Community Conservation Assistance Program
Design Manual
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1.0 - Introduction

We first want to offer our gratitude and appreciation to all those that participated in developing this manual. The talented team at North Carolina State University's Biological and Agricultural Engineering Department developed the first manual, printed in 2007. Dr. Bill Hunt, Jon Hathaway, and Ryan Smith wrote the first manual that educated and trained well over 75 district employees and associates in the proper design and implementation of urban stormwater practices. Well over 800 practices were installed in more than 70 counties across the state with practices ranging from rain gardens to stream restoration. Our sincere thanks to this team for their work

This updated manual will serve to further the efforts made at the inception of the program. The contribution, dedication, and hard work from the team listed below will serve to further improve water quality benefits to important watersheds across the state from increasingly urbanizing areas. The continued success of this program can be attributed to the following individuals and entities:

***The Soil and Water Conservation Commission** – responsible for carrying out the Community Conservation Program, establishing priorities, dedicating funding, rules, and implementing the program:*

Vicki Porter – Cabarrus District - Chairwoman
Craig Frazier – Randolph District – Vice Chairman
Donald Heath – Craven District - member
Tommy Houser – Lincoln District - member
Charles Hughes – Lenoir District - member
John Langdon – Johnston District - member
Bill Yarborough – Haywood District – member

***The Division of Soil and Water Conservation Management Team** – responsible for carrying out the day to day programmatic actions established by the Commission:*

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Our most sincere thanks to those above for reviewing, commenting on, and improving this manual.

Introduction to the Community Conservation Assistance Program

In the past 4 decades, the population of North Carolina has nearly doubled to reach 9.5 million people in year 2010. As the population grows, this leads to a conversion of land to residential and commercial development and a decline in the number of farms statewide. North Carolina remains a leader in agriculture and the existing programs must continue, but providing natural resource conservation to the entire community becomes increasingly essential.

As the landscape of North Carolina continues to change, the role of soil and water conservation districts (districts) is also expanding to address nonpoint source pollution issues on non-agricultural lands. Increased population has led to stormwater runoff carrying nutrients, sediment, bacteria, and resulting water quality degradation. Districts are a crucial component in efforts to treat this runoff, and over 75% of districts are involved in some form of community conservation. Efforts include: sediment and erosion control, stormwater management, watershed education, and land conservation.

The North Carolina Division of Soil and Water Conservation (Division) addresses nonpoint source pollution from non-agricultural lands. The Soil and Water Conservation Commission (Commission) received authorizing legislation to establish the Community Conservation Assistance Program (CCAP) through Session Law 2006-78. CCAP is designed to improve water quality through the voluntary installation of various best management practices (BMPs) on urban, suburban and rural lands, not directly involved in agricultural production. Local districts provide educational, technical and financial assistance, and the Division and Commission administer the program. The CCAP program operates under the same guidance and accountability as the successful NC Agriculture Cost Share Program.

CCAP BMPs include: backyard rain gardens, cisterns, riparian buffers, stormwater wetlands, stream restoration, and more. Eligible landowners, including homeowners, businesses, local government, schools, parks, and others, may be reimbursed up to 75 percent of the cost of retrofitting these BMPs. CCAP focuses its efforts on retrofitting stormwater BMPs on existing land uses; it is not used to assist new development meet state and federal stormwater mandates. Districts have the technical expertise and a successful history of promoting voluntary conservation practices. The financial incentives encourage landowners throughout the community to incorporate water quality BMPs within their landscape where BMPs are not required by regulation.

Beginning in only 17 counties, CCAP funds were allocated to 70 soil and water conservation districts in PY 2012. Program funding is primarily derived from grants. Over $1.5 million has been received from the following sources: the NC Clean Water Management Trust Fund

(CWMTF), EPA's Section 319 Clean Water Act grant, the NC Coastal Federation, and the NC Attorney General's Environmental Enhancement Grant (EEG) Program. Since its inception, there has also been an annual State appropriation for CCAP, in the amount of $200,000 recurring funds, to include one full time position. District demand for CCAP still far exceeds the current funding levels.

As of November 2012, over 800 BMPs have been installed, expending over $2.0 million. The most popular BMPs include: rain gardens and bioretention areas, abandoned well closures, cisterns, pet waste receptacles, riparian buffers, stormwater wetlands, and stream stabilization and restoration.

1.2 The CCAP Best Management Practice Design Manual

The purpose of the CCAP Best Management Practice (BMP) Design Manual is to be a resource for soil and water conservation district employees in siting, selecting, designing, installing, and maintaining stormwater BMPs. This manual is intended to provide guidance for the implementation of effective water quality improvement practices while efficiently distributing funds throughout participating districts.

This detailed guidance serves as supplemental information to the existing BMP standards, specifications, and program requirements defined in the CCAP Program Manual. In addition, the annual CCAP Average Cost List provides further information on cost estimates and potential cost share reimbursement. These documents, along with any additional design tools, should be referenced in conjunction with the CCAP Best Management Practice Design Manual to fulfill the intentions of the program. These documents are found online at the Division of Soil and Water Conservation website.

2.0 Introduction to Stormwater

2.1 Definition of Stormwater

Stormwater is produced immediately following a rainfall event or as a result of snowmelt. When a rainfall event occurs, there are four potential fates for the precipitation: (1) infiltration into the soil, (2) plant uptake and transpiration, (3) evaporation (4) runoff from pervious and impervious areas. This final fraction is stormwater.

2.2 Effects of Urbanization – Impervious Surfaces

North Carolina's communities are considered among the best places to live in America; as a result, the state's growth rate is consistently one of the highest in the country. The resulting urban influx affects many facets of the state's infrastructure–more cars drive on our roads, more children enroll in our schools, increased population creates higher wastewater discharges, and more development necessitates stormwater runoff controls. How does urbanization affect stormwater runoff? Impermeable surfaces, such as roads, parking lots, sidewalks, homes, and offices replace the natural, and permeable, landscape. Rainfall that once soaked into vegetated areas is now transported as stormwater runoff. As more surfaces become impermeable, water simply runs off of them. Impermeable surfaces and storm sewers efficiently convey water to streams at greater rates and in larger volumes (Figure 2.1).

Figure 2.1 Stormwater runoff in a highly urbanized watershed.

There are many effects of this increase in impermeable area: (1) more stormwater reaches streams because there is less opportunity for it to infiltrate into the ground or evapotranspire; (2) peak flows increase because the impermeable surfaces rapidly transport runoff from large areas; (3) velocities in the stream increase, causing a larger erosion potential; and (4) baseflow is lower during dry weather due to a lack of infiltration into the underlying groundwater. Open areas with natural ground cover transfer approximately 50% of the annual rainfall to evapotranspiration, 25% of the annual rainfall goes into the shallow groundwater, 20% goes into deep infiltration, and 5% runs off. When urbanization occurs, about 35% of the annual rainfall is lost to evapotranspiration, 10% of the annual rainfall goes into the shallow groundwater, 5% goes into deep infiltration, and 15% runs off (Leopold, 1968; Swank and Crossley, 1988). Figure 2.2 illustrates the impact of urbanization.

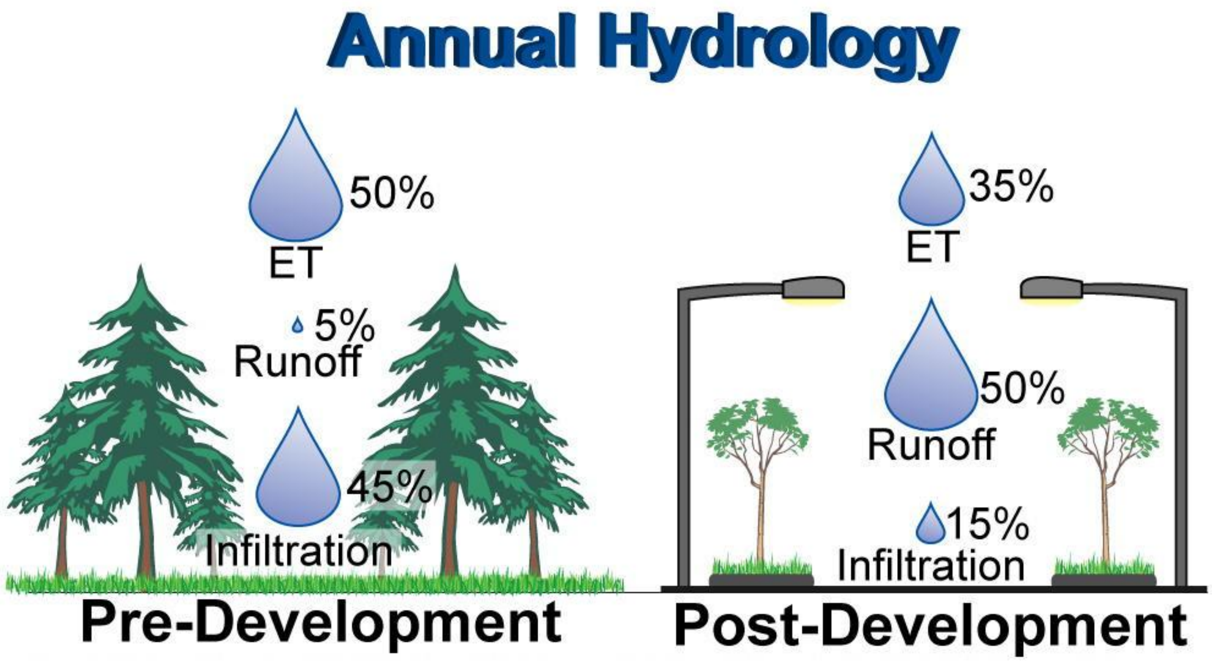

Figure 2.2 Watershed hydrology pre- and post-development (Swank and Crossley, 1988).

Using traditional analyses such as the Natural Resources Conservation Services' stormwater model, TR-55, or the U.S. Army Corps of Engineers' HEC model, the model shows that peak flows alone can increase by up to five-fold from pre- to post-development conditions. The public knows this effect of urbanization as flooding. While an increase in stormwater runoff is a conspicuous result of urbanization, there are many less visible water quality impacts associated with development. Erosion and sedimentation have long been recognized as water quality concerns. Although the North Carolina legislature passed laws to curb sediment pollution in 1973, sediment remains the number one pollutant of N.C. waters (Sutherland, 2002). In addition to sediment, metals and chemicals from vehicles and industries pollute stormwater runoff. Under forested conditions, these pollutants would only be found in trace amounts.

Nutrients are found in the urban environment in a variety of forms, one such form being fertilizer. Fertilizer contains nutrients for plants to grow, but excess fertilizer or fertilizer that is inadvertently applied to pavement harms water quality. Even if proper amounts of fertilizer are applied, nutrients can enter our streams in other ways, including atmospheric deposition, wildlife and pet waste, and septic system malfunction. There are numerous ways to reduce pollutant loadings, including source reduction–such as proper application of fertilizer and correctly maintaining septic systems. Structural devices can also help curb this problem. This manual will provide design guidance for several structural best management practices (BMPs) that can be constructed to treat runoff and thereby reduce the amount of pollution entering streams.

2.3 Connected Imperviousness

Impervious areas were discussed above in section 2.2; however, not all impervious areas substantially contribute to stormwater runoff in a given watershed. Impervious areas that immediately drain to a drainage system (such as a pipe or storm sewer) are considered to be "connected impervious" areas and more readily produce runoff within urban environments. For example, a rooftop that drains to a gutter which drains directly into a nearby street and into the street drainage would be considered "connected impervious." Conversely, if a rooftop drained onto a lawn where runoff would sheet flow across the grass, the rooftop would not be considered connected impervious. Runoff from disconnected impervious areas is routed to a pervious area where it has a chance to infiltrate. As a rule of thumb, if a rooftop or pavement is allowed to sheet flow for at least 30 feet before it re-concentrates (e.g. forming a swale or spilling into a drop inlet), it may be considered a disconnected impermeable surface.

Please note this is generalized guidance and the 30 foot area does not take into account soil type or treatment of lawn, etc. This determination will be site specific and need to incorporate the individual project site and landscape characteristics.

For the purposes of this manual's guidance, the differentiation between connected and disconnected impervious coverage is for informational and project prioritization purposes only. Connected impervious areas should receive priority project funding over disconnected impervious. Please note, sizing of BMPs with the Simple Method (Section 3.2) does not differentiate between connected and disconnected impervious coverage. The total impervious area is utilized.

2.4 Best Management Practices (BMPs)

An urban BMP is a method of treating or limiting pollutants in stormwater runoff. It can be as simple as applying the proper amount of fertilizer to a home lawn or as complex as building an engineered structure such as a stormwater wetland. Each BMP has certain conditions under which it will function properly. The pollutants to be treated, size of watershed, imperviousness of the watershed, local water table, and amount of available land for the practice all influence the selection of a BMP. Some of the BMPs are relatively well known and researched, while others are in their infancy. This document will focus on BMPs that can be installed in small-scale settings, such as individual residences and small businesses. The best management practices that will be discussed in this document are backyard rain gardens, backyard wetlands, cisterns, vegetated swales, impervious surface removal, and permeable pavements. Each of these BMPs can be valuable in treating the stormwater leaving a catchment. Guidance on BMP selection (based on site conditions) will be discussed in detail in the next two sections.

3.0 General Stormwater BMP Design Considerations

3.1 The First Flush

The term "first flush" has become common nomenclature in the stormwater management field. The concept behind this term is that pollutants that have collected on impervious surfaces will wash off during the first portion of a storm event. Essentially, the first portion of a given rain event will "flush" the impervious surface of its pollutants, resulting in stormwater runoff that contains more pollutants than runoff produced later in the storm. This theory involves capturing and treating the first half inch of runoff (or, the first one inch of rainfall) in a stormwater practice. About 90% of the pollutants leaving the site would be treated in this scenario (Schueler, 2000). Thus, capturing the runoff associated with 1 inch of rainfall was previously considered the standard for capturing the first flush in non-coastal portions of the North Carolina.

A study was performed by BAE for NCDENR to evaluate the first flush (or water quality event) in various locations throughout North Carolina (Bean, 2005). For the basis of this study, the water quality storm event was defined as the event size (in depth) which 90% of all storms are equal to or less than. Prior to the study, the water quality storm was considered to be 1 inch in all areas of North Carolina excluding Coastal Area Management Act (CAMA) counties. In CAMA counties, the water quality storm was considered 1.5 inches. Figure 3.1 shows a map of the CAMA counties in North Carolina.

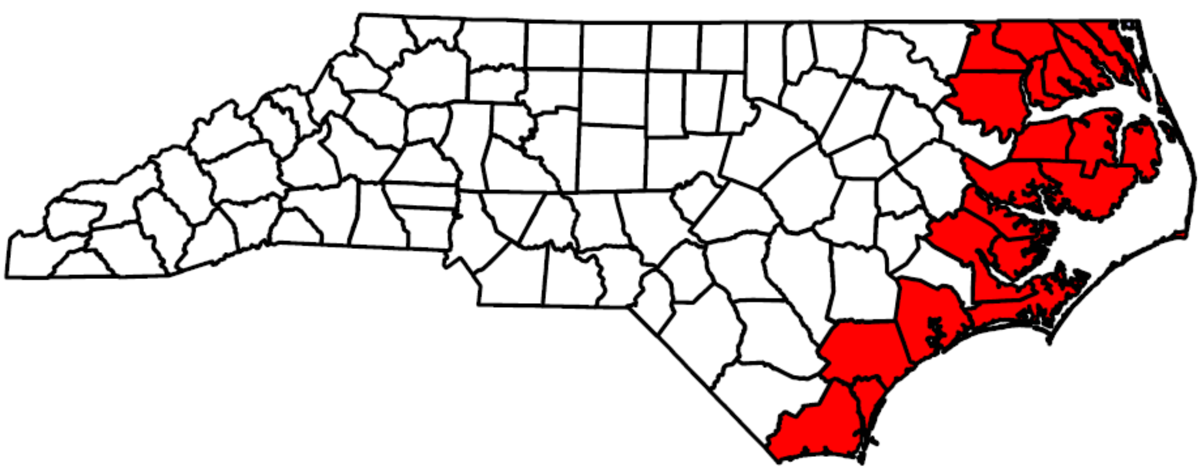

Figure 3.1 Map of CAMA counties in North Carolina.

Thirty years of rainfall data were analyzed from 9 locations in North Carolina. For most of North Carolina, capturing approximately 1 inch of rainfall would only result in capturing 80% of all the rainfall that fell on a given watershed. Likewise, in CAMA counties, 1.5 inches would result in capturing approximately 80% of all the rainfall. Because of the premise that the majority of pollution is carried in the earlier portions of the storm, it was assumed that at least 90% of pollution would be transported by the runoff produced by 80% of the rainfall. NCDENR considered these values to be acceptable based on this assumption, so the stormwater design standards remained the same. There are a few supporting studies in literature for this (Flint and Davis, 2007), but the theory has not been proven completely (Sansalone and Cristina, 2004).

3.2 The Simple Method

The water quality storm can easily be used to calculate the anticipated volume of runoff that will leave a given catchment through the application of the Simple Method (Schueler, 1987). The required information is as follows: (1) area that will be draining to the proposed BMP location in square feet, (2) the percentage of the drainage area that is impervious, and (3) the desired depth of rainfall targeted for capture (normally the water quality event, which is 1 inch except in CAMA counties, where it is 1.5 inches). The Simple Method is described in equations 3-1 and 3-2 below.

Equation 3-1: Calculate Runoff Coefficient

$$Rv = 0.05 + (0.009 * I)$$

Equation 3-2: Calculate Runoff Volume

$$V = Rv * A * (P/12)$$

Where:

Rv = Runoff Coefficient (fraction of rainfall that will produce runoff)
I = Impervious percentage in watershed (%)
V = Volume of runoff (ft^3)
A = Area that drains to BMP (ft^2)
P = Depth of storm to be captured (in)

Please note: "I" includes the total impervious percentage in the watershed and does not differentiate between connected and disconnected impervious area.

Figures 3.2-3.5 use the Simple Method to calculate the volume of water that can be expected from a given watershed; these values are calculated using water quality events of either 1 inch or 1.5 inches (as defined in figure title).

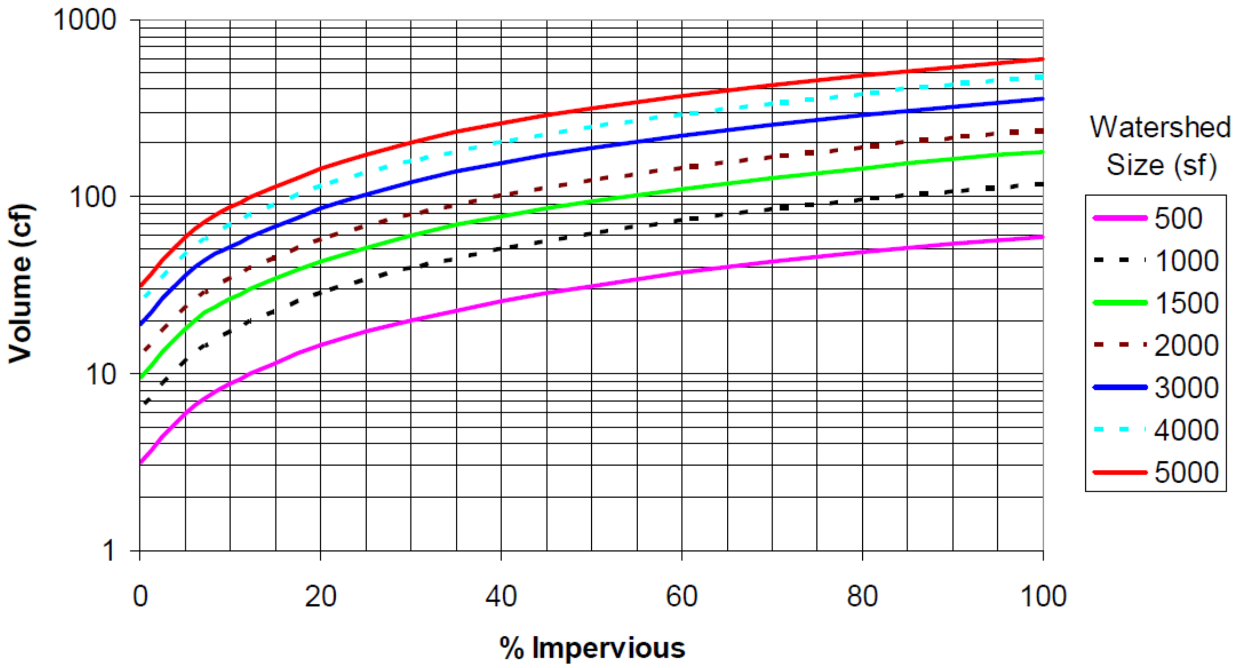

Figure 3.2 Estimated runoff volumes from watersheds <5000 ft^2 for 1-inch rainfall.

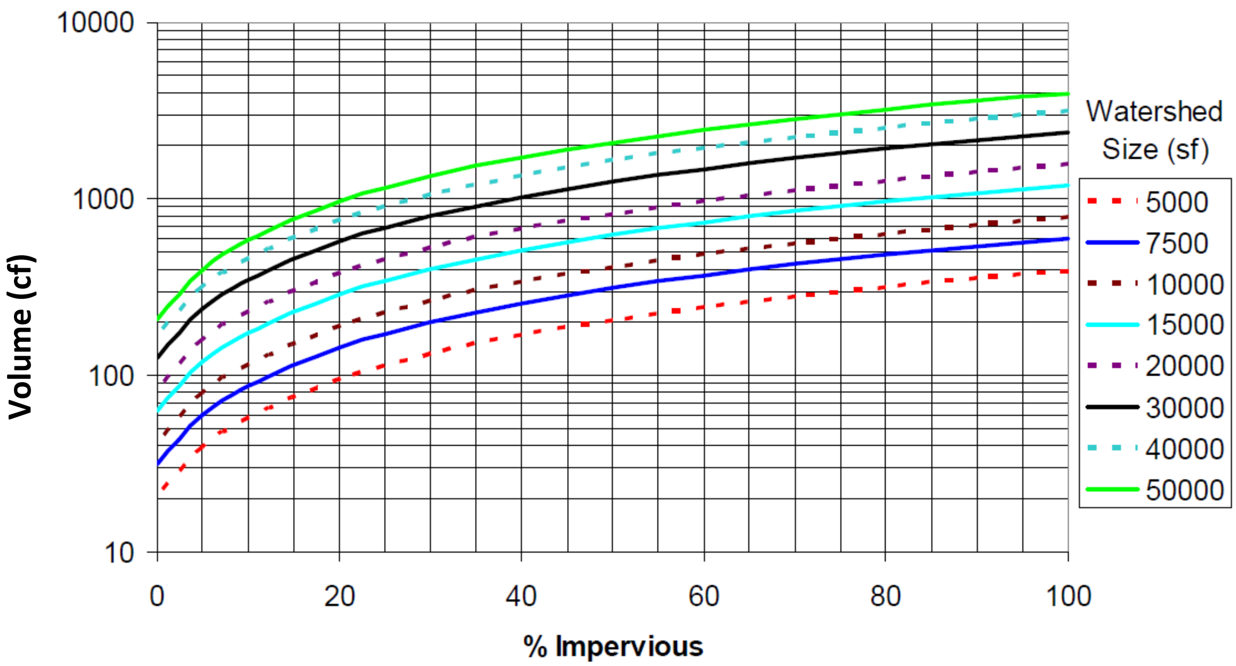

Figure 3.3 Estimated runoff volumes from watersheds >5000 ft^2 for 1-inch rainfall.

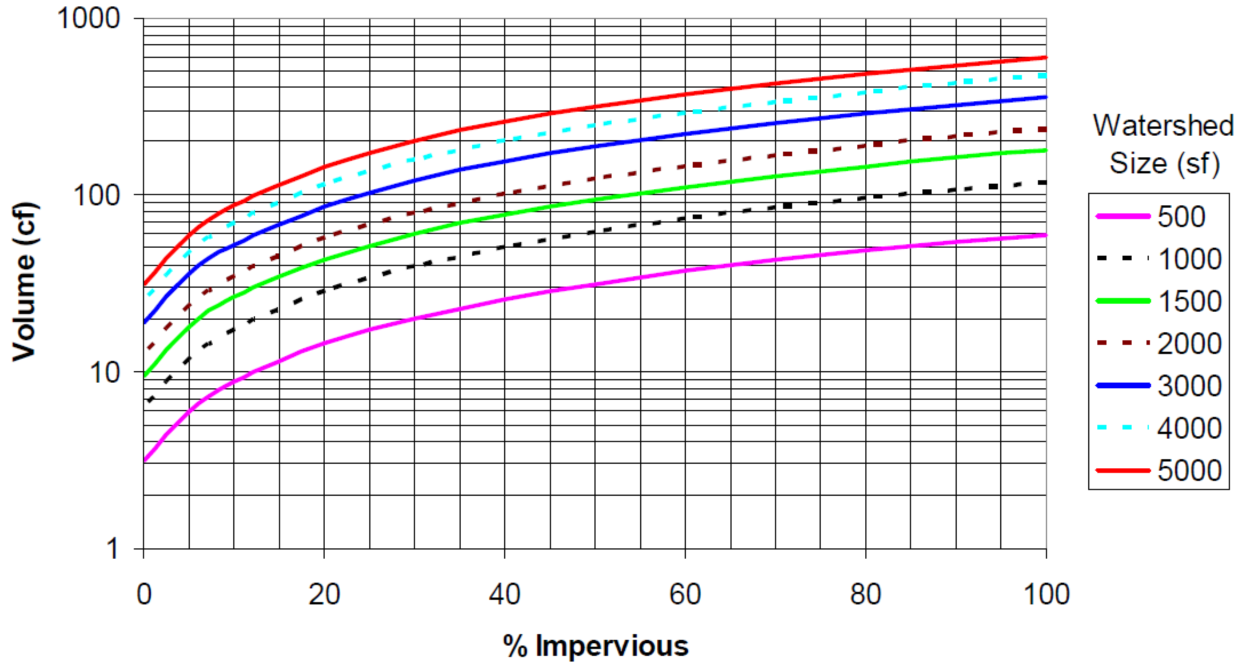

Figure 3.4 Estimated runoff volumes from watersheds <5000 ft^2 for 1.5-inch rainfall.

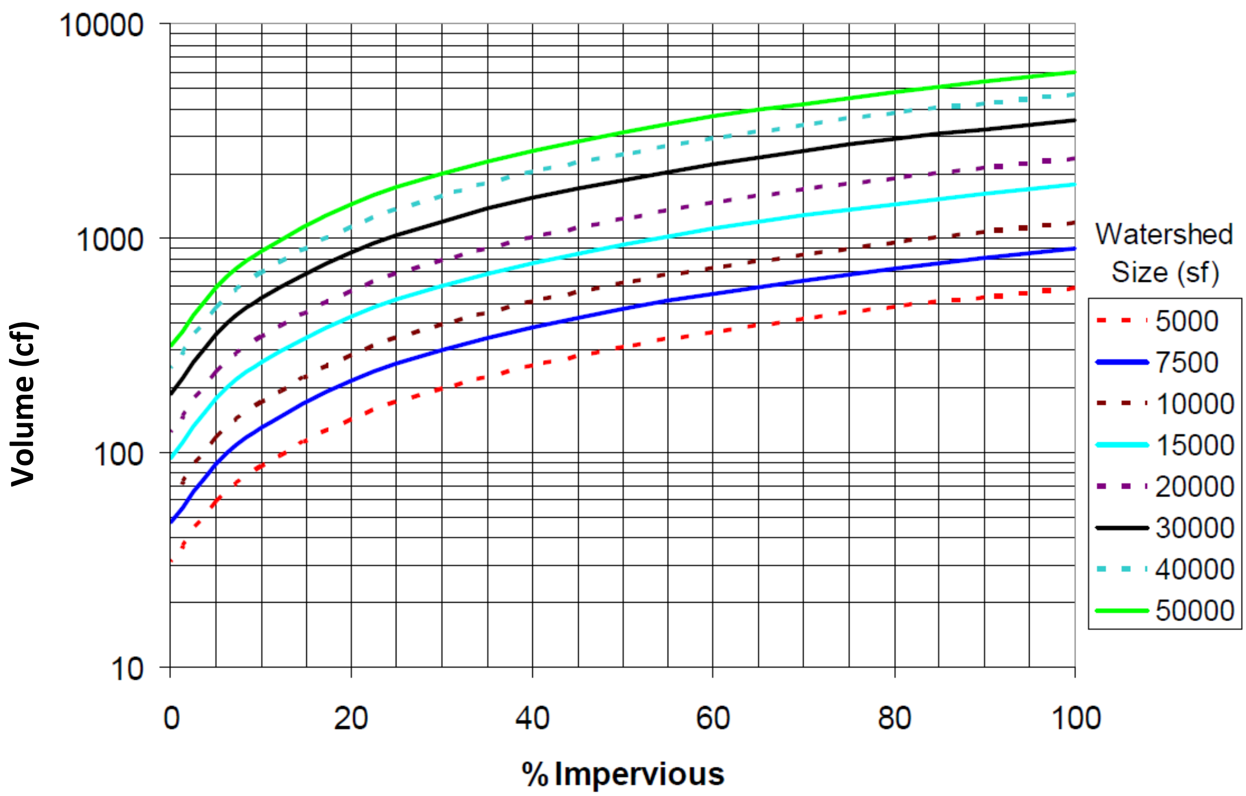

Figure 3.5 Estimated runoff volumes from watersheds >5000 ft^2 for 1.5-inch rainfall.

3.3 Peak Flow Rate

Determining the peak flow rate leaving a watershed during a design storm is important when designing many best management practices. The peak flow is the largest flow that leaves the watershed through the course of a storm event. Figure 3.6 shows a sample flow versus time relationship and the associated peak flow. The depth of rain that falls throughout the event can be observed as a bar graph with the rainfall depth on the secondary vertical axis.

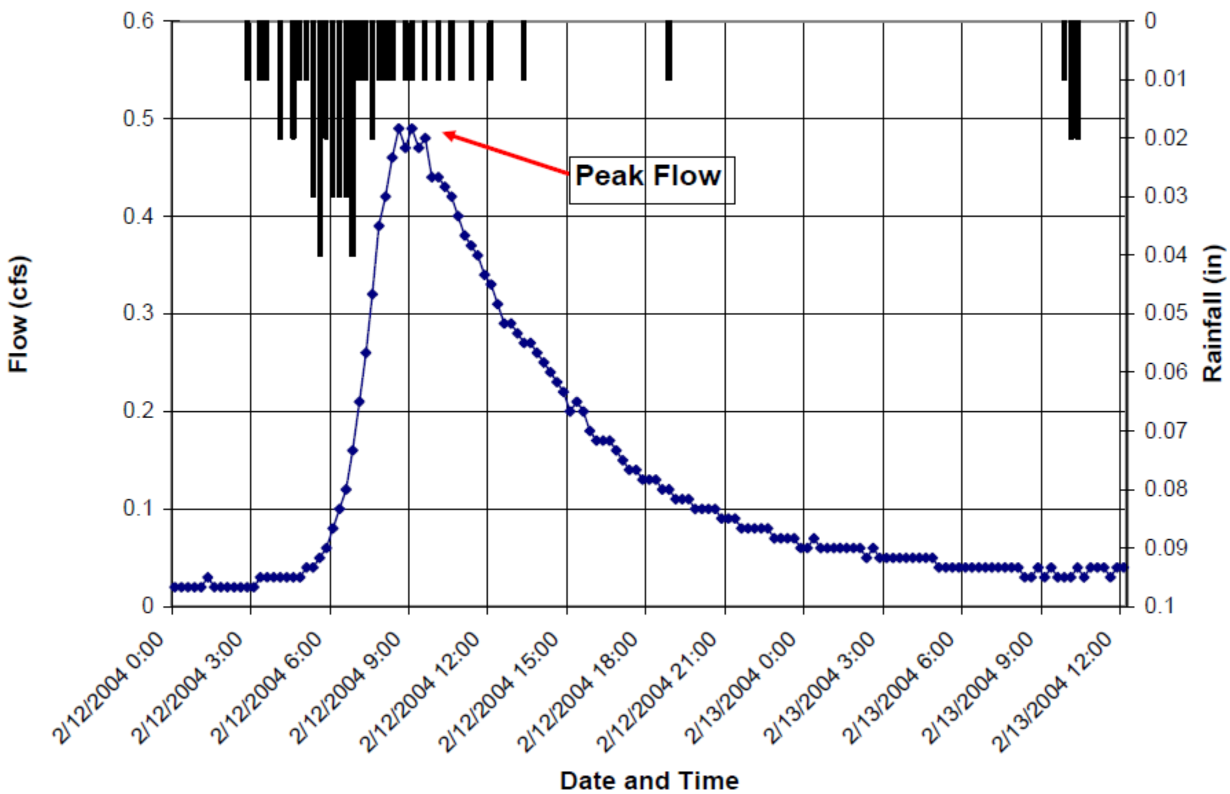

Figure 3.6 Hydrograph with peak flow rate emphasized.

The peak flow is used to determine the proper size of conveyances such as swales and drainage pipes and can also be used to determine the proper size of high flow bypass devices. Peak flow can be calculated easily using the Rational Method (Bedient and Huber, 1992). The Rational Method is a simple model used to estimate the peak flow from a given watershed. For applications such as backyard stormwater practices, where small, highly impervious watersheds will be treated, the Rational Method offers a somewhat coarse, but adequate, estimate of peak flow. The Rational Method is as follows:

Equation 3-3: Rational Method

$$Q = C \times I \times A$$

Where:

Q = Peak flow (ft^3/s)

C = Runoff Coefficient (dimensionless) – varies based on land use
A = Watershed area being treated (acres)
I = Intensity of storm event to be captured (in/hr)
(Note: There are 43,560 ft^2 in 1 acre)

3.3.1 Storm Intensity

The Rational Method is highly adaptable to various land uses, storm events, and watershed characteristics. For the purpose of this manual, some generalizations can be made to simplify the calculation. Rainfall intensity varies throughout the course of a storm. For small watersheds (those being treated by the backyard BMPs constructed as part of this program) stormwater from the far end of the connected impervious area does not have a large distance to travel to the BMP; thus, the time it takes stormwater to reach the BMP from all parts of the watershed is short. With these watershed characteristics, the peak flow from the watershed will be produced by the most intense portion of the storm. A short duration of high intensity rainfall is the most intense part of the storm; therefore, the amount of rainfall that falls during the most intense 5 minutes of the storm will be chosen as the intensity used in the Rational Method calculation. Table 3.1 shows the 5-minute peak intensity for various North Carolina cities for the 2, 5, 10, and 25-year storm events. Data from the city closest to the proposed BMP location can be used (Table 3.1) or further information can be gathered for a specific city by visiting the National Weather Service's Hydrometeorological Design Studies Center (http://hdsc.nws.noaa.gov/hdsc/pfds/orb/nc_pfds.html).

Table 3.1 Peak Intensity (in/hr) for Various Storm Events (5-minute duration).

Location	2-yr	5-yr	10-yr	25-yr
Asheville	4.78	5.75	6.48	7.45
Boone	5.71	6.64	7.42	8.46
Charlotte	5.66	6.59	7.26	8.03
Durham	5.69	6.53	7.25	7.97
Elizabeth City	6.11	7.02	7.96	8.98
Fayetteville	6.11	7.14	7.92	8.89
Greensboro	5.41	6.29	6.86	7.49
Greenville	6.18	7.12	8.04	9.07
Hickory	5.22	6.18	6.91	7.82
Raleigh	5.53	6.36	7.04	7.75
Wilmington	7.39	8.65	9.64	10.88
Winston-Salem	5.32	6.24	6.86	7.58

Source: National Weather Service.

3.3.2 Runoff Coefficient

Although it is assumed that the BMPs implemented as part of the CCAP will treat catchments that are primarily impervious (rooftops, driveways, parking lots), there will likely be other land uses associated with each watershed, such as landscaped areas, lawns, and other pervious areas. The rational method is versatile enough to account for both the impervious and pervious areas of each watershed.

that can be applied to a given watershed, a C value of 0.95 should be applied to all impervious areas, and a C value of 0.25 should be applied to all pervious areas. Equation 3-4 can be used to determine a C value that can be applied to the whole watershed.

Equation 3-4: Determine the Composite Runoff Coefficient

$$C = [((\text{Impervious Area}) \times 0.95) + ((\text{Pervious Area}) \times 0.25)]/\text{Watershed Area}$$

3.4 Routing Water to the BMP

In certain situations, a small "shoulder berm", "water bar" or similar mechanism may be required to route more water to a practice. These are earthen structures that are designed to intercept and direct stormwater to the BMP. They can increase the effectiveness of the BMP by allowing it to treat a larger watershed.

The side slopes should not be graded steeper than 2:1, and the height should not exceed 1 foot. If greater than a 1 foot height is required, PE approval is required. These installations can be covered with grass or mulch depending on the landscape and the expected runoff velocities. Erosion control matting should be used for cover while vegetation is being established.

Please contact a DSWC engineer for more information.

3.5 Determining Outlet Size

3.5.1 Determining Outlet Size

The outlet weir rectangular notch should be sized such that the berm is not overtopped during a 10-year storm event. The weir notch must be long enough to allow the peak flow associated with the 10-year storm to pass without the water rising high enough that the top of the berm is reached. To determine the appropriate length of weir notch to pass the 10-year storm, the weir equation can be applied. The weir equation is as follows:

Equation 3-9: Weir Equation

$$Q = C_W \times L \times H^{1.5}$$

Where:

Q = Flow (ft^3/s) – *Use peak flow from 10-year event*
C_W = Weir Coefficient (dimensionless) – *Use 3.0*
L = Length of Weir (ft)
H = Height of Water Over Top of Weir (ft) – *Use 0.5 feet*

The flow that should be passed is the flow associated with the 10-year event as determined using the Rational Method (Section 3.4). The weir coefficient is set to 3.0, and the height of the water over the top of the weir should be no higher than 6 inches (0.5 feet), so the water will not flow over the containment berm. As a result, the only unknown in the equation is the length of the weir. This equation can be rearranged to solve for the weir length:

Equation 3-10: Weir Equation

$$L = Q \div (C_W \times H^{1.5})$$

Sample 10-year peak flow calculations for various watershed scenarios are shown in Appendix A. Included is a required weir length for each watershed scenario.

3.5.2 Outlet installation

Appendix B shows a diagram of a wooden weir structure that could be used for an outlet control structure on large systems. For any type of outlet used, concentrated flows should only pass over a structure or undisturbed and vegetated soil. All wooden weir structures should be tied into the underlying soils. Soils filled around structures should be compacted and protected.

Note: *The engineers are working on consistent guidance regarding the use of an earthen vs wooden weir. It appears that the maximum velocities possible from a backyard practice's maximum drainage area would not require the need for a wooden weir. An earthen weir should be appropriate for most backyard practices.*

The one exception is that an earthen weir is only appropriate on natural ground where vegetation establishment is possible. A wooden structure may be required on some areas with fill material.

Proposed guidance for sizing of an earthen weir include:

- Always use a H (height of water over top of the weir) = 0.5 ft
- The minimum size (L) of a weir should be = 2 ft
- Always use temporary matting to assure vegetation establishment

4.0 BMP Siting

4.1 Avoid Concentrated Flow

Stormwater collects and concentrates very easily into depressions, swales, and natural runoff conveyances. Concentrated flow can also occur as water overflows from a backyard rain garden or wetland, or as water passes from a cistern that is filled to capacity. This can lead to erosion of berms, riparian buffers, lawns, or other ground cover.

If possible, backyard BMPs should be sited near or in the path of the current drainage way leading from the watershed being treated (Figure 4.1). The existing drainage path can also be utilized as a way to convey water away from the BMP when a storm produces overflow. If the drainage path is eroding, see section 8.0 for information on swale protection.

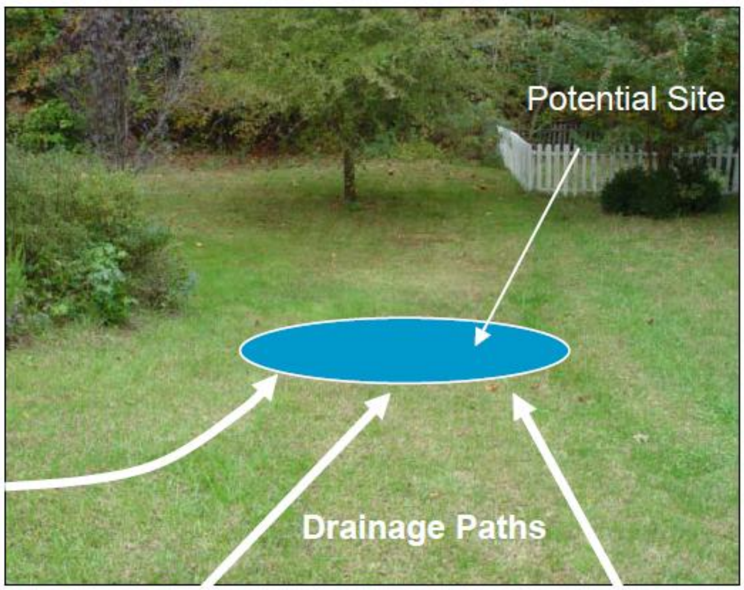

Figure 4.1 A low area in the drainage path provides a suitable location for a backyard BMP.

4.2 Multiple Property Owners

Before a site is chosen for a backyard BMP, the property boundaries should be clearly defined by a SWCD staff member. This is to ensure that no part of the stormwater practice is sited on property belonging to an individual not participating in the program. If an BMP is to be sited in such a way that multiple property owners will be impacted, all property owners should be contacted and should agree upon the project. Also, BMPs are designed to slow and capture stormwater as it leaves a property; thus a pool of water can form as water slows and enters the BMP. This pool of water should not extend to a neighbor’s property without consent. Typically, the downstream property owner usually benefits from their upslope neighbor’s installation of backyard BMPs, which bring about a potential reduction in flooding and erosion on the downstream owner’s property.

4.3 Considerations for Backyard BMP Siting

4.3.1 Topography and Drainage

The preliminary step in any backyard stormwater practice design is to determine the flow paths of stormwater on the property. There are a number of ways that this could be achieved: (1) observe the site during a rainfall event to determine surface flow patterns, (2) use a GIS contour map to determine flow paths, or (3) survey the topography of the site with a site level, laser level, or total station. Flow paths are especially important for impervious surfaces such as rooftops and driveways. Flow direction on a rooftop will be easy to observe on most houses and businesses, where the eaves of the roof will determine which direction water flows. This can be determined from an aerial map or from a site visit. A GIS contour map can be useful for initial investigation, but should not be trusted without some site investigation to corroborate its contours. The best methods to determine site topography are to observe flow paths during a rain event or to use survey equipment to create a topographic map of the site. Installation of backyard stormwater practices should always utilize existing topography and drainage patterns; this will require less grading or digging, reducing cost.

4.3.2 Downspouts

The location of downspouts is extremely important when locating a stormwater practice. Downspouts form small catchments on rooftops. During site reconnaissance, locations of downspouts should be marked on a site map, so that separate rooftop catchment sizes can later be determined. Based on site topography, flow paths for each downspout can be determined. An attempt should be made to capture the largest number of downspouts in a backyard stormwater practice. It may be possible to use corrugated plastic pipe extensions to direct water from a downspout directly to a stormwater practice, either above or below ground (Figure 4.2). In order for this to be possible, the installer must make sure that there is a slope from the downspout to the stormwater BMP, so that the corrugated plastic pipe drains between storm events. This is important for mosquito prevention. It may also be possible to re-route existing yard inlets to a stormwater practice. Typically, this will be completed by using a “pop-up” in the BMP, where water trickles out into the BMP. Again, there must be a slope from the bottom of the pipe to the top of the “pop-up,” to allow for the pipe to drain (Figure 4.3).

Figure 4.2 Using corrugated plastic pipe to deliver stormwater to a backyard rain garden.

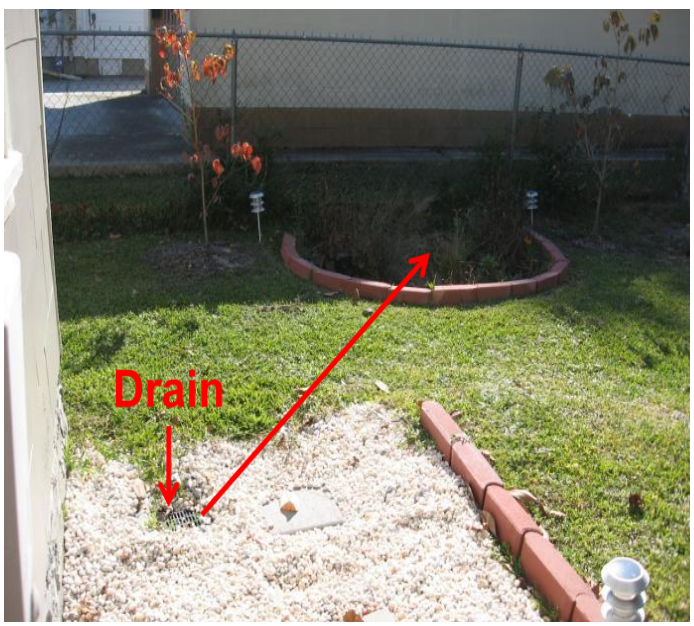

Figure 4.3 Using an existing yard inlet to deliver stormwater to a backyard rain garden.

4.3.3 Surface Ponding

Observe the site for surface ponding or points of collection after a rain event. If surface ponding occurs in an area for more than 3 days after a rain event, it may be a good location for a pocket wetland. Locations of surface ponding are destinations of surface runoff. Potentially, a rain garden could be placed between the runoff source (a rooftop or other impervious area) and this ponded area (the destination).

4.3.4 Existing Landscape
Working with the existing landscape is extremely important when constructing a backyard BMP. Specifically, this will help to reduce the time and effort that construction requires. It will result in less digging (either by hand or with an excavator), which can be a substantial time saver. Working with the existing landscape, as opposed to attempting to change it, will also result in substantial cost savings.

4.4 Constraints for Backyard BMP Siting

4.4.1 Utilities
It is important to consider utilities any time a stormwater practice is installed. Before a design has been created, the utilities on site need to be marked. The North Carolina one-call center can be reached by calling 811. Stormwater practices that infiltrate water (permeable pavement and rain gardens) should be located more than 10 feet from a wellhead and not uphill of the wellhead.

4.4.2 Basements, Crawl Spaces, and Septic Systems
For practices designed to infiltrate stormwater, it is important to consider what this near-surface groundwater may impact. For instance, a homeowner should not install a rain garden near their home's foundation, basement or crawl space. This precaution is to avoid flooding these spaces. Also, septic drain fields are designed to treat a certain volume of water per day; infiltrating water into the drain field has the potential to overtax these systems. For these reasons, it is recommended that an infiltrating stormwater practice be located at least 10 feet from a home's foundation, basement or crawl space and at least 25 feet from a septic drain field. These practices should never be located upslope from these areas.

4.4.3 Soil Type
Best management practices are impacted significantly by the soil in which they are constructed; therefore, it is important to know which soil types are present at a given location before designing or constructing a stormwater practice. Soils underneath backyard practices that rely heavily on infiltration (rain gardens and permeable pavement) must drain within 48 hours of a rain event; further details are provided specifically in the rain garden, backyard wetland, and permeable pavement sections of this document. In North Carolina, the presence of a substantial clay fraction precludes using soils from many parts of the state as the underlying soil for permeable pavement (As discussed in section 10.2, the need for infiltration in the underlying soils of permeable pavement prohibits its use in locations other than the Coastal Plain and Sandhills). Conversely, BMPs that require saturated soils to maintain function and plant vitality, such as backyard wetlands, require that water be easily accessible to plant roots via the water table or that poorly drained soils at the site will hold the captured stormwater long after a rain event (Section 6.0). When a site is evaluated for BMP implementation, determining the soil type can be performed by collecting information from soil surveys and, most importantly, from field inspection.

Generally, the soil types that are present from the soil surface to 36 inches below the soil surface are the most crucial for backyard BMP siting. If the soils in this range (0 – 36 inches deep) mostly consist of sand or loam, they may be suitable for backyard rain gardens. If the soils in this range consist primarily of sandy soils, they may also be suitable for permeable pavement (only install in Coastal Plain or Sandhills). Lastly, if the soils in this range consist primarily of clay, they are potentially suitable for backyard wetlands.

4.4.4 Water Table

The location of the seasonal high water table is an important factor in determining which BMP would be best for a particular location. This is an evaluation of the highest consistent level that the water table reaches with respect to the ground surface during the year. When soils are observed that have a grey matrix and contain brown or orange mottles (spots of color), this soil is likely in contact with the water table for extended periods of time. If the seasonal high water table is found within 2 feet of the ground surface, the site is likely not a good candidate for certain best management practices (rain gardens and permeable pavement). If such conditions exist at a site, a backyard wetland may be a more appropriate BMP choice.

4.4.5 Watershed Stability

A stormwater feature, such as a pocket wetland, a rain garden, or permeable pavement, needs a stable upslope watershed in order to maintain long-term functionality. If not, the systems will clog and will require arduous maintenance, including removal of all silt and sediment. Observe the areas that are upslope of your chosen location for a BMP. Are there areas of bare soil? Is construction ongoing (Figure 4.4)? If so, construction of the stormwater practice should be postponed until the upslope watershed is stabilized. This is especially important for permeable pavement and rain gardens, where infiltration is needed in order for the system to function.

Figure 4.4 Example of an unstable watershed contributing sediment.

4.5 Determining Outlet Location

Close attention should be paid to where the water from an BMP exits a property. During small rain events, depending on soil conditions, all the stormwater produced in a small catchment may be retained in the BMP. However, the BMP will also experience larger rain events that overload it with stormwater. During these events, the stormwater practice will fill to capacity and overflow into the adjoining area. Special care should be taken to ensure that the area to which the excess stormwater spills is able to convey the stormwater safely to a nearby drainageway (such as a culvert or swale).

The easiest way to allow excess stormwater to leave a property is to direct it into the existing drainage pathways. For instance, if a roof drain leads to a swale which routes the water off the property, an BMP could be placed in the path of the swale, whereby small amounts of runoff are retained and treated and stormwater from larger storms flows out of the BMP and continues through the swale.

Other drainage conveyances can be used to safely allow large stormwater volumes to leave a property, such as yard inlets, swales, and ditches. In some cases a swale must be constructed between the BMP and the closest natural drainageway to allow proper drainage of the system. More information on swales is available in section 8.0.

When berms are used to retain stormwater (a common practice in rain garden and backyard wetland design), there is opportunity for the berm to erode if the BMP fills to capacity and spills over the berm. In these cases, it is good practice to design and protect a spillway from the additional stormwater.

An opening in the berm (a weir) should be constructed where the stormwater will be conveyed out of the system. A piece of hardwood with a rectangular notch cut in it can be installed in the berm in this opening so the stormwater passes over a stable edge. This lumber acts as a weir to spread the flow, thus reducing velocities.

Additionally, a compacted soil weir reinforced with erosion control matting and vegetated with grass may be used for smaller, backyard practices. More information on BMP outlet design and construction is given in Section 3.5.

4.6 Riparian Buffer Considerations

Many regulations have been implemented to improve the quality of surface waters in North Carolina, including the riparian buffer rules detailed by the North Carolina Division of Water Quality in the “Redbook” of surface waters and wetlands standards (Administrative Code 15A NCAC 02B .0100, .0200 & .0300).

These rules state that a 50 foot riparian buffer should be maintained around surface waters in the Tar-Pamlico Basin, Neuse River Basin, the main stem of the Catawba River, and in the Randleman Lake watershed, among others; all these water bodies being nutrient sensitive. The purpose of these rules is to make use of the inherent ability of riparian buffers to remove nutrients and other pollutants from stormwater runoff. These riparian buffer rules can impact the function and siting of a backyard stormwater BMPs.

When siting a backyard BMP in one of the nutrient sensitive watersheds described in the NCDWQ Redbook, a measurement should be made perpendicular to the stream from the stream bank towards the area being considered for the BMP. No part of the BMP should be located within this 50 foot boundary. Additionally, backyard swales cannot be constructed in the riparian buffer. Only existing swales can be utilized to route water through the riparian buffer.

The riparian buffer rules not only include a requirement to maintain a 50 foot buffer along the stream bank, they also require that stormwater released into the buffer be diffuse in nature. This means that in systems where water will be collected and dispersed through an outlet (wetlands, rain gardens, etc.) the outlet should be designed to spread the water out as it enters the riparian buffer. No newly constructed channel should be used to convey the water into the buffer, instead, a large weir or berm can be used. The North Carolina Division of Water Quality – 401/404 Wetlands Unit should be contacted for additional information should a newly constructed drainage way be necessary. General level spreader guidance is found in Hathaway and Hunt,
2006 and Winston et al. 2010 (Appendix C), and online via the North Carolina Division of Water Quality – Wetlands and Stormwater Branch (http://h2o.enr.state.nc.us/ncwetlands). Avoiding the installation of CCAP projects in areas adjacent to riparian buffers is generally recommended. If a project is located in a watershed with protected riparian buffers, the BMP discharge should be routed into any existing drainage ways if at all possible.

5.0 Backyard Rain Garden Design

5.1 Overview of Practice

A rain garden (a small bioretention area) is a depressed area in the landscape designed to retain and infiltrate stormwater runoff (Figures 5.1 and 5.2). Rain gardens offer an attractive, versatile and multi-functional option for stormwater treatment. Rain gardens can sometimes be installed without the help of heavy equipment although a small excavator is beneficial in many cases. Surface ponding should not occur for more than 3 days in a rain garden, wetter systems would be considered “backyard wetlands”. Rain gardens are typically planted with a combination of trees, shrubs and perennials and mulched. Grass can also be used as cover without other vegetation or along with trees, shrubs or perennials. Cover and layout of rain gardens can be very flexible.

Figures 5.1 & 5.2 A completed rain garden in Oak Ridge, NC (left) and Wilmington, NC (right).

5.2 Rain Garden Siting

5.2.1 Choosing a site

There are a number of siting concerns regarding rain gardens. Rain gardens should ideally be located between the source of runoff (roofs, driveways, sidewalks, etc.) and the runoff destination (storm drains, streams, low spots, etc.). The lowest spot in a yard, or an area that stays wet for extended periods of time after rainfall events, is not a suitable location for a rain garden. These locations are better suited for backyard wetlands. It is best to locate a rain garden so that it will intercept the water quality volume during storm events and convey overflows to existing drainage structures or paths (Figure 5.3).

Figure 5.3 Locate rain gardens between the runoff source and its destination (an existing storm drain).

To avoid damage to buildings and building foundations, rain gardens should be located at least 10 feet away from structures. For buildings with a basement or crawl space, rain gardens should only be located lateral to or downslope of the building. If a building is built on a slab foundation (no basement and no crawl space), the rain garden may be located uphill, but should still be at least 10 feet away. Additionally, the rain garden should be located lateral to or downslope of septic system drain fields and well heads with a minimum 25 feet of separation. Rain gardens should be sited to avoid conflicts with utilities, which should be located and marked prior to construction. Finally, for the best plant growth, the rain garden should be located in an area that receives partial to full sun exposure.

5.2.2 Rain Garden Soils

Soils with moderate to good permeability must be present in order for a rain garden to function properly. At each location that meets the siting requirements above, dig a 1-foot deep hole. Fill these holes with water, let them drain, and then fill them again. Record the drainage time for each test hole.

If the hole drains in less than 12 hours, the site is suitable for a quick-draining rain garden. If the drainage time is between 12 hours and 3 days, the site is suitable for a standard rain garden. If the hole takes longer than 3 days to drain, the practice should be designed as a backyard wetland (Chapter 6). See the table below.

Infiltration Test: The Results

Drain Time	Appropriate BMP
< 12 hours	Quick-Draining Rain Garden
12 hours – 3 days	Standard Rain Garden
> 3 days	Backyard Wetland

Please note: These are backyard rain gardens and backyard wetlands. Larger bioretention areas and stormwater wetlands require design and approval by a Professional Engineer (PE). If the area of impervious surface draining to the BMP exceeds 2500 square feet, the engineered practice is required, along with design approval by a PE.

For sites located in a floodplain, a low-lying area, or east of Interstate 95, an additional test is highly encouraged to determine the height of the water table and check for the presence of wetland soils.

Wetland soils and/or a high water table will limit drainage from the system between rain events. A visual analysis of the subsurface soil is sufficient when checking for a high water table. Dig a hole 2 feet in depth. Soils with a grey matrix with brown or orange mottles (areas of color) are indicative of areas where the soil is in contact with the water table for extended periods of time. As the soil is removed from the hole, it should be observed for these signs of saturation. The seasonal high water table is located at the depth where mottled soils are first encountered. If groundwater is encountered as the hole is being dug, the site very likely has a high water table (Section 4.4.4). Seasonally high water tables are described in greater detail in Richardson and Vepraskas (2001). Districts may also contact division technical services staff to assist with soil analysis, if needed. If water or indications of saturated soils are encountered in the 2 foot hole, the site is not suitable for a rain garden. A backyard wetland (Chapter 6) should be considered or another location should be selected.

The soil extracted from the 2-foot hole may be submitted to the NC Department of Agriculture and Consumer Services Soils Laboratory to determine if lime is necessary for proper plant growth. The soils test report should indicate the amount of lime needed (for more information on soils testing visit http://ncagr.gov/agronomi/sthome.htm). Fertilizer should only be applied to rain gardens during initial plant establishment, if it is needed at all based on the soils test.

5.3 Rain Garden Sizing

5.3.1 Determine watershed and impervious area draining to BMP
After a suitable location is chosen for the rain garden, the next step is determining the watershed area that drains to the proposed rain garden site. The contributing watershed should contain impervious areas such as driveways, sidewalks and/or rooftops. The best way to determine drainage patterns is to visit the site during a storm event. A visual analysis of the site during dry weather may also be used to identify landscape features that affect the flow of water (swales, hills, raised flower beds, curbs, etc.). Detailed topographic surveys are another method of revealing the direction of flow on the site. Using USGS topographic maps or online GIS mapping program contours should only be a preliminary method of determining drainage patterns, as they are not detailed enough at the site scale.

Rooftops are drained via gutters which may not drain to the proposed location. In this case, a pipe can be used to route water to the proposed location. The pipe should be sized to equal or exceed the cross-sectional area of the existing downspout. For example, if an existing downspout is 3" x 4", it has a total cross-sectional area of 12 in^2. A 4-inch pipe has a cross-sectional area of 12.5in^2, so it exceeds the area of the downspout and may be used to route the downspout to the rain garden. Use extreme caution when combining downspouts; again, make sure the cross-sectional area of the pipe is at least the total area of the contributing downspouts.

A rule of thumb for sizing downspouts is that there should be 1 inch of downspout per 100 square feet of roof. Downspouts that are undersized for the roof area will result in the roof runoff overflowing the gutter, reducing the expected volume of harvested water.

After any modifications are considered (such as routing rooftop drainage to the proposed area), calculate the watershed area and impervious area draining to the proposed location. Field measurements taken with a tape measure will suffice for determining the area draining to the BMP. GIS mapping programs can also be used to measure the area of the contributing watershed and the total impervious area.

Once these two areas are determined, calculate the percent impervious.
Percent impervious = (Impervious area / Total watershed area) X 100

5.3.2 Sizing the Rain Garden
Rain gardens should be sized to capture the first flush event. The runoff capture depth is the amount of rainfall that you want the rain garden to treat; usally 1 inch in North Carolina. Once the percent impervious has been calculated, the Simple Method (Section 3.3) can be used to determine the volume of water that will enter the BMP during the first flush event. The surface area required for the rain garden is the runoff volume divided by the ponding depth, which is the depth water will pond within the rain garden before overflowing. A depth of 6" is recommended, but may vary between 3" and 9". A depth greater than 9" is not recommended, as this risks becoming a safety hazard and decreases plant survival.

The depth of ponding in the rain garden can be selected based upon topography, available area and home owner preference. Shallow rain gardens (a smaller ponding depth) take up more surface area than deeper systems (a larger ponding depth). Keep in mind that the ponding depth of the BMP will affect the type of plants that can thrive, so if there is a particular preference of the plants to be used, the ponding depth should be selected accordingly.

5.3.3 Rain garden construction

Determine where utility lines are located BEFORE starting to dig. Although the N.C. one-call should have been called and utility lines located before the rain garden site was selected, this step should be repeated prior to digging. Talking with the landowner may also be helpful to identify utilities that are not marked by 811 (such as gas lines running to a grill, outdoor lighting that was installed by the homeowner, etc.).

Once it has been determined that the selected site is clear of utilities, mark the outline of the rain garden with paint, flags or rope (Figure 5.4). Consult with the landowner/homeowner when laying out the rain garden to ensure they are content with the location. The shape of the rain garden may vary greatly, so long as the area is equal or greater than the required size determined in Section 5.3.2.

Figure 5.4 Laying out the boundary of a rain garden with paint and flags.

A typical lawn has three soil layers: sod, topsoil and sub-soil. If sod is present on the site, remove this by skimming a shovel just below the root mat of the sod. Place the sod aside – it can be used for the berm or weir. Next, remove any and all topsoil and stockpile for later use. Finally, the ponding area of the rain garden can be excavated. Digging may be done by hand or with heavy equipment (backhoe, etc.). The depth of excavation (after the removal of sod and topsoil) should be the chosen ponding depth (discussed in Section 5.3.3), plus as additional 3” to account for mulch. For example, excavation for a rain garden with a 6” ponding depth would be a total of 9” (6” for ponding depth, 3” for mulch).

After excavating to the appropriate depth, use a tiller, backhoe bucket teeth or other implement to break up the underlying 4”-6” of soil. Mix in the topsoil that was removed from the area prior to excavation. This increases infiltration and helps plants survive. If the results from the soils test performed (discussed in Section 5.3.1) indicate that lime is needed to raise the soil pH, lime should be mixed in at this time also.

5.3.4 Berm construction
The excess soil from excavation can be used to create a berm around the downslope side of the rain garden. A berm is an earthen dam used to hold water inside the garden. A berm can help reduce the amount of excavation necessary and can also help tie a rain garden into a sloped surface. When constructing the berm, place soil in 4”-6” lifts and compact tightly.

It is strongly recommended that the berm be planted with sod to assure proper stabilization. Seeding and mulching the berm may be appropriate and more cost effective, but care should be taken to assure that proper ground cover is established due to potential difficulties with establishing vegetation on fill material.

The berm should have a top width of 2-3 feet. The slide slope should preferably be 3:1 or a maximum slope of 2:1. The height of the berm should be 3-6 inches above the height of the water when the weir is flowing at its design depth.

Figure 5.5 Examples of a berm and a weir in a backyard stormwater practice.

5.3.5 Inlet protection and pretreatment
Water entering the rain garden needs to be slowed down prior to entering the ponding area to limit erosion of mulch and soil. Also, sediment carried by the stormwater will settle out when the water velocity decreases. There are several types of pretreatment:

- Direct flow into the garden as sheet flow over a vegetated surface, such as a lawn (Figure 5.6). This spreads the stormwater out, creating sheet flow, thereby avoiding concentrated flow and erosive velocities. It is important the vegetated area over which water is flowing is flat, as this is the only way to ensure sheet flow. To determine if an area is level, insert two stakes in the ground, one on each side of the area. Tie a string line between the stakes and attach a bubble level (sold at the hardware store) to the string line. Keeping the string taught, adjust the stakes until the string line is level. The ground may then be graded (either cut or filled) to meet the elevation of the string.

- Water can be introduced into the rain garden via a vegetated swale, which aids in slowing water down, allows infiltration to occur, and settling of sediment. See Section 8.0 for more information on designing swales.
- Measures may be required where flow entering the rain garden may cause scour and erosion. If this is necessary, these components would require approval by a PE
- A small forebay will allow stormwater to pool, settle out sediment, and dissipate energy before flow enters the main body of the rain garden (See Figure 5.7). These features should be used particularly in larger watersheds. The forebay may be either lined with rip-rap or sodded. During construction of the forebay, the berm that separates the forebay and the rain garden should be installed in 4”-6” lifts, with each lift well compacted. If using sod to vegetate the berm, the sod set aside during construction of the rain garden can be placed on the berm and staked down. If using seed, scarify the surface of the berm, sow the seed and cover with erosion control matting. Rip-rap berms are not recommended.
- A gravel verge is frequently used when space is limited or when stormwater enters as sheet flow from an impervious surface directly adjacent to the garden, such as from a driveway. Figure 5.8 shows a gravel verge and vegetated filter strip combination on the slope of a rain garden. The gravel verge consists of washed #57 stone placed over geotextile fabric. The grass filter strip is typically immediately downslope of the gravel verge; both should be at least 1 foot wide.

Figure 5.6 Stormwater flowing across flat, grassed slope before entering a rain garden.

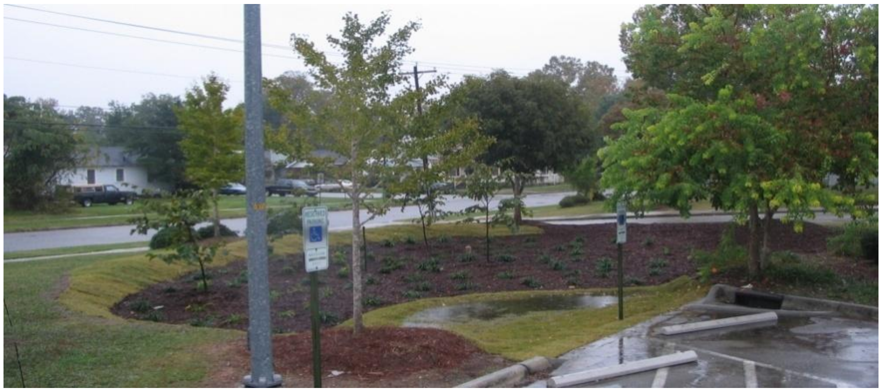

Figure 5.7 Rain garden in Wilmington, NC with a small forebay.

Figure 5.8 Examples of a gravel verge and vegetated filter strip receiving sheet flow from a parking lot.

5.3.6 Outlet design

The outlet structure controls the ponding depth in the rain garden. It also should allow overflow to exit the rain garden in a controlled, non-erosive manner. The most common outlet used for rain gardens is a weir, a flat opening in the berm of a rain garden (Figure 5.9). To determine how long the weir should be, the Rational Method (discussed in Section 3.4) should be used to calculate the peak flow rate from the watershed. The Rational Method requires rainfall intensity for a given design storm as an input. The design storm for rain gardens in the CCAP program is the 10-year, 5 minute storm. Using the peak flow rate, the minimum weir length can be determined using Equation 3-10. Section 3.7.1 discusses weir sizing in greater detail.

Figure 5.9 An example of a wooden weir installation.

Figure 5.10 Earthen weir immediately following installation.

Weirs may be wooden or earthen (Figure 5.9 and 5.10). An earthen weir is constructed by creating a flat length of lower elevation in the berm of the rain garden. The width of this opening should be at least the length calculated using Equation 3-10. Care should be taken to ensure the opening is level, as any low spots will lead to erosion. Lay sod over the weir and stake it down or seed the weir and cover it with erosion control matting. Sod is the preferable vegetative material for an earthen weir.

A weir may also be constructed of wood. This is a popular choice for larger rain gardens, as it is easier to construct a level weir out of wood than soil. Also, a wooden weir is stable immediately after construction, while an earthen weir needs vegetation to establish before becoming stable. To construct a wooden weir, dig a small trench, approximately 4”-5” wide and at least 2 feet longer than the minimum required weir size. Stack 4”x4” boards in the trench, caulking between them to prevent leaks. The top of the last board should be at the height of the ponding depth above the surface of the mulch. For example, in a rain garden that has a 3” ponding depth, the boards should protrude 3” above the mulch surface, thus allowing water to pond 3” deep before overflowing. Fill soil around the boards in 4”-6” lifts and compact tightly.

Appendix B describes another method of constructing a wooden weir structure that can be used for larger practices or practices receiving high flows. Typically, treated 2”x8” or treated 2”x12” will suffice. A weir notch will have to be cut into the uppermost board. Regardless of the board size, all structures should extend at least 6 inches below final grade at the base and 12 inches into the sides of the berm. The rain garden ponding zone should be designed so that no sensitive upstream areas (houses, driveways, etc.) are flooded because of the garden during any rain event.

Note: *The engineers are working on consistent guidance regarding the use of an earthen vs wooden weir. It appears that the maximum velocities possible from a backyard practice’s maximum drainage area would* ***not*** *require the need for a wooden weir. An earthen weir should be appropriate for most backyard practices.*

The one exception is that an earthen weir is only appropriate on natural ground where vegetation establishment is possible. A wooden structure may be required on some areas with fill material.

Proposed guidance for sizing of an earthen weir include:

- *Always use a H (height of water over top of the weir) = 0.5 ft (See Equation 3-9)*
- *The minimum size (L) of a weir should be = 2 ft*
- *Always use temporary matting to assure vegetation establishment*

Engineering Notes: *An earthen weir should be appropriate for most backyard raingardens. The height of water over the top of the weir (H, in Equation 3.9) = 0.5 ft. The minimum length of the weir (L in Equation 3.9) should be a minimum of 2 feet*

See the CCAP Rain Garden Checklist and Rain Garden Design Worksheets for more information on rain garden sizing and eligibility.

5.3.7 Plant selection

Rain garden plants should be selected based upon the drainage rate of the practice.
When the rain garden drains in less than 12 hours, the bioretention plant list in Appendix E can be used as a guide to plant selection. When the garden drains between 12 and 24 hours, the plants in Appendix F should be used. In each case it is good to use a variety of native plants for aesthetic value and to improve the chances of plant survival. In gardens that have deeper ponding depths or have slower drainage times, it may be helpful to place water-loving plants in the ponding zone of the garden and plants that prefer drier conditions in higher areas and on the banks. When planting shrubs or trees, it is recommended that they be planted ‘high’. In other words, when the plant is placed in the hole, the top of the root ball should be 1”-2” above the surface of the ground.

Grass may be used as an alternative to other vegetation or in combination with other vegetation. Warm season grasses (e.g. Bermuda, Centipede, Zoysia) are recommended in much of the state, but cool season grasses (Fescue, Kentucky 31) can be used in cooler climates or to match existing lawn. It may be necessary to re-seed the cell in the fall.
When using mulch, triple-shredded hardwood mulch is best. While all mulch floats, this type of mulch floats less than others (such as pine straw, pine bark nuggets, etc.). Mulch should be applied at a depth of 3 inches.

5.4 Rain Garden Maintenance

Inlet pretreatment devices such as vegetated swales, gravel verges, and forebays should be inspected regularly to ensure they are stable and functioning properly. If erosion within the rain garden is evident, further steps should be taken to slow down the incoming water and dissipate the energy. This can be done by installing rip rap or creating a small forebay. The outlet structure should be checked frequently to make sure it is functioning properly. Any and all sediment accumulated within the rain garden should be removed as soon as possible to prevent clogging. Trash and debris should be removed from the garden regularly.

Irrigating plants in the rain garden may be necessary during establishment and during periods of drought. Fertilizers should not be used in rain gardens, as sufficient nutrients for the plants are delivered from the watershed. Fertilizers may be used on the berm surrounding the garden to help establish vegetation. Take care not to over fertilize these areas, as excess fertilizer can wash into the garden. Weeds will need occasional removal. Pesticides are not recommended for weed control in rain gardens. Shrubs and trees need to be pruned annually.

Mulch may need to be replenished 1 or 2 times per year to maintain a depth of 3 inches and to keep weeds out. The depth of mulch should never exceed 3 inches. Mulch should be completely removed and replaced every 3 years.

See the CCAP Rain Garden Operation & Maintenance Plan for more information.

6.0 Backyard Wetland Design

6.1 Overview of Practice

A backyard wetland, also referred to as a “pocket wetland” or a “wetland garden,” is built in an area that is perennially moist. The wetland is designed such that it will usually be wet, even several days to several weeks after a rain event, and is constructed as an alternative to a rain garden. A typical backyard wetland will be a shallow, excavated bowl ranging from 3 to 12 inches deep. A variety of wetland vegetation is planted. It is essential that a variety of plants are grown in the wetland to avoid a monoculture, which provides good mosquito habitat. Wetland vegetation tends to grow densely. Pocket wetlands capture runoff from small watersheds such as an individual property. Figures 6.1 and 6.2 show a wet spot in a yard (an ideal location for a pocket wetland) and types of vegetation found in a backyard wetland, respectively.

6.2 Backyard Wetland Siting

Backyard wetlands should be located in a low area where stormwater naturally drains. The wetland should be sited near the current surface drainage system (the drop inlet or swale that currently drains the watershed). This will allow the designer to direct overflow offsite. There are a number of other siting concerns for backyard wetlands. To avoid contact between the infiltrated stormwater and any building foundations, a wetland should be located at least 10 feet away from building foundations. The wetland should be at least 25 feet away from a septic system drain field or a well head. Utility lines should be located and marked prior to any soil excavation. For the best plant growth, the stormwater wetland should be located in an area that receives partial to full sun exposure.

In general, backyard wetlands should be selected over other BMPs when site conditions involve poorly drained soils and/or high water tables. When an initial soil investigation is performed, if the seasonal high water table (Section 4.4.4) is within 2 feet of the soil surface, the site should be considered for a backyard wetland. Additionally, if the soil investigation shows the soils to be poorly drained (Section 4.4.3) the site will be more suitable for a backyard wetland than a rain garden. If a location on a property has standing water present for multiple days after a rain event, it is a strong candidate for a wetland. If the initial simplified soil infiltration test described in Section 5.3.1 results in the 1 foot deep test hole draining in more than 3 days, a backyard wetland should be constructed at the site.

Figure 6.1 A perennially wet spot in a yard is a good location for a pocket wetland.
Figure 6.2 This pocket wetland in Tarboro, NC, features vegetation such as lily pads, pickerelweed, and joe pye weed.

SWCD staff should evaluate sites with poorly drained soils extremely carefully.
The overwhelming majority of CCAP projects will be too small to impact jurisdictional wetlands; if wetland soils are detected on a large project (> ¼ acre), then the location should be evaluated by a member of the Army Corps of Engineers and/or the North Carolina Division of Water Quality – 401/404 Wetlands Unit for jurisdictional wetland status.

6.3 Backyard Wetland Design

Please note: If the impervious area draining to the BMP exceeds 2500 square feet, design approval is required by a PE and the design recommendations and BMP policies for a Stormwater Wetland are required.

6.3.1 Determining wetland watershed characteristics

In order to capture stormwater runoff from driveways and other associated parking areas, the drainage must naturally flow to the proposed location. Rooftops normally are drained via gutters which may or may not drain to the proposed location. To maximize drainage to the wetland, either a 4- to 6-inch plastic flexible pipe (see Section 5.3.2) or a diversion berm (Section 3.5) can be used to direct this water to the proposed backyard wetland location. After any modifications are considered (for example, routing rooftop drainage to the proposed area), the total area draining to the proposed location and the percentage of impervious area in the watershed should be calculated. Measurements taken with a tape measure can help determine the watershed area, as well as the area draining from driveways, patios, and parking areas. The rooftop area draining to the wetland can be measured manually or GIS maps may be used.

6.3.2 Backyard wetland sizing

Backyard wetlands should be sized such that the ponding depth of the captured runoff is no more than 9 inches. Sizing is completed in a similar fashion to rain gardens – the simple method can be used to calculate the volume of stormwater produced by the water quality event. The wetland surface area will simply be this volume divided by the ponding depth desired for the site.

In some cases, a property owner may desire a larger wetland; if so, the ponding depth can be as little as 3 to 6 inches. The shape of backyard wetlands will vary based upon topography, obstructions (e.g., trees and utilities), landowner needs, available space, and aesthetic appeal. In general, neither the length nor the width should be less than 3 feet. In general, a 6 inch ponding depth is preferred to the 3 inch, because this depth "guarantees" more contact time for water with the vegetation.

6.3.3 Backyard wetland inlet considerations

As stormwater enters the wetland from a pipe or swale, the energy of the stormwater can cause erosion. Placing a check dam in the path of the stormwater just before it enters the wetland will reduce the velocity of the water. This check dam can be constructed of rolled erosion control matting or with 6" – 8" nominal diameter rip-rap.

This may not be required in all situations; however, if the slope of the swale or pipe entering the backyard wetland is steep (>6%), erosion is likely to occur. Examples of check dams constructed of erosion control matting and rock are shown below in Figures 6.3 and 6.4.

Figure 6.3 Swale leading to BMP with check dams constructed of rolled erosion control matting.

Figure 6.4 Swale with check dam constructed of stone.
(Source – USDA – Natural Resource Conservation Service – Illinois)

6.3.4 Backyard wetland outlet considerations

Similar to rain gardens, the outlet structure controls the ponding depth in the backyard wetland and allows excess flows to exit in a controlled manner. The first step in designing an outlet structure is determining the peak flow of the desired design storm for the given watershed (typically the 10-year, 5 minute storm). Section 3.4 discusses the use of the Rational Method for calculating peak flow rate. A weir structure is commonly used for wetlands, with the weir length sized to safely pass the 10-year storm. During the peak flow of the 10-year storm, all higher velocity outflow should be in contact with the weir, not contacting soil composing the berm. Section 3.5.2 discusses weir sizing. Appendix B describes the layout and construction of a wooden weir structure. A compacted, soil weir may also be used, but needs to be well vegetated with grass or sod. See the rain garden chapter (Section 5.3.7) for more information on outlet weirs.

See the CCAP Backyard Wetland Design Worksheet for more information.

6.3.5 Backyard wetland plants

Wetland plants thrive in perennially wet environments. Most notably for backyard wetlands, water depth plays an important role in plant selection. For the purposes of the CCAP, these water depths will be divided into three groups: upland plants (not normally in contact with surface water – planted around rim of wetland where roots can access moist soil), shallow water plants (water depth between 0 and 4 inches), and deep water plants (depths greater than 4 inches).

A short list of plants which thrive in each environment is shown in Tables 6.1, 6.2, and 6.3. Additional plant choices are available, especially with regard to perennials. A local cooperative extension horticulture agent should be contacted for additional plant choices. In times of extreme drought, the land owner is encouraged to water the wetland as needed based on the condition of the plants. Most backyard wetlands will NOT retain water deep enough for a long enough period to support deep water plants. However, if after the wetland has been constructed the property owner observes 6- to 9-inch deep water reliably in the spring, summer, and fall, the plants listed in table 6.1 could potentially be incorporated into the planting scheme.

Some rules-of-thumb for backyard wetland plant selection include:
(1) Choose native species. Nearly all the species provided in Tables 6.1 through 6.3 are native to most of North Carolina
(2) Include evergreen vegetation to provide some color in the backyard wetland during the winter months
(3) Select a few species of plants with showy flowers, which will attract butterflies and dragonflies. This will add aesthetic appeal and provide an important mosquito predator (dragonflies).

Table 6.1 Sample deep water wetland plants.

Common Name	Scientific Name	Comments
American Lotus	*Nelumbo lutea*	Bold plant with foliage and flower stems standing 4' - 6' above water's surface. Large, showy yellow flowers produced throughout summer.
Spadderdock - Cow Lily	*Nuphar luteum*	Heart shaped leaves float on water's surface, 1"-2" wide, globe shaped, yellow flowers are born throughout summer
Fragrant Water-Lily	*Nymphaea odorata*	Rounded, heart shaped leaves float on water's surface. Large, white, sweetly fragrant flowers open throughout summer

It should be noted that if the water level in the wetland is not consistent and normally drains in between rain events, the deep water plants should not be used.

Table 6.2 Sample shallow water wetland plants.

Common Name	Scientific Name	Comments
Arrow Arum	*Peltandra virginica*	Elegant arrowhead shaped leaves and interesting green flowers on a clump forming plant
Pickerelweed	*Pontederia cordata*	Upright plant producing numerous 3' tall spikes topped with blue flowers all summer. Tough and attractive.
Lizard's Tail	*Saururus cernuus*	Spreading perennial that will grow in shallow standing water and wet soils. Pendant spikes of white flowers in late spring and summer.
Duck Potato	*Sagittaria latifolia*	Tough emergent aquatic with arrowhead shaped leaves and spikes of white flowers produced throughout summer. Reproduces rapidly.
Soft Rush	*Juncus effusus*	Common rush found throughout NC. 2' - 3' tall with dark green spiky foliage. Green flowers are to brown seed pods throughout summer. Near evergreen.
Woolgrass	*Scirpus cyperinus*	Large, 3' - 4' tall and wide clump forming bulrush producing wooly green flower heads in summer that age to an attractive rusty brown as seed mature

Table 6.3 Sample upland wetland plants.

Common Name	Scientific Name	Comments
Swamp Milkweed	*Asclepias incarnata*	Pink flowers in early summer. Larval food of monarch butterflies.
Joe Pye Weed	*Eupatorium fistulosum*	Masses of rosy-mauve flowers in late summer-fall attract butterflies
Swamp Sunflower	*Helianthus angustifolius*	Towers of 3" wide golden sunflowers in fall - attracts butterflies
Red Star Hibiscus	*Hibiscus coccineus*	Tough, clump forming, sturdy plant with star shaped red flowers in summer
Rose Mallow	*Hibiscus moscheutos*	Tough, durable plants with huge white, pink or rose flowers in summer
Cardinal Flower	*Lobelia cardinalis*	Tall spikes of crimson red flowers in late summer and fall - attracts hummingbirds and butterflies
Soft Rush	*Juncus effusus*	Common rush found throughout NC. 2' - 3' tall with dark green spiky foliage. Green flowers are to brown seed pods throughout summer.

6.4 Backyard Wetland Construction

6.4.1 Laying out the wetland

Once the wetland surface area has been calculated and a location has been selected, marking paint, string and rope, or flags can be used to lay out the perimeter of the wetland (Figures 6.5). The wetland dimensions will vary based on site conditions and landscaping preferences. The layout should be measured multiple times before digging to ensure that the surface area of the wetland is properly sized.

Figure 6.5 Mark wetland area prior to excavating the area.

6.4.2 Digging the wetland

After the wetland area has been laid out, digging can commence. Topsoil should be removed and set aside for later use. If the BMP is built on a slope, the remaining soil removed from the wetland area should be placed around the wetland perimeter to create a berm that will retain the stormwater (Figures 6.6 and 6.7). If it is not built on a slope, the entire BMP can be cut into the ground and no berm is required (Figure 6.8).

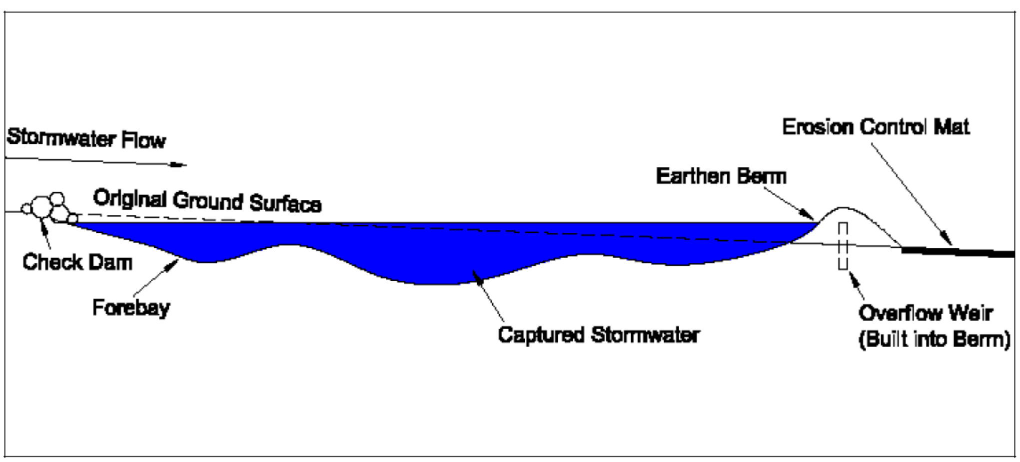

Figure 6.6 Illustration of backyard wetland constructed on 4% slope.

Figure 6.7 Berm construction at downslope edge of BMP.

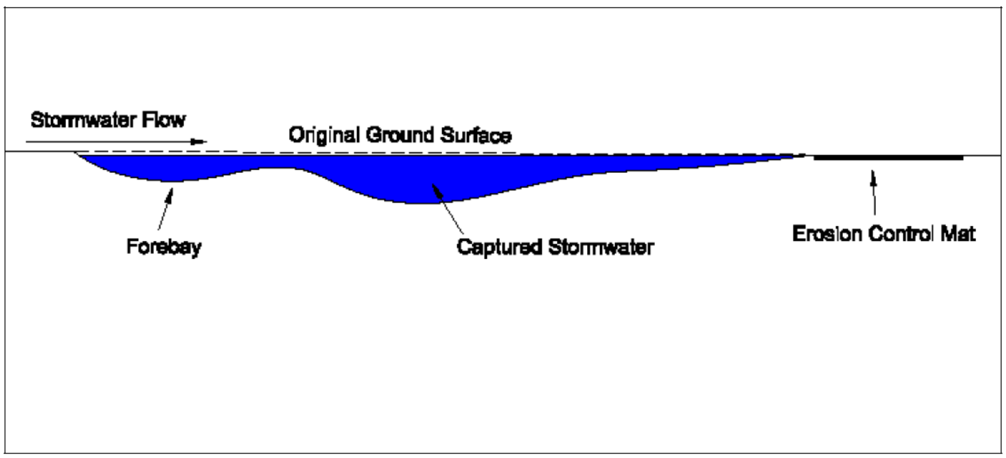

Figure 6.8 Illustration of backyard wetland constructed on 0.5% slope.

Since an average depth of 9 inches is desired, some areas in the wetland can be as deep as 1-foot, while other areas will be 3 inches or less. The depth is calculated by measuring from the top of the overflow weir (or lowest elevation along the wetland perimeter if no weir is used) to the excavated soil surface. Building variability into the wetland with respect to ponding depths encourages plant diversity. If the water table is encountered while digging the wetland, this is a good sign that wetland vegetation will survive in this location. The topsoil is then added back after digging; thus, the wetland may have to be a little deeper to account for the reapplication of the topsoil. A small, deeper section (forebay) can be included in the wetland design were the stormwater initially enters. This forebay will cause some sediment to fall out and will dissipate the energy of the stormwater, reducing erosion inside the BMP. Often, if the watershed is small (<0.5 acres) and stable, a forebay is not needed.

When a backyard wetland is constructed on a slope, the berm height will vary based on the severity of the slope. In general, the berm should not be more than 1 foot higher than the surrounding ground surface. This will minimize the erosive potential of any stormwater that spills over the back side of the berm. The berm should be stabilized with grass seed and straw or sod after the construction is complete.

During the period before the grass has been established, the berm will be susceptible to erosion and should be checked after every rain event. If the property owner desires, sod strips can be used to stabilize the outlet berm. An outlet should be constructed as described in Section 5.3.7 to provide safe passage of stormwater overflow whenever a berm is necessary. Whether the BMP is constructed on a flat landscape or one that is sloped, a strip of erosion control fabric (the width of one roll of fabric, which is approximately 6 feet) should be added immediately downslope of the backyard wetland (Figures 6.6 and 6.8). After the berm and outlet structure have been constructed, the internal cavity, or bowl, of the wetland can be prepared. If the wetland is not sited where the water table will be readily accessed by plant roots (See sections 4.4.3-4.4.4), the wetland plants will rely on ponded stormwater remaining in the wetland due to poor infiltration. In locations where the water table is not encountered, a hand tamper or other mechanical compactor can be used to compact the underlying soils. This compaction will result in reduced soil infiltration, leading to improved water retention within the wetland.

After the underlying soils have been prepared, the topsoil that was removed should be reapplied on top of the underlying soils at a depth of 2 – 3 inches. This topsoil can be raked into the underlying soils to provide a suitable media for plant growth. One application of fertilizer may be applied to the area based on a soil test report to initiate plant growth. After initial fertilization, the wetland should not be fertilized again. In many cases, the wetland soil should also be limed. To verify pH, soil samples can be sent to the NCDA&CS laboratory in Raleigh for testing.

6.4.3 Planting the wetland
Some wetland plants can be purchased at home improvement stores, while others will only be available at specialty wetland plant nurseries. Plant nurseries can also provide valuable insight on plant selection. A trowel or shovel can be used to create a small hole for planting. Wetland plants should be placed in the ponding zone in which they are best suited (Section 6.3.5). The depth of zones is found by measuring from the top of the overflow weir (or lowest elevation along the wetland perimeter if no weir is used) to the underlying soil.

6.5 Backyard Wetland Maintenance

Backyard wetlands must be maintained to ensure their long term functionality. As mentioned earlier, the BMP should initially be checked frequently (every month) for signs of erosion around the containment berm (if one is present), the inlet of the wetland, and the outlet of the wetland. All three of these locations may be prone to erosion. If erosion is observed, the area can be graded with a rake and shovel and reseeded. Erosion control matting and check dams can be installed if additional protection is required. Once the vegetation has established and if there are no signs of erosion, inspection frequency can be decreased to only following storms exceeding 2 inches.

Invasive species can result in reduced plant diversity within the wetland. Cattails are one such species that often establishes in stormwater wetlands. Aquatic formulations of glyphosate should be wiped onto the cattail stalks, resulting in plant mortality. This should be performed the first time a cattail is identified in the wetland, typically in midspring. Care should be taken when using these chemicals. One way to apply the chemical is to wear a cloth glove over the chemical resistant glove and to let some of the chemical soak into the cloth glove. For a detailed description of this method of removing cattails, please see Stormwater Wetland and Wet Pond Maintenance (Hunt and Lord) available in Appendix G.

Additional maintenance activities include such things as cleaning out the sediment that has accumulated in the forebay of the BMP (using a shovel), and picking up any trash that has entered the wetland (Table 6.4).

Table 6.4 Maintenance activities for backyard wetlands.

Activity	Frequency
Monitor wetland for signs of erosion	Initially every month until stabilization and after any large storm (> 2 inches)
Remove sediment from forebay	As frequently as once per year, if ever.
Remove trash from wetland	As needed
Remove invasive species	As needed, typically mid-spring.
Remove debris from around overflow weir	As needed

7.0 Cistern Design

7.1 Overview of Practice

Cisterns, or rainwater harvesting systems, are used to capture runoff, primarily from roof tops. Sometimes runoff from pavement is also temporarily held in cisterns. A cistern is simply a tank that stores runoff and range in size from 50 gallons (commonly referred to as rain barrels) to thousands of gallons. Cisterns can be employed above or below ground, with the former type of cistern typically being cheaper to purchase and install. Above ground cisterns will be the focus of this document. These systems vary in size, color, and shape. Preference shall be given to dark colored, non-translucent or covered cisterns as this limits the ability of light to penetrate the tank and cause algal growth. Figures 7.1, 7.2, and 7.3 show examples of cisterns installed in various locations in North Carolina.

Figure 7.1 3,000-gallon cistern installation in Greenville, N.C.

Figure 7.2 5,600-gallon cistern in Kinston, N.C.

Figure 7.3 300-gallon cistern in Greenville, N.C.

Screening overflow outlet pipes are recommended to help to reduce insect and rodent access.

The cistern is part of a larger system consisting of gutters and inflow piping, outlet piping, and often a pump (Figure 7.5). Rainwater captured in cisterns is used, or harvested, for uses such as irrigation, toilet flushing, vehicle washing, and clothes washing. Irrigation and car washing are expected to be the primary use for stormwater collected in backyard cisterns. These uses are non-potable (non-drinkable) only. It is important to alert users that this water is not for drinking. This can be done with a sign, such as the one shown in Figure 7.4. The demand for cistern water and the size of the cistern relative to the contributing watershed (rooftop) govern how much runoff reduction the water harvesting system provides.

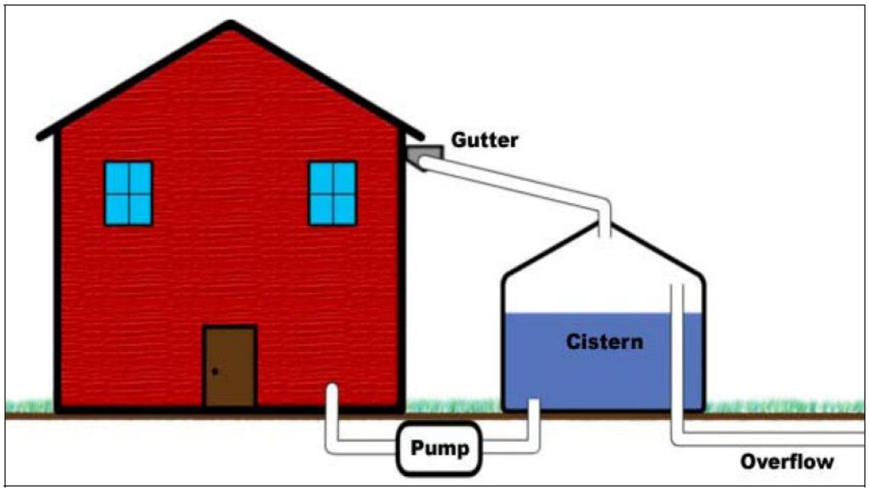

Figure 7.4 Schematic of cistern system.

Figure 7.5. Warning signs on a cistern to prevent human consumption of harvested rainwater.

7.2 Selection of this practice over others

The primary advantage of installing a stormwater cistern is that the stormwater can be captured and used as a substitute for potable water. In other BMPs, stormwater is lost to the atmosphere, is used by plants, or drains into the soil. A property owner should be able to describe the intended use of the stormwater to SWCD staff. This is important because the cistern is only an effective BMP if it has storage space. Storage space is created by using the cistern water between rain events. Cisterns can be installed, in many cases, without excessive digging, and soil type and water table depth have little impact on above-ground cistern installation. The disadvantage of using cisterns is that they will only treat runoff from rooftops in a backyard stormwater BMP setting. Thus, rain gutters are necessary on the rooftops being treated. SWCD will not provide any cost-share for gutter installation. Any runoff produced by parking lots or other impervious surfaces is typically not captured by the cistern unless significant treatment is included in the design of the system.

See the CCAP Cistern Checklist for more information.

7.3 Cistern Design

7.3.1 Determining the area draining to a cistern

As the cisterns installed through the CCAP program will be receiving drainage from a rooftop, the rooftop area draining to the gutters feeding the cistern should be determined. Design plans, internet tax maps, and site measurements can be used to determine the drainage area.

Choosing the downspouts that will be diverted to the cistern should be a factor of the cistern location and the area draining to each downspout. The area draining to the cistern should roughly match the anticipated size of the system, as it is unreasonable to have a 55 gallon rain barrel drain a 2,000 ft^2 roof area. A rule of thumb is to allow 1 gallon of storage for every square foot of drainage area; therefore, if the property owner is only interested in a 500 gallon cistern, approximately 500ft^2 of roof should drain to it.

Extreme care should be taken when combining multiple downspouts into one pipe. Per North Carolina building code, gutters must be sized for a certain rainfall intensity to avoid water backing up into gutters and on the roof. When diverting downspouts to a cistern, the pipe draining a downspout should be at least the size of the cross-sectional area of the downspout. For example, if the existing downspout is 2”x3” (a cross-sectional area of 6in^2), the pipe used to divert this downspout to the cistern should have an area of at least 6in^2 (approximately that of a 3-inch diameter pipe). When combining downspouts, the resulting pipe should have a minimum cross-sectional area of the cumulative areas of the contributing pipe. For example, if two 2”x3” downspouts (or two 3”-diameter pipes) are combined, the resulting pipe should have a cross-sectional of at least 12in^2 (approximately that of a 4-inch diameter pipe). Plugging downspout openings should be avoided, as the remaining openings in the gutters are not big enough to handle additional flow. An alternative to combining downspouts or plugging openings is to have multiples pipes entering the cistern (i.e. one pipe per downspout).

7.3.2 Cistern sizing

The preferred way to determine the size of a cistern is to run the simple water budget model available on the following website: http://www.bae.ncsu.edu/topic/waterharvesting. This model simulates 30 years of actual rainfall data from several cities in North Carolina and couples this “supply” of water with user defined demands – such as the number of gallons of water used per week to irrigate and wash vehicles. Determining the optimal size of a cistern requires the user to conduct multiple iterations using varying cistern sizes and comparing the outputs from the model for different system sizes. The steps one should take to do this are outlined below. See the CCAP – Rainwater Harvest Guide for more information.

The main page of the model is shown in Figure 7.6. Rainfall data are selected by clicking the “Browse” button under the “Rainfall Input File” heading. Clicking this button brings up the window shown in Figure 7.7. Users should select the file for the location closest to the site of interest. In most cases the daily data files are preferred for performing simulations. Hourly data files should only be used if hourly water usage information is available, as using hourly data requires longer run times and does not produce water quality results (water quality volume captured and annual nitrogen removed). After highlighting the appropriate data file, click “Open.”

The user should then enter the area of roof draining to the cistern, the city closest to the site of interest, and the applicable water quality volume depth (1 inch for non-CAMA counties, 1.5 inches for CAMA counties). A cistern volume and cost must be entered for the initial simulation. Note that the model will not run if there is not a cost entered. A rule of thumb to use for this initial volume is 1 gallon of storage for every square foot of contributing roof area. The “Backup water supply” option is rarely used for some residential applications but can be utilized if a backup water source is included in the system design. To utilize this option, check the box beside “Backup water supply” and specify the start and stop trigger volume. This volume is expressed as a percent of the total storage volume of the cistern.

The next step is entering water usage data into the model. Before a cistern is installed, it is highly recommended that the eventual operator of the cistern know how much water he/she is using on a daily basis. This information can be obtained using a simple hose-attached water meter, available for purchase at most garden centers. Determining the optimal cistern data is highly dependent upon the accuracy of the water usage data. There are three methods for entering water usage data in the model: basic usage, custom usage, irrigation. Each of these categories is located under a different tab in the model, the screens for which are shown in Figures 7.8, 7.9 and 7.10.

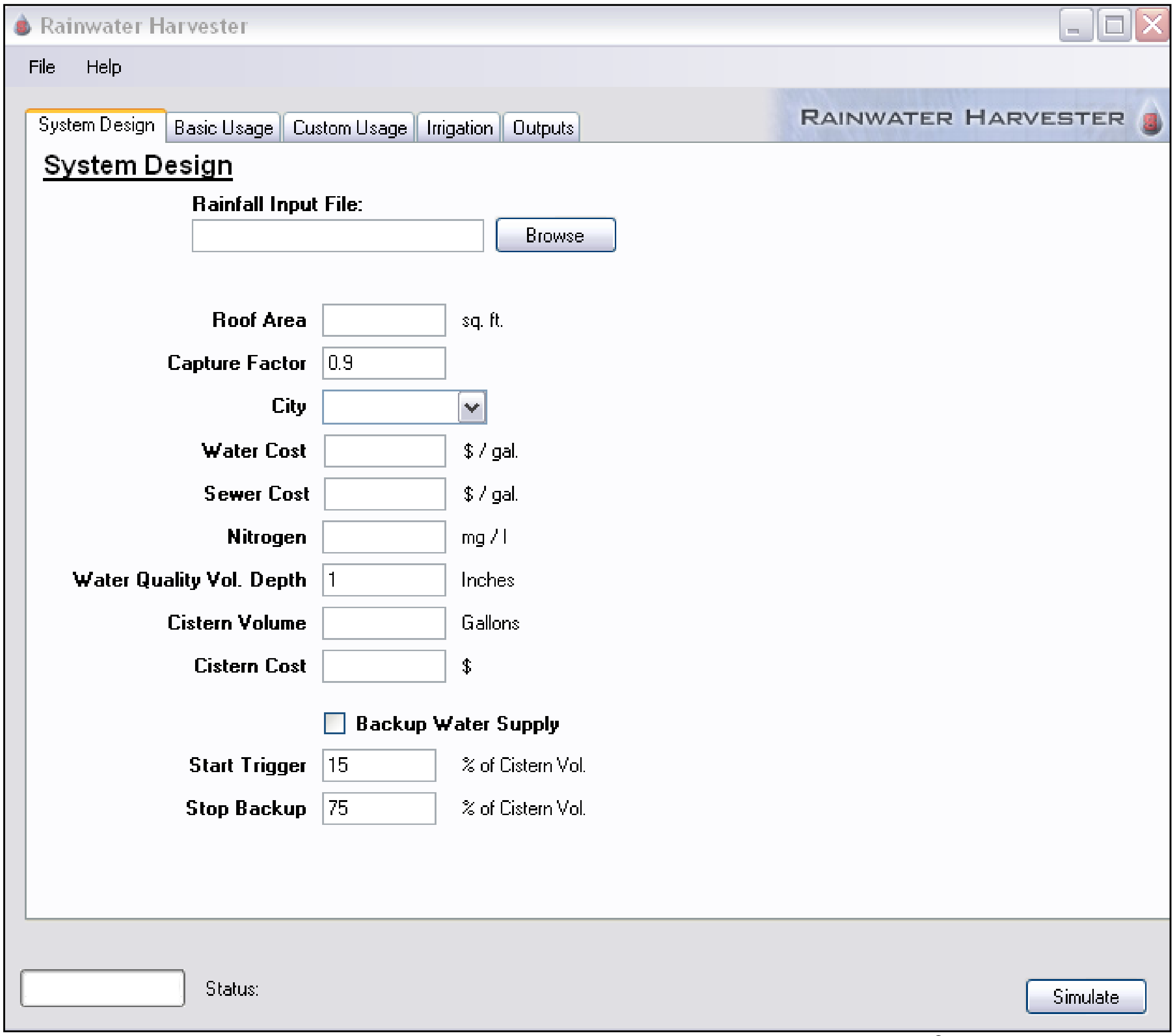

Figure 7.6. Main page of NCSU's Rainwater Harvester Model®.

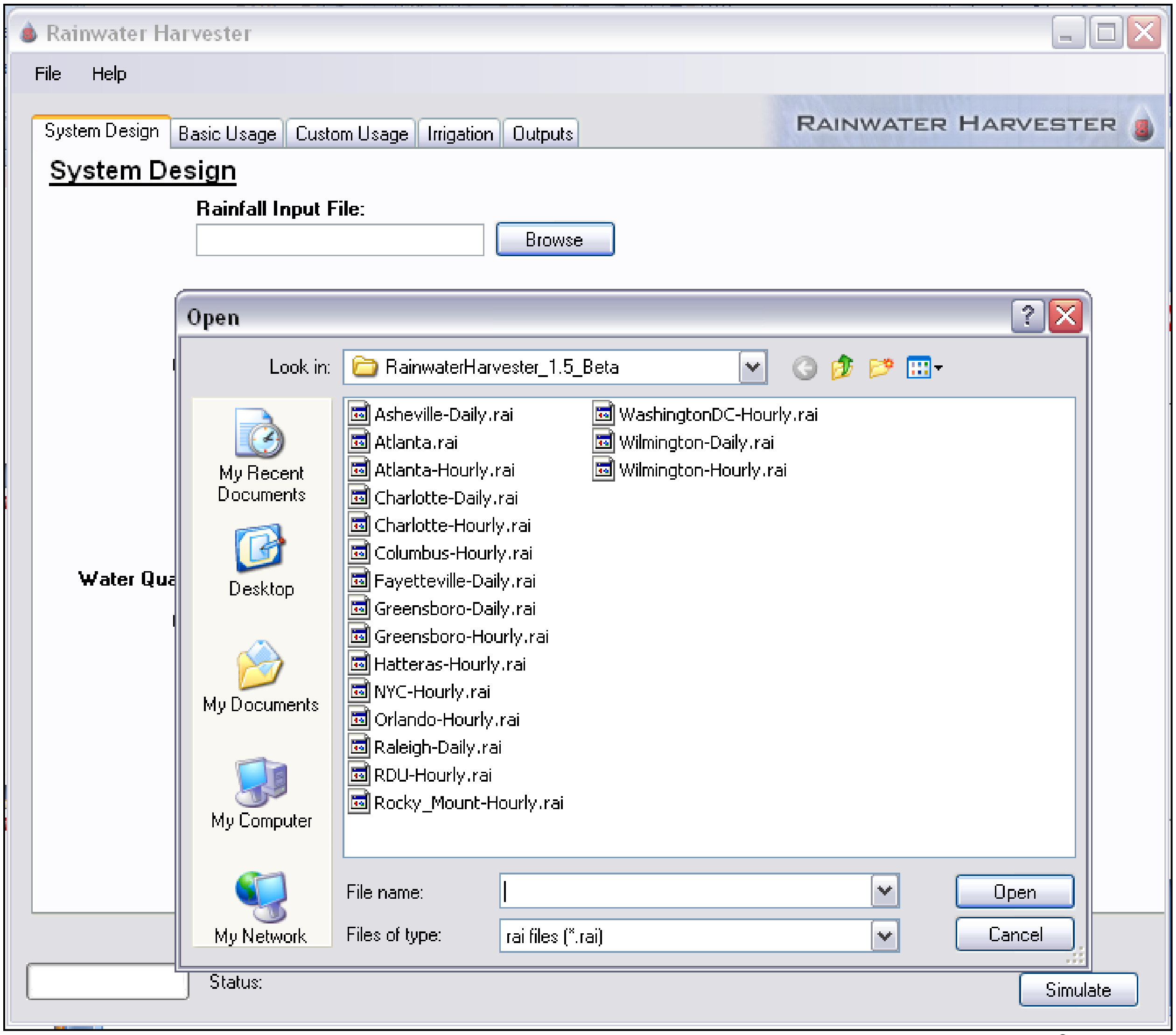

Figure 7.7. Rainfall data file selection page of NCSU's Rainwater Harvester Model®.

The basic water usage tab (Figure 7.8) includes options for toilet flushing or a consistent daily usage. The toilet flushing option requires the following information to be entered: the number of persons using the facilities, the number of gallons per flush (the default value of 1.6 gallons is representative of low-flow toilets), and the presence of weekend usage. To use this option, simply enter the number of people using the toilets per day, adjust the number of gallons per flush to reflect the site conditions and indicate if the facilities are being used on weekends. The consistent daily usage option should only be used if the anticipated water usage occurs every day, regardless of week, month or season. The "Constant water supply" option is to account for water being introduced to the system in addition to rainwater, such as air conditioning condensation.

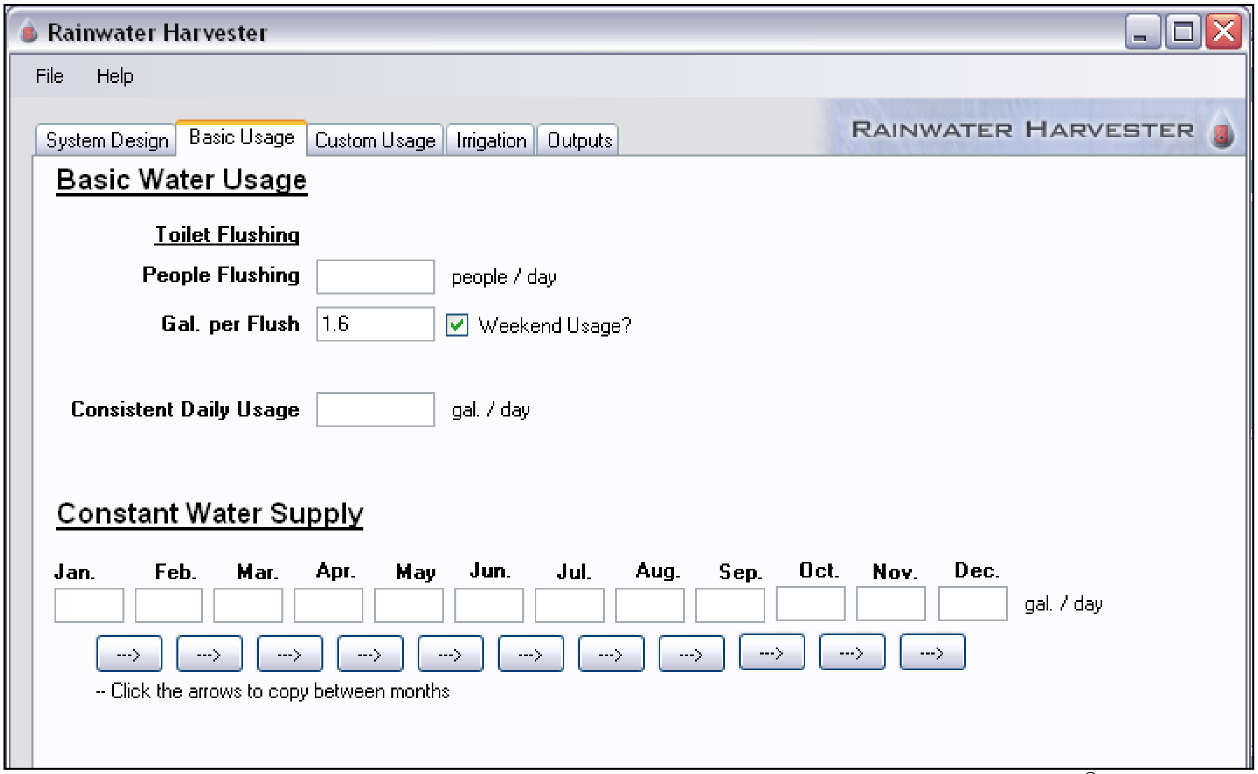

Figure 7.8. Basic water usage page of NCSU's Rainwater Harvester Model®.

The "Custom water usage" option (Figure 7.9) offers more options in terms of water usage. Usage can be varied by month and day. The times of day that usage occurs may also be specified; however, this option should not be used unless hourly rainfall data is used for the simulation. If multiple time slots are checked in this option, the total usage entered is evenly distributed among the selected slots.

The final option for entering water usage is the "Irrigation" tab (Figure 7.10). Note that this is only valid for irrigation systems that are controlled by soil water depletion (i.e. sensors measure soil moisture content and adjust irrigation frequency and amounts accordingly). To use this option, first load potential evapotranspiration (PET) data in the same manner rainfall data was selected. Next enter the amount of irrigated area, select the type of irrigation system, soil texture and irrigated crop. Entering these values will automatically fill in default values for irrigation efficiency, plant available water and effective root depth, although these values may be adjusted if the user thinks it necessary. The allowable water depletion is what dictates how dry the irrigated crop may get before the irrigation system is triggered. The default value for the model is 50%, but this can be adjusted by the user. Finally, the months that irrigation will occur should be specified at the bottom of the screen using the checkboxes.

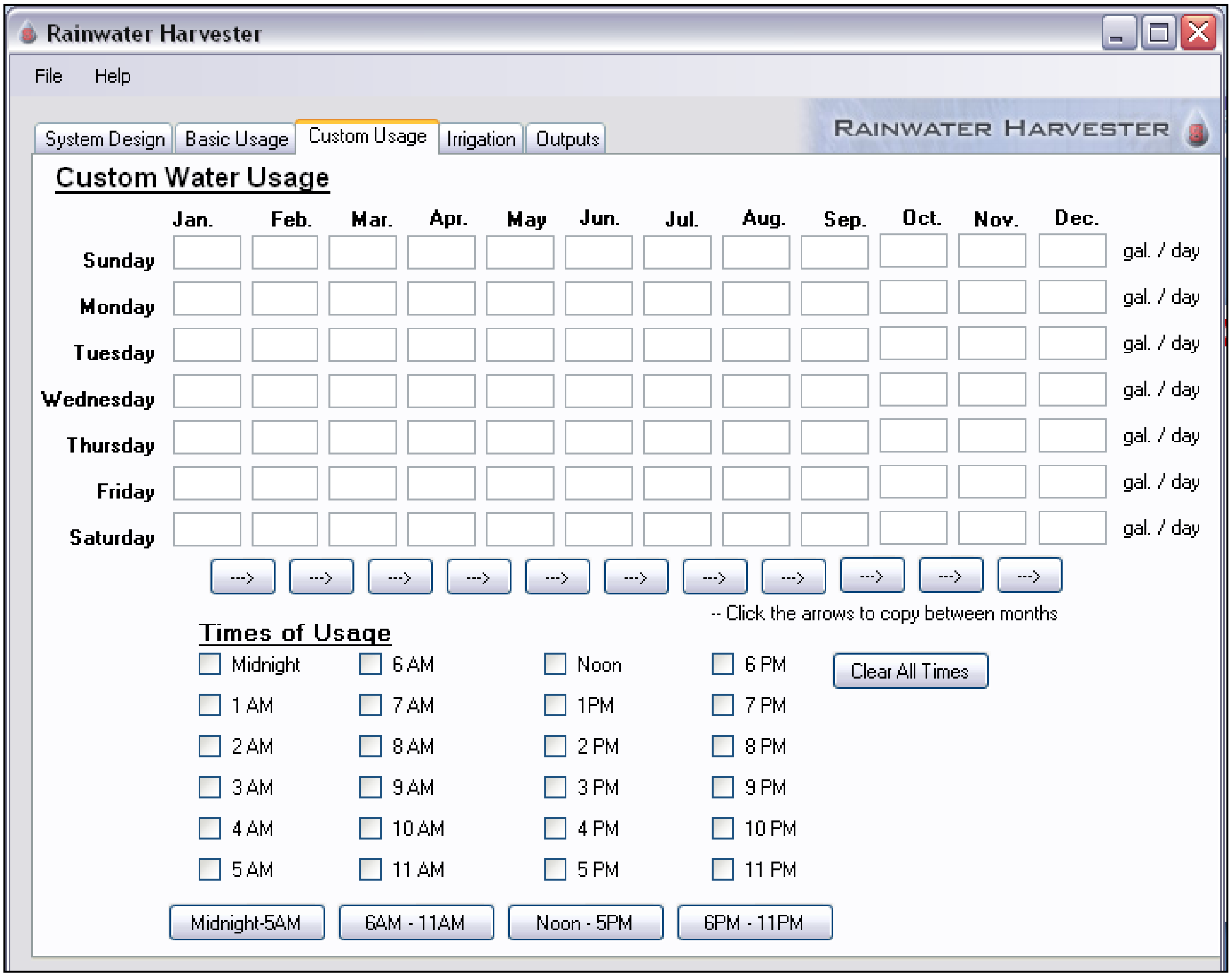

Figure 7.9. Basic water usage page of NCSU's Rainwater Harvester Model®.

Once the system design and water usage information is entered, click the "Simulate" button at the bottom right of the screen. The results are displayed in the "Outputs" tab, shown in Figure 7.11. The results from one simulation provide useful information regarding the one size of the system; however, to determine the optimal cistern size, multiple simulations must be performed with varying cistern sizes and the results compared. It is recommended to perform simulations for at least 2 sizes smaller than the initial volume and 2 sizes larger than the initial volume. It is also strongly recommended that the sizes selected be of equal intervals. For example, if the cistern volume used for the initial simulation was 500 gallons (for a 500ft^2 roof area), simulations could be run for 50, 250, 750 and 1,000 gallons. Consider available cistern sizes when selecting cistern volumes, as it is not useful to include a certain volume as an option if that particular size is not available on the market. Record the following variables for each simulation for comparison: total volume captured, usage replaced, overflow frequency, dry cistern frequency, and payback period. It is helpful to put these values in table format for each comparison. An example is shown in Table 7.2.

The optimal cistern size should maximize the total volume captured and usage replaced while minimizing the overflow frequency, dry cistern frequency, and payback period. There is no 'magic number' for any of these variables – it is strictly the comparison between multiple cistern sizes that will allow one to determine the optimal size. An easy way to identify the optimal size is to compare the difference between a given variable for each simulation. When the difference in a variable for simulations begins to decrease as the cistern volume increases, this is an indication that increasing the size of the system does not provide as much benefit. The point at which this occurs is the optimal system size. Consider the water quality benefit of cisterns installed through CCAP. The annual nitrogen removed value on the Rainwater Harvester Model output may be used as a guide to determine the water quality benefit of the cistern.

Table 7.3 shows the relative difference in variables for multiple simulations. Based upon the data shown in this table, the 3,000 gallon sized system would be the optimal size, as the benefit of increasing the size to 4,000 or 5,000 gallons is substantially less than increasing the size from 1,000 gallons to 2,000 gallons or 3,000 gallons. The payback period could be added to this table to provide a cost component to the decision. If any design components change (contributing roof area, water usage, etc.), these simulations should be re-run and the optimal system size chosen based on the new design.

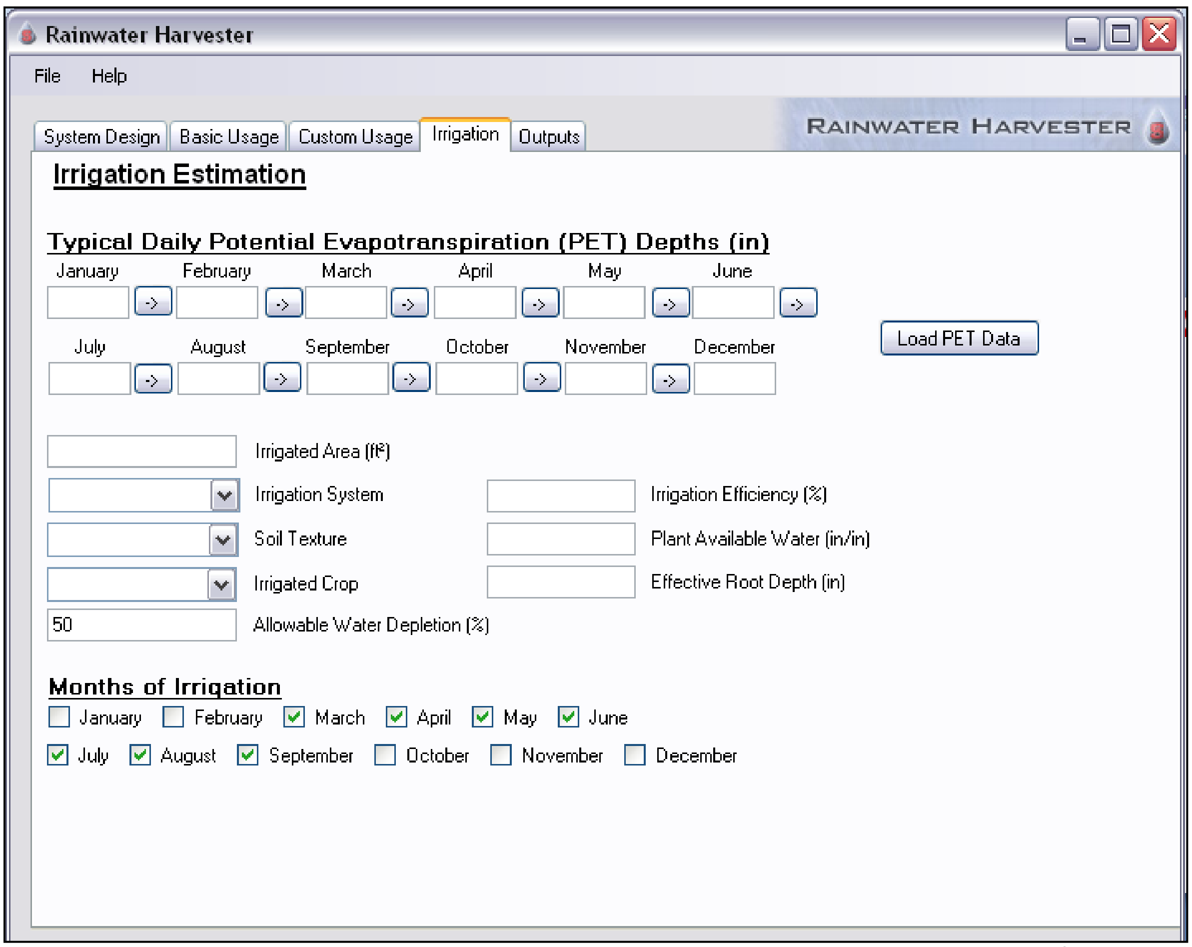

Figure 7.10. Basic water usage page of NCSU's Rainwater Harvester Model®.

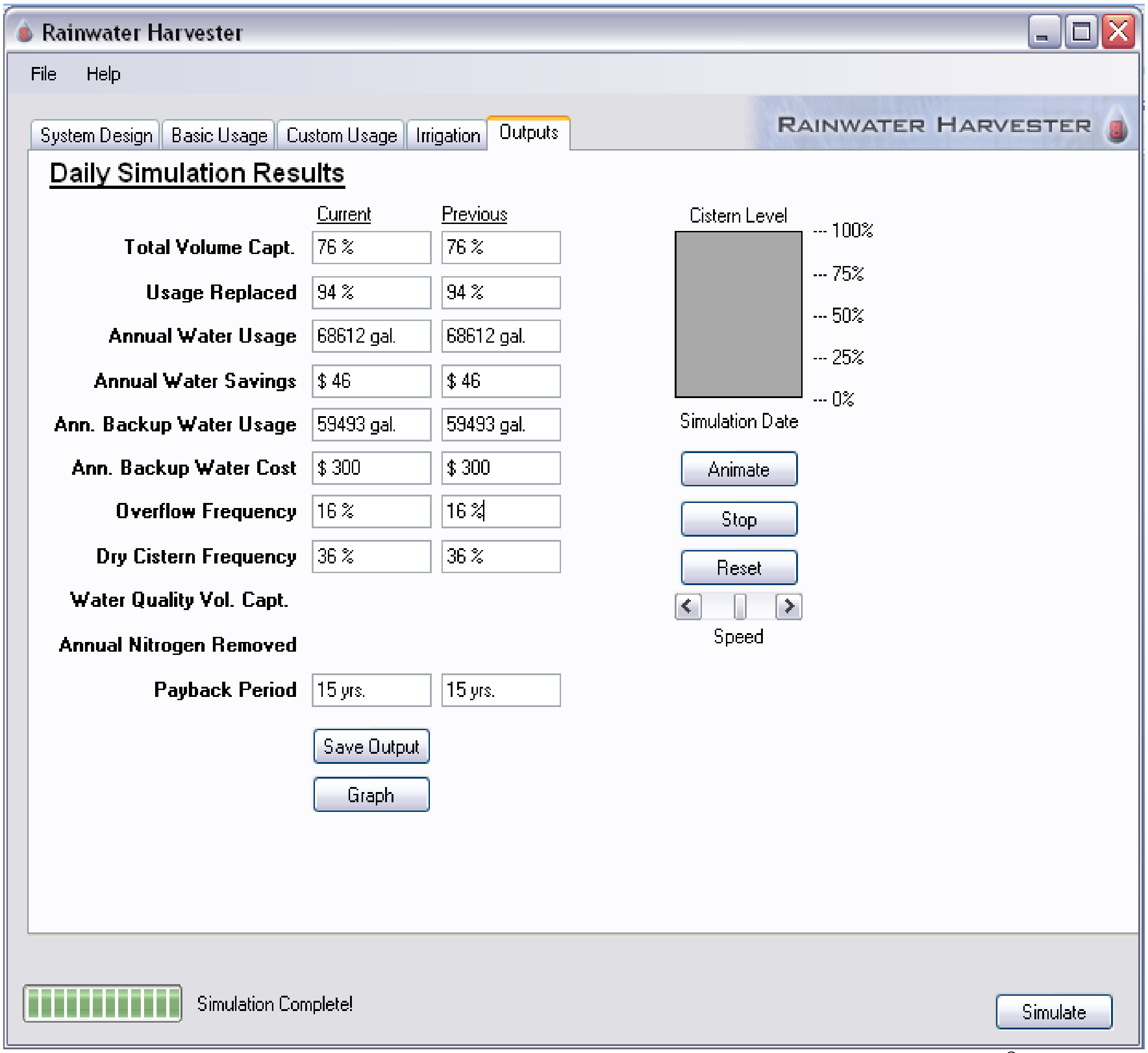

Figure 7.11. Basic water usage page of NCSU's Rainwater Harvester Model®.

7.3.3 Additional Cistern Components

Table 7.1. Example of a table used to compare results from multiple model simulations.

Cistern Size (gal)	Volume Captured (%)	Usage Replaced (%)	Overflow Frequency (%)	Dry Cistern Frequency (%)
1000	55	67	28	38
2000	60	73	24	31
3000	66	80	20	23
4000	69	84	17	18
5000	72	87	16	15

Table 7.2. Relative differences in variables used to compare results from multiple model simulations.

Cistern Size (gal)	Volume Captured (%)	Usage Replaced (%)	Overflow Frequency (%)	Dry Cistern Frequency (%)
1000	55	67	28	38
2000	60 (+5)	73 (+6)	24 (-4)	31 (-7)
3000	66 (+6)	80 (+7)	20 (-4)	23 (-8)
4000	69 (+3)	84 (+4)	17 (-3)	18 (-5)
5000	72 (+3)	87 (+3)	16 (-1)	15 (-3)

Figure 7.12 Debris filters just below gutter downspout.

An overflow assembly is part of the cistern as well. If the cistern does not have enough storage space to capture an entire rain event, a pipe that penetrates the cistern allows any overflow stormwater to leave the cistern and discharge onto the ground below without cascading down the side of the cistern (Figure 7.13 and 7.14). It is important that the cross-sectional area of the overflow pipe be equal to or greater than the cumulative cross-sectional areas of all inflow pipes. In other words, water must be able to exit the cistern as fast as it enters to avoid backing up into the gutters and on the roof.

Figures 7.13 and 7.14 Overflow assembly on cistern.

Additional equipment is needed to access the cistern water, such as spigots and other pipes. Water can be extracted from the cistern (or rain barrel) via a hose bib placed at the bottom of the cistern, or via a pump-fed spigot or hose. Without a pump, the pressure of the water exiting the hose bib will be only that provided by gravity. This is ideal if the owner will only be filling open containers (buckets, watering cans, etc.). If the intent of the owner is the use the water with a garden hose or other dispersal device that requires pressure, a pump will be needed. A cistern vendor can be contacted to determine exactly what outlet configuration will be required to access the cistern water for a given water usage. Cistern vendors can also give some guidance on pump sizing. A North Carolina Cooperative Extension publication has been produced that can also aid in pump selection. This document has been attached as Appendix I.

7.3.4 Overflow routing

The quantity of stormwater that overflows or bypasses the cistern will vary depending on event size. Thus, overflow from the cistern should be routed to a nearby drainageway or BMP via a swale or pipe. Failure to do so may result in the formation of an erosion channel where the stormwater leaves the cistern. Rip rap or energy dissipation at the outlet of the overflow pipe may be required, depending on soil type. Overflow or runoff from the cistern to a rain garden or backyard wetland is also recommended. When BMPs are cost shared in combination, the impervious area treated must be appropriately defined and each BMP must be sized accordingly.

7.4 Cistern Construction

7.4.1 Preparing the soil base

A stable, level, soil base is needed to ensure the stability of the cistern, as cisterns are extremely heavy when full of water. The cistern base should be level to avoid the loss of storage space and/or the cistern falling over. The area to be occupied by the cistern should be cleared of any vegetation or debris and a level depression excavated (Figure 7.15a). The depth of the depression should be at least 12-18 (see comment below) inches deep to avoid freezing of any pipes entering or existing the bottom of the cistern; however, cistern should not be buried more than 2 feet deep, as they are not strong enough to withstand the pressure of soil on the sides of the tank and will collapse. The area of excavation should be approximately 2 feet greater in diameter than the cistern to allow for optimum positioning and room for plumbing. For cisterns 1,500 gallons and smaller, a gravel base 6-8 inches deep should be put in the depression and leveled out. The type of gravel generally used includes crusher run or #57 stone but others types may be used as well. For cisterns greater than 1,500 gallons, a concrete pad 4-6 inches thick should be poured into the depression and leveled for the base (Figure 7.16). In cases where the excavation of a depression is not feasible (on paved surfaces or on foundations), the cistern may be placed on ground surface; however, it is important that there still be a gravel or concrete base of the appropriate thickness to support the cistern. Also, any exposed piping that remains full of water between times of use should be well insulated to prevent freezing.

The depth of the depression should be at least 12-18 inches. **COMMENT:** ***The NC Building code for footings is 12 inches below the frost freeze line, which in Raleigh is 4 inches, for a total depth of 16 inches. Recommending excavation below the footing depth of a building could compromise the footing and structural integrity of the building. This excavation may also compromise the footing drain tile of the structure and allow water to flow into the cistern foundation. Footing drain tiles are only 12 inches deep according to building code. Eastern counties have only a 12 inch requirement for footings and a 6 inch minimum depth for footing tile drains.*** Based upon the NC Building Code, if a depression is necessary for the installation of the cistern, ensure that the excavation does not compromise the integrity of the footing and/or foundation drain tile of the structure. The placement of the cistern shall be placed away from the footing and foundation drain so as to not compromise the structure. ***Please refer to the NC Building Code sections 1803.5.7 and 1804.1 to ensure compliance with this important provision at the following link:*** http://ecodes.biz/ecodes_support/free_resources/2012NorthCarolina/Building/PDFs/Chapter%2018%20-%20Soils%20and%20Foundations.pdf

Make sure to call 811 and locate all utilities prior to siting the cistern.

Please note: Reinforcement of the concrete pad is not needed unless the cistern is larger than 10,000 gallons. As mentioned, any cistern system over 3,000 gallons must be designed by a PE. All cistern installations must follow manufacturer's recommendations and Appendix C-1 of the NC Plumbing Code.

http://www.ncdoi.com/OSFM/Engineering_and_Codes/Documents/BCC_Minutes/2010%2012%2013~December%2013-14,%202010%20%28Item%20B-10,%20Appendix%20C-1,%20Rainwater%20Collection%20and%20Distribution%20Systems,%20for%20public%20comment%29_.pdf

Figures 7.15a Cistern site preparation and b. Preparing the gravel support base.

Figure 7.16. Concrete pads constructed to support cisterns greater than 1,500 gallons.

7.4.2 Getting water into the cistern

As mentioned previously, gutters should already be installed when a cistern is to be implemented. The existing gutter downspout will flow into the debris filter. Placement of the downspout debris filter should be such that is can be easily seen and maintained while still allowing for positive drainage to the tank (Figure 7.6). There should be approximately 2-3 inches of clearance between the downspout opening and the debris filter to allow for easy removal of debris and leaves. The downspout can be cut with a hack saw, or by another method that will produce a smooth, straight edge.

The debris filter should be mounted on the wall and a pipe should be attached to the bottom of the filter to convey water from the filter to the tank (Figure 7.17a). Again, be sure the pipe is at least as big as the existing gutter downspout. A rubber gasket should be used where the pipe enters the cistern to prevent leaking and ensure a tight fit (Figure 7.17b). These gaskets come in multiple sizes and can be purchased from most cistern vendors.

Figure 7.17. (a) Pipe leading from debris filter to the tank; (b) Rubber gasket used to create leak-free seal when pipe enters the tank.

First flush diverters are used in some cases. They may be needed on systems that do not employ complex debris filters (i.e. vortex filters), or on systems that have a lot of overhanging or nearby vegetation (especially pine trees). Pollen is the primary reason to have them, as this will not be removed by a typical debris filter.

It is critical for first flush diverters to be maintained frequently to work correctly. The drain port must be checked frequently, especially during high pollen times. If the port isn't cleaned out, water will bypass the filter completely (rendering it useless) or, in the winter, the water will freeze and burst the pipe on the filter.

7.4.3 Overflow routing

The overflow pipe should be inserted into the tank at a height at or below that of the inflow pipe. A rubber gasket should be used to create a water-tight seal where the overflow pipe enters the tank. The overflow pipe should be positioned such that water is directed away from the tank and any building foundations. Ideally, the overflow water should be piped or diverted to a BMP such as a rain garden. It is not necessary for the overflow piping to be leak-proof (i.e. HDPE pipe may be used in lieu of PVC); however, it is necessary to use PVC pipe when first exiting the tank due to its size (relative to the gasket) and rigidity.

7.4.4. Extracting water from the cistern

The last step in the construction process is to plumb any spigots or other distribution apparatus. As state previously, the extract point may be gravity-fed or controlled by a pump. Pumps should be installed per manufacturer’s recommendation. Any exposed piping (i.e. connecting an external pump to the cistern, or connecting a spigot to the pump) must be either buried at least a foot or otherwise insulated to prevent freezing or bursting. It is recommended to include a drain valve at the bottom of the tank to facilitate draining of the cistern for maintenance or winterizing.

7.5 Cistern Maintenance

Maintenance is crucial to cistern performance. Most notably, the gutters and the debris screen should be checked for leaves and other debris after every major storm event, particularly when a tree canopy is near a roof top. Failure to do so will result in water backing up into gutters and onto roofs due to clogging piping and filters. In-line pipe filters, pump intake filters, and spigot filters should be checked annually to ensure they don't become clogged.

Any hose or pipe connections associated with the cistern should be checked for leaks, especially after freezing temperatures. Some owners chose to decommission the system during winter months to prevent damage associated with freezing. To 'winterize' a system, drain all pipes, tanks and hoses associated with the cistern. Remove pumps and place them in a climate-controlled location protected from the weather. The drain valve at the bottom of the tank should be left open to allow any water entering the tank to drain out. This water may be diverted to a grassed area or a BMP as the overflow is.

The cistern should be checked for stability prior to high-wind events (such as hurricanes or severe thunderstorms). If the cistern is consistently low on stormwater, it may become light and require some sort of anchoring system to keep it in pace. The owner of the cistern may want to fill it part way with potable water to prevent wind from tipping the cistern. A list of maintenance activities and their associated frequency is shown in Table 7.3.

If water within the cistern is not used for an extended period of time, it may become stagnant and develop a strong odor. To correct this problem, one should drain the stagnant water out of the cistern and add 2 fluid ounces (1/4 cup) of bleach to the tank for every 1,000 gallons of storage. **Be sure to allow the tank to fill up prior to using water**; otherwise the bleach will not be diluted enough to safely use the water. Debris filters are often not fine enough to prevent pollen from entering the tank. While this is generally not problematic, some people find pollen can also create an unpleasant odor. To correct this, add bleach as described above.

Table 7.3 Cistern Maintenance Activities

Activity	Frequency
Clean gutters of debris that have accumulated, check for leaks	Bi-annual
Clean debris screen to allow unobstructed stormwater flow into the cistern	Monthly
Winter-proof system	Fall
Check cistern for stability, anchor system if necessary	Bi-annual (Spring / Fall)
Check accuracy of water level indicator if present	Annual
Check pipe and valve connection for leaks	Annual
Make sure cistern manhole is accessible, operational, and secure	Annual
Fill tank ½ full with water (if tank is less than ½ full)	Before any major wind related storms (such as tropical storms or hurricanes)

See the CCAP Cistern Operation & Maintenance Plan for more information.

8.0 Vegetated Swales

8.1 Overview of Practice

Swales often serve to convey water around and away from businesses and residences. They are vegetated, open channels, most often lined with grass. From a water quality perspective, they are preferable to pipes because they allow more soil and water contact, as well as more opportunity for infiltration. Filtration of sediment and debris can also occur within swales, especially if the grass is kept relatively long. Figure 8.1 shows grassed swales in Durham and Wake Counties.

Figure 8.1 shows two swales in the Raleigh-Durham area. Both have turf reinforcement mats. The former is mowed while the latter contains a taller grass stand.

8.2 Determining Site Constraints

CCAP does not allow a total riprap lined channel unless recommended by a PE. They cost share on TRM if it's within the designer's JAA or recommended by a PE.

The first step in designing a vegetated swale is to determine the constraints of the site.

Slope

The swale must convey flow from an upland area to an area that is lower in elevation. Often, swales will lead from a point in the watershed to an SCM or from an SCM to the existing drainage infrastructure. This information can be used to determine the allowable slope of the swale. The swale should have a relatively constant slope between its inception and destination. If changes in slope are necessary, they should be gradual.

Slope (S) = elevation change from start to end (ft) ÷ length of swale (ft)

Top Width

The maximum width of the swale may be dictated by site constraints. Determine the maximum width before beginning calculations.

Side Slopes
It may be desirable at some sites to leave the side slopes of a swale mild enough that they can be mowed with a riding lawn mower. If this is the case, a slope of 4:1 (H:V) or flatter is recommended, no steeper than 3:1 is recommended in most cases, and never more than 2:1. Triangular swales may be used on small catchments less than 2 acres but is dependent upon the slope, the velocities may not allow it.

Shape
Both trapezoidal and triangular cross-sections are used for water quality swales. The depth of flow within these channels is shallow during small storms which allows increased soil and grass contact with the stormwater, and therefore increased infiltration and filtration. Triangular shaped swales are more appropriate for small drainage areas, but trapezoidal swales may also be used.

Peak Flow
Swales should be designed to convey the peak flow of the 10-year storm without overtopping, which is calculated using the Rational Method (section 3.4). During extreme events (e.g. 25 or 100-year storms), portions of the swale may be breached and should be repaired by the property owner as necessary.

8.3 Depth and Velocity Calculations

Swales should be able to carry their design flow without overtopping or eroding. If the velocity is too high for grass cover in a given swale design and the slope and cross-section cannot be adjusted, the swale can be reinforced with rip-rap or turf reinforcement matting, which can withstand a higher velocity. There are several approaches to designing a swale. A site may have constraints which dictate the channel slope and cross-section, in which case the designer must simply ensure that the channel lining will be strong enough to handle the velocities produced. Conversely, there may be flexibility with respect to the channel cross-section, and the designer may choose to size it such that a simple grass lining, which reduces installation costs, will be sufficient to prevent erosion. Figure 8.2 shows a diagram of a swale with a trapezoidal cross-section and illustrates some of the parameters discussed in this section. The equations used in trapezoidal channel design are as follows:

Equation 8-1: The Continuity Equation

$$Q = VA$$

Where:
Q = flow rate (cfs)
V = average velocity of the cross-section (ft/s)
A = cross-sectional area of the flow (ft^2)

And:
$A = bd + xd^2$ (refer to figure 8.2)

Equation 8-2: Manning's Equation

$$V = 1.49 * (1/n) * R^{2/3} * S^{1/2}$$

Where:
V = velocity (ft/s)
n = Manning roughness for a chosen channel lining (Table 8.1)
R = hydraulic radius (ft)
S = channel bed slope (ft/ft)

The hydraulic radius (R) is equal to the cross-sectional area of flow (A) divided by the wetted perimeter (Wp) (see Figure 8.2), or for trapezoidal channels:

$$R = (bd + xd^2) / (b + 2dx)$$
*all dimensions in ft

For convenience, the top width of the trapezoidal channel can be calculated as:

Swale Top Width = b + 2Dx
*all dimensions in ft

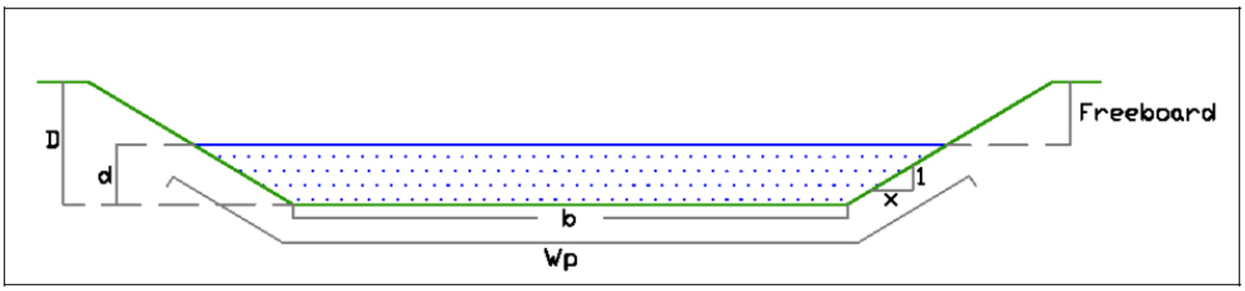

Figure 8.2 Trapezoidal swale cross-section.

The correct cross-section must be determined by trial and error. A computer spreadsheet or other software (e.g., TR-55) would be helpful in this process and may be obtained from SWCD personnel in Raleigh. First, assume a channel geometry, and use the Continuity Equation (Equation 8-1) and Manning's Equation (Equation 8-2) to determine the average velocity of flow for the design storm. By using the maximum permissible velocity method, it can be determined whether the channel will erode. Table 8.2 shows maximum permissible velocities for a variety of channel linings.

Manufactured products should have maximum permissible velocity specifications available. If the channel velocity exceeds the maximum permissible velocity for a given surface lining, erosion will occur. It is good practice to design conservatively. Multiply the calculated velocity by a safety factor of 1.3 when comparing with the maximum permissible velocities in Table 8.2.

Assume that grass will not be mowed regularly when selecting a Manning n. Leave at least 0.3 feet of freeboard at the top of the swale during the 10-yr storm. The channel can be reinforced with turf reinforcement matting (Figure 8.3) or riprap if velocities cannot be lowered sufficiently by enlarging the swale.

Table 8.1 Manning's n values for various channels.

Type of Channel Lining	Design n
Grass	0.033
Riprap	0.035
Turf Reinforcement Matting	0.038

Table 8.2 Maximum permissible velocities for various channel linings.

Type of Channel Lining	Maximum Permissible Velocity (ft/s)
Grass	4
Riprap	6.5
Turf Reinforcement Matting	*9.5

Please check the manufacturer's specifications to determine the maximum permissible velocities for Turf Reinforced Matting as these vary from product to product. The table above is a general listing for the maximum permissible velocities for TRMs.

Figure 8.3 Turf reinforcement mats used along a swale at Umstead State Park.

8.4 Simplified Triangular Swale Design

8.4.1 Adjusting Manning's equation for triangular swale design

In many cases, a given watershed will be small enough to justify the use of a triangular swale. Some assumptions and generalizations can be made when designing triangular swales, which simplify the design process. When the triangular swale cross section is split in half, two right angles are formed (Figure 8.4).

Figure 8.4 Triangular swale cross section – divided into two right angles.

Dividing the swale into two right angles allows for some simplification of the swale design method. By the Pythagorean Theorem, the length of the unknown side "x" can be determined. In triangular swales with 3:1, 4:1, or gentler side slopes, the length of "x" is found to be approximately the same as the length "y." The "y" value is equal to half of the swale width; thus, the unknown distance "x" is also approximately equal to half the swale width. Because the wetted perimeter of a triangular swale is calculated as the sum of the two "x" distances seen in the figure above, the wetted perimeter is approximately equal to the swale width.

When constructing a swale with known side slopes, the width of the swale can be defined in terms of the depth. For example, 3:1 side slopes on a swale indicates that for every 1 foot of depth, each side slope will be 3 feet wide, for a total swale width of 6 feet.

Also, we can define the area of the swale as:

Swale area = ½ x width x depth

With these geometrical assumptions, the equations used to size swales
can be simplified since the area and wetted perimeter terms can both be written in terms of depth in the hydraulic radius calculation. Therefore, the equations for triangular swale design are as follows:

Equation 8-3: Manning's Equation for triangular swales (side slope = 3:1)

$$Qp = (1.49/n) \times 1.04 \times D^{2.67} \times S^{1/2}$$

Or

$$D = [Qp \times n \div (1.55 \times S^{1/2})]^{0.375}$$

Where: Qp = Peak Flow (ft^3/s - section 8.2)
n = Manning's n value (Table 8.2)
D = Swale depth (ft)
S = Swale slope (ft/ft)

Equation 8-4: Manning's Equation for triangular swales (side slope = 4:1)

$$Qp = (1.49/n) \times 1.26 \times D^{2.67} \times S^{1/2}$$

Or

$$D = [Qp \times n \div (1.88 \times S^{1/2})]^{0.375}$$

Equation 8-5 Manning's Equation for triangular swales (sideslope = 5 to 1)

$$Qp = (1.49/n) \times 1.46 \times D^{2.67} \times S^{1/2}$$

Or

$$D = [Qp \times n \div (2.18 \times S^{1/2})]^{0.375}$$

8.4.2 Simplified triangular swale design process

With the simplifications made to the Manning's equation for triangular swales, the design process for these practices becomes straightforward. In a basic design scenario, the slope (S) of the swale will likely be set. Likewise, the peak flow (Qp) from the catchment will be calculated using the rational method. Therefore, the depth of swale (D) and Manning's n will be the only unknowns once a given swale geometry is chosen. If space is available, side slopes of 4:1 or 5:1 can be used. This will allow easy access to the swale for mowing equipment. If limited space is available, 3:1 side slopes may be used.

The design process requires iterations to achieve an acceptable design. In general, the steps of the design process are as follows:

1. Calculate peak flow for the 10 year storm from the catchment.
2. Determine slope from swale beginning to end.
3. Select swale geometry (typically 3:1 or 4:1 side slopes).
4. Assume Manning's n value from Table 8.1 depending on chosen liner type.
5. Use equations 8-3, 8-4, and 8-5 to determine D, the depth of swale when flowing full during 10 year storm).
6. Use D to calculate swale area as define in Section 8.4.1. Also calculate channel width as defined in Section 8.4.1 – make sure space is available – if not, steeper side slopes may be used.
7. Use area calculated in step 6 and Qp to determine the velocity of the stormwater in the swale during the 10-yr storm (use Equation 8-1 - the continuity equation).
8. Compare velocity to permissible velocities in Table 8.2 to determine if grass can withstand the velocity produced in the channel – if so, the design is complete.
9. If grass cannot withstand the velocity produced in the channel, turf reinforcement matting can be used. If turf reinforcement matting is not desired, rock can be used; however, the design process must be repeated using a different Manning's n value.

Always perform a check to determine if the velocity produced in the channel can be passed by the channel lining without eroding.

10. If a safe velocity cannot be achieved with a given swale design, the slope of the system, the side slopes, or the liner type can be adjusted and the above calculations repeated.

8.5 Construction Guidance

Swales can be constructed using a variety of heavy equipment. The equipment used will depend on the size of the swale. A small excavator would suffice on smaller jobs and may be on site for construction of other SCMs.

If turf reinforcement matting is used, it should be installed according to the manufacturer's recommendations. Use plenty of staples to stabilize the mat, and maintain good contact between the mat and the ground surface in all locations. It is helpful to use short lengths of matting on curves to avoid bunching. Seed and lime should be applied under the matting or as suggested by the manufacturer. Native grass will perform the best; however, the grass should only be applied at the proper time of year (proper time varies depending on grass type). The property owner may desire that the grass planted match what is already in their yard. County extension offices can help with grass selection and planting. Temporary seed can be used if construction must take place during a time of year when the onsite grass will not germinate. For example, Annual Rye grass can be used in cool seasons or Millet in warm seasons. If temporary seed is used, the swale must be re-seeded with perennial grass at the proper time of year.

For grassed swales, the surface should be protected using a suitable erosion control product while seed is being established to avoid erosion. Sod is acceptable as well, and it may be easier and cheaper to install than a seed and erosion control matting combination.

8.6 Maintenance

Swale maintenance should consist mostly of mowing. Adjusting the mower to keep the grass long is preferable for filtration. Scalping the grass should be avoided to prevent erosion. If erosion occurs, the swale may be re-shaped and stabilized. If substantial sediment deposition occurs, it must be removed to allow unobstructed flow in the channel.

Table 8.3 Maintenance Activities for Swale.

Maintenance Activity	Frequency
Mow grassed channel	minimum quarterly - as needed
Check swale for erosion or gully formation	after large/intense storm events
Remove trash from swale	As needed
Remove deposited sediment	As needed
Reseed	As needed - late spring or late summer
Repair turf reinforcement matting	As needed - move mower deck up to avoid catching the mat with the blade

9.0 Impervious Removal

9.1 Overview of Practice

As discussed in section 2.2, urbanization (characterized by increases in impervious area) can cause a substantial increase in stormwater runoff. One basic stormwater management practice is to reduce the amount of impervious area in a given urbanized area. If an area has already been built out, this can be accomplished by removing impervious areas that are no longer needed. Patios, walkways, parking areas, and driveways can all be removed and converted to pervious areas. Gardens, lawn, and permeable pavements all can be used in place of the impervious area. For permeable pavement costs to be offset by CCAP, it must be accompanied by impervious surface removal.

9.2 Selection of this practice over others

Impervious surface removal should only take place when there is a patio, walkway, parking area, or driveway that is no longer being used or is going to be converted to a permeable surface. Impervious areas that drain directly into the stormwater sewer system should be targeted. Impervious areas that are directly connected (see connected imperviousness – Section 3.2) to the larger stormwater drainage system have the greatest impact on stormwater runoff. Impervious areas that drain onto pervious areas before collecting in the storm drainage network present less of an impact since runoff from these impermeable surfaces has an opportunity to infiltrate into the pervious area. Impervious surface removal can provide a water quality benefit when there is limited space to construct a rain garden, backyard wetland, or other SCM.

Impervious removal should be performed in combination with the creation of pervious areas such as lawn, gardens, or permeable pavement. Permeable pavement conversion can only be performed in the Sandhills and Coastal Plain as part of the CCAP (see Chapter 10.0).

9.3 Carrying Out Impervious Removal

While removing impervious area is a simple way to limit stormwater runoff, removing asphalt, concrete, or brick can be challenging. Breaking the impervious area into small pieces and removing these pieces should be performed by a contractor to avoid injury. Once broken up, the impervious area will consist of very heavy, sharp-edged debris. A large truck will be required to transport the debris from the location to a disposal site after heavy equipment, such as a backhoe, breaks the pavement apart and carries it to the truck.

Following the removal of impervious surfaces, the soils need to be amended to aid in establishment of vegetation. Soils underneath driveways and patios have been compacted. A small roto-tiller should be used to loosen the soil. Before doing so, ensure that all rubble and debris have been removed. A sample of the soil should be sent for analysis to the NCDA laboratory for free soil testing to determine if lime and fertilizer needs to be applied. Finally, a small layer (nominally 2 inches thick) of topsoil should be placed over the disturbed area and tilled in to the native soil. Grass, shrubs, or trees should be able to establish on this amended soil. Follow planting recommendations for the species that the landowner desires.

10.0 Permeable Pavement

10.1 Overview of Practice

Traditional asphalt and concrete pavements are impermeable, which convert nearly all rainfall to runoff. These pavements were designed to withstand heavy traffic loads. Permeable pavement allows water to pass through it, reducing runoff (Figure 10.1). This pavement is best used in low traffic situations similar to those found in patios, parking pads, and driveways, which makes it a good "backyard" stormwater control measure. Permeable pavements may be constructed of permeable asphalt, pervious concrete, permeable interlocking concrete pavers (PICP), concrete grid pavers, and grassy pavers (Figure 10.2). They are typically underlain by a gravel support layer ranging in thickness from 4 to 12 inches. Permeable pavements function best when sited on sandy soils, such as those found on barrier islands, the Coastal Plain, and the Sandhills. Permeable pavement should not be placed near active construction zones, as they are prone to clog. An example of a patio constructed of permeable pavement is shown in Figure 10.3, and a residential driveway application is shown in Figure 10.4.

Figure 10.1 Illustration of permeable pavement function – garden hose dispensing onto permeable concrete.

Figure 10.2 Four types of permeable pavements (starting top left corner and moving clockwise): permeable concrete, permeable interlocking concrete pavement, grass pavers, and concrete grid pavers.

Figure 10.3 Permeable pavement patio outside a café in Swansboro, NC.

Figure 10.4 Permeable pavement driveway.

10.2 Permeable Pavement Siting

In parts of North Carolina, NC DENR awards a runoff reduction credit if permeable pavement is used in place of impermeable pavement. This blanket credit for permeable pavement as a stormwater control measure is only available in the Sandhills, Coastal Plain, and Barrier Islands; however, credit on a case-by-case basis can be given in the Piedmont and Mountains. The CCAP will only provide funding for permeable pavement projects in the Coastal Plain, Sandhills, and barrier islands. The reason for this geographic limitation is that the stormwater infiltration is limited by the native soils. Sandhill and Coastal Plain soils are often sandy and well-drained.

It is imperative that in situ soils are analyzed in depth before permeable pavements are installed. A three foot hole should be dug in multiple locations in the proximity of the proposed permeable pavement site. The soils should be well drained (See Section 3.7), with no signs of wetland characteristics within the soil profile. (See Section 3.8) Additionally, the infiltration rate at the site should exceed 0.5 in/hr throughout the top 3 feet of soil. Field determination of infiltration rate is described below in Section 10.3.1.

The site where the SCM is to be installed must currently consist of impervious area that will be removed and replaced with permeable pavement. The area should ideally have a very slight slope (less than 0.5%) to allow maximum stormwater storage to lessen engineering design. This practice should only be used for backyard patios, sidewalks, and residential parking pads. The sites that are selected for permeable pavement installation should not experience heavy vehicular traffic such as garbage trucks. The traffic load should be consistent with normal residential use. Any parking lot either associated with a business or larger than 2 stalls should be designed by an engineer to ensure structural stability. Any permeable pavement lot that is to be sited on an existing slope of more than 0.5% should also be designed by an engineer.

Permeable pavement should not be used to treat runoff from any adjoining areas larger than the square footage of the permeable pavement itself. It is imperative that these pavements are surrounded by a stable catchment. No disturbed soil should be present in areas draining to the permeable pavement. Permeable pavement is used primarily to infiltrate the rain that falls onto it. Typically, if grassed and rooftop areas are to be treated at a given residence, a SCM other than permeable pavement may be more desirable.

10.3 Permeable Pavement Design

10.3.1 Initial Soil Analysis Field Test

The infiltration rate at the site should be 0.5 in/hr throughout the top 3 feet of soil. To test this, three holes will be required, each at least 4 feet away from the other (again, this should be done in multiple locations around the proposed site). Each of the 3 holes will have a different depth: 1-foot, 2-foot, and 3-foot. Each hole should be filled with water. The 1-foot hole should be drain in 6 hours, the 2-foot hole in 12 hours, and the 3-foot hole in 18 hours. This test is performed to ensure no impermeable layer is present in the top 3 feet of soil. Permeable pavement should never be installed without field testing of soil infiltration rate. Additionally, field tests of infiltration rate may be performed with a double-ring infiltrometer or a constant head permeameter and may be preferable to the simple field test described above.

In general, the soil classification should be no finer than a Loamy Very Fine Sand as defined by the United States Department of Agriculture – Natural Resources Conservation Service. More detail on permeable pavement is available in Chapter 18 of the North Carolina Stormwater BMP Manual (NCDENR, 2007). If these infiltration criteria are met, the soils at the site will meet the screening criteria for permeable pavement installation; however, detailed soil analysis should be performed to ensure that the site is suitable. If soils at the site are questionable for permeable pavement installation, it is recommended that a soil scientist or a competent professional in evaluating soils be consulted to determine the soil's permeability.

10.3.2 Soil Analysis Lab Test

If the initial field soil test described in section 10.3.1 indicates that the soils may need further analysis, soil samples should be taken from the area where this SCM is to be implemented. These samples should be taken to a laboratory for analysis to ensure that they will be structurally sufficient to support the permeable pavement and will be suitable for infiltrating the captured stormwater. One sample should be taken for every 200 square feet of surface area to be constructed. Samples may be taken along the periphery of the existing impermeable area.

At each sampling location, a hole should be dug to a depth of 3 feet. The topsoil can be discarded (top 6 inches); however, all other soil excavated from the hole should be placed in a bucket and mixed until all soil layers are combined homogeneously. A sample should be taken from this bucket and placed into a vessel that is approved by the laboratory that will be analyzing the sample (the laboratory selection should be approved by SWCD staff). The laboratory should perform a sieve analysis to determine what percentage of the soil sample consists of fines (total clay and silt particles). If the percentage of fines is less than 8%, or the amount passing the 270 sieve, which means the sample consists primarily of sand and loamy soils, the soils are suitable as a base for the permeable pavement.

10.3.3 Concrete Edging

Concrete edging should be used around the perimeter of the paved area whenever permeable interlocking concrete pavers are installed (see Figure 10.5). The edging should be approximately 18 inches deep and have a width of 6 inches. This edging will reduce the movement of the pavement blocks under the traffic load. Permeable concrete and concrete grid pavers will not require this edging provided that the edge of the paved area is not exposed to vehicular traffic.

Figure 10.5 Pavers abutting a concrete edge.

10.3.4 Gravel Base

The gravel base that is laid over the existing soils is used to (1) store captured stormwater and (2) provide structural stability (Figure 10.6). The depth and type of stone in the gravel base will vary depending on whether permeable concrete or PICP are installed. If the soil criteria described in sections 10.3.1 and 10.3.2 is met, the total gravel base should be approximately 6 inches deep. Any stone used as a gravel base should be washed to reduce the amount of fines in the gravel. These fines if not removed will migrate to the soil sub base and clog the soil pores. This clogging would result in reduced infiltration and, thus, reduced permeable pavement performance.

Figure 10.6 Gravel layers under permeable pavers.

When permeable concrete is used for a given location, the gravel base will consist of a washed #57 stone that is approximately 6 inches thick. The permeable concrete can be poured on top of this gravel base after the base has been properly compacted. Compaction is usually completed using a plate compactor. If washed #57 stone is unavailable, a semi-angular to angular stone alternative can be used. Round support stone will not interlock, allowing shifts in pavement to occur, such as rocking or splitting.

When permeable block pavers or plastic grid pavements are used for the SCM, 4 inches of washed #57 stone can act as the gravel base that is placed on top of the in situ soil; however, the pavers must sit on a bedding layer of smaller stone. This bedding layer should consist of washed #78 stone and be approximately 2 inches thick. The #78 stone should also be used to fill any voids present in between the permeable paver blocks after they are installed (Figure 10.7). Once again, compaction of the gravel base will need to be undertaken with a plate compactor to ensure that the gravel base does not shift under loading. The plate compactor should be used to compact the #57 stone after it has been placed to a 4 inch depth. Next the #78 stone should be added, and the plate compactor used again to lock all of the gravel in place. The #78 stone should be screeded, and the PICP can then be installed.

Figure 10.7 Filling permeable paver voids with gravel.

10.3.5 Permeable Pavement Sizing Criteria

Permeable pavement SCMs used as part of the CCAP will treat only direct rainfall and run-on from an area of equal area to the permeable pavement. The size of the permeable pavement lot will generally be the same as the square footage of impervious area that was removed. The thickness of the permeable pavers is determined by the manufacturer (normally approximately 3.25 inches). Plastic grid pavers tend to be 2 inches thick. Permeable concrete should be poured to a thickness of 6 inches.

10.4 Permeable Pavement Construction

Due to the scale of many permeable pavement installations, it is recommended that a certified permeable pavement contractor install permeable pavements. Installing permeable concrete or PICP requires experience and expertise and should not be attempted by the general public. A list of professionals who are certified to install permeable interlocking concrete pavers (PICP) and concrete grid pavers (CGP) is available from the Interlocking Concrete Pavement Institute (ICPI) at www.icpi.org. Carolinas Ready Mixed Concrete Association (CRMCA) can be contacted for a list of professionals with experience in installing permeable concrete (www.crmca.com). The only exception to this would be small, backyard patios that will be installed using permeable block pavers.

The construction steps below can be completed by an experienced contractor with minimal instruction. The key points from each section should be conveyed to the contractor, and a SWCD staff member or the design engineer should be on-site during construction.

10.4.1 Soil excavation

For permeable pavement to be used as part of the CCAP, a certain amount of impervious removal must be performed. After the impervious area has been removed, such as an driveway, sidewalk, parking pad, or patio, the site excavation can commence.

Excavation depth should be measured from the soil surface down. Fill should not be used to bring the surrounding soil to the top of pavement level. To prevent compaction, the excavated area should not be driven on by any construction equipment to avoid reducing the soil's infiltration capacity. During the construction, a SWCD staff member should be on-site to verify that the excavated area is brought to the correct depth. A survey instrument (such as a site level, laser level, or total station) would be beneficial for this process.

10.4.2 Gravel base

Washed or double washed stone should be used for any permeable pavement installation. The gravel base installation will vary slightly depending on whether permeable concrete or permeable pavers are being installed.

If permeable concrete is being installed, a 6-inch layer of washed #57 stone can be placed in the excavated area. The stone should be spread and leveled to the appropriate slope. The stone should then be compacted with a minimum 10 ton static roller (at least 4 passes). The stone should be compacted until there is no visible movement within the gravel base (Smith, 2000).

If permeable pavers are being installed, the same procedure that is described for the permeable concrete gravel base would be performed with a 4 inch thick layer of washed #57 stone. Next, a 2 inch layer of #78 stone should be added to the top of the #57 stone layer. This layer should be compacted using the same process that was used for the first layer. The gravel base will now be structurally ready to support permeable pavement.

10.4.3 Concrete edging

When permeable interlocking concrete pavers are installed, some edging will be required to keep the pavers stable along the edges of the new permeable area. As stated in section 10.3.3, a 6 inch wide, 18 inch deep concrete curb should be sufficient. It is easiest to construct the curbing prior to placement of gravel. The curbing should run along the perimeter of the permeable area to provide support to the pavers on the edge of the lot.

10.4.4 Permeable pavement installation

As stated above, installing permeable concrete or permeable pavers should be performed by a professional familiar with proper installation. The methods used to install permeable concrete vary from those used to install standard concrete. Because permeable pavement contains void spaces which allow stormwater to infiltrate, the integrity of these pores must be maintained. Vibratory screens, such as those used in some cases to compact standard concrete, should not be used during permeable concrete installation. Such instruments can smear the surface of the concrete resulting in reduced or restricted infiltration. Additionally, concrete vibrators, which are employed to reduce air pockets, are not to be used. A heavy steel roller is used in place to provide adequate compaction without smearing the concrete. Finishing exercises such as floating and brooming are not necessary and could result in surface sealing on the lot. Permeable concrete does not contain the same curing compounds as traditional concrete; thus, plastic is placed over the concrete for up to a week to prevent drying (Ferguson, 2005). The plastic should never be drug across the pavement, as smearing could result.

Installing PICP is similar to installing regular block pavers; the difference in these systems is that voids are maintained between the pavers, allowing water to infiltrate. The blocks are placed on top of the compacted #78 stone. Once set into place, the blocks are compacted before additional #78 stone is added to the top of the pavement area and allowed to fall into the voids in between the permeable paver blocks. Excess #78 stone is swept off of the area and the permeable paver blocks are compacted one final time. Tight placement of the blocks is essential to maintaining the structural integrity of the system (Smith, 2000).

10.5 Permeable Pavement Maintenance

Like any other SCM, permeable pavement requires maintenance to be effective over time. The greatest concern related to these systems is clogging of the surface void spaces. Once these surface voids become clogged, the system loses its function and effectively becomes an impervious area.

One means of removing sediment and debris from the permeable pavement area is to vacuum and sweep the area. On most commercial sites, this can be done easily by running a vacuum truck over the area. This may not be possible in a backyard SCM setting; however, the site should be swept regularly and cleared of all debris. As mentioned in section 10.4.5, the area around the permeable pavement lot should continually be evaluated to verify that sediment from adjoining areas is not washing onto the permeable pavement. This sediment can clog the permeable pavement over time. Additionally, any weeds or mosses that grow in the pavement voids can be removed using herbicide or be flamed.

Finally, over time, the stone that is used to fill the voids in PICP can be lost as tires track it off of the lot and as the gravel settles. This rock should be replaced periodically to restore the proper amount of gravel in the void spaces. Table 10.1 shows the maintenance activities associated with permeable pavements and the frequency with which these activities should take place.

Table 10.1 Permeable Pavement Maintenance Activities.

Location	Potential Problem	Maintenance Activity	Frequency
Perimeter of the Permeable Pavement	Bare soil contributing sediment	Re-grade soil and establish ground cover. Provide lime and fertilizer once if needed.	As Needed
	Grass clippings on permeable pavement	Remove grass clippings after mowing.	As Needed
	Leaves and Trash	Remove from areas surrounding pavement.	Once per month, more frequently during leaf-fall.
	Structure of Curbing is Damaged or Degrading	Seek guidance from an engineer familiar with permeable pavement, re-pour curbing.	As Needed
Permeable Pavement Surface	Clogging of Pavement Surface	Sweep and/or vacuum pavement surface.	Once per month
	Weeds growing in permeable pavement	Spray herbicide on weeds. Do not pull out weeds, as this may dislodge gravel.	Once every 6 months
	Replacement of Gravel Between Pavers	Use washed #57 stone. Sweep in with a push broom.	Every 6 months initially, less frequently with time
	The Pavement does not drain between storms	Sweep or vacuum the pavement. If it still does not dewater, consult a professional.	As Needed
	Structure of pavement surface is damaged or degrading	Consult an engineer familiar with permeable pavement.	As Needed

11.0 References:

Bean, E.Z. 2005. A Field Study to Evaluate Permeable Pavement Surface Infiltration Rates, Runoff Quantity, Runoff Quality, and Exfiltrate Quality. M.S. thesis. Raleigh, NC: Biological and Agricultural Engineering Department, North Carolina State University.

Bedient, P.B., and W.C. Huber. 1992. Hydrology and Floodplain Analysis, 2nd Edition, Reading, Massachusetts: Addison-Wesley Publishing Company.

Butler, J.D., and T. Caudill. 2005. Citizen's Guide to Protecting Wilmington's Waterways. City of Wilmington, NC: Storm Water Services.

Donaldson, Susan. 2007. The Effects of Urbanization on the Water Cycle. Nevada Cooperative Extension. Fact Sheet 04-43. Ferguson, B.K., ed. 2005. Porous Pavements. Boca Raton, FL: CRC Press LLC.

Ferguson, B.K. 2005. Porous Pavements. CRC Press, Boca Raton, FL.

Flint, K.R. and A.P. Davis. 2007. Pollutant Mass Flushing Characterization of Highway Stormwater Runoff from an Ultra Urban Area. Journal of Environmental Engineering 133(6): 616-626.

Hathaway, J.M., and W.F. Hunt. 2006. Stormwater BMP Costs: Division of Soil and Water Conservation Community Conservation Assistance Program. Raleigh, NC: Biological and Agricultural Engineering Department – North Carolina State University.

Leopold, L.B. 1968. Hydrology for Urban Land Planning, U.S. Geological Survey, Circular 544. North Carolina Division of Water Quality. Stormwater Unit: What is Stormwater?.

NC Department of Environment and Natural Resources, Division of Water Quality (NCDENR). 2007. Stormwater Best Management Practices Manual. Raleigh, NC.

Richardson, J.L., and M.J. Vepraskas, eds. 2001. Wetland Soils: Genesis, Hydrology, Landscapes, and Classification. Boca Raton, FL: CRC Press LLC.

Sansalone, J.J., and C.M. Cristina. 2004. First Flush Concepts for Suspended and Dissolved Solids in Small Impervious Watersheds. Journal of Environmental Engineering 130(11): 1301-1314.

Schueler, T.R., and H.K. Holland, eds. 2000. The Practice of Watershed Protection. Ellicott City, MD: Center for Watershed Protection.

Schueler, T. 1987. Controlling Urban Runoff – A practical Manual for Planning and Designing Urban Best Management Practices. Metropolitan Washington Council of Governments. Washington, DC 240 pp.

Smith, D.R. 2000. Permeable Interlocking Concrete Pavements: Selection, Design, Construction, Maintenance. 2nd edition, Washington, DC: Interlocking Concrete Pavement Institute.

Sutherland, A.B., Meyer, J.L., and Gardiner, E.P. 2002. Effects of Land Cover on Sediment Regime and Fish Assemblage Structure in Four Southern Appalachian Streams. *Freshwater Biology*. 47: 1791-1805.

Swank, W.T. and D.A. Crossley. 1988. Forest Hydrology and Ecology at Coweeta. New York, NY, Springer-Verlag Publishing.

USDA-NRCS. 1986. Technical Release 55: Urban Hydrology for Small Watersheds. Available: http://www.cpesc.org/reference/tr55.pdf.