G3691-3

The
Wisconsin
Storm Water
MANUAL

Infiltration Basins and Trenches

Infiltration structures provide runoff volume control because they detain the runoff, slowly releasing the water into the groundwater. When peak reduction is desired, storage is increased, and the outflow riser elevation and the release rate are controlled. By diverting a significant portion of the runoff into the soil, infiltration structures can recharge groundwater, augment low flows and preserve base flow in streams, protect downstream aquatic biota and help minimize erosion and flooding downstream. Infiltration structures are reasonably cost effective if they are located on permeable soils with the depth to groundwater and bedrock well below the bottom of the basin.

Pretreatment and infiltration basins and trenches should be designed for relatively frequent rainfall. Larger flows should bypass the infiltration basin by a separate pipe or overflow device. Studies of infiltration basin performance suggest that limiting the flow that basins receive and avoiding overload conditions will improve long term operation.

Pretreatment

The performance of infiltration structures depends on how much storm water is diverted to groundwater. Their ability to capture nutrients depends on the soil and the basin's detention volume. Infiltration structures should include provisions for pretreating the water to prevent premature clogging of the basin. The combination of pretreatment and infiltration removes the greatest amount of pollutants.

Significant disadvantages of infiltration structures are their potential for groundwater contamination and their tendency to lose effectiveness over time due to clogging. While metals and many nutrients are captured in the first foot or two of soil, some soluble pollutants travel much greater distances. Groundwater contamination problems can be minimized by pretreatment or diversion of some runoff water from the infiltration structure. Pretreatment can remove sediment, oil and grease, and is necessary to increase the life of the infiltration area by reducing surface clogging.

Recommended pretreatment options include presettling basins, sand filters, sediment sumps, biofiltration swales and vegetative filter strips. When contaminants cannot be removed by pretreatment, surface runoff should be diverted from the infiltration structure. Runoff sources that cause particular problems for infiltration basins include, but are not limited to:

- Sites with high pesticide or pathogen levels
- Construction site runoff due to high sediment loads
- Manufacturing and industrial sites because of high concentrations of soluble toxicants and soluble heavy metals
- Snowmelt runoff because of salts
- Combined sewer system overflows because of sewage contamination

Runoff from residential areas (rooftops and lawns) is considered the least polluted and, therefore, the safest runoff for discharge to infiltration structures and eventual return to groundwater. An economic advantage to infiltration of runoff from low to medium density residential areas is that it requires less pretreatment prior to infiltration, provided care has been taken in the use of fertilizers and pesticides on lawns.

Pollutant removal

Table 1 shows estimates of typical pollutant removal rates for basins and trenches based on field tests of similarly designed, rapid infiltration, land treatment systems built for wastewater applications.

Table 1. Typical pollutant removal rates for infiltration basins and trenches

Pollutant	Removal rate
Sediment	99%
Total P	65–75%
Total N	60–70%
Trace Metals	95–99%
BOD	90%
Bacteria	98%

(Schueler, 1987)

This information assumes pretreatment and infiltration of 90% of the design flow. Soluble and fine particulate pollutants are removed in the soil through sorption, precipitation, trapping, straining and bacterial degradation or transformation. Trace metals are usually captured with the sediment in the first one or two feet of soil. Phosphorus removal can be as high as 70–99% given optimum physical and chemical soil characteristics. Nitrification is essentially complete in the soil, and nitrate removal depends on the presence of a carbon source to encourage denitrification. With effective denitrification, nitrogen removal can be as high as 80% (US-EPA, 1981).

An infiltration basin or trench will not increase temperature or reduce dissolved oxygen concentrations in storm water because flows are not held for long periods of time, and the water cools as it travels through the soil. However, nitrate, chloride, gasoline and other heavier, less-volatile, very-soluble hydrocarbons may eventually migrate into the groundwater.

Recommended storm water quality monitoring to evaluate potential groundwater contamination

Urban runoff contaminants with the potential to adversely affect groundwater

- Nutrients (especially nitrates)
- Salts (especially chloride)
- Volatile organic compounds, or VOCs. If these are expected in the runoff (such as that from manufacturing, industrial or vehicle service areas) screen for VOCs with purgeable organic carbon analyses
- Pathogens (especially enteroviruses, along with other pathogens such as Pseudomonas aeruginosa, Shigella, and pathogenic protozoa)
- Bromide and total organic carbon (estimates disinfection byproduct generation potential if disinfection by either chlorination or ozone is being considered.)
- Pesticides, in both filterable and total sample components (especially lindane and chlordane)
- Other organics, in both filterable and total sample components (especially 1,3 dichlorobenzene, pyrene, fluoranthene, benzo(a)anthracene, bis(2-ethylhexyl) phthalate, pentachlorophenol, and phenanthrene)
- Heavy metals, in both filterable and total sample components (especially chromium, lead, nickel and zinc).

Urban runoff compounds with the potential to adversely affect infiltration operations

- Sodium, calcium and magnesium (allows calculation of the sodium adsorption ratio to predict clogging of clay soils).
- Suspended solids (to determine the need for sedimentation pretreatment to prevent clogging).

(Pitt, R., et al. 1994)

Site selection, proper design and construction, and a sustained maintenance program are critical to the life of infiltration structures. These structures may have fairly high failure rates and require frequent maintenance. A study of 12 infiltration basins in Maryland showed that all had failed within the first two years of operation (Galli, 1992). Reasons for failure were listed as:

- Poor site selection (especially separation distance to groundwater)
- Poor soil textures
- Clogging of the soil by contaminants in the runoff
- Compaction of the soil

None of the basins had built-in pretreatment systems. In addition, internal sediment loading from poorly stabilized side slopes was as much a problem as external sediment loading. Proper site selection, stabilization of the contributing area, and pretreatment to remove pollutants that can clog the infiltration structure bed will effectively minimize these problems.

Infiltration basins

An infiltration basin is an open impoundment created either by excavation or embankment with a flat, densely vegetated floor. It is situated on permeable soils and temporarily stores and allows a designated runoff volume to infiltrate the soil. Constructing an infiltration basin is an effective management practice for converting surface runoff to groundwater recharge and for removing many nutrients and pollutants.

Planning guidelines

Feasibility study

Building an infiltration basin is an appropriate management practice when baseflow recharge or reduction of thermal impacts is a high priority for the watershed. Since soil properties are critical factors in designing infiltration basins, a preliminary screening of potential sites is necessary. The feasibility study should begin by examining any available local, county or U.S. Natural Resources Conservation Service (NRCS) soil surveys and maps. These reports will identify areas where the soil textures may meet the infiltration requirements, and may also provide information on the depth to groundwater and bedrock. If information is available, check for slopes in the area and to see if the area contains fill material. This information should be used only for screening, since some surveys are dated and land practices might have resulted in erosion or compaction of soils. Also, such surveys do not provide the detail needed to site infiltration practices.

Soils with shallow groundwater or fractured bedrock, sandy soils with low adsorption rates and high infiltration rates, areas with high loadings of soluble pollutants, and areas where the groundwater is a critical resource that must be protected from contamination usually are not suitable for infiltration structures (Davenport, 1991). In areas where groundwater quality impacts are especially critical, consideration should be given to a greater than five-foot separation distance from the bottom of the basin and high groundwater to minimize the effect of seepage from the pond.

A hydrogeologic investigation should be conducted before designing an infiltration basin to determine the:

- Depth to high groundwater
- Groundwater flow direction and rate of flow
- Vertical and horizontal gradients
- Presence and extent of perched groundwater
- Soil descriptions
- In-field infiltration rates
- Depth to bedrock
- Type of bedrock.

Delineation of the saturated and unsaturated soil zones is important because these zones use different pollutant removal mechanisms. The critical factor in protection of the groundwater is how well the unsaturated zone removes pollutants and prevents their migration through the soil.

Soil properties

Once a potential site is located, soil borings or test pits are required to confirm preliminary findings. For design purposes, the engineer must determine site-specific soil properties by laboratory and field tests at the proposed location. In-field investigation at the basin site should be completed to depths sufficient to document that the distance to high groundwater and bedrock is at least five feet from the bottom of the basin or greater if dictated by local ordinance. Investigators in the Maryland study of 12 infiltration basins suggested a separation distance of at least 15 feet (Galli, 1992). While a 15-foot minimum distance is probably not justified in many cases, it illustrates the importance of adequate separation to protect groundwater quality.

An in-field, double-ring infiltrometer test is the preferred method for gathering information on site suitability (ASTM, 1994). The test must be done at the depth of the proposed infiltration basin bottom, which may not be the current ground surface. The number of tests conducted depends on the site's size and uniformity. A minimum of three tests is recommended. To ensure that the basin is not undersized, design infiltration rates must be conservative. Over the years the infiltration rate may decrease, but pretreatment and a conservative design will help extend the basin's life.

Soil permeabilities must be at least 0.5 in/hr and at most 5.0 in/hr in the field. This restricts application to soils of Hydrologic Soil Group B, and some soils in groups A and C. Hydrologic soil groupings are available from the NRCS (USDA-SCS, 1975). Type C soils will provide very slow infiltration but maximum treatment due to the higher percent fines and greater adsorptive capacity.

Soils with more than 30% clay are not suitable because of their low infiltration rates; soils with 40% silt and clay are prone to frost heave and should not be used. High clay soils have a tendency to develop vertical fractures and channels, bypassing treatment of the storm water. Type A soils may provide rapid infiltration but minimal treatment, since sand acts like a sieve and does not bind pollutants.

In the interest of providing treatment, the soils should contain at least 5% fines. This increases the adsorptive capability of the soil. Soils of choice include loamy sand, sandy loam, loam and silt loam. The existence of an impermeable layer in the soil profile may interfere with optimum basin operation. In some cases this layer may be removed during construction, but often such areas must be avoided.

Other considerations

Infiltration basins are commonly used for drainage areas of 5–50 acres with land slopes of less than 20%. Steep slopes can cause water leakage in the lower levels and may reduce infiltration rates due to lateral movement. The basin itself should be located more than 50 feet from slopes greater than 20%. Basins must not be located on fill materials or on soils compacted by construction. Compaction reduces the infiltration rate and may make fill materials unstable. Slippage may occur along the interface of fill and in-situ soils which could be further aggravated by saturated conditions.

Design guidelines

Infiltration basins are usually irregularly shaped, elongated impoundments with vegetated or riprapped inflow and outflow areas. The typical depth of a basin is 3–12 ft, with the maximum depth dependent on the soil type. Basins should be designed to hold and allow infiltration of the water in a dead storage zone, to hold and infiltrate water from the design storm, and to safely pass through, or preferably bypass, flows up to the level produced by the 24-hour, 100-year storm.

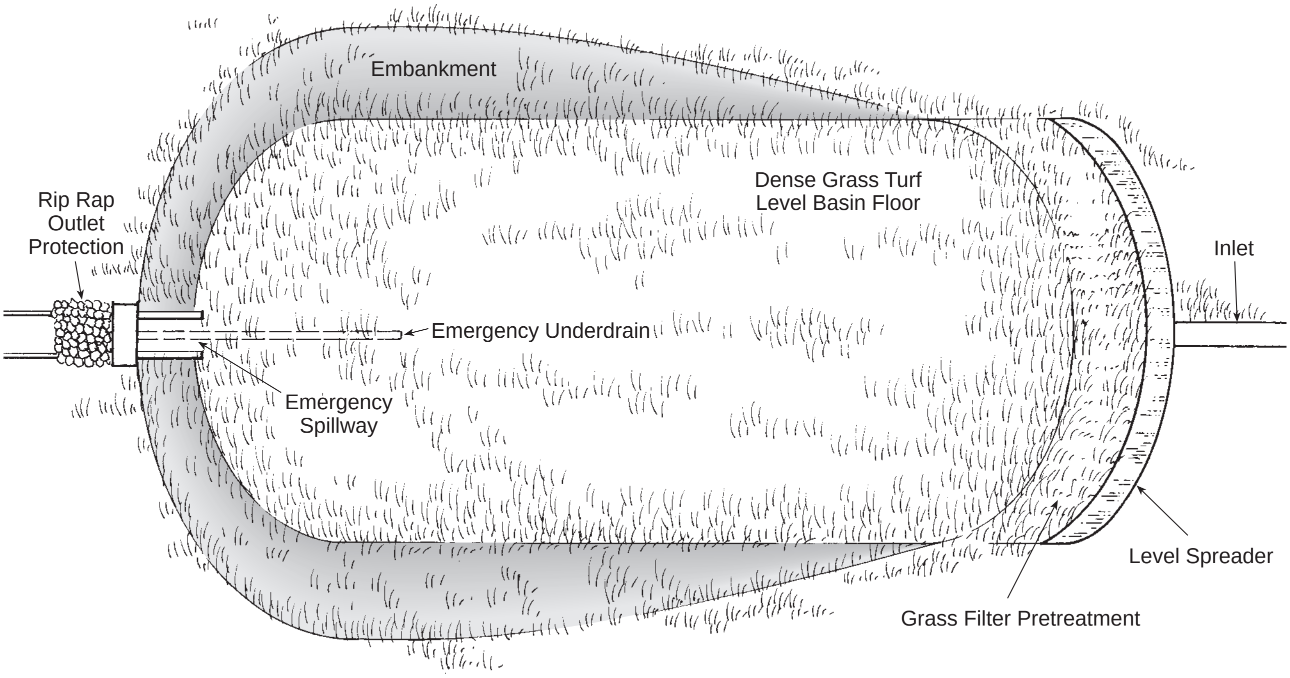
From the standpoint of water quality, the optimum infiltration basin is an off-line impoundment in soils with an adequate infiltration rate. The grass cover and underlying soils must have sufficient organic matter and root systems to bind, decompose and trap pollutants. Finally, such a basin must be large enough to remain aerobic. In some cases, a facility may be built in combination with another treatment structure.

A common configuration for an infiltration facility is shown in figure 1. The detention basin can precede or be a part of the infiltration basin. Pretreatment to remove sediments that might clog the infiltration bed is critical to maintaining infiltration. Sediment is usually trapped either in a separate pretreatment structure or in a sediment bay of the infiltration basin. A riser in the combined infiltration / detention basin drains flows above the water quality volume.

Infiltration basins are not sediment control devices. The size and location of the infiltration basin must be adjusted to provide for removal of most particulates in a pretreatment unit. Pretreatment is a requirement for all infiltration basins that receive any storm water containing particulate matter or pollutants that might clog the infiltration structure or leach to groundwater. Some modification or downsizing of the infiltration structure may be expected when a unit capable of full treatment is used for pretreatment only.

Access to the pretreatment facility is necessary for frequent cleaning and removal of sediment build-up. If oil and grease are contained in the runoff from the watershed, an oil and grit separator, oil and water separator, floating skimmer or filter should be a pretreat-

Figure 1. Schematic of an infiltration basin.



ment component. To encourage uniform use of the infiltration basin and to prevent channeling on the basin floor, a grass filter or level spreader should be used to create sheet flow across the basin floor.

Effective infiltration basin design will include the following features.

Site evaluation

A minimum of three soil borings should be conducted at each basin site with more required (at a rate of one per 5,000 square feet of infiltrating surface area) for larger basins or for basins with varying soil types. The soil tests must establish a minimum infiltration rate of 0.5 in/hr, a maximum of 5.0 in/hr, and a minimum separation distance to bedrock and seasonal high groundwater of 5 feet from the proposed bottom of the basin. Separation distances to seasonal high groundwater should be confirmed by looking at the static water elevation in the soil boring, changes in the soil moisture content, and soil mottling. The design infiltration rate should be based on in-field infiltration testing. With the inconsistency of soil testing and permeabilities, a safety factor of at least two is recommended for determining basin size. It is recommended that the engineer use half the measured infiltration rate as the design infiltration rate (WA-DOE, 1992). The more conservative the design rate, the longer the life of the infiltration basin. The Washington State storm water design manual recommends a minimum cation exchange capacity (CEC) of 5 milliequivalent/100 grams of dry soil to provide adequate treatment levels.

Since storm water can carry pollutants similar to pollutants found in wastewater or hazardous waste, minimum setback distances from private water supply wells must be 100 feet, and 1,200 feet for public wells. If it is desirable to locate a facility within 1,200 feet of a public water supply, a study of the groundwater flow in the area should be made to determine the site's pollution potential. In Wisconsin, all new municipal water supply wells (installed after April 1992) must have a Wellhead Protection Plan that governs separation distances to the well. In some cases this distance may be greater than 1,200 feet. Basins must be located at least 10 feet downslope and 100 feet upslope from building foundations to prevent the foundations from settling and basements from flooding. The engineer should consider an even more conservative setback distance if large quantities of storm water are reaching the subsoil.

Infiltration structures must not be located in the floodplain and must meet all other applicable state and federal requirements. Embankments may be subject to dam construction regulations.

Watershed size

Infiltration basins designed solely for water quality control are appropriate for watershed areas of 5 to 25 acres. For combination basins (detention and infiltration), up to 50 acres is typical, although larger areas may be considered. If more than half of a given watershed is impervious, an infiltration basin might not be an appropriate application, because the amount of flow will be large and the space required for infiltration might not be available.

Infiltration time

The water quality infiltration volume must be equal to the runoff volume from the design-level storm plus the rainfall on the structure. To ensure adequate treatment of the stormwater in the soil for groundwater protection, infiltration should be completed in not less than 6 hours or more than 48 to 72 hours, depending on soil and vegetative conditions. This will help ensure adequate treatment of the storm water for groundwater protection, protect vegetation and avoid the possibility of anaerobic soil conditions. Effective operation includes both treatment and movement of the water out of the basin in time for the next storm. A load and rest operation will encourage aerobic soil conditions. Infiltration times as great as 72 hours may be used for infiltration basins on some hydrologic B soils and moisture tolerant vegetation.

Basin shape

All basins must be flat on the bottom with stable side slopes. Consider side slopes of 4:1 or flatter for ease of maintenance and safety. The basin shape can be any configuration that blends with the surrounding landscape. Groundwater mounding, or a raising of the water table elevation just under the basin floor, is common in infiltration systems. Groundwater mounding can restrict the amount of downward flow, reducing the infiltration rate. Less groundwater mounding will occur under a basin with a long, narrow configuration.

Vegetation

Plant a water-tolerant, fast-germinating, hardy grass on the bottom and side slopes. Mow to maintain a dense turf. Mow when the surface is dry to avoid rutting and compaction. Generally, fertilizers should not be applied. If fertilization appears necessary, conduct a soil test and apply fertilizer to match the nutrient needs indicated by the test.

Basin inlets

Erosion protection is required at the inlet. Riprap aprons or other energy dissipators help to reduce velocities and spread flows. A 20-foot filter strip with a level spreader will also provide sheet flow. The inlet should discharge at the basin floor.

Winter operation

When the soil freezes, infiltration may cease. While infiltration may occur under some frozen conditions, the basin cannot be depended upon to treat rain or snowmelt during the winter since the system will often be frozen.

Enhancing pollutant removal

An infiltration basin is designed in part to treat runoff to improve water quality. A number of design features will enhance pollutant removal rates.

- Large, shallow basins are more effective than small, deep configurations.
- Deep tilling after construction helps prevent compaction.
- Riprap at the inlet and outlet channels stabilizes velocities and spreads flows.
- During construction, flows from the watershed should be diverted around the proposed treatment site.
- The basin floor should be as flat as possible to ensure uniform ponding over the surface.
- All upland soils and the slopes on the sidewalls must be stable before the basin is placed in operation. Slopes of 4:1 or flatter should be considered for maintenance and safety considerations.
- The grass should not be cut below 3 inches or it will not survive flooding.
- Storm water should not be introduced into the basin until a dense, water tolerant grass sod is established in the basin.
- Hydrologic soil group B soils provide the optimum infiltration rates and treatment capabilities.
- A load and rest operation is important in maintaining the aerobic condition of the soil.
- Pretreatment will make the basin last longer and be more effective.
- While the basin can provide both quantity and quality control in one practice, separate, interconnected practices are more effective.
- The design should include an emergency drain to facilitate maintenance.
- Compactions during and after construction must be avoided. The basin should not be used for parking or as a recreational facility.

Basin buffer

A vegetative screen around the basin to restrict views from nearby properties may improve the aesthetics of the site and public acceptance of the facility. Mowing the basin regularly will prevent woody vegetation growth that might migrate in from the buffer area to the infiltration basin. Mechanical rather than chemical removal is recommended for undesirable plant invasion at the site. Removing the clippings will remove some nutrients from the basin; however, nutrients from clippings usually are quite small compared to the total load.

Access

A public right-of-way around the basin is necessary for maintenance access. The access route should not be constructed over the emergency spillway. Access is a topic that must be considered while the facility is being sited.

Safety

Fencing around the basin can serve as a safety feature if the intent is to deny public access to the basin. If the area around the facility has a recreational use, considerations should be given to construction of a safety shelf for times when the basin is flooded. Steep slopes should be avoided. Signs should warn against deep water or health risks. Provide an emergency spillway to safely bypass or move high flows through the basin to prevent structural failure. A spill or accident that results in harmful chemicals being flushed into an infiltration basin is a serious problem and could affect the basin’s ability to treat and/or infiltrate storm water. If the basin serves an area where a spill could occur, it is critical to control the spill at its source to prevent it from draining to the storm water treatment facility.

Storage

Storage volume for runoff from design storms and for precipitation directly on the basin should be calculated. Storage depth will be limited by the infiltration characteristics of the soil as described in the section on design calculations.

Design calculations

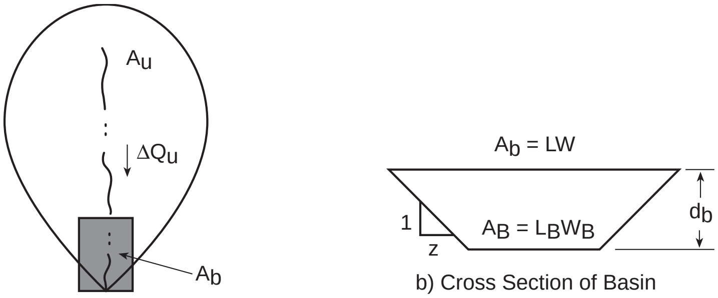
The size of the basin depends on the infiltration rate of the soil and on the volume of runoff from the tributary area. A rough estimate for determining the basin area is that the infiltration surface area should be greater than half of the contributing impervious surface (Stahre and Urbonas, 1990). To determine the design dimensions of the basin, a hydrologic analysis of the contributing watershed must be conducted to predict the runoff from the design storm using small storm hydrology. The storage volume can then be calculated given the infiltration rate for the basin area and the desired infiltration time.

Some designers take into account the infiltration rate through the sides of the basin at $1/3$ the rate through the bottom. In most cases, the volume infiltrated through the sides is a relatively small portion of the total water infiltrated and can be neglected.

The following design calculations assume infiltration only through the bottom surface area. This provides an additional design safety factor. For illustration purposes, a trapezoidal infiltration basin is assumed. Three design relationships must be considered:

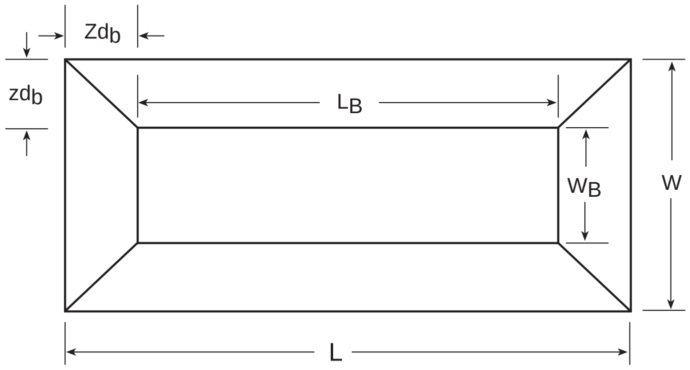
1. Storage volume
2. Maximum basin depth
3. Basin volume.

Figure 2. Schematic of basin nonmenclature



a) Plan View of Site

b) Cross Section of Basin



c) Top View of Basin

Storage volume

The average end-area equation can be used to estimate the storage volume of the infiltration basin. For a rectangular basin, as illustrated in figure 2, this equation can be written as:

$$V_W = ((A_B + A_b)/2)(d) = (LW + L_B W_B)/2)(d)$$

where V_W = the basin volume

A_b = the water surface area at the design depth

A_B = the bottom surface area

d = design depth

L = the top basin length

W = the top basin width

$L_B = L - 2zd$ = the bottom length

$W_B = W - 2zd$ = the bottom width

z = horizontal component of the side slopes.

Maximum basin depth

The maximum depth (d_m) can be determined by multiplying the design infiltration rate (f) times the maximum allowed ponding time (T_p).

$$d_m = fT_p$$

Basin volume

The required capacity may be determined as the design runoff from the upland area plus direct precipitation on the basin surface minus the infiltration from the basin during the runoff event. The volume equation can then be written as:

$$V_W = QA_u + PA_b - fTA_B$$

where A_u = area of the upland watershed

Q = the upland runoff depth

P = the design precipitation

T = the effective runoff time.

T is a small number (commonly 1 to 2 hours based on engineering judgement) since it reflects only the time when the inflow exceeds the outflow (in this case outflow by infiltration into the soil). In fact, fTA_b may be so small in relation to the amount of runoff and rainfall that it can be eliminated from the equation without significant error.

Additional design considerations

Basin design based on the three equations on page 7 must also consider site conditions and owner preferences. For example, if area is limited, it is desirable to maximize the basin's depth. If sufficient area is available a smaller design depth may be desirable to reduce ponding time, improve safety or reduce cost. A long, narrow basin generally improves infiltration, and may influence the selection of a length to width ratio. The side slope steepness will depend on maintenance practices and safety issues.

The maximum depth should be calculated and serve as the upper limit for the design depth. The required storage volume must also be calculated from the design storm and the watershed characteristics. The side slope steepness must be selected. The length or width of the basin is set and the equation solved for the remaining dimension. Double-check that L and W are greater than $2Zd_b$, and that the bottom elevation of the basin is at least 5 feet above seasonal high groundwater. Adjust L, W and d until the desired basis configuration is achieved.

Example

To see how these calculations and considerations would be applied in a real-world situation, assume the following conditions for the design of a rectangular infiltration basin:

Design rainfall = 1 inch

Design runoff depth from contributing area = 0.5 inch

Runoff contributing area = 3 acres

Runoff time = 2 hours

Design infiltration rate = 0.75 inches per hour

Maximum infiltration time = 48 hours

Owner prefers that basin be not more than 2 feet deep, that the length not exceed 100 feet, and the side slopes to be 4:1 for safety and maintenance.

What should be the width of the basin?

Step 1. Check to make sure the 2-ft depth is less than the maximum depth for the basin.

$d_m = fT_p$ = 0.75 in/hr x 48 hrs = 36 inches = 3 feet

Therefore, 2-ft design depth is within acceptable limits.

Step 2. Calculate storage volume required.

$V_W = QA_u + PA_b - fTA_b$ = 0.5 in x 3 acres + 1 in x A_b - 0.75 in/hr x 2 hr x A_b

In this example it is assumed that the area of the basin receiving rainfall and the infiltration area are the same. For shallow depths this approximation will not cause design problems. For deep basins a distinction should be made between the two areas.

Step 3. Determine the required dimensions for the infiltration area.

$V_W = ((LW + L_BW_B)/2) \times d$

$QA_u + PA_b - fTAb = ((LW + L_BW_B)/2) \times d$

For d = 2 ft, L = 100 ft, and z = 4 the above expression may be written as:

0.5 inch x 3 acres x 43,560 square feet/acre x 0.083 feet/inch + 1 inch x W x 100 feet x 0.083 feet/inch - 0.75 inch/hour x 2 hour x W x 100 feet x 0.083 feet/inch = ((100 x W) + (84 x (W-16))/2) x 2 W = 37 feet

Construction guidelines

Infiltration basins usually fail for one or more of the following reasons:

- Premature clogging
- A design infiltration rate greater than the actual infiltration rates
- Because the basin site was used for construction site erosion control
- Soil was compacted during construction
- The upland soils or basin walls were not stabilized with vegetation, and sediment was delivered to the basin.

Note that all these failures result from improper planning, design or construction.

If the infiltration basin is to operate effectively, special care must be taken before construction begins. The development plan sheets should list the proper construction sequence so that the basin site is protected during construction and not placed in operation until upland areas are stabilized. All heavy equipment, sediment and runoff must be diverted away from the basin site during construction in the watershed. To avoid soil compaction, the site intended for the basin should not be used while construction proceeds in the watershed. If a temporary basin for construction site erosion control is to be used, it should be located outside the perimeter of the final infiltration basin. If the basin site must be used, all accumulated sediment plus two additional feet should be excavated to ensure that the surface is not clogged.

Excavate the basin during dry periods, using only light earth-moving equipment or over-sized tires. If feasible, excavate from the sides so all equipment will be kept off the basin's floor. Avoid using bulldozers and end loaders. The site should be deep-tilled and leveled after excavation. Engineering standards, such as NRCS *Technical Guide Practice 378* for embankment construction, must be followed. (USDA-SCS, 1987)

Seed vegetation shortly after construction (USDA-SCS *Technical Guide Practice 342*) for a low-maintenance, fast-germinating, stoloniferous grass. Non-grass species such as sedges and forbes may also be acceptable. Highly invasive plants such as reed canary grass or creeping red fescues are not recommended. Plant species native to Wisconsin are biologically and aesthetically more valuable than non-native species and may provide a longer-lived, stable system for infiltration. The following native species are recommended (Trochlell, 1994):

- Canada bluejoint grass (*Calamagrostis canadensis*)
- Prairie cordgrass (*Spartina pectinata*)
- Woolgrass (*Scirpus cyprinus*)
- Rice cutgrass (*Leersia oryzoides*)

Native species should be purchased from reputable plant nurseries that have collected the seeds from the local region (within 100 miles) when possible.

During early growth, check the vegetation and reseed or irrigate as necessary. If a dense mat does not develop, consider a different seed mixture. A dense grass mat has two primary benefits for the infiltration basin: 1) the roots will help maintain infiltration capacity; and 2) the grass will hold the sediment and decrease resuspension during high inflow velocities.

Native plantings should not be fertilized because fertilizers tend to encourage weeds. Also, it might take up to 2 years to establish native grasses; during this time the plants might appear sparse while their root systems develop. Planting a top-cover of annual rye or oats is a good way to give native grasses time to grow while maintaining ground cover. Fertilization, if needed for non-native grasses, must be carefully controlled to minimize phosphorus loading to the receiving stream or lake or nitrate leaching to groundwater.

Maintenance

An infiltration basin is a high maintenance facility. A storm water management plan must include maintenance, inspection, access and enforcement of the basin's operating requirements or the system will fail (Lindsey et al., 1992). Identify the party responsible for maintenance early in the planning process, and provide funding for routine and non-routine maintenance. An operation and maintenance manual should be written before the basin is put into operation. Following construction, inspect the basin monthly, as well as after every major storm, to see if the basin is draining within the design time limits. If it is not, evaluate and repair the facility in accordance with the installation performance bond or construction agreement with the contractor.

Inspect annually or seminannally for settling, cracking, erosion, leakage, tree growth on the embankment, the condition of the inlet and outlet channels, sediment accumulation in the basin, and the health and density of the grass turf. Always check a facility after large storms to correct any damage high flows may have caused. Eroded areas should be revegetated immediately.

The basin should be mowed twice a year to prevent woody growth, stimulate grass growth and enhance nutrient removal. Do not mow when the ground is wet to avoid compacting the soil and matting the grass. Also remove any trash or debris at this time. If the surrounding site has recreational value, more frequent mowing will be necessary.

If the soils are marginal for infiltration and the basin is prone to ponding, periodic tilling and reseeding might be needed. If this is the case, till and revegetate in the late summer.

Over time, an infiltration basin is likely to accumulate sediment and the infiltration rate might decrease. Deep tilling, regrading and replanting will help restore the original infiltration rate. When the basin is thoroughly dry, remove the top cracked layer of sediment, and till and grade the remaining soil. Some basins have a 6- to 12-inch layer of sand on the bottom or a filter fabric to facilitate sediment removal.

In a vegetated basin, sedimentation must not occur faster than the grass can grow through it. If it does, the pretreatment system should be re-evaluated. Maintenance of the pretreatment facility, including sediment removal, oil and grease skimming and mowing of the grass filter strip must occur on a regular schedule to prevent these materials from washing into the infiltration basin. An emergency drain built in the basin will allow for easier maintenance. In general, the lifetime of a pretreatment or inlet/bypass structure might be shorter than the lifetime of the infiltration basin itself, and will require occasional structural or equipment repair or replacement.

Infiltration trenches

An infiltration trench is an excavation, 2–10 feet deep, often lined with a sand base, a protective layer of filter fabric on the sides, and filled with coarse stone aggregate (figure 3). The empty spaces between the stone provide temporary storage of runoff, with the runoff making its final infiltration through the undisturbed subsoils at the bottom of the trench. The top layer of the trench may be a stone, gabion, sand or topsoil with a vegetative cover with or without an inlet. Sometimes trenches are located beneath grass swales. Infiltration trenches are appropriate in small drainage areas such as residential lots, commercial areas, parking lots and open space.

Place infiltration trenches on permeable soils, with a 5-foot separation distance from the bottom of the aggregate to seasonal high groundwater and / or bedrock. If they are sited correctly, infiltration trenches can recharge groundwater, control runoff volume and augment low flow for headwater streams. Depending on their size, these trenches are able to divert up to 90% of the annual runoff volume into the soil.

Trenches are most effective when used for storm water runoff from small to moderately sized storms. Trenches can help prevent localized streambank erosion on small streams by reducing the runoff rate, but they are generally too small to have a significant impact on larger streams. An additional advantage of infiltration trenches is that they fit easily into non-utilized areas, perimeters and margins of a developing site or in-fill development. The disadvantages of trenches are similar to infiltration basins—they clog easily, can be a threat to groundwater and require regular maintenance.

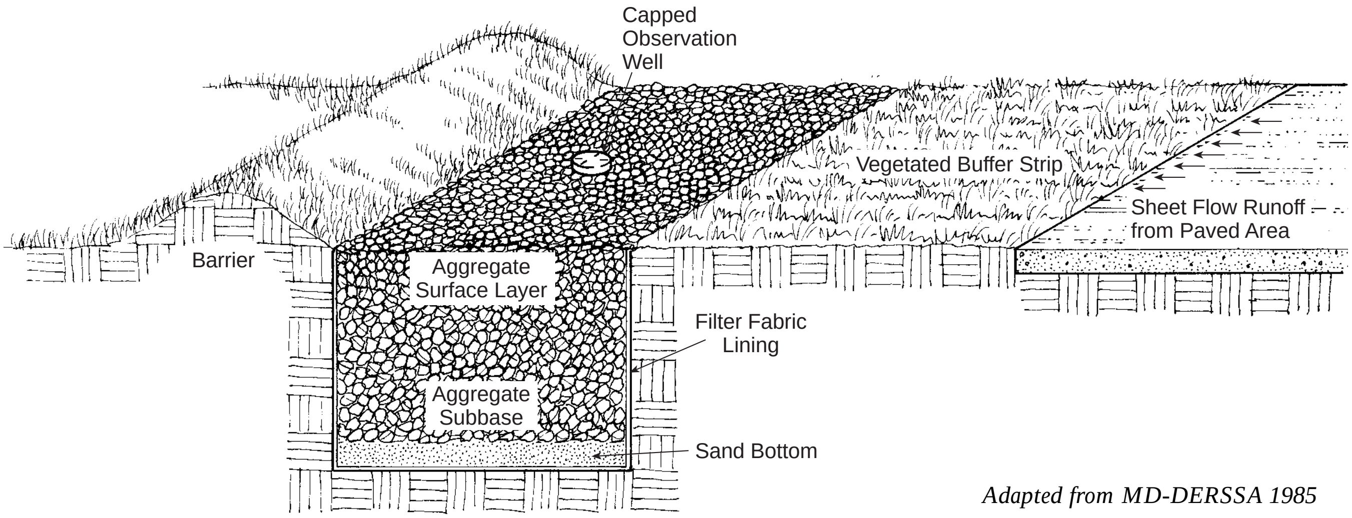
Infiltration trenches return runoff to the groundwater. They can be sized to provide volume and / or water quality control by storing and infiltrating all flows equal to or less than the design water quality volume. Higher flows will pass through or be diverted from the system via an overflow channel.

Planning guidelines

In determining the suitability of a given site for an infiltration trench, several factors must be considered, including separation distances, the size of the tributary area and the physical constraints of the site. Because site suitability is a critical issue in locating trenches, the soils in the area should be screened for adequate permeability, slope, depth to groundwater and depth to bedrock. Local soils maps and survey information are available from NRCS. Actual infiltration rates must be determined through field tests.

Trenches should not be located where the watershed slopes are 20% or greater. Slopes less than 5% are preferred. A trench should be located at least 100 feet from a private water supply well and 1,200 feet from a public well. Some municipalities might have established wellhead protection areas using a calculated fixed radius greater than 1,200 feet. No infiltration structure can be constructed within a wellhead protection area. Contact local officials for other restrictions on locating near public wells.

Figure 3. Typical trench configuration



Adapted from MD-DERSSA 1985

Trenches should be at least 10 feet down-slope and 100 feet up-slope from a building foundation to reduce the potential for wet basements and saturated soils around structures. Designers should consider a more conservative building separation if the amount of water coming to the trench is substantial. Trenches generally serve developments smaller than 5 acres but could be considered for 5- to 15-acre sites. In the case of large tributary areas, the larger area may be divided into subareas with individual trenches.

Design guidelines

Soils investigation

A hydrogeologic investigation should be conducted prior to design of the infiltration trench to determine the following:

- Depth to high groundwater
- Groundwater flow rate and direction
- Vertical and horizontal gradients
- Presence and extent of perched groundwater
- Soil descriptions
- In-field infiltration rates
- Depth to bedrock
- Type of bedrock

Hydrologic Soil Groups A, B and some C soils can be considered for an infiltration trench if the measured infiltration rate is at least 0.5 in / hr and less than 5 in / hr. Hydrologic soil groupings are available from the Natural Resources Conservation Service (USDA-SCS, 1975). This includes some sands, loamy sand, sandy loam, loam and silty loam. Sand with at least 5% silt or clay is necessary to provide treatment in the soil. A maximum infiltration rate of 5.0 in / hr is also recommended to protect the groundwater from pollutants which may not be filtered by soils with rapid permeability. Soils with more than 30% clay or 40% combined silt and clay may not be suitable, due to frost heave. The bottom of the trench must be below the frost line for successful operation in the winter.

Clay lenses or other restrictive layers below the bottom of the trench will reduce infiltration rates unless excavated. Trenches must not be located on fill material due to its unstable condition and the potential for movement at the interface between the fill and in-situ soils.

Design storm

Local regulations should be consulted to determine the design storm return period and duration. Generally, a storm that occurs relatively frequently is used as the model for trench design. In Wisconsin, capacity to handle the runoff from a 1.5-inch storm is recommended (WI-DNR, 1997). Additional storage may be needed if peak flow control is to be included in the design. A trench can be built in combination with another facility to meet water quality and quantity requirements.

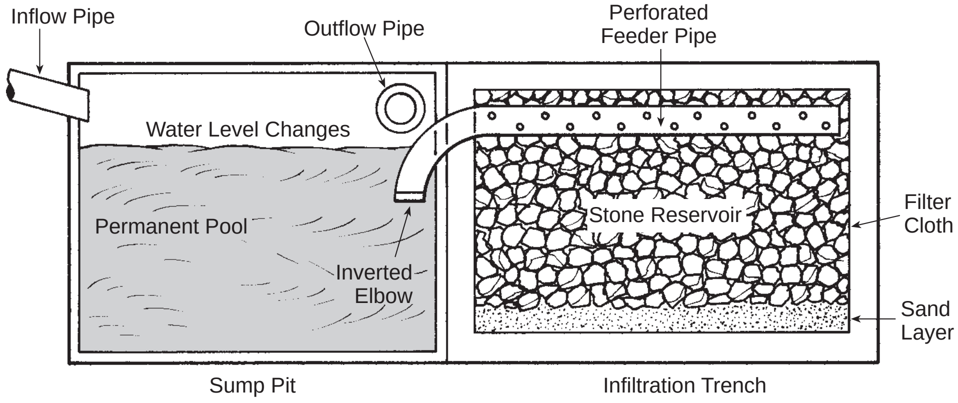
Alternatively, an outlet elevation can be set to store and allow infiltration of flows less than or equal to the water quality volume, while using the outlet for slow release of flows above that volume.

Pretreatment

To prevent clogging, sediment, oil, grease, floatable organic materials and solids capable of settling must be removed before the runoff enters the infiltration trench. If the trench has a surface inlet, the system must be designed to capture sediment either through a vegetated filter strip, grass swale or mechanical sediment trap such as a sump pit (figure 4). A sand filter system or oil / grit separator should be considered for oil and grease removal.

In a Maryland study, trenches with sump pit pretreatment lasted longer than trenches with grass filter strips for pretreatment (Galli, 1992). The sump

Figure 4. A sump pit



Adapted from Galli, 1992

pit, shown in Figure 4, captures coarse-grained, inorganic sediment, some fines, and large organic matter. Oil and grease can be trapped if the intake elbow to the trench is located about one foot below the permanent pool elevation of the sump pit. Scouring and resuspension of solids will occur if the sump pit is not cleaned frequently.

Depth to groundwater and bedrock

Soil borings or test pits are needed to establish that the depth to seasonally high groundwater and bedrock is at least 5 feet below the proposed bottom of the trench. The bottom of the trench is defined as the surface at the top of the native soil where infiltration will occur. The 5-foot separation distance exists to allow treatment of the storm water as it travels through the soil. This reduces the potential for groundwater contamination, and prevents long term soil saturation due to groundwater mounding at the bottom of the trench.

Storage volume

The design storage volume depends on the runoff from the design storm, the infiltration rate for the soil, and the porosity of the rock storage. A stone aggregate of clean, washed gravel, 1.5 to 3.0 inches in diameter, has a porosity of 30–40%. Since infiltration tests are the least precise measure used in the design calculations, the infiltration trench should be oversized to account for the uncertainty. Use half the measured infiltration rate to provide a safety factor of two for sizing (WA-DOE, 1992).

Configuration

Infiltration trenches can be constructed in a variety of configurations, with a rectangular cross-section being the most common. The primary variation is the method by which the runoff is introduced into the trench. Infiltration trenches can be built as surface trenches into which water either infiltrates through a layer of topsoil about one foot thick or they can be built directly into the rock fill. They may also have an inlet grate for overland flow of runoff into the trench. Finally, there can be underground inlets that allow runoff to reach the trench through a sub-surface pipe. Underground systems are not visible at the surface other than for the observation wells. Underground systems, with storm water entering through a piping system must not be designed as injection wells as defined by EPA regulations.

The bottom slope of a trench should be flat across its length and width to evenly distribute flows and encourage uniform infiltration through the bottom. A series of trenches rather than one long trench will provide a better flow pattern. This configuration also reduces the rate of clogging, since the first trench will receive and trap the heaviest sediment loads. Easy maintenance access must also be built into the design.

At one time it was common practice to install drywells or french drains for disposal of storm water. While these practices have some characteristics in common with infiltration trenches, they must be avoided. There is a concern that some trenches using perforated piping to direct storm water underground meet the U.S. Environmental Protection Agency (EPA) definition of a Class V injection well. Injection wells for disposal of pollutants are prohibited under NR 812.05 Wis. Adm Code. A trench could be considered an injection well if it is deeper than it is wide.

Drain times and trench depth

The trench should completely drain in 48 to 72 hours. The depth of water in the trench that will allow drainage within 72 hours is dictated by the soil's infiltration rate. Trenches are usually less than 10 feet deep, and depths less than 8 feet allow for easier maintenance. Trench dimensions can be varied to accommodate depth limitations.

Filter fabric

The infiltration trench should be lined on the sides and top by an appropriate geotextile fabric. The top layer of fabric is located 1 foot below the top of the trench and serves to prevent surface sediment from passing into the stone aggregate. Since this top layer serves as a sediment barrier, it will need to be replaced more frequently and should be readily separable from the side sections.

Filter fabric can be placed on the bottom of the trench, but it is better to use a 6-inch layer of clean, washed sand. Clogging often occurs at the filter fabric layer, and sand restricts downward flow less than fabric. The sand also encourages drainage and prevents compaction of the native soil while the stone aggregate is added.

Aggregate material

The stone aggregate in the trench should be washed, bank-run gravel. This material is least likely to cause clogging by dust from the stone, which can fill the void spaces or settle to the bottom. If a crushed rock is used, it must be thoroughly washed to minimize dust problems.

Overflow

A diversion path rather than an emergency spillway should be used to pass excess flows over the trench to a waterway. The path must be constructed to prevent erosion from concentrated, uncontrolled flows.

Observation wells

Trenches must have observation wells to determine how quickly the trench drains after a storm and to observe the sediment build-up in the bottom. The well should be constructed as indicated in figure 5. The observation well should be a perforated PVC pipe, 4- to 6- inches in diameter, extending to the bottom of the trench where it is connected to a foot plate. Cap and lock it to prevent vandalism or tampering.

Vegetation

If the trench is covered with native top soils and planted in grass it will be similar to any other greenway in a developed area. If not covered, the stone aggregate will be visible. A vegetated buffer strip 20–25 feet wide on either side of the trench will help protect it from sediment build-up. The buffer should be stabilized prior to placing the trench in operation. The trench and buffer vegetation should blend in with the surrounding area; native grasses are preferable if compatible with the area.

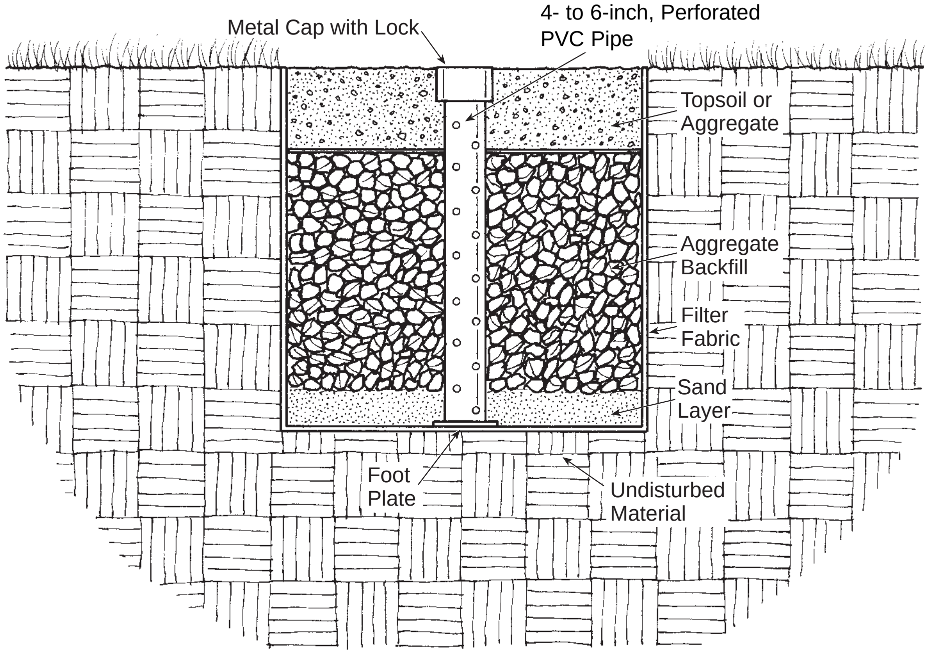
Winter operation

Infiltration trenches can be operated in the winter if the bottom of the trench lies below the frost line. Freezing is not as likely if a subsurface pipe brings the storm water into the stone aggregate. If the trench has a surface inlet grate, it must be kept free of ice and snow to operate effectively. Trenches covered with top soil may not operate efficiently during the winter because frozen soils tend to reduce infiltration.

Safety

In general, trenches are not likely to pose a physical threat to the public and do not need to be fenced. The primary public safety concern is ponding from an improperly draining trench, which could create a hazard, habitat for mosquitoes or some other nuisance condition. Inlet areas and observation wells are accessible and need to be locked to protect against vandalism.

Figure 5. Observation well construction



Adapted from MD-DERSSA, 1985

Design calculations

Depth

The infiltration rate and the porosity of the rock determine the maximum allowable depth (d_{max})(in):

$d_{max} = fT_s/n$

where f = design infiltration rate (in/hr)

T_s = maximum storage time (hours)

n = porosity

For a given soil and stone aggregate, the maximum depth of the trench can be determined. This depth may also be affected by groundwater or bedrock elevation at the site, which might require a shallower trench than the d_{max} calculated from this equation.

Volume

The volume of the trench is based on the water quality volume, plus the volume of rain that falls on the trench, minus the infiltration volume from the bottom of the trench during the runoff period.

$V_w = QA_u + PA_t - fTA_t$

Where A_u = the upland area

A_t = the trench area in the horizontal plane

Q = the water quality runoff depth

P = rainfall

T = the time the inflow is greater than the outflow and the trench fills (generally less than 2 hours)

f = the design infiltration rate

V_w = required trench capacity

The trench storage volume can also be written as the ratio of the volume of water that must be stored over the porosity (V_w/n). It is also the depth (ft) times the surface area (ft^2) or ($d_t A_t$). Combining these two equations leaves

$V_t = V_w/n = d_t A_t$ or

$V_w = d_t A_t n$

Enhancing pollutant removal

Following the basic guidelines will help ensure design of a successful infiltration trench. Close adherence to a few key points provides a greater margin of safety and enhances pollutant removal.

- Surface area. Broader, shallower trenches reduce the risk of clogging by spreading the flow over a larger area for infiltration, and increase the separation distance to groundwater.
- Subsoils. The objective of the trench is both to treat pollutants in the storm water and to move water through the underlying soils. A balance of pollutant-removing qualities, along with the infiltration potential of the soil, is necessary for successful operation. The clay and organic content of the soil determines the amount of sorption and bacterial degradation of pollutants. The texture of the soil largely determines movement. Fine textured soils, such as clays, optimize sorption while sandy soils optimize movement. Intermediate textured soils provide the best combination of treatment and movement.
- Drain time. A 48- to 72-hour drain time is appropriate for design. For marginal (finer textured) soils, a 48-hour drain time will build in a sufficient safety factor. Marginal soils tend to clog faster than sandier soils, so a more conservative design will prolong the facility's life. For adequate pollutant removal, the minimum recommended drain time is 6 hours.
- Maintenance. If the trench drains in less than 6 hours or more than 72 hours after a significant storm, remedial measures will be needed. These measures could include reworking the trench, rototilling or removing and replacing a clogged filter fabric. Close observation of the trench during start-up and regular inspection thereafter is necessary to determine how well it is operating.

Equating the two previous equations:

$d_t A_t n = Q A_u + P A_t - fTA_t$

The surface area will then equal:

$A_t = Q A_u /(n_r d_t - P + fT)$

The factor d_t can be based on the maximum allowable depth, or a depth chosen to match site restrictions. Trenches are often used in small, restrictive sites so the length (L_t) or width (W_t) might already be decided. The trench configuration then depends on the remaining dimensions.

$L_t = (Q A_u)/ ((n_r d_t - P + fT) W_t)$

Additional storage will be needed if the infiltration trench is to be used for peak shaving. Use TR-55 or another acceptable method to estimate this volume.

Construction guidelines

Premature clogging is often a result of poor construction techniques or improper control of sediment during construction. The following guidelines will help minimize the problem.

- Before any construction begins, divert storm water runoff and construction traffic away from the site of the trench.
- Trench construction should not begin until the upland site is stabilized or runoff diverted. The trench site should not be used as part of the construction site erosion control plan.

- Excavate the trench using a backhoe or trencher with oversized tires to prevent compaction, following the U.S. Occupational Safety and Health Administration (OSHA) Trench Safety Code for acceptable construction practice. Do not use bulldozers or front-end loaders. Each trench section should be dug, filled with rock and covered before a new section is dug. Start only a portion of the trench that can be completed in one work day. Place excavated materials at least 10 feet away from the edge of the excavation to prevent backsliding or cave-ins.
- After the trench is dug, roughen or scarify the bottom and sides to restore infiltration capacity that may have been compromised by rainfall or smearing of the soil surface during digging.
- Cover the trench bottom with 6 inches of clean sand. Place a geotextile filter fabric on the sides and one foot below the top of the trench, overlapping it at the seams to prevent soil fines from entering the stone aggregate. The fabric should be flush with the walls. If voids have occurred during excavation, fill these spaces with soil. Trim tree roots flush with the sides to prevent tearing or puncture while the fabric is placed. Select a suitable filter fabric, since they vary significantly in permeability and strength. Filter fabrics must be able to retain the soil at the site while allowing water flow without clogging. Non-woven geotextile fabrics retain more soil fines, are less prone to clogging and have very good permeability characteristics as compared to woven geotextiles. The filter fabric should meet the requirement in Natural Resources Conservation Service Material Specification 592 Geotextile Table 1 or 2, Class 1, with an equivalent opening size of 30 for non-woven and 50 for woven fabric. Filter fabric is susceptible to ultraviolet degradation, so take care to minimize exposure during construction.
- Install an observation well to locate the site and provide access for collection of operational data.
- Clean, washed, 1.5- to 3.0-inch stone aggregate should be placed in the trench in lifts and lightly compacted with a plate compactor. Using unwashed stone will result in premature clogging from the stone's heavy sediment load. If the stone aggregate is contaminated by sediment during construction, remove and replace it with clean aggregate.
- Place filter fabric horizontally over the aggregate approximately 1 foot below the surface, and then cover it with permeable top soils or with larger aggregate. The top filter cloth will capture sediment from surface runoff and reduce the chance of clogging at the infiltrating surface layer.
- A 20- to 25- foot vegetative buffer around the trench will intercept surface runoff, protect the structure and prolong its life.
- Vehicle traffic must be kept off the trench before, during and after construction to prevent compaction.
- Sediment control after construction is critical. Sodding the upland areas and the vegetative buffer will speed up the stabilization of the area. If upland areas are seeded, the area must be inspected regularly until it is well established. (Refer to NRCS Technical Guide #342 *Practice Standards and Specifications for Critical Area Planting.)*

Maintenance

Trenches are prone to clogging by sediment, oil, grease and debris. Keeping the pretreatment facility in good condition will reduce maintenance and improve the trench's operation. Before construction, determine responsibility for maintenance of the system and set aside funds for both routine and non-routine work. A maintenance manual should be developed and reviewed by both the party responsible for maintenance and the owner of the infiltration structure.

Monitor the trench frequently in the first year to determine how well the system is performing. If there are problems, continue monitoring on a more frequent basis. In the absence of problems, an annual observation with drain times recorded will be sufficient.

Sediment will naturally build up in the pretreatment portion of the trench. A sump pit used as pretreatment will need frequent cleaning. Other pretreatment facilies must be monitored for sediment build-up and cleaned as appropriate. Sediment can also build up on the top foot of the trench itself. Estimate the level of sediment clogging by digging a small hole down to the filter fabric.

Maintain the buffer and surface vegetation by reseeding bare spots and mowing as often as dictated by the aesthetic needs of the area. The grass should not be cut shorter than 3 inches to maintain filter performance. Mowing will also prevent undesirable woody growth on the surface of the trench.

Even well-designed, constructed and maintained trenches will lose effectiveness over time. The maintenance plan should include non-routine maintenance such as rehabilitation of a trench after it clogs.

Surface trenches often clog at the top. This can be corrected by stripping off the top layer, replacing the clogged filter fabric, and replacing the top foot of aggregate or soil. Underground-loading trenches typically clog at the bottom filter fabric or sand layer because storm water flows are piped directly to the aggregate layer. Correcting a clogged, underground-loading filter can be very costly, because it requires removal of all aggregate, tilling the bottom and replacing the top layers.

References

Barfield, B. J., R. C. Warner and C. T. Haan. 1983. Applied Hydrology and Sedimentology for Disturbed Areas, Oklahoma Technical Press, Oklahoma, 1983.

Leopold, L.B., 1968. Hydrology of Urban Land Planning—a Guidebook on the Hydrologic Effects of Urban Land Use. USGS Circular 554.

MD-DERSSA. 1991. The Prince George's County Stormwater Management Design Manual. Department of Environmental Resource, Sediment and Stormwater Administration. Baltimore.

MD-DERSSA. 1985. Inspector's Guidelines Manual for Stormwater Management Infiltration Practices. Maryland Department of the Environment, Sediment and Storm Water Administration. Baltimore.

Pitt, R., 1994. Stormwater Wet Detention Pond Design for Water Quality Benefits. From Designing Stormwater Quality Management Practices. Engineering Professional Development. University of Wisconsin-Extension. Madison.

Schueler, T. R. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMP's. Metropolitan Washington Council of Governments. Washington. D. C.

Stahre, P. and B. Urbanos. 1990. Stormwater Detention: For Drainage, Water Quality, and CSO Management. Prentice Hall. Englewood Cliffs, NJ.

US-EPA. 1983. Results of the Nationwide Urban Runoff Program. Water Planning Division Vol.1 NTIS # PB84-185552.

USDA-SCS. 1986. Urban Hydrology for Small Watersheds. Tech Release 55. Soil Conservation Service. Washington. DC.

USDA-SCS. 1985. Field Office Technical Guide—Dam, Floodwater Retarding. Sec. 402. WI-NRCS. Madison.

USDA-SCS. 1987. Field Office Technical Guide—Pond. Sec. 378. WI-NRCS. Madison.

USDA-SCS. 1987. Ponds. Wis. Tech. Guide. Natural Resources Conservation Service. Madison.

USDA-SCS. 1993. Field Office Technical Guide—Lined Waterway or Outlet. Sec. 468. WI-NRCS. Madison.

W.W. Walker, Jr. 1987. Design Calculations for Wet Detention Ponds. Prepared for St. Paul Water Utility. St. Paul, MN.

WA-DOE. 1992. Stormwater Management Manual for the Puget Sound Basin. Department of Ecology. Olympia.

WI-DNR 1997. Personal Communication.

Wolman, M.G. and Schick, A.P., 1967. Effect of Construction on Fluvial Sediment: Urban and Suburban Areas of Maryland. Water Resources Research 3:451-462.

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