Swales

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Water quality swales (WQ swales) are linear, vegetated, channeled depressions in the landscape that convey and treat runoff from a variety of surfaces. Runoff may be piped or channeled, or may flow overland to a swale. As water passes through the channel, some runoff infiltrates into the soil.

WQ swales differ from conveyance swales in that their design accounts for water quality considerations in addition to conveyance. Conveyance swales, for instance, may be very narrow, have no vegetation, and may quickly convey runoff from one place to another, a feature that would provide poor water-quality treatment.

WQ swales can be dry or wet, and dry swales are usually either vegetated or grassy. These design elements vary in several aspects including function, vegetation type, physical setting, and with other areas of design, such as underdrains and geotextile fabric requirements. The primary difference between wet and dry swales is that dry swales have an underlying filtering bed that allows them to drain more rapidly between storms, while wet swales can be installed in areas with high groundwater tables or poorly draining soils that cause them to remain wet and more marshlike.

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Vegetated swale.

In Portland and other places, the terms "rain garden" (or "vegetated infiltration basin") and "swale" are often used interchangeably, but rain gardens hold runoff and treat it, while swales treat runoff as it is conveyed. Depending on the design, the resulting water-quality benefits can differ greatly between rain gardens and swales.

Design

All swales share similar design criteria. Variations in design can increase the efficiency of swales, either in conveyance or water quality (Field 2007). In general, the faster water flows through the facility, the less effective the water quality treatment will be. Unlike rain gardens, which are modeled as ponds, swales without check dams are modeled as conveyance systems (or reaches) and should capture and treat the volume of the water-quality storm for your region. Clean Water Services in Washington County has required water-quality swales for many years and has some excellent guidance on the hydraulic and hydrologic modeling available on their Web site (CWS 2007a).

Gray infrastructure-conveyance systems (such as pipes) are required to convey the 25-year storm, and

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Courtesy of Steve Fancher, City of Gresham

A swale is used for pretreatment to reduce suspended solids before it enters a larger facility in the Columbia South Shore of Gresham.

green infrastructure-conveyance systems should also be designed to convey those same flows. In the case of dry WQ swales, however, some infiltration into the native soils and initial storage in the soil filter will reduce the peak flow of the 25-year storm, implying that a reduced cross-section may be appropriate. Freeboard (the depth from the maximum flow depth to the top of the facility) for these facilities varies by jurisdiction, and could also vary on a case-by-case basis, depending on the safety or hazards of an overflow event. A freeboard of 6 inches should be provided for a facility designed to handle a 10-year storm (Field 2007, Barr 2001).

More information and enhancement techniques can be found in Field 2007. *Check your local planning department for specific design requirements for your area.*

SIZING

Dimensions for a water-quality conveyance swale are calculated in relation to the water-quality volume (WQV) they will treat and convey (BES 2008). Flow depths should not exceed 6 inches, as studies have shown that flows over this depth through vegetation do not receive adequate water-quality treatment (CWS 2007a). For runoff flowing over and out of the facility, 9 minutes is the minimum recommended retention time for adequate water-quality treatment.

For runoff volume held in the filter soil, the facility should drain this volume within 24 to 30 hours, either via infiltration in the native soils or via an underdrain (Barr 2001). If underdrains with perforated pipes are incorporated into the design, refer to the underground injection control (UIC) Regulations section below for suggestions on avoiding triggers to UIC requirements.

For facilities with check dams, a ponding depth of 12 inches is recommended, up to a maximum of 18 inches (Field 2007, Barr 2001). Jurisdictions in Oregon seem to prefer a depth of 6 to 9 inches. Measurements of shape, length, width, depth, slope, and surface roughness are all needed to calculate flow velocities and the resulting retention time.

SHAPE

A swale with a trapezoidal cross-sectional shape is most frequently recommended because it is the easiest to maintain, causes the least scouring, and creates the least runoff (NCDWQ 2007, Field 2007). This shape is the most difficult to build, however, because soil doesn't tend to conform to hard angles. In a wider facility, runoff will have contact with greater surface area, so pollutant-removal levels will be higher (Field 2007, NCDWQ 2007). Other shapes include parabolic, which is acceptable if its width is equal to a trapezoidal design (Field 2007), and triangular or v-shaped, which is accepted as a curb replacement in low-density areas (NCDWQ 2007).

DIMENSIONS

A minimum length of 100 feet is suggested for those WQ conveyance swales located in low-density areas where they are often used in place of curbs. However, setting a 100-foot minimum makes sense only if swale dimensions and planting density (channel roughness) are specified. Bottom widths generally range from 2 to 8 feet, as less than 2 feet complicates maintenance. In a wider facility, the flow will be shallower and slower, characteristics that will improve the water-quality treatment capacity of the swale (NCDWQ 2007).

The initial depth of a swale is impacted by the method of conveyance to it. For example, if the swale receives either overland flow or concentrated flow from lateral flow through an open-ended trench drain, it will be shallower than a swale that has runoff piped to it, since pipes need a minimum of 12 inches of cover. A number of jurisdictions require a freeboard of 6 to 12 inches, and this requirement can also greatly impact the depth of the facility.

When using underdrains, exercise care in the design of the swale dimensions to avoid triggering state UIC requirements. *See UIC Regulations section below.*

SLOPES

Side slopes for the facility should be 3 feet horizontal to 1 foot vertical (often seen written as 3:1) (Field 2007). Flatter slopes provide greater surface area contact for the runoff, and therefore will increase pollutant removal levels (NCDWQ 2007).

The longitudinal slope of a facility should measure appropriately to control erosive flow velocities, taking into consideration the other parameters used to calculate flow velocity.

CHECK DAMS

Check dams are berms that slow flows by allowing water to back up behind them before overflowing into the next bermed length of the swale. They can be constructed of stone or timber (but never use treated wood) and are generally 3 to 6 inches high (NCDWQ 2007). Earthen check dams are not suggested because of potential for erosion (Field 2007), although vegetated dams used successfully. Portland has used check dams made of large pieces of crushed rock (the same material used for riprap) successfully in a number of its public facilities.

Flow velocities through swales are dependent on the slopes and area of the basin contributing runoff. Check dams can be used to slow velocities and ensure that water flows down into the soil and not out of the outlet too quickly. Within the facility, slopes greater than 5% could cause high flow velocities, potentially leading to erosion. In this case, check dams should be installed (Barr 2001, NCDWQ 2007).

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Rock-check dam in swale holding back water to slow high-velocity flow and make the facility function more like a rain garden.

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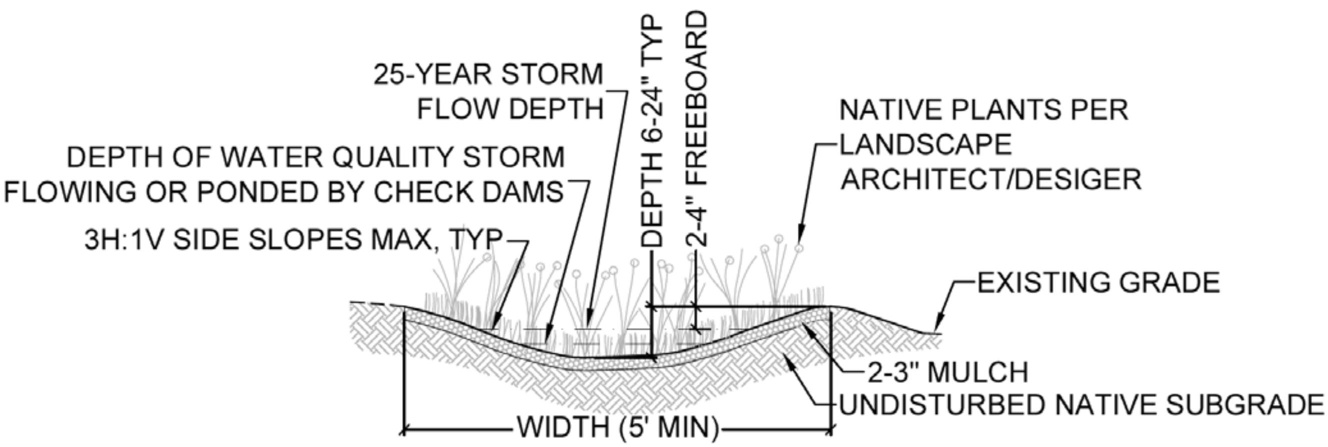

Infiltration swale detail for soils that don't need amendment. Detail provided as a resource with these fact sheets.

ENERGY DISSIPATERS

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. When this material is used, however, a specific length, width, and depth must be designed that is based on the diameter of the rock used for the riprap and the predicted maximum flow velocity. Crushed rock, which is angular, is better at reducing velocities than rounded rock. If the swale is designed properly, many solids will settle out as runoff passes over the riprap, an occurrence that provides some protection from clogging the facility.

Dense vegetation at the inlet can also be used, but may be difficult to clean out. Also, vegetation should not be so dense that it will impede flow into the facility. There are many ways to create a rough surface to slow flows, including the use of baffles or even modified catch basins. Smooth concrete channels are not recommended, since they will simply transfer erosive flows from the entrance to the end of the channel.

SOILS AND MEDIUM

Since a swale conveys runoff, soil can easily erode. Many swale details call for 2 inches of bark mulch to cover the facility, but this material has been observed to float, leaving soil bare even during small storms. In non-stormwater landscape areas, bark mulch is used to control soil temperature for seed germination and to control weeds. Instead of bark mulch, we recommend using 2.5 to 3 inches (CWS 2007b) of rock mulch and feeding the plants as needed with compost tea, which is often supplied by the same companies that supply bark mulch. If organic mulch is preferred, coarse wood chips may be used. This material also floats, but not as much as bark mulch because mushroom spores in the air will react with wood chips (but not bark) to form a mat that will bind the chips together.

Swales may not need any amendments if native soils can support plant life and infiltrate at least the volume of the water-quality storm. Swales in native soils with low permeability should incorporate amended planting soil or amended native soils with infiltration rates that are not too low nor too high: *Rates should be high enough to pass at least small storms through the soil column from treatment, but not so high that stormwater doesn't have enough "retention time" in the soil.* The ideal infiltration rate is between ½ inch 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, 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) and cation exchange capacity (>5 millequivalents/100 grams). Also, the resulting soil mix should be 60% sandy loam and 40% compost (LIDC 2003). Be sure that imported soil and compost are free of weed seeds and other potential pollutants, such as metals (PSP 2009).

Native soils should always be tested in the proposed swale location to determine the infiltration rate of the native, undisturbed soils below the amended topsoil. When an infiltration facility is required, the infiltration rate should be at least ½ inch per hour, although some jurisdictions 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 soil in this case.

If the facility is to be used for water quality only by replacing native soils with amended planting soil, then neither the infiltration rate nor the depth to bedrock are considerations. For wet swales, any soil type is acceptable. This kind of facility is intended to pond water and create more of a marsh or wetland-like appearance (PSMM 2008, Barr 2001, Field 2007). For dry soils, the native soils will be replaced or amended and treated water will flow downhill between the interface of the amended and native soils where it will need to be collected in an underdrain.

VEGETATION

The interaction of soil, plants, and the beneficial microbes that concentrate on plant roots and structures will slow flows in a swale, which is ultimately what provides the filtration benefit of the system; more plants results in higher-quality treatment. While you may see a number of examples that look like dry creek beds with plants around the edges, this approach does not provide adequate treatment for the small, frequent storms with low ponding depths, as water may never reach the plants on the side slopes.

A variety of trees, shrubs, grasses, and ground covers are acceptable for swale vegetation in both sun and shade conditions. Plantings in swales should be dense to reduce flow velocities, prevent erosion, and control weeds (UDFCD 2008). 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 without fertilizers, herbicides, or insecticides, and with minimum to no watering after establishment. Swales should be designed to fit into the landscape: they can be built in zones varying from wetland to upland conditions, so the vegetation should be selected based on local conditions. Vegetation such as perennial flowers, ornamental grasses, and shrubs can add significant appeal to the facility.

Swales 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, take special care to avoid noxious weeds (invasive plant species). A list of noxious weeds is available on the Oregon Department of Agriculture's Web site (ODA 2007).

Vegetation in a swale should be a minimum of 4 to 5 inches tall, have deep root systems, and be resistant to flooding and flattening (Field 2007). Trees and shrubs are an option, but should be planted only in swales with greater than minimum design dimensions (PSMM 2008). Vegetation should be planted as soon as possible after the facility design is complete, and before water is allowed to pass through the channel. Refer to the general manual and Appendix C in

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When vegetation is densely planted, the facility provides better water-quality treatment and is easier to keep weed free.

State of Virginia Department of Conservation and Recreation

Grassy swale with check dams will pond water and provide less conveyance, but better water quality.

Gresham (2007) and BES (2008) for lists of plants and suggested spacing.

In most cases, native plants are preferred, not just because nonnative 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. While native insects and birds may 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

As discussed earlier, runoff entering a swale should be slowed through a pretreatment facility, such as a sediment forebay. The forebay slows water velocities and allows sediments to settle out. Pretreatment areas can be constructed by placing a check dam between the inlet and main body of the facility. To distribute flows, level spreaders can be installed, such as a weir placed perpendicularly across the bottom of the channel or a trench drain with a perforated pipe (Field 2007). If underdrains with perforated pipe are used, UIC requirements could be triggered, depending on where the pipe discharges (*see Permits section below*). If flows are slow enough, a riprap outfall can be placed at the inlet to slow flows.

Outflow from the facility should not have velocities high enough to cause erosion down-gradient. The facility should also have a high-flow bypass facility, which will allow runoff exceeding the design storm volume to pass around the swale (Field 2007).

Setbacks

There are typically no setbacks for lined swales. Setbacks for infiltration swales vary by jurisdiction. Following the Oregon Building Code,[1] the City of Portland requires infiltration swales 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 bans building walls within 5 feet of the property line, thereby ensuring 10 feet of building setback. Swales should also be set back a minimum of 100 feet from down-gradient slopes of 10 percent. Add 5 feet of setback for each additional percentage point up to 30 percent, and avoid installing an infiltration swale where the down-gradient slope exceeds 30 percent. The Oregon DEQ requires a minimum soil depth of 3 feet from the bottom of the swale to the seasonal high groundwater table (DEQ 1998). Check with your local jurisdiction for specific setbacks in your area.

Physical Setting

Runoff from all types of impervious and pervious surfaces is acceptable for management in swales (Gresham 2007, Barr 2001). However, only dry swales are recommended for "hot spots" with high traffic loading, such as convenience stores.

The channel and linear design of swales makes them suitable for roadside (highway or residential) runoff capture, but residential areas with frequent, closely spaced driveway

1 Available at http://www.cbs.state.or.us/bcd/index.html culverts may not be ideal locations for these facilities (Barr 2001).

Wet swales are typically placed along property boundaries and incorporated into natural grades. This is not a limiting criterion, however, and wet swales can be located anywhere with sufficient space (Barr 2001).

Potential areas for swales include front and back yards, parking lots, and beneath roof spouts (Barr 2001). Dry swales are ideal for residential areas. A lack of standing water allows these facilities to be mowed as an extension to a backyard. For water quality purposes, however, this planting approach should be used as a last resort. Swales can also serve as substitutes for curbs or gutters. Siting a swale on stable soils can also prevent erosion (Field 2007). Both infiltration and filtration facilities have been used successfully on private property, public property, and within the public right-of-way. Swales can be built in both new and existing developments. Although they are generally designed for smaller areas, swales can be constructed to help manage the appropriate volume of runoff in larger areas (see the Design section for sizing criteria). Some siting criteria for soils have been mentioned already, and additional criteria follow.

Infiltration swales can be used in locations where

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

Lined filtration swales should be used instead of infiltration swales

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

Pollutant Removal

Generally, swales are most effective at removing sediment-bound pollutants and are less effective at providing peak flow attenuation or volume capture (NCDWQ 2007). However, the addition of check dams that hold runoff will turn the swale lengths into miniature rain gardens with an improved capacity to treat and infiltrate. The shape of the bottom of the facility will also impact the effectiveness of these facilities: A flatter and wider facility will lower the flows, resulting in greater opportunity for treatment. Methods of pollutant removal include settling out sediments, infiltration through soils and media, and biological uptake through plantings within the facility.

Wet swales can be likened to wetlands in runoff function because they also pool surface water, but they are suspected to be less effective than dry swales. Dry swales are likely to provide better treatment because of their additional capacity to treat runoff by passing it through soil. Based on published research, the Center for Watershed Protection estimated that the event mean concentration phosphorus-removal rates for both wet and dry swale designs are 20 to 40%, and nitrogen removal rates are 25 to 35%. Runoff reduction was estimated at a conservative 0% because there are few documented studies providing this information. However, if check dams are used or infiltration is intentionally incorporated into the design, runoff reduction will occur (CWP 2008).

In general, lower removal rates have been found for grassy swales than for vegetated swales, so the former probably should be considered only for low-sediment-loading applications, such as residential. For grassy swales, which can easily be mistaken for a place to recreate or walk the dog, educational signage might help to reduce the pollutants generated directly in the facility (EPA 2006). The Center for Watershed Protection estimated that the event mean concentration phosphorus removal rates for grassy swale designs are 15%, and nitrogen removal rates are 20% (CWP 2008).

Construction

Swales should be constructed before impervious surfaces are installed and allowed to establish before runoff is directed to them. For infiltration facilities, equipment should only be operated along the sides of swales, rather than on the bottom, in order

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Swale bottom clogged by the fines in the native soils after a rain event.

to prevent soil compaction and disturbance (NCDWQ 2007).

If the soils are exposed to rain, fine soil particles that are picked up and moved around may clog the native subgrade soils, so it is important to rake the surface to loosen soil before proceeding. If the swale is dug by hand, raking will also be required, since foot traffic in the facility area may be unavoidable.

Maintenance

Swales should be inspected once every 3 months, and sedimentation buildup should be removed at least once each year—and when it builds to 4 inches, covers grasses, or reaches 25% of design volume. Buildup may occur after large storms so swales, particularly wet swales, should be examined after every large storm. Other maintenance tasks include reseeding grassy swales, repairing eroded areas, regrading. Revegetating should be performed on an as-needed basis.

Grassy swales should also be mowed on an as-needed basis, but at least once per year, outside the primary bird nesting period from April 15 to July 31, to prevent woody vegetation growth. Wet swales will be difficult to mow. Swales should not be irrigated beyond the establishment period, since this will change the hydrologic regime of the site by infiltrating water during historically dry periods.

Vegetation should be maintained through integrated pest management. When possible, fertilizers, herbicides, and pesticides should be avoided for all areas draining to and within the facility.

With proper maintenance ensuring low velocities and supporting dense vegetation, these facilities are very reliable (Arnold 1993).

Cost

Costs include permitting, construction, and maintenance. Because many swales are used as replacements for curbs and gutters, they are generally cost-effective, although they do occupy larger areas. Ongoing maintenance costs are relatively low, but sediment removal and erosion repair are generally more costly, so care should be taken in all phases of the project to prevent damage (Arnold 1993).

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. When building a planter on a non-residential site, a commercial building permit is required in many cases, and a clearing, grading, and erosion control permit may 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 Environmental Quality's UIC program (OAR chapter authorizing ODEQ to regulate UICs:: http://arcweb.sos.state.or.us/rules/OARs_300/OAR_340/340_04).4.html). 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 following paragraphs are for designers who are considering a swale to treat runoff before discharging it to surface water. These guidelines will help the designer avoid triggering UIC requirements in the design of a swale. If a swale 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.

When sizing a swale, avoid designing a facility that is deeper than the widest surface dimension.

An unlined water-quality swale designed and installed per the details shown is not considered to be a UIC. However, changes to the design detail that might allow runoff to shortcut infiltration through the top of the facility could turn the facility into a UIC. For example, underdrains composed of perforated pipe that convey runoff from large storm events down into the ground may trigger state UIC requirements. If the pipe discharges to surface waters, the designer should use an underdrain that is perforated only on the top and sides to route the runoff that exceeds the capacity of the facility to a stormwater conveyance system.

A lined water-quality swale, is not, by definition, a UIC, because it does not infiltrate. For more information on low impact development and UICs, see the DEQ's fact sheet, "Underground Injection Control Stormwater Information," on their Web site (DEQ 2005).

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