RAIN GARDEN SIZING & ENGINEERING DESIGN FOR HOMEOWNERS

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A. Introduction

This document will provide the basics for homeowner rain garden engineering design. Rain gardens, including small homeowner and community gardens, are an important tool for watershed conservation and preservation. Rain gardens work by capturing, holding, and infiltrating rainwater runoff on individual sites. Rain gardens keep excess water from entering the storm drains and subsequently degrading rivers and streams.

In regions, with poorly infiltrating soils, such as commonly found in the Rouge River watershed, the design of a properly functioning rain garden may be complicated. This guidance document is intended for the homeowner interested in installing a rain garden. Specific steps for locating and sizing on-site rain gardens are provided.

B. What Is a Rain Garden and How Does It Work?

A rain garden is a depression in the landscape, designed and planted to trap, absorb, and filter storm water runoff and improve water quality. In a typical rain garden, each component performs an important role. A grass or rock buffer along the edge decreases velocity of the water entering the garden and filters out fine sediments that can clog a rain garden surface. The rain garden surface should be fairly level to spread out the incoming water and to promote infiltration. The mulch layer on top filters out pollutants, protects the underlying planting mix and provides an environment for micro-organisms to degrade petroleum based products and other pollutants. The planting mix provides nutrients for the plants while also filtering out and absorbing pollutants. The plants can assimilate nutrients and pollutants while providing biodiversity and beauty.

C. Where Should I Locate My Rain Garden?

The first step in designing a rain garden is deciding where on your property to place the garden. This requires observation of flow paths during and after heavy rainfall events. Ask yourself, "where is the water coming from and where is it heading?" There are three sources of rainwater used for rain gardens:

1. Rain water from the roof and downspout (locate the garden at least 10 feet from the foundation;
2. Rain water from paved surfaces such as driveways or roads in a front yard drainage swale.
3. Rain water trapped in seasonally wet area in the front yard or back yard.

Rain gardens are very good at collecting water from paved surfaces and roofs. Rain water may be directed to the garden from the end of a roof downspout or from the driveway or road. This approach provides benefits to the entire community (as well as your household) by capturing and treating runoff that otherwise might flow directly into a storm sewer and then to the Rouge River.

Rain gardens can also be used to collect water from neighboring properties that flow onto your yard. However, it is important to determine the area of the land that will contribute to the rain garden prior to designing the rain garden. Expectations should be realistic: it is not possible to capture very large quantities of rainwater from neighboring properties. As a first step, observe flows during a heavy rainfall event. Look for land on or near your property that are at a higher elevation than your yard, thereby contributing water. Make a sketch of your home landscape and keep records over several months.

Rain gardens can be used to dry out low spots where water might temporarily pool or areas that are “wet”. A rain garden filled with compost can act like a sponge to “soak up” rainwater and eventually release it back into the atmosphere and/or slowly infiltrate it into the ground. However, it may not be a good idea to place your rain garden in a low spot that is perpetually wet since this area has poor infiltration and/or a high water table; and many plant species will “drown” if submerged for too long a period of time.

To avoid collecting too much water, consider how excess water from very heavy rainfall events will exit your rain garden. Excess water pooling can be avoided by utilizing an overflow such as a low spot along the edge of your rain garden or through an underground drainage system. It’s also important to not locate rain gardens in close proximity to foundations, since basement flooding could be an issue. Also, avoid disturbing mature trees and don’t locate rain gardens in the drip zone of a tree. Mature trees have excellent root systems that are already performing important ecological functions which should not be disturbed. Last, but hardly least, telephone 1-800-Miss-Dig to determine the location of underground utilities!

D. How Do I Determine How Rainwater Will Infiltrate Into the Ground?

The next, and most critical, step in designing a properly functioning rain garden is determining your local infiltration rate, or, in other words, how fast the water will seep into the ground. Once you have decided where to locate your rain garden, the infiltration rate can be approximated with a simple test:

1) Dig a hole 18 inches deep and 6 inches in diameter (a post hole digger will suffice).
2) Fill the hole to the top with water and let it drain (this will saturate the surrounding soil).
3) Re-fill the hole with water and measure how quickly it drains using a yard stick. If the hole drains 3 inches in a 6-hour period, your local infiltration rate is 0.5 inches per hour.

4) If the hole doesn't drain completely in 48 hours, then this location doesn't have good drainage. It may not be suitable for a rain garden unless the soil is amended or infiltration improved through mechanical means, such as placing an underdrain or tilling the native soils beneath the garden to improve infiltration.

Ideally, it is best to know the infiltration at the bottom of your rain garden. Therefore, if you are planning on excavating down 2 feet as part of your design, it is preferred to excavate the 2 ft of topsoil before digging your 18-inch deep hole and measuring infiltration. In addition, if you encounter standing water in your original hole before you add water, you have reached the seasonal water table for your location and might want to consider placing your rain garden in another location or designing a very shallow rain garden. For example, if the seasonal water table (signified by water in the test hole during wet months like April or May) is 3 feet below the ground, then you might want to design your rain garden to be only 1 foot deep. If you are planning your rain garden well in advance of construction, you might consider performing this test once in the spring and once in the summer dry season to see how drainage and the local water table varies.

E. How Can I Size My Rain Garden?

Once you know your local infiltration, it is time to size your rain garden. The movement of water through soil can be described using a formula commonly know in science and engineering as Darcy's Law. Since the function of rain gardens is based on the flow of water through soils, a version of Darcy's Law can be used as part of the sizing process. A simplified version of Darcy's Law can be found in the equation box below. In this equation, the surface area of the rain garden (*SA*) is a function of the run-off coefficient (*c*) which measures how much rain will flow off a surface, the total drainage area (*DA*) that contributes to the rain garden, the depth of the planting mix (*depth*), the height of ponding above the planting surface (*ponding*), and the infiltration rate of the native soils (*i*).

$$SA = \frac{0.04 \times c \times DA \times depth}{(i) \times (depth + ponding)}$$

$SA = surface\ area\ of\ rain\ garden\ (ft^2)$

$DA = drainage\ area\ (ft^2)$

$depth = planting\ bed\ depth\ (ft)$

$i = infiltration\ rate\ (ft\ per\ day)$

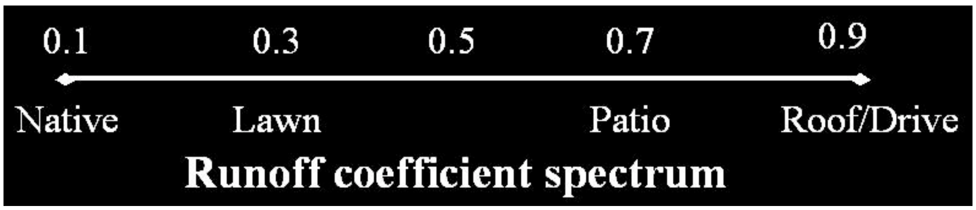
$c = runoff\ coefficient\ (between\ 0.1\ and\ 0.9\ as\ described\ below)$

$ponding = average\ ponding\ depth\ (ft)$

The advantage of using this formula to calculate your rain garden size is that it allows the homeowner to include information about local native soils by measuring the infiltration rate (i) where the garden will be placed. It also allows the homeowner to decide how deep of rain garden to excavate and how much ponding, if any, is desired. To simplify the more complex version of Darcy's Law, several assumptions have already been made including that the rain garden will capture and treat the first 1 inch of rainfall and that it will drain over a 48 hour timeframe. In southeast Michigan, over 90% of all rainfall events are less than 1 inch so a rain garden will receive more than 1 inch of rainfall only a few times a year. This formula also assumes a well-maintained rain garden with a planting mix consisting of primary compost and sand. A well-maintained garden will have infiltration rates greater than the soil below, which is why the native soil infiltration is the key design component in Darcy's Law. However, a rain garden that includes a significant amount of topsoil or that has been compacted by foot traffic or has been clogged by fine sediments might not infiltrate properly. To maintain a properly infiltrating rain garden, make sure to replace the mulch every couple of years, consider aerating or breaking up sections of the top layer of planting mix, have a grass or rock buffer around the edge to keep fine sediments out of the garden, and maintain good healthy plants.

The last important variable in the above equation is the runoff coefficient. The easiest way to conceptualize the runoff coefficient is to think of a spectrum between 0 and 1. A run-off coefficient of 0 would mean no run-off would result from a rainfall event (think of pouring a cup of water on a large sponge). The opposite end of the spectrum is a coefficient of 1, which mean every drop of water would runoff (think of pouring a cup of water on a baking tray). Realistically, the runoff coefficient for your yard will be between 0.1 and 0.9 as indicated in the figure below. A runoff coefficient of 0.1 would be a yard with exclusively naturalized areas and a runoff coefficient of 0.9 would be an area of all pavements.

For example, if you were designing a rain garden to accommodate water from a downspout, than you would use a runoff coefficient of 0.9. If you were designing a rain garden to handle water flowing from your lawn, than you would use a runoff coefficient of 0.3. If you are placing your rain garden to receive water from your driveway, a section of your manicured lawn, and perhaps a porous paver patio, than a run-off coefficient of 0.5 might be appropriate.



Runoff coefficient spectrum

To determine the drainage area of each land use type flowing into a rain garden, use a tape measure to determine the approximate length and width of the area that will flow into the garden. The area is than the length times the width. For example, if your rain garden is designed to hold runoff from a 300 foot long stretch of 30 feet wide road (**half** of which drains into your yard) via a front yard swale, then the drainage area for the sizing criteria would be 300 feet x 15 feet = 5400 square feet.

As a design example, assume that you are designing a rain garden to accommodate flow from a downspout that drains 1000 square feet of roof (50 ft x 20 ft). Therefore, your runoff coefficient is 0.9. As part of your plan, you would like to have 1 foot of planting mix. You have conducted your post hole infiltration test and determined your infiltration rate to be 0.5 ft/day (moderately clay soil). Finally, the garden is in the front yard and you would prefer no more than 3 inches of standing water for a short period of time. Using Darcy's Law,

$$SA = \frac{0.04 \times c \times DA \times depth}{(i) \times (depth + ponding)} = \frac{0.04 \times 0.9 \times 1000 \times 1}{0.5 \times (1 + .25)} = 57.6\ sq\ ft$$

yields a rain garden surface area of 57.6 square feet or roughly a 6 ft by 10 ft garden. Increasing the allowable ponding to 6 inches will shrink the garden to 48 sq ft or roughly a 6 ft by 8 ft garden. If you don't have 48 square feet to devote to a rain garden, you may construct a smaller garden, but make sure there is an overflow area or add an underground drain such that the excess water can escape without drowning all the plants. In this case, the overflow path needs to be no more than 6" higher than the top of the rain garden such that excess ponding will run off. In addition, don't forget the 3 inches of mulch. If the rain garden will have 1 foot (12 inches) of planting mix, you will need to excavate down 15 inches to accommodate for the 3 inch mulch layer.

In addition, some general sizing and design recommendation include keeping the overall drainage area into your rain garden to less than 0.5 acres. It is better to have multiple smaller gardens spread out over a site than to try to design one larger rain garden to hold all of the water from the site. This is especially true for clay soil sites where infiltration will be poor. Rain gardens should be wider in the direction of a majority of incoming runoff. This will allow the water to spread out and improve drainage. The slope of the land adjacent to the rain garden should be no more than 3 feet in the horizontal direction to 1 foot in the vertical direction so the water entering the rain garden isn't draining too quickly. Conversely, there needs to be some slope on the adjacent land (at least 10 feet in the horizontal to 1 foot in the vertical) to ensure the water flows into the garden and isn't directed elsewhere. It is very important to maintain a grass or gravel buffer around a rain garden to limit incoming water velocities and to filter out fine sediments that might clog a rain garden. This is especially true from roof downspouts from which the water will flow with high velocity.

G. What Should I Use as a Soil Mix?

In the Rouge River basin, we have found that a mixture of sharp non-rounded sand (between 0% and 50%) and compost (between 50% and 100%) works well for homeowner rain gardens, especially for rain gardens on poorly draining clay soil sites. The amount of each material you choose depends on your infiltration and water retention goals. Compost has twice the porosity of sand. In other words, compost can hold twice as much water as sand. Because of this, compost acts like a sponge and will hold more than its weight in water. Therefore, if the goal of the rain garden design is to maximize water retention, then the amount of sand should be limited. This would be especially true if your native soils have poor infiltration or high clay content. In these cases, the water will not infiltrate into the underlying soils so more compost should be used (even 100%) since it will absorb the excess runoff and release it back into the air through evaporation. In fact, in cases of poorly draining sites, it would be advisable to increase the surface area size of your rain garden and limit the depth since the water won't infiltrate quickly through underlying soils.

Conversely, sand allows faster infiltration and will drain up to twice as fast as compost. Therefore, if your goal is to have water flow through a rain garden into to an underdrain or into permeable layers of natural soil below, then the addition of sand will increase flow through the medium and limit the amount of water retention that will occur.

Many rain garden design manuals recommend including topsoil (either from your yard or purchased from a garden store), but we recommend avoiding topsoil because of the potential for high clay content. The inclusion of topsoil in the mix can greatly reduce infiltration and also ultimately causes less water to be retained. Therefore, from a water runoff point of view, topsoil should be avoided.

Finally, now that you know the size of your rain garden (6 feet by 10 feet in the above example) and what your planting mix will be (say 80% compost and 20% sand) its easy to calculate the amount of material you will need. A 60 sq ft surface area that is 1 ft deep will require 60 cubic feet of material. Since 80% of the planting mix is compost, you will need 48 cubic feet of compost (approximately 1.8 cubic yards) and 12 cubic feet of sharp sand (approximately 0.5 cubic yards). In addition, you will need 3" of mulch across the entire surface area, which equates to 15 cubic feet of hardwood mulch (approximately 0.6 cubic yards).

FOR FURTHER INFORMATION:

"An Investigation of Rain Garden Planting Mixtures and the Implications for Design", by Donald D. Carpenter and Laura Hallam, Lawrence Technological University, August 2007/

www.socwa.org: Rain Gardens for the Rouge, 4 page "how-to-do-it" bulletin.