Rain Gardens

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A rain garden is a "sunken garden bed" that collects and treats stormwater runoff, primarily from rooftops, driveways, sidewalks, parking lots, and streets. It is a landscaped area in a basin shape designed to capture runoff and settle and filter out sediment and pollutants. Runoff is piped or channeled to the basin, where it is temporarily stored until it infiltrates the soil.

Other names for rain gardens that are often used include *bioretention basins* and *vegetated basins*. Swales with check dams or berms that allow water to back up behind them function like rain gardens, and flow-through planters have been described as "rain gardens in a box." What they all have in common is that they allow water to be retained in an area with plants and soil, and the water is allowed to pass through the plant roots and the soil column.

In general, there are two kinds of rain gardens. Rain gardens that cleanse, detain, and reduce runoff volumes by allowing water to seep into the surrounding soils are called *infiltration* rain gardens. *Filtration* rain gardens cleanse and detain stormwater runoff. Because they are specifically lined to prevent infiltration in unsafe conditions, they don't significantly reduce stormwater volumes.

Candace Stoughton, EMSWCD

An established rain garden in Portland, Oregon.

Infiltration Rain Gardens

Infiltration rain gardens allow runoff to pass through the top mulch and the middle amended soil layers of the rain garden, but they control runoff volumes from the site by infiltrating runoff into the native soils. This automatically detains stormwater because it's taking an entirely different route through the soil instead of in a pipe to arrive at waterways, therefore, a layer of washed drain rock similar to designs used in the filtration rain garden (see filtration description below) is needed only if the rain garden can't be sized to accommodate the required runoff volumes. An underdrain pipe is probably not needed at all, but it may be used to ensure that the facility has drained in time to manage the next storm and that standing water does not impact the vegetation. In this case, an underdrain pipe could be used to convey runoff volumes exceeding the facility, but care should be exercised during design to avoid triggering additional state permit requirements (see UIC Regulations section below).

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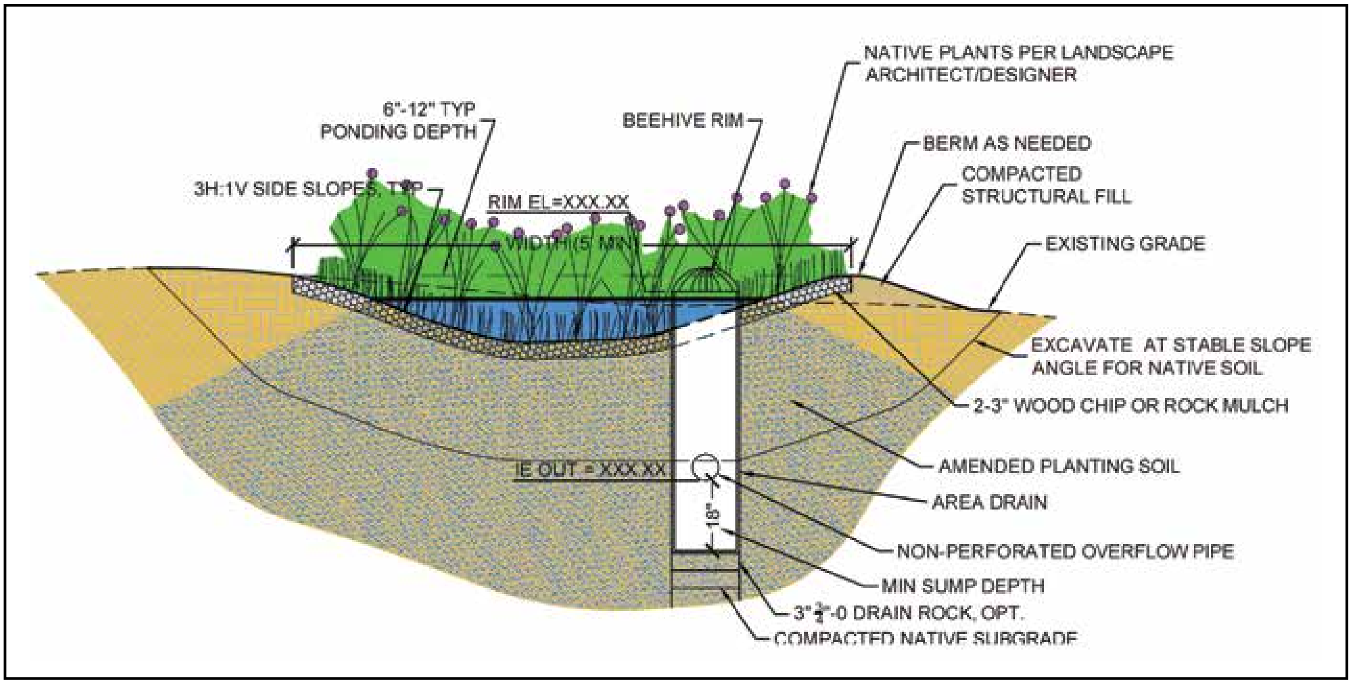


Cross-section detail of an infiltration rain garden with planting soil. (See this and other details provided.)

Filtration Rain Gardens

These rain gardens also allow runoff to pass through the top mulch and the middle, amended soil layers of the rain garden before being collected in a pipe and routed to an approved disposal point. They are used in situations in which infiltration to the underlying soil layers is unsafe. That's why we gave them the infiltration garden with an underdrain. Typically, a 12-inch layer of ¾-inch, washed drain rock is used in combination with a perforated, 4-inch HDPE (high density polyethylene) pipe, to allow for detention and conveyance of the water (Gresham 2007). Sometimes the depth of rock is increased to further detain the desired storm event.

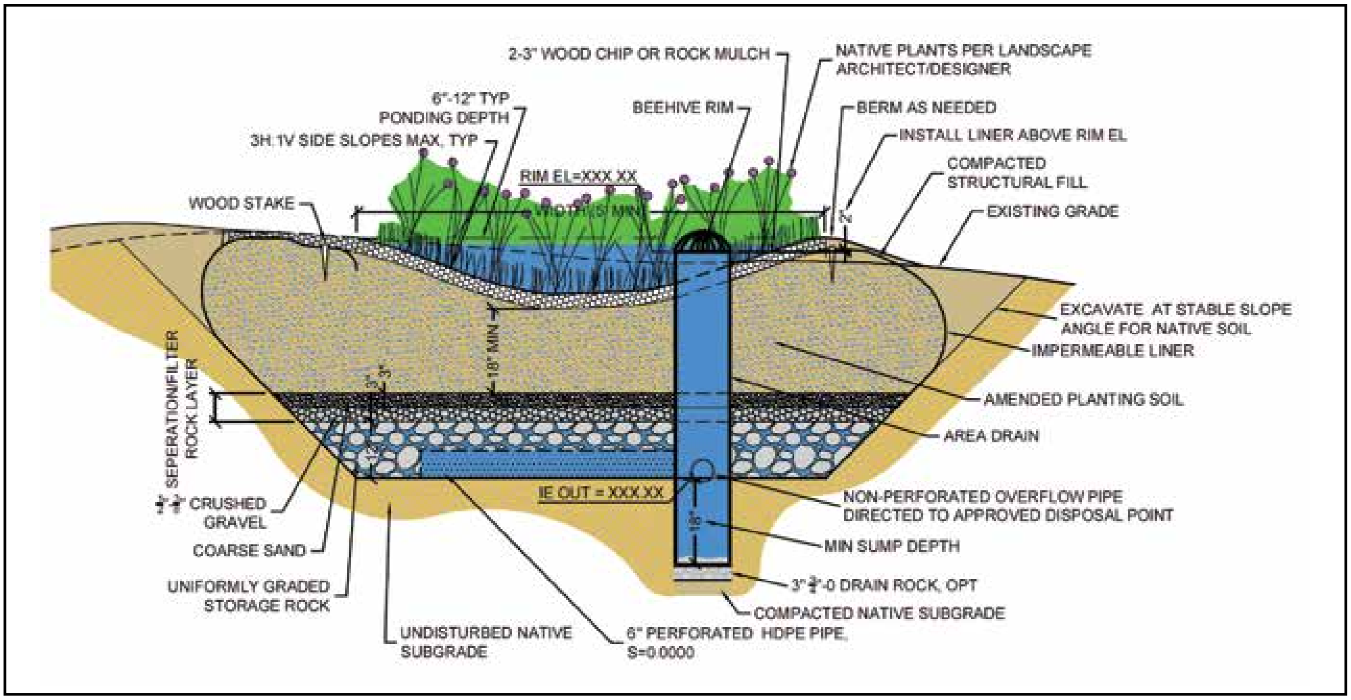
The City of Portland recommends a layer of ¾- to ¼-inch washed, crushed rock between the soil medium and gravel layer, to prevent the soil from mixing with the drain rock (PSMM 2008). The University of New Hampshire has a rain garden that has been successful with a pea-gravel layer on top of a coarse sand layer.[1] Some jurisdictions require the use of a geotextile filter fabric instead of rocks, but otherwise we recommend using washed, crushed rock layers instead, because "fines" (fine rocks) in the soil are easily transported in regularly inundated waters and often clog the geotextile, thereby precluding stormwater storage in the gravel layer below and will inhibit proper flow out of the facility, causing the plants to have constant "wet feet."

In situations where water should not be allowed to infiltrate the underlying soils due to nearby structures (adjacent impervious pavement, site and building walls, etc.), property lines, steep slopes (high erosion potential), high water tables, or possible groundwater contamination, it's best to use an impermeable liner along the bottom of the facility to prevent infiltration to soils beneath the garden. These liners are typically 60-mil PVC (Gresham 2007), but bentonite clay mats can be just as effective.

Design

Rain gardens are typically designed to capture and treat the stormwater runoff from surfaces draining to the garden during 80 to 90% of annual storm events, on average. In Oregon, this is usually a 1-inch, 24-hour design storm. In some cases, cities may require rain gardens to infiltrate larger storm events, especially where local soils drain well. *Check with your local planning department for specific design requirements for your area.*

1 http://www.unh.edu/erg/cstev/fact_sheets/bio_ii_fact_sheet_08.pdf



Maria Cahill

Cross-section detail of a filtration rain garden. (See this and other details provided.)

SIZING

Rain gardens are designed to drain within 24 to 36 hours and to overflow only during larger storm events. This ensures that they won't be haven for mosquitoes and will be available for the next round of rainfall. In situations where the surfaces are impervious and essentially all rainfall becomes runoff (for example, rooftops, driveways, and sidewalks and areas of fill—even if landscaped), the footprint of the rain garden typically ranges from 6 to 15% of the impervious surfaces draining to it. This guideline was created by jurisdictions with dense, urban areas for places where there is very little landscape area; however, areas of fill, even when they're landscaped, can generate significant amounts of rainfall. If you have any doubts about flooding, consult a civil engineer or landscape architect.

To properly size a rain garden, you must account for the amount of runoff routed to the garden, the depth allowed for the water to pond before overflowing the garden (ponding depth), the side slopes of the garden, and the rate at which the water infiltrates into the native soils (infiltration rate). (See LID Infiltration Facility Calculator.)

The amount of runoff routed to the rain garden depends on local rainfall patterns, area of surfaces draining to the garden, and how much of the water runs off these surfaces. Impervious surfaces will generate the most runoff, simple landscapes like lawn will generate a moderate amount of runoff and complex garden areas with trees and shrubs and mulch will generate the least, if any, runoff. The ponding depth of the rain garden ranges between 6 and 12 inches, and the side slopes should be gently sloping (3 feet horizontal to 1 foot vertical). Side slopes that exceed this recommendation require mechanical compaction, which will ruin the infiltration capacity of the amended soil in this area and also make it much more difficult to establish plantings.

SOILS AND MEDIUM

Rain gardens often have mulch on top and amended planting soils in the middle. Infiltration rain gardens also use the native uncompacted soils at the bottom.

Since a rain garden is routinely inundated, soil can easily erode. Many rain garden details call for 2 inches of bark mulch to cover the facility, but this has been observed to float and leave soil bare—even during small storms that simply redistribute the mulch around the garden, not to mention the large storms that carry it right out through the overflow structure. As with any organic mate-

City of Gresham

A rain garden in Gresham, Oregon, fills with rain. Note the use of rocks at the outflow point near the top.

rial, as mulch breaks down it could decrease the amount of available oxygen in the downstream water body. In non-stormwater landscape areas, bark mulch is used to control soil temperature for seed germination, to control weeds, and to feed the plants. Instead of bark mulch, we recommend using 2-inch coarse compost or arborist wood chips in the regularly inundated area. Above the regularly inundated area, you might continue with coarse compost or switch to fine compost.

In western Oregon, this compost will form a mat of mycelium (mushroom roots) that will hold it together and keep it from floating. In facilities with high flows, consider using 2 inches of rock mulch and feeding the plants with compost tea (often supplied by the same companies that supply bark mulch) if needed. Densely vegetating the bottoms of the facilities without using any mulch is also an effective way to control erosion.

Rain gardens should have amended planting soil or amended native soils with infiltration rates that are not too low, so that at least small storms pass through the soil column for treatment, but not so high that stormwater lacks "retention time" in the soil. The ideal infiltration rate is between ½ inch/hour and 12 inches/hour.[1] The top 18 inches of soil is typically amended with organic compost and soil mixtures to create a sandy loam soil. In some cases, the existing topsoil is replaced with a soil mix, as specified by the local jurisdiction. In addition to infiltration rates, other key considerations for robust plant establishment and stormwater treatment by plants and soil include soil pH between 5.5 and 7.5,[2] cation exchange capacity of >5 millequivalents/100grams, and the resulting soil mix should be 60% sandy loam and 40% compost. Be sure that imported soil and compost is free of weed seeds.

Native soils should always be tested in the proposed rain garden location to determine the infiltration rate of the native undisturbed soils below the amended topsoil. The infiltration rate should be at least ½ inch per hour when using an infiltration facility; some jurisdictions require higher rates. Because stormwater has already passed through the middle, amended soil layer and received treatment, there is no recommended maximum infiltration rate for the native soils. If infiltration rates are so low that the plants will have wet feet for too long, you may consider building a filtration rain garden, either lined or unlined, because the underdrain pipe will allow the water to leave the bottom of the facility. As noted above and discussed in the Permitting section below, care should be exercised to avoid triggering additional requirements when using underdrains in an infiltration rain garden.

VEGETATION

The interaction of soil, plants, and the beneficial microbes that concentrate on plant roots is what ultimately provides the filtration benefit of rain gardens; the more plants, the more treatment. While you may see a number of examples of rain gardens with a dry creek-bed look and plants around the edges, this approach doesn't provide adequate treatment for the small, frequent storms with ponding depths that may never reach the plants on the side slopes.

1 http://www.psparchives.com/publications/our_work/stormwater/BSMResults-Guidelines%20Final.pdf
2 Low Impact Development Center specifications: http://www.lowimpactdevelopment.org/epa03/biospec_left.htm

USDA Plants Database

Indian plum and common camas are two species native to Oregon appropriate for rain gardens.

Chris LaBelle, OSU

This Willamette Valley rain garden is planted with "Autumn Joy" Sedum (Sedum telephium), *slough sedge* (Carex obnupta), *New Zealand sedge* (Carex testacea), *yellow-eyed grass* (Sisyrinchium californicum) *and mallow* (Malva spp.).

A variety of trees, shrubs, grasses, and ground covers are acceptable for rain garden vegetation in both sun and shade conditions. The garden should be densely vegetated for maximum runoff treatment and to control weeds. Local jurisdictions often provide specifications for density, size, and types of vegetation to use. Vegetation should be selected based on its tolerance to flooding and its ability to survive in the local climate conditions with no fertilizers, no herbicides or insecticides, and minimum to no watering after establishment. The rain garden will have zones varying from wetland to upland conditions, and the vegetation should be selected based on these conditions. Rain gardens should be designed to fit into the landscape.

Vegetation such as perennial flowers, ornamental grasses, and shrubs can add significant appeal to the facility. Rain gardens can also be designed to attract beneficial insects and wildlife. Contact your local OSU Extension Service office or planning department for a list of plants appropriate for your area. Because downstream seed dispersal during flooding is well documented in natural wetlands, it's important to avoid noxious weeds (aka invasive plant species). A list of noxious weeds is available on the Oregon Department of Agriculture's Web site at http://www.oregon.gov/ODA/PLANT/WEEDS/.

In most cases, native plants are preferred not just because non-native seeds and rhizomes can greatly impact the habitat potential of our natural drainageways, but also because native plants will provide more food for native insects and birds. Even though native insects and birds may find non-native plants appealing, non-native plants don't provide as much nutrition. Finally, native plants support native microbes and other native soil life, while non-natives have been found to negatively impact the composition of the soil life.

ROUTING

Runoff at inlets can be erosive, especially when concentrated to enter the swale at a particular place. Many facilities have riprap placed at the entrance of the facility; however, a specific length, width, and depth must be designed based on the diameter of the rock used for the riprap and predicted maximum flow velocity.[1] If designed properly, many solids will settle out as runoff passes over the riprap, protecting the facility somewhat from clogging.

Dense vegetation at the inlet may also be used but may be difficult to clean out. Vegetation shouldn't be so dense that it impedes flow into the facility. There are many ways to

1 FHWA Urban Drainage Design Manual: http://www.fhwa.dot.gov/engineering/hydraulics/pubs/10009/10009.pdf

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Runoff can enter a facility only if regular maintenance for debris removal is conducted.

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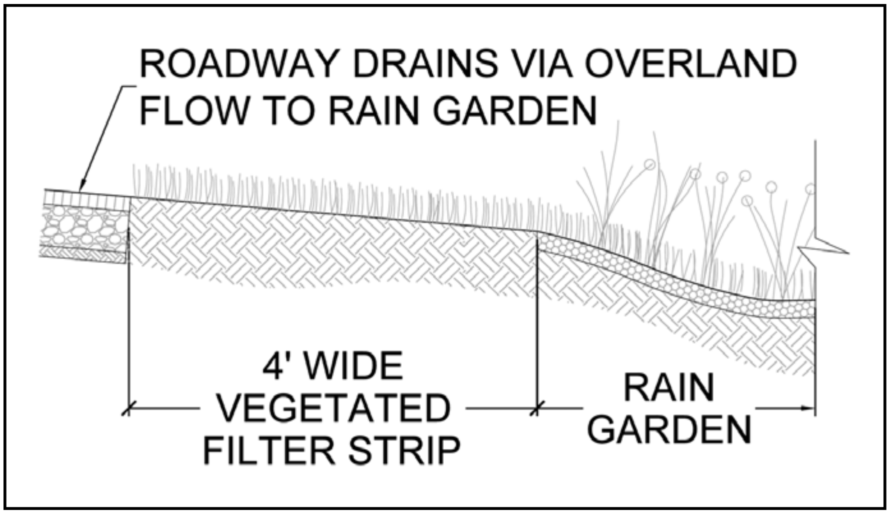


Pretreatment with a vegetated filter strip can extend the life of a rain garden.

create a rough surface to slow flows, including the use of baffles or modified inlets. Smooth concrete channels are not recommended, because they will simply transfer erosive flows from the entrance to the end of the channel.

In cases where the runoff is being collected overland from an impervious surface with substantial sediment loads, the runoff should be pretreated by directing it through a 4-foot-wide strip of turf grass (with less than a 10% slope) or a strip of washed pea gravel or river rock. If runoff if being piped, it can be pretreated by specifying a catch basin with a sump.

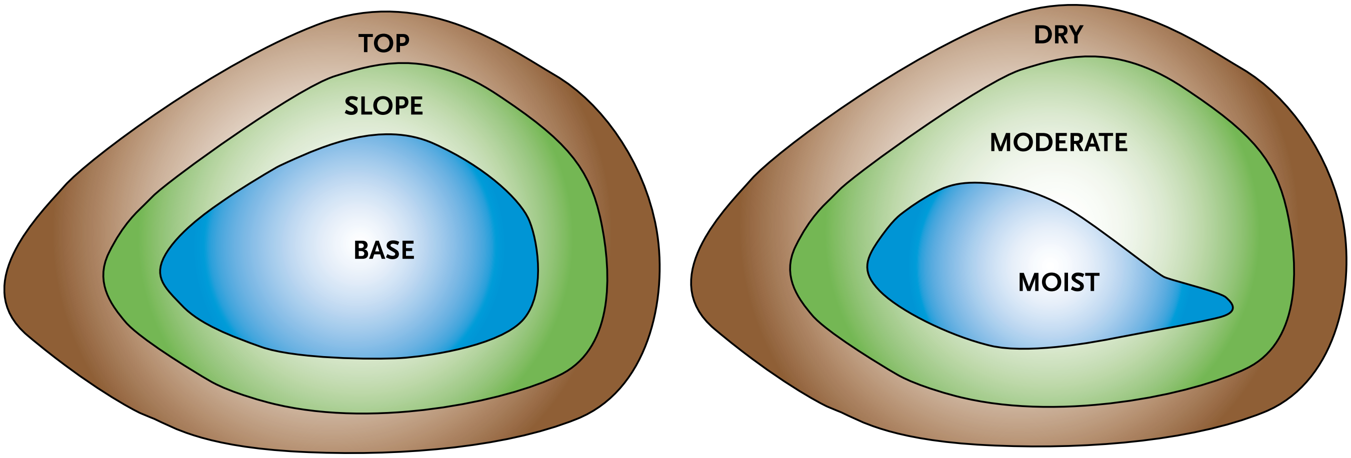
Using a check dam to spread flows and settle out solids at the inlet can greatly simplify sediment removal during maintenance. This maintains the integrity of the garden itself as well as the storage volume (Barr 2001, PSMM 2008) and reduces maintenance.

You should use a facility overflow as a backup, in case the facility becomes clogged or does not infiltrate the entire storm event. This can be done with a berm or an overflow pipe or catch basin. Build a berm to establish a minimum of 2 inches of freeboard above the ponding depth (6 to 12 inches) controlled by the outlet (Barr 2001, PSMM 2008). The outlet may be a rock-lined channel if a safe escape route exists that maintains public safety and prevents property damage. Alternatively, pipes can be set at an elevation for maximum ponding depth, and then convey runoff to an approved disposal point. An underdrain is used in filtration facilities to route water to an approved disposal point, and could be used in conjunction with the overflow pipe or catch basin or by itself. In all cases, it's important to think through every storm event that the rain garden will experience and make sure the design includes redundant, safe overflows, should one or more outlet routes plug or become ineffective over time.

Robert Emanuel, Oregon Sea Grant

An outflow notch in a Portland, Oregon, rain garden, protected by rock to prevent soil erosion.

Contact your local planning department for approved disposal methods and locations for routing overflow (for example, drainage ditches, nearby streams, and existing stormdrain systems). A disposal point that injects runoff into the ground will trigger state underground injection control (UIC) requirements. To avoid permit costs, designers should strive to route runoff from the rain garden to a public stormwater conveyance system or surface water. If this is not feasible, see the Permits section below for more information on UIC requirements. Piping is typically cast-iron, ABS SCH40, or PVC SCH40, between 3 and 4 inches in diameter for gardens draining up to 3,500 square feet of impervious area. Sometimes public facilities require larger diameter pipes. Piping installation must follow the current Oregon Uniform Plumbing Code. Contact your local planning department regarding permits and specifications.



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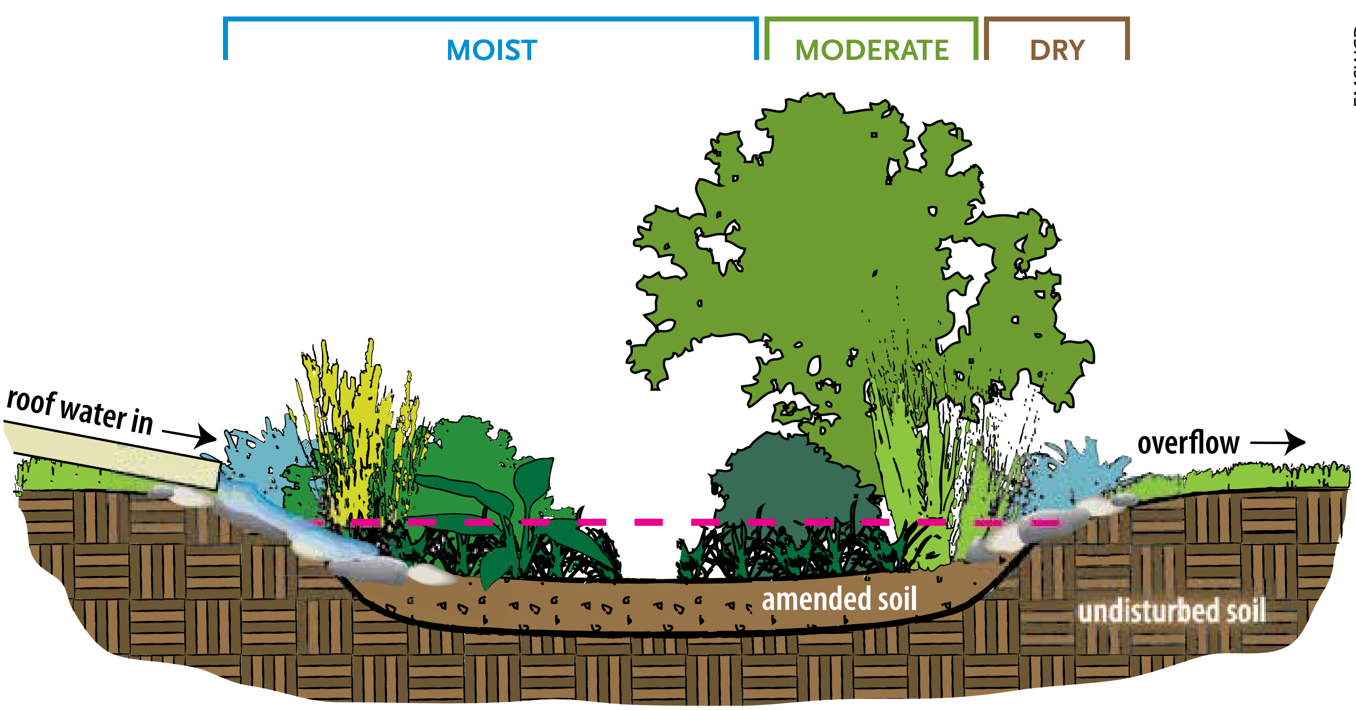
Planting zones reflect the areas where the garden will have the most and least water when flooded, as well as during the dry season. The graphic on the left illustrates the topographic zones of the rain garden, the graphic on the right illustrates zones of high and low soil moisture during the dry season.

SETBACKS

There are typically no setbacks for lined filtration rain gardens. Setbacks for infiltration rain gardens vary by jurisdiction. The City of Portland (PSMM 2008) requires infiltration rain gardens to be set back at least 10 feet from building foundations and 5 feet from property lines. Along with this is a minimum landscape requirement in their zoning codes that bans building walls within 5 feet of the property line, thereby ensuring the 10 feet of building setback. They should also be set back a minimum of 100 feet from down-gradient slopes of 10%. Add 5 feet of setback for each additional% up to 30%, and avoid installing an infiltration rain garden where the down-gradient slope exceeds 30%.

PHYSICAL SETTING

Runoff from all types of impervious surfaces is acceptable for rain garden



EMSWCD

Planting zones in this cross section illustrate where soil will be moist during the wet season.

Judy Scott, Oregon State University

A "dry" stream bed conveys water across a surface before it enters a rain garden.

management, as well as pervious surfaces such as lawns (Gresham 2007, Barr 2001). Potential areas for rain gardens include front and back yards, parking lots, and beneath roof downspouts (Barr 2001). Both infiltration and filtration facilities have been used successfully on private property, public property, and within the public right-of-way. Rain gardens may be built in both new and existing developments. Although generally designed for smaller areas, rain gardens can be constructed to help manage the appropriate volume of runoff (see the "Design" section for sizing criteria). Some siting criteria for soils have been mentioned already; additional criteria follow.

Infiltration rain gardens can be used where

- the seasonal high groundwater table is lower than 36 inches from the bottom of the rain garden
- the bedrock is lower than 24 inches from the bottom of the rain garden

Filtration rain gardens should be used instead of infiltration rain gardens

- where the seasonal high groundwater table is higher than 36 inches from the bottom of the rain garden
- where the bedrock is higher than 24 inches from the bottom of the rain garden
- in potential stormwater hotspots (vehicle fueling areas, industrial loading, unloading, and material storage areas)
- in contaminated soils or groundwater
- on slopes exceeding 10% or in landslide areas
- where adequate setbacks discussed previously cannot be met

Pollutant Removal

Rain gardens are very effective at reducing stormwater flow rates and volumes that negatively affect stream health through bioretention, which can include a number of processes that depend on healthy soil and plants. Rain gardens filter and settle sediment and pollutants, and they remove pollutants through nutrient cycling or by sequestering pollutants in the soil or in the plants themselves. It is common for larger jurisdictions to create design recommendations to remove 70% of the total suspended solids from 80 to 90% of the average annual runoff (see "Design" section), to meet National Pollutant Discharge Elimination System (NPDES) permit requirements from the Oregon Department of Environmental Quality. Based on published research, the Center for Watershed Protection estimated the event mean concentration[1] phosphorus removal rate to be 25 to 50%; nitrogen removal rate was estimated at 40 to 60% (CWP 2008).

1 The Center for Watershed Protection published event mean concentrations for "Bioretention," which is an equivalent term for rain gardens.

Construction

Like all stormwater management facilities, care must be taken to properly construct a rain garden.

INFILTRATION GARDENS

If the facility will be for infiltration, the proposed rain garden location should be fenced off to prevent vehicular and foot traffic that will compact soils and reduce the infiltration rate of the native soils. Construction techniques such as using track equipment or excavating from the sides of the infiltration area should be employed to protect the soils during excavation. If the soils are exposed to rain, fine soil particles will be picked up and moved around, and may clog the native subgrade soils. Rake the surface to loosen soil before proceeding. Raking will also be needed if the rain garden is dug by hand, because foot traffic in the facility area is probably unavoidable.

FILTRATION GARDENS

If the facility is a filtration garden, it won't be necessary to protect the native soils in the facility area from compaction If a plastic liner will be used, make sure it's a single, solid piece of plastic big enough to be installed under the entire pond area.

Robert Emanuel, Oregon Sea Grant

Excavator is located outside of the rain garden in order to make sure the machine does not compact soil in the rain garden.

Robert Emanuel, Oregon Sea Grant

Grading is made simpler by using four stakes, one at the inflow point and three at the opposite or lower end of the rain garden—including, most importantly, the outflow point.

Overlapping plastic sheets will not adequately prevent infiltration. If you choose to line the facility with a bentonite clay mat, installation is relatively simple. If you choose bentonite powder, the most challenging part will be mixing the bentonite clay with water and placing it so that it creates an impermeable seal. In all cases, of course, follow the manufacturer's recommendations for installation, and make sure the liner is installed high enough in the facility to protect infrastructure for all storm intensities and volumes that the facility make experience.

The underdrain pipe will be a perforated pipe that won't require compaction. Just lay it down on top of the liner and place the rock storage layer over it.

ALL GARDENS

Regardless of the type of facility, it's likely that some special planting soil recipe will be specified. Mixing of the compost, soil, and aggregate mix is best done in a mechanical mixer, but any way that will create a uniform mixture is acceptable. If the pH isn't quite right, it may be reduced by adding iron sulfate and sulfur or increased by adding lime or recycled, ground, gypsum board. Other specifications for metals and nutrients may also need to be met; lab testing might be needed to prove that the planting soil itself will not be a source of pollutants.

Place the soil in 6- to 12-inch lifts, and lightly compact with water by saturating the entire area after each lift is placed.[1] The final proposed elevations must be met after this compaction—not before—or there will be too little soil and a deeper garden than planned for. After placing the soil, fence the entire rain garden area to protect from traffic.

Ideally, plants will be allowed to start their establishment for 3 months before allowing runoff to flow into the facility. This will help hold the soil, especially if the bottom of the facility has been hydroseeded.

1 Low Impact Development Center specifications: http://www.lowimpactdevelopment.org/epa03/biospec_left.htm

City of Gresham

A newly established rain garden in Gresham, Oregon.

Maintenance

Maintenance requirements are typical of vegetated areas, but additional structures such as catch basins will require additional care. If properly maintained, a facility can last indefinitely (Barr 2001). Watering and weeding may be needed frequently within the first 1 to 3 years during Oregon's very dry summers, but this will taper off dramatically if you choose plants that require little to no watering after establishment. Remember, the more you water, the more weeds you can expect. It's important to inspect the facility after major storm events and tend to them as needed. Because these systems are not very effective at treating soluble pollutants such as nitrogen and phosphorous, integrated pest managementn of the entire site is recommended. At a minimum, do not use pesticides, herbicides, or fungicides in the faciity itself.

- Remove sediment and debris. This may require removal and replacement of mulch if the facility design doesn't include pretreatment.
- Clean and repair inlets and outlets, embankments, and berm dams.
- Control erosion.
- Ensure proper drainage.
- Replace plants.
- Remove weeds by hand.

Permits

Consult your local planning and building department. Ask about applicable permits, plumbing codes, and piping requirements. Find out if there are any maps, as-built drawings, or site-specific constraints. In many cases, if building a planter on a nonresidential site, a commercial building permit is required. A clearing, grading, and erosion control permit may also be required if ground disturbance is large enough.

UIC REGULATIONS

A Class V Underground Injection Control (UIC) is a system designed "for the subsurface placement of fluids" and is regulated through the Oregon Department of

Candace Stoughton, EMSWCD

Rain garden at Astor Elementary School in Portland, Oregon.

Environmental Quality's UIC program. This program protects groundwater resources from injection of pollutants directly underground and depending on the potential of various pollutants to be on-site, may be rule-authorized or require a more formal permitting process. According to the U.S. Environmental Protection Agency, a Class V UIC well is by definition any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension. Given this, the guidelines in the paragraph below are for designers who are considering a rain garden to treat runoff before discharging it to surface water. These guidelines will help the designer avoid triggering UIC requirements in the design of a rain garden. If the rain garden is being used to pretreat runoff before discharging it to a UIC such as a drywell or soakage trench, the designer should contact DEQ's UIC Program during the early planning stages for information about the UIC approval process and how to expedite this process.

An infiltration rain garden designed and installed per the details shown is not considered a UIC; however, changing the detail could trigger UIC permitting requirements. When sizing an infiltration rain garden, one must avoid designing a facility that is deeper than the widest surface dimension. In addition, an infiltration rain garden that is designed without an underdrain, or with an underdrain perforated on the top and sides but not the bottom and which routes runoff to a stormwater conveyance system discharging to surface water, is not considered a UIC.

A filtration rain garden is not considered a UIC because, by design, it does not infiltrate runoff. For more information on LID and UICs, see the DEQ"s fact sheet, "Underground Injection Control Storm Water Information," at http://www.deq.state.or.us/wq/pubs/factsheets/uic/uicstormwater.pdf.

Cost

Rain gardens are cost-effective when compared to conventional stormwater management for flow rate, volume control, and water quality treatment, but they vary with size, site conditions, vegetation, and materials required for drainage and routing.

If the rain garden has no pretreatment, maintenance costs can vary with the choice of long-term erosion control—compost mulch, rock mulch, or dense vegetation—because the mulch option will probably be removed with the sediment and have to be replaced. Rock mulch has a more expensive up-front cost than compost mulch.

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ADDITIONAL RESOURCES

LID Infiltration Calculator (used for sizing vegetated infiltration facilities). Go to http://extension.oregonstate.edu/watershed/rain-gardens and choose the Rain Garden Calculator button.

The Oregon Rain Garden Guide: A Step-by-Step Guide to Landscaping for Clean Water and Healthy Streams. 2010. Available for purchase or free download from Oregon Sea Grant: http://seagrant.oregonstate.edu/sgpubs/index.html

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