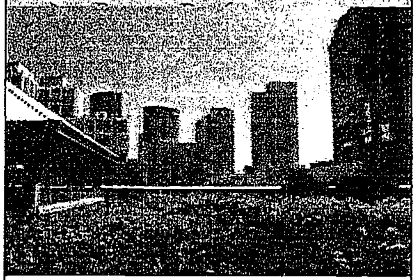
HSC-5: Green Roof / Brown Roof

> **Also known as:**
> - *Ecoroofs*
> - *Roof Gardens*
> - *Vegetated Roof Covers*



Green Roof
Source: Milwaukee Department of Environmental Sustainability

Green roofs are also known as ecoroofs, roof gardens, or vegetated roof covers. Green roofs are roofing systems that layer a soil/vegetative cover over a waterproofing membrane. There are two types of green roofing systems; extensive, which is a light weight system and intensive, which is a heavier system that allows for larger plants but requires additional maintenance. A green roof mimics pre-development conditions by limiting the impervious area created by development. Green roofs filter, absorb, and evapotranspire precipitation to help mitigate the effects of urbanization on water quality and delivery of excess runoff to the local storm water conveyance systems.

Brown roofs are essentially a type of green roof designed to maximize biodiversity. Brown roofs typically utilize natural soil and locally available substrates to create a protected biodiverse habitat for specific species of local flora and fauna. Rather than landscaping the roof during construction, plants are left to germinate and grow on their own in the native soils, thus the "brown" (i.e., initially unvegetated) designation. Hand-seeding may be implemented where self-colonization via airborne seeds is unlikley.

Feasibility Screening Considerations

- Green roofs should be selected with consideration for their impacts on irrigation during the dry season and during dry periods of the wet season.

Opportunity Criteria

- Green roofs can be applied to multi-family residential, commercial, or institutional land uses including rooftops and decks above building structures (e.g., parking structures, outdoor eating area roofs, or storage facilities.
- Roofs are ideally multi-story with significant structural over-design to support the additional weight of the soil, retained water, and plants, as confirmed by a licensed structural engineer.
- Roofs are ideally relatively flat.

OC-Specific Design Criteria and Considerations

- [ ] Saturated soil will weigh approximately 10 – 25 lbs/square foot. If the building and roof are not designed to hold this weight (such as in a retrofit situation), a licensed structural engineer should be consulted.
- [ ] Soil depth should be consistent with minimum depths provided in **Appendix IX**.
- [ ] A drain pipe (gutter) is required to convey runoff safely from the roof.
- [ ] Depending on the design of the roof, a drainage layer may be required to move the excess runoff off of the roof.

- ☐ A waterproof membrane, preventing the roof runoff from penetrating and damaging the roofing material, should be used. There are many materials available for this purpose; they come in various forms (i.e., rolls, sheets, liquid) and exhibit different characteristics (e.g., flexibility, strength, etc.). Depending on the type of membrane chosen a root barrier may be required to prevent roots from compromising the integrity of the membrane.
- ☐ Green roofs should be about 90% vegetated with a mix of erosion resistant plant species that effectively bind the soil and can withstand the extreme environment of rooftops (i.e., heat, cold, and high winds).
- ☐ A diverse selection of low growing plants that thrive under the specific site, climatic, and watering conditions should be specified. A mixture of drought tolerant, self-sustaining (perennial or self-sowing without need for fertilizers, herbicides, and or pesticides) is most effective. Native or adapted sedum/succulent plants are preferred because they generally require less fertilizer, limited maintenance, and are more drought resistant than exotic plants. When appropriate, green roofs may be planted with larger plants; however, this depends on structural support, soil depth, and irrigation requirements.
- ☐ Irrigation is required if the seed is planted in spring or summer. Use of a permanent smart (self-regulating) irrigation system, or other watering system, may help provide maximal water quality performance. Drought-tolerant plants should be specified to minimize irrigation requirements. For projects seeking "High Performance Building" recognition, ASHRAE Standard 189.1 states that potable water cannot be used for irrigating green roofs after they are established.
- ☐ Locate the green roof in an area without excessive shade to avoid poor vegetative growth. For moderately shaded areas, shade tolerant plants should be used.
- ☐ Project-specific planting recommendations should be provided by a landscape professional including recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation growth.

Sizing

Appendix IX provides minimum criteria for green roofs to be considered self-retaining and shall be the governing sizing basis for green roofs.

Configuration for Use in a Treatment Train

- If implemented in a treatment train, green roofs are typically at the most upstream end. A green roof placed upgradient of a cistern can improve the quality and reduce the rate and volume of water flowing to the cistern. Alternatively, a planter box could be placed downstream of a downspout that drains the green roof.

Additional References for Design Guidance

- Los Angeles Unified School District Stormwater Technical Manual, 2009. http://www.laschools.org/employee/design/fs-studies-and-reports/download/white_paper_report_material/Storm_Water_Technical_Manual_2009-opt-red.pdf?version_id=76975850
- City of Santa Barbara, Technical Guidance Manual for Post-Construction Storm Water Management, 2008. http://www.santabarbaraca.gov/NR/rdonlyres/91D1FA75-C185-491E-A882-49EE17789DF8/0/Manual_071008_Final.pdf
- Portland Stormwater Management Manual. http://www.portlandonline.com/bes/index.cfm?c=35122&a=55791
- San Diego County – Low Impact Development Fact Sheets. http://www.sdcounty.ca.gov/dplu/docs/LID-Appendices.pdf

- Brown Roofs. http://www.brownroofs.co.uk/brown-roof-maintenance.php

HSC-6: Blue Roof

Blue roofs, also known as rooftop detention systems, serve as a rooftop storage designed to reduce runoff peaks and volumes. Captured stormwater, up to the design depth, is held on the rooftop until the water either evaporates or is slowly metered out via flow restriction valves. With sufficent waterproofing blue roofs can be implemented on exisiting structures, given that the roof and building are of sufficient structural integrity to support the weight for the ponded water. As blue roofs lack vegetation, they require significantly less maintenance than green or brown roofs. *Note: Blue roofs should not be designed to hold standing water longer than 96 hours in order to mitigate vector hazards.*

Also known as:

- Rooftop Detention Systems

Blue Roof
Source: New York Department of Environmental Protection

Feasibility Screening Considerations

- Potential feasibility concerns for blue roofs relate to standing water (vectors) and structural requirements, however these constaints can generally be overcome with careful design.

Opportunity Criteria

- Blue roofs can be applied to multi-family residential, commercial, or institutional land uses including rooftops and decks above building structures (e.g., parking structures, outdoor eating area roofs, or storage facilities).
- Building structure must be adequate to support the additional weight of the retained water.
- Roof slope must be flat.

OC-Specific Design Criteria and Considerations

- ☐ A licensed structural engineer should be consulted regarding the weight bearing capacity of the structure prior to design. Retrofit may be required.
- ☐ Blue roof discharges must be treated by an acceptable biotreatment BMP.
- ☐ A drain pipe (gutter) is required to convey runoff safely from the roof.
- ☐ A waterproof membrane, preventing the retained water from penetrating and damaging the roofing material, should be used. There are many materials available for this purpose; they come in various forms (i.e., rolls, sheets, liquid) and exhibit different characteristics (e.g., flexibility, strength, etc.).
- ☐ Unless covered, the maximum detention time should comply with all local, state, and federal regulations. Maximum hold time is typically 72-hours to prevent the breeding of mosquitoes.
- ☐ Over time rooftop vegetation may sprout by means of windblown sediment and seeds, especially in a dusty, windy environment. Roof drains should be inspected for clogging, as this may adversely affect downstream BMPs.

Sizing

- Blue roofs will not generally be able to achieve full retention of the DCV and are most applicable as HSCs as the first part of a treatment train. In this role, the retention depth of the blue roof would be removed from the remaining sizing criteria for downstream BMPs.

Configuration for Use in a Treatment Train

- A blue roof would serve as the first unit within a treatment train, with captured flows metered to a planter box, rain garden, infiltration gallery, or, if the site is not conducive for infiltration, potentially to a cistern or underground detention area for on-site rainwater use.

Additional References for Design Guidance

- City of New York – Sustainable Stormwater Management Plan, 2008. http://www.nyc.gov/html/planyc2030/downloads/pdf/sustainable_stormwater_plan.pdf
- Enviornmental Protection – Blue Roofs the Stormwater-Sustainability Link. http://eponline.com/blogs/planetshed/2010/04/blue-roofs-the-stormwatersustainability-link.aspx

XIV.2. Miscellaneous BMP Design Element Fact Sheets (MISC)

MISC-1: Planting/Storage Media

Also known as:

- Bioretention soil media (BSM)

Street-end biofiltration with planting/storage media
Source: City of Portland

Planting and storage media is a critical design element for several common BMP types, including bioretention, bioinfiltration, swales, filter strips, and greenroofs. This fact sheet is intended to be used as referenced from these fact sheets.

General Design Criteria

- Planting/storage media should be designed to achieve the long term hydraulic design requirements associated with the design of the facility (i.e., design K_{sat}).
- The planting media shall be designed to address pollutants of concern at the design hydraulic capacity.
- Bioretention soil shall also support vigorous plant growth.
- Planting media should consist of 60 to 80% fine sand and 20 to 40% compost.
- Planting media for projects draining to nutrient sensitive receiving water should adhere to recommendations for nutrient sensitive planting media provided below.

Sand

- Sand should be free of wood, waste, coating such as clay, stone dust, carbonate, etc., or any other deleterious material. All aggregate passing the No. 200 sieve size should be non-plastic. Sand for bioretention should be analyzed by an accredited lab using #200, #100, #40, #30, #16, #8, #4, and 3/8 sieves (ASTM D 422 or as approved by the local permitting authority) and meet the following gradation (Note: all sands complying with ASTM C33 for fine aggregate comply with the gradation requirements below):

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
3/8 inch	100	100
#4	90	100
#8	70	100
#16	40	95
#30	15	70
#40	5	55
#100	0	15
#200	0	5

- Note: the gradation of the sand component of the media is believed to be a major factor in the hydraulic conductivity of the media mix. If the desired hydraulic conductivity of the media cannot be achieved within the specified proportions of sand and compost (#2), then it may be necessary to utilize sand at the coarser end of the range specified in the table above ("minimum" column).

Compost

Compost should be a well decomposed, stable, weed free organic matter source derived from waste materials including yard debris, wood wastes, or other organic materials not including manure or biosolids meeting standards developed by the US Composting Council (USCC). The product shall be certified through the USCC Seal of Testing Assurance (STA) Program (a compost testing and information disclosure program). Compost quality should be verified via a lab analysis to be:

- Feedstock materials shall be specified and include one or more of the following: landscape/yard trimmings, grass clippings, food scraps, and agricultural crop residues.
- Organic matter: 35-75% dry weight basis.
- Carbon and Nitrogen Ratio: 15:1 < C:N < 25:1
- Maturity/Stability: shall have dark brown color and a soil-like odor. Compost exhibiting a sour or putrid smell, containing recognizable grass or leaves, or is hot (120 F) upon delivery or rewetting is not acceptable.
- Toxicity: any one of the following measures is sufficient to indicate non-toxicity:
  - NH4:NH3 < 3
  - Ammonium < 500 ppm, dry weight basis
  - Seed Germination > 80% of control
  - Plant trials > 80% of control
- Solvita® > 5 index value
- Nutrient content:
  - Total Nitrogen content 0.9% or above preferred
  - Total Boron should be <80 ppm, soluble boron < 2.5 ppm
- Salinity: < 6.0 mmhos/cm
- pH between 6.5 and 8 (may vary with plant palette)
- Compost for bioretention should be analyzed by an accredited lab using #200, ¼ inch, ½ inch, and 1 inch sieves (ASTM D 422 or as approved by the local permitting authority) and meet the following gradation:

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
1 inch	99	100
½ inch	90	100
¼ inch	40	90
#200	2	10

- Tests should be sufficiently recent to represent the actual material that is anticipated to be delivered to the site. If processes or sources used by the supplier have changed significantly since the most recent testing, new tests should be requested.
- Note: the gradation of compost used in bioretention media is believed to play an important role in the saturated hydraulic conductivity of the media. To achieve a higher saturated hydraulic conductivity, it may be necessary to utilize compost at the coarser end of this range ("minimum" column). The percent passing the #200 sieve (fines) is believed to be the most important factor in hydraulic conductivity. In addition, a coarser compost mix provides more heterogeneity of the bioretention media, which is believed to be advantageous for more rapid development of soil structure needed to support health biological processes. This may be an advantage for plant establishment with lower nutrient and water input.

Mulch

- Planting area should generally be covered with 2 to 4 inches (average 3 inches) of mulch at the start and an additional placement of 1 to 2 inches of mulch should be added annually. *The intention is that to help sustain the nutrient levels, suppress weeds, retain moisture, and maintain infiltration capacity.*
- For nutrient-sensitive planting/storage media design, inorganic mulch such as gravel, may be used.

Planting/Storage Media Design for Nutrient Sensitive Receiving Waters

Where the BMP discharges to receiving waters with nutrient impairments or nutrient TMDLs, the planting media placed should be designed with the specific goal of minimizing the potential for initial and long term leaching of nutrients from the media.

- In general, the potential for leaching of nutrients can be minimized by:
  - Utilizing stable, aged compost (as required of media mixes under all conditions).
  - Utilizing other sources of organic matter, as appropriate, that are safe, non-toxic, and have lower potential for nutrient leaching than compost.
  - Reducing the content of compost or other organic material in the media mix to the minimum amount necessary to support vigorous plant growth and healthy biological processes.
- A landscape architect should be consulted to assist in the design of planting/storage media to balance the interests of plant establishment, water retention capacity (irrigation demand), and the potential for nutrient leaching. The following practices should be considered in developing the media mix design:
  - The actual nutrient content and organic content of the selected compost source should be considered when specifying the proportions of compost and sand. The compost specification allows a range of organic content over approximately a factor of 2 and nutrient content may vary more widely. Therefore determining the actual organic content and nutrient content of the compost expected to be supplied is important in determining the proportion to be used for amendment.
  - A commitment to periodic soil testing for nutrient content and a commitment to adaptive management of nutrient levels can help reduce the amount of organic amendment that must be provided initially. Generally, nutrients can be added planting areas through the addition of organic mulch, but cannot be removed.
  - Plant palettes and the associated planting mix should be designed with native plants where possible. Native plants generally have a broader tolerance for nutrient content, and can be longer lived in leaner/lower nutrient soils. An additional benefit of lower nutrient levels is that native plants will generally have less competition from weeds.

- Nutrients are better retained in soils with higher cation exchange capacity (CEC). CEC can be increased through selection of organic material with naturally high CEC, such as peat, and/or selection of inorganic material with high CEC such as some sands or engineered minerals (e.g., low P-index sands, zeolites, rhyolites, etc). Including higher CEC materials would tend to reduce the net leaching of nutrients.
- Soil structure can be more important than nutrient content in plant survival and biologic health of the system. If a good soil structure can be created with very low amounts of compost, plants survivability should still be provided. Soil structure is loosely defined as the ability of the soil to conduct and store water and nutrients as well as the degree of aeration of the soil. While soil structure generally develops with time, planting/storage media can be designed to promote earlier development of soil structure. Soil structure is enhanced by the use of amendments with high hummus content (as found in well-aged organic material). In addition, soil structure can be enhanced through the use of compost/organic material with a distribution of particle sizes (i.e., a more heterogeneous mix). Finally, inorganic amendments such as polymer beads may be useful for promoting aeration and moisture retention associated with a good soil structure. An example of engineered soil to promote soil structure can be found here:

  http://www.hort.cornell.edu/uhi/outreach/pdfs/custructuralsoilwebpdf.pdf
- Younger plants are generally more tolerant of lower nutrient levels and tend to help develop soil structure as they grow. Starting plants from smaller transplants can help reduce the need for organic amendments and improve soil structure. The project should be able to accept a plant mortality rate that is somewhat higher than starting from larger plants and providing high organic content.

- With these considerations, it is anticipated that less than 10 percent compost amendment could be used, while still balancing plant survivability and water retention.

We wish to express our gratitude to following individuals for their feedback on the design of planting/storage media for nutrient sensitive receiving waters in Southern California.

Deborah Deets, City of Los Angeles Bureau of Sanitation

Drew Ready, LA and San Gabriel Rivers Watershed Council

Rick Fisher, ASLA, City of Los Angeles Bureau of Engineering

Dr. Garn Wallace, Wallace Laboratories

Glen Dake, GDML

Jason Schmidt, Tree People

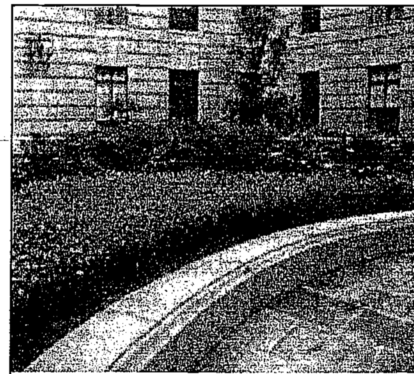
The guidance provided herein does not reflect the individual opinions of any individual listed above and should not be cited or otherwise attributed to those listed.

Selecting Plants for Planting/Storage Media

- Plant materials should be tolerant of summer drought, ponding fluctuations, and saturated soil conditions for 48 to 96 hours.
- It is recommended that a minimum of three types of tree, shrubs, and/or herbaceous groundcover species be incorporated to protect against facility failure due to disease and insect infestations of a single species.
- Native plant species and/or hardy cultivars that are not invasive and do not require chemical inputs should be used to the maximum extent feasible.

MISC-2: Amended Soils

Soil amendments alter the soil characteristics to allow it to absorb, infiltrate, and retain more water to help reduce runoff volume and velocity, filter pollutants, increase the quality and quantity of vegetation, and reduce erosion potential more effectively than soils without soil amendments. Mulch is an amendment that is added on the top of the soil, rather than mixed into the soil, which reduces evaporation and adds to the aesthetics of a site. Compost and fertilizers are common soil amendments that must be completely mixed into the soil to function properly.



Soil amended area at U.S. EPA Ariel Rios building.
Source: http://www.epa.gov/oaintrnt/stormwater/hq_projects.htm

General Criteria

- Compost, soil conditioners, and fertilizers should be roto-tilled into the native soil to a minimum depth of 6" (12 inches preferred). Mulch at grade should be spread over all planting areas to a depth of 3".
- Sand can be used as an amendment to improve the drainage rates of amended soils. Sand should be free of stones, stumps, roots or other similar objects larger than 5 mm
- Incorporating compost and other organics into the root zone results in enhanced biological activity, attenuation of envrionemntal contaminants, increased moisture holding capacity, and improved soil structure. Compost shall meet the specifications below.
- All soil amendments should be free of stones, stumps, roots or other similar objects larger than 2 inches.
- All soil amendments should be free of glass, plastic, metal, and other deleterious materials.

Accounting for Soil Amendments in Sizing Calculations

No retention credit is given for amended soils alone. Amended soils should be used as part of HSC-2 Impervious Area Dispersion, and to increase the retention volume of Infiltration and Biotreatment BMPs.

Additional References

Los Angeles Unified School District (LAUSD) Stormwater Technical Manual, Chapter 3: http://www.laschools.org/employee/design/fs-studies-and-reports/download/white_paper_report_material/Storm_Water_Technical_Manual_2009-opt-red.pdf?version_id=76975850

Santa Barbara BMP Guidance Manual, Chapter 5: http://www.santabarbaraca.gov/NR/rdonlyres/91D1FA75-C185-491E-A882-49EE17789DF8/0/Manual_071008_Final.pdf

- San Diego County LID Handbook Appendix 4 (Factsheet 30): http://www.sdcounty.ca.gov/dplu/docs/LID-Appendices.pdf

XIV.3. Infiltration BMP Fact Sheets (INF)

INF-1: Infiltration Basin Fact Sheet

An infiltration basin consists of an earthen basin constructed in naturally pervious soils (Type A or B soils) with a flat bottom. An energy dissipating inlet must be provided, along with an emergency spillway to control excess flows. An optional relief underdrain may be provided to drain the basin if standing water conditions occur. A forebay settling basin or separate treatment control measure must be provided as pretreatment. An infiltration basin retains the stormwater quality design volume in the basin and allows the retained runoff to percolate into the underlying soils in 72 hours or less. The bottom of an infiltration basin is typically vegetated with dryland grasses or irrigated turf grass; however other types of vegetation are permissible if they can survive periodic inundation and long inter-event dry periods.

Feasibility Screening Considerations

- Infiltration bains shall pass infeasibility screening criteria to be considered for use
- Infiltration basins pose a potential risk of groundwater contamination if underlying soils have very high permeability and low pollutant assimilation capacity; pretreatment should always be provided.
- Evaporation tends to be minor, therefore increases in infiltration compared to natural conditions may result.
- The potential for groundwater mounding should be evaluated if depth to seasonally high groundwater (unmounded) is less than 15 feet.

Also known as:
- *Recharge basins*
- *Infiltration pond*

Infiltration Basin

Source: Pennsylvania Stormwater BMP Manual

Opportunity Criteria

- Soils are adequate for infiltration or can be amended to provide an adequate infiltration rate.
- Typically need 2-5 percent of drainage area available for infiltration.
- Space available for pretreatment (biotreatment or treatment control BMP as described below).
- Potential for groundwater contamination can be mitigated through isolation of pollutant sources, pretreatment of inflow, and/or demonstration of adequate treatment capacity of underlying soils.
- Infiltration is into native soil, or
- The depth of engineered fill is ≤ 5 feet from the bottom of the facility to native material and infiltration into fill is approved by a geotechnical professional.
- Tributary area land uses include mixed-use and commercial, sngle-family and multi-family, roads and parking lots, and parks and open spaces. Basins can be integrated into parks and open spaces. High pollutant land uses should not be tributary to infiltration BMPs.

OC-Specific Design Criteria and Considerations

☐ Placement of BMPs shall observe geotechnical recommendations with respect to geological hazards (e.g. landslides, liquefaction zones, erosion, etc.) and set-backs (e.g., foundations, utilities, roadways, etc.)

- ☐ For facilities with tributary area less than 5 acres, minimum separation to mounded seasonally high groundwater of 5 feet shall be observed.
- ☐ For facilities with tributary area greater than 5 acres, minimum separation to mounded seasonally high groundwater of 10 feet shall be observed.
- ☐ Minimum pretreatment (settling forebay or separate BMP) should be provided upstream of the infiltration basin, and water bypassing pretreatment should not be directed to the infiltration basin.
- ☐ If a settling forebay is used, forebay should have a volume equal to 25% of facility volume and have a minimum length to width ratio of 2:1
- ☐ Infiltration basins should not be used for drainage areas with high sediment production potential unless preceded by full treatment control with a BMP effective for sediment removal.
- ☐ Side-slopes should be no steeper than 3H:1V.
- ☐ Design infiltration rate should be determined consistent with guidance contained in **Appendix VII.**
- ☐ Energy dissipators should be provided at inlet and outlet to prevent erosion.
- ☐ An overflow device must be provided if basin is on-line.
- ☐ A minimum freeboard of one foot should be provided above the overflow device (for an on-line basin) or the outlet (for an off-line basin).
- ☐ Infiltration basin bottom must be as flat as possible.
- ☐ Basin length to width ratio should be a minimum of 2:1 L:W.

Simple Sizing Method for Infiltration Basins

If the Simple DCV Sizing Method is used to size an infiltration basin, the user calculates the DCV and designs the BMP geometry required to draw down the DCV in 48 hours. The sizing steps are as follows:

Step 1: Determine Infiltration Basin DCV

Calculate the DCV using the Simple Design Capture Volume Sizing Method described in **Appendix III.3.1.**

Step 2: Determine the 48-hour Depth

The depth of water that can be drawn down in 48 hours can be calculated using the following equation:

$$d_{48} = K_{DESIGN} \times 4$$

Where:

d_{48} = basin 48-hour drawdown depth, ft

K_{DESIGN} = basin design infiltration rate, in/hr (See **Appendix VII**)

This is the maximum depth of the basin below the overflow device to achieve drawdown in 48 hours.

Step 3: Calculate the Required Infiltrating Area

The required infiltrating area (i.e. basin area at mid ponding depth) can be calculated using the following equation:

$$A = DCV / (d_P)$$

Where:

A = required basin infiltrating area, sq-ft (assumed to be the basin area at mid-ponding depth)

DCV = design capture volume, cu-ft (see Step 1)

d_P = ponding depth, ft (should be equal to or less than d_{48})

Capture Efficiency Method for Infiltration Basins

If BMP geometry has already been defined and deviates from the 48 hour drawdown time, the designer can use the Capture Efficiency Method for Volume-Based, Constant Drawdown BMPs (See **Appendix III.3.2**) to determine the fraction of the DCV that must be provided to manage 80 percent of average annual runoff volume. This method accounts for drawdown time different than 48 hours.

Step 1: Determine the drawdown time associated with the selected basin geometry

$$DD = (d_P / K_{DESIGN}) \times 12$$

Where:

DD = time to completely drain infiltration basin ponding depth, hours

d_P = ponding depth below overflow device, ft

K_{DESIGN} = basin design infiltration rate, in/hr (See **Appendix VII**)

Step 2: Determine the Required Adjusted DCV for this Drawdown Time

Use the Capture Efficiency Method for Volume-Based, Constant Drawdown BMPs (**Appendix III.3.2**) to calculate the fraction of the DCV the basin must hold to achieve 80 percent capture of average annual stormwater runoff volume based on the basin drawdown time calculated above.

Step 3: Determine the Basin Infiltrating Area Needed

The required infiltrating area (i.e. basin bottom) can be calculated using the following equation:

$$A = DCV/ ((d_P)$$

Where:

A = required basin infiltrating area, sq-ft (assumed to be the basin area at mid-ponding depth)

DCV = design capture volume, adjusted for drawdown time, cu-ft (see Step 1)

d_P = ponding depth, ft

If the area required is greater than the selected basin area, adjust surface area or adjust ponding depth and recalculate required area until the required area is achieved.

Configuration for Use in a Treatment Train

- Infiltration basins may be preceeded in a treatment train by HSCs in the drainage area, which would reduce the required design volume of the basins.
- Infiltration basins must be preceeded by some form of pretreatment, which may be biotreatment or a treatment control BMP; if an approved biotreatment BMP is used as pretreatment, the overflow from the infiltration basin may be considered "biotreated" for the purposes of meeting the LID requirements.
- The overflow or bypass from an infiltration basin can be routed to a downstream biotreatment BMP and/or a treatment control BMP if additional control is required to achieve LID or treatment control requirements.

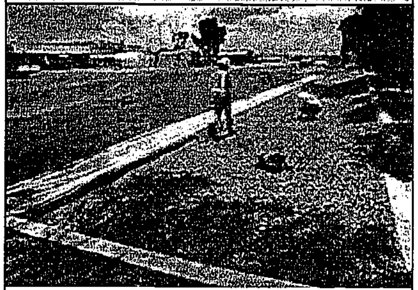
Additional References for Design Guidance

- CASQA BMP Handbook for New and Redevelopment: http://www.cabmphandbooks.com/Documents/Development/TC-11.pdf
- SMC LID Manual (pp 139): http://www.lowimpactdevelopment.org/guest75/pub/All_Projects/SoCal_LID_Manual/SoCalLID_Manual_FINAL_040910.pdf
- Los Angeles County Stormwater BMP Design and Maintenance Manual, Chapter 6: http://dpw.lacounty.gov/DES/design_manuals/StormwaterBMPDesignandMaintenance.pdf
- City of Portland Stormwater Management Manual (Basin, page 2-57) http://www.portlandonline.com/bes/index.cfm?c=47954&a=202883
- San Diego County LID Handbook Appendix 4 (Factsheet 2): http://www.sdcounty.ca.gov/dplu/docs/LID-Appendices.pdf

INF-2: Infiltration Trench Fact Sheet

Also known as:

- French Drains
- Rock Trenches
- Exfiltration Trenches
- Soak-aways
- Soakage Trenches



Infiltration Trench

Source: www.dot.ca.gov

An infiltration trench is a long, narrow, rock-filled trench with no outlet other than an overflow outlet. Runoff is stored in the void space between stones and infiltrates through the bottom and sides of the trench. Infiltration trenches provide the majority of their pollutant removal benefits through volume reduction. Pretreatment is important for limiting amounts of coarse sediment entering the trench which can clog and render the trench ineffective. *Note: if an infiltration trench is "deeper than its widest surface dimension," or includes an assemblage of perforated pipes, drain tiles, or other similar mechanisms intended to distribute runoff below the surface of the ground, it would probably be considered a "Class V Injection Well" under the federal Underground Injection Control (UIC) Program, which is regulated in California by U.S. EPA Region 9. A UIC permit may be required for such a facility (for details see* **http://www.epa.gov/region9/water/groundwater/uic-classv.html**).

Feasibility Screening Considerations

- Infiltration trenches shall pass infeasibility screening criteria to be considered for use
- Infiltration trenches, particularly deeper designs, may not provide significant attenuation of stormwater pollutants if underlying soils have high permeability; potential risk of groundwater contamination.
- The potential for groundwater mounding should be evaluated if depth to seasonally high groundwater (unmounded) is less than 15 feet.

Opportunity Criteria

- Soils are adequate for infiltration or can be amended to provide an adequate infiltration rate.
- Drainage area area is ≤ 5 acres and has low to moderate sediment production.
- 2-3 percent of drainage area available for infiltration (generally requires less surface area than infiltration basins and bioretention areas without underdrain).
- Space available for pretreatment (biotreatment or treatment control BMP as described below).
- Potential for groundwater contamination can be mitigated through isolation of pollutant sources, pretreatment of inflow, and/or demonstration of adequate treatment capacity of underlying soils.
- Infiltration is into native soil, or depth of engineered fill is ≤ 5 feet from the bottom of the facility to native material and infiltration into shallow fill is approved by a geotechnical professional.
- Tributary area land uses include open areas adjacent to parking lots, driveways, and buildings, and roadway medians and shoulders.

OC-Specific Design Criteria and Considerations

☐ Must comply with local, state, and federal UIC regulations if applicable; a permit may be required.

- ☐ Placement of BMPs should observe geotechnical recommendations with respect to geological hazards (e.g. landslides, liquefaction zones, erosion, etc.) and set-backs (e.g., foundations, utilities, roadways, etc.)
- ☐ For facilities with tributary area less than 1 acre and less than 3 foot depth, minimum separation to mounded seasonally high groundwater of 5 feet shall be observed.
- ☐ For facilities with tributary area greater than 1 acre or deeper than 3 feet, minimum separation to mounded seasonally high groundwater of 10 feet shall be observed.
- ☐ Minimum pretreatment should be provided upstream of the infiltration trench, and water bypassing pretreatment should not be directed to the infiltration trench.
- ☐ Infiltration trenches should not be used for drainage areas with high sediment production potential unless preceded by full treatment control with a BMP effective for sediment removal.
- ☐ Ponded water should not persist within 1 foot of the surface of the facility for longer than 72 hours following the end of a storm event (observation well is needed to allow observation of drain time).
- ☐ Energy dissipators should be provided at inlet and outlet to prevent erosion.
- ☐ An overflow device must be provided if basin is on-line.
- ☐ A minimum freeboard of one foot should be provided above the overflow device (for an on-line basin) or the outlet (for an off-line basin).
- ☐ Longitudinal trench slope should not exceed 3%.
- ☐ Side slopes above trench fill should not be steeper than 3:1.

Simple Sizing Method for Infiltration Trenches

If the Simple Design Capture Volume Sizing Method is used to size an infiltration trench, the user calculates the DCV and then designs the geometry required to draw down the DCV in 48 hours. The sizing steps are as follows:

Step 1: Determine Infiltration Basin DCV

Calculate the DCV using the Simple Design Capture Volume Sizing Method described in **Appendix III.3.1**.

Step 2: Determine the 48-hour Effective Depth

The depth of water that can be drawn down in 48 hours can be calculated using the following equation:

$$d_{48} = K_{DESIGN} \times SACF \times 48 \text{ hours}$$

Where:

d_{48} = trench effective 48-hour depth, ft

K_{DESIGN} = basin design infiltration rate, in/hr (See **Appendix VII**)

SACF = Surface Area Correction Factor = ranges from 1.0 (sides insignificant or not accounted) to 2.0 (sides plus bottom are 2 times the surface area of the bottom at mid depth) to account for the ratio of infiltration through the sides of the trench to the bottom footprint of the trench; should be based on anticipated trench geometry and wetted surface area at mid-depth.

This is the maximum effective depth of the trench below the overflow device to achieve drawdown in 48 hours.

Step 3: Determine the Trench Ponding Depth and Trench Depth

The depth of water stored in the ponding depth (i.e. above the trench fill) and within the trench itself should be equal or less than d_{48}. Determine the ponding depth and the trench fill depth such that:

$$d_{48} \geq (n_T \times d_T + d_P)$$

Where:

d_{48} = trench effective 48-hour depth, ft (from Step 2)

n_T = porosity of trench fill; 0.35 may be assumed where other information is not available

d_T = depth of trench fill, ft

d_P = ponding depth, ft (should not exceed 1 ft)

Step 4: Calculate the Required Infiltrating Area

The required footprint area can be calculated using the following equation:

$$A = DCV / ((n_T \times d_T) + d_P)$$

Where:

A = required trench footprint area, sq-ft

DCV = design capture volume, cu-ft (see Step 1)

n_T = porosity of trench fill; 0.35 may be assumed where other information is not available

d_T = depth of trench fill, ft

d_P = ponding depth, ft

Capture Efficiency Method for Infiltration Trenches

If BMP geometry has already been defined and deviates from the 48 hour drawdown time, the designer can use the Capture Efficiency Method for Volume-Based, Constant Drawdown BMPs (**Appendix III.3.2**) to determine the fraction of the DCV that must be provided to manage 80 percent of average annual runoff volume. This method accounts for drawdown time different than 48 hours.

Step 1: Determine the drawdown time associated with the selected trench geometry

$$DD = ((n_T \times d_T) + d_P) / (K_{DESIGN} \times SACF) \times 12$$

Where:

DD = time to completely drain infiltration basin ponding depth, hours

n_T = porosity of trench fill; 0.35 may be assumed where other information is not available

d_T = depth of trench fill, ft

d_P = ponding depth, ft

SACF = Surface Area Correction Factor = ranges from 1.0 (sides insignificant or not accounted) to 2.0 (sides plus bottom are 2 times the surface area of the bottom at mid depth) to account for the ratio of infiltration through the sides of the trench to the bottom footprint of the trench; should be based on anticipated trench geometry and wetted surface area at mid-depth.

K_{DESIGN} = basin design infiltration rate, in/hr (See **Appendix VII**)

Step 2: Determine the Required Adjusted DCV for this Drawdown Time

Use the Capture Efficiency Method for Volume-Based, Constant Drawdown BMPs (**Appendix III.3.2**) to calculate the required fraction of the DCV the basin must hold to achieve 80 percent capture of average annual stormwater runoff volume based on the trench drawdown time calculated above.

Step 3: Determine the Trench Infiltrating Area Needed

The required footprint area can be calculated using the following equation:

$$A = DCV / ((n_T \times d_T) + d_P)$$

Where:

A = required trench footprint area, sq-ft

DCV = design capture volume, cu-ft (see Step 1)

n_T = porosity of trench fill; 0.35 may be assumed where other information is not available

d_T = depth of trench fill, ft

d_P = ponding depth, ft

If the area required is greater than the selected trench area, adjust surface area or adjust ponding and/or trench depth and recalculate required area until the required area is achieved.

Configuration for Use in a Treatment Train

- Infiltration trenches may be preceeded in a treatment train by HSCs in the drainage area, which would reduce the required volume of the trench.
- Infiltration trenches must be preceeded by some form of pretreatment which may be biotreatment or a treatment control BMP; if an approved biotreatment BMP is used as pretreatment, the overflow from the infiltration trench may be considered "biotreated" for the purposes of meeting the LID requirments
- The overflow or bypass from an infiltration trench can be routed to a downstream biotreatment BMP and/or a treatment control BMP if additional control is required to achieve LID or treatment control requirements

Additional References for Design Guidance

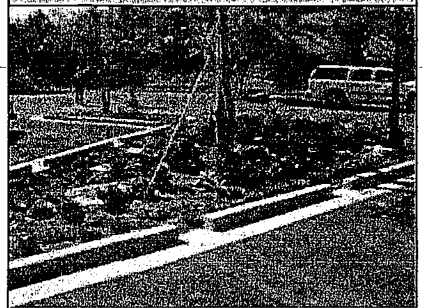
- CASQA BMP Handbook for New and Redevelopment: http://www.cabmphandbooks.com/Documents/Development/TC-10.pdf
- SMC LID Manual (pp 141): http://www.lowimpactdevelopment.org/guest75/pub/All_Projects/SoCal_LID_Manual/SoCalLID_Manual_FINAL_040910.pdf
- Los Angeles County Stormwater BMP Design and Maintenance Manual, Chapter 6: http://dpw.lacounty.gov/DES/design_manuals/StormwaterBMPDesignandrainageareaintenance.pdf
- City of Portland Stormwater Management Manual (Soakage Trenches, page 2-82) http://www.portlandonline.com/bes/index.cfm?c=47954&a=202883
- San Diego County LID Handbook Appendix 4 (Factsheet 1): http://www.sdcounty.ca.gov/dplu/docs/LID-Appendices.pdf

INF-3: Bioretention with no Underdrain

Bioretention stormwater treatment facilities are landscaped shallow depressions that capture and filter stormwater runoff. These facilities function as a soil and plant-based filtration device that removes pollutants through a variety of physical, biological, and chemical treatment processes. The facilities normally consist of a ponding area, mulch layer, planting soils, and plants. As stormwater passes down through the planting soil, pollutants are filtered, adsorbed, and biodegraded by the soil and plants. For areas with low permeability native soils or steep slopes, bioretention areas can be designed with an underdrain system that routes the treated runoff to the storm drain system rather than depending entirely on infiltration.

Also known as:

- *Rain gardens*
- *Infiltration planter*



Bioretention
Source: Geosyntec Consultants

Feasibility Screening Considerations

- Bioretention with no underdrains shall pass infiltration infeasibility screening criteria to be considered for use.

Opportunity Criteria

- Land use may include commercial, residential, mixed use, institutional, and subdivisions. Bioretention may also be applied in parking lot islands, cul-de-sacs, traffic circles, road shoulders, and road medians.
- Drainage area is ≤ 5 acres, preferrably ≤ 1 acre.
- Area available for infiltration.
- Soils are adequate for infiltration or can be amended to improve infiltration capacity. Site slope is less than 15 percent.

OC-Specific Design Criteria and Considerations

- ☐ Placement of BMPs should observe geotechnical recommendations with respect to geological hazards (e.g. landslides, liquefaction zones, erosion, etc.) and set-backs (e.g., foundations, utilities, roadways, etc.)
- ☐ Depth to mounded seasonally high groundwater shall not be less than 5 feet.
- ☐ If sheet flow is conveyed to the treatment area over stabilized grassed areas, the site must be graded in such a way that minimizes erosive conditions; sheet flow velocities should not exceed 1 foot per second.
- ☐ Ponding depth should not exceed 18 inches; fencing may be required if ponding depth exceeds 6 inches to mitigate the risk of drowning.
- ☐ Planting/storage media shall be based on the recommendations contained in MISC-1: Planting/Storage Media
- ☐ The minimum amended soil depth is 1.5 feet (3 feet is preferred).
- ☐ The maximum drawdown time of the planting soil is 48 hours.

- ☐ Infiltration pathways may need to be restricted due to the close proximity of roads, foundations, or other infrastructure. A geomembrane liner, or other equivalent water proofing, may be placed along the vertical walls to reduce lateral flows. This liner should have a minimum thickness of 30 mils.
- ☐ Plant materials should be tolerant of summer drought, ponding fluctuations, and saturated soil conditions for 48 hours; native plant species and/or hardy cultivars that are not invasive and do not require chemical fertilizers or pesticides should be used to the maximum extent feasible.
- ☐ The bioretention area should be covered with 2-4 inches (average 3 inches) of mulch at startup and an additional placement of 1-2 inches of mulch should be added annually.
- ☐ An optional gravel drainage layer may be installed below planting media to augment storage volume.
- ☐ An overflow device is required at the top of the ponding depth.
- ☐ Dispersed flow or energy dissipation (i.e. splash rocks) for piped inlets should be provided at basin inlet to prevent erosion.

Simple Sizing Method for Bioretention with no Underdrain

If the Simple Design Capture Volume Sizing Method described in **Appendix III.3.1** is used to size a bioretention area with underdrains, the user calculates the DCV and designs the system with geometry required to draw down the DCV in 48 hours. The sizing steps are as follows:

Step 1: Determine the Bioretention Design Capture Volume

Calculate the DCV using the Simple Design Capture Volume Sizing Method described in **Appendix III.3.1.**

Step 2: Determine the 48-hour Ponding Depth

The depth of effective storage depth that can be drawn down in 48 hours can be calculated using the following equation:

$$d_{48} = K_{DESIGN} \times 4$$

Where:

d_{48} = bioretention 48-hour effective depth, ft

K_{DESIGN} = bioretention design infiltration rate, in/hr (See **Appendix VII**)

This is the maximum effective depth of the basin below the overflow device to achieve drawdown in 48 hours. Effective depth includes ponding water and media/aggregate pore space.

Step 3: Design System Geometry to Provide d_{48}

Design system geometry such that

$$d_{48} \geq d_{EFFECTIVE} = (d_P + n_M d_M + n_G d_G)$$

Where:

d_{48} = depth of water that can drain in 48 hours

$d_{EFFECTIVE}$ = total effective depth of water stored in bioretention area, ft

d_P = bioretention ponding depth, ft (should be less than or equal to 1.5 ft)

n_M = bioretention media porosity

d_M = bioretention media depth, ft

n_G = bioretention gravel layer porosity; 0.35 may be assumed where other information is not available

d_G = bioretention gravel layer depth, ft

Step 4: Calculate the Required Infiltrating Area

The required infiltrating area (i.e. measured at the media surface) can be calculated using the following equation:

$A = DCV / d_{EFFECTIVE}$

Where:

A = required infiltrating area, sq-ft (measured as the media surface area)

DCV = design capture volume, cu-ft (see Step 1)

$d_{EFFECTIVE}$ = total effective depth of water stored in bioretention area, ft (from Step 3)

This does not include the side slopes, access roads, etc. which would increase bioretention footprint.

Capture Efficiency Method for Bioretention with no Underdrain

If BMP geometry has already been defined and deviates from the 48 hour drawdown time, the designer can use the Capture Efficiency Method for Volume-Based, Constant Drawdown BMPs (See **Appendix III.3.2**) to determine the fraction of the DCV that must be provided to manage 80 percent of average annual runoff volume. This method accounts for drawdown time different than 48 hours.

Step 1: Determine the drawdown time associated with the selected basin geometry

$DD = (d_{EFFECTIVE} / K_{DESIGN}) \times 12$ in/ft

Where:

DD = time to completely drain infiltration basin ponding depth, hours

$d_{EFFECTIVE} \leq (d_P + n_M d_M + n_G d_G)$

d_P = bioretention ponding depth, ft (should be less than or equal to 1.5 ft)

n_M = bioretention media porosity

d_M = bioretention media depth, ft

n_G = bioretention gravel layer porosity; 0.35 may be assumed where other information is not available

d_G = bioretention gravel layer depth, ft

K_{DESIGN} = basin design infiltration rate, in/hr (See **Appendix VII**)

Step 2: Determine the Required Adjusted DCV for this Drawdown Time

Use the Capture Efficiency Method for Volume-Based, Constant Drawdown BMPs (See **Appendix III.3.2**) to calculate the fraction of the DCV the basin must hold to achieve 80 percent capture of average annual stormwater runoff volume based on the basin drawdown time calculated above.

Step 4: Check that the Bioretention Effective Depth Drains in no Greater than 96 Hours

$DD = (d_{EFFECTIVE} / K_{DESIGN}) \times 12$

Where:

DD = time to completely drain bioretention facility, hours

$d_{EFFECTIVE}$ = total effective depth of water stored in bioretention area, ft (from Step 3)

K_{DESIGN} = basin design infiltration rate, in/hr (See **Appendix VII**)

If DD_{ALL} is greater than 96 hours, adjust bioretention media depth and/or gravel layer depth until DD is less than 96 hours. This duration is based on preventing extended periods of saturation from causing plant mortality.

Step 5: Determine the Basin Infiltrating Area Needed

The required infiltrating area (i.e. the surface area of the top of the media layer) can be calculated using the following equation:

$A = DCV/ d_{EFFECTIVE}$

Where:

A = required infiltrating area, sq-ft (measured at the media surface)

DCV = design capture volume, adjusted for drawdown time, cu-ft (see Step 1)

$d_{EFFECTIVE}$ = total effective depth of water stored in bioretention area, ft (from Step 3)

This does not include the side slopes, access roads, etc. which would increase bioretention footprint. If the area required is greater than the selected basin area, adjust surface area or adjust ponding depth and recalculate required area until the required area is achieved.

Configuration for Use in a Treatment Train

- Bioretention areas may be preceeded in a treatment train by HSCs in the drainage area, which would reduce the required volume of the bioretention cell.
- Bioretention areas can be incorporated in a treatment train to provide enhanced water quality treatment and reductions in runoff volume and rate. For example, runoff can be collected from a roadway in a vegetated swale that then flows to a bioretention area. Similarly, bioretention could be used to manage overflow from a cistern.

Additional References for Design Guidance

- CASQA BMP Handbook for New and Redevelopment: http://www.cabmphandbooks.com/Documents/Development/TC-32.pdf
- SMC LID Manual (pp 68): http://www.lowimpactdevelopment.org/guest75/pub/All_Projects/SoCal_LID_Manual/SoCalLID_Manual_FINAL_040910.pdf
- Los Angeles County Stormwater BMP Design and Maintenance Manual, Chapter 5: http://dpw.lacounty.gov/DES/design_manuals/StormwaterBMPDesignandMaintenance.pdf
- San Diego County LID Handbook Appendix 4 (Factsheet 7): http://www.sdcounty.ca.gov/dplu/docs/LID-Appendices.pdf
- Los Angeles Unified School District (LAUSD) Stormwater Technical Manual, Chapter 4. http://www.laschools.org/employee/design/fs-studies-and-reports/download/white_paper_report_material/Storm_Water_Technical_Manual_2009-opt-red.pdf?version_id=76975850

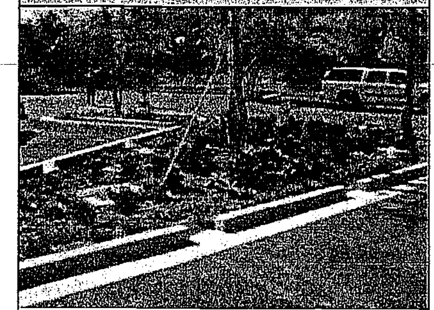
  County of Los Angeles Low Impact Development Standards Manual, Chapter 5: http://dpw.lacounty.gov/wmd/LA_County_LID_Manual.pdf

INF-4: Bioinfiltration Fact Sheet

Bioinfiltration facilities are designed for partial infiltration of runoff and partial biotreatment. These facilities are similar to bioretention devices with underdrains but they include a raised underdrain above a gravel sump designed to facilitate infiltration. These facilities can be used in areas where there are no hazards associated with infiltration, but infiltration of the full DCV may not be feasible due to low infiltration rates or high depths of fill. These facilities may not result in retention of the full DCV but they can be used to achieve the maximum feasible infiltration and ET.

Also known as:

- *Rain gardens*
- *Infiltration planter*



Bioretention
Source: Geosyntec Consultants

Feasibility Screening Considerations

- Bioinfiltration shall pass infeasibility screening criteria for infiltration BMPs (**TGD Section 2.4.2**) to be considered for use.
- Infiltration rates are allowed to be less than 0.3 inches per hour.

Opportunity Criteria

- Land use may include commercial, residential, mixed use, institutional, and subdivisions. Bioretention may also be applied in parking lot islands, cul-de-sacs, traffic circles, road shoulders, and road medians.
- Drainage area is ≤ 5 acres, preferrably ≤ 1 acre.
- Area is available for infiltration.
- Site slope is less than 15 percent.

OC-Specific Design Criteria and Considerations

- ☐ Placement of BMPs should observe geotechnical recommendations with respect to geological hazards (e.g. landslides, liquefaction zones, erosion, etc.) and set-backs (e.g., foundations, utilities, roadways, etc.)
- ☐ Depth to mounded seasonally high groundwater shall not be less than 5 feet.
- ☐ If sheet flow is conveyed to the treatment area over stabilized grassed areas, the site must be graded in such a way that minimizes erosive conditions; sheet flow velocities should not exceed 1 foot per second.
- ☐ Ponding depth should not exceed 18 inches; fencing may be required if ponding depth exceeds 6 inches to mitigate the risk of drowning.
- ☐ Planting/storage media shall be based on the recommendations contained in MISC-1: Planting/Storage Media
- ☐ The minimum amended soil depth is 1.5 feet (3 feet is preferred).
- ☐ The depth of gravel below the underdrain elevation must be designed so that the effective depth that would infiltrate in 48 hours is stored in the gravel layer.
- ☐ Underdrain should be placed at the top of the gravel drainage layer to facilitate infiltration.

☐ Infiltration pathways may need to be restricted due to the close proximity of roads, foundations, or other infrastructure. A geomembrane liner, or other equivalent water proofing, may be placed along the vertical walls to reduce lateral flows. This liner should have a minimum thickness of 30 mils.

☐ Plant materials should be tolerant of summer drought, ponding fluctuations, and saturated soil conditions for 48 hours; native plant species and/or hardy cultivars that are not invasive and do not require chemical fertilizers or pesticides should be used to the maximum extent feasible

☐ The bioinfiltration area should be covered with 2-4 inches (average 3 inches) of mulch at startup and an additional placement of 1-2 inches of mulch should be added annually.

☐ An overflow device is required at the top of the ponding depth.

☐ Dispersed flow or energy dissipation (i.e. splash rocks) for piped inlets should be provided at basin inlet to prevent erosion.

☐ Planting/storage media shall be based on the recommendations contained in MISC-1: Planting/Storage Media

☐ Ponding area side slopes shall be 3H:1V.

Simple Sizing Method for Bioinfiltration

If the Simple Design Capture Volume Sizing Method described in **Appendix III.3.1** is used to size a bioinfiltration facility, the user selects the basin geometry and then determines the volume retained. The sizing steps are as follows:

Step 1: Select Bioinfiltration Geometry

Determine the desired ponding depth (not to exceed 1.5 ft), gravel depth, surface area, and media saturated hydraulic conductivity. A target media hydraulic conductivity of 5 inches per hour is recommended.

Step 2: Verify that the Ponding Depth will Draw Down within 48 Hours

The ponding area drawdown time can be calculated using the following equation:

$$DD_P = (d_P / K_{MEDIA}) \times 12$$

Where:

DD_P = time to drain ponded water, hours

$d_{EFFECTIVE}$ = total effective depth of water stored in bioretention area, ft (from Step 3)

K_{MEDIA} = media design infiltration rate, in/hr (equivalent to the media hydraulic conductivity with a factor of safety of 2; K_{MEDIA} of 2.5 in/hr should be used as a default unless other information is available to support an alternative value.)

If the drawdown time exceeds 48 hours, adjust ponding depth and/or media filter until 48 hour drawdown time is achieved.

Step 3: Verify That Gravel Depth is Designed for 48 Hour Drawdown

In order to demonstrate that bioinfiltration systems have been designed to achieve the maximum feasible retention (See **Appendix XI**), the gravel depth below the underdrains must be designed with a thickness such that it draws down in 48 hours.

$$DD_G = ((d_G \times n_G) / K_{DESIGN}) \times 12$$

Where:

DD_G = time to drain gravel layer, hours

n_G = bioretention gravel layer porosity; 0.35 may be assumed where other information is not available

d_G = bioretention gravel layer depth, ft

K_{DESIGN} = bioretention design infiltration rate, in/hr (See **Appendix VII**)

If DD_G is less than 48 hours, adjust d_G until DD_G is at least 48 hours or greater.

Step 4: Determine the BMP Area Needed

The required infiltrating area (i.e. the surface area of the top of the media layer) can be calculated using the following equation:

$A = DCV / d_{EFFECTIVE}$

Where:

A = required infiltrating area, sq-ft (measured at the media surface)

DCV = design capture volume, cu-ft (see Step 1)

$d_{EFFECTIVE}$ = total effective depth of water stored in bioretention area, ft

$d_{EFFECTIVE} = (d_P + n_M d_M + n_G d_G)$

d_P = bioretention ponding depth, ft (should be less than or equal to 1.5 ft)

n_M = bioretention media porosity

d_M = bioretention media depth, ft

n_G = bioretention gravel layer porosity; 0.35 may be assumed where other information is not available

d_G = bioretention gravel layer depth, ft

This does not include the side slopes, access roads, etc. which would increase bioretention footprint. If the area required is greater than the selected basin area, adjust surface area or adjust ponding depth and recalculate required area until the required area is achieved.

Capture Efficiency Method for Bioinfiltration

Option 1: Accounting for Retention plus Biotreatment in Capture Efficiency Calculation

To size bioinfiltration facilities using the Capture Efficiency Method, the system should be divided into its retention and biotreatment components and analyzed as a treatment train per instructions in **Appendix III.5** Sizing Approaches for Treatment Trains and Hybrid Systems.

- Retention Storage: Water stored in gravel below underdrains.
- Biotreatment Storage: Water stored in surface ponding and media pore space.

The retention component should be analyzed as the first component of the treatment train, and will yield a capture efficiency that is used as an input to the biotreatment sizing approach.

The retention component should be sized such that the depth of gravel drains in 48 hours at the design infiltration rate.

Option 2: Sizing of Biotreatment Only; Presumptive Approach for Retention

Alternatively, bioinfiltration BMPs can be sized accounting for only the capture efficiency of the biotreatment component (See BIO-1: Bioretention with Underdrains for sizing methods). The retention component should be sized such that the depth of gravel drains in 48 hours or greater at the design infiltration rate. This provides presumption that water is infiltrated without quantifying the volume that is infiltrated. It is inherently a conservative sizing method.

Configuration for Use in a Treatment Train

- Bioinfiltration areas are inherently a treatment train BMP because they include both retention and biotreatment components.
- Bioinfiltration areas may be preceded in a treatment train by HSCs in the drainage area, which would reduce the required volume of the bioretention cell.
- Bioinfiltration areas can be incorporated in a treatment train to provide enhanced water quality treatment and reductions in runoff volume and rate.

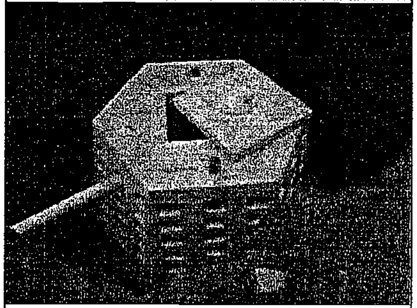
Additional References for Design Guidance

- CASQA BMP Handbook for New and Redevelopment: http://www.cabmphandbooks.com/Documents/Development/TC-32.pdf
- SMC LID Manual (pp 68): http://www.lowimpactdevelopment.org/guest75/pub/All_Projects/SoCal_LID_Manual/SoCalLID_Manual_FINAL_040910.pdf
- Los Angeles County Stormwater BMP Design and Maintenance Manual, Chapter 5: http://dpw.lacounty.gov/DES/design_manuals/StormwaterBMPDesignandMaintenance.pdf
- San Diego County LID Handbook Appendix 4 (Factsheet 7): http://www.sdcounty.ca.gov/dplu/docs/LID-Appendices.pdf
- Los Angeles Unified School District (LAUSD) Stormwater Technical Manual, Chapter 4: http://www.laschools.org/employee/design/fs-studies-and-reports/download/white_paper_report_material/Storm_Water_Technical_Manual_2009-opt-red.pdf?version_id=76975850
- County of Los Angeles Low Impact Development Standards Manual, Chapter 5: http://dpw.lacounty.gov/wmd/LA_County_LID_Manual.pdf

INF-5: Drywell

Also known as:

- Soakaway Pits
- Infiltration Sumps
- Rock Sumps
- Underground Injection Controls



Drywell
Source: K&A Enterprises

Drywells are similar to infiltration trenches in their design and function, but generally have a greater depth to footprint area ratio and can be installed at relatively large depths. A drywell is a subsurface storage facility designed to temporarily store and infiltrate runoff, primarily from rooftops or other impervious areas with low pollutant loading. A drywell may be either a small excavated pit filled with aggregate or a prefabricated storage chamber or pipe segment. Drywells can be used to reduce the volume of runoff from roofs and other relatively clean surfaces. While roofs are generally not a significant source of stormwater pollutants, they can be a major contributor of runoff volumes. Therefore, drywells can indirectly enhance water quality by reducing the water quality design volume that must be treated by other, downstream stormwater management facilities. *Note: A drywell is considered a "Class V Injection Wells" under the federal Underground Injection Control (UIC) Program regulated in California by U.S. EPA Region 9. A UIC permit may be required (for details see http://www.epa.gov/region9/water/groundwater/uic-classv.html).*

Feasibility Screening Considerations

- Drywells shall pass infiltration infeasibility screening criteria (**TGD Section 2.4.2**) to be considered for use.
- Dry wells provide a more direct pathway for stormwater to groundwater, therefore pose a greater risk to groundwater quality than surface infiltration systems.

Opportunity Criteria

- Drywells may be used to infiltrate roof runoff, either directly or from the overflow from a cistern.
- Soils are adequate for infiltration or can be amended to provide an adequate infiltration rate.
- Space available for pretreatment (biotreatment or treatment control BMP as described below).
- The drywell must be located in native soil; over-excavated by at least one foot in depth and replaced uniformly without compaction.
- Potential for groundwater contamination can be mitigated through isolation of pollutant sources, pretreatment of inflow, and/or demonstration of adequate treatment capacity of underlying soils.
- Infiltration is into native soil, or depth of engineered fill is ≤ 5 feet from the bottom of the facility to native material and infiltration into fill is approved by a geotechnical professional.

OC-Specific Design Criteria and Considerations

☐ Must comply with local, state, and federal UIC regulations; a permit may be required.

☐ Minimum set-backs from foundations and slopes should be observed

- [ ] Infiltration should not cause geotechnical concerns related to slope stability, liquefaction, or erosion.
- [ ] Minimum separation to mounded seasonally high groundwater of 10 feet shall be observed.
- [ ] Drywells should not receive untreated stormwater runoff, except rooftop runoff. Pretreatment of runoff from other surfaces is necessary to prevent premature failure that results from clogging with fine sediment, and to prevent potential groundwater contamination due to nutrients, salts, and hydrocarbons.
- [ ] Design infiltration rate should be determined with an infiltration test at each drywell location.
- [ ] Drywell should be encased by 1 foot of coarse (3/4" to 2 ½"), round river rock on sides and bottom of facility.
- [ ] Maximum facility depth is 25 feet with the approval of a geotechnical professional; preferred depth less than 10 feet does not require geotechnical approval.
- [ ] If inlet is an underground pipe, a fine mesh screen should be installed to prevent coarse solids from entering drywell.
- [ ] An overflow route must be installed for flows that overtop facility.

Sizing Criteria for Drywells

Drywell sizing is highly site-specific. Sizing calculations shall demonstrate via the methods described in **Appendix III** or via project-specific methods that the system captures and fully discharges the DCV within 48 hours following the end of precipitation, or captures and infiltrates 80 percent of average annual runoff volume.

Configuration for Use in a Treatment Train

- Drywells may be preceded in a treatment train by HSCs in the drainage area, which would reduce the required volume of the drywell.
- Drywells treating any areas other than roof tops must be preceded by a robust biotreatment or conventional treatment capable of addressing all potentially generated pollutants.
- Drywells may be used in conjunction with other infiltration BMPs to increase the infiltration capacity of the entire treatment train system.

Additional References for Design Guidance

- Stormwater Management in Western Washington (Volume III: Hydrologic Analysis and Flow Control Design BMPs) http://www.ecy.wa.gov/pubs/0510031.pdf
- Los Angeles Unified School District (LAUSD) Stormwater Technical Manual, Chapter 4: http://www.laschools.org/employee/design/fs-studies-and-reports/download/white_paper_report_material/Storm_Water_Technical_Manual_2009-opt-red.pdf?version_id=76975850
- City of Portland Stormwater Management Manual (Drywell, page 2-87) http://www.portlandonline.com/bes/index.cfm?c=47954&a=202883
- San Diego County LID Handbook Appendix 4 (Factsheet 25): http://www.sdcounty.ca.gov/dplu/docs/LID-Appendices.pdf
- City of Santa Barbara Storm Water BMP Guidance Manual, Chapter 6: http://www.santabarbaraca.gov/NR/rdonlyres/91D1FA75-C185-491E-A882-49EE17789DF8/0/Manual_071008_Final.pdf

INF-6: Permeable Pavement (concrete, asphalt, and pavers)

Also known as:

- *Pervious pavement*
- *Porous concrete*
- *Pavers*
- *Permeable asphalt*

Permeable Pavement
Source: Geosyntec Consultants

Permeable pavements contain small voids that allow water to pass through to a gravel base. They come in a variety of forms; they may be a modular paving system (concrete pavers, grass-pave, or gravel-pave) or poured in place pavement (porous concrete, permeable asphalt). All permeable pavements treat stormwater and remove sediments and metals to some degree within the pavement pore space and gravel base. While conventional pavement result in increased rates and volumes of surface runoff, properly constructed and maintained porous pavements, allow stormwater to percolate through the pavement and enter the soil below. This facilitates groundwater recharge while providing the structural and functional features needed for the roadway, parking lot, or sidewalk. The paving surface, subgrade, and installation requirements of permeable pavements are more complex than those for conventional asphalt or concrete surfaces. For porous pavements to function properly over an expected life span of 15 to 20 years, they must be properly sited and carefully designed and installed, as well as periodically maintained. Failure to protect paved areas from construction-related sediment loads can result in their premature clogging and failure.

Feasibility Screening Considerations

- Permeable pavement shall pass infiltration infeasibility screening to be considered for use.
- Permeable pavements pose a potential risk of groundwater contamination; they may not provide significant attenuation of stormwater pollutants if underlying soils have high permeability.

Opportunity Criteria

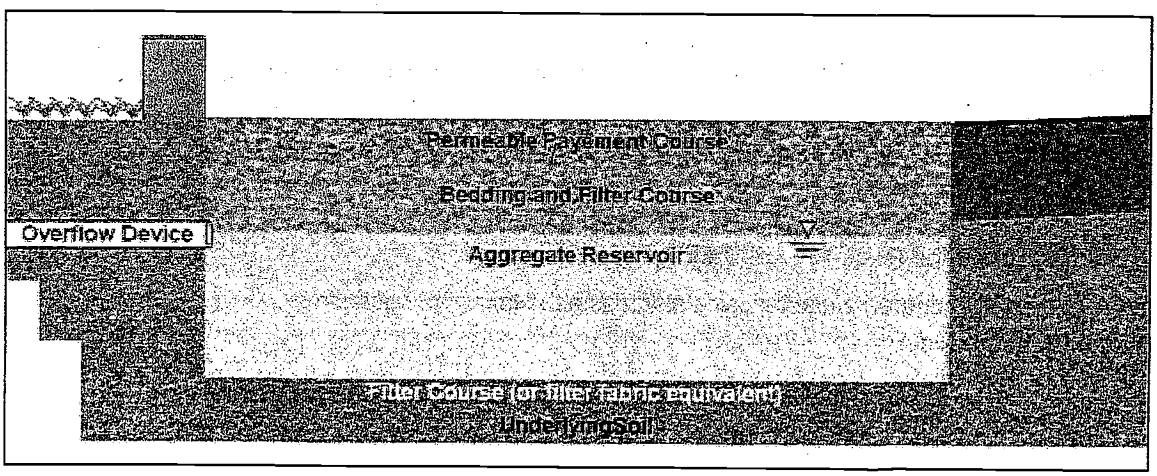
- Permeable pavement areas can be applied to individual lot driveways, walkways, parking lots, low-traffic roads, high-traffic (with low speeds) roads/lots, golf cart paths, within road right-of-ways, and in parks and along open space edges. Impervious surfaces draining to the BMP are limited to surfaces immediately adjacent to the permeable pavement, rooftop runoff, and other nearby surfaces that do not contain significant sediment loads.
- Soils are adequate for infiltration or can be amended to provide an adequate infiltration rate.
- Infiltration is into native soil, or depth of engineered fill is ≤ 5 feet from the bottom of the facility to native material and infiltration into fill is approved by a geotechnical professional.

OC-Specific Design Criteria and Considerations

- ☐ Placement of BMPs should observe geotechnical recommendations with respect to geological hazards (e.g. landslides, liquefaction zones, erosion, etc.) and set-backs (e.g., foundations, utilities, roadways, etc)
- ☐ Minimum separation to mounded seasonally high groundwater of 5 feet shall be observed.

- ☐ A biotreatment BMP should be provided for all runoff from off-site sources that are not directly adjacent to the permeable pavement, with the exception of rooftops.
- ☐ Permeable pavement should not be used for drainage areas with high sediment production potential (e.g., landscape areas) unless preceded by full treatment control with a BMP effective for sediment removal
- ☐ All aggregate used to construct permeable pavement shall be thoroughly washed before being delivered to the construction site.
- ☐ The top or wearing layer course (permeable pavement course) should consist of asphalt or concrete with greater than normal percentage of voids, or paving stones.
- ☐ A layer of washed fine aggregate (e.g., No. 8) just under the permeable pavement course may be installed to provide a level surface for installing the permeable pavement and also acts as a filter to trap particles and help prevent the reservoir layer from clogging. This layer can also act as interstitial media between pavers.
- ☐ Below this layer, the bedding and filter course course should be 1.5 to 3 inches deep and may be underlain by choking stone to prevent the smaller sized aggregate from migrating into the large aggregate base layer.
- ☐ The bedding, filter, and choke stone layers, as applicable, are referred to collectively as the bedding and filter course.
- ☐ The aggregate reservoir layer should be designed to function as a support layer as well as a reservoir layer the reservoir layer should be washed, open-graded No. 57 aggregate without any fine sands.
- ☐ The type of pedestrian traffic should be considered when determining which type of permeable pavement to use in particular locations (e.g., pavers may not be a good option for locations where people wearing high heels will be walking).
- ☐ An overflow device is required in the form of perimeter control or overflow pipes. This should generally be set at an elevation to prevent ponding of water into the bedding and filter course.

Figure XIV.1: Schematic Diagram of Permeable Pavement without Underdrains



Simple Sizing Method for Permeable Pavement

Permeable pavement that manages only direct rainfall and runoff from adjacent impermeable surfaces less than 50 percent the size of the permeable pavement are are not required to conduct sizing calculations. These areas are assumed to be self-retaining for the purpose of drainage planning.For permeable pavement with larger tributary area ratios, sizing calculations must be performed.

If the Simple Design Capture Volume Sizing Method described in **Appendix III.3.1** is used to size permeable pavement, the user calculates the DCV, designs the geometry required to draw down the DCV in 48 hours, then determines the area that is needed for the BMP. The area of the porous pavement itself as well as the area of the tributary areas should be considered in calculating the DCV. The sizing steps are as follows:

Step 1: Determine Permeable Pavement DCV

Calculate the DCV using the Simple Design Capture Volume Sizing Method described in **Appendix III.3.1**.

Step 2: Determine the 48-hour Effective Depth

The depth of water that can be drawn down in 48 hours can be calculated using the following equation:

$d_{48} = K_{DESIGN} \times 48 \text{ hours} \times 1 \text{ ft/12 inches}$

Where:

d_{48} = pavement effective 48-hour drawdown depth, ft

K_{DESIGN} = basin design infiltration rate, in/hr (See **Appendix VII**)

This is the maximum effective depth of water storage in the aggregate reservoir to achieve drawdown in 48 hours.

Step 3: Determine the Aggregate Reservoir Depth

The depth of water stored in the gravel reservoir should be equal or less than d_{48}. Determine the reservoir depth such that:

$d_{48} \geq (n_R \times d_R)$

Where:

d_{48} = trench effective 48-hour depth, ft (from Step 2)

n_R = porosity of aggregate reservoir fill; 0.35 may be assumed where other information is not available

d_R = depth of trench fill, ft

Step 4: Calculate the Required Infiltrating Area

The required infiltrating area can be calculated using the following equation:

$A = DCV / (n_R \times d_R)$

Where:

A = required footprint area, sq-ft

DCV = design capture volume, cu-ft (see Step 1)

n_R = porosity of trench fill; 0.35 may be assumed where other information is not available

d_R = depth of trench fill, ft

This area is equal to the required pavement area.

The ratio total tributary area (including the porous pavement) to the area of the porous pavement should not exceed 4:1.

Capture Efficiency Method for Permeable Pavement

If BMP geometry has already been defined and deviates from the 48 hour drawdown time, the designer can use the Capture Efficiency Method for Volume-Based, Constant Drawdown BMPs (See **Appendix III.3.2**) to determine the fraction of the DCV that must be provided to manage 80 percent of average annual runoff volume. This method accounts for drawdown time different than 48 hours.

Option 1: Pavement Geometry is Predefined

Step 1: Determine the Drawdown Time Associated with the Selected Pavement Geometry

$DD = ((n_R \times d_R) / K_{DESIGN}) \times 12$ in/ft

Where:

DD = time to completely drain pavement, hours

n_R = porosity of reservoir fill; 0.35 may be assumed where other information is not available

d_R = depth of reservoir, ft

K_{DESIGN} = basin design infiltration rate, in/hr (See **Appendix VII**)

Step 2: Determine the Required Adjusted DCV for this Drawdown Time

Use the Capture Efficiency Method for Volume-Based, Constant Drawdown BMPs (See **Appendix III.3.2**) to calculate the draw-down adjusted DCV that the basin must hold to achieve 80 percent capture of average annual stormwater runoff volume based on the pavement drawdown time calculated above.

Step 3: Determine the Pavement Infiltrating Area Needed

The required infiltrating area can be calculated using the following equation:

$A = DCV / (n_R \times d_R)$

Where:

A = required footprint area, sq-ft

DCV = design capture volume, cu-ft (see Step 1)

n_R = porosity of reservoir fill; 0.35 may be assumed where other information is not available

d_R = depth of reservoir, ft

If the area required is greater than the selected pavement area, adjust reservoir depth and recalculate required area until the required area is achieved.

Configuration for Use in a Treatment Train

- Permeable pavement may be preceded in a treatment train by HSCs in the drainage area, which would reduce the runoff volume to be infiltrated by the permeable pavement
- Permeable pavement areas can be designed to be self-retaining to lessen the pollutant and volume load on downstream BMPs.

Additional References for Design Guidance

- SMC LID Manual (pp 84): http://www.lowimpactdevelopment.org/guest75/pub/All_Projects/SoCal_LID_Manual/SoCalLID_Manual_FINAL_040910.pdf

- Los Angeles Unified School District (LAUSD) Stormwater Technical Manual, Chapter 5: http://www.laschools.org/employee/design/fs-studies-and-reports/download/white_paper_report_material/Storm_Water_Technical_Manual_2009-opt-red.pdf?version_id=76975850
- City of Portland Stormwater Management Manual (Pervious Pavement, page 2-40) http://www.portlandonline.com/bes/index.cfm?c=47954&a=202883

San Diego County LID Handbook Appendix 4 (Factsheets 8, 9 & 10): http://www.sdcounty.ca.gov/dplu/docs/LID-Appendices.pdf

City of Santa Barbara Storm Water BMP Guidance Manual, Chapter 6: http://www.santabarbaraca.gov/NR/rdonlyres/91D1FA75-C185-491E-A882-49EE17789DF8/0/Manual_071008_Final.pdf

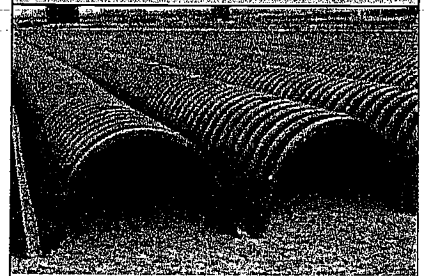
County of Los Angeles Low Impact Development Standards Manual, Chapter 5: http://dpw.lacounty.gov/wmd/LA_County_LID_Manual.pdf

INF-7: Underground Infiltration

Underground infiltration is a vault or chamber with an open bottom that used to store runoff and percolate into the subsurface. A number of vendors offer proprietary infiltration products that allow for similar or enhanced rates of infiltration and subsurface storage while offering durable prefrabricated structures. There are many varieties of proprietary infiltration BMPs that can be used for roads and parking lots, parks and open spaces, single and multi-family residential, or mixed-use and commercial uses.

Also known as:

- *Infiltration vault*
- *Recharge vault*



Underground Infiltration

Source: http://www.contech-cpi.com

Feasibility Screening Considerations

- Infiltration bains shall pass infeasible screening criteria to be considered for use.
- Underground infiltration galleries pose a potential risk of groundwater contamination; pretreatment should be used.

Opportunity Criteria

- Soils are adequate for infiltration or can be amended to provide an adequate infiltration rate.
- Appropriate for sites with limited surface space.
- Can be placed beneath roads, parking lots, parks, and athletic fields.
- Potential for groundwater contamination can be mitigated through isolation of pollutant sources, pretreatment of inflow, and/or demonstration of adequate treatment capacity of underlying soils.
- Infiltration is into native soil, or depth of engineered fill is ≤ 5 feet from the bottom of the facility to native material and infiltration into fill is approved by a geotechnical professional.
- Tributary area land uses include mixed-use and commercial, sngle-family and multi-family, roads and parking lots, and parks and open spaces. High pollutant land uses should not be tributary to infiltration BMPs.

OC-Specific Design Criteria and Considerations

- ☐ Placement of BMPs should observe geotechnical recommendations with respect to geological hazards (e.g. landslides, liquefaction zones, erosion, etc.) and set-backs (e.g., foundations, utilities, roadways, etc.)
- ☐ Minimum separation to mounded seasonally high groundwater of 10 feet shall be observed.
- ☐ Minimum pretreatment should be provided upstream of the infiltration facility, and water bypassing pretreatment should not be directed to the facility.
- ☐ Underground infiltration should not be used for drainage areas with high sediment production potential unless preceded by full treatment control with a BMP effective for sediment removal.
- ☐ Design infiltration rate should be determined as described in Appendix VII.
- ☐ Inspection ports or similar design features shall be provided to verify continued system performance and identify need for major maintenance.

- [ ] For infiltration facilities beneath roads and parking areas, structural requirements should meet H-20 load requirements.

Computing Underground Infiltration Device Size

Underground infiltration devices vary by design and by proprietary designs. The sizing method selected for use must be based on the BMP type it most strongly resembles.

- For underground infiltration devices with open pore volume (e.g., vaults, crates, pipe sections, etc), sizing will be most similar to infiltration basins.
- For underground infiltration devices with pore space (e.g., aggregate reservoirs), sizing will be most similar to permeable pavement.

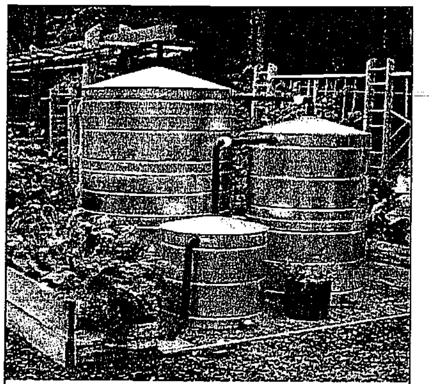
Additional References for Design Guidance

- Los Angeles Unified School District (LAUSD) Stormwater Technical Manual, Chapter 5: http://www.laschools.org/employee/design/fs-studies-and-reports/download/white_paper_report_material/Storm_Water_Technical_Manual_2009-opt-red.pdf?version_id=76975850

XIV.4. Harvest and Use BMP Fact Sheets (HU)

HU-1: Above-Ground Cisterns

Cisterns are large rain barrels. While rain barrels are less than 100 gallons, cisterns range from 100 to more than 10,000 gallons in capacity. Cisterns collect and temporarily store runoff from rooftops for later use as irrigation and/or other non-potable uses. The following components are generally required for installing and utilizing a cistern: (1) pipes that divert rooftop runoff to the cistern, (2) an overflow for when the cistern is full, (3) a pump, and (4) a distribution system to supply the intended end uses.

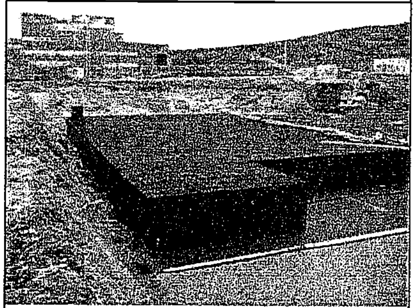


Above-Ground Cisterns
Source: Sunset Publishing Corporation

Feasibility screening consideration, opportunity criteria, design criteria, etc. for this BMP are listed below under HU-2: Underground Detention.

HU-2: Underground Detention

Underground detention facilities are subsurface tanks, vaults, or oversized pipes that store stormwater runoff. Similar to cisterns, underground detention facilities can store water for later use as irrigation and/or other non-potable uses.



Underground detention tank
Source: www.webtecgeos.com

Feasibility Screening Considerations

- The primary feasibility considerations for harvest and use systems for stormwater management is the presence of consistent and reliable demand that is sufficient to drain the systems relatively quickly between storms. **Appendix X** provides guidance for calculating harvested water demand.
- Use of harvested water should not conflict with applicable plumbing and health codes at the time of project application.

Opportunity Criteria

- Cisterns may collect rooftop runoff, and if located underground, may collect ground-level runoff.
- Cisterns may be installed in any type of land use provided space is available and adequate water demand exists.
- Stored water may supply non-potable water use demands such as irrigation and toilet flushing.
- Cisterns and underground detention facilities may also be used for peak flow control if active storage volume and hydraulic controls are provided above the retained storage or systems are operated with advanced controllers.

OC-Specific Design Criteria and Considerations for Above-Ground Cisterns

☐ Cistern systems should include prescreening in the form of screens on gutters and downspouts to remove vegetative debris and sediment from the runoff prior to entering the cistern.

- ☐ Above-ground cisterns should be secured in place and comply with applicable building codes.
- ☐ Above-ground cisterns should not be located on uneven or sloped surfaces; if installed on a sloped surface, the base where the cistern will be installed should be leveled and designed for the weight of the filled cistern prior to installation.
- ☐ Child-resistant covers and mosquito screens should be placed on all water entry holes.
- ☐ A first flush diverter may be installed so that initial runoff bypasses the cistern.
- ☐ Above-ground cisterns should be installed in a location with easy access for maintenance or replacement.
- ☐ Plumbing systems should be installed in accordance with the current California Building and Plumbing Codes (CBC – part of California Code of Regulations, Title 24).
- ☐ When a potable water supply line is connected to a cistern system to provide dry-season make-up water, cross-contamination should be prevented by providing a backflow prevention system on the potable water supply line and/or an air gap.
- ☐ In cases where there is non-potable indoor use demand, proper pretreatment measures should be installed such as pre-filtration, cartridge filtration, and/or disinfection.

OC-Specific Design Criteria and Considerations for Underground Cisterns/Detention Systems

- ☐ Access entry covers (36" diameter minimum) should be locking and within 50 feet of all areas of the detention tank.
- ☐ In cases where the detention facility provides sediment containment, the facility should be laid flat and there should be at least ½ foot of dead storage within the tank or vault.
- ☐ Outlet structures should be designed using the 100-year storm as overflow and should be easily accessible for maintenance activities.
- ☐ For detention facilities beneath roads and parking areas, structural requirements should meet H-20 load requirements.
- ☐ In cases where shallow groundwater may cause flotation, buoyant forces should be counteracted with backfill, anchors, or other measures.
- ☐ Underground detention facilities should be installed on consolidated and stable native soil; if the facility is constructed in fill slopes, a geotechnical analysis should be performed to ensure stability.
- ☐ Plumbing systems should be installed in accordance with the current California Building and Plumbing Codes (CBC – part of California Code of Regulations, Title 24).
- ☐ When a potable water supply line is connected to a cistern system to provide dry-season make-up water, cross-contamination should be prevented by providing a backflow prevention system on the potable water supply line and/or an air gap.
- ☐ In cases where there is non-potable indoor reuse demand, proper pretreatment measures should be installed such as pre-filtration, cartridge filtration, and/or disinfection.

Types of Harvested Water Demands

Harvested rainwater can be used for irrigation and other non-potable uses (if local, State, and Federal ordinances allow). The use of captured stormwater allows a reduced demand on the potable water supply.

Irrigation Use

- Subsurface (or drip) irrigation should not require disinfection pretreatment prior to use; other irrigation types, such as spray irrigation, may require additional pretreatment prior to use
- Selecting native and/or drought tolerant plants for landscaped area will reduce irrigation demand, thereby reducing the needed size of the storage facility and the amount of tributary area that can be successfully managed with a harvest and use system.

Indoor Use

- Indoor uses generally require filtration and disinfection and should only be considered if permitted by local, State, or Federal codes and ordinances.
- Domestic uses (single-family uses) may include toilet flushing.
- Offices, commercial developments, and industrial facility indoor uses may use cistems for toilet and urinal flushing. Demands for these specific land uses are include in Appendix X.
- Pretreatment requirements per local, State, or Federal codes and ordinances should be applied

Other Non-Potable Uses

- Other non-potable uses may include vehicle/equipment washing, evaporative cooling, industrial processes, and dilution water for recycled water systems (if local, State, and Federal ordinances allow)
- Pretreatment requirements per local, State, or Federal codes and ordinances should be applied

Harvested Water Demand Calculations and Feasibility Thresholds

Appendix X provides guidance for estimating harvesting water demand and determining whether demand is potentially sufficient to provide a significant benefit for stormwater management.

Simple Sizing Method for Cisterns

If the Simple Design Capture Volume Sizing Method described in **Appendix** III.3.1 is used to size harvest and use systems, the user calculates the DCV and determines whether demand is sufficient to drain the tank in 48 hours following the end of rainfall. The sizing steps are as follows:

Step 1: Determine Cistern DCV

Calculate the DCV using the Simple Design Capture Volume Sizing Method described in **Appendix** III.3.1. This is the required cistern size.

Step 2: Determine the 48-hour Required Demand

Calculate the daily demand needed to draw down the DCV in 48 hours using the following equation:

$$Demand_{48} = (DCV/2)*7.48$$

Where:

$Demand_{48}$ = daily demand required (gal/day)

DCV = design capture volume, cu-ft

Use the guidance in Appendix X determine the non-potable uses needed to generate the required demand.

Designing Cisterns to Achieve the Maximum Feasible Retention Volume

It is rare that cisterns can be sized to capture the full DCV and use this volume in 48 hours. However, if the demand exceeds minimum harvested water demand thresholds, cisterns should be sized to achieve at least 40 percent capture of average annual runoff volume.

Step 1: Determine if the Project Meets the Minimum Harvested Water Demand Thresholds

Determine the Project's design capture storm depth, then use the TUTIA thresholds table (**Appendix X**) for indoor uses, or the Irrigated Area thresholds table (**Appendix X**) for outdoor uses, to determine whether the project meets the minimum harvested water demand thresholds. If the project does not meet the minimum harvested water demand thresholds, harvest and use does not meet the minimum incremental benefit required to such that its use must be evaluated. .

If the project meets or exceeds the minimum harvested water demand thresholds, continue to Step 2 **or** Step 3 (equally-allowable pathways).

Step 2: Iteratively Determine the Cistern Volume for 80 percent capture of average annual stormwater runoff volume

Cisterns can be sized using the Capture Efficiency Method for Volume-Based, Constant Drawdown BMPs (See **Appendix** III.3.2). This approach requires an iterative sizing process in which the user selects the initial cistern size and the project harvested water demand, then calculates the time required for the cistern to drain. Based on the drain time, the cistern size is increased or decreased and the calculations are done again until the initially assumed size and the required size are within 10 percent.

a. Calculate wet season harvested water demand using guidance contained in **Appendix X**.

b. Select cistern size in terms of the design rainfall depth.

c. Calculate the cistern volume using hydrologic method described in **Appendix** III.1.1.

d. Compute the drawdown time of the cistern as:

   Drawdown Time (hr) = [Volume (cu-ft) × 7.48 gal/cu-ft× 24hr/day]/[Demand (gpd)]

e. Based on design rainfall depth and drawdown time using guidance provided in **Appendix** III to calculate long term average capture efficiency.

f. If capture is between 75 and 85 percent, further iterations are not required.

g. If capture is less than 80 percent capture of average annual stormwater runoff volume, return to Step (b) and increase design rainfall depth.

h. If capture is greater than 80 percent, return to Step (b) and increase design rainfall depth.

Step 3: Determine Cistern Volume and Drawdown to Achieve Maximum Practicable Capture Efficiency

The applicant is not required to provide a cistern greater than the DCV to demonstrate that BMPs have been designed to achieve the maximum feasible retention. The following steps should be used to compute the maximum feasible fraction of stormwater than can be retained with harvest and use BMPs:

a. Calculate wet season harvested water demand using guiance contained in **Appendix X**, accounting for all applicable demands.

b. Calculate the DCV using hydrologic method described in **Appendix** III.1.1 and size the cistern for this volume.

c. Compute the drawdown time of the cistern as:

   Drawdown Time (hr) = [Volume (cu-ft) × 7.48 gal/cu-ft× 24hr/day]/[Demand (gpd)]

d. Based on 1.0 × design capture storm depth and the drawdown time computed in Step I, calculate the long term average capture efficiency using the Capture Efficiency Method for Volume-Based, Constant Drawdown BMPs (See **Appendix III.3.2**).

e. If capture efficiency is less than 40 percent, harvest and use is not required to be considered for use on the project.

f. If capture efficiency is greater than 40 percent, provide a cistern sized for the DCV and provide volume or flowate to treat the remaining volume up to 80 percent total average annual capture using biotreatment BMP.

Configuration for Use in a Treatment Train

- Cisterns can be combined into a treatment train to provide enhanced water quality treatment and reductions in the runoff volume and rate. For example, if a green roof is placed upgradient of a cistern, the rate and volume of water flowing to the cistern can be reduced and the water quality enhanced.
- Cisterns can be incorporated into the landscape design of a site and can be aesthetically pleasing as well as functional for irrigation purposes.
- Treatment of the captured rainwater (i.e. disinfection) may be required depending on the end use of the water.
- Cisterns can be designed to overflow to biotreatment BMPs.

Additional References for Design Guidance

- Santa Barbara BMP Guidance Manual, Chapter 6: http://www.santabarbaraca.gov/NR/rdonlyres/91D1FA75-C185-491E-A882-49EE17789DF8/0/Manual_071008_Final.pdf
- County of Los Angeles Low Impact Development Standards Manual, Chapter 5: http://dpw.lacounty.gov/wmd/LA_County_LID_Manual.pdf
- SMC LID Manual (pp 114): http://www.lowimpactdevelopment.org/guest75/pub/All_Projects/SoCal_LID_Manual/SoCalLID_Manual_FINAL_040910.pdf
- San Diego County LID Handbook Appendix 4 (Factsheet 26): http://www.sdcounty.ca.gov/dplu/docs/LID-Appendices.pdf

XIV.5. Biotreatment BMP Fact Sheets (BIO)

Conceptual criteria for biotreatment BMP selection, design, and maintenance are contained in **Appendix XII**. These criteria are generally applicable to the design of biotreatment BMPs in Orange County and BMP-specific guidance is provided in the following fact sheets.

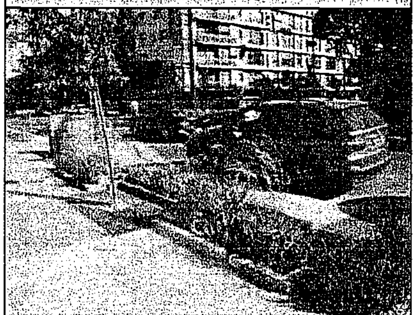
Note: Biotreatment BMPs shall be designed to provide the maximum feasible infiltration and ET based on criteria contained in ***Appendix*** XI.2.

BIO-1: Bioretention with Underdrains

Bioretention stormwater treatment facilities are landscaped shallow depressions that capture and filter stormwater runoff. These facilities function as a soil and plant-based filtration device that removes pollutants through a variety of physical, biological, and chemical treatment processes. The facilities normally consist of a ponding area, mulch layer, planting soils, and plants. As stormwater passes down through the planting soil, pollutants are filtered, adsorbed, biodegraded, and sequestered by the soil and plants. Bioretention with an underdrain are utilized for areas with low permeability native soils or steep slopes where the underdrain system that routes the treated runoff to the storm drain system rather than depending entirely on infiltration. **Bioretention must be designed without an underdrain** in areas of high soil permeability.

Also known as:

- *Rain gardens with underdrains*
- *Vegetated media filter*
- *Downspout planter boxes*



Bioretention
Source: Geosyntec Consultants

Feasibility Screening Considerations

- If there are no hazards associated with infiltration (such as groundwater concerns, contaminant plumes or geotechnical concerns), **bioinfiltration facilities**, which achieve partial infiltration, should be used to maximize infiltration.
- Bioretention with underdrain facilities should be lined if contaminant plumes or geotechnical concerns exist. If high groundwater is the reason for infiltration infeasibility, bioretention facilities with underdrains do not need to be lined.

Opportunity Criteria

- Land use may include commercial, residential, mixed use, institutional, and subdivisions. Bioretention may also be applied in parking lot islands, cul-de-sacs, traffic circles, road shoulders, road medians, and next to buildings in planter boxes.
- Drainage area is ≤ 5 acres.
- Area is available for infiltration.

- Site must have adequate relief between land surface and the stormwater conveyance system to permit vertical percolation through the soil media and collection and conveyance in underdrain to stormwater conveyance system.

OC-Specific Design Criteria and Considerations

- ☐ Ponding depth should not exceed 18 inches; fencing may be required if ponding depth is greater than 6 inches to mitigate drowning.
- ☐ The minimum soil depth is 2 feet (3 feet is preferred).
- ☐ The maximum drawdown time of the bioretention ponding area is 48 hours. The maximum drawdown time of the planting media and gravel drainage layer is 96 hours, if applicable.
- ☐ Infiltration pathways may need to be restricted due to the close proximity of roads, foundations, or other infrastructure. A geomembrane liner, or other equivalent water proofing, may be placed along the vertical walls to reduce lateral flows. This liner should have a minimum thickness of 30 mils.
- ☐ If infiltration in bioretention location is hazardous due to groundwater or geotechnical concerns, a geomembrane liner must be installed at the base of the bioretention facility. This liner should have a minimum thickness of 30 mils.
- ☐ The planting media placed in the cell shall be designed per the recommendations contained in MISC-1: Planting/Storage Media
- ☐ Plant materials should be tolerant of summer drought, ponding fluctuations, and saturated soil conditions for 48 hours; native place species and/or hardy cultivars that are not invasive and do not require chemical inputs should be used to the maximum extent feasible
- ☐ The bioretention area should be covered with 2-4 inches (average 3 inches) or mulch at the start and an additional placement of 1-2 inches of mulch should be added annually.
- ☐ Underdrain should be sized with a 6 inch minimum diameter and have a 0.5% minimum slope. Underdrain should be slotted polyvinyl chloride (PVC) pipe; underdrain pipe should be more than 5 feet from tree locations (if space allows).
- ☐ A gravel blanket or bedding is required for the underdrain pipe(s). At least 0.5 feet of washed aggregate must be placed below, to the top, and to the sides of the underdrain pipe(s).
- ☐ An overflow device is required at the top of the bioretention area ponding depth.
- ☐ Dispersed flow or energy dissipation (i.e. splash rocks) for piped inlets should be provided at basin inlet to prevent erosion.
- ☐ Ponding area side slopes shall be no steeper than 3:1 (H:V) unless designed as a planter box BMP with appropriate consideration for trip and fall hazards.

Simple Sizing Method for Bioretention with Underdrain

If the Simple Design Capture Volume Sizing Method described in **Appendix III.3.1** is used to size a bioretention with underdrain facility, the user selects the basin depth and then determines the appropriate surface area to capture the DCV. The sizing steps are as follows:

Step 1: Determine DCV

Calculate the DCV using the Simple Design Capture Volume Sizing Method described in **Appendix III.3.1**.

Step 2: Verify that the Ponding Depth will Draw Down within 48 Hours

The ponding area drawdown time can be calculated using the following equation:

$DD_P = (d_P / K_{MEDIA}) \times 12$ in/ft

Where:

DD_P = time to drain ponded water, hours

d_P = depth of ponding above bioretention area, ft (not to exceed 1.5 ft)

K_{MEDIA} = media design infiltration rate, in/hr (equivalent to the media hydraulic conductivity with a factor of safety of 2; K_{MEDIA} of 2.5 in/hr should be used unless other information is available)

If the drawdown time exceeds 48 hours, adjust ponding depth and/or media infiltration rate until 48 hour drawdown time is achieved.

Step 3: Determine the Depth of Water Filtered During Design Capture Storm

The depth of water filtered during the design capture storm can be estimated as the amount routed through the media during the storm, or the ponding depth, whichever is smaller.

$d_{FILTERED}$ = Minimum [(($K_{MEDIA} \times T_{ROUTING}$)/12), d_P]

Where:

$d_{FILTERED}$ = depth of water that may be considered to be filtered during the design storm event, ft

K_{MEDIA} = media design infiltration rate, in/hr (equivalent to the media hydraulic conductivity with a factor of safety of 2; K_{MEDIA} of 2.5 in/hr should be used unless other information is available)

$T_{ROUTING}$ = storm duration that may be assumed for routing calculations; this should be assumed to be no greater than 3 hours. If the designer desires to account for further routing effects, the Capture Efficiency Method for Volume-Based, Constant Drawdown BMPs (See **Appendix** III.3.2) should be used.

d_P = depth of ponding above bioretention area, ft (not to exceed 1.5 ft)

Step 4: Determine the Facility Surface Area

$A = DCV / (d_P + d_{FILTERED})$

Where:

A = required area of bioretention facility, sq-ft

DCV = design capture volume, cu-ft

$d_{FILTERED}$ = depth of water that may be considered to be filtered during the design storm event, ft

d_P = depth of ponding above bioretention area, ft (not to exceed 1.5 ft)

Capture Efficiency Method for Bioretention with Underdrains

If the bioretention geometry has already been defined and the user wishes to account more explicitly for routing, the user can determine the required footprint area using the Capture Efficiency Method for Volume-Based, Constant Drawdown BMPs (See **Appendix** III.3.2) to determine the fraction of the DCV that must be provided to manage 80 percent of average annual runoff volume. This method accounts for drawdown time different than 48 hours.

Step 1: Determine the drawdown time associated with the selected basin geometry

$DD = (d_p / K_{DESIGN}) \times 12$ in/ft

Where:

DD = time to completely drain infiltration basin ponding depth, hours

d_P = bioretention ponding depth, ft (should be less than or equal to 1.5 ft)

K_{DESIGN} = design media infiltration rate, in/hr (assume 2.5 inches per hour unless otherwise proposed)

If drawdown is less than 3 hours, the drawdown time should be rounded to 3 hours or the Capture Efficiency Method for Flow-based BMPs **(See Appendix III.3.3)** shall be used.

Step 2: Determine the Required Adjusted DCV for this Drawdown Time

Use the Capture Efficiency Method for Volume-Based, Constant Drawdown BMPs (See **Appendix III.3.2**) to calculate the fraction of the DCV the basin must hold to achieve 80 percent capture of average annual stormwater runoff volume based on the basin drawdown time calculated above.

Step 3: Determine the Basin Infiltrating Area Needed

The required infiltrating area (i.e. the surface area of the top of the media layer) can be calculated using the following equation:

$$A = \text{Design Volume} / d_p$$

Where:

A = required infiltrating area, sq-ft (measured at the media surface)

Design Volume = fraction of DCV, adjusted for drawdown, cu-ft (see Step 2)

d_p = ponding depth of water stored in bioretention area, ft (from Step 1)

This does not include the side slopes, access roads, etc. which would increase bioretention footprint. If the area required is greater than the selected basin area, adjust surface area or adjust ponding depth and recalculate required area until the required area is achieved.

Configuration for Use in a Treatment Train

- Bioretention areas may be preceeded in a treatment train by HSCs in the drainage area, which would reduce the required design volume of the bioretention cell. For example, bioretention could be used to manage overflow from a cistern.
- Bioretention areas can be used to provide pretreatment for underground infiltration systems.

Additional References for Design Guidance

- CASQA BMP Handbook for New and Redevelopment: http://www.cabmphandbooks.com/Documents/Development/TC-32.pdf
- SMC LID Manual (pp 68): http://www.lowimpactdevelopment.org/guest75/pub/All_Projects/SoCal_LID_Manual/SoCalLID_Manual_FINAL_040910.pdf
- Los Angeles County Stormwater BMP Design and Maintenance Manual, Chapter 5: http://dpw.lacounty.gov/DES/design_manuals/StormwaterBMPDesignandMaintenance.pdf
- San Diego County LID Handbook Appendix 4 (Factsheet 7): http://www.sdcounty.ca.gov/dplu/docs/LID-Appendices.pdf
- Los Angeles Unified School District (LAUSD) Stormwater Technical Manual, Chapter 4: http://www.laschools.org/employee/design/fs-studies-and-reports/download/white_paper_report_material/Storm_Water_Technical_Manual_2009-opt-red.pdf?version_id=76975850
- County of Los Angeles Low Impact Development Standards Manual, Chapter 5: http://dpw.lacounty.gov/wmd/LA_County_LID_Manual.pdf

BIO-2: Vegetated Swale

Also known as:
- *Bioswale*
- *Biofiltration swale*
- *Grass swale*

Vegetated Swale
Source: Geosyntec Consultants

Vegetated swale filters (vegetated swales) are open, shallow channels with low-lying vegetation covering the side slopes and bottom that collect and slowly convey runoff flow to downstream discharge points. Vegetated swales provide pollutant removal through settling and filtration in the vegetation (usually grasses) lining the channels. In addition, they provide the opportunity for volume reduction through infiltration and ET, and reduce the flow velocity in addition to conveying storm water runoff. Where soil conditions allow, volume reduction in vegetated swales can be enhanced by adding a gravel drainage layer underneath the swale allowing additional flows to be retained and infiltrated. Where slopes are shallow and soil conditions limit or prohibit infiltration, an underdrain system or low flow channel for dry weather flows may be required to minimize ponding and convey treated and/or dry weather flows to an acceptable discharge point. An effective vegetated swale achieves uniform sheet flow through a densely vegetated area for a period of several minutes. The vegetation in the swale can vary depending on its location within the project area and is generally the choice of the designer, subject to the design criteria outlined in this section.

Feasibility Screening Considerations

- Swales may cause incidental infiltration; however, infiltration is not a mandatory mechanism for pollutant removal for swales and it may create hazards in some circumstances. Therefore, conditions should be evaluated to determine whether circumstances require an impermeable liner to avoid infiltration into the subsurface.

Opportunity Criteria

- Open areas are needed for vegetated swales, including, but not limited to, road shoulders, road medians, parks and athletic fields and can be constructed in residential or commercial areas.
- Site slope is less than 10 percent.
- Drainage area is ≤ 5 acres.
- Vegetated swales must not interfere with flood control functions of existing conveyance and detention structures.

OC-Specific Design Criteria and Considerations

☐ Swales should have a minimum bottom width of 2 feet and a maximum bottom width of 10 feet. Swale dividers should be used if the bottom width must exceed 10 feet to promote even distribution of flow across the swale. Local juridictions may require larger minimum widths based on maintenance requirements.

☐ The channel side slope should not exceed 2:1 (H:V) for a total swale depth of 1 foot or less. For deeper swales or mowed grass swales, the maximum channel side slope should be 3:1. Where space is constrained, swales may have vertical concrete or block walls provided that slope stability, maintenance access and public safety considerations are met.

- ☐ The minimum swale length for biotreatment applications is 100 feet. The minimum residence time for flows in the swale is 10 minutes.
- ☐ If slope is less than 1.5%, underdrains should be provided for the length of the swale
- ☐ A gravel blanket or bedding is required around the underdrain pipe(s). At least 0.5 feet of washed aggregate must be placed below, to the top, and to the sides of the underdrain pipe(s).
- ☐ If an underdrain is included, an amended soil layer of 1 foot minimum thickness must be provided above the underdrain meeting the specifications of MISC-1: Planting/Storage Media.
- ☐ The maximum bed slope in flow direction should not exceed 6% (unles check dams are provided).
- ☐ The maximum flow velocity should not exceed 1.0 ft/sec for water quality treatment swales.
- ☐ For infrequently mowed swales, a maximum flow depth of 4 inches should be implemented. For frequently mowed turf swales, the maximum flow depth is 2 inches.
- ☐ The vegetation height should be maintained between 4 to 6 inches.
- ☐ Gradual meandering bends in the swale are desirable for aesthetic purposes and to promote slower flow and particulate settling.
- ☐ Blockages in the swale that result in uneven flow distribution and points of concentrated flow should be avoided. Blockages that should be avoided include trees, bushes, light pole piers, and utility vaults or pads.

Sizing Method for Vegetated Swales

The Design Capture Method for Flow-based BMPs should be used to determine the design flowrate for a vegetated swale. The user then selects the design flow depth and longitudinal slope and uses the sizing steps below to determine the length and width of the swale. The sizing steps are as follows:

Step 1: Determine Design Flowrate (Q)

Calculate the Design Flowrate (Q) using the Capture Efficiency Method for Flow-based BMPs **(See Appendix III.3.3)**. Inputs include the time of concentration of the catchment (T_c) and the capture efficiency achieved upstream by HSCs or other BMPs.

Step 2: Estimate the Swale Bottom Width

For shallow flow depths, channel side slopes can be ignored and the bottom width can be calculated using a simplified form of Manning's formula:

$$b = (Q \times n_{WQ}) / (1.49 \times y^{1.67} \times s^{0.5})$$

Where:

b = estimated swale bottom width, ft

Q = design flowrate, cfs

n_{WQ} = Manning's roughness coefficient for shallow flow conditions, use 0.2 unless other information is available

y = design flow depth, ft (not to exceed 4 inches or 0.33 ft)

s = longitudinal slope in flow direction, ft/ft (not to exceed 0.06)

If b is between 2 and 10 feet, proceed to step 3.

If b is less than 2 feet, increase b to 2 feet and recalculate design flow depth using the following:

$y = ((Q \times n_{WQ}) / (1.49 \times b \times s^{0.5}))^{0.6}$

If b is greater than 10 feet, one of the following steps is necessary:

- Increase longitudinal slope to a maximum of 6% or 0.06, and recalculate b
- Increase design flow depth to a maximum of 4 inches or 0.33 ft, and recalculate b
- Install a divider lengthwise along swale bottom at least three-quarters of the swale length, beginning at the inlet. The swale width can be increased to 16 feet if a divider is provided.

Step 3: Determine Design Flow Velocity

Calculate the design flow velocity using the following equation:

$V_{WQ} = Q / A_{WQ}$

Where:

V_{WQ} = design flow velocity, fps

Q = design flowrate, cfs

$A_{WQ} = by + Zy^2$, cross sectional area of flow at design depth

Z = side slope length per unit height

If the design flow velocity exceeds 1 foot per second, design parameters in Step 2 should be adjusted (slope, bottom width, or design flow depth) until V_{WQ} is equal or less than 1 fps.

Step 4: Calculate Swale Length

Calculate the swale length needed to achieve a minimum hydraulic residence time of 10 minutes using the following equation:

$L = 60 \times t_{HR} \times V_{WQ}$

Where:

L = swale length, ft

t_{HR} = hydraulic residence time, min (minimum 10 minutes)

V_{WQ} = design flow velocity, fps

Step 5: If Needed, Adjust Swale Length to Site Constraints

Note that oftentimes swale length can be accomodated by providing a meandering swale. However, if swale length is too large for the site, the length can be adjusted as follows:

- Calculate the swale treatment top area (A_{top}), based on the swale length calculated in Step 4:

$A_{TOP} = (b_i + b_{SLOPE}) \times L_i$

Where:

A_{TOP} = top area (ft^2) at the design treatment depth

b_i = bottom width (ft), calculated in Step 2

b_{SLOPE} = the additional top width (ft) above the side slope for the design water depth (for 3:1 side slopes and a 4-inch water depth, b_{slope} = 2 feet)

L_i = initial length (ft) calculated in Step 4

- Use the swale top area and a reduced swale length (L_f) to increase the bottom width, using the following equation:

$L_F = A_{TOP} / (b_F + b_{SLOPE})$

Where:

L_F = reduced swale length (ft)

b_F = increased bottom width (ft)

- Recalculate V_{WQ} according to Step 3 using the revised cross-sectional area A_{WQ} based on the increased bottom width (b_F). Revise the design as necessary if the design flow velocity exceeds 1 foot per second.
- Recalculate to ensure that the 10 minute retention time is retained.

Configuration for Use in a Treatment Train

- Vegetated swales can be incorporated in a treatment train to provide enhanced water quality treatment and reductions in runoff volume and rate. For example, if a vegetated swale is placed upgradient of a dry extended detention (ED) basin, the rate and volume of water flowing to the dry ED basin can be reduced and the water quality enhanced. As another example, dry ED basins may be placed upstream a vegetated swale to reduce the size of the vegetated swale.
- Vegetated swales can be used as pretreatment for infiltration BMPs.
- If designed with an infiltration sump, vegetated "bioinfiltration" swales can provide retention and biotreatment capacity.

Additional References for Design Guidance

Los Angeles Unified School District (LAUSD) Stormwater Technical Manual, Chapter 4: http://www.laschools.org/employee/design/fs-studies-and-reports/download/white_paper_report_material/Storm_Water_Technical_Manual_2009-opt-red.pdf?version_id=76975850

Santa Barbara BMP Guidance Manual, Chapter 6: http://www.santabarbaraca.gov/NR/rdonlyres/91D1FA75-C185-491E-A882-49EE17789DF8/0/Manual_071008_Final.pdf

- County of San Diego Drainage Design Manual for design criteria, Section 5.5: http://www.co.san-diego.ca.us/dpw/floodcontrol/floodcontrolpdf/drainage-designmanual05.pdf

County of Los Angeles Low Impact Development Standards Manual, Chapter 5: http://dpw.lacounty.gov/wmd/LA_County_LID_Manual.pdf

- Los Angeles County Stormwater BMP Design and Maintenance Manual: http://dpw.lacounty.gov/DES/design_manuals/StormwaterBMPDesignandMaintenance.pdf

BIO-3: Vegetated Filter Strip

Also known as:

- *Buffer strip*
- *Vegetated buffer*

Vegetated filter strips are designed to treat sheet flow runoff from adjacent impervious surfaces or intensive landscaped areas such as golf courses. Filter strips decrease runoff velocity, filter out total suspended solids and associated pollutants, and provide some infiltration into underlying soils. While some assimilation of dissolved constituents may occur, filter strips are generally more effective in trapping sediment and particulate-bound metals, nutrients, and pesticides. Filter strips are more effective when the runoff passes through the vegetation and thatch layer in the form of shallow, uniform flow. Biological and chemical processes may help break down pesticides, uptake metals, and utilize nutrients that are trapped in the filter.

Vegetated filter strip.
Source: http://www.wsdot.wa.gov/Environment/WaterQuality/Research/Reports.htm

Feasibility Screening Considerations

- Vegetated filter strips may cause incidental infiltration. Therefore, an evaluation of site conditions should be conducted to evaluate whether the BMP should include an impermeable liner to avoid infiltration into the subsurface.

Opportunity Criteria

- Filter strips provide an attractive and inexpensive vegetative storm water runoff BMP that can be easily incorporated into the landscape design of a site.
- Open areas are needed for vegetated filter strips, including road and highway shoulders, small parking lots, and residential, commercial, or institutional landscaped areas.
- Must be sited adjacent to impervious surfaces which can sheet flow onto filter strips.
- Shallow, evenly distributed flow across entire width of strip is recommended.
- Steep terrain and/or a large tributary area may cause concentrated, erosive flows. The site slope should not exceed 5%.
- Drainage area is ≤ 2 acres with a maximum length (in the direction of flow towards the filter strip) of 150 feet.

OC-Specific Design Criteria and Considerations

☐ For biotreatment applications, the minimum length in the flow direction is 15 feet, and the maximum length in the flow direction is 150 feet. If filter strip is used for pretreatment, the minimum filter strip length is 7.5 feet.

☐ The width of the filter strip should extend across the full width of the tributary area, with the upstream boundary of the filter strip located contiguous to the developed area.

☐ A minimum design residence time of 10 minutes is recommended for biotreatment applications, or 5 minutes for pretreatment uses.

☐ The bed slope in flow direction should be between 2 - 6%.

- [ ] The slope in the direction perpendicular to flow should not exceed 4%.
- [ ] The maximum design flow depth should be 1 inch.
- [ ] The design flow velocity should not exceed 1 ft/sec.
- [ ] Irrigated turf grass or approved equal should be used for vegetation. Grass height should be maintained between 2 – 4 inches.
- [ ] The top of the strip should be installed 2 to 5 inches below the adjacent pavement to allow for vegetation and sediment accumulation at the edge of the strip. A beveled transition is acceptable and may be required per roadside design specifications

Sizing Approach for Vegetated Filter Strip

The Design Capture Method for Flow-based BMPs should be used to determine the design flowrate for a vegetated filter strip. The user then selects the design flow depth and longitudinal slope and uses the sizing steps below to determine the length and width of the swale. The sizing steps are as follows:

Step 1: Determine Design Flowrate (Q)

Calculate the Design Flowrate (Q) using the Capture Efficiency Method for Flow-based BMPs **(See Appendix** III.3.3**)**. Inputs include the time of concentration of the catchment (T_c) and the capture efficiency achieved upstream by HSCs or other BMPs.

Step 2: Calculate the Minimum Filter Strip Width

$$W_{MIN} = Q / q_{A,MIN}$$

Where:

W_{MIN} = minimum width of filter strip (and tributary area), ft

Q = design flow, cfs

$q_{A,MIN}$ = minimum linear unit application rate, 0.005 cfs/ft

Step 3: Calculate the Design Flow Depth

$$d_F = 12 \times ((Q \times n_{WQ}) / (1.49 \times W_{TRIB} \times s^{0.5}))^{0.6}$$

Where:

d_F = design flow depth, in

Q = design flow, cfs

n_{WQ} = Manning's roughness coefficient for shallow flow conditions, use 0.2 unless other information is available

W = width of strip (and tributary area), ft (should be equal or greater than W_{MIN})

s = longitudinal slope in flow direction, ft/ft (not to exceed 0.06)

Step 4: Calculate the Filter Strip Design Velocity

Calculate the filter strip design velocity using the following equation:

$$V_{WQ} = Q / (d_F \times W)$$

Where:

V_{WQ} = filter strip design flow velocity, fps

d_F = design flow depth, in

Q = design flow, cfs

W = width of strip (and tributary area), ft

The design flow velocity should not exceed 1 foot per second. If the velocity exceeds 1 fps, adjust the strip longitudinal slope to decrease the velocity.

Step 5: Calculate Filter Strip Length

Calculate the filter strip length required to achieve the required minimum residence time using the following equation:

$L = 60 \times t_{HR} \times V_{WQ}$

Where:

L = filter strip length, ft (must be 15 ft to 150 ft for biotreatment)

t_{HR} = hydraulic residence time, min (minimum 10 minutes for biotreatment)

V_{WQ} = design flow velocity, fps

Configuration for Use in a Treatment Train

- Filter strips are often used as pretreatment devices for other larger capacity BMPs such as bioretention areas and assist by filtering sediment and associated pollutants prior to entering the larger capacity BMP, preventing clogging and reducing the maintenance requirements for larger capacity BMPs.

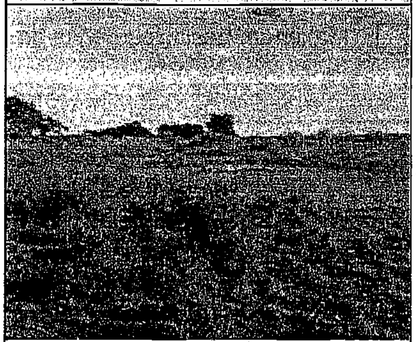
Additional References for Design Guidance

- Santa Barbara BMP Guidance Manual, Chapter 6: http://www.santabarbaraca.gov/NR/rdonlyres/91D1FA75-C185-491E-A882-49EE17789DF8/0/Manual_071008_Final.pdf
- Los Angeles County Stormwater BMP Design and Maintenance Manual, Chapter 4: http://dpw.lacounty.gov/DES/design_manuals/StormwaterBMPDesignandMaintenance.pdf
- Los Angeles Unified School District (LAUSD) Stormwater Technical Manual, Chapter 4: http://www.laschools.org/employee/design/fs-studies-and-reports/download/white_paper_report_material/Storm_Water_Technical_Manual_2009-opt-red.pdf?version_id=76975850
- SMC LID Manual (pp 135): http://www.lowimpactdevelopment.org/guest75/pub/All_Projects/SoCal_LID_Manual/SoCalLID_Manual_FINAL_040910.pdf

BIO-4: Wet Detention Basin

Wet detention basins are constructed, naturalistic ponds with a permanent or seasonal pool of water (also called a "wet pool" or "dead storage"). Aquascape facilities, such as artificial lakes, are a special form of wet pool facility that can incorporate innovative design elements to allow them to function as a stormwater treatment facility in addition to an aesthetic water feature. Wet ponds require base flows to exceed or match losses through evaporation and/or infiltration, and they must be designed with the outlet positioned and/or operated in such a way as to maintain a permanent pool. Wet ponds can be designed to provide extended detention of incoming flows using the volume above the permanent pool surface.

Also known as:
- *Wet Ponds*
- *Retention Ponds*



Wet Detention Basin
Source: Geosyntec Consultants

Feasibility Screening Considerations

- Feasibility screening is not applicable to wet ponds; however the potential risk of groundwater contamination should be considered in selection and design.

Opportunity Criteria

- Can provide aesthetic/recreational value for a project.
- Requires relatively large open space area at outlet of drainage area.
- Generally most applicable for drainage areas larger than 10 acres; however may be applied to smaller drainage areas.
- Applicable in drainage areas with source of base flow to maintain water level.

OC-Specific Design Criteria and Considerations

☐ Minimum set-backs from foundations and slopes should be observed.

☐ Retention of permanent pool volume should not cause geotechnical concerns related to slope stability. Proposed basins in areas with slopes greater than 15 percent or within 200 feet from the top of a hazardous slope or landslide area require geotechnical investigation.

☐ Design should include a sediment forebay to remove coarse solids.

☐ Flow path length to width ratio is 2:1 (minimum) and 3:1 or greater (preferred).

☐ Maximum side slope (H:V) should be 4:1 interior and 3:1 exterior, unless protected from public access by fencing and approved for stability by a geotechnical professional.

☐ Wetland vegetation must not occupy more than 25% of surface area.

☐ A buffer zone with a minimum width of 25 feet should be provided around the top perimeter of the wet detention basin.

- ☐ Inlets and outlets should be positioned to maximize flowpaths through the facility. All inlets should enter the first cell of the wet detention basin.
- ☐ The inlet to wet detention basin should be submerged to dissipate the energy of incoming flow. Energy dissipation should also be used at the outlet of the basin.
- ☐ Minimum freeboard should be 1 foot (2 feet preferred) above the maximum water surface elevation for on-line basins and 1 foot maximum for off-line basins.
- ☐ Maximum basin residence time for dry weather flows is 7 days.

Computing Sizing Criteria for Wet Detention Basins

- This document does not provide specific sizing guidance for wet detention basins. Wet basins should be designed by a team of specialists that understand wetland ecology and biology and are familiar with methods to avoid stagnation, odors, and vector issues associated with maintaining a permanent pool. The BMP designer(s) must demonstrate that the facility is sized to capture and treat the volume of runoff not being addressed by upstream BMPs such that 80 percent of average annual stormwater runoff volume from the site is retained or biotreated.
- The retention volume within a wet detention basin is the equal to the permanent pool volume. The drawdown time criteria, or the rate at which the retention volume becomes available, does not apply to wet detention basins. All runoff in excess of the retention volume that flows through the basin is considered biotreated.
- The permanent pool volume should be at least 50 percent of the volume of active (extended detention) storage.

Configuration for Use in a Treatment Train

- Wet detention basins would generally be designed to serve as the final BMP before discharging runoff off-site.
- Wet detention basins may be preceeded in a treatment train by HSCs and LID BMPs in the drainage area, which would reduce the pollutant load and volume of runoff entering the basin, thereby reducing the sizing requirments of the wet detention basin.
- Wet detention basins can be designed to precede other LID or treatment control BMPs, providing equalization and pretreatment.

Additional References for Design Guidance

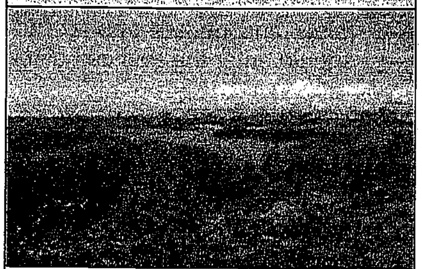
- CASQA BMP Handbook for New and Redevelopment: http://www.cabmphandbooks.com/Documents/Development/TC-20.pdf
- Los Angeles County Stormwater BMP Design and Maintenance Manual: http://dpw.lacounty.gov/DES/design_manuals/StormwaterBMPDesignandMaintenance.pdf
- LA County LID Manual, Chapter 5: http://dpw.lacounty.gov/wmd/LA_County_LID_Manual.pdf
- Portland Stormwater Management Manual: http://www.portlandonline.com/bes/index.cfm?c=47953&
- Western Washington Stormwater Management Manual, Volume V, Chapter 10: http://www.ecy.wa.gov/pubs/0510033.pdf

BIO-5: Constructed Wetland

A constructed wetland is a system consisting of a sediment forebay and one or more permanent micro-pools with aquatic vegetation covering a significant portion of the basin. Constructed treatment wetlands typically include components such as an inlet with energy dissipation, a sediment forebay for settling out coarse solids and to facilitate maintenance, shallow sections (1 to 2 feet deep) planted with emergent vegetation, deeper areas or micro pools (3 to 5 feet deep), and a water quality outlet structure. The interactions between the incoming stormwater runoff, aquatic vegetation, wetland soils, and the associated physical, chemical, and biological unit processes are a fundamental part of constructed wetlands.

Also known as:

- *Stormwater Wetlands*
- *Wetland Basins*
- *Treatment Wetland*



Constructed Wetland
Source: Geosyntec Consultants

Feasibility Screening Considerations

- Feasibility screening is not applicable to constructed wetlands; however the potential risk of groundwater contamination should be considered in selection and design.

Opportunity Criteria

- Potential regional treatment for a relatively large watershed drainage area.
- Applicable for use with projects involving roads, highways, commercial residences, parks, open spaces, or golf courses.
- Requires large footprint area. Applicable for drainage areas treating areas larger than 10 acres and less than 10 square miles.
- Applicable in drainage areas with source of base flow to maintain water level.
- Wetlands present potential safety concerns and habitat for mosquito and midge breeding.

OC-Specific Design Criteria and Considerations

- ☐ Minimum set-backs from foundations and slopes should be observed.
- ☐ Infiltration should not cause geotechnical concerns related to slope stability or erosion. Proposed basins in areas with slopes greater than 7 percent or within 200 feet from the top of a hazardous slope or landslide area require geotechical investigation and report completed by licensed civil engineer.
- ☐ A natural shape and range of intermixed depths is recommended for constructed wetland geometry.
- ☐ Design includes sediment forebay to remove coarse solids.
- ☐ Maximum residence time equals 7 days (dry weather).
- ☐ Flow path length to width ratio is 3:1 (minimum) and 4:1 or greater (preferred).

- [ ] Minimum side slope ratio (H:V) should be 4:1 for interior side slopes, 2:1 for exterior sideslopes, and 3:1 for landscaped slopes.
- [ ] A buffer zone with a minimum width of 25 feet should be provided around the top perimeter of the constructed treatment wetlands.
- [ ] A source of water should be provided if water balance indicates losses will exceed inputs.
- [ ] Inlets and outlets should be positioned to maximize flowpaths through the facility. All inlets should enter the first cell of the wet detention basin.
- [ ] Minimum freeboard should be 1 foot above the maximum water surface elevation.

Computing Sizing Criteria for Constructed Wetlands

This document does not provide specific sizing guidance for constructed wetlands. Wetlands should be designed by a team of wetland specialists that understand wetland ecology and biology and are familiar with methods to avoid stagnation, odors, and vector issues associated with maintaining a permanent pool. The BMP designer(s) must demonstrate that the facility is sized to capture and treat the volume of runoff not being addressed by upstream BMPs such that 80 percent of the total average annual runoff from the site is retained or treated.

The retention volume within a constructed wetland is the equal to the permanent pool volume. The drawdown time criteria, or the rate at which the retention volume becomes available, does not apply to constructed wetlands. All runoff in excess of the retention volume that flows through the wetland is considered biotreated.

Configuration for Use in a Treatment Train

- Constructed wetland basins would generally be designed to serve as the final BMP before discharging runoff off-site.
- Constructed wetland basins may be preceded in a treatment train by HSCs and LID BMPs in the drainage area, which would reduce the pollutant load and volume of runoff entering the basin, thereby reducing the sizing requirments of the wet detention basin.

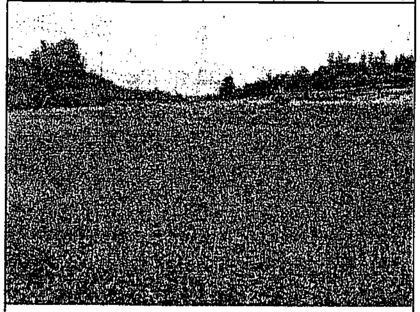
Additional References for Design Guidance

- Western Washington Stormwater Management Manual, Volume V, Chapter 10: http://www.ecy.wa.gov/pubs/0510033.pdf
- CASQA BMP Handbook for New and Redevelopment: http://www.cabmphandbooks.com/Documents/Development/TC-21.pdf
- Los Angeles County Stormwater BMP Design and Maintenance Manual, Chapter 7: http://dpw.lacounty.gov/DES/design_manuals/StormwaterBMPDesignandMaintenance.pdf
- LA County LID Manual, Chapter 5: http://dpw.lacounty.gov/wmd/LA_County_LID_Manual.pdf
- SMC LID Manual: http://www.lowimpactdevelopment.org/guest75/pub/All_Projects/SoCal_LID_Manual/SoCalLID_Manual_FINAL_040910.pdf

BIO-6: Dry Extended Detention Basin

Dry extended detention basins (DEDBs) are basins whose outlets have been designed to detain the stormwater quality design volume, SQDV, for 36 to 48 hours to allow particulates and associated pollutants to settle out. DEDBs do not have a permanent pool; they are designed to drain completely between storm events. They can also be used to provide hydromodification and/or flood control by modifying the outlet control structure and providing additional detention storage. The slopes, bottom, and forebay of DEDBs are typically vegetated. Considerable stormwater volume reduction can occur in DEDBs when they are located in permeable soils and are not lined with an impermeable barrier.

Also known as:
- *Dry Ponds*
- *Detention Ponds*



Dry Extended Detention Basin,

For dry extended detention basins to be considered as biotreatment BMPs, they must meet all applicable guidelines described in this Fact Sheet and in **Appendix XII**.

If dry extended detention basins do not meet these guidelines, they shall be considered treatment control BMPs.

Level 1 Screening Considerations

- Infiltration feasibility is not generally applicable to DEDBs; however some incidental infiltration will occur.
- The potential risk of groundwater contamination and geotechnical hazards should be considered in determining whether a liner is needed.

Opportunity Criteria

- Most applicable for larger drainage areas where significant area is available at the downstream end of the drainage area.
- Can be integrated into open areas or play fields.
- Not ideal in areas where high seasonal groundwater would limit depth or require lining.
- Can be integrated into flood control facilities where essential functions of flood control facilities are not compromised.

Criteria for Categorization of DEDBs as Biotreatment BMP

In order to to be categorized as Biotreatment BMPs, DEDBs should be designed to meet the following minimum criteria. DEDBs not meeting these criteria but meeting the OC-Specific design criteria listed next are categorized as treatment control BMPs.

☐ Maximum treatment depth should be 6 feet

☐ Robust, diverse, and extensive vegetation should be designed and maintained to an average height not less than > 12 inches. Soils should be amended per soil amendment criteria contained in MISC-2: Amended Soils if vegetation cannot be readily established.

- [ ] Hardscape within basin should be limited to essential access roads.
- [ ] Design should include a vegetated sediment forebay that encompasses between 20 and 30 percent of the basin volume.
- [ ] The basin should be designed to draw down over 48 to 72 hours. The basin should be designed such that drawdown time for the bottom 50 percent of the treatment volume is not less than 2/3 of the entire drawdown time.
- [ ] The L:W ratio of the basin should meet or exceed 2:1.
- [ ] A micropool should be provided upstream of the outlet structure and/or media filtration should be integrated with the outlet structure.

OC-Specific Design Criteria and Considerations

- [ ] Minimum set-backs from foundations and slopes should be observed
- [ ] Infiltration should not cause geotechnical concerns related to slope stability or erosion. Proposed basins in areas with slopes greater than 15 percent or within 200 feet from the top of a hazardous slope or landslide area require geotechnical investigation.
- [ ] Depth from bottom of facility to seasonal high groundwater table should be ≥ 2 feet.
- [ ] DEDBs are preferrably off-line, designed to bypass peak flows.
- [ ] Minimum freeboard equals 1 foot for offline facilities and 2 feet for online facilities.
- [ ] Maximum side slope (H:V) preferably equals 4:1 interior and 3:1 exterior; steeper slopes permitted with fencing and geotechnical analysis.
- [ ] Longitudinal slope preferably 0%-2%.
- [ ] Low flow channel with gravel infiltration trench preferably provided where infiltration is allowable; designed to eliminate maximum estimated dry weather flowrate.

Computing Sizing Criteria for Dry Extended Detention Basins

- DEDBs should be sized for the DCV, calculated per the Simple Design Capture Volume Sizing Method.
- Routing calculations should demonstrate that the outlet structure is designed to acheve the target drawdown time and pattern: The basin should be designed to draw down over 48 to 72 hours. The basin should be designed such that drawdown time for the bottom 50 percent of the treatment volume is not less than 2/3 of the entire drawdown time.

Configuration for Use in a Treatment Train

- Dry extended detention basins may be preceeded in a treatment train by HSCs and LID BMPs in the drainage area, which would reduce the remaining biotreatment/treatment control requirements and allow the basin to be smaller in volume.
- Dry extended detention basins can be located upstream of LID or treatment control BMPs to provide peak flow equalization.

Additional References for Design Guidance

- CASQA BMP Handbook for New and Redevelopment: http://www.cabmphandbooks.com/Documents/Development/TC-22.pdf

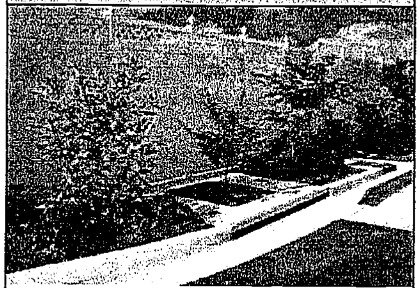
- SMC LID Manual (pp 145): http://www.lowimpactdevelopment.org/guest75/pub/All_Projects/SoCal_LID_Manual/SoCalLID_Manual_FINAL_040910.pdf
- Los Angeles County Stormwater BMP Design and Maintenance Manual, Chapter 2: http://dpw.lacounty.gov/DES/design_manuals/StormwaterBMPDesignandMaintenance.pdf
- City of Portland Stormwater Management Manual (Pond, page 2-68) http://www.portlandonline.com/bes/index.cfm?c=47954&a=202883
- San Diego County LID Handbook Appendix 4 (Factsheet 3): http://www.sdcounty.ca.gov/dplu/docs/LID-Appendices.pdf

BIO-7: Proprietary Biotreatment

Proprietary biotreatment devices are devices that are manufactured to mimic natural systems such as bioretention areas by incorporating plants, soil, and microbes engineered to provide treatment at higher flow rates or volumes and with smaller footprints than their natural counterparts. Incoming flows are typically filtered through a planting media (mulch, compost, soil, plants, microbes, etc.) and either infiltrated or collected by an underdrain and delivered to the storm water conveyance system. Tree box filters are an increasingly common type of proprietary biotreatment device that are installed at curb level and filled with a bioretention type soil. For low to moderate flows they operate similarly to bioretention systems and are bypassed during high flows. Tree box filters are highly adaptable solutions that can be used in all types of development and in all types of soils but are especially applicable to dense urban parking lots, street, and roadways.

Also known as:

- *Catch basin planter box*
- *Bioretention vault*
- *Tree box filter*



Proprietary biotreatment
Source: http://www.americastusa.com/index.php/filterra/

Feasibility Screening Considerations

- Proprietary biotreatment devices that are unlined may cause incidental infiltration. Therefore, an evaluation of site conditions should be conducted to evaluate whether the BMP should include an impermeable liner to avoid infiltration into the subsurface.

Opportunity Criteria

- Drainage areas of 0.25 to 1.0 acres.
- Land use may include commercial, residential, mixed use, institutional, and subdivisions. Proprietary biotreatment facilities may also be applied in parking lot islands, traffic circles, road shoulders, and road medians.
- Must not adversely affect the level of flood protection provided by the drainage system.

OC-Specific Design Criteria and Considerations

- [ ] Frequent maintenance and the use of screens and grates to keep trash out may decrease the likelihood of clogging and prevent obstruction and bypass of incoming flows.
- [ ] Consult proprietors for specific criteria concerning the design and performance.
- [ ] Proprietary biotreatment may include specific media to address pollutants of concern. However, for proprietary device to be considered a biotreatment device the media must be capable of supporting rigorous growth of vegetation.
- [ ] Proprietary systems must be acceptable to the reviewing agency. Reviewing agencies shall have the discretion to request performance information. Reviewing agencies shall have the discretion to deny the use of a proprietary BMP on the grounds of performance, maintenance considerations, or other relevant factors.

☐ In right of way areas, plant selection should not impair traffic lines of site. Local jurisdictions may also limit plant selection in keeping with landscaping themes.

Computing Sizing Criteria for Proprietary Biotreatment Device

- Proprietary biotreatment devices can be volume based or flow-based BMPs.
- Volume-based proprietary devices should be sized using the Simple Design Capture Volume Sizing Method described in **Appendix** III.3.1 or the Capture Efficiency Method for Volume-Based, Constant Drawdown BMPs described in **Appendix** III.3.2.
- The required design flowrate for flow-based proprietary devices should be computed using the Capture Efficiency Method for Flow-based BMPs **described in Appendix** III.3.3).

Additional References for Design Guidance

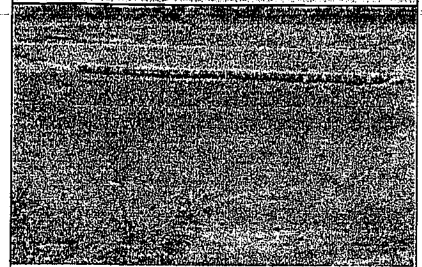
- Los Angeles Unified School District (LAUSD) Stormwater Technical Manual, Chapter 4: http://www.laschools.org/employee/design/fs-studies-and-reports/download/white_paper_report_material/Storm_Water_Technical_Manual_2009-opt-red.pdf?version_id=76975850
- Los Angeles County Stormwater BMP Design and Maintenance Manual, Chapter 9: http://dpw.lacounty.gov/DES/design_manuals/StormwaterBMPDesignandMaintenance.pdf
- Santa Barbara BMP Guidance Manual, Chapter 6: http://www.santabarbaraca.gov/NR/rdonlyres/91D1FA75-C185-491E-A882-49EE17789DF8/0/Manual_071008_Final.pdf

XIV.6. Treatment Control BMP Fact Sheets (TRT)

TRT-1: Sand Filters

Also known as:

➢ *Bed Media Filter*



Media Filter
Source: CABMPHB, TC-40

Sand filters operate by filtering stormwater through a constructed media bed (generally sand) with an underdrain system. Runoff enters the filter and spreads over the surface. As flows increase, water backs up on the surface of the filter where it is held until it can percolate through the sand. The treatment pathway is vertical (downward through the media) to an engineered underdrain system that is connected to the downstream storm drainage system. As stormwater passes through the sand, pollutants are trapped on the surface of the filter, in the small pore spaces between sand grains, or are adsorbed to the sand surface.

Feasibility

- Site conditions should be assess to determine if systems should be lined to prevent incidental infiltration.

Opportunity Criteria

- Intended for use when retention and biotreatment options are infeasible.
- Locate away from trees producing leaf litter or areas contributing significant sediment that could cause clogging.
- Pretreatment is necessary to eliminate significant sediment load or other large particles that could reduce the infiltration capacity of the filter. Refer to Section XIV.7 for information on pretreatment devices. Pretreatment can also be performed in a sedimentation chamber, which precedes the filter bed.
- Drainage area topography and downstream drainage configuration must have adequate relief to allow for percolation through the sand and collection and conveyance through the underdrain stormwater conveyance system; four feet is recommended between inlet and outlet of filter.
- Not applicable in areas of permanent or seasonal high groundwater (less than five feet below ground surface)
- Open bed sand filters should not be placed in areas subject to seed sources and where hydrologic conditions promote prolific germination of plants in the media. Undesired plant growth will substantially increase maintenance costs and threaten to damage the filter or impair its performance.

OC-Specific Design Criteria and Considerations

☐ Where incidental infiltration would potentially cause geotechnical concerns, systems should be lined with an impermeable membrane or layer.

☐ Minimum set-backs from foundations and slopes should be observed if the facility is not lined.

☐ Filter bed depth (i.e., media thickness) is at least 24 inches, but 36 inches preferred.

- ☐ Max ponding depth above filter should not exceed 6 feet.
- ☐ Saturated hydraulic conductivity of media should be selected to address pollutants of concern and factors of safety in design should be set to account for deterioration of performance between maintenance.
- ☐ Side slopes should not exceed and 2:1 H:V unless stabilization approved by licensed geotechnical engineer.
- ☐ Minimum pretreatment should be provided upstream of the filter, and water bypassing pretreatment should not be directed to the filter.
- ☐ Filters should be designed and maintained such that ponded water should not persist for longer than 72 hours following a storm event.

Computing Sizing Criteria for Media Filter

- Media filters with significant surface storage should be sized as volume-based BMPs.
- Alternatively, media filters may be sized as flow-based BMPs when storage is not significant.

Calculating Sand Filter Drawdown Rate for Volume-based Sizing Calculations

Volume-based sizing of sand filters should be conducted identically to bioretention with underdrains.

Maximum ponding depth should be increased to 6 feet in this sizing calculation.

Calculating Sand Filter Design Flowrate Rate if Sized as Flow-based BMP

The required design flowrate should be calculated based on the **Capture Efficiency Method for Flow-based BMPs** (See **Appendix III.3.3**).

The flow-based treatment capacity of a sand filter may be estimated as:

$$Q_{capacity} = K_{sat} \times I_{full} \times A / [24 \text{ hr/day}]$$

Where,

K_{sat} = design saturated hydraulic conductivity, feet/day (set to account for long-term deterioration of performance)

I_{full} = gradient across filter bed when storage is full = (depth of water at overflow + depth of media bed)/(depth of media bed)

A = surface area of media bed, sq-ft

Configuration for Use in a Treatment Train

- Sand filters may be preceded in a treatment train by HSCs and LID BMPs in the drainage area, which would reduce the required size of the filter.
- Sand filters should be preceded by some form of pretreatment which will remove the largest particles before entering and potentially clogging the sand filter.
- Sand filters can be used to provide pretreatment for infiltration basins or other LID infiltration BMPs.

Additional References for Design Guidance

- CASQA BMP Handbook for New and Redevelopment: http://www.cabmphandbooks.com/Documents/Development/TC-40.pdf

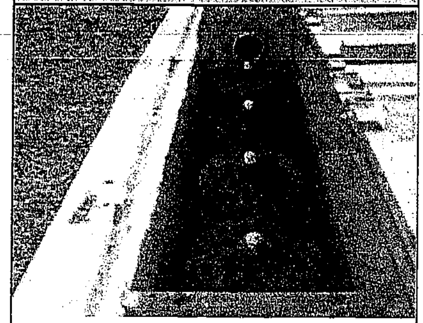
- Los Angeles County Stormwater BMP Design and Maintenance Manual, Chapter 8: http://dpw.lacounty.gov/DES/design_manuals/StormwaterBMPDesignandMaintenance.pdf
- LA County LID Manual: http://dpw.lacounty.gov/wmd/LA_County_LID_Manual.pdf
- San Diego County LID Handbook Appendix 4 (Factsheet 6): http://www.sdcounty.ca.gov/dplu/docs/LID-Appendices.pdf
- SMC LID Manual: http://www.lowimpactdevelopment.org/guest75/pub/All_Projects/SoCal LID_Manual/SoCalLID_Manual_FINAL_040910.pdf
- LA County LID Manual: http://dpw.lacounty.gov/wmd/LA_County_LID_Manual.pdf
- Portland Stormwater Management Manual: http://www.portlandonline.com/bes/index.cfm?c=47953&
- Western Washington Stormwater Management Manual: http://www.ecy.wa.gov/pubs/0510033.pdf

TRT-2: Cartridge Media Filter

Cartridge media filters (CMFs) are manufactured devices that consist of a series of modular filters packed with engineered media that can be contained in a catch basin, manhole, or vault that provide treatment through filtration and sedimentation. The manhole or vault may be divided into multiple chambers where the first chamber acts as a pre-settling basin for removal of coarse sediment while another chamber acts as the filter bay and houses the filter cartridges. A variety of media types are available from various manufacturers which can target pollutants of concern.

Also known as:

- Manufactured Media Filters



Cartridge Media Filter
Source: Contech Stormwater Solution, Inc.

Feasibility Screening Considerations

- Not applicable

Opportunity Criteria

- Intended for use when retention and biotreatment options are infeasible.
- Recommended for drainage area with limited available surface area or where surface BMPs would restrict uses.
- For drainage areas with significant areas of non-stabilized soil, permanent soil stablization must be achieved before before cartridge media filters are installed and put on line to minimize risk of clogging.
- Depending on the number of cartridges, maintenance events can have long durations. Care should be exercised in siting these facilities so that maintenance events will not significantly disrupt businesses or traffic.

OC-Specific Design Criteria and Considerations

- ☐ Cartridge media filter BMP vendors should be consulted regarding design and specifications.
- ☐ Filter media should be selected to target pollutants of concern. A combination of media may be appropriate to remove a variety of pollutants.
- ☐ If CMF are integrated with a vault for equalization, the system should be designed to completely drain the vault within 96 hours of storm event or otherwise protect against standing water and mosquito breeding concerns.

Computing Sizing Criteria for Cartridge Media Filters

The required design flowrate should be calculated based on the **Capture Efficiency Method for Flow-based BMPs** (See **Appendix** III.3.3).

Additional References for Design Guidance

- Los Angeles County Stormwater BMP Design and Maintenance Manual, Chapter 9: http://dpw.lacounty.gov/DES/design_manuals/StormwaterBMPDesignandMaintenance.pdf

- SMC LID Manual: http://www.lowimpactdevelopment.org/guest75/pub/All_Projects/SoCal_LID_Manual/SoCalLID_Manual_FINAL_040910.pdf
- Western Washington Stormwater Management Manual, Volume V, Chapter 12: http://www.ecy.wa.gov/pubs/0510033.pdf

XIV.7. Pretreatment/Gross Solids Removal BMP Fact Sheets (PRE)

PRE-1: Hydrodynamic Separation Device

Hydrodynamic separation devices are inline pretreatment units designed to remove trash, debris, and coarse sediment using screening, gravity settling, and centrifugal forces generated by forcing the influent into a circular motion. Several companies manufacture units with a variety of design components including separate chambers, baffles, sorbent media, screens, and flow control orifices. Therefore, additional constituents may be targeted depending on the design; however, the short residence time and potential for captured materials to be released during high flows limits the acceptable use of this BMP type as a standalone treatment control BMP.

Also known as:

- *Vortex Separators*
- *Swirl Concentrators*
- *Gross solids removal devices (GSRDs)*

Hydrodynamic Separation Device
Source: Contech Stormwater Solution, Inc.

Opportunity Criteria

- Hydrodynamic separation devices are effective for the removal of coarse sediment, trash, and debris, and are useful as pretreatment in combination with other BMP types that target smaller particle sizes. They are most effective in urban areas where coarse sediment, trash, and debris are pollutants of concern.
- Hydrodynamic devices represent a wide range of device types that have different unit processes and design elements (e.g., storage versus flow-through designs, inclusion of media filtration, etc.) that vary significantly within the category. These design features likely have significant effects on BMP performance; therefore, generalized performance data for hydrodynamic devices is not practical.

OC-Specific Design Criteria and Considerations

- ☐ Proprietary hydrodynamic device BMP vendors are constantly updating and expanding their product lines so refer to the latest design guidance from each of the vendors. General guidelines on the performance, operations and maintenance of proprietary devices are provided by the vendors.
- ☐ Operations and maintenance requirements include: clearing trash, debris, and sediment around insert grate and inside chamber, and repairing screens and media if damaged or severely clogged.

Computing Sizing Criteria for Hydrodynamic Devices

- Hydrodynamic separation devices should be adequately sized to pretreat the entire design volume or design flow rate of the downstream BMP.
- The required design flowrate should be calculated based on the Capture Efficiency Method for Flow-based BMPs (See **Appendix** III) to achieve 80 percent capture of the average annual stormwater runoff volume.

Proprietary Hydrodynamic Device Manufacturer Websites

- Table XIV.1 is a list of manufacturers that provide hydrodynamic separation devices. The inclusion of these manufacturers does not represent an endorse of their products. Other devices and manufacturers may be acceptable for pretreatment.

Table XIV.1: Proprietary Hydrodynamic Device Manufacturer Websites

Device	Manufacturer	Website
Rinker In-Line Stormceptor®	Rinker Materials™	www.rinkerstormceptor.com
FloGard® Dual-Vortex Hydrodynamic Separator	KriStar Enterprises Inc.	www.kristar.com
Contech® CDS^{a}™	Contech® Construction Products Inc.	www.contech-cpi.com
Contech® Vortechs™	Contech® Construction Products Inc.	www.contech-cpi.com
Contech® Vorsentry™	Contech® Construction Products Inc.	www.contech-cpi.com
Contech® Vorsentry™ HS	Contech® Construction Products Inc.	www.contech-cpi.com
BaySaver BaySeparator	Baysaver Technologies Inc.	www.baysaver.com

Additional References for Design Guidance

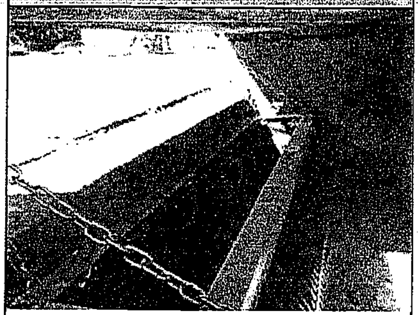
- CASQA BMP Handbook for New and Redevelopment: http://www.cabmphandbooks.com/Documents/Development/MP-51.pdf
- Los Angeles County Stormwater BMP Design and Maintenance Manual, Chapter 9: http://dpw.lacounty.gov/DES/design_manuals/StormwaterBMPDesignandMaintenance.pdf

PRE-2: Catch Basin Insert Fact Sheet

Catch basin inserts are manufactured filters or fabric placed in a drop inlet to remove sediment and debris and may include sorbent media (oil absorbent pouches) to remove floating oils and grease. Catch basin inserts are selected specifically based upon the orientation of the inlet and the expected sediment and debris loading.

Also known as:

- *Drop Inlet Filters*
- *Catch Basin Filters*



Catch Basin Insert (DrainPac™)

Opportunity Criteria

- Catch basin inserts come in such a wide range of configurations that it is practically impossible to generalize the expected performance. Inserts should mainly be used for catching coarse sediments and floatable trash and are effective as pretreatment in combination with other types of structures that are recognized as water quality treatment BMPs. Trash and large objects can greatly reduce the effectiveness of catch basin inserts with respect to sediment and hydrocarbon capture.
- Catch basin inserts are applicable for drainage area that include parking lots, vehicle maintenance areas, and roadways with catch basins that discharge directly to a receiving water.

OC-Specific Design Criteria and Considerations

- ☐ Frequent maintenance and the use of screens and grates to keep trash out may decrease the likelihood of clogging and prevent obstruction and bypass of incoming flows.
- ☐ Consult proprietors for specific criteria concerning the design of catch basin inserts.
- ☐ Catch basin inserts can be installed with specific media for pollutants of concern.

Proprietary Manufacturer / Supplier Websites

- Table XIV.2 is a list of manufacturers that provide catch basin inserts. The inclusion of these manufacturers does not represent an endorse of their products. Other devices and manufacturers may be acceptable for pretreatment.

Table XIV.2: Proprietary Catch Basin Insert Manufacturer Websites

Device	Manufacturer	Website
AbTech Industries Ultra-Urban Filter™	AbTech Industries	www.abtechindustries.com
Aquashield Aqua-Guardian™ Catch Basin Insert	Aquashield™ Inc.	www.aquashieldinc.com
Bowhead StreamGuard™	Bowhead Environmental & Safety, Inc.	http://www.shopbowhead.com/
Contech® Triton Catch Basin Filter™	Contech® Construction Products Inc.	www.contech-cpi.com
Contech® Triton Curb Inlet Filter™	Contech® Construction Products Inc.	www.contech-cpi.com

Table XIV.2: Proprietary Catch Basin Insert Manufacturer Websites

Device	Manufacturer	Website
Contech® Triton Basin StormFilter™	Contech® Construction Products Inc.	www.contech-cpi.com
Contech® Curb Inlet StormFilter™	Contech® Construction Products Inc.	www.contech-cpi.com
Curb Inlet Basket	SunTree Technologies Inc.	www.suntreetech.com
Curb Inlet Grates	EcoSense International™	http://www.ecosenseint.com/
DrainPac™	United Storm Water, Inc.	http://www.unitedstormwater.com
Grate Inlet Skimmer Box	SunTree Technologies Inc.	www.suntreetech.com
KriStar FloGard+PLUS®	KriStar Enterprises Inc.	www.kristar.com
KriStar FloGard®	KriStar Enterprises Inc.	www.kristar.com
KriStar FloGard LoPro Matrix Filter®	KriStar Enterprises Inc.	www.kristar.com
Nyloplast Storm-PURE Catch Basin Insert	Nyloplast Engineered Surface Drainage Products	www.nyloplast-us.com
StormBasin®	FabCo® Industries Inc.	www.fabco-industries.com
Stormdrain Solutions Interceptor	FabCo® Industries Inc.	www.fabco-industries.com
Stormdrain Solutions Inceptor®	Stormdrain Solutions	www.stormdrains.com
StormPod®	FabCo® Industries Inc.	www.fabco-industries.com
Stormwater Filtration Systems	EcoSense International™	http://www.ecosenseint.com/
Ultra-CurbGuard®	UltraTech International Inc.	www.spillcontainment.com
Ultra-DrainGuard®	UltraTech International Inc.	www.spillcontainment.com
Ultra-GrateGuard®	UltraTech International Inc.	www.spillcontainment.com
Ultra-GutterGuard®	UltraTech International Inc.	www.spillcontainment.com
Ultra-InletGuard®	UltraTech International Inc.	www.spillcontainment.com

APPENDIX XV. WORKSHEETS

This section provides hyperlinks to each of the worksheets embedded in text of the TGD Appendices.

- Worksheet A: Hydrologic Source Control Calculation Form
- Worksheet B: Simple Design Capture Volume Sizing Method
- Worksheet C: Capture Efficiency Method for Volume-Based, Constant Drawdown BMPs
- Worksheet D: Capture Efficiency Method for Flow-Based BMPs
- Worksheet E: Determining Capture Efficiency of Volume Based, Constant Drawdown BMP based on Design Volume
- Worksheet F: Determining Capture Efficiency of a Flow-based BMP based on Treatment Capacity
- Worksheet G: Alternative Compliance Volume Worksheet
- Worksheet H: Factor of Safety and Design Infiltration Rate and Worksheet
- Worksheet I: Summary of Groundwater-related Feasibility Criteria
- Worksheet J: Summary of Harvested Water Demand and Feasibility