Appendix C: The Nuts and Bolts of Stormwater Management Strategies for Streets and Parking Lots

This appendix discusses some of the key design considerations to keep in mind when implementing green streets and parking lots. The information is not overly technical; however, it does emphasize areas that should receive specialized design attention:

- **Pedestrian circulation:** One of the most overlooked design issues is not providing good pedestrian circulation in conjunction with stormwater facilities. It is uncomfortable and inconvenient for people to to walk through vegetation to reach their destination.

- **Getting water in and out:** Another key design element in stormwater design is assuring that water will be able to enter and exit rain gardens as designed.

- **Dealing with sediment:** Removing sediment in rain gardens is an ongoing maintenance activity that can be less of a burden when applying certain design techniques.

- **Controlling the ponding of water:** Using check dams and weirs dictates how much water will be retained in a rain garden. Allowing flexibility in design options is a key consideration in areas with variable soil conditions.

- **Long-term maintenance:** Frequent maintenance of rain gardens is critical for their long-term acceptance and health.

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Figure C-1. Careful design allows water to move through pedestrian walkways.

Pedestrian Circulation

On-Street Parking and Pedestrian Circulation

Pedestrian circulation is a priority in dense urban areas, and access, such as bridges or walkways between the street and sidewalk, is critical. In busy commercial downtowns or town centers, on-street parking might appear to be an obstacle to green streets. However, rain gardens can be integrated into commercial rights-of-way without losing on-street parking, provided the right-of-way is wide enough. When on-street parking is next to planters or swales in the furnishing zone, it is critical to consider where people will walk when they get out of their cars. Likewise, when people get out of their cars, they need to have a place to step that does not interfere with the stormwater facility. The green street example illustrated in Figure C-3 accommodates on-street parking and allows efficient flow of pedestrians between the street and sidewalk.

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Figure C-2. A street using stormwater planters. Notice the 3-foot egress zone between the parked cars and the edge of the stormwater planter.

On-Street Parking and Pedestrian Circulation—Swales

Because swales require long linear areas, they are often built between the street and the sidewalk. Swales can be integrated along streets with on-street parking. However, it is important to allow adequate space for pedestrian egress and circulation.

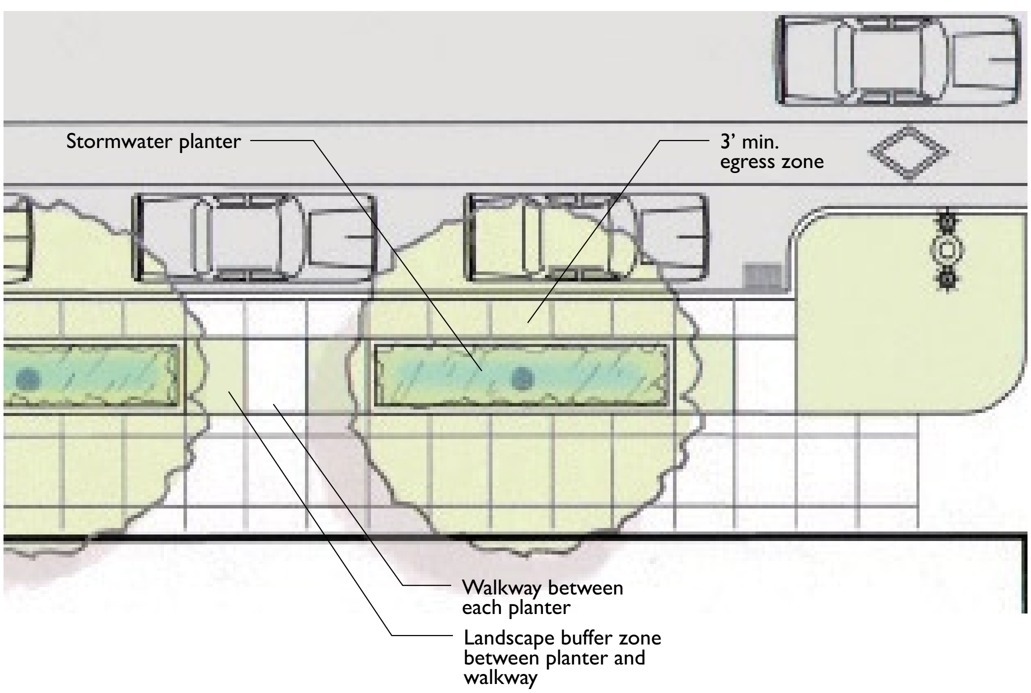

Figure C-3. Pedestrian circulation in street applications—plan view.

On-Street Parking and Pedestrian Circulation—Planters

Planters are a good choice for commercial areas where on-street parking is a priority. They can be designed to fit within the street's furnishing zone, often between existing signs, trees, and driveways. If on-street parking is required, planters can be designed to include a narrow paved strip next to the curb to allow passengers a place to step out of their cars.

On-Street Parking and Pedestrian Circulation—Curb Extensions

One disadvantage of curb extensions is that they usually take the place of one or more parking spaces. Planners can carefully consider this against curb extensions' other benefits that are desirable in dense areas, such as traffic calming and creating shorter crossing distances for pedestrians. Curb extensions can be designed to be smaller and more efficient by designing them as planters (with vertical walls). They may also be used in combination with planters in the furnishing zone or with pervious paving so they don't need to take up as much parking.

On-Street Parking and Pedestrian Circulation—Infiltration Gardens

Because infiltration gardens are typically built in larger areas off the street edge, they don't usually affect on-street parking. When infiltration garden areas reclaim unused pieces of the right-of-way, the ways that pedestrians may cross or access them is something to consider. Creating a "pocket park" for pedestrians at infiltration gardens—at a bus stop, for example—is a great tool for community outreach and education about stormwater.

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Figure C-4. Pedestrians can access their vehicles by using pathways that lead to the sidewalk zone.

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Figure C-5. Bridges over stormwater facilities allow access and maximize space to manage runoff.

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Figure C-6. A raised curb alerts pedestrians of a grade change in the rain garden.

Figure C-7. Failed circulation in parking lot. Due to poor design, people have trampled this parking lot swale to the point that the landscape cannot thrive.

Figure C-8. Good circulation in parking lot. This parking lot swale allows pedestrians to access their destinations without walking through the swale.

Pedestrian Circulation in Parking Lots

When using rain gardens in parking lots, pedestrian circulation is an important design consideration. Designers should consider where the primary pedestrian destination(s) are in relation to the parking lot. For stormwater management, it is best to align rain gardens perpendicular to the sheet flow of water to maximize the potential for capturing runoff. However, this optimum alignment may conflict with the desired pedestrian flow. If this is the case, bridges or pathways over the rain garden or sidewalks alongside the rain gardens can be provided to give people a safe place to walk while protecting the rain garden.

If convenient, prescribed crossing points are not provided, people will probably cut through the rain gardens. This often results in trampled plants, compacted soil, increased erosion, and an overall unhealthy rain garden.

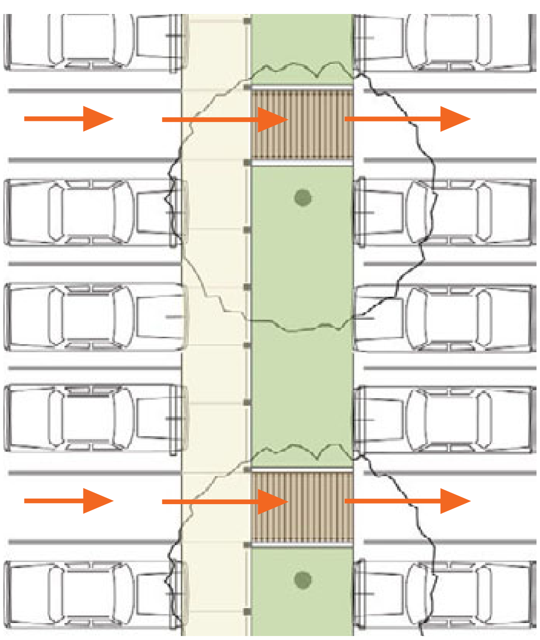

Figure C-9. Pedestrian flow perpendicular to rain garden.

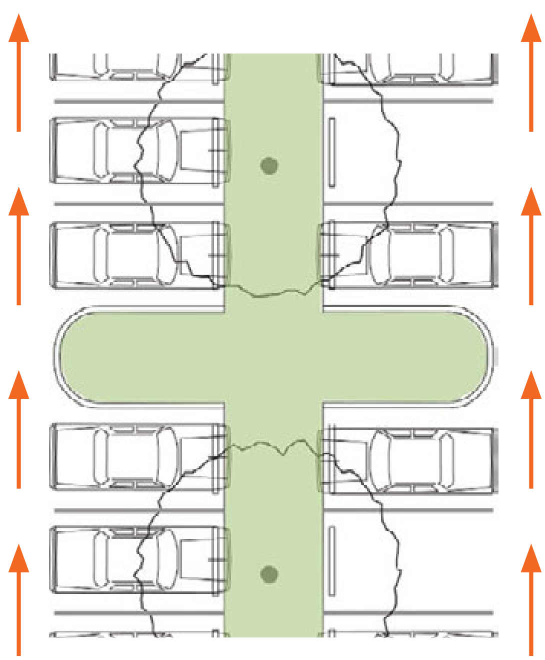

Figure C-10. Pedestrian flow parallel to rain garden.

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Figure C-11. Curbless street allows for sheet flow of stormwater.

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Figure C-12. A typical curb cut allows water to enter a curb extension.

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Figure C-13. Sheet flow of stormwater runoff enters a stormwater swale from a public plaza.

Getting the Water In and Out

The primary consideration for designing stormwater facilities with streets and parking lots is how the water enters a rain garden. Runoff is directed into rain gardens in one of two ways: sheet flow or curb cuts. Sheet flow describes stormwater runoff to a rain garden evenly distributed on the pavement surface without concentrating flow. Curb cuts allow stormwater to enter a rain garden at specific points along a curbed condition, thus concentrating runoff both in velocity and in volume.

Of the two methods, sheet flow is the better design because it mimics the natural flow of water across the landscape, it employs a less complicated design, and it is less prone to failure. The sheet flow of “curbless” streets and parking lots typically involves a concrete band edging that is flush with both the rain garden and the street/parking lot surface. This concrete band creates a clean separation between the more malleable asphalt surface, and it is easier to fine-grade concrete to direct water into the rain garden.

Using curb cuts within a raised curb system is a common way for water to flow into rain gardens, However, this approach channelizes water flow and can be prone to failure if the curb cut is poorly designed and/or there sediment or debris builds up at the curb cut. If curb cuts are used, the design requires careful attention, and they should be spaced as frequently as possible to distribute the water flow evenly.

In new street design, typically the decision to have curbed or uncurbed streets depends on the street’s desired traffic capacity and speed. In general, the higher the traffic speed and the less pedestrian-oriented the street is, the more likely that it will require a raised curbed street edge. Conversely, streets that have slower traffic and are more pedestrian friendly are good candidates for a curbless condition. Even commercial streets with on-street parking can be designed as curbless streets if there is enough right-of-way space and traffic speeds are relatively low.

Curb cuts along rain gardens should be as wide as possible to accept flow from along the street or parking lot edge. A common flaw in curb cut design is to try to "cover" or create a notched curb cut. These designs often fail because the opening for stormwater runoff is too restricted and encourages the trapping of sediment and debris. Sediment in a covered or notched curb cut can often unnoticed. An 18-inch minimum width "open" curb is a good standard to accept stormwater flow. On steeper streets, a small, low-profile asphalt or concrete berm at each curb cut inlet will force stormwater to make the 90-degree turn into the curb cut and into the rain garden. Without such a measure during intense storm events, runoff can easily slip past the curb cut and not enter the stormwater facility. Grated curb cuts are often used in street applications to allow water to flow underneath pedestrian walkways. Grated curb cuts for green streets need special design attention and maintenance to assure water will flow into the stormwater facility. Also, grates need to be slip resistant and compliant with the Americans with Disabilities Act requirements.

Whether a sheet flow or a curb cut is used, there must be a minimum of a 2-inch drop in grade between the street or parking lot grade and the finish grade of the rain garden. This drop in grade assures that water will freely enter the rain garden even if some sediment accumulates.

Curb Cut Examples to Avoid

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Figure C-14. Notched curb cut.

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Figure C-15 Curb cut right next to the overflow.

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Figure C-16. Curb cut that is too small for the amount of runoff entering it.

Street Profile

The street profile determines how a particular street allows stormwater to flow. Streets can be crowned or reverse crowned, drain to one side, or be flat.

The most common street profile is a crowned street with stormwater draining to the sides. The water runs to the sides of the street, often within a concrete gutter along the curb, and enters a storm drain. Storm drains are located at the middle or end of each block depending on the block length.

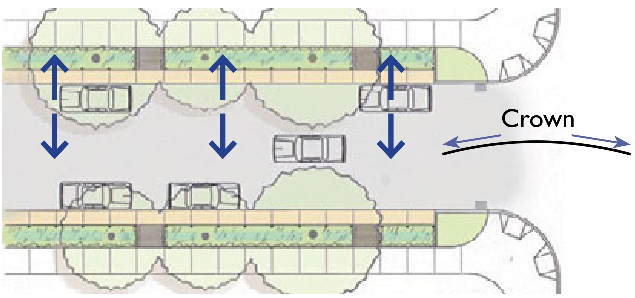

Figure C-17. Crowned street.

A variation of the crowned street is a "double crowned street." This type of street profile is essentially two crowned streets next to each other with a median in the middle. It is common in arterial streets.

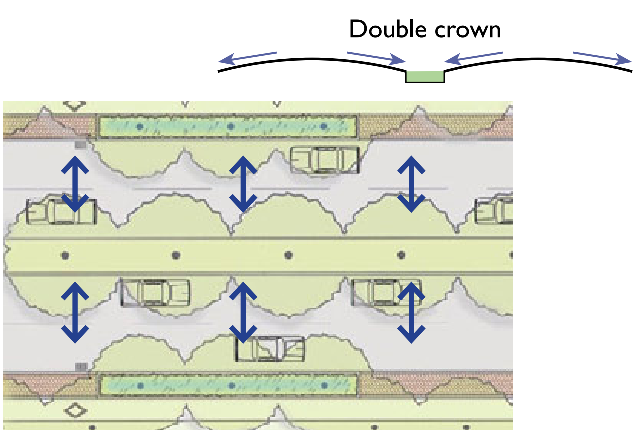

Figure C-18. Double crowned street.

A reverse crowned street directs water to the center line of the street. This type of street is common in alleys.

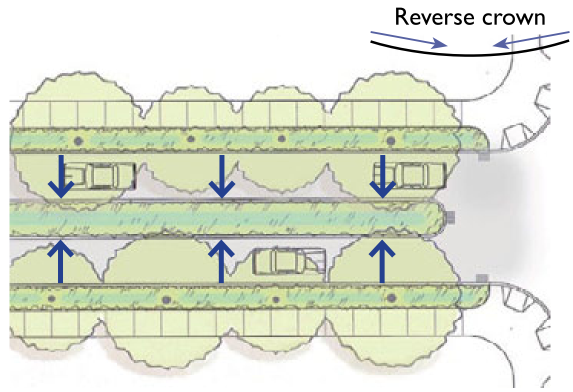

Figure C-19. Reverse crowned street.

Streets can be also be designed to shed all the water to one side.

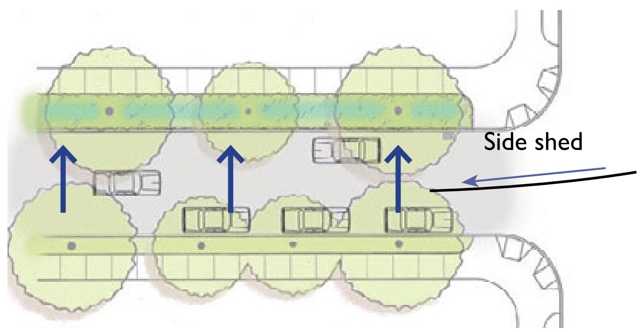

Figure C-20. Shed street (drain to one side).

Flat drainage is referred to in this document in the context of pervious paving. With pervious paving, water drains primarily through the paving surface into the subsoil. Typically these streets are slightly graded so they drain to the sides or center if there is too much water to filter through the paving.

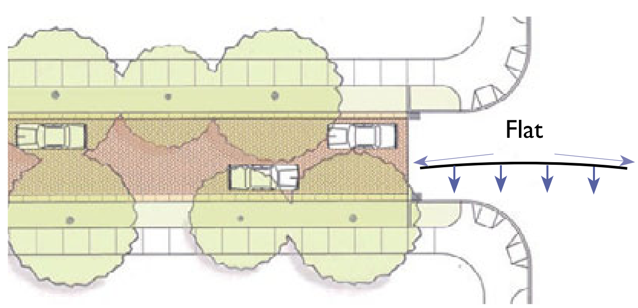

Figure C-21. Flat street.

New Construction:

When building new streets, deciding what kind of street profile a particular street will have is one of the first steps in determining what kind of rain garden to use. Ultimately, a street's design should allow as much stormwater as possible to enter a rain garden, keeping in mind the physical capability for the landscape to effectively manage the stormwater. New construction offers more flexibility because the street profile can be designed in a variety of ways. Retrofit projects do not offer as much flexibility.

Retrofits:

When retrofitting existing streets, one of the first details to look for is where the street drains. It can be prohibitively expensive to rebuild the street profile and underground infrastructure. Hence, the simplest and most cost-effective approach to retrofitting a street to include rain gardens is a design solution that conforms to the existing street profile. This greatly minimizes the amount of street reconstruction.

Figure C-22 illustrates a common street condition: a crowned street with a median at the high point of the crown. Retrofitting this landscape median is a good opportunity for stormwater management; however, the existing profile of the street drains water away from the median to the outside curb of the street. Regrading the street could turn a simple retrofit into an expensive project. In this case, a better option could be to build rain gardens between the street and sidewalk or use stormwater curb extensions. If this example was a new street rather than a retrofit, the center median would be a good place for a swale to collect stormwater.

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Figure C-22. An existing landscaped median on a crowned street can be a difficult retrofit project because water flow is directed away from the middle of the street.


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Figure C-23. Typical sediment forebay.


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Figure C-24. Sediment forebay in a street planter.


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Figure C-25. Sediment forebay in a street infiltration garden.

Dealing With Sediment

When choosing between a curbed system with curb cuts or a curbless system allowing the sheet flow of water into a rain garden, one consideration is the need for a sediment forebay. In sheet flow situations, sediments drop out evenly along the length of the rain garden, which can reduce the need for frequent removal of sediment. When curb cuts are used and the water enters the rain garden in concentrated locations, so too does the sediment load. In most curb cut conditions, a sediment forebay can be used to allow material to collect at one spot and make sediment removal easier.

Sediment forebays help define a space at the entry of a rain garden for sediment and debris to collect and be periodically removed. Providing this space can help reduce maintenance burdens by trapping sediment before it is transported into established landscape areas. The goal of a sediment forebay is to help minimize the amount of sediment, not to completely eliminate it.

A sediment forebay can be sized and designed so that it is seamlessly integrated into the landscape area. It can be as simple as leaving a small, shallow-graded, non-planted area right after the entry curb cut. Because stormwater flows can be fast as the water enters a curb cut, mulching the sediment forebay with pea gravel can minimize erosion. High-density planting on the downstream side of a sediment forebay can act as a containment dam for sediment and debris. The use of sediment forebays depends on how much sediment debris the street typically produces. Some rain gardens may not need a sediment forebay. Others, particularly those on streets that have high traffic loads or substantial leaf drop, would likely benefit from having a sediment forebay and a regular maintenance schedule to clear debris from it.

Controlling the Ponding of Water

Check dams and weirs can be made of any durable material, including rock, concrete, metal, or wood. The best check dam designs and material choices allow for flexibility so that the ponding depth can be easily manipulated. Weirs allow maximum flexibility by having an adjustable system to dictate ponding depth.

Check dams and weirs can be strategically placed in rain gardens to dictate the ponding depth of runoff. The standard is that a check dam or weir be placed in a rain garden facility for every 4 to 6 inches of longitudinal fall. Check dams can also be placed in swales and planters that have little or no longitudinal slope to help slow water flow and/or promote infiltration.

Check dams can retain stormwater to relatively shallow depths, with a maximum ponding depth of 6 to 8 inches of runoff during storm events. On sites that have a particularly high water table, or where soil infiltration potential is relatively low, a good option is to have the stormwater facility retain less runoff, allow water to simply slow down, and allow sediments and pollutants to settle out. Retaining water at shallower depths in poor soil conditions will allow a shorter duration of ponding water and more potential for evapotranspiration.


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Figure C-26. Concrete check dam with an adjustable weir.


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Figure C-27. Stacked concrete check dam.


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Figure C-28. River rock check dam.


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Figure C-29. Log check dam.

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Figure C-30. A curb notch allows overflow to re-enter the street.

Overflow Options

Overflow within stormwater curb extensions can be managed in several ways, depending on what type of stormwater infrastructure is already in place. In retrofit conditions, the most cost-effective and least intensive option is simply allowing water to overflow the landscape area through a curb cut and exit back onto the street to where it can eventually be captured by an existing storm inlet. Another option is to allow overflow runoff to enter a new storm inlet either in the curb extension or immediately adjacent to an exit curb cut.

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Figure C-31. A small-scale overflow stand pipe.

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Figure C-32. A curb cut serves as the only overflow in this infiltration garden.

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Figure C-33. A weir retains stormwater to a 8" depth before overlowing into the storm system.

Long-Term Maintenance

Maintenance plans are specific to each type of stormwater facility and are outside the scope of this report. However, as a starting point, here are some key points to consider in designing rain garden systems.

The first and foremost consideration for assuring long-term success of rain gardens is to determine early on during the design process who will be conducting maintenance activities and how they will be funded. Because rain gardens are designed on both public land (such as streets) and private land (such as parking lots and buildings), confusion can arise as to who is responsible for what. Once the responsible party is identified, that party can determine how much maintenance will be required, keeping in mind not to design a stormwater facility that can't realistically be maintained by the party responsible for it. In some cases, a maintenance agreement might be needed between a public agency and a private entity (e.g., property owners, neighborhood associations, developers, etc.) to assure collaboration on maintenance tasks.

Because most of the rain garden design strategies illustrated in section 5.2 have a strong landscape component, it is important for the maintenance crew to understand how to maintain landscape systems, not pipe systems. Note that the simpler the rain garden design is, the greater ability residents have to maintain the space themselves without considerable effort.

Taking care of rain gardens is similar to taking care of people. During the first years of life, the initial investment is higher to assure that the "infant" rain garden can grow up healthy and achieve a long life. The two predominant maintenance activities that will occur during the first years of the establishment (infancy) period include weeding (by non-chemical means) and summer irrigation as needed. Supplemental maintenance activities during the establishment period could include periodic plant trimming, plant replacement, and mulching. An aggressive and regular maintenance program during the first establishing years gives a rain garden the best opportunity of thriving in the long term. A general rule of thumb is to conduct quarterly maintenance visits for the first two years.

Ongoing maintenance activities for rain gardens, performed both during and after the establishment period, include sediment removal, keeping stormwater entry and exit points clear of debris, and removing litter. The schedule of these activities may vary depending on the type of rain garden and where it is sited. For example, stormwater planters accepting rooftop runoff will typically have much less sedimentation than a stormwater planter managing runoff from a parking lot or street. Hence, street and parking lot stormwater applications will need more frequent maintenance visits to remove sediment from rain garden entry points. The maintenance plan needs to be specific to the type of rain garden involved and the origin of the runoff.

Developing a Maintenance Plan

A maintenance plan should be organized into two sections:

- The functional component describes what is needed to ensure that the site functions correctly for stormwater management and site safety. It discusses keeping the entry and exit points (i.e., curb cuts, downspouts, and overflow points) free of debris to allow stormwater to freely enter and potentially exit the rain gardens. This is particularly important during the spring and fall months when tree debris and street sediments can build up against curb cut openings and overflow points. Check dams and weirs need to be inspected regularly to ensure that they are retaining the correct water depth and that there are no erosion or standing water issues. Check dam and weir heights should be adjusted as necessary to retain as little or as much as the natural hydrologic conditions can handle. There should be no standing water in rain gardens 48 hours after the end of a storm event.

- The landscape component describes what is needed to ensure adequate plant and soil health as well as site aesthetics. The landscape component involves taking care of the plant material so that it will consistently thrive. The best designed rain garden projects will need very little additional landscape attention after the establishment period. However, this goal is often difficult to achieve. A good post-establishment landscape maintenance goal is to have semi-annual visits to weed the rain gardens and possibly trim plants.

Design Tips for Easier Maintenance

There are several ways that a rain garden's design can help ease the maintenance burden:

- To help out-compete weed growth, rain gardens should be planted in high densities and with the largest plantings that the project can afford.
- Use a sediment forebay for parking lots and streets that typically have high sediment loading.
- Plant at least 80 percent of a rain garden with evergreen plants. Evergreen plants tend to need less pruning or trimming than deciduous plants.
- When possible, design the landscape plan with a variety of plant species so that if weeds do appear, they blend into the mixture of textures and colors.

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