URBAN WATERWAYS

Designing Rain Gardens (Bio-Retention Areas)

As communities in North Carolina develop, more and more land is converted into impermeable surfaces, which do not allow water to infiltrate. These include driveways, parking lots, homes, offices, schools, highways, and paved walkways. Much of this expanding infrastructure is needed to maintain a desired quality of life. Everything from a dry place to work, eat, and sleep to easy access to hospitals depends on a system of impervious surfaces. However, without careful consideration, impermeable land can dramatically harm the quality of the state's waters, adjacent wetlands and forests, and other natural areas. Water that once soaked into the ground—or infiltrated—now runs on top of roads or through gutters, often heading straight to nearby streams and lakes and carrying potentially harmful pollutants. Often a network of impervious surfaces serves as a "stormwater superhighway" that quickly conveys stormwater and associated pollutants into streams.

Increased stormwater runoff introduces many undesirable effects:

1) More flooding during storms and less groundwater (or base flow) during dry weather.
2) Increased erosion and subsequent sedimentation (settling) of eroded particles in streams or flood plains.
3) Streambank erosion resulting from high stream velocities.
4) More chemicals and metals being deposited by vehicles and equipment, eventually reaching streams.
5) Nutrients, such as nitrogen and phosphorus, gaining easier access to natural water bodies via an "efficient" storm sewer.
6) Increased numbers of potentially harmful bacteria and other pathogens from humans, pets, and wildlife entering the state's waters.
7) All the pollutants—from sediment to toxic chemicals to bacteria—harming plants and animals living in or near North Carolina's streams, lakes, and estuaries.

Fortunately, there are techniques that can minimize flooding, erosion, and the amount of metals, nutrients, and bacteria that enter the state's waters. These measures are often called stormwater Best Management Practices (BMPs). BMPs can include relatively simple changes in homeowner actions, such as proper application of fertilizer. Others involve reduction at the source through site design or mitigation measures, such as preserving vegetation along streams or other sensitive areas. Still other BMPs are structural; that is, they are built. The most well-known structural BMP is the pond or reservoir, but many others are becoming more common, such as stormwater wetlands, sand filters, grassy swales, and, more recently, rain gardens. These BMPs tend to disrupt the "stormwater superhighway," allowing for infiltration or retention of the water. For a more detailed survey of several structural BMPs, please refer to the first publication in the Urban Waterways series,

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Urban Stormwater Structural Best Management Practices (BMPs), AG-588-1, available through your local Cooperative Extension center.

Selecting a BMP depends on many factors, including available land and its cost, homeowner and community attitudes, topography, source and type of pollution, soil type, watershed size, and land cover. In areas where land is limited, where aesthetics are an important concern of the community (or homeowner), where nuisances need to be avoided at all cost, or where "childproof" safety is required, rain gardens may prove to be the optimal BMP to install.

Rain Gardens: What Are They?

Pioneered in Prince George's County, Maryland, rain gardens are designed to merge two important goals: aesthetics and water quality. Rain gardens (also known as bio-retention areas) are intended to be landscaped areas that treat stormwater runoff. Homeowners or custodians can treat these gardens, giving them significant attention, or they can blend them into the landscape and make them look "natural." Whatever the context, a rain garden should look like part of the landscape: plants—particularly shrubs and trees—surrounded by mulch.

However, the true nature of a rain garden is to treat stormwater. Water is directed into them by pipes, swales, or curb openings. The garden is a depression or bowl that temporarily holds water, as opposed to shedding it away. The trees and shrubs growing in rain gardens are water tolerant, rather than water loving (as discussed later).

Figure 1. Rain garden installed at Neuseway Nature Center (Kinston, N.C.). Stormwater runoff enters through the 6-inch-diameter pipe near the right foreground. The garden receives rainfall from a nearby rooftop. This rain garden is a small depression in sandy soil. The mulch is hardwood.

Rain gardens can be installed in a variety of soil types from clays to sands. A rain garden constructed in sandy soil in Kinston, North Carolina, is shown in Figure 1; a clay soil rain garden in Cary, North Carolina, is shown in Figure 2.

Rain gardens can vary in size. They can be installed in a corner of your lawn, placed along the edges of roads, or put in the medians of parking lots. The size and design of the rain garden depend on the area that drains to it and the type of soil in which the garden is placed.

How Rain Gardens Remove Pollution

Rain gardens remove pollutants using physical, chemical, and biological mechanisms. Specifically, they use absorption, microbial action, plant uptake, sedimentation, and filtration. In addition, rain gardens sited in appropriate soils can be designed to allow infiltration of most stormwater runoff, thus replenishing groundwater. An explanation of each of these mechanisms is provided below and in Table 1.

Absorption is a chemical process that removes some forms of metals and phosphorus. The process takes place on mulch and soil particles lying on the floor of the rain garden. Soil particles have charges—similar to a magnet—as do dissolved metals and soluble phosphorus. When these charges are complementary, dissolved metals and phosphorus are attracted to the open soil particles. This process is called absorption. One drawback to absorption is that there is a finite number of charged soil particles at the bottom of a rain garden. Once all the available charged mulch and soil particles have sorbed with metals and phosphorus, the absorption potential of a rain garden decreases dramatically. Scientists and engineers wrestle with this problem today, but research-

Figure 2. Bio-retention median in a Cary, N.C., parking lot. Bio-retention is a practical alternative for treating stormwater runoff from heavily impervious commercial areas.

ers monitoring rain gardens in Maryland suggest that the capacity of soil to retain pollutants could last for more than 10 years. Decomposed mulch helps replenish the soil's absorptive capacity. It has been found important to have a relatively "fresh" layer of mulch, making landscape management very important.

Microbes found in rain gardens break down organic substances and may eat harmful pathogens. The shallow root zone-soil interface of rain gardens provides a medium for these microbial processes to occur.

Exposure to sunlight and dryness helps kill pathogens, which typically prefer wet conditions. Because it is inherent in the design of rain gardens to dry out quickly, they could be good at combating pathogens. Management of rain gardens is important: pets and wildlife should be discouraged from making their home in rain gardens if pathogens from their waste are a concern.

Though not a significant means of removing nitrogen and phosphorus from inflow, plants do take up these nutrients. Rain garden vegetation uses nutrients as it grows. Plant die-off can be a concern because decaying vegetation does release nutrients back into the system. Removing dead vegetation from a rain garden should keep this problem to a minimum.

Rain gardens also treat pollutants by allowing stormwater to infiltrate. Once stormwater becomes part of shallow groundwater, nutrients in it can then be treated as it flows through riparian buffers (vegetated areas adjacent to streams). Without rain gardens, stormwater on the surface probably would be quickly ferried into nearby streams and lakes via the storm drainage network. For information on riparian buffers, please refer to other fact sheets available from North Carolina Cooperative Extension and the North Carolina Department of Environment and Natural Resources' Division of Water Quality.

Sedimentation and filtration are physical processes that remove soil particles, litter, and other debris from water. Although rain gardens are not good at removing sediment long term, any BMP that can contribute to this end is helpful because sediment is the state's number one water pollutant.

Sedimentation occurs because water slows down once it enters a rain garden. Faster-moving water has more energy and is, therefore, able to carry sediment, trash, and other debris. Once the water slows down inside the rain garden, it loses its ability to carry these pollutants; thus, suspended particles tend to settle to the bottom of rain gardens. Vegetation, particularly grass, provides a limited amount of filtration and aids in sedimentation. Because the inflow water must pass through vegetation, some pollutants can be "snagged" by the plant mass. This is the process of filtration. Because rain gardens tend not to be densely planted, the amount of filtration that rain gardens provide is typically *very* limited. Sedimentation and filtration are primary mechanisms for removing total suspended solids (TSS), litter and debris, nutrients attached to sediment particles—such as some forms of phosphorus, and bacteria and other pathogens that are also affixed to sediment. It is best to construct rain gardens, however, in established watersheds, such as shopping centers or subdivisions, because they can clog very easily. While rain gardens can be very effective devices for removing sediment initially, they only maintain their function if they are maintained constantly when they are constructed in watersheds with sediment inputs. As a result, rain gardens are very rarely used for sedimentation control.

The exact ability of rain gardens to remove pollutants has not yet been quantified fully. Research has just begun on these new practices. However, rain gardens do appear to be effective at removing the most critical pollutants found in urban stormwater runoff, including most metals, total phosphorus, and total nitrogen. Initial results suggest that rain gardens are not effective at removing nitrate-nitrogen, but that treatment could occur later when water passes through other vegetated areas, such as riparian buffers.

Table 1. Pollutant removal mechanisms used in rain gardens

Pollutant Removal Mechanism	Pollutants
Absorption to soil particles Plant uptake	Dissolved metals and soluble phosphorus Small amounts of nutrients including phosphorus and nitrogen
Microbial processes	Organics, pathogens
Exposure to sunlight and dryness	Pathogens
Infiltration of runoff	Minor abatement of localized flooding, minor increase in localized base flow of groundwater, allowing some nutrients to be removed when groundwater flows through buffer
Sedimentation and filtration	Total suspended solids, floating debris, trash, soil-bound phosphorus, some soil-bound pathogens

(Adapted from Brix, 1993)

Designing a Rain Garden: Sandy Soils

Sandy soils simplify the design of rain gardens. Locate the rain garden where it can receive water. Slightly depressed areas are good candidates, provided these depressions do NOT have a seasonally high water table. If the surface is frequently saturated, the site may be too wet, stunting or killing many of the rain garden's plants. A high water table would encourage the growth of wetland plants, which many homeowners sometimes want to avoid. If a suitable depression does not exist, a flat site works best. Dig a small bowl in a flat area downstream of runoff no deeper than 6 to 12 inches, with 9 inches as a standard. This range of depth allows for vegetative diversity while still improving water quality. Deeper water ponding depths tend to limit vegetative diversity, and depths of more than 2 feet have proven to be too much to allow most types of vegetation to subsist.

Sizing a Rain Garden

Designers commonly want to know how much land area is needed to build a rain garden. The state of Maryland suggests that the area of the rain garden should vary between 5 percent and 7 percent of the drainage area depending upon the percentage of impervious surface in the contributing watershed. Another way to answer the question is to make the rain garden large enough to hold runoff from the first inch of rainfall in the drainage area, no matter the soil type in the rain garden. To do this, use the following equation from the Natural Resources Conservation Service:

Runoff depth in inches = $(\mathbf{P} - 0.2\ \mathbf{S})^2 \div (\mathbf{P} + 0.8\ \mathbf{S})$,

where **P** = Precipitation (typically use 1 inch) and
S = 1,000 ÷ **CN** – 10.
CN = Curve Number
CN, or Curve Number, is a measure of how much water will infiltrate during a storm. Curve numbers vary by soil type and land use. A short list of curve numbers is given in Table 2.

When rain gardens treat only impervious areas, such as rooftops and parking lots, use the standard curve number of 98. Assuming a 100 percent impervious area (and a curve number of 98), one would arrive at 0.79 inch of runoff from 1 inch of rain. By multiplying this runoff depth by the area of the watershed, the volume of runoff from a 1-inch rain falling on a given watershed can be calculated. So, if the watershed is a rooftop that has a surface area of 2,000 square feet, the volume of runoff from a 1-inch storm would be calculated to be:

Runoff volume (cubic feet) = **Area** × **Runoff depth**

2,000 square feet × 0.79 inch ×
(1 foot/12 inches ≅ 130 cubic feet

This is the amount of water the rain garden would be designed to hold.

Because rain gardens are often designed to hold water 9 inches deep (though values ranging from 6 to 12 inches are commonly used), the surface area required of a rain garden can be found using the following equation:

Rain garden surface area = **Rain garden volume** ÷ **Average depth of water**

In the example given, this equation would be:

Surface area = 130 cubic feet ÷ [(9 inches) × (1 foot/12 inches)] = **170 square feet**, or roughly 8 percent of the watershed (rooftop).

As more pervious area becomes a part of the watershed, the relative size of the rain garden diminishes substantially. For example, if the watershed consists of a 2,000-

Table 2. Partial listing of NRCS curve numbers in urban areas. Please note that Soil Groups A and B are sandier and Soil Groups C and D are more clayey. These soil classifications would be found in a county soil survey available at any Soil and Water Conservation District office or North Carolina Cooperative Extension center.

Land Use/Cover	Soil Group A	Soil Group B	Soil Group C	Soil Group D
100% Impervious (parking lots, rooftops, paved sidewalks)	98	98	98	98
Open space (lawns and golf courses) with grass cover < 50%	68	79	86	89
Open space with grass cover 50% to 75%	49	69	79	84
Open space with grass cover > 75%	39	61	74	80
Woods in fair hydrologic condition	36	60	73	79

(Taken from USDA-NRCS, 1986)

square-foot building surrounded by 6,000 square feet of lawn, the rain garden would require 270 square feet of surface area or roughly 3 percent of the contributing watershed. Rain garden design parameters for sandy soils are summarized in Table 3.

Designing the Overflow

As noted earlier, rain gardens are designed to treat runoff from the first flush (typically the first inch of rainfall). But what if it rains more than 1 inch? This happens 11 to 12 times a year, on average, in Raleigh, North Carolina[1], and even more frequently in other parts of the state. Therefore, it is important to design an overflow to divert excess water either around or out of the rain garden. In many cases water can simply flow "out the back" of the rain garden. This is allowed in rain gardens that are constructed in flat areas. Water would leave the rain garden simultaneously from several places along the back side. This works only in virgin—or unaltered—soil with a turf cover.

If the perimeter of the rain garden is altered during construction, this soil will likely erode if water flows over it for any length of time. Rain gardens that have disturbed soil must have a designated water overflow area for larger storms. Rocks or turf reinforcement mats can be used to line the outlet area.

In commercial and industrial settings, an overflow pipe often is installed in the middle of the rain garden. The top of the pipe or overflow box is set at the desired maximum water depth (ranging from 6 to 12 inches generally, with 9 inches considered a standard). A diagram of this type of overflow system is shown in Figure 3, and the photo in Figure 4 shows a similar system in Maryland. For additional design information on outlet controls, please refer to *Elements of Stormwater Design* by H. R. Malcom or see the website : http://www2.ncsu.edu/eos/info/bae/cont_ed/bio_ret_course/, which has a sample overflow design.

[1]Determined from 10 years of data (1988-1998) from the Southeastern Climate Data Center.

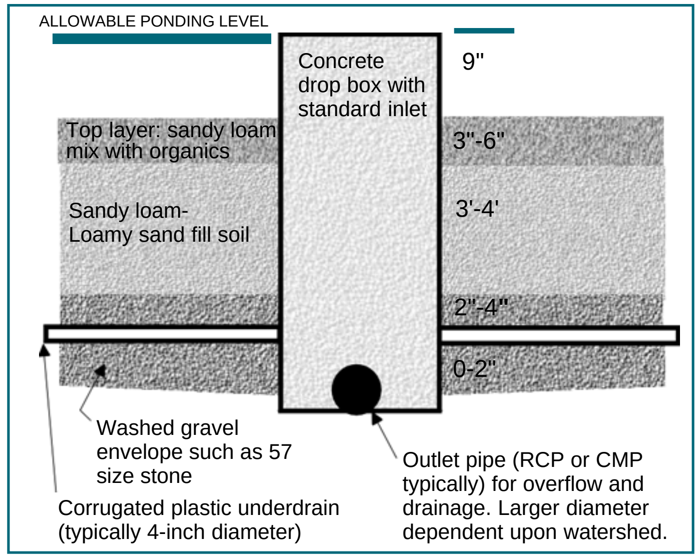

Figure 3. Rain garden cross-section with an overflow box (note: not to scale)

Figure 4. Bio-retention median or rain garden in Maryland with overflow drain visible on the right. The top of the overflow, shown here as a metal grate, is typically 9 inches above the bottom elevation of the bio-retention area.

Table 3. Summary of design parameters for rain gardens constructed in sandy soils

Infiltration rate	Greater than 1 inch per hour (typical for sandy loam, loamy sand, and sand).
Maximum depth of water	Range from 6 to 12 inches, with 9 inches standard. Some applications have deeper water allowances, which make plant growth difficult.
Relative size of rain garden	Varies, but typically 3 to 8 percent of contributing watershed, depending upon the amount of impervious surfaces.
Topographic feature	Flat areas that are downstream of impervious surfaces work best. A shallow bowl naturally serves as a rain garden.
Existing water table	Seasonally high water table should not come within 2 feet of the surface.
Places to avoid placing rain gardens	Areas that flood regularly (at least yearly) for at least two weeks and areas immediately adjacent to building and road foundations.
Mulches	A minimum of 2 inches is needed; 3 to 4 inches are preferable. Mulch should be hardwood, not pine bark nuggets (which float). Double-shredded hardwood works well. Pine straw may be used.

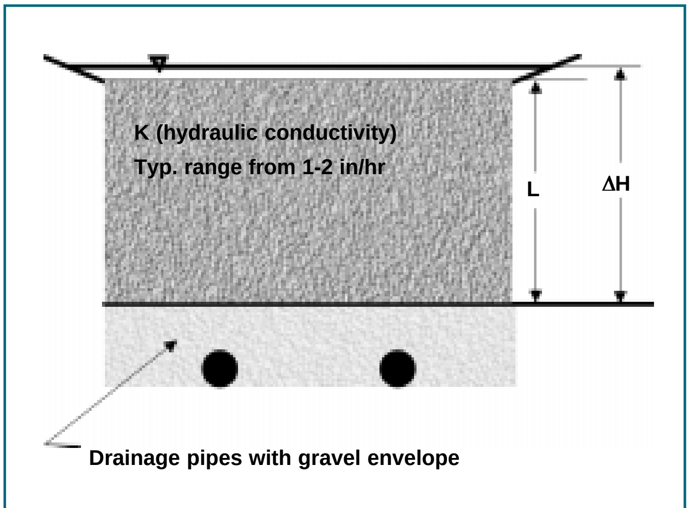

Figure 5. Darcy's Law applied to a rain garden cross-section. Specific discharge (q) is equal to hydraulic conductivity (K) multiplied by the ratio of water height (ΔH) divided by layer thickness (L).

Designing a Rain Garden: Clay Soils

Unlike those in sandy soils, rain gardens in clay soils must be designed to include drainage. Rain gardens in clay soils are essentially vegetated sand filters. Connecting a rain garden to an existing drainage network or siting it in a "table" area—a relatively flat area with a defined edge that steeply slopes away—can limit the higher costs of rain gardens in clay soils. The table area minimizes the length of drainage pipe needed. As with sandy soil rain gardens, it is important to site the rain garden in an area without a seasonally high water table.

Figure 3 on page 5 shows a cross-sectional view of a rain garden constructed in clay soil. There are three principal parts to the cross section:

1. The drainage area, which is comprised of drainage pipe and washed stone,
2. The soil zone, where the plants take root and much of the water treatment occurs, and
3. The vegetation and mulch zone, the visible part of the rain garden.

As noted in the illustration, the soil zone is at least 3 feet deep unless grass is the only vegetation, in which case it should be 1.5 feet deep. The soil is usually imported. This depth ensures enough room for the roots of shrubs and small, shallow-rooting trees. If possible, a depth of 4 to 5 feet is preferable. A deeper depth allows for additional treatment of pollutants. The depth of the drain system varies between 6 and 12 inches, depending on the type and size of drainage pipe used. Typically, 4- to 6-inch-diameter corrugated plastic pipes that are slotted with holes are used. The number and diameter of pipes vary according to drainage needs. Between the rock layer and the soil, a permeable geotextile is placed, which allows water to pass through but effectively keeps soil particles separated from the rock layer.

Importing Soils

The success of a rain garden in clay soils hinges on its ability to move water through the system. As with sandy soils, water ponding at the surface for long periods can hamper plant growth in rain gardens with clay soils. Perhaps a more natural structure for areas with high water tables is a small stormwater wetland. The wetland could better thrive in these wetter areas. For more information on stormwater wetlands, see *Designing Stormwater Wetlands for Small Watersheds*, AG-588-2.

The designer controls two factors that influence the drainage capability of the system: the type of soil used for media and the size and number of drainage pipes. Soil type is the limiting factor of the two. The soil selected must have enough fines (clays) to support plant growth and capture particles of pollutants. The soil also must be permeable enough to allow water to pass. This balance is best achieved by using sandy loam to loamy sand. Typical permeabilities for these soils range from 1 to 6 inches per hour. These permeabilities can be reached by either importing the appropriate soil or amending the existing soil with an import that is typically more permeable.

You can estimate the rate at which water moves through this soil layer by using Darcy's Law. The following equation and Figure 5 will illustrate Darcy's Law:

$$\mathbf{q = K\ \Delta H / L},$$

where **q** = Flow per cross-sectional area, **K** is hydraulic conductivity, **ΔH** is change in head (height of water), and **L** is thickness of soil layer.

For deep rain gardens, ΔH and L are nearly the same number ($\Delta H \cong L$). In these cases, the rate of water movement can be reasonably estimated by the relationship, $q = K$.

You must ascertain how long water will be within the top 2 feet of the surface. Designs in Maryland suggest that water must be removed within 48 hours of rainfall to a level 2 feet below the surface. This is not a problem when sandy loam or loamy sand fill soils are used. For a thorough explanation of Darcy's Law, consider several references in the hydraulics and hydrogeological field, including *Applied Hydrogeology* by C. W. Fetter.

Selecting Underdrain Pipes

Pipes must be selected so that they drain water from the rock layer substantially faster than water enters from the soil fill layer above. The removal capacity of the underdrain should be an order of magnitude higher than the inflow amount. Peak inflow is achieved when water is at its highest level in the rain garden (typically set at 9 inches). Using Darcy's Law, a rain garden that has a 1,000-square-foot area, a fill soil layer 4 feet thick, and a permeability of 2 inches per hour would have a peak inflow (**q_p**) of:

q_p = (2 in/hr) x (4.75 feet) ÷ (4 feet) = 2.4 in/hr per unit area. Multiplying by the area of the rain garden (1,000 square feet) will then determine the total flow that the underdrain pipes must be able to remove from the rain garden. This is shown below:

$Q = q_p$ x Area = 2.375 in/hr x 1,000 square feet x (1 ft/ 12 inches) x (1 hour/3,600 sec) ≅ 0.05 cubic feet per second

By sizing the pipe system to carry at least 10 times this minimum amount, the design flow becomes 0.5 cubic feet per second.

To determine the number of pipes and their associated diameter, the Manning Equation is used.

$$\mathbf{N} \times \mathbf{D} = 16 \times \{\mathbf{Q} \times \mathbf{n} \div \mathbf{s}^{0.5}\}^{3/8},$$

Where **N** = number of pipes
D = diameter of pipes (inches)
Q = flow to be carried (cfs)
n = Manning coefficient (0.014 for 4- to 6-inch single-wall corrugated pipe)
s = slope of pipe (for this site, assume 0.5%)

Solving this equation for the example site,

$$N \times D = 16 \times \{0.5 \text{ cfs} \times 0.014 \div 0.005^{0.5}\}^{3/8}$$

N x D must equal 6.72 inches. Therefore, two 4-inch (N x D = 8 in) diameter single-wall corrugated pipes would carry water from the gravel layer at a rate at least 10 times faster than water enters the gravel layer from the in-fill soil layer. A list of Manning coefficients applicable to rain gardens is provided in Table 4.

Sizing a rain garden's surface area, designing overflow, and selecting mulch for rain gardens in clay soils does not differ from designing a rain garden in sandy soils. Please refer to the previous section for this information. A summary of design parameters for rain gardens constructed in clay soils is given in Table 5.

Table 4. Manning roughness coefficients for selected underdrain pipe sizes

Pipe type and diameter	Manning roughness coefficient
4" Single-wall corrugated plastic	0.014-0.015
4" Smooth-wall plastic	0.010-0.011
6" Single-wall corrugated plastic	0.014-0.015
6" Smooth-wall plastic	0.010-0.011
8" Single-wall corrugated plastic	0.015-0.016

Other Design Considerations

After you locate, size, and excavate the rain garden, take a few more measures. First, stabilize all water inlets. If water enters the garden in a concentrated flow, such as from a pipe or ditch, it may be necessary to

Table 5. Summary of design parameters for rain gardens constructed in clay soils

Infiltration rate	Between 1 and 6 inches per hour for imported soil (typical of sandy loam, loamy sand).
Maximum depth of water	Range from 6 to 12 inches, with 9 inches standard. Some applications have deeper water allowances, which make plant growth difficult.
Relative size of rain garden	Varies, but typically 3 to 8 percent of contributing watershed, depending upon the amount of impervious surfaces.
Topographic feature	Flat areas that are downstream of impervious surfaces work best, provided they are adjacent to an existing stormwater sewer network. A table area (flat with relatively steep drop-off at edge) is necessary if existing storm sewer is not nearby.
Existing water table	Seasonally high water table should be below the bottom of the rain garden (typically 4 to 6 feet below the surface of the rain garden).
Places to avoid placing rain gardens	Areas that flood regularly (at least yearly) for at least two weeks and areas adjacent to building and road foundations.
Mulches	A minimum of 2 inches is needed; 3 to 4 inches are preferable. Mulch should be hardwood, not pine bark nuggets (which float). Double-shredded hardwood works well. Pine straw may be used.
Rock for gravel layer	Washed stone is preferable. Separate gravel from fill soil with a permeable geotextile.
Drainage pipes	Design to carry 10 times the maximum inflow from soil layer.

place rock at the end of the conveyance (pipe or swale). This rock dissipates the energy of the water as it enters the rain garden. A level spreader (device used to spread water flow into sheet flow) is used to evenly distribute water as it enters the rain garden. For more information, see *Urban Stormwater Structural Best Management Practices (BMPs)*, AG-588-1. As long as velocity is not greater than 1 to 2 feet per second (fps), there is little chance for erosion. If a rain garden will treat concentrated flow from a large watershed (at least 1 acre), consult the state of North Carolina's *Erosion and Sediment Control Planning and Design Manual*, which describes how to size stilling areas. However, rain gardens normally serve small watersheds or have several water entry points, thus limiting the amount of "concentrated" water.

If a TSS load is possible, consider using grass buffer strips and force sheet flow through them. The grass strip will filter much of the solids, keeping the rain garden free of this clogging agent. Grass strips should run the length of the garden where sheet flow would be expected to enter at a nominal width of 5 feet, though these strips have been as narrow as a few feet or much wider than 5 feet depending upon the application.

If the rain garden will treat runoff from and is being constructed adjacent to a parking lot, leave a 2- to 3-inch drop from the edge of the parking lot to the surface of the rain garden. If the rain garden at the edge of the parking lot is even with the pavement, eventual plant growth and debris buildup in the rain garden (or grass filter strip) will create a miniature dam, forcing water to move laterally along the pavement rather than through the strip and into the rain garden. Figures 6 and 7 illustrate this concept.

Once you stabilize the drainage area, it is time to plant. Rain garden plant recommendations are given in a later section. After planting, cover the exposed soil with mulch. The mulch layer should be at least 2 inches thick—though 3 to 4 inches are preferable—and should be a hardwood mulch, not a pine mulch. Experience from Maryland has shown that double-shredded hardwood mulches are much less apt to float, which is a real concern in an area that will frequently experience temporary flooding. Pine bark mulch floats too well to be used for this purpose.

A plan view of a rain garden is shown in Figure 8. This rain garden is designed to treat runoff from a parking lot and to serve as a bio-retention median.

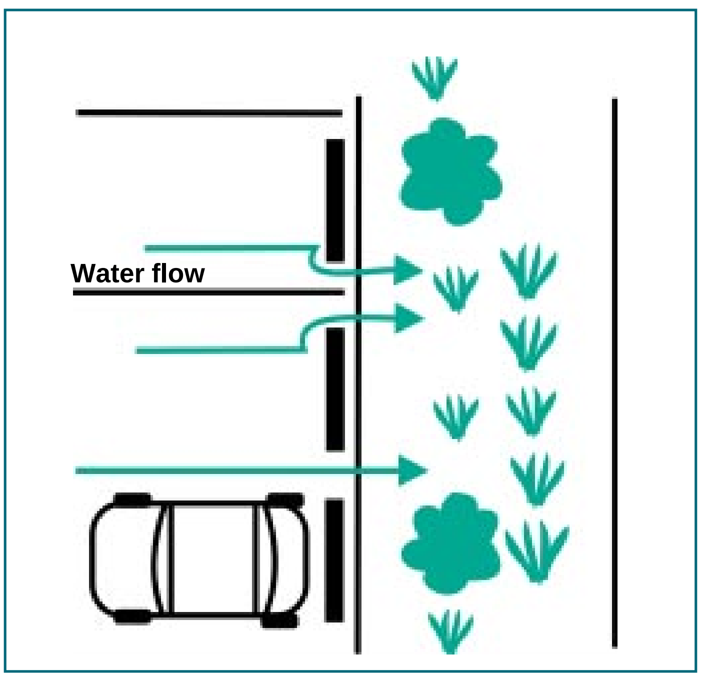

Figure 6. Overland flow from parking lot into rain garden/bio-retention area. Water flows between parking stops before spilling into the bio-retention median.

Landscaping with Rain Garden-Appropriate Plants

Rain gardens were specifically intended *not* to be wetlands. They are designed so that water does not regularly saturate or inundate the garden for long periods. Therefore, rain gardens are too dry for many obligate wetland plants, such as cattails, common reed, and water lillies. Conversely, rain gardens are designed to receive stormwater runoff; therefore, the vegetation must be able to withstand brief periods of inundation. Biologists have classified five types of wetland and upland vegetation (see Table 6). Typically, neither obligate wetland nor obligate upland vegetation is

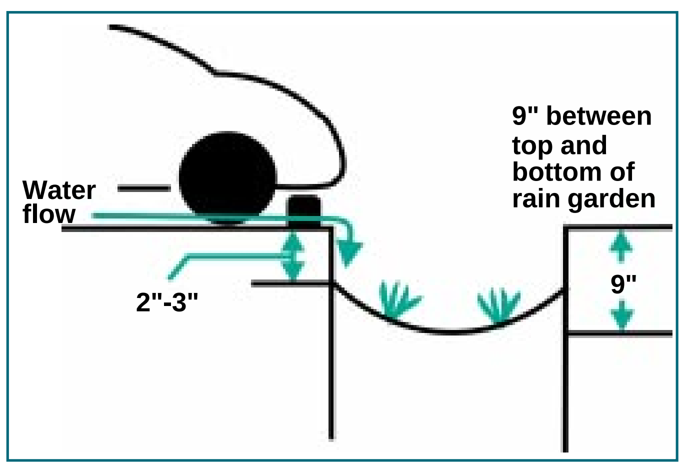

Figure 7. Profile view of runoff entering rain garden/bio-retention area from parking lot. Note the 2- to 3-inch distance between the top of the bio-retention area and the end of the curb.

appropriate for rain gardens.

The dryness of a rain garden—which depends upon how much water is directed to it, how quickly the garden drains, and how frequently it rains—usually dictates the type of vegetation that can thrive in the garden. Work in Maryland and North Carolina has revealed that facultative plants usually work best in rain gardens; however, certain species of facultative-wetland and facultative-upland plants survive depending on the wetness of the site. Rain garden vegetation must also be drought-tolerant if the site is to be maintained infrequently. Rain gardens are wet only during and immediately after rain events. Plants in the garden must also be able to tolerate some periods without substantial moisture if the garden is ignored.

Table 7 on page 10 lists several trees and shrubs that can be grown in rain gardens. Their Latin name, common name, habitat, and size are given. This table is a not a complete list. Moreover, certain plants listed are primarily found in either the eastern or western portions of North Carolina. Before deciding which vegetation to plant, be sure to consult more authoritative sources, such as your county Extension agent, nursery specialist, or landscape contractor. Two excellent references are *Manual of Woody Landscape Plants* by M. Dirr and *Carolina Landscape Plants* by G. Halfacre.

A few other significant factors are used to determine which plants to grow in rain gardens. For those constructed in clay soils, it is very important to select trees and shrubs that do not have overly aggressive roots. Plants like willows can quickly send roots into drainage pipes in search of water, clogging the pipes. It is important to note that all plants seek out water. There is no foolproof way of keeping tree and shrub roots out of drainage pipes. Because sandy soil rain gardens are not drained by pipes, plants with aggressive roots are typically not a concern. Another plant to avoid is any type of cherry tree. When inundated, cherry tree roots release a poison that kills the tree.

Aesthetics play an important role in plant selection, especially for the homeowner. Several plants have attractive blooms. Evergreen species should also be selected to maintain color in the rain garden during the winter. Consult your nursery or landscape professional to help select material that suits your situation.

The best time to plant shrubs and trees depends upon

Table 6. Definitions for wetland indicator status

Plant type	Where plant type occurs
Obligate wetland (OBL)	Plants almost always occur in wetlands (> 99% of the time)
Facultative wetland (FACW)	Plants usually occur in wetlands (67-99% of the time)
Facultative (FAC)	Plants just as likely to occur in wetland or non-wetland areas (34-66% chance of occurring in wetlands or non-wetlands)
Facultative upland (FACU)	Plants that occasionally occur in wetlands (1-33% of the time)
Obligate upland (UPL)	Plants that almost never occur in wetlands (< 1% of the time)

(Taken from N.C. DENR, 1997)

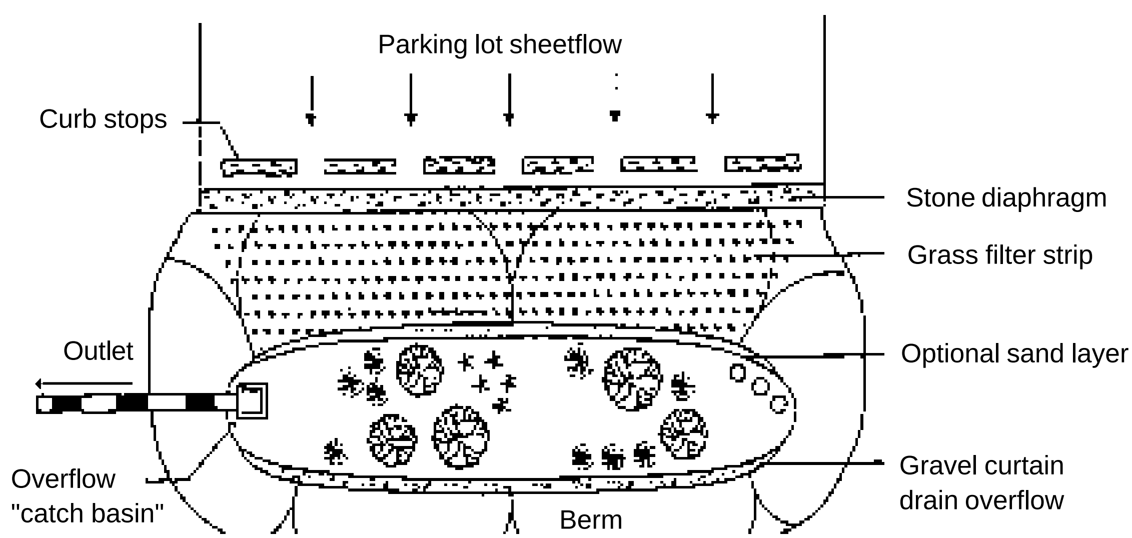

Figure 8. Plan view of a rain garden/bio-retention area. Reproduced from *Stormwater Modules* with permission from the Center for Watershed Protection.

plant type. Ornamental grasses and evergreens are well suited for spring planting. Deciduous trees and shrubs are best planted in the fall to early winter. Smaller herbaceous species can be planted in spring or fall. Planting the rain garden often dictates the timing of construction. It is very important that the watershed draining into the rain garden be stable before planting.

As with any garden, rain gardens must be maintained. Make sure you know the horticultural needs of the plants you choose. Once the plants are in the ground they cannot be entirely ignored and be expected to survive. It is important to inspect rain gardens seasonally or after substantial rainfall—particularly early on. Small maintenance needs include removing trash and other unwanted debris from the garden and replacing mulch. The more a rain garden is treated as a garden, the more apt it is to be attractive and flourish.

Costs

Costs of rain gardens are affected by four primary factors: 1) the type of in-situ soil (sand or clay), 2) the topography (flat or hilly), 3) the types of vegetation selected, and 4) the required surface area. The first two factors can make rain garden construction much less expensive in the coastal plain and sandhills than in the piedmont and mountains (though some mountain soils, particularly in abandoned flood plains, tend to be quite sandy).

The type of soil dictates the costs of excavating, hauling, installing pipes, and importing new soil and rocks. With sandy soils, most excavation and hauling costs are minimized; there are often no pipe and soil importation costs. However, if the rain garden site is located in an area where heavy equipment has passed several times (such as a townhouse construction site), it may be important to install underdrain pipes even in

Table 7. Listing of shrubs and trees potentially used in rain gardens/bio-retention areas

Latin name	Common name	N.C. habitat	Size/form
Acer negundo	Box elder	Across N.C.	Small tree
Acer rubrum	Red maple	Across N.C.	Medium tree
Aronia arbutifolia	Red chokeberry	Across N.C.	Medium shrub
Cercis canadensis	Redbud	Across N.C.	Large shrub
Clethra alnifolia	Sweet pepperbush	Coastal plain, piedmont	Medium shrub
Cornus sericea ssp. stolonifera	Red osier dogwood	Piedmont, mountains	Medium-small shrub
Cyrilla racemiflora	Ti-ti	Coastal plain	Large shrub (semi-evergreen)
Diospyros virginiana	Persimmon	Piedmont, mountains	Small-medium tree
Euonymus americana	Strawberry bush	Across N.C.	Small shrub
Fraxinus pennsylvanica	Green ash	Piedmont, coastal plain	Medium tree
Hypericum frondosum	St. John’s wort	Piedmont, coastal plain	Ground cover/herbaceous
Ilex vomitoria	Dwarf yaupon	Coastal plain	Small shrub (evergreen)
Juniperus virginiana	Grey owl red cedar	Across N.C.	Shrub (evergreen)
Magnolia virginiana	Sweetbay (magnolia)	Coastal plain	Small tree (evergreen)
Myrica cerifera	Wax myrtle	Across N.C.	Large shrub (evergreen)
Pinus palustris	Longleaf pine	Coastal plain, piedmont	Tall tree (evergreen)
Pinus taeda	Loblolly pine	Piedmont, coastal plain	Medium tree (evergreen)
Quercus pagoda	Cherrybark oak	Piedmont, coastal plain	Large tree
Sambucus canadensis	American elderberry	Across N.C.	Medium shrub
Scuttellaria integrifolia	Scull cap	Across N.C.	Ground cover

rather sandy soils.

Topography affects the amount of soil hauling, excavation, and pipe installation, too. A flat area is best for constructing the body of a rain garden. In areas requiring underdrains, it is important to have a relatively steep area adjacent to the body of the rain garden to minimize pipe costs.

The number, species, and age of vegetation greatly influence costs as well. Certain species are rarer and therefore cost more. Plant density in the rain garden changes total cost as does the age of the vegetation. Young, small plants cost less than their larger, more mature counterparts.

In general, construction costs for rain gardens in the coastal plain, sandhills, and sandy areas in the N.C. mountains range from $1.50 to $3 per square foot of rain garden area. In the piedmont, costs range from $4 to $6 per square foot.

Maintenance costs vary depending upon the level of attention the rain garden warrants. The rain garden's underdrains must be inspected at least yearly to make sure they are not clogged. The mulch layer will decompose, so mulch must be added as needed. This keeps up the appearance of the rain garden (minimizing weeds) and continues to provide a key water quality function. This maintenance needs to be performed once or twice per year. During droughts, it may be important to water the garden. As with any garden, the more care plants receive, the more able they are to survive. Also, all vegetation eventually dies, so the gardens will have to be replanted over time. This is not expected to be a yearly occurrence, however. It is reasonable to assume that vegetation will need to be replaced every 10 years, but this has not been verified.

Table 8 summarizes the costs for two rain gardens, one in the coastal plain and a second in the piedmont.

Summary

Rain gardens are a very attractive BMP because they can improve environmental quality while meeting landscape requirements. Rain gardens that treat stormwater runoff can appeal to homeowners and developers. The gardens can be constructed in both residential and commercial areas across the state, though more easily in the coastal plain, sandhills, and abandoned floodplains of the mountains. For more information, please contact your local North Carolina Cooperative Extension Center or N.C. DENR's Division of Water Quality.

Table 8. Calculating rain garden costs—two case studies

1. **Relatively flat coastal plain site. Very sandy soils. Mature plants not densely placed. Total area = 250 square feet.**
2. **Relatively flat piedmont site. Very clayey soils. Young plants and free transplants used. Total area = 900 square feet.**

Construction Element	Coastal plain		Piedmont	
	Unit Cost	Total	Unit Cost	Total
Excavation (including labor and equipment rental)	Cubic yard	$100	$9.50/cubic yard (also includes excavation for pipe trench)	$1,600
Hauling	Included in above price	Included in above price	Included in above price	Included in above price
Importing rock and sand	N/A	N/A	$0.40/cubic foot	$1,280
Piping and filter fabric	N/A	N/A	$2/linear foot	$800
Mulch	$0.30/square foot	$80	$0.30/square foot	$250
Vegetation	$2/square foot (mature plants, somewhat dense)	$400	$0.30/square foot (young plants and free transplants)	$250
Total		$580		$4,180
Total per square foot		$2.32		$4.65

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Please see other fact sheets in the Urban Waterways series, AG-588, including:
Urban Stormwater Structural Best Management Practices (BMPs) (AG-588-1)
Designing Stormwater Wetlands for Small Watersheds (AG-588-2).

Another fact sheet is available from your local Extension center: *Stormwater Management for Homeowners,* AG-567-6.

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