C.3. Workshop: Track 1 – Basic C.3. Topics
June 17, 2009

Overview of Stormwater Treatment BMP Design

Jill Bicknell, P.E., EOA, Inc.
Santa Clara Valley Urban Runoff Pollution Prevention Program

and

Scott Taylor, P.E.
RBF Consulting

Presentation Overview

- Calculating Design Volume and Flow
- Vegetated Swales / Strips
- Detention Basins
- Bioretention Areas

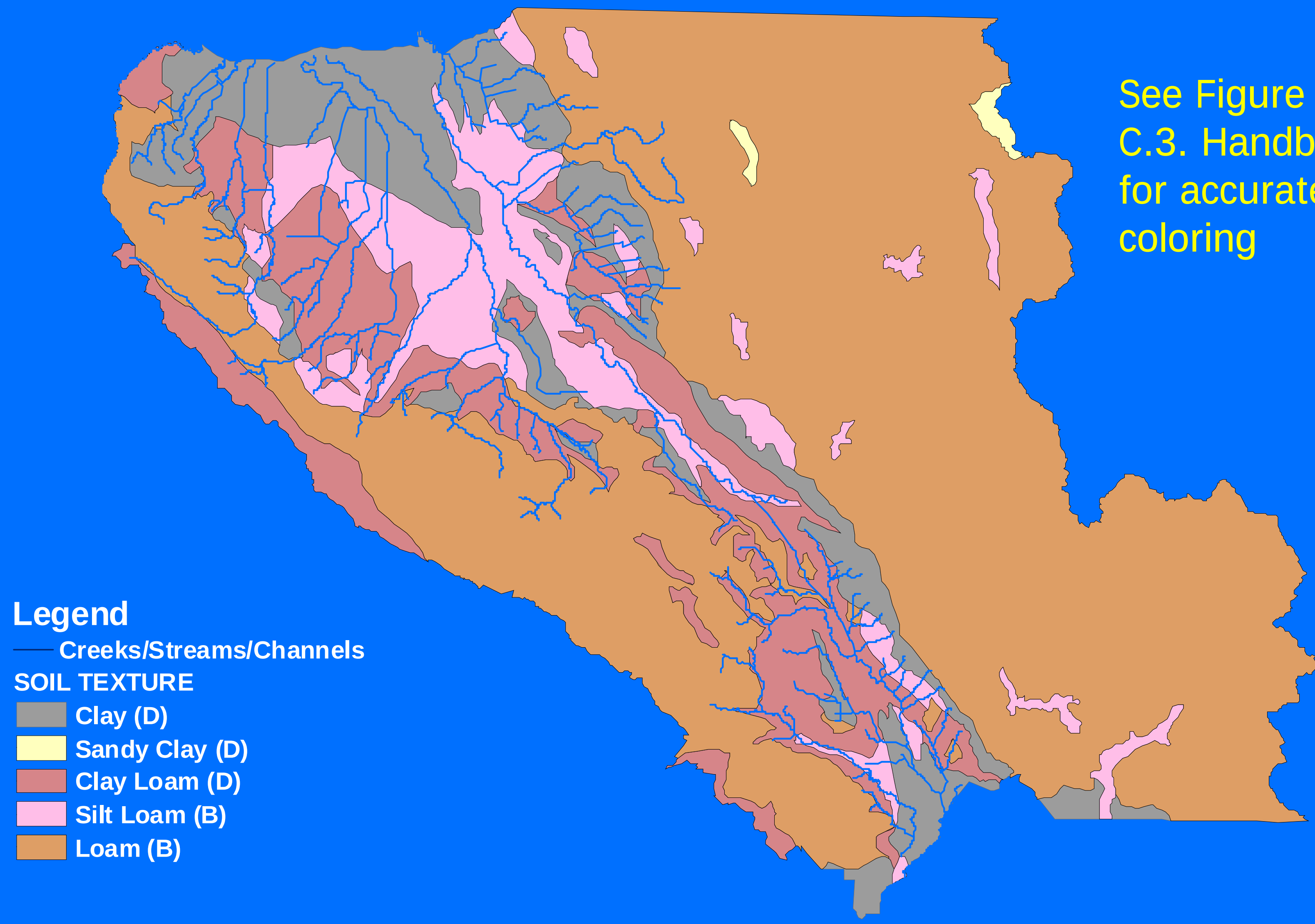
C.3. Sizing Methods

- 2 methods for volume-based BMPs:
  - URQM Method
  - CA BMP Handbook Method
- 3 methods for flow-based BMPs:
  - Factored Flow Method
  - CA BMP Handbook Method
  - Uniform Intensity

Preferred Volume Method: CA BMP Handbook Method

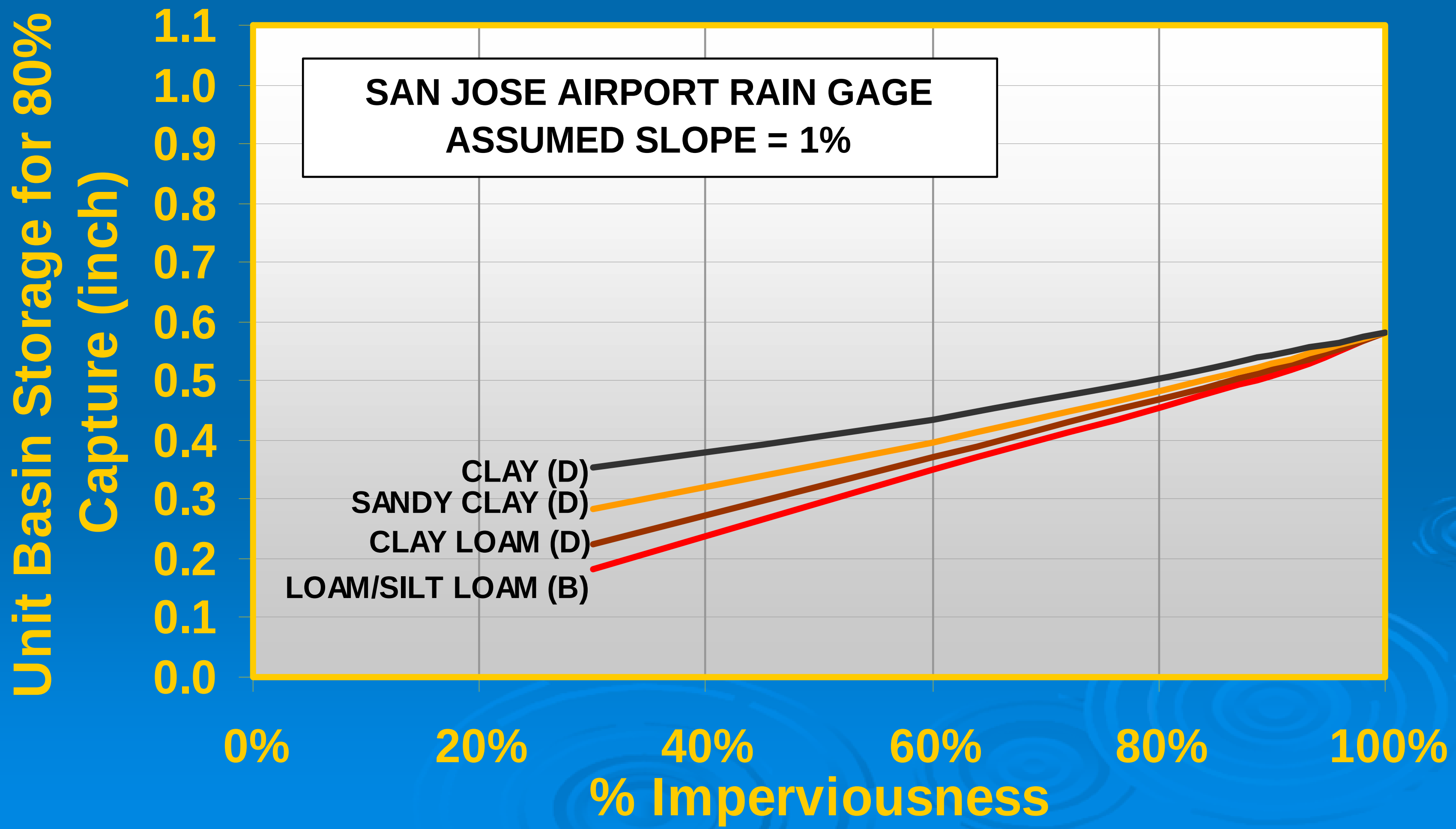
- Sizing curves developed using continuous hydrologic model that accounts for inflow, storage, and outflow from detention basin
- Curves take into account outflow during storm, and possibility that basin may be partially full if storms occur close together
- Curves include effects of soil texture (infiltration) and slope

Soil Textures in Santa Clara County



See Figure 1 C.3. Handbook for accurate coloring

Unit Basin Volume for 80 % Capture: San Jose



NCDC Rain Gauges and Mean Annual Rainfall Contours

- Santa Clara County
- Rain gauge locations are approximate

Figure 1
C.3. Handbook

Determining Design Volume

- Determine imperviousness of drainage area to basin
- Go to “soil-type” curve and find unit basin storage for capture of 80% of annual runoff (<u>inches</u>)
- Adjust unit basin storage for:
  - Slope (interpolate 1% and 15% curves)
  - Location (multiply by ratio of MAP)
- Multiply unit basin storage by drainage area (acres) to basin to get design volume in acre-inches

C.3. Sizing Methods for Flow Based Controls

- Factored Flood Flow: 10% of the 50-year peak rainfall intensity
- CA BMP Handbook: The flow produced by a rain event equal to at least 2 times the 85th percentile hourly rainfall intensity
- Uniform Intensity: The flow produced by a rain event equal to 0.2 in/hr

Design Rainfall Intensity for Four Rain Gauges

Rain Gauge	*Rainfall Intensity (in/hr) (85th Percentile)*	*Design Rainfall Intensity (in/hr) (2 x 85th Percentile)*
Palo Alto	**0.096**	**0.19**
San Jose	**0.087**	**0.17**
Gilroy	**0.11**	**0.21**
Morgan Hill	**0.12**	**0.24**

Recommended Design Flow Method

- Use CA BMP Handbook Method (#2) and value for San Jose (0.17 in/hr) OR
- Use Uniform Intensity (0.2 in/hr) (do not have to adjust for location)

* Note that intensity represents rate of rainfall (a depth or volume per hour) and must be converted to a flow of <u>runoff</u> from the drainage area to BMP

Determining Design Flow

- Calculate flow from intensity by applying rational formula **Q=CIA**
- Where:
  - ***Q = flow (cfs)***
  - ***C = runoff coefficient***
  - ***I = design intensity (in/hr)***
  - ***A = Area draining to BMP (acres)***
- No conversion factor needed

Vegetated Swales / Strips

Swales vs Buffer Strips

- Swales
  - Designed to convey concentrated flow through dense vegetation
  - Generally a flat bottomed channel
  - Up to about 10 tributary acres
- Strips
  - Designed for diffuse, shallow, sheet flow across a vegetated surface
  - Tributary area in square feet
- Both provide filtration, some infiltration

Vegetated Swales vs. Vegetated Strips

- Concentrated flow
- Shallow channels
- Vegetated sideslopes and bottom

- Sheet flow from adjacent area
- Vegetated flat surface

Vegetated Swale

Vegetated Strip

Advantages

- Viewed as landscape
- Inexpensive
- Urban development or roadway drainage conveyance
- Minimal maintenance
- Significant water quality benefit

Limitations

- Cannot treat a very large drainage area (<10 Ac)
- No significant attenuation of the volume and rate of runoff during intense rain events
- Not for industrial sites where spills may occur
- Dissolved constituents removal only through infiltration
- Channelization may occur in vegetated strips

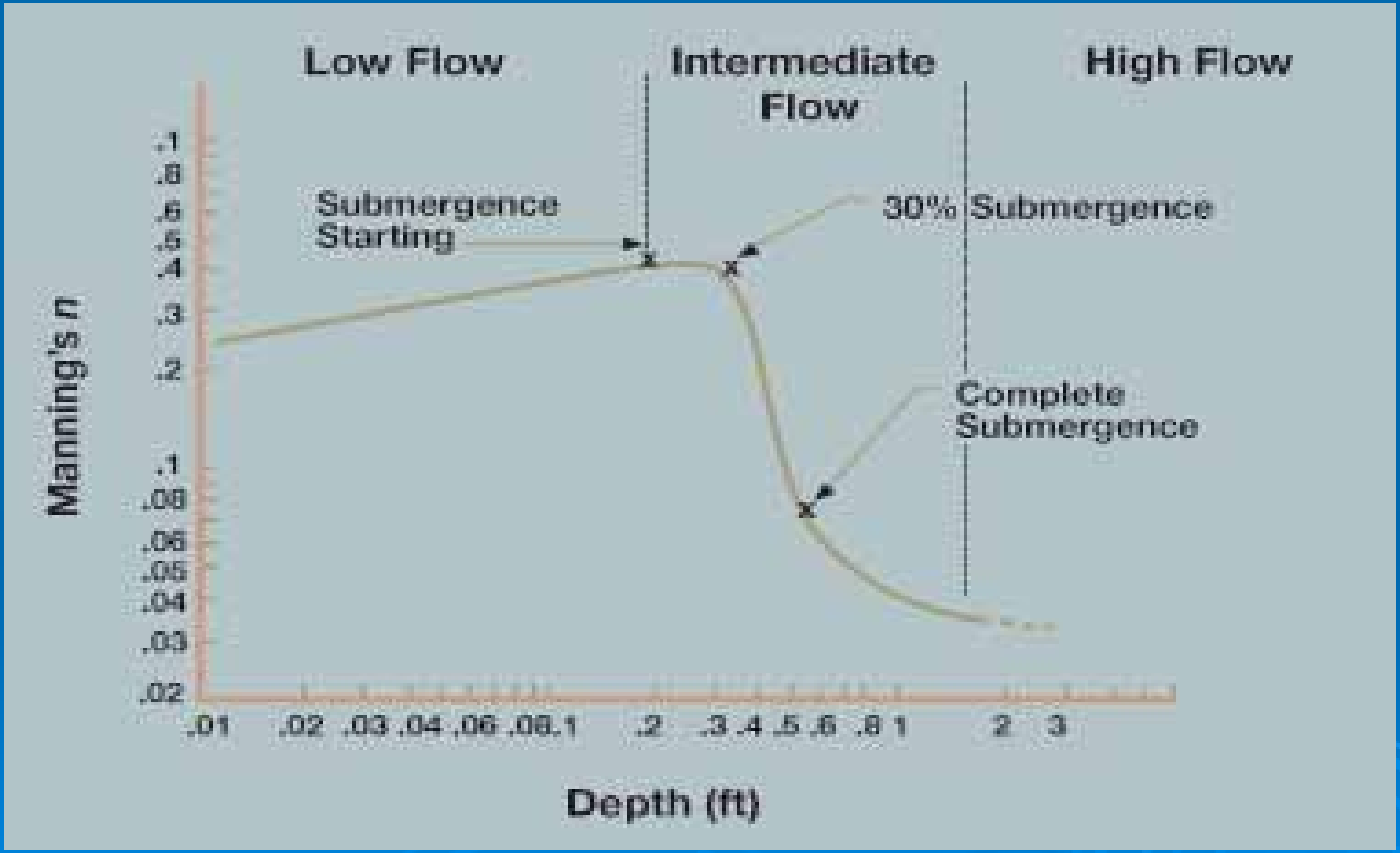
Siting Criteria - Swales

- Tributary Area < 10 Acres
- Construct in cut (preferable)
- Concentrated flows
- Adequate access for maintenance
- Water source for plant establishment
- If in-line, OK for flood conveyance (10 – 100-yr storm)

Design Criteria - Swales

- Flow-based BMP (Q=CiA, where i=0.2 in/hr)
- Longitudinal slope – velocity based.
- Typically trapezoidal channel
- Select low growing grass/plants that thrive at the site, climate, and watering conditions
- Optimum grass height = 6 inches
- Manning's n = 0.25 (WQ)
- Manning's n = 0.022 (flood conveyance)

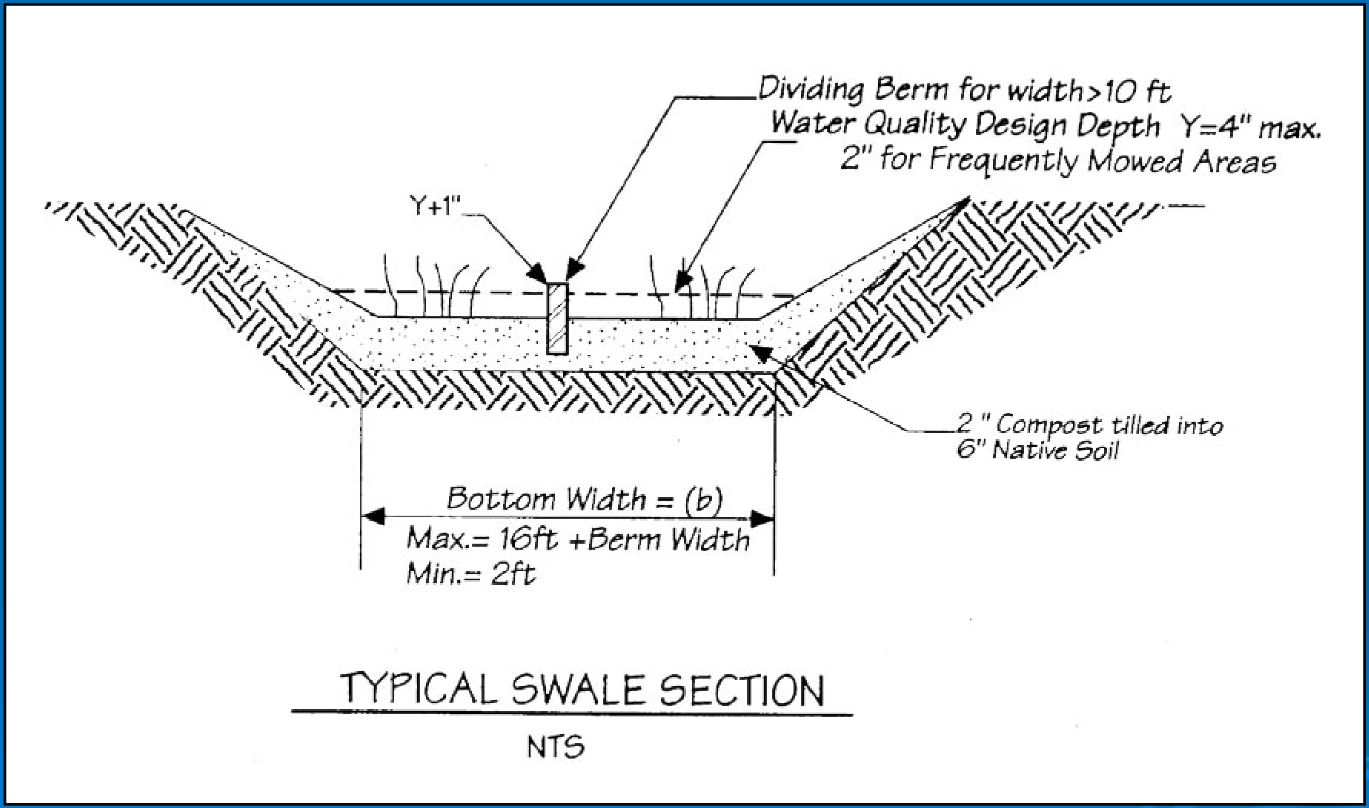
Manning’s Coefficient Selection



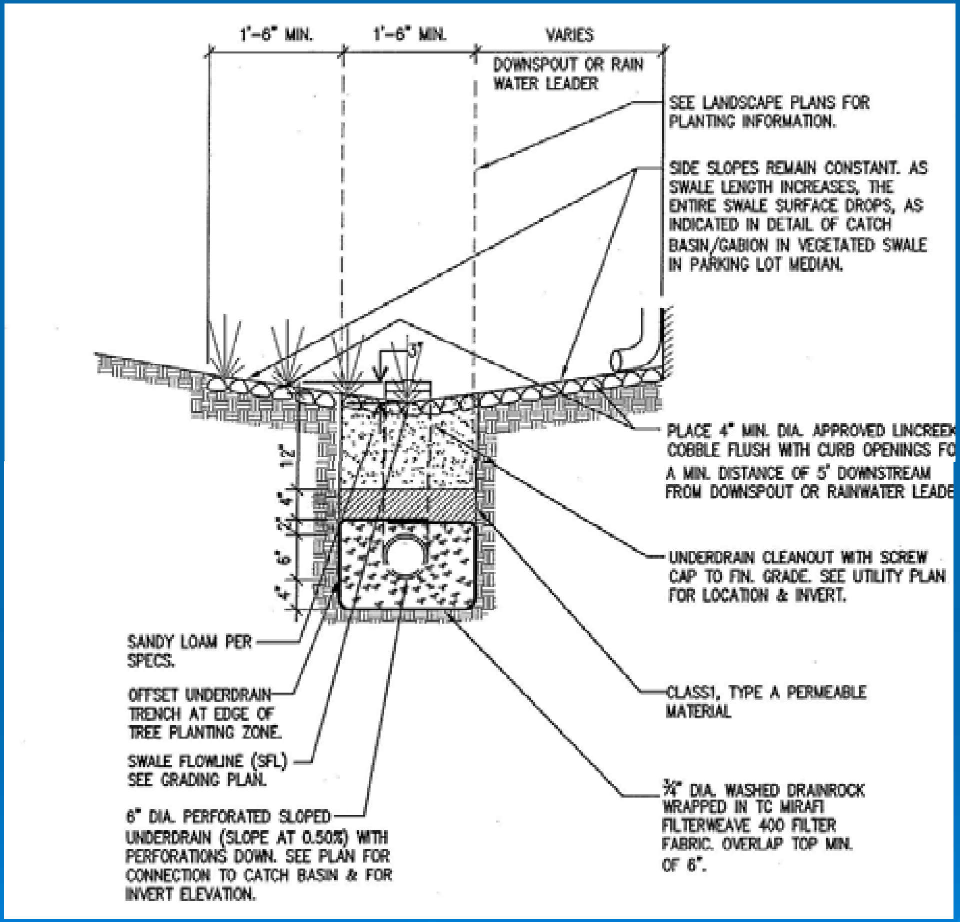
Design Criteria - Swales

- Length = 100 ft (minimum)
- Hydraulic Residence Time = 10 minutes (7 min is ok)
- Flow Velocity: < 1 ft/sec
- Bottom Width: 8 ft desired, 2 ft minimum
- Slope: 2% preferred, 5% max (guidelines)
- Side Slope: 4:1 preferred, 2:1 max
- Flow Depth: 1/3 to 1/2 height of vegetation or 4” max

Swale Schematic

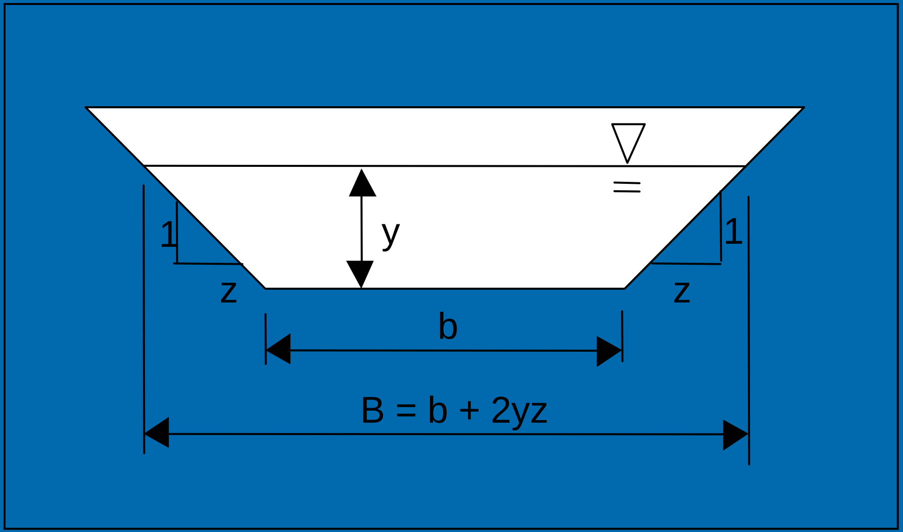


Swale Schematic



Manning's Equation

$$Q = \frac{1}{n} A R^{2/3} S^{1/2}$$



Where:

n = Manning's coefficient;

(0.25 for Water Quality Flow)

Cross Sectional Area (A) = (b + zy)y

Wetted Perimeter (P) = b + 2(y2+y2z2)0.5

Hydraulic Radius (R) = A/P

S = Longitudinal Slope (m/m)

Vegetated Swale Performance (% Load Removed)

	Veg filter Strip	Veg filter Swale
TSS	85	86
Nitrate	83	73
TKN	90	75
Phosphorus	73	20
Copper	86	80
Lead	83	81
Zinc	82	92

Extended Detention Basins

Site Selection

- Need about 0.5 to 2 % of tributary area for basin area (for large tributary areas)
  - Tributary area of at least 5 acres
  - For 5-10 acres, may need 5-10% for basin area
- Low point in watershed
- Suitable outlet location
- Maintenance ingress/egress

Design Guidance

- Volume: Compute required design volume (i.e., from C.3 Permit Conditions)
- Access: All weather access road around perimeter and to invert
- Detention Time: Relatively longer time provided to allow particles to settle out of the water column as compared to flood control basin detention time

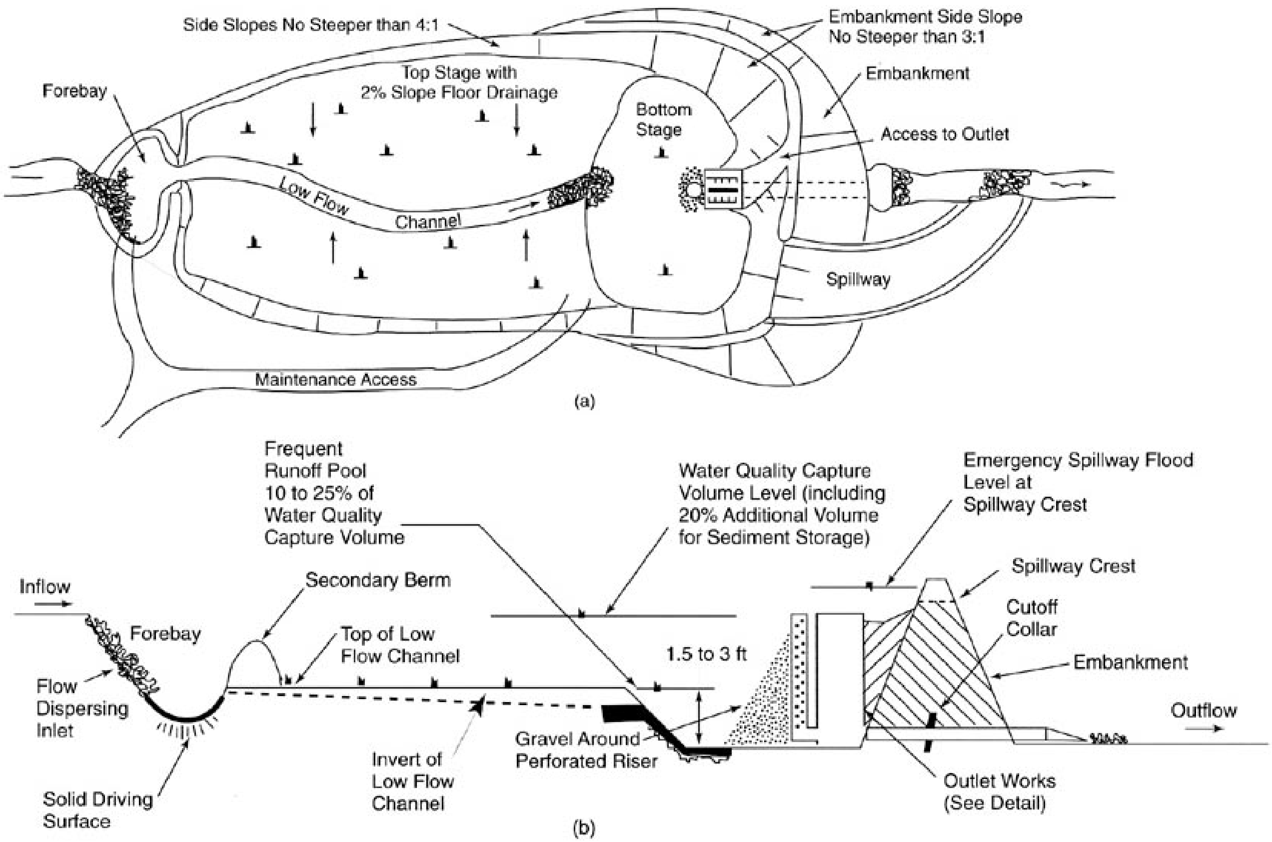
Design Guidance (Con't)

- Detention Time (con't): Goal is average detention time (residence time) of 24 hours. Provide a full basin draw-down time of 96 hours, no more than 50% of volume in first 24 hours.
- Basin Geometry: Maximize hydraulic flow length. L:W ratio of 1.5:1 or greater is desirable but not mandatory.
- Depths up to 7 feet, 2-5 feet optimum.

Design Guidance

- Basin Side Slopes: 4:1 or flatter.
  2:1 is absolute minimum (with fencing).
- Inlet Structure: Provide energy dissipation, locate as far as possible from basin outlet.
- Keep below dam safety guidelines.
- Sediment forebay may be used for locations with high sediment production/delivery (10% of basin area).

Typical Detention Basin



An idealized extended detention basin: (a) plan (not to scale) and (b) section (not to scale) (ft × 0.304 8 = m) (UDFCD, 1992).

Outlet Configurations

Extended Detention Basin

EDB - Operation

Extended Detention Basin

Extended Detention, Denver

Denver Low Flow Channel

Calculations

- Determine Design Water Quality Volume
- Check outflow with Orifice Equation

  $Q = CA(2gH)^{0.5}$

  Where: Q is discharge (cfs)

  C is orifice coefficient

  A is area of orifice (sq. ft)

  H is depth of water to center of orifice (ft)
- Best done with spreadsheet or routing program
- Design overflow weir with weir equation: $Q=CLH^{3/2}$

Performance Notes

- Effective in particulate removal
- Some dissolved constituent removal (infiltration)
- Detention time is key parameter
- No Bacteria removal (or negative)
- No TPH (oil or diesel)

Detention Basin Performance

Constituent	Average Removal (%)
TSS	64
Nitrate	41
TKN	39
Phosphorus (total)	44
Copper	38
Lead	62
Zinc	59

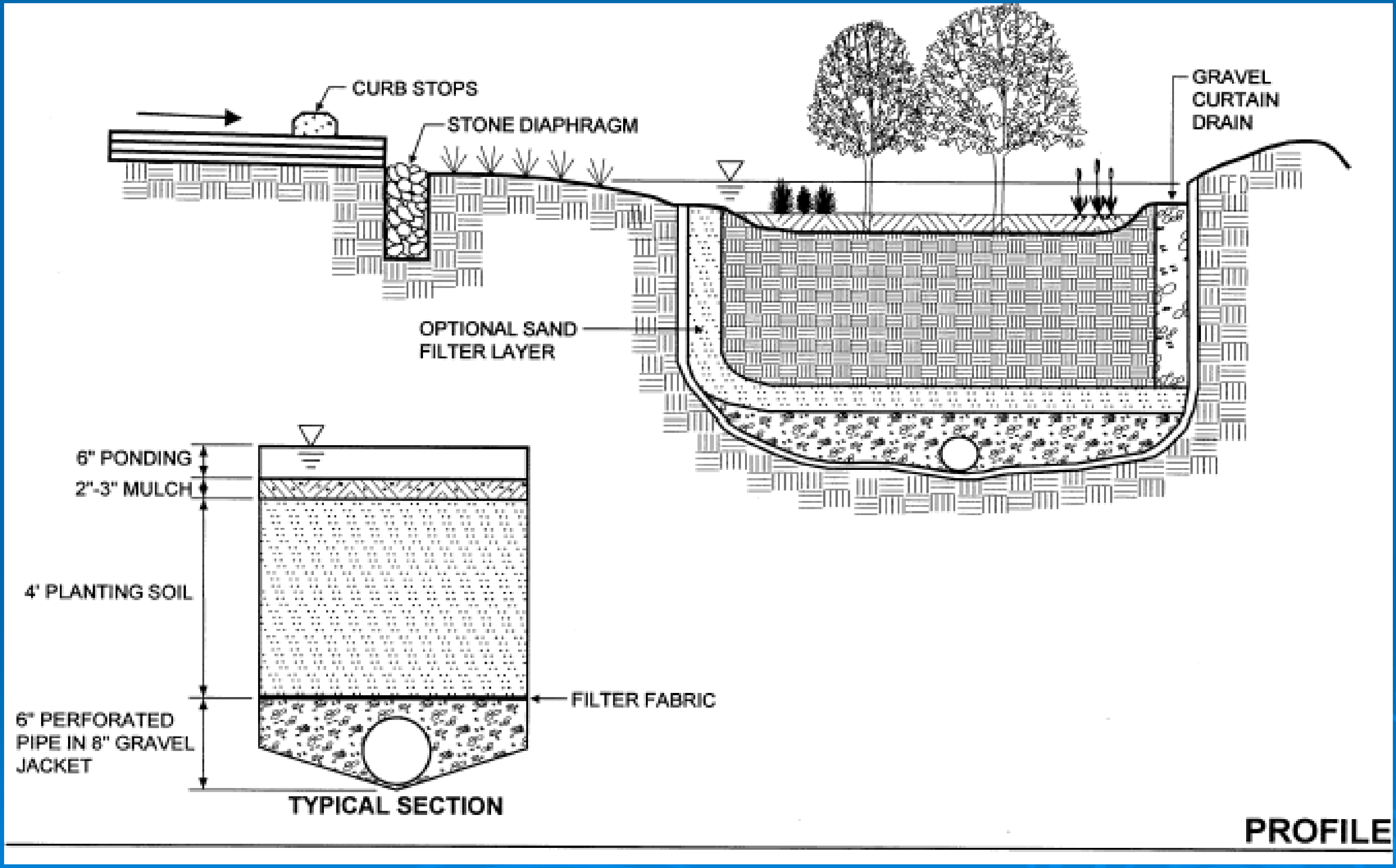
Hitachi - Cottle Road Park

Hitachi - Cottle Road Park

Hitachi - Linear Park

Bioretention Areas

Bioretention Area Profile



Advantages of Bioretention

- Can be used in any type of development
- Aesthetic landscape design element
- Surface area can be any shape
- Treatment accomplished via downward filtration through soil and plant uptake
- Can be used with wide variety of plants (not dependent on filtration through plants)
- Can design with or without underdrain
- Low maintenance

Limitations

- Tributary area should not exceed 2 acres
- Not appropriate for
  - Slopes > 5%
  - High water tables
  - Unstable soils
- Requires irrigation
- Susceptible to clogging, especially if installed prior to construction site soil stabilization

Approaches to Sizing Bioretention Areas

- Flow-Based Method: assume capacity limited by infiltration rate of soil (no storage)
- Volume-Based Method: size based on available storage on top of unit and in pore spaces (no allowance for flow through unit)
- Flow and Volume Method: takes advantage of infiltration rate and storage volume for efficient design (used by BMP Sizing Tool)

Approaches to Sizing Bioretention Areas

- Flow-Based Method: assume capacity limited by infiltration rate of soil (no storage)
- Volume-Based Method: size based on available storage on top of unit and in pore spaces (no allowance for flow through unit)
- Flow and Volume Method: takes advantage of infiltration rate and storage volume for efficient design (used by BMP Sizing Tool)

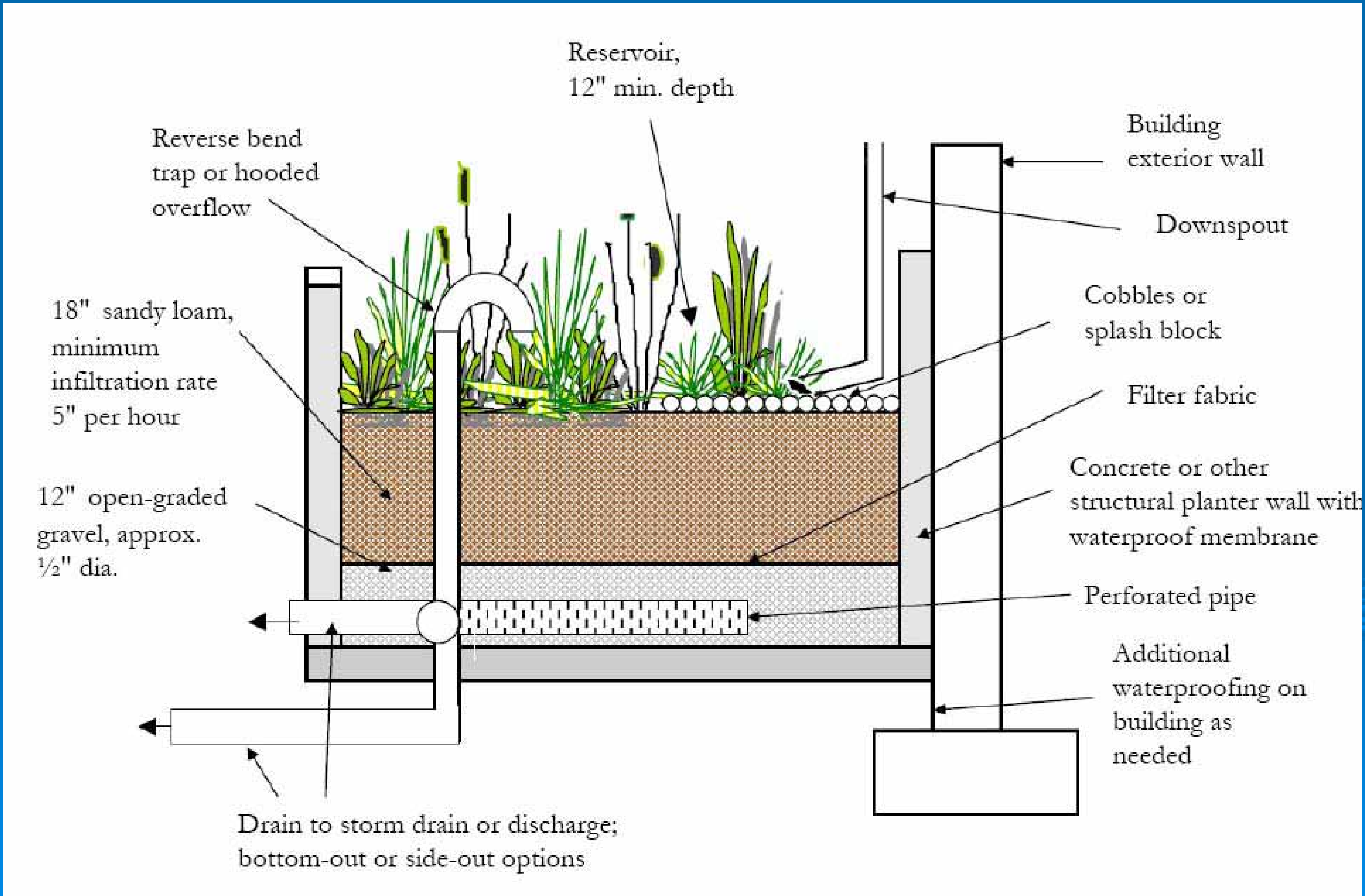
Design Guidelines

- Preliminary sizing – required area is 4% of drainage area to BMP (based on ratio of 0.2 in/hr design rainfall to 5 in/hr infiltration rate)
- Planting soil should have min. 5 in/hr and max. 10 in/hr percolation rate (verify in situ)
  - Use engineered soil mix, typically blend of top soil, sand, and compost, to achieve this
  - Local soil specifications have been developed for Alameda, Contra Costa
- Most locations in Bay Area will require an underdrain system

Design Guidelines, cont.

- Plants should be suitable to well-drained soil with occasional innundation
- Plantings can include shrubs and small trees with spreading roots, not deep tap roots
- Surface ponding depths are typically 6 inches; can go as high as 12 inches
- Provide overflow inlet to convey excess flows to storm drain
- Protect inlet areas with rocks or splash blocks.

Flow Through Planter



Flow Through Planter

- Very similar in function and design to bioretention areas
- Good for treating roof runoff
- Good for dense urban areas
- Can be located close to structures or where infiltration is not desired
- Can be any shape
- Low maintenance

Planters at Hampton Park