

4.7. Swales

A swale is a vegetated open channel, planted with a combination of grasses and other herbaceous plants, shrubs, or trees. A traditional swale reduces peak flow at the discharge point by increasing travel time and friction along the flow path. Swales can provide some infiltration and water quality treatment; these functions can be enhanced by incorporating retentive grading, or check dams periodically along the length of the swale. In cohesive soil types, installation of a filtering substrate (for example, a mixture of 1/3 each soil, sand and organic matter) and a perforated underdrain enhance simulated infiltration capacity of swales in order to provide additional water quality treatment. In this manner, the perennial outlet is the underdrain with the retentive grading or check dams providing high flow relief. Therefore, the volume of storm water forced to infiltrate to the underdrain is temporarily providing storage en route to the primary detention facility. This will decrease the required size of primary detention facilities versus conventional pipe conveyance. The Designer should be encouraged to incorporate swales into the landscape and hardscape to the extent possible in order to increase aesthetic value, decrease construction cost, and provide attenuation characteristics throughout the storm water system. Swales planted with turf grass provide some of these functions but turf grass is not as effective as deeper-rooted vegetation at decreasing peaks, encouraging infiltration, and decreasing erosion. A swale can be more aesthetically pleasing than a rock-lined drainage system and is generally less expensive to construct.



Key elements :

- Open channel design that balances storage, treatment, and infiltration with peak flow conveyance needs
- Check dams or lateral, permeable berms to increase storage, dissipate energy, and control erosion
- Native vegetation to increase frictional resistance and stabilize soil
- Designed to fit into many types of landscapes in an aesthetically pleasing manner

Table 4.7.1: Swales Potential Application and Storm Water Regulation

Potential applications		Storm water regulations		
			Infiltration	No Infiltration
Residential Subdivision:	Yes	Water Quality Benefit	Yes	Yes
Commercial:	Yes	Volume Reduction	Yes	No
Ultra Urban:	Limited	Attenuation Benefit	Yes	Yes
Industrial:	Yes			
Retrofit:	Yes			
Highway Road:	Yes			

Acceptable forms of pre-treatment

Filter strips (Optional)

Sediment Forebay (Optional)

Swales in the Urban Landscape

Swales are landscaped channels that convey storm water and reduce peak flows by increasing travel time and flow resistance. Depending on design and underlying soil permeability, they can effectively reduce runoff volume and improve water quality. Check dams increase these functions by creating ponding areas where settling and infiltration can occur. As the number of check dams increases, a swale may resemble a series of bioinfiltration/bioretention basins while still being designed to convey peak flows. The first ponding area may be designed as a sediment forebay and function as a pretreatment practice for the remainder of the swale or other storm water management facilities.

Swales are applicable in many urban settings such as parking, commercial and light industrial facilities, roads and highways, and residential developments. For instance, a swale is a practical replacement for roadway median strips and parking lot curb and gutter. Swales can be an effective means of decentralizing storm water management so that primary detention facilities become less necessary.



SWALE IN EASEMENT OF SUBDIVISION

Commercial, Light Industrial, and Institutional Sites

These facilities often have landscaped or grassed areas that can also function as drainage pathways and infiltration areas.

Roads and Highways

Swales can be installed in some median strips and shoulders. In some cases, these systems may replace costly curb and gutter systems.

Residential Development

With approved property agreements, swales can be constructed parallel to the sidewalks and streets. Alternatively they can collect storm water from multiple properties and convey it to a shared facility.

Components of a Swale

Swale systems often include the following components:

- Inlet Control
- Pretreatment (Optional)
- Excavated Channel
- Permeable Soil
- Outlet Control
- Check dams or lateral, permeable berms
- Stone (Optional)
- Underdrain (Limited Application)
- Vegetation

Inlet Control

Runoff can enter the swale through a curb opening, pipe, weir, or other design. Runoff may flow off a curbless parking lot or road and down a swale slope in a diffuse manner.

Pretreatment (Optional)

Pretreatment is optional but can extend the life of the design if the swales are designed to accrue sediment. Vegetated or stone filter strips are options for pretreatment. A sediment forebay may be constructed at the swale inlet, or the first swale segment and a check dam may be designed as a sediment forebay and the primary maintenance point.

Excavated Channel

The channel itself provides the storage volume and conveyance capacity of the swale. Swale design should balance the infiltration and treatment requirements of small storms with needs for conveyance during large storms.

Soil and Stone

The soil provides a growing medium for plants and allows for infiltration. Growing medium may consist of amended native soils or soil mixtures specified for infiltration. A crushed stone layer may be added beneath the soil to increase storage and promote infiltration. Stone will perform this function most effectively when placed in ponded areas.

Check Dams

It is recommended that swale designs include check dams or lateral, permeable berms. Ponding behind check dams provides storage, increases infiltration, increases travel time, reduces peaks, and helps prevent erosion by dissipating energy. Lateral, permeable berms provide a similar function, providing longitudinal filtration in addition to the functions described above.

Underdrain

In some cases, an underdrain and piping system may be provided to prevent prolonged ponding of storm water or to collect and convey water to another facility such as an infiltration trench. Underdrained systems may be appropriate in locations where conditions are not ideal for infiltration. In general underdrains should be installed unless the underlying soil is permeable and has been certified by a registered geologist, soil scientist, or engineer.



RIVER ROCK SWALE

Outlet Control

A swale may have an outlet control to convey water to a sewer or receiving water.

Recommended Design Procedures

- Determine the desired Water Quality and Quantity requirements to be met by the swale on the site. The designer may choose to provide all necessary storage within the swales, or just decrease the demands at the most downstream detention facility.
- Create a Conceptual Site Plan for the entire site, and determine what portion of the requirements the vegetated swale will meet. Consider the site's natural topography in siting the swale; if possible, locate the swale along contours and natural drainage pathways.
- Investigate the feasibility of infiltration according to conditions in the area proposed for the vegetated swale. If infiltration is feasible, determine the saturated vertical infiltration rate. Infiltration to groundwater will remove storm water volume.
- Create a conceptual design for the vegetated swale.

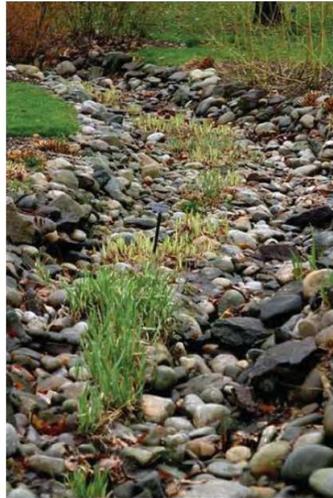


Table 4.7.2: Suggested Swale Starting Design Values

Bottom Width	2-8 Feet
Side Slopes	3-4 horizontal to one vertical recommended; 2:1 maximum*
Check Dams	Evenly spaced, 6-12 inches high**
*Swales may be trapezoidal or parabolic in shape. Recommended widths and slopes in this table may be used as a general guide for parabolic channels	
**Check dams are recommended for most applications to improve infiltration and water quality. They are strongly recommended for swales in which flow in combination with soil, slope, and vegetation may result in erosive conditions.	

- Consider an underdrain under any of the following conditions:
 - in areas with separate storm sewers or direct discharge to receiving waters where infiltration is infeasible and the vegetated swale is needed only to provide water quality treatment;
 - in areas with combined sewers where sufficient detention or travel time can be designed into the system to meet release rate requirements; or
 - in combination with other storm infrastructure where the system as a whole meets storage and release criteria.
- Estimate the portion of Water Quality and Water Quantity requirements met by the design.
- Using infiltration area and the saturated vertical infiltration rate of the native soil, estimate how long storage behind check dams will take to drain. The maximum drain time for the entire storage volume is recommended to be 72 hours, but the Designer may choose a shorter time based on site conditions and Owner preference but no shorter than 24 hours. If storage does not drain in the time allowed, adjust channel shape, number of check dams, check dam height, or optional underdrain design. Adjust the design so that performance and drainage time constraints are met concurrently.
- Check the capacity of the swale system to perform during the 100 year regulatory event defined in the Storm Water Design and Specification Manual. An average ponding depth of 12 inches or less, and a maximum ponding depth of 18 inches is required. If higher stages are anticipated, vegetation should be selected per expected hydrologic conditions. Flow over check dams should be estimated using a weir equation, while underdrain conveyance should be modeled as a series outlet representing (1) infiltration rate over horizontal wetted area to (2) orifice flow at the underdrain daylight. Ultimately, the level of service provided on the site during large events is a joint decision of the Engineer and Owner based on safety, appearance, and potential property damage.
- Choose soil mix and swale vegetation. A minimum of 6 inches of prepared soil is recommended for the channel bottom and slopes.
- Check resistance of the swale to erosion. For long term functionality, it is recommended that the swale convey the 2-year, 24-hour design storm without erosion. For water quality purposes, channel velocities during a water quality event should not exceed resuspension velocities. Adjusting soil mix, vegetation, and temporary or permanent stabilization measures as needed.
- Design inlet controls, outlet controls, and pretreatment if desired.
- Check that the design meets all requirements concurrently, and adjust design as needed.
- Complete construction plans and specifications.

Materials

Soil

- Swale soil shall have a sandy loam, loamy sand, or loam texture per USDA textural triangle.

Vegetation

- It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Select plants from the list of native species provided in Chapter 5: Storm Water Landscape Guidance. Consider ponding depth, drain time, sunlight, salt tolerance, and other conditions when selecting plants from this list. Turf grass is generally not recommended but may be acceptable provided the designer can show it meets all requirements.

Check Dams

- Check dams can be constructed from natural wood, concrete, stone, boulders, earth, or other materials. The Designer should coordinate with the Department of Metropolitan Development regarding the use of non-conventional materials in the storm water infrastructure.
- If a stone check-dam is designed to be overtopped, appropriate selection of aggregate will ensure stability during flooding events. In general, one stone size for a dam is recommended for ease of construction. However, two or more stone sizes may be used, provided a larger stone (e.g. R-4) is placed on the downstream side, since flows are concentrated at the exit channel of the weir. Several feet of smaller stone (e.g. AASHTO #57) can then be placed on the upstream side. Smaller stone may also be more appropriate at the base of the dam for constructability purposes.

Storage Stone

- Stone used to provide additional storage shall be uniformly-graded, crushed, washed stone meeting the specifications of AASHTO No. 3 or AASHTO No. 5.
- Stone shall be separated from soil medium by a non-woven geotextile or a pea gravel filter.

Non-Woven Geotextile

- Geotextile shall consist of needled non-woven polypropylene fibers and meet the following properties:
 - Grab Tensile Strength (ASTM-D4632) \geq 120 lbs
 - Mullen Burst Strength (ASTM-D3786) \geq 225 psi
 - Flow Rate (ASTM-D4491) \geq 95 gal/min/ft²
 - UV Resistance after 500 hrs (ASTM-D4355) \geq 70%
 - Heat-set or heat-calendared fabrics are not permitted

Pipe

- Pipe used for an underdrain shall be continuously perforated and have a smooth interior with a minimum inside diameter of 4-inches. High-density polyethylene (HDPE) pipe shall meet the specifications of AASHTO M252, Type S or AASHTO M294, Type S.

Construction Guidelines

- Begin vegetated swale construction only when the up gradient site has been sufficiently stabilized and temporary erosion and sediment control measures are in place. Vegetated swales should be constructed and stabilized very early in the construction schedule, preferably before mass earthwork and paving increase the rate and volume of runoff. If the swales are constructed to assist with temporary drainage during construction, the facilities should be graded to final design grade and stabilized at the cessation of mass earthwork.
- Rough grade the vegetated swale. Equipment shall avoid excessive compaction and/or land disturbance. Excavating equipment should operate from the side of the swale and never on the bottom. If excavation leads to substantial compaction of the subgrade (where an infiltration trench is not proposed), 18 inches shall be removed and replaced with a blend of topsoil and sand to promote infiltration and biological growth. At the very least, topsoil shall be rototilled into the subgrade in order to penetrate the compacted zone and promote aeration and the formation of macropores. Following this, the area should be disked prior to final grading of topsoil.
- Construct check dams, if specified.
- Fine grade the vegetated swale. Accurate grading is crucial for swales. Even the smallest nonconformities may compromise flow conditions and may lead to ponding in undesirable locations. The accidental creation of a preferential flow path in the swale will encourage scour rather than the desired smooth laminar flow across the cross-section.
- Seed and vegetate according to final planting list. Initial seeding with an annual turf grass is recommended to provide temporary stabilization. Plant the swale at a time of the year when successful establishment without irrigation is most likely. However, temporary irrigation may be needed in periods of little rain or drought. Vegetation should be established as soon as possible to prevent erosion and scour.
- Concurrent with the previous step, stabilize freshly seeded swales with appropriate temporary or permanent soil stabilization methods, such as erosion control matting or blankets. If runoff velocities are high, consider sodding the swale or diverting runoff until vegetation is fully established.
- Once the swale is sufficiently stabilized, remove temporary erosion and sediment controls. It is very important that the swale be stabilized before receiving storm water flow.

Maintenance Guidelines

The following schedule of inspection and maintenance activities is recommended:

Activity	Schedule
Remulch void areas.	As needed
Treat or replace diseased trees and shrubs.	
Keep overflow free and clear of obstructions.	
Inspect soil and repair eroded areas.	Monthly
Remove litter and debris.	
Clear leaves and debris from overflow.	
Inspect trees and shrubs to evaluate health.	Biannually
Add additional mulch.	
Inspect for sediment buildup, erosion, vegetative conditions, etc.	Annually
Maintain records of all inspections and maintenance activity.	Ongoing
Mowing of vegetated swales is design dependent	Ongoing

Note:

Design of swales are not limited to the examples shown within this text. Successful storm water management plans will combine appropriate materials and designs specific to each site.

4.7.1. Swale Designer/Reviewer Checklist

Item	Yes	No	N/A	Notes
Can the swale safely (with freeboard) convey the 10-year event?				
Are bottom slopes between one percent and six percent?				
Are check dams provided for slopes > 3%?				
Are check dams adequately keyed into swale bottom and sides?				
Are two-year and ten-year flows non-erosive?				
Will the swale completely drain in 72 hours?				
Are side slopes between 3:1 and 5:1 H:V?				
Are swale soils loam, loamy sand or sandy loam?				
Vegetation and Mannings coefficient selected?				
Non-erosive inflow condition(s)?				
Erosion control provided during construction?				
Maintenance accounted for and plan provided?				

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