Appendix D. Fact Sheets

Bioretention

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 Chapter 3 for details.

Drainage Area: Less than 5 acres and fully stabilized.

Aquifer Protection Zones and Karst: Use impermeable liner to protect subsurface resources and prevent sinkholes.

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.

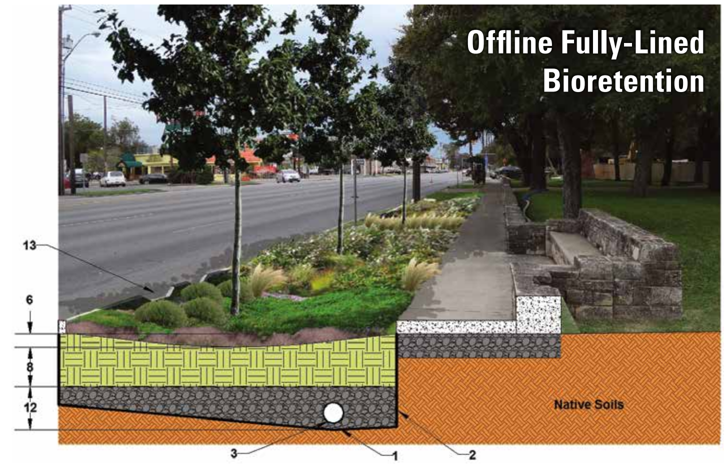
Water Table & Bedrock: At least 3 ft separation must be provided between bottom of cut (subgrade) and seasonal high water table, bedrock, or other restrictive features.

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.

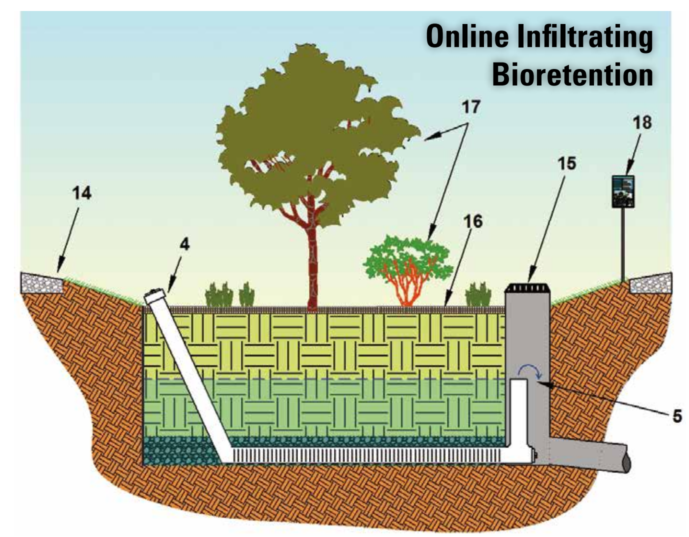
Areas of Concern: Infiltration is not allowed at sites with known soil contamination or *hot spots*, such as gas stations. An appropriate impermeable liner must be used in areas of concern.

Design Considerations & Specifications
(see Appendix B *for details)*

		Design Component	General Specification
Drainage Design	1	Impermeable liner	If non-infiltrating (per geotechnical investigation), use clay liner, geomembrane liner, or concrete.
Drainage Design	2	Lateral hydraulic restriction barriers	May use concrete or geomembrane to restrict lateral flows to adjacent subgrades, foundations, or utilities.
Drainage Design	3	Underdrain/ Infiltration	Underdrain required if subsoil infiltration < 0.5 in/hr. Schedule 40 PVC pipe with perforations (slots or holes) every 6 inches. 4-inch diameter lateral pipes spaced no more than 10 ft on center should join a 6-inch collector pipe. If design is fully-infiltrating, ensure that subgrade compaction is minimized.
Drainage Design	4	Cleanouts/ Observation Wells	Provide cleanout ports/observation wells for each underdrain pipe at spacing consistent with local regulations.
Drainage Design	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.
Drainage Design	6	Temporary Ponding Depth	6–18 inches (6–12 inches near schools or in residential areas); average ponding depth of 9 inches is recommended.
Drainage Design	7	Drawdown Time	Surface drawdown: 12–24 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).
Soil Media	9	Soil Media Composition	85–88% sand, 8–12% fines, 2–5% plant-derived organic matter (animal wastes or byproducts should never be applied).
Soil Media	10	Media Permeability	1–6 in/hr infiltration rate (1–2 in/hr recommended).
Soil Media	11	Chemical Analysis	Total phosphorus < 15 ppm, pH 6–8, CEC > 5 meq/100 g soil.
Soil Media	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	Provide stabilized inlets and energy dissipation.
Routing	14	Pretreatment	Rock armored forebay (concentrated flow), gravel fringe and vegetated filter strip (sheet flow), or vegetated swale.
Routing	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	Mulch	Dimensional chipped hardwood or triple shredded, well-aged hardwood mulch 3-inches-deep.
Landscape	17	Vegetation	Native, deep rooting, drought tolerant plants.
Landscape	18	Multi-Use Benefits	Provide educational signage, artwork, or wildlife amenities.



This schematic represents an offline situation where higher flows bypass the system to the existing downstream network. Infiltration is restricted due to hypothetic subsurface conflicts and adjacency to infrastructure.



This schematic represents an online situation where all flow is routed through the system—an outlet structure is provided to allow overflow during higher flow events. The underdrain is upturned to enhance capture and infiltration of runoff and to improve soil moisture for plant survival.

Maintenance Considerations *(see* Appendix F *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	Less than 3 inches of mulch remaining	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	Plant die-off tends to be highest during the first year (commonly 10% or greater). 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.

BEXAR REGIONAL WATERSHED MANAGEMENT

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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BEXAR REGIONAL WATERSHED MANAGEMENT

Bioswale

Siting and Suitability

Bioswales are highly versatile stormwater BMPs that effectively reduce pollutants. With a narrow width, bioswales can be integrated into site plans with various configurations and components. Ideal sites for bioswales 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. Bioswales can be combined with other basic and stormwater runoff BMPs to form a treatment train, reducing the required size of a single BMP unit.

Drainage Area: Less than 2 acres and fully stabilized.

Aquifer Protection Zones and Karst: Use impermeable liner to protect subsurface resources and prevent sinkholes.

Head Requirements: Bioswale 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 bioswale 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% (average slope should not exceed 5% 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.

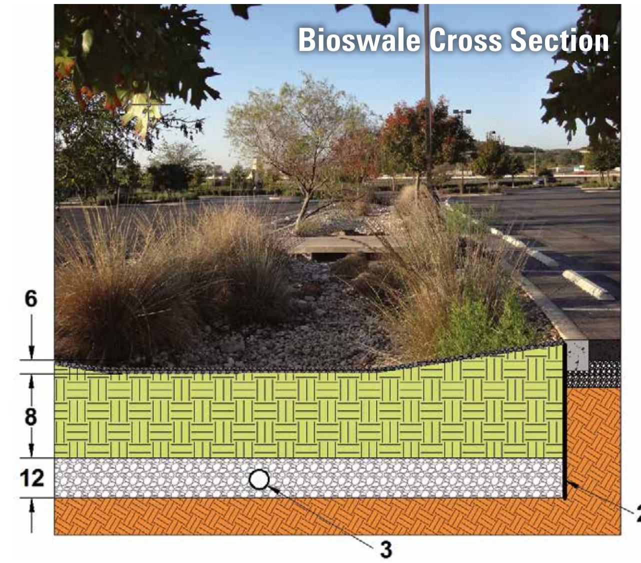
Water Table & Bedrock: At least 3 ft separation must be provided between bottom of cut (subgrade) and seasonal high water table, bedrock, or other restrictive features.

Soil Type: Bioswale 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.

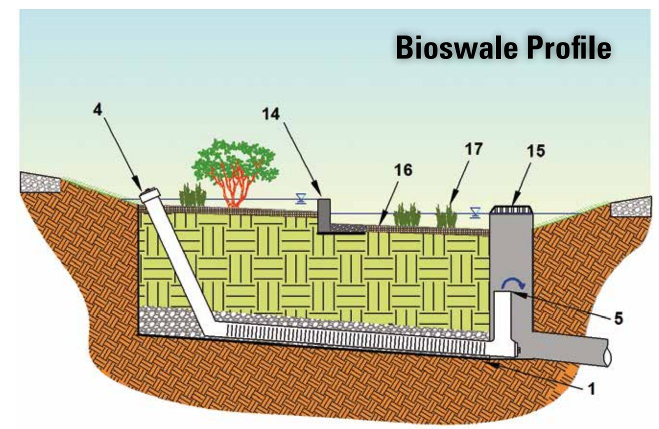
Areas of Concern: Infiltration is not allowed at sites with known soil contamination or *hot spots*, such as gas stations. An appropriate impermeable liner must be used in areas of concern.

Design Considerations & Specifications
(see Appendix B *for details)*

		Design Component	General Specification
BMP Function	1	Impermeable liner	If non-infiltrating (per geotechnical investigation), use clay liner, geomembrane liner, or concrete.
BMP Function	2	Lateral hydraulic restriction barriers	May use concrete or geomembrane to restrict lateral seepage to adjacent subgrades, foundations, or utilities.
BMP Function	3	Underdrain/ Infiltration	Underdrain required if subsoil infiltration < 0.5 in/hr. Schedule 40 PVC pipe with perforations (slots or holes) every 6 inches. 4-inch diameter lateral pipes spaced no more than 10 ft on center should join a 6-inch collector pipe. If design is fully-infiltrating, ensure that subgrade compaction is minimized.
BMP Function	4	Cleanouts/ Observation Wells	Provide cleanout ports/observation wells for each underdrain pipe at spacing consistent with local regulations.
BMP Function	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.
BMP Function	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.
BMP Function	7	Drawdown Time	Surface drawdown: 12–24 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).
Soil Media	9	Soil Media Composition	85–88% sand, 8–12% fines, 2–5% plant-derived organic matter (animal wastes or byproducts should never be applied).
Soil Media	10	Media Permeability	1–6 in/hr infiltration rate (1–2 in/hr recommended).
Soil Media	11	Chemical Analysis	Total phosphorus < 15 ppm, pH 6–8, CEC > 5 meq/100 g soil.
Soil Media	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 and energy dissipation. Install rock armored forebay for concentrated flows, gravel fringe and vegetated filter strip for sheet flows.
Routing	14	Slope and Grade Control	If necessary, use check dams to maintain maximum 2% bed slope. Check dams should extend sufficiently deep to prevent piping (undercutting) below the check dam.
Routing	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	Mulch	Dimensional chipped hardwood or triple shredded, well-aged hardwood mulch 3-inches-deep.
Landscape	17	Vegetation	Native, deep rooting, drought tolerant plants.
Landscape	18	Multi-Use Benefits	Provide educational signage, artwork, or wildlife amenities.



A bioswale captures, conveys, and filters runoff at the Rim Retail Center. Lateral hydraulic restriction barriers protect the adjacent pavement subgrade while allowing vertical infiltration.



This schematic represents an online, infiltrating bioswale where all flow is routed through the system—check dams control the longitudinal slope and ensure capture of the design storm volume. Internal water storage is provided to enhance water retention and plant survival by upturning the underdrain.

Maintenance Considerations *(see* Appendix F *for detailed checklist)*

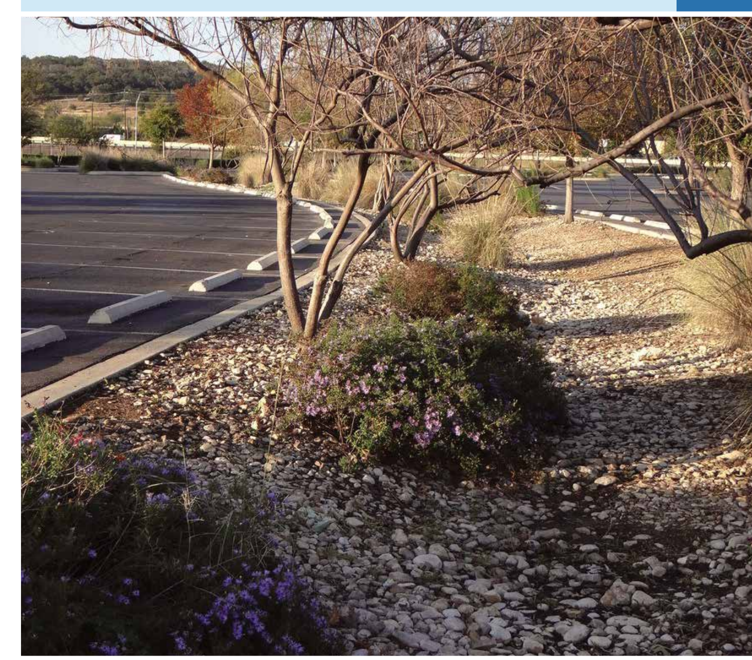
Task	Frequency	Indicator Maintenance is Needed	Maintenance Notes
Catchment inspection	Weekly or biweekly with routine property maintenance	Excessive sediment, trash, and/or debris accumulation on the surface of bioswale	Permanently stabilize any exposed soil and remove any accumulated sediment. Adjacent 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 bioswale is as designed. Remove any accumulated sediment.
Litter/leaf removal and misc. upkeep		Accumulation of litter and debris within bioswale 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	Less than 3 inches of mulch remaining	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	Plant die-off tends to be highest during the first year (commonly 10% or greater). 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.

Description

Bioswales are shallow, open channels that are designed to reduce runoff volume through infiltration. Additionally, bioswales 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 bioswale is infiltration and water quality enhancement rather than conveyance. In addition to reducing the mass of pollutants in runoff, properly maintained bioswales 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



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Permeable Pavement

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.

Aquifer Protection Zones and Karst: Permeable pavement can be used in sensitive geology if impermeable liners and a sand filter layer are used. In areas outside the Edwards Aquifer Recharge and Transition Zones, infiltration into native subsoils is encouraged.

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.

Water Table and Bedrock: Permeable pavement is applicable where depth from subgrade to seasonal high water table, bedrock, or other restrictive feature is 3 feet or greater.

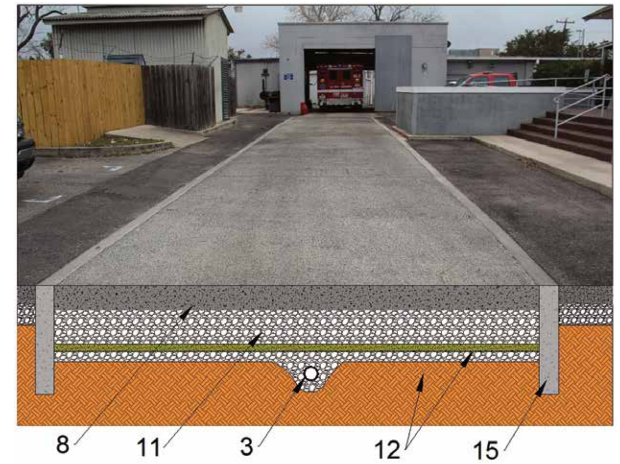
Soil Type: Examine site compaction and soil characteristics. Minimize compaction during construction; do not place the bed bottom on compacted fill. Determine site-specific permeability; it is ideal to have well-drained soils.

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.

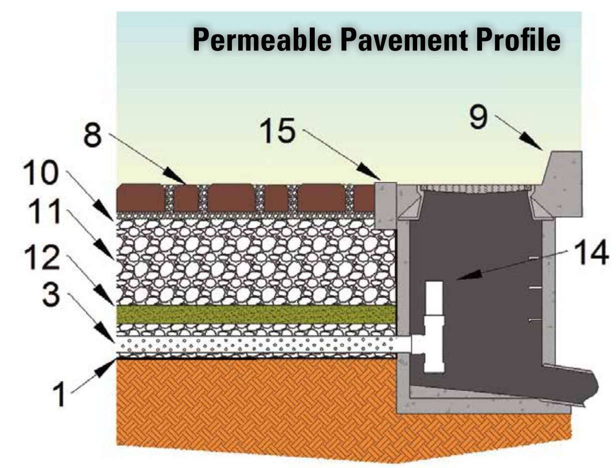
Design Considerations & Specifications
(see Appendix B *for details)*

		Design Component	General Specification
BMP 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. 4-inch diameter lateral pipes should join a 6-inch collector pipe. 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 (in Edwards Aquifer Zones)	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	Soil/Sand Filter Layer	With underdrains or when subsoils are not suitable for filtration (per geotechnical investigation: min. 4-inch layer of ASTM C-33 washed sand above gravel of underdrain drainage layer. No underdrains: min. 12-inch of native subsoil as subgrade.
	13	Structural Design	A pavement structural analysis should be completed by a qualified and licensed professional.
Routing	14	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	15	Edge Restraints and Dividers	Provide a concrete divider strip between any permeable and impermeable surfaces and around the perimeter of PICP installations.
	16	Signage	Signage should prohibit activities that cause premature clogging and indicate to pedestrians and maintenance staff that the surface is intended to be permeable.
	17	Multi-Use Benefits	Provide educational signage, enhanced pavement colors, or stormwater reuse systems.

Permeable Pavement Cross Section



Pervious concrete captures runoff from the Alamo Heights Fire Station. An impermeable concrete transition strip delineates the pervious concrete for maintenance personnel and functions as a hydraulic restriction barrier to protect adjacent pavement and infrastructure from lateral seepage.



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 F *for detailed checklist)*

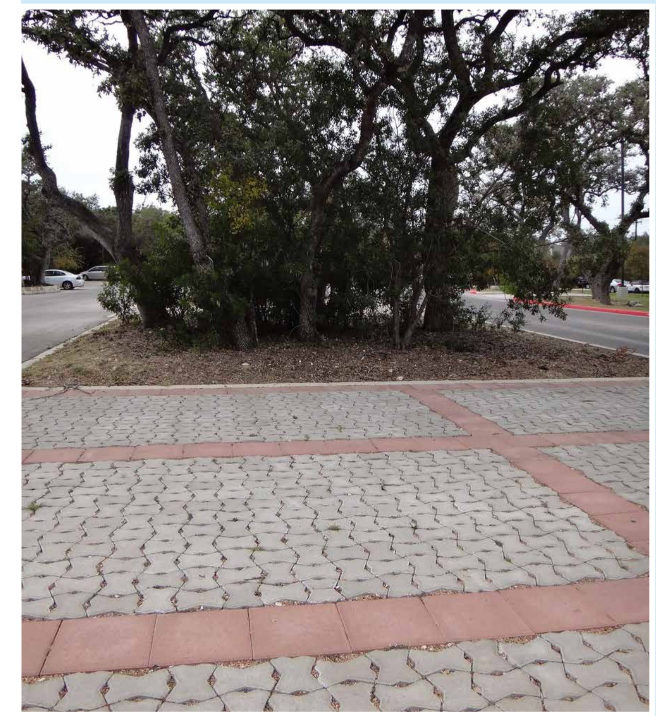
Task	Frequency	Indicator Maintenance is Needed	Maintenance Notes
Catchment inspection	Weekly or biweekly during routine property maintenance	Sediment accumulation on adjacent impervious surfaces or in voids/joints of permeable pavement	Stabilize any exposed soil and remove any accumulated sediment. Adjacent 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.

BEXAR REGIONAL WATERSHED MANAGEMENT

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.

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



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Siting and Suitability

Planter boxes 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 planter boxes 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.

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

Aquifer Protection Zones and Karst: Planter boxes can be used in areas with sensitive geology, but outflow should be directed to the storm drain network or used for irrigation (per geotechnical investigation).

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 box.

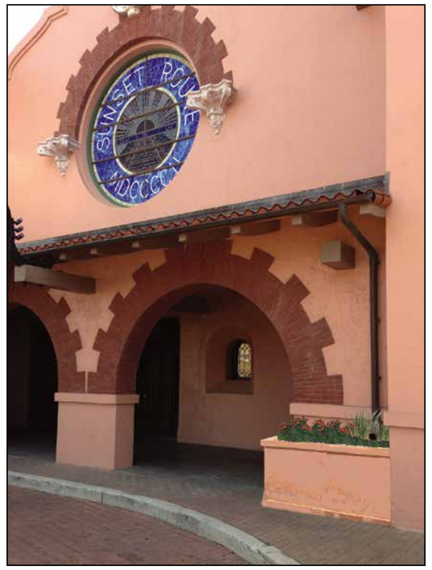
Soil Type: Soils within the drainage area must be stabilized. If planter boxes are fully contained, local soils must provide structural support.

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

Design Considerations & Specifications
(see Appendix B *for details)*

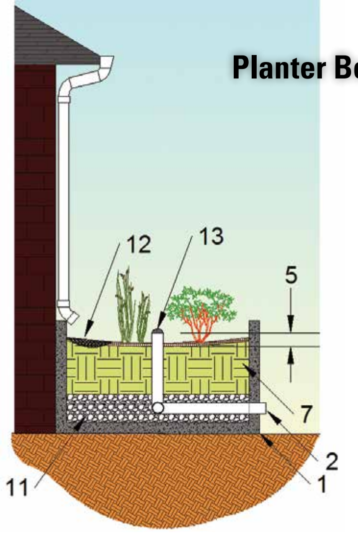
		Design Component/ Consideration	General Specification
BMP Function	1	Impermeable liner	Planter boxes are typically contained within a concrete vault.
BMP Function	2	Underdrain (required)	Underdrain required if subsoil infiltration < 0.5 in/hr. Schedule 40 PVC pipe with perforations (slots or holes) every 6 inches. 4-inch diameter lateral pipes spaced no more than 10 ft on center should join a 6-inch collector pipe. If design is fully infiltrating, ensure that subgrade compaction is minimized.
BMP Function	3	Cleanouts/ Observation Wells	Provide cleanout ports/observation wells for each underdrain pipe at spacing consistent with local regulations.
BMP Function	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.
BMP Function	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.
BMP Function	6	Drawdown Time	Surface drawdown: 12–24 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).
Soil Media	8	Soil Media Composition	85–88% sand, 8–12% fines, 2–5% plant-derived organic matter (animal wastes or byproducts should never be applied).
Soil Media	9	Media Permeability	1–6 in/hr infiltration rate (1–2 in/hr recommended).
Soil Media	10	Chemical Analysis	Total phosphorus < 15 ppm, pH 6–8, CEC > 5 meq/100 g soil.
Soil Media	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.
Routing	12	Inlet/ Pretreatment	Provide stabilized inlets and energy dissipation. Install rock armored forebay, gravel splash pad, or upturn incoming pipes.
Routing	13	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	14	Mulch	Dimensional chipped hardwood or triple shredded, well-aged hardwood mulch 3-inches-deep.
Landscape	15	Vegetation	Native, deep rooting, drought tolerant plants.
Landscape	16	Multi-Use Benefits	Provide educational signage, artwork, or wildlife habitat.

Planter Box at Sunset Depot (rendering)



This rendering illustrates an example of a planter box retrofit to an existing historical building.

Planter Box Cross Section



This figure shows the major components of a planter box.

Maintenance Considerations *(see* Appendix F *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 bioswale	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 bioswale is as designed. Remove any accumulated sediment.
Litter/leaf removal and misc. upkeep		Accumulation of litter and debris within bioswale 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	Less than 3 inches of mulch remaining	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	Plant die-off tends to be highest during the first year (commonly 10% or greater). 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.

BEXAR REGIONAL WATERSHED MANAGEMENT

Planter Boxes

Description

Planter boxes are vegetated BMP units that capture, temporarily store, and filter storm water runoff. The vegetation, ponding areas, and soil media in the planter boxes remove contaminants and retain storm water flows from small drainage areas before directing the treated storm water to an underdrain system. Typically, planter boxes 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. Planter boxes offer considerable flexibility and can be incorporated into small spaces, enhancing natural aesthetics of the landscape.

Planter boxes are effective for removing

Treatment Efficiency

Runoff Volume	Low	Metals	High
Sediment	High	Oil & Grease	High
Nutrients	Medium	Organics	High
Pathogens	High		

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Greenroofs

BEXAR REGIONAL WATERSHED MANAGEMENT

Description

Greenroofs are vegetated surfaces generally installed on flat or gently sloped rooftops. They consist of drought tolerant vegetation grown in a thin layer of media underlain by liner and drainage components. They 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. Greenroofs 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 Greenroofs also may improve property values of adjacent buildings and provide air quality benefits. In addition to these functions greenroofs can serve as passive recreation areas and provide wildlife habitat.

Treatment Efficiency

Runoff Volume	High	Bacteria	Medium
TSS	Medium	Nutrients	Medium
Trash/debris	Medium	Heavy Metals	High
Organics	Medium	Oil & Grease	NA

Siting and Suitability

Greenroofs 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 greenroof. Where installed on existing buildings the structure should be evaluated by a structural engineer to determine suitability. Greenroofs 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.

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

Aquifer Protection Zones and Karst: Not applicable. The use of greenroofs may reduce the need for downstream components to address these issues.

Head Requirements: Not applicable

Slopes: Green 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 greenroof.

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

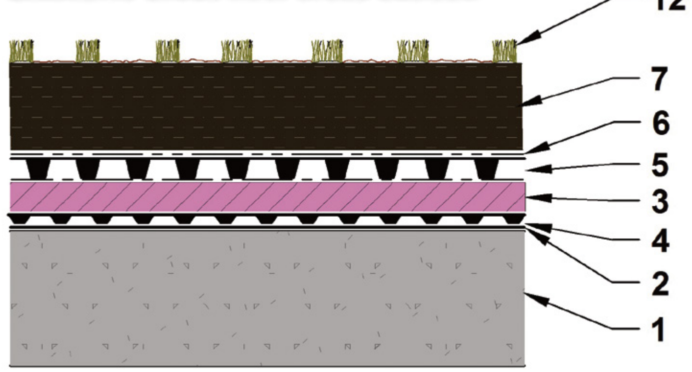
Design Considerations & Specifications
(see Appendix B *for details)*

		Design Component	General Specification
BMP Function	1	Roof Slope	Greenroofs 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.
BMP Function	2	Waterproof Liner	All greenroof systems should incorporate a waterproof liner to protect the roof deck and underlying structure from leaks.
BMP Function	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.
BMP Function	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
BMP Function	5	Drainage Layer	Aggregate: Minimum of 2 inches of clean washed synthetic or inorganic aggregate material such as no 8 stone or suitable alternatives. 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.
BMP Function	6	Root 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.
Growth Media	8	Media Composition	80–90% lightweight inorganic materials such as expanded slates, shales, or pumice. No more than 20% organic materials with a low potential for leaching nutrients.
Other Considerations	9	Roof Drains and Scuppers	Setback greenroof 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 greenroof components.
Other Considerations	10	Other Infrastructure	Separate greenroof 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.
Other Considerations	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).
Landscape	13	Multi-Use Benefits	Include features to enhance habitat, aesthetics, recreation, and public education as desired.

Extensive Green Roof

A modular extensive green roof in Fallbrook, California, was installed on the roof of a public library. Prefabricated plastic trays were planted with colorful varieties of stonecrop.

Extensive Green Roof 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 F *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 greenroof	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 greenroof 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.

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Sand Filters

Siting and Suitability

Sand filters require less space than many LID BMPs 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 the *Storm Water Design Standards* Manual specifications 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.

Aquifer Protection Zones and Karst: Sand filters can be used in sensitive geology if impermeable liners are used.

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.

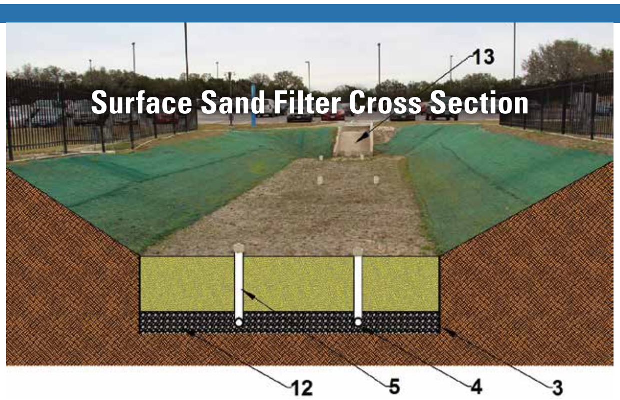
Water Table and Bedrock: Sand filters are applicable where depth from subgrade to seasonal high water table, bedrock, or other restrictive feature is 3 ft or greater.

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.

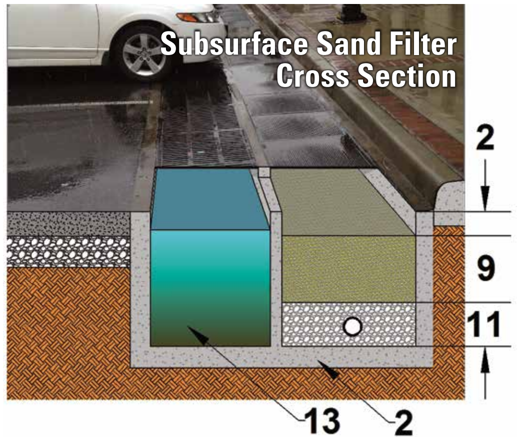
Areas of Concern: Sand filters, if lined, can be used for sites with known soil contamination or *hot spots* such as gas stations. Impermeable membranes must be used to contain infiltration within areas of concern.

Design Considerations & Specifications
(see Appendix B *for details)*

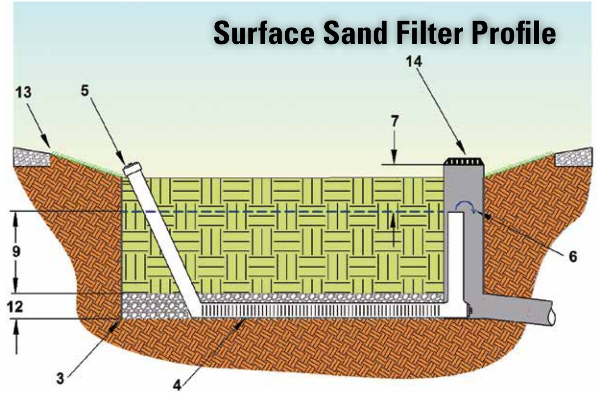
		Design Component	General Specification
BMP Function	1	BMP Type	Surface sand filters: installed in shallow depressions on surface. Require pretreatment by vegetated swales, filter strip, or forebay. Subsurface sand filters: can be installed along the edges of roads and parking lots to conserve space. Must include a sedimentation chamber for pretreatment.
	2	Impermeable liner	If non-infiltrating (per geotechnical investigation), use clay liner, geomembrane liner, or concrete.
	3	Lateral hydraulic restriction barriers	May use concrete or geomembrane to restrict lateral seepage to adjacent subgrades, foundations, or utilities.
	4	Underdrain/ Infiltration	Underdrain required if subsoil infiltration < 0.5 in/hr. Schedule 40 PVC pipe with perforations (slots or holes) every 6 inches. 4-inch diameter lateral pipes should join a 6-inch collector pipe. If design is fully infiltrating, ensure that subgrade compaction is minimized.
	5	Cleanouts/ Observation Wells	Provide cleanout ports/observation wells for each underdrain pipe at spacing consistent with local regulations.
	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.
	7	Temporary Ponding Depth	No greater than 8 feet (shallower depth should be used in residential areas or near schools and parks).
	8	Drawdown Time	Surface drawdown: 12–24 hrs.
Soil Media	9	Soil Media Depth	1.5–4 feet (deeper for better pollutant removal, hydrologic benefits, and deeper rooting depths).
	10	Gradation	Washed concrete sand (ASTM C-33) free of fines, stones, and other debris.
	11	Chemical Analysis	Total phosphorus < 15 ppm.
	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 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).
	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 captures and filters runoff diverted from a parking lot at the University of Texas at San Antonio.



A subsurface sand filter captures parking lot runoff in a sedimentation chamber for pretreatment. Flow then passes through slots in the divider wall into the sand filter chamber.



Maintenance Considerations *(see* Appendix F *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.

BEXAR REGIONAL WATERSHED MANAGEMENT

Description

Sand filters are filtering BMPs 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

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Stormwater Wetlands

Siting and Suitability

Stormwater wetlands are typically constructed in the lowest elevation of a site to convey runoff via gravity flow and to minimize excavation requirements. However, sufficient elevation gradient to the existing stormwater network is required to discharge effluent. Constructed wetlands can be incorporated along the perimeter of a site by designing a long, linear footprint, or can serve as an attractive amenity in common areas of developments. If the entire design volume cannot be stored in a single location or if utility conflicts are apparent, wetland pockets can be distributed between several locations and connected with vegetated channels and/or buried conduit. Most importantly, proper function of stormwater wetlands relies on the adequate supply of groundwater, baseflow, or runoff to maintain permanent pools during dry periods. Stormwater wetlands can provide additional site benefits, such as public/youth education and wildlife habitat, and be incorporated as part of open space plans across various land uses.

Drainage Area: A 10-acre minimum drainage area is recommended.

Aquifer Protection Zones and Karst: Use impermeable liner to protect subsurface resources and prevent sinkholes.

Head Requirements: Wetlands typically require a minimum of 3.0 ft of elevation difference.

Slopes: Interior side slopes above the shallow water zone should be 3:1 (H:V) or flatter. 2:1 side slopes are appropriate within the deep pool zones.

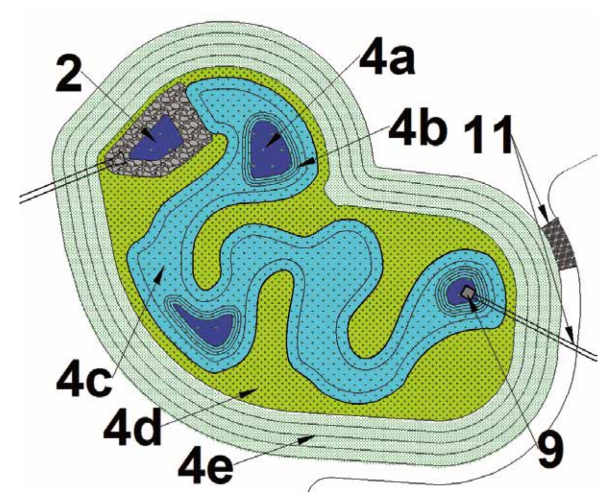
Setbacks: Provide 10-ft setback from structures/foundations, 100-ft setback from septic fields and water supply wells, and 50-ft setback from steep slopes.

Areas of Concern: Within residential, school, and other uncontrolled public areas, safety measures such as a protective perimeter fence should be considered.

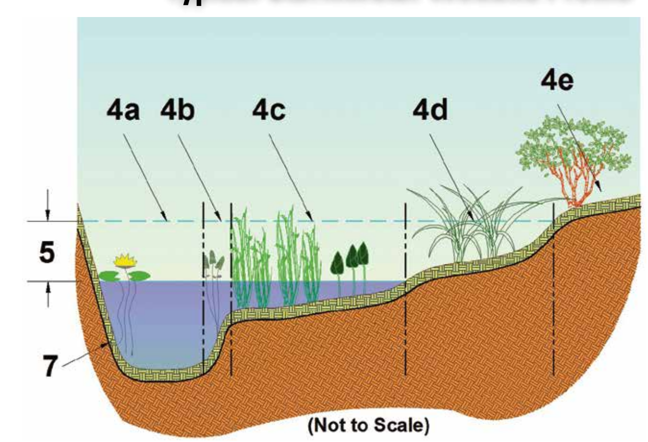
Design Considerations & Specifications
(see Appendix B *for details)*

		Design Component	General Specification
BMP Function	1	Water Balance: Evapotranspiration/Infiltration	Rate of water loss during dry months should not exceed supply from groundwater, baseflow, or runoff to ensure water is maintained in permanent pools.
	2	Sediment Forebay	Forebay should be 18- to 36-inches-deep, 10% of the temporary ponding surface area, and should be lined with riprap for energy dissipation.
	3	Maximum Flow Path	The minimum length-to-width (L:W) ratio should be 2:1, but L:W should be maximized by creating a sinuous flow path and placing the outlet as far from the inlet as possible.
	4a	Wetland Zones	Deep Pools: 15–20% of wetland surface area (including forebay), 18- to 36-inches-deep.
	4b		Transition: 10–15% of wetland surface area, transition between deep pool and shallow water, 12–18 inches deep, maximum slopes of 1.5:1.
	4c		Shallow Water: 40% of wetland surface area, 3- to 6-inches-deep, flat or 6:1 slope (at least 6-foot radius around all deep pools to provide safety shelf).
	4d		Temporary Ponding: 30–40% of wetland surface area, up to 12-inches-deep, 3:1 slopes.
	4e		Detention Storage/Upland: Additional ponding depth can be provided for peak flow mitigation, as needed, but depth should generally not exceed 4 feet above the permanent pool elevation.
	5	Temporary Ponding Depth	Provide 6–12 inches temporary ponding above normal pool.
	6	Drawdown Time	Drawdown orifice is designed to discharge the water quality volume in 2 to 5 days (longer times maximize treatment efficiency).
Topsoil	7	Topsoil Depth	1–4 inches of topsoil should be applied to support plant growth. Depth depends on specified plantings and underlying soil characteristics.
	8	Topsoil Composition	Natural, friable soil representative of productive, well-drained soils in the area. It shall be free of subsoil, stumps, rocks larger than 1-inch diameter, brush weeds, toxic substances, and other material detrimental to plant growth. Low phosphorus (TP < 15 ppm) with pH 5.5–7.
Routing	9	Outlet Configuration	Online: All runoff is routed through the wetland basin—install an elevated riser structure or weir with an orifice at the permanent pool elevation and an overflow at the maximum temporary ponding elevation. Offline: Runoff in excess of the design water quality volume bypasses the wetland.
	10	Design Drawdown Orifice	Non-clogging orifices should feature a downturned pipe that extends 6 to 12 inches below the permanent pool elevation in an area of open water (deep pool).
	11	Outfall Pipe and Emergency Overflow	The outlet barrel should incorporate an anti-seepage device as appropriate to prevent lateral seepage, and discharge to an adequately stabilized area; an emergency spillway should be provided to safely bypass extreme flood flows.
	12	Maintenance/Emergency Dewatering Design	A protected inlet should be provided near the base of the outlet structure with a tamper-proof manual valve (intake should be sized one standard pipe size larger than needed to dewater the basin in 24 hours).
Landscape	13	Vegetation	Primarily annual and perennial wetland plants specified by zones.
	14	Multi-Use Benefits	Include features to enhance habitat, aesthetics, recreation, and public education as desired.

Typical Wetland Plan



Typical Stormwater Wetland Profile



Diverse wetland zones provide important water quality functions and ecosystem services. To enhance plant survival, vegetation should be carefully selected for the water depth and hydroperiod of each zone.

Maintenance Considerations *(see* Appendix F *for detailed checklist)*

Task	Frequency	Indicator Maintenance is Needed	Maintenance Notes
Forebay Inspection	Weekly or biweekly	Internal erosion or excessive sediment, trash, and/or debris accumulation	Check for sediment accumulation to ensure that forebay capacity is as designed. Remove any accumulated sediment.
Basin Inspection	1 time/year	Excessive sediment, trash, and/or debris accumulation in the wetland	Remove any accumulated sediment. Adjacent pervious areas may need to be re-graded.
Outlet Inspection	Weekly or biweekly with routine property maintenance	Accumulation of litter and debris within wetland area, large debris around outlet, internal erosion	Litter, leaves, and debris should be removed to reduce the risk of outlet clogging and to improve facility aesthetics. Erosion should be repaired and stabilized.
Mowing	2-12 times/year	Overgrown vegetation on embankment or adjacent areas	Frequency depends on location and desired aesthetic appeal.
Embankment Inspection	1 time/year	Erosion at embankment	Repair eroded areas and re-vegetate.
Remove and Replace Dead Vegetation	1 time/year	Dead plants or excessive open areas in wetland	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.

Description

Constructed stormwater wetlands are basins that retain a permanent body of shallow water that facilitates the growth of a range of dense wetland vegetation. Constructed to mimic the functions of natural wetlands, stormwater wetlands are a multi-functional, bio-diverse BMP that employ a range of pollutant removal mechanisms. Wetlands create a shallow matrix of sediment, plants, water, and detritus that collectively remove multiple pollutants through a series of complementary physical, chemical, and biological processes. Despite having a higher land requirement as compared to other detention-based BMPs, stormwater wetlands are one of the best practices for removing TSS, nitrogen, and phosphorus while also providing stormwater peak flow attenuation. In addition to their water quality function, stormwater wetlands can also improve site aesthetics and provide an excellent habitat for wildlife and waterfowl.

Treatment Efficiency

Runoff Volume	Low	Bacteria	High
TSS	High	Nutrients	Medium
Trash/debris	High	Heavy Metals	High
Organics	High	Oil & Grease	High

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.

Drainage Area: Rooftop area.

Aquifer Protection Zones and Karst: Harvested water may be used for irrigation only if irrigated area contains at least 12 inches of native soil. No runoff should result from irrigation.

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

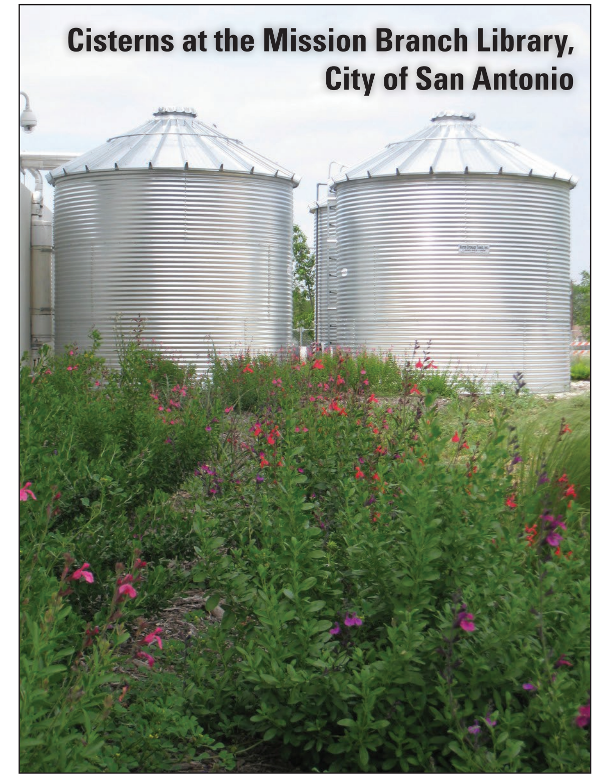
Water Table: The seasonal high water table should be located below the bottom of the cistern, particularly underground cisterns, to prevent buoyant forces from affecting the cistern.

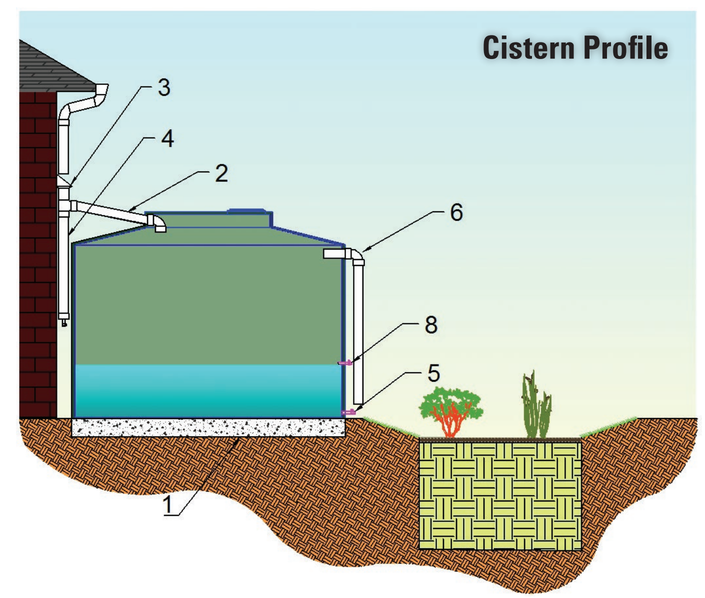
Soil Type: Ensure that the cistern is securely mounted on stable soils. If structural capacity of the site is in question, complete a geotechnical report to determine the structural capacity of soils.

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 B *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: • Dry conveyance: conduit freely drains to cistern with no water storage in pipe • 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 Pantone color #512 and be labeled as reclaimed 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.


Cisterns at the Mission Branch Library, City of San Antonio



This schematic represents a water harvesting system with dry conveyance (water freely drains from the roof gutter to tank). Water from the low flow drawdown and the overflow are directed away from the building to an adjacent irrigation area.

Maintenance Considerations *(see* Appendix F *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

BEXAR REGIONAL WATERSHED MANAGEMENT

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 BMP or landscaped area for infiltration. Because of the peak-flow reduction and storage for potential beneficial uses, subsequent treatment train BMPs 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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