CDM

Using the County's Design Guidance Manual for Treatment BMP Design

Luis R. León, P.E.

June 8, 2005

Agenda

- Definitions
- Volume and Flow Based Design Standards
- Treatment BMPs
  - Applications
  - Photo Examples

Treatment BMPs

- Treatment control measures, or treatment BMPs, are engineered technologies designed to remove pollutants from stormwater runoff
- Designed to treat runoff from frequent, low-flow storm events and first-flush events

Treatment BMP Design Standards

- Treatment BMPs are designed to treat the SQDV, SQDF, or both
- No additional water quality benefit for designing BMPs to treat more than the SQDV and SQDF

Volume-based Design Standards

- Stormwater Quality Design Volume (SQDV)
  - Volume necessary to capture and treat 80% or more of the average annual runoff volume from the site at the design drawdown period
  - Fact sheets specify design drawdown periods

Flow-based Design Standards

- Stormwater Quality Design Flow (SQDF)
  - Defined to be equal to 10 percent of the peak rate of runoff flow from the 50-year storm
  - Determined using the procedures set forth in the *Hydrology Manual*

Sizing Criteria for Treatment Control Measures

	Treatment Control Measure	Design Basis
T-1	Grass Strip Filter	SQDF
T-2	Grass Swale Filter	SQDF
T-3	Dry Detention Basin	SQDV
T-4	Wet Detention Basin	SQDV
T-5	Constructed Wetland	SQDV
T-6	Detention Basin/Sand Filter	SQDV
T-7	Porous Pavement Detention	SQDV
T-8	Porous Landscape Detention	SQDV
T-9	Infiltration Basin	SQDV
T-10	Infiltration Trench	SQDV
T-11	Media Filter	SQDV
T-12	Proprietary Control Measures	SQDV or SQDF

Contributing Impervious Area Determination

- Impervious area factors into calculations for SQDV and SQDF
- Following calculation sheet can be used as a guide for determining impervious area

Site Element	Unit Area (ft^2)	Percent Imperviousness	Weighting Factor[2]	Weighted % Imperviousness[3,4]
Asphalt/concrete pavement		100		
Gravel pavement		40		
Roofs		90		
Porous pavement		35[5]		
Lawn/turf		0		
Open space		0		
Total Contributing Area[1]		–	–	

Design Standards for Volume-based Treatment BMPs

- Volume-based treatment BMPs shall be designed for at least 80% annual runoff capture
  - Based on procedures set forth in the Ventura Co. Land Development Guidelines
- Typical BMPs include:
  - Detention basins
  - Retention basins
  - Wetlands

SQDV Calculation Procedure

1. Determine effective imperviousness (I_{WQ}) of the drainage area
2. Refer to Figure 5-1 in the Design Manual
3. Using I_{WQ} determined in Step 1, determine the interception point with the drawdown period line
4. Read the Unit Basin Storage Volume along the vertical axis
5. Multiply the Unit Basin Storage Volume by the contributing drainage area

Design Standards for Flow-based Treatment BMPs

- Flow based post construction treatment control BMPs shall be sized to handle the flow generated from 10% of the 50-year design flow rate
- Typical BMPs include:
  - Swales
  - Biofilters
  - Diversion facilities

SQDF Calculation Procedure

1. The Stormwater Quality Design Flow (SQDF) in Ventura County is defined as $Q_{P,SQDF}$
2. Calculate the peak rate of flow from the 50-year storm ($Q_{P,50\ yr}$) using the procedures set forth in the *Hydrology Manual* or as directed by the local agency Drainage Master Plan
3. Convert $Q_{P,\ 50yr}$ (Step 2) to $Q_{P,\ SQDF}$ (Step 1)

   $Q_{P,SQDF} = 0.1 \times Q_{P,50yr}$

Treatment BMPs

Applications and Examples

Content of Treatment BMP Fact Sheets

- Description
- General Application
- Advantages/Disadvantages
  - Site Suitability
  - Pollutant Removal
- Design Criteria and Procedures
- Design Example
- Construction Considerations
- Maintenance Requirements

T-1 Grass Strip Filter (GSTF)

- Uniformly graded and densely vegetated strips of turf grass
- Runoff flow is distributed uniformly across the top width of the strip to achieve sheet flow down the length of the strip
- Maintenance requirements typically limited to routine landscape practices such as irrigation and mowing

T-1 GSTF Applications

- Appropriate for use in residential, commercial, industrial and institutional settings
- Typically located adjacent to impervious areas to be mitigated
- Tributary areas typically < 5 acres
- Provide opportunity for infiltration of runoff and reduction of peak flows

T-1 GSTF Applications *cont.*

- High to moderate removal effectiveness for sediment, particulate forms of metals, nutrients and other pollutants
- Particularly effective when used as an upstream control measure in combination with grass swale filters, sand filters, and infiltration control measures

T-1 Grass Strip Filter (GSTF)

Industrial – Oxnard

Lake Tahoe, CA

(Prairie Crossing – Grayslake, IL)

T-2 Grass Swale Filter (GSWF)

- **Densely vegetated (turf grass) drainageways with gentle side slopes and gradual slopes in the direction of flow**
- **Runoff is collected and slowly conveyed to downstream points of discharge**
- **Maintenance requirements typically limited to routine landscape practices such as irrigation and mowing**

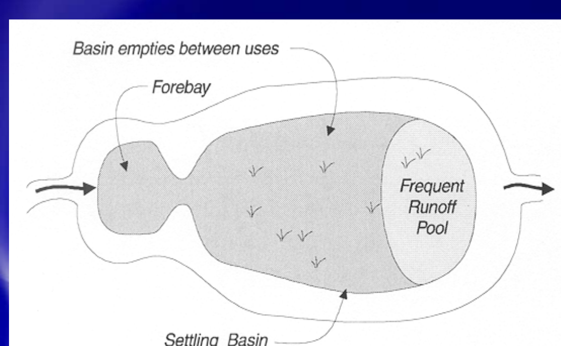
T-2 GSWF Applications

- Appropriate for use in residential, commercial, industrial and institutional settings
- Often used in conjunction with Turf Buffers or GSTFs to provide effluent collection and conveyance
- Tributary areas are typically < 5 acres

T-2 Grass Swale Filter (GSWF)

T-3 Extended Detention Basin (EDB)

- Settling basin with an outlet sized to slowly release detained runoff over a 40-hour period
- Temporarily detains the SQDV of stormwater runoff to allow sedimentation of particulates to occur



T-3 EDB Applications

- Typically used for tributary areas > 10 acres
- Appropriate for residential, commercial, and some industrial applications
- May be designed to provide benefits such as recreation, wildlife habitat, and open space
- Removal effectiveness for sediments, particulate forms of metals, nutrients and other pollutants is considered high to moderate
- Removal effectiveness for dissolved pollutants is considered low

Extended Detention Basin

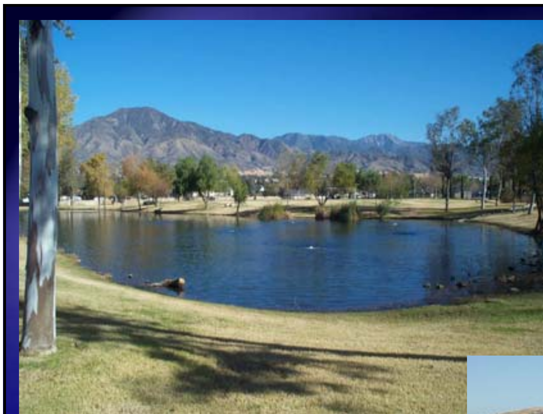
T-4 Wet Detention Basin (WDB)

- Settling basin with outlet sized to slowly release detained runoff over a 12-hour period
- A dry-weather base flow is required to maintain a permanent pool of water
- Stormwater runoff (influent) displaces water in the pool during storm events
- Temporarily detains the SQDV of stormwater runoff to allow sedimentation of particulates to occur

T-4 WDB Applications

- Typically used for tributary areas > 10 acres
- Appropriate for residential, commercial, and some industrial applications
- Can serve as passive recreational areas during the dry season
- Can be designed into flood control basins or retrofitted into existing flood control basins
- Removal effectiveness of WDBs for sediment and particulate forms of metals, nutrient and other settleable solids is considered high to moderate
- Remove floatables and achieve a limited degree of dissolved contaminant removal

Wet Detention Basin



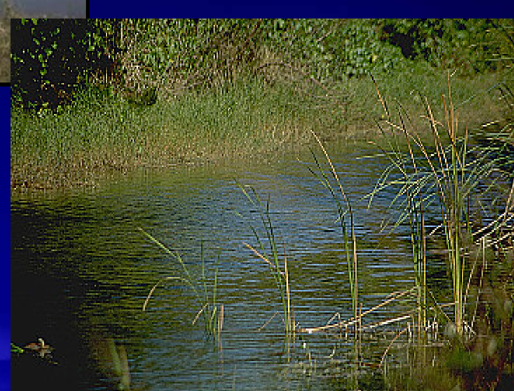
T-5 Constructed Wetland Basin (CWB)

- Single-stage treatment system consisting of a forebay and a permanent micropool with aquatic plants
- Influent runoff flow water mixes with and displaces a permanent pool as it enters the basin
- Surcharge volume above the permanent pool is slowly released over a specified period (40 hours for SQDV)

T-5 CWB Applications

- Suitable for large residential developments
- Good for commercial, institutional and industrial areas where incorporation of a green space and a wetland into the landscape is desirable and feasible
- CWBs offer the potential for wildlife habitat and passive recreation
- Remove a variety of constituents
- Pollutant removal effectiveness varies based on periodic sediment removal and plant harvesting
- Expected removal efficiencies for sediments, organic matter, and metals can be moderate to high; for phosphorus and nitrogen, low to moderate

Constructed Wetland Basin



T-6 Detention Basin / Sand Filter (DBSF)

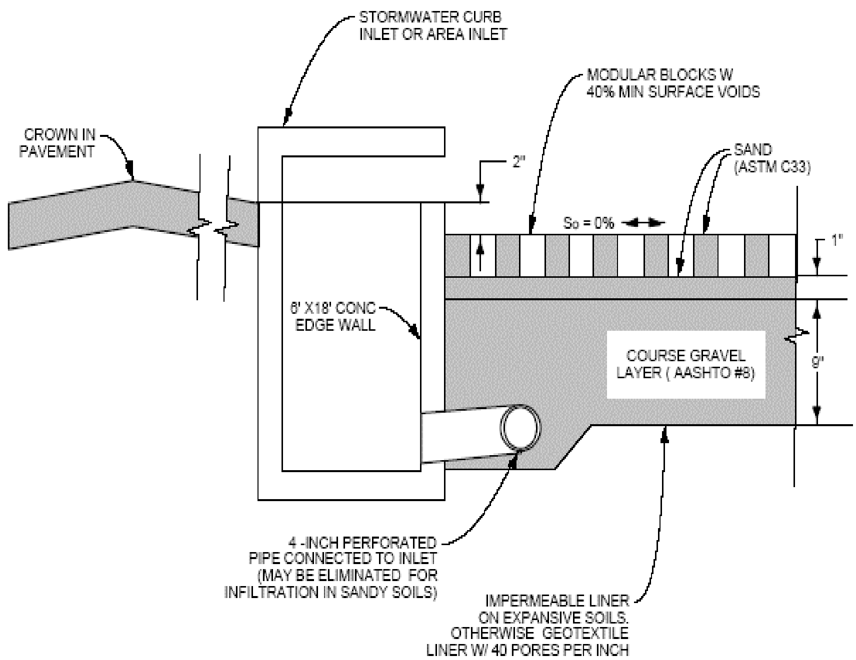
- Consists of a runoff storage zone underlain by a sand bed filter with an underdrain system constructed in an earthen basin
- Basin is divided into a forebay settling basin to remove large sediment followed by sand filter basin

T-6 DBSF Applications

- Suitable for offline, onsite configurations where there is no base flow and the sediment load is relatively low
- Suitable for drainage areas $\leq$ 100 acres
- Effective water quality enhancement through settling and filtering
- Removal effectiveness for sediment and particulate forms of metals, nutrients and other pollutants is considered high to moderate
- Removal effectiveness for dissolved pollutants is considered low

T-7 Porous Pavement Detention Basin (PPD)

- Installation of flat, Modular Block Porous (MBP) pavement
- 2-inch deep surcharge zone to temporarily store the WQCV draining from an adjacent area
- Runoff through the sand and gravel of the modular block voids and entrapment in the gravel media provides pollutant removal mechanism



T-7 PPD Applications

- Ideal for low vehicle-movement zones such as residential driveways
- Often used as a parking pad surface
- May be installed without free draining subsoils when provided with underdrains
- Can be used in sites with limited open areas
- Modular Block patterns, colors and materials can serve functional and aesthetic purposes

T-7 PPD Applications

- Removal rates for both suspended sediment and associated constituents are projected to be high to moderate
- Removal rates for dissolved constituents are expected to be low to moderate
- PPD can reduce flooding potential by infiltrating or slowing down runoff

(Pacific Grove, CA)

T-8 Porous Landscape Detention Basin (PLD)

- Similar to PPD, but uses vegetation instead of modular block porous pavement
- Shallow surcharge zone to temporarily detain the WQCV draining from an adjacent area
- Underdrain gradually dewaters the sand bed

T-8 PLD Applications

- Suitable for sites with limited open area available for stormwater detention
- Ideally suited for small installations
  - Parking lot islands
  - Street medians
  - Roadside swale features
  - Site entrance or buffer features

T-8 PLD Applications

- Relatively high degree of pollutant removal provided
- Pollutant removal is significant and should equal or exceed the removal effectiveness provided by sand filters
- Provides filtering, adsorption, and biological uptake of constituents
- Reduction in flood potential
- Natural moisture source for vegetation, enabling "green areas" to exist with reduced irrigation

T-9 Infiltration Basin (INB)

- Earthen basin constructed in pervious soils, inlet structure, and emergency spillway
- Retains the SQDV in the basin
- Allows the retained runoff to percolate into the underlying native soils over a specified period of time (40 hours)

T-9 INB Applications

- Appropriate for large drainage areas (10-50 ac)
- Controls runoff volumes
- Can function as dual-purpose facilities when not in use
- Significant pollutant removal, rate equals or exceeds removal rates provided by sand filters
- In addition to settling, infiltration basins provide filtering, adsorption, and biological uptake of constituents

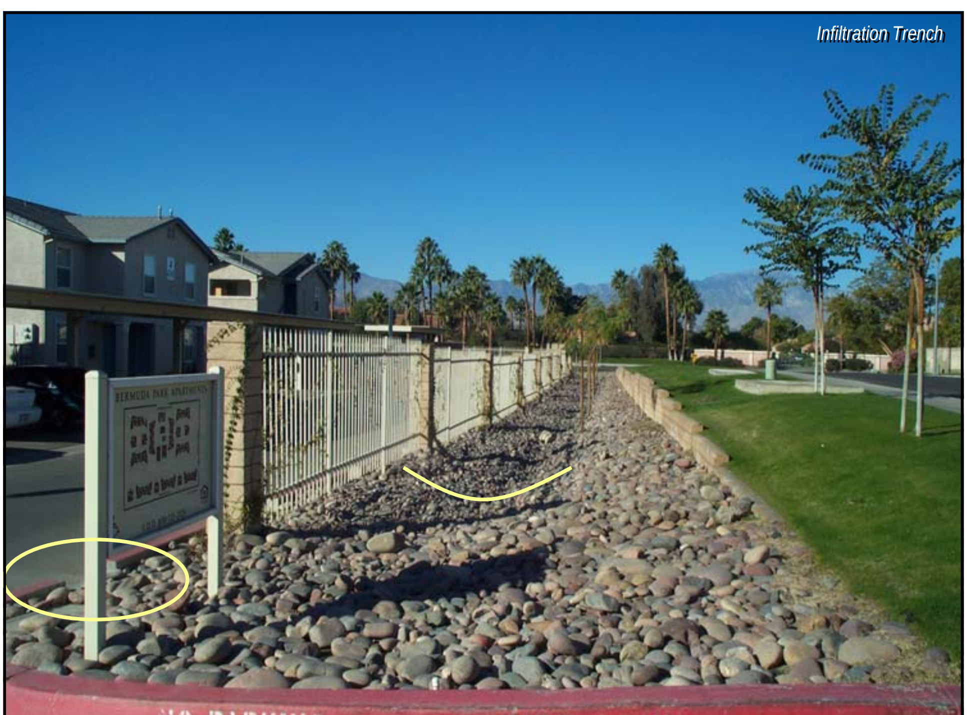
T-10 Infiltration Trench (INT)

- Subsurface gravel and sand bed constructed in pervious soils
- Retains and infiltrates the SQDV over a specified period of time (40 hours)
- Typically combined with upstream treatment control measures to reduce sediment loading

T-10 INT Applications

- Typically used in areas < 10 acres
- Controls runoff volumes
- Significant pollutant removal, rate equals or exceeds removal rates provided by sand filters
- In addition to settling, infiltration trenches provide filtering, adsorption, and biological uptake of constituents


Infiltration Trench


Infiltration Trench
NO PARKING
FIRE LANE

T-11 Media Filter (MF)

- Two-stage constructed treatment system
  - Pretreatment settling basin
  - Filter bed containing sand or other filter media
- Suitable for offline, onsite configurations
- Functions best in areas with no base flow and low sediment loads

T-11 MF Types

- Austin Sand Filter System
  - Large units
  - Above or below surface
  - Used in large drainage areas (up to 50 acres)
- DC Underground Sand Filter
  - Underground line system
  - Used for small drainage areas (up to 1.5 acres)
  - Receives concentrated flows

T-11 MF Types cont.

- Delaware (Linear) Sand Filter
  - Situated along perimeter of small drainage area (up to 5 acres)
  - Receives sheet or concentration flows
  - Can be used in areas of high ground water

T-11 MF Applications

- Removes particulate and floatable materials
- Appropriate for drainage areas of $\leq$ 100 acres
- Vegetation not required
- Requires less space than other treatment control measures and can be located underground
- Pollutant removal by settling and filtering
- Effectively removes:
  - Sediments
  - Pollutants associated with sediments

T-12 Alternative and Proprietary Control Measures

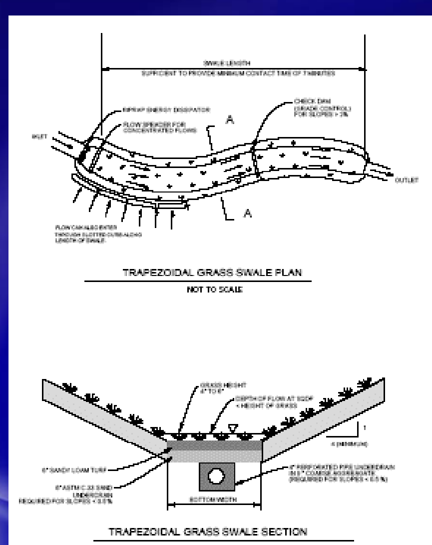
- Permittees will consider the use of alternative or proprietary control measures under 4 conditions
  - Existing site constraints preclude installation of standard treatment controls
  - Costs of standard treatment controls are substantially greater
  - Permittees retain the discretion of using a lesser performance or design standard prior to accepting proprietary devices
  - Alternative or proprietary treatment control devices will only be considered for approval after standard treatment control measures in the guidance manual have been rejected

Example Problem
Using BMP Sizing Criteria to design a Grass Swale Filter

Example GSWF

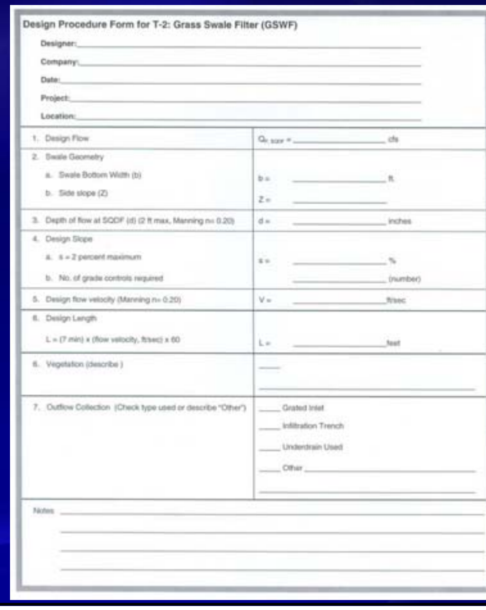
- Design a grass swale filter to treat a flow of 1 cfs
  - Desired design flow depth is 3 inches with a Manning's roughness (n) of 0.2
- Find a trapezoid section that will satisfy side slope and flow velocity criteria
  - Velocity < 1 ft/sec and greater than 0.2 ft/sec
  - Side slopes no steeper than 4:1 (H:V)
- Determine the length of the swale

Grass Swale Filter (GSWF)



Design Procedure Form

- Ventura Countywide Stormwater Quality Management Program
  - Technical Guidance Manual for Stormwater Quality Control Measures



Design Procedure Form for T-2: Grass Swale Filter (GSWF)

Designer: ____
Company: ____
Date: ____
Project: ____
Location: ____

1. Design Flow	Q_{SQDF} = ____ cfs
2. Swale Geometry a. Swale Bottom Width (b) b. Side slope (Z)	b = ____ ft Z = ____
3. Depth of flow at SQDF (d) (2 ft max, Manning n= 0.20)	d = ____ inches
4. Design Slope a. s = 2 percent maximum b. No. of grade controls required	s = ____ % ____ (number)
5. Design flow velocity (Manning n= 0.20)	V = ____ ft/sec
6. Design Length L = (7 min) x (flow velocity, ft/sec) x 60	L = ____ feet
6. Vegetation (describe)	____
7. Outflow Collection (Check type used or describe "Other")	____ Grated Inlet ____ Infiltration Trench ____ Underdrain Used ____ Other ____

Notes ____

Example - Grass Swale Filter

Design of Grass Swale Filter (GSWF)

- Step 1: Calculate design flow for the GSWF (Q_{sqdf})
  - Calculate 50 year return period flow (Q_{50})
    - See Ventura County Hydrology Manual
  - Calculate design flow for the GSWF (Q_{sqdf})
  - $Q_{sqdf} = 0.1 * Q_{50}$

If the 50 year design flow is 10 cfs

$Q_{sqdf} = 0.1 * 10 \text{ cfs} = 1 \text{ cfs}$

Design of Grass Swale Filter (GSWF)

- Step 2: Determine swale geometry
  - Either trapezoid or triangular cross section

    Assume trapezoid shape
- Step 3: Determine side slopes and bottom width (W_b)
  - Must not be steeper than 4:1 (H:V)

    Assume 10:1 side slopes

    Assume 10 foot bottom width

Example - Grass Swale Filter

Design of Grass Swale Filter (GSWF)

- Step 4: Determine minimum and maximum longitudinal slope (S_o)
  - Must be greater than 0.2 % and less than 2.0 %

    Assume a longitudinal slope of 1.5%
- Step 5: Determine design flow depth (d_{SQDF})
  - Must not exceed 3 to 5 inches when Manning's roughness (n) = 0.2

    Assume a design flow depth of 3 inches

Design of Grass Swale Filter (GSWF)

- Step 6: Calculate cross sectional area (A) and wetted perimeter (WP) at design flow

$$A = W_b * d_{SQDF} + Side\ Slope * d_{SQDF}^2$$
$$WP = W_b + \left[2 * d_{SQDF} * \sqrt{1 + Side\ Slope^2}\right]$$

*A = (10 * 0.25) + (10 * 0.25^2)= 3.1 ft^2*

*WP = 10 + [2 * 0.25 * $(1+10^2)^{0.5}$] = 15 ft*

Design of Grass Swale Filter (GSWF)

- Step 7: Calculate hydraulic radius (R)

$$R = \frac{Cross\ Section\ Area}{Wetted\ Perimeter}$$

R = 3.1 / 15 = 0.21

- Step 8: Determine design velocity (V)
  - Flow velocity must not exceed 1 ft/sec when Manning's roughness (n) = 0.2, but should be above 0.2 ft/sec

Set design velocity to 0.4 ft/sec

Design of Grass Swale Filter (GSWF)

- **Step 9: Calculate flow and velocity using Manning's equation for Q_{SQDF}**

$$Q_{SQDF} = \frac{1.49A}{n} \times R^{2/3} \times S_o^{1/2}$$

$$V = \frac{Q_{SQDF}}{A}$$

Q = (1.49 * 3.1 / 0.2) * (0.21$^{(2/3)}$) * (0.015$^{(1/2)}$) = 1.0 cfs

V = 1 cfs / 3.1 ft^2 = 0.32 ft/sec Below design velocity!

Example - Grass Swale Filter

Design of Grass Swale Filter (GSWF)

- **Step 10: Adjust design parameters**
  - **Iterative procedure to obtain design velocity (0.4 ft/sec) and flow (1 cfs) while meeting specified design criteria**

Increase slope to 2.0%

Reduce bottom width to 9.0 ft

Increase side slopes to 4:1

Design of Grass Swale Filter (GSWF)

- Step 11: Recalculate

$A = (9 * 0.25) + 4 * 0.25^2 = 2.5\ ft^2$

$WP = 9 + [2 * 0.25 * (1+4^2)^{0.5}] = 11.1\ ft$

$R = 2.5 / 11.1 = 0.23$

$Q = (1.49 * 2.5 / 0.2) * (0.23^{(2/3)}) * (0.02^{(1/2)}) = \boxed{1.0\ cfs}$

$V = 1.0\ cfs / 2.5\ ft^2 = \boxed{0.4\ ft/sec}$

Design of Grass Swale Filter (GSWF)

- Step 12: Determine minimum swale length
  - Must provide at least 7 minutes of contact time with GSWF

$$L = 60 sec/min * V(ft/sec) * 7 minute\ contact\ time$$

$L = 60 * 0.4 * 7 = 168\ ft$

- Step 13: Select vegetation and mow to 4 to 6 inches

- Step 14: Provide additional capacity for flood event flows when close to critical areas or structures

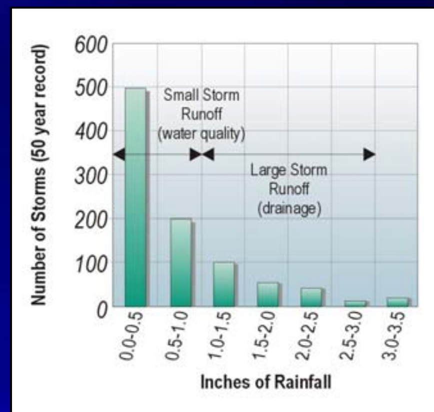
Design of Grass Swale Filter (GSWF)

- There are many solutions
- Iterative procedure
  - Determine limiting variable (Velocity in example problem)
  - Adjust Manning's equation variables within allowable ranges to achieve design flow rate
- Calculate necessary length when other parameters are correct
  - Velocity can be used as a limiting variable to adjust the required length at the design flow

Designing for Water Quality vs. Peak Flow

Water Quality vs. Flood Control Design Issues

- Focus of WQ BMPs is to control POCs from small storms (WQV, WQF)
- Conventional drainage design (flood hazard protection) focuses on peak storm flows
- Several key issues related to peak flow may need to be considered when designing WQ BMPs



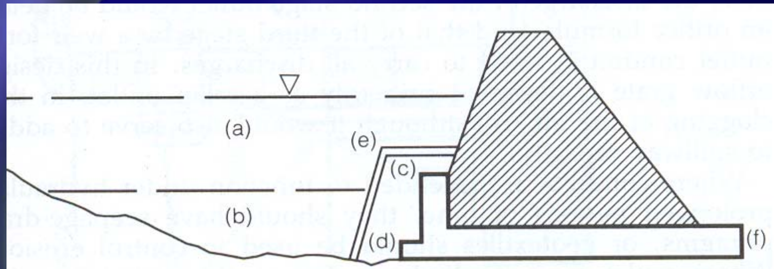
Water Quality vs. Flood Control Issues

- Designing water quality BMPs to safely pass or bypass peak flows and not affect performance
- Integrating peak flow detention (peak shaving) with water quality extended detention into single basin
- Evaluating potential for hydromodification of natural water bodies and, where necessary incorporating controls to minimize adverse impacts

Integrating WQ Treatment with Peak Shaving

- Determine required storage volumes for each function
- Determine outlet hydraulics for each (significantly different)
- Design staged or “stacked” outlet controls to achieve each function
- Incorporate emergency spillway or overflow
- Potentially isolate forebay from larger flows to minimize disturbance and pollutant resuspension

Outlet Controls



Dual-purpose detention basin outlets: (a) volume to control 100-year storm, (b) volume to control settleability storm, (c) flood control outlet, (d) water quality, (e) trash racks, and (f) downstream outlet.