6 - Introduction to Green Infrastructure Practices

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amec

Module Content

- General Overview
- Intrinsic Green Infrastructure Practices
- Structural Green Infrastructure Practices

Green Infrastructure Practices

Ecosystem-based approaches that strategically integrates stormwater controls throughout the urban/rural landscape to achieve the desired site runoff quantity and quality.

(GIPs)

Green Infrastructure Practices (GIPs)

- Intended to mimic the natural hydrologic condition and allow stormwater to infiltrate into the ground, evaporate into the air, evapotranspirate by plant uptake or captured for reuse.
- Designed to meet multiple stormwater management objectives, including reductions in runoff volume, peak flow rate reductions, and water quality protection.
- Decentralized stormwater management strategies of multiple small, localized controls that may be combined into a "treatment train" to provide comprehensive stormwater treatment.
- Constructed individually, or as part of larger construction projects.

Green Infrastructure Practices (GIPs)

- Selection of Effective GIPs

Table 1 – Effectiveness of BMPs in Meeting Stormwater Management Objectives			
Practices	**Volume**	**Peak Discharge**	**Water Quality**
Bioretention	●	●	●
Urban Bioretention	◉	◉	●
Permeable Pavement	●	●	◉
Infiltration Trench	●	●	●
Water Quality Swales (Dry)	◉	◉	●
Extended Detention	○	●	○
Downspout Disconnection	◉	◉	◉
Grass Channels	○	○	○
Sheet Flow	●	●	◉
Reforestation	●	●	●
Rain Tanks/Cisterns*	◉	○	○
Green Roofs	◉	●	●

* A single cistern typically provides greater volume reduction than a single rain tank

Green Infrastructure Practices (GIPs)

Table 2 – Green Stormwater Infrastructure Land Use and Land Area Selection Matrix

Practices	Criteria							
	Land Use							Land Area Required
	Schools	Com.	Indust.	SF Res.	MF Res.	Parks/Open Space	Roads/ Roadside	
Bioretention	●	●		●	●	●	●	◉
Urban Bioretention	◉	●			●	●	●	○
Permeable Pavement	●	●	◉	●	●	●	●	○
Infiltration Trench	●	●		●	●	●	◉	○
Water Quality Swales (Dry)	●	●			●		●	◉
Extended Detention	●	●	●		●		●	○
Downspout Disconnection	●	◉		●	●	●		○
Grass Channels	●	●		●	●	◉	●	◉
Sheet Flow	●	●		●	●	◉	●	◉
Reforestation	◉		◉	◉	◉	●	●	○/●
Rain Tanks/Cisterns	●	◉	◉	●	●			○
Green Roofs	●	●	●		●			○

● - Well suited for land use applications or high relative dedicated land area required.
◉ - Average suitability for land use applications or moderate relative dedicated land area required.
○ - Low relative dedicated land area required.
Blank – Not applicable for land use.

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Green Infrastructure Practices (GIPs)

- Application to Site Design
  - During the design process, intrinsic GIPs are applied to the site first and then, <u>if required</u>, structural GIPs are applied.
  - Runoff Reduction Credit (RR Credit), Level 1 (L1) and Level 2 (L2), are applied based on the physical design of the GIP.

- GOAL

Weighted Rv < 0.20

Green Infrastructure Practices (GIPs)

Intrinsic GIPs Overview

- General Considerations
  - Take advantage of and/or enhance the ability of existing pervious, natural or landscape, surfaces to reduce and treat stormwater run-off.

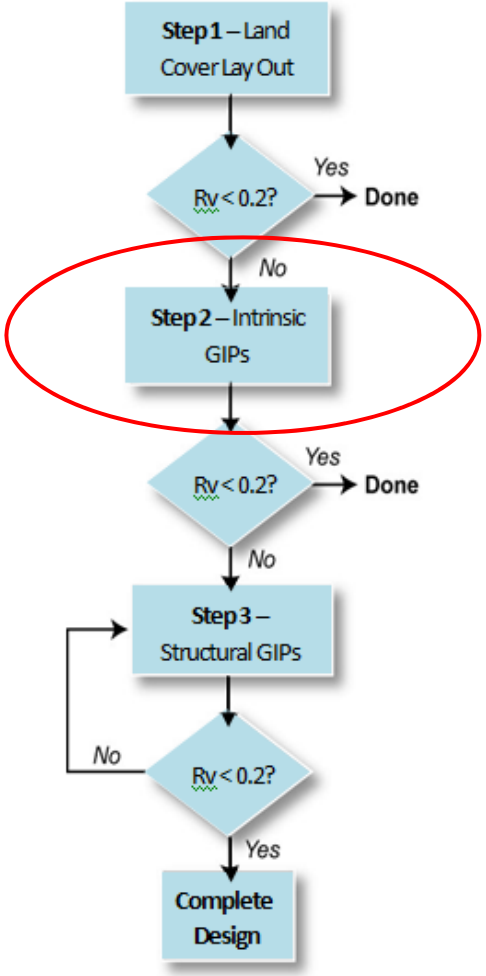
- GIPs

Disconnected Downspouts

Sheet Flow

Reforestation

(less design, more landscaping)



Downspout Disconnection

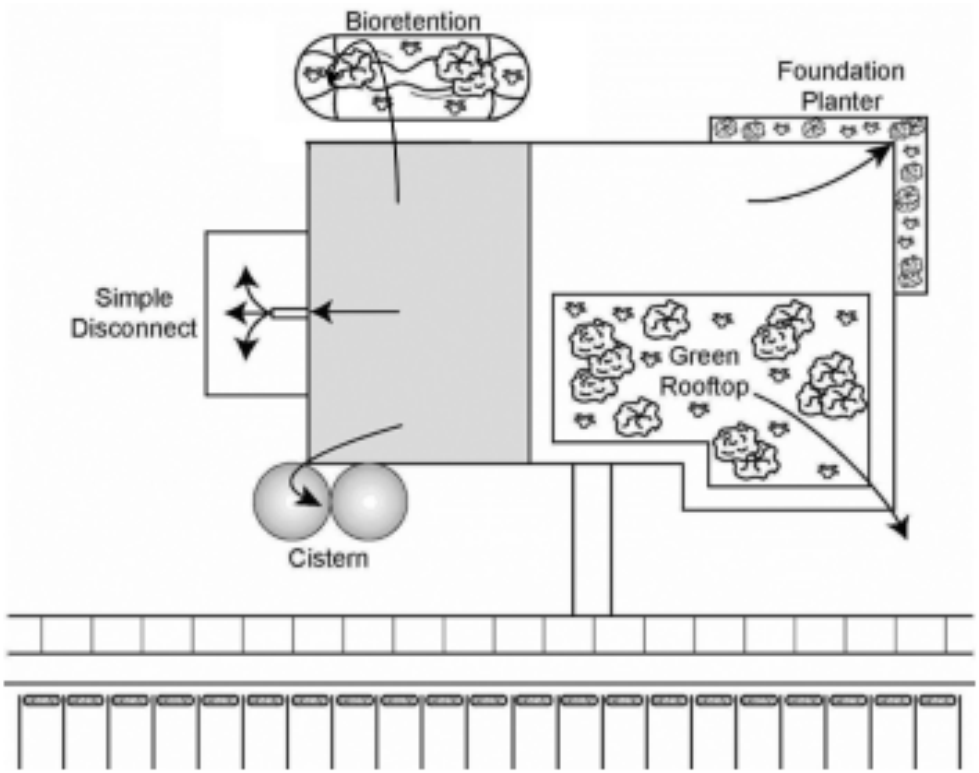
Source: www.lowimpactdevelopment.org

Downspout Disconnection

- Roof downspouts are disconnected from direct flow into sewer inlets or impervious areas (driveways, parking lots, roads) leading directly into a public stormwater system.
- Runoff is redirected to a downstream pervious areas or other GIPs.

Downspout Disconnection

- Methods
  - Simple – disconnect and route to pervious area
  - Series – leads to a downstream GIP



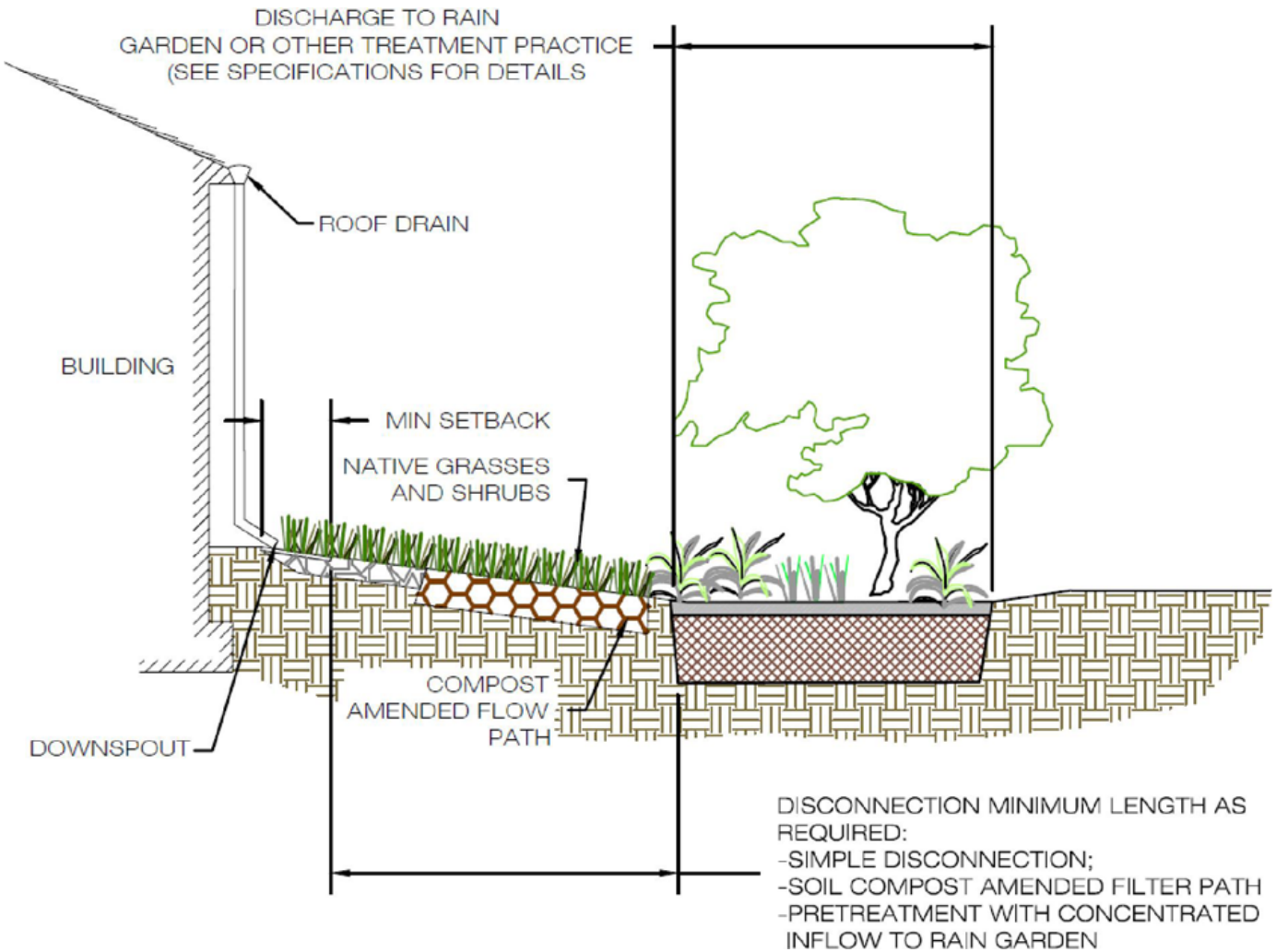
Source: VADCR, 2011

Downspout Disconnection

- Performance
  - Runoff is slowed and given more opportunity to for infiltration, evapotranspiration and rainwater harvesting/reuse.
  - RR Credit: Level 1 = 25%; Level 2 = 50% (used with other GIPs).

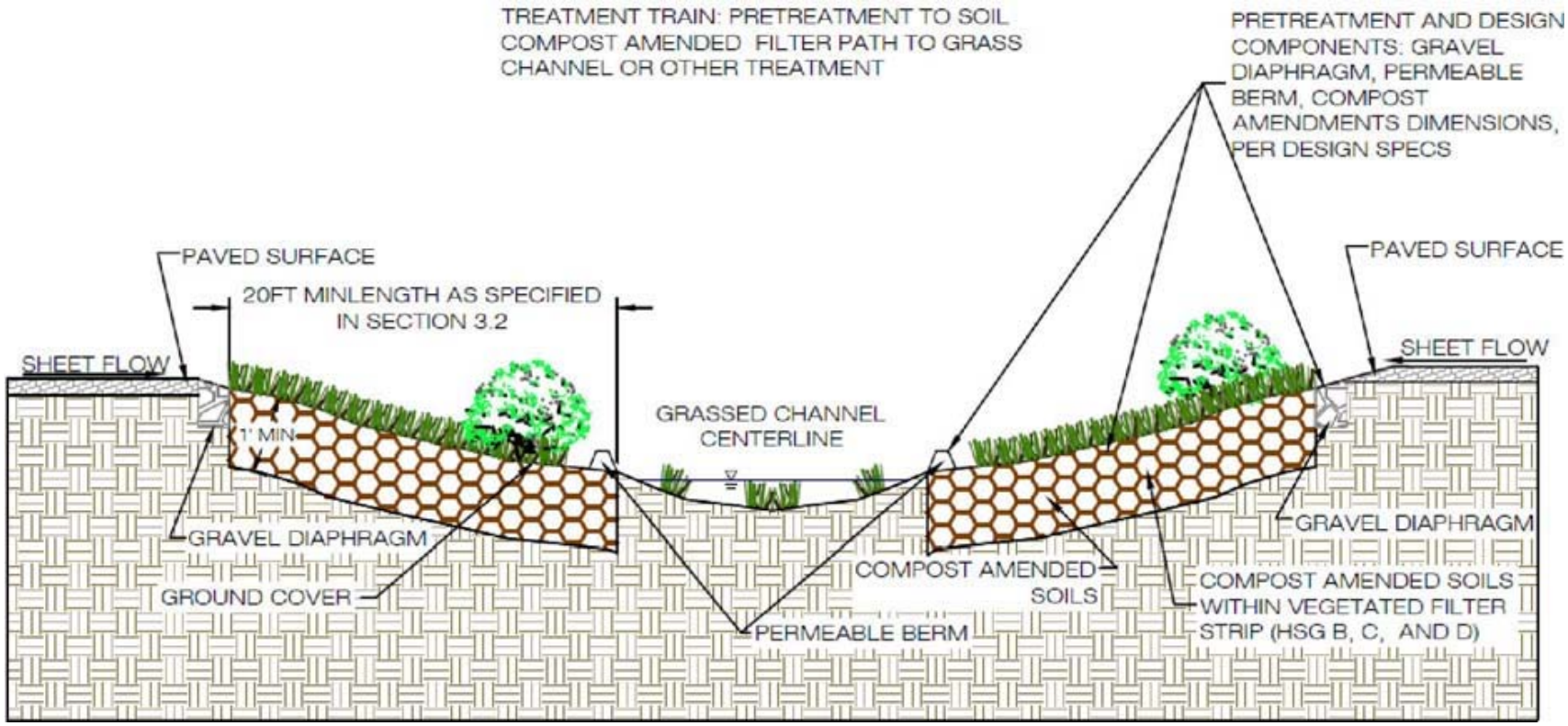
- Special Considerations
  - Typically requires pervious area equal to or greater than the impervious CDA.
  - Usually involves periodic lawn or landscaping maintenance in the filter path, unless directed to rain barrel or a natural, undisturbed setting.

Downspout Disconnection



Rooftop Disconnection – Section View: Simple Disconnection to downstream Bioretention (Source: VADCR, 2011)

Downspout Disconnection



Amended Filter Path to Downstream Grass Channel, or other treatment (Source: VADCR, 2011)

Sheet Flow

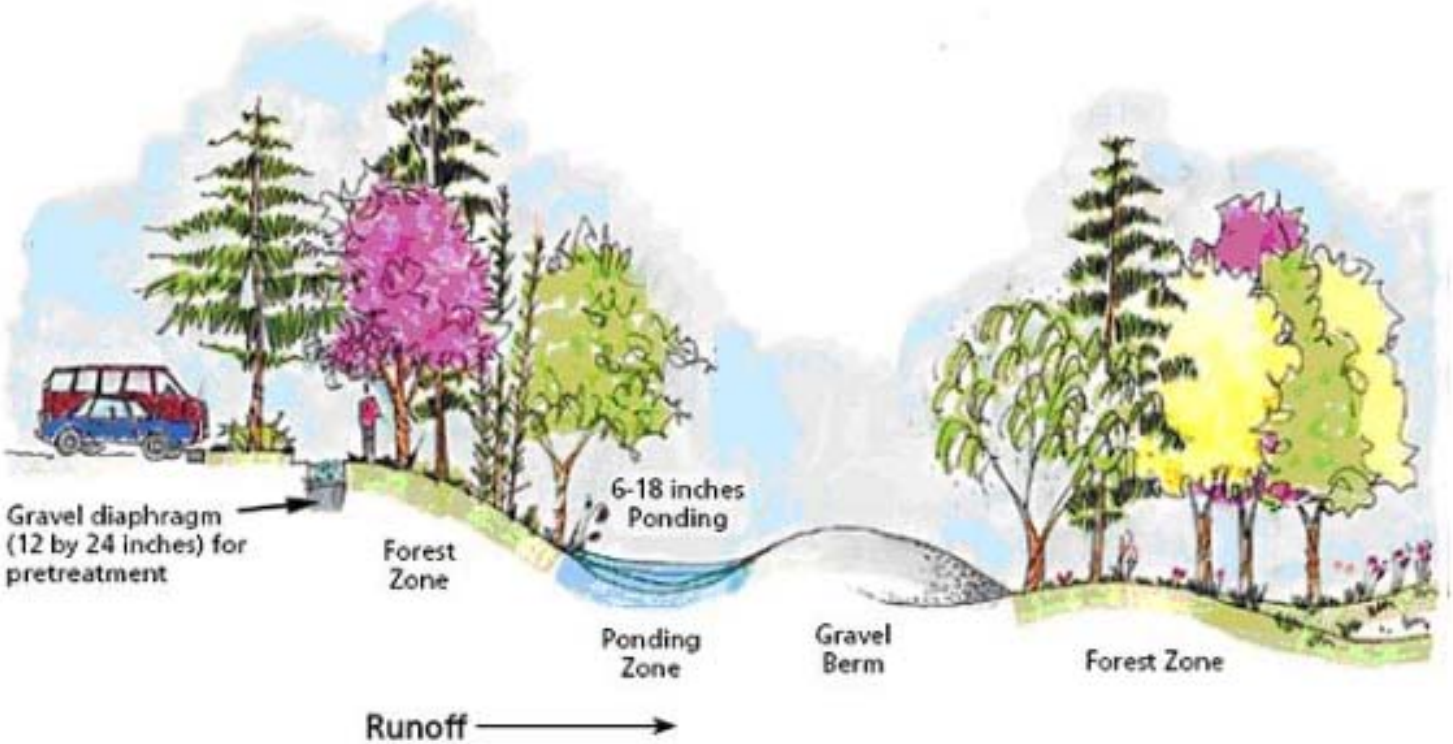
Sheet Flow

- Impervious areas are disconnected and runoff is directed through a level spreader creating sheet flow onto an adjacent pervious area.

- Two basic variations:
  - Conserved open space
  - Vegetated filter strip

Sheet Flow

- Conserved open space



Typical Sheet flow to Conserved Open Space (Hathaway and Hunt 2006)

Sheet Flow

- Vegetated filter strip

Filter strip surrounding bioretention cell, Fort Bragg, NC.
(Source: N.Weinstein, LIDC)

Sheet Flow

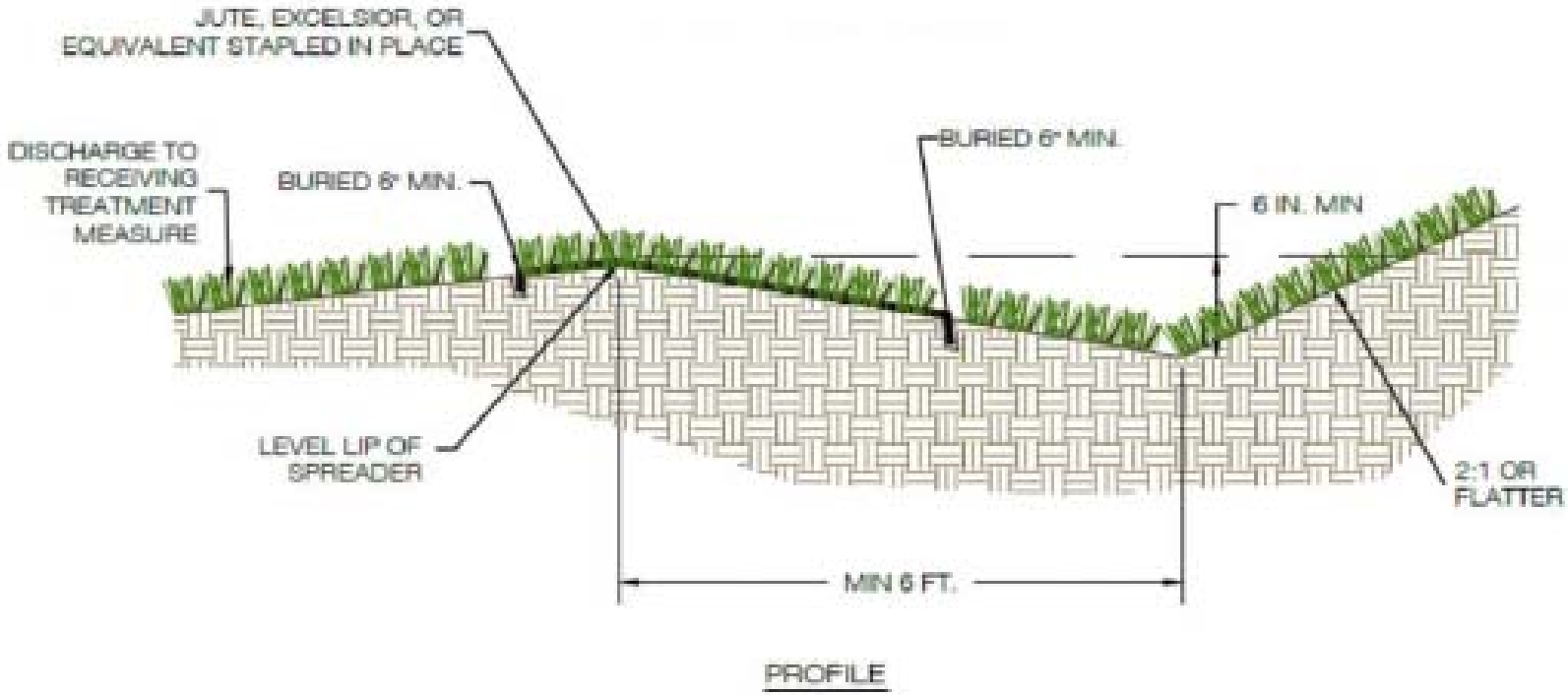
- Performance
  - Soil based system
  - Impervious contributative drainage area ~ 5,000 sf (maximum)
  - Runoff to be slowed, redirected and to give more opportunity to for infiltration, and sediment removal of runoff.
  - Vary depending on the underlying soil permeability.
  - RR Credit: Level 1 – 50%; Level 2 – 75% (Soil dependant)

Sheet Flow

- Special Considerations
  - Application of runoff reduction credit dependant on meeting appropriate minimum design criteria.
  - Sheet flow and hydraulic connectivity must be maintained.
  - Level spreader (vegetated, gravel diaphragm, permeable berm, engineered structure) is an integral part of the GIP function.
  - Usually involves periodic maintenance of level spreader and landscaping maintenance of vegetated filter strip or conserved open space.

Sheet Flow

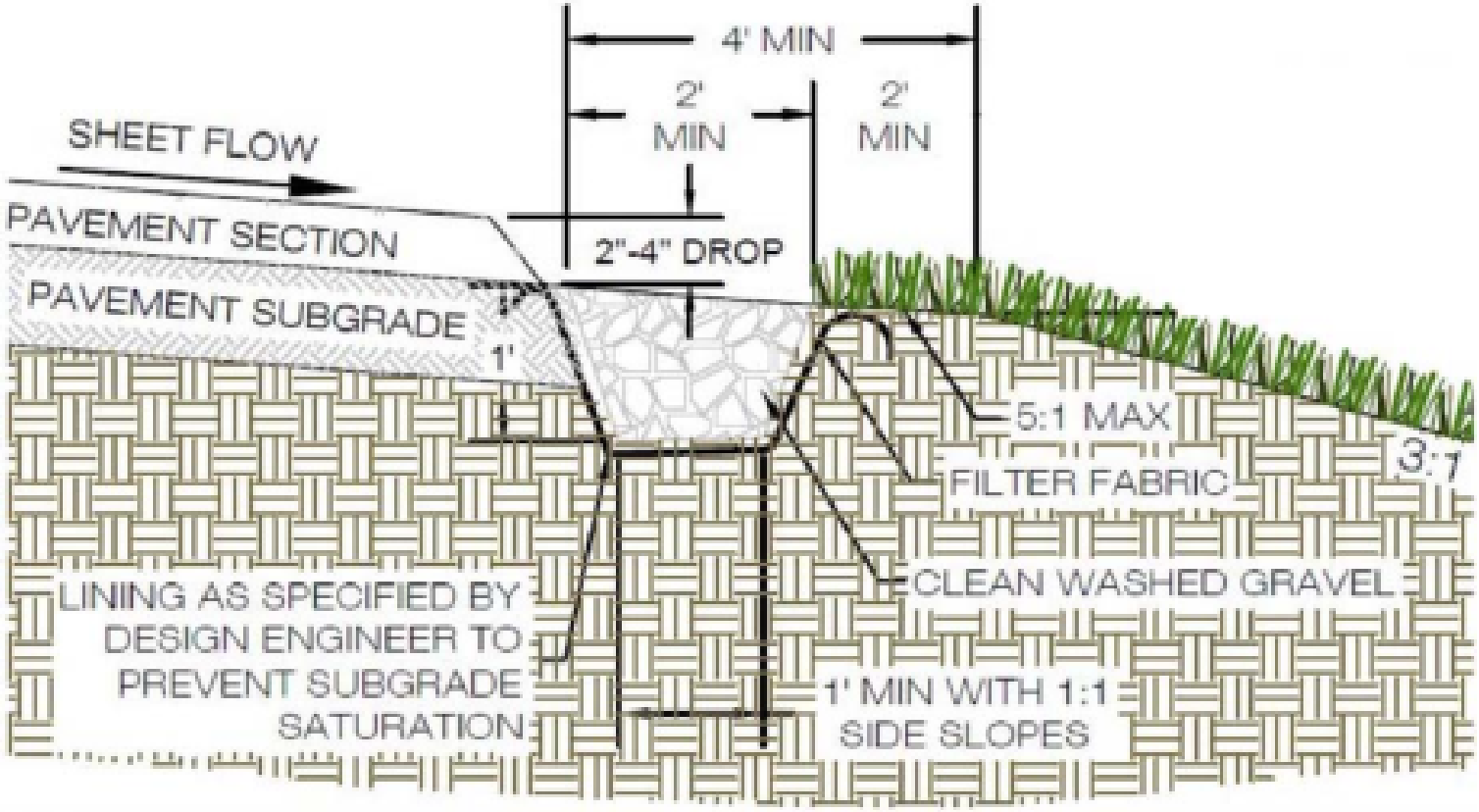
- Level Spreader



Level Spreader with Vegetated Lip (source: VADCR, 2011)

Sheet Flow

- Level Spreader



Gravel Diaphragm – Sheet Flow Pre-treatment (source: VADCR, 2011)

Reforestation

Reforestation

- Reforestation refers to (primarily) trees planted in groups in urban areas such as: parking lots, right of ways (ROW), parks, schools, public lands, vacant land, and neighborhood open spaces.
- Provides shade, stormwater retention and adds the sites aesthetic value.
- The explicit goal is to establish a mature forest canopy that will intercept rainfall, increase evapotranspiration, and enhance soil infiltration rates.

Reforestation

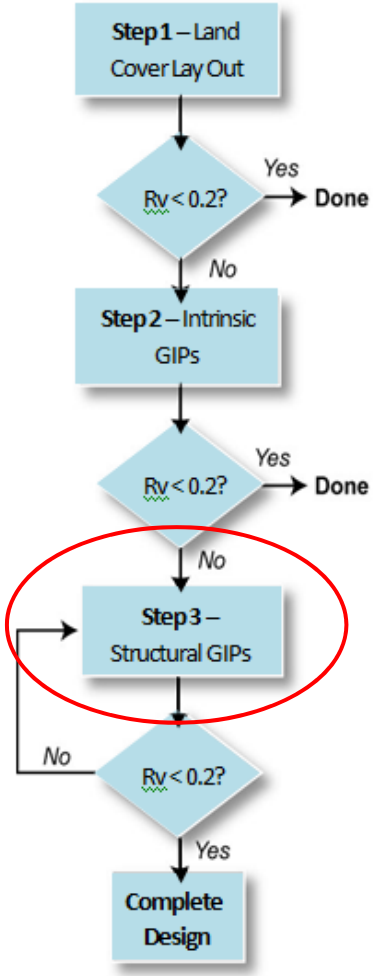
- Performance
  - Soil based system.
  - Minimum area size ~ 5,000 sf (contiguous)
  - Reforested area Rv based on HSG soil type and amendment.
  - Additional runoff reduction credit available if used as vegetated filter strip for sheet flow.
  - RR Credit: (Soil dependant)
    - Level 1; 90% - 96% (no amended soils)
    - Level 2; 95% - 98% (with amended soils)

Reforestation

- Special Considerations
  - Usually requires large dedicated area to provide for tree growth and for significant reduction in stormwater runoff.
  - Vegetation (tree) selection.

Structural GIPs Overview

- Engineered practices that are designed, constructed and maintained to facilitate infiltration, evaporation, evapotranspiration of stormwater runoff and rainwater harvesting for reuse.
- General Considerations
  - Soils (HSG / Infiltration rates / Planting requirements).
  - Impervious Contributing Drainage Area.
  - Depth to water table or bedrock.
  - Existing pollution

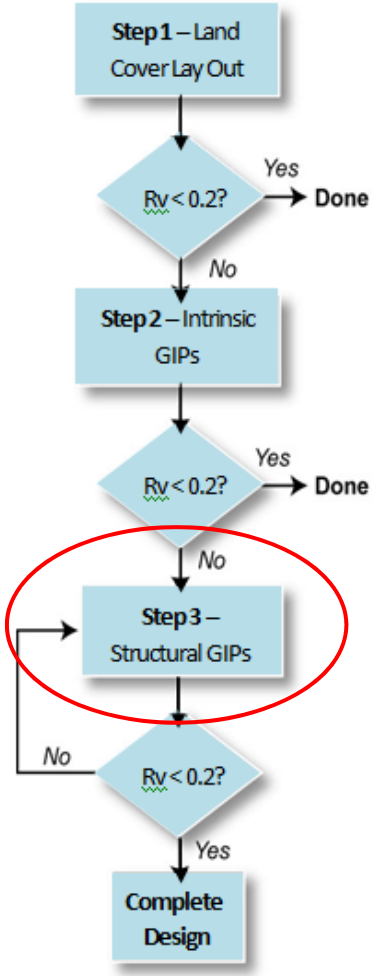


Structural GIPs Overview

- GIPs

Bioretention	Urban Bioretention
Water Quality Swale	Green Roof
Grass Channel	Cistern
Permeable Pavements	Infiltration Trench
Extended Detention	

(more design, less landscaping)



Bioretention

Bioretention

- Vegetated, shallow depressions.
- Captured runoff is treated by filtration through an engineered soil medium, and is then either infiltrated into the subsoil or exfiltrated through an underdrain.
- Primary component is the filter bed, which has a mixture of sand, soil and organic material (filtering media) with a surface mulch layer.
- On a smaller scale these are popularly know as “Rain Gardens”.
- Variations
  - Without underdrains, subsoils with infiltration rate greater than ½” per hour
  - With underdrains, subsoils with infiltration rate less than ½” per hour

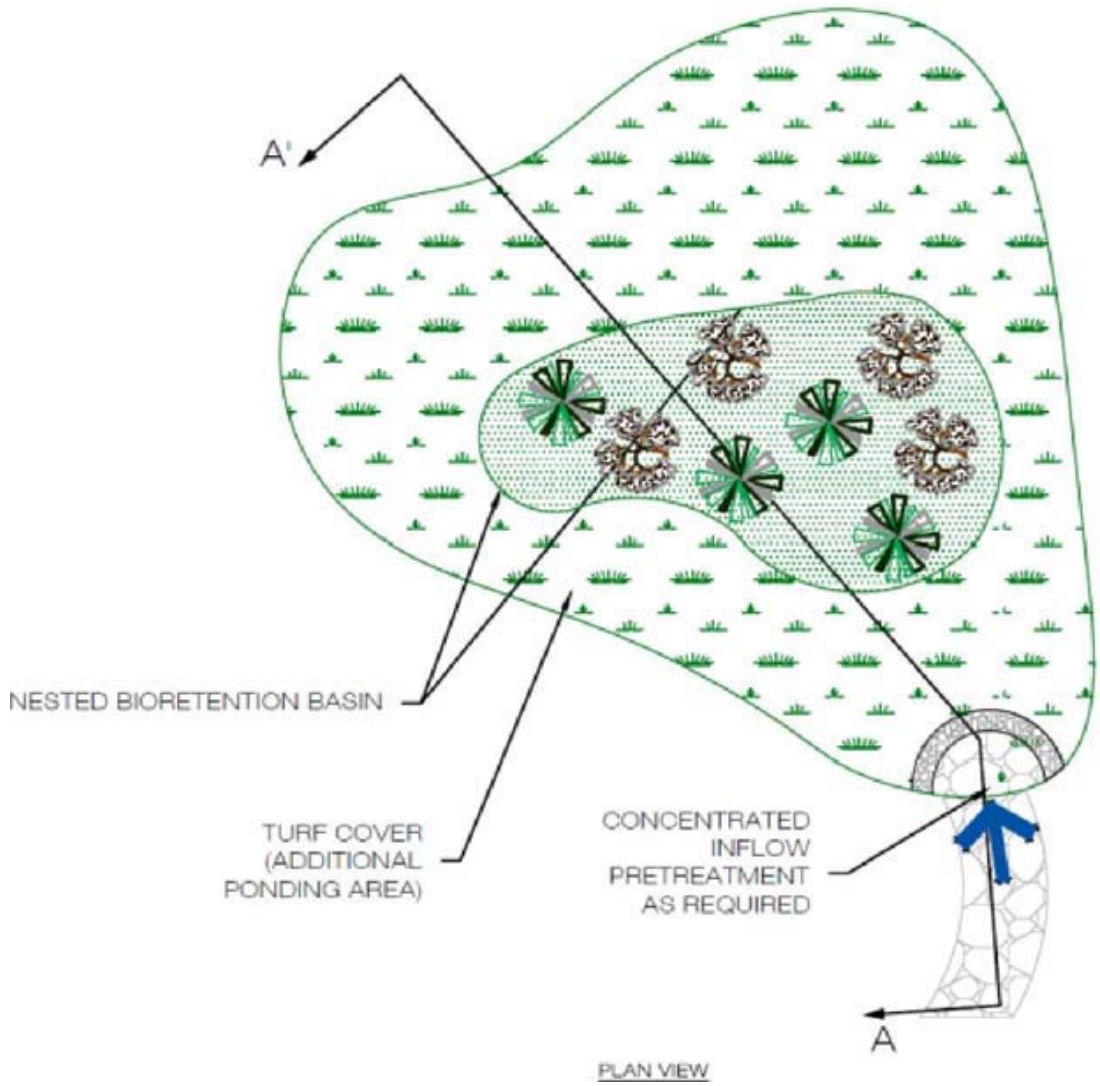
Bioretention

- Performance
  - Soil filtration / gravel based storage / infiltration system.
  - Impervious CDA ~ 2.5 acres, multiple cells can serve larger areas.
  - Good environment for runoff reduction, filtration, biological uptake, and microbial activity, and provides high pollutant removal.
  - Can become an attractive landscaping feature with high amenity value and community acceptance.
  - Performance levels based on filter media depth.
  - RR Credit: Level 1 – 60%; Level 2 – 80%

Bioretention

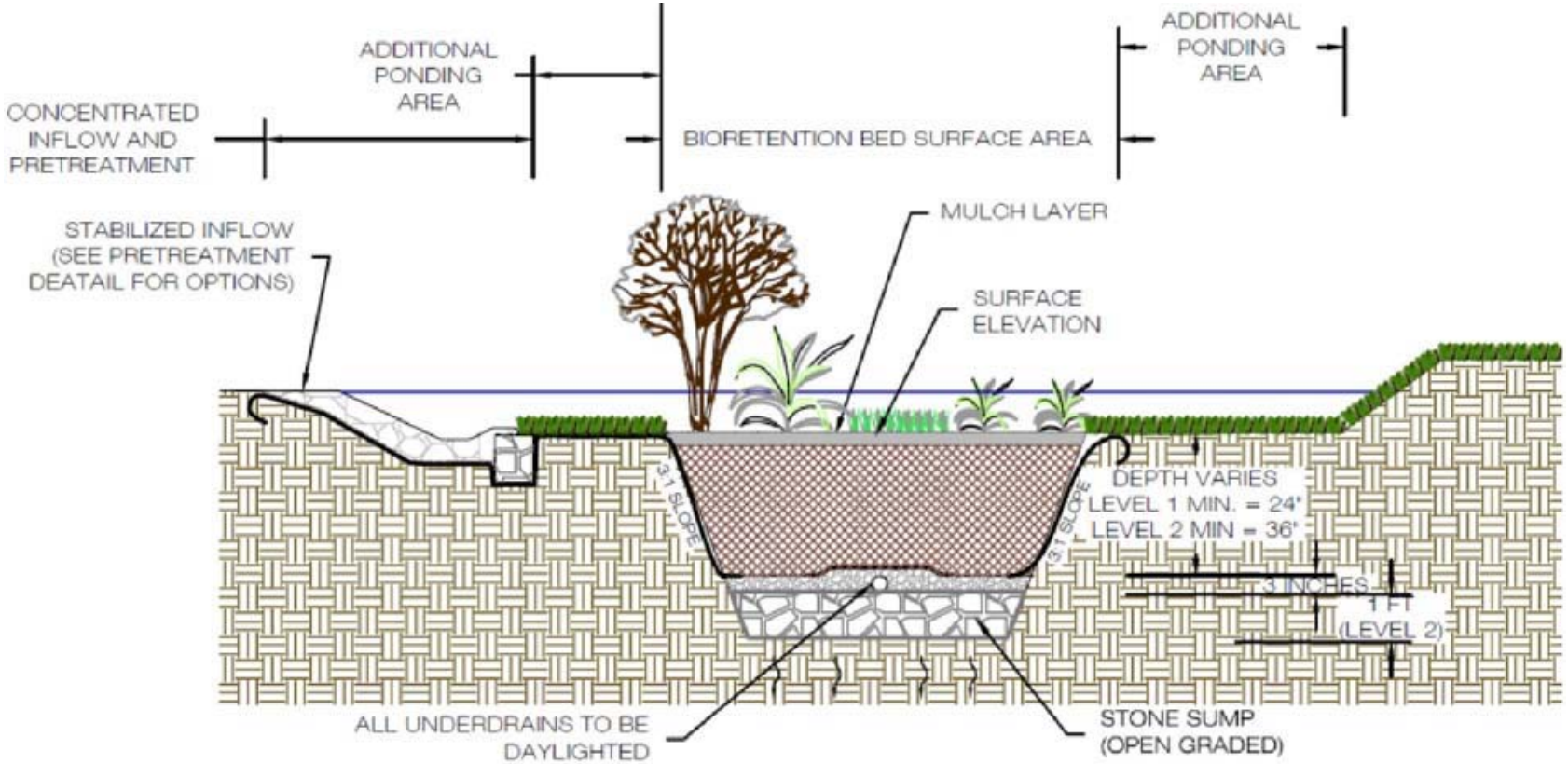
- Special Considerations
  - Pre-treatment required to remove course sediments.
  - Can be installed:
    - Online, must provide for overflow
    - Offline, alternate flow when full
  - In general, vegetative goal is to achieve surface area coverage of at least 75%.
  - For a bioretention area to qualify for L2 design, a minimum of one tree must be planted for every 400 square feet.
  - Once established, typical only spring cleanup maintenance.

Bioretention



Source: VADCR, 2010

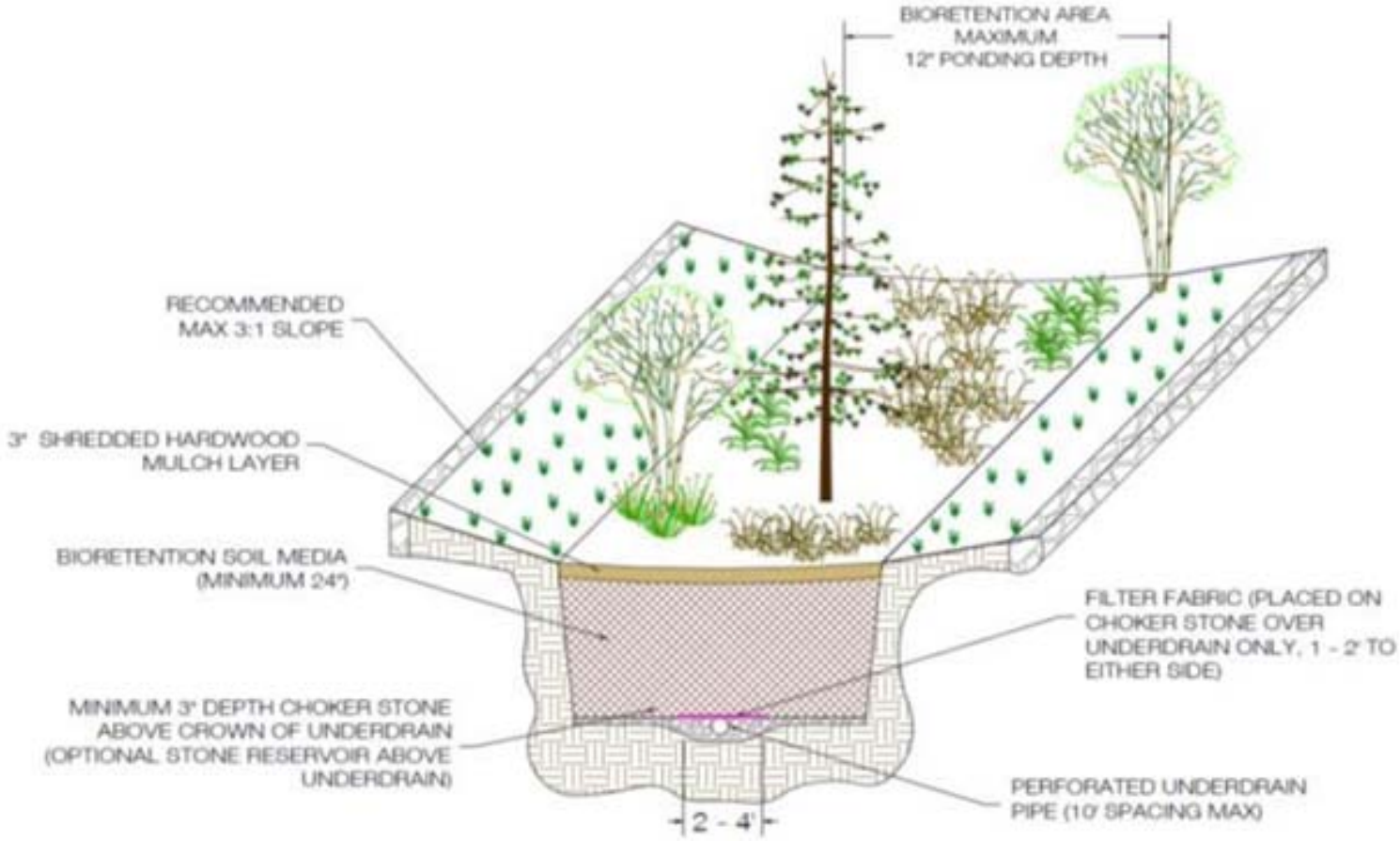
Bioretention



SECTION VIEW

Source: VADCR, 2011

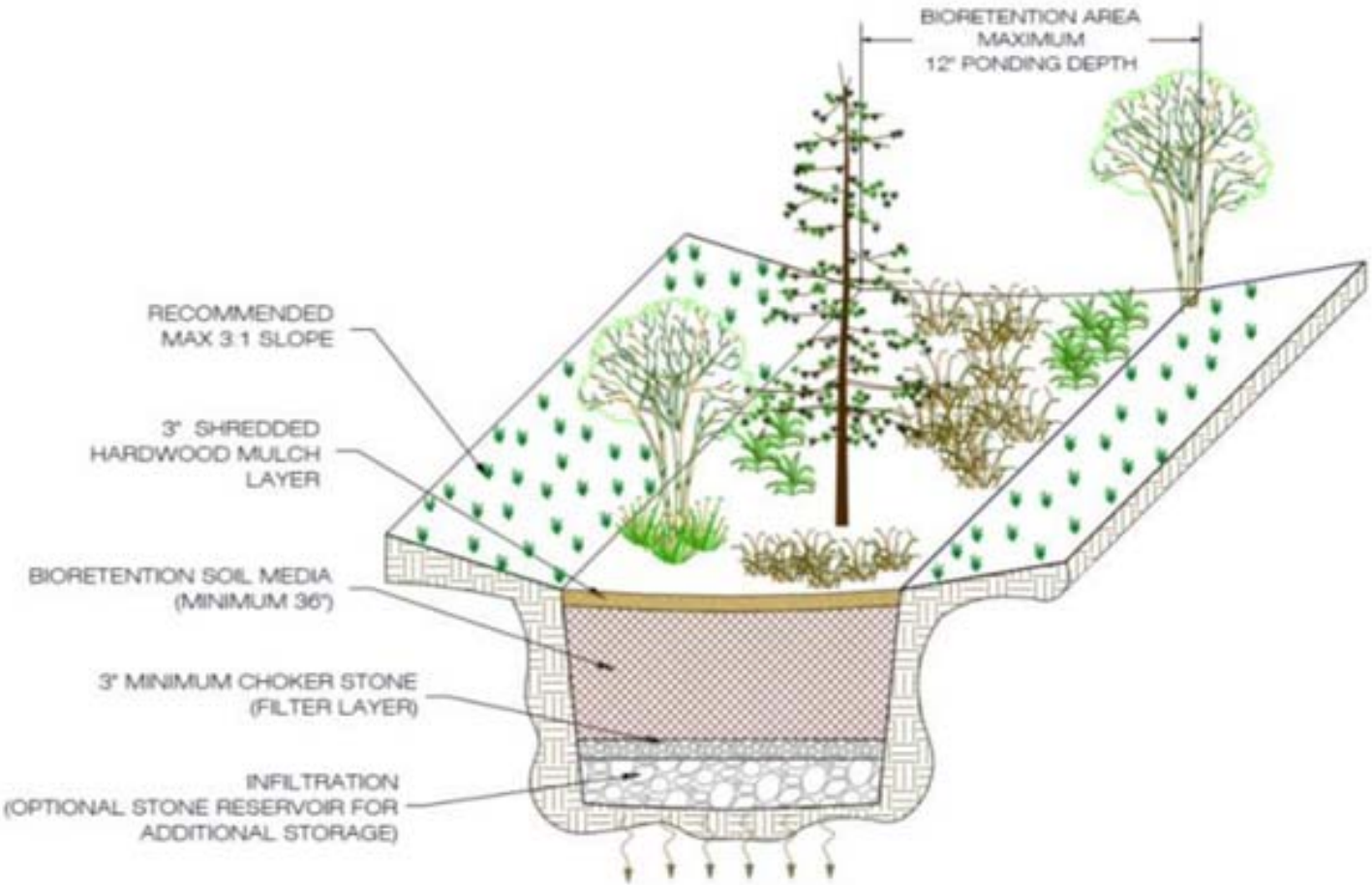
Bioretention



Typical Bioretention RRP with Underdrain (No Infiltration)

Source: VA-DCR, 2013

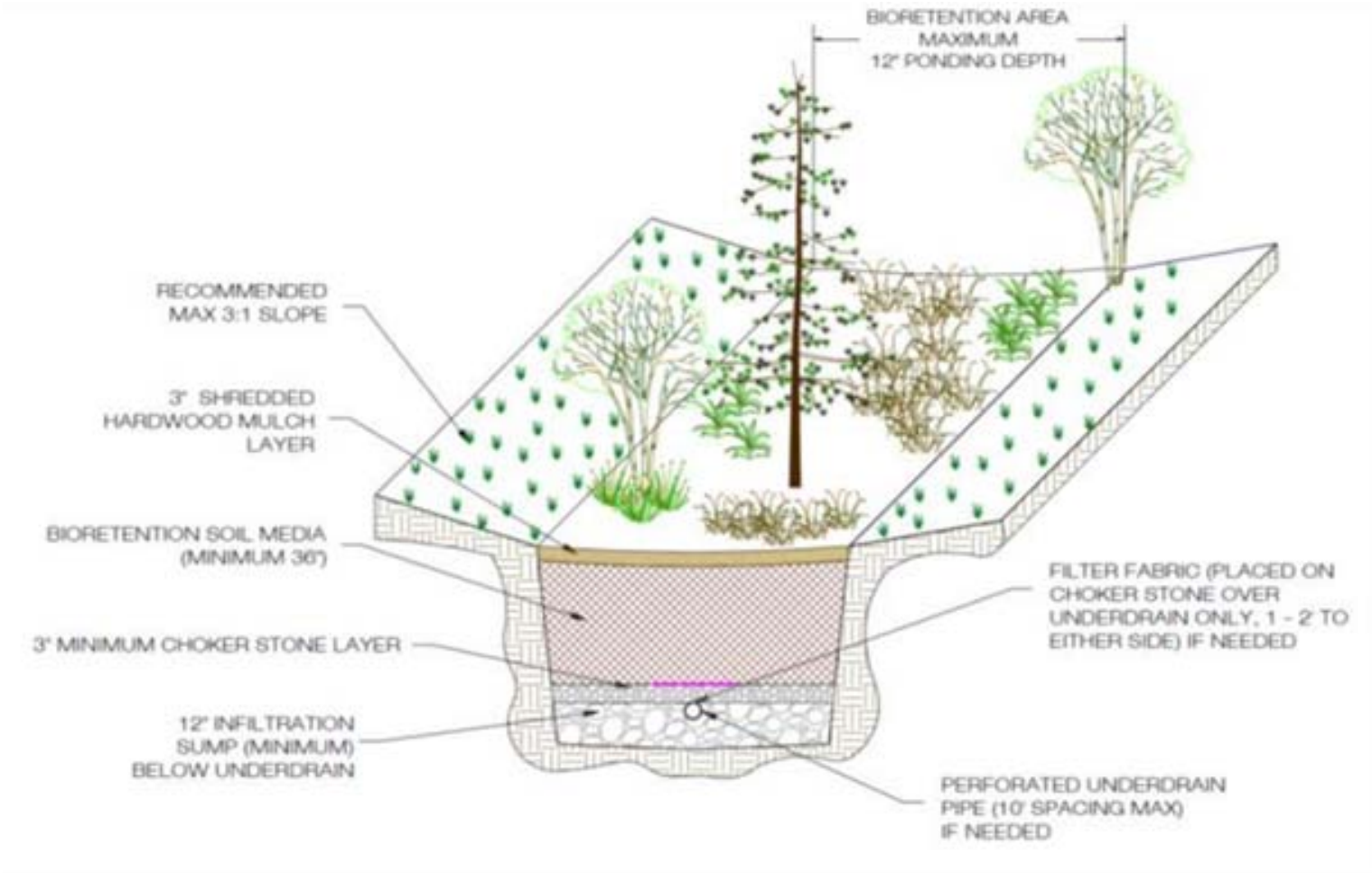
Bioretention



Typical Bioretention RRP without Underdrain (Infiltration Only)

Source: VA-DCR, 2013

Bioretention



Typical Bioretention

Source: VA-DCR, 2013

Urban Bioretention

Stormwater Planters (source: City of Portland, OR)

Urban Bioretention

- Urban Bioretention is similar to traditional bioretention practices, but is fit into hard-sided containers within urban landscapes such as planter boxes or tree planters.
- Captured runoff is treated by filtration through an engineered soil medium, and is then either infiltrated into the subsoil or exfiltrated through an underdrain.
- Primary use is for small fragmented drainage areas and feature “hard edges”.
- Variations:
  - Stormwater planters – between buildings, sidewalks and roadways
  - Green Streets – roadsides and medians

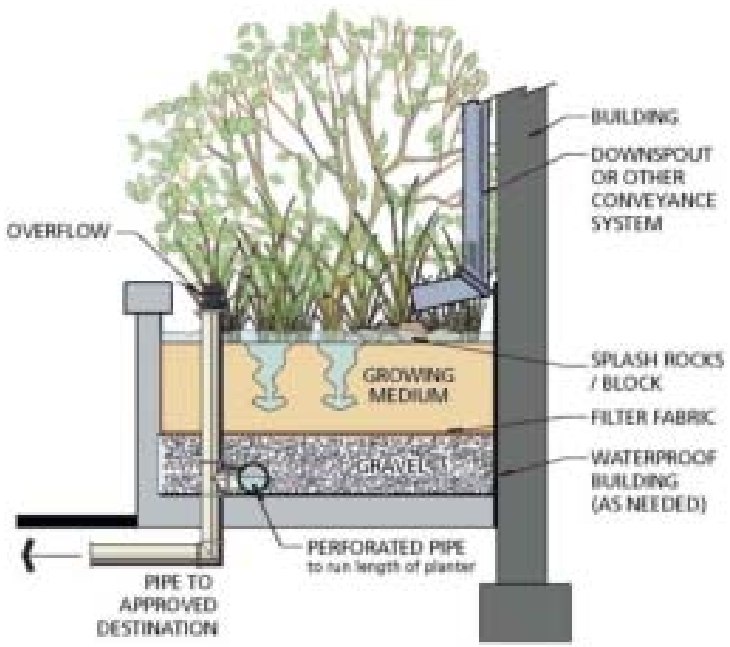
Urban Bioretention

- Performance
  - Soil filtration / gravel based storage / infiltration system
  - Impervious CDA ~ 2,500 sf (maximum)
  - Urban Bioretention creates a good environment for runoff reduction, filtration, biological uptake, and microbial activity, and provides high pollutant removal. Urban Bioretention can become an attractive landscaping feature with high amenity value and community acceptance.
  - RR Credit: Level 1 – 60%

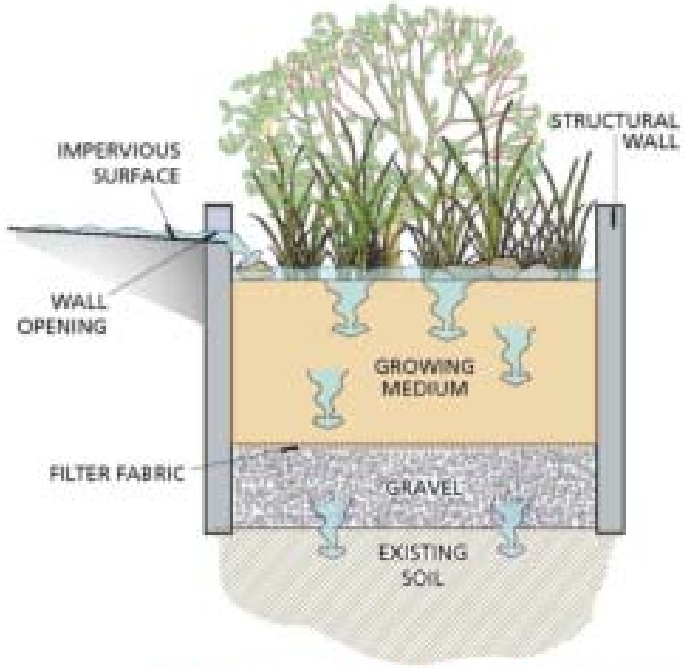
Urban Bioretention

- Special Considerations
  - Small impervious CDA.
  - Usually requires flow diversion and underdrain with connections to local stormwater system.
  - Protection of adjacent building foundations and location of overhead and underground utilities.
  - Consider visual obstructions, utilities and maintenance for plantings chosen.
  - Maintenance
    - Landscape and trash removal.
    - May require irrigation during periods of drought.

Urban Bioretention



Flow-through planter.
(Source: Portland Bureau of Environmental Services)



Infiltration planter (Not for ROW).
(Source: Portland Bureau of Environmental Services)

Water Quality Swale

Water Quality Swale

- Vegetated open channels designed to capture and infiltrate stormwater runoff within a dry storage layer beneath the base of the channel.
- Swales are essentially bioretention cells that are shallower, configured as linear channels.
- Can be planted with turf grass, tall meadow grasses, decorative herbaceous cover or trees.
- Swale is a soil filter system that temporarily stores and then filters the desired treatment volume.
- Conveyance channel to downstream GIP.
- Variations:
  - Without underdrains, subsoils with infiltration rate greater than ½" per hour
  - With underdrains, subsoils with infiltration rate less than ½" per hour

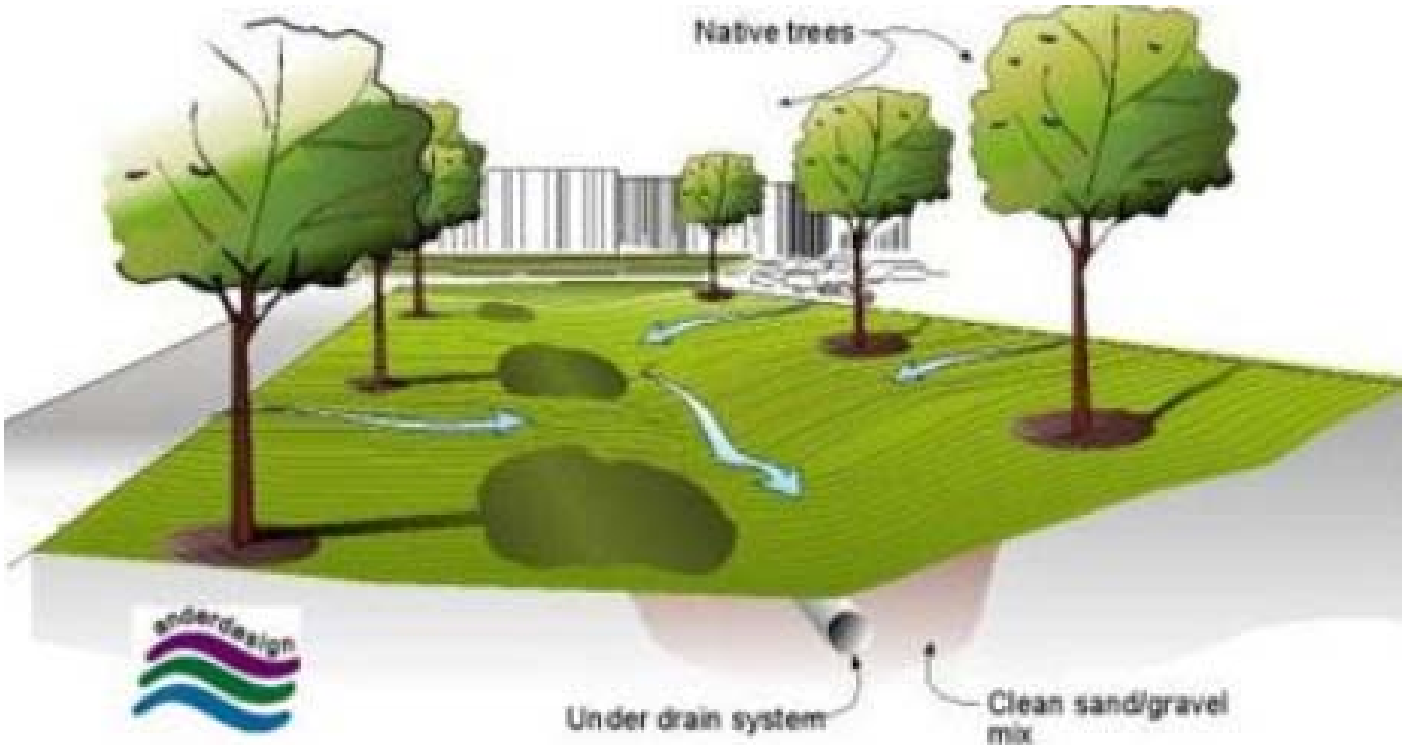
Water Quality Swale

- Performance
  - Soil filtration / gravel based storage / infiltration system.
  - Impervious CDA ~ 2.5 acres
  - Primary pollutant removal mechanisms operating in swales are settling, filtering infiltration and plant uptake.
  - RR Credit: Level 1 – 40%; Level 2 – 60%

Water Quality Swale

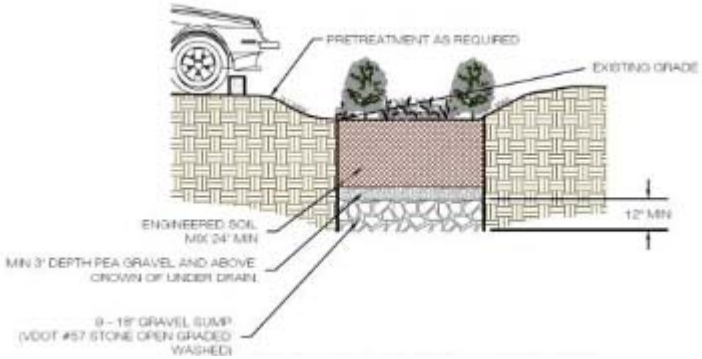
- Special Considerations
  - Runoff acceptance can be either longitudinal or lateral.
  - Slopes less than 2% or provide check dams to slow channel velocities.
  - Underdrains may be required with HSG C & HSG D soils.
  - Multiple variations in geometry to fit existing site topography
  - Maintenance
    - Landscape and trash removal.
    - Once established, typical only spring cleanup.

Water Quality Swale

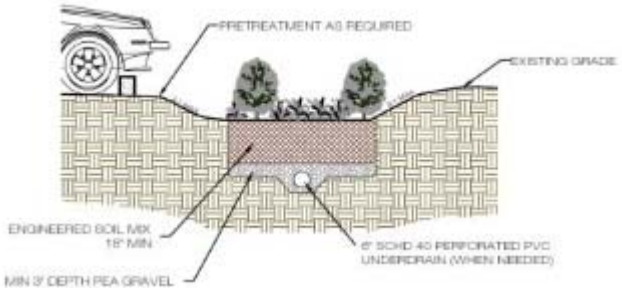


Conceptual Water Quality Swale Design for an Urban Setting *(Source: SuDS Wales)*

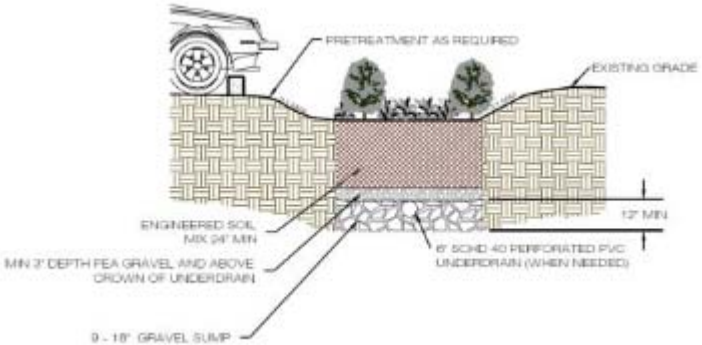
Water Quality Swale



Storage/ Infiltration without Underdrain



With Underdrain



Storage/ Infiltration with Underdrain

Source: VADCR, 2011

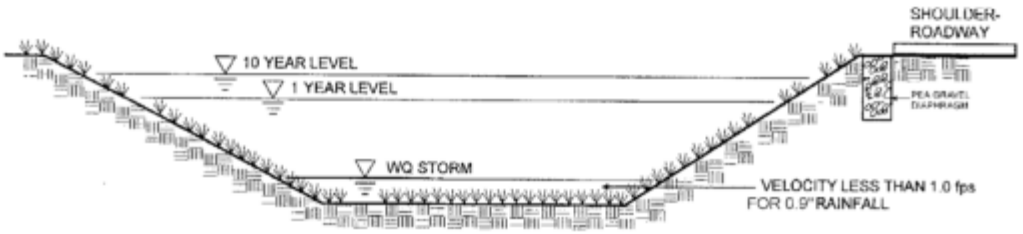
Grass Channel

Grass Channel

- Conveyance channels that are designed to provide some treatment of runoff, as well as to slow down runoff velocities for treatment by other downstream GIPs.
- Appropriate for a number of applications including treating runoff from paved roads and other impervious areas.
- Limited application structural control intended for small drainage areas.
- A preferable alternative to both curb and gutter stormwater conveyance, where development density, topography and soils permit.

Grass Channel

- Performance
  - Soil based system.
  - Impervious CDA ~ 5 acres
  - Channels that are vegetated and are designed to filter stormwater runoff through settling and biological uptake mechanisms, as well as to slow water for treatment by another structural control.
  - Vary depending on the underlying soil permeability.
  - RR Credit: Level 1 – 10%, 20%; Level 2 – 20%, 30% (Soil dependant)



Grass Channel along Roadway – Typical Plan, Profile and Section (Source: VADCR, 2011)

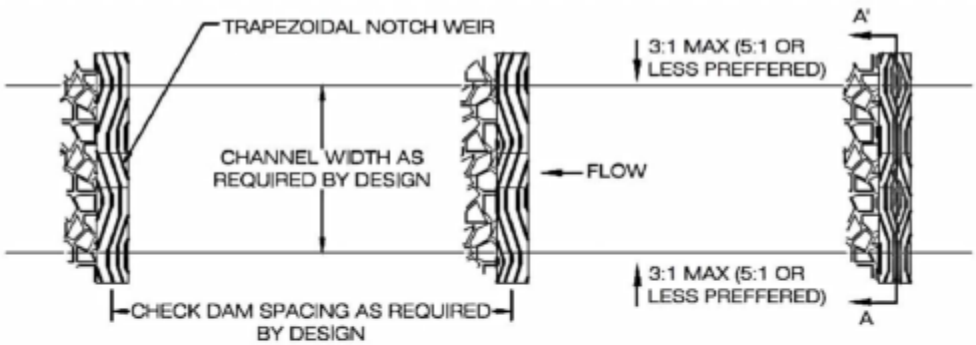
Grass Channel

- Special Considerations
  - Slopes less than 2% or provide check dams to slow channel velocities.
  - HSG C & HSG D soils should be amended to improve performance.
  - Grasses should be seeded (not sodded) to provide 90% turf (thick, dense) coverage.
  - Grasses should be flood and drought tolerant.
- Maintenance
  - Maintain grass height of 3 to 4 inches.
  - Removal of sediment buildup in channel bottom when it accumulates to 25% of original total channel volume.
  - Ensure that rills and gullies have not formed on side slopes.
  - Remove trash and debris build up.
  - Replant areas where vegetation has not been successfully established.
  - Once established, spring cleanup.

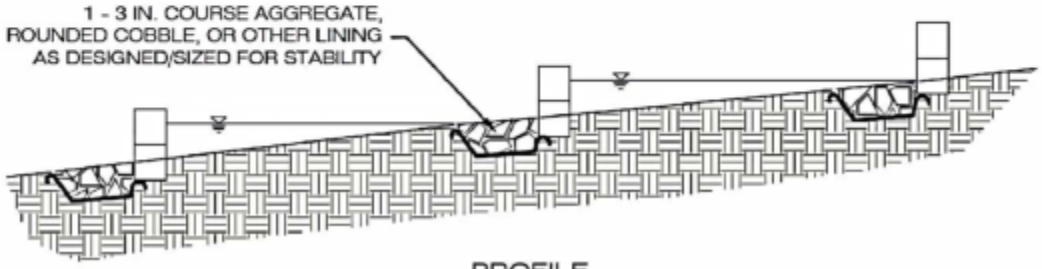
Grass Channel

Typical Grass Channel

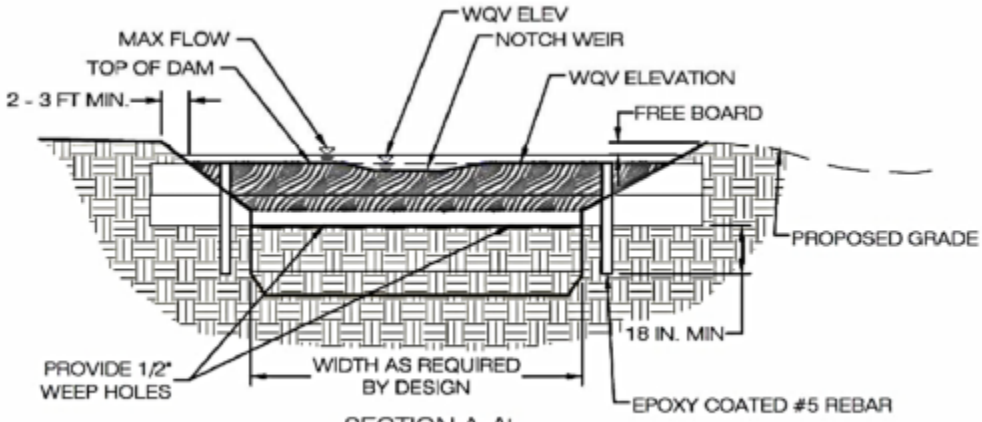
Grass Channel



PLANVIEW

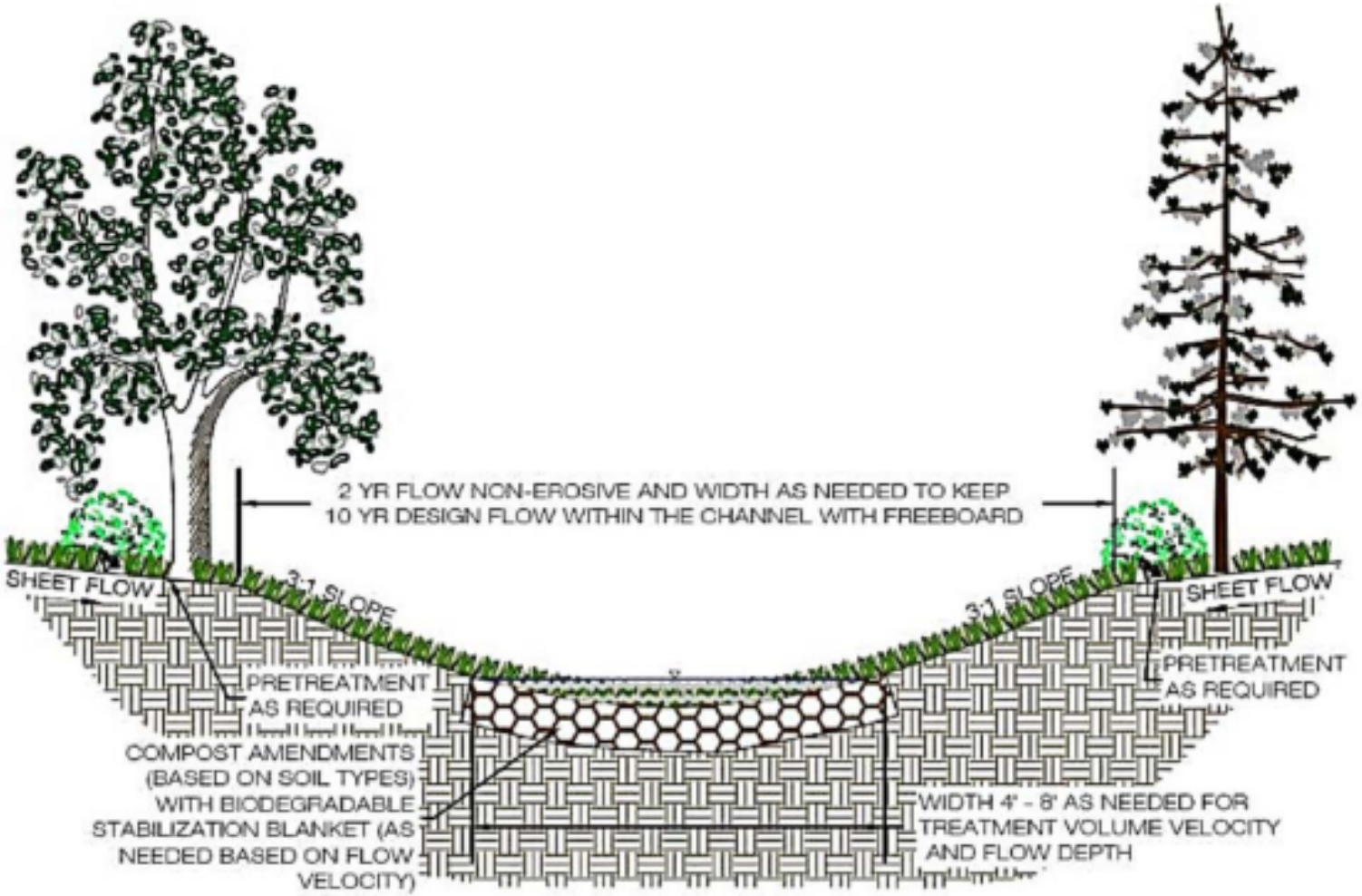


PROFILE



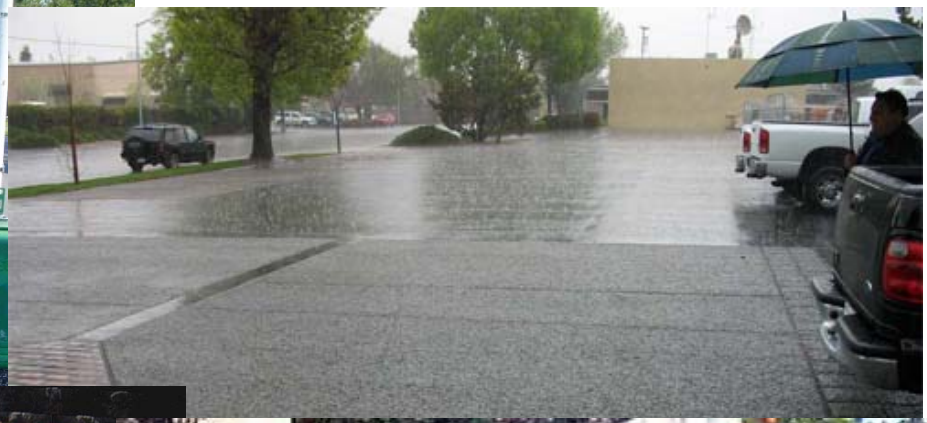
SECTION A-A'

Grass Channel



Grass Channel with Compost Amendments - Section

Permeable Pavements



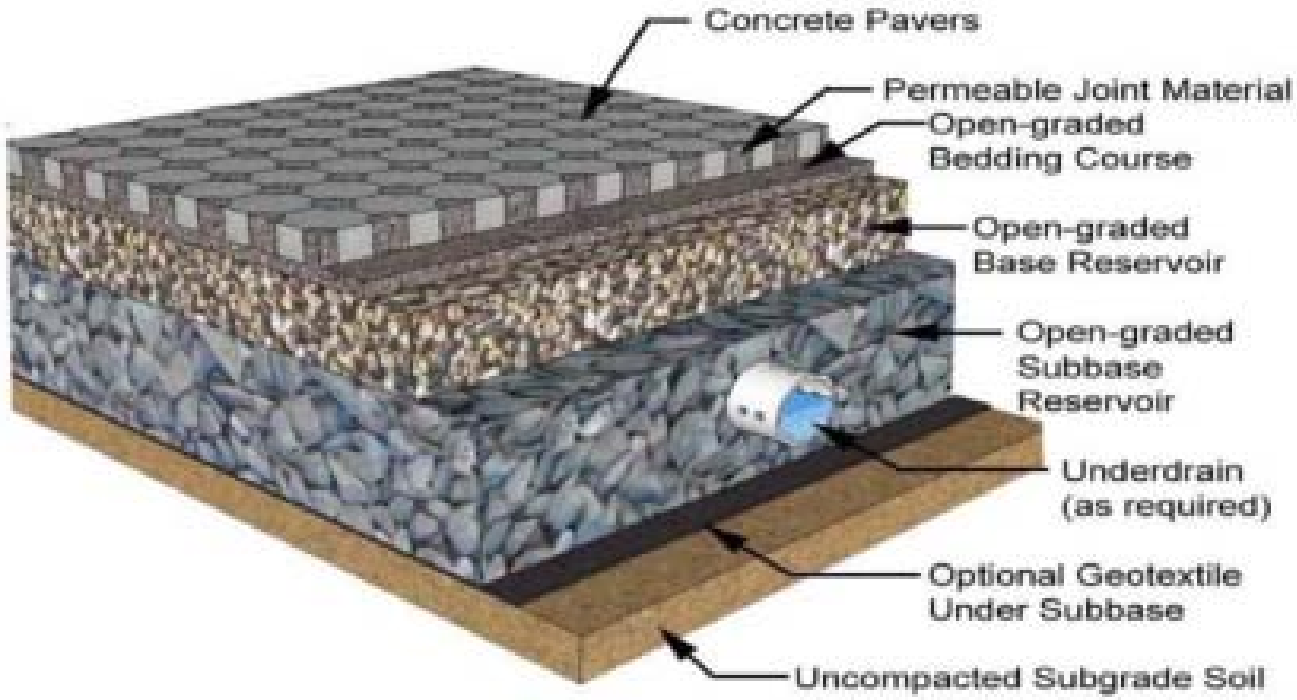
Permeable Pavements

- Allow stormwater runoff to filter through voids in the pavement surface into an underlying stone reservoir, where it is temporarily stored and/or infiltrated.
- Several design variants, but all have a similar structure, consisting of a surface pavement layer, an underlying stone aggregate reservoir layer and a filter layer or fabric installed on the bottom.
- Major Categories:
  - Modular block systems
  - Pervious concrete
  - Porous Asphalt
  - Grass and gravel

Permeable Pavements

- Performance
  - Gravel based storage / infiltration system.
  - Design goal is to maximize runoff reduction (Tv capture).
  - RR Credit:
    - Level 1; 45% (allowed to handle up to twice impervious CDA)
    - Level 2; 75% (only allowed handling rainfall on its surface)
- Special Considerations
  - Underdrain required if subsoil infiltration rate less than ½" per hour.
  - Prime locations on HSG A and HSG B soils.
  - Sensitive to high sediment and debris (trash loading).
  - Sensitive to traffic loads (shear stresses).
- Maintenance
  - Usually involves vacuum sweeping of pavement surfaces.

Permeable Pavements



Typical Detail of Concrete Paver (Source: Smith, 2009)

Infiltration Trench

Infiltration Trench

- Trenches are excavations typically filled with stone (#57) to create an underground reservoir for stormwater runoff.
- Runoff volume gradually exfiltrates through the bottom and sides of the trench into the subsoils and over a period of time eventual reaching the water table.
- By diverting runoff into the soil, the trench not only treats the water quality volume, but also helps to preserve the natural water balance on a site and can recharge groundwater, preserving the base flow.
- Limited to areas with highly porous soils where the water table and/or bedrock are located well below the bottom of the trench.

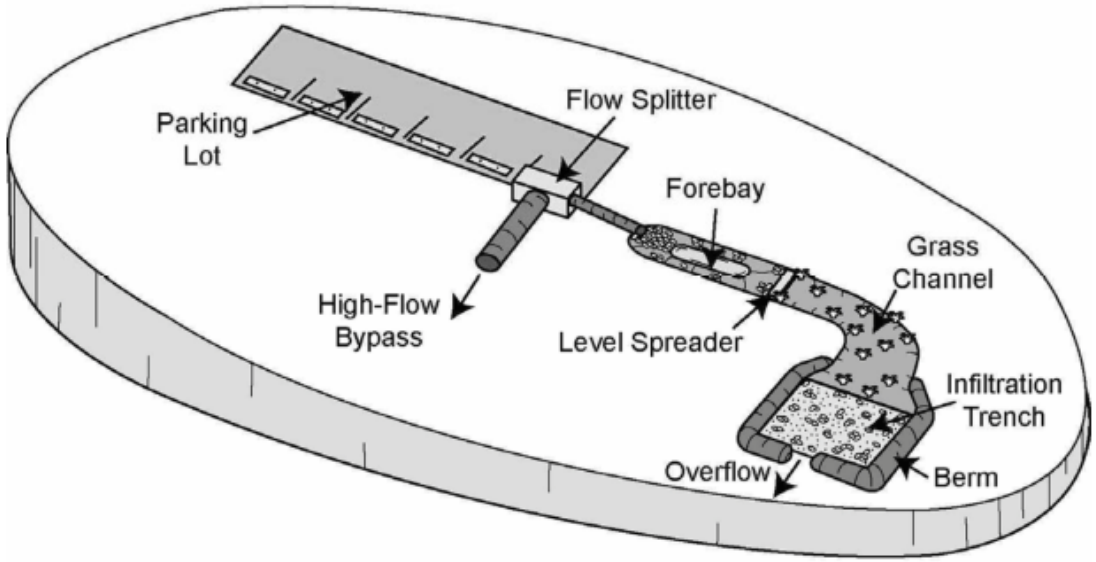
Infiltration Trench

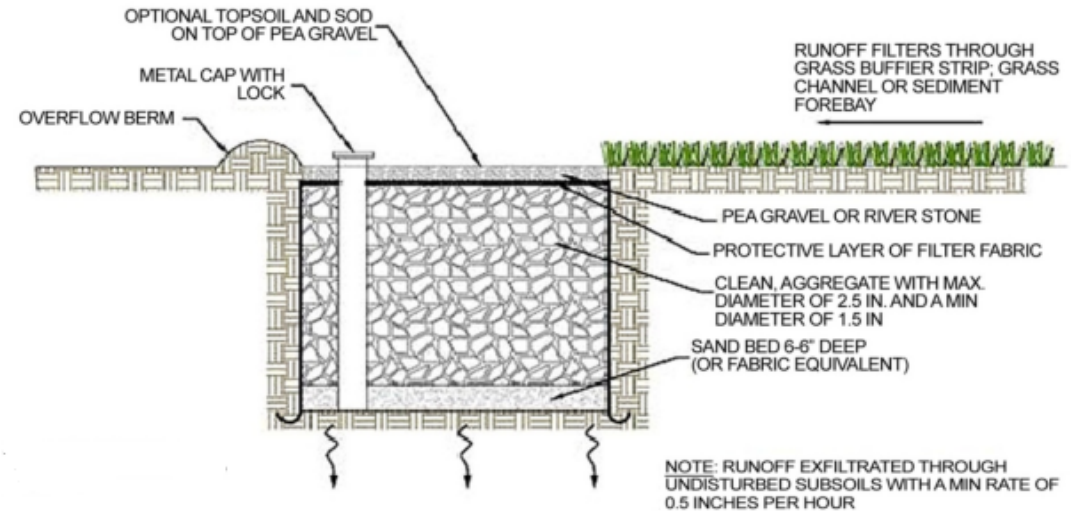
- Performance
  - Gravel base storage, soil based infiltration.
  - Impervious CDA ~ 2.5 acres
  - Wide variety of pollutants from stormwater through absorption, precipitation, filtering, and bacterial and chemical degradation.
  - RR Credit: Level 1 – 50%; Level 2 – 90%
- Special Considerations
  - Sediment load and other suspended solids should be removed from runoff by pretreatment measures.
  - On-line and off-line applications.
  - Requires infiltration rates greater than ½" per hour.
  - Not applicable for runoff from pollution hotspots.

Infiltration Trench

- Maintenance
  - Ensure that contributing area and inlets are clear of debris.
  - Remove sediment and oil/grease from pretreatment and overflow devices.
  - Check observation wells following 3 days of dry weather. Failure to percolate indicates clogging.
  - Remove trees that start to grow in the vicinity of the trench.
  - Replace pea gravel/topsoil and top surface filter fabric (when clogged).

Infiltration Trench





Infiltration Plan and Section (VADCR, 2011)

Green Roof

Green Roof

- Are alternative roof surfaces that typically consist of waterproofing and drainage material and an engineered growing media that is designed to support plant growth (also known as vegetated roofs, living roofs or ecoroofs) .
- Capture and temporarily store stormwater runoff in the growing media before it is conveyed into the storm drain system.
- A portion of the captured stormwater evaporates or is taken up by plants (evapotranspiration), reducing runoff volumes, peak runoff and pollutant loads.
- Two Types:
  - Extensive
  - Intensive – deeper growing media

Green Roof

Green Roof

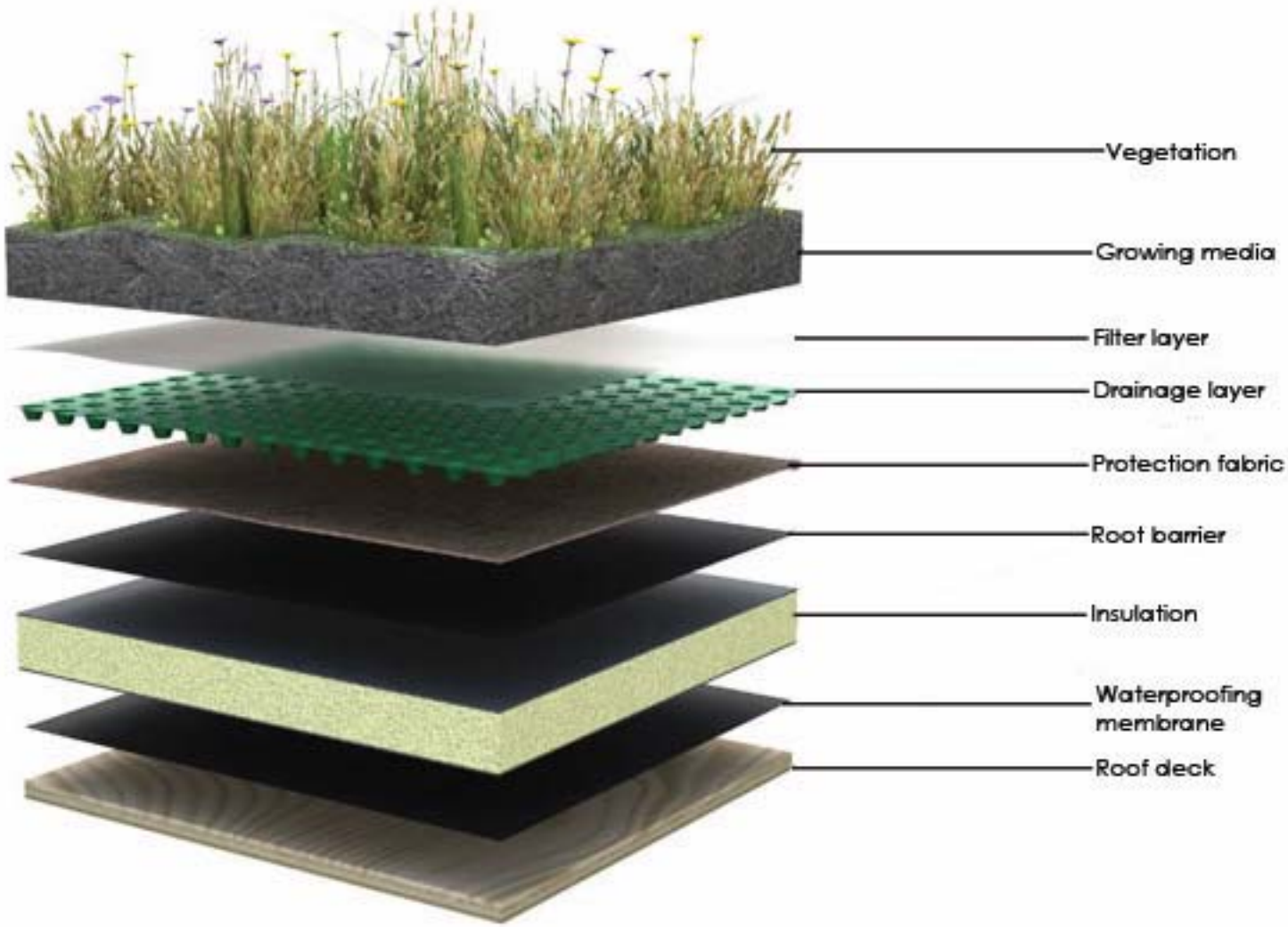
Green Roof

- Performance
  - Capture / engineered growth media infiltration.
  - Roof area (maximum) with non-vegetated areas < 20%.
  - Primarily runoff reduction by evaporation and plant uptake.
  - RR Credit: Level 1 – 80%; Level 2 – 90%
- Maintenance
  - Hand weeding and fertilizing.
  - Plant replacement.
  - Roof leak repair.

Green Roof

- Special Considerations
  - All designs must be in conformance to ASTM (2005) International Green (Vegetated) Roof Standards.
  - Designs may be limited to roof structural capacity and access.
  - Plant selection for vegetated rooftops is an integral design consideration, which is governed by local climate and design objectives. The primary ground cover for most vegetated roof installations is a hardy, low-growing succulents that are matched to the local climate conditions and can tolerate the difficult growing conditions (sunlight, drought, saturated soil) .
  - Requirement for irrigation during periods of drought.
  - Protection from building maintenance activities, particularly involving cleaning (overspray) of chemical agents.

Green Roof


Vegetation
Growing media
Filter layer
Drainage layer
Protection fabric
Root barrier
Insulation
Waterproofing membrane
Roof deck

Cistern

Cistern

- Rain tanks and cisterns are used to intercept, divert, store and release rain falling on rooftops for future use.
- Two methods:
  - Above ground
  - Below ground

Cistern

- Performance
  - Capture and non-potable water reuse.
  - Capture volume based on storage (tank) capacity. Capacity is primarily based on anticipated demand, roof area and rainfall.
  - Primarily based on dedicated reuse demand.
  - RR Credit: Variable up to 90% reduction(treatment volume).
- Special Considerations
  - Steep terrain application where other GIPs are not appropriate.
  - Various system design configurations:
    - Year round indoor use with optional seasonal outdoor use.
    - Seasonal outdoor use and optional year-round secondary runoff reduction practice.
    - Year-round indoor use, seasonal outdoor irrigation, and non-seasonal treatment in a secondary runoff reduction practice.

Cistern

- Maintenance
  - Inspected twice yearly (spring / fall).
  - Usually cleaning of filters and sediment accumulation in storage tank(s).

Extended Detention

Extended Detention

- Constructed stormwater detention basin that has a permanent pool, or micropool.
- Runoff from each rain event is captured and treated through settlement of suspended solids.
- Variations:
  - Wet extended detention
  - Micropool extended detention.
  - Multiple pond system.

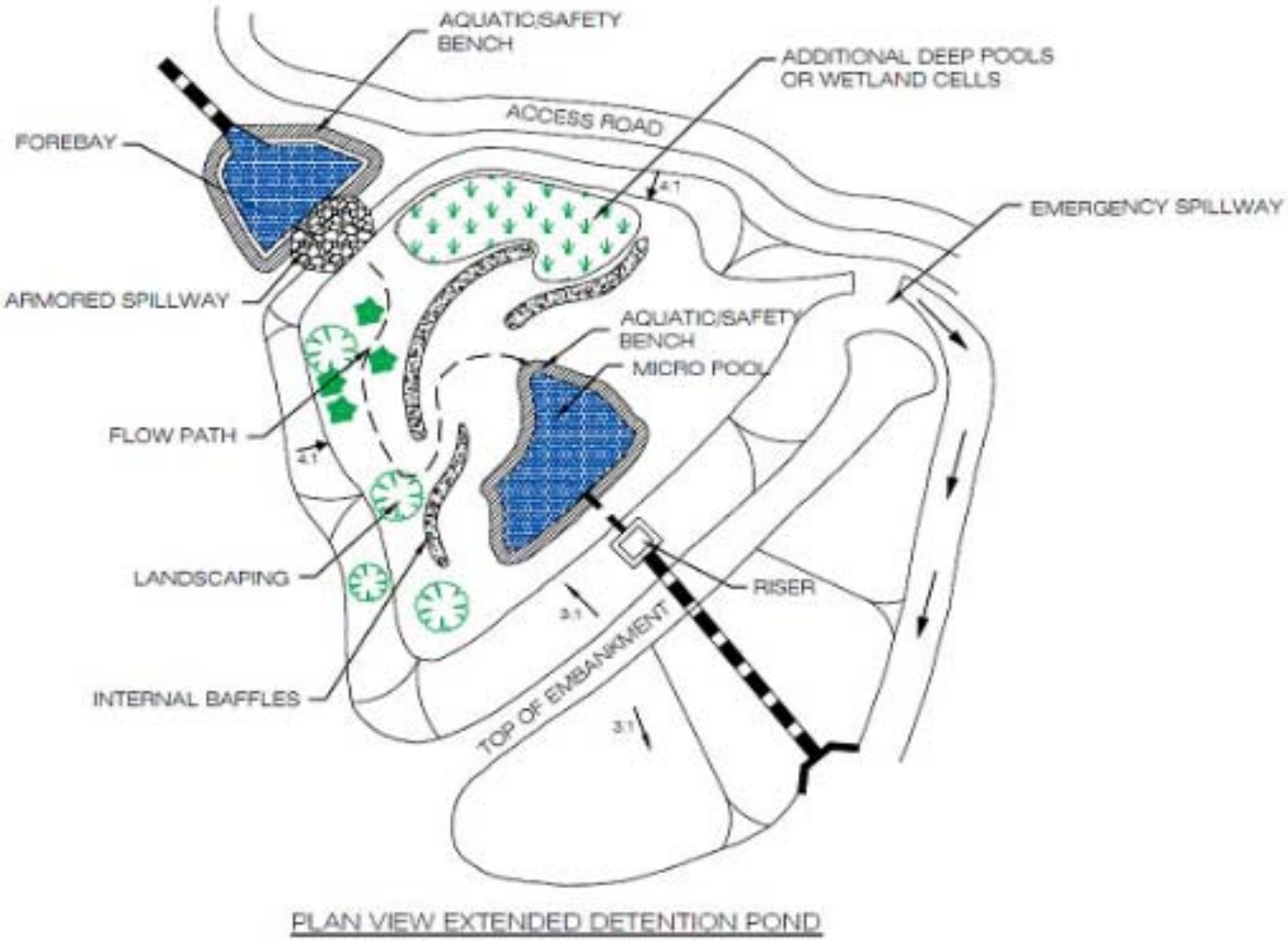
Extended Detention

- Performance
  - The temporary ponding enables particulate pollutants to settle out and reduces the maximum peak discharge to the downstream channel reducing the effective shear stress on the downstream banks.
  - RR Credit: Level 1 – 15%
- Maintenance
  - Inspected annually.
  - Typical activities:
    - Low flow orifice maintenance (twice yearly).
    - Removal of trash and floatable materials.
    - Sediment removal.
    - Vegetation maintenance.

Extended Detention

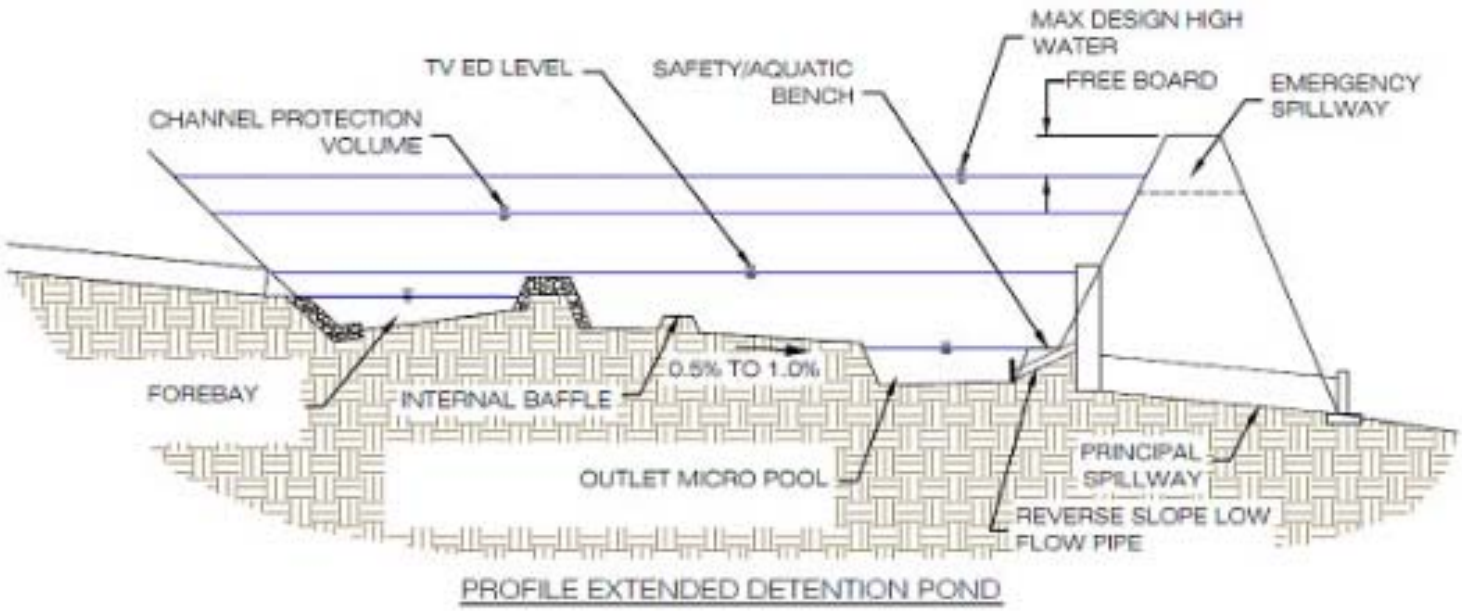
- Special Considerations
  - Design to achieve a minimum drawdown time (24 hours), rather than peak flow.
  - Access for maintenance and inspection.
  - Emergency spillway for large storm events.
  - No-erosive inlet/outfall velocity.
  - Screening of low flow orifices.
  - Landscaping and planting plans.
  - Mosquito abatement.
  - Tennessee Safe Dams Act may apply to ponds with storage volumes and embankment heights large enough to fall under the regulation for dam safety.
  - Multi-use functionality.

Extended Detention



Typical Extended Detention Pond Details (source: VADCR, 2011)

Extended Detention



Typical Extended Detention Pond Details (source: VADCR, 2011)

Module Topic Summary

- General Overview
- Intrinsic Green Infrastructure Practices
  - Key: Taking advantage of existing natural landscape.
- Structural Green Infrastructure Practices
  - Key:

Table 5 – Green Infrastructure Practices Runoff Reduction Credit Percentages

Green Infrastructure Practice	% Rainfall Volume Removed/Captured – RR Credit							
	Level 1**				Level 2**			
1. Bioretention	60				80			
2. Urban Bioretention	60				N/A			
3. Permeable Pavement	45				75			
4. Infiltration Trench	50				90			
5. Water Quality Swale	40				60			
6. Extended Detention	15				N/A			
7. Downspout Disconnection*	25				50			
8. Grass Channel	10/20				20/30			
9. Sheet Flow *	50				75			
10. Reforestation (A, B, C, D soils)	96	94	92	90	98	97	96	95
11. Rain Tanks/Cisterns	Design dependent							
12. Green Roof	80				90			

*See GIP for additional RR credits.

**See GIP for additional information of the distinction between Level 1 and Level 2 design.

Questions?