LOW IMPACT DEVELOPMENT AND STORMWATER MANAGEMENT

3.1 Introduction

This Chapter discusses the management of stormwater at its source by retaining water on-site rather than disposing of it as waste. This is commonly known as low impact development (LID) and refers to a group of engineering techniques used to mimic natural drainage systems. LID techniques manage rainfall with passive, non-structural practices that promote ground water infiltration or evaporation at or near the rainfall site. This Chapter adapts techniques from the Georgia Stormwater Manual and other sources. (Figures 3.1.a and 3.1.b)

Figure 3.1a Conventional Approach: Manage Stormwater with Centralized Regional Facility

Image Courtesy of: PGDER

Figure 3.1b Decentralized Approach: Manage Stormwater at source with LID Techniques

Image Courtesy of: PGDER

Site development in the coastal region differs comparatively to development in Georgia's Piedmont area, where site development involves moving vast quantities of fill material to flatten hilly terrain for building. In the coastal region, sites are generally flat to mildly sloping. Based on this, developers in this area seek enough change in elevation to prevent the site from flooding. This is often accomplished by digging ponds to provide a low point to receive stormwater, and using the fill generated (from the creation of the pond) to elevate building pads. Upland soils in this region tend to be sandy and have high infiltration rates. In the Piedmont, upland soils generally have high clay content and characteristically low infiltration rates. These differences drive a change in emphasis in recommended LID practices for the coastal area.

However, many issues affecting development activity are quite similar. Land development in both regions involves removing forested canopy and replacing it with impervious cover such as roads, parking lots and rooftops. Chapter 2 discussed the importance of retaining as much of the forested canopy within a development as possible, as well as replacing the canopy that is lost with new plantings. When an area of forest is converted to pavement, the area generates eight times more volume of runoff based on the loss of cover factor alone. According to the EPA, going from grassed areas to pavement generates at least twice the runoff. This runoff reaches the receiving streams in much less time than from forested areas.

Hydrologists often refer to a hydrograph when determining the peak flow of a storm event. Development activity changes this peak flow by increasing the volume of, and speed at which rainfall becomes runoff. The hydrograph illustrates the changes in peak flow for pre-development and post-development conditions in coastal Georgia. (Figure 3.1.c)

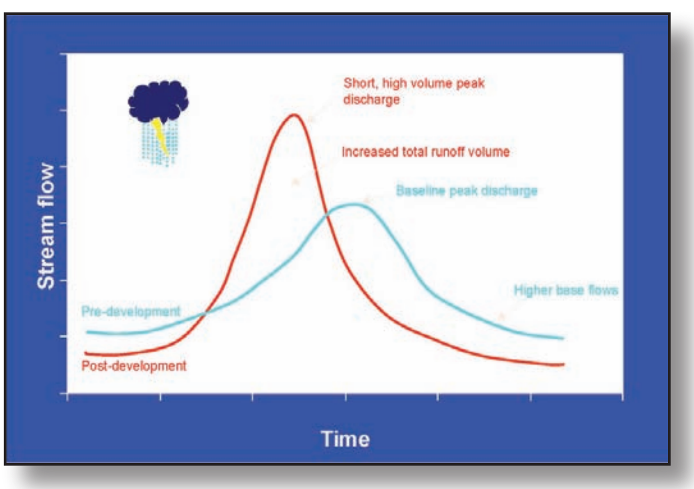


Figure 3.1c Hydrograph Representing Pre-and Post-development Conditions

Image Courtesy of: State.ga.us

Changes also occur in the quality of the runoff. Rainfall landing on impervious areas picks up pollutants and moves them to receiving streams and other water bodies. Dissolved oxygen (DO) in the water is reduced in urban runoff, sometimes to levels fatal to fish and other aquatic life. In the process, rainfall temperatures are elevated as the water moves across hot surfaces. These changes to water quality are referred to as "non-point source pollution" and are "the leading source of water quality degradation in Georgia" (Georgia Stormwater Management Manual, 2001). (Figure 3.1.d)

Figure 3.1d Algal Bloom in Lake Caused by Increased Levels of Nitrogen and Phosphorus from Non-Point Source Pollution

Receiving streams are significantly affected by the quantity and quality of stormwater runoff. Runoff leaving the site at higher velocity and in greater quantity scours the stream bed and creates changes to the channel profile, eroding the stream banks and drastically changing aquatic habitat (see Chapter 4). With an additional pollutant load, lower dissolved oxygen, and elevated water temperatures, habitat degradation is amplified. Also, since more water runs off the site sooner, there is less water slowly percolating through the system to support base flows in the stream, creating another challenge for aquatic species.

With all of these impacts in mind, low impact development strives to achieve a natural hydrological system that can maintain and even reduce pre-development runoff rates. Secondary goals include:

- Water quality improvement,
- Recharge of local groundwater aquifer,
- Stream protection,
- Wetland preservation,

- ◆ Wildlife habitat creation,
- ◆ Reduced urban "heat island" effects,
- ◆ Improved air quality, and
- ◆ Enhanced community aesthetical appearance.

Green Growth Guidelines (using LID principles) balances development with inherent natural site features while enhancing lot yields, reducing development costs, and encouraging development and economic growth. These guidelines seek to eliminate, minimize, and mitigate the root causes of development-generated impacts at the source by integrating stormwater management measures that make the development's landscape more ecologically and hydrologically functional. (Figure 3.1.e)

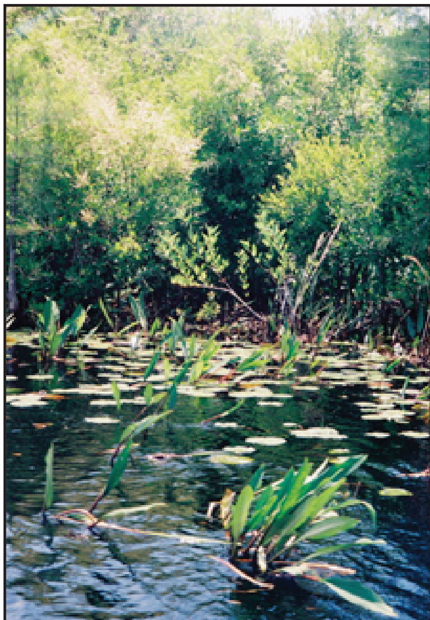


Figure 3.1e Healthy Wetland Habitat

Photo Courtesy of: Chere Peterson

3.2 Natural Processes for Stormwater Management

Natural processes that remove pollutants from stormwater runoff include: (Figure 3.2.a)

- ◆ Infiltration and filtration,
- ◆ Sedimentation,
- ◆ Detention and retention, and
- ◆ Interaction of stormwater with vegetation.

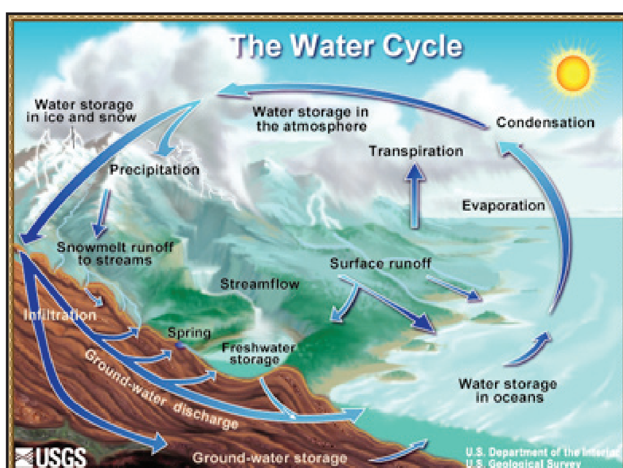


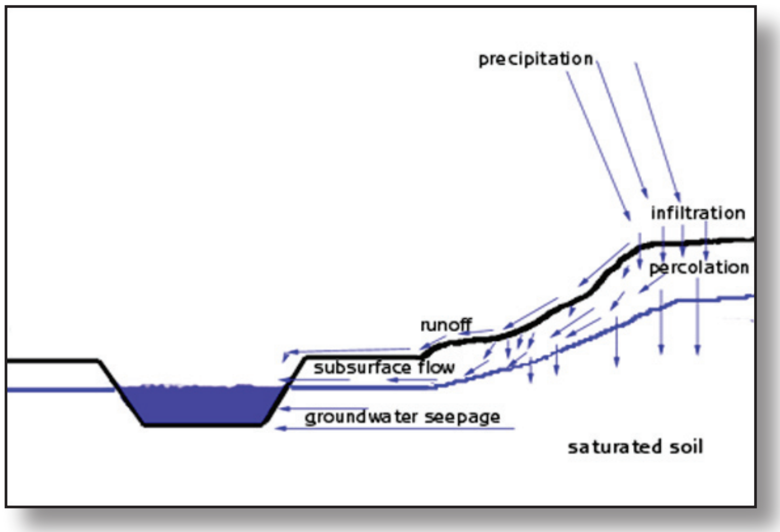
Figure 3.2a The Water Cycle

Photo Courtesy of: John Evans, USGS

3.2.1 Infiltration and Filtration

Infiltration, water's entry into dry, unsaturated soil, is the most natural and direct way to handle stormwater in coastal Georgia. It allows rainwater to quickly enter groundwater before accumulating a pollutant load. In a rainfall event, this unsaturated area is a shrinking zone between rain-soaked soil at the surface and the groundwater saturated soil at the water table. Where water tables are particularly high, as is the case in the coastal region, this unsaturated gap is often measured in a few feet or even inches. (Figure 3.2.1.a)

Figure 3.2.1a Illustration of Infiltration Process



Stormwater tends to pool on the surface, or depending on grade, becomes runoff. Standing water or sheet flow can infiltrate soil, saturating it from the top down. Soil type and compaction determine the speed at which the water percolates or moves downward through the soil. Thereby, soil types affect the infiltration process. Infiltration is dependent on the presence of a well-drained soil capable of accepting water and facilitating its entry. Soils with large particle sizes (sands and gravels) have greater infiltration rates. Certain clays and organic soils (much smaller particle size) can also play major roles in chemical activities that remove or immobilize pollutants. Assessing the soils, topography, and hydrology during site fingerprinting (see Chapter 1) is essential to finding suitable areas for infiltration as well as preventing or discouraging it in unsuitable areas.

Infiltration is most effective in areas with higher ground elevations. However, lower elevations can be used for infiltration if they possess sufficient depth to the water table and adequate soil percolation rates. Infiltration can only be used in areas where runoff is relatively free of pollutants (chemicals, harmful bacteria) that can leach into and contaminate groundwater. Great care must be taken to ensure that the water table is protected.

Various stormwater techniques use infiltration to manage stormwater. Infiltration basin and trenches work better in the coastal plain than in other parts of Georgia. They are less subject to clogging from runoff and have higher percolation rates due to sandy soils. Other techniques that combine infiltration with vegetative filtering include bioretention areas, enhanced swales, and rain gardens.

3.2.2 Detention and Retention

The second key method of using natural processes to delay runoff is achieved by two similar, though intrinsically different processes: detention and retention. These processes mitigate the hydrologic and water quality impacts of stormwater runoff (due to increased impervious area and increased runoff volume) by storing and releasing stormwater at rates similar to rates existing prior to site development. Additionally, these processes control the rate of water flow that reduces downstream channel flood damage and erosion. (Figure 3.2.2.a)

Figure 3.2.2a Natural Detention in Wetlands

Photo Courtesy of: Tara Merrill

While the line between detention and retention may blur, the overall difference is clear. Detention slows the timing of stormwater runoff to lessen its impact, but does not necessarily reduce the quantity or improve the quality of the runoff water. Retention simply retains and disposes of the runoff through natural hydrological processes. Since many hydrological processes can also remove pollutants, retention can also improve water quality. Retention delays the release of runoff by incorporating or enhancing the natural hydrological actions that purify and redistribute rainwater.

LID techniques primarily use retention strategies. With the exception of excess runoff flow that may be routed around the retention system, runoff is not released to a channel, pipe, or watercourse but is essentially disposed of on site. A retention system focuses on the release of runoff though evapotranspiration (loss of water from the soil by plants via gas exchange) and infiltration. In many retention practices, most notably infiltration trenches, the void spaces between stone fill allows for localized movement of water below the soil surface, eventually assisting the return of water to the soil.

Certain retention practices place more emphasis on storage or impoundment than others. A dry retention pond is a good example. (Figure 3.2.2.b) It is normally empty and is filled during a rainfall event. Then, it disposes of its volume through natural hydrological processes, including groundwater recharge, rather than by direct discharge into a watercourse.

Figure 3.2.2b Dry Retention Pond
Photo Courtesy of: Dan Fischer

Some retention practices impact water quality more than others. For example, in a multiple cell pond, constructing small berms in a sequence across the pond slows runoff flow, promotes sediment removal and allows the stormwater to interact with vegetation planted on the berms and along the sides. This combination of techniques improves water quality in several ways. The first cell serves as a sediment forebay allowing soil particles to drop out of the water column. The vegetation shades the water surface and provides significant surface area promoting biologic activity that serves to clean up the water.

Detention encompasses a wide range of techniques including storage in ponds, swales, and natural forested wetlands. The water that enters a detention system can be processed for further treatment but is eventually released to a watercourse.

Detention may create some improvements to water quality. For example, simply holding the water for a day or so in a reservoir allows some sedimentation and separation to occur. In low- or no-flow conditions, particulates naturally drop out of the water column and some substances, such as hydrocarbons, rise to the top. Some detention pond designs are intended to have more impact on water quality during the holding period. Wet ponds, for example, permanently retain water and support vegetation that can assist in water quality treatment. Pond volume is primarily reduced by the release to a watercourse, rather than re-integration into the environment. Wet ponds are generally excavated to the seasonal high water table, creating an additional hydrological interaction. Ponds that incorporate permanent pools of water are designed to use the biological action of plants and organisms to trap and then treat pollutants.

For both detention and retention, some form of impoundment is required. For example, vegetation and forest floor organic matter in a buffer zone may provide sufficient chemical or biochemical action to treat the water during its impoundment. Simple temporary surface pooling may also contribute to retention.

3.2.3 Sedimentation

The settling out or deposition of eroded soils is referred to as sedimentation. By volume, sediment makes up the largest percentage of pollutants entering streams, ponds and lakes. Preventing erosion is the first and best line of defense against sedimentation.

Erosion begins in a rainfall event when water strikes an exposed soil surface or washes across it as the runoff, loosening soil particles and suspending them in the water. Sedimentation begins when runoff carrying this load of eroded material slows, allowing particles to fall from the water column, and deposit it on the streambed or bank.

Sedimentation occurs gradually with heavier particles such as sand dropping out first since they require higher flow velocity to remain suspended. The lighter the soil particle, the more time it needs to drop out of the water column. As flow velocities continue to decrease, the smallest, lightest particles (clay) settle out in the slow-moving areas of the water. (Figure 3.2.3)

Figure 3.2.3 Extreme Sedimentation of River

Photo Courtesy of: The University of Florida Center for Aquatic and invasive Plants

While soil loss through erosion can significantly damage the landscape, its deposition as sediment into streams can also have the following adverse effects:

- Increased flooding due to reduction of channel size by sediment deposits,
- Eventual change in the path or nature of the stream,
- Filled secondary channels, cut off from the main stream,
- Clogged flood control and/or treatment structures,
- Reduced fish spawning areas from changes in stream characteristics,
- Modified fish populations, often in favor of less desirable species,
- Reduced aquatic insect communities, especially the more beneficial species, as a result of sedimentation-induced changes,
- Impairment or destruction of terrestrial (shore) habitats because sediment clogs an existing channel and makes the stream spread, causing inundation of sensitive wildlife habitat along the stream bank,

- Reduced recreational opportunities,
- Adverse impact on commercial fisheries,
- Reduced stream navigability, and
- Increased costs of keeping harbors and marinas usable.

In the stormwater practices discussed later in this Chapter and in the bank stabilization techniques discussed in Chapter 4, the capture of sediments on-site before reaching streams, rivers and other waterbodies is emphasized.

3.2.4 Interaction of Stormwater with Vegetation

Vegetation plays an important role in improving water quality. While soil microorganisms and soil-based chemical reactions remove a variety of nutrients, pathogens, and heavy metals, vegetation assists this process in a number of ways: (Figure 3.2.4.a)

Figure 3.2.4a Buffered Stream Flowing Through Farmland

This buffer will slow nutrient loaded runoff before it reaches the stream.

Photo Courtesy of: Landstudies.com

- Slows runoff flow,
- Filters large particulates,
- Provides considerable amounts of surface area on which pollutant-removing microorganisms thrive,
- Uses water for direct metabolic or storage purposes,
- Decomposes into an organic soil layer active in neutralizing heavy metals,
- Releases oxygen into the soil, improving water quality, and
- Provides shade for the water surface, reducing water temperature.

3.3 Stormwater Management Practices

3.3.1 Introduction

The following eight stormwater management techniques are designed to replicate pre-development hydrology by using a collection of natural processes. This section introduces simple site-specific practices that integrate green space, native landscaping and natural hydrologic functions to capture and treat runoff from developed land. These following practices are highly effective water quality solutions when installed and maintained correctly:

- Stormwater ponds,
- Stormwater wetlands,
- Bioretention areas,
- Infiltration devices,
- Filtration devices,
- Green roofs,
- Permeable paving,
- Oil/water separators.

These techniques specifically treat non-point source pollutants at their source. These practices are quite adept at removing solids, nutrients, pathogens, hydrocarbons and metals as seen in the pollutant removal table below:

Pollutants (% Removal)					
Stormwater Technique	**Suspended Solids**	**Phosphorus**	**Nitrogen**	**Fecal Coliform**	**Heavy Metals**
Stormwater Ponds	80%	50%	30%	70%	50%
Stormwater Wetlands	80%	40%	30%	70%	50%
Bioretention Areas	80%	60%	50%	not available	80%
Infiltration Trench	80%	60%	60%	90%	90%
Enhanced Swale	50%	25%	20%	not available	30%
Filter Strips	50%	20%	20%	not available	40%
Porous Concrete	not applicable	50%	65%	not available	60%
Oil/Water Separator	40%	5%	5%	not available	not available

Table 3.1: Atlanta Regional Commission. Overall Pollutant Removal Capabilities for Various Stormwater Techniques: Georgia Stormwater Management Manual, Volumes 1-2: Technical Handbook. First Edition – August 2001.

3.3.2 Technique 1 - Stormwater Ponds

Stormwater Ponds DESCRIPTION

A wet detention pond or stormwater pond is a constructed basin and wetland system that removes most pollutants from runoff by physical, chemical, and biological processes. In coastal Georgia, these basins are generally excavated, as opposed to being created by siting a dam across a valley as is done in the upper portions of the state. The more time runoff water remains in the system as well as vegetation type and density in wetlands are both important to process effectiveness. While there is no set pond size, the amount of runoff expected as well as the quantity and nature of pollutants to be removed should be considered when determining the appropriate size. The system is designed to retain water in pools year-round. (Figure 3.3.2.a)

Figure 3.3.2a Wet Pond at Daniels Island

Photo Courtesy of: Matthew R. Baker

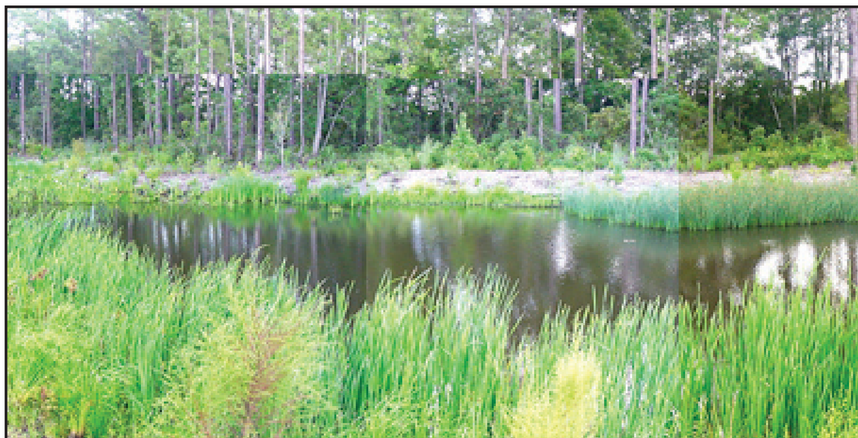
Although the pond is treated as a single unit, it is most effective when it is comprised of at least two relatively deep, excavated basins. The first is called a forebay (or entry pond) and is separated from the main body of the pond by an underwater earthen berm with water on it shallow enough to support wetland vegetation. The forebay serves to trap sediment before it reached the rest of the pond and is located near an access road for easy cleanout. The forebay is typically encircled by a thick ring of vegetation that slows water and further traps sediments. Much of the main body of the pond has wetland shelves. (Figure 3.3.2.b)

Figure 3.3.2b Vegetated Forebay

Photo Courtesy of: Matthew R. Baker

In nature, lakes and ponds have a vegetated shelf, known as the littoral shelf, that surrounds the pond along the peripheral edge. In constructed ponds, this planted shelf or shallow wetland area (from 4 to 24 inches deep) enhances system efficiency by wrapping around the larger pool and forebay. This created shallow region along the margin of the system is planted with emergent and submergent vegetation. This vegetation assists in removing pollutants through vegetative uptake and soil-related processes including microbial action. The following plants are native to coastal Georgia and can be used to vegetate the edges of both freshwater and tidally influenced ponds. (Figures 3.3.2.c and 3.3.2.d-i)

Figure 3.3.2c
Vegetated Pond Shelf
Photo Courtesy of:
Matthew R. Baker



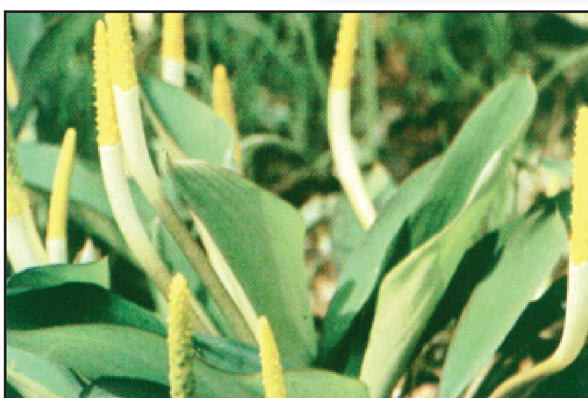


Figure 3.3.2d Golden Club
Photo Courtesy of: Tara Merrill

Figure 3.3.2e Duckpotato
Photo Courtesy of: Tara Merrill

Figure 3.3.2f Soft Rush

Photo Courtesy of: Tara Merrill

Figure 3.3.2g Water Lily

Photo Courtesy of: Tara Merrill

Figure 3.3.2h Blue Flag Iris

Photo Courtesy of: Tara Merrill

Figure 3.3.2i Arrow Arum

Photo Courtesy of: Tara Merrill

Stormwater Ponds BENEFITS

- Water quality is improved based on the amount of detention time.
- Sediment is trapped, mostly in the forebay, allowing for periodic removal.
- Downstream flooding may be reduced because the pond can provide additional water storage capacity.
- A variety of wildlife habitat is created.
- Associated buffer zones enhance system effectiveness by providing infiltration opportunities and expanding the wildlife habitat area.
- The wet detention pond is less expensive to create and maintain than piping and other infrastructure for off-site treatment.
- The pond and wetland combination creates an aesthetically pleasing landscape feature that may prove a pleasant attraction on a pathway. Pathways may be

pedestrian, bicycle or handicapped access oriented.
- The pond provides educational opportunities for wetlands and wildlife study.

POLLUTANT REDUCTION	
Suspended Solids	80%
Phosphorus	50%
Nitrogen	30%
Heavy Metals	50%
Pathogens	70%

Table 3.2: Atlanta Regional Commission. Georgia Stormwater Management Manual, Volumes 1- 2: Technical Handbook. First Edition, August 2001.

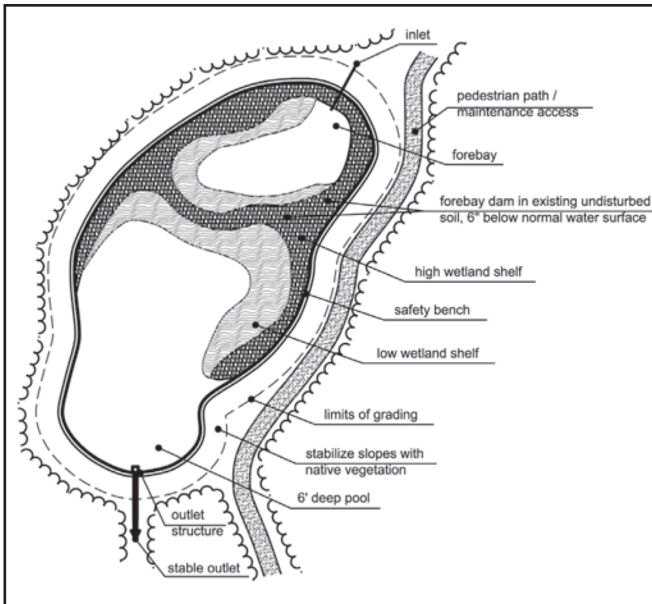
Stormwater Ponds APPLICATION

- Runoff detention in the system for a period of at least one day is necessary to remove significant percentages of total suspended solids ("TSS"), phosphorus and dissolved nutrients (Schueler, *et. al.*, 1997). These removal percentages generally increase with the length of the detention period. Extended detention of 2 weeks can increase solids removal as well as significantly remove lead and zinc while positively impacting chemical and biochemical oxygen demand (Hartigan 1988).
- Detention ponds should be used in penetrable soils, preferably with high infiltration rates. Yousef and Brown (1985) reported consistently higher removal rates for all pollutants, particularly soluble, at a site in Florida where infiltration rates were at or above 38 mm/hr (1.5 in/hr).
- Drainage area should be at least 25 acres.
- A slope of up to 5 percent is usable for a detention pond. The local slope within the pond should be relatively shallow. There is no minimum slope requirement, but the drop from inlet to outlet must be sufficient to keep water moving through the system.
- The detention pond may interact with ground water, except in cases where contamination is known or suspected.
- Wet ponds can easily be retrofitted into an existing system. Dry ponds built for flood control can be converted by excavation to wet ponds to add a water quality control component to the system. The outlet structure of such converted dry ponds can be modified for downstream channel protection. New wet ponds may

also be installed in streams or open areas as part of a comprehensive watershed retrofit program.

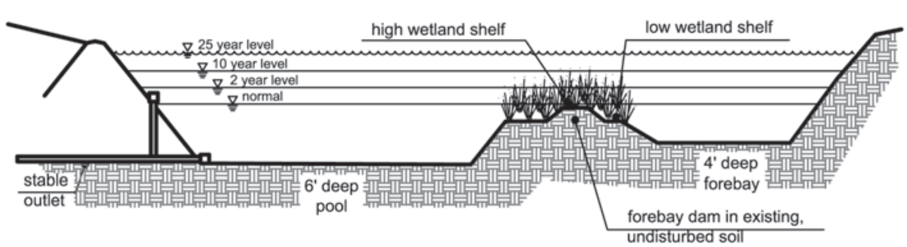
- Unless the detention pond is apt to receive runoff from a pollution hot spot, it can interact freely with groundwater. Separation from groundwater is required for the system to be appropriate in situations where pollution runoff from such hotspots may contaminate groundwater.

Stormwater Ponds DESIGN
(Figure 3.3.2.j)



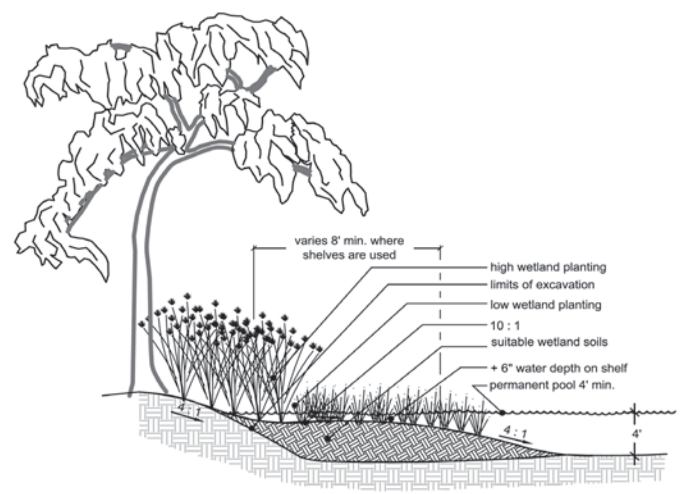
Stormwater Pond with Forebay - Plan
Figure 3.3.2.j - nts

- Although minimum excavation is recommended to reduce soil disturbance, the main pool should be at least 6 feet deep. Depths ranging from 3 to 8 feet have been used, with efficiency reduced at depths of less than 3 feet.
- The forebay should be at least 10 percent or more of the total pond volume, excluding wetland areas, to allow for sufficient sedimentation and settlement. It should be designed and located for ease of maintenance, primarily for the removal of accumulated sediment.
- A depth of 4 feet is recommended for the forebay. In certain circumstances, it may be deeper to increase capacity and reduce maintenance frequency. (Figure 3.3.2.k)



Stormwater Pond with Forebay - Profile
Figure 3.3.2.k - nts

- ◆ The ratio of length to width of the main pond should be at least 1.5 to 1 or greater to increase the amount of time stormwater remains in the pond.
- ◆ The wetland area surrounding and separating the ponds should be effectively divided into two shelves of different depths; the shallower nearest the bank, the deeper nearest the pond. This will support more types of aquatic vegetation, increasing the system's effectiveness and biodiversity. The drop-off between shelves need not be abrupt and will not remain so anyway due to silt and particulate accumulation in the denser vegetation closer to the bank.
- ◆ The depth of the high wetland shelf should be from 4 to 12 inches. This is the area nearest the bank and at the center of the dam separating pond and forebay. The depth of the low wetland shelf should be from 1 to 2 feet.
- ◆ The dam portion of the vegetated wetland area separating the forebay and main pond should be high and wide enough to slow water movement between the deeper pools, increasing forebay effectiveness as a sediment trap.
- ◆ Undisturbed native soil should be used for dams or berms where possible to provide stability.
- ◆ Wetland shelves can serve as effective safety benches. Shelves provide a shallow area along the entire perimeter of the pond that separates the deeper water from the land's edge. These shelves further reduce the danger of injury should a person fall into the pond. (Figure 3.3.2.l)



Wetland Shelf - Section
Figure 3.3.2.L - nts

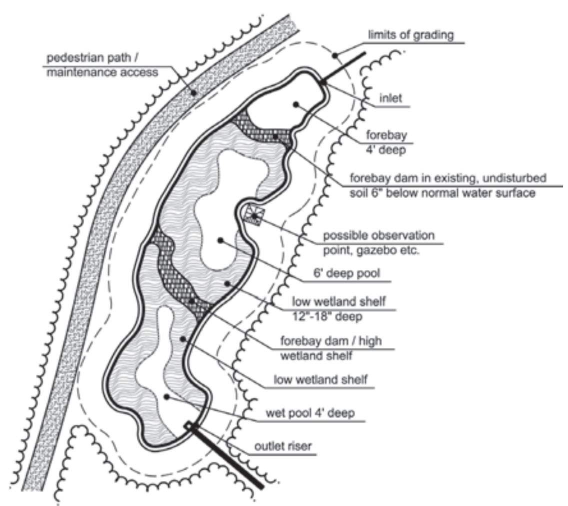
- ◆ Grading above the waterline of the pond should be stabilized with vegetation as quickly as possible to prevent erosion.
- ◆ In coastal Georgia where most of the ponds are excavated, finding an outlet can be a challenge. If the available outlet is shallow, a simple weir may be all that is needed to discharge excess rainwater. When a deeper ditch or stream is available, water may be discharged using an outlet consisting of a vertical riser attached to a horizontal barrel that passes water to the receiving stream. The outlet design

is intended to release excess water while maintaining a permanent pool. Risers, when used, are placed at the edge of the pond and are capped with a trash rack.

- A low flow outlet should be provided to maintain water circulation even in drier periods.
- The outlet and pond banks should be shaded to cool water released from the pond system. Shading also benefits wildlife using the pond, especially during summer months and extended drought conditions.

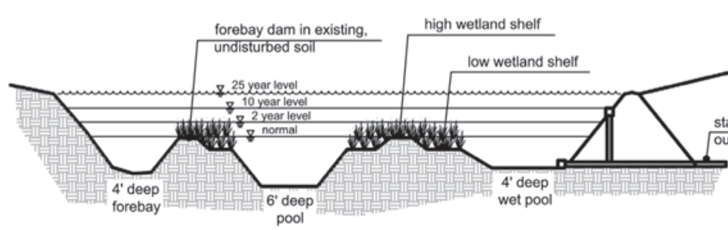
3.3.2.1 Multiple Ponds

Multiple ponds may be created by separating two or more deep-water areas with underwater dams to form a forebay and micropools. This linked pond arrangement can significantly increase system effectiveness by providing a longer flow route and extended treatment time. The linked ponds may become successively shallower with a 6-foot depth for the primary pond and a 5- or 4-foot depth for the secondary pond downstream from the forebay. (Figures3.3.2.1.a and 3.3.2.1.b)



Multiple Pond Cells - Plan

Figure 3.3.2.1.a - nts



Multiple Pond Cells - Profile

Figure 3.3.2.1.b - nts

OTHER CONSIDERATIONS for Stormwater Ponds

Additional maintenance considerations include providing direct access to the forebay for sediment removal and to the main pool if necessary. Sediment should be cleaned from the forebay every 5 to 7 years depending on the accumulation rate and its effect on the functionality of the inlet.

3.3.3 Technique 2- Stormwater Wetlands

Stormwater Wetlands DESCRIPTION

Stormwater wetlands are designed and built to facilitate natural processes in removing pollutants from urban stormwater runoff. (Figure 3.3.3.a) The stormwater wetland is designed, sized, vegetated, and sited to reduce peak flows and provide water quality improvements. The larger the wetland, the larger the watershed area it can serve and the greater the opportunities for biodiversity.

Figure 3.3.3a A Constructed Wetland with Cypress Planting

Photo Courtesy of: Dan Fischer

Stormwater Wetlands BENEFITS

- Sediment is trapped and removed from runoff entering the wetland beginning with a forebay.
- Vegetation interacting with stormwater with provides considerable surface area on which microbes digest pollutants.
- Plant uptake and chemical action also clean pollutants from water.
- Vegetated buffers can help slow floodwaters, reducing erosion and stabilizing soils by root networks.

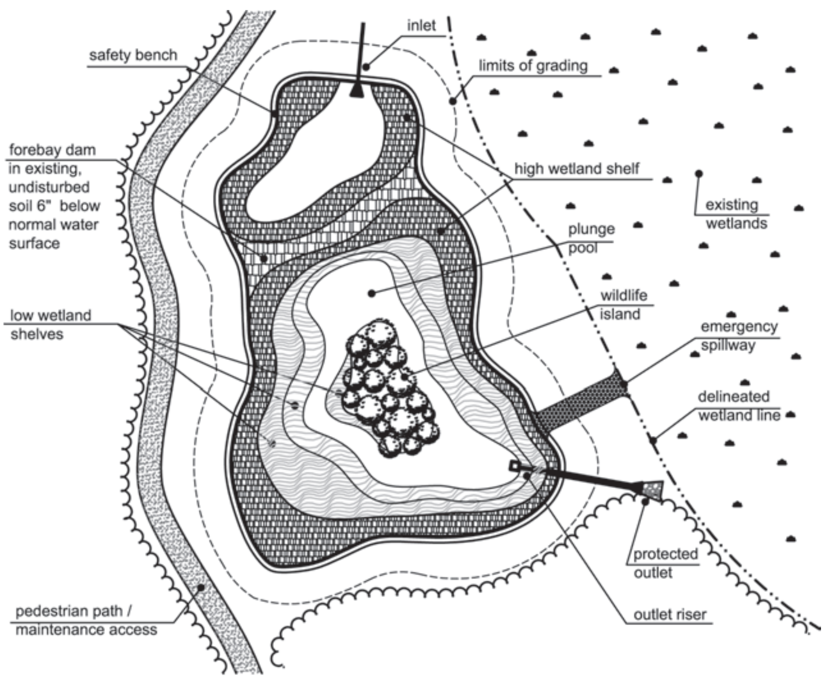
- The wetland and its adjoining buffer provide a wide range of aquatic, terrestrial, and avian habitat. Wetland trees and plants play an important role in providing cover, food, and nesting areas for these animals.
- The vegetated buffer zone located along the wetland fringe slows incoming stormwater and stabilizes the area from erosion.
- Naturally, wetlands are located in low-lying areas. This is an advantageous location for stormwater detention being water can be routed to these areas with little difficulty. For this reason, stormwater wetlands are inexpensive solutions that require minor earthworks and simple technology to implement, usually excavated swales or ditches, constructed perimeter berms, and weirs to control flow.
- Maintenance costs are low, consisting of forebay sediment cleanout and the removal of excess vegetation, a process that will have be required every few years; exact intervals depend on local conditions.
- With its surrounding buffer zone, the stormwater wetland is the perfect location for paths that can combine education with local transportation needs. Depending on the wetlands extent and location relative to the community, some paths may actually be critical shortcuts in the local transportation network for pedestrians and cyclists.
- Stormwater wetlands can be sited to create natural views for residents.
- Perimeter paths following the shaded outer fringe of the buffer zone can also provide desirable views. These paths can be brought through the buffer directly to the wetland edge to provide dramatic views down their length.

POLLUTANT REDUCTION	
Suspended Solids	80%
Phosphorus	40%
Nitrogen	30%
Heavy Metals	50%
Pathogens	70%

Table 3.3: Atlanta Regional Commission. Georgia Stormwater Management Manual, Volumes 1- 2: Technical Handbook. First Edition, August 2001.

Stormwater Wetlands APPLICATION

- The stormwater wetland is a viable treatment practice for areas where the appropriate hydrology can be created. In coastal Georgia, this is most often accomplished by two ways: a shallow excavation or the construction of a small earthen perimeter berm. The former is most applicable to constructed wetlands while the latter applies to existing wetlands. Both methods of detention usually require some form of outlet. (Figure 3.3.3.b)



Stormwater Wetland with Wildlife Island - Plan
Figure 3.3.3.b - nts

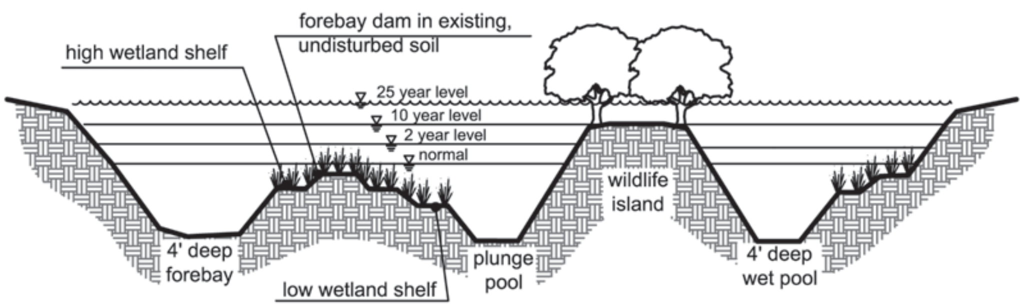
- As a rule of thumb, the size requirement for a stormwater wetland is 3 to 5 percent of the contributing drainage area.
- In coastal areas, stormwater wetlands should be sited such that the normal pool elevation is at or slightly below the water table. In such cases, runoff from two or more acres can be sufficient to replenish the wetland's basic pool.
- Since stormwater wetlands in coastal areas freely interact with groundwater, runoff from any stormwater hotspot or any other area with a high pollutant loads should be avoided.
- It is possible, however, to design a wetland area that is separated completely from the water table using an EDPM or other heavy-duty liner. In such cases, specific

wetlands can be designed to treat hot spots or other heavy pollutant loads.

- A maximum upstream slope of up to 15 percent is usable for a stormwater wetland. The minimum slope is simply the elevation drop necessary for hydraulic conveyance of runoff, generally ½ to 1 percent in coastal areas.
- Water can be conveyed from an urban environment for treatment in a larger, multi-community wetland. Off-site treatment facilities are often applied as a retrofit solution for existing flooding problems.

Stormwater Wetlands DESIGN

- The forebay should be about 10 percent of the surface area of the wetland area.
- The forebay should be located for easy sediment removal.
- A length to width ratio of 1.5 to 1 or greater is recommended for the wetland pool to help increase the amount of time water remains in the system. (Figure 3.3.3.c)



Stormwater Wetland with Wildlife Island - Profile

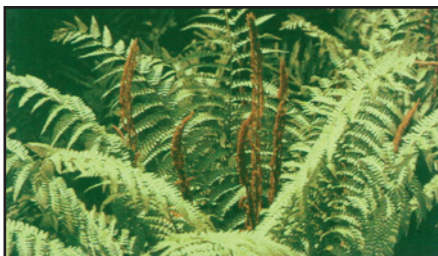
Figure 3.3.3.c - nts

- An island can remain in the main pond to provide habitat. This wildlife island should have retained or planted trees as well as other native woody and herbaceous vegetation to enhance its biodiversity. As the trees grow, they will provide shade, cooling the pond water for fish and other aquatic species.
- Wetlands should have at least two vegetative zones: a shallow zone of about 6 inches in depth, and a deeper zone roughly triple the depth of the inundation in the shallow area.
- Native plants are preferred, though cultivated species can be used if they are non-invasive.
- A wetland may have multiple inlets, some of which function only under high

water conditions. It may not have an outlet, although overflow or conveyance measures can be installed to make it part of an integrated flood control system. An emergency spillway for unusual rainfall events may be necessary in some cases.

- These are various wetland species of plants available that are acclimated to coastal conditions. Examples include: (from left to right) Cinnamon Fern, Buttonbush, Red Maple, Coastal Sweet Pepperbush, Bald Cypress and Buckwheat Tree.

Photos courtesy of Tara Merrill.

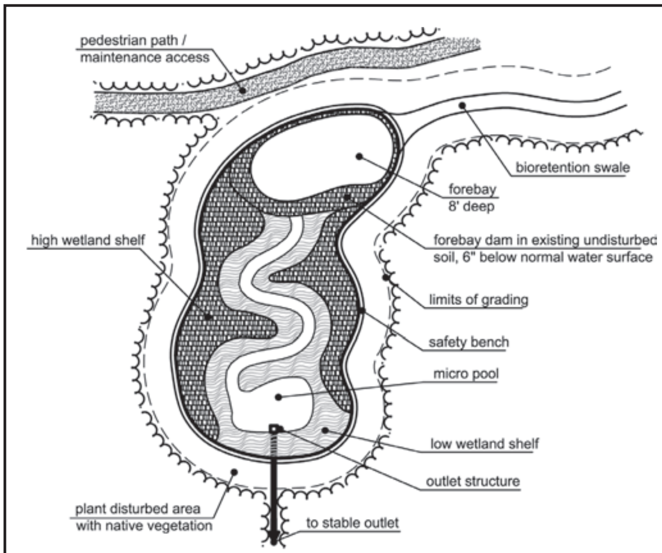


3.3.3.1 Retrofit Applications

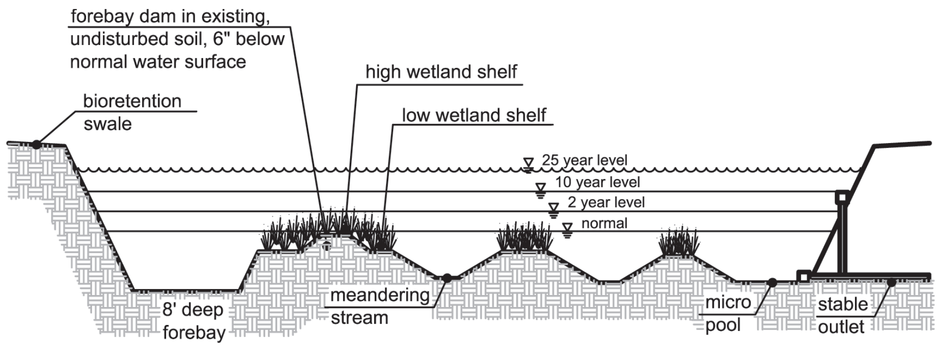
Stormwater wetlands can be used as a retrofit application for small or large areas. For example, 3 to 5 percent of a large drainage area (1,000 acre watershed), if treated alone by stormwater wetlands, would require 30 to 50 acres of wetlands along with associated buffer zones (Georgia Stormwater Management Manual, August 2001). In reality, a judicious mix of on-site treatment practices would be employed, substantially reducing the amount of constructed or natural wetlands required for runoff treatment.

3.3.3.2 Pocket Wetlands

In smaller drainage areas, a pocket wetland can be created to control and treat stormwater runoff. This practice consists of a deeper forebay (8 feet or perhaps greater), connected to a micropool by a sinuous channel meandering through the wetland. The pocket wetland is created by excavating the forebay, the micropool, and then the winding channel that connects the deep-water pockets. Underwater wetland shelves and separating berms can be constructed using stockpiled hydric soils, if necessary. Extending the length and adding bends to the channel increases the time runoff remains in the channel resulting in overall system effectiveness. Wetland trees and plants improve this process by slowing and filtering runoff received as sheet flow. To further enhance the process, runoff may enter a pocket wetland, through a bioretention swale or a filter strip. (Figures 3.3.3.2.a and 3.3.3.2.b)



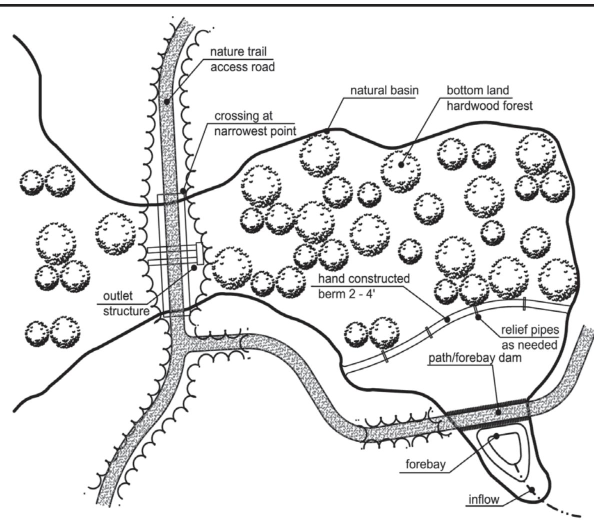
Pocket Wetland with Sinuous Channel - Plan
Figure 3.3.3.2.a - nts



Pocket Wetland with Sinuous Channel - Profile
Figure 3.3.3.2.b - nts

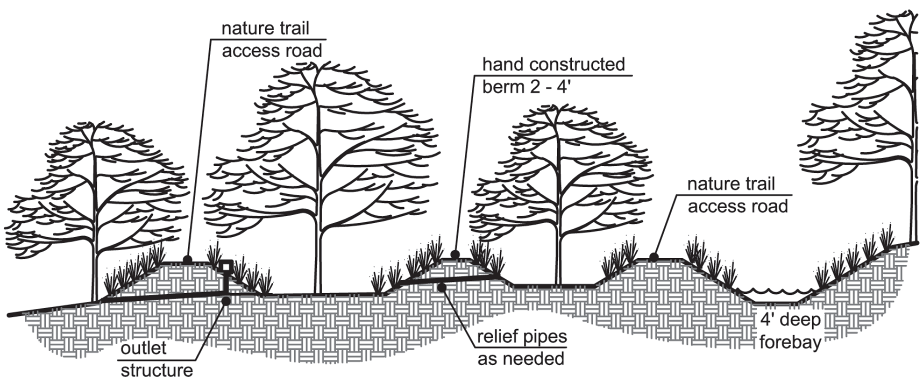
3.3.3.3 Natural Detention using Forested Wetlands

On certain sites in coastal Georgia, a natural basin can be used to detain stormwater. These areas may not be as efficient as wetlands built to meet site-specific needs, but for smaller volumes and lighter pollutant loads, natural detention can be an effective practice. The natural detention area is typically sited over an existing wooded depression (bottomland hardwood forest). Often there is an access road crossing the depression at the narrowest point that forms an embankment. This embankment is fitted with an outlet structure (similar to a stormwater pond outlet) designed to pass the required storm based on the use of the roadway or trail on the embankment. The outlet in this case, however, is designed to completely drain the basin over several days. A forebay is created at the pond entrance to trap sediments entering the system. The crossing acts as a dam detaining water behind it, allowing the stormwater to infiltrate and interact with the vegetation remaining on the forest floor. The crossing has small pipes slightly above grade with allows water to slowly percolate into the ground. These pipes pass larger storms safely while preventing the crossing from overtopping in all but the largest storm events. (Figure 3.3.3.3.a)



Natural Detention with Forebay - Plan
Figure 3.3.3.3.a - nts

Generally, bottomland hardwood wetlands are subject to soil saturation within the upper 12-18 inches, a minimum of 10-15% of the annual growing season (up to 300 days in coastal Georgia). These areas can tolerate seasonal inundation up to a depth of 18" for long periods. Given that bottomland hardwood forests form on broad flat areas, it is relatively easy to spread the water over this large area and keep it below 12-18 inches. Bottomlands are covered by hardwood species such as Cypress, Tupelo, Water Oak, and Maple. The trees exhibit morphological (structural) adaptations to wet conditions over time such as covered or exposed roots, and aerial roots from portions of branches in contact with water. These trees are able to live in saturated conditions due to these physical adaptations. In the case of emergent wetlands (generally grassy, depressional wetlands), ponding depth can be as high as 24-36" above ground level following major rain events. (Figure 3.3.3.3.b)



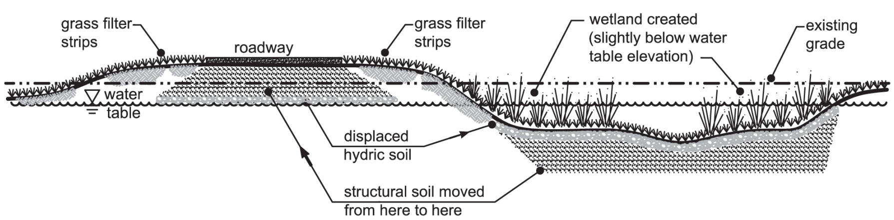
Natural Detention with Forebay - Profile

Figure 3.3.3.3.b - nts

This is a practical, multi-functional solution for developments that must cross wetlands to access the buildable area of the tract. This practice creates a large green space area for the community, while detaining stormwater in the wetlands for infiltration and treatment by the soils and native vegetation. These natural detention areas can be installed with very little disturbance and require very little maintenance.

3.3.3.4 Roadside Wetland Creation

Roadside wetland creation is suitable for wetland crossings typical of transportation projects, of any scale. In such projects, the roadway must be elevated above normal flood elevation. This is achieved by using suitable soil beneath the wetland being crossed. The deeper layers of soil below the hydric wetland soil often posses the requirements of suitable material. In this example, the structural soil is excavated from below the wetland area and used as fill material to elevate the road being constructed. Then this area is backfilled with unsuitable material excavated along the route of the proposed road. Graded and sloped as a swale, the created wetland then serves as a roadside stormwater wetland or bioretention area, treating runoff as it leaves the roadway. (Figure 3.3.3.4.b.)



Roadside Wetland Creation

Figure 3.3.3.4.b - nts

OTHER CONSIDERATIONS for Stormwater Wetlands

Mosquito problems can be controlled by a variety of measures, including preserving native species that are natural enemies to the mosquito and allowing for the highest feasible velocity and continuity of water flow. Creating fish habitat and stocking wetland ponds with fish that eat mosquito larvae can effectively reduce populations. Also, dragonflies and bats are good natural predators of mosquito larva. Installing bat boxes in the trees and planting flowering vegetation in or around the wetland can attract dragonflies and other mosquito-eating insects. (Figures 3.3.3.j, 3.3.3.k, 3.3.3.l and 3.3.3.m)

Figure 3.3.3j Guppy

Photo Courtesy of: EPA.gov

Figure 3.3.3k Mosquito Fish

Photo Courtesy of: EPA.gov

Figure 3.3.3l Dragonfly

Photo Courtesy of: EPA.gov

Figure 3.3.3m Brown Bats

Photo Courtesy of: EPA.gov

For all stormwater wetland detention techniques, sediment removal from the forebay area will be required every few years. Five to seven years is normal depending on forebay size and runoff sediment content. Excess debris must be removed from inlets and overflows to prevent clogging. Areas surrounding inlets and outfall structures should be routinely checked for erosion.

3.3.4 Technique 3 - Bioretention Areas

Bioretention Areas DESCRIPTION

Bioretention areas are shallow stormwater basins, swales, or depressed landscaped areas ("rain gardens") with suitable soils and vegetation that captures and treats runoff flowing from adjacent impervious surfaces. Bioretention areas can be used adjacent to roadways and parking areas or located anywhere on the site as a landscaped "rain garden". Originally designed as a treatment element for water quality control, recent studies have shown that these areas can also provide flood protection as well. The treatment area consists of sand or grassed filter strip, a perforated drain pipe, permeable soil, an organic layer of mulch, a pond area, an overflow outlet, and vegetation capable of living in saturated and drought conditions. (Figures 3.3.4a, 3.3.4.b, and 3.3.4.c)

Figure 3.3.4a Residential Rain Garden

Photo Courtesy of: raingardens.org

Figure 3.3.4b Bioretention Swales with Curb Cut

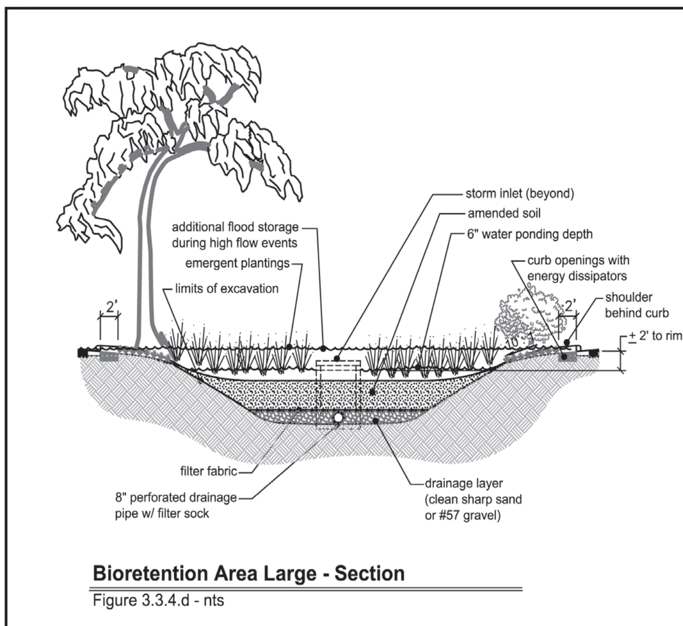
Photo Courtesy of: Matthew R. Baker

Figure 3.3.4c Bioretention Swales Using Wheelstops

Photo Courtesy of: William Dietz and Karolina Bako

Bioretention Areas BENEFITS

(Figure 3.3.4.d)



- ◆ Bioretention areas are designed to drain collected stormwater within 48 hours, reducing the potential for mosquito infestation.
- ◆ Improves water quality by filtering pollutants from collected runoff using a combination of microbial soil processes, infiltration, evaporation and appropriate plantings
- ◆ Creates attractive, highly effective features for parking medians, tree islands, and other landscaped areas
- ◆ Provides basic on-site flood relief and adequate storage during smaller rainfall events
- ◆ Use of drought-tolerant plants reduces the need for irrigation, thereby conserving water

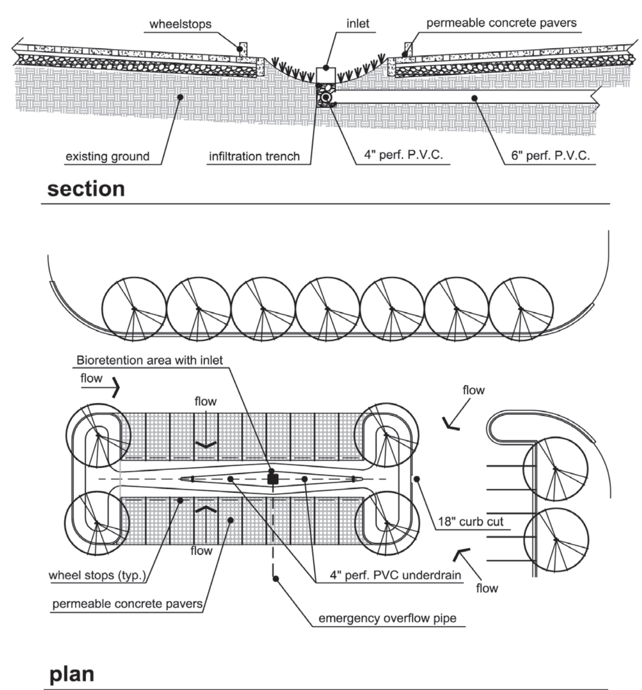
- ◆ Costs less to install and maintain than conventional landscaped areas
- ◆ The cost of curb and gutter can be eliminated for the parking area, generally replaced with curb stops draining to landscaped areas.
- ◆ Reduces both pipe and landscaping costs; installed costs for bioretention plantings are one-quarter of the cost of conventional landscape materials.

POLLUTANT REDUCTION	
Suspended Solids	80%
Phosphorus	60%
Nitrogen	50%
Heavy Metals	Moderate
Pathogens	Insufficient Data

Table 3.4: Atlanta Regional Commission. Georgia Stormwater Management Manual, Volumes 1- 2: Technical Handbook. First Edition, August 2001.

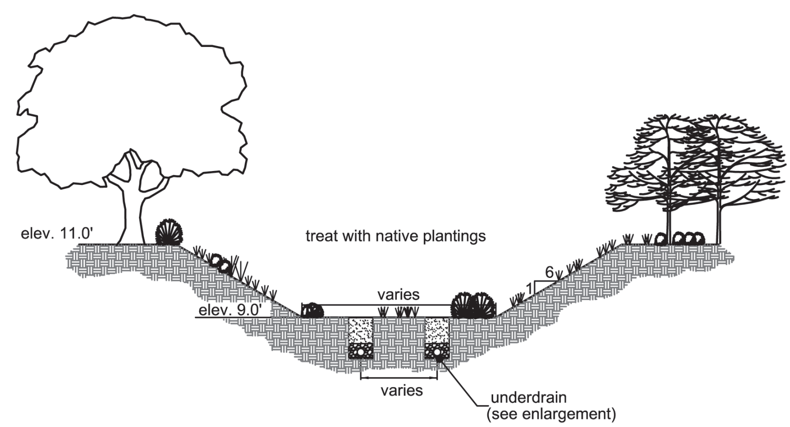
Bioretention Areas APPLICATION

- ◆ The bioretention area is suitable for a broad array of applications including residential and commercial developments, transportation and drainage projects, and greenways. Specific examples include their use in medians of roadways and in between parking bays, along driveways, alleys, roads, canals, sidewalks, and trails.
- ◆ The drainage area can be up to 2-3 acres, preferably less than 1 acre for highly impervious areas. (Figure 3.3.4.e)
- ◆ Capable of treating “first flush” runoff generated during a 2-year storm event.
- ◆ To draw down pooled water within 4-6 hours of a rainfall event, the infiltration rate should be a minimum of 1.5 inches per hour.



Bioretention in Parking Median
Figure 3.3.4.e - nts

◆ During high flow events, inlets with overflow pipes are used to bypass the bioretention area and direct runoff to nearby collection and conveyance systems. The system may require using an additional infiltration or retention basin to pass runoff from larger storm events. Hand calculations and/or hydraulic/hydrologic modeling can determine the required storage volume. (Figure 3.3.4.f)



Bioretention Swale Large - Section

Figure 3.3.4.f - nts

◆ Bioretention is most effective in sandy, loamy, and other well-drained soils (USDA recommended Class A and B soil types).

◆ Underdrain pipe systems are recommended to increase filtration rates, especially in coastal areas subject to seasonal high water tables. Due to high water tables, the underdrain should be located away from wellheads and septic tanks.

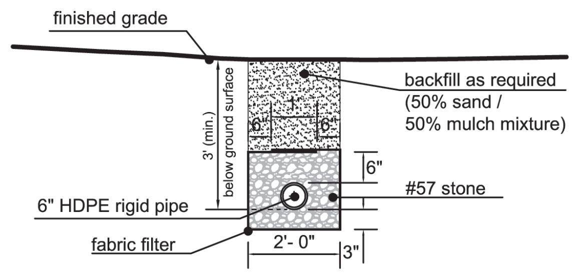
◆ Vegetation must be able to tolerate variable soil moisture content as well as be able to withstand both droughts and saturated root systems. Tree species that provide desirable bird habitat and shade should be selected; small leaves that biodegrade quickly and showy flowers are a bonus.

Bioretention Areas DESIGN

◆ Grade side slopes of the bioretention swale at a maximum of a 6:1, preferably 10:1 angle.

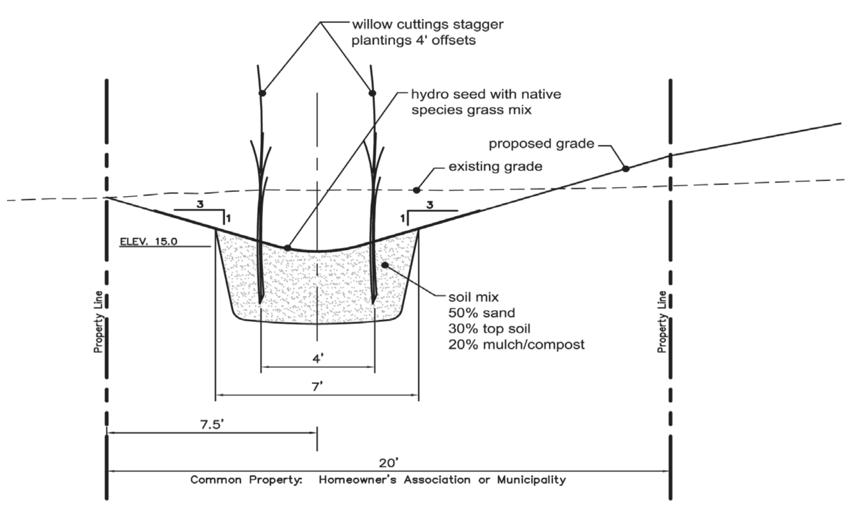
◆ Excavate the center of the channel 3-5 feet deep in most cases.

◆ Install an underdrain pipe system. The systems consists of a 6-8 inch perforated drainage pipe with filter sock, a drainage layer of sharp sand or #57 gravel, and a top layer of filter fabric to prevent clogging. In sandy, freely drained soils, only the drain with sock is required. (Figure 3.3.4.g)



Bioretention Swale Large - Underdrain enlargement
Figure 3.3.4.g - nts

- If siting the bioretention area in polluted soils, include a liner below the underdrain system to prevent contamination of the system. (Neal Weinstein, LID. org).
- Add a layer of unconsolidated, well-drained soil. Use excavated material if suitable. Desirable soils are typically a homogenous mix of 50 percent sand, 30 percent topsoil with less than 5 percent clay content, and 20 percent organic matter. (Figure 3.3.4.h)



Bioretention Swale Small - Section
Figure 3.3.4.h - nts

- The top of the planting area should be 6 inches below the surrounding grade
- Install an overflow outlet, in most instances, at 6” above the surface of the organic layer. This allows for 6” of ponding before the overflow drain system activates.

- Plant bioretention area with a mix of flood tolerant trees, shrubs, and perennial groundcovers. Grasses, rushes, and sedges are good herbaceous cover.

OTHER CONSIDERATIONS for Bioretention Areas

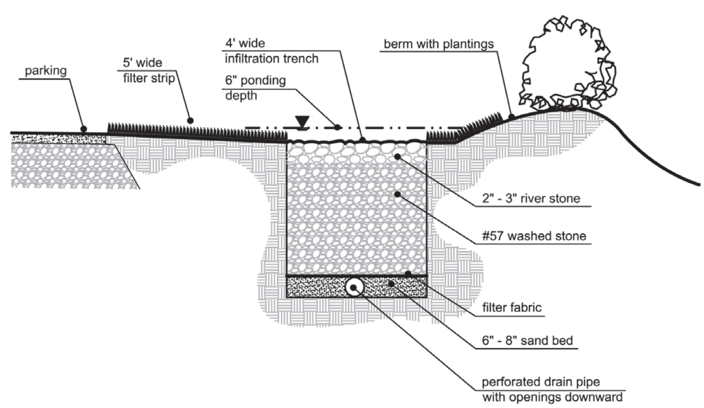
Maintenance is similar to that of any landscaped area, with mulching, pruning for shape or vigor, inspecting plants for pests and disease, and regular litter removal. Aside from normal landscape care, bioretention areas are self-sustaining and low maintenance. Since the landscaped area is located below the parking lot grade with tolerant plantings, it is primarily self-watering and requires little or no irrigation.

3.3.5 Technique 4 - Infiltration Devices

Infiltration trenches & Basins DESCRIPTION

3.3.5.1 Trenches

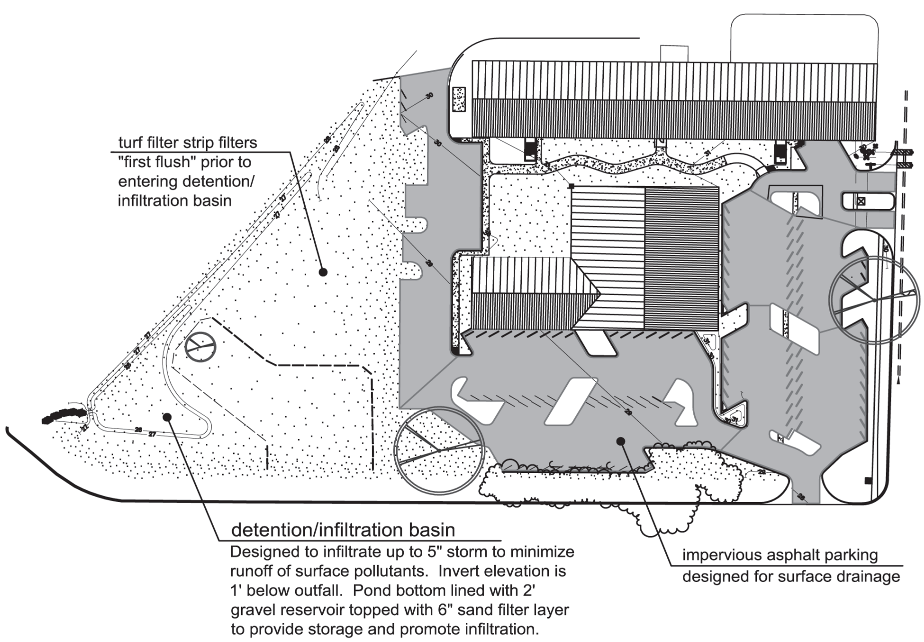
Infiltration trenches are simple stone-filled trenches designed to store water in the void spaces between the stone fill and expedite the water's infiltration into the soil. The substantial length of the trench is relative to its narrow width, which maximizes the opportunities for water from the saturated surface to enter the trench. (Figures 3.3.5.1.a) Depth is determined by two local conditions including: (1) the depth of soil layers conducive to infiltration, and (2) the depth of the water table. The bottom of the ditch is backfilled with stone or coarse gravel wrapped in a filter fabric. Once the trench has been filled with stone to the desired level, it is topped with sand and is covered by a layer of topsoil that is vegetated with turf or other appropriate planting. Thus, the infiltration structure literally disappears into the landscape. A grassed overflow weir leading to a swale creates an emergency outlet. Otherwise, the normal outlet for the trench is infiltration into unsaturated soil.



Infiltration Trench - Section
Figure 3.3.5.1.a - nts

3.3.5.2 Basins

The infiltration basin is an expanded version of the trench. The difference is that a relatively thin layer of stone, usually 2 feet deep, is spread over a wide area, again topped by a filter fabric and a layer of sandy soil. Usually, the basin is then planted with grasses. The basin disperses water over a wider area rather than a greater depth. In some circumstances, this can allow for infiltration beneath otherwise impervious areas like certain pavements or constructed features. Designed and originally used to improve water quality through settlement and filtration, the infiltration trench has been widely adopted as a stormwater practice since it stores runoff until circumstances allow for infiltration. (Figure 3.3.5.2.a) Local soil types and water table level dictate the design and effectiveness of an infiltration trench. In most cases, infiltration trenches can handle runoff from normal rain events, but may also require other methods such as stormwater ponds or filter strips to help regulate entrance to the infiltration system. Provision for an underdrain system to remove excess water if the system becomes waterlogged may be needed if heavier rainfall events are expected and other measures are not in place to handle overflow.



Filter Strip and Infiltration/Detention Basin
Figure 3.3.5.2.a - nts

Infiltration BENEFITS

- Facilitates the natural return of rainwater to the soil by allowing for temporary runoff storage until unsaturated soil for infiltration becomes available.

◆ Improves water quality in multiple stages while the water is: (Figure 3.3.5.a)

Figure 3.3.5a Infiltration Trench in Highway Median

Photo Courtesy of: Dot.state.ohi.us

- ◆ Passing through sandy backfill into the stone-filled trench,
- ◆ Residing in and moving through the voids between the stones in the trench, and
- ◆ Infiltrating into and through the native soil surrounding the trench.

◆ Fits into narrow areas such as along roads or on the perimeters of other impervious surfaces producing sheet flow runoff. This allows the treatment to be situated close to the source.

◆ Is extremely versatile as to exact size, shape and location, to allow virtually seamless integration into a variety of local topographical and hydrological situations. Although generally represented and implemented as a straight trench, it may include curves or finger-like extrusions from the main trench to take full advantage of local soil conditions.

◆ Provides groundwater recharge and preserves baseflow in nearby streams.

◆ Assists in removing suspended solids, particle pollutants, coliform bacteria, organics, and some soluble forms of metals and nutrients from stormwater runoff.

POLLUTANT REDUCTION	
Suspended Solids	80%
Phosphorus	60%
Nitrogen	60%
Heavy Metals	90%
Pathogens	90%

Table 3.5: Atlanta Regional Commission. Georgia Stormwater Management Manual, Volumes 1- 2: Technical Handbook. First Edition, August 2001.

Infiltration APPLICATION

In general, infiltration trenches can handle normal drainage from areas as large as 5 acres. They should be used as part of a system of appropriate stormwater control measures when the drainage area exceeds 2 acres or unusual circumstances are expected.

- Infiltration trenches can be strategically sited to be most effective in local situations using three major criteria:
    - Source proximity – infiltration trenches may be located to capture runoff from nearby impervious areas such as roads or parking lots.
    - Sensitive feature protection – infiltration trenches may be located to control sheet flow runoff that threatens ecologically sensitive areas such as wetlands. The trench may be used to store runoff until it can be infiltrated into unsaturated soil.
    - Optimally, infiltration trenches are sited to take advantage of a situation where highly permeable soils and a deep water table maximizes the capacity and effectiveness of the treatment.
- To be effective, the infiltration trench must be capable of infiltrating 0.5 inches of water per hour minimum. In order to achieve this rate, the trench must be excavated in suitable soils, preferably sand, loamy sand, sandy loam, and loam. Soils should have no greater than 20 percent clay content and less than 40 percent silt clay content. Suitable soil types are within the A and B hydrologic groups as defined by the USDA NRCS published soil surveys. (Figures 3.3.5.e and 3.3.5.f)

Figure 3.3.5e Infiltration Basin After Rain Event

Photo Courtesy of: Dan Fischer

Figure 3.3.5f Dry Infiltration Basin 12 Hours After Rain Event

Photo Courtesy of: Dan Fischer

- Since the recommended soils have moderate to high percolation rates, it is important to allow for a minimum separation distance of 2 feet to the seasonal high groundwater table to avoid potential groundwater contamination.
- Infiltration trenches must be located on grades less than 6 percent.
- Pretreatment measures are required to remove sediments and prevent clogging of the free space in the rock-filled trench. Other specific pollutants can be targeted with pretreatment techniques sited to intercept flow from hot spots or other likely sources. Grass filter strips work well in concert with infiltration trenches along roadsides and the margins of other pavements. For areas with heavy sediment loads, a forebay may be required. (Figure 3.3.5.b)

Figure 3.3.5b Filter Strip Beneath Vegetated Swale

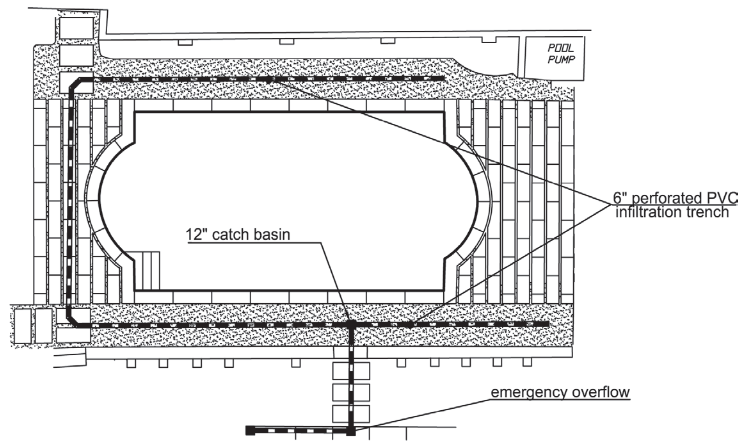
Photo Courtesy of: Lanier

- The length of the trench varies depending on intended use, soil type, location, and the volume of stormwater to be treated. For example, an infiltration trench alongside a road or at the perimeter of an impervious area such as a parking lot could be as long as the length or perimeter of the area that serves as the primary source of sheet runoff for the trench. Total trench volume required can be computed based on expected runoff. The depth of the trench is determined by the depth of the seasonal high water table (minus two feet); length and width become the two variables that can be adjusted to achieve the calculated volume requirement.

Infiltration DESIGN

- Slope and grade site drainage to allow for low velocity sheet flow to the trench.
- A grass filter strip is sited along the edge of the trench to remove sediments or hydrocarbons before entry into the trench.
- Underdrain system consists of a perforated drainage pipe placed in a 6-12 inch washed stone bed and covered with filter fabric to prevent clogging.

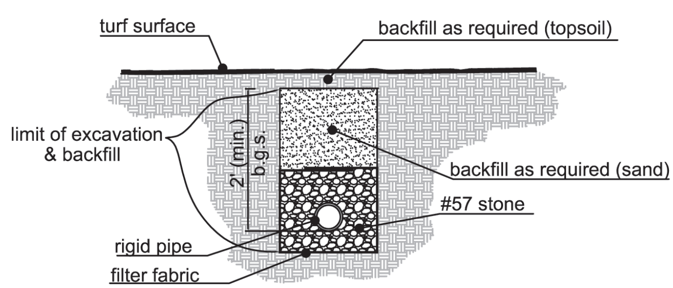
- Usually the remainder of the trench is filled with clean sand. For urban settings, an optional layer of filter fabric and topsoil can be added and planted with turf grass. (Figure 3.3.5.c)



Infiltration Trench in an Urban Setting - Plan

Figure 3.3.5.c - nts

- Infiltration trench designs can vary considerably based on site characteristics and intended use.
- In coastal Georgia, trenches are generally excavated to a depth of 3-5 feet depending on depth to groundwater. Length of trench varies depending on application, location, and the volume of stormwater to be treated. (Figure 3.3.5.d)



Infiltration Trench in an Urban Setting - Section

Figure 3.3.5.d - nts

OTHER CONSIDERATIONS of Infiltration

Infiltration trenches should be inspected semi-annually for sediment build-up and structural damage. Standard maintenance practices generally include replacing the top few inched of sand, if it has become clogged and removing debris and sediment from the grass filter strip. Systems using a forebay also require periodic sediment removal.

3.3.6 Technique 5 - Filtration Devices

Filtration Devices DESCRIPTION

Filtration systems filter stormwater using some sort of media to remove undesirable constituents from runoff. Sand, gravel, peat, compost, vegetation, and natural or synthetic fabric can all be used. Since filters can be overloaded by excessive flow volumes or velocities, a multi-chambered, often structural, system may be necessary to store water and regulate flow through the filtration process.

Filtration systems are generally used in conjunction with other controls and may be selected for size, design and media type specifically to achieve a targeted pre- or post-treatment result such as removing a particular pollutant or substance unaffected by other treatments. Depending on the overall runoff control system design and local conditions, some pollutants may require special treatment for removal. Filtration may also be used in conjunction with other controls for effectiveness in channel protection, over bank flood protection, and extreme flood protection, if required. The two main filtration system designs are as follows:

- **Enhanced Swale –** An enhanced swale is a long, vegetated depression or channel to capture and treat storm water runoff by allowing it to pool and percolate through a filter media before infiltration into the soil.

- **Filter Strip –** Filter strips are grassy buffer zones designed to filter sheet flow runoff and promote infiltration. Runoff flows down a gentle uniform grade through vegetation (dense grass is ideal). Effectiveness can be enhanced and filter strip size decreased by installing a low berm at the bottom of the grade to create a ponding effect that can increase infiltration rates.

Filtration Devices BENEFITS

Enhanced Swale

- Stormwater contaminants are removed primarily through engineered media in dry swale systems.
- Removes suspended solids and particulates, fecal coliform bacteria and other pollutants.

- Both sediment accumulation and biological removal are used in a wet swale to remove stormwater contaminants.
- A swale may be designed to capture and detain full channel protection storage volume; however, another structural control must be used for channel protection.

POLLUTANT REDUCTION	
Suspended Solids	80%
Phosphorus (Wet Swale / Dry Swale)	50% / 25%
Nitrogen (Wet Swale / Dry Swale)	50% / 40%
Heavy Metals	40%
Pathogens	Insufficient Data

Table 3.6: Atlanta Regional Commission. Georgia Stormwater Management Manual, Volumes 1- 2: Technical Handbook. First Edition, August 2001.

Filter Strip

- Infiltrates runoff when used in pervious soils.
- Contributes to groundwater recharge in pervious soils.
- Offers lower construction costs than many other treatment measures.
- The filter strip appears to be a landscape feature.
- Vegetation holds soil in place, preventing erosion.
- Removes suspended solids and some heavy metals from runoff.

POLLUTANT REDUCTION	
Suspended Solids	50%
Phosphorus	20%
Nitrogen	20%
Heavy Metals	40%
Pathogens	Insufficient Data

Table 3.7: Atlanta Regional Commission. Georgia Stormwater Management Manual, Volumes 1- 2: Technical Handbook. First Edition, August 2001.

Filtration Devices APPLICATION

Enhanced Swales

- Applicable generally to areas of low to moderate development density where impervious cover does not take up a great percentage of the drainage area. Such areas include most residential and some institutional areas as well as areas along roads and highways that pass through otherwise essentially pervious areas.
- An enhanced swale can serve a maximum drainage area of 5 acres. (Figure 3.3.6.a)

Figure 3.3.6a Bio-Retention Swale in Parking Lot

Photo Courtesy of: William Dietz and Karolina Bako

- The longitudinal slope should not be more than 4 percent.
- A separation of at least 2 feet between the bottom of the dry swale and the seasonally high water table is required. Wet swales may be in part below the water table or placed in poorly drained soils.
- Engineered media is usually required for dry swales.

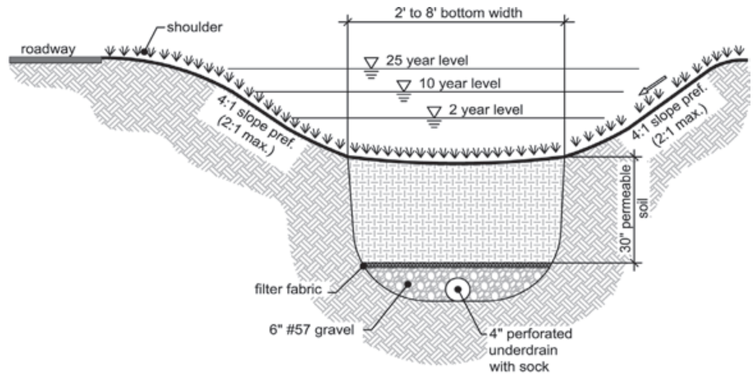
Filter Strip

- Well-suited for treating runoff from roadways, alleys, sidewalks, and driveways.
- Useful for treating runoff from downspouts, very small parking lots and small areas of pervious surface.
- Can be used as an outer zone for a forested stream buffer. The strip should be built outside the buffer to increase the width and effectiveness of this area.
- Filter strips have good potential for use as pretreatment control; can be used in combination with infiltration trenches and basins or oil grit separators.
- Filter strips can serve as buffers between incompatible land uses (between residential and commercial or industrial uses).
- The filter strip requires sheet flow runoff to function properly.

Filtration Devices DESIGN

Enhanced Swales

- Should be designed to pass the 25-year storm safely. (Figure 3.3.6.b)



Enhanced Swale
Figure 3.3.6.b - nts

- Concentrated flows should be routed through a forebay before entering the enhanced swale.
- Runoff can also enter along the sides of the channel through sheet flow.
- A dry swale system consists of an open conveyance channel with a filter bed of permeable soils overlaying an underdrain system. Flow passes into and is detained in the main portion of the channel where it is filtered into the soil bed. Runoff is collected and conveyed by the perforated pipe and gravel underdrain system to the outlet.
- The wet swale or wetland channel consists of an open conveyance channel that has been excavated to the water table or in poorly drained soils.
- Check dams are used to create multiple wetland cells that act as miniature shallow wetlands.
- In swales with longitudinal slopes greater than 2%, drop structures (6 inch each) are recommended to control the flow energy within the channel. The energy slope or energy gradient should be kept within the range of 1 to 2 inches to ensure passage of the runoff through the swale's filter media. The drop in elevation facilitates continual movement of water through the swale.
- Each individual drop actually provides excess energy at the drop-off point. This energy is dissipated by distance of flow through the filtration media. Spacing

intervals for adequate energy dissipation is determined by the volume of water being conveyed, the soil media that it is passing through or over, and the distance to the next available discharge point.

- Storage depth at the downstream end should not exceed 18 inches.
- A bottom width of 2 to 8 feet ensures adequate filtration.
- The filter area is sized based an assumption of 3.5 ft/day permeability for sand. This is a coefficient used in the actual calculation of filter size for a particular volume of runoff flow.
- The filter bed should completely drain within 40 hours or less.
- Filter media should consist of a 12- to 18-inch layer of clean washed medium sand (concrete sand or fine aggregate) on top of the underdrain system.
- The 4-inch perforated PVC pipe underdrain is situated in a gravel layer.
- The underdrain must have minimum grade of 1/8 inch per foot (1 percent slope).
- Holes in the underdrain pipe should be 3/8-inch in diameter and spaced approximately 6 inches on center.
- Permeable filter fabric is placed between the gravel layer containing the underdrain and the filter media.
- Gravel should be clean, washed aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches with void space of about 40 percent.

Filter Strip

- Both the top and toe of the filter strip grade should be as flat as possible to prevent erosion.
- The strip should be at least 15 feet long, although 25 feet is recommended. (Figure 3.3.6.c)

Figure 3.3.6c Bioretention Swale with Filter Strip in Median

Photo Courtesy of: Alec Metzger

- Soil that can maintain a dense grass cover is required. The filter strip can be mowed to keep a manicured appearance, if desired.
- Grass should be selected that can withstand high entry flows as well as wet and dry periods.
- The filter strip grade should not exceed 6 percent nor be less than 2 percent.
- Sheet flow is the preferred method of runoff entry into the filter strip. A flow spreader may be employed to create sheet flow from concentrated entry points. A gravel weep curtain is an effective flow spreader that also serves a pretreatment function, trapping sediment. Other flow spreader options include low berms, concrete sills, and curb and gutter with frequent openings.
- Should ponding be anticipated, grasses for the area should be selected to withstand frequent inundation for periods not exceeding 24 hours.
- Berm height should not exceed 12 inches.
- The berm should be built of sand, gravel, and sandy loam. This soil mix is pervious while encouraging grass cover.
- Drainpipes should be installed through the bottom of the berm to ensure drainage of the pond area within 24 hours.
- Flows in excess of the design flow should be diverted from crossing the filter strip by a spillway or protected channel.

OTHER CONSIDERATIONS for Filtration

Pedestrian traffic across filter strips should be discouraged. Maintenance is very important for filter strips to prevent or repair erosion. Periodic checks for erosion are required.

3.3.7 Technique 6 - Green Roofs

Green Roofs DESCRIPTION

A green roof is created by placing a vegetative layer on top of a roofing system. The system may be specifically built or an existing roofing system may be retrofitted.

There are two types of green roof systems: extensive and intensive. The extensive system uses less growing medium, as little as 1 or 2 inches compared to the foot or more required for the intensive system. Costs and weight loads are both substantially lower for the extensive design. Both types can positively influence an urban environment. (Figure 3.3.7.a)

Figure 3.3.7a ReNatur Norrweigan House

Photo Courtesy of: Greenroofs.com

Intensive systems are landscaped, garden-like areas with a wide mixture of plants. They are often intended for public access and use. Extensive systems are designed and vegetated primarily for environmental reasons, so plant selection focuses on survivability, ease of maintenance, and ability to perform the desired environmental functions. (Figure 3.3.7.b)

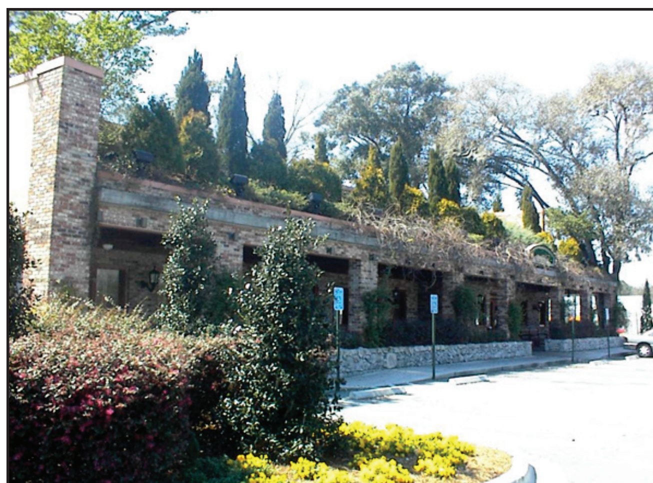


Figure 3.3.7b Green Roof Above Carrabba's Restaurant

Photo Courtesy of: Dan Fischer

At its most basic, and without regard to type, a green roof system includes:

- Plants, selected to suit the prevailing conditions and the goals of the project,
- Growing substrate, whether engineered, natural soil, or a hybrid,
- Containment for growing media and roots,
- Drainage system that may include reservoirs,
- Roofing system including a waterproofing layer, and
- Structure supporting the roof.

Green Roofs BENEFITS

- An average of 75 percent of water is retained on an extensive green roof, both in the plants and the soil layer.
- The 25 percent of precipitation that becomes runoff does so some hours after peak flow as excess water percolates through the soil and into the drainage system. The incorporation of reservoirs into the drainage system precludes the actual release of this water and such stored water may be used in an irrigation system, if needed.
- Green roofs mitigate the urban heat island effect by reducing the temperature of individual roofs. This is important in densely developed areas where opportunities to use the cooling effects of vegetation are otherwise limited. Although figures vary from location to location, a Temple University green roof proposal gives a comparison of 140 degrees Fahrenheit for a flat roof and 77 degrees for a green roof at an unspecified summer air temperature (Scholz-Barth, Katrin, 2001). (Figure 3.3.7.c)

Figure 3.3.7c Ford Factory Rooftop Gardens

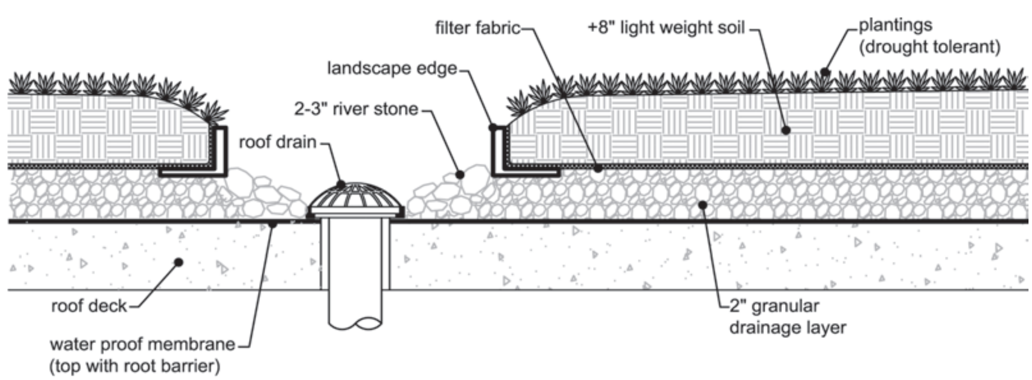
Photo Courtesy of: Zinco, Inc.

- Vegetation transforms heat and soil moisture into humidity through evapotranspiration, actually cooling the air immediately above the roof and resulting in a more pleasant microclimate in the roof area that translates into savings in reduced air conditioning use and lower energy costs.
- The green roof has some impact as insulation in winter, but this is dependent on moisture content of the soil. Dry soil or moderately wet soil adds about 25 percent effectiveness to insulation while wet soil can reduce heat loss by 50 percent.
- A green roof can have double the life span of a conventional roof, due to protection of roofing materials from extreme temperature fluctuations, ultraviolet radiation, and other stresses and damage. Forty years is a reasonable lifespan.

◆ Cost savings include: (1) reduced size of HVAC equipment and insulation on new or retrofitted buildings, (2) reduced utility cost, and (3) reduced maintenance, repair and replacement cost.
◆ 12 centimeters of growing medium can reduce sound by 40 decibels, with the growing medium blocking lower frequencies and the plants blocking higher frequencies.
◆ A green roof, especially of the intensive variety, can provide amenity space for leisure activities.
◆ Air quality can also be improved by green roofs. Vegetation filters particulates. Reduced air temperature can impede formation of ozone, a smog component. Other atmospheric pollutants are also reduced.
◆ The green roof may have an impact on interior air quality.
◆ When viewed from above, greenroofs dramatically improve the appearance of the rooftop. If many buildings in a city had greenroofs, the improvement is magnified. In coastal Georgia, one may see these views from surrounding buildings, bridges, and from the air.

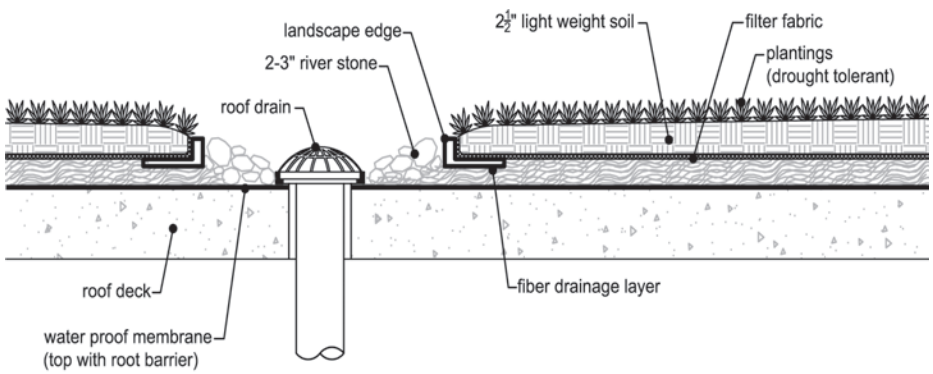
Green Roofs APPLICATION

◆ A wide variety of roof types can be green roofs. Flat roofs can be used, as can slopes of up to 40 degrees with appropriate measures to retain growing media and vegetation in place.
◆ Green roofs can be applied on an inverted or traditional roofing system.
◆ Growing medium can consist of mixtures of sand, gravel, crushed brick, peat, organic matter and some soil. (Figure 3.3.7.d)



Greenroof - Intensive - Section
Figure 3.3.7.d - nts

- Extensive greenroofs have between 2 to 4 inches of soil and can add 16-25 lbs. per square foot when saturated. (Figure 3.3.7.e)



Greenroof - Extensive - Section
Figure 3.3.7.e - nts

- Intensive greenroofs are more soil-based with a depth between 8 to 48-inches and add 60 to 250 lbs. per square foot when fully saturated, including small plants and shrubs.
- Weight of trees added to an intensive greenroof must be done on an individual basis, considering the mature height and weight of the tree. Additional wind loads must also be considered when siting trees on an intensive greenroof.
- Intensive gardens may be used as distinctive building features.
- Additional loading is one of the main factors in determining both the viability and the cost of a green roof installation. New roof structures should be built to handle the projected load. Existing roofs should be carefully studies to determine if they can be cost-effectively modified to meet the new load requirements. When load is calculated, wind loading must be factored in as well.
- Vegetation should be selected to withstand unprotected exposure to wind and sunlight.

Green Roofs DESIGN

- The preferred roofing material is 60- to 80-mil PVC roof systems. This material is preferred because it is heat-seamed, reducing the chance of leakage, and preventing root penetration.
- Other roofing and waterproofing materials include rubber membrane (EPDM), or hypolan (CSPE). Thermoplastic polyolifins (TPO) may also be used for green

roof base waterproofing and are generally considered more environmentally acceptable but have not been subject to as much testing in the United States market. Some U.S. manufactured TPO also contains bromides that have the potential to impact the membrane's long-term performance.

- Using an asphalt-based roofing system requires a protective layer of high-density polyethylene (HDPE) membrane between the soil and roofing since asphalt, an organic material, will be penetrated by the roots.
- If the existing roofing system is inverted, determine whether the insulation can be replaced by an equivalent R- value of growing medium. If the insulation is to remain, good drainage and integrity of the waterproofing is required to prevent contact between insulation and water from the roof or damage will result.
- If the membrane, existing or new, contains bitumen or any other organic material, it is crucial to maintain a continuous separation between the membrane and the plant layer, since the membrane is susceptible to root penetration.
- The chemical makeup of the membrane must also be compatible with the structural system components with which it will be in direct contact.
- Maintaining proper drainage on the roof is very important. Parapets, edges, flashing, and roof penetrations made by skylights, mechanical systems, vents, and chimneys must be well protected with gravel skirts and sometimes weeping drain pipes.
- A drainage layer should separate the roof membrane from the growing medium to prevent pooling of excess water. The drainage layer may be made of small gravel and chipping, lava and pumice stone, swelled burned slate or plastic/polystyrene webbing or chambers.
- The drainage layer may also incorporate reservoirs to retain water for irrigation during dry periods.
- If the drainage layer is too thin or if the roof drains become blocked, membrane leakage may occur due to hydraulic pressure. The growing medium itself may sour, causing the plants to drown or rot.
- Landscape or filter cloth should be laid over the drainage layer to prevent root blockage of drains and constrain the growing medium.
- On a roof slope greater than 20 degrees, ensure that the sod or plant layer does not slip or slump through its own weight, especially when it becomes wet. This can be prevented using horizontal strapping of wood, plastic or metal, placed under either the membrane or loose-laid on top and attached with stainless steel cables to the roof peak under ridge cap up seal. Plastic HDPE webbing like those used

to stabilize slopes and stream banks may be attached in a similar manner.

- Note that the potential maximum weight of the soil or growing substrate is the saturated rather than dry weight of the growing medium.
- Modular growing systems are also available. Green Tech, for example, has developed a system where essential elements including drainage and growing media are provided and the structural elements fit together like a giant jigsaw puzzle.
- An irrigation system may be useful for initial planting and to nurture the roof vegetation through drought periods.
- The growing substrate is limited by the load-bearing capability of the roof. Both type and depth of soil or other medium are themselves critical factors in vegetation selection.
- For new projects, topsoil from on site is an economical and effective growing medium. It is assumed that the new design would take into consideration the weight of this type of medium.
- Mixing topsoil with expanded clay or slate improves water retention ability, as does the incorporation of a horticultural grade hydrogel.
- An engineered growing medium may be used instead of soil due to weight or other considerations. This medium need not contain natural soil but should possess the following characteristics:
    - Lightweight,
    - Absorbent,
    - Porous enough to allow runoff,
    - Meet plant nutrient needs, and
    - Allow anchoring of plant root systems.
- Materials that may be used in an engineered growing medium include: mineral and organic soil components, soil mixture of humus, and mineral bulk material with either a high or low proportion of organic matter.
- Location, wind, rainfall, air pollution, building height, shade, and soil depth are all factors in determining what plants can be grown and where.
- Root size and depth should also be considered in determining how much growing medium will be required for a plant to stabilize.
- Commonly used plants are succulents and other low growing plants with water storage capability, whether in fleshy leaves, bulbs, or roots.
- Planting in summer months may require additional irrigation.
- Fall planting will depend on the availability of suitable plant stock and timing to

allow the plants to be established before cold weather.

- Plant plugs with fully established root structures. They quickly spread horizontally across the roof and form a dense mat of vegetation in a few seasons. However, since plugs are more expensive than cuttings including a more time-consuming installation process, cuttings are often used for initial economy. However, the survival rate for plugs is 80 percent and for cuttings only 50 percent. Use of cuttings may mean eventual higher cost and some loss of effectiveness.
- Compartmentalization of the green roof into sections may allow for easier access to the membranes and the roof drains, for inspection and maintenance, without having to pull up the whole installation.
- Vegetation on greenroofs can also be accomplished with hydromulching. (Figure 3.3.7.f)

Figure 3.3.7f Hydromulching on Rooftop Gardens

Photo Courtesy of: Ecotrust,Inc.

OTHER CONSIDERATIONS for Green Roofs

Plant and membrane maintenance are required; intensive systems require weekly visits at minimum. Extensive systems can make do with a few visits a year. Maintenance and visual inspections of the membrane can be complicated, as the green roof completely covers the membrane. Newer electronic leak detention systems can pinpoint the exact location of water leaks.

Local planning and zoning may qualify a green roof as green space or landscaped open space. If accessible by the public, then the design must also comply with requirements for occupancy, exiting, lighting, guardrails, and barrier free access. Access to the green roof is critical for both installation and ongoing maintenance.

3.3.8 Technique 7 - Permeable Paving

Permeable Paving DESCRIPTION

Permeable paving allows water to move through it and is another option for reducing impervious cover. Many permeable pavement options are available, which can be generally organized into two groups: structural and non-structural. The structural variety is intended to be load-bearing and include unit pavers, either themselves permeable or with voids between them, reinforced systems that allow vehicles to move across grass or aggregate surfaces, and monolithic systems such as pervious concrete. Non-structural examples include non-reinforced aggregates, like gravels, shells, and sands, as well as other materials such as shredded rubber and mulch. The main idea of using pervious pavement is to encourage stormwater infiltration, reducing peak flows while protecting water quality and reducing costs associated with stormwater conveyance. (Figure 3.3.8.a)

Figure 3.3.8a Pervious Concrete Used in Wal-mart Parking Lot

Photo Courtesy of: Chere Peterson

Permeable paving solutions, in the past, have been relegated to low automotive traffic and pedestrian areas, primarily due to doubts about the load-bearing ability of these non-conventional solutions and their strict siting requirements. In fact, the many permeable pavement possibilities present a wide array of durability and strength characteristics.

Considerable experience has been amassed in coastal Georgia to indicate that permeable paving is a viable tool when implemented correctly and with understanding of the issues. There are many commercial examples, for instance in Savannah, where stormwater has been handled almost entirely using porous concrete. Such structural versions of permeable paving have the widest range of applications. (Figure 3.3.8.b)

Figure 3.3.8b Overflow Parking Using Gravel Pave, Grass Pave, and Porous Pavement

Photo Courtesy of: USAB

Non-structural systems such as turf, reinforced with synthetic grids, can also be used as paving in some instances. Local materials such as crushed shell can be employed as can cobbles or gravel in some applications. Gravel, sand and even mulch can be used to pave pedestrian pathways, depending on usage requirements.

To increase strength and durability as well as enhanced potential for water retention, permeable paving solutions should be set on a properly graded bed of gravel combined with a sand filter on the gravel base designed to suit the pavement type and local conditions. In light load areas like sidewalks over highly permeable soil, pervious paving can be installed directly on the prepared sub-base without a gravel bed.

Permeable Paving BENEFITS

- Reduces surface runoff volume and attenuates peak discharge.
- Protects water quality, when properly installed, by trapping pollutants
- Lowers cost for stormwater conveyance by allowing the storm drains to be downsized or eliminated
- May restore soil infiltration in an urban landscape.
- Even when mixed with impervious paving travel lanes, permeable paving allows on-site infiltration of at least some stormwater, reducing the load on other treatment practices serving that specific area.
- Permeable paving systems may contribute to improved water quality by removal of both nutrients and heavy metals depending on pavement system type and local conditions.

Porous Concrete POLLUTANT REDUCTION	
Suspended Solids	Not Applicable
Phosphorus	50%
Nitrogen	65%
Heavy Metals	60%
Pathogens	Insufficient Data

Table 3.8: Atlanta Regional Commission. Georgia Stormwater Management Manual, Volumes 1- 2: Technical Handbook. First Edition, August 2001.

Modular Pavers POLLUTANT REDUCTION	
Suspended Solids	Not Applicable
Phosphorus	80%
Nitrogen	80%
Heavy Metals	90%
Pathogens	Insufficient Data

Table 3.9: Atlanta Regional Commission. Georgia Stormwater Management Manual, Volumes 1- 2: Technical Handbook. First Edition, August 2001.

Permeable Paving APPLICATION

- Pervious pavements can be used for new installations or as a replacement to existing impervious pavements.
- Light load or seldom-used areas include:
  - Overflow parking (Figure 3.3.8.c)

Figure 3.3.8c Overflow Parking at Westfarms Mall Used During Special Events and the Christmas Shopping Season

Photo Courtesy of: Chere Peterson

- Sidewalks
- Emergency lanes for fire and police vehicles
- Service lanes
- Next to tree islands (Figure 3.3.8.d)

Figure 3.3.8d Permeable Pavers Around Parking and Drive Areas

Photo Courtesy of: Dan Fischer

- Pedestrian/jogging paths (Figure 3.3.8.e)
- Handicapped accessible areas. (Porous concrete is often required for barrier-free areas because modular pavers may create rougher than desired surfaces for handicapped transit. Grasspave 2 is also ADA lab certified.)

Figure 3.3.8e Pervious Concrete Pathway Dyed to Match Native Soils

Photo Courtesy of: Chere Peterson

- Bicycle/golf cart paths
- Residential driveways and parking (Figure 3.3.8.f)

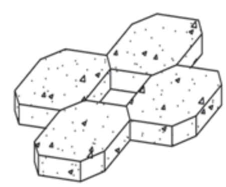
Figure 3.3.8f Gravel Pave and Slope Tame on Residential Diveway

Photo Courtesy of: Chere Peterson

- Patios and residential walkways
    - Alleys
- Heavier load or often-used applications include:
    - On-street parking areas
    - Commercial areas such as shopping centers, restaurants and office parks
    - Residential streets
    - Public use facilities such as municipal buildings, boat landings, and recycling centers
- Permeable unit pavers or widely spaced stepping-stones can be installed on the gravel bed of an infiltration system, appearing to most observers as a walkway.
- Slopes should be flat or gentle to increase the time water stands on the pervious paving, encouraging infiltration rather than runoff in fast moving sheets of water.
- The entire permeable paving section including the gravel base should be a minimum of 2 feet above the seasonally high water table to prevent groundwater contamination and allow for infiltration.
- Permeable paving can be used where sub-soils have an infiltration rate between 0.5 and 3.0 inches per hour.

Permeable Paving DESIGN

- During construction and preparation of sub-grade, special care must be taken to avoid over-compaction of soils. Soil compaction should be within 92% and 95% Modified Proctor Density to allow soil infiltration. (Figure 3.3.8.g)



Interlocking Permeable Concrete Pavers isometric

Figure 3.3.8.g - nts

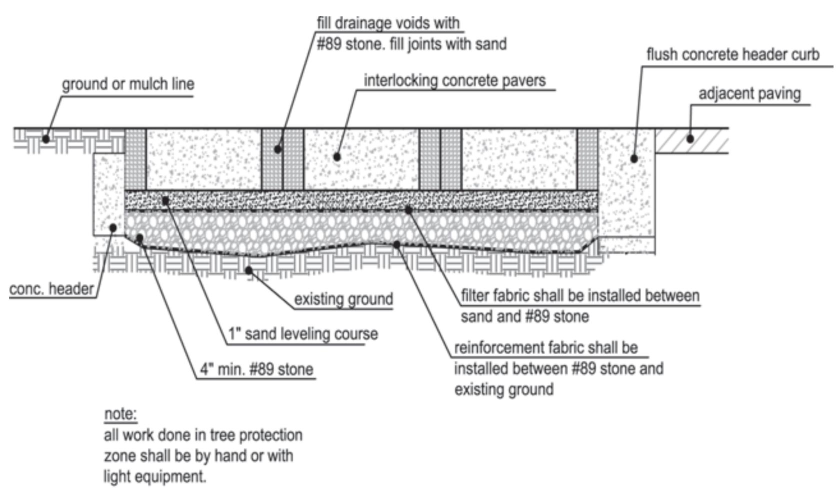
- Install permeable paving over the following base system unless its use is very light-duty and it is being installed on soils with infiltration rates exceeding 1 inch per hour. For unit pavers, the top 1-2 inches of the base is a layer of sand that also acts as a leveling course. Below that is a gravel base (porous concrete can be installed directly on the gravel base), which in medium duty pavements, can be 4 to 8 inches of #89 stone; in heavy-duty pavements, use, from top down, 3 inches each of half-inch, three-quarter inch and one inch stone. Underlay the stone with filter fabric, to prevent it from moving into the sub-base.

- Avoid using graded aggregate base (GAB – also called CABC for compacted aggregate base course) since it contains fine particles and when compacted, is impervious.
- In coastal Georgia, the bottom of the stone reservoir should be completely flat so that runoff will be able to infiltrate through the entire surface.
- Pervious paving should be used in applications where the pavement receives runoff only from impervious areas. Runoff from lawns and landscape areas contain sediments that will clog the pervious pavement.
- When combined with impervious pavement, the ratio of contributing impervious area to the permeable pavement surface should be no greater than 3:1.
- Porous pavement should be located with the bottom of the gravel base course at least 2 above the seasonally high groundwater table and at least 100 feet away from drinking water wells.
- Pavers should be able to support the maximum load for the specific application.
- Porous concrete consists of a specially formulated mixture of Portland cement, uniform, open graded course aggregate, and water. The use of larger aggregate without the fines gives it porosity at some loss of structural strength. The strength of the porous concrete section increases with its depth. Some guidelines are:
  - 4" minimum depth for sidewalks
  - 6" minimum depth for passenger vehicles and light trucks
  - 7" depth if a sanitation truck drives on it once a week
  - 8" minimum depth for unrestricted use
- Sand has a high infiltration rate; a sandy loam has a substantially lower infiltration rate, but will provide for growth of a grass cover and can be used for a turf paving solution.
- Consider the infiltration rate for the permeable pavement being installed. Properly installed porous concrete has an infiltration rate in excess of the ability of a double ring infiltrometer to be able to measure its flow. (Hunt, 2003). Unit pavers, unless they themselves are porous, have much lower infiltration rates since they rely on void spaces between the units. Design the system so that runoff from major storm events that exceed the infiltration ability of the permeable pavement can be safely handled.

◆ Permeable asphalt may not be applicable in some coastal areas due to high temperatures that tend to melt the asphalt, which settles to the bottom of the section, effectively sealing it and making it no longer porous.
◆ Avoid using permeable paving in areas receiving runoff from "hot-spots" (sources of known contamination).
◆ Avoid using permeable paving where wind borne sediment will be deposited, such as near the beach, since the sediment will clog the pavement.

OTHER CONSIDERATIONS for Permeable Paving

To ensure continued permeability, routine vacuum sweeping is required. High-pressure washing is to be avoided since it only pushes pollutants further into the pores and may damage the matrix. (Figure 3.3.8.h)



Interlocking Permeable Concrete Pavers
Figure 3.3.8.h - nts

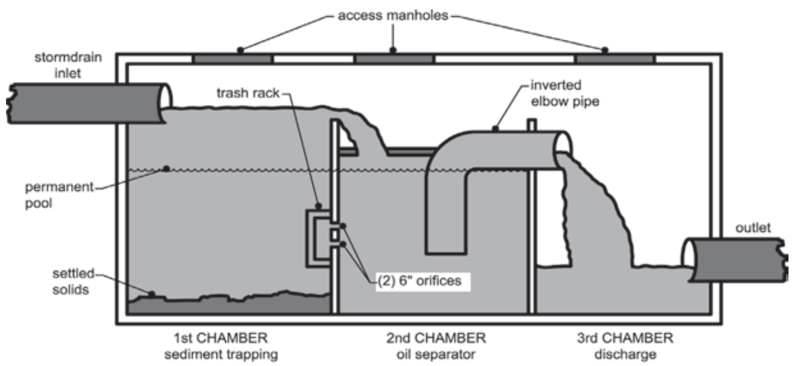
In addition to the relatively strict site constraints for porous pavement, a major limitation to the practice is the high failure rate some techniques have experienced in the field. According to EPA studies, 75% of porous pavement systems fail due to poor design, improper installation, use on soils with low permeability, traffic which exceeds the loading capacity and poor maintenance.

A higher than average degree of care and skill in installation is required to prevent pervious pavement failure. This is usually the case for modular pavers and porous concrete.

3.3.9 Technique 8 - Oil & Grit Separators

Oil/Grit Separators DESCRIPTION

Known as gravity or oil separators, these treatment devices remove oil and grease, heavy metals, solids, and debris from stormwater runoff using multiple processes including settlement, skimming and trapping. (Figure 3.3.9.a)



Oil-Grit Separator
Figure 3.3.9.a - nts

Oil/Grit Separators BENEFITS

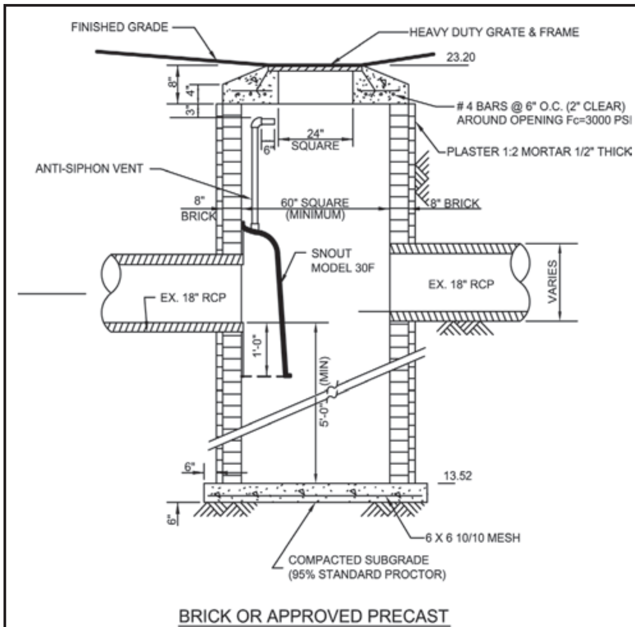
- The treatment is generally installed underground. These are excellent for areas with limited space, where control of grit and/or oil and grease is needed.
- Prefabricated systems can be purchased and installed at nominal expense.

POLLUTANT REDUCTION	
Suspended Solids	40%
Phosphorus	5%
Nitrogen	5%
Heavy Metals	Insufficient Data
Pathogens	Insufficient Data

Table 3.10: Atlanta Regional Commission. Georgia Stormwater Management Manual, Volumes 1- 2: Technical Handbook. First Edition, August 2001.

Oil/Grit Separators APPLICATION

- Best used in commercial, industrial and transportation land uses, oil-grit separators are a pre-treatment measure for high-density, industrial, and ultra urban sites.
- Primarily intended as a pre-treatment measure for inlets and outfall structures.
- Separators should not be used as an online treatment because of the potential for overflow and redistribution of harmful pollutants trapped in the structure.
- Separators should be located at the outfall of a pollutant accumulating area, or at the inlet to further treatment processes.
- Where there is some hydrocarbon load at a site, an appropriately sized (usually small) separator can be used at the inlet or outlet prior to conveyance to a detention area. (Figure 3.3.9.b)
- Separators may be combined with other treatments such as filter strips to further enhance water quality.



Inlet with Water Quality Outlet (Snout)
Figure 3.3.9.b - nts

Oil/Grit Separators DESIGN

- Oil-grit separators may be purchased as a fabricated unit and installed in a new or existing stormwater management system. The unit should be sized for the intended task. (Figure 3.3.9.c-d)

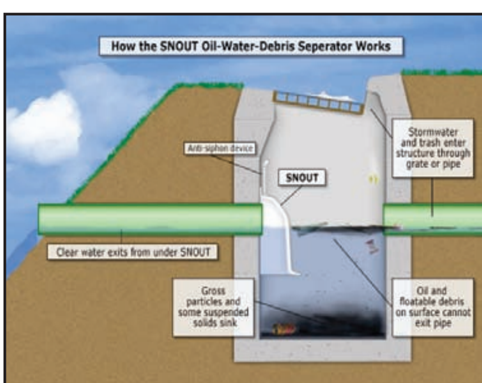


Figure 3.3.9c Illustration of a Snout Structure

Image Courtesy of: Bestmp.com

Figure 3.3.9d Snout Structure in Place

Photo Courtesy of: Bestmp.com

- Separator systems, especially in unusual or high volume applications, may also be constructed on-site from concrete. This approach allows exact adjustments of design and compartment sizing to suit the specific site conditions.
- To prevent floating debris from becoming oil-soaked or clogging passages between compartments, a trash rack should be installed at or near the inlet to the system.
- The oil-grit separator requires an initial settlement area of minimum water flow to allow sediment to settle from the runoff and oils and other hydrocarbons to rise to the top. The larger the initial chamber and the lower the flow rate, the more effective the treatment.
- A mechanical skimmer may remove hydrocarbons from the top of the first chamber for diversion to storage, or the dividing partition between chambers may be designed so that flow over the top is diverted and a second connection about halfway down the first chamber wall allows cleaner water to flow into the second chamber. Grit and sediment remains at the bottom of the entry chamber. If the overflow method is used, a float switch is required as a safety measure to prevent drawdown from allowing a falling water level to admit hydrocarbons into the next treatment chamber.
- The second chamber allows for additional sediment settlement and hydrocarbon flotation if needed. A skimmer may be used in this chamber.
- The outlet from the second, possibly final, compartment should be at or near the vertical center of the compartment bulkhead to allow passage of the cleanest water into additional chambers or exiting the treatment.
- The volume of the oil-grit separator treatment chambers should be as large as practicable since the effectiveness of the treatment depends on the length of detention time. The longer the detention time, the more chance for separation to take place. The *Georgia Stormwater Management Manual* recommends total wet storage in the treatment chambers to be a minimum of 400 cubic feet per contributing impervious acre. This minimum may not be realistic in situations where either heavy sediment or hydrocarbon pollution loads may be expected and additional volume may be required for effective separation. The designer should not be concerned with oversizing the system except as cost and available space dictate.
- Careful input volume control is required to prevent system overload.
- Arrangements must be made to bypass the system in case of overloading or malfunction.

- Flow velocity through the treatment chambers should be as low as possible to maximize the opportunity for treatment to work most effectively. Periodic interruption of input flow enhances sedimentation. All internal flow velocities should be kept at a minimum.
- Permanent pools should have as great a volume as possible and the depth should be sufficient to allow for several feet of relatively clear water between the hydrocarbons collected at the top and the sediment at the bottom. As sediment accumulates, the effective depth of the pool decreases due to the rising sediment level.
- Remove settled debris with a front-end loader, vacuum truck, or manually, depending on the type of system accessibility allowed by the installation. Remove accumulated hydrocarbons from their containment area by pumping or drainage.
- The standard separator may be enhanced with a pretreatment swirl concentrator chamber, an oversized settlement and detention area for a higher solids separation potential or by oil draw-off devices.
- Access must be provided to each chamber for maintenance and inspection.
- Since the separator essentially accumulates pollutants in a confined space, it should be completely isolated from surrounding soils; it should be absolutely watertight and protected against overflow.

OTHER CONSIDERATIONS for Oil/Grit Separators

Maintenance and cleaning are critical. Inspect, including a careful review of sediment and hydrocarbon accumulation, as often as possible. Systems should be inspected after each major rainfall event. Overloading the system with sediment can result in re-suspension of solids. Manual cleaning and pollutant removal may be necessary.

By itself, a separator cannot meet the 80% removal target and is intended for use in treating hot spots where space is limited and pre-treatment is required. Dissolved pollutants are not effectively removed. Performance is dependent on design, sizing, and frequent cleanout.

The oil-grit separator is designed to accumulate hydrocarbons and other pollutants. It is essentially a created pollution hot spot. Overflow due to poor maintenance can release a considerable load of hydrocarbons to the stormwater.