MANAGING STORMWATER RUNOFF FOR RURAL LANDOWNERS

Bioinfiltration Swales

Figure 1. A fully planted bioinfiltration swale[1]

Introduction

In rural areas, you may not have city services like storm drains that conveniently carry stormwater away, but there are still many ways to solve drainage issues. This fact sheet describes one of the ways you can manage drainage issues on your property. By removing standing water in your yard, preventing erosion, dealing with minor flooding, and redirecting water away from your building foundations, you will be protecting your investment and water quality in nearby lakes, streams, and marine waters.

This fact sheet provides general concepts about when bioinfiltration swales might help manage stormwater, including general design, construction, and maintenance guidelines. Consult with your local planning office after reading this document. Depending on the amount of stormwater flow, the design of a bioinfiltration swale and the construction may require professional expertise, such as a licensed engineer. In addition, an individual homeowner should not attempt to manage large-flow situations independently.

There are many considerations when determining how to best manage stormwater in a specific location. To assist you in making the best decision for your needs, please refer to the fact sheets on **Understanding Your Site Conditions** and **Options for Managing Surface Water Drainage**.

What is a bioinfiltration swale?

A bioinfiltration swale is a stormwater conveyance system that moves water from one place to another while allowing for infiltration and treatment. The swale consists of an excavated channel for stormwater with a gentle downgradient slope. There is vegetation planted on the channel bottom and sides. Bioinfiltration swales are an excellent alternative to standard ditches or traditional piped stormwater conveyance systems because they are designed to move water to locations that can handle excess stormwater while simultaneously treating and infiltrating the water as it moves through the swale.

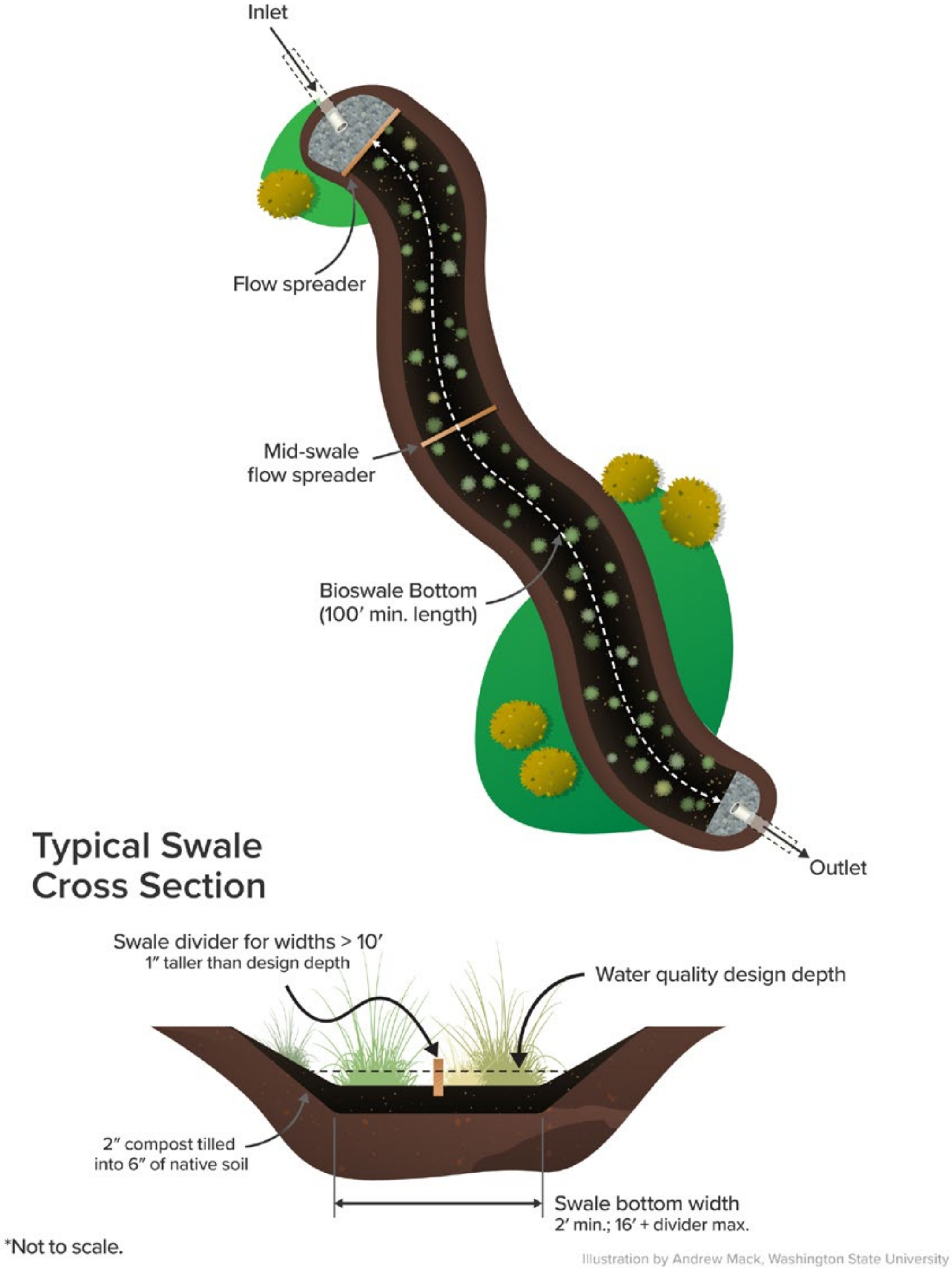

Figure 2. Anatomy of a bioinfiltration swale[2]

Figure 3. Juvenile coho salmon are impacted by high pollutant loads in the first flush of stormwater after a dry spell. Credit: D. McNamara

How do bioinfiltration swales improve water quality?

The primary way a bioinfiltration swale improves water quality is by reducing sediment in the flowing water. Sedimentation is a water quality issue because it fills in and smothers the gravel habitat that salmon and a host of other aquatic organisms depend on.

Sediment and associated particulate pollutants, such as heavy metals suspended in stormwater, are trapped by vegetation in the swale as the water slowly flows down the gentle slope. Therefore, a minimum vegetation cover of 70 percent is recommended[3] to treat stormwater adequately.

The soil used in bioinfiltration swales is usually amended to increase the organic matter and promote stormwater infiltration into the bottom of the channel. Amending the soil with compost helps promote infiltration of the "first flush" (see sidebar) of runoff, increasing pollutant removal[4]. Typically, compost is tilled into a depth of about six inches to ensure that it does not get washed out.

Bioinfiltration swales do not effectively remove dissolved pollutants such as nitrogen or metals. Therefore, other methods are recommended to treat dissolved pollutants upstream or downstream of the bioinfiltration swale.

How are bioinfiltration swales different from bioretention systems and drainage ditches?

Bioinfiltration swales are different from bioretention systems. Bioinfiltration swales are conveyance systems where most stormwater flows along the length of the system on a gradient from a high point to a low point.

Bioretention systems do ***not*** convey water across the landscape; they capture water, filter it, and retain it, allowing it to soak into the ground. A rain garden is an example of a bioretention system.

Drainage ditches are designed to ***move*** large volumes of water, usually quickly, to remove it from the area; thus, they are not designed to ***treat*** water quality. Table 1 compares bioinfiltration swales to other methods.

What is "first flush"?

After a long summer of dry weather, the first rainstorm is usually welcomed, but that rain runoff also delivers a summer's worth of pollution buildup to nearby streams and water bodies. During a dry spell, our roads, highways, sidewalks, driveways, and other hard surfaces accumulate sediment, heavy metals, oils, pesticides, fertilizers, and pollutants from various sources on the landscape. The first rain transports this unnoticed material into ditches, storm drains, and nearby water bodies. This is sometimes referred to as "first flush." For ***each*** storm event, there is also the "first flush," which is when enough rain has fallen and begins running off across paved areas and the landscape.

Table I. Comparing infiltration methods

Features	Bioinfiltration Swale	Bioretention System / Rain Garden	Drainage Ditch
Designed for	Moving water slowly from one area to another, treating and infiltrating it along the way, thereby improving water quality and reducing some flooding.	Stopping water, treating, and infiltrating it onsite, thereby improving water quality and reducing flooding.	Moving water quickly from one area to another, reducing flooding.
How it works	Flat bottomed channel sloping at a slight gradient to slow water as it is conveyed. Dense plantings also slow water and sediment, to allow treatment while still moving water to a more desirable location. Effective for trapping sediment and associated pollution.	Flat bottom retains water and allows it to soak into the ground through a special soil mix designed to filter out pollutants.	U- or V-shaped bottom with varying downhill slope conveys large volumes of water from the area. Little to no water quality treatment.
General shape	Linear channel with gentle downhill gradient and gently sloping sides.	Any shape, but usually round or kidney-shaped to fit landscape. Flat bottom area for infiltration, gently sloping sides.	Linear with gentle downhill gradient. Sides are typically a 1:1 or 2:1 (H:V) slope.
Soils	Often amended with compost.	Special "Bioretention Soil Mix" (usually 60% sand, 40% compost), placed about 18" deep.	Native soils. No amendment.
Vegetation	Yes. 70% coverage minimum; hardy grass-like plants in treatment area.	Yes. Plants at the bottom and sides of the rain garden must be able to thrive in wet and dry conditions.	No. Not planted.
Mulch	No.	Yes. Up to 4" of arborists' woodchips or other mulch.	No.
Maintenance	Mowing. Leaf and sediment removal as needed.	Weed, remove sediment, clean inflow and overflow, and mulch as needed.	Removal of plants and sediment as needed.

Converting a drainage ditch to a bioinfiltration swale

The advantages of bioinfiltration swales are that they improve water quality and reduce the amount of stormwater by providing some infiltration. However, modifying a drainage ditch to a bioinfiltration swale can pose challenges: since drainage ditches are designed to move large volumes of water, they may be too steep or sized wrong to convey water as slowly as needed for a bioretention swale[4]. Therefore, it is recommended that only small drainage ditches are converted to bioinfiltration swales, with possible modifications to reduce the grade if necessary to slow conveyance.

Advantages and disadvantages of bioinfiltration swales

Advantages of bioinfiltration swales include:

- Reducing sediment and associated particulate pollutants.
- Conveying water and providing flood storage, potentially reducing downstream flooding.[5]
- Contributing to groundwater recharge when the existing soils below the bottom of a bioinfiltration swale consist of high-infiltration soils.[6]

The limitations of bioinfiltration swales include:

- They can be complex to size correctly and design; a professional is often required.
- If too much sediment accumulates in the swale, water cannot flow through the soil/plant interface, limiting the swale's ability to remove stormwater pollutants.[7]
- They are prone to be taken over by invasive plants if not planted or maintained correctly.
- They may be ineffective in removing pollution if improperly designed.

Bioinfiltration swales are not effective:

- For treating stormwater with high pollutant loads or high sediment loads.[6]
- Where soils are saturated for extended periods, because many plants will not survive if in wet conditions continuously, although some design and plant-selection adjustments can address this.[5]
- In arid regions, unless irrigation is provided as needed, since high plant density is critical to ensure particulate trapping—although some plant-selection choices can mitigate for this.
- If located downstream of runoff sources carrying pollutants that might kill vegetation in the bioinfiltration swale.

Design considerations

Bioinfiltration swales are somewhat complex to design. They must be able to transport stormwater continuously. In addition, bioinfiltration swales are designed to convey the most prominent peak flows and ensure that the "water quality design flow" is treated.[8]

The "water quality design flow" is the basis for calculating the dimensions of a bioinfiltration swale. This flow rate is at or below which 91% of the total runoff volume, will be treated[4]. Once the water quality design flow is determined, the bioinfiltration swale's bottom width and length can be calculated. A licensed civil/water resources engineer should make these design calculations.

The bottom width and length of the bioinfiltration swale define the "bioinfiltration swale area" (the area below the water quality design depth is known as the "swale treatment area"); this should be between 10 to 20 percent of the contributing area[6] feeding stormwater to the system.

Typical dimensions

The size of a bioinfiltration swale is dependent on the size of the contributing area and site constraints, but the typical dimensions of a bioinfiltration swale[8] are:

- ***Minimum*** bottom width 2 ft
- ***Minimum*** longitudinal slope 0.25 percent. (1 to 2 percent preferred)
- ***Maximum*** longitudinal slope 6 percent
- If the longitudinal slope exceeds 6 percent, check dams with vertical drops that do not exceed 12 inches are needed. In addition, the spacing between check dams should ensure that the slope does not exceed 6 percent between drop sections.[4]

Specific design and planting requirements pertain to the bioinfiltration swale area. For example, the side slopes of the bioinfiltration swale should be 3H:1V but cannot exceed 2H:1V.

Special circumstances

Flat terrain
When the terrain is flat, a typical bioinfiltration swale with a slope less than 0.25 percent will not meet the goals of water quality treatment; some essential refinements to the design are therefore needed. Two refinements that enable bioinfiltration swales to be installed in flat terrain are adding underdrains or designing them as wet bioinfiltration swales. These two refinements are broadly described below.

When an underdrain is needed
An underdrain is necessary to ensure that water in a bioinfiltration swale with a gentle slope will flow through the plant-soil interface to achieve some level of water quality treatment. A perforated pipe encased in drain rock is installed approximately one foot below the bioinfiltration swale bottom and 4-6 inches above the native soils below. Ensuring that water can flow freely to the underdrain pipe is critical.

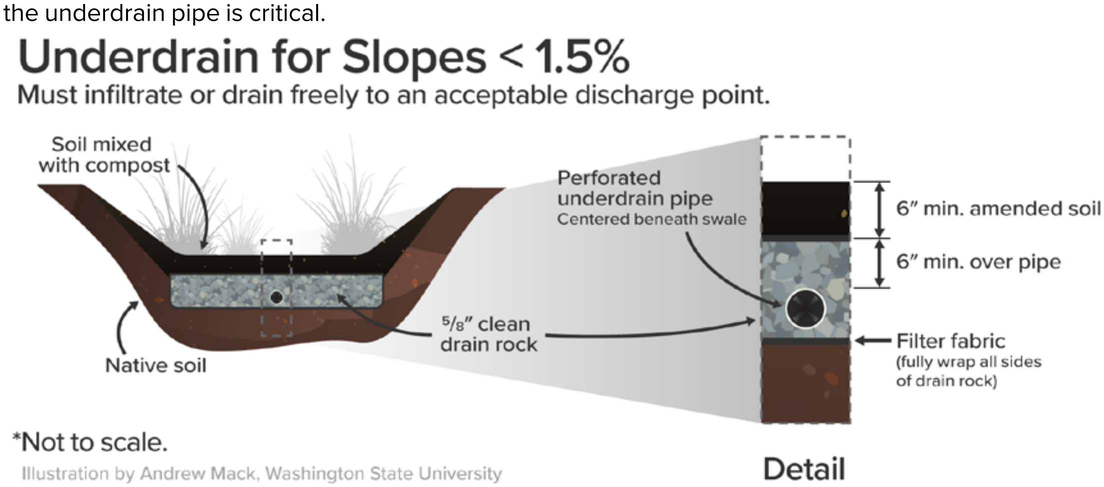

Figure 4. The details of a bioinfiltration swale with an underdrain[2]

Wet bioinfiltration swales are appropriate when drainage is needed in flat terrain, and the water table is close to the ground surface resulting in wet or saturated soils. This condition can also occur when there are compacted till soils or clayey soils. Therefore, plants must be chosen that can survive these specific soil conditions.

High Flows
If design flow velocity exceeds 4 cubic ft/sec, use a turf reinforcement mat.[8] High design flow velocities are expected when the bioinfiltration swale has a steep gradient. It is critical to provide erosion control after construction[10] and ensure that vegetation is well established in the newly constructed swale before runoff is allowed to flow into the bioinfiltration swale. It is also essential that weed sources are not introduced in the newly exposed soils of a bioinfiltration swale; existing weed roots should be thoroughly removed from the subsoil.

What to plant

Grass-like plants should be established across the whole worksite. If using seeds, apply in spring or fall by hydroseeding or broadcast application.[4]

The treatment area needs plants that provide a dense cover to limit erosion.[4] A minimum of 70 percent planting coverage should be the goal of any bioinfiltration swale planting design. The plants must withstand (remain upright) the forces exerted on them by the design water quality event.[4] The plants should be chosen to withstand the soil conditions within the bioinfiltration swale in terms of pH, compaction, soil moisture, or lack of moisture.[5]

Newly planted bioinfiltration swales must be protected from runoff until the plants are well established.[4]

King County approved two seed mixes for the treatment area for use in typical bioinfiltration swales; those mixes are detailed in Chapter 6 of the 2021 King County Surface Water Design Manual.[4] Plant recommendations for a wet bioinfiltration swale are also provided in that document. Please consult with a landscape or erosion control specialist for regions outside of western Washington for recommended plant mixes, fertilizer, and mulch.

For areas of the swale above the treatment zone, standard lawn mixes or landscape plantings can be used. Plants that can bind the bank soils to prevent erosion are critical in bioinfiltration swales that are likely to see high flows. A list of suitable ground covers and grasses for the regions above the treatment area zone can be found in Chapter 6 of the 2021 King County Surface Water Design Manual.[4]

Maintaining your swale

Periodic inspections and maintenance of bioinfiltration swales are critical for ensuring their proper functioning. The following is recommended for a well-functioning swale:

- Inspect swale twice a year at a minimum.[11]
- Remove deposited sediments and trash periodically.[3]
- Mow grass in the areas of the bioinfiltration swale above the water quality treatment zone monthly during the growing season—grass clippings from mowing should be removed and disposed of or composted.[4]
- Irrigate and prune plants.[3] A temporary irrigation system may be needed to ensure plants survive, especially if installed in the dry season.
- Remove leaf litter so it does not clog the system. Remove any volunteer trees/shrubs.
- Ensure there is no standing water after a storm event.
- Regrade swale if standing water persists[12] or if channelization or erosion has occurred.[4] If regrading is needed annually, there may be a more significant, more systemic issue with the bioinfiltration swale that might need to be addressed.
- Remove accumulated sediments up-grade of check dams (if any)[11] and from the head of the swale.[4]

In the first two years after planting, frequently check for excessively tall or nuisance vegetation during the growing season. After the first two years, check annually. Monitor plant health and identify causes for plant stress.[11]

Resources

For more information, visit Rural Stormwater Solutions (https://ruralstormwater.wsu.edu/resources/).

References

For links to these references, visit Rural Stormwater Solutions (https://ruralstormwater.wsu.edu/references/).

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