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"Rain Gardens – A How-to Manual for Homeowners"

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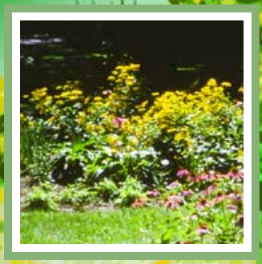
RAIN GARDENS



A how-to manual for homeowners

RAIN GARDENS

Your personal contribution to cleaner water

Homeowners in many parts of the country are catching on to rain gardens – landscaped areas planted to wild flowers and other native vegetation that soak up rain water, mainly from the roof of a house or other building. The rain garden fills with a few inches of water after a storm and the water slowly filters into the ground rather than running off to a storm drain. Compared to a conventional patch of lawn, a rain garden allows about 30% more water to soak into the ground.

Why are rain gardens important? As cities and suburbs grow and replace forests and agricultural land, increased stormwater runoff from impervious surfaces becomes a problem. Stormwater runoff from developed areas increases flooding; carries pollutants from streets, parking lots and even lawns into local streams and lakes; and leads to costly municipal improvements in stormwater treatment structures.

By reducing stormwater runoff, rain gardens can be a valuable part of changing these trends. While an individual rain garden may seem like a small thing, collectively they produce substantial neighborhood and community environmental benefits. Rain gardens work for us in several ways:

- Increasing the amount of water that filters into the ground, which recharges local and regional aquifers;
- Helping protect communities from flooding and drainage problems;
- Helping protect streams and lakes from pollutants carried by urban stormwater – lawn fertilizers and pesticides, oil and other fluids that leak from cars, and numerous harmful substances that wash off roofs and paved areas;
- Enhancing the beauty of yards and neighborhoods;
- Providing valuable habitat for birds, butterflies and many beneficial insects.

Who should use this manual?

This manual provides homeowners and landscape professionals with the information needed to design and build rain gardens on residential lots. Guidelines presented in this manual can also be used to treat roof runoff at commercial and institutional sites. However, the manual should not be used to design rain gardens for parking lots, busy streets and other heavily used paved areas where stormwater would require pretreatment before entering a rain garden.

Frequently asked questions

Does a rain garden form a pond?

No. The rain water will soak in so the rain garden is dry between rainfalls. (Note: some rain gardens can be designed to include a permanent pond, but that type of rain garden is not addressed in this publication).

Are they a breeding ground for mosquitoes?

No. Mosquitoes need 7 to 12 days to lay and hatch eggs, and standing water in the rain garden will last for a few hours after most storms. Mosquitoes are more likely to lay eggs in bird baths, storm sewers, and lawns than in a sunny rain garden. Also rain gardens attract dragonflies, which eat mosquitoes!

Do they require a lot of maintenance?

Rain gardens can be maintained with little effort after the plants are established. Some weeding and watering will be needed in the first two years, and perhaps some thinning in later years as the plants mature.

Is a rain garden expensive?

It doesn't have to be. A family and a few friends can provide the labor. The main cost will be purchasing the plants, and even this cost can be minimized by using some native plants that might already exist in the yard or in a neighbor's yard.

Sizing and Siting the Rain Garden

This section of the manual covers rain garden basics – where to put the rain garden, how big to make it, how deep to dig it, and what kind of soils and slope are best. Following the instructions in this section is the best way to ensure a successful rain garden project.

An extension of PVC pipe helps direct downspout water to this rain garden.

If you already know the size you want your rain garden to be, then skip ahead to the section about building the rain garden. However, take time read the pointers about location, and do find the slope of the lawn. If the location has a slope more than about 12%, it's best to pick a different location because of the effort it will take to create a level rain garden.

Where should the rain garden go?

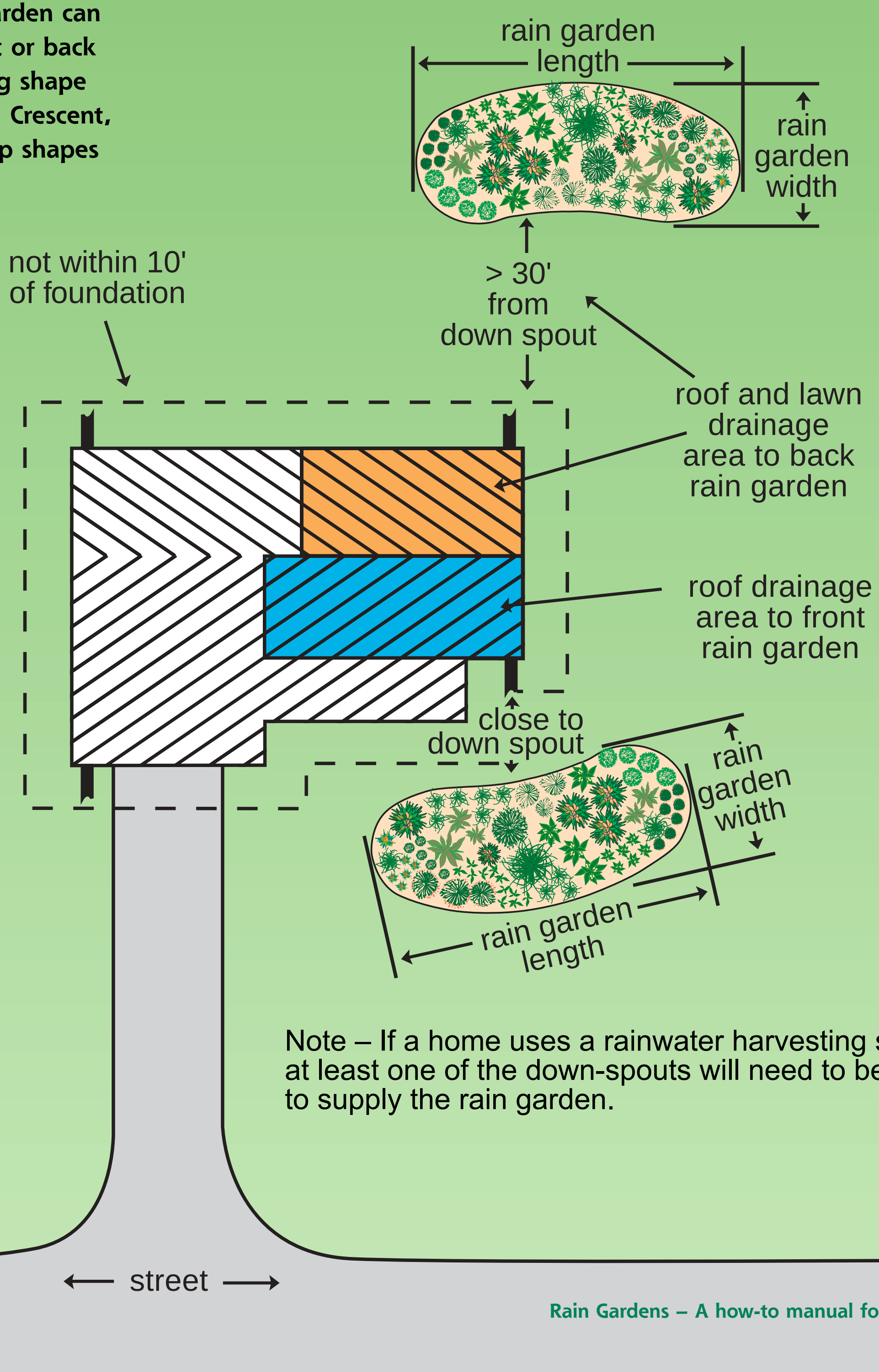
Home rain gardens can be in one of two places – near the house to catch only roof runoff or farther out on the lawn to collect water from the lawn and roof. (Figure 1 shows the possible locations on a residential lot.) To help decide where to put a rain garden, consider these points:

- The rain garden should be at least 10 feet from the house so infiltrating water doesn't seep into the foundation.
- Do not place the rain garden directly over a septic system.
- It may be tempting to put the rain garden in a part of the yard where water already ponds. Don't! The goal of a rain garden is to encourage infiltration, and your yard's wet patches show where infiltration is slow.
- It is better to build the rain garden in full or partial sun, not directly under a big tree.
- Putting the rain garden in a flatter part of the yard will make digging much easier. For example, a rain garden 10 feet wide on a 10% slope must be 12 inches deep to be level, unless you import topsoil or use cut and fill.

Consider your overall landscape

When considering placement of your rain garden, design with the end in mind. Carefully consider how the rain garden can be integrated into existing and future landscaping. Also, pay attention to views from inside the house as well as those throughout the landscape. Determine how far or how close you want your rain garden to outdoor gathering spaces or other play areas. Why not locate it near a patio where you can take advantage of the colors and fragrances for hours on end!

Figure 1 **A rain garden can be built in the front or back yard. Pick a pleasing shape for the rain garden. Crescent, kidney, and teardrop shapes seem to work well.**



Note – If a home uses a rainwater harvesting system, at least one of the down-spouts will need to be diverted to supply the rain garden.

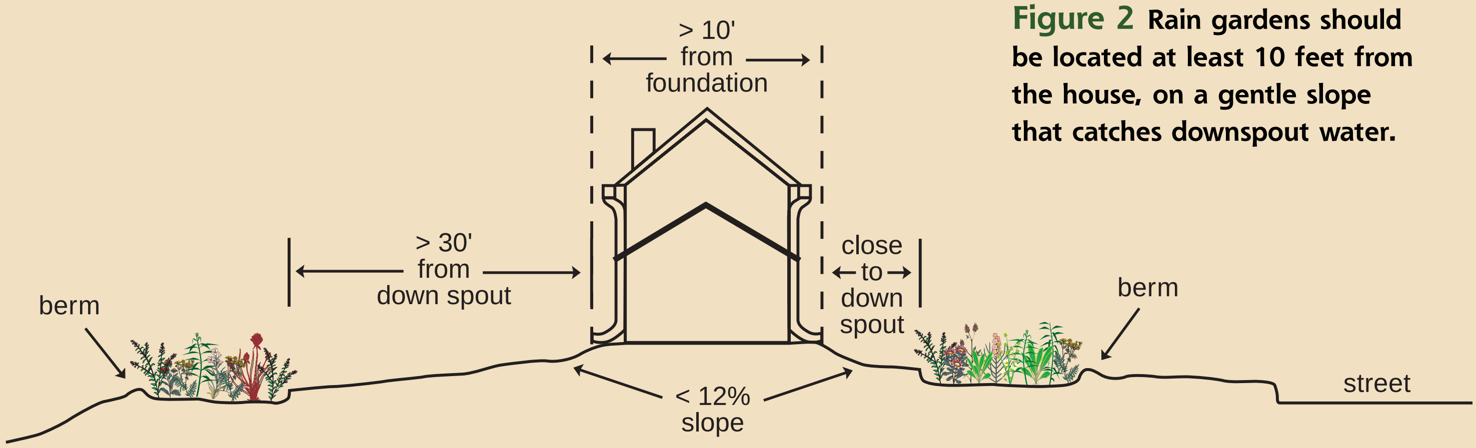


Figure 2 **Rain gardens should be located at least 10 feet from the house, on a gentle slope that catches downspout water.**

How big should the rain garden be?

The surface area of the rain garden can be almost any size, but time and cost will always be important considerations in sizing decisions. Any reasonably sized rain garden will provide some stormwater runoff control. A typical residential rain garden ranges from 100 to 300 square feet. Rain gardens can be smaller than 100 square feet, but very small gardens have little plant variety. If a rain garden is larger than 300 square feet it takes a lot more time to dig, is more difficult to make level, and could be hard on your budget.

The size of the rain garden will depend on

- how deep the garden will be,
- what type of soils the garden will be planted in, and
- how much roof and/or lawn will drain to the garden.

This information, along with the sizing factor from the tables on page 9, will determine the surface area of the rain garden.

Digging with a rented backhoe.

Guidelines are not rules...

The sizing guidelines described in this manual are based on a goal of controlling 100% of the runoff for the average rainfall year while keeping the size of the rain garden reasonable. Establishing a 100% runoff goal helps compensate for some of the errors that creep into the design and construction of any rain garden.

If you follow the guidelines in the manual and decide the calculated surface area is just too large for your goals, it is perfectly acceptable to make the rain garden smaller. The rain garden can be up to 30% smaller and still control almost 90% of the annual runoff. On the other hand, it is fine to make the rain garden bigger than the guidelines indicate.

How Deep Should the Rain Garden Be?

A typical rain garden is between four and eight inches deep. A rain garden more than eight inches deep might pond water too long, look like a hole in the ground, and present a tripping hazard for somebody stepping into it. A rain garden much less than four inches deep will need an excessive amount of surface area to provide enough water storage to infiltrate the larger storms.

No matter what the depth of the rain garden, the goal is to keep the garden level. Digging a very shallow rain garden on a steep lawn will require bringing in extra topsoil to bring the downslope part of the garden up to the same height as the up-slope part of the garden. As the slope gets steeper, it is easier to dig the rain garden a little deeper to make it level.

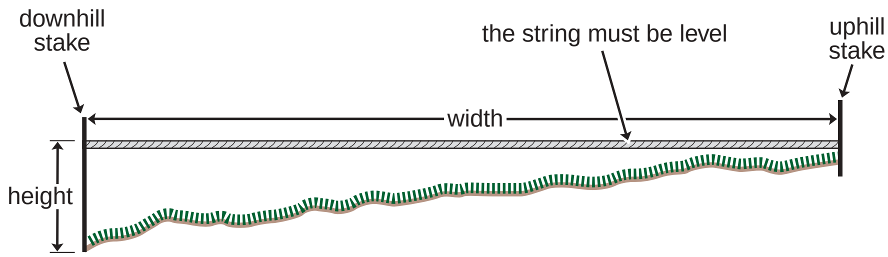


Figure 3 The string should be tied to the base of the uphill stake, then tied to the downhill stake at the same level.

The slope of the lawn should determine the depth of the rain garden. Find the slope of your lawn by following these steps. (Figure 3 shows how the stakes and string should look.)

1. Pound one stake in at the uphill end of your rain garden site and pound the other stake in at the downhill end. The stakes should be about 15 feet apart.
2. Tie a string to the bottom of the uphill stake and run the string to the downhill stake.
3. Using a string level or the carpenter's level, make the string horizontal and tie the string to the downhill stake at that height.
4. Measure the width (in inches) between the two stakes.
5. Now measure the height (in inches) on the downhill stake between the ground and string.
6. Divide the height by the width and multiply the result by 100 to find the lawn's percent slope. If the slope is more than 12%, it's best to find another site or talk to a professional landscaper.

Using the slope of the lawn, select the depth of the rain garden from the following options:

- If the slope is less than 4%, it is easiest to build a 3 to 5-inch deep rain garden.
- If the slope is between 5 and 7%, it is easiest to build one 6 to 7 inches deep.
- If the slope is between 8 and 12%, it is easiest to build one about 8 inches deep.

EXAMPLE

Todd measures the length of the string between the stakes; it is 180 inches long. The height is 9 inches. He divides the height by the width to find his lawn's percent slope.

$$\frac{\text{height}}{\text{width}} \times 100 = \%\text{ slope} \qquad \frac{9\text{ inches}}{180\text{ inches}} \times 100 = 5\%\text{ slope}$$

With a 5% slope, Todd should build a 6 inch deep rain garden.

What type of soils are on the rain garden site?

After choosing a rain garden depth, identify the lawn's soil type as sandy, silty, or clayey. Sandy soils have the fastest infiltration; clayey soils have the slowest. Since clayey soils take longer to absorb water, rain gardens in clayey soil must be bigger than rain gardens in sandy or silty soil. If the soil feels very gritty and coarse, you probably have sandy soil. If your soil is smooth but not sticky, you have silty soil. If it is very sticky and clumpy, you probably have clayey soil.

How big is the area draining to the rain garden?

The next step in choosing your rain garden size is to find the area that will drain to the rain garden. As the size of the drainage area increases so should the size of the rain garden. There is some guesswork in determining the size of a drainage area, especially if a large part of the lawn is up-slope from the proposed garden site. Use the suggestions below to estimate the drainage area without spending a lot of time.

Rain gardens less than 30 feet from the downspout

1. In this case, where the rain garden is close to the house, almost all water will come from the roof downspout. Walk around the house and estimate what percent of the roof feeds to that downspout. Many houses have four downspouts, each taking about 25% of the roof's runoff.
2. Next find your home's footprint, the area of the first floor. If you don't already know it, use a tape measure to find your house's length and width. Multiply the two together to find the approximate area of your roof.
3. Finally, multiply the roof area by the percent of the roof that feeds to the rain garden downspout. This is the roof drainage area.

Rain gardens more than 30 feet from the downspout

1. If there is a significant area of lawn uphill that will also drain to the rain garden, add this lawn area to the roof drainage area. First find the roof drainage area using the steps above for a rain garden less than 30' from the downspout.
2. Next find the area of the lawn that will drain to the rain garden. Stand where your rain garden will be and look up toward the house. Identify the part of the lawn sloping into the rain garden.
3. Measure the length and width of the uphill lawn, and multiply them to find the lawn area.
4. Add the lawn area to the roof drainage area to find the total drainage area.

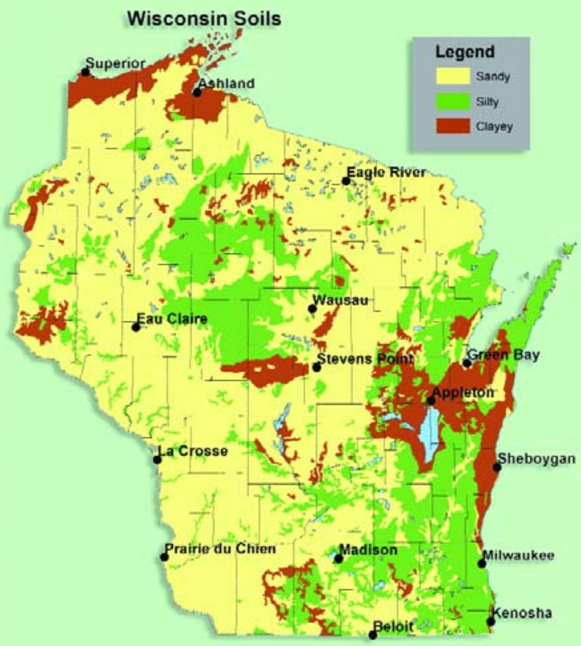
▸ If the rain garden is far from the house, and you don't want a swale or downspout cutting across the lawn, run a PVC pipe underground from the downspout to the rain garden. In this case do calculations as for a rain garden less than 30 feet from the house.

✓ EXAMPLE

Todd's house is 60 feet by 40 feet, so the roof area is 2400 square feet. He estimates that the downspout collects water from 25% of the roof, so he multiplies 2400 by 0.25 to get a downspout drainage area of 600 square feet.

Roof Area: 60 ft by 40 ft = 2400 square ft.

Drainage Area: 2400 square ft. x 0.25 = 600 square ft.



Simple soil tests

Two small tests can ensure your soil can handle a rain garden:

- **Dig a hole about 6 inches deep where the rain garden is to go and fill the hole with water. If the water takes more than 24 hours to soak in, the soil is not suitable for a rain garden.**
- **Take a handful of soil and dampen it with a few drops of water. After kneading the soil in your fingers, squeeze the soil into a ball. If it remains in a ball, then work the soil between your forefinger and thumb, squeezing it upward into a ribbon of uniform thickness. Allow the ribbon to emerge and extend over the forefinger until it breaks from its own weight. If the soil forms a ribbon more than an inch long before it breaks, and it also feels more smooth than gritty, the soil is not suitable for a rain garden.**

The map is a starting point for assessing what type of soils you might find in your yard. However, the soil on a small plot of a yard can be very different from the soils indicated on the map. Use the simple soil test described here for a more accurate representation of the soils in the possible rain garden location. More information about sampling and testing lawn and garden soils can be obtained at county UW-Extension offices.

Using the Rain Garden Size Factors

Having estimated the drainage area, soil type, and depth for your rain garden, use Table 1 or Table 2 to determine the rain garden's surface area. Use Table 1 if the rain garden is less than 30 feet from the downspout, and use Table 2 if it is more than 30 feet from the downspout.

Table 1 **Rain gardens less than 30 feet from downspout.**

	3-5 in. deep	6-7 in. deep	8 in. deep
Sandy soil	0.19	0.15	0.08
Silty soil	0.34	0.25	0.16
Clayey soil	0.43	0.32	0.20

Table 2 **Rain gardens more than 30 feet from downspout.**

	Size Factor, for all depths
Sandy soil	0.03
Silty soil	0.06
Clayey soil	0.10

1. Find the size factor for the soil type and rain garden depth.
2. Multiply the size factor by the drainage area. This number is the recommended rain garden area.
3. If the recommended rain garden area is much more than 300 square feet, divide it into smaller rain gardens.

EXAMPLE

Todd's rain garden is less than 30 feet from the downspout, and his lawn has a 5% slope, so he will have a 6-inch deep rain garden. His lawn is silty, so Table 1 recommends a size factor of 0.25. He multiplies the downspout drainage area, 600 square feet, by 0.25 to find the recommended rain garden area, 150 square feet.

600 square ft. by 0.25 = 150 square ft.

Runoff flows into a new rain garden (shown before plants are fully grown).

How long and how wide should the rain garden be?

Before building the rain garden, think about how it will catch water. Runoff will flow out of a downspout and should spread evenly across the entire length of the rain garden. The rain garden must be as level as possible so water doesn't pool at one end and spill over before it has a chance to infiltrate.

Choose a size that is best for your yard

Remember that these are only guidelines. The size of the rain garden also depends on how much money you want to spend, how much room you have in your yard, and how much runoff you want to control. Again, you can reduce the size of your rain garden by as much as 30% and still control almost 90% of the runoff. If the sizing table suggests that the rain garden be 200 square feet, but there is only enough room for a 140-square-foot rain garden, that's fine. A smaller rain garden will usually work to control most stormwater runoff, although some bigger storms might over-top the berm.

The longer side of the rain garden should face upslope; that is, the length of the rain garden should be perpendicular to the slope and the downspout. This way the garden catches as much water as possible. However, the rain garden should still be wide enough for the water to spread evenly over the whole bottom and to provide the space to plant a variety of plants. A good rule of thumb is that the rain garden should be about twice as long (perpendicular to the slope) as it is wide.

When choosing the width of the garden, think about the slope of the lawn. Wide rain gardens and rain gardens on steep slopes will need to be dug very deep at one end in order to be level. If the rain garden is too wide, it may be necessary to bring in additional soil to fill up the downhill half. Experience shows that making a rain garden about 10 feet wide is a good compromise between the effect of slope and how deep the rain garden should be. A rain garden should have a maximum width of about 15 feet, especially for lawns with more than about an 8 percent slope.

To determine the length of the rain garden:

1. Pick the best rain garden width for your lawn and landscaping.
2. Divide the size of your rain garden by the width to find your rain garden's length.

✓ EXAMPLE

Todd wants a 10-foot wide rain garden, so he divides 150 by 10 to find the rain garden length, 15 feet.

$$\frac{\text{rain garden area}}{\text{width}} = \text{length} \qquad \frac{150\ \text{ft}^2}{10\ \text{ft}} = 15\ \text{ft}$$

Step Building the Rain Garden

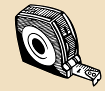
Now that the size and place for the rain garden are set, it's time to get a shovel and start digging. Working alone, it will take about six hours to dig an average-size rain garden. If friends help it will go much faster, possibly only an hour or two.

Before you start digging, call Digger's Hotline at 1-800-242-8511.

If you are building the rain garden into an existing lawn, digging time can be reduced by killing the grass first. A chemical such as Round-Up can be used, but a more environmentally friendly approach is to place black plastic over the lawn until the grass dies. Also, the best time to build the rain garden is in the spring. It will be easier to dig, and the plants are more likely to thrive.

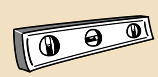
A note on tools

The following tools will help in building the rain garden. Some of the tools are optional.

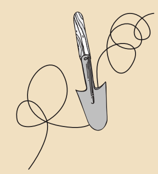


- **Tape measure**

- **Shovels**
- **Rakes**
- **Trowels**
- **Carpenter's level**



- **Wood stakes, at least 2 ft long**



- **String**
- **2x4 board, at least 6 ft long (optional)**
- **Small backhoe with cater-pillar treads (optional)**

Leveling the rain garden

One way to check the level of the rain garden is to just "eyeball" it. To do it more accurately follow these steps:

- **When the whole area has been dug out to about the right depth, lay the 2x4 board in the rain garden with the carpenter's level sitting on it. Find the spots that aren't flat. Fill in the low places and dig out the high places.**
- **Move the board to different places and different directions, filling and digging as necessary to make the surface level.**
- **When the rain garden is as level as you can get it, rake the soil smooth.**

The perimeter of a rain garden is defined with string before digging.

Digging the rain garden

While digging the rain garden to the correct depth, heap the soil around the edge where the berm will be. (The berm is a low "wall" around three sides of the rain garden that holds the water in during a storm.) On a steeper lawn the lower part of the rain garden can be filled in with soil from the uphill half, and extra soil might need to be brought in for the berm.

Start by laying string around the perimeter of your rain garden. Remember that the berm will go outside the string. Next, put stakes along the uphill and downhill sides, lining them up so that each uphill stake has a stake directly downhill. Place one stake every 5 feet along the length of the rain garden.

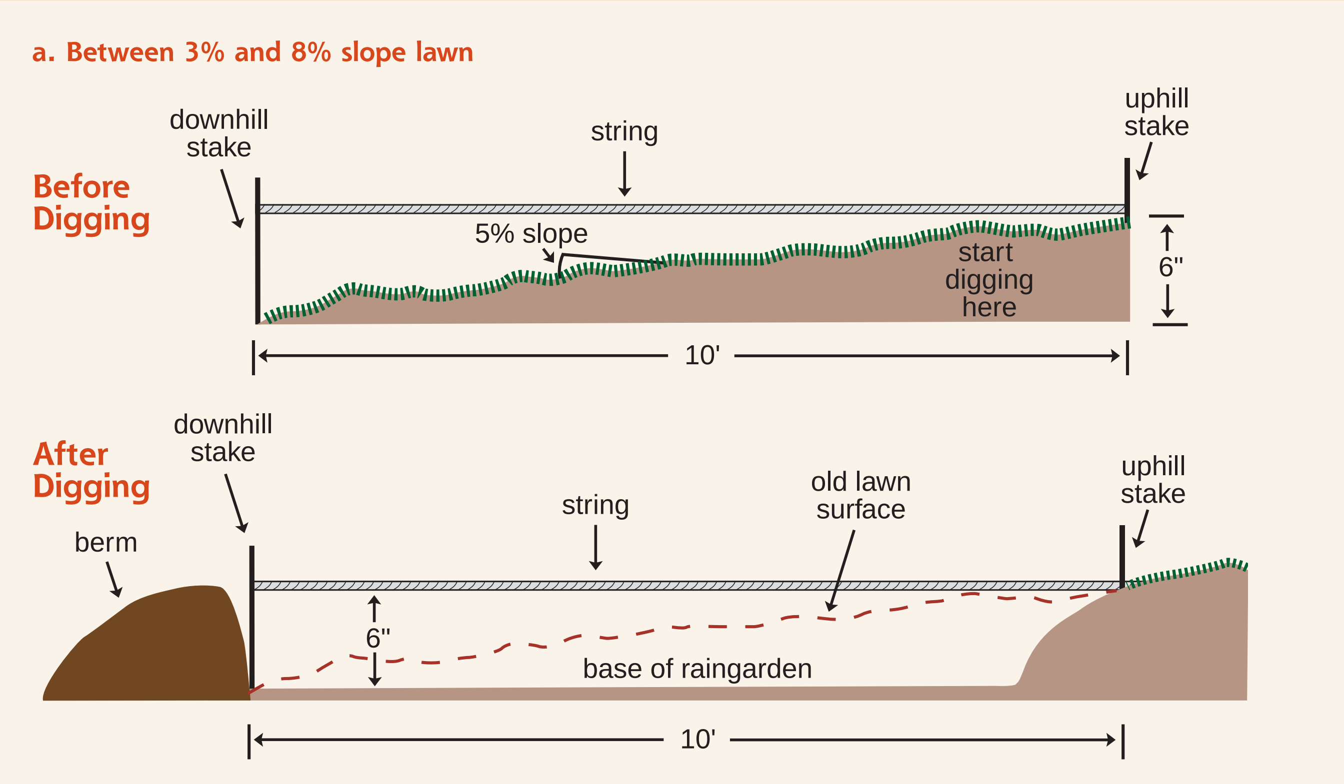
Start at one end of the rain garden and tie a string to the uphill stake at ground level. Tie it to the stake directly downhill so that the string is level. Work in 5-foot-wide sections, with only one string at a time. Otherwise the strings will become an obstacle.

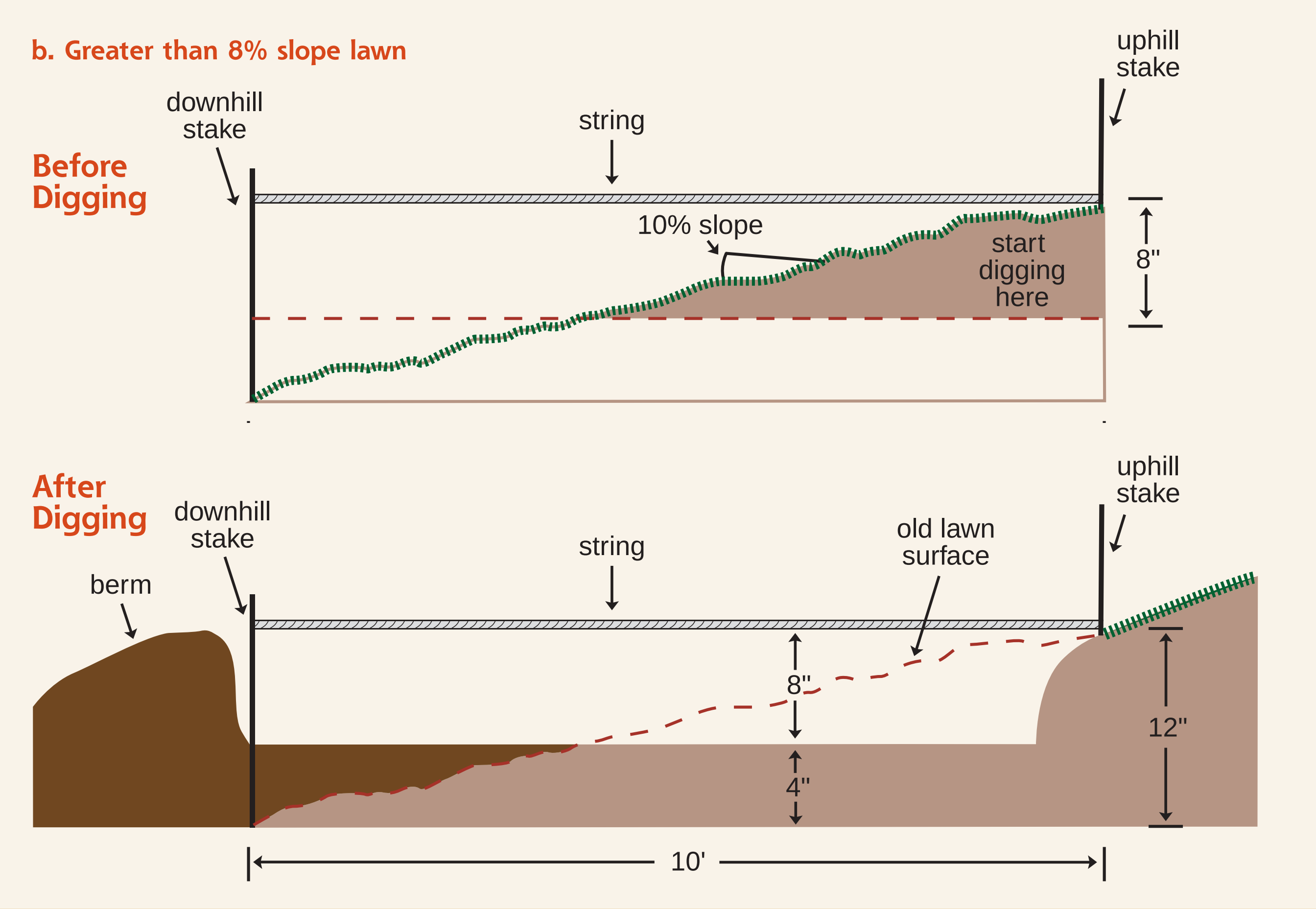
Start digging at the uphill side of the string. Measure down from the string and dig until you reach the depth you want the rain garden to be. If the rain garden will be four inches deep, then dig four inches down from the string. Figure 4 shows how.

If the lawn is almost flat, you will be digging at the same depth throughout the rain garden and using the soil for the berm. If the lawn is steeper, the high end of the rain garden will need to be dug out noticeably more than the low end, and some of the soil from the upper end can be used in the lower end to make the rain garden level. Continue digging and filling one section at a time across the length of your rain garden until it is as level as possible.

In any garden, compost will help the plants become established and now is the time to mix in compost if needed. Using a roto-tiller can make mixing much easier, but isn't necessary. If you do add compost, dig the rain garden a bit deeper. To add two inches of compost, dig the rain garden one to two inches deeper than planned.

Figure 4 **Where to dig and where to put the soil you've dug.**





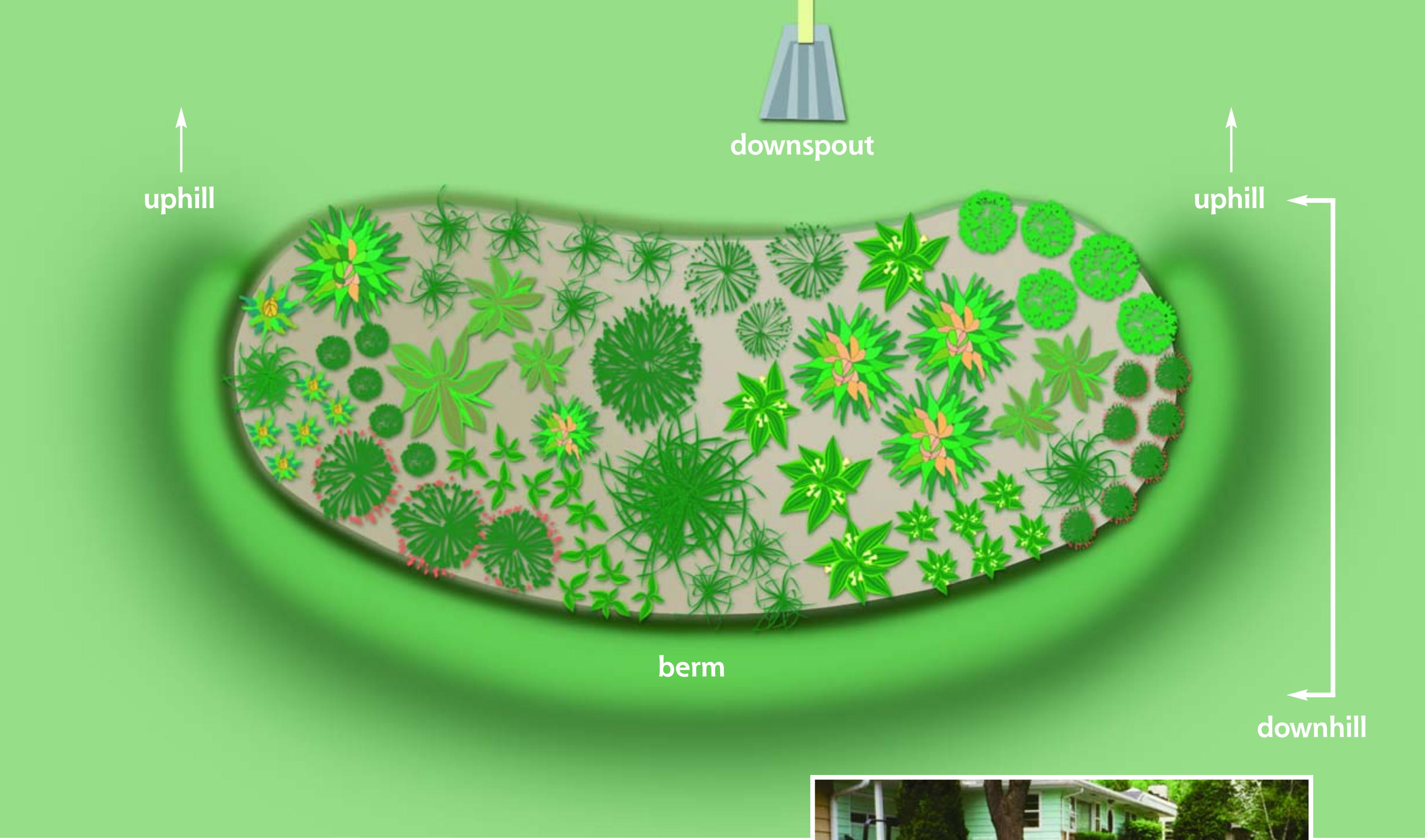


Figure 5 The top of the downhill part of the berm should come up to the same elevation as the entry to the rain garden at the uphill end.

On a gentle slope, soil from digging out the garden can be used to create the berm. This rain garden is 4 inches deep.

Making the Berm

Water flowing intro the rain garden will naturally try to run off the downhill edge. A berm is needed to keep the water in the garden, The berm is a "wall" across the bottom and up the sides of the rain garden. The berm will need to be highest at the downhill side. Up the sides of the rain garden, the berm will become lower and gradually taper off by the time it reaches the top of the rain garden. Figure 5 shows how the berm should look.

On a flat slope there should be plenty of soil from digging out the rain garden to use for a berm. On a steeper slope, most of the soil from the uphill part of the rain garden was probably used to fill in the downhill half, and soil will have to be brought in from somewhere else. After shaping the berm into a smooth ridge about a foot across, stomp on it. It is very important to have a well-compacted berm, so stomp hard. The berm should have very gently sloping sides; this helps smoothly integrate the rain garden with the surrounding lawn and also makes the berm less susceptible to erosion.

To prevent erosion, cover the berm with mulch or plant grass. Use straw or erosion-control mat to protect the berm from erosion while the grass is taking root.

If you don't want to plant grass or mulch over the outside of the berm, you can also plant dry-tolerant prairie species. Some potential berm species are prairie dropseed, little bluestem, prairie smoke, blue-eyed grass, prairie phlox, and shooting star.

Note: If the downspout is a few feet from the entry to the rain garden, make sure the water runs into the garden by either digging a shallow grass swale or attaching an extension to the downspout.

Tips for designing an attractive rain garden

While rain gardens are a highly functional way to help protect water quality, they are also gardens and should be an attractive part of your yard and neighborhood. Think of the rain garden in the context of your home's overall landscape design. Here are a few tips:

When choosing native plants for the garden, it is important to consider the height of each plant, bloom time and color, and its overall texture. Use plants that bloom at different times to create a long flowering season. Mix heights, shapes, and textures to give the garden depth and dimension. This will keep the rain garden looking interesting even when few wildflowers are in bloom.

When laying plants out, randomly clump individual species in groups of 3 to 7 plants to provide a bolder statement of color. Make sure to repeat these individual groupings to create repetition and cohesion in a planting. This will provide a more traditional formal look to the planting.

Try incorporating a diverse mixture of sedges, rushes, and grasses with your flowering species (forbs). This creates necessary root competition that will allow plants to follow their normal growth patterns and not outgrow or out-compete other species. In natural areas, a diversity of plant types not only adds beauty but also create a thick underground root matrix that keeps the entire plant community in balance. In fact, 80% of the plant mass in native prairie communities is underground. Once the rain garden has matured and your sedges, rushes and grasses have established a deep, thick root system, there will be less change in species location from year to year, and weeds will naturally decline.

Finally, consider enhancing the rain garden by using local or existing stone, ornamental fences, trails, garden benches, or additional wildflower plantings. This will help give the new garden an intentional and cohesive look and provide a feeling of neatness that the neighbors will appreciate.

Step Planting and Maintaining the Rain Garden

Planting the rain garden is the fun part! A number of planting designs and lists of suggested plants are included at the end of this publication. Use these for ideas, but don't be afraid to be creative – there's no single best way to plant a rain garden. Anyone who has ever done any gardening will have no problem planting a rain garden, but a few basic reminders are listed below.

Planting the rain garden

Select plants that have a well established root system. Usually one or two-year-old plants will have root systems that are beginning to circle or get matted. (Note: use only nursery-propagated plants; do not collect plants from the wild).

Make sure to have at least a rough plan for which plants will be planted where. Lay out the plants as planned one foot apart in a grid pattern, keeping them in containers if possible until they are actually planted to prevent drying out before they get in the ground.

Dig each hole twice as wide as the plant plug and deep enough to keep the crown of the young plant level with the existing grade (just as it was growing in the cell pack or container). Make sure the crown is level and then fill the hole and firmly tamp around the roots to avoid air pockets.

Apply double-shredded mulch evenly over the bed approximately two inches thick, but avoid burying the crowns of the new transplants. Mulching is usually not necessary after the second growing season unless the "mulched look" is desired.

Stick plant labels next to each individual grouping. This will help identify the young native plants from non-desirable species (weeds) as you weed the garden.

As a general rule plants need one inch of water per week. Water immediately after planting and continue to water twice a week (unless rain does the job) until the plugs are established. You should not have to water your rain garden once the plants are established. Plugs can be planted anytime during the growing season as long as they get adequate water.

Fire safety

Make sure burning is allowed in your locale. If so, be sure to notify the local fire department and obtain a burn permit if needed. It's also wise – not to mention neighborly – to make sure the neighbors know that you're burning and that all safety precautions are being taken. Basic fire precautions include:

- **Make sure there is a fire-break (non-burnable area, such as turfgrass) at least 10-feet wide surrounding the area to be burned.**
- **Never burn on windy days.**
- **Never leave an actively burning fire unattended.**
- **Keep a garden hose handy in case fire strays where it is not wanted. Also have a metal leaf rake in hand to beat out flames that creep beyond the burn zone.**

Maintaining the rain garden

Weeding will be needed the first couple of years. Remove by hand only those plants you are certain are weeds. Try to get out all the roots of the weedy plants. Weeds may not be a problem in the second season, depending on the variety and tenacity of weeds present. In the third year and beyond, the native grasses, sedges, rushes, and wildflowers will begin to mature and will out-compete the weeds. Weeding isolated patches might still be needed on occasion.

After each growing season, the stems and seedheads can be left for winter interest, wildlife cover and bird food. Once spring arrives and new growth is 4-6-inches tall, cut all tattered plants back. If the growth is really thick, hand-cut the largest plants and then use a string trimmer to mow the planting back to a height of six to eight inches. Dead plant material can also be removed with a string trimmer or weed whacker (scythe) and composted or disposed of as appropriate.

The best way to knock back weeds and stimulate native plant growth is to burn off the dead plant material in the rain garden. However, burning is banned in most municipalities. Another option is to mow the dead plant material. If the mowing deck of your lawn mower can be raised to a height of six inches or so, go ahead and simply mow your rain garden. Then, rake up and compost or properly dispose of the dead plant material.

If the mower deck won't raise that high, use a string trimmer or weed-eater to cut the stems at a height of 6-8 inches. On thicker stems, such as cup plant, goldenrods and some asters, a string trimmer may not be strong enough. For these, use hand clippers or pruning shears to cut the individual stems.

What does a rain garden cost?

The cost of a rain garden will vary depending on who does the work and where the plants come from. If you grow your own plants or borrow plants from neighbors there can be very little or no cost at all. If you do all the work but use purchased prairie plants, a rain garden will cost approximately $3 to $5 per square foot. If a landscaper does everything, it will cost approximately $10 to $12 per square foot.

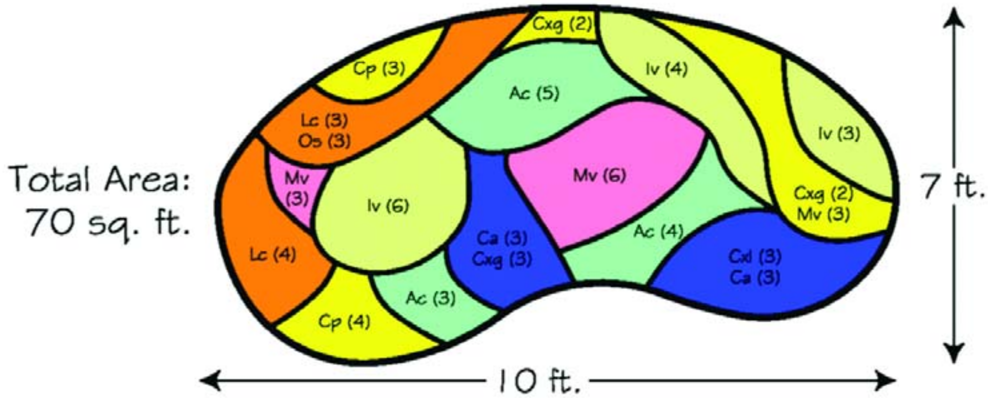
It might seem easiest to sow native wildflower seed over the garden, but experience shows that seeding a rain garden has its problems. Protecting the seeds from wind, flooding, weeds, and garden pests is very difficult, and the rain garden will be mostly weeds for the first two years. Growing plugs from seed indoors or dividing a friend's plants is much better. If you grow plugs, start them about four months before moving them to the rain garden. When the roots have filled the pot and the plants are healthy, they may be planted in the rain garden

Rain Garden Designs and Plant Lists

The following pages contain conceptual planting designs and plant lists for rain gardens with varying sun and soil conditions. Keep in mind that design possibilities for rain gardens are almost limitless. Many landscape nurseries, particularly those specializing in native plants and landscaping, can provide other ideas, designs and suggested plants.

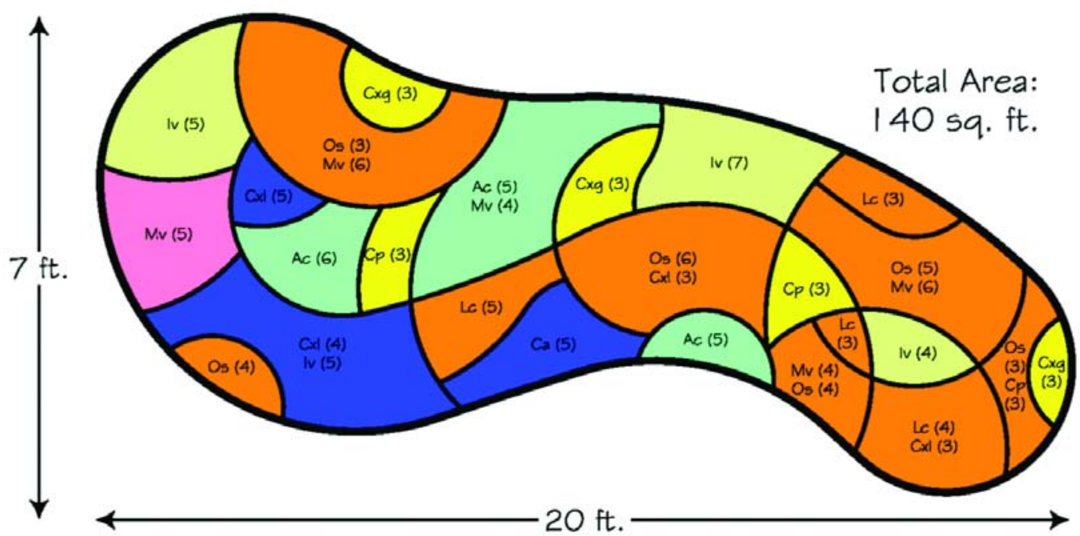
The following eight designs and plant lists have been provided by Applied Ecological Services, Inc., Brodhead, WI.

10 feet wide; full to partial shade with clay soils



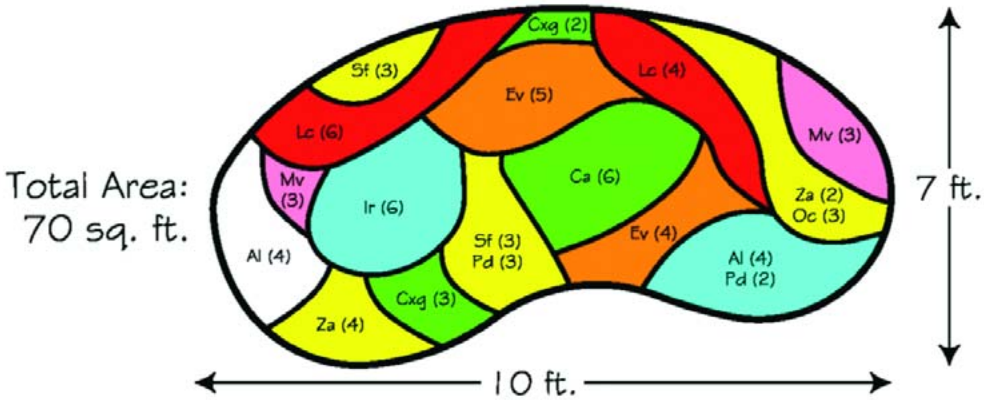
Symbol	Species Name	Common Name	No. of Plants
Ac	Acorus calamus	Sweet flag	12
Ca	Campanula americana	Tall bellflower	6
Cp	Caltha palustris	Marsh marigold	7
Cxg	Carex Grayii	Bur sedge	7
Cxl	Carex lupulina	Hop sedge	3
Iv	Iris virginica-shrevei	Wild blue flag iris	13
Lc	Lobelia cardinalis	Cardinal flower	7
Mv	Mertensia virginica	Virginia bluebells	12
Os	Onoclea sensibilis	Sensitive fern	3
		Total Plants Needed	70

20 feet wide; full to partial shade with clay soils



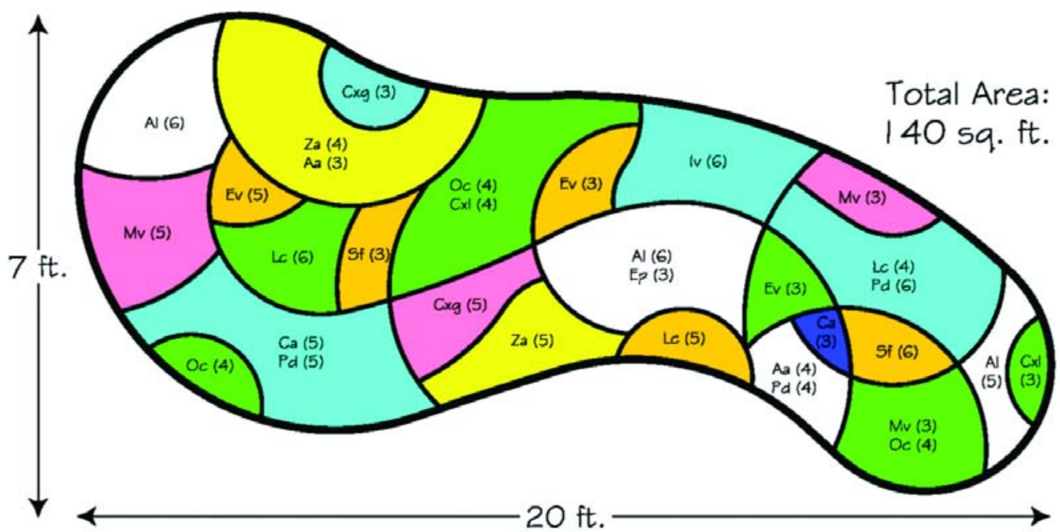
Symbol	Species Name	Common Name	No. of Plants
Ac	Acorus calamus	Sweet flag	16
Cp	Caltha palustris	Marsh marigold	9
Ca	Campanula americana	Tall bellflower	5
Cxg	Carex Grayii	Bur sedge	9
Cxl	Carex lupulina	Hop sedge	15
Iv	Iris virginica-shrevei	Wild blue flag iris	21
Lc	Lobelia cardinalis	Cardinal flower	15
Mv	Mertensia virginica	Virginia bluebells	25
Os	Onoclea sensibilis	Sensitive fern	25
		Total Plants Needed	140

10 feet wide; full to partial shade with silty & sandy soils



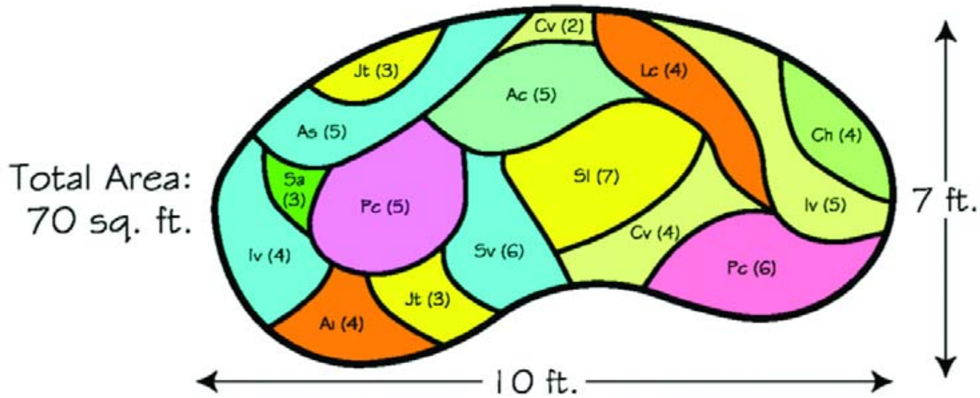
Symbol	Species Name	Common Name	No. of Plants
Al	Aster lateriflorus	Side-flowering aster	8
Ca	Campanula americana	Tall bellflower	6
Cxg	Carex Grayii	Bur sedge	5
Ev	Elymus virginicus	Virginia wild rye	9
Iv	Iris virginica-shrevei	Wild blue flag iris	6
Lc	Lobelia cardinalis	Cardinal flower	10
Mv	Mertensia virginica	Virginia bluebells	6
Oc	Osmunda clayoniana	Interupted fern	3
Pd	Phlox divaricata	Woodland phlox	5
Sf	Solidago flexicaulis	Zig zag goldenrod	6
Za	Zizia aurea	Golden Alexander	6
		Total Plants Needed	70

20 feet wide; full to partial shade with silty & sandy soils



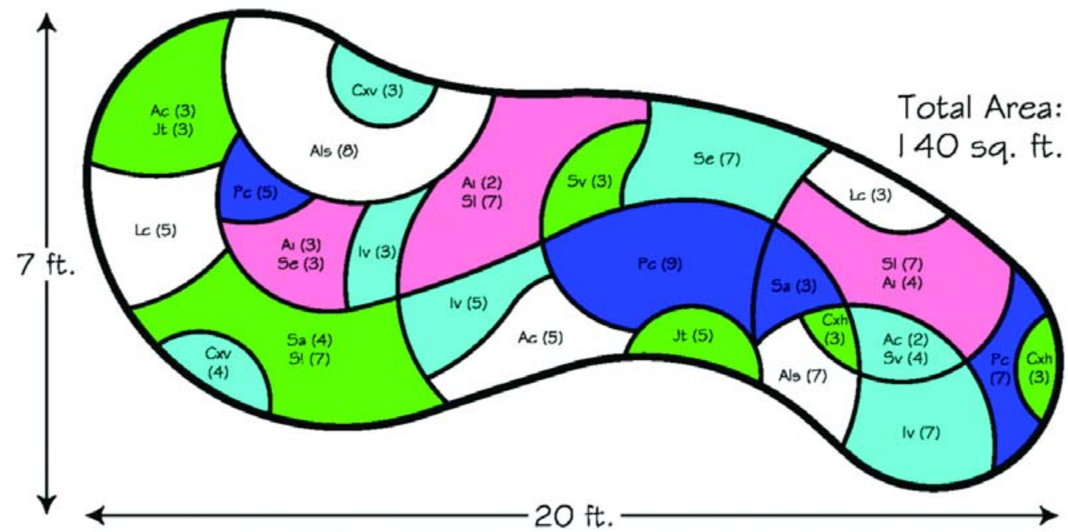
Symbol	Species Name	Common Name	No. of Plants
Aa	Arisaema atrorubens	Jack-in-the-pulpit	7
Al	Aster lateriflorus	Side-flowering aster	17
Ca	Campanula americana	Tall bellflower	8
Cxg	Carex Grayii	Bur sedge	8
Cxl	Carex lupulina	Hop sedge	7
Ev	Elymus virginicus	Virginia wild rye	11
Ep	Eupatorium purpureum	Purple Joe-Pye weed	3
Iv	Iris virginica-shrevei	Wild blue flag iris	6
Lc	Lobelia cardinalis	Cardinal flower	15
Mv	Mertensia virginica	Virginia bluebells	11
Oc	Osmunda clayoniana	Interupted fern	12
Pd	Phlox divaricata	Woodland phlox	15
Sf	Solidago flexicaulis	Zig zag goldenrod	9
Za	Zizia aurea	Golden Alexander	14
		Total Plants Needed	143

10 feet wide; full to partial sun with clay soils



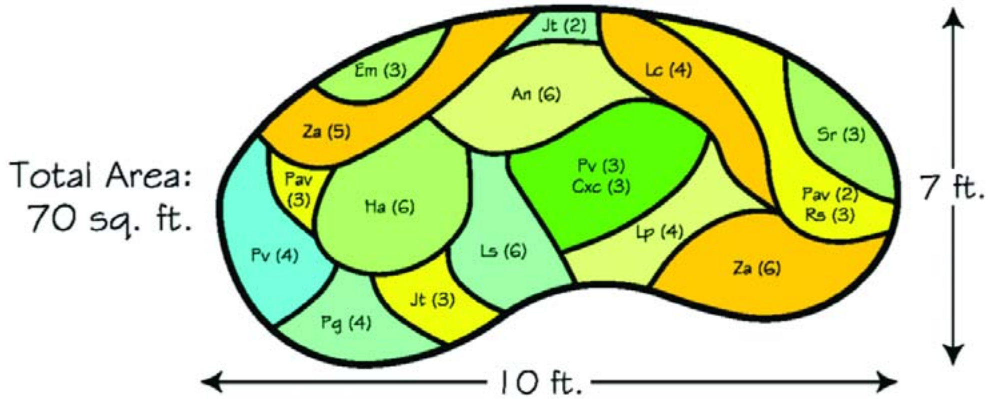
Symbol	Species Name	Common Name	No. of Plants
Ac	Acorus calamus	Sweet flag	5
As	Asclepias incarnata	Swamp milkweed	4
Als	Alisma subcordatum	Water plantain	5
Cxh	Carex hystricina	Bottle brush sedge	4
Cxv	Carex vulpinoidea	Fox sedge	6
Iv	Iris virginica-shrevei	Wild blue flag iris	9
Jt	Juncus torreyi	Torrey's rush	6
Lc	Lobelia cardinalis	Cardinal flower	4
Pc	Pontedaria cordata	Pickerel weed	11
Sl	Sagittaria latifolia	Arrowhead	7
Sa	Scirpus atrovirens	Green bulrush	3
Sv	Scripus validus creber	Soft-stemmed bulrush	6
		Total Plants needed	70

20 feet wide; full to partial sun with clay soils



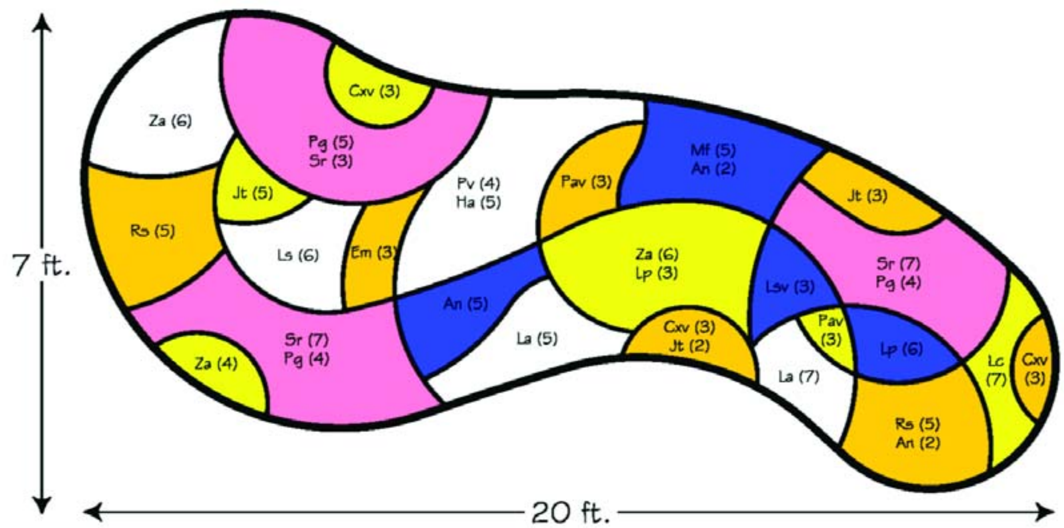
Symbol	Species Name	Common Name	No. of Plants
Ac	Acorus calamus	Sweet flag	10
Ai	Asclepias incarnata	Swamp milkweed	9
Als	Alisma subcordatum	Water plantain	15
Cxh	Carex hystricina	Bottle brush sedge	6
Cxv	Carex vulpinoidea	Fox sedge	7
Iv	Iris virginica-shrevei	Wild blue flag iris	15
Jt	Juncus torreyi	Torrey's rush	8
Lc	Lobelia cardinalis	Cardinal flower	8
Pc	Pontedaria cordata	Pickerel weed	21
Sl	Sagittaria latifolia	Arrowhead	21
Sa	Scirpus atrovirens	Green bulrush	7
Sv	Scripus validus creber	Soft-stemmed bulrush	7
Se	Sparganium eurycarpum	Common bur-reed	10
		Total Plants needed	144

10 feet wide; full to partial sun with silt and sandy soils



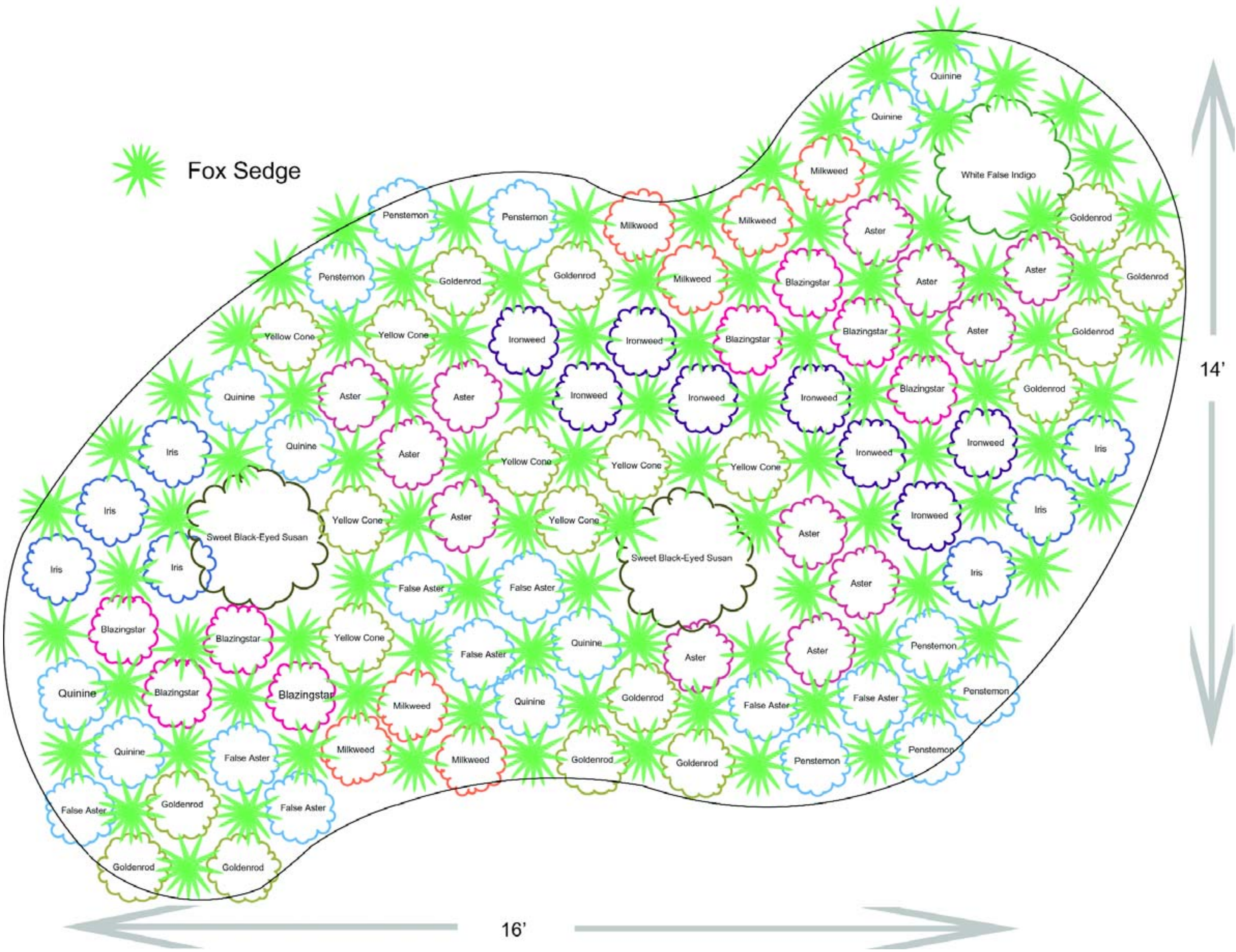
Symbol	Species Name	Common Name	No. of Plants
An	Aster novae-angliae	New England Aster	6
Cxc	Carex comosa	Bottlebrush sedge	3
Ep	Eupatorium maculatum	Spotted Joe-Pye weed	3
Ha	Helenium autumnale	Sneezeweed	6
Jt	Juncus torreyi	Torrey's rush	5
Lp	Liatris pycnostachya	Gayfeather	4
Lc	Lobelia cardinalis	Cardinal flower	4
Ls	Lobelia siphlitica	Great blue lobelia	6
Pav	Panicum virgatum	Switch grass	5
Pg	Phlox glaberrima	Marsh phlox	4
Pv	Pycnanthemun virginianum	Mountain mint	7
Rs	Rudbeckia subtomentosa	Sweet coneflower	5
Sr	Solidago Riddelli	Riddell's goldenrod	3
Za	Zizia aurea	Golden Alexander	11
		Total Plants needed	72

20 feet wide; full to partial sun with silt and sandy soils



Symbol	Species Name	Common Name	No. of Plants
An	Aster novae-angliae	New England Aster	9
Cxv	Carex vulpinoidea	Fox sedge	9
Ep	Eupatorium maculatum	Spotted Joe-Pye weed	3
Ha	Helenium autumnale	Sneezeweed	5
Jt	Juncus torreyi	Torrey's rush	10
Lp	Liatris pycnostachya	Gayfeather	9
Lc	Lobelia cardinalis	Cardinal flower	7
Ls	Lobelia siphlitica	Great blue lobelia	9
La	Lythrum alatum	Winged loosestrife	12
Mf	Monarda fistulosa	Wild Bergamot	5
Pav	Panicum virgatum	Switch grass	6
Pg	Phlox glaberrima	Marsh phlox	13
Pv	Pycnanthemun virginianum	Mountain mint	4
Rs	Rudbeckia subtomentosa	Sweet coneflower	10
Sr	Solidago Riddelli	Riddell's goldenrod	17
Za	Zizia aurea	Golden Alexander	16
		Total Plants needed	144

The following three designs and plant lists have been provided by Prairie Nursery, Inc., Westfield, WI

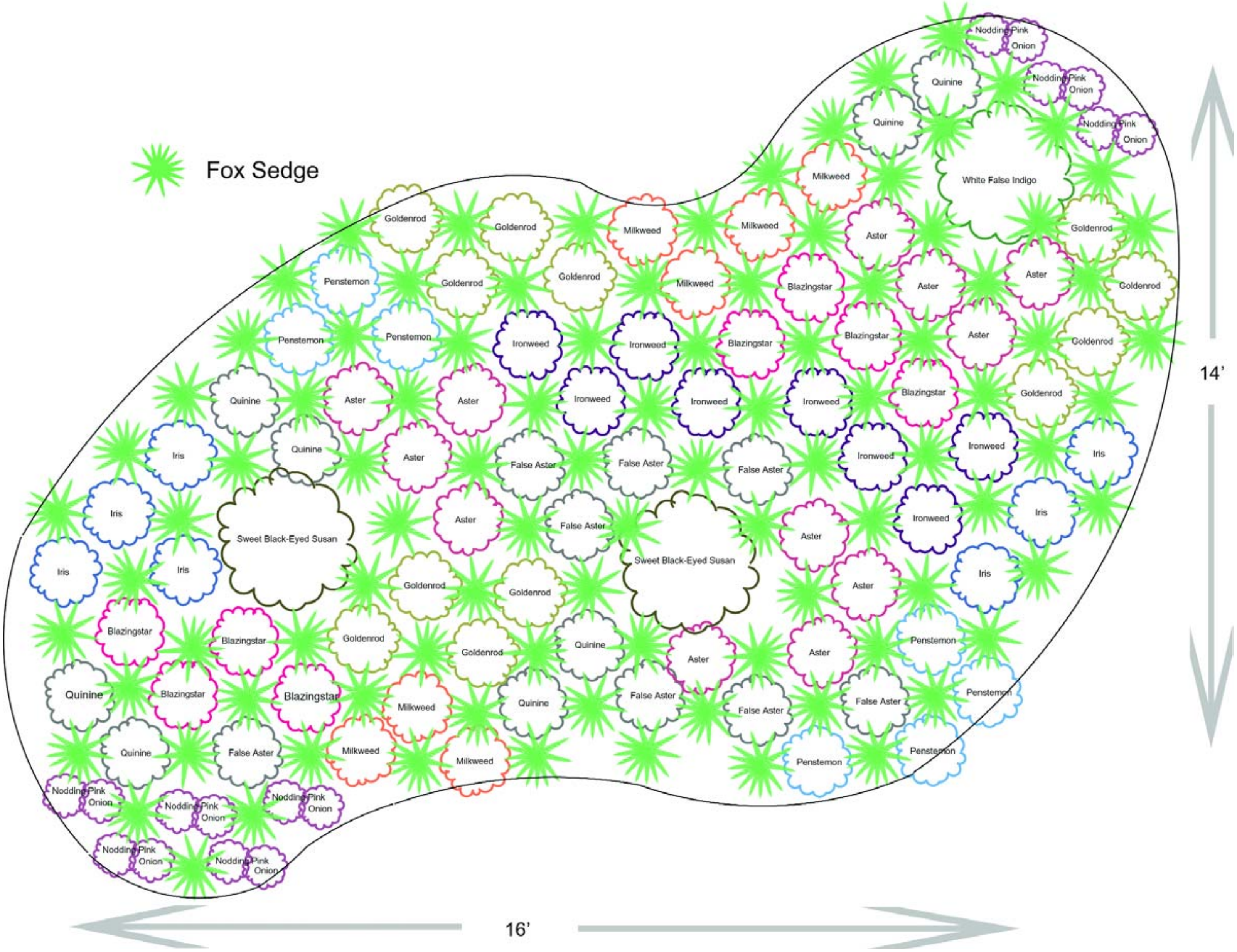

Fox Sedge
White False Indigo
Quinine
Milkweed
Aster
Goldenrod
Blazingstar
Ironweed
Iris
Yellow Cone
Penstemon
Sweet Black-Eyed Susan
False Aster
14'
16'

RAIN GARDEN FOR CLAY SOILS AND FULL SUN

AREA: 192 Square Feet

Designed to thrive through conditions of periodic water infiltrations as well as dry periods
Designed to control 45% of annual runoff from an average sized rooftop (500 to 700 square feet)
Install at least 10′ from your foundation, in-line with a down-spout and/or downslope to intercept the rooftop water
Depth of the garden designed to be 3.5″ to 4″ deep to hold about 200 gallons of water during periods of heavy rainfall

LATIN NAME	COMMON NAME	AMT	BLOOM TIME	BLOOM COLOR	HEIGHT	SPACING
Asclepias incarnata	Red Milkweed	7	early summer	red	3′-5′	1′
Baptisia lactea	White False Indigo	1	early summer	white	3′-5′	2′
Iris versicolor	Blue Flag Iris	7	early summer	blue	2′-3′	1′
Penstemon digitalis	Smooth Penstemon	7	early summer	white	2′-3′	1′
Liatris pycnostachya	Prairie Blazingstar	8	summer	pink	3′-5′	1′
Parthenium integrifolium	Wild Quinine	8	summer	white	3′-5′	1′
Ratibida pinnata	Yellow Coneflower	8	summer	yellow	3′-6′	1′
Boltonia asteroides	False Aster	8	late summer	white/pink	2′-4′	1′
Rudbeckia subtomentosa	Sweet Black-Eyed Susan	2	late summer	yellow	4′-6′	2′
Vernonia fasciculata	Ironweed	8	late summer	magenta	4′-6′	1′
Aster novae-angliae	New England Aster	12	fall	pink/purple	3′-6′	1′
Solidago rigida	Stiff Goldenrod	12	fall	yellow	3′-5′	1′
Carex vulpinoidea	Fox Sedge	96			1′-3′	1′
		184 plants				


Fox Sedge
14'
16'
White False Indigo
Sweet Black-Eyed Susan
Nodding Pink Onion
Quinine
Milkweed
Goldenrod
Aster
Blazingstar
Penstemon
Ironweed
False Aster
Iris

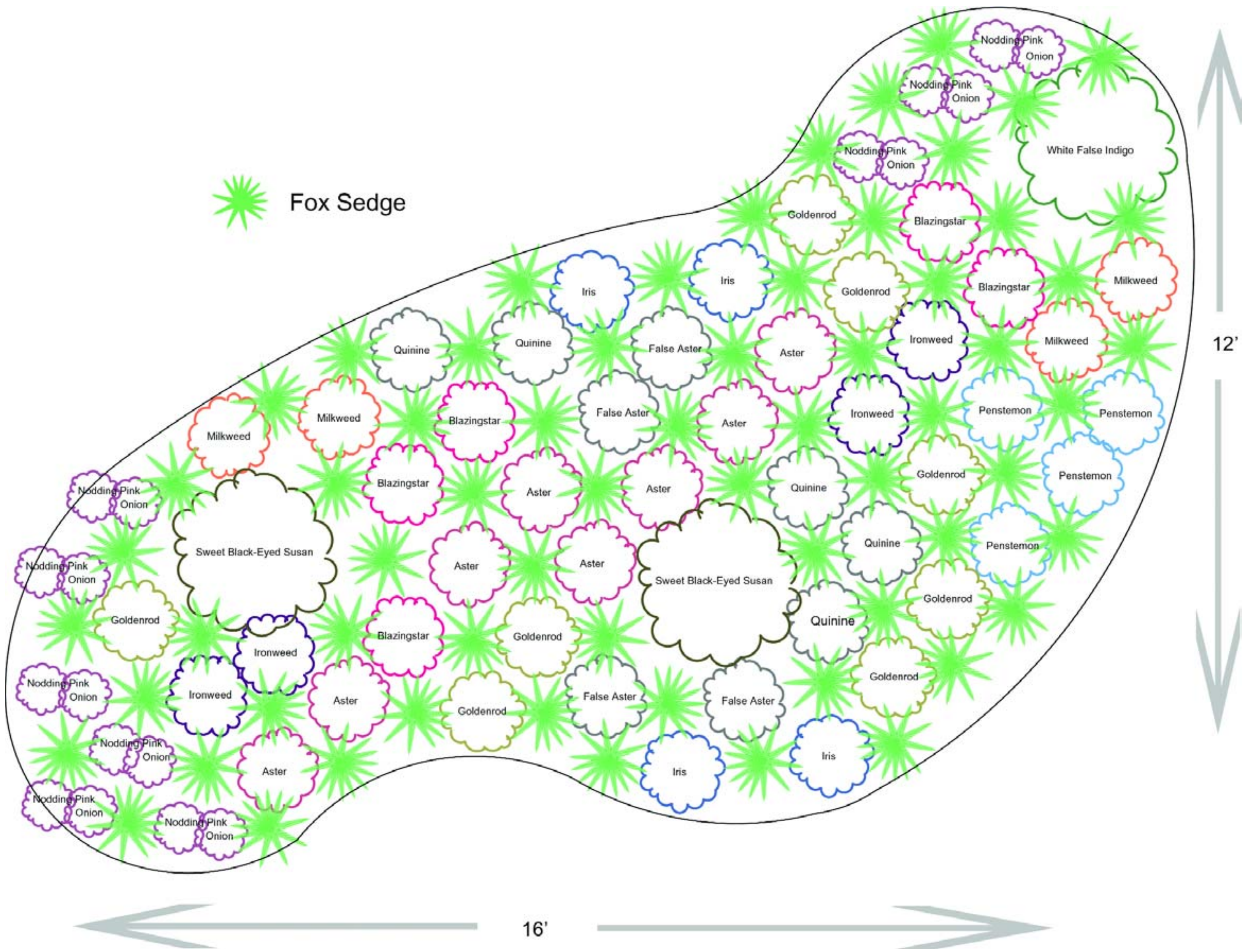
RAIN GARDEN FOR LOAM TO SANDY/LOAM SOILS AND FULL SUN

AREA: 192 Square Feet

Designed to thrive through conditions of periodic water infiltrations as well as dry periods
Designed to control 90% of annual runoff from an average sized rooftop (500 to 700 square feet)
Install at least 10' from your foundation, in-line with a down-spout and/or downslope to intercept the rooftop water
Depth of the garden designed to be 3.5" to 4" deep to hold about 400 gallons of water during periods of heavy rainfall

LATIN NAME	COMMON NAME	AMT	BLOOM TIME	BLOOM COLOR	HEIGHT	SPACING
Asclepias incarnata	Red Milkweed	7	early summer	red	3'-5'	1'
Baptisia lactea	White False Indigo	1	early summer	white	3'-5'	2'
Iris versicolor	Blue Flag Iris	7	early summer	blue	2'-3'	1'
Penstemon digitalis	Smooth Penstemon	7	early summer	white	2'-3'	1'
Allium cernuum	Nodding Pink Onion	16	summer	pink	1'-2'	6"
Liatris pycnostachya	Prairie Blazingstar	8	summer	pink	3'-5'	1'
Parthenium integrifolium	Wild Quinine	8	summer	white	3'-5'	1'
Boltonia asteroides	False Aster	8	late summer	white/pink	2'-4'	1'
Rudbeckia subtomentosa	Sweet Black-Eyed Susan	2	late summer	yellow	4'-6'	2'
Vernonia fasciculata	Ironweed	8	late summer	magenta	4'-6'	1'
Aster novae-angliae	New England Aster	12	fall	pink/purple	3'-6'	1'
Solidago ohioensis	Ohio Goldenrod	12	fall	yellow	3'-4'	1'
Carex vulpinoidea	Fox Sedge	96			1'-3'	1'

192 plants



Fox Sedge
12'
16'
Nodding Pink Onion
Nodding Pink Onion
White False Indigo
Nodding Pink Onion
Goldenrod
Blazingstar
Iris
Iris
Goldenrod
Blazingstar
Milkweed
Quinine
Quinine
False Aster
Aster
Ironweed
Milkweed
Milkweed
Milkweed
Blazingstar
False Aster
Aster
Ironweed
Penstemon
Penstemon
Nodding Pink Onion
Blazingstar
Aster
Aster
Quinine
Goldenrod
Penstemon
Sweet Black-Eyed Susan
Aster
Aster
Sweet Black-Eyed Susan
Quinine
Penstemon
Nodding Pink Onion
Goldenrod
Goldenrod
Quinine
Ironweed
Blazingstar
Goldenrod
Goldenrod
Nodding Pink Onion
Ironweed
Aster
Goldenrod
False Aster
False Aster
Nodding Pink Onion
Aster
Iris
Iris
Nodding Pink Onion
Nodding Pink Onion

RAIN GARDEN FOR SANDY SOILS AND FULL SUN

AREA: 128 Square Feet

Designed to thrive through conditions of periodic water infiltrations as well as dry periods
Designed to control 90% of annual runoff from an average sized rooftop (500 to 700 square feet)
Install at least 10' from your foundation, in-line with a down-spout and/or downslope to intercept the rooftop water
Depth of the garden designed to be 3.5" to 4" deep to hold about 400 gallons of water during periods of heavy rainfall

LATIN NAME	COMMON NAME	AMT	BLOOM TIME	BLOOM COLOR	HEIGHT	SPACING
Asclepias incarnata	Red Milkweed	4	early summer	red	3'-5'	1'
Baptisia lactea	White False Indigo	1	early summer	white	3'-5'	2'
Iris versicolor	Blue Flag Iris	4	early summer	blue	2'-3'	1'
Penstemon digitalis	Smooth Penstemon	4	early summer	white	2'-3'	1'
Allium cernuum	Nodding Pink Onion	18	summer	pink	1'-2'	6"
Liatris pycnostachya	Prairie Blazingstar	5	summer	pink	3'-5'	1'
Parthenium integrifolium	Wild Quinine	5	summer	white	3'-5'	1'
Boltonia asteroides	False Aster	4	late summer	white/pink	2'-4'	1'
Rudbeckia subtomentosa	Sweet Black-Eyed Susan	2	late summer	yellow	4'-6'	2'
Vernonia fasciculata	Ironweed	4	late summer	magenta	4'-6'	1'
Aster novae-angliae	New England Aster	8	fall	pink/purple	3'-6'	1'
Solidago ohioensis	Ohio Goldenrod	8	fall	yellow	3'-4'	1'
Carex vulpinoidea	Fox Sedge (sedge)	64			1'-3'	1'

128 plants

Special Rain Garden Locations

In addition to conventional lawns, there are other locations where rain gardens can be created. A rectangular-shaped rain garden (above) was located in a narrow sideyard between two homes. A new rain garden (below), now helps control runoff that would flow into a parking lot.

Rain garden designs and plant lists provided by John Gishnock, Applied Ecological Services, Inc. (pages 19-22) and Jennifer Baker, Prairie Nursery Inc. (pages 24-29).

RAIN GARDENS

A how-to manual for homeowners

A frosted rain garden in autumn.

This publication developed by Roger Bannerman, Wisconsin Department of Natural Resources and Ellen Considine, U.S. Geological Survey. Special thanks to John Gishnock, Applied Ecological Services, Inc., Jennifer Baker, Prairie Nursery Inc. and Joyce Powers, CRM Ecosystems Inc.

Photos by Roger Bannerman, Wisconsin Department of Natural Resources.

Layout design/production by Jeffrey Strobel, and editorial assistance by Bruce Webendorfer, University of Wisconsin–Extension Environmental Resources Center.

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The publication can also be viewed and printed from pdf format on the web at clean-water.uwex.edu/pubs/raingarden

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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.

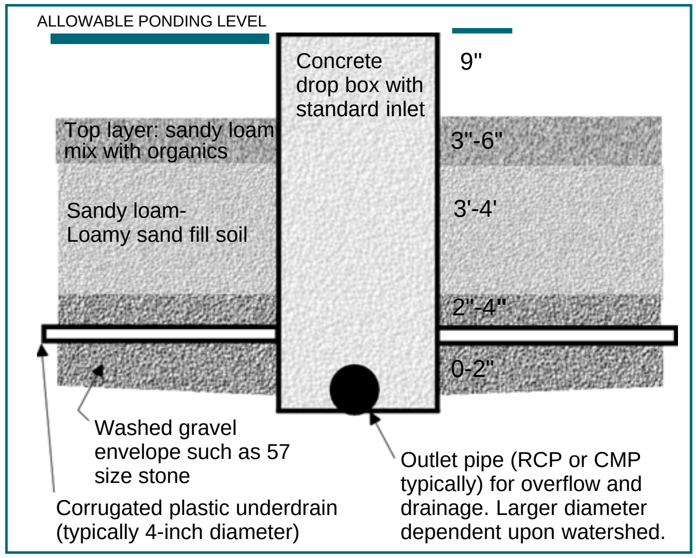

Figure 3. Rain garden cross-section with an overflow box (note: not to scale)

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.

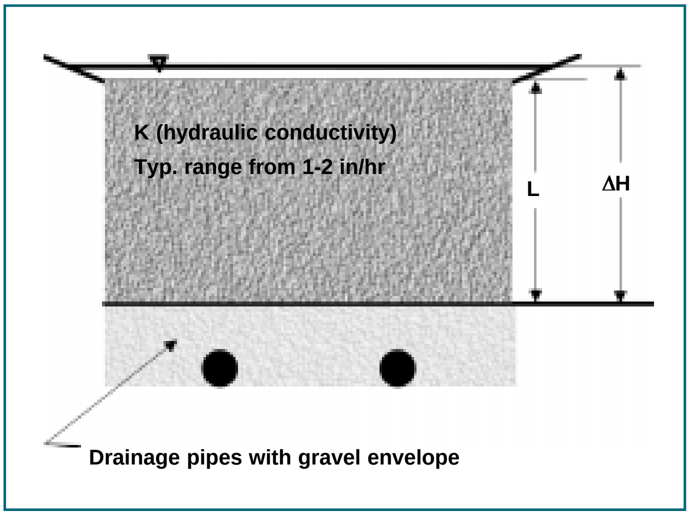

Figure 5. Darcy's Law applied to a rain garden cross-section. Specific discharge (q) is equal to hydraulic conductivity (K) multiplied by the ratio of water height (ΔH) divided by layer thickness (L).

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 ($\mathbf{q_p}$) of:

$\mathbf{q_p}$ = (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.

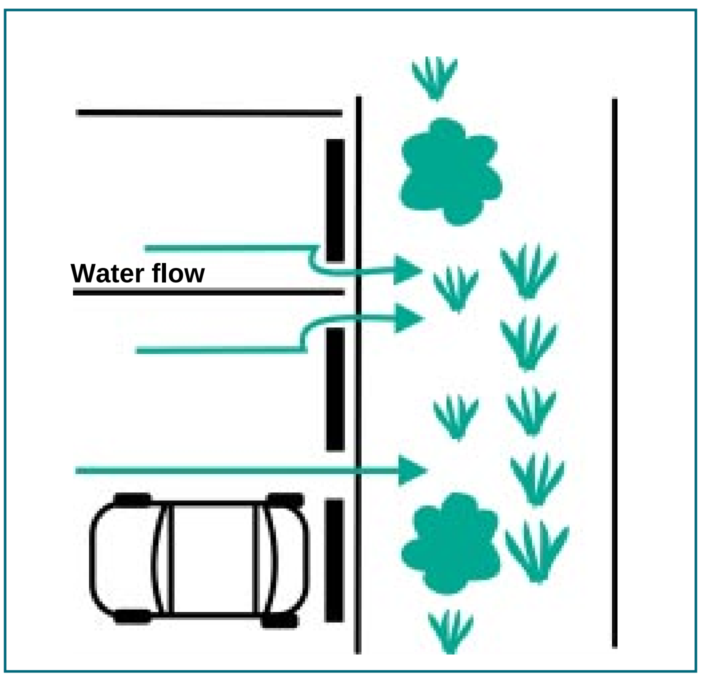

Figure 6. Overland flow from parking lot into rain garden/bio-retention area. Water flows between parking stops before spilling into the bio-retention median.

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.

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

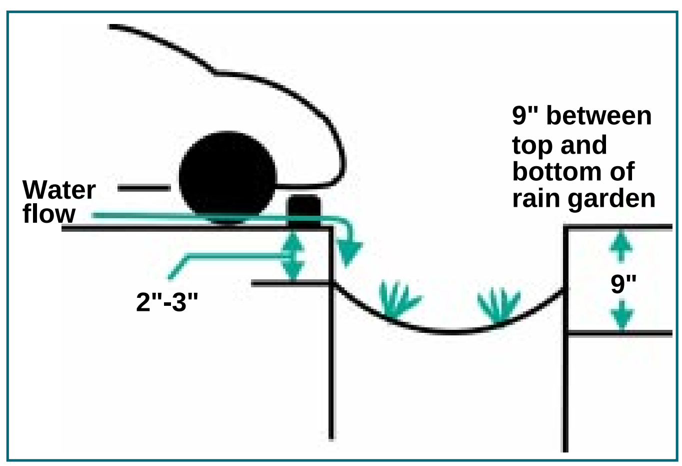

Figure 7. Profile view of runoff entering rain garden/bio-retention area from parking lot. Note the 2- to 3-inch distance between the top of the bio-retention area and the end of the curb.

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)

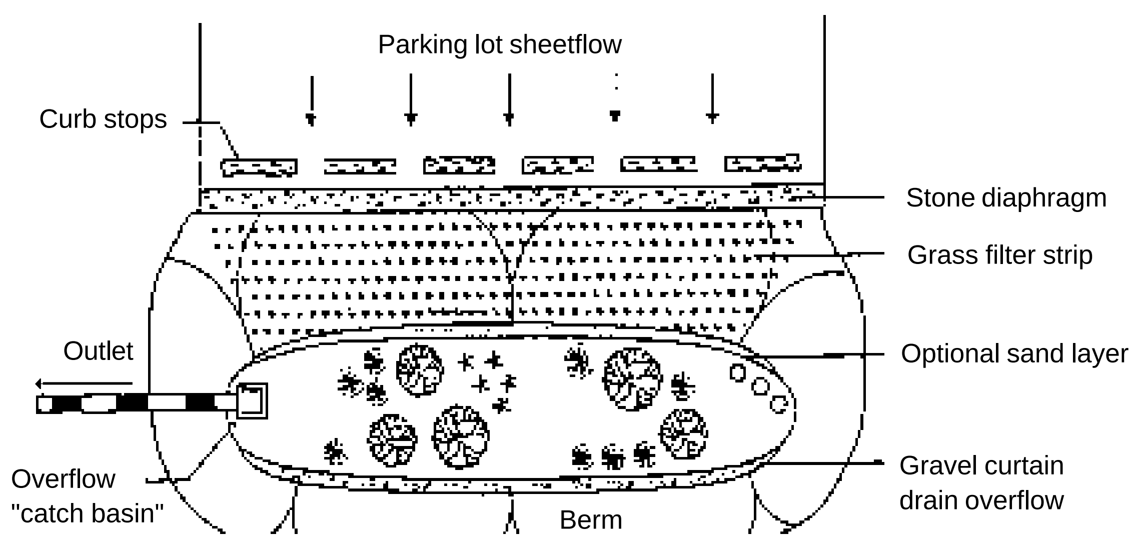

Figure 8. Plan view of a rain garden/bio-retention area. Reproduced from *Stormwater Modules* with permission from the Center for Watershed Protection.

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

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