Texas AgriLife Extension Service
Texas Water Resources Institute

Provide Assistance to Improve Water Quality in Hood County

FY 10 Federal Appropriated Funds
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TWRI Project Manager: Danielle Kalisek

Quarter no. 3 From 1/1/11 Through 3/31/11

Project Goals and Objectives

The goal for this project is to provide a mechanism to educate local stakeholders about water quality issues that are affecting Lake Granbury. This project will provide an assessment of existing and potential water quality threats related to on-going non-point source (NPS) water pollution within the Lake Granbury Watershed. The Texas Water Resources Institute (TWRI) and Texas AgriLife Extension Service will also assist BRA and TCEQ in developing a Watershed Protection Plan (WPP), aimed to improve and protect water quality within the Brazos River Basin. Educational information developed from this project will provide Federal, State and local decision makers with a variety of mechanisms that can be employed to prevent additional degradation of water quality in the watershed.

Key objectives of this project include:

- Holding public meetings to educate stakeholders and clients within the watershed about water quality and its protection
- Providing public educational programs to help achieve improved water quality
- Conduct training events on proper operation and maintenance of on-site wastewater treatment systems and collective facilities

Progress in Meeting Project Milestones and Output Commitments

Task, Deliverables, and Schedules

The Texas Water Resources Institute (TWRI) and the Texas AgriLife Extension Service continued on this year’s project deliverables during the second quarter. Project efforts focused upon conducting educational/outreach events for local residents. Additional fact sheets are in progress.

In looking forward to the next quarter, Texas AgriLife Extension Service specialists and the local County Extension Agent will continue planning programs for homeowners, will distribute news releases, fact sheets and educational materials, will discuss using rainwater harvesting to control stormwater, and will construct a rain garden. Several new rainwater harvesting demonstrations and trainings are planned for next quarter. A couple pet waste demonstrations are also in the planning stages.

The status of tasks, milestones and deliverables will be defined using the following terms:

Pending	Work has not started on the deliverable
Initiated	Work has started
Completed	The objectives were achieved and deliverables are finished
Deferred	Work has started, but further action is delayed pending other information, the completion of another objective, staff restraints, etc.
Ongoing	Work will continue throughout the term of the contract

Task 1 Education

Date	Status	Deliverables
12/31/10	Initiated	1. Develop an informational fact sheet on the design of rain gardens for stormwater abatement.
9/15/10	Completed	2. Develop educational presentations regarding water quality in Lake Granbury and the identified best management practices outlined in the watershed protection plan.
6/30/11	Ongoing	3. Implement a best management practice demonstration project on site water management utilizing a rainwater harvesting system in the Lake Granbury watershed.
6/30/11	Initiated	4. Develop a pet waste management demonstration in the Lake Granbury watershed.
6/30/11	Ongoing	5. Work on implementation of the Lake Granbury WPP in cooperation with BRA and TCEQ.
6/30/11	Ongoing	6. Hold informational meetings with the cooperation of the local AgriLife Extension agent, HOAs and civic organizations regarding BMPs to meet water quality goals detailed in the Lake Granbury WPP.
6/30/11	Pending	7. Conduct on-site sewage facility training for continuing education of practitioners.
6/30/11	Ongoing	8. Continue to offer basic septic system maintenance programs for homeowners surrounding Lake Granbury and provide educational resources.

Comments:

- The informational fact sheet on the design of rain gardens for stormwater abatement has been developed and is currently in the final stages of review. The document is currently receiving additional review. The document will be submitted to AgriLife Communications for publication. Draft publication is attached at the end of this report.

- We continue to work with BRA and TCEQ to facilitate implementation of the Lake Granbury WPP.
- We are looking to schedule informational meetings through cooperation with the local AgriLife Extension agent on different BMPs to meet water quality goals detailed in the Lake Granbury WPP.
- We will continue to distribute all previously developed and printed educational material to individuals in the Lake Granbury watershed.
- Pet waste management demonstration material has been purchased. We will now schedule a date to install the demonstrations.
- We have scheduled with the local county Extension agent to host a homeowner septic system training on the evenings of April 19, July 12, and September 19, 2011.
- A 2-day rainwater harvesting training has been scheduled for July 13-14, 2011. This training will teach participants about stormwater management through various rainwater harvesting techniques.
- A rainwater harvesting tank has been obtained to be installed as a demonstration in Hood County.

Task 2 Administration

Date	**Status**	**Deliverables**
10/10/10	Completed	1. Quarterly Progress Report
1/10/11	Completed	2. Quarterly Progress Report
4/10/11	Completed	3. Quarterly Progress Report
7/10/11	Pending	4. Quarterly Progress Report
10/10/11	Pending	5. Final Report

Comments:

- TWRI continues to update and distribute the one-page fact sheets as needed. The fact sheets identify project needs and goals and are used to gain stakeholder involvement and publicize project activity.
- TWRI continues to setup project meetings as needed/requested and regularly communicates with project members to ensure deliverables are being met and to be involved in project-related meetings.
- The Institute continues to maintain a website specifically for the Lake Granbury Water Quality Project. The website can be accessed at: http://lakegranbury.tamu.edu.

Problems or Obstacles Encountered and Remedial Actions Taken

None to report at this time.

Work Planned for Next Reporting Period

Task 1: Education

Texas AgriLife Extension Service will continue working with BRA, TCEQ, the local County Extension Agent and local watershed stakeholder group to develop and present information on water quality. Texas AgriLife Extension Service has scheduled the following events listed below and are currently planning additional activities:

- Scheduling and planning for the discussion of rainwater harvesting as a means of controlling stormwater in Hood County at local public meetings will continue.
- Distribution of the printed fact sheets and developed educational materials will continue.
- We expect to finalize the informational fact sheet on the design of rain gardens for stormwater abatement and submit the fact sheet to AgriLife Communications for publishing.
- We will continue to offer basic septic system maintenance programs for homeowners surrounding Lake Granbury upon request.
- We will continue to work in cooperation with BRA and TCEQ on the implementation of the developed WPP.
- We are looking to install the pet waste management demonstration during the next quarter in the Granbury Hike and Bike Trail
- We plan to install a 1,500 gallon tank for rainwater harvesting at the Acton Nature Center in Hood County in April or May.

Task 2: Administration

TWRI will continue working with BRA, TCEQ, NRCS and Texas AgriLife Extension Service in moving forward with project deliverables and publicizing the project to raise awareness of water quality issues within the study area. TWRI will continue to work with project participants to communicate about project status and reporting.

Stormwater Management: Rain Gardens

Fouad Jaber[*] and Dotty Woodson[**]
[*]Assistant Professor and Extension Specialist, Texas AgriLife Extension Service
[**]Extension Program Specialist, Texas AgriLife Extension Service

Rain Gardens

In this publication, rain garden (also known as bioretention areas) as effective post-construction BMPs are discussed. A rain garden is a landscape feature consisting of a planted shallow depression that collects rainwater runoff from roofs, parking lots and other impervious surfaces. While a rain garden can blend into the landscape and receive special attention by homeowners as a garden, the main function is to retain and treat stormwater collected from roofs or impervious surfaces. Rain gardens are either bowl-shaped or surrounded by a berm in order to retain water. Rain gardens are typically planted with native or adapted vegetation that will tolerate water logging and periods of drought.

Rain gardens are constructed in a variety of soils, from sand to clay, and vary in size depending on the catchment area. (The catchment area is the area from which any runoff will end up in the rain garden.) Rain gardens can be incorporated in a homeowner's landscape or can be built to collect and treat stormwater from retail parking lots (Figures 1and 2).

Benefits of rain gardens include:

1. Reduction of the total stormwater volume
2. Reduction of the runoff flow rate
3. Treatment of the pollutants in stormwater
4. Increase groundwater recharge.

Figure 1. Rain garden built to capture rainwater off parking lot and roof

Figure 2. Rain garden built as an island in a retail parking lot (Courtesy of USDA, NRCS).

How Do Rain Gardens work?

Rain gardens utilize the chemical, biological and physical properties of soils, plants and microbes to remove or retain pollutants from stormwater. This occurs through four processes:

1. Settling
2. Chemical reactions in soil
3. Plant uptake
4. Biological degradation in root zone

1. Settling:

Settling is the deposition of soil particles and debris in the rain garden due to the slowing of the runoff at the inflow. The presence of vegetation further slows the water, making the process of settling more efficient. The vegetation also traps some of the pollutants attached to sediments in a process known as filtration. Total suspended solids (TSS), debris, soil particle bound pollutants such as phosphorous and some microbes are the main pollutants trapped in rain gardens. Because sediments tend to settle on top of the rain garden and potentially clog it, it is important to perform regular maintenance to help it remove sediments efficiently.

2. Chemical Reactions in Soil

The soil in rain gardens interacts with pollutants and is an essential part of the treatment function of this BMP. Soil chemical reactions fall under two main processes:

a. Adsorption
b. Volatilization

Adsorption: The attraction between charged soil particles and oppositely charged pollutants. Adsorption binds these pollutants to the soil.
Volatilization: The conversion of a substance to a more volatile vapor form. The transformation of complex hydrocarbons to CO_2 is an example. This process also occurs due to microbial activity.

3. Plant Uptake

Nutrients are taken up through the root systems of plants and utilized for growth and other processes. While this is not a very efficient process in itself, plants can be selected such that they have a high nutrient uptake. Nutrients may be released back into the rain garden when plants die off. This release can be prevented by regularly removing dead vegetation.

4. Biological Degradation in Soil

Microbes in the soil break down organic and inorganic compounds, including oil and grease and help eliminate harmful pathogens. Two microbial processes by which nitrogen is removed in the soil include nitrification and de-nitrification.
Nitrification: The conversion by bacteria of nitrogen products not readily taken by plants (ammonia and ammonium) into products that are soluble in water and thus easily absorbed by the root system (nitrate).
De-nitrification: The conversion of nitrate by bacteria into volatile nitrogen products (e.g. nitrogen gas) that are released into the atmosphere. De-nitrification happens only when the right conditions are present, such as low oxygen (e.g. waterlogged conditions), high temperature and organic matter content.

Design and Construction of Rain Gardens

There are two common designs of rain gardens used for stormwater retention. The first consists of a planted depression placed downstream from a drainage area. This design is commonly used in home and retail landscapes to collect rain from roofs, or in sandy soil areas with high infiltration rates. An excellent resource describing the design and construction of a rain garden can be found in Texas AgriLIFE Extension publication L-5482 “Rainwater Harvesting: Raingardens”. The second design consists of replacing the existing soil with layers of high infiltration soils, gravel and mulch, and planted with a variety of vegetation. This design also commonly includes a perforated pipe used for drainage placed at the bottom of the growing media, but above the gravel layer. The second design is best suited for clay soil, parking lots, and highway medians.

1. Selecting a Site for the Rain Garden

To select the location for a rain garden, consider the existing land use, vegetation, slope, proximity to building foundations, and the aesthetic value of the site. A rain garden should be designed to collect runoff from an area of no more than 1 -2 acres. Larger areas can produce flows that cause erosion from the rain garden soil. If the rain garden is planned to collect runoff from a parking lot, replace a paved area instead of placing the rain garden in an existing grassed area that is already filtering stormwater. Avoid placement in areas close to soil disturbed by construction to prevent the rain garden from being clogged by sediments associated with the construction site runoff. In case the rain garden is close to the disturbance, use accepted construction BMPs such as silt fences to protect the garden.

2. Determining the Catchment (or Contributing) Area

If the rain garden will be utilized to collect roof runoff, the catchment area will consist of the roof dimensions, in addition to the area between the building and the rain garden. For parking lots, knowledge of the drainage pattern (or drainage design) is helpful in estimating the catchment area. If the parking lot is not level, and water flows out in more than one location, delineation of the catchment area from a topographic map is necessary. A surveyor can do this step manually or using Geographic Information System (GIS) software. If the area is larger than two acres, consider two or more rain garden cells (see figure 3). Rain gardens can be placed as islands in parking lots with concrete curb cut openings (figure 4).

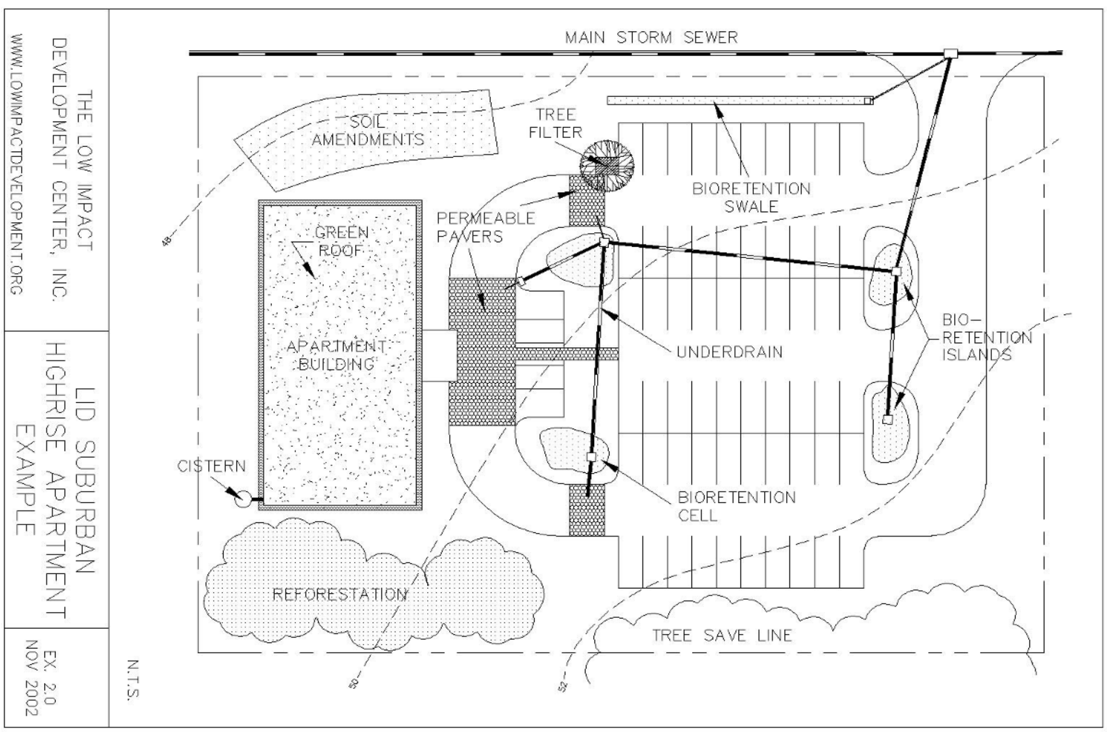

Figure 3. Parking lot design showing several rain garden cells connected with underground drains (Courtesy of the Low Impact Development Center, Inc)

Figure 4. Curb cut opening (Courtesy of USDA, NRCS)

3. Runoff Volume Calculation

Not all rain becomes stormwater. Rain is trapped in depressions, some infiltrates and some evaporates before running off the surface. There are various ways to estimate runoff after a rainfall event. One of the most commonly used methods is the Natural Resources and Conservation Service (NRCS) Curve Number Method:

$$Runoff\ \ Depth = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

Where P is precipitation (inches), $S = \frac{1000}{CN} - 10$, and CN is the Curve Number.

The Curve Number is a land use and soil type factor that reflects the imperviousness of the ground surface. A list of curve numbers is listed in Table 1.

Table 1. Curve numbers for various types of land and hydrologic groups.

Cover Type and Hydrologic Soil Group	**A**	**B**	**C**	**D**
Open space (lawns, parks, golf courses, cemeteries, etc.)	49	69	79	84
Paved parking lots, roofs, driveways, etc.	98	98	98	98
Streets and roads:				
Paved; curbs and storm drains	98	98	98	98
Paved; open ditches	83	89	92	93
Gravel	76	85	89	91
Dirt	72	82	87	89
Urban districts:				

Commercial and business (85% impervious)	89	92	94	95
Industrial (72% impervious)	81	88	91	93
Developing urban areas: Newly graded areas (pervious areas only, no vegetation)	77	86	91	94

(Adapted from TXDOT Hydraulic Design Manual)

Hydrologic Soil Group Descriptions:

A -- Well-drained sand and gravel; high permeability.
B -- Moderate to well-drained; moderately fine to moderately coarse texture; moderate permeability.
C -- Poor to moderately well-drained; moderately fine to fine texture; slow permeability.
D -- Poorly drained, clay soils with high swelling potential, permanent high water table, claypan, or shallow soils over nearly impervious layer(s).

Most rain gardens are designed for a one inch storm event. This allows rain gardens to perform as a first flush system. The first flush of runoff, usually resulting from the first inch of rainfall, is usually the most polluted as it carries all the debris and pollution that accumulated since the previous rainfall event. Rainfall in excess of one inch is designed to go through an overflow system. As a first flush system, a rain garden will retain the majority of rainfall events during the course a year. For example, storms with more than 1 inch per day happen only 12 times per year on average in Dallas, TX.
To calculate the total volume, we multiply the runoff depth by the catchment surface area using the following formula:

$$Runoff\ \ Volume\,(Gals) = Runoff\ \ Depth\,(inches) \times Area\,(\,ft^2\,) \times 0.623$$

Example 1: Calculating Runoff Volume

Maggie wants to build a rain garden to collect stormwater flowing off the 3000 square foot paved parking lot of her store built on clay soils. She first calculates the runoff depth resulting from a one inch rainfall event. From the curve number table, she identifies that her Hydrologic soil group is D, and for paved parking lots, the curve number CN is 98. She then calculates the value of *S* from the curve number method equation:

$$S = \frac{1000}{CN} - 10 = \frac{1000}{98} - 10 = 0.20$$

She then calculates the runoff resulting from a 1 inch rainfall using the following equation:

$$Runoff\ \ Depth = \frac{(P - 0.2S)^2}{(P + 0.8S)} = \frac{(1 - 0.2 \times 0.2)^2}{(1 + 0.8 \times 0.2)} = 0.79\ inches$$

She then figures out the volume in gallons 0.79 inches make on 3000 square feet of parking lot:

3000 ft^2

$$Runoff\ \ Volume\,(Gals) = Runoff\ \ Depth\,(inches) \times Area\,(\,ft^2\,) \times 0.623$$
$$Runoff\ \ Volume\,(Gals) = 0.79\,(inches) \times 3000(\,ft^2\,) \times 0.623 = 1869(gallons)$$

4. Rain Garden Design

The rain garden is usually 3 feet deep. The bottom foot is filled with gravel (0.5-1.5 in. in diameter- #57 stone). This is known as the retention zone. At the top of this layer place a perforated underdrain for drainage purposes (Figure 5). Place a filter fabric over the gravel and the drain to reduce the silting of the gravel zone (figure 6). Place a foot and a half of soil over the filter fabric. Bring soil in from another area if the native soil is of low infiltration (e.g. clayey soils). The soil should mainly consist of sand or another coarse material (e.g. crushed expanded shale) yet still contain some fine material and organics to support plant growth. For clay soil use a mix of 50%compost, 25% native soil and 25% expanded shale (or similar material). For sandy soils a 50-75% native soil and 25-50% compost mix should be used.Well aged yard waste compost should be used Add two inches of mulch, preferably well aged shredded hardwood, which will not float, on top of the soil around the plants. Build the rain garden to hold 6-9 inches of water over the top of the soil (Figure 7).

Assuming a pore space of 30% for the gravel and 30% pore space for the soil (sand/clay/compost mix), calculate the depth of water that that the rain garden will hold at full capacity. One foot of gravel with 30% pore space will hold 3.6 inches of water. One and a half feet of expanded shale/clay/compost mix with 30% pore space will hold 5.4 inches of water. Add the 6 inches of standing water on top of the rain garden soil for a total water depth of 15 inches (Figure 8).

Figure 5. Placing a perforated pipe on top of the gravel

Figure 6. Placing the filter fabric

Figure 7. Completed rain garden.

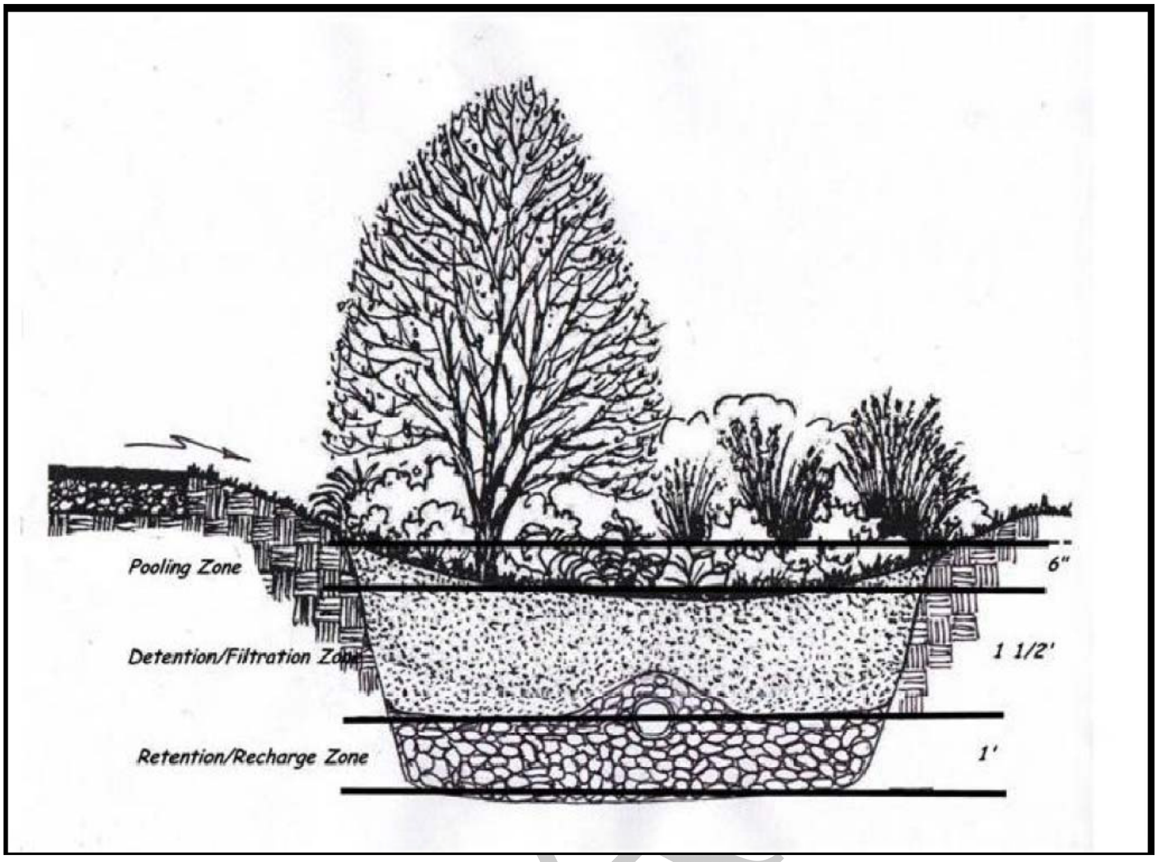

Figure 8. Typical cross section of rain garden (Courtesy of George's County, Maryland).

5. Rain Garden sizing

In order to determine the surface area of the rain garden, divide the total volume of runoff by the depth of water held at full capacity. The water volume in gallons held in a square foot of rain garden is:

$$Volume\ per\ square\ foot\,(gallons) = Water\ depth\,(inches) \times 0.623$$

$$Surface\ Area\ of\ Rain\ Garden\ (ft^2) = \frac{Volume\ of\ Runoff\ (gallons)}{Volume\ per\ Square\ Foot\ (gallons\ per\ ft^2)}$$

Example 2: Calculating the Size of the Rain Garden

After determining the runoff volume generated from her parking lot, Maggie needs to calculate the size of her rain garden. Knowing that her rain garden holds a water depth of 15 inches, she first calculates the volume of water that is held in each square foot of rain garden using the following equation:

$$Volume\ per\ square\ foot\,(gallons) = Water\ depth\,(inches) \times 0.623$$

$$Volume\ per\ square\ foot\,(gallons) = 15\,(inches) \times 0.623 = 9.35\ gallons$$

Using this number and the total runoff volume from Example 1, she calculates the surface area required to build her rain garden:

$$Surface\ Area\ of\ Rain\ Garden\ (ft^2) = \frac{Volume\ of\ Runoff\ (gallons)}{Volume\ per\ Square\ Foot\ (gallons\ per\ ft^2)}$$

$$Surface\ Area\ of\ Rain\ Garden\ (ft^2) = \frac{1869\ gallons}{9.35\ gallons\ per\ ft^2} = 200\ ft^2$$

Maggie needs 200 square feet to build a rain garden that will hold runoff from 1 inch of rainfall falling on her parking lot. This amounts to 6.67% of the total catchment area. Typically, rain gardens range from 3-10% of the total catchment area.

6. Drainage Pipe sizing

The drainage pipe placed under the soil area (1.5 feet) should be designed to carry up to 10 times the minimum flow through the soil calculated using Darcy's law:

$$\boxed{Q = AK\frac{h}{L}}$$

Where Q is the flow through the soil media (cfs), A is the rain garden surface area, K is the hydraulic conductivity of the soil or how fast water flows through the soil, h is the height of water above the drain and L is the depth of the soil (see figure 9). Hydraulic conductivities for various soils are in Table 2.

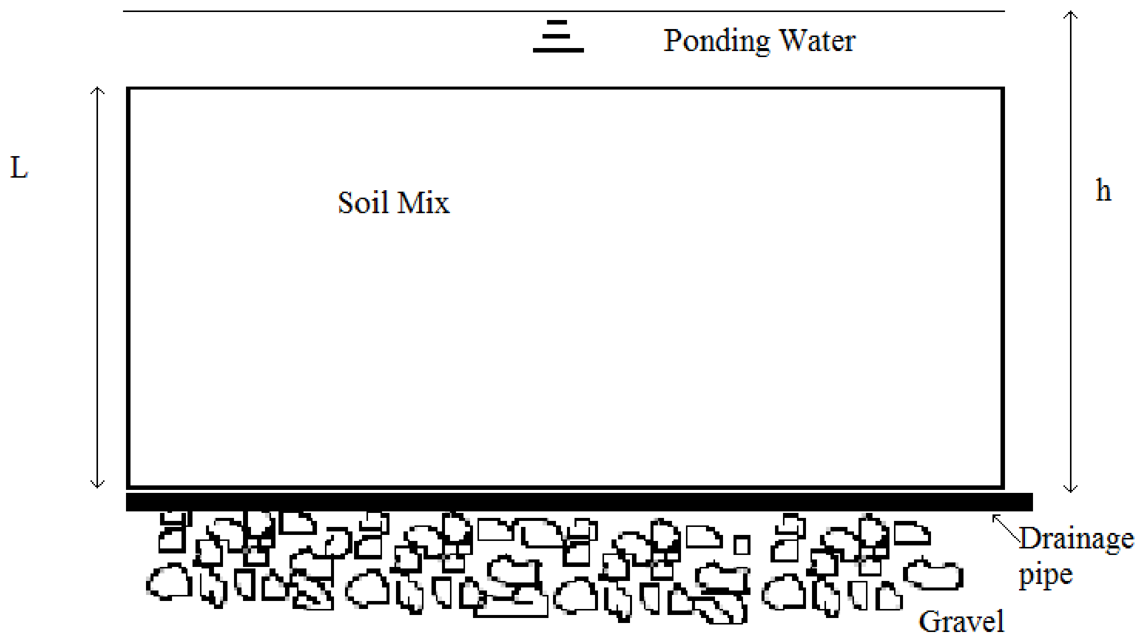

Figure 9. Cross section of rain garden showing the h and L of Darcy's law.

Table 2. Typical hydraulic conductivity (K) ranges for various soil types.

Soil Texture	Saturated Conductivity (in/hr)
Sand	8.27
Loamy sand	2.41
Sandy loam	1.02
Sandy clay loam	0.17
Loam	0.52
Silt loam	0.27
Clay loam	0.09
Silty clay loam	0.06
Silty clay	0.04
Clay	0.02

(Adapted from *Handbook of Soil Science*, Sumner ME, 2000)

To determine the size of the perforated pipe needed the Manning's equation can be used:

$$\boxed{D = 16 \times \left[\frac{n \times Q}{S^{0.5}}\right]^{3/8}}$$

Where
D = diameter of pipes (inches)
Q = flow to be carried (cfs)
n = Manning roughness coefficient (0.01 for smooth plastic pipe)

S = slope of pipe (for this site, assume 0.1%)

A list of Manning's roughness coefficients for various pipe types is in Table 3.

Table 3. Manning's roughness coefficient for various types of pipes

Surface Material	**Manning's Roughness Coefficient n**
Brass	0.011
Brick	0.015
Cast-iron, new	0.012
Copper	0.011
Corrugated metal	0.022
Galvanized iron	0.016
Plastic	0.009
Steel - Coal-tar enamel	0.010
Steel - New unlined	0.011
Steel - Riveted	0.019

Example 3: Sizing the drainage pipe

In Example 2, Maggie determined that her rain garden needs to be 200 square foot. To size her underdrain, she needs to calculate the flow going through her loamy sand soil at capacity. The depth of her soil L is 1.5 feet. The height of the waer above the drain *h* is the 1.5 feet of soil plus the 6 inches of standing water, which is equal to 2 feet. From Table 2, a loamy sand will have a hydraulic conductivity of 2 in/hour. Applying the Darcy equation:

$$q = K\frac{h}{L}$$

$q = 2.41\, in/hr\,\frac{2\,ft}{1.5\,ft} = 3.21\, in/hr$ per square foot of rain garden. For 200 square feet, the total flow is

$$Q = 200\, ft^2 \times 3.21 in/hr \times (\frac{1}{12} in/\ ft) \times (\frac{1}{3600} hour/\sec) = 0.015\ \ cfs.$$

The pipe needs to be designed for 10 times the calculated flow, i.e. 0.15 cfs. To determine the pipe size, using a plastic pipe, we need to determine the roughness coefficient from Table 3. For plastic n = 0.009. If the pipe is laid at a 0.1% (0.001) slope, we can calculate the size of the pipe using Manning's equation:

$$D = 16 \times \left[\frac{n \times Q}{S^{0.5}}\right]^{3/8}$$

$$D = 16 \times \left[\frac{0.009 \times 0.15}{0.001^{0.5}}\right]^{3/8} = 4.90 \text{ inches}$$

Rounded up to the nearest available pipe size, we find that an 6 inch pipe is needed to carry the water ten times the minimum flow rate from this site.

7. Overflow Design

If the rainfall rate exceeds the infiltration rate of the growing media, the rain garden may overflow. Any rain garden design should account for this possibility. It can be as simple as allowing the water overflow at the downstream end. This design would require a large enough vegetated area to absorb the overflowing water. If the rain garden is adjacent to an impervious area (e.g. road), an alternative strategy, such as redirecting overflow, is necessary. To route overflow into an adjacent drain or ditch, install an overflow drop box (Figure 10). Place the top (inflow) of the drop box at least 6 inches higher than the top of rain garden soil. This allows for holding six inches of water on top of the rain garden. Connect the outlet of the drop box to a pipe that routes the water to the adjacent drainage system.

Figure 10. Drop box that can be used for overflow in rain gardens.

Plant Selection

Plants placed in rain gardens should be able to withstand short periods of inundation (up to 48 hours), but unlike wetlands plants, rain garden vegetation should also withstand drought conditions. The vegetation selected will depend on regional weather conditions and the adaptability of the plants. Since Texas includes several climatic regions, consulting with the county horticulture extension agent, local horticulturist, Texas Master Gardeners or local nursery managers is advisable. A list of plants suitable for rain gardens in Texas is shown in Table 4. This list is not exhaustive.

Table 4. List and characteristics of rain garden plants

Botanical Name	Common Name	Height/Width	S/SH	W/D
Perennials				
Achillea millefolium	Yarrow	1'/1'	S	D
Acorus calamus	Sweet Flag	4'/2'	S	W
Alstromeria pulchella	Peruvian	3'/2'	S/PSH	W/D
Aquilegia hinckleyana	Texas Columbine	12"/12"	S	W/D
Asclepias tuberosa	Butterfly Weed	3'/6"	S	D
Aspidistra elatior	Cast Iron Plant	24"/24"	SH	W/D

Botanical Name	Common Name	Height/Width	S/SH	W/D
Baptista australis	Blue False Indigo	3' to 6'/24"	S	W
Calyptocarpus vialis	Horseherb	4"/18"	SH	W/D
Canna generalis	Canna	2' to 6'/2' to 6'	S	W
Coreopsis verticillata 'Moonbeam'	Moonbean Coreopsis	1'/1'	S/PSH	W/D
Dichondra argentea 'Silver Falls'	Silver Falls	2"/4"	S/PSH	D
Echinacea purpurea	Purple Cone Flower	2'/2'	S	W/D
Eupatorium coelestinum	Blue Mistflower	8"/16"	S	W/D
Eupatorium purpureum	Joe-Pye Weed	4-4'/2'	S/SH	W
Heliopsis helianthoides	Ox-eyed Sunflower	3-5"/30"	S	W
Hibiscus moscheutos	Rose Mallow	3-4'	S	W/D
Hymenocallis liriosme	Spider Lily	2'/1'	S	W/D
Ipomopsis rubra	Standing Cypress	2' to 6'/6" to 12"	S	W
Iris Breaded spp and hybrids	Iris	12"/6"	S	D
Iris brevicaulis Louisiana spp and Hybrids	Louisiana Iris	Up to 40"/6"	S/PSH	W
Kosteletzkya virginica	Marsh Mallow	6'/6'	S	W
Liatris spicata	Gayfeather	2'/18"	S	W
Lobelia cardinalis	Cardinal Flower	2' to 4'/2'	S/PSH	W
Lythrum salicaria	Loosestrife	3'/3'	S	W/D
Monarda didyma	Bee Balm	2'/2'	S	W/D
Rudbeckia hirta	Black-eyed Susan	1-2'/1'	S	W/D
Ruellia brittoniana 'Katie's'	Ruella Katie	6"/12"	S	W/D
Setcreasea pallida	PurpleHeart	12"/24"	S/PSH	W/D
Sisyrinchium angustifolium	Blue-eyed grass	6" to 12"/12"	S	W/D
Solidago altissima	Goldenrod	2' to 4'/3-5'	S	W/D
Stachys byzantina	Lamb's Ear	6"/12"	S	D
Tradescantia occidentalis	Spiderwort	2'/1'	SH/PSH	W/D
Vernonia fasciculata	Ironweed	4-6'	S	W
Zephyranthes	Rain Lily	6"-10"	S	W
Ornamental Grasses				
Carex spp	Sedge	Varies	Varies	W/D
Chasmanthium latifolium	Inland Seaoats	2'to 4'	SH	W
Muhlenbergia reverchoni	Seep Muhly	2-4'	S	W
Panicum virgatum	Switch Grass	3-4'	S	W/D
Shrubs				
Callicarpa americana	American Beauty Berry	4' to 6'/5' to 8'	S/SH	W/D
Ilex decidua	Possumhaw Holly	20'/15'	S/SH	W/D
Ilex vomitoria	Yaupon	20'/20'	S/SH	W/D
Myrica cerifera	Southern Wax Myrtle	15'/10'	S/SH	W/D

Botanical Name	Common Name	Height/Width	S/SH	W/D
Sabal minor	Dwarf Palmetto	4'/5'	SH	W/D
Spirea x bumalda 'Anthony Waterer'	Anthony Water Spirea	2-3'/3'	S	D
Trees				
Acer rubrun var. drummondi	Southern Swamp Maple	70'/30'	S	W/D
Sophora affinis	Eve's Necklace	30'/20'	S	W/D
Taxodium distichum	Bald Cypress	70'/30'	S	W/D

S – Sun SH – Shade PSH – Part Shade W – Wet D – Dry

Cost

Construction activity and material required to build a rain garden include:

- Excavation and hauling of existing soil
- Importing new soil
- Gravel
- Filter fabric
- Mulch
- Perforated pipes
- Overflow drop box
- Plants

The per unit area (e.g. square foot) cost of building a rain garden will vary based on the size of the rain garden, the type of soil and the design (bowl shaped vs. gravel and soil design). An estimate of the costs for the above mentioned activities and material are listed in Table 5. The cost of building the example rain garden are also calculated and normalized per square foot.

Table 5. Cost estimate for rain garden construction.

Activity/Material	Unit	Unit cost	Cost for 200 ft^2
Excavation/Hauling	Cubic yard	$6.30	$150
New soil import and installation	Cubic foot	$.5	$200
Gravel import and installation	Cubic foot	$.5	$150
Filter fabric	Square foot	$.5	$100
Mulch	Square foot	$0.5	$100
Perforated pipe	Linear foot	$2	$50
Overflow drop box	1 box	$50	$50
Plants	Square foot	$2	$400
Total			**$1200**
Cost/ft^2			**$6**

Operation and Maintenance

Rain gardens operate best when they are regularly maintained as any other BMP. While the selection of the plants form the list above can go a long way in reducing daily care for the rain garden, the following practices need to be performed on a regular basis:

- Control weeds and invasive plants by weeding regularly, preferably by hand to reduce water contamination.
- Monitor diseases and insects and remove infected plants as soon as detected.
- Use aeration equipment and add compost regularly to reduce compaction and decreases in the rate of infiltration.
- Make sure that clay pans are not forming on the top of the rain garden and remove any clay layer that forms on top of the rain garden from sedimentation with shovels.
- Irrigate in times of drought and high heat, usually if less than 0.5 in of rain have been received in the past 3 weeks.

Resources

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