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BioRetention Cells/Rain Gardens, a Stormwater BMP

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Introduction

As communities continue to develop, more and more land is converted into impermeable surfaces such as driveways, parking lots, homes, offices, schools, highways, and paved walkways. These impermeable areas can dramatically alter the stormwater quantity and quality from these areas. Water, which once soaked into the ground – or infiltrated – now runs off forming a “stormwater superhighway” that delivers the runoff and associated pollutants straight into nearby streams and lakes. Bioretention cells (sometimes called rain gardens) can attenuate stormwater peak runoff rates, infiltrate up to 90% of the annual rainfall, and greatly improves the quality of stormwater runoff. The purpose of this fact sheet is to provide design guidance to engineers and planners on how to properly develop a bioretention cell.

Bioretention Cells/Rain Gardens: What are they? Pioneered in Prince George’s County, MD, bioretention cells are landscaped depressions that capture and treat stormwater runoff. Bioretention cells are a fraction (usually between one-twentieth and one-fourth) of the impermeable area and may be installed in lawns, along the edges of roads, or in the medians of parking lots. The size and design of the bioretention cell depends upon the area it drains and the type of soil in which the cell is placed. Stormwater is directed into the cell by pipes, swales, or curb openings. The depression temporarily captures and holds the first flush, usually the runoff from one-inch of runoff water from an impermeable area. Trees and shrubs selected to grow in the bioretention cell must be water tolerant. Bioretention cells can be installed in a variety of soil types from clayey to sandy soils. A typical bioretention cell is shown in Figure 1.

Stormwater Volume and Peak Reduction by Bioretention

Bioretention cells sited in appropriate soils can be designed to infiltrate of 85 to 90% of the annual stormwater runoff, thus replenishing groundwater. When properly designed, bioretention cells have been shown to provide sufficient storage to attenuate the peak rates of runoff from the impermeable areas to the peak rates of runoff experienced before the area was developed. Bioretention cells have been shown to remove 95 to 98% of the metals (Cd, Zn, Pb, etc) found in stormwater runoff. They can reduce total nitrogen by 40% and nitrate-nitrogen by 15 to 75%. Bioretention cells have also been shown to reduce phosphorus by as much as 65%.

Overview

A bioretention cell is a stormwater best management practice (BMP) designed to capture and treat the first flush of runoff from impermeable surfaces. It is well documented that this first flush contains a large portion of the pollutants that leave an impermeable area.

Figure 1. Typical bioretention cell.

In a bioretention cell, the first flush is captured and infiltrated into the soil profile, where it is treated and released to the local ground or surface water. When the local soil has a percolation rate greater than about 0.2 in/hr, these treated waters can be released (infiltrated) to the groundwater. When soil percolation rates are slower than about 0.2 in/hr, these treated waters are returned to the surface waters via an underdrain system (see Figure 2). For those large rains (usually 3 to 5 storms per year) that produce more than a first flush of runoff, excess runoff (that runoff in excess of the first flush) is diverted to the local surface water system.

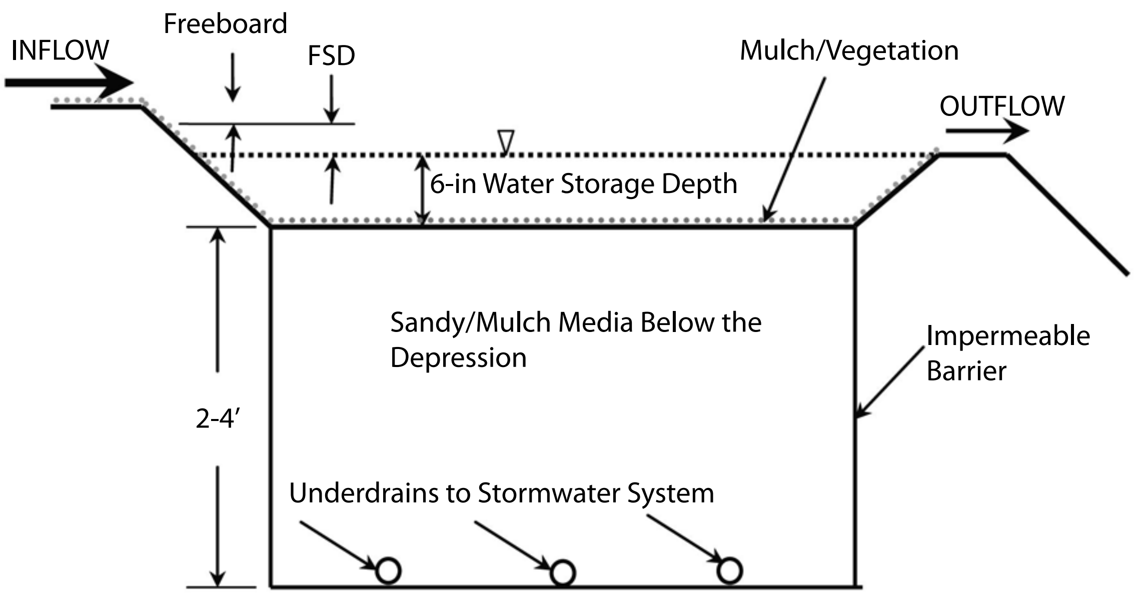

Figure 2. Schematic of a bioretention cell with underdrains.

The Design Process

The bioretention cell should be located where it can receive water from the impermeable area(s). Slightly depressed areas are good candidates, provided these depressions do NOT have a seasonally high water table that reaches to within 4 feet of the soil surface and not designated as a wetland. A high water table would encourage the growth of wetland plants, which many homeowners want to avoid. If a suitable depression does not exist, then a flat site can be engineered.

Rapidly Permeable Soils. When the natural soils are permeable enough to infiltrate the captured water (permeability > 0.2 in/hr), a small downstream depression should be created in a flat area to receive the impermeable area runoff.

Slowly Permeable Soils. When the natural soil permeability is too slow to infiltrate captured runoff water (permeability < 0.2 in/hr), it will be necessary to excavate the area under the bioretention cell to a depth of 2 to 4 feet. An underdrain system is then placed on the bottom of the excavated area before the hole is filled with a mixture of sandy soil and hardwood bark mulch mixture with a permeability of at least 2 in/hr (see Figure 2).

Sizing the Bioretention Cell. A surface depression is created to receive the runoff (see Figure 2). This 9- to 12-inch depth will receive up to 6 inches of runoff from the impermeable area. Since the depth of runoff expected from one-inch of rain falling on an impermeable surface (CN = 98) is 0.79 inches, the 6-inch storage in the bioretention cell represents the runoff from an impermeable area with an area 7.5 times larger than the bioretention cell. Thus, if the impermeable area is 3 acres in size, the surface area of the bioretention cell will need to be (3.0/7.5 =) 0.4 acres in size. This will permit the 0.79-inch first flush from the 3-acre impermeable area to fill the 0.4-acre bioretention cell to a depth of 6 inches. If the depth of storage in the bioretention area is increased to greater than 6 inches or decreased to less then 6 inches, the ratio of impermeable area to first flush can be adjusted accordingly.

Designing the Overflow. Any additional runoff water beyond the first flush (expected if the rainfall depth exceeds one inch) will increase the depth in the bioretention depression by a small amount. This additional water should either be diverted around the bioretention cell or passed through the bioretention cell.

In many cases the is excess water can simply flow “out the back” of the bioretention cell. This is allowed in bioretention cells that are constructed in flat areas. Water would leave the bioretention cell simultaneously from several places along the back-side of the bioretention cell. This only works in original, undisturbed soil with a turf cover. If the perimeter of the bioretention cell is altered during construction, this soil will likely erode if water flows over it for any length of time. It is necessary to have a designated water overflow area for larger storms in bioretention cells that have imported soil. Rocks or turf reinforcement mats can be used to line the designated outlet area. In commercial and industrial settings, an overflow riser pipe is often installed within the bioretention cell. The top of the riser or overflow box is set at the desired maximum water elevation, generally to the top of the 6-inch capture depth. Any additional water will exit through the riser and its discharge pipe.

Other Design Considerations

After the bioretention cell is located, sized and excavated, a few more measures need to be taken. First, all water inlets must be stabilized. If water enters the cell in a concentrated flow such as from a pipe or ditch, it may be necessary to place rock at the end of the conveyance (pipe or swale) to dissipate the energy of the water as it enters the bioretention cell. A level spreader (device used to spread water flow into sheet flow) can be used to evenly distribute water as it enters the bioretention cell. As long as velocity is not greater than 1-2 fps, there is little chance for erosion.

If suspended sediment is expected in the runoff, the designer may want to consider using grass buffer strips and force sheet flow through them. The grass strip will filter much of the sediment, keeping the bioretention cell free of this clogging agent. Grass strips run the length of the cell where sheet flow would be expected to enter at a nominal width of five feet, though these strips can either be as narrow as a few feet or much wider than five feet depending upon the application.

If the bioretention cell is treating runoff from and is being constructed adjacent to a parking lot, there should be a 1- to 3-inch drop from the edge of the parking lot to the maximum water level within the bioretention cell. If the soil in the parking lot is even with the pavement, eventual growth and debris build-up in the bioretention cell (or grass filter strip) will create a miniature dam, forcing water to move laterally along the pavement rather than into the bioretention cell.

Landscaping Bioretention Cells. Once the bioretention cell has been constructed, it is time to plant vegetation and mulch the cell. It is important that a high degree of vegetative diversity exist in the bioretention cell. Bioretention cells are not intended to be wetlands. They are designed so that water is not regularly saturating or inundating the cell for long periods of time. Therefore, bioretention cells are too dry for many wetland plants, such as cattails, common reed, and water lillies to survive. Bioretention cells are designed to receive stormwater runoff; therefore, the vegetation must be able to withstand brief periods of water inundation.

The dryness of a bioretention cell – which depends on how much water is directed to them, how quickly the cell drains, and how frequently it rains – usually dictates the type of vegetation that can thrive in the cell. Bioretention cell vegetation must also be drought tolerant if the site is to receive infrequent maintenance. Bioretention cells are wet only during and immediately after runoff events. Plants in the cell must also be able to tolerate some periods without substantial moisture. Before deciding which vegetation to plant, be sure to consult more knowledgeable sources such as your local county extension agent, nursery specialist, or landscape contractor.

There are a few other significant factors used to determine which plants are grown in bioretention cells. For those constructed in clay soils, it is very important to select trees and shrubs that do not have overly aggressive roots that will send their roots into drainage pipes in search of air, thereby clogging the pipes. Another plant to avoid is any type of cherry tree. When inundated, cherry tree roots release a poison which 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 bioretention cell during the winter. Consult your nursery or landscape professional to help select material that suits your situation. Planting the bioretention cell often dictates the timing of construction. It is very important that the watershed draining into the bioretention cell is stable prior to planting. As with any garden, bioretention cells must be maintained. The more a bioretention cell is treated as a garden, the more apt it is to be attractive and flourish.

After the cell has been planted, a 2- to 4-inch thick layer of hardwood (not pine) mulch should cover the entire cell. Double- shredded hardwood mulches are much less apt to float, which is real concern in an area that will frequently experience periodic flooding.

Costs. In general, construction costs for bioretention cells in highly permeable soils range from $1.50 to $3.00 per square foot of bioretention cell area. In slowly permeable soils expect costs to range from $4.00 to $6.00 per square foot.

Maintenance costs will vary depending upon the level of attention the bioretention cell warrants. At a minimum, it is necessary to yearly inspect the bioretention cell's underdrains to make sure they are not clogged. Mulch will need to be added to the bioretention cell periodically. This keeps up the appearance of the cell (minimizing weeds) and continues to provide a key water quality function. This maintenance will need to be performed 1-2 times per year. During drought times it may be important to water the plants in the cell. As with any garden, the more care given, the more able the plants will be to survive. As in any natural setting, all vegetation will eventually die, so the cells 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 require replacement approximately every 10 years.

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