 6-7 drivers per hour to road side assistance calls
- Developed communication skills by providing quality customer service in high pressure situations
- Gained a working understanding of small business operations

LEADERSHIP AND ACTIVITIES

Penn State Eco-Action Club — **University Park, PA**
President — Aug 2015- Present

- Lead a club of approximately 35 members
- Coordinate specific programs and events, and service activities throughout the year
- Develop weekly meeting plans and delegate tasks to Executive Committee Members
- Communicate with adviser and PSU affiliates to ensure all rules and procedures are met and followed

Member — Aug 2013- Present

American Society of Agricultural and Biological Engineers (ASABE) PSU Student Branch — **University Park, PA**
Treasurer — Aug 2015- Present

- Balance accounts and advise the Exec Committee on spending
- Work with the rest of the Exec Committee to plan and organize events and meetings

Member — Aug 2014- Present

Student Sustainability Advisory Council — **University Park, PA**
Member — Sept 2015-Present

- Sit on a council appointed by the President to give the students a voice in sustainability on campus
- Report recommendations each semester to the PSU Vice Presidents and administration on suggestions for improvements to policies, operation, and sustainability initiatives
- Researched, benchmarked, collected data, and proposed an outdoor recycling initiative at University Park

RELEVANT COURSES

Environmental Law, Principles of Soil and Water Engineering, Soil Science, Intro to Environmental Engineering, Honors Leadership Ed.

SOFTWARE

Microsoft Word, Microsoft Excel, Microsoft PowerPoint, MATLAB, ArcGIS, MicroStation

HONORS

Biological and Agricultural Engineering Award- College of Agricultural Sciences - *Recipient*
Penn State Schreyer Honors College Academic Excellence Award - *Recipient*
Alpha Epsilon (Honor Society for Agricultural and Biological Engineers) – *Accepted Member*
Internship Award-College of Agricultural Sciences- *Recipient*

Section III

Michael W. Henderson

917 N. Manor Road | mwh5489@psu.edu
Honey Brook, PA 19344 | (484)-663-3730

EDUCATION:

THE PENNSYLVANIA STATE UNIVERSITY - COLLEGE OF ENGINEERING — University Park, PA
Bachelor of Science in Biological Engineering — Graduation May 2017
Minor in Environmental Engineering — Major GPA: 3.25/4.00
Minor in Watersheds & Water Resources — Cumulative GPA: 2.57/4.00

WORK EXPERIENCE:

Henderson Apartments — Honey Brook, PA
Co-Manager, Landscaper — June 2008 – Present
Responsible for handling tenants concerns and needs
Handle taxes for apartment business
Maintenance, tractor work, push mow, weed whacking, snow removal

DuFault Tree Service — West Chester, PA
Groundsman — June – July 2016
Responsible for keeping equipment, trucks, trailers and job sites and yard organized
Performed preventative maintenance for equipment & trucks – clean, lubricate daily
Responsible for operating large and small equipment
Assisted with reading of site plans for lot clearings

Earth Care Inc. (Landscaping and Erosion Control) — Honey Brook, PA
Laborer — May – Aug. 2015
Constructed silk and super fence
Planted trees, small bushes and flowers
Laid sod, grass seed and straw

Wyebrook Farm — Honey Brook, PA
Handyman, Landscaper — June 2011 – Aug. 2013
Responsible for moving and feeding 200 cattle, 2,400 chickens, 75 pigs
Operation of farm equipment
Tractor work, Push mow, Weed wack for 360 acre property

LEADERSHIP ACTIVITIES:

Pillar THON Organization — University Park, PA
Member — Sept. 2015 – Apr. 2016
Raise money yearly to help kids with Pediatric Cancer
Monies raised goes to The Four Diamonds

Twin Valley High School Band Camp — Elverson, PA
Volunteer — Aug. 2012 – Present
Worked on 5 member team in charge of 80-90 students
Direct and instruct for football field shows

SKILLS:

Basic knowledge in Autodesk Revit, Autodesk Inventor, AutoCAD, GIS

Relevant Course:

Capstone Project – Provide water runoff data and best management practices for the Cree Manor development by calculating rainfall runoff, using GIS, and observing site designs

Design of Storm water and Erosion Control Facilities – Design sediment impoundments, storm water impoundments, and erosion control structures with the use of basins, impact development practices, and open channel designs

Section IV

Current Address:
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Apt. #431
State College, PA 16801

Kaitlyn A. Morrow

kam6216@psu.edu
(717) 578-2688

Permanent Address:
617 Aslan Court
York, PA 17404

EDUCATION

The Pennsylvania State University — **University Park, PA**
College of Engineering — Graduation May 2017
Bachelor of Science in Biological Engineering, Natural Resource Engineering Option — **GPA: 3.64/4.00**
Minors in Environmental Engineering, English Literature
Dean's List 4 semesters

WORK EXPERIENCES

U.S. Fish and Wildlife Service — **University Park, PA**
Stream Restoration Technical Intern — May 2016- August 2016

- Gathered data such as soil composition, stream type and quality, and watershed volume
- Wrote and distributed permit documents and construction documents such as Erosion and Sedimentation Plans and Area of Impact Maps
- Built and installed in-stream erosion determent structures such as log vanes and mudsills
- Used Total Station Surveying to determine stream profile, as-built descriptions, and stake-out known points of interest

Soil Science Lab — **University Park, PA**
Soil Technician and Teaching Assistant — January 2015- May 2015

- Teamed with other undergraduate and graduate teaching assistants to prepare weekly soil science laboratory experiments for 40 students
- Read and corrected bi-weekly, written homework assignments
- Assisted in teaching labs in soil pH, bulk density and porosity, soil delineation and characteristics, soil remediation applications
- Wrote and delivered own laboratory mini lecture before weekly laboratory experiment of my choosing

The Penn State Berkey Creamery — **University Park, PA**
Crew Member — May 2015-December 2015

- Delivered exceptional customer service in a timely manner
- Managed high pressure situations and customer complaints accordingly
- Answered miscellaneous questions about Penn State, its history, and the University Park Campus
- 16,270 cones and bowls served over 3 days at the Central Pennsylvania Festival of the Arts Weekend

LEADERSHIP AND ACTIVITIES

American Society of Agricultural and Biological Engineers Student Chapter — **University Park, PA**
Social Events/ Recruiting Chair — May 2016- Present

- Helped grow the club from 2 general members to 30 general members
- Planned and executed social and academic events for 30 student members
- Scheduled events include group hikes, a factory tour, and industry guest speakers

Pennsylvania State University Dance Marathon (THON) — **University Park, PA**
Committee Member, Administrative Assistant, Merchandise Chair — October 2013-Feburary 2016

- Improved communication and compromise skills by working with diverse groups of students
- Wrote and distributed weekly meeting minutes for a group of 32 student volunteers
- Worked effectively as a team to maintain a safe and healthy environment for THON and pre-THON events by removing waste and recycling from the Bryce Jordan Center
- Designed, ordered, and distributed committee apparel for 31 student volunteers

Boulevard — **University Park, PA**
Member — October 2013-Present

- A service organization focused on positively influencing the State College and Penn State communities
- Developed interpersonal skills through service, fundraising, and recreational activities.
- Service events include: Shavers Creek, Epilepsy 5K Run/Walk, Arboretum Clean-Up

Member, Alpha Epsilon, Honor Society of Agricultural and Biological Engineering — **University Park, PA**

- Inducted September 2015

SKILLS

AutoCAD, Total Station Surveying, Campbell Scientific Hydrology Monitoring Equipment, ArcGIS- Geographic Information System, MATLAB

Section V

Zachary J. Klueber

School:
219 South Sparks Street, Apartment #1
State College, PA, 16801
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724-672-6548

Home:
709 High Lane
New Alexandria, PA, 15670
zklueber@gmail.com
724-668-8976

Education:

The Pennsylvania State University (Anticipated Graduation Date – May 2017) University Park, PA
Intended Bachelor of Science – ABET accredited
Biological Engineering with a focus on Natural Resource Engineering
Minoring in Environmental Engineering, Watersheds and Water Resources, and History
Two time recipient of Jarrett Scholarship in Biological Engineering, Recipient Peikert and Shute Scholarships in Ag. and Biological Engineering, and Paschall Scholarship in Agricultural Sciences
Dean's List in the College of Engineering four times
Cumulative GPA: 3.63, In Major GPA: 3.86

Relevant Courses

- Soil and Water Engineering
- Intro. To Environmental Engineering
- Hydrologic Systems
- Ag. Meas. And Control
- Fluid Mechanics
- Thermodynamics

Greensburg Salem High School (2009-2013) Greensburg, PA
Graduated with 3.97 GPA; Studied AP Physics, AP Biology, AP Calculus, and Honors Chemistry
Member of the AXIS Gifted Program for four years, Captain of Cross Country and Track and Field Teams

Experience:

Penn State, Biological Engineering Department (January 2016-Present) University Park, PA

- Recipient of the Erickson Discovery Grant during summer 2016. Focused on determining the effectiveness of riparian buffer strips on poultry farms. Used AutoCAD and information obtained from rainfall data to design system of weirs in riparian strips that will allow water to pool so that concentrations of hormones and other substances may be determined
- Work will continue during the fall semester when the weir systems will be implemented. ISCO samplers will be programmed to collect water behind the weirs. The water samples will then be analyzed in the lab.
- Awarded undergraduate research position in the Department of Biological Engineering beginning in January 2016. Work included analyzing spatial and temporal variations of soil hydraulic functions at Penn State's Living Filter by use of electromagnetic induction and infiltrometers. These parameters were measured while the ground was frozen in the winter, thawing in the spring, and soft in the summer
- After the data is processed, these properties will be mapped using ArcGIS and the effect that these changing properties had on engineering and agricultural projects will be determined
- Worked 30-40 hrs/week under Dr. Heather Gall, who may be contacted at heg12@psu.edu or 814-863-1817

Wal-Mart (May-August 2015) Delmont, PA

- Employed as a sales associate in the Sporting Goods department, worked 30-40 hours per week
- Worked 40 hrs/week under Dan Lewis, who may be contacted at 724-610-5798 or dlewi024@aol.com

Westmoreland Conservation District (2012-2013) Greensburg, PA

- Designed and Constructed a Modular Rain Planter, a device that is used to collect and clean rooftop runoff by diverting contaminated water through layers of soil and geotextile fabric.
- Analyzed and organized documents concerning worksites
- Worked five hrs/week under Kathy Hamilton who may be contacted at 724-837-5271

Clubs and Organizations:

American Society of Agricultural and Biological Engineers, 3D Printing Club, Engineers for a Sustainable World

Relevant Skills:

AutoCAD ArcGIS MATLAB

Section VI

PENNSTATE

sustainable communities

Partnerships and Possibilities

Cree Manor Stormwater

Sustainable Communities Collaborative, Fall 2016/Spring 2017

Community Project Partner:

Collaborator: Walker Twsp Municipality
814-627-1890
julie@walkertwp.comcastbiz.net

Principle: Julie Johns , julie@walkertwp.comcastbiz.net

Secondary: Ilona Ballreich, ixb20@psu.edu

University Project Contact:

Course Instructor: Megan Marshall, BE 460/466
814-865-3392
mnm11@psu.edu

Sustainability Institute:

Michele Halsell: 814-867-4578
mwh16@psu.edu

Ilona Ballreich: 814-865-2291
ixb20@psu.edu

Student Team: CREEation Station 4+09

Brittany Ayers, boa5134@psu.edu
Michael Henderson, mwh5489@psu.edu
Kaitlyn Morrow, kam6216@psu.edu
Zachary Klueber, zjk5043@psu.edu

The Project

Problem Statement:

The purpose of this project is to understand and mitigate stormwater and flooding issues in the Cree Manor development. Cree Manor is a relatively small development of roughly 27 acres built in 1995 in Huntindgon, PA. This rural neighborhood was built before stormwater laws came into effect, and, therefore, does not have a stormwater management plan. It was built in phases on a hill of about a 3.5 percent slope. This slope, along with the volume of stormwater that runs through the neighborhood, causes major flooding issues. The flooding is perpetuated as the dominant hydrologic soil group of the area, D soil, is characterized by a high runoff potential and slow infiltration rate. The culvert that outlets the water from Cree Manor under Station Road and into Crooked Creek was not designed to support the inflow of stormwater volume that the neighborhood produces. In addition, the culvert has some functional issues as it its inlet is actually sloped upward, preventing water from getting through. Water backs up at the bottom of the neighborhood causing flooding. In addition, the fast flowing, large volume of water from the top of the development and the storage facility located there cause erosion issues and exacerbate the downstream flooding. The uphill development, Shenecoy Manor may also contribute to increases in water volume in downstream Cree Manor. The major issue at hand seems to be overall water volume and velocity. We will work to solve the flooding and erosion issues while balancing the limitations of the environment and keeping the homeowners in mind.

Community Partner Objectives:

Our community partner's objectives for the completion of this project are to quantify the volume of runoff and to determine possible solutions for reducing the amount of flooding. In addition, they would like us to quantify the water that is flowing under the culvert at the Station Road Intersection and to provide a solid argument as to why the State of Pennsylvania should come in and fix the insufficient culvert. It is also important to keep in mind that any solutions implemented need not only be for Cree Manor, but also perhaps for the uphill development, Shenecoy Manor. Any possible solutions should have cost and the benefit to the homeowners in mind.

Community Partner's preferred mode of communication:

___ Phone: (814-627-1890)

_X_ E-Mail: julie@walkertwp.comcastbiz.net

___ Text: N/A

Partner Responsibilities:

- Meet with student team to discuss project (one member of student team will be identified as contact to communicate with sponsor)
- Provide all relevant information regarding the project: data, background information, contact information of applicable resources/personnel if available, etc.
- Be available to answer questions and provide feedback to students and faculty
- Complete sponsor evaluation for student team at end of fall and end of spring semester

Description of Course:

BE 460 – Semester: Fall, Day: T 6:00-7:55 PM. BE 466W – Semester: Spring, Days: TR 3:35-5:30 PM. Department: Agricultural and Biological Engineering. College: Engineering. Enrollment: 47 (19 students on SCC projects)

Students will develop skills and techniques for managing and executing engineering design projects in the following fields: agricultural engineering, food and biological processing engineering, and/or natural resource engineering. Projects are sponsored by faculty, industry, or community initiatives and are structured to span two semesters. In the Fall semester, the emphasis is on classroom lectures and project proposal development. In the Spring semester, the emphasis is on hands-on laboratory activities, project execution, and report preparation. Project teams perform all facets of the design process. This includes problem identification, planning of the project, formulation of design specifications, development and evaluation of alternative conceptual designs, development of detailed designs, consideration of safety and design optimization, design implementation, design testing, and analysis and documentation of results. Students improve their writing skills through preparation and refinement of various documents including a design notebook, proposal, statement of work, design specification, status reports, and a final report. Students also present their results in other formats, including poster and oral presentations for both technical and non-technical audiences.

Course Information & Learning Objectives:

- Course Learning Objectives (list below)

The BE 460/466W course sequence is entirely project-based. In BE 460, student teams develop their project proposals and learn some tools that will help them execute their projects. In BE 466W, student teams complete and report on their design projects. Upon completing the courses, students should be able to:

01. Interact with a sponsor (supervisor, co-worker, client) to formulate equitable design criteria (time, cost, specifications) for a meaningful engineering project
02. Develop an action plan to complete the project on time and within budget
03. Conceptualize systems to satisfy design criteria
04. Analyze technical and economic merits of design alternatives
05. Work effectively in a team that includes co-workers, customers and vendors
06. Communicate well using verbal, written and electronic methods
07. Develop and improve writing skills
08. Demonstrate professionalism in interactions with colleagues, faculty, and staff
09. Demonstrate an appreciation of economic, global, societal, and ethical issues
10. Demonstrate knowledge of contemporary issues

- Estimated number of students involved in the project: 3-4
  - Roles of Student Team Members: Who is doing what?
    Brittany Ayers serves as the team's public relations representative. She is the point of contact for the sponsor and advisors. She also relays information from sponsors and advisors to the rest of the team. Kaitlyn Morrow serves as the scribe. She records meeting minutes including team assignments and also updates and populates an online meeting minute notebook for all to see. Mike Henderson serves as the librarian. He populates the team's online file with documents such as data, design plans, and scanned copies of physical documentation. Finally, Zach Kleuber serves as the team's historian. He finds and relays precedents to the

Cree Manor Stormwater

Sustainable Communities Collaborative, Fall 2016/Spring 2017

group. He also documented all existing conditions on site. The team works together to quantify, design, and find solutions to the problem at hand.

- Estimated number of hours for completion of the project: senior capstone design project that team will complete over two semesters (in spring, 4 hours per week of scheduled class time are for project work, plus additional time outside class)

University Responsibilities:

- Provide clear instruction to students about the project.
- Provide this PAF to students to help define the project, share information and helpful hints about project components;
- Share the date and time of the end of semester event with students and link to evaluation survey
- SCC will visit classes in the first weeks of the semester and conduct a mid-semester check-in with partners and faculty

Expected Deliverables & Timeline:

The project proposal (to sponsor and course instructors) will be submitted by December 12th, 2016. Starting on January 13th, the sponsor and course instructors will receive weekly memos, updating them on the status of the project. The final solutions proposal will be completed by April 7, 2017. Please see the following chart for specific dates and milestones by which different tasks will be completed.

Task Name	Start	End	Duration (days)
* Pre-development Analysis and Comparison	1/9/2017	1/20/2017	11
Delineate watersheds Pre-development	1/9/2017	1/13/2017	4
Delineate watersheds Post-development	1/16/2017	1/20/2017	4
Compare and explain changes	1/16/2017	1/20/2017	4
* BMP sizing and Design Calculations	1/23/2017	3/17/2017	53
Choose the size of all BMP's	1/23/2017	2/3/2017	11
Calculate design and impacts of BMP's	2/6/2017	3/17/2017	39
Compare different designs	3/13/2017	3/17/2017	4
* Placing BMP's	3/20/2017	3/31/2017	11
Where BPM's should be located	3/20/2017	3/24/2017	4
Explain why the chosen location	3/27/2017	3/31/2017	4
* Final Design and PowerPoint Presentation	4/3/2017	4/28/2017	25
Finalize design	4/3/2017	4/7/2017	4
Create PowerPoint slides	4/10/2017	4/14/2017	4
Practice Presentation	4/17/2017	4/21/2017	4
Presentation	4/24/2017	4/28/2017	4

* = milestones

PENNSTATE

sustainable... communities

Partnerships and Possibilities

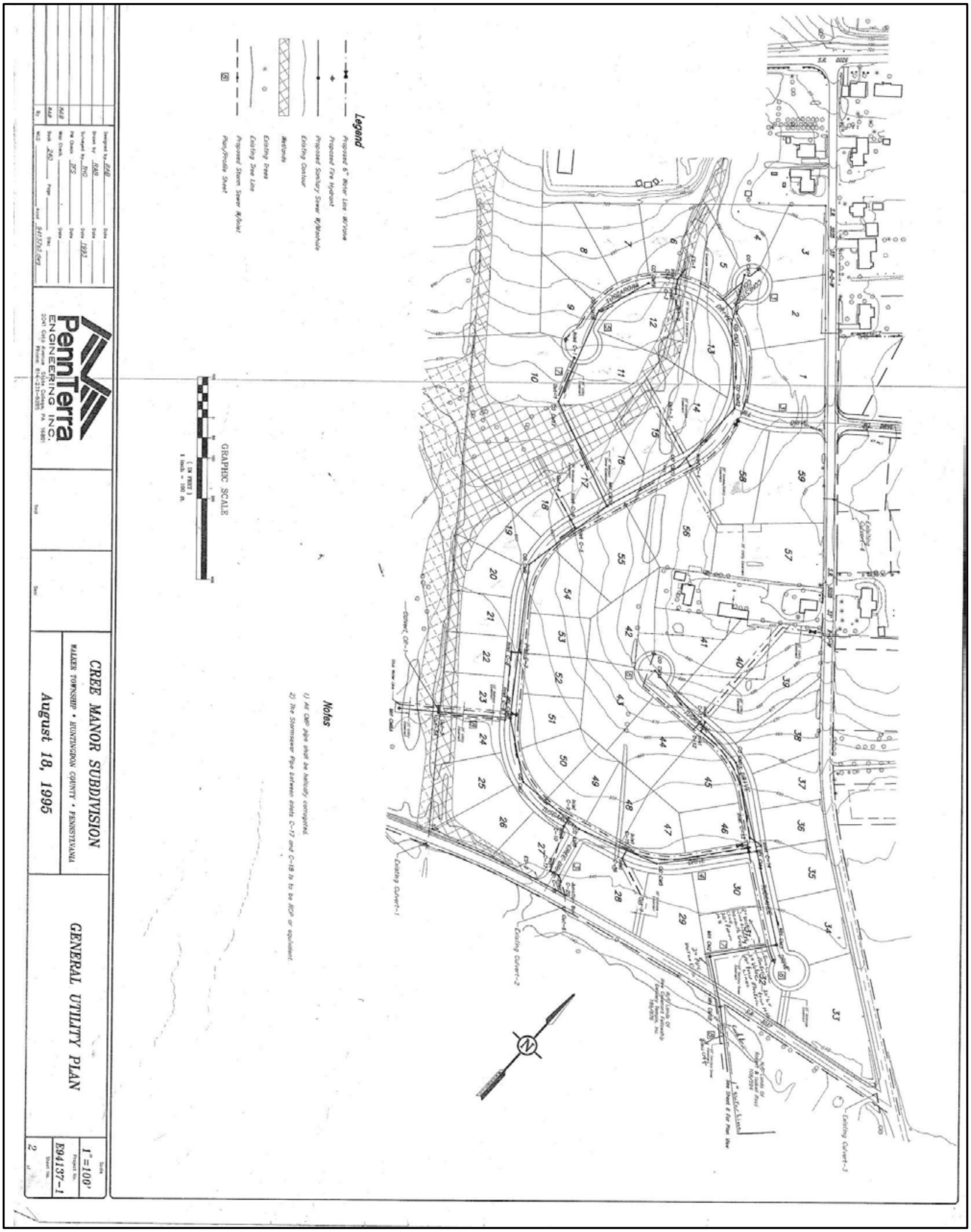
Cree Manor Stormwater

Sustainable Communities Collaborative, Fall 2016/Spring 2017

Timeline of Tasks

- **September**
  - Establish date and time for students and community partner to meet
- **November**
  - Complete project agreement/deliverables form by November 18th
- **December**
  - Attend the Campus & Community Sustainability Expo, Dec. 7, 2016 from 5 to 7 pm in the State College Borough Building (246 S. Allen Street)
  - Complete project proposal report and presentation by December 12th
- **January – March**
  - Complete design specifications report
  - Present poster to Industrial and Professional Advisory Council (IPAC)
- **April – May**
  - Present poster at Campus & Community Sustainability Expo, TBD
  - Complete final design report and presentation
  - Provide final deliverables to community project partner

Section VII


CREE MANOR SUBDIVISION
WALKER TOWNSHIP • HUNTINGDON COUNTY • PENNSYLVANIA
August 18, 1995
GENERAL UTILITY PLAN
1"=100'
E94137-1
PennTerra
ENGINEERING INC.
GRAPHIC SCALE
Legend
Notes