



Design Considerations

- Tributary Area
- Area Required
- Slope
- Water Availability

Targeted	
Constituent	Removal

Sediment	Med
Nutrients	Low
Trash	High
Metals	Med
Bacteria	Low
Oil and Grease	Med
Organics	Med
Flow Control	Med

Description

Vegetated swales are open, shallow channels with vegetation covering the side slopes and bottom that collect and slowly convey runoff flow to downstream discharge points. They are designed to treat runoff by filtering through vegetation in the channel, the subsoil matrix, and/or infiltration into the underlying soils. Swales can be natural or manmade. They trap particulate pollutants (suspended solids and trace metals), promote infiltration, and reduce the flow velocity of stormwater runoff. Vegetated swales typically provide conveyance and can serve as part of a stormwater drainage system to replace curbs, gutters and storm sewer systems in conjunction with other treatment control BMPs such as bioretention areas.



California Experience

Caltrans constructed and monitored six vegetated swales in southern California. These swales were generally effective in reducing the volume and mass of pollutants in runoff. Even in the areas where the annual rainfall was only about 10 inches/yr, the vegetation did not require additional irrigation. One factor that strongly affected performance was the presence of large numbers of gophers at most of the sites. The gophers created mounds, destroyed vegetation, and generally reduced the effectiveness of the controls for TSS reduction.

Advantages

- If properly designed, swales can serve as an aesthetic, potentially inexpensive urban development or roadway drainage conveyance measure with significant water quality benefits.

Limitations

- Swales are more susceptible to failure (excessive erosion, channelization) than other BMPs. Grass cover must be properly maintained.
- Not appropriate for areas with concentrated runoff (i.e. locations where spills may occur).
- Cannot treat large areas, but large areas can be divided and treated using multiple swales.
- Can be restricted by law, some municipalities require curb and gutter systems in residential areas.

Performance

Vegetated swales represent a practical and potentially effective technique for controlling urban runoff quality (Table 1). Check dams, slight slopes, permeable soils, dense grass cover, increased contact time, and small storm events all contribute to successful pollutant removal by the swale system.

Table 1. Typical pollutant removal for constituents and removal processes

Pollutant	Typical Removal	Median Effluent Concentration ¹	Removal Processes	References
Sediment	High (20% to 98%)	<u>13.6 mg/L</u>	Sedimentation and filtration.	Deletic and Fletcher 2006; Yu et al. 2001; Bäckström 2002, 2003, 2006; Geosyntec Consultants and Wright Water Engineering 2012; Scholes 2007; Barrett, 2008; Caltrans 2002
Metals	Medium (37%-93%)	<u>TAs: 1.17 µg/L,</u> <u>TCd: 0.31 µg/L,</u> <u>TCr: 2.32 µg/L,</u> <u>TCu: 6.54 µg/L,</u> <u>TFe: 86 µg/L,</u> <u>TPb: 2.02 µg/L,</u> <u>TNi: 3.16 µg/L,</u> <u>TZn: 22.9 µg/L</u>	Removal with sediment.	Fassman 2011; Geosyntec Consultants and Wright Water Engineering 2012; Backstrom, 2003; Barrett, 1998, 2008; Scholes, 2007; Caltrans 2002
Total phosphorus	Low (18%-63%)	<u>0.19 mg/L</u>	Settling with sediment and plant uptake.	Deletic et al. 2006; Geosyntec Consultants and Wright Water Engineering 2012; Yu, 2001; Scholes, 2007; Barrett, 1998;
Total nitrogen	Low (20%-67%)	<u>TN: 0.71 mg/L,</u> <u>TKN: 0.62 mg/L,</u> <u>NO_{2,3}-N: 0.25 mg/L</u>	Settling, sedimentation (TKN) and plant uptake.	Deletic et al. 2006; Geosyntec Consultants and Wright Water Engineering 2012; Caltrans 2002; Barrett, 1998; Yu, 2001
Bacteria	Low (typically exports pathogens)	<u>E. coli: 4190 MPN/100 mL,</u> <u>Fecal coliform: 5000 MPN/100 mL</u>	Limited sedimentation, desiccation, predation, and photolysis at surface.	EPA 2012; Geosyntec Consultants and Wright Water Engineering 2012; Barrett, 1998

¹ Underlined effluent concentrations were (statistically) significantly lower than influent concentrations, as determined by statistical hypothesis testing on the available sampled data. Effluent concentrations displayed in *italics* were (statistically) significantly higher than influent concentrations.

The effectiveness of vegetated swales can be enhanced by adding check dams at approximately 17 meter (50 foot) increments along their length. These dams maximize the retention time within the swale, decrease flow velocities, and promote particulate settling. Finally, the incorporation of vegetated filter strips parallel to the top of the channel banks can help to treat sheet flows entering the swale.

Suitability and Design

The suitability of a swale at a site will depend on land use, size of the area serviced, soil type, slope, imperviousness of the contributing watershed, and dimensions and slope of the swale system (Schueler et al., 1992). The constraints of each site dictate the appropriate sizing and design considerations. Fundamental bioretention design components are as follows:

- Flow rate based design determined by local requirements or sized so that 85% of the annual runoff volume is discharged at less than the design rainfall intensity.
- Identify natural topographic lows and natural drainage courses as ideal locations (Young et al., 1996).
- BMP footprint approximately 10-20% of the drainage area, drainage area less than 2 acres.
- 10-ft setback from foundations, 100-ft from septic fields and water supply wells, and 50-ft from steep slopes.
- Minimum residence time of 10 minutes.
- Maximum design flow velocity of 1 foot per second or less to minimize erosion.
- Availability of irrigation to maintain the vegetation.

Table 2 details a number of core construction components and corresponding design considerations. Retrofitting can increase costs because of demolition of existing pervious surfaces.

Table 2. Cost of design components and associated considerations

Component	Cost	Design Consideration
Excavation	\$0.80/ft ²	2 to 8 ft wide. If greater than 8 ft, channel dividers may be necessary to prevent meandering. Flow depth during the water quality treatment event should not exceed 2/3 the height. Flow depth (100-yr) should be fully contained within the swale.
Fine Grading	\$0.24/ft ²	1% to 6% overall slope (1% to 2% optimum). Slopes greater than 2.5% should incorporate check dams. Side slopes: 3:1 (H:V) or flatter to prevent bank erosion. Swale should not be less than 100 feet in length
Vegetation Sod (buffalo) Seeding	\$0.67/ft ² \$0.15-\$0.22/ft ²	Swales must be thickly vegetated. Turf grasses (not bunch grasses) should be maintained on the surface to prevent erosion and improve treatment. Water and spot fertilize during first year

Vegetation

It is best to install swales at the time of the year when there is a reasonable chance of successful establishment without irrigation. When seeds are used, erosion controls will be necessary to protect seeds for at least 75 days after the first rainfall of the season. If sod tiles must be used, they should be placed so that there are no gaps between the tiles; stagger the ends of the tiles to prevent the formation of channels along the swale or strip. Use a roller on the sod to ensure that no air pockets form between the sod and the soil.

When sustaining regular vegetation is infeasible, earthen swales are a viable alternative (Figure 1), however, a reduction in performance related to the absence of vegetation may result.

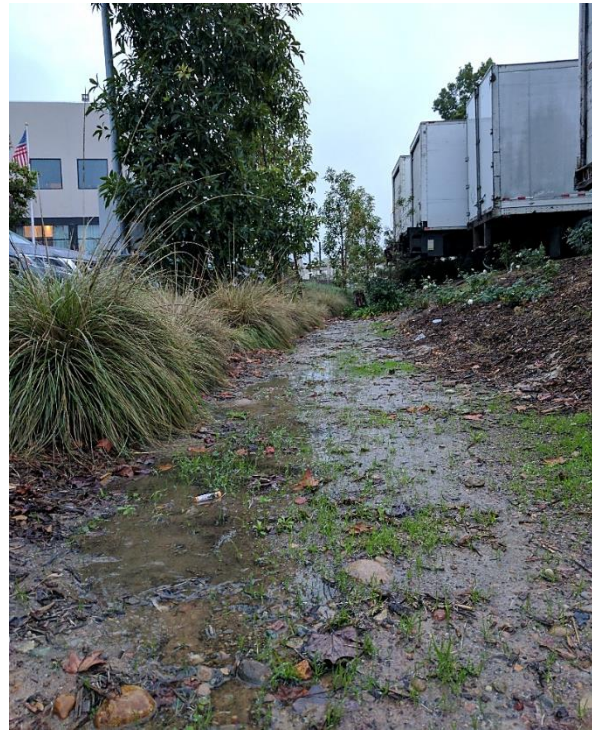


Figure 1. Earthen swale conveying stormwater in San Diego, CA

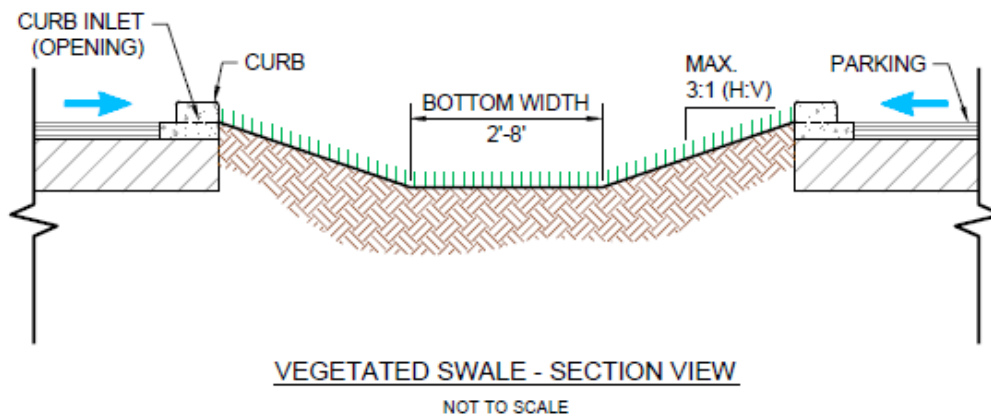
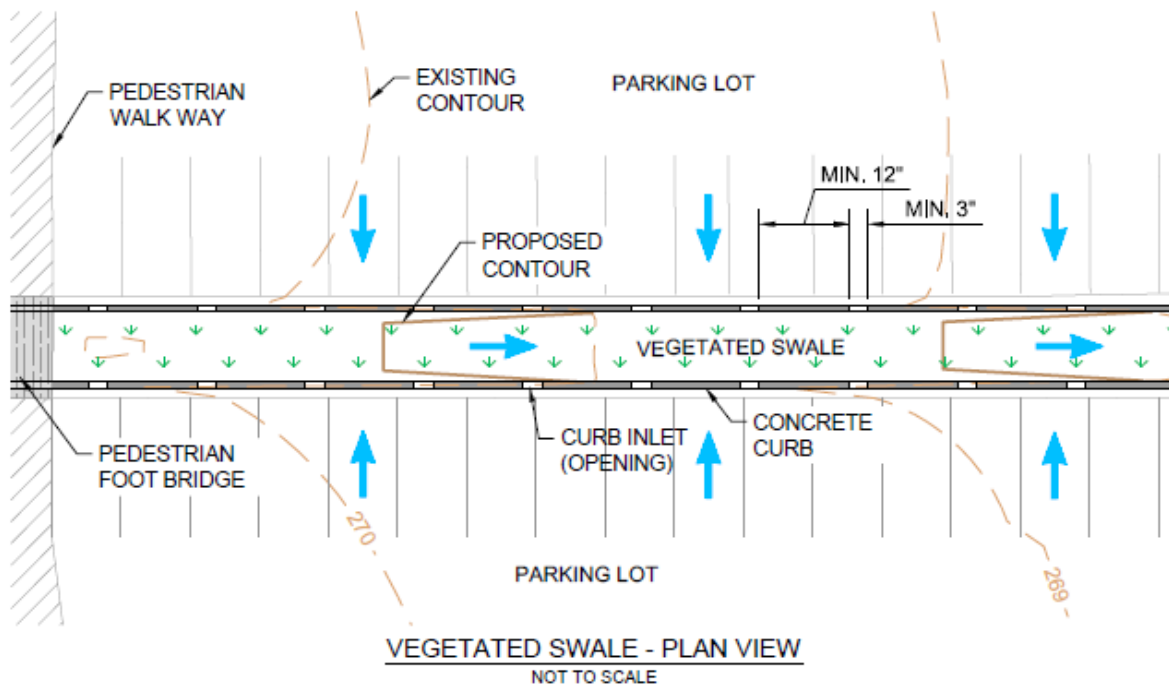
Maintenance

If properly designed and regularly maintained, vegetated swales can last indefinitely. The maintenance objectives for vegetated swale systems include keeping up the hydraulic and removal efficiency of the channel and maintaining a dense, healthy grass cover. Accumulated sediment should be removed manually to avoid concentrated flows in the swale. The application of fertilizers and pesticides should be minimal. Table 3 offers general maintenance activities, costs and frequencies.

Table 3. Typical maintenance activities and associated costs and frequency

Frequency	Cost	Activity
Routine Maintenance (required monthly to every 2 years)		
Routine (small)	\$3.73/ft ²	Remove excess sediment, trash, and debris across the surface, inlet, and outlet. Check for sediment accumulation and erosion. Mow once or twice yearly. Inspect for ponding water to mitigate vector breeding. Repair holes created by rodents.
Routine (medium)	\$1.40/ft ²	
Routine (large)	\$1.01/ft ²	
End of Life Replacement (service life of 20 years)		
Replacement (small)	\$4.17/ft ²	Excavate to the depth of soil media. Test soil for excessive soil contamination of common stormwater pollutants (e.g. metals, nutrients). Continue to remove underlying soil if pollutants exceed standard for contaminated soil. Replace with clean soil.
Replacement (medium)	\$2.33/ft ²	
Replacement (large)	\$2.02/ft ²	
Note: Small System = 500 ft ² ; Medium System = 2000 ft ² ; Large System = 4000 ft ²		

Schematic



VEGETATED SWALE NOTES

1. IF BOTTOM WIDTH GREATER THAN 8 FT., CHANNEL DIVIDERS SHOULD BE INSTALLED TO PREVENT MEANDERING AND LOW-FLOW CHANNEL FORMATION.
2. FLOW DEPTH: WATER QUALITY FLOW DEPTH SHOULD NOT EXCEED 2/3 THE HEIGHT OF THE VEGETATION. 100-YR FLOW DEPTH SHOULD BE FULLY CONTAINED WITHIN THE SWALE.
3. LONGITUDINAL SLOPE: 1% TO 6% OVERALL SLOPE (1% TO 2% RECOMMENDED). SLOPES GREATER THAN 2.5% SHOULD INCORPORATE GRADE CONTROL TO MAINTAIN AN AVERAGE SLOPE OF 2.5% OR LESS. SLOPES FLATTER THAN 0.5% MAY RESULT IN POOR DRAINAGE AND STANDING WATER. FLOW VELOCITY SHOULD NOT EXCEED 3 FT./S IN GRASSED SWALES
4. GRADE CONTROL: PROVIDE 6 IN. TO 18 IN. GRAVEL, WOOD, OR CONCRETE CHECK DAMS WITH GRAVEL SPLASH PADS (ASTM NO. 57 STONE) ON THE DOWNSLOPE SIDE TO MAINTAIN 2.5% SLOPES OR FLATTER.
5. PRETREATMENT: PROVIDE VEGETATED FILTER STRIP (SHEET FLOW) OR COBBLE ENERGY DISSIPATER WHERE PRACTICABLE.
6. VEGETATION: SEE VEGETATION SPECIFICATIONS
7. CURB CUTS AND INLETS SHOULD BE ARMORED

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