TEXAS PARKS & WILDLIFE

Discussion Document

Habitat Restoration Workgroup

Feasibility Study for Habitat Restoration/Modification to Improve Water Quality in the Arroyo Colorado

Deliverable 3

TPWD Project 101732

TPWD Contract 153411

ALAN PLUMMER ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS • DESIGNERS • SCIENTISTS

TABLE OF CONTENTS

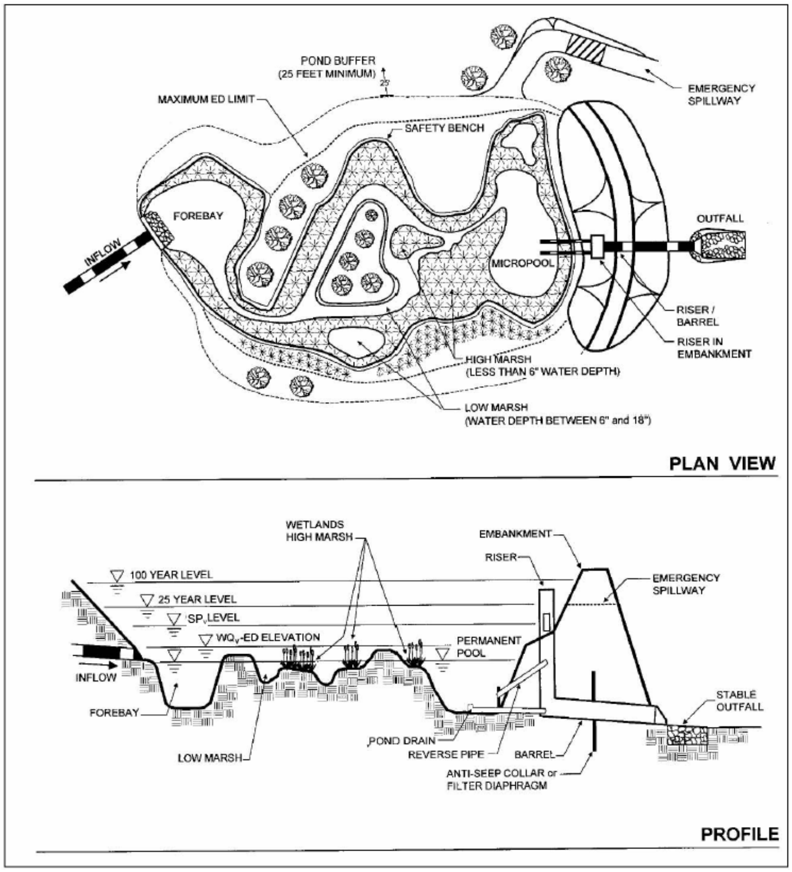
1. NON-POINT SOURCE TREATMENT SYSTEMS

1.1 Stormwater Runoff Wetland Treatment Systems

Wetland Stormwater Runoff Treatment Systems are capable of providing both detention/retention and water quality improvement. The ability to also provide habitat is highly dependent on location within the landscape. Stormwater wetland designs typically consist of a mixture of shallow marsh areas, open water, and semi-wet areas above the permanent water elevation.

1.1.1 Extended Detention Shallow Wetland/Pocket Wetland/Pond/Wetland Systems

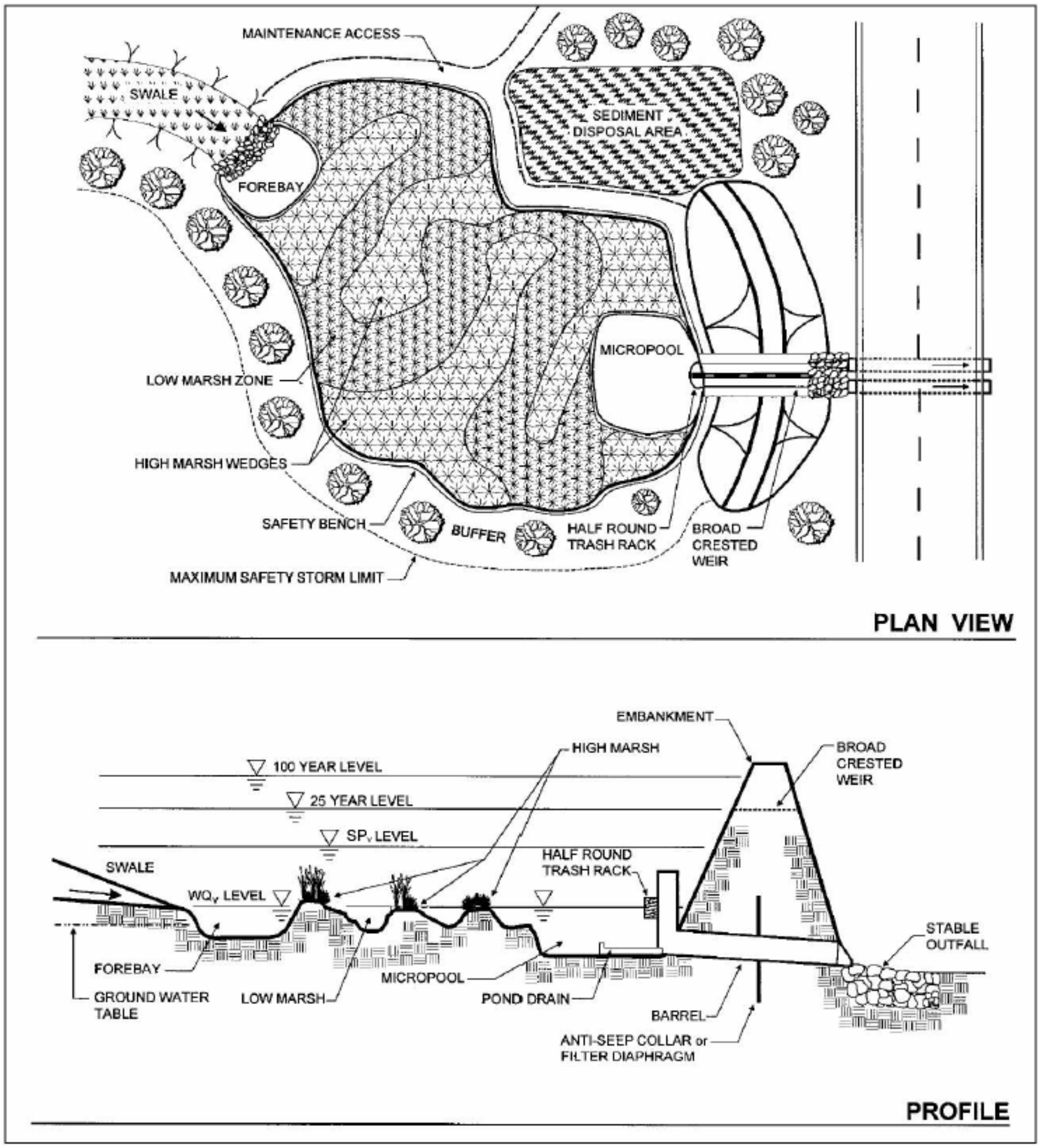
Schematics/Pictures



WQ = Water Quantity, SP = Storm Pool

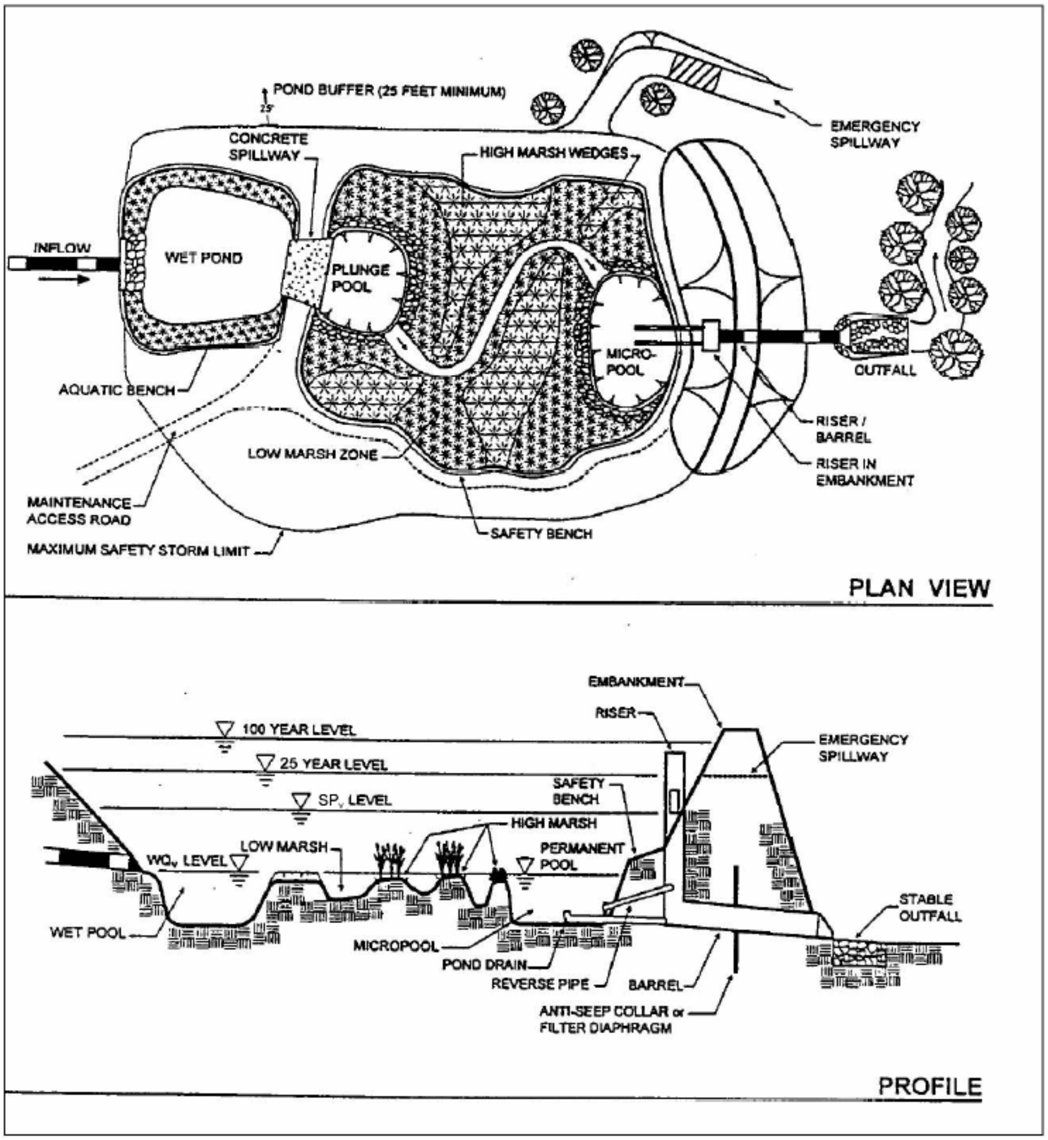
Extended Detention Shallow Wetland

(Source: Center for Watershed Protection)



Pocket Wetland

(Source: Center for Watershed Protection)



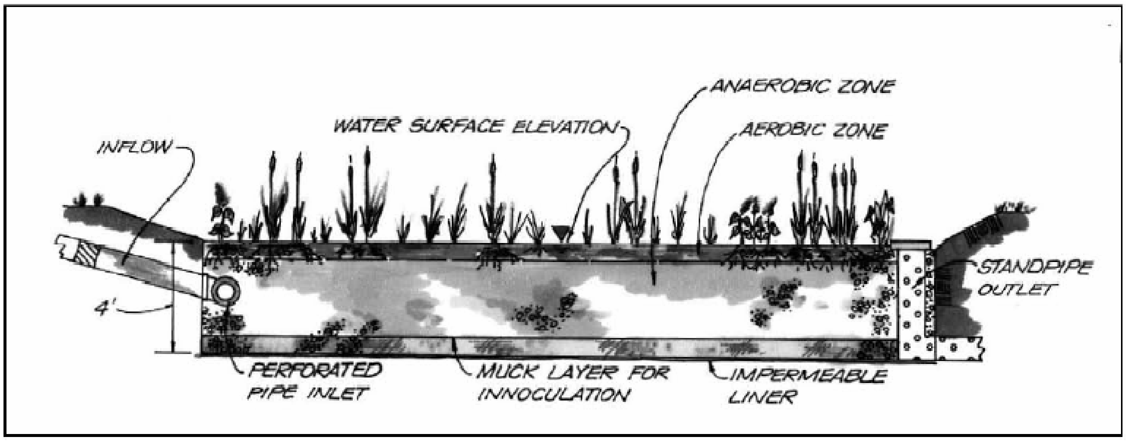
Pond/Wetland System

(Source: Center for Watershed Protection)

1.1.2 Submerged Gravel Wetland Systems

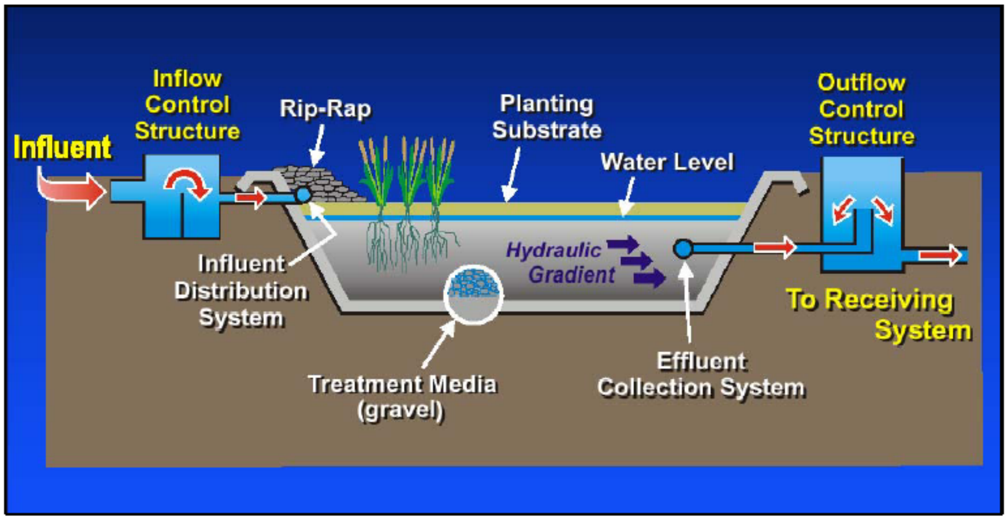
Submerged gravel wetland systems utilize wetland plants in either submerged gravel or similar media to remove pollutants. These systems perform well in mid- to high-density environments where the use of other structural controls may not be desirable.

Schematics/Pictures



Submerged Gravel Wetland System

(Source: Center for Watershed Protection)



Submerged Gravel Wetland System

(Source: Roux Associates Inc.)

1.1.3 Series of wetland cells within small drainage

Small weirs constructed across a drainage channel can be used to create a series of wetland cells. Conveyance capacity requirements for storm runoff or other drainage need to be assessed since some channel volume will be lost due to volume of retained water and vegetative biomass established in cells.

Schematics/Pictures

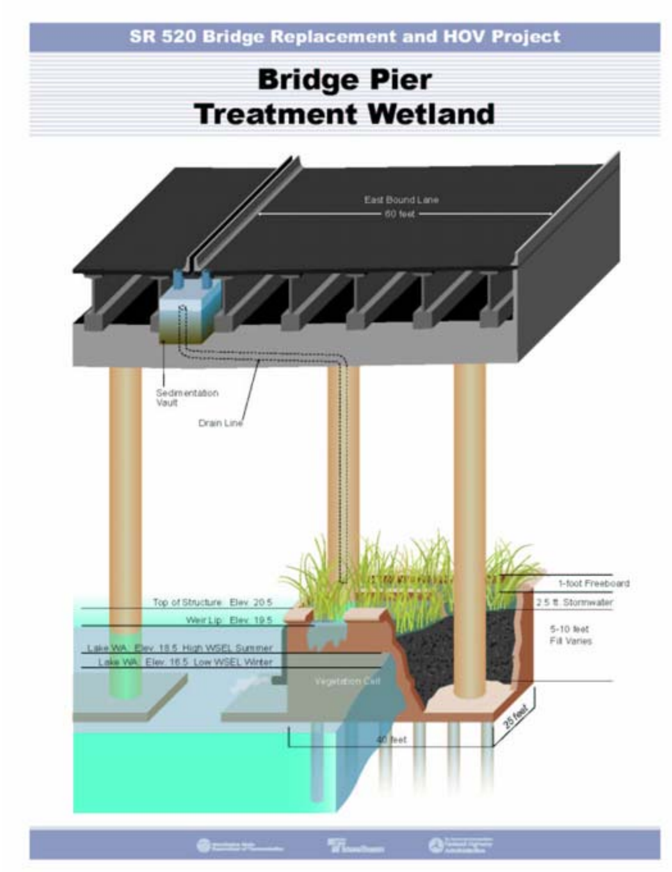
(Chaipattana Foundation Journal)

1.1.4 Wetland Swales

Similar to series of wetland cells within small drainage above, but does not involve construction of weirs although small check dams may be employed along swales with steeper gradients. If elevation grade along channel is low, moist soils resulting from frequent urban or agricultural drainage sustains growth of aquatic macrophytes including grasses, rushes, sedges, and spikerushes.

1.1.5 Bridge Pier Treatment Wetland

Stormwater runoff from highway bridges typically drains directly to underlying water bodies. An innovative design from the Washington State Department of Transportation utilizes stormwater treatment wetlands for providing water quality improvement of bridge drainage prior to discharge to receiving water.



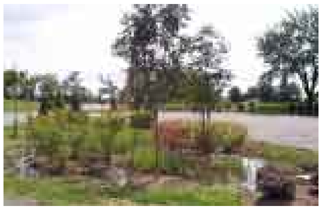
(Washington State Department of Transportation)

1.2 Bioretention

Bioretention areas are intended to treat the first flush of runoff from impervious surfaces in a shallow stormwater basin or landscaped depressional area. These area use engineered soils and vegetation to capture and treat the stormwater prior to discharge to a conveyance system or through exfiltration into soil in combination with evapotranspiration from the vegetative cover. Bioretention areas are designed to be used in urban and suburban areas as off-line systems which treat first flush of runoff.

1.2.1 Low Impact Development Strategies

Schematics/Pictures



Parking lot bioretention cell day after storm. Cell designed to store water for no more than 72 hours after storm. (Massachusetts Low Impact Development Toolkit)

Rain garden bioretention cell for rooftop and driveway of single residence. (Massachusetts Low Impact Development Toolkit)

Bioretention Area

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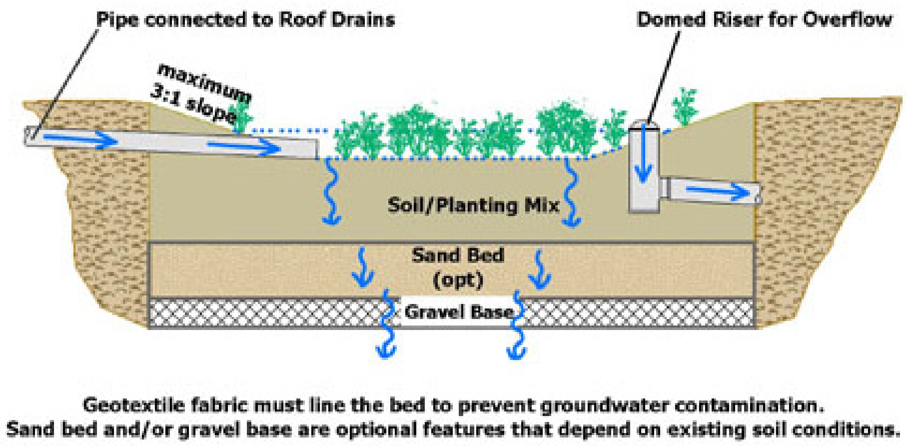
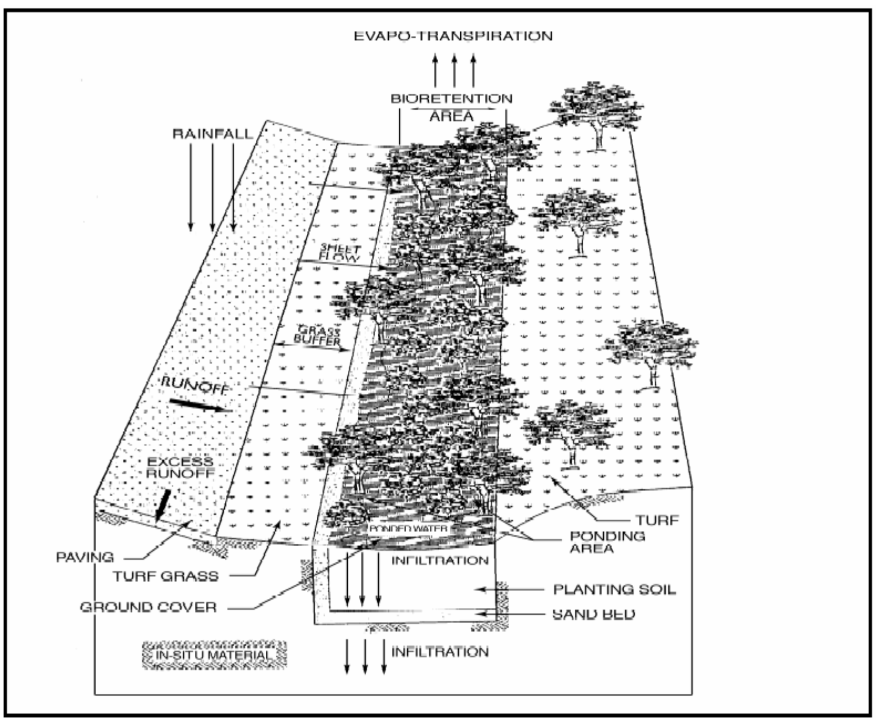
* Descriptions of strategies taken from Integrated Stormwater Management Design Manual by NCTCOG, Freese and Nichols, Inc., AMEC Earth and Environmental, Alan Plummer Associates, Inc., and Caffey Engineering, Inc.

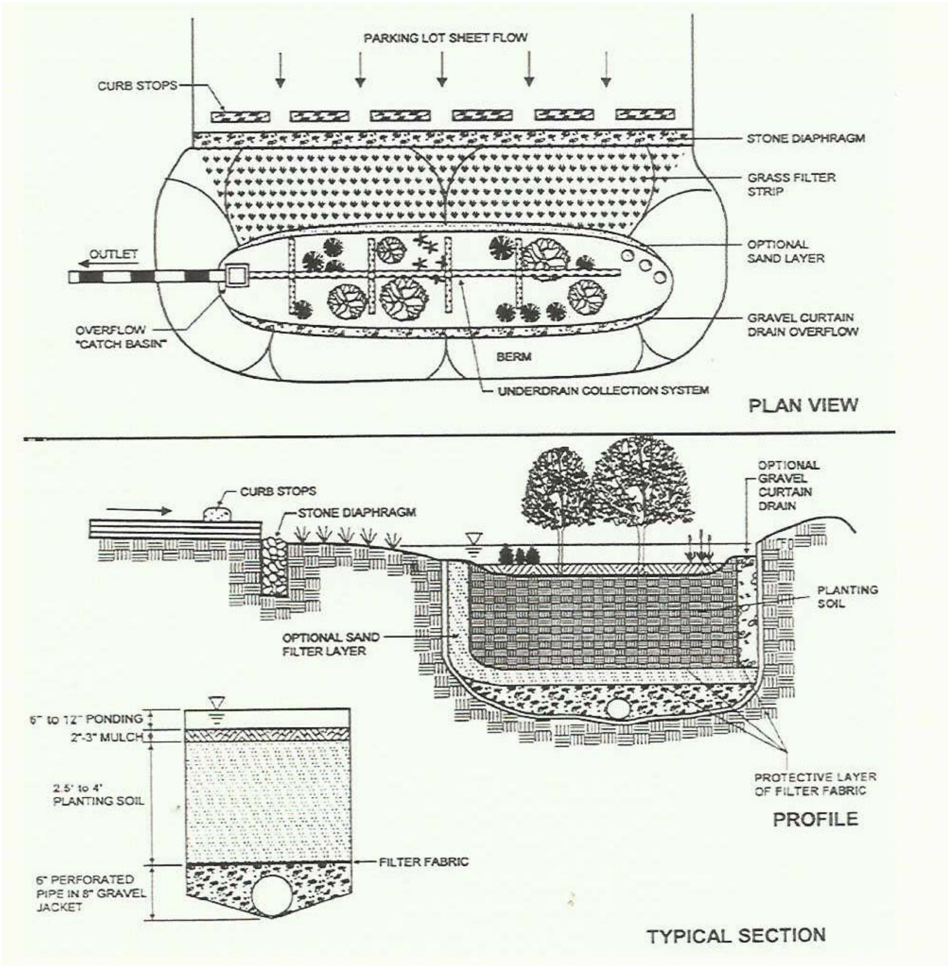


Cahill Associates



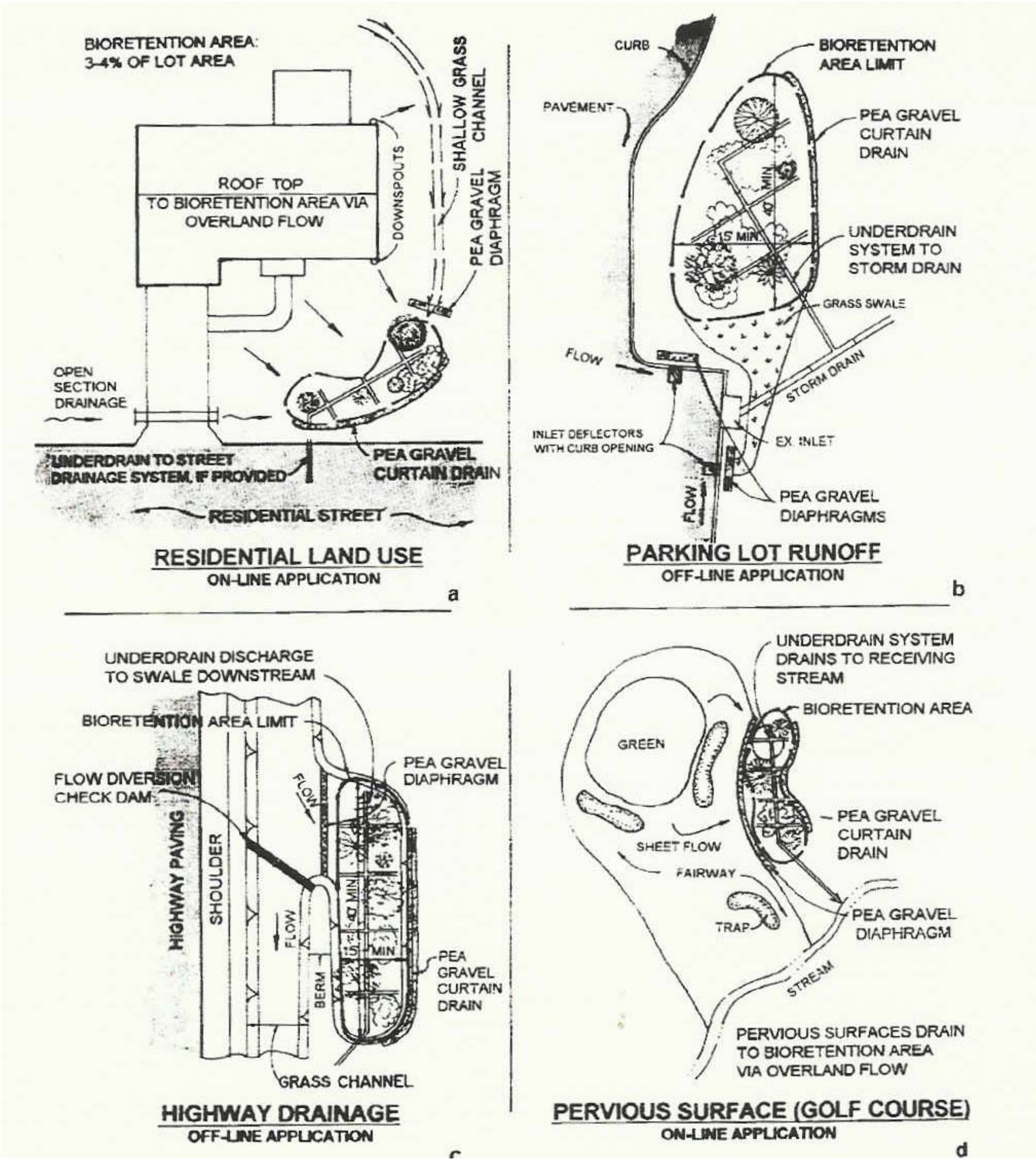
Cross-Section of Bioretention Cell

(Prince George County Department of Environmental Resources, 1993)

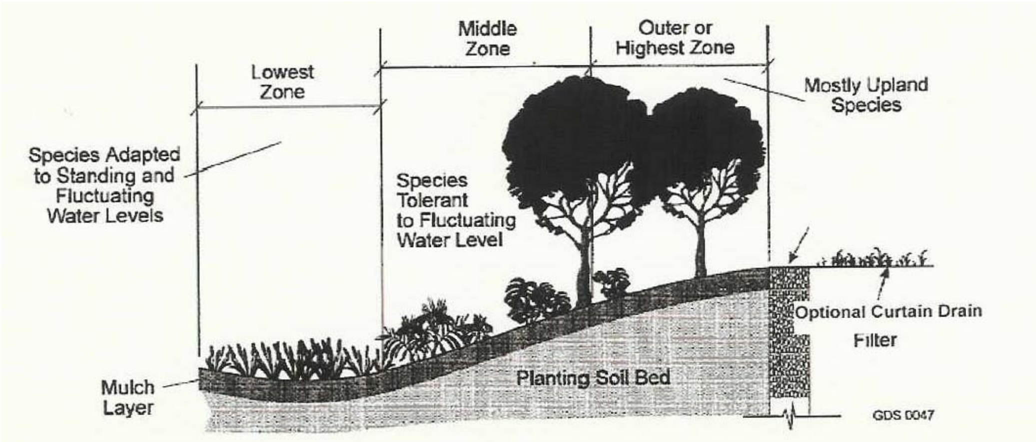


Plan and Section View of Bioretention Cell

(MDE, 2000) (from EPA/600/R-04/121A)



Schematic Designs of Various Applications of Bioretention Cells (Clar and Green, 1993 and CRC, 1996 used with permission) (from EPA/600/R-04/121A)



Suggested Planting Zones for Bioretention Facilities

(MDE, 2000) (from EPA/600/R-04/121A)

Proper selection and installation of plant materials is key to a successful bioretention system that provides multiple benefits and minimizes maintenance. Three zones are recommended within a facility. The lowest zone supports plants that are adapted to standing and fluctuating water levels. The middle elevation supports plants that require or tolerate periodic short-term inundation but where soils don't stay saturated for extended periods. The outer or highest zone generally supports plants adapted to dryer conditions. A natural plant layout that situates appropriate species native to the local area within the three zones should be used.

Additional Information

KEY CONSIDERATIONS

DESIGN CRITERIA:

- Maximum contributing drainage area of 5 acres (< 2 acres recommended)
- Often located in "landscaping islands"
- Treatment area consists of grass filter, sand bed, ponding area, organic/mulch layer, planting soil, and vegetation
- Typically requires 5 feet of head

ADVANTAGES / BENEFITS:

- Applicable to small drainage areas
- Good for highly impervious areas, flexible siting
- Good retrofit capability
- Relatively low maintenance requirements
- Can be planned as an aesthetic feature

DISADVANTAGES / LIMITATIONS:

- Requires extensive landscaping if in public area
- Not recommended for areas with steep slopes

MAINTENANCE REQUIREMENTS:

- Inspect and repair/replace treatment area components

IMPLEMENTATION CONSIDERATIONS

M **Land Requirement**

M **Capital Cost**

L **Maintenance Burden**

Residential Subdivision Use: *Yes*

High Density/Ultra-Urban: *Yes*

Drainage Area: *5 acres max. (< 2 acres recommended)*

Soils: *Planting soils must meet specified criteria; No restrictions on surrounding soils*

Other Considerations:

- *Use of native plants is recommended*

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(M = Moderate, L = Low)

1.3 Channels

Enhanced swales or vegetated open swales are designed and constructed to capture and treat stormwater runoff in dry or wet cells formed by check dams or low weirs.

Grass channels provide "biofiltering" of stormwater runoff. Grass channels should be employed in conjunction with other methods as part of a treatment train since a grass channel alone is not sufficient to meet most water quality improvement goals.

1.3.1 Dry Swale

The dry swale is an open channel that has been modified to enhance its water quality treatment capability by adding a filtering media consisting of a soil bed over an underdrain system. Dry swales are sized to allow the entire volume to be filtered or infiltrated through the bottom of the swale, usually within approximately one day. Check dams may be installed in the swale perpendicular to flow and anchored to the side slopes to reduce velocity of flow through the swale, increase contact time for flow to infiltrate through the soil, and increase pollutant removal efficiency. Check dams are typically constructed of earth, riprap, gabions, railroad ties, or pressure-treated wood logs. Earthen check dams should be protected from erosion with riprap to dissipate energy and spread flow.

Schematics/Pictures

Enhanced Dry Swale

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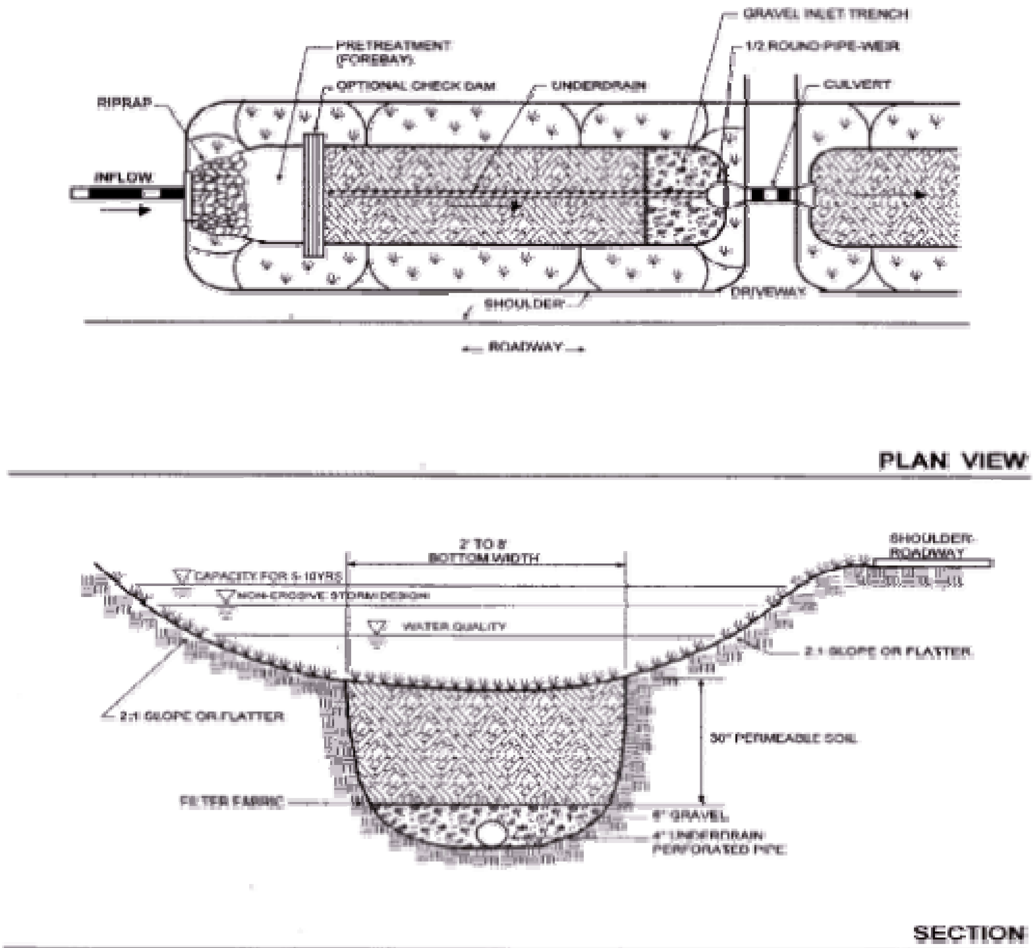
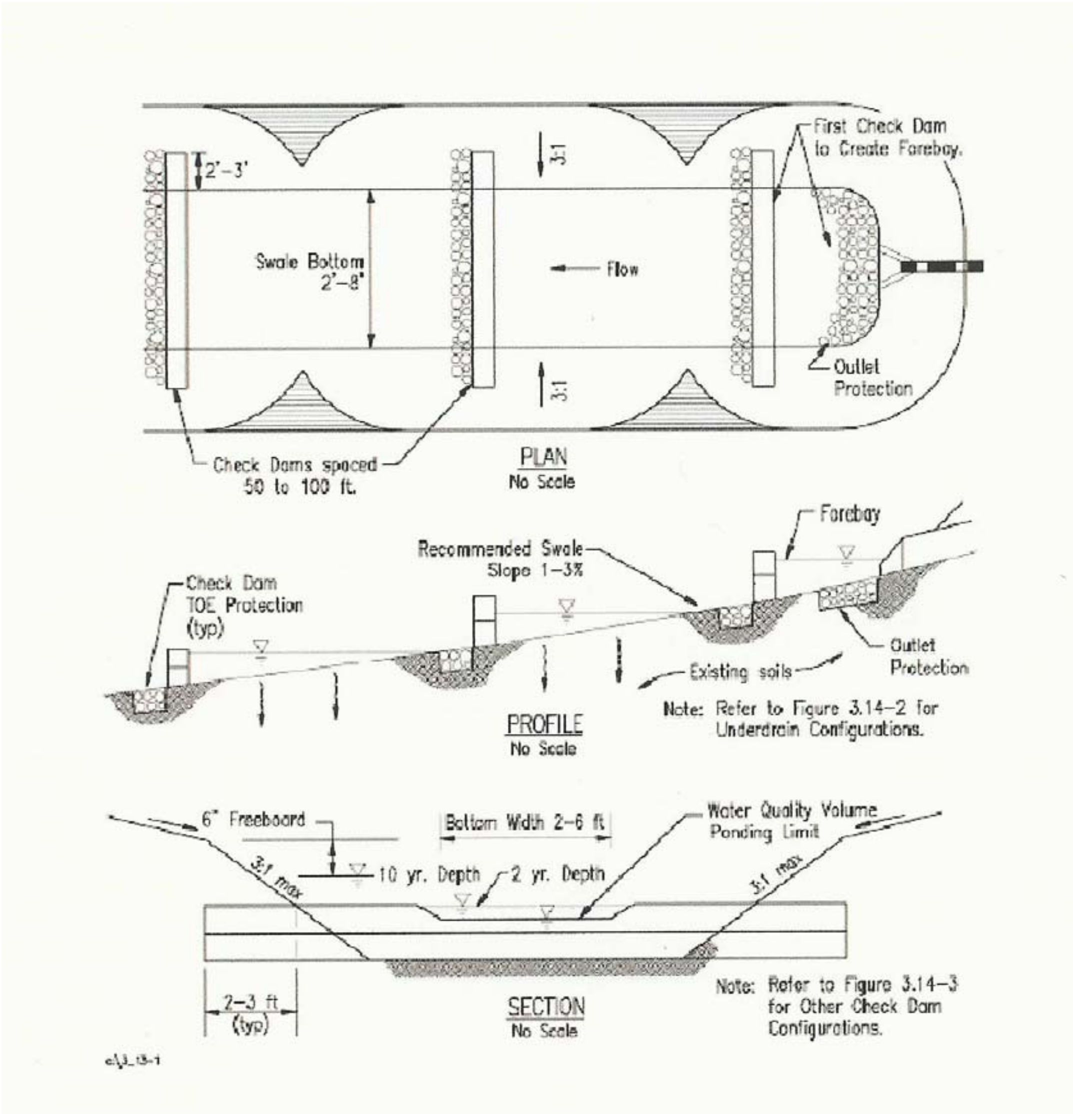


Dry Swale with Filter Media
(MDE,2000) (from EPA/600/R-04/121A)



Typical Swale with Check Dam Configuration
(VA DEC, 1999) (from EPA/600/R-04/121A)

Additional Information

KEY CONSIDERATIONS

DESIGN CRITERIA:

- Longitudinal slopes must be less than 4%
- Bottom width of 2 to 8 feet
- Side slopes 2:1 or flatter; 4:1 recommended
- Convey the 25-year storm event with a minimum of 6 inches of freeboard

ADVANTAGES / BENEFITS:

- Combines storm water treatment with runoff conveyance system
- Less expensive than curb and gutter
- Reduces runoff velocity

DISADVANTAGES / LIMITATIONS:

- Higher maintenance than curb and gutter systems
- Cannot be used on steep slopes
- Possible resuspension of sediment
- Potential for odor / mosquitoes (wet swale)
- Concerns with aesthetics of 4"-6" high grass in residential areas

MAINTENANCE REQUIREMENTS:

- Maintain grass heights of approximately 4 to 6 inches (dry swale)
- Remove sediment from forebay and channel

Residential Subdivision Use: *Yes*

High Density/Ultra-Urban: *No*

Drainage Area: *5 acres max.*

Soils: *No restrictions*

Other Considerations:

- *Permeable soil layer (dry swale)*
- *Wetland plants (wet swale)*

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1.3.2 Grass Channel (biofilter) and Open Conveyance Channel

Grass swales are low cost stormwater conveyance systems traditionally used in low to medium density residential developments. Perceived in recent years as a potentially important element in stormwater management which includes water quality considerations due to slower flow velocities, reduction in peak discharges, filtering of pollutants by grass media, infiltration of runoff into soil profile, and uptake of pollutants by plant roots. A grass channel is similar to a dry swale but is not constructed with installed filtering media or underdrain system.

Schematics/Pictures

Grass Channel

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Grass Swale (VA DCR, 1999) (from EPA/600/R-04/121A)

Additional Information

REASONS FOR LIMITED USE

- Cannot alone achieve the 80% TSS removal target
- May require more maintenance than curb and gutter system

KEY CONSIDERATIONS

- Can be used as part of the runoff conveyance system to provide pretreatment
- Grass channels can act to partially infiltrate runoff from small storm events if underlying soils are pervious
- Less expensive to construct than curb and gutter systems
- Should not be used on slopes greater than 4%; slopes between 1% and 2% recommended
- Ineffective unless carefully designed to achieve low flow rates in the channel (<1.0 ft/s)
- Potential for bottom erosion and re-suspension
- Standing water may not be acceptable in some areas

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An open channel is a conduit in which water flows with a free surface. Open channels include conveyance channels or drainage ditches; grass channels; and enhanced swales. An open conveyance channel is designed for conveyance purposes only. It does not have an underlying filtering bed but is constructed directly with existing soils.

Schematics/Pictures

Open conveyance channel

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Additional Information

KEY CONSIDERATIONS

- Can be aesthetically pleasing
- Vegetated channels provide natural habitats
- Once established, little maintenance is required
- A maximum of 2:1 should be used for channel side slopes. Roadside ditches should have maximum side slope of 3:1.
- Channel banks should be stabilized at site
- Velocity will limit the type of channel lining, for example, vegetated channels require slower velocities and lower longitudinal slopes

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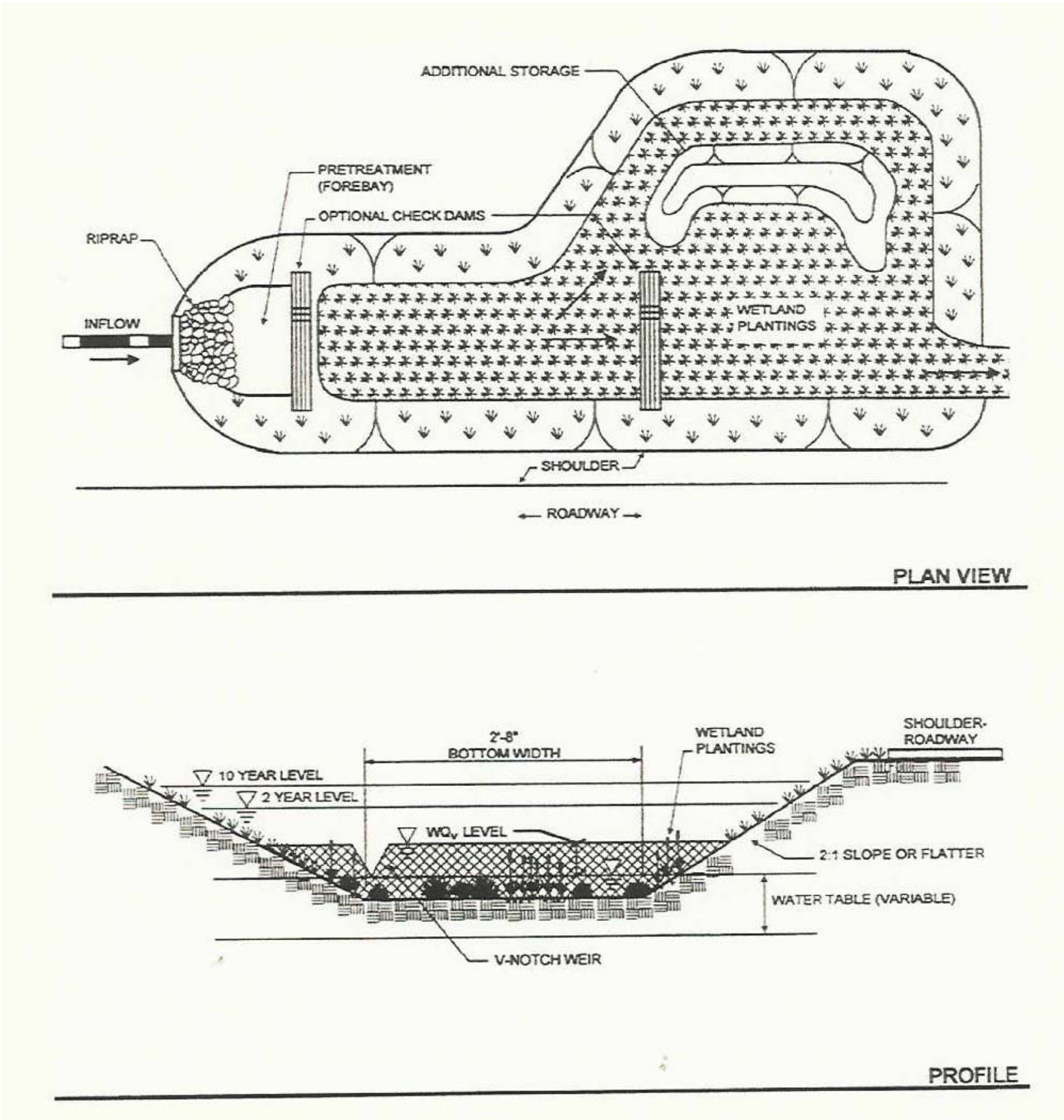
1.3.3 Wet Swale/Wetland Channel

Wet swales also consist of broad open channels but do not have an underlying filtering bed and the bottom of the channel is at or near the water table or flows are detained by periodic check dams so that bottom soil stays saturated or slightly inundated following storm events. The wet swale is similar to the series of wetland cells within small drainage described above and has similar water quality treatment mechanisms including settling of suspended solids, adsorption, and uptake of pollutants by vegetative root systems.

Schematics/Pictures



Wet Swale (MDE, 2000) (from EPA/600/R-04/121A)

1.3.4 Arroyo Colorado On-Channel Weirs

The Port of Harlingen Authority, working with the City of Harlingen, propose to install three rock weirs within the reach of the Arroyo Colorado adjacent to the hike and bike trail constructed by the City of Harlingen. NRS Consulting Engineers developed the plan for the weirs and they should be contacted for further information regarding the design and water quality improvement potential.

1.4 Detention

Dry detention basins and dry extended detention (ED) basins are surface facilities intended to provide for the temporary storage of stormwater runoff to reduce downstream water quantity impacts.

Multi-purpose detention areas are on-site areas used for one or more specific activities, such as parking lots and rooftops, which are also designed for temporary storage of runoff.

Underground detention tanks and vaults are an alternative to surface dry detention for space-limited areas where there is not adequate land for a dry detention basin or multi-purpose detention area.

1.4.1 Dry Detention/Dry Extended Detention Basin

A surface storage basin or facility designed to provide water quantity control through detention and/or extended detention of stormwater runoff.

Schematics/Pictures

Dry Detention Basin

Additional Information

REASONS FOR LIMITED USE

Controls for storm water quantity primarily –extended detention may provide limited water quality treatment and streambank protection

KEY CONSIDERATIONS

- Typically less costly than storm water (wet) ponds for equivalent flood storage, as less excavation is required
- Used in conjunction with water quality structural control
- Recreational and other open space opportunities between storm runoff events

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1.4.2 Multipurpose Detention Areas

A facility designed primarily for another purpose, such as parking lots and rooftops that can provide water quantity control through detention of stormwater runoff.

Schematics/Pictures

Multipurpose Detention Area

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Additional Information

REASONS FOR LIMITED USE

- Controls for storm water quantity only – not intended to provide water quality protection
- Localized flooding of area as intended may lead to property damage and additional liability

KEY CONSIDERATIONS

- Allows for multiple uses of site areas and reduces the need for downstream detention facilities
- Can be Used in conjunction with water quality structural control
- Adequate grading and drainage must be provided to allow full use of facility's primary purposes following a storm event

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1.4.3 Underground Detention

Detention storage located in underground pipe/tank systems or vaults designed to provide water quantity control through detention and/or extended detention of stormwater runoff.

Schematics/Pictures

Underground Detention

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Additional Information

REASONS FOR LIMITED USE

- Controls for storm water quantity only – not intended to provide water quality treatment
- Intended for space-limited applications
- High initial construction cost as well as replacement cost at the end of its economic life

KEY CONSIDERATIONS

- Does not take up surface space
- Used in conjunction with water quality structural control
- Concrete vaults or pipe/tank systems can be used

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1.5 Filtration

Filter strips provide "biofiltering" of stormwater runoff as it flows across the grass surface. However, filter strips alone cannot meet typical TSS removal performance goals, so they are normally used as pretreatment measure or as part of a treatment train approach.

Organic filters are surface sand filters where organic materials such as a leaf compost or peat/sand mixture are used as the filter media. These media may be able to provide enhanced removal of some contaminants, such as heavy metals. Given their potentially high maintenance requirements, they are typically used only in environments that warrant their use.

Sand filters are multi-chamber structures designed to treat stormwater runoff through filtration, using a sand bed as its primary filter media. Filtered runoff may be returned to a conveyance system or allowed to partially exfiltrate into the soil.

1.5.1 Filter Strips Buffer Zones

Filter strips are uniformly graded and densely vegetated sections of land engineered and designed to treat runoff from and remove pollutants through vegetative filtering and infiltration.

Schematics/Pictures

Filter Strip Buffer Zone

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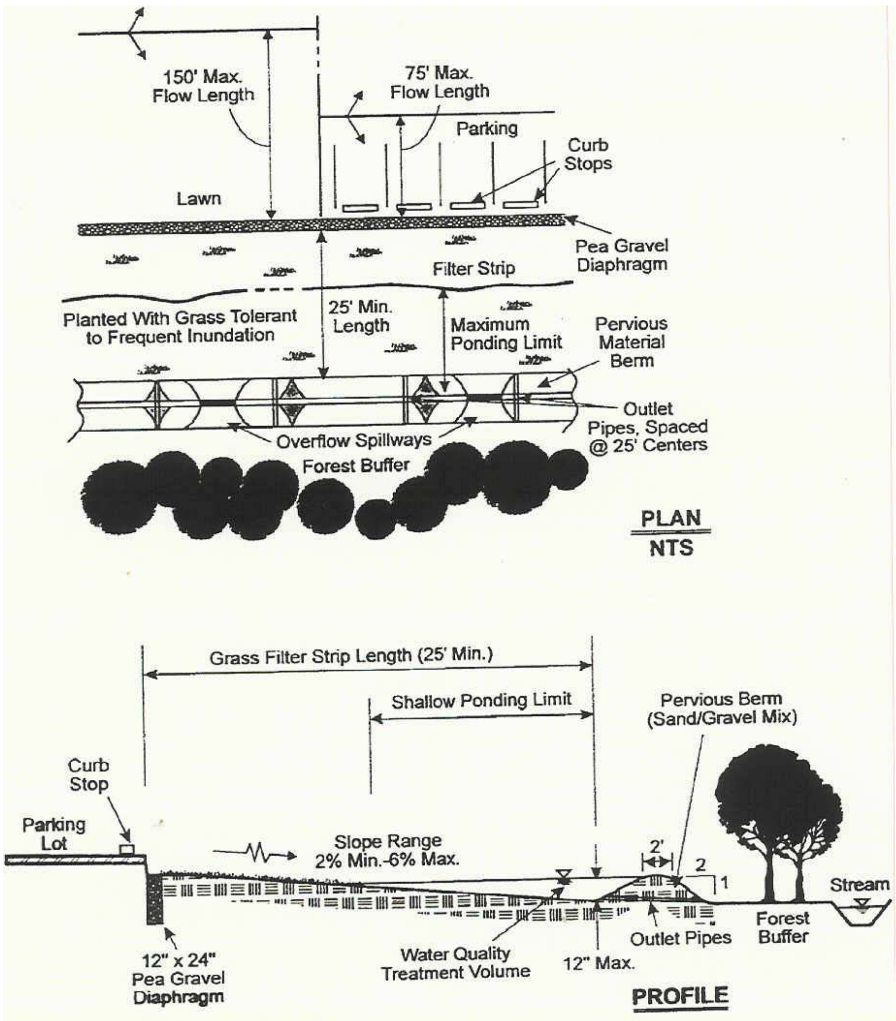

Vegetative Filter Strip (CRC, 1996 used with permission) (from EPA/600/R-04/121A)

Additional Information

REASONS FOR LIMITED USE

- Cannot alone achieve the 80% TSS removal target

KEY CONSIDERATIONS

- Runoff from an adjacent impervious area must be evenly distributed across the filter strip as sheet flow
- Can be used as part of the runoff conveyance system to provide pretreatment
- Can provide groundwater recharge
- Reasonably low construction cost
- Large land requirement
- Requires periodic repair, regrading, and sediment removal to prevent channelization

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1.5.2 Organic Filter

Design variant of the surface sand filter using organic materials in the filter media.

Schematics/Pictures

Organic Filter

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Additional Information

REASONS FOR LIMITED USE

- Intended for hotspot or space-limited applications, or for areas requiring enhanced pollutant removal capability
- High maintenance requirements

KEY CONSIDERATIONS

- High pollutant removal capability
- Removal of dissolved pollutants is greater than sand filters due to cation exchange capacity
- Filter may require more frequent maintenance than most of the other storm water controls
- Minimum head requirement of 5 to 8 feet
- Severe clogging potential if exposed soil surfaces exist upstream

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1.5.3 Sand Filter

Multi-chamber structure designed to treat stormwater runoff through filtration, using a sediment forebay, a sand bed as its primary filter media and, typically, an underdrain collection system.

Schematics/Pictures

Sand Filter

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Additional Information

KEY CONSIDERATIONS

DESIGN CRITERIA:

- Typically requires 2 to 6 feet of head
- Maximum contributing drainage area of 10 acres for surface sand filter; 2 acres for perimeter sand filter
- Sand filter media with underdrain system

ADVANTAGES / BENEFITS:

- Applicable to small drainage areas
- Good for highly impervious areas
- Good retrofit capability

DISADVANTAGES / LIMITATIONS:

- High maintenance burden
- Not recommended for areas with high sediment content in storm water or clay/silt runoff areas
- Relatively costly
- Possible odor problems

MAINTENANCE REQUIREMENTS:

- Inspect for clogging – rake first inch of sand
- Remove sediment from forebay/chamber
- Replace sand filter media as needed

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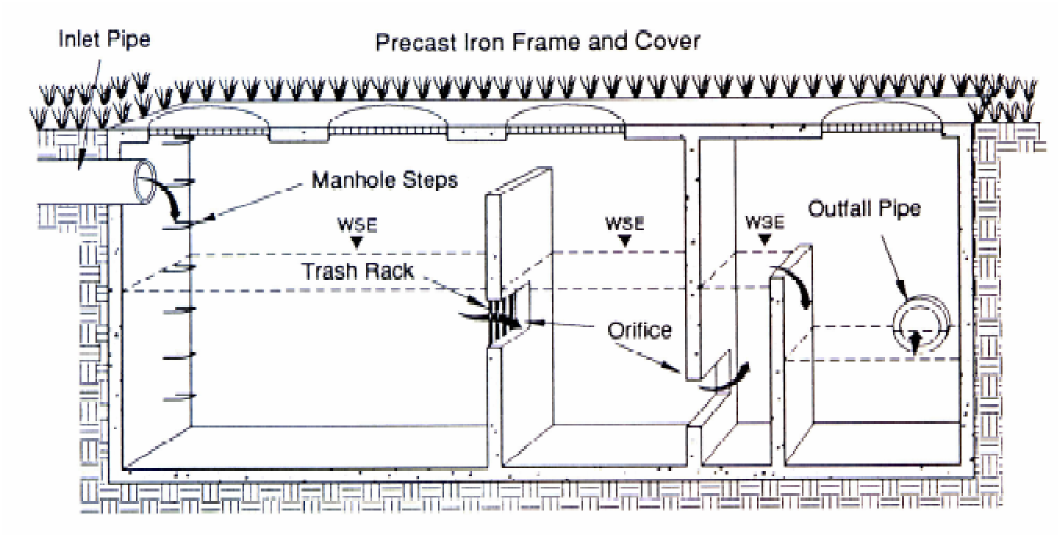
1.6 Hydrodynamic Devices

Hydrodynamic controls use the movement of stormwater runoff through a specially designed structure to remove target pollutants. They are typically used on smaller impervious commercial sites and urban hotspots. These controls typically do not meet the primary TSS removal performance goal and therefore should only be used as a pretreatment measure and as part of a treatment train approach.

1.6.1 Gravity (oil-grit) Separator

Hydrodynamic separation device designed to remove settleable solids, oil and grease, debris, and floatables from stormwater runoff through gravitational settling and trapping of pollutants.

Schematics/Pictures



Oil/grit separtor

Source: NVRC, 1992

Additional Information

REASONS FOR LIMITED USE

- Cannot alone achieve the 80% TSS removal target
- Intended for hotspot, space-limited, or pretreatment applications
- Limited performance data

KEY CONSIDERATIONS

- Intended for the removal of settleable solids (grit and sediment) and floatable matter, including oil and grease
- Dissolved pollutants are not effectively removed
- Frequent maintenance required
- Performance dependent on design and frequency of inspection and cleanout of unit

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1.7 Infiltration

Infiltration techniques are used to decrease surface runoff from impervious surfaces found in urban areas. Infiltration techniques are employed to remove suspended solids, particulate pollutants, coliform bacteria, organics, and some soluble forms of metals and nutrients from stormwater runoff. Infiltration techniques are used where land availability is limited for installation of larger Best Management Practices. An infiltration trench is an excavated trench filled with stone aggregate used to capture and allow infiltration of stormwater runoff into the surrounding soils from the bottom and sides of the trench.

Soakage trenches are a variation of infiltration trenches. Soakage trenches drain through a perforated pipe buried in gravel. They are used in highly impervious areas where conditions do not allow surface infiltration and where pollutant concentrations in runoff are minimal (i.e. non-industrial rooftops). They may be used in conjunction with other stormwater devices.

1.7.1 Infiltration Trench

An infiltration trench consists of an excavated trench, 3 to 12 feet deep, filled with stone aggregate and lined with filter fabric. A small portion of the runoff, usually the first flush, is diverted to the infiltration trench for filtering into the surrounding soils from the bottom and sides of the trench. The use of infiltration areas may be limited by type of native soils, climate, and location of groundwater tables and bedrock.

Schematics/Pictures

Infiltration Trench

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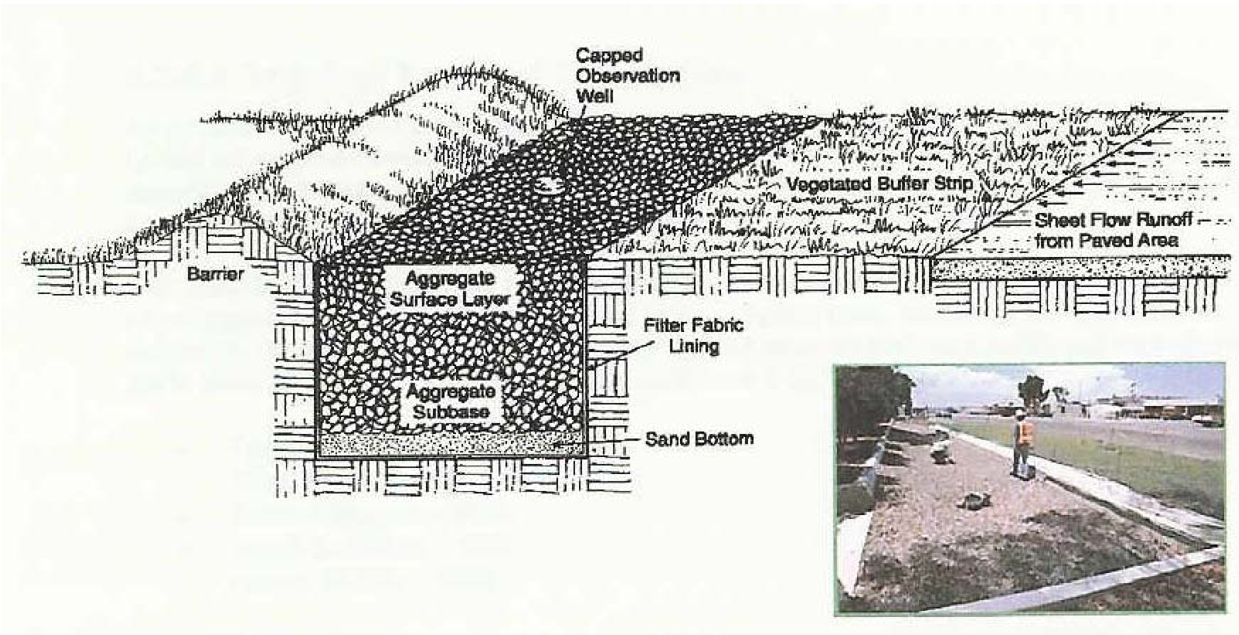

Infiltration Trench Example (Georgia Stormwater Management Manual)

Additional Information

KEY CONSIDERATIONS

DESIGN CRITERIA:

- Soil infiltration rate of 0.5 in/hr or greater required
- Excavated trench (3 to 8 foot depth) filled with stone media (1.5- to 2.5-inch diameter); pea gravel, and sand filter layers
- A sediment forebay and grass channel, or equivalent upstream pretreatment, must be provided
- Observation well to monitor percolation

ADVANTAGES / BENEFITS:

- Provides for groundwater recharge
- Good for small sites with porous soils

DISADVANTAGES / LIMITATIONS:

- Potential for groundwater contamination
- High clogging potential; should not be used on sites with fine-particled soils (clays or silts) in drainage area
- Significant setback requirements
- Restrictions in karst areas
- Geotechnical testing required, two borings per facility

MAINTENANCE REQUIREMENTS:

- Inspect for clogging
- Remove sediment from forebay
- Replace pea gravel layer as needed

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1.7.2 Soakage Trench

Soakage trenches are a variation of infiltration trenches. Soakage trenches drain through a perforated pipe buried in gravel. They are used in highly impervious areas where conditions do not allow surface infiltration and where pollutant concentrations in runoff are minimal (i.e. non-industrial rooftops. They may be used in conjunction with other stormwater devices, such as draining downspouts or planter boxes).

Schematics/Pictures

Soakage Trench

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Examples of soakage trenches used in various areas including multi-family residential and circular driveway (Lower Columbia River Field Guide to Water Quality Friendly Development)

Additional Information

REASONS FOR LIMITED USE

- Intended for space-limited applications
- Subsurface pipe considered an injection well and may require special permit

KEY CONSIDERATIONS

- Filtration provides pollutant removal capability
- Reservoir decreases peak flow rates
- Like other infiltration devices, soakage trenches should not be used for storm water containing high sediment loads to minimize clogging

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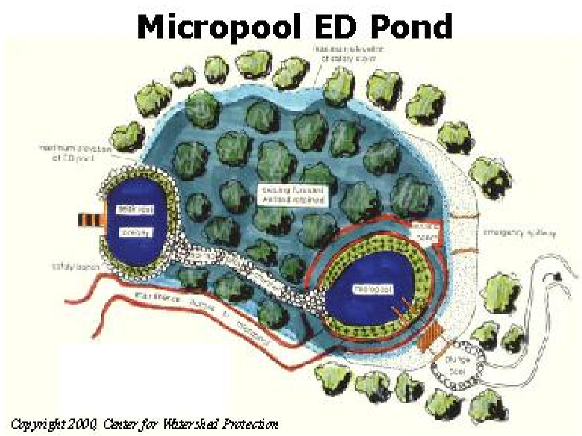
1.8 Ponds

Stormwater ponds are constructed stormwater retention basins that have a permanent pool (or micropool) of water. Runoff from each rain event is detained and treated in the pool through settling and biological activity. Stormwater ponds are among the most cost-effective and commonly used stormwater management technique. When designed properly, they can provide multiple benefits including habitat and aesthetics.

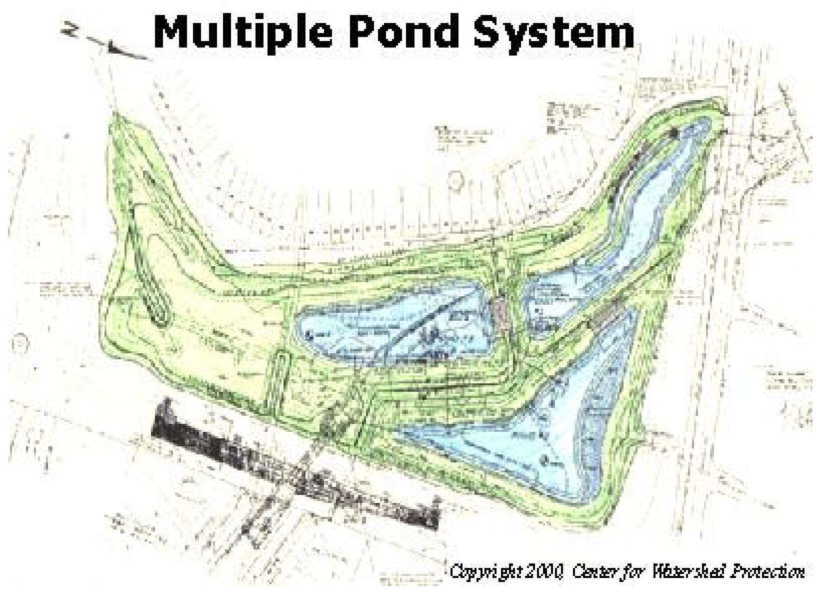
1.8.1 Micropool Extended Detention Pond/ Multiple Pond Systems/ Wet Extended Detention Pond/Wet Pond

Schematics/Pictures



(From Center for Watershed Protection Slideshow "A Review of Stormwater Treatment Practices")

Micropool Extended Detention Pond System (From Center for Watershed Protection Slideshow "A Review of Stormwater Treatment Practices")



(From Center for Watershed Protection Slideshow “A Review of Stormwater Treatment Practices”)

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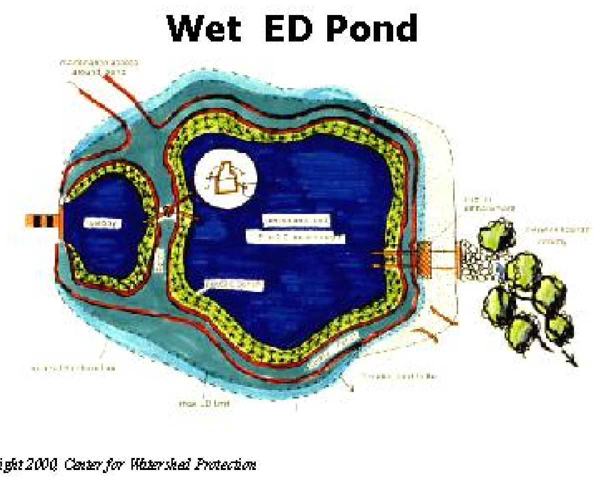
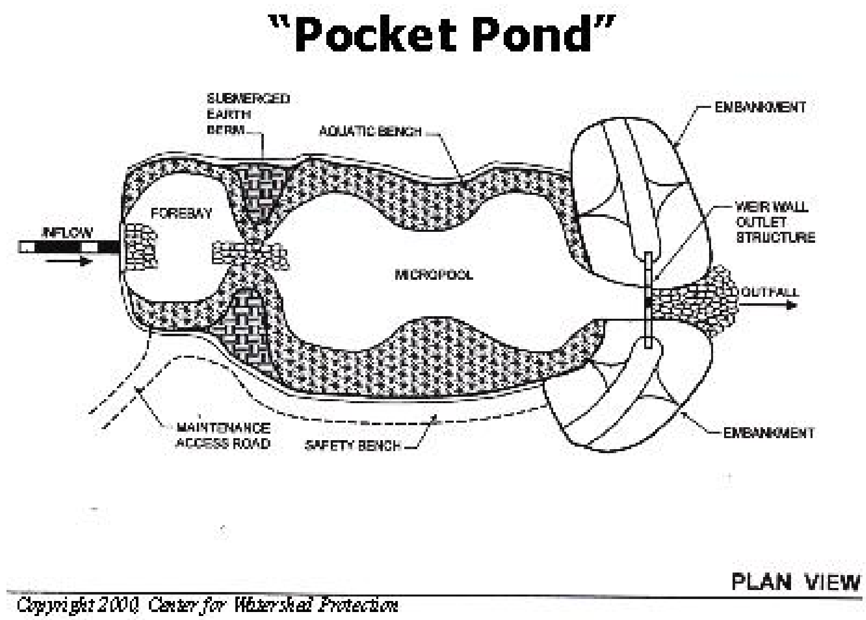


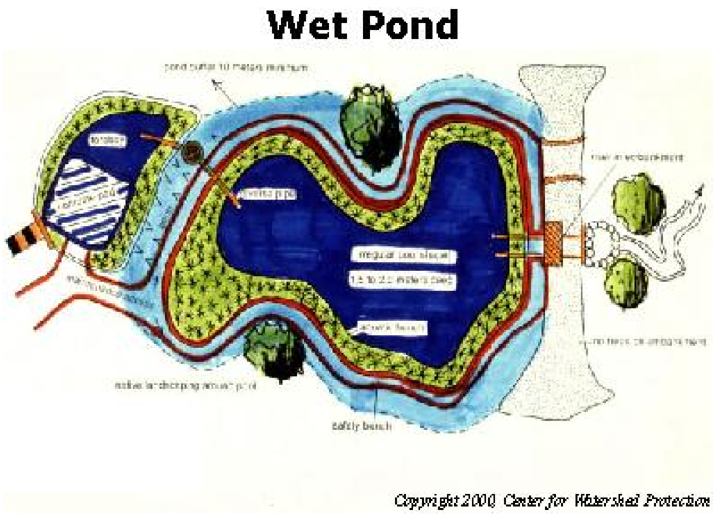
(From Center for Watershed Protection Slideshow “A Review of Stormwater Treatment Practices”)

Examples of Wet Extended Detention Ponds (From Center for Watershed Protection Slideshow “A Review of Stormwater Treatment Practices”)



(From Center for Watershed Protection Slideshow "A Review of Stormwater Treatment Practices")

Example of pocket pond (From Center for Watershed Protection Slideshow "A Review of Stormwater Treatment Practices")



(From Center for Watershed Protection Slideshow “A Review of Stormwater Treatment Practices”)

Examples of wet ponds (From Center for Watershed Protection Slideshow “A Review of Stormwater Treatment Practices”)

1.9 Porous Surfaces

A green roof uses a small amount of substrate over an impermeable membrane to support a covering of plants. The green roof slows down runoff from the otherwise impervious roof surface as well as moderating rooftop temperatures. With the right plants, a green roof will also provide aesthetic or habitat benefits.

Modular porous paver systems consist of open void paver units laid on a gravel subgrade. Both porous concrete and porous paver systems provide water quality and quantity benefits, but have high workmanship and maintenance requirements, as well as high failure rates.

Porous surfaces are permeable pavement surfaces with an underlying stone reservoir to temporarily store surface runoff before it infiltrates into the subsoil. Porous concrete is the term for a mixture of course aggregate, Portland cement and water that allows for rapid infiltration of water.

1.9.1 Green Roofs

Green roofs have been used in Europe for decades. Various examples of green roof design are shown below as presented in the Lower Columbia River Field Guide to Water Quality Friendly Development. Many of these roof designs capture runoff not absorbed by the soil and plants on the rooftops and drain to other devices such as infiltration planter boxes or cisterns for use as irrigation.

Schematics/Pictures

Green Roof

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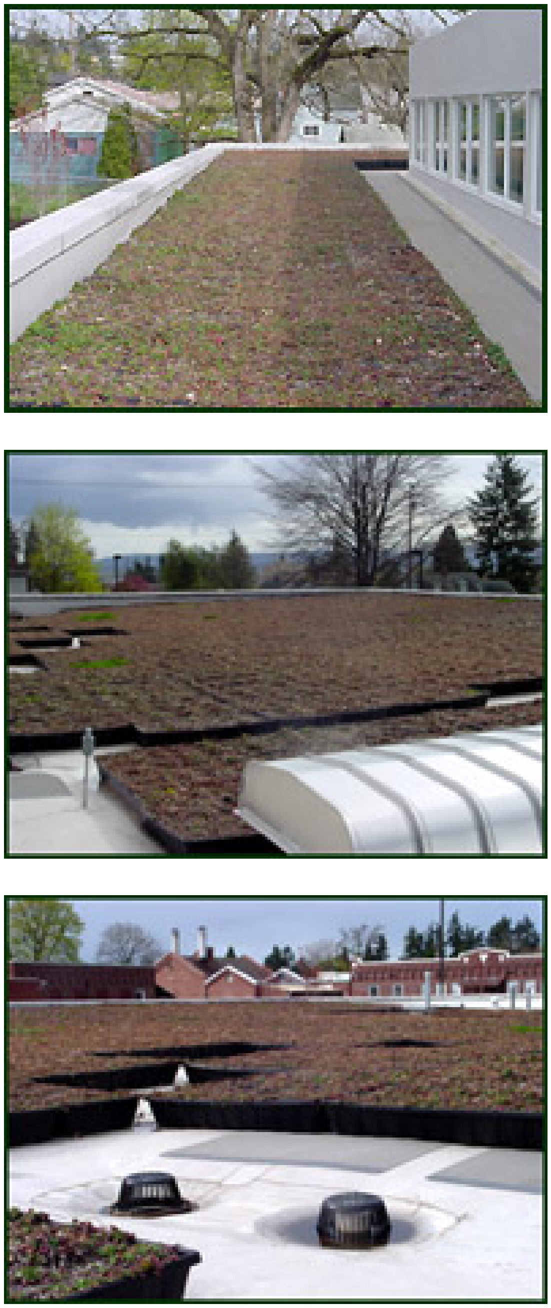
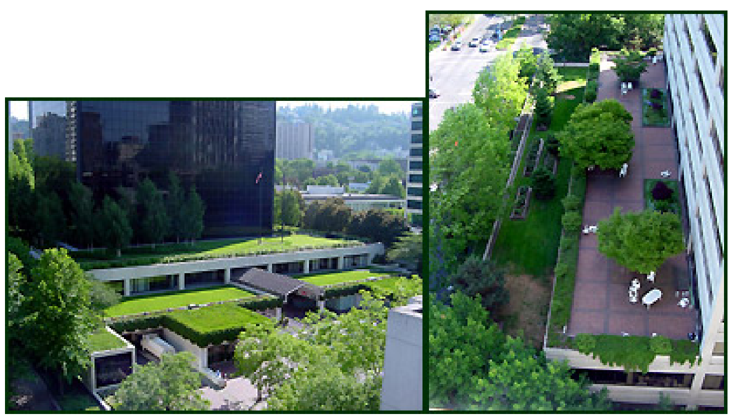


Example of green roof design at Ogden Resource Center, Vancouver, WA (Lower Columbia River Field Guide to Water Quality Friendly Development)

Example of green roof design at Peoples Food Coop, Portland, OR (Lower Columbia River Field Guide to Water Quality Friendly Development)

Example of green roof design at Avalon Hotel, Portland, OR (Lower Columbia River Field Guide to Water Quality Friendly Development)



Examples of green roof designs on commercial buildings, Portland, OR (Lower Columbia River Field Guide to Water Quality Friendly Development)

Additional Information

REASONS FOR LIMITED USE

- Relatively new in North America
- Requires additional roof support
- Requires more maintenance than regular roofs
- Special attention to design and construction needed
- Requires close coordination with plant specialists

KEY CONSIDERATIONS

- Provides reduction in runoff volume
- Higher initial cost when compared to conventional roofs, but potential for lower life cycle costs through longevity
- Potential for high failure rate if poorly designed, poorly constructed, not adequately maintained.
- Potential for leakage due to plant roots penetrating membrane.

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1.9.2 Modular Porous Paver Systems and Porous Concrete

A pavement surface composed of structural units with void areas that are filled with pervious materials such as sand or grass turf. Porous pavers are installed over a gravel base course that provides storage as runoff infiltrates through the porous paver system into underlying permeable soils.

Schematics/Pictures

Porous Paver

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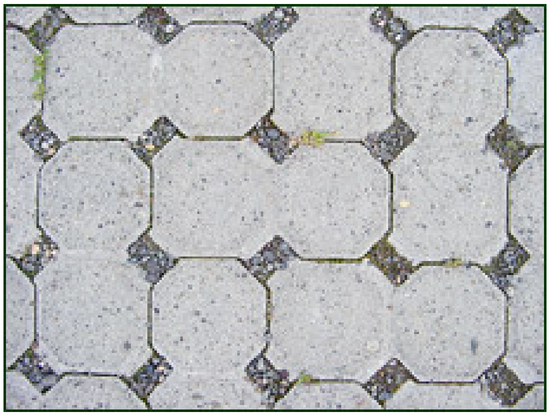

Example of porous pavement (Lower Columbia River Field
Guide to Water Quality Friendly Development)

Examples of porous pavement uses for parking areas at office building and park facilities in Portland Oregon (Lower Columbia River Field Guide to Water Quality Friendly Development)

Porous concrete is the term for a mixture of coarse aggregate, portland cement and water that allows for rapid infiltration of water and overlays a stone aggregate reservoir. This reservoir provides temporary storage as runoff infiltrates into underlying permeable soils and/or out through an underdrain system.

Schematics/Pictures

Porous Concrete

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Additional Information

REASONS FOR LIMITED USE

- Traditionally high failure rate and short life span
- Intended for low volume auto traffic areas, or for overflow parking applications
- High maintenance requirements
- Special attention to design and construction needed
- Should not be used in areas of soils with low permeability, wellhead protection zones, or recharge areas of water supply aquifer recharge areas.
- Restrictions on use by heavy vehicles

KEY CONSIDERATIONS

- Soil infiltration rate of 0.5 in/hr or greater required
- Excavated area filled with stone media; gravel and sand filter layers with observation well
- Pre-treat runoff if sediment present
- Provides reduction in runoff volume
- Somewhat higher cost when compared to conventional pavements
- Potential for high failure rate if poorly designed, poorly constructed, not adequately maintained, or used in unstabilized areas
- Potential for groundwater contamination

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1.10 Reuse

Rain harvesting is a container system designed to capture and store rainwater discharged from a roof. The rain harvesting system consists of a storage container, a downspout diversion, a sealed lid, and an overflow system. Typical rain harvesting systems hold between 50 and 500 gallons of water, and may work in series to provide larger volumes of storage.

1.10.1 Rain Harvesting

Schematics/Pictures

Rain Harvesting System

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Examples of rain harvesting systems at various residences in Portland, OR (Lower Columbia River Field Guide to Water Quality Friendly Development)

Additional Information

REASONS FOR LIMITED USE

- Small storage capacity
- Requires some attention
- If not attended to after a rain, leaking can cause damage to adjacent building foundation
- High construction cost when compared to the low cost of municipal water supply
- Certain roofing materials can cause runoff contamination (re-use)

KEY CONSIDERATIONS

- Provides reduction in runoff volume
- Low-cost, effective, and easy to maintain
- Offers flexibility with volume of water to capture
- Potential water savings
- Healthier for plants and gardens due to non-chlorinated water

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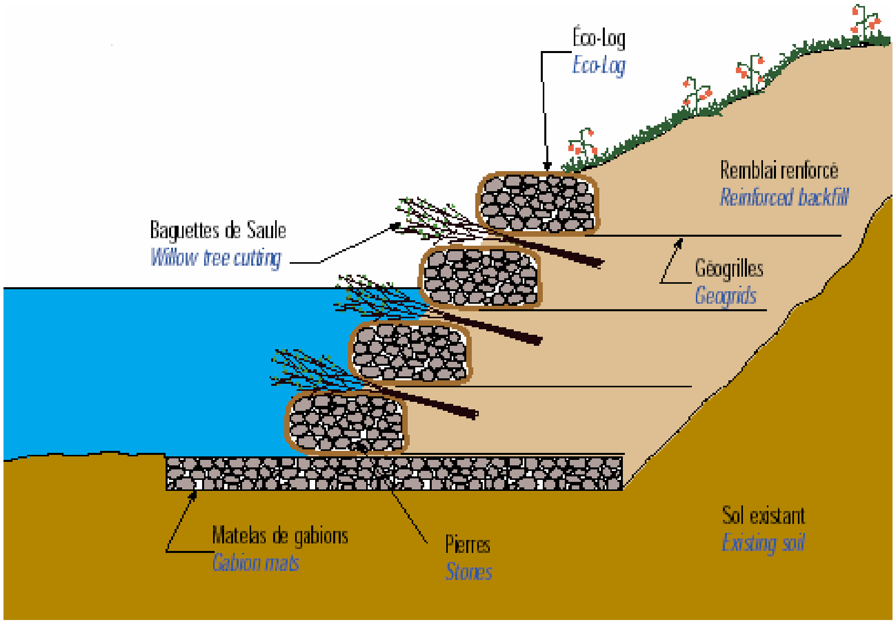
1.11 Bank/Slope Stabilization

Bioengineering involves the use of plant materials to provide structural integrity and stability to eroding slopes and stream banks. Bioengineering mimics nature by utilizing appropriate native plants and other locally available materials but can also be used in combination with traditional engineering techniques such as rock or concrete structures.

Structural revetments include “hard” engineering techniques such as rock or concrete facings to sustain banks and slopes.

Schematics/Pictures

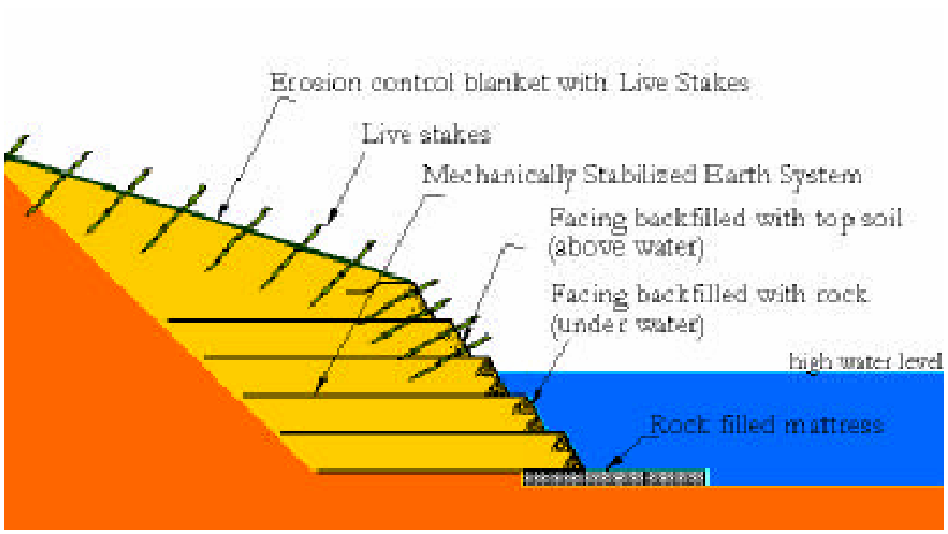


Macaferri

Bank Stabilization Using Vegetation with Gabions

* This would require a license from the IBWC

Comment: 10/18/05 Tim Noack, from Habitat Restoration meeting, per Gary Jones, IBWC



Macaferri

Bank Stabilization

1.11.1 Bioengineering with vegetation

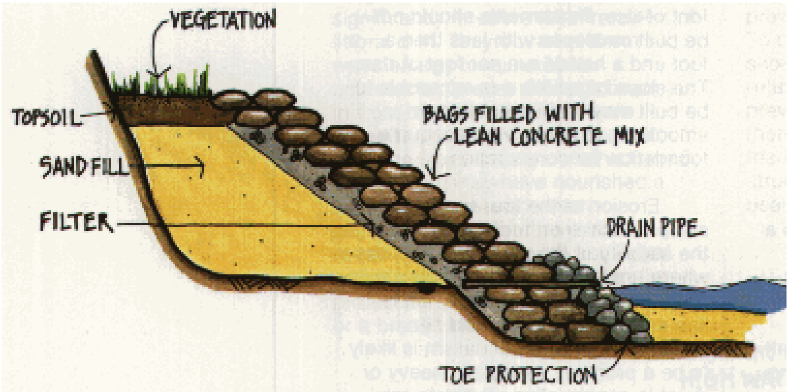
Schematics/Pictures

Examples of bioengineering using native vegetation and native rock for slope stabilization from Austin, TX. (from City of Austin's Watershed Protection Development Review website http://www.ci.austin.tx.us/watershed/erosionprojects.htm

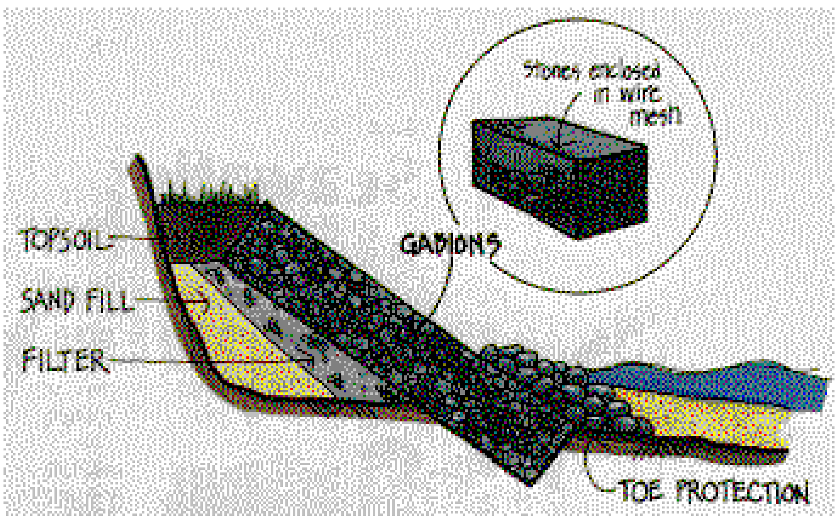
1.11.2 Revetments

Structural methods may be required for stream bank protection where high velocity flows are present or where infrastructure such as utility lines, roads or buildings are endangered by erosion.

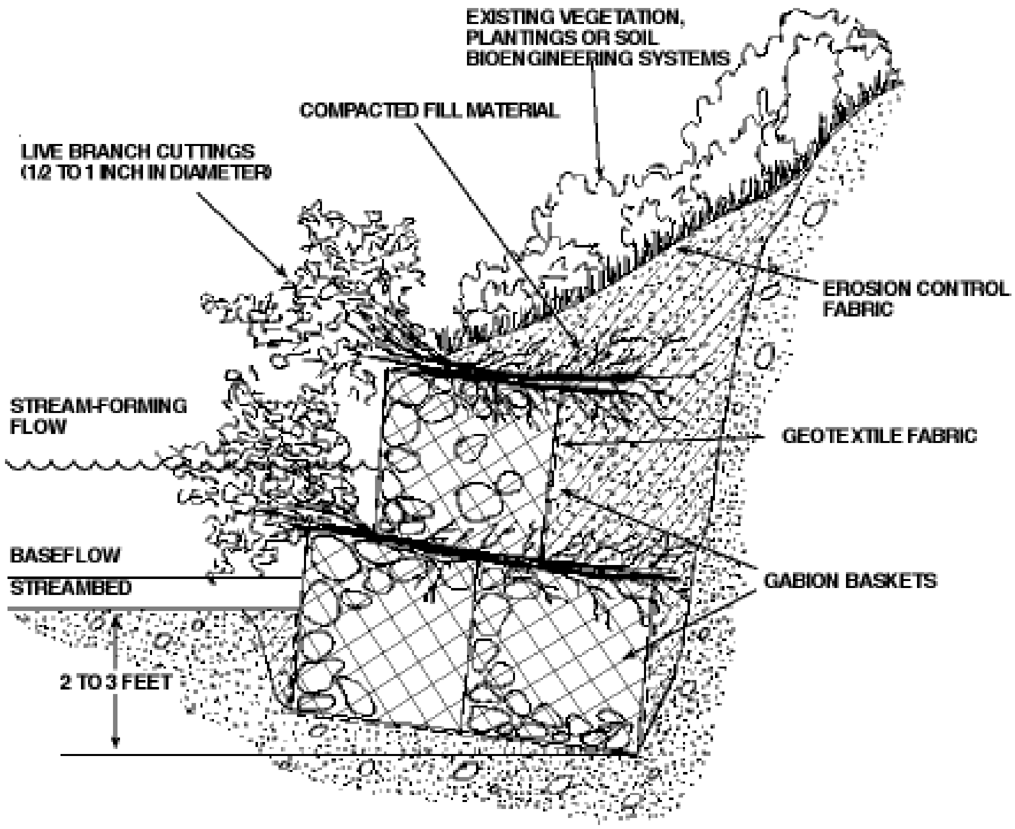
Schematics/Pictures



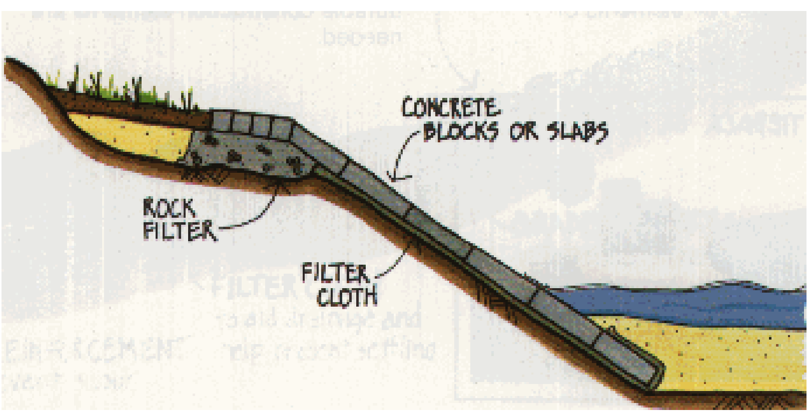
Cross Section of Burlap Bags filled with Sand or Lean Concrete Mix (Source: **http://www.lre.usace.army.mil/shore.protection/revcm.html**)



Cross Section of Gabion Revetment (Source: **http://www.lre.usace.army.mil/shore.protection/revcm.html**)



Cross Section of Gabion Revetment Incorporating Woody Vegetation Cuttings (Ohio Stream Management Guide)



Concrete Revetment (Source: **http://www.lre.usace.army.mil/shore.protection/revcm.html**)

2. POINT SOURCE TREATMENT SYSTEMS

2.1 Constructed Wetlands for tertiary treatment following mechanical or lagoon treatment plants

Constructed wetland treatment systems include both surface-flow and subsurface-flow systems. Wetland treatment systems use rooted, water-tolerant plant species and shallow, flooded, or saturated soil conditions to provide water quality improvement. Wetland treatment systems are effective in removing biochemical oxygen demand, suspended solids, nitrogen, and phosphorus, as well as for reducing metals, organics, and pathogens.

Surface-flow (SF) wetlands are densely vegetated by a variety of plant species and typically have water depths less than 18 inches. Open water areas may be incorporated into the design to provide for optimization of hydraulics and for wildlife habitat enhancement.

Subsurface-flow (SSF) wetlands use a bed of soil or gravel as a substrate for growth of rooted wetland plants. Pretreated wastewater flows by gravity, horizontally through the bed substrate where it contacts a mixture of facultative microbes living in association with the substrate and plant roots. Bed depths are typically less than 2 feet and the bottom of the bed is sloped to minimize surfacing of water.

2.1.1 At individual WWTP (municipal, industrial, agriculture, aquaculture)

2.1.2 Regional Wetland systems polishing flows from multiple WWTPs in close proximity

Schematics/Pictures

Tarrant Regional Water District's Pilot-Scale Demonstration Wetland (approximately 2.5 acres of wetland surface area) (Alan Plummer Associates Inc.)

City of Denison's Constructed Wetland at GCAWWTP (approximately 6 acres of wetland surface area) (Alan Plummer Associates Inc.)

DuPont (Invista) Victoria Constructed Wetland
(approximately 53 acres of wetland surface area)(Alan Plummer Associates Inc.)

Tarrant Regional Water District Field-Scale Wetland (approximately 243 acres of wetland surface area) (Alan Plummer Associates Inc.)

2.2 Polishing Ponds

Polishing ponds are used to improve effluent quality, particularly in the removal of helminth eggs and fecal coliform.

2.2.1 At individual WWTP (municipal, industrial, agriculture, aquaculture)

Polishing Pond with no aeration

(Lopp Consulting Engineers)

Polishing pond with SolarBee circulator from SolarBee Web site
http://www.solarbee.com/picts.tpl

Polishing pond with SolarBee circulator (Photo from SolarBee Web site http://www.solarbee.com/picts.tpl

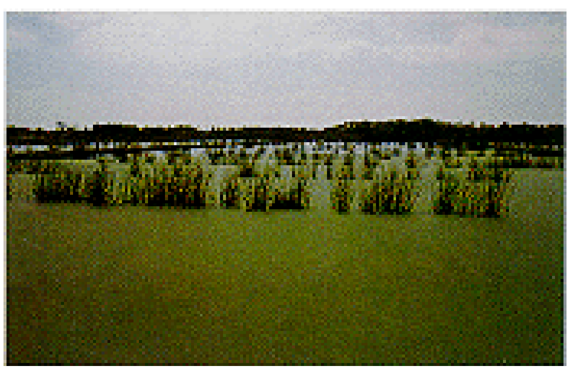
Polishing pond with Pond Doctor circulator (Photo from Pond Doctor web site http://www.ponddoctor.com/photos.shtml

Polishing pond with Pond Doctor DA circulator (Photo from Pond Doctor web site http://www.ponddoctor.com/photos.shtml

Pond systems may also employ floating aquatic plants such as water hyacinths (*Eichhornia crassipes*), duckweed (*Lemna spp.*), or pennywort (*Hydrocotyle spp*)

Water hyacinths are considered an exotic, invasive plant that creates nuisance conditions in natural waterways, irrigation canals, and ponds. Therefore, use of this plant in wastewater treatment pond system is not recommended. Duckweed, as all floating aquatic plants, is subject to being moved by wind and may stack up in windrows along shorelines. For effective treatment in a pond system, either a floating grid system should be installed to maintain even growth of the duckweed across the water surface or tall emergent plants such as giant bulrush should be grown in the pond to provide a windbreak and natural grid system to sustain the duckweed cover. Harvesting of the duckweed is promoted to improve removal efficiency of nutrients.

Water hyacinth **(NOT RECOMMENDED)**



Duckweed growing with giant bulrush.

Close-up of duckweed on water surface.

2.3 Chemical Nutrient Removal

A large majority of organic and inorganic phosphorus, suspended solids, and heavy metals can be removed by precipitation with the use of alum or lime with or without polymer. Addition of mineral salts for phosphorus precipitation can significantly increase the quantity of solids generated from a wastewater treatment plant because of production of metal-phosphate precipitates and metal hydroxides and improved suspended solids removal.

2.3.1 Alum/Lime Treatment

Chemical treatment of stormwater runoff entering a wet pond by injecting liquid alum into storm sewer lines on a flow-weighted basis during rain events.

Schematics/Pictures

Alum Treatment

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Additional Information

REASONS FOR LIMITED USE

- Intended for areas requiring regional storm water treatment from a piped storm water drainage system
- High maintenance requirements
- Alum application will lower pH of receiving waters
- High capital and operations and maintenance costs

KEY CONSIDERATIONS

- Requires no additional land purchase
- Reduces concentrations of total phosphorus, total aluminum and heavy metals
- Dependent on pH level ranging from 6.0 to 7.5 during treatment process

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2.4 Reuse

Reclaimed wastewater effluent may be utilized for irrigation of golf courses, public and/or private landscapes, or agricultural crops. Some advantages of reuse of wastewater effluent for irrigation are: increased farmland value, additional volumes of water available for use, and reduction or elimination of effluent discharge to surface waters. Selection of crops is an important early step in the design because crop selection affects the level of preapplication treatment, type of distribution system, and hydraulic loading rate. Double cropping in warm climates increases revenue potential. Storage of wastewater is required to accommodate cold- or wet-weather periods.

2.4.1 Storage and Irrigation

Storage of reclaimed wastewater is usually accomplished through man-made off-channel ponds. Construction methods necessary for the ponds will be dependant upon the treatment methods and associated water quality. Ponds can be designed such that they can be used as water amenities for various settings.

Schematics/Pictures

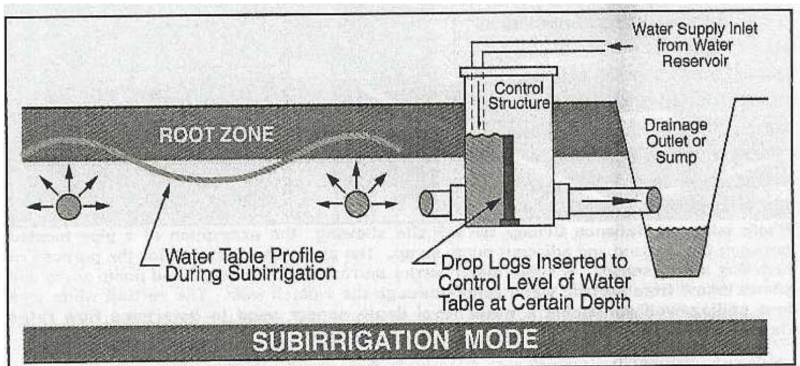
Reuse storage pond for irrigation of Koele Golf Course on the Island of Lanai, Hawaii.

Direct use of reclaimed water is appropriate for a number of domestic, industrial, and irrigation needs where the potential for human contact is limited. Irrigation with reclaimed water is regulated by the Texas Comission on Environmental Quality under Chapter 210 of the Texas Administrative Code. Irrigation of crops with reclaimed water is a viable method of effluent disposal, and provides the benefits of water and nutrients to the crop. Irrigation methods include flood, sprinkler, and drip.

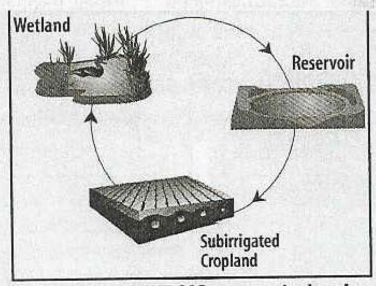
Subsurface drip irrigation of agricultural products for human consumption using treated wastewater effluent has been investigated in many places around the world including arid and semiarid regions of the United States. Subsurface drip irrigation allows the soil surface to remain dry and minimizes contact with pathogens. This method of irrigation also results in less loss of water through evaporation. Nutrients in the effluent reduce or eliminate the requirement for additional fertilizer. Subsurface drip irrigation is also being increasingly used with reclaimed water for landscape and commercial turf applications.

Irrigation of public landscapes including parks and golf courses with treated wastewater effluent. (Koele Golf Course)

Schematics/Pictures



Schematic of weir-type hydraulic control structure used to regulate water table depth in subirrigated fields. (Graphic by Leslie Zucker, Ohio State University Extension)



Schematic of WRSIS concept showing interrelationship between wetland, reservoir, and subirrigated cropland. (Graphic by Leslie Zucker, Ohio State University Extension)

(From <u>Land and Water</u>, May/June 2000)

Photos of subsurface drip irrigation system from Jimmy Wedel Farm, Muleshoe, TX

3. COLLECTIVE (NPS and PS)

3.1 Large-scale constructed wetland system

3.1.1 On-Channel (Llano Grande)

Construction of an on-channel wetland system is typically not considered feasible due to a number of factors including inappropriate water depths for establishment of emergent vegetation, very high potential for short-circuiting of flows through the system and resulting ineffective contaminant removals, substantial deposition of sediments, impedance of storm flow flows within the floodway, and frequency of significant damage to plant community from high velocity flows from storm events. However, at the request of the Habitat Restoration Workgroup, this strategy was included in the comprehensive list due to consideration of one potential site for an on-channel wetland system. Llano Grande is an on-channel lake formed by flow control structures within the branched Arroyo Colorado where flood flows are divided between the Arroyo Colorado and the North Floodway. Since Llano Grande is located within a Texas Parks and Wildlife Department State Park, possible water quality improvement associated with habitat enhancement within this on-channel segment is desired.

Photo of central portion of Llano Grande taken August 5, 2005.

3.1.2 Off-Channel (Regional Wetland System)

Potentially, an off-channel regional constructed wetland system could either receive collective flows prior to their reaching the Arroyo Colorado or water could be diverted from the Arroyo Colorado to a large-scale wetland polishing system, either within or outside the floodway levees.

Schematics/Pictures

Tarrant Regional Water District field-scale wetland (approximately 243 acres of wetland surface area) is first train of proposed 2,000 acre constructed wetland system (Alan Plummer Associates Inc.)

4. Management Strategies

4.1 IBWC

4.1.1 Maintenance Activities in the Floodway

IBWC mowing activities within the floodway upstream of Harlingen include the area from the bank of the Arroyo Colorado up to the 21,000 cfs mark (indicated by steel pole markers painted red). Also, one bat-wing mower width (about 15') on flat at toe of levees is mown.

IBWC does not own all the land within the floodway. Any bank stabilization projects proposing modification of stream banks or plantings would need to involve the private land owners as well as cities and counties that own property within the floodway.

IBWC does not restrict operations on private land within the floodway other than requiring that operations do not impede flood conveyance.

Manning's n values used in HEC-RAS model runs of hydraulic modeling for the Arroyo Colorado Floodway conducted by IBWC ranged from 0.065 to 0.07 for the bank areas upstream of State Highway 448 in Harlingen. Downstream of State Highway 448, Manning's n values used for bank areas of the Arroyo Colorado were 0.2. The 0.065 to 0.07 n values used represent vegetative growth where the average depth of flow is less than half the height of vegetation as characterized by bushy willow trees about 1 year old intergrown with weeds along side slopes with all vegetation in full foliage, or dense cattails growing along the channel bottom, or trees intergrown with weeds and brush and all vegetation in full foliage. The 0.2 n value used represents fully vegetated banks with dense understory and all vegetation in full foliage.

4.1.2 Dredging Operations

Periodic maintenance dredging of the Gulf Intracoastal Waterway -Tributary Channel to Harlingen and Turning Basin to remove restrictive shoals is conducted by the U.S. Army Corps of Engineers. Water, elutriate, and sediment samples are collected and analyzed for a variety of pollutants including metals, volatile and semi-volatile organics, pesticides, chlorinated hydrocarbons, polychlorinated biphenyls, organonitrogen compounds, and others. Previously identified upland confined placement areas are selected based on the location of the proposed dredging.

Levee Repair/Reconstruction

Condition assessment of the Lower Rio Grande Flood Control Project (LRGFCP) levees (approximately 520 miles of U.W. river and interior floodways levees) to determine structural integrity and current level of flood protection have been on-going since 2001. Levee reaches in the LRGFCP requiring structural improvements or raising were identified and prioritized following the investigations based on proximity to urban areas or high potential for downstream flooding, such as below the floodway diversion points. Several repair and reconstruction projects are proposed along the LRGFCP to address identified deficiencies in structural integrity or flood protections.

4.2 Port of Harlingen

Normal port operations such as off-loading can affect bacterial and viral contamination of commercial fish and shellfish, deplete oxygen levels in water, and cause bioaccumulation of toxins in fish. Increased implementation of management strategies for containment and remediation of spills directly affects water quality in ports. Environmental management practices (EMPs) currently in use at over 30 U.S. ports were surveyed by the American Association of Port Authorities (AAPA) to determine effectiveness. The EMPs were divided into two main areas: development-related EMPs that focus on preventing adverse impacts to environmental media through construction activities and operations-related EMPs placed on operational activities.

4.2.1 Off Loading Procedures

Texas Commission on Environmental Quality (TCEQ) provided estimates of up to 100 lbs of fertilizer lost in spillage (potentially directly to the water) per each off-loading procedure with 2-3 off-loading procedures per year. Additional spillage of agricultural products including processed sugar cane is also reported as common. Large nutrient and oxygen demand loadings at the port can negate any improved water quality measures implemented for flows reaching the Arroyo Colorado upstream of the Port of Harlingen. EMP No. 0-3 relates to bulk storage and handling of dry cargo and includes development and operational EMPs that would pertain to off-loading of fertilizers and on-loading of bulk agricultural products at the Port of Harlingen. On-site evaluation of existing port procedures needs to be conducted before recommendations of appropriate EMPs for employment can be determined.

Comment: 10/18/05 Tim Noack, from Habitat Restoration meeting

4.2.2 Containment and Remediation of Spills

Spills from handling large quantities of bulk commodities at the Port that do not directly fall into the water may be washed into the Turning Basin or Channel if rainfall runoff washes these materials into the stormwater system. Assessment of similar operations at the Port of Sacramento after implementation of best management practices indicated that treatment was also required to reduce nutrient loading to the Turning Basin. Stormwater was intercepted into a collection system, conveyed to storage and treatment facilities, with treatment including a high-rate trickling filter followed by a constructed wetland before stormwater was discharged to the Turning Basin.

4.2.3 Ballast Water

Regulations regarding discharge of ballast water are promulgated to address both water quality impacts and potential discharge of non-indigenous aquatic species which may cause economic or environmental harm. Management of ballast water is being studied around the globe and AAPA is working through an international network regarding development of regulations.

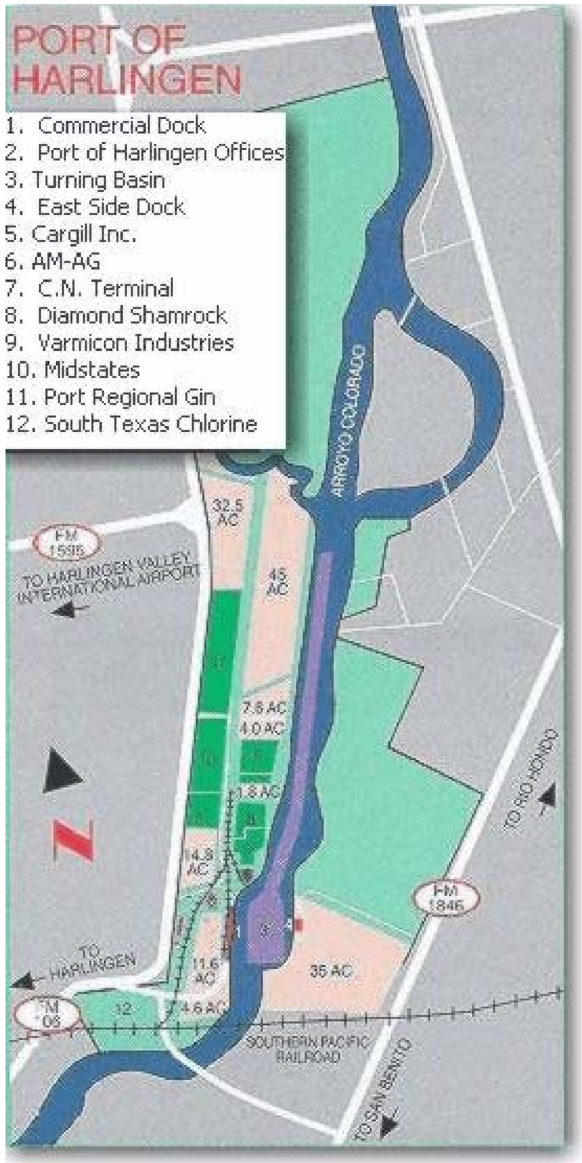
4.2.4 SWPPP

A Stormwater Pollution Prevention Plan (SWPPP) should include operational controls and an assessment of upgrading needs for stormwater drainage infrastructure to improve the quality of storm runoff discharges to the Turning Basin and Channel. The SWPPP for the Port of Harlingen should be designed to meet or exceed the minimum requirements mandated by the TCEQ TPDES Industrial Stormwater Program. Monitoring of water quality of stormwater runoff conveyed through the stormwater drainage infrastructure should indicate if any requirements for additional treatment prior to discharge are needed.

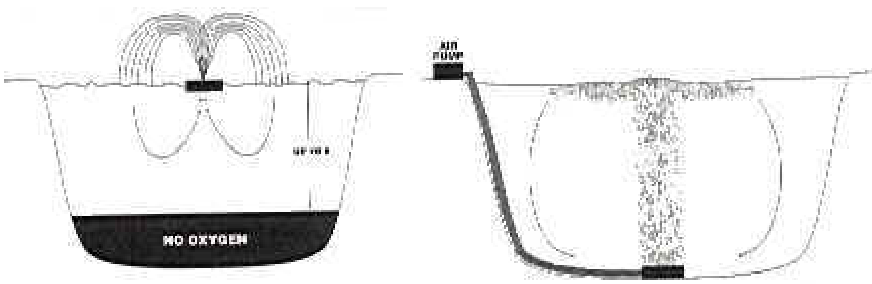
4.2.5 Aeration of Turning Basin

Aeration of the Turning Basin to enhance dissolved oxygen levels may be accomplished through installation of fountains and/or diffused aerators, if the mechanical equipment for these can be installed such that they will not interfere with shipping traffic. Coordination with the Port of Harlingen and any other jurisdictional authorities will be required for installation of these devices. Either a solar powered system can be employed or electrical power will need to be provided for any aeration system installed in the Turning Basin.

Schematics/Pictures



Port of Harlingen
Port of Harlingen Authority



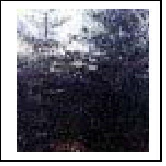
Schematic of fountain aeration system versus diffused aeration system. (from http://www.pondsolutions.com/aerators.htm)

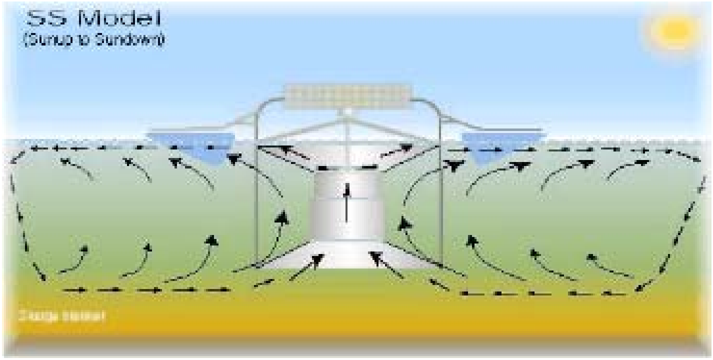
Kasco 3400 Aeration Fountain (Example of fountain aerator)

Otterbine diffused aeration system (Example of diffused aeration system)

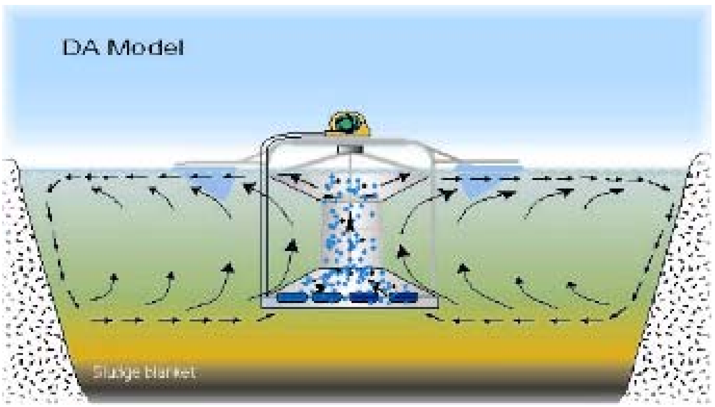
SolarBee 10000 solar-powered circulation aerator ready for installation

SolarBee installed in Missouri Water Supply Reservoir (from www.solarbee.com)





Pond Doctor solar-powered circulation aerator schematic



Pond Doctor solar-powered circulation aerator dissolved air model schematic

Pond Doctor installed. (from www.ponddoctor.com)