SW Flowpath Disconnection

PLACER COUNTY LOW IMPACT DEVELOPMENT GUIDEBOOK

Fact Sheet RM-1

GENERAL DESCRIPTION

Stormwater disconnection is a technique that reduces the volume of stormwater delivered to storm drains by disconnecting the runoff from roofs, impervious areas on the site and minor roads and redirecting the runoff to permeable areas (e.g., vegetation) that promote runoff filtration and infiltration. Design variations include:

- Rooftop direct runoff and downspout disconnection
- On-site (driveway, walkway, small parking areas, and patio) disconnection
- Minor road runoff disconnection via curb cuts and curb removal

PLANNING AND DESIGN STRATEGIES

GENERAL GUIDELINES

COMPONENT	GUIDELINE
Rooftop Direct Runoff and On-Site Disconnection	
Site Layout	Building Setback – 20' Drainage Area – Average is 500 sf; maximum is 1,000 sf Topography – 10% maximum
Design Criteria	Impervious/Porous Ratio – 2:1 maximum Slope – Must discharge to a gradual slope away from the building at 1% to 5% Soil – Amend soils with infiltration rates less than 1 in/hr or use an underdrain Water Table – 2' minimum separation, 10' minimum separation for infiltration devices Design water surface elevation below the road subbase
Conveyance and Overflow	Level Spreading Device – Place a level spreading device (e.g., pea gravel diaphragm) or energy dissipating device (e.g., splash pad) at the downspout discharge location to distribute runoff evenly over the pervious area
Minor Road Disconnection	
Site Layout	Available Space – Minimum disconnection flow length: 60' Drainage Area – 1 ac maximum per unit Topography – 10% maximum
Design Criteria	Soil – Amend soils with infiltration rates less than 1 in/hr Water Table – 2' minimum separation
Materials	Vegetation – Intervals of vegetated areas are dictated by the design storm, road slope, sinuosity, location and other factors. An initial target distance of 20' can be used for both road length and vegetative flow path length.

Curb Cut, Sierra Tract 1b, South Lake Tahoe, CA. *Credit: Eric Friedlander, CSLT*

DESIGN STRATEGIES

- **Reduce amount and peak of stormwater flow.** Where possible, use shallow unchannelized flow in lieu of piped discharge to increase the time of concentration of flow.
- **Direct flow into stabilized vegetated areas for infiltration and detention.** Flow can also be diverted from impervious surfaces via sheet flow to these vegetated areas.
- **Use curb cuts and curb removal for minor road runoff disconnection.** Peak flow can be attenuated using one of the strategies below: Disconnect runoff in streets by removing part of a curb and allow for infiltration into a depression or planter box; Install curb cuts at intervals and route flows through street and vegetated areas in an alternating fashion.

BENEFITS

- Applicable with limited space constraints and under all soil conditions
- Reduces runoff volume and peak flow, provides infiltration and disconnects flow path
- Provides treatment of sediment, nutrients, metals, O&G and temperature
- Water Quantity: Reduces runoff volume and peak flow, provides infiltration and disconnects flow path
- Water Quality: Provides treatment of sediment, nutrients, metals, and temperature
- Relatively low construction and O&M cost and ease of maintenance
- Promotes groundwater recharge, and is aesthetically pleasing
- Conserves water and promotes groundwater recharge, and is aesthetically pleasing
- Takes advantage of already-required landscape areas; no additional space required
- Can reduce size of downstream stormwater quality treatment measures by reducing the volume required to treat
- Allows for tree preservation in areas requiring pavement
- Vegetated areas provide green space

LIMITATIONS

- Potential for vector concerns due to standing water in vegetated features
- Water barrier will be required where porous material abuts regular asphalt/concrete pavement and there is concern about water infiltrating the regular pavement subbase
- Subsurface infiltration devices may eventually clog with sediment, requiring costly reconstruction
- Soil permeability may limit applicability of subsurface infiltration structures
- Do not use on sites with a likelihood of O&G or other hazardous spills
- Some very rocky/granite soils may allow for only limited infiltration

COLD CLIMATE CONSIDERATIONS

- **Depth of Freeze:** Insert underground components below the frost line to prevent frost heave and prevent water from freezing in pipes. Reduced soil infiltration will likely occur during winter months.
- **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Reduced soil infiltration, and nutrient removal will likely occur during winter months. Little or no roof runoff may occur during winter months.
- **Length of Growing Season:** Select cold climate appropriate plants for vegetated areas.
- **Rain on Snow Events:** Higher runoff volumes may occur during these events.
- **Snow Depth:** Select vegetation to withstand expected snow depths. Incorporate snow volume estimates when sizing storage volumes. Road deicers may cause additional sediment and/or pollutant loads during winter months.

CONSTRUCTION CONSIDERATIONS

- **Soil Disturbance and Compaction:** Allow only vehicular traffic necessary for construction on the pervious areas where flow will be discharged. If vehicle traffic is unavoidable, then the pervious area should be tilled to a depth of 1' to loosen the compacted soil.
- **Erosion and Sediment Control:** If possible, direct construction runoff away from the proposed discharge location. After the contributing drainage area and the discharge location are stabilized and vegetated, remove erosion and sediment control structures.
- **Standing Water and Ponding:** Test areas to be vegetated to verify that standing water infiltrates or evaporates within 48 hours following a runoff event. When longer ponding periods are observed, improve soil infiltration by dethatching, aerating, tilling, regrading and/or adding compost.

OPERATIONS AND MAINTENANCE CONSIDERATIONS

- Irrigate and maintain vegetated areas to maintain infiltration and filtering capacity.
- Periodically check for clogging of any subsurface pipes or infiltration systems and repair as needed.
- Develop a maintenance agreement with property owners or managers to ensure that downspouts remain disconnected and the pervious area remains pervious.
- If ponding of water for longer than 48 hours occurs, the pervious area should be dethatched and aerated.
- If ponding persists, regrading or tilling to reverse compaction and/or addition of compost to improve soil moisture retention may be required.

Left: Downspout routed through sinuous gravel-lined decorative stormwater feature. *Photo credit: Carrie Pak, CWS.*

Below: Roof runoff flows to energy dissipator under gutter downspout. South Lake Tahoe, CA. *Photo credit: Dana Olson, TRCD*

REFERENCES

- See Section 4.4 in the text for more information.
- *Low Impact Development Approaches Handbook*, 2009. CWS, *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- TRCA, *Low Impact Development Stormwater Management Planning and Design Guide*, 2010.
- SEMCOG, *Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers*. 2008.

Rainwater and Snowmelt Harvesting

GENERAL DESCRIPTION

Rainwater and snowmelt harvesting consists of collecting, conveying and storing rainfall and snowfall for future indoor and outdoor uses. The purpose of this harvesting is to collect high quality water to offset potable water demands. The rain or snow that falls upon an impervious surface (e.g. roof, driveway, or walkway) is collected and conveyed into a storage tank (e.g. rain barrel or cistern). With minimal pretreatment (e.g., gravity filtration or first-flush diversion), the captured rainwater or snowmelt can be used for outdoor non-potable water uses such as irrigation and pressure washing, or in the building to flush toilets or urinals.

PLANNING AND DESIGN STRATEGIES

GENERAL GUIDELINES

COMPONENT	GUIDELINE
Site Layout	Available Space – Place storage tanks underground, indoors, on roofs, or adjacent to buildings, outside of County ROW Building Setback – Make tanks water tight to avoid ponding or saturation of soils within 10' of building foundations Drainage Area – Dependent upon conveyance and storage tank sizing Topography – Influences the placement of the storage tank and design of the distribution and overflow systems
Design Criteria	Head – Locate rain barrels or above ground cisterns with gravity distribution systems up-gradient from irrigated areas Soil – Locate underground cisterns in native, rather than fill soil for stability Utility/Tree Clearance – Utilities may constrain the location of underground storage tanks Water Table – Can be used under various depth to water ranges
Pretreatment	Pretreat runoff to remove debris, dust, leaves, and other debris Use Leaf and mosquito screens (1 mm mesh size), first-flush diverter, or in-tank filter Use settling compartment for tanks over 2,500 gallons
Conveyance and Overflow	Rain barrels use head and gravity to feed hoses via a tap and spigot Use a water pump for underground cisterns. Indoor systems usually require a pump, pressure tank, back-up water supply line and backflow preventer Include an overflow system in the design (outflow pipe = inflow pipe size)
Storage	Tank size varies based on rainfall and snowfall frequencies and totals, end-use of water, the catchment surface area, aesthetics, and budget Storage tanks range in size from rain barrels for residential land uses (typically 50 to 100 gallons), to large cisterns (200-400 gallons) for industrial, commercial and institutional land uses Use opaque, potable or food-grade structurally sound materials to construct storage tanks Install tanks in locations where native soils or building structures can support the load from the stored water Childproof rain barrels and cisterns and seal against mosquitoes
Materials	Roof – Metal roofs are recommended Downspouts and Eavestroughs – Materials include PVC pipe, vinyl, aluminum and galvanized steel Do not use lead as solder

DESIGN STRATEGIES

- **Reduce volume of stormwater runoff** by directing downspout to a rain barrel with gravity distribution, routing multiple downspouts to a cistern and pump to reuse water, or collecting flows from impervious areas. Roof can also be used for snow storage, prior to snowmelt collection.
- **Reduce potable water demands** by using diverted and stored stormwater in lieu of potable water. Stored rain water and snowmelt can be used for non-potable uses, such as, landscaping, flushing toilets, and powerwashing.
- **Reuse stormwater prior to pollutant contamination,** as rainwater or snowmelt at the source is much cleaner than downstream runoff. Water from the roof or from low traffic areas is of higher quality and can be reused readily.

BENEFITS

- Applicable with limited space constraints and under all soil conditions
- Reduces runoff volume and peak flow and disconnects flow path
- Does not add additional pollutants to runoff
- Relatively low construction and O&M cost and ease of maintenance
- Conserves water and promotes groundwater recharge
- Managing stormwater runoff (including rainfall and snowmelt) and pollutants close to the source can minimize costs of conveyance features
- Cisterns can be combined with pervious parking areas
- Rainwater harvesting systems can help reduce demand on municipal treated water supplies
- Reduced loads delay expansion of treatment and distribution systems, conserve energy used for pumping and treating water and lower consumer water bills
- It is estimated that these applications alone can reduce household municipal water consumption by up to half
- Where site designs permit, cisterns may be quite large, and shared by multiple households, achieving economies of scale
- Can be retrofitted into existing property

LIMITATIONS

- Potential vector concerns should be addressed by using filter screens and keeping storage tanks covered.
- The stormwater volume/peak discharge rate benefits of cisterns and rain barrels depend on the amount of storage available at the beginning of each storm. One rain barrel may provide a useful amount of water for garden irrigation, but it will have little effect on overall runoff volumes, especially if the entire tank is not drained in between storms.
- Greater effectiveness can be achieved by having more storage volume and by designing the system with a continuous discharge to an infiltration mechanism, so that there is always available volume for retention.
- Rain barrels and cisterns offer no primary pollutant removal benefits. However, this water is often cleaner than downstream runoff.
- The water collected is for nonpotable uses only.
- Immediate use of harvested water is preferred to storage.

COLD CLIMATE CONSIDERATIONS

- **Depth of Freeze:** Pipes are at risk for frost heave if they are above local frost penetration depth. Frozen outlet pipes may be overwhelmed by first flush runoff.
- **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice . Little or no roof runoff may occur during winter months.

To prevent ice accumulation and damage during winter, place first-flush diverters or in-ground filters in a temperature controlled environment, bury below the local frost penetration depth or insulate or equip with heat tracing. Do the same with dual use cisterns and conveyance pipes leading to cisterns. Tank placement is recommended on the south side of the building. Insulate the tank outlet hose to the pump or services with mineral wool mat or molded insulation foam.

CONSTRUCTION CONSIDERATIONS

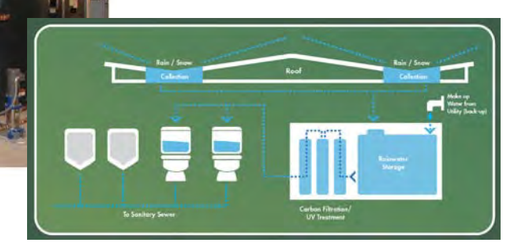
- **Soil Disturbance and Compaction:** Allow only vehicular traffic necessary for construction on the pervious areas where flow will be discharged. If vehicle traffic is unavoidable, then the pervious area should be tilled to a depth of 1' to loosen the compacted soil.
- **Erosion and Sediment Control:** If possible, direct construction runoff away from the proposed discharge location. After the contributing drainage area and the discharge location are stabilized and vegetated, remove erosion and sediment control structures.
- **Standing Water and Ponding:** Test areas to be vegetated to verify that standing water infiltrates or evaporates within 48 hours following a runoff event. When longer ponding periods are observed, improve soil infiltration by dethatching, aerating, tilling, regrading and/or adding compost.

OPERATIONS AND MAINTENANCE CONSIDERATIONS

- Maintenance requirements for rainwater harvesting systems vary according to use
- Systems that are used to provide supplemental irrigation water have relatively low maintenance requirements, while systems designed for indoor uses have much higher maintenance requirements.
- Perform regular inspections every six months during the spring and fall seasons to keep leaf screens, eavestroughs and downspouts free of leaves and other debris; check screens and patch holes or gaps; clean and maintain first flush diverters and filters, especially those on drip irrigation systems; inspect and clean storage tank lids, paying special attention to vents and screens on inflow and outflow spigots; and replace damaged system components as needed.
- If screening is not sufficient to deter mosquitoes, use vegetable oil to smother larvae, or use mosquito dunks or pellets containing larvicide.

Left: TCES Rainfwater Harvesting System with UV, *Photo Credit: Heather Segale, TERC*

Below: Water Capture System, *Credit: Heather Segale, TERC*



REFERENCES

- See Section 4.4 in the text for more information.
- KJ, *Truckee Meadows Structural Control Design Manual*, 2007.
- CWS, *LID Approaches Handbook*, 2009.
- *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- MAPC, *Mass LID Toolkit*, 2007.
- CASQA, *California Stormwater Best Management Practice Handbook, New Development and Redevelopment*, 2003.
- UDFCD, *Best Management Practices*, 1999.

Infiltration Trench and Dry Well

PLACER COUNTY LOW IMPACT DEVELOPMENT GUIDEBOOK

Fact Sheet RM-3

GENERAL DESCRIPTION

Dry wells and infiltration trenches store water in the void (pore) space between crushed stone or gravel where the water slowly percolates downward into the subsoil. An overflow outlet is needed for runoff from large storms that cannot be fully infiltrated by the trench or dry well.

PLANNING AND DESIGN STRATEGIES

GENERAL GUIDELINES

COMPONENT	GUIDELINE
Site Layout	Building Setback – 20' minimum distance Drainage Area – <5ac maximum per unit Topography – 5% maximum contributing slope Install outside of County ROW
Design Criteria	Soil – Infiltration rates of existing site soils must be a minimum of 0.5 in/hr and a maximum of 2.4 in/hr, or use an underdrain Slope – do not apply on slopes greater than 20 percent Utility/Tree Clearance – do not locate under tree drip lines; Consider removing all trees within 10' Water Table – 10' minimum separation Wellhead Protection – 100' setback from potable water wells Maximum trench depth recommended is 10" The maximum depth of the stone in the dry well pit is 5'
Infiltration Rate	Drill borings to determine infiltration rate (one boring at each dry well, two borings at each infiltration trench), with additional borings at 50 feet intervals Determine the infiltrative capacity using a double-ring infiltrometer Base trench/drywell sizing on the slowest rate Do not use trenches or dry wells where soils are >30% clay or >40% silt clay
Pretreatment	Remove sediment prior to treatment to prevent reduction of infiltration capacity Vegetated filter strip, Vegetated swale, and Bioretention are all suitable pretreatment measures
Conveyance and Overflow	Inlet pipes are typically perforated pipe connected to a standard non-perforated pipe or eavestrough The overflow outlet can be the perforated pipe inlet that backs up and discharges to a splash pad and pervious area at grade or can be a pipe that is at the top of the gravel layer and is connected to a storm sewer Outlet pipes must have capacity equal to or greater than the inlet. Use distribution pipes with perforations of 0.5" that are capped at least 1 foot short of the wall of the trench or well
Materials	The dry well should be filled with uniformly-graded, washed 2" diameter stone with a 40% void capacity Trench should be filled with washed 3/4" to 1 1/2" drain rock Add optional horizontal layer of geotextile fabric layer 2"-6" below the trench surface to reduce sediment Non-woven filter cloth should be used to line the trench to prevent the pore space between the stones from being blocked by surrounding native material Trim tree roots flush with the trench sides in order to prevent puncturing or tearing the filter fabric Use an HDPE underdrain pipe that has a perforated, smooth interior, and minimum inside diameter of 4". Perforated pipe should run lengthwise through the dry well Install containment borders using pressure treated lumber, recycled composites, brick, stone, cobble, or other landscape edging material

Driveway runoff conveyed by slotted channel drain to infiltration system
Photo Credits: Dana Olson, TRCD

Sloped driveway conveys runoff to infiltration trench

DESIGN STRATEGIES

- **Reduce peak discharge rate and total runoff volume** by infiltrating a portion of stormwater generated on-site, which will result in modest groundwater recharge.

BENEFITS

- Reduce stormwater runoff volume, including most of the runoff from small frequent storms
- Reduce peak discharge rates by retaining the first flush of stormwater runoff and creating longer flow paths for runoff
- Reduce the size of more expensive downstream stormwater management structures

LIMITATIONS

- Potential vector concerns due to standing water during infiltration
- Cannot receive untreated stormwater runoff, except roof- top runoff. Pretreatment is necessary to prevent premature failure that results from fine sediment, and to prevent potential groundwater contamination due to nutrient, salts, and hydrocarbons
- Can not be used to treat runoff from portions of the site that are not stabilized, and might result in erosion
- Rehabilitation of failed infiltration trenches requires complete reconstruction
- Difficult to use in slowly permeable soils or in fill areas

COLD CLIMATE CONSIDERATIONS

- **Depth of Freeze:** Pipes are at risk for freezing and/or frost heave if they are above local frost penetration depth. Frozen outlet pipes may be overwhelmed by first flush runoff.
- **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Reduced soil infiltration, and nutrient removal will likely occur during winter months.
- **Rain on Snow Events:** Higher runoff volumes may occur during these events.

To prevent ice accumulation and damage during winter, place conveyance pipes below the local frost penetration depth and/or insulate pipes. Increase depth of feature to keep stored runoff below frost line. Incorporate snow volume estimates when sizing storage volumes. Due to increased sediment and pollutant loads do not treat snow that has been exposed to deicers without pretreatment.

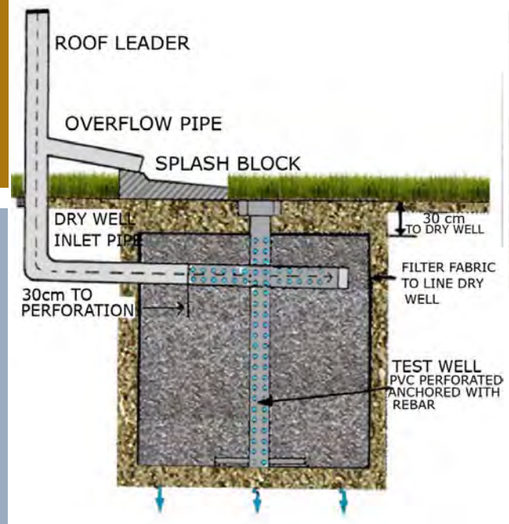
Infiltration Trench contoured along house
Photo Credit: TRCA, 2010

CONSTRUCTION CONSIDERATIONS

- **Soil Disturbance and Compaction:** Before site work begins, clearly mark areas for dry well pits. Only allow vehicular traffic used for construction close to the strip.
- **Erosion and Sediment Control:** Do not use infiltration practices as a sediment control device during construction. Direct construction runoff away from the proposed filter strip site. After the site is vegetated, remove erosion and sediment control structures.

OPERATIONS AND MAINTENANCE CONSIDERATIONS

- After construction, inspect after every major storm for the first few months to ensure stabilization and proper function.
- On a monthly basis, remove sediment and oil/grease from pretreatment devices, overflow structures, and the surface of infiltration trenches.
- Semi-annually, check observation wells 3 days after a major storm. Failure to percolate within this time period indicates clogging.
- Semi-annually, inspect pretreatment devices and diversion structures for structural damage.
- If ponding occurs on the surface of an infiltration trench, remove and replace the topsoil or first layer of stone and top layer of filter fabric.
- Upon failure, perform total rehabilitation of the trench to maintain a storage capacity within 2/3 of the design treatment volume and 72-hour exfiltration rate.



Credit: TRCA, 2010

Dry Rock Dry Well
Photo Credit: Dana Olson, TRCD

REFERENCES

- See Section 4.4 in the text for more information.
- KJ, *Truckee Meadows Structural Control Design Manual*, 2007.
- CWS, *LID Approaches Handbook*, 2009.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- *Massachusetts LID Toolkit*, 2007.
- TRCD and NTCD, *Drip Line Infiltration Trench*, 2006.

Bioretention

PLACER COUNTY LOW IMPACT DEVELOPMENT GUIDEBOOK

Fact Sheet RM-4

GENERAL DESCRIPTION

Bioretention areas (raingardens, tree pits, planters, and curb extensions) are planted depressions that store and filter rainwater to enhance water quality. Stormwater runoff flows into the cell and slowly percolates through the soil (which acts as a filter) and into the groundwater; some of the water is also taken up by the plants. Bioretention areas are usually designed to allow shallow ponding, with an overflow outlet to prevent flooding during heavy storms.

PLANNING AND DESIGN STRATEGIES

GENERAL GUIDELINES

COMPONENT	GUIDELINE
Site Layout	Available Space – Minimum dimensions 15′ wide by 40′ long Building Setback – If no impermeable liner, minimum 10′ setback Drainage Area – Typically 1,000 sf to 1 ac Topography – Contributing slopes between 1 to 5%
Design Criteria	Freeboard – Allow 3″ of freeboard above ponding depth to prevent flooding to adjacent parking areas Head – 3′ minimum vertical distance from invert to inflow point Inlets and outlets should be located as far apart as possible Soil – Infiltration rates of existing site soils must be a minimum of 0.5 in/hr and a maximum of 2.4 in/hr, or use an underdrain Slope – Do not apply on slopes greater than 20 percent Water Table – Minimum 5′ separation Wellhead Protection – Minimum separation of 100′ from potable water supply wells
Pretreatment	Pre-treatment measures include, grass filter strip, and vegetated swale May also be used to infiltrate overflow from infiltration trench/drywell or rainwater harvesting
Conveyance and Overflow	The inflow conveyance may consist of, downspout, sheet flow, curb cuts, covered drain, or pop-up emitters. Overflow can either be diverted by: • Sizing curb openings to capture only the water quality volume while higher flows remain in the gutter • Utility landscaping type inlets or standpipes with trash guards as overflow devices • Using a pre-treatment chamber with a weir design that limits flow to the filter bed area
Storage	Snow can be stored in shallow depressions Water can be stored in pool areas
Materials	Vegetation – Planting plan generally includes one tree or shrub per 50 s.f. of bioretention area, and at least 3 species each of native herbaceous perennials, shrubs, and trees. Select plants that tolerate intermittent flooding, occasionally saline conditions, and extended dry periods. Filter medium – 85% sand, 10% fines, 5% organic matter Mulch layer – Shredded hardwood or bark Geotextile: Should be woven monofilament or non-woven needle punched fabrics. Woven slit film and non-woven heat bonded fabrics should not be used as they are prone to clogging. Gravel: Washed 2″ diameter stone should be used to surround the underdrain and for the gravel drainage layer

DESIGN STRATEGIES

- **Provide water quality treatment through filtration:** Bioretention areas treat stormwater runoff by passing it through a mixture of sand, soil, and organic material.
- **Increase groundwater recharge through infiltration:** Bioretention areas allow infiltration to occur over an extended time period to enhance overall infiltration.
- **Reduce peak discharge rates and total runoff volume:** Bioretention areas may be used to store excess stormwater when the downstream infiltration system has been surcharged.
- **Improve site landscaping:** Bioretention areas are typically installed in commercial, institutional, and residential sites in spaces that are traditionally pervious and landscaped.

BENEFITS

- Properly designed cells remove suspended solids, metals, and nutrients, and can infiltrate an inch or more of rainfall.
- Can provide excellent pollutant removal and recharge for the "first flush" of stormwater runoff
- Increase groundwater recharge as compared to a conventional "pipe and pond" approach
- Low-tech, decentralized bioretention areas are also less costly to design, install, and maintain than conventional stormwater technologies that treat runoff at the end of the pipe.
- Bioretention areas enhance the landscape in a variety of ways: they improve the appearance of developed sites, provide wind breaks, absorb noise, provide wildlife habitat, and reduce the urban heat island effect.

LIMITATIONS

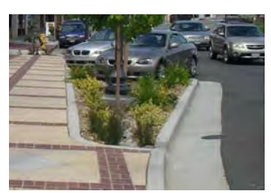
- Potential vector concerns due to standing water in vegetated features
- Not suitable for locations where the seasonally high groundwater table is near the surface
- Clogging may be a problem in areas with high sediment loads in runoff
- Vegetation may require irrigation

COLD CLIMATE CONSIDERATIONS

- **Depth of Freeze:** Pipes are at risk for freezing and/or frost heave if they are above local frost penetration depth. Frozen outlet pipes may be overwhelmed by first flush runoff.
- **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Reduced soil infiltration, and nutrient removal will likely occur during winter months.
- **Length of Growing Season:** Select cold climate appropriate plants for vegetated areas.
- **Rain on Snow Events:** Higher runoff volumes may occur during these events.
- **Snow Depth:** Select vegetation to withstand expected snow depths.

To prevent ice accumulation and damage during winter, place conveyance pipes below the local frost penetration depth and/or insulate pipes. Size facilities for coldest temperature removal rates (decreased biological activity, settling etc.), expect enhanced removal during non-winter months.

Incorporate snow volume estimates when sizing storage volumes. Road deicers may cause additional sediment and/or pollutant loads during winter months.



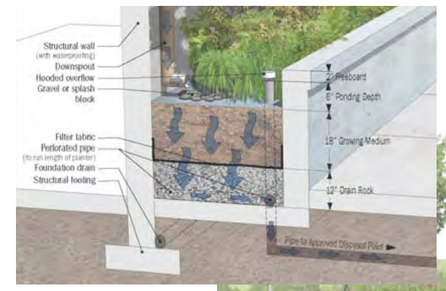
Left: Flow-through-Planter
Photo Credit: Ed Armstrong, Foothill

Right: Rain Garden
Photo Credit: Dana Olson, TRCD

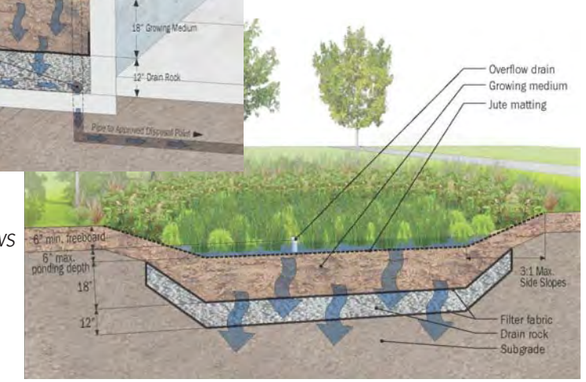
CONSTRUCTION CONSIDERATIONS

- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded, seeded, and/or planted areas with suitable erosion control materials.
- For planters flush with the surrounding landscape, install sediment controls (staked straw wattles) around the planter to prevent high sediment loads from entering during construction activities.
- Focus on erosion and sediment control, materials elevation, and landscape stabilization during Construction Inspection.

POLLUTANT	% REMOVAL
TSS	75-90
TP	70-80
TN	65-80
ZINC	75-80
LEAD	75-80
ORGANICS	75-90
BACTERIA	75-90



Left: Flow through planter



Right: Rain garden

Credits: Carrie Pak, CWS

OPERATIONS AND MAINTENANCE CONSIDERATIONS

- Inspect pretreatment devices and bioretention cells regularly for sediment build-up, structural damage, and standing water.
- Inspect soil and repair eroded areas monthly. Re-mulch void areas as needed. Remove litter and debris monthly.
- Treat diseased vegetation as needed. Remove and replace dead vegetation twice per year.
- Remove invasive species as needed to prevent these species from spreading into the bioretention area.
- Replace mulch every two years, in the early spring.
- Upon failure, excavate bioretention area, scarify bottom and sides, replace filter fabric and soil, replant, and mulch.

REFERENCES

- See Section 4.4 in the text for more information.
- KJ, *Truckee Meadows Structural Control Design Manual*, 2007.
- CWS, *LID Approaches Handbook*, 2009.
- *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- CASQA, *California Stormwater Best Management Practice Handbook, New Development and Redevelopment*, 2003.
- UDFCD, *Best Management Practices*, 1999.

Vegetated Filter Strip

PLACER COUNTY LOW IMPACT DEVELOPMENT GUIDEBOOK

GENERAL DESCRIPTION

Vegetated filter strips (buffer strips and grass filter strips) are gently sloping, densely vegetated areas that treat runoff as sheet flow from adjacent impervious areas. They slow runoff velocity, filter out suspended sediment, provide some infiltration into underlying soils and are effective as a pretreatment practice. Vegetation may be comprised of a variety of trees, shrubs and groundcovers to add aesthetic value as well as water quality benefits. Vegetated Filter Strips provide a convenient area for snow storage and treatment, and are particularly valuable due to their capacity for snowmelt infiltration.

Vegetated filter strip
Photo Credit: Carrie Pak, CWS

PLANNING AND DESIGN STRATEGIES

GENERAL GUIDELINES

COMPONENT	GUIDELINE
Site Layout	Available Space – Ratio of drainage area and footprint = 6:1. Minimum 20' in direction of flow, 60' maximum for impervious surfaces, and 100' maximum for pervious surfaces Building Setback – 10' minimum separation
Design Criteria	Soil – All soil types Slope – Specify slopes should be between 1% and 15%, though slopes less than 5% are preferred. Design the top and toe of the slope to be as flat as possible. Water Table – Minimum 3' separation Sheet flow must be maintained across strips Vegetation – Requires dense vegetation minimum of 2" to 4" tall Normal velocity should be <1.0 ft/s for design flow, with maximum permissible velocity of 3.0 ft/s for peak discharge during 10-yr storm
Pretreatment	Functions well as a pretreatment device
Conveyance and Overflow	Use a cement level spreader or pea gravel diaphragm at the top of the slope. Filter strips can be designed with a pervious berm of sand and gravel at the toe of the slope. This feature provides an area for shallow ponding at the bottom of the filter strip. Runoff ponds behind the berm and gradually flows through outlet pipes in the berm. The volume ponded behind the berm should be equal to the water quality volume.
Storage	Snow can be stored on feature
Materials	Soil – If soils on the filter strip site are highly compacted, or of such low fertility that vegetation cannot become established, they should be tilled to a depth of 1' and amended with compost to achieve an organic content of 8 to 15% by weight or 30 to 40% by volume. Vegetation – Select vegetation that can withstand calculated flow velocities, and both wet and dry periods. Also consider depth to groundwater and choose facultative wetland species if appropriate.

Vegetated filter strip traffic island
Photo Credit: Carrie Pak, CWS

DESIGN STRATEGIES

- **Reduce peak discharge rate and total runoff volume:** Vegetated filter strips redirect stormwater from pervious areas and slow the flow due to increased roughness in the vegetation.
- **Provide snow storage areas:** Grass filter strips provide areas where snow can be stored.

BENEFITS

- **Provide runoff pretreatment by trapping, filtering and infiltrating particulates and associated pollutants.** Effectiveness depends largely on the quantity of water treated, the slope and length of the filter strip, the type of vegetation, and the soil infiltration rate
- **Reduce runoff velocities and increase the time of concentration as compared to channelized flow,** resulting in a reduction of erosion and peak discharge rates

LIMITATIONS

- Because filter strips infiltrate runoff to groundwater, they could be inappropriate at stormwater "hotspots" (such as gas stations) with higher potential pollutant loads. Combine them with other LID features to ensure adequate treatment of polluted runoff prior to discharge.
- Channelization and premature failure may result from poor design, imprecise construction, or lack of maintenance. Proper design requires a great deal of finesse, and slight problems in the construction, such as improper grading, can render the practice less effective in terms of pollutant removal.
- Filter strips have low removal rates for nutrients, so use them in conjunction with other LID features.
- Filter strips often require lots of space, making them often infeasible in urban environments where land prices are high.
- Vegetation may require irrigation.

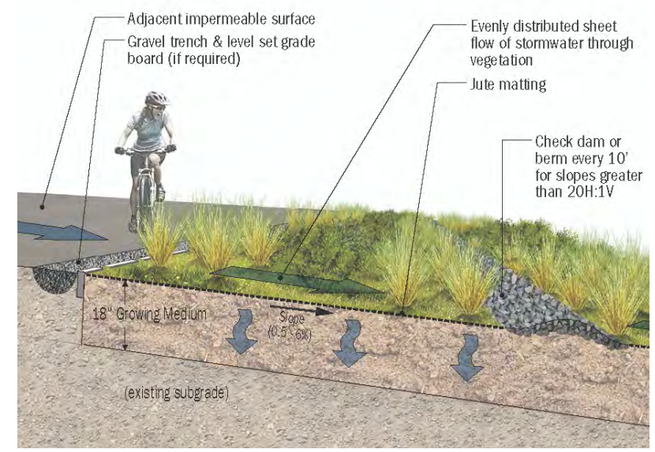
COLD CLIMATE CONSIDERATIONS

- **Depth of Freeze:** Pipes are at risk for freezing and/or frost heave if they are above local frost penetration depth. Frozen outlet pipes may be overwhelmed by first flush runoff.
- **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Reduced soil infiltration, and nutrient removal will likely occur during winter months.
- **Length of Growing Season:** Select cold climate appropriate plants for vegetated areas.
- **Rain on Snow Events:** Higher runoff volumes may occur during these events
- **Snow Depth:** Select vegetation to withstand expected snow depths.

Install pipes components below the frost line to prevent frost heave and preventing water from freezing in pipes. Size facilities for coldest temperature removal rates (decreased biological activity, settling etc.), expect enhanced removal during non-winter months. Road deicers may cause additional sediment and/or pollutant loads during winter months.

CONSTRUCTION CONSIDERATIONS

- **Soil Disturbance and Compaction:** Clearly show the limits of disturbance on all construction drawings. Before site work begins, clearly mark areas for filter strips and protect them by using acceptable signage and silt fencing. Isolate construction vehicular traffic so that other traffic does not come near the filter strip.
- **Erosion and Sediment Control:** Direct construction runoff away from the proposed filter strip site. If used for sediment control during construction, regrade and revegetate after construction is finished.



Vegetated filter strip profile *Credit: Carrie Pak, CWS*

OPERATIONS AND MAINTENANCE CONSIDERATIONS

- Inspect level spreader monthly and remove built-up sediment.
- Inspect vegetation monthly for rills and gullies and correct. Fill any depressions or channels. Seed or sod bare areas.
- In the year following construction, inspect the filter strip regularly to ensure that grass has established. If not, replace with an alternative species. Allow natural succession by native grasses and shrubs if it occurs.
- Mow grass, as rarely as 2-3 times per year, to maintain 4" to 6" of dense grass cover. Grass clippings should be collected and composted elsewhere. Provide a minimum of fertilizer only when necessary. Mow when the soil is dry and firm to prevent rutting.
- Semi-annually, remove sediment that has accumulated to prevent berms or channels.

REFERENCES

- See Section 4.4 in the text for more information.
- KJ, *Truckee Meadows Structural Control Design Manual*, 2007.
- CWS, *LID Approaches Handbook*, 2009.
- *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- CASQA, *California Stormwater Best Management Practice Handbook, New Development and Redevelopment*, 2003.
- UDFCD, *Best Management Practices*, 1999.

Vegetated Swale

PLACER COUNTY LOW IMPACT DEVELOPMENT GUIDEBOOK

Fact Sheet RM-6

GENERAL DESCRIPTION

Vegetated swales are essentially bioretention cells that are configured as linear channels.

They are stormwater conveyance and soil filter systems that temporarily store and then filter the desired water quality volume. Stormwater is conveyed slowly through a vegetated swale due to roughness associated with plants, where it can pool behind shallow check dams. Stormwater is treated by filtering through the soil bed which can then flow to an underdrain, which conveys treated runoff back to the conveyance system further downstream.

PLANNING AND DESIGN STRATEGIES

GENERAL GUIDELINES

COMPONENT	GUIDELINE
Site Layout	Available Space – Footprint 5% to 15% of drainage area. Swale length > culvert length, Minimum swale length 100' Building Setback – Minimum 10' setback Drainage Area – Maximum drainage area 5 ac Topography – Do not apply in areas with adjacent slopes of 5% or greater or in areas with highly erodible soils
Design Criteria	Head – Elevation drop needed between inflow and outflow Soil – Minimum infiltration rate of 0.5 in/hr and a maximum of 2.4 in/hr, or use an underdrain Water Table – Minimum 2' separation Wellhead Protection – Minimum separation of 100' from potable water supply wells Shape – a trapezoidal or parabolic shape is preferable for aesthetic, maintenance and hydraulic reasons Bottom Width – 2' to 8' Side Slopes – Max 3:1 Swale Longitudinal Slope: Moderately flat with a slope between 1% and 2% is recommended. Slopes of up to 4% can be utilized, if check dams are used. It should be wide enough for maintenance access.
Pretreatment	Pre-treatment measures include, grass filter strip, and bioretention May also be used to infiltrate flow from roadway disconnection, infiltration trench/drywell or rainwater harvesting
Conveyance and Overflow	Inflow controls include: • Gravel diaphragm (sheet flow) at the end of pavement, perpendicular to the flow path. Select gravel that is clean and washed. • Rip rap and/or dense vegetation (channel flow) can be used on smaller swales Dry swales should be designed for a max velocity of 1 ft/s for the water quality design storm. The swale should also convey the locally required design storm (usually the 10 yr storm) at non-erosive velocities. Check dams at 50' intervals (<2' drop) help to maximize retention time, increase infiltration, promote particulate settling, and decrease flow velocities. Check dams are not necessary with very low longitudinal slopes. Provide scour protection below check dam.
Storage	Snow can be stored in shallow depressions Water can be stored behind check dams
Materials	Filter Media – soil mixture should be 85% sand, 10% soil fines, and 5% organic matter. Underdrain – Use a soil bed depth of 2' to 3' with a gravel/pipe underdrain system. The minimum interface between the underdrain gravel and the underlying soil should be 0.5'. Vegetation – Select salt-tolerant, native grasses, herbaceous plants, or trees that can withstand both wet and dry periods. Use taller and denser grasses, though the species is less important than good stabilization.

DESIGN STRATEGIES

- **Provide water quality treatment through filtration:** Vegetated swales treat stormwater runoff by conveying it through a rough vegetated pathway, where flow can infiltrate through a soil medium.
- **Increase groundwater recharge through infiltration:** Vegetated swales allow infiltration to occur over an extended duration of time. Small check dams can be added perpendicular to the flow to add infiltration or step pools.
- **Reduce peak discharge rates and total runoff volume:** Vegetated swales may be used to store excess stormwater when the downstream system has been surcharged.
- **Provide a location for snow storage:** Vegetated swales provide an area for snow storage, where snow can be infiltrated as it melts.

BENEFITS

- Swales help to control peak discharges by reducing runoff velocity, lengthening flow paths, and increasing time of concentration.
- Infiltration through the natural substrate helps to reduce total stormwater runoff volume.
- Swales provide effective pretreatment for downstream BMPs by trapping, filtering and infiltrating particulates and associated pollutants.
- Swales accent the landscape and may help to satisfy landscaping and greenspace requirements.
- Swales can provide a location for snow storage during winter months.
- Roadside swales effectively keep stormwater flows away from street surfaces.
- Construction may cost less than conventional curb and gutter systems.

LIMITATIONS

- Potential vector concerns due to standing water in vegetated features
- Effectiveness decreased by compacted soils, frozen ground conditions, short grass heights, steep slopes, large storm events, high discharge rates, high velocities and short runoff contact time
- Effectiveness may be limited in areas where gophers or other burrowing animals are abundant
- Use swales carefully on industrial sites or areas of higher pollutant concentrations. If used, use them as part of a "treatment train" that includes other treatment features.
- Swales not effective at reducing soluble nutrients such as phosphorous
- In some places, the use of swales is restricted by law; many local municipalities may require curb and gutter systems in residential areas.
- Vegetation may require irrigation
- Swales take up more site area than conventional curb and gutter systems

COLD CLIMATE CONSIDERATIONS

- **Depth of Freeze:** Pipes are at risk for freezing and/or frost heave if they are above local frost penetration depth. Frozen outlet pipes may be overwhelmed by first flush runoff.
- **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Reduced soil infiltration, and nutrient removal will likely occur during winter months.
- **Length of Growing Season:** Select cold climate appropriate plants for vegetated areas.
- **Rain on Snow Events:** Higher runoff volumes may occur during these events.
- **Snow Depth:** Select vegetation to withstand expected snow depths.

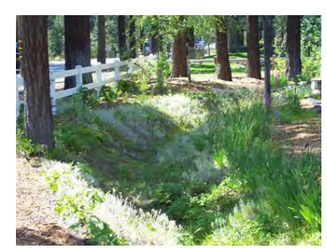
To prevent ice accumulation and damage during winter, place conveyance pipes below the local frost penetration depth and/or insulate pipes. Size facilities for coldest temperature removal rates (decreased biological activity, settling etc.), expect enhanced removal during non-winter months. Incorporate snow volume estimates when sizing storage volumes. Road deicers may cause additional sediment and/or pollutant loads during winter months.

CONSTRUCTION CONSIDERATIONS

- Prevent soil compaction by locating vegetated swales outside the limit of disturbance until construction of the swale begins.
- Do not locate vegetated swales in areas where sediment basins were located during construction, as the concentration of fines will prevent post-construction infiltration.
- To prevent sediment from clogging the surface of a vegetated swale, divert stormwater away from the swale until the drainage area is fully stabilized.
- Used clean and washed gravel for the underdrain, if present, so that no fines are present in the material.
- Rapidly stabilize the swale channel and side slopes with biodegradable geotextile blankets and seeding before bringing the swale "on-line".

OPERATIONS AND MAINTENANCE CONSIDERATIONS

- Develop permits for vegetated swales that specify schedules and responsibility for inspection and maintenance.
- Inspect on a semi-annual basis: Assess slope integrity, soil moisture, vegetative health, soil stability, compaction, erosion, ponding, and sedimentation.
- Mow at least once per year, but do not cut grass shorter than the design flow depth because the effectiveness of the vegetation in reducing flow velocity and pollutant removal may be reduced. Grass cuttings should be removed from the swale and composted.
- Remove accumulated sediment when it is 3" deep or higher than the turf, to minimize potential concentrated flows and sediment resuspension.
- Irrigate only as necessary to prevent vegetation from dying.
- Apply fertilizers and pesticides minimally.
- Reseed periodically to maintain dense turf.
- Remove trash or obstructions that cause standing water.
- Prevent off-street parking or other activities that can cause rutting or soil compaction.



Vegetated Swales in Tahoe
Left: Photo Credit: Dana Olson, TRCD
Right: Photo Credit: Allen Breuch, Placer County

REFERENCES

- See Section 4.4 in the text for more information.
- KJ, *Truckee Meadows Structural Control Design Manual*, 2007.
- CWS, *LID Approaches Handbook*, 2009.
- *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- MAPC, *Mass LID Toolkit*, 2007.
- CASQA, *California Stormwater Best Management Practice Handbook, New Development and Redevelopment*, 2003.
- UDFCD, *Best Management Practices*, 1999.

POLLUTANT	% REMOVAL
TSS	60-95
TP	5-45
TN	16-65
NITRATE	-25-65
METALS	20-90
ORGANICS	75-90
BACTERIA	75-90

Permeable Pavement

PLACER COUNTY LOW IMPACT DEVELOPMENT GUIDEBOOK

Fact Sheet RM-7

GENERAL DESCRIPTION

Permeable paving allows rainwater to percolate through the paving and into the ground before it runs off. This approach reduces stormwater runoff volumes and minimizes the pollutants introduced into stormwater runoff from parking areas. All permeable paving systems consist of a durable, load bearing, pervious surface overlying a crushed stone base that stores rainwater before it infiltrates into the underlying soil. Permeable paving techniques include porous asphalt, pervious concrete, paving stones, and manufactured "grass pavers" made of concrete or plastic. Permeable paving may be used for walkways, patios, plazas, driveways, parking stalls, and overflow parking areas.

PLANNING AND DESIGN STRATEGIES

GENERAL GUIDELINES

COMPONENT	GUIDELINE
Site Layout	Available Space – Impervious areas should not exceed 2x the permeable pavement area Building Setback – Minimum 10' setback Drainage Area – Impervious areas should not exceed 2x the permeable pavement area Topography – Typical 1% to 5% slope. Maximum slope of contributing area: 20%
Design Criteria	Head – Minimum vertical distance between inflow and outlet is 1.5' to 3' Soil – Soils with infiltration less than 1 in/hr will need underdrain Utility/Tree Clearance – Consult local utilities for design guidance Water Table – Minimum separation of 3' Wellhead Protection – Minimum separation of 100' from potable water supply wells
Conveyance and Overflow	Underdrain – Construct with 4" perforated pipes Terminate outflow pipe 1' short of side of opening for base
Storage	Can be used for snow storage if snow is free of pollutants (e.g. sediment, oil) that may clog pavement Water can be stored in base course below permeable pavement prior to infiltration/runoff
Materials	Base Course – Reservoir layer of 1" to 2" crushed stone; depth to be determined by storage required and frost penetration depth Choice of base material is a compromise between stiffness, permeability, and storage capacity Use angular crushed rock material with a high surface friction to prevent traffic compaction and rutting Filter Course – 2" thick layer of 0.5" crushed stone is applied over the base course Geotextile fabric may be laid at the top of the filter layer to trap sediment and pollutants. Vegetation – select durable grass varieties and install by plug, seed, or sod
Pervious Concrete Specs	NO4-RG-S7 Proven to have the best freeze-thaw durability after 300 freeze- thaw cycles 28 day compressive strength = 5.5MPa to 20MPa Void Ratio = 14% to 31% Permeability= 35in/hr to 800in/hr
Permeable Paver Specs	Pavers to meet minimum material and physical properties set forth in the ASTM C 936 Pigment on concrete pavers must conform to ASTM C979 Max allowable breakage – 5% Min paver thickness 3" (vehicular) and 2.5" (pedestrian) Joint width max 0.6" (pedestrian)

DESIGN STRATEGIES

- **Provide water quality treatment through filtration:** Permeable pavement acts as a filter to remove particulate matter from stormwater.
- **Increase groundwater recharge through infiltration:** Permeable pavement allows infiltration to occur.
- **Reduce peak discharge rates and total runoff volume:** The portion of flow that is filtered through the permeable pavement will reduce the overall amount of stormwater flowing downstream.
- **Infiltrate into storage areas:** Permeable pavement can be used to infiltrate stormwater into underground cisterns or storage areas (infiltration galleries)

BENEFITS

- Permeable paving can infiltrate as much as 70% to 80% of annual rainfall.
- Porous pavement can reduce peak discharge rates significantly by diverting stormwater into the ground and away from the pipe-and-pond stormwater management system.
- Grass pavers can improve site appearance by providing vegetation.
- Porous paving increases effective developable area on a site because portions of the stormwater management system are located underneath the paved areas, and the infiltration provided by permeable paving can significantly reduce the need for large stormwater management structures on a site.

LIMITATIONS

- Typically not to be applied on streets with speeds greater than 30 mph or streets with high traffic loads
- Permeable paving can be prone to clogging from sand and fine sediments that fill void spaces and the joints between pavers.
- In cold climates, the potential for frost heave may be a concern for the use of permeable paving. Some design manuals recommend excavating the base course to below the frost line, but this may not be necessary in rapidly permeable soils. In addition, the dead air and void spaces in the base course provide insulation so that the frost line is closer to the surface.
- Snow plows can catch the edge of grass pavers and some paving stones. Rollers should be attached to the bottom edge of a snowplow to prevent this problem.
- Permeable paving should not receive stormwater from other drainage areas, especially any areas that are not fully stabilized.

COLD CLIMATE CONSIDERATIONS

- **Depth of Freeze:** Pipes are at risk for freezing and/or frost heave if they are above local frost penetration depth. Frozen outlet pipes may be overwhelmed by first flush runoff.
- **Extreme and Sustained Cold Temperature:** Extreme or sustained cold temperatures could lead to pipe freezing and permanent pool ice. Reduced soil infiltration, and nutrient removal will likely occur during winter months.
- **Rain on Snow Events:** Higher runoff volumes may occur during these events.

To prevent frost heave, increase depth of aggregate base to keep stored runoff below frost line. Incorporate snow volume estimates when sizing storage volumes. Do not use road deicers on permeable paving or allow contact with runoff that has been exposed to road deicers, to prevent clogging from added sediment load. Raise blades or add rollers on snow removal equipment in order to prevent damage to permeable pavement.

Base layer during construction

After pouring *Photo Credits: Stefan Schuster, CDM*

CONSTRUCTION CONSIDERATIONS

- Fully protect treatment area throughout construction
- Compact aggregate with a minimum 10 ton steel drum
- Avoid extremely high and low temperatures during construction
- Test materials onsite
- Consult industry reps should be consulted for specifications on batching and placement
- Construct as one of the last items to be built on a development site, after most heavy construction vehicles are finished and after the majority of the landscaping work is completed.

OPERATIONS AND MAINTENANCE CONSIDERATIONS

- The blade of the snow plow should be set 1 inch higher than normal when plowing on these surfaces. When contamination is an issue, do not direct snow piles and melt toward these systems.
- Post signs identifying porous pavement areas
- Minimize use of salt or sand during winter months
- Keep landscaped areas well-maintained and prevent soil from being transported onto the pavement
- Clean the surface using vacuum sweeping machines
- For paving stones, periodically add joint material (sand) to replace material that has been transported
- Monitor regularly to ensure that the paving surface drains properly after storms
- Do not reseal or repave with impermeable materials
- Inspect the surface annually for deterioration
- Grass pavers may require periodic reseeding to fill in bare spots
- Clean out drainage pipes and structures within or draining to the subsurface bedding beneath porous pavement at regular intervals

Leveling

Finished Project
Photo Credits: PR Design & Engineering

REFERENCES

- See Section 4.4 in the text for more information.
- KJ, *Truckee Meadows Structural Control Design Manual*, 2007.
- CWS, *LID Approaches Handbook*, 2009.
- *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- MAPC, *Mass LID Toolkit*, 2007.
- UDFCD, *Best Management Practices*, 1999.

POLLUTANT	% REMOVAL
TSS	70-90
TP	40-55
TN	10-20
ZINC	40-80
LEAD	60-70
ORGANICS	75-90
BACTERIA	75-90

Green Roof

PLACER COUNTY LOW IMPACT DEVELOPMENT GUIDEBOOK

GENERAL DESCRIPTION

Green roofs, also known as "living roofs" or "eco-roofs," consist of a layer of vegetation and soil installed on top of a conventional flat or sloped roof. Green roofs are touted for their benefits to cities, as they can improve energy efficiency, reduce heat island effects, and create urban green space for passive recreation or aesthetics. Hydrologically speaking, the green roof assembly acts like a lawn or meadow by storing rainwater in the soil and pond areas. Excess rainfall flows to underdrains and overflow points and is conveyed in a typical building drainage system. After a storm, stored water either evaporates or is evapotranspired by the plants.

PLANNING AND DESIGN STRATEGIES

GENERAL GUIDELINES

COMPONENT	GUIDELINE
Site Layout	Available Space – Limited to rooftop Drainage Area – Green rooftops are designed to capture rainfall directly onto the surface Topography – Green rooftops may be installed on roofs with slopes up to 10%
Design Criteria	Soil – Soils with adequate infiltration rates (1 in/hr) Load – Roof structure must be able to support soil and plants of the green roof assembly, and maintenance staff accessing the roof. Slope – Can be used on roof slopes up to 10%. ASTM International released the following Green Roof standards in 2005: • E2396-05 Standard Test Method for Saturated Water Permeability of Granular Drainage Media; • E2397-05 Standard Determination of Dead Loads and Live Loads associated with Green Roof Systems; • E2398-05 Standard test method for water capture and media retention of geocomposite drain layers for green roof systems; • E2399-05 Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems; and • E2400-06 Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems.
Conveyance and Overflow	The drainage system includes a porous drainage layer and a geosynthetic filter mat to prevent fine soil particles from clogging the porous media. The drainage layer can be made up of gravels or recycled-polyethylene materials that are capable of water retention and efficient drainage. The depth of the drainage layer depends on the load bearing capacity of the roof structure and the stormwater retention requirements. The porosity of the drainage layer should be greater than or equal to 25%.
Materials	Waterproof Membrane – Modified asphalts (bitumens), synthetic rubber (EPDM), hypolan (CPSE), and reinforced PVC Modified asphalts usually require a root barrier, while EPDM and reinforced PVC generally do not Common european membrane design is a 60-80 mil PVC singleply roof system Growing Medium – Typically a mixture of sand, gravel, crushed brick, compost or organic matter combined with soil, 3" to 6" in depth, increasing the roof load by 16 lb/sqft to 35 lb/sqft when fully saturated Do not use growing media that contain phosphorus rich fertilizers or excessive nutrient levels Vegetation – Use low-growing, spreading perennial or self-sowing annuals that are drought tolerant including: sedum, delospermum, sempervivium, creeping thyme, allium, phloxes, anntenaria, ameria, and abretia Vegetation may be planted as vegetation mats, plugs or potted plants, sprigs (cuttings), or seeds

Cedar Hotel Vegetated Roof
Photo Credit: Cedar House Sport Hotel

DESIGN STRATEGIES

- **Reduce peak discharge rates and total runoff volume:** The portion of flow that is collected by a green roof will reduce the overall amount of stormwater flowing downstream.
- **Reduce heating and cooling costs through roof insulation:** Green roofs provide cooling effects through soil, plant, and water mixture on the roof which provides insulation.

BENEFITS

- Green roofs reduce peak discharge rates by retaining runoff and creating longer flow paths. Research indicates that peak flow rates are reduced by 50% to 90% compared to conventional roofs, and peak discharge is delayed by an hour or more.
- Green roofs lower heating and cooling costs because the trapped air in the underdrain layer and in the root layer help to insulate the roof of the building. During the summer, sunlight drives evaporation and plant growth, instead of heating the roof surface. During the winter, a green roof can reduce heat loss by 25% or more.
- Because green roofs shield roof membranes from intense heat and direct sunlight, the entire roofing system has a longer lifespan than conventional roofs.
- The presence of a green roof helps to reduce air temperatures around the building, reducing the "heat island" effect and reducing the production of smog and ozone, which forms in the intense heat (175 degrees F) over large conventional roofs. The vegetation on green roofs also consumes carbon dioxide and increases the local levels of oxygen and humidity.
- Green roofs have demonstrated aesthetic benefits that can increase community acceptance of a high-visibility project; they may also add value to the property if marketed effectively.

LIMITATIONS

- Load restrictions are usually the main limitation for green roofs in retrofit applications. A professional structural engineer must assess the necessary load reserves and design a roof structure that meets state and local codes.
- Slopes greater than 15% require a wooden lath grid or other retention system to hold substrate in place until plants form a thick vegetation mat.
- Green roofs should not be used where groundwater recharge is a priority, such as in aquifer recharge areas or watersheds experiencing low-flow stresses.
- The initial construction cost is higher than conventional roofs.
- Vegetation may require irrigation

COLD CLIMATE CONSIDERATIONS

- **Extreme and Sustained Cold Temperature:** Permanent pool ice covering, reduced biological activity
- **Length of Growing Season:** Select cold climate appropriate plants for vegetated areas.

Size facilities for coldest temperature removal rates (decreased biological activity, settling etc.), but will see enhanced removal during non-winter months. Select climate appropriate vegetation.

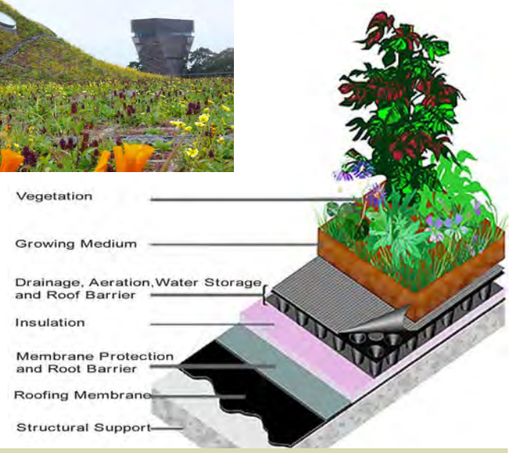
CONSTRUCTION CONSIDERATIONS

- Use an experienced professional green roof installer to install the green roof designed by an architect (or landscape architect) who must work with contractor to ensure that the waterproofing membrane installed is appropriate for use under a green roof assembly.
- Construct conventional green roof assemblies in sections for easier inspection and maintenance access to the membrane and roof drains.
- Green roofs can be purchased as a complete system from specialized suppliers who distribute all the assembly components, including the waterproofing membrane. Alternatively a professional landscape architect can design a customized green roof and specify different suppliers for each component of the system.

OPERATIONS AND MAINTENANCE CONSIDERATIONS

- Green roofs require some support during establishment and then yearly maintenance thereafter. Irrigate plants or sprigs until established, and additional plants or sprigs added to ensure good plant coverage if necessary. With drought-resistant vegetation, irrigation of an extensive green roof is rarely necessary after the two-year establishment period.
- Weed and mulch during the establishment period and periodically thereafter over the life of the roof. Remove any woody plants which become established on the roof.
- If necessary (many roofs can survive on deposition of airborne nitrogen and biomass breakdown), apply a slow-release fertilizer once a year will ensure continued vigorous growth of the vegetation. Do not use soluble nitrogen fertilizers and compost due to the potential for nutrient and bacteria export.

Above: California Academy of Sciences Green Roof
Photo Credit: California Academy of Sciences



Green Roof Layers
Credit: TRCA

REFERENCES

- See Section 4.4 in the text for more information.
- CWS, *LID Approaches Handbook*, 2009.
- *Stormwater Quality Design Manual for the Sacramento and South Placer Regions*, 2007.
- CWP, *Stormwater BMP Design Supplement for Cold Climates*, 1997.
- TRCA, *LID Stormwater Management Planning and Design Guide*, 2010.
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