# APPENDIX C. FACT SHEETS

## CONTENTS

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## Siting and Suitability

Bioretention areas offer flexibility in design and can easily be incorporated into new or existing infrastructure such as parking lot islands and edges, street rights-of-way and medians, roundabouts, pedestrian walkways, public transit stops, or building drainage areas. The available space and site topography often dictate the geometry and size of the bioretention areas. Additional site objectives include incorporation into the site's natural hydrologic regime and further enhancement of natural landscape features in an urban setting. See Section 3 for details.

**Drainage Area:** Less than 5 acres and fully stabilized.

**Head Requirements:** Bioretention typically requires a minimum of 2.5 to 3.5 ft of elevation difference between the inlet and outlet to the receiving storm drain network.

**Slopes:** Slopes draining to bioretention should be 15% or less, side slopes should be 3:1 (H:V) or flatter, and internal longitudinal slope should be 2% or less.

**Setbacks:** Provide 10-ft setback from structures/foundations, 100-ft setback from septic fields and water supply wells, and 50-ft setback from steep slopes.

**Water Table & Bedrock:** At least 10 ft separation must be provided between bottom of cut (subgrade) and seasonal high water table, bedrock, or other restrictive features.

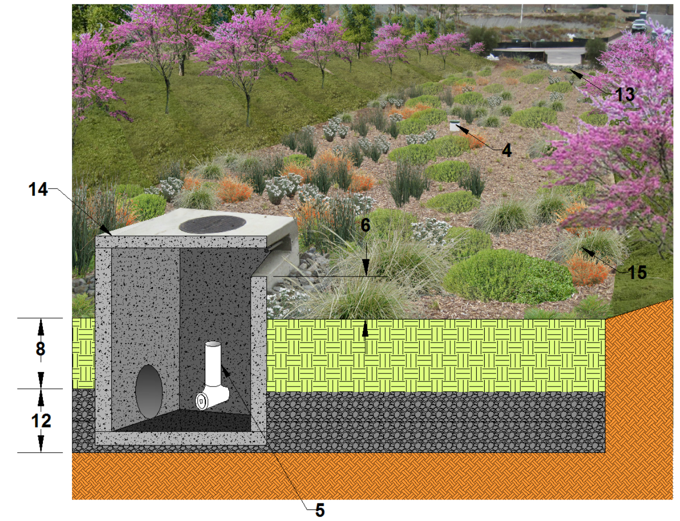
**Soil Type:** Bioretention can be used in any soils. If subsoil infiltration is less than 0.5 in/hr, an underdrain should be installed. A liner may be needed if subsoils contain expansive clays or calcareous minerals.

**Areas of Concern:** Infiltration is not allowed at sites with known soil contamination or *hot spots*, such as gas stations. An appropriate impermeable liner must be used in areas of concern.

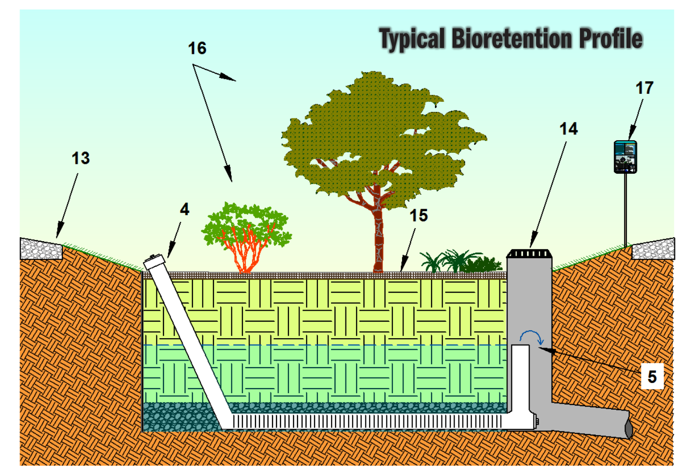
## Design Considerations & Specifications *(see Appendices A & G for details)*

| | | Design Component | General Specification |
|---|---|---|---|
| Drainage Design | 1 | Impermeable liner | If non-infiltrating (per geotechnical investigation), use clay liner, geomembrane liner, or concrete. |
| | 2 | Lateral hydraulic restriction barriers | May use concrete or geomembrane to restrict lateral flows to adjacent subgrades, foundations, or utilities. |
| | 3 | Underdrain/ Infiltration | Underdrain required if subsoil infiltration < 0.5 in/hr. Schedule 40 PVC pipe with perforations (slots or holes) every 6 inches. If design is fully-infiltrating, ensure that subgrade compaction is minimized. |
| | 4 | Cleanouts/ Observation Wells | Provide 6-inch diameter cleanout ports/observation wells for each underdrain pipe. |
| | 5 | Internal Water Storage (IWS) | If using underdrain, the underdrain outlet can be elevated to create a sump for additional moisture retention to promote plant survival and treatment. Top of IWS should be greater than 18 inches below surface. |
| | 6 | Temporary Ponding Depth | 6–18 inches (6–12 inches near schools or in residential areas); average ponding depth of 9 inches is recommended. |
| | 7 | Drawdown Time | Surface drawdown: 12–96 hrs, Subsurface dewatering: 48 hrs. |
| Soil Media | 8 | Soil Media Depth | 1.5–4 feet (deeper for better pollutant removal, hydrologic benefits, and deeper rooting depths). |
| | 9 | Soil Media Composition | 65% sand, 20% sandy loam, and 15% compost (from vegetation-based feedstock; animal wastes or by-products should not be applied) by volume. |
| | 10 | Media Permeability | 5 in/hr infiltration rate for the flow-based SUSMP method (1–6 in/hr for alternative designs, as approved by local jurisdiction). |
| | 11 | Chemical Analysis | Total phosphorus < 15 ppm, pH 6–8, CEC > 5 meq/100 g soil. Organic Matter Content < 5% by weight. |
| | 12 | Drainage Layer | Separate media from underdrain with 2 to 4 inches of washed sand (ASTM C-33), followed by 2 inches of choking stone (ASTM No. 8) over a 1.5 ft envelope of ASTM No. 57 stone. |
| Routing | 13 | Inlet/Pretreatment | Provide stabilized inlets at least 12 inches wide and energy dissipation. Install rock armored forebay for concentrated flows, gravel fringe and vegetated filter strip for sheet flows, or vegetated swale. |
| | 14 | Outlet Configuration | Online: All runoff is routed through system—install an elevated overflow structure or weir at the elevation of maximum ponding. Offline: Only treated volume is diverted to system—install a diversion structure or allow bypass of high flows. |
| Landscape | 15 | Mulch | Dimensional chipped hardwood or triple shredded, well-aged hardwood mulch 3-inches-deep. |
| | 16 | Vegetation | Native, deep rooting, drought tolerant plants. |
| | 17 | Multi-Use Benefits | Provide educational signage, artwork, or wildlife amenities. |

**Bioretention Area Cross Section**
**Seaside Ridge Development, San Diego, CA**




A bioretention area intercepts and treats runoff from a residential development. IWS is demonstrated in the rendered cross section by upturning the underdrain in the outlet structure. Note: photograph was enhanced by rendering additional vegetation.




This diagram shows the major design components of bioretention. Underdrains should be excluded when subsoil infiltration rates are suitable. Additional hydromodification control can be provided by increasing surface storage volume or subsurface drainage layer storage depth.

## Maintenance Considerations *(see Appendix D for detailed checklist)*

| Task | Frequency | Indicator Maintenance is Needed | Maintenance Notes |
|---|---|---|---|
| **Catchment inspection** | Weekly or biweekly with routine property maintenance | Excessive sediment, trash, and/or debris accumulation on the surface of bioretention | Permanently stabilize any exposed soil and remove any accumulated sediment. Adjacent pervious areas may need to be regraded. |
| **Inlet inspection** | | Internal erosion or excessive sediment, trash, and/or debris accumulation | Check for sediment accumulation to ensure that flow into the bioretention is as designed. Remove any accumulated sediment. |
| **Litter/leaf removal and misc. upkeep** | | Accumulation of litter and debris within bioretention area, mulch around outlet, internal erosion | Litter, leaves, and debris should be removed to reduce the risk of outlet clogging, reduce nutrient inputs to the bioretention area, and to improve facility aesthetics. Erosion should be repaired and stabilized. |
| **Pruning** | 1–2 times/year | Overgrown vegetation that interferes with access, lines of sight, or safety | Nutrients in runoff often cause bioretention vegetation to flourish. |
| **Mowing** | 2–12 times/year | Overgrown vegetation that interferes with access, lines of sight, or safety | Frequency depends on location and desired aesthetic appeal and type of vegetation. |
| **Outlet inspection** | 1 time/year | Erosion at outlet | Remove any accumulated mulch or sediment. |
| **Mulch removal and replacement** | 1 time/2–3 years | 2/3 of mulch has decomposed | Remove decomposed fraction and top off with fresh mulch to a total depth of 3 inches |
| **Remove and replace dead plants** | 1 time/year | Dead plants | Within the first year, 10 percent of plants can die. Survival rates increase with time. |
| **Temporary Watering** | 1 time/2–3 days for first 1–2 months | Until establishment and during severely-droughty weather | Watering after the initial year might be required. |
| **Fertilization** | 1 time initially | Upon planting | One-time spot fertilization for first year vegetation. |

# Bioretention

## Description

Bioretention areas are small-scale, vegetated depressions designed to provide stormwater storage and filtration through engineered media. Using detention, sedimentation, filtration and adsorption, bioretention enhances the removal of contaminants from stormwater by both plants and soils.

Bioretention can also incorporate pretreatment (i.e., vegetated filter strips, vegetated swales or settling forebays), allowing increased sedimentation and capture of debris from heavily trafficked areas. Finally, bioretention can be used in-line with traditional stormwater conveyance systems.

| Treatment Efficiency | |
|---|---|
| Runoff Volume | High (unlined)/Low (lined) |
| Sediment | High |
| Nutrients | Medium |
| Pathogens | High |
| Metals | High |
| Oil & Grease | High |
| Organics | High |

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# Bioretention Swale

## Description

Bioretention swales are shallow, open channels that are designed to reduce runoff volume through infiltration. Additionally, bioretention swales remove pollutants such as trash and debris by filtering water through vegetation within the channel. Swales can serve as conveyance for stormwater and can be used in place of traditional curbs and gutters; however, when compared to traditional conveyance systems the primary objective of a bioretention swale is infiltration and water quality enhancement rather than conveyance. In addition to reducing the mass of pollutants in runoff, properly maintained bioretention swales can enhance the aesthetics of a site.

| Treatment Efficiency | | | |
|---|---|---|---|
| Runoff Volume | High (unlined)/ Low (lined) | Bacteria | High |
| Sediment | High | Nutrients | Medium |
| Trash/ debris | High | Heavy Metals | High |
| Organics | High | Oil & Grease | High |

## Siting and Suitability

Bioretention swales are highly versatile stormwater IMPs that effectively reduce pollutants. With a narrow width, bioretention swales can be integrated into site plans with various configurations and components. Ideal sites for bioretention swales include the right-of-way of linear transportation corridors and along borders or medians of parking lots. In heavily trafficked areas, curb cuts can be used to delineate boundaries. Bioretention swales can be combined with other basic and stormwater runoff BMPs to form a treatment train, reducing the required size of a single IMP unit. See Section 3 for details.

**Drainage Area:** Less than 2 acres and fully stabilized.

**Head Requirements:** Bioretention swale typically requires a minimum of 2.5 to 3.5 ft of elevation difference between the inlet and outlet to the receiving storm drain network.

**Slopes:** Slopes draining to bioretention swale should be 15% or less, side slopes should be 3:1 (H:V) or flatter, and check dams should be used to provide longitudinal bed slopes of 2.5% (average slope should not exceed 4% from inlet to outlet).

**Setbacks:** Provide 10-ft setback from structures/foundations, 100-ft setback from septic fields and water supply wells, and 50-ft setback from steep slopes.

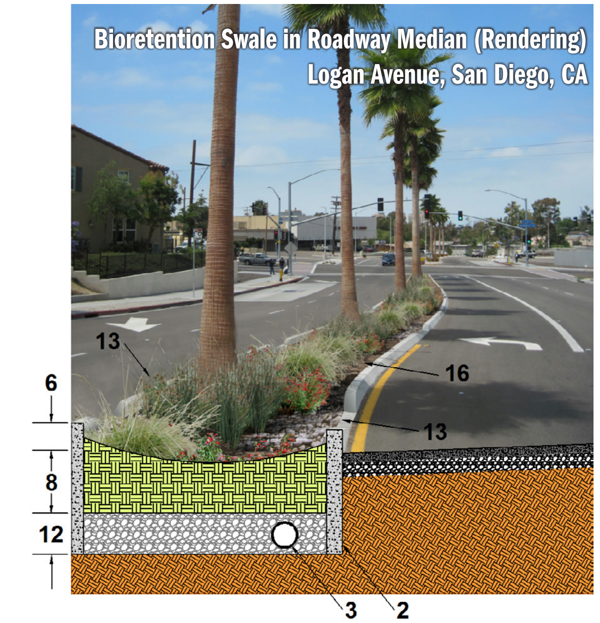
**Water Table & Bedrock:** At least 10 ft separation must be provided between bottom of cut (subgrade) and seasonal high water table, bedrock, or other restrictive features.

**Soil Type:** Bioretention swale can be used in any soils. If subsoil infiltration is less than 0.5 in/hr, an underdrain should be installed. A liner may be needed if subsoils contain expansive clays or calcareous minerals.

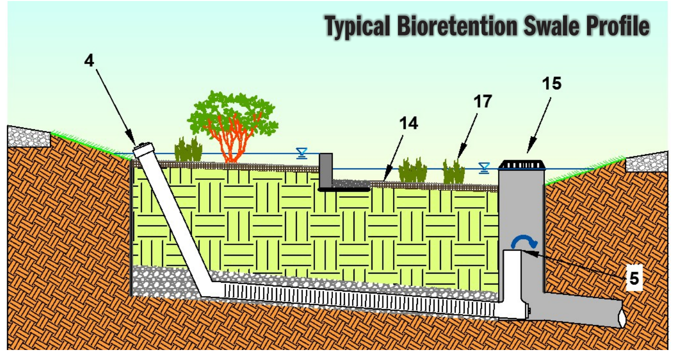
**Areas of Concern:** Infiltration is not allowed at sites with known soil contamination or *hot spots*, such as gas stations. An appropriate impermeable liner must be used in areas of concern.

## Design Considerations & Specifications *(see Appendices A & G for details)*

| Design Component | | | General Specification |
|---|---|---|---|
| IMP Function | 1 | Impermeable liner | If non-infiltrating (per geotechnical investigation), use clay liner, geomembrane liner, or concrete. |
| | 2 | Lateral hydraulic restriction barriers | May use concrete or geomembrane to restrict lateral seepage to adjacent subgrades, foundations, or utilities. |
| | 3 | Underdrain/ Infiltration | Underdrain required if subsoil infiltration < 0.5 in/hr. Schedule 40 PVC pipe with perforations (slots or holes) every 6 inches. If design is fully-infiltrating, ensure that subgrade compaction is minimized. |
| | 4 | Cleanouts/ Observation Wells | Provide 6-inch diameter cleanout ports/observation wells for each underdrain pipe. |
| | 5 | Internal Water Storage (IWS) | If using underdrain, the underdrain outlet can be elevated to create a sump for additional moisture retention to promote plant survival and treatment. Top of IWS should be greater than 18 inches below surface. |
| | 6 | Temporary Ponding Depth | Use check dams to provide 6–18 inches (6–12 inches near schools or in residential areas); average ponding depth of 9 inches is recommended. |
| | 7 | Drawdown Time | Surface drawdown: 12–96 hrs, Subsurface dewatering: 48 hrs. |
| Soil Media | 8 | Soil Media Depth | 2–4 feet (deeper for better pollutant removal, hydrologic benefits, and deeper rooting depths). |
| | 9 | Soil Media Composition | 65% sand, 20% sandy loam, and 15% compost (from vegetation-based feedstock; animal wastes or by-products should not be applied) by volume. |
| | 10 | Media Permeability | 5 in/hr infiltration rate for the flow-based SUSMP method (1–6 in/hr for alternative designs, as approved by local jurisdiction) |
| | 11 | Chemical Analysis | Total phosphorus < 15 ppm, pH 6–8, CEC > 5 meq/100 g soil.<br>Organic Matter Content < 5% by weight. |
| | 12 | Drainage Layer | Separate media from underdrain with 2 to 4 inches of washed concrete sand (ASTM C-33), followed by 2 inches of choking stone (ASTM No. 8) over a 1.5 ft envelope of ASTM No. 57 stone. |
| Routing | 13 | Inlet/Pretreatment | Provide stabilized inlets at least 12 inches wide and energy dissipation. Install rock armored forebay for concentrated flows, gravel fringe and vegetated filter strip for sheet flows. |
| | 14 | Slope and Grade Control | If necessary, use check dams to maintain maximum 2.5% bed slope. Check dams should extend sufficiently deep to prevent piping (undercutting) below the check dam. |
| | 15 | Outlet Configuration | Online: All runoff is routed through system—install an elevated overflow structure or weir at the elevation of maximum ponding.<br>Offline: Only treated volume is diverted to system—install a diversion structure or allow bypass of high flows. |
| Landscape | 16 | Mulch | Dimensional chipped hardwood or triple shredded, well-aged hardwood mulch 3-inches-deep. |
| | 17 | Vegetation | Native, deep rooting, drought tolerant plants. |
| | 18 | Multi-Use Benefits | Provide educational signage, artwork, or wildlife amenities. |




This rendering demonstrates the application of bioretention swales as green street retrofits. Runoff enters the bioretention swale through curb cuts and is filtered vertically through the soil media. Lateral hydraulic restriction layers protect adjacent infrastructure from lateral seepage while allowing infiltration from the bottom of the bioretention swale. The underdrain is offset to avoid roots of existing vegetation.




This schematic shows the major design elements of a bioretention swale. IWS is incorporated for enhanced infiltration and water quality treatment by upturning the underdrain in the outlet structure. Check dams ensure capture of the water quality volume and slow surface flow during larger storms.

## Maintenance Considerations *(see Appendix D for detailed checklist)*

| Task | Frequency | Indicator Maintenance is Needed | Maintenance Notes |
|---|---|---|---|
| **Catchment inspection** | Weekly or biweekly with routine property maintenance | Excessive sediment, trash, and/or debris accumulation on the surface of bioretention swale | Permanently stabilize any exposed soil and remove any accumulated sediment. Adjacent pervious areas may need to be regraded. |
| **Inlet inspection** | | Internal erosion or excessive sediment, trash, and/or debris accumulation | Check for sediment accumulation to ensure that flow into the bioretention swale is as designed. Remove any accumulated sediment. |
| **Litter/leaf removal and misc. upkeep** | | Accumulation of litter and debris within bioretention swale area, mulch around outlet, internal erosion | Litter, leaves, and debris should be removed to reduce the risk of outlet clogging, reduce nutrient inputs to the bioretention area, and to improve facility aesthetics. Erosion should be repaired and stabilized. |
| **Pruning** | 1–2 times/year | Overgrown vegetation that interferes with access, lines of sight, or safety | Nutrients in runoff often cause bioretention vegetation to flourish. |
| **Mowing** | 2–12 times/year | Overgrown vegetation that interferes with access, lines of sight, or safety | Frequency depends on location and desired aesthetic appeal and type of vegetation. |
| **Outlet inspection** | 1 time/year | Erosion at outlet | Remove any accumulated mulch or sediment. |
| **Mulch removal and replacement** | 1 time/2–3 years | 2/3 of mulch has decomposed | Remove decomposed fraction and top off with fresh mulch to a total depth of 3 inches |
| **Remove and replace dead plants** | 1 time/year | Dead plants | Within the first year, 10 percent of plants can die. Survival rates increase with time. |
| **Temporary Watering** | 1 time/2–3 days for first 1–2 months | Until establishment and during severely-droughty weather | Watering after the initial year might be required. |
| **Fertilization** | 1 time initially | Upon planting | One-time spot fertilization for first year vegetation. |

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## Siting and Suitability

The use of permeable pavement is encouraged for sites such as parking lots, driveways, pedestrian plazas, rights-of-way, and other lightly traveled areas. Numerous types and forms of permeable pavers exist and offer a range of utility, strength, and permeability. Permeable pavement must be designed to support the maximum anticipated traffic load but should not be used in highly trafficked areas. For designs that include infiltration, surrounding soils must allow for adequate infiltration. Precautions must be taken to protect soils from compaction during construction. See Section 3 for details.

**Available Space:** Permeable pavement is typically designed to treat storm water that falls on the pavement surface area and runon from other impervious surfaces. It is most commonly used at commercial, institutional, and residential locations in area that are traditionally impervious. Permeable pavement should not be used in high-traffic areas.

**Underground Utilities:** Complete a utilities inventory to ensure that site development will not interfere with or affect utilities.

**Existing Buildings:** Assess building effects on the site. Permeable pavement must be set away from building foundations at least 10 feet and 50 feet from steep slopes and 100 feet from water supply wells.

**Water Table and Bedrock:** Permeable pavement is applicable where depth from subgrade to seasonal high water table, bedrock, or other restrictive feature is 10 feet or greater.

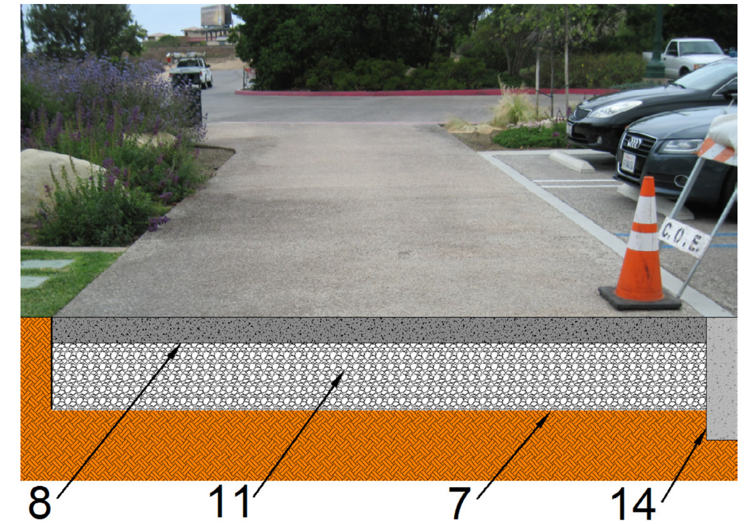
**Soil Type:** Examine site compaction and soil characteristics. Minimize compaction during construction; do not place the bed bottom on compacted fill. Determine site-specific permeability; it is ideal to have well-drained soils.

**Areas of Concern:** Permeable pavement that includes infiltration in design is not recommended for sites with known soil contamination or *hot spots* such as gas stations. Impermeable membrane can be used to contain flow within areas of concern.

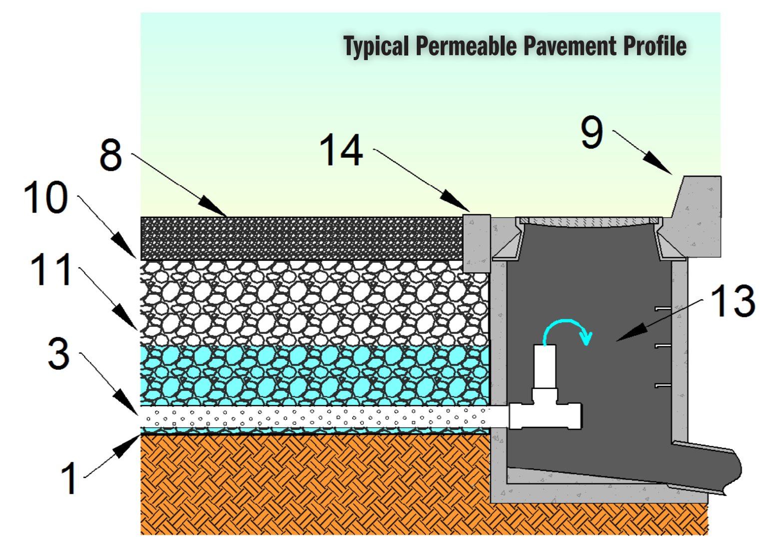
## Design Considerations & Specifications *(see* Appendix A *for details)*

| Design Component | | | General Specification |
|---|---|---|---|
| IMP Function | 1 | Impermeable liner | If non-infiltrating (per geotechnical investigation), use clay liner, geomembrane liner, or concrete. |
| | 2 | Lateral hydraulic restriction barriers | May use concrete or geomembrane to restrict lateral seepage to adjacent subgrades, foundations, or utilities. |
| | 3 | Underdrain/ Infiltration | Underdrain required if subsoil infiltration < 0.5 in/hr. Schedule 40 PVC pipe with perforations (slots or holes) every 6 inches. If design is fully infiltrating, ensure that subgrade compaction is minimized. |
| | 4 | Observation Wells | Provide capped observation wells to monitor drawdown. |
| | 5 | Internal Water Storage (IWS) | If using underdrain in infiltrating systems, the underdrain outlet can be elevated to create a sump to enhance infiltration and treatment. |
| | 6 | Drawdown Time | If using fully-lined system, provide orifice at underdrain outlet sized to release water quality volume over 2–5 days. |
| | 7 | Subgrade Slope and Geotextile | Subgrade slope should be 0.5% or flatter. Baffles should be used to ensure water quality volume is retained. Geotextile should be used along perimeter of cut to prevent soil from entering the aggregate voids. |
| Profile | 8 | Surface Course | Pervious concrete, porous asphalt, and permeable interlocking concrete pavers (PICP) are the preferred types of permeable pavement because detailed industry standards and certified installers are available. |
| | 9 | Temporary Ponding Depth | Surface ponding should be provided (by curb and gutter) to capture the design storm in the event that the permeable pavement surface clogs. |
| | 10 | Bedding Course (for PICP) | Use a 2-inch bedding course of ASTM No. 8 stone. |
| | 11 | Reservoir Layer | Base layer should be washed ASTM No. 57 stone (washed ASTM No. 2 may be used as a subbase layer for additional storage). |
| | 12 | Structural Design | A pavement structural analysis should be completed by a qualified and licensed professional. |
| Routing | 13 | Large Storm Routing | For poured in place systems (pervious concrete or porous asphalt): system can overflow internally or on the surface. For modular/paver-type systems (PICP): internal bypass is required to prevent upflow and transport of bedding course. |
| Other | 14 | Edge Restraints and Dividers | Provide a concrete divider strip between any permeable and impermeable surfaces and around the perimeter of PICP installations. |
| | 15 | Signage | Signage should prohibit activities that cause premature clogging and indicate to pedestrians and maintenance staff that the surface is intended to be permeable. |
| | 16 | Multi-Use Benefits | Provide educational signage, enhanced pavement colors, or stormwater reuse systems. |

**Pervious Concrete Cross Section**
**Cottonwood Creek Park, Encinitas, CA**




**Permeable pavements can be used to treat and reduce stormwater runoff in parking lots, roadway parking lanes, and pedestrian plazas. A reservoir layer below the permeable surface detains stormwater as it infiltrates or is slowly release through underdrain pipes.**




**This schematic represents a typical permeable pavement profile with internal water storage to enhance capture and infiltration of the design storm volume. An orifice can be provided at the invert of the underdrain to slowly dewater captured runoff in non-infiltrating systems.**

## Maintenance Considerations *(see* Appendix D *for detailed checklist)*

| Task | Frequency | Indicator Maintenance is Needed | Maintenance Notes |
|---|---|---|---|
| **Catchment inspection** | Weekly or biweekly during routine property maintenance | Sediment accumulation on adjacent impervious surfaces or in voids/joints of permeable pavement | Stabilize any exposed soil and remove any accumulated sediment. Adjacent pervious areas may need to be graded to drain away from permeable pavement. |
| **Miscellaneous upkeep** | Weekly or biweekly during routine property maintenance | Trash, leaves, weeds, or other debris accumulated on permeable pavement surface | Immediately remove debris to prevent migration into permeable pavement voids. Identify source of debris and remedy problem to avoid future deposition. |
| **Preventative vacuum/ regenerative air street sweeping** | Twice a year in higher sediment areas | N/A | Pavement should be swept with a vacuum power or regenerative air street sweeper at least twice per year to maintain infiltration rates. |
| **Replace fill materials** | As needed | For paver systems, whenever void space between joints becomes apparent or after vacuum sweeping | Replace bedding fill material to keep fill level with the paver surface. |
| **Restorative vacuum/ regenerative air street sweeping** | As needed | Surface infiltration test indicates poor performance or water is ponding on pavement surface during rainfall | Pavement should be swept with a vacuum power or regenerative air street sweeper to restore infiltration rates. |

# Permeable Pavement

## Description

Permeable pavement allows for percolation of stormwater through subsurface aggregate and offers an alternative to conventional concrete and asphalt paving. Typically, stormwater that drains through the permeable surface is allowed to infiltrate underlying soils and excess runoff drains through perforated underdrain pipes. Permeable pavement can be designed as a self-treating or self-retaining area.

| Treatment Efficiency | |
|---|---|
| Runoff Volume | High (unlined)/Low (lined) |
| Sediment | High |
| Nutrients | Low |
| Pathogens | Medium |
| Metals | High |
| Oil & Grease | Medium |
| Organics | Low |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# Rock Infiltration Swale

## Description

Rock infiltration swales are shallow, open channels that are designed to reduce runoff volume through infiltration. Rock infiltration swales are identical to bioretention swales except the surface is typically covered by cobble rather than mulch and vegetation. Rock infiltration swales can serve as conveyance for stormwater and can be used in place of traditional curbs and gutters; however, when compared to traditional conveyance systems the primary objective of a rock infiltration swale is infiltration and water quality enhancement rather than conveyance. In addition to reducing the mass of pollutants in runoff, properly maintained rock infiltration swales can enhance the aesthetics of a site.

| Treatment Efficiency | | | |
|---|---|---|---|
| Runoff Volume | High (unlined)/ Low (lined) | Bacteria | High |
| Sediment | High | Nutrients | Medium |
| Trash/ debris | High | Heavy Metals | High |
| Organics | High | Oil & Grease | High |

TETRA TECH

## Siting and Suitability

Rock infiltration swales are highly versatile stormwater IMPs that effectively reduce pollutants. With a narrow width, rock infiltration swales can be integrated into site plans with various configurations and components. Ideal sites for rock infiltration swales include the right-of-way of linear transportation corridors and along borders or medians of parking lots. In heavily trafficked areas, curb cuts can be used to delineate boundaries. Rock infiltration swales can be combined with other basic and stormwater runoff BMPs to form a treatment train, reducing the required size of a single IMP unit. See Section 3 for details.

**Drainage Area:** Less than 2 acres and fully stabilized.

**Head Requirements:** Rock infiltration swale typically requires a minimum of 2.5 to 3.5 ft of elevation difference between the inlet and outlet to the receiving storm drain network.

**Slopes:** Slopes draining to rock infiltration swale should be 15% or less, side slopes should be 3:1 (H:V) or flatter, and check dams should be used to provide longitudinal bed slopes of 2.5% (average slope should not exceed 4% from inlet to outlet).

**Setbacks:** Provide 10-ft setback from structures/foundations, 100-ft setback from septic fields and water supply wells, and 50-ft setback from steep slopes.

**Water Table & Bedrock:** At least 10 ft separation must be provided between bottom of cut (subgrade) and seasonal high water table, bedrock, or other restrictive features.

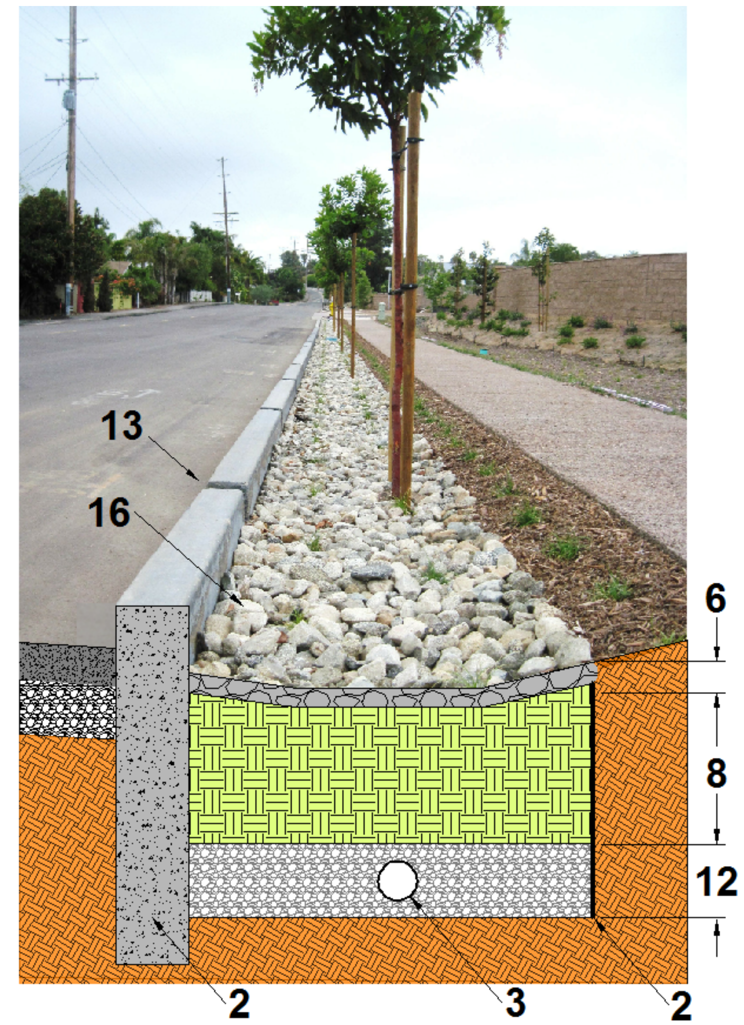
**Soil Type:** Rock infiltration swale can be used in any soils. If subsoil infiltration is less than 0.5 in/hr, an underdrain should be installed. A liner may be needed if subsoils contain expansive clays or calcareous minerals.

**Areas of Concern:** Infiltration is not allowed at sites with known soil contamination or *hot spots*, such as gas stations. An appropriate impermeable liner must be used in areas of concern.

## Design Considerations & Specifications *(see Appendices A & G for details)*

| | | Design Component | General Specification |
|---|---|---|---|
| IMP Function | 1 | Impermeable liner | If non-infiltrating (per geotechnical investigation), use clay liner, geomembrane liner, or concrete. |
| | 2 | Lateral hydraulic restriction barriers | May use concrete or geomembrane to restrict lateral seepage to adjacent subgrades, foundations, or utilities. |
| | 3 | Underdrain/ Infiltration | Underdrain required if subsoil infiltration < 0.5 in/hr. Schedule 40 PVC pipe with perforations (slots or holes) every 6 inches. If design is fully-infiltrating, ensure that subgrade compaction is minimized. |
| | 4 | Cleanouts/ Observation Wells | Provide 6-inch diameter cleanout ports/observation wells for each underdrain pipe. |
| | 5 | Internal Water Storage (IWS) | If using underdrain, the underdrain outlet can be elevated to create a sump for additional moisture retention treatment. Top of IWS should be greater than 18 inches below surface. |
| | 6 | Temporary Ponding Depth | Use check dams to provide 6–18 inches (6–12 inches near schools or in residential areas); average ponding depth of 9 inches is recommended. |
| | 7 | Drawdown Time | Surface drawdown: 12-96 hrs, Subsurface dewatering: 48 hrs. |
| Soil Media | 8 | Soil Media Depth | 2–4 feet (deeper for better pollutant removal, hydrologic benefits, and deeper rooting depths). |
| | 9 | Soil Media Composition | 65% sand, 20% sandy loam, and 15% compost (from vegetation-based feedstock; animal wastes or by-products should not be applied) by volume. |
| | 10 | Media Permeability | 5 in/hr infiltration rate for the flow-based SUSMP method (1–6 in/hr for alternative designs, as approved by local jurisdiction). |
| | 11 | Chemical Analysis | Total phosphorus < 15 ppm, pH 6–8, CEC > 5 meq/100 g soil. Organic Matter Content < 5% by weight. |
| | 12 | Drainage Layer | Separate media from underdrain with 2 to 4 inches of washed concrete sand (ASTM C-33), followed by 2 inches of choking stone (ASTM No. 8) over a 1.5 ft envelope of ASTM No. 57 stone. |
| Routing | 13 | Inlet/Pretreatment | Provide stabilized inlets at least 12 inches wide and energy dissipation. Install rock armored forebay for concentrated flows, gravel fringe and vegetated filter strip for sheet flows. |
| | 14 | Slope and Grade Control | If necessary, use check dams to maintain maximum 2.5% bed slope. Check dams should extend sufficiently deep to prevent piping (undercutting) below the check dam. |
| | 15 | Outlet Configuration | Online: All runoff is routed through system—install an elevated overflow structure or weir at the elevation of maximum ponding. Offline: Only treated volume is diverted to system—install a diversion structure or allow bypass of high flows. |
| Landscape | 16 | Surface | Armor surface with cobble. If planted (optional), install drought-tolerant, low-maintenance trees and shrubs. |
| | 17 | Multi-Use Benefits | Provide educational signage, artwork, or wildlife amenities. |

**Rock Infiltration Swale Cross Section, Encinitas, CA**




**This schematic shows the major components of a rock infiltration swale. The rock infiltration swale in the photograph intercepts roadway runoff through curb cuts and filters it through subsurface soil media.**

## Maintenance Considerations *(see Appendix D for detailed checklist)*

| Task | Frequency | Indicator Maintenance is Needed | Maintenance Notes |
|---|---|---|---|
| **Catchment inspection** | Weekly or biweekly with routine property maintenance | Excessive sediment, trash, and/or debris accumulation on the surface of rock infiltration swale | Permanently stabilize any exposed soil and remove any accumulated sediment in a manner that does not cause an illegal discharge. Adjacent pervious areas may need to be regraded. |
| **Inlet inspection** | | Internal erosion or excessive sediment, trash, and/or debris accumulation | Check for sediment accumulation to ensure that flow into the rock infiltration swale is as designed. Remove any accumulated sediment. |
| **Litter/leaf removal and misc. upkeep** | | Accumulation of litter and debris within rock infiltration swale area, mulch around outlet, internal erosion | Litter, leaves, and debris should be removed to reduce the risk of outlet clogging, reduce nutrient inputs to the bioretention area, and to improve facility aesthetics. Erosion should be repaired and stabilized. |
| **Outlet inspection** | 1 time/year | Erosion at outlet | Remove any accumulated mulch or sediment. |
| **Temporary Watering** | 1 time/2-3 days for first 1–2 months | Until establishment and during severely-droughty weather | Watering after the initial year might be required. |
| **Fertilization** | 1 time initially | Upon planting | One-time spot fertilization for first year vegetation. |

## Siting and Suitability

Flow-through planters require relatively little space and can be easily adapted for urban retrofits such as building and rooftop runoff catchments or into new street and sidewalk designs. Because flow-through planters are typically fully-contained systems, available space presents the most significant limitation. To ensure healthy vegetation in the planter box, proper plant and media selection are important considerations for accommodating the drought, ponding fluctuations, and brief periods of saturated soil conditions. See Section 3 for details.

**Drainage Area:** To be less than 0.35 acres and fully stabilized.

**Underground Utilities:** Complete a utilities inventory to ensure that site development will not interfere with or affect the utilities.

**Existing Buildings:** Assess building effects (runoff, solar shadow) on the site. When completely contained, building setbacks are less of a concern.

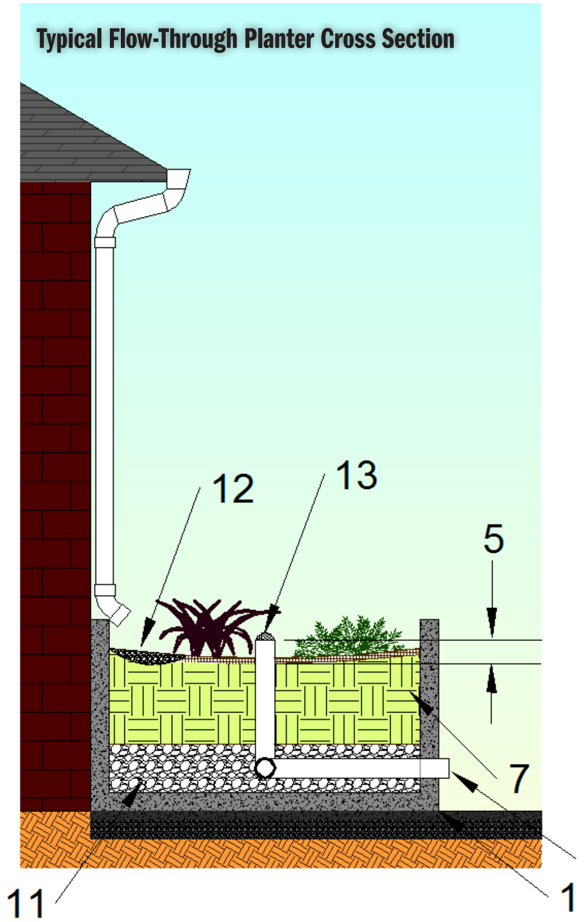
**Water Table:** Seasonal high water table should be located below the bottom of the planter.

**Soil Type:** Soils within the drainage area must be stabilized. If flow-through planters are fully contained, local soils must provide structural support.

**Areas of Concern:** Fully-contained flow-through planters can be used in areas with known soil contamination or in *hot spots*.

## Design Considerations & Specifications *(see* Appendices A & G *for details)*

| | | Design Component/ Consideration | General Specification |
|---|---|---|---|
| IMP Function | 1 | Impermeable liner | Planter boxes are typically contained within a concrete vault. |
| | 2 | Underdrain (required) | Underdrain required if subsoil infiltration < 0.5 in/hr. Schedule 40 PVC pipe with perforations (slots or holes) every 6 inches. If design is fully infiltrating, ensure that subgrade compaction is minimized. |
| | 3 | Cleanouts/ Observation Wells | Provide 6-inch diameter cleanout ports/observation wells for each underdrain pipe. |
| | 4 | Internal Water Storage (IWS) | With careful plant selection, the outlet can be slightly elevated to create a sump for additional moisture retention to promote plant survival and enhanced treatment. Top of IWS should be greater than 18 inches below surface. |
| | 5 | Temporary Ponding Depth | Provide 6–18 inches surface ponding (6–12 inches near schools or in residential areas); average ponding depth of 9 inches is recommended. |
| | 6 | Drawdown Time | Surface drawdown: 12–96 hrs, Subsurface dewatering: 48 hrs. |
| Soil Media | 7 | Soil Media Depth | 2–4 feet (deeper for better pollutant removal, hydrologic benefits, and deeper rooting depths). |
| | 8 | Soil Media Composition | 65% sand, 20% sandy loam, and 15% compost (from vegetation-based feedstock; animal wastes or by-products should not be applied) by volume. |
| | 9 | Media Permeability | 5 in/hr infiltration rate for the flow-based SUSMP method (1–6 in/hr for alternative designs, as approved by local jurisdiction). |
| | 10 | Chemical Analysis | Total phosphorus < 15 ppm, pH 6–8, CEC > 5 meq/100 g soil.<br>Organic Matter Content < 5% by weight. |
| | 11 | Drainage Layer | Separate soil media from underdrain with 2 to 4 inches of washed concrete sand (ASTM C33), followed by 2 inches of choking stone (ASTM No. 8) over a 1.5 ft envelope of ASTM No. 57 stone. Additional aggregate storage depth can be provided for hydromodification control. |
| Routing | 12 | Inlet/ Pretreatment | Provide stabilized inlets and energy dissipation. Install rock armored forebay, gravel splash pad, or upturn incoming pipes. |
| | 13 | Outlet Configuration | Online: All runoff is routed through system—install an elevated overflow structure or weir at the elevation of maximum ponding.<br>Offline: Only treated volume is diverted to system—install a diversion structure or allow bypass of high flows. |
| Landscape | 14 | Mulch | Dimensional chipped hardwood or triple shredded, well-aged hardwood mulch 3-inches-deep. |
| | 15 | Vegetation | Native, deep rooting, drought tolerant plants. |
| | 16 | Multi-Use Benefits | Provide educational signage, artwork, or wildlife habitat. |




**This diagram shows the design elements of a flow-through planter installed for water quality control. Flow-through planters can be used in highly urbanized settings or areas where infiltration is restricted. Additional surface storage or subsurface aggregate storage can be provided for hydromodification control.**

## Maintenance Considerations *(see* Appendix D *for detailed checklist)*

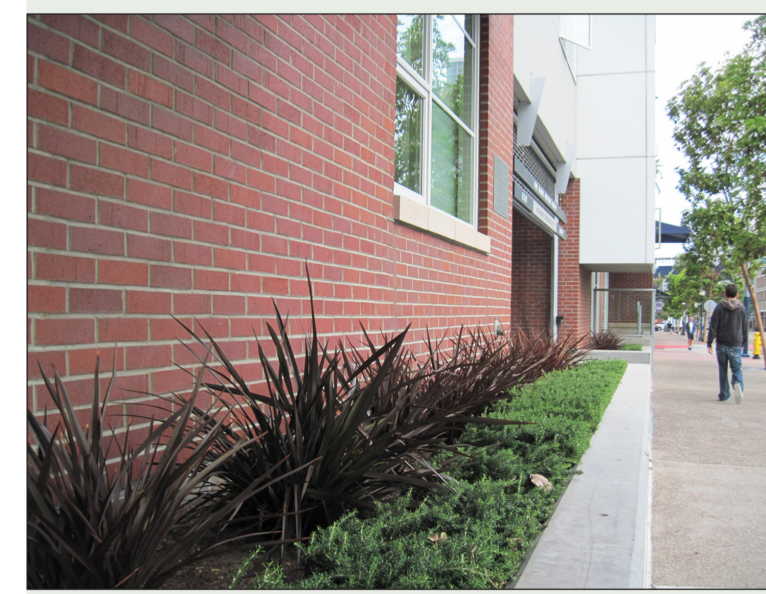
| Task | Frequency | Indicator Maintenance is Needed | Maintenance Notes |
|---|---|---|---|
| **Catchment inspection** | Weekly or biweekly with routine property maintenance | Excessive sediment, trash, and/or debris accumulation on the surface of bioretention swale | Permanently stabilize any exposed soil and remove any accumulated sediment. Adjacent pervious areas may need to be regraded. |
| **Inlet inspection** | | Internal erosion or excessive sediment, trash, and/ or debris accumulation | Check for sediment accumulation to ensure that flow into the bioretention swale is as designed. Remove any accumulated sediment. |
| **Litter/leaf removal and misc. upkeep** | | Accumulation of litter and debris within bioretention swale area, mulch around outlet, internal erosion | Litter, leaves, and debris should be removed to reduce the risk of outlet clogging, reduce nutrient inputs to the bioretention area, and to improve facility aesthetics. Erosion should be repaired and stabilized. |
| **Pruning** | 1–2 times/year | Overgrown vegetation that interferes with access, lines of sight, or safety | Nutrients in runoff often cause bioretention vegetation to flourish. |
| **Mowing** | 2–12 times/year | Overgrown vegetation that interferes with access, lines of sight, or safety | Frequency depends on location and desired aesthetic appeal and type of vegetation. |
| **Outlet inspection** | 1 time/year | Erosion at outlet | Remove any accumulated mulch or sediment. |
| **Mulch removal and replacement** | 1 time/2–3 years | 2/3 of mulch has decomposed | Remove decomposed fraction and top off with fresh mulch to a total depth of 3 inches |
| **Remove and replace dead plants** | 1 time/year | Dead plants | Within the first year, 10 percent of plants can die. Survival rates increase with time. |
| **Temporary Watering** | 1 time/2–3 days for first 1–2 months | Until establishment and during severely-droughty weather | Watering after the initial year might be required. |
| **Fertilization** | 1 time initially | Upon planting | One-time spot fertilization for first year vegetation. |

# Flow-Through Planters

## Description

Flow-through planters are vegetated IMP units that capture, temporarily store, and filter storm water runoff. The vegetation, ponding areas, and soil media in the flow-through planters remove contaminants and retain storm water flows from small drainage areas before directing the treated storm water to an underdrain system. Typically, Flow-through planters are completely contained systems; for this reason, they can be used in areas where geotechnical constraints prevent or limit infiltration or in areas of concern where infiltration should be avoided. Flow-through planters offer considerable flexibility and can be incorporated into small spaces, enhancing natural aesthetics of the landscape.

| Treatment Efficiency | | | |
|---|---|---|---|
| Runoff Volume | Low | Metals | High |
| Sediment | High | Oil & Grease | High |
| Nutrients | Medium | Organics | High |
| Pathogens | High | | |



TETRA TECH

# Vegetated Roofs

## Description

Vegetated roofs are vegetated surfaces generally installed on flat or gently sloped rooftops. Sometimes called green roofs, they consist of drought tolerant vegetation grown in a thin layer of media underlain by liner and drainage components. Vegetated roofs reduce stormwater runoff volume and improve water quality by intercepting rainfall which is either filtered by the media, evaporated from the roof surface or utilized by the vegetation. Vegetated roofs can be installed on a wide range of building types and may provide additional functions such as extending roof-life and reducing energy requirements of the building. Research has shown that vegetated roofs also may improve property values of adjacent buildings and provide air quality benefits. In addition to these functions vegetated roofs can serve as passive recreation areas and provide wildlife habitat. Vegetated roofs are considered self-treating areas and drainage requires no further treatment control.

| Treatment Efficiency | | | |
|---|---|---|---|
| Runoff Volume | High | Bacteria | Low |
| TSS | Medium | Nutrients | Low |
| Trash/debris | Medium | Heavy Metals | High |

TETRA TECH

## Siting and Suitability

Vegetated roofs are typically constructed on flat or gently sloped rooftops of a wide variety of shapes and sizes. Where installed on new construction, building structural design should consider the additional load of the vegetated roof. Where installed on existing buildings the structure should be evaluated by a structural engineer to determine suitability. Vegetated roofs can be implemented on a wide range of building types and settings and can integrate with other roof infrastructure such as HVAC components, walkways, and solar panels. See Section 3 for details.

**Drainage Area:** Varies widely from a few square feet to several acres.

**Head Requirements:** Not applicable

**Slopes:** Vegetated roofs can be installed on roof surfaces that are flat or are sloped.

**Setbacks:** Not applicable

**Structural Requirements:** a structural engineer should evaluate the structure to ensure that it is capable of supporting the vegetated roof.

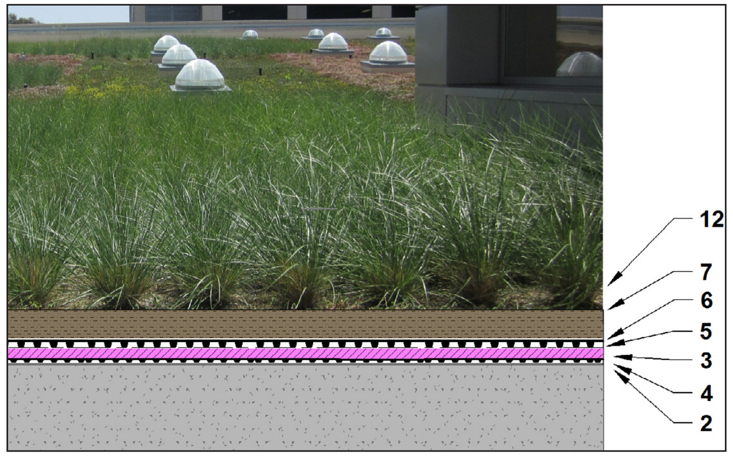
**Areas of Concern:** In areas of significant wind loads design considerations may be necessary to ensure security of media or a vegetated roof may not be suitable.

## Design Considerations & Specifications *(see Appendix A for details)*

| | | Design Component | General Specification |
|---|---|---|---|
| IMP Function | 1 | Roof Slope | Vegetated roofs may be constructed on slopes from 1% to 30%. Where slopes approach 30% media retention practices such as baffles or geo-grids should be incorporated into the design. |
| | 2 | Waterproof Liner | All vegetated roof systems should incorporate a waterproof liner to protect the roof deck and underlying structure from leaks. |
| | 3 | Insulation (optional) | Insulation may be placed either above or below the waterproof liner to enhance the energy efficiency of the building and to provide additional protection of the roof deck. |
| | 4 | Root Barrier | Root barrier is placed directly above the waterproof liner, or insulation as appropriate, to prevent plant roots from impacting the integrity of the liner |
| | 5 | Drainage Layer | Aggregate: Minimum of 2 inches of clean washed synthetic or inorganic aggregate material such as no 8 stone or suitable alternatives.<br>Manufactured: A wide range of prefabricated drainage layers are available which incorporate drainage and storage or rainfall. Minimum storage capacity should be 0.8 inches. |
| | 6 | Permeable Filter Fabric | A semipermeable filter fabric is placed between the drainage layer and growth media to prevent migration of the media into the drainage layer. |
| Growth Media | 7 | Media Depth | Minimum 4 inches of growth media. |
| | 8 | Media Composition | 80–90% lightweight inorganic materials such as expanded slates, shales, or pumice.<br>No more than 20% organic materials with a low potential for leaching nutrients. |
| Other Considerations | 9 | Roof Drains and Scuppers | Setback vegetated roof media and drainage layers a minimum of 12 inches from all roof drains and scupper and fill these areas with washed no. 57 stone to a depth equal to or greater than the depth of the vegetated roof components. |
| | 10 | Other Infrastructure | Setback vegetated roof 24 inches from other rooftop infrastructure such as vents, HVAC components, etc. Setback areas may be filled with washed no. 57 gravel or suitable alternative. |
| | 11 | Access | Adequate access to the roof must be provided to allow routine maintenance. |
| Landscape | 12 | Vegetation | Primarily drought tolerant species which can thrive in a rooftop environment without supplemental irrigation; see Plant List (Appendix E). |
| | 13 | Multi-Use Benefits | Include features to enhance habitat, aesthetics, recreation, and public education as desired. |


The extensive vegetated roof on this public library features modular units containing lightweight media and various drought-tolerant vegetation.

**Extensive Vegetated Roof at County of San Diego Operations Center - Cross Section**




Typical components of an extensive green roof. The cross section of intensive green roofs will be deeper and vary from site to site based on desired functions and structural capacity of the underlying structure.

## Maintenance Considerations *(see Appendix D for detailed checklist)*

| Task | Frequency | Indicator Maintenance is Needed | Maintenance Notes |
|---|---|---|---|
| **Media Inspection** | 2 times/year | Internal erosion of media from runoff or wind scour, exposed underlayment components | Replace eroded media and vegetation. Adopt additional erosion prevention practices as appropriate. |
| **Liner Inspection** | 1 time/year | Liner is exposed or tenants have experienced leaks | Evaluate liner for cause of leaks. Repair or replace as necessary. |
| **Outlet Inspection** | 2 times/year | Accumulation of litter and debris around the roof drain or scupper or standing water in adjacent areas. | Litter, leaves, and debris should be removed to reduce the risk of outlet clogging. If sediment has accumulated in the gravel drain buffers remove and replaces the gravel. |
| **Vegetation Inspection** | 1 time/year | Dead plants or excessive open areas on vegetated roof | Within the first year, 10 percent of plants can die. Survival rates increase with time. |
| **Invasive Vegetation** | 2 times/year | Presence of unwanted or undesirable species | Remove undesired vegetation. Evaluate vegetated roof for signs of excessive water retention. |
| **Temporary Watering** | 1 time/2–3 days for first 1–2 months | Until establishment and during severely-droughty weather | Watering after the initial year might be required. |

## Siting and Suitability

Sand filters require less space than many LID IMPs and are typically used in areas with restricted space such as parking lots or other highly impervious areas. Sizing should be based on the desired water quality treatment volume and should take into account all runoff at ultimate build-out, including off-site drainage. The design phase should also identify where pretreatment will be needed. Aboveground units should be designed with a vegetated filter strip or forebay as a pretreatment element, and belowground units should incorporate a forebay sediment chamber. See Section 3 for details.

**Underground Utilities:** A complete utilities inventory should be done to ensure that site development will not interfere with or affect the utilities.

**Existing Buildings:** If used underground, ensure that the sand filter will not interfere with existing foundations.

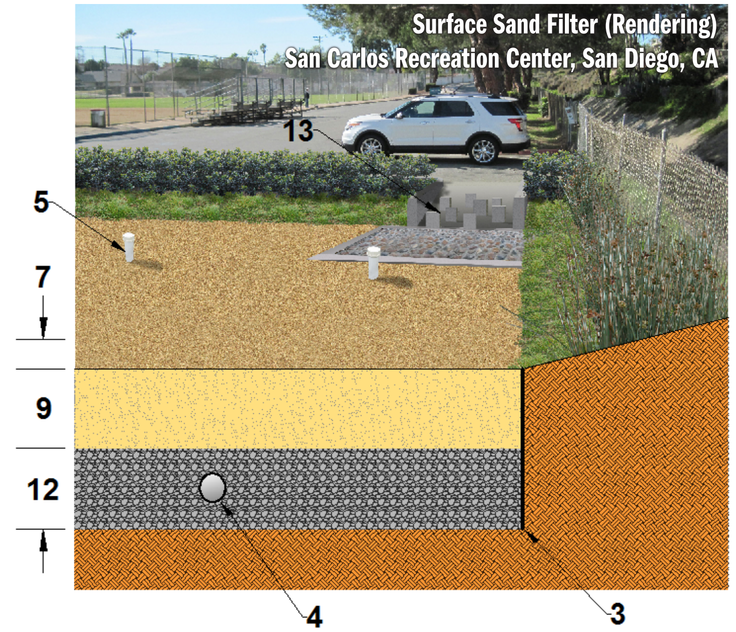
**Water Table and Bedrock:** Sand filters are applicable where depth from subgrade to seasonal high water table, bedrock, or other restrictive feature is 10 ft or greater.

**Soil Type:** If infiltration is planned to existing soils, examine site compaction and soil characteristics. Determine site-specific permeability. It is ideal to have well-drained soils. If native soils show less than 0.5 in/hr infiltration rate, underdrains should be included.

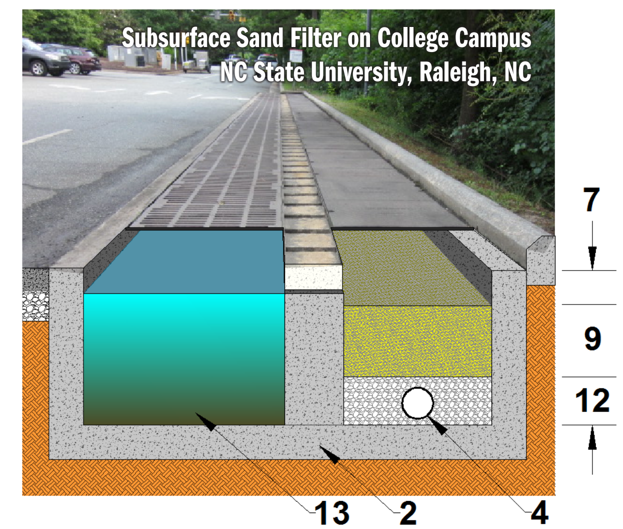
**Areas of Concern:** Sand filters, if lined, can be used for sites with known soil contamination or *hot spots* such as gas stations. Impermeable membranes must be used to contain infiltration within areas of concern.

## Design Considerations & Specifications *(see Appendix A for details)*

| | | Design Component | General Specification |
|---|---|---|---|
| IMP Function | 1 | IMP Type | Surface sand filters: installed in shallow depressions on surface. Require pretreatment by vegetated swales, filter strip, or forebay. Subsurface sand filters: can be installed along the edges of roads and parking lots to conserve space. Must include a sedimentation chamber for pretreatment. |
| IMP Function | 2 | Impermeable liner | If non-infiltrating (per geotechnical investigation), use clay liner, geomembrane liner, or concrete. |
| IMP Function | 3 | Lateral hydraulic restriction barriers | May use concrete or geomembrane to restrict lateral seepage to adjacent subgrades, foundations, or utilities. |
| IMP Function | 4 | Underdrain/ Infiltration | Underdrain required if subsoil infiltration < 0.5 in/hr. Schedule 40 PVC pipe with perforations (slots or holes) every 6 inches. If design is fully infiltrating, ensure that subgrade compaction is minimized. |
| IMP Function | 5 | Cleanouts/ Observation Wells | Provide 6-inch diameter cleanout ports/observation wells for each underdrain pipe. |
| IMP Function | 6 | Internal Water Storage (IWS) | If using underdrain in infiltrating systems, the underdrain outlet can be elevated to create a sump for enhanced infiltration and treatment. Top of IWS should be greater than 10 inches below surface. |
| IMP Function | 7 | Temporary Ponding Depth | No greater than 8 feet (shallower depth should be used in residential areas or near schools and parks). |
| IMP Function | 8 | Drawdown Time | Surface drawdown: 12-96 hrs. Subsurface dewatering: 48 hrs. |
| Soil Media | 9 | Soil Media Depth | 1.5–4 feet (deeper for better pollutant removal, hydrologic benefits, and deeper rooting depths). |
| Soil Media | 10 | Gradation | Washed concrete sand (ASTM C-33) free of fines, stones, and other debris. |
| Soil Media | 11 | Chemical Analysis | Total phosphorus < 15 ppm. |
| Soil Media | 12 | Drainage Layer | Separate soil media from underdrain with 2 to 4 inches of washed concrete sand (ASTM C-33), followed by 2 inches of choking stone (ASTM No. 8) over a 1.5 ft envelope of ASTM No. 57 stone. |
| Routing | 13 | Inlet/ Pretreatment | Provide stabilized inlets at least 12 inches wide and energy dissipation. Install rock armored forebay for concentrated flows, gravel fringe and vegetated filter strip for sheet flows to surface sand filters. For subsurface sand filters, a sedimentation chamber is provided (should be dewatered between storm events). |
| Routing | 14 | Outlet Configuration | Online: All runoff is routed through system—install an elevated overflow structure or weir at the elevation of maximum ponding. Offline: Only treated volume is diverted to system—install a diversion structure or allow bypass of high flows. |
| Other | 15 | Multi-Use Benefits | Provide features to enhance aesthetics and public education. |




A surface sand filter intercepts and filters runoff from a parking lot. Underdrains discharge to the adjacent creek.




A subsurface sand filter intercepts sheet flow from a parking lot through grate inlets. Runoff is pretreated in a sedimentation chamber to remove coarse sediment and debris, then flows through slot weirs into the sand filter chamber. Underdrain discharge and overflow are routed to an adjacent catch basin structure.

## Maintenance Considerations *(see Appendix D for detailed checklist)*

| Task | Frequency | Indicator Maintenance is Needed | Maintenance Notes |
|---|---|---|---|
| **Catchment inspection** | Weekly or biweekly with routine property maintenance | Excessive sediment, trash, and/or debris accumulation on the surface of sand filter. | Permanently stabilize any exposed soil and remove any accumulated sediment. Adjacent pervious areas may need to be regarded. |
| **Inlet inspection** | Once after first major rain of the season, then every 2 to 3 months depending on observed sediment and debris loads | Debris or sediment has blocked inlets. | Remove any accumulated material. |
| **Sedimentation chamber/forebay inspection** | Every two months | Sediment has reached 6-inches-deep (install a fixed vertical sediment depth marker) or litter and debris has clogged weirs between sedimentation chamber and sand filter chamber (for subsurface filters). | Remove accumulated material from sedimentation chamber. Remove and replace top 2 to 3 inches of sand filter if necessary. |
| **Sand filter surface infiltration inspection** | After major storm events or biannually | Surface ponding draws down in greater than 48 hours. | Remove and replace top 2 to 3 inches of sand filter, or as needed to restore infiltration capacity. Inspect watershed for sediment sources. |
| **Outlet inspection** | Once after first major rain of the season, then monthly | Erosion or sediment deposition at outlet. | Check for erosion at the outlet and remove any accumulated sediment. |
| **Miscellaneous upkeep** | 12 times/year | | Tasks include trash collection, spot weeding, soil media replacement, and removal of visual contamination. |

# Sand Filters

## Description

Sand filters are filtering IMPs that can be installed on the surface or subsurface. They remove pollutants by filtering stormwater vertically through a sand media and can also be designed for infiltration. Although they function similar to bioretention, sand filters lack the pollutant removal mechanisms provided by the biological activity and fine clay particles found in bioretention media.

| Treatment Efficiency | |
|---|---|
| Runoff Volume | Low |
| Sediment | High |
| Nutrients | Low |
| Pathogens | Medium |
| Metals | Low |
| Oil & Grease | Medium |
| Organics | Medium |

TETRA TECH

# Cisterns

## Description

Cisterns are storage vessels that can collect and store rooftop runoff from a downspout for later use. Sized according to rooftop area and desired volume, cisterns can be used to collect both residential and commercial building runoff. By temporarily storing the runoff, less runoff enters the storm water drainage system, thereby reducing the amount of pollutants discharged to surface waters. Additionally, cisterns and their smaller counterpart referred to as rain barrels are typically used in a treatment train system where collected runoff is slowly released into another IMP or landscaped area for infiltration. Because of the peak-flow reduction and storage for potential beneficial uses, subsequent treatment train IMPs can be reduced in size. Cisterns can collect and hold water for commercial uses, most often for non-potable uses such as irrigation or toilet flushing.

| Treatment Efficiency | |
|---|---|
| Runoff Volume | Varies based on cistern size and drawdown mechanisms |
| Water Quality | Water quality improvements depend on downstream practices—high pollutant removal can be achieved if paired with an infiltrating or filtering practice |

TETRA TECH

## Siting and Suitability

Cisterns should be placed near a roof downspout, but can also be located remotely if a "wet conveyance" configuration is used. The structural capacity of soils should be investigated to determine whether a footer is needed. Cisterns are available commercially in numerous sizes, shapes, and materials. The configuration will be determined by available space, intended reuse strategy, and aesthetic preference. An overflow mechanism is important to prevent water from backing up onto rooftops—overflow should be conveyed in a safe direction away from building foundations. See Section 3 for details.

**Drainage Area:** Rooftop area.

**Existing Buildings:** Ideally, cistern overflows should be set away from building foundations at least 5 feet.

**Water Table:** The seasonal high water table should be located below the bottom of the cistern, particularly underground cisterns, to prevent buoyant forces from affecting the cistern.

**Soil Type:** Ensure that the cistern is securely mounted on stable soils. If structural capacity of the site is in question, complete a geotechnical report to determine the structural capacity of soils.

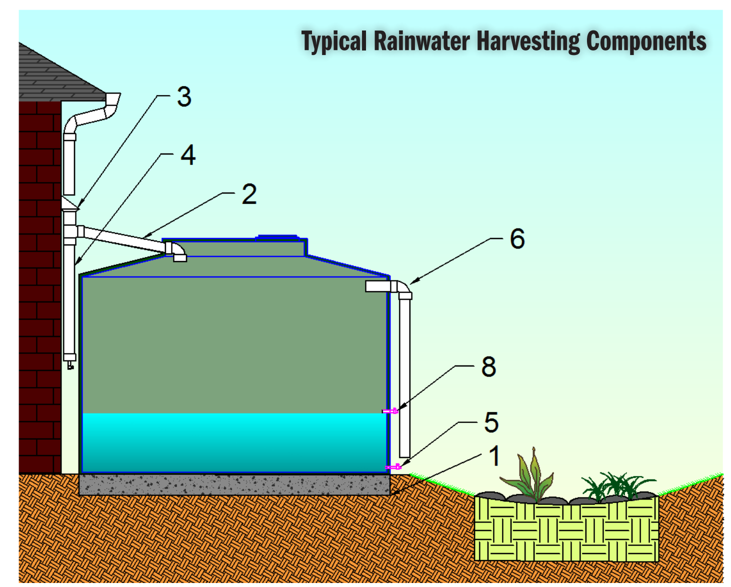
**Areas of Concern:** Overflow volume or outflow volume should not be directed to areas where infiltration is not desired. Such areas may include *hot spots*, where soils can be contaminated.

## Design Considerations & Specifications *(see* Appendix A *for details)*

| | | Design Component | General Specification |
|---|---|---|---|
| Configuration and Function | 1 | Cistern material and foundation | Tanks should typically be opaque to prevent algal growth. A foundation of gravel should be provided if the weight of the cistern at capacity is less than 2000 pounds, otherwise a concrete foundation should be provided. |
| | 2 | Conveyance configuration | Runoff should be conveyed to the cistern such that no backwater onto roofs occurs during the 100-yr event. Two types of inlet configurations are available:<br>· Dry conveyance: conduit freely drains to cistern with no water storage in pipe<br>· Wet conveyance: a bend in the conduit retains water between rainfall events (allows cistern to be placed further from buildings) |
| | 3 | Inlet filter | A self-cleaning inlet filter should be provided to strain out large debris such as leaves. Some systems incorporate built-in bypass mechanisms to divert high flows. |
| | 4 | First flush diverter | A passive first flush diverter should be incorporated in areas with high pollutant loads to capture the first washoff of sediment, debris, and pollen during a rainfall event. First flush diverters are typically manually dewatered between events. |
| | 5 | Low-flow outlet | An outlet should be designed to dewater the water quality storage volume to a vegetated area in no less than 2 days. The elevation of the outlet depends on the volume of water stored for alternative purposes. |
| | 6 | Overflow or bypass | Emergency overflow (set slightly below the inlet elevation) or bypass must be provided to route water safely out of the cistern when it reaches full capacity. |
| Reuse and Safety | 7 | Signage | Signage indicating: "Caution: Reclaimed Water, Do Not Drink" (preferably in English and Spanish) must be provided anywhere cistern water is piped or outlets. |
| | 8 | Pipe color and locking features | All pipes conveying harvested rainwater should be purple in color and be labeled as reclaimed or recycled water. All valves should feature locking features. |
| | 9 | Routing water for use | Regardless of gravity or pumped flow, adequate measures must be taken to prevent contamination of drinking water supplies. |
| | 10 | Makeup water supply | A makeup water supply can be provided to refill the cistern to a desired capacity when harvested water has a dedicated use. |
| | 11 | Vector control | All inlets and outlets to the cistern must be covered with a 1-mm or smaller mesh to prevent mosquito entry/egress. |
| Other | 12 | Multi-use benefits | Harvested rainwater should be used to offset potable water uses, such as irrigation, toilet flushing, car washing, etc. Additionally, educational signage and aesthetically-pleasing facades should be specified. |

**Residential Cistern**


**Smaller cisterns or rain barrels can be used to capture and reuse residential rooftop runoff for irrigation and other non-potable uses.**




**This diagram illustrates the major design elements of a rainwater harvesting system. In this configuration, detention storage is provided above the low flow outlet and water for reuse is stored in the lower half of the cistern. Note that the cistern is paired with a bioretention area to achieve both hydromodification and water quality control.**

## Maintenance Considerations *(see* Appendix D *for detailed checklist)*

| Task | Frequency | Indicator Maintenance is Needed | Maintenance Notes |
|---|---|---|---|
| **Gutter and rooftop inspection** | Biannually and before heavy rains | Inlet clogged with debris | Clean gutters and roof of debris that have accumulated, check for leaks |
| **Remove accumulated debris** | Monthly | Inlet clogged with debris | Clean debris screen to allow unobstructed stormwater flow into the cistern |
| **Structure inspection** | Biannually | Cistern leaning or soils slumping/eroding | Check cistern for stability, anchor system if necessary |
| **Structure inspection** | Annually | Leaks | Check pipe, valve connections, and backflow preventers for leaks |
| **Add ballast** | Before any major wind-related storms | Tank is less than half-full | Add water to half full |
| **Miscellaneous upkeep** | Annually | | Make sure cistern manhole is accessible, operational, and secure |

## Siting and Suitability

Site evaluation must first determine the volume of water to be conveyed through the swale. To accommodate the volume, design considerations must incorporate three components: the longitudinal slope, resistance to flow, and cross-sectional area. Incorporating vegetated filter strips along the top of the channel banks and using sheet flow for entry can enhance treatment in swales. Avoid slopes and soil conditions that limit infiltration as they could lead to excessive ponding. See Section 3 for details.

**Drainage Area:** Less than 2 acres.

**Available Space:** The footprint of swales is dependent on drainage area, typically sized as 10 to 20 percent of the upstream drainage. If space allows, pretreatment can be incorporated into design.

**Underground Utilities:** A complete utilities inventory should be done to ensure that site development will not interfere with or affect utilities.

**Existing Buildings:** Assess building effects (runoff, solar shadow) on the site. Swales must be setback from building foundations at least 10 feet.

**Water Table:** Swales are applicable where depth to water table is more than 2 feet to limit the potential of undesired ponding.

**Soil Type:** Examine site compaction and soil characteristics. Determine site-specific permeability; it is ideal to have well-drained soils for volume reduction and treatment in swales.

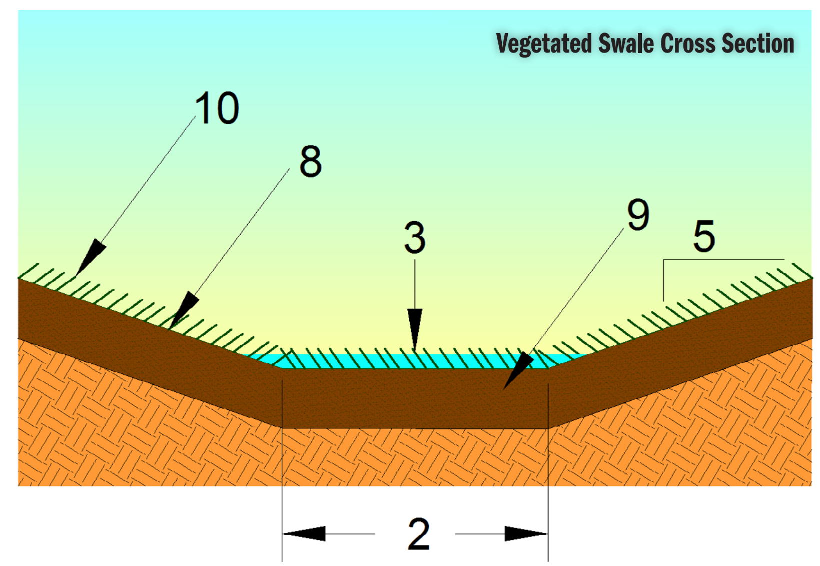
**Areas of Concern:** Swales should not be used to receive storm water runoff from storm water *hot spots*, unless adequate pretreatment is provided upstream.

## Design Considerations & Specifications *(see Appendix A for details)*

| | Design Component | | General Specification |
|---|---|---|---|
| IMP Dimensions | 1 | Footprint and flowpath | Determine allowable swale dimensions per site constraints. Maximize flow path to optimize treatment. |
| | 2 | Swale bottom width | 2 ft to 8 ft width. If wider than 8 ft, channel dividers may be necessary to prevent meandering and low-flow channel formation. |
| | 3 | Flow depth | Water quality flow: flow depth during the water quality treatment event should not exceed two-thirds the height of the vegetation for optimum treatment.<br>100-yr flow: flow depth should be fully contained within the swale so as not to flood adjacent property or infrastructure. |
| | 4 | Longitudinal slope | 1% to 6% overall slope (1% to 2% optimum). Slopes greater than 2.5% should incorporate grade control (see below). Slopes flatter than 0.5% may result in nuisance ponding. Flow should not exceed 3 feet/second in grassed swales. |
| | 5 | Side slopes | 3:1 (H:V) or flatter to prevent bank erosion. |
| IMP Design Features | 6 | Channel dividers | If bottom width exceeds 8 ft, channel dividers may be necessary to prevent meandering and low-flow channel formation. |
| | 7 | Grade and erosion control | Grade control provided by 6–18 inch check dams to maintain <2.5% longitudinal invert slope. For particularly flashy catchments, turf reinforcement mats may be necessary to prevent erosion. |
| | 8 | Pretreatment | Where practicable provide vegetated filter strip (sheet flow) or cobble energy dissipater (concentrated flow) for pretreatment. |
| | 9 | Soil amendments | Soils can be amended with organic matter or bioretention media to improve volume reduction. |
| | 10 | Vegetation | Turf grasses (not bunch grasses) should be maintained on the surface to prevent erosion and improve treatment. |

**Vegetated Swale at Public Park, San Diego County, CA**

**A vegetated swale conveys and treats runoff from a public park. Proper design, maintenance of dense vegetation, and accurate fine grading ensure optimum treatment and minimize the risks of erosion or standing water.**




**This schematic labels the typical design components of swales.**

## Maintenance Considerations *(see Appendix D for detailed checklist)*

| Task | Frequency | Maintenance Notes |
|---|---|---|
| **Inlet Inspection** | Twice annually | Check for sediment accumulation and erosion within the swale. |
| **Mowing** | 2-12 times per year | Frequency depends upon location and desired aesthetic appeal. |
| **Watering** | 1 time per 2-3 days for first 1-2 months; sporadically after establishment | If drought conditions exist, watering after the initial year may be required. |
| **Fertilization** | 1 time initially | One time spot fertilization for "first year" vegetation. |
| **Remove and replace dead plants** | 1 time per year | Within first year 10 percent of plants may die. Survival rates increase with time. |
| **Check dams** | One prior to the wet season and monthly during the wet season | Check for sediment accumulation and erosion around or underneath the dam materials. |
| **Miscellaneous upkeep** | 12 times per year | Tasks include trash collection and spot weeding. |

# Vegetated Swales

## Description

Swales are shallow, open channels that are designed remove pollutants such as sediment by physically straining and filtering water through vegetation or cobble within the channel. Additionally, swales can serve as conveyance for storm water and can be used in place of traditional curbs and gutters; however, when compared to traditional conveyance systems the primary objective of a swale is filtration and water quality enhancement rather than conveyance. Some designs also include infiltration through subsurface soil media, or underlying soils to reduce peak runoff volume during storms.

| Treatment Efficiency | | | |
|---|---|---|---|
| Runoff Volume | Low | Bacteria | Low |
| Sediment | High | Nutrients | Low |
| Trash/debris | High | Heavy Metals | Medium |
| Organics | Medium | Oil & Grease | Medium |

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