Stormwater Best Management Practices

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Low Impact Development Technologies

Introduction

A. Low Impact Development: An Alternative Site Design Strategy

Low Impact Development (LID) is an alternative site design strategy that uses natural and engineered infiltration and storage techniques to control storm water where it is generated. LID combines conservation practices with distributed storm water source controls and pollution prevention to maintain or restore watershed functions. The objective is to disperse LID devices uniformly across a site to minimize runoff.

LID reintroduces the hydrologic and environmental functions that are altered with conventional storm water management. LID helps to maintain the water balance on a site and reduces the detrimental effects that traditional end-of-pipe systems have on waterways and the groundwater supply. LID devices provide temporary retention areas; increase infiltration; allow for nutrient (pollutant) removal; and control the release of storm water into adjacent waterways.

Some examples of LID technologies include:

- Engineered systems that filter storm water from parking lots and impervious surfaces, such as bioretention cells, filter strips, and tree box filters;
- Engineered systems that retain (or store) storm water and slowly infiltrate water, such as sub-surface collection facilities under parking lots, bioretention cells, and infiltration trenches;
- Modifications to infrastructure to decrease the amount of impervious surfaces such as curbless, gutterless, and reduced width streets;
- Low-tech vegetated areas that filter, direct, and retain storm water such as rain gardens and bio-swales;
- Innovative materials that help break up (disconnect) impervious surfaces or are made of recycled material such as porous concrete, permeable pavers, or site furnishings made of recycled waste;
- Water collection systems such as subsurface collection facilities, cisterns, or rain barrels; and
- Native or site-appropriate vegetation.

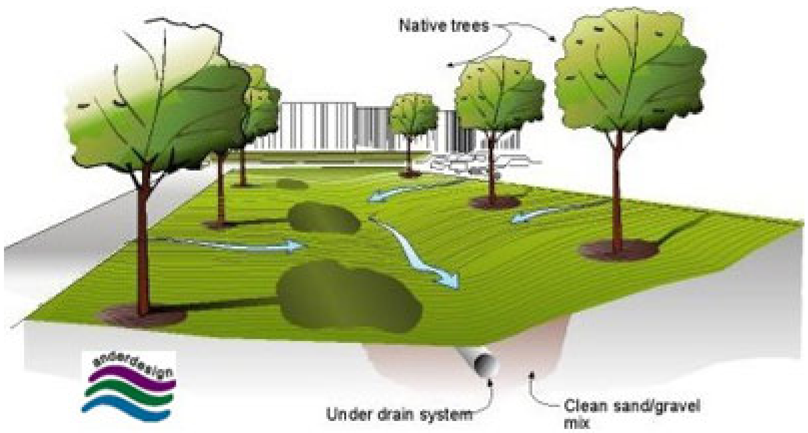


Fig. 1: Bio-swale schematic

B. Conventional Design

Fig. 2 Conventional site design

Conventional storm water management techniques direct all of the storm water to storm drains to remove it from the site as quickly as possible. End-of-pipe facilities are typically designed to store and detain runoff to reduce peak flows for storm events that are infrequent, such as the 10 year, 24-hour storm. Controls are often not in place to reduce flows for smaller, more frequently occurring events. Controls also are not structured to address non-point source pollution problems or to recharge the groundwater. Since runoff needs to be managed on the site, large ponds, or a series of ponds, are required. These controls take up a significant portion of land.

Storm water ponds are characteristically constructed with fences around the periphery for health and safety reasons. The outbreak of the West Nile virus and concern about fecal droppings of migratory birds has heightened concern about the suitability and maintenance of retention ponds. Ponds require annual maintenance and can require expensive long-term rehabilitation costs.

Fig. 3. LID site design

In contrast, the requirement for storm water retention is achieved with LID through the use of distributed controls. The retention areas are designed into the open space, or below existing infrastructure (such as parking lots), and create opportunities for new design configurations that are less dependent on inlets, pipes, and ponds. Additionally, LID technologies eliminate the need for costly maintenance contracts, typically requiring only routine landscape maintenance, with the exception of engineered systems such as tree box filters and sand filters.

The graphics show a conventional site design and a LID site design. The LID approach illustrates the potential for innovative site design alternatives with the elimination of retention ponds. The comparison exemplifies how land used for retention ponds could be allocated differently with the implementation of a distributed storm water program.

C. Economic Indicators and the "Greening" Movement

Economic indicators signify a shift in consumer and corporate purchasing toward "green" building. Homeowners are willing to pay a higher premium for homes that are more energy efficient and for properties that are adjacent to open space. Likewise, corporations are inclined to spend more on energy-efficient buildings with enhanced site amenities as they improve employee performance. This is causing builders, developers, and product manufacturers to take notice. LID can assist in reducing the bottom line while providing significant environmental benefits.

Some benefits of a LID site design strategy include:

Reduced infrastructural costs for ponds, curbs and gutters, inlets, and pipes

Increased lot yield,

Reduced life-cycle costs,

Increased marketability, and

Increased property values.

D. Examples of Profitable LID Development

1) Somerset Community—A $916,382 Cost Savings

Fig. 4: Aerial view of Somerset Community

One of the oldest communities in the United States to implement LID on a large scale is the Somerset Community in Prince Georges County, Maryland. The developer successfully integrated LID technologies into the 60-acre development in 1995, where 199 homes were sited on 10,000 square foot lots. The alternative development pattern that used distributed storm water management systems yielded 6 additional lots, which resulted in increased revenues at $40,000 each. The final cost breakdown was:

a. $300,000 savings on LID vs. storm water ponds
   LID Cost: $100,000
   Conventional Cost: $400,000
b. $240,000 additional revenue on 6 additional lots (space previously allocated to ponds) 6 lots x $40,000 Net
c. $916,382 overall cost savings or $4,600 savings per lot

The streets in Somerset have no curbs or gutters and use shallow swales adjacent to the streets to store and infiltrate storm water. Every lawn has a bioretention cell (or rain garden). The swales and bioretention cells are important because they handle the first flush of a storm, which contains the greatest amount of pollutants, and they allow the water to be stored (for less than 24 hours) and infiltrate into the ground. A conventional system does not filter the storm water from the streets and sends large amounts of untreated water into nearby waterways, via one or more detention ponds.

Fig. 5-6: bioretention cells in Somerset Community

The downspouts of the roofs direct rainwater into vegetated areas or rain barrels. The groundwater supply is recharged and collected rainwater satisfies irrigation needs. Community cooperation has been positive as the residents understand their role in preserving the Chesapeake Bay. Ongoing community participation and upkeep of the bioretention cells has been positive, as shown in the recent photos.

Although the streets do not have curbs and gutters, they are exceptionally wide (36') due to building regulations at the time of development. This is not a recommended practice; minimizing impervious cover is a LID concept. Eliminating one lane of on-street parking in this subdivision could have resulted in a substantial savings.

2) Northridge Community—The Sustainable Alternative

Northridge Community, also in Prince Georges County, Maryland, is an example of a subdivision with reduced street widths, bio-swales adjacent to curbless streets, and a substantial tree preservation program. In 1988 the developer, Michael T. Rose, spent $23 million dollars on the 855 unit, 356 acre development. In lieu of conventional infrastructure costs (wider streets, detention ponds, catch basins, curbs and gutters) the developer spent the cost differential on a community center, a lake, and additional open space. Although a regulatory and permitting challenge, the project was instrumental in advancing forest conservation programs and the use of LID technologies.

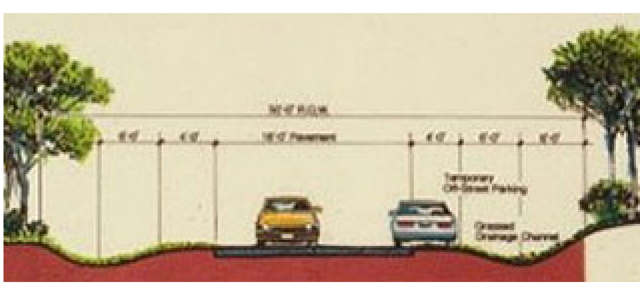


Fig. 7 *(left)*: Curbless roads in Northridge Community and Fig. 8 *(right)*: Amenities in Northridge Community

Northridge has received a considerable amount of certificates and awards both in the environmental and business realms.

E. Benefits of the LID Site Design Strategy

Benefits of LID:

1. Reduce infrastructural costs for ponds, curbs, and gutters
2. Increase the lot yield
3. Reduce life-cycle costs,
4. Increase marketability, and
5. Increase property values.

1) LID Reduces Infrastructure Costs and Increases Lot Yield

In the LID site design strategy buildings, roads, sidewalks, and open space are used for multiple purposes and are designed to maximize site functions. The use of distributed LID technologies reduces or eliminates the need for large-scale, end-of-pipe systems and thus reduces the infrastructural costs of a network of pipes, gutters, and ponds. Space traditionally set aside for detention ponds can now be designated for an alternative use, such as architectural, entertainment/recreational, or reforestation/conservation.

Small-scale LID technologies are positioned in precise locations to accomplish specific water quality or water quantity objectives. (See Table 1 below.) The most effective location of the devices is close to the source. For example, bioretention cells (or rain gardens) are located adjacent to parking lots so that they can filter and treat runoff directly. Tree box filters are located on streets that require curbs and gutters to filter and treat surface runoff before it enters the waterways. Vegetated swales are placed adjacent to curbless roads and are effective at filtering and infiltrating storm water and recharging the groundwater supply. Rain barrels or cisterns collect rainwater off rooftops to irrigate landscaped areas. Subsurface collection facilities (under parking lots or sidewalks) constructed at varying depths accommodate large storms and filter, retain and/or store water for reuse or for slow-release infiltration.

2) Enhanced Livability = Increased Property Value

Improved site design has a direct correlation to enhanced livability and community aesthetics. LID not only facilitates the stabilization of the hydrologic condition of a site, but it improves the market appreciation.

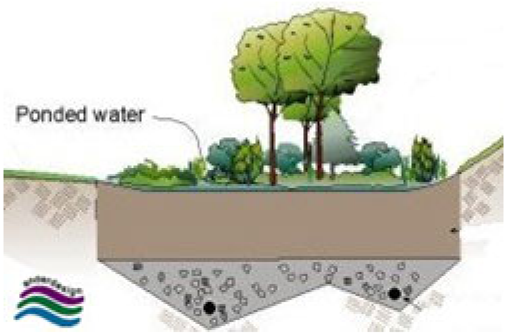


Fig. 9: Open space is used for storm water control via a Bioretention Cell

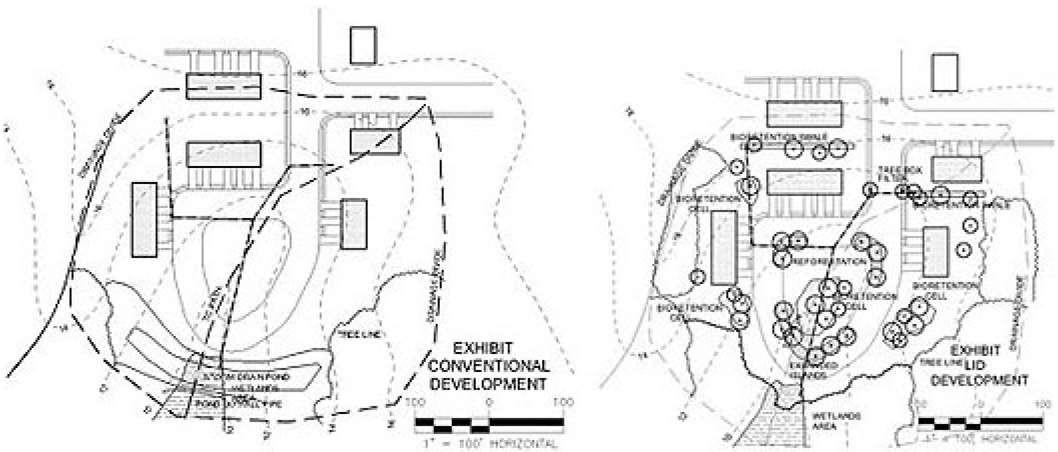
The management of the site through the distributed controls allows for unprecedented design schemes. Consider the intangible benefits that result from "whole site design controls" as shown in the graphic above. It demonstrates that a bioretention cell can be constructed to provide retention and also beautify the open space. The graphic below illustrates how space can be used for multiple purposes. A common area between homes that accommodates a bioretention cell to store and infiltrate water during storms, is suitable for light recreation (e.g., walking on trails) during dry periods.

Fig. 10: A bioretention cell can be used for light recreation

F. LID Site Design Examples

1) Community Design—Townhomes

These illustrations compare a conventional site design with a LID site design. The building footprint and circulation are identical in each. The LID site design addresses the unique conditions of the site and uses an arrangement of distributed LID controls to meet storm water management requirements. It also utilizes the existing wetlands to function as a natural filtration zone, as they have historically. There is no need to add a retention pond, as the site is configured to make an allowance for the added impervious surfaces and balance the hydrologic requirements.



Figs. 11-12: Site design comparison

The site is arranged with rain gardens, bioretention cells, and bio-swales. Other LID options not represented in this site design include reduced street widths, curbless roads, permeable parking bays, permeable sidewalks, cisterns, and rain barrels.

2) Community Design—Single Family Homes

Pierce County, Washington, developed a storm water management manual for developers, engineers, planners, and designers that demonstrate the LID site design strategy. The drawings were produced for Kensington Estates community to compare the conventional design approach with the LID design. The project also included a thorough cost comparison.

The 24-acre development yielded 103 lots with the conventional scheme. The LID redesign, which integrated conservation practices, yielded 103 lots at 4 units per acre. This design preserved the density while designating half of the site as open space. The cost comparison showed that the LID design achieved a 20% cost savings on construction.

Fig. 13 illustrates the site inventory with existing vegetation, wind patterns, wetlands, drainage patterns, soil types, and view sheds.

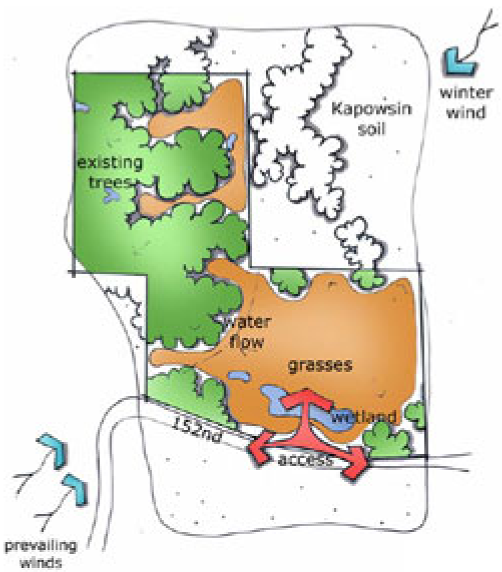


Fig. 13 (left): Site inventory and Fig. 14 (right): Conventional site design

Fig. 14 shows a conventional development pattern with roads and lots placed on the land to maximize the available space. The existing hydrologic patterns are not preserved, nor are the existing forests conserved. The storm water will be managed in a conventional manner.

Fig. 15 shows a LID design strategy. The existing natural resources are the point of departure for the design: the placement of lots, roads, and open space is dictated by existing drainage patterns and forested areas. The decision to design within the land composition influenced the lot size. In the LID scheme it was determined that the best use of the property was smaller lots and greater density.

Fig. 15 (left): LID site design and Fig. 16 (right): Site drainage pattern

Fig. 16 shows the overall LID drainage pattern. The open space is designated as the infiltration/overflow area. The hydrologic integrity of the site is maintained by conforming the development to pre-development patterns.

Each lot in the community manages storm water for the most frequent storm events at the source with rain gardens, swales, bioretention cells, pervious driveways, and conservation areas, as seen in Fig.17. However, engineered swales and infiltration areas (typically in the open space) are integrated into the design to accommodate large storms.

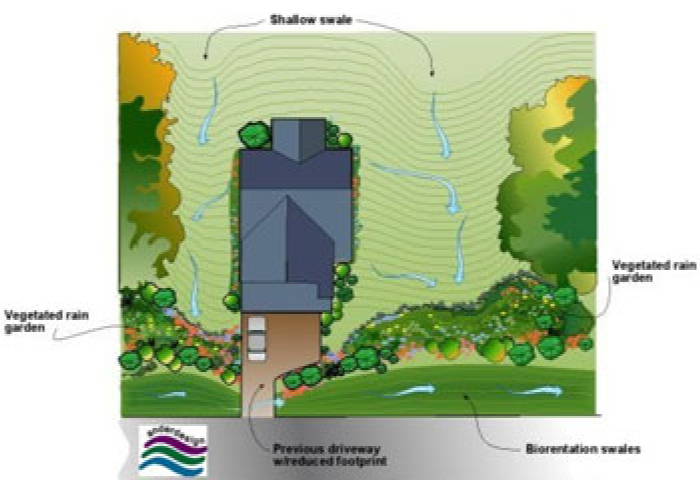


Fig. 17: LID lot design

The developer pursued the conventional scheme, but in the end had to purchase 2 additional acres off-site to achieve the required storm water management controls. They were fortunate to have been grandfathered in under the old storm drain rules. Otherwise the current regulations would have required them to purchase 6 additional acres and lose 10 housing units at a cost of $1 million. The LID cost savings under the new storm drain rules are even more significant.

G. The Storm Water Utility Fee

Of concern to developers, designers, and engineers is the national trend toward storm water utility fees, or taxes, for storm water that exits a property. Fees are typically calculated on the impervious area of a lot, such as roofs, roads, and driveways. LID will reduce or eliminate storm water utility fees by reducing impervious surfaces or mitigating their impact, promoting infiltration, and dispersing flows. LID site design lowers the volume of runoff leaving a site. This should be considered as an additional cost savings beyond reduced maintenance costs.

H. LID: An Urban, Suburban, or Rural Solution

LID can be incorporated into any development scenario, whether urban, ultra-urban, suburban, or rural. The range of sizes and scales of the devices allows for unlimited configurations even where space is limited. LID is particularly effective for targeting non-point source pollution in dense, urban areas, because the LID controls can be used below paved surfaces, in easements or right-of-ways, and in open space to increase the site's storage and infiltration capacity.

Description of LID Technologies

A. LID Practices and Benefits

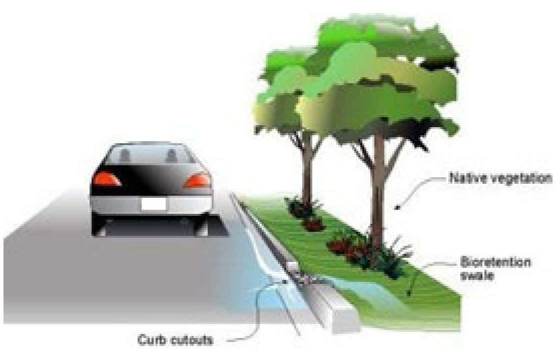


Fig. 18: Curb cut schematic

The LID site design approach is a precise arrangement of natural and engineered technologies. The devices, or Integrated Management Practices (IMPs), function as a comprehensive system across the site to achieve the goals of:

Peak flow control

Volume reduction

Water quality improvement (filter and treat pollutants), and

Water conservation.

Table 1 illustrates several LID technologies and their associated benefit(s). A brief description of commonly used LID practices and suitable applications follows.

Table 1: LID Practices and Benefits

LID PRACTICE / DEVICE	Peak Flow Control	Volume Reduction	Water Quality Improvement	Water Conservation
Bioretention Cell	•	•	•	
Cistern	•	•		•
Downspout Disconnection	•	•	•	
Grassed Swale	•	•	•	
Green Roof	•		•	
Infiltration Trench	•	•	•	
Narrow Road Design	•	•	•	
Permeable Pavers/Pavement	•	•	•	
Rain Barrel	•	•		•
Rain Garden	•	•	•	
Sand Filter	•		•	
Tree Box Filter	•		•	
Tree Planting	•	•		

B. Common LID Practices

Below are examples of common LID practices. A brief overview of the storm water controls that can be implemented on a project is also included. The techniques should be evaluated for their suitability for each project.

1) Bioretention Cell (Rain Garden)

A bioretention cell (strip or trench) is an engineered natural treatment system consisting of a slightly recessed landscaped area constructed with a specialized soil mixture, an aggregate base, an underdrain, and site-appropriate plant materials that tolerate both moist and dry conditions. The site is graded to intercept runoff from paved areas, swales, or roof leaders. The soil and plants filter and store runoff, remove petroleum products, nutrients, metals, and sediments, and promote groundwater recharge through infiltration. The cells are designed to drain in 24 hours, with no risk of standing water and breeding of mosquitoes.

A rain garden typically does not have the full spectrum of engineered features that bioretention cells have, such as underdrains and the entire soil mix. They can be designed and built by homeowners and located near a drainage area, such as a roof downspout.

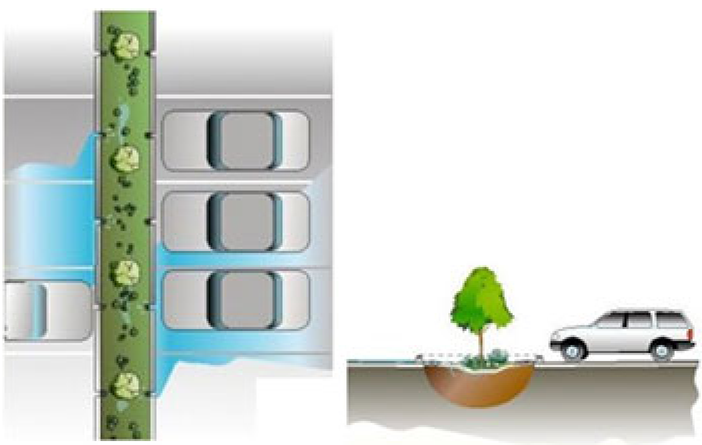


Fig. 19: Bioretention cell schematic

Typical Uses: Parking lot islands, edges of paved areas (roads or parking lots), adjacent to buildings, open space, median strips, swales.

Land Use: Ideal for commercial, industrial, and residential (urban, suburban, ultra-urban). They are widely used in transportation projects (highway medians and rail projects).

They are suitable for new construction and retrofit projects.

Approximate Cost: Residential costs average $3-$4 per square foot of size plus excavation and soil amendment costs. Plant materials are comparable to conventional landscaping costs.

Commercial, industrial, and institutional site costs can range from $10-$40 per square foot, based on the need for control structures, curbing, storm drains, and underdrains.

Maintenance: Routine maintenance is required and can be performed as part of the regular site landscaping program (i.e., biannual evaluation of trees and shrubs, regular pruning schedule). The use of native, site-appropriate vegetation reduces the need for fertilizers, pesticides, excessive water, and overall maintenance requirements.

Additional Benefits: Easily customized to various projects (size, shape, and depth) and land uses; enhances aesthetic value of site; uses small parcels of land, easements, right-of-ways; easily retrofitted into existing buildings/open space.

2) Vegetated Swale (Bio-swale)

A vegetated or grassed swale is an area with dense vegetation that retains and filters the first flush of runoff from impervious surfaces. It is constructed downstream of a runoff source. After the soil-plant mixture below the channel becomes saturated, the swale acts as a conveyance structure to a bioretention cell, wetland, or infiltration area.

There is a range of designs for these systems. Some swales are designed to filter pollutants and promote infiltration and others are designed with a geo-textile layer that stores the runoff for slow release into depressed open areas or an infiltration zone.

Alternative Devices: Filter strip or vegetated buffer.

Typical Uses: Edges of paved areas (roads or parking lots), parking lot islands, intermediary common spaces, open space, or adjacent to buildings.

Land Use: Commercial, industrial, residential (urban, suburban, ultra-urban); transportation projects (highway medians and rail projects); new construction and retrofit projects.

Approximate Cost: $0.25 per square foot for construction only; $0.50 per square foot for design and construction.

Maintenance: Routine maintenance is required. Maintenance of a dense, healthy vegetated cover; periodic mowing; weed control; reseeding of bare areas; and clearing of debris and accumulated sediment.

Additional Benefits: Easily customized to various projects (size, shape, and depth) and land uses; enhances aesthetic value of site; uses small parcels of land, easements, right-of-ways; easily retrofitted into existing buildings/open space.

Design Specs and Supplementary Information:

Virginia Department of Conservation and Recreation—Virginia Stormwater Management Program

3) Permeable Pavement

Disconnecting impervious areas is a fundamental component of the LID approach. Roofs, sidewalks, and paved surfaces are disconnected from each other to allow for more uniform distribution of runoff into pervious areas. Conveying runoff into vegetated areas keeps the water from directly entering the storm drain network, reduces runoff volume, and promotes distributed infiltration.

Since paved surfaces make up a large portion of the urban (or developed) landscape, the use of permeable pavement is very effective at stabilizing the hydrologic condition of a site. Permeable surfaces can be used in conjunction with subsurface infiltration galleries (subsurface retention facilities) as seen in Section 6.

A secondary benefit of permeable paving is its performance in snowy conditions. Cahill Associates reports an increase in demand for the installation of permeable asphalt in the Northeast as a result of reduced maintenance costs (snow shoveling and desalting) due to rapid snowmelt on permeable surfaces.

Types of permeable pavement include permeable asphalt, permeable concrete, grid block pavers, plastic grids, vegetated grids, Belgium block (in photo), turf block, gravel, cobbles, brick, natural stone, etc.


Fig. 20 (left): Belgium block pavers in parking bays and
Fig. 21. (right): Permeable parking bays

Typical Uses: Parking bays, parking lanes, sidewalks, roads. Blocks and porous pavement are generally used in high traffic parking and roadway applications; respectively grid systems are more commonly used in auxiliary parking areas and roadways.

Land Use: Ideal for commercial, industrial, and residential (urban, suburban, ultra-urban); suitable for new construction and retrofit projects.

Approximate Cost: Varies according to product. Typically, the cost is higher than conventional paving systems; however, they help reduce the overall storm water infrastructure costs.

Maintenance: Varies according to product. Routine street sweeping will sustain the infiltration capacity of voids. Porous concrete/asphalt require annual vacuuming, to remove accumulated sediment and dirt.

Additional Benefits: Easily customized to various projects and land uses; enhances aesthetic value of site; easily retrofitted into existing paving configurations.

4) Subsurface Retention Facilities

Subsurface retention facilities are typically constructed below parking lots (either permeable or impervious) and can be built to any depth to retain, filter, infiltrate, and alter the runoff volume and timing. This practice is well suited to dense urban areas. Subsurface facilities can provide a considerable amount of runoff storage.

Fig. 22 shows that the porous parking bay has an infiltration gallery (with 40% void space) below it for storm water retention. The water is filtered through the stone aggregate and infiltrates into the ground. An alternative strategy is to construct the subsurface facility with a filtering and pumping mechanism so that collected water can be reused for non-potable uses such as irrigation or flushing of toilets.

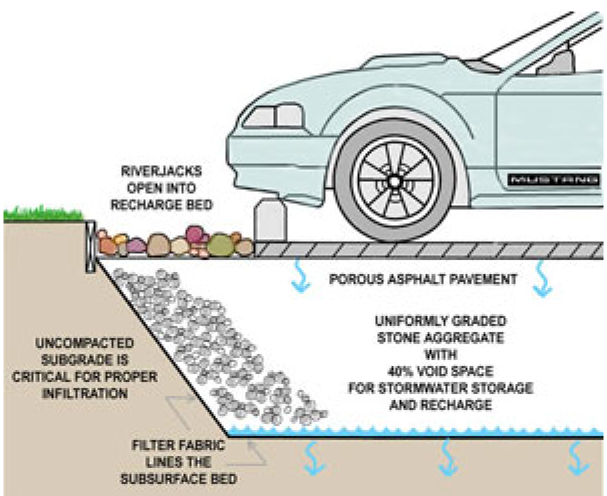


Fig. 22: Cross section of porous asphalt pavement

Similar techniques include gravel storage galleries, sand filters, infiltration basins, and infiltration trenches (for areas with space constraints).

Typical Uses: Parking lots, sidewalks, and roads.

Land Use: Ideal for commercial, industrial, and residential (urban, suburban, ultra-urban); suitable for new construction and retrofit projects.

Approximate Cost: Costs are typically higher than conventional paving systems; however, they help reduce the overall storm water infrastructure costs (land allocated for ponds, cost of pipes, inlets, curbs/gutters).

Maintenance: Varies according to manufacturer; routine street sweeping and vacuuming will retain infiltration capacity of voids.

Additional Benefits: Easily customized to various projects and land uses; enhances aesthetic value of site; easily retrofitted into existing paving configurations.

Design Specs and Supplementary Information: These are specialized systems and should be designed by, or under the direct supervision of, an appropriate licensed professional.

Porous Asphalt with Subsurface Infiltration/Storage Bed (Cahill Associates)

The reduction of street widths (i.e., from 36' to 24') can result in a cost savings of approximately $70,000 per mile in street infrastructure costs (estimated paving cost = $15 per square yard).

Land Use: Residential, commercial, industrial.

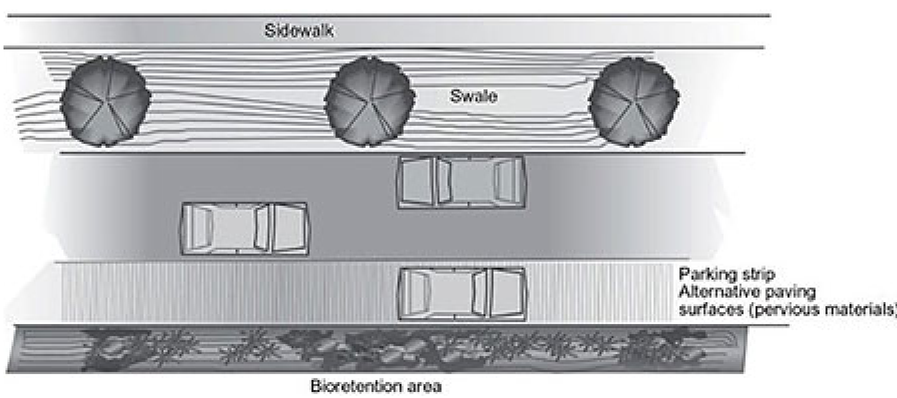


Fig. 23: Reduced road widths and vegetated swales

5) Tree Box Filter

Tree box filters are essentially 'boxed' bioretention cells that are placed at the curb (typically where storm drain inlets are positioned). They receive the first flush of runoff along the curb and the storm water is filtered through layers of vegetation and soil before it enters a catch basin. Tree box filters also beautify the streetscape with landscape plantings such as street trees, shrubs, ornamental grasses, or perennials and can be used to improve the appearance of an area or to provide habitat.

Typical Uses: Positioned along the curb of a street; particularly effective at targeting point source pollution in urban areas by retrofitting/ replacing existing storm drains.

Land Use: Commercial, residential (urban, suburban, ultra-urban), and industrial areas.

Approximate Cost: Approximately $6,000 per unit per 1/4 acre of impervious surface. This estimate includes two years of operating maintenance and filter material and plants. Additional costs include installation and annual maintenance. Installation is approximately $1,500 per unit (varies with each site).

Maintenance: Tree box filters require more specialized maintenance to ensure filter media is not clogged and there is no accumulation of toxic materials, such as heavy metals. Maintenance is typically performed by Departments of Transportation or agencies responsible for storm drain maintenance. Annual manufacturer maintenance is $500 per unit; owner maintenance costs are approximately $100 per unit.

Additional Benefits: Improves water quality and enhances the community.

6) Disconnected Downspouts

Downspouts can be disconnected from underdrains and the runoff directed to vegetated areas to reduce runoff volume, promote infiltration, and change runoff timing.

7) Rain Barrels and Cisterns

Rain barrels are placed outside of a building at roof downspouts to collect and store rooftop runoff for later reuse in lawn and garden watering. They can be used to change runoff timing and to reduce runoff volume. Rain barrels have many advantages in urban settings. They take up very little space, are inexpensive, and are very easy to install.

Cisterns are larger storage facilities for non-potable use in residential, commercial, or industrial applications. They store water in manufactured tanks or underground storage areas. They can be used with any type of roof structure to intercept runoff and reduce runoff volume. The water can be treated and used for domestic purposes, fountains, pools, gray water, air conditioning, and other purposes. Both cisterns and rain barrels can be implemented without the use of pumping devices, instead relying on gravity flow.

Typical Uses: Placed outside of homes or businesses to irrigate landscaping.

Land Use: Residential, commercial, industrial.

Approximate Cost: Rain barrels cost approximately $120; the cost of cisterns varies depending on their size, material, location (above or below ground), and whether they are prefabricated or constructed on site. They range in volumes from hundreds of gallons for residential use to tens of thousands of gallons for commercial and industrial use.

Maintenance: Rain barrels require regular maintenance by the home/ business owner, including draining after rainstorms and removal of leaves and debris collected on screens. Cisterns, along with all their components and accessories, should undergo regular inspection at least twice a year.

8) Site Appropriate Landscaping

Fig. 24: Native plants thrive in dry conditions

When selecting plants for a landscape design, it is important to have knowledge of the site conditions. Plant materials should be selected for their form, color, and texture, as well as solar, soil, and moisture requirements. Plants that do well in various micro-climates on a site are considered "site appropriate."

It is increasingly recommended that native plants (vegetation that grows naturally in particular climates or regions) be used because of their performance, site enhancement, and life-cycle cost benefits. Native plants typically cost more initially (depending on local availability); however, they are more cost-effective in the long run because they require less water and fertilizer, and are more resistant to local pests and diseases than non-native ornamentals. Life-cycle costs are reduced due to reduced maintenance and replanting requirements. Native plants are also known to be very effective in managing storm water because many species have deep root systems which stabilize soil and facilitate the infiltration of storm water runoff. Additionally, native plants provide habitat for local/regional wildlife.

Care should be taken to not plant invasive species as they tend to crowd out the native species. Some common groundcovers, shrubs, and vines are invasive and are prohibited from being planted. Refer to your state list of invasive plants.

9) Other LID Technologies Include:

a. Green Roofs—Vegetated rooftops that use a plant-soil complex to store, detain, and filter rainfall. They reduce runoff volume and improve runoff timing. These multilayered systems use a lightweight soil mixture and sedums (not grass) to provide energy conservation benefits and aesthetic improvements to buildings. They can be used on expansive concrete roof buildings ("big boxes") or small-scale residential roof structures.

b. Soil Amendments and Aeration—Soil amendments increase the infiltration and water storage capabilities to reduce runoff from a site. Additionally, the compost, lime, or organic materials alter the physical, chemical, and biological characteristics of the soils to improve plant growth. Aeration of the soil, which can be done in conjunction with routine mowing activities, can increase the storage, infiltration, and pollutant filtering capabilities of grassed areas.

c. Pollution Prevention Lawn Care—Proper fertilizer and pesticide applications will significantly contribute to lowering nutrients and chemical impairments. These include fall fertilization to decrease nutrient runoff.

Low Impact Development Technologies

Refer to Achieving Sustainable Site Design through Low Impact Development Practices Resource Page for more detailed descriptions about the LID site design approach, the site design process, and case studies.

Relevant Codes and Standards

Regulatory Compliance

Chesapeake Bay Agreement 2000

Clean Water Act

Section 303. Total Maximum Daily Loads

Section 311. Spill Prevention, Control, and Countermeasure Requirements

Section 319. State Non-Point Source Management Program

Section 401. Certification and Wetlands

Section 402. National Pollutant Discharge Elimination System (NPDES) Program

Section 404. Regulation of Dredged or Fill Material

Coastal Zone Management Act

Energy Policy Act of 1992

Estuaries and Clean Waters Act of 2000

National Environmental Policy Act of 1969

Safe Drinking Water Act Wellhead Protection Program

Federal Directives

Executive Order 13693, "Planning for Federal Sustainability in the Next Decade"