Tool-Box Approach to Wet Growth

Module 2

Low-Impact Development

Cover: Green roof in Chicago Illinois. (Photo: U.S. Environmental Protection Agency)

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Introduction

Low-Impact Development (LID) is an innovative approach to manage storm water, reduce runoff, and conserve and improve water quality. LID techniques are very versatile and can be used in new developments or retrofitted to existing sites. Basically, LID uses a set of site planning and landscape design tools to manage storm water runoff at the source and restore the original hydrological functions of landscapes after development. Examples include infiltration, frequency and volume of discharge, ground water recharge, etc.

LID is a relatively new concept. Instead of managing and treating storm water in large and very expensive end of pipes facilities, LID manages storm water through small and cost effective landscape features. These landscaping features are located at the lot level itself.

"Ten Common LID Practices" are listed below (Arnold, 2009):

- Rain gardens and bioretention
- Rooftop gardens
- Sidewalk storage
- Vegetated swales,
- Buffers and strips and tree preservation
- Roof leader disconnection
- Rain barrels and cisterns; permeable pavers
- Soil amendments
- Impervious surface reduction and disconnection
- Pollution prevention and good housekeeping

Traditional site design methods and development practices tend to remove more trees and vegetation and add more impervious surface (like roofs and parking lots) than LID techniques. Runoff from impervious surfaces enters water sources at a high velocity and alters the natural flow of water in the environment, which eventually changes the original structure of watersheds. This water also picks up pollution from impervious surfaces and carries it to water sources, degrading water quality. By using smarter LID design methods, developments have less negative impact on the volume, velocity and quality of runoff. It protects otherwise deteriorating aquatic ecosystem and preserves the physical structure of the receiving streams. The techniques of LID cannot only be implemented in open spaces but also in roof tops, streetscapes, parking lots, sidewalks and so on. Several goals that LID aims to achieve are listed below:

- Provide improved and advanced techniques for protection of receiving waters
- Manage storm water as close to its source as possible
- Protect the natural features and flow of water
- Minimize the impacts of development and protect the environment
- Optimize site design for water management after site analysis is completed
- Achieve the full potential of environmentally sensitive site planning and design
- Reduce construction and maintenance costs of storm water infrastructure

Benefits of Low-Impact Development

LID has enormous environmental, economic and social benefits. Its techniques manage high storm water flows; remove pollutants from storm water, and refill streams and wetlands. Since LID techniques reduce impervious surfaces, this approach thus helps to increase vegetation and infiltration which results in less runoff and thereby decrease the possibility of flooding from big storms.

Urban sprawl as depicted by miles of residential subdivision development. (Photo: U.S. Department of Agriculture National Resources Conservation Services.)

Today, most areas are facing the negative environmental impacts of urban sprawl as it consumes green space, promotes auto dependency, and widens urban areas. LID addresses most of these impacts. LID techniques promote a greener environment which in turn helps to improve air quality. Because the technique also helps to lower the ambient temperature, the consumption of energy to cool down homes may also be greatly reduced. Furthermore, LID maintains the ecological and biological systems as it lessens the impact on many local terrestrial and aquatic plants and animals.

LID practices have a lot of economic benefits as well. Since LID techniques costs less to install, operate and maintain, it provides more cost-effective storm water management compared to traditional storm water control approaches. Furthermore, LID practice significantly reduces the development costs by reducing amount of materials needed to construct impervious surfaces such as streets, curbs, gutters, sidewalks, etc.

Low-impact development helps to preserve the natural environment and maintain a balance in ecological system (Photo: U.S. Environmental Protection Agency)

Reducing the cost of land clearing, grading and decreasing the use of storm drain piping, inlet structures and storm water ponds can also lower development cost. LID approaches not only lowers construction costs, but also lower regulatory costs significantly. Several communities offer simpler development permit processes and other incentives if LID techniques are implemented. Moreover, LID projects often require lower impact fees as there is less impact on the environment. Municipalities achieve economic benefits from LID techniques as the cost for municipal infrastructure and utility maintenance is greatly reduced (U.S. Department of Housing and Urban Development [HUD], 2003).

LID practices increase the appearance and aesthetics of a community and provide a stronger sense of a place. Since this technique allows for more trees and vegetation and less impervious surfaces, it helps communities look greener and more habitable which in turn improves the property values. LID can also offer benefits outside the obvious. For example, one major LID technique is a narrower street which means lower vehicular traffic speeds. When the speed is lowered, there is less chance for pedestrian accidents and fatalities. Thus, LID approach increases public safety in the community. LID practices have social as well as environmental and economic benefits.

Limitations of Low-Impact Development

While there are several benefits of LID practices for the environment, developers, municipalities and even local communities, challenges sometimes arise during the development process of proposed LID techniques. Since local ordinances, subdivision codes, zoning regulations, parking and street standards generally guide the design and construction of new developments these ordinances sometimes appear to be restrictive. LID practices could be incompatible with development practices adopted in outdated ordinances. Developers who are willing to use LID techniques may have to obtain variances or special use permits from local planning agencies until the local codes are updated to reflect current practices. This can delay the approval and permitting process which may hamper the developers financially. However, this situation could be avoided if municipalities update codes and ordinances to allow LID in land development projects.

Community perception regarding LID may also prevent implementation. Some homeowners will still want large lots, and wide streets that are inconsistent with the LID approach. Moreover, some people may believe they will experience flood and subsurface structural damage without traditional management practices like curbs, gutters and end of pipe water management. Altering these beliefs may be a challenge, but providing educational presentations or publications on LID may help homeowners or even municipal officials better understand the benefits of this approach.

Low-Impact Development and the Community

Growing concern with the impact of development on water resources is leading many communities to begin to consider enacting measures to “turn the tide” and ensure further degradation of water resources is prevented. Measures to ameliorate and the impact of development and curb future impacts can be extremely complex (see below for a list of many suggestions considered across the nation). Local governments interested in promoting or requiring low impact development in their community could easily be daunted by process. Understandably, busy planners, developers, and elected officials may not have the time to read all the literature available. This guide takes a modular approach designed to quickly bring the busy professional up-to-date with the many measures being taken by local governments in conjunction with the development community to bring LID practices into the mainstream.

Basically, the idea of LIDs is to mitigate the impact of impervious surfaces, such as parking lots, roofs, and roads, and to discourage the planting of water intensive plants in regions not naturally suited for such plantings. Communities have good reason to start taking measures to include LIDs in their plans for the future. LID practices offer the potential to address many concerns in developed areas such as disappearing open space, and nonpoint source pollution (Nolon, 2007).

Low-impact development is essential in protecting and preserving natural wetlands. (Photo: U.S. Fish and Wildlife Service)

Additionally, the federal government, through the Clean Water Act §402(p) is authorized to regulate storm water discharges from municipalities. This is done through the mechanism of regulating "point source pollution," or pollution that can be traced to a single source, such as a pollution-emitting pipe. Most urban watersheds violate water standards under the measure. Property owners in these urban watersheds are often the owners of some structure, sometimes as seemingly innocuous as a drainpipe, that could be regulated under the letter of the law as a point source that contributes to impairment of the waterway (Owen, 2011).

Local governments play an important part in sustainable development around water resources. Action at the local level regulates and permits developments that create impervious surfaces. Planning boards and commissions can enforce standards in comprehensive plans and zoning codes when developers seek approval for projects. The comprehensive plan can be an effective vehicle for regulation since in most states new developments must meet the standards enacted in the plan. Examples of uses of local land use rules include:

- Some zoning codes create overlay zones to protect especially sensitive areas.
- Other codes follow natural barriers to optimize protection.
- Codes may require all developments are built to have a neutral impact on runoff; requiring sites hold water on site and release it slowly as would occur without impervious surface.
- Procedures may incentivize LID incorporation with density bonuses, expedited approval processes, and reduced sewer charges.
- Subdivision approval may be contingent of best management practices for the lessening of the sites impacts.

- Tree preservations ordinances can limit developer's freedom to remove local trees from a development or to offer an explanation of the necessity of removing any trees on site (Nolon, 2007).

Local measures are extremely important and can be very effective, but their success depends on development at the local level of measures appropriate for the community enacting the measures. While a city such as Los Angeles will have access to professional resources necessary for assisting developers with integrating complex regulatory requirements, and later enforcing compliance with requirements, other areas may need to start more modestly (Subcommittee on Water Resources and Environment, 2010). For some communities, this guide may be useful only to fill in small gaps in local efforts to promote LIDs. For other communities, this guide may help identify important first steps recommended by experts who have analyzed efforts already undertaken.

Nonpoint source pollution. (Photo: U.S. Fish and Wildlife Service)

The Center for Watershed Protection (1998) suggests a four-step process:

1. Learn what the development rules are in your community. This can be complicated and in some cases this will involve several local and state agencies that exert some authority over development rules. It will at least involve locating rules for subdivision, the comprehensive plan, zoning code, land development codes, and rules for the local sewer district.
2. Checking the local codes against model codes and ideas from other communities. Some might find the worksheet in *Appendix B* useful to see how local rules compare. It is important to note, however, that water management is not one-size-fits-all. A plan that works in one place may fail in another because of regional differences.
3. Consider which development rules might be changed. Changing local rules requires considerable effort, which means it is important to only change those with potential to yield real improvement.
4. Start a local roundtable process. Changes in rules pertaining to developments will result in some resistance from residents concerned with the impacts of new rules. A professional preparing to begin a discussion should be prepared to answer economic and social concerns raised by the development. Many LIDs will have positive economic and social results, being both less expensive in some instances than other options for infrastructure and often providing aesthetical features. Stakeholders should be carefully identified to make sure elected officials, members of the development and environmental community, and citizen groups are present for the discussion. Strong local buy-in is important for the success of measures to promote LID. For detailed information on partnerships between local governments and the development community see *Useful Resources* on page 22.

An important starting point for local governments is to make sure applicable land use regulation requires developers to justify not using LID practices, and not applying for permission to incorporate them into plans. A community can start with relatively simple goals such as:

- Minimizing native vegetation loss with landscaping and tree standards.
- Minimizing impervious surface creation by reducing parking requirements and subdivision standards.
- Minimizing storm water surface runoff by considering modifications of clearing and grading ordinances and standards (Puget Sound Organization, 2011).

Communities should also consider obtaining a water flow analysis. Water flow analyses use geographical information systems software with satellite imagery to calculate the impact of development on water flow in an area. Metropolitan governments may already employ specialists with the knowledge required to conduct such studies. Planners in smaller communities may look to resources available through their state government and local universities. In some cases the information may already exist (Nolon, 2007).


An aerial view of how water flows through a region. (Photo: U.S. Fish and Wildlife Service)

Percentage of impervious surface in an area, which will be part of the analysis, can serve as a benchmark for planners. An area may find through research that the watershed can handle, for example, 11 percent impervious surface without being impaired by the runoff from the surfaces. An area would begin to regulate new developments based on this figure, usually allowing for a margin of error (such as allowing 9 percent in the example) to account for the limitations of estimates of watershed capacities. This method, based on Total Maximum Daily Loads (TMDLs), sets a ceiling on the amount of runoff caused by impervious surfaces acceptable in an area. While effective in many areas, TMDLs is currently in a legal gray area and has not yet been tested in court (Owen, 2011).

Generally, however, local governments are allowed to make their own standards as long as these standards are not in conflict (pre-empted) by state laws. Again, it is important to know what your state allows. Some states directly authorize augmentation of environmental regulation by communities. Currently, local regulation runs the gamut from extremely sophisticated to non-existent (Owen, 2011). The *Appendix* is a source for model codes, though it is important to remember a community should be careful to ensure a code meets local needs.

Philadelphia is one of the nation’s leaders in promoting LID. The storm water management plan is designed to manage the first inch of runoff on a third of the impervious cover within the city’s combined sewer drainage area and restore two miles of urban stream corridor. This is achieved through promotion of tree trenches, street/ sidewalk planters, bioswales, rain gardens, porous pavement, green roofs, living walls, and infiltration beds (Subcommittee on Water Resources and Environment, 2010).

On the ground the program is characterized by:

- Strong storm water regulations. Developers must manage storm water on-site. This reduces collective costs for managing storm water in Philadelphia.
- "Cost of service" storm water charge encourages land owners to use their properties in a sustainable manner through such methods as:
    1. Impervious pavement in parking;
    2. Carving out green space on site;
    3. Planting trees; and
    4. Paying for the privilege of the city collecting their rain water for them.
- Encouraging developers and property owners to use LID to meet storm water requirements (Philadelphia is second only to Chicago in number of green roofs).
- Urban in-lieu fee program to help developers identify sites for remediation as a trade-off for water takings or wetland losses due to construction activities. Also, they have developed an evaluative tool to make mitigation funds available to be used to improve urban streams and wetlands in areas of the city often overlooked and underfunded for such activities.

An important consideration for a community interested in enacting design-based codes, those designed to promote LID features, is the difficulty of enforcing standards. Complex standards are not likely to be followed without the help of competent code enforcers. Details become extremely important. Attention must be paid to address many considerations (quoted from Center for Watershed Protection, 1998):

- What conditions are imposed on subdivisions and site plans?
- How detailed are they?
- Where are they recorded?
- Are they on the filed subdivision or site plan plat?
- Are subsequent purchasers on notice of them?
- Who decides that the conditions are not being met?
- What procedures are to be followed if they are not (both during and after construction)
- What are the penalties for violating land use conditions?
- What is the process for imposing them? Is this the role of a public attorney as prosecutor?

What follows is a series of suggestions organized into categories of improvements a community might make to their code to facilitate incorporation of LID principles into developments. No community will feature all these measures, as compliance would be extremely costly and difficult. The list is intended to consolidate many suggestions for local action to promote LID. The general structure of the list and all suggestions not otherwise citied are from the Center for Watershed Protection (1998).

Suggestions

Residential Streets and Parking Lots

1. Design residential streets for minimum required pavement, based on traffic volume.
2. Consider street layout for minimum length of residential streets, design to maximize houses per length of residential streets.
3. Residential street right-of-way widths should reflect the min require to accommodate travel-way, sidewalk, and vegetated open channels. Utilities and storm drains should be located in the pavement section of the right of way when feasible
4. Minimize number of residential street cul-de-sacs and incorporate landscaped areas to reduce their impervious cover. Radius of cul-de-sacs should be the minimum required to accommodate emergency and maintenance vehicles. Alternative turnarounds should be considered.
5. Where area allows (density, topography, soils, slope) vegetated open channels should be used in the street right-of-ways to convey and treat storm water runoff.
6. Parking ratio governing particular land use or activity should be enforced as both a maximum and minimum. Take into account local and national experience to evaluate adequacy.
7. Parking codes should be revised to lower parking requirements where mass transit is available or enforceable shared parking arrangements are made.
8. Provide compact car spaces, minimize stall dimensions, incorporate efficient parking lanes, and use pervious material used in spillover areas.
9. Provide meaningful incentives to encourage structured and shared parking to make it more economically viable.
10. When possible, provide storm water treatment for parking lot.

Lot Development

11. Advocate open space development that incorporates smaller lot sizes to minimize total impervious area, reduce total construction costs, conserve natural areas, provide community recreational space, promote watershed protection.
12. Relax side yard setbacks and allow narrower frontages to reduce total road length in the community and overall site imperviousness. Relax front setback required to minimize driveway lengths and reduce overall lot imperviousness.
13. Promote flexible design standards for residential subdivision sidewalks linking pedestrian areas.
14. Reduce overall lot imperviousness by promoting alternative driveway surfaces and shared driveways that connect two or more homes together.
15. Clearly specify how community open space will be managed and designate a sustainable legal entity responsible for managing both natural and recreational open space.
16. Direct rooftop runoff to pervious areas such as yards, open channels, or vegetative areas and avoid routing rooftop runoff to the roadway or storm water conveyance system.

17. Require the use of LID techniques as a condition for subdivisions. Include language in code to ensure appropriate measures are used to manage storm water with LID where feasible. Emphasize conservation and use of on-site, natural features.
    - LID should be used unless proven infeasible.
    - Provisions should be included to preserve open space, native vegetation sensitive environmental features, and minimize impervious surfaces.
    - Require applicants to conduct an LID site analysis and bring results to pre-application conferences. Work with developer to identify proposed LID best management practices (Puget Sound Organization, 2011).
18. Require a portion of the lot based on land use and density to be devoted to native species of plants.
19. Require a portion of native trees on site; attach a table of trees to the code that meet the requirement.

Conservation of Natural Areas

20. Riparian stream buffer should be preserved or restored with native vegetation that can be maintained throughout the delineation, plan review, construction, and occupancy stages of development.
21. Clearing and grading of forests and native vegetation at a site should be limited to the minimum amount needed to build lots, allow access and provide fire protection. A fixed portion of any community open space should be managed as protected green space in a consolidated manner.
22. Conserve trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting use of native plants. Whenever practical, manage community open space, street rights-of-way, parking lot islands, and other landscaped areas to promote natural vegetation.

Incentives

23. Use incentives and flexibility in the form of density compensation, buffer averaging, property tax reduction, storm water credits, and by-right open space development should be encouraged to promote conservation of stream buffers, forests, meadows, and other areas of environmental value.
24. New storm water outfalls should not discharge unmanaged storm water into jurisdictional wetlands, sole-source aquifers, or sensitive areas.
25. Transfer of Development Rights credits for LID
    - Has been suggested as a way to achieve most cost effective distribution of storm water abatement within a watershed
    - But hard to monitor with nonpoint source schemes (Eason, Dixon, Feeney, VonRoon, Keenan and Craig, n.d.).
26. Waivers of code requirements as a trade-off for incorporation of LIDs.

Others

27. Portland charges for storm water treatment, allows mitigation up to 100 percent for impervious surface minimization and retention of large trees.
28. Charging for external costs of conventional development such as damage created by runoff from impervious surfaces.
29. Public Education may increase willingness-to-pay. Public education has been shown to provide a significant incentive for changing behavior (Eason, et al., n.d.).

Low-Impact Development Site Planning Concept

Before planning a site, it is necessary to conduct a site analysis. Site analysis is a process by which the developer examines the site's natural characteristics and features. This helps the developer understand development opportunities and constraints. Soils, vegetative patterns, water resources, topography, hydrology, micro climate, and solar orientation are only some of the features analyzed in this process. For LIDs, the site analysis is followed by site planning. The primary goal of LID site planning is to maximize development of a property while still maintaining the sites original hydrological functions. LID site planning techniques provide the correct measures to facilitate the development of site plans that are adapted to natural topography. Site planning helps to minimize a site's impact on hydrology, maintain lot yield, and provide an aesthetically pleasing environment with less expensive storm water management controls. The site's hydrological goals and objectives should therefore be incorporated into the site planning process as early as possible. There are a few fundamental concepts that are essential to low impact development. These should be integrated into the site planning process to achieve a successful and workable plan. These concepts, developed by the U.S. Environmental Protection Agency (EPA) (1999) are described below:

1. *Using hydrology as the integrating framework*: Hydrology means the movement of water into and across the site. A hydrologically integrated site plan maintains predevelopment hydrology. To integrate hydrology into the site planning process sensitive areas that affect hydrology should be identified and preserved. These sensitive areas may be streams, wetlands, floodplains, buffers, steep slopes, high-permeability soils and woodland conservation zones. After the sensitive areas are identified, the potential site development and layout should be performed to reduce, minimize and disconnect the total impervious area at the site. Further analysis should be conducted on unavoidable impervious areas to reduce the directly connected impervious surfaces. The final result of this analysis is an integrated hydrologically functional site plan that maintains the predevelopment hydrology and improves site aesthetics as well.

2. *Thinking micromanagement*: To make the LID concept successfully work, the developer must think small. This requires a change in approach to the area being controlled. Micromanagement techniques implemented on small areas or residential lots allow for the distribution of storm water control throughout the entire site. This provides significant opportunities to maintain a site's key hydrological functions like infiltration, depression storage, interception and also a reduction in concentration time. Moreover,

micromanagement techniques provide a broad range of control practices that can be adapted according to site conditions, it also helps provide volume control and maintain predevelopment groundwater recharge functions.

3. *Controlling storm water at the source*: The best approach to restore the predevelopment hydrological functions is to reduce and mitigate the hydrological impact of land use activities as close to the source of generation as possible. Several natural functions such as depression storage, interception and infiltration are homogenously distributed throughout an undeveloped site. Therefore these functions should be restored as close to the source as possible to where the impact or disturbance is actually generated. Controlling storm water at the source is beneficial from an economic standpoint as the cost of conveyance and control or treatment increases with the increase in distance from the source.

4. *Using simplistic and nonstructural methods*: Simple solutions and approaches often have potential to be more effective in preserving the hydrological functions of site. Simplistic methods in LID techniques can decrease the use of typical building materials such as steal or concrete. It is easier to integrate natural materials like native plants, soil and gravel into the landscape compared to artificially engineered systems. Natural features are also more aesthetically pleasing and this might increase the homeowner's acceptance and willingness to adopt the system. Important additional advantages of the small, distributed, micro-control systems is that one or more of the systems can fail without hampering the overall integrity of the site's water management and causing the management strategy to fail. Furthermore, these landscape features could result in significant cost savings in maintenance and up-keep.

5. *Creating a multifunctional landscape*: LID allows strategically integrating storm water controls into any urban or rural landscape. Several urban and landscape features like roof, streets, parking lots, and sidewalks could be innovatively designed to create a multifunctional landscape and infrastructures. This can be done by incorporating the LID techniques to retain, detain, filtrate, use and treat runoff within the landscape features that are unique to a site. The best way to achieve this is by establishing bioretention cells at the site (a detailed explanation of bioretention cells is given on page 12).

Site Planning Process in Low-Impact Development

The site planning process explains how fundamental design concepts could be used to minimize the hydrological effects of developments. Several steps in the LID site planning process are listed below:

Step 1: Identify applicable zoning, land use, subdivision and other local regulations
Step 2: Define development envelope
Step 3: Use drainage/hydrology as a design element
Step 4: Reduce/Minimize total site impervious areas
Step 5: Integrate preliminary site layout plan
Step 6: Minimize directly connected impervious areas
Step 7: Modify/Increase drainage flow paths
Step 8: Compare pre- and post-development hydrology

Step 9: Complete LID site plan

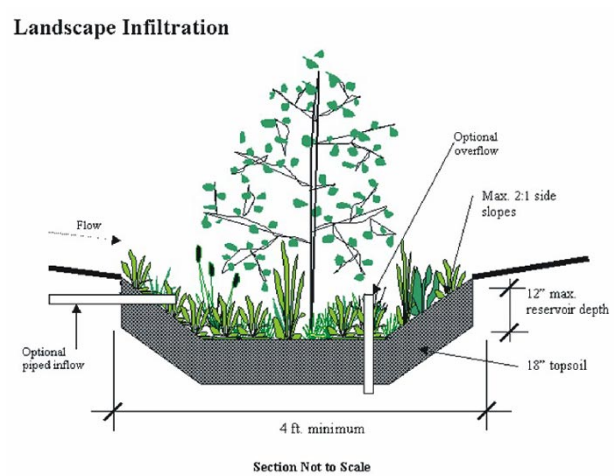
Further details on LID site planning concept and site planning process can be found in *"Low-Impact Development Design Strategies - An Integrated Design Approach"* prepared by Prince George's County, Maryland. Click here

Low-Impact Development Design Strategies

As discussed previously, LID can be both simple and effective. It implements several economic devices to control runoff at the source itself rather than using complex and expensive collection, conveyance, storage and treatment systems. Bioretention, green roofs, permeable and porous surfaces, grass swales, rain gardens, and soil quality restoration are a few of many LID design strategies that are used to restore predevelopment hydrology of a site and prevent impervious surfaces from discharging runoff into the storm drainage system.

Bioretention

Often times, LID practices uses microscale and distributed management techniques to maintain the natural hydrology of site even after the development. These techniques are known as Integrated Management Practices (IMPs). There are several management practices that are best suited for LID. Bioretention systems are one of them. Bioretention or rain gardens are relatively small scaled landscaping features that treat and manage storm water runoff. This is a natural method of controlling the pollutants from entering the urban water bodies. This concept of storm water management was first introduced in 1990s by the Prince George's County, Maryland Department of Environmental Resources as an alternative to conventional Best Management Practice (BMP) structures. Bioretention systems are designed based on soil type, site conditions, and land uses. Most often bioretention techniques are used in residential and commercial areas. They are occasionally used in industrial areas. Bioretention areas are basically shallow topographic depressions that contain vegetation like shrubs, perennials and trees and a soil mixture. The soil mixture used is usually altered and compacted and usually includes gravel and specified mixture of sand, compost and topsoil. These elements retain, treat and infiltrate the runoff from pervious structures like parking lots, streets, driveways, and roof tops.

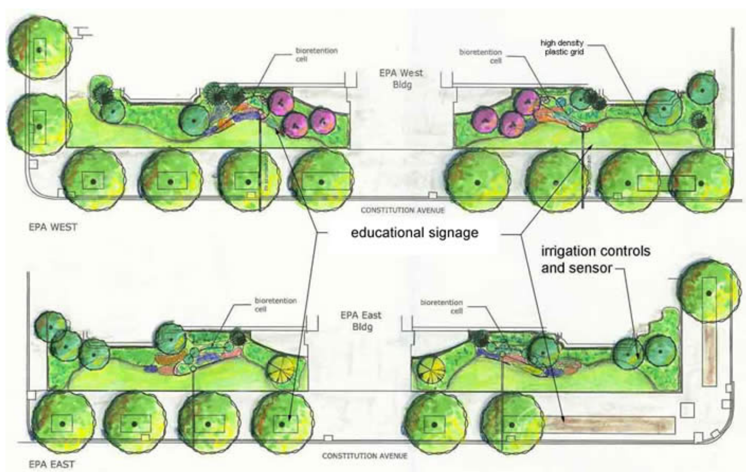


(Illustration: U.S. Environmental Protection Agency)

Usually, bioretention areas are designed to receive water volume from up to a 1.5 inch of rain. Since bioretention systems are designed for the temporary storage of rainwater the system removes pollutants from water. In this regard, bioretention is one of the most recognized LID techniques for storm water management. Bioretention facilities typically have six components (U.S. Environmental Protection Agency [EPA], 1999). These are listed below:

- Grass buffer strips – to reduce the runoff velocity and filtrate the pollutants;
- Sand bed – to provide aeration and drainage of the planting soil and to assist in sweeping away pollutants from soil materials;
- Ponding area – to provide storage of excess runoff and to help settle particles and evaporate excess water;
- Organic layer – to decompose organic material and provide an appropriate environment for biological growth to degrade the petroleum based pollutants;
- Planting soil – to absorb pollutants like hydrocarbon, heavy metal and nutrients as it contains some amount of clay;
- Vegetation – to help in the removal of water through evaporation and transpiration and to remove pollutants through nutrient cycle.

Generally, appropriately designed and constructed bioretention cells can remove several heavy metals associated with runoff. This technique is expected to remove more than 90 percent of copper, zinc, lead that are present in water with only minor variations. It has also been found that about 98 percent – 99 percent of zinc and lead have been efficiently removed in many cases. The removal of phosphorous is associated with the depth of the facility. The maximum amount phosphorus is removed at depths of two feet to three feet.



(Illustration: U.S. Environmental Protection Agency)

In the lower level of sampled bioretention cells, there was about 70 percent to 80 percent reduction in ammonia. Several studies have shown that heavy metals are the main pollutants in most of the urban areas. Therefore in such areas, bioretention facility with a thicker layer of mulch is recommended since it will help with pollutant removal. However, pollutants in residential areas are usually nitrogen and phosphorus. In this case, the depth may vary from two feet to three feet (click here for more information).

Benefits and limitations

Bioretention is a very simple and effective approach for the treatment of storm water runoffs. This system not only manages and decreases the surface runoffs but also enhances the quality of downstream water bodies by treating pollutants through various processes and increases the volume of ground water recharge. Compared to traditional methods of storm water management, bioretention retains the natural hydrologic conditions more closely and permits the infiltration processes. It also allows evaporation and transpiration to occur. Bioretention is also an effective method to preserve wildlife and aquatic habitat and minimize erosion. Additionally, it provides shade and wind breaks, absorbs noise and improves the appearance of an area. Bioretention techniques are superior to traditional storm water conveyance systems in terms of better environmental protection, but also in term of less installation and maintenance cost. There is an obvious reduction in the construction cost as bioretention technique use less of storm drain pipes compared to the conventional system (HUD, 2003).

However, there are still some drawbacks associated with a bioretention system and the usefulness of this technique is limited to some sites. Bioretention facilities are not an appropriate management practice at all locations, especially where the water table is within 1.8 meters (or six feet) of the ground surface or the slope of the area is greater than 20 percent (EPA, 1999). Also it cannot be used to manage a large drainage area. This technique is also not feasible where the soil stratum is not stable. Moreover, in cold climates, the soil may freeze which may then prevent runoffs from penetrating the planting soil. There may also be problems of clogging if the bioretention facility receives runoffs with high sediments loads.

Associated Costs

Bioretention facilities are slightly expensive to establish than the cost of landscaping for a new developed area. The cost associated with this LID techniques are related with following works (EPA, 1999, pp.7):

- Excavation from 0.6 meter to one meter (two feet to three feet);
- Planting of trees and shrubs (one to two trees; three to five shrubs);
- Filling the area with planting soil;
- Additional cost in retrofitting (demolition of concrete, asphalt, other existing structures);
- On average, bioretention cost $3 to $4 per square foot depending upon the quantity of water treated and excavation (Dietz, 2007); and
- Plant material cost approximately $6.40 per cubic feet of storm water treated (Dietz, 2007).

Case Studies

1. *Poplar Street Apartments, Aberdeen, North Carolina*: The Poplar Street Apartment complex is designed as a 270-unit building. It utilized LID techniques like bioretention, topographical depressions, grass channels, swales, and storm water basins. This resulted in significant reduction in construction costs and an effective storm water treatment. The design created a longer path of flow, decreased in volume of runoffs, filtration of pollutants from runoffs. Additionally, it prevents nearly all storm water runoff. The project was a success and the U. S. Department of Housing and Urban Development reported that the use of these LID techniques led to savings of 72 percent (EPA, 2007).

2. *Inglewood Demonstration Project, Largo, Maryland*: A study to analyze a possible bioretention method for the removal of pollutants was conducted in the parking lot of the Inglewood Plaza.

   Project Description

   An area of 50 sq. ft. in the south facility was studied for the simulated rainfall event. The bioretention facility located 32.5 inches below the surface contained a T-shaped under drain that ran the entire length of the system. The under drain was directly connected to the storm drainage system. Output samples were collected every 30 minutes from a pool of water in the storm drain observation area. Since the soil was dry due to the lack of rainfall for several days, at the onset of the experiment a synthetic rainfall was applied at a rate of 1.6 inches per hour for a total of six hours (EPA, 2000).

   The findings from the experiment were:

   - Retrofitting an existing parking facility is feasible for pollutant removal.
   - Retrofitting at approximately $4,500 was more cost effective in filtering pollutants than other devices which could have cost anywhere from $15,000 to $20,000.
   - Bioretention decreases the runoff volume and temperature more significantly than other mechanisms.
   - This technique adds aesthetics to the parking lot in the plaza.

(Photo: U.S. Environmental Protection Agency)

Vegetative (or Green) Roofs

The Low Impact Development Center, in Beltsville, Maryland defines a green roof as a multilayered construction consisting of a vegetative layer, media, a geotextile layer and a synthetic drain layer. There are two main types of vegetative roofs, which may be incorporated into existing buildings and new construction alike.

Types of Green Roofs

Shallow Systems (or "extensive") have a depth of approximately 4"-6" and are typically only accessible for maintenance. Extensive systems are not intended for daily use or recreational purposes. There are three types:

- *Modular tray systems* allows for growing medium and vegetation in 'modules' or trays
- *Modular continuous systems* allows for rolls of growing medium and vegetation

- *Loose laid systems* allow varying depths of growing medium in traditional green roof layering of materials.

Deep Systems (or *green roof gardens* and "*intensive*" systems) typically have a depth of growing medium that exceeds 6-8". Intensive systems allow for greater plant diversity but are also heavier. The typical weights of deeper green roofs vary between 80 to 150+ pounds per square foot. Their advantages over extensive systems include greater plant diversity and biodiversity, and better storm water management. Deep systems allow for daily use and access.


Green roof. (Photo: U.S. Environmental Protection Agency

Benefits and Limitations of Green Roofs

In urban areas, green roofs improve the lifespan of roofs, reduce energy costs and conserve land that would otherwise be required for storm water runoff controls. Research has shown that by using a green roof, 60–70 percent reductions in storm water runoff volume from a roof are to be expected (Dietz, 2007). This is important in cities where space for storm water treatment is expensive and limited. By reducing the percentage of impervious surfaces in urban areas, vegetative roofs are particularly effective in older urban areas with chronic combined sewer overflow (CSO) problems that result from high levels of imperviousness. Regardless of these benefits, green roofs remain troublesome due to a high initial cost, whether from the increased structural reinforcement required, or installation costs. The benefits for these interventions, however, are experienced in the long run. For information about mediating these factors with potential developers and buyers, refer to the *Low-Impact Development and Public Outreach* section on page 20 of this module.

Costs Associated with Green Roofs

Green roof costs projects vary wildly across the country due to several variables that influence the overall project cost. Cases studies are a more effective way of looking at potential costs, as cost varies with construction type, market location, as well as the following factors:

- Retrofit versus new construction;
- Potential structural upgrades and/or re-roofing;
- Type of green roof – shallow or deeper (extensive versus intensive);
- Accessibility;
- Maintenance costs; and
- Maturity of market in city/region.

Case Studies

For more information, please visit the National Low Impact Development (LID) Atlas, available online at http://clear2.uconn.edu:8080/lidmap/index.php. This resource provides nation-wide examples of various types of LID interventions. Another helpful resource is the Green Roof Database, accessible at http://www.greenroofs.com/projects/.

1. *U.S. Environmental Protection Agency (EPA) Region 8 Headquarters Green Roof*

The following case study showcases an Extensive modular tray system, quoted from "Design Guidelines and Maintenance Manuals for Green Roofs in the Semi-Arid and Arid West" (Tolderlund, 2010)

Location: Denver, CO
Completion: 2006
Green Roof Category: New
Green Roof System: Extensive; modular tray
Size: ~20,000 square feet
Media Depth: 4 inches
Cost: $15.50 per square foot (waterproofing, modular systems, irrigation and two years of maintenance/guaranteed plant survival)

Project Description: The primary objective of EPA's green roof is to absorb the precipitation which contacts the roof surfaces, and to release it at a reduced and measured pace. The green roof is expected to reduce peak flow and runoff volumes from rain and snow-melt events to mimic a more natural landscape. Reducing the peak flow will minimize impact to the South Platte River from concentrated storm water runoff.

2. *Mary Catherine Bunting Center at Mercy Medical Center*

Location: Baltimore MD
Completion: 2010
Green Roof Category: New
Green Roof System: Intensive
Size: 17,500 square feet
Cost: $57.00 per square foot

Project Description: "The new Mary Catherine Bunting Center at Mercy Medical Center is an 18-story, 688,000 sq. ft. hospital facility located in the 300 block of St. Paul Place, Baltimore, adjacent to Mercy's current campus. Mercy installed 17,500 sq. ft. of green roofs in three different locations, with costs totaling about $1 million. Covering half the roof's surface, the gardens provide a respite for patients, families and staff members in an otherwise very urban environment. The gardens also help reduce the amount of energy needed to heat and cool the interior of the hospital. The rooftop gardens feature recycled furnishing materials, native plantings and a water feature. A planted trellis creates a green façade buffer for patient room privacy as well as provides additional vertical garden space.” (Green Roof Project Database, n.d.)

Permeable Pavements


Grid blocks allow water from rain events to soak into the underlying soil. (Photo: U.S. Environmental Protection Agency)

Pervious or porous materials may increase infiltration and reduce surface flow. Permeable pavements are a smart alternate treatment of site surfacing, especially in comparison to concrete and asphalt. This particular strategy is effective as it reduces imperviousness in a drainage basin. The best location for this type of site coverage is in low or medium traffic areas, which for most developments are parking lots and sidewalks. Nonetheless, these materials may also be incorporated into alleys, highway shoulders, and emergency vehicle access-ways. Though typically carrying a more expensive installation cost, permeable materials allow for storm water to infiltrate into the underlying soils, which allows for the treatment and recharge of pollutants. This is a contrast to asphalt and concrete, the traditional approaches, which produce large volumes of runoff from rainwater resulting in added cost for transference and treatment. Some strategies for this LID strategy are as follows:

- *Porous grass (or turf)*: Open green space under certain management and maintenance can act as pavement and support vehicular and pedestrian traffic. Turf may be substituted if soil is not compacted by excessive weight caused by traffic.
- *Concrete blocks and grids*: Precast concrete can be shaped as grid blocks with open voids that allow for runoff infiltration into underlying soil.
- *Pervious asphalt*: Also known as permeable asphalt, this is a variation of the commonly used road surface that omits a portion of the traditional aggregate. The variation results in an infiltration capacity.
- *Pervious concrete*: Also a variation, this concrete mix omits the fine sands used in typical concrete, and requires more rigorous pouring and installation. Its benefits include a lower runoff coefficient and runoff volume (Dietz, 2007).
- *Others*: Gravel patterns, and loose aggregate.

Benefits and Limitations

The EPA LID practices and strategies assert that permeable pavements are an effective way of reducing imperviousness in a drainage basin. The EPA cites 30 studies that document findings showing that stream, lake, and wetland quality is reduced when the impervious cover in an upstream watershed is above 10 percent. This underscores the importance and effectiveness of including permeable pavements as part of a LID. However, this strategy does have some limitations. Firstly, pervious surfaces are not recommended when surface grades exceed 5 percent. (EPA Low Impact Development Center, 2000) Colder climate also presents a limitation, as it may result in freezing or swelling. This particular limitation can be mediated. For a helpful example, visit the University of California at Davis Center for Water and Land Use, which provides useful information on design alternatives. Other site considerations that might complicate the use of such technique are groundwater contamination from runoff and storm water, as well as soil quality of the particular site.

Costs Associated

Pervious pavers have a higher initial cost in relation to traditional materials. The pervious or porous pavers may range in the $3 to $6 per square foot range, whereas traditional concrete and asphalt will range from 50 cents to $1 per square foot range. Maintenance costs will also be higher. Nonetheless, it can be expected that using this materials may remove the need for storm drainpipes, storm water and sewer systems. This may lower cost for installation and maintenance/repair for the latter.

Case Studies

For more information, please visit the National Low-Impact Development Atlas, available online by clicking here. This resource provides nation-wide examples of various types of LID interventions.

1. *Deer Point Lake Dirt Road Stabilization*

This project is located in the St Andrew Bay Watershed in Florida. The treatment area was of 32 miles. The main goal was to reduce nonpoint source pollution entering Deer Point Lake, a primary water source for Bay County, Florida. The project goals were as follows:

- Stabilize 32 miles of dirt roads using a permeable pavement, in this case an open-grade hot mix asphalt;
- Create a vegetated roadside swale for storm water runoff; and
- Reduce sediments from entering the water bodies.

The total cost for the four-phased project was close to $4.5 million which was provided by the Florida Forever Competitive Capital Improvement Grant Program. For more information, and a project description, please click here for a project overview.

2. *Galbraith and Associates Parking Lot*

This project, located in Medford, Oregon was the renovation of a parking lot for a private landscape architecture firm's parking lot in 2005. The project aimed to renovate the parking lot while saving a mature oak tree, complying with city drainage requirements, and reducing cost.

The soil type was Coleman loam, which is deep and moderately drained. The 1,085 sq. ft. parking lot is connected to an asphalt alleyway. The layering for the project was an 8-inch layer of 1-inch diameter rock under a 4-inch layer of StoneyCrete pervious pavement. This allowed for the root system of the existing oak tree to remain, effectively saving the tree. The cost for the project was $6,500 for the entire parking lot. This averages to about $6.50 per square foot, only slightly above the $4.50 per square foot for traditional concrete. The pervious surfaces removed the need for a storm sewer connection, saving the firm $6,000. For a project overview and description, please click here for a downloadable PDF.

Low-Impact Development and Public Outreach Programs

Both developers and local public agencies must communicate the benefits of low-impact development as well as its maintenance responsibilities to potential and existing property owners. Improper installation or maintenance of LID systems may yield inefficient results, or polluted runoff. It is much more cost-efficient to prevent the pollutants from entering the storm water than it is to remove the pollutants once they are in the system. (Prince George's Maryland Department of Environmental Resources, 1999) Consequently, a critical component to the success of LID is the proper maintenance of installed systems, as well as avoiding the spread of pollutants into the soil. As well, cities, developers, and private property owners, through comprehensive education programs, can encourage the practice of LID design strategies. Public outreach is, in many ways, a marketing tool. The following steps to guide the creation of public outreach programs is a summary of more extensive suggestions outlined by the Department of Environmental Resources for St. George's County in Maryland. The full document can be accessed online through this link.

Steps to Develop a Public Outreach Program

1. *DEFINE your program's objectives*: The objectives identified will determine what messages are developed and how the outreach materials are distributed. The developer should coordinate the public outreach program with the review agencies. This effort should begin during the site-planning phase.

2. *IDENTIFY your target audience(s)*: For each LID property, whether it is residential, commercial, or industrial, there are different audiences that the developer needs to reach. Specific messages must be tailored to each of these audiences based on the kind of property in question. Examples of possible audiences and their respective suggested messages are as follows:

- Potential buyers: The developer has the opportunity to promote the sustainable aspects of low-impact development and the measures that were included in the development.
- Builders and site construction managers: Proper communication may avoid potential problems during construction that might require remedial actions.

Crucial information to communicate includes appropriate phasing and construction practices for LID techniques.

- New property owners: The developer must allow the new property owner to examine any conditions that have to be met with the purchase of the land. LID sometimes requires legal information ensuring that facilities will be properly maintained.
- Existing property owners: It is the responsibility of the community and property owner to implement maintenance procedures for LID. The developer may assign a representative to the homeowners association, to monitor and train the new property owners on proper maintenance procedures.
- Industrial and commercial property owners: In many instances, LID approaches may save industrial and commercial property owners' money by requiring less land for storm water management, reducing the amount of piping and engineering required to convey storm water, and lowering ongoing maintenance costs.

3. *DEVELOP outreach materials*: When identifying different target audiences it is important to consider the best formats for the audience. For example, homeowners may read a fact sheet, but commercial and industrial properties may benefit from a training session with accompanying materials to explain maintenance requirements. Outreach materials are readily accessible online, and can be modified to meet specific needs. A useful source is through the Center for Watershed Protection, and its Outreach Material Page. Factsheets like the ones in this resource can help educate local stakeholders and the community itself.

4. *DISTRIBUTE outreach materials*: The developer may distribute the outreach materials at certain moments in the property transfer process, such as:

- Construction: This ensures that the planned systems are not disturbed during the building phase
- Potential buyers: Information on the benefits as well as the responsibilities of owning a LID property is useful for this group as a way to promote the property.
- Homeowner Association meetings: A good approach is a presentation after which experts answer questions about LID maintenance requirements.

Useful Resources

A very good model code with instructions for implementation is available from New York state government: www.dec.ny.gov/docs/water_pdf/localaw06.pdf .

For a thorough treatment of LID register with the Center for Watershed protection. The document entitled *Better Site Design: A Handbook for Changing Development Rules in Your Community* is a great resource: http://www.cwp.org/documents/cat_view/77-better-site-design-publications.html .

A document prepared on bioretention which contains graphical explanation of bioretention methods and places for application can be found in this link:
http://vwrrc.vt.edu/swc/april_22_2010_update/DCR_BMP_Spec_No_9_BIORETENTION_FinalDraft_v1-8_04132010.htm .

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