Section 3

LID Practices

3.0 BIORETENTION SYSTEMS

General Description

Bioretention systems consist of depressed vegetated areas with porous engineered soils designed and to capture and treat urban runoff and infiltrate treated water to the subsurface where existing site soils allow. Bioretention systems are also known as landscape detention, rain gardens, tree box filters, and storm water planters. This type of LID practice is very versatile and can be implemented in most areas where landscaping is to be incorporated into new development or redevelopment projects. Bioretention systems are very effective at reducing the volume and pollutant loading of removing urban runoff because they utilize a combination of porous engineered soils, plants, and their root systems. The volume of urban runoff is reduced by soil retention, plant uptake, evapotranspiration and infiltration. Pollutants are effectively removed by a number of processes including physical filtering, ion exchange, adsorption, biological processing, and conversion. Bioretention systems can be installed into existing site soils or within concrete enclosures. When existing soils are excavated and replaced with engineered soils to create a bioretention system, a layer of pea gravel (not filter fabric) should be used at the base of the excavated pit. Although generally not considered necessary, a geotextile filter fabric or an impermeable liner such as visqueen can be placed along the sides of the excavation to separate the engineered soils from the existing site soils.

A typical bioretention system design includes a depressed ponding area (at a grade below adjacent impervious surfaces), an engineered soil mix, and where existing soils have slow infiltration rates, an underdrain system. The ponding area is designed to capture, detain and infiltrate the water quality volume (WQ_V) into an engineered soil mix consisting of a well mixed combination of topsoil, clean sand, and certified compost and/or peat moss. Where underlying existing site soils have relatively slow infiltration rates (less than 0.5 inch/hr or greater than 120 min/inch), an underdrain system consisting of a perforated pipe in a gravel layer should be included in the design to facilitate proper drainage. Discharge from the underdrain pipe can be routed to a down gradient storm drain pipe or channel. Urban runoff from relatively small storm events, as well as from upgradient washing and irrigation activities; passes through pipes, slotted curbs curb cuts or curb inlets and is distributed evenly at non erosive velocities along the length of the flat ponding area of bioretention systems. Runoff ponds to a depth of approximately 6 to 12 inches and then gradually filters through the engineered soils mix, where it is retained in the porous soils, utilized by plants, evapotranspired, and either infiltrated into the underlying soils, or drained into an underdrain system over a period of days.

Erosion control/energy dissipation features should be provided where runoff enters bioretention systems (e.g. cobbles or riprap beneath a curb cut opening or a splash block beneath a roof drain downspout). In addition, vegetated swales or filter strips can be added to the design to provide pretreatment (e.g. for sediment reduction). Excess runoff from large storm events should be allowed to bypass bioretention systems and flow towards the conventional storm drain system or another downstream BMP. This can be accomplished by providing overflow outlets or inlet control structures such as weirs, inlet pipes and/or grade control features.

Additional performance data, design and construction criteria, and inspection and maintenance requirements is presented in the Truckee Meadows Structural Controls Design Manual.

3.0 BIORETENTION SYSTEMS

Photo: Center for Watershed Protection

Photo: Seattle SEA Streets Project

Figure 3-1: Bioretention systems located on-lot in a multifamily development (left) and in a street right of way of a residential development (right).

Photo: Kennedy/Jenks Consultants

Figure 3-2: Parking lot island bioretention system.

Photo: Kennedy/Jenks Consultants

Figure 3-4: Roadway ROW bioretention system.

Photo: Filterra ™

Figure 3-3: Tree box filter bioretention system.

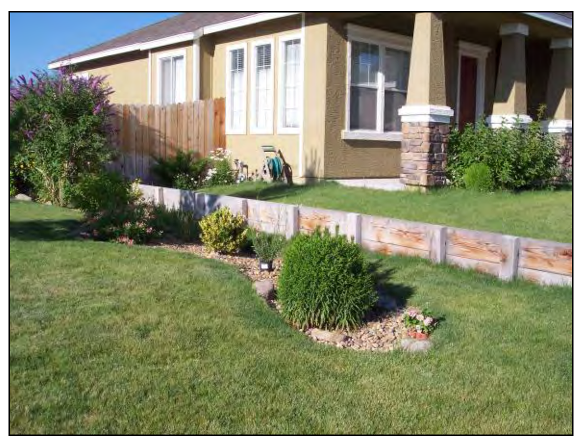

Photo: Kennedy/Jenks Consultants

Figure 3-5: Residential on-lot bioretention system.

3.0 BIORETENTION SYSTEMS

Bioretention systems can be incorporated into all aspects of urban development, including residential, commercial, municipal, and industrial areas. They are well suited for planters along buildings, within street median strips, parking lot islands, and roadside areas where landscaping is planned. In addition to providing significant water quality benefits, bioretention systems can provide shade and wind breaks, absorb noise, improve an area's aesthetics, reduce irrigation needs, and reduce or eliminate the need for an underground storm drain system. Bioretention systems should be integrated into a site's overall landscaping to reduce the volume, rate and pollutant loading of urban runoff to pre-development levels.

Figures 3-1 through 3-6 provide examples of some of the various applications of bioretention systems. These versatile LID practices can be applied to:

- Parking lot islands
- Parking lot perimeters – curbless or curbed with curb cuts
- Tree wells and tree box filters – boxed bioretention cells placed at the curb typically just upstream of storm drain inlets
- Within right-of-ways along roads
- Street median strips
- Driveway perimeters
- Cul-de-sacs
- Landscaped areas in apartment complexes and multifamily housing
- Landscaped areas in commercial, industrial, and municipal developments
- Residential on-lot bioretention – landscape detention or rain gardens
- Planters at rooftop eaves
- Rooftop gardens, particularly on large commercial structures and parking garages

General Design Considerations

- The temporary ponding area in bioretention systems should be designed to retain the water quality volume (WQ_V) determined using the method outlined in the Structural Controls Design Manual.
- Bioretention systems should include an engineered soil mix consisting of a well mixed combination of 50-60% clean sand, 20-30% topsoil, and 5-20% certified compost and/or peat installed to a minimum depth of 18 inches beneath the temporary ponding area.
- Bioretention systems installed in existing site soils with infiltration rates of 0.5 in/hr or greater (120 min/inch or less) typically do not require an underdrain system. Discharge from underdrain pipes can be directed to nearby underground storm drain pipes, channels or other drainage features if sufficient head is available.
- If an underdrain system is required, at a minimum it should consist of a 3 to 4 inch diameter perforated pipe inside the bioretention system, surrounded by an envelope of clean coarse aggregate and pea gravel.
- Filter fabric should <u>not</u> be installed at the base of bioretention systems because it can be prone to clogging. Therefore filter fabric liners should not be placed at the bottom of

excavated basins to separate engineered soils from existing site soils or at the bottom of a concrete box than includes drainage holes to facilitate infiltration into existing site soils.

- Bioretention systems should include design features which will allow large flows from relatively large storm events to either bypass the system or overflow to a conventional storm drain structure such as a channel, a curb and gutter system, or a storm drain inlet. Bypass flows or overflows can also be routed to another downstream storm water treatment system such as a vegetated swale or an extended detention basin.

Figure 3-6: Bioretention system incorporated into a traffic calming feature with inflow and overflow through curb openings.

3.0.0 Landscape Detention

Description

Landscape detention is a type of bioretention system that is also known as a bioretention basin or porous landscape detention. It consists of a low-lying vegetated area underlain by an engineered soil mix. If underlying existing site soils allow for a significant amount of infiltration (0.5 inch/hr or more or 120 min/inch of less), an underdrain system may not be needed. Storm water runoff from relatively small storm events and urban water use (e.g. washing and irrigation) typically passes through curb opening and onto a rock apron, which slows its velocity and distributes it evenly along the length of the ponding area. Water ponded to approximately 6 to 12 inches gradually infiltrates through the engineered soil mix an infiltrates into underlying soils and/or into an underdrain system (if included). The surrounding impervious area should be graded to direct runoff into the landscape detention area. The drainage area for each landscape detention area should be less than 1 acre. Curb openings, weirs or grade controls structures should be included in the design to divert excess runoff from large events away from the landscape detention area towards the conventional storm drain system. Flows in excess of the WQ_V should bypass the landscape detention basin or overflow and flow to the conventional storm drain system or another downstream BMP.

Photo: Center for Watershed Protection

Photo: Colorado AWARE

Figure 3-7: Landscape detention basins located at the edge of a parking lot (left photo) and in a parking lot island with turf and shrubs and trees (right photo).

Photo: Center for Watershed Protection

Photo: Center for Watershed Protection

Figure 3-8: Curb opening design for a landscape detention system located upstream of a conventional storm drain inlet (left photo). A bioretention system retrofit into an existing parking lot island (right photo).

Figures 3-9 and 3-10 show schematic cross sectional views of landscape detention basins that overflow through a curb opening and onto a paved section that slopes away from the basin and flow towards the conventional storm drain system. Figures 3-11, 3-12 and 3-13 show landscape detention basins that overflow to storm drain inlets located into and next to the basins.

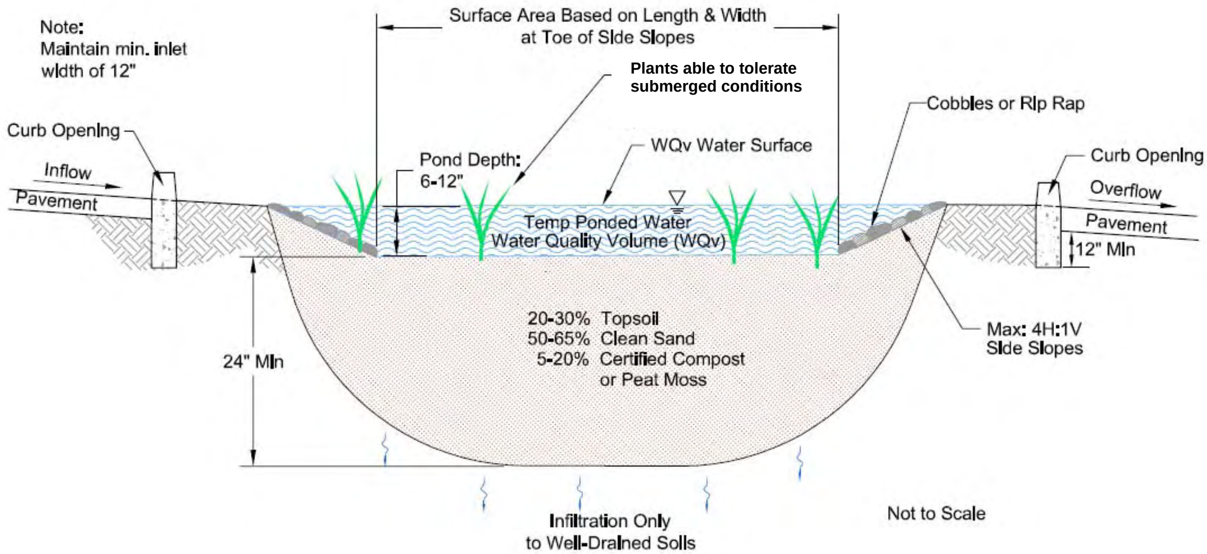

Figure 3-9: Schematic of a landscape detention basin located in existing (native) site soils with an infiltration of 0.5 inch/hr or greater (120 min/inch or less). (Source: Kennedy/Jenks Consultants)

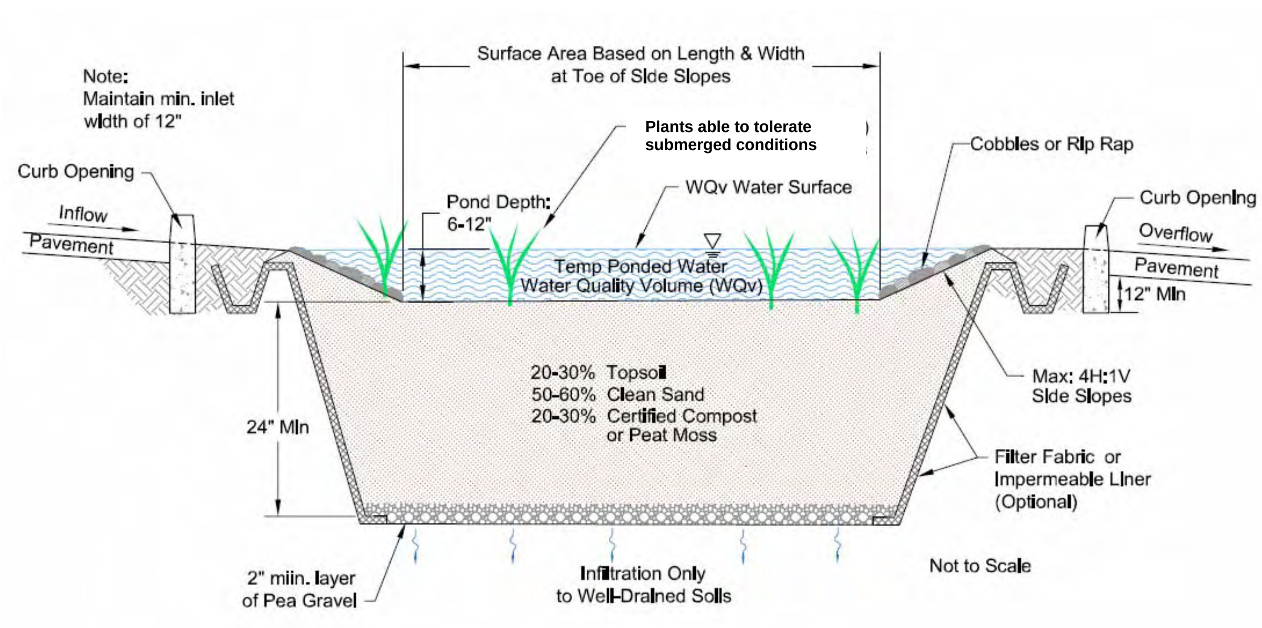

Figure 3-10: Schematic of a landscape detention basin in well draining soils with an optional filter fabric liner installed along the basin side walls. (Source: Kennedy/Jenks Consultants)

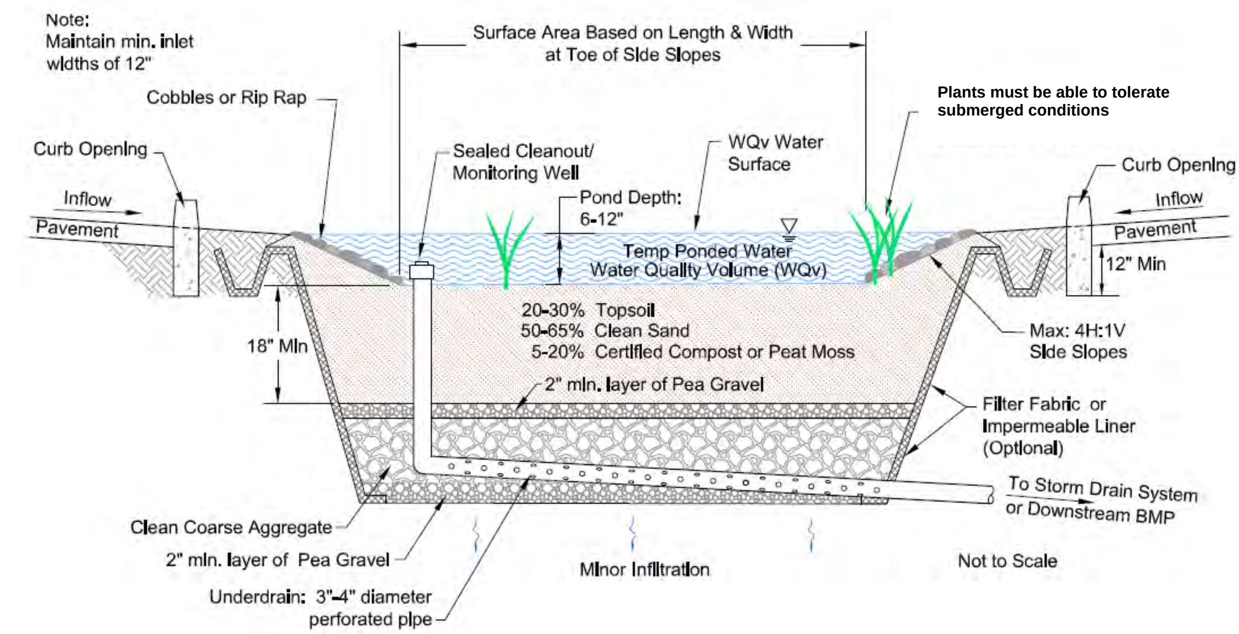

Figure 3-11: Landscape detention basin in slow draining soils with an underdrain system piped to a nearby downgradient storm drain pipe, channel, or BMP. Source: Kennedy/Jenks Consultants)

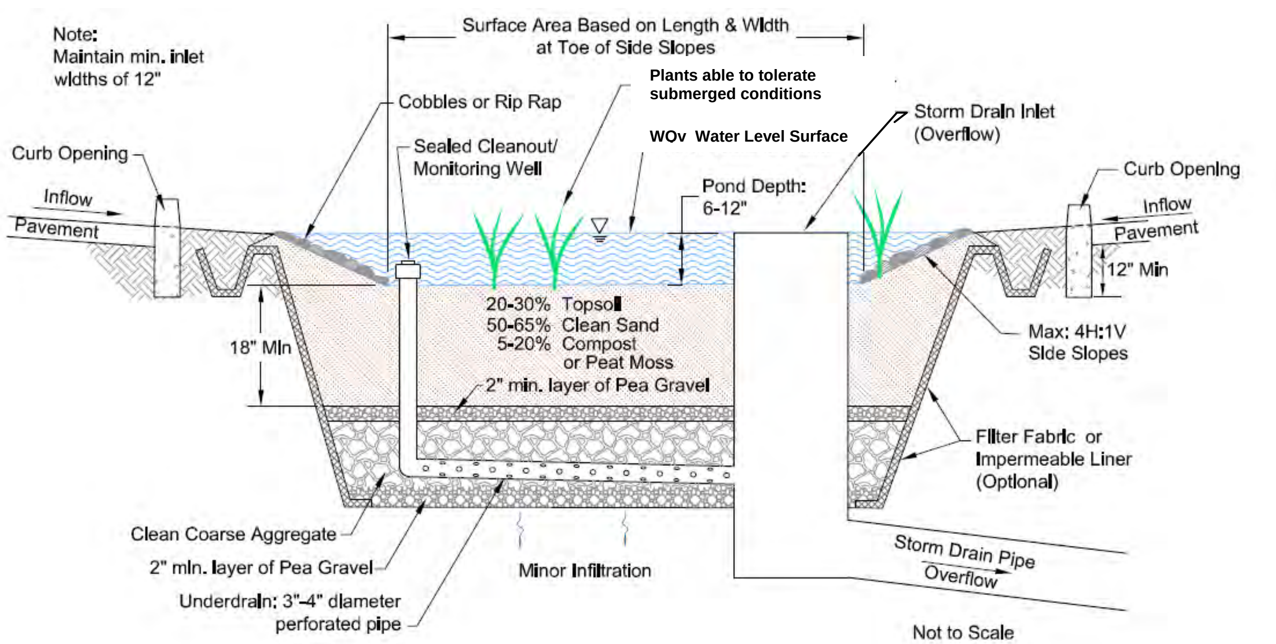

Figure 3-12: Landscape detention basin in slow draining soils with an underdrain system and a storm drain inlet located inside the basin to capture overflow from relatively large storm events. (Source: Kennedy/Jenks Consultants).

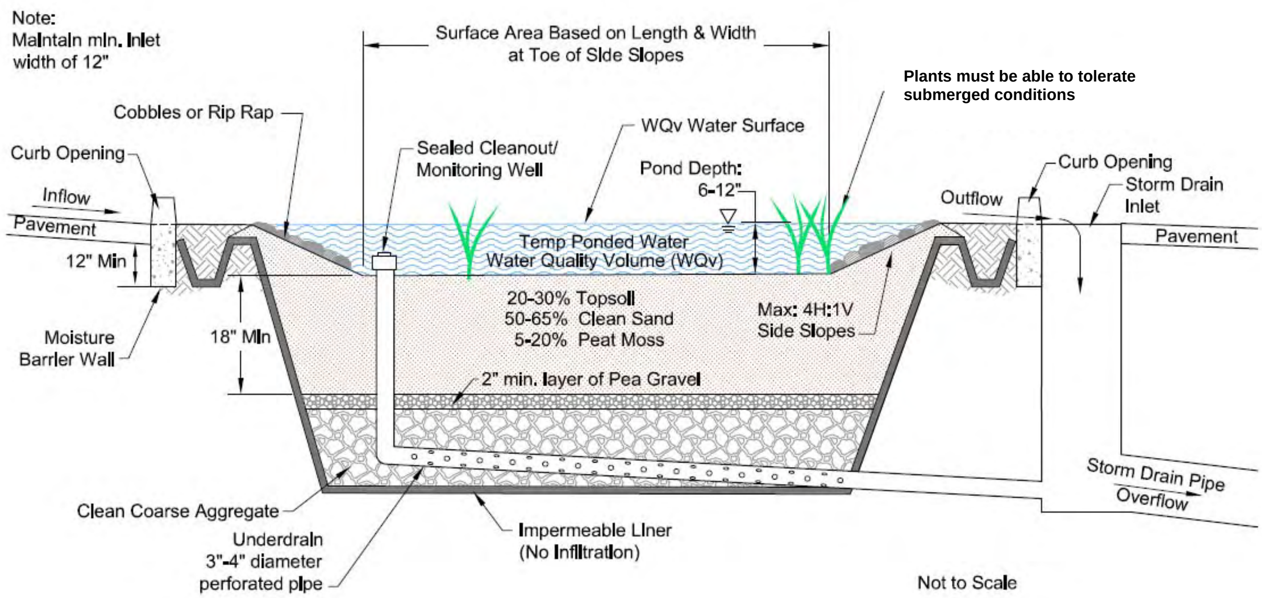

Figure 3-13: Landscape detention basin located in expansive clays or where there is outdoor storage or use of chemicals or materials within the drainage area that could threaten groundwater quality if a spill were to occur. (Source: Kennedy/Jenks Consultants).

Examples

1. In 1995, a new development called Somerset in Prince George's County, Maryland, incorporated rain gardens into each of the nearly 200 lots of a 60-acre development. Combined with grassy swales that replaced curbs and gutters, and disconnection of impervious areas through rain barrels and other LID strategies, the development had considerably lower runoff volumes and peak flow rates when compared to a neighboring conventional development (Cheng, 2003). The cost of installing LID storm water facilities when compared to conventional storm drainage facilities brought about a savings of approximately $300,000. Additionally, utilization of LID techniques in the development yielded six additional lots, where storm water ponds would traditionally have been housed if conventional storm water strategies had been applied (Guillette, 2005).

2. In Maplewood, Minnesota, as a demonstration project, residents of a two-block area of a residential neighborhood volunteered to have small rain gardens constructed on their property. This neighborhood had been experiencing periodic flooding and was slated for repaving, curbs and gutters, and a conventional underground storm drain system. The rain gardens effectively controlled runoff by slowing and infiltrating storm water, negating the need for curbs and gutters and costly underground storm drain infrastructure. The success of this project prompted the City of Maplewood to incorporate rain gardens into other neighborhoods (Hager, 2003).

3. In central North Carolina, a field-scale bioretention study was conducted to assess hydraulic retention and the effectiveness of the saturated zone at removal of phosphorus and nitrogen from storm water. The study contained two pairs of bioretention cells in two separate locations. The first pair, in Greensboro, consisted of one conventionally drained cell and one cell containing an induced saturated zone (an anaerobic zone). The cells were contained within a small shopping center with a parking lot. The second pair of bioretention cells was situated alongside the Tar River in Louisburg, North Carolina. Both of the Louisburg cells consisted of an engineered soil matrix and a conventional underdrain system to a total depth of 36 inches. The soil media used in these cells had a very low P-index and contained approximately 90 percent sand and 8 percent clay. One cell in this pair was lined with impermeable plastic. Both pairs of cells were planted with trees and shrubs and topped with 7-10 cm of double-shredded hardwood mulch.

   It was found that each bioretention cell in the study considerably reduced runoff with 76 to 93 percent of the runoff received being infiltrated. It was also noted that there was a lag time to runoff from the cells, highlighting a bioretention cell's ability to dampen peak flows. The anaerobic drainage configuration at the Greensboro site resulted in significantly lower Total Phosphorus concentrations in outflow than the conventional cells. The anaerobic drainage configuration was also found to have higher pollutant load removals and lower outflow concentrations during the non-growing season than the conventional cells. At the Louisburg site, it was found that the lined cell produced more outflow than the unlined cell and that pollutant removal was greater in the lined cell. Another finding from this study is a strong correlation between Total Phosphorus reduction rates and the P-index of the engineered soil matrix. Therefore, this study recommended that non-agricultural fill soils containing a low P-index be used in the engineered soil matrix of bioretention systems (Hunt and Sharkey, 2005).

3.0 BIORETENTION SYSTEMS

3.0.1 Tree Box Filters

Tree box filters are bioretention systems typically enclosed in concrete boxes that drain and filter runoff from paved areas via a standard storm drain inlet structure. They are typically located upstream of a conventional storm drain inlet and should not be located in sump areas (e.g. topographic low points). Where existing site soils are sufficiently permeable (infiltration rates > 0.5 in/hr), tree box filters can be designed to drain directly to underlying soils via drain holes installed in the base of the concrete box. Where slow draining native soils exist, they should be designed with an underdrain pipe which is typically connected to the conventional storm drain system pipe in the street. Tree box filters should generally be designed per the bioretention system design criteria outlined in the Structural Controls Design Manual. Setback standards generally don't apply if a tree box filter is contained in an impermeable container such as a concrete box and only drains to an underdrain system that discharges to the conventional storm drain system.

Filterra™ manufactures a proprietary tree box filter system. Therefore designers should contact Filterra™ to avoid potential patent right infringement claims if a tree box filter design is similar to the Filterra™ system noted in the figures below.

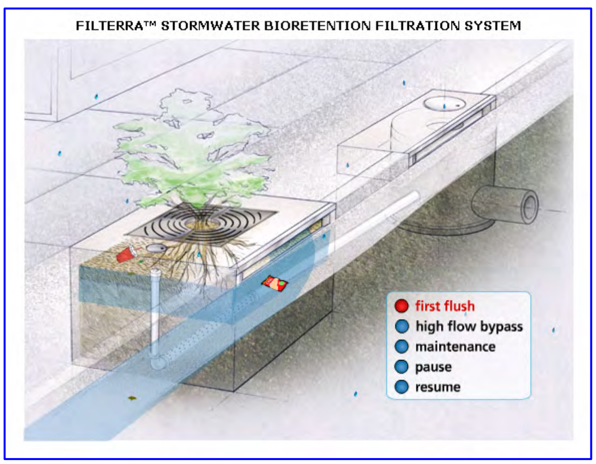

Figure 3-14: Schematic and photo of a tree box filter, which is a manufactured (proprietary) bioretention system.
(figure and photo provided by Filterra™)

Providing parking lot treatment by impaired waters.

Typical Filterra placement at a fast food chain.

Even the largest Filterra unit blends in with landscaping.

Filterra used with a flumed bypass in a commercial parking lot.

Ideal for stormwater treatment where space is tight.

Filterra featuring a beautiful Crape Myrtle in bloom.

Figure 3-15: Various Filterra™ tree box filter configurations. (photographs provided by Filterra™)

3.0.2 Storm Water Planters

Storm water planters, also known as infiltration planters or flow through planters, are also bioretention systems in enclosed in concrete structures. They can be designed to drain runoff from paved areas via curb inlet structures (Figure 3-16) or pipes (Figure 3-17), or located under roof drain downspouts (Figure 3-18) for treatment of roof runoff. Where existing site soils are sufficiently permeable (infiltration rates > 0.5 in/hr), storm water planters can be designed as flow through systems with concrete walls on 4 sides and no floor (Figure 3- 16). When located next to buildings and other structures, or when slow draining native soils exist, they should be designed with an underdrain pipe. Waterproofing should be incorporated into the designs of storm water planters sited near buildings and other structures. When designed with underdrains and waterproofing, storm water planters typically do not need to apply setback standards and infiltration testing.

Most of the general design standards noted above for landscape detention basins also apply to storm water planters. For example, the ponding area in storm water planters should be designed to detain the Water Quality Volume (WQ_V) per the method outlined in the Structural Controls Design Manual. In addition, storm water planters should be designed with engineered soil mixtures such as noted on Figures 3-9 through 3-13 above.

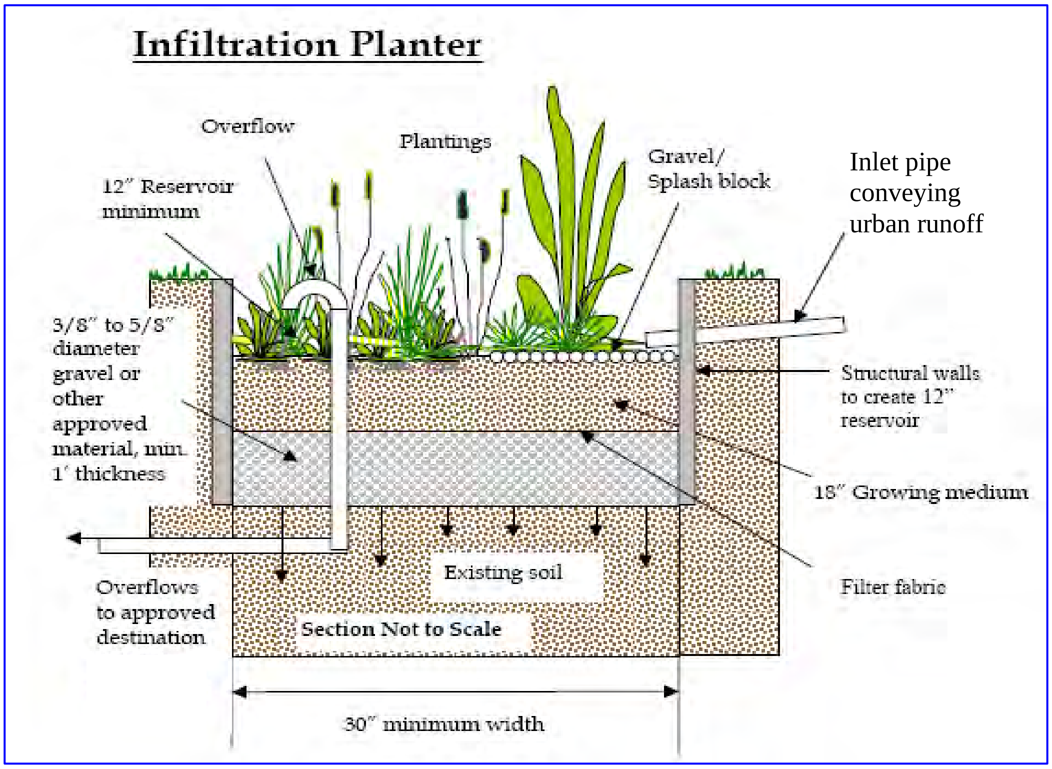

Figure 3-16: Schematic of a storm water planter that receives urban runoff from a pipe, drains directly to underlying soils, and overflows to the conventional storm drain system via an overflow pipe. (adapted from Portland BES).

3.0 BIORETENTION SYSTEMS

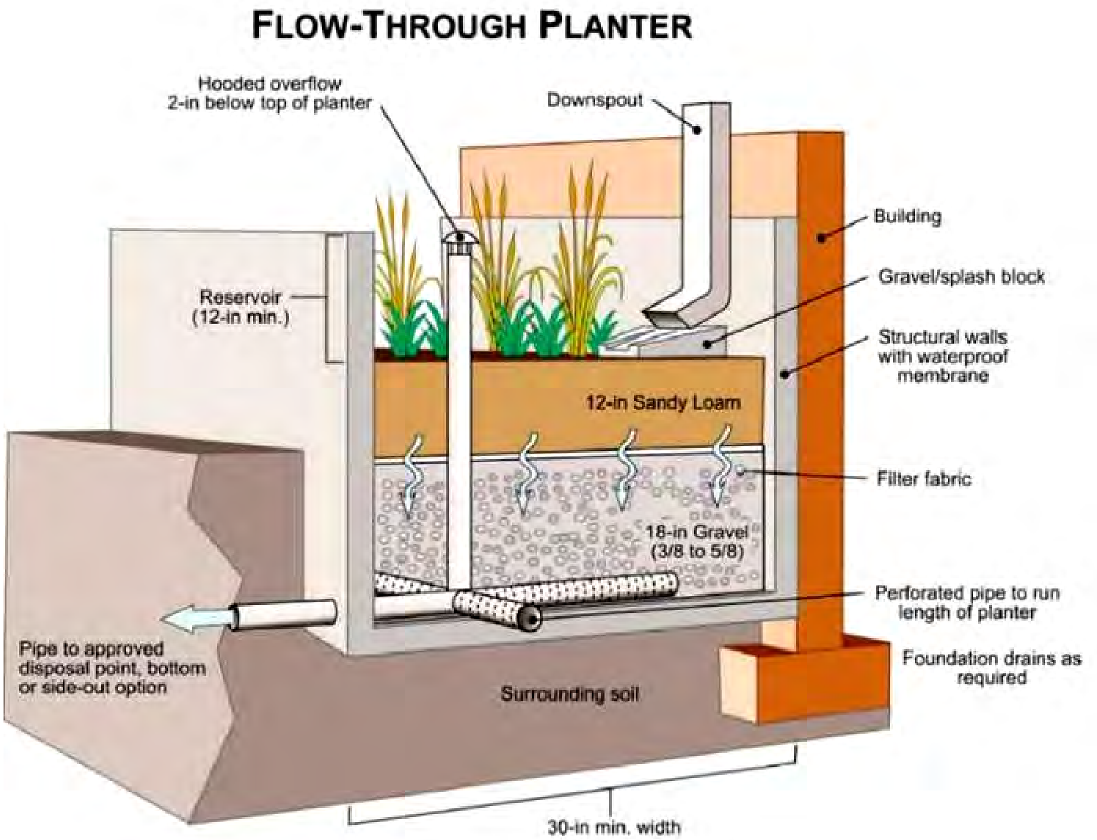

Figure 3-17: Schematic of a storm water planter that detains and treats roof runoff, and drains and overflows to the conventional storm drain system via an underdrain and overflow pipe system.
(Source: Portland BES)


Figure 3-18: Storm water planters installed next to office buildings.
(Source: Portland BES)

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3.1 SWALES AND BUFFER STRIPS

GENERAL DESCRIPTION

Swales and buffer strips are storm water treatment systems that rely upon vegetation and the subsoil matrix to filter pollutants from runoff. They can also provide infiltration and groundwater recharge. These systems reduce the velocity of urban runoff, can serve as part of the storm drain system, and can provide pretreatment for other structural controls and LID practices. Storm water treatment occurs though filtration and biological processes. Swales and buffer strips can be accessed by grade design, curb cuts, or they can replace curbs, gutters, and subsurface storm drain pipe systems. By designing the grade of impervious surfaces such as driveways and sidewalks to flow towards vegetated areas instead of towards streets, they can be accessed directly. The edges of driveways and sidewalks can also be designed to be 2 to 5 inches above the adjacent edge of swales and buffer strips.

Swales are shallow open channels. Also known as vegetated swales, biofiltration swales or grassy swales, they are commonly vegetated with grasses (Figure 3-19). Rock lined low flow channels and underdrain systems can be added where native soils have poor infiltration characteristics (Figure 3-20) and grades that are less than 0.5 percent. Low flow channels and underdrain systems can reduce the potential of extended ponding and mosquito breeding. Xeriscape swales (Figure 3-21) are planted with native vegetation or low water use plants interspersed among rock and have little to no water requirements once established. Storm water runoff is conveyed along the length of the low slope channel, which decreases the velocity, traps sediments, and reduces erosion. Storm water runoff is treated by filtering sediments and associated pollutants through the engineered subsoil and vegetation and by infiltration into the underlying soils. Pollutant removal and treatment efficiency improves as contact time and the amount of infiltration increases.

Figure 3-19. Grassy swale

Figure 3-20. Swale with rock lined low flow channel

Grassy and xeriscape swales are simple to design and install. They can serve as part of the storm drain system or can be used in place of curbs and gutters. These practices can also be used with other structural treatment controls and LID practices as part of a treatment train. They can be used to convey and treat runoff from parking lots, buildings, and roadways and can be applied in residential, commercial, industrial, and municipal land uses. Xeriscape swales are recommended wherever possible to assist with water conservation strategies. Grassy swales are appropriate in parks or private landscaped areas that are irrigated.

Figure 3-21. Xeriscape swale

Buffer strips are also known as vegetated buffer strips and filter strips. They are gently sloping and uniformly graded vegetated strips that provide storm water treatment to relatively small drainage areas. Buffer strips slow the velocity of runoff to promote filtration of sediments and pollutants and infiltration into underlying soils. They require sheet flow to function properly and often require a flow spreader to evenly distribute runoff across the width of the buffer. This may be a porous pavement strip or another type of structure. Grassed or vegetated buffers consist of uniformly graded, densely vegetated turf surfaces that can be interspersed with shrubs and trees to improve aesthetics and provide shade. In the semi arid climate of the Truckee Meadows, irrigation is typically required for grassy buffer strips to maintain a healthy and dense vegetative cover capable of withstanding the erosive forces of runoff from adjacent impervious areas.

Xeriscaped buffer strips use the same concept as vegetated buffer strips except they incorporate low to no water use plants and rock, allowing for water conservation. Buffer strips are typically located on the edge of landscaping areas and can provide pretreatment for other treatment controls. Xeriscape buffer strips (Figure 3-21) are ideal at the edge of landscaping features to reduce runoff and conserve water. Lawn areas adjacent to sidewalks, driveways and streets are typically hotter and drier and require more water than areas not adjacent to these impervious surfaces. By planting a xeriscape buffer between sidewalks, driveways, and streets and the lawn, water needs will be reduced. Less runoff will also occur as the xeriscape buffer strip captures and infiltrates the water leaving the lawn area. This can be particularly useful where lawn areas are located directly downwind of prevailing winds. In the Truckee Meadows, lawns located adjacent to the west side of streets are particularly prone to irrigation overspray and runoff into the street when prevailing winds blow to the east. In this case, up to 40 percent of the water that leaves sprinklers can be lost to overspray, runoff, and evaporation.

3.1 SWALES AND BUFFER STRIPS

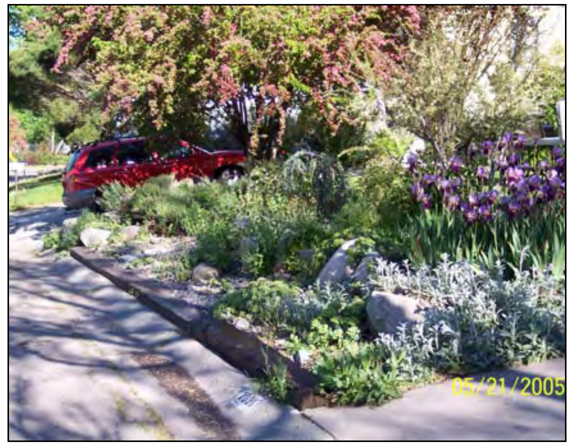

Figure 3-22. Xeriscape buffer strips between the lawn and sidewalk, and the lawn and the street.

DESIGN CONSIDERATIONS

Both Swales and Buffer Strips

- Fertilizers and soil amendments should be applied based on soil testing results and vegetation requirements.
- For plant considerations, consult a local nursery and refer to TMWA's *Landscaping in the Truckee Meadows* guidebook.
- For xeriscape swales and buffer strips, a permeable filter fabric should be applied to act as a weed barrier and to separate engineered soils from native soils.
- Care must be taken to avoid compaction of swales and buffer strips during construction.
- Swales and buffer strips are flow-based storm water treatment controls and must be sized to convey the water quality flow (WQ_F) determined using the method outlined in Section 3.2.1 of the *Truckee Meadows Structural Controls Design Manual*.

Swales

- When development is proposed on previously undeveloped land, the preferred location for swales is in natural channels. Studies have shown that recharge through natural ephemeral channels can be significant and these areas should be preserved to allow groundwater recharge.
- Flat curbs or curb cuts should be utilized to direct runoff into swales.
- Place cobbles at curb cuts to dissipate energy and reduce erosion potential.
- To provide adequate contact time for pollutant removal, generally the minimum length of the swale should be 100 feet.

- Swales should be established with a minimum longitudinal slope of 0.5 percent and a maximum longitudinal slope of 2.5 percent. Adjacent slopes should not exceed 5 percent.

- Trapezoidal or parabolic channels with flat graded bottoms are recommended.

- 1,200 ft^2 of swale surface area is required per acre of drainage area and the maximum drainage area for swales is 10 acres.

- The minimum bottom width of swales should be no less than 2 feet and the maximum bottom width should not exceed 10 ft.

- Effectiveness of pollutant removal can be improved in swales by installing check dams at regular intervals.

- An underdrain should be provided in type C and D soils to increase infiltration capacity in swales and to prevent the extended ponding of nuisance flows.

- Swales must not hold standing water for more than 7 days during the period from May through October, the local mosquito-breeding season.

- Swale designs must meet local ordinances and should be shown on site plans.

- For further design considerations see the *Truckee Meadows Structural Controls Design Manual* fact sheet TC-10 Vegetated Swales.

Buffer Strips

- Slopes should not be greater than 10 percent (2 to 4 percent is preferred).

- The maximum drainage area for buffer strips is 5 acres.

- Sheet flows must be maintained across buffer strips. To create sheet flows, install a level spreader at the top edge of the buffer strip along a contour. Porous pavement may also be used to create sheet flow conditions.

- The top of the buffer strip should be installed 2 to 5 inches lower than the impervious surface being drained.

- For further design considerations see the Truckee Meadows Structural Controls Design Manual fact sheet TC-11 Vegetated Buffer Strips.

LIMITATIONS

- Grassy swales and buffer strips typically require supplemental irrigation.

- The effectiveness of vegetated swales is decreased by compacted soils, frozen ground conditions, short grass heights, steep slopes, large storm events, high discharge rates, high velocities, and a short runoff contact time.

- These practices may not be appropriate for industrial sites or locations where spills may occur.

- Vegetated swales and buffer strips require dense vegetated cover to function properly.

- The infiltration rates of local soils can limit the application of swales.

- Buffer strips are not capable of treating storm water from large drainage areas.

- Mosquito breeding habitat may form if water does not drain or infiltrate in swales.

- Sheet flow is required for buffer strips. Channelization and erosion may occur if not achieved.

- Swales and buffer strips do not attenuate the volume and rate of runoff during large storm events.

MAINTENANCE CONSIDERATIONS

- Proper maintenance includes mowing, weed control, removal of debris, watering during the dry season, aeration if turf is used, and reseeding of bare areas.

- When mowing, grass should be maintained at a height of 2 to 4 inches.

- Inspect swales and buffer strips at least twice annually, preferably before and after winter, for damage to vegetation, erosion, sediment accumulation and ponded water standing longer than 7 days.

- Periodic litter and debris collection and removal will be necessary, especially if the swale or buffer strip is located adjacent to a main road or highway

- Sediments that accumulate along the upper edge of buffer strips and/or level spreaders should be collected and removed at least once a year.

- Vegetation must be replaced if it dies or is scoured.

- Vegetation must be removed and the facility re-graded and replanted if it consistently creates standing water for more than 7 days during the period from May through October.

- The top edge of swales and buffer strips planted with turf should initially be 2 to 5 inches lower than the impervious surface being drained. Over time, sediment will accumulate and the top edge of grass swales and buffer strips may rise above the adjacent impervious surface, causing ponding to occur. If ponded areas do not drain within 7 days, lay back the turf, remove several inches of soil and replace the turf.

3.1 SWALES AND BUFFER STRIPS

EXAMPLES

The Morton Arboretum in DuPage County, Illinois is a 1,700+ acre outdoor museum of woody plants adjacent to Meadow Lake and the East Branch of the DuPage River. When a new visitor center was proposed for the facility a “green” parking lot was constructed to accommodate the anticipated increase in visitation. The parking lot utilized biofiltration swales as parking lot medians to drain the parking lot. Also utilized were grassy filter strips, permeable pavement, created wetlands, vegetated channels, and vortex-type oil traps.

The biofiltration swales were designed along 9-foot wide medians in the parking lot with a barrier curb along the swales that incorporated 3-foot gaps to minimize the amount of concentrated flow into the swales. The curb cuts were spaced 3 stalls apart and located along parking lot stripes to avoid the potential for small vehicles or motorcycles from driving into the swales. Curb structures were specially graded with the gutter being pitched from the middle to slope at approximately 0.5 percent to the curb cut.

The swales were constructed to pond to a depth of 0.5 ft prior to overflowing to the conventional storm drain system. Side slopes were graded at a 3 H:1V slope, being approximately 1 foot below the edge of the pavement, and having a 3-foot bottom width. The soil consisted of a sandy loam mix with approximately 5 percent coarse organic matter.

After a year of use, the parking lot biofiltration swales appear to be functioning properly. The only concern is utilization by pedestrians through some of the curb cuts. It is believed that through proper plantings and the installation of stepping-stones this problem can be mitigated. Funding for this project was largely obtained through a grant from the USEPA (Kelsey and Sikich, 2005).

Photo: Sacramento, 2007

3.1 SWALES AND BUFFER STRIPS

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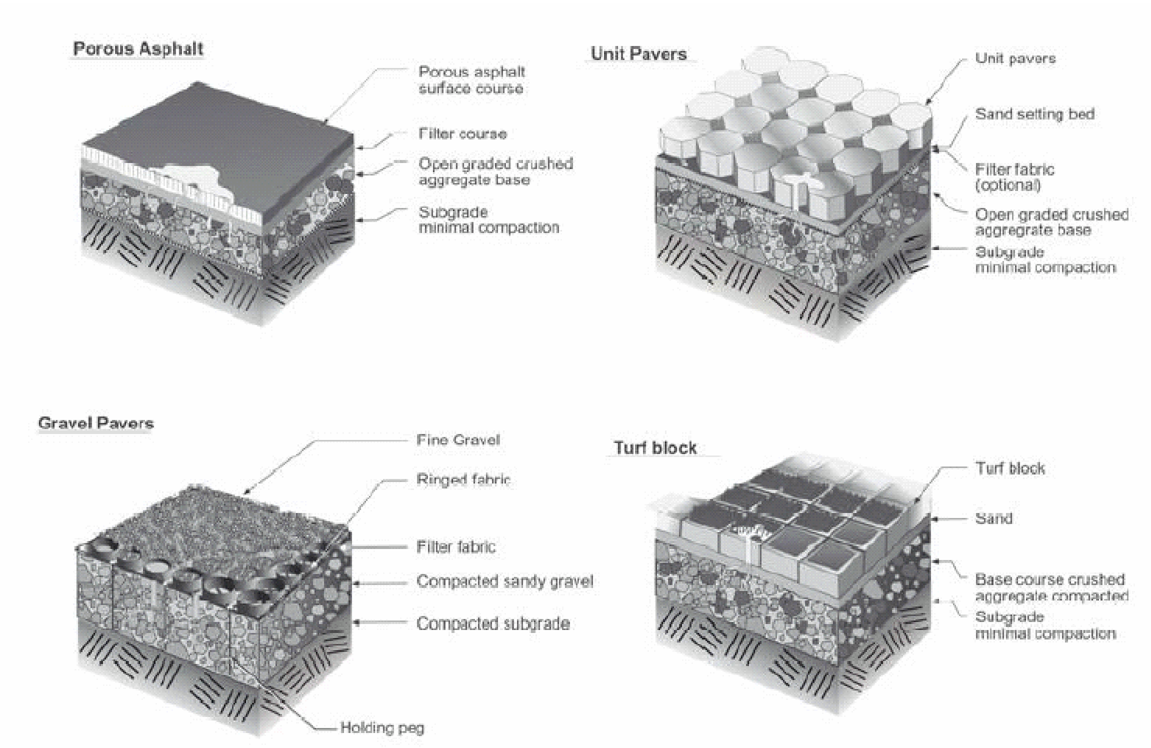
3.2 POROUS PAVING SYSTEMS

GENERAL DESCRIPTION

Porous paving systems allow infiltration of storm water while providing a stable load-bearing surface for walking and driving. These systems contain void spaces to provide infiltration of runoff into their underlying engineered porous materials and then into native soils. Generally, underlying engineered materials consist of clean sands or gravels separated from native soils by a synthetic filter fabric. Underlying engineered materials detain and filter pollutants prior to infiltration into underlying soils or discharge to a conventional storm drain system through an underdrain system. Porous paving systems can preserve natural drainage patterns, enhance groundwater recharge and soil moisture, and can help establish and maintain roadside vegetation. Although a good substitute for conventional concrete and asphalt, porous paving systems are typically not suitable for heavily trafficked applications. There are several different types of porous paving systems, which are referred to here as 'Porous Concrete and Asphalt', and 'Permeable Pavers'.



3.2 POROUS PAVING SYSTEMS

3.2.0 POROUS CONCRETE AND ASPHALT

GENERAL DESCRIPTION

Porous concrete and asphalt both make a continuous, smooth paving surface like their impervious counterparts. However, they have reduced or no fine material (sand and finer), and therefore contain void spaces that allow water to pass through to a permeable subbase layer. Porous materials such as clean gravels placed below the porous concrete or asphalt detain and filter pollutants prior to infiltration into the underlying soils or discharge to an underdrain and the conventional storm drain system.

Porous concrete and asphalt are ideal for light to medium duty applications such as residential access roads, residential street parking lanes, parking lot stalls in parking lots, overflow parking areas, utility access, sidewalks, bike paths, maintenance walkways/trails, residential driveways, stopping lanes on divided highways, and patios. Porous asphalt has, however, also been used in heavy applications such as airport runways and highways because its porosity creates a favorable driving surface in rainy weather (BASMAA, 1999).

Figure 3-14. Porous asphalt and standard asphalt in a parking lot (left). Porous concrete slab with water being poured over it (below).

Photo courtesy of Cahill Associates

Photo taken from NEMO UConn

Figure 3-23. Demonstration project at Lake Tahoe. Underlying clean gravels being installed (left) and water rapidly infiltrating into porous concrete (right).

3.2 POROUS PAVING SYSTEMS

Porous concrete and asphalt can also reduce icing hazards during winter freeze and thaw cycles as runoff will tend to infiltrate rather than freeze onto the surface of roadways, parking lots, driveways and sidewalks.

DESIGN CONSIDERATIONS

- Avoid installing in high traffic areas.
- Slopes should be flat or very gentle (less than 5 percent).
- Filter fabric should be placed on the bottom and sides of the subbase reservoir.
- Use a single size grading to provide open voids in the gravel subbase.
- Erosion and sediment introduction from surrounding areas must be strictly controlled during and after construction to prevent clogging of void spaces in base material and permeable surface.
- Install porous asphalt and concrete towards the end of construction activities to minimize sediment problems.
- During construction, do not allow construction or heavy vehicles to traverse excavated recharge beds or areas of completed porous pavement.
- During emplacement of porous concrete, boards should be used to separate individual pours and to produce uniform seams between adjacent pours.
- The surface of each pour should be finished as soon as possible as porous concrete can set up very rapidly in our local arid environment.
- Overall project cost savings can be realized where porous asphalt or concrete is installed in well draining soils (e.g. infiltration rates of 0.5 in/hr or greater), and conventional storm drain pipes and catch basins can be reduced.
- Refer to *Truckee Meadows Structural Controls Design Manual* fact sheet TC-62 for more detailed information.

LIMITATIONS

- Typically not to be applied on streets where speeds exceed 30 mph or streets that experience high-traffic loads.
- Not recommended for slopes over 5 percent.
- Not applicable where the seasonal high groundwater table is less than 3 feet below the bottom of the gravel subbase.

- Sand and salt applied to porous roadways, parking lots, and sidewalks in winter can clog void spaces and render permeability ineffective if not removed annually.
- Porous concrete may experience raveling if not properly installed.
- Porous asphalt and concrete may become clogged if not protected from nearby construction activities, areas of bare soil without landscaping, downslope of steep, erosion-prone areas, or when not maintained.
- Applications with underdrain systems are typically more expensive than conventional asphalt and concrete.
- Porous asphalt and concrete should be avoided in drainage areas with activities generate highly contaminated runoff.

MAINTENANCE CONSIDERATIONS

- The overall maintenance goal is to avoid clogging of the void spaces.
- Inspect porous asphalt and concrete several times during the first few storms to insure proper infiltration and drainage. After the first year, inspect at least once a year.
- Permeable pavements and materials should be cleaned with a vacuum-type street cleaner a minimum of twice a year (before and after the winter).
- Hand held pressure washers can be effective for cleaning the void spaces of small areas.
- Maintenance personnel must be instructed not to seal or pave with non-porous materials.

EXAMPLES

1. A porous concrete parking lot was installed at the site of the relocated Lake Mansion on Arlington and Court Streets in Reno. During installation of the porous concrete, delays occurred between pours and the concrete set up quickly in the hot and dry summer conditions. The contractor did not separate each pour by boards and the finished parking lot experienced raveling problems. Subsequently the surface of the porous concrete was covered with a seal coat layer to stabilize the surface. The seal coat effectively produced an impervious layer over the porous concrete such that the parking lot is no longer porous. However, an important lesson was learned and must be considered when installing porous concrete in the Truckee Meadows. During emplacement of porous concrete, boards should be used to separate individual pours and to produce uniform seams between adjacent pours. The surface of each pour should also be finished as soon as possible as porous concrete sets up rapidly due to the lack of air moisture in the local arid environment. The contractor is anxious to install another porous concrete parking lot in the Truckee Meadows and apply the lessons learned from the Lake Mansion site.

2. In Durham, New Hampshire, a porous asphalt pavement parking lot was constructed in October 2004 to test cold climate applications of porous asphalt for storm water treatment. Built and maintained by the University of New Hampshire Stormwater Center for research and demonstration purposes, the pavement is qualitatively monitored for signs of distress due to snowplows. Infiltration rates at three randomly selected locations in the porous asphalt pavement parking lot were conducted monthly from November 2004 through April 2005. Each location showed fairly consistent rates over time with the exception of one location within the parking lot having a lower infiltration rate than the other two locations. This could be due to over-compaction after placement of the porous asphalt, stressing a key variable to be considered when placing the asphalt surface being that compaction directly affects the rate of infiltration of the system. In respect to pavement stress, the porous asphalt survived the first winter intact and in good condition. The abrasion due to plowing has not compromised the integrity of the pavement and heavy sand and salt application has had no significant effect on surface infiltration rates. There was an area where uneven application of the sand-salt mixture did occur, and may have reduced infiltration where it was applied most heavily. (Briggs et al, 2005)

3. The oldest porous asphalt pavement surface in the United States can be found at the University of Delaware Visitors' Center. It was built in 1973 and is still permeable and structurally sound (BASMAA, 1999).

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3.2 Porous Paving Systems

3.2.1 Permeable Pavers

General Description

Permeable pavers are an alternative to conventional pavement and can create an opportunity for infiltration of storm water runoff and groundwater recharge. For areas that are not heavily trafficked, permeable pavers are also an alternative to conventional asphalt and concrete. Permeable pavers are modular systems with pervious openings that allow water to seep through. Runoff permeated through is either detained in an underlying gravel bed, infiltrated into the underlying soil, or both. Types of permeable pavers include open-celled unit pavers or modular blocks made of concrete or brick with pervious openings.

Open-celled unit pavers are pre-assembled, flexible plastic grid networks that utilize soil and turf grass or gravel backfill to fill the blocks and create a flat surface. Figure 3-24 demonstrates a type of open-celled unit paver known as a turf block paver. The grid systems have a solid support structure surrounding an open cell where the grass or gravel is placed. Some systems have hollow rings or honeycombs with a base, others have open cells without bases. The plastic grids are flexible, allowing for use on uneven surfaces. These systems work well in overflow parking areas, driveways and sidewalks. Open-celled unit pavers can also be made out of concrete.

Concrete block pavers (Figure 3-25), and brick pavers (Figure 3-26), are designed to set on sand and form an interlocking pavement surface. Modular block pavers are designed to bear heavy loads and are well suited for industrial and commercial parking lots, utility access, residential access roads, driveways, and walkways.

Figure 3-24. Plastic grid pavers (photo from ToolBase Services)

Figure 3-25. Concrete block pavers (photo taken from NEMO UConn)

Figure 3-26. Brick pavers (photo taken from NEMO Nevada)

3.2 Porous Paving Systems

Design Considerations

- Erosion and sediment introduction from surrounding areas must be strictly controlled during and after construction to prevent clogging of void spaces in base material and permeable surface.
- Runoff should not be directed from surrounding areas to the pavement surface. However, if infiltration rates and storage volumes allow, runoff can enter the system after pre-treatment through other controls (buffer strips, drainage swales, etc.) to remove sediments to prevent clogging of the system.
- Filter fabric should be placed on the bottom and sides of the subbase layer.
- Subbase layers should be capable of bearing an appropriate load without deforming.
- Permeable pavers should be the last element installed during construction or redevelopment.
- Use single size grading in subbase materials to provide open voids.
- During construction, do not allow construction or heavy vehicles to traverse excavated recharge beds or areas of completed porous pavement.
- Utilization of correct design specifications is essential for adequate infiltration, storage, and structural integrity of permeable paving systems.
- Contractors should be trained and have experience with installation of the product.
- Refer to *Truckee Meadows Structural Controls Design Manual* fact sheet TC-62 for more detailed information.

Limitations

- Due to the irregular surface area that can occur with permeable pavers, porous asphalt or concrete should be considered for disabled parking spaces and walkways.
- May result in uneven driving surfaces and may be problematic for high heeled shoes.
- If not installed correctly, snow removal equipment may damage blocks. The plow blade should be set slightly above the surface.
- Areas with high water tables, impermeable soil layers, or shallow depth to bedrock may not be suitable as infiltration areas with an open graded base.
- Not recommended in areas with high grease or oil loads, such as near restaurant waste disposal areas, gas stations and truck stops.

- Not recommended in areas where high sediment loads are deposited on the surface, such as downslope of steep, erosion-prone areas.
- Not recommended in areas where heavy sanding regularly occurs in the winter.
- Modular blocks are not recommended for slopes exceeding 10 percent.

MAINTENANCE CONSIDERATIONS

- Concrete pavers should not be washed to remove debris and sediment in the openings between pavers, rather sweeping with suction should be utilized.
- Joints between block pavers may require occasional weed suppression.
- Grassed open-celled unit pavers require the same maintenance as lawns.
- Pavers can be removed individually and replaced when utility work is needed.
- Top course aggregate can be removed or replaced in open-celled unit paving systems if they become clogged or contaminated.
- In open-celled unit pavers, grid segments should be replaced when three or more adjacent rings are broken or damaged.
- Replace aggregate material in grid systems as needed.
- Must not be sealed with non-porous materials.

EXAMPLES

The Morton Arboretum in DuPage County, Illinois is a 1700+ acre outdoor museum of woody plants adjacent to Meadow Lake and the East Branch of the DuPage River. When a new visitor center was proposed for the facility a “green” parking lot was constructed to accommodate the anticipated increase in visitation. Funding for this project was obtained through grant funding from the EPA. The parking lot utilized a concrete paving system, biofiltration swales, grassy filter strips, created wetlands, vegetated channels, and vortex-type oil traps.

A concrete paver system was utilized for the parking lot based on their durability and high strength to withstand heavy traffic loading. The decision was also based on consideration of cost estimation, factoring in initial cost, anticipated maintenance, and lifespan of the system. With an expected lifespan of 50 years, it was determined that in a cold climate such as where it was being applied, a concrete paver system was almost half the cost of an asphalt system at $45/sq yd when compared to $80/ sq yd when considering a total 50 year cost (totals in 2002 dollars).

The entire subbase for the parking lot was made up of a permeable uniformly graded, washed, granular base, which provides stormwater storage and opportunity for infiltration into underlying soils. Perforated storm sewers were utilized along the length of each biofiltration swale so that stormwater entering the storm sewer could have a chance to infiltrate back into the ground. A control structure was installed at the downstream end of the system to restrict flows and allow more time for water to infiltrate into the ground, which is removable in case the subbase becomes overly saturated.

The subgrade course is composed of an angular, crushed stone with no fines, ranging from approximately 1½ to 3 inches in size. The base course is composed of 6 inches of a uniformly graded, crushed aggregate approximately ¾ inches in size, with no fines. The setting bed is composed of a 1½ inch lift of 3/8 inch crushed aggregate with no fines. This material was also suitable to be used for the filler material in the holes created by the pavers. However, crushed granite was used for the filler instead because it most closely matched the paver color.

After a year of use the paving system is functioning properly with a 2-year study currently underway to determine the effects of this parking lot and the combination of the BMP's utilized. Funding for this project was largely obtained through grant funding from the EPA. (Kelsey and Sikich, 2005)

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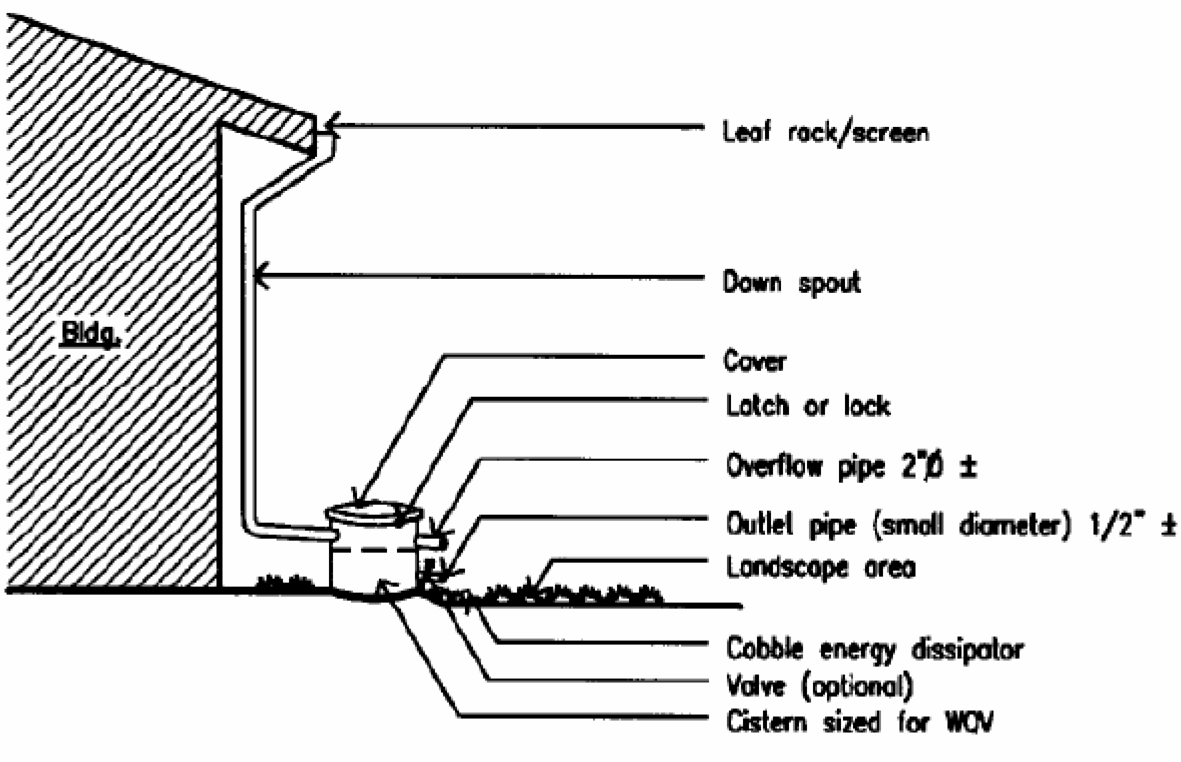
3.3 RAINWATER CATCHMENT SYSTEMS

General Description

Rainwater catchment systems (also known as rainwater harvesting) have been used for thousands of years in many parts of the world, particularly in arid areas where water is scarce. They are simple structures that are designed to collect and store storm water runoff from impervious surfaces such as roofs, paved terraces, and patios. Storm water from these impervious surfaces is conveyed through gutters and downspouts, and through a screening device to remove leaves and other debris before discharging to above or below ground storage tanks or cisterns. The water collected by these systems may be reused for non-potable water uses within a house or building, or for exterior landscape irrigation purposes. Uses can include water for toilets and irrigation at exterior hose bibs.

Rainwater catchment systems can reduce a sites water needs and provide storm water management benefits, including reducing rate, volume and pollutant loading of urban runoff from developed sites. Reducing the water used from the City water system can reduce a site's water bill. However, a water budget should be developed and rainwater catchment systems may be required to meet plumbing and health department codes prior to use.



Bay Area Stormwater Management Agencies Association, *Start at the Source* (1999)

Figure 3-27: Rainwater catchment system schematic.

3.3 RAINWATER CATCHMENT SYSTEMS

Applications and Advantages

Rainwater catchment systems can provide a storm water management solution where impervious surfaces are unavoidable and site constraints limit the use of other LID practices. Such situations may include highly urbanized areas (such as downtown centers) or dense housing developments without adequate space for storm water infiltration or detention or where soil and groundwater conditions do not permit infiltration. In addition to storm water management benefits, rainwater catchment systems can be utilized as a sustainable building approach to reduce a development's dependence on municipal water supplies.

Rainwater catchment systems can be designed to fit a wide range of site conditions. Storage tanks and cisterns should be sized according to the impervious surfaces feeding into the system utilizing the water quality volume (WQ_V) method outlined in the Structural Controls Design Manual. Additional storage capacity can also be provided to assist with site water needs. In addition to determining the required storage tank volume, a regular use for the non-potable water needs to be planned into the system such that there is an assurance that there will be available volume to capture the WQ_V from subsequent storm events (e.g. a consistent use such as toilet flushing and/or regular irrigation). Therefore, a water budget should be developed for each proposed rainwater catchment system to determine the minimum required storage volume (e.g. the WQ_V), dedicated water uses, and the schedule necessary to maintain a regular use. If a rainwater catchment system is proposed for storm water management, a water budget should be included as part of the development plans to be reviewed by City of County staff. Such calculations will help evaluate whether a rainwater catchment system is a feasible storm water management strategy for a particular site.

Figure 3-28: A rainwater catchment system on a residential home.
(Photo: Kennedy/Jenks Consultants)

Storm Water Management

<u>Flow and volume control</u>: In areas where on-site infiltration is not feasible, rainwater catchment systems can provide significant flow rate and volume reduction into the offsite conventional storm drain system and local receiving waters.

<u>Pollution reduction</u>: As a result of the significant reduction in off-site flows that can be achieved, a significant reduction in the discharge of pollutants associated with storm water can also be accomplished. This can be particularly significant where rainwater catchment systems are used to capture and reuse roof runoff from large industrial or commercial facilities or from elevated parking garages.

3.3 RAINWATER CATCHMENT SYSTEMS

Limitations

As discussed above Rainwater Catchment Systems have potential to serve as a storm water management technique and can reduce the rate, volume and pollutant loading of urban runoff. There are however, several management and maintenance factors for the owners of the Rainwater Catchment Systems. Such management responsibilities may become the City's burden to maintain or enforce. This should be considered when and if the City permits the use of these systems as a storm water management approach. Considerations include:

Regular use for harvested water volume: The storage capacity needs to be available to catch the next storm event's flow. For example, if the water in the storage tank is only used for landscape irrigation and the need for irrigation water during the rainy season is minimal, the tank may fill after the first few storms and the overflow during subsequent storms. Therefore, rainwater catchment systems that are only used for landscape irrigation may not be effective for storm water management during the rainy season. However, if a rainwater catchment system is plumbed to a structures toilets and urinals, the storage tanks and cisterns would be more likely to be emptied throughout the year and have available capacity for storm water management during the rainy season. Development of a water budget and careful review of the calculations by City staff should be conducted prior to permitting.

Mosquitoes: Water standing for more than 72 hours can provide mosquito breeding habitat. To prevent mosquitoes from breeding in rainwater catchment systems, the storage tanks and cisterns need to remain tightly sealed and screened. Mosquitoes can fit into holes as small at 1/16". Vector control will likely need to closely monitor these systems.

Siting: As discussed in the Siting Criteria section below, there are a number of considerations in the placement of a water tank on a site that may limit the viability of this technique.

Climate: Seasonal rainfall patterns of the Truckee Meadows area make water storage and reuse less practical than in some other climates.

Siting Criteria

If it is determined that Rainwater Catchment Systems may be an appropriate storm water management option, further criteria will determine where the system can be placed on the site. The tanks need to be placed on level pads in areas not vulnerable to settling, erosion or slope failure. Tanks should be located at least 10 feet from a building to avoid foundation damage in case the tank leaks (unless secondary containment and/or foundation waterproofing is provided). In addition to storing water, tanks can serve multiple functions such as shading, providing visual screens, and moderating hot and cold temperature extremes within a building. The higher on the site above-ground tanks are located, the more gravity-feed pressure will be available. Water can be distributed by gravity flow or by a booster pump via hoses, irrigation systems, channels, or perforated pipes. The interior space of the tanks will also need to be easily accessible for regular maintenance.

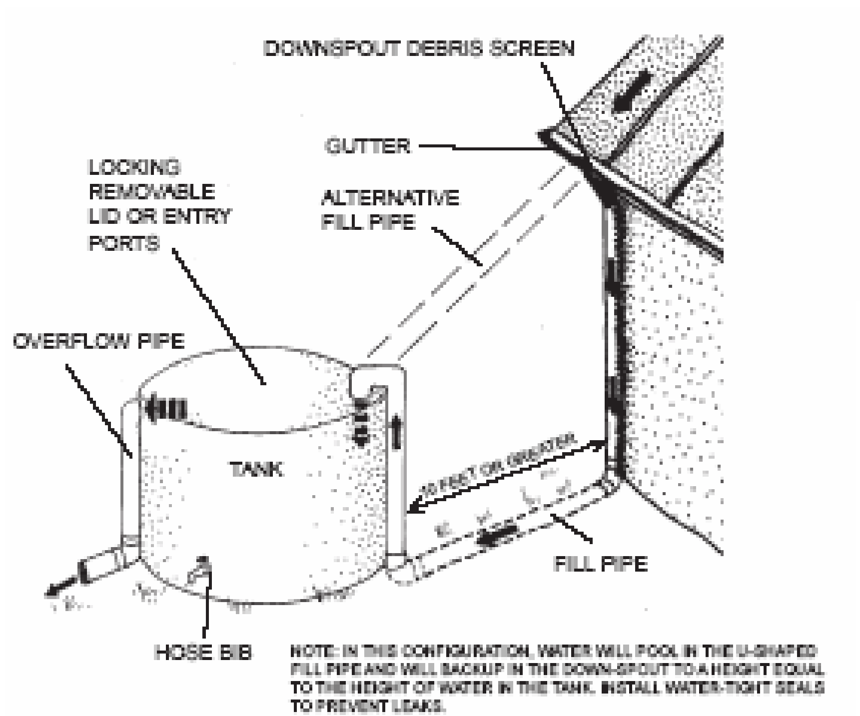
Design and Construction Criteria

The site, development program, and water use will inform the design of the system. The size of the storage tanks, the shape and placement of impervious surfaces, soils composition, slopes, and water use will direct the placement of the of the rainwater catchment system.

3.3 RAINWATER CATCHMENT SYSTEMS

Though rainwater catchment systems can be designed with various materials and configurations, components of a basic system should consist of the following:

- An impervious surface to collect runoff from (e.g. roofs or elevated paved surfaces);
- Devices to collect and convey water from the impervious surfaces (e.g. gutters, and downspouts);
- A debris screening device (also known as a “First Flush” or “Foul Flush” filter);
- Pipes to carry the water to the tank 10’ from the building’s foundation (e.g. fill pipe);
- Tank(s) or cistern(s) to contain the water quality volume (WQ_V) as outlined in the Structural Controls Design Manual plus any additional water desired for site needs (e.g. toilets and landscape irrigation);
- A locking (recommended), removable lid or entry port;
- An overflow pipe;
- An exit point to distribute the harvested rainwater (e.g. hose bib); and,
- A booster pump (if gravity alone cannot deliver the water to its destination).



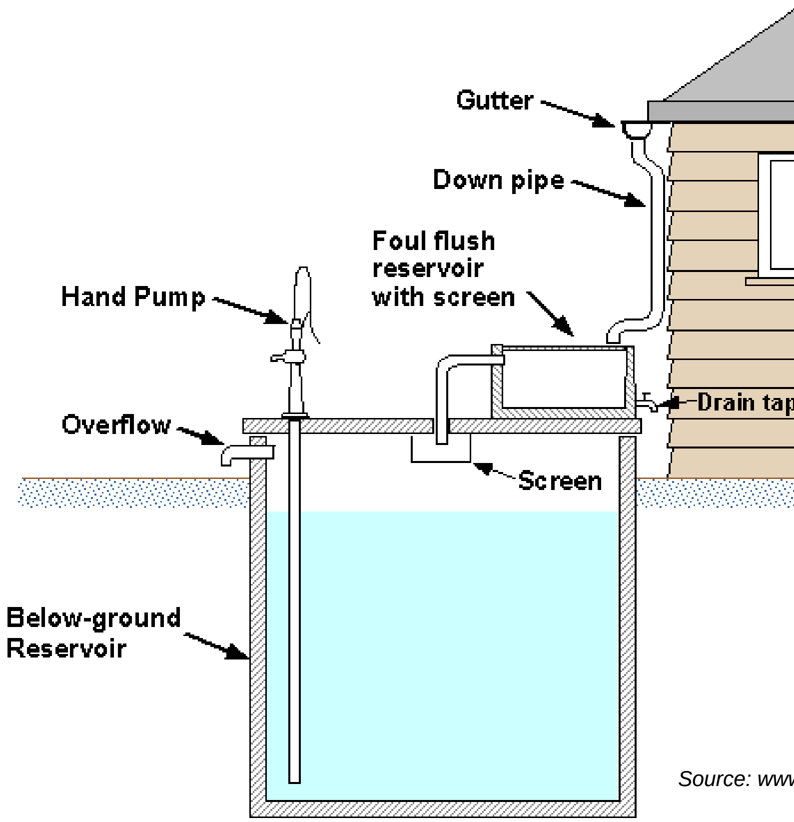
Source: City of Tucson, AZ

Figure 3-29: Rainwater catchment system schematic with an above-ground storage tank.

The following parameters should be considered in the design and construction of any Rainwater Catchment System:

3.3 Rainwater Catchment Systems

- Prefabricated tanks of plastic, metal, or concrete that can be purchased and installed professionally.
- Tanks should be securely capped with opaque material to prevent evaporation, mosquito breeding, and algae growth. Lock all caps and entry ports for safety.
- The interior of the storage tank(s) should be accessible for periodic inspection and maintenance.
- Downspouts, inlets and outlets must be screened to keep mosquitoes, animals and debris out of the tank (e.g. with a “First Flush” filter, which are commercially available).
- Position outlet pipes several inches above the bottom of the tank to allow sediment to settle in the bottom.
- All tanks need an overflow pipe of equal or greater capacity than the fill pipe.
- Overflow pipes must be able to operate passively (i.e. not be dependent on a pump).



Source: www.worlhungeryear.org

Figure 3-30: Rainwater catchment system schematic with a below-ground storage tank or cistern.

- Below-ground tanks save land area, but typically require substantially more construction and booster pumps to supply the water to its intended uses.
- Route overflow water into a bioretention basin, adjacent tank, French drain, or other useful location away from buildings.

- Water in aboveground tanks should be delivered by gravity flow alone to low-pressure uses nearby whenever possible.
- A booster pump can be added to increase water pressure. Tank water should be filtered before it enters supply pipes, particularly to keep debris from plugging the irrigation system and prior to entering interior building pipes that supply water to toilets.
- Tanks can be constructed individually or in a series with the overflow from one tank filling the adjoining tank, or connected at the bottom to maintain the same water level in all tanks.
- Avoid placing vegetation with intrusive roots near or on top of below-ground tanks.

Inspection and Maintenance

Regular maintenance is critical to any dependable Rainwater Catchment System. The following inspection and maintenance practices are recommended.

- Clean out gutters, inflow and outflow pipes of leaves and debris as needed.
- Make sure gutters and downspouts are free of debris prior to the rainy season. The "first flush", or the runoff created by the first storm event after a long dry spell, will need to be carefully monitored to ensure that the system is working properly.
- Inspect water tanks periodically and any remove debris and sediment that may interfere with the proper function of the system.
- Screen inlet and outlet pipes to keep the system closed to mosquitoes. No opening shall be greater the 1/16" on systems where water will be retained for more than 72 hours.
- Cap and lock tanks for safety. Caps should have access ports for interior inspection and maintenance.

Proper monitoring and maintenance is important for any Rainwater Catchment System to work appropriately and efficiently. Each configuration will perform differently. After the system has stabilized, inspection and maintenance might be needed several times a year and particularly prior to the rainy season and after heavy rainfall events.

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3.4 GREEN ROOFS

General Description

A Green Roof is a vegetated roofing system that typically consists of a number of layers: a waterproofing membrane, a drainage system, root protection, growing media (soil) and vegetation. Green Roofs provide numerous environmental benefits and offer a valuable tool for integrated storm water management.

Photo: Jonathan Feldman

Figure 3-31: Green roof on Carmel Valley, CA residence.

Photo: www.infrastructures.com

Figure 3-32: Green roof on a commercial office building.

Green Roofs have been a popular sustainable building practice to improve urban environments in Europe since the 1970s. However, it is still an immature market and evolving practice in the United States[1]. Many terms may be used to describe Green Roof systems. The list below describes some of the related terms:

- *Ecoroof* is used to describe lightweight vegetated roof systems, implemented as a sustainable building technique that limits impacts on the natural environment.
- *Roof garden* is a term generally describes a useable garden space that includes some vegetation. This type of roof system typically requires extra structural support and consequently, costs more to build.
- *Vegetated roof* is a general term that may describe a number of Green Roof objectives.
- *Living roof* is a general term that may describe a number of Green Roof objectives.

[1] Rozenzweig, C. etal., and Green Roofs for Healthy Cities

3.4 GREEN ROOFS

Structurally, there are two types of Green Roofs: intensive and extensive. Extensive Green Roofs are lightweight vegetated roofs consisting of 4-8 inches of growth media (or soil), planted with hardy, drought-tolerant species to minimize additional irrigation, maintenance, cost and weight[2]. They typically require supplemental irrigation to support growth during extended dry periods.

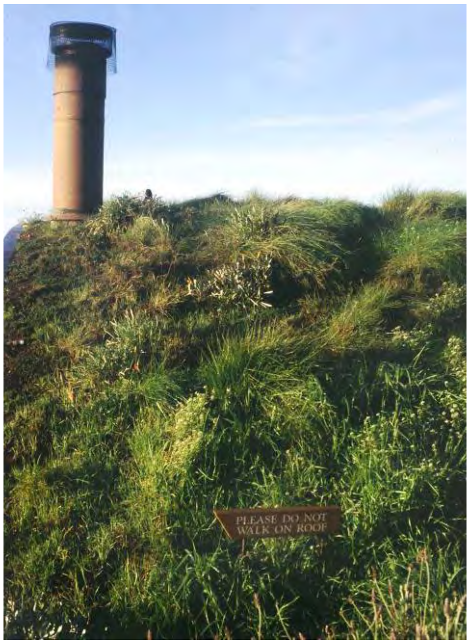

Photo: Rana Creek

Figure 3-33: Extensive green roof Big Sur, California.

Photo: Rana Creek

Figure 3-34: Extensive green roof at Post Ranch Inn, Big Sur, CA.

Alternatively, *intensive* Green Roofs can be designed to support lawns, trees, and create a useable outdoor garden space; often referred to as *roof gardens*. While these amenities do not preclude environmental benefits of Green Roofs, they do require extra structural support, cost, and have functional goals in addition to sustainable building objectives. They also typically require supplemental irrigation systems.

Photo: Rana Creek

Photo: Rana Creek

Figure 3-35: Intensive Green Roof on a parking structure at Stanford University, Palo Alto, California.

[2] Rozenzweig, C. etal. and City of Portland, Bureau of Environmental Services

3.4 Green Roofs

Storm water management

As a storm water management strategy, Green Roofs can help meet the following Low Impact Development (LID) objectives:

- Absorbs rainfall
- Reduces urban runoff at its source
- Increases evapotranspiration
- Reduces heat island effect

Green Roofs provide small-scale decentralized controls that collect, absorb, and increase the evopotranspiration rates of rainfall. Additionally, Green Roofs are effective in reducing the heat island effect of urbanized areas containing large impervious surfaces. By reducing the temperatures of the runoff, the thermal impacts of urban runoff on local waterways are reduced.

Benefits

Green Roofs provide numerous environmental, economic and social benefits listed below.

- **Absorbs rainfall at the source.** 10-100% of roof runoff is absorbed and utilized by the vegetation[3]. Peak storm water flow rates are also reduced.
- **Improves building insulation**. This reduces heating and cooling costs and energy consumption.[4]
- **Reduces heat island effect** and the associated effects on waterway temperatures.
- **Increases wildlife habitat** for birds and insects that is often scarce in urban areas.
- **Absorbs noise pollution** through soils, plants, and trapped layers of air.
- **Reduces glare** that affects adjacent buildings and habitat.
- **Increases life-span of roof** by protecting the roof's structural elements from UV rays, wind and temperature fluctuations. Green Roofs typically last twice as long as conventional roofs.[5]
- **Improves air quality** by reducing air temperatures, filtering smog, binding dust particles, and converting carbon dioxide to oxygen through photosynthesis.
- **Provides an attractive roof.** In urbanized areas, Green Roofs integrate living systems into the built environment. In less urbanized areas, Green Roofs can help blend a structure into the surrounding landscape.

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[3] City of Portland, Bureau of Environmental Services. Note: estimates vary depending on the climate, depth of growing media, and plant materials.

[4] Rozenzweig, C. etal.

[5] Green Roofs for Healthy Cities, City of Portland, Bureau of Environmental Services, and Rosenzweig, C. et al.

3.4 GREEN ROOFS

Siting Criteria

Regional Criteria:

As a storm water management strategy, Green Roofs are best utilized in highly urbanized areas where there is little pervious ground surface to infiltrate and manage storm water or on buildings with significant roof areas such as industrial facilities, warehouses, shopping centers, and office buildings. Though environmental benefits still pertain in less urbanized areas, the initial cost of Green Roof implementation may preclude their use as a storm water management strategy in these areas because more cost effective solutions that utilize open spaces or landscaped areas may be available. Green Roofs can also be utilized to blend structures into the scenic landscapes and protect native plant species.

The arid climate of the Truckee Meadows is amenable to succulents, grasses, and native perennials that are recommended for Green Roofs. Short bursts of supplemental irrigation may be necessary to maintain a green appearance and for fire protection during the dry season. The roofs of large warehouses provide potential locations for green roofs that can substantially reduce runoff and associated conventional storm drain infrastructure.

Photo: Jonathan Feldman

Figure 3-36: Residential green roof, Carmel Valley, CA.

Photo: Rana Creek

Figure 3-37: Green roof at GAP Corporate Campus, San Bruno, CA.

Limitations

- **Initial costs** can be prohibitive, especially for re-roofing a standard roof. However, it should be noted that extensive Green Roofs can be competitive on a life cycle basis.
- **Specific maintenance**, such as irrigation and cleaning out drainage features will need to be factored into the long-term building care.
- **Untraditional** design and installation may stall the permitting process. Green Roof systems are still an evolving market and practice that needs perfecting in North America.
- **Immature market and government policies**. Not yet widely understood, regional and local governments may not yet be providing economic or policy incentives to implement Green Roofs.

3.4 GREEN ROOFS

Figure 3-38: Comparison of green vs. conventional roofing costs.

(Source: City of Portland, OR)

	Ecoroof (cost per square foot)	Conventional Roof (cost per square foot)
New construction (including structural support)	$10 to $15	$3 to $9
Re-roofing	$15 to $25	$5 to $20

Source: Bureau of Environmental Services estimates based on City of Portland demonstration projects, and information obtained from roof contractors.

As shown in the comparison of roofing costs above, it is important to note that there is a wide range of costs depending on many factors. Since Green Roofs typically last twice as long as conventional roofs, the life cycle costs are competitive with conventional roofs.

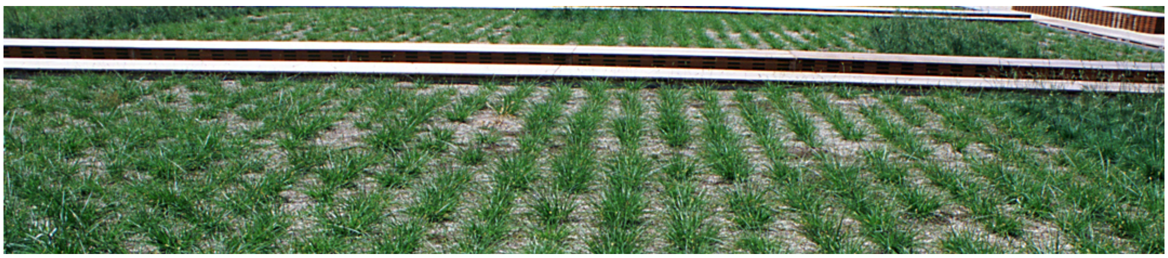

Photo: Rana Creek

PROGRESSIVE POLICIES AND INCENTIVES

Numerous economic benefits can help to offset initial costs of Green Roofs including: reduced energy costs, extended roof life, increased property values. Some jurisdictions are promoting their implementation through various incentive programs such as:

- Lowered storm water utility fees
- Increased floor to area ratios and/or density bonuses
- Faster permitting for new projects
- Energy tax credits
- Grants and subsidies for Green Roofs and energy efficient building
- LEED credits from the U.S. Green Building Council

Design and Construction

Green Roofs can be placed on flat or pitched roof structures at slopes up to 40 percent (or 5 in 12 pitch).[6] Green Roofs can be incorporated into new construction or to re-roof existing buildings. Though several site factors will need to be considered, such as the aspect of the roof, the microclimate of the site, prevailing winds and the building's functions – most factors can be accommodated into a successful Green Roof design.

Extensive Green Roof systems are composed of several layers. The roof systems may be modular interlocking components or each layer may be installed separately. Either way an

[6] City of Portland, Bureau of Environmental Services.

extensive Green Roof is constructed with the following basic layers (starting at the bottom): structural support, a waterproof roofing membrane (including flashing), a root barrier, drainage, a filter fabric (for fine soils), growing medium (soil) and plant materials and mulch. Other elements shown in the diagram below may be optional or required depending upon the conditions of the roof design.

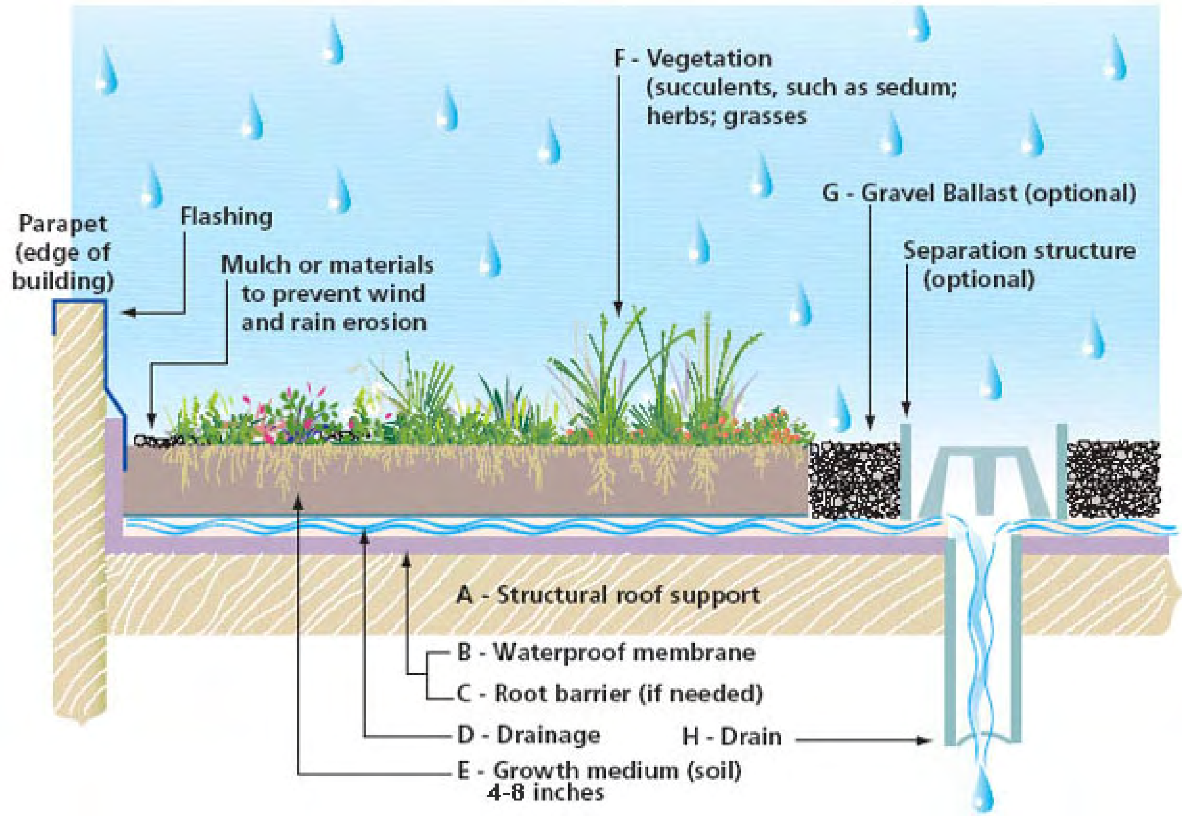

Figure 3-39: Green roof construction detail schematic.

Generally, a building's structure must be able to support an additional 10-25 pounds per square foot of saturated weight, depending on the growth media and vegetation used. For New construction, the load requirement of the Green Roof can be addressed as part of the building's design process. Additional structural support may be necessary for a re-roofing project; however, many existing buildings are structurally sound enough to accommodate a Green Roof.[7]

Green Roofs can be designed by architects, landscape architects, and building contractors. Since Green Roof systems include materials not found on convention roofs, it is recommended that qualified roofing contractor with Green Roof experience is chosen to install the design.[8]

Green Roofs may require maintenance beyond standard roof care, though such care is likely similar in cost. Long term management should be factored into appropriate siting of Green Roofs.

[7] City of Portland, Bureau of Environmental Services.
[8] Green Roofs for Healthy Cities

3.4 Green Roofs

Inspection and Maintenance

- Upon installation, the Green Roof system should be inspected monthly for the first year and after each large storm event for erosion, plant survival, proper drainage and water proofing.
- Inspections can be reduced to a quarterly schedule once the Green Roof system has proven to work properly and vegetation is established.
- If necessary, irrigate in short bursts only (3-5 minutes) to prevent runoff. Irrigation frequencies should be established by the designer using an automated system.
- Clean out drain inlets as needed.
- Weeding and mulching may be necessary during the establishment period, depending on the planting design.
- Replace or fill in vegetation as needed.
- Inspect soil levels semi-annually to ensure plant survival and rainfall absorption.
- If the vegetation used is flammable during the dry season, it should be mowed or watered as needed to prevent fire.

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3.5 LID SITE DESIGN

GENERAL DESCRIPTION

LID site designs use planning and design techniques to minimize the quantity and improve the quality of storm water from new development and redevelopment. LID site designs function to maintain a site's essential pre-developed hydrologic functions. Site techniques involve reducing impervious surfaces, directly disconnecting impervious areas from storm drains, maximizing opportunities for on-lot infiltration and conveyance through vegetated and landscaped features, minimizing disturbance from development, maximizing open space, protecting sensitive natural features and processes, and linking greenways, parks, wilderness, and conservation land.

Cluster and open space development are LID site design strategies that concentrate development to specific areas of a site, leaving portions of the development in open space. These designs include strategies such as smaller lot sizes, minimized setbacks and frontages, alternative street layouts to reduce road networks (see section 3.5.1 'LID Street and Road Design'), alternative driveway designs (see section 3.5.2 'LID Driveway Design'), and alternative sidewalk designs (see section 3.5.3 'LID Sidewalk Design'). Often, a community's zoning regulations may need to be revised to meet these goals. When choosing the development envelope for a site, site features such as riparian areas, woodland conservation areas, steep slopes, and highly erosive or permeable soils must be protected.

Figure 3-40. Comparison of a LID site plan to a conventional site plan on the same site.
(Images courtesy of **Puget Sound Action Team**)

Conventional Site Plan

LID Site Plan Utilizing Open Space and Cluster Development

3.5 LID SITE DESIGN

DESIGN CONSIDERATIONS

- Designate protected areas within the site to determine the development envelope that minimizes environmental impact.
- Concentrate development to specific areas of a site.
- Reduce lot sizes, front and side yard setbacks and lot frontage requirements.
- Utilize alternate street layouts and reduce road widths (see section 3.5.1 'LID Street and Road Design').
- Reduce cross streets and lengthen street blocks.
- Promote alternate forms of transportation by creating direct connections for pedestrian and bicycle access to open space and other streets through mid-block paths.
- Reduce driveway width and consider alternate designs (see section 3.5.2 'LID Driveway Design').
- Install measures for on-lot storm water infiltration, detention, and conveyance.

LIMITATIONS

- Existing zoning regulations and ordinances may limit application of this LID technique.

MAINTENANCE CONSIDERATIONS

- There are no additional maintenance issues associated with this LID technique.

EXAMPLES

In northern Fredrick County, Maryland a half-acre plot residential development called Pembroke used Low Impact Development site design strategies to address storm water management within the subdivision. By utilizing LID strategies and preserving two-and-a-half acres of undisturbed open space and wetlands to aid in storm water runoff control, two storm water ponds were eliminated from the site plan, saving the developer $200,000 in infrastructure costs. LID site foot-printing techniques allowed for preservation of 50 percent of the site in undisturbed wooded condition. Two additional lots were also gained from LID site design increasing the site yield from 68 to 70 on the 43-acre site. Replacing curbs and gutters with vegetated swales and reducing road width from 36 to 30 feet reduced impervious cover. Paving cost was lowered by 17 percent with a $60,000 saving in utilizing swales. (NRDC, 2001)

3.5 LID SITE DESIGN

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3.5 LID SITE DESIGN

3.5.0 LID PARKING LOT DESIGN

GENERAL DESCRIPTION

Parking lots contribute a sizeable area of impervious coverage to a community, and are significant sources of storm water runoff and the discharge of associated pollutants to the storm drain system and local surface waters. Several strategies can be implemented to mitigate this impact, including reducing impervious surfaces using permeable paving alternatives in overflow parking areas and landscaped detention (bioretention) basins installed in parking lot islands and perimeter landscaping.

Managing Runoff

Storm water management in parking lots can mimic natural hydrologic functions by installing design features that capture, treat, and infiltrate storm water runoff rather than conveying it directly into the storm drain system. Management options include:

- Landscaped detention areas (Figure 3-41) can be installed within and/or at the perimeter of parking lots to capture and infiltrate runoff (see sections 3.0 'Bioretention', 3.1 and 'Swales and Buffer Strips').

- Parking groves, which include permeable landscaped areas designed with grades several inches below the impervious parking surface can delineated by flat concrete curbs, shrubs, trees and bollards (Figure 3-42).

Figure 3-41. Parking lot bioretention

Figure 3-42. Parking grove made of a permeable paving surface (photo from ToolBase Services)

- Landscaped detention areas in parking lots can also reduce the icing problems typically associated with conventional mounded parking lot islands. Melting snow stockpiled on landscaped detention areas will tend to infiltrate into the basin, instead of draining onto the adjacent paved surface and refreezing at night.

- Porous surfaces can be installed in down gradient parking stalls and in overflow parking areas. Permeable materials that can be utilized include permeable pavers, porous asphalt, and porous concrete (see section 3.2 'Porous Paving Systems'). In some circumstances, gravel or wood chips can also be used.

- Storm water runoff from the top floor of parking garages can be drained to planter boxes located at the perimeter of the parking lot or at street level.

Reducing Impervious Surfaces

Research has shown that zoning regulations typically require more parking spaces than are needed. Parking lot size is usually based on peak demand rather than average usage. Parking codes should be reviewed and revised to reduce parking minimums. Parking codes should also be revised to allow shared parking for businesses with different hours of peak demand. Bus and shuttle services can be provided between commercial centers that only experience peak demands during holidays and parking areas such as government facilities and schools that are typically vacant over holidays. Other strategies that can also be implemented to reduce the total parking area include compact parking spaces, a reduction in stall dimensions, and determining the most space-efficient design for parking spaces (e.g. angled or perpendicular). Consideration should be given to design options such as underground parking or multi-storied garages. As noted above, vegetation and landscaping can be designed to intercept rainfall and capture storm water. Including trees in parking lot landscaping should also be considered. In addition to reducing impervious coverage, trees reduce the urban heat island effect of parking lots by shading heat-adsorbing surfaces.

DESIGN CONSIDERATIONS

- Revise parking ratio requirements.

- Utilize minimum stall dimensions and compact parking spaces. In larger commercial lots, 30 percent compact parking spaces is suggested.

- Use porous concrete, porous asphalt or permeable pavers in overflow parking areas or down gradient parking stalls (e.g. at areas located at low points in the parking lot).

- Utilize the most space-efficient design for parking stalls.

- Utilize vegetation and landscaping for capture and infiltration of rainfall and storm water runoff, for impervious surface reduction, and for shading.

- Utilize flat curbs or curb cuts (Figure 3-43) to direct runoff into landscaped areas.

3.5 LID SITE DESIGN

Figure 3-43. Curb cuts direct water into this parking lot bioretention system.

LIMITATIONS

- Parking requirements and codes.

MAINTENANCE CONSIDERATIONS

- Regular maintenance of landscaped areas is required.
- Irrigation of landscaped areas may be required.
- To avoid excessive accumulation of sediments, snow should not be regularly stockpiled in landscaped detention areas.

EXAMPLES

1. Based on construction cost estimates provided by the City of Reno, storm drainage systems for parking lots with landscape detention basins installed in well draining soils (see section 3.0 'Bioretention') would be expected to cost approximately 50% less than conventional storm drainage systems. Landscape detention basins installed in well draining soils typically do not include underdrain systems and only a limited amount of conventional storm drain infrastructure. Conventional storm drain infrastructure, such as catch basins and underground concrete pipe, are often one of the most expensive items in conventional parking lot construction. When landscape detention basins are installed in poorly draining soils, such as soils with a high silt or clay content, LID parking lot storm drainage system costs are comparable to conventional parking lot storm drainage system costs. However, conventional parking lot storm drainage systems increase the rate and volume of storm water runoff, and the associated pollutant loads to receiving waters. Whereas LID parking lot storm drainage systems reduce the storm water runoff and pollutant loads produced by the impervious surfaces of parking lots.

2. The Morton Arboretum in DuPage County, Illinois is a 1700+ acre outdoor museum of woody plants adjacent to Meadow Lake and the East Branch of the DuPage River.

When a new visitor center was proposed for the facility a "green" parking lot was constructed to accommodate the anticipated increase in visitation.

A concrete paver system was utilized for the parking lot based on their durability and high strength to withstand heavy traffic loading. Biofiltration swales were designed along 9-foot medians in the parking lot to capture and infiltrate runoff from the parking lot. Perforated storm sewers were utilized along the length of each biofiltration swale so that run-off entering the storm sewer could have a chance to infiltrate back into the ground. A control structure was installed at the downstream end of the system to restrict flows and allow more time for water to infiltrate into the ground, which is removable in case the sub-base becomes overly saturated. Also utilized were grassy filter strips, created wetlands, vegetated channels, and vortex-type oil traps.

After a year of use the paving system is functioning properly with a 2-year study currently underway to determine the effects of this parking lot and the combination of the BMP's utilized. Funding for this project was largely obtained through grant funding from the EPA. (Kelsey and Sikich, 2005)

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3.5 LID SITE DESIGN

3.5.1 LID Street and Road Design

GENERAL DESCRIPTION

Streets and roads include a significant portion of impervious coverage in a community and are one of the largest contributors of storm water flows and pollutant loads. LID street and road design is a strategy to curb this impact by reducing impervious coverage and maximizing storm water infiltration and pollutant uptake.

Elements of LID Street and Road Design:

- Road layout – consider alternatives that reduce impervious coverage, reducing the length of the road network by exploring alternative street layouts. Clustering homes and narrowing lot frontages can reduce road length by reducing the overall development area. Another approach is to lengthen street blocks and reduce cross streets, providing pedestrian and bicycle paths mid-block to increase access.

- Street width – determine based on a function of land use, density, road type, average daily traffic, traffic speeds, street layout, lot characteristics and parking, drainage and emergency access needs.

- Cul-de-sac design – cul-de-sacs create large areas of impervious coverage in neighborhoods. Alternatives to the traditional cul-de-sac that can reduce impervious coverage include landscaped center islands with bioretention (shown in Figure 3-23), reduction of the radius to 30 feet, a T-shaped hammerhead design, or a loop road network.

Figure 3-44. Landscaped cul-de-sac

- Right-of-way – should reflect the minimum required to accommodate the travel lane, parking, sidewalk, and vegetation, if present.

- Permeable materials – use in alleys and on-street parking.

- Increased access – create paths to open space and other streets for pedestrians and bicyclists in subdivisions where alternative street layouts such as loop networks and cul-de-sacs are utilized.

- Traffic calming features – traffic circles, chicanes, chokers, speed tables, center islands, and speed humps offer the opportunity for storm water management through the use of bioretention areas or infiltration within these areas while providing pedestrian safety.

- Drainage options:

<u>Maximize drainage</u> – preserve natural drainage patterns and avoid locating streets in low areas or highly permeable soils.

<u>Uncurbed roads</u> – where feasible, build uncurbed roads using vegetated swales as an alternative (see example on Figure 3-44).

<u>Urban curb/swale system</u> – runoff runs along a curb and enters a surface swale via a curb cut, instead of entering a catch basin to the storm drain system.

<u>Dual drainage system</u> – a pair of catch basins with the first sized to capture the water quality volume into a swale while the second collects the overflow into a storm drain.

<u>Concave medians</u> – median is depressed below the adjacent pavement and designed to receive runoff by curb inlets or sheet flow. Can be designed as a landscaped swale or a biofilter.

Figure 3-45. An uncurbed road utilizing a vegetated swale

Benefits of LID Street Designs:

- Storm water runoff is reduced.

- Narrower streets slow traffic and increase pedestrian, bicycle and driver safety.

- Less runoff generated from decreased impervious surfaces creates a reduction in storm water runoff, which may result in a decrease in expenses in storm water management structures and treatment.

- Paving costs of street network are reduced.

3.5 LID SITE DESIGN

DESIGN CONSIDERATIONS

- Reduce the length of residential streets by reviewing minimum lot widths and exploring alternative street layouts.
- When siting streets, consider natural drainage patterns and soil permeability.
- Consider access for large vehicles, equipment, and emergency vehicles when designing alternative street layouts and widths.
- Impervious cover created by each cul-de-sac turnaround option is presented below. (Schueler, 1995)

Turnaround Option	Impervious Area (square feet)
40-foot radius	5,024
40-foot radius with island	4,397
30-foot radius	2,826
30-foot radius with island	2,512
Hammerhead	1,250

LIMITATIONS

- Local zoning standards may require wide streets, sidewalks on one or both sides of streets, and curbed roads.
- Arterial, collector and other street types with greater traffic volumes are not candidates for narrower streets.
- Street width and turnaround design need to accommodate snowplows and other large vehicles and equipment.

MAINTENANCE CONSIDERATIONS

- Narrower streets should require less maintenance than wider streets as they present less surface area to maintain and repair.
- Landscaped and bioretention cul-de-sacs and traffic calming areas will require routine maintenance associated with these areas.

EXAMPLES

In Seattle, WA, a pilot project, Street Edge Alternatives Project (SEA Streets), attempts to mimic pre-developmental hydrologic conditions by reducing impervious surfaces 11 percent less than a traditional street, incorporating LID principles such as reducing on-street parking, narrowing street widths, reducing sidewalks, eliminating curbs and gutters by providing surface detention in swales, and adding 100 evergreen trees and 1100 shrubs. One of the most prominent features of the project is the 14-foot wide curvilinear streets, which is wide enough for two standard size cars to pass each other slowly. The edge of the roadway has no curb and has a two-foot grass shoulder capable of bearing traffic loading to accommodate emergency vehicle passage. Parking stalls are grouped between swales and driveways with the number of spaces determined by homeowner needs. The sidewalk also follows a curvilinear design and is only located on one side of the street. Swales are located in the right of way adjacent to the street to capture runoff from the street, sidewalk and adjacent property. After two years of monitoring, the project has reduced the total volume of storm water leaving the street by 98 percent for a two-year storm event. (Seattle Public Utilities District, 2003)

Figure 3-46. Images of SEA Project streets (images courtesy of Seattle Public Utilities District)

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3.5.2 LID Driveway Design

GENERAL DESCRIPTION

Driveways add a significant amount of impervious coverage to a community and are an element of a site's design that can be altered to minimize total impervious coverage. Driveways often slope directly to the street and storm drain system and contribute significantly to storm water pollution. There are several strategies that can be implemented to reduce this impact, including:

- Utilize shared driveways to provide access to several homes.
- Reduce driveway length by reducing front yard setbacks.
- Reduce driveway width by allowing tandem parking (one car in front of the other).
- Install a narrowed driveway with a flared entrance for multi-car garage access.
- Disconnect the driveway by directing surface flow from the driveway to a permeable landscaped area (see section 3.0 'Bioretention').
- Consider ribbon driveways, which consist of two strips of pavement with grass or some other permeable surface in between the strips.
- Utilize porous surfaces such as porous concrete or asphalt (see section 3.2.0 'Porous Concrete and Asphalt'), permeable pavers (see section 3.2.1 'Permeable Pavers'), or crushed aggregate.
- Create a temporary parking area where parking or access is infrequent. These areas can be paved with permeable surfaces.

Figure 3-47. This driveway is designed with multiple LID strategies including permeable pavers and a slotted drain built in to catch sediment and runoff, which is funneled into a landscaped area. (Photo courtesy of NEMO Nevada)

3.5 LID SITE DESIGN

DESIGN CONSIDERATIONS

- For shared driveways:
  - Shared driveways can provide access to several homes.
  - Access may not need to be as wide as residential streets.
- For disconnected driveway:
  - The driveway cross slope must be greater than the longitudinal slope in order for runoff to be directed into adjacent landscape.
  - Adjacent landscape must be sized to accommodate the water quality volume.
  - The edge of the driveway must be approximately 3 inches above the vegetated area so to not impede flow from the driveway.
  - A slotted channel drain is installed at or below the surface of the driveway roughly perpendicular to the flow path, captures flow from driveway and directs it to an infiltration system or vegetated area. Should have removable grates to allow access for cleaning. (See Figure 3-48)

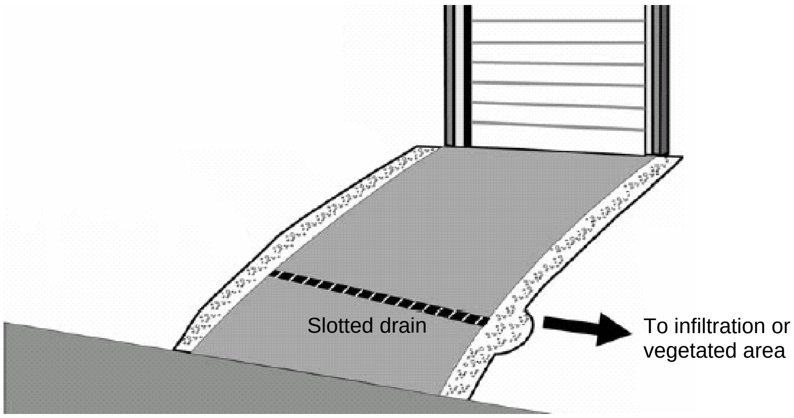

Figure 3-48. A schematic of a driveway containing a slotted drain.
(adapted from BMP Retrofit Partners, 2003)

- For ribbon driveways:
  - Wheel tracks should be wide enough to accommodate variability in driving and vehicle widths.
  - For soils with low infiltration rates, a perforated drain line buried between the wheel tracks may be appropriate to collect and direct runoff.
  - If vegetation is incorporated, it should be irrigated.

- For flared driveways:
  - Single lane width at street with flare at garage to serve multiple garage door openings.
  - Provide adequate space in front of multi-car garage for vehicle parking and maneuvering.
- For crushed aggregate driveways:
  - Use open-graded crushed aggregate rather than rounded stones.
  - Utilize a rigid edging material such as wood, concrete, metal, or brick to contain aggregate material.
- For permeable pavers and porous concrete and asphalt driveway surfaces see section 3.2 'Porous Paving Systems'.
- For temporary parking see section 3.2.1 'Permeable Pavers'.

LIMITATIONS

- Driveway length is generally determined by front yard setback requirements.
- Driveway width is usually mandated by municipal codes.

MAINTENANCE CONSIDERATIONS

- For maintenance of permeable surfaces see section 3.2 'Porous Paving Systems'.
- For driveways connected to landscaped areas, maintenance and edging of the adjacent lawn is important to allow unimpeded flow.
- For ribbon driveways, the area between the wheel tracks requires edging and maintenance, including periodic weed control.
- Crushed aggregate driveways may require periodic weed control and replenishment of the aggregate.
- Slotted channel drains generally need to be cleaned twice a year, in the spring and fall, and should be swept or vacuumed out. Clear any loose surface debris on a regular basis. The outlet should be checked periodically for clogging.

3.5 LID SITE DESIGN

REFERENCES AND ADDITIONAL SOURCES OF INFORMATION

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BMP Retrofit Partners. 2003. *How to Install Best Management Practices in the Lake Tahoe Basin: Manual for Building Landscaping Professionals*. University of Nevada Cooperative Extension.

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Kennedy/Jenks Consultants. 2004. *Truckee Meadows Structural Controls Design Manual* prepared for the Truckee Meadows Regional Storm Water Quality Management Program. http://www.cityofreno.com/gov/pub_works/stormwater/management/controls/

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3.5.3 LID SIDEWALKS AND BIKE PATHS

GENERAL DESCRIPTION

Sidewalks and bike paths are another source of impervious coverage that can adversely affect water quality by the runoff generated from their surface. Several management opportunities and strategies are available to reduce this impact, including:

- Reducing sidewalks to one side of the street.
- Disconnect bike paths from streets. Bike paths separated from roadways by vegetated strips reduce runoff and traffic hazards.
- Utilizing pervious materials to infiltrate or increase time of concentration of storm flows.
- Reducing sidewalk width when possible.
- Directing sidewalk runoff to adjacent vegetation to capture, infiltrate, and treat runoff.
- Installing a bioretention area or swale between the street and sidewalk and grading runoff from the sidewalk to these areas (see section 3.0 'Bioretention' and section 3.1 'Swales and Buffer Strips' for more information).
- Planting trees between the sidewalk and streets to capture and infiltrate runoff.
- Installing grated infiltration systems in sidewalks and bike paths to receive runoff as sheet flow. These can be installed to protect trees or can provide off-line storm water management via a grate over an infiltration trench.

Figure 3-49. This sidewalk at Pennsylvania State University is made of porous concrete. (Photo courtesy of Cahill Associates)

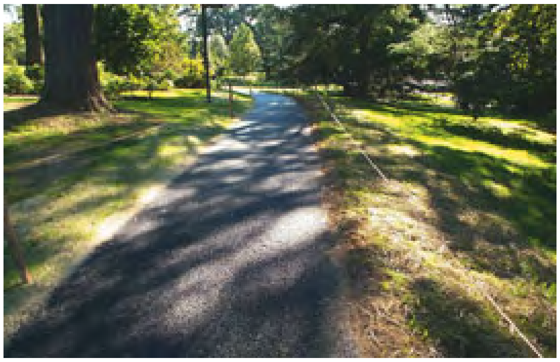


Figure 3-50. This walkway is made of porous asphalt. (Photo courtesy of Stormwater Journal)

3.5 LID SITE DESIGN

DESIGN CONSIDERATIONS

- Grade sidewalks and bike paths at a two percent slope to direct runoff to an adjacent vegetated area.
- For design of bioretention areas see section 3.0 ‘Bioretention’.
- For design of swales see section 3.1 ‘Swales and Buffer Strips’.
- Pervious materials such as permeable pavers, porous concrete or asphalt, gravel, or mulch can be utilized for sidewalk surfaces. For more information see section 3.2 ‘Porous Paving Systems.’
- In some cases, sidewalks and bike paths can be placed between rows of homes to increase access and decrease overall effective imperviousness.
- Grated infiltration systems should include removable grates to allow for maintenance, and must be capable of bearing the weight of pedestrians. For further information on infiltration trenches, see section 3.5.2 ‘Infiltration Trenches and Basins’.

LIMITATIONS

- Ordinances may require sidewalks on both sides of the street.
- Groundwater table must not be within 3 feet of the bottom of infiltration trenches.
- Bioretention or swales may require supplemental irrigation.
- Vector breeding may occur in bioretention and swales if not properly designed or maintained.

MAINTENANCE CONSIDERATIONS

- For maintenance of pervious surfaces, including porous concrete and asphalt and permeable pavers see section 3.2 ‘Porous Paving Systems’.
- For maintenance of bioretention areas see section 3.0 ‘Bioretention’.
- For maintenance of swales see section 3.1 ‘Swales and Buffer Strips’.
- For maintenance of grated infiltration trenches see section 3.5.1 ‘Infiltration Trenches and Basins’.

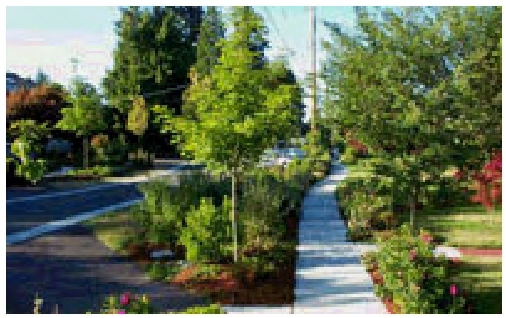
3.5 LID SITE DESIGN

EXAMPLES

In Seattle, WA, a pilot project, Street Edge Alternatives Project (SEA Streets), attempts to mimic pre-developmental hydrologic conditions by reducing impervious surfaces 11 percent less than a traditional street, incorporating LID principles such as reducing on-street parking, narrowing street widths, reducing sidewalks, eliminating curbs and gutters by providing surface detention in swales, and adding 100 evergreen trees and 1100 shrubs.

One of the most prominent features of the project are the 14-foot wide curvilinear streets, which is wide enough for two standard size cars to pass each other slowly. The sidewalk also follows a curvilinear design and is only located on one side of the street. Swales are located in the right-of-way adjacent to the street to capture runoff from the street, sidewalk and adjacent property. After two years of monitoring, the project has reduced the total volume of storm water leaving the street by 98 percent for a two-year storm event. (Seattle Public Utilities District, 2003)

Figure 3-51. Images of SEA Project streets sidewalks (images courtesy of Seattle Public Utilities District)



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California Stormwater Quality Association (CASQA), 2003. Stormwater Best Management Practice Handbook – New Development and Redevelopment. http://www.cabmphandbooks.com/

Kennedy/Jenks Consultants. 2004. *Truckee Meadows Structural Controls Design Manual* prepared for the Truckee Meadows Regional Storm Water Quality Management Program. http://www.cityofreno.com/gov/pub_works/stormwater/management/controls/

Prince George's County, Maryland. 2002. *Low Impact Development: Integrated Management Practices Handbook.* Department of Environmental Resources Programs & Planning Division. http://www.epa.gov/watertrain/smartgrowth/resources/pdf/LID_National_Manual.pdf

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3.6 ADDITIONAL LID STRATEGIES

INTRODUCTION

This section presents various additional LID strategies that can be implemented in new development and redevelopment projects, or incorporated into existing developments. Since increased runoff and storm water pollution is directly related to impervious surfaces, it is important to reduce and/or disconnect them as much as possible. Impervious surface reduction can be achieved by reducing the width roadways and driveways. Impervious surface disconnection can be achieved by directing runoff from rooftops and paved surfaces towards vegetated areas, instead of towards curb and gutter systems that drain directly to the storm drain system. Soil amendments can be particularly useful in areas with silty or clayey soils that lack good infiltration characteristics. Typical soil amendments include clean sand and leaf compost installed to a depth of 12 inches. Roof rainwater collection systems such as rain barrels and cisterns are useful in reducing the volume of runoff and can assist with water conservation. Roof rainwater is also typically very high quality water and can be particularly useful with sensitive plant species and recent plantings. Roof leader disconnection is a form of impervious surface disconnection, whereby downspouts from roof drainage systems are directed towards vegetated areas or other pervious areas, instead directly onto driveways that are directly connected to streets.

Pollution prevention, good housekeeping, and storm water education are closely related. They involve widespread use of common sense practices such as picking up and properly disposing of pet wastes, proper containment and disposal of used automobile oil, and the washing of automobiles on lawns or at commercial car washes. Educating the public that almost everything that enters the storm drain system is eventually discharged into local streams, rivers and lakes without treatment is critical. Community events that include storm drain stenciling help the public to understand that the storm drain system and the sanitary sewer system are separate. Once the public understands that the collective impact individual practices can be significant, pollution prevention and good housekeeping can have a significant impact on protecting the quality of local water resources.

3.6 ADDITIONAL LID STRATEGIES

3.6.0 IMPERVIOUS SURFACE REDUCTION AND DISCONNECTION

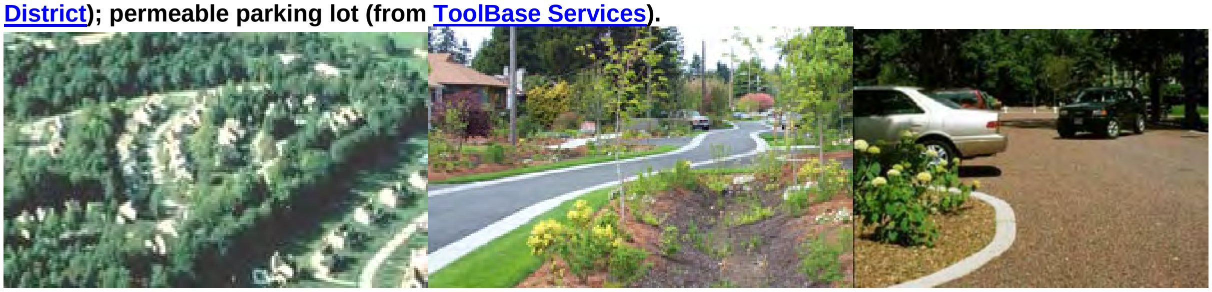
GENERAL DESCRIPTION

Impervious areas directly connected to the storm drain system are a significant source of nonpoint source storm water pollution. Disconnection of impervious surfaces can be achieved by grading surfaces toward vegetated or porous areas to avoid concentrated storm water flows. This can include areas such as driveways, basketball, tennis, and other sports courts, sidewalks, patios, parking lots, and streets.

Impervious surface reduction is another storm water management strategy that can include such practices as:

- Roof gardens, which consist of freestanding containers and planters to capture and infiltrate rainwater.
- Incorporation of landscaped areas into development to reduce impervious coverage.
- Narrow residential roads and alternative street designs (see section 3.5.1 'LID Street and Road Design').
- Alternative driveway designs (see section 3.5.2 'LID Driveway Design').
- LID parking lot design (see section 3.5.0 'LID Parking Lot Design')
- Utilization of porous materials (see section 3.2 'Porous Paving Systems').
- Sidewalk reduction or alternative designs (see section 3.5.3 'LID Sidewalk Design').
- Cluster and open space development (see section 3.5 'LID Site Design').

From (left to right): Cluster development utilizing open space design bordering a conventional neighborhood (from Massachusetts Low Impact Development Toolkit) ; LID street design (from Seattle Public Utilities District); permeable parking lot (from ToolBase Services).



By disconnecting and reducing impervious surfaces, expensive storm drain systems can be minimized or even eliminated in new developments, reducing development costs and resulting in significant savings.

3.6 ADDITIONAL LID STRATEGIES

DESIGN CONSIDERATIONS

- For paved areas sloped towards vegetated areas, the width of vegetation needed is dependent on the area of contributing pavement.
- Roof gardens are ideal for commercial buildings, parking garages, and any building with a flat roof.
- Roof gardens should be planted with drought tolerant species to reduce irrigation needs.
- Landscaped areas should be planted with drought tolerant species to reduce irrigation needs.
- Green roofs, which consist of structurally improved roofs covered with an impermeable layer, soil and low water use plants, are typically not practical in arid environments.
- Refer to section 3.5.1 ‘LID Street and Road Design’ for narrow residential roads and alternative street design considerations.
- Refer to section 3.5.2 ‘LID Driveway Design’ for alternative driveway design considerations.
- Refer to section 3.5.2 ‘LID Sidewalk Design’ for sidewalk reduction or alternative sidewalk design considerations.
- Refer to section 3.5.2 ‘LID Site Design’ for cluster and open space development design considerations.
- Refer to the *Truckee Meadows Structural Controls Design Manual* fact sheet TC-62 for more information on Porous Pavement.

LIMITATIONS

- Roof gardens and landscaped areas may require supplemental irrigation.
- Roof gardens are not applicable on sloped rooftops.
- Local zoning standards may limit narrower roads and sidewalk alternatives.
- Porous paving systems should not be used in heavily trafficked areas.
- Porous paving systems may become clogged if not properly installed and maintained.

3.6 ADDITIONAL LID STRATEGIES

MAINTENANCE CONSIDERATIONS

- Narrower streets should require less maintenance than wider streets, as they consist of less surface area to maintain and repair.
- Roof gardens and landscaped areas require routine landscape maintenance.
- For maintenance of porous materials see section 3.2 ‘Porous Paving Systems’.

EXAMPLES

In Seattle, the Seattle Public Utilities District (SPU) has partnered with Seattle Housing Authority (SHA) to integrate a natural drainage system into a redevelopment project being undertaken, named the High Point Redevelopment Project (High Point). This project will encompass 120 acres of mixed income housing creating 34 blocks of new streets including new utilities, street trees, sidewalks, parks, and open space. The project is located within the high-priority, salmon-bearing watershed of Longfellow Creek, which terminates in Puget Sound, and is estimated to be about 10% of the Longfellow Creek Watershed, providing the project with an exceptional opportunity to improve water quality flows to the creek. Redeveloping with a naturalistic drainage approach and treating storm water runoff at the source by controlling peak flows is a critical component to protection of aquatic life and the creek and a critical component of this project.

The goal of the project is to develop the overall site with 60% impervious to 40% pervious coverage. To meet this goal, SPU and SHA are utilizing mitigation measures to treat storm water closer to the source, including: roof drainage sheet flow across lawn areas; soil amendments to lawn and landscaping to improve absorption capabilities; drainage swales to treat storm water runoff from adjacent properties and streets; utilizing porous paving materials; and mitigating allowable impervious and pervious areas for a site. Throughout the development there will be an extensive alternative natural drainage system incorporated throughout the 34 blocks of right-of-way. The project proposes to integrate 22,000 lineal feet of vegetated and grassy swales throughout the development within the planting strip of the right-of-way, with each swale designed to treat runoff from the road and housing from the adjacent block (Seattle Public Utilities District, 2003). At the end of each block, runoff from the natural system swale will drop into a traditional system mainline to convey flows off the site to a storm water pond, which is designed to manage the larger 25 and 100-year storm events, before being discharged to Longfellow Creek.

An open space strategy has also been utilized for the site plan with neighborhood, community, and pocket parks scattered throughout the site. The only challenge to the natural drainage system approach was integrating a traditional street design with curbs, gutters, and two sidewalks into the design to compliment surrounding neighborhoods. The savings accrued from utilizing the natural systems approach as opposed to a traditional drainage network – estimated at $2.9 million – could have been further reduced had those components not been integrated. Construction on the High Point Redevelopment Project began in 2003 and completion is anticipated in 2008. (Maupin, 2003)

3.6 ADDITIONAL LID STRATEGIES

REFERENCES AND ADDITIONAL SOURCES OF INFORMATION

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ToolBase Services. *Permeable Pavement.* http://www.toolbase.org/tertiaryT.asp?TrackID=&DocumentID=2160&CategoryID=38

3.6 ADDITIONAL LID STRATEGIES

3.6.1 SOIL AMENDMENTS

GENERAL DESCRIPTION

Development activities often remove, disturb and compact topsoil from construction sites. The outcome is a decrease in the infiltration and water storage capacity of post development soils, and an increase in storm water runoff potential. By amending soils with sand and organic materials, their hydrologic characteristics can be enhanced, leading to increased infiltration and water storage characteristics. Benefits accrued by incorporating soil amendments include decreased storm water runoff, a decrease in polluted runoff from landscaping practices, and water conservation.

Soils in the high desert climate of the Truckee Meadows tend to lack organic matter and nutrients, and often have a high silt and/or clay content. Soils high in clay content have slow infiltration rates, resulting in high runoff potential. By adding soil amendments, infiltration and water storage capacity of these soils can be improved.

Landscaped areas in residential and commercial areas that include turf grass are a major contributor to storm water runoff contaminated by fertilizers and pesticides. In landscaped areas where soils have been compacted and not amended, soils can behave like impervious areas, generating considerable amounts of runoff. By amending soils with sand and organic materials, the runoff potential can be reduced. This also reduces irrigation needs, as water is more easily infiltrated into the ground and retained in the soil matrix where it can be utilized by plants. Fertilizer needs can also be reduced by incorporating appropriate soil amendments, thereby reducing storm water pollution.

DESIGN CONSIDERATIONS

- The most cost-effective strategy is to save and reuse native topsoil, and to protect areas of native vegetation wherever possible.
- Soils should be analyzed by a lab to determine the specific soil amendments needed.
- Common soil amendments include: leaf compost, peat moss and composted manure.
- Topsoil should have a minimum depth of 8 inches. Subsoils below topsoil applications should be scarified to a depth of at least 4 inches, with some topsoil incorporated.
- Incorporate amendments at the end of site development.
- For sites with poor drainage characteristics, lawn alternatives and or soil amendments should be considered.
- For areas that incorporate turf, annual soil aeration should be conducted.
- A landscaping professional should be consulted to determine how close to a tree or shrub root base soil amendments can be added without causing root damage to existing trees and shrubs.

3.6 ADDITIONAL LID STRATEGIES

MAINTENANCE CONSIDERATIONS

- Protect from excessive foot traffic and equipment to prevent compaction and erosion.
- Plant and mulch areas immediately after amending the soil to stabilize the site.
- Minimize use of pesticides and fertilizers.

EXAMPLES

In Seattle, WA, a pilot project, Street Edge Alternatives Project (SEA Streets), attempts to mimic pre-developmental hydrologic conditions by reducing impervious surfaces to 11 percent less than a traditional street by incorporating LID principles. LID principles incorporated into the project include reduced on-street parking, narrower street widths, reduction in sidewalks, removal of curbs and gutters by providing surface detention in swales, and the planting of an additional 100 evergreen trees and 1100 shrubs. In this project, soils were amended with organic compost to reduce application of fertilizers and to reduce water needs. After two years of monitoring, the project has reduced the total volume of storm water leaving the street by 98 percent for a two-year storm event. (Seattle Public Utilities District, 2003)

REFERENCES AND ADDITIONAL SOURCES OF INFORMATION

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3.6 ADDITIONAL LID STRATEGIES

3.6.2 ROOF LEADER DISCONNECTION

GENERAL DESCRIPTION

Runoff from the roofs of buildings and homes contributes to the volume of storm water runoff as well as conveying pollutants. During a storm event, runoff from rooftops is generally collected in gutters and poured into downspouts, or, when downspouts are not present, it flows from eaves in concentrated sheet flows and causes erosion. This water is directed to the storm drain system from downspouts or drip lines, picking up nutrients and sediments on the way. Controlling roof runoff by filtering it through landscaped bioretention systems, vegetated swales or buffer strips, storing it for irrigation, or allowing for infiltration reduces the peak flow rates and volume of storm water runoff and associated pollutants loads.

Figure 3-52. A downspout directed to a landscaped area.

DESIGN CONSIDERATIONS

- Downspouts can be directed towards vegetated swales or buffers (see section 3.1 'Swales and Buffer Strips'), landscaped bioretention systems (see section 3.0 'Bioretention'), infiltration trenches or basins (see section 3.5.2 'Infiltration Trenches and Basins').
- Infiltration trenches should not be installed within 100 feet upslope of building foundations.
- Roof runoff can be stored for irrigation by directing downspouts to roof rainwater collection devices (see section 3.4.2 'Roof Rainwater Collection Systems').
- Foundation plantings, box planters, and rock-lined trenches under roofline/dripline can help to control erosion from concentrated sheet flow off of the roof and promote infiltration.

3.6 ADDITIONAL LID STRATEGIES

- Splash blocks or gravel splash pads should be used to dissipate runoff energy from downspouts.
- Refer to the *Truckee Meadows Structural Controls Design Manual* fact sheets TC-10 and TC-11 for information on the design and construction of vegetated swales and buffers.
- Refer to *Truckee Meadows Structural Controls Design Manual* fact sheets TC-20 and TC-21 for information on the design and construction of infiltration trenches and basins.

LIMITATIONS

- Plantings under rooflines must be able to withstand heavy runoff sheet flows and soil saturation.
- Soil permeability may limit applicability of infiltration trenches.
- Infiltration systems have limited applicability in areas with high groundwater tables and can be associated with an increased risk of groundwater quality degradation, particularly if improperly located in areas where spills are likely to occur.

MAINTENANCE CONSIDERATIONS

- Routine landscape maintenance required for plantings.
- Inspect and maintain infiltration trenches and basins as noted in section 3.5.2 'Infiltration Trenches and Basins'.
- Inspect and maintain bioretention systems as noted in section 3.0 'Bioretention'.
- Inspect and maintain vegetated swales and buffers as noted in section 3.1 'Swales and Buffer Strips'.

REFERENCES AND ADDITIONAL SOURCES OF INFORMATION

Bay Area Stormwater Management Agencies Association (BASMAA). 1999. *Start at the Source: Design Guidance Manual for Stormwater Quality Protection.* Prepared by Tom Richman & Associates. www.basmaa.org

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