

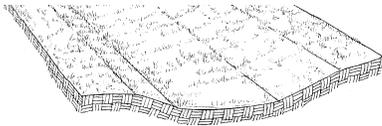
Vegetated Infiltration Swale (1005)

Interim Technical Standard

Wisconsin Department of Natural Resources
Conservation Practice Standard

I. Definition

Vegetated infiltration swales are stormwater conveyance systems designed to enhance the infiltration runoff. A vegetated infiltration swale can be a natural elongated depression or a constructed channel. A vegetated infiltration swale differs from a conventional drainage channel or ditch in that it is constructed specifically to promote infiltration.



II. Purposes

The primary purpose of this practice is to infiltrate storm water, while limiting groundwater contamination by providing filtering of pollutants. Vegetated swales can also help attenuate peak flows through reducing runoff velocities and volumes.

III. Conditions where Practice Applies

Vegetated infiltration swales are best suited for

- *low- to medium-density residential land uses*¹, and
- Non-residential areas where infiltration of runoff is allowable under Chapter NR 151.

Swales are often placed along roads and in drainage easements in side/back lot lines. Swales are intended to treat relatively flat and small drainage areas with contributory areas less than 5 acres. Swales are not suitable in areas of steep topography or areas with erodible soils without implementation of additional measures to reduce flow velocities and protect against erosion.

This standard does not apply to swales installed to meet the swale treatment option set forth in ss. NR 151.24(10) and Trans 401.106(10).

IV. Federal, State, and Local Laws

Users of this standard shall be aware of applicable Federal, State, and local laws, rules, regulations, or

permit requirements governing vegetated infiltration swales. This standard does not contain the text of Federal, State, or local laws.

V. Criteria

Vegetated infiltration swales shall be designed to infiltrate runoff and can be a component of a system intended to meet the runoff infiltration requirements of Chapter NR 151. The swale may also be a component of the stormwater conveyance/storage system.

- A. **Site Assessment** - A site assessment shall be conducted and documented meeting the requirements of the WDNR Conservation Practice Standard "Site Evaluation for Stormwater Infiltration" (1002). In addition, the site assessment shall evaluate the alignment of the infiltration swale in relation to ground slopes; drainage patterns; and proximity to buildings.
- B. **Determination of Effective Infiltration Area** – In order to take credit towards the infiltration requirements in NR 151.12(5)(c), the swale must meet the criteria outlined in this standard.

The effective infiltration area is the area that can be counted toward the requirements in NR 151.12(5)(c) and is calculated based on wetted perimeter of the vegetated infiltration swale at a flow depth of 1-inch multiplied by the length of vegetated infiltration swale.

$$\text{Effective Infiltration Area (ft}^2\text{)} = \frac{1}{2} * \text{Wetted Perimeter (ft) at 1-inch depth of flow} * \text{Length of Vegetated Infiltration Swale (ft)}$$

Details on the calculation methodology can be found in Attachment 1.

Vegetated infiltration swales receiving runoff from source areas outlined under NR 151.12(5)(c)(4) cannot be counted toward the effective infiltration area unless the water is effectively pre-treated prior to entering the swale. The area of the

¹ Words in the standard that are shown in italics are described in IX. Definitions. The words are italicized the first time they are used in the text.

pre-treatment device shall not be counted toward the effective infiltration area.

- C. **Pre-treatment** - As with other infiltration devices, vegetated infiltration swales require pretreatment of stormwater to remove sediment from source areas listed in NR 151.12 (5)(c)(4). Pretreatment can be accomplished through the use of practices such as grassed swales, detention basins, and vegetated filter strips.

If a pre-treatment swale is used, the length of pre-treatment shall be calculated based on the following equation with a minimum length of 200 feet:

$$L = v * HRT * 60s/m$$

Where:

L = Swale length in feet

v = Peak flow velocity in fps for 2-year, 24-hour design storm

HRT = Hydraulic residence time in minutes shall be either:

- 5-minutes for infiltration rate greater than or equal to 0.5 inches per hour (sandy loam).
- 8-minutes for infiltration rate less than 0.5 inches per hour (sandy loam).

Infiltration rates shall be determined in accordance with WDNR Conservation Practice Standard Code 1002, "Site Evaluation for Stormwater Infiltration."

If a pre-treatment swale is used, the area of the pre-treatment swale shall not be counted toward the effective infiltration area

- D. **Design Infiltration Rate** - The *design infiltration rate* for swale (K_{swale}) shall be $\frac{1}{2}$ the infiltration rate (K_{static}) determined in accordance with WDNR Conservation Practice Standard Code 1002, "Site Evaluation for Stormwater Infiltration." This is to account for the dynamic nature of a swale in which water is moving through the system rather than the static nature of the infiltration tests where the water is allowed to pond.

$$K_{swale} \text{ (inches/hr.)} = \frac{1}{2} K_{static}$$

- E. **Infiltration Volume Credit** - The volume of water infiltrated and the resulting pollutant reduction must be quantified through the use of an *approved model*.

- F. **Velocity and Depth Criteria** – A maximum velocity is based on providing adequate residence time for infiltration, allowing for a stable swale design, and preventing re-suspension and scour of sediment.

1. Peak flow velocity for the 2-year, 24-hour design storm shall not exceed 1.5 feet per second and have a maximum flow depth of 12-inches. For larger design storms greater than the 2-year, 24-hour, velocities shall be non-erosive.
2. Manning's roughness coefficients, "n", shall be selected consistent with the type of vegetation, mowing height, and depth of flow. Attachment 2 provides guidance on selection of Manning's n values for shallow depth of flows.

When calculating the infiltration volume, if the approved model does not vary Manning's n with the depth of flow, a default value of 0.30 can be used for the Manning's n provided the flow depth does not submerge the vegetation.
3. Ditch checks, if allowed by the regulatory authority, shall be installed as necessary to reduce velocities, extend detention time, or retain a design volume. Refer to Technical Standard 1062 Ditch Checks for design requirements.

If utilizing ditch checks, ensure that the design allows for no standing water within 24 hours after a rainfall / runoff event.

- G. **Swale Geometry Criteria**^a -

1. Swales shall have side slopes no steeper than three horizontal to one vertical (3:1) for trapezoidal channels and 4:1 for triangular shaped swales. Flatter side slopes are recommended to reduce erosion potential and increase infiltration area.
2. The bottom width of the swale is shape dependent but shall be a maximum of 6-feet. If widths greater than 6-feet are needed then length-wise dividers shall be

^a This standard does not set forth criteria for the analysis of site hydrology, system hydraulic analysis for large flows, or channel stability See Reference Section X.

employed such that the maximum width of any given cell is 6-feet.

3. The longitudinal slope of the swale shall be between 1% and 4%.

H. **Vegetation** - Swales shall be planted with native vegetation or seeded with turf grass. A specific planting guide shall be prepared for each project. A companion (cover) crop may be necessary for establishing native vegetation. Depending on location of the swale, vegetation shall be selected that is tolerant of road salt and wetness. A planting medium that can support the selected vegetation shall be installed.

To maintain vegetation, infiltration swales shall be designed to have no standing water within 24 hours after a rainfall / runoff event.

Sod shall not be used. Sod does not establish roots as well as seed and often has muck soils not conducive to infiltration.

I. **Site Layout** - The site layout shall consider features such as location of infiltration swales relative to buildings, water supply wells, lot boundaries, and existing or proposed public rights-of-way.

1. Where a swale accepts runoff from more than one property, it shall be located in a legally established drainage easement granting access for maintenance, or in a public right-of-way.
2. Swales shall not be *hydraulically connected* to foundations or cause negative impacts to structures.
3. Swales shall not be located such that overflow from the swale could cause flooding of existing or proposed buildings during storms with recurrence intervals commensurate with the degree of hazard.

J. **Construction Criteria** - Following excavation, exclude vehicles and heavy equipment from entering the infiltration swale area to prevent compaction. To minimize or mitigate the effects of compaction during construction and to control soil erosion associated with construction:

1. **Compaction Mitigation** – The effects of compaction shall be mitigated using the following methods:

- a. Incorporate soil additives consisting of two inches of *compost* and two inches of topsoil.
- b. The compost shall be incorporated into the existing soil using a chisel plow or rotary device with the capability of reaching to 12 inches below the existing surface.
- c. The compost component shall meet Wisconsin Department of Natural Resources Specifications S100 Compost.

2. A construction erosion control plan shall be prepared. Prior to compaction mitigation and final grading of the infiltration swale, the drainage area to the swale shall have proper erosion controls in place to prevent sediment from entering the swale, and the lot(s) adjacent to the swale shall be stabilized. Any sediment entering the swale during construction shall be removed after the tributary area is stabilized. The infiltration swale itself shall also be stabilized following compaction mitigation and final grading. Stabilize swale prior to receiving runoff. For stabilization design criteria for tributary areas and the swale itself, refer to WDNR Conservation Practice Standards Channel Erosion Mat (1053), Mulching for Construction Sites (1054) and Seeding for Construction Site Erosion Control (1059).

VI. Considerations

These additional factors are set forth to enhance the use of this practice, or to address special cases that may arise in the implementation of the practice.

- A. Swales should be designed to have hydraulic capacities that meet applicable local government or state agency requirements for conveying runoff from large storms, and they should also be designed as part of a *major stormwater management system* as defined in this standard.
- B. The number and length of swales is dictated by the topography and amounts of runoff from the contributing area. For a given depth of flow, the width of a swale depends on the rate and velocity of flow through the swale. Minimum length and width requirements to achieve infiltration and water quality improvements may limit the use of a swale at some sites.
- C. The establishment of deep-rooted vegetation will enhance infiltration.

- D. Swale geometry should attempt to maximize the infiltrative surface but avoid convergence of flows that may result in erosion or gullies.
- E. Excavation hoes, light equipment with turf-type tires, marsh equipment, or wide-track loaders should be used to construct swales.
- F. Public education is recommended to inform local residents of the swale's purpose and to discourage dumping of leaves or parking on the edge of the swale.
- G. This infiltration device is not suitable for treating chlorides. Chloride use on source areas tributary to a swale can be reduced or eliminated by minimizing the amount of compound used, using alternative de-icers or using clean sand.

VII. Plans and Specifications

Plans and specifications shall be prepared in accordance with the criteria of this standard and shall describe the requirements for applying the practice to achieve its intended use. Plans shall specify the materials, construction processes, locations, size and elevations of all components of the practice to allow for certification of construction upon completion.

VIII. Operation and Maintenance

- A. An operation and maintenance plan for the specific swales shall be prepared. The responsible party shall be identified.
- B. Consider prevention of off-street parking or other activities that may cause rutting or soil compaction in the swale.
- C. Pesticides and fertilizer shall be used in moderation, and only if needed to establish or maintain dense vegetation.
- D. Vegetation shall be mowed or cut such that the proper design height is maintained. To take credit for potential phosphorus removal by the swale, mowed/cut vegetation must be removed as part of routine maintenance.
- E. Sediment shall be removed when infiltration rates are impeded or sediment reaches a height of 2-inches. Minimize serious disturbance of the vegetation and avoid compaction of the soil in the swale during the sediment removal process. After sediment removal, repair any damaged or eroded

areas. Fill any eroded areas with topsoil and reseed.

- F. If during construction or maintenance erosion becomes severe enough to prevent establishment of vegetation, additional erosion control measures shall be taken. Refer to WDNR Conservation Practice Standards 1053, 1054, and 1059 for further guidance.
- G. When maintenance is required the infiltration capacity of the swale shall be restored. Vegetation shall be reestablished following compaction mitigation.
- H. Annual inspections shall be made to detect and remedy nuisance conditions such as mosquitoes, weeds, woody growth and trash dumping.

IX. Definitions

Approved Model (V.E.): A computer model with an infiltration component that adequately accounts for the hydraulic nature of swales and that has been approved by the applicable regulatory authority. Examples include SLAMM, P-8, and RECARGA.

Compost (J.1.): A mixture that consists largely of aerobically decayed organic waste.

Design Infiltration Rate (V.D.): A velocity, based on soil structure and texture, at which precipitation or runoff enters and moves into or through soil. The design rate is used to size an infiltration device or system. Rates are selected to be minimal rates for the different types of soils. Selection of minimal rates will provide a robust design and maximize the longevity of the device.

Effective Infiltration Area (V.B.): The area of the infiltration system that is used to infiltrate runoff. Does not include the area used for pretreatment.

Hydraulically Connected (I.): Two entities are considered to be hydraulically connected if a surface or subsurface link exists between the two exist such that water is transmitted from one entity to the other.

Low -density Residential Land Use (III): Single-family houses on lots with areas of 19,000 square feet or greater.

Major Stormwater Management System (VI.A): The stormwater management facilities that are intended to convey and/or store runoff in excess of the capacity of the minor system. The minor system is designed to

function frequently to prevent nuisance flooding and is sized for a smaller storm than the major system, generally a 10-year storm. The major system is primarily designed to function infrequently to prevent flooding of buildings and ponding of runoff in locations where it could promote harmful infiltration and inflow to sanitary sewers. The major system is generally designed for a 100-year storm. It consists of the components of the minor system, such as overland flow, swales, curbs and gutters, storm sewers, and detention/retention basins, and also includes the entire roadway cross section and associated swales or overland flow paths ultimately discharging to receiving streams.

Medium-density Residential Land Use (III): Single-family houses on lots with areas ranging from 10,900 to 18,999 square feet.

X. References^b

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Washington State Department of Ecology, *Stormwater Management Manual for the Puget Sound Basin (The Technical Manual)*, Washington State Department of Ecology, February 1992

^b Methods for hydraulic analysis and channel stability are well documented and are; therefore; not included in this standard.. For more background, see open channel hydraulics texts such as Open Channel Hydraulics, Chow, 1988; Open Channel Flow, Henderson, 1966; and Open-Channel Hydraulics, French, 1985.

Attachment 1: Calculation of Effective Infiltration Area Vegetated Infiltration Swales (1005)

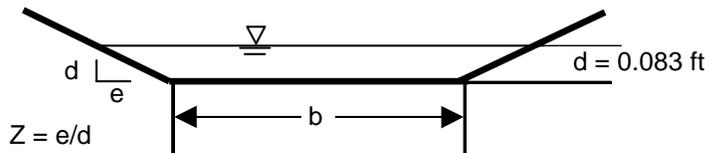
The effective infiltration area as outlined in NR 151 is defined as the area of the infiltration system that is used to infiltrate runoff and does not include the area used for site access, berms, or pretreatment. The area of infiltration is calculated for a swale based on the wetted perimeter of the swale. However, the swale is rarely flowing at capacity under the numerous smaller rainfall events that dominate an average year, so the wetted perimeter at the design capacity of the swale (typically a 2-year or 10-year storm) is not appropriate. The effective infiltration area is determined as follows:

$$\text{Effective Infiltration Area (ft}^2\text{)} = \frac{1}{2} * \text{Wetted Perimeter (ft)} * \text{Length of Vegetated Infiltration Swale (ft)}$$

For the purpose of NR 151, the wetted perimeter will be calculated at a 1-inch (0.083 feet) depth of flow. The 1-inch depth of flow is intended to simulate the water quality volume. The multiplication by 1/2 is to account for the reduced infiltration rate in swales compared to other practices such as infiltration basins where water is allowed to pond. Wetted perimeter can be calculated as outlined below.

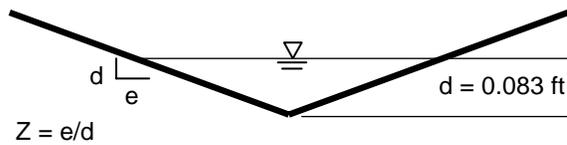
Trapezoidal Channel Cross section:

Wetted Perimeter, p
$p = b + 2d (Z^2 + 1)^{1/2}$



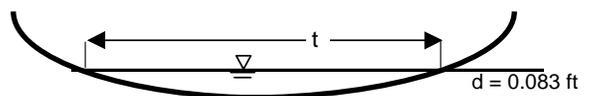
Triangular Channel Cross section:

Wetted Perimeter, p
$p = 2d (Z^2 + 1)^{1/2}$



Parabolic Channel Cross section

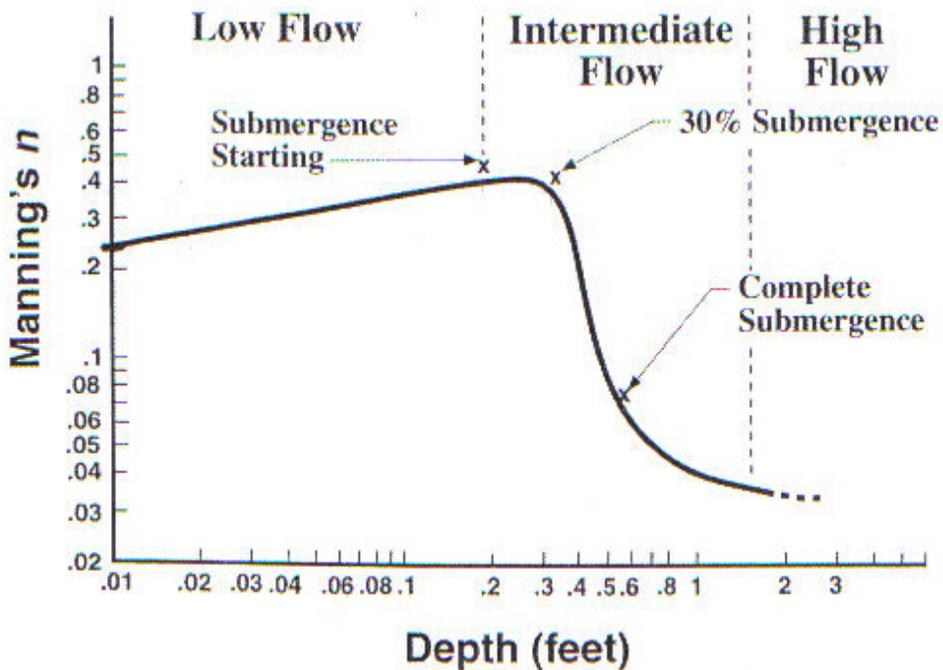
Wetted Perimeter, p	Top Width of flow, t	Cross-sectional Area of flow, a
$p = t + (8 d^2) / (3 t)$	$t = a / (0.67 d)$	$a = 2/3 (t d)$



Attachment 2: Calculation of Manning's n Values Vegetated Infiltration Swales (1005)

Manning's n, the roughness coefficient, varies with the type and height of vegetation and the depth of flow. Typically, vegetation creates a significant flow resistance at lower flows when the grass remains erect and the water surface is below the top of the vegetation. Vegetated infiltration swales are designed to convey runoff from smaller more frequent storm events and thus at lower flow depths than typically encountered using the typical design-storm methodology (i.e. 2-year or 10-year storm). Figure 1 shows a variation of Manning's n with flow depth. Figure 1 assumes dense turf type vegetation mowed to a height of 4-inches. This is consistent with published values that show a Manning's n value of 0.030 for short turf grass under higher flow conditions (Chow, 1959) in which the vegetation is submerged.

Figure 1: Manning's n Under Different Flow Depths



Source: Minton 2005

Research has shown that Manning's n can be related to the product of the flow velocity and the hydraulic radius. This relationship is further dependent again on the type and height of vegetation. Currently, data does not exist for native prairie vegetation.