3. BMP DESCRIPTIONS

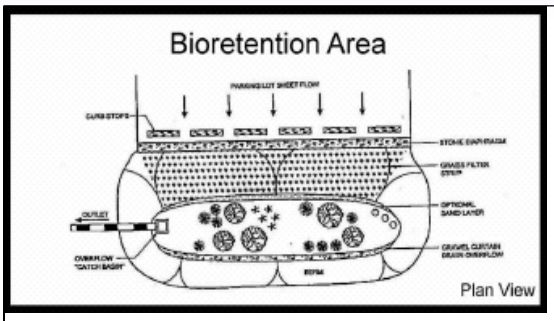
The following pages provide descriptions of nineteen BMPs that can be implemented in Lincoln for effective stormwater management. As has been described in these guidelines, these descriptions provide basic information to provide ideas of how and what practices can be used. This guide presents several practical site design and drainage Best Management Practices for developments in the City of Lincoln. Most of the BMPs apply to residential, commercial and industrial developments. All of them are effective in reducing the quantity and improving the quality of stormwater runoff. The following information is presented for each of the recommended BMP approaches:

- Description
- Effectiveness
- Advantages and Disadvantages
- Implementation Considerations
- Cost
- Main Design Components

The following BMP descriptions are provided:

- Bioretention Area
- Wet Detention (Ponds and Lakes)
- Dry Detention Basin
- Filter Strip
- Grassed Swale
- Green Roof
- Infiltration Basin
- Infiltration Planter
- Infiltration Trench
- Natural/Native Vegetation
- Pervious Pavement
- Rain Barrels and Cisterns
- Rain Garden
- Soil Management
- Stormwater Treatment Train
- Subsurface Storage
- Urban Forest
- Vegetated Bioswale
- Wetland

3.1 Bioretention Area

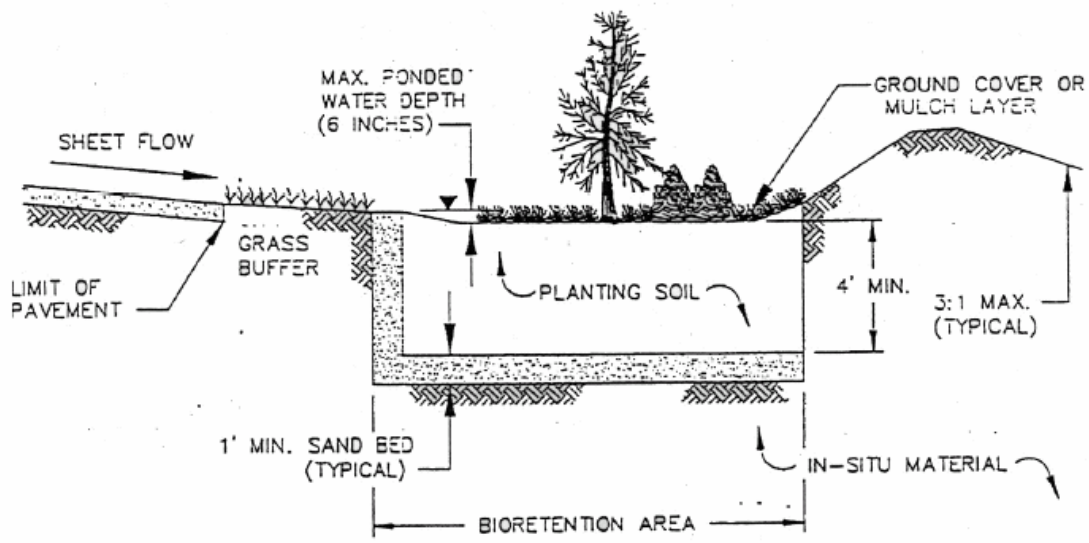


Bioretention Area at 63rd Street and Platte. Lincoln

Description	Bioretention areas are soil- and plant-based stormwater management practices that filter runoff from developed sites by mimicking natural vegetated systems; these naturally control hydrology through infiltration and evapotranspiration. A typical application for a bioretention area is to infiltrate and treat surface runoff from parking lots, in which the bioretention area may consist of a recessed, slotted-curb parking island. Bioretention areas are small vegetated depressions into which surface water is diverted. Stormwater flows into the bioretention area, ponds on the surface, and gradually infiltrates into the soil bed. Pollutants are removed by processes that include adsorption, filtration, volatilization, ion exchange, and decomposition. Treated water is allowed to infiltrate into the surrounding soil, or is collected by an underdrain system and discharged to the stormwater system or directly to receiving waters.
Effectiveness	Improves water quality. According to estimates, bioretention areas have the potential to remove 90 percent of suspended solids, 65 percent of phosphorous, 50 percent of nitrogen, and 80 percent of metals from stormwater.
Advantages	• Provides effective stormwater flood control by slowing down runoff and increasing water infiltration into the soil. • Minimally consumes land. • Reduces site runoff. • Provides aesthetic enhancement. • Increases groundwater recharge. • Can be used as a stormwater retrofit.
Disadvantages	• Should not be installed until the entire contributing drainage area has been stabilized. • Requires proper plant selection and maintenance.

Disadvantages	• Susceptible to clogging by sediment, may require pretreatment. • Treats a relatively small drainage area.
Implementation Considerations	• Pine mulch and wood chips are not acceptable in the mulch layer because they are displaced during storm events. • Provide clean-out pipes on the underdrain to facilitate cleaning. • Incorporate a uniform mix of the planting soil during construction so that stormwater infiltrates evenly and does not create preferential pathways. • Minimize compaction of the base and planting soil as compaction results in design failure because it reduces infiltration. • Vegetation for the bioretention area should consist of native plant species with hydric tolerances. Do not place woody vegetation near the stormwater inflow location. Plant trees primarily along the perimeter of the bioretention area. • Water should remain on site for less than 48 hours to prevent mosquito breeding.
Cost	Typical costs can be from $0.50 to over $1.00 per cubic foot (USEPA, 1999). Cost range reflects economies of scale in designing detention basins.
Main Design Components	• The surface area of the bioretention system should be between 5 to 10 percent of the impervious area it is draining. • Bioretention areas are best applied to areas with relatively shallow slopes (usually about 5 percent or less). • Bioretention areas can be applied in almost any soils as runoff percolates through a made soil bed and is returned to the stormwater system. It is also possible to design a bioretention system like an infiltration system. • Bioretention should be separated from the water table to ensure that the groundwater does not intersect with the bottom of the bioretention area. A typical bioretention system involves the following components: • Pretreatment: Because bioretention areas are susceptible to clogging from sediments, pretreatment to remove suspended sediments is recommended. • Ponding area: A ponding area provides surface storage of stormwater before it filters through the soil bed. • Organic mulch layer: This layer protects the soil layer from erosion, retains moisture to sustain plants, and provides a medium for biological activity to decompose organic pollutants and adsorb inorganic pollutants. • Planting soil bed: Provides water and nutrients to support plant life in the bioretention system. Stormwater filters through the planting soil bed where pollutants are removed by sorption and biodegradation. • Under-drain: An under-drain is a perforated pipe in a gravel bed installed along the bottom of a sand bed to collect and filter stormwater directing it to an outflow or stormwater systems.

Main Design Components	• Provide redundant overflow structures to convey flow from large storms to the storm drain system. • Plants: Plants are an important component of a bioretention system. They remove water through transpiration, remove pollutants, enhance soil biological activity, and promote water infiltration. The plant species selected should replicate a native forest or grassland system, and be able to survive flooded conditions.



Example of the Basic Lay-Out of a Bioretention System

3.2 Wet Detention (Ponds and Lakes)

Kennedy and Rockford Drive Pond, Lincoln

Description	Wet detention is typically a constructed pond or lake, or it may be a pond or lake incorporated into a stormwater treatment system. They are generally considered "end-of-the-pipe" BMPs. Lakes and ponds are standing bodies of water defined in terms of capacity, effective height, and effective storage. Lakes are larger than ponds, generally with total storage greater than 50 acre-feet, and the product of the effective height (in feet) and effective storage (in acre-feet) greater than 1,250. All developments involving lake and pond construction must conform to local, state, and federal regulations. Preserve undisturbed ponds and lakes during development according to federal and state laws and regulations. Preserving the natural drainage system, instead of replacing it with stormwater systems or concrete channels, reduces the potential for downstream degradation because of increased runoff. Ponds can be modified to increase their storage capacity and enhanced with vegetation to increase their water-quality treatment effectiveness. The primary pollutant removal mechanism in wet detention is sedimentation, with a moderate to high potential for removing metals, nutrients, and organics. Since wet ponds have the capability of removing soluble pollutants, they are suitable for sites where nutrient or pollutant loads are expected to be high.
Effectiveness	Efficient pollutant removal. Studies indicate that wet detention ponds can remove up to 50 to 90 percent of suspended solids, 30 to 90 percent of total phosphorous, 40 to 80 percent of soluble nutrients, 40 to 80 percent of metals, and 20 to 40 percent of biochemical compounds.

Advantages	• Improve runoff control, including reductions of overall runoff from adjacent sites with proper design. • Create wildlife habitat. • Encourage community recreation facilities. • Aesthetically pleasing. • May increase property values. Requires significantly less expense for maintenance if natural vegetation is used along the banks.
Disadvantages	• Reduces the amount of developable land. • May require approval from dam safety authorities. • May require maintenance at regular intervals to remove sediments deposited in the base of the pool. • If not designed or maintained correctly, could become a mosquito vector.
Implementation Considerations	• Vegetation on dams may need to be monitored and invasive species removed. • May require cleaning and removal of debris after major storm events. • May require removal of accumulated sediment. • May require monitoring and maintenance of erosion in the emergency spillway during establishment of vegetation.
Cost	Variable, depending on the size and amount of construction needed to create the lake or pond. Typical costs can be from $0.50 to over $1.00 per cubic foot (USEPA, 1999). Cost range reflects economies of scale based on the size of the pond, as well as pre-existing conditions.
Main Design Components	• Storage volume: The City of Lincoln has established requirements in the Drainage Criteria Manual. • Sediment control: A sediment forebay is highly recommended. • An emergency spillway should be included in the basin design. • The basin should include a low-flow drain to assist in maintenance of the detention area. • Sediment storage life span. Typically, in most areas, the 25-year sediment volume is calculated for the pond. • Pond or lake depth: An average pool depth of 3 to 6 feet is recommended. Depths greater than 10 feet may have thermal stratification and anoxic conditions. Depths less than 3 feet increase sediment resuspension, water temperature, and algal blooms. • Flow path: Maximize the flowpath length between the inlet and outlet. The length to width ratio should be at least 3:1.

Main Design Components	• Slopes: Side slopes of a permanent pool should not be greater than 3:1. Flatter slopes minimize bank erosion. Slopes leading to the pool should be less than 3:1. • Inlet points should be designed with energy dissipaters to reduce inflow velocity.

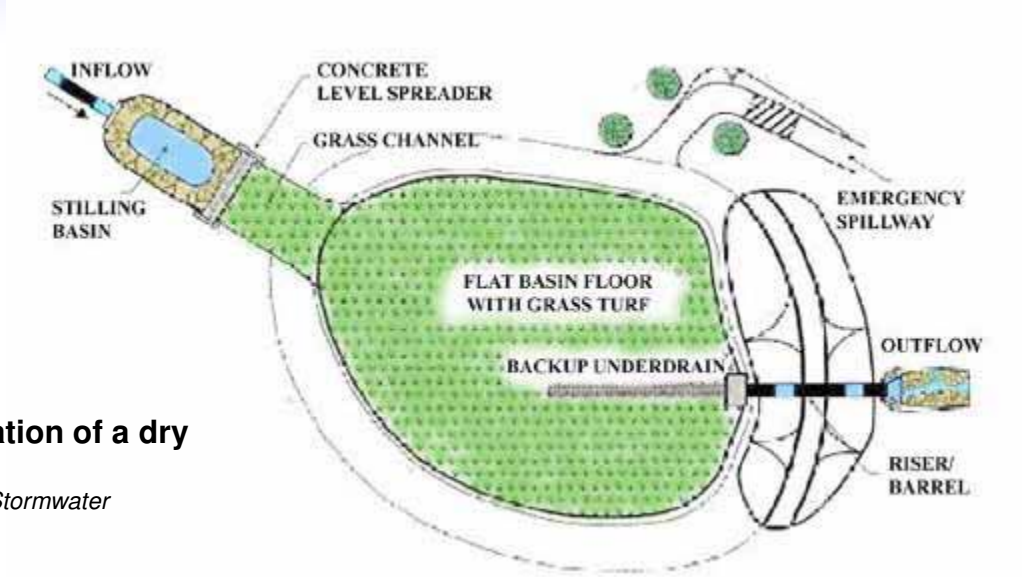
Holmes Park Road and Sherman Street, Lincoln

3.3 Dry Detention Basin

Dry Detention Basin at NW 12th St & Keating Drive,

Description	Dry detention basins, also called dry ponds, are stormwater basins that are designed to intercept a volume of stormwater runoff and temporarily impound the water for gradual release to the receiving stream or stormwater system. Dry detention basins are typically on-line, end-of-pipe BMPs. Dry detention basins are designed to completely empty out between runoff events, typically within 48 hours, and therefore provide mainly runoff control as opposed to water quality control. They can provide limited settling of particulate matter, but a large portion of this material can be resuspended by subsequent runoff events. Detention basins can limit downstream scour and loss of aquatic habitat by reducing the peak flow rate and energy of stormwater discharges. As a general rule, dry detention basins should be designed for drainage of areas greater than 10 acres. In many areas, the detention basins, when dry, can be used for other recreational purposes.
Effectiveness	Detention basins may remove from 10 to 90 percent of suspended solids depending on the volume of stormwater held in the basin, and how long it resides there. Removal of pollutants is less efficient, and generally contingent on holding period of stormwater, which is typically substantially greater than the holding period required for reducing the peak period of storm periods.
Advantages	• Reduces peak flow rate and energy of stormwater discharges, therefore limiting downstream erosion and scouring. • Good potential for removal of sediments. • Can be used for recreation when dry. • Can serve as green space, supporting wet prairie functions and wildlife habitat. • Using native plants reduces mowing costs.

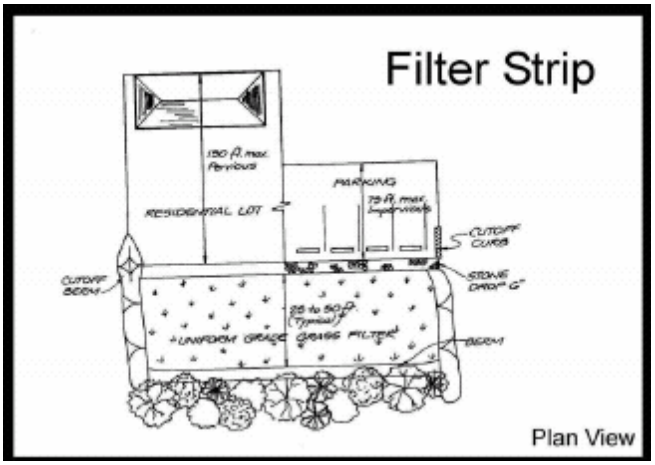
Disadvantages	• Generally not prescribed for drainages less than 10 acres. • Potential for clogging of outlets. • Can be considered unattractive by residents if not designed or maintained correctly. • Limited ability to remove pollutants. • Depending on size and volume of stormwater capture, basin designs may require approval of dam safety authorities.
Implementation Considerations	• The required volume of the dry detention basin, called the "flood storage volume," is dependent on the City's policies as provided in the City's Drainage Criteria Manual. Typically, storm volumes ranging from the 2- to the 100-year events are required. • A detention time of 48 hours or less should be targeted. Water should not remain more than 48 hours after a runoff event. • Smaller drainage areas can be considered if the dry detention is part of a stormwater treatment train. • Maximum depth of water, when full, should be 6 to 10 feet.
Cost	Costs may range from less than $1.00 to more than $1.50 per cubic foot of detention, depending on the size of the basin. Costs will also vary depending on the existing condition, vegetation, and amount of excavation and construction to be completed.
Main Design Components	• The outlet area should be a deeper micropool to provide final settling and prevent resuspension of sediments. The outlet pipe should be located in the pond embankment wherever possible for ease of maintenance. • In some cases, emergency spillways should be included in the basin design. • The basin should include a low-flow drain to assist in maintenance of the detention area. • Proper design and maintenance of the embankments will prolong the integrity of the basin structure. The embankments should have minimum side slopes of 3:1 and a top width of at least 4 feet, and should be well vegetated. • A low flow vegetated channel may need to be installed in the basin to ensure that the basin dries out completely between storm events. • Scour control is important to maintain the function of the dry detention basin and reduce erosion. • All federal, state, and local permit requirements must be established prior to construction of the dry detention basin.



Typical configuration of a dry detention basin

Source: Pennsylvania Stormwater Management Manual

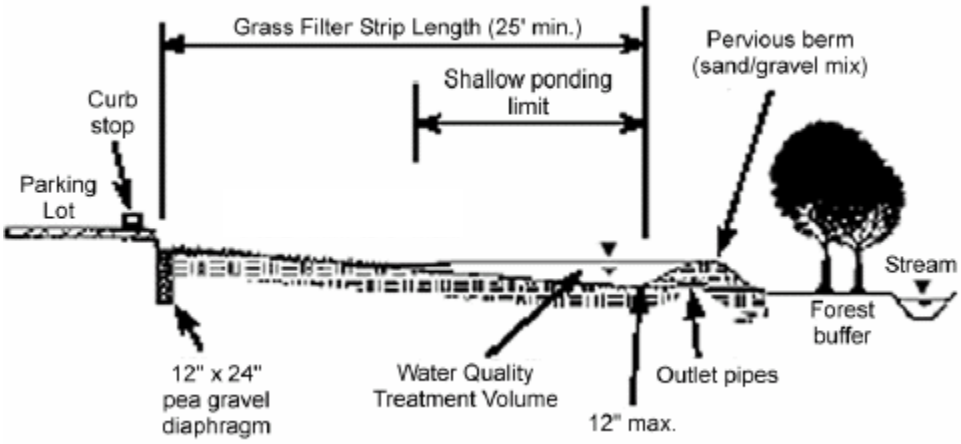
3.4 Filter Strip



Description	Filter Strips are densely-vegetated, often grassed practices that accept sheet flow runoff from adjacent surfaces. They slow runoff; filter out sediment and other pollutants; and enhance infiltration of surface water runoff. Use filter strips to treat shallow sheet flows and evenly distribute storm flows over very short contributing distance areas. Filter strips are well suited to areas adjacent to parking lots and other impervious surfaces where runoff can be conveyed and filtered before it is discharged into swales, stormwater systems, or surface water bodies. Filter strips are also appropriate for construction sites and developing land to filter sediment from overland sheet flow. Well maintained filter strips can be very effective in reducing runoff volumes, particularly when the impervious drainage area is not overly large. Filter strips are most effective in reducing surface runoff volumes – by up to 40 percent – for small storm events (storms up to the magnitude that may occur, on average, once every year or every other year).
Effectiveness	Depending on the type of vegetation and the size of the filter strip, effectiveness of this BMP will vary. Filter strips with dense, high vegetation can remove up to 80 percent of suspended solids. Filter strips utilizing grass only, particularly turf grass, are much less effective in slowing water and/or removing solids. If the filter strip is constructed with porous media in which water will readily infiltrate, the removal capability for sediments and pollutants will be as high as 98 percent (USEPA, 1999).
Advantages	• Provides effective stormwater flood control by slowing down runoff and storing water, including water infiltration into the soil. • Improves water quality by filtering pollutants from stormwater (oils, greases, metals, and sediments that can be picked up from paved surfaces).

Advantages	• Can be used as a system by itself, or in conjunction with other BMPs. • Easy to plan and build. • Reduces erosion. • May help maintain temperature of receiving waters. • Flexible to incorporate existing natural features and a variety of vegetation types. • Preserves natural/native vegetation and provides habitat for wildlife. • Protects adjacent properties.
Disadvantages	• Need to maintain vegetative cover for controlling erosion and reducing particulates in the runoff. • Not appropriate for hilly or highly impervious terrain. • Requires maintenance to remove trash.
Implementation Considerations	• The maximum drainage area into the filter strip should be 5 acres. • The filter strip width (dimension perpendicular to the flow path) should be as close to the width of the impervious area flowing into the filter strip as practical. • The filter strip length (dimension parallel to flow) depends on the filter strip width and drainage area. • The maximum slope of a filter strip should be 6 percent, unless additional flow spreader devices are installed every 100 feet to maintain sheet flow.
Cost	Low. In most cases there is no additional cost associated with establishing filter strips. Typically, all that is required is to direct runoff to an open vegetated area rather than a stormwater system. Costs may range from $0 to $1,200 per 1,000 square feet, depending on site preparation and vegetation.
Main Design Components	• Filter slopes should be no less than 1 or 2 percent slope, and no greater than 6 percent. Greater slopes will encourage concentrated flow and flatter slopes may result in ponding. • Top and toe of slope should be as flat as possible to encourage sheet flow. • Concentrated flow should not be dischared into filter strips. If flow are concentrated, a level spreader should be included to spread the flow over the entire length of the filter strip. • To enhance the effectiveness of the filter strip, install a pervious berm of sand and gravel at the toe of the slope. • Select plants that are able to withstand flowing water and both wet and dry periods.

Main Design Components	• Depending on adjacent land use and traffic, filter strips may require fencing to control destructive access by vehicles, pedestrians, and animals. • Filter strips are typically designed to handle flows from 1- to 2-year storm events and are usually not able to reduce flows from larger storms.



Typical design cross section for a filter strip

3.5 Grassed Swale

Source: City of Eugene Stormwater Management Manual

Description	Grassed swales are low-cost alternatives to conventional hard-engineered conveyance in residential and commercial neighborhoods. Like Vegetated Bioswales (page 69), they consist simply of a shallow channel, or swale, that conveys water down a slight gradient away from its source. As runoff travels down the swale, suspended solids and pollutants settle out, preventing them from entering stream systems.
Effectiveness	Grassed swales are most effective for dispersing the flow of stormwater across a greater area and distance. Grassed swales are not significantly effective for removal of suspended sediments or pollutants.
Advantages	• Less expensive than conventional, hard-engineering conveyance practices, in both the initial construction and maintenance phases. • Encourages infiltration.
Disadvantages	• Less effective than vegetated bioswales at filtering and reducing rates and volumes of runoff. • Swales can only treat a limited area.
Implementation Considerations	• Deep-rooted native grasses and wildflowers facilitate more effective infiltration and pollutant filtration, and a greater reduction in flow rates and volumes than conventional turfgrasses such as Kentucky bluegrass. • Mowing of grassed swales should be avoided, or should be done as infrequently as possible. • Extent of drainage area. • Planning and engineering of effective treatment train appropriate for each area. • Determine the necessary space and length to achieve stormwater management goals and water quality.

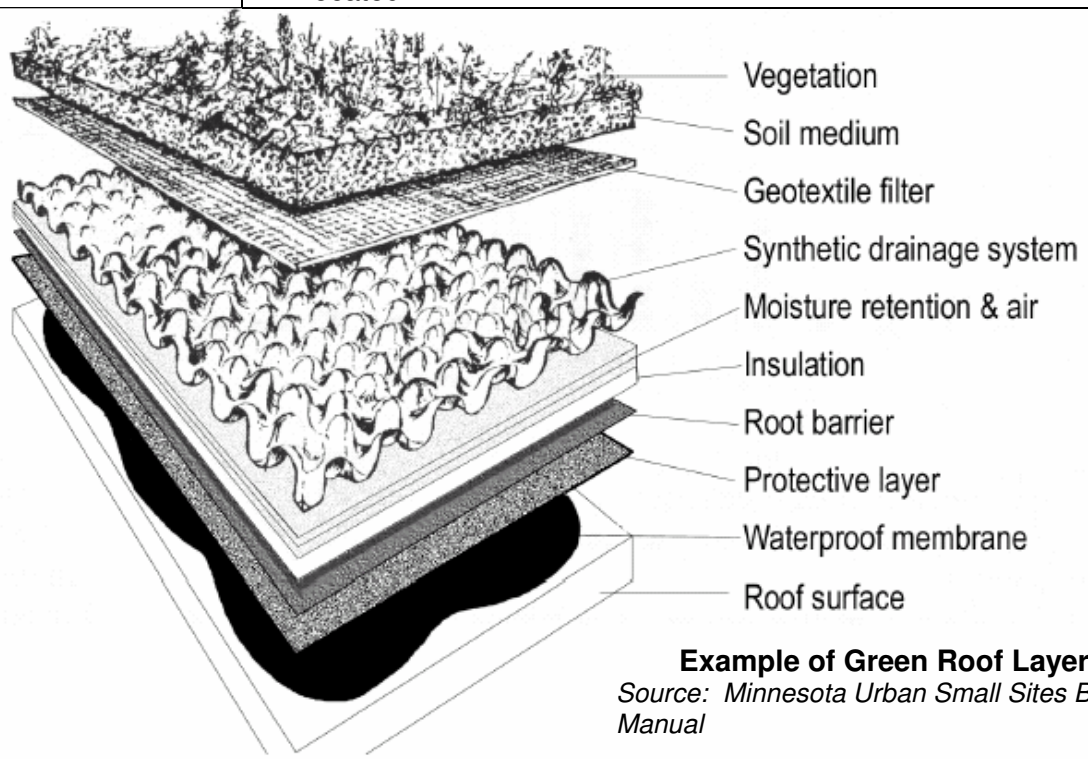
Cost	Low – less than costs for traditional hard-engineered practices. Generally, approximate costs will range from $0 to $375 per 1,000 square feet, depending on preparation and final planting (seed vs. sod).
Main Design Components	• Minimize slope (< 4:1) and depth of the swale to prevent erosion of side slopes. • Channel bottom should be relatively flat to prevent channelization that would lead to increased erosion. • Runoff should be distributed uniformly across the channel bottom at its entry point. • The bottom of the swale should be at least three feet above groundwater in order to prevent the swale bottom from remaining too wet. • The flat channel bottom should be between two and eight feet wide to ensure sufficient filtering surface for water quality treatment. • Unless existing soils are highly permeable, they should be replaced with a sand/soil mix that meets minimum permeability requirements. • An underdrain system may also be installed under the soil bed. Typically, the underdrain system is created by a gravel layer which encases a perforated pipe

3.6 Green Roof

Description	Green roofs have been used for hundreds, if not thousands of years, from sod roofs in Europe to sod houses in the Great Plains of the United States. What have changed are the materials, designs and new implementations of green roof technology. Further, a greater understanding on how green roofs function has led to using green roofs for stormwater management and building climate control. Essentially a green roof consists of placing layers of plants and rooting medium over a traditional roofing system. Green roofs are grouped into two categories: extensive and intensive. Extensive roofs are lightweight systems of manufactured root medium which typically have low plant diversity; they are more easily incorporated into conventional building construction and require little maintenance. Intensive roofs typically use a deep rooting medium such as topsoil and can incorporate a wide variety of plants but require special considerations due to higher roof loading and greater maintenance.
Effectiveness	Depending on the type of green roof used, effectiveness will vary. In most situations however, nearly all configurations will effectively reduce the volume of runoff from rooftops. If runoff is maintained through a constructed soil media, filtering capacity of sediments and pollutants may be higher than 80 percent.
Advantages	**Extensive** • Can reduce summer cooling costs. • Low maintenance. • Placement on up to 25-30° roof pitch. • Lightweight. • Suitable for retrofit. • Easier to install. • Slow stormwater runoff.

Advantages	• Aesthetically pleasing. • Provides insulation for roof. • Extends life of roof. • Reduction in impervious area for the property. **Intensive** • Greater plant diversity, better aesthetics. • Good insulation properties. • Potential access for recreation. • Slower stormwater runoff, larger detention capacity. • More amenable to wildlife. • Reduction in impervious area for the property.
Disadvantages	**Extensive** • Unattractive to some, especially in winter. • Limited plants, native species may not be possible. • No access for recreation. **Intensive** • Greater roof loads. • Expensive design and construction. • Irrigation and drainage systems necessary. • Higher maintenance than extensive roof. • Potential fire hazard during dormant season, especially with native plants.
Implementation Considerations	• Public outreach and acceptance for existing developments or communities. • Load-bearing capacity of roof structure and building. • Mechanisms to address fire hazard. • Life of the structure.
Cost	High (initial capital costs). Costs will vary depending on roof size and materials used. Low (life cycle replacement and resurfacing costs), additional cost savings through reduced summer cooling costs.

Main Design Components	• The load-bearing capacity of the underlying roof structure is critical in the design of a vegetated rooftop. Generally, greenroofs weighing more than 17 pounds per square foot saturated require consultation with a structural engineer. • Flat roofs are easiest to design and install. The maximum slope for a green roof is about 25 percent. • Follow federal and state standards for wind resistance. Since uplift pressures tend to be higher at roof corners, these areas may be considered for vegetation-free zones. • Monolithic membrane, applied as a hot liquid, provides superior waterproofing. • Protective layers are placed on top of waterproofing, including root barriers to prevent roots from damaging the waterproof layers. • A drainage system needs to be designed that will retain water for plant uptake, and retain excess water for storage. • Soil for green roofs are lighter than typical soil mixtures, generally with about 75 percent mineral matter, and 25 percent organic matter. • A range of plants are suitable for green roofs. In Lincoln, native plants offer a variety of opportunities to create effective vegetative schemes. For extensive roofs (shallow soil systems), shallow-rooted plants that can withstand heat and drought are best. • It is esential to mark the position of roof drain outlets and irrigation pipe inlets before installing protective layers so they can be easily located.



Example of Green Roof Layers.
Source: Minnesota Urban Small Sites BMP Manual

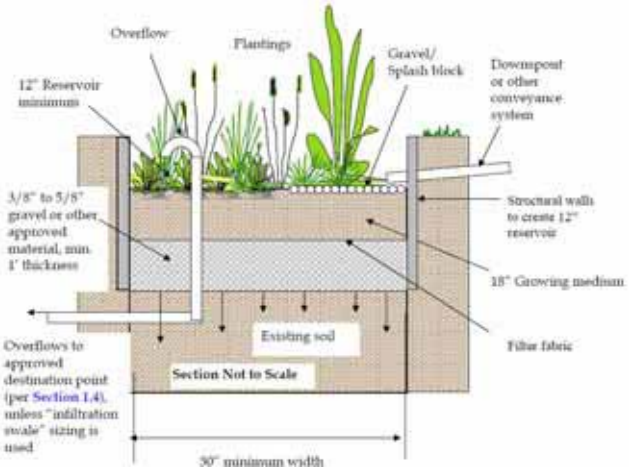
3.7 Infiltration Basin

Description	An infiltration basin is an impoundment designed to capture stormwater runoff and allowing it infiltrate into the ground over a period of a couple of days. It does not retain a permanent pool of water. Infiltration basins are typically off-line, end-of-pipe BMPs that vary is size and shape. The infiltration basins described in this section typically treat water from larger areas, from multiple lots to large parking lots, to broad areas such as neighborhoods. Infiltration basins use existing soil and vegetation to facilitate percolation of water into the ground and evapotranspiration of water through vegetation into the atmosphere. Vegetation is key to success of the infiltration basin. Deep-rooting vegetation will enhance infiltration of water while also staying well-anchored against disturbance from water or other factors. Another key element of the infiltration basin is having enough area to maintain a shallow pool that will infiltrate within 48 hours or less.
Effectiveness	Infiltration basins may remove from 10 to 90 percent of suspended solids depending on the volume of stormwater held in the basin, and how long it resides there. Removal of pollutants is dependent on the soil media and the ability to adsorb or decompose pollutant compounds. Removal of pollutants is contingent on the holding period of stormwater, which typically is substantially greater than the holding period required for reducing the peak period of storm periods.
Advantages	• Reduces peak flow rate and energy of stormwater discharges, therefore limiting downstream erosion and scouring. • Can be used for recreation when dry. • Can help to maintain baseflow of nearby streams. • Can serve as greenspace, supporting wet prairie functions and wildlife habitat. • Reduces local flooding.
Disadvantages	• Generally not prescribed for drainages greater than 10 acres. • Potential for fouling infiltration capacity of the soil if runoff is sediment-laden.

Disadvantages	• Can be considered unattractive by residents if not designed or maintained correctly.
Implementation Considerations	• Re-Vegetation: For existing unvegetated areas or for infiltration basins that require excavation, vegetation may be added. Planting in the infiltration area will improve water quality, encourage infiltration, and promote evapotranspiration. This vegetation may range from a meadow mix to more substantial woodland species. The planting plan should be sensitive to hydrologic variability anticipated in the basin, as well as to larger issues of native plants and habitat, aesthetics, and other planting objectives. The use of turf grass, which requires frequent mowing is discouraged due to soil compaction. • A grassed Infiltration Basin can be used for recreation in dry periods. Heavy machinery and vehicular traffic of any type should be avoided so as not to compact the infiltration area. • Soil infiltration tests should be conducted. For soils with poor infiltration rates, a layer of sand (6") or gravel can be placed on the bottom of the Infiltration Basin, or the soil can be amended to increase the permeability of the basin. • This BMP is not practicable in areas with high water tables. Guidelines for infiltration should be considered, including depth of water table, permeability of soils, and vegetation types.
Cost	The cost for infiltration basins are relatively low, ranging from less than $0.50 to more than $1.30 per cubic foot depending on size and existing conditions.
Main Design Components	• Uncompacted sub-grade. • Soil Infiltration Guidelines and Soil Testing Protocols apply. • Preserve existing vegetation, if possible. • Design to hold/infiltrate volume difference in 2-yr storm. • Provide stormwater overflow through engineered outlet structure. • Allow 3 ft buffer between bed bottom and seasonal high groundwater table and 2 ft buffer for rock. • When possible, place on upland soils. • The slope of the infiltration basin should be flat or less than 1 percent. • There should be at least 2 feet of freeboard between the invert out and the top of the berms. • Inlets should have erosion protection.

3.8 Infiltration Planter

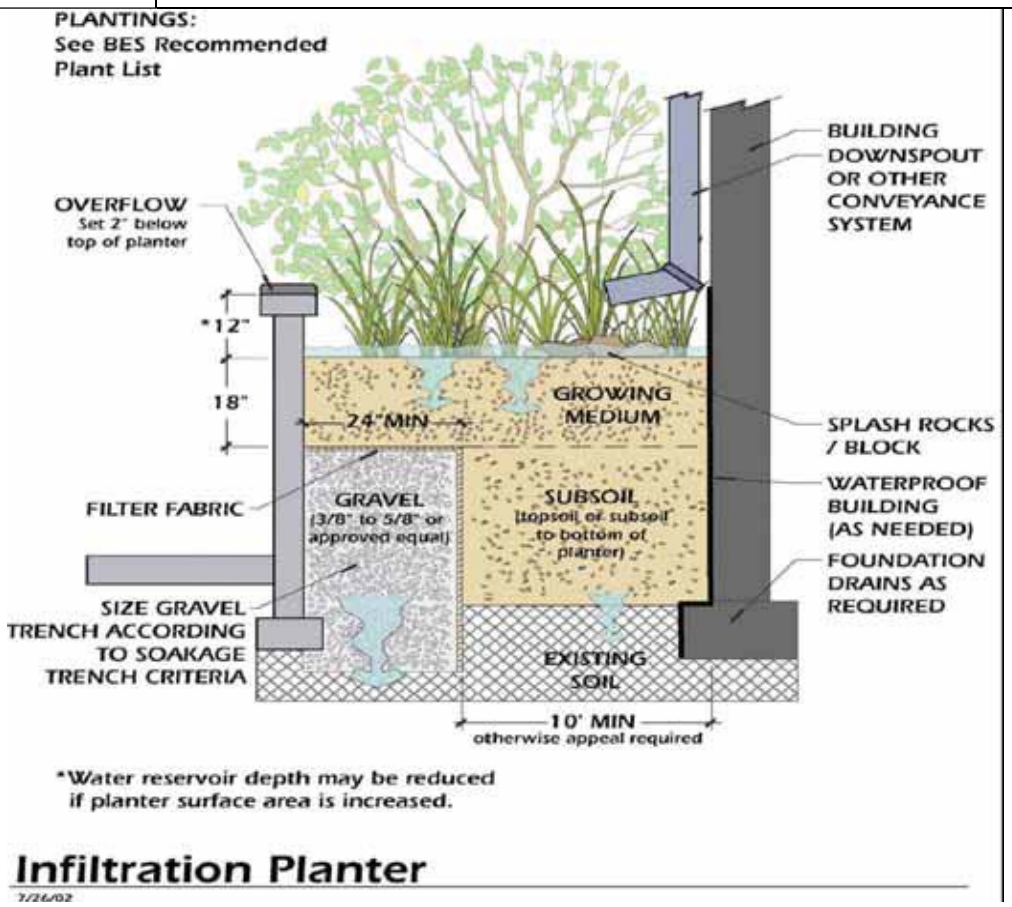
Source: City of Eugene Stormwater Management Manual



Source: City of Eugene Stormwater Management Manual

Description	Infiltration planters are raised structural planting beds that filter and infiltrate runoff from surrounding rooftops, parking lots, or sidewalks. They can be installed in a variety of sizes and styles, integrating an endless variety of plants, to suit any architectural style. Infiltration planters work well at the scale of individual residential, commercial, residential, or governmental parcel levels.
Effectiveness	Infiltration planters have limited capability to reduce significant amounts of runoff, with limitations based on the receiving area of runoff flowing to the planter, and the size of the planter itself. For runoff that enters the planter, removal of sediments and pollutants is high, often exceeding 80 percent.
Advantages	• Provides filtration of pollutants, as well as infiltration of runoff. • Reduces flow rates and volumes. • Suitable in areas with limited space. • May be used as part of a traditional landscaping plan. • Should reduce the amount of watering necessary to maintain vegetation.
Disadvantages	• Though infiltration planters will require less watering than traditional landscaping, they may require maintenance to prevent clogging of permeable medium.
Implementation Considerations	• Requires soils that allow at least two inches of infiltration per hour. • The walls of the planter should allow up to a foot of standing water to accumulate for less than twelve hours at a time. • A minimum of three feet of permeable medium (washed gravel or other aggregate) should exist between the bottom of the growing medium (topsoil) and above impermeable layers or seasonally high water table.

Cost	Overall relative costs are expected to be low, with costs dependent upon construction materials and the size of the planter. Costs on a unit basis (cubic foot) are expected to be higher than other BMPs.
Main Design Components	• Planter walls should be constructed of durable, impervious materials, but should not employ chemically treated wood that may leach chemicals into groundwater. • Planters should incorporate trees and shrubs where feasible • An overflow should be installed to divert excess water during high-flow runoff events



Source: City of Eugene Stormwater Management Manual

3.9 Infiltration Trench

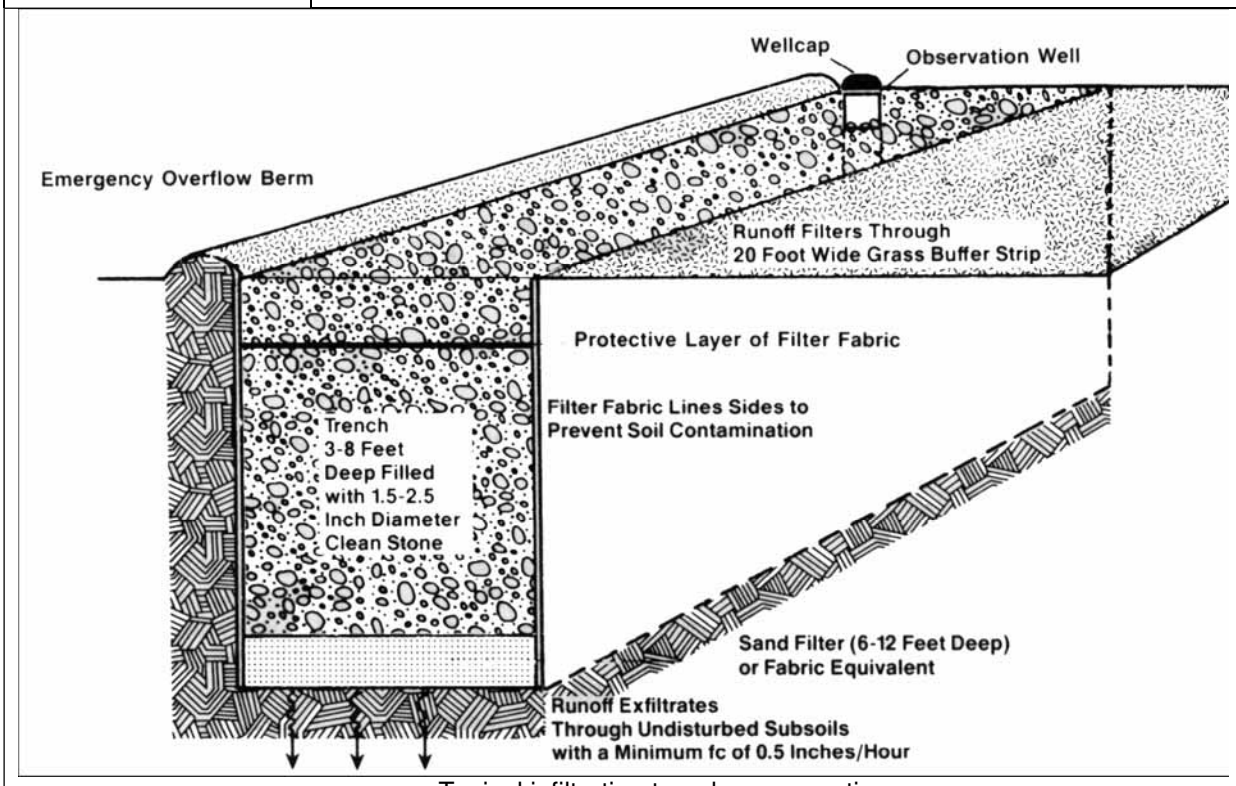
Description

Infiltration trenches are excavations that are lined with filter fabric and backfilled with aggregate. During runoff events water enters the trench where it is initially stored and then infiltrated into surrounding soil. Pollutants are filtered out as water passes through the aggregate and filter fabric, and into the soil. Infiltration trenches can treat and detain runoff for areas at the scale of residential blocks or individual commercial and governmental parcels. Their ability to remove a variety of pollutants, as well as their relatively small footprints, makes them ideally suited for applications such as parking lot island.

Infiltration trenches are most effective when applied in conjunction with other BMP types. For example, placing a vegetated filter strip around the trench decreases the amount of sediment flowing into the trench, reducing maintenance requirements and increasing the filtration efficiency.

Effectiveness	Infiltration trenches can be very effective for reducing runoff volume and for filtering sediments. Removal efficiency for pollutants can vary, but is expected to be relatively low. Infiltration trenches must be maintained as they are susceptible to clogging from fine particles.
Advantages	• Effectively removes or reduces many pollutants, including suspended solids, bacteria, and trace metals. • Reduces runoff volumes during storm events. • Increases baseflow in nearby streams.
Disadvantages	• Infiltration trenches may require periodic maintenance to prevent clogging.
Implementation Considerations	• Soils adjacent to planned trench site should be adequately permeable so as to allow infiltration • Slopes adjacent to the trench should be less than 12-15%. • Bottom of trench must be far enough from seasonally high water table to allow filtration by intermediate soil. • Trenches should not be employed where the potential is high for spills that might contaminate groundwater via the trench. • Pre-treatment practices, such as a vegetated filter strip, vegetated bioswale, or oil-grit separator are required where sediment loads from the contributing area would otherwise clog the trench, such as in parking lots and along roadsides.

Implementation Cosiderations	• Infiltration trenches in Lincoln should be constructed so a portion of the trench is below the frost line and so that ice and snow can be removed from the surface, ensuring proper functioning during cold weather. • During construction, care should be taken to avoid compacting soil surrounding the trench site, by using light equipment. • The contributing area must be stabilized before construction. Unstable areas will contribute excessive sediment to the trench, quickly clogging.
Cost	Low – approximate costs are estimate between $1.00 to $1.50 per cubic foot (USEPA, 1999)
Main Design Components	• Trenches should be excavated to a depth of approximately 3-8' and filled with washed aggregate of a diameter between approximately 1.5 to 3 inches. • The surface of the trench may be covered by aggregate, pea gravel, or vegetation. Pea gravel and vegetation both increase sediment filtering and prolong the life of the trench. If a vegetated surface is desired, it should be installed in approximately one foot of soil. • A vegetated filter strip at least 20 feet wide should be constructed upslope from the trench, to increase sediment capture and prolong the life of the trench. • Simple observation wells, constructed of PVC pipe, allow monitoring of water levels and evaluation of performance. • Flow into the trench should be evenly distributed.

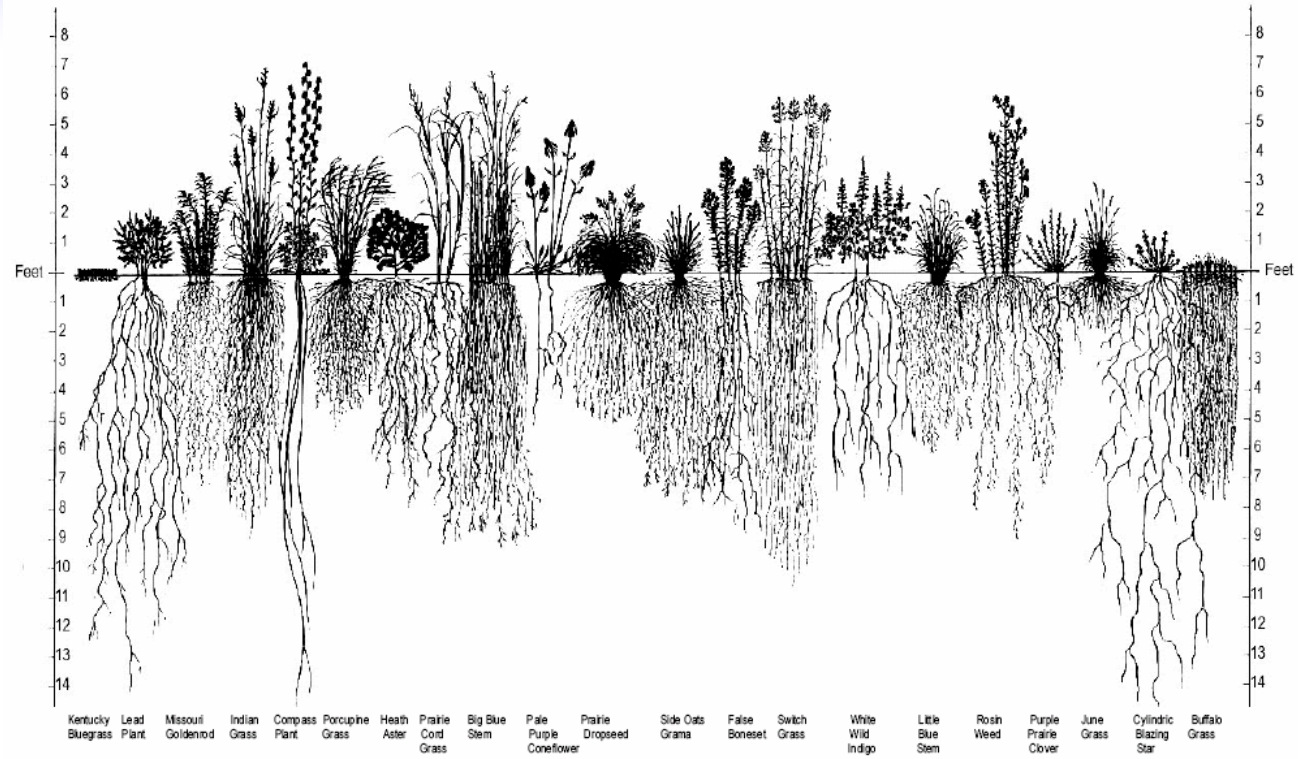


Typical infiltration trench cross section

3.10 Natural/Native Vegetation

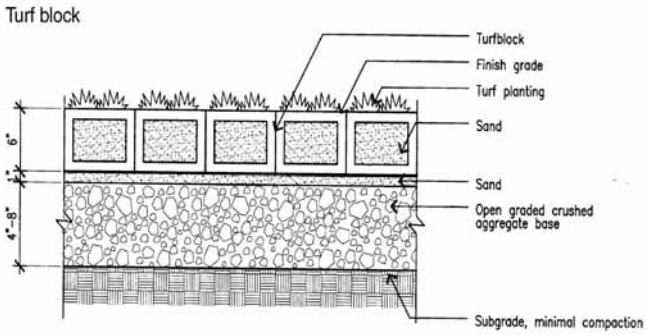
Description	"Uplands" are lands elevated above bottomlands and floodplains that are neither deepwater aquatic habitats nor special aquatic sites. They are seldom or never inundated. Prairie grasses and a few tree species typically dominate undisturbed and native landscaped uplands. The prairie grasses can include, but are not limited to, Big Bluestem, Little Bluestem, and Canada wild rye. Tree species include, but are not limited to, Hickory, Oak, and Black Locust. Undisturbed or native landscaped uplands can serve many BMP functions. They can help reduce erosion by protecting the underlying soil from splash erosion and slowing velocity of runoff. They can reduce off-site runoff by providing infiltration. They can filter sediment and other pollutants from stormwater runoff. They can also provide wildlife habitat and aesthetic values for the public. Native prairie planting, after the first two years, requires less maintenance than "tame" or domestic turf grass planting, reducing operations and maintenance costs. Native vegetation is also better suited than turf grasses for poor soils. Native grasses have deeper roots and can access more nutrients and water. Mowing and fertilizer application are not required to maintain a healthy stand of native vegetation. If controlled burning is not an option, mowing can control woody growth that may encroach on prairie plantings.
Effectiveness	Native vegetation is the core of using alternative strategies for reducing runoff volumes and pollutant transport. In uplands, native vegetation including grasses, forbs, and woody vegetation/trees, effectively slows runoff where if falls, maximizing infiltration and reducing the volume of pollutants that would otherwise be transported downstream.
Advantages	• Preserves predevelopment hydrology effectively. • Slows surface flows, promotes infiltration, and reduces erosion. • Traps sediment and sediment-bound pollutants. • Improves soil structure. • Transforms nutrients into usable forms and breaks down many pollutants.

Advantages	• Typically requires less maintenance than non-native landscaping. • Preserves wildlife habitat and provides aesthetic and recreational benefits. • Requires significantly less expense. • May increase property values.
Disadvantages	• Requires planning to maximize land available for development. • May require close maintenance until established. • May require a cover crop. • Cannot be established during winter.
Implementation Considerations	• To establish native uplands, choose plant species suited to the location. Consider moisture regimes, soils, light levels, runoff properties (pollutants, concentrated flow, and sheet flow), intended land use, and level of maintenance. Determine seeding rates considering the intended purpose of the site. Typically, an installation and management plan is appropriate. • Seedbed preparation is critical to success of plantings — do not over compact the soil. • Preserving existing upland native vegetation ultimately demands less maintenance than turf grass plantings or other landscaping, reducing operations and maintenance costs. • Minimal mowing and herbicide application is needed to maintain a healthy stand of native vegetation. • Some mechanical means may be necessary to control invasive species and preserve the health of the system. • Minimal fertilization is required. • Establishing native uplands necessitates that seeded areas be kept moist during the first weeks of establishment; mulch also may be needed. Reseeding may be necessary if the first seeding does not produce a vigorous stand.
Cost	Low – Cost will range from approximately $0.08 to $0.76 per square foot of ground depending on types of vegetation used. Lower costs come with the economy of scale from larger areas, high costs with small areas.
Main Design Components	• Seed should be applied uniformly (cyclone, drill, or hydroseeder). If feasible, broadcast seed should be covered by light raking followed by a roller. • Sod has the advantage of immediate erosion control, however native grass sod is rarely available. Native grasses can be installed as “plugs,” (i.e. young, individual grass plants).



Comparative demonstration of above- and below-ground biomass of native plants, including turf (far left).
Source: Conservation Research Institute, 1995

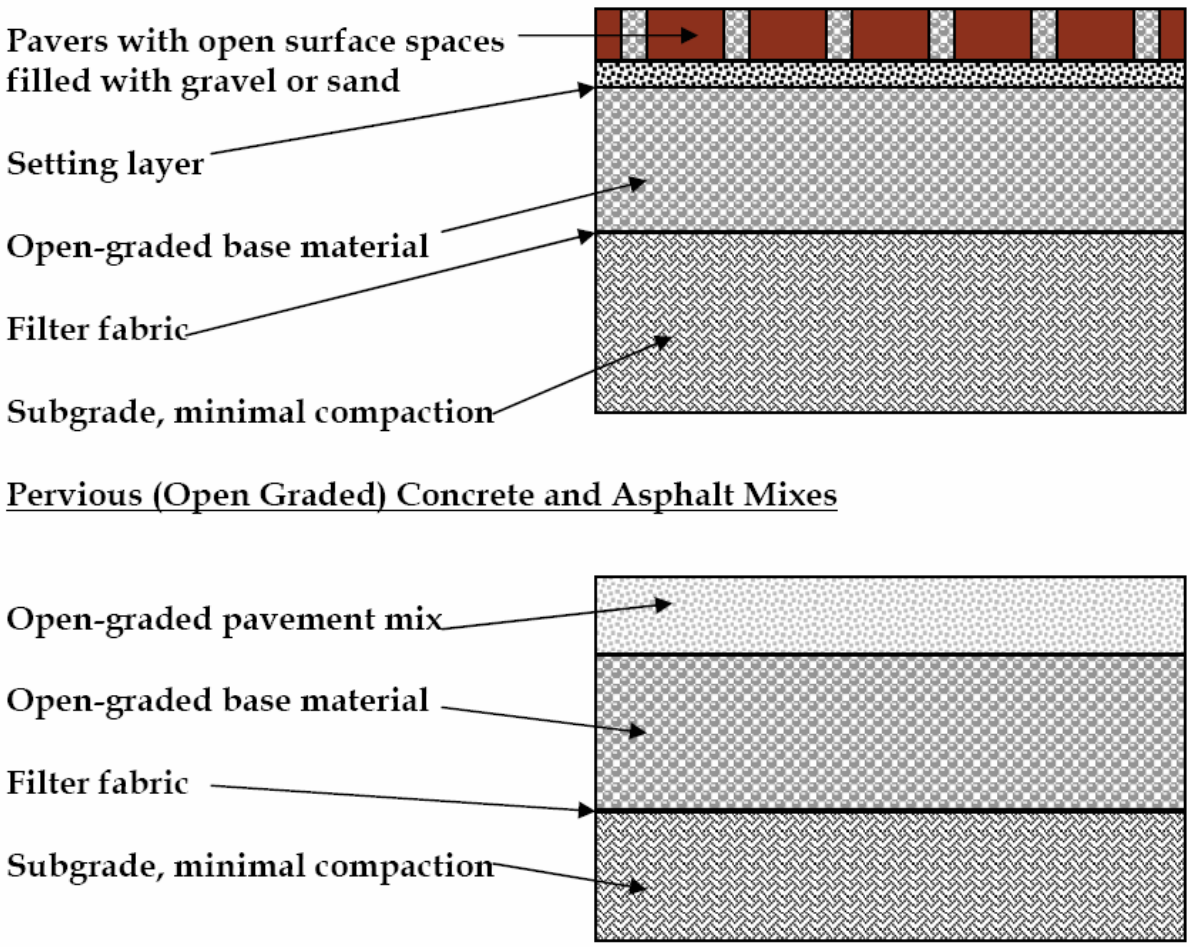
3.11 Pervious Pavement



Source: City of Eugene Stormwater Management Manual

Description	Pervious pavement allows precipitation to infiltrate by way of vertical pore spaces in the paving material. A wide variety of materials are used in the creation of pervious pavement, including brick, concrete, asphalt, plastic, rock, and gravel. A pervious pavement system may make use of porous concrete or asphalt, or it may make use of cobbles, bricks, or other evenly spaced paving units. Paving systems may even integrate vegetation within spaces in the paving units, augmenting the infiltration and filtration capacity. Studies of existing pervious pavement indicate removal rates of over 80 percent for sediment and for a number of other pollutants. Infiltration of precipitation falls where it intercepts parking lots, roads, and sidewalks reducing the volume of runoff that must be handled by stormwater management systems. Pervious pavement is suitable at a variety of scales, including individual driveways, trails, overflow parking lots, and light traffic roadways.
Effectiveness	Pervious or porous pavement, when properly maintained, has been shown to remove from 65 to 95 percent of pollutants and sediments (USEPA, 1999). Some monolithic porous pavement materials, however, have been show to clog within one- to two years. Clogging can be remediated to restore the function of the pavement material.
Advantages	• Reduces runoff volumes. • Reduces impervious surface area. • Depending on pavement system, may provide pollutant filtering.
Disadvantages	• Certain pervious pavement types have a high potential for failure unless properly designed, constructed, and maintained. Restricting pervious pavement to areas with relatively low traffic volumes and relatively light vehicles will also increase the success rate. • May require costly maintenance if pavement becomes clogged with sediment and no longer allows infiltration.

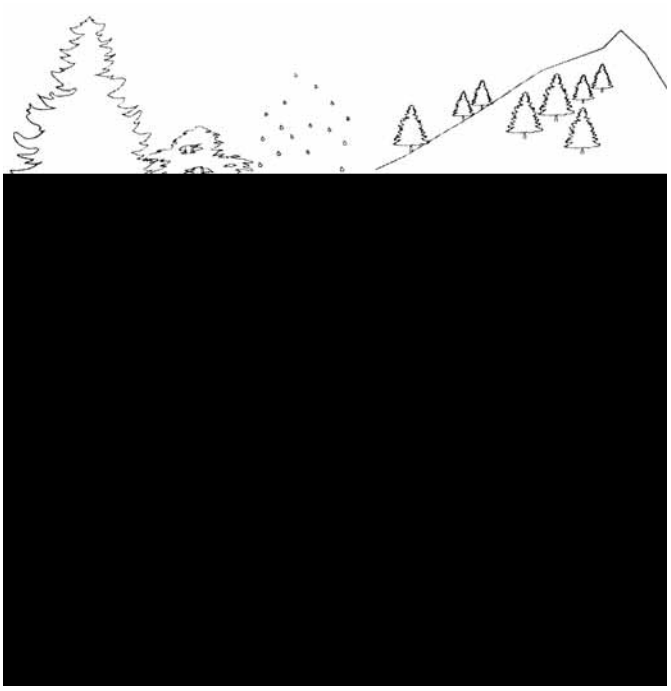
Implementation Considerations	• Excessive runoff from adjacent impervious surfaces may lead to clogging of paving systems. • Pervious pavement should not be used in sites where excessive oil, grease, or other chemical deposition may lead to groundwater contamination, such as automotive repair shops. • Given the potential for contamination by chemicals associated with automobile traffic, pervious pavement should not be employed near groundwater drinking supplies. • The type of traffic a surface receives (i.e. pedestrian, light vehicular, heavy vehicular) will determine the most suitable pavement type. • Snowplowing must be done carefully to avoid damaging the surface and paving units, and sanding and de-icing should be avoided as they will increase clogging. • Required maintenance, especially for porous concrete and asphalt paving includes vacuum sweeping to remove deposited sediment as well as washing with a high-pressure hose to remove clogs in the surface of the pavement.
Cost	Moderate – may be 2-3 times more expensive than conventional pavement.
Main Design Components	• Pavement surface must allow water to infiltrate to a permeable infiltration medium below. • An underdrain system may be required where soils beneath paving system do not allow adequate infiltration (more than two inches per hour). • Slopes should be less than 5-10% to allow infiltration rather than runoff. • Integration with other BMPs improves the effectiveness of pervious pavement. For example, placing a vegetated filter strip around the pervious pavement will reduce sediment transport to the project area, reducing the amount of maintenance required.



Source: City of Eugene Stormwater Management Manual

3.12 Rain Barrels and Cisterns

Source: Stormwater Manager's Resource Center



Source: City of Portland Code Guide

Description	A rain barrel is any above-ground container modified to receive, store, and distribute rooftop runoff for non-potable uses. Rain cisterns are similar systems designed for below-ground use, but typically provide much greater storage and more complex construction techniques. Rain barrels are ideal BMP applications for residential or small commercial sites. Both practices supply water for gardens, lawns, and flowerbeds. Homeowners with large gardens, or small businesses may want to consider installing a cistern, instead of a rain barrel, since they offer much greater storage capacity.
Effectiveness	Rainbarrels and Cisterns are effective in storing limited volumes of water from rooftops. Larger cisterns can provide effective volume reduction of runoff during storms. For example, a 0.1" rainfall event falling on a 1000 square foot roof produces about 60 gallons of runoff – more than enough to fill an average-sized 55-gallon rain barrel. These systems are not effective for removal of pollutants, and sediments may collect in the vessels that will have to be removed.
Advantages	• Reduces flow volumes, thereby reducing demands on stormwater management systems. • Provides free supply of water for non-potable uses, easing demands on potable drinking water sources. • Provides homeowners and small businesses with water for irrigation.

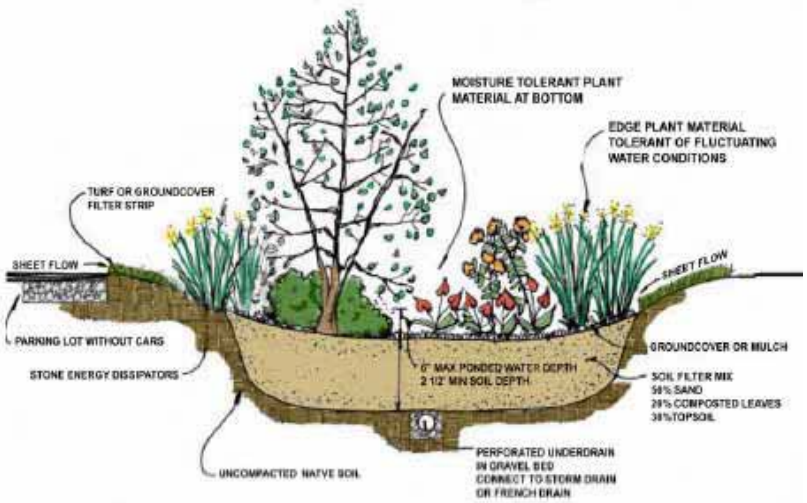
Disadvantages	• Rain barrels may not provide sufficient water in drier climates. • Rain cisterns are more expensive and require somewhat more complex design and construction.
Implementation Considerations	• Rain barrel should be sized to adequately capture runoff based on precipitation patterns in this area. • Occasional cleaning may be necessary to remove debris, such as leaves, coming off the rooftop. The barrel must also be sealed during warm months to avoid mosquito breeding, and should be drained prior to winter to prevent damage caused by freezing. • Water should be drained between rainfall events (for irrigation) to maximize effectiveness. • Rain barrels are most effective when they are designed to help meet demands for non-potable water, such as irrigation.
Cost	Low. Ready-made rain barrels range from $20 to $150. Homeowners can reduce costs by constructing their own.
Main Design Components	• Complete rain barrels can be purchased from a number of retailers, or they can be constructed relatively easily and economically. • Instructions for creating your own rain barrel can be found at Maryland Environmental Design Program Website. (http://www.dnr.state.md.us/ed/rainbarrel.html) • The main components of a rain barrel include tubing to connect the barrel to a downspout, a cover to prevent mosquitoes from entering, a faucet to allow regulated use of the captured water, and an overflow pipe to divert excess water once the barrel is filled. • The basic components of a rain cistern are much the same as with rain barrels, but with a much larger storage tank that is buried underground. This means a pump must also be installed to bring water out of the cistern.

3.13 Rain Garden

Description	A rain garden is a small residential depression planted with native wetland and prairie vegetation (rather than a turfgrass lawn) where sheet flow runoff collects and infiltrates. Rain gardens function similar to larger-scale bioretention areas. Typical sites for rain gardens include residential yards and community common areas.
Effectiveness	Raingardens are effective in removing from 30 to 90 percent of nutrients (such and nitrogen and phosphorus) and 80 percent of sediments as well as reducing runoff volumes.
Advantages	• Provides localized stormwater control by collecting and storing water, allowing water infiltration into the soil. • Improves water quality by filtering pollutants from stormwater. • Easy to plan and build. • Aesthetically pleasing. • Flexible to incorporate existing natural features. • Preserves natural/native vegetation. • Protects adjacent properties.
Disadvantages	• May need to irrigate to maintain vegetation during dry periods. • Requires annual maintenance to maintain vegetation and aesthetic qualities.
Implementation Considerations	• The maximum drainage area into rain gardens should be less than one acre. • The ponding depth of a rain garden is typically 4 to 6 inches. • Limit ponding in the depressional area to 3 days or less to avoid nuisance insects.

Implementation Considerations	• Line the depressional area with a mulch and organic layer in which vegetation is planted. • The mulch holds moisture and aids removal of metals. • Underneath the mulch and organic layer is the planting soil. • Place rain gardens a minimum of 10 feet away from building foundations. • Placement of the rain garden and overflow path should not interfere with adjoining property drainage patterns. • Rain gardens should not be located in areas where ponded water may create problems for surrounding vegetation or land use.
Cost	The cost of rain gardens vary and are scale dependent. On a unit basis, the cost may range from less than $2 to more than $14 per cubic foot, depending on size of the garden, vegetation used, and age of the vegetation planted. If seedling plugs are used, the cost increases. If the garden is prepared from seed, the cost is substantially less.
Main Design Components	• Ponding depths restricted to 6 inches or less. • Deep rooted perennials and trees are encouraged. • The planting soil should be a mixture of sand, loam, and clay to provide water and nutrients to the plants. • Native species that are tolerant of both wet and dry cycles are highly recommended. • Modify soil with compost to increase permeability. • Provide a drain tile system if soil permeability is a problem. • Maintenance, including mowing and weeding, is typically required two times a year.

Typical Rain Garden Cross Section *(Source: Pennsyvania Stormwater BMP Manual, 2005)*



3.14 Soil Management

Description

Soils are the primary medium of stormwater infiltration and storage. Soil management, whether by managing existing soils, or amending soil with supplemental materials to facilitate stormwater infiltration and treatment, is essential for the success of nearly all best management practices. Essentially, retaining the natural soil structure where possible is the preferred approach for soil management. Even with clay soils that may typically have low permeability, proper soil management will enhance stormwater infiltration.

Soil texture is the term applied to describe the sand, silt, and clay content of the soil. Sandier soils are more permeable and allow water to move into and through them more rapidly. Clay soils have smaller, tighter pores, and water moves into and through clayey soils more slowly.

Soil structure is the term applied to the arrangement of soil components – the sand, silt, and clay, as well as organic matter, into secondary units, or aggregates. Soil structure may be more important than soil texture, as soil structure more effectively describes the soil's capability to infiltrate and move water through the profile. "Good" soil structure usually describes soil that is friable, or easily broken into smaller pieces, and that has a combination of large and small pores. This soil will typically be high in organic matter and allow plant roots to grow freely and water to move rapidly into the soil. Even clay soils can have good soil structure and provide an optimal medium for stormwater management BMPs.

Soil Amendments

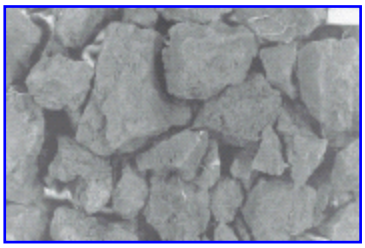
The clayey soils in Southeast Nebraska can limit stormwater infiltration, especially soils in developed areas. Where soils have little topsoil and are predominantly clay or fine silt, soil amendments may be necessary to "open up" the soil with greater macroporosity and better soil structure. Soil amendments typically include manure or compost, plant materials, or chemicals that will help aggregate soil particles. When soil amendments are added to existing soils, they need to be thoroughly mixed and integrated into the soil. Soil amendments can also be added to sandy soils to increase water holding capacity and its ability to support plants.

Effectiveness	Proper soil management is essential for nearly all stormwater BMPs. Soil that provides adequate infiltration will filter more than 90 percent of pollutants, 100 percent of sediments, and substantially reduce surface runoff. Soil management is most effective with native vegetation cover to stabilize soils and reduce erosion.
Advantages	• Retaining native or natural soils on a site allows for more rapid and successful plant establishment. Plants in soils with good structure and high organic matter will survive climate extremes better than plants in "poor" soils. • Retaining topsoil maximizes rainwater infiltration and storage capacity. One foot of topsoil can store more than one-inch of precipitation. • Soils high in organic matter filter pollutants and break down organic compounds. • Organic matter in soils hold more water, acting like a sponge. The water is released as needed for plant use. • Organic matter in soils hold and provide nutrients for plant growth. • Soils with good structure and high organic matter are more stable.
Disadvantages	• Re-building soils with good porosity and structure can be expensive. • If improperly managed, soils high in clay may not support stormwater infiltration or good plant growth. • Development may require removing topsoil, grading, and then replacing the topsoil. • To much heavy equipment on soils may compact them, resulting in poor BMP performance. • Soil amended with other materials must be carefully mixed to assure uniformity.
Implementation Considerations	• Local soils and soil conditions should be examined before site construction begins. • Soil tests should be completed to determine if the physical and chemical properties are adequate for absorbing rainwater or supporting vegetation. • BMP goals (infiltration, detention, biotreatment) should be established prior to determining what appropriate soil characteristics are desired. • Avoid stripping topsoil from construction sites if possible. • Maximize soil porosity and organic content where possible.
Cost	Low cost if native soil is used, medium to high if soil is re-engineered. Cost will vary substantially depending on existing soil and vegetation conditions, and amendments that may need to be added.

Main Design Components	• Depth of soil. • Clay content. • Soil permeability, organic content, infiltration rate. • Subsoil consistency, depending on performance criteria of BMP. • Effective homogenization of soils to assure effective porosity, texture, and particle distribution.

Examples of Typical Soil Structure

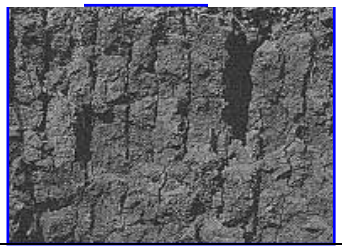
Granular Structure



Blocky Structure

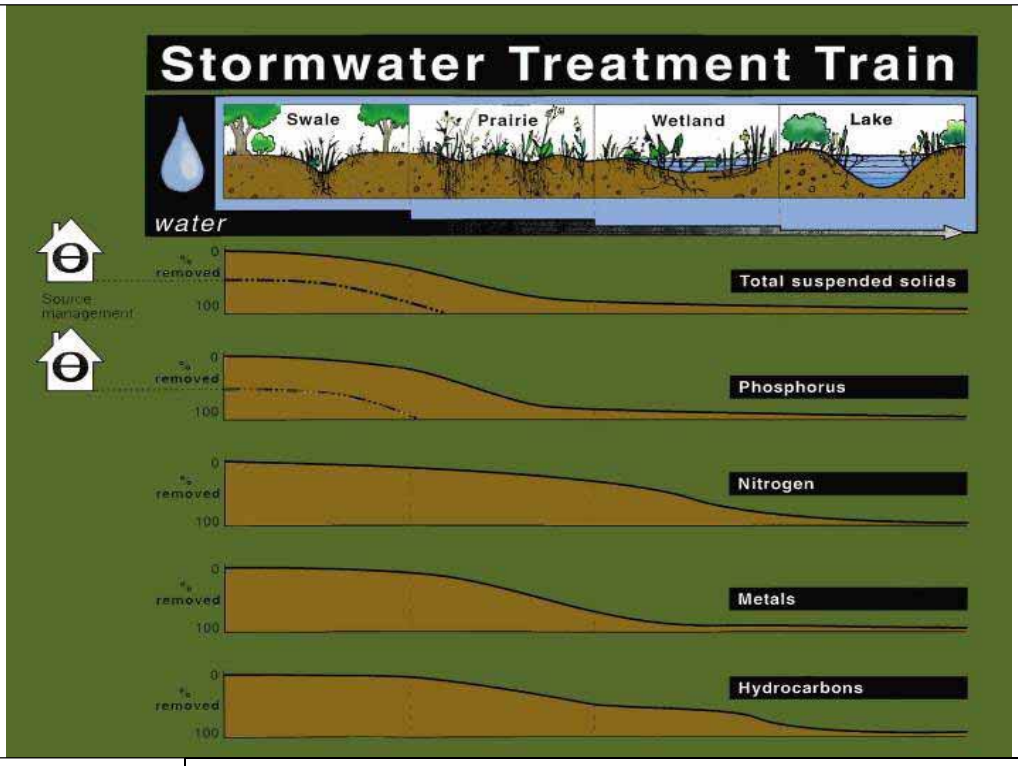
Platy Structure

Massive Structure



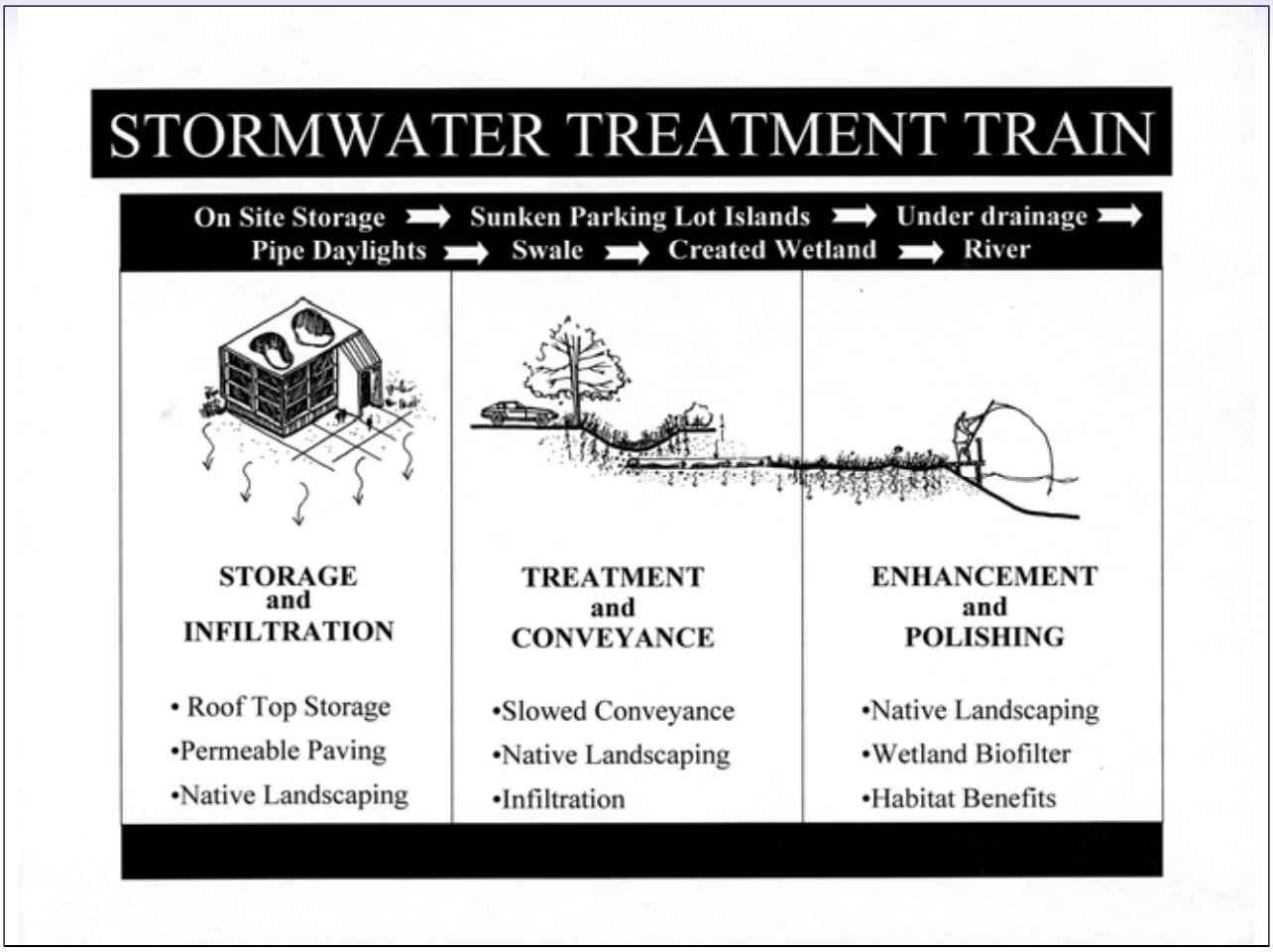
Prismatic Structure

3.15 Stormwater Treatment Train

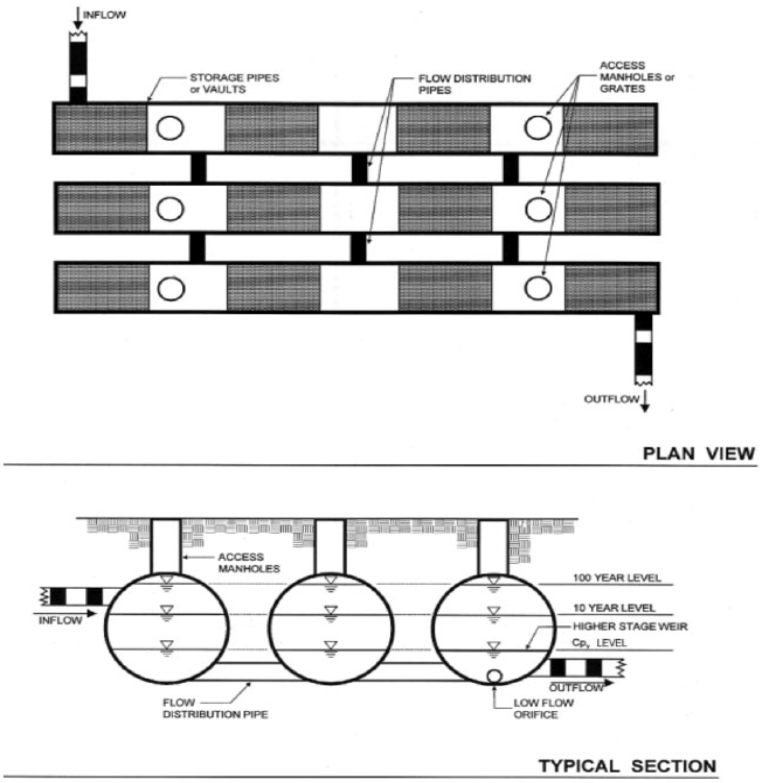


Description	The Stormwater Treatment Train (STT) represents an ecological approach to stormwater management and has proven effective and versatile in its various applications. The STT was designed with sequential components that contribute to the treatment of stormwater before it leaves the site. The components of the Stormwater Treatment Train system were designed to treat stormwater runoff for water quality benefits and to reduce stormwater runoff peaks and volumes. Based on hydrologic modeling and published information on BMP effectiveness, the STT approach can be expected to reduce surface runoff volumes by 65 percent and reduce solids, nutrients, and heavy metals loads by 85 percent to 100 percent. Source controls (upstream from the initial swale component) minimize the impacts of the development even further. This alternative approach to stormwater management not only has the potential to reduce infrastructure costs, but it also reduces maintenance costs. As described above, native plants are adapted to the environment, and do not need extensive watering, chemical treatment, mowing, and replanting that non-native species demand. In addition, there is also a substantial benefit to downstream neighbors. By treating stormwater where it falls on the land, responsible landowners are reducing their contribution to downstream flooding and sedimentation.
Effectiveness	The STT incorporates a number of BMPs with varying effectiveness for removing particulates and pollutants while also reducing runoff volume.

Advantages	• Provides effective stormwater flood control by slowing down runoff and storing water, including water infiltration into the soil. • Improves water quality by filtering pollutants from stormwater (oils, greases, metals, and sediments that can be picked up from paved surfaces). • Reduces erosion. • Flexible to incorporate existing natural features and/or introduced stormwater control features. • Provides open space that can be used for recreation and aesthetic value. • Preserves natural/native vegetation and provides habitat for wildlife. • Protects adjacent properties. • Improves property values.
Disadvantages	• May require more space than is available. • Requires planning and stakeholder acceptance.
Implementation Considerations	• Public outreach and acceptance for existing developments or communities. • Affect on long-term stormwater management infrastructure. • Demonstration of improved property values and cost of development with implementation of the Stormwater Treatment Train. • Planning and engineering of effective treatment train appropriate for each area. • Determine the necessary space and length to achieve stormwater management goals and water quality.
Cost	Variable, depending on best management practices and extent of the treatment system. Overall cost is less, however, than stormwater collection and conveyance systems for a similar area.
Main Design Components	Not applicable.


STORMWATER TREATMENT TRAIN
On Site Storage → Sunken Parking Lot Islands → Under drainage →
Pipe Daylights → Swale → Created Wetland → River
STORAGE and INFILTRATION
• Roof Top Storage
•Permeable Paving
•Native Landscaping
TREATMENT and CONVEYANCE
•Slowed Conveyance
•Native Landscaping
•Infiltration
ENHANCEMENT and POLISHING
•Native Landscaping
•Wetland Biofilter
•Habitat Benefits

3.16 Subsurface Storage

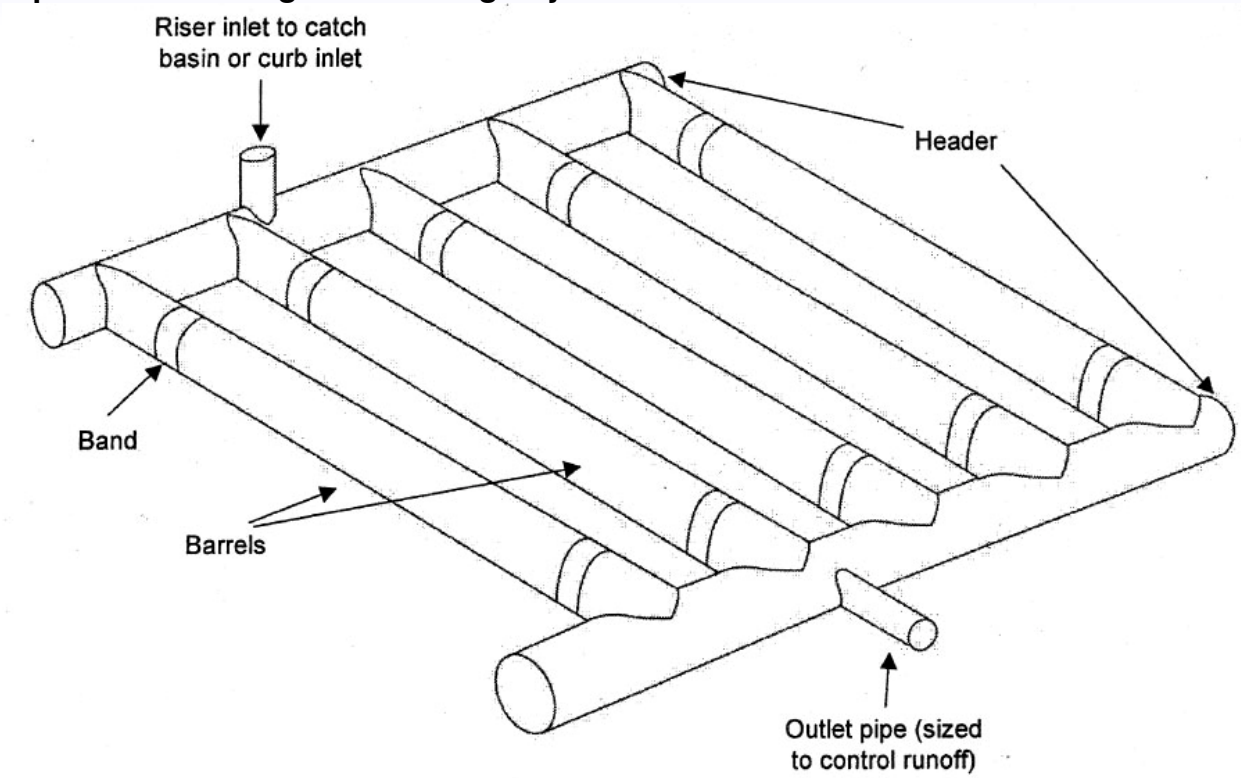


Source: Vermont Stormwater Management Manual

Description	In relatively dense urban areas where a large percentage of the landscape may already be developed, subsurface facilities may be the most practical way to achieve substantial flow volume and rate reductions. Although costs for constructing subsurface storage practices may be high, it may be the most economical way to detain stormwater in urban settings where land values are high. There are a number of types of subsurface storage available. In the simplest system, oversized pipes replace standard pipes in a storm drain, providing temporary storage of water. More storage can be achieved by using a series of interconnected pipes or a single large storage vault. Since these systems offer little or no water quality enhancement when used on their own, they should be coupled with other BMPs in a Stormwater Treatment Train™ to achieve water pollution control objectives. Certain measures, such as sand filters or sediment traps will reduce the amount of maintenance required to keep subsurface storage systems functioning properly.
Effectiveness	Subsurface storage is effective for reducing stormwater runoff, however little reduction of sediments or pollutants occurs without supplemental means to filter stormwater.

Advantages	• Provides substantial storage in areas with limited or no land left undeveloped. • Can be constructed under parking lots or other surfaces, allowing multiple uses for land. • Subsurface storage facilities can be constructed relatively quickly and are quite durable once constructed. • Safer than above-ground storage such as ponds, since residents will not have access to them. • Water captured in subsurface storage can be used for non-potable uses on-site, such as toilet flushing, irrigation, or evaporative air-conditioning.
Disadvantages	• Does not provide water quality benefits, unless other measures, such as oil/grit separators, sand filters, or water quality inlets, are integrated into the design. • May be relatively expensive to implement. • Requires removal of existing surface. • May require more excavation than aboveground storage facilities. • Maintenance may be more difficult than for aboveground storage.
Implementation Considerations	• The size and shape of the available site will determine the correct system. Large continuous areas are more suited to large vault-type systems, while more linear, angular sites are better suited for pipe-based system. • Plastic pipes used in storage may float upward if water table is too high. • Construction materials are influenced by the usable depth and size of the site. Sites requiring more shallow construction should use concrete, since corrugated steel and plastic must be surrounded by more fill.
Cost	Variable – depends primarily on amount of storage required and material used for storage structure, but may average around $400 per cubic yard of maximum instantaneous storage volume.
Main Design Components	• May consist of a simple storage pipe or chambers, or a more complex network of inlets, pipes, chambers, joints, outlets, and access points. • All underground storage must have, at a minimum, an inlet structure, an outlet structure, and an access point, such as a manhole, to the chamber. • HDPE or corrugated metal pipes are more economical, and easier to install, but require greater fill for stabilization and support.

Pipe-Based Underground Storage System



Source: EPA, Storm Water Technology Fact Sheet: On-Site Underground Retention/Detention

Simplified Oversized Pipe Section

Source: Minnesota Urban Small Sites BMP Manual

3.17 Urban Forest

Lincoln's Wilderness Park

Description	Trees clean the air and water, provide protection from the wind, improve the view from our homes, and create green space that provides recreational and educational opportunities. Trees along streams cool the water, provide food for stream organisms, add structure to the stream channel, and stabilize streambanks. While sod and other ground cover hold topsoil in place, tree roots penetrate deep and spread out anchoring large blocks of soil. Densely-planted trees and shrubs can do additional duty by keeping bikes, foot traffic, and motor vehicles off slopes and fragile soils that are prone to wind and water erosion.
Effectiveness	Trees intercept rainfall, reducing its velocity and impact by holding a substantial portion of the rain in the canopy. In one study, a 32-foot tall tree intercepting rainfall reduced stormwater runoff by 327 gallons. Trees and shrubs planted in bioswales, wetlands, and riparian forest buffers can filter out contaminants as they slow and capture stormwater runoff.
Advantages	• Trees improve soil erosion and sediment control. • Trees provide excellent streambank stabilization. • Create green space for riparian zones, and utilization for recreation. • Require minimal or no maintenance. • Trees provide food, shelter, nesting, and travel corridors for wildlife. • Trees provide many additional environmental values including noise reduction, temperature modification, and aesthetic benefits. • Trees resist environmental extremes. • Improve value of property.

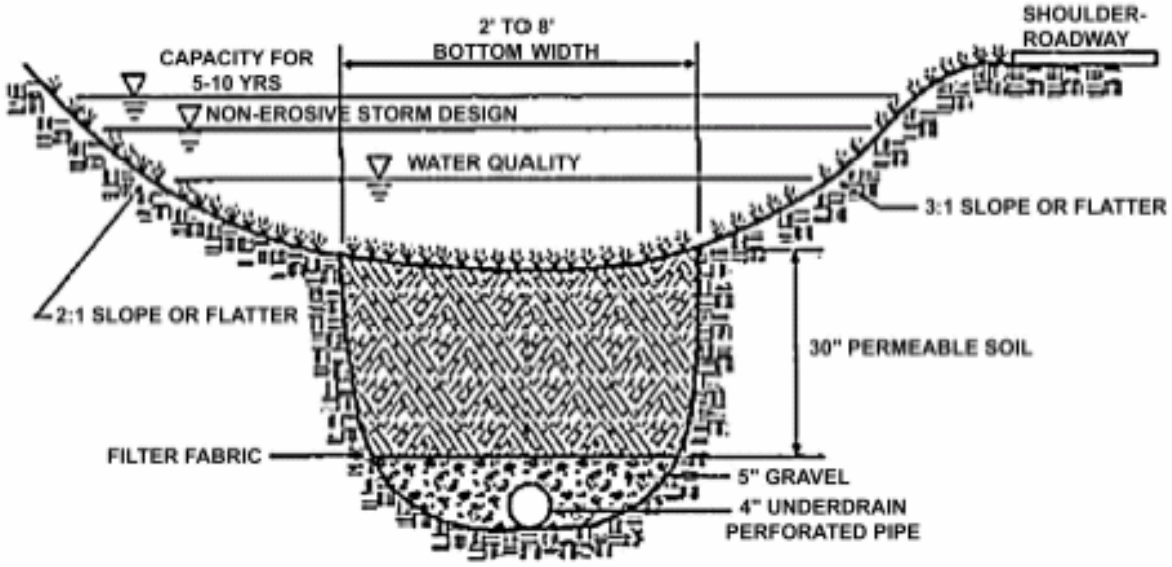
Disadvantages	• Slow growth, therefore benefits are not immediately realized. • May require substantial space if many trees are desired.
Implementation Considerations	• Green spaces should be designed with a variety of plant species to guard against major losses from insects and disease and help diversify the urban landscape. • Species should be chosen that are indigenous to the area and will tolerate climatic extremes. • Surrounding environment, including soils, hydrology, and land-use, should be considered in picking the types of trees used and where they will be planted. • Surrounding vegetation should not out-compete young trees.
Cost	Low if seedlings or young trees are planted, high if more mature trees are planted.
Main Design Components	• If buildings will be nearby future tree canopy height and extension must be considered. • Depth of soil. • Surface and subsurface hydrology. (How much water will support the tree?) • When possible, design developments around stands of existing trees; avoid complete clearing, and replant trees.

Lincoln's Wilderness Park

3.18 Vegetated Bioswale

Description	Vegetated swales are basically a filter strip located along a gentle ditch known as a "swale". Drainage swales that are planted with native vegetation are commonly called bioswales. Swales have gently sloping sides and are used to convey the overland flow of stormwater down a subtle gradient. Swales accomplish many of the same functions provided by filter strips (slowing and cleaning water, encouraging infiltration, etc.), while also providing directed conveyance. This conveyance function is particularly important when managing concentrated flows and during severe storm events when stormwater needs to be directed to a destination, such as a wetland. Swales should be designed with native species for the reasons described above, and can be augmented with check dams and other techniques to maximize their effectiveness at managing stormwater.
Effectiveness	Vegetated bioswales are effective in slowing stormwater and reducing significant amounts of runoff. Removal of sediments and pollutants is high, ranging from 20 to 40 percent, but removal rates have been reported to exceed 80 percent (USEPA, 1999).
Advantages	• Provides effective stormwater flood control by slowing down runoff and storing water, including water infiltration into the soil. • Improves water quality by filtering pollutants from stormwater (oils, greases, metals, and sediments that can be picked up from paved surfaces). • Can be used as a system by itself or in conjunction with other Best Management Practices. • Easy to plan and build. • Reduces erosion. • Flexible to incorporate existing natural features. • Preserves natural/native vegetation and provides habitat for wildlife.

Advantages	• Protects adjacent properties. • Although periodic cleaning may be required, swales should never need to be replaced, in contrast to conventional stormwater systems.
Disadvantages	• May require planning and stakeholder acceptance depending on location. • Requires proper sloping. • Not the fastest conveyance method—carefully design and place swales to minimize risk of flooding. • Swales can only treat a limited area.
Implementation Considerations	• Public outreach and acceptance for existing developments or communities. • Extent of drainage area. • Demonstration of improved property values and cost of development with implementation of the Stormwater Treatment Train. • Planning and engineering of effective treatment train appropriate for each area. • Determine the necessary space and length to achieve stormwater management goals and water quality.
Cost	Low. Roadside swales in residential settings achieve substantial documented cost savings over conventional curb and gutter and stormwater systems. In a suburban example in Chicago, a savings of about $800 per residence was estimated. Generally, costs may range from less than $0.10 to as much as $0.50 per cubic foot.
Main Design Components	• Individual swales should be designed to treat relatively small, flat drainage areas. If swales use slopes steeper than four percent, or if they treat areas larger than 5 acres, the flow velocity may be too great for effective treatment and erosion could occur. • Unless existing soils are highly permeable, they are replaced with a sand/soil mix that meets minimum permeability requirements. An underdrain system may also be installed under the soil bed. Typically, the underdrain system is created by a gravel layer which encases a perforated pipe. • The bottom of the swale should be at least three feet above groundwater in order to prevent the swale bottom from remaining too wet. • The swale should have trapezoidal or parabolic cross section with relatively flat side slopes (less than 3:1). • The flat channel bottom should be between two and eight feet wide to ensure sufficient filtering surface for water quality treatment.

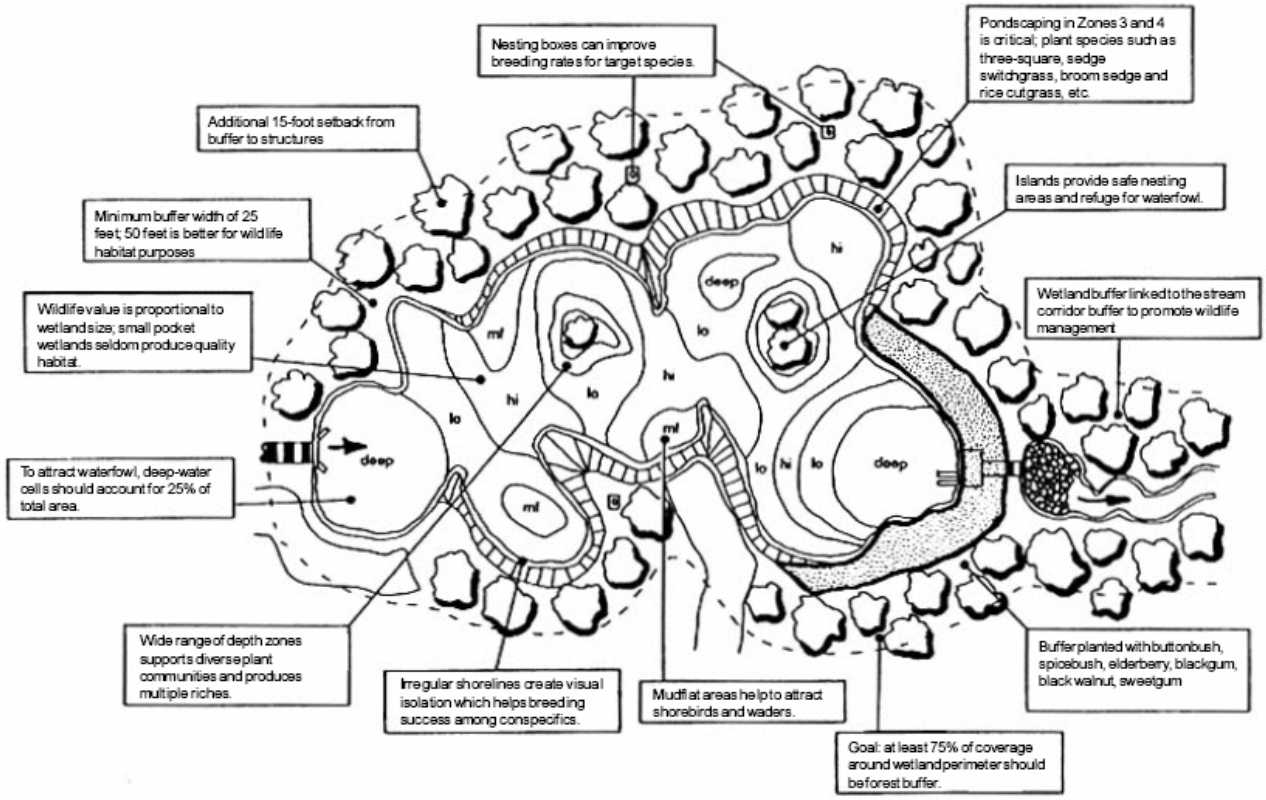


Typical cross section of a parabolic vegetated swale

3.19 Wetland

Urban Wetland, First Street, South of Cornhusker Highway, Lincoln

Description	Stormwater wetlands are shallow marsh systems planted with emergent vegetation that are designed to treat stormwater runoff. While they are one of the best BMPs for pollutant removal, stormwater wetlands can also mitigate peak rates and even reduce runoff volume to a certain degree. They also can provide considerable aesthetic and wildlife benefits. Wetlands use a relatively large amount of space and require an adequate source of inflow to maintain the permanent water surface. Like detention basins and wet ponds, stormwater wetlands may be used in connection with other BMP components, such as forebays and micropools.
Effectiveness	Properly designed wetlands can remove significant amounts of nitrogen and phosphorus, suspended solids, and other pollutants from urban environments. The relative amounts of pollutant and suspended solid removal is similar to other BMPs, however, with removal rates ranging from 40 to 80 percent. Wetlands are very effective for reducing runoff volume and velocity.
Advantages	• Improvements in downstream water quality. • Settlement of particulates. • Removal of pollutants. • Flood attenuation and reduction of peak discharge. • Enhancement of biological diversity and wildlife habitat in urban areas. • Aesthetic enhancement and valuable addition to community green space. • Relatively low maintenance costs.

Disadvantages	• May be difficult to maintain vegetation under a variety of flow conditions. • May require larger land requirements than other BMPs. • Pollutant removal efficiencies may be low until vegetation is established. • Relatively high construction costs. • If not designed properly, wetlands may not receive favorable community attention.
Implementation Considerations	• Site must have adequate water flow and appropriate underlying soils. • Baseflow must be sufficient to maintain a shallow pool in the wetland. • Underlying soils should allow only allow small infiltration losses.
Cost	The costs of constructed wetlands are estimated to range from $0.75 to $1.60 per cubic foot. Costs will vary based on plant selection and density of plantings, and if plantings are from live stems or from seed.
Main Design Components	• Sediment forebays are recommended to decrease the velocity and sediment loading to the wetland. • The wetland design should include a buffer to separate the wetland from surrounding land. • Above-ground berms or marsh wedges should be placed at approximately 50 foot intervals to increase the dry weather flow path within the wetland. • Before the outlet, a four- to six-foot micropool should be included in the design to prevent the outlet from clogging. The micropool should hold at least 10 percent of the total treatment volume. • The outlet from the micropool should be at least one foot below the normal pool surface. • Install a bottom drain pipe with inverted elbow to prevent sediment clogging in order to drain the wetland in case of emergencies or for routine maintenance. • As the wetland-to-watershed ratio increases, the average runoff residence time increases and the effectiveness of the wetland for pollutant removal also increases. • The stormwater wetland's effectiveness for removing pollutants depends on the residence time of water in the wetland. • Vegetation can be established by allowing volunteer vegetation to become established, or, from planting nursery stock.

Main Design Components	• Give priority to species that have already been used successfully in constructed wetlands. • Lincoln has unique saline wetlands that are home to the threatened and endangered Salt Creek Tiger Beetle at some locations. Special care must be taken when designing wetlands near or around these sensitive environments.