Stormwater Planters

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Stormwater planters are structures made of a durable material (such as stone, brick, or concrete[1]) that are designed to capture runoff and settle and filter out sediment and pollutants. Runoff is piped, channeled, or directed by overland flow to the surface of the planter, where it is temporarily stored and then infiltrated or conveyed to another approved disposal point. In general, there are two kinds of planters: infiltration and filtration (aka flow-through).

Infiltration planters reduce runoff volumes by allowing water to seep into the surrounding soils. By contrast, filtration planters only cleanse stormwater runoff; they do not allow infiltration. In fact, they are lined specifically to prevent infiltration in unsafe conditions. Infiltration and filtration planters have been described as "rain gardens in a box," but they differ slightly in their location, piping requirements, and some design features. Stormwater planters can be modified to fit almost any physical setting, and are therefore optimal alternatives for sites with conditions that restrict the use of other best management practices (BMPs). Because of their flexible location requirements and range of designs, planters can add aesthetic appeal to a landscape, and can also attract wildlife (LCREP 2006). Planters can also fulfill certain landscaping requirements on a site.

Bureau of Environmental Services

Stormwater planter at Epler Hall on the Portland State University campus.

Filtration Planters

These planters allow runoff to pass through the top mulch and the middle amended soil layers before being collected in a pipe and routed to an approved disposal point. They are used in situations where infiltration to the underlying soil layers is unsafe or where infiltration rates of the native soils and the area available for the planter are so limited that the facility won't drain quickly enough to ensure the survival of the plants. 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

1 Treated wood is not recommended as it may leak chemicals into the stormwater.

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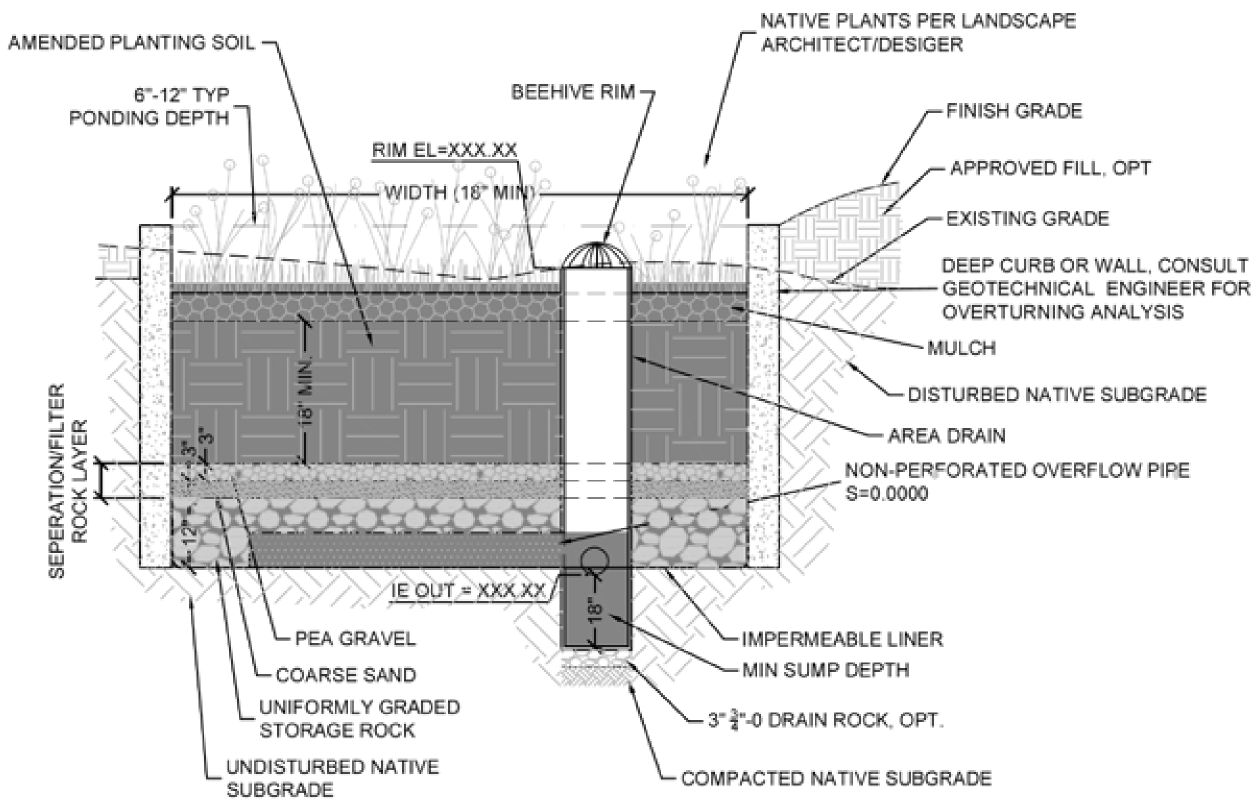

Filtration (aka flow-through) planter.

conveyance of the water (Gresham 2007). However, recent preliminary studies indicate a detention time of only 13 minutes and a reduction in volume of only 20% for ½-inch, 24-hour storms in our rainy season's early storms only, when soils aren't saturated.[2]

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 (BES 2008). The University of New Hampshire has a rain garden installed with a pea-gravel layer on top of a coarse sand layer that has been successful (UNHSC n.d.). Some jurisdictions require the use of a geotexile filter fabric instead of rocks, but otherwise we recommend using washed, crushed rock because "fines" (fine rocks) in the soil are easily transported in regularly inundated waters and will often clog the geotextile, thereby precluding stormwater storage in the gravel layer below.

In situations where water should not be allowed to infiltrate the underlying soils, use an impermeable liner along the bottom of the facility to prevent infiltration to soils beneath the planter. Conditions where use of the liner is appropriate include presence of nearby structures (such as adjacent impervious pavement, or site and building walls), property lines, steep slopes with high erosion potential, high water tables, or possible groundwater contamination. These liners are typically 60-mil PVC (DES and CEDD 2007), but 30-mil polyethylene pond liners and bentonite clay mats can be just as effective. As noted in the Underground Injection Control (UIC) Regulations section below, filtration planters by their design do not trigger UIC requirements.

Infiltration Planters

Like filtration planters, infiltration planters allow runoff to pass through the top mulch and the middle amended soil layers of the planter, but they also control runoff volumes from the site by infiltrating runoff into the native soils. This system

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2 Research by Alan Yeakley and Kate Norton, "Assessment of rainwater detention structures for an urban development in Wilsonville, Oregon," presented at the Urban Ecology and Conservation Symposium, January 25, 2010.

automatically detains stormwater because it takes an entirely different route—through the soil instead of through a pipe—to arrive at our waterways. Therefore, the 12-inch layer of washed drain rock in the infiltration planter is needed only if the facility can't be sized to accommodate the required runoff volumes. An underdrain pipe is probably not needed, but may be used at the designer's discretion. When using an underdrain pipe in infiltration facilities, we recommend raising the bottom invert elevation so that water can be stored in the soil (and/or optional gravel) for infiltration, since placing the pipe at the bottom of the facility will create the path of least resistance and not much infiltration will occur. *Refer to the UIC Permitting section below for recommendations on designing an infiltration planter to avoid triggering state UIC requirements.*

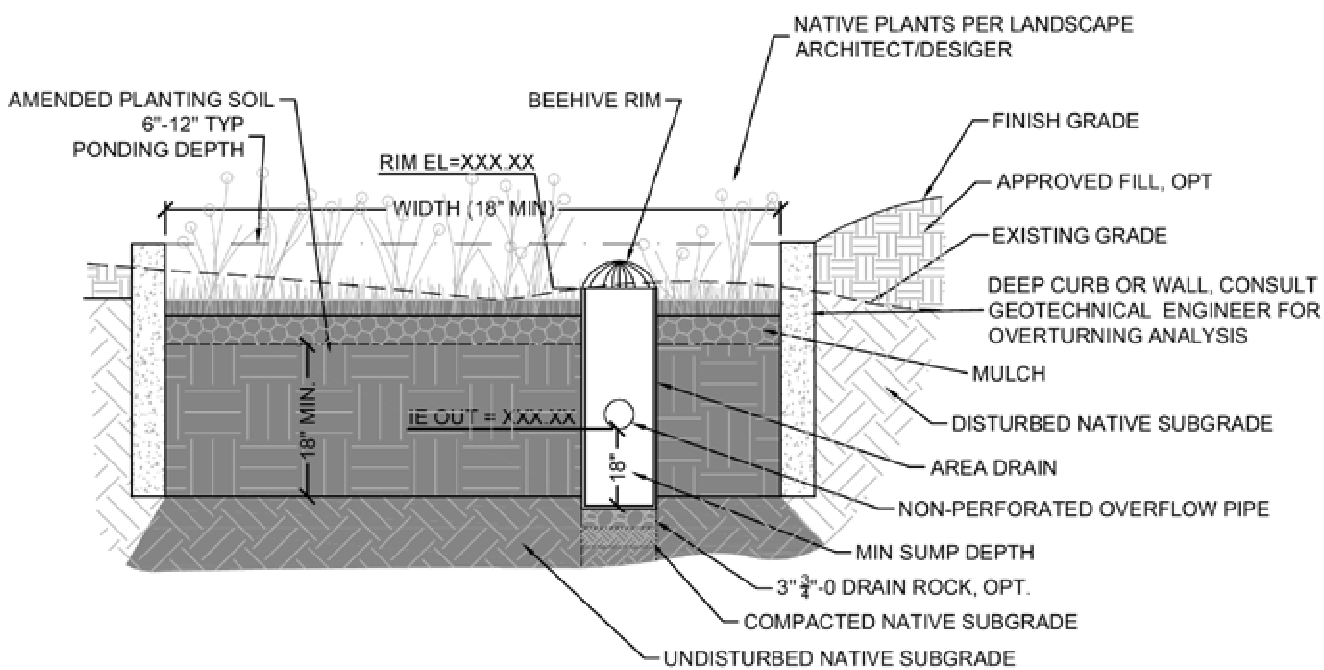
Design

Planters are typically designed to capture and treat the stormwater runoff from surfaces draining to them 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 planters to infiltrate larger storm events, especially where local soils drain well. Check with your local planning department for specific design requirements for your area.

SIZING

Planters are designed to drain through the soil within 24 to 36 hours and to bypass the soil only during larger storm events. This ensures that they won't become a haven for mosquitoes and will be available for the next round of rainfall. In situations where 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 planter typically ranges from 4% to 15% of the impervious surfaces draining to it. The footprint of infiltration planters may be increased beyond 15% if soils are poorly draining. To avoid triggering additional permitting when sizing these facilities, make sure that the opening width is equal to or wider than the depth of the planter. *See UIC Regulations discussion below.*

Filtration planters can be smaller than infiltration planters because their chief purpose is cleansing runoff from small, frequent water-quality storms instead of infiltrating large quantities of runoff. The suggested minimum width for both types of planters, however, is 18 inches, measured within the walls (BES 2008). This guideline was cre-



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Infiltration planter during a water-quality storm.

ated by jurisdictions incorporating dense, urban areas for places where there is very little landscape area. If you have any doubts about an area's potential for flooding, consult a civil engineer or landscape architect.

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

The amount of runoff routed to the planter depends on local rainfall patterns, the area of surfaces draining to the planter, and the volume of water that 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, shrubs, and mulch will generate the least, if any, runoff. The ponding depth should range between 9 and 12 inches (DES and CEDD 2007), with about 12 inches between the top of the amended planting soil and the overflow inlet (BES 2008). The slope of the bottom of the facility should not exceed 0.5% (LCREP 2006).

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Filtration planter built into a private residence, Mignonette Estates, Gresham, Oregon.

Because planters have vertical or near-vertical walls, they should be designed in such a way that no two adjacent grades (elevations) differ by more than 30 inches. According to Oregon law, if you exceed this measurement, you must include a handrail or some other barrier adequate for fall protection.

SOILS AND MEDIUM

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

Since a planter is routinely inundated, soil can easily erode. Many planter details call for a 2-inch layer of bark mulch to cover the facility. It has been observed, however, that this material can float and leave soil bare, even during small storms that simply redistribute the mulch around the garden; large storms may carry it right out through the overflow structure. As with any organic material, as mulch breaks down, the amount of available oxygen in the downstream water body can decrease. 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 a 2-inch layer of coarse compost or arborist wood chips in the regularly inundated area. Above the regularly inundated area, either 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 a 2-inch layer of rock mulch and feeding the plants as needed with compost tea, which is often supplied by the same companies that supply bark mulch. Another effective way to control erosion is to plant dense vegetation on the bottoms of the facilities without using any mulch. However, this approach may make weeding more difficult.

Planters should have amended planting soil or amended native soils with infiltration rates that are not too low or too high; rates should be high enough to pass the desired-size storm through the soil but not so high that the stormwater doesn't spend enough time in the soil for treatment (aka "retention time"). The ideal infiltration rate is between ½ inch per hour and 12 inches per hour (PSP 2009). The top 18 inches of soil is typically amended with organic compost and soil mixtures to create a sandy loam soil. In some cases, 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) and cation-exchange capacity (>5 millequivalents/100 grams) (LIDC 2003). The resulting soil mix should be 60% sandy loam and 40% compost. Be sure that imported soil and compost are free of weed seeds.

Native soils should always be tested in the proposed infiltration planter location at the design depth (or as close to that depth as possible) to determine the infiltration rate of the native undisturbed soils below the amended topsoil *(see the publication in this series on Infiltration Testing)*. The minimum infiltration rate is defined by the area available for infiltration: the larger the infiltration area, the lower the soil's infiltration rate can be while still managing the required storm. Most jurisdictions recommend at least ½ inch per hour when using an infiltration facility, and some require higher rates. Since 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, consider building a smaller, unlined filtration planter, because the underdrain pipe will allow the water to leave the bottom of the facility.

STORAGE ROCK

Some facilities sited on soils with lower infiltration rates will require storage rock to store runoff before infiltration or conveyance. This should be a granular subbase material meeting gradation requirements of AASHTO #3 or #4 aggregate (CDOT 703, #3 or #4), which is a specification for uniformly graded gravel (UDFCD 2008). Although this specification calls for "fractured faces," (a specification for crushed rock, which would be needed only if the rock was required for structural stability), rounded rock is acceptable for this application.

VEGETATION

The interaction of soil, plants, and the beneficial microbes that concentrate on plant roots is what ultimately provides the filtration benefit of planters. To make full use of this benefit, a facility designed with more plants will result in greater treatment capacity.

A variety of trees, shrubs, grasses, and ground covers are acceptable for vegetation in both sun and shade conditions. The planter 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 tolerance to flooding and ability to survive in the local climate conditions with no fertilizers, herbicides, or insecticides, and minimum to no watering after establishment.

Planters should be designed to fit into the landscape, and vegetation such as perennial flowers, ornamental grasses, and shrubs can add significant appeal to the facility. Planters 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. Downstream seed dispersal during flooding is well documented in natural wetlands, so take special care to avoid noxious weeds (aka invasive plant species). A list of noxious weeds is available on the Oregon Department of Agriculture's Web site (ODA 2007).

In most cases, native plants are preferred not just because nonnative seeds and rhizomes can greatly impact the habitat potential and hydrology of our natural drainageways, but also because native plants are a better food source for native insects and birds. Even when native insects and birds find nonnative plants appealing, nonnative plants do not provide as much nutrition. Finally, native plants support native microbes and other native soil life, while nonnatives have been found to negatively impact the composition of the soil life.

ROUTING

All facilities should have an overflow bypass for large storms. A freeboard (depth from the maximum flow depth to the top of the facility) of at least 2 inches should be used (BES 2008). Beehive grates or U-shaped overflows make good overflow devices because they are less likely to get clogged than a flat catch-basin grate, but the U-shaped grates are commonly placed at too high an elevation (*see figure at right*). Make sure that if you use this system, the bottom of the pipe, not the top, is set to ensure adequate freeboard of at least 2 inches below the top of the facility.

In filtration planters, the overflow device is connected to a perforated pipe in the gravel bed below. This perforated pipe allows water to drain through and be treated by the soil column and then conveyed away so plants don't become waterlogged. If the facility is lined, the perforated pipe is completely enclosed in the facility and cannot infiltrate to the native soils, so this would not be considered a UIC. Perforated pipes that don't drain to an approved disposal point (such as a surface infiltration facility or a nonperforated pipe) may trigger UIC requirements and are reviewed on a case-by-case basis.

For pipe sizing, download Chapter 11 of the Oregon Plumbing Code at http://www.cbs.state.or.us/bcd/programs/plumbing/2008_opsc/Chapter_11.pdf. Oregon Public facilities in streets require 6- or 8-inch ASTM 3034 SDR 35 PVC pipe. Private facilities require cast-iron ABS SCH40, or PVC SCH40 (BES 2008). Outlet size should be selected to drain the planter over 12 hours or more (UDFCD 2008).

Filtration facilities require perforated pipe beneath the planter (DES and CEDD 2007). Check with local plumbing codes when pipes are used; Portland's Sewer Design manual provides more piping detail (BES 2008). Infiltration planters require an

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Improperly installed U-shaped overflow.

overflow drain 9 to 12 inches high—the height of ponded water (DES and CEDD 2007). The overflow must also drain to an approved disposal point (LCREP 2006).

SETBACKS

There are typically no setbacks for lined filtration planters, and setbacks for infiltration planters vary by jurisdiction. The City of Portland requires infiltration planters to be set back at least 10 feet from building foundations and 5 feet from property lines (BES 2008). Along with this stipulation, a minimum landscape requirement in the zoning code bans building walls within 5 feet of the property line, thereby ensuring the 10 feet of building setback. Infiltration planters should also be set back a minimum of 100 feet from down-gradient slopes exceeding 10%. Add 5 feet of setback for each additional percentage point up to 30%, and avoid installing an infiltration planter where the down-gradient slope exceeds 30%. To ensure proper water-quality treatment, the bottom of the infiltration planter should be situated at least 24 inches from bedrock and 36 inches from the seasonal high groundwater table.

Physical Setting

Stormwater planters are often used in green street applications in the public right-of-way (DES and CEDD 2007). They are also often seen on private sites where space available for stormwater management is limited by steep slopes. The main advantage planters have over rain gardens is that the structure allows more water to be stored, which reduces the footprint of the facility.

Potential areas for planters include front and back residential yards, parking lots, and under roof spouts

(Barr 2001). Planters located on slopes greater than 10% should be designed as lined filtration planters.

Filtration planters with liners can be used anywhere, but an improperly designed infiltration planter has the potential to contaminate groundwater, destabilize slopes, or undermine foundations. Use a filtration planter instead of an infiltration planter

- where the seasonal high groundwater table is closer than 36 inches from the bottom of the facility;
- where bedrock is closer than 24 inches from the bottom of the facility;
- in areas of new fill (rule of thumb: fill < 5 years old);
- in areas with contaminated soils or groundwater;
- within 100 feet of a well;
- in potential stormwater hotspots (vehicle fueling areas, industrial loading, unloading, and material storage areas);
- on slopes exceeding 10% or landslide areas;
- in possible spill areas; or
- where the stormwater facility cannot be placed more than 10 feet from a building or other wall footing.

Pollutant Removal

Runoff from all types of impervious surfaces is acceptable for stormwater planter management (DES and CEDD 2007). Storage of runoff within the planter allows sediments and pollutants to settle out. Vegetation also purifies water through bioretention (removal of pollutants by a media and biological system). As with all infiltration facilities, infiltration planters are effective at reducing stormwater flow rates and volumes, which decreases the amount of runoff and subsequent pollutants leaving the system. Based on published research, the Center for Watershed Protection estimated the event mean concentration[3] phosphorus removal rate to be 25% to 50% and nitrogen removal 40% to 60% (CWP 2008). Runoff reduction was estimated at 40% to 80%. Further pollutant removal information can be found in table SQ-6 in the Urban Drainage and Flood Control District's *Drainage Criteria Manual*, which provides documentation of influent and effluent pollutant concentrations for specific pollutants and BMPs (UDFCD 2008).

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Stormwater planter in the public right-of-way, Portland, Oregon.

Construction

Like all stormwater management facilities, special care must be taken to properly construct an infiltration planter. Since we rely on the native subgrade soils to infiltrate stormwater, planter areas should be marked off-limits to construction traffic and stockpiling activities by using orange protection or chain-link fence. Avoid vehicle traffic within 10 feet of an infiltration planter, except for that needed to construct the facility (BES 2008). Use construction techniques that will protect the soils during excavation, such as track equipment or excavating from the sides of the infiltration area. If the soils are exposed to rain, fine soil particles that may clog the native subgrade soils will be picked up and moved around. Rake the surface to loosen soil before proceeding.

Once the native subgrade has been exposed, install geotextile or a rock filter (*see figure on page 2*) to preserve the voids in the overlying gravel storage rock (SEMCOG 2008).

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Foot traffic during construction can easily compact soils, especially clay, reducing or eliminating infiltration capacity.

If soils have a fast infiltration rate, then neither the base rock nor the geotextile are needed. If geotextile fabrics are required, they should be high quality and resistant to punctures from sharp edges and rocks (UDFCD 2008). Overlap sheets by at least 12 inches and lay them across the intended area. Include an additional 4 feet of coverage beyond the edges of the planter to ensure that sediment and runoff do not enter the bed during construction (SEMCOG 2008). For aesthetic reasons, cut the additional geotextile a few inches below the planting-medium level at the very end of construction.

Next, install the storage rock, if needed. Dust or fine particles not washed away could clog the geotextile (Hicks and Lundy 1998), so rock should be delivered clean from the quarry and also washed on site, by either hosing the rock off in the delivery truck when it arrives or dumping the rock and washing off the pile. With either method, scoop the rock from the surface and monitor it closely for fines. As you work your way down the pile, fines from above might have been washed off only halfway through. Pay careful attention to this step, as the geotextile fabric could become clogged, which would create an unintentional impervious surface at the interface between the geotextile and the rock.

Place the planting medium in 6-inch lifts and compact it lightly with boot tamping or water compaction to avoid settlement after the first storm. Vibratory compaction should never be used, as this will over-compact the soil and negatively impact the many benefits the soil provides.

Next, place the mulch. Allow plants to establish for at least 3 months before allowing stormwater to route to the facility. Given this time, the plant roots will have a better hold on the soil, and erosion from the facility can be decreased.

Maintenance

Maintenance requirements are typical of vegetated areas. If properly maintained, a facility can last indefinitely (Barr 2001). If the facility receives large volumes of silt and clay, clogging is possible. Frequent watering and weeding may be needed in the first 1 to 3 years during Oregon's very dry summers, but this requirement will taper off dramatically if you choose plants that require little to no watering after establishment. It is important to inspect the facility after major storm events and tend to them as needed by

- removing sediment and debris;
- cleaning and repairing inlets and outlets, embankments, and berm dams;
- controlling erosion;
- ensuring proper drainage; and
- replacing plants as necessary.

Permits

Consult your local planning and building department, and ask about the applicable permits, plumbing codes, and piping requirements. Find out if there are any maps, as-built drawings, or site-specific constraints. In many cases, when building a

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5 The Center for Watershed Protection published event mean concentrations for "Bioretention," which is an equivalent term for stormwater planters.

planter on a nonresidential site, a commercial building permit is required, and a clearing, grading, and erosion-control permit may be required if the area of ground disturbance is large enough (LCREP 2006). Permitting requirements may depend on the design of the facility.

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 Environmental Quality's (DEQ) UIC program. This program protects groundwater resources from injection of pollutants directly underground and may be rule-authorized or require a more formal permitting process, depending on the potential of various pollutants to be on-site.

According to the U.S. Environmental Protection Agency, a Class V UIC well is also by definition "any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension" (http://water.epa.gov/type/groundwater/uic/class5/types_stormwater.cfm). Given this definition, the guidelines in the next paragraph are for designers who are considering a stormwater planter to treat runoff before discharging it to surface water. These guidelines will help the designer avoid triggering UIC requirements in the design of a stormwater planter. If a stormwater planter is being considered for pretreating runoff before discharging it to a UIC, 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 planter designed and installed per the details shown in the figure on page 3 is not considered a UIC if the discharge point is to surface water. However, changes to the design that would allow runoff to shortcut infiltration through the top of the facility could turn the facility into a UIC. Also, when sizing an infiltration planter, avoid designing a facility that is deeper than the widest surface dimension. If the area drain is perforated on the top, sides, and bottom with no routing to a stormwater conveyance system that discharges to surface waters, this would be considered a UIC. Alternatively, it would not be a UIC if an area drain or underdrain is used and designed with perforations on the top and sides with a solid bottom, and the excess runoff is routed to stormwater conveyance system that discharges to surface water. Finally, conveying runoff to the surface of an infiltration planter and routing the excess runoff to surface water will help you avoid triggering state UIC requirements.

A filtration planter is not a UIC because, by design, it does not infiltrate. Instead, it filters runoff through mulch and amended soil mix. This filtered runoff is then routed via a nonperforated overflow pipe and ultimately to a stormwater conveyance system discharging to surface water. For more information on Low Impact Development and UICs, see the DEQ fact sheet "Underground Injection Control Storm Water Information" at their Web site (DEQ 2005).

Cost

Planters will vary with size, site conditions, and vegetation, and are generally used only where sites are too constrained to build a rain garden. The structural requirement of creating vertical walls makes this system one of the most expensive kinds of

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Poor pretreatment design and long-term maintenance has allowed sediment to clog the first section of this planter.

facilities to build. Filtration planters are more costly than infiltration planters, due to piping requirements and, since they are often constructed close to buildings, waterproofing concerns.

If a planter has no pretreatment, maintenance costs can vary with the choice of long-term erosion control—compost mulch, rock mulch, or dense vegetation—since 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 but requires less maintenance.

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